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REVIEW OF PARTICLE PHYSICS*

Particle Data Group

Abstract

This biennial Review summarizes much of Particle Physics. Using data from previous editions, plus 1600 new measurements from 550 papers, we list, evaluate, and average measured properties of gauge bosons, leptons, quarks, mesons, and baryons. We also summarize searches for hypothetical particles such as Higgs bosons, heavy neutrinos, and supersymmetric particles. All the particle properties and search limits are listed in Summary Tables. We also give numerous tables, figures, formulae, and reviews of topics such as the Standard Model, particle detectors, probability, and statistics. A booklet is available containing the Summary Tables and abbreviated versions of some of the other sections of this full Review. All tables, listings, and reviews (and errata) are also available on the Particle Data Group website: http://pdg.1bl.gov.

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INTRODUCTION

1. Overview

The Review of Particle Physics and the abbreviated version, the Particle Physics Booklet, are reviews of the field of Particle Physics. This complete Review includes a compilation/evaluation of data on particle properties, called the "Particle Listings." These Listings include 1900 new measurements from 700 papers, in addition to the 14,000 measurements from 4000 papers that first appeared in previous editions.

Both books include Summary Tables with our best values and limits for particle properties such as masses, widths or lifetimes, and branching fractions, as well as an extensive summary of searches for hypothetical particles. In addition, we give a long section of "Reviews, Tables, and Plots" on a wide variety of theoretical and experimental topics, a quick reference for the practicing particle physicist.

The Review and the Booklet are published in evennumbered years. This edition is an updating through December 1995 (and, in some areas, well into 1996). As described in the section "Using Particle Physics Databases" following this introduction, the content of this Review is available on the World-Wide Web, and is updated between printed editions (http://pdg.lbl.gov/).

The Summary Tables give our best values of the properties of the particles we consider to be well established, a summary of search limits for hypothetical particles, and a summary of experimental tests of conservation laws.

The Particle Listings contain all the data used to get the values given in the Summary Tables. Other measurements considered recent enough or important enough to mention, but which for one reason or another are not used to get the best values, appear separately just beneath the data we do use for the Summary Tables. The Particle Listings also give information on unconfirmed particles and on particle searches, as well as short "reviews" on subjects of particular interest or controversy.

The Particle Listings were once an archive of all published data on particle properties. This is no longer possible because of the large quantity of data. We refer interested readers to earlier editions for data now considered to be obsolete.

We organize the particles into six categories:

Gauge and Higgs bosons

Leptons Quarks

Mesons

Baryons

Searches for monopoles,

supersymmetry, compositeness, etc.

The last category only includes searches for particles that do not belong to the previous groups; searches for heavy charged leptons and massive neutrinos, by contrast, are with the leptons.

In Sec. 2 of this Introduction, we list the main areas of responsibility of the authors, and also list our large number of consultants, without whom we would not have been able to produce this Review. In Sec. 3, we mention briefly the naming scheme for hadrons. In Sec. 4, we discuss our procedures for choosing among measurements of particle

properties and for obtaining best values of the properties from the measurements.

The accuracy and usefulness of this Review depend in large part on interaction between its users and the authors. We appreciate comments, criticisms, and suggestions for improvements of any kind. Please send them to the appropriate author, according to the list of responsibilities in Sec. 2 below, or to the LBNL addresses below.

To order a copy of the Review or the Particle Physics Booklet from North and South America, Australia, and the Far East, write to

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- M. Jimack (University of Birmingham)
- J.A. Kadyk (LBNL)
- R.W. Kenney (LBNL)
- R.D. Kephart (Fermilab)
- M. Klein (DESY)
- B. Klima (Fermilab)
- B. Kniehl (Max-Planck Inst., Münich)
- D. Koetke (Carleton University)
- I. Koop (Budker Inst. of Nuclear Physics)
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- W.C. Martin (NIST)
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- D. Morgan (Rutherford Appleton Lab)
- A.S. Nikolaev (COMPAS Group, IHEP, Serpukhov)
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3. Naming scheme for hadrons

We introduced in the 1986 edition [2] a new naming scheme for the hadrons. Changes from older terminology affected mainly the heavier mesons made of u, d, and s quarks. Otherwise, the only important change to known hadrons was that the F^{\pm} became the D_s^{\pm} . None of the lightest pseudoscalar or vector mesons changed names, nor did the $c\bar{c}$ or $b\bar{b}$ mesons (we do, however, now use χ_c for the $c\bar{c}$ χ states), nor did any of the established baryons. The Summary Tables give both the new and old names whenever a change has occurred.

The scheme is described in "Naming Scheme for Hadrons" (p. 80) of this Review.

We give here our conventions on type-setting style. Particle symbols are italic (or slanted) characters: e^- , p, Λ , π^0 , K_L , D_s^+ , b. Charge is indicated by a superscript: B^- , Δ^{++} . Charge is not normally indicated for p, n, or the quarks, and is optional for neutral isosinglets: η or η^0 . Antiparticles and particles are distinguished by charge for charged leptons and mesons: τ^+ , K^- . Otherwise, distinct antiparticles are indicated by a bar (overline): $\overline{\nu}_\mu$, \overline{t} , \overline{p} , \overline{K}^0 , and $\overline{\Sigma}^+$ (the antiparticle of the Σ^-).

4. Procedures

4.1. Selection and treatment of data: The Particle Listings contain all relevant data known to us that are published in journals. With very few exceptions, we do not include results from preprints or conference reports. Nor do we include data that are of historical importance only (the Listings are not an archival record). We search every volume of 20 journals through our cutoff date for relevant data. We also include later published papers that are sent to us by the authors (or others).

In the Particle Listings, we clearly separate measurements that are used to calculate or estimate values given in the Summary Tables from measurements that are not used. We give explanatory comments in many such cases. Among the reasons a measurement might be excluded are the following:

- It is superseded by or included in later results.
- No error is given.
- It involves assumptions we question.
- It has a poor signal-to-noise ratio, low statistical significance, or is otherwise of poorer quality than other data available.
- It is clearly inconsistent with other results that appear to be more reliable. Usually we then state the criterion, which sometimes is quite subjective, for selecting "more reliable" data for averaging. See Sec. 4.
- It is not independent of other results.
- It is not the best limit (see below).
- It is quoted from a preprint or a conference report.

In some cases, none of the measurements is entirely reliable and no average is calculated. For example, the masses of many of the baryon resonances, obtained from partial-wave analyses, are quoted as estimated ranges thought to probably include the true values, rather than as averages with errors. This is discussed in the Baryon Particle Listings.

For upper limits, we normally quote in the Summary Tables the strongest limit. We do not average or combine upper limits except in a very few cases where they may be re-expressed as measured numbers with Gaussian errors.

As is customary, we assume that particle and antiparticle share the same spin, mass, and mean life. The Tests of Conservation Laws table, following the Summary Tables, lists tests of CPT as well as other conservation laws.

We use the following indicators in the Particle Listings to tell how we get values from the tabulated measurements:

- OUR AVERAGE—From a weighted average of selected data
- OUR FIT—From a constrained or overdetermined multiparameter fit of selected data.
- OUR EVALUATION—Not from a direct measurement, but evaluated from measurements of related quantities.
- OUR ESTIMATE—Based on the observed range of the data. Not from a formal statistical procedure.
- OUR LIMIT—For special cases where the limit is evaluated by us from measured ratios or other data. Not from a direct measurement.

An experimentalist who sees indications of a particle will of course want to know what has been seen in that region in the past. Hence we include in the Particle Listings all reported states that, in our opinion, have sufficient statistical merit and that have not been disproved by more reliable data. However, we promote to the Summary Tables only those states that we feel are well established. This judgment is, of course, somewhat subjective and no precise criteria can be given. For more detailed discussions, see the minireviews in the Particle Listings.

- 4.2. Averages and fits: We divide this discussion on obtaining averages and errors into three sections:
- (1) treatment of errors; (2) unconstrained averaging;
- (3) constrained fits.
- **4.2.1.** Treatment of errors: In what follows, the "error" δx means that the range $x \pm \delta x$ is intended to be a 68.3% confidence interval about the central value x. We treat this error as if it were Gaussian. Thus when the error is Gaussian, δx is the usual one standard deviation (1 σ). Many experimenters now give statistical and systematic errors separately, in which case we usually quote both errors, with the statistical error first. For averages and fits, we then add the two errors in quadrature and use this combined error for δx

When experimenters quote asymmetric errors $(\delta x)^+$ and $(\delta x)^-$ for a measurement x, the error that we use for that measurement in making an average or a fit with other measurements is a continuous function of these three quantities. When the resultant average or fit \overline{x} is less than $x-(\delta x)^-$, we use $(\delta x)^-$; when it is greater than $x+(\delta x)^+$, we use $(\delta x)^+$. In between, the error we use is a linear function of x. Since the errors we use are functions of the result, we iterate to get the final result. Asymmetric output errors are

determined from the input errors assuming a linear relation between the input and output quantities.

In fitting or averaging, we usually do not include correlations between different measurements, but we try to select data in such a way as to reduce correlations. Correlated errors are, however, treated explicitly when there are a number of results of the form $A_i \pm \sigma_i \pm \Delta$ that have identical systematic errors Δ . In this case, one can first average the $A_i \pm \sigma_i$ and then combine the resulting statistical error with Δ . One obtains, however, the same result by averaging $A_i \pm (\sigma_i^2 + \Delta_i^2)^{1/2}$, where $\Delta_i = \sigma_i \Delta [\sum (1/\sigma_j^2)]^{1/2}$. This procedure has the advantage that, with the modified systematic errors Δ_i , each measurement may be treated as independent and averaged in the usual way with other data. Therefore, when appropriate, we adopt this procedure. We tabulate Δ and invoke an automated procedure that computes Δ_i before averaging and we include a note saying that there are common systematic errors.

Another common case of correlated errors occurs when experimenters measure two quantities and then quote the two and their difference, e.g., m_1 , m_2 , and $\Delta = m_2 - m_1$. We cannot enter all of m_1 , m_2 and Δ into a constrained fit because they are not independent. In some cases, it is a good approximation to ignore the quantity with the largest error and put the other two into the fit. However, in some cases correlations are such that the errors on m_1 , m_2 and Δ are comparable and none of the three values can be ignored. In this case, we put all three values into the fit and invoke an automated procedure to increase the errors prior to fitting such that the three quantities can be treated as independent measurements in the constrained fit. We include a note saying that this has been done.

4.2.2. Unconstrained averaging: To average data, we use a standard weighted least-squares procedure and in some cases, discussed below, increase the errors with a "scale factor." We begin by assuming that measurements of a given quantity are uncorrelated, and calculate a weighted average and error as

$$\overline{x} \pm \delta \overline{x} = \frac{\sum_{i} w_{i} \ x_{i}}{\sum_{i} w_{i}} \pm \left(\sum_{i} w_{i}\right)^{-1/2} , \qquad (1)$$

where

$$w_i = 1/(\delta x_i)^2 .$$

Here x_i and δx_i are the value and error reported by the *i*th experiment, and the sums run over the N experiments. We then calculate $\chi^2 = \sum w_i(\overline{x} - x_i)^2$ and compare it with N-1, which is the expectation value of χ^2 if the measurements are from a Gaussian distribution.

If $\chi^2/(N-1)$ is less than or equal to 1, and there are no known problems with the data, we accept the results.

If $\chi^2/(N-1)$ is very large, we may choose not to use the average at all. Alternatively, we may quote the calculated average, but then make an educated guess of the error, a conservative estimate designed to take into account known problems with the data.

Finally, if $\chi^2/(N-1)$ is greater than 1, but not greatly so, we still average the data, but then also do the following:

(a) We increase our quoted error, $\delta \overline{x}$ in Eq. (1), by a scale factor S defined as

$$S = \left[\chi^2 / (N - 1) \right]^{1/2} . \tag{2}$$

Our reasoning is as follows. The large value of the χ^2 is likely to be due to underestimation of errors in at least one of the experiments. Not knowing which of the errors are underestimated, we assume they are all underestimated by the same factor S. If we scale up all the input errors by this factor, the χ^2 becomes N-1, and of course the output error $\delta \overline{x}$ scales up by the same factor. See Ref. 3.

When combining data with widely varying errors, we modify this procedure slightly. We evaluate S using only the experiments with smaller errors. Our cutoff or ceiling on δx_i is arbitrarily chosen to be

$$\delta_0 = 3N^{1/2} \, \delta \overline{x} \, ,$$

where $\delta \overline{x}$ is the unscaled error of the mean of all the experiments. Our reasoning is that although the low-precision experiments have little influence on the values \overline{x} and $\delta \overline{x}$, they can make significant contributions to the χ^2 , and the contribution of the high-precision experiments thus tends to be obscured. Note that if each experiment has the same error δx_i , then $\delta \overline{x}$ is $\delta x_i/N^{1/2}$, so each δx_i is well below the cutoff. (More often, however, we simply exclude measurements with relatively large errors from averages and fits: new, precise data chase out old, imprecise data.)

Our scaling procedure has the property that if there are two values with comparable errors separated by much more than their stated errors (with or without a number of other values of lower accuracy), the scaled-up error $\delta \overline{x}$ is approximately half the interval between the two discrepant values.

We emphasize that our scaling procedure for errors in no way affects central values. And if you wish to recover the unscaled error $\delta \overline{x}$, simply divide the quoted error by S.

(b) If the number M of experiments with an error smaller than δ_0 is at least three, and if $\chi^2/(M-1)$ is greater than 1.25, we show in the Particle Listings an ideogram of the data. Figure 1 is an example. Sometimes one or two data points lie apart from the main body; other times the data split into two or more groups. We extract no numbers from these ideograms; they are simply visual aids, which the reader may use as he or she sees fit.

Each measurement in an ideogram is represented by a Gaussian with a central value x_i , error δx_i , and area proportional to $1/\delta x_i$. The choice of $1/\delta x_i$ for the area is somewhat arbitrary. With this choice, the center of gravity of the ideogram corresponds to an average that uses weights $1/\delta x_i$ rather than the $(1/\delta x_i)^2$ actually used in the averages. This may be appropriate when some of the experiments have seriously underestimated systematic errors. However, since for this choice of area the height of the Gaussian for each measurement is proportional to $(1/\delta x_i)^2$, the peak position of the ideogram will often favor the high-precision measurements at least as much as does the least-squares average. See our 1986 edition [2] for a detailed discussion of the use of ideograms.

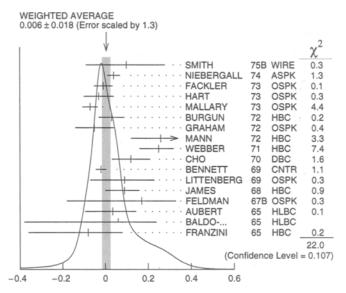


Figure 1: A typical ideogram. The arrow at the top shows the position of the weighted average, while the width of the shaded pattern shows the error in the average after scaling by the factor S. The column on the right gives the χ^2 contribution of each of the experiments. Note that the next-to-last experiment, denoted by the incomplete error flag (\bot) , is not used in the calculation of S (see the text).

4.2.3. Constrained fits: Except for trivial cases, all branching ratios and rate measurements are analyzed by making a simultaneous least-squares fit to all the data and extracting the partial decay fractions P_i , the partial widths Γ_i , the full width Γ (or mean life), and the associated error matrix

Assume, for example, that a state has m partial decay fractions P_i , where $\sum P_i = 1$. These have been measured in N_r different ratios R_r , where, e.g., $R_1 = P_1/P_2$, $R_2 = P_1/P_3$, etc. [We can handle any ratio R of the form $\sum \alpha_i P_i / \sum \beta_i P_i$, where α_i and β_i are constants, usually 1 or 0. The forms $R = P_i P_j$ and $R = (P_i P_j)^{1/2}$ are also allowed.] Further assume that each ratio R has been measured by N_k experiments (we designate each experiment with a subscript k, e.g., R_{1k}). We then find the best values of the fractions P_i by minimizing the χ^2 as a function of the m-1 independent parameters:

$$\chi^2 = \sum_{r=1}^{N_r} \sum_{k=1}^{N_k} \left(\frac{R_{rk} - R_r}{\delta R_{rk}} \right)^2 , \qquad (3)$$

where the R_{rk} are the measured values and R_r are the fitted values of the branching ratios.

In addition to the fitted values \overline{P}_i , we calculate an error matrix $\langle \delta \overline{P}_i \ \delta \overline{P}_j \rangle$. We tabulate the diagonal elements of $\delta \overline{P}_i = \langle \delta \overline{P}_i \ \delta \overline{P}_i \rangle^{1/2}$ (except that some errors are scaled as discussed below). In the Particle Listings, we give the complete correlation matrix; we also calculate the fitted value of each ratio, for comparison with the input data, and list it above the relevant input, along with a simple unconstrained average of the same input.

Three comments on the example above:

(1) There was no connection assumed between measurements of the full width and the branching ratios. But

often we also have information on partial widths Γ_i as well as the total width Γ . In this case we must introduce Γ as a parameter in the fit, along with the P_i , and we give correlation matrices for the widths in the Particle Listings.

- (2) We do not allow for correlations between input data. We do try to pick those ratios and widths that are as independent and as close to the original data as possible. When one experiment measures all the branching fractions and constrains their sum to be one, we leave one of them (usually the least well-determined one) out of the fit to make the set of input data more nearly independent.
- (3) We calculate scale factors for both the R_r and P_i when the measurements for any R give a larger-than-expected contribution to the χ^2 . According to Eq. (3), the double sum for χ^2 is first summed over experiments k=1 to N_k , leaving a single sum over ratios $\chi^2 = \sum \chi_r^2$. One is tempted to define a scale factor for the ratio r as $S_r^2 = \chi_r^2/\langle \chi_r^2 \rangle$. However, since $\langle \chi_r^2 \rangle$ is not a fixed quantity (it is somewhere between N_k and N_{k-1}), we do not know how to evaluate this expression. Instead we define

$$S_{r}^{2} = \frac{1}{N_{k}} \sum_{k=1}^{N_{k}} \frac{\left(R_{rk} - \overline{R}_{r}\right)^{2}}{(\delta R_{rk})^{2} - (\delta \overline{R}_{r})^{2}} , \qquad (4)$$

where $\delta \overline{R}_r$ is the fitted error for ratio r. With this definition the expected value of S_r^2 is one.

The fit is redone using errors for the branching ratios that are scaled by the larger of S_r and unity, from which new and often larger errors $\delta \overline{P}_i'$ are obtained. The scale factors we finally list in such cases are defined by $S_i = \delta \overline{P}_i'/\delta \overline{P}_i$. However, in line with our policy of not letting S affect the central values, we give the values of \overline{P}_i obtained from the original (unscaled) fit.

There is one special case in which the errors that are obtained by the preceding procedure may be changed. When a fitted branching ratio (or rate) \overline{P}_i turns out to be less than three standard deviations $(\delta \overline{P}_i')$ from zero, a new smaller error $(\delta \overline{P}_i'')^-$ is calculated on the low side by requiring the area under the Gaussian between $\overline{P}_i - (\delta \overline{P}_i'')^-$ and \overline{P}_i to be 68.3% of the area between zero and \overline{P}_i . A similar correction is made for branching fractions that are within three standard deviations of one. This keeps the quoted errors from overlapping the boundary of the physical region.

4.3. Discussion: The problem of averaging data containing discrepant values is nicely discussed by Taylor in Ref. 4. He considers a number of algorithms that attempt to incorporate inconsistent data into a meaningful average. However, it is difficult to develop a procedure that handles simultaneously in a reasonable way two basic types of situations: (a) data that lie apart from the main body of the data are incorrect (contain unreported errors); and (b) the opposite—it is the main body of data that is incorrect. Unfortunately, as Taylor shows, case (b) is not infrequent. He concludes that the choice of procedure is less significant than the initial choice of data to include or exclude.

We place much emphasis on this choice of data. Often we solicit the help of outside experts (consultants). Sometimes, however, it is simply impossible to determine which of a set of discrepant measurements are correct. Our scale-factor technique is an attempt to address this ignorance by increasing the error. In effect, we are saying that present experiments do not allow a precise determination of this

quantity because of unresolvable discrepancies, and one must await further measurements. The reader is warned of this situation by the size of the scale factor, and if he or she desires can go back to the literature (via the Particle Listings) and redo the average with a different choice of data.

Our situation is less severe than most of the cases Taylor considers, such as estimates of the fundamental constants like \hbar , etc. Most of the errors in his case are dominated by systematic effects. For our data, statistical errors are often at least as large as systematic errors, and statistical errors are usually easier to estimate. A notable exception occurs in partial-wave analyses, where different techniques applied to the same data yield different results. In this case, as stated earlier, we often do not make an average but just quote a range of values.

A brief history of early Particle Data Group averages is given in Ref. 3. Figure 2 shows some histories of our values of a few particle properties. Sometimes large changes occur. These usually reflect the introduction of significant new data or the discarding of older data. Older data are discarded in favor of newer data when it is felt that the newer data have smaller systematic errors, or have more checks on systematic errors, or have made corrections unknown at the time of the older experiments, or simply have much smaller errors. Sometimes, the scale factor becomes large near the time at which a large jump takes place, reflecting the uncertainty introduced by the new and inconsistent data. By and large, however, a full scan of our history plots shows a dull progression toward greater precision at central values quite consistent with the first data points shown.

We conclude that the reliability of the combination of experimental data and our averaging procedures is usually good, but it is important to be aware that fluctuations outside of the quoted errors can and do occur.

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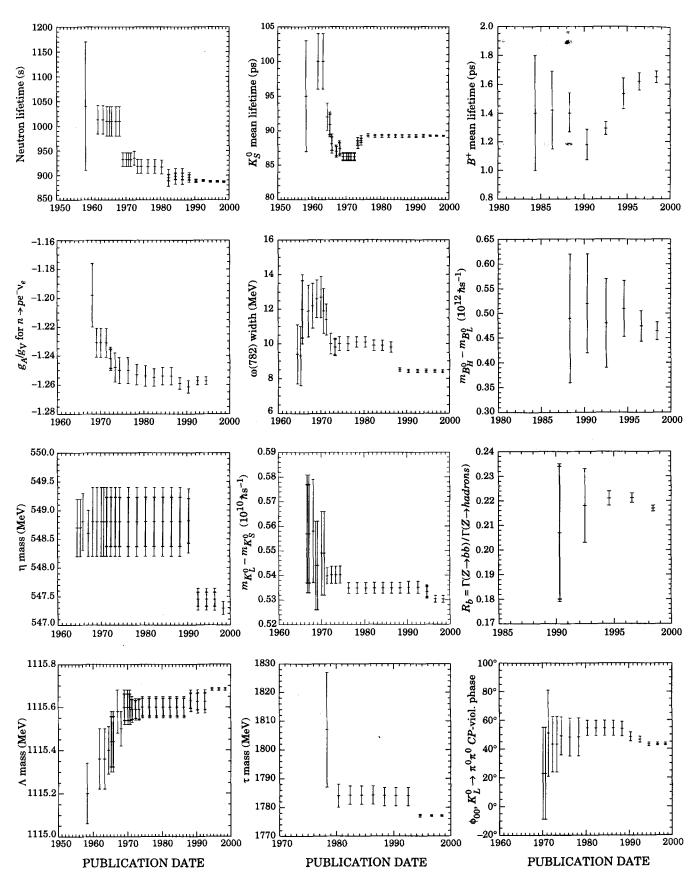


Figure 2: An historical perspective of values of a few particle properties tabulated in this *Review* as a function of date of publication of the *Review*. A full error bar indicates the quoted error; a thick-lined portion indicates the same but without the "scale factor."

ONLINE PARTICLE PHYSICS INFORMATION

Revised April 1998 by P. Kreitz (SLAC).

The purpose of this list is to organize a broad set of online catalogs, databases, directories, World-Wide Web (WWW) pages, etc., that are of value to the particle physics physics community. While a substantial amount of particle physics physics information is computer accessible through the Internet's World-Wide Web, most listings do not provide descriptions of a resource's scope and content so that searchers know which source to use for a specific information need. This compilation lists the main information sources with brief annotations and basic Internet WWW addresses (URL's). Because this list must be fixed in print, it is important to consult the updated version of this compilation which includes newly added resources and hypertext links to more complete information at:

http://www.slac.stanford.edu/library/pdg/hepinfo.html

In this edition, a resource is excluded if it provides information primarily of interest to one institution. In some cases, multiple databases covering much the same material have been included with the assumption that users will make subsequent choices based on Internet speeds, search system interfaces, or differences in scope, presentation, and coverage. Databases and resources focusing primarily on accelerator physics have been excluded in deference to the excellent compilation at the World Wide Web Virtual Library of Accelerator Physics:

http://www.slac.stanford.edu/grp/arb/dhw/dpb/w3v1/w3.html

My thanks to Betty Armstrong, Particle Data Group, Richard Dominiak, SLAC Library, and the many particle physics Web site and database maintainers who have all given me their generous assistance. Please send suggestions, additions, changes, ideas for category groupings, exclusions, etc., via the WWW form linked to the URL above, or by e-mail to pkreitz@slac.stanford.edu.

1. Particles & Properties Data:

• REVIEW OF PARTICLE PHYSICS (RPP): A comprehensive review of the field of Particle Physics produced by the Particle Data Group (PDG). Includes a compilation/evaluation of data on particle properties, summary tables with best values and limits for particle properties, extensive summaries of searches for hypothetical particles, and a long section of reviews, tables, and plots on a wide variety of theoretical and experimental topics of interest to particle and astrophysicists. The linked table of contents provides access to particle listings, reviews, summary tables, errata, indices, etc. The current printed version is European Physical Journal C3, 1 (1998). Maintained at:

http://pdg.lbl.gov/

 PARTICLE PHYSICS BOOKLET: An extract from the most recent edition of the full Review of Particle Physics. Contains images in an easy-to-read print useful for classroom studies:

http://pdg.lbl.gov/rpp/booklet/contents.html

 PARTICLE PROPERTIES Database: Durham/RAL provides a simple index to the PDG particle properties information contained in the Review of Particle Physics. Maintained at:

http://durpdg.dur.ac.uk/HEPDATA/PART

 COMPUTER-READABLE FILES: Currently available from the PDG: tables of masses, widths, and PDG Monte Carlo particle numbers and cross section data, including hadronic total and elastic cross sections vs laboratory momenta and total center-of-mass energy. Overview page at:

http://pdg.lbl.gov/computer_read.html

 PARTICLE PHYSICS DATA SYSTEM: Maintained by the COM-PAS group at IHEP, this system, currently under construction, provides an online version of the Guide to Experimental Elementary Particle Physics Literature (1895-1995). Permits searching by author, title, accelerator, detector, reaction, particle, etc. For research from 1950 to the present, it will provide online searching of compilations of integrated cross section data and numerical data on observables in reactions. Also provides a chronology of key events in particle physics:

http://mesa.lbl.gov:8001/ppds.html

REACTION DATA Database: (Durham) This is the main reaction
data database containing numerical results for a wide variety of
particle physics topics. Included are cross sections (differential and
total), polarization measurements, structure functions, spin-density
matrices, etc., from e⁺e⁻ annihilation, inclusive hadron and lepton
physics, deep inelastic scattering, photoproduction and two-body
(and quasi-two-body) scattering. This database is a collaboration
of Durham and the COMPAS Group for the PDG.

http://durpdg.dur.ac.uk/HEPDATA/REAC

 PHYSICS AROUND THE WORLD: Reference: From the subsection entitled 'Reference,' choose links to pages of data and tables, fundamental or material constants, physics laws, periodic tables, patents, and standards.

http://www.tp.umu.se/TIPTOP/paw

2. Collaborations & Experiments:

EXPERIMENTS Database: Contains more than 1,800 experiments
in elementary particle physics. Search and browse by author; title;
experiment number or prefix; institution; date approved, started
or completed; accelerator or detector; polarization, reaction, final
state or particle; or by papers produced. Maintained at SLAC for
the Particle Data Group. Supplies the information for "Current
Experiments in Particle Physics (LBL-91)." Updated every second
year (next: Summer 1998):

http://www.slac.stanford.edu/find/experiments

EXPERIMENTS ONLINE: Home Pages of HEP Experiments: A
list from SLAC of accelerator and non-accelerator experiments
with an active link to each home page. Accelerator experiments
are organized by institution, machine, and experiment name.
Non-accelerator experiments are alphabetical by name:

http://www.slac.stanford.edu/find/explist.html

 HIGH ENERGY PHYSICS EXPERIMENTS: A HEPNET page providing links to HEP collaborations around the world. Arranged alphabetically by institution and then collaboration or experiment

http://www.hep.net/experiments/collabs.html

3. Conferences:

• CONFERENCES: Contains conferences, schools, and meetings of interest to high-energy physicists with links, when available, to the conference home page. Searchable database produced jointly by the SLAC and DESY libraries of over 8,000 listings covering 1973 to 1999+. Search or browse by title, acronym, date, location. Includes information about published proceedings, links to submitted papers from the SPIRES-HEP database, and links to the electronic versions of the papers if available:

http://www.slac.stanford.edu/ spires/form/confspif.html

• CONFERENCES AND CONFERENCES: (Subtitled: There Are Too Many Conferences!): Lists current and future meetings in many fields of physics. Searchable by research area. Provides links to the conference Web page and the contact. Most useful as a listsery to which you can subscribe to get conference announcements. Web conference pages and an e-mail interface (robot@physics.umd.edu with CONFMENU in the subject line):

http://www.physics.umd.edu/robot/confer/confmenu.html

CONFERENCES, WORKSHOPS, AND SUMMER SCHOOLS:
 By The Internet Pilot to Physics. Covers national and regional meetings worldwide for all subfields of physics. Searchable by

sub-discipline or by free text words. Provides a Web form and email address for adding a conference. Automatically uploads new entries to the EPS EurophysNet meeting list.

http://www.tp.umu.se/TIPTOP/FORUM/CONF/

• EUROPHYSICS MEETINGS LIST: Meta-level international list of other conference lists with active links to the URL'S of the organization's meeting calendar, the conference database, etc. Useful for searching by organization, and for providing access to meetings and conferences that are of peripheral interest. Maintained by the European Physical Society. Organized alphabetically by the name of the resource or organization:

http://epswww.epfl.ch/conf/urls.html

 HEP EVENTS: A list maintained by CERN of upcoming conferences, schools, workshops, seminars, and symposia of interest to high-energy physics organized by type of meeting, e.g.: school, workshop:

http://www.cern.ch/Physics/Conferences

PHYSICS CONFERENCE ANNOUNCEMENTS by Thread:
 Lists current year's conference announcements with links to Web pages. Posting is voluntary. List can be browsed by date, subject, or author:

http://xxx.lanl.gov/Announce/Conference/

4. Current Notices & Announcement Services:

CONFERENCES, WORKSHOPS, AND SUMMER SCHOOLS:
 By The Internet Pilot to Physics. Provides a Web form or an
 email address for adding a conference and automatically uploads
 new entries to the EPS EurophysNet meeting list. Directions on
 the top-level page enable you to sign up to receive weekly email
 notification about conferences and deadlines.

http://www.tp.umu.se/TIPTOP/FORUM/CONF/

- CONFNEWS & WEBNEWS: Provides a system for broadcasting a conference or job opening to "a large number of physicists worldwide." For further information, e-mail: kim@umdhep.umd.edu
- E-PRINT ARCHIVES Listserv Notices: The LANL-based E-Print Archives provides daily notices of high-energy physics preprints submitted to the archives as full text electronic documents. Use the Web-accessible listings:

http://xxx.lanl.gov/ or subscribe:

http://xxx.lanl.gov/help/subscribe

Note: Use the library pages below to find announcement lists for recently received preprints, books, and proceedings. Use the online journal links below for journal table of contents. Conference announcements can also be sent via e-mail to most of the conference database providers listed above who often supply their e-mail address at the bottom of their Web pages.

5. Directories:

5.1. Directories—Research Institutions:

 CERN RESEARCH INSTITUTES: Contains HEP Institutes used in the CERN Library catalog. Provides addresses, and, where available, the following: phone and fax numbers; e-mail addresses; active Web links; and information about the institution's physics program. Search by free text, organization, country, or town:

http://alice.cern.ch/Institutes

• HEP INSTITUTIONS ONLINE: Active links to the home pages of more than 200 HEP-related institutions with Web servers. Maintained by SLAC. Organized by country, and then alphabetically by institution:

http://www.slac.stanford.edu/find/instlink.html

INSTITUTIONS: Database of over 5,500 high-energy physics
institutes, laboratories, and university departments in which some
research on elementary particle physics is performed. Covers six
continents and almost one hundred countries. Searchable by name,
acronym, location, etc. Provides address, phone and fax numbers,
and e-mail and Web links where available. Has pointers to the
recent HEP papers from an institution. Maintained by SLAC:

http://www.slac.stanford.edu/ spires/form/instspif.html

 DIRECTORY FOR PHYSICS DEPARTMENTS: Maintained by TIPTOP Physics Around the World. Lists departments worldwide. Searchable by field of research or by country or a combination of both.

http://www.tp.umu.se/TIPTOP/paw/dsearch.html

WWW VIRTUAL LIBRARY—HIGH ENERGY PHYSICS: An
alphabetical listing of organizations involved in high-energy physics
with links to the institution's Web pages. Maintained by CERN.
Because the listings are by institutional acronym or by short
name, this is less useful for people unfamiliar with the institution's
nickname.

http://www.cern.ch/Physics/HEP.html

5.2. Directories—People:

 HEPNAMES: Searchable database of 33,200 e-mail addresses of people related to high-energy physics. Access by individual name, and, in the near future, by institution or place.

http://www-spires.slac.stanford.edu/find/hepnames

This site is mirrored at Durham under a different name (EMAIL-ID) and with a search interface written and maintained by Durham:

http://durpdg.dur.ac.uk/HEPDATA/ID

 HEP VIRTUAL PHONEBOOK: A list of links to phonebooks and directories of high-energy physics sites and collaborations around the world. Maintained by HEPNET:

http://www.hep.net/sites/directories.html

 US-HEPFOLK: A searchable database of almost 3,500 physicists from 155 U.S. institutions based on a survey conducted in 1997.
 Searchable by first or last name, by affiliation, and/or by email address. Also provides some interesting demographic plots of the survey data:

http://pdg.lbl.gov/us-hepfolk/index.html

5.3. Directories—Libraries:

• Argonne National Lab Library:

http://www.ipd.anl.gov/aim/alec/

• Berkeley Lab (LBNL) Library:

http://www-library.lbl.gov/

• Brookhaven National Lab Library:

http://www.bnl.gov/RESLIB/reslib.html

• (CERN) European Laboratory for Particle Physics Library: http://wwwas.cern.ch/library/library_general/ welcome.html

• Deutsches Elektronen-Synchrotron (DESY) Library:

http://www.desy.de/library/homepage.html

• Fermilab Library:

http://fnalpubs.fnal.gov/library/welcome.html

• Jefferson Lab Library:

http://www.jlab.org/div_dept/admin/library/

- (KEK) National Laboratory for High Energy Physics Library: http://www-lib.kek.jp/publib.html
- Lawrence Livermore National Laboratory Library: http://www.llnl.gov/tid/Library.html
- Los Alamos National Laboratory Library: http://lib-www.lanl.gov/
- Oak Ridge National Laboratory Library:
 http://www.ornl.gov/Library/library-home.html
- Sandia National Laboratory Library: http://www.sandia.gov/library.htm
- Stanford Linear Accelerator Center Library:
 http://www.slac.stanford.edu/FIND/spires.html

5.4. Directories—Publishers:

 COMPANIES/PUBLISHERS: Contains 44 links to institutions, societies, or companies involved in supplying physics-related information:

http:www.tp.umu.se/TIPTOP/paw/paw.html/ ?k=Companies/Publishers&t=k&f=1

 DIRECTORY OF PUBLISHERS AND VENDORS: Contains hundreds of links to publishers and vendors divided by type (government or university) and by subject. The science section is extensive. Secondary page to "Other Links" leads to more arcane and specialized suppliers and information:

http://www.library.vanderbilt.edu/law/acqs/pubr.html

5.5. Directories—Scholarly Societies:

- American Association for the Advancement of Science: http://www.aaas.org/
- American Association of Physics Teachers: http://www.aapt.org/
- American Astronomical Society: http://www.aas.org
- American Institute of Physics: http://aip.org/
- American Physical Society: http://aps.org
- American Mathematical Society: http://www.ams.org/
- European Physical Society: http://epswww.epfl.ch/
- IEEE Nuclear and Plasma Sciences Society:: http://hibp7.ecse.rpi.edu/~connor/ieee/npss.html
- Institute of Physics: http://www.iop.org/
- RESOURCES OF SCHOLARLY SOCIETIES—PHYSICS: Maintained by the University of Waterloo Electronic Library's Scholarly Societies Project. Links to the home pages of close to a hundred scholarly societies worldwide. Very up to date:

http://www.lib.uwaterloo.ca/society/physics_soc.html

6. E-Prints/Pre-Prints, Papers, & Reports:

 CERN PREPRINTS CATALOGUE: The CERN Library's database which contains citations to more than 200,000 monographs, series, preprints, and official committee documents held by the Library or the Archives:

http://alice.cern.ch/Preprints

Also provides links to CERN's full text preprint server:

http://preprints.cern.ch/weeklist.html#preprints

• HEP DATABASE (SLAC/SPIRES): Contains over 350,000 bibliographic summaries for particle physics papers (e-prints, journal articles, preprints, reports, theses, etc.). Covers 1974 to the present and is updated daily with links to electronic texts (e.g. from LANL, CERN, KEK, and other HEP servers). Searchable by all authors and authors' affiliations, title, topic, report number, citation (footnotes), e-print archive number, date, journal, etc.: A joint project of the SLAC and DESY libraries with the collaboration of many other research institutions and scholarly societies such as the APS:

http://www.slac.stanford.edu/find/hep

 KISS (KEK Information Service System) for Preprints: KEK Library preprint database. Contains bibliographic records of preprints and technical reports held in the KEK library with links to the full text images of close to 100,000 items in their collection:

http://www-lib.kek.jp/KISS.v3/kiss_prepri.html

• LANL E-PRINT ARCHIVES: An automated electronic repository of physics, mathematics, and nonlinear science preprints. Used heavily by the sub-disciplines of high-energy physics. Began with a core set of archives in 1991. Provides access to the full text of the electronic versions of these preprints. Permits searching by author, title, keyword in abstract. Allows limiting by subfield archive or by date. Papers are sent electronically to the archives by authors:

http://xxx.lanl.gov

ONE-SHOT WORLD-WIDE PREPRINTS SEARCH: This is a
prototype service for a global lookup search throughout most
on-line scientific preprint repositories in the world. A very efficient
system permitting author or title searching, limiting by year and
by broad geographical regions:

http://www.ictp.trieste.it/indexes/preprints.html

PARTICLE PHYSICS DATA SYSTEM—PPDS: A search interface
to the bibliography of the print publication "A Guide to
Experimental Elementary Particle Physics Literature" (LBL-90).
This bibliography covers the published literature of theoretical
and experimental particle physics. Coverage is from 1895 to the
present:

http://mesa.lbl.gov:8001/ppds.html

• PPF: PREPRINTS IN PARTICLES AND FIELDS: A weekly listing of approximately 220 new preprints of interest to the high-energy physics community. Contains bibliographic listings for and, in the Web version, full text links to, the new preprints received by and cataloged into the SPIRES-HEP database. Approximately 30% of new titles are not available from the LANL e-print archives. Directions for subscribing to an email version can be found on the page listing the most recent week's preprints received:

http://www.slac.stanford.edu/library/documents/newppf.html

7. Particle Physics Journals & Reviews:

7.1. Online Journals and Tables of Contents:

Note: Only a selection of direct title URL's have been listed. Where many titles are available from the same publisher, a link to a summary online journals page from that publisher has been listed. Also please note, some of these journals and publishers may limit access to subscribers; check with your institution's library.

 American Astronomical Society: Astrophysical Journal Electronic Edition:

http://www.journals.uchicago.edu/ApJ/

 American Institute of Physics: The top-level page for their electronic journals may be found at:

http://www.aip.org/ojs/service.html

• American Journal of Physics:

http://www.amherst.edu/~ajp/

 American Physics Society: The top-level page for the APS research journals is:

http://publish.aps.org/

 Elsevier Science (Publishers): The top-level page for Nuclear Physics Electronic is:

http://www.nucphys.nl/www/pub/nucphys/npe.html

 European Physical Society: Their journals are handled by various publishers but may be reached from this top-level page:

http://epswww.epfl.ch/pub/index.html

 Institute of Physics: This page provides links to their online services, electronic journals and magazines, and Physics Express Letters:

http://www.iop.org

 Journal of High Energy Physics: A refereed journal written, run, and distributed by electronic means:

http://jhep.sissa.it/

• Modern Physics Letters: A and B

http://www.wspc.com.sg/journals/mpla/mpla.html http://www.wspc.com.sg/journals/mplb/mplb.html

• Journal of the Physical Society of Japan:

http://wwwsoc.nacsis.ac.jp/jps/jpsj/index.html

 Springer Publishing: Physics: This link provides a list of Springer journals covering topics of interest to physicists. Small bullets containing the letter 'E' beside each title indicate which journals are also in electronic format:

http://link.springer.de/ol/pol/all.htm

• Physics—Uspekhi

http://ufn.ioc.ac.ru/

• Reviews of Modern Physics

http://www.phys.washington.edu/~rmp/Welcome.html

Science

http://www.sciencemag.org/

• DESY Library Electronic Journals: Use this Web page for upto-date links to electronic journals of interest to particle physics. Contains a broader list than is included in this compilation:

http://www.desy.de/library/eljnl.html

• WWW Virtual Library of E-Journals: An excellent source to use when you are wondering if a title is available electronically. This Web site attempts to catalog all electronic journals, newsletters, magazines, and newspapers. Organized by broad subject or source e.g.: academic and reviewed journals, email newsletters, political journals. Also permits a title search across all categories:

http://www.edoc.com/ejournal/

7.2. Online Review Publications:

Net Advance of Physics: A free electronic service providing review
articles and tutorials in an encyclopedic format. Covers all areas
of physics. Includes hypertext links to the items reviewed when
available, including e-prints, book announcements, full text of
electronic books, and other resources. Welcomes contributions of
original review articles:

http://web.mit.edu/afs/athena.mit.edu/ user/r/e/redingtn/www/netadv/welcome.html

• Physics Reports:

http://www.elsevier.nl:80/inca/publications/store/5/0/5/7/0/3

• Reviews of Modern Physics

http://www.phys.washington.edu/~rmp/Welcome.html

Particle Physics: An independent online review service providing
the field of experimental and theoretical particle physics (including
cosmology) with a selected list of preprints from the established
public domain preprint servers. Selections are made by independent
nomination and then are reviewed by consulting editors. Listed
preprints include links to the papers' full text online versions.
 While hosted by a commercial site, this is an independent and
voluntary service for the international physics community.

http://www.eagle.co.uk/ppj/home.html

8. Particle Physics Education Sites:

8.1. Particle Physics Education: DOE Sites:

 Argonne National Laboratory Gee Whiz!: Includes links to other interesting and publically-accessible information such as the Rube Goldberg Machine Contest; Arts in Science; and the parts of the movie 'Chain Reaction' that were filmed at Argonne:

http://www.anl.gov/OPA/geewhiz.htm

 Brookhaven National Laboratory: Science Museum Programs: http://www.pubaf.bnl.gov/bnl_museum.htm

 Contemporary Physics Education Project (CPEP): Provides charts, brochures, Web links, and classroom activities:

http://pdg.lbl.gov/cpep.html

Center for Particle Astrophysics in Berkeley:
 http://physics7.berkeley.edu/home.html

Fermilab: Education and Outreach Resources for Particle Physicists: Outstanding collection of resources from the 'grandmother' of all physics lab educational programs:

http://www-ed.fnal.gov/trc/phys_resc.html

• Stanford Linear Accelerator Center: Check here soon for the Virtual Visitor's Center:

http://www.slac.stanford.edu/gen/edu/education.html

8.2. Particle Physics Education: Meta-Sites:

ESTEEM: The Department of Energy's exciting and visually appealing meta-site for Education in Science, Technology, Energy, Engineering and Math. Organized both textually and graphically as a 'city'. Users can explore resources by source (energy and science museums), by subject (windmills, 'playground'—virtual experiments, computers), or by targeted audience (university, middle or elementary students). Provides a rich access to many other sites including other meta-sites such as NASA and NSF and and the White House.

http://www.sandia.gov/ESTEEM/home.html

 PhysicsEd: Physics Education Resources: From a group renowned for doing research on physics education. Provides links to courses and topics; curriculum development; resources for demonstrations; software; research and projects in physics education; textbooks, journals, newsletters, and discussion groups; reference resources, organizations and companies; and much more:

http://www-hpcc.astro.washington.edu/scied/physics.html

8.3. Particle Physics Education: Ask-a-Scientist Sites:

 Ask A Scientist: Questions are answered by volunteer scientists throughout the world. Service provided by the Newton BBS through Argonne National Lab:

http://newton.dep.anl.gov/#AAS

 Mad Scientist's Network: Ask A Question: Responds to hundreds of questions a week. Contains an extensive archive of answered questions:

http://www.madsci.org/submit.html

 The Science Club: An excellent compilation of places to ask science questions. Organized by 'general' sites and then by sites that specialize in specific subjects or professions:

http://www.halcyon.com/sciclub/kidquest.html

8.4. Particle Physics Education: Experiments, Demos, & Fun

 Albert Einstein: A meta-Einstein site with links to dozens of places with resources by and about this scientist:

http://www/sas/upenn.edu/~smfriedm/einstein.html

Mad Scientist's Network: The Edible/Inedible Experiments
 Archive: Organized by scientific field. For each experiment, uses
 common materials and identifies whether the experiment is edible,
 inedible, or (in one case!?) 'partially drinkable':

http://www.madsci.org/experiments/

Physics Around the World: There are several useful links to collections of resources on this page, particularly the links to: Hands-On Experiments; Exercises and Problems; and Demonstrations.
 Targeted to the university level:

http://www.tp.umu.se/TIPTOP/paw/

 Science for the Millenium: Expo Web: Aimed at diverse audiences, this site focuses chiefly on astronomy, astrophysics, advanced computation, and virtual environments to showcase recent advances in these fields. The content is deep and the site is well-designed, permitting hierarchical and serendipitous use. Maintained by NCSA with significant help from the Electronic Visualization Laboratory:

http://www.ncsa.uiuc.edu/Cyberia/Expo/ information-pavilion.html

The Virtual Laboratory: A series of experiments using Java
that are targeted at physics classes for non-majors where there
are no physical lab sections. The experiments provide conceptual
interfaces to the equations of physics and represent interaction
with data that simulates a real physics experiment. Includes links
to a broader collection of physics experiments:

http://physics.hallym.ac.kr/education/oregon/ vlab/index.html

9. Software Directories:

 CERNLIB: CERN PROGRAM LIBRARY: Includes the CERN Program Library (Fortran), a new C++ Libraries (a C++ 'replacement' for CERNLIB), and CERNLIB and related Software including complete programs for GEANT, PAW and PAW++. Also includes links to commercial, free, and other software:

http://wwwcn.cern.ch/pl/index.html

 FREEHEP: A collection of software and information about software useful in high-energy physics. Searching can be done by title, subject, date acquired, or date updated, or by browsing an alphabetical list of all packages:

http://heplibw3.slac.stanford.edu:80/FIND/FHMAIN.HTML

FERMILAB SOFTWARE TOOLS PROGRAM: Software repository of Fermilab-developed software packages of value to the HEP community. Permits searching for packages by title or subject, by browsing FTP site, and by recent acquisitions:

http://www.fnal.gov/fermitools/

HEPIC: SOFTWARE AND TOOLS USED IN HEP RESEARCH:
 A meta-level site with links to major other sites of HEP-related software and computing tools:

http://www.hep.net/software.html

 PHYSICS AROUND THE WORLD: COMPUTING: An excellent meta-list with links to separate Web listings of: software archives; hands-on experiments; graphics & visualization; parallel computing; Java applets; and computing centers. Provides links to other Web compendia of software repositories and directories:

http://www.tp.umu.se/TIPTOP/paw/

SUMMARY TABLES OF PARTICLE PHYSICS

Gauge and	d :	Hi	ggs	I	309	SOI	ıs								. •						19
Leptons																					21
Quarks																					24
Mesons																					
Baryons																					50
Searches*																					61
Tests	0	fс	on	se	rva	ati	on	la	ws					•		•	•	•		•	62
1	M	esc	n '	\mathbf{Q}_1	uic	k l	Re	fei	ren	.ce	T	ab	le								48
1	Ва	гу	on	Ç)ui	ck	R	efe	re	nc	e .	[a]	ble	;	•						49

^{*} There are also search limits in the Summary Tables for the Gauge and Higgs Bosons, the Leptons, the Quarks, and the Mesons.

SUMMARY TABLES OF PARTICLE PROPERTIES

Extracted from the Particle Listings of the Review of Particle Physics Published in Eur. Jour. Phys. C3, 1 (1998) Available at http://pdg.lbl.gov

Particle Data Group Authors:

C. Caso, G. Conforto, A. Gurtu, M. Aguilar-Benitez, C. Amsler, R.M. Barnett, P.R. Burchat, C.D. Carone, O. Dahl, M. Doser, S. Eidelman, J.L. Feng, M. Goodman, C. Grab, D.E. Groom, K. Hagiwara, K.G. Hayes, J.J. Hernández, K. Hikasa, K. Honscheid, F. James, M.L. Mangano, A.V. Manohar, K. Mönig, H. Murayama, K. Nakamura, K.A. Olive, A. Piepke, M. Roos, R.H. Schindler, R.E. Shrock, M. Tanabashi, N.A. Törnqvist, T.G. Trippe, P. Vogel, C.G. Wohl, R.L. Workman, W.-M. Yao

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(c) Regents of the University of California (Approximate closing date for data: January 1, 1998)

GAUGE AND HIGGS BOSONS

$$I(J^{PC}) = 0.1(1^{-})$$

Mass $m < 2 \times 10^{-16}$ eV Charge $q < 5 \times 10^{-30}$ e Mean life $\tau = Stable$



$$I(J^P) = 0(1^-)$$

Mass m = 0 [a] SU(3) color octet

W

$$J = 1$$

Charge $= \pm 1 e$ Mass $m = 80.41 \pm 0.10 \text{ GeV}$ $m_Z - m_W = 10.78 \pm 0.10 \text{ GeV}$ $m_{W^+} - m_{W^-} = -0.2 \pm 0.6 \text{ GeV}$ Full width $\Gamma=2.06\pm0.06$ GeV

W modes are charge conjugates of the modes below.

W+ DECAY MODES	F	raction (Γ_I /	(F) C	onfidence level	(MeV/c
ℓ ⁺ ν	[b]	(10.74±0.	33) %		
e ⁺ ν		(10.9 ±0.	4)%		4020
$\mu^+ \nu$		(10.2 ±0.	5)%		4020
$\tau^+ \nu$		(11.3 ±0.	8)%		4018
hadrons		(67.8 ±1.	0)%		-
$\pi^+\gamma$		< 2.2	× 10	4 95%	4020

Z

J = 1

*Charge = 0 Mass $m = 91.187 \pm 0.007$ GeV [c] Full width $\Gamma=2.490\pm0.007~\text{GeV}$ $\Gamma(\ell^+\ell^-) = 83.83 \pm 0.27 \text{ MeV}^{[b]}$ $\Gamma(\text{invisible}) = 498.3 \pm 4.2 \text{ MeV}^{[d]}$ $\Gamma(\text{hadrons}) = 1740.7 \pm 5.9 \text{ MeV}$ $\Gamma(\mu^{+}\mu^{-})/\Gamma(e^{+}e^{-}) = 1.000 \pm 0.005$ $\Gamma(\tau^+\tau^-)/\Gamma(e^+e^-) = 0.998 \pm 0.005$ [e]

Average charged multiplicity

 $\langle N_{charged} \rangle = 21.00 \pm 0.13$

Couplings to leptons

 $g_V^\ell = -0.0377 \pm 0.0007$ $= -0.5008 \pm 0.0008$ $g^{\nu_e} = 0.53 \pm 0.09$ $g^{\nu_{\mu}} = 0.502 \pm 0.017$

Asymmetry parameters [f]

 $A_e = 0.1519 \pm 0.0034$ $A_{\mu} = 0.102 \pm 0.034$ $A_{\tau} = 0.143 \pm 0.008$ $A_c = 0.59 \pm 0.19$ $A_b = 0.89 \pm 0.11$

Charge asymmetry (%) at Z pole

 $A_{FB}^{(0t)} = 1.59 \pm 0.18$ $A_{FB}^{(0u)} = 4.0$ $\frac{100}{100} = 9.9 \pm 3.1 \quad (S = 1.2)$ $\binom{0c}{cc} = 7.32 \pm 0.58$ $= 10.02 \pm 0.28$

Z DECAY MODES	Fraction (Γ_I/Γ)	Confidence level	p (MeV/c)
e+e-	(3.366±0.008) %	45594
$\mu^+\mu^-$	(3.367±0.013) %	45593
τ+τ-	(3.360±0.015) %	45559
ℓ ⁺ ℓ ⁻	[b] (3.366±0.006) %	-
invisible	(20.01 ±0.16) %	_
hadrons	(69.90 ±0.15) %	-
(uū+c̄c̄)/2	(10.1 ±1.1) %	_
$(d\overline{d} + s\overline{s} + b\overline{b})/3$	(16.6 ±0.6) %	-
cc	(12.4 ±0.6) %	-
bŪ	(15.16 ±0.09) %	-
EEE	< 1.1	% 95%	-
$\pi^0\gamma$	< 5.2	× 10 ⁻⁵ 95%	45593
$\eta \gamma$	< 5.1	× 10 ⁻⁵ 95%	45592
$\omega \gamma$	< 6.5	×10 ⁻⁴ 95%	45590
$\eta'(958)\gamma$	< 4.2	× 10 ⁻⁵ 95%	45588
77	< 5.2	× 10 ⁻⁵ 95%	45594
$\gamma\gamma\gamma$	< 1.0	× 10 ⁻⁵ 95%	45594
$\pi^{\pm}W^{\mp}$	[g] < 7	× 10 ⁻⁵ 95%	10139
$ ho^{\pm}W^{\mp}$	[g] < 8.3	× 10 ⁻⁵ 95%	10114
$J/\psi(15)X$	(3.66 ±0.23		-
$\psi(2S)X$	(1.60 ±0.29) × 10 ⁻³	-
$\chi_{c1}(1P)X$	(2.9 ±0.7) × 10 ⁻³	-
$\chi_{c2}(1P)X$	< 3.2	× 10 ⁻³ 90%	-
$T(1S) \times + T(2S) \times + T(3S) \times$	(1.0 ±0.5) × 10 ⁻⁴	
$r(1\hat{s})x'$	< 5.5	× 10 ⁻⁵ 95%	_
<i>r</i> (2 <i>s</i>)x	< 1.39	× 10 ⁻⁴ 95%	_
τ(35)X	< 9.4	× 10 ⁻⁵ 95%	-
$(D^{0}/\overline{D}^{0}) \times$	(20.7 ±2.0) %	-
D±X	(12.2 ±1.7) %	-
D*(2010)±X	[g] (11.4 ±1.3) %	-
$B_s^0 \dot{X}$	seen	•	-
anomalous γ+ hadrons	[h] < 3.2	× 10 ⁻³ 95%	_
e+e-γ	[h] < 5.2	× 10 ⁻⁴ 95%	
$\mu^{+}\mu^{-}\gamma$	[h] < 5.6	× 10 ⁻⁴ 95%	45593
$\tau^+\tau^-\gamma$	[h] < 7.3	× 10 ⁻⁴ 95%	
$\ell^+\ell^-\gamma\gamma$	[/] < 6.8	× 10 ⁻⁶ 95%	
α α	[I] < 5.5	× 10 ⁻⁶ 95%	-

Gauge & Higgs Boson Summary Table

$ u \overline{ u} \gamma \gamma$		[/] < 3.3	1 × 10 ⁻⁶	95%	45594
$e^{\pm}\mu^{\mp}$	LF	[g] < 1.7	7 × 10 ⁻⁶	95%	45593
$e^{\pm} au^{\mp}$	LF	[g] < 9.8	8 × 10 ⁻⁶	95%	45576
$\mu^{\pm} \tau^{\mp}$	LF	[g] < 1.2	2 × 10 ⁻⁵	95%	45576

Higgs Bosons — H^0 and H^{\pm} , Searches for

```
H^0 Mass m > 77.5 GeV, CL = 95%
```

 H_1^0 in Supersymmetric Models $(m_{H_1^0} < m_{H_2^0})$

Mass m > 62.5 GeV, CL = 95%

A⁰ Pseudoscalar Higgs Boson in Supersymmetric Models [/]

Mass m > 62.5 GeV, CL = 95% $tan \beta > 1$

 H^{\pm} Mass m > 54.5 GeV, CL = 95%

See the Particle Listings for a Note giving details of Higgs Bosons.

Heavy Bosons Other Than Higgs Bosons, Searches for

Additional W Bosons

W_R — right-handed W

Mass m > 549 GeV

(assuming light right-handed neutrino)

W' with standard couplings decaying to $e \nu$, $\mu \nu$

Mass m > 720 GeV. CL = 95%

Additional Z Bosons

 Z'_{SM} with standard couplings

Mass m > 690 GeV, CL = 95% ($p\bar{p}$ direct search)

Mass m > 779 GeV, CL = 95% (electroweak fit)

 Z_{LR} of $SU(2)_L \times SU(2)_R \times U(1)$

(with $g_L = g_R$)

Mass m > 630 GeV, CL = 95% ($p\overline{p}$ direct search)

Mass m > 389 GeV, CL = 95% (electroweak fit)

 Z_{χ} of SO(10) \rightarrow SU(5)×U(1) χ

(coupling constant derived from G.U.T.)

Mass m > 595 GeV, CL = 95% ($p\overline{p}$ direct search)

Mass m > 321 GeV, CL = 95% (electroweak fit)

 Z_{ψ} of $E_6 \rightarrow SO(10) \times U(1)_{\psi}$

(coupling constant derived from G.U.T.)

Mass m > 590 GeV, CL = 95% ($p\bar{p}$ direct search)

Mass m > 160 GeV, CL = 95% (electroweak fit)

 Z_{η} of $E_6 \rightarrow SU(3)\times SU(2)\times U(1)\times U(1)_{\eta}$

(coupling constant derived from G.U.T.);

charges are $Q_{\eta}=\sqrt{3/8}Q_{\chi}-\sqrt{5/8}Q_{\psi}$)

Mass m > 620 GeV, CL = 95% ($p\bar{p}$ direct search)

Mass m > 182 GeV, CL = 95% (electroweak fit)

Scalar Leptoquarks

Mass m > 225 GeV, CL = 95% (1st generation, pair prod.)

Mass m > 237 GeV, CL = 95% (1st gener, single prod.)

Mass m > 119 GeV, CL = 95% (2nd gener., pair prod.)

Mass m > 73 GeV, CL = 95% (2nd gener., single prod.)

Mass m > 99 GeV, CL = 95% (3rd gener., pair prod.)

(See the Particle Listings for assumptions on leptoquark quantum numbers and branching fractions.)

Axions (A^0) and Other Very Light Bosons, Searches for

The standard Peccei-Quinn axion is ruled out. Variants with reduced couplings or much smaller masses are constrained by various data. The Particle Listings in the full *Review* contain a Note discussing axion searches.

The best limit for the half-life of neutrinoless double beta decay with Majoron emission is $> 7.2 \times 10^{24}$ years (CL = 90%).

NOTES

In this Summary Table:

When a quantity has "(S = ...)" to its right, the error on the quantity has been enlarged by the "scale factor" S, defined as $S = \sqrt{\chi^2/(N-1)}$, where N is the number of measurements used in calculating the quantity. We do this when S > 1, which often indicates that the measurements are inconsistent. When S > 1.25, we also show in the Particle Listings an ideogram of the measurements. For more about S, see the Introduction.

A decay momentum p is given for each decay mode. For a 2-body decay, p is the momentum of each decay product in the rest frame of the decaying particle. For a 3-or-more-body decay, p is the largest momentum any of the products can have in this frame.

- [a] Theoretical value. A mass as large as a few MeV may not be precluded.
- [b] ℓ indicates each type of lepton $(e, \mu, \text{ and } \tau)$, not sum over them.
- [c] The Z-boson mass listed here corresponds to a Breit-Wigner resonance parameter. It lies approximately 34 MeV above the real part of the position of the pole (in the energy-squared plane) in the Z-boson propagator.
- [d] This partial width takes into account Z decays into $\nu\overline{\nu}$ and any other possible undetected modes.
- [e] This ratio has not been corrected for the τ mass.
- [f] Here $A \equiv 2g_V g_A / (g_V^2 + g_A^2)$.
- [g] The value is for the sum of the charge states of particle/antiparticle states indicated.
- [h] See the Z Particle Listings for the γ energy range used in this measurement.
- [i] For $m_{\gamma\gamma}=(60\pm 5)$ GeV.
- [j] The limits assume no invisible decays.

LEPTONS

e

$$J=\frac{1}{2}$$

Mass $m=0.51099907\pm0.00000015$ MeV $^{[a]}=(5.485799111\pm0.000000012)\times10^{-4}$ u $(m_{e^+}-m_{e^-})/m<4\times10^{-8}$, CL =90% $|q_{e^+}+q_{e^-}|/e<4\times10^{-8}$ Magnetic moment $\mu=1.001159652193\pm0.000000000010$ $\mu_{\mathcal{B}}$ $(g_{e^+}-g_{e^-})$ / $g_{average}=(-0.5\pm2.1)\times10^{-12}$ Electric dipole moment $d=(0.18\pm0.16)\times10^{-26}$ ecm Mean life $\tau>4.3\times10^{23}$ yr, CL =68% $^{[b]}$

μ

$$J=\frac{1}{2}$$

Mass $m=105.658389\pm0.000034$ MeV $^{[c]}=0.113428913\pm0.000000017$ u Mean life $\tau=(2.19703\pm0.00004)\times10^{-6}$ s $\tau_{\mu^+}/\tau_{\mu^-}=1.00002\pm0.00008$ $_{CT}=658.654$ m Magnetic moment $\mu=1.0011659230\pm0.00000000084$ $e\hbar/2m_{\mu}$ ($g_{\mu^+}-g_{\mu^-}$) / $g_{\rm average}=(-2.6\pm1.6)\times10^{-8}$ Electric dipole moment $d=(3.7\pm3.4)\times10^{-19}$ e cm

Decay parameters [d]

 $\begin{array}{l} \rho = 0.7518 \pm 0.0026 \\ \eta = -0.007 \pm 0.013 \\ \delta = 0.749 \pm 0.004 \\ \xi P_{\mu} = 1.003 \pm 0.008 \\ \xi^{\prime} = 1.003 \pm 0.008 \\ \xi^{\prime} = 1.00 \pm 0.04 \\ \xi^{\prime\prime} = 0.7 \pm 0.4 \\ \alpha/A = (0 \pm 4) \times 10^{-3} \\ \alpha^{\prime}/A = (0 \pm 4) \times 10^{-3} \\ \beta/A = (4 \pm 6) \times 10^{-3} \\ \beta^{\prime}/A = (2 \pm 6) \times 10^{-3} \\ \overline{\eta} = 0.02 \pm 0.08 \end{array}$

 μ^+ modes are charge conjugates of the modes below.

μ ⁻ DECAY MODES		Fraction (Γ_I/Γ)	Confidence level	(MeV/c)
$e^- \overline{\nu}_e \nu_\mu$		≈ 100%			53
$e^- \overline{ u}_e u_\mu \gamma$		[f] (1.4±0	.4) %		53
$e^-\overline{\nu}_e u_\mue^+e^-$		[g] (3.4±0).4) × 10 ^{-!}	5	53
Lepton	Family :	number (<i>LF</i>)	violating	modes	
$e^- \nu_e \overline{\nu}_\mu$	ĻF	[h] < 1.2	%	90%	53
$e^-\gamma$	ĹF	< 4.9	× 10 ⁻²	11 90%	53
e ⁻ γ e ⁻ e ⁺ e ⁻	LF	< 1.0	× 10 ⁻³	12 9 0%	53
$e^-2\gamma$	LF	< 7.2	× 10 ⁻²	11 90%	53
,	L1	\ 1.Z	A 10	3076	



Mass $m=1777.05^{+0.29}_{-0.26}~{\rm MeV}$ Mean life $\tau=(290.0\pm1.2)\times10^{-15}~{\rm s}$ $c\tau=86.93~\mu{\rm m}$

Magnetic moment anomaly >-0.052 and <0.058, CL = 95% Electric dipole moment d>-3.1 and $<3.1\times10^{-16}$ ecm, CL = 95%

Weak dipole moment

 $\mathrm{Re}(d_{\tau}^{W}) < 0.56 \times 10^{-17} \ \mathrm{e\,cm}, \ \mathrm{CL} = 95\% \ \mathrm{Im}(d_{\tau}^{W}) < 1.5 \times 10^{-17} \ \mathrm{e\,cm}, \ \mathrm{CL} = 95\% \ \mathrm{CL}$

Weak anomalous magnetic dipole moment

 $Re(\alpha_{\tau}^{W}) < 4.5 \times 10^{-3}, CL = 90\%$ $Im(\alpha_{\tau}^{W}) < 9.9 \times 10^{-3}, CL = 90\%$

Decay parameters

See the au Particle Listings for a note concerning au-decay parameters.

$$\begin{split} \rho^{\tau}(e \text{ or } \mu) &= 0.748 \pm 0.010 \\ \rho^{\tau}(e) &= 0.745 \pm 0.012 \\ \rho^{\tau}(\mu) &= 0.741 \pm 0.030 \\ \xi^{\tau}(e \text{ or } \mu) &= 1.01 \pm 0.04 \\ \xi^{\tau}(e) &= 0.98 \pm 0.05 \\ \xi^{\tau}(\mu) &= 1.07 \pm 0.08 \\ \eta^{\tau}(e \text{ or } \mu) &= 0.01 \pm 0.07 \\ \eta^{\tau}(\mu) &= -0.10 \pm 0.18 \\ (\delta \xi)^{\tau}(e \text{ or } \mu) &= 0.749 \pm 0.026 \\ (\delta \xi)^{\tau}(e) &= 0.733 \pm 0.033 \\ (\delta \xi)^{\tau}(\mu) &= 0.78 \pm 0.05 \\ \xi^{\tau}(\pi) &= 0.99 \pm 0.05 \\ \xi^{\tau}(\rho) &= 0.996 \pm 0.010 \\ \xi^{\tau}(a_1) &= 1.02 \pm 0.04 \\ \xi^{\tau}(\text{all hadronic modes}) &= 0.997 \pm 0.009 \end{split}$$

 au^+ modes are charge conjugates of the modes below. " h^\pm " stands for π^\pm or K^\pm . " ℓ " stands for e or μ . "Neutral" means neutral hadron whose decay products include γ 's and/or π^0 's.

r- DECAY MODES	F	raction (Γ_f/Γ)	Scale factor/ Confidence level	p (MeV/c)
Modes with	1 004	e charged partick	•	
particle ⁻ ≥ 0 neutrals $\geq 0K_L^0\nu_{\tau}$ ("1-prong")		(84.71± 0.13) %		-
particle ≥ 0 neutrals $\geq 0K^0\nu_{\tau}$		(85.30± 0.13) %	S=1.2	_
$\mu^- \overline{\nu}_\mu \overline{\nu}_\tau$	[/]	(17.37± 0.09) %		885
$\mu^- \overline{\nu}_\mu \nu_\tau \gamma$	[g]	$(3.0 \pm 0.6) \times$	10-3	_
$e^-\overline{\nu}_e^{}\nu_{\tau}$	[/]	(17.81± 0.07) %		889
$h^- \geq 0$ neutrals $\geq 0 K_L^0 \nu_{ au}$	•	(49.52± 0.16) %	S=1.2	_
$h^- \geq 0K_I^0 \nu_{\tau}$		(12.32± 0.12) %	S=1.5	-
$h^- u_ au$		(11.79± 0.12) %	S=1.5	_
$\pi^{-} \nu_{ au}$	[/]	(11.08± 0.13) %	S=1.4	883
$K^- u_{ au}$	[/]	(7.1 ± 0.5)×	₁₀ -3	820
$h^- \geq 1$ neutrals $ u_ au$		(36.91± 0.17) %	S=1.2	-
$h^-\pi^0 u_{\overline{t}}$		(25.84± 0.14) %	S=1.1	-
$\pi^-\pi^0 u_{ au}$	[/]	(25.32 ± 0.15) %	S=1.1	878
$\pi^-\pi^0$ non- $\rho(770)\nu_{ au}$		$(3.0 \pm 3.2) \times$		878
$\kappa^-\pi^0 u_{\tau}$	[/]	(5.2 ± 0.5)×		814
$h^- \geq 2\pi^0 \nu_{ au}$		(10.79± 0.16) %		-
$h^{-}2\pi^{0}\nu_{\tau}$		(9.39± 0.14) %		_
$h^{-}2\pi^{0}\nu_{\tau}(ex.K^{0})$		(9.23± 0.14) %		-
$\pi^{-}2\pi^{0}\nu_{\tau}(ex.K^{0})$	[/]	(9.15 ± 0.15) %		862
$K^{-}2\pi^{0}\nu_{\tau}(ex.K^{0})$	[1]	$(8.0 \pm 2.7) \times$		796
$h^- \geq 3\pi^0 u_ au$ $h^- 3\pi^0 u_ au$		(1.40± 0.11) %		_
$\frac{n}{\pi^{-}}3\pi^{0}\nu_{\tau}$ (ex. K^{0})	t n	(1.23 ± 0.10) %		836
, , ,	[/]			
$K^-3\pi^0\nu_{\tau}$ (ex. K^0)	[/]	$(4.3 \ ^{+10.0}_{-2.9}) \times$	10-4	766
$h^-4\pi^0 u_{ au}({ m ex}.K^0)$		(1.7 ± 0.6)×		_
$h^- 4\pi^0 \nu_{\tau} (ex.K^0, \eta)$	[/]	$(1.1 \pm 0.6) \times$	₁₀ -3	-
$K^- \geq 0\pi^0 \geq 0K^0 \nu_{\tau}$		(1.66± 0.10) %	•	-
$K^- \geq 1 \; (\pi^0 \; \text{or} \; K^0) \; \nu_{\tau}$		(9.5 ± 1.0) ×	10-3	-
Ma	مماء	with <i>K</i> ⁰ 's		
K^0 (particles) $^-\nu_{ au}$		(1.66 ± 0.09) %	S=1.4	_
$h^-\overline{K}^0 \ge 0$ neutrals $\ge 0K_L^0\nu_{\tau}$		(1.62 ± 0.09) %		_
$h^-\overline{K^0}_{\nu_{\tau}}$		(9.9 ± 0.8)×		_
$\pi^-\overline{\mathcal{K}}^{\acute{0}} u_{oldsymbol{ au}}$	ſΛ	(8.3 ± 0.8)×		812
$\pi^-\overline{K}^0$	• •		10 ⁻³ CL=95%	812
$(\text{non-}K^*(892)^-)\nu_{\tau}$				
$K^-K^0\nu_{\tau}$	[/]	(1.59 ± 0.24) ×	10-3	737
$h^{-}\overline{K}{}^{0}\pi^{0}\nu_{\tau}$		(5.5 ± 0.5) ×		-
$\pi^-\overline{\mathcal{K}}{}^0\pi^0 u_{ au}$	[/]	(3.9 ± 0.5) ×		794
$\overline{K}^0 \rho^- \nu_{\tau}$		$(1.9 \pm 0.7) \times$		-
$K^-K^0\pi^0\nu_{ au}$	[/]	(1.51 ± 0.29) ×		685
$\pi^-\overline{K}{}^0\pi^0\pi^0\nu_{\tau}$		(6 ± 4)×		-
$K^{-}K^{0}\pi^{0}\pi^{0}\nu_{\tau}$			10 ⁻⁴ CL=95%	_
$\pi^- {\mathcal K}^0 \overline{\mathcal K}{}^0 u_ au$	[/]	(1.21 ± 0.21) ×	10 ⁻³ \$=1.2	682

Lepton Summary Table

```
\pi^{-}K_{S}^{0}K_{S}^{0}\nu_{\tau}
                                                          (3.0 \pm 0.5) \times 10^{-4}
                                                                                                                                  K_2^*(1430)^-\nu_{\tau}
                                                                                                                                                                                          < 3
                                                                                                                                                                                                                \times 10^{-3} CL=95%
           \pi^- K_5^{\vec{0}} K_L^{\vec{0}} \nu_{\tau}
                                                          ( 6.0~\pm~1.0 ) \times\,10^{-4}
                                                                                                                                                                                                                × 10<sup>-4</sup> CL=95%
                                                                                              S=1.2
                                                                                                                                  \eta \pi^{-} \nu_{\tau}
\eta \pi^{-} \pi^{0} \nu_{\tau}
                                                                                                                                                                                          < 1.4
                                                                                                                                                                                                                                                 798
       \pi^{-}K_{S}^{0}K_{S}^{0}\pi^{0}\nu_{\tau}
\pi^{-}K_{S}^{0}K_{L}^{0}\pi^{0}\nu_{\tau}
                                                                                                                                                                                      [/] ( 1.74 \pm 0.24) \times 10^{-3}
                                                                             × 10<sup>-4</sup> CL=95%
                                                        < 2.0
                                                                                                                                                                                                                                                778
                                                                                                                                  \eta \pi^{-} \pi^{0} \pi^{0} \nu_{\tau}
                                                                                                                                                                                            (1.4 \pm 0.7) \times 10^{-4}
                                                         ( 3.1 \pm 1.2 ) \times 10<sup>-4</sup>
                                                                                                                                                                                                                                                 746
K^-K^0 \ge 0 neutrals \nu_{\tau}

K^0 h^+ h^- h^- \ge 0 neutrals \nu_{\tau}
                                                                                                                                  \eta K^- \nu_{\tau}
                                                                                                                                                                                            (2.7 \pm 0.6) \times 10^{-4}
                                                         ( 3.1 \pm 0.4 ) \times\,10^{-3}
                                                                                                                                                                                                                                                 720
                                                                                                                                                                                                               × 10<sup>-3</sup>
                                                                                                                                  \eta \pi^+ \pi^- \pi^- \geq 0 neutrals \nu_{\tau}
                                                                                                                                                                                          < 3
                                                                                                                                                                                                                             CL=90%
                                                                           × 10<sup>-3</sup>
                                                        < 1.7
                                                                                           CL=95%
                                                                                                                                     \eta\pi^-\pi^+\pi^-\nu_{	au}
                                                                                                                                                                                           (3.4 \pm 0.8) \times 10^{-4}
   K^0 h^+ h^- h^- \nu_{\tau}
                                                         (2.3 \pm 2.0) \times 10^{-4}
                                                                                                                                                                                                                ×. 10<sup>-4</sup>
                                                                                                                                     \eta a_1(1260)^- \nu_{\tau} \rightarrow \eta \pi^- \rho^0 \nu_{\tau}
                                                                                                                                                                                          < 3.9
                                                                                                                                                                                                                            CL=90%
                               Modes with three charged particles
                                                                                                                                  \begin{array}{l} \eta \eta \pi^- \nu_\tau \\ \eta \eta \pi^- \pi^0 \nu_\tau \end{array}
                                                                                                                                                                                                                × 10<sup>-4</sup>
                                                                                                                                                                                          < 1.1
                                                                                                                                                                                                                             CL=95%
                                                                                                                                                                                                                                                 637
h^-h^-h^+ \geq 0 neut. \nu_{\tau} ("3-prong")
                                                         (15.18± 0.13) %
                                                                                                                                                                                                                × 10<sup>-4</sup>
                                                                                               5=1.2
                                                                                                                                                                                                                            CL=95%
                                                                                                                                                                                          < 2.0
                                                                                                                                                                                                                                                 559
   h^-\,h^-\,h^+\,\geq\,0 neutrals 
u_{	au}
                                                                                                                                                                                                                × 10<sup>-5</sup>
                                                          (14.60 ± 0.13) %
                                                                                                                                  \eta'(958)\pi^{-}\nu_{\tau}
                                                                                              S=1.2
                                                                                                                                                                                          < 7.4
                                                                                                                                                                                                                            CL=90%
        (ex. K_5^0 \rightarrow \pi^+\pi^-)
                                                                                                                                  \eta'(958)\pi^{-}\pi^{0}\nu_{\tau}
                                                                                                                                                                                                                × 10<sup>-5</sup>
                                                                                                                                                                                          < 8.0
                                                                                                                                                                                                                            CL=90%
   \pi^-\pi^+\pi^- \ge 0 neutrals \nu_{\tau}
                                                                                                                                                                                                                × 10<sup>-4</sup>
                                                          (14.60 \pm 0.14)\%
                                                                                                                                  \phi \pi^- \nu_{\tau}
                                                                                                                                                                                          < 2.0
                                                                                                                                                                                                                            CL=90%
                                                                                                                                                                                                                                                 585
   h^- h^- h^+ 
u_	au
                                                                                                                                                                                                                × 10<sup>-5</sup>
                                                                                                                                  \phi K^- \nu_{\tau}
                                                          (9.96 \pm 0.10)\%
                                                                                              S=1.1
                                                                                                                                                                                          < 6.7
                                                                                                                                                                                                                            CL=90%
   h^- h^- h^+ \nu_{\tau} (ex.K^0)
                                                          ( 9.62 ± 0.10) %
                                                                                                                                  f_1(1285)\pi^-\nu_{\tau}
                                                                                                                                                                                            ( 5.8 \pm 2.3 ) \times 10<sup>-4</sup>
                                                                                              S=1.1
   h^- h^- h^+ \nu_{\tau} (\text{ex.} K^0, \omega)
                                                          ( 9.57 ± 0.10) %
                                                                                               S=1.1
                                                                                                                                      f_1(1285)\pi^-\nu_{\tau} \to
                                                                                                                                                                                            (1.9 \pm 0.7) \times 10^{-4}
   \pi^-\pi^+\pi^-\nu_{\tau}
                                                                                                                                          \eta \pi^- \pi^+ \pi^- \nu_{\tau}
                                                          ( 9.56± 0.11) %
                                                                                              S=1.1
   \pi^-\pi^+\pi^-\nu_{\tau}(ex.K^0)
                                                                                                                                  h^-\omega \geq 0 neutrals \nu_{\tau}
                                                          (9.52 \pm 0.11)\%
                                                                                                                 _
                                                                                              5=1.1
                                                                                                                                                                                            (2.36 \pm 0.08)\%
   \pi^-\pi^+\pi^-\nu_{\tau}(ex.K^0,\omega)
                                                                                                                                     h^-\omega \nu_{	au}
h^-\omega \pi^0 \nu_{	au}
                                                        ( 9.23± 0.11) %
                                                                                              5=1.1
                                                                                                                                                                                      [/] ( 1.93 ± 0.06) %
   h^-h^-h^+\geq 1 neutrals 
u_	au
                                                                                                                                                                                      [1] ( 4.3 \pm 0.5 ) \times 10<sup>-3</sup>
                                                          (5.18 \pm 0.11)\%
                                                                                               5=1.2
                                                                                                                 _
    h^-h^-h^+ \ge 1 neutrals \nu_{\tau} (ex.
                                                                                                                                      h^-\omega 2\pi^0\nu_{\tau}
                                                          (4.98 \pm 0.11)\%
                                                                                              S=1.2
                                                                                                                                                                                            (1.9 \pm 0.8) \times 10^{-4}
        K_5^0 \rightarrow \pi^+\pi^-
                                                                                                                                                       Lepton Family number (LF), Lepton number (L),
       h^{-}h^{-}h^{+}\pi^{0}\nu_{\tau}
                                                          (4.50 \pm 0.09)\%
                                                                                              S=1.1
                                                                                                                                                              or Baryon number (B) violating modes
       h^- h^- h^+ \pi^0 \nu_{\tau} (ex. K^0)
                                                          (4.31 \pm 0.09)\%
                                                                                              S=1.1
                                                                                                                                                (In the modes below, \ell means a sum over e and \mu modes)
       h^- h^- h^+ \pi^0 \nu_\tau (ex. K^0, \omega)
                                                          ( 2.59± 0.09) %
       \pi^-\pi^+\pi^-\pi^0\nu_{	au}
                                                          (4.35 \pm 0.10)\%
                                                                                                                                              L means lepton number violation (e.g. \tau^- \rightarrow e^+ \pi^- \pi^-). Following
       \pi^-\pi^+\pi^-\pi^0\nu_{\tau}(ex.K^0)
                                                          ( 4.22 ± 0.10) %
                                                                                                                                              common usage, LF means lepton family violation and not lepton number
       \pi^{-}\pi^{+}\pi^{-}\pi^{0}\nu_{\tau}(ex.K^{0},\omega)
                                                                                                                                              violation (e.g. \tau^- \rightarrow e^- \pi^+ \pi^-). B means baryon number violation.
                                                    [i] (2.49 \pm 0.10)\%
       h^-(\rho\pi)^0\nu_\tau
                                                                                                                                  e^-\gamma
                                                                                                                                                                                                                \times 10^{-6} CL=90%
                                                                                                                                                                           LF
                                                                                                                                                                                          < 2.7
                                                         ( 2.88 ± 0.35) %
                                                                                                                                                                                                                                                888
                                                                                                                                  e^{-\gamma}
                                                                                                                                                                                                                × 10<sup>-6</sup> CL=90%
           (a_1(1260)h)^-\nu_{\tau}
                                                        < 2.0
                                                                                           CL=95%
                                                                                                                                                                           1 F
                                                                                                                                                                                          < 3.0
                                                                                                                                                                                                                                                885
                                                                                                                                                                                                                × 10<sup>-6</sup>
           h^-\rho\pi^0\nu_{\tau}
                                                                                                                                                                            LF
                                                                                                                                                                                          < 3.7
                                                                                                                                                                                                                            CL=90%
                                                          (1.35 \pm 0.20)\%
                                                                                                                                  \mu^-\pi^0
          h^-\rho^+h^-\nu_{	au}
                                                                                                                                                                                                                ×.10<sup>-6</sup>
                                                                                                                                                                                                                            CL=90%
                                                                                                                                                                           LF
                                                          ( 4.5 \pm 2.2 ) \times\,10^{-3}
                                                                                                                 _
                                                                                                                                                                                          < 4.0
                                                                                                                                                                                                                                                880
                                                                                                                                  e- K0
                                                                                                                                                                                                               × 10<sup>-3</sup>
                                                                                                                                                                           LF
           h^-\rho^-h^+\nu_{	au}
                                                          (1.17 \pm 0.23)\%
                                                                                                                                                                                          < 1.3
                                                                                                                                                                                                                            CL=90%
                                                                                                                                                                                                                                                819
                                                                                                                                  \mu^- K^0
                                                                                                                                                                                                                × 10<sup>-3</sup> CL=90%
       h^- h^- h^+ 2\pi^0 \nu_{\tau}
                                                          ( 5.4 \pm 0.4 ) \times\,10^{-3}
                                                                                                                                                                           LF
                                                                                                                                                                                          < 1.0
                                                                                                                                                                                                                                                815
       h^- h^- h^+ 2\pi^0 \nu_{\tau} (\text{ex}.K^0)
                                                                                                                                  e^-\eta
                                                                                                                                                                            LF
                                                                                                                                                                                                                \times 10^{-6}
                                                          ( 5.3 \pm 0.4 ) \times\,10^{-3}
                                                                                                                 _
                                                                                                                                                                                          < 8.2
                                                                                                                                                                                                                             CL=90%
                                                                                                                                                                                                                                                 804
                                                                                                                                                                                                               × 10<sup>-6</sup>
       h^- h^- h^+ 2\pi^0 \nu_\tau (ex.K^0, \omega, \eta) [i] (1.1 ± 0.4) × 10<sup>-3</sup>
                                                                                                                                  \mu^- \eta
e^- \rho^0
                                                                                                                                                                           LF
                                                                                                                                                                                          < 9.6
                                                                                                                                                                                                                             CL=90%
                                                                                                                                                                                                                                                800
                                                                                                                                                                                                                × 10<sup>-6</sup>
                                                                                                                                                                           LF
                                                                                                                                                                                          < 2.0
                                                                                                                                                                                                                            CL=90%
                                                                                                                                                                                                                                                722
                                                    [/] ( 1.4 ^+ ^{0.9}_{-} ) 	imes 10^{-3}
       h^- h^- h^+ \ge 3\pi^0 \nu_{\tau}
                                                                                              S=1.5
                                                                                                                                  \mu^- \rho^0
                                                                                                                                                                                                                × 10<sup>-6</sup>
                                                                                                                                                                           LF
                                                                                                                                                                                                                            CL=90%
                                                                                                                                                                                          < 6.3
                                                                                                                                                                                                                                                718
           h^- h^- h^+ 3\pi^0 \nu_{\tau}
                                                          ( 2.9~\pm~0.8 ) \times\,10^{-4}
                                                                                                                 _
                                                                                                                                  e^{-}K^{*}(892)^{0}
                                                                                                                                                                                                               × 10<sup>-6</sup>
                                                                                                                                                                           LF
                                                                                                                                                                                          < 5.1
                                                                                                                                                                                                                             CL=90%
                                                                                                                                                                                                                                                663
   K^-\,h^+\,h^- \ge 0 neutrals \nu_{	au}
                                                          (5.4 \pm 0.7) \times 10^{-3}
                                                                                                                                  \mu^- K^* (892)^0
                                                                                                                                                                                                                × 10<sup>-6</sup>
                                                                                              S=1.1
                                                                                                                                                                           LF
                                                                                                                                                                                          < 7.5
                                                                                                                                                                                                                            CL=90%
                                                                                                                                                                                                                                                657
       K^-\pi^+\pi^- \geq 0 neutrals \nu_{	au}
                                                                                                                                  e-K*(892)0
                                                          (3.1 \pm 0.6) \times 10^{-3}
                                                                                                                                                                                                                × 10<sup>-6</sup>
                                                                                              S=1.1
                                                                                                                                                                           LF
                                                                                                                                                                                          < 7.4
                                                                                                                                                                                                                            CL=90%
                                                                                                                                                                                                                                                663
           K^-\pi^+\pi^-\nu_{\tau}
                                                          ( 2.3 \pm 0.4 ) \times\,10^{-3}
                                                                                                                                  \mu^{-}\overline{K}^{*}(892)^{0}
                                                                                                                                                                                                                × 10<sup>-6</sup>
                                                                                                                                                                           LF
                                                                                                                                                                                          < 7.5
                                                                                                                                                                                                                             CL=90%
                                                                                                                                                                                                                                                657
          K^{-}\pi^{+}\pi^{-}\nu_{\tau} (ex.K^{0})

K^{-}\pi^{+}\pi^{-}\pi^{0}\nu_{\tau}
                                                    [/] ( 1.8 \pm 0.5 ) \times\,10^{-3}
                                                                                                                                  e^-\phi
                                                                                                                                                                                                                × 10<sup>-6</sup>
                                                                                                                                                                           LF
                                                                                                                                                                                          < 6.9
                                                                                                                                                                                                                            CL=90%
                                                                                                                                                                                                                                                596
                                                         (8 \pm 4) \times 10^{-4}
                                                                                                                                                                                                                × 10<sup>-6</sup>
                                                                                                                                  \mu^-\phi
                                                                                                                                                                           LF
                                                                                                                                                                                          < 7.0
                                                                                                                                                                                                                            C1 = 90\%
                                                                                                                                                                                                                                                590
          K^-\pi^+\pi^-\pi^0\nu_{	au} (ex.K^0)
                                                                                                                                                                                                                × 10<sup>-4</sup>
                                                    [/] (2.4 + 4.3 \\ -1.6) \times 10^{-4}
                                                                                                                                  \pi^- \gamma \\ \pi^- \pi^0
                                                                                                                                                                                          < 2.8
                                                                                                                                                                            L
                                                                                                                                                                                                                            CL=90%
                                                                                                                                                                                                                                                883
                                                                                                                                                                                                                × 10<sup>-4</sup>
                                                                                                                                                                                                                            CL=90%
                                                                                                                                                                           L
                                                                                                                                                                                          < 3.7
                                                                                                                                                                                                                                                878
       K^-\pi^+K^- \ge 0 neut. \nu_{	au}
                                                                            × 10<sup>-4</sup>
                                                       < 9
                                                                                          CL=95%
                                                                                                                                                                                                               × 10<sup>-6</sup>
                                                                                                                                  e^{-}e^{+}e^{-}
       K^-K^+\pi^- \ge 0 neut. \nu_{	au}
                                                                                                                                                                           LF
                                                          ( 2.3 \pm 0.4 ) \times 10<sup>-3</sup>
                                                                                                                                                                                          < 2.9
                                                                                                                                                                                                                            CL=90%
                                                                                                                                                                                                                                                888
                                                                                                                 _
                                                                                                                                  e^-\,\mu^+\,\mu^-
                                                                                                                                                                                                                × 10<sup>-6</sup>
          K^{-}K^{+}\pi^{-}\nu_{\tau}
K^{-}K^{+}\pi^{-}\pi^{0}\nu_{\tau}
                                                                                                                                                                            LF
                                                                                                                                                                                          < 1.8
                                                                                                                                                                                                                            CL=90%
                                                                                                                                                                                                                                                882
                                                    [/] (1.61 \pm 0.26) \times 10^{-3}
                                                                                                               685
                                                                                                                                                                                                                × 10<sup>-6</sup>
                                                                                                                                  e^{+}\mu^{-}\mu^{-}
                                                                                                                                                                           LF
                                                                                                                                                                                                                            CL=90%
                                                                                                                                                                                          < 1.5
                                                                                                                                                                                                                                                882
                                                    [/] ( 6.9 \pm 3.0 ) \times 10^{-4}
                                                                         × 10<sup>-3</sup> CL=95%
                                                                                                                                                                                                                × 10<sup>-6</sup>
                                                                                                                                  \mu^{-}e^{+}e^{-}
                                                                                                                                                                           LF
                                                                                                                                                                                          < 1.7
                                                                                                                                                                                                                            CL=90%
                                                                                                                                                                                                                                                885
       K^-K^+K^- \ge 0 neut. \nu_{\tau}
                                                        < 2.1
           K^-K^+K^-\nu_{\tau}
                                                                                                                                  \mu^{+}e^{-}e^{-}
                                                                                                                                                                           LF
                                                                                                                                                                                                                \times 10^{-6}
                                                                                                                                                                                          < 1.5
                                                                                                                                                                                                                            CL=90%
                                                                                                                                                                                                                                                885
                                                                             × 10<sup>-4</sup> CL=90%
                                                        < 1.9
                                                                                                                                                                                                                × 10<sup>-6</sup>
                                                                                                                                  \mu^{-} \mu^{+} \mu^{-}
                                                                                                                                                                           LF
                                                                                                                                                                                          < 1.9
                                                                                                                                                                                                                            C1 = 90\%
                                                                                                                                                                                                                                                873
                                                                              × 10<sup>-3</sup> CL=95%
   \pi^- K^+ \pi^- \ge 0 neut. \nu_{	au}
                                                                                                                 _
                                                        < 2.5
                                                                                                                                                                                                                × 10<sup>-6</sup>
                                                                                                                                  e^{-}\pi^{+}\pi^{-}
                                                                                                                                                                            LF
e^-e^-e^+\overline{\nu}_e\nu_{	au}
                                                                                                                                                                                          < 2.2
                                                                                                                                                                                                                            CL=90%
                                                         ( 2.8 \pm 1.5 ) \times 10<sup>-5</sup>
                                                                                                              889
                                                                                                                                  e^{+}\pi^{-}\pi^{-}
                                                                                                                                                                                                                × 10<sup>-6</sup>
                                                                                                                                                                           L
                                                                                                                                                                                          < 1.9
                                                                                                                                                                                                                             CL=90%
                                                                                                                                                                                                                                                877
\mu^- e^- e^+ \overline{\nu}_\mu \nu_\tau
                                                                              × 10<sup>-5</sup> CL=90%
                                                        < 3.6
                                                                                                              885
                                                                                                                                                                                                               × 10<sup>-6</sup>
                                                                                                                                  \mu^{-}\pi^{+}\pi^{-}
                                                                                                                                                                           LF
                                                                                                                                                                                          < 8.2
                                                                                                                                                                                                                            CL=90%
                                                                                                                                                                                                                                                866
                                                                                                                                  \mu^{+}\pi^{-}\pi^{-}
                                                                                                                                                                                                                × 10<sup>-6</sup>
                                 Modes with five charged particles
                                                                                                                                                                                          < 3.4
                                                                                                                                                                                                                            CL =90%
                                                                                                                                                                                                                                                866
                                                                                                                                                                            L
                                                                                                                                  e-π+K-
                                                                                                                                                                                                                × 10<sup>-6</sup>
3h^-2h^+ \ge 0 neutrals \nu_{\tau}
(ex. K_S^0 \to \pi^-\pi^+)
                                                         (9.7 \pm 0.7) \times 10^{-4}
                                                                                                                                                                            LF
                                                                                                                                                                                          < 6.4
                                                                                                                                                                                                                            CL=90%
                                                                                                                                                                                                                                                814
                                                                                                                                                                                                                × 10<sup>-6</sup>
                                                                                                                                  e^{-}\pi^{-}K^{+}
                                                                                                                                                                                                                             CL=90%
                                                                                                                                                                           LF
                                                                                                                                                                                          < 3.8
                                                                                                                                                                                                                                                814
     ("5-prong")
                                                                                                                                  e^{+}\pi^{-}K^{-}
                                                                                                                                                                                                                × 10<sup>-6</sup>
                                                                                                                                                                                          < 2.1
                                                                                                                                                                                                                            CL=90%
                                                                                                                                                                            ı
                                                                                                                                                                                                                                                814
   3h^{-}2h^{+}\nu_{\tau}(ex.K^{0})

3h^{-}2h^{+}\pi^{0}\nu_{\tau}(ex.K^{0})
                                                                                                                                                                                                                × 10<sup>-6</sup>
                                                                                                                                  e- K+ K-
                                                                                                                                                                                          < 6.0
                                                    [i] (7.5 \pm 0.7) \times 10^{-4}
                                                                                                                                                                            LF
                                                                                                                                                                                                                            CL=90%
                                                                                                                                                                                                                                                739
                                                                                                                                                                                                                × 10<sup>-6</sup>
                                                    [i] ( 2.2 \pm 0.5 ) \times 10<sup>-4</sup>
                                                                                                                                  e+ K- K-
                                                                                                                                                                            L
                                                                                                                                                                                          < 3.8
                                                                                                                                                                                                                            CL=90%
                                                                                                                                                                                                                                                739
   3h^-2h^+2\pi^0\nu_{\tau}
                                                                                                                                                                                          < 7.5
                                                                                                                                                                                                                × 10<sup>-6</sup>
                                                                              × 10<sup>-4</sup> CL=90%
                                                                                                                                  \mu^{-}\pi^{+}K^{-}
                                                                                                                                                                           LF
                                                                                                                                                                                                                             CL=90%
                                                                                                                                                                                                                                                800
                                                        < 1.1
                                                                                                                                  \mu^-\pi^-K^+
                                                                                                                                                                                                                × 10<sup>-6</sup>
                                                                                                                                                                                          < 7.4
                                                                                                                                                                                                                             CL=90%
                                                                                                                                                                           LF
                                                                                                                                                                                                                                                800
                               Miscellaneous other allowed modes
                                                                                                                                  \mu^+\pi^-K^-
                                                                                                                                                                                                                × 10<sup>-6</sup>
                                                                                                                                                                            L
                                                                                                                                                                                          < 7.0
                                                                                                                                                                                                                            CL=90%
                                                                                                                                                                                                                                                800
(5\pi)^{-}\nu_{\tau}
                                                         (7.4 \pm 0.7) \times 10^{-3}
                                                                                                                                                                                                                × 10<sup>-5</sup>
                                                                                                                                  \mu^{-}K^{+}K^{-}
                                                                                                                                                                            LF
                                                                                                                                                                                          < 1.5
                                                                                                                                                                                                                            CL=90%
                                                                                                                                                                                                                                                699
4h^-3h^+ \ge 0 neutrals \nu_{\tau}
                                                                              × 10<sup>-6</sup> CL=90%
                                                        < 2.4
                                                                                                                                                                                                                × 10<sup>-6</sup>
                                                                                                                                  \mu^{+} K^{-} K^{-}
                                                                                                                                                                                          < 6.0
                                                                                                                                                                                                                            CL=90%
                                                                                                                                                                           L
                                                                                                                                                                                                                                                699
     ("7-prong")
                                                                                                                                  e^{-\pi^{0}\pi^{0}}
                                                                                                                                                                                          < 6.5
                                                                                                                                                                                                                × 10<sup>-6</sup>
                                                                                                                                                                                                                            CL=90%
                                                                                                                                                                           LF
                                                                                                                                                                                                                                                878
K^*(892)^- \ge 0 (h^0 \ne K_S^0) \nu_\tau

K^*(892)^- \ge 0 neutrals \nu_\tau
                                                                                                                                                                                                               × 10<sup>-5</sup>
                                                                                                                 -
                                                                                                                                  \mu^-\pi^0\pi^0
                                                         (1.94 \pm 0.31)\%
                                                                                                                                                                           LF
                                                                                                                                                                                          < 1.4
                                                                                                                                                                                                                            CL=90%
                                                                                                                                                                                                                                                867
                                                                                                                                                                                                               × 10<sup>-5</sup>
                                                          (1.33 \pm 0.13)\%
                                                                                                                                                                                          < 3.5
                                                                                                                                  e^-\eta\eta
                                                                                                                                                                            LF
                                                                                                                                                                                                                            CL=90%
                                                                                                                                                                                                                                                700
   K^*(892)^{-}\nu_{\tau}
                                                          (1.28 \pm 0.08)\%
                                                                                                              665
                                                                                                                                                                                                                × 10<sup>-5</sup>
                                                                                                                                                                                          < 6.0
                                                                                                                                  \mu^-\eta\eta
                                                                                                                                                                            LF
                                                                                                                                                                                                                            CL=90%
                                                                                                                                                                                                                                                654
K^*(892)^0 K^- \geq 0 neutrals \nu_{	au}
                                                          ( 3.2 \pm 1.4 ) \times 10<sup>-3</sup>
                                                                                                                                                                                                                × 10<sup>-5</sup>
                                                                                                                                  e^-\pi^0\eta
                                                                                                                                                                                          < 2.4
                                                                                                                                                                           LF
                                                                                                                                                                                                                            CL=90%
                                                                                                                                                                                                                                                798
   \dot{K}^*(892)^0 K^- \nu_{\tau}
                                                          ( 2.1 \pm 0.4 ) \times\,10^{-3}
                                                                                                                                                                                                               × 10<sup>-5</sup>
                                                                                                              539
                                                                                                                                                                                          < 2.2
                                                                                                                                  \mu^{-}\pi^{0}\eta
                                                                                                                                                                            LF
                                                                                                                                                                                                                            CL=90%
\overline{K}^*(892)^0\pi^- \geq 0 neutrals \nu_{\tau}
                                                         ( 3.8 \pm 1.7 ) \times\,10^{-3}
                                                                                                                                                                                                               × 10<sup>-4</sup>
                                                                                                                                                                                          < 2.9
                                                                                                                                  \overline{p}\gamma
                                                                                                                                                                           L,B
                                                                                                                                                                                                                            CL=90%
                                                                                                                                                                                                                                                641
   \vec{K}^*(892)^0 \pi^- \nu_{\tau}
                                                          ( 2.2 \pm 0.5 ) \times\,10^{-3}
                                                                                                                                  \overline{\rho}\pi^0
                                                                                                                                                                                                                × 10~4
                                                                                                                                                                                          < 6.6
                                                                                                               653
                                                                                                                                                                            L,B
                                                                                                                                                                                                                            CL=90%
                                                                                                                                                                                                                                                632
(\overline{K}^*(892)\pi)^-\nu_{\tau} \rightarrow \pi^-\overline{K}^0\pi^0\nu_{\tau}
                                                          (1.1 \pm 0.5) \times 10^{-3}
                                                                                                                                                                                          < 1.30
                                                                                                                                                                                                                × 10~3
                                                                                                                                                                            L.B
                                                                                                                                                                                                                            CL=90%
                                                                                                                                                                                                                                                476
                                                                                                                                                                                          < 2.7
                                                                                                                                                                                                                × 10~3
                                                                                                                                                                           LF
                                                                                                                                  e-light boson
                                                                                                                                                                                                                           CL=95%
                                                                                                                                                                                                               × 10<sup>-3</sup> CL=95%
K_1(1270)^-\nu_{\tau}
                                                         (4 \pm 4) \times 10^{-3}
                                                                                                              433
                                                                                                                                                                           LF
                                                                                                                                                                                          < 5
                                                                                                                                  \mu^- light boson
K_1(1400)^-\nu_{\tau}
                                                         (8 \pm 4 ) \times 10<sup>-3</sup>
                                                                                                              335
```

Heavy Charged Lepton Searches

L± - charged lepton

Mass m > 80.2 GeV, CL = 95% $m_{\nu} \approx 0$

L± - stable charged heavy lepton

Mass m > 84.2 GeV, CL = 95%

Neutrinos

See the Particle Listings for a Note "Neutrino Mass" giving details of neutrinos, masses, mixing, and the status of experimental searches.



$$J=\frac{1}{2}$$

Mass m: Unexplained effects have resulted in significantly negative m² in the new, precise tritium beta decay experiments. It is felt that a real neutrino mass as large as 10–15 eV would cause observable spectral distortions even in the presence of the end-point count excesses.

Mean life/mass, $\tau/m_{\nu_e} > 7 \times 10^9$ s/eV (solar) Mean life/mass, $\tau/m_{\nu_e} > 300$ s/eV, CL = 90% (reactor) Magnetic moment $\mu < 1.8 \times 10^{-10}~\mu_B$, CL = 90%



$$J=\frac{1}{2}$$

Mass m<0.17 MeV, CL = 90% Mean life/mass, $\tau/m_{\nu_{\mu}}>15.4$ s/eV, CL = 90% Magnetic moment $\mu<7.4\times10^{-10}~\mu_{B}$, CL = 90%



$$J=\frac{1}{2}$$

Mass m<18.2 MeV, CL = 95% Magnetic moment $\mu<5.4\times10^{-7}~\mu_B$, CL = 90% Electric dipole moment $d<5.2\times10^{-17}~e$ cm, CL = 95%

Number of Light Neutrino Types

(including $\nu_e, \, \nu_\mu, \, {\rm and} \, \, \nu_ au)$

Number $N=2.994\pm0.012$ (Standard Model fits to LEP data) Number $N=3.07\pm0.12$ (Direct measurement of invisible Z width)

Massive Neutrinos and Lepton Mixing, Searches for

For excited leptons, see Compositeness Limits below.

See the Particle Listings for a Note "Neutrino Mass" giving details of neutrinos, masses, mixing, and the status of experimental searches.

While no direct, uncontested evidence for massive neutrinos or lepton mixing has been obtained, suggestive evidence has come from solar neutrino observations, from anomalies in the relative fractions of ν_e and ν_μ observed in energetic cosmic-ray air showers, and possibly from a $\overline{\nu}_e$ appearance experiment at Los Alamos. Sample limits are:

Stable Neutral Heavy Lepton Mass Limits

Mass m > 45.0 GeV, CL = 95% (Dirac) Mass m > 39.5 GeV, CL = 95% (Majorana)

Neutral Heavy Lepton Mass Limits

Mass m>69.0 GeV, CL = 95% (Dirac ν_L coupling to e, μ, τ with $\left|U_{\ell J}\right|^2>10^{-12}$)
Mass m>58.2 GeV, CL = 95% (Majorana ν_L coupling to e, μ, τ with $\left|U_{\ell J}\right|^2>10^{-12}$)

Solar Neutrinos

Detectors using gallium ($E_{\nu}\gtrsim 0.2$ MeV), chlorine ($E_{\nu}\gtrsim 0.8$ MeV), and Čerenkov effect in water ($E_{\nu}\gtrsim 7$ MeV) measure significantly lower neutrino rates than are predicted from solar models. The deficit in the solar neutrino flux compared with solar model calculations could be explained by oscillations with $\Delta m^2 \leq 10^{-5}$ eV² causing the disappearance of ν_e .

Atmospheric Neutrinos

Underground detectors observing neutrinos produced by cosmic rays in the atmosphere have measured a ν_{μ}/ν_{e} ratio much less than expected and also a deficiency of upward going ν_{μ} compared to downward. This could be explained by oscillations leading to the disappearance of ν_{μ} with $\Delta m^{2}\approx 10^{-3}$ to 10^{-2} eV².

 ν oscillation: $\nabla_{\boldsymbol{\theta}} \not \rightarrow \nabla_{\boldsymbol{\theta}} (\boldsymbol{\theta} = \text{mbdng angle})$ $\Delta m^2 < 9 \times 10^{-4} \text{ eV}^2, \text{ CL} = 90\% \quad (\text{if } \sin^2 2\theta = 1)$

 $\sin^2 2\theta < 0.02$, CL = 90% (if $\Delta(m^2)$ is large) ν oscillation: $\nu_{\mu} (\bar{\nu}_{\mu}) \rightarrow \nu_{e} (\bar{\nu}_{e})$ (any combination)

 $\begin{array}{lll} \Delta \textit{m}^2 &<~0.075~\text{eV}^2,~\text{CL} = 90\% & \text{(if } \sin^2\!2\theta = 1)\\ \sin^2\!2\theta &<~1.8\times10^{-3},~\text{CL} = 90\% & \text{(if } \Delta(\textit{m}^2)~\text{is large)} \end{array}$

NOTES

In this Summary Table:

When a quantity has "(S = ...)" to its right, the error on the quantity has been enlarged by the "scale factor" S, defined as S = $\sqrt{\chi^2/(N-1)}$, where N is the number of measurements used in calculating the quantity. We do this when S > 1, which often indicates that the measurements are inconsistent. When S > 1.25, we also show in the Particle Listings an ideogram of the measurements, For more about S, see the Introduction.

A decay momentum p is given for each decay mode. For a 2-body decay, p is the momentum of each decay product in the rest frame of the decaying particle. For a 3-or-more-body decay, p is the largest momentum any of the products can have in this frame.

- [a] The uncertainty in the electron mass in unified atomic mass units (u) is ten times smaller than that given by the 1986 CODATA adjustment, quoted in the Table of Physical Constants (Section 1). The conversion to MeV via the factor 931.49432(28) MeV/u is more uncertain because of the electron charge uncertainty. Our value in MeV differs slightly from the 1986 CODATA result.
- [b] This is the best "electron disappearance" limit. The best limit for the mode $e^- \to \nu \gamma$ is $> 2.35 \times 10^{25}$ yr (CL=68%).
- [c] The muon mass is most precisely known in u (unified atomic mass units). The conversion factor to MeV via the factor 931.49432(28) MeV/u is more uncertain because of the electron charge uncertainty.
- [d] See the "Note on Muon Decay Parameters" in the μ Particle Listings for definitions and details.
- [e] P_{μ} is the longitudinal polarization of the muon from pion decay. In standard V-A theory, $P_{\mu}=1$ and $\rho=\delta=3/4$.
- [f] This only includes events with the γ energy > 10 MeV. Since the $e^-\overline{\nu}_e\nu_\mu$ and $e^-\overline{\nu}_e\nu_\mu\gamma$ modes cannot be clearly separated, we regard the latter mode as a subset of the former.
- [g] See the μ Particle Listings for the energy limits used in this measurement.
- [h] A test of additive vs. multiplicative lepton family number conservation.
- [i] Basis mode for the τ .

Quark Summary Table

QUARKS

The u-, d-, and s-quark masses are estimates of so-called "current-quark masses," in a mass-independent subtraction scheme such as $\overline{\rm MS}$ at a scale $\mu\approx 2$ GeV. The c- and b-quark masses are estimated from charmonium, bottomonium, D, and B masses. They are the "running" masses in the $\overline{\rm MS}$ scheme. These can be different from the heavy quark masses obtained in potential models.

$$I(J^P)=\tfrac{1}{2}(\tfrac{1}{2}^+)$$

Mass m = 1.5 to 5 MeV [a] $m_u/m_d = 0.20$ to 0.70

$$Charge = \frac{2}{3} e \quad I_z = +\frac{1}{2}$$

$$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$$

Mass m = 3 to 9 MeV ^[a] Char $m_s/m_d = 17$ to 25

Charge =
$$-\frac{1}{3} e I_z = -\frac{1}{2}$$

 $\overline{m} = (m_u + m_d)/2 = 2 \text{ to 6 MeV}$

$$I(J^P)=0(\tfrac{1}{2}^+)$$

Mass m=60 to 170 MeV ^[a] Charge $=-\frac{1}{3}e$ Strangeness =-1 $(m_S-(m_U+m_d)/2)/(m_d-m_U)=34$ to 51

$$I(J^P)=0(\tfrac{1}{2}^+)$$

Mass m = 1.1 to 1.4 GeV

Charge =
$$\frac{2}{3}e$$
 Charm = +1

$$I(J^P)=0(\tfrac{1}{2}^+)$$

Mass m=4.1 to 4.4 GeV

Charge =
$$-\frac{1}{3}e$$
 Bottom = -1

t

$$I(J^P)=0(\tfrac{1}{2}^+)$$

$$Charge = \frac{2}{3} e \qquad Top = +1$$

Mass $m=173.8\pm5.2$ GeV (direct observation of top events) Mass $m=170\pm7$ (+14) GeV (Standard Model electroweak fit, assuming $M_H=M_Z$. Number in parentheses is shift from changing M_H to 300 GeV.

b' (4th Generation) Quark, Searches for

Mass m > 128 GeV, CL = 95% ($p\overline{p}$, charged current decays) Mass m > 46.0 GeV, CL = 95% (e^+e^- , all decays)

Free Quark Searches

All searches since 1977 have had negative results.

NOTES

[a] The ratios m_u/m_d and m_s/m_d are extracted from pion and kaon masses using chiral symmetry. The estimates of u and d masses are not without controversy and remain under active investigation. Within the literature there are even suggestions that the u quark could be essentially massless. The s-quark mass is estimated from SU(3) splittings in hadron masses.

LIGHT UNFLAVORED MESONS (S=C=B=0)

For I=1 $(\pi,\,b,\,\rho,\,a)$: $u\overline{d},\,(u\overline{u}-d\overline{d})/\sqrt{2},\,d\overline{u};$ for I=0 $(\eta,\,\eta',\,h,\,h',\,\omega,\,\phi,\,f,\,f')$: $c_1(u\overline{u}+d\overline{d})+c_2(s\overline{s})$

 π^{\pm}

$$I^{G}(J^{P}) = 1^{-}(0^{-})$$

Mass $m = 139.56995 \pm 0.00035$ MeV Mean life $\tau = (2.6033 \pm 0.0005) \times 10^{-8} \text{ s}$ (S = 1.2) $c\tau = 7.8045 \text{ m}$

 $\pi^{\pm} \rightarrow \ell^{\pm} \nu \gamma$ form factors [a]

$$F_V = 0.017 \pm 0.008$$

 $F_A = 0.0116 \pm 0.0016$ (S = 1.3)
 $R = 0.059^{+0.009}_{-0.008}$

 π^- modes are charge conjugates of the modes below.

		Confidence level	(iviev/c)
(99.9877	0±0.000	04) %	30
(1.24	±0.25) × 10 ⁻⁴	30
(1.230	±0.004) × 10 ⁻⁴	70
(1.61	±0.23) × 10 ⁻⁷	70
(1.025	±0.034) × 10 ⁻⁸	4
(3.2	±0.5		70
< 5		× 10 ⁻⁶ 90%	70
	(1.24 (1.230 (1.61 (1.025 (3.2	(1.24 ±0.25 (1.230 ±0.004 (1.61 ±0.23 (1.025 ±0.034 (3.2 ±0.5	(99.98770±0.00004) % (1.24 ±0.25)×10 ⁻⁴ (1.230 ±0.004)×10 ⁻⁴ (1.61 ±0.23)×10 ⁻⁷ (1.025 ±0.034)×10 ⁻⁸ (3.2 ±0.5)×10 ⁻⁹ < 5 ×10 ⁻⁶ 90%

Lepton Family number (LF) or Lepton number (L) violating modes

$\mu^+ \overline{\nu}_e$	Ĺ	[d] <	1.5	× 10 ⁻³ 90%	30
	LF	[d] <	8.0	× 10 ⁻³ 90%	30
$\mu^+ \nu_e \\ \mu^- e^+ e^+ \nu$	LF	<	1.6	× 10 ⁻⁶ 90%	30



 $\mu^{+}e^{-} + e^{-}\mu^{+}$

$$I^{G}(J^{PC}) = 1^{-}(0^{-})$$

 \times 10⁻⁸ CL=90%

× 10-8 CL=90%

Mass $m=134.9764\pm0.0006$ MeV $m_{\pi^{\pm}} - m_{\pi^0} = 4.5936 \pm 0.0005 \; \mathrm{MeV}$ Mean life $\tau = (8.4 \pm 0.6) \times 10^{-17} \text{ s}$ (S = 3.0) $c\tau = 25.1 \text{ nm}$

±0 DECAY MODES	Fraction (Γ_I/Γ)	Scale factor/ Confidence level	p (MeV/c)
2γ	(98.798±0.032)	% S=1.1	67
e ⁺ e ⁻ γ	(1.198±0.032)	% S=1.1	67
γ positronium	(1.82 ±0.29)	× 10 ⁻⁹	67
e+ e+ e- e-	(3.14 ±0.30)	× 10 ⁻⁵	67
e+ e-	(7.5 ±2.0)	× 10 ⁻⁸	67
4γ	< 2	× 10 ⁻⁸ CL=90%	67
ν <u>ν</u>	[e] < 8.3	$\times 10^{-7}$ CL=90%	67
$\nu_e \overline{\nu}_e$	< 1.7	× 10 ⁻⁶ CL=90%	67
$\nu_{\mu}\overline{\nu}_{\mu}$	< 3.1	× 10 ⁻⁶ CL=90%	67
$\nu_{\tau}\overline{\nu}_{\tau}$	< 2.1	× 10 ⁻⁶ CL=90%	67

< 3.1

< 1.72

LF

7

$$I^{G}(J^{PC}) = 0^{+}(0^{-})$$

Mass $m = 547.30 \pm 0.12 \text{ MeV}$ Full width $\Gamma = 1.18 \pm 0.11 \text{ keV}^{[f]}$ (S = 1.8)

C-nonconserving decay parameters

 $\pi^+\pi^-\pi^0$ Left-right asymmetry = (0.09 \pm 0.17) \times 10⁻² $\pi^+\pi^-\pi^0$ Sextant asymmetry = $(0.18 \pm 0.16) \times 10^{-2}$ $\pi^{+}\pi^{-}\pi^{0}$ Quadrant asymmetry = $(-0.17 \pm 0.17) \times 10^{-2}$ Left-right asymmetry = $(0.9 \pm 0.4) \times 10^{-2}$ β (*D*-wave) = 0.05 ± 0.06 (S = 1.5)

Dalitz plot parameter

$$\pi^0 \pi^0 \pi^0$$
 $\alpha = -0.039 \pm 0.015$

η DECAY MODES	Fraction (Γ_I/Γ)	Scale factor/ Confidence level	p (MeV/c)
	Neutral modes		
neutral modes	(71.5 ±0.6) %	S=1.4	-
2γ	[f] (39.21±0.34) %	S=1.4	274
$3\pi^0$	(32.2 ±0.4) %	S=1.3	178
$\pi^{0}2\gamma$	(7.1 ±1.4)×	10-4	257
other neutral modes	< 2.8 %	CL=90%	-
	Charged modes		
charged modes	(28.5 ±0.6) %	S=1.4	_
$\pi^+\pi^-\pi^0$	(23.1 ±0.5) %	S=1.4	173
$\pi^+\pi^-\gamma$	(4.77±0.13) %	S=1.3	235
$e^+e^-\gamma$	(4.9 ±1.1)×	₁₀ -3	274
$\mu^+\mu^-\gamma$	(3.1 ±0.4)×		252
e+ e-	< 7.7 ×	10 ⁻⁵ CL=90%	274
$\mu^+\mu^-$	(5.8 ±0.8)×	₁₀ –6	252
$\pi^{+}\pi^{-}e^{+}e^{-}$	$(1.3 \begin{array}{c} +1.2 \\ -0.8 \end{array}) \times$	₁₀ -3	235
$\pi^+\pi^-2\gamma$	< 2.1 ×	10-3	235
$\pi^+\pi^-\pi^0\gamma$	< 6 ×	10 ⁻⁴ CL=90%	173
$\pi^0\mu^+\mu^-\gamma$	< 3 ×	10 ⁻⁶ CL=90%	210
Charge	e conjugation (C), Parity (conjugation × Parity (CP)), or	

Lepton Family number (LF) violating modes

$\pi^+\pi^-$	P.CP < 9	× 10 ⁻⁴	CL=90%	235
3γ	C < 5	× 10 ⁻⁴	CL=95%	274
$^{3\gamma}_{\pi^0 e^+ e^-}$	C [g] < 4	× 10 ⁻⁵	CL=90%	257
$\pi^{0} \mu^{+} \mu^{-}$	C = [g] < 5	× 10 ⁻⁶	CL=90%	210
$\mu^{+}e^{-} + \mu^{-}e^{+}$	LF < 6	× 10 ⁻⁶	CL=90%	263

f₀(400–1200) [h] or σ

$$I^{G}(J^{PC}) = 0^{+}(0^{+})$$

Mass m = (400-1200) MeV Full width $\Gamma = (600-1000)$ MeV

f ₀ (400-1200) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
ππ	dominant	-
$\gamma\gamma$	seen	-

Meson Summary Table

ρ(770)	[1]

 $I^{G}(J^{PC}) = 1^{+}(1^{-})$

Mass $m=770.0\pm0.8$ MeV (S = 1.8) Full width $\Gamma=150.7\pm1.1$ MeV $\Gamma_{ee}=6.77\pm0.32$ keV

ρ(770) DECAY MODES	Fraction (Γ_I/Γ)	Scale factor/ Confidence level	
ππ	~ 100	%	358
	$\rho(770)^{\pm}$ decays		
$\pi^{\pm}\gamma$	(4.5 ±0.5):	× 10 ⁻⁴ S=2.2	372
$ \begin{array}{l} \pi^{\pm} \gamma \\ \pi^{\pm} \eta \\ \pi^{\pm} \pi^{+} \pi^{-} \pi^{0} \end{array} $	< 6	× 10 ⁻³ CL=84%	146
$\pi^{\pm}\pi^{+}\pi^{-}\pi^{0}$	< 2.0	× 10 ⁻³ CL=84%	249
	$\rho(770)^0$ decays		
$\pi^+\pi^-\gamma$	(9.9 ±1.6):	× 10 ⁻³	358
$\pi^0\gamma$	(6.8 ±1.7):		372
$\eta\gamma$	$(2.4 \begin{array}{c} +0.8 \\ -0.9 \end{array})$	× 10 ⁻⁴ S=1.6	189
$\mu^+\mu^-$	[/] (4.60±0.28)	× 10 ⁵	369
e+ e-	[/] (4.49±0.22):	× 10 ⁻⁵	384
$\pi^{+}\pi^{-}\pi^{0}$	< 1.2	× 10 ⁻⁴ CL=90%	319
$\pi^{+}\pi^{-}\pi^{+}\pi^{-}$	< 2	× 10 ⁻⁴ CL=90%	246
$\pi^{+}\pi^{-}\pi^{0}\pi^{0}$	< 4	× 10 ⁻⁵ CL=90%	252

ω(782)

$$I^{G}(J^{PC}) = 0^{-}(1^{-})$$

Mass $m=781.94\pm0.12$ MeV (S = 1.5) Full width $\Gamma=8.41\pm0.09$ MeV $\Gamma_{ee}=0.60\pm0.02$ keV

ω(782) DECAY MODES	Fraction (Γ_I/Γ)	Scale factor/ Confidence level	p (MeV/c)
$\pi^{+}\pi^{-}\pi^{0}$	(88.8 ±0.7)	%	327
$\pi^0\gamma$	(8.5 ±0.5)	%	379
$\pi^+\pi^-$	(2.21±0.30)	%	365
neutrals (excluding $\pi^0\gamma$)	$(5.3 \begin{array}{c} +8.7 \\ -3.5 \end{array})$	× 10 ⁻³	-
$\eta\gamma$	(6.5 ±1.0)	× 10 ⁻⁴	199
$\pi^0 e^+ e^-$	(5.9 ±1.9)	× 10 ⁻⁴	379
$\pi^{0} \mu^{+} \mu^{-}$	(9.6 ±2.3)	× 10 ⁻⁵	349
e ⁺ e ⁻	(7.07±0.19)	× 10 ⁻⁵ S=1.1	391
$\pi^{+} \pi^{-} \pi^{0} \pi^{0}$	< 2	% CL=90%	261
$\pi^+\pi^-\gamma$	< 3.6	× 10 ⁻³ CL=95%	365
$\pi^{+}\pi^{-}\pi^{+}\pi^{-}$	< 1	× 10 ⁻³ CL=90%	256
$\pi^0\pi^0\gamma$	(7.2 ±2.5)	× 10 ⁻⁵	367
$\mu^+\mu^-$ 3 γ	< 1.8	$\times 10^{-4}$ CL=90%	376
3γ	< 1.9	× 10 ⁻⁴ CL=95%	391
Charge conjugati	ion (<i>C</i>) violating	g modes	
$\eta \pi^0$	< 1	$\times 10^{-3}$ CL=90%	162
$3\pi^0$ C	< 3	× 10 ⁻⁴ CL=90%	329

$\eta'(958)$

$$I^{G}(J^{PC}) = 0^{+}(0^{-})$$

Mass $m = 957.78 \pm 0.14$ MeV Full width $\Gamma = 0.203 \pm 0.016$ MeV (S = 1.3)

η ['] (958) DECAY MODES	Fraction (Γ_I/Γ)	Scale factor/ Confidence level	p (MeV/c)
$\pi^+\pi^-\eta$	(43.8 ±1.5)%	S=1.1	232
$ ho^0\gamma$ (including non- resonant $\pi^+\pi^-\gamma$)	(30.2 ±1.3)%	S=1.1	169
$\pi^0\pi^0\eta$	(20.7 ±1.3)%	S=1.2	239
$\omega \gamma$	(3.01±0.30) %		160
$\gamma \gamma_{\underline{}}$	(2.11±0.13) %	5=1.2	479
$3\pi^0$	(1.54±0.26) ×	10 ⁻³	430
$\mu^+\mu^-\gamma_{\perp}$	(1.03±0.26)×	10-4	467
$\pi^{+}\pi^{-}\pi^{0}$	< 5 %	CL=90%	427
$\pi^0 \rho^0$	< 4 %	CL=90%	118
$\pi^{+}\pi^{+}\pi^{-}\pi^{-}$	< 1 %	CL=90%	372
$\pi^+\pi^+\pi^-\pi^-$ neutrals	< 1 %	CL=95%	-
$\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{0}$	< 1 %	CL=90%	298
6π	< 1 %	CL=90%	189
$\pi^{+}\pi^{-}e^{+}e^{-}$	< 6 x	10 ⁻³ CL=90%	458
$\pi^{0}\gamma\gamma$	< 8 x	10 ⁻⁴ CL=90%	469
$4\pi^0$	< 5 ×	10 ⁻⁴ CL=90%	379
e ⁺ e ⁻	< 2.1 ×	10 ⁻⁷ CL=90%	479

	Charge conjugation (C) o	w F	arity	(P) violating i	nodes	
$\pi^+\pi^-$	P,CP		<	2	%	CL=90%	458
$\pi^0\pi^0$	P,CP		<	9	× 10 ⁻⁴	CL=90%	459
$\pi^{0}e^{+}e^{-}$	c	[g]	<	1.3	%	CL=90%	469
$\eta e^+ e^-$	С	[g]	<	1.1	%	CL=90%	322
3γ	С		<	1.0	× 10 ⁻⁴	CL=90%	479
$\mu^{+}\mu^{-}\pi^{0}$	С	[g]	<	6.0	× 10 ⁻⁵	CL=90%	445
$\frac{\mu^+\mu^-\eta}{}$	С	[g]	<	1.5	× 10 ⁻⁵	CL=90%	274

f₀(980) [k]

$$I^{G}(J^{PC}) = 0^{+}(0^{+})$$

Mass $m = 980 \pm 10$ MeV Full width $\Gamma = 40$ to 100 MeV

ති(980) DECAY MODES	Fraction (Γ_I/Γ)	Confidence level	p (MeV/c)
ππ	dominant		470
κR	seen		-
$\gamma\gamma$	(1.19±0.33) ×	₁₀ -5	490
e ⁺ e ⁻	< 3 ×	10 ⁻⁷ 90%	490

a₀(980) [k]

$$I^{G}(J^{PC}) = 1^{-}(0^{+})$$

Mass $m=983.4\pm0.9~{\rm MeV}$ Full width $\Gamma=50~{\rm to}~100~{\rm MeV}$

a ₀ (980) DECAY MODES	Fraction $(\Gamma_{\tilde{I}}/\Gamma)$	p (MeV/c)	
$\eta\pi$	dominant	321	
κR	seen	-	
$\gamma\gamma$	seen	492	

$\phi(1020)$

$$I^{G}(J^{PC}) = 0^{-}(1^{-})$$

Mass $m = 1019.413 \pm 0.008$ MeV Full width $\Gamma = 4.43 \pm 0.05$ MeV

♦(1020) DECAY MODES	Fraction (Γ_i/Γ)		cale factor/ idence level	<i>p</i> (MeV/ <i>c</i>)
K+K-	(49.1 ±0.8) %	5=1.3	127
K^0_K^0_S	(34.1 ±0.6) %	S=1.2	110
$\rho\pi + \pi^+\pi^-\pi^0$	(15.5 ± 0.7)) %	S=1.5	-
$\eta \gamma \\ \pi^0 \gamma$	(1.26±0.06		S=1.1	363
	(1.31±0.13			501
e+ e-	(2.99±0.08		S=1.2	510
$\mu^+\mu^-$	(2.5 ± 0.4)) × 10 ⁻⁴		499
$\eta e^+ e^-$	(1.3 $^{+0.8}_{-0.6}$) × 10 ⁻⁴		363
$\pi^+\pi^-$	(8 ⁺⁵) × 10 ⁻⁵	S=1.5	490
$\omega \gamma$	< 5	%	CL=84%	210
$\rho\gamma$	< 7	× 10 ⁻⁴	CL=90%	219
$\pi^+\pi^-\gamma$	< 3	× 10 ⁻⁵	CL=90%	490
$f_0(980)\gamma$ $\pi^0\pi^0\gamma$	< 1	× 10 ⁻⁴	CL=90%	39
	< 1	× 10 ⁻³	CL=90%	492
$\pi^{+}\pi^{-}\pi^{+}\pi^{-}$	< 8.7	× 10 ⁻⁴	CL=90%	410
$\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{0}$	< 1.5	× 10 ⁻⁴	CL=95%	341
$\pi^{0}e^{+}e^{-}$	< 1.2	× 10 ⁻⁴	CL=90%	501
$\pi^{0}\eta\gamma$	< 2.5	× 10 ⁻³	CL=90%	346
$a_0(980)\gamma$	< 5	× 10 ⁻³	CL=90%	36
$\eta'(958)\gamma$	$(1.2 \begin{array}{c} +0.7 \\ -0.5 \end{array})$) × 10 ⁻⁴		-
$\frac{\mu^+\mu^-\gamma}{}$	(2.3 ±1.0) × 10 ⁻⁵		

h₁(1170)

$$I^{G}(J^{PC}) = 0^{-}(1^{+})^{-}$$

Mass $m=1170\pm20$ MeV Full width $\Gamma=360\pm40$ MeV

h1(1170) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
ρπ	seen	310

b₁(1235)

 $I^{G}(J^{PC}) = 1^{+}(1^{+})$

Mass $m = 1229.5 \pm 3.2$ MeV (S = 1.6) Full width $\Gamma = 142 \pm 9$ MeV (S = 1.2)

b1(1235) DECAY MODES	Fraction (f	₁ /Γ)	Confidence level	p (MeV/c)
$\omega \pi$ [D/S amplitude ratio =	domina 0.29 ± 0.04]	nt		348
$\pi^{\pm}\gamma$	(1.6±0	.4) × 10	₎ -3	608
$\eta \rho$	seen			_
$\frac{\pi^{+}\pi^{+}\pi^{-}\pi^{0}}{(K\overline{K})^{\pm}\pi^{0}}$	< 50	%	84%	536
$(K\overline{K})^{\pm}\pi^{0}$	< 8	%	90%	248
$K_s^0 K_l^0 \pi^{\pm}$	< 6	%	90%	238
K ⁰ ₅ K ⁰ ₆ π [±] K ⁰ ₅ K ⁰ ₅ π [±]	< 2	%	90%	238
$\phi\pi$	< 1.5	%	84%	146

a₁(1260) [/]

$$I^{G}(J^{PC}) = 1^{-}(1^{++})$$

Mass $m=1230\pm40~{\rm MeV}~{}^{[m]}$ Full width $\Gamma=250~{\rm to}~600~{\rm MeV}$

a1(1260) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$\rho\pi$ [D/S amplitude ratio =	dominant -0.100 ± 0.028]	356
$\pi\gamma$	seen	607
$\pi(\pi\pi)_{5 ext{-wave}}$	possibly seen	575

 $f_2(1270)$

$$I^{G}(J^{PC}) = 0^{+}(2^{+})$$

Mass $m = 1275.0 \pm 1.2 \text{ MeV}$ Full width $\Gamma = 185.5^{+3.8}_{-2.7} \text{ MeV}$ (S = 1.5)

f ₂ (1270) DECAY MODES	Fraction (Γ_I/Γ)	Scale factor/ Confidence level	<i>p</i> (MeV/c)
ππ	$(84.6 \begin{array}{c} +2.5 \\ -1.3 \end{array}) \%$	S=1.3	622
$\pi^{+}\pi^{-}2\pi^{0}$	$(7.2 \ ^{+1.5}_{-2.7})\%$	S=1.3	562
κ κ	(4.6 ±0.4)%	S=2.8	403
$2\pi^{+}2\pi^{-}$	(2.8 ±0.4) %	S=1.2	559
$\eta\eta_{_}$	(4.5 ±1.0)×1	10 ⁻³ 5=2.4	327
$4\pi^0$	$(3.0 \pm 1.0) \times 1$	₁₀ –3	564
$\gamma\gamma$	$(1.32^{+0.17}_{-0.16}) \times 3$	10-5	637
$\eta \pi \pi$	< 8 × 1	10 ⁻³ CL=95%	475
$K^0K^-\pi^+ + c.c.$		10 ⁻³ CL=95%	293
e ⁺ e ⁻	< 9 × 1	10 ⁻⁹ CL=90%	637

f₁(1285)

$$I^G(J^{PC}) = 0^+(1^{++})$$

Mass $m = 1281.9 \pm 0.6$ MeV (S = 1.7) Full width $\Gamma = 24.0 \pm 1.2$ MeV (S = 1.4)

 $(4\pi = \rho(\pi\pi)_{Pwave})$

f ₁ (1285) DECAY MODES	Fraction (Γ_f/Γ)	Scale factor/ Confidence level	<i>p</i> (MeV/ <i>c</i>)
4π	(35 ± 4)%	S=1.6	563
$\pi^{0}\pi^{0}\pi^{+}\pi^{-}$	(23.5 ± 3.0) %	S=1.6	566
$2\pi^{+}2\pi^{-}$	(11.7 ± 1.5) %	S=1.6	563
$\rho^0 \pi^+ \pi^-$	(11.7± 1.5) %	S=1.6	340
$2\pi^{\frac{1}{2}}2\pi^{-\frac{1}{2}}$ $\rho^{0}\pi^{+}\pi^{-\frac{1}{2}}$	< 7 × 10	-4 CL=90%	568
$\eta \pi \pi$	(50 ±18)%		479
$a_0(980)\pi$ [ignoring $a_0(980) \rightarrow K\overline{K}$]	(34 ± 8)%	S=1.2	234
$\eta \pi \pi$ [excluding $a_0(980)\pi$]	$(15 \pm 7)\%$	S=1.1	-
$K\overline{K}\pi$	(9.6± 1.2) %	S=1.5	308
<i>K</i> K *(892)	not seen		-
$\gamma \rho^0$	(5.4± 1.2) %	S=2.3	410
$\phi \gamma$	(7.9± 3.0) × 10	-4	236

 $\eta(1295)$

$$I^{G}(J^{PC}) = 0^{+}(0^{-})$$

Mass $m=1297.0\pm2.8$ MeV Full width $\Gamma=53\pm6$ MeV

η(1295) DECAY MODES	Fraction $(\Gamma_{\underline{i}}/\Gamma)$	p (MeV/c)
$\eta \pi^+ \pi^-$	seen	488
$a_0(980)\pi$ $\eta \pi^0 \pi^0$	seen	245
$\eta \pi^0 \pi^0$	seen	_
$\eta(\pi\pi)$ s-wave	seen	-

 $\pi(1300)$

$$I^{G}(J^{PC}) = 1^{-}(0^{-}+)$$

Mass $m = 1300 \pm 100 \text{ MeV}^{[m]}$ Full width $\Gamma = 200 \text{ to } 600 \text{ MeV}$

x(1300) DECAY MODES	Fraction $(\Gamma_{\tilde{I}}/\Gamma)$	p (MeV/c)
$ ho \pi$	seen	406
$\pi(\pi\pi)_{S ext{-wave}}$	seen	_

a₂(1320)

$$I^{G}(J^{PC}) = 1^{-}(2^{+})$$

Mass $m=1318.1\pm0.6$ MeV (S = 1.1) Full width $\Gamma=107\pm5$ MeV $^{[m]}$ ($K^\pm K^0_5$ and $\eta\pi$ modes)

a2(1320) DECAY MODES	Fraction (Γ_I/Γ)	Scale factor/ Confidence level	<i>p</i> (MeV/ <i>c</i>)
$ ho\pi$	(70.1±2.7) %	S=1.2	419
$\eta\pi$	(14.5 ± 1.2) %		535
$\omega \pi \pi$	(10.6 ± 3.2) %	5=1.3	362
κ κ	(4.9±0.8) %		437
$\eta'(958)\pi$ $\pi^{\pm}\gamma$	$(5.3\pm0.9)\times10$	₎ –3	287
$\pi^{\pm}\gamma$	·(2.8±0.6) × 10	₎ –3	652
77	$(9.4\pm0.7)\times10$	₎ 6	659
$\pi^+\pi^-\pi^-$	< 8 %	CL=90%	621
e+ e-	< 2.3 × 10) ⁻⁷ CL=90%	659

 $f_0(1370)^{[k]}$

$$I^{G}(J^{PC}) = 0^{+}(0^{+})$$

Mass m = 1200 to 1500 MeV Full width $\Gamma = 200$ to 500 MeV

රි(1370) DECAY MODES	Fraction (Γ _I /Γ)	p (MeV/c)
ππ	seen	_
4π	seen	-
$4\pi^0$	seen	-
$2\pi^{+}2\pi^{-}$	seen	-
$\pi^{+}\pi^{-}2\pi^{0}$	seen	-
2(ππ) _{5-wave}	seen	-
ηη Κ Κ	seen	
κ κ	seen	-
$\gamma\gamma$	seen	-
e+e-	not seen	-

f₁(1420) [n]

$$I^{G}(J^{PC}) = 0^{+}(1^{+})$$

Mass $m=1426.2\pm1.2~{\rm MeV}~{\rm (S=1.3)}$ Full width $\Gamma=55.0\pm3.0~{\rm MeV}$

f ₁ (1420) DECAY MODES	Fraction $(\Gamma_{\hat{I}}/\Gamma)$	p (MeV/c)
KKπ	dominant	439
$K\overline{K}^*(892) + c.c.$	dominant	155
$\eta \pi \pi$	possibly seen	571

ω(1420) ^[o]

$$I^{G}(J^{PC}) = 0^{-}(1^{-})$$

Mass $m=1419\pm31~{\rm MeV}$ Full width $\Gamma=174\pm60~{\rm MeV}$

ω(1420) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
ρπ	dominant	488

Meson Summary Table

η(1440) ^[p]

 $I^{G}(J^{PC}) = 0^{+}(0^{-})$

Mass m=1400 - 1470 MeV $^{[m]}$ Full width $\Gamma=50$ - 80 MeV $^{[m]}$

7(1440) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$\overline{KK\pi}$	seen	
$K\overline{K}^*(892) + \text{c.c.}$	seen	_
$\eta \pi \pi$	seen	-
$a_0(980)\pi$	seen	-
$\eta(\pi\pi)_{S ext{-wave}}$	seen	-
4π	seen	-

a₀(1450)

$$I^{G}(J^{PC}) = 1^{-}(0^{+})$$

Mass $m=1474\pm19~{\rm MeV}$ Full width $\Gamma=265\pm13~{\rm MeV}$

a ₀ (1450) DECAY MODES	Fraction (Γ _I /Γ)	p (MeV/c)
$\pi\eta$	seen	613
$\pi \eta'$ (958) $K\overline{K}$	seen	392
κ κ	seen	530

ρ(1450) ^[q]

$$I^{G}(J^{PC}) = 1^{+}(1^{-})$$

Mass $m=1465\pm25$ MeV [m]Full width $\Gamma=310\pm60$ MeV [m]

ρ(1450) DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	<i>p</i> (MeV/c)
ππ	seen		719
4π	, seen		665
$\omega\pi$	<2.0 %	95%	512
e^+e^-	seen		732
$\eta \rho$	<4 %		317
$\phi\pi$	<1 %		358
κ κ	$<1.6 \times 10^{-3}$	95%	541

f₀(1500) [r]

$$I^{G}(J^{PC}) = 0^{+}(0^{+})$$

Mass $m=1500\pm 10$ MeV (S = 1.3) Full width $\Gamma=112\pm 10$ MeV

(1500) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
$\eta \eta'(958)$	seen	_
$\eta\eta$	seen	513
4π	seen	-
$4\pi^{0} \ 2\pi^{+}2\pi^{-}$	seen	690
$2\pi^{+}2\pi^{-}$	seen	686
2π	seen	-
$\pi^+\pi^-$	seen	737
$2\pi^{0}$	seen	738
$\pi^+\pi^ 2\pi^0$ $K\overline{K}$	seen	563

f'_2(1525)

$$I^{G}(J^{PC}) = 0^{+}(2^{+})$$

Mass $m=1525\pm 5$ MeV [m]Full width $\Gamma=76\pm 10$ MeV [m]

f' ₂ (1525) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
κ κ	(88.8 ±3.1) %	581
$\eta\eta$	$(10.3 \pm 3.1)\%$	531
$\pi\pi$	$(8.2 \pm 1.5) \times 10^{-3}$	750
$\gamma\gamma$	$(1.32\pm0.21)\times10^{-6}$	763

ω(1600) [s]

$$I^{G}(J^{PC}) = 0^{-}(1^{-})$$

Mass $m = 1649 \pm 24$ MeV (S = 2.3) Full width Γ = 220 ± 35 MeV (S = 1.6)

ω(1600) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
ρπ	seen	637
$\omega\pi\pi$	seen	601
e+ e-	seen	824

 $\omega_3(1670)$

$$I^{G}(J^{PC}) = 0^{-}(3^{-})$$

Mass $m=1667\pm 4$ MeV Full width $\Gamma=168\pm 10$ MeV $^{[m]}$

3(1670) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
οπ	seen	647
$\omega\pi\pi$	seen	614
$b_1(1235)\pi$	possibly seen	359

 $\pi_2(1670)$

$$I^{G}(J^{PC}) = 1^{-}(2^{-})$$

 $\label{eq:mass_m} \begin{array}{l} {\rm Mass}~m=1670\pm20~{\rm MeV}~^{[m]} \\ {\rm Full~width}~\Gamma=258\pm18~{\rm MeV}~^{[m]} \end{array}~({\rm S}=1.7) \end{array}$

π ₂ (1670) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
3π	(95.8±1.4) %	806
$f_2(1270)\pi$	(56.2±3.2) %	325
$\rho\pi$	(31 ±4)%	649
$f_0(1370)\pi$	(8.7±3.4) %	-
$K\overline{K}^*(892) + c.c.$	$(4.2\pm1.4)\%$	453

 $\phi(1680)$

$$I^{G}(J^{PC}) = 0^{-}(1^{-})$$

Mass $m=1680\pm 20~{
m MeV}~{}^{[m]}$ Full width $\Gamma=150\pm 50~{
m MeV}~{}^{[m]}$

♦(1680) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
$\overline{KK^*(892)}$ + c.c.	dominant	463
Κ <u>ς</u> Κπ ΚΚ	seen	620
	seen	681
e+e-	seen	840
$\omega\pi\pi$	not seen	622

 $\rho_3(1690)$

$$I^{G}(J^{PC}) = 1^{+}(3^{-})$$

 J^P from the 2π and $K\overline{K}$ modes. Mass $m=1691\pm 5$ MeV $^{[m]}$ Full width $\Gamma=160\pm 10$ MeV $^{[m]}$ (S = 1.5)

ρ ₃ (1690) DECAY MODES	Fraction (Γ_I/Γ)	p Scale factor (MeV/c)
4π	(71.1 ± 1.9) %	788
$\pi^{\pm}\pi^{+}\pi^{-}\pi^{0}$	(67 ±22)%	788
$\omega\pi$	$(16 \pm 6)\%$	656
$\pi\pi$	(23.6 ± 1.3)%	834
$K\overline{K}\pi$	$(3.8 \pm 1.2)\%$	628
κ κ	(1.58± 0.26) %	1.2 686
$\eta \pi^+ \pi^-$	seen	728

ρ(1700) ^[q]

$$I^{G}(J^{PC}) = 1^{+}(1^{-})$$

Mass $m=1700\pm20$ MeV $^{[m]}$ $(\eta\,\rho^0$ and $\pi^+\pi^-$ modes) Full width $\Gamma=240\pm60$ MeV $^{[m]}$ $(\eta\,\rho^0$ and $\pi^+\pi^-$ modes)

ρ(1700) DECAY MODES	Fraction (Γ_j/Γ)	p (MeV/c)
ρππ	dominant	640
$2(\pi^+\pi^-)$	large	792
$\rho^{0}\pi^{+}\pi^{-}$	large	640
$ ho^{\pm}\pi^{\mp}\pi^{0}$	large	642
$\pi^+\pi^-$	seen	838
$\pi^-\pi^0$	seen	839
$K\overline{K}^*(892) + c.c.$	seen	479
	seen	533
η <i>ρ</i> Κ Κ	seen	692
e+e-	seen	850
$\pi^0\omega$	seen	662

 $f_J(1710)^{[t]}$

$$I^{G}(J^{PC}) = 0^{+}(\operatorname{even}^{+})$$

Mass $m = 1712 \pm 5 \text{ MeV}$ (S = 1.1) Full width $\Gamma=133\pm14$ MeV (S = 1.2)

f (1710) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
κ κ	seen	690
$\eta\eta$	seen	648
$\pi\pi$	seen	837

 $\pi(1800)$

$$I^{G}(J^{PC}) = 1^{-}(0^{-})$$

Mass $m = 1801 \pm 13 \text{ MeV}$ (S = 1.9) Full width $\Gamma = 210 \pm 15 \text{ MeV}$

₹(1800) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
$\pi^{+}\pi^{-}\pi^{-}$	seen	
$f_0(980)\pi^-$	seen	623
$f_0(1370)\pi^-$	seen	-
$\rho \pi^-$	not seen	728
$\eta\eta\pi^-$	seen	-
$a_0(980)\eta$	seen	459
$f_0(1500)\pi^-$	seen	240
$\eta \eta'(958) \pi^-$	seen	
$K_0^*(1430)K^-$	seen	-
K*(892)K-	not seen	560

 $\phi_3(1850)$

$$I^{G}(J^{PC}) = 0^{-}(3^{-})$$

Mass $m = 1854 \pm 7 \text{ MeV}$ Full width $\Gamma = 87^{+28}_{-23} \text{ MeV}$ (S = 1.2)

♦3(1850) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
κ κ	seen	785
Κ͡Κ*(892)+ c.c.	seen	602

f₂(2010)

$$I^{G}(J^{PC}) = 0^{+}(2^{+})$$

Seen by one group only.

Mass $m = 2011^{+60}_{-80}$ MeV

Full width $\Gamma = 202 \pm 60 \text{ MeV}$

f2(2010) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c		
$\phi \phi$	seen	-		

a₄(2040)

$$I^G(J^{PC}) = 1^-(4^{\,+\,+})$$

 $\overline{\text{M}}$ ass $m = 2020 \pm 16 \text{ MeV}$ Full width $\Gamma=387\pm70~\text{MeV}$

a ₄ (2040) DECAY MODES	Fraction (Γ _I /Γ)	р (MeV/c)		
KK	seen	892		
$\pi^{+}\pi^{-}\pi^{0}$	seen	-		
$\eta \pi^0$	seen	941		

f₄(2050)

$$I^{G}(J^{PC}) = 0^{+}(4^{+})$$

Mass $m = 2044 \pm 11 \text{ MeV}$ (S = 1.4) Full width $\Gamma = 208 \pm 13 \text{ MeV}$ (S = 1.2)

f4(2050) DECAY MODES	Fraction (Γ_{j}/Γ)	p (MeV/c)	
ωω	(26 ±6)%	658	
$\pi\pi$	$(17.0 \pm 1.5) \%$	1012	
κ κ	$(6.8^{+3.4}_{-1.8}) \times 10^{-3}$	895	
$\eta \eta$	$(2.1\pm0.8)\times10^{-3}$	863	
$\eta \eta \over 4\pi^0$	< 1.2 %	977	

f₂(2300)

$$I^{G}(J^{PC}) = 0^{+}(2^{+})$$

Mass $m = 2297 \pm 28 \text{ MeV}$ Full width $\Gamma=149\pm40~\text{MeV}$

f2(2300) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
$\phi \phi$	seen	529

f₂(2340)

$$I^{G}(J^{PC}) = 0^{+}(2^{+})$$

Mass $m=2339\pm60~{\rm MeV}$ Full width $\Gamma = 319^{+80}_{-70}$ MeV

f2(2340) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
$\phi\phi$	seen	573

STRANGE MESONS $(S = \pm 1, C = B = 0)$

 $K^+ = u\overline{s}$, $K^0 = d\overline{s}$, $\overline{K}^0 = \overline{d}s$, $K^- = \overline{u}s$, similarly for K^* 's

Κ±

$$I(J^P) = \frac{1}{2}(0^-)$$

Mass $m = 493.677 \pm 0.016 \text{ MeV}^{[u]}$ (S = 2.8) Mean life $\tau = (1.2386 \pm 0.0024) \times 10^{-8}$ s (S = 2.0)

Slope parameter $g^{[v]}$

(See Particle Listings for quadratic coefficients)

$$\begin{array}{lll} K^+ \to & \pi^+\pi^+\pi^- = -0.2154 \pm 0.0035 & (S=1.4) \\ K^- \to & \pi^-\pi^-\pi^+ = -0.217 \pm 0.007 & (S=2.5) \\ K^\pm \to & \pi^\pm\pi^0\pi^0 = 0.594 \pm 0.019 & (S=1.3) \end{array}$$

K^{\pm} decay form factors [a,w]

$$K_{e3}^+$$
 $\lambda_+ = 0.0286 \pm 0.0022$

$$K_{\mu 3}^{+}$$
 $\lambda_{+} = 0.032 \pm 0.008$ (S = 1.6)

$$K_{\mu3}^+$$
 $\lambda_0 = 0.006 \pm 0.007$ (S = 1.6)

$$K_{e3}^{+}$$
 $|f_S/f_+| = 0.084 \pm 0.023$ (S = 1.2)

$$K_{e3}^{+}$$
 $|f_T/f_+| = 0.38 \pm 0.11$ (S = 1.1)

$$K_{\mu 3}^{+} |f_T/f_+| = 0.02 \pm 0.12$$

$$K^+ \to e^+ \nu_e \gamma |F_A + F_V| = 0.148 \pm 0.010$$

$$K^{+} \rightarrow \mu^{+} \nu_{\mu} \gamma \quad |F_{A} + F_{V}| < 0.23, \text{ CL} = 90\%$$
 $K^{+} \rightarrow e^{+} \nu_{e} \gamma \quad |F_{A} - F_{V}| < 0.49$

$$K^+ \rightarrow e^+ \nu_e \gamma |F_A - F_V| < 0.49$$

 $K^+ \to \mu^+ \nu_\mu \gamma |F_A - F_V| = -2.2 \text{ to } 0.3$

 K^- modes are charge conjugates of the modes below.

		Scale factor/	p
K+ DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	(MeV/c)
$\mu^+ u_{\mu}$	(63.51±0.18) %	S=1.3	236
$e^+\nu_e$	(1.55±0.07) ×	10 ^{–5}	247
$\pi^+\pi^{0}$	(21.16±0.14) %	S=1.1	205
$\pi^{+}\pi^{+}\pi^{-}$	(5.59±0.05) %	S=1.8	125
$\pi^{+}\pi^{0}\pi^{0}$	(1.73±0.04) %	S=1.2	133
$\pi^0 \mu^+ \nu_{\mu}$	(3.18±0.08) %	S=1.5	215
Called $K_{\mu 3}^+$.		•	
$\pi^0 e^+ \nu_e$	(A.82±0.06) %	S=1.3	228
Called K_{e3}^+ .			
$\pi^{0}\pi^{0}e^{+}\nu_{e}$	(2.1 ±0.4)×	10 ⁵	206
$\pi^+\pi^-e^+ u_e$	(3.91±0.17) ×	10 ⁻⁵	203
$\pi^+\pi^-\mu^+ u_\mu$	(1.4 ±0.9)×	₁₀ -5	151
$\pi^{0}\pi^{0}\pi^{0}e^{+}\nu_{e}$	< 3.5 ×	10 ⁻⁶ CL=90%	135
$\pi^+\gamma\gamma$	[x] $(1.10\pm0.32) \times 10^{-1}$	10-6	227
$\pi^+3\gamma$	$[x] < 1.0 \times 1$		227
$\mu^+ u_{\mu} u\overline{ u}$	< 6.0 x	10 ⁻⁶ CL=90%	236
$e^+ \nu_e \nu_{\overline{\nu}}$	< 6 ×	10 ⁻⁵ CL=90%	247
$\mu^+ u_\mue^+e^-$	(1.3 ±0.4)×	10 ⁻⁷	236
$e^+ u_e e^+ e^-$	$(3.0^{+3.0}_{-1.5}) \times$	10-8	247
$\mu^+ u_\mu\mu^+\mu^-$	< 4.1 ×	10 ⁻⁷ CL=90%	185
$\mu^+ u_\mu \gamma$	[x,y] (5.50±0.28) ×	₁₀ 3	236
$\pi^+\pi^0\gamma$	[x,y] (2.75 ± 0.15) ×		205
$\pi^+\pi^0\gamma(DE)$	[x,z] (1.8 ±0.4)×	₁₀ –5	205
$\pi^+\pi^+\pi^-\gamma$	[x,y] (1.04±0.31) ×	10-4	125
$\pi^+\pi^0\pi^0\gamma$	$[x,y]$ (7.5 $^{+5.5}_{-3.0}$) ×	₁₀ -6	133
$\pi^0 \mu^+ u_\mu \gamma$	$[x,y] < 6.1 \times$	10 ⁻⁵ CL≈90%	215
$\pi^0 e^+ \nu_e \gamma$	[x,y] (2.62±0.20) ×		228
$\pi^0 e^+ \nu_e \gamma$ (SD)	[aa] < 5.3 ×	10 ⁻⁵ CL≃90%	228
$\pi^0\pi^0e^+\nu_e\gamma$	< 5 ×	10 ⁻⁶ CL=90%	206
- '			

Lepton Family number (LF), Lepton number (L), $\Delta S = \Delta Q$ (SQ) violating modes, or $\Delta S=1$ weak neutral current (S1) modes

$\pi^+\pi^+e^-\overline{\nu}_e$	5Q	<	ς .	1.2	× 10 ⁻⁸	CL=90%	203
$\pi^+\pi^+\mu^-\overline{\nu}_{\mu}$	SQ	<	<	3.0	× 10 ⁻⁶	CL=95%	151
$\pi^+e^+e^-$	51		(2.74±0.23)	$\times 10^{-7}$		227
$\pi^{+}\mu^{+}\mu^{-}$	51		(5.0 ±1.0)	× 10 ⁻⁸		172
$\pi^+ u\overline{ u}$	51		($4.2 \begin{array}{c} +9.7 \\ -3.5 \end{array}$	× 10 ⁻¹⁰		227
$\mu^- \nu e^+ e^+$	LF	<	<	2.0	× 10 ⁻⁸	CL=90%	236
$\mu^+ \nu_e$	LF	[d] <	<	4	× 10 ⁻³	CL=90%	236
$\pi^{+}\mu^{+}e^{-}$	LF	<	<	2.1	$\times 10^{-10}$	CL=90%	214
$\pi^{+}\mu^{-}e^{+}$	LF	<	<		× 10 ⁻⁹	CL=90%	214
$\pi^{-}\mu^{+}e^{+}$	L	<	<	7	× 10 ⁻⁹	CL=90%	214
$\pi^{-}e^{+}e^{+}$	L	<	<	1.0	× 10 ⁻⁸	CL=90%	227
$\pi^- \mu^+ \mu^+$	L	[d] <	<	1.5	× 10 ⁻⁴	CL=90%	172
$\mu^+ \overline{\nu}_e$	L	[d] <	<		× 10 ⁻³	CL=90%	236
$\pi^0 e^+ \overline{\nu}_e$	L	<	<	3	× 10 ⁻³	CL=90%	228

K⁰

$$I(J^{\mathsf{P}}) = \frac{1}{2}(0^-)$$

50%
$$K_{S}$$
, 50% K_{L}
Mass $m=497.672\pm0.031~{\rm MeV}$
 $m_{K^{0}}-m_{K^{\pm}}=3.995\pm0.034~{\rm MeV}$ (S = 1.1)
 $\left|m_{K^{0}}-m_{\overline{K}^{0}}\right|/m_{{\rm average}}<10^{-18}~{\rm [bb]}$

$$I(J^P) = \frac{1}{2}(0^-)$$

Mean life $au = (0.8934 \pm 0.0008) \times 10^{-10} \text{ s}$ $c\tau = 2.6762 \text{ cm}$

CP-violation parameters [cc]

$$lm(\eta_{+-0}) = -0.002 \pm 0.008$$

 $lm(\eta_{000})^2 < 0.1$, CL = 90%

K ⁰ DECAY MODES		Fraction (Γ_i/Γ)	Scale factor/ Confidence level	<i>p</i> (MeV/ <i>c</i>)
$\frac{\pi^+\pi^-}{\pi^-}$	-	(68.61±0.28) %	6 S=1.2	206
$\pi^{0}\pi^{0}$		(31.39±0.28) 9	% S≃1.2	209
$\pi^+\pi^-\gamma$	[y,do	f] (1.78 ± 0.05) >	< 10 ⁻³	206
77	_	(2.4 ±0.9) ×	< 10 ^{−6}	249
$\pi^+\pi^-\pi^0$		(3.4 +1.1)>	× 10 ⁻⁷	133
$3\pi^{0}$		< 3.7 ×	c 10 ⁻⁵ CL=90%	139
$\pi^{\pm}e^{\mp}\nu$	[ec	e] (6.70±0.07) ×	< 10 ⁻⁴ S=1.1	229
$\pi^{\pm}\mu^{\mp}\nu$	[ec	e] (4.69±0.06)>	< 10 ⁻⁴ S=1.1	216
$\Delta S = 1$	weak neu	tral current (S1)	modes	
$\mu^{+}\mu^{-}$	51	< 3.2 >	c 10 ⁻⁷ CL=90%	225
$\mu^{+}\mu^{-}$ $e^{+}e^{-}$	S 1	< 1.4	<10 ⁻⁷ CL=90%	249
$\pi^0 e^+ e^-$	S1	< 1.1	< 10 ⁻⁶ CL=90%	231



$$I(J^P) = \frac{1}{2}(0^-)$$

$$\begin{array}{l} m_{K_L} - m_{K_S} = (0.5301 \pm 0.0014) \times 10^{10} \; \hbar \; \mathrm{s}^{-1} \\ = (3.489 \pm 0.009) \times 10^{-12} \; \mathrm{MeV} \\ \mathrm{Mean} \; \mathrm{life} \; \tau = (5.17 \pm 0.04) \times 10^{-8} \; \mathrm{s} \quad (\mathrm{S} = 1.1) \\ c\tau = 15.51 \; \mathrm{m} \end{array}$$

Slope parameter $g^{[\nu]}$

(See Particle Listings for quadratic coefficients)

$$K_L^0 \rightarrow \pi^+\pi^-\pi^0 = 0.670 \pm 0.014$$
 (S = 1.6)

K_L decay form factors [w]

$$K_{e3}^{0} |f_{S}/f_{+}| < 0.04$$
, CL = 68%

$$K_{e3}^0 |f_T/f_+| < 0.23$$
, CL = 68%

$$K_{\mu 3}^{0} |f_{T}/f_{+}| = 0.12 \pm 0.12$$

$$K_L \rightarrow e^+ e^- \gamma$$
: $\alpha_{K^*} = -0.28 \pm 0.08$

CP-violation parameters [cc]

 $\begin{array}{l} \delta = (0.327 \pm 0.012)\% \\ |\eta_{00}| = (2.275 \pm 0.019) \times 10^{-3} \quad (S = 1.1) \\ |\eta_{+-}| = (2.285 \pm 0.019) \times 10^{-3} \\ |\eta_{00}/\eta_{+-}| = 0.9956 \pm 0.0023 ^{[ff]} \quad (S = 1.8) \\ \epsilon'/\epsilon = (1.5 \pm 0.8) \times 10^{-3} ^{[ff]} \quad (S = 1.8) \\ \phi_{+-} = (43.5 \pm 0.6)^{\circ} \\ \phi_{00} = (43.4 \pm 1.0)^{\circ} \\ \phi_{00} - \phi_{+-} = (-0.1 \pm 0.8)^{\circ} \\ f \text{ for } K_L^0 \to \pi^+\pi^-\pi^0 = 0.0011 \pm 0.0008 \\ |\eta_{+-\gamma}| = (2.35 \pm 0.07) \times 10^{-3} \\ \phi_{+-\gamma} = (44 \pm 4)^{\circ} \end{array}$

$\Delta S = -\Delta Q \ln K_{L3}^0 \text{ decay}$

Re $x = 0.006 \pm 0.018$ (S = 1.3) Im $x = -0.003 \pm 0.026$ (S = 1.2)

 $|\epsilon'_{+-\gamma}|/\epsilon$ < 0.3, CL = 90%

CPT-violation parameters

Re Δ = 0.018 \pm 0.020 im Δ = 0.02 \pm 0.04

KO DECAY MODES		Fraction	(r _i /r)		ale factor/ lence level	<i>р</i> (MeV/ <i>c</i>)
$3\pi^0$		(21.12	±0.27) %	S=1.1	139
$\pi^+\pi^-\pi^0$		(12.56	±0.20) %	S=1.7	133
$\pi^{\pm}\mu^{\mp}\nu$ Called $K_{\mu 3}^{0}$.	[gg]	(27.17	±0.25) %	S=1.1	216
$\pi^{\pm} e^{\mp} \nu_e$ Called K_{e3}^0 .	[88]	(38.78	±0.27) %	S=1.1	229
2γ		(5.92	±0.15	$) \times 10^{-4}$		249
$\frac{3\gamma}{\pi^0}$ 2γ		< 2.4		× 10 ⁻⁷	CL=90%	249
$\pi^0 2\gamma$	[<i>hh</i>]	(1.70	±0.28) × 10 ⁻⁶		231
$\pi^0\pi^{\pm}e^{\mp}\nu$	[gg]	(5.18	±0.29	$) \times 10^{-5}$		207
$(\pi \mu atom) \nu$		(1.06	±0.11) × 10 ⁻⁷		-
$\pi^{\pm} e^{\mp} \nu_e \gamma$	[y.gg.hh]	(3.62	+0.26 -0.21) × 10 ⁻³		229
$\pi^+\pi^-\gamma$	[y,hh]	(4.61	±0.14	$) \times 10^{-5}$		206
$\pi^0\pi^0\gamma$		< 5.6		× 10 ⁻⁶		209

Charge conjugation \times Parity (*CP*, *CPV*) or Lepton Family number (*LF*) violating modes, or $\Delta S = 1$ weak neutral current (*S1*) modes

						, 	
CPV		(2.06	7±0.03	5) × 10 ⁻	S=1.1	206
CPV		(9.36	±0.20) × 10 ⁻	4	209
S1		(7.2	±0.5) × 10~	·9 S=1.4	225
51							225
S 1		<	4.1		× 10	·11CL=90%	249
51		(9.1	±0.5) × 10	-6	249
51							249
51	[hh]	<	4.6		× 10	7 CL=90%	206
51							225
S1		(4.1	±0.8			249
CP,S	1 [#]	<	5.1		× 10 ⁻	^{.9} CL=90%	177
CP,S	1 [11]	<	4.3		× 10 ⁻	⁹ CL=90%	231
CP,S	1 [W]	<	5.8				231
LF	[gg]	<	3.3				238
LF	[gg]	<	6.1		× 10	9 CL=90%	-
	CPV CPV S1 S1 S1 S1 S1 S1 CP,S. CP,S.	CPV CPV S1 S1 S1 S1 [hh] S1 [hh] CP,S1 [I] CP,	CPV (CPV (S1 (S1 (S1 (S1 (S1 [hh] (S1 [hh] (S1 [hh] (CP,S1 [h] (CP,S	$\begin{array}{cccc} CPV & (& 2.06\\ CPV & (& 9.36\\ SI & (& 7.2\\ SI & (& 3.25\\ SI & < & 4.1\\ SI & (& 9.1\\ SI & [hh] & (& 6.5\\ SI & [hh] < & 4.6\\ SI & (& 2.9\\ \end{array}$	CPV (2.067±0.03 CPV (9.36 ±0.20 S1 (7.2 ±0.5 S1 (3.25 ±0.28 S1 (9.1 ±0.5 S1 (9.1 ±0.5 S1 (6.5 ±1.2 S1 (1.6 ±0.5 S1 (2.9 ±6.7 −2.4 S1 (4.1 ±0.8 CP,S1 [] < 5.1	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$

K*(892)

$$I(J^P) = \frac{1}{2}(1^-)$$

 $K^*(892)^\pm$ mass $m=891.66\pm0.26$ MeV $K^*(892)^0$ mass $m=896.10\pm0.28$ MeV (S = 1.4) $K^*(892)^\pm$ full width Γ = 50.8 ± 0.9 MeV $K^*(892)^\pm$ full width Γ = 50.5 ± 0.6 MeV (S = 1.1)

K*(892) DECAY MODES	Fraction (Γ_I/Γ)	Confidence level	<i>p</i> (MeV/ <i>c</i>)
Κπ	~ 100	%	291
$K^0\gamma$	(2.30±0.20)	× 10 ⁻³	310
$K^{\pm}\gamma$	(9.9 ±0.9)	× 10 ⁻⁴	309
Κππ	< 7	× 10 ⁻⁴ 95%	224

K₁(1270)

$$I(J^P) = \tfrac12(1^+)$$

Mass $m = 1273 \pm 7 \text{ MeV}^{[m]}$ Full width $\Gamma = 90 \pm 20 \text{ MeV}^{[m]}$

Fraction (Γ_I/Γ)	p (MeV/c)	
(42 ±6)%	76	
(28 ±4)%	_	
(16 ±5)%	301	
(11.0±2.0) %	_	
(3.0±2.0) %	-	
	(42 ±6)% (28 ±4)% (16 ±5)% (11.0±2.0)%	

K₁(1400)

$$I(J^P) = \frac{1}{2}(1^+)$$

Mass $m=1402\pm7$ MeV Full width $\Gamma=174\pm13$ MeV (S = 1.6)

K ₁ (1400) DECAY MODES	Fraction (Γ _I /Γ)	p (MeV/c)
K*(892)π	(94 ±6)%	401
Kρ	(3.0 ± 3.0) %	298
K f ₀ (1370)	(2.0±2.0) %	-
Κω	(1.0±1.0) %	285
$K_0^*(1430)\pi$	not seen	_

K*(1410)

$$I(J^P) = \frac{1}{2}(1^-)^{-1}$$

Mass $m = 1414 \pm 15$ MeV (S = 1.3) Full width $\Gamma = 232 \pm 21$ MeV (S = 1.1)

K*(1410) DECAY MODES	Fraction (Γ ₁ /Γ)	Confidence level	p (MeV/c)
K*(892)π	> 40	%	95%	408
Κπ	(6.6±	1.3) %		611
Κρ	< 7	%	95%	309

K*(1430) [kk]

$$I(J^P) = \frac{1}{2}(0^+)$$

Mass $m=1429\pm 6$ MeV Full width $\Gamma=287\pm 23$ MeV

K ₀ *(1430) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
Κπ	(93±10) %	621

K*(1430)

$$I(J^P) = \frac{1}{2}(2^+)$$

 $K_2^*(1430)^\pm$ mass $m=1425.6\pm1.5$ MeV (S = 1.1) $K_2^*(1430)^0$ mass $m=1432.4\pm1.3$ MeV $K_2^*(1430)^\pm$ full width $\Gamma=98.5\pm2.7$ MeV (S = 1.1) $K_2^*(1430)^0$ full width $\Gamma=109\pm5$ MeV (S = 1.9)

K2(1430) DECAY MODES	Fraction (Γ_I/Γ)	Scale factor/ Confidence level	р (MeV/c)
Κπ	(49.9±1.2) %		622
K*(892)π	(24.7±1.5) %		423
$K^*(892)\pi\pi$	(13.4±2.2) %		375
Kρ	(8.7±0.8) %	S≃1.2	331
Κω	(2.9±0.8) %		319
$K^+\gamma$	(2.4±0.5) × 10	o ⁻³ S=1.1	627
Κη	$(1.5^{+3.4}_{-1.0}) \times 10$) ⁻³ S=1.3	492
Κωπ	< 7.2 × 10	-4 CL=95%	110
$K^0\gamma$	< 9 × 10)-4 CL=90%	631

Meson Summary Table

K*(1680)

 $I(J^P) = \frac{1}{2}(1^-)$

Mass $m = 1717 \pm 27$ MeV (S = 1.4) Full width $\Gamma = 322 \pm 110$ MeV (S = 4.2)

K*(1680) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
Κπ	(38.7 ± 2.5) %	779
Κρ	$(31.4^{+4.7}_{-2.1})$ %	571
$K^*(892)\pi$	(29.9 ^{+2.2} _{-4.7}) %	615

K₂(1770) [#]

 $I(J^P)=\tfrac{1}{2}(2^-)$

Mass $m=1773\pm 8$ MeV Full width $\Gamma=186\pm 14$ MeV

Fraction (Γ_i/Γ)	p (MeV/c)
	_
dominant	287
seen	653
seen	-
seen	441
seen	608
	dominant seen seen seen

K*(1780)

$$I(J^P) = \frac{1}{2}(3^-)$$

Mass $m = 1776 \pm 7$ MeV (S = 1.1) Full width Γ = 159 ± 21 MeV (S = 1.3)

K*(1780) DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	(MeV/c)
Kρ	(31 ± 9)%		612
$K^*(892)\pi$	(20 ± 5)%		651
$K\pi$	(18.8± 1.0) %		810
$K\eta$	(30 ±13)%		715
$K_2^*(1430)\pi$	< 16 %	95%	284

K₂(1820) [mm]

$$I(J^P) = \frac{1}{2}(2^-)$$

Mass $m=1816\pm13~{\rm MeV}$ Full width $\Gamma=276\pm35~{\rm MeV}$

K2(1820) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
$K_2^*(1430)\pi$	seen	325
$K^*(892)\pi$	seeп	680
K f ₂ (1270)	seen	186
κ_{ω}	seen	638

K*(2045)

$$I(J^P) = \frac{1}{2}(4^+)$$

Mass $m=2045\pm 9$ MeV (S = 1.1) Full width $\Gamma=198\pm 30$ MeV

K4 (2048) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
Κπ	(9.9±1.2) %	958
$K^*(892)\pi\pi$	(9 ±5)%	800
$K^*(892)\pi\pi\pi$	(7 ±5)%	764
ρΚπ	$(5.7\pm3.2)\%$	742
$\omega K \pi$	(5.0±3.0) %	736
$\phi K \pi$	(2.8±1.4) %	591
φK*(892)	(1.4±0.7) %	363

CHARMED MESONS

 $(C=\pm 1)$

 $D^+ = c \overline{d}, D^0 = c \overline{u}, \overline{D}{}^0 = \overline{c} u, D^- = \overline{c} d,$ similarly for D^* 's

D±

$$I(J^P) = \tfrac{1}{2}(0^-)$$

Mass $m=1869.3\pm0.5~{\rm MeV}~{\rm (S}=1.1)$ Mean life $\tau=(1.057\pm0.015)\times10^{-12}~{\rm s}$ $c\tau=317~{\rm \mu m}$

CP-violation decay-rate asymmetries

$$A_{CP}(K^+K^-\pi^\pm) = -0.017 \pm 0.027$$

$$A_{CP}(K^\pm K^{*0}) = -0.02 \pm 0.05$$

$$A_{CP}(\phi \pi^\pm) = -0.014 \pm 0.033$$

$$A_{CP}(\pi^+\pi^-\pi^\pm) = -0.02 \pm 0.04$$

$D^+ ightarrow \ \overline{K}{}^*(892)^0 \ell^+ u_\ell$ form factors

 $\begin{aligned} r_2 &= 0.72 \pm 0.09 \\ r_V &= 1.85 \pm 0.12 \\ \Gamma_L/\Gamma_T &= 1.23 \pm 0.13 \\ \Gamma_+/\Gamma_- &= 0.16 \pm 0.04 \end{aligned}$

D⁻ modes are charge conjugates of the modes below.

D+ DECAY MODES	Fraction (Γ_I/Γ)	Scale factor/ Confidence level	•
	inclusive modes		
e ⁺ anything	(17.2 ±1.9) 9	4	_
K ⁻ anything	(24.2 ±2.8) 5	6 S=1.4	-
\overline{K}^0 anything $+ K^0$ anything	(59 ±7) 5	6	-
K ⁺ anything	(5.8 ± 1.4)	6	-
η anything	[nn] < 13	% CL=90%	-
Leptonic	and semileptonic mo	des	
$\mu^+ u_{\mu}$	< 7.2	< 10 ⁻⁴ CL=90%	932
$\overline{K}^0\ell^+\nu_{\ell}$	[oo] (6.8 ±0.8)	6	868
$\overline{K}^0 e^+ \nu_e$	(6.7 ±0.9)	%	868
$\overline{K}{}^{0}\mu^{+} u_{\mu}$	(7.0 +3.0)	%	865
$K^-\pi^+e^+ u_e$	$(4.1 \begin{array}{c} +0.9 \\ -0.7 \end{array})^{\circ}$	%	863
$\overline{K}^*(892)^0 e^+ \nu_e$	(3.2 ±0.33)	%	720
\times B($\overline{K}^{*0} \rightarrow K^-\pi^+$)			
$K^-\pi^+e^+ u_e$ nonresonant	< 7	< 10 ⁻³ CL=90%	863
$K^-\pi^+\mu^+\nu_\mu$	(3.2 ±0.4)	% S=1.1	851
$\overline{K}^*(892)^{0} \mu^+ \nu_{\mu}$	(2.9 ± 0.4)	%	715
$\times B(\overline{K}^{*0} \rightarrow K^-\pi^+)$			
$K^-\pi^+\mu^+ u_\mu$ nonresonant	(2.7 ±1.1):	< 10 ^{−3}	851
$(\overline{K}^*(892)\pi)^0 e^+ \nu_e$	< 1.2	% CL=90%	714
$(\overline{K}\pi\pi)^0 e^+ \nu_e$ non- \overline{K}^* (892)	< 9	< 10 ⁻³ CL=90%	846
$K^-\pi^+\pi^0\mu^+\nu_\mu$	< 1.4	<10 ^{−3} CL=90%	825-
$\pi^0\ell^+\nu$	[pp] (3.1 ±1.5):		930

Fractions of some of the following modes with resonances have already appeared above as submodes of particular charged-particle modes.

$\overline{K}^*(892)^0 \ell^+ \nu_{\ell}$	[oo] (4.7 ±0.4) %		720
$\vec{K}^*(892)^0 e^+ \nu_e$	(4.8 ±0.5) %		720
$\overline{K}^*(892)^0 \mu^+ \nu_{\mu}$	(4.4 ±0.6) %	S=1.1	715
$\rho^0 e^+ \nu_e$	(2.2 ±0.8) × 10 ⁻³		776
$\rho^0 \mu^+ \nu_{\mu}$	(2.7 ±0.7) × 10 ⁻³		772
$\phi e^+ \nu_e$	< 2.09	%	CL=90%	657
$\phi \mu^+ \nu_{\mu}$	< 3.72	%	CL=90%	651
$\eta \ell^+ \nu_\ell$	< 5	× 10 ⁻³	CL=90%	_
$\eta'(958) \mu^+ \nu_{\mu}$	< 9	× 10 ⁻³	CL±90%	684
11-4		フィヤ		

Hadronic modes	with a R or RKR		
$\overline{K}{}^{0}\pi^{+}$	(2.89±0.26) %	S=1.1	862
$K^-\pi^+\pi^+$ [qq]	(9.0 ±0.6)%		845
$\overline{K}^*(892)^0\pi^+$	$(1.27 \pm 0.13)\%$		712
\times B($\overline{K}^{*0} \rightarrow K^-\pi^+$)			
$\overline{K}_{0}^{*}(1430)^{0}\pi^{+}$	(2.3 ±0.3)%		368
\times B(\overline{K}_0^* (1430) ⁰ \rightarrow $K^-\pi^+$)			
$\overline{K}^*(1680)^{0}\pi^+$	$(3.7 \pm 0.8) \times 10^{-3}$		65
$\times B(\overline{K}^*(1680)^0 \to K^-\pi^+)$,		
$K^-\pi^+\pi^+$ nonresonant	(8.5 ±0.8)%		845
$\overline{K}^0 \pi^+ \pi^0$ [qq]	(9.7 ±3.0)%	S=1.1	845

```
\overline{K}{}^{0}\rho^{+}
                                                                                                                                                                                         Plonic modes
                                                             (6.6 ±2.5)%
                                                                                                                   680
   \overline{K}^*(892)^0\pi^+
                                                                                                                                        \pi^{+}\pi^{0}
                                                                                                                                                                                                   ( 2.5~\pm0.7 ) \times\,10^{-3}
                                                            ( 6.3 \pm 0.4 ) \times 10^{-3}
                                                                                                                                                                                                                                                          925
                                                                                                                                        \pi^{+}\pi^{+}\pi^{-}
       \times B(\overline{K}^{*0} \rightarrow \overline{K}^{0}\pi^{0})
                                                                                                                                                                                                    (3.6 \pm 0.4) \times 10^{-3}
                                                                                                                                                                                                                                                          908
   \overline{K}{}^0\pi^+\pi^0 nonresonant
                                                                                                                                           \rho^0 \pi^+
                                                                                                                                                                                                    (1.05\pm0.31)\times10^{-3}
                                                                                                                                                                                                                                                          769
                                                            (1.3 \pm 1.1)\%
                                                                                                                   845
K^-\pi^+\pi^+\pi^0
                                                                                                                                           \pi^+\pi^+\pi^- nonresonant
                                                                                                                                                                                                    ( 2.2 \pm 0.4 ) \times\,10^{-3}
                                                    [qq] ( 6.4 ±1.1 )%
                                                                                                                   816
                                                                                                                                                                                                                                                          908
   \overline{K}^*(892)^0 \rho^+ \text{total}
 \times B(\overline{K}^{*0} \to K^- \pi^+)
                                                            (1.4 \pm 0.9)\%
                                                                                                                   423
                                                                                                                                        \pi^{+}\pi^{+}\pi^{-}\pi^{0}
                                                                                                                                                                                                    (1.9 \begin{array}{c} +1.5 \\ -1.2 \end{array})\%
                                                                                                                                                                                                                                                          882
                                                                                                                                           \eta \pi^+ \times B(\eta \rightarrow \pi^+ \pi^- \pi^0)
                                                                                                                                                                                                   (1.7 \pm 0.6) \times 10^{-3}
                                                                                                                                                                                                                                                           848
   \overline{K}_1(1400)^0\pi^+
                                                             ( 2.2 \pm 0.6 ) %
                                                                                                                   390
                                                                                                                                           \omega \pi^+ \times B(\omega \to \pi^+ \pi^- \pi^0)
                                                                                                                                                                                                                     \times 10<sup>-3</sup>
                                                                                                                                                                                                 < 6
                                                                                                                                                                                                                                      CL=90%
                                                                                                                                                                                                                                                          764
        \times B(\vec{K}_1(1400)^0 \to K^-\pi^+\pi^0)
                                                                                                                                                                                                   ( 2.1 \pm 0.4 ) \times\,10^{-3}
                                                                                                                                        \pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}
                                                                                                                                                                                                                                                          845
    K^-\rho^+\pi^+total
                                                             (3.1 \pm 1.1)\%
                                                                                                                   616
                                                                                                                                        \pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{0}
                                                                                                                                                                                                   (2.9 \ ^{+2.9}_{-2.0}) \times 10^{-3}
       \dot{K}^- \rho^+ \pi^+ 3-body
                                                                                                                                                                                                                                                          799
                                                             (1.1 \pm 0.4)\%
                                                                                                                   616
   \overline{K}^*(892)^0\pi^+\pi^0 total
                                                             ( 4.5 ±0.9 ) %
                                                                                                                   687
       \times B(\overline{K}^{*0} \rightarrow K^-\pi^+)
                                                                                                                                                    Fractions of some of the following modes with resonances have already
        \overline{K}*(892)0 \pi+ \pi0 3-body
                                                                                                                                                    appeared above as submodes of particular charged-particle modes.
                                                             ( 2.8 ±0.9 ) %
                                                                                                                   687
           \times B(\overline{K}^{*0} \rightarrow K^-\pi^+)
                                                                                                                                       ^{\eta\pi^+}_{\rho^0\pi^+}
                                                                                                                                                                                                   ( 7.5 \pm 2.5 ) \times\,10^{-3}
                                                                                                                                                                                                                                                          848
                                                                                                                                                                                                   (1.05\pm0.31)\times10^{-3}
    K^*(892)^-\pi^+\pi^+3-body
                                                             (7 \pm 3) \times 10^{-3}
                                                                                                                   688
                                                                                                                                                                                                                                                           769
                                                                                                                                                                                                                      \times 10<sup>-3</sup>
       \times B(K^{*-} \rightarrow K^{-}\pi^{0})
                                                                                                                                        \omega \pi^+
                                                                                                                                                                                                 < 7
                                                                                                                                                                                                                                      CL=90%
                                                                                                                                                                                                                                                           764
    K^-\pi^+\pi^+\pi^0 nonresonant
                                                                                                                                       \eta \rho^+
                                                                                                                                                                                                                       %
                                                    [rr] ( 1.2 ±0.6 )%
                                                                                                                   816
                                                                                                                                                                                                 < 1.2
                                                                                                                                                                                                                                      CL=90%
                                                                                                                                                                                                                                                          658
\overline{K}^0\pi^+\pi^+\pi^-
                                                                                                                                                                                                                       × 10<sup>-3</sup>
                                                                                                                                        \eta'(958)\pi^{+}
                                                                                                                                                                                                 < 9
                                                    [qq]
                                                            (7.0 \pm 0.9)\%
                                                                                                                   814
                                                                                                                                                                                                                                      CL=90%
                                                                                                                                                                                                                                                           680
   \overline{K}^0 a_1(1260)^+
                                                                                                                                        \eta'(958) \rho^+
                                                             ( 4.0 ±0.9 )%
                                                                                                                                                                                                 < 1.5
                                                                                                                                                                                                                       %
                                                                                                                                                                                                                                      CL=90%
                                                                                                                                                                                                                                                           355
       \times B(a_1(1260)^+ \to \pi^+\pi^+\pi^-)
                                                                                                                                                                          Hadronic modes with a K\overline{K} pair
   \overline{K}_1(1400)^0\pi^+
                                                             ( 2.2 ±0.6 )%
                                                                                                                   390
                                                                                                                                        K + \overline{K}^0
                                                                                                                                                                                                   ( 7.4 \pm 1.0 ) \times\,10^{-3}
        \times B(\overline{K}_1(1400)^0 \rightarrow \overline{K}^0 \pi^+ \pi^-)
                                                                                                                                                                                                                                                          792
                                                                                                                                        K^+K^-\pi^+
                                                                                                                                                                                           [qq] ( 8.8 \pm 0.8 ) \times 10<sup>-3</sup>
                                                                                                                                                                                                                                                           744
    K^*(892)^-\pi^+\pi^+3-body
                                                             (1.4 \pm 0.6)\%
                                                                                                                   688
                                                                                                                                           \phi \pi^+ \times B(\phi \rightarrow K^+ K^-)
                                                                                                                                                                                                    (3.0 \pm 0.3) \times 10^{-3}
                                                                                                                                                                                                                                                           647
       \times B(K^{*-} \rightarrow \overline{K}^0 \pi^-)
                                                                                                                                            K+ K*(892)0
                                                                                                                                                                                                    ( 2.8 \pm 0.4 ) \times\,10^{-3}
   \overline{K}{}^0 \, \rho^0 \, \pi^+ \, \mathrm{total}
                                                                                                                                                                                                                                                           610
                                                             (4.2 \pm 0.9)\%
                                                                                                                   614
                                                                                                                                               \times B(\overline{K}^{*0} \rightarrow K^-\pi^+)
       \overline{K}^0 \rho^0 \pi^+ 3-body
                                                             (5 \pm 5) \times 10^{-3}
                                                                                                                   614
                                                                                                                                            K^+K^-\pi^+ nonresonant
                                                                                                                                                                                                    (4.5 \pm 0.9) \times 10^{-3}
    \overline{K}{}^0\pi^+\pi^+\pi^- nonresonant
                                                             (8 \pm 4 ) \times 10<sup>-3</sup>
                                                                                                                   814
                                                                                                                                        K^0\overline{K}^0\pi^+
                                                                                                                                                                                                                                                           741
K^-\pi^+\pi^+\pi^+\pi^-
                                                            ( 7.2 \pm 1.0 ) \times\,10^{-3}
                                                                                                                   772
                                                                                                                                            K^*(892)^+ \overline{K}{}^0
    \overline{K}^*(892)^0\pi^+\pi^+\pi^-
                                                                                                                                                                                                    (2.1 \pm 1.0)\%
                                                                                                                                                                                                                                                           611
                                                             ( 5.4 \pm 2.3 ) \times\,10^{-3}
                                                                                                                   642
                                                                                                                                               \times B(K^{*+} \rightarrow K^0 \pi^+)
       \times B(\overline{K}^{*0} \rightarrow K^-\pi^+)
                                                                                                                                        K^+K^-\pi^+\pi^0
                                                                                                                                                                                                                                                           682
       \overline{K}^*(892)^0 \rho^0 \pi^+ \times B(\overline{K}^{*0} \to K^- \pi^+)
                                                             (1.9 \begin{array}{c} +1.1 \\ -1.0 \end{array}) \times 10^{-3}
                                                                                                                   242
                                                                                                                                            \phi \pi^+ \pi^0 \times B(\phi \rightarrow K^+ K^-)
                                                                                                                                                                                                   ( 1.1 \pm 0.5 )%
                                                                                                                                                                                                                                                           619
                                                                                                                                                                                                                      × 10<sup>-3</sup>
                                                                                                                                               \phi \rho^+ \times B(\phi \rightarrow K^+ K^-)
                                                                                                                                                                                                  < 7
                                                                                                                                                                                                                                      CL=90%
                                                                                                                                                                                                                                                           268
        \overline{K}^*(892)^0\pi^+\pi^+\pi^-\text{no-}\rho
                                                             (2.9 \pm 1.1) \times 10^{-3}
                                                                                                                   642
                                                                                                                                                                                                   ( 1.5 ^{+0.7}_{-0.6} )%
                                                                                                                                            K^{+}K^{-}\pi^{+}\pi^{0} non-\phi
                                                                                                                                                                                                                                                           682
           \times B(\overline{K}^{*0} \rightarrow K^-\pi^+)
                                                                                                                                        K^+\overline{K}{}^0\pi^+\pi^-
                                                             ( 3.1~\pm 0.9 ) \times\,10^{-3}
    K^{-}\rho^{0}\pi^{+}\pi^{+}
                                                                                                                                                                                                  < 2
                                                                                                                                                                                                                       %
                                                                                                                                                                                                                                      CL=90%
                                                                                                                                                                                                                                                           678
                                                                                                                   529
    K^-\pi^+\pi^+\pi^+\pi^- nonresonant
                                                                              × 10<sup>-3</sup>
                                                                                                                                        K^{0}K^{-}\pi^{+}\pi^{+}
                                                                                                                                                                                                    ( 1.0 \pm0.6 )%
                                                                                               CL=90%
                                                                                                                                                                                                                                                           678
                                                           < 2.3
                                                                                                                   772
                                                                                                                                            K^*(892)^+\overline{K}^*(892)^0
                                                                                                                                                                                                    (1.2 \pm 0.5)\%
                                                                                                                                                                                                                                                           273
K^-\pi^+\pi^+\pi^0\pi^0
                                                             ( 2.2 ^{+5.0}_{-0.9} ) %
                                                                                                                                                \times B<sup>2</sup>(K*+ \rightarrow K<sup>0</sup>\pi+
\overline{K}{}^{0}\pi^{+}\pi^{+}\pi^{-}\pi^{0}
                                                             (5.4 \begin{array}{c} +3.0 \\ -1.4 \end{array})\%
                                                                                                                                            K^{0}K^{-}\pi^{+}\pi^{+} non-K^{*+}\overline{K}^{*0}
                                                                                                                                                                                                                       \times 10^{-3}
                                                                                                                   773
                                                                                                                                                                                                                                      CL=90%
                                                                                                                                                                                                                                                           678
                                                                                                                                                                                                  < 7.9
                                                                                                                                        K^{+}K^{-}\pi^{+}\pi^{+}\pi^{-}
\overline{K}^{0}\pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}
                                                                                                                                                                                                                                                           600
                                                             (8 \pm 7) \times 10^{-4}
                                                                                                                   714
                                                                                                                                            \phi \pi^+ \pi^+ \pi^-
                                                                                                                                                                                                                       \times 10^{-3}
K^-\pi^+\pi^+\pi^+\pi^-\pi^0
                                                                                                                                                                                                  < 1
                                                                                                                                                                                                                                      CL=90%
                                                             (2.0 \pm 1.8) \times 10^{-3}
                                                                                                                   718
\overline{K}{}^{0}\overline{K}{}^{0}K^{+}
                                                                                                                                               \times B(\phi \rightarrow K^+K^-)
                                                             (1.8 \pm 0.8)\%
                                                                                                                   545
                                                                                                                                            K^+K^-\pi^+\pi^+\pi^- nonresonant
                                                                                                                                                                                                  < 3
                                                                                                                                                                                                                                      CL=90%
                                                                                                                                                                                                                                                           600
             Fractions of some of the following modes with resonances have already
                                                                                                                                                    Fractions of the following modes with resonances have already appeared
            appeared above as submodes of particular charged-particle modes.
                                                                                                                                                    above as submodes of particular charged-particle modes.
\frac{\overline{K}^0 \rho^+}{\overline{K}^0 a_1 (1260)^+}
                                                             (6.6 ±2.5)%
                                                                                                                   680
                                                                                                                                        \phi \pi^+
                                                                                                                                                                                                    (6.1 \pm 0.6) \times 10^{-3}
                                                                                                                                                                                                                                                           647
                                                             ( 8.0 \pm 1.7 ) %
                                                                                                                   328
                                                                                                                                        \phi\pi^+\pi^0
\overline{K}^0 a_2(1320)^+
                                                                                                                                                                                                    ( 2.3 \pm1.0 )%
                                                                                                                                                                                                                                                           619
                                                                                \times 10<sup>-3</sup>
                                                           < 3
                                                                                               CL=90%
                                                                                                                   199
                                                                                                                                            \phi \rho^+
                                                                                                                                                                                                                                       CL=90%
                                                                                                                                                                                                                                                           268
                                                                                                                                                                                                  < 1.4
\overline{K}^*(892)^0\pi^+
                                                             ( 1.90±0.19) %
                                                                                                                   712
                                                                                                                                         \phi \pi^+ \pi^+ \pi^-
                                                                                                                                                                                                                       \times 10^{-3}
                                                                                                                                                                                                  < 2
                                                                                                                                                                                                                                                           565
                                                                                                                                                                                                                                      CL=90%
\overline{K}^*(892)^0 \rho^+ \text{ total}
                                                     [rr] ( 2.1 ±1.3 )%
                                                                                                                   423
    \frac{(892)^{0} \rho^{+} \text{ total}}{K^{*}(892)^{0} \rho^{+} S\text{-wave}}
\frac{K^{*}(892)^{0} \rho^{+} P\text{-wave}}{K^{*}(892)^{0} \rho^{+} D\text{-wave}}
                                                                                                                                                                                                    ( 4.2 \pm 0.5 ) \times\,10^{-3}
                                                                                                                                        K+K*(892)0
                                                                                                                                                                                                                                                           610
                                                     [rr] (1.6 \pm 1.6)\%
                                                                                                                   423
                                                                                                                                        K*(892)+ K0
                                                                                                                                                                                                    (3.2 \pm 1.5)\%
                                                                                                                                                                                                                                                           611
                                                                                \times 10<sup>-3</sup>
                                                           < 1
                                                                                                                   423
                                                                                                                                         K^*(892)^+\overline{K}^*(892)^0
                                                                                                                                                                                                                                                           273
                                                                                                                                                                                                    (2.6 \pm 1.1)\%
                                                                    \pm 7 ) × 10<sup>-3</sup>
                                                             (10
                                                                                                                   423
    \overline{K}^*(892)^0 \rho^+ D-wave longitu-
                                                                                × 10<sup>-3</sup>
                                                           < 7
                                                                                               CI = 90\%
                                                                                                                   423
                                                                                                                                                                    Doubly Cabibbo suppressed (DC) modes,
\overline{K}_1(1270)^0\pi^+
                                                                                                                                                                 \Delta C = 1 weak neutral current (C1) modes, or
                                                                               × 10<sup>-3</sup>
                                                           < 7
                                                                                               CI = 90\%
                                                                                                                   487
                                                                                                                                                Lepton Family number (LF) or Lepton number (L) violating modes
\overline{K}_1(1400)^0\pi^+
                                                             (4.9 \pm 1.2)\%
                                                                                                                   390
                                                                                                                                        K^{+}\pi^{+}\pi^{-}
                                                                                                                                                                                                    ( 6.8 \pm 1.5 ) \times 10^{-4}
                                                                                                                                                                                  DC
                                                                                                                                                                                                                                                           845
\overline{K}^*(1410)^0\pi^+
                                                           < 7
                                                                               \times 10^{-3}
                                                                                                                   382
                                                                                                                                            K^+\rho^0
                                                                                                                                                                                                    ( 2.5 \pm 1.2 ) \times 10<sup>-4</sup>
                                                                                                                                                                                   DC
                                                                                                                                                                                                                                                           681
\overline{K}_{0}^{*}(1430)^{0}\pi^{+}
                                                             (3.7 \pm 0.4)\%
                                                                                                                   368
                                                                                                                                            K^*(892)^0\pi^+
                                                                                                                                                                                                    ( 3.6 \pm 1.6 ) \times 10^{-4}
                                                                                                                                                                                                                                                           712
                                                                                                                                                                                   DC
\overline{K}^*(1680)^0\pi^+
                                                                                                                     65
                                                             (1.43\pm0.30)\%
                                                                                                                                                                                                    ( 2.4 \pm 1.2 ) \times 10<sup>-4</sup>
                                                                                                                                            K^+\pi^+\pi^- nonresonant
                                                                                                                                                                                  DC
                                                                                                                                                                                                                                                           845
\overline{K}^*(892)^0\pi^+\pi^0 total
                                                                                                                   687
                                                             (6.7 \pm 1.4)\%
                                                                                                                                                                                                                       \times 10^{-4}
                                                                                                                                         K+K+K-
                                                                                                                                                                                   DC
                                                                                                                                                                                                  < 1.4
                                                                                                                                                                                                                                       CL=90%
                                                                                                                                                                                                                                                           550
    \hat{K}^*(892)^0\pi^+\pi^03-body
                                                     [rr] (4.2 \pm 1.4)\%
                                                                                                                   687
                                                                                                                                            \phi K^+
                                                                                                                                                                                                                        × 10<sup>-4</sup>
                                                                                                                                                                                   DC
                                                                                                                                                                                                  < 1.3
                                                                                                                                                                                                                                      CL=90%
                                                                                                                                                                                                                                                           527
     K^*(892)^-\pi^+\pi^+3-body
                                                             (2.0 \pm 0.9)\%
                                                                                                                   688
                                                                                                                                                                                                                        × 10<sup>-5</sup>
                                                                                                                                         \pi^{+}\,e^{+}\,e^{-}
                                                                                                                                                                                   C1
                                                                                                                                                                                                  < 6.6
                                                                                                                                                                                                                                       CL=90%
 K^-\rho^+\pi^+ total
                                                             (3.1 \pm 1.1)\%
                                                                                                                   616
                                                                                                                                                                                                                        \times 10<sup>-5</sup>
                                                                                                                                        \pi^+\mu^+\mu^-
                                                                                                                                                                                                  < 1.8
                                                                                                                                                                                                                                       CL=90%
                                                                                                                                                                                                                                                           917
                                                                                                                                                                                   C1
        -\rho^+\pi^+3-body
                                                             (1.1 \pm 0.4)\%
                                                                                                                   616
                                                                                                                                                                                                                        × 10<sup>-4</sup>
                                                                                                                                        \rho^+\mu^+\mu^-
                                                                                                                                                                                   C1
                                                                                                                                                                                                  < 5.6
                                                                                                                                                                                                                                       Cl = 90\%
                                                                                                                                                                                                                                                           759
\overline{K}{}^{0} \rho^{0} \pi^{+} \text{total}
                                                             (4.2 \pm 0.9)\%
                                                                                                CL=90%
                                                                                                                   614
                                                                                                                                                                                                                        × 10<sup>-4</sup>
                                                                                                                                         K+ e+ e-
                                                                                                                                                                                                                                                           869
                                                                                                                                                                                            [55] < 2.0
                                                                                                                                                                                                                                       CL=90%
    \dot{K}^0 \rho^0 \pi^+ 3-body
                                                             (5 \pm 5) \times 10^{-3}
                                                                                                                    614
                                                                                                                                                                                                                        \times 10<sup>-5</sup>
                                                                                                                                        K^{+}\mu^{+}\mu^{-}
                                                                                                                                                                                            [ss] < 9.7
                                                                                                                                                                                                                                       CL=90%
                                                                                                                                                                                                                                                           856
 \overline{K}^{0} f_{0}(980) \pi^{+}
                                                                                \times 10^{-3}
                                                           < 5
                                                                                                CL=90%
                                                                                                                    461
                                                                                                                                        \pi^+ e^+ \mu^-
                                                                                                                                                                                                                        \times 10<sup>-4</sup>
                                                                                                                                                                                   LF
                                                                                                                                                                                                                                       CL=90%
                                                                                                                                                                                                  < 1.1
                                                                                                                                                                                                                                                           926
                                                             ( 8.1~\pm3.4~)\times10^{-3}
 \overline{K}^*(892)^0\pi^+\pi^+\pi^-
                                                                                                   S=1.7
                                                                                                                   642
                                                                                                                                        \pi^+e^-\mu^+
                                                                                                                                                                                                                        \times 10<sup>-4</sup>
                                                                                                                                                                                   LF
                                                                                                                                                                                                  < 1.3
                                                                                                                                                                                                                                       CL=90%
                                                                                                                                                                                                                                                           926
                                                                                                                                                                                                                        × 10<sup>-4</sup>
    \overline{K}^*(892)^0 \rho^0 \pi^+
                                                             (2.9 \ ^{+1.7}_{-1.5}) \times 10^{-3}
                                                                                                   S=1.8
                                                                                                                   242
                                                                                                                                         K^{+}e^{+}\mu^{-}
                                                                                                                                                                                   LF
                                                                                                                                                                                                       1.3
                                                                                                                                                                                                                                       CL=90%
                                                                                                                                                                                                                                                           866
    \overline{K}^*(892)^0\pi^+\pi^+\pi^- no- \rho
                                                             (4.3 \pm 1.7) \times 10^{-3}
                                                                                                                    642
 K^-\rho^0\pi^+\pi^+
                                                             ( 3.1 \pm 0.9 ) \times 10^{-3}
```

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Meson Summary Table

ivieson Summa	ary rable					
$K^+e^-\mu^+$	F < 1.2 × 10 ⁻⁴	CL=90%	866	$K^-\pi^+\pi^0$	qq] (13.9 ±0.9)%	S=1.3 844
$\pi^-e^+e^+$	< 1.1 × 10 ⁻⁴	CL=90%	929	$\kappa^-\rho^+$	(10.8 ±1.0)%	678
$\pi^-\mu^+\mu^+$	$< 8.7 \times 10^{-5}$	CL=90%	917	K*(892)-π+	(1.7 ±0.2) %	711
$\pi^-e^+\mu^+$	$< 1.1 \times 10^{-4}$	CL=90%	926	$\underline{\hspace{1cm}} \times \hspace{1cm} B(K^{*-} \to \hspace{1cm} K^- \pi^0)$	•	
$\rho^-\mu^+\mu^+$	< 5.6 × 10 ⁻⁴	CL=90%	759	$K^*(892)^0\pi^0$	$(2.1 \pm 0.3)\%$	709
$K^-e^+e^+$ $K^-\mu^+\mu^+$ ι	$< 1.2 \times 10^{-4}$ $< 1.2 \times 10^{-4}$	CL≃90%	869	$\times B(\overline{K}^{*0} \rightarrow K^-\pi^+)$ $K^-\pi^+\pi^0$ nonresonant		•••
$K - e^+ \mu^+$	$< 1.2 \times 10^{-4}$ $< 1.3 \times 10^{-4}$	CL≃90% CL≃90%	856 866	$\overline{K}^0\pi^0\pi^0$	$(6.9 \pm 2.5) \times 10^{-3}$, 844 843
$K^*(892)^- \mu^+ \mu^+$	< 8.5 × 10 ⁻⁴	CL=90%	703	$\frac{n}{K}$ *(892) $^{0}\pi^{0}$	(1.1 ±0.2)%	709
				$\times B(\overline{K}^{*0} \to \overline{K}^0\pi^0)$	(5.5 25.2) //	
	1/4P> 1/0=>			$\overline{K}{}^0\pi^0\pi^0$ nonresonant	$(7.9 \pm 2.1) \times 10^{-3}$	843
D^0	$I(J^P)=\tfrac{1}{2}(0^-)$			$K^-\pi^+\pi^+\pi^-$		5=1.1 812
	\pm 0.5 MeV (S = 1.1)			$\mathcal{K}^-\pi^+ ho^0$ total $\mathcal{K}^-\pi^+ ho^0$ 3-body	(6.3 ±0.4)%	612
$m_{D^{\pm}}-m_{D^0}=4$	$.76 \pm 0.10 \text{ MeV} (S = 1.1)$			$K^*(892)^0 \rho^0$	$(4.8 \pm 2.1) \times 10^{-3}$ $(9.8 \pm 2.2) \times 10^{-3}$	612 418
•	$415 \pm 0.004) \times 10^{-12}$ s			$\times \stackrel{\text{(6.52)}}{\times} \stackrel{F}{K^{+0}} \rightarrow \stackrel{K^{-}}{\pi^{+}})$	(9.0 ±2.2) × 10	410
$c\tau = 124.4 \mu\text{m}$			$K^-a_1(1260)^+$	(3.6 ±0.6) %	327	
$ m_{D_1^0} - m_{D_2^0} < 24 \times 10^{10} \ h \ s^{-1}, \ CL = 90\% \ ^{[tt]}$			$\times B(a_1(1260)^+ \rightarrow \pi^+\pi^+$	π^{-})		
$ \Gamma_{D_1^0} - \Gamma_{D_2^0} /\Gamma_{D^0} < 0.20, CL = 90\%$ [tt]			$K^*(892)^0 \pi^+ \pi^- \text{total}$	$(1.5 \pm 0.4)\%$	683	
$\Gamma(K^+\ell^-\overline{ u}_\ell$ (via \overline{D}^0))/ $\Gamma(K^-\ell^+ u_\ell)<0.005$, CL = 90%			$\frac{\times B(\overline{K}^{*0} \to K^-\pi^+)}{\overline{K}^*(892)^0 \pi^+\pi^-3\text{-body}}$	4 3		
				$\begin{array}{c} K^+(892)^\circ\pi^+\pi^-3\text{-body} \\ \times B(\overline{K}^{*0}\to K^-\pi^+) \end{array}$	$(9.5 \pm 2.1) \times 10^{-3}$	683
$\frac{\Gamma(K^+\pi^- \text{ or } K^+\pi^-\pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi$	$\frac{\pi}{\pi} \frac{(V a D^2)}{(V \pi^+ \pi^-)} < 0.0085 \text{ (or } < 0.0085)$	0.0037), C	L =	the second secon	[rr] $(3.6 \pm 1.0) \times 10^{-3}$	483
90% [uu]	•			$\times B(K_1(1270)^- \to K^-\pi^+\pi^+\pi^-)$		103
CP-violation decay-ra	te asymmetries			$K^-\pi^+\pi^+\pi^-$ nonresonant	(1.76±0.25) %	812
$A_{CP}(K^+K^-) = 0$	-				qq] (10.0 ±1.2)%	812
$A_{CP}(\pi^+\pi^-) = -$				$\overline{K}^0 \eta \times B(\eta \to \pi^+\pi^-\pi^0)$	$(1.6 \pm 0.3) \times 10^{-3}$	772
$A_{CP}(K_S^0\phi) = -0$				$\overline{K}^0\omega \times B(\omega \to \pi^+\pi^-\pi^0)$	(1.9 ±0.4)%	670
$A_{CP}(K_S^0\pi^0) = -$				$K^*(892)^- \rho^+ \times B(K^{*-} \to \overline{K}{}^0 \pi^-)$	(4.1 ±1.6) %	422
_				$\overline{K}^*(892)^0\rho^0$	$(4.9 \pm 1.1) \times 10^{-3}$	418
D ^O modes are charge cor	jugates of the modes below.			$\times B(\overline{K}^{*0} \to \overline{K}^0\pi^0)$	(/	
-0		cale factor/	p	$K_1(1270)^-\pi^+$	[rr] (5.1 ±1.4)×10 ⁻³	483
DO DECAY MODES	Fraction (Γ_i/Γ) Conf	idence level	(MeV/c)	$\times B(K_1(1270)^- \rightarrow \overline{K}{}^0\pi^-\pi$		
	Inclusive modes			$\overline{K}^*(892)^0\pi^+\pi^-3$ -body $\times B(\overline{K}^{*0} \to \overline{K}^0\pi^0)$	$(4.8 \pm 1.1) \times 10^{-3}$	683
e ⁺ anything	(6.75±0.29) %		-	$K^0\pi^+\pi^-\pi^0$ nonresonant	(21 +21)9/	012
μ^+ anything	(6.6 ±0.8)%		-	$K^-\pi^+\pi^0\pi^0$	(2.1 ±2.1) % (15 ±5) %	812 815
K^- anything K^0 anything K^0	(53 ±4)%	S=1.3	_	$K^-\pi^+\pi^+\pi^-\pi^0$	(4.1 ±0.4)%	771
	(42 ±5)%		_	$\overline{K}^*(892)^0\pi^+\pi^-\pi^0$	(1.2 ±0.6)%	641
K ⁺ anything	$(3.4 \begin{array}{c} +0.6 \\ -0.4 \end{array})\%$		-	$\times B(\overline{K}^{*0} \to K^-\pi^+)$		
η anything	[nn] < 13	CL=90%	-	$\overline{K}^*(892)^0 \eta$ $\times B(\overline{K}^{*0} \to K^- \pi^+)$	$(2.9 \pm 0.8) \times 10^{-3}$	580
:	Semileptonic modes			$\begin{array}{c} \times \ B(K^{-1} \to K^{-1}\pi^{-1}) \\ \times \ B(\eta \to \pi^{+}\pi^{-}\pi^{0}) \end{array}$		
$K^-\ell^+ u_\ell$	[oo] (3.50±0.17) %	S=1.3	867	$\kappa^-\pi^+\omega \times B(\omega \to \pi^+\pi^-\pi^0)$	(2.7 ±0.5)%	605
$K^-e^+\nu_e$	(3.66±0.18) %		867	$\overline{K}^*(892)^0\omega$	$(7 \pm 3) \times 10^{-3}$	406
$K^-\mu^+ u_\mu$	(3.23±0.17) %		863	$\times B(\overline{K}^{*0} \to K^-\pi^+)$		
$K^-\pi^0e^+ u_e$	$(1.6 \begin{array}{c} +1.3 \\ -0.5 \end{array})\%$		861	$\times B(\omega \to \pi^+\pi^-\pi^0)$		
$\overline{K}^0\pi^-e^+\nu_e$	$(2.8 \ ^{+1.7}_{-0.9})\%$		860	$\overline{K}^0\pi^+\pi^+\pi^-\pi^-$	$(5.8 \pm 1.6) \times 10^{-3}$	768
$\overline{K}^*(892)^-e^+\nu_e$	(1.35±0.22) %		719	$\overline{K}{}^{0}\pi^{+}\pi^{-}\pi^{0}\pi^{0}(\pi^{0})$	$(10.6 \begin{array}{c} +7.3 \\ -3.0 \end{array}) \%$	771
\times B($K^{*-} \rightarrow \overline{K}{}^{0}\pi^{-}$)	(,			K ⁰ K+ K−	$(9.4 \pm 1.0) \times 10^{-3}$	544
$K^*(892)^{-}\ell^{+}\nu_{\ell}$	-		-	$\overline{\mathcal{K}}^0 \phi imes B(\phi o \mathcal{K}^+ \mathcal{K}^-) \ \overline{\mathcal{K}}^0 \mathcal{K}^+ \mathcal{K}^- non \cdot \phi$	$(4.3 \pm 0.5) \times 10^{-3}$	520-
$\overline{K}^*(892)^0\pi^-e^+\nu_e$			708		$(5.1 \pm 0.8) \times 10^{-3}$ $(8.4 \pm 1.5) \times 10^{-4}$	544 538
$K^{-}\pi^{+}\pi^{-}\mu^{+}\nu_{\mu}$	< 1.2 × 10 ⁻³	CL=90%	821	$K_S^0 K_S^0 K_S^0 K^+ K^- K^- \pi^+$	$(2.1 \pm 0.5) \times 10^{-4}$	434
$(\overline{K}^*(892)\pi)^-\mu^+ u_\mu \\ \pi^-e^+ u_e$	< 1.4 × 10 ⁻³	CL=90%	693	$K^+K^-\overline{K}^0\pi^0$	$(7.2 + \frac{4.8}{-3.5}) \times 10^{-3}$	435
π e ν_e	$(3.7 \pm 0.6) \times 10^{-3}$		927		-3.5 / ~ 20	455
A fraction of the following	resonance mode has already appea	red above as		Fractions of many of the follow	wing modes with resonances have	already
a submode of a charged-	particle mode,			appeared above as submodes of	particular charged-particle modes.	(Modes
K*(892) ⁻ e ⁺ ν _e	(2.02±0.33) %		719	for which there are only upper li below.)	imits and \overline{K}^* (892) $ ho$ submodes only	appear
Hadroni	modes with a \overline{K} or $\overline{K}K\overline{K}$			$\mathcal{K}^{0}\eta$	$(7.1 \pm 1.0) \times 10^{-3}$	772
$K^-\pi^+$	(3.85±0.09) %		861	$\frac{\kappa}{K}^{0} \frac{\eta}{\rho^{0}}$	(1.21±0.17) %	676
$\overline{K}^0\pi^0$	(2.12±0.21) %	5=1.1	860	K ⁻ ρ ⁺	· · · · · · · · · · · · · · · · · · ·	S=1.2 678
$\overline{K}{}^{0}\pi^{+}\pi^{-}$	[qq] (5.4 ±0.4)%	S=1.2	842	$\overline{\mathcal{K}}{}^0\omega$	(2.1 ±0.4) %	670
$\overline{K}^0 \rho^0$ $\overline{K}^0 f_0(980)$	$(1.21\pm0.17)\%$ $(3.0\pm0.8)\times10^{-3}$		676 549	$\overline{K}^0 \eta'(958)$	(1.72±0.26) %	565
$\times B(f_0 \to \pi^+\pi^-)$	(3.0 ±0.0) x 10 °		347	$\overline{K}^0 f_0(980)$	$(5.7 \pm 1.6) \times 10^{-3}$	549
$\overline{K}^0 f_2(1270)$	$(2.4 \pm 0.9) \times 10^{-3}$		263	$\overline{K}^0\phi$	$(8.6 \pm 1.0) \times 10^{-3}$	520
$\times B(f_2 \rightarrow \pi^+\pi^-)$	•			$\frac{K^-a_1(1260)^+}{K^0a_1(1260)^0}$	(7.3 ±1.1) % < 1.9 % CL	327 =90% 322
$\overline{K}^0 f_0(1370)$	$(4.3 \pm 1.3) \times 10^{-3}$		-	$K^0 f_2(1270)$	$(4.2 \pm 1.5) \times 10^{-3}$.=90% 322 263
$\times B(f_0 \rightarrow \pi^+\pi^-)$,			$K^{-}a_{2}(1320)^{+}$.=90% 197
$K^*(892)^-\pi^+ \times B(K^{*-} \rightarrow \overline{K}^0\pi^-)$	(3.4 ±0.3)%		711	$\overline{K}^0 f_0(1370)$	$(7.0 \pm 2.1) \times 10^{-3}$	-
$\times B(K^* \to K^*\pi)$ $K_0^*(1430)^-\pi^+$	$(6.4 \pm 1.6) \times 10^{-3}$		364	$K^*(892)^-\pi^+$, ,	S=1.2 711
$\times B(K_0^*(1430)^- \to \overline{K}^0$			304	$K^*(892)^0 \pi^0$	(3.2 ±0.4) %	709
$\overline{K}^0\pi^+\pi^-$ nonresonant	7) (1.47±0.24) %		842	$\overline{K}^*(892)^0\pi^+\pi^-$ total $\overline{K}^*(892)^0\pi^+\pi^-$ 3-body	(2.3 ±0.5) %	683 683
	=			7 (032) N N 3-DOGY	(1.43±0.32) %	003

239

614

 \times 10⁻³

 $(1.08\pm0.29)\times10^{-3}$

(6 ±3)×10⁻⁴

< 2.1

$K^-\pi^+\rho^0$ total	(6.3 ±0.4)%		612	$\phi\omega$
$K^-\pi^+\rho^0$ 3-body	$(4.8 \pm 2.1) \times 10^{-3}$		612	$\phi\pi^+\pi^-$
$\overline{K}^*(892)^0 \rho^0$	(1.47±0.33) %		418	$\phi \rho^0$
$\overline{K}^*(892)^0 \rho^0$ transverse	(1.5 ±0.5)%		418	$\phi \pi^+ \pi$
\overline{K}^* (892) 0 ρ^0 S-wave \overline{K}^* (892) 0 ρ^0 S-wave long. \overline{K}^* (892) 0 ρ^0 P-wave	(2.8 ±0.6)%		418	K*(892)
$K^*(892)^{\circ} \rho^{\circ} S$ -wave long.	< 3 × 10 ⁻³	CL=90%	418	K*(89
$K^*(892)^0 \rho^0 P$ -wave	< 3 × 10 ⁻³	CL=90%	418	
$\overline{K}^*(892)^0 \rho^0 D$ -wave	(1.9 ±0.6)%		418	
K*(892) ⁻ ρ ⁺	(6.1 ±2.4)%		422	
$K^*(892)^-\rho^+$ longitudinal	(2.9 ±1.2)%		422	
$K^*(892)^-\rho^+$ transverse	(3.2 ±1.8)%		422	K+ℓ- v,
$K^*(892)^- \rho^+ P$ -wave	< 1.5 %	CL=90%	422	$K^+\pi^-$ or
$K^-\pi^+f_0(980)$	< 1.1 %	CL=90%	459	K+π
$\overline{K}^*(892)^0 f_0(980)$	$< 7 \times 10^{-3}$	CL=90%	-	κ+π- "
$K_1(1270)^-\pi^+$	[rr] (1.06±0.29) %		483	κ+π-(v
$K_1(1400)^-\pi^+$	< 1.2 %	CL=90%	386	$K^+\pi^-\pi$
$\overline{K}_1(1400)^0\pi^0$	< 3.7 %	CL=90%	387	$K^+\pi^-\pi^-$
$K^*(1410)^-\pi^+$	< 1.2 %	CL=90%	378	μ anyth
$K_0^*(1430)^-\pi^+$	(1.04±0.26) %		364	e^+e^-
$K_2^*(1430)^-\pi^+$	< 8 × 10 ⁻³	CL=90%	367	$\mu^+\mu^-$
$\overline{K_{2}^{*}}(1430)^{0}\pi^{0}$	$< 4 \times 10^{-3}$	CL=90%	363	$\pi^{0}e^{+}e^{-}$
$\overline{K}^{*}(892)^{\circ}\pi^{+}\pi^{-}\pi^{\circ}$	(1.8 ±0.9)%		641	$\pi^0 \mu^+ \mu^-$
$\vec{K}^*(892)^0 \eta$	(1.9 ±0.5)%		580	$\eta e^+ e^-$
$\kappa^-\pi^+\omega$	(3.0 ±0.6) %		605	
$K^*(892)^0 \omega$	(1.1 ±0.5) %		406	$\eta \mu^{+} \mu^{-}$
$K^-\pi^+\eta'(958)$	$(7.0 \pm 1.8) \times 10^{-3}$		479	$\rho^0 e^+ e^-$
$\overline{K}^*(892)^0 \eta'(958)$	< 1.1 × 10 ⁻³	CL=90%	99	$ ho^0 \mu^+ \mu^-$
11 (032) 17 (330)	< 1.1 × 10	CL_90/6	77	ω e ⁺ e ⁻
	Pionic modes			$\omega \mu^+ \mu^-$
π ⁺ π ⁻	$(1.53\pm0.09)\times10^{-3}$		922	$\phi e^+ e^-$
$\pi^{0}\pi^{0}$	$(8.5 \pm 2.2) \times 10^{-4}$		922	$\frac{\phi \mu^+ \mu^-}{160}$
$\pi^{+}\pi^{-}\pi^{0}$	(1.6 ±1.1)%	5=2.7	907	$\overline{K}^0e^+e^-$
$\pi^{+}\pi^{+}\pi^{-}\pi^{-}$	$(7.4 \pm 0.6) \times 10^{-3}$		879	$\overline{K}^0\mu^+\mu^-$
$\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{0}$	(1.9 ±0.4)%		844	K*(892)
$\pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{-}$	$(4.0 \pm 3.0) \times 10^{-4}$		795	K*(892)
Hadronk	c modes with a $K\overline{K}$ pair			$\pi^+\pi^-\pi^0$
K+K-	$(4.27\pm0.16)\times10^{-3}$		701	$\mu^{\pm} e^{\mp}$
$K^0\overline{K}^0$			791	$\pi^0 e^{\pm} \mu^{\mp}$
$K^0K^-\pi^+$	$(6.5 \pm 1.8) \times 10^{-4}$	S=1.2	788	$\eta e^{\pm} \mu^{\mp}$
$\frac{K}{K}$ *(892) ⁰ K ⁰	$(6.4 \pm 1.0) \times 10^{-3}$ < 1.1 $\times 10^{-3}$	S=1.1	739	$\rho^0 e^{\pm} \mu^{\mp}$
$\times B(\overline{K}^{*0} \to K^-\pi^+)$	$< 1.1 \times 10^{-3}$	CL=90%	605	$\omega e^{\pm} \mu^{\mp}$
$K^*(892)^+K^-$	$(2.3 \pm 0.5) \times 10^{-3}$		610	$\phi e^{\pm} \mu^{\mp}$
$\times B(K^{*+} \to K^0 \pi^+)$	(2.3 ±0.5) x 10 °		610	$\overline{K}^0 e^{\pm} \mu^{\mp}$
$K^0K^-\pi^+$ nonresonant	$(2.3 \pm 2.3) \times 10^{-3}$		739	K *(892)¹
$\overline{K}^0K^+\pi^-$	• • • • • • • • • • • • • • • • • • • •			
$K^*(892)^0\overline{K}^0$	$(5.0 \pm 1.0) \times 10^{-3}$ $< 5 \times 10^{-4}$	CI -009/	739	0*/20
$\times B(K^{*0} \to K^+\pi^-)$	< 5 × 10 ⁻⁴	CL=90%	605	D'(20
$K^*(892)^-K^+$	(40.107)			
$\times B(K^{*-} \rightarrow \overline{K}^0 \pi^-)$	$(1.2 \pm 0.7) \times 10^{-3}$		610	
$\overline{K}{}^0K^+\pi^-$ nonresonant	$(3.9 \begin{array}{c} +2.3 \\ -1.9 \end{array}) \times 10^{-3}$		739	
$K^{+}K^{-}\pi^{0}$	$(1.3 \pm 0.4) \times 10^{-3}$		742	7
$K_5^0 K_5^0 \pi^0$	< 5.9 × 10 ⁻⁴		739	
$K^{+}K^{-}\pi^{+}\pi^{-}$	[w] $(2.52\pm0.24)\times10^{-3}$		676	
$\phi \pi^+ \pi^- \times B(\phi \to K^+ K^-)$			614	D*(2007)
$\phi \rho^0 \times B(\phi \to K^+K^-)$	$(3.0 \pm 1.6) \times 10^{-4}$		260	$D^0\pi^0$
$K^+K^-\rho^0$ 3-body	$(9.1 \pm 2.3) \times 10^{-4}$		309	$D^0\gamma$
$K^*(892)^0 K^- \pi^+ + c.c.$	$[ww] < 5 \times 10^{-4}$		528	- ,
$\times B(K^{*0} \to K^+\pi^-)$	[##] < 3 × 10		320	
$K^*(892)^0 \overline{K}^*(892)^0$	(6 ±2)×10 ⁻⁴		257	D*(20
$\times B^2(K^{*0} \to K^+\pi^-)$	(U ±2) × 10		231	[-,-
$K^+K^-\pi^+\pi^-$ non- ϕ			676	
$K^+K^-\pi^+\pi^-$ nonresonant	< 8 × 10 ⁻⁴	CL=90%	676	
$K^0\overline{K^0}\pi^+\pi^-$		CL=90%	676	
$K^{+}K^{-}\pi^{+}\pi^{-}\pi^{0}$	$(6.9 \pm 2.7) \times 10^{-3}$		673	
D D π : π - π	$(3.1 \pm 2.0) \times 10^{-3}$		600	
Exactions of word of the	alloudes mades with	have al		
	ollowing modes with resonances less of particular charged-particle m			
				D*(2010)
K*(892) ⁰ K ⁰	$< 1.6 \times 10^{-3}$	CL=90%	605	``_`
K*(892)+ K-	$(3.5 \pm 0.8) \times 10^{-3}$		610	$D^{0}\pi^{+}$
K*(892) ⁰ K ⁰	< 8 × 10 ⁻⁴	CL=90%	605	$D^+\pi^0$
K*(892)-K+	$(1.8 \pm 1.0) \times 10^{-3}$	er	610	$D^+\gamma$
$\phi \pi^0$	$< 1.4 \times 10^{-3}$	CL=90%	644	
$\phi\eta$	$< 2.8 \times 10^{-3}$	CL=90%	489	

$\phi \rho^0$		(6 ±3) × 10 ⁻⁴		260
$\phi \pi^+ \pi^-$ 3-body		(7 ±5) × 10 ⁻⁴		614
$K^*(892)^0 K^- \pi^+ + \text{c.c.}$		[ww] < 8	× 10 ⁻⁴	CL=90%	-
$\hat{K}^*(892)^0 \overline{K}^*(892)^0$		(1.4 ±0.5	5)×10 ⁻³		257
Doubh	Cabibb	o suppressed (D			
		en via mixing (C			
AC-1	mak ne	eutral current (C	214) modec	3, Ar	
		umber (<i>LF</i>) viol			
$K^+\ell^-\overline{\nu}_\ell$ (via \overline{D}^0)	C2M	< 1.7	× 10 ⁻⁴	CL=90%	_
$K^+\pi^-$ or	C2M	< 1.0	× 10 ⁻³	CL=90%	_
$K^+\pi^-\pi^+\pi^-$ (via $\overline{D}{}^0$		< 1.0	X 10 -	CL=90%	_
$K^+\pi^-$	DC	(2.8 ±0.9	1 1 10-4		861
$K^+\pi^-$ (via \overline{D}^0)	DC	< 1.9	× 10 ⁻⁴	CL=90%	861
$K^+\pi^-\pi^+\pi^-$	DC	(1.9 ±2.7		CL-30/0	812
$K^+\pi^-\pi^+\pi^-$ (via \overline{D}^0)	DC	(1.9 ±2.0	× 10 ⁻⁴	CL=90%	812
μ^- anything (via \overline{D}^0)		< 4	× 10 ⁻⁴	CL=90%	012
e+e-	C1	< 1.3	× 10 ⁻⁵	CL=90%	932
$\mu_{\perp}^{+}\mu_{-}^{-}$	C1	< 4.1	× 10 ⁻⁶	CL=90% CL≃90%	926
$\pi^{0} e^{+} e^{-}$	C1	< 4.5	× 10 ⁻⁵	CL=90%	920
$\pi^{0}\mu^{+}\mu^{-}$	C1	< 1.8	× 10 ⁻⁴	CL=90%	915
$\eta e^+ e^-$	CI	< 1.1	× 10 ⁻⁴	CL=90%	852
$\eta \mu^+ \mu^-$	C1	< 5.3	× 10 ⁻⁴	CL=90%	838
$\rho^0 e^+ e^-$	C1	< 1.0	× 10 ⁻⁴	CL=90% CL=90%	773
$\rho^0 \mu^+ \mu^-$	C1	< 2.3	× 10 ⁻⁴	CL=90%	756
$\omega e^+ e^-$	C1	< 1.8	× 10 ⁻⁴	CL=90% CL=90%	768
$\omega \mu^+ \mu^-$	C1	< 8.3	× 10 ⁻⁴	CL=90%	751
$\phi e^+ e^-$	C1	< 5.2	× 10 ⁻⁵	CL=90%	654
$\phi \mu^+ \mu^-$	C1	< 4.1	× 10 ⁻⁴	CL=90%	631
$\frac{\nabla F}{K^0}e^+e^-$	C1	[ss] < 1.1	× 10 ⁻⁴	CL=90%	866
$\overline{K}^0\mu^+\mu^-$		[ss] < 2.6	× 10 ⁻⁴	CL=90%	852
$K^*(892)^0 e^+ e^-$		[ss] < 1.4	× 10 ⁻⁴	CL=90%	717
$\overline{K}^*(892)^0 \mu^+ \mu^-$		[ss] < 1.18	× 10 ⁻³	CL=90%	698
$\pi^{+}\pi^{-}\pi^{0}\mu^{+}\mu^{-}$	C1	< 8.1	× 10 ⁻⁴	CL=90%	863
μ± e∓	LF	[gg] < 1.9	× 10 ⁻⁵	CL=90%	929
$\pi^0 e^{\pm} \mu^{\mp}$	LF	[gg] < 8.6	× 10 ⁻⁵	CL=90%	924
$\eta e^{\pm} \mu^{\mp}$	LF	[gg] < 1.0	× 10 ⁻⁴	CL=90%	848
$ ho^0 e^{\pm} \mu^{\mp}$	LF	[gg] < 4.9	× 10 ⁻⁵	CL=90%	769
$\omega e^{\pm} \mu^{\mp}$	LF	[gg] < 1.2	× 10 ⁻⁴	CL=90%	764
$\phi e^{\pm} \mu^{\mp}$	LF	[gg] < 3.4	× 10 ⁻⁵	CL=90%	648
$\overline{K}^0 e^{\pm} \mu^{\mp}$	LF	[gg] < 1.0	× 10 ⁻⁴	CL=90%	862
$\overline{K}^*(892)^0 e^{\pm} \mu^{\mp}$	LF	[gg] < 1.0	× 10 ⁻⁴	CL=90%	712

D*(2007)0

 $I(J^P) = \frac{1}{2}(1^-)$ I, J, P need confirmation.

Mass $m = 2006.7 \pm 0.5 \text{ MeV}$ (S = 1.1) $m_{D^{*0}} - m_{D^0} = 142.12 \pm 0.07$ MeV Full width $\Gamma < 2.1$ MeV, CL = 90%

 $\overline{\it D}^*(2007)^0$ modes are charge conjugates of modes below.

D*(2007)0 DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
$D^0 \pi^0$	(61.9±2.9) %	43
$D^0\gamma$	(38.1 ± 2.9) %	137

$D^*(2010)^{\pm}$

 $I(J^{P}) = \frac{1}{2}(1^{-})$ I(J, J, P need confirmation.) $I(J = \frac{1}{2}(1^{-})$ I(J, J, P need confirmation.) $I(J = \frac{1}{2}(1^{-})$ $I(J = \frac{1}{2$ $m_{D^*(2010)^+} - m_{D^+} = 140.64 \pm 0.10$ MeV (S = 1.1) $m_{D^*(2010)^+} - m_{D^0} = 145.397 \pm 0.030$ MeV Full width Γ < 0.131 MeV, CL = 90%

 $D^*(2010)^-$ modes are charge conjugates of the modes below.

D*(2010)* DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$D^{0}\pi^{+}$	(68.3±1.4) %	39
$D^+\pi^0$	(30.6±2.5) %	38
$D^+\gamma$	$(1.1^{+2.1}_{-0.7})\%$	136

Meson Summary Table

$D_1(2420)^0$

$$I(J^P) = \frac{1}{2}(1^+)$$

I, J, P need confirmation.

Mass $m=2422.2\pm1.8~{\rm MeV}~{\rm (S=1.2)}$ Full width $\Gamma=18.9^{+4.6}_{-3.5}~{\rm MeV}$

 $\overline{\mathcal{D}}_1(2420)^0$ modes are charge conjugates of modes below.

D1(2420)0 DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$D^*(2010)^+\pi^-$	seen	355
$D^+\pi^-$	not seen	474

$D_2^*(2460)^0$

$$I(J^P) = \frac{1}{2}(2^+)$$

 $J^P=2^+$ assignment strongly favored (ALBRECHT 89B). Mass $m=2458.9\pm2.0$ MeV (S = 1.2) Full width $\Gamma=23\pm5$ MeV

 $\overline{D}_2^*(2460)^0$ modes are charge conjugates of modes below.

D ₂ (2460) ⁰ DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
$D^+\pi^-$	seen	503
$D^*(2010)^+\pi^-$	seen	387

$D_2^*(2460)^{\pm}$

$$I(J^{P})=\tfrac{1}{2}(2^{+})$$

 $J^P=2^+$ assignment strongly favored (ALBRECHT 89B). Mass $m=2459\pm4$ MeV (S = 1.7) $m_{D_2^*(2460)^\pm}-m_{D_2^*(2460)^0}=0.9\pm3.3$ MeV (S = 1.1) Full width $\Gamma=25^{+8}_{-7}$ MeV

 $D_2^*(2460)^-$ modes are charge conjugates of modes below.

$D_2^{\bullet}(2460)^{\pm}$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$D^0\pi^+$	seen	508
$D^{*0}\pi^{+}$	seen	390

CHARMED, STRANGE MESONS $(C = S = \pm 1)$

 $D_s^+ = c\overline{s}$, $D_s^- = \overline{c}s$, similarly for D_s^* 's

Ds was F±

$$I(J^P) = 0(0^-)$$

Mass $m=1968.5\pm0.6~{\rm MeV}~{\rm (S}=1.1)$ $m_{D_s^\pm}-m_{D^\pm}=99.2\pm0.5~{\rm MeV}~{\rm (S}=1.1)$ Mean life $\tau=(0.467\pm0.017)\times10^{-12}~{\rm s}$ $c\tau=140~{\rm \mu m}$

D# form factors

$$r_2 = 1.6 \pm 0.4$$

 $r_V = 1.5 \pm 0.5$
 $\Gamma_L/\Gamma_T = 0.72 \pm 0.18$

Branching fractions for modes with a resonance in the final state include all the decay modes of the resonance. $D_{\rm S}^-$ modes are charge conjugates of the modes below.

D+ DECAY MODES	ı	Fraction	ι (Γ ₁ /Γ)		Scale factor/ Confidence level	<i>p</i> (MeV/c)
			<u> </u>			
-	nciush	ve mo		۱.0/		
K-anything		(13	+14)%		_
\overline{K}^0 anything + K^0 anything		(39	±28) %		_
K ⁺ anything		(20	+18 -14) %		_
non-KK anything		(64	±17) %		-
e ⁺ anything		(8	+ 6 - 5) %		-
ϕ anything		(18	+15 -10) %		-
Leptonic	and se	emilep	tonic n	node	5	
$\mu^+ \nu_{\mu}$		(4.0	+ 2.2 - 2.0) ×	10 ⁻³ S=1.4	981
$\tau^+ \nu_{\tau}$			± 4			182
$\phi \ell^+ \nu_\ell$	[xx]	•	± 0.5	•		_
$\eta \ell^+ \nu_{\ell} + \eta'(958) \ell^+ \nu_{\ell}$	[xx]	•	± 1.0			-
$\eta \ell^+ \nu_\ell$			± 0.7		10-3	_
$\eta'(958)\ell^+\nu_\ell$		•	± 3.4	•		_
Hadronic modes with	th a K		-		from a ϕ)	
$K^+\overline{K}^0$ $K^+K^-\pi^+$	(1	-	± 1.1		S=1.1	850 805
$\phi \pi^+$	[qq] [yy]	•	± 1.2 ± 0.9	•	5=1.1	712
κ+ κ *(892) ⁰	[yy]		± 0.9			682
$f_0(980)\pi^+$	[yy]	(1.8	± 0.8		S=1.3	732
$K^+\overline{K}_0^*(1430)^0$	[עע]	(7	± 4		10-3	186
$f_{J}(1710)\pi^{+} \rightarrow K^{+}K^{-}\pi^{+}$	[zz]		± 1.9			204
$K^+K^-\pi^+$ nonresonant $K^0\overline{K}^0\pi^+$		(9	± 4) ×	10-3	805 802
$K^*(892)^+\overline{K}^0$	[yy]	(4.3	± 1.4)%		683
$K^+K^-\pi^+\pi^0$		•		•		748
$\phi \pi^+ \pi^0$	[уу]					687
$\phi ho^+ \ \phi\pi^+\pi^0$ 3-body	[yy]		± 2.3		CL=90%	407
$\kappa^+ \kappa^- \pi^+ \pi^0$ non- ϕ	ועט	< 2.6 < 9	•	% %	CL=90% CL=90%	
$K^{+}\overline{K}{}^{0}\pi^{+}\pi^{-}$		< 2.8	3	%	CL=90%	
$K^{0}K^{-}\pi^{+}\pi^{+}$			± 1.5			744
$K^*(892)^+\overline{K}^*(892)^0$	[עע]		± 2.5			412
$K^0K^-\pi^+\pi^+$ non- $K^{*+}\overline{K}^{*0}$ $K^+K^-\pi^+\pi^+\pi^-$		< 2.9) 3 ± 3.3	% ∨ ()	CL=90%	744 673
$\phi \pi^+ \pi^+ \pi^-$	[yy]		18± 0.3			640
$K^+K^-\pi^+\pi^+\pi^-$ non- ϕ			+ 3.0 - 2.0		10-3	673
Hadror	nic ma	des wi	thout	K's		
$\pi^{+}\pi^{+}\pi^{-}$			± 0.4) %	S=1.2	
$\rho^0\pi^+$		< 8			10 ⁻⁴ CL=90%	
$f_0(980)\pi^+$ $f_2(1270)\pi^+$			3 ± 0.8 3 ± 1.3		\$=1.7	732 559
$f_0(1500)\pi^+ \rightarrow \pi^+\pi^-\pi^+$	[yy] [aaa]		3 ± 1.6			391
$\pi^+\pi^+\pi^-$ nonresonant	()	< 2.8			10 ⁻³ CL=90%	
$\pi^{+}\pi^{+}\pi^{-}\pi^{0}$		< 12		%	CL=90%	
$\eta \pi^+$	[77]	(2.0	± 0.6	5)%		902

⊬ 0 +	Modes with one or three K 's		016
$\eta'(958)\pi^+\pi^0$ 3-body	[yy] < 3.1 %	CL=90%	720
$\eta'(958)\rho^+$	[yy] (12 ± 4)%		470
$\pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{0}\pi^{0}$	_		803
$\eta'(958)\pi^{+}$	[yy] (4.9 ± 1.8)%		743
$\pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{0}$	$(4.9 \pm 3.2)\%$		856
$\eta \pi^+ \pi^0$ 3-body	[yy] < 3.0 %	CL=90%	886
$\eta \rho^+$	[yy] (10.3 ± 3.2)%		727
$\pi^{+}\pi^{+}\pi^{-}\pi^{0}\pi^{0}$	-		902
$\pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}$	$(6.9 \pm 3.0) \times 10^{-3}$		899
$\omega \pi^+$	[yy] $(3.1 \pm 1.4) \times 10^{-3}$		822

	Modes with one or three	K'S		
$\kappa^0\pi^+$	< 8	× 10 ⁻³	CL=90%	916
$K^+\pi^+\pi^-$	(1.0 ± 0	.4) %		900
$K^+ ho^0$	< 2.9	× 10 ⁻³	CL=90%	747
$K^*(892)^0\pi^+$	[yy] (6.5 ± 2	$.8) \times 10^{-3}$		773
K+K+K-	< 6	× 10 ⁻⁴	CL=90%	628
ϕK^+	[yy] < 5	× 10 ⁻⁴	CL=90%	607

$\Delta C = 1$ weak neutral current (C1) modes, or Lepton number (L) violating modes

$\pi^+\mu^+\mu^-$		[ss] < 4.3	× 10 ⁻⁴	CL=90%	968
$K^+\mu^+\mu^-$	C1	< 5.9	× 10 ⁻⁴	CL=90%	909
$K^*(892)^+\mu^+\mu^-$	C1	< 1.4	× 10 ⁻³	CL=90%	765
$\pi^-\mu^+\mu^+$	L	< 4.3	× 10 ⁻⁴	CL=90%	968
$K^-\mu^+\mu^+$	L	< 5.9	× 10 ⁻⁴	CL≔90%	909
$K^*(892)^-\mu^+\mu^+$	L	< 1.4	× 10 ⁻³	CL=90%	765



$$I(J^P) = 0(??)$$

 J^P is natural, width and decay modes consistent with 1^- .

Mass
$$m=2112.4\pm0.7~{\rm MeV}~{\rm (S}=1.1)$$
 $m_{D_s^{\pm\pm}}-m_{D_s^{\pm}}=143.8\pm0.4~{\rm MeV}$ Full width $\Gamma<1.9~{\rm MeV},~{\rm CL}=90\%$

 D_s^{*-} modes are charge conjugates of the modes below.

D#+ DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
$\frac{D_s^+ \gamma}{D_s^+ \pi^0}$	(94.2±2.5) %	139
$D_s^+\pi^0$	(5.8±2.5) %	48

$D_{s1}(2536)^{\pm}$

$$I(J^P) = 0(1^+)$$

J, P need confirmation.

Mass $m=2535.35\pm0.34\pm0.5$ MeV Full width Γ < 2.3 MeV, CL = 90%

 $D_{\rm S1}(2536)^{-}$ modes are charge conjugates of the modes below.

D _{s1} (2536) ⁺ DECAY MODES	Fraction (Γ_{i}/Γ)	p (MeV/c)	
$D^*(2010)^+ K^0$	seen	150	
D*(2007)0 K+	seen	169	
D+ K ⁰	not seen	382	
D ⁰ K ⁺	not seen	392	
$D_s^{*+}\gamma$	possibly seen	389	

$D_{sJ}(2573)^{\pm}$

$$I(J^P) = 0(??)$$

 ${\it J}^{\it P}$ is natural, width and decay modes consistent with 2^+ .

Mass $m = 2573.5 \pm 1.7 \text{ MeV}$ Full width $\Gamma = 15^{+5}_{-4} \text{ MeV}$

 $D_{s,I}(2573)^-$ modes are charge conjugates of the modes below.

$D_{aJ}(2573)^+$ DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
D ⁰ K ⁺	seen	436
D*(2007) ⁰ K+	not seen	245

BOTTOM MESONS $(B = \pm 1)$

 $B^+ = u\overline{b}$, $B^0 = d\overline{b}$, $\overline{B}{}^0 = \overline{d}b$, $B^- = \overline{u}b$, similarly for B^* 's

B-particle organization

Many measurements of B decays involve admixtures of B hadrons. Previously we arbitrarily included such admixtures in the B^\pm section, but because of their importance we have created two new sections: " B^\pm/B^0 Admixture" for $\Upsilon(4S)$ results and " $B^\pm/B^0/B_s^0/B$ -baryon Admixture" for results at higher energies. Most inclusive decay branching fractions are found in the Admixture sections. $B^0-\overline{B^0}$ mixing data are found in the B^0 section, while $B_s^0-\overline{B^0}$ mixing data and $B-\overline{B}$ mixing data for a B^0/B_s^0 admixture are found in the B_s^0 section. CP-violation data are found in the B^0 section. B^0 -baryons are found near the end of the Baryon section.

The organization of the ${\it B}$ sections is now as follows, where bullets indicate particle sections and brackets indicate reviews.

[Production and Decay of *b*-flavored Hadrons] [Semileptonic Decays of *B* Mesons]

• B±

mass, mean life branching fractions

B⁰

mass, mean life branching fractions polarization in B^0 decay $B^0-\overline{B}^0$ mixing $[B^0-\overline{B}^0]$ Mixing and CP Violation in B Decay]

CP violation \bullet B^{\pm} B^{0} Admixtures

branching fractions

 B[±]/B⁰/B⁰_s/b-baryon Admixtures mean life production fractions branching fractions

• B*

mass

B⁰

mass, mean life branching fractions polarization in B_s^0 decay $B_s^0 - \overline{B}_s^0$ mixing $B - \overline{B}$ mixing (admixture of B_s^0 , B_s^0)

At end of Baryon Listings:

Λ_b

mass, mean life branching fractions

 b-baryon Admixture mean life branching fractions

Meson Summary Table

```
D_s^+ \overline{K}^0
                                                                                                                                                                                                      × 10<sup>-3</sup>
                                                                                                                                                                                   < 1.1
                                                                                                                                                                                                                     CL=90%
                                                         I(J^P) = \frac{1}{2}(0^-)
                                                                                                                                                                                                                                      2241
  B±
                                                                                                                             D_s^{*+} \overline{K}^0

D_s^{+} \overline{K}^* (892)^0
                                                                                                                                                                                                       × 10<sup>-3</sup>
                                                                                                                                                                                   < 1.1
                                                                                                                                                                                                                     CL=90%
                                                                                                                                                                                                                                      2184
                                                                                                                                                                                                      × 10<sup>-4</sup>
                                                                                                                                                                                   < 5
                                                                                                                                                                                                                     CL=90%
                                                                                                                                                                                                                                      2171
      I, J, P need confirmation. Quantum numbers shown are quark-model
                                                                                                                             D*+ K*(892)0
                                                                                                                                                                                                      \times 10<sup>-4</sup>
                                                                                                                                                                                   < 4
                                                                                                                                                                                                                     CL=90%
                                                                                                                                                                                                                                      2110
                                                                                                                             D_s^- \pi^+ K^+
                                                                                                                                                                                                       × 10<sup>-4</sup>
                                                                                                                                                                                   < 8
                                                                                                                                                                                                                     CL=90%
                                                                                                                                                                                                                                      2222
                 Mass m_{B^{\pm}} = 5278.9 \pm 1.8 \text{ MeV}
                                                                                                                             D_s^{*-}\pi^+K^+
                                                                                                                                                                                                      \times 10^{-3}
                                                                                                                                                                                   < 1.2
                                                                                                                                                                                                                    CL=90%
                                                                                                                                                                                                                                      2164
                 Mean life \tau_{B^\pm}=(1.65\pm0.04)\times10^{-12}~\mathrm{s}
                                                                                                                                                                                                      × 10<sup>-3</sup>
                                                                                                                             D_{s}^{-}\pi^{+}K^{*}(892)^{+}
                                                                                                                                                                                   < 6
                                                                                                                                                                                                                    CL=90%
                                                                                                                                                                                                                                      2137
                      c\tau = 495 \ \mu \text{m}
                                                                                                                             D_s^{*-}\pi^+K^*(892)^+
                                                                                                                                                                                                       × 10<sup>-3</sup>
                                                                                                                                                                                                                                      2075
           B modes are charge conjugates of the modes below. Modes which do not
                                                                                                                                                                      Charmonium modes
           Identify the charge state of the B are listed in the B^{\pm}/B^{0} ADMIXTURE
                                                                                                                             J/\psi(15)K^{+}
                                                                                                                                                                                    (9.9 \pm 1.0) \times 10^{-4}
                                                                                                                                                                                                                                      1683
                                                                                                                             J/\psi(1S)K^{+}\pi^{+}\pi^{-}
                                                                                                                                                                                     (1.4 \pm 0.6) \times 10^{-3}
                                                                                                                                                                                                                                      1612
           The branching fractions listed below assume 50% B^0\,\overline{B}{}^0 and 50% B^+\,B^-
                                                                                                                             J/\psi(15)K^*(892)^+
                                                                                                                                                                                    (1.47\pm0.27)\times10^{-3}
                                                                                                                                                                                                                                      1571
           production at the \Upsilon(45). We have attempted to bring older measurements
                                                                                                                                                                                    ( 5.0 \pm 1.5 ) \times\,10^{-5}
                                                                                                                             J/\psi(15)\pi^{+}
                                                                                                                                                                                                                                      1727
           up to date by rescaling their assumed \Upsilon(4S) production ratio to 50:50
                                                                                                                             J/\psi(15)\rho^+
                                                                                                                                                                                                      × 10<sup>-4</sup>
                                                                                                                                                                                   < 7.7
                                                                                                                                                                                                                     CL=90%
                                                                                                                                                                                                                                      1613
           and their assumed D, D_{\mathcal{S}}, D^*, and \psi branching ratios to current values
                                                                                                                             J/\psi(15) a_1(1260)^+
                                                                                                                                                                                                      \times 10^{-3}
                                                                                                                                                                                                                     CL=90%
           whenever this would affect our averages and best limits significantly.
                                                                                                                                                                                   < 1.2
                                                                                                                                                                                                                                      1414
                                                                                                                                                                                    (6.9 \pm 3.1) \times 10^{-4}
                                                                                                                             \psi(25)K^{+}
                                                                                                                                                                                                                       S=1.3
                                                                                                                                                                                                                                      1284
           indentation is used to indicate a subchannel of a previous reaction. All
                                                                                                                             \psi(2S)K^*(892)^+
                                                                                                                                                                                   < 3.0
                                                                                                                                                                                                      \times 10^{-3}
                                                                                                                                                                                                                     CL=90%
                                                                                                                                                                                                                                      1115
           resonant subchannels have been corrected for resonance branching frac-
                                                                                                                             \psi(25)K^{+}\pi^{+}\pi^{-}
                                                                                                                                                                                    ( 1.9 \pm1.2 ) \times 10<sup>-3</sup>
           tions to the final state so the sum of the subchannel branching fractions
                                                                                                                                                                                                                                       909
                                                                                                                             \chi_{c1}(1P)K^+
                                                                                                                                                                                    ( 1.0 \pm 0.4 ) \times\,10^{-3}
                                                                                                                                                                                                                                      1411
                                                                                                                             \chi_{c1}(1P)K^*(892)^+
                                                                                                                                                                                                      \times 10<sup>-3</sup>
                                                                                                                                                                                   < 2.1
                                                                                                                                                                                                                     CL=90%
                                                                                                                                                                                                                                      1265
                                                                                   Scale factor/
B<sup>+</sup> DECAY MODES
                                                     Fraction (\Gamma_I/\Gamma)
                                                                               Confidence level (MeV/c)
                                                                                                                                                                         K or K* modes
                                                                                                                             K^0\pi^+
                                                                                                                                                                                    ( 2.3 \pm 1.1 ) \times 10<sup>-5</sup>
                                                                                                                                                                                                                                      2614
                                Semileptonic and leptonic modes
                                                                                                                             K^+\pi^0
                                                                                                                                                                                                      × 10<sup>-5</sup>
                                                                                                                                                                                   < 1.6
                                                                                                                                                                                                                                      2615
                                                                                                                                                                                                                     CL=90%
\ell^+ \frac{\nu_\ell}{D^0} anything
                                               [pp] (10.3 ±0.9)%
                                                                                                                             \eta' K^+
                                                                                                                                                                                    (6.5 \pm 1.7) \times 10^{-5}
                                                                                                                                                                                                                                      2528
                                                       ( 1.86±0.33) %
                                                [pp]
                                                                                                                                                                                                      \times 10<sup>-4</sup>
                                                                                                                             \eta' K^*(892)^+
                                                                                                                                                                                   < 1.3
                                                                                                                                                                                                                                      2472
   \overline{D}^*(2007)^0 \ell^+ \nu_{\ell}
                                                                                                                                                                                                                     CL=90%
                                                      (5.3 ±0.8)%
                                                                                                                             \eta K^+
                                                                                                                                                                                                      \times 10<sup>-5</sup>
                                                                                                                                                                                   < 1.4
                                                                                                                                                                                                                     CL=90%
                                                                                                                                                                                                                                      2587
   \pi^0 \dot{e}^+ \nu_e
                                                                         \times 10<sup>-3</sup>
                                                      < 2.2
                                                                                       CL=90%
                                                                                                         2638
                                                                                                                             ηK*(892)+
                                                                                                                                                                                                      \times 10<sup>-5</sup>
                                                                                                                                                                                   < 3.0
                                                                                                                                                                                                                     CL=90%
                                                                         × 10<sup>-4</sup>
   \omega \ell^+ \nu_{\ell}
                                                |pp| < 2.1
                                                                                       CL=90%
                                                                                                                             K^*(892)^0\pi^+
                                                                                                                                                                                   < 4.1
                                                                                                                                                                                                      \times 10^{-5}
                                                                                                                                                                                                                     CL=90%
                                                                                                                                                                                                                                      2561
   \rho^0 \ell^+ \nu_\ell
                                                                         × 10<sup>-4</sup>
                                                [pp] < 2.1
                                                                                       CL=90%
                                                                                                                             K^*(892)^+\pi^0
                                                                                                                                                                                                      \times 10<sup>-5</sup>
                                                                                                                                                                                   < 9.9
                                                                                                                                                                                                                     CL=90%
                                                                                                                                                                                                                                      2562
   e^+ \nu_e
                                                                         \times 10<sup>-5</sup>
                                                                                        CL=90%
                                                      < 1.5
                                                                                                         2639
                                                                                                                                                                                                      \times 10<sup>-5</sup>
                                                                                                                             K^{+}\pi^{-}\pi^{+} nonresonant
                                                                                                                                                                                   < 2.8
                                                                                                                                                                                                                     CL=90%
                                                                                                                                                                                                                                      2609
   \mu^+ \nu_\mu
                                                                         \times 10<sup>-5</sup>
                                                      < 2.1
                                                                                       CL=90%
                                                                                                         2638
                                                                                                                                                                                                      \times 10<sup>-5</sup>
                                                                                                                             K^-\pi^+\pi^+ nonresonant
                                                                                                                                                                                   < 5.6
                                                                                                                                                                                                                     CL=90%
                                                                         × 10<sup>-4</sup>
   \tau^+ \nu_{	au}
                                                      < 5.7
                                                                                       CL=90%
                                                                                                         2340
                                                                                                                             K_1(1400)^0 \pi^+
                                                                                                                                                                                                      \times 10^{-3}
                                                                                                                                                                                   < 2.6
                                                                                                                                                                                                                     CL=90%
                                                                                                                                                                                                                                      2451
   e^+ \nu_e \gamma
                                                                         × 10<sup>-4</sup>
                                                                                                                            K_2^*(1430)^0 \pi^+

K^+ \rho^0

K^0 \rho^+
                                                      < 2.0
                                                                                       CL=90%
                                                                                                                                                                                                      × 10<sup>-4</sup>
                                                                                                                                                                                   < 6.8
                                                                                                                                                                                                                     CL=90%
                                                                                                                                                                                                                                      2443
   \mu^+\,\nu_\mu\,\gamma
                                                                          \times 10<sup>-5</sup>
                                                      < 5.2
                                                                                       CL=90%
                                                                                                                                                                                                      \times 10^{-5}
                                                                                                                                                                                   < 1.9
                                                                                                                                                                                                                     CL=90%
                                                                                                                                                                                                                                      2559
                                                                                                                                                                                                      \times 10<sup>-5</sup>
                                         D, D^*, or D_s modes
                                                                                                                                                                                   < 4.8
                                                                                                                                                                                                                     CL=90%
                                                                                                                                                                                                                                      2559
                                                                                                                             K^*(892)^+\pi^+\pi^-
                                                                                                                                                                                                      \times 10<sup>-3</sup>
\overline{D}{}^0\pi^+
                                                        (5.3 \pm 0.5) \times 10^{-3}
                                                                                                                                                                                   < 1.1
                                                                                                                                                                                                                     CL=90%
                                                                                                         2308
                                                                                                                             K^*(892)^+ \rho^0
K_1(1400)^+ \rho^0
\overline{D}^{0}\rho^{+}
                                                                                                                                                                                   < 9.0
                                                                                                                                                                                                      \times 10^{-4}
                                                                                                                                                                                                                                      2505
                                                                                                                                                                                                                     CL=90%
                                                        (1.34 \pm 0.18)\%
                                                                                                         2238
                                                                                                                                                                                                      × 10<sup>-4</sup>
\overline{D}^{0}\pi^{+}\pi^{+}\pi^{-}
                                                                                                                                                                                   < 7.8
                                                                                                                                                                                                                     CL=90%
                                                                                                                                                                                                                                      2389
                                                        (1.1 \pm 0.4)\%
                                                                                                         2289
                                                                                                                             K_{2}^{*}(1430)^{+}\rho^{0}

K^{+}\overline{K}^{0}
                                                                                                                                                                                                      × 10<sup>-3</sup>
                                                                                                                                                                                                                     CL=90%
   \overline{D}{}^0\pi^+\pi^+\pi^- nonresonant
                                                        (5 \pm 4 ) \times 10^{-3}
                                                                                                                                                                                   < 1.5
                                                                                                                                                                                                                                      2382
                                                                                                         2289
   \overline{D}{}^0\pi^+\rho^0
                                                        ( 4.2 \pm 3.0 ) \times 10<sup>-3</sup>
                                                                                                                                                                                   < 2.1
                                                                                                                                                                                                      \times 10^{-5}
                                                                                                                                                                                                                     CL=90%
                                                                                                                                                                                                                                      2592
                                                                                                         2209
      \overline{D}{}^0 a_1(1260)^+
                                                                                                                             K^+K^-\pi^+ nonresonant
                                                                                                                                                                                                      \times 10<sup>-5</sup>
                                                        (5 \pm 4) \times 10^{-3}
                                                                                                         2123
                                                                                                                                                                                   < 7.5
                                                                                                                                                                                                                     CL=90%
                                                                                                                             K+K-K+
                                                                                                                                                                                                      × 10~4
   D^*(2010)^-\pi^+\pi^+
                                                        ( 2.1 \pm 0.6 ) \times\,10^{-3}
                                                                                                                                                                                   < 2.0
                                                                                                                                                                                                                     CL=90%
                                                                                                                                                                                                                                      2522
                                                                                                         2247
                                                                                                                                K^+\phi
                                                                        × 10<sup>-3</sup>
                                                                                                                                                                                                       \times 10<sup>-5</sup>
D^{-}\pi^{+}\pi^{+}
                                                                                                                                                                                   < 1.2
                                                                                                                                                                                                                     CL=90%
                                                                                                                                                                                                                                      2516
                                                      < 1.4
                                                                                       C1 = 90\%
                                                                                                         2299
\overline{D}^*(2007)^0\pi^+
                                                                                                                                 K^+K^-K^+ nonresonant
                                                                                                                                                                                                      × 10<sup>-5</sup>
                                                       ( 4.6 \pm 0.4 ) \times 10^{-3}
                                                                                                                                                                                   < 3.8
                                                                                                                                                                                                                     CL=90%
                                                                                                                                                                                                                                      2516
                                                                                                         2256
D^*(2010)^+\pi^0
                                                                                                                             K*(892)+K+K-
                                                                                                                                                                                                      \times 10<sup>-3</sup>
                                                                        × 10<sup>-4</sup>
                                                      < 1.7
                                                                                                         2254
                                                                                                                                                                                   < 1.6
                                                                                                                                                                                                                     CL=90%
                                                                                                                                                                                                                                      2466
                                                                                                                                                                                                      \times 10<sup>-5</sup>
\overline{D}^*(2007)^0 \rho^+
\overline{D}^*(2007)^0 \pi^+ \pi^+ \pi^-
                                                        ( 1.55±0.31) %
                                                                                                                                 K^*(892)^+\phi
                                                                                                                                                                                   < 7.0
                                                                                                                                                                                                                                      2460
                                                                                                                                                                                                                     CL=90%
                                                                                                         2183
                                                                                                                              K_1(1400)^{+}\phi
                                                                                                                                                                                   < 1.1
                                                                                                                                                                                                       × 10<sup>-3</sup>
                                                                                                                                                                                                                    CL=90%
                                                                                                                                                                                                                                      2339
                                                        ( 9.4 \pm 2.6 ) \times 10^{-3}
                                                                                                         2236
   \overline{D}^*(2007)^0 a_1(1260)^+
                                                                                                                                                                                                       × 10<sup>-3</sup>
                                                                                                                             K_2^*(1430)^+\phi
                                                                                                                                                                                   < 3.4
                                                        ( 1.9 ±0.5 )%
                                                                                                                                                                                                                     CL=90%
                                                                                                                                                                                                                                      2332
D^*(2010)^-\pi^+\pi^+\pi^0

D^*(2010)^-\pi^+\pi^+\pi^+\pi^-
                                                                                                                             K^+ f_0(980)
                                                                                                                                                                                                       \times 10<sup>-5</sup>
                                                        (1.5 \pm 0.7)\%
                                                                                                                                                                                   < 8
                                                                                                                                                                                                                                      2524
                                                                                                         2235
                                                                                                                                                                                    (5.7 \pm 3.3) \times 10^{-5}
                                                                                                                             K^*(892)^+\gamma
                                                                                                                                                                                                                                      2564
                                                      < 1
                                                                         %
                                                                                       C1 = 90\%
                                                                                                         2217
                                                                                                                                                                                                      \times 10<sup>-3</sup>
\overline{D}_{1}^{*}(2420)^{0}\pi^{+}
                                                                                                                             K_1(1270)^+\gamma
                                                        ( 1.5 \pm 0.6 ) \times\,10^{-3}
                                                                                           S=1.3
                                                                                                                                                                                   < 7.3
                                                                                                                                                                                                                     CL=90%
                                                                                                                                                                                                                                      2486
                                                                                                         2081
\frac{\overline{D}_{1}^{*}(2420)^{0}\rho^{+}}{\overline{D}_{2}^{*}(2460)^{0}\pi^{+}}
                                                                         × 10<sup>-3</sup>
                                                                                                                             K_1(1400)^+ \gamma
                                                                                                                                                                                   < 2.2
                                                                                                                                                                                                       \times 10<sup>-3</sup>
                                                                                                                                                                                                                                      2453
                                                      < 1.4
                                                                                                                                                                                                                     CL=90%
                                                                                       CL=90%
                                                                                                         1997
                                                                                                                             K_2^*(1430)^+\gamma
                                                                                                                                                                                                       × 10<sup>-3</sup>
                                                                                                                                                                                                                     CL=90%
                                                                                                                                                                                                                                      2447
                                                                         \times 10<sup>-3</sup>
                                                                                                                                                                                   < 1.4
                                                      < 1.3
                                                                                       CL=90%
                                                                                                         2064
                                                                                                                             κ*(1680)+γ
                                                                                                                                                                                                       × 10<sup>-3</sup>
\overline{D}_{2}^{2}(2460)^{0}\rho^{+}
                                                                         \times 10<sup>-3</sup>
                                                                                                                                                                                   < 1.9
                                                                                                                                                                                                                     CL=90%
                                                                                                                                                                                                                                      2361
                                                      < 4.7
                                                                                       CL=90%
                                                                                                         1979
                                                                                                                             K_3^*(1780)^+\gamma
\overline{D}^{\circ}D^{+}
                                                                                                                                                                                   < 5.5
                                                                                                                                                                                                       \times 10^{-3}
                                                                                                                                                                                                                     CL=90%
                                                                                                                                                                                                                                      2343
                                                       ( 1.3 ±0.4 )%
                                                                                                         1815
                                                                                                                             K_4^*(2045)^+\gamma
                                                                                                                                                                                                       \times 10<sup>-3</sup>
DO D*+
                                                                                                                                                                                   < 9.9
                                                                                                                                                                                                                     CL=90%
                                                                                                                                                                                                                                      2243
                                                        (9 \pm 4) \times 10^{-3}
                                                                                                         1734
\overline{D}^*(2007)^0 D_+^+
                                                        ( 1.2 \pm 0.5 )%
                                                                                                                                                               Light unflavored meson modes
                                                                                                         1737
\overline{D}^*(2007)^0 D_*^{*+}
                                                                                                                             \pi^{+}\pi^{0}
                                                                                                                                                                                                       \times 10<sup>-5</sup>
                                                        (2.7 \pm 1.0)\%
                                                                                                         1650
                                                                                                                                                                                   < 2.0
                                                                                                                                                                                                                     CL=90%
                                                                                                                                                                                                                                      2636
                                                                                                                                                                                                      \times 10<sup>-4</sup>
                                                                                                                             \pi^{+}\pi^{+}\pi^{-}
D_s^+\pi^0
                                                                                                                                                                                                                    CL=90%
                                                                                                                                                                                                                                      2630
                                                      < 2.0
                                                                         \times 10^{-4}
                                                                                       CL=90%
                                                                                                         2270
                                                                                                                                                                                   < 1.3
                                                                                                                                \rho^0\pi^+
                                                                                                                                                                                                      \times 10<sup>-5</sup>
D_s^{*+}\pi^0
D_s^+\eta
                                                                         × 10<sup>-4</sup>
                                                                                                                                                                                   < 4.3
                                                                                                                                                                                                                     CL=90%
                                                                                                                                                                                                                                      2582
                                                      < 3.3
                                                                                       CL=90%
                                                                                                         2214
                                                                                                                                 \pi^+ f_0(980)
                                                                                                                                                                                                       \times 10^{-4}
                                                                                                                                                                                                                     CL=90%
                                                                                                                                                                                   < 1.4
                                                                                                                                                                                                                                      2547
                                                                         × 10<sup>-4</sup>
                                                      < 5
                                                                                       CL=90%
                                                                                                         2235
                                                                                                                                                                                                      × 10<sup>-4</sup>
                                                                                                                                 \pi^+ t_2(1270)
                                                                                                                                                                                                                     CL=90%
                                                                                                                                                                                                                                      2483
                                                                                                                                                                                   < 2.4
D^{*+}\eta
                                                                         \times 10^{-4}
                                                      < 8
                                                                                       CL=90%
                                                                                                         2177
                                                                                                                                \pi^+\pi^-\pi^+ nonresonant
                                                                                                                                                                                                       × 10<sup>-5</sup>
                                                                                                                                                                                                                     CL=90%
D_s^{-1} \rho^0
                                                                                                                                                                                   < 4.1
                                                                         × 10<sup>-4</sup>
                                                                                                                             \pi^{+}\pi^{0}\pi^{0}
                                                      < 4
                                                                                        CL=90%
                                                                                                         2198
                                                                                                                                                                                                       × 10<sup>--4</sup>
                                                                                                                                                                                                                     CL=90%
                                                                                                                                                                                                                                      2631
                                                                                                                                                                                   <
                                                                                                                                                                                       8.9
     ÷ρ0
                                                                         × 10<sup>-4</sup>
D**

ho^+\pi^0
                                                                                                                                                                                                      × 10<sup>-5</sup>
                                                                                       CL=90%
                                                      < 5
                                                                                                         2139
                                                                                                                                                                                   < 7.7
                                                                                                                                                                                                                     CL=90%
                                                                                                                                                                                                                                      2582
D_s^+ \omega
                                                                         × 10<sup>-4</sup>
                                                                                                                                                                                                      \times 10<sup>-3</sup>
                                                      < 5
                                                                                       CL=90%
                                                                                                         2195
                                                                                                                                 \pi^{-}\pi^{+}\pi^{0}
                                                                                                                                                                                                                     CL≃90%
                                                                                                                                                                                   < 4.0
                                                                                                                                                                                                                                      2621
D^{*+}\omega
                                                                                                                                \rho^+ \rho^0
                                                                                                                                                                                                      × 10<sup>-3</sup>
                                                                         \times 10<sup>-4</sup>
                                                      < 7
                                                                                       CL=90%
                                                                                                         2136
                                                                                                                                                                                   < 1.0
                                                                                                                                                                                                                     CL≃90%
                                                                                                                                                                                                                                      2525
D_{c}^{5} a_{1}(1260)^{0}
                                                                                                                                                                                                      × 10<sup>-3</sup>
                                                                                                                                 a_1(1260)^+\pi^0
                                                                         × 10<sup>-3</sup>
                                                                                                                                                                                   < 1.7
                                                                                                                                                                                                                     CL=90%
                                                                                                                                                                                                                                      2494
                                                      < 2.2
                                                                                       CL=90%
                                                                                                         2079
                                                                                                                                                                                                       × 10<sup>-4</sup>
                                                                                                                                 a_1(1260)^0\pi^+
                                                                                                                                                                                   < 9.0
                                                                                                                                                                                                                     CL=90%
                                                                                                                                                                                                                                      2494
D^{*+}a_1(1260)^0
                                                                         \times 10<sup>-3</sup>
                                                      < 1.6
                                                                                       CL=90%
                                                                                                         2014
D_s^+ \phi
                                                                                                                                                                                                       × 10<sup>-4</sup>
                                                                         × 10<sup>-4</sup>
                                                                                                                                                                                   < 4.0
                                                                                                                                                                                                                                      2580
                                                      < 3.2
                                                                                       CL=90%
                                                                                                         2141
                                                                         × 10<sup>-4</sup>
D_s^{*+}\phi
                                                                                       CL =90%
                                                      < 4
                                                                                                         2079
```

Scale factor/

$\eta \pi^+$	<	1.5	$\times 10^{-5}$	CL=90%	2609			
$\eta'\pi^+$	<	3.1	× 10 ⁻⁵	CL=90%	2550			
$\eta' \rho^+$	<	4.7	$ imes$ 10 $^{-5}$	CL=90%	2493			
$\eta \rho^+$	<	3.2	× 10 ⁻⁵	CL=90%	2554			
$\pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}$	<	8.6	× 10 ⁻⁴	CL=90%	2608			
$ ho^0 a_1(1260)^+$	<	6.2	× 10 ⁻⁴	CL=90%	2434			
$\rho^0 a_2(1320)^+$	<	7.2	× 10 ⁻⁴	CL=90%	2411			
$\pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{0}$	<	6.3	$\times 10^{-3}$	CL=90%	2592			
$a_1(1260)^+ a_1(1260)^0$	<	1.3	%	CL=90%	2335			
Baryon modes								
$p\bar{p}\pi^+$	<	1.6	$\times 10^{-4}$	CL=90%	2439			
$p \overline{p} \pi^+$ nonresonant	<	5.3	$\times 10^{-5}$	CL=90%	-			
$p\overline{p}\pi^{+}\pi^{+}\pi^{-}$	<	5.2	$\times 10^{-4}$	CL=90%	2369			
p p K ⁺ nonresonant	<	8.9	× 10 ⁻⁵	CL=90%	_			
pΛ	<	6	$\times 10^{-5}$	CL=90%	2430			
$p \overline{\Lambda} \pi^+ \pi^-$	<	2.0	× 10 ⁻⁴	CL=90%	2367			
$\overline{\Delta}^0 p$	<	3.8	$\times 10^{-4}$	CL=90%	2402			
$\Delta^{++}\overline{p}$	<	1.5	$\times 10^{-4}$	CL=90%	2402			
$\Lambda_c^- p \pi^+$	(6.2 ±2.7) × 10 ⁻⁴		-			
$\Lambda_c^- p \pi^+ \pi^0$	<	3.12	× 10 ⁻³	CL=90%	-			
$\Lambda_c^- p \pi^+ \pi^+ \pi^-$	<	1.46	$\times 10^{-3}$	CL=90%	_			
$\Lambda_c^- p \pi^+ \pi^+ \pi^- \pi^0$	<	1.34	% ·	CL=90%	-			

Lepton Family number (LF) or Lepton number (L) violating modes, or $\Delta B = 1$ weak neutral current (B1) modes

	∇D = 1 Meg μ μ	icu ii ai	Curre	ur (51) uiodea		
$\pi^{+} e^{+} e^{-}$	B1	<	3.9	× 10 ⁻³	CL=90%	2638
$\pi^{+}\mu^{+}\mu^{-}$	B1	<	9.1	× 10 ⁻³	CL=90%	2633
K+ e+ e-	B1	<	6	× 10 ⁻⁵	CL=90%	2616
$K^+\mu^+\mu^-$	B1	<	1.0	× 10 ⁻⁵	CL=90%	2612
$K^*(892)^+e^+e^-$	B1	<	6.9	× 10 ⁻⁴	CL=90%	2564
$K^*(892)^+ \mu^+ \mu^-$	B1	<	1.2	× 10 ⁻³	CL=90%	2560
$\pi^{+}e^{+}\mu^{-}$	LF	<	6.4	× 10 ⁻³	CL=90%	2637
$\pi^{+}e^{-}\mu^{+}$	LF	<	6.4	× 10 ⁻³	CL=90%	2637
$K^{+}e^{+}\mu^{-}$	LF	<	6.4	× 10 ⁻³	CL=90%	2615
$K^{+}e^{-}\mu^{+}$	LF	<	6.4	× 10 ⁻³	CL=90%	2615
$\pi^{-}e^{+}e^{+}$	L	<	3.9	× 10 ⁻³	CL=90%	2638
$\pi^{-}\mu^{+}\mu^{+}$	L	<	9.1	× 10 ⁻³	CL=90%	2633
$\pi^{-}e^{+}\mu^{+}$	· LF	<	6.4	× 10 ⁻³	CL=90%	2637
K ⁻ e ⁺ e ⁺	L	<	3.9	× 10 ⁻³	CL=90%	2616
$K^{-}\mu^{+}\mu^{+}$	L	<	9.1	× 10 ⁻³	CL=90%	2612
$K^-e^+\mu^+$	LF	<	6.4	× 10 ⁻³	CL=90%	2615

B⁰

$$I(J^P) = \frac{1}{2}(0^-)$$

 ${\it I}, {\it J}, {\it P}$ need confirmation. Quantum numbers shown are quark-model predictions.

Mass
$$m_{B^0} = 5279.2 \pm 1.8$$
 MeV $m_{B^0} - m_{B^\pm} = 0.35 \pm 0.29$ MeV (S = 1.1) Mean life $\tau_{B^0} = (1.56 \pm 0.04) \times 10^{-12}$ s $c\tau = 468~\mu\text{m}$ $\tau_{B^+}/\tau_{B^0} = 1.02 \pm 0.04$ (average of direct and inferred) $\tau_{B^+}/\tau_{B^0} = 1.04 \pm 0.04$ (direct measurements) $\tau_{B^+}/\tau_{B^0} = 0.95^{+0.15}_{-0.12}$ (inferred from branching fractions)

$B^0-\overline{B}{}^0$ mixing parameters

$$\chi_d = 0.172 \pm 0.010$$

 $\Delta m_{B^0} = m_{B^0_H} - m_{B^0_L} = (0.464 \pm 0.018) \times 10^{12} \ \hbar \ s^{-1}$
 $\chi_d = \Delta m_{B^0} / \Gamma_{B^0} = 0.723 \pm 0.032$

CP violation parameters

$$\left| \mathrm{Re}(\epsilon_{B^0}) \right| = 0.002 \pm 0.008$$

 B^0 modes are charge conjugates of the modes below. Reactions indicate the weak decay vertex and do not include mixing. Modes which do not identify the charge state of the B are listed in the B^\pm/B^0 ADMIXTURE section.

The branching fractions listed below assume 50% $B^0\overline{B}^0$ and 50% B^+B^- production at the T(45). We have attempted to bring older measurements up to date by rescaling their assumed Υ (45) production ratio to 50:50 and their assumed D, D_5 , D^* , and ψ branching ratios to current values whenever this would affect our averages and best limits significantly.

Indentation is used to indicate a subchannel of a previous reaction. All resonant subchannels have been corrected for resonance branching fractions to the final state so the sum of the subchannel branching fractions can exceed that of the final state.

-0					ale factor/	p
BO DECAY MODES	Frac	tion (F	_į /Γ)	Confid	ience level	(MeV/c)
$\ell^+ u_\ell$ anything	[pp] (1	105 +	0.8) %			_
$D^-\ell^+\nu_\ell$			0.25) %			_
$D^*(2010)^- \ell^+ \nu_{\ell}$			0.27) %			_
$\rho^-\ell^+ u_\ell$			0.8 1.0) × 1	104		_
• •						
$\pi^-\ell^+ u_\ell$	(1.8 ±	0.6) × 1	10 -		_
	nciusive :					
K ⁺ anything	(7	78 ±	80)%			-
D,	D*, or D	, mod	les			
$D^-\pi^+$			0.4) × 1	10-3		2306
$D^-\rho^+$	(7.9 ±	1.4) × 1			2236
$\overline{D}{}^0\pi^+\pi^-$		1.6		10~3	CL=90%	2301
$D^*(2010)^-\pi^+$			0.21) × 1			2254
$D^-\pi^+\pi^+\pi^-$			2.5) × 1			2287
$(D^-\pi^+\pi^+\pi^-)$ nonresonant			1.9) × 1			2287
$D^-\pi^+ ho^0 \ D^-a_1(1260)^+$			1.0) × 1 3.3) × 1			2207 2121
$D^*(2010)^-\pi^+\pi^0$			0.5) %	LU -		2247
D*(2010) - ρ+	-		3.3) × 1	₁₀ –3		2181
$D^*(2010)^-\pi^+\pi^+\pi^-$			1.7) x 1		S=1.3	2235
$(D^*(2010)^-\pi^+\pi^+\pi^-)$ non-			2.5) x 1			2235
resonant	-		Ť	•		
$D^*(2010)^-\pi^+\rho^0$			3.1) × 1	10-3		2151
$D^*(2010)^- a_1(1260)^+$			0.27) %			2061
$D^*(2010)^-\pi^+\pi^+\pi^-\pi^0$			1.8) %	3	CL=90%	2218
$\overline{D}_{2}^{*}(2460)^{-}\pi^{+}$	<	2.2 4.9		10-3 10-3	CL=90%	2064
$\overline{D}_{2}^{*}(2460)^{-}\rho^{+}$					CL=90%	1979
$D^-D_s^+$			3.0) × :			1812
$D^*(2010)^- D_s^+$	•		3.4) × :	10 3		1735
D-D*+ D*(2010)-D*+	•		0.5) %			1731
$D^*(2010)^-D_s^{*+}$	•		0.7) %			1649
$D_s^+\pi^-$	<	2.8		10-4	CL≃90%	2270
$D_{5}^{*+}\pi^{-}$	<	5		10-4	CL=90%	2214
$D_{s}^{+}\rho^{-}$	<	7		10-4	CL=90%	2198
$D_{5}^{*+}\rho^{-}$	<			10-4	CL=90%	2139
$D_s^+ a_1(1260)^-$	<			10-3	CL=90%	2079
$D_s^{*+} a_1(1260)^{-}$	<	2.2		10-3	CL=90%	2014
$D_s^- K^+$	<			10-4	CL=90%	2242
D*-K+	<			10-4	CL=90%	2185
$D_s^- K^*(892)^+$	<	9.9		10-4	CL=90%	2172
$D_s^{*-}K^*(892)^+$	<	1.1		10-3	CL=90%	2112
$D_s^-\pi^+K^0$	<	5		10-3	CL=90%	2221
$D_s^{*-}\pi^+K^0$	<	3.1		10-3	CL=90%	2164
$D_s^- \pi^+ K^*(892)^0$	<	4		10-3	CL=90%	2136
$D_s^{*-}\pi^+K^*(892)^0$	<	2.0		10-3	CL=90%	2074
$\overline{D}^0\pi^0$	<	1.2		10-4	CL=90%	2308
$\overline{D}^0 \rho^0$	<	3.9	×	10-4	CL=90%	2238
$\overline{D}^{0} \eta$ $\overline{D}^{0} \eta'$	<	1.3		10-4	CL=90%	2274
$\frac{D^2 \eta}{D^0 \omega}$	<	9.4 5.1		10 ⁻⁴ 10 ⁻⁴	CL=90% CL=90%	2198 2235
$\overline{D}^*(2007)^0\pi^0$	<	4.4		10-4	CL=90%	2256
$\overline{D}^*(2007)^0 \rho^0$	<	5.6		10-4	CL=90%	2183
$\overline{D}^*(2007)^0\eta$	<	2.6		10-4	CL=90%	2220
$\overline{D}^*(2007)^0 \eta'$	<	1.4		10-3	CL=90%	2141
$\overline{D}^*(2007)^0\dot{\omega}$	<	7.4	×	10-4	CL=90%	2180
D*(2010)+D*(2010)-	<	2.2	×	10-3	CL=90%	1711
D*(2010)+D-	<	1.8		10-3	CL=90%	1790
D+ D*(2010)-	<	1.2	×	10-3	CL=90%	1790
	armoniui					
$J/\psi(1S)K^0$	(8.9 ±	1.2)×			1683
$J/\psi(1S)K^+\pi^-$	(1.1 ±	0.6) ×	10-3		1652
$J/\psi(1S)K^*(892)^0$			0.18) ×			1570
$J/\psi(1S)\pi^0$	<	5.8		10 ⁻⁵	CL=90%	1728
$J/\psi(1S)\eta$	<	1.2		10 ⁻³	CL=90%	1672
$J/\psi(1S)\rho^0$	<	2.5	×	10-4	CL=90%	1614

Meson Summary Table

$J/\psi(1S)\omega$	< 2.	7 × 10 ⁻⁴	CL=90%	1609
$\psi(2S)K^0$	< 8	× 10 ⁻⁴	CL=90%	1283
$\psi(2S)K^{+}\pi^{-}$	< 1	× 10 ⁻³	CL=90%	1238
$\psi(2S) K^*(892)^0$	(1.	$4 \pm 0.9 \times 10^{-3}$		1113
$\chi_{c1}(1P)K^0$	< 2.		CL=90%	1411
$\chi_{c1}(1P)K^*(892)^0$	< 2.	1 × 10 ⁻³	CL=90%	1263
	K or K* me	ndes		
K+π-	(1.			2615
$\kappa^0\pi^0$				
	< 4.		CL=90%	2614
$\eta' K^0$	(4.	$7 + \frac{2.8}{-2.2} \times 10^{-5}$		2528
η' K*(892) ⁰	< 3.		CL=90%	2472
$\eta K^*(892)^0$	< 3.		CL=90%	2534
η K ⁰ K+ K-	< 3.	_	CL=90% CL=90%	2593
$\kappa^0 \overline{\kappa}^0$	< 4. < 1.		CL=90% CL=90%	2593 2592
K+ρ-	< 3.		CL=90%	2559
$K^0 \rho^0$	< 3.	_	CL=90%	2559
K ⁰ f ₀ (980)	< 3.	6 × 10 ⁻⁴	CL=90%	2523
$K^*(892)^+\pi^-$	< 7.		CL=90%	2562
$K^*(892)^0\pi^0$	< 2.		CL=90%	2562
$K_2^*(1430)^+\pi^-$	< 2.		CL=90%	2445
$K^0K^+K^ K^0\phi$	< 1.		CL=90%	2522
$\kappa^- \varphi$ $\kappa^- \pi^+ \pi^+ \pi^-$	< 8. [bbb] < 2.	_	CL=90% CL=90%	2516 2600
$K^*(892)^0\pi^+\pi^-$	[bbb] < 2. $< 1.$		CL=90%	2556
K*(892) ⁰ ρ ⁰	< 4.		CL=90%	2504
K*(892) ⁰ f ₀ (980)	< 1.		CL=90%	2467
$K_1(1400)^+\pi^-$	< 1.		CL=90%	2451
$K^-a_1(1260)^+$	[bbb] < 2.		CL=90%	2471
K*(892)0 K+ K-	< 6.		CL=90%	2466
$\hat{K}^*(892)^0 \phi$	< 4.		CL=90%	2459
$K_1(1400)^0 \rho^0$ $K_1(1400)^0 \phi$	< 3. < 5.		CL=90% CL=90%	2389 233 9
$K_2^*(1430)^0 \rho^0$	< 5. < 1.	-	CL=90%	2380
$K_2^*(1430)^0 \phi$	< 1.	•	CL=90%	2330
K*(892) ⁰ γ		0 ± 1.9)×10 ⁻⁵	/•	2564
$K_1(1270)^0 \gamma$	< 7.		CL=90%	2486
$K_1(1400)^0 \gamma$	< 4.		CL=90%	2453
$K_2^*(1430)^0 \gamma$	< 4.		CL=90%	2445
$K^*(1680)^0 \gamma$	< 2		CL=90%	2361
$K_3^*(1780)^0\gamma$	< 1		CL=90%	2343
$K_4^*(2045)^0\gamma$.3 × 10 ⁻³	CL=90%	2244
$\phi\phi$	< 3	.9 × 10 ⁻⁵	CL=90%	2435
Li	ght unflavored m			
$\pi^{+}\pi^{-}$	< 1		CL=90%	2636
$\pi^{0}\pi^{0}$	< 9		CL=90%	2636
$\eta \pi^0$	< 8	× 10 ⁻⁶ .8 × 10 ⁻⁵	CL=90% CL=90%	2609 2582
$\eta \eta \eta' \pi^0$	< 1 < 1		CL=90%	2551
$\eta' \dot{\eta'}$.7 × 10 ⁻⁵	CL≃90%	2460
$\eta' \eta$	< 2	.7 × 10 ⁻⁵	CL=90%	2522
$n' \rho^0$	< 2		CL=90%	2493
$\eta \rho^0$.3 × 10 ⁻⁵	CL=90%	2554
$\pi^+\pi^-\pi^0$ $\rho^0\pi^0$.2 × 10 ⁻⁴		2631
$ ho^{\sigma}\pi^{\sigma} ho^{\mp}\pi^{\pm}$.4 × 10 ⁻⁵ .8 × 10 ⁻⁵	CL=90% CL=90%	2582 2582
$\pi^{+}\pi^{-}\pi^{+}\pi^{-}$.3 × 10 ⁻⁴	CL=90%	2621
		.8 × 10 ⁻⁴		2525
$a_1(1260)^{\mp}\pi^{\pm}$	[gg] < 4	.9 × 10 ⁴	CL=90%	2494
$a_2(1320)^{\mp}\pi^{\pm}$.0 × 10 ⁻⁴	CL=90%	2473
π^+ $\pi^ \pi^0$ π^0		.1 × 10 ⁻³		2622
ρ+ρ-		.2 × 10 ⁻³	CL=90% CL=90%	2525
$a_1(1260)^0 \pi^0$ $\omega \pi^0$.1 × 10 ⁻³ .6 × 10 ⁻⁴	CL=90% CL=90%	2494 2580
$\frac{\omega \pi^{-}}{\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{0}}$.6 × 10 ⁴ .0 × 10 ³	CL=90% CL=90%	2580 2609
$a_1(1260)^+\rho^-$.4 × 10 ⁻³		2434
$a_1(1260)^0 \rho^0$.4 × 10 ⁻³		2434
$\pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{-}$	< 3	.0 × 10 ⁻³	CL=90%	2592
$a_1(1260)^+ a_1(1260)^-$.8 × 10 ⁻³		2336
$\pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{-}\pi^{0}$	< 1	.1 %	CL=90%	2572

	Baryon modes			
ρ p	< 1.8	× 10 ⁻⁵	CL=90%	2467
$p\overline{p}\pi^+\pi^-$	< 2.5	× 10 ⁻⁴	CL=90%	2406
$p \Lambda \pi^-$	< 1.8	× 10 ⁻⁴	CL=90%	2401
$\Delta^0 \overline{\Delta}{}^0$	< 1.5	× 10 ⁻³	CL=90%	2334
Δ++ Δ−−	< 1.1	× 10 ⁻⁴	CL=90%	2334
$\overline{\Sigma}_{c}^{}\Delta^{++}$	< 1.0	× 10 ⁻³	CL=90%	1839
$\Lambda_c^- p \pi^+ \pi^-$	$(1.3 \pm 0.6$) × 10 ⁻³		-
$\Lambda_c^- p$	< 2.1	× 10 ⁻⁴	CL=90%	2021
$\Lambda_c^- p \pi^0$	< 5.9	× 10 ⁻⁴	CL=90%	-
$\Lambda_c^- p \pi^+ \pi^- \pi^0$	< 5.07	× 10 ⁻³	CL=90%	-
$\Lambda_c^- p \pi^+ \pi^- \pi^+ \pi^-$	< 2.74	× 10 ⁻³	CL=90%	-
1 4 5 1				

Lepton Family number (LF) violating modes, or $\Delta B = 1$ weak neutral current (B1) modes

$\gamma \gamma$	B1	<	3.9	× 10 ⁻⁵	CL=90%	2640
e+ e-	81	<	5.9	× 10 ⁻⁶	CL=90%	2640
$\mu^+\mu^-$	B1	<	6.8	× 10 ⁻⁷	CL=90%	2637
$K^0e^+e^-$	B1	<	3.0	× 10 ⁻⁴	CL=90%	2616
$K^0\mu^+\mu^-$	B1	<	3.6	× 10 ⁻⁴	CL=90%	2612
K*(892) ⁰ e ⁺ e ⁻	B1	<	2.9	× 10 ⁻⁴	CL=90%	2564
$K^*(892)^0 \mu^+ \mu^-$. B1	<	2.3	× 10 ⁻⁵	CL=90%	2559
K*(892) ⁰ ν̄ν	B1	<	1.0	× 10 ⁻³	CL=90%	2244
e±µ∓	LF	[gg] <	5.9	× 10 ⁻⁶	CL=90%	2639
e [±] τ [∓]	LF	[gg] <	5.3	× 10 ⁻⁴	CL=90%	2341
$\mu^{\pm} \tau^{\mp}$	LF	[gg] <	8.3	× 10 ⁻⁴	CL=90%	2339

B±/B0 ADMIXTURE

The branching fraction measurements are for an admixture of B mesons at the $\Upsilon(4S)$. The values quoted assume that $B(\Upsilon(4S) \to B\overline{B}) = 100\%$.

For inclusive branching fractions, e.g., $B \to D^\pm$ anything, the treatment of multiple D's in the final state must be defined. One possibility would be to count the number of events with one-or-more D's and divide by the total number of B's. Another possibility would be to count the total number of D's and divide by the total number of B's, which is the definition of average multiplicity. The two definitions are identical when only one of the specified particles is allowed in the final state. Even though the 'one-or-more' definition seems sensible, for practical reasons inclusive branching fractions are almost always measured using the multiplicity definition. For heavy final state particles, authors call their results inclusive branching fractions while for light particles some authors call their results multiplicities. In the B sections, we list all results as inclusive branching fractions can exceed 100% and that inclusive partial widths can exceed total widths, just as inclusive cross sections can exceed total cross sections.

 $\overline{{\it B}}$ modes are charge conjugates of the modes below. Reactions indicate the weak decay vertex and do not include mixing.

B DECAY MODES		Fra	ction ((r _i /r)		ale factor/ dence level	p (MeV/c)		
Semileptonic and leptonic modes									
$B \rightarrow e^+ \nu_e$ anything	[ccc]			±0.29)		5=1.2	-		
$B \rightarrow \overline{p}e^+\nu_e$ anything		<	1.6		$\times 10^{-3}$	CL=90%	-		
$B \rightarrow \mu^+ \nu_\mu$ anything	[ccc]	(10.3	±0.5)	%		-		
	p,ccc]	(10.45	5±0.21)	%		-		
$B \rightarrow D^- \ell^+ \nu_{\ell}$ anything	[<i>pp</i>]	(2.7	±0.8)	%		-		
$B \rightarrow \overline{D}{}^0 \ell^+ \nu_{\ell}$ anything	[pp]	(7.0	±1.4	%		-		
$B \rightarrow \overline{D}^{**} \ell^+ \nu_{\ell}$ [p.				±0.7			-		
$B \rightarrow \overline{D}_1(2420) \ell^+ \nu_{\ell}$ any-		(7.4	±1.6)	× 10 ⁻³		-		
thing									
$B \rightarrow D\pi \ell^+ \nu_\ell$ anything +		(2.3	±0.4	1 %		-		
$D^*\pi\ell^+ u_\ell$ anything					_				
$B \rightarrow \overline{D}_2^*(2460)\ell^+\nu_\ell$ any-		<	6.5		× 10 ⁻³	CL=95%	-		
thing									
$B ightarrow~D^{*-}\pi^+\ell^+ u_\ell$ any-		(1.00	0.34)	%		-		
thing					,				
$B \rightarrow D_s^+ \ell^+ \nu_\ell$ anything	[pp]	<	9			CL=90%	-		
$B \rightarrow D_s^- \ell^+ \nu_\ell K^+$ any-	[<i>pp</i>]	<	6		× 10 ⁻³	CL=90%	-		
thing									
$B \rightarrow D_s^- \ell^+ \nu_\ell K^0$ anythin	g [<i>pp</i>]	<	9		× 10 ⁻³	CL≃90%	-		
$B \rightarrow K^+ \ell^+ \nu_{\ell}$ anything	[pp]	(6.0	±0.5	%		-		
$B \rightarrow K^- \ell^+ \nu_{\ell}$ anything	[<i>pp</i>]	(10	±4) × 10 ⁻³		-		
$B \to K^0 / \overline{K}^0 \ell^+ \nu_\ell$ anything	[<i>pp</i>]	. (4.4	±0.5	%		-		

```
D, D^{\bullet}, or D_{z} modes
B \rightarrow D^{\pm} anything
                                                         ( 24.1 ±1.9 )%
B \rightarrow D^0/\overline{D}^0 anything
                                                         (63.1 ±2.9)%
                                                                                             S=1.1
B \rightarrow D^*(2010)^{\pm} anything
                                                         ( 22.7 ±1.6 )%
B \rightarrow D^*(2007)^0 anything
                                                         ( 26.0 ±2.7 )%
B \rightarrow D_s^{\pm} anything
                                                 [gg] ( 10.0 ±2.5 )%
b \rightarrow c \overline{c} s
                                                         (22 ±4 )%
B \rightarrow D_s D, D_s^* D, D_s D^*, \text{ or }
                                                 [gg]
                                                        ( 4.9 ±1.3)%
     D_s^*D^*
B \rightarrow D^*(2010)\gamma
                                                                            \times 10^{-3} CL=90%
                                                       < 1.1
B \to D_s^+ \pi^-, D_s^{*+} \pi^-,
                                                                             × 10<sup>-4</sup> CL=90%
                                                 [gg] < 5
     D_s^+ \rho^-, D_s^{*+} \rho^-, D_s^+ \pi^0,
     D_s^{*+}\pi^0, D_s^+\eta, D_s^{*+}\eta,
     D_s^+ \rho^0, D_s^{*+} \rho^0, D_s^+ \omega,
     D_s^{*+}\omega
B \rightarrow D_{s1}(2536)^+ anything
                                                       < 9.5
                                                                             × 10<sup>-3</sup> CL=90%
                                          Charmonium modes
B \rightarrow J/\psi(1S) anything
                                                         ( 1.13±0.06)%
                                                         ( 8.0 \pm0.8 ) \times 10<sup>-3</sup>
   B \rightarrow J/\psi(1S) (direct) any-
        thing
B \rightarrow \psi(2S) anything
                                                         (3.5 \pm 0.5) \times 10^{-3}
B \rightarrow \chi_{c1}(1P) anything
                                                         ( 4.2 \pm 0.7 ) \times 10^{-3}
    B \rightarrow \chi_{c1}(1P) (direct) any-
                                                         (3.7 \pm 0.7) \times 10^{-3}
        thing
                                                                             \times 10^{-3} CL=90%
B \rightarrow \chi_{c2}(1P) anything
                                                       <
                                                             3.8
B \rightarrow \eta_c(1S) anything
                                                                             \times 10^{-3} CL=90%
                                                             9
                                                        <
                                              K or K* modes
B \rightarrow K^{\pm} anything
                                                 [gg] ( 78.9 ±2.5 ) %
    B \rightarrow K^+ anything
                                                         (66 ±5)%
    B \rightarrow K^- anything
                                                         (13 ±4 )%
B \to K^0 / \overline{K}^0 anything
                                                 [gg] (64 ±4 )%
B \rightarrow K^*(892)^{\pm} anything
                                                         (18 ±6)%
B \to K^*(892)^0 / \overline{K}^*(892)^0 any- [gg] (14.6 ±2.6)%
    thing
B \rightarrow K_1(1400)\gamma
                                                                             \times 10<sup>-4</sup> CL=90%
                                                        <
                                                             4.1
B \rightarrow K_2^*(1430)\gamma
                                                                             × 10<sup>-4</sup>
                                                        <
                                                             8.3
                                                                                         CL=90%
                                                                             × 10<sup>-3</sup>
B \rightarrow K_2(1770)\gamma
                                                        <
                                                             1.2
                                                                                         CL=90%
                                                                             × 10<sup>-3</sup>
B \rightarrow K_3^*(1780)\gamma
                                                        <
                                                             3.0
                                                                                          CL=90%
                                                                             × 10<sup>-3</sup>
B \rightarrow K_4^*(2045)\gamma
                                                             1.0
                                                                                          CL=90%
                                                        <
                                                         (2.3 \pm 0.7) \times 10^{-4}
B \rightarrow \overline{b} \rightarrow \overline{s}\gamma
B \rightarrow \overline{b} \rightarrow \overline{s} gluon
                                                                             %
                                                                                          CL=90%
                                                        <
                                                             6.8
                                   Light unflavored meson modes
B \rightarrow \pi^{\pm} anything
                                             [gg,eee] (359 \pm 7 )%
B \rightarrow \eta anything
                                                         ( 17.6 ±1.6 )%
B \rightarrow \rho^0 anything
                                                         (21 \pm 5)\%
                                                        < 81
B \rightarrow \omega anything
                                                                             %
                                                                                          CL=90%
B \rightarrow \phi anything
                                                         ( 3.5 \pm 0.7)%
                                                                                             S=1.8
                                               Baryon modes
B \rightarrow \Lambda_c^{\pm} anything
                                                         (6.4 \pm 1.1)\%
B \rightarrow \Lambda_c^- e^+ anything
                                                                            \times 10^{-3} CL=90%
                                                        < 3.2
 B \rightarrow \Lambda_c^- p anything
                                                         (3.6 \pm 0.7)\%
                                                                             \times 10<sup>-3</sup>
 B \rightarrow A_c^- pe^+ \nu_e
                                                        < 1.5
                                                                                         CL=90%
\begin{array}{ll} B \to \overline{\Sigma_c} & \text{anything} \\ B \to \overline{\Sigma_c} & \text{anything} \\ B \to \overline{\Sigma_c} & \text{anything} \\ \end{array}
                                                         ( 4.2 \pm 2.4 ) \times 10^{-3}
                                                                             \times 10^{-3}
                                                        < 9.6
                                                         ( 4.6 \pm 2.4 ) \times\,10^{-3}
B \to \overline{\Sigma_c^0} N(N = p \text{ or } n)
                                                                            × 10<sup>-3</sup>
                                                                                         CL=90%
                                                        < 1.5
 B \rightarrow \Xi_{c}^{0} anything
                                                         (1.4 \pm 0.5) \times 10^{-4}
      \times B(\Xi_c^0 \to \Xi^-\pi^+)
 B \rightarrow \Xi_c^+ anything
                                                         (4.5 \begin{array}{c} +1.3 \\ -1.2 \end{array}) \times 10^{-4}
      \times B(\Xi_c^+ \to \Xi^- \pi^+ \pi^+)
 B \rightarrow p/\overline{p} anything
                                                  [gg] ( 8.0 ±0.4)%
 B \rightarrow p/\overline{p}(direct) anything
                                                  [gg] ( 5.5 ±0.5 )%
B \rightarrow \Lambda/\overline{\Lambda} anything
                                                         ( 4.0 ±0.5)%
                                                  [22]
 B \rightarrow \Xi^-/\overline{\Xi}^+ anything
                                                         (2.7 \pm 0.6) \times 10^{-3}
 B \rightarrow \text{ baryons anything}
                                                         ( 6.8 ±0.6)%
 B \rightarrow p\overline{p} anything
                                                         ( 2.47±0.23)%
 B \rightarrow \Lambda \bar{p}/\bar{\Lambda} p anything
                                                 [gg] ( 2.5 \pm 0.4)%
                                                                             × 10-3 CL=90%
 B \rightarrow \Lambda \overline{\Lambda} anything
                                                             5
```

Lepton Family number (LF) violating modes or $\Delta B = 1$ weak neutral current (B1) modes

Β →	e ⁺ e ⁻ s	B1	<	5.7	$\times 10^{-5}$	CL=90%	
<i>B</i> →	$\mu^+\mu^-s$	B1	<	5.8	× 10 ⁻⁵	CL=90%	
B→	e± u∓ s	LF	<	2.2	$\times 10^{-5}$	CL=90%	

$B^{\pm}/B^{0}/B_{s}^{0}/b$ -baryon ADMIXTURE

mixture

These measurements are for an admixture of bottom particles at high energy (LEP, Tevatron, $Sp\overline{p}S$).

```
Mean life \tau=(1.564\pm0.014)\times10^{-12} s Mean life \tau=(1.72\pm0.10)\times10^{-12} s Charged b-hadron admixture Mean life \tau=(1.58\pm0.14)\times10^{-12} s Neutral b-hadron ad-
```

 $au_{
m charged}$ $b_{
m -hadron}/ au_{
m neutral}$ $b_{
m -hadron}=1.09\pm0.13$

The branching fraction measurements are for an admixture of B mesons and baryons at energies above the $\Upsilon(4S)$. Only the highest energy results (LEP, Tevatron, SPPS) are used in the branching fraction averages. The production fractions give our best current estimate of the admixture at LEP

For inclusive branching fractions, e.g., $B\to D^\pm$ anything, the treatment of multiple D's in the final state must be defined. One possibility would be to count the number of events with one-or-more D's and divide by the total number of B's. Another possibility would be to count the total number of D's and divide by the total number of B's, which is the definition of average multiplicity. The two definitions are identical when only one of the specified particles is allowed in the final state. Even though the "one-or-more" definition seems sensible, for practical reasons inclusive branching fractions are almost always measured using the multiplicity definition. For heavy final state particles, authors call their results inclusive branching fractions while for light particles some authors call their results multiplicities. In the B sections, we list all results as inclusive branching fractions, adopting a multiplicity definition. This means that inclusive branching fractions can exceed 100% and that inclusive partial widths can exceed total widths, lust as inclusive cross sections can exceed total cross sections.

The modes below are listed for a \widetilde{b} initial state. b modes are their charge conjugates. Reactions indicate the weak decay vertex and do not include mixing.

T DECAY MODES

Fraction (Γ_I/Γ) Cor

Confidence level (MeV/c)

PRODUCTION FRACTIONS

The production fractions for weakly decaying b-hadrons at the Z have been calculated from the best values of mean lives, mixing parameters, and branching fractions in this edition by the LEP B Oscillation Working Group as described in the note "Production and Decay of b-Flavored Hadrons" in the B^\pm Particle Listings. Values assume

$$\begin{array}{ll} \mathsf{B}(\overline{b} \to B^+) = \mathsf{B}(\overline{b} \to B^0) \\ \mathsf{B}(\overline{b} \to B^+) + \mathsf{B}(\overline{b} \to B^0) + \mathsf{B}(\overline{b} \to B^0) + \mathsf{B}(b \to \Lambda_b) = 100 \ \%. \end{array}$$

The notation for production fractions varies in the literature $(f_{\overline{B}^0}, f(b \to \overline{B}^0), Br(b \to \overline{B}^0))$. We use our own branching fraction notation here, $B(\overline{b} \to B^0)$.

```
B^{+} ( 39.7 \pm \frac{1.8}{2.2} ) % - B^{0} ( 39.7 \pm \frac{1.8}{2.2} ) % - B_{s}^{0} ( 10.5 \pm \frac{1.8}{1.7} ) % - A_{b} ( 10.1 \pm \frac{3.9}{3.1} ) % -
```

DECAY MODES

Semileptonic and leptonic modes

```
(23.1 \pm 1.5)\%
ν anything
   \ell^+ \nu_\ell anything
                                                         (10.99 \pm 0.23)\%
    e^+ \nu_e anything
                                                [ccc] ( 10.9 ± 0.5 ) %
   \mu^+ 
u_\mu anything
                                                [ccc] ( 10.8 ± 0.5 ) %
       D^-\ell^+\nu_\ell anything
                                                 [pp]
                                                         ( 2.02 ± 0.29) %
       \overline{D}{}^0\ell^+\nu_\ell anything
                                                         (6.5 \pm 0.6)\%
                                                 [pp]
       D^{*-}\ell^+\nu_{\ell} anything
                                                         ( 2.76 ± 0.29) %
                                                 [pp]
       \overline{D}{}_{I}^{0}\ell^{+}\nu_{\ell} anything
                                             [pp,fff]
                                                           seen
       D_1^-\ell^+\nu_\ell anything
                                             [pp,fff]
                                                           seen
       \overline{D}_{2}^{*}(2460)^{0}\ell^{+}\nu_{\ell} anything
       D_2^*(2460)^-\ell^+\nu_\ell anything
                                                           seen
    \tau^+ \bar{\nu_{	au}} anything
                                                         (2.6 \pm 0.4)\%
                                                 [pp] ( 7.8 ± 0.6 )%
\overline{c} \rightarrow \ell^- \overline{\nu}_{\ell} anything
```

Meson Summary Table

Cha	armed meson and baryon modes					
\overline{D}^0 anything	$(60.1 \pm 3.2)\%$	_				
D ⁻ anything	(23.7 ± 2.3) %	-				
\overline{D}_s anything	(18 ± 5)%	-				
Λ_c anything	(9.7 ± 2.9)%	-				
♂/canything	[eee] (117 ± 4)%	-				
	Charmonium modes					
$J/\psi(1S)$ anything	(1.16± 0.10) %	-				
$\psi(2S)$ anything	$(4.8 \pm 2.4) \times 10^{-3}$	-				
$\chi_{c1}(1P)$ anything	$(1.8 \pm 0.5)\%$	-				
	K or K* modes					
$\overline{s}\gamma$	< 5.4 × 10 ⁻⁴ 90%	-				
K^{\pm} anything	(88 ±19)%	-				
K _S anything	$(29.0 \pm 2.9)\%$	-				
	Pion modes					
π^0 anything	[eee] (278 ±60)%	-				
	Baryon modes					
p/\overline{p} anything	(14 ± 6)%	_				
	Other modes					
charged anything	[cee] (497 ± 7)%	-				
hadron+ hadron-	$(1.7 + \frac{1.0}{0.7}) \times 10^{-5}$	_				
charmless	$(7 \pm 21) \times 10^{-3}$	_				
Baryon modes						
$\Lambda/\overline{\Lambda}$ anything	(5.9 ± 0.6)%	-				
$\Delta B =$	1 weak neutral current (B1) modes					
$\mu^+\mu^-$ anything	$81 < 3.2 \times 10^{-4} 90\%$	-				

₿*

$$I(J^P) = \frac{1}{2}(1^-)$$

I, J, P need confirmation. Quantum numbers shown are quark-model

Mass
$$m_{B^*} = 5324.9 \pm 1.8 \text{ MeV}$$

 $m_{B^*} - m_B = 45.78 \pm 0.35 \text{ MeV}$

B* DECAY MODES	Fraction $(\Gamma_{\hat{I}}/\Gamma)$	p (MeV/c)
Βγ	dominant	46

BOTTOM, STRANGE MESONS $(B = \pm 1, S = \mp 1)$

 $B_s^0 = s\overline{b}, \overline{B}_s^0 = \overline{s}b,$ similarly for B_s^* 's

 B_s^0

$$I(J^P) = 0(0^-)$$

I, J, P need confirmation. Quantum numbers shown are quark-model predictions.

Mass
$$m_{B_s^0}=5369.3\pm2.0$$
 MeV Mean life $\tau=(1.54\pm0.07)\times10^{-12}$ s $c au=462~\mu{\rm m}$

$B_s^0 - \overline{B}_s^0$ mixing parameters

$$\chi_B$$
 at high energy = $f_d \chi_d + f_s \chi_s = 0.118 \pm 0.006$
 $\Delta m_{B_s^0} = m_{B_s^0} - m_{B_s^0} > 9.1 \times 10^{12} \ h \ s^{-1}$, CL = 95% $\chi_s = \Delta m_{B_s^0} / \Gamma_{B_s^0} > 14.0$, CL = 95% $\chi_s > 0.4975$, CL = 95%

These branching fractions all scale with $B(\overline{b} \to B_S^0)$, the LEP B_S^0 production fraction. The first four were evaluated using $B(\overline{b} \rightarrow B_s^0) =$ $(10.5^{+1.8}_{-1.7})\%$ and the rest assume B($\overline{b} \rightarrow B_s^0$) = 12%.

The branching fraction B(B_S^0 ightarrow D_S^- $\ell^+
u_\ell$ anything) is not a pure measurement since the measured product branching fraction $B(\overline{b} \to B_s^0) \times$ $B(B_0^0 \to D_b^- \ell^+ \nu_\ell$ anything) was used to determine $B(\overline{b} \to B_0^0)$, as described in the note on "Production and Decay of *b*-Flavored Hadrons."

BO DECAY MODES	Fraction (I	' _/ /୮) Confi	dence level	<i>p</i> (MeV/c)
D _s anything	(92 ±	33) %		_
$D_s^-\ell^+\nu_\ell$ anything	[ggg] (8.1 ±	2.5) %		_
$D_{s}^{-}\pi^{+}$	< 13	%		2321
$J/\psi(1S)\phi$	(9.3 ±	$3.3) \times 10^{-4}$		1590
$J/\psi(1S)\pi^0$	< 1.2	× 10 ⁻³	90%	1788
$J/\psi(1S)\eta$	< 3.8	× 10 ⁻³	90%	1735
$\psi(2S)\phi$	seen			1122
$\pi^+\pi^-$	< 1.7	× 10 ⁻⁴	90%	1122
$\pi^{0}\pi^{0}$	< 2.1	× 10 ⁻⁴	90%	2861
$\eta \pi^0$	< 1.0	× 10 ⁻³	90%	2655
$\eta \eta$	< 1.5	× 10 ⁻³	90%	2628
π^+K^-	< 2.1	× 10 ⁻⁴	90%	2660
K+K-	< 5.9	× 10 ⁻⁵	90%	2639
ρ p	< 5.9	× 10 ⁻⁵	90%	2515
77	< 1.48	× 10 ⁻⁴	90%	2685
$\phi \gamma$	< 7	× 10 ⁻⁴	90%	2588
Lepton Family	number (LF) vk	plating modes	or	
$\Delta B = 1$ we	ak neutral curren	t (<i>B1</i>) mode	1	
$\mu^+\mu^-$ B		× 10 ⁻⁶	90%	2682
e+e- B	1 < 5.4	× 10 ⁻⁵	90%	2864
$e^{\pm}\mu^{\mp}$	[gg] < 4.1	× 10 ⁻⁵	90%	2864
$\phi u \overline{ u}$ B		× 10 ⁻³	90%	-

_	/1	c١
IJς	(z	. J

$$I^{G}(J^{PC}) = 0^{+}(0^{-})$$

Mass $m = 2979.8 \pm 2.1$ MeV (S = 2.1) Full width $\Gamma = 13.2^{+3.8}_{-3.2}$ MeV

$\eta_{c}(1S)$ DECAY MODES	Fraction (F	₁ /Γ) (Confidence level	(MeV/c)
Decays inv	rolving hadronic	resonance	S	
$\eta'(958)\pi\pi$	(4.1 ±1	.7) %		1319
$\rho\rho$	(2.6 ±0	.9) %		1275
$K^*(892)^0 K^- \pi^+ + \text{c.c.}$	(2.0 ±0			1273
K*(892) K*(892)	(8.5 ±3	.1) × 10 ⁻³	i	1193
$\phi \phi$	(7.1 ± 2)	.8) × 10 ³	1	1086
$a_0(980)\pi$	< 2	%	90%	1323
$a_2(1320)\pi$	< 2	%	90%	1193
$K^*(892)\overline{K} + \text{c.c.}$	< 1.28	%	90%	1307
$f_2(1270)\eta$	< 1.1	%	90%	1142
ωω	< 3.1	× 10 ⁻³	90%	1268
Deca	ys into stable ha	drons		
$K\overline{K}\pi$	(5.5 ±1	.7) %		1378
$\eta\pi\pi$	(4.9 ±1	.8) %		1425
$\pi^{+}\pi^{-}K^{+}K^{-}$	(2.0 +0	.7 .6) %		1342
2(K ⁺ K ⁻)	(2.1 ±1	.2) %		1053
$2(\pi^{+}\pi^{-})$	(1.2 ±0	.4) %		1457
	(1.2 ±0	.4) × 10 ⁻³	3	1157
p <u>p</u> KΚη	< 3.1	%	90%	1262
$\pi^+\pi^-\rho\overline{\rho}$	< 1.2	%	90%	1023
Λ Λ	< 2	× 10 ⁻³	90%	987
	Radiative decays	5		
$\gamma\gamma$	(3.0 ±1	.2) × 10 ⁻⁴	ı	1489

$J/\psi(1S)$

$$I^{G}(J^{PC}) = 0^{-}(1^{-})$$

Mass $m = 3096.88 \pm 0.04 \text{ MeV}$ Full width $\Gamma=87\pm5~\text{keV}$ $\Gamma_{e\,e} = 5.26 \pm 0.37 \; \text{keV} \quad (\text{Assuming } \Gamma_{e\,e} = \Gamma_{\mu\,\mu})$

1 88 - 0.20 ± 0.01 NO	(,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	$-\cdot\mu\mu$	
J/ψ(15) DECAY MODES	Fraction (Γ_I/Γ)	Scale factor/ Confidence level	р (MeV/c)
hadrons	(87.7 ±0.5) %		
$virtual_{\gamma} \rightarrow hadrons$	(17.0 ±2.0)%		_
e+ e-	(6.02±0.19) %		1548
$\mu^+\mu^-$	(6.01±0.19) %		1545
Decays involving	ng hadronic resona	nces	
$ ho\pi$	(1.27±0.09) %		1449
$\rho^0\pi^0$	(4.2 ±0.5)×	10-3	1449
$a_2(1320)\rho$	(1.09±0.22) %		1125
$\omega \pi^+ \pi^+ \pi^- \pi^-$	(8.5 ±3.4)×	10-3	1392
$\omega \pi^+ \pi^-$	(7.2 ±1.0) ×		1435
$\omega f_2(1270)$	(4.3 \pm 0.6) \times	10-3	1143
$K^*(892)^0 \overline{K}_2^*(1430)^0 + \text{c.c.}$	(6.7 \pm 2.6) \times		1005
$\omega K^*(892)\overline{K} + \text{c.c.}$	(5.3 ±2.0)×	10^{-3}	1098
$K^{+}\overline{K}^{*}(892)^{-}$ + c.c.	(5.0 ±0.4)×	10-3	1373
$K^0\overline{K}^*(892)^0 + \text{c.c.}$	(4.2 ±0.4)×		1371
$\omega \pi^0 \pi^0$	(3.4 ±0.8)×		1436
	gg] (3.0 \pm 0.5) \times		1299
$\omega K^{\pm} K_{S}^{0} \pi^{\mp}$	[gg] (3.0 ±0.7) ×		1210
$b_1(1235)^0 \pi^0$	(2.3 \pm 0.6) \times	10 ⁻³	1299
$\phi K^*(892)\widetilde{K} + \text{c.c.}$	(2.04 ± 0.28) ×		969
ω Κ Κ	(1.9 ±0.4)×	10 ⁻³	1268
$\omega f_J(1710) \rightarrow \omega K \overline{K}$	(4.8 \pm 1.1) \times		878
$\phi 2(\pi^{+}\pi^{-})$	(1.60±0.32) ×		1318
$\Delta(1232)^{++}\overline{\rho}\pi^{-}$	(1.6 ± 0.5) \times		1030
$\omega\eta$	(1.58±0.16) ×		1394
$\phi K \overline{K}$	(1.48 ± 0.22) ×		1179
$\phi f_J(1710) \rightarrow \phi K \overline{K}$	(3.6 ±0.6)×		875
$p\overline{p}\omega$	(1.30±0.25) ×		769
$\Delta(1232)^{++}\overline{\Delta}(1232)^{}$	(1.10±0.29) ×		938
	gg] (1.03±0.13)×		692
$p\overline{p}\eta'(958)$	(9 ±4)×		596
$\phi f_2'(1525)$	(8 ±4)×	10 ⁻⁴ 5=2.7	871

$\phi \pi^+ \pi^-$		/ a n	± 1.2) $\times 10^{-4}$		1365
$\phi K^{\pm} K_S^0 \pi^{\mp}$		(0.0	±1.2) × 10		
			± 0.9) $\times 10^{-4}$		1114
$\omega f_1(1420)$			± 2.4) $\times 10^{-4}$		1062
$\phi\eta$		(6.5	± 0.7) $\times 10^{-4}$		1320
<i>≣</i> (1530)− <i>≣</i> +			± 1.5) $\times 10^{-4}$		597
$p K^{-} \overline{\Sigma} (1385)^{0}$		(5.1	$\pm 3.2) \times 10^{-4}$		645
$\omega \pi^0$			± 0.6) $\times 10^{-4}$	S=1.4	1447
				3-1.4	
$\phi \eta'(958)$		•	± 0.4) × 10 ⁻⁴		1192
$\phi f_0(980)$			± 0.9) × 10^{-4}	S=1.9	1182
Ξ (1530) ⁰ Ξ ⁰		(3.2	± 1.4) × 10 ⁻⁴		608
$\Sigma(1385)^{-}\overline{\Sigma}^{+}$ (or c.c.)	[gg]	(3.1	± 0.5) × 10^{-4}		857
$\phi f_1(1285)$		(2.6	± 0.5) $\times 10^{-4}$	S=1.1	1032
ρη			±0.23) × 10 ⁻⁴		1398
$\omega \eta'$ (958)			$\pm 0.25) \times 10^{-4}$		1279
' ' '		(1.07	±0.25) × 10		
$\omega f_0(980)$			± 0.5) $\times 10^{-4}$		1271
$\rho \eta'(958)$			$5\pm0.18)\times10^{-4}$		1283
$p\overline{p}\phi$		(4.5	± 1.5) $\times 10^{-5}$		527
$a_2(1320)^{\pm}\pi^{\mp}$	[gg] <	4.3	× 10 ⁻³	CL=90%	1263
$K \overline{K}_{2}^{*}(1430) + \text{c.c.}$		4.0	× 10 ⁻³	CL=90%	1159
$K_2^*(1430)^0 \overline{K}_2^*(1430)^0$			× 10 ⁻³	CL=90%	588
		2.9	_		
$K^{*}(892)^{0}\overline{K}^{*}(892)^{0}$	<	5	× 10 ⁻⁴	CL=90%	1263
$\phi f_2(1270)$	<	3.7	× 10 ⁻⁴	CL=90%	1036
$\rho \overline{\rho} \rho$	<	3.1	× 10 ⁻⁴	CL=90%	779
$\phi \eta(1440) \rightarrow \phi \eta \pi \pi$		2.5	× 10 ⁻⁴	CL=90%	946
$\omega f_2'(1525)$		2.2	× 10 ⁻⁴	CL=90%	1003
Σ (1385) $^{0}\overline{\Lambda}$	<	2	× 10 ⁻⁴	CL=90%	911
$\Delta(1232)^{+}\overline{p}$	<	1	× 10 ⁻⁴	CL=90%	1100
$\Sigma_0 \underline{\lambda}$	<	9	× 10 ⁻⁵	CL=90%	1032
$\phi \pi^0$		6.8	× 10 ⁻⁶	CL=90%	1377
Ψ".	Ì		A 20	02-7070	
	Decays into s	table	hadrons		
$2(\pi^{+}\pi^{-})\pi^{0}$		(3.37	±0.26) %		1496
$3(\pi^{+}\pi^{-})\pi^{0}$		•	±0.6)%		1433
		•	•		
$\pi^{+}\pi^{-}\pi^{0}$)±0.20) %		1533
$\pi^{+}\pi^{-}\pi^{0}K^{+}K^{-}$		(1.20	0±0.30) %		1368
$4(\pi^{+}\pi^{-})\pi^{0}$		(9.0	± 3.0) $\times 10^{-3}$		1345
$\pi^{+}\pi^{-}K^{+}K^{-}$		(7.2	± 2.3) $\times 10^{-3}$		1407
$K\overline{K}\pi$			± 1.0) $\times 10^{-3}$		1440
$p\overline{p}\pi^{+}\pi^{-}$			± 0.5) $\times 10^{-3}$	5=1.3	1107
• • •				3-1.3	
$2(\pi^{+}\pi^{-})$			± 1.0) × 10^{-3}		1517
$3(\pi^{+}\pi^{-})$			± 2.0) $\times 10^{-3}$		1466
$n \overline{n} \pi^+ \pi^-$		(4	± 4) × 10 ⁻³		1106
$\Sigma^0 \overline{\Sigma}{}^0$		(1.27	$(\pm 0.17) \times 10^{-3}$		992
$2(\pi^{+}\pi^{-})K^{+}K^{-}$			± 1.3) $\times 10^{-3}$		1320
$p\overline{p}\pi^+\pi^-\pi^0$	[hhh]		± 0.9) × 10^{-3}	S=1.9	1033
	[,,,,,1	(2.1	$\pm 0.10) \times 10^{-3}$		1232
p <u>ē</u> 					
$p\overline{p}\eta$		(2.09	$0 \pm 0.18) \times 10^{-3}$		948
pππ [—]		(2.00	$0 \pm 0.10) \times 10^{-3}$		1174
nπ		(1.9	± 0.5) $\times 10^{-3}$		1231
<u> </u>		(1.8	± 0.4) $\times 10^{-3}$	S=1.8	818
$\Lambda \overline{\Lambda}$		(1.3	$5\pm0.14)\times10^{-3}$	S=1.2	1074
$p\overline{p}\pi^0$		(1.00	$0 \pm 0.09) \times 10^{-3}$		1176
$\Lambda \overline{\Sigma}^- \pi^+$ (or c.c.)	f1				
$pK^{-}\overline{\Lambda}$	[gg]		$5\pm0.12)\times10^{-3}$		945
		(8.9	± 1.6) $\times 10^{-4}$		876
$2(K^{+}K^{-})$		(7.0	± 3.0) $\times 10^{-4}$		1131
$pK^{-}\overline{\Sigma}^{0}$		(2.9	± 0.8) $\times 10^{-4}$		820
K+ K-			$7 \pm 0.31) \times 10^{-4}$		1468
$\Lambda \overline{\Lambda} \pi^0$			± 0.7) $\times 10^{-4}$		998
$\pi^+\pi^-$			$7 \pm 0.23) \times 10^{-4}$		1542
$K_{S}^{0}K_{I}^{0}$					
			$3\pm0.14)\times10^{-4}$		1466
$\Lambda \overline{\Sigma} + c.c.$	<	1.5	× 10 ⁻⁴	CL=90%	1032
$K_S^0 K_S^0$	<	5.2	× 10 ⁻⁶	CL=90%	1466
5 5	.				
	Radiativ		-		
$\gamma \eta_c(1S)$		(1.3	±0.4)%		116
$\gamma \pi^+ \pi^- 2\pi^0$		(8.3	± 3.1) $\times 10^{-3}$		1518
$\gamma \eta \pi \pi$			± 1.0) $\times 10^{-3}$		1487
$\gamma \eta (1440) \rightarrow \gamma K \overline{K} \pi$	fa)	/ 01	± 1.8) × 10^{-4}		1223
	[<i>P</i>]	(3.1	±1.4 \ \ 10-5		
$\gamma \eta(1440) \rightarrow \gamma \gamma \rho^0$			± 1.4) × 10 ⁻⁵		1223
$\gamma \eta(1440) \rightarrow \gamma \eta \pi^+ \pi^-$			± 0.7) × 10^{-4}		-
$\gamma \rho \rho$			± 0.8) $\times 10^{-3}$		1343
$\gamma \eta'(958)$		(4.3	$1\pm0.30)\times10^{-3}$		1400
$\gamma 2\pi^+ 2\pi^-$			± 0.5) $\times 10^{-3}$	5≕1.9	1517
$\gamma f_4(2050)$			± 0.7) $\times 10^{-3}$		874
$\gamma \omega \omega$			$9\pm0.33)\times10^{-3}$		1337
				C-12	
$\gamma \eta (1440) \rightarrow \gamma \rho^0 \rho^0$			± 0.4) $\times 10^{-3}$	S=1.3	1223
$\gamma f_2(1270)$			$8 \pm 0.14) \times 10^{-3}$		1286
$\gamma f_J(1710) \rightarrow \gamma K \overline{K}$		(8.5	$^{+1.2}_{-0.9}$) × 10 ⁻⁴	S=1.2	1075
/-3()		,	-0.9 /	-	

Meson Summary Table

$\gamma\eta$	(8.6 ±0.8	3)×10 ⁻⁴		1500
$\gamma f_1(1420) \rightarrow \gamma K \overline{K} \pi$	(8.3 ±1.	5)×10 ⁻⁴		1220
$\gamma f_1(1285)$	$(6.5 \pm 1.0$) × 10 ⁻⁴		1283
$\gamma f_2'(1525)$	(4.7 ^{+0.7} -0.9	7) × 10 ⁻⁴		1173
$\gamma \phi \phi$	(4.0 ± 1.3)	2)×10 ⁻⁴	S=2.1	1166
$\gamma P \overline{P}$	$(3.8 \pm 1.0$)×10 ⁻⁴		1232
$\gamma \eta$ (2225)	(2.9 ±0.0	5)×10 ⁻⁴		834
$\gamma \eta(1760) \rightarrow \gamma \rho^0 \rho^0$	(1.3 ±0.9) × 10 ^{−4}		1048
$\gamma \pi^0$	(3.9 ± 1.3)	3)×10 ⁻⁵		1546
$\gamma p \overline{p} \pi^+ \pi^-$	< 7.9	× 10 ⁻⁴	CL=90%	1107
$\gamma\gamma$	< 5	× 10 ⁻⁴	CL=90%	1548
$\gamma \Lambda \overline{\Lambda}$	< 1.3	× 10 ⁻⁴	CL=90%	1074
3γ	< 5.5	× 10 ⁻⁵	CL=90%	1548
$\gamma f_J(2220)$	> 2.50	× 10 ⁻³	CL=99.9%	_
$\gamma f_0(1500)$	(5.7 ± 0.3)	3)×10 ⁻⁴		1184
γe ⁺ e ⁻	(8.8 ±1.	4)×10 ⁻³		-

$\chi_{c0}(1P)$

$$I^{G}(J^{PC}) = 0^{+}(0^{+})$$

Mass $m = 3417.3 \pm 2.8$ MeV Full width $\Gamma = 14 \pm 5$ MeV

X _{c0} (1P) DECAY MODES	Fraction (Γ_{1}/Γ)	Confidence level	(MeV/c)
	Hadronic decays		
$2(\pi^{+}\pi^{-})$ $\pi^{+}\pi^{-}K^{+}K^{-}$	(3.7 ± 0.7) %		1679
$\pi^{+}\pi^{-}K^{+}K^{-}$	(3.0 ± 0.7) %		1580
$ ho^0\pi^+\pi^-$	(1.6 ± 0.5) %		1608
$3(\pi^{+}\pi^{-})$	(1.5±0.5) %		1633
$K^{+}\overline{K}^{*}(892)^{0}\pi^{-}+\text{c.c.}$	(1.2±0.4) %		1522
$\pi^+\pi^-$	$(7.5\pm2.1)\times10^{-}$	-3	1702
K ⁺ K ⁻	$(7.1\pm2.4)\times10^{-1}$	-3	1635
$\pi^+\pi^-\rho\widetilde{\rho}$	$(5.0\pm2.0)\times10^{-1}$	-3	1320
ρ p	< 9.0 × 10	-4 90%	1427
	Radiative decays		
$\gamma J/\psi(15)$	$(6.6 \pm 1.8) \times 10^{-1}$	-3	303
77	< 5 × 10 ⁻		1708

 $\chi_{c1}(1P)$

$$I^{G}(J^{PC}) = 0^{+}(1^{+})$$

Mass $m=3510.53\pm0.12$ MeV Full width $\Gamma=0.88\pm0.14$ MeV

X _{C1} (1P) DECAY MODES	Fraction (Γ _I /Γ)	p (MeV/c)
	Hadronic decays	
$3(\pi^{+}\pi^{-})$	(2.2±0.8) %	1683
$2(\pi^{+}\pi^{-})$	(1.6±0.5) %	1727
$\pi^+\pi^-K^+K^-$	$(9 \pm 4) \times 10^{-3}$	1632
$ ho^0\pi^+\pi^-$	$(3.9\pm3.5)\times10^{-3}$	1659
$K^{+}\overline{K}^{*}(892)^{0}\pi^{-}+\text{c.c.}$	$(3.2\pm2.1)\times10^{-3}$	1576
$\pi^+\pi^-\rho\overline{\rho}$	$(1.4\pm0.9)\times10^{-3}$	1381
ρp	$(8.6\pm1.2)\times10^{-5}$	1483
$ \rho \widetilde{\rho} $ $ \pi^+ \pi^- + K^+ K^- $	$< 2.1 \times 10^{-3}$	-
	Radiative decays	
$\gamma J/\psi(1S)$	$(27.3 \pm 1.6) \%$	389

 $\chi_{c2}(1P)$

$$I^{G}(J^{PC}) = 0^{+}(2^{+})$$

Mass $m=3556.17\pm0.13$ MeV Full width $\Gamma=2.00\pm0.18$ MeV

X _{C2} (1P) DECAY MODES	Fraction (Γ_I/Γ)	Confidence level	(MeV/c)
	Hadronic decays		
$2(\pi^{+}\pi^{-})$ $\pi^{+}\pi^{-}K^{+}K^{-}$	(2.2±0.5) %		1751
	(1.9±0.5) %		1656
$3(\pi^{+}\pi^{-})$ $\rho^{0}\pi^{+}\pi^{-}$	(1.2±0.8) %		1707
	(7 ±4)×10	₁ -3	1683
$K^{+}\overline{K}^{*}(892)^{0}\pi^{-}+\text{c.c.}$	(4.8±2.8) × 10	₁ –3	1601
$\pi^+\pi^-p\overline{p}$	$(3.3\pm1.3)\times10$	₁ –3	1410
$\pi^+\pi^-$	$(1.9\pm1.0)\times10$	₁ –3	1773
K+K-	$(1.5\pm1.1)\times10$		1708
ρ p	$(10.0 \pm 1.0) \times 10$	₁ –5	1510
$J/\psi(1S)\pi^{+}\pi^{-}\pi^{0}$	< 1.5 %	90%	185

Radiative decays			
$\gamma J/\psi(1S)$	$(13.5 \pm 1.1) \%$	430	
$\gamma\gamma$	$(1.6\pm0.5)\times10^{-4}$	1778	

 $\psi(2S)$

$$I^{G}(J^{PC}) = 0^{-}(1^{-})$$

$$\begin{split} &\text{Mass } m = 3686.00 \pm 0.09 \text{ MeV} \\ &\text{Full width } \Gamma = 277 \pm 31 \text{ keV} \quad \text{(S} = 1.1) \\ &\Gamma_{ee} = 2.14 \pm 0.21 \text{ keV} \quad \text{(Assuming } \Gamma_{ee} = \Gamma_{\mu\mu} \text{)} \end{split}$$

♦(25) DECAY MODES	Fraction (Γ_f/Γ)		cale factor/ idence level	p (MeV/c)
hadrons	(98.10±0.30)	%		-
virtual $\gamma ightarrow hadrons$.	(2.9 ±0.4)			-
e+ e-	(8.5 ±0.7)	× 10 ⁻³		1843
$\mu^+\mu^-$	(7.7 ± 1.7)	× 10 ⁻³		1840
Decays Into J	$/\psi(1S)$ and anyt	hing		
$J/\psi(1S)$ anything	(54.2 ± 3.0)	%		-
$J/\psi(1S)$ neutrals	(22.8 ±1.7)	%		_
$J/\psi(1S)\pi^+\pi^-$	(30.2 ± 1.9)	%		477
$J/\psi(1S)\pi^0\pi^0$	(17.9 ±1.8)	%		481
$J/\psi(1S)\eta$	(2.7 ±0.4)	%	S=1.7	200
$J/\psi(1S)\pi^0$	(9.7 ±2.1)	× 10 ⁻⁴		527
$J/\psi(15)\mu^+\mu^-$	(10.0 ± 3.3)	× 10 ⁻³		-
Hadı	ronic decays			
$3(\pi^{+}\pi^{-})\pi^{0}$	(3.5 ±1.6)	× 10 ⁻³		1746
$2(\pi^{+}\pi^{-})\pi^{0}$	(3.0 ±0.8)	× 10 ⁻³		1799
$\pi^+\pi^-K^+K^-$	(1.6 ±0.4)			1726
$\pi^+\pi^-p\overline{p}$	(8.0 ±2.0)	× 10 ⁻⁴		1491
$K^{+}\overline{K}^{*}(892)^{0}\pi^{-}+\text{c.c.}$	(6.7 ±2.5)	× 10 ⁻⁴		1673
$2(\pi^{+}\pi^{-})$	(4.5 ± 1.0)			1817
$\rho^0 \pi^+ \pi^-$	(4.2 ±1.5)	× 10 ⁻⁴		1751
p ρ	(1.9 ±0.5)	× 10 ⁻⁴		1586
$3(\pi^{+}\pi^{-})$	(1.5 ±1.0)	× 10 ⁻⁴		1774
$\overline{p}p\pi^0$	(1.4 ± 0.5)	× 10 ⁻⁴		1543
K+K-	(1.0 ± 0.7)	× 10 ⁻⁴		1776
$\pi^{+}\pi^{-}\pi^{0}$	(9 ±5)	× 10 ⁻⁵		1830
$ ho\pi$		× 10 ⁻⁵	CL=90%	1760
$\pi^+\pi^-$	(8 ±5)	× 10 ⁻⁵		1838
$\Lambda \overline{\Lambda}$	< 4	× 10 ⁻⁴	CL=90%	1467
<u>=</u> - <u>=</u> +	< 2	× 10 ⁻⁴	CL=90%	1285
$K^{+}K^{-}\pi^{0}$	< 2.96	× 10 ⁻⁵	CL=90%	1754
$K^{+}\overline{K}^{*}(892)^{-}$ + c.c.	< 5.4	× 10 ⁻⁵	CL=90%	1698
Radi	ative decays			
$\gamma \chi_{c0}(1P)$	(9.3 ±0.9)	%		261
$\gamma \chi_{c1}(1P)$	(8.7 ±0.8)	%		171
$\gamma \chi_{c2}(1P)$	(7.8 ± 0.8)			127
$\gamma \eta_c(15)$	(2.8 ± 0.6)	× 10 ⁻³		639
$\gamma \eta'(958)$	< 1.1	× 10 ⁻³	CL=90%	1719
77		× 10 ⁻⁴	CL=90%	1843
$\gamma \eta(1440) \rightarrow \gamma K \overline{K} \pi$	< 1.2	× 10 ⁻⁴	CL=90%	1569

 $\psi(3770)$

$$I^{G}(J^{PC}) = ??(1 - -)$$

Mass $m=3769.9 \pm 2.5$ MeV (S = 1.8) Full width Γ = 23.6 ± 2.7 MeV (S = 1.1) Γ_{ee} = 0.26 ± 0.04 keV (S = 1.2)

♦(3770) DECAY MODES	Fraction (Γ_I/Γ)	Scale factor	(MeV/c)
DD	dominant		242
e+e-	$(1.12\pm0.17)\times10^{-5}$	1.2	1885

ψ(4040) ^{[iii}]

$$I^{G}(J^{PC}) = ?^{?}(1^{-})$$

$$\label{eq:mass_m} \begin{split} \text{Mass} &~m = 4040 \pm 10 \text{ MeV} \\ \text{Full width } \Gamma = 52 \pm 10 \text{ MeV} \\ \Gamma_{ee} &= 0.75 \pm 0.15 \text{ keV} \end{split}$$

♦(4040) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
e+ e-	$(1.4\pm0.4)\times10^{-5}$	2020
$D^0 \overline{D}{}^0$	seen	777
$D^*(2007)^0 \overline{D}{}^0 + \text{c.c.}$	seen	578
$D^*(2007)^0 \overline{D}^*(2007)^0$	seen	232

p

ψ(4160) ^{[///}]

 $I^{G}(J^{PC}) = ?^{?}(1^{-})$

 $\begin{aligned} &\text{Mass} \ m = 4159 \pm 20 \ \text{MeV} \\ &\text{Full width} \ \Gamma = 78 \pm 20 \ \text{MeV} \\ &\Gamma_{ee} = 0.77 \pm 0.23 \ \text{keV} \end{aligned}$

♦(4160) DECAY MODE	Fra
e+e-	(10

Fraction (Γ_I/Γ) p (MeV/c) $(10\pm4)\times10^{-6}$ 2079

ψ(4415) ^{[///}

 $I^{G}(J^{PC}) = ??(1 - -)$

Mass $m=4415\pm 6$ MeV Full width $\Gamma=43\pm 15$ MeV (S = 1.8) $\Gamma_{ee}=0.47\pm 0.10$ keV

¢(4415) DECAY MODES	Fraction (Γ _I /F)	p (MeV/c)
hadrons	dominant	_
e ⁺ e ⁻	$(1.1\pm0.4)\times10^{-5}$	2207

bb MESONS

T(15)

$$I^{G}(J^{PC}) = 0^{-}(1^{-})$$

Mass $m = 9460.37 \pm 0.21$ MeV (S = 2.7) Full width $\Gamma = 52.5 \pm 1.8$ keV $\Gamma_{ee} = 1.32 \pm 0.05$ keV

T(15) DECAY MODES	Fraction (F	₁ /Γ) Co	Scale factor/ onfidence level	p (MeV/c)
τ+τ-	(2.67+0	.14) %		4384
e+e-	(2.52±0			4730
$\mu^+\mu^-$	(2.48±0	•	5=1.1	4729
<i>μ</i> μ	(2.40±0	.01) /4	3-1.1	4123
Hadi	ronic decays	3		
$J/\psi(1S)$ anything	(1.1 ± 0)	.4)×10 ⁻³		4223
$ ho\pi$	< 2	× 10 ⁻⁴	CL=90%	4698
$\pi^+\pi^-$	< 5	× 10 ⁻⁴	CL=90%	4728
K+K-	< 5	× 10 ⁻⁴	CL=90%	4704
$p\overline{p}$	< 5	× 10 ⁻⁴	CL=90%	4636
Radi	ative decays	3		
$\gamma 2h^+2h^-$	(7.0 ±1	.5) × 10 ⁻⁴		4720
$\gamma 3h^{+}3h^{-}$.0) × 10 ⁻⁴		4703
$\gamma 4h^+4h^-$.5) × 10 ⁻⁴		4679
$\gamma \pi^+ \pi^- K^+ K^-$.9) × 10 ⁻⁴		4686
$\gamma_{2\pi^{+}2\pi^{-}}$.9) × 10 ⁻⁴		4720
$\gamma 3\pi^{+}3\pi^{-}$.2) × 10 ⁻⁴		4703
$\gamma 2\pi^{+}2\pi^{-}K^{+}K^{-}$.2) × 10 ⁻⁴		4658
$\gamma \pi^+ \pi^- p \overline{p}$.6)×10 ⁻⁴		4604
$\gamma 2\pi + 2\pi - p\overline{p}$	(4 ±6			4563
72K+2K-	(2.0 ± 2)	.0) × 10 ⁻⁵		4601
$\gamma \eta'(958)$	< 1.3	× 10 ⁻³	CL=90%	4682
$\gamma\eta$	< 3.5	× 10 ⁻⁴	CL=90%	4714
$\gamma f_2'(1525)$	< 1.4	× 10 ⁻⁴	CL=90%	4607
$\gamma f_2(1270)$	< 1.3	× 10 ⁻⁴	CL=90%	4644
$\gamma\eta(1440)$	< 8.2	× 10 ⁻⁵	CL=90%	4624
$\gamma f_J(1710) \rightarrow \gamma K \overline{K}$	< 2.6	× 10 ⁻⁴	CL=90%	4576
$\gamma f_0(2200) \rightarrow \gamma K^+ K^-$	< 2	× 10 ⁻⁴	CL=90%	4475
$\gamma f_J(2220) \rightarrow \gamma K^+ K^-$	< 1.5	× 10 ⁻⁵		4469
$\gamma \eta(2225) \rightarrow \gamma \phi \phi$	< 3	× 10 ⁻³	CL=90%	4469
γX	< 3	× 10 ⁻⁵	CL=90%	-
X = pseudoscalar with m < 7	.2 GeV)			
$\gamma X \overline{X}$	< 1	× 10 ⁻³	CL=90%	-
$X\overline{X}$ = vectors with $m < 3.1$ (oeV)			

χ_ю(1Р) ^Ш

 $I^G(J^{PC}) = 0^+(0^{++})$ J needs confirmation.

Mass $m = 9859.8 \pm 1.3 \text{ MeV}$

X _{b0} (1P) DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	(MeV/c)
γ r (1 S)	<6 %	90%	391

X_{b1}(1P) ^[脚]

 $I^G(J^{PC}) = 0^+(1^{++})$ J needs confirmation.

Mass $m = 9891.9 \pm 0.7 \text{ MeV}$

X _{b1} (1P) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
γ T(15)	(35±8) %	422

X_{b2}(1P) ^Ш

 $I^G(J^{PC}) = 0^+(2^{++})$ J needs confirmation.

Mass $m = 9913.2 \pm 0.6 \text{ MeV}$

443

T(25)

$$I^{G}(J^{PC}) = 0^{-}(1^{-})$$

 $\begin{aligned} \text{Mass } m &= 10.02330 \pm 0.00031 \text{ GeV} \\ \text{Full width } \Gamma &= 44 \pm 7 \text{ keV} \\ \Gamma_{ee} &= 0.520 \pm 0.032 \text{ keV} \end{aligned}$

T(25) DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	(MeV/c)
$r(1S)\pi^+\pi^-$	(18.5 ±0.8) %		475
$\Upsilon(1S)\pi^0\pi^0$	(8.8 ±1.1) %		480
$\tau^+\tau^-$	(1.7 ±1.6)%		4686
$\mu^+\mu^-$	(1.31±0.21) %		5011
e ⁺ e ⁻	(1.18±0.20) %		5012
$\Upsilon(1S)\pi^0$	< 8 ×	10 ⁻³ 90%	531
$\Upsilon(1S)\eta$	< 2 ×	10 ⁻³ 90%	127
$J/\psi(1S)$ anything	< 6 ×	10 ⁻³ 90%	4533
	Radiative decays		
$\gamma X_{b1}(1P)$	(6.7 ±0.9)%		131
$\gamma X_{b2}(1P)$	(6.6 ±0.9) %		110
$\gamma \chi_{b0}(1P)$	(4.3 ±1.0) %		162
$\gamma f_J(1710)$	< 5.9 ×	10 ⁻⁴ 90%	4866
$\gamma f_2'(1525)$	< 5.3 ×	10 ⁻⁴ 90%	4896
$\gamma f_2(1270)$	< 2.41 ×	10 ⁻⁴ 90%	4931

х_ю(2Р) ^Ш

 $I^G(J^{PC}) = 0^+(0^{++})$ J needs confirmation.

Mass $m = 10.2321 \pm 0.0006$ GeV

X _{b0} (2P) DECAY MODES	Fraction (Γ_{I}/Γ)	p (MeV/c)
γ T(25)	(4.6 ± 2.1) %	210
$\gamma T(15)$	$(9 \pm 6) \times 10^{-3}$	746

χ_{b1}(2P) ^{[[]]}

 $I^G(J^{PC}) = 0^+(1^{++})$ J needs confirmation.

Mass $m=10.2552\pm0.0005~{\rm GeV}$ $m\chi_{b1(2P)}-m\chi_{b0(2P)}=23.5\pm1.0~{\rm MeV}$

X _{b1} (2P) DECAY MODES	Fraction (Γ_I/Γ)	Scale factor	(MeV/c)
$\gamma \Upsilon(2S)$	(21 ±4)%	1.5	229
$\gamma \Upsilon(1S)$	(8.5 ± 1.3) %	1.3	764

х_{ы2}(2Р) ^Ш

 $I^G(J^{PC}) = 0^+(2^{++})$ J needs confirmation.

Mass $m=10.2685\pm0.0004$ GeV $m\chi_{b2}(2P)-m\chi_{b1}(2P)=13.5\pm0.6$ MeV

X _{b2} (2P) DECAY MODES	Fraction (Γ ₁ /Γ)	p (MeV/c)
γ T(2S)	(16.2±2.4) %	242
$\gamma \Upsilon(1S)$	(7.1±1.0) %	776

Meson Summary Table

T(35)

$$I^{G}(J^{PC}) = 0^{-}(1^{-})$$

Mass $m = 10.3553 \pm 0.0005$ GeV Full width $\Gamma = 26.3 \pm 3.5$ keV

T(35) DECAY MODES	Fraction (Γ_I/Γ)	Scale factor/ Confidence level	р (MeV/c)
$\Upsilon(2S)$ anything	(10.6 ±0.8) %		296
$\Upsilon(2S)\pi^+\pi^-$	(2.8 ±0.6)%	S=2.2	177
$\Upsilon(2S)\pi^0\pi^0$	(2.00±0.32) %		190
$\Upsilon(25)\gamma\gamma$	(5.0 ±0.7)%		327
$\Upsilon(1S)\pi^+\pi^-$	(4.48±0.21) %		814
$\Upsilon(1S)\pi^0\pi^0$	(2.06±0.28) %		816
$\Upsilon(15)\eta$	< 2.2 × 1	.0 ⁻³ CL=90%	-
$\mu^+\mu^-$	(1.81±0.17) %		5177
e ⁺ e ⁻	seen		5177
	Radiative decays		
$\gamma \chi_{b2}(2P)$	(11.4 ±0.8) %	S=1.3	87
$\gamma \chi_{b1}(2P)$	(11.3 ±0.6) %		100
$\gamma \chi_{b0}(2P)$	(5.4 ±0.6) %	S=1.1	123

T(4S) or T(10580)

$$I^{G}(J^{PC}) = ?^{?}(1 - -)$$

Mass $m = 10.5800 \pm 0.0035$ GeV Full width $\Gamma = 10 \pm 4$ MeV $\Gamma_{ee} = 0.248 \pm 0.031$ keV (S = 1.3)

T(4S) DECAY MODES	Fraction (I	Γ _I /Γ)	Confidence level	(MeV/c)
BB	> 96	%	95%	_
non-BB	< 4	%	95%	-
e ⁺ e ⁻	(2.8±0	0.7) × 10 ⁻	-5	5290
J/ψ (3097) anything	(2.2±0	0.7) × 10 ⁻	-3	-
D^{*+} anything $+$ c.c.	< 7.4	%	90%	5099
ϕ anything	< 2.3	× 10 ⁻	-3 90%	5240
$\varUpsilon(1S)$ anything	< 4	× 10	-3 90%	1053
	•		•	

T(10860)

$$I^{G}(J^{PC}) = ?^{?}(1^{-})$$

Mass $m=10.865 \pm 0.008$ GeV (S = 1.1) Full width Γ = 110 ± 13 MeV Γ_{ee} = 9.31 ± 0.07 keV (S = 1.3)

7(10860) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
e+ e-	$(2.8\pm0.7)\times10^{-6}$	5432

7(11020)

$$I^{G}(J^{PC}) = ?^{?}(1^{-})$$

Mass $m=11.019\pm0.008$ GeV Full width $\Gamma=79\pm16$ MeV $\Gamma_{ee}=0.130\pm0.030$ keV

T(11020) DECAY MODES	Fraction (Γ _i /Γ)	p (MeV/c)
e+ e-	$(1.6\pm0.5)\times10^{-6}$	5509

NOTES

In this Summary Table:

When a quantity has "(S = ...)" to its right, the error on the quantity has been enlarged by the "scale factor" S, defined as S = $\sqrt{\chi^2/(N-1)}$, where N is the number of measurements used in calculating the quantity. We do this when S > 1, which often indicates that the measurements are inconsistent. When S > 1.25, we also show in the Particle Listings an ideogram of the measurements. For more about S, see the Introduction.

A decay momentum p is given for each decay mode. For a 2-body decay, p is the momentum of each decay product in the rest frame of the decaying particle. For a 3-or-more-body decay, p is the largest momentum any of the products can have in this frame.

- [a] See the "Note on $\pi^\pm \to \ell^\pm \nu \gamma$ and $K^\pm \to \ell^\pm \nu \gamma$ Form Factors" in the π^\pm Particle Listings for definitions and details.
- [b] Measurements of $\Gamma(e^+\nu_e)/\Gamma(\mu^+\nu_\mu)$ always include decays with γ 's, and measurements of $\Gamma(e^+\nu_e\gamma)$ and $\Gamma(\mu^+\nu_\mu\gamma)$ never include low-energy γ 's. Therefore, since no clean separation is possible, we consider the modes with γ 's to be subreactions of the modes without them, and let $[\Gamma(e^+\nu_e) + \Gamma(\mu^+\nu_\mu)]/\Gamma_{\text{total}} = 100\%$.
- [c] See the π^\pm Particle Listings for the energy limits used in this measurement; low-energy γ 's are not included.
- [d] Derived from an analysis of neutrino-oscillation experiments.
- [e] Astrophysical and cosmological arguments give limits of order 10^{-13} ; see the π^0 Particle Listings.
- [f] See the "Note on the Decay Width $\Gamma(\eta\to\gamma\gamma)$ " in our 1994 edition, Phys. Rev. **D50**, 1 August 1994, Part I, p. 1451.
- $[g]\ C$ parity forbids this to occur as a single-photon process.
- [\hbar] See the "Note on scalar mesons" in the $f_0(1370)$ Particle Listings . The interpretation of this entry as a particle is controversial.
- [i] See the "Note on $\rho(770)$ " in the $\rho(770)$ Particle Listings .
- [j] The e^+e^- branching fraction is from $e^+e^- \to \pi^+\pi^-$ experiments only. The $\omega\rho$ interference is then due to $\omega\rho$ mixing only, and is expected to be small. If $e\mu$ universality holds, $\Gamma(\rho^0 \to \mu^+\mu^-) = \Gamma(\rho^0 \to e^+e^-) \times 0.99785$.
- [k] See the "Note on scalar mesons" in the $f_0(1370)$ Particle Listings .
- [/] See the "Note on $a_1(1260)$ " in the $a_1(1260)$ Particle Listings
- [m] This is only an educated guess; the error given is larger than the error on the average of the published values. See the Particle Listings for details.
- [n] See the "Note on the $f_1(1420)$ " in the $\eta(1440)$ Particle Listings.
- [o] See also the $\omega(1600)$ Particle Listings.
- [p] See the "Note on the $\eta(1440)$ " in the $\eta(1440)$ Particle Listings.
- [q] See the "Note on the ho(1450) and the ho(1700)" in the ho(1700) Particle
- [r] See the "Note on non-q \overline{q} mesons" in the Particle Listings (see the index for the page number).
- [s] See also the $\omega(1420)$ Particle Listings.
- [t] See the "Note on $f_J(1710)$ " in the $f_J(1710)$ Particle Listings .
- [u] See the note in the K^{\pm} Particle Listings.
- [ν] The definition of the slope parameter g of the $K \to 3\pi$ Dalitz plot is as follows (see also "Note on Dalitz Plot Parameters for $K \to 3\pi$ Decays" in the K^{\pm} Particle Listings):

$$|M|^2 = 1 + g(s_3 - s_0)/m_{\pi^+}^2 + \cdots$$

Meson Summary Table

- [w] For more details and definitions of parameters see the Particle Listings.
- [x] See the K^\pm Particle Listings for the energy limits used in this measurement.
- [y] Most of this radiative mode, the low-momentum γ part, is also included in the parent mode listed without γ 's.
- [z] Direct-emission branching fraction.
- [aa] Structure-dependent part.
- [bb] Derived from measured values of ϕ_{+-} , ϕ_{00} , $|\eta|$, $|m_{K_L^0}-m_{K_S^0}|$, and $\tau_{K_L^0}$, as described in the introduction to "Tests of Conservation Laws."
- [cc] The CP-violation parameters are defined as follows (see also "Note on CP Violation in $K_S\to 3\pi$ " and "Note on CP Violation in K_L^0 Decay" in the Particle Listings):

$$\begin{split} \eta_{+-} &= \left| \eta_{+-} \right| \mathrm{e}^{\mathrm{i}\phi_{+-}} = \frac{A(K_{0}^{1} \to \pi^{+}\pi^{-})}{A(K_{S}^{0} \to \pi^{+}\pi^{-})} = \epsilon + \epsilon' \\ \eta_{00} &= \left| \eta_{00} \right| \mathrm{e}^{\mathrm{i}\phi_{00}} = \frac{A(K_{0}^{1} \to \pi^{0}\pi^{0})}{A(K_{S}^{0} \to \pi^{0}\pi^{0})} = \epsilon - 2\epsilon' \\ \delta &= \frac{\Gamma(K_{0}^{1} \to \pi^{-}\ell^{+}\nu) - \Gamma(K_{0}^{0} \to \pi^{+}\ell^{-}\nu)}{\Gamma(K_{0}^{1} \to \pi^{-}\ell^{+}\nu) + \Gamma(K_{0}^{1} \to \pi^{+}\ell^{-}\nu)} , \\ \mathrm{Im}(\eta_{+-0})^{2} &= \frac{\Gamma(K_{S}^{0} \to \pi^{+}\pi^{-}\pi^{0})^{CP \ viol.}}{\Gamma(K_{0}^{1} \to \pi^{+}\pi^{-}\pi^{0})} , \\ \mathrm{Im}(\eta_{000})^{2} &= \frac{\Gamma(K_{S}^{0} \to \pi^{0}\pi^{0}\pi^{0})}{\Gamma(K_{0}^{1} \to \pi^{0}\pi^{0}\pi^{0})} . \end{split}$$

where for the last two relations *CPT* is assumed valid, i.e., ${\rm Re}(\eta_{+-0})\simeq 0$ and ${\rm Re}(\eta_{000})\simeq 0$.

- [dd] See the K_5^0 Particle Listings for the energy limits used in this measurement
- [ee] Calculated from K_L^0 semileptonic rates and the K_S^0 lifetime assuming ΔS
- [ff] ϵ'/ϵ is derived from $\left|\eta_{00}/\eta_{+-}\right|$ measurements using theoretical input on phases.
- [gg] The value is for the sum of the charge states of particle/antiparticle states indicated
- [hh] See the K_L^0 Particle Listings for the energy limits used in this measurement.
- [ii] Allowed by higher-order electroweak interactions.
- [jj] Violates CP in leading order. Test of direct CP violation since the indirect CP-violating and CP-conserving contributions are expected to be suppressed.
- [kk] See the "Note on $f_0(1370)$ " in the $f_0(1370)$ Particle Listings and in the 1994 edition.
- [II] See the note in the L(1770) Particle Listings in Reviews of Modern Physics **56** No. 2 Pt. II (1984), p. S200. See also the "Note on $K_2(1770)$ and the $K_2(1820)$ " in the $K_2(1770)$ Particle Listings .
- [mm] See the "Note on $K_2(1770)$ and the $K_2(1820)$ " in the $K_2(1770)$ Particle Listings .

- [nn] This is a weighted average of D^\pm (44%) and D^0 (56%) branching fractions. See " D^+ and $D^0 \to (\eta \text{ anything}) / (\text{total } D^+ \text{ and } D^0)$ " under " D^+ Branching Ratios" in the Particle Listings.
- [oo] This value averages the e^+ and μ^+ branching fractions, after making a small phase-space adjustment to the μ^+ fraction to be able to use it as an e^+ fraction; hence our ℓ^+ here is really an e^+ .
- [pp] An ℓ indicates an e or a μ mode, not a sum over these modes.
- [qq] The branching fraction for this mode may differ from the sum of the submodes that contribute to it, due to interference effects. See the relevant papers in the Particle Listings.
- [rr] The two experiments measuring this fraction are in serious disagreement. See the Particle Listings.
- [ss] This mode is not a useful test for a ΔC=1 weak neutral current because both quarks must change flavor in this decay.
- [tt] The D_1^0 - D_2^0 limits are inferred from the D^0 - \overline{D}^0 mixing ratio $\Gamma(K^+\ell^-\overline{\nu}_\ell({\rm via}\ \overline{D}^0)) / \Gamma(K^-\ell^+\nu_\ell)$.
- [uu] The larger limit (from E791) allows interference between the doubly Cabibbo-suppressed and mixing amplitudes; the smaller limit (from E691) doesn't. See the papers for details.
- [vv] The experiments on the division of this charge mode amongst its submodes disagree, and the submode branching fractions here add up to considerably more than the charged-mode fraction.
- [ww] However, these upper limits are in serious disagreement with values obtained in another experiment.
- [xx] For now, we average together measurements of the $Xe^+\nu_e$ and $X\mu^+\nu_\mu$ branching fractions. This is the average, not the sum.
- [yy] This branching fraction includes all the decay modes of the final-state resonance.
- [zz] This value includes only K^+K^- decays of the $f_J(1710)$, because branching fractions of this resonance are not known.
- [aaa] This value includes only $\pi^+\pi^-$ decays of the $f_0(1500)$, because branching fractions of this resonance are not known.
- $[bbb]\ B^0$ and B^0_s contributions not separated. Limit is on weighted average of the two decay rates,
- [ccc] These values are model dependent. See 'Note on Semileptonic Decays' in the ${\cal B}^+$ Particle Listings.
- [ddd] D^{**} stands for the sum of the $D(1\,^1\!P_1)$, $D(1\,^3\!P_0)$, $D(1\,^3\!P_1)$, $D(1\,^3\!P_2)$, $D(2\,^1\!S_0)$, and $D(2\,^1\!S_1)$ resonances.
- [eee] Inclusive branching fractions have a multiplicity definition and can be greater than 100%.
- [fff] D_j represents an unresolved mixture of pseudoscalar and tensor D** (P-wave) states.
- [ggg] Not a pure measurement. See note at head of B_s^0 Decay Modes.
- [hhh] Includes $p\overline{p}\pi^+\pi^-\gamma$ and excludes $p\overline{p}\eta$, $p\overline{p}\omega$, $p\overline{p}\eta'$.
- [iii] J^{PC} known by production in e^+e^- via single photon annihilation. I^G is not known; interpretation of this state as a single resonance is unclear because of the expectation of substantial threshold effects in this energy region.
- [jjj] Spectroscopic labeling for these states is theoretical, pending experimental information.

See also the table of suggested $q\overline{q}$ quark-model assignments in the Quark Model section.

- Indicates particles that appear in the preceding Meson Summary Table. We do not regard
 the other entries as being established.
- \dagger Indicates that the value of J given is preferred, but needs confirmation.

LIGHT UNFLAVORED			STRANGE		BOTTOM, STRANGE		
		=B=0)	-C (.BC)	$(S = \pm 1, C)$		$(B=\pm 1, S=\mp 1)$	
	$I^{G}(J^{PC})$		$I^{G}(J^{PC})$		I(J ^P)		$I^{G}(J^{PC})$
• π [±]	1-(0-)	X(1650)	0+(??-)	• K [±]	1/2(0-)	$\bullet B_s^0$	0(0-)
• π ⁰	1-(0-+)	 ω₃(1670) 	0-(3)	• K ⁰	1/2(0-)	B*	0(1-)
• η	0+(0-+)	• $\pi_2(1670)$	1-(2-+)	• K _S ⁰	1/2(0-)	$B_{sJ}^{*}(5850)$?(? [?])
• f ₀ (400–1200)	$0^{+}(0^{+}+)$	• $\phi(1680)$	0-(1)	• K ⁰ _L	1/2(0-)		
 ρ(770) 	1+(1)	 ρ₃(1690) 	1+(3)	• K*(892)	$1/2(1^{-})$	воттом, с	
• ω(782)	0-(1)	 ρ(1700) 	1+(1)	• K ₁ (1270)	1/2(1 ⁺)	(B = C	
 η'(958) 	0+(0-+)	• f _J (1710)	0 ⁺ (even ⁺ +)	• K ₁ (1400)	1/2(1+)	B_c^{\pm}	0(0-)
• f ₀ (980)	$0^{+}(0^{+}+)$	$\eta(1760)$	0+(0-+)	• K*(1410)	1/2(1-)	c	:
• a ₀ (980)	$1^{-}(0^{+}+)$	X(1775)	1-(?-+)	 K₀[*](1430) 	1/2(0 ⁺)		0+(0-+)
• $\phi(1020)$	0-(1)	 π(1800) 	1-(0-+)	• K*(1430)	1/2(2+)	$\bullet \eta_c(1S)$	0-(0-)
• $h_1(1170)$	0-(1+-)	f ₂ (1810)	0+(2++)	K(1460)	1/2(0-)	$\bullet J/\psi(15)$	0+(0++)
• $b_1(1235)$	1+(1+-)	• $\phi_3(1850)$	0-(3)	K ₂ (1580)	1/2(2-)	$\bullet \chi_{c0}(1P)$	0+(0++)
• a ₁ (1260)	$1^{-}(1^{+})$	$\eta_2(1870)$	$0^{+}(2^{-}+)$	$K_1(1650)$	1/2(1+)	$\bullet \chi_{c1}(1P)$??(???)
• f ₂ (1270)	0+(2++)	X(1910)	0 ⁺ (? ^{?+})	• K*(1680)	1/2(1-)	$h_c(1P)$	0 ⁺ (2 ⁺ +)
• f ₁ (1285)	0+(1++)	f ₂ (1950)	$0^{+}(2^{+})$	• K ₂ (1770)	1/2(2-)	• $\chi_{c2}(1P)$	3;(3;+)
 η(1295) 	0+(0-+)	X(2000)	1-(??+)	• K*(1780)	1/2(3-)	$\eta_c(2S)$	0-(1)
 π(1300) 	1-(0-+)	• f ₂ (2010)	0+(2++)	• K ₂ (1820)	1/2(2-)	$\bullet \psi(2S)$ $\bullet \psi(3770)$??(1)
• a ₂ (1320)	1-(2++)	f ₀ (2020)	0+(0++)	K(1830)	1/2(0-)	$\bullet \psi(3770)$ $\bullet \psi(4040)$??(1)
• f ₀ (1370)	0+(0++)	• a ₄ (2040)	1-(4++)	$K_0^*(1950)$	1/2(0+)	$\bullet \psi(4040)$ $\bullet \psi(4160)$??(1)
$h_1(1380)$?-(1+-)	• f ₄ (2050)	0+(4++)	K*(1980)	1/2(2+)	$\bullet \psi(4160)$ $\bullet \psi(4415)$??(1)
$\hat{ ho}(1405)$	1-(1-+)	f ₀ (2060)	0+(0++)	• K*(2045)	1/2(4+)	Ψ Ψ(4415)	: (1)
• $f_1(1420)$	0+(1++)	$\pi_2(2100)$	$1^{-}(2^{-+})$	K ₂ (2250)	1/2(2-)	bΪ	-
• ω(1420)	0-(1)	f ₂ (2150)	0+(2++)	K ₃ (2320)	1/2(3+)	• Υ(1S)	0-(1)
f ₂ (1430)	0+(2++)	ho(2150)	1+(1)	K ₅ (2380)	1/2(5-)	$\bullet \chi_{b0}(1P)$	0+(0++)
 η(1440) 	0+(0-+)	$f_0(2200)$	0+(0++)	K ₄ (2500)	1/2(4)	$\bullet \chi_{b1}(1P)$	$0^{+}(1++)$
• a ₀ (1450)	1-(0++)	f _J (2220)	0 ⁺ (2 ⁺ + or	K(3100)	??(???)	$\bullet \chi_{b2}(1P)$	0+(2++)
 ρ(1450) 	1+(1)	(4++)			• T(25)	0-(1)
• $f_0(1500)$	0+(0++)	$\eta(2225)$	0+(0-+)	CHARI		$\bullet \chi_{b0}(2P)$	0+(0++)
$f_1(1510)$	0+(1++)	$\rho_3(2250)$	1+(3)	(C =	±1)	$\bullet \chi_{b1}(2P)$	0+(1++)
• f' ₂ (1525)	0+(2++)	• f ₂ (2300)	0+(2++)	• D [±]	1/2(0 [—])	$\bullet \chi_{b2}(2P)$	0+(2++)
f ₂ (1565)	0+(2++)	f ₄ (2300)	0+(4++)	• D ⁰	1/2(0-)	• r(35)	0-(1)
• ω(1600)	0-(1)	• f ₂ (2340)	0+(2++)	• D*(2007) ⁰	1/2(1-)	• r(45)	$?^{?}(1)$
X(1600)	2+(2++)	$\rho_5(2350)$	1+(5)	• D*(2010)±	1/2(1-)	• \(\gamma(10860) \)	$?^{?}(1)$
$f_2(1640)$	0+(2++)	a ₆ (2450)	$1^{-}(6^{++})$	• $D_1(2420)^0$	1/2(1+)	• \(\gamma(11020) \)	$?^{?}(1)$
$\eta_2(1645)$	0+(2-+)	f ₆ (2510)	0 ⁺ (6 ^{+ +}) ? [?] (? ^{??})	$D_1(2420)^{\pm}$	1/2(??)		
		X(3250)	1.(1)	• $D_2^*(2460)^0$	1/2(2+)	NON-q q CA	NDIDATES
-		OTHER LIGHT	UNFLAVORED	• D ₂ *(2460)+	1/2(2 ⁺)	Non-qq Candi	dates
		(S=C)	=B=0)	CHARMED,	STRANGE	1	
		a+a-(1100-)	2200) ? [?] (1)	(C = S =			
1		$\overline{N}N(1100-36)$			0(0-)	1	
		X(1900-3600	•	• D*±	0(0) 0(? [?])		
		7(1300-3000	′)	• D*±			
				• $D_{s1}(2536)^{\pm}$	0(1 ⁺)		
	•	1		• $D_{sJ}(2573)^{\pm}$	0(??)	1	
				ВОТТ	OM	1	
				(B =			
				• B±	1/2(0-)	1	
				• B ⁰	$1/2(0^{-})$		
				• B*	$1/2(1^{-})$		
1		l .		B _J (5732)	?(??)		
	<u> </u>			= 3()			

This short table gives the name, the quantum numbers (where known), and the status of baryons in the Review. Only the baryons with 3-or 4-star status are included in the main Baryon Summary Table. Due to insufficient data or uncertain interpretation, the other entries in the short table are not established as baryons. The names with masses are of baryons that decay strongly. See our 1986 edition (Physics Letters 170B) for listings of evidence for Z baryons (KN resonances).

	· · · · · · · · · · · · · · · · · · ·		l			T					·	·		
p	P_{11}	****	∆ (1232)	P_{33}	****	Λ	P_{01}	****	Σ^+	P_{11}	****	=0	P_{11}	****
n	P_{11}	****	∆ (1600)	P_{33}	***	Λ(1405)	S_{01}	****	Σ^0	P_{11}	****	<u>=</u> -	P_{11}	****
N(1440)	P_{11}	****	∆ (1620)	S_{31}	****	Λ(1520)	D_{03}	****	Σ-	P_{11}	****	<i>Ξ</i> (1530)	P_{13}	****
N(1520)	D_{13}	****	Δ (1700)	D_{33}	****	Λ(1600)	P_{01}	***	Σ (1385)	P_{13}	****	<i>Ξ</i> (1620)		*
N(1535)	S_{11}	****	Δ (1750)	P_{31}	*	Λ(1670)	S_{01}	****	$\Sigma(1480)$		*	<i>Ξ</i> (1690)		***
N(1650)	S_{11}	****	<i>∆</i> (1900)	S_{31}	**	Λ(1690)	D_{03}	****	$\Sigma(1560)$		**	<i>Ξ</i> (1820)	D_{13}	***
N(1675)	D_{15}	****	∆(1905)	F ₃₅	****	A(1800)	S ₀₁	***	Σ (1580)	D_{13}	**	<i>Ξ</i> (1950)		***
N(1680)	F ₁₅	****	Δ (1910)	P_{31}	****	Λ(1810)	P_{01}	***	Σ (1620)	S_{11}	**	<i>Ξ</i> (2030)		***
N(1700)	D_{13}	***	∆(1920)	P ₃₃	***	Λ(1820)	F ₀₅	****	Σ(1660)	P_{11}	***	<i>Ξ</i> (2120)		*
N(1710)	P_{11}	***	∆(1930)	D ₃₅	***	Λ(1830)	D_{05}	****	Σ (1670)	D_{13}	****	<i>Ξ</i> (2250)		**
N(1720)	P_{13}	****	∆(1940)	D ₃₃	*	A(1890)	P_{03}	****	Σ(1690)		**	<i>Ξ</i> (2370)		**
N(1900)	P_{13}	**	∆(1950)	F ₃₇	****	A(2000)		*	Σ (1750)	S_{11}	***	<i>Ξ</i> (2500)		*
N(1990)	F ₁₇	**	∆(2000)	F ₃₅	**	A(2020)	F ₀₇	*	$\Sigma(1770)$	P_{11}	*			
N(2000)	F ₁₅	**	∆(2150)	S ₃₁	*	A(2100)	G ₀₇	****	Σ(1775)	D_{15}	****	Ω^-		****
N(2080)	D_{13}	**	∆(2200)	G ₃₇	*	A(2110)	F ₀₅	***	Σ(1840)	P_{13}	*	$\Omega(2250)^{-}$		***
N(2090)	S_{11}	*	∆(2300)	H ₃₉	**	A(2325)	D_{03}	*	$\Sigma(1880)$	P_{11}	**	$\Omega(2380)^{-}$		**
N(2100)	P_{11}	*	∆(2350)	D_{35}	*	A(2350)	H_{09}^{00}	***	Σ(1915)	F ₁₅	****	$\Omega(2470)^{-}$		**
N(2190)	G ₁₇	****	∆(2390)	F ₃₇	*	A(2585)	•	**	Σ(1940)	D_{13}	***			
N(2200)	D_{15}	**	∆(2400)	G ₃₉	**	` ′			Σ(2000)	S ₁₁	*	Λ _c ⁺		****
N(2220)	H_{19}	****	∆(2420)	$H_{3,11}$	****				Σ(2030)	F ₁₇	****	$\Lambda_c(2593)^+$		***
N(2250)	G ₁₉	****	∆(2750)	l _{3,13}	**				Σ(2070)	F ₁₅	*	$\Lambda_c(2625)^+$		***
N(2600)	<i>I</i> _{1,11}	***	∆(2950)	K _{3,15}	**				Σ(2080)	P_{13}	**	$\Sigma_c(2455)$		****
N(2700)	K _{1,13}	**	12(2)00)	,,3,15					Σ(2100)	G ₁₇	*	$\Sigma_c(2520)$		***
` ′	1,10								Σ(2250)		***	Ξ+		***
									Σ(2455)		**	Ξο		***
									Σ(2620)		**	$\Xi_c(2645)$		***
									Σ(3000)		*	Ω_0°		***
									Σ(3170)		*	٠		
									` ´			Λ_b^0		***
												\equiv_b^0, \equiv_b^-		*
												- pr - p		

^{****} Existence is certain, and properties are at least fairly well explored.

^{***} Existence ranges from very likely to certain, but further confirmation is desirable and/or quantum numbers, branching fractions, etc. are not well determined.

^{**} Evidence of existence is only fair.

^{*} Evidence of existence is poor.

N BARYONS (S=0, I=1/2)p, $N^+ = uud$; n, $N^0 = udd$

 $I(J^P)=\tfrac{1}{2}(\tfrac{1}{2}{}^+)$

Mass $m = 938.27231 \pm 0.00028$ MeV [a] $= 1.007276470 \pm 0.000000012 \ u$ $\left|\frac{q_{\overline{p}}}{m_{\overline{p}}}\right|/\left(\frac{q_{\overline{p}}}{m_{\overline{p}}}\right) = 1.0000000015 \pm 0.0000000011$ $|q_p + q_{\overline{p}}|/e < 2 \times 10^{-5}$ $|q_p + q_e|/e < 1.0 \times 10^{-21} [b]$ Magnetic moment $\mu = 2.79284739 \pm 0.00000006 \, \mu_N$ Electric dipole moment $d = (-4 \pm 6) \times 10^{-23} e \text{ cm}$ Electric polarizability $\overline{\alpha} = (12.1 \pm 0.9) \times 10^{-4} \text{ fm}^3$ Magnetic polarizability $\overline{\beta} = (2.1 \pm 0.9) \times 10^{-4} \text{ fm}^3$ Mean life $\tau > 1.6 \times 10^{25}$ years (independent of mode) $> 10^{31}$ to 5×10^{32} years ^[c] (mode dependent)

Below, for N decays, p and n distinguish proton and neutron partial lifetimes. See also the "Note on Nucleon Decay" in our 1994 edition (Phys. Rev. **D50**, 1673) for a short review.

The "partial mean life" limits tabulated here are the limits on au/B_I , where au is the total mean life and $B_{\hat{I}}$ is the branching fraction for the mode in question.

p DECAY MODES	Partial mean life (10 ³⁰ years)	Confidence level	<i>p</i> (MeV/c)
	Antilepton + meson		
$N \rightarrow e^+ \pi$	> 130 (n), > 550 (p	90%	459
$N \rightarrow \mu^+ \pi$	> 100 (n), > 270 (p	90%	453
$N \rightarrow \nu \pi$	> 100 (n), > 25 (p)	90%	459
$p \rightarrow e^+ \eta$	> 140	90%	309
$p \rightarrow \mu^+ \eta$	> 69	90%	296
$n \rightarrow \nu \eta$	> 54	90%	310
$N \rightarrow e^+ \rho$	> 58 (n), > 75 (p)	90%	153
$N \rightarrow \mu^+ \rho$	> 23 (n), > 110 (p)	90%	119
$N \rightarrow \nu \rho$	> 19 (n), > 27 (p)	90%	153
$p \rightarrow e^+ \omega$	> 45	90%	142
$p \rightarrow \mu^+ \omega$	> 57	90%	104
$n \rightarrow \nu \omega$	> 43	90%	144
$N \rightarrow e^+ K$	> 1.3 (n), > 150 (p)	90%	337
$p \rightarrow e^+ K_S^0$	> 76	90%	337
$p \rightarrow e^+ K_I^{0}$	> 44	90%	337
$N \rightarrow \mu^+ K$	> 1.1 (n), > 120 (p)	90%	326
$p \rightarrow \mu^+ K_S^0$	> 64	90%	326
$p \rightarrow \mu^+ K_L^{\delta}$	> 44	90%	326
$N \rightarrow \nu K$	> 86 (n), > 100 (p)		339
$p \rightarrow e^+ K^*(892)^0$	> 52	90%	45
$N \rightarrow \nu K^*(892)$	> 22 (n), > 20 (p)	90%	45
	Antilepton + mesons		
$p \rightarrow e^+ \pi^+ \pi^-$	> 21	90%	448
$p \rightarrow e^+ \pi^0 \pi^0$	> 38	90%	449
$n \rightarrow e^+\pi^-\pi^0$	> 32	90%	449
$\rho \rightarrow \mu^+ \pi^+ \pi^-$	> 17	90%	425
$p \rightarrow \mu^+ \pi^0 \pi^0$	> 33	90%	427
$n \rightarrow \mu^{+}\pi^{-}\pi^{0}$	> 33	90%	427
$n \rightarrow e^+ K^0 \pi^-$	> 18	90%	319
	Lepton + meson		
$n \rightarrow e^- \pi^+$	> 65	90%	459
$n \rightarrow \mu^- \pi^+$	> 49	90%	453
$n \rightarrow e^- \rho^+$	> 62	90%	154
$n \rightarrow \mu^- \rho^+$	> 7	90%	120
$n \rightarrow e^- K^+$	> 32	90%	340
$n \rightarrow \mu^- K^+$	> 57	90%	330
	Lepton + mesons		
$p \rightarrow e^- \pi^+ \pi^+$	> 30	90%	448
$n \rightarrow e^- \pi^+ \pi^0$	> 29	90%	449
$\rho \rightarrow \mu^- \pi^+ \pi^+$	> 17	90%	425
$n \rightarrow \mu^- \pi^+ \pi^0$	> 34	90%	427
$p \rightarrow e^- \pi^+ K^+$	> 20	90%	320
$p \rightarrow \mu^- \pi^+ K^+$	> 5	90%	279

	Antilepton + photon(s)		
$p \rightarrow e^+ \gamma$	> 460	90%	469
$p \rightarrow \mu^+ \gamma$	> 380	90%	463
$\Pi \rightarrow \nu \gamma$	> 24	90%	470
$p \rightarrow e^{+} \gamma \gamma$	> 100	90%	469
	Three (or more) leptons		
$p \rightarrow e^+ e^+ e^-$	> 510	90%	469
$p \rightarrow e^+ \mu^+ \mu^-$	> 81	90%	457
$p \rightarrow e^+ \nu \nu$	> 11	90%	469
$n \rightarrow e^+ e^- \nu$	> 74	90%	470
$n \rightarrow \mu^+ e^- \nu$	> 47	90%	464
$n \rightarrow \mu^+ \mu^- \nu$	> 42	90%	458
$p \rightarrow \mu^+ e^+ e^-$	> 91	90%	464
$p \rightarrow \mu^+ \mu^+ \mu^-$	> 190	90%	439
$p \rightarrow \mu^+ \nu \nu$	> 21	90%	463
$p \rightarrow e^- \mu^+ \mu^+$	> 6	90%	457
$n \rightarrow 3\nu$	> 0.0005	90%	470
	Inclusive modes		
$N \rightarrow e^+$ anything	> 0.6 (n, p)	90%	-
$N ightarrow \mu^+$ anything	> 12 (n, p)	90%	-
$N ightarrow e^+ \pi^0$ anything	> 0.6 (n, p)	90%	-
	$\Delta B = 2$ dinucleon modes		

The following are lifetime limits per iron nucleus.

$pp \rightarrow \pi^+\pi^+$	> 0.7	90%	-
$pn \rightarrow \pi^+\pi^0$	> 2	90%	-
$nn \rightarrow \pi^+\pi^-$	> 0.7	90%	-
$nn \rightarrow \pi^0\pi^0$	> 3.4	90%	-
$pp \rightarrow e^+e^+$	> 5.8	90%	-
$p p \rightarrow e^+ \mu^+$	> 3.6	90%	-
$pp \rightarrow \mu^+ \mu^+$	> 1.7	90%	-
$pn \rightarrow e^+ \overline{\nu}$	> 2.8	90%	-
$pn \rightarrow \mu^+ \overline{\nu}$	> 1.6	90%	-
$n n \rightarrow \nu_e \overline{\nu}_e$	> 0.000012	90%	-
$n n \rightarrow \nu_{\mu} \overline{\nu}_{\mu}$	> 0.00006	90%	-

P DECAY MODES

DECAY MODES	Partial mean life (years)	Confidence level	р (MeV/c)
$\overline{p} \rightarrow e^- \gamma$	> 1848	95%	469
$ \overline{p} \rightarrow e^{-} \gamma $ $ \overline{p} \rightarrow e^{-} \pi^{0} $	> 554	95%	459
$\overline{p} \rightarrow e^- \eta$	> 171	95%	309
$\overline{p} \rightarrow e^- K_S^0$	> 29	95%	337
$ \overline{p} \rightarrow e^{-} K_{S}^{0} $ $ \overline{p} \rightarrow e^{-} K_{L}^{0} $	> 9	95%	337

 $I(J^P)=\tfrac{1}{2}(\tfrac{1}{2}^+)$ п

> Mass $m = 939.56563 \pm 0.00028$ MeV [a] $= 1.008664904 \pm 0.000000014 u$

 $m_n - m_p = 1.293318 \pm 0.000009 \text{ MeV}$ $= 0.001388434 \pm 0.000000009 \, \mathrm{u}$

Mean life $\tau = 886.7 \pm 1.9 \text{ s}$ (S = 1.2)

 $c\tau = 2.658 \times 10^8 \text{ km}$

Magnetic moment $\mu = -1.9130428 \pm 0.0000005 \; \mu_{N}$ Electric dipole moment $d < 0.97 \times 10^{-25} e \, \mathrm{cm}$, CL = 90%

Electric polarizability $\alpha = (0.98^{+0.19}_{-0.23}) \times 10^{-3} \text{ fm}^3 \quad (S = 1.1)$ Charge $q = (-0.4 \pm 1.1) \times 10^{-21} e$

Mean $n\bar{n}$ -oscillation time > 1.2×10^8 s, CL = 90% [d] (bound n) $> 0.86 \times 10^8$ s, CL = 90% (free n)

Decay parameters $^{[e]}$

 $g_A/g_V = -1.2670 \pm 0.0035$ (S = 1.9) $\rho e^- \overline{\nu}_e$ $A = -0.1162 \pm 0.0013$ (S = 1.8) $B = 0.990 \pm 0.008$ $a=-0.102\,\pm\,0.005$ $\phi_{AV} = (180.07 \pm 0.18)^{\circ} [f]$ $D = (-0.5 \pm 1.4) \times 10^{-3}$

n DECAY MODES		Frac	tion (Γ_i/Γ)	Confidence level	(MeV/c)
$pe^{-}\overline{\nu}_{e}$		10	00 %		1.19
	Charge conserva	rtion (Q) violating	mode	
$p \nu_e \overline{\nu}_e$	Q	<	8 × 10 ⁻²⁷	68%	1.29

N(1440) P₁₁

$$I(J^P) = \tfrac12(\tfrac12^+)$$

Breit-Wigner mass = 1430 to 1470 (\approx 1440) MeV Breit-Wigner full width = 250 to 450 (\approx 350) MeV $p_{\rm beam} = 0.61~{\rm GeV}/c$ $4\pi\lambda^2 = 31.0~{\rm mb}$ Re(pole position) = 1345 to 1385 (\approx 1365) MeV $-2{\rm Im}({\rm pole~position}) = 160$ to 260 (\approx 210) MeV

N(1440) DECAY MODES	Fraction (Γ_{j}/Γ)	p (MeV/c)	
$N\pi$	60–70 %	397	
$N\pi\pi$	30-40 %	342	
$\Delta\pi$	20-30 %	143	
$N\rho$	<8 %	t	
$N(\pi\pi)_{S-\text{wave}}^{I=0}$	5–10 %	_	
$p\gamma$	0.0350.048 %	414	
$p\gamma$, helicity=1/2	0.035-0.048 %	414	
$n\gamma$	0.009-0.032 %	413	
$n\gamma$, helicity=1/2	0.009-0.032 %	413	

N(1520) D₁₃

$$I(J^P) = \frac{1}{2}(\frac{3}{2}^-)$$

Breit-Wigner mass = 1515 to 1530 (\approx 1520) MeV Breit-Wigner full width = 110 to 135 (\approx 120) MeV $p_{\rm beam} = 0.74~{\rm GeV/c}$ $4\pi\lambda^2 = 23.5~{\rm mb}$ Re(pole position) = 1505 to 1515 (\approx 1510) MeV $-2{\rm Im}({\rm pole~position}) = 110$ to 120 (\approx 115) MeV

N(1520) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)	
Nπ	50–60 %	456	
Νππ	40-50 %	410	
$\Delta\pi$	15-25 %	228	
Nρ	15-25 %	†	
$N(\pi\pi)_{S-\text{wave}}^{l=0}$	<8 %	_	
$p\gamma$	0.46-0.56 %	470	
$p\gamma$, helicity=1/2	0.001-0.034 %	470	
$p\gamma$, helicity=3/2	0.44-0.53 %	470	
$n\gamma$	0.30-0.53 %	470	
$n\gamma$, helicity=1/2	0.04-0.10 %	470	
$n\gamma$, helicity=3/2	0.25-0.45 %	470	

N(1535) S₁₁

$$I(J^P) = \frac{1}{2}(\frac{1}{2})$$

Breit-Wigner mass = 1520 to 1555 (≈ 1535) MeV Breit-Wigner full width = 100 to 250 (≈ 150) MeV $p_{\rm beam} = 0.76 \; {\rm GeV/c} \qquad 4\pi {\rm X}^2 = 22.5 \; {\rm mb}$ Re(pole position) = 1495 to 1515 (≈ 1505) MeV $-2{\rm Im}({\rm pole \; position}) = 90 \; {\rm to \; 250} \; (\approx 170) \; {\rm MeV}$

N(1535) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
Nπ	35-55 %	467
$N\eta$	30-55 %	182
Νππ	1–10 %	422
$\Delta\pi$	<1 %	242
Nρ	<4 %	t
$N(\pi\pi)_{S-\text{wave}}^{I=0}$	<3 %	_
N(1440)π	<7 %	t
$P\gamma$	0.15-0.35 %	481
$p\gamma$, helicity=1/2	0.15-0.35 %	481
$\eta \gamma$	0.004-0.29 %	480
$n\gamma$, helicity= $1/2$	0.004-0.29 %	480

N(1650) S₁₁

$$I(J^P)=\tfrac{1}{2}(\tfrac{1}{2}^-)$$

Breit-Wigner mass = 1640 to 1680 (\approx 1650) MeV Breit-Wigner full width = 145 to 190 (\approx 150) MeV $p_{\rm beam} = 0.96~{\rm GeV}/c$ $4\pi\lambda^2 = 16.4~{\rm mb}$ Re(pole position) = 1640 to 1680 (\approx 1660) MeV $-2{\rm Im}({\rm pole~position}) = 150~{\rm to~170~}(\approx$ 160) MeV

N(1650) DECAY MODES	Fraction (Γ_j/Γ)	p (MeV/c)
Νπ	55-90 %	547
$N\eta$	3–10 %	346
ΛK	3–11 %	161
$N\pi\pi$	10-20 %	511
$\Delta\pi$	1-7 %	344
Nρ	4-12 %	t
$N(\pi\pi)_{S-\text{wave}}^{I=0}$	<4 %	-
N(1440)π	<5 %	147
Pγ	0.04-0.18 %	558
$p\gamma$, helicity=1/2	0.04-0.18 %	558
$n\gamma$	0.003-0.17 %	557
$n\gamma$, helicity=1/2	0.003-0.17 %	557

N(1675) D₁₅

$$I(J^P) = \frac{1}{2}(\frac{5}{2}^-)$$

Breit-Wigner mass = 1670 to 1685 (≈ 1675) MeV Breit-Wigner full width = 140 to 180 (≈ 150) MeV $\rho_{\rm beam} = 1.01 \; {\rm GeV/c} \qquad 4\pi {\rm X}^2 = 15.4 \; {\rm mb}$ Re(pole position) = 1655 to 1665 (≈ 1660) MeV $-2{\rm Im}({\rm pole \; position}) = 125 \; {\rm to \; 155} \; (≈ 140) \; {\rm MeV}$

N(1675) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
Nπ	40-50 %	563
ΛK	<1 %	209
$N\pi\pi$	50-60 %	529
$\Delta\pi$	50-60 %	364
$N\rho$	< 1–3 %	†
$p\gamma$	0.004-0.023 %	575
$p\gamma$, helicity=1/2	0.0-0.015 %	575
$p\gamma$, helicity=3/2	0.0-0.011 %	575
$n\gamma$	0.02-0.12 %	574
$n\gamma$, helicity=1/2	0.006-0.046 %	574
$n\gamma$, helicity=3/2	0.01-0.08 %	574

N(1680) F₁₅

$$I(J^P) = \frac{1}{2}(\frac{5}{2}^+)$$

Breit-Wigner mass = 1675 to 1690 (\approx 1680) MeV Breit-Wigner full width = 120 to 140 (\approx 130) MeV $p_{\rm beam} = 1.01 \; {\rm GeV/c} \qquad 4\pi \lambda^2 = 15.2 \; {\rm mb}$ Re(pole position) = 1665 to 1675 (\approx 1670) MeV $-2{\rm Im}({\rm pole \; position}) = 105 \; {\rm to \; 135} \; (\approx 120) \; {\rm MeV}$

N(1680) DECAY MODES	Fraction (Γ_j/Γ)	p (MeV/c)
Nπ	60-70 %	567
Νππ	30-40 %	532
$\Delta\pi$	5-15 %	369
Nρ	3-15 %	t
$N(\pi\pi)_{S-\text{wave}}^{I=0}$	5–20 %	
$p\gamma$	0.21-0.32 %	578
$p\gamma$, helicity=1/2	0.001-0.011 %	578
$p\gamma$, helicity=3/2	0.20-0.32 %	578
$n\gamma$	0.021-0.046 %	577
$n\gamma$, helicity=1/2	0.004-0.029 %	577
$n\gamma$, helicity=3/2	0.01-0.024 %	577

Baryon Summary Table

N(1700) D₁₃

$$I(J^P) = \frac{1}{2}(\frac{3}{2}^-)$$

Breit-Wigner mass = 1650 to 1750 (\approx 1700) MeV Breit-Wigner full width = 50 to 150 (\approx 100) MeV $p_{\rm beam} = 1.05~{\rm GeV}/c$ $4\pi\lambda^2 = 14.5~{\rm mb}$ Re(pole position) = 1630 to 1730 (\approx 1680) MeV $-2{\rm Im}({\rm pole~position}) = 50$ to 150 (\approx 100) MeV

N(1700) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
Nπ	5~15 %	580
ΛK	<3 %	250
Νππ	85 -9 5 %	547
Nρ	<35 %	t
$p\gamma$	0.01~0.05 %	591
$p\gamma$, helicity=1/2	0.0-0.024 %	591
$p\gamma$, helicity=3/2	0.002-0.026 %	591
πγ	0.01-0.13 %	590
$n\gamma$, helicity=1/2	0.0-0.09 %	590
$n\gamma$, helicity=3/2	0.01-0.05 %	590

N(1710) P₁₁

$$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$$

Breit-Wigner mass = 1680 to 1740 (\approx 1710) MeV Breit-Wigner full width = 50 to 250 (\approx 100) MeV $p_{beam} = 1.07 \text{ GeV}/c$ $4\pi\lambda^2 = 14.2 \text{ mb}$ Re(pole position) = 1670 to 1770 (\approx 1720) MeV $-2\text{Im}(\text{pole position}) = 80 \text{ to } 380 (\approx 230) \text{ MeV}$

N(1710) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
Nπ	10-20 %	587
ΛK	5-25 %	264
Νππ	40-90 %	554
$\Delta\pi$	15-40 %	393
$N\rho$	525 %	48
$N(\pi\pi)_{S-\text{wave}}^{I=0}$	10-40 %	-
$p\gamma$	0.002-0.05%	598
$p\gamma$, helicity=1/2	0.002-0.05%	598
$n\gamma$	0.0-0.02%	597
$n\gamma$, helicity=1/2	0.0-0.02%	597

N(1720) P₁₃

$$I(J^P) = \frac{1}{2}(\frac{3}{2}^+)$$

Breit-Wigner mass = 1650 to 1750 (\approx 1720) MeV Breit-Wigner full width = 100 to 200 (\approx 150) MeV $p_{\text{Deam}} = 1.09 \text{ GeV}/c$ $4\pi\lambda^2 = 13.9 \text{ mb}$ Re(pole position) = 1650 to 1750 (\approx 1700) MeV $-2\text{Im}(\text{pole position}) = 110 \text{ to } 390 (<math>\approx$ 250) MeV

N(1720) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
Nπ	10-20 %	594
ΛK	1–15 %	278
Νππ	>70 %	561
Nρ	70-85 %	104
$p\gamma$	0.003-0.10 %	604
$p\gamma$, helicity=1/2	0.003~0.08 %	604
$p\gamma$, helicity=3/2	0.001-0.03 %	- 604
$n\gamma$	0.002-0.39 %	603
$n\gamma$, helicity=1/2	0.0-0.002 %	603
$n\gamma$, helicity=3/2	0.001-0.39 %	603

N(2190) G₁₇

$$I(J^P) = \frac{1}{2}(\frac{7}{2}^-)$$

Breit-Wigner mass = 2100 to 2200 (\approx 2190) MeV Breit-Wigner full width = 350 to 550 (\approx 450) MeV $p_{\rm beam} = 2.07 \; {\rm GeV}/c \qquad 4\pi\lambda^2 = 6.21 \; {\rm mb}$ Re(pole position) = 1950 to 2150 (\approx 2050) MeV $-2{\rm Im}({\rm pole \; position}) = 350 \; {\rm to \; 550} \; (\approx$ 450) MeV

N(2190) DECAY MODES	Fraction (Γ_i/Γ)	ρ (MeV/c)
Νπ	10-20 %	888

N(2220) H₁₉

$$I(J^P) = \frac{1}{2}(\frac{9}{2}^+)$$

Breit-Wigner mass = 2180 to 2310 (\approx 2220) MeV Breit-Wigner full width = 320 to 550 (\approx 400) MeV $p_{\text{beam}} = 2.14 \text{ GeV}/c$ $4\pi\lambda^2 = 5.97 \text{ mb}$ Re(pole position) = 2100 to 2240 (\approx 2170) MeV $-2\text{Im}(\text{pole position}) = 370 \text{ to } 570 (<math>\approx$ 470) MeV

N(2220) DECAY MODES	Fraction (Γ _I /Γ)	p (MeV/c)
Νπ	10-20 %	905

N(2250) G₁₉

$$I(J^P) = \frac{1}{2}(\frac{9}{2}^-)$$

Breit-Wigner mass = 2170 to 2310 (≈ 2250) MeV Breit-Wigner full width = 290 to 470 (≈ 400) MeV $p_{\text{beam}} = 2.21 \text{ GeV}/c$ $4\pi\lambda^2 = 5.74 \text{ mb}$ Re(pole position) = 2080 to 2200 (≈ 2140) MeV -2Im(pole position) = 280 to 680 (≈ 480) MeV

N(2250) DECAY MODES	Fraction (Γ_{i}/Γ)	p (MeV/c)
Νπ	5-15 %	923

N(2600) I_{1,11}

$$I(J^P) = \frac{1}{2}(\frac{11}{2})$$

Breit-Wigner mass = 2550 to 2750 (≈ 2600) MeV Breit-Wigner full width = 500 to 800 (≈ 650) MeV $p_{\rm beam} = 3.12 \; {\rm GeV/c}$ $4\pi x^2 = 3.86 \; {\rm mb}$

N(2600) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
Νπ	5–10 %	1126

\triangle BARYONS (S=0, I=3/2)

 $\Delta^{++} = uuu$, $\Delta^{+} = uud$, $\Delta^{0} = udd$, $\Delta^{-} = ddd$

$\Delta(1232) P_{33}$

$$I(J^P) = \frac{3}{2}(\frac{3}{2}+)$$

Breit-Wigner mass (mixed charges) = 1230 to 1234 (\approx 1232) MeV

Breit-Wigner full width (mixed charges) = 115 to 125 (≈ 120) MeV

Δ(1232) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
Νπ	>99 %	227
$N\gamma$	0.52-0.60 %	259
$N\gamma$, helicity=1/2	0.11-0.13 %	259
$N\gamma$, helicity=3/2	0.41-0.47 %	259

$\Delta(1600) P_{33}$

$$I(J^P) = \frac{3}{2}(\frac{3}{2}^+)$$

Breit-Wigner mass = 1550 to 1700 (\approx 1600) MeV Breit-Wigner full width = 250 to 450 (\approx 350) MeV $p_{\rm beam} = 0.87~{\rm GeV}/c$ $4\pi\lambda^2 = 18.6~{\rm mb}$ Re(pole position) = 1500 to 1700 (\approx 1600) MeV $-2{\rm lm}({\rm pole~position}) = 200$ to 400 (\approx 300) MeV

Fraction (Γ_I/Γ)	p (MeV/c)
10-25 %	512
75-90 %	473
40-70 %	301
<25 %	t
10–35 %	74
0.001-0.02 %	525
0.0-0.02 %	525
0.001~0.005 %	525
	10-25 % 75-90 % 40-70 % <25 % 10-35 % 0.001-0.02 % 0.0-0.02 %

△(1620) S₃₁

$$I(J^P)=\tfrac{3}{2}(\tfrac{1}{2}^-)$$

Breit-Wigner mass = 1615 to 1675 (\approx 1620) MeV Breit-Wigner full width = 120 to 180 (\approx 150) MeV $p_{\rm beam} = 0.91~{\rm GeV}/c$ $4\pi\lambda^2 = 17.7~{\rm mb}$ Re(pole position) = 1580 to 1620 (\approx 1600) MeV $-2{\rm Im}({\rm pole~position}) = 100$ to 130 (\approx 115) MeV

△(1620) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
Nπ	20-30 %	526
$N\pi\pi$	70–80 %	488
$\Delta\pi$	30-60 %	318
Nρ	7–25 %	t
$N\gamma$	0.004-0.044 %	538
$N\gamma$, helicity=1/2	0.004-0.044 %	538

Δ(1700) D₃₃

$$I(J^P) = \frac{3}{5}(\frac{3}{5}^-)$$

Breit-Wigner mass = 1670 to 1770 (\approx 1700) MeV Breit-Wigner full width = 200 to 400 (\approx 300) MeV $p_{\rm beam} = 1.05~{\rm GeV/c}$ $4\pi\lambda^2 = 14.5~{\rm mb}$ Re(pole position) = 1620 to 1700 (\approx 1660) MeV $-2{\rm Im}({\rm pole~position}) = 150~{\rm to~250~}(\approx$ 200) MeV

△(1700) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
Nπ	10–20 %	580
Νππ	80-90 %	547
$\Delta\pi$	30 -6 0 %	385
Nρ	30-55 %	t
N_{γ}	0.12-0.26 %	591
$N\gamma$, helicity=1/2	0.08-0.16 %	591
$N\gamma$, helicity=3/2	0.025-0.12 %	591

Δ(1905) F₃₅

$$I(J^P)=\tfrac{3}{2}(\tfrac{5}{2}^+)$$

Breit-Wigner mass = 1870 to 1920 (\approx 1905) MeV Breit-Wigner full width = 280 to 440 (\approx 350) MeV $p_{\rm beam} = 1.45 \; {\rm GeV}/c \qquad 4\pi\lambda^2 = 9.62 \; {\rm mb}$ Re(pole position) = 1800 to 1860 (\approx 1830) MeV $-2{\rm Im}({\rm pole \; position}) = 230 \; {\rm to \; 330} \; (\approx 280) \; {\rm MeV}$

△(1906) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
Νπ	5–15 %	713
$N\pi\pi$	85 -9 5 %	687
$\Delta\pi$	<25 %	542
Nρ	>60 %	421
Nγ	0.01-0.03 %	721
Nγ, helicity=1/2	0.0-0.1 %	721
$N\gamma$, helicity=3/2	0.004-0.03 %	721

△(1910) P₃₁

$$I(J^P) = \frac{3}{2}(\frac{1}{2}^+)$$

Breit-Wigner mass = 1870 to 1920 (\approx 1910) MeV Breit-Wigner full width = 190 to 270 (\approx 250) MeV $p_{\text{Deam}} = 1.46 \text{ GeV}/c$ $4\pi\lambda^2 = 9.54 \text{ mb}$ Re(pole position) = 1830 to 1880 (\approx 1855) MeV $-2\text{Im}(\text{pole position}) = 200 \text{ to } 500 (<math>\approx$ 350) MeV

A(1910) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
Νπ	15-30 %	716
$N\gamma$	0.0-0.2 %	725
$N\gamma$, helicity=1/2	0.0-0.2 %	725

$\Delta(1920) P_{33}$

$$I(J^P) = \frac{3}{2}(\frac{3}{2}^+)$$

Breit-Wigner mass = 1900 to 1970 (≈ 1920) MeV Breit-Wigner full width = 150 to 300 (≈ 200) MeV $p_{\text{beam}} = 1.48 \text{ GeV}/c$ $4\pi\lambda^2 = 9.37 \text{ mb}$ Re(pole position) = 1850 to 1950 (≈ 1900) MeV -2Im(pole position) = 200 to 400 (≈ 300) MeV

△(1920) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
Νπ	5–20 % .	722

Δ (1930) D_{35}

$$I(J^P) = \frac{3}{2}(\frac{5}{2}^-)$$

Breit-Wigner mass = 1920 to 1970 (\approx 1930) MeV Breit-Wigner full width = 250 to 450 (\approx 350) MeV $p_{\rm beam} = 1.50 \; {\rm GeV}/c \qquad 4\pi\lambda^2 = 9.21 \; {\rm mb}$ Re(pole position) = 1840 to 1940 (\approx 1890) MeV $-2{\rm Im}({\rm pole \; position}) = 200 \; {\rm to \; 300} \; (\approx 250) \; {\rm MeV}$

△(1930) DÉCAY MODES	Fraction (Γ_{j}/Γ)	p (MeV/c)
Nπ	10-20 %	729
$N\gamma$	0.0-0.02 %	737
$N\gamma$, helicity=1/2	0.0-0.01 %	737
$N\gamma$, helicity=3/2	0.0-0.01 %	737

Δ (1950) F_{37}

$$I(J^P) = \frac{3}{2}(\frac{7}{2}^+)$$

Breit-Wigner mass = 1940 to 1960 (\approx 1950) MeV Breit-Wigner full width = 290 to 350 (\approx 300) MeV $p_{\rm beam} = 1.54 \; {\rm GeV/c} \qquad 4\pi\lambda^2 = 8.91 \; {\rm mb}$ Re(pole position) = 1880 to 1890 (\approx 1885) MeV $-2{\rm Im}({\rm pole \; position}) = 210 \; {\rm to \; } 270 \; (\approx 240) \; {\rm MeV}$

△(1950) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
Nπ	35-40 %	741
Νππ		716
$\Delta\pi$	20-30 %	574
Nρ	<10 %	469
Nγ	0.08-0.13 %	749
Nγ, helicity=1/2	0.03-0.055 %	749
Nγ, helicity=3/2	0.05-0.075 %	749

△(2420) H_{3,11}

$$I(J^P) = \frac{3}{2}(\frac{11}{2}^+)$$

Breit-Wigner mass = 2300 to 2500 (\approx 2420) MeV Breit-Wigner full width = 300 to 500 (\approx 400) MeV $p_{\text{beam}} = 2.64 \text{ GeV/}c$ $4\pi\lambda^2 = 4.68 \text{ mb}$ Re(pole position) = 2260 to 2400 (\approx 2330) MeV $-2\text{Im}(\text{pole position}) = 350 \text{ to } 750 (\approx 550) \text{ MeV}$

△(2420) DECAY MODES	Fraction (Γ ₁ /Γ)	p (MeV/c)
Nπ	5-15 %	1023

Baryon Summary Table

Λ BARYONS (S = -1, I = 0) $\Lambda^0 = uds$

Λ

$$I(J^P)=0(\tfrac{1}{2}^+)$$

Mass $m=1115.683\pm0.006$ MeV Mean life $\tau=(2.632\pm0.020)\times10^{-10}$ s (S = 1.6) c au=7.89 cm

Magnetic moment $\mu=-0.613\pm0.004~\mu_N$ Electric dipole moment $d<~1.5\times10^{-16}~{\rm e\,cm},~{\rm CL}=95\%$

Decay parameters

$p\pi^-$	$\alpha_{-} = 0.642 \pm 0.013$
**	$\phi_{-} = (-6.5 \pm 3.5)^{\circ}$
	$\gamma = 0.76 [g]$
n	$\Delta_{-}=(8\pm4)^{\circ}{}^{[g]}$
$n\pi^0$	$\alpha_0 = +0.65 \pm 0.05$
$pe^-\overline{\nu}_e$	$g_A/g_V = -0.718 \pm 0.015$ [e]

A DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
ρπ-	(63.9 ±0.5)%	101
$n\pi^0$	(35.8 ±0.5) %	104
$n\gamma$	$(1.75\pm0.15)\times10^{-3}$	162
$p\pi^-\gamma$	[h] (8.4 ± 1.4) \times 10 ⁻⁴	101
pe⁻⊽ _e	$(8.32\pm0.14)\times10^{-4}$	163
$p\mu^-\overline{ u}_{\mu}$	$(1.57\pm0.35)\times10^{-4}$	131

Λ(1405) S₀₁

$$I(J^P)=0(\tfrac{1}{2}^-)$$

Mass $m=1407\pm 4$ MeV Full width $\Gamma=50.0\pm 2.0$ MeV Below \overline{K} N threshold

A(1405) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
Σπ	100 %	152

Λ(1520) D₀₃

$$I(J^P)=0(\tfrac{3}{2}^-)$$

Mass $m=1519.5\pm 1.0$ MeV $^{[i]}$ Full width $\Gamma=15.6\pm 1.0$ MeV $^{[i]}$ $p_{\mathrm{beam}}=0.39$ GeV/c $4\pi\lambda^2=82.8$ mb

A(1520) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
NK	45 ± 1%	244
$\Sigma \pi$	42 ± 1%	267
Λππ	10 ± 1%	252
Σππ	$0.9 \pm 0.1\%$	152
$\Lambda\gamma$	$0.8 \pm 0.2\%$	351

Λ(1600) P₀₁

$$I(J^P)=0(\tfrac{1}{2}^+)$$

Mass m=1560 to 1700 (≈ 1600) MeV Full width Γ = 50 to 250 (≈ 150) MeV $p_{\rm beam}=0.58$ GeV/c $4πλ^2=41.6$ mb

A(1600) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
NK	15-30 %	343
$\Sigma \pi$	10-60 %	336

Λ(1670) S₀₁

$$I(J^P)=0(\tfrac{1}{2}^-)$$

Mass m=1660 to 1680 (≈ 1670) MeV Full width $\Gamma=25$ to 50 (≈ 35) MeV $p_{\rm beam}=0.74$ GeV/c $4πλ^2=28.5$ mb

Fraction (Γ_I/Γ)	p (MeV/c)
15-25 %	414
20-60 %	393
15-35 %	64
	15-25 % 20-60 %

Λ(1690) D₀₃

$$I(J^P)=0(\tfrac{3}{2}^-)$$

Mass m=1685 to 1695 (≈ 1690) MeV Full width Γ = 50 to 70 (≈ 60) MeV $p_{\rm beam}=0.78~{\rm GeV}/c$ $4\pi \lambda^2=26.1~{\rm mb}$

A(1690) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
NK	20–30 %	433
$\Sigma \pi$	20-40 %	409
Λππ	~ 25 %	415
$\sum \pi \pi$	~ 20 %	350

Λ(1800) S₀₁

$$I(J^P)=0(\tfrac{1}{2}^-)$$

Mass m=1720 to 1850 (\approx 1800) MeV Full width $\Gamma=200$ to 400 (\approx 300) MeV $p_{\rm beam}=1.01~{\rm GeV}/c$ $4\pi\lambda^2=17.5~{\rm mb}$

A(1800) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
NK .	25-40 %	528
Σπ	seen	493
$\Sigma(1385)\pi$ $NK^*(892)$	seen	345
N K *(892)	seen	t

Λ(1810) P₀₁

$$I(J^P)=0(\tfrac{1}{2}^+)$$

Mass m=1750 to 1850 (\approx 1810) MeV Full width $\Gamma=50$ to 250 (\approx 150) MeV $p_{\rm beam}=1.04~{\rm GeV}/c$ $4\pi\lambda^2=17.0~{\rm mb}$

A(1810) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
NK	20–50 %	537
$\Sigma \pi$	10-40 %	501
$\Sigma(1385)\pi$	seen	356
NK*(892)	30-60 %	t

Λ(1820) F₀₅

$$I(J^P) = 0(\frac{5}{2}^+)$$

Mass m=1815 to 1825 (≈ 1820) MeV Full width $\Gamma=70$ to 90 (≈ 80) MeV $p_{\rm beam}=1.06$ GeV/c $4\pi X^2=16.5$ mb

A(1820) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
NK	55-65 %	545
$\Sigma \pi$	8–14 %	508
$\Sigma(1385)\pi$	5–10 %	362

Λ(1830) D₀₅

$$I(J^P)=0(\frac{5}{2}^-)$$

Mass m=1810 to 1830 (≈ 1830) MeV Full width $\Gamma=60$ to 110 (≈ 95) MeV $p_{\rm beam}=1.08~{\rm GeV}/c$ $4\pi \lambda^2=16.0~{\rm mb}$

A(1830) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
NK	3–10 %	553
$\Sigma \pi$	35-75 %	515
$\Sigma(1385)\pi$	>15 %	371

Λ(1890) P₀₃

$$I(J^P)=0(\tfrac{3}{2}^+)$$

Mass m=1850 to 1910 (\approx 1890) MeV Full width $\Gamma=60$ to 200 (\approx 100) MeV $p_{\rm beam}=1.21~{\rm GeV}/c$ $4\pi\lambda^2=13.6~{\rm mb}$

A(1890) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
NK	20-35 %	599
$\Sigma \pi$	3-10 %	559
$\Sigma(1385)\pi$	seen	420
NK*(892)	seen	233

Λ(2100) G₀₇

$$I(J^P) = 0(\frac{7}{2}^-)$$

Mass m=2090 to 2110 (\approx 2100) MeV Full width $\Gamma=100$ to 250 (\approx 200) MeV $p_{\mathrm{beam}}=1.68~\mathrm{GeV}/c$ $4\pi\lambda^2=8.68~\mathrm{mb}$

A(2100) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
NK	25–35 %	751
Σπ	~ 5 %	704
$\Lambda\eta$	<3 %	617
ΞK	<3 %	483
$\Lambda\omega$	<8 %	443
NK*(892)	10-20 %	514

Λ(2110) F₀₅

$$I(J^P)=0(\tfrac{5}{2}^+)$$

Mass m=2090 to 2140 (\approx 2110) MeV Full width $\Gamma=150$ to 250 (\approx 200) MeV $p_{\mathrm{beam}}=1.70~\mathrm{GeV}/c$ $4\pi\lambda^2=8.53~\mathrm{mb}$

A(2110) DECAY MODES	Fraction (Γ_j/Γ)	p (MeV/c)
NK	5–25 %	757
$\Sigma \pi$	10-40 %	711
$\Lambda \omega$	seen	455
$\Sigma(1385)\pi$	seen	589
NK*(892)	10–60 %	524

Λ(2350) H₀₉

$$I(J^P) = 0(\frac{9}{2}^+)$$

Mass m=2340 to 2370 (≈ 2350) MeV Full width $\Gamma=100$ to 250 (≈ 150) MeV $p_{\rm beam}=2.29~{\rm GeV}/c$ $4\pi\lambda^2=5.85~{\rm mb}$

A(2350) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
NK	~ 12 %	915
$\Sigma\pi$	~ 10 %	867

$$\Sigma$$
 BARYONS $(S=-1, I=1)$

$$\Sigma^+ = uus$$
, $\Sigma^0 = uds$, $\Sigma^- = dds$

Σ+

$$I(J^P)=1(\tfrac{1}{2}^+)$$

Mass $m=1189.37\pm0.07$ MeV (S = 2.2) Mean life $\tau=(0.799\pm0.004)\times10^{-10}$ s $c\tau=2.396$ cm Magnetic moment $\mu=2.458\pm0.010~\mu_N$ (S = 2.1)

 $\Gamma(\bar{\Sigma}^+ \to n\ell^+\nu)/\Gamma(\bar{\Sigma}^- \to n\ell^-\bar{\nu}) < 0.043$ Decay parameters

$$\begin{array}{lll} \rho \pi^0 & \alpha_0 = -0.980^{+0.017}_{-0.015} \\ \text{"} & \phi_0 = (36 \pm 34)^\circ \\ \text{"} & \gamma_0 = 0.16 \, ^{[g]} \\ \text{"} & \Delta_0 = (187 \pm 6)^\circ \, ^{[g]} \\ \text{"} & \alpha_+ = 0.068 \pm 0.013 \\ \text{"} & \phi_+ = (167 \pm 20)^\circ \, \, (5 = 1.1) \; . \\ \text{"} & \gamma_+ = -0.97 \, ^{[g]} \\ \text{"} & \Delta_+ = (-73^{+133}_{-10})^\circ \, ^{[g]} \\ \rho \gamma & \alpha_\gamma = -0.76 \pm 0.08 \end{array}$$

Σ+ DECAY MODES		Fra	ction (Γ_I/Γ)	Conf	idence level	ρ (MeV/c)
$p\pi^0$		(51.57±0.30) %		189
$n\pi^+$		(48.31 ± 0.30) %		185
$p\gamma$		(1.23 ± 0.05	$) \times 10^{-3}$		225
$n\pi^+\gamma$	[h] (4.5 ±0.5	$) \times 10^{-4}$		185
$\Lambda e^+ \nu_e$		(2.0 ± 0.5) × 10 ⁻⁵		71
	$= \Delta Q$ (So				;	
$ne^+\nu_e$	5Q	<	5	× 10-6	90%	224
$\Pi \mu^+ \nu_{\mu}$	5Q	<	3.0	\times 10 ⁻⁵	90%	202
· , •				c		

< 7

Σο

pe+e-

$$I(J^P)=1(\tfrac{1}{2}^+)$$

× 10⁻⁻⁶

225

Mass $m=1192.642\pm0.024$ MeV $m_{\varSigma^-}-m_{\varSigma^0}=4.807\pm0.035$ MeV (S = 1.1) $m_{\varSigma^0}-m_A=76.959\pm0.023$ MeV Mean life $\tau=(7.4\pm0.7)\times10^{-20}$ s $c\tau=2.22\times10^{-11}$ m

Σ ⁰ DECAY MODES	Fraction (Γ_j/Γ)	Confidence level	<i>p</i> (MeV/c)
Λγ	100 %		74
Λγγ	< 3%	90%	74
Λe ⁺ e ⁻	[/] 5×10^{-3}		74

Transition magnetic moment $|\mu_{\Sigma A}| = 1.61 \pm 0.08 \; \mu_N$

Baryon Summary Table

Σ-

$$I(J^P)=1(\tfrac{1}{2}^+)$$

Mass $m=1197.449\pm0.030$ MeV (S = 1.2) $m_{\mathcal{L}^-}-m_{\mathcal{L}^+}=8.08\pm0.08$ MeV (S = 1.9) $m_{\mathcal{L}^-}-m_{\Lambda}=81.766\pm0.030$ MeV (S = 1.2) Mean life $\tau=(1.479\pm0.011)\times10^{-10}$ s (S = 1.3) $c\tau=4.434$ cm

Magnetic moment $\mu=-1.160\pm0.025~\mu_N~~(S=1.7)$

Decay parameters

$n\pi^-$	$\alpha_{-} = -0.068 \pm 0.008$
(I	$\phi_{-} = (10 \pm 15)^{\circ}$
н	$\gamma_{-}=0.98[g]$
#	$\Delta_{-} = (249^{+}_{-120})^{\circ} [g]$
$ne^-\overline{\nu}_e$	$g_A/g_V = 0.340 \pm 0.017^{[e]}$
"	$f_2(0)/f_1(0) = 0.97 \pm 0.14$
H	$D = 0.11 \pm 0.10$
$\Lambda e^- \overline{\nu}_e$	$g_V/g_A = 0.01 \pm 0.10^{[e]}$ (S = 1.5)
11	$g_{WM}/g_A = 2.4 \pm 1.7$ [e]

I DECAY MODES	Fraction (Γ _I /Γ)	p (MeV/c)
$n\pi^-$	(99.848±0.005) %	193
$n\pi^-\gamma$	[h] $(4.6 \pm 0.6) \times 10^{-4}$	193
ne− v _e	$(1.017\pm0.034)\times10^{-3}$	230
$n\mu^-\overline{\nu}_{\mu}$	$(4.5 \pm 0.4) \times 10^{-4}$	210
$\Lambda e^- \overline{\nu}_e$	$(5.73 \pm 0.27) \times 10^{-5}$	79

Σ (1385) P_{13}

$$I(J^P)=1(\tfrac{3}{2}^+)$$

 $\begin{array}{lll} \varSigma(1385)^{+} \text{mass } m = 1382.8 \pm 0.4 \text{ MeV} & (\text{S} = 2.0) \\ \varSigma(1385)^{0} \text{ mass } m = 1383.7 \pm 1.0 \text{ MeV} & (\text{S} = 1.4) \\ \varSigma(1385)^{-} \text{mass } m = 1387.2 \pm 0.5 \text{ MeV} & (\text{S} = 2.2) \\ \varSigma(1385)^{+} \text{full width } \Gamma = 35.8 \pm 0.8 \text{ MeV} \\ \varSigma(1385)^{0} \text{ full width } \Gamma = 36 \pm 5 \text{ MeV} \\ \varSigma(1385)^{-} \text{full width } \Gamma = 39.4 \pm 2.1 \text{ MeV} & (\text{S} = 1.7) \\ \text{Below } \overline{K} N \text{ threshold} \end{array}$

E(1385) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
Λπ	88±2 %	208
$\Sigma \pi$	12±2 %	127

Σ(1660) P₁₁

$$I(J^P)=1(\tfrac{1}{2}^+)$$

Mass m=1630 to 1690 (≈ 1660) MeV Full width $\Gamma=40$ to 200 (≈ 100) MeV $p_{\rm beam}=0.72~{\rm GeV}/c$ $4\pi\lambda^2=29.9~{\rm mb}$

∑(1660) DECAY MODES	Fraction (Γ_I/Γ)	 p (MeV/c)
NK	10-30 %	405
$\Lambda\pi$	seen	439
$\Sigma \pi$	seen	385

$\Sigma(1670) D_{13}$

$$I(J^P)=1(\tfrac{3}{2}^-)$$

Mass m=1665 to $1685~(\approx 1670)$ MeV Full width $\Gamma=40$ to $80~(\approx 60)$ MeV $p_{\rm beam}=0.74~{\rm GeV}/c$ $4\pi\lambda^2=28.5~{\rm mb}$

Σ(1670) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
NK	7–13 %	414
Λπ	5–15 %	447
$\Sigma \pi$	30-60 %	393

Σ (1750) S_{11}

$$I(J^P)=1(\frac{1}{2}^-)$$

Mass m=1730 to 1800 (≈ 1750) MeV Full width Γ = 60 to 160 (≈ 90) MeV $\rho_{\rm beam}=0.91~{\rm GeV/}c$ $4\pi \lambda^2=20.7~{\rm mb}$

E(1750) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
NK	10-40 %	486
Λπ	seen	507
Σπ	<8 %	455
Ση	15-55 %	81

Σ(1775) D₁₅

$$I(J^{\overline{P}})=1(\frac{5}{2}^{-})$$

Mass m=1770 to 1780 (\approx 1775) MeV Full width Γ = 105 to 135 (\approx 120) MeV $p_{\rm beam}=0.96~{\rm GeV}/c$ $4\pi\lambda^2=19.0~{\rm mb}$

E(1775) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
NK	37-43%	508
$\Lambda\pi$	14-20%	525
Σπ	2-5%	474
$\Sigma(1385)\pi$	8-12%	324
$\Lambda(1520)\pi$	17-23%	198

Σ(1915) F₁₅

$$I(J^P)=1(\tfrac{5}{2}^+)$$

Mass m=1900 to 1935 (\approx 1915) MeV Full width $\Gamma=80$ to 160 (\approx 120) MeV $p_{\mathrm{beam}}=1.26$ GeV/c $4\pi\lambda^2=12.8$ mb

Σ(1915) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
NK	5-15 %	618
$\Lambda\pi$	seen	622
Σπ	seen	577
$\Sigma(1385)\pi$	<5 %	440

Σ(1940) D₁₃

$$I(J^P)=1(\tfrac32^-)$$

Mass m = 1900 to 1950 (≈ 1940) MeV Full width Γ = 150 to 300 (≈ 220) MeV $p_{\text{beam}} = 1.32 \text{ GeV/}c$ $4\pi X^2 = 12.1 \text{ mb}$

Σ(1940) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
NK	<20 %	637
$\Lambda\pi$	seen	639
Σπ	seen	594 ·
$\Sigma(1385)\pi$	seen	460
$\Lambda(1520)\pi$	seen	354
$\Delta(1232)\overline{K}$	seen	410
N K*(892)	seen	320

Σ(2030) F₁₇

$$I(J^P) = 1(\frac{7}{5}^+)$$

Mass m = 2025 to 2040 (≈ 2030) MeV Full width Γ = 150 to 200 (≈ 180) MeV $p_{\text{beam}} = 1.52 \text{ GeV/}c$ $4\pi X^2 = 9.93 \text{ mb}$

I(2030) DECAY MODES	Fraction (Γ_I/Γ)	p_(MeV/c)
NK	17-23 %	702
Λπ	17-23 %	700
Σπ	5–10 %	657
ΞK	<2 %	412
Σ (1385) π	5–15 %	529
$\Lambda(1520)\pi$	10-20 %	430
$\Delta(1232)\overline{K}$	10-20 %	498
N K*(892)	<5 %	438

Σ(2250)

$$I(J^P)=1(??)$$

Mass m=2210 to 2280 (≈ 2250) MeV Full width $\Gamma=60$ to 150 (≈ 100) MeV $p_{\rm beam}=2.04~{\rm GeV}/c$ $4\pi \lambda^2=6.76~{\rm mb}$

Σ(2250) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)	
NK	<10 %	851	
$\Lambda\pi$	seen	842	
$\Sigma \pi$	seen	803	

$$\Xi$$
 BARYONS
($S=-2$, $I=1/2$)
 $\Xi^0 = uss$, $\Xi^- = dss$



$$I(J^P)=\tfrac{1}{2}(\tfrac{1}{2}^+)$$

 $\ensuremath{\textit{P}}$ is not yet measured; + is the quark model prediction.

 $\begin{aligned} & \text{Mass } m = 1314.9 \pm 0.6 \text{ MeV} \\ & m_{\Xi^-} - m_{\Xi^0} = 6.4 \pm 0.6 \text{ MeV} \\ & \text{Mean life } \tau = (2.90 \pm 0.09) \times 10^{-10} \text{ s} \\ & c\tau = 8.71 \text{ cm} \end{aligned}$

Magnetic moment $\mu = -1.250 \pm 0.014 \ \mu_N$

Decay parameters

≡ ⁰ DECAY MODES		Fraction (F	/Γ) Confide	nce level	(MeV/c)
$\Lambda \pi^0$		(99.54±0	.05) %		135
$\Lambda\gamma$		(1.06 ± 0)	$(.16) \times 10^{-3}$		184
$ \Lambda_{\gamma} $ $ \Sigma^{0}_{\gamma} $		(3.5 ± 0)	$.4) \times 10^{-3}$		117
$\Sigma^+ e^- \overline{\nu}_e$		< 1.1	× 10 ⁻³	90%	120
$\Sigma^+\mu^-\overline{ u}_{\mu}$		< 1.1	× 10 ⁻³	90%	64
	$S = \Delta Q (SC$ $\Delta S = 2 \text{ fort}$				
$\Sigma^- e^+ \nu_e$	5Q	< 9	× 10 ⁻⁴	90%	112
$\Sigma^-\mu^+ u_\mu$	5Q	< 9	× 10 ⁻⁴	90%	49
$p\pi^{-}$	52	< 4	× 10 ⁻⁵	90%	299
pe−⊽ _e	52	< 1.3	× 10 ⁻³		323
$p\mu^-\overline{\nu}_{\mu}$	52	< 1.3	× 10 ⁻³		309



$$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$$

P is not yet measured; + is the quark model prediction.

Mass $m=1321.32\pm0.13$ MeV Mean life $\tau=(1.639\pm0.015)\times10^{-10}$ s

 $c\tau = 4.91 \text{ cm}$

Magnetic moment $\mu = -0.6507 \pm 0.0025 \; \mu_{N}$

Decay parameters

$$\Lambda \pi^ \alpha = -0.456 \pm 0.014$$
 (S = 1.8)
" $\phi = (4 \pm 4)^\circ$
" $\gamma = 0.89$ [g]
" $\Delta = (188 \pm 8)^\circ$ [g]
 $\Lambda e^- \overline{\nu}_e$ $g_A/g_V = -0.25 \pm 0.05$ [e]

= DECAY MODES	Fraction (Γ_I/Γ)	Confidence level	p (MeV/c)
$\Lambda \pi^-$	(99.887±0.035)	%	139
$\Sigma^-\gamma$	(1.27 ±0.23)	× 10 ⁻⁴	118
Λe ⁻ $\overline{\nu}_e$	(5.63 ±0.31)	× 10 ⁻⁴	190
$\Lambda \mu^- \overline{ u}_{\mu}$	$(3.5 \begin{array}{c} +3.5 \\ -2.2 \end{array})$	× 10 ⁻⁴	163
$\Sigma^0 e^- \overline{\nu}_e$	(8.7 ±1.7)	× 10 ⁻⁵	122
$\Sigma^0 \mu^- \overline{\nu}_{\mu}$	< 8	× 10 ⁻⁴ 90%	70
$\Xi^0 e^- \overline{\nu}_e$	< 2.3	× 10 ⁻³ 90%	6

	$\Delta S = 2$ fort	abbk	n (<i>S2</i>) r	nodes		
$n\pi^-$	52	<	1.9	× 10 ⁻⁵	90%	303
пе [—] $\overline{ u}_e$	S2	<	3.2	× 10 ⁻³	90%	327
п $\mu^-\overline{ u}_\mu$	52	<	1.5	%	90%	314
$p\pi^-\pi^-$	52	<	4	× 10 ⁻⁴	90%	223
$p\pi^-e^-\overline{\nu}_e$	52	<	4	× 10 ⁻⁴	90%	304
$p\pi^-\mu^-\overline{ u}_{\mu}$	S2	<	4	× 10 ⁻⁴	90%	250
ρμ-μ-	L	<	4	× 10 ⁻⁴	90%	272

Ξ(1530) P₁₃

$$I(J^P) = \frac{1}{2}(\frac{3}{2}^+)$$

 $\Xi(1530)^0$ mass $m=1531.80\pm0.32$ MeV (S = 1.3) $\Xi(1530)^-$ mass $m=1535.0\pm0.6$ MeV $\Xi(1530)^0$ full width $\Gamma=9.1\pm0.5$ MeV $\Xi(1530)^-$ full width $\Gamma=9.9^{+1.7}_{-1.9}$ MeV

Fraction $(\Gamma_{\tilde{I}}/\Gamma)$	Confidence level	(MeV/c)
100 %		152
<4 %	90%	200
	100 %	100 %

Ξ(1690)

$$I(J^P) = \frac{1}{2}(??)$$

Mass $m=1690\pm 10$ MeV ^[/] Full width $\Gamma < 50$ MeV

≡(1690) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)	
$\Lambda \overline{K}$	seen	240	
$\Sigma \overline{K}$	seen	51	
$\equiv \pi^+\pi^-$	possibly seen	214	

Ξ(1820) D₁₃

$$I(J^P) = \frac{1}{2}(\frac{3}{2}^-)$$

Mass $m = 1823 \pm 5 \text{ MeV}^{[I]}$ Full width $\Gamma = 24^{+15}_{-10} \text{ MeV}^{[I]}$

≡(1820) DECAY MODES	Fraction (Γ_i/Γ)	ρ (MeV/c)
ΛK	large	400
$\Sigma \overline{K}$	small	320
$\equiv \pi$	small	413
$\Xi(1530)\pi$	smali	234

Ξ(1950)

$$I(J^P) = \frac{1}{2}(??)$$

Mass $m=1950\pm15$ MeV ^[I] Full width $\Gamma=60\pm20$ MeV ^[I]

≡(1950) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
ΛK	seen	522
$\Sigma \overline{K}$	possibly seen	460
$\Xi\pi$	seen	518

Ξ(2030)

$$I(J^P) = \frac{1}{2}(\geq \frac{5}{2}?)$$

Mass $m = 2025 \pm 5 \text{ MeV}^{[I]}$ Full width $\Gamma = 20^{+15}_{-5} \text{ MeV}^{[I]}$

≡(2030) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)	
ΛK	~ 20 %		589
$\Sigma \overline{K}$	~ 80 %		533
$\equiv \pi$	small		573
$\Xi(1530)\pi$ $\Lambda \overline{K}\pi$	small		421
$\Lambda \overline{K} \pi$	small		501
$\Sigma \overline{K} \pi$	small	•	430

Ω BARYONS (S=-3, l=0)

 $\Omega^-=sss$



$$I(J^P) = 0(\frac{3}{2}^+)$$

 J^P is not yet measured; $\frac{3}{2}$ is the quark model prediction.

Mass $m=1672.45\pm0.29~{
m MeV}$ Mean life $\tau=(0.822\pm0.012)\times10^{-10}~{
m s}$ $c\tau=2.46~{
m cm}$

Magnetic moment $\mu = -2.02 \pm 0.05~\mu_N$

Decay parameters

 $\Lambda K^ \alpha = -0.026 \pm 0.026$ $\Xi^0 \pi^ \alpha = 0.09 \pm 0.14$ $\Xi^- \pi^0$ $\alpha = 0.05 \pm 0.21$

Ω [−] DECAY MODES	Fraction (F	_i /r) Co	nfidence level	(MeV/c)
ΛK-	(67.8±0	.7) %		211
$\equiv^0\pi^-$	(23.6±0	.7) %		294
$\equiv \pi^0$	(8.6±0.	4) %		290
$\Xi^-\pi^+\pi^-$	(4.3^{+3}_{-1})	$\binom{4}{3}$) × 10 ⁻⁴		190
$\Xi(1530)^{0}\pi^{-}$	(6.4 ⁺⁵	$\binom{1}{0}$ × 10 ⁻⁴		17
$\Xi^0 e^- \overline{\nu}_e$	(5.6±2.	$(8) \times 10^{-3}$		319
$\equiv \gamma$	< 4.6	× 10 ⁻⁴	90%	314
Δ	S=2 forbidden (S2)	modes		
$\Lambda\pi^-$	52 < 1.9	× 10 ⁻⁴	90%	449

$\Omega(2250)^-$

$$I(J^P) = 0(??)$$

Mass $m=2252\pm 9~{\rm MeV}$ Full width $\Gamma=55\pm 18~{\rm MeV}$

Ω(2250) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)	
Ξ-π+K-	seen	531	
Ξ(1530) ⁰ K−	seen	437	

CHARMED BARYONS (C=+1)

 $\begin{array}{lll} \varLambda_c^+ = udc, & \varSigma_c^{++} = uuc, & \varSigma_c^+ = udc, & \varSigma_c^0 = ddc, \\ \Xi_c^+ = usc, & \Xi_c^0 = dsc, & \varOmega_c^0 = ssc \end{array}$



$$I(J^P)=0(\tfrac{1}{2}^+)$$

J not confirmed; $\frac{1}{2}$ is the quark model prediction.

Mass $m=2284.9\pm0.6~{\rm MeV}$ Mean life $\tau=(0.206\pm0.012)\times10^{-12}~{\rm s}$ $c\tau=61.8~{\mu}{\rm m}$

Decay asymmetry parameters

 $\Lambda \pi^+$ $\alpha = -0.98 \pm 0.19$ $\Sigma^+ \pi^0$ $\alpha = -0.45 \pm 0.32$ $\Lambda \ell^+ \nu_\ell$ $\alpha = -0.82^{+0.11}_{-0.07}$

Nearly all branching fractions of the Λ_c^+ are measured relative to the $\rho K^-\pi^+$ mode, but there are no model-independent measurements of this branching fraction. We explain how we arrive at our value of $\mathrm{B}(\Lambda_c^+\to\rho K^-\pi^+)$ in a Note at the beginning of the branching-ratio measurements, in the Listings. When this branching fraction is eventually well determined, all the other branching fractions will slide up or down proportionally as the true value differs from the value we use here.

A+ DECAY MODES	F	Fraction (Γ_I/Γ)	Scale factor/ Confidence level	р (MeV/c)
Hadronic r	nodes v	vith a p and on	ne $\mathcal K$	
p K ⁰		(2.5 ± 0.7)		872
$pK^-\pi^+$	[k]			822
$p\overline{K}^*(892)^0$	[/]	(1.8 ± 0.6)		681
$\Delta(1232)^{++}K^{-}$		(8 ± 5):		709
$\Lambda(1520)\pi^{+}$	[/]	(4.5 + 2.5)	× 10 ⁻³	626
$pK^-\pi^+$ nonresonant		(2.8 ± 0.9)	% .	822
$p K^0 \eta$		(1.3 ± 0.4)		567
$p\overline{K^0}\pi^+\pi^-$ $pK^-\pi^+\pi^0$		(2.4 ± 1.1) °	%	753
$pK^{\pi} \pi^{\pi}$ $pK^{*}(892)^{-}\pi^{+}$	[/]	seen (1.1 ± 0.6)	0/	758 579
$p(K^-\pi^+)_{\text{nonresonant}}\pi^0$	tr)	(3.6 ± 1.2)		758
$\Delta(1232)K^*(892)$		seen	.•	416
$pK^{-}\pi^{+}\pi^{+}\pi^{-}$		(1.1 ± 0.8)	× 10 ⁻³	670
$pK^{-}\pi^{+}\pi^{0}\pi^{0}$		(8 ± 4):		676
$\rho K^{-} \pi^{+} \pi^{0} \pi^{0} \pi^{0}$		(5.0 ± 3.4)	× 10 ⁻³	573
Hadronic mode	s with			
$p\pi^{+}\pi^{-}$		(3.5 ± 2.0)	4	926
$p f_0(980)$ $p \pi^+ \pi^+ \pi^- \pi^-$	[4]			621
ρπ · π · π · π ρΚ+ Κ-		(1.8 ± 1.2) : (2.3 ± 0.9) :		851 615
$p\phi$	[/]	(2.3 ± 0.5)		589
•		•		
$\Lambda\pi^+$	c mode	s with a hypero		
$\Lambda \pi^+ \pi^0$		(9.0 ± 2.8) :		863
$\Lambda \rho^+$,	% CL=95%	843 638
$\Lambda \pi^+ \pi^+ \pi^-$		(3.3 ± 1.0)		806
$\Lambda \pi^+ \eta$		(1.7 ± 0.6)		690
$\Sigma(1385)^+\eta$	[/]	(8.5 ± 3.3)	× 10 ⁻³	569
$\Lambda K^+ \overline{K}^0$		(6.0 ± 2.1)		441
$\Sigma^0\pi^+$		(9.9 ± 3.2)		824
$\Sigma^+\pi^0$		(1.00 ± 0.34)		826
$\Sigma^+ \eta \ \Sigma^+ \pi^+ \pi^-$		(5.5 ± 2.3)		712
$\Sigma^+ \pi^0$		(3.4 ± 1.0) (< 1.4	% CL=95%	803 578
$\Sigma^{-}\pi^{+}\pi^{+}$		(1.8 ± 0.8)		798
$\sum_{0}^{0} \pi^{+} \pi^{0}$		(1.8 ± 0.8)		802
$\Sigma^0\pi^+\pi^+\pi^-$		(1.1 ± 0.4)		762
$\Sigma^+\pi^+\pi^-\pi^0$				766
$\Sigma^+\omega$	[/]	(2.7 ± 1.0)		568
$\Sigma^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}$		(3.0 + 4.1)	× 10 ⁻³	707
Σ+ K+ K-		(3.5 ± 1.2)		346
$\Sigma^+\phi$	[/]	(3.5 ± 1.7)	× 10 ⁻³	292
$\Sigma^+ K^+ \pi^-$		$(7 + \frac{6}{4})$	× 10 ⁻³	668
Ξ0 K+		(3.9 ± 1.4)		652
Ξ-K+π+		(4.9 ± 1.7)	× 10 ⁻³	564
Ξ(1530) ⁰ Κ+	[/]	(2.6 ± 1.0)	× 10 ⁻³	471
•	emileat	onic modes		
$\Lambda \ell^+ \nu_{\ell}$	[m]		%	_
Λe ⁺ ν _e		(2.1 ± 0.6)		_
$\Lambda \mu^+ \nu_{\mu}^-$		(2.0 ± 0.7)	%	-
e ⁺ anything		(4.5 ± 1.7)		- - - -
pe ⁺ anything		(1.8 ± 0.9)	%	-
Λe ⁺ anything		_		_
$\Lambda \mu^+$ anything $\Lambda \ell^+ \nu_\ell$ anything		_		_
ric νεαιιγυπικ				_
n andhian	inclusiv	re modes	9/	
p anything p anything (no Λ)		(50 ±16) (12 ±19)	% %	-
p hadrons		(12 ±17)	70	_
n anything		(50 ±16)	%	_
n anything (no Λ)		•	%	_
∧ anything		•	% S=1.4	-
Σ^{\pm} anything	[n]	•	%	_

$\Delta C = 1$ weak neutral current (C1) modes, or Lepton number (L) violating modes

		. (~)	,	
$ ho \mu^+ \mu^- \ \Sigma^- \mu^+ \mu^+$	C1	< 3.4	× 10 ⁻⁴ CL=90%	936
$\Sigma^-\mu^+\mu^+$	L	< 7.0	× 10 ⁻⁴ CL=90%	811

$\Lambda_c(2593)^+$

$$I(J^P)=0(\tfrac{1}{2}^-)$$

The spin-parity follows from the fact that $\Sigma_c(2455)\pi$ decays, with little available phase space, are dominant.

Mass
$$m=2593.9\pm0.8~{\rm MeV}$$
 $m-m_{\Lambda_{\rm c}^+}=308.9\pm0.6~{\rm MeV}~{\rm (S=1.1)}$ Full width $\Gamma=3.6^{+2.0}_{-1.3}~{\rm MeV}$

 Λ_C^+ π^- and its submode $\Sigma_C(2455)\pi^-$ — the latter just barely — are the only strong decays allowed to an excited Λ_C^+ having this mass; and the Λ_C^+ π^+ π^- mode seems to be largely via Σ_C^{++} π^- or Σ_C^0 π^+ .

A _C (2593) ⁺ DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
$\Lambda_c^+\pi^+\pi^-$	[o] ≈ 67 %	124
$\Sigma_c(2455)^{++}\pi^{-}$	24 ± 7 %	. 17
$\Sigma_c(2455)^0\pi^+$	24 ± 7 %	23
$\Lambda_c^+ \pi^+ \pi^-$ 3-body	18 ± 10 %	124
$\Lambda_c^+ \tilde{\pi^0}$	not seen	261
$\Lambda_c^{\frac{1}{2}} \gamma$	not seen	290

$\Lambda_c(2625)^+$

$$I(J^P)=0(??)$$

 J^P is expected to be $3/2^-$.

Mass
$$m=2626.6\pm0.8$$
 MeV (S = 1.2) $m-m_{\Lambda_c^\pm}=341.7\pm0.6$ MeV (S = 1.6) Full width Γ < 1.9 MeV, CL = 90%

 $\Lambda_c^+\pi\pi$ and its submode $\Sigma(2455)\pi$ are the only strong decays allowed to an excited Λ_c^+ having this mass.

A _C (2625)+ DECAY MODES	Fraction (Γ_{j}/Γ)	p (MeV/c)
$\Lambda^+_c \pi^+ \pi^-$	seen	184
$\Sigma_c(2455)^{++}\pi^- \Sigma_c(2455)^0\pi^+$	small	100
$\Sigma_c(2455)^0 \pi^+$	small	101
$\Lambda_c^+ \pi^+ \pi^-$ 3-body	large	184
$A_c^+ \pi^0$ $A_c^+ \gamma$	not seen	293
$\Lambda_c^{\frac{1}{1}} \gamma$	not seen	319

$\Sigma_c(2455)$

$$I(J^P)=1(\tfrac{1}{2}^+)$$

 J^P not confirmed; $\frac{1}{2}$ is the quark model prediction.

$$\Sigma_c(2455)^{++}$$
mass $m=2452.8\pm0.6$ MeV $\Sigma_c(2455)^{+}$ mass $m=2453.6\pm0.9$ MeV $\Sigma_c(2455)^{0}$ mass $m=2452.2\pm0.6$ MeV $m_{\Sigma_c^{++}}-m_{\Lambda_c^{+}}=167.87\pm0.19$ MeV $m_{\Sigma_c^{+}}-m_{\Lambda_c^{+}}=168.7\pm0.6$ MeV $m_{\Sigma_c^{-}}-m_{\Lambda_c^{+}}=167.30\pm0.20$ MeV $m_{\Sigma_c^{-}}-m_{\Lambda_c^{-}}=167.30\pm0.20$ MeV $m_{\Sigma_c^{+}}-m_{\Sigma_c^{0}}=0.57\pm0.23$ MeV $m_{\Sigma_c^{+}}-m_{\Sigma_c^{0}}=1.4\pm0.6$ MeV

 $\Lambda_c^+\pi$ is the only strong decay allowed to a Σ_c having this mass.

Σ_{c} (2455) DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
$\Lambda_c^+\pi$	≈ 100 %	90

$\Sigma_c(2520)$

$$I(J^P) = 1(??)$$

$$\begin{split} & \Sigma_c(2520)^{++} \text{mass } m = 2519.4 \pm 1.5 \text{ MeV} \\ & \Sigma_c(2520)^0 \quad \text{mass } m = 2517.5 \pm 1.4 \text{ MeV} \\ & m_{\Sigma_c(2520)^{++}} - m_{\Lambda_c^+} = 234.5 \pm 1.4 \text{ MeV} \\ & m_{\Sigma_c(2520)^{+}} - m_{\Lambda_c^+} = 232.6 \pm 1.3 \text{ MeV} \\ & m_{\Sigma_c(2520)^{++}} - m_{\Sigma_c(2520)^0} = 1.9 \pm 1.9 \text{ MeV} \\ & \Sigma_c(2520)^{++} \text{full width } \Gamma = 18 \pm 5 \text{ MeV} \\ & \Sigma_c(2520)^0 \quad \text{full width } \Gamma = 13 \pm 5 \text{ MeV} \end{split}$$

Ξ†

$$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$$

 $I(J^P)$ not confirmed; $\frac{1}{2}(\frac{1}{2}^+)$ is the quark model prediction.

Mass
$$m=2465.6\pm1.4$$
 MeV Mean life $\tau=(0.35^{+0.07}_{-0.04})\times10^{-12}$ s $c\tau=106~\mu\mathrm{m}$

E DECAY MODES	Fraction (Γ_f/Γ)	p (MeV/c)
$\Lambda K^-\pi^+\pi^+$	seen	784
$\Lambda \overline{K}^*(892)^0 \pi^+$	лоt seen	601
Σ (1385)+ $K^-\pi^+$	not seen	676
$\Sigma^{+}K^{-}\pi^{+}$	seen	808
$\Sigma^{+}\overline{K}^{*}(892)^{0}$	seen	653
$\Sigma^0 K^- \pi^+ \pi^+$	seen	733
$\equiv^0 \pi^+$	seen	875
$\Xi^-\pi^+\pi^+$	seen	850
$\Xi(1530)^{0}\pi^{+}$	not seen	748
$\equiv^0 \pi^+ \pi^0$	seen	854
$\equiv^0 \pi^+ \pi^+ \pi^-$	seen	817
$\Xi^0 e^+ \nu_e$	seen	882

Ξ°

$$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$$

 $I(J^P)$ not confirmed; $\frac{1}{2}(\frac{1}{2}+)$ is the quark model prediction.

Mass
$$m=2470.3\pm1.8$$
 MeV (S = 1.3) $m_{\Xi_0^0}-m_{\Xi_0^+}=4.7\pm2.1$ MeV (S = 1.2) Mean life $\tau=(0.098^{+0.023}_{-0.015})\times10^{-12}$ s $c\tau=29~\mu{\rm m}$

=0 DECAY MODES	Fraction (Γ_I/Γ)	p (MeV/c)
$\Lambda \overline{K}^0$	seen	864
$\Xi^-\pi^+$	seen	875
$= -\pi^{+}\pi^{+}\pi^{-}$	seen	816
$pK^{-}\overline{K}^{*}(892)^{0}$	seen	406
Ω- K+	seen ·	522
$\Xi^-e^+ u_e$	seen	882
$\Xi^-\ell^+$ anything	seen	-

$\Xi_c(2645)$

$$I(J^P) = ?(??)$$

$$\Xi_c(2645)^+$$
 mass $m=2644.6\pm 2.1$ MeV (S = 1.2) $\Xi_c(2645)^0$ mass $m=2643.8\pm 1.8$ MeV $m_{\Xi_c(2645)^+}-m_{\Xi_c^0}=174.3\pm 1.1$ MeV $m_{\Xi_c(2645)^0}-m_{\Xi_c^+}=178.2\pm 1.1$ MeV $\Xi_c(2645)^+$ full width $\Gamma < 3.1$ MeV, CL = 90% $\Xi_c(2645)^0$ full width $\Gamma < 5.5$ MeV, CL = 90%

 $\Xi_{C}\pi$ is the only strong decay allowed to a Ξ_{C} resonance having this mass.

Fraction (Γ_{I}/Γ)	p (MeV/c)
seen	101
seen	107
	seen

Baryon Summary Table



$$I(J^P)=0(\tfrac{1}{2}^+)$$

 $I(J^P)$ not confirmed; $O(\frac{1}{2}^+)$ is the quark model prediction.

Mass
$$m=2704\pm4$$
 MeV (S = 1.8) Mean life $\tau=(0.064\pm0.020)\times10^{-12}$ s $c\tau=19~\mu{\rm m}$

Ω° DECAY MODES	Fraction (Γ_{f}/Γ)	p (MeV/c)
$\Sigma^+ K^- K^- \pi^+$	seen	697
$\Xi^-K^-\pi^+\pi^+$	seen	838
$\Omega^-\pi^+$	seen	827
$\Omega^-\pi^-\pi^+\pi^+$	seen	759

BOTTOM BARYONS (B=-1)

$$\Lambda_b^0 = udb$$
, $\Xi_b^0 = usb$, $\Xi_b^- = dsb$



$$I(J^P)=0(\tfrac{1}{2}^+)$$

$$I(J^P)$$
 not yet measured; $0(\frac{1}{2}^+)$ is the quark model prediction. Mass $m=5624\pm 9$ MeV $(S=1.8)$ Mean life $\tau=(1.24\pm 0.08)\times 10^{-12}$ s $c\tau=372~\mu \mathrm{m}$

These branching fractions are actually an average over weakly decaying b-baryons weighted by their production rates in Z decay (or high-energy $p\overline{\rho}$), branching ratios, and detection efficiencies. They scale with the LEP Λ_b production fraction $B(b\to\Lambda_b)$ and are evaluated for our value $B(b\to\Lambda_b)=(10.1,\frac{+3.9}{3.1})\%.$

The branching fractions $B(b\text{-baryon} \to \Lambda \ell^- \overline{\nu}_\ell$ anything) and $B(\Lambda_b^0 \to \Lambda_c^+ \ell^- \overline{\nu}_\ell$ anything) are not pure measurements because the underlying measured products of these with $B(b \to \Lambda_b)$ were used to determine $B(b \to \Lambda_b)$, as described in the note "Production and Decay of b-Flavored Hadrons."

AD DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	<i>р</i> (MeV/ <i>c</i>)
$J/\psi(1S)\Lambda$	(4.7±2.8) × 10	-4	1744
$\Lambda_c^+\pi^-$	seen		2345
$\Lambda_c^+ a_1(1260)^-$	seen		2156
$\Lambda_c^+ \ell^- \overline{ u}_\ell$ anything	$[\rho] (9.0^{+3.1}_{-3.8}) \%$		-
•pπ- pK-	< 5.0 × 10	₀ -5 90%	2732
pK ⁻	< 5.0 × 10	₉₀ %	2711

b-baryon ADMIXTURE $(\Lambda_b, \Xi_b, \Sigma_b, \Omega_b)$

Mean life
$$\tau = (1.20 \pm 0.07) \times 10^{-12}$$
 s

These branching fractions are actually an average over weakly decaying b-baryons weighted by their production rates in Z decay (or high-energy $p\bar{p}$), branching ratios, and detection efficiencies. They scale with the LEP Λ_b production fraction $B(b \to \Lambda_b)$ and are evaluated for our value $B(b \to \Lambda_b) = (10.1 + \frac{3.9}{3.1})\%$.

The branching fractions B(b-baryon $\to \Lambda \ell^- \overline{\nu}_\ell$ anything) and B($\Lambda^0_b \to \Lambda^+_c \ell^- \overline{\nu}_\ell$ anything) are not pure measurements because the underlying measured products of these with B(b $\to \Lambda_b$) were used to determine B(b $\to \Lambda_b$), as described in the note "Production and Decay of b-Flavored Hadrons."

b-baryon ADMIXTURE $(A_b,\Xi_b,\Sigma_b,\Omega_b)$	Fraction (Γ_f/Γ)	p (MeV/c)
$p\mu^-\overline{\nu}$ anything	(4.9± 2.4) %	_
$\Lambda \ell^- \overline{\nu}_\ell$ anything	$(3.1^{+}_{-}1.0^{1})\%$	-
$\Lambda/\overline{\Lambda}$ anything	(35 +12)%	-
$\Xi^-\ell^-\overline{ u}_\ell$ anything	$(5.5^{+}_{-})^{2.0}_{2.4} \times 10^{-3}$	_

NOTES

This Summary Table only includes established baryons. The Particle Listings include evidence for other baryons. The masses, widths, and branching fractions for the resonances in this Table are Breit-Wigner parameters, but pole positions are also given for most of the N and Δ resonances.

For most of the resonances, the parameters come from various partial-wave analyses of more or less the same sets of data, and it is not appropriate to treat the results of the analyses as independent or to average them together. Furthermore, the systematic errors on the results are not well understood. Thus, we usually only give ranges for the parameters. We then also give a best guess for the mass (as part of the name of the resonance) and for the width. The Note on N and Δ Resonances and the Note on N and Σ Resonances in the Particle Listings review the partial-wave analyses.

When a quantity has "(S = ...)" to its right, the error on the quantity has been enlarged by the "scale factor" S, defined as $S = \sqrt{\chi^2/(N-1)}$, where N is the number of measurements used in calculating the quantity. We do this when S > 1, which often indicates that the measurements are inconsistent. When S > 1.25, we also show in the Particle Listings an ideogram of the measurements. For more about S, see the Introduction.

A decay momentum p is given for each decay mode. For a 2-body decay, p is the momentum of each decay product in the rest frame of the decaying particle. For a 3-or-more-body decay, p is the largest momentum any of the products can have in this frame. For any resonance, the *nominal* mass is used in calculating p. A dagger ("†") in this column indicates that the mode is forbidden when the nominal masses of resonances are used, but is in fact allowed due to the nonzero widths of the resonances.

- [a] The masses of the p and n are most precisely known in u (unified atomic mass units). The conversion factor to MeV, $1~u=931.49432\pm0.00028$ MeV, is less well known than are the masses in u.
- [b] The limit is from neutrality-of-matter experiments; it assumes $q_n=q_p+q_e$. See also the charge of the neutron.
- [c] The first limit is geochemical and independent of decay mode. The second entry, a range of limits, assumes the dominant decay modes are among those investigated. For antiprotons the best limit, inferred from the observation of cosmic ray \bar{p} 's is $\tau_{\bar{p}} > 10^7$ yr, the cosmic-ray storage time, but this limit depends on a number of assumptions. The best direct observation of stored antiprotons gives $\tau_{\bar{p}}/B(\bar{p} \to e^-\gamma) > 1848$ yr.
- [d] There is some controversy about whether nuclear physics and model dependence complicate the analysis for bound neutrons (from which the best limit comes). The second limit here is from reactor experiments with free neutrons.
- [e] The parameters g_A , g_V , and g_{WM} for semileptonic modes are defined by $\overline{B}_f[\gamma_\lambda(g_V+g_A\gamma_5)+i(g_{WM}/m_{B_i})\ \sigma_{\lambda\nu}\ \phi']B_i$, and ϕ_{AV} is defined by $g_A/g_V=|g_A/g_V|e^{i\phi_{AV}}$. See the "Note on Baryon Decay Parameters" in the neutron Particle Listings.
- [f] Time-reversal invariance requires this to be 0° or 180° .
- [g] The decay parameters γ and Δ are calculated from α and ϕ using

$$\gamma = \sqrt{1-lpha^2}\cos\phi$$
 , $\tan\Delta = -rac{1}{lpha}\,\sqrt{1-lpha^2}\sin\phi$.

See the "Note on Baryon Decay Parameters" in the neutron Particle Listings.

- [h] See the Particle Listings for the pion momentum range used in this measurement
- [i] The error given here is only an educated guess. It is larger than the error on the weighted average of the published values.
- [j] A theoretical value using QED.
- [k] See the "Note on Λ_c^+ Branching Fractions" in the Branching Fractions of the Λ_c^+ Particle Listings.
- [I] This branching fraction includes all the decay modes of the final-state resonance.
- [m] An ℓ indicates an e or a μ mode, not a sum over these modes.
- [n] The value is for the sum of the charge states of particle/antiparticle states indicated
- [o] Assuming isospin conservation, so that the other third is $\Lambda_c^+ \pi^0 \pi^0$.
- [p] Not a pure measurement. See note at head of Λ_h^0 Decay Modes.

MONOPOLES, SUPERSYMMETRY, COMPOSITENESS, etc., SEARCHES FOR

Magnetic Monopole Searches

Isolated supermassive monopole candidate events have not been confirmed. The most sensitive experiments obtain negative results.

Best cosmic-ray supermassive monopole flux limit:

 $< 1.0 \times 10^{-15} \text{ cm}^{-2} \text{sr}^{-1} \text{s}^{-1}$ for $1.1 \times 10^{-4} < \beta < 0.1$

Supersymmetric Particle Searches

Limits are based on the Minimal Supersymmetric Standard Model. Assumptions include: 1) $\widetilde{\chi}_1^0$ (or $\widetilde{\gamma}$) is lightest supersymmetric particle; 2) R-parity is conserved; 3) All scalar quarks (except \widetilde{t}_L and \widetilde{t}_R) are degenerate in mass, and $m_{\widetilde{q}_R} = m_{\widetilde{q}_L}$. 4) Limits for selectrons and smuons refer to the $\widetilde{\ell}_R$ states.

See the Particle Listings for a Note giving details of supersymmetry.

$$\begin{array}{lll} \widetilde{\chi}_{I}^{0} - \text{neutralinos (mixtures of } \widetilde{\gamma}, \, \widetilde{Z}^{0}, \, \text{and } \widetilde{H}_{I}^{0}) \\ & \text{Mass } m_{\widetilde{\chi}_{1}^{0}} \ \, > \ \, 10.9 \,\, \text{GeV, CL} = 95\% \\ & \text{Mass } m_{\widetilde{\chi}_{2}^{0}} \ \, > \ \, 45.3 \,\, \text{GeV, CL} = 95\% \\ & \text{Mass } m_{\widetilde{\chi}_{3}^{0}} \ \, > \ \, 75.8 \,\, \text{GeV, CL} = 95\% \\ & \text{Mass } m_{\widetilde{\chi}_{2}^{0}} \ \, > \ \, 127 \,\, \text{GeV, CL} = 95\% \\ & \text{Mass } m_{\widetilde{\chi}_{2}^{0}} \ \, > \ \, 127 \,\, \text{GeV, CL} = 95\% \\ \end{array} \label{eq:constraint}$$

$$\widetilde{\chi}_{I}^{\pm}$$
 — charginos (mixtures of \widetilde{W}^{\pm} and \widetilde{H}_{I}^{\pm})

Mass $m_{\widetilde{\chi}_{1}^{\pm}} > 65.7$ GeV, CL = 95% $[m_{\widetilde{\chi}_{1}^{\pm}} - m_{\widetilde{\chi}_{1}^{0}} \geq 2 \text{ GeV}]$

Mass $m_{\widetilde{\chi}_{2}^{\pm}} > 99$ GeV, CL = 95% [GUT relations assumed]

 $\tilde{\nu}$ — scalar neutrino (sneutrino)

Mass m > 37.1 GeV, CL = 95% [one flavor] Mass m > 43.1 GeV, CL = 95% [three degenerate flavors]

 \widetilde{e} — scalar electron (selectron) Mass m>58 GeV, CL = 95% $[m_{\widetilde{e}_R}-m_{\widetilde{\chi}^0_1} \ge 4$ GeV]

 $\widetilde{\mu}$ — scalar muon (smuon) Mass m > 55.6 GeV, CL = 95% $[m_{\widetilde{\mu}_R} - m_{\widetilde{\chi}_1^0} \ge 4$ GeV]

 $ilde{ au}$ — scalar tau (stau) Mass m>45 GeV, CL = 95% [if $m_{\widetilde{\chi}_1^0}<38$ GeV]

q — scalar quark (squark)

These limits include the effects of cascade decays, evaluated assuming a fixed value of the parameters μ and $\tan\beta$. The limits are weakly sensitive to these parameters over much of parameter space. Limits assume GUT relations between gaugino masses and the gauge coupling; in particular that for $|\mu|$ not small, $m_{\widetilde{\chi}^0_1} \approx m_{\widetilde{g}}/6$.

$$\begin{array}{ll} \text{Mass } m > \ 176 \ \text{GeV}, \ \text{CL} = 95\% & [\text{any } m_{\widetilde{g}} < 300 \ \text{GeV}, \\ \mu = -250 \ \text{GeV}, \ \tan\beta = 2] \\ \text{Mass } m > \ 224 \ \text{GeV}, \ \text{CL} = 95\% & [m_{\widetilde{g}} \leq m_{\widetilde{q}}, \\ \mu = -400 \ \text{GeV}, \ \tan\beta = 4] \end{array}$$

 \tilde{g} — gluino

There is some controversy on whether gluinos in a low-mass window (1 $\lesssim m_{\widetilde{g}} \lesssim$ 5 GeV) are excluded or not. See the Supersymmetry Listings for details.

The limits summarised here refere to the high-mass region $(m_{\widetilde{g}}\gtrsim 5~{\rm GeV}),$ and include the effects of cascade decays, evaluated assuming a fixed value of the parameters μ and $\tan\beta.$ The limits are weakly sensitive to these parameters over much of parameter space. Limits assume GUT relations between gaugino masses and the gauge coupling; in particular that for $|\mu|$ not small, $m_{\widetilde{\chi}_1^0} \approx m_{\widetilde{g}}/6.$

$$\begin{array}{ll} \text{Mass } m > 173 \text{ GeV, CL} = 95\% & [\text{any } m_{\overline{q}}, \ \mu = -200 \text{ GeV,} \\ & \tan\beta = 2] \\ \text{Mass } m > 212 \text{ GeV, CL} = 95\% & [m_{\overline{g}} \geq m_{\overline{q}}, \ \mu = -250 \text{ GeV,} \\ & \tan\beta = 2] \end{array}$$

Quark and Lepton Compositeness, Searches for

Scale Limits A for Contact Interactions (the lowest dimensional Interactions with four fermions)

If the Lagrangian has the form

$$\pm \frac{g^2}{2\Lambda^2} \overline{\psi}_L \gamma_\mu \psi_L \overline{\psi}_L \gamma^\mu \psi_L$$

(with $g^2/4\pi$ set equal to 1), then we define $\Lambda \equiv \Lambda_{LL}^{\pm}$. For the full definitions and for other forms, see the Note in the Listings on Searches for Quark and Lepton Compositeness in the full *Review* and the original literature.

$$\begin{array}{lll} \Lambda_{LL}^{+}(eeee) &> 2.4 \; {\rm TeV}, \; {\rm CL} = 95\% \\ \Lambda_{LL}^{-}(eeee) &> 3.6 \; {\rm TeV}, \; {\rm CL} = 95\% \\ \Lambda_{LL}^{+}(ee\mu\mu) &> 2.6 \; {\rm TeV}, \; {\rm CL} = 95\% \\ \Lambda_{LL}^{+}(ee\mu\mu) &> 2.9 \; {\rm TeV}, \; {\rm CL} = 95\% \\ \Lambda_{LL}^{+}(ee\tau\tau) &> 1.9 \; {\rm TeV}, \; {\rm CL} = 95\% \\ \Lambda_{LL}^{+}(ee\tau\tau) &> 3.0 \; {\rm TeV}, \; {\rm CL} = 95\% \\ \Lambda_{LL}^{+}(\ell\ell\ell\ell) &> 3.5 \; {\rm TeV}, \; {\rm CL} = 95\% \\ \Lambda_{LL}^{+}(\ell\ell\ell\ell) &> 3.8 \; {\rm TeV}, \; {\rm CL} = 95\% \\ \Lambda_{LL}^{+}(eeqq) &> 2.5 \; {\rm TeV}, \; {\rm CL} = 95\% \\ \Lambda_{LL}^{+}(eeeqq) &> 3.7 \; {\rm TeV}, \; {\rm CL} = 95\% \\ \Lambda_{LL}^{+}(eebb) &> 3.1 \; {\rm TeV}, \; {\rm CL} = 95\% \\ \Lambda_{LL}^{+}(eebb) &> 2.9 \; {\rm TeV}, \; {\rm CL} = 95\% \\ \Lambda_{LL}^{+}(\mu\mu qq) &> 2.9 \; {\rm TeV}, \; {\rm CL} = 95\% \\ \Lambda_{LL}^{+}(\mu\mu qq) &> 4.2 \; {\rm TeV}, \; {\rm CL} = 95\% \\ \Lambda_{LR}^{+}(\nu_{\mu}\nu_{e}\mu e) &> 3.1 \; {\rm TeV}, \; {\rm CL} = 90\% \\ \Lambda_{LL}^{+}(qqqq) &> 1.6 \; {\rm TeV}, \; {\rm CL} = 95\% \\ \end{array}$$

Excited Leptons

The limits from $\ell^{*+}\ell^{*-}$ do not depend on λ (where λ is the $\ell\ell^*$ transition coupling). The λ -dependent limits assume chiral coupling, except for the third limit for e^* which is for nonchiral coupling. For chiral coupling, this limit corresponds to $\lambda_{\gamma}=\sqrt{2}$.

e*± — excited electron

 $\mu^{*\pm}$ — excited muon

Mass
$$m > 85.3$$
 GeV, CL = 95% (from $\mu^{*+}\mu^{*-}$)
Mass $m > 91$ GeV, CL = 95% (if $\lambda_Z > 1$)

 $au^{*\pm}$ — excited tau

Mass
$$m > 84.6$$
 GeV, CL = 95% (from $\tau^{*+}\tau^{*-}$)
Mass $m > 90$ GeV, CL = 95% (if $\lambda_Z > 0.18$)

 ν^* — excited neutrino

Mass
$$m>84.9$$
 GeV, CL = 95% (from $\nu^*\overline{\nu}^*$)
Mass $m>91$ GeV, CL = 95% (if $\lambda_Z>1$)
Mass $m=$ none 40–96 GeV, CL = 95% (from $ep\to\nu^*X$)

q* — excited quark

Mass
$$m > 45.6$$
 GeV, CL = 95% (from $q^* \overline{q}^*$)
Mass $m > 88$ GeV, CL = 95% (if $λ_Z > 1$)
Mass $m > 570$ GeV, CL = 95% ($p\overline{p} \rightarrow q^*X$)

Color Sextet and Octet Particles

Color Sextet Quarks (q₆)

Mass
$$m > 84$$
 GeV, $CL = 95\%$ (Stable q_6)

Color Octet Charged Leptons (\ell_8)

Mass
$$m > 86$$
 GeV, CL = 95% (Stable ℓ_8)

Color Octet Neutrinos (ν_8)

Mass
$$m > 110$$
 GeV, CL = 90% $(\nu_8 \rightarrow \nu g)$

TESTS OF CONSERVATION LAWS

Revised by L. Wolfenstein and T.G. Trippe, May 1998.

In keeping with the current interest in tests of conservation laws, we collect together a Table of experimental limits on all weak and electromagnetic decays, mass differences, and moments, and on a few reactions, whose observation would violate conservation laws. The Table is given only in the full Review of Particle Physics, not in the Particle Physics Booklet. For the benefit of Booklet readers, we include the best limits from the Table in the following text. Limits in this text are for CL=90% unless otherwise specified. The Table is in two parts: "Discrete Space-Time Symmetries," i.e., C, P, T, CP, and CPT; and "Number Conservation Laws," i.e., lepton, baryon, hadronic flavor, and charge conservation. The references for these data can be found in the the Particle Listings in the Review. A discussion of these tests follows.

CPT INVARIANCE

General principles of relativistic field theory require invariance under the combined transformation CPT. The simplest tests of CPT invariance are the equality of the masses and lifetimes of a particle and its antiparticle. The best test comes from the limit on the mass difference between K^0 and \overline{K}^0 . Any such difference contributes to the CP-violating parameter ϵ . Assuming CPT invariance, ϕ_{ϵ} , the phase of ϵ should be very close to 44°. (See the "Note on CP Violation in K^0_L Decay" in the Particle Listings.) In contrast, if the entire source of CP violation in K^0_L decays were a $K^0 - \overline{K}^0_L$ mass difference, ϕ_{ϵ} would be $44^\circ + 90^\circ$. Assuming that there is no other source of CPT_L violation than this mass difference, it is possible to deduce that [1]

$$m_{\overline{K}^0} - m_{K^0} \approx \frac{2(m_{K^0_L} - m_{K^0_S}) \, |\eta| \, (\frac{2}{3}\phi_{+-} + \frac{1}{3}\phi_{00} - \phi_0)}{\sin\phi_0} \; ,$$

where $\phi_0=43.5^\circ$ with an uncertainty of less than 0.1°. Using our best values of the CP-violation parameters, we get $|(m_{\overline{K}^0}-m_{K^0})/m_{K^0}| \leq 10^{-18}$. Limits can also be placed on specific CPT-violating decay amplitudes. Given the small value of $(1-|\eta_{00}/\eta_{+-}|)$, the value of $\phi_{00}-\phi_{+-}$ provides a measure of CPT violation in $K_L^0 \to 2\pi$ decay. Results from CERN [1] and Fermilab [2] indicate no CPT-violating effect.

CP AND T INVARIANCE

Given CPT invariance, CP violation and T violation are equivalent. So far the only evidence for CP or T violation comes from the measurements of $\eta_{+-},\,\eta_{00},$ and the semileptonic decay charge asymmetry for K_L , e.g., $|\eta_{+-}| = |A(K_L^0 \to \pi^+\pi^-)/A(K_S^0$ $\rightarrow \pi^{+}\pi^{-})| = (2.285 \pm 0.019) \times 10^{-3} \text{ and } [\Gamma(K_L^0 \to \pi^- e^+ \nu) - 10^{-3}]$ $\Gamma(K_L^0 \to \pi^+ e^- \overline{\nu}) / [\text{sum}] = (0.333 \pm 0.014)\%$. Other searches for CP or T violation divide into (a) those that involve weak interactions or parity violation, and (b) those that involve processes otherwise allowed by the strong or electromagnetic interactions. In class (a) the most sensitive are probably the searches for an electric dipole moment of the neutron, measured to be $< 1.0 \times 10^{-25}$ e cm, and the electron $(-0.18 \pm 0.16) \times$ 10^{-26} e cm. A nonzero value requires both P and T violation. Class (b) includes the search for C violation in η decay, believed to be an electromagnetic process, e.g., as measured by $\Gamma(\eta \to \mu^+ \mu^- \pi^0)/\Gamma(\eta \to \text{all}) < 5 \times 10^{-6}$, and searches for T violation in a number of nuclear and electromagnetic reactions.

CONSERVATION OF LEPTON NUMBERS

Present experimental evidence and the standard electroweak theory are consistent with the absolute conservation of three separate lepton numbers: electron number L_e , muon number L_{μ} , and tau number L_{τ} . Searches for violations are of the following types:

- a) $\Delta L=2$ for one type of lepton. The best limit comes from the search for neutrinoless double beta decay $(Z,A) \rightarrow (Z+2,A)+e^-+e^-$. The best laboratory limit is $t_{1/2}>1.1\times 10^{25}$ yr (CL=90%) for ⁷⁶Ge.
- b) Conversion of one lepton type to another. For purely leptonic processes, the best limits are on $\mu \to e\gamma$ and $\mu \to 3e$, measured as $\Gamma(\mu \to e\gamma)/\Gamma(\mu \to \text{all}) < 5 \times 10^{-11}$ and $\Gamma(\mu \to 3e)/\Gamma(\mu \to \text{all}) < 1.0 \times 10^{-12}$. For semileptonic processes, the best limit comes from the coherent conversion process in a muonic atom, $\mu^- + (Z,A) \to e^- + (Z,A)$, measured as $\Gamma(\mu^-\text{Ti} \to e^-\text{Ti})/\Gamma(\mu^-\text{Ti} \to \text{all}) < 4 \times 10^{-12}$. Of special interest is the case in which the hadronic flavor also changes, as in $K_L \to e\mu$ and $K^+ \to \pi^+e^-\mu^+$, measured as $\Gamma(K_L \to e\mu)/\Gamma(K_L \to \text{all}) < 3.3 \times 10^{-11}$ and $\Gamma(K^+ \to \pi^+e^-\mu^+)/\Gamma(K^+ \to \text{all}) < 2.1 \times 10^{-10}$. Limits on the conversion of τ into e or μ are found in τ decay and are much less stringent than those for $\mu \to e$ conversion, e.g., $\Gamma(\tau \to \mu\gamma)/\Gamma(\tau \to \text{all}) < 3.0 \times 10^{-6}$ and $\Gamma(\tau \to e\gamma)/\Gamma(\tau \to \text{all}) < 2.7 \times 10^{-6}$.
- c) Conversion of one type of lepton into another type of antilepton. The case most studied is $\mu^- + (Z,A) \rightarrow e^+ + (Z-2,A)$, the strongest limit being $\Gamma(\mu^- \text{Ti} \rightarrow e^+ \text{Ca})/\Gamma(\mu^- \text{Ti} \rightarrow \text{all}) < 9 \times 10^{-11}$.
- d) Relation to neutrino mass. If neutrinos have mass, then it is expected even in the standard electroweak theory that the lepton numbers are not separately conserved, as a consequence of lepton mixing analogous to Cabibbo quark mixing. However, in this case lepton-number-violating processes such as $\mu \to e\gamma$ are expected to have extremely small probability. For small neutrino masses, the lepton-number violation would be observed first in neutrino oscillations, which have been the subject of extensive experimental searches. For example, searches for $\overline{\nu}_e$ disappearance, which we label as $\overline{\nu}_e \not \to \overline{\nu}_e$, give measured limits $\Delta(m^2) < 9 \times 10^{-4} \text{ eV}^2 \text{ for } \sin^2(2\theta) = 1, \text{ and } \sin^2(2\theta) < 0.02$ for large $\Delta(m^2)$, where θ is the neutrino mixing angle. Possible evidence for mixing has come from two sources. The deficit in the solar neutrino flux compared with solar model calculations could be explained by oscillations with $\Delta(m^2) \leq 10^{-5} \text{ eV}^2$ causing the disappearance of ν_e . In addition underground detectors observing neutrinos produced by cosmic rays in the atmosphere have measured a ν_{μ}/ν_{e} ratio much less than expected and also a deficiency of upward going ν_{μ} compared to downward. This could be explained by oscillations leading to the disappearance of ν_{μ} with $\Delta(m^2)$ of the order 10^{-2} – 10^{-3} eV².

CONSERVATION OF HADRONIC FLAVORS

In strong and electromagnetic interactions, hadronic flavor is conserved, *i.e.* the conversion of a quark of one flavor (d, u, s, c, b, t) into a quark of another flavor is forbidden. In the Standard Model, the weak interactions violate these conservation laws in a manner described by the Cabibbo-Kobayashi-Maskawa mixing (see the section "Cabibbo-Kobayashi-Maskawa Mixing Matrix"). The way in which these conservation laws are violated is tested as follows:

a) $\Delta S = \Delta Q$ rule. In the semileptonic decay of strange particles, the strangeness change equals the change in charge of the hadrons. Tests come from limits on decay rates such as

 $\Gamma(\Sigma^+ \to n e^+ \nu)/\Gamma(\Sigma^+ \to {\rm all}) < 5 \times 10^{-6}$, and from a detailed analysis of $K_L \to \pi e \nu$, which yields the parameter x, measured to be $({\rm Re}\, x, {\rm Im}\, x) = (0.006 \pm 0.018, -0.003 \pm 0.026)$. Corresponding rules are $\Delta C = \Delta Q$ and $\Delta B = \Delta Q$.

- b) Change of flavor by two units. In the Standard Model this occurs only in second-order weak interactions. The classic example is $\Delta S=2$ via $K^0-\overline{K}^0$ mixing, which is directly measured by $m(K_S)-m(K_L)=(3.489\pm0.009)\times10^{-12}$ MeV. There is now evidence for $B^0-\overline{B}^0$ mixing $(\Delta B=2)$, with the corresponding mass difference between the eigenstates $(m_{B_1^0}-m_{B_1^0})=(0.723\pm0.032)\Gamma_{B^0}=(3.05\pm0.12)\times10^{-10}$ MeV, and for $B_s^0-\overline{B}_s^0$ mixing, with $(m_{B_{sH}^0}-m_{B_{sL}^0})>14\Gamma_{B_s^0}$ or $>6\times10^{-9}$ MeV (CL=95%). No evidence exists for $D^0-\overline{D}^0$ mixing, which is expected to be much smaller in the Standard Model.
- c) Flavor-changing neutral currents. In the Standard Model the neutral-current interactions do not change flavor. The low rate $\Gamma(K_L \to \mu^+ \mu^-)/\Gamma(K_L \to \text{all}) = (7.2 \pm 0.5) \times 10^{-9} \text{ puts}$ limits on such interactions; the nonzero value for this rate is attributed to a combination of the weak and electromagnetic interactions. The best test should come from $K^+ \to \pi^+ \nu \overline{\nu}$, which occurs in the Standard Model only as a second-order weak process with a branching fraction of $(1 \text{ to } 8) \times 10^{-10}$. Observation of one event has been reported [4], yielding $\Gamma(K^+ \to$ $\pi^+\nu\overline{\nu})/\Gamma(K^+\to \text{all})=(4.2^{+9.7}_{-3.5})\times 10^{-10}$. Limits for charmchanging or bottom-changing neutral currents are much less stringent: $\Gamma(D^0 \to \mu^+\mu^-)/\Gamma(D^0 \to \text{all}) < 4 \times 10^{-6}$ and $\Gamma(B^0 \to \mu^+ \mu^-)/\Gamma(B^0 \to \text{all}) < 7 \times 10^{-7}$. One cannot isolate flavor-changing neutral current (FCNC) effects in non leptonic decays. For example, the FCNC transition $s \to d + (\overline{u} + u)$ is equivalent to the charged-current transition $s \to u + (\overline{u} + d)$. Tests for FCNC are therefore limited to hadron decays into lepton pairs. Such decays are expected only in second-order in the electroweak coupling in the Standard Model.

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TESTS OF DISCRETE SPACE-TIME SYMMETRIES

CHARGE CONJUGATION (C) INVARIANCE

$\Gamma(\pi^0 \to 3\gamma)/\Gamma_{\text{total}}$		$<3.1 \times 10^{-8}$, CL = 90%
η C-nonconserving decay parameters		
$\pi^+\pi^-\pi^0$ left-right asymmetry parameter		$(0.09 \pm 0.17) \times 10^{-2}$
$\pi^+\pi^-\pi^0$ sextant asymmetry parameter		$(0.18 \pm 0.16) \times 10^{-2}$
$\pi^+\pi^-\pi^0$ quadrant asymmetry parameter		$(-0.17 \pm 0.17) \times 10^{-2}$
$\pi^+\pi^-\gamma$ left-right asymmetry parameter		$(0.9 \pm 0.4) \times 10^{-2}$
$\pi^+\pi^-\gamma$ parameter eta (<i>D</i> -wave)		$0.05 \pm 0.06 (S = 1.5)$
$\Gamma(\eta \rightarrow 3\gamma)/\Gamma_{\text{total}}$		$<5 \times 10^{-4}$, CL = 95%
$\Gamma(\eta \to \pi^0 e^+ e^-)/\Gamma_{\text{total}}$	[a]	$<4 \times 10^{-5}$, CL = 90%
$\Gamma(\eta \to \pi^0 \mu^+ \mu^-)/\Gamma_{\text{total}}$	[a]	$<5 \times 10^{-6}$, CL = 90%
$\Gamma(\omega(782) \rightarrow \eta \pi^0)/\Gamma_{\text{total}}$		$<1 \times 10^{-3}$, CL = 90%
$\Gamma(\omega(782) \rightarrow 3\pi^{0})/\Gamma_{\text{total}}$		$<3 \times 10^{-4}$, CL = 90%
$\Gamma(\eta'(958) \rightarrow \pi^0 e^+ e^-)/\Gamma_{\text{total}}$	[a]	$<1.3 \times 10^{-2}$, CL = 90%
$\Gamma(\eta'(958) \rightarrow \eta e^+e^-)/\Gamma_{\text{total}}$	[a]	$<1.1 \times 10^{-2}$, CL = 90%
$\Gamma(\eta'(958) \rightarrow 3\gamma)/\Gamma_{\text{total}}$		$<1.0 \times 10^{-4}$, CL = 90%
$\Gamma(\eta'(958) \rightarrow \mu^{+}\mu^{-}\pi^{0})/\Gamma_{\text{total}}$	[a]	$<6.0 \times 10^{-5}$, CL = 90%
$\Gamma(\eta'(958) \rightarrow \mu^{+}\mu^{-}\eta)/\Gamma_{\text{total}}$	[a]	$<1.5 \times 10^{-5}$ CL = 90%

PARITY (P) INVARIANCE

e electric dipole moment	$(0.18 \pm 0.16) \times 10^{-26}$ ecm
μ electric dipole moment	$(3.7 \pm 3.4) \times 10^{-19} \text{ ecm}$
$ au$ electric dipole moment $(d_{ au})$	> -3.1 and $< 3.1 \times 10^{-16}$ ecm, CL = 95%
$\Gamma(\eta \to \pi^+\pi^-)/\Gamma_{\text{total}}$	$<9 \times 10^{-4}$, CL = 90%
$\Gamma(\eta'(958) \rightarrow \pi^+\pi^-)/\Gamma_{\text{total}}$	$<2 \times 10^{-2}$, CL = 90%
$\Gamma(\eta'(958) \rightarrow \pi^0\pi^0)/\Gamma_{\text{total}}$	$<9 \times 10^{-4}$, CL = 90%
p electric dipole moment	$(-4 \pm 6) \times 10^{-23}$ ecm
n electric dipole moment	$< 0.97 \times 10^{-25} \text{ ecm, CL} = 90\%$
A electric dipole moment	$< 1.5 \times 10^{-16} \text{ ecm, CL} = 95\%$

TIME REVERSAL (T) INVARIANCE

Limits on e, μ , τ , p, n, and Λ electric dipole moments under Parity Invariance above are also tests of Time Reversal Invariance.

```
μ decay parameters
       transverse e+ polarization normal to
                                                                      0.007 \pm 0.023
              plane of \mu spin, e^+ momentum
                                                                      (0 \pm 4) \times 10^{-3}
                                                                      (2 \pm 6) \times 10^{-3}
       \beta'/A
                                                                      > -3.1 \text{ and } < 3.1 \times 10^{-16} \text{ ecm,}
	au electric dipole moment (d_{	au})
                                                                             CL = 95\%
\operatorname{Im}(\xi) in K_{\mu 3}^{\pm} decay (from transverse \mu pol.)
                                                                       -0.017 \pm 0.025
\operatorname{Im}(\xi) in K^0_{\mu3} decay (from transverse \mu pol.)
                                                                       -0.007 \pm 0.026
n \rightarrow pe^-\nu decay parameters
       \phi_{AV}, phase of g_A relative to g_V
                                                                [b] (180.07 \pm 0.18)^{\circ}
       triple correlation coefficient D
                                                                      (-0.5 \pm 1.4) \times 10^{-3}
triple correlation coefficient D for \Sigma^- \rightarrow
                                                                      0.11 \pm 0.10
       ne<sup>−</sup>⊽e
```

CP INVARIANCE

$\operatorname{Re}(d_{\tau}^{\mathbf{w}})$		$< 0.56 \times 10^{-17} \text{ ecm, CL} = 95\%$
$\operatorname{Im}(d_{\tau}^{W})$		$< 1.5 \times 10^{-17} \text{ ecm, CL} = 95\%$
$\Gamma(\eta \to \pi^+\pi^-)/\Gamma_{\text{total}}$		$<9 \times 10^{-4}$, CL = 90%
$\Gamma(\eta'(958) \rightarrow \pi^+\pi^-)/\Gamma_{\text{total}}$		$<2 \times 10^{-2}$, CL = 90%
$\Gamma(\eta'(958) \rightarrow \pi^0 \pi^0)/\Gamma_{\text{total}}$		$<9 \times 10^{-4}$, CL = 90%
$\mathcal{K}^{\pm} ightarrow \pi^{\pm}\pi^{+}\pi^{-}$ rate difference/average		$(0.07 \pm 0.12)\%$
$K^{\pm} \rightarrow \pi^{\pm} \pi^{0} \pi^{0}$ rate difference/average		$(0.0 \pm 0.6)\%$
$\mathcal{K}^{\pm} ightarrow \ \pi^{\pm} \pi^{0} \gamma$ rate difference/average		$(0.9 \pm 3.3)\%$
$(g_{\tau^{+}} - g_{\tau^{-}}) / (g_{\tau^{+}} + g_{\tau^{-}}) \text{ for } K^{\pm} \rightarrow \pi^{\pm} \pi^{+} \pi^{-}$		$(-0.7 \pm 0.5)\%$
CP-violation parameters in K _S decay		
$Im(\eta_{+-0}) = Im(A(K_5^0 \to \pi^+\pi^-\pi^0,$		-0.002 ± 0.008
CP-violating) / $A(K_I^0 \rightarrow$		
$\pi^+\pi^-\pi^0)$		
$Im(\eta_{000})^2 = \Gamma(K_S^0 \to 3\pi^0) /$		<0.1, CL = 90%
$\Gamma(K_L^0 \to 3\pi^0)$		
charge asymmetry j for $K_L^0 \rightarrow \pi^+\pi^-\pi^0$		0.0011 ± 0.0008
$ \epsilon'_{+-\gamma} /\epsilon$ for $K_L^0 \to \pi^+\pi^-\gamma$		<0.3, CL = 90%
$\Gamma(K_L^0 \rightarrow \pi^0 \mu^+ \mu^-)/\Gamma_{\text{total}}$	[c]	$<5.1 \times 10^{-9}$, CL = 90%
$f(K_I^0 \rightarrow \pi^0 e^+ e^-)/\Gamma_{\text{total}}$	[c]	$<4.3 \times 10^{-9}$, CL = 90%
$\Gamma(K_I^{0} \rightarrow \pi^0 \nu \overline{\nu})/\Gamma_{\text{total}}$	[d]	$<$ 5.8 \times 10 ⁻⁵ , CL $=$ 90%
$A_{CP}(K^+K^-\pi^\pm)$ in $D^\pm \to K^+K^-\pi^\pm$		-0.017 ± 0.027
$A_{CP}(K^{\pm}K^{*0})$ in $D^+ \rightarrow K^+\overline{K}^{*0}$ and		-0.02 ± 0.05
$D^- \rightarrow \kappa^- \kappa^{*0}$		
$A_{CP}(\phi\pi^{\pm})$ in $D^{\pm} ightarrow \phi\pi^{\pm}$		-0.014 ± 0.033
$A_{CP}(\pi^+\pi^-\pi^\pm)$ in $D^\pm \to \pi^+\pi^-\pi^\pm$		-0.02 ± 0.04
$A_{CP}(K^+K^-)$ in D^0 , $\overline{D}{}^0 \rightarrow K^+K^-$		0.026 ± 0.035
$A_{CP}(\pi^+\pi^-)$ in D^0 , $\overline{D}{}^0 \rightarrow \pi^+\pi^-$		-0.05 ± 0.08
$A_{CP}(K_S^0\phi)$ in D^0 , $\overline{D}{}^0 \rightarrow K_S^0\phi$		-0.03 ± 0.09
$A_{CP}(K_S^0\pi^0)$ in D^0 , $\overline{D}{}^0 \rightarrow K_S^0\pi^0$		-0.018 ± 0.030
$ \text{Re}(\epsilon_{R0}) $		0.002 ± 0.008
$\left[\alpha_{-}(\Lambda) + \alpha_{+}(\overline{\Lambda})\right] / \left[\alpha_{-}(\Lambda) - \alpha_{+}(\overline{\Lambda})\right]$		-0.03 ± 0.06

CPT INVARIANCE

(m _{W+} - m _{W-}) / m _{average}		-0.002 ± 0.007
$(m_{e^+} - m_{e^-}) / m_{\text{average}}$		$<4 \times 10^{-8}$, CL = 90%
$ q_{e^+} + q_{e^-} /e$		$<2 \times 10^{-18}$
$(g_{e^+} - g_{e^-}) / g_{average}$		$(-0.5 \pm 2.1) \times 10^{-12}$
$(au_{\mu^+} - au_{\dot{\mu}^-}) / au_{average}$		$(2 \pm 8) \times 10^{-5}$
$(g_{\mu^+} - g_{\mu^-}) / g_{\text{average}}$		$(-2.6 \pm 1.6) \times 10^{-8}$
$(m_{\pi^+} - m_{\pi^-}) / m_{\text{average}}$		$(2 \pm 5) \times 10^{-4}$
$(au_{\pi^+} - au_{\pi^-}) / au_{average}$		$(6 \pm 7) \times 10^{-4}$
$(m_{K^+} - m_{K^-}) / m_{average}$		$(-0.6 \pm 1.8) \times 10^{-4}$
$(\tau_{K^+} - \tau_{K^-}) / \tau_{average}$		$(0.11 \pm 0.09)\% (S = 1.2)$
${\it K}^{\pm} ightarrow \mu^{\pm} u_{\mu}$ rate difference/average		$(-0.5 \pm 0.4)\%$
$K^{\pm} ightarrow \pi^{\pm} \pi^{0}$ rate difference/average		$(0.8 \pm 1.2)\%$
$ m_{K^0} - m_{\overline{K^0}} / m_{\text{average}}$	(g)	<10 ⁻¹⁸
phase difference ϕ_{00} - ϕ_{+-}		$(-0.1 \pm 0.8)^{\circ}$
CPT-violation parameters in K ⁰ decay		
real part of Δ		0.018 ± 0.020
imaginary part of △		0.02 ± 0.04
$(rac{q_{\overline{p}}}{m_{\overline{p}}} -rac{q_{\overline{p}}}{m_{\overline{p}}})/ rac{q}{m} _{average}$		$(1.5 \pm 1.1) \times 10^{-9}$
$ q_p + q_{\overline{p}} /e$		<2 × 10 ⁻⁵
$(\mu_{p} + \mu_{\overline{p}}) / \mu _{\text{average}}$		$(-2.6 \pm 2.9) \times 10^{-3}$
(m _n − m _n ̄) / m _{average}		$(9 \pm 5) \times 10^{-5}$
$(m_{\Lambda} - m_{\overline{\Lambda}}) / m_{\Lambda}$		$(-1.0 \pm 0.9) \times 10^{-5}$
$(\tau_{\Lambda} - \tau_{\overline{\Lambda}}) / \tau_{\text{average}}$		0.04 ± 0.09
$(\mu_{\Sigma^+} + \mu_{\overline{\Sigma}^-}) / \mu _{\text{average}}$		0.014 ± 0.015
(m ₌₋ - m ₌₊) / m _{average}		$(1.1 \pm 2.7) \times 10^{-4}$
$(\tau_{\Xi^-} - \tau_{\Xi^+}) / \tau_{\text{average}}$		$\textbf{0.02} \pm \textbf{0.18}$
$(m_{\Omega^-} - m_{\overline{\Omega}^+}) / m_{\text{average}}$		$(0 \pm 5) \times 10^{-4}$

CP VIOLATION OBSERVED

K_L^0 branching ratios	
charge asymmetry in K_{f3}^0 decays	
$\delta(\mu) = [\Gamma(\pi^- \mu^+ \nu_{\mu})]$	(0.304 ± 0.025)%
$-\Gamma(\pi^+\mu^-\overline{ u}_{\mu})]/sum$	
$\delta(e) = [\Gamma(\pi^- e^+ \nu_e)$	$(0.333 \pm 0.014)\%$
$-\Gamma(\pi^+e^-\overline{ u}_e)]/sum$	
parameters for $K_L^0 \rightarrow 2\pi$ decay	
$ \eta_{00} = A(K^0_L \to 2\pi^0) /$	$(2.275 \pm 0.019) \times 10^{-3} (S = 1.1)$
$A(K_S^0 \rightarrow 2\pi^0)$	
$ \eta_{+-} = A(K_L^0 \to \pi^+\pi^-) /$	$(2.285 \pm 0.019) \times 10^{-3}$
$A(K_S^0 \rightarrow \pi^+\pi^-) $	
$\epsilon'/\epsilon \approx \operatorname{Re}(\epsilon'/\epsilon) = (1- \eta_{00}/\eta_{+-})/3$	[e] $(1.5 \pm 0.8) \times 10^{-3} (S = 1.8)$
ϕ_{+-} , phase of η_{+-}	(43.5 ± 0.6)°
ϕ_{00} , phase of η_{00}	$(43.4 \pm 1.0)^{\circ}$
parameters for $K_L^0 o \pi^+\pi^-\gamma$ decay	
$ \eta_{+-\gamma} = A(K_I^0 \rightarrow \pi^+\pi^-\gamma, CP) $	$(2.35 \pm 0.07) \times 10^{-3}$
$ \nabla A(K_S^0 \to \pi^+\pi^-\gamma) $	
$\phi_{+-\gamma} = \text{phase of } \eta_{+-\gamma}$	(44 ± 4)°
$\Gamma(K_I^0 \to \pi^+\pi^-)/\Gamma_{\text{total}}$	$(2.067 \pm 0.035) \times 10^{-3} \text{ (S} = 1.1)$
$\Gamma(\kappa_I^0 \to \pi^0 \pi^0)/\Gamma_{\text{total}}$	$(9.36 \pm 0.20) \times 10^{-4}$

TESTS OF NUMBER CONSERVATION LAWS

LEPTON FAMILY NUMBER

Lepton family number conservation means separate conservation of each of $L_{\theta},~L_{\mu},~L_{\tau}.$

$\Gamma(Z \rightarrow e^{\pm} \mu^{\mp})/\Gamma_{\text{total}}$	[h] $<1.7 \times 10^{-6}$, CL = 95%
$\Gamma(Z \rightarrow e^{\pm} \tau^{\mp})/\Gamma_{\text{total}}$	$[h] < 9.8 \times 10^{-6}, CL = 95\%$
$\Gamma(Z \rightarrow \mu^{\pm} \tau^{\mp})/\Gamma_{\text{total}}$	$[h] < 1.2 \times 10^{-5}, CL = 95\%$
limit on $\mu^- \rightarrow e^-$ conversion	
$\sigma(\mu^{-32}S \rightarrow e^{-32}S)$ /	$< 7 \times 10^{-11}$, CL = 90%
$\sigma(\mu^{-32}S \rightarrow \nu_{\mu}^{32}P^*)$	
$\sigma(\mu^+ \text{Ti} \rightarrow e^- \text{Ti}) /$	$<4.3 \times 10^{-12}$, CL = 90%
$\sigma(\mu^- TI \rightarrow capture)$	
$\sigma(\mu^- Pb \rightarrow e^- Pb) /$	$<4.6 \times 10^{-11}$, CL = 90%
$\sigma(\mu^- Pb \rightarrow capture)$	
limit on muonium → antimuonium	<0.018, CL = 90%
conversion $R_g = G_C / G_F$	_
$\Gamma(\mu^- \rightarrow e^- \nu_e \overline{\nu}_\mu) / \Gamma_{\text{total}}$	[/] $<1.2 \times 10^{-2}$, CL = 90%
$\Gamma(\mu^- \rightarrow e^- \gamma)/\Gamma_{\text{total}}$	$<4.9 \times 10^{-11}$, CL = 90%
$\Gamma(\mu^- \rightarrow e^- e^+ e^-)/\Gamma_{\text{total}}$	$<1.0 \times 10^{-12}$, CL = 90%
$\Gamma(\mu^- \rightarrow e^- 2\gamma)/\Gamma_{\text{total}}$	$< 7.2 \times 10^{-11}$, CL = 90%
$\Gamma(\tau^- \rightarrow e^- \gamma)/\Gamma_{\text{total}}$	$< 2.7 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \rightarrow \mu^- \gamma)/\Gamma_{\text{total}}$	$<3.0 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \rightarrow e^- \pi^0)/\Gamma_{\text{total}}$	$< 3.7 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \rightarrow \mu^- \pi^0)/\Gamma_{\text{total}}$	$<4.0 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \rightarrow e^- K^0)/\Gamma_{\text{total}}$	$<1.3 \times 10^{-3}$, CL = 90%
$\Gamma(\tau^- \to \mu^- K^0)/\Gamma_{\text{total}}$	$<1.0 \times 10^{-3}$, CL = 90%
$\Gamma(\tau^- \rightarrow e^- \eta)/\Gamma_{\text{total}}$	$< 8.2 \times 10^{-6}, CL = 90\%$
$\Gamma(\tau^- \rightarrow \mu^- \eta)/\Gamma_{\text{total}}$	$<9.6 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \rightarrow e^- \rho^0)/\Gamma_{\text{total}}$	$<2.0 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \rightarrow \mu^- \rho^0)/\Gamma_{\text{total}}$	$<6.3 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \rightarrow e^- K^*(892)^0)/\Gamma_{\text{total}}$	$<5.1 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \rightarrow \mu^- K^*(892)^0)/\Gamma_{\text{total}}$	$< 7.5 \times 10^{-6}, CL = 90\%$
$\Gamma(\tau^- \rightarrow e^- \overline{K}^*(892)^0)/\Gamma_{\text{total}}$	$< 7.4 \times 10^{-6}$, CL = 90%
$\Gamma(\tau^- \to \mu^- \overline{K}^* (892)^0) / \Gamma_{\text{total}}$	$< 7.5 \times 10^{-6}$, CL = 90%

 $<3.9 \times 10^{-3}$, CL = 90%

 $< 9.1 \times 10^{-3}$, CL = 90%

 $\Gamma(B^+ \rightarrow K^- e^+ e^+)/\Gamma_{\text{total}}$

 $\Gamma(B^+ \to K^- \mu^+ \mu^+)/\Gamma_{\text{total}}$

```
\Gamma(\tau^- \rightarrow e^- \phi)/\Gamma_{\text{total}}
                                                                                        <6.9 \times 10^{-6}, CL = 90%
                                                                                                                                                                    \Gamma(D^+ \rightarrow K^+ e^+ \mu^-)/\Gamma_{\text{total}}
                                                                                                                                                                                                                                                            <1.3 \times 10^{-4}, CL = 90%
\Gamma(\tau^- \rightarrow \mu^- \phi)/\Gamma_{\text{total}}
                                                                                        < 7.0 \times 10^{-6}, CL = 90%
                                                                                                                                                                    \Gamma(D^+ \rightarrow K^+ e^- \mu^+)/\Gamma_{\text{total}}
                                                                                                                                                                                                                                                            <1.2 \times 10^{-4}, CL = 90%
\Gamma(\tau^- \rightarrow e^- e^+ e^-)/\Gamma_{\text{total}}
                                                                                        < 2.9 \times 10^{-6}, CL = 90%
                                                                                                                                                                    \Gamma(D^0 \to \mu^{\pm} e^{\mp})/\Gamma_{\text{total}}
                                                                                                                                                                                                                                                    [h] <1.9 \times 10^{-5}, CL = 90%
\Gamma(\tau^- \rightarrow e^- \mu^+ \mu^-)/\Gamma_{\text{total}}
                                                                                                                                                                    \Gamma(D^0 \to \pi^0 e^{\pm} \mu^{\mp})/\Gamma_{\text{total}}
                                                                                        <1.8 \times 10^{-6}, CL = 90%
                                                                                                                                                                                                                                                    [h] <8.6 × 10<sup>-5</sup>, CL = 90%
\Gamma(\tau^- \rightarrow e^+ \mu^- \mu^-)/\Gamma_{\text{total}}
                                                                                        <1.5 \times 10^{-6}, CL = 90%
                                                                                                                                                                    \Gamma(D^0 \to \eta e^{\pm} \mu^{\mp})/\Gamma_{\text{total}}
                                                                                                                                                                                                                                                    [h] <1.0 \times 10^{-4}, CL = 90%
\Gamma(\tau^- \rightarrow \mu^- e^+ e^-)/\Gamma_{\text{total}}
                                                                                        <1.7 \times 10^{-6}, CL = 90%
                                                                                                                                                                    \Gamma(D^0 \to \rho^0 e^{\pm} \mu^{\mp})/\Gamma_{\text{total}}
                                                                                                                                                                                                                                                    [h] < 4.9 \times 10^{-5}, CL = 90\%
\Gamma(\tau^- \rightarrow \mu^+ e^- e^-)/\Gamma_{\text{total}}
                                                                                        <1.5 \times 10^{-6}, CL = 90%
                                                                                                                                                                    \Gamma(D^0 \rightarrow \omega e^{\pm} \mu^{\mp})/\Gamma_{\text{total}}
                                                                                                                                                                                                                                                    [h] <1.2 \times 10^{-4}, CL = 90%
\Gamma(\tau^- \rightarrow \mu^- \mu^+ \mu^-)/\Gamma_{\text{total}}
                                                                                                                                                                    \Gamma(D^0 \to \phi \, e^\pm \, \mu^\mp)/\Gamma_{\rm total}
                                                                                                                                                                                                                                                    [h] <3.4 × 10<sup>-5</sup>, CL = 90%
                                                                                        <1.9 \times 10^{-6}, CL = 90%
\Gamma(\tau^- \rightarrow e^- \pi^+ \pi^-)/\Gamma_{\text{total}}
                                                                                        < 2.2 \times 10^{-6}, CL = 90%
                                                                                                                                                                    \Gamma(D^0 \to \overline{K}^0 e^{\pm} \mu^{\mp})/\Gamma_{\text{total}}
                                                                                                                                                                                                                                                    [h] <1.0 × 10<sup>-4</sup>, CL = 90%
\Gamma(\tau^- \rightarrow \mu^- \pi^+ \pi^-)/\Gamma_{\text{total}}
                                                                                        < 8.2 \times 10^{-6}, CL = 90%
                                                                                                                                                                    \Gamma(D^0 \to \overline{K}^*(892)^0 e^{\pm} \mu^{\mp})/\Gamma_{\text{total}}
                                                                                                                                                                                                                                                    [h] <1.0 \times 10^{-4}, CL = 90%
\Gamma(\tau^- \rightarrow e^- \pi^+ K^-)/\Gamma_{\text{total}}
                                                                                        <6.4 \times 10^{-6}, CL = 90%
                                                                                                                                                                    \Gamma(B^+ \rightarrow \pi^+ e^+ \mu^-)/\Gamma_{\text{total}}
                                                                                                                                                                                                                                                            <6.4 \times 10^{-3}, CL = 90%
                                                                                                                                                                    \Gamma(B^+ \rightarrow \pi^+ e^- \mu^+)/\Gamma_{\text{total}}
\Gamma(\tau^- \rightarrow e^-\pi^-K^+)/\Gamma_{\text{total}}
                                                                                        < 3.8 \times 10^{-6}, CL = 90%
                                                                                                                                                                                                                                                            <6.4 \times 10^{-3}, CL = 90%
\Gamma(\tau^- \rightarrow e^- K^+ K^-)/\Gamma_{\text{total}}
                                                                                        <6.0 \times 10^{-6}, CL = 90%
                                                                                                                                                                    \Gamma(B^+ \rightarrow K^+ e^+ \mu^-)/\Gamma_{\text{total}}
                                                                                                                                                                                                                                                            <6.4 \times 10^{-3}, CL = 90%
                                                                                                                                                                    \Gamma(B^+ \rightarrow K^+ e^- \mu^+)/\Gamma_{\text{total}}
\Gamma(\tau^- \rightarrow \mu^- \pi^+ K^-)/\Gamma_{\text{total}}
                                                                                        < 7.5 \times 10^{-6}, CL = 90%
                                                                                                                                                                                                                                                            <6.4 \times 10^{-3}, CL = 90%
\Gamma(\tau^- \rightarrow \mu^- \pi^- K^+)/\Gamma_{\text{total}}
                                                                                        < 7.4 \times 10^{-6}, CL = 90%
                                                                                                                                                                    \Gamma(B^+ \rightarrow \pi^- e^+ \mu^+)/\Gamma_{\text{total}}
                                                                                                                                                                                                                                                            <6.4 \times 10^{-3}, CL = 90%
                                                                                                                                                                    \Gamma(B^+ \rightarrow K^- e^+ \mu^+)/\Gamma_{\text{total}}
\Gamma(\tau^- \rightarrow \mu^- K^+ K^-)/\Gamma_{\text{total}}
                                                                                        <1.5 \times 10^{-5}, CL = 90%
                                                                                                                                                                                                                                                            <6.4 \times 10^{-3}, CL = 90%
\Gamma(\tau^- \rightarrow e^- \pi^0 \pi^0) / \Gamma_{\text{total}}
                                                                                        <6.5 \times 10^{-6}, CL = 90%
                                                                                                                                                                    \Gamma(B^0\to~e^{\pm}\,\mu^{\mp})/\Gamma_{\rm total}
                                                                                                                                                                                                                                                    [h] <5.9 \times 10^{-6}, CL = 90%
                                                                                        <1.4 \times 10^{-5}, CL = 90%
                                                                                                                                                                    \Gamma(B^0 \rightarrow e^{\pm} \tau^{\mp})/\Gamma_{\text{total}}
\Gamma(\tau^- \to \mu^- \pi^0 \pi^0)/\Gamma_{\rm total}
                                                                                                                                                                                                                                                    [h] <5.3 \times 10^{-4}, CL = 90%
\Gamma(\tau^- \rightarrow e^- \eta \eta)/\Gamma_{\rm total}
                                                                                        < 3.5 \times 10^{-5}, CL = 90%
                                                                                                                                                                    \Gamma(B^0 \to \mu^{\pm} \tau^{\mp})/\Gamma_{\text{total}}
                                                                                                                                                                                                                                                    [h] < 8.3 \times 10^{-4}, CL = 90%
\Gamma(\tau^- \rightarrow \mu^- \eta \eta)/\Gamma_{\text{total}}
                                                                                        <6.0 \times 10^{-5}, CL = 90%
                                                                                                                                                                    \Gamma(B \rightarrow e^{\pm} \mu^{\mp} s)/\Gamma_{\text{total}}
                                                                                                                                                                                                                                                            < 2.2 \times 10^{-5}, CL = 90%
\Gamma(\tau^- \rightarrow e^- \pi^0 \eta) / \Gamma_{\text{total}}
                                                                                        < 2.4 \times 10^{-5}, CL = 90%
                                                                                                                                                                    \Gamma(B_c^0 \rightarrow e^{\pm} \mu^{\mp})/\Gamma_{total}
                                                                                                                                                                                                                                                    [h] <4.1 \times 10^{-5}, CL = 90%
\Gamma(\tau^- \rightarrow \mu^- \pi^0 \eta)/\Gamma_{\text{total}}
                                                                                        < 2.2 \times 10^{-5}, CL = 90%
\Gamma(\tau^- \rightarrow e^- \text{ light boson})/\Gamma_{\text{total}}
                                                                                        < 2.7 \times 10^{-3}, CL = 95%
                                                                                                                                                                                                                  TOTAL LEPTON NUMBER
\Gamma(\tau^- \to \mu^- \text{light boson})/\Gamma_{\text{total}}
                                                                                        <5 \times 10^{-3}, CL = 95%
\nu oscillations. (For other lepton mixing effects in particle decays, see the Particle Listings.)
                                                                                                                                                                                     Violation of total lepton number conservation also implies violation
                                                                                                                                                                                     of lepton family number conservation.
        \Delta(m^2) for \sin^2(2\theta) = 1
                                                                                        <9 \times 10^{-4} \text{ eV}^2, CL = 90%
        \sin^2(2\theta) for "Large" \Delta(m^2)
                                                                                        <0.02, CL = 90%
                                                                                                                                                                     limit on \mu^- \rightarrow e^+ conversion
                                                                                                                                                                             \sigma(\mu^{-32}S \rightarrow e^{+32}Si^*) /
                                                                                                                                                                                                                                                            < 9 \times 10^{-10}, CL = 90%
        \Delta(m^2) for \sin^2(2\theta) = 1
                                                                                        < 9 \text{ eV}^2, CL = 90\%
                                                                                                                                                                                      \sigma(\mu^{-\,32}\text{S}\to\;\nu_{\mu}^{\,\,32}\text{P*})
        \sin^2(2\theta) for "Large" \Delta(m^2)
                                                                                        <0.25. CL = 90%
                                                                                                                                                                              \sigma(\mu^{-127}I \rightarrow e^{+127}Sb^*) /
                                                                                                                                                                                                                                                            <3 \times 10^{-10}, CL = 90%
                                                                                                                                                                                     \sigma(\mu^{-127}I \rightarrow \text{anything})
        \sin^2(2\theta) for "Large" \Delta(m^2)
                                                                                        <0.7, CL = 90%
                                                                                                                                                                              \sigma(\mu^- \text{Ti} \rightarrow e^+ \text{Ca}) /
                                                                                                                                                                                                                                                            < 8.9 \times 10^{-11}, CL = 90%
\nu_{\mu} \rightarrow \nu_{e}
                                                                                                                                                                                    \sigma(\mu^- \text{Ti} \rightarrow \text{capture})
        \Delta(m^2) for \sin^2(2\theta) = 1
                                                                                        < 0.09 \text{ eV}^2, CL = 90%
                                                                                                                                                                     \Gamma(\tau^- \rightarrow \pi^- \gamma)/\Gamma_{\text{total}}
                                                                                                                                                                                                                                                            < 2.8 \times 10^{-4}, CL = 90%
                                                                                        <3.0 \times 10^{-3}, CL = 90%
        sin^2(2\theta) for "Large" \Delta(m^2)
                                                                                                                                                                    \Gamma(\tau^- \rightarrow \pi^- \pi^0)/\Gamma_{\text{total}}
                                                                                                                                                                                                                                                            < 3.7 \times 10^{-4}, CL = 90%
\overline{\nu}_{\mu} \rightarrow \overline{\nu}_{e}
                                                                                                                                                                    \Gamma(\tau^- \rightarrow e^+ \pi^- \pi^-)/\Gamma_{\text{total}}
                                                                                                                                                                                                                                                            <1.9 \times 10^{-6}, CL = 90%
        \Delta(m^2) \text{ for } \sin^2(2\theta) = 1
                                                                                        < 0.14 \text{ eV}^2, CL = 90%
                                                                                                                                                                    \Gamma(\tau^- \rightarrow \mu^+ \pi^- \pi^-)/\Gamma_{\text{total}}
                                                                                                                                                                                                                                                            < 3.4 \times 10^{-6}, CL = 90%
        sin^2(2\theta) for "Large" \Delta(m^2)
                                                                                        <0.004, CL = 95%
                                                                                                                                                                    \Gamma(\tau^- \rightarrow e^+\pi^-K^-)/\Gamma_{\text{total}}
                                                                                                                                                                                                                                                            < 2.1 \times 10^{-6}, CL = 90%
\nu_{\mu}(\overline{\nu}_{\mu}) \rightarrow \nu_{e}(\overline{\nu}_{e})
                                                                                                                                                                    \Gamma(\tau^- \rightarrow e^+ K^- K^-)/\Gamma_{\text{total}}
                                                                                                                                                                                                                                                            < 3.8 \times 10^{-6}, CL = 90%
        \Delta(m^2) for \sin^2(2\theta) = 1
                                                                                        < 0.075 \text{ eV}^2, CL = 90\%
                                                                                                                                                                    \Gamma(\tau^- \rightarrow \mu^+ \pi^- K^-)/\Gamma_{\text{total}}
                                                                                                                                                                                                                                                            < 7.0 \times 10^{-6}, CL = 90%
        \sin^2(2\theta) for "Large" \Delta(m^2)
                                                                                        <1.8 \times 10^{-3}, CL = 90%
                                                                                                                                                                    \Gamma(\tau^- \rightarrow \mu^+ K^- K^-)/\Gamma_{\text{total}}
                                                                                                                                                                                                                                                            <6.0 \times 10^{-6}, CL = 90%
\nu_{\mu} \rightarrow \nu_{\tau}
                                                                                                                                                                     \Gamma(\tau^- \rightarrow \overline{p}\gamma)/\Gamma_{\text{total}}
                                                                                                                                                                                                                                                            < 2.9 \times 10^{-4}, CL = 90%
        \Delta(m^2) for \sin^2(2\theta) = 1
                                                                                        <0.9 \text{ eV}^2, CL = 90%
                                                                                                                                                                                                                                                            <6.6 \times 10^{-4}, CL = 90%
                                                                                                                                                                     \Gamma(\tau^- \rightarrow \bar{p}\pi^0)/\Gamma_{\text{total}}
        \sin^2(2\theta) for "Large" \Delta(m^2)
                                                                                        <0.004, CL = 90%
                                                                                                                                                                    \Gamma(\tau^- \rightarrow \bar{p}\eta)/\Gamma_{\text{total}}
                                                                                                                                                                                                                                                            <1.30 \times 10^{-3}, CL = 90%
\overline{\nu}_{\mu} \to \ \overline{\nu}_{\tau}
                                                                                                                                                                     \nu_e \rightarrow (\bar{\nu}_e)_L
         \Delta(m^2) \text{ for } \sin^2(2\theta) = 1
                                                                                        <2.2 eV<sup>2</sup>, CL = 90%
                                                                                                                                                                              \alpha\Delta(m^2) for \sin^2(2\theta) = 1
                                                                                                                                                                                                                                                            < 0.14 \text{ eV}^2, CL = 90%
        \sin^2(2\theta) for "Large" \Delta(m^2)
                                                                                        <4.4 \times 10^{-2}, CL = 90%
                                                                                                                                                                              \alpha^2 \sin^2(2\theta) for "Large" \Delta(m^2)
                                                                                                                                                                                                                                                            <0.032, CL = 90%
\nu_{\mu}(\overline{\nu}_{\mu}) \rightarrow \nu_{\tau}(\overline{\nu}_{\tau})
                                                                                                                                                                     \nu_{\mu} \rightarrow (\overline{\nu}_e)_L
        \Delta(m^2) for \sin^2(2\theta) = 1
                                                                                        <1.5 \text{ eV}^2, CL = 90%
                                                                                                                                                                              \alpha\Delta(m^2) for \sin^2(2\theta) = 1
                                                                                                                                                                                                                                                            < 0.16 \text{ eV}^2, CL = 90%
                                                                                        < 8 \times 10^{-3}, CL = 90%
        \sin^2(2\theta) for "Large" \Delta(m^2)
                                                                                                                                                                              \alpha^2 \sin^2(2\theta) for "Large" \Delta(m^2)
                                                                                                                                                                                                                                                            <0.001, CL = 90%
                                                                                                                                                                                                                                                     [/] <1.5 \times 10^{-3}, CL = 90%
\nu_e \not\leftarrow \nu_e
                                                                                                                                                                    \Gamma(\pi^+ \to \ \mu^+ \overline{\nu}_e)/\Gamma_{\rm total}
        \Delta(m^2) for \sin^2(2\theta) = 1
                                                                                        < 0.17 \text{ eV}^2, CL = 90%
                                                                                                                                                                    \Gamma(K^+ \rightarrow \pi^- \mu^+ e^+)/\Gamma_{\text{total}}
                                                                                                                                                                                                                                                            <7 \times 10^{-9}, CL = 90%
                                                                                        < 7 \times 10^{-2}, CL = 90%
                                                                                                                                                                    \Gamma(K^+ \rightarrow \pi^- e^+ e^+)/\Gamma_{\text{total}}
        \sin^2(2\theta) for "Large" \Delta(m^2)
                                                                                                                                                                                                                                                            <1.0 \times 10^{-8}, CL = 90%
                                                                                                                                                                     \Gamma(K^+ \rightarrow \pi^- \mu^+ \mu^+)/\Gamma_{\text{total}}
                                                                                                                                                                                                                                                     [f] <1.5 \times 10^{-4}, CL = 90%
                                                                                                                                                                    \Gamma(K^+ \rightarrow \mu^+ \overline{\nu}_e)/\Gamma_{\text{total}}
         \Delta(m^2) for \sin^2(2\theta) = 1
                                                                                        <0.23 or >1500 eV<sup>2</sup>
                                                                                                                                                                                                                                                     [/] < 3.3 \times 10^{-3}, CL = 90%
        \sin^2(2\theta) for \Delta(m^2) = 100 \text{eV}^2
                                                                                 [J] <0.02, CL = 90%
                                                                                                                                                                     \Gamma(K^+ \rightarrow \pi^0 e^+ \overline{\nu}_e) / \Gamma_{\text{total}}
                                                                                                                                                                                                                                                            <3 \times 10^{-3}, CL = 90%
                                                                                                                                                                    \Gamma(D^+ \rightarrow \pi^- e^+ e^+)/\Gamma_{\text{total}}
                                                                                                                                                                                                                                                            <1.1 \times 10^{-4}, CL = 90%
        \Delta(m^2) for \sin^2(2\theta) = 1
                                                                                        <7 \text{ or } > 1200 \text{ eV}^2
                                                                                                                                                                    \Gamma(D^+ \rightarrow \pi^- \mu^+ \mu^+)/\Gamma_{\text{total}}
                                                                                                                                                                                                                                                            < 8.7 \times 10^{-5}, CL = 90%
        \sin^2(2\theta) for 190 eV<sup>2</sup> < \Delta(m^2) <
                                                                                [k] <0.02, CL = 90%
                                                                                                                                                                    \Gamma(D^+ \rightarrow \pi^- e^+ \mu^+)/\Gamma_{\text{total}}
                                                                                                                                                                                                                                                            <1.1 \times 10^{-4}, CL = 90%
                320 eV<sup>2</sup>
                                                                                                                                                                    \Gamma(D^+ \rightarrow \rho^- \mu^+ \mu^+)/\Gamma_{\text{total}}
                                                                                                                                                                                                                                                            <5.6 \times 10^{-4}, CL = 90%
\Gamma(\pi^+ 	o \bar{\mu^+} \nu_e)/\Gamma_{	ext{total}}
                                                                                 [/] < 8.0 \times 10^{-3}, CL = 90%
                                                                                                                                                                    \Gamma(D^+ \rightarrow K^- e^+ e^+)/\Gamma_{\text{total}}
                                                                                                                                                                                                                                                            <1.2 \times 10^{-4}, CL = 90%
\Gamma(\pi^+ \rightarrow \mu^- e^+ e^+ \nu)/\Gamma_{\text{total}}
                                                                                        <1.6 \times 10^{-6}, CL = 90%
                                                                                                                                                                     \Gamma(D^+ \rightarrow K^- \mu^+ \mu^+)/\Gamma_{\text{total}}
                                                                                                                                                                                                                                                            <1.2 \times 10^{-4}, CL = 90%
\Gamma(\pi^0 \rightarrow \mu^+ e^- + e^- \mu^+)/\Gamma_{\text{total}}
                                                                                        <1.72 \times 10^{-8}, CL = 90%
                                                                                                                                                                    \Gamma(D^+ \rightarrow K^- e^+ \mu^+)/\Gamma_{\text{total}}
                                                                                                                                                                                                                                                            <1.3 \times 10^{-4}, CL = 90%
\Gamma(\eta \rightarrow \mu^+ e^- + \mu^- e^+)/\Gamma_{\text{total}}
                                                                                        <6 \times 10^{-6}, CL = 90%
                                                                                                                                                                    \Gamma(D^+ \rightarrow K^*(892)^- \mu^+ \mu^+)/\Gamma_{\text{total}}
                                                                                                                                                                                                                                                            < 8.5 \times 10^{-4}, CL = 90%
\Gamma(K^+ \rightarrow \mu^- \nu e^+ e^+)/\Gamma_{\text{total}}
                                                                                        < 2.0 \times 10^{-8}, CL = 90%
                                                                                                                                                                    \Gamma(D_c^+ \to \pi^- \mu^+ \mu^+)/\Gamma_{\text{total}}
                                                                                                                                                                                                                                                            <4.3 \times 10^{-4}, CL = 90%
\Gamma(K^+ \to ~\mu^+\nu_e)/\Gamma_{\rm total}
                                                                                 [I] < 4 \times 10^{-3}, CL = 90%
                                                                                                                                                                    \Gamma(D_s^+ \to K^- \mu^+ \mu^+)/\Gamma_{\text{total}}
                                                                                                                                                                                                                                                            <5.9 \times 10^{-4}, CL = 90%
\Gamma(K^+ \rightarrow \pi^+ \mu^+ e^-)/\Gamma_{\text{total}}
                                                                                        < 2.1 \times 10^{-10}, CL = 90%
                                                                                                                                                                    \Gamma(D_s^+ \to K^*(892)^- \mu^+ \mu^+)/\Gamma_{\text{total}}
                                                                                                                                                                                                                                                            <1.4 \times 10^{-3}, CL = 90%
\Gamma(K^+ \rightarrow \pi^+ \mu^- e^+)/\Gamma_{\text{total}}
                                                                                        < 7 \times 10^{-9}, CL = 90%
                                                                                                                                                                                                                                                            < 3.9 \times 10^{-3}, CL = 90%
\Gamma(K_L^0 \rightarrow e^{\pm} \mu^{\mp})/\Gamma_{\text{total}}
                                                                                                                                                                    \Gamma(B^+ \rightarrow \pi^- e^+ e^+)/\Gamma_{\text{total}}
                                                                                [h] < 3.3 \times 10^{-11}, CL = 90%
                                                                                                                                                                    \Gamma(B^+ \rightarrow \pi^- \mu^+ \mu^+)/\Gamma_{\text{total}}
                                                                                                                                                                                                                                                            <9.1 \times 10^{-3}, CL = 90%
\Gamma(\kappa_I^{\bar{0}} \rightarrow e^{\pm}e^{\pm}\mu^{\mp}\mu^{\mp})/\Gamma_{\text{total}}
                                                                                [h] <6.1 × 10<sup>-9</sup>, CL = 90%
```

 $<1.1 \times 10^{-4}$, CL = 90%

 $<1.3 \times 10^{-4}$, CL = 90%

 $\Gamma(D^+ \to \pi^+ e^+ \mu^-)/\Gamma_{\text{total}}$

Tests of Conservation Laws

r(<i>Ξ</i> − →	$p\mu^-\mu^-)/\Gamma_{\text{total}}$	$<4 \times 10^{-4}$, CL = 90%
		$< 7.0 \times 10^{-4}$, CL = 90%

BARYON NUMBER

$\Gamma(\tau^- \to \overline{p}\gamma)/\Gamma_{\text{total}}$	$< 2.9 \times 10^{-4}$, CL = 90%
$\Gamma(\tau^- \to \overline{p}\pi^0)/\Gamma_{\text{total}}$	$<6.6 \times 10^{-4}$, CL = 90%
$\Gamma(\tau^- \to \overline{p}\eta)/\Gamma_{\text{total}}$	$<1.30 \times 10^{-3}$, CL = 90%
p mean life	$> 1.6 \times 10^{25}$ years
A few examples of proton or bound neutron decay decay channels, see the Baryon Summary Table.	follow. For limits on many other nucleon
$\tau(N \to e^+\pi)$	$> 130 (n), > 550 (p) \times 10^{30}$ years, CL = 90%
$\tau(N \to \mu^+ \pi)$	$> 100 (n)$, $> 270 (p) \times 10^{30}$ years, CL = 90%
$\tau(N \to e^+ K)$	$> 1.3 (n), > 150 (p) \times 10^{30}$ years, CL = 90%
$\tau(N \to \mu^+ K)$	$> 1.1 (n), > 120 (p) \times 10^{30}$ years, CL = 90%
limit on $n\overline{n}$ oscillations (bound n)	$[m] > 1.2 \times 10^8 \text{ s, CL} = 90\%$

ELECTRIC CHARGE (Q)

e mean life / branching fraction $\Gamma(n\to~p\,\nu_e\,\overline{\nu}_e)/\Gamma_{\rm total}$

limit on $n\overline{n}$ oscillations (free n)

[n]
$$>4.3 \times 10^{23}$$
 yr, CL = 68%
 $<8 \times 10^{-27}$, CL = 68%

 $>0.86 \times 10^8$ s, CL = 90%

$\Delta S = \Delta Q$ RULE

Allowed in second-order weak interactions.

$\Gamma(K^+ \rightarrow \pi^+ \pi^+ e^- \overline{\nu}_e) / \Gamma_{\text{total}}$	$<1.2 \times 10^{-8}$, CL = 90%
$\Gamma(K^+ \rightarrow \pi^+ \pi^+ \mu^- \overline{\nu}_{\mu})/\Gamma_{\text{total}}$	$< 3.0 \times 10^{-6}$, CL = 95%
$x = A(\overline{K}^0 \rightarrow \pi^- \ell^+ \nu)/A(K^0 \rightarrow \pi^- \ell^+ \nu) = A(\Delta^0 \rightarrow \pi^- \ell^+ \nu)$	$\Delta S = -\Delta Q$)/A($\Delta S = \Delta Q$)
real part of x	$0.006 \pm 0.018 (S = 1.3)$
imaginary part of x	$-0.003 \pm 0.026 (S = 1.2)$
$\Gamma(\Sigma^+ \to n\ell^+\nu)/\Gamma(\Sigma^- \to n\ell^-\overline{\nu})$	< 0.043
$\Gamma(\Sigma^+ \to ne^+ \nu_e)/\Gamma_{\text{total}}$	$<5 \times 10^{-6}$, CL = 90%
$\Gamma(\Sigma^+ \to n\mu^+\nu_\mu)/\Gamma_{\text{total}}$	$< 3.0 \times 10^{-5}$, CL = 90%
$\Gamma(\Xi^0 \to \Sigma^- e^+ \nu_e)/\Gamma_{\text{total}}$	$< 9 \times 10^{-4}$, CL = 90%
$\Gamma(\Xi^0 \to \Sigma^- \mu^+ \nu_\mu) / \Gamma_{\text{total}}$	$< 9 \times 10^{-4}$, CL = 90%

$\Delta S = 2$ FORBIDDEN

Allowed in second-order weak interactions.

$\Gamma(\Xi^0 \to p\pi^-)/\Gamma_{\text{total}}$	$<$ 4 $ imes$ 10 $^{-5}$, CL $=$ 90%
$\Gamma(\Xi^0 \to pe^-\overline{\nu}_e)/\Gamma_{\text{total}}$	$< 1.3 \times 10^{-3}$
$\Gamma(\Xi^0 \to p\mu^-\overline{\nu}_{\mu})/\Gamma_{\text{total}}$	$<1.3 \times 10^{-3}$
$\Gamma(\Xi^- \to n\pi^-)/\Gamma_{\text{total}}$	$<1.9 \times 10^{-5}$, CL = 90%
$\Gamma(\Xi^- \to ne^- \overline{\nu}_e)/\Gamma_{\text{total}}$	$< 3.2 \times 10^{-3}$, CL = 90%
$\Gamma(\Xi^- \rightarrow n\mu^-\overline{\nu}_{\mu})/\Gamma_{\text{total}}$	$<1.5 \times 10^{-2}$, CL = 90%
$\Gamma(\Xi^- \to p\pi^-\pi^-)/\Gamma_{\text{total}}$	$<4 \times 10^{-4}$, CL = 90%
$\Gamma(\Xi^+ \to p\pi^-e^-\overline{\nu}_e)/\Gamma_{\text{total}}$	$<4 \times 10^{-4}$, CL = 90%
$\Gamma(\Xi^- \rightarrow p\pi^-\mu^-\overline{\nu}_{\mu})/\Gamma_{\text{total}}$	$<4 \times 10^{-4}$, CL = 90%
$\Gamma(\Omega^- \to \Lambda \pi^-)/\Gamma_{\text{total}}$	$<1.9 \times 10^{-4}$, CL = 90%

$\Delta S = 2 \text{ VIA MIXING}$

Allowed in second-order weak interactions, e.g. mixing.

$$m_{K_L^0} - m_{K_S^0}$$
 (0.5301 ± 0.0014) × 10¹⁰ \bar{n} s⁻¹ $m_{K_L^0} - m_{K_S^0}$ (3.489 ± 0.009) × 10⁻¹² MeV

$\Delta C = 2 \text{ VIA MIXING}$

Allowed in second-order weak interactions, e.g. mixing.

$\Delta B = 2 \text{ VIA MIXING}$

Allowed in second-order weak interactions, e.g. mixing.

$$\begin{array}{lll} x_d & 0.172 \pm 0.010 \\ \Delta m_{B^0} = m_{B^0_H} - m_{B^0_L} & (0.464 \pm 0.018) \times 10^{12} \ \hbar \ s^{-1} \\ x_d = \Delta m_{B^0} / \Gamma_{B^0} & 0.723 \pm 0.032 \\ x_B \ \text{at high energy} & 0.118 \pm 0.006 \\ \Delta m_{B^0_S} = m_{B^0_{S^H}} - m_{B^0_{SL}} & >9.1 \times 10^{12} \ \hbar \ s^{-1}, \ \text{CL} = 95\% \\ x_S = \Delta m_{B^0_S} / \Gamma_{B^0_S} & >14.0, \ \text{CL} = 95\% \\ x_S & >0.4975, \ \text{CL} = 95\% \end{array}$$

$\Delta S = 1$ WEAK NEUTRAL CURRENT FORBIDDEN

Allowed by higher-order electroweak interactions.

$\Gamma(K^+ \rightarrow \pi^+ e^+ e^-)/\Gamma_{\text{total}}$		$(2.74 \pm 0.23) \times 10^{-7}$
$\Gamma(K^+ \rightarrow \pi^+ \mu^+ \mu^-)/\Gamma_{\text{total}}$		$(5.0 \pm 1.0) \times 10^{-8}$
$\Gamma(K^+ \rightarrow \pi^+ \nu \overline{\nu})/\Gamma_{\text{total}}$		$(4.2^{+9.7}_{-3.5}) \times 10^{-10}$
$\Gamma(\kappa_S^0 \to \mu^+ \mu^-)/\Gamma_{\text{total}}$		$< 3.2 \times 10^{-7}$, CL = 90%
$\Gamma(K_S^0 \rightarrow e^+e^-)/\Gamma_{\text{total}}$		$<1.4 \times 10^{-7}$, CL = 90%
$\Gamma(\kappa_S^{\bar{0}} \rightarrow \pi^0 e^+ e^-)/\Gamma_{\text{total}}$		$<1.1 \times 10^{-6}$, CL = 90%
$\Gamma(K_L^{\bar{0}} \rightarrow \mu^+\mu^-)/\Gamma_{\text{total}}$		$(7.2 \pm 0.5) \times 10^{-9} (S = 1.4)$
$\Gamma(\kappa_L^{\bar{0}} \to \mu^+ \mu^- \gamma)/\Gamma_{\text{total}}$		$(3.25 \pm 0.28) \times 10^{-7}$
$\Gamma(\kappa_L^{0} \rightarrow e^+e^-)/\Gamma_{\text{total}}$		$<4.1 \times 10^{-11}$, CL = 90%
$\Gamma(\kappa_L^0 \to e^+e^-\gamma)/\Gamma_{\text{total}}$		$(9.1 \pm 0.5) \times 10^{-6}$
$\Gamma(\kappa_L^0 \to e^+e^-\gamma\gamma)/\Gamma_{\text{total}}$	[q]	$(6.5 \pm 1.2) \times 10^{-7}$
$\Gamma(K_L^{0} \rightarrow \pi^+\pi^-e^+e^-)/\Gamma_{\text{total}}$	[q]	$<4.6 \times 10^{-7}$, CL = 90%
$\Gamma(K_L^{0} \rightarrow \mu^+\mu^-e^+e^-)/\Gamma_{\text{total}}$		$(2.9^{+6.7}_{-2.4}) \times 10^{-9}$
$\Gamma(\kappa_L^{0} \rightarrow e^+e^-e^+e^-)/\Gamma_{\text{total}}$		$(4.1 \pm 0.8) \times 10^{-8} (S = 1.2)$
$\Gamma(\kappa_L^{0} \rightarrow \pi^0 \mu^+ \mu^-)/\Gamma_{\text{total}}$		$<$ 5.1 \times 10 ⁻⁹ , CL = 90%
$\Gamma(\kappa_L^0 \to \pi^0 e^+ e^-)/\Gamma_{\text{total}}$		$<4.3 \times 10^{-9}$, CL = 90%
$\Gamma(K_L^{\bar{0}} \to \pi^0 \nu \overline{\nu})/\Gamma_{\text{total}}$		$<$ 5.8 \times 10 ⁻⁵ , CL $=$ 90%
$\Gamma(\Sigma^+ \to pe^+e^-)/\Gamma_{\text{total}}$		$< 7 \times 10^{-6}$

$\Delta C = 1$ WEAK NEUTRAL CURRENT FORBIDDEN

Allowed by higher-order electroweak interactions.

$\Gamma(D^+ \rightarrow \pi^+ e^+ e^-)/\Gamma_{\text{total}}$	$<6.6 \times 10^{-5}$, CL = 90%
$\Gamma(D^+ \rightarrow \pi^+ \mu^+ \mu^-)/\Gamma_{\text{total}}$	$<1.8 \times 10^{-5}$, CL = 90%
$\Gamma(D^+ \rightarrow \rho^+ \mu^+ \mu^-)/\Gamma_{\text{total}}$	$< 5.6 \times 10^{-4}$, CL = 90%
$\Gamma(D^0 \rightarrow e^+e^-)/\Gamma_{\text{total}}$	$<1.3 \times 10^{-5}$, CL = 90%
$\Gamma(D^0 \rightarrow \mu^+ \mu^-)/\Gamma_{\text{total}}$	$<4.1 \times 10^{-6}$, CL = 90%
$\Gamma(D^0 \to \pi^0 e^+ e^-)/\Gamma_{\text{total}}$	$<4.5 \times 10^{-5}$, CL = 90%
$\Gamma(D^0 \rightarrow \pi^0 \mu^+ \mu^-)/\Gamma_{\text{total}}$	$<1.8 \times 10^{-4}$, CL = 90%
$\Gamma(D^0 \to \eta e^+ e^-)/\Gamma_{\text{total}}$	$<1.1 \times 10^{-4}$, CL = 90%
$\Gamma(D^0 \rightarrow \eta \mu^+ \mu^-)/\Gamma_{\text{total}}$	$<5.3 \times 10^{-4}$, CL = 90%
$\Gamma(D^0 \rightarrow \rho^0 e^+ e^-)/\Gamma_{\text{total}}$	$<1.0 \times 10^{-4}$, CL = 90%
$\Gamma(D^0 \rightarrow \rho^0 \mu^+ \mu^-)/\Gamma_{\text{total}}$	$<2.3 \times 10^{-4}$, CL = 90%
$\Gamma(D^0 \rightarrow \omega e^+ e^-)/\Gamma_{\text{total}}$	$<1.8 \times 10^{-4}$, CL = 90%
$\Gamma(D^0 \to \omega \mu^+ \mu^-)/\Gamma_{\text{total}}$	$< 8.3 \times 10^{-4}, CL = 90\%$
$\Gamma(D^0 \rightarrow \phi e^+ e^-)/\Gamma_{\text{total}}$	$<5.2 \times 10^{-5}$, CL = 90%
$\Gamma(D^0 \to \phi \mu^+ \mu^-)/\Gamma_{\text{total}}$	$<4.1 \times 10^{-4}$, CL = 90%

$\Gamma(D^0 \rightarrow \pi^+\pi^-\pi^0\mu^+\mu^-)/\Gamma_{\text{total}}$	$< 8.1 \times 10^{-4}$, CL = 90%
$\Gamma(D_s^+ \to K^+ \mu^+ \mu^-)/\Gamma_{\text{total}}$	$<$ 5.9 \times 10 ⁻⁴ , CL = 90%
$\Gamma(D_s^+ \to K^*(892)^+ \mu^+ \mu^-)/\Gamma_{\text{total}}$	$<1.4 \times 10^{-3}$, CL = 90%
$\Gamma(\Lambda_c^{+} \rightarrow \rho \mu^{+} \mu^{-})/\Gamma_{\text{total}}$	$< 3.4 \times 10^{-4}$, CL = 90%

$\Delta B = 1$ WEAK NEUTRAL CURRENT FORBIDDEN

Allowed by higher-order electroweak interactions.

$\begin{array}{lll} \Gamma(B^+ \to \pi^+ e^+ e^-)/\Gamma_{\text{total}} & <3.9 \times 10^{-3}, \text{CL} = 90\% \\ \Gamma(B^+ \to \pi^+ \mu^+ \mu^-)/\Gamma_{\text{total}} & <9.1 \times 10^{-3}, \text{CL} = 90\% \\ \Gamma(B^+ \to K^+ e^+ e^-)/\Gamma_{\text{total}} & <6 \times 10^{-5}, \text{CL} = 90\% \\ \Gamma(B^+ \to K^+ \mu^+ \mu^-)/\Gamma_{\text{total}} & <1.0 \times 10^{-5}, \text{CL} = 90\% \\ \Gamma(B^+ \to K^* (892)^+ e^+ e^-)/\Gamma_{\text{total}} & <6.9 \times 10^{-4}, \text{CL} = 90\% \\ \Gamma(B^0 \to \gamma\gamma)/\Gamma_{\text{total}} & <1.2 \times 10^{-3}, \text{CL} = 90\% \\ \Gamma(B^0 \to \gamma\gamma)/\Gamma_{\text{total}} & <3.9 \times 10^{-5}, \text{CL} = 90\% \end{array}$
$\begin{array}{lll} \Gamma(B^+ \to \pi^+ \mu^+ \mu^-)/\Gamma_{\text{total}} & <9.1 \times 10^{-3}, \text{CL} = 90\% \\ \Gamma(B^+ \to K^+ e^+ e^-)/\Gamma_{\text{total}} & <6 \times 10^{-5}, \text{CL} = 90\% \\ \Gamma(B^+ \to K^+ \mu^+ \mu^-)/\Gamma_{\text{total}} & <1.0 \times 10^{-5}, \text{CL} = 90\% \\ \Gamma(B^+ \to K^* (892)^+ e^+ e^-)/\Gamma_{\text{total}} & <6.9 \times 10^{-4}, \text{CL} = 90\% \\ \Gamma(B^+ \to K^* (892)^+ \mu^+ \mu^-)/\Gamma_{\text{total}} & <1.2 \times 10^{-3}, \text{CL} = 90\% \end{array}$
$ \begin{array}{lll} \Gamma(B^+ \to K^+ e^+ e^-)/\Gamma_{\text{total}} & <6 \times 10^{-5}, \text{CL} = 90\% \\ \Gamma(B^+ \to K^+ \mu^+ \mu^-)/\Gamma_{\text{total}} & <1.0 \times 10^{-5}, \text{CL} = 90\% \\ \Gamma(B^+ \to K^*(892)^+ e^+ e^-)/\Gamma_{\text{total}} & <6.9 \times 10^{-4}, \text{CL} = 90\% \\ \Gamma(B^+ \to K^*(892)^+ \mu^+ \mu^-)/\Gamma_{\text{total}} & <1.2 \times 10^{-3}, \text{CL} = 90\% \\ \end{array} $
$ \Gamma(B^+ \to K^+ \mu^+ \mu^-)/\Gamma_{\text{total}} $ <1.0 × 10 ⁻⁵ , CL = 90% $\Gamma(B^+ \to K^*(892)^+ e^+ e^-)/\Gamma_{\text{total}} $ <6.9 × 10 ⁻⁴ , CL = 90% $\Gamma(B^+ \to K^*(892)^+ \mu^+ \mu^-)/\Gamma_{\text{total}} $ <1.2 × 10 ⁻³ , CL = 90%
$\Gamma(B^+ \to K^*(892)^+ e^+ e^-)/\Gamma_{\text{total}}$ <6.9 × 10 ⁻⁴ , CL = 90% $\Gamma(B^+ \to K^*(892)^+ \mu^+ \mu^-)/\Gamma_{\text{total}}$ <1.2 × 10 ⁻³ , CL = 90%
$\Gamma(B^+ \to K^*(892)^+ \mu^+ \mu^-)/\Gamma_{\text{total}}$ <1.2 × 10 ⁻³ , CL = 90%
$\Gamma(8^0 \rightarrow \gamma \gamma)/\Gamma_{\text{base}}$ <39 × 10 ⁻⁵ Cl = 90%
(5.5 × 10) CE = 50%
$\Gamma(B^0 \to e^+ e^-)/\Gamma_{\text{total}}$ <5.9 × 10 ⁻⁶ , CL = 90%
$\Gamma(B^0 \to \mu^+ \mu^-)/\Gamma_{\text{total}}$ <6.8 × 10 ⁻⁷ , CL = 90%
$\Gamma(B^0 \to K^0 e^+ e^-)/\Gamma_{\text{total}}$ <3.0 × 10 ⁻⁴ , CL = 90%
$\Gamma(B^0 \to K^0 \mu^+ \mu^-)/\Gamma_{\text{total}}$ <3.6 × 10 ⁻⁴ , CL = 90%
$\Gamma(B^0 \to K^*(892)^0 e^+ e^-)/\Gamma_{\text{total}}$ <2.9 × 10 ⁻⁴ , CL = 90%
$\Gamma(B^0 \to K^*(892)^0 \mu^+ \mu^-)/\Gamma_{\text{total}}$ <2.3 × 10 ⁻⁵ , CL = 90%
$\Gamma(B^0 \to K^*(892)^0 \nu \bar{\nu})/\Gamma_{\text{total}}$ <1.0 × 10 ⁻³ , CL = 90%
$\Gamma(B \to e^+e^-s)/\Gamma_{\text{total}}$ <5.7 x 10 ⁻⁵ , CL = 90%
$\Gamma(B \to \mu^+ \mu^- s)/\Gamma_{\text{total}}$ <5.8 × 10 ⁻⁵ , CL = 90%
$\Gamma(\overline{b} \rightarrow \mu^{+}\mu^{-} \text{ anything})/\Gamma_{\text{total}}$ <3.2 × 10 ⁻⁴ , CL = 90%
$\Gamma(B_s^0 \to \mu^+ \mu^-)/\Gamma_{\text{total}}$ <2.0 × 10 ⁻⁶ , CL = 90%
$\Gamma(B_s^0 \to e^+ e^-)/\Gamma_{\text{total}}$ <5.4 × 10 ⁻⁵ , CL = 90%
$\Gamma(B_s^0 \to \phi \nu \overline{\nu})/\Gamma_{\text{total}}$ <5.4 × 10 ⁻³ , CL = 90%

NOTES

In this Summary Table:

When a quantity has "(S = ...)" to its right, the error on the quantity has been enlarged by the "scale factor" S, defined as $S=\sqrt{\chi^2/(N-1)}$, where N is the number of measurements used in calculating the quantity. We do this when S > 1, which often indicates that the measurements are inconsistent. When S > 1.25, we also show in the Particle Listings an ideogram of the measurements. For more about S, see the Introduction.

- [a] C parity forbids this to occur as a single-photon process.
- [b] Time-reversal invariance requires this to be 0° or 180°.
- [c] Allowed by higher-order electroweak interactions.
- [d] Violates CP in leading order. Test of direct CP violation since the indirect CP-violating and CP-conserving contributions are expected to be suppressed.
- $[e]~\epsilon'/\epsilon$ is derived from $\left|\eta_{00}/\eta_{+-}\right|$ measurements using theoretical input on phases.
- [f] Neglecting photon channels. See, e.g., A. Pais and S.B. Treiman, Phys. Rev. D12, 2744 (1975).
- [g] Derived from measured values of ϕ_{+-} , ϕ_{00} , $|\eta|$, $|m_{K_L^0}-m_{K_S^0}|$, and $\tau_{K_L^0}$, as described in the introduction to "Tests of Conservation Laws."
- [h] The value is for the sum of the charge states of particle/antiparticle states indicated.
- $[\emph{i}]$ A test of additive vs. multiplicative lepton family number conservation.
- $[j] \Delta(m^2) = 100 \text{ eV}^2.$
- $[k] 190 \text{ eV}^2 < \Delta(m^2) < 320 \text{ eV}^2.$
- [/] Derived from an analysis of neutrino-oscillation experiments.
- [m] There is some controversy about whether nuclear physics and model dependence complicate the analysis for bound neutrons (from which the best limit comes). The second limit here is from reactor experiments with free neutrons.
- [n] This is the best "electron disappearance" limit. The best limit for the mode e $^ \to$ $\nu\gamma$ is $> 2.35 \times 10^{25}$ yr (CL=68%).
- [o] The D_1^0 - D_2^0 limits are inferred from the D^0 - \overline{D}^0 mixing ratio $\Gamma(K^+\ell^-\overline{\nu}_\ell({\rm via}\ \overline{D}^0)) / \Gamma(K^-\ell^+\nu_\ell)$.
- [p] The larger limit (from E791) allows interference between the doubly Cabibbo-suppressed and mixing amplitudes; the smaller limit (from E691) doesn't. See the papers for details.
- [q] See the K⁰_L Particle Listings for the energy limits used in this measurement.

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Table 1.1. Reviewed 1998 by B.N. Taylor (NIST). Based mainly on the "1986 Adjustment of the Fundamental Physical Constants" by E.R. Cohen and B.N. Taylor, Rev. Mod. Phys. 59, 1121 (1987). The last group of constants (beginning with the Fermi coupling constant) comes from the Particle Data Group. The figures in parentheses after the values give the 1-standard-deviation uncertainties in the last digits; the corresponding uncertainties in parts per million (ppm) are given in the last column. This set of constants (aside from the last group) is recommended for international use by CODATA (the Committee on Data for Science and Technology).

Since the 1986 adjustment, new experiments have yielded improved values for a number of constants, including the Rydberg constant R_{∞} , the Planck constant h, the fine-structure constant α , and the molar gas constant R, and hence also for constants directly derived from these, such as the Boltzmann constant k and Stefan-Boltzmann constant σ . The new results and their impact on the 1986 recommended values are discussed extensively in "Recommended Values of the Fundamental Physical Constants: A Status Report," B.N. Taylor and E.R. Cohen, J. Res. Natl. Inst. Stand. Technol. 95, 497 (1990); see also E.R. Cohen and B.N. Taylor, "The Fundamental Physical Constants," Phys. Today, August 1997 Part 2, BG7. In general, the new results give uncertainties for the affected constants that are 5 to 7 times smaller than the 1986 uncertainties but the changes in the values themselves are smaller than twice the 1986 uncertainties. Because the output values of a least-squares adjustment are correlated, the new results cannot readily be incorporated with the 1986 values. Until the next complete adjustment of the constants (expected by the end of 1998), the 1986 CODATA set, given (in part) below, remains the set of choice. The full 1986 set (to be replaced by the new set, when available) may be found at http://physics.nist.gov/cuu.

Quantity	Symbol, equation	Value Un	cert. (ppm)
speed of light in vacuum	c	299 792 458 m s ⁻¹	exact*
Planck constant	h	$6.626\ 075\ 5(40)\times10^{-34}\ \mathrm{J}\ \mathrm{s}$	0.60
Planck constant, reduced	$\hbar \equiv h/2\pi$	$1.054\ 572\ 66(63) \times 10^{-34}\ \text{J s}$	0.60
		$= 6.582\ 122\ 0(20) \times 10^{-22}\ \text{MeV s}$	0.30
electron charge magnitude	e	$1.602\ 177\ 33(49) \times 10^{-19}\ C = 4.803\ 206\ 8(15) \times 10^{-10}\ esu$	
conversion constant	$\hbar c (\hbar c)^2$	197.327 053(59) MeV fm 0.389 379 66(23) GeV ² mbarn	0.30
	(116)		0.59
electron mass	m_e	$0.510 999 06(15) \text{ MeV}/c^2 = 9.109 389 7(54) \times 10^{-31} \text{ kg}$	0.30, 0.59
proton mass	m_p	938.272 31(28) MeV/ c^2 = 1.672 623 1(10)×10 ⁻²⁷ kg	0.30, 0.59
T. 4		$= 1.007 \ 276 \ 470(12) \ \mathbf{u} = 1836.152 \ 701(37) \ m_e$	0.012, 0.020
deuteron mass	m_d	$1875.613\ 39(57)\ \text{MeV}/c^2$	0.30
unified atomic mass unit (u)	$(\text{mass}\ ^{12}\text{C}\ \text{atom})/12 = (1\ \text{g})/(N_A\ \text{mol})$		0.30, 0.59
permittivity of free space	$\left. egin{array}{c} \epsilon_0 \\ \mu_0 \end{array} ight. \left. \left. \epsilon_0 \mu_0 = 1/c^2 \right. ight.$	8.854 187 817 ×10 ⁻¹² F m ⁻¹	exact
permeability of free space	μ_0 \int $\epsilon_0 \mu_0 = 1/\epsilon$	$4\pi \times 10^{-7} \text{ N A}^{-2} = 12.566 \ 370 \ 614 \dots \times 10^{-7} \text{ N A}^{-2}$	exact
fine-structure constant	$lpha=e^2/4\pi\epsilon_0\hbar c$	$1/137.0359895(61)^{\dagger}$	0.045
classical electron radius	$r_e = e^2/4\pi\epsilon_0 m_e c^2$	2.817 940 92(38)×10 ⁻¹⁵ m	0.13
electron Compton wavelength	$\lambda_e = \hbar/m_e c = r_e \alpha^{-1}$	$3.861\ 593\ 23(35) \times 10^{-13}\ \mathrm{m}$	0.089
Bohr radius $(m_{ m nucleus} = \infty)$	$a_{\infty} = 4\pi\epsilon_0 \hbar^2/m_e e^2 = r_e \alpha^{-2}$	$0.529\ 177\ 249(24)\times 10^{-10}\ \mathrm{m}$	0.045
wavelength of 1 eV/ c particle	hc/e	1.239 842 44(37)×10 ⁻⁶ m	0.30
Rydberg energy	$hcR_{\infty} = m_e e^4 / 2(4\pi\epsilon_0)^2 \hbar^2 = m_e c^2 \alpha^2 / 2$		0.30
Thomson cross section	$\sigma_T = 8\pi r_e^2/3$	0.665 246 16(18) barn	0.27
Bohr magneton	$\mu_B=e\hbar/2m_e$	$5.788~382~63(52)\times10^{-11}~{ m MeV}~{ m T}^{-1}$	0.089
nuclear magneton	$\mu_N = e\hbar/2m_p$	$3.152\ 451\ 66(28)\times10^{-14}\ MeV\ T^{-1}$	0.089
electron cyclotron freq./field	$\omega_{ m cycl}^{m e}/B=e/m_{m e}$	$1.758\ 819\ 62(53)\times10^{11}\ \mathrm{rad\ s^{-1}\ T^{-1}}$	0.30
proton cyclotron freq./field	$\omega_{\mathrm{cycl}}^{p}/B=e/m_{p}$	$9.578~830~9(29)\times10^7~{\rm rad~s^{-1}~T^{-1}}$	0.30
gravitational constant [‡]	G_N .	$6.672\ 59(85)\times10^{-11}\ \mathrm{m^3\ kg^{-1}\ s^{-2}}$	128
	•	$= 6.707 11(86) \times 10^{-39} \hbar c (\text{GeV}/c^2)^{-2}$	128
standard grav. accel., sea level	g	9.806 65 m s ⁻²	exact
Avogadro constant	N_A	$6.022\ 136\ 7(36) \times 10^{23}\ \mathrm{mol}^{-1}$	0.59
Boltzmann constant	k	$1.380\ 658(12) \times 10^{-23}\ \mathrm{J\ K^{-1}}$	8.5
		$= 8.617 \ 385(73) \times 10^{-5} \ eV \ K^{-1}$	8.4
molar volume, ideal gas at STP	$N_A k(273.15 \mathrm{\ K})/(101\ 325 \mathrm{\ Pa})$	$22.414\ 10(19)\times10^{-3}\ m^3\ mol^{-1}$	8.4
Wien displacement law constant	$b = \lambda_{\max} T$	2.897 756(24)×10 ⁻³ m K	8.4
Stefan-Boltzmann constant	$\sigma = \pi^2 k^4 / 60 \hbar^3 c^2$	$5.670\ 51(19)\times10^{-8}\ W\ m^{-2}\ K^{-4}$	34
Fermi coupling constant**	$G_F/(\hbar c)^3$	$1.166\ 39(1) \times 10^{-5}\ GeV^{-2}$	9
weak mixing angle	$\sin^2\widehat{ heta}(M_Z)$ $(\overline{ ext{MS}})$	0.23124(24)	1000
W^{\pm} boson mass	m_W	$80.41(10) \text{ GeV}/c^2$	1200
Z^0 boson mass	m_Z	91.187(7) GeV/c^2	77
strong coupling constant	$\alpha_s(m_Z)$	0.119(2)	17000
$\pi = 3.141\ 592\ 653\ 5$			
	$\equiv 10^{-4} \text{T}$ 1 eV = 1.6	$602\ 177\ 33(49) \times 10^{-19} \text{ J}$ $kT \text{ at } 300 \text{ K} = [38.681\ 490]$	33)] ⁻¹ eV
•	•	782 662 $70(54) \times 10^{-36} \text{ kg}$ 0 °C = 273.15 K	
$1 \text{ barn} \equiv 10^{-28} \text{ m}^2$ 1 erg	$\equiv 10^{-7} \text{ J}$ 2.997 924 $58 \times 10^9 \text{ esu} = 160$	1 atmosphere $\equiv 760 \text{ torr} \equiv 101 325 \text{ Pa}$	

^{*} The meter is the length of the path traveled by light in vacuum during a time interval of 1/299 792 458 of a second.

 $^{^{\}dagger}$ At $Q^2=0.$ At $Q^2\approx m_W^2$ the value is approximately 1/128.

[‡] Absolute lab measurements of G_N have been performed only on scales of $10^{-1\pm1}$ m.

^{**} See discussion in Sec. 10 "Electroweak model and constraints on new physics."

2. ASTROPHYSICAL CONSTANTS

Table 2.1. Revised 1997 by D.E. Groom (LBNL) with the help of G.F. Smoot, M.S. Turner, and R.C. Willson. The figures in parentheses after some values give the one-standard deviation uncertainties in the last digit(s). While every effort has been made to obtain the most accurate current values of the listed quantities, the table does not represent a critical review or adjustment of the constants, and is not intended as a primary reference.

Quantity	Symbol, equation	Value	Reference
speed of light	c	299 792 458 m s ⁻¹	defined Ref. [1]
Newtonian gravitational constant	G_N	$6.67259(85) \times 10^{-11} \text{ m}^3 \text{ kg}^{-1} \text{ s}^{-2}$	Ref. [2]
astronomical unit	$\mathbf{A}\mathbf{\hat{U}}$	$1.4959787066(2) \times 10^{11}\mathrm{m}$	Ref. [3,4]
tropical year (equinox to equinox) (1994)	yr	31 556 925.2 s	Ref. [3]
sidereal year (fixed star to fixed star) (1994)	•	31 558 149.8 s	Ref. [3]
mean sidereal day		23 ^h 56 ^m 04 ^s 090 53	Ref. [3]
Jansky	$\mathbf{J}_{\mathbf{y}}$	$10^{-26} \text{ W m}^{-2} \text{Hz}^{-1}$	
Planck mass	$\sqrt{\hbar c/G_N}$	$1.221047(79) \times 10^{19} \text{ GeV}/c^2$ = $2.17671(14) \times 10^{-8} \text{ kg}$	uses Ref. [2]
parsec (1 AU/1 arc sec)	рс	$3.0856775807(4) \times 10^{16} \text{ m} = 3.262\text{ly}$	Ref. [5]
light year (deprecated unit)	ly	0.3066 pc = 0.9461×10^{16} m	(-)
Schwarzschild radius of the Sun	$2G_N M_{\odot}/c^2$	2.953 250 08 km	Ref. [6]
solar mass	M_{\odot}		Ref. [7]
solar luminosity	L_{\odot}	$1.98892(25) \times 10^{30} \text{ kg}$ $(3.846 \pm 0.008) \times 10^{26} \text{ W}$	Ref. [8]
solar equatorial radius	R_{\odot}	$6.96 \times 10^8 \text{ m}$	Ref. [3]
Earth equatorial radius	R_{\oplus}	$6.378140 \times 10^6 \text{ m}$	
Earth mass		$5.97370(76) \times 10^{24} \text{ kg}$	Ref. [3]
Earth mass	M_{\oplus}	5.915 10(16) × 10 kg	Ref. [9]
luminosity conversion	$oldsymbol{L}$	$3.02 \times 10^{28} \times 10^{-0.4} M_b$ W	Ref. [10]
	-	$(M_b = \text{absolute bolometric magnitude})$	1001. [10]
		` •	
flux conversion	<i>9</i>	= bolometric magnitude at 10 pc) $2.52 \times 10^{-8} \times 10^{-0.4} m_b \text{ W m}^{-2}$	f h
nux conversion	*		from above
		$(m_b = \text{apparent bolometric magnitude})$	
v_{\odot} around center of Galaxy	Θο	$220(20) \text{ km s}^{-1}$	Ref. [11]
solar distance from galactic center	R_{\circ}	8.0(5) kpc	Ref. [12]
Hubble expansion rate [†]	H_0	$100 \ h_0 \ { m km \ s^{-1} \ Mpc^{-1}}$	
		$= h_0 \times (9.77813 \text{ Gyr})^{-1}$	Ref. [13]
normalized Hubble expansion rate [†]	h_0	$0.6 < h_0 < 0.8$	Ref. [14]
critical density of the universe [†]	$\rho_c = 3H_0^2/8\pi G_N$	$2.77536627 \times 10^{11}h_0^2M_{\odot}{ m Mpc}^{-3}$	()
	PC0/ 14	$= 1.87882(24) \times 10^{-29} h_0^2 \text{ g cm}^{-3}$	
		$= 1.053 94(13) \times 10^{-5} h_0^2 \text{ GeV cm}^{-3}$	
local disk density	0.11.1	$3-12 \times 10^{-24} \text{ g cm}^{-3} \approx 2-7 \text{ GeV}/c^2 \text{ cm}^{-3}$	Ref. [15]
local halo density	ρ _{disk}	$2-13 \times 10^{-25} \text{ g cm}^{-3} \approx 0.1-0.7 \text{ GeV/c}^2 \text{ cm}^{-3}$	Ref. [16]
pressureless matter density of the universe [†]	$rac{ ho_{ m halo}}{\Omega_M \equiv ho_M/ ho_c}$	$0.2 < \Omega_M < 1$	Ref. [17]
		_ =-=	
scaled cosmological constant	$\Omega_{\Lambda} = \Lambda c^2/3H_0^2$	$-1 < \Omega_{\Lambda} < 2$	Ref. [18]
scale factor for cosmological constant	$c^2/3H_0^2$	$2.853 imes 10^{51} h_0^{-2} \mathrm{m}^2$	•
age of the universe ^T	t_0	$11.5 + 1 \pm 1.5 \; \mathrm{Gyr}$	Ref. [19]
	$\Omega_0 h_0^2$ for $\Lambda = 0$	$\leq 2.4 \text{ for } t_0 \geq 10 \text{ Gyr}$	Ref. [10]
	-	$\leq 1 \text{ for } t_0 \geq 10 \text{ Gyr}, h_0 > 0.4$	Ref. [10]
		$\leq 0.4 \text{ for } t_0 \geq 10 \text{ Gyr}, h_0 > 0.6$	Ref. [10]
cosmic background radiation (CBR) temperature	e^{\dagger} T_{0}	$2.728 \pm 0.002 \text{ K}$	Ref. [20,21]
solar velocity with respect to CBR	-	$369.3 \pm 2.5 \text{ km s}^{-1}$	Ref. [21,22]
energy density of CBR	$ ho_{\gamma}$	$4.6623 \times 10^{-34} (T/2.728)^4 \text{ g cm}^{-3}$	Ref. [10,21]
	• 1	$= 0.26153 (T/2.728)^4 \text{ eV cm}^{-3}$	r 1
energy density of relativistic particles (CBR + ν	$ ho_R$	$7.8388 \times 10^{-34} (T/2.728)^4 \mathrm{g \ cm^{-3}}$	Ref. [10,21]
		$= 0.43972 (T/2.728)^4 \text{ eV cm}^{-3}$	
number density of CBR photons	n_{γ}	$411.87 (T/2.728)^3 \text{ cm}^{-3}$	Ref. [10,21]
entropy density/Boltzmann constant	s/k	$2899.3\;(T/2.728)^3\;\mathrm{cm^{-3}}$	Ref. [10]

[†] Subscript 0 indicates present-day values.

References:

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 The set of constants resulting from this adjustment has been recommended for international use by CODATA (Committee on Data for Science and Technology).

In the context of the scale dependence of field theoretic quantities, it should be remarked that absolute lab measurements of G_N have been performed only on scales of $10^{-1\pm 1}$ m.

- The Astronomical Almanac for the year 1994, U.S. Government Printing Office, Washington, and Her Majesty's Stationary Office, London (1993). Where possible, the values as adjusted for the fitting of the ephemerides to all the observational data are used.
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- 5. 1 AU divided by $\pi/648000$; quoted error is from the JPL Planetary Ephemerides value of the AU [4].
- 6. Heliocentric gravitational constant from Ref. 3 times $2/c^2$. The given 9-place accuracy appears to be consistent with uncertainties in actually defining the earth's orbital parameters.
- 7. Obtained from the heliocentric gravitational constant [3] and G_N [2]. The error is the 128 ppm standard deviation of G_N .
- 8. 1996 mean total solar irradiance (TSI) = 1367.5 ± 2.7 [23]; the solar luminosity is $4\pi \times (1 \text{ AU})^2$ times this quantity. This value increased by 0.036% between the minima of solar cycles 21 and 22. It was modulated with an amplitude of 0.039% during solar cycle 21 [24].

Sackmann et al. [25] use TSI = 1370 ± 2 W m⁻², but conclude that the solar luminosity ($L_{\odot} = 3.853 \times 10^{26}$ J s⁻¹) has an uncertainty of 1.5%. Their value is based on three 1977-83 papers, and they comment that the error is based on scatter among the reported values, which is substantially in excess of that expected from the individual quoted errors.

The conclusion of the 1971 review by Thekaekara and Drummond [26] $(1353 \pm 1\% \ W \ m^{-2})$ is often quoted [27]. The conversion to luminosity is not given in the Thekaekara and Drummond paper, and we cannot exactly reproduce the solar luminosity given in Ref. 27.

Finally, a value based on the 1954 spectral curve due to Johnson [28] $(1395\pm1\%~W~m^{-2}, {\rm or}~L_{\odot}=3.92\times10^{26}~{\rm J~s}^{-1})$ has been used widely, and may be the basis for higher value of the solar luminosity and corresponding lower value of the solar absolute bolometric magnitude (4.72) still common in the literature [10].

- Obtained from the geocentric gravitational constant [3] and G_N [2]. The error is the 128 ppm standard deviation of G_N.
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- 13. Conversion using length of tropical year.
- 14. See the section on the Hubble Constant (Sec. 17 of this Review).
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 - The value 0.3 GeV/c^2 has been taken as "standard" in several papers setting limits on WIMP mass limits, e.g. in M. Mori et al., Phys. Lett. **B289**, 463 (1992).
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3. INTERNATIONAL SYSTEM OF UNITS (SI)

See "The International System of Units (SI)," NIST Special Publication 330, B.N. Taylor, ed. (USGPO, Washington, DC, 1991); and "Guide for the Use of the International System of Units (SI)," NIST Special Publication 811, 1995 edition, B.N. Taylor (USGPO, Washington, DC, 1995).

Physical quantity	Name of unit	Symbol
	Base units	I
length	meter	m
mass	kilogram	kg
time -	second	s
electric current	ampere	A
thermodynamic temperature	kelvin	К
amount of substance	mole	mol
luminous intensity	candela	cd
Derived uni	ts with special name	es
plane angle	radian	rad
solid angle	steradian	sr
frequency	hertz	Hz
energy	joule	J
force	newton	N
pressure	pascal	Pa
power	watt	w
electric charge	coulomb	C
electric potential	volt	v
electric resistance	ohm	Ω
electric conductance	siemens	S
electric capacitance	farad	F
magnetic flux	weber	Wb
inductance	henry	н
magnetic flux density	tesla	Т
luminous flux	lumen	lm
illuminance	lux	lx
celsius temperature	degree celsius	°C
activity (of a radioactive source)*	becquerel	Bq
absorbed dose (of ionizing radiation)*	gray	Gy
dose equivalent*	sievert	Sv

^{*}See our section 26, on "Radioactivity and radiation protection," p. 163.

SI	prefixe	s
10^{24}	yotta	(Y)
10^{21}	zetta	(Z)
10^{18}	exa	(E)
10^{15}	peta	(P)
10^{12}	tera	(T)
10 ⁹	giga	(G)
10^{6}	mega	(M)
10^{3}	kilo	(k)
10^2	hecto	(h)
10	deca	(da)
10^{-1}	deci	(d)
10^{-2}	centi	(c)
10^{-3}	milli	(m)
10^{-6}	micro	(μ)
10^{-9}	nano	(n)
10^{-12}	pico	(p)
10^{-15}	femto	(f)
10-18	atto	(a)
10^{-21}	zepto	(z)
10^{-24}	yocto	(y)

4. PERIODIC TABLE OF THE ELEMENTS

(u). Errors range from 1 to 9 in the last digit quoted. Relative isotopic abundances often vary considerably, both in natural and commercial samples. A number in parentheses is the mass of the longest-lived isotope of that element—no stable isotope exists. However, although Th, Pa, and U have no stable isotopes, they do have characteristic terrestrial compositions, and meaningful weighted masses can be given. For elements 110–112, the atomic numbers of known isotopes are given. Adapted from the Commission of Atomic Weights and Isotopic Abundances, "Atomic Weights of the Elements 1995," Pure and Applied Chemistry 68, 2339 (1996), and G. Audi and A.H. Wapstra, "The 1993 Mass Evaluation," Nucl. Phys. A565, 1 (1993). The names given below for elements 104 to 109 are those recommended by the Table 4.1. Revised 1997 by C.G. Wohl (LBNL). The atomic number (top left) is the number of protons in the nucleus. The atomic mass (bottom) is weighted by isotopic abundances in the Earth's surface. Atomic masses are relative to the mass of the carbon-12 isotope, defined to be exactly 12 unified atomic mass units international Union of Pure and Applied Chemistry in late 1997.

₹																	18 VIIIA
1	H												{ } !		 		2 He
Hydrogen	2											13	14	15	16	17	Helium
1.00794	M											≝	\$	∀	ΛΙΑ	VIIA	4.002602
3	3 Li 4 Be	r			1							5 B	O 0	2	B 6 C 7 N 8 O 9 F 10 Ne	9 F	10 Ne
Lithium	Lithium Beryllium		PER	IODIC	TABI	PERIODIC TABLE OF THE ELEMENTS	THE E	LEME	SLV			Boron		Carbon Nitrogen	Oxygen	Fluorine	Neon
6.941	9.012182											10.811	12.0107	14.00674	10.811 12.0107 14.00674 15.9994 18.9984032 20.1797	18.9984032	20.1797
11 N	11 Na 12 Mg	,										13 Al	14 Si	15 P	13 Al 14 Si 15 P 16 S 17 Cl 18	17 CI	18 Ar
Sodium	Sodium Magnesium	89	4	ಸು	9	<u>-</u>	ø	O	10	11	12	Aluminum	Silicon	Aluminum Silicon Phosph.	Sulfur	Chlorine	Argon
22.98977	22.989770 24.3050 IIIB IVB VB VIB	HIB	Ş	ΛB	ΝB	VIIB	[1	ſ	<u>8</u>	IB	26.981538	28.0855	30.973761	26.981538 28.0855 30.973761 32.066	35.4527	39.948
19	K 20 Ca	21 Sc	22 Ti	23 V	24 Cr	Cr 25 Mn 26	26 Fe	27 Co	Fe 27 Co 28 Ni 29 Cu 30	29 Cu	30 Zn	31 Ga	32 Ge	33 As	Zn 31 Ga 32 Ge 33 As 34 Se 35 Br 36	35 Br	36 Kr
Potassiur	Potassium Calcium Scandium Titanium Vanadium Chromium Manganese Iron	Scandium	Titanium	Vanadium	Chromium	Manganese	Iron	Cobalt	Cobalt Nickel Copper	Copper		Gallium	German.	Arsenic	Zinc Gallium German. Arsenic Selenium Bromine	Bromine	Krypton
39.0983	39.0983 40.078 44.955910 47.867 50.9415 51.9961	44.955910	47.867	50.9415	51.9961	54.938049	55.845	58.933200	58.6934	63.546	62.39	69.723	72.61	74.92160	54.938049 55.845 58.933200 58.6934 63.546 65.39 69.723 72.61 74.92160 78.96	79.904	83.80
37 R	38 Sr 39 V 40 Zr 41 Nb 42 Mo 43 Tc 44 Ru 45 Rh 46 Pd 47 Ag 48 Cd 49 In 50 Sn 51 Sb 52 Te 53	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te		1 54 Xe
Rubidim	Rubidium Strontium Yttrium Zirconium Niobium Molybd.	Yttrium	Zirconium	Niobium		Technet.	Ruthen.	Rhodium	Palladium	Silver	Cadmium	Indium	Tin	Antimony	Technet. Ruthen. Rhodium Palladium Silver Cadmium Indium Tin Antimony Tellurium Iodine	Iodine	Xenon
85.4678	85.4678 87.62 88.90585 91.224 92.90638 95.94	88.90585	91.224	92.90638		(97.907215)	101.07	102.90550	106.42	107.8682	112.411	114.818	118.710	121.760	97.907215) 101.07 102.90550 106.42 107.8682 112.411 114.818 118.710 121.760 127.60 126.90447	126.90447	131.29
55 C	55 Cs 56 Ba	1	72 Hf	73 Ta	74 W	75 Re	20 9z	11 LL	78 Pt	79 Au	80 Hg	81 TI	82 Pb	83 Bi	57-71 72 Hf 73 Ta 74 W 75 Re 76 Os 77 Ir 78 Pr 79 Au 80 Hg 81 Ti 82 Pb 83 Bi 84 Po 85 At 86	85 At	86 Rn
Cesium	Cesium Barium Lautha- Hafnium Tantalum Tungsten	Lantha-	Hafnium	Tantalum	Tungsten	Rhenium	Osmium	Iridium	Platinum	Gold	Mercury	Rhenium Osmium Iridium Platinum Gold Mercury Thallium	Lead	Bismuth	Lead Bismuth Polonium Astatine	Astatine	Radon
132.9054	132.90545 137.327 nides 178.49 180.9479 183.84	nides	178.49	180.9479	183.84	186.207	190.23	192.217	190.23 192.217 195.078 196.96655 200.59	196.96655	200.59	204.3833		208.98038	207.2 208.98038 (208.982415) (209.987131) (222.017570)	(209.987131)	(222.017570)
87 F	87 Fr 88 Ra 89-103 104 Rf 105 Db 106 Sg 107 Bh 108 Hs 109 Mt 110	89-103	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt		111	112						
Francium	Francium Radium Actinides Rutherford Dubnium Seaborg.	Actinides	Rutherford	Dubnium	Seaborg.	Bohrium Hassium Meitner.	Hassium	Meitner.									
(223.01973	(223.019731) (226.025402)		(261.1089) (262.1144) (263.1186)	(262.1144)	(263.1186)	(262.1231)	(265.1306)	(266.1378)	(262.1231) (265.1306) (266.1378) (269, 273) (272)	(272)	(277)						

Lu lum 167	اھ ي تــ
71 L Lutetiun 174.967	103 1 Lawrenc 262.1098
δ ¶ 4	S II (2)
Nd 61 Pm 62 Sm 63 Eu 64 Gd 65 Tb 66 Dy 67 Ho 68 Er 69 Tm 70 Yb 71 Lu lym. Prometh. Samarium Buropium Gadolin. Terbium Dyspros. Holmium Brbium Thulium Ytterbium Lutetium .24 (144.912745) 150.36 157.25 158.92534 162.50 164.93032 167.26 168.93421 173.04 174.967	39 Ac 90 Th 91 Pa 92 U 93 Np 94 Pu 95 Am 96 Cm 97 Bk 98 Cf 99 Es 100 Fm 101 Md 102 No 103 Lr Actinium Protactin. Uranium Neptunium Plutonium Plutonium Americ. Curium Berkelium Californ. Einstein. Fermium Mendelev. Nobelium Lawrenc. 227.02747) 232.0381 231.03588 238.0289 (237.048.064197) (243.061372) (247.070298) (251.079579) (252.08297) (257.095096) (256.0984277) (255.1011) (262.1098)
Tm 3421	Md elev. 8427)
69 Thul 168.9	101 Mend (258.09
136 ∰ EP	Fm ium isose)
68 Erbj	100 Ferm (257.09
H H 3032	Es tein. 8297)
67 Holm 164.9	99 Einst
S & Q	57.9 57.9
6 Dyspr 162.	8 Califo 51.079
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erbiu	rkeliv 7.0702
d 65	n 97
G dolin 57.25	17 mrium 07034
64 Ga	96 [247. C. 26
Eu Prium 964	Am eric. 61372
63 Euro 151	95 Am (243.0
Sm iium 36	Pu nium 4197)
62 Sama 150	94 Plutoi
Pm th. 745)	Np ium 166)
1 rome	3 eptun 37.048
9 1 2	0 × 0 × 0 × 0 × 0 × 0 × 0 × 0 × 0 × 0 ×
2.21	1 2 20
2 is 2	a 92
P eodyr 19076	P tactir 0358
59 Pras 140	91 Pro 231
Ce 116	Trium 0381
25 cr 140	90 17ho 232.
57 La 58 Ce 59 Pr 60 Lanthan. Cerium Praseodym. Neod 138,9055 140,116 140,90765 144,144	89 Ac 90 Th 91 Pa 92 Actinium Thorium Protactin. Uran (227.027747) 232.0381 231.03588 238.0
57 Lanth 138.9	39 Actini 27.02
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anide ieries	Actinide series
Lanthanide series	Act
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5. ELECTRONIC STRUCTURE OF THE ELEMENTS

Table 5.1. Reviewed 1998 by W.C. Martin (NIST). The electronic configurations and the ionization energies (except for a few newer values, marked with an *) are taken from "Atomic Spectroscopy," W.C. Martin and W.L. Wiese, in Atomic, Molecular, and Optical Physics Reference Book, G.W.F. Drake, ed., Amer. Inst. Phys., 1995. The electron configuration for, say, iron indicates an argon electronic core (see argon) plus six 3d electrons and two 4s electrons. The ionization energy is the least energy necessary to remove to infinity one electron from an atom of the element.

			Electron configuration			Ground state	Ionization energy
	Elen	nent	$(3d^5 = \text{five } 3d \text{ electron})$	s, etc.)		$^{2S+1}L_J$	(eV)
1	H	Hydrogen	18			² S _{1/2}	13.5984
2	He	Helium	$1s^2$			$^{1}S_{0}$	24.5874
3	Li	Lithium	(He) 2s			$^{2}S_{1/2}$	5.3917
4	Be	Beryllium	$(\mathrm{He})2s^2$			$^{1}S_{0}^{1/2}$	9.3227
5	В	Boron	$(\mathrm{He})2s^2 \;\; 2p$			${}^{2}P_{1/2}$	8.2980
6	C	Carbon	$(\mathrm{He})2s^2 2p^2$			${}^{3}P_{0}^{1/2}$	11.2603
7	N	Nitrogen	$(\mathrm{He})2s^22p^3$			$^{4}S_{3/2}$	14.5341
8	0	Oxygen	(He) $2s^2 2p^4$			3P_2	13.6181
9	\mathbf{F}	Fluorine	$(\mathrm{He})2s^2\ 2p^5$			$^{2}P_{3/2}$	17.4228
10	Ne	Neon	(He) $2s^2 2p^6$			${}^{1}S_{0}^{7}$	21.5646
11	Na	Sodium	(Ne) 3s			$^{2}S_{1/2}$	5.1391
12	Mg	Magnesium	$(Ne)3s^2$			$^{\iota}S_{0}$	7.6462
13	Al	Aluminum	$(Ne) 3s^2 3p$			${}^{2}P_{1/2}$	5.9858
14	Si	Silicon	$(Ne) 3s^2 3p^2$			$^{3}P_{0}$	8.1517
15	P	Phosphorus	$(Ne)3s^2 3p^3$			$^{4}S_{3/2}$	10.4867
16	S	Sulfur	(Ne) $3s^2 3p^4$			3P_2	10.3600
17	Cl	Chlorine	(Ne) $3s^2 3p^5$			$^{2}P_{3/2}$	12.9676
18	Ar	Argon	(Ne) $3s^2 3p^6$			${}^{1}S_{0}^{-}$	15.7596
19	К	Potassium	(Ar) 4s			$^{2}S_{1/2}$	4.3407
20	Ca	Calcium	(Ar) $4s^2$			${}^{1}S_{0}^{1/2}$	6.1132
21	Sc	Scandium	$(Ar) 3d 4s^2$	T		$^{2}D_{3/2}$	6.5615
22	Ti	Titanium	$(Ar) 3d^2 4s^2$	r		3F_2	6.8281
23	v	Vanadium	$(Ar) 3d^3 4s^2$	a	e l	${}^4F_{3/2}$	6.7463
24	Cr	Chromium	$(Ar) 3d^5 4s$	n	e	${}^{7}S_{3}$	6.7665
25	Mn	Manganese	$(Ar) 3d^5 4s^2$	S	m	$^{6}S_{5/2}$	7.4340
26	Fe	Iron	$(Ar) 3d^6 4s^2$	i	e	$^5D_4^{0/2}$	7.9024
27	Co	Cobalt	$(Ar) 3d^7 4s^2$	t i	n	$^4F_{9/2}$	7.8810
28	Ni	Nickel	$(Ar) 3d^8 4s^2$	0	t	$^3F_{A}$	7.6398
29	Cu	Copper	$({ m Ar})3d^{10}4s$	n	S	$^{2}S_{1/2}$	7.7264
30	$\mathbf{Z}\mathbf{n}$	Zinc	$(Ar) 3d^{10} 4s^2$			${}^{1}S_{0}$	9.3942
31	 Ga	Gallium	$(Ar) 3d^{10} 4s^2 4p$			${}^{2}P_{1/2}$	5.9993
32	Ge	Germanium	$(Ar) 3d^{10} 4s^2 4p^2$			$^{\mathfrak{d}}P_{0}$	7.8994
33	As	Arsenic	$(Ar) 3d^{10} 4s^2 4p^3$			$^{4}S_{3/2}$	9.7886
34	Se	Selenium	$(Ar) 3d^{10} 4s^2 4p^4$,		3P_2	9.7524
35	Br	Bromine	$(Ar) 3d^{10} 4s^2 4p^5$			$^{2}P_{3/2}$	11.8138
36	Kr	Krypton	$(Ar) 3d^{10} 4s^2 4p^6$			${}^{1}S_{0}^{5/2}$	13.9996
37	Rb	Rubidium	(Kr) 5s			² S _{1/2}	4.1771
38	Sr	Strontium	(Kr) 5s ²			${}^{1}S_{0}^{-7}$	5.6949
39	Y	Yttrium	(Kr) 4d 5s ²	T		$^{2}D_{3/2}$	6.2171
40	Zr	Zirconium	$(Kr)4d^2$ $5s^2$	r		${}^{3}F_{2}^{5/2}$	6.6339
41	Nb	Niobium	(Kr) 4d ⁴ 5s	a	e l	$^{6}D_{1/2}$	6.7589
42	Mo	Molybdenum	$(Kr)4d^5$ 5s	n	e	$^{7}S_{3}^{^{1/2}}$	7.0924
43	Tc	Technetium	$(\mathrm{Kr}) 4d^5 5s^2$	s	m	$^6S_{5/2}$	7.28
44	Ru	Ruthenium	$(Kr)4d^7$ 5s	i	e	$^{5}F_{5}$	7.3605
45	Rh	Rhodium	$(Kr) 4d^8 5s$	t i	n	$^4F_{9/2}$	7.4589
46	Pd	Palladium	$({\rm Kr})4d^{10}$	0	t	$^{1}S_{0}$	8.3369
47	Ag	Silver	$({ m Kr}) 4d_{-}^{10} 5s$	n	S	$^{2}S_{1/2}$	7.5763
48	Cd	Cadmium	$({ m Kr})4d^{10}5s^2$			${}^{1}S_{0}{}^{'}$	8.9938

49	In	Indium	$(Kr) 4d^{10} 5s^2 5p$		${}^{2}P_{1/2}$	5.7864
50	Sn	Tin	$(Kr)4d^{10}5s^2 5p^2$		3P_0	7.3439
51	Sb	Antimony	$(Kr) 4d^{10} 5s^2 5p^3$		$^{4}S_{3/2}$	8.6084
52	Te	Tellurium	$(\text{Kr}) 4d^{10} 5s^2 5p^4 (\text{Kr}) 4d^{10} 5s^2 5p^5$		$^{J}P_2$	9.0096
53	I	Iodine			${}^{2}P_{3/2}$	10.4513
54	Xe	Xenon	$(Kr) 4d^{10} 5s^2 5p^6$		$^{1}S_{0}$	12.1298
55	Cs	Cesium	(Xe) 6s		$^{2}S_{1/2}$	3.8939
56	Ba	Barium	(Xe) $6s^2$		$^{1}S_{0}$	5.2117
57	La	Lanthanum	(Xe) $5d 6s^2$		$^{2}D_{3/2}$	5.5770
58	Ce	Cerium	$(Xe)4f 5d 6s^2$		${}^{1}G_{4}$	5.5387
59	Pr	Praseodymium	$(Xe)4f^3$ $6s^2$	L	$^{4}I_{9/2}$	5.464
60	Nd	Neodymium	$(Xe) 4f^4 \qquad 6s^2$	a	5I_4	5.5250
61	Pm	Promethium	$(Xe)4f^5$ $6s^2$	n	$^{6}H_{5/2}$	5.58
62	Sm	Samarium	$(Xe) 4f^6 6s^2$	t	7F_0	5.6436
63	$\mathbf{E}\mathbf{u}$	Europium	$(Xe)4f^7 6s^2$	h	$^8S_{7/2}$	5.6704
64	Gd	Gadolinium	$(Xe)4f^7 \ 5d \ 6s^2$	a n	9D_2	6.1501
65	Tb	Terbium	$(Xe)4f^9 6s^2$	i	$^{6}H_{15/2}$	5.8638
66	Dy	Dysprosium	$(Xe)4f^{10}$ $6s^2$	d	$^{5}I_{8}$	5.9389
67	Ho	Holmium	$(Xe) 4f^{11} 6s^2$. е	$^{4}I_{15/2}$	6.0215
68	\mathbf{Er}	Erbium	$(Xe)4f^{12}$ $6s^2$	S	3H_6	6.1077
69	Tm	Thulium	$(Xe)4f^{13}$ $6s^2$		$^{2}F_{7/2}$	6.1843
70	Yb	Ytterbium	$(Xe)4f^{14} \qquad 6s^2$		$^{1}S_{0}$	6.2542
71	Lu	Lutetium	$(Xe)4f^{14}5d - 6s^2$		$^{2}D_{3/2}$	5.4259
72	Hf	Hafnium	$(Xe)4f^{14}5d^2 6s^2$	T	3F_2	6.8251
73	Ta	Tantalum	$(Xe)4f^{14}5d^3 6s^2$	r	${}^{4}F_{3/2}$	7.5496
74	w	Tungsten	$(Xe)4f^{14}5d^4 6s^2$	a l	${}^{5}D_{0}^{3/2}$	7.8640
75	Re	Rhenium	$(Xe)4f^{14}5d^5 6s^2$	n e	$^{6}S_{5/2}$	7.8335
76	Os	Osmium	$(Xe)4f^{14}5d^6 6s^2$	s m	5D_4	8.4382*
77	Ιr	Iridium	$(Xe)4f^{14}5d^7 6s^2$	i e	${}^4F_{9/2}$	8.9670*
78	Pt	Platinum	$(Xe)4f^{14}5d^9$ 6s	t n	${}^{3}D_{3}^{-9/2}$	8.9587
79	Au	Gold	$(Xe)4f^{14}5d^{10}6s$	i t	$2S_{1/2}$	9.2255
80	Hg	Mercury	$({ m Xe})4f^{14}5d^{10}6s^2$	n s	${}^{1}S_{0}^{i_{1}i_{2}}$	10.4375
		<i></i>	- -	· ⁻		
81	Tl	Thallium	$(Xe)4f^{14}5d^{10}6s^2 6p$ $(Xe)4f^{14}5d^{10}6s^2 6p^2$		${}^{2}P_{1/2}$	6.1082
82 83	Pb Bi	Lead	$(Xe)4f^{14}5d^{10}6s^2 6p^3$ $(Xe)4f^{14}5d^{10}6s^2 6p^3$		${}^{3}P_{0}^{-7}$	7.4167
		Bismuth Polonium	$(Xe)4f^{14}5d^{10}6s^2 6p^4$		${}^4S_{3/2} \ {}^3P_2$	7.2856
84 85	Po At	Astatine	$(Xe)4f^{14}5d^{10}6s^{2} 6p^{5}$ $(Xe)4f^{14}5d^{10}6s^{2} 6p^{5}$		${}^{2}P_{3/2}$	8.4167
86	Rn	Radon	$(Xe)4f^{14}5d^{10}6s^2 6p^6$		${}^{1}S_{0}^{3/2}$	10.7485
						
87	Fr	Francium	(Rn) 7s		$\frac{{}^{2}S_{1/2}}{1}$	4.0727
88	Ra	Radium	(Rn) $7s^2$		${}^{1}S_{0}$.	5.2784
89	Ac	Actinium	(Rn) $6d 7s^2$		$^{2}D_{3/2}$	5.17
90	$\mathbf{T}\mathbf{h}$	Thorium	$(Rn) \qquad 6d^2 \ 7s^2$		3F_2	6.3067
91	Pa	Protactinium	$(Rn)5f^2 \ 6d \ 7s^2$	A	$^{4}K_{11/2}$	5.89
92 `	U	Uranium	$(Rn)5f^3 6d 7s^2$	c	5L_6	6.1941
93	Np	Neptunium	$(Rn)5f^4 6d 7s^2$	t	$^{6}L_{11/2}$	6.2657
94	Pu	Plutonium	$(Rn)5f^6 7s^2$	i	$^{7}F_{0}$	6.0262
95	Am	Americium	$(Rn)5f^7$ $7s^2$	n i	$^8S_{7/2}$	5.9738
96	\mathbf{Cm}	Curium	$(\operatorname{Rn})5f^7 \ 6d \ 7s^2$	ď	9D_2	5.9915*
97	Bk	Berkelium	$(\mathrm{Rn})5f^9 \qquad 7s^2$	e	$^{6}H_{15/2}$	6.1979*
98	Cf	Californium	$(\text{Rn})5f^{10}$ $7s^2$	S	$^{5}I_{8}$	6.2817*
99	$\mathbf{E}\mathbf{s}$	Einsteinium	$(\text{Rn})5f^{11}$ $7s^2$		$^{4}I_{15/2}$	6.42
100	Fm	Fermium	$(\text{Rn})5f^{12}$ $7s^2$		$^{3}H_{6}$	6.50
101	Md	Mendelevium	$(Rn)5f^{13}$ $7s^2$		${}^{2}F_{7/2}$	6.58
102	No	Nobelium	$(\text{Rn})5f^{14}$ $7s^2$ $(\text{Rn})5f^{14}$ $7s^2$ $7p$?		${}^{1}S_{0}$	6.65
103	Lr	Lawrencium	- 		$^{2}P_{1/2}$?	
104	Rf	Rutherfordium	$(Rn)5f^{14}6d^2 7s^2$?		$^{3}F_{2}$?	6.0?

6. ATOMIC AND NUCLEAR PROPERTIES OF MATERIALS

Table 6.1. Revised April 1998 by D.E. Groom (LBNL). Gases are evaluated at 20°C and 1 atm (in parentheses) or at STP [square brackets]. Densities and refractive indices without parentheses or brackets are for solids or liquids, or are for cryogenic liquids at the indicated boiling point (BP) at 1 atm. Refractive indices are evaluated at the sodium D line. Data for compounds and mixtures are from Refs. 1 and 2.

Material	Z	A	$\langle Z/A \rangle$	collision length λ_T	Nuclear a interaction length λ_I $\{g/cm^2\}$	$rac{\mathrm{MeV}}{\mathrm{g/cm^2}} brace$		X_0 X_0 X	$\{\mathrm{g/cm^3}\}\ (\{\mathrm{g/\ell}\}$	Liquid boiling point at 1 atm(K)	Refractive index n $((n-1)\times 10^6$ for gas)
H ₂ gas	1	1.00794	0.99212	43.3	50.8	(4.103)	61.28 d	(731000)	(0.0838)[0.0899]		[139.2]
H_2	1	1.00794	1.00794	43.3	50.8	4.045 e	61.28^{d}	866	0.0708	20.39	1.112
D_2	1	2.0140	0.49652	45.7	54.7	(2.052)	122.4	724	0.169[0.179]	23.65	1.128 [138]
He	2	4.002602	0.49968	49.9	65.1	(1.937)	94.32	756	0.1249[0.1786]	4.224	1.024 [34.9]
Li	. 3	6.941	0.43221	54.6	73.4	1.639	82.76	155	0.534		
Be	4	9.012182	0.44384	55.8	75.2	1.594	65.19	35.28	1.848		
C .	6	12.011	0.49954	60.2	86.3	1.745	42.70	18.8	2.265 f		
N ₂	7	14.00674	0.49976	61.4	87.8	(1.825)	37.99	47.1	0.8073[1.250]	77.36	1.205 [298]
O ₂	8	15.9994	0.50002	63.2	91.0	(1.801)	34.24	30.0	1.141[1.428]	90.18	1.22 [296]
F ₂	9	18.9984032	0.47372	65.5	95.3	(1.675)	32.93	21.85	1.507[1.696]	85.24	[195]
Ne Al	10 13	20.1797 26.981539	0.49555 0.48181	66.1 70.6	96.6 106.4	(1.724) 1.615	$28.94 \\ 24.01$	24.0 8.9	1.204[0.9005] 2.70	27.09	1.092 [67.1]
Si	14	28.0855	0.49848	70.6	106.0	1.664	21.82	9.36	2.33		3.95
Ar	18	39.948	0.45059	76.4	117.2	(1.519)	19.55	14.0	1.396[1.782]	87.28	1.233 [283]
Ti	22	47.867	0.45948	79.9	124.9	1.476	16.17	3.56	4.54	01120	
Fe	26	55.845	0.46556	82.8	131.9	1.451	13.84	1.76	7.87		
Cu	29	63.546	0.45636	85.6	134.9	1.403	12.86	1.43	8.96		_
Ge	32	72.61	0.44071	88.3	140.5	1.371	12.25	2.30	5.323		_
Sn	50	118.710	0.42120	100.2	163	1.264	8.82	1.21	7.31		_
Xe	54	131.29	0.41130	102.8	169	(1.255)	8.48	2.40	2.953[5.858]	165.0	[701]
w	74	183.84	0.40250	110.3	185	1.145	6.76	0.35	19.3		
Pt	78	195.08	0.39984	113.3	189.7	1.129	6.54	0.305	21.45		
Pb	82	207.2	0.39575	116.2	194	1.123	6.37	0.56	11.35		
U	92	238.0289	0.38651	117.0	199	1.082	6.00	≈0.32	≈18.95 		
Air, (20°C, 1 a	atm.), [S	STP]	0.49919	62.0	90.0	(1.815)	36.66	[30420]	(1.205)[1.2931]	78.8	(273) [293]
H_2O			0.55509	60.1	83.6	1.991	36.08	36.1	1.00	373.15	1.33
CO_2			0.49989	62.4	89.7	(1.819)	36.2	[18310]	[1.977]		[410]
Shielding conc			0.50274	67.4	99.9	1.711	26.7	10.7	2.5		-
Borosilicate gl	` •	rex) "	0.49707	66.2	97.6	1.695	28.3	12.7	2.23		1.474
SiO ₂ (fused qu	,		0.49926	66.5	97.4	1.70 ⁱ	27.05	12.3	$2.20^{\ j}$	040.	1.458
Dimethyl ethe)20	0.54778	59.4	82.9		38.89		 -	248.7	
Methane, CH_4			0.62333	54.8	73.4	(2.417)	46.22	[64850]	0.4224[0.717]	111.7	[444]
Ethane, C ₂ H ₆			0.59861	55.8	75.7	(2.304)	45.47	[34035]	0.509(1.356) k		$(1.038)^{k}$
Propane, C ₃ H		CTT.	0.58962	56.2	76.5	(2.262)	45.20	[1 0000]	(1.879)	231.1	
Isobutane, (CI			0.58496	56.4	77.0	(2.239)	45.07	[16930]	[2.67]	261.42	[1900]
Octane, liquid Paraffin wax,			0.57778 0.57275	56.7 56.9	77.7 78.2	2.123 2.087	44.86 44.71	63.8 48.1	0.703 0.93	398.8	1.397
		-2/n≈23 ○113									-
Nylon, type 6		\ m	0.54790	58.5	81.5	1.974	41.84	36.7	1.14		_
Polycarbonate			0.52697	59.5	83.9	1.886	41.46	34.6	1.20		
Polyethylene to Polyethylene o		ate (Mylar)	0.52037 0.57034	60.2 57.0	85.7 78.4	1.848 2.076	39.95 44.64	$28.7 \\ \approx 47.9$	1.39 0.92-0.95		
Polyimide film		nn) p	0.51264	60.3	85.8	1.820	40.56	≈47.9 28.6	1.42		_
Lucite, Plexig	٠ -	·,	0.53937	59.3	83.0	1.929	40.49	≈34.4	1.16-1.20		≈1.49
Polystyrene, se		or ^r	0.53768	58.5	81.9	1.936	43.72	42.4	1.032		1.581
Polytetrafluor			0.47992	64.2	93.0	1.671	34.84	15.8	2.20		_
Polyvinyltolul			0.54155	58.3	81.5	1.956	43.83	42.5	1.032		_
Barium fluorio	le (BaF	2)	0.42207	92.0	145	1.303	9.91	2.05	4.89		1.56
Bismuth germ			0.42065	98.2	157	1.251	7.97	1.12	7.1		2.15
Cesium iodide		,	0.41569	102	167	1.243	8.39	1.85	4.53		1.80
Lithium fluori)	0.46262	62.2	88.2	1.614	39.25	14.91	2.632		1.392
Sodium fluorio)	0.47632	66.9	98.3	1.69	29.87	11.68	2.558	•	1.336
Sodium iodide	(NaI)		0.42697	94.6	151	1.305	9.49	2.59	3.67		1.775
											10.00
Silica Aerogel	υ		0.52019	64	92	1.83	29.83	≈150	0.1 - 0.3		$1.0+0.25\rho$

Material	Dielectric	Young's	Coeff. of	Specific	Electrical	Thermal
	constant $(\kappa = \epsilon/\epsilon_0)$	modulus	thermal	heat	resistivity	conductivity
	() is $(\kappa - 1) \times 10^6$	$[10^6~\mathrm{psi}]$	expansion	[cal/g-°C]	$[\mu\Omega \mathrm{cm}(@^{\circ}\mathrm{C})]$	[cal/cm-°C-sec]
	for gas		$[10^{-6}\mathrm{cm/cm}\text{-}^{\circ}\mathrm{C}]$			
$\overline{\mathrm{H}_2}$	(253.9)			_		
He	(64)			_		_
Li	_		56	0.86	8.55(0°)	0.17
Ве	_	37	12.4	0.436	5.885(0°)	0.38
C	_	0.7	0.6-4.3	0.165	1375(0°)	0.057
N_2	(548.5)	_		-	-	_
O_2	(495)			_	_	
Ne	(127)	_		_		
Al	_	10	23.9	0.215	$2.65(20^{\circ})$	0.53
Si	11.9	16	2.8 - 7.3	0.162	_	0.20
Ar	(517)	_			_	
Ti		16.8	8.5	0.126	50(0°)	_
Fe	_	28.5	11.7	0.11	9.71(20°)	0.18
Cu		16	16.5	0.092	1.67(20°)	0.94
Ge	16.0	_	5.75	0.073	<u>.</u>	0.14
\mathbf{Sn}		6	20	0.052	$11.5(20^{\circ})$	0.16
Xe	-					
W		50	4.4	0.032	5.5(20°)	0.48
\mathbf{Pt}	_	21	8.9	0.032	9.83(0°)	0.17
Pb	_	2.6	29.3	0.038	20.65(20°)	0.083
U	_	_	36.1	0.028	29(20°)	0.064

- 1. R.M. Sternheimer, M.J. Berger, and S.M. Seltzer, Atomic Data and Nuclear Data Tables 30, 261-271 (1984).
- 2. S.M. Seltzer and M.J. Berger, Int. J. Appl. Radiat. 33, 1189-1218 (1982).
- 3. S.M. Seltzer and M.J. Berger, Int. J. Appl. Radiat. 35, 665-676 (1984).
- a. σ_T , λ_T and λ_I are energy dependent. Values quoted apply to high energy range, where energy dependence is weak. Mean free path between collisions (λ_T) or inelastic interactions (λ_I) , calculated from $\lambda^{-1} = N_A \sum w_j \sigma_j / A_j$, where N is Avogadro's number and w_j is the weight fraction of the jth element in the element, compound, or mixture. σ_{total} at 80-240 GeV for neutrons ($\approx \sigma$ for protons) from Murthy et al., Nucl. Phys. **B92**, 269 (1975). This scales approximately as $A^{0.77}$. $\sigma_{\text{inelastic}} = \sigma_{\text{total}} \sigma_{\text{elastic}} \sigma_{\text{quasielastic}}$; for neutrons at 60-375 GeV from Roberts et al., Nucl. Phys. **B159**, 56 (1979). For protons and other particles, see Carroll et al., Phys. Lett. **80B**, 319 (1979); note that $\sigma_I(p) \approx \sigma_I(n)$. σ_I scales approximately as $A^{0.71}$.
- b. For minimum-ionizing pions (results are very slightly different for other particles). Minimum dE/dx calculated in 1994, using density effect correction coefficients from Ref. 1. For electrons and positrons see Ref. 3. Ionization energy loss is discussed in Sec. 23.
- c. From Y.S. Tsai, Rev. Mod. Phys. 46, 815 (1974); X_0 data for all elements up to uranium are given. Corrections for molecular binding applied for H_2 and D_2 . For atomic H, $X_0 = 63.05 \text{ g/cm}^2$.
- e. Density effect constants evaluated for $\rho = 0.0600 \text{ g/cm}^3$ (H₂ bubble chamber?).
- d. For molecular hydrogen (deuterium). For atomic H, $X_0 = 63.047$ g cm⁻².
- f. For pure graphite; industrial graphite density may vary $2.1-2.3 \text{ g/cm}^3$.
- g. Standard shielding blocks, typical composition O₂ 52%, Si 32.5%, Ca 6%, Na 1.5%, Fe 2%, Al 4%, plus reinforcing iron bars. The attenuation length, $\ell=115\pm5$ g/cm², is also valid for earth (typical $\rho=2.15$), from CERN-LRL-RHEL Shielding exp., UCRL-17841 (1968).
- h. Main components: 80% SiO₂ + 12% B₂O₃ + 5% Na₂O.
- i. Calculated using Sternheimer's density effect parameterization for $\rho = 2.32$ g cm⁻³. Actual value may be slightly lower.
- j. For typical fused quartz. The specific gravity of crystalline quartz is 2.64.
- k. Solid ethane density at -60°C; gaseous refractive index at 0°C, 546 mm pressure.
- l. Nylon, Type 6, $(NH(CH_2)_5CO)_n$
- m. Polycarbonate (Lexan), $(C_{16}H_{14}O_3)_n$
- n. Polyethylene terephthlate, monomer, $C_5H_4O_2$
- o. Polyethylene, monomer CH₂ = CH₂
- p. Polymide film (Kepton), $(C_{22}H_{10}N_2O_5)_n$
- q. Polymethylmethacralate, monomer $CH_2 = C(CH_3)CO_2CH_3$
- r. Polystyrene, monomer C₆H₅CH=CH₂
- s. Teflon, monomer $CF_2 = CF_2$
- t. Polyvinyltolulene, monomer 2-CH₃C₆H₄CH=CH₂
- u. Bismuth germanate (BGO), (Bi₂O₃)₂(GeO₂)₃
- $v. n(SiO_2) + 2n(H_2O)$ used in Čerenkov counters, $\rho = \text{density in } g/\text{cm}^3$. From M. Cantin et al., Nucl. Instrum. Methods 118, 177 (1974).
- w. G10-plate, typical 60% SiO2 and 40% epoxy.

7. ELECTROMAGNETIC RELATIONS

Quantity	Gaussian CGS	SI
Conversion factors:		
Charge:	$2.99792458 \times 10^9 \text{ esu}$	= 1 C = 1 A s
Potential:	(1/299.792 458) statvolt (ergs/esu)	$= 1 V = 1 J C^{-1}$
Magnetic field:	$10^4 \text{ gauss} = 10^4 \text{ dyne/esu}$	$= 1 T = 1 N A^{-1}m^{-1}$
Lorentz force:	$\mathbf{F} = q\left(\mathbf{E} + \frac{\mathbf{v}}{c} \times \mathbf{B}\right)$	$\mathbf{F} = q(\mathbf{E} + \mathbf{v} \times \mathbf{B})$
Maxwell equations:	$\nabla \cdot \mathbf{D} = 4\pi \rho$	$\nabla \cdot \mathbf{D} = \rho$
	$\mathbf{ abla} imes \mathbf{H} - rac{1}{c} rac{\partial \mathbf{D}}{\partial t} = rac{4\pi}{c} \mathbf{J}$	$\nabla \times \mathbf{H} - \frac{\partial \mathbf{D}}{\partial t} = \mathbf{J}$
	$\nabla \cdot \mathbf{B} = 0$	$\nabla \cdot \mathbf{B} = 0$
	$\nabla \times \mathbf{E} + \frac{1}{c} \frac{\partial \mathbf{B}}{\partial t} = 0$	$\mathbf{ abla} imes \mathbf{E} + rac{\partial \mathbf{B}}{\partial t} = 0$
Constitutive relations:	$\mathbf{D} = \mathbf{E} + 4\pi \mathbf{P}, \mathbf{H} = \mathbf{B} - 4\pi \mathbf{M}$	$\mathbf{D} = \epsilon_0 \mathbf{E} + \mathbf{P}, \mathbf{H} = \mathbf{B}/\mu_0 - \mathbf{M}$
Linear media:	$\mathbf{D} = \epsilon \mathbf{E}, \mathbf{H} = \mathbf{B}/\mu$	$\mathbf{D} = \epsilon \mathbf{E}, \mathbf{H} = \mathbf{B}/\mu$
Permitivity of free space:	1	$\epsilon_0 = 8.854 \ 187 \dots \times 10^{-12} \ \mathrm{F \ m^{-1}}$
Permeability of free space:	1	$\mu_0 = 4\pi \times 10^{-7} \text{ N A}^{-2}$
Fields from potentials:	$\mathbf{E} = -\nabla V - \frac{1}{c} \frac{\partial \mathbf{A}}{\partial t}$	$\mathbf{E} = -\nabla V - \frac{\partial \mathbf{A}}{\partial t}$
	$\mathbf{B} = \mathbf{\nabla} \times \mathbf{A}$	$\mathbf{B} = \mathbf{\nabla} \times \mathbf{A}$
Static potentials: (coulomb gauge)	$V = \sum_{\mathrm{charges}} rac{q_i}{r_i} = \int rac{ ho\left(\mathbf{r'} ight)}{\left \mathbf{r}-\mathbf{r'} ight } d^3x'$	$V = rac{1}{4\pi\epsilon_0} \sum_{ ext{charges}} rac{q_i}{r_i} = rac{1}{4\pi\epsilon_0} \int rac{ ho\left(ext{r}' ight)}{ ext{r}- ext{r}' } \ d^3x'$
	$\mathbf{A} = \frac{1}{c} \oint \frac{I \mathrm{d}\boldsymbol{\ell}}{ \mathbf{r} - \mathbf{r}' } = \frac{1}{c} \int \frac{\mathbf{J}(\mathbf{r}')}{ \mathbf{r} - \mathbf{r}' } d^3 x'$	$\mathbf{A} = \frac{\mu_0}{4\pi} \oint \frac{I \mathrm{d}\ell}{ \mathbf{r} - \mathbf{r}' } = \frac{\mu_0}{4\pi} \int \frac{\mathbf{J}(\mathbf{r}')}{ \mathbf{r} - \mathbf{r}' } d^3x'$
Relativistic transformations:	$\mathbf{E}'_{\parallel} = \mathbf{E}_{\parallel}$	$\mathbf{E}'_{\parallel} = \mathbf{E}_{\parallel}$
(v is the velocity of the primed frame as seen	$\mathbf{E}'_{\perp} = \gamma (\mathbf{E}_{\perp} + rac{1}{c} \mathbf{v} imes \mathbf{B})$	$\mathbf{E}'_{\perp} = \gamma(\mathbf{E}_{\perp} + \mathbf{v} \times \mathbf{B})$
in the unprimed frame)	$\mathbf{B}'_{\parallel} = \mathbf{B}_{\parallel}$	$\mathbf{B}'_{\parallel} = \mathbf{B}_{\parallel}$
	$\mathbf{B}_{\perp}' = \gamma (\mathbf{B}_{\perp} - \frac{1}{c} \mathbf{v} \times \mathbf{E})$	$\mathbf{B}'_{\perp} = \gamma (\mathbf{B}_{\perp} - \frac{1}{c^2} \mathbf{v} \times \mathbf{E})$
$\frac{1}{4\pi\epsilon_0} = c^2 \times 10^{-7} \text{ N A}^{-2} = 8.98$	$37.55 \times 10^9 \text{ m F}^{-1}$; $\frac{\mu_0}{4\pi} = 10^{-7} \text{ N A}^{-1}$	$c = \frac{1}{\sqrt{\mu_0 \epsilon_0}} = 2.99792458 \times 10^8 \text{ m s}^{-1}$

7.1. Impedances (SI units)

 ρ = resistivity at room temperature in $10^{-8} \Omega$ m:

~ 1.7 for Cu ~ 5.5 for W ~ 2.4 for Au ~ 73 for SS 304 ~ 2.8 for Al ~ 100 for Nichrome (Al alloys may have double the Al value.)

For alternating currents, instantaneous current I, voltage V, angular frequency ω :

$$V = V_0 e^{j\omega t} = ZI. ag{7.1}$$

Impedance of self-inductance L: $Z = j\omega L$.

Impedance of capacitance C: $Z = 1/j\omega C$.

Impedance of free space: $Z=\sqrt{\mu_0/\epsilon_0}=376.7~\Omega$.

High-frequency surface impedance of a good conductor:

$$Z=rac{\left(1+j
ight)
ho}{\delta}$$
 , where $\delta= ext{skin depth}$; (7.2)

$$\delta = \sqrt{\frac{\rho}{\pi \nu \mu}} \approx \frac{6.6 \text{ cm}}{\sqrt{\nu (\text{Hz})}} \text{ for Cu}.$$
 (7.3)

7.2. Capacitance \widehat{C} and inductance \widehat{L} per unit length (SI units) [negligible skin depth]

Flat rectangular plates of width w, separated by $d \ll w$ with linear medium (ϵ, μ) between:

$$\widehat{C} = \epsilon \frac{w}{d} \; ; \qquad \widehat{L} = \mu \frac{d}{w} \; ; \tag{7.4}$$

 $\epsilon/\epsilon_0 = 2$ to 6 for plastics; 4 to 8 for porcelain, glasses; (7.5)

$$\mu/\mu_0 \simeq 1 \ . \tag{7.6}$$

Coaxial cable of inner radius r_1 , outer radius r_2 :

$$\widehat{C} = \frac{2\pi \epsilon}{\ln (r_2/r_1)}; \quad \widehat{L} = \frac{\mu}{2\pi} \ln (r_2/r_1). \tag{7.7}$$

Transmission lines (no loss):

Impedance:
$$Z = \sqrt{\widehat{L}/\widehat{C}}$$
 . (7.8)

Velocity:
$$v = 1/\sqrt{\widehat{L} \ \widehat{C}} = 1/\sqrt{\mu \epsilon}$$
. (7.9)

7.3. Synchrotron radiation (CGS units)

For a particle of charge e, velocity $v=\beta c$, and energy $E=\gamma mc^2$, traveling in a circular orbit of radius R, the classical energy loss per revolution δE is

$$\delta E = \frac{4\pi}{3} \, \frac{e^2}{R} \, \beta^3 \, \gamma^4 \, . \tag{7.10}$$

For high-energy electrons or positrons ($\beta \approx 1$), this becomes

$$\delta E \text{ (in MeV)} \approx 0.0885 \ [E(\text{in GeV})]^4 / R(\text{in m}) \ .$$
 (7.11)

For $\gamma\gg 1$, the energy radiated per revolution into the photon energy interval $d(\hbar\omega)$ is

$$dI = \frac{8\pi}{9} \alpha \gamma F(\omega/\omega_c) d(\hbar\omega) , \qquad (7.12)$$

where $\alpha = e^2/\hbar c$ is the fine-structure constant and

$$\omega_c = \frac{3\gamma^3 c}{2R} \tag{7.13}$$

is the critical frequency. The normalized function F(y) is

$$F(y) = \frac{9}{8\pi} \sqrt{3} y \int_{y}^{\infty} K_{5/3}(x) dx , \qquad (7.14)$$

where $K_{5/3}(x)$ is a modified Bessel function of the third kind. For electrons or positrons,

$$\hbar\omega_{\rm c} ({\rm in~keV}) \approx 2.22 \ [E({\rm in~GeV})]^3/R({\rm in~m}) \ .$$
 (7.15)

Fig. 7.1 shows F(y) over the important range of y.

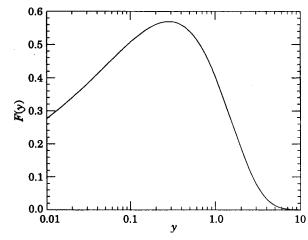


Figure 7.1: The normalized synchrotron radiation spectrum F(y).

For $\gamma \gg 1$ and $\omega \ll \omega_c$,

$$\frac{dI}{d(\hbar\omega)} \approx 3.3\alpha (\omega R/c)^{1/3} , \qquad (7.16)$$

whereas for

$$\gamma \gg 1$$
 and $\omega \gtrsim 3\omega_c$,

$$\frac{dI}{d(\hbar\omega)} \approx \sqrt{\frac{3\pi}{2}} \alpha \gamma \left(\frac{\omega}{\omega_c}\right)^{1/2} e^{-\omega/\omega_c} \left[1 + \frac{55}{72} \frac{\omega_c}{\omega} + \ldots\right] . \tag{7.17}$$

The radiation is confined to angles $\lesssim 1/\gamma$ relative to the instantaneous direction of motion. The mean number of photons emitted per revolution is

$$N_{\gamma} = \frac{5\pi}{\sqrt{3}}\alpha\gamma \ , \tag{7.18}$$

and the mean energy per photon is

$$\langle \hbar \omega \rangle = \frac{8}{15\sqrt{3}} \hbar \omega_c \ . \tag{7.19}$$

When $\langle \hbar \omega \rangle \gtrsim O(E)$, quantum corrections are important.

See J.D. Jackson, Classical Electrodynamics, $2^{\rm nd}$ edition (John Wiley & Sons, New York, 1975) for more formulae and details. In his book, Jackson uses a definition of ω_c that is twice as large as the customary one given above.

8. NAMING SCHEME FOR HADRONS

Maintained 1996 by M. Roos (University of Finland) and C.G. Wohl (LBNL).

8.1. Introduction

We introduced in the 1986 edition [1] a new naming scheme for the hadrons. Changes from older terminology affected mainly the heavier mesons made of the light (u, d, and s) quarks. Old and new names were listed alongside until 1994. Names also change from edition to edition because some characteristic like mass or spin changes. The Summary Tables give both the new and old names whenever a change occurred.

8.2. "Neutral-flavor" mesons (S=C=B=T=0)

Table 8.1 shows the names for mesons having the strangeness and all heavy-flavor quantum numbers equal to zero. The scheme is designed for all ordinary non-exotic mesons, but it will work for many exotic types too, if needed.

Table 8.1: Symbols for mesons with the strangeness and all heavy-flavor quantum numbers equal to zero.

,	$J^{PC} =$	{0 ^{−+} 2 ^{−+} ⋮	1+- 3+- :	1 2 :	0 ⁺⁺ 1 ⁺⁺ :
$q\overline{q}$ content	$^{2S+1}L_J =$	$^1(L{\rm even})_J$	$^1(L \operatorname{odd})_J$	$^3(L{\rm even})_J$	$^3(L \operatorname{odd})_J$
$u\overline{d}, u\overline{u} - d\overline{d},$	$d\overline{u}$ $(I=1)$	π	b	ρ	a
$d\overline{d} + u\overline{u}$ and/or $s\overline{s}$	$\left.\begin{array}{l} I = 0 \end{array}\right)$	η,η'	h, h'	ω,ϕ	f, f'
$c\overline{c}$	•	η_c	h_c	ψ^\dagger	χc
$b\overline{b}$		η_b	h_b	r	χ_b
$t\bar{t}$		η_t	h_t	θ	χ_t

[†]The J/ψ remains the J/ψ .

First, we assign names to those states with quantum numbers compatible with being $q\bar{q}$ states. The rows of the Table give the possible $q\bar{q}$ content. The columns give the possible parity/charge-conjugation states,

$$PC = -+, +-, --, \text{ and } ++;$$

these combinations correspond one-to-one with the angular-momentum state ${}^{2S+1}L_J$ of the $q\overline{q}$ system being

$$^{1}(L \text{ even})_{J}$$
, $^{1}(L \text{ odd})_{J}$, $^{3}(L \text{ even})_{J}$, or $^{3}(L \text{ odd})_{J}$.

Here $S,\ L$, and J are the spin, orbital, and total angular momenta of the $q\overline{q}$ system. The quantum numbers are related by

$$P = (-1)^{L+1}$$
, $C = (-1)^{L+S}$, and G parity $= (-1)^{L+S+I}$,

where of course the C quantum number is only relevant to neutral mesons.

The entries in the Table give the meson names. The spin J is added as a subscript except for pseudoscalar and vector mesons, and the mass is added in parentheses for mesons that decay strongly. However, for the lightest meson resonances, we omit the mass.

Measurements of the mass, quark content (where relevant), and quantum numbers I, J, P, and C (or G) of a meson thus fix its symbol. Conversely, these properties may be inferred unambiguously from the symbol.

If the main symbol cannot be assigned because the quantum numbers are unknown, X is used. Sometimes it is not known whether a meson is mainly the isospin-0 mix of $u\overline{u}$ and $d\overline{d}$ or is mainly $s\overline{s}$. A prime (or pair ω , ϕ) may be used to distinguish two such mixing states.

We follow custom and use spectroscopic names such as $\Upsilon(1S)$ as the primary name for most of those ψ , Υ , and χ states whose spectroscopic identity is known. We use the form $\Upsilon(9460)$ as an alternative, and as the primary name when the spectroscopic identity is not known.

Names are assigned for $t\bar{t}$ mesons, although the top quark is evidently so heavy that it is expected to decay too rapidly for bound states to form.

Gluonium states or other mesons that are not $q\overline{q}$ states are, if the quantum numbers are *not* exotic, to be named just as are the $q\overline{q}$ mesons. Such states will probably be difficult to distinguish from $q\overline{q}$ states and will likely mix with them, and we make no attempt to distinguish those "mostly gluonium" from those "mostly $q\overline{q}$."

An "exotic" meson with J^{PC} quantum numbers that a $q\overline{q}$ system cannot have, namely $J^{PC}=0^{--},0^{+-},1^{-+},2^{+-},3^{-+},\cdots$, would use the same symbol as does an ordinary meson with all the same quantum numbers as the exotic meson except for the C parity. But then the J subscript may still distinguish it; for example, an isospin-0 1^{-+} meson could be denoted ω_1 .

8.3. Mesons with nonzero S, C, B, and/or T

Since the strangeness or a heavy flavor of these mesons is nonzero, none of them are eigenstates of charge conjugation, and in each of them one of the quarks is heavier than the other. The rules are:

 The main symbol is an upper-case italic letter indicating the heavier quark as follows:

$$s o \overline{K} \qquad c o D \qquad b o \overline{B} \qquad t o T$$
 .

We use the convention that the flavor and the charge of a quark have the same sign. Thus the strangeness of the s quark is negative, the charm of the c quark is positive, and the bottom of the b quark is negative. In addition, I_3 of the u and d quarks are positive and negative, respectively. The effect of this convention is as follows: Any flavor carried by a charged meson has the same sign as its charge. Thus the K^+ , D^+ , and B^+ have positive strangeness, charm, and bottom, respectively, and all have positive I_3 . The D_s^+ has positive charm and strangeness. Furthermore, the $\Delta({\rm flavor}) = \Delta Q$ rule, best known for the kaons, applies to every flavor.

- If the lighter quark is not a u or a d quark, its identity is given by a subscript. The D_s⁺ is an example.
- 3. If the spin-parity is in the "normal" series, $J^P = 0^+, 1^-, 2^+, \cdots$, a superscript "*" is added.
- The spin is added as a subscript except for pseudoscalar or vector mesons.

8.4. Baryons

The symbols N, Δ , Λ , Σ , Ξ , and Ω used for more than 30 years for the baryons made of light quarks (u, d, and s quarks) tell the isospin and quark content, and the same information is conveyed by the symbols used for the baryons containing one or more heavy quarks (c, b, and t quarks). The rules are:

- Baryons with three u and/or d quarks are N's (isospin 1/2) or Δ's (isospin 3/2).
- Baryons with two u and/or d quarks are A's (isospin 0) or Σ's (isospin 1). If the third quark is a c, b, or t quark, its identity is given by a subscript.
- Baryons with one u or d quark are \(\mathcal{\pi}\)'s (isospin 1/2). One or two subscripts are used if one or both of the remaining quarks are heavy: thus \(\mathcal{\pi}_c\), \(\mathcal{\pi}_{cc}\), \(\mathcal{\pi}_b\), etc.
- Baryons with no u or d quarks are \(\Omega\)'s (isospin 0), and subscripts indicate any heavy-quark content.

In short, the number of u plus d quarks together with the isospin determine the main symbol, and subscripts indicate any content of heavy quarks. A Σ always has isospin 1, an Ω always has isospin 0, etc.

Reference:

 Particle Data Group: M. Aguilar-Benitez et al., Phys. Lett. 170B (1986).

9. QUANTUM CHROMODYNAMICS

9.1. The QCD Lagrangian

Revised September 1997 by I. Hinchliffe (LBNL).

Quantum Chromodynamics (QCD), the gauge field theory which describes the strong interactions of colored quarks and gluons, is one of the components of the SU(3)×SU(2)×U(1) Standard Model. A quark of specific flavor (such as a charm quark) comes in 3 colors; gluons come in eight colors; hadrons are color-singlet combinations of quarks, anti-quarks, and gluons. The Lagrangian describing the interactions of quarks and gluons is (up to gauge-fixing terms)

$$L_{\text{QCD}} = -\frac{1}{4} F_{\mu\nu}^{(a)} F^{(a)\mu\nu} + i \sum_{q} \overline{\psi}_{q}^{i} \gamma^{\mu} (D_{\mu})_{ij} \psi_{q}^{j} - \sum_{q} m_{q} \overline{\psi}_{q}^{i} \psi_{qi}, \qquad (9.1)$$

$$F_{\mu\nu}^{(a)} = \partial_{\mu} A_{\nu}^{a} - \partial_{\nu} A_{\mu}^{a} + g_{s} f_{abc} A_{\mu}^{b} A_{\nu}^{c} , \qquad (9.2)$$

$$(D_{\mu})_{ij} = \delta_{ij} \,\,\partial_{\mu} - ig_s \,\,\sum_{\alpha} \frac{\lambda_{i,j}^{\alpha}}{2} A_{\mu}^{\alpha} \,\,, \tag{9.3}$$

where g_s is the QCD coupling constant, and the f_{abc} are the structure constants of the SU(3) algebra (the λ matrices and values for f_{abc} can be found in "SU(3) Isoscalar Factors and Representation Matrices," Sec. 33 of this Review). The $\psi_q^i(x)$ are the 4-component Dirac spinors associated with each quark field of (3) color i and flavor q, and the $A^a_\mu(x)$ are the (8) Yang-Mills (gluon) fields. A complete list of the Feynman rules which derive from this Lagrangian, together with some useful color-algebra identities, can be found in Ref. 1.

The principle of "asymptotic freedom" (see below) determines that the renormalized QCD coupling is small only at high energies, and it is only in this domain that high-precision tests-similar to those in QED-can be performed using perturbation theory. Nonetheless, there has been in recent years much progress in understanding and quantifying the predictions of QCD in the nonperturbative domain, for example, in soft hadronic processes and on the lattice [2]. This short review will concentrate on QCD at short distances (large momentum transfers), where perturbation theory is the standard tool. It will discuss the processes that are used to determine the coupling constant of QCD. Other recent reviews of the coupling constant measurements may be consulted for a different perspective [3].

9.2. The QCD coupling and renormalization scheme

The renormalization scale dependence of the effective QCD coupling $\alpha_s=g_s^2/4\pi$ is controlled by the β -function:

$$\mu \frac{\partial \alpha_s}{\partial \mu} = -\frac{\beta_0}{2\pi} \alpha_s^2 - \frac{\beta_1}{4\pi^2} \alpha_s^3 - \frac{\beta_2}{64\pi^3} \alpha_s^4 - \cdots, \qquad (9.4a)$$

$$\beta_0 = 11 - \frac{2}{3}n_f \,, \tag{9.4b}$$

$$\beta_1 = 51 - \frac{19}{3} n_f \,, \tag{9.4c}$$

$$\begin{split} \beta_1 &= 51 - \frac{19}{3} n_f \; , \\ \beta_2 &= 2857 - \frac{5033}{9} n_f + \frac{325}{27} n_f^2 \; ; \end{split} \tag{9.4c}$$

where n_f is the number of quarks with mass less than the energy scale μ . The expression for the next term in this series (β_3) can be found in Ref. 4. In solving this differential equation for α_s , a constant of integration is introduced. This constant is the one fundamental constant of QCD that must be determined from experiment. The most sensible choice for this constant is the value of α_s at a fixed-reference scale μ_0 , but it is more conventional to introduce the dimensional parameter Λ , since this provides a parametrization of the μ dependence of α_s . The definition of Λ is arbitrary. One way to define it (adopted here) is to write a solution of Eq. (9.4) as an expansion in inverse powers of $\ln (\mu^2)$:

$$\alpha_{s}(\mu) = \frac{4\pi}{\beta_{0} \ln(\mu^{2}/\Lambda^{2})} \left[1 - \frac{2\beta_{1}}{\beta_{0}^{2}} \frac{\ln\left[\ln(\mu^{2}/\Lambda^{2})\right]}{\ln(\mu^{2}/\Lambda^{2})} + \frac{4\beta_{1}^{2}}{\beta_{0}^{4} \ln^{2}(\mu^{2}/\Lambda^{2})} \right] \times \left(\left(\ln\left[\ln(\mu^{2}/\Lambda^{2})\right] - \frac{1}{2} \right)^{2} + \frac{\beta_{2}\beta_{0}}{8\beta_{1}^{2}} - \frac{5}{4} \right) \right]. \tag{9.5a}$$

The last term in this expansion is

$$\mathcal{O}\left(\frac{\ln^2\left[\ln\left(\mu^2/\Lambda^2\right)\right]}{\ln^3\left(\mu^2/\Lambda^2\right)}\right) , \qquad (9.5b)$$

and is usually neglected in the definition of Λ . We choose to include it. For a fixed value of $\alpha_s(M_Z)$, the inclusion of this term shifts the value of Λ by ~ 15 MeV. This solution illustrates the asymptotic freedom property: $\alpha_s \to 0$ as $\mu \to \infty$. Alternative definitions of Λ are possible. We adopt this as the standard. Values given by experiments using other definitions are adjusted as needed to meet our definition.

Consider a "typical" QCD cross section which, when calculated perturbatively, starts at $\mathcal{O}(\alpha_s)$:

$$\sigma = A_1 \alpha_s + A_2 \alpha_s^2 + \cdots . \tag{9.6}$$

The coefficients A_1 , A_2 come from calculating the appropriate Feynman diagrams. In performing such calculations, various divergences arise, and these must be regulated in a consistent way. This requires a particular renormalization scheme (RS). The most commonly used one is the modified minimal subtraction (\overline{MS}) scheme [5]. This involves continuing momentum integrals from 4 to 4-2 ϵ dimensions, and then subtracting off the resulting $1/\epsilon$ poles and also $(\ln 4\pi - \gamma_E)$, which is another artifact of continuing the dimension. (Here γ_E is the Euler-Mascheroni constant.) To preserve the dimensionless nature of the coupling, a mass scale μ must also be introduced: $g \to \mu^{\epsilon} g$. The finite coefficients A_i (i > 2) thus obtained depend implicitly on the renormalization convention used and explicitly on the scale μ .

The first two coefficients (β_0, β_1) in Eq. (9.4) are independent of the choice of RS's. In contrast, the coefficients of terms proportional to α_s^n for n > 3 are RS-dependent. The form given above for β_2 is in the MS scheme. It has become conventional to use the MS scheme for calculating QCD cross sections beyond leading order.

The fundamental theorem of RS dependence is straightforward. Physical quantities, in particular the cross section, calculated to all orders in perturbation theory, do not depend on the RS. It follows that a truncated series does exhibit RS dependence. In practice, QCD cross sections are known to leading order (LO), or to next-to-leading order (NLO), or in a few cases, to next-to-next-to-leading order (NNLO); and it is only the latter two cases, which have reduced RS dependence, that are useful for precision tests. At NLO the RS dependence is completely given by one condition which can be taken to be the value of the renormalization scale μ . At NNLO this is not sufficient, and μ is no longer equivalent to a choice of scheme; both must now be specified. One, therefore, has to address the question of what is the "best" choice for μ within a given scheme, usually $\overline{\text{MS}}$. There is no definite answer to this question-higher-order corrections do not "fix" the scale, rather they render the theoretical predictions less sensitive to its variation.

One could imagine that choosing a scale μ characteristic of the typical energy scale (E) in the process would be most appropriate. In general, a poor choice of scale generates terms of order $\ln (E/\mu)$ in the A_i 's. Various methods have been proposed including choosing: the scale for which the next-to-leading-order correction vanishes ("Fastest Apparent Convergence [6]"); the scale for which the next-toleading-order prediction is stationary [7], (i.e., the value of μ where $d\sigma/d\mu = 0$); or the scale dictated by the effective charge scheme [8] or by the BLM scheme [9]. By comparing the values of α_s that different reasonable schemes give, an estimate of theoretical errors can be obtained. It has also been suggested to replace the perturbation series by its Pade approximant [10]. Results obtained using this method have, in certain cases, a reduced scale dependence [11,12].

An important corollary is that if the higher-order corrections are naturally small, then the additional uncertainties introduced by the μ dependence are likely to be less than the experimental measurement errors. There are some processes, however, for which the choice of scheme can influence the extracted value of $\Lambda_{\overline{MS}}$. There is no resolution to this problem other than to try to calculate even more terms in the perturbation series. It is important to note that,

since the perturbation series is an asymptotic expansion, there is a limit to the precision with which any theoretical quantity can be calculated. In some processes, the highest-order perturbative terms may be comparable in size to nonperturbative corrections (sometimes called higher-twist or renormalon effects, for a discussion see [13]); an estimate of these terms and their uncertainties is required if a value of α_s is to be extracted.

In the cases where the higher-order corrections to a process are known and are large, some caution should be exercised when quoting the value of α_s . In what follows, we will attempt to indicate the size of the theoretical uncertainties on the extracted value of α_s . There are two simple ways to determine this error. First, we can estimate it by comparing the value of $\alpha_s(\mu)$ obtained by fitting data using the QCD formula to highest known order in α_s , and then comparing it with the value obtained using the next-to-highest-order formula (μ is chosen as the typical energy scale in the process). The corresponding Λ 's are then obtained by evolving $\alpha_s(\mu)$ to $\mu=M_Z$ using Eq. (9.4) to the same order in α_s as the fit. Alternatively, we can vary the value of μ over a reasonable range, extracting a value of Λ for each choice of μ . This method is of its nature imprecise, since "reasonable" involves a subjective judgment. In either case, if the perturbation series is well behaved, the resulting error on $\alpha_s(M_Z)$ will be small.

In the above discussion we have ignored quark-mass effects, i.e., we have assumed an idealized situation where quarks of mass greater than μ are neglected completely. In this picture, the β -function coefficients change by discrete amounts as flavor thresholds are crossed when integrating the differential equation for α_s . It follows that, for a relationship such as Eq. (9.5) to remain valid for all values of μ , A must also change as flavor thresholds are crossed. This leads to the concept of a different Λ for each range of μ corresponding to an effective number of massless quarks: $\Lambda \to \Lambda^{(n_f)}$. There is some arbitrariness in how this relationship is set up. As an idealized case, consider QCD with $n_f - 1$ massless quarks and one quark of mass M. Now imagine an experiment at energy scale μ ; for example, this could be $e^+e^- \to \text{hadrons}$ at center-of-mass energy μ . If $\mu \gg M$, the mass M is negligible and the process is well described by QCD with n_f massless flavors and its parameter $\Lambda^{(n_f)}$ up to terms of order M^2/μ^2 . Conversely if $\mu \ll M$, the heavy quark plays no role and the process is well described by QCD with $n_f - 1$ massless flavors and its parameter $\Lambda^{(n_f-1)}$ up to terms of order μ^2/M^2 . If $\mu \sim M$, the effects of the quark mass are process-dependent and cannot be absorbed into the running coupling.

A mass scale μ' is chosen where the relationship between $\Lambda^{(n_f-1)}$ and $\Lambda^{(n_f)}$ will be fixed. μ' should be of order M and the relationship should not depend on it. A prescription has been given [14] which has this property. We use this procedure choosing $\mu' = M_Q$, where M_Q is the mass of the value of the running quark mass defined in the $\overline{\rm MS}$ scheme (see the note on "Quark Masses" in the Particle Listings for more details), i.e., where $M_{\overline{\rm MS}}(M_Q) = M_Q$. Then [14]

$$\begin{split} \beta_0^{n_f-1} \ln \left(\frac{\Lambda^{(n_f)}}{\Lambda^{(n_f-1)}} \right)^2 &= (\beta_0^{n_f} - \beta_0^{n_f-1}) \ln \left(\frac{M_Q}{\Lambda^{(n_f)}} \right) \\ &+ 2 \Big(\frac{\beta_1^{n_f}}{\beta_0^{n_f}} - \frac{\beta_1^{n_f-1}}{\beta_0^{n_f-1}} \Big) \ln \left[\ln \left(\frac{M_Q}{\Lambda^{(n_f)}} \right)^2 \right] \\ &- \frac{2\beta_1^{n_f-1}}{\beta_0^{n_f-1}} \ln \left(\frac{\beta_0^{n_f}}{\beta_0^{n_f-1}} \right) \\ &+ \frac{4 \frac{\beta_1^{n_f}}{(\beta_0^{n_f})^2} \Big(\frac{\beta_1^{n_f}}{\beta_0^{n_f}} - \frac{\beta_1^{n_f-1}}{\beta_0^{n_f-1}} \Big) \ln \left[\ln \left(\frac{M_Q}{\Lambda^{n_f}} \right)^2 \right]}{\ln \left(\frac{M_Q}{\Lambda^{(n_f)}} \right)^2} \\ &+ \frac{\frac{1}{\beta_0^{n_f}} \Big[\Big(\frac{2\beta_1^{n_f}}{\beta_0^{n_f}} \Big)^2 - \Big(\frac{2\beta_1^{n_f-1}}{\beta_0^{n_f-1}} \Big)^2 - \frac{\beta_2^{n_f}}{2\beta_0^{n_f}} + \frac{\beta_2^{n_f-1}}{2\beta_0^{n_f-1}} - \frac{22}{9} \Big]}{\ln \left(\frac{M_Q}{\Lambda^{(n_f)}} \right)^2} \,. \end{split}$$

This result is valid to order α_s^3 (or alternatively to terms of order $1/\ln^2[(M_O/\Lambda^{(n_f)})^2]$). The order α_s^4 expression is also available [15].

An alternative matching procedure can be used [16]. This procedure requires the equality $\alpha_s(\mu)^{(n_f)} = \alpha_s(\mu)^{(n_f-1)}$ for $\mu = M_Q$. This matching is somewhat arbitrary; a different relation between $\Lambda^{(n_f)}$ and $\Lambda^{(n_f-1)}$ would result if $\mu = M_Q/2$ were used. In practice, the differences between these procedures are very small. $\Lambda^{(5)} = 200$ MeV corresponds to $\Lambda^{(4)} = 289$ MeV in the scheme of Ref. 16 and $\Lambda^{(4)} = 280$ MeV in the scheme adopted above. Note that the differences between $\Lambda^{(5)}$ and $\Lambda^{(4)}$ are numerically very significant.

Data from deep-inelastic scattering are in a range of energy where the bottom quark is not readily excited, and hence, these experiments quote $\Lambda_{\overline{\rm MS}}^{(4)}$. Most data from PEP, PETRA, TRISTAN, LEP, and SLC quote a value of $\Lambda_{\overline{\rm MS}}^{(5)}$ since these data are in an energy range where the bottom quark is light compared to the available energy. We have converted it to $\Lambda_{\overline{\rm MS}}^{(4)}$ as required. A few measurements, including the lattice gauge theory values from the ψ system and from τ decay are at sufficiently low energy that $\Lambda_{\overline{\rm MS}}^{(3)}$ is appropriate.

In order to compare the values of α_s from various experiments, they must be evolved using the renormalization group to a common scale. For convenience, this is taken to be the mass of the Z boson. This evolution uses third-order perturbation theory and can introduce additional errors particularly if extrapolation from very small scales is used. The variation in the charm and bottom quark masses $(m_b=4.3\pm0.2$ and $m_c=1.3\pm0.3$ are used) can also introduce errors. These result in a fixed value of $\alpha_s(2\text{ GeV})$ giving an uncertainty in $\alpha_s(M_Z)=\pm0.001$ if only perturbative evolution is used. There could be additional errors from nonperturbative effects that enter at low energy. All values are in the $\overline{\text{MS}}$ scheme unless otherwise noted.

9.3. QCD in deep-inelastic scattering

The original and still one of the most powerful quantitative tests of perturbative QCD is the breaking of Bjorken scaling in deep-inelastic lepton-hadron scattering. In the leading-logarithm approximation, the measured structure functions $F_i(x,Q^2)$ are related to the quark distribution functions $q_i(x,Q^2)$ according to the naive parton model, by the formulae in "Cross-section Formulae for Specific Processes," Sec. 36 of this *Review*. (In that section, q_i is denoted by the notation f_q). In describing the way in which scaling is broken in QCD, it is convenient to define nonsinglet and singlet quark distributions:

$$F^{NS} = q_i - q_j F^S = \sum_i (q_i + \overline{q}_i) . (9.8)$$

The nonsinglet structure functions have nonzero values of flavor quantum numbers such as isospin or baryon number. The variation with Q^2 of these is described by the so-called DGLAP equations [17,18]:

$$Q^2 \frac{\partial F^{NS}}{\partial Q^2} = \frac{\alpha_s(|Q|)}{2\pi} P^{qq} * F^{NS}$$
 (9.9a)

$$Q^{2} \frac{\partial}{\partial Q^{2}} \begin{pmatrix} F^{S} \\ G \end{pmatrix} = \frac{\alpha_{s}(|Q|)}{2\pi} \begin{pmatrix} P^{qq} & 2n_{f}P^{qg} \\ P^{gq} & P^{gg} \end{pmatrix} * \begin{pmatrix} F^{S} \\ G \end{pmatrix}$$
(9.9b)

where * denotes a convolution integral:

$$f * g = \int_{x}^{1} \frac{dy}{y} f(y) g\left(\frac{x}{y}\right) . \tag{9.10}$$

The leading-order Altarelli-Parisi [18] splitting functions are

$$P^{qq} = \frac{4}{3} \left[\frac{1+x^2}{(1-x)_+} \right] + 2\delta(1-x) , \qquad (9.11a)$$

$$P^{qg} = \frac{1}{2} \left[x^2 + (1-x)^2 \right] , \qquad (9.11b)$$

$$P^{gq} = \frac{4}{3} \left[\frac{1 + (1 - x)^2}{x} \right] , \qquad (9.11c)$$

$$P^{gg} = 6 \left[\frac{1-x}{x} + x(1-x) + \frac{x}{(1-x)_{+}} + \frac{11}{12} \delta(1-x) \right] - \frac{n_f}{3} \delta(1-x) . \tag{9.11d}$$

Here the gluon distribution $G(x,Q^2)$ has been introduced and $1/(1-x)_+$ means

$$\int_0^1 dx \frac{f(x)}{(1-x)_+} = \int_0^1 dx \, \frac{f(x) - f(1)}{(1-x)} \,. \tag{9.12}$$

The precision of contemporary experimental data demands that higher-order corrections also be included [19]. The above results are for massless quarks. At low Q^2 values, there are also important "higher-twist" (HT) contributions of the form:

$$F_i(x,Q^2) = F_i^{(LT)}(x,Q^2) + \frac{F_i^{(HT)}(x,Q^2)}{Q^2} + \cdots$$
 (9.13)

Leading twist (LT) indicates a term whose behavior is predicted by perturbative QCD. These corrections are numerically important only for $Q^2 < \mathcal{O}(\text{few GeV}^2)$ except for x very close to 1. At very large values of x corrections proportional to $\log(1-x)$ can become important [20].

A detailed review of the current status of the experimental data can be found, for example, in Refs. [21–23], and only a brief summary will be presented here. We shall only include determinations of Λ from the recently published results; the earlier editions of this *Review* should be consulted for the earlier data. In any event, the recent results will dominate the average since their errors are smaller. Data now exist from HERA at much smaller values of x than the fixed-target data. They provide valuable information about the shape of the antiquark and gluon distribution functions at $x \sim 10^{-4}$ [24].

From Eq. (9.9), it is clear that a nonsinglet structure function offers in principle the most precise test of the theory, since the Q^2 evolution is independent of the unmeasured gluon distribution. The CCFR collaboration fit to the Gross-Llewellyn Smith sum rule [25] is known to order α_s^3 [26]

$$\int_{0}^{1} dx \left(F_{3}^{\nu p}(x, Q^{2}) + F_{3}^{\nu p}(x, Q^{2}) \right) = 3 \left[\left(1 - \frac{\alpha_{s}}{\pi} (1 + 3.58 \frac{\alpha_{s}}{\pi} + 19.0 (\frac{\alpha_{s}}{\pi})^{2} \right) - \Delta HT \right] , \quad (9.14)$$

where the higher-twist contribution $\Delta HT = (0.09 \pm 0.045)/Q^2$ [26,27]. Using the CCFR data [28], this gives α_s (1.76 GeV) = 0.26 ± 0.035 (expt.) ± 0.03 (theory). The error from higher-twist terms dominates the theoretical error, the higher-twist term being approximately 50% larger than the α_s^3 term. The CCFR data have been recalibrated since this result was published [29] so this result can be expected to change; it should not therefore be included in an average. An experiment at Serpukov [30] has measured the sum rule at $\langle Q^2 \rangle = 1.7 \text{ GeV}^2$ and obtains α_s (1.7 GeV) = 0.35 ± 0.03 (expt.) or $\Lambda_{\overline{\text{MS}}}^{(4)} = 359 \pm 59(\text{expt.})$ MeV. The error does not include (theoretical) errors arising from the choice of μ and the higher-twist terms. Estimating the uncertainty from the higher-twist terms as 50% of their effect gives ±60 MeV of additional error in the extracted value of $\Lambda_{\overline{\text{MS}}}^{(4)}$.

Measurements involving singlet-dominated structure functions, such as F_2 , result in correlated measurements of $\Lambda_{\overline{MS}}^{(4)}$ and the gluon distribution. By utilizing high-statistics data at large x (> 0.25) and

large Q^2 , where F_2 behaves like an nonsinglet and F_3 at smaller x, a nonsinglet fit can be performed with better statistical precision, and hence, the error on the measured value of $\Lambda_{\overline{\rm MS}}^{(4)}$ is much reduced. Recently, CCFR gives $\Lambda_{\overline{\rm MS}}^{(4)}=337\pm28\pm13$ (higher-twist) MeV [29] from $F_2(\nu N)$ and $F_3(\nu N)$. There is an additional uncertainty of ±59 MeV from the choice of scale. The NMC collaboration [31] gives $\alpha_s(7~{\rm GeV}^2)=0.264\pm0.018$ (stat.) ±0.070 (syst.) ±0.013 (higher-twist). The systematic error is larger than the CCFR result, partially because the data are at smaller values of x and the gluon distribution is more important. A reanalysis [32] of EMC data [33] gives $\Lambda_{\overline{\rm MS}}^{(4)}=211\pm80\pm80$ MeV from $F_2(\nu N)$. Finally a combined analysis [34] of SLAC [35] and BCDMS [36] data gives $\Lambda_{\overline{\rm MS}}^{(4)}=263\pm42\pm55$ MeV. Here the systematic error is an estimate of the uncertainty due to the choice of Q^2 used in the argument of α_s , and in the scale at which the structure functions (factorization scale) used in the QCD calculation are evaluated.

The results from Refs. [29–32], [34], and [37] can be combined to give $\Lambda_{\overline{MS}}^{(4)}=305\pm25\pm50$ MeV which corresponds to $\alpha_s(M_Z)=0.117\pm0.002\pm0.004$, Here the first error is a combination of statistical and systematic errors, and the second error is due to the scale uncertainty. This result is an average of the results weighted by their statistical and systematic errors. The scale error, which is common to all, is then reapplied to the average.

The spin-dependent structure functions, measured in polarized lepton nucleon scattering, can also be used to determine α_s . Here the values of $Q^2 \sim 2.5 \text{ GeV}^2$ are small and higher-twist corrections are important. A fit [38] using the measured spin dependent structure functions themselves [39] gives $\alpha_s(M_Z)=0.120^{+0.004}_{-0.005}(\text{expt.})^{+0.009}_{-0.006}(\text{theory})$. These authors also determine α_s from the Bjorken sum rule [40] and obtain $\alpha_s(M_Z) = 0.118^{+0.010}_{-0.024}$; consistent with an earlier determination [41], the larger error being due to the extrapolation into the (unmeasured) small x region. Theoretically, the sum rule is preferable as the perturbative QCD result is known to higher order and these terms are important at the low Q^2 involved. It has been shown that the theoretical errors associated with the choice of scale are considerably reduced by the use of Pade approximants [11] which results in $\alpha_s(1.7 \text{ GeV}) =$ $0.328 \pm 0.03 (\text{expt.}) \pm 0.025 (\text{theory})$ corresponding to $\alpha_s(M_Z)$ = $0.116^{+0.003}_{-0.005}(\text{expt.}) \pm 0.003(\text{theory})$. No error is included from the extrapolation into the region of x that is unmeasured. If data were to become available at smaller values of x so that this extrapolation could be more tightly constrained, the sum rule method would provide the best determination of α_s ; the more conservative result from the structure functions themselves is used in the average.

At very small values of x and Q^2 , the x and Q^2 dependence of the structure functions is predicted by perturbative QCD [42]. Here terms to all orders in $\alpha_s \ln(1/x)$ are summed. The data from HERA [24] on $F_2^{ep}(x,Q^2)$ can be fitted to this form [43], including the NLO terms which are required to fix the Q^2 scale. The data are dominated by $4 \text{ GeV}^2 < Q^2 < 100 \text{ GeV}^2$. The fit [45] using H1 data [46] gives $\alpha_s(M_Z) = 0.122 \pm 0.004 \text{ (expt.)} \pm 0.009 \text{ (theory)}$. (The theoretical error is taken from Ref. 43.) The dominant part of the theoretical error is from the scale dependence; errors from terms that are suppressed by $1/\log(1/x)$ in the quark sector are included [44] while those from the gluon sector are not.

Typically, Λ is extracted from the deep inelastic scattering data by parameterizing the parton densities in a simple analytic way at some Q_0^2 , evolving to higher Q^2 using the next-to-leading-order evolution equations, and fitting globally to the measured structure functions to obtain $\Lambda_{\overline{\rm MS}}^{(4)}$. Thus, an important by-product of such studies is the extraction of parton densities at a fixed-reference value of Q_0^2 . These can then be evolved in Q^2 and used as input for phenomenological studies in hadron-hadron collisions (see below). To avoid having to evolve from the starting Q_0^2 value each time, a parton density is required; it is useful to have available a simple analytic approximation to the densities valid over a range of x and Q^2 values. A package is available from the CERN computer library that includes an exhaustive set of fits [47]. Most of these fits are obsolete. In using a parameterization to predict event rates, a next-to-leading

order fit must be used if the process being calculated is known to next-to-leading order in QCD perturbation theory. In such a case, there is an additional scheme dependence; this scheme dependence is reflected in the $\mathcal{O}(\alpha_s)$ corrections that appear in the relations between the structure functions and the quark distribution functions. There are two common schemes: a deep-inelastic scheme where there are no order α_s corrections in the formula for $F_2(x,Q^2)$ and the minimal subtraction scheme. It is important when these next-to-leading order fits are used in other processes (see below), that the same scheme is used in the calculation of the partonic rates.

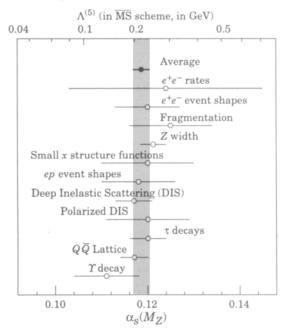


Figure 9.1: Summary of the values of $\alpha_s(M_Z)$ and $\Lambda^{(5)}$ from various processes. The values shown indicate the process and the measured value of α_s extrapolated up to $\mu=M_Z$. The error shown is the *total* error including theoretical uncertainties.

9.4. QCD in decays of the τ lepton

The semi-leptonic branching ratio of the tau $(\tau \to \nu_{\tau} + \text{hadrons}, R_{\tau})$ is an inclusive quantity. It is related to the contribution of hadrons to the imaginary part of the W self energy $(\Pi(s))$. However, it is more inclusive than R since it involves an integral

$$R_{ au} \sim \int_{0}^{m_{ au}^2} rac{ds}{m_{ au}^2} (1 - rac{s}{m_{ au}^2})^2 \ {
m Im} \left(\Pi(s)
ight) \ .$$

Since the scale involved is low, one must take into account nonperturbative (higher-twist) contributions which are suppressed by powers of the τ mass.

$$R_{\tau} = 3.058 \left[1 + \frac{\alpha_s(m_{\tau})}{\pi} + 5.2 \left(\frac{\alpha_s(m_{\tau})}{\pi} \right)^2 + 26.4 \left(\frac{\alpha_s(m_{\tau})}{\pi} \right)^3 + a \frac{m^2}{m_{\tau}^2} + b \frac{m\psi\overline{\psi}}{m_{\tau}^4} + c \frac{\psi\overline{\psi}\psi\overline{\psi}}{m_{\tau}^6} + \cdots \right]. \tag{9.15}$$

Here a,b, and c are dimensionless constants and m is a light quark mass. The term of order $1/m_\tau^2$ is a kinematical effect due to the light quark masses and is consequently very small. The nonperturbative terms are estimated using sum rules [48]. In total, they are estimated to be -0.014 ± 0.005 [49,50]. This estimate relies on there being no term of order Λ^2/m_τ^2 (note that $\frac{\alpha_s(m_\tau)}{\pi} \sim (\frac{0.5 \text{ GeV}}{m_\tau})^2$). The a,b, and c can be determined from the data [51] by fitting to moments of the $\Pi(s)$. The values so extracted [52,53] are consistent with the theoretical estimates. If the nonperturbative terms are omitted from the fit, the extracted value of $\alpha_s(m_\tau)$ decreases by ~ 0.02 .

For $\alpha_s(m_\tau)=0.35$ the perturbative series for R_τ is $R_\tau\sim 3.058(1+0.112+0.064+0.036)$. The size (estimated error) of the nonperturbative term is 20% (7%) of the size of the order α_s^3 term. The perturbation series in not very well convergent; if the order α_s^3 term is omitted, the extracted value of $\alpha_s(m_\tau)$ increases by 0.05. The order α_s^4 term has been estimated [54] and attempts made to resum the entire series [55,56]. These estimates can be used to obtain an estimate of the errors due to these unknown terms [57,58]. We assign an uncertainty of ± 0.02 to $\alpha_s(m_\tau)$ from these sources.

 R_{τ} can be extracted from the semi-leptonic branching ratio from the relation $R_{\tau}=1/(\mathrm{B}(\tau\to e\nu\bar{\nu})-1.97256;$ where $\mathrm{B}(\tau\to e\nu\bar{\nu})$ is measured directly or extracted from the lifetime, the muon mass, and the muon lifetime assuming universality of lepton couplings. Using the average lifetime of 290.7 \pm 1.3 fs and a τ mass of 1777.00 \pm 0.30 MeV from the PDG fit gives $R_{\tau}=3.642\pm0.024.$ The direct measurement of $\mathrm{B}(\tau\to e\nu\bar{\nu})$ can be combined with $\mathrm{B}(\tau\to \mu\nu\bar{\nu})$ to give $\mathrm{B}(\tau\to e\nu\bar{\nu})=0.1783\pm0.0007$ which $R_{\tau}=3.636\pm0.021.$ Averaging these yields $\alpha_s(m_{\tau})=0.350\pm0.008$ using the experimental error alone. We assign a theoretical error equal to 40% of the contribution from the order α^3 term and all of the nonperturbative contributions. This then gives $\alpha_s(m_{\tau})=0.35\pm0.03$ for the final result.

9.5. QCD in high-energy hadron collisions

There are many ways in which perturbative QCD can be tested in high-energy hadron colliders. The quantitative tests are only useful if the process in question has been calculated beyond leading order in QCD perturbation theory. The production of hadrons with large transverse momentum in hadron-hadron collisions provides a direct probe of the scattering of quarks and gluons: $qq \rightarrow qq$, $qg \rightarrow qg$, $gg \rightarrow gg$, etc. Recent higher-order QCD calculations of the jet rates [59] and shapes are in impressive agreement with data [60]. This agreement has led to the proposal that these data could be used to provide a determination of α_s [61]. Data are also available on the angular distribution of jets; these are also in agreement with QCD expectations [62,63].

QCD corrections to Drell-Yan type cross sections (i.e., the production in hadron collisions by quark-antiquark annihilation of lepton pairs of invariant mass Q from virtual photons, or of real W or Z bosons), are known [64]. These $\mathcal{O}(\alpha_s)$ QCD corrections are sizable at small values of Q. It is interesting to note that the corresponding correction to W and Z production, as measured in $p\bar{p}$ collisions at $\sqrt{s} = 0.63$ TeV and $\sqrt{s} = 1.8$ TeV, has essentially the same theoretical form and is of order 30%.

The production of W and Z bosons and photons at large transverse momentum can also be used to test QCD. The leading-order QCD subprocesses are $q\overline{q} \to \gamma g$ and $qg \to \gamma q$. If the parton distributions are taken from other processes and a value of $\Lambda_{\overline{MS}}^{(4)}$ assumed, then an absolute prediction is obtained. Conversely, the data can be used to extract information used to extract information on quark and gluon distributions and on the value of $\Lambda_{\overline{MS}}^{(4)}$. The next-to-leading-order QCD corrections are known [65,66] (for photons), and for W/Z production [67], and so a precision test is possible in principle. Data exist from the CDF and DØ collaborations [68,69]. The UA2 collaboration [70] has extracted a value of $\alpha_s(M_W) = 0.123 \pm 0.018(\text{stat.}) \pm 0.017(\text{syst.})$ from the measured ratio $R_W = \frac{\sigma(W+1\mathrm{jet})}{\sigma(W+0\mathrm{jet})}$. The result depends on the algorithm used to define a jet, and the dominant systematic errors due to fragmentation and corrections for underlying events (the former causes jet energy to be lost, the latter causes it to be increased) are connected to the algorithm. The scale at which $\alpha_s(M)$ is to be evaluated is not clear. A change from $\mu = M_W$ to $\mu = M_W/2$ causes a shift of 0.01 in the extracted α_s . The quoted error should be increased to take this into account. There is dependence on the parton distribution functions, and hence, α_s appears explicitly in the formula for R_W , and implicitly in the distribution functions. The DØ collaboration has performed an analysis similar to UA2. They are unable to obtain a fit where the two values of α_s are consistent with one another, and do not quote a value of α_s [71]. The values from this process are no longer used in determining the overall average value of

9.6. QCD in heavy-quarkonium decay

Under the assumption that the hadronic and leptonic decay widths of heavy $Q\overline{Q}$ resonances can be factorized into a nonperturbative part—dependent on the confining potential—and a calculable perturbative part, the ratios of partial decay widths allow measurements of α_s at the heavy-quark mass scale. The most precise data come from the decay widths of the $1^{--}J/\psi(1S)$ and Υ resonances. The total decay width of the Υ is predicted by perturbative QCD [72]

$$\begin{split} R_{\mu}(\varUpsilon) &= \frac{\Gamma(\varUpsilon \to \text{hadrons})}{\Gamma(\varUpsilon \to \mu^{+}\mu^{-})} \\ &= \frac{10(\pi^{2} - 9)\alpha_{s}^{3}(M)}{9\pi\alpha_{\text{em}}^{2}} \\ &\times \left[1 + \frac{\alpha_{s}}{\pi} \left(-19.4 + \frac{3\beta_{0}}{2} \left(1.162 + \ln\left(\frac{2M}{M_{\Upsilon}}\right)\right)\right)\right] \ (9.16) \end{split}$$

Data are available for the Υ , Υ' , Υ'' , and J/ψ . The result is very sensitive to α_s and the data are sufficiently precise $(R_{\mu}(T) = 32.5 \pm 0.9)$ [73] that the theoretical errors will dominate. There are theoretical corrections to this simple formula due to the relativistic nature of the $Q\overline{Q}$ system; $v^2/c^2 \sim 0.1$ for the Υ . They are more severe for the J/ψ . There are also nonperturbative corrections of the form Λ^2/m_T^2 ; again these are more severe for the J/ψ . A fit to Υ , Υ' , and Υ'' [74] gives $\alpha_s(M_Z)=0.113\pm0.001$ (expt.). The results from each state separately and also from the J/ψ are consistent with each other. There is an uncertainty of order ±0.005 from the choice of scale; the error from v^2/c^2 corrections is a little larger. The ratio of widths $\frac{T \to \gamma gg}{T \to ggg}$ has been measured by the CLEO collaboration who use it to determine $\alpha_s(9.45 \text{ GeV}) = 0.163 \pm 0.002 \pm 0.014$ [76] which corresponds to $\alpha_s(M_Z) = 0.110 \pm 0.001 \pm 0.007$. The error is dominated by theoretical uncertainties associated with the scale choice. The theoretical uncertainties due to the production of photons in fragmentation [75] are small [76].

9.7. Perturbative QCD in e^+e^- collisions

The total cross section for $e^+e^- \to \text{hadrons}$ is obtained (at low values of \sqrt{s}) by multiplying the muon-pair cross section by the factor $R=3\Sigma_q e_q^2$. The higher-order QCD corrections to this quantity have been calculated, and the results can be expressed in terms of the factor:

$$R = R^{(0)} \left[1 + \frac{\alpha_s}{\pi} + C_2 \left(\frac{\alpha_s}{\pi} \right)^2 + C_3 \left(\frac{\alpha_s}{\pi} \right)^3 + \cdots \right] , \qquad (9.17)$$

where $C_2 = 1.411$ and $C_3 = -12.8$ [77].

 $R^{(0)}$ can be obtained from the formula for $d\sigma/d\Omega$ for $e^+e^- \to f\overline{f}$ by integrating over Ω . The formula is given in Sec. 36.2 of this *Review*. This result is only correct in the zero-quark-mass limit. The $\mathcal{O}(\alpha_s)$ corrections are also known for massive quarks [78]. The principal advantage of determining α_s from R in e^+e^- annihilation is that there is no dependence on fragmentation models, jet algorithms, *etc*.

A comparison of the theoretical prediction of Eq. (9.17) (corrected for the b-quark mass), with all the available data at values of \sqrt{s} between 20 and 65 GeV, gives [79] $\alpha_s(35 \text{ GeV}) = 0.146 \pm 0.030$. The size of the order α_s^3 term is of order 40% of that of the order α_s^2 and 3% of the order α_s . If the order α_s^3 term is not included, a fit to the data yields α_s (34 GeV) = 0.142 ± 0.03, indicating that the theoretical uncertainty is smaller than the experimental error.

Measurements of the ratio of hadronic to leptonic width of the Z at LEP and SLC, Γ_h/Γ_μ probe, the same quantity as R. Using the average of $\Gamma_h/\Gamma_\mu=20.783\pm0.029$ gives $\alpha_s(M_Z)=0.124\pm0.0043$ [80] There are theoretical errors arising from the values of top-quark and Higgs masses which enter due to electroweak corrections to the Z width and from the choice of scale.

While this method has small theoretical uncertainties from QCD itself, it relies sensitively on the electroweak couplings of the Z to quarks [81]. The presence of new physics which changes these

couplings via electroweak radiative corrections would invalidate the value of $\alpha_s(M_Z)$. However, given the excellent agreement [82] of the many measurements at the Z, there is no reason not to use the value of $\alpha_s(M_Z)=0.1214\pm0.0031$ from the global fits of the various precision measurements at LEP/SLC and the W and top masses in the world average (see the section on "Electroweak model and constraints on new physics," Sec. 10 of this Review)

An alternative method of determining α_s in $e^+e^{-\bullet}$ annihilation is from measuring quantities that are sensitive to the relative rates of two-, three-, and four-jet events. A recent review should be consulted for more details [83] of the issues mentioned briefly here. In addition to simply counting jets, there are many possible choices of such "shape variables": thrust [84], energy-energy correlations [85], average jet mass, etc. All of these are infrared safe, which means they can be reliably calculated in perturbation theory. The starting point for all these quantities is the multijet cross section. For example, at order α_s , for the process $e^+e^- \to qqg$: [86]

$$\frac{1}{\sigma} \frac{d^2 \sigma}{dx_1 dx_2} = \frac{2\alpha_s}{3\pi} \frac{x_1^2 + x_2^2}{(1 - x_1)(1 - x_2)},$$
 (9.18)

where

$$x_i = \frac{2E_i}{\sqrt{s}} \tag{9.19}$$

are the center-of-mass energy fractions of the final-state (massless) quarks. A distribution in a "three-jet" variable, such as those listed above, is obtained by integrating this differential cross section over an appropriate phase space region for a fixed value of the variable. The order α_s^2 corrections to this process have been computed, as well as the 4-jet final states such as $e^+e^- \to qqgg$ [87].

There are many methods used by the e^+e^- experimental groups to determine α_s from the event topology. The jet-counting algorithm, originally introduced by the JADE collaboration [88], has been used by many other groups. Here, particles of momenta p_i and p_j are combined into a pseudo-particle of momentum $p_i + p_j$ if the invariant mass of the pair is less than $y_0\sqrt{s}$. The process is then iterated until no more pairs of particles or pseudo-particles remain. The remaining number is then defined to be the number of jets in the event, and can be compared to the QCD prediction. The Durham algorithm is slightly different: in computing the mass of a pair of partons, it uses $M^2 = 2\min(E_1^2, E_2^2)(1 - \cos\theta_{ij})$ for partons of energies E_i and E_j separated by angle θ_{ij} [89].

There are theoretical ambiguities in the way this process is carried out. Quarks and gluons are massless, whereas the observed hadrons are not, so that the massive jets that result from this scheme cannot be compared directly to the massless jets of perturbative QCD. Different recombination schemes have been tried, for example combining 3-momenta and then rescaling the energy of the cluster so that it remains massless. These schemes result in the same data giving a slightly different values [90,91] of α_s . These differences can be used to determine a systematic error. In addition, since what is observed are hadrons rather than quarks and gluons, a model is needed to describe the evolution of a partonic final state into one involving hadrons, so that detector corrections can be applied. The QCD matrix elements are combined with a parton-fragmentation model. This model can then be used to correct the data for a direct comparison with the parton calculation. The different hadronization models that are used [92-95] model the dynamics that are controlled by nonperturbative QCD effects which we cannot yet calculate. The fragmentation parameters of these Monte Carlos are tuned to get agreement with the observed data. The differences between these models contribute to the systematic errors. The systematic errors from recombination schemes and fragmentation effects dominate over the statistical and other errors of the LEP/SLD experiments.

The scale M at which $\alpha_s(M)$ is to be evaluated is not clear. The invariant mass of a typical jet (or $\sqrt{sy_0}$) is probably a more appropriate choice than the e^+e^- center-of-mass energy. While there is no justification for doing so, if the value is allowed to float in the fit

to the data, the data tend to prefer values of order $\sqrt{s}/10$ GeV for some variables, whereas others have only a preferred range of M>3 GeV [91,96]; the exact value depends on the variable that is fitted.

The perturbative QCD formulae can break down in special kinematical configurations. For example, the thrust distribution contains terms of the type $\alpha_s \ln^2(1-T)$. The higher orders in the perturbation expansion contain terms of order $\alpha_s^n \ln^m (1-T)$. For $T \sim 1$ (the region populated by 2-jet events), the perturbation expansion is unreliable. The terms with $n \leq m$ can be summed to all orders in α_s [97]. If the jet recombination methods are used higherorder terms involve $\alpha_A^n \ln^m(y_0)$, these too can be resummed [98]. The resummed results give better agreement with the data at large values of T. Some caution should be exercised in using these resummed results because of the possibility of overcounting; the showering Monte Carlos that are used for the fragmentation corrections also generate some of these leading-log corrections. Different schemes for combining the order α_s^2 and the resummations are available [99]. These different schemes result in shifts in α_s of order ± 0.002 . An average of the recent results at the Z resonance from SLD [91], OPAL [100], L3 [101], ALEPH [102], and DELPHI [103], using the combined α_s^2 and resummation fitting to a large set of shape variables, gives $\alpha_s(M_Z) = 0.122 \pm 0.007$. The errors in the values of $\alpha_s(M_Z)$ from these shape variables are totally dominated by the theoretical uncertainties associated with the choice of scale, and the effects of hadronization Monte Carlos on the different quantities fitted.

Similar studies on event shapes have been undertaken at TRISTAN, at PEP/PETRA, and at CLEO. A combined result from various shape parameters by the TOPAZ collaboration gives $\alpha_s(58~{\rm GeV})=0.125\pm0.009$, using the fixed order QCD result, and $\alpha_s(58~{\rm GeV})=0.132\pm0.008$ (corresponding to $\alpha_s(M_Z)=0.123\pm0.007$), using the same method as in the SLD and LEP average [104]. The measurements of event shapes at PEP/PETRA are summarized in earlier editions of this note. The results are consistent with those from Z decay, but have larger errors. We use $\alpha_s(34~{\rm GeV})=0.14\pm0.02$ [105]. A recent analysis by the TPC group [106] gives $\alpha_s(29~{\rm GeV})=0.160\pm0.012$, using the same method as TOPAZ. This value corresponds to $\alpha_s(M_Z)=0.131\pm0.010$

The CLEO collaboration fits to the order α_s^2 results for the two jet fraction at $\sqrt{s}=10.53$ GeV, and obtains $\alpha_s(10.93)=0.164\pm0.004$ (expt.) ±0.014 (theory) [107]. The dominant systematic error arises from the choice of scale (μ) , and is determined from the range of α_s that results from fit with $\mu=10.53$ GeV, and a fit where μ is allowed to vary to get the lowest χ^2 . The latter results in $\mu=1.2$ GeV. Since the quoted result corresponds to $\alpha_s(1.2)=0.35$, it is by no means clear that the perturbative QCD expression is reliable and the resulting error should, therefore, be treated with caution. A fit to many different variables as is done in the LEP/SLC analyses would give added confidence to the quoted error.

Recently studies have been carried out at ~130 GeV [108]. These can be combined to give $\alpha_s(130~\text{GeV}) = 0.114 \pm 0.008$. Preliminary data from ~ 165 GeV [109] are consistent with the decrease in α_s expected at the higher energy.

Since the errors in the event shape measurements are dominantly systematic, and are common to the experiments, the results from PEP/PETRA, TRISTAN, LEP, SLC, and CLEO are combined to give $\alpha_s(M_Z)=0.121\pm0.007$. All of the experiments are consistent with this average and, taken together, provide verification of the running of the coupling constant with energy.

The total cross section $e^+e^- \to b\bar{b} + X$ near threshold can be used to determine α_s [110]. The result quoted is $\alpha_s(M_Z) = 0.109 \pm 0.001$. The relevant process is only calculated to leading order and the BLM scheme [9] is used. This results in $\alpha_s(0.632\ m_b)$. If $\alpha_s(m_b)$ is used, the resulting $\alpha_s(M_Z)$ shifts to ~ 0.117 . This result is not used in the average.

9.8. Scaling violations in fragmentation functions

Measurements of the fragmentation function $d_i(z, E)$, being the probability that a hadron of type i be produced with energy zE in e^+e^- collisions at $\sqrt{s}=2E$, can be used to determine α_s . As in the case of scaling violations in structure functions, QCD predicts only the E dependence. Hence, measurements at different energies are needed to extract a value of α_s . Because the QCD evolution mixes the fragmentation functions for each quark flavor with the gluon fragmentation function, it is necessary to determine each of these before α_s can be extracted. The ALEPH collaboration has used data from energies ranging from $\sqrt{s} = 22$ GeV to $\sqrt{s} = 91$ GeV. A flavor tag is used to discriminate between different quark species, and the longitudinal and transverse cross sections are used to extract the gluon fragmentation function [111]. The result obtained is $\alpha_s(M_Z) = 0.126 \pm 0.007$ (expt.) ± 0.006 (theory) [112]. The theory error is due mainly to the choice of scale. The OPAL collaboration [113] has also extracted the separate fragmentation functions. DELPHI [114] has also performed a similar analysis using data from other experiments at lower energy with the result $\alpha_s(M_Z) = 0.124 \pm 0.007 \pm 0.009$ (theory). The larger theoretical error is due to the larger range of scales that were used in the fit. These results can be combined to give $\alpha_s(M_Z) = 0.125 \pm 0.005 \pm 0.008$ (theory).

 e^+e^- can also be used to study photon-photon interaction, which can be used to measure the structure function of a photon [115]. This process was included in earlier versions of this Review [115] which can be consulted for details on older measurements [116–119]. More recent data has become available from LEP [120,121] and from TRISTAN [122,123] which show Q^2 dependence of the structure function that is consistent with QCD expectations.

9.9. Jet rates in ep collisions

At lowest order in α_s , the ep scattering process produces a final state of (1+1) jets, one from the proton fragment and the other from the quark knocked out by the process $e + quark \rightarrow e + quark$. At next order in α_s , a gluon can be radiated, and hence a (2+1) jet final state produced. By comparing the rates for these (1+1) and (2+1) jet processes, a value of α_s can be obtained. A NLO QCD calculation is available [124]. The basic methodology is similar to that used in the jet counting experiments in e^+e^- annihilation discussed above. Unlike those measurements, the ones in ep scattering are not at a fixed value of Q^2 . In addition to the systematic errors associated with the jet definitions, there are additional ones since the structure functions enter into the rate calculations. Results from H1 [125] and ZEUS [126] can be combined to give $\alpha_s(M_Z) = 0.118 \pm 0.001$ (expt.) ± 0.008 (syst.). The contributions to the systematic errors from experimental effects (mainly the hadronic energy scale) in the case of ZEUS (H1) are comparable to (smaller than) the theoretical ones arising from scale choice, structure functions, and jet definitions. The theoretical errors are common to the two measurements; therefore, we have not reduced the systematic error after forming the average.

9.10. Lattice QCD

Lattice gauge theory calculations can be used to calculate, using non-perturbative methods, a physical quantity that can be measured experimentally. The value of this quantity can then be used to determine the QCD coupling that enters in the calculation. For a recent review of the methodology see Ref. 127. For example, the energy levels of a $Q\overline{Q}$ system can be determined and then used to extract α_s . The masses of the $Q\overline{Q}$ states depend only on the quark mass and on α_s . A limitation is that calculations cannot be performed for three light quark flavors. Results are available for zero ($n_f = 0$, quenched approximation) and two light flavors, which allow extrapolation to three. The coupling constant so extracted is in a lattice renormalization scheme, and must be converted to the MS scheme for comparison with other results. Using the mass differences of Υ and Υ' and Υ'' and χ_b , Davies et al. [128] extract a value of $\alpha_s(M_Z) = 0.1174 \pm 0.0024$. A similar result with larger errors is reported by [129], where results are consistent with $\alpha_s(M_Z) = 0.111 \pm 0.006$. A combination of the results from quenched [130] and $(n_f = 2)$ [131] gives $\alpha_s(M_Z) = 0.116 \pm 0.003$ [132]. Calculations [133] using the strength of the force between two heavy quarks computed in the quenched approximation obtains a value of $\alpha_s(5 \text{ GeV})$ that is consistent with these results. There have also been investigations of the running of α_s [134]. These show remarkable agreement with the two loop perturbative result of Eq. (9.4).

There are several sources of error in these estimates of $\alpha_s(M_Z)$. The experimental error associated with the measurements of the particle masses is negligible. The conversion from the lattice coupling constant to the $\overline{\rm MS}$ constant is obtained using a perturbative expansion where one coupling expanded as a power series in the other. This series is only known to second order. A third order calculation exists only from the $n_f=0$ case [135]. Its inclusion leads to a shift in the extracted value of $\alpha_s(M_Z)$ of +0.002. Other theoretical errors arising from the limited statistics of the Monte-Carlo calculation, extrapolation in n_f , and corrections for light quark masses are smaller than this.

The result with a more conservative error $\alpha_s(M_Z) = 0.117 \pm 0.003$ will be used in the average.

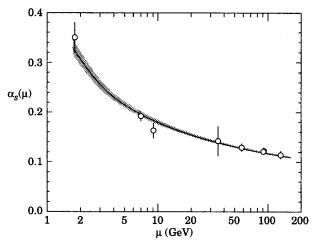


Figure 9.2: Summary of the values of $\alpha_s(\mu)$ at the values of μ where they are measured. The lines show the central values and the $\pm 1\sigma$ limits of our average. The figure clearly shows the decrease in $\alpha_s(\mu)$ with increasing μ .

9.11. Conclusions

The need for brevity has meant that many other important topics in QCD phenomenology have had to be omitted from this review. One should mention in particular the study of exclusive processes (form factors, elastic scattering, ...), the behavior of quarks and gluons in nuclei, the spin properties of the theory, the interface of soft and hard QCD as manifest, for example, by hard diffractive processes, and QCD effects in hadron spectroscopy.

We have focused on those high-energy processes which currently offer the most quantitative tests of perturbative QCD. Figure 9.1 shows the values of $\alpha_s(M_Z)$ deduced from the various experiments. Figure 9.2 shows the values and the values of Q where they are measured. This figure clearly shows the experimental evidence for the variation of $\alpha_s(Q)$ with Q.

An average of the values in Fig. 9.1 gives $\alpha_s(M_z)=0.1189$, with a total χ^2 of 3.3 for eleven fitted points, showing good consistency among the data. The error on the average, assuming that all of the errors in the contributing results are uncorrelated, is ± 0.0015 , and is an underestimate. Almost all of the values used in the average are dominated by systematic, usually theoretical errors. Only some of these, notably from the choice of scale, are correlated. Two of the results with the smallest errors are the ones from τ decay and lattice gauge theory. If these errors are increased to ± 0.006 , the average is unchanged and the error increases to 0.0020. We quote our average value as $\alpha_s(M_Z)=0.119\pm 0.002$, which corresponds to $\Lambda^{(5)}=219^{+25}_{-23}$ MeV using Eq. (9.5a), only the two-loop result (i.e. dropping the last term in Eq. (9.5a)) gives $\Lambda^{(5)}=237^{+26}_{-24}$ MeV. Future experiments can

be expected to improve the measurements of α_s somewhat. Precision at the 1% level may be achievable if the systematic and theoretical errors can be reduced [136].

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10. ELECTROWEAK MODEL AND CONSTRAINTS ON NEW PHYSICS

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- 10.1 Introduction
- 10.2 Renormalization and radiative corrections
- 10.3 Cross-section and asymmetry formulas
- $10.4 \quad W \text{ and } Z \text{ decays}$
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10.1. Introduction

The standard electroweak model is based on the gauge group [1] $\mathrm{SU}(2) \times \mathrm{U}(1)$, with gauge bosons W_{μ}^i , i=1,2,3, and B_{μ} for the $\mathrm{SU}(2)$ and $\mathrm{U}(1)$ factors, respectively, and the corresponding gauge coupling constants g and g'. The left-handed fermion fields $\psi_i = \begin{pmatrix} \nu_i \\ \ell_i^- \end{pmatrix}$ and $\begin{pmatrix} u_i \\ d_i^i \end{pmatrix}$ of the i^{th} fermion family transform as doublets under $\mathrm{SU}(2)$, where $d_i' \equiv \sum_j V_{ij} \ d_j$, and V is the Cabibbo-Kobayashi-Maskawa mixing matrix. (Constraints on V are discussed in the section on the Cabibbo-Kobayashi-Maskawa mixing matrix.) The right-handed fields are $\mathrm{SU}(2)$ singlets. In the minimal model there are three fermion families and a single complex Higgs doublet $\phi \equiv \begin{pmatrix} \phi^+ \\ \phi^0 \end{pmatrix}$.

After spontaneous symmetry breaking the Lagrangian for the fermion fields is

$$\begin{split} \mathscr{L}_{F} &= \sum_{i} \overline{\psi}_{i} \left(i \, \partial - m_{i} - \frac{g m_{i} H}{2 M_{W}} \right) \psi_{i} \\ &- \frac{g}{2 \sqrt{2}} \sum_{i} \overline{\psi}_{i} \, \gamma^{\mu} \, (1 - \gamma^{5}) (T^{+} \, W_{\mu}^{+} + T^{-} \, W_{\mu}^{-}) \, \psi_{i} \\ &- e \sum_{i} q_{i} \, \overline{\psi}_{i} \, \gamma^{\mu} \, \psi_{i} \, A_{\mu} \\ &- \frac{g}{2 \cos \theta_{W}} \sum_{i} \overline{\psi}_{i} \, \gamma^{\mu} (g_{V}^{i} - g_{A}^{i} \gamma^{5}) \, \psi_{i} \, Z_{\mu} \, . \end{split}$$
(10.1)

 $\theta_W \equiv \tan^{-1}(g'/g)$ is the weak angle; $e = g \sin \theta_W$ is the positron electric charge; and $A \equiv B \cos \theta_W + W^3 \sin \theta_W$ is the (massless) photon field. $W^{\pm} \equiv (W^1 \mp i W^2)/\sqrt{2}$ and $Z \equiv -B \sin \theta_W + W^3 \cos \theta_W$ are the massive charged and neutral weak boson fields, respectively. T^+ and T^- are the weak isospin raising and lowering operators. The vector and axial couplings are

$$g_V^i \equiv t_{3L}(i) - 2q_i \sin^2 \theta_W , \qquad (10.2)$$

$$g_A^i \equiv t_{3L}(i) , \qquad (10.3)$$

where $t_{3L}(i)$ is the weak isospin of fermion i (+1/2 for u_i and ν_i ; -1/2 for d_i and e_i) and q_i is the charge of ψ_i in units of e.

The second term in \mathscr{L}_F represents the charged-current weak interaction [2]. For example, the coupling of a W to an electron and a neutrino is

$$-\frac{e}{2\sqrt{2}\sin\theta_W} \left[W_{\mu}^{-} \, \bar{e} \, \gamma^{\mu} (1 - \gamma^5) \nu + W_{\mu}^{+} \, \bar{\nu} \, \gamma^{\mu} \, (1 - \gamma^5) e \right] \, . \tag{10.4}$$

For momenta small compared to M_W , this term gives rise to the effective four-fermion interaction with the Fermi constant given (at tree level, *i.e.*, lowest order in perturbation theory) by $G_F/\sqrt{2} = g^2/8M_W^2$. CP violation is incorporated in the Standard Model by a single observable phase in V_{ij} . The third term in \mathcal{L}_F describes electromagnetic interactions (QED), and the last is the weak neutral-current interaction.

In Eq. (10.1), m_i is the mass of the i^{th} fermion ψ_i . For the quarks these are the current masses. For the light quarks, as described in the Particle Listings, $\overline{m}_u \approx 2-8$ MeV, $\overline{m}_d \approx 5-15$ MeV, and $\overline{m}_s \approx 100-300$ MeV (these are running $\overline{\text{MS}}$ masses evaluated at $\mu=1$ GeV). For the heavier quarks, the $\overline{\text{MS}}$ masses are $\overline{m}_c(\mu=\overline{m}_c)\approx 1.0-1.6$ GeV and $\overline{m}_b(\mu=\overline{m}_b)\approx 4.1-4.5$ GeV. The average of the recent CDF [4] and DØ [5] values for the top quark

"pole" mass is $m_t=175\pm5$ GeV. See "The Note on Quark Masses" in the Particle Listings for more information.

H is the physical neutral Higgs scalar which is the only remaining part of ϕ after spontaneous symmetry breaking. The Yukawa coupling of H to ψ_i , which is flavor diagonal in the minimal model, is $gm_i/2M_W$. The H mass is not predicted by the model. Experimental limits are given in the Higgs section. In nonminimal models there are additional charged and neutral scalar Higgs particles [6].

10.2. Renormalization and radiative corrections

The Standard Model has three parameters (not counting M_H and the fermion masses and mixings). A particularly useful set is:

- (a) The fine structure constant α = 1/137.0359895 (61), determined from the quantum Hall effect. In most electroweak-renormalization schemes, it is convenient to define a running α dependent on the energy scale of the process, with α⁻¹ ~ 137 appropriate at low energy. (The running has recently been observed directly [7].) At energies of order M_Z, α⁻¹ ~ 128. For example, in the modified minimal subtraction (MS) scheme [8], one has α̂(M_Z)⁻¹ = 127.88 ± 0.09, while the conventional (on-shell) QED renormalization yields [9] α(M_Z)⁻¹ = 128.88 ± 0.09, which differs by finite constants from α̂(M_Z)⁻¹. The uncertainty, due to the low-energy hadronic contribution to vacuum polarization, is the dominant theoretical uncertainty in the interpretation of precision data. Other recent evaluations [10–14] of this effect are in reasonable agreement. Further improvement will require better measurements of the cross section for e⁺e⁻ → hadrons at low energy.
- (b) The Fermi constant, $G_F = 1.16639(1) \times 10^{-5} \text{ GeV}^{-2}$, determined from the muon lifetime formula [15],

$$\tau_{\mu}^{-1} = \frac{G_F^2 m_{\mu}^5}{192\pi^3} F\left(\frac{m_e^2}{m_{\mu}^2}\right) \left(1 + \frac{3}{5} \frac{m_{\mu}^2}{M_W^2}\right) \times \left[1 + \frac{\alpha(m_{\mu})}{2\pi} \left(\frac{25}{4} - \pi^2\right)\right] , \qquad (10.5a)$$

where

$$F(x) = 1 - 8x + 8x^3 - x^4 - 12x^2 \ln x , \qquad (10.5b)$$

and

$$\alpha(m_{\mu})^{-1} = \alpha^{-1} - \frac{2}{3\pi} \ln\left(\frac{m_{\mu}}{m_{\tau}}\right) + \frac{1}{6\pi} \approx 136$$
, (10.5c)

where the uncertainty in G_F is from the input quantities. There are additional uncertainties from higher order radiative corrections, which can be estimated from the magnitude of the known $\alpha^2 \ln(m_\mu/m_e)$ term of $\sim 1.8 \times 10^{-10}$ (alternatively, one can view Eq. (10.5) as the exact definition of G_F ; then the theoretical uncertainty appears instead in the formulae for quantities derived from G_F).

- (c) $\sin^2 \theta_W$, determined from the Z mass and other Z pole observables, the W mass, and neutral-current processes [16]. The value of $\sin^2 \theta_W$ depends on the renormalization prescription. There are a number of popular schemes [18–23] leading to $\sin^2 \theta_W$ values which differ by small factors which depend on m_t and M_H . The notation for these schemes is shown in Table 10.1. Discussion of the schemes follows the table.
 - (i) The on-shell scheme promotes the tree-level formula $\sin^2\theta_W=1-M_W^2/M_Z^2$ to a definition of the renormalized $\sin^2\theta_W$ to all orders in perturbation theory, i.e., $\sin^2\theta_W\to s_W^2\equiv 1-M_W^2/M_Z^2$. This scheme is simple conceptually. However, M_W is known much less precisely than M_Z and in practice one extracts s_W^2 from M_Z alone using

$$M_W = \frac{A_0}{s_W(1 - \Delta r)^{1/2}} , \qquad (10.6a)$$

$$M_Z = \frac{M_W}{c_W} \,, \tag{10.6b}$$

Table 10.1: Notations used to indicate the various schemes discussed in the text. Each definition of $\sin \theta_W$ leads to values that differ by small factors depending on m_t and M_H .

Scheme	Notation
On-shell	$s_W = \sin \theta_W$
NOV	$s_{M_Z} = \sin \theta_W$
MS	$\widehat{s}_Z^- = \sin \theta_W$
$\overline{\text{MS}}$ ND	$\widehat{s}_{ND} = \sin heta_W$
Effective angle	$\overline{s}_f = \sin \theta_W$

where $s_W \equiv \sin\theta_W$, $c_W \equiv \cos\theta_W$, $A_0 = (\pi\alpha/\sqrt{2}G_F)^{1/2} = 37.2802$ GeV, and Δr includes the radiative corrections relating α , $\alpha(M_Z)$, G_F , M_W , and M_Z . One finds $\Delta r \sim \Delta r_0 - \rho_t/\tan^2\theta_W$, where $\Delta r_0 \approx 1 - \alpha/\alpha(M_Z) \approx 0.06$ is due to the running of α and $\rho_t = 3G_F m_t^2/8\sqrt{2}\pi^2 \approx 0.0096(m_t/175 \text{ GeV})^2$ represents the dominant (quadratic) m_t dependence. There are additional contributions to Δr from bosonic loops, including those which depend logarithmically on the Higgs mass M_H . One has $\Delta r = 0.0349 \mp 0.0019 \pm 0.0007$ for $(m_t, M_H) = (175 \pm 5 \text{ GeV}, M_Z)$, where the second uncertainty is from $\alpha(M_Z)$. Thus the value of s_W^2 extracted from M_Z includes a large uncertainty (∓ 0.0006) from the currently allowed range of m_t .

(ii) A more precisely determined quantity s_{MZ}^2 can be obtained from M_Z by removing the (m_t, M_H) dependent term from Δr [19], i.e.,

$$s_{M_Z}^2 c_{M_Z}^2 \equiv \frac{\pi \alpha(M_Z)}{\sqrt{2} G_F M_Z^2} \ . \tag{10.7}$$

This yields $s_{M_Z}^2=0.23116\pm0.00022$, with most of the uncertainty from α rather than M_Z . Scheme (ii) is equivalent to using M_Z rather than $\sin^2\theta_W$ as the third fundamental parameter. However, it recognizes that $s_{M_Z}^2$ is still a useful derived quantity. The small uncertainty in $s_{M_Z}^2$ compared to other schemes is because the m_t dependence has been removed by definition. However, the m_t uncertainty reemerges when other quantities $(e.g., M_W)$ or other Z pole observables) are predicted in terms of M_Z .

Both s_W^2 and $s_{M_Z}^2$ depend not only on the gauge couplings but also on the spontaneous-symmetry breaking, and both definitions are awkward in the presence of any extension of the Standard Model which perturbs the value of M_Z (or M_W). Other definitions are motivated by the tree-level coupling constant definition $\theta_W = \tan^{-1}(g'/g)$.

(iii) In particular, the modified minimal subtraction $(\overline{\rm MS})$ scheme introduces the quantity $\sin^2 \widehat{\theta}_W(\mu) \equiv \widehat{g}^{\prime 2}(\mu) / [\widehat{g}^{2}(\mu) +$ $\widehat{g}^{\prime 2}(\mu)$, where the couplings \widehat{g} and \widehat{g}^{\prime} are defined by modified minimal subtraction and the scale μ is conveniently chosen to be M_Z for electroweak processes. The value of $\widehat{s}_Z^2 = \sin^2 \widehat{\theta}_W(M_Z)$ extracted from M_Z is less sensitive than s_W^2 to m_t (by a factor of $\tan^2 \theta_W$), and is less sensitive to most types of new physics than s_W^2 or $s_{M_Z}^2$. It is also very useful for comparing with the predictions of grand unification. There are actually several variant definitions of $\sin^2 \widehat{\theta}_W(M_Z)$, differing according to whether or how finite $\alpha \ln(m_t/M_Z)$ terms are decoupled (subtracted from the couplings). One cannot entirely decouple the $\alpha \ln(m_t/M_Z)$ terms from all electroweak quantities because $m_t \gg m_b$ breaks SU(2) symmetry. The scheme that will be adopted here decouples the $\alpha \ln(m_t/M_Z)$ terms from the $\gamma - Z$ mixing [8,20], essentially eliminating any $\ln(m_t/M_Z)$ dependence in the formulae for asymmetries at the Z pole when written in

terms of \hat{s}_{Z}^{2} . The various definitions are related by

$$\hat{s}_{Z}^{2} = c(m_{t}, M_{H}) s_{W}^{2} = \bar{c}(m_{t}, M_{H}) s_{M_{Z}}^{2},$$
 (10.8)

where $c=1.0376\pm0.0021$ for $m_t=175\pm5$ GeV and $M_H=M_Z$. Similarly, $\overline{c}=1.0003\mp0.0007$. The quadratic m_t dependence is given by $c\sim 1+\rho_t/\tan^2\theta_W$ and $\overline{c}\sim 1-\rho_t/(1-\tan^2\theta_W)$, respectively. The expressions for M_W and M_Z in the $\overline{\rm MS}$ scheme are

$$M_W = \frac{A_0}{\widehat{s}_Z(1 - \Delta \widehat{r}_W)^{1/2}}$$
, (10.9a)

$$M_Z = \frac{M_W}{\widehat{\rho}^{1/2}\widehat{c}_Z} \ . \tag{10.9b}$$

One predicts $\Delta \hat{r}_W = 0.0698 \pm 0.0001 \pm 0.0007$ for $m_t = 175 \pm 5$ GeV and $M_H = M_Z$. $\Delta \hat{r}_W$ has no quadratic m_t dependence, because shifts in M_W are absorbed into the observed G_F , so that the error in $\Delta \hat{r}_W$ is dominated by $\Delta r_0 = 1 - \alpha/\alpha(M_Z)$, which induces the second quoted uncertainty. Similarly, $\hat{\rho} \sim 1 + \rho_t$. Including bosonic loops, $\hat{\rho} = 1.0109 \pm 0.0006$ for $(m_t, M_H) = (175 \pm 5 \text{ GeV}, M_Z)$.

(iv) A variant $\overline{\rm MS}$ quantity $\widehat{s}_{\rm ND}^2$ (used in the 1992 edition of this Review) does not decouple the $\alpha \ln(m_t/M_Z)$ terms [21]. It is related to \widehat{s}_Z^2 by

$$\widehat{s}_Z^2 = \widehat{s}_{\rm ND}^2 / \left(1 + \frac{\widehat{\alpha}}{\pi} d\right) , \qquad (10.10a)$$

$$d = \frac{1}{3} \left(\frac{1}{\widehat{s}^2} - \frac{8}{3} \right) \left[\left(1 + \frac{\widehat{\alpha}_s}{\pi} \right) \ln \frac{m_t}{M_Z} - \frac{15\widehat{\alpha}_s}{8\pi} \right] (10.10b)$$

where $\widehat{\alpha}_s$ is the QCD coupling at M_Z . Thus, $\widehat{s}_Z^2 - \widehat{s}_{\rm ND}^2 \sim -0.0002$ for $m_t=175$ GeV.

(v) Yet another definition, the effective angle [22,23] \bar{s}_f^2 for Z coupling to fermion f, is described at the end of Sec. 10.3.

Experiments are now at such a level of precision that complete $\mathcal{O}(\alpha)$ radiative corrections must be applied. For neutral-current and Z pole processes, these corrections are conveniently divided into two classes:

- QED diagrams involving the emission of real photons or the exchange of virtual photons in loops, but not including vacuum polarization diagrams. These graphs often yield finite and gaugeinvariant contributions to observable processes. However, they are dependent on energies, experimental cuts, etc., and must be calculated individually for each experiment.
- 2. Electroweak corrections, including γγ, γZ, ZZ, and WW vacuum polarization diagrams, as well as vertex corrections, box graphs, etc., involving virtual W's and Z's. Many of these corrections are absorbed into the renormalized Fermi constant defined in Eq. (10.5). Others modify the tree-level expressions for Z pole observables and neutral-current amplitudes in several ways [16]. One-loop corrections are included for all processes. In addition, certain two-loop corrections are also important. In particular, two-loop corrections involving the top-quark modify ρ_t in ρ̂, Δr, and elsewhere by

$$\rho_t \to \rho_t [1 + R(M_H, m_t)\rho_t/3] .$$
(10.11)

 $R(M_H,m_t)$ is best described as an expansion in M_Z^2/m_t^2 . The unsuppressed terms were first obtained in Ref. 24, and are known analytically [25]. Contributions proportional to M_Z^2/m_t^2 were studied in Ref. 26 with the help of small and large Higgs mass expansions, which can be interpolated. These contributions are about as large as the leading ones in Refs. 24 and 25. Very recently, a subset of the relevant two-loop diagrams has been calculated numerically without any heavy mass expansion [27]. This serves as a valuable check on the M_H dependence of the leading terms obtained in Refs. 24–26. The difference turned out to be small. For M_H above its lower direct limit, -17 < R < -11. Mixed QCD-electroweak loops of order $\alpha \alpha_s m_t^2$ [28] and $\alpha \alpha_s^2 m_t^2$ [29]

increase the predicted value of m_t by 6%. This is, however, almost entirely an artifact of using the pole mass definition for m_t . The equivalent corrections when using the MS definition $\overline{m}_t(\overline{m}_t)$ increase m_t by less than 0.5%. The leading electroweak [24,25] and mixed [30] two-loop terms are also known for the $Z \to b\bar{b}$ vertex, but not the respective subleading ones.

10.3. Cross-section and asymmetry formulas

It is convenient to write the four-fermion interactions relevant to ν -hadron, νe , and parity violating e-hadron neutral-current processes in a form that is valid in an arbitrary gauge theory (assuming massless left-handed neutrinos). One has

$$-\mathcal{L}^{\nu \text{Hadron}} = \frac{G_F}{\sqrt{2}} \, \overline{\nu} \, \gamma^{\mu} \, (1 - \gamma^5) \nu$$

$$\times \sum_i \left[\epsilon_L(i) \, \overline{q}_i \, \gamma_{\mu} (1 - \gamma^5) q_i + \epsilon_R(i) \, \overline{q}_i \, \gamma_{\mu} (1 + \gamma^5) q_i \right] , \quad (10.12)$$

$$-\mathscr{L}^{\nu e} = \frac{G_F}{\sqrt{2}} \, \overline{\nu}_{\mu} \, \gamma^{\mu} (1 - \gamma^5) \nu_{\mu} \, \overline{e} \, \gamma_{\mu} (g_V^{\nu e} - g_A^{\nu e} \gamma^5) e \qquad (10.13)$$

(for $\nu_e e$ or $\nu_e e$, the charged-current contribution must be included), and

$$-\mathscr{L}^{\mathrm{eHadron}} = -\frac{G_F}{\sqrt{2}}$$

$$\times \sum_{i} \left[C_{1i} \bar{e} \gamma_{\mu} \gamma^{5} e \bar{q}_{i} \gamma^{\mu} q_{i} + C_{2i} \bar{e} \gamma_{\mu} e \bar{q}_{i} \gamma^{\mu} \gamma^{5} q_{i} \right] . \quad (10.14)$$

(One must add the parity-conserving QED contribution.)

The Standard Model expressions for $\epsilon_{L,R}(i)$, $g_{V,A}^{\nu e}$, and C_{ij} are given in Table 10.2. Note that $g_{V,A}^{\nu e}$ and the other quantities are coefficients of effective four-fermi operators, which differ from the quantities defined in Eq. (10.2) and Eq. (10.3) in the radiative corrections and in the presence of possible physics beyond the Standard Model.

A precise determination of the on-shell s_W^2 , which depends only very weakly on m_t and M_H , is obtained from deep inelastic neutrino scattering from (approximately) isoscalar targets [31]. The ratio $R_{\nu} \equiv \sigma_{\nu N}^{NC}/\sigma_{\nu N}^{CC}$ of neutral- to charged-current cross sections has been measured to 1% accuracy by the CDHS [32] and CHARM [33] collaborations at CERN [34], and the CCFR collaboration at Fermilab [35,36] has obtained an even more precise result, so it is important to obtain theoretical expressions for R_{ν} and $R_{\nu} \equiv \sigma_{\nu N}^{NC}/\sigma_{\nu N}^{CC}$ (as functions of $\sin^2\theta_W$) to comparable accuracy. Fortunately, most of the uncertainties from the strong interactions and neutrino spectra cancel in the ratio.

A simple zeroth-order approximation is

$$R_{\nu} = g_L^2 + g_R^2 r \; , \tag{10.15a}$$

$$R_{\nu} = g_L^2 + \frac{g_R^2}{r} \,, \tag{10.15b}$$

where

$$g_L^2 \equiv \epsilon_L (u)^2 + \epsilon_L (d)^2 \approx \frac{1}{2} - \sin^2 \theta_W + \frac{5}{9} \sin^4 \theta_W , \qquad (10.16a)$$

$$g_R^2 \equiv \epsilon_R (u)^2 + \epsilon_R (d)^2 \approx \frac{5}{9} \sin^4 \theta_W$$
, (10.16b)

and $r \equiv \sigma_{\overline{\nu}N}^{CC}/\sigma_{\nu N}^{CC}$ is the ratio of $\overline{\nu}$ and ν charged-current cross sections, which can be measured directly. (In the simple parton model, ignoring hadron energy cuts, $r \approx (\frac{1}{3} + \epsilon)/(1 + \frac{1}{3}\epsilon)$, where $\epsilon \sim 0.125$ is the ratio of the fraction of the nucleon's momentum carried by antiquarks to that carried by quarks.) In practice, Eq. (10.15) must be corrected for quark mixing, quark sea effects, c-quark threshold effects, nonisoscalarity, W-Z propagator differences, the finite muon mass, QED and electroweak radiative corrections. Details of the neutrino spectra, experimental cuts, x and Q^2 dependence of structure functions, and longitudinal structure functions enter only at the level of these corrections and therefore lead to very small uncertainties. The largest theoretical uncertainty is associated with the c-threshold, which

Table 10.2: Standard Model expressions for the neutral-current parameters for ν -hadron, νe , and e-hadron processes. At tree level, $\rho = \kappa = 1$, $\lambda = 0$. If radiative corrections are included, $\rho_{\nu N}^{NC} = 1.0084$, $\hat{\kappa}_{\nu N} = 0.9964$ (at $\langle Q^2 \rangle = 35 \text{ GeV}^2$), $\lambda_{uL} = -0.0031$, $\lambda_{dL} = -0.0025$, and $\lambda_{dR} = 2\lambda_{uR} = 7.5 \times 10^{-5}$ for $m_t = 175$ GeV and $M_H = M_Z = 91.1867$ GeV. For νe scattering, $\rho_{\nu e} = 1.0130$ and $\hat{\kappa}_{\nu e} = 0.9970$ (at $\langle Q^2 \rangle = 0$). For atomic parity violation and the SLAC polarized electron experiment, $\rho_{eq}' = 0.9879$, $\rho_{eq} = 1.0009$, $\hat{\kappa}_{eq}' = 1.0029$, $\hat{\kappa}_{eq} = 1.0304$, $\lambda_{1d} = -2\lambda_{1u} = 3.7 \times 10^{-5}$, $\lambda_{2u} = -0.0121$ and $\lambda_{2d} = 0.0026$. The dominant m_t dependence is given by $\rho \sim 1 + \rho_t$, while $\hat{\kappa} \sim 1$ (MS) or $\kappa \sim 1 + \rho_t / \tan^2 \theta_W$ (on-shell).

Quantity	Standard Model Expression
$\epsilon_L(u)$	$ ho_{ u N}^{NC} \left(rac{1}{2} - rac{2}{3} \widehat{\kappa}_{ u N} \widehat{\mathfrak{d}}_{Z}^{2} ight) + \lambda_{uL}$
$\epsilon_L(d)$	$ ho_{ u N}^{NC} \left(-rac{1}{2} + rac{1}{3} \widehat{\kappa}_{ u N} \ \widehat{s}_{m{Z}}^2 ight) + \lambda_{dL}$
$\epsilon_R(u)$	$ ho_{ u N}^{NC} \left(-rac{2}{3} \widehat{\kappa}_{ u N} \; \widehat{s}_{Z}^{2} ight) + \lambda_{u R}$
$\epsilon_R(d)$	$ ho_{ u N}^{NC} \left(rac{1}{3} \widehat{\kappa}_{ u N} \ \widehat{s}_{Z}^{2} ight) + \lambda_{dR}$
$g_V^{ u e}$	$ ho_{ u e} \left(-rac{1}{2} + 2 \widehat{\kappa}_{ u e} \; \widehat{s}_Z^2 ight)$
$g_A^{ u e}$	$ \rho_{\nu e}\left(-\frac{1}{2}\right) $
C_{1u}	$ ho_{eq}^{\prime}\left(-rac{1}{2}+rac{4}{3}\widehat{\kappa}_{eq}^{\prime}\;\widehat{s}_{Z}^{2} ight)+\lambda_{1u}$
C_{1d}	$ ho_{f eq}^\prime \left(rac{1}{2} - rac{2}{3} \widehat{\kappa}_{f eq}^\prime \; \widehat{s}_{f Z}^2 ight) + \lambda_{1d}$
C_{2u}	$ ho_{f eq}\left(-rac{1}{2}+2\widehat{\kappa}_{f eq}\;\widehat{m s}_{m Z}^2 ight)+\lambda_{m 2u}$
C _{2d}	$ ho_{eq}\left(rac{1}{2}-2\widehat{\kappa}_{eq}\;\widehat{s}_{Z}^{2} ight)+\lambda_{2d}$

mainly affects σ^{CC} . Using the slow rescaling prescription [37] the central value of $\sin^2\theta_W$ from CCFR varies as $0.0111(m_c$ [GeV] -1.31), where m_c is the effective mass. For $m_c=1.31\pm0.24$ GeV (determined from ν -induced dimuon production [38]) this contributes ±0.003 to the total uncertainty $\Delta\sin^2\theta_W \sim \pm0.004$. This would require a high-energy neutrino beam for improvement. (The experimental uncertainty is also ±0.003). The CCFR group quotes $s_W^2=0.2236\pm0.0041$ for $(m_t, M_H)=(175, 150)$ GeV with very little sensitivity to (m_t, M_H) . Combining all of the precise deep-inelastic measurements, one obtains $s_W^2=0.2260\pm0.0039$.

The laboratory cross section for $\nu_{\mu}e \to \nu_{\mu}e$ or $\overline{\nu}_{\mu}e \to \overline{\nu}_{\mu}e$ elastic scattering is

$$\begin{split} \frac{d\sigma_{\nu_{\mu},\nu_{\mu}}}{dy} &= \frac{G_F^2 m_e E_{\nu}}{2\pi} \\ &\times \left[(g_V^{\nu e} \pm g_A^{\nu e})^2 + (g_V^{\nu e} \mp g_A^{\nu e})^2 (1-y)^2 \right. \\ &\left. - (g_V^{\nu e^2} - g_A^{\nu e^2}) \frac{y m_e}{E_{\nu}} \right] \,, \end{split} \tag{10.17}$$

where the upper (lower) sign refers to $\nu_{\mu}(\overline{\nu}_{\mu})$, and $y \equiv E_e/E_{\nu}$ (which runs from 0 to $(1 + m_e/2E_{\nu})^{-1}$) is the ratio of the kinetic energy of the recoil electron to the incident ν or $\overline{\nu}$ energy. For $E_{\nu} \gg m_e$ this yields a total cross section

$$\sigma = \frac{G_F^2 \ m_e \ E_{\nu}}{2\pi} \left[(g_V^{\nu e} \pm g_A^{\nu e})^2 + \frac{1}{3} (g_V^{\nu e} \mp g_A^{\nu e})^2 \right] \ . \tag{10.18}$$

The most accurate leptonic measurements [39-41] of $\sin^2\theta_W$ are from the ratio $R \equiv \sigma_{\nu\mu e}/\sigma_{\overline{\nu}\mu e}$ in which many of the systematic uncertainties cancel. Radiative corrections (other than m_t effects) are small compared to the precision of present experiments and have negligible effect on the extracted $\sin^2\theta_W$. The most precise experiment (CHARM II) [41] determined not only $\sin^2\theta_W$ but g_{VA}^{ν} as well. The cross sections for $\nu_e e$ and $\overline{\nu}_e e$ may be obtained from

Eq. (10.17) by replacing $g_{V,A}^{\nu e}$ by $g_{V,A}^{\nu e}+1$, where the 1 is due to the charged-current contribution.

The SLAC polarized-electron experiment [42] measured the parity-violating asymmetry

$$A = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L} \,, \tag{10.19}$$

where $\sigma_{R,L}$ is the cross section for the deep-inelastic scattering of a right- or left-handed electron: $e_{R,L}N\to e{\rm X}$. In the quark parton model

$$\frac{A}{Q^2} = a_1 + a_2 \, \frac{1 - (1 - y)^2}{1 + (1 - y)^2} \,, \tag{10.20}$$

where $Q^2 > 0$ is the momentum transfer and y is the fractional energy transfer from the electron to the hadrons. For the deuteron or other isoscalar targets, one has, neglecting the s-quark and antiquarks,

$$a_1 = rac{3G_F}{5\sqrt{2}\pilpha} \left(C_{1u} - rac{1}{2}C_{1d}
ight) pprox rac{3G_F}{5\sqrt{2}\pilpha} \left(-rac{3}{4} + rac{5}{3}\sin^2 heta_W
ight) \,, \ (10.21a)$$

 $a_2 = \frac{3G_F}{5\sqrt{2}\pi\alpha} \left(C_{2u} - \frac{1}{2}C_{2d} \right) \approx \frac{9G_F}{5\sqrt{2}\pi\alpha} \left(\sin^2\theta_W - \frac{1}{4} \right) . \quad (10.21b)$

There are now precise experiments measuring atomic parity violation [43] in cesium (at the 0.4% level) [44], thallium [45], lead [46], and bismuth [47]. The uncertainties associated with atomic wave functions are quite small for cesium, for which they are $\sim 1\%$ [48]. The theoretical uncertainties are 3% for thallium [49] but larger for the other atoms. For heavy atoms one determines the "weak charge"

$$Q_W = -2 \left[C_{1u} \left(2Z + N \right) + C_{1d} (Z + 2N) \right]$$

$$\approx Z (1 - 4 \sin^2 \theta_W) - N . \tag{10.22}$$

The recent Boulder experiment in cesium also observed the parity-violating weak corrections to the nuclear electromagnetic vertex (the anapole moment [50]).

In the future it should be possible to reduce the theoretical wave function uncertainties by taking the ratios of parity violation in different isotopes [43,51]. There would still be some residual uncertainties from differences in the neutron charge radii, however [52].

The forward-backward asymmetry for $e^+e^- \to \ell^+\ell^-$, $\ell=\mu$ or τ , is defined as

$$A_{FB} \equiv \frac{\sigma_F - \sigma_B}{\sigma_F + \sigma_B} \,, \tag{10.23}$$

where $\sigma_F(\sigma_B)$ is the cross section for ℓ^- to travel forward (backward) with respect to the e^- direction. A_{FB} and R, the total cross section relative to pure QED, are given by

$$R=F_1, \qquad (10.24)$$

$$A_{FB} = 3F_2/4F_1 , \qquad (10.25)$$

where

$$F_1 = 1 - 2\chi_0 \; g_V^e \; g_V^\ell \; \cos \delta_R + \chi_0^2 \left(g_V^{e2} + g_A^{e2} \right) \left(g_V^{\ell2} + g_A^{\ell2} \right), \eqno(10.26a)$$

$$F_2 = -2\chi_0 g_A^e g_A^{\ell} \cos \delta_R + 4\chi_0^2 g_A^e g_A^{\ell} g_V^{\ell} g_V^{\ell} , \qquad (10.26b)$$

$$\tan \delta_R = \frac{M_Z \Gamma_Z}{M_Z^2 - s} , \qquad (10.27)$$

$$\chi_0 = \frac{G_F}{2\sqrt{2}\pi\alpha} \frac{sM_Z^2}{\left[(M_Z^2 - s)^2 + M_Z^2\Gamma_Z^2\right]^{1/2}} , \qquad (10.28)$$

and \sqrt{s} is the CM energy. Eq. (10.26) is valid at tree level. If the data is radiatively corrected for QED effects (as described above), then the remaining electroweak corrections can be incorporated [53,54] (in an approximation adequate for existing PEP, PETRA, and TRISTAN data, which are well below the Z pole) by replacing χ_0 by $\chi(s) \equiv (1+\rho_t)\chi_0(s)\alpha/\alpha(s)$, where $\alpha(s)$ is the running QED coupling, and evaluating g_V in the $\overline{\rm MS}$ scheme. Formulas for $e^+e^-\to {\rm hadrons}$ may be found in Ref. 55.

At LEP and SLC, there are high-precision measurements of various Z pole observables [56-61]. These include the Z mass and total width, Γ_Z , and partial widths $\Gamma(f\overline{f})$ for $Z \to f\overline{f}$ where fermion f = e, μ , τ , hadrons, b, or c. The data is consistent with lepton-family universality, $\Gamma(e^+e^-) = \Gamma(\mu^+\mu^-) = \Gamma(\tau^+\tau^-)$, so one may work with an average width $\Gamma(\ell^+\ell^-)$. It is convenient to use the variables M_Z , Γ_Z , $R_\ell \equiv \Gamma(\mathrm{had})/\Gamma(\ell^+\ell^-)$, $\sigma_{\mathrm{had}} \equiv 12\pi\Gamma(e^+e^-)\Gamma(\mathrm{had})/M_Z^2 \Gamma_Z^2$, $R_b \equiv \Gamma(b\bar{b})/\Gamma(\text{had})$, and $R_c \equiv \Gamma(c\bar{c})/\Gamma(\text{had})$, most of which are weakly correlated experimentally. ($\Gamma(had)$ is the partial width into hadrons.) The largest correlation coefficient of -0.20 occurs between R_b and R_c . R_ℓ is insensitive to m_t except for the $Z \to b\bar{b}$ vertex and final state corrections and the implicit dependence through $\sin^2 \theta_W$. Thus it is especially useful for constraining α_s . The width for invisible decays [57], $\Gamma(\text{inv}) = \Gamma_Z - 3\Gamma(\ell^+\ell^-) - \Gamma(\text{had}) = 500.1 \pm 1.8 \text{ MeV},$ can be used to determine the number of neutrino flavors much lighter than $M_Z/2$, $N_{
u}=\Gamma({
m inv})/\Gamma^{
m theory}(
u\overline{
u})=2.990\pm0.011$ for $(m_t, M_H) = (175 \pm 5 \text{ GeV}, M_Z).$

There are also measurements of various Z pole asymmetries. These include the polarization or left-right asymmetry

$$A_{LR} \equiv \frac{\sigma_L - \sigma_R}{\sigma_L + \sigma_R} \,, \tag{10.29}$$

where $\sigma_L(\sigma_R)$ is the cross section for a left- (right)-handed incident electron. A_{LR} has been measured precisely by the SLD collaboration at the SLC [59], and has the advantages of being extremely sensitive to $\sin^2\theta_W$ and that systematic uncertainties largely cancel. In addition, the SLD collaboration has extracted the final-state couplings A_b , A_c , A_τ , and A_μ from left-right forward-backward asymmetries [57,60], using

$$A_{LR}^{FB}(f) = \frac{\sigma_{LF}^{f} - \sigma_{LB}^{f} - \sigma_{RF}^{f} + \sigma_{RB}^{f}}{\sigma_{LF}^{f} + \sigma_{LB}^{f} + \sigma_{RF}^{f} + \sigma_{RB}^{f}} = \frac{3}{4}A_{f} , \qquad (10.30)$$

where, for example, σ_{LF} is the cross section for a left-handed incident electron to produce a fermion f traveling in the forward hemisphere. Similarly, A_{τ} is measured at LEP [57] through the negative total τ polarization, \mathcal{P}_{τ} , and A_{ε} is extracted from the angular distribution of \mathcal{P}_{τ} . An equation such as (10.30) assumes that initial state QED corrections, photon exchange, $\gamma-Z$ interference, the tiny electroweak boxes, and corrections for $\sqrt{s} \neq M_Z$ are removed from the data, leaving the pure electroweak asymmetries. This allows the use of effective tree-level expressions,

$$A_{LR} = A_e P_e , \qquad (10.31)$$

$$A_{FB} = \frac{3}{4} A_f \frac{A_e + P_e}{1 + P_o A_e} \,, \tag{10.32}$$

where

$$A_f \equiv \frac{2\bar{g}_Y^f \bar{g}_A^f}{\bar{g}_Y^{f2} + \bar{g}_A^{f2}} , \qquad (10.33)$$

and

$$\bar{g}_V^f = \sqrt{\rho_f} \left(t_{3L}^{(f)} - 2q_f \kappa_f \sin^2 \theta_W \right) ,$$
 (10.33b)

$$\overline{g}_A^f = \sqrt{\rho_f} \, t_{3L}^{(f)} \ . \tag{10.33c}$$

 P_e is the initial e^- polarization, so that the second equality in Eq. (10.30) is reproduced for $P_e=1$, and the Z pole forward-backward asymmetries at LEP ($P_e=0$) are given by $A_{FB}^{(0,f)}=\frac{3}{4}A_eA_f$ where $f=e,\ \mu,\ \tau,\ b,\ c,\ s,\$ and $q,\$ and where $A_{FB}^{(0,q)}$ refers to the hadronic charge asymmetry. The initial state coupling, A_e , is also determined through the left-right charge asymmetry [61] and in polarized Bhabba scattering [60] at the SLC.

The electroweak-radiative corrections have been absorbed into corrections $\rho_f - 1$ and $\kappa_f - 1$, which depend on the fermion f and on the renormalization scheme. In the on-shell scheme, the quadratic m_t dependence is given by $\rho_f \sim 1 + \rho_t$, $\kappa_f \sim 1 + \rho_t/\tan^2\theta_W$, while in $\overline{\rm MS}$, $\widehat{\rho}_f \sim \widehat{\kappa}_f \sim 1$, for $f \neq b$ ($\widehat{\rho}_b \sim 1 - \frac{4}{3}\rho_t$, $\widehat{\kappa}_b \sim 1 + \frac{2}{3}\rho_t$). In the $\overline{\rm MS}$ scheme the normalization is changed according to $G_F M_Z^2/2\sqrt{2}\pi \to \widehat{\alpha}/4\widehat{s}_Z^2\widehat{c}_Z^2$.

(If one continues to normalize amplitudes by $G_FM_Z^2/2\sqrt{2}\pi$, as in the 1996 edition of this Review, then $\hat{\rho}_f$ contains an additional factor of $\hat{\rho}$.) In practice, additional bosonic and fermionic loops, vertex corrections, leading higher order contributions, etc., must be included. For example, in the $\overline{\rm MS}$ scheme one has, for $(m_t,M_H)=(175~{\rm GeV},M_Z)$, $\hat{\rho}_\ell=0.9978,\,\hat{\kappa}_\ell=1.0013,\,\hat{\rho}_b=0.9868~{\rm and}\,\hat{\kappa}_b=1.0067.$ It is convenient to define an effective angle $\overline{s}_f^2\equiv\sin^2\overline{\theta}_{Wf}\equiv\hat{\kappa}_f\widehat{s}_Z^2=\kappa_fs_W^2$, in terms of which \overline{g}_V^f and \overline{g}_A^f are given by $\sqrt{\rho_f}$ times their tree-level formulae. Because \overline{g}_V^ℓ is very small, not only $A_{LR}^0=A_e$, $A_{FB}^{(0,\ell)}$, and \mathcal{P}_τ , but also $A_{FB}^{(0,b)}$, $A_{FB}^{(0,c)}$, $A_{FB}^{(0,e)}$, and the hadronic asymmetries are mainly sensitive to \overline{s}_L^g . One finds that $\hat{\kappa}_f$ $(f\neq b)$ is almost independent of (m_t,M_H) , so that one can write

$$\bar{s}_{\ell}^2 \sim \hat{s}_{Z}^2 + 0.00029$$
 (10.34)

Thus, the asymmetries determine values of $\overline{\mathfrak{d}}_{\ell}^2$ and $\widehat{\mathfrak{d}}_{Z}^2$ almost independent of m_t , while the κ 's for the other schemes are m_t dependent.

10.4. W and Z decays

The partial decay width for gauge bosons to decay into massless fermions $f_1\overline{f}_2$ is

$$\Gamma(W^{+} \to e^{+}\nu_{e}) = \frac{G_{F}M_{W}^{3}}{6\sqrt{2}\pi} \approx 226.5 \pm 0.3 \text{ MeV} , \qquad (10.35a)$$

$$\Gamma(W^{+} \to u_{i}\overline{d}_{j}) = \frac{CG_{F}M_{W}^{3}}{6\sqrt{2}\pi} |V_{ij}|^{2} \approx (707 \pm 1)|V_{ij}|^{2} \text{ MeV} , \qquad (10.35b)$$

$$\Gamma(Z \to \psi_{i}\overline{\psi}_{i}) = \frac{CG_{F}M_{Z}^{3}}{6\sqrt{2}\pi} \left[g_{V}^{i2} + g_{A}^{i2}\right] \qquad (10.35c)$$

$$\approx \begin{cases} 167.25 \pm 0.08 & \text{MeV } (\nu \overline{\nu}), 84.01 \pm 0.05 & \text{MeV } (e^+e^-), \\ 300.3 \pm 0.2 & \text{MeV } (u\overline{u}), 383.1 \pm 0.2 & \text{MeV } (d\overline{d}), \\ 376.0 \mp 0.1 & \text{MeV } (b\overline{b}), \end{cases}$$

where the numerical values are for $(m_t, M_H) = (175 \pm 5 \text{ GeV}, M_Z)$. For leptons C=1, while for quarks $C=3(1+\alpha_s(M_V)/\pi)$ $+1.409\alpha_s^2/\pi^2-12.77\alpha_s^3/\pi^3$), where the 3 is due to color and the factor in parentheses represents the universal part of the QCD corrections [62] for massless quarks [63]. The $Z \to f\overline{f}$ widths contain a number of additional corrections: universal (non-singlet) top-mass contributions [64]; fermion mass effects and further QCD corrections proportional to m_q^2 [65] (m_q is the running quark mass evaluated at the Z scale) which are different for vector and axial-vector partial widths; and singlet contributions starting from two-loop order which are large, strongly top-mass dependent, family universal, and flavor non-universal [66]. All QCD effects are known and included up to three loop order. The QED factor $1 + 3\alpha q_f^2/4\pi$, as well as two-loop $\alpha\alpha_s$ and α^2 corrections [67,68] are also included. Working in the on-shell scheme, i.e., expressing the widths in terms of $G_F M_{WZ}^3$ incorporates the largest radiative corrections from the running QED coupling [18,69]. Electroweak corrections to the Z widths are then incorporated by replacing $g_{V,A}^{i2}$ by $\overline{g}_{V,A}^{i2}$. Hence, in the on-shell scheme the Z widths are proportional to $\rho_i \sim 1 + \rho_t$. The $\overline{\rm MS}$ normalization (see the end of the previous section) accounts also for the leading electroweak corrections [22]. There is additional (negative) quadratic m_t dependence in the $Z \to b\bar{b}$ vertex corrections [70] which causes $\Gamma(b\overline{b})$ to decrease with m_t . The dominant effect is to multiply $\Gamma(b\overline{b})$ by the vertex correction $1 + \delta \rho_{b\bar{b}}$, where $\delta \rho_{b\bar{b}} \sim 10^{-2} (-\frac{1}{2} \frac{m_t^2}{M_Z^2} + \frac{1}{5})$. In practice, the corrections are included in ρ_b and κ_b , as discussed before.

$$\Gamma_Z \approx 2.496 \pm 0.001 \text{ GeV}$$
 , (10.36)
 $\Gamma_W \approx 2.093 \pm 0.002 \text{ GeV}$. (10.37)

We have assumed $\alpha_s=0.120$. An uncertainty in α_s of ± 0.003 introduces an additional uncertainty of 0.1% in the hadronic widths, corresponding to ± 1.6 MeV in Γ_Z . These predictions are to be compared with the experimental results $\Gamma_Z=2.4948\pm 0.0025$ GeV and $\Gamma_W=2.062\pm 0.059$ GeV.

For 3 fermion families the total widths are predicted to be

10.5. Experimental results

Table 10.3: Principal LEP and other recent observables, compared with the Standard Model predictions for M_Z = 91.1867 \pm 0.0020 GeV, $M_H=M_Z$, and the global best fit values $m_t=173\pm4$ GeV, $\alpha_s=0.1214\pm0.0031$, and $\widehat{\alpha}(M_Z)^{-1} = 127.90 \pm 0.07$. The LEP averages of the ALEPH, DELPHI, L3, and OPAL results include common systematic errors and correlations [57]. $\bar{s}_{\ell}^2(A_{FB}^{(0,q)})$ is the effective angle extracted from the hadronic charge asymmetry. The values of $\Gamma(\ell^+\ell^-)$, $\Gamma(\text{had})$, and $\Gamma(\text{inv})$ are not independent of Γ_Z , R_ℓ , and $\sigma_{\rm had}$. The first M_W value is from CDF, UA2, and DØ [71] while the second includes the measurements at LEP [57]. M_W and M_Z are correlated, but the effect is negligible due to the tiny M_Z error. The four values of A_ℓ are (i) from A_{LR} for hadronic final states [59]; (ii) the combined value from SLD including leptonic asymmetries; (iii) from the total τ polarization; and (iv) from the angular distribution of the τ polarization. The two values of s_W^2 from deep-inelastic scattering are from CCFR [36] and the global average, respectively. Similarly, the $g_{VA}^{\nu e}$ are from CHARM II [41] and the world average. The second errors in Q_W are theoretical [48,49]. Older low-energy results are not listed but are included in the fits. In the Standard Model predictions, the uncertainty is from M_Z , m_t , $\Delta \alpha(M_Z)$ and α_s . In parentheses we show the shift in the predictions when M_H is changed to 300 GeV which is its 90% CL upper limit. The errors in Γ_Z , $\Gamma(\text{had})$, R_ℓ , and σ_{had} are completely dominated by the uncertainty in α_s .

- Control of the Cont					
Quantity	Value	Standard Model			
mt [GeV]	175 ± 5	$173 \pm 4 \ (+5)$			
M_W [GeV]	80.405 ± 0.089	$80.377 \pm 0.023 \; (-0.036)$			
	80.427 ± 0.075				
$M_{Z} \; [{ m GeV}]$	91.1867 ± 0.0020	$91.1867 \pm 0.0020 (+0.0001)$			
Γ_Z [GeV]	2.4948 ± 0.0025	$2.4968 \pm 0.0017 (-0.0007)$			
$\Gamma({ m had}) \; [{ m GeV}]$	1.7432 ± 0.0023	$1.7433 \pm 0.0016 \; (-0.0005)$			
$\Gamma(inv)$ [MeV]	500.1 ± 1.8	$501.7 \pm 0.2 \; (-0.1)$			
$\Gamma(\ell^+\ell^-)$ [MeV]	83.91 ± 0.10	$84.00 \pm 0.03 (-0.04)$			
$\sigma_{ m had} [m nb]$	41.486 ± 0.053	$41.469 \pm 0.016 \; (-0.005)$			
R_{ℓ}	20.775 ± 0.027	$20.754 \pm 0.020 \; (+0.003)$			
R_b	0.2170 ± 0.0009	$0.2158 \pm 0.0001 (-0.0002)$			
R_c	0.1734 ± 0.0048	$0.1723 \pm 0.0001 \; (+0.0001)$			
$A_{FB}^{(0,\ell)}$	0.0171 ± 0.0010	$0.0162 \pm 0.0003 (-0.0004)$			
$A_{FB}^{(0,b)}$	0.0984 ± 0.0024	$0.1030 \pm 0.0009 (-0.0013)$			
$A_{FB}^{(0,c)}$	0.0741 ± 0.0048	$0.0736 \pm 0.0007 (-0.0010)$			
$A_{FB}^{(0,s)}$	0.118 ± 0.018	$0.1031 \pm 0.0009 (-0.0013)$			
$ar{s}_{m{\ell}}^2(A_{FB}^{(0,q)})$	0.2322 ± 0.0010	$0.2315 \pm 0.0002 (+0.0002)$			
A_{ℓ}	0.1550 ± 0.0034	$0.1469 \pm 0.0013 (-0.0018)$			
	0.1547 ± 0.0032				
	0.1411 ± 0.0064				
	0.1399 ± 0.0073				
A_b	0.900 ± 0.050	$0.9347 \pm 0.0001 \; (-0.0002)$			
A_c	0.650 ± 0.058	$0.6678 \pm 0.0006 (-0.0008)$			
$s_W^2(u { m N})$	0.2236 ± 0.0041	$0.2230 \pm 0.0004 (+0.0007)$			
	0.2260 ± 0.0039				
$g_V^{ u e}$	-0.035 ± 0.017	$-0.0395 \pm 0.0005 (+0.0002)$			
	-0.041 ± 0.015				
$g_A^{ u e}$	-0.503 ± 0.017	$-0.5064 \pm 0.0002 (+0.0002)$			
	-0.507 ± 0.014	•			
$Q_{m{W}}(\mathrm{Cs})$	$-72.41 \pm 0.25 \pm 0.80$	$-73.12 \pm 0.06 (+0.01)$			
$Q_{m{W}}(\mathrm{Tl})$	$-114.8 \pm 1.2 \pm 3.4$	-116.7 ± 0.1			

The values of the principal Z pole observables are listed in Table 10.3, along with the Standard Model predictions for $M_Z=91.1867\pm0.0020,\ m_t=173\pm4$ GeV, $M_H=M_Z$ and $\alpha_s=0.1214\pm0.0031.$ Note, that the values of the Z pole observables (as well as M_W) differ from those in the Particle Listings because they include recent preliminary results [57,58,59,71]. The values and predictions of M_W [57,71], the Q_W for cesium [44] and thallium [45], and recent results from deep inelastic [32–36] and $\nu_\mu e$ scattering [39–41] are also listed. The agreement is excellent. Even the largest discrepancies, A_{LR}^0 , $A_{FB}^{(0,b)}$, and $A_{FB}^{(0,\tau)}$, deviate by only 2.4 σ , 1.9 σ and 1.7 σ , respectively.

Other observables like $R_b = \Gamma(b\bar{b})/\Gamma(\text{had})$ and $R_c = \Gamma(c\bar{c})/\Gamma(\text{had})$ which showed significant deviations in the past, are now in perfect (R_c) or at least better agreement. In particular, R_b whose measured value deviated as much as 3.7 σ from the Standard Model prediction is now only 1.3 σ high. Many types of new physics could contribute to R_b (the implications of this possibility for the value of $\alpha_s(M_Z)$ extracted from the fits are discussed below) and A_b and as a consequence to $A_{FB}^{(0,b)} = \frac{3}{4}A_eA_b$. Indeed, A_b can be extracted from $A_{FB}^{(0,b)}$ when A_e is taken from leptonic asymmetries (using lepton universality), and combined with the measurement at the SLC. The result, $A_b = 0.877 \pm 0.023$, is 2.5 σ below the Standard Model prediction. (Alternatively, one can use $A_{\ell} = 0.1469 \pm 0.0013$ from the global fit and obtain $A_b = 0.894 \pm 0.021$ which is 1.9 σ low.) However, this deviation of about 6% cannot arise from new physics radiative corrections since a 30% correction to $\hat{\kappa}_b$ would be necessary to account for the central value of A_b . Only a new type of physics which couples at the tree level preferentially to the third generation, and which does not contradict R_b (including the off-peak R_b measurements by DELPHI [72]), can conceivably account for a low A_b [73].

The left-right asymmetry, $A_{LR}^0=0.1550\pm0.0034$ [59], based on all hadronic data from 1992–1996 has moved closer to the Standard Model expectation of 0.1469 ± 0.0013 than previous values. However, because of the smaller error A_{LR}^0 is still $2.4~\sigma$ above the Standard Model prediction. There is also an experimental difference of $\sim 1.9~\sigma$ between the SLD value of $A_\ell(\text{SLD})=0.1547\pm00032$ from all A_{LR} and $A_{LR}^{FB}(\ell)$ data on one hand, and the LEP value $A_\ell(\text{LEP})=0.1461\pm0.0033$ obtained from $A_{FB}^{(0,\ell)}$, $A_\tau(\mathcal{P}_\tau)$ on the other hand, in both cases assuming lepton-family universality.

Despite these discrepancies the χ^2 value of the fit for the Standard Model is excellent. It is 25 for 30 d.o.f. when fitting to the independent observables in Table 10.3, and 181 for 209 d.o.f. when the older neutral current observables are included. The probability of a larger χ^2 is 0.73 and 0.92 for the two cases, respectively. (The low χ^2 for the older data is likely due to overly conservative estimates of systematic errors.)

With the latest value of $A_{FB}^{(0,\tau)}$ the data is now in reasonable agreement with lepton-family universality, which will be assumed. The observables in Table 10.3 (including correlations on the LEP lineshape and LEP/SLD heavy flavor observables), as well as all low-energy neutral-current data [16,17], are used in the global fits described below. The parameter $\sin^2\theta_W$ can be determined from Z pole observables, M_W , and from a variety of neutral-current processes spanning a very wide Q^2 range. The results [16], shown in Table 10.4, are in impressive agreement with each other, indicating the quantitative success of the Standard Model. The one discrepancy is the value $\hat{s}_Z^2 = 0.23023 \pm 0.00043$ from $A_\ell(\text{SLD})$ which is 2.3 σ below the value 0.23124 \pm 0.00017 from the global fit to all data and 2.6 σ below the value 0.23144 \pm 0.00019 obtained from all data other than $A_\ell(\text{SLD})$.

The data allow a simultaneous determination of $\sin^2\theta_W$, m_t , and the strong coupling $\alpha_s(M_Z)$. The latter is determined mainly from R_ℓ , Γ_Z , and $\sigma_{\rm had}$, and is only weakly correlated with the other variables. The global fit to all data, including the CDF/DØ value, $m_t=175\pm5$ GeV, yields

$$\begin{split} \widehat{s}_Z^2 &= 0.23124 \pm 0.00017 \, (+0.00024) \; , \\ m_t &= 173 \pm 4 \, (+5) \; \mathrm{GeV} \; , \\ \alpha_s(M_Z) &= 0.1214 \pm 0.0031 \, (+0.0018) \; , \\ M_H &= M_Z \; . \end{split} \tag{10.38}$$

In parentheses we show the effect of changing M_H to 300 GeV which is the conservative 90% CL upper limit (see below). In all fits, the errors include full statistical, systematic, and theoretical uncertainties. The \hat{s}_{Z}^{2} error reflects the error on $\bar{s}_{f}^{2} \sim \pm 0.00023$ from the Z pole asymmetries. In the on-shell scheme one has $s_W^2 = 0.22304 \pm 0.00044$, the larger error due to the stronger sensitivity to mt. The extracted value of α_s is based on a formula with negligible theoretical uncertainty (± 0.0005 in α_s) if one assumes the exact validity of the Standard Model. It is in excellent agreement with other precise values [74], such as 0.122 ± 0.005 from τ decays, 0.121 ± 0.005 from jet-event shapes in e^+e^- annihilation, and the very recent result [75], 0.119 ± 0.002 (exp) ± 0.004 (scale), from deep-inelastic scattering. It is slightly higher than the values from lattice calculations of the b ar b $(0.1174 \pm 0.0024 \ [76])$ and $c\bar{c} \ (0.116 \pm 0.003 \ [77])$ spectra, and from decays of heavy quarkonia $(0.112 \pm 0.006 [74])$. For more details, see our Section 9 on "Quantum Chromodynamics" in this Review. The average $\alpha_s(M_Z)$ obtained from Section 9 when ignoring the precision measurements discussed in this Section is 0.1178 ± 0.0023 . We use this value as an external constraint for the second fit in Table 10.5. The resulting value,

$$\alpha_s = 0.1191 \pm 0.0018 \,(+0.0006)$$
, (10.39)

can be regarded as the present world average.

Table 10.4: Values obtained for s_W^2 (on-shell) and $\hat{s}_Z^2(\overline{MS})$ from various reactions assuming the global best fit values (for $M_H = M_Z$) $m_t = 173 \pm 4$ GeV and $\alpha_s = 0.1214 \pm 0.0031$.

Reaction	s_W^2		3	\hat{i}_Z^2
M_Z	0.2231 ± 0	.0005	0.2313	± 0.0002
M_W	0.2228 ± 0	.0006	0.2310	± 0.0005
$\Gamma_Z/M_Z^3,R,\sigma_{ m had}M_Z^2$	0.2235 ± 0	.0011	0.2316	± 0.0011
$A_{FB}^{(0,\ell)}$	0.2225 ± 0	.0007	0.2307	± 0.0006
LEP asymmetries	0.2235 ± 0	.0004	0.2317	± 0.0003
A_{LR}^0	0.2220 ± 0	.0005	0.2302	± 0.0004
$\overline{A}_b, \overline{A}_c$	0.230 ± 0	.016	0.239	$\pm\ 0.016$
Deep inelastic (isocalar)	0.226 ± 0	.004	0.234	± 0.004
$\nu_{\mu}(\overline{\nu}_{\mu})p \rightarrow \nu_{\mu}(\overline{\nu}_{\mu})p$	0.203 ± 0	.032	0.211	±0.032
$\nu_{\mu}(\overline{\nu}_{\mu})e \rightarrow \nu_{\mu}(\overline{\nu}_{\mu})e$	0.221 ± 0	.008	0.229	±0.008
atomic parity violation	0.220 ± 0	.003	0.228	± 0.003
$\operatorname{SLAC}eD$	0.213 ± 0	.019	0.222	±0.018
All data	0.2230 ± 0	.0004	0.23124	± 0.00017

The value of R_b is 1.3 σ above the Standard Model expectation. If this is not just a fluctuation but is due to a new physics contribution to the $Z \to b\bar{b}$ vertex (many types would couple preferentially to the third family), the value of $\alpha_s(M_Z)$ extracted from the hadronic Z width would be reduced [17]. Allowing for this possibility one obtains $\alpha_s(M_Z)=0.1166\pm0.0048$ (+0.0007). Similar remarks apply in principle for R_c and the other quark and lepton flavors, and one should keep in mind that the Z lineshape value of α_s is very sensitive to many types of new physics.

The data indicate a preference for a small Higgs mass. There is a strong correlation between the quadratic m_t and logarithmic M_H terms in $\widehat{\rho}$ in all of the indirect data except for the $Z \to b \overline{b}$ vertex. Therefore, observables (other than R_b) which favor m_t values higher than the Tevatron range favor lower values of M_H . This effect is enhanced by R_b , which has little direct M_H dependence but favors the lower end of the Tevatron m_t range. M_W has additional M_H dependence through $\Delta \widehat{\tau}_W$ which is not coupled to m_t^2 effects. The strongest individual pulls towards smaller M_H are from M_W , A_{LR}^0 , and $A_{FB}^{(0,\ell)}$ (when combined

with M_Z), as well as R_b . The difference in χ^2 for the global fit is $\Delta\chi^2=\chi^2(M_H=1000~{\rm GeV})-\chi^2(M_H=77~{\rm GeV})=16.6$. Hence, the data favor a small value of M_H , as in supersymmetric extensions of the Standard Model, and m_t on the lower side of the Tevatron range. If one allows M_H as a free fit parameter and does not include any constraints from direct Higgs searches, one obtains $M_H = 69^{+85}_{-43}$ GeV, i.e., the central value below the direct lower bound, $M_H \ge 77$ GeV (95% CL) [78]. Including the results of the direct searches as an extra contribution to the likelihood function drives the best fit value to the present kinematic reach ($M_H \sim 83$ GeV), and we obtain the upper limit $M_H < 236$ (287) GeV at 90 (95)% CL. The extraction of M_H from the precision data depends strongly on the value used for $\alpha(M_Z)$. The value derived by Martin and Zeppenfeld [11] relying on the predictions of perturbative QCD down to smaller values of \sqrt{s} is higher and has a smaller stated error. Using this value would give a best fit at $M_H = 140$ GeV, and an upper limit $M_H < 300$ (361) GeV at 90 (95)% CL. Clearly, a consensus on the applicability of perturbative QCD in e^+e^- annihilation is highly desirable.

The most deviating observable, A_{LR} , has a strong impact on the Higgs mass limits as well [17,79]. The Introduction to this *Review* suggests an unbiased treatment of deviating observables r through the introduction of scale factors S_r . It is instructive to study the impact of this more conservative procedure on M_H . For the case of a fit to the Standard Model, we define

$$S_r = \max(\sqrt{\chi_r^2}, 1)$$
, (10.40)

where χ_r^2 is the χ^2 contribution of observable r to a global fit in which M_H is allowed as a free fit parameter (with no direct constraints included). We then repeat the fit with all errors multiplied by S_r , and proceed iteratively until the procedure has converged. This way we obtain

$$\begin{split} S_{A_{LR}^0} &= 2.76, \qquad S_{A_{FB}^{(0,b)}} = 2.05, \qquad S_{A_{FB}^{(0,\tau)}} = 1.83, \\ S_{A_{LR}^{FB}(\tau)} &= 1.45, \qquad S_{A_{LR}^{FB}(\mu)} = 1.34, \qquad S_{R_b} = 1.33, \end{split}$$

as well as $S_{A_{\bf e}(\mathcal{P}_{\bf r})}=1.02,$ and $S_{\bf r}=1$ for all other observables. The result of the global fit is

$$\begin{split} \widehat{s}_Z^2 &= 0.23141 \pm 0.00031 \;, \\ m_t &= 174 \pm 5 \; \mathrm{GeV} \;, \\ \alpha_s(M_Z) &= 0.1222 \pm 0.0034 \;, \\ M_H &= 122^{+134}_{-77} \; \mathrm{GeV} \;, \end{split} \eqno(10.41)$$

where the larger errors compared to Eq. (10.38) are from M_H rather than the S_r . Since the central value of M_H is much larger than the present direct lower bound, and $\log(M_H)$ is approximately normal distributed, it is justified to include the error due to M_H (with all correlations properly taken into account) in a Gaussian way in the uncertainties of the other parameters. For comparison with other fits we also list the results for fixed M_H in Table 10.5. Including the direct constraint we obtain an upper limit $M_H < 329$ (408) GeV at 90 (95)% CL, which is higher by $\mathcal{O}(100 \text{ GeV})$ than the one without scale factors. It is in good agreement with the bound we obtained above by switching to the higher $\alpha(M_Z)$. Indeed, both analyses decrease the impact of A_{LR} on the Higgs mass limit.

A few comments are in order: (i) The procedure used here is not unambiguous. It depends on whether results from different experiments (e.g., the various experimental groups at LEP or the Tevatron) are combined or used as individual pieces of input. We use combined result, primarily in order to avoid insurmountable complications with cross correlations between different experimental groups on top of the correlations between the observables. Even the result on a single observable quoted by an individual group, is in general a combination of various channels, with different types of systematic errors (which are the prime reason for the introduction of scale factors in the first place). Thus, ideally, one would prefer to define the S_r at this level. In practice, however, this is virtually impossible to achieve. In the case of M_W we use the individual

determinations, since they are uncorrelated and are based on entirely different processes. (ii) None of the definitions of scale factors in the Introduction to this Review is directly applicable to our case. However, we have tried to work as closely as possible in spirit to the definitions given there. One major difference is that central values of fit parameters (in particular of M_H) change upon introducing S_r ; on the other hand, central values of measurements remain unchanged. (iii) The procedure used here relies on the validity of the Standard Model, since in the presence of new physics, some discrepancies will be shifted into new physics parameters. When fits to new types of physics are to be compared to Standard Model fits as is done in Section 10.5 one has to refrain from using scale factors.

One can also carry out a fit to the indirect data alone, i.e., without including the value $m_t=175\pm 5$ GeV observed directly by CDF and DØ. (The indirect prediction is for the $\overline{\rm MS}$ mass which is in the end converted to the pole mass using an BLM optimized [80] version of the two-loop perturbative QCD formula [81]; this should correspond approximately to the kinematic mass extracted from the collider events.) One obtains $m_t=170\pm 7$ (+14) GeV, with little change in the $\sin^2\theta_W$ and α_s values, in remarkable agreement with the direct CDF/DØ value. The results of fits to various combinations of the data are shown in Table 10.5 and the relation between \widehat{s}_Z^2 and m_t for various observables in Fig. 10.1.

Table 10.5: Values of \widehat{s}_Z^2 and s_W^2 (in parentheses), α_s , and m_t for various combinations of observables. The central values and uncertainties are for $M_H=M_Z$ while the third numbers show the shift (positive unless specified) from changing M_H to 300 GeV.

Data	$\widehat{s}_{Z}^{2} \ (s_{W}^{2})$	$\alpha_s (M_Z)$	m _t [GeV]
All indirect $+ m_t$	0.23124(17)(24) ±0.0004 (+0.0007))	0.1214(31)(18)	173(4)(5)
All indirect $+ m_t + \alpha_s$		0.1191(18)(6)	173(4)(5)
All indirect $+ m_t + S_r$		0.1218(31)(21)	173(4)(5)
All indirect (0.2234	0.23129(19)(11) ±0.0007 (-0.0002))	0.1216(31)(14)	170(7)(14)
Z pole $(0.2236$	$0.23135(21)(10) \pm 0.0008 (-0.0003))$	0.1218(31)(13)	168(8)(14)
LEP 1 (0.2247	0.23170(24)(13) $\pm 0.0009 (-0.0002))$	0.1232(31)(14)	160(8)(14)
$SLD + M_Z $ (0.2192)	0.23023(43) ±0.0017 (-0.0008))	0.1200 (fixed)	203(13)(17)
$A_{FB}^{(0,b)} + M_Z \tag{0.2261}$	0.23209(45) ±0.0018 (-0.0009))	0.1200 (fixed)	147(17)(21)
$M_W + M_Z \tag{0.2221}$	0.23101(43)(22) ±0.0015)	0.1200 (fixed)	181(12)(12)

Using $\alpha(M_Z)$ and \widehat{s}_Z^2 as inputs, one can predict $\alpha_s(M_Z)$ assuming grand unification. One predicts [82] $\alpha_s(M_Z) = 0.130 \pm 0.001 \pm 0.01$ for the simplest theories based on the minimal supersymmetric extension of the Standard Model, where the first (second) uncertainty is from the inputs (thresholds). This is consistent with the experimental $\alpha_s(M_Z) = 0.1216 \pm 0.0031 \pm 0.0003$ from the Z lineshape (with the second error corresponding to $M_H < 150$ GeV, as is appropriate to the lower M_H range appropriate for supersymmetry) and with the world average 0.119 ± 0.002 . Nonsupersymmetric unified theories predict the low value $\alpha_s(M_Z) = 0.073 \pm 0.001 \pm 0.001$. See also the note on "Low-Energy Supersymmetry" in the Particle Listings.

One can also determine the radiative correction parameters Δr : including the CDF and DØ data, one obtains $\Delta r = 0.0355 \pm$

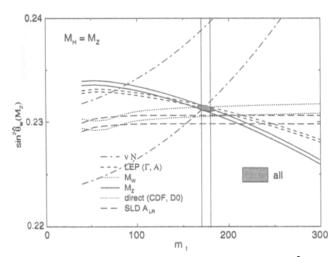


Figure 10.1: One-standard-deviation uncertainties in $\sin^2 \hat{\theta}_W$ as a function of m_t , the direct CDF and DØ range 175 \pm 5 GeV, and the 90% CL region in $\sin^2 \hat{\theta}_W - m_t$ allowed by all data, assuming $M_H = M_Z$.

0.0014 (+0.0021) and $\Delta \hat{\tau}_W = 0.0697 \pm 0.0005$ (+0.0001), in excellent agreement with the predictions 0.0349 \pm 0.0020 and 0.0698 \pm 0.0007. M_W measurements [57,71] (when combined with M_Z) are equivalent to measurements of $\Delta r = 0.0325 \pm 0.0045$.

Table 10.6: Values of the model-independent neutral-current parameters, compared with the Standard Model predictions for $M_Z = 91.1867 \pm 0.0020$ GeV, $M_H = M_Z$, and the global best fit values $m_t = 173 \pm 4$ GeV, $\alpha_s = 0.1214 \pm 0.0031$, and $\widehat{\alpha}(M_Z)^{-1} = 127.90 \pm 0.07$. There is a second $g_{V,A}^{V}$ solution, given approximately by $g_V^{Ve} \leftrightarrow g_A^{Ve}$, which is eliminated by e^+e^- data under the assumption that the neutral current is dominated by the exchange of a single Z. θ_i , i = L or R, is defined as $\tan^{-1}[\epsilon_i(u)/\epsilon_i(d)]$.

Quantity	Experimental Value	Standard Model Prediction	c	orrelation
$\epsilon_L(u)$	0.328 ±0.016	0.3461±0.0002		
$\epsilon_L(d)$	-0.440 ± 0.011	-0.4292 ± 0.0002		non-
$\epsilon_R(u)$	-0.179 ± 0.013	-0.1548 ± 0.0001		Gaussian
$\epsilon_R(d)$	$-0.027 ^{+0.077}_{-0.048}$	0.0775 ± 0.0001		
g_L^2	0.3009±0.0028	0.3040±0.0003		
$g_R^{\widetilde{2}}$	0.0328 ± 0.0030	0.0300		small
$ heta_L$	2.50 ± 0.035	2.4629 ± 0.0001		
$ heta_R$	$4.56 \begin{array}{c} +0.42 \\ -0.27 \end{array}$	5.1765		
$g_V^{ u e}$	-0.041 ±0.015	-0.0395±0.0005		-0.04
$g_A^{ u e}$	-0.507 ± 0.014	-0.5064 ± 0.0002		
Clu	-0.216 ± 0.046	-0.1885±0.0003	-0.997	-0.78
C_{1d}	0.361 ± 0.041	0.3412 ± 0.0002		0.78
$C_{2u}-\tfrac{1}{2}C_{2d}$	-0.03 ± 0.12	-0.0488 ± 0.0008		

Most of the parameters relevant to ν -hadron, νe , e-hadron, and e^+e^- processes are determined uniquely and precisely from the data in "model independent" fits (i.e., fits which allow for an arbitrary electroweak gauge theory). The values for the parameters defined in Eqs. (10.12)–(10.14) are given in Table 10.6 along with the predictions of the Standard Model. The agreement is excellent. The low-energy e^+e^- results are difficult to present in a model-independent way because Z propagator effects are non-negligible at TRISTAN, PETRA, and PEP energies. However, assuming $e^-\mu^-\tau$ universality, the lepton asymmetries imply [55] $4(g_A^e)^2=0.99\pm0.05$, in good agreement with the Standard Model prediction $\simeq 1$.

The results presented here are generally in reasonable agreement with the ones obtained by the LEP Electroweak Working Group [57]. We obtain slightly higher values for α_s and significantly lower best fit values for M_H . We could trace the differences to be due to (i) the inclusion of recent higher order radiative corrections, in particular, $\mathcal{O}(\alpha^2 m_t^2)$ [26] and $\mathcal{O}(\alpha \alpha_s)$ vertex [68] corrections, as well as the leading $\mathcal{O}(\alpha_s^4)$ contribution to hadronic Z decays; (ii) the use of a slightly higher value of $\alpha(M_Z)$ [9]; (iii) a more complete set of low energy data (which is not very important for Standard Model fits, but is for physics beyond the Standard Model); and (iv) scheme dependences. Taking into account these differences, the agreement is excellent.

10.6. Constraints on new physics

The Z pole, W mass, and neutral-current data can be used to search for and set limits on deviations from the Standard Model. In particular, the combination of these indirect data with the direct CDF and DØ value for m_t allows stringent limits on new physics. We will mainly discuss the effects of exotic particles (with heavy masses $M_{\text{new}} \gg M_Z$ in an expansion in M_Z/M_{new}) on the gauge boson self-energies. (Brief remarks are made on new physics which is not of this type.) Most of the effects on precision measurements can be described by three gauge self-energy parameters S, T, and U. We will define these, as well as related parameters, such as ρ_0 , ϵ_i , and $\hat{\epsilon}_i$, to arise from new physics only. I.e., they are equal to zero ($\rho_0 = 1$) exactly in the Standard Model, and do not include any contributions from m_t or M_H , which are treated seperately. Our treatment differs from most of the original papers. We also allow a $Zb\bar{b}$ vertex correction parameter γ_b .

Many extensions of the Standard Model are described by the ρ_0 parameter:

$$\rho_0 \equiv M_W^2 / (M_Z^2 \, \hat{c}_Z^2 \, \hat{\rho}) \,, \tag{10.42}$$

which describes new sources of SU(2) breaking that cannot be accounted for by Higgs doublets or m_t effects. In the presence of $\rho_0 \neq 1$, Eq. (10.42) generalizes Eq. (10.9b), while Eq. (10.9a) remains unchanged. Provided that the new physics which yields $\rho_0 \neq 1$ is a small perturbation which does not significantly affect the radiative corrections, ρ_0 can be regarded as a phenomenological parameter which multiplies G_F in Eqs. (10.12)–(10.14), (10.28), and Γ_Z in Eq. (10.35). There is now enough data to determine ρ_0 , $\sin^2\theta_W$, m_t , and α_s simultaneously. In particular, the direct CDF and $D\emptyset$ events and R_b yield m_t independent of ρ_0 , the asymmetries yield \widehat{s}_Z^2 , R_t gives α_s , and M_Z and the widths constrain ρ_0 . From the global fit,

$$\begin{array}{ll} \rho_0 = 0.9998 \pm 0.0008 \, (+0.0014) \; , & (10.43) \\ \widehat{s}_Z^2 = 0.23126 \pm 0.00019 \, (+0.00010) \; , & (10.44) \\ \alpha_s = 0.1219 \pm 0.0034 \, (-0.0009) \; , & (10.45) \\ m_t = 174 \pm 5 \; \text{GeV} \; , & (10.46) \end{array}$$

where the central values are for $M_H=M_Z$ and in parentheses we show the effect of changing M_H to 300 GeV. (As in the case $\rho_0=1$, the best fit value for M_H is below its direct lower limit.) The allowed regions in the $\rho_0-\widehat{s}_Z^2$ plane are shown in Fig. 10.2:

The result in Eq. (10.43) is in remarkable agreement with the Standard Model expectation, $\rho_0=1$. It can be used to constrain higher-dimensional Higgs representations to have vacuum expectation values of less than a few percent of those of the doublets. Indeed, the relation between M_W and M_Z is modified if there are Higgs multiplets with weak isospin > 1/2 with significant vacuum expectation values. In order to calculate to higher orders in such theories one must define a set of four fundamental renormalized parameters which one may conveniently choose to be α , G_F , M_Z , and M_W , since M_W and M_Z are directly measurable. Then \hat{s}_Z^2 and ρ_0 can be considered dependent parameters.

Eq. (10.43) can also be used to constrain other types of new physics. For example, nondegenerate multiplets of heavy fermions or scalars break the vector part of weak SU(2) and lead to a decrease in the value of M_Z/M_W . A nondegenerate SU(2) doublet $\binom{f_1}{f_2}$ yields a

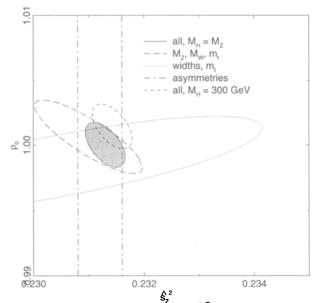


Figure 10.2: The allowed regions in $\sin^2 \hat{\theta}_W - \rho_0$ at 90% CL. m_t is a free parameter and $M_H = M_Z$ is assumed except for the dashed contour for all data which is for $M_H = 300$ GeV. The horizontal (width) band uses the experimental value of M_Z in Eq. (10.35).

positive contribution to ρ_t of [83]

$$\frac{CG_F}{8\sqrt{2}\pi^2}\Delta m^2 , \qquad (10.47)$$

where

$$\Delta m^2 \equiv m_1^2 + m_2^2 - \frac{4m_1^2m_2^2}{m_1^2 - m_2^2} \ln \frac{m_1}{m_2} \ge (m_1 - m_2)^2 , \qquad (10.48)$$

and C=1 (3) for color singlets (triplets). Thus, in the presence of such multiplets, one has

$$\frac{3G_F}{8\sqrt{2}\pi^2}\sum_i \frac{C_i}{3} \Delta m_i^2 = \rho_0 - 1 , \qquad (10.49)$$

where the sum includes fourth-family quark or lepton doublets, $\binom{t'}{b'}$ or $\binom{E^0}{E^-}$, and scalar doublets such as $\binom{\tilde{t}}{b}$ in supersymmetry (in the absence of L-R mixing). This implies

$$\sum_{i} \frac{C_{i}}{3} \Delta m_{i}^{2} < (49 \text{ GeV})^{2} \text{ and } (83 \text{ GeV})^{2}$$
 (10.50)

for $M_H = M_Z$ and 300 GeV, respectively, at 90% CL.

Nondegenerate multiplets usually imply $\rho_0 > 1$. Similarly, heavy Z' bosons decrease the prediction for M_Z due to mixing and generally lead to $\rho_0 > 1$ [84]. On the other hand, additional Higgs doublets which participate in spontaneous symmetry breaking [85], heavy lepton doublets involving Majorana neutrinos [86], and the vacuum expectation values of Higgs triplets or higher-dimensional representations can contribute to ρ_0 with either sign. Allowing for the presence of heavy degenerate chiral multiplets (the S parameter, to be discussed below) affects the determination of ρ_0 from the data, at present leading to a smaller value.

A number of authors [87–92] have considered the general effects on neutral current and Z and W pole observables of various types of heavy (i.e., $M_{\rm new}\gg M_Z$) physics which contribute to the W and Z self-energies but which do not have any direct coupling to the ordinary fermions. In addition to nondegenerate multiplets, which break the vector part of weak SU(2), these include heavy degenerate multiplets of chiral fermions which break the axial generators. The effects of one degenerate chiral doublet are small, but in technicolor

theories there may be many chiral doublets and therefore significant effects [87].

Such effects can be described by just three parameters, S, T, and U at the (electroweak) one loop level. (Three additional parameters are needed if the new physics scale is comparable to M_Z [93].) T is proportional to the difference between the W and Z self-energies at $Q^2=0$ (i.e., vector SU(2)-breaking), while S (S+U) is associated with the difference between the Z (W) self-energy at $Q^2=M_{Z,W}^2$ and $Q^2=0$ (axial SU(2)-breaking). In the $\overline{\rm MS}$ scheme [20]

$$\begin{split} \alpha(M_Z)T &\equiv \frac{\Pi^{\text{new}}_{WW}(0)}{M_W^2} - \frac{\Pi^{\text{new}}_{ZZ}(0)}{M_Z^2} \;, \\ \frac{\alpha(M_Z)}{4\widehat{s}_Z^2\widehat{c}_Z^2}S &\equiv \frac{\Pi^{\text{new}}_{ZZ}(M_Z^2) - \Pi^{\text{new}}_{ZZ}(0)}{M_Z^2} \;, \\ \frac{\alpha(M_Z)}{4\widehat{s}_Z^2}(S+U) &\equiv \frac{\Pi^{\text{new}}_{WW}(M_W^2) - \Pi^{\text{new}}_{WW}(0)}{M_W^2} \;, \end{split} \tag{10.51}$$

where Π^{new}_{WW} and Π^{new}_{ZZ} are, respectively, the contributions of the new physics to the W and Z self-energies. S, T, and U are defined with a factor of α removed, so that they are expected to be of order unity in the presence of new physics. They are related to other parameters $(\hat{\epsilon}_i, h_i, S_i)$ defined in [20,88,89] by

$$\begin{split} T &= h_V = \hat{\epsilon}_1/\alpha \;, \\ S &= h_{AZ} = S_Z = 4 \hat{s}_Z^2 \hat{\epsilon}_3/\alpha \;, \\ U &= h_{AW} - h_{AZ} = S_W - S_Z = -4 \hat{s}_Z^2 \hat{\epsilon}_2/\alpha \;. \end{split} \tag{10.52}$$

A heavy nondegenerate multiplet of fermions or scalars contributes positively to T as

$$\rho_0 = \frac{1}{1 - \alpha T} \simeq 1 + \alpha T \; , \tag{10.53}$$

where ρ_0 is given in Eq. (10.49). The effects of nonstandard Higgs representations cannot be separated from heavy nondegenerate multiplets unless the new physics has other consequences, such as vertex corrections. Most of the original papers defined T to include the effects of loops only. However, we will redefine T to include all new sources of SU(2) breaking, including nonstandard Higgs, so that T and ρ_0 are equivalent by Eq. (10.53).

A multiplet of heavy degenerate chiral fermions yields

$$S = C \sum_{i} (t_{3L}(i) - t_{3R}(i))^{2} / 3\pi , \qquad (10.54)$$

where $t_{3L,R}(i)$ is the third component of weak isospin of the left-(right-) handed component of fermion i and C is the number of colors. For example, a heavy degenerate ordinary or mirror family would contribute $2/3\pi$ to S. In technicolor models with QCD-like dynamics, one expects [87] $S \sim 0.45$ for an isodoublet of technifermions, assuming $N_{TC}=4$ technicolors, while $S\sim 1.62$ for a full technique ration with $N_{TC} = 4$; T is harder to estimate because it is model dependent. In these examples one has $S \geq 0$. However, the QCD-like models are excluded on other grounds (flavor-changing neutral currents, and too-light quarks and pseudo-Goldstone bosons [94]). In particular, these estimates do not apply to models of walking technicolor [94], for which S can be smaller or even negative [95]. Other situations in which S < 0, such as loops involving scalars or Majorana particles, are also possible [96]. Supersymmetric extensions of the Standard Model generally give very small effects [97]. Most simple types of new physics yield U = 0, although there are counter-examples, such as the effects of anomalous triple-gauge vertices [89].

The Standard Model expressions for observables are replaced by

$$\begin{split} M_Z^2 &= M_{Z0}^2 \frac{1 - \alpha T}{1 - G_F M_{Z0}^2 S / 2\sqrt{2}\pi} \;, \\ M_W^2 &= M_{W0}^2 \frac{1}{1 - G_F M_{W0}^2 (S + U) / 2\sqrt{2}\pi} \;, \end{split} \tag{10.55}$$

where M_{Z0} and M_{W0} are the Standard Model expressions (as functions of m_t and M_H) in the $\overline{\rm MS}$ scheme. Furthermore,

$$\begin{split} \Gamma_{Z} &= \frac{1}{1 - \alpha T} M_{Z}^{3} \beta_{Z} \; , \\ \Gamma_{W} &= M_{W}^{3} \beta_{W} \; , \\ A_{i} &= \frac{1}{1 - \alpha T} A_{i0} \; , \end{split} \tag{10.56}$$

where β_Z and β_W are the Standard Model expressions for the reduced widths Γ_{Z0}/M_{Z0}^3 and Γ_{W0}/M_{W0}^3 , M_Z and M_W are the physical masses, and A_i (A_{i0}) is a neutral current amplitude (in the Standard Model).

The $Z \to b\bar{b}$ vertex is sensitive to certain types of new physics which primarily couple to heavy families. It is useful to introduce an additional parameter γ_b by [98]

$$\Gamma(Z \to b\bar{b}) = \Gamma^0(Z \to b\bar{b})(1 + \gamma_b) , \qquad (10.57)$$

where Γ^0 is the Standard Model expression (or the expression modified by S, T, and U). Experimentally, R_b is 1.3 σ above the Standard Model expectations, favoring a positive γ_b . Extended technicolor interactions generally yield negative values of γ_b of a few percent [99], although it is possible to obtain a positive γ_b in models for which the extended technicolor group does not commute with the electroweak gauge group [100] or for which diagonal interactions related to the extended technicolor dominate [101]. Topcolor and topcolor-assisted technicolor models do not generally give a significant contribution to γ_b because the extended technicolor contribution to m_t is small [102]. Supersymmetry can yield (typically small) contributions of either sign [103,104].

The data allow a simultaneous determination of \widehat{s}_Z^2 (e.g., from the Z pole asymmetries), S (from M_Z), U (from M_W), T (e.g., from the Z decay widths), α_s (from R_ℓ), m_t (from CDF and DØ), and γ_b (from R_b) with little correlation among the Standard Model parameters:

$$S = -0.16 \pm 0.14 (-0.10) ,$$

$$T = -0.21 \pm 0.16 (+0.10) ,$$

$$U = 0.25 \pm 0.24 (+0.01) ,$$

$$\gamma_b = 0.007 \pm 0.005 ,$$

$$(10.58)$$

and $\widehat{s}_Z^2 = 0.23118 \pm 0.00023$, $\alpha_s = 0.1191 \pm 0.0051$, $m_t = 175 \pm 5$ GeV, where the uncertainties are from the inputs. The central values assume $M_H = M_Z$, and in parentheses we show the change for $M_H = 300$ GeV. The parameters in Eq. (10.58) which by definition are due to new physics only, are all consistent with the Standard Model values of zero near the 1σ level, although at present there is a slight tendency for negative S and T, and positive U and γ_b . With the latest value of R_b , the extracted $\alpha_s = 0.1191 \pm 0.0051$ is now in perfect agreement with other determinations, even in the presence of the large class of new physics allowed in this fit. Its error is slightly higher than in Eq. (10.38) for the Standard Model, but the central value is independent of M_H . Using Eq. (10.53) the value of ρ_0 corresponding to T is 0.9984 \pm 0.0012 (+0.0008). The values of the $\widehat{\epsilon}$ parameters defined in Eq. (10.52) are

$$\widehat{\epsilon}_3 = -0.0013 \pm 0.0012 \ (-0.0009) \ ,$$

$$\widehat{\epsilon}_1 = -0.0016 \pm 0.0012 \ (+0.0008) \ ,$$

$$\widehat{\epsilon}_2 = -0.0022 \pm 0.0021 \ (-0.0001) \ .$$
(10.59)

There is a strong correlation between γ_b and the predicted α_s (the correlation coefficient is -0.69), just as in the model with S=T=U=0 [17]. For $\gamma_b=0$ one obtains $\alpha_s=0.1239\pm0.0037$, with little change in the other parameters. The largest correlation coefficient (+0.73) is between S and T. The allowed region in S-T is shown in Fig. 10.3. From Eq. (10.58) one obtains S<0.03 (0.08) and T<0.09 (0.15) at 90 (95)% CL for $M_H=M_Z$ (S) and 300 GeV (T). If one fixes $M_H=600$ GeV and requires the constraint $S\geq0$ (as is appropriate in QCD-like technicolor models) then S<0.12 (0.15). Allowing arbitrary S, an extra generation of ordinary fermions is now excluded at the 99.2% CL. This is in agreement with a fit to the

number of light neutrinos, $N_{\nu}=2.993\pm0.011$. The favored value of S is problematic for simple technicolor models with many techni-doublets and QCD-like dynamics, as is the value of γ_b . Although S is consistent with zero, the electroweak asymmetries, especially the SLD left-right asymmetry, favor S<0. The simplest origin of S<0 would probably be an additional heavy Z' boson [84], which could mimic S<0. Similarly, there is a slight indication of negative T, while, as discussed above, nondegenerate scalar or fermion multiplets generally predict T>0.

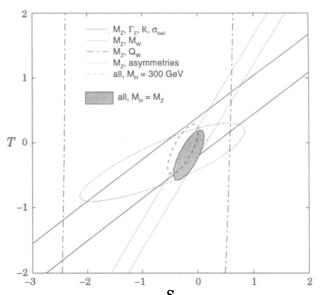


Figure 10.3: 90% CL limits on S and T from various inputs. S and T represent the contributions of new physics only. (Uncertainties from m_t are included in the errors.) The contours assume $M_H = M_Z$ except for the dashed contour for all data which is for $M_H = 300$ GeV. The fit to M_W and M_Z assumes U = 0, while U is arbitrary in the other fits.

There is no simple parametrization that is powerful enough to describe the effects of every type of new physics on every possible observable. The S, T, and U formalism describes many types of heavy physics which affect only the gauge self-energies, and it can be applied to all precision observables. However, new physics which couples directly to ordinary fermions, such as heavy Z' bosons [84] or mixing with exotic fermions [105] cannot be fully parametrized in the S, T, and U framework. It is convenient to treat these types of new physics by parametrizations that are specialized to that particular class of theories (e.g., extra Z' bosons), or to consider specific models (which might contain, e.g., Z' bosons and exotic fermions with correlated parameters). Constraints on various types of new physics are reviewed in [17,106,107]. Fits to models with technicolor, extended technicolor, and supersymmetry are described, respectively, in [100], [108], and [109]. An alternate formalism [110] defines parameters, ϵ_1 , ϵ_2 , ϵ_3 , ϵ_b in terms of the specific observables M_W/M_Z , $\Gamma_{\ell\ell}$, $A_{FB}^{(0,\ell)}$, and R_b . The definitions coincide with those for $\hat{\epsilon}_i$ in Eqs. (10.51) and (10.52) for physics which affects gauge self-energies only, but the ϵ 's now parametrize arbitrary types of new physics. However, the ϵ 's are not related to other observables unless additional model-dependent assumptions are made. Another approach [111-113] parametrizes new physics in terms of gaugeinvariant sets of operators. It is especially powerful in studying the effects of new physics on nonabelian gauge vertices. The most general approach introduces deviation vectors [106]. Each type of new physics defines a deviation vector, the components of which are the deviations of each observable from its Standard Model prediction, normalized to the experimental uncertainty. The length (direction) of the vector represents the strength (type) of new physics.

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11. THE CABIBBO-KOBAYASHI-MASKAWA MIXING MATRIX

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In the Standard Model with $SU(2) \times U(1)$ as the gauge group of electroweak interactions, both the quarks and leptons are assigned to be left-handed doublets and right-handed singlets. The quark mass eigenstates are not the same as the weak eigenstates, and the matrix relating these bases was defined for six quarks and given an explicit parametrization by Kobayashi and Maskawa [1] in 1973. It generalizes the four-quark case, where the matrix is parametrized by a single angle, the Cabibbo angle [2].

By convention, the mixing is often expressed in terms of a 3×3 unitary matrix V operating on the charge -e/3 quarks (d, s, and b):

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix} . \tag{11.1}$$

The values of individual matrix elements can in principle all be determined from weak decays of the relevant quarks, or, in some cases, from deep inelastic neutrino scattering. Using the constraints discussed below together with unitarity, and assuming only three generations, the 90% confidence limits on the magnitude of the elements of the complete matrix are:

$$\begin{pmatrix} 0.9745 \text{ to } 0.9760 & 0.217 & \text{to } 0.224 & 0.0018 \text{ to } 0.0045 \\ 0.217 & \text{to } 0.224 & 0.9737 \text{ to } 0.9753 & 0.036 & \text{to } 0.042 \\ 0.004 & \text{to } 0.013 & 0.035 & \text{to } 0.042 & 0.9991 \text{ to } 0.9994 \end{pmatrix} . \quad (11.2)$$

The ranges shown are for the individual matrix elements. The constraints of unitarity connect different elements, so choosing a specific value for one element restricts the range of others.

There are several parametrizations of the Cabibbo-Kobayashi-Maskawa matrix. We advocate a "standard" parametrization [3] of V that utilizes angles θ_{12} , θ_{23} , θ_{13} , and a phase, δ_{13} :

$$V = \begin{pmatrix} c_{12}c_{13} & s_{12}c_{13} & s_{13}e^{-i\delta_{13}} \\ -s_{12}c_{23}-c_{12}s_{23}s_{13}e^{i\delta_{13}} & c_{12}c_{23}-s_{12}s_{23}s_{13}e^{i\delta_{13}} & s_{23}c_{13} \\ s_{12}s_{23}-c_{12}c_{23}s_{13}e^{i\delta_{13}} & -c_{12}s_{23}-s_{12}c_{23}s_{13}e^{i\delta_{13}} & c_{23}c_{13} \end{pmatrix}$$

$$(11.3)$$

with $c_{ij}=\cos\theta_{ij}$ and $s_{ij}=\sin\theta_{ij}$ for the "generation" labels i,j=1,2,3. This has distinct advantages of interpretation, for the rotation angles are defined and labeled in a way which relate to the mixing of two specific generations and if one of these angles vanishes, so does the mixing between those two generations; in the limit $\theta_{23}=\theta_{13}=0$ the third generation decouples, and the situation reduces to the usual Cabibbo mixing of the first two generations with θ_{12} identified with the Cabibbo angle [2]. The real angles θ_{12} , θ_{23} , θ_{13} can all be made to lie in the first quadrant by an appropriate redefinition of quark field phases.

The matrix elements in the first row and third column, which can be directly measured in decay processes, are all of a simple form, and as c_{13} is known to deviate from unity only in the sixth decimal place, $V_{ud}=c_{12},\,V_{us}=s_{12},\,V_{ub}=s_{13}\,\,e^{\delta_{13}},\,V_{cb}=s_{23},\,{\rm and}\,\,V_{tb}=c_{23}$ to an excellent approximation. The phase δ_{13} lies in the range $0\leq\delta_{13}<2\pi$, with non-zero values generally breaking CP invariance for the weak interactions. The generalization to the n generation case contains n(n-1)/2 angles and (n-1)(n-2)/2 phases. The range of matrix elements in Eq. (11.2) corresponds to 90% CL limits on the sines of the angles of $s_{12}=0.217$ to $0.222,s_{23}=0.036$ to $0.042,\,{\rm and}\,\,s_{13}=0.0018$ to 0.0044.

Kobayashi and Maskawa [1] originally chose a parametrization involving the four angles, θ_1 , θ_2 , θ_3 , δ :

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} c_1 & -s_1 c_3 & -s_1 s_3 \\ s_1 c_2 & c_1 c_2 c_3 -s_2 s_3 e^{i\delta} & c_1 c_2 s_3 + s_2 c_3 e^{i\delta} \\ s_1 s_2 & c_1 s_2 c_3 + c_2 s_3 e^{i\delta} & c_1 s_2 s_3 - c_2 c_3 e^{i\delta} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix} , \qquad (11.4)$$

where $c_i=\cos\theta_i$ and $s_i=\sin\theta_i$ for i=1,2,3. In the limit $\theta_2=\theta_3=0$, this reduces to the usual Cabibbo mixing with θ_1 identified (up to a sign) with the Cabibbo angle [2]. Several different forms of the Kobayashi-Maskawa parametrization are found in the literature. Since all these parametrizations are referred to as "the" Kobayashi-Maskawa form, some care about which one is being used is needed when the quadrant in which δ lies is under discussion.

A popular approximation that emphasizes the hierarchy in the size of the angles, $s_{12}\gg s_{23}\gg s_{13}$, is due to Wolfenstein [4], where one sets $\lambda\equiv s_{12}$, the sine of the Cabibbo angle, and then writes the other elements in terms of powers of λ :

$$V = \begin{pmatrix} 1 - \lambda^2/2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1 - \lambda^2/2 & A\lambda^2 \\ A\lambda^3(1 - \rho - i\eta) & -A\lambda^2 & 1 \end{pmatrix} .$$
 (11.5)

with A, ρ , and η real numbers that were intended to be of order unity. No physics can depend on which of the above parametrizations (or any other) is used as long as a single one is used consistently and care is taken to be sure that no other choice of phases is in conflict.

Our present knowledge of the matrix elements comes from the following sources:

(1) $|V_{ud}|$ - Analyses have been performed comparing nuclear beta decays that proceed through a vector current to muon decay. Radiative corrections are essential to extracting the value of the matrix element. They already include [5] effects of order $Z\alpha^2$, and most of the theoretical argument centers on the nuclear mismatch and structure-dependent radiative corrections [6,7]. New data have been obtained on superallowed $0^+ \to 0^+$ beta decays [8]. Taking the complete data set for nine decays, the values obtained in analyses by two groups are:

$$ft = 3146.0 \pm 3.2$$
 (Ref. 8)
 $ft = 3150.8 \pm 2.8$ (Ref. 9) . (11.6)

Averaging these results (essentially for $|V_{ud}|^{-2}$), but keeping the same error bar, we obtain $|V_{ud}| = 0.9735 \pm 0.0005$. It has been argued [10] that the change in charge-symmetry-violation for quarks inside nucleons that are in nuclear matter results in a further increase of the ft value by 0.075 to 0.2%, leading to a systematic underestimate of $|V_{ud}|$. While more work needs to be done to clarify the structure-dependent effects, for now we add linearly a further $0.1 \pm 0.1\%$ to the ft values coming from nuclear decays, obtaining a value:

$$|V_{nd}| = 0.9740 \pm 0.0010 . (11.7)$$

(2) $|V_{us}|$ - Analysis of K_{e3} decays yields [11]

$$|V_{us}| = 0.2196 \pm 0.0023 . (11.8)$$

With isospin violation taken into account in K^+ and K^0 decays, the extracted values of $|V_{us}|$ are in agreement at the 1% level. A reanalysis [7] obtains essentially the same value, but quotes a somewhat smaller error which is only statistical. The analysis [12] of hyperon decay data has larger theoretical uncertainties because of first order SU(3) symmetry breaking effects in the axial-vector couplings. This has been redone incorporating second order SU(3) symmetry breaking corrections in models [13] applied to the WA2 data [14] to give a value of $|V_{us}| = 0.2176 \pm 0.0026$ with the "best-fit" model, which is consistent with Eq. (11.8). Since the values obtained in the models differ outside the errors and generally do not give good fits, we retain the value in Eq. (11.8) for $|V_{us}|$.

(3) $|V_{cd}|$ – The magnitude of $|V_{cd}|$ may be deduced from neutrino and antineutrino production of charm off valence d quarks. The dimuon production cross sections of the CDHS group [15] yield $\overline{B}_c |V_{cd}|^2 = 0.41 \pm 0.07 \times 10^{-2}$, where \overline{B}_c is the semileptonic branching fraction of the charmed hadrons produced. The corresponding value from a more recent Tevatron experiment [16], where a next-to-leading-order

QCD analysis has been carried out, is $0.534 \pm 0.021^{+0.025}_{-0.081} \times 10^{-2}$, where the last error is from the scale uncertainty. Assuming a similar scale error for the CDHS result and averaging these two results gives $0.49 \pm 0.05 \times 10^{-2}$. Supplementing this with data [17] on the mix of charmed particle species produced by neutrinos and PDG values for their semileptonic branching fractions to give [16] $\overline{B}_c = 0.099 \pm 0.012$, then yields

$$|V_{cd}| = 0.224 \pm 0.016 \tag{11.9}$$

(4) $|V_{cs}|$ – Values of $|V_{cs}|$ from neutrino production of charm are dependent on assumptions about the strange quark density in the parton-sea. The most conservative assumption, that the strange-quark sea does not exceed the value corresponding to an SU(3) symmetric sea, leads to a lower bound [15], $|V_{cs}| > 0.59$. It is more advantageous to proceed analogously to the method used for extracting $|V_{us}|$ from K_{e3} decay; namely, we compare the experimental value for the width of D_{e3} decay with the expression [18] that follows from the standard weak interaction amplitude:

$$\Gamma(D \to \overline{K}e^+\nu_e) = |f_+^D(0)|^2 |V_{cs}|^2 (1.54 \times 10^{11} \text{ s}^{-1}).$$
 (11.10)

Here $f_+^D(q^2)$, with $q=p_D-p_K$, is the form factor relevant to D_{e3} decay; its variation has been taken into account with the parametrization $f_+^D(t)/f_+^D(0)=M^2/(M^2-t)$ and $M=2.1~{\rm GeV}/c^2$, a form and mass consistent with direct measurements [19]. Combining data on branching ratios for D_{e3} decays with accurate values for the D lifetimes [19] yields a value of $(0.818\pm0.041)\times10^{11}~{\rm s}^{-1}$ for $\Gamma(D\to \overline{K}e^+\nu_e)$. Therefore

$$|f_{+}^{D}(0)|^{2} |V_{cs}|^{2} = 0.531 \pm 0.027$$
 (11.11)

A very conservative assumption is that $|f_+^D(0)| < 1$, from which it follows that $|V_{cs}| > 0.62$. Calculations of the form factor either performed [20,21] directly at $q^2 = 0$, or done [22] at the maximum value of $q^2 = (m_D - m_K)^2$ and interpreted at $q^2 = 0$ using the measured q^2 dependence, gives the value $f_+^D(0) = 0.7 \pm 0.1$. It follows that

$$|V_{cs}| = 1.04 \pm 0.16 . (11.12)$$

The constraint of unitarity when there are only three generations gives a much tighter bound (see below).

(5) $|V_{cb}|$ – The heavy quark effective theory [24](HQET) provides a nearly model-independent treatment of B semileptonic decays to charmed mesons, assuming that both the b and c quarks are heavy enough for the theory to apply. From measurements of the exclusive decay $B \to \overline{D}^*\ell^+\nu_\ell$, the value $|V_{cb}| = 0.0387 \pm 0.0021$ has been extracted [25] using corrections based on the HQET. Exclusive $B \to \overline{D}\ell^+\nu_\ell$ decays give a consistent but less precise result. Analysis of inclusive decays, where the measured semileptonic bottom hadron partial width is assumed to be that of a b quark decaying through the usual V - A interaction, depends on going from the quark to hadron level. This is also understood within the context of the HQET [26], and the results for $|V_{cb}|$ are again consistent with those from exclusive decays. Combining all these results [25]:

$$|V_{cb}| = 0.0395 \pm 0.0017 , \qquad (11.13)$$

which is now the third most accurately measured CKM matrix element.

(6) $|V_{ub}|$ – The decay $b \to u\ell\bar{\nu}$ and its charge conjugate can be observed from the semileptonic decay of B mesons produced on the $\Upsilon(4S)$ $(b\bar{b})$ resonance by measuring the lepton energy spectrum above the endpoint of the $b \to c\ell\bar{\nu}_\ell$ spectrum. There the $b \to u\ell\bar{\nu}_\ell$ decay rate can be obtained by subtracting the background from nonresonant e^+e^- reactions. This continuum background is determined from auxiliary measurements off the $\Upsilon(4S)$. The interpretation of the result in terms of $|V_{ub}/V_{cb}|$ depends fairly strongly on the theoretical model used to generate the lepton energy spectrum, especially for $b \to u$ transitions [21,22,27]. Combining the experimental and theoretical uncertainties, we quote

$$|V_{ub}/V_{cb}| = 0.08 \pm 0.02 . {(11.14)}$$

This result is supported by the first exclusive determinations of $|V_{ub}|$ from the decays $B\to\pi\ell\nu_\ell$ and $B\to\rho\ell\nu_\ell$ by the CLEO experiment [28] to obtain $|V_{ub}|=3.3\pm0.4\pm0.7\times10^{-3}$, where the first error is experimental and the second reflects systematic uncertainty from different theoretical models of the exclusive decays. While this result is consistent with Eq. (11.14) and has a similar error bar, given the theoretical model dependence of both results we do not combine them, and retain the inclusive result for V_{ub} .

(7) V_{tb} – The discovery of the top quark by the CDF and DØ collaborations utilized in part the semileptonic decays of t to b. One can set a (still rather crude) limit on the fraction of decays of the form $t \to b \ \ell^+ \ \nu_\ell$, as opposed to semileptonic t decays that involve s or d quarks, of Ref. 29

$$\frac{|V_{tb}|^2}{|V_{td}|^2 + |V_{ts}|^2 + |V_{tb}|^2} = 0.99 \pm 0.29 . \tag{11.15}$$

For many of these CKM matrix elements, the primary source of error is no longer statistical, but rather theoretical. This arises from explicit model dependence in interpreting data or in the use of specific hadronic matrix elements to relate experimental measurements to weak transitions of quarks. This is even more the case in extracting CKM matrix elements from loop diagrams discussed below. Such errors are generally not Gaussian. We have taken a " 1σ " range to correspond to a 68% likelihood that the true value lies within " $\pm 1\sigma$ " of the central value.

The results for three generations of quarks, from Eqs. (11.7), (11.8), (11.9), (11.12), (11.13), (11.14), and (11.15) plus unitarity, are summarized in the matrix in Eq. (11.2). The ranges given there are different from those given in Eqs. (11.7)–(11.15) because of the inclusion of unitarity, but are consistent with the one-standard-deviation errors on the input matrix elements. Note in particular that the unitarity constraint has pushed $|V_{ud}|$ about one standard deviation higher than given in Eq. (11.7).

The data do not preclude there being more than three generations. Moreover, the entries deduced from unitarity might be altered when the CKM matrix is expanded to accommodate more generations. Conversely, the known entries restrict the possible values of additional elements if the matrix is expanded to account for additional generations. For example, unitarity and the known elements of the first row require that any additional element in the first row have a magnitude $|V_{ub}t| < 0.08$. When there are more than three generations, the allowed ranges (at 90% CL) of the matrix elements connecting the first three generations are

where we have used unitarity (for the expanded matrix) and the same measurements of the magnitudes of the CKM matrix elements.

Further information, particularly on CKM matrix elements involving the top quark, can be obtained from flavor-changing processes that occur at the one-loop level. We have not used this information in the discussion above since the derivation of values for V_{td} and V_{ts} in this manner from, for example, B mixing or $b \to s \gamma$, require an additional assumption that the top-quark loop, rather than new physics, gives the dominant contribution to the process in question. Conversely, the agreement of CKM matrix elements extracted from loop diagrams with the values based on direct measurements and three generations can be used to place restrictions on new physics.

The measured value [25] of $\Delta M_{B_d}=0.472\pm0.018~{\rm ps}^{-1}$ from $B_d^0-\overline{B}_d^0$ mixing can be turned in this way into information on $|V_{tb}^*V_{td}|$, assuming that the dominant contribution to the mass difference arises from the matrix element between a B_d and a \overline{B}_d of an operator that corresponds to a box diagram with W bosons and top quarks as sides. Using the characteristic hadronic matrix element that then occurs, $\widehat{B}_{B_d}f_{B_d}^2=(1.4\pm0.1)(175\pm25~{\rm MeV})^2$ from lattice QCD calculations [30], which we regard as having become the most

B = (1.0)

reliable source of such matrix elements, next-to-leading-order QCD corrections ($\eta_{\rm QCD}=0.55$) [31], and the running top-quark mass, $\overline{m}_t(m_t)=166\pm 5$ GeV, as input,

$$|V_{tb}^* \cdot V_{td}| = 0.0084 \pm 0.0018$$
 , (11.17)

where the uncertainty comes primarily from that in the hadronic matrix elements, whose estimated errors are combined linearly.

In the ratio of B_s to B_d mass differences, many common factors (such as the QCD correction and dependence on the top-quark mass) cancel, and we have

$$\frac{\Delta M_{B_s}}{\Delta M_{B_d}} = \frac{M_{B_s}}{M_{B_d}} \frac{\widehat{B}_{B_s} f_{B_s}^2}{\widehat{B}_{B_d} f_{B_d}^2} \frac{|V_{tb}^* \cdot V_{ts}|^2}{|V_{tb}^* \cdot V_{td}|^2} \,. \tag{11.18}$$

With the experimentally measured masses [19], $\widehat{B}_{B_s}/\widehat{B}_{B_d}=1.01\pm0.04$ and $f_{B_s}/f_{B_d}=1.15\pm0.05$ from lattice QCD [30], and the improved experimental lower limit [25] at 95% CL of $\Delta M_{B_s}>10.2~{\rm ps}^{-1}$,

$$|V_{td}|/|V_{ts}| < 0.27 . (11.19)$$

Since with three generations, $|V_{ts}| \approx |V_{cb}|$, this result converts to $|V_{td}| < 0.011$, which is a significant constraint by itself (see Fig. 11.2).

The CLEO observation [32] of $b\to s\gamma$ can be translated [33] similarly into $|V_{ts}|/|V_{cb}|=1.1\pm0.43$, where the large uncertainty is again dominantly theoretical. In $K^+\to\pi^+\nu\bar{\nu}$ there are significant contributions from loop-diagrams involving both charm and top quarks. Experiment is just beginning to probe the level predicted in the Standard Model [34]. All these additional indirect constraints are consistent with the matrix elements obtained from the direct measurements plus unitarity, assuming three generations; with the recent results on B mixing and theoretical improvements in lattice calculations, adding the indirect constraints to the fit reduces the range allowed for $|V_{td}|$.

Direct and indirect information on the CKM matrix is neatly summarized in terms of the "unitarity triangle." The name arises since unitarity of the 3×3 CKM matrix applied to the first and third columns yields

$$V_{ud} V_{ub}^* + V_{cd} V_{cb}^* + V_{td} V_{tb}^* = 0. (11.20)$$

The unitarity triangle is just a geometrical presentation of this equation in the complex plane [35]. We can always choose to orient the triangle so that V_{cd} V_{cb}^* lies along the horizontal; in the parametrization we have chosen, V_{cb} is real, and V_{cd} is real to a very good approximation in any case. Setting cosines of small angles to unity, Eq. (11.20) becomes

$$V_{ub}^* + V_{td} = s_{12} \ V_{cb}^* \ ,$$
 (11.21)

which is shown as the unitarity triangle in Fig. 11.1(a). Rescaling the triangle by a factor $[1/|s_{12}|V_{cb}|]$ so that the base is of unit length, the coordinates of the vertices become

$$A\big({\rm Re}(V_{ub})/|s_{12}\ V_{cb}|\ ,\ -{\rm Im}(V_{ub})/|s_{12}\ V_{cb}|\big)$$
 , $B(1,0)$, $C(0,0)$.
 (11.22

In the Wolfenstein parametrization [4], the coordinates of the vertex A of the unitarity triangle are simply (ρ, η) , as shown in Fig. 11.1(b).

CP-violating processes will involve the phase in the CKM matrix, assuming that the observed CP violation is solely related to a nonzero value of this phase. This allows additional constraints to be brought to bear. More specifically, a necessary and sufficient condition for CP violation with three generations can be formulated in a parametrization-independent manner in terms of the non-vanishing of the determinant of the commutator of the mass matrices for the charge 2e/3 and charge -e/3 quarks [36]. CP violating amplitudes or differences of rates are all proportional to the CKM factor in this quantity. This is the product of factors $s_{12}s_{13}s_{23}c_{12}c_{13}^2c_{23}s_{613}$ in the parametrization adopted above, and is $s_1^2s_2s_3c_1c_2c_3s_6$ in that of

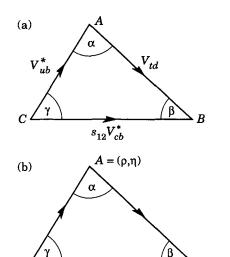


Figure 11.1: (a) Representation in the complex plane of the triangle formed by the CKM matrix elements V_{ub}^* , V_{td} , and s_{12} V_{cb}^* . (b) Rescaled triangle with vertices $A(\rho, \eta)$, B(1, 0), and C(0, 0).

C = (0.0)

Ref. 1. With the approximation of setting cosines to unity, this is just twice the area of the unitarity triangle.

While hadronic matrix elements whose values are imprecisely known generally enter the calculations, the constraints from CP violation in the neutral kaon system, taken together with the restrictions on the magnitudes of the CKM matrix elements shown above, are tight enough to restrict considerably the range of angles and the phase of the CKM matrix. For example, the constraint obtained from the CP-violating parameter ϵ in the neutral K system corresponds to the vertex A of the unitarity triangle lying on a hyperbola for fixed values of the hadronic matrix elements [37,38]. The constraints on the vertex of the unitarity triangle that follow from $|V_{ub}|$, B mixing, and ϵ are shown in Fig. 11.2. The improved limit in Eq. (11.19) that arises from the ratio of B_s to B_d mixing eliminates a significant region for the vertex A of the unitarity triangle, otherwise allowed by direct measurements of the CKM matrix elements. This limit is more robust theoretically since it depends on ratios (rather than absolute values) of hadronic matrix elements and is independent of the top mass or QCD corrections (which cancel in the ratio). Ultimately in the Standard Model, the CP-violating process $K_L \to \pi^0 \nu \overline{\nu}$ offers high precision in measuring the imaginary part of $V_{td} \cdot V_{ts}^*$ to yield Im V_{td} , the altitude of the unitarity triangle. However, the experimental upper limit is presently many orders of magnitude away from the requisite sensitivity.

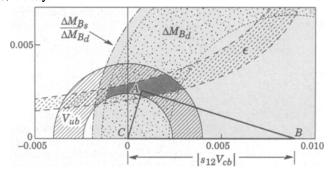


Figure 11.2: Constraints on the position of the vertex, A, of the unitarity triangle following from $|V_{ub}|$, B-mixing, and ϵ . A possible unitarity triangle is shown with A in the preferred region.

For CP-violating asymmetries of neutral B mesons decaying to CP eigenstates, there is a direct relationship between the magnitude

of the asymmetry in a given decay and $\sin 2\phi$, where $\phi = \alpha$, β , γ is an appropriate angle of the unitarity triangle [35]. The combination of all the direct and indirect information can be used to find the implications for future measurements of CP violation in the B system. (See Sec. 12 on CP Violation and the review on "CP Violation in B Decay – Standard Model Predictions" in the B Listings.)

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12. CP VIOLATION

Revised August 1997 by L. Wolfenstein (Carnegie-Mellon Univ.)

The symmetries C (particle-antiparticle interchange) and P (space inversion) hold for strong and electromagnetic interactions. After the discovery of large C and P violation in the weak interactions, it appeared that the product CP was a good symmetry. In 1964 CP violation was observed in K^0 decays at a level given by the parameter $\epsilon \approx 2.3 \times 10^{-3}$. Larger CP-violation effects are anticipated in B^0 decays.

12.1. CP violation in Kaon decay

CP violation has been observed in the semi-leptonic decays $K_L^0 \to \pi^\mp \ell^\pm \nu$ and in the nonleptonic decay $K_L^0 \to 2\pi$. The experimental numbers that have been measured are

$$\delta = \frac{\Gamma(K_L^0 \to \pi^- \ell^+ \nu) - \Gamma(K_L^0 \to \pi^+ \ell^- \nu)}{\Gamma(K_L^0 \to \pi^- \ell^+ \nu) + \Gamma(K_L^0 \to \pi^+ \ell^- \nu)}$$
(12.1a)

$$\begin{split} \eta_{+-} &= A(K_L^0 \to \pi^+ \pi^-) / A(K_S^0 \to \pi^+ \pi^-) \\ &= |\eta_{+-}| \ e^{i\phi_{+-}} \\ \eta_{00} &= A(K_L^0 \to \pi^0 \pi^0) / A(K_S^0 \to \pi^0 \pi^0) \end{split} \tag{12.1b}$$

$$= |\eta_{00}| e^{i\phi_{00}} . (12.1c)$$

Thus there are five real numbers, three magnitudes, and two phases. The present data gives $|\eta_{+-}| \approx |\eta_{00}| = 2.28 \times 10^{-3}$, $\phi_{+-} \approx \phi_{00} = 44^{\circ}$, and $\delta = 3.3 \times 10^{-3}$.

CP violation can occur either in the $K^0-\overline{K}^0$ mixing or in the decay amplitudes. Assuming CPT invariance, the mass eigenstates of the $K^0-\overline{K}^0$ system can be written

$$|K_S\rangle = p|K^0\rangle + q|\overline{K}^0\rangle$$
, $|K_L\rangle = p|K^0\rangle - q|\overline{K}^0\rangle$. (12.2)

If CP invariance held, we would have q=p so that K_S would be CP even and K_L CP odd. (We define $|\overline{K}^0\rangle$ as CP $|K^0\rangle$). CP violation in $K^0-\overline{K}^0$ mixing is then given by the parameter $\widetilde{\epsilon}$ where

$$\frac{p}{q} = \frac{(1+\tilde{\epsilon})}{(1-\tilde{\epsilon})} \ . \tag{12.3}$$

CP violation can also occur in the decay amplitudes

$$A(K^0 \to \pi\pi(I)) = A_I e^{i\delta_I}$$
, $A(\overline{K}^0 \to \pi\pi(I)) = A_I^* e^{i\delta_I}$, (12.4)

where I is the isospin of $\pi\pi$, δ_I is the final-state phase shift, and A_I would be real if CP invariance held. The CP-violating observables are usually expressed in terms of ϵ and ϵ' defined by

$$\eta_{+-} = \epsilon + \epsilon', \quad \eta_{00} = \epsilon - 2\epsilon', \quad (12.5a)$$

One can then show [1]

$$\epsilon = \tilde{\epsilon} + i \text{ (Im } A_0/\text{Re } A_0), \qquad (12.5b)$$

$$\sqrt{2}\epsilon' = ie^{i(\delta_2 - \delta_0)} (\text{Re } A_2/\text{Re } A_0) \text{ (Im } A_2/\text{Re } A_2 - \text{Im } A_0/\text{Re } A_0) ,$$

$$(12.5c)$$

$$\delta = 2\text{Re } \epsilon/(1 + |\epsilon|^2) \approx 2\text{Re } \epsilon .$$

$$(12.5d)$$

In Eq. (12.5c) small corrections of order $\epsilon' \times \text{Re } (A_2/A_0)$ are neglected and Eq. (12.5d) assumes the $\Delta S = \Delta Q$ rule.

The quantities Im A_0 , Im A_2 , and Im ϵ depend on the choice of phase convention since one can change the phases of K^0 and \overline{K}^0 by a transformation of the strange quark state $|s\rangle \rightarrow |s\rangle e^{i\alpha}$; of course, observables are unchanged. It is possible by a choice of phase convention to set Im A_0 or Im ϵ to zero, but none of these is zero may be the usual phase conventions in the Standard Model. The choice Im $A_0 = 0$ is called the Wu-Yang phase convention [2] in which case $\epsilon = \epsilon$. The value of ϵ' is independent of phase convention and a nonzero value would demonstrate CP violation in the decay amplitudes, referred to as direct CP violation. The possibility that

direct CP violation is essentially zero and that CP violation occurs only in the mixing matrix is referred to as the superweak theory [3].

By applying CPT invariance and unitarity the phase of ϵ is given approximately by

$$\phi(\epsilon) \approx \tan^{-1} \frac{2(m_{K_L} - m_{K_S})}{\Gamma_{K_S} - \Gamma_{K_L}} = 43.49 \pm 0.08^{\circ}$$
 (12.6a)

while Eq. (12.5c) gives

$$\phi(\epsilon') = \delta_2 - \delta_0 + \frac{\pi}{2} \approx 48 \pm 4^{\circ} ,$$
 (12.6b)

where the numerical value is based on an analysis of $\pi-\pi$ scattering [4]. The approximation in Eq. (12.6a) depends on the assumption that direct CP violation is very small in all K^0 decays. This is expected to be good to a few tenths of a degree as indicated by the small value of ϵ' and of η_{+-0} , the CP violation parameter in the decay $K_S \to \pi^+\pi^-\pi^0$ [5], although limits on η_{000} are still poor. The relation in Eq. (12.6a) is exact in the superweak theory so this is sometimes called the superweak phase. The most important point for the analysis is that $\cos[\phi(\epsilon') - \phi(\epsilon)] \simeq 1$. The consequence is that only two real quantities need be measured, the magnitude of ϵ and the value of (ϵ'/ϵ) including its sign. The measured quantity $|\eta_{00}/\eta_{+-}|^2$, which is very close to unity, is given to a good approximation by

$$|\eta_{00}/\eta_{+-}|^2 \approx 1 - 6\text{Re}\left(\epsilon'/\epsilon\right) \approx 1 - 6\epsilon'/\epsilon$$
 (12.7)

The values of ϕ_{+-} and $\phi_{00}-\phi_{+-}$ are used to set limits on CPT violation. [See Tests of Conservation Laws.]

In the Standard Model, CP violation arises as a result of a single phase entering the CKM matrix (Sec. 11). As a result in what is now the standard phase convention, two elements have large phases, $V_{ub} \sim e^{-i\gamma}$, $V_{td} \sim e^{-i\beta}$. Because these elements have small magnitudes and involve the third generation, CP violation in the K^0 system is small. In general a nonzero value for ϵ'/ϵ is expected but uncertainties in evaluating hadronic matrix elements make the prediction uncertain. Most theoretical calculations [6] give a value between zero and 10^{-3} , but somewhat larger values or small negative values may be possible. On the other hand, large effects are expected in the B^0 system, which is a major motivation for B factories.

12.2. CP violation in B decay

CP violation in the B^0 system can be observed by comparing B^0 and \overline{B}^0 decays [7]. For a final CP eigenstate a, the decay rate has a time dependence given by

$$\Gamma_a \sim e^{-\Gamma t} \left(\left[1 + |\lambda_a|^2 \right] \pm \left[1 - |\lambda_a|^2 \right] \cos(\Delta M t) \right.$$

$$\mp \operatorname{Im} \lambda_a \sin(\Delta M t) \right) \tag{12.8}$$

where the top sign is for B^0 and the bottom for $\overline{B}{}^0$ and

$$\lambda_a = (q_B/p_B) \ \overline{A}_a/A_a \ . \tag{12.9}$$

The quantities p_B and q_B come from the analogue for B^0 of Eq. (12.2), and $A_a(\overline{A}_a)$ is the decay amplitude to state a for $B^0(\overline{B}^0)$. However, for B^0 the eigenstates are expected to have a negligible lifetime difference and are only distinguished by the mass difference ΔM ; also as a consequence $|q_B/p_B| \approx 1$ so that $\tilde{\epsilon}_B$ is purely imaginary.

If only one quark weak transition contributes to the decay, $|\overline{A}_a/A_a|=1$ so that $|\lambda_a|=1$ and the $\cos(\Delta Mt)$ term vanishes. In this case, the difference between B^0 and \overline{B}^0 decays is given by the $\sin(\Delta Mt)$ term with the asymmetry coefficient

$$a_{a} = \frac{\Gamma_{a}(t) - \overline{\Gamma}_{a}(t)}{(\Gamma_{a}(t) + \overline{\Gamma}_{a}(t))\sin(\Delta M t)} = \eta_{a}\sin(2(\phi_{M} + \phi_{D})), \quad (12.10)$$

where $2\phi_M$ is the phase of the $B^0-\overline{B}^0$ mixing, ϕ_D is the weak phase of the decay transition, and η_a is the CP eigenvalue of a.

For $B^0(\overline{B}^0) \to \psi K_S$ from the transition $b \to c\overline{c}s$, one finds in the Standard Model that the asymmetry is given directly in terms of a CKM phase with no hadronic uncertainty:

$$a_{\psi K_S} = -\sin 2\beta \ . \tag{12.11}$$

From the constraints on the CKM matrix (Sec. 11) $\sin 2\beta$ is predicted to be between 0.3 and 0.9. A significantly different value could be a sign of new physics.

A second decay of interest is B^0 $(\overline B{}^0)\to \pi^+\pi^-$ from the transition $b\to u\overline u d$ with

$$a_{\pi\pi} = \sin 2(\beta + \gamma) \ . \tag{12.12}$$

While either of these asymmetries could be ascribed to $B^0-\overline{B}^0$ mixing $(q_B/p_B \text{ or } \widetilde{\epsilon}_B)$, the difference between the two asymmetries is evidence for direct CP violation. From Eq. (12.9) it is seen that this corresponds to a phase difference between $A_{\psi K_S}$ and $A_{\pi^+\pi^-}$. Thus this is analogous to ϵ' . In the standard phase convention, 2β in Eqs. (12.11) and (12.12) arises from $B^0-\overline{B}^0$ mixing whereas the γ in Eq. (12.12) comes from V_{ub} in the transition $b \to u\overline{u}d$. The result in Eq. (12.12) may have a sizeable correction due to what is called a penguin diagram. This is a one-loop graph producing $b \to d$ + gluon with a W and a quark, predominantly the t quark, in the loop. This leads to an amplitude proportional to $V_{tb}^*V_{td}$, which has a weak phase different from that of the original tree amplitude proportional to $V_{ub}V_{ud}^*$. There are several methods to approximately determine this correction using additional measurements [8].

CP violation in the decay amplitude is also revealed by the $\cos(\Delta Mt)$ term in Eq. (12.8) or by a difference in rates of B^+ and B^- to charge-conjugate states. These effects, however, require two contributing amplitudes to the decay (such as a tree amplitude plus a penguin) and also require final-state interaction phases. Predicted effects are very uncertain and are generally small [9].

In the case of the B_s system, the mass difference ΔM is much larger than for B^0 and has not yet been measured. As a result, it will be difficult to isolate the $\sin(\Delta Mt)$ term to measure asymmetries. Furthermore, in the Standard Model with the standard phase convention, ϕ_M is very small so that decays due to $b \to c\overline{c}s$, yielding $B_s \to \psi \eta^i$, would have zero asymmetry. Decays due to $b \to u\overline{u}d$, yielding $B_s \to \rho^0 K_S$, would have an asymmetry $\sin 2\gamma$ in the tree approximation. The width difference $\Delta\Gamma$ is also expected to be much larger for B_s so that $\Delta\Gamma/\Gamma$ might be a large as 0.15. In this case, there might be a possibility of detecting CP violation as in the case of K^0 by observing the B_s states with different lifetimes decaying into the same CP eigenstate [10].

For further details, see the notes on CP violation in the K_L^0 , K_S^0 , and B^0 Particle Listings of this Review.

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13. QUARK MODEL

Revised April 1998 by C. Amsler (Univ. of Zürich) and C.G. Wohl (LBNL).

13.1. Quantum numbers of the quarks

Each quark has spin 1/2 and baryon number 1/3. Table 13.1 gives the additive quantum numbers (other than baryon number) of the three generations of quarks. Our convention is that the *flavor* of a quark (I_s , S, C, B, or T) has the same sign as its *charge*. With this convention, any flavor carried by a *charged* meson has the same sign as its charge; e.g., the strangeness of the K^+ is +1, the bottomness of the B^+ is +1, and the charm and strangeness of the D_s^- are each -1.

By convention, each quark is assigned positive parity. Then each antiquark has negative parity.

Table 13.1: Additive quantum numbers of the quarks.

Property Quark	d	น	8	с	ь	t
Q - electric charge	$-\frac{1}{3}$	+2/3	- 1 3	+3	-13	$+\frac{2}{3}$
l _s – isospin z-component	$-\frac{1}{2}$	$+\frac{1}{2}$	0	0	0	0
S – strangeness	0	0	-1	0	0	0
C – charm	0	0	0	+1	0	0
B - bottomness	0	0	0	0	-1	0
T - topness	0	0	0	0	0	+1

13.2. Mesons: $q\overline{q}$ states

Nearly all known mesons are bound states of a quark q and an antiquark \overline{q}' (the flavors of q and q' may be different). If the orbital angular momentum of the $q\overline{q}'$ state is L, then the parity P is $(-1)^{L+1}$. A state $q\overline{q}$ of a quark and its own antiquark is also an eigenstate of charge conjugation, with $C=(-1)^{L+S}$, where the spin S is 0 or 1. The L=0 states are the pseudoscalars, $J^P=0^-$, and the vectors, $J^P=1^-$. Assignments for many of the known mesons are given in Table 13.2. States in the "normal" spin-parity series, $P=(-1)^J$, must, according to the above, have S=1 and hence CP=+1. Thus mesons with normal spin-parity and CP=-1 are forbidden in the $q\overline{q}'$ model. The $J^{PC}=0^{--}$ state is forbidden as well. Mesons with such J^{PC} may exist, but would lie outside the $q\overline{q}'$ model.

The nine possible $q\bar{q}'$ combinations containing u, d, and s quarks group themselves into an octet and a singlet:

$$\mathbf{3} \otimes \overline{\mathbf{3}} = \mathbf{8} \oplus \mathbf{1} \tag{13.1}$$

States with the same IJ^P and additive quantum numbers can mix. (If they are eigenstates of charge conjugation, they must also have the same value of C.) Thus the I=0 member of the ground-state pseudoscalar octet mixes with the corresponding pseudoscalar singlet to produce the η and η' . These appear as members of a nonet, which is shown as the middle plane in Fig. 13.1(a). Similarly, the ground-state vector nonet appears as the middle plane in Fig. 13.1(b).

A fourth quark such as charm can be included in this scheme by extending the symmetry to SU(4), as shown in Fig. 13.1. Bottom extends the symmetry to SU(5); to draw the multiplets would require four dimensions.

For the pseudoscalar mesons, the Gell-Mann-Okubo formula is

$$m_{\eta}^2 = \frac{1}{3}(4m_K^2 - m_{\pi}^2) , \qquad (13.2)$$

assuming no octet-singlet mixing. However, the octet η_8 and singlet η_1 mix because of SU(3) breaking. In general, the mixing angle is

mass dependent and becomes complex for resonances of finite width. Neglecting this, the physical states η and η' are given in terms of a mixing angle θ_P by

$$\eta = \eta_8 \cos \theta_P - \eta_1 \sin \theta_P \tag{13.3a}$$

$$\eta' = \eta_8 \sin \theta_P + \eta_1 \cos \theta_P . \tag{13.3b}$$

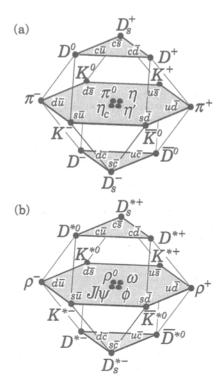


Figure 13.1: SU(4) 16-plets for the (a) pseudoscalar and (b) vector mesons made of u, d, s, and c quarks. The nonets of light mesons occupy the central planes, to which the $c\overline{c}$ states have been added. The neutral mesons at the centers of these planes are mixtures of $u\overline{u}$, $d\overline{d}$, $s\overline{s}$, and $c\overline{c}$ states.

These combinations diagonalize the mass-squared matrix

$$M^2 = \begin{pmatrix} M_{11}^2 & M_{18}^2 \\ M_{18}^2 & M_{88}^2 \end{pmatrix} , (13.4)$$

where $M_{88}^2 = \frac{1}{3}(4m_K^2 - m_\pi^2)$. It follows that

$$\tan^2 \theta_P = \frac{M_{88}^2 - m_{\eta}^2}{m_{\eta'}^2 - M_{88}^2} \,. \tag{13.5}$$

The sign of θ_P is meaningful in the quark model. If

$$\eta_1 = (u\overline{u} + d\overline{d} + s\overline{s})/\sqrt{3} \tag{13.6a}$$

$$\eta_8 = (u\overline{u} + d\overline{d} - 2s\overline{s})/\sqrt{6} , \qquad (13.6b)$$

then the matrix element M_{18}^2 , which is due mostly to the strange quark mass, is negative. From the relation

$$an heta_P = rac{M_{88}^2 - m_\eta^2}{M_{18}^2} \; , ag{13.7}$$

we find that $\theta_P < 0$. However, caution is suggested in the use of the η - η' mixing-angle formulas, as they are extremely sensitive to SU(3)

Table 13.2: Suggested $q\bar{q}$ quark-model assignments for most of the known mesons. Some assignments, especially for the 0⁺⁺ multiplet and for some of the higher multiplets, are controversial. Mesons in bold face are included in the Meson Summary Table. Of the light mesons in the Summary Table, the $f_0(1500)$, $f_1(1510)$, $f_1(1710)$, $f_2(2300)$, $f_2(2340)$, and one of the two peaks in the $\eta(1440)$ entry are not in this table. Within the $q\bar{q}$ model, it is especially hard to find a place for the first three of these f mesons and for one of the $\eta(1440)$ peaks. See the "Note on Non- $q\bar{q}$ Mesons" at the end of the Meson Listings.

		$u\overline{d},u\overline{u},d\overline{d}$	$u\overline{u},d\overline{d},s\overline{s}$	$c\overline{c}$	$b\overline{b}$	īu, īd	$c\overline{u},c\overline{d}$	c s	$\bar{b}u, \bar{b}d$	$\bar{b}s$	$\bar{b}c$
$N^{2S+1}L_J$	J^{PC}	I = 1	I = 0	I = 0	I = 0	I=1/2	I=1/2	I = 0	I=1/2	I = 0	I=0
$1 \ ^{1}S_{0}$	0-+	π	η,η'	η_c		K	D	D_s	В	B_s	B_c
$1\ ^{3}S_{1}$	1	ρ	ω, ϕ	$J/\psi(1S)$	Y(1S)	K*(892)	D*(2010)	D_s^*	B*	B_s^*	
1 ¹ P ₁	1+-	$b_1(1235)$	$h_1(1170), h_1(1380)$	$h_c(1P)$		K_{1B}^{\dagger}	$D_1(2420)$	$D_{s1}(2536)$			
1 ³ P ₀	0++	$a_0(1450)^*$	$f_0(1370)^*$	$\chi_{c0}(1P)$	$\chi_{b0}(1P)$	$K_0^*(1430)$,,,,,,	
1 ³ P ₁	1++	$a_1(1260)$	$f_1(1285), f_1(1420)$	$\chi_{c1}(1P)$	$\chi_{b1}(1P)$	K_{1A}^{\dagger}					
1 ³ P ₂	2++	$a_2(1320)$	$f_2(1270), f_2'(1525)$	$\chi_{c2}(1P)$	$\chi_{b2}(1P)$	$K_2^*(1430)$	$D_2^*(2460)$				
1 ¹ D ₂	2-+	$\pi_2(1670)$	$\eta_2(1645), \eta_2(1870)$			$K_2(1770)$					
1 ³ D ₁	1	ho(1700)	$\omega(1600)$	$\psi(3770)$		K*(1680) [‡]					
1 ³ D ₂	2					$K_2(1820)$					
1 ³ D ₃	3	$ ho_3(1690)$	$\omega_3(1670), \phi_3(1850)$			$K_3^{\star}(1780)$					
1 ³ F ₄	4++	a ₄ (2040)	$f_4(2050), f_4(2220)$			$K_4^*(2045)$					
2 ¹ S ₀	0-+	$\pi(1300)$	$\eta(1295),\eta(1440)$	$\eta_c(2S)$		K(1460)					
2 ³ S ₁	1	ho(1450)	$\omega(1420),\phi(1680)$	$\psi(2S)$	$\Upsilon(2S)$	K*(1410) [‡]					
2 ³ P ₂	2++		$f_2(1810), f_2(2010)$		$\chi_{b2}(2P)$	$K_2^*(1980)$					
3 ¹ S ₀	0-+	$\pi(1800)$	$\eta(1760)$			K(1830)					

^{*} See our scalar minireview in the Particle Listings. The candidates for the I=1 states are $a_0(980)$ and $a_0(1450)$, while for I=0 they are: $f_0(400-1200)$, $f_0(980)$, and $f_0(1370)$. The light scalars are problematic, since there may be two poles for one $q\overline{q}$ state and $a_0(980)$, $f_0(980)$ may be $K\overline{K}$ bound states.

If we allow $M_{88}^2=\frac{1}{3}(4m_K^2-m_\pi^2)$ $(1+\Delta),$ the mixing angle is determined by

$$\tan^2\theta_P = 0.0319(1+17\Delta) \tag{13.8}$$

$$\theta_P = -10.1^{\circ}(1 + 8.5\Delta) \tag{13.9}$$

to first order in Δ . A small breaking of the Gell-Mann-Okubo relation can produce a major modification of θ_P .

For the vector mesons, $\pi \to \rho, \ K \to K^*, \ \eta \to \phi, \ {\rm and} \ \eta' \to \omega, \ {\rm so}$ that

$$\phi = \omega_8 \cos \theta_V - \omega_1 \sin \theta_V \tag{13.10}$$

$$\omega = \omega_8 \sin \theta_V + \omega_1 \cos \theta_V . \tag{13.11}$$

For "ideal" mixing, $\phi=s\bar{s}$, so $\tan\theta_V=1/\sqrt{2}$ and $\theta_V=35.3^\circ$. Experimentally, θ_V is near 35°, the sign being determined by a formula like that for $\tan\theta_P$. Following this procedure we find the mixing angles given in Table 13.3.

Table 13.3: Singlet-octet mixing angles for several nonets, neglecting possible mass dependence and imaginary parts. The sign conventions are given in the text. The values of $\theta_{\rm quad}$ are obtained from the equations in the text, while those for $\theta_{\rm lin}$ are obtained by replacing m^2 by m throughout. Of the two isosinglets in a nonet, the mostly octet one is listed first.

J^{PC}	Nonet members	$\theta_{ ext{quad}}$	$ heta_{ m lin}$
0-+	π, K, η, η'	-10°	-23°
1	$ ho,K^*(892),\phi,\omega$	39°	36°
2++	$a_2(1320), K_2^*(1430), f_2^l(1525), f_2(1270)$	28°	26°
3	$\rho_3(1690), K_3^*(1780), \phi_3(1850), \omega_3(1670)$	29°	28°

[†] The K_{1A} and K_{1B} are nearly equal (45°) mixes of the $K_1(1270)$ and $K_1(1400)$.

[‡]The $K^*(1410)$ could be replaced by the $K^*(1680)$ as the 2 3S_1 state.

In the quark model, the coupling of neutral mesons to two photons is proportional to $\sum_i Q_i^2$, where Q_i is the charge of the *i*-th quark. This provides an alternative characterization of mixing. For example, defining

$$\operatorname{Amp}\left[P \to \gamma(k_1) \ \gamma(k_2)\right] = M \epsilon^{\mu\nu\alpha\beta} \ \epsilon_{1\mu}^* \ k_{1\nu} \ \epsilon_{2\alpha}^* \ k_{2\beta} \ , \tag{13.12}$$

where $\epsilon_{i\lambda}$ is the λ component of the polarization vector of the i^{th} photon, one finds

$$\frac{M(\eta \to \gamma \gamma)}{M(\pi^0 \to \gamma \gamma)} = \frac{1}{\sqrt{3}} (\cos \theta_P - 2\sqrt{2} \sin \theta_P)$$

$$= \frac{1.73 \pm 0.18}{\sqrt{3}}$$
(13.13a)

$$= \frac{1762332}{\sqrt{3}}$$

$$\frac{M(\eta' \to \gamma\gamma)}{M(\pi^0 \to \gamma\gamma)} = 2\sqrt{2/3} \left(\cos\theta_P + \frac{\sin\theta_P}{2\sqrt{2}}\right)$$

$$= 2\sqrt{2/3} \left(0.78 \pm 0.04\right),$$

$$(13.13a)$$

where the numbers with errors are experimental. These data favor $\theta_P \approx -20^\circ$, which is compatible with the quadratic mass mixing formula with about 12% SU(3) breaking in M_{88}^2 .

13.3. Baryons: qqq states

All the established baryons are apparently 3-quark (qqq) states, and each such state is an SU(3) color singlet, a completely antisymmetric state of the three possible colors. Since the quarks are fermions, the state function for any baryon must be antisymmetric under interchange of any two equal-mass quarks (up and down quarks in the limit of isospin symmetry). Thus the state function may be written as

$$|qqq\rangle_A = |\operatorname{color}\rangle_A \times |\operatorname{space}, \operatorname{spin}, \operatorname{flavor}\rangle_S,$$
 (13.14)

where the subscripts S and A indicate symmetry or antisymmetry under interchange of any two of the equal-mass quarks. Note the contrast with the state function for the three nucleons in 3H or 3He :

$$|NNN\rangle_A = |\text{space, spin, isospin}\rangle_A$$
. (13.15)

This difference has major implications for internal structure, magnetic moments, etc. (For a nice discussion, see Ref. 1.)

The "ordinary" baryons are made up of u, d, and s quarks. The three flavors imply an approximate flavor SU(3), which requires that baryons made of these quarks belong to the multiplets on the right side of

$$\mathbf{3} \otimes \mathbf{3} \otimes \mathbf{3} = \mathbf{10}_S \oplus \mathbf{8}_M \oplus \mathbf{8}_M \oplus \mathbf{1}_A \tag{13.16}$$

(see Sec. 34, on "SU(n) Multiplets and Young Diagrams"). Here the subscripts indicate symmetric, mixed-symmetry, or antisymmetric states under interchange of any two quarks. The 1 is a uds state (Λ_1) and the octet contains a similar state (Λ_8). If these have the same spin and parity they can mix. An example is the mainly octet D_{03} $\Lambda(1690)$ and mainly singlet D_{03} $\Lambda(1520)$. In the ground state multiplet, the SU(3) flavor singlet Λ is forbidden by Fermi statistics. The mixing formalism is the same as for η - η' or ϕ - ω (see above), except that for baryons the mass M instead of M^2 is used. Section 33, on "SU(3) Isoscalar Factors and Representation Matrices", shows how relative decay rates in, say, $10 \to 8 \otimes 8$ decays may be calculated. A summary of results of fits to the observed baryon masses and decay rates for the best-known SU(3) multiplets is given in Appendix II of our 1982 edition [2].

The addition of the c quark to the light quarks extends the flavor symmetry to SU(4). Figures 13.2(a) and 13.2(b) show the (badly broken) SU(4) baryon multiplets that have as their "ground floors" the SU(3) octet that contains the nucleons and the SU(3) decuplet that contains the $\Delta(1232)$. All the particles in a given SU(4) multiplet have the same spin and parity. The only charmed baryons that have been discovered each contain one charmed quark. These belong to the first floor of the multiplet shown in Fig. 13.2(a); for details, see the "Note on Charmed Baryons" in the Baryon Particle Listings. The addition of a b quark extends the flavor symmetry to SU(5); it would require four dimensions to draw the multiplets.

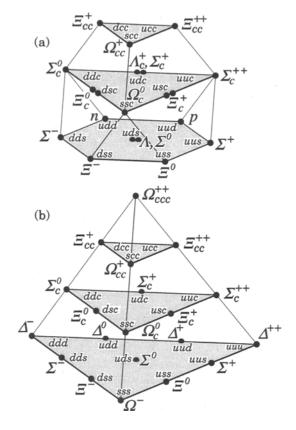


Figure 13.2: SU(4) multiplets of baryons made of u, d, s, and c quarks. (a) The 20-plet with an SU(3) octet. (b) The 20-plet with an SU(3) decuplet.

For the "ordinary" baryons, flavor and spin may be combined in an approximate flavor-spin SU(6) in which the six basic states are $d\uparrow$, $d\downarrow$, \cdots , $s\downarrow$ (\uparrow , \downarrow = spin up, down). Then the baryons belong to the multiplets on the right side of

$$\mathbf{6} \otimes \mathbf{6} \otimes \mathbf{6} = \mathbf{56}_S \oplus \mathbf{70}_M \oplus \mathbf{70}_M \oplus \mathbf{20}_A . \tag{13.17}$$

These SU(6) multiplets decompose into flavor SU(3) multiplets as follows:

$$\mathbf{56} = {}^{4}\mathbf{10} \oplus {}^{2}\mathbf{8} \tag{13.18a}$$

$$70 = {}^{2}10 \oplus {}^{4}8 \oplus {}^{2}8 \oplus {}^{2}1 \tag{13.18b}$$

$$20 = {}^{2}8 \oplus {}^{4}1 , \qquad (13.18c)$$

where the superscript (2S+1) gives the net spin S of the quarks for each particle in the SU(3) multiplet. The $J^P=1/2^+$ octet containing the nucleon and the $J^P=3/2^+$ decuplet containing the $\Delta(1232)$ together make up the "ground-state" 56-plet in which the orbital angular momenta between the quark pairs are zero (so that the spatial part of the state function is trivially symmetric). The 70 and 20 require some excitation of the spatial part of the state function in order to make the overall state function symmetric. States with nonzero orbital angular momenta are classified in SU(6) \otimes O(3) supermultiplets. Physical baryons with the same quantum numbers do not belong to a single supermultiplet, since SU(6) is broken by spin-dependent interactions, differences in quark masses, etc. Nevertheless, the SU(6) \otimes O(3) basis provides a suitable framework for describing baryon state functions.

It is useful to classify the baryons into bands that have the same number N of quanta of excitation. Each band consists of a number of supermultiplets, specified by (D, L_N^P) , where D is the dimensionality of the SU(6) representation, L is the total quark orbital angular momentum, and P is the total parity. Supermultiplets contained in bands up to N=12 are given in Ref. 3. The N=0 band,

which contains the nucleon and $\Delta(1232)$, consists only of the $(56,0_0^+)$ supermultiplet. The N=1 band consists only of the $(70,1_1^-)$ multiplet and contains the negative-parity baryons with masses below about 1.9 GeV. The N=2 band contains five supermultiplets: $(56,0_2^+)$, $(70,0_2^+)$, $(56,2_2^+)$, $(70,2_2^+)$, and $(20,1_2^+)$. Baryons belonging to the $(20,1_2^+)$ supermultiplet are not ever likely to be observed, since a coupling from the ground-state baryons requires a two-quark excitation. Selection rules are similarly responsible for the fact that many other baryon resonances have not been observed [4].

In Table 13.4, quark-model assignments are given for many of the established baryons whose $SU(6)\otimes O(3)$ compositions are relatively unmixed. We note that the unestablished resonances $\varSigma(1480)$, $\varSigma(1560)$, $\varSigma(1580)$, $\varSigma(1770)$, and $\varSigma(1620)$ in our Baryon Particle Listings are too low in mass to be accommodated in most quark models [4,5].

Table 13.4: Quark-model assignments for many of the known baryons in terms of a flavor-spin SU(6) basis. Only the dominant representation is listed. Assignments for some states, especially for the $\Lambda(1810)$, $\Lambda(2350)$, $\Xi(1820)$, and $\Xi(2030)$, are merely educated guesses.

J^P	(D,L_N^P)	\boldsymbol{S}		Octet n	nembers	•	Singlets
1/2+	$(56,0_0^+)$	1/2	N(939)	A(1116)	$\Sigma(1193)$	Ξ(1318)	
$1/2^{+}$	$(56,0^+_2)$	1/2	N(1440)	1 (1600)	$\Sigma(1660)$	$\varXi(?)$	
$1/2^{-}$	$(70,1_1^-)$	1/2	N(1535)	$\Lambda(1670)$	$\varSigma(1620)$	$\varXi(?)$	$\Lambda(1405)$
$3/2^{-}$	$(70,1_1^-)$	1/2	N(1520)	A(1690)	$\varSigma(1670)$	$\mathcal{\Xi}(1820)$	A(1520)
$1/2^{-}$	$(70,1_1^-)$	3/2	N(1650)	A(1800)	$\varSigma(1750)$	$\varXi(?)$	
$3/2^{-}$	$(70,1_1^-)$	3/2	N(1700)	$\Lambda(?)$	$\varSigma(?)$	$\varXi(?)$	
$5/2^{-}$	$(70,1_1^-)$	3/2	N(1675)	$\Lambda(1830)$	$\varSigma(1775)$	$\varXi(?)$	
1/2+	$(70,0_2^+)$	1/2	N(1710)	$\Lambda(1810)$	$\Sigma(1880)$	$\varXi(?)$	$\Lambda(?)$
$3/2^{+}$	$(56,2_2^+)$	1/2	N(1720)	$\Lambda(1890)$	$\mathcal{\Sigma}(?)$	$\varXi(?)$	
$5/2^{+}$	$(56,2_2^+)$	1/2	N(1680)	$\Lambda(1820)$	$\Sigma(1915)$	$\mathcal{\Xi}(2030)$	
$7/2^{-}$	$(70,3_3^-)$	1/2	N(2190)	$\Lambda(?)$	$\varSigma(?)$	$\Xi(?)$	$\Lambda(2100)$
$9/2^{-}$	$(70,3_3^-)$	3/2	N(2250)	$\Lambda(?)$	$\Sigma(?)$	$\Xi(?)$	
9/2+	$(56,4_4^+)$	1/2	N(2220)	$\Lambda(2350)$	$\Sigma(?)$	$\varXi(?)$	
	Decuplet members						
	,						

 $(56,0_0^+)$ 3/2 $\Delta(1232)$ $\Sigma(1385)$ $\Xi(1530)$ $\Omega(1672)$ $\Xi(?)$ 1/2- $(70,1_1^-)$ 1/2 $\Delta(1620)$ $\Sigma(?)$ $\Omega(?)$ $(70,1_1^-)$ 1/2 $\Delta(1700)$ $\Sigma(?)$ $\Xi(?)$ $\Omega(?)$ 3/2- $\Xi(?)$ $5/2^{+}$ $(56,2^{+}_{2})$ 3/2 $\Delta(1905)$ $\Sigma(?)$ $\Omega(?)$ $7/2^{+}$ (56,2 $^{+}$) 3/2 Δ (1950) Σ (2030) Ξ (?) $\Omega(?)$ $11/2^+$ (56,4⁺₄) 3/2 Δ (2420) Σ (?) $\Xi(?)$ $\Omega(?)$

The quark model for baryons is extensively reviewed in Ref. 6 and 7.

13.4. Dynamics

Many specific quark models exist, but most contain the same basic set of dynamical ingredients. These include:

- i) A confining interaction, which is generally spin-independent.
- ii) A spin-dependent interaction, modeled after the effects of gluon exchange in QCD. For example, in the S-wave states, there is a spin-spin hyperfine interaction of the form

$$H_{HF} = -\alpha_S M \sum_{i>j} (\overrightarrow{\sigma} \lambda_a)_i (\overrightarrow{\sigma} \lambda_a)_j , \qquad (13.19)$$

where M is a constant with units of energy, λ_a $(a=1,\dots,8,)$ is the set of SU(3) unitary spin matrices, defined in Sec. 33, on "SU(3) Isoscalar Factors and Representation Matrices," and the sum runs over constituent quarks or antiquarks. Spin-orbit interactions, although allowed, seem to be small.

- iii) A strange quark mass somewhat larger than the up and down quark masses, in order to split the SU(3) multiplets.
- iv) In the case of isoscalar mesons, an interaction for mixing $q\overline{q}$ configurations of different flavors (e.g., $u\overline{u} \leftrightarrow d\overline{d} \leftrightarrow s\overline{s}$), in a manner which is generally chosen to be flavor independent.

These four ingredients provide the basic mechanisms that determine the hadron spectrum.

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14. EXPERIMENTAL TESTS OF GRAVITATIONAL THEORY

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Einstein's General Relativity, the current "standard" theory of gravitation, describes gravity as a universal deformation of the Minkowski metric:

$$g_{\mu\nu}(x^{\lambda}) = \eta_{\mu\nu} + h_{\mu\nu}(x^{\lambda})$$
, where $\eta_{\mu\nu} = \text{diag}(-1, +1, +1, +1)$. (14.1)

Alternatively, it can be defined as the unique, consistent, local theory of a massless spin-2 field $h_{\mu\nu}$, whose source must then be the total, conserved energy-momentum tensor [1]. General Relativity is classically defined by two postulates. One postulate states that the Lagrangian density describing the propagation and self-interaction of the gravitational field is

$$\mathcal{L}_{\rm Ein}[g_{\mu\nu}] = \frac{c^4}{16\pi G_N} \sqrt{g} g^{\mu\nu} R_{\mu\nu}(g) , \qquad (14.2)$$

$$R_{\mu\nu}(g) = \partial_{\alpha}\Gamma^{\alpha}_{\mu\nu} - \partial_{\nu}\Gamma^{\alpha}_{\mu\alpha} + \Gamma^{\beta}_{\alpha\beta}\Gamma^{\alpha}_{\mu\nu} - \Gamma^{\beta}_{\nu\alpha}\Gamma^{\alpha}_{\mu\beta} , \qquad (14.3)$$

$$\Gamma^{\lambda}_{\mu\nu} = \frac{1}{2} g^{\lambda\sigma} (\partial_{\mu} g_{\nu\sigma} + \partial_{\nu} g_{\mu\sigma} - \partial_{\sigma} g_{\mu\nu}) , \qquad (14.4)$$

where G_N is Newton's constant, $g=-\det(g_{\mu\nu})$, and $g^{\mu\nu}$ is the matrix inverse of $g_{\mu\nu}$. A second postulate states that $g_{\mu\nu}$ couples universally, and minimally, to all the fields of the Standard Model by replacing everywhere the Minkowski metric $\eta_{\mu\nu}$. Schematically (suppressing matrix indices and labels for the various gauge fields and fermions and for the Higgs doublet),

$$\mathcal{L}_{\text{SM}}[\psi, A_{\mu}, H, g_{\mu\nu}] = -\frac{1}{4} \sum \sqrt{g} g^{\mu\alpha} g^{\nu\beta} F^{a}_{\mu\nu} F^{a}_{\alpha\beta} - \sum \sqrt{g} \overline{\psi} \gamma^{\mu} D_{\mu} \psi - \frac{1}{2} \sqrt{g} g^{\mu\nu} \overline{D_{\mu} H} D_{\nu} H - \sqrt{g} V(H) - \sum \lambda \sqrt{g} \overline{\psi} H \psi ,$$
 (14.5)

where $\gamma^{\mu}\gamma^{\nu} + \gamma^{\nu}\gamma^{\mu} = 2g^{\mu\nu}$, and where the covariant derivative D_{μ} contains, besides the usual gauge field terms, a (spin dependent) gravitational contribution $\Gamma_{\mu}(x)$ [2]. From the total action $S_{\text{tot}}[g_{\mu\nu}, \psi, A_{\mu}, H] = c^{-1} \int d^4x (\mathcal{L}_{\text{Ein}} + \mathcal{L}_{\text{SM}})$ follow Einstein's field equations,

$$R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} = \frac{8\pi G_N}{c^4} T_{\mu\nu} . \qquad (14.6)$$

Here $R=g^{\mu\nu}R_{\mu\nu}$, $T_{\mu\nu}=g_{\mu\alpha}g_{\nu\beta}T^{\alpha\beta}$, and $T^{\mu\nu}=(2/\sqrt{g})\delta \mathcal{L}_{\rm SM}/\delta g_{\mu\nu}$ is the (symmetric) energy-momentum tensor of the Standard Model matter. The theory is invariant under arbitrary coordinate transformations: $x'^{\mu}=f^{\mu}(x^{\nu})$. To solve the field equations Eq. (14.6) one needs to fix this coordinate gauge freedom. E.g. the "harmonic gauge" (which is the analogue of the Lorentz gauge, $\partial_{\mu}A^{\mu}=0$, in electromagnetism) corresponds to imposing the condition $\partial_{\nu}(\sqrt{g}g^{\mu\nu})=0$.

In this Review, we only consider the classical limit of gravitation (i.e. classical matter and classical gravity). Considering quantum matter in a classical gravitational background already poses interesting challenges, notably the possibility that the zero-point fluctuations of the matter fields generate a nonvanishing vacuum energy density $\rho_{\rm vac}$, corresponding to a term $-\sqrt{g}$ $\rho_{\rm vac}$ in $\mathcal{L}_{\rm SM}$ [3]. This is equivalent to adding a "cosmological constant" term $+\Lambda g_{\mu\nu}$ on the left-hand side of Einstein's equations Eq. (14.6), with $\Lambda = 8\pi G_N \, \rho_{\rm vac}/c^4$. Cosmological observations set bounds on Λ (see "Astrophysical Constants," Sec. 2 of this Review) which, when translated in particle physics units, appear suspiciously small: $\rho_{\rm vac} \lesssim 10^{-46}~{\rm GeV}^4$. This bound shows that $\rho_{\rm vac}$, even if it is not strictly zero, has a negligible effect on the tests discussed below. Quantizing the gravitational field itself poses a very difficult challenge because of the perturbative non-renormalizability of Einstein's Lagrangian. Supergravity and superstring theory offer promising avenues toward solving this challenge.

14.1. Experimental tests of the coupling between matter and gravity

The universality of the coupling between $g_{\mu\nu}$ and the Standard Model matter postulated in Eq. (14.5) ("Equivalence Principle") has many observable consequences. First, it predicts that the outcome of a local non-gravitational experiment, referred to local standards, does not depend on where, when, and in which locally inertial frame, the experiment is performed. This means, for instance, that local experiments should neither feel the cosmological evolution of the universe (constancy of the "constants"), nor exhibit preferred directions in spacetime (isotropy of space, local Lorentz invariance). These predictions are consistent with many experiments and observations. The best limit on a possible time variation of the basic coupling constants concerns the fine-structure constant $\alpha_{\rm em}$ and has been obtained by analyzing a natural fission reactor phenomenon which took place at Oklo, Gabon, two billion years ago [4]

$$-6.7 \times 10^{-17} \rm{yr}^{-1} < \frac{\dot{\alpha}_{\rm em}}{\alpha_{\rm em}} < 5.0 \times 10^{-17} \rm{yr}^{-1} \ . \eqno(14.7)$$

The highest precision tests of the isotropy of space have been performed by looking to possible quadrupolar shifts of nuclear energy levels [5]. The (null) results can be interpreted as testing the fact that the various pieces in the matter Lagrangian Eq. (14.5) are indeed coupled to one and the same external metric $g_{\mu\nu}$ to the 10^{-27} level.

The universal coupling to $g_{\mu\nu}$ postulated in Eq. (14.5) implies that two (electrically neutral) test bodies dropped at the same location and with the same velocity in an external gravitational field fall in the same way, independently of their masses and compositions. The universality of the acceleration of free fall has been verified at the 10^{-12} level both for laboratory bodies [6],

$$\left(\frac{\Delta a}{a}\right)_{\text{BeCu}} = (-1.9 \pm 2.5) \times 10^{-12} ,$$
 (14.8)

and for the gravitational accelerations of the Moon and the Earth toward the Sun [7],

$$\left(\frac{\Delta a}{a}\right)_{\text{MoonFarth}} = (-3.2 \pm 4.6) \times 10^{-13} \ .$$
 (14.9)

Finally, Eq. (14.5) also implies that two identically constructed clocks located at two different positions in a static external Newtonian potential $U(\boldsymbol{x}) = \sum G_N m/r$ exhibit, when intercompared by means of electromagnetic signals, the (apparent) difference in clock rate,

$$\frac{\tau_1}{\tau_2} = \frac{\nu_2}{\nu_1} = 1 + \frac{1}{c^2} [U(\boldsymbol{x}_1) - U(\boldsymbol{x}_2)] + O\left(\frac{1}{c^4}\right) , \qquad (14.10)$$

independently of their nature and constitution. This universal gravitational redshift of clock rates has been verified at the 10^{-4} level by comparing a hydrogen-maser clock flying on a rocket up to an altitude $\sim 10,000$ km to a similar clock on the ground [8]. For more details and references on experimental gravity see, e.g., Refs. 9 and 10.

14.2. Tests of the dynamics of the gravitational field in the weak field regime

The effect on matter of one-graviton exchange, i.e. the interaction Lagrangian obtained when solving Einstein's field equations Eq. (14.6) written in, say, the harmonic gauge at first order in $h_{\mu\nu}$,

$$\Box h_{\mu\nu} = -\frac{16\pi G_N}{c^4} (T_{\mu\nu} - \frac{1}{2}T\eta_{\mu\nu}) + O(h^2) + O(hT) , \qquad (14.11)$$

reads $-(8\pi G_N/c^4)T^{\mu\nu}\Box^{-1}(T_{\mu\nu}-\frac{1}{2}T\eta_{\mu\nu})$. For a system of N moving point masses, with free Lagrangian $L^{(1)}=\sum_{A=1}^N-m_Ac^2\sqrt{1-v_A^2/c^2}$, this interaction, expanded to order v^2/c^2 , reads (with $r_{AB}\equiv |x_A-x_B|$, $n_{AB}\equiv (x_A-x_B)/r_{AB}$)

$$\begin{split} L^{(2)} = & \frac{1}{2} \sum_{A \neq B} \frac{G_N \, m_A \, m_B}{r_{AB}} \left[1 + \frac{3}{2c^2} (v_A^2 + v_B^2) - \frac{7}{2c^2} (v_A \cdot v_B) \right. \\ & \left. - \frac{1}{2c^2} (n_{AB} \cdot v_A) (n_{AB} \cdot v_B) + O\left(\frac{1}{c^4}\right) \right] \,. \end{split} \tag{14.12}$$

The two-body interactions Eq. (14.12) exhibit v^2/c^2 corrections to Newton's 1/r potential induced by spin-2 exchange. Consistency at the "post-Newtonian" level $v^2/c^2 \sim G_N \, m/rc^2$ requires that one also considers the three-body interactions induced by some of the three-graviton vertices and other nonlinearities (terms $O(h^2)$ and O(hT) in Eq. (14.11)),

$$L^{(3)} = -\sum_{B \neq A \neq C} \frac{G_N^2 \, m_A \, m_B \, m_C}{r_{AB} \, r_{AC} \, c^2} + O\left(\frac{1}{c^4}\right) . \tag{14.13}$$

All currently performed gravitational experiments in the solar system, including perihelion advances of planetary orbits, the bending and delay of electromagnetic signals passing near the Sun, and very accurate ranging data to the Moon obtained by laser echoes, are compatible with the post-Newtonian results Eqs. (14.11)–(14.13).

Similarly to what is done in discussions of precision electroweak experiments (see Section 10 in this Review), it is useful to quantify the significance of precision gravitational experiments by parameterizing plausible deviations from General Relativity. Endowing the spin-2 excitations with a (Pauli-Fierz) mass term is excluded both for phenomenological (discontinuities in observable predictions [11]) and theoretical (no energy lower bound [12]) reasons. Therefore, deviations from Einstein's pure spin-2 theory are defined by adding new, bosonic, ultra light or massless, macroscopically coupled fields. The addition of a vector (spin 1) field necessarily leads to violations of the universality of free fall and is constrained by "fifth force" experiments. See Refs. [6,13] for compilations of constraints. The addition of a scalar (spin 0) field is the most studied type of deviation from General Relativity, being motivated by many attempts to unify gravity with the Standard Model (Kaluza-Klein program, supergravity, string theory). The technically simplest class of tensor-scalar (spin 2 \oplus spin 0) theories consists in adding a massless scalar field φ coupled to the trace of the energy-momentum tensor $T=g_{\mu\nu}T^{\mu\nu}$ [14]. The most general such theory contains an arbitrary function $a(\varphi)$ of the scalar field, and can be defined by the Lagrangian

$$\mathcal{L}_{\text{tot}}[g_{\mu\nu}, \varphi, \psi, A_{\mu}, H] = \frac{c^4}{16\pi G} \sqrt{g} (R(g) - 2g^{\mu\nu} \partial_{\mu} \varphi \partial_{\nu} \varphi) + \mathcal{L}_{\text{SM}}[\psi, A_{\mu}, H, \tilde{g}_{\mu\nu}], \qquad (14.14)$$

where G is a "bare" Newton constant, and where the Standard Model matter is coupled not to the "Einstein" (pure spin-2) metric $g_{\mu\nu}$, but to the conformally related ("Jordan-Fierz") metric $\widetilde{g}_{\mu\nu}=\exp(2a(\varphi))g_{\mu\nu}$. The scalar field equation $\Box_g\varphi=-(4\pi G/c^4)\alpha(\varphi)T$ displays $\alpha(\varphi)\equiv\partial a(\varphi)/\partial\varphi$ as the basic (field-dependent) coupling between φ and matter [15]. The one-parameter Jordan-Fierz-Brans-Dicke theory [14] is the special case $a(\varphi)=\alpha_0\varphi$ leading to a field-independent coupling $\alpha(\varphi)=\alpha_0$.

In the weak field, slow motion, limit appropriate to describing gravitational experiments in the solar system, the addition of φ modifies Einstein's predictions only through the appearance of two "post-Einstein" dimensionless parameters: $\bar{\gamma} = -2\alpha_0^2/(1+\alpha_0^2)$ and $\overline{\beta} = +\frac{1}{2}\beta_0\alpha_0^2/(1+\alpha_0^2)^2$, where $\alpha_0 \equiv \alpha(\varphi_0)$, $\beta_0 \equiv \partial\alpha(\varphi_0)/\partial\varphi_0$, φ_0 denoting the vacuum expectation value of φ . These parameters show up also naturally (in the form $\gamma_{PPN} = 1 + \overline{\gamma}$, $\beta_{PPN} = 1 + \overline{\beta}$) in phenomenological discussions of possible deviations from General Relativity [16,9]. The parameter $\overline{\gamma}$ measures the admixture of spin 0 to Einstein's graviton, and contributes an extra term $+ \bar{\gamma}(v_A - v_B)^2/c^2$ in the square brackets of the two-body Lagrangian Eq. (14.12). The parameter $\overline{\beta}$ modifies the three-body interaction Eq. (14.13) by a factor $1 + 2\overline{\beta}$. Moreover, the combination $\eta \equiv 4\overline{\beta} - \overline{\gamma}$ parameterizes the lowest order effect of the self-gravity of orbiting masses by modifying the Newtonian interaction energy terms in Eq. (14.12) into $G_{AB}m_Am_B/r_{AB}$, with a body-dependent gravitational "constant" $G_{AB} = G_N[1 + \eta(E_A^{\sf grav}/m_Ac^2 + E_B^{\sf grav}/m_Bc^2) + O(1/c^4)],$ where $G_N = G \exp[2a(\varphi_0)](1 + \alpha_0^2)$ and where $E_A^{\sf grav}$ denotes the gravitational binding energy of body A.

The best current limits on the post-Einstein parameters $\overline{\gamma}$ and $\overline{\beta}$ are (at the 68% confidence level): (i) $|\overline{\gamma}| < 2 \times 10^{-3}$ [17] deduced from the Viking mission measurement of the gravitational time delay [18] of radar signals passing near the Sun (with similar limits coming from Very Long Baseline Interferometry (VLBI) measurements of the deflection of radio waves by the Sun [19]), and (ii) $4\overline{\beta} - \overline{\gamma} = -0.0007 \pm 0.0010$ [7] from Lunar Laser Ranging measurements of a possible polarization of the Moon toward the Sun [20]. More stringent limits on $\overline{\gamma}$ are obtained in models (e.g., string-inspired ones [21]) where scalar couplings violate the Equivalence Principle.

14.3. Tests of the dynamics of the gravitational field in the radiative and/or strong field regimes

The discovery of pulsars (i.e. rotating neutron stars emitting a beam of radio noise) in gravitationally bound orbits [22,23] has opened up an entirely new testing ground for relativistic gravity, giving us an experimental handle on the regime of radiative and/or strong gravitational fields. In these systems, the finite velocity of propagation of the gravitational interaction between the pulsar and its companion generates damping-like terms at order $(v/c)^5$ in the equations of motion [24]. These damping forces are the local counterparts of the gravitational radiation emitted at infinity by the system ("gravitational radiation reaction"). They cause the binary orbit to shrink and its orbital period Pb to decrease. The remarkable stability of the pulsar clock has allowed Taylor and collaborators to measure the corresponding very small orbital period decay $\dot{P}_b \equiv dP_b/dt \sim (v/c)^5 \sim 10^{-12}$ [23,25], thereby giving us a direct experimental confirmation of the propagation properties of the gravitational field. In addition, the surface gravitational potential of a neutron star $h_{00}(R) \simeq 2Gm/c^2R \simeq 0.4$ being a factor $\sim 10^8$ higher than the surface potential of the Earth, and a mere factor 2.5 below the black hole limit $(h_{00} = 1)$, pulsar data are sensitive probes of the strong-gravitational-field regime.

Binary pulsar timing data record the times of arrival of successive electromagnetic pulses emitted by a pulsar orbiting around the center of mass of a binary system. After correcting for the Earth motion around the Sun and for the dispersion due to propagation in the interstellar plasma, the time of arrival of the Nth pulse t_N can be described by a generic, parameterized "timing formula [26]" whose functional form is common to the whole class of tensor-scalar gravitation theories:

$$t_N - t_0 = F[T_N(\nu_p, \dot{\nu}_p, \ddot{\nu}_p); \{p^K\}; \{p^{PK}\}].$$
 (14.15)

Here, T_N is the pulsar proper time corresponding to the Nth turn given by $N/2\pi = \nu_p T_N + \frac{1}{2}\dot{\nu}_p T_N^2 + \frac{1}{6}\ddot{\nu}_p T_N^3$ (with $\nu_p \equiv 1/P_p$ the spin frequency of the pulsar, etc.), $\{p^K\} = \{P_b, T_0, e, \omega_0, x\}$ is the set of "Keplerian" parameters (notably, orbital period P_b , eccentricity e and projected semi-major axis $x = a \sin i/c$), and $\{p^{PK}\} = \{k, \gamma_{\text{timing}}, \dot{P}_b, r, s, \delta_\theta, \dot{e}, \dot{x}\}$ denotes the set of (separately

measurable) "post-Keplerian" parameters. Most important among these are: the fractional periastron advance per orbit $k \equiv \dot{\omega} P_b/2\pi$, a dimensionful time-dilation parameter $\gamma_{\rm timing}$, the orbital period derivative \dot{P}_b , and the "range" and "shape" parameters of the gravitational time delay caused by the companion, r and s.

Without assuming any specific theory of gravity, one can phenomenologically analyze the data from any binary pulsar by least-squares fitting the observed sequence of pulse arrival times to the timing formula Eq. (14.15). This fit yields the "measured" values of the parameters $\{\nu_p,\dot{\nu}_p,\ddot{\nu}_p\}$, $\{p^K\}$, $\{p^{PK}\}$. Now, each specific relativistic theory of gravity predicts that, for instance, k, γ_{timing} , \dot{P}_b , r and s (to quote parameters that have been successfully measured from some binary pulsar data) are some theory-dependent functions of the Keplerian parameters and of the (unknown) masses m_1 , m_2 of the pulsar and its companion. For instance, in General Relativity, one finds (with $M \equiv m_1 + m_2$, $n \equiv 2\pi/P_b$)

$$\begin{split} k^{\text{GR}}(m_1, m_2) &= 3(1 - e^2)^{-1} (G_N M n/c^3)^{2/3} , \\ \gamma^{\text{GR}}_{\text{timing}}(m_1, m_2) &= e n^{-1} (G_N M n/c^3)^{2/3} m_2 (m_1 + 2m_2)/M^2 , \\ \dot{P}_b^{\text{GR}}(m_1, m_2) &= - (192 \pi/5 c^5) (1 - e^2)^{-7/2} \left(1 + \frac{73}{24} e^2 + \frac{37}{96} e^4\right) \\ &\qquad \times (G_N M n/c^3)^{5/3} m_1 m_2/M^2 , \\ r(m_1, m_2) &= G_N m_2/c^3 , \\ s(m_1, m_2) &= n x (G_N M n/c^3)^{-1/3} M/m_2 . \end{split}$$
(14.16)

In tensor-scalar theories, each of the functions $k^{\text{theory}}(m_1, m_2)$, $\gamma_{\text{timing}}^{\text{theory}}(m_1, m_2)$, $\dot{P}_b^{\text{theory}}(m_1, m_2)$, etc is modified by quasi-static strong field effects (associated with the self-gravities of the pulsar and its companion), while the particular function $\dot{P}_b^{\text{theory}}(m_1, m_2)$ is further modified by radiative effects (associated with the spin 0 propagator) [15,27].

Let us summarize the current experimental situation. In the first discovered binary pulsar PSR1913 + 16 [22,23], it has been possible to measure with accuracy the three post-Keplerian parameters k, $\gamma_{\rm timing}$ and \dot{P}_b . The three equations $k^{\rm measured} = k^{\rm theory}(m_1,m_2)$, $\gamma_{\rm timing}^{\rm measured} = \gamma_{\rm timing}^{\rm theory}(m_1,m_2)$, $\dot{P}_b^{\rm measured} = \dot{P}_b^{\rm theory}(m_1,m_2)$ determine, for each given theory, three curves in the two-dimensional mass plane. This yields one (combined radiative/strong-field) test of the specified theory, according to whether the three curves meet at one point, as they should. After subtracting a small ($\sim 10^{-14}$ level in $\dot{P}_b^{\rm obs} = (-2.422 \pm 0.006) \times 10^{-12}$), but significant, Newtonian perturbing effect caused by the Galaxy [28], one finds that General Relativity passes this $(k - \gamma_{\rm timing} - \dot{P}_b)_{1913+16}$ test with complete success at the 10^{-3} level [23,25]

$$\begin{bmatrix} \dot{P}_b^{\rm obs} - \dot{P}_b^{\rm galactic} \\ \dot{P}_b^{\rm GR}[k^{\rm obs}, \gamma_{\rm timing}^{\rm obs}] \end{bmatrix}_{1913+16} = 1.0032 \pm 0.0023 (\rm obs) \pm 0.0026 (\rm galactic) \\ = 1.0032 \pm 0.0035 \ . \tag{14.17}$$

Here $\dot{P}_b^{\rm GR}[k^{\rm obs},\gamma_{\rm timing}^{\rm obs}]$ is the result of inserting in $\dot{P}_b^{\rm GR}(m_1,m_2)$ the values of the masses predicted by the two equations $k^{\rm obs}=k^{\rm GR}(m_1,m_2)$, $\gamma_{\rm timing}^{\rm obs}=\gamma_{\rm timing}^{\rm GR}(m_1,m_2)$. This experimental evidence for the reality of gravitational radiation damping forces at the 0.3% level is illustrated in Fig. 14.1, which shows actual orbital phase data (after subtraction of a linear drift).

The discovery of the binary pulsar PSR1534 + 12 [29] has allowed one to measure the four post-Keplerian parameters k, γ_{timing} , r and s, and thereby to obtain two (four observables minus two masses) tests of strong field gravity, without mixing of radiative effects [30]. General Relativity passes these tests within the measurement accuracy [30,23]. The most precise of these new, pure, strong-field tests is the one obtained by combining the measurements of k, γ , and s. Using the data reported in [31], one finds agreement at the 1% level:

$$\left[\frac{s^{\text{obs}}}{s^{\text{GR}}[k^{\text{obs}}, \gamma_{\text{timing}}^{\text{obs}}]}\right]_{1534+12} = 1.010 \pm 0.008 \ . \tag{14.18}$$

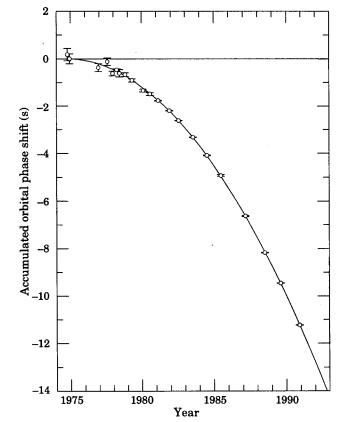


Figure 14.1: Accumulated shift of the times of periastron passage in the PSR 1913+16 system, relative to an assumed orbit with a constant period. The parabolic curve represents the general relativistic prediction, modified by Galactic effects, for orbital period decay from gravitational radiation damping forces. (Figure obtained with permission from Ref. 23.)

Recently, it has been possible to measure the orbital period change of PSR1534 + 12. General Relativity passes the corresponding $(k - \gamma_{\text{timing}} - \dot{P}_b)_{1534+12}$ test with success at the 15% level [32].

Several other binary pulsar systems, of a nonsymmetric type (nearly circular systems made of a neutron star and a white dwarf), can also be used to test relativistic gravity [33,34]. The constraints on tensor-scalar theories provided by three binary-pulsar "experiments" have been analyzed in [27] and shown to exclude a large portion of the parameter space allowed by solar-system tests.

The tests considered above have examined the gravitational interaction on scales between a few centimeters and a few astronomical units. Millimeter scale tests of Newtonian gravity have been reported in Ref. 35. On the other hand, the general relativistic action on light and matter of an external gravitational field on a length scale ~ 100 kpc has been verified to $\sim 30\%$ in some gravitational lensing systems (see, e.g., [36]). Some tests on cosmological scales are also available. In particular, Big Bang Nucleosynthesis (see Section 15 of this Review) has been used to set significant constraints on the variability of the gravitational "constant" [37].

14.4. Conclusions

All present experimental tests are compatible with the predictions of the current "standard" theory of gravitation: Einstein's General Relativity. The universality of the coupling between matter and gravity (Equivalence Principle) has been verified at the 10^{-12} level. Solar system experiments have tested the weak-field predictions of Einstein's theory at the 10^{-3} level. The propagation properties of relativistic gravity, as well as several of its strong-field aspects, have been verified at the 10^{-3} level in binary pulsar experiments. Several important new developments in experimental gravitation are expected in the near future. The approved NASA Gravity Probe B mission

(a space gyroscope experiment; due for launch in 2000) will directly measure the gravitational spin-orbit and spin-spin couplings, thereby measuring the weak-field post-Einstein parameter $\overline{\gamma}$ to the 10^{-5} level (an improvement by two orders of magnitude). The planned NASA-ESA MiniSTEP mission (a satellite test of the Equivalence Principle) should test the universality of acceleration of free fall down to the 10^{-18} level (an improvement by six orders of magnitude). Finally, the various kilometer-size laser interferometers under construction (notably LIGO in the USA and VIRGO in Europe) should, soon after 2000, directly detect gravitational waves arriving on Earth. As the sources of these waves are expected to be extremely relativistic objects with strong internal gravitational fields (e.g., coalescing binary neutron stars, or neutron stars plunging into large black holes), their detection will allow one to experimentally probe gravity in highly dynamical circumstances.

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15. BIG-BANG COSMOLOGY

Revised April 1998 by K.A. Olive (University of Minnesota).

At early times, and today on a sufficiently large scale, our Universe is very nearly homogeneous and isotropic. The most general space-time metric for a homogeneous, isotropic space is the Friedmann-Robertson-Walker metric (with c=1) [1,2,3]:

$$ds^{2} = dt^{2} - R^{2}(t) \left[\frac{dr^{2}}{1 - \kappa r^{2}} + r^{2} (d\theta^{2} + \sin^{2}\theta \, d\phi^{2}) \right] . \tag{15.1}$$

R(t) is a scale factor for distances in comoving coordinates. With appropriate rescaling of the corrdinates, κ can be chosen to be +1, -1, or 0, corresponding to closed, open, or spatially flat geometries. Einstein's equations lead to the Friedmann equation

$$H^2 \equiv \left(\frac{\dot{R}}{R}\right)^2 = \frac{8\pi G_N \rho}{3} - \frac{\kappa}{R^2} + \frac{\Lambda}{3} ,$$
 (15.2)

as well as to

$$\frac{\ddot{R}}{R} = \frac{\Lambda}{3} - \frac{4\pi G_N}{3} \ (\rho + 3p) \ , \tag{15.3}$$

where H(t) is the Hubble parameter, ρ is the total mass-energy density, p is the isotropic pressure, and Λ is the cosmological constant. (For limits on Λ , see the Table of Astrophysical Constants; we will assume here $\Lambda=0$.) The Friedmann equation serves to define the density parameter Ω_0 (subscript 0 indicates present-day values):

$$\kappa/R_0^2 = H_0^2(\Omega_0 - 1)$$
, $\Omega_0 = \rho_0/\rho_c$; (15.4)

and the critical density is defined as

$$\rho_{\rm c} \equiv \frac{3H^2}{8\pi G_N} = 1.88 \times 10^{-29} \, h^2 \, {\rm g \, cm}^{-3} \, , \tag{15.5}$$

with

$$H_0 = 100 h_0 \text{ km s}^{-1} \text{ Mpc}^{-1} = h_0/(9.78 \text{ Gyr})$$
. (15.6)

Observational bounds give $0.4 < h_0 < 1$. The three curvature signatures $\kappa = +1, -1$, and 0 correspond to $\Omega_0 > 1$, < 1, and = 1. Knowledge of Ω_0 is even poorer than that of h_0 . Luminous matter (stars and associated material) contribute $\Omega_{lum} \leq 0.01$. There is no lack of evidence for copious amounts of dark matter: rotation curves of spiral galaxies, virial estimates of cluster masses, gravitational lensing by clusters and individual galaxies, and so on. The minimum amount of dark matter required to explain the flat rotation curves of spiral galaxies only amounts to $\Omega_0 \sim 0.1$, while estimates for Ω_0 based upon cluster virial masses suggests $\Omega_0\,\sim\,0.2-0.4.$ The highest estimates for the mass density come from studies of the peculiar motions of galaxies (including our own); estimates for Ω_0 obtained by relating peculiar velocity measurements to the distribution galaxies within a few hundred Mpc approach unity. A conservative range for the mass density is: $0.1 \le \Omega_0 \le 2$. The excess of Ω_0 over Ω_{lum} leads to the inference that most of the matter in the Universe is nonluminous dark matter.

In an expanding universe, the wavelength of light emitted from a distant source is shifted towards the red. The redshift z is defined such that 1+z is the ratio of the detected wavelength (λ) to emitted (laboratory) wavelength (λ_e) of some electromagnetic spectral feature. It follows from the metric given in Eq. (15.1) that

$$1 + z = \lambda/\lambda_{\rm e} = R_0/R_{\rm e} \tag{15.7}$$

where $R_{\rm e}$ is the value of the scale factor at the time the light was emitted. For light emitted in the not too distant past, one can expand $R_{\rm e}$ and write $R_{\rm e} \simeq R_0 + (t_{\rm e} - t_0) \dot{R}_0$. For small (compared to H_0^{-1}) $\Delta t = (t_{\rm e} - t_0)$, Eq. (15.7) takes the form of Hubble's law

$$z \approx \Delta t \frac{\dot{R}_0}{R_0} \approx \ell H_0 , \qquad (15.8)$$

where ℓ is the distance to the source.

Energy conservation implies that

$$\dot{\rho} = -3(\dot{R}/R)(\rho + p) ,$$
 (15.9)

so that for a matter-dominated (p=0) universe $\rho \propto R^{-3}$, while for a radiation-dominated $(p=\rho/3)$ universe $\rho \propto R^{-4}$. Thus the less singular curvature term κ/R^2 in the Friedmann equation can be neglected at early times when R is small. If the Universe expands adiabatically, the entropy per comoving volume $(\equiv R^3 s)$ is constant, where the entropy density is $s=(\rho+p)/T$ and T is temperature. The energy density of radiation can be expressed (with $\hbar=c=1$) as

$$\rho_{\tau} = \frac{\pi^2}{30} N(T)(kT)^4 , \qquad (15.10)$$

where N(T) counts the effectively massless degrees of freedom of bosons and fermions:

$$N(T) = \sum_{R} g_{B} + \frac{7}{8} \sum_{F} g_{F} . \qquad (15.11)$$

For example, for $m_{\mu} > kT > m_e$, $N(T) = g_{\gamma} + 7/8 (g_e + 3g_{\nu}) = 2 + 7/8 [4 + 3(2)] = 43/4$. For $m_{\pi} > kT > m_{\mu}$, N(T) = 57/4. At temperatures less than about 1 MeV, neutrinos have decoupled from the thermal background, i.e., the weak interaction rates are no longer fast enough compared with the expansion rate to keep neutrinos in equilibrium with the remaining thermal bath consisting of γ, e^{\pm} . Furthermore, at temperatures $kT < m_e$, by entropy conservation, the ratio of the neutrino temperature to the photon temperature is given by $(T_{\nu}/T_{\gamma})^3 = g_{\gamma}/(g_{\gamma} + \frac{7}{8}g_e) = 4/11$.

In the early Universe when $\rho \approx \rho_r$, then $\dot{R} \propto 1/R$, so that $R \propto t^{1/2}$ and $Ht \to 1/2$ as $t \to 0$. The time-temperature relationship at very early times can then be found from the above equations:

$$t = \frac{2.42}{\sqrt{N(T)}} \left(\frac{1 \text{ MeV}}{kT}\right)^2 \text{ sec} .$$
 (15.12)

At later times, since the energy density in radiation falls off as R^{-4} and the energy density in non-relativistic matter falls off as R^{-3} , the Universe eventually became matter dominated. The epoch of matter-radiation density equality is determined by equating the matter density at $t_{\rm eq}$, $\rho_m = \Omega_0 \rho_c (R_0/R_{\rm eq})^3$ to the radiation density, $\rho_r = (\pi^2/30)[2 + (21/4)(4/11)^{4/3}](kT_0)^4(R_0/R_{\rm eq})^4$ where T_0 is the present temperature of the microwave background (see below). Solving for $(R_0/R_{\rm eq}) = 1 + z_{\rm eq}$ gives

$$\begin{split} z_{\rm eq} + 1 &= \Omega_0 h_0^2 / 4.2 \times 10^{-5} = 2.4 \times 10^4 \, \Omega_0 h_0^2 \; ; \\ kT_{\rm eq} &= 5.6 \, \Omega_0 h_0^2 \, {\rm eV} \; ; \\ t_{\rm eq} &\approx 0.39 (\Omega_0 H_0^2)^{-1/2} (1 + z_{\rm eq})^{-3/2} \\ &= 3.2 \times 10^{10} (\Omega_0 h_0^2)^{-2} \, {\rm sec} \; . \end{split} \tag{15.13}$$

Prior to this epoch the density was dominated by radiation (relativistic particles; see Eq. (15.10)), and at later epochs matter density dominated. Atoms formed at $z\approx 1300$, and by $z_{\rm dec}\approx 1100$ the free electron density was low enough that space became essentially transparent to photons and matter and radiation were decoupled. These are the photons observed in the microwave background today.

The age of the Universe today, t_0 , is related to both the Hubble parameter and the value of Ω_0 (still assuming that $\Lambda=0$). In the Standard Model, $t_0\gg t_{\rm eq}$ and we can write

$$t_0 = H_0^{-1} \int_0^1 \left(1 - \Omega_0 + \Omega_0 x^{-1} \right)^{-1/2} dx . \tag{15.14}$$

Constraints on t_0 yield constraints on the combination $\Omega_0 h_0^2$. For example, $t_0 \geq 13 \times 10^9$ yr implies that $\Omega_0 h_0^2 \leq 0.25$ for $h_0 \geq 0.5$, or $\Omega_0 h_0^2 \leq 0.45$ for $h_0 \geq 0.4$, while $t_0 \geq 10 \times 10^9$ yr implies that $\Omega_0 h_0^2 \leq 0.8$ for $h_0 \geq 0.5$, or $\Omega_0 h_0^2 \leq 1.1$ for $h_0 \geq 0.4$.

The present temperature of the microwave background is $T_0=2.728\pm0.002$ K as measured by COBE [4], and the number density of photons $n_{\gamma}=(2\zeta(3)/\pi^2)(kT_0)^3\approx412$ cm⁻³. The energy density in photons (for which $g_{\gamma}=2$) is $\rho_{\gamma}=(\pi^2/15)(kT_0)^4$. At the present epoch, $\rho_{\gamma}=4.66\times10^{-34}$ g cm⁻³ = 0.262 eV cm⁻³. For nonrelativistic matter (such as baryons) today, the energy density is $\rho_B=m_Bn_B$ with $n_B\propto R^{-3}$, so that for most of the history of the Universe n_B/s is constant. Today, the entropy density is related to the photon density by $s=(4/3)(\pi^2/30)[2+(21/4)(4/11)](kT_0)^3=7.0\,n_{\gamma}$. Big Bang nucleosynthesis calculations limit $\eta=n_B/n_{\gamma}$ to $2.8\times10^{-10}\leq\eta\leq4.0\times10^{-10}$. The parameter η is also related to the portion of Ω in baryons

$$\Omega_B = 3.67 \times 10^7 \eta \ h_0^{-2} \ (T_0/2.728 \ \text{K})^3 \ ,$$
 (15.15)

so that 0.010 < $\Omega_B \ h_0^2 <$ 0.015, and hence the Universe cannot be closed by baryons.

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16. BIG-BANG NUCLEOSYNTHESIS

Revised July 1997 by K.A. Olive (Univ. of Minnesota) and D.N. Schramm (deceased).

Among the successes of the standard big-bang model is the agreement between the predictions of big-bang nucleosynthesis (BBN) for the abundances of the light elements, D, $^3{\rm He},\,^4{\rm He},\,$ and $^7{\rm Li},\,$ and the primordial abundances inferred from observational data (see [1–3] for a more complete discussion). These abundances span some nine orders of magnitude: $^4{\rm He}$ has an abundance by number relative to hydrogen of about 0.08 (accounting for about 25% of the baryonic mass), while $^7{\rm Li},\,$ the least abundant of the elements with a big-bang origin, has a abundance by number relative to hydrogen of about $\sim 10^{-10}$.

16.1. Big-bang nucleosynthesis theory

The BBN theory matches the observationally determined abundances with a single well-defined parameter, the baryon-to-photon ratio, η . All the light-element abundances can be explained with η in the range $(1.5-6.3)\times 10^{-10}$, or $\eta_{10}\equiv \eta\times 10^{10}=1.5-6.3$. Equivalently, this range can be expressed as the allowed range for the baryon mass density, $\rho_B=1.0-4.3\times 10^{-31}$ g cm⁻³, and can be converted to the fraction, Ω , of the critical density, ρ_c .

The synthesis of the light elements was affected by conditions in the early Universe at temperatures $T\lesssim 1$ MeV, corresponding to an age as early as 1 s. At somewhat higher temperatures, weak-interaction rates were in equilibrium, thus fixing the ratio of the neutron and proton number densities. At $T\gg 1$ MeV, $n/p\approx 1$, since the ratio was given approximately by the Saha relation, $n/p\approx e^{-Q/T}$, where Q is the neutron-proton mass difference. As the temperature fell, the Universe approached the point ("freeze-out") where the weak-interaction rates were no longer fast enough to maintain equilibrium. The final abundance of ⁴He is very sensitive to the n/p ratio at freeze-out.

The nucleosynthesis chain begins with the formation of deuterium in the process $pn \to D\gamma$. However, photo-dissociation by the high number density of photons $(n_\gamma/n_B=\eta^{-1}\sim 10^{10})$ delays production of deuterium (and other complex nuclei) well past the point where T reaches the binding energy of deuterium, $E_B=2.2$ MeV. (The average photon energy in a blackbody is $\overline{E}_\gamma\approx 2.7$ T.) When the quantity $\eta^{-1}\exp(-E_B/T)$ reaches about 1 (at $T\approx 0.1$ MeV), the photo-dissociation rate finally falls below the nuclear production rate.

The 25% fraction of mass in ⁴He due to BBN is easily estimated by counting the number of neutrons present when nucleosynthesis begins. When the weak-interaction rates freeze-out at about $T \approx 0.8$ MeV, the n-to-p ratio is about 1/6. When free-neutron decays prior to deuterium formation are taken into account, the ratio drops to $n/p \lesssim 1/7$. Then simple counting yields a primordial ⁴He mass fraction

$$Y_p = \frac{2(n/p)}{1 + n/p} \lesssim 0.25 . {(16.1)}$$

In the Standard Model, the ⁴He mass fraction depends primarily on the baryon-to-photon ratio η , as it is this quantity that determines when nucleosynthesis via deuterium production may begin. But because the n/p ratio depends only weakly on η , the ⁴He mass fraction is relatively flat as a function of η . The effect of the uncertainty in the neutron half-life, $\tau_n=887\pm2$ s, is now small. Lesser amounts of the other light elements are produced: D and ³He at the level of a few times 10^{-5} by number relative to H, and ⁷Li/H at the level of about 10^{-10} , when η is in the range $1-10\times10^{-10}$.

When we go beyond the Standard Model, the ⁴He abundance is very sensitive to changes in the expansion rate, which can be related to the effective number of neutrino flavors. This will be discussed below.

The calculated abundances of the light elements are shown in Fig. 16.1 as a function of η_{10} . The curves for the ⁴He mass fraction, Y_p , bracket the range based on the uncertainty of the neutron mean-life, $\tau_n = 887 \pm 2$ s. The spread in the ⁷Li curves is due to the 1σ uncertainties in nuclear cross sections leading to ⁷Li and ⁷Be which subsequently decays to ⁷Li [4–6]. The uncertainties in the D and ³He

predictions are small and have been neglected here. The boxes show the observed abundances with their range of uncertainty, discussed below. Since the observational boxes line up on top of each other, there is an overall agreement between theory and observations for η_{10} in the range 1.5–6.3.

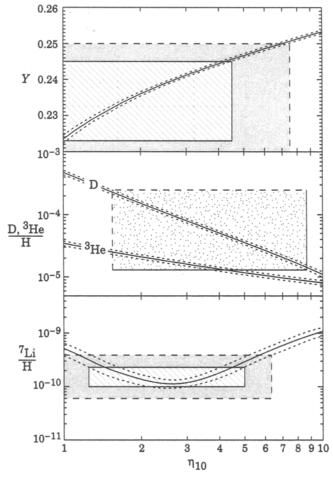


Figure 16.1: The abundances of D, ³He, ⁴He and ⁷Li as predicted by the standard model of big-bang nucleosynthesis. Also shown by a series of boxes is the comparison between these predictions and the observational determination of the light element abundances. See text for details.

16.2. Observations

Because stars produce helium as well as heavier elements, one must search for primordial helium in regions where stellar processing has been minimal, *i.e.*, in regions where abundances of elements such as carbon, nitrogen and oxygen are very low. There are extensive compilations of observed abundances of ⁴He, N, and O in many different extra-galactic regions of ionized H [7-9]. Extrapolating the ⁴He abundances from the data leads to a observational estimate for Y_p of [10-12]

$$Y_p = 0.234 \pm 0.002 \pm 0.005$$
. (16.2)

(Here and elsewhere, the first error is the statistical standard deviation, and the second systematic.) The large box in Fig. 16.1 bracketing the 4 He curves covers the range 0.223 to 0.245, where the half height is given as twice the errors when added in quadrature. There has been some debate on the size of systematic errors [4] and the dashed box is obtained using a larger error, allowing Y_p to take a maximal value of 0.250.

Observations for deuterium and ³He abundances currently present certain difficulties. All deuterium is primordial [13], but some of the primordial deuterium has been destroyed. Thus, as can be seen in the figure, the present deuterium abundance gives us an absolute upper limit to η . However, to get more information requires either an understanding of galactic chemical evolution of deuterium or a direct measurement of primordial deuterium. Even more problematical is ${}^3\text{He}$: Not only is primordial ${}^3\text{He}$ destroyed in stars but it is very likely that at least some low-mass stars are net producers of ${}^3\text{He}$. Neither the galactic chemical evolution of ${}^3\text{He}$ nor the production of ${}^3\text{He}$ in stars is well understood with standard models and observations presenting an inconsistent picture.

It appears that D/H has decreased over the age of the galaxy. Samples obtained deep inside meteorites provide measurements of the true (pre)-solar system abundance of ³He, while measurements on meteoritic near-surface samples, the solar wind, and lunar soil samples also contain ³He converted from deuterium in the early pre-main-sequence stage of the sun. The best current values are [14]

$$\left(\frac{D + {}^{3}\text{He}}{H}\right)_{\odot} = (4.1 \pm 1.0) \times 10^{-5} ,$$

$$\left(\frac{{}^{3}\text{He}}{H}\right)_{\odot} = (1.5 \pm 0.3) \times 10^{-5} . \tag{16.3}$$

The difference between these is the pre-solar D abundance. There has also been a recent measurement of HD in the atmosphere of Jupiter [15] yielding a value D/H = $(5 \pm 2) \times 10^{-5}$. This would be an important measurement if it can be acertained that isotopic fractionation of deuterium did not occur, however, this point is debatable at the present time.

The present interstellar-medium abundance of D/H is [16]

$$D/H = 1.60 \pm 0.09^{+0.05}_{-0.10} \times 10^{-5}$$
. (16.4)

It is this lowest value of D/H that provides the most robust upper bound on η , since D is only destroyed. It is shown (decreased by twice the errors added in quadrature) as the lower right corner of the D and ³He box in Fig. 16.1. Thus, with confidence we can be sure that $\eta_{10} < 9$ And correspondingly $\Omega_B h^2 < 0.033$

Deuterium has also been detected in high-redshift, low-metallicity quasar absorption systems [17-19]. These measured abundances should represent the primordial value, but they are at present not consistent: Two [17,18] give a relatively high value for D/H $\approx 2 \times 10^{-4}$ while the other [19] gives D/H $\approx 2.3 \pm 0.3 \times 10^{-5}$. Although it appears that the quality of the low D/H data is better than those showing high D/H, the latter can be used at the very least as an upper limit to primordial D/H and this is shown by the dashed box in Fig. 16.1. As one can see, the corresponding value of Y_p (at the same value of η as inferred by the observation of a high D/H) is in excellent agreement with the data. 7Li is also acceptable at this value as well. However, due to the still somewhat preliminary status of this observation, it is premature to use it to fix the primordial abundance. A high value for the D abundance would require an even greater degree of D destruction over the age of the galaxy. The lower measurement for D/H requires that systematics work coherently for both ⁴He and ⁷Li to give an overlap with this data. Eventually, the primordial D/H issue will hopefully be resolved and give a correspondingly narrow allowed range in η and perhaps change the nature of the ³He and ⁷Li (see below) arguments which are currently dominated by galactic and/or stellar evolution issuses.

Finally, we turn to ^7Li . In old, hot, population-II stars, ^7Li is found to have a very nearly uniform abundance. For stars with a surface temperature T > 5500 K and a metallicity less than about 1/20th solar (so that effects such as stellar convection may not be important), the abundances show little or no dispersion beyond that consistent with the errors of individual measurements. Much data has been obtained recently from a variety of sources, and the best estimate for the mean ^7Li abundance and its statistical uncertainty in halo stars is [20](the estimate of the systematic uncertainty discussed below is our own)

$$\text{Li/H} = (1.6 \pm 0.1^{+0.4}_{-0.3}^{+1.6}_{-0.5}) \times 10^{-10}$$
. (16.5)

The first error is statistical, and the second is a systematic uncertainty that covers the range of abundances derived by various methods. The

box in Fig. 16.1 corresponds to these errors (as before, with a half height of $2\sigma_{\rm stat} + \sigma_{\rm syst}$). The third set of errors in Eq. (16.5) accounts for the possibility that as much as half of the primordial ⁷Li has been destroyed in stars, and that as much as 30% of the observed ⁷Li was produced in cosmic ray collisions rather than in the Big Bang. These uncertainties are shown by the dashed box in Fig. 16.1. Observations of ⁶Li, Be, and B help constrain the degree to which these effects play a role [21–23].

16.3. A consistent value for η

For the Standard Model of BBN to be deemed successful, theory and observation of the light element abundances must agree using a single value of η . We summarize the constraints on η from each of the light elements. From the ⁴He mass fraction, $Y_p < (0.245-0.250)$, we have $\eta_{10} < (4.5-7.6)$ as a 2σ upper limit (the highest values use possible systematic errors up to their extreme range). Because of the sensitivity to the assumed upper limit on Y_p and Li/H, the upper limit on η from D/H, is still of value. From D/H $> 1.3 \times 10^{-5}$, we have $\eta_{10} \lesssim 9$.

The lower limit on η_{10} can be obtained from either D/H or ⁷Li. From the high D/H measurement in quasar absorption systems, we obtain $\eta_{10} > 1.5$. ⁷Li allows a broad range for η_{10} consistent with the other elements. When uncertainties in the reaction rates and systematic uncertainties in the observed abundances are both taken into account, ⁷Li allows values of η_{10} between (1.0-6.3).

The determination of η depends on our certainty that the observations of the light elements abundances can be translated into primordial abundances. This is perhaps more straightforward for ⁴He and ⁷Li, where the element abundances are determined in primitive low metallicity environments. If it turns out that a consistent value for D/H can be obtained from quasar absorption systems, then because of the slope of D/H with respect to η , D/H will be the best isotopic ratio for the determination of η . Until then, the use of the D and ³He abundance determinations is necessarily complicated by the evolution of the abundances of these elements over the star forming history of the galaxy. Uncertainties in the ³He evolution are compounded by uncertainties of stellar production/destruction mechanisms. The resulting overall consistent range for η_{10} is extended to (1.5-6.3) when systematic errors are pushed to their limits. These bounds on η_{10} constrain the fraction of critical density in baryons, Ω_B , to be

$$0.005 < \Omega_B h_0^2 < 0.024 \tag{16.6}$$

for a Hubble parameter, h_0 , between 0.4 and 1.0. The corresponding range for Ω_B is 0.005–0.15.

Perhaps the best test of BBN will come when anisotropies in the microwave background check the determination of Ω_B . At present, other measurements (such as of hot x-ray gas in clusters of galaxies, Lyman- α clouds, or microwave anisotropies) of Ω_B give considerably larger uncertainties than those from BBN, but they are consistent with the BBN range.

16.4. Beyond the Standard Model

Limits on particle physics beyond the Standard Model come mainly from the observational bounds on the ⁴He abundance. As discussed earlier, the neutron-to-proton ratio is fixed by its equilibrium value at the freeze-out of the weak-interaction rates at a temperature $T_f \sim 1$ MeV, with corrections for free neutron decay. Furthermore, freeze-out is determined by the competition between the weak-interaction rates and the expansion rate of the Universe,

$$G_F^2 T_f^5 \sim \Gamma_{wk}(T_f) = H(T_f) \sim \sqrt{G_N N} T_f^2$$
, (16.7)

where N counts the total (equivalent) number of relativistic particle species. The presence of additional neutrino flavors (or of any other relativistic species) at the time of nucleosynthesis increases the energy density of the Universe and hence the expansion rate, leading to a larger value of T_f , n/p, and ultimately Y_p . It is clear that just as one can place limits [25] on N, any changes in the weak or gravitational coupling constants can be similarly constrained.

In the Standard Model, the number of particle species can be written as $N=5.5+\frac{7}{4}N_{\nu}$; 5.5 accounts for photons and e^{\pm} , and N_{ν} is the number of (massless) neutrino flavors. The helium curves in Fig. 16.1 were computed assuming $N_{\nu}=3$, and the computed ⁴He abundance scales roughly as $\Delta Y_{\rm BBN}\approx 0.012-0.014$ ΔN_{ν} . Clearly the central value for N_{ν} from BBN will depend on η . If the best value for the observed primordial ⁴He abundance is 0.234, then, for $\eta_{10}\sim 1.8$, the central value for N_{ν} is 3. By means of a likelihood analysis on η and N_{ν} based on ⁴He and ⁷Li [24,26], (see also [27]), it was found that the 95% CL ranges are $1.6 \leq N_{\nu} \leq 4.0$, and $1.3 \leq \eta_{10} \leq 5.0$.

The limits on N_{ν} can be translated into limits on other types of particles or particle masses that would affect the expansion rate of the Universe just prior to nucleosynthesis. In some cases, it is the interaction strengths of new particles which are constrained. Particles with less than full weak strength interactions contribute less to the energy density than particles that remain in equilibrium up to the time of nucleosynthesis [28].

We close with a simple example. Suppose there exist three righthanded neutrinos with only right-handed interactions of strength $G_R < G_F$. The standard left-handed neutrinos are no longer in equilibrium at temperatures below ~ 1 MeV. Particles with weaker interactions decouple at higher temperatures, and their number density $(\propto T^3)$ relative to neutrinos is reduced by the annihilations of particles more massive than 1 MeV. If we use the upper bound N_{ν} < 4.0, then the three right-handed neutrinos must have a temperature $3(T_{\nu_R}/T_{\nu_L})^4 < 1$. Since the temperature of the decoupled ν_R 's is determined by entropy conservation, $T_{\nu_R}/T_{\nu_L} = [(43/4)/N(T_f)]^{1/3} < 0.76$, where T_f is the freeze-out temperature of the ν_R 's. Thus $N(T_f) > 24$ and decoupling must have occurred at $T_f > 140$ MeV. Finally, the decoupling temperature is related to G_R by $(G_R/G_F)^2 \sim (T_f/3 \text{ MeV})^{-3}$, where 3 MeV corresponds to the decoupling temperature for ν_L . This yields a limit $G_R \lesssim 10^{-2} G_F$. These limits are strongly dependent on the assumed upper limit to N_{ν} ; for N_{ν} < 3.5, the limit on G_R strengthened to G_R < 0.002 G_F , since T_f is constrained to be larger than the temperature corresponding to the QCD transition in the early Universe.

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17. THE HUBBLE CONSTANT

Revised August 1997 by C.J. Hogan (University of Washington).

In a uniform expanding universe, the position r and velocity v of any particle relative to another obey Hubble's relation $v = H_0 r$, where H_0 is Hubble's constant.* As cosmological distances are measured in Mpc, the natural unit for H_0 is km s⁻¹ Mpc⁻¹, which has the dimensions of inverse time: $[100 \text{ km s}^{-1} \text{ Mpc}^{-1}]^{-1} = 9.78 \times 10^9 \text{ yr.}$

The real universe is nonuniform on small scales, and its motion obeys the Hubble relation only as a large scale average. As typical non-Hubble motions ("peculiar velocities") are less than about 500 km s⁻¹, on scales more than about 5,000 km s⁻¹ the deviations from Hubble flow are less than about 10%, so the notion of a global Hubble constant is well defined. The value of H_0 averaged over the local 15,000 km s⁻¹ volume is known to lie within 10% of its global value even if H_0 itself is not known this precisely [1-3].

Measurement of H_0 thus entails measuring large absolute distances. Traditionally, certain astronomical systems ("Standard Candles") are used to measure relative distance, and are tied to an absolute trigonometric parallax scale by a series of distance ratios (or "distance ladder") [4–9]. Several relatively new techniques now allow direct absolute calibration using physical models.

Table 17.1 lists several candles and calibrators with a typical range of distance accessible to each. The ranges are not precisely defined; the near end suffers from small numbers of accessible objects and the far end from faint signal. The precision quoted is in units of astronomical "distance modulus," given by $\mu=5\log_{10}(distance\ in\ parsecs)-5.0$; a ±0.1 magnitude error in magnitude or distance modulus corresponds to a 5% error in distance. In the case of distance ratios the precision is estimated by cross-checking indicators on a galaxy-by-galaxy basis. Some options often used for verification and absolute calibration are listed. The Hubble relation itself is included, as it is the most precise indication of relative distance for large distances, and is used to verify the standardization of several candles.

Table 17.1: Selected extragalactic distance indicators.

Technique	Range of distance	Accuracy (1σ)	Verification/calibration
Cepheids	<lmc 25="" mpc<="" td="" to=""><td>0.15 mag</td><td>LMC/parallax</td></lmc>	0.15 mag	LMC/parallax
SNIa	4 Mpc to > 2 Gpc	0.2 mag	Hubble/Cepheid
EPM/SNII	LMC to 200 Mpc	0.4 mag	Hubble/Cepheid
PNLF	LMC to 20 Mpc	0.1 mag	SBF/Cepheid
SBF	1 Mpc to 100 Mpc	0.1 mag	PNLF/Cepheid
TF	1 Mpc to 100 Mpc	0.3 mag	Hubble/Cepheid
BCG	50 Mpc to 1 Gpc	0.3 mag	Hubble/SBF
GCLF	1 Mpc to 100 Mpc	0.4 mag	SBF/MWG
SZ	100 Mpc to > 1 Gpc	0.4 mag	Hubble/Model
$_{ m GL}$	∼5 Gpc	0.4 mag	Model
Hubble	20 Mpc to ≳1Gpc	500 km s ⁻¹ ÷ H_0D	BCG, SNeIa/ H_0

MWG = Milky Way Galaxy †Extracted from [4-9].

17.1. Calibration of Cepheid variables

Using stars as standard candles and the Earth's orbit as a baseline, distances in the nearby Galaxy are tied directly to trigonometric parallax measurements. With the release in 1997 of the first results of the Hipparcos satellite, the range, precision, and size of calibrating samples have greatly improved. The early recalibrations of the absolute scale of the Galaxy indicate an increase in the distance scale for Cepheid variables which propagates to all larger scale measurements, reducing previous measurements of H_0 by 0.1 to 0.2 mag [10,11]. (Note that the RRLyrae distance scale, used to calibrate the distances to old globular clusters within the Galaxy, has also increased [12], which increases the stellar brightness and decreases

their estimated age, possibly reconciling the cosmic age and Hubble parameter for a wider range of cosmological models [11,13].) The revised distance scale however would also increase the distance to the Large Magellanic Cloud (LMC) which is constrained by geometrical arguments from SN 1987A [14]. Another promising method is based on detailed knowledge of orbits of gas in N4258 precisely constrained by observations of maser gas emission. This has the potential to calibrate the Cepheid scale independently [23].

The best studied and most trusted of the absolute calibrators, Cepheids are bright stars undergoing overstable oscillations driven by the variation of helium opacity with temperature. The period of oscillation is tightly correlated with the absolute brightness of the star, though this "period-luminosity relation" [15] may vary with metallicity [16,17]. With Hubble Space Telescope (HST), Cepheids are now measured in over a dozen galaxies out to 25 Mpc ($\mu=32$) allowing direct absolute calibration of many other indicators to better than 10% accuracy [18–22].

17.2. Type Ia supernovae (SNIa)

A SNIa occurs when a degenerate dwarf, of the order of a solar mass and of CNO composition, undergoes explosive detonation or deflagration by nuclear burning to iron-group elements (Ni, Co, Fe). Their uniformity arises because the degenerate material only becomes unstable when it is gravitationally compressed to where the electrons become close to relativistic, which requires approximately a Chandrasekhar mass (1.4 solar masses). Theoretical models of the explosion predict approximately the right peak brightness, but cannot give a precise calibration. SNIa are very bright, so their brightness distribution can be studied using the distant Hubble flow as a reference. Indeed, the Hubble diagram of distant SNIa shows that they can yield remarkably precise relative distances; even though they display large variations in brightness, with detailed knowledge of the shape of the light curve and colors, the relative intrinsic brightness of a single SNIa can be predicted to $\Delta m \simeq 0.2$ mag and its distance estimated to $\simeq 10\%$ accuracy [24-26]. Distant SNIa constrain the global deviations from a linear Hubble law including those from cosmic deceleration [27-28].

17.3. Type II supernovae (SNII)

A SNII occurs when a massive star has accumulated 1.4 solar masses of iron group elements in its core; there is then no source of nuclear energy and the core collapses by the Chandrasekhar instability. The collapse to a neutron star releases a large gravitational binding energy, some of which powers an explosion. The large variety of envelopes around collapsing cores means that SNII are not at all uniform in their properties. However, their distances can be calibrated absolutely by the fairly reliable "expanding photosphere method" (EPM). In principle the spectral temperature and absolute flux yield the source angular size; spectral lines yield the expansion velocity, which combined with elapsed time gives a physical size; and the two sizes yield a distance. Models of real photospheres are not so simple but yield individual distances accurate to about 20% [29]. This is in principle an independent absolute distance, but is verified by comparison with Cepheids in several cases, the distant Hubble diagram and Tully-Fisher distance ratios in several others, and by multiple-epoch fits of the same object.

17.4. Planetary nebula luminosity function (PNLF)

A planetary nebula (PN) forms when the gaseous envelope is ejected from a low-mass star as its core collapses to a white dwarf. We see bright fluorescent radiation from the ejected gas shell, excited by UV light from the hot proto-white dwarf. The line radiation makes PN's easy to find and measure even in far-away galaxies; a bright galaxy can have tens of thousands, of which hundreds are bright enough to use to construct a PNLF. It is found empirically that the range of PN brightnesses has a sharp upper cutoff possibly as a consequence of the very narrow range in core masses that result from normal stellar evolution. The cutoff appears to provide a good empirical standard candle [30], verified by comparison with SBF distance ratios.

17.5. Surface brightness fluctuations (SBF)

In images of galaxies, individual stars are generally too crowded to resolve. However, with modern linear detectors, it is still possible to measure the moments of the distribution of stellar brightness in a population (in particular, the brightness-weighted average stellar brightness) from surface brightness fluctuations. Stellar populations in elliptical galaxies appear to be universal enough for this to be one of the most precise standard candles, as verified by comparison with PNLF and Cepheids, although absolute calibration must be done on the bulge components of spiral galaxies. With HST data it can now be applied into the far Hubble flow [31–32].

17.6. Tully-Fisher (TF) and diameter-dispersion $(D_n-\sigma)$

The TF relation refers to a correlation of the properties of whole spiral galaxies, between rotational velocity and total luminosity. In rough terms, the relation can be understood as a relation between mass and luminosity, but given the variation in structural properties and stellar populations the narrow relation is a surprisingly good relative distance indicator. The TF distance ratios and precision have been verified by cross-checking against all of the above methods, and against the Hubble flow, particularly galaxy cluster averages, which permit greater precision. HST has permitted absolute calibration of TF in a larger, more representative, and more distant sample, including galaxies in the Virgo and Fornax clusters [33]. For elliptical galaxies, a similar relation (" D_n - σ ") is particularly useful for verifying distance ratios of galaxy clusters, whose cores contain almost no spirals.

17.7. Brightest cluster galaxies (BCG)

As a result of agglomeration, rich clusters of galaxies have accumulated the largest and brightest galaxies in the universe in their centers, which are remarkably homogenous. They provide a check on the approach to uniform Hubble flow on large scales [2-3] and are now tied to an absolute scale via SBF [34].

17.8. Globular cluster luminosity function (GCLF)

Many galaxies have systems of globular clusters orbiting them, each of which contain hundreds of thousands of stars and hence is visible at large distances. Empirically it appears that similar galaxies have similar distributions of globular cluster luminosity [35]

17.9. Sunyaev-Zeldovich effect (SZ)

The electron density and temperature of the hot plasma in a cluster of galaxies can be measured in two ways which depend differently on distance: the thermal x-ray emission, which is mostly bremsstrahlung by hot electrons, and the Sunyaev-Zeldovich effect on the microwave background, caused by Compton scattering off the same electrons. This provides in principle an absolute calibration. Although the model has other unconstrained parameters, such as the gas geometry, which limit the precision and reliability of distances, in the handful of cases which have been studied most recently the distances are broadly in accord with those obtained by the other techniques. [36–38]

17.10. Gravitational lenses (GL)

The time delay δt between different images of a high redshift gravitationally lensed quasar is $\delta t = C\delta\theta^2/H_0\approx 1$ yr for image separations $\delta\theta$ of the order of arcseconds, with a numerical factor C typically of order unity determined by the specific lens geometry (the angular distribution of the lensing matter) and background cosmology. Variability of the double quasar 0957+561 has permitted measurements of δt from time series correlation, 417 ± 3 days [39-40], with well controlled theoretical errors in deriving constraints on H_0 [41]; measurements of other lens systems are also improving [42]. It is an amazing sanity check that this technique, which relies on no other intermediate steps for its calibration, gives estimates on the scale of the Hubble length which are consistent with local measures of H_0 .

Table 17.2: Some recent estimates of Hubble's constant

Technique	Calibration*	Ties to Hubble flow	Result* $(\text{km s}^{-1} \text{ Mpc}^{-1})$	Ref.
EPM	EPM model, Cepheids	Direct EPM Hubble Diagram + Flow model or TF	73 ± 6 ± 7	[29,19]
SNeIa	Host galaxy Cepheids	Direct SNIa Hubble Diagram	63 ± 3.4 58 ± 8	[25] [21]
Clusters	Virgo mean (M100 Cepheids) + local + M101 Cepheids	Virgo infall model Virgo/Coma ratio Cluster TF + LS flow model fit	$81 \pm 11^{\dagger}$ $73-77 \pm 10^{\dagger}$ $82 \pm 11^{\dagger}$	[19] [19] [19]
	M96 Cepheids	LeoI to Virgo and Coma	69 ± 8	[22]
Field TF	Local Cepheids	Field TF Hubble Diagram + Malmquist bias correction	80 ± 10	[43]
BCG	SBF, Cepheids	BCG	82 ± 8	[34]
SZ	SZ model + X-ray maps + SZ maps	Single cluster velocities A478,A2142,A2256 Coma	54 ± 14 74 ± 29	[38] [37]
GL	Lens model, time delay	Direct, Q0957+561	63 ± 12	[40]

^{*} For all methods except SZ and GL, add a common multiplicative error of ± 0.15 mag or 7% in H_0 for absolute calibration of Cepheids. These values assume the pre-Hipparcos calibration of the Cepheid PL relation.

[†] Plus Virgo depth uncertainty (scales with M100/Virgo ratio).

17.11. Estimates of H_0

The central idea is to find "landmark" systems whose distance is given by more than one technique. The number of techniques and the range of each has now increased enough for reliable overlapping calibration at each stage of the distance scale. The reason for the diversity of estimates of the Hubble constant lies in the many different ways to combine these techniques to obtain an absolute distance calibration in the Hubble flow. There is now broad agreement within the errors among a wide variety of semi-independent ladders with different systematics. As examples, we cite a variety of (somewhat arbitrarily chosen) independent methods, which illustrate some of the choices and tradeoffs, summarized in Table 17.2. Note that most of the quoted values depend in common on the absolute Cepheid calibration.

- 1. Expanding photosphere method (EPM) distances give an absolute calibration to objects in the distant Hubble flow. A small sample of these direct distances with small flow corrections gives $H_0=73\pm6$ (statistical) ±7 (systematic).The distance estimates and limits on the systematic error component are verified by Cepheid distances in three cases, where the Cepheid/EPM distances come out to 1.02 ± 0.08 (LMC), $1.01^{+0.23}_{-0.17}$ (M101) and 1.13 ± 0.28 (M100).
- 2. With HST, it is now possible to calibrate SNIa directly with Cepheid distances to host galaxies. The light from brighter SNIa decays more slowly than from faint ones, so the best fits to the distant Hubble diagram include information about the light curve shape rather than simply assuming uniformity.
- 3. The distance to Virgo or any other local cluster is tied to H_0 via the distant Hubble diagram for TF or D_n - σ distances for galaxies in distant clusters. This can be done with a large scale flow model fit to many clusters or using the distance ratio to a fiducial reference such as the Coma cluster.
- 4. TF comparison with distant field galaxies in the Hubble flow (after corrections for Malmquist bias in the samples, which is worse than in cluster samples) yield $H_0 = 80 \pm 10 \; \mathrm{km \; s^{-1} \; Mpc^{-1}}$.
- 5. The distant BCG sample is now calibrated with SBF directly.
- Recent SZ and GL estimates lie squarely in the range of the other techniques and are completely independent of them, although errors are not yet well constrained with such small samples.

The central values by most reliably calibrated methods lie in the range $H_0=60$ to $80~{\rm km~s^{-1}~Mpc^{-1}}$, and indeed this corresponds roughly with the range of estimates expected from the internally estimated errors. Thus systematic errors are at least not overwhelming, although there are still discrepencies which are not understood.

Footnote and References:

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18. DARK MATTER

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There is strong evidence from a variety of different observations for a large amount of dark matter in the universe [1]. The phrase "dark matter" means matter whose existence has been inferred only through its gravitational effects. There is also extensive circumstantial evidence that at least some of this dark matter is nonbaryonic: that is, composed of elementary particles other than protons, neutrons, and electrons. These particles must have survived from the Big Bang, and therefore must either be stable or have lifetimes in excess of the current age of the universe.

The abundance of dark matter is usually quoted in terms of its mass density $\rho_{\rm dm}$ in units of the critical density, $\Omega_{\rm dm}=\rho_{\rm dm}/\rho_{\rm c}$; the critical density $\rho_{\rm c}$ is defined in Eq. (15.5) (in Section 15 on "Big-Bang Cosmology" in this *Review*). The total amount of visible matter (that is, matter whose existence is inferred from its emission or absorption of photons) is roughly $\Omega_{\rm vis}\simeq 0.005$, with an uncertainty of at least a factor of two.

The strongest evidence for dark matter is from the rotation curves of spiral galaxies [1,2]. In these observations, the circular velocity v_c of hydrogen clouds surrounding the galaxy is measured (via Doppler shift) as a function of radius r. If there were no dark matter, at large rwe would find $v_c^2 \simeq G_N M_{\rm vis}/r$, since the visible mass $M_{\rm vis}$ of a spiral galaxy is concentrated at its center. However, observations of many spiral galaxies instead find a velocity v_c which is independent of r at large r, with a typical value $v_c \sim 200 \, \mathrm{km \ s^{-1}}$. Such a "flat rotation curve" implies that the total mass within radius r grows linearly with $r,\,M_{
m tot}(r)\simeq G_N^{-1}v_{
m c}^2r.\,$ A self-gravitating ball of ideal gas at a uniform temperature of $kT = \frac{1}{2}m_{\rm dm}v_{\rm c}^2$ would have this mass profile; here $m_{
m dm}$ is the mass of one dark matter particle. The rotation curves are measured out to some tens of kiloparsecs, implying a total mass within this radius which is typically about ten times the visible mass. This would imply $\Omega_{\rm dm} \gtrsim 10\,\Omega_{\rm vis}\,\simeq\,0.05.$ In our own galaxy, estimates of the local density of dark matter typically give $ho_{
m dm} \simeq 0.3\,{
m GeV}~{
m cm}^{-3},$ but this result depends sensitively on how the halo of dark matter is

Other indications of the presence of dark matter come from observations of the motion of galaxies and hot gas in clusters of galaxies [3]. The overall result is that $\Omega_{dm}\sim 0.2$. Studies of large-scale velocity fields result in $\Omega_{dm}\gtrsim 0.3$ [4]. However, these methods of determining Ω_{dm} require some astrophysical assumptions about how galaxies form.

None of these observations give us any direct indication of the nature of the dark matter. If it is baryonic, the forms it can take are severely restricted, since most forms of ordinary matter readily emit and absorb photons in at least one observable frequency band [5]. Possible exceptions include remnants (white dwarfs, neutron stars, black holes) of an early generation of massive stars, or smaller objects which never initiated nuclear burning (and would therefore have masses less than about $0.1\,M_\odot$). These massive compact halo objects are collectively called machos. Results from one of the ongoing searches for machos via gravitational lensing effects [6] indicate that a significant fraction (roughly 20% to 60%, depending on the details of the model of the galaxy which is assumed) of the mass of our galaxy's halo is composed of machos.

There are, also, several indirect arguments which argue for a substantial amount of nonbaryonic dark matter. First, nucleosynthesis gives the limits $0.010 \le \Omega_{\rm b} h_0^2 \le 0.016$ for the total mass of baryons; h_0 is defined in Eq. (15.6) (in Section 15 on "Big-Bang Cosmology" in this Review). The upper limit on $\Omega_{\rm b}$ is substantially below the value $\Omega_{\rm dm} \gtrsim 0.3$ given by large scale measurements, even if h_0 is near the lower end of its optimistically allowed range, $0.4 \le h_0 \le 1.0$. A second, purely theoretical argument is that inflationary models (widely regarded as providing explanations of a number of otherwise puzzling paradoxes) generically predict $\Omega_{\rm total} = 1$. Finally, it is difficult to construct a model of galaxy formation without nonbaryonic dark matter that predicts sufficiently small fluctuations in the cosmic microwave background radiation [7].

For purposes of galaxy formation models, nonbaryonic dark matter is classified as "hot" or "cold," depending on whether the dark matter particles were relativistic or nonrelativistic at the time when the horizon of the universe enclosed enough matter to form a galaxy. If the dark matter particles are in thermal equilibrium with the baryons and radiation, then only the mass of a dark matter particle is relevant to knowing whether the dark matter is hot or cold, with the dividing line being $m_{\rm dm} \sim 1 \, {\rm keV}$. In addition, specifying a model requires giving the power spectrum of initial density fluctuations. Inflationary models generically predict a power spectrum which is nearly scale invariant. Given this, models with only cold dark matter are much more successful than models with only hot dark matter at reproducing the observed structure of our universe, but there are still serious discrepancies [8]. Some of the suggestions proposed to alleviate these include a nonzero value of the cosmological constant A [9], significant deviations from scale invariance in the spectrum of initial fluctuations [10], and a mixture of both hot and cold dark matter [11]. Another class of models uses mass fluctuations due to topological defects [12].

The best candidate for hot dark matter is one of the three neutrinos, endowed with a Majorana mass m_{ν} . Such a neutrino would contribute $\Omega_{\nu} = 0.56\,G_N\,T_0^3\,H_0^{-2}m_{\nu} = m_{\nu}/(92\,h_0^2\,\mathrm{eV})$, where T_0 is the present temperature of the cosmic microwave background radiation. There is another constraint on neutrinos (or any light fermions) if they are to comprise the halos of dwarf galaxies: the Fermi-Dirac distribution in phase space restricts the number of neutrinos that can be put into a halo [13], and this implies a lower limit on the neutrino mass of $m_{\nu} \gtrsim 80\,\mathrm{eV}$.

There are no presently known particles which could be cold dark matter. However, many proposed extensions of the Standard Model predict a stable (or sufficiently long-lived) particle. The key question then becomes the predicted value of $\Omega_{\rm dm}$.

If the particle is its own antiparticle (or there are particles and antiparticles present in equal numbers), and these particles were in thermal equilibrium with radiation at least until they became nonrelativistic, then their relic abundance is determined by their annihilation cross section $\sigma_{\rm ann}\colon\Omega_{\rm dm}\sim G_N^{3/2}T_0^3H_0^{-2}\langle\sigma_{\rm ann}v_{\rm rel}\rangle^{-1}$. Here $v_{\rm rel}$ is the relative velocity of the two incoming dark matter particles, and the angle brackets denote an averaging over a thermal distribution of velocities for each at the freezeout temperature $T_{\rm fr}$ when the dark matter particles go out of thermal equilibrium with radiation; typically $T_{\rm fr}\simeq\frac{1}{20}m_{\rm dm}$. One then finds (putting in appropriate numerical factors) that $\Omega_{\rm dm}h_0^2\simeq 3\times 10^{-27}\,{\rm cm}^3\,{\rm s}^{-1}/\langle\sigma_{\rm ann}v_{\rm rel}\rangle$. The value of $\langle\sigma_{\rm ann}v_{\rm rel}\rangle$ needed for $\Omega_{\rm dm}\simeq 1$ is remarkably close to what one would expect for a weakly interacting massive particle (wimp) with a mass of $m_{\rm dm}=100\,{\rm GeV}$: $\langle\sigma_{\rm ann}v_{\rm rel}\rangle\sim\alpha^2/8\pi m_{\rm dm}^2\sim 3\times 10^{-27}\,{\rm cm}^3\,{\rm s}^{-1}$.

If the dark matter particle is not its own antiparticle, and the number of particles minus antiparticles is conserved, then an initial asymmetry in the abundances of particles and antiparticles will be preserved, and can give relic abundances much larger than those predicted above.

If the dark matter particles were never in thermal equilibrium with radiation, then their abundance today must be calculated in some other way, and will in general depend on the precise initial conditions which are assumed.

The two best known and most studied cold dark matter candidates are the neutralino and the axion. The neutralino is predicted by supersymmetric extensions of the Standard Model [14,15]. It qualifies as a wimp, with a theoretically expected mass in the range of tens to hundreds of GeV. The axion is predicted by extensions of the Standard Model which resolve the strong CP problem [16]. Its mass must be approximately $10^{-5}\,\mathrm{eV}$ if it is to be a significant component of the dark matter. Axions can occur in the early universe form of a Bose condensate which never comes into thermal equilibrium. The axions in this condensate are always nonrelativistic, and can be a significant component of the dark matter if the axion mass is approximately $10^{-5}\,\mathrm{eV}$.

There are prospects for direct experimental detection of both these candidates (and other wimp candidates as well). Wimps will scatter off nuclei at a calculable rate, and produce observable nuclear recoils [15,17]. This technique has been used to show that all the dark matter cannot consist of massive Dirac neutrinos or scalar neutrinos (predicted by supersymmetric models) with masses in the range of $10~{\rm GeV} \lesssim m_{\rm dm} \lesssim 4~{\rm TeV}$ [18]. The neutralino is harder to detect because its scattering cross section with nuclei is considerably smaller. Condensed axions can be detected by axion to photon conversion in an inhomogeneous magnetic field, and limits on the allowed axion-photon coupling (for certain ranges of the axion mass) have been set [16]. Both types of detection experiments are continuing.

Wimp candidates can have indirect signatures as well, via presentday annihilations into particles which can be detected as cosmic rays [15]. The most promising possibility arises from the fact that wimps collect at the centers of the sun and the earth, thus greatly increasing their annihilation rate, and producing high energy neutrinos which can escape and arrive at the earth's surface in potentially observable numbers.

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19. COSMIC BACKGROUND RADIATION

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19.1. Introduction

The observed cosmic microwave background (CMB) radiation provides strong evidence for the hot big bang. The success of primordial nucleosynthesis calculations (see Sec. 16, "Big-bang nucleosynthesis") requires a cosmic background radiation (CBR) characterized by a temperature $kT \sim 1\,\mathrm{MeV}$ at a redshift of $z \simeq 10^9$. In their pioneering work, Gamow, Alpher, and Herman [1] realized this and predicted the existence of a faint residual relic, primordial radiation, with a present temperature of a few degrees. The observed CMB is interpreted as the current manifestation of the required CBR.

The CMB was serendipitously discovered by Penzias and Wilson [2] in 1965. Its spectrum is well characterized by a $2.73\pm0.01\,\mathrm{K}$ black-body (Planckian) spectrum over more than three decades in frequency (see Fig. 19.1). A non-interacting Planckian distribution of temperature T_i at redshift z_i transforms with the universal expansion to another Planckian distribution at redshift z_r with temperature $T_r/(1+z_r)=T_i/(1+z_i)$. Hence thermal equilibrium, once established (e.g. at the nucleosynthesis epoch), is preserved by the expansion, in spite of the fact that photons decoupled from matter at early times. Because there are about 10^9 photons per nucleon, the transition from the ionized primordial plasma to neutral atoms at $z\sim1000$ does not significantly alter the CBR spectrum [3].

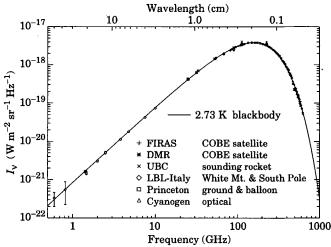


Figure 19.1: Precise measurements of the CMB spectrum. The line represents a 2.73 K blackbody, which describes the spectrum very well, especially around the peak of intensity. The spectrum is less well constrained at 10 cm and longer wavelengths. (References for this figure are at the end of this section under "CMB Spectrum References.")

19.2. The CMB frequency spectrum

The remarkable precision with which the CMB spectrum is fitted by a Planckian distribution provides limits on possible energy releases in the early Universe, at roughly the fractional level of 10^{-4} of the CBR energy, for redshifts $\lesssim 10^7$ (corresponding to epochs $\gtrsim 1\,\text{year}$). The following three important classes of theoretical spectral distortions (see Fig. 19.2) generally correspond to energy releases at different epochs. The distortion results from the CBR photon interactions with a hot electron gas at temperature T_e .

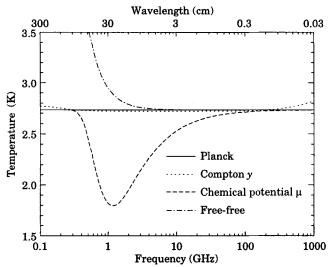


Figure 19.2: The shapes of expected, but so far unobserved, CMB distortions, resulting from energy-releasing processes at different epochs.

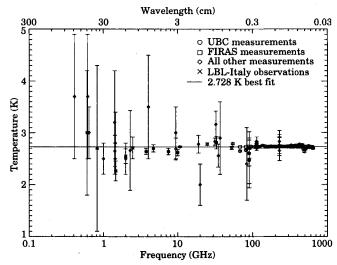


Figure 19.3: Observed thermodynamic temperature as a function frequency.

19.2.1. Compton distortion: Late energy release $(z \lesssim 10^5)$. Compton scattering $(\gamma e \to \gamma' e')$ of the CBR photons by a hot electron gas creates spectral distortions by transfering energy from the electrons to the photons. Compton scattering cannot achieve thermal equilibrium for y < 1, where

$$y = \int_0^z \frac{kT_e(z') - kT_{\gamma}(z')}{m_e c^2} \sigma_T n_e(z') c \frac{dt}{dz'} dz', \qquad (19.1)$$

is the integral of the number of interactions, $\sigma_T n_e(z) c dt$, times the mean-fractional photon-energy change per collision [4]. For $T_e \gg T_\gamma$ y is also proportional to the integral of the electron pressure $n_e k T_e$ along the line of sight. For standard thermal histories y < 1 for epochs later than $z \simeq 10^5$.

The resulting CMB distortion is a temperature decrement

$$\Delta T_{\rm RJ} = -2y \, T_{\gamma} \tag{19.2}$$

in the Rayleigh-Jeans $(h\nu/kT\ll 1)$ portion of the spectrum, and a rapid rise in temperature in the Wien $(h\nu/kT\gg 1)$ region, *i.e.* photons are shifted from low to high frequencies. The magnitude of the distortion is related to the total energy transfer [4] ΔE by

$$\Delta E/E_{\rm CBR} = e^{4y} - 1 \simeq 4y \ . \tag{19.3}$$

A prime candidate for producing a Comptonized spectrum is a hot intergalactic medium. A hot $(T_c>10^5\,\mathrm{K})$ medium in clusters of galaxies can and does produce a partially Comptonized spectrum as seen through the cluster, known as the Sunyaev-Zel'dovich effect. Based upon X-ray data, the predicted large angular scale total combined effect of the hot intracluster medium should produce $y\lesssim 10^{-6}$ [5].

19.2.2. Bose-Einstein or chemical potential distortion: Early energy release ($z \sim 10^5-10^7$). After many Compton scatterings (y > 1), the photons and electrons will reach statistical (not thermodynamic) equilibrium, because Compton scattering conserves photon number. This equilibrium is described by the Bose-Einstein distribution with non-zero chemical potential:

$$n = \frac{1}{e^{x+\mu_0}-1} \,, \tag{19.4}$$

where $x \equiv h\nu/kT$ and $\mu_0 \simeq 1.4~\Delta E/E_{\rm CBR}$, with μ_0 being the dimensionless chemical potential that is required.

The collisions of electrons with nuclei in the plasma produce free-free (thermal bremsstrahlung) radiation: $eZ \rightarrow eZ\gamma$. Free-free emission thermalizes the spectrum to the plasma temperature at long wavelengths. Including this effect, the chemical potential becomes frequency-dependent,

$$\mu(x) = \mu_0 e^{-2x_b/x} , \qquad (19.5)$$

where x_b is the transition frequency at which Compton scattering of photons to higher frequencies is balanced by free-free creation of new photons. The resulting spectrum has a sharp drop in brightness temperature at centimeter wavelengths [6]. The minimum wavelength is determined by Ω_B .

The equilibrium Bose-Einstein distribution results from the oldest non-equilibrium processes ($10^5 < z < 10^7$), such as the decay of relic particles or primordial inhomogeneities. Note that free-free emission (thermal bremsstrahlung) and radiative-Compton scattering effectively erase any distortions [7] to a Planckian spectrum for epochs earlier than $z \sim 10^7$.

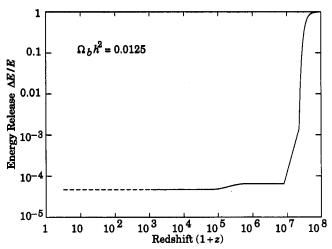


Figure 19.4: Upper Limits (95% CL) on fractional energy $(\Delta E/E_{\rm CBR})$ releases from processes at different epochs as set by resulting lack of CMB spectral distortions. These can be translated into constraints on the mass, lifetime and photon branching ratio of unstable relic particles, with some additional dependence on cosmological parameters such as Ω_B [9,10].

19.2.3. Free-free distortion: Very late energy release $(z \ll 10^3)$. Free-free emission can create rather than erase spectral distortion in the late Universe, for recent reionization $(z < 10^3)$ and from a warm intergalactic medium. The distortion arises because of the lack of Comptonization at recent epochs. The effect on the present-day CMB spectrum is described by

$$\Delta T_{ff} = T_{\gamma} Y_{ff}/x^2, \tag{19.6}$$

where T_{γ} is the undistorted photon temperature, x is the dimensionless frequency, and Y_{ff}/x^2 is the optical depth to free-free emission:

$$Y_{ff} = \int_0^z \frac{T_e(z') - T_{\gamma}(z')}{T_e(z')} \frac{8\pi e^6 h^2 n_e^2 g}{3m_e (kT_{\gamma})^3 \sqrt{6\pi m_e kT_e}} \frac{dt}{dz'} dz' . \quad (19.7)$$

Here h is Planck's constant, n_c is the electron density and g is the Gaunt factor [8].

19.2.4. Spectrum summary: The CMB spectrum is consistent with a blackbody spectrum over more than three decades of frequency around the peak. A least-squares fit to all CMB measurements yields:

$$\begin{split} T_{\gamma} &= 2.728 \pm 0.002 \text{ K} &\quad (1\sigma \text{ error}) \\ n_{\gamma} &= (2\zeta(3)/\pi^2)T_{\gamma}^3 \simeq 412 \text{ cm}^{-3} \\ \rho_{\gamma} &= (\pi^2/15)T_{\gamma}^4 \simeq 4.68 \times 10^{-34} \text{ g cm}^{-3} \simeq 0.262 \text{ eV cm}^{-3} \\ |y| &< 1.2 \times 10^{-5} &\quad (95\% \text{ CL}) \\ |\mu_{0}| &< 9 \times 10^{-5} &\quad (95\% \text{ CL}) \\ |Y_{ff}| &< 1.9 \times 10^{-5} &\quad (95\% \text{ CL}) \end{split}$$

The limits here [11] correspond to limits [11–13] on energetic processes $\Delta E/E_{\rm CBR} < 2 \times 10^{-4}$ occurring between redshifts 10^3 and 5×10^6 (see Fig. 19.4). The best-fit temperature from the COBE FIRAS experiment is $T_{\gamma} = 2.728 \pm 0.002$ K [11].

19.3. Deviations from isotropy

Penzias and Wilson reported that the CMB was isotropic and unpolarized to the 10% level. Current observations show that the CMB is unpolarized at the 10^{-5} level but has a dipole anisotropy at the 10^{-3} level, with smaller-scale anisotropies at the 10^{-5} level. Standard theories predict anisotropies in linear polarization well below currently achievable levels, but temperature anisotropies of roughly the amplitude now being detected.

It is customary to express the CMB temperature anisotropies on the sky in a spherical harmonic expansion,

$$\frac{\Delta T}{T}(\theta,\phi) = \sum_{\ell m} a_{\ell m} Y_{\ell m}(\theta,\phi) , \qquad (19.8)$$

and to discuss the various multipole amplitudes. The power at a given angular scale is roughly $\ell \sum_m |a_{\ell m}|^2/4\pi$, with $\ell \sim 1/\theta$.

19.3.1. The dipole: The largest anisotropy is in the $\ell=1$ (dipole) first spherical harmonic, with amplitude at the level of $\Delta T/T=1.23\times 10^{-3}$. The dipole is interpreted as the result of the Doppler shift caused by the solar system motion relative to the nearly isotropic blackbody field. The motion of the observer (receiver) with velocity $\beta=v/c$ relative to an isotropic Planckian radiation field of temperature T_0 produces a Doppler-shifted temperature

$$T(\theta) = T_0 (1 - \beta^2)^{1/2} / (1 - \beta \cos \theta)$$

= $T_0 \left(1 + \beta \cos \theta + (\beta^2/2) \cos 2\theta + O(\beta^3) \right)$. (19.9)

The implied velocity [11,14] for the solar-system barycenter is $\beta=0.001236\pm0.000002$ (68% CL) or $v=371\pm0.5~{\rm km\,s^{-1}}$, assuming a value $T_0=2.728\pm0.002~{\rm K}$, towards $(\alpha,\delta)=(11.20^{\rm h}\pm0.01^{\rm h},-7.22^{\rm o}\pm0.08^{\rm o})$, or $(\ell,b)=(264.31^{\rm o}\pm0.17^{\rm o},48.05^{\rm o}\pm0.10^{\rm o})$. Such a solar-system velocity implies a velocity for the Galaxy and the Local Group of galaxies relative to the CMB. The derived velocity is $v_{\rm LG}=627\pm22~{\rm km\,s^{-1}}$

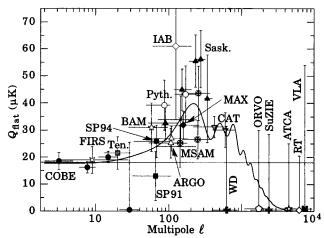


Figure 19.5: Current status of CMB anisotropy observations, adapted from Scott, Silk, & White (1995) [18]. This is a representation of the results from COBE, together with a wide range of ground- and balloon-based experiments which have operated in the last few years. Plotted are the quadrupole amplitudes for a flat (unprocessed scale-invariant spectrum of primordial perturbations, i.e., a horizontal line) anisotropy spectrum that would give the observed results for each experiment. In other words each point is the normalization of a flat spectrum derived from the individual experiments. The vertical error bars represent estimates of 68% CL, while the upper limits are at 95% CL. Horizontal bars indicate the range of ℓ values sampled. The curve indicates the expected spectrum for a standard CDM model ($\Omega_0 = 1, \Omega_B = 0.05, h = 0.5$), although true comparison with models should involve convolution of this curve with each experimental filter function. The dashed line is the best fitted flat spectrum derived from the COBE data alone [24]. (References for this figure are at the end of this section under "CMB Anisotropy References.")

toward $(\ell, b) = (276^{\circ} \pm 3^{\circ}, 30^{\circ} \pm 3^{\circ})$, where most of the error comes from uncertainty in the velocity of the solar system relative to the Local Group.

The Doppler effect of this velocity and of the velocity of the Earth around the Sun, as well as any velocity of the receiver relative to the Earth, is normally removed for the purposes of CMB anisotropy study. The resulting high degree of CMB isotropy is the strongest evidence for the validity of the Robertson-Walker metric.

19.3.2. The quadrupole: The rms quadrupole anisotropy amplitude is defined through $Q_{\rm rms}^2/T_\gamma^2=\sum_m|a_{2m}|^2/4\pi$. The current estimate of its value is $4\,\mu{\rm K}\leq Q_{\rm rms}\leq 28\,\mu{\rm K}$ for a 95% confidence interval [15]. The uncertainty here includes both statistical errors and systematic errors, which are dominated by the effects of galactic emission modelling. This level of quadrupole anisotropy allows one to set general limits on anisotropic expansion, shear, and vorticity; all such dimensionless quantities are constrained to be less than about 10^{-5} .

. For specific homogeneous cosmologies, fits to the whole anisotropy pattern allow stringent limits to be placed on, for example, the global rotation at the level of about 10^{-7} of the expansion rate [16].

19.3.3. Smaller angular scales: The COBE-discovered [17] higher-order $(\ell > 2)$ anisotropy is interpreted as being the result of perturbations in the energy density of the early Universe, manifesting themselves at the epoch of the CMB's last scattering. Hence the detection of these anisotropies has provided evidence for the existence of primordial density perturbations which grew through gravitational instability to form all the structure we observe today.

In the standard scenario the last scattering takes place at a redshift of approximately 1100, at which epoch the large number of photons was no longer able to keep the hydrogen sufficiently ionized. The optical thickness of the cosmic photosphere is roughly $\Delta z \sim 100$ or about 5 arcminutes, so that features smaller than this size are damped.

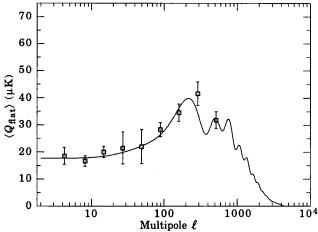


Figure 19.6: This is a binned version of the previous figure. To obtain this figure we took all reported detections, split the multipole range into equal logarithmic 'bins,' and calculated the weighted average in each bin. Although this is not a statistically rigorous procedure, the resulting figure gives a visual indication of the current consensus. It is also worth mentioning that there is no strong indication for excess scatter (above Gaussian) within each bin.

Anisotropies are observed on angular scales larger than this damping scale (see Fig. 19.5 and 19.6), and are consistent with those expected from an initially scale-invariant power spectrum (flat = independent of scale) of potential and thus metric fluctuations. It is believed that the large scale structure in the Universe developed through the process of gravitational instability, where small primordial perturbations in energy density were amplified by gravity over the course of time. The initial spectrum of density perturbations can evolve significantly in the epoch z>1100 for causally connected regions (angles $\lesssim 1^{\circ}~\Omega_{\rm tot}^{1/2}$). The primary mode of evolution is through adiabatic (acoustic) oscillations, leading to a series of peaks that encode information about the perturbations and geometry of the Universe, as well as information on $\Omega_0,~\Omega_B,~\Omega_\Lambda$ (cosmological constant), and H_0 [18]. The location of the first acoustic peak is predicted to be at $\ell \sim 220~\Omega_{\rm tot}^{-1/2}$ or $\theta \sim 0.3^{\circ}~\Omega_{\rm tot}^{1/2}$ and its amplitude is a calculable function of the parameters.

Theoretical models generally predict a power spectrum in spherical harmonic amplitudes, since the models lead to primordial fluctuations and thus $a_{\ell m}$ that are Gaussian random fields, and hence the power spectrum in ℓ is sufficient to characterize the results. The power at each ℓ is $(2\ell+1)C_\ell/(4\pi)$, where $C_\ell \equiv \langle |a_{\ell m}|^2 \rangle$ and a statistically isotropic sky means that all m's are equivalent. For an idealized full-sky observation, the variance of each measured C_ℓ is $[2/(2\ell+1)]C_\ell^2$. This sampling variance (known as cosmic variance) comes about because each C_ℓ is chi-squared distributed with $(2\ell+1)$ degrees of freedom for our observable volume of the Universe [19].

Thomson scattering of the anisotropic radiation field also generates linear polarization at the roughly 5% level [20]. Although difficult to detect, the polarization signal should act as a strong confirmation of the general paradigm.

Figure 19.7 shows the theoretically predicted anisotropy power spectrum for a sample of models, plotted as $\ell(\ell+1)C_\ell$ versus ℓ which is the power per logarithmic interval in ℓ or, equivalently, the two-dimensional power spectrum. If the initial power spectrum of perturbations is the result of quantum mechanical fluctuations produced and amplified during inflation, then the shape of the anisotropy spectrum is coupled to the ratio of contributions from density (scalar) and gravitational wave (tensor) perturbations [21]. If the energy scale of inflation at the appropriate epoch is at the level of $\simeq 10^{16}\,\mathrm{GeV}$, then detection of the effect of gravitons is possible, as well as partial reconstruction of the inflaton potential. If the energy scale is $\lesssim 10^{14}\,\mathrm{GeV}$, then density fluctuations dominate and less constraint is possible.

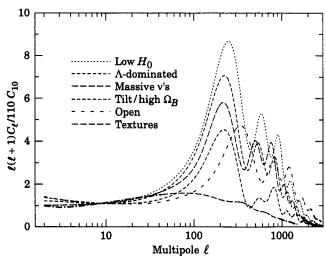


Figure 19.7: Examples of theoretically predicted $\ell(\ell+1)C_\ell$ or CMB anisotropy power spectra [22]. The plot indicates that precise measurements of the CMB anisotropy power spectrum could distinguish between models which are currently favored from galaxy clustering and other considerations. The textures model is from Ref. 23.

Fits to data over smaller angular scales are often quoted as the expected value of the quadrupole $\langle Q \rangle$ for some specific theory, e.g. a model with power-law initial conditions (primordial density perturbation power spectrum $P(k) \propto k^n$). The full 4-year COBE DMR data give $\langle Q \rangle = 15.3^{+3.7}_{-2.8}~\mu \text{K}$, after projecting out the slope dependence, while the best-fit slope is $n=1.2\pm0.3$, and for a pure n=1 (scale-invariant potential perturbation) spectrum $\langle Q \rangle$ (n=1) = $18\pm1.6~\mu \text{K}$ [15,24]. The conventional notation is such that $\langle Q \rangle^2/T_\gamma^2 = 5C_2/4\pi$, and an alternative convention is to plot the "band-power" $\sqrt{\ell(2\ell+1)C_\ell/4\pi}$). The fluctuations measured by other experiments can also be quoted in terms of Q_{flat} , the equivalent value of the quadrupole for a flat (n=1) spectrum, as presented in Fig. 19.5.

It now seems clear that there is more power at sub-degree scales than at COBE scales, which provides some model-dependent information on cosmological parameters [18,25], for example Ω_B . In terms of such parameters, fits to the COBE data alone yield $\Omega_0 > 0.34$ at 95% CL [26] and $\Omega_{\rm tot} < 1.5$ also at 95% CL [27], for inflationary models. Only somewhat weak conclusions can be drawn based on the current smaller angular scale data (see Fig. 19.5). A sample preliminary fit [28] finds Ω_0 $h^{1/2} \simeq 0.55 \pm 0.10$ ($\equiv 68\%$ CL).

However, new data are being acquired at an increasing rate, with a large number of improved ground- and balloon-based experiments being developed. It appears that we are not far from being able to distinguish crudely between currently favored models, and to begin a more precise determination of cosmological parameters. A vigorous suborbital and interferometric program could map out the CMB anisotropy power spectrum to about 10% accuracy and determine several parameters at the 10 to 20% level in the next few years.

There are also now two approved satellite missions: the NASA Millimetre Anisotropy Probe (MAP), scheduled for launch in 2000; and the ESA Planck Surveyor, expected to launch around 2004. The improved sensitivity, freedom from earth-based systematics, and all-sky coverage allow a simultaneous determination of many of the cosmological parameters to unprecedented precision: for example, Ω_0 and n to about 1%, Ω_B and H_0 at the level of a few percent [29].

Furthermore, detailed measurement of the polarization signal provides more precise information on the physical parameters. In particular it allows a clear distinction of any gravity wave contribution, which is crucial to probing the $\sim 10^{16}~{\rm GeV}$ energy range. The fulfillment of this promise may await an even more sensitive generation of satellites.

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20. COSMIC RAYS

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20.1. Primary spectra

The cosmic radiation incident at the top of the terrestrial atmosphere includes all stable charged particles and nuclei with lifetimes of order 10^6 years or longer. Technically, "primary" cosmic rays are those particles accelerated at astrophysical sources and "secondaries" are those particles produced in interaction of the primaries with interstellar gas. Thus electrons, protons and helium, as well as carbon, oxygen, iron, and other nuclei synthesized in stars, are primaries. Nuclei such as lithium, beryllium, and boron (which are not abundant end-products of stellar nucleosynthesis) are secondaries. Antiprotons and positrons are partly, if not entirely, secondaries, but the fraction of these particles that may be primary is a question of current interest.

Apart from particles associated with solar flares, the cosmic radiation comes from outside the solar system. The incoming charged particles are "modulated" by the solar wind, the expanding magnetized plasma generated by the Sun, which decelerates and partially excludes the lower energy galactic cosmic rays from the inner solar system. There is a significant anticorrelation between solar activity (which has an eleven-year cycle) and the intensity of the cosmic rays with energies below about 10 GeV. In addition, the lower-energy cosmic rays are affected by the geomagnetic field, which they must penetrate to reach the top of the atmosphere. Thus the intensity of any component of the cosmic radiation in the GeV range depends both on the location and time.

There are four different ways to describe the spectra of the components of the cosmic radiation: (1) By particles per unit rigidity. Propagation (and probably also acceleration) through cosmic magnetic fields depends on gyroradius or magnetic rigidity, R, which is gyroradius multiplied by the magnetic field strength:

$$R = \frac{p c}{Z e} = r_L B . \qquad (20.1)$$

(2) By particles per energy-per-nucleon. Fragmentation of nuclei propagating through the interstellar gas depends on energy per nucleon, since that quantity is approximately conserved when a nucleus breaks up on interaction with the gas. (3) By nucleons per energy-per-nucleon. Production of secondary cosmic rays in the atmosphere depends on the intensity of nucleons per energy-per-nucleon, approximately independently of whether the incident nucleons are free protons or bound in nuclei. (4) By particles per energy-per-nucleus. Air shower experiments that use the atmosphere as a calorimeter generally measure a quantity that is related to total energy per particle.

The units of differential intensity I are $[cm^{-2}s^{-1}sr^{-1}\mathcal{E}^{-1}]$, where \mathcal{E} represents the units of one of the four variables listed above.

The intensity of primary nucleons in the energy range from several GeV to somewhat beyond 100 TeV is given approximately by

$$I_N(E) \approx 1.8 E^{-\alpha} \frac{\text{nucleons}}{\text{cm}^2 \text{ s sr GeV}},$$
 (20.2)

where E is the energy-per-nucleon (including rest mass energy) and $\alpha \ (\equiv \gamma+1)=2.7$ is the differential spectral index of the cosmic ray flux and γ is the integral spectral index. About 79% of the primary nucleons are free protons and about 70% of the rest are nucleons bound in helium nuclei. The fractions of the primary nuclei are nearly constant over this energy range (possibly with small but interesting variations). Fractions of both primary and secondary incident nuclei are listed in Table 20.1. Figure 20.1 [1] shows the major components as a function of energy at a particular epoch of the solar cycle.

The spectrum of electrons and positrons incident at the top of the atmosphere is steeper than the spectra of protons and nuclei, as shown in Fig. 20.2 [2]. The positron fraction is about 10% in the region in which it is measured (< 20 GeV), but it is not yet fully understood [5].

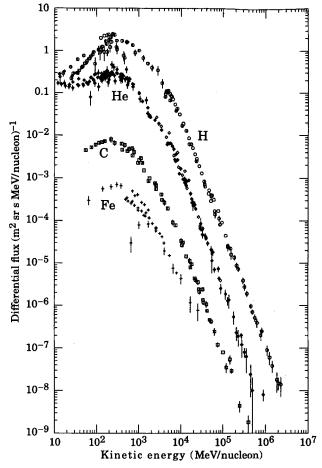


Figure 20.1: Major components of the primary cosmic radiation (from Ref. 1).

Table 20.1: Relative abundances F of cosmic-ray nuclei at 10.6 GeV/nucleon normalized to oxygen (\equiv 1) [3]. The oxygen flux at kinetic energy of 10.6 GeV/nucleon is 3.26×10^{-6} cm⁻² s⁻¹ sr⁻¹ (GeV/nucleon)⁻¹. Abundances of hydrogen and helium are from Ref. 4.

\boldsymbol{Z}	Element	F	\boldsymbol{z}	Element	F
1	H	730	13-14	Al-Si	0.19
2	${ m He}$	34	15-16	P-S	0.03
3-5	Li-B	0.40	17-18	Cl-Ar	0.01
6-8	C-O	2.20	19–2 0	K-Ca	0.02
9–10	F-Ne	0.30	21-25	Sc-Mn	0.05
11-12	Na-Mg	0.22	26-28	Fe-Ni	0.12

Above 10 GeV the fraction of antiprotons to protons is about 10^{-4} , and there is evidence for the kinematic suppression at lower energy expected for secondary antiprotons [5]. There is at this time no evidence for a significant primary component of antiprotons.

20.2. Cosmic rays in the atmosphere

Figure 20.3 shows the vertical fluxes of the major cosmic ray components in the atmosphere in the energy region where the particles are most numerous (except for electrons, which are most numerous near their critical energy, which is about 81 MeV in air). Except for protons and electrons near the top of the atmosphere, all particles are produced in interactions of the primary cosmic rays in the air. Muons

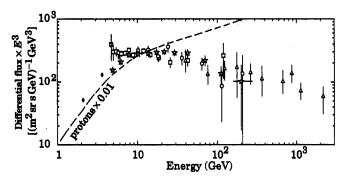


Figure 20.2: Differential spectrum of electrons plus positrons multiplied by E^3 (from Ref. 2).

and neutrinos are products of the decay of charged mesons, while electrons and photons originate in decays of neutral mesons.

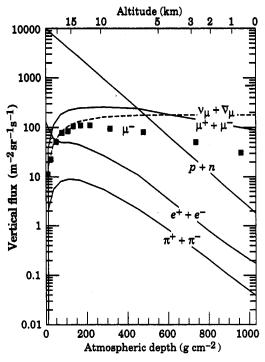


Figure 20.3: Vertical fluxes of cosmic rays in the atmosphere with E>1 GeV estimated from the nucleon flux of Eq. (20.2). The points show measurements of negative muons with $E_{\mu}>1$ GeV [7].

Most measurements are made at ground level or near the top of the atmosphere, but there are also measurements of muons and electrons from airplanes and balloons. Fig. 20.3 includes a recent measurement of negative muons [7]. Since $\mu^+(\mu^-)$ are produced in association with $\nu_{\mu}(\mathcal{P}_{\mu})$, the measurement of muons near the maximum of the intensity curve for the parent pions serves to calibrate the atmospheric ν_{μ} beam [6]. Because muons typically lose almost two GeV in passing through the atmosphere, the comparison near the production altitude is important for the sub-GeV range of $\nu_{\mu}(\mathcal{P}_{\mu})$ energies.

The flux of cosmic rays through the atmosphere is described by a set of coupled cascade equations with boundary conditions at the top of the atmosphere to match the primary spectrum. Numerical or Monte Carlo calculations are needed to account accurately for decay and energy-loss processes, and for the energy-dependences of the cross sections and of the primary spectral index γ . Approximate analytic solutions are, however, useful in limited regions of energy [8]. For example, the vertical intensity of nucleons at depth X (g cm⁻²) in the

atmosphere is given by

$$I_N(E,X) \approx I_N(E,0) e^{-X/\Lambda}$$
, (20.3)

where Λ is the attenuation length of nucleons in air.

The corresponding expression for the vertical intensity of charged pions with energy $E_\pi \ll \epsilon_\pi = 115$ GeV is

$$I_{\pi}(E_{\pi}, X) \approx \frac{Z_{N\pi}}{\lambda_N} I_N(E_{\pi}, 0) e^{-X/\Lambda} \frac{X E_{\pi}}{\epsilon_{\pi}}$$
 (20.4)

This expression has a maximum at $t=\Lambda\approx 120~{\rm g~cm^{-2}}$, which corresponds to an altitude of 15 kilometers. The quantity $Z_{N\pi}$ is the spectrum-weighted moment of the inclusive distribution of charged pions in interactions of nucleons with nuclei of the atmosphere. The intensity of low-energy pions is much less than that of nucleons because $Z_{N\pi}\approx 0.079$ is small and because most pions with energy much less than the critical energy ϵ_π decay rather than interact.

20.3. Cosmic rays at the surface

20.3.1. Muons: Muons are the most numerous charged particles at sea level (see Fig. 20.3). Most muons are produced high in the atmosphere (typically 15 km) and lose about 2 GeV to ionization before reaching the ground. Their energy and angular distribution reflect a convolution of production spectrum, energy loss in the atmosphere, and decay. For example, $E_{\mu} = 2.4$ GeV muons have a decay length of 15 km, which is reduced to 8.7 km by energy loss. The mean energy of muons at the ground is ≈ 4 GeV. The energy spectrum is almost flat below 1 GeV, steepens gradually to reflect the primary spectrum in the 10-100 GeV range, and steepens further at higher energies because pions with $E_{\pi} > \epsilon_{\pi} \approx 115$ GeV tend to interact in the atmosphere before they decay. Asymptotically $(E_{\mu} \gg 1 \text{ TeV})$, the energy spectrum of atmospheric muons is one power steeper than the primary spectrum. The integral intensity of vertical muons above 1 GeV/c at sea level is $\approx 70 \text{ m}^{-2}\text{s}^{-1}\text{sr}^{-1}$ [9,10]. Experimentalists are familiar with this number in the form $I \approx 1 \text{ cm}^{-2} \text{ min}^{-1}$ for horizontal detectors.

The overall angular distribution of muons at the ground is $\propto \cos^2 \theta$, which is characteristic of muons with $E_{\mu} \sim 3$ GeV. At lower energy the angular distribution becomes increasingly steeper, while at higher energy it flattens and approaches a $\sec \theta$ distribution for $E_{\mu} \gg \epsilon_{\pi}$ and $\theta < 70^{\circ}$.

Figure 20.4 shows the muon energy spectrum at sea level for two angles. At large angles low energy muons decay before reaching the surface and high energy pions decay before they interact, thus the average muon energy increases. An approximate extrapolation formula valid when muon decay is negligible $(E_{\mu}>100/\cos\theta~{\rm GeV})$ and the curvature of the Earth can be neglected $(\theta<70^{\circ})$ is

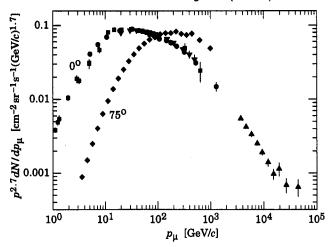


Figure 20.4: Spectrum of muons at $\theta = 0^{\circ}$ (\blacksquare [12], \bullet [13], \blacktriangledown [14], \blacktriangle [15]), and $\theta = 75^{\circ}$ \blacklozenge [16]).

$$\frac{dN_{\mu}}{dE_{\mu}} \approx \frac{0.14 \, E^{-2.7}}{\text{cm}^2 \, \text{s sr GeV}} \times \left\{ \frac{1}{1 + \frac{1.1E_{\mu} \cos \theta}{115 \, \text{GeV}}} + \frac{0.054}{1 + \frac{1.1E_{\mu} \cos \theta}{850 \, \text{GeV}}} \right\} , \quad (20.5)$$

where the two terms give the contribution of pions and charged kaons. Eq. (20.5) neglects a small contribution from charm and heavier flavors which is negligible except at very high energy [17].

The muon charge ratio reflects the excess of π^+ over π^- in the forward fragmentation region of proton initiated interactions together with the fact that there are more protons than neutrons in the primary spectrum. The charge ratio is between 1.2 and 1.3 from 250 MeV up to 100 GeV [9].

20.3.2. Electromagnetic component: At the ground, this component consists of electrons, positrons, and photons primarily from electromagnetic cascades initiated by decay of neutral and charged mesons. Muon decay is the dominant source of low-energy electrons at sea level. Decay of neutral pions is more important at high altitude or when the energy threshold is high. Knock-on electrons also make a small contribution at low energy [11]. The integral vertical intensity of electrons plus positrons is very approximately 30, 6, and 0.2 m⁻²s⁻¹sr⁻¹ above 10, 100, and 1000 MeV respectively [10,18], but the exact numbers depend sensitively on altitude, and the angular dependence is complex because of the different altitude dependence of the different sources of electrons [11,18,19]. The ratio of photons to electrons plus positrons is approximately 1.3 above a GeV and 1.7 below the critical energy [19].

20.3.3. **Protons**: Nucleons above 1 GeV/c at ground level are degraded remnants of the primary cosmic radiation. The intensity is approximately represented by Eq. (20.3) with the replacement $t \to t/\cos\theta$ for $\theta < 70^\circ$ and an attenuation length $\Lambda = 123$ g cm⁻². At sea level, about 1/3 of the nucleons in the vertical direction are neutrons (up from $\approx 10\%$ at the top of the atmosphere as the n/p ratio approaches equilibrium). The integral intensity of vertical protons above 1 GeV/c at sea level is $\approx 0.9 \text{ m}^{-2}\text{s}^{-1}\text{sr}^{-1}$ [10,20].

20.4. Cosmic rays underground

Only muons and neutrinos penetrate to significant depths underground. The muons produce tertiary fluxes of photons, electrons, and hadrons.

20.4.1. Muons: As discussed in Section 23.9 of this *Review*, muons lose energy by ionization and by radiative processes: bremsstrahlung, direct production of e^+e^- pairs, and photonuclear interactions. The total muon energy loss may be expressed as a function of the amount of matter traversed as

$$-\frac{dE_{\mu}}{dX} = a + b E_{\mu} , \qquad (20.6)$$

where a is the ionization loss and b is the fractional energy loss by the three radiation processes. Both are slowly varying functions of energy. The quantity $\epsilon \equiv a/b$ (≈ 500 GeV in standard rock) defines a critical energy below which continuous ionization loss is more important the radiative losses. Table 20.2 shows a and b values for standard rock as a function of muon energy. The second column of Table 20.2 shows the muon range in standard rock (A = 22, Z = 11, $\rho = 2.65$ g cm⁻³). These parameters are quite sensitive to the chemical composition of the rock, which must be evaluated for each experimental location.

The intensity of muons underground can be estimated from the muon intensity in the atmosphere and their rate of energy loss. To the extent that the mild energy dependence of a and b can be neglected, Eq. (20.6) can be integrated to provide the following relation between the energy $E_{\mu,0}$ of a muon at production in the atmosphere and its average energy E_{μ} after traversing a thickness X of rock (or ice or water):

$$E_{\mu} = (E_{\mu,0} + \epsilon) e^{-bX} - \epsilon . \qquad (20.7)$$

Table 20.2: Average muon range R and energy loss parameters calculated for standard rock. Range is given in km-water-equivalent, or 10^5 g cm⁻².

E_{μ} GeV	R km.w.e.	$^{a}_{\rm MeVg^{-1}cm^{2}}$		b _{brems} 10 ⁻⁶ g		
10	0.05	2.15	0.73	0.74	0.45	1.91
100	0.41	2.40	1.15	1.56	0.41	3.12
1000	2.42	2.58	1.47	2.10	0.44	4.01
10000	6.30	2.76	1.64	2.27	0.50	4.40

Especially at high energy, however, fluctuations are important and an accurate calculation requires a simulation that accounts for stochastic energy-loss processes [21].

Fig. 20.5 shows the vertical muon intensity versus depth. In constructing this "depth-intensity curve," each group has taken account of the angular distribution of the muons in the atmosphere, the map of the overburden at each detector, and the properties of the local medium in connecting measurements at various slant depths and zenith angles to the vertical intensity. Use of data from a range of angles allows a fixed detector to cover a wide range of depths. The flat portion of the curve is due to muons produced locally by charged-current interactions of ν_{μ} .

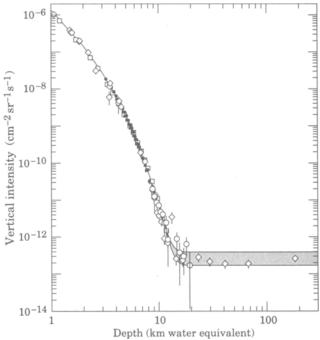


Figure 20.5: Vertical muon intensity vs. depth (1 km.w.e. = 10^5 g cm⁻² of standard rock). The experimental data are from: \Diamond : the compilations of Crouch [29], \Box : Baksan [30], \bigcirc : LVD [31], \bullet : MACRO [32], \blacksquare : Frejus [33]. The shaded area at large depths represents neutrino induced muons of energy above 2 GeV. The upper line is for horizontal neutrino-induced muons, the lower one for vertically upward muons.

The energy spectrum of atmospheric muons underground can be estimated from Eq. (20.7). The muon energy spectrum at slant depth X is

$$\frac{dN_{\mu}(X)}{dE_{\mu}} = \frac{dN_{\mu}}{dE_{\mu,0}} e^{bX} , \qquad (20.8)$$

where $E_{\mu,0}$ is the solution of Eq. (20.7). For $X \ll b^{-1} \approx 2.5$ km water equivalent, $E_{\mu,0} \approx E_{\mu}(X) + aX$. Thus at shallow depths the differential muon energy spectrum is approximately constant for $E_{\mu} < aX$ and steepens to reflect the surface muon spectrum for

 $E_{\mu} > aX$. For $X \gg b^{-1}$ the differential spectrum underground is again constant for small muon energies but steepens to reflect the surface muon spectrum for $E_{\mu} > \epsilon \approx 0.5$ TeV. In this regime the shape is independent of depth although the intensity decreases exponentially with depth.

20.4.2. Neutrinos: Because neutrinos have small interaction cross sections, measurements of atmospheric neutrinos require a deep detector to avoid backgrounds. There are two types of measurements: contained (or semi-contained) events, in which the vertex is determined to originate inside the detector, and neutrino-induced muons. The latter are muons that enter the detector from zenith angles so large (e.g., nearly horizontal or upward) that they cannot be muons produced in the atmosphere. In neither case is the neutrino flux measured directly. What is measured is a convolution of the neutrino flux and cross section with the properties of the detector (which includes the surrounding medium in the case of entering muons).

Contained events reflect the neutrinos in the GeV region where the product of increasing cross section and decreasing flux is maximum. In this energy region the neutrino flux and its angular distribution depend on the geomagnetic location of the detector and to a lesser extent on the phase of the solar cycle. Naively, we expect $\nu_{\mu}/\nu_{e}=2$ from counting the neutrinos of the two flavors coming from the chain of pion and muon decay. This ratio is only slightly modified by the details of the decay kinematics. Experimental measurements have also to account for the ratio of $\overline{\nu}/\nu$, which have cross sections different by a factor of 3 in this energy range. In addition, detectors will generally have different efficiencies for detecting muon neutrinos and electron neutrinos. Even after correcting for these and other effects, some detectors [22,23] infer a ν_{μ}/ν_{e} ratio lower by $\approx 4\sigma$ from the expected value. (See Tables in the Particle Listings of this Review.) This effect is sometimes cited as possible evidence of neutrino oscillations and is a subject of current investigation. Figure 20.6 shows the data of Refs. 22,23 for the distributions of visible energy in electron-like and muon-like charged-current events, which appear to be nearly equal in number. Corrections for detection efficiencies and backgrounds are insufficient to account for the difference from the expected value of two.

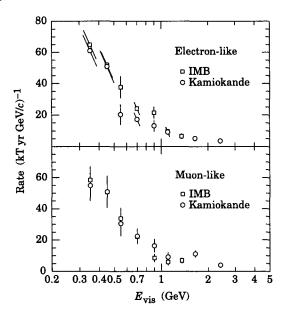


Figure 20.6: Contained neutrino interactions from IMB [23](\square) and Kamiokande [22].

Muons that enter the detector from outside after production in charged-current interactions of neutrinos naturally reflect a higher energy portion of the neutrino spectrum than contained events because the muon range increases with energy as well as the cross section. The relevant energy range is $\sim 10 < E_{\nu} < 1000$ GeV, depending somewhat on angle. Like muons (see Eq. (20.5)), high energy neutrinos show

a "secant theta" effect which causes the flux of horizontal neutrino induced muons to be approximately a factor two higher than the vertically upward flux. The upper and lower edges of the horizontal shaded region in Fig. 20.5 correspond to horizontal and vertical intensities of neutrino-induced muons. Table 20.3 gives the measured fluxes of neutrino induced muons.

Table 20.3: Measured fluxes $(10^{-13} \text{ cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1})$ of neutrino-induced muons as a function of the minimum muon energy E_{μ} .

$E_{\mu} >$	1 GeV	1 GeV	1 GeV	2 GeV	3 GeV
Ref.	CWI [24]	Baksan [25]	MACRO [26]	IMB [27]	Kam [28]
F_{μ}	2.17±0.21	2.77 ± 0.17	2.48 ± 0.27	2.26 ± 0.11	2.04±0.13

20.5. Air showers

So far we have discussed inclusive or uncorrelated fluxes of various components of the cosmic radiation. An air shower is caused by a single cosmic ray with energy high enough for its cascade to be detectable at the ground. The shower has a hadronic core, which acts as a collimated source of electromagnetic subshowers, generated mostly from $\pi^0 \to \gamma \gamma$. The resulting electrons and positrons are the most numerous particles in the shower. The number of muons, produced by decays of charged mesons, is an order of magnitude lower.

Air showers spread over a large area on the ground, and arrays of detectors operated for long times are useful for studying cosmic rays with primary energy $E_0>100~{\rm TeV}$, where the low flux makes measurements with small detectors in balloons and satellites difficult.

Greisen [46] gives the following approximate expressions for the numbers and lateral distributions of particles in showers at ground level. The total number of muons N_{μ} with energies above 1 GeV is

$$N_{\mu}(> 1 \text{ GeV}) \approx 0.95 \times 10^5 \left(\frac{N_e}{10^6}\right)^{3/4} ,$$
 (20.9)

where N_e is the total number of charged particles in the shower (not just e^{\pm}). The number of muons per square meter, ρ_{μ} , as a function of the lateral distance r (in meters) from the center of the shower is

$$\rho_{\mu} = \frac{1.25 \, N_{\mu}}{2\pi \, \Gamma(1.25)} \left(\frac{1}{320}\right)^{1.25} \, r^{-0.75} \, \left(1 + \frac{r}{320}\right)^{-2.5} \, , \qquad (20.10)$$

where Γ is the gamma function. The number density of charged particles is

$$\rho_e = C_1(s, d, C_2) x^{(s-2)} (1+x)^{(s-4.5)} (1+C_2 x^d) . \tag{20.11}$$

Here s, d, and C_2 are parameters in terms of which the overall normalization constant $C_1(s, d, C_2)$ is given by

$$\begin{split} C_1(s,d,C_2) &= \frac{N_e}{2\pi r_1^2} [\, B(s,4.5-2s) \\ &\quad + C_2 \, B(s+d,\,4.5-d-2s)]^{-1} \,\,, \end{split} \tag{20.12}$$

where B(m,n) is the beta function. The values of the parameters depend on shower size (N_e) , depth in the atmosphere, identity of the primary nucleus, etc. For showers with $N_e \approx 10^6$ at sea level, Greisen uses s=1.25, d=1, and $C_2=0.088$. Finally, x is r/r_1 , where r_1 is the Molière radius, which depends on the density of the atmosphere and hence on the altitude at which showers are detected. At sea level $r_1 \approx 78$ m. It increases with altitude.

The lateral spread of a shower is determined largely by Coulomb scattering of the many low-energy electrons and is characterized by the Moliere radius. The lateral spread of the muons (ρ_{μ}) is larger and depends on the transverse momenta of the muons at production as well as multiple scattering.

There are large fluctuations in development from shower to shower, even for showers of the same energy and primary mass—especially for small showers, which are usually well past maximum development when observed at the ground. Thus the shower size N_e and primary energy E_0 are only related in an average sense, and even this relation depends on depth in the atmosphere. One estimate of the relation is [35]

$$E_0 \sim 3.9 \times 10^6 \text{ GeV } (N_e/10^6)^{0.9}$$
 (20.13)

for vertical showers with $10^{14} < E < 10^{17}$ eV at 920 g cm⁻² (965 m above sea level). Because of fluctuations, N_e as a function of E_0 is not the inverse of Eq. (20.13). As E_0 increases the shower maximum (on average) moves down into the atmosphere and the relation between N_e and E_0 changes. At the maximum of shower development, there are approximately 2/3 particles per GeV of primary energy.

Detailed simulations and cross-calibrations between different types of detectors are necessary to establish the primary energy spectrum from air-shower experiments [35,36]. Figure 20.7 shows the "all-particle" spectrum. In establishing this spectrum, efforts have been made to minimize the dependence of the analysis on the primary composition. In the energy range above 10^{17} eV, the Fly's Eye technique [48] is particularly useful because it can establish the primary energy in a model-independent way by observing most of the longitudinal development of each shower, from which E_0 is obtained by integrating the energy deposition in the atmosphere.

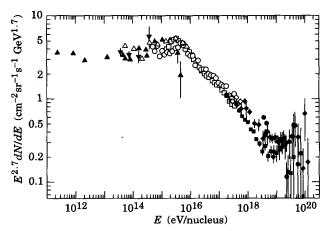


Figure 20.7: The all-particle spectrum: \blacktriangle [37], \blacktriangledown [38], \triangle [39], \Box [40], \bigcirc [35], \blacksquare [48], \spadesuit [42], \spadesuit [43].

In Fig. 20.7 the differential energy spectrum has been multiplied by $E^{2.7}$ in order to display the features of the steep spectrum that are otherwise difficult to discern. The steepening that occurs between 10^{15} and 10^{16} eV is known as the *knee* of the spectrum. The feature between 10^{18} and 10^{19} eV is called the *ankle* of the spectrum. Both these features are the subject of intense interest at present [44].

The ankle has the classical characteristic shape [45] of a higher energy population of particles overtaking a lower energy population. A possible interpretation is that the higher energy population represents cosmic rays of extragalactic origin. If this is the case and if the cosmic rays are cosmological in origin, then there should be a cutoff around 5×10^{19} eV, resulting from interactions with the microwave background [46,47]. It is therefore of special interest that several events have been assigned energies above 10^{20} eV [48,49,50].

If the cosmic ray spectrum below 10^{18} eV is of galactic origin, the knee could reflect the fact that some (but not all) cosmic accelerators have reached their maximum energy. Some types of expanding supernova remnants, for example, are estimated not to be able to accelerate particles above energies in the range of 10^{15} eV total energy per particle. Effects of propagation and confinement in the galaxy [51] also need to be considered.

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21. ACCELERATOR PHYSICS OF COLLIDERS

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21.1. Introduction

This article is intended to be a mini-introduction to accelerator physics, with emphasis on colliders. Essential data are summarized in the "Tables of Collider Parameters" (Sec. 22). Luminosity is the quantity of most immediate interest for HEP, and so we begin with its definition and a discussion of the various factors involved. Then we talk about some of the underlying beam dynamics. Finally, we comment on present limitations and possible future directions.

The focus is on colliders because they provide the highest c.m. energy, and so the longest potential discovery reach. All present-day colliders are synchrotrons with the exception of the SLAC Linear Collider. In the pursuit of higher c.m. energy with electrons, synchrotron radiation presents a formidable barrier to energy beyond LEP. The LHC will be the first proton collider in which synchrotron radiation has significant design impact.

21.2. Luminosity

The event rate R in a collider is proportional to the interaction cross section σ_{int} and the factor of proportionality is called the *luminosity*:

$$R = \mathcal{L}\sigma_{\text{int}} \quad . \tag{21.1}$$

If two bunches containing n_1 and n_2 particles collide with frequency f, then the luminosity is

$$\mathscr{L} = f \frac{n_1 n_2}{4\pi \sigma_x \sigma_y} \tag{21.2}$$

where σ_x and σ_y characterize the Gaussian transverse beam profiles in the horizontal (bend) and vertical directions. Though the initial distribution at the source may be far from Gaussian, by the time the beam reaches high energy the normal form is a very good approximation thanks to the central limit theorem of probability and diminished importance of space charge effects.

Luminosity is normally expressed in units of $\rm cm^{-2}s^{-1}$, and tends to be a large number; the highest instantaneous luminosity achieved to date is about $4.5\times 10^{32}~\rm cm^{-2}s^{-1}$ at CESR, and for protons, $2.3\times 10^{32}~\rm cm^{-2}s^{-1}$ at the now-decommissioned ISR. The critical quantity for HEP is the integrated luminosity, often stated in $\rm pb^{-1}$. For example, during the most-recent two-year Tevatron run, an integrated luminosity of 150 $\rm pb^{-1}$ was obtained.

The beam size can be expressed in terms of two quantities, one termed the transverse emittance, ϵ and the other, the amplitude function, β . The transverse emittance is a beam quality concept reflecting the process of bunch preparation, extending all the way back to the source for hadrons and, in the case of electrons, mostly dependent on synchrotron radiation. The amplitude function is a beam optics quantity and is determined by the accelerator magnet configuration.

The transverse emittance is a measure of the phase space area associated with either of the two transverse degrees of freedom, x and y. These coordinates represent the position of a particle with reference to some ideal design trajectory. Think of x as the "horizontal" displacement (in the bend plane for the case of a synchrotron), and y as the "vertical" displacement. The conjugate coordinates are the transverse momenta, which at constant energy are proportional to the angles of particle motion with respect to the design trajectory, x' and y'. Various conventions are in use to characterize the boundary of phase space. Beam sizes are usually given as the standard deviations characterizing Gaussian beam profiles in the two transverse degrees of freedom. In each degree of freedom, the one- σ contour in displacement and angle is frequently used and we will follow this choice.

Suppose that at some location in the collider, the phase space boundary appears as an upright ellipse where the coordinates are the displacement x (using the horizontal plane for instance) and the angle x' with respect to the beam axis. The choice of an elliptical

contour will be justified under Beam Dynamics below. If σ and σ' are the ellipse semi-axes in the x and x' directions respectively, then the emittance may be defined by $\epsilon \equiv \pi \sigma \sigma'$. Transverse emittance is often stated in units of mm-mrad.

The aspect ratio, σ/σ' , is the so-called *amplitude function*, β , and its value depends on position within the focusing structure. When expressed in terms of σ and β the transverse emittance becomes

$$\epsilon = \pi \frac{\sigma^2}{\beta} \ . \tag{21.3}$$

Of particular significance is the value of the amplitude function at the interaction point, β^* . To achieve high luminosity, one wants β^* to be as small as possible; how small depends on the capability of the hardware to make a near-focus at the interaction point. For example, in the HERA proton ring, β^* at one of the major detectors is 1 m while elsewhere in the synchrotron typical values of the amplitude function lie in the range 30–100 m.

Eq. (21.2) can now be recast in terms of emittances and amplitude functions as

$$\mathscr{L} = f \frac{n_1 n_2}{4\sqrt{\epsilon_x \beta_x^* \epsilon_y \beta_y^*}} \ . \tag{21.4}$$

Thus, to achieve high luminosity, all one has to do is make high population bunches of low emittance to collide at high frequency at locations where the beam optics provides as low values of the amplitude functions as possible.

Depending on the particular facility, there are other ways of stating the expression for the luminosity. In a multibunch collider, the various bunch populations will differ, in a facility such as HERA, the electron and proton bunches may differ in emittance, the variation of the beam size in the neighborhood of the interaction point may be significant, and so on.

21.3. Beam dynamics

A major concern of beam dynamics is stability: conservation of adequate beam properties over a sufficiently long time scale. Several time scales are involved, and the approximations used in writing the equations of motion reflect the time scale under consideration. For example, when, in Sec. 21.3.1 below, we write the equations for transverse stability no terms associated with phase stability or synchrotron radiation appear; the time scale associated with the last two processes is much longer than that demanded by the need for transverse stability.

21.3.1. Betatron oscillations: Present-day high-energy accelerators employ alternating gradient focusing provided by quadrupole magnetic fields [1]. The equations of motion of a particle undergoing oscillations with respect to the design trajectory are

$$x'' + K_x(s) x = 0$$
 , $y'' + K_y(s) y = 0$, (21.5)

with

$$x' \equiv dx/ds$$
, $y' \equiv dy/ds$ (21.6)

$$K_x \equiv B'/(B\rho) + \rho^{-2} \ , \ K_y \equiv -B'/(B\rho)$$
 (21.7)

$$B' \equiv \partial B_u / \partial x \quad . \tag{21.8}$$

The independent variable s is path length along the design trajectory. This motion is called a betatron oscillation because it was initially studied in the context of that type of accelerator. The functions K_x and K_y reflect the transverse focussing—primarily due to quadrupole fields except for the radius of curvature, ρ , term in K_x for a synchrotron—so each equation of motion resembles that for a harmonic oscillator but with spring constants that are a function of position. No terms relating to synchrotron oscillations appear, because their time scale is much longer and in this approximation play no role.

These equations have the form of Hill's equation and so the solution in one plane may be written as

$$x(s) = A\sqrt{\beta(s)} \cos(\psi(s) + \delta), \tag{21.9}$$

where A and δ are constants of integration and the phase advances according to $d\psi/ds=1/\beta$. The dimension of A is the square root of length, reflecting the fact that the oscillation amplitude is modulated by the square root of the amplitude function. In addition to describing the envelope of the oscillation, β also plays the role of an 'instantaneous' λ . The wavelength of a betatron oscillation may be some tens of meters, and so typically values of the amplitude function are of the order of meters rather than on the order of the beam size. The beam optics arrangement generally has some periodicity and the amplitude function is chosen to reflect that periodicity. As noted above, at the interaction point a small value of the amplitude function is desired, and so the focussing optics is tailored in the neighborhood to provide a suitable β^* .

The number of betatron oscillations per turn in a synchrotron is called the *tune* and is given by

$$\nu = \frac{1}{2\pi} \oint \frac{ds}{\beta} \ . \tag{21.10}$$

Expressing the integration constant A in the solution above in terms of x, x' yields the Courant-Snyder invariant

$$A^2 = \gamma(s) x(s)^2 + 2\alpha(s) x(s) x'(s) + \beta(s) x'(s)^2$$

where

$$\alpha \equiv -\beta'/2, \ \gamma \equiv \frac{1+\alpha^2}{\beta}$$
 (21.11)

(The Courant-Snyder parameters α , β and γ employ three Greek letters which have other meanings and the significance at hand must often be recognized from context.) Because β is a function of position in the focusing structure, this ellipse changes orientation and aspect ratio from location to location but the area πA^2 remains the same.

As noted above the transverse emittance is a measure of the area in x, x' (or y, y') phase space occupied by an ensemble of particles. The definition used in Eq. (21.3) is the area that encloses 39% of a Gaussian beam.

For electron synchrotrons the equilibrium emittance results from the balance between synchrotron radiation damping and excitation from quantum fluctuations in the radiation rate. The equilibrium is reached in a time small compared with the storage time.

For present-day hadron synchrotrons, synchrotron radiation does not play a similar role in determining the transverse emittance. Rather the emittance during storage reflects the source properties and the abuse suffered by the particles throughout acceleration and storage. Nevertheless it is useful to argue as follows: Though x' and x can serve as canonically conjugate variables at constant energy this definition of the emittance would not be an adiabatic invariant when the energy changes during the acceleration cycle. However, $\gamma(v/c)x'$, where here γ is the Lorentz factor, is proportional to the transverse momentum and so qualifies as a variable conjugate to x. So often one sees a normalized emittance defined according to

$$\epsilon_N = \gamma \frac{v}{c} \epsilon. \tag{21.12}$$

21.3.2. Phase stability: The particles in a circular collider also undergo synchrotron oscillations. This is usually referred to as motion in the longitudinal degree-of-freedom because particles arrive at a particular position along the accelerator earlier or later than an ideal reference particle. This circumstance results in a finite bunch length, which is related to an energy spread.

For dynamical variables in longitudinal phase space, let us take ΔE and Δt , where these are the energy and time differences from that of the ideal particle. A positive Δt means a particle is behind the ideal particle. The equation of motion is the same as that for a physical pendulum and therefore is nonlinear. But for small oscillations, it reduces to a simple harmonic oscillator:

$$\frac{d^2\Delta t}{dn^2} = -(2\pi\nu_s)^2\Delta t \tag{21.13}$$

where the independent variable n is the turn number and ν_s is the number of synchrotron oscillations per turn, analogous to the betatron oscillation tune defined earlier.

In the high-energy limit, where $v/c \approx 1$,

$$\nu_s = \left[\frac{h\eta \, eV \, \cos\phi_s}{2\pi E}\right]^{1/2} \quad . \tag{21.14}$$

There are four as yet undefined quantities in this expression: the harmonic number h, the slip factor η , the maximum energy eV gain per turn from the acceleration system, and the synchronous phase ϕ_s . The frequency of the RF system is normally a relatively high multiple, h, of the orbit frequency. The slip factor relates the fractional change in the orbit period τ to changes in energy according to

$$\frac{\Delta \tau}{\tau} = \eta \frac{\Delta E}{E} \ . \tag{21.15}$$

At sufficiently high energy, the slip factor just reflects the relationship between path length and energy, since the speed is a constant; η is positive for all the synchrotrons in the tables.

The synchronous phase is a measure of how far up on the RF wave the average particle must ride in order to maintain constant energy in the face of synchrotron radiation. That is, $\sin \phi_s$ is the ratio of the energy loss per turn to the maximum energy per turn that can be provided by the acceleration system. For hadron colliders built to date, $\sin \phi_s$ is effectively zero. This is not the case for electron storage rings; for example, the electron ring of HERA runs at a synchronous phase of 45°.

Now if one has a synchrotron oscillation with amplitudes $\widehat{\Delta t}$ and $\widehat{\Delta E}$,

$$\Delta t = \widehat{\Delta t} \sin(2\pi \nu_s n) , \qquad \Delta E = \widehat{\Delta E} \cos(2\pi \nu_s n)$$
 (21.16)

then the amplitudes are related according to

$$\widehat{\Delta E} = \frac{2\pi\nu_s E}{n\tau} \widehat{\Delta t} . \qquad (21.17)$$

The longitudinal emittance ϵ_{ℓ} may be defined as the phase space area bounded by particles with amplitudes $\widehat{\Delta t}$ and $\widehat{\Delta E}$. In general, the longitudinal emittance for a given amplitude is found by numerical integrations. For $\sin\phi_s=0$, an analytical expression is as follows:

$$\epsilon_{\ell} = \left[\frac{2\pi^3 EeVh}{\tau^2 \eta}\right]^{1/2} (\widehat{\Delta t})^2 \tag{21.18}$$

Again, a Gaussian is a reasonable representation of the longitudinal profile of a well-behaved beam bunch; if $\sigma_{\Delta t}$ is the standard deviation of the time distribution, then the bunch length can be characterized by

$$\ell = c \, \sigma_{\Delta t} \ . \tag{21.19}$$

In the electron case the longitudinal emittance is determined by the synchrotron radiation process just as in the transverse degrees of freedom. For the hadron case the history of acceleration plays a role and because energy and time are conjugate coordinates, the longitudinal emittance is a quasi-invariant.

For HEP bunch length is a significant quantity because if the bunch length becomes larger than β^* the luminosity is adversely affected. This is because β grows parabolically as one proceeds from the IP and so the beam size increases thus lowering the contribution to the luminosity from such locations.

21.3.3. Synchrotron radiation [2]: A relativistic particle undergoing centripetal acceleration radiates at a rate given by the Larmor formula multiplied by the 4th power of the Lorentz factor:

$$P = \frac{1}{6\pi\epsilon_0} \frac{e^2 a^2}{c^3} \gamma^4. \tag{21.20}$$

Here, $a=v^2/\rho$ is the centripetal acceleration of a particle with speed v undergoing deflection with radius of curvature ρ . In a synchrotron

that has a constant radius of curvature within bending magnets, the energy lost due to synchrotron radiation per turn is the above multiplied by the time spent in bending magnets, $2\pi\rho/v$. Expressed in familiar units, this result may be written

$$W = 8.85 \times 10^{-5} \frac{E^4}{\rho}$$
 MeV per turn (21.21)

for electrons at sufficiently high energy that $v \approx c$. The energy E is in GeV and ρ is in kilometers.

The characteristic time for synchrotron radiation processes is the time during which the energy must be replenished by the acceleration system. If f_0 is the orbit frequency, then the characteristic time is given by

$$\tau_0 = \frac{E}{f_0 W} \ . \tag{21.22}$$

Oscillations in each of the three degrees of freedom either damp or antidamp depending on the design of the accelerator. For a simple separated function alternating gradient synchrotron, all three modes damp. The damping time constants are related by Robinson's Theorem [3], which, expressed in terms of τ_0 , is

$$\frac{1}{\tau_x} + \frac{1}{\tau_y} + \frac{1}{\tau_s} = 2\frac{1}{\tau_0} . {(21.23)}$$

Even though all three modes may damp, the emittances do not tend toward zero. Statistical fluctuations in the radiation rate excite synchrotron oscillations and radial betatron oscillations. Thus there is an equilibrium emittance at which the damping and excitation are in balance. The vertical emittance is non-zero due to horizontal-vertical coupling.

The radiation rate for protons is of course down by a factor of the fourth power of the mass ratio, and is given by

$$W = 7.8 \times 10^{-3} \frac{E^4}{\rho}$$
 keV per turn (21.24)

where E is now in TeV and ρ in km. As noted in the Introduction, the LHC will the first proton facility in which synchrotron radiation plays a significant role.

21.3.4. Beam-beam tune shift: In a bunch-bunch collision the particles of one bunch see the other bunch as a nonlinear lens. Therefore the focussing properties of the ring are changed in a way that depends on the transverse oscillation amplitude. And so there is a spread in the frequency of betatron oscillations.

There is an extensive literature on the subject of how large this tune spread can be. In practice, the limiting value is hard to predict. It is consistently larger for electrons because of the beneficial effects of damping from synchrotron radiation.

In order that contributions to the total tune spread arise only at the detector locations, the beams in a multibunch collider are kept apart elsewhere by a variety of techniques. For equal energy particles of opposite charge circulating in the same vacuum chamber, electrostatic separators may be used assisted by a crossing angle if appropriate. For particles of equal energy and of the same charge, a crossing angle is needed not only for tune spread reasons but to steer the particles into two separate beam pipes. In HERA, because of the large ratio of proton to electron energy, separation can be achieved by bending magnets.

21.3.5. Luminosity lifetime: In electron synchrotrons the luminosity degrades during the store primarily due to particles leaving the phase stable region in longitudinal phase space as a result of quantum fluctuations in the radiation rate and bremsstrahlung. For hadron colliders the luminosity deteriorates due to emittance dilution resulting from a variety of processes. In practice, stores are intentionally terminated when the luminosity drops to the point where a refill will improve the integrated luminosity.

21.4. Status and prospects

Present facilities represent a balance between available technology and the desires of High Energy Physics. For forty-five years, beam optics has exploited the invention of alternating gradient focussing. This principle is employed in all colliders both linear and circular. Superconducting technology has grown dramatically in importance during the last two decades. Superconducting magnets are vital to the Tevatron, HERA, and to the future LHC. Superconducting accelerating structures are necessary to CESR, LEP, HERA, Jefferson Laboratory and other facilities requiring high-gradient long pulse length RF systems. Present room temperature accelerating structures produce very short pulses, but with gradients well in excess of the superconducting variety [7].

At present, the next potential facilities are perceived to include the LHC and an electron linear collider. The LHC is an approved project that will represent a major step forward in superconducting magnet technology. No linear collider project has been approved as yet, and the conventional and superconducting approaches compete for prominence. Of perhaps more immediate impact are the B and τ "factories" that are designed to go beyond the $10^{33}~\rm cm^{-2}s^{-1}$ level in luminosity.

In addition to the possibilities of the preceding paragraph, there are other synchrotron-based collider studies underway. Despite formidable R&D challenges a muon-muon collider may become feasible. Proponents of a very large hadron collider at higher energy than the cancelled SSC project are exploring low-cost magnets and tunnels for a facility on the 100 TeV c.m. energy scale.

Ideas abound in accelerator R&D for the long term. Approaches such as wakefield accelerators, plasma-laser combinations, and related investigations may if successful deliver gradients far higher than anything realized today. These studies could potentially lead to a new vision for HEP facilities.

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HIGH-ENERGY COLLIDER PARAMETERS: e^+e^- Colliders (I)

The numbers here were received from representatives of the colliders in 1998 (contact C.G. Wohl, LBNL). Many of the numbers of course change with time, and only the latest values (or estimates) are given here; those in brackets are for coming upgrades. Quantities are, where appropriate, r.m.s. H and V indicate horizontal and vertical directions. Parameters for the defunct SPEAR, DORIS, PETRA, PEP, and TRISTAN colliders may be found in our 1996 edition (Phys. Rev. **D54**, 1 July 1996, Part I).

	VEPP-2M [round beams] (Novosibirsk)	DAΦNE (Frascati)	ϕ FACTORY (Novosibirsk)	$ au ext{-CHARM} FACTORY (Novosibirsk)$	BEPC (China)	VEPP-4M (Novosibirsk)
Physics start date	1974 [1998]	1998	2001	?	1989	1994
Maximum beam energy (GeV)	0.7 [0.55]	0.510 (0.75 max.)	0.55	2.1	2.2	6
Luminosity (10 ³⁰ cm ⁻² s ⁻¹)	5 [100]	135(→540)	2500	10000	10 at 2 GeV	50
Time between collisions (μs)	0.03	0.0108(→0.0027)	0.007	0.027	0.8	0.6
Crossing angle (μ rad)	0	$\pm (1.0 \text{ to } 1.5) \times 10^4$	0	0	0	0
Energy spread (units 10 ⁻³)	0.36	0.40	0.43	0.002-0.7	0.58 at 2.2 GeV	1
Bunch length (cm)	3	3.0	1	1	≈ 5	5
Beam radius (10 ⁻⁶ m)	H/V: 300/10 [90 (round)]	H: 2100 V: 21	35 (beams are round)	33	H: 890 V: 37	H: 1000 V: 30
Free space at interaction point (m)	±1	±0.46 (±157 mrad cone)	±2	±1.5	±2.15	±2
Luminosity lifetime (hr)	continuous	2	continuous	continuous	7–12	2
Filling time (min)	continuous	3 (topping up)	continuous	continuous	30	15
Acceleration period (s)	-	_	_	_	120	150
Injection energy (GeV)	0.2-0.6 [0.2-0.55]	0.510		2.1	1.55	1.8
Transverse emittance $(10^{-9}\pi \text{ rad-m})$	H/V: 110/1.3 [170]	H: 1000 V: 10	125	H: 100–10000 V: 1–10000	H: 660 V: 28	H: 400 V: 20
β*, amplitude function at interaction point (m)	H/V: 0.45/0.045 [0.05]	#: 4.5 V: 0.045	0.01	0.01	H: 1.2 V: 0.05	H: 0.75 V: 0.05
Beam-beam tune shift per crossing (units 10 ⁻⁴)	H/V: 200/500 [1000]	400	1000	500	350	500
RF frequency (MHz)	200	368.25	700	700	199.53	180
Particles per bunch (units 10 ¹⁰)	2 [6.7]	8.9	5	20	20 at 2 GeV	15
Bunches per ring per species	1	30(→120)	11	95	1	2
Average beam current per species (mA)	50 [160]	1313(→5250)	550	1120	40 at 2 GeV	80
Circumference or length (km)	0.018	0.0977	0.047	0.773	0.2404	0.366
Interaction regions	2	2	1	1	2	1
Utility insertions	1	2 × 2	1	1	4	1
Magnetic length of dipole (m)	1	e^+ : 1.21/0.99 e^- : 1.21/0.99	0.8	1.47	1.6	2
Length of standard cell (m)	4.5 [9.0]		_	5	6.6	7.2
Phase advance per cell (deg)	280 [560]		_	60	≈ 60	65
Dipoles in ring	8	e ⁺ : 8(+4 wigglers) e ⁻ : 8(+4 wigglers)	22	112	40 + 4 weak	78
Quadrupoles in ring	20 [12]	e^{+}/e^{-} : 53/53	22	112	68	150
Peak magnetic field (T)	1.8 [1.5]	1.2(→1.76) dipoles 1.8 wigglers	1.8	0.13	0.9028 at 2.8 GeV	0.6

HIGH-ENERGY COLLIDER PARAMETERS: e^+e^- Colliders (II)

The numbers here were received from representatives of the colliders in 1998. Many of the numbers of course change with time, and only the latest values (or estimates) are given here. Quantities are, where appropriate, r.m.s. H and V indicate horizontal and vertical directions; s.c. indicates superconducting.

	CESR (Cornell)	KEKB (KEK)	PEP-II (SLAC)	SLC (SLAC)	LEP (CERN)
Physics start date	1979	1999	1999	1989	1989
Maximum beam energy (GeV)	6	$e^- \times e^+: 8 \times 3.5$	e^- : 7-12 (9.0 nominal) e^+ : 2.5-4 (3.1 ") (nominal $E_{\rm cm} = 10.5~{\rm GeV}$)	50	92 in 1997 (100=max. foreseen
Luminosity (10 ³⁰ cm ⁻² s ⁻¹)	470 at 5.3 GeV	10000	3000	2.5	24 at Z^0 50 at > 90 GeV
Time between collisions (μs)	0.028 to 0.22	0.002	0.0042	8300	22
Crossing angle (µ rad)	±2000	±11,000	0	0	0
Energy spread (units 10 ⁻³)	0.6 at 5.3 GeV	0.7	e ⁻ /e ⁺ : 0.61/0.77	1.2	1.0
Bunch length (cm)	1.8	0.4	e^{-}/e^{+} : 1.1/1.0	0.1	1.0
Beam radius (μm)	H: 500 V: 10	H: 77 V: 1.9	H: 181 V: 5.4	H: 1.5 V: 0.5	H: 200 V: 8
Free space at interaction point (m)	±2.2 (±0.6 to REC quads)	+0.75/-0.58 (+300/-500) mrad cone	±0.2, ±300 mrad cone	±2.8	±3.5
Luminosity lifetime (hr)	3–4	2	2.5	_	$20 \text{ at } Z^0$ 10 at > 90 GeV
Filling time (min)	10 (topping up)	8 (topping up)	3 (topping up)	_	20 to setup 20 to accumulate
Acceleration period (s)		_	_	-	550
Injection energy (GeV)	6	$e^-/e^+: 8/3.5$	2.5–12	45.64	22
Transverse emittance (π rad-nm)	H: 240 V: 6	H: 18 V: 0.36	e ⁻ : 48 (H), 1.5 (V) e ⁺ : 64 (H), 2.0 (V)	H: 0.5 V: 0.05	$H: 35$ $V: 0.25 \rightarrow 1$
β*, amplitude function at interaction point (m)	H: 1.0 V: 0.018	H: 0.33 V: 0.01	e ⁻ : 0.67 (H), 0.02 (V) e ⁺ : 0.50 (H), 0.015 (V)	H: 0.0025 V: 0.0015	H: 1.5 V: 0.05
Beam-beam tune shift per crossing (units 10 ⁻⁴)	420	H: 390 V: 520	300	_	500
RF frequency (MHz)	500	508.887	476	_	352.2
Particles per bunch (units 10 ¹⁰)	15	e ⁻ /e ⁺ : 1.3/3.2	e ⁻ /e ⁺ : 2.7/5.9	4.0	30 in collision 60 in single beam
Bunches per ring per species	9 trains of 2 bunches	5120	1658	1	4 trains of 1 or 2
Average beam current per species (mA)	180	e ⁻ /e ⁺ : 1100/2600	e ⁻ /e ⁺ : 995/2161	0.0008	4 at Z ⁰ 2.5 at > 90 GeV
Beam polarization (%)	_		_	e=: 80	55
Circumference or length (km)	0.768	3.016	2.2	1.45 +1.47	26.66
Interaction regions	1	1	1 (2 possible)	1	4
Utility insertions	3	3	5	_	4
Magnetic length of dipole (m)	1.6-6.6	$e^-/e^+: 5.86/0.915$	e^-/e^+ : 5.4/0.45	2.5	11.66/pair
Length of standard cell (m)	16	e ⁻ /e ⁺ : 75.7/76.1	15.2	5.2	79
Phase advance per cell (deg)	45-90 (no standard cell)	450	e ⁻ /e ⁺ : 60/90	108	90/60
Dipoles in ring	86	e ⁻ /e ⁺ : 116/112	e^-/e^+ : 192/192	460+440	3280+24 inj. + 64 weak
Quadrupoles in ring	104	e ⁻ /e ⁺ : 452/452	e ⁻ /e ⁺ : 290/326		520+288 + 8 s.c.
Peak magnetic field (T)	0.3 normal at 8 0.8 high field GeV	$e^-/e^+: 0.25/0.72$	e^-/e^+ : 0.18/0.75	0.597	0.135

HIGH-ENERGY COLLIDER PARAMETERS: $ep, \bar{p}p$, and pp Colliders

The numbers here were received from representatives of the colliders in 1998. Many of the numbers of course change with time, and only the latest values (or estimates) are given here. Quantities are, where appropriate, r.m.s. H, V, and, s.c. indicate horizontal and vertical directions, and superconducting. The SSC is kept for purposes of comparison.

	HERA (DESY)	$Sp\overline{p}S$ (CERN)	TEVATRON [†] (Fermilab)		HC ERN)	SSC (USA)
Physics start date	1992	1981	1987	2	005	Terminated
Physics end date	-	1990			_	
Particles collided	ер	$p\overline{p}$	$p\overline{p}$	pp	Pb Pb	pp
Maximum beam energy (TeV)	e: 0.030 p: 0.82	0.315 (0.45 in pulsed mode)	1.0	7.0	2.76 TeV/u	20
Luminosity $(10^{30} \text{ cm}^{-2} \text{s}^{-1})$	14	6	210	1.0 × 10 ⁴	0.002	1000
Time between collisions (μs)	0.096	3.8	0.396	0.025	0.125	0.016678
Crossing angle (µ rad)	0	0	0	≥ 200	≤ 200	100 to 200 (135 nominal)
Energy spread (units 10 ⁻³)	e: 0.91 p: 0.2	0.35	0.09	0.1	0.1	0.055
Bunch length (cm)	e: 0.83 p: 8.5	20	38	7.5	7.5	6.0
Beam radius (10 ⁻⁶ m)	e: 280(H), 50(V) p: 265(H), 50(V)	p: 73(H), 36(V) $\bar{p}: 55(H), 27(V)$	p: 34 p̄: 29	16	15	4.8
Free space at interaction point (m)	±5.8	16	±6.5	38	38	±20
Luminosity lifetime (hr)	10	15	7–30	10	6.7	~24
Filling time (min)	e: 60 p: 120	0.5	30	6	20	72
Acceleration period (s)	e: 200 p: 1500	10	86	1	200	1500
Injection energy (TeV)	e: 0.012 p: 0.040	0.026	0.15	0.450	177.4 GeV/u	2
Transverse emittance $(10^{-9}\pi \text{ rad-m})$	e: $42(H), 6(V)$ p: $5(H), 5(V)$	p: 9 p̄: 5	p: 3.5 p: 2.5	0.5	0.5	0.047
β*, amplitude function at interaction point (m)	e: $1(H), 0.7(V)$ p: $7(H), 0.5(V)$	0.6 (H) 0.15 (V)	0.35	0.5	0.5	0.5
Beam-beam tune shift per crossing (units 10 ⁻⁴)	e: 190(H), 360(V) p: 12(H), 9(V)	50	p: 38 p: 97	34	_	8 head on 13 long range
RF frequency (MHz)	e: 499.7 p: 208.2/52.05	100+200	53	400.8	400.8	359.75
Particles per bunch (units 10 ¹⁰)	e: 3 p: 7	p: 15 p: 8	p: 27 p: 7.5	10.5	0.0094	0.8
Bunches per ring per species	e: 189 p: 180	6	36	2835	608	17,424
Average beam current per species (mA)	e: 40 p: 90	p: 6 p: 3	p: 81 p: 22	536	7.8	71
Circumference (km)	6.336	6.911	6.28		3.659	87.12
Interaction regions	ep: 2; e,p: 1 each, internal fixed target	2	2 high £	2 high £ +1	1	4
Utility insertions	4		4		4	2
Magnetic length of dipole (m)	e: 9.185 p: 8.82	6.26	6.12	1	14.3	Mostly 14.928
Length of standard cell (m)	e: 23.5 p: 47	64	59.5	10	06.90	180
Phase advance per cell (deg)	e: 60 p: 90	90	67.8		90	90
Dipoles in ring	e: 396 p: 416	744	774		232 dipoles	$\left\{\begin{array}{cc} H: 8336 \\ V: 88 \end{array}\right\}$ in 2 rings
Quadrupoles in ring	e: 580 p: 280	232	216		ocussing 8 skew	2084 } 2 rings
34	e: C-shaped	H type with	s.c.	1	8.C.	s.c.
Magnet type	p: s.c., collared, cold iron	bent-up coil ends	$\cos \theta$ warm iron	1	in 1 d iron	$\cos \theta$ cold iron
Peak magnetic fold (T)	e: 0.274	1.4 (2 in		 		
Peak magnetic field (T) p source accum. rate (hr ⁻¹)	p: 4.65	pulsed mode) 6 × 10 ¹⁰	4.4 20×10 ¹⁰		8.3	6.790
	-					-
Max. no. \vec{p} in accum. ring		1.2×10^{12}	2.6×10 ¹²			

 $^{^\}dagger\text{TEVATRON}$ numbers are for the year 2000, when it again runs in collider mode.

23. PASSAGE OF PARTICLES THROUGH MATTER

Revised May 1998 by D.E. Groom (LBNL).

23.1. Notation

Table 23.1: Summary of variables used in this section. The kinematic variables β and γ have their usual meanings.

Symbol	Definition	Units or Value
α	Fine structure constant	1/137.035 989 5(61)
M	Incident particle mass	${ m MeV}/c^2$
\boldsymbol{E}	Incident particle energy γMc^2	MeV
T	Kinetic energy	MeV
m_ec^2	Electron mass $\times c^2$	0.510 999 06(15) MeV
r_e	Classical electron radius $e^2/4\pi\epsilon_0 m_e c^2$	2.817 940 92(38) fm
N_A	Avogadro's number	$6.0221367(36)\times10^{23}\mathrm{mol}^{-1}$
ze	Charge of incident particle	• •
\boldsymbol{z}	Atomic number of medium	
\boldsymbol{A}	Atomic mass of medium	$g mol^{-1}$
K/A	$4\pi N_A r_e^2 m_e c^2/A$	0.307075 MeV g^{-1} cm ² for $A = 1$ g mol ⁻¹
I	Mean excitation energy	eV
δ	Density effect correction to ion	ization energy loss
$\hbar\omega_p$	Plasma energy $\sqrt{4\pi N_e r_e^3} \ m_e c^2/\alpha$	$28.816\sqrt{ ho\langle Z/A\rangle} \text{ eV}^{(a)}$
N_c	Electron density	(units of r_e) ⁻³
w_j	Weight fraction of the jth elem	ent in a compound or mixture
n_{j}	∝ number of jth kind of atoms	
X_0	Radiation length	g cm ⁻²
_	$4\alpha re^2 N_A/A$	$(716.408 \text{ g cm}^{-2})^{-1}$ for $A = 1 \text{ g mol}^{-1}$
E_c	Critical energy	MeV
E_s	Scale energy $\sqrt{4\pi/\alpha} \ m_e c^2$	21.2052 MeV
R_{M}	Molière radius	$ m MeV~g^{-1}~cm^2$

⁽a) For ρ in g cm⁻³.

23.2. Ionization energy loss by heavy particles [1-5]

Moderately relativistic charged particles other than electrons lose energy in matter primarily by ionization. The mean rate of energy loss (or stopping power) is given by the Bethe-Bloch equation,

$$-\frac{dE}{dx} = Kz^2 \frac{Z}{A} \frac{1}{\beta^2} \left[\frac{1}{2} \ln \frac{2m_e c^2 \beta^2 \gamma^2 T_{\text{max}}}{I^2} - \beta^2 - \frac{\delta}{2} \right] . \tag{23.1}$$

Here $T_{\rm max}$ is the maximum kinetic energy which can be imparted to a free electron in a single collision, and the other variables are defined in Table 23.1. The units are chosen so that dx is measured in mass per unit area, e.g., in g cm⁻².

In this form, the Bethe-Bloch equation describes the energy loss of pions in a material such as copper to about 1% accuracy for energies between about 6 MeV and 6 GeV. At lower energies corrections for tightly-bound atomic electrons and other effects must be made, and at higher energies radiative effects begin to be important. These limits of validity depend on both the effective atomic number of the absorber and the mass of the slowing particle. Low-energy effects will be discussed in Sec. 23.2.2.

The function as computed for pions on copper is shown by the solid curve in Fig. 23.1, and for pions on other materials in Fig. 23.2. A minor dependence on M at the highest energies is introduced through $T_{\rm max}$, but for all practical purposes in high-energy physics dE/dx in a given material is a function only of β . Except in hydrogen, particles of the same velocity have very similar rates of energy loss in different materials; there is a slow decrease in the rate of energy loss with increasing Z. The qualitative difference in stopping power behavior at high energies between a gas (He) and the other materials shown in Fig. 23.2 is due to the density-effect correction, δ , discussed below.

The stopping power functions are characterized by broad minima whose position drops from $\beta \gamma = 3.5$ to 3.0 as Z goes from 7 to 100.

In practical cases, most relativistic particles (e.g., cosmic-ray muons) have energy loss rates close to the minimum, and are said to be minimum ionizing particles, or mip's.

Eq. (23.1) may be integrated to find the total range R for a particle which loses energy only through ionization. Since dE/dx depends only on β , R/M is a function of E/M or pc/M. In practice, range is a useful concept only for low-energy hadrons ($R \lesssim \lambda_I$, where λ_I is the nuclear interaction length), and for muons below a few hundred GeV (above which radiative effects dominate). R/M as a function of $\beta\gamma = pc/M$ is shown for a variety of materials in Fig. 23.3.

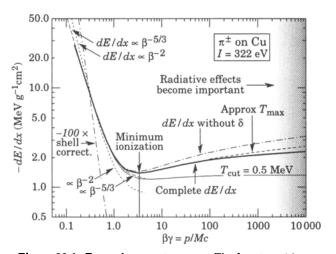


Figure 23.1: Energy loss rate in copper. The function without the density-effect correction, δ , is also shown, as is the loss rate excluding energy transfers with T>0.5 MeV. The shell correction is indicated. The conventional β^{-2} low-energy approximation is compared with $\beta^{-5/3}$.

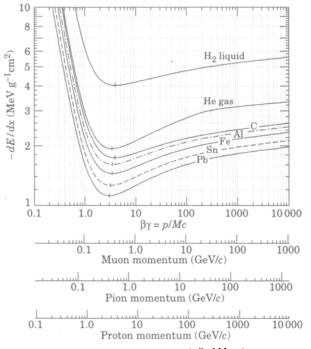


Figure 23.2: Energy loss rate in liquid (bubble chamber) hydrogen, gaseous helium, carbon, aluminum, tin, and lead.

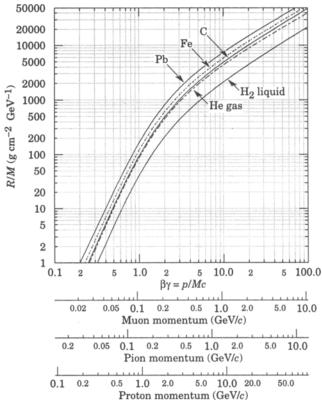


Figure 23.3: Range of heavy charged particles in liquid (bubble chamber) hydrogen, helium gas, carbon, iron, and lead. For example: For a K^+ whose momentum is 700 MeV/c, $\beta\gamma=1.42$. For lead we read $R/M\approx396$, and so the range is 195 g cm⁻².

For a particle with mass M and momentum $M\beta\gamma c$, T_{\max} is given by

$$T_{\rm max} = \frac{2m_e c^2 \, \beta^2 \gamma^2}{1 + 2\gamma m_e/M + (m_e/M)^2} \; . \tag{23.2}$$

It is usual [1,2] to make the "low-energy" approximation $T_{\rm max}=2m_ec^2\,\beta^2\gamma^2$, valid for $2\gamma m_e/M\ll 1$; this, in fact, is done implicitly in many standard references. For a pion in copper, the error thus introduced into dE/dx is greater than 6% at 100 GeV. The correct expression should be used.

At energies of order 100 GeV, the maximum 4-momentum transfer to the electron can exceed 1 GeV/c, where structure effects significantly modify the cross sections. This problem has been investigated by J.D. Jackson [6], who concluded that for hadrons (but not for large nuclei) corrections to dE/dx are negligible below energies where radiative effects dominate. While the cross section for rare hard collisions is modified, the average stopping power, dominated by many softer collisions, is almost unchanged.

The mean excitation energy I is $(10\pm 1~{\rm eV})\times Z$ for elements heavier than sulphur. The values adopted by the ICRU for the chemical elements [7] are now in wide use; these are shown in Fig. 23.4. Machine-readable versions can also be found [8]. Given the availability of these constants and their variation with atomic structure, there seems little point to depending upon approximate formulae, as was done in the past.

Ionization losses by electrons and positrons [7,9,10] are not discussed here. Above the critical energy, which is a few tens of MeV in most materials (see Fig. 23.7, bremsstrahlung is the dominant source of energy loss. This important case is discussed below. The contributions of various electron energy-loss processes in lead are shown in Fig. 24.4.

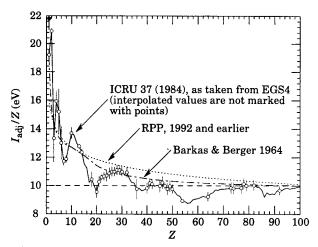


Figure 23.4: Excitation energies (divided by Z) as adopted by the ICRU [7]. Those based on measurement are shown by points with error flags; the interpolated values are simply joined. The solid point is for liquid H_2 ; the open point at 19.2 is for H_2 gas. Also shown are curves based on two approximate formulae.

23.2.1. The density effect: As the particle energy increases, its electric field flattens and extends, so that the distant-collision contribution to Eq. (23.1) increases as $\ln \beta \gamma$. However, real media become polarized, limiting the field extension and effectively truncating this part of the logarithmic rise [4,11-14]. At very high energies,

$$\delta/2 \to \ln(\hbar\omega_p/I) + \ln\beta\gamma - 1/2$$
, (23.3)

where $\delta/2$ is the density effect correction introduced in Eq. (23.1) and $\hbar\omega_p$ is the plasma energy defined in Table 23.1. A comparison with Eq. (23.1) shows that |dE/dx| then grows as $\ln\beta\gamma$ rather than $\ln\beta^2\gamma^2$, and that the mean excitation energy I is replaced by the plasma energy $\hbar\omega_p$. The stopping power as calculated with and without the density effect correction is shown in Fig. 23.1. Since the plasma frequency scales as the square root of the electron density, the correction is much larger for a liquid or solid than for a gas, as is illustrated by the examples in Fig. 23.2.

The density effect correction is usually computed using Sternheimer's parameterization [11]:

iner's parameterization [11]:
$$\delta = \begin{cases} 2(\ln 10)x - \overline{C} & \text{if } x \geq x_1; \\ 2(\ln 10)x - \overline{C} + a(x_1 - x)^k & \text{if } x_0 \leq x < x_1; \\ 0 & \text{if } x < x_0 \text{ (nonconductors)}; \\ \delta_0 10^{2(x-x_0)} & \text{if } x < x_0 \text{ (conductors)} \end{cases}$$

Here $x = \log_{10} \eta = \log_{10}(p/Mc)$. \overline{C} (the negative of the C used in Ref. 11) is obtained by equating the high-energy case of Eq. (23.4) with the limit given in Eq. (23.3). The other parameters are adjusted to give a best fit to the results of detailed calculations for momenta below $Mc\exp(x_1)$. Parameters for elements and nearly 200 compounds and mixtures of interest are published in a variety of places, notably in Ref. 14. A recipe for finding the coefficients for nontabulated materials given by Sternheimer and Peierls [13] is summarized in Ref. 10.

The remaining relativistic rise can be attributed to large energy transfers to a few electrons. If these escape or are otherwise accounted for separately, the energy deposited in an absorbing layer (in contrast to the energy lost by the particle) approaches a constant value, the Fermi plateau (see Sec. 23.2.5 below). The curve in Fig. 23.1 labeled " $T_{\rm cut}=0.5$ MeV" illustrates this behavior. At extreme energies (e.g., > 321 GeV for muons in iron), radiative effects are more important than ionization losses. These are especially relevant for high-energy muons, as discussed in Sec. 23.6.

23.2.2. Energy loss at low energies: A shell correction C/Z is often included in the square brackets of Eq. (23.1) [3,5,7] to correct for atomic binding having been neglected in calculating some of the contributions to Eq. (23.1). We show the Barkas form [3] in Fig. 23.1. For copper it contributes about 1% at $\beta\gamma=0.3$ (kinetic energy 6 MeV for a pion), and the correction decreases very rapidly with energy.

Eq. (23.1) is based on a first-order Born approximation. Higher-order corrections, again important only at lower energy, are normally included by adding a term $z^2L_2(\beta)$ inside the square brackets.

An additional "Barkas correction" $zL_1(\beta)$ makes the stopping power for a negative particle somewhat larger than for a positive particle with the same mass and velocity. In a 1956 paper, Barkas et al. noted that negative pions had a longer range than positive pions [15]. The effect has been measured for a number of negative/positive particle pairs, most recently for antiprotons at the CERN LEAR facility [16].

A detailed discussion of low-energy corrections to the Bethe formula is given in ICRU Report 49 [5]. When the corrections are properly included, the accuracy of the Bethe-Bloch treatment is accurate to about 1% down to $\beta \approx 0.05$, or about 1 MeV for protons.

For $0.01 < \beta < 0.05$, there is no satisfactory theory. For protons, one usually relies on the empirical fitting formulae developed by Andersen and Ziegler [5,17]. For particles moving more slowly than $\approx 0.01c$ (more or less the velocity of the outer atomic electrons), Lindhard has been quite successful in describing electronic stopping power, which is proportional to β [18,19]. Finally, we note that at low energies, e.g., for protons of less than several hundred eV, non-ionizing nuclear recoil energy loss dominates the total energy loss [5,19,20].

As shown in ICRU49 [5] (using data taken from Ref. 17), the nuclear plus electronic proton stopping power in copper is 113 MeV cm² g $^{-1}$ at $T=10~{\rm keV}$, rises to a maximum of 210 MeV cm² g $^{-1}$ at 100–150 keV, then falls to 120 MeV cm² g $^{-1}$ at 1 MeV. Above 0.5–1.0 MeV the corrected Bethe-Block theory is adequate.

23.2.3. Fluctuations in energy loss: The quantity $(dE/dx)\delta x$ is the mean energy loss via interaction with electrons in a layer of the medium with thickness δx . For finite δx , there are fluctuations in the actual energy loss. The distribution is skewed toward high values (the Landau tail) [1,21]. Only for a thick layer $[(dE/dx)\delta x\gg T_{\rm max}]$ is the distribution nearly Gaussian. The large fluctuations in the energy loss are due to the small number of collisions involving large energy transfers. The fluctuations are smaller for the so-called restricted energy loss rate, as discussed in Sec. 23.2.5 below.

23.2.4. Energy loss in mixtures and compounds: A mixture or compound can be thought of as made up of thin layers of pure elements in the right proportion (Bragg additivity). In this case,

$$\frac{dE}{dx} = \sum w_j \left. \frac{dE}{dx} \right|_j , \qquad (23.5)$$

where $dE/dx|_j$ is the mean rate of energy loss (in MeV g cm⁻²) in the jth element. Eq. (23.1) can be inserted into Eq. (23.5) to find expressions for $\langle Z/A \rangle$, $\langle I \rangle$, and $\langle \delta \rangle$; for example, $\langle Z/A \rangle = \sum w_j Z_j/A_j = \sum n_j Z_j/\sum n_j A_j$. However, $\langle I \rangle$ as defined this way is an underestimate, because in a compound electrons are more tightly bound than in the free elements, and $\langle \delta \rangle$ as calculated this way has little relevance, because it is the electron density which matters. If possible, one uses the tables given in Refs. 14 and 10, which include effective excitation energies and interpolation coefficients for calculating the density effect correction for the chemical elements and nearly 200 mixtures and compounds. If a compound or mixture is not found, then one uses the recipe for δ given in Ref. 13 (or Ref. 22), and calculates $\langle I \rangle$ according to the discussion in Ref. 9. (Note the "13%" rule!)

23.2.5. Restricted energy loss rates for relativistic ionizing particles: Fluctuations in energy loss are due mainly to the production of a few high-energy knock-on electrons. Practical detectors often measure the energy deposited, not the energy lost. When energy is carried off by energetic knock-on electrons, it is more appropriate to consider the mean energy loss excluding energy transfers greater than

some cutoff Tcut. The restricted energy loss rate is

$$-\frac{dE}{dx}\Big|_{T < T_{\text{cut}}} = Kz^2 \frac{Z}{A} \frac{1}{\beta^2} \left[\frac{1}{2} \ln \frac{2m_e c^2 \beta^2 \gamma^2 T_{\text{upper}}}{I^2} - \frac{\beta^2}{2} \left(1 + \frac{T_{\text{upper}}}{T_{\text{max}}} \right) - \frac{\delta}{2} \right]$$
(23.6)

where $T_{\rm upper} = {\rm MIN}(T_{\rm cut},T_{\rm max})$. This form agrees with the equation given in previous editions of this Review [23] for $T_{\rm cut} \ll T_{\rm max}$ but smoothly joins the normal Bethe-Bloch function (Eq. (23.1)) for $T_{\rm cut} > T_{\rm max}$.

23.2.6. Energetic knock-on electrons (δ rays): The distribution of secondary electrons with kinetic energies $T \gg I$ is given by [1]

$$\frac{d^2N}{dTdx} = \frac{1}{2} K z^2 \frac{Z}{A} \frac{1}{\beta^2} \frac{F(T)}{T^2}$$
 (23.7)

for $I \ll T \leq T_{\rm max}$, where $T_{\rm max}$ is given by Eq. (23.2). The factor F is spin-dependent, but is about unity for $T \ll T_{\rm max}$. For spin-0 particles $F(T) = (1-\beta^2T/T_{\rm max})$; forms for spins 1/2 and 1 are also given by Rossi [1]. When Eq. (23.7) is integrated from $T_{\rm cut}$ to $T_{\rm max}$, one obtains the difference between Eq. (23.1) and Eq. (23.6). For incident electrons, the indistinguishability of projectile and target means that the range of T extends only to half the kinetic energy of the incident particle. Additional formulae are given in Ref. 24. Equation (23.7) is inaccurate for T close to I: for $2I \lesssim T \lesssim 10I$, the $1/T^2$ dependence above becomes approximately $T^{-\eta}$, with $3 \lesssim \eta \lesssim 5$ [25].

23.2.7. Ionization yields: Physicists frequently relate total energy loss to the number of ion pairs produced near the particle's track. This relation becomes complicated for relativistic particles due to the wandering of energetic knock-on electrons whose ranges exceed the dimensions of the fiducial volume. For a qualitative appraisal of the nonlocality of energy deposition in various media by such modestly energetic knock-on electrons, see Ref. 26. The mean local energy dissipation per local ion pair produced, W, while essentially constant for relativistic particles, increases at slow particle speeds [27]. For gases, W can be surprisingly sensitive to trace amounts of various contaminants [27]. Furthermore, ionization yields in practical cases may be greatly influenced by such factors as subsequent recombination [28].

23.3. Multiple scattering through small angles

A charged particle traversing a medium is deflected by many small-angle scatters. Most of this deflection is due to Coulomb scattering from nuclei, and hence the effect is called multiple Coulomb scattering. (However, for hadronic projectiles, the strong interactions also contribute to multiple scattering.) The Coulomb scattering distribution is well represented by the theory of Molière [29]. It is roughly Gaussian for small deflection angles, but at larger angles (greater than a few θ_0 , defined below) it behaves like Rutherford scattering, having larger tails than does a Gaussian distribution.

If we define

$$\theta_0 = \theta_{\text{plane}}^{\text{rms}} = \frac{1}{\sqrt{2}} \theta_{\text{space}}^{\text{rms}}$$
 (23.8)

then it is sufficient for many applications to use a Gaussian approximation for the central 98% of the projected angular distribution, with a width given by [30,31]

a width given by [30,31]
$$\theta_0 = \frac{13.6 \text{ MeV}}{\beta cp} z \sqrt{x/X_0} \left[1 + 0.038 \ln(x/X_0) \right]. \tag{23.9}$$

Here p, βc , and z are the momentum, velocity, and charge number of the incident particle, and x/X_0 is the thickness of the scattering medium in radiation lengths (defined below). This value of θ_0 is from a fit to Molière distribution [29] for singly charged particles with $\beta=1$ for all Z, and is accurate to 11% or better for $10^{-3} < x/X_0 < 100$.

Eq. (23.9) describes scattering from a single material, while the usual problem involves the multiple scattering of a particle traversing many different layers and mixtures. Since it is from a fit to a Molière distribution, it is incorrect to add the individual θ_0 contributions in quadrature; the result is systematically too small. It is much more accurate to apply Eq. (23.9) once, after finding x and X_0 for the combined scatterer.

Lynch and Dahl have extended this phenomenological approach, fitting Gaussian distributions to a variable fraction of the Molière distribution for arbitrary scatterers [31], and achieve accuracies of 2% or better.

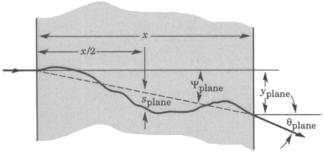


Figure 23.5: Quantities used to describe multiple Coulomb scattering. The particle is incident in the plane of the figure.

The nonprojected (space) and projected (plane) angular distributions are given approximately by [29]

$$\frac{1}{2\pi\,\theta_0^2}\,\exp\left(-\frac{\theta_{\rm space}^2}{2\theta_0^2}\right)\,d\Omega\;,\tag{23.10}$$

$$\frac{1}{\sqrt{2\pi}\,\theta_0}\,\exp\left(-\frac{\theta_{\rm plane}^2}{2\theta_0^2}\right)\,d\theta_{\rm plane}\;, \tag{23.11}$$

where θ is the deflection angle. In this approximation, $\theta_{\mathrm{space}}^2 \approx (\theta_{\mathrm{plane},x}^2 + \theta_{\mathrm{plane},y}^2)$, where the x and y axes are orthogonal to the direction of motion, and $d\Omega \approx d\theta_{\mathrm{plane},x} \, d\theta_{\mathrm{plane},y}$. Deflections into $\theta_{\mathrm{plane},x}$ and $\theta_{\mathrm{plane},y}$ are independent and identically distributed.

Figure 23.5 shows these and other quantities sometimes used to describe multiple Coulomb scattering. They are

$$\psi_{\text{plane}}^{\text{rms}} = \frac{1}{\sqrt{3}} \theta_{\text{plane}}^{\text{rms}} = \frac{1}{\sqrt{3}} \theta_0$$
, (23.12)

$$y_{\text{plane}}^{\text{rms}} = \frac{1}{\sqrt{3}} x \theta_{\text{plane}}^{\text{rms}} = \frac{1}{\sqrt{3}} x \theta_0$$
, (23.13)

$$s_{\text{plane}}^{\text{rms}} = \frac{1}{4\sqrt{3}} x \theta_{\text{plane}}^{\text{rms}} = \frac{1}{4\sqrt{3}} x \theta_0. \qquad (23.14)$$

All the quantitative estimates in this section apply only in the limit of small $\theta_{\mathrm{plane}}^{\mathrm{rms}}$ and in the absence of large-angle scatters. The random variables $s,\ \psi,\ y,$ and θ in a given plane are distributed in a correlated fashion (see Sec. 28.1 of this *Review* for the definition of the correlation coefficient). Obviously, $y \approx x\psi$. In addition, y and θ have the correlation coefficient $\rho_{y\theta} = \sqrt{3}/2 \approx 0.87$. For Monte Carlo generation of a joint $(y_{\mathrm{plane}},\theta_{\mathrm{plane}})$ distribution, or for other calculations, it may be most convenient to work with independent Gaussian random-variables (z_1,z_2) with mean zero and variance one, and then set

$$y_{\text{plane}} = z_1 x \,\theta_0 (1 - \rho_{y\theta}^2)^{1/2} / \sqrt{3} + z_2 \,\rho_{y\theta} x \,\theta_0 / \sqrt{3}$$
$$= z_1 x \,\theta_0 / \sqrt{12} + z_2 x \,\theta_0 / 2 ; \qquad (23.15)$$

$$\theta_{\text{plane}} = z_2 \, \theta_0 \, . \tag{23.16}$$

Note that the second term for $y_{\rm plane}$ equals $x\,\theta_{\rm plane}/2$ and represents the displacement that would have occurred had the deflection $\theta_{\rm plane}$ all occurred at the single point x/2.

For heavy ions the multiple Coulomb scattering has been measured and compared with various theoretical distributions [32].

23.4. Radiation length and associated quantities

In dealing with electrons and photons at high energies, it is convenient to measure the thickness of the material in units of the radiation length X_0 . This is the mean distance over which a high-energy electron loses all but 1/e of its energy by bremsstrahlung, and is the appropriate scale length for describing high-energy electromagnetic cascades. X_0 has been calculated and tabulated by Y.S. Tsai [33]:

$$\frac{1}{X_0} = 4\alpha r_e^2 \frac{N_A}{A} \left\{ Z^2 \left[L_{\rm rad} - f(Z) \right] + Z L'_{\rm rad} \right\}. \tag{23.17}$$

For A=1 g mol⁻¹, $4\alpha re^2N_A/A=(716.408 \text{ g cm}^{-2})^{-1}$. $L_{\rm rad}$ and $L'_{\rm rad}$ are given in Table 23.2. The function f(Z) is an infinite sum, but for elements up to uranium can be represented to 4-place accuracy by $f(Z)=a^2[(1+a^2)^{-1}+0.20206$

$$-0.0369 a^2 + 0.0083 a^4 - 0.002 a^6$$
 (23.18)

where $a = \alpha Z$ [34].

Table 23.2: Tsai's L_{rad} and L'_{rad} , for use in calculating the radiation length in an element using Eq. (23.17).

Element	\boldsymbol{z}	$L_{ m rad}$	$L'_{ m rad}$
H	1	5.31	6.144
\mathbf{He}	2	4.79	5.621
Li	3	4.74	5.805
Be	4	4.71	5.924
Others	> 4	$\ln(184.15Z^{-1/3})$	$\ln(1194 Z^{-2/3})$

Although it is easy to use Eq. (23.17) to calculate X_0 , the functional dependence on Z is somewhat hidden. Dahl provides a compact fit to the data [35]:

$$X_0 = \frac{716.4 \text{ g cm}^{-2} A}{Z(Z+1) \ln(287/\sqrt{Z})}$$
 (23.19)

Results obtained with this formula agree with Tsai's values to better than 2.5% for all elements except helium, where the result is about 5% low.

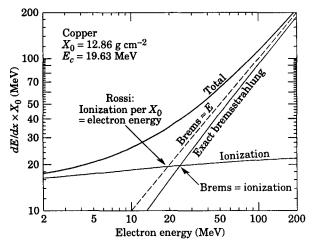


Figure 23.6: Two definitions of the critical energy E_c .

The radiation length in a mixture or compound may be approximated by

$$1/X_0 = \sum w_j/X_j \,\,, \tag{23.20}$$

where w_j and X_j are the fraction by weight and the radiation length for the jth element.

An electron loses energy by bremsstrahlung at a rate nearly proportional to its energy, while the ionization loss rate varies only logarithmically with the electron energy. The critical energy E_c is sometimes defined as the energy at which the two loss rates are equal [36]. Berger and Seltzer [36] also give the approximation $E_c = (800 \text{ MeV})/(Z+1.2)$. This formula has been widely quoted, and has been given in previous editions of this Review [23]. Among alternate definitions is that of Rossi [1], who defines the critical energy as the energy at which the ionization loss per radiation length is equal to the electron energy. Equivalently, it is the same as the first definition with the approximation $|dE/dx|_{\text{brems}} \approx E/X_0$. These definitions are illustrated in the case of copper in Fig. 23.6.

The accuracy of approximate forms for E_c has been limited by the failure to distinguish between gases and solid or liquids, where there

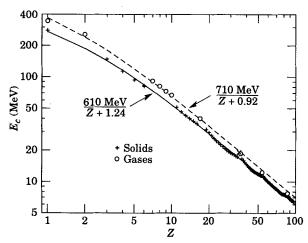


Figure 23.7: Electron critical energy for the chemical elements, using Rossi's definition [1]. The fits shown are for solids and liquids (solid line) and gases (dashed line). The rms deviation is 2.2% for the solids and 4.0% for the gases. (Computed with code supplied by A. Fassó.)

is a substantial difference in ionization at the relevant energy because of the density effect. We distinguish these two cases in Fig. 23.7. Fits were also made with functions of the form $a/(Z+b)^{\alpha}$, but α was essentially unity.

The transverse development of electromagnetic showers in different materials scales fairly accurately with the *Molière radius* R_M , given by [37,38]

$$R_M = X_0 E_s / E_c , (23.21)$$

where $E_s \approx 21$ MeV (see Table 23.1), and the Rossi definition of E_c is used

In a material containing a weight fraction w_j of the element with critical energy E_{cj} and radiation length X_j , the Molière radius is given by

$$\frac{1}{R_M} = \frac{1}{E_s} \sum \frac{w_j E_{cj}}{X_j} . {23.22}$$

For very high-energy photons, the total e^+e^- pair-production cross section is approximately

$$\sigma = \frac{7}{9}(A/X_0N_A) , \qquad (23.23)$$

where A is the atomic weight of the material and N_A is Avogadro's number. Equation Eq. (23.23) is accurate to within a few percent down to energies as low as 1 GeV. The cross section decreases at lower energies, as shown in Fig. 24.4 of this *Review*. As the energy decreases, a number of other processes become important, as is shown in Fig. 24.3 of this *Review*.

23.5. Electromagnetic cascades

When a high-energy electron or photon is incident on a thick absorber, it initiates an electromagnetic cascade as pair production and bremsstrahlung generate more electrons and photons with lower energy. The longitudinal development is governed by the high-energy part of the cascade, and therefore scales as the radiation length in the material. Electron energies eventually fall below the critical energy, and then dissipate their energy by ionization and excitation rather than by the generation of more shower particles. In describing shower behavior, it is therefore convenient to introduce the scale variables

$$t = x/X_0$$

$$y = E/E_c , \qquad (23.24)$$

so that distance is measured in units of radiation length and energy in units of critical energy.

Longitudinal profiles for an EGS4 [22] simulation of a 30 GeV electron-induced cascade in iron are shown in Fig. 23.8. The number of particles crossing a plane (very close to Rossi's II function [1]) is sensitive to the cutoff energy, here chosen as a total energy of

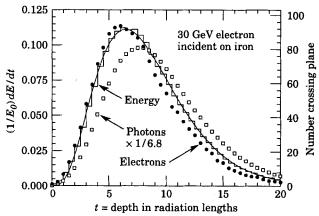


Figure 23.8: An EGS4 simulation of a 30 GeV electron-induced cascade in iron. The histogram shows fractional energy deposition per radiation length, and the curve is a gamma-function fit to the distribution. Circles indicate the number of electrons with total energy greater than 1.5 MeV crossing planes at $X_0/2$ intervals (scale on right) and the squares the number of photons with $E \geq 1.5$ MeV crossing the planes (scaled down to have same area as the electron distribution).

1.5 MeV for both electrons and photons. The electron number falls off more quickly than energy deposition. This is because, with increasing depth, a larger fraction of the cascade energy is carried by photons. Exactly what a calorimeter measures depends on the device, but it is not likely to be exactly any of the profiles shown. In gas counters it may be very close to the electron number, but in glass Čerenkov detectors and other devices with "thick" sensitive regions it is closer to the energy deposition (total track length). In such detectors the signal is proportional to the "detectable" track length T_d , which is in general less than the total track length T_d . Practical devices are sensitive to electrons with energy above some detection threshold E_d , and $T_d = T F(E_d/E_c)$. An analytic form for $F(E_d/E_c)$ obtained by Rossi [1] is given by Fabjan [39]; see also Amaldi [40].

The mean longitudinal profile of the energy deposition in an electromagnetic cascade is reasonably well described by a gamma distribution [41]:

$$\frac{dE}{dt} = E_0 b \frac{(bt)^{a-1} e^{-bt}}{\Gamma(a)}$$
 (23.25)

The maximum $t_{\rm max}$ occurs at (a-1)/b. We have made fits to shower profiles in elements ranging from carbon to uranium, at energies from 1 GeV to 100 GeV. The energy deposition profiles are well described by Eq. (23.25) with

$$t_{\text{max}} = (a-1)/b = 1.0 \times (\ln y + C_j)$$
, $j = e, \gamma$, (23.26)

where $C_e=-0.5$ for electron-induced cascades and $C_{\gamma}=+0.5$ for photon-induced cascades. To use Eq. (23.25), one finds (a-1)/b from Eq. (23.26) and Eq. (23.24), then finds a either by assuming $b\approx 0.5$ or by finding a more accurate value from Fig. 23.9. The results are very similar for the electron number profiles, but there is some dependence on the atomic number of the medium. A similar form for the electron number maximum was obtained by Rossi in the context of his "Approximation B," [1] (see Fabjan's review in Ref. 39), but with $C_e=-1.0$ and $C_{\gamma}=-0.5$; we regard this as superseded by the EGS4 result.

The "shower length" $X_s = X_0/b$ is less conveniently parameterized, since b depends upon both Z and incident energy, as shown in Fig. 23.9. As a corollary of this Z dependence, the number of electrons crossing a plane near shower maximum is underestimated using Rossi's approximation for carbon and seriously overestimated for uranium. Essentially the same b values are obtained for incident electrons and photons. For many purposes it is sufficient to take $b \approx 0.5$.

The gamma distribution is very flat near the origin, while the EGS4 cascade (or a real cascade) increases more rapidly. As a result Eq. (23.25) fails badly for about the first two radiation lengths; it was necessary to exclude this region in making fits.

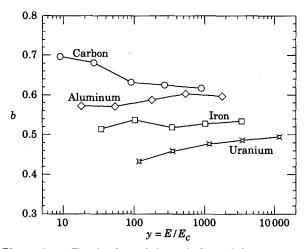


Figure 23.9: Fitted values of the scale factor b for energy deposition profiles obtained with EGS4 for a variety of elements for incident electrons with $1 \le E_0 \le 100$ GeV. Values obtained for incident photons are essentially the same.

Because fluctuations are important, Eq. (23.25) should be used only in applications where average behavior is adequate. Grindhammer et al. have developed fast simulation algorithms in which the variance and correlation of a and b are obtained by fitting Eq. (23.25) to individually simulated cascades, then generating profiles for cascades using a and b chosen from the correlated distributions [42].

Measurements of the lateral distribution in electromagnetic cascades are shown in Refs. 37 and 38. On the average, only 10% of the energy lies outside the cylinder with radius R_M . About 99% is contained inside of $3.5R_M$, but at this radius and beyond composition effects become important and the scaling with R_M fails. The distributions are characterized by a narrow core, and broaden as the shower develops. They are often represented as the sum of two Gaussians, and Grindhammer [42] describes them with the function

$$f(r) = \frac{2r R^2}{(r^2 + R^2)^2} , \qquad (23.27)$$

where R is a phenomenological function of x/X_0 and $\ln E$.

23.6. Muon energy loss at high energy

At sufficiently high energies, radiative processes become more important than ionization for all charged particles. For muons and pions in materials such as iron, this "critical energy" occurs at several hundred GeV. Radiative effects dominate the energy loss of energetic muons found in cosmic rays or produced at the newest accelerators. These processes are characterized by small cross sections, hard spectra, large energy fluctuations, and the associated generation of electromagnetic and (in the case of photonuclear interactions) hadronic showers [45–53]. As a consequence, at these energies the treatment of energy loss as a uniform and continuous process is for many purposes inadequate.

It is convenient to write the average rate of muon energy loss as [43]

$$-dE/dx = a(E) + b(E)E. (23.28)$$

Here a(E) is the ionization energy loss given by Eq. (23.1), and b(E) is the sum of e^+e^- pair production, bremsstrahlung, and photonuclear contributions. To the approximation that these slowly-varying functions are constant, the mean range x_0 of a muon with initial energy E_0 is given by

$$x_0 \approx (1/b) \ln(1 + E_0/E_{\mu c})$$
, (23.29)

where $E_{\mu c}=a/b$. Figure 23.10 shows contributions to b(E) for iron. Since $a(E)\approx 0.002$ GeV g⁻¹ cm², b(E)E dominates the energy loss above several hundred GeV, where b(E) is nearly constant. The rate of energy loss for muons in hydrogen, uranium, and iron is shown in Fig. 23.11 [44].

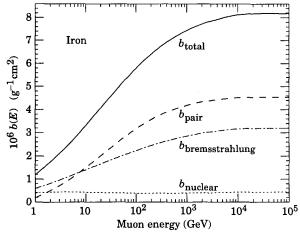


Figure 23.10: Contributions to the fractional energy loss by muons in iron due to e^+e^- pair production, bremsstrahlung, and photonuclear interactions, as obtained from Lohmann *et al.* [44].

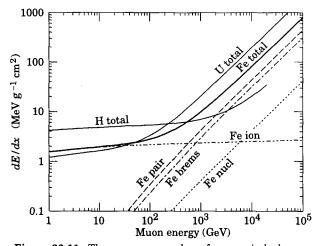


Figure 23.11: The average energy loss of a muon in hydrogen, iron, and uranium as a function of muon energy. Contributions to dE/dx in iron from ionization and the processes shown in Fig. 23.10 are also shown.

The "muon critical energy" $E_{\mu c}$ can be defined more exactly as the energy at which radiative and ionization losses are equal, and can be found by solving $E_{\mu c} = a(E_{\mu c})/b(E_{\mu c})$. This definition corresponds to the solid-line intersection in Fig. 23.6, and is different from the Rossi definition we used for electrons. It serves the same function: below $E_{\mu c}$ ionization losses dominate, and above $E_{\mu c}$ dominate. The dependence of $E_{\mu c}$ on atomic number Z is shown in Fig. 23.12.

The radiative cross sections are expressed as functions of the fractional energy loss ν . The bremsstrahlung cross section goes roughly as $1/\nu$ over most of the range, while for the pair production case the distribution goes as ν^{-3} to ν^{-2} (see Ref. 55). "Hard" losses are therefore more probable in bremsstrahlung, and in fact energy losses due to pair production may very nearly be treated as continuous. The calculated momentum distribution of an incident 1 TeV/c muon beam after it crosses 3 m of iron is shown in Fig. 23.13. The most probable loss is 9 GeV, or 3.8 MeV g⁻¹cm². The full width at half maximum is 7 GeV/c, or 0.7%. The radiative tail is almost entirely due to bremsstrahlung; this includes most of the 10% that lost more than 2.8% of their energy. Most of the 3.3% that lost more than 10% of their incident energy experienced photonuclear interactions, which are concentrated in rare, relatively hard collisions. The latter can exceed nominal detector resolution [56], necessitating the reconstruction of lost energy. Electromagnetic and hadronic cascades in detector materials can obscure muon tracks in detector planes and reduce tracking efficiency [57].

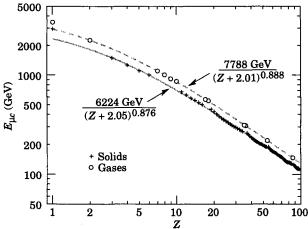


Figure 23.12: Muon critical energy for the chemical elements, defined as the energy at which radiative and ionization energy loss rates are equal. The equality comes at a higher energy for gases than for solids or liquids with the same atomic number because of a smaller density effect reduction of the ionization losses. The fits shown in the figure exclude hydrogen. Alkali metals fall 3-4% above the fitted function for alkali metals, while most other solids are within 2% of the function. Among the gases the worst fit is for neon (1.4% high). (Courtesy of N.V. Mokhov and S.I. Striganov.)

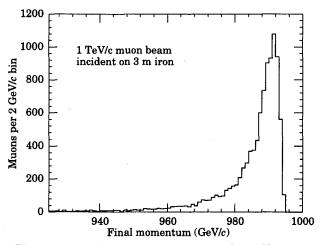


Figure 23.13: The momentum distribution of 1 TeV/c muons after traversing 3 m of iron, as obtained with Van Ginniken's TRAMU muon transport code [55].

23.7. Čerenkov and transition radiation [4,58,59]

A charged particle radiates if its velocity is greater than the local phase velocity of light (Čerenkov radiation) or if it crosses suddenly from one medium to another with different optical properties (transition radiation). Neither process is important for energy loss, but both are used in high-energy physics detectors.

<u>Čerenkov Radiation</u>. The half-angle θ_c of the Čerenkov cone for a particle with velocity β_c in a medium with index of refraction n is

$$\theta_c = \arccos(1/n\beta)$$
 $\approx \sqrt{2(1-1/n\beta)}$ for small θ_c , e.g. in gases. (23.30)

The threshold velocity β_t is 1/n, and $\gamma_t = 1/(1 - \beta_t^2)^{1/2}$. Therefore, $\beta_t \gamma_t = 1/(2\delta + \delta^2)^{1/2}$, where $\delta = n - 1$. Values of δ for various commonly used gases are given as a function of pressure and wavelength in Ref. 60. For values at atmospheric pressure, see Table 6.1. Data for other commonly used materials are given in Ref. 61.

The number of photons produced per unit path length of a particle with charge ze and per unit energy interval of the photons is

$$\frac{d^2 N}{dE dx} = \frac{\alpha z^2}{\hbar c} \sin^2 \theta_c = \frac{\alpha^2 z^2}{r_e m_e c^2} \left(1 - \frac{1}{\beta^2 n^2(E)} \right)$$

$$\approx 370 \sin^2 \theta_c(E) \text{ eV}^{-1} \text{cm}^{-1} \qquad (z = 1) , \qquad (23.31)$$

or, equivalently,

$$\frac{d^2N}{dxd\lambda} = \frac{2\pi\alpha z^2}{\lambda^2} \left(1 - \frac{1}{\beta^2 n^2(\lambda)}\right) . \tag{23.32}$$

The index of refraction is a function of photon energy E, as is the sensitivity of the transducer used to detect the light. For practical use, Eq. (23.31) must be multiplied by the the transducer response function and integrated over the region for which $\beta n(E) > 1$. Further details are given in the discussion of Čerenkov detectors in the Detectors section (Sec. 25 of this *Review*).

<u>Transition Radiation</u>. The energy radiated when a particle with charge ze crosses the boundary between vacuum and a medium with plasma frequency ω_p is

$$I = \alpha z^2 \gamma \hbar \omega_p / 3 , \qquad (23.33)$$

where

$$\begin{split} \hbar\omega_p &= \sqrt{4\pi N_e r_e^3} \ m_e c^2/\alpha \\ &= \sqrt{4\pi N_e a_\infty^3} \ 2\times 13.6 \ \text{eV} \ . \end{split} \tag{23.34}$$

Here N_e is the electron density in the medium, r_e is the classical electron radius, and a_{∞} is the Bohr radius. For styrene and similar materials, $\sqrt{4\pi N_e a_{\infty}^3} \approx 0.8$, so that $\hbar \omega_p \approx 20$ eV. The typical emission angle is $1/\gamma$.

The radiation spectrum is logarithmically divergent at low energies and decreases rapidly for $\hbar\omega/\gamma\hbar\omega_p>1$. About half the energy is emitted in the range $0.1 \le \hbar\omega/\gamma\hbar\omega_p \le 1$. For a particle with $\gamma=10^3$, the radiated photons are in the soft x-ray range 2 to 20 eV. The γ dependence of the emitted energy thus comes from the hardening of the spectrum rather than from an increased quantum yield. For a typical radiated photon energy of $\gamma\hbar\omega_p/4$, the quantum yield is

$$N_{\gamma} \approx \frac{1}{2} \frac{\alpha z^2 \gamma \hbar \omega_p}{3} / \frac{\gamma \hbar \omega_p}{4}$$

 $\approx \frac{2}{3} \alpha z^2 \approx 0.5\% \times z^2$. (23.35)

More precisely, the number of photons with energy $\hbar\omega > \hbar\omega_0$ is given by [4]

$$N_{\gamma}(\hbar\omega > \hbar\omega_0) = \frac{\alpha z^2}{\pi} \left[\left(\ln \frac{\gamma \hbar\omega_p}{\hbar\omega_0} - 1 \right)^2 + \frac{\pi^2}{12} \right] , \qquad (23.36)$$

within corrections of order $(\hbar\omega_0/\gamma\hbar\omega_p)^2$. The number of photons above a fixed energy $\hbar\omega_0\ll\gamma\hbar\omega_p$ thus grows as $(\ln\gamma)^2$, but the number above a fixed fraction of $\gamma\hbar\omega_p$ (as in the example above) is constant. For example, for $\hbar\omega>\gamma\hbar\omega_p/10$, $N_\gamma=2.519\,\alpha z^2/\pi=0.59\%\times z^2$.

The yield can be increased by using a stack of plastic foils with gaps between. However, interference can be important, and the soft x rays are readily absorbed in the foils. The first problem can be overcome by choosing thicknesses and spacings large compared to the "formation length" $D = \gamma c/\omega_p$, which in practical situations is tens of μ m. Other practical problems are discussed in Sec. 25.

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24. PHOTON AND ELECTRON INTERACTIONS WITH MATTER

Revised April 1998 by D.E. Groom (LBNL).

Photon Attenuation Length

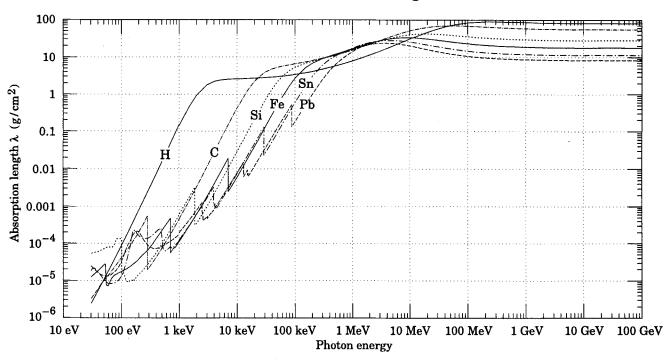


Figure 24.1: The photon mass attenuation length (or mean free path) $\lambda = 1/(\mu/\rho)$ for various elemental absorbers as a function of photon energy. The mass attenuation coefficient is μ/ρ , where ρ is the density. The intensity I remaining after traversal of thickness t (in mass/unit area) is given by $I = I_0 \exp(-t/\lambda)$. The accuracy is a few percent. For a chemical compound or mixture, $1/\lambda_{\text{eff}} \approx \sum_{\text{elements}} w_Z/\lambda_Z$, where w_Z is the proportion by weight of the element with atomic number Z. The processes responsible for attenuation are given in Fig. 24.4. Since coherent processes are included, not all these processes result in energy deposition.

The data for 30 eV < E < 1 keV are obtained from http://www-cxro.lbl.gov/optical_constants (courtesy of Eric M. Gullikson, LBNL). The data for 1 keV < E < 100 GeV are from http://physics.nist.gov/PhysRefData, through the courtesy of John H. Hubbell (NIST).

Photon Pair Conversion Probability

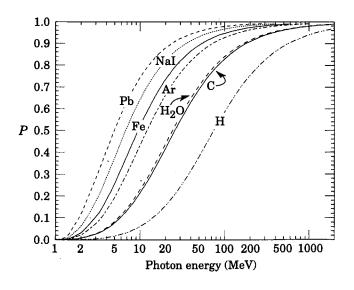


Figure 24.2: Probability P that a photon interaction will result in conversion to an e^+e^- pair. Except for a few-percent contribution from photonuclear absorption around 10 or 20 MeV, essentially all other interactions in this energy range result in Compton scattering off an atomic electron. For a photon attenuation length λ (Fig. 24.1), the probability that a given photon will produce an electron pair (without first Compton scattering) in thickness t of absorber is $P[1-\exp(-t/\lambda)]$.



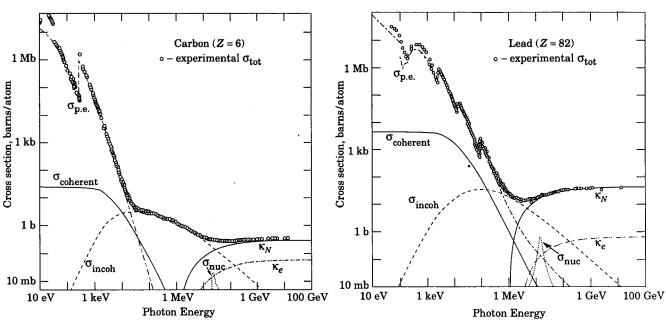


Figure 24.3: Photon total cross sections as a function of energy in carbon and lead, showing the contributions of different processes:

 $\sigma_{p.e.}$ = Atomic photo-effect (electron ejection, photon absorption)

 $\sigma_{\mathrm{coherent}} = \mathrm{Coherent}$ scattering (Rayleigh scattering—atom neither ionized nor excited)

 $\sigma_{\mathrm{incoherent}} = \mathrm{Incoherent}$ scattering (Compton scattering off an electron)

 κ_n = Pair production, nuclear field

 κ_e = Pair production, electron field

 $\sigma_{\rm nuc}$ = Photonuclear absorption (nuclear absorption, usually followed by emission of a neutron or other particle)

From Hubbell, Gimm, and Øverbø, J. Phys. Chem. Ref. Data 9, 1023 (80). Data for these and other elements, compounds, and mixtures may be obtained from http://physics.nist.gov/PhysRefData. The photon total cross section is assumed approximately flat for at least two decades beyond the energy range shown. Figures courtesy J.H. Hubbell (NIST).

Fractional Energy Loss for Electrons and Positrons in Lead

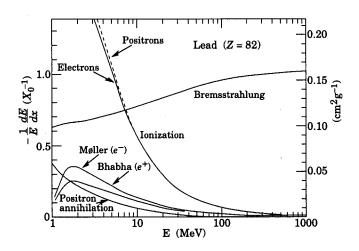


Figure 24.4: Fractional energy loss per radiation length in lead as a function of electron or positron energy. Electron (positron) scattering is considered as ionization when the energy loss per collision is below 0.255 MeV, and as Moller (Bhabha) scattering when it is above. Adapted from Fig. 3.2 from Messel and Crawford, Electron-Photon Shower Distribution Function Tables for Lead, Copper, and Air Absorbers, Pergamon Press, 1970. Messel and Crawford use $X_0(Pb) = 5.82 \text{ g/cm}^2$, but we have modified the figures to reflect the value given in the Table of Atomic and Nuclear Properties of Materials, namely $X_0(Pb)$ $= 6.4 \text{ g/cm}^2$. The development of electron-photon cascades is approximately independent of absorber when the results are expressed in terms of inverse radiation lengths (i.e., scale on left of plot).

25. PARTICLE DETECTORS

Revised 1997 (see the various sections for authors).

In this section we give various parameters for common detector components. The quoted numbers are usually based on typical devices, and should be regarded only as rough approximations for new designs. A more detailed discussion of detectors can be found in Ref. 1. In Table 25.1 are given typical spatial and temporal resolutions of common detectors.

Table 25.1: Typical detector characteristics.

Detector Type	Accuracy (rms)	Resolution Time	Dead Time
Bubble chamber	10 to 150 μm	1 ms	50 ms
Streamer chamber	$300~\mu\mathrm{m}$	$2~\mu s$	100 ms
Proportional chamber	$\geq 300~\mu\mathrm{m}^{b,c}$	50 ns	200 ns
Drift chamber	50 to 300 μm	2 ns^d	100 ns
Scintillator		150 ps	10 ns
Emulsion	$1~\mu\mathrm{m}$		_
Silicon strip	$\frac{\text{pitch }^e}{3 \text{ to } 7}$	f	f
Silicon pixel	$2 \mu m^g$	f	f

- ^a Multiple pulsing time.
- ^b 300 μ m is for 1 mm pitch.
- ^c Delay line cathode readout can give $\pm 150~\mu m$ parallel to anode wire.
- d For two chambers.
- ^e The highest resolution ("7") is obtained for small-pitch detectors ($\lesssim 25 \ \mu m$) with pulse-height-weighted center finding.
- f Limited at present by properties of the readout electronics. (Time resolution of ≤ 15 ns is planned for the SDC silicon tracker.)
- g Analog readout of 34 μm pitch, monolithic pixel detectors.

25.1. Organic scintillators

Written October 1995 by K.F. Johnson (FSU).

Organic scintillators are broadly classed into three types, crystalline, liquid, and plastic, all of which utilize the ionization produced by charged particles (see the section on "Passage of particles through matter" (Sec. 23.2) of this *Review*) to generate optical photons, usually in the blue to green wavelength regions [2]. Plastic scintillators are by far the most widely used and we address them primarily; however, most of the discussion will also have validity for liquid scintillators with obvious caveats. Crystal organic scintillators are practically unused in high-energy physics.

Densities range from 1.03 to 1.20 g cm⁻³. Typical photon yields are about 1 photon per 100 eV of energy deposit [3]. A one-cm-thick scintillator traversed by a minimum-ionizing particle will therefore yield $\approx 2\times 10^4$ photons. The resulting photoelectron signal will depend on the collection and transport efficiency of the optical package and the quantum efficiency of the photodetector.

Plastic scintillators do not respond linearly to the ionization density. Very dense ionization columns emit less light than expected on the basis of dE/dx for minimum-ionizing particles. A widely used semi-empirical model by Birks posits that recombination and quenching effects between the excited molecules reduce the light yield [9]. These effects are more pronounced the greater the density of the excited molecules. Birks' formula is

$$\frac{d\mathcal{L}}{dx} = \mathcal{L}_0 \frac{dE/dx}{1 + k_B dE/dx} , \qquad (25.1)$$

where \mathscr{L} is the luminescence, \mathscr{L}_0 is the luminescence at low specific ionization density, and k_B is Birks' constant, which must be determined for each scintillator by measurement.

Decay times are in the ns range; risetimes are much faster. The combination of high light yield and fast response time allows the possibility of sub-ns timing resolution [4]. The fraction of light emitted during the decay "tail" can depend on the exciting particle. This allows pulse shape discrimination as a technique to carry out particle identification. Because of the hydrogen content (carbon to hydrogen ratio ≈ 1) plastic scintillator is sensitive to proton recoils from neutrons. Ease of fabrication into desired shapes and low cost has made plastic scintillators a common detector component. Recently, plastic scintillators in the form of scintillating fibers have found widespread use in tracking and calorimetry [5].

25.1.1. Scintillation mechanism:

Scintillation: A charged particle traversing matter leaves behind it a wake of excited molecules. Certain types of molecules, however, will release a small fraction ($\approx 3\%$) of this energy as optical photons. This process, scintillation, is especially marked in those organic substances which contain aromatic rings, such as polystyrene, polyvinyltoluene, and napthalene. Liquids which scintillate include toluene and xylene.

Fluorescence: In fluorescence, the initial excitation takes place via the absorption of a photon, and de-excitation by emission of a longer wavelength photon. Fluors are used as "waveshifters" to shift scintillation light to a more convenient wavelength. Occurring in complex molecules, the absorption and emission are spread out over a wide band of photon energies, and have some overlap, that is, there is some fraction of the emitted light which can be re-absorbed [6]. This "self-absorption" is undesirable for detector applications because it causes a shortened attenuation length. The wavelength difference between the major absorption and emission peaks is called the Stokes' shift. It is usually the case that the greater the Stokes' shift, the smaller the self absorption—thus, a large Stokes' shift is a desirable property for a fluor.

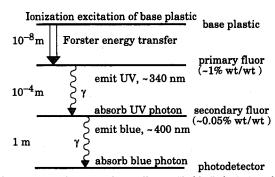


Figure 25.1: Cartoon of scintillation "ladder" depicting the operating mechanism of plastic scintillator. Approximate fluor concentrations and energy transfer distances for the separate sub-processes are shown.

Scintillators: The plastic scintillators used in high-energy physics are binary or ternary solutions of selected fluors in a plastic base containing aromatic rings. (See the appendix in Ref. 7 for a comprehensive list of plastic scintillator components.) Virtually all plastic scintillators contain as a base either polyvinyltoluene, polystyrene, or acrylic, whereby polyvinyltoluene-based scintillator can be up to 50% brighter than the others. Acrylic is non-aromatic and has therefore a very low scintillation efficiency. It becomes an acceptable scintillator when napthalene, a highly aromatic compound, is dissolved into the acrylic at 5% to 20% weight fraction. Thus, in "acrylic" scintillator the active component is napthalene. The fluors must satisfy additional conditions besides being fluorescent. They must be sufficiently stable, soluble, chemically inert, fast, radiation tolerant, and efficient.

The plastic base is the ionization-sensitive (i.e., the scintillator) portion of the plastic scintillator (see Fig. 25.1). In the absence of fluors the base would emit UV photons with short attenuation length (several mm). Longer attenuation lengths are obtained by dissolving a "primary" fluor in high concentration (1% by weight) into the

base, which is selected to efficiently reradiate absorbed energy at wavelengths where the base is more transparent.

The primary fluor has a second important function. The decay time of the scintillator base material can be quite long—in pure polystyrene it is 16 ns, for example. The addition of the primary fluor in high concentration can shorten the decay time by an order of magnitude and increase the total light yield. At the concentrations used (1% and greater), the average distance between a fluor molecule and an excited base unit is around 100 Å, much less than a wavelength of light. At these distances the predominant mode of energy transfer from base to fluor is not the radiation of a photon, but a resonant dipole-dipole interaction, first described by Foerster, which strongly couples the base and fluor [8]. The strong coupling sharply increases the speed and the light yield of the plastic scintillators.

Unfortunately, a fluor which fulfills other requirements is usually not completely adequate with respect to emission wavelength or attenuation length, so it is necessary to add yet another waveshifter (the "secondary" fluor), at fractional percent levels, and ocassionally a third (not shown in Fig. 25.1).

External wavelength shifters: Light emitted from a plastic scintillator may be absorbed in a (nonscintillating) base doped with a waveshifting fluor. Such wavelength shifters are widely used to aid light collection in complex geometries. The wavelength shifter must be insensitive to ionizing radiation and Čerenkov light. A typical wavelength shifter uses an acrylic base (without napthalene!) because of its good optical qualities, a single fluor to shift the light emerging from the plastic scintillator to the blue-green, and contains ultra-violet absorbing additives to deaden response to Čerenkov light.

25.1.2. Caveats and cautions: Plastic scintillators are reliable, robust, and convenient. However, they possess quirks to which the experimenter must be alert.

Aging and Handling: Plastic scintillators are subject to aging which diminishes the light yield. Exposure to solvent vapors, high temperatures, mechanical flexing, irradiation, or rough handling will aggravate the process. A particularly fragile region is the surface which can "craze"—develop microcracks—which rapidly destroy the capability of plastic scintillators to transmit light by total internal reflection. Crazing is particularly likely where oils, solvents, or fingerprints have contacted the surface.

Attenuation length: The Stokes' shift is not the only factor determining attenuation length. Others are the concentration of fluors (the higher the concentration of a fluor, the greater will be its self-absorption); the optical clarity and uniformity of the bulk material; the quality of the surface; and absorption by additives, such as stabilizers, which may be present.

<u>Afterglow</u>: Plastic scintillators have a long-lived luminescence which does not follow a simple exponential decay. Intensities at the 10^{-4} level of the initial fluorescence can persist for hundreds of ns [10].

Atmospheric quenching: Plastic scintillators will decrease their light yield with increasing partial pressure of oxygen. This can be a 10% effect in an artificial atmosphere [11]. It is not excluded that other gasses may have similar quenching effects.

<u>Magnetic field</u>: The light yield of plastic scintillators may be changed by a magnetic field. The effect is very nonlinear and apparently not all types of plastic scintillators are so affected. Increases of $\approx 3\%$ at 0.45 T have been reported [12]. Data are sketchy and mechanisms are not understood.

Radiation damage: Irradiation of plastic scintillators creates color centers which absorb light more strongly in the UV and blue than at longer wavelengths. This poorly understood effect appears as a reduction both of light yield and attenuation length. Radiation damage depends not only on the integrated dose, but on the dose rate, atmosphere, and temperature, before, during and after irradiation, as well as the materials properties of the base such as glass transition temperature, polymer chain length, etc. Annealing also occurs,

accelerated by the diffusion of atmospheric oxygen and elevated temperatures. The phenomena are complex, unpredictable, and not well understood [13]. Since color centers are less intrusive at longer wavelengths, the most reliable method of mitigating radiation damage is to shift emissions at every step to the longest practical wavelengths, e.g., utilize fluors with large Stokes' shifts.

25.2. Inorganic scintillators

Written October 1995 by C.L. Woody (BNL).

Table 25.2 gives a partial list of commonly-used inorganic scintillators in high-energy and nuclear physics [14-21]. These scintillating crystals are generally used where high density and good energy resolution are required. In a crystal which contains nearly all of the energy deposited by an incident particle, the energy resolution is determined largely, but not totally, by the light output. The table gives the light output of the various materials relative to NaI, which has an intrinsic light output of about 40000 photons per MeV of energy deposit. The detected signal is usually quoted in terms of photoelectrons per MeV produced by a given photodetector. The relationship between photons/MeV produced and p.e.'s/MeV detected involves factors for light collection efficiency (typically 10-50%, depending on geometry) and the quantum efficiency of the detector ($\sim 15-20\%$ for photomultiplier tubes and $\sim 70\%$ for silicon photodiodes for visible wavelengths). The quantum efficiency of the detector is usually highly wavelength dependent and should be matched to the particular crystal of interest to give the highest quantum yield at the wavelength corresponding to the peak of the scintillation emission. The comparison of the light output given in Table 25.2 is for a standard photomultiplier tube with a bialkali photocathode. Results with photodiodes can be significantly different; e.g., the CsI(Tl) response relative to NaI(Tl) is 1.4 rather than 0.40 [21]. For scintillators which emit in the UV, a detector with a quartz window should be used.

25.3. Čerenkov detectors

Written October 1993 by D.G. Coyne (UCSC).

Čerenkov detectors utilize one or more of the properties of Čerenkov radiation discussed in the Passages of Particles through Matter section (Sec. 23 of this Review): the existence of a threshold for radiation; the dependence of the Čerenkov cone half-angle θ_c on the velocity of the particle; the dependence of the number of emitted photons on the particle's velocity. The presence of the refractive index n in the relations allows tuning these quantities for a particular experimental application (e.g., using pressurized gas and/or various liquids as radiators).

The number of photoelectrons (p.e.'s) detected in a given device or channel is

$$N_{\rm p.e.} = L \frac{\alpha^2 z^2}{r_e \, m_e c^2} \int \epsilon_{\rm coll}(E) \, \epsilon_{\rm det}(E) \sin^2 \theta_c(E) dE \,, \qquad (25.2)$$

where L is the path length in the radiator, $\epsilon_{\rm coll}$ is the efficiency for collecting the Čerenkov light, $\epsilon_{\rm det}$ is the quantum efficiency of the transducer (photomultiplier or equivalent), and $\alpha^2/(r_e\,m_ec^2)=370~{\rm cm}^{-1}{\rm eV}^{-1}$. The quantities $\epsilon_{\rm coll}$, $\epsilon_{\rm det}$, and θ_c are all functions of the photon energy E, although in typical detectors θ_c (or, equivalently, the index of refraction) is nearly constant over the useful range of photocathode sensitivity. In this case,

$$N_{\rm p.e.} \approx L N_0 \left\langle \sin^2 \theta_c \right\rangle$$
 (25.3)

with

$$N_0 = \frac{\alpha^2 z^2}{r_e \, m_e c^2} \int \epsilon_{\rm coll} \, \epsilon_{\rm det} dE \ . \tag{25.4}$$

We take z=1, the usual case in high-energy physics, in the following discussion.

Threshold Čerenkov detectors make a simple yes/no decision based on whether the particle is above/below the Čerenkov threshold velocity

Table 25.2: Properties of several inorganic crystal scintillators.

		- Toportio				
NaI(Tl)	BGO	BaF_2	CsI(Tl)	CsI(pure)	PbWO ₄	CeF ₃
Density	(g cm	⁻³):				
3.67	7.13	4.89	4.53	4.53	8.28	6.16
Radiati	on leng	th (cm):				
2.59	1.12	2.05	1.85	1.85	0.89	1.68
Molière	radius	(cm):				
4.5	2.4	3.4	3.8	3.8	2.2	2.6
dE/dx	(MeV/	ст) (рег	mip):			
4.8	9.2	6.6	5.6	5.6	13.0	7.9
Nucl. i	nt. leng	gth (cm):	:			
41.4	22.0	29.9	36.5	36.5	22.4	25.9
Decay t	ime (n	s):				
250	300	0.7^{f}	1000	$10,36^{f}$	5-15	10-30
		620°		$\sim 1000^s$		
Peak er	nission	λ (nm):				
410	480	220^{f}	565	305^f	440-500	310-340
		310 ^s		$\sim 480^{s}$		
Refract	ive ind	ex:	the state of the			
1.85	2.20	1.56	1.80	1.80	2.16	1.68
Relativ	e light	output:*				
1.00		0.05^{f}	0.40	0.10^{f}	0.01	0.10
		0.20^{s}		0.02^{s}		
Hygros	copic:					
very	no	slightly	somewhat	somewhat	no	no

^{*} For standard photomultiplier tube with a bialkali photocathode. See Ref. 21 for photodiode results.

f =fast component, s =slow component

 $eta_t=1/n$. Careful designs give $\langle\epsilon_{\rm coll}\rangle\gtrsim90\%$. For a photomultiplier with a typical bialkali cathode, $\int\epsilon_{\rm det}dEpprox0.27$, so that

$$N_{\rm p.e.}/L \approx 90~{\rm cm}^{-1}~\left<\sin^2\theta_c\right>~(i.e.,~N_0=90~{\rm cm}^{-1})$$
 . (25.5)

Suppose, for example, that n is chosen so that the threshold for species a is p_t ; that is, at this momentum species a has velocity $\beta_a = 1/n$. A second, lighter, species b with the same momentum has velocity β_b , so $\cos \theta_c = \beta_a/\beta_b$, and

$$\frac{N_{\rm p.e.}}{L} \approx 90 \text{ cm}^{-1} \frac{m_a^2 - m_b^2}{p_t^2 + m_a^2} . \tag{25.6}$$

For K/π separation at p=1 GeV/c, $N_{\rm p.e.}/L\approx 16$ cm⁻¹ for π 's and (by design) 0 for K's.

For limited path lengths $N_{\rm p.e.}$ can be small, and some minimum number is required to trigger external electronics. The overall efficiency of the device is controlled by Poisson fluctuations, which can be especially critical for separation of species where one particle type is dominant [22].

A related class of detectors uses the number of observed photoelectrons (or the calibrated pulse height) to discriminate between species or to set probabilities for each particle species [23].

<u>Differential Čerenkov detectors</u> exploit the dependence of θ_c on β , using optical focusing and/or geometrical masking to select particles having velocities in a specified region. With careful design, a velocity resolution of $\sigma_{\beta}/\beta \approx 10^{-4}$ - 10^{-5} can be obtained [22,24].

Ring-Imaging Čerenkov detectors use all three properties of Čerenkov radiation in both small-aperture and 4π geometries. They are

principally used as hypothesis-testing rather than yes/no devices; that is, the probability of various identification possibilities is established from θ_c and $N_{\rm p.e.}$ for a particle of known momentum. In most cases the optics map the Čerenkov cone onto a circle at the photodetector, often with distortions which must be understood.

The 4π devices [25,26] typically have both liquid (C_6F_{14} , n=1.276) and gas (C_5F_{12} , n=1.0017) radiators, the light from the latter being focused by mirrors. They achieve 3 σ separation of $e/\pi/K/p$ over wide ranges, as shown in Table 25.3. Great attention to detail, especially with the minimization of UV-absorbing impurities, is required to get $\langle \epsilon_{\rm coll} \rangle \gtrsim 50\%$.

Table 25.3: Momentum range for 3σ separation in the SLD ring-imaging Čerenkov detector.

Particle pair	Mom. range for 3 σ separation
e/π	$p \lesssim 5 \text{ GeV}/c$
π/K	$0.23 \lesssim p \lesssim 20 \text{ GeV}/c$
K/p	$0.82 \lesssim p \lesssim 30 $

The phototransducer is typically a TPC/wire-chamber combination sensitive to single photoelectrons and having charge division or pads. This construction permits three-dimensional reconstruction of photoelectron origins, which is important for transforming the Čerenkov cone into a ring. Single photoelectrons are generated by doping the TPC gas (for instance, ethane/methane in some proportion) with $\sim 0.05\%$ TMAE [tetrakis(dimethylamino)ethylene] [27], leading to photon absorption lengths along the Čerenkov cone of ~ 30 mm. The readout wires must be equipped with special structures (blinds or wire gates) to prevent photon feedback from avalanches generating cross-talk photoelectrons in the TPC. Drift-gas purity must be maintained to assure mean drift lengths of the order of meters without recombination (i.e., lifetimes of $\gtrsim 100~\mu s$ at typical drift velocities of $\gtrsim 4~cm/\mu s$). The net $(\epsilon_{\rm det})$'s reach 30%, with the limitation being the TMAE quantum efficiency.

Photon energy cutoffs are set by the TMAE $(E>5.4~{\rm eV})$, the UV transparency of fused silica glass $(E<7.4~{\rm eV})$, and the ${\rm C_6F_{14}}$ $(E<7.1~{\rm eV})$. With effort one gets $50\leq N_0\leq 100$ for complete rings using liquid or gas. This includes losses due to electrostatic shielding wires and window/mirror reflections, but not gross losses caused by total internal reflection or inadequate coverage by the TPC's.

Such numbers allow determination of ring radii to $\sim 0.5\%$ (liquid) and $\sim 2\%$ (gas), leading to the particle species separations quoted above. Since the separation efficiencies may have "holes" as a function of p, detailed calculations are necessary.

25.4. Transition radiation detectors (TRD's)

Revised February 1998 by D. Froidevaux (CERN).

It is clear from the discussion in the Passages of Particles Through Matter section (Sec. 23 of this *Review*) that transition radiation (TR) only becomes useful for particle detectors when the signal can be observed as x rays emitted along the particle direction for Lorentz factors γ larger than 1000. In practice, TRD's are therefore used to provide electron/pion separation for 0.5 GeV/ $c \lesssim p \lesssim 100$ GeV/c. The charged-particle momenta have usually been measured elsewhere in the detector in the past [28].

Since soft x rays, in the useful energy range between 2 and 20 keV, are radiated with about 1% probability per boundary crossing, practical detectors use radiators with several hundred interfaces, e.g. foils or fibres of low-Z materials such as polypropylene (or, more rarely, lithium) in a gas. Absorption inside the radiator itself and in the inactive material of the x-ray detector is important and limits the usefulness of the softer x rays, but interference effects are even larger, and saturate the x-ray yield for electron energies above a few GeV [29,30].

A classical detector is composed of several similar modules, each consisting of a radiator and an x-ray detector, which is usually a wire chamber operated with a xenon-rich mixture, in order efficiently

to absorb the x rays. Since transition-radiation photons are mostly emitted at very small angles with respect to the charged-particle direction, the x-ray detector most often detects the sum of the ionization loss (dE/dx) of the charged particle in the gas and energy deposition of the x rays. The discrimination between electrons and pions can be based on the charges measured in each detection module, on the number of energy clusters observed above an optimal threshold (usually in the 5 to 7 keV region), or on more sophisticated methods analysing the pulse shape as a function of time. Once properly calibrated and optimized, most of these methods yield very similar results.

More recent development work has aimed at increasing the intrinsic quality of the TRD-performance by increasing the probability per detection module of observing a signal from TR-photons produced by electrons. This has been achieved experimentally by distributing small-diameter straw-tube detectors uniformly throughout the radiator material [31]. This method has thereby also cured one of the major drawbacks of more classical TRD's, that is, their need to rely on another detector to measure the charged-particle trajectory. For example, in the straw tracker proposed for one of the LHC experiments [32], charged particles cross about 40 straw tubes embedded in the radiator material. Dedicated R&D work and detailed simulations have shown that the combination of charged-track measurement and particle identification in the same detector will provide a very powerful tool even at the highest LHC luminosity.

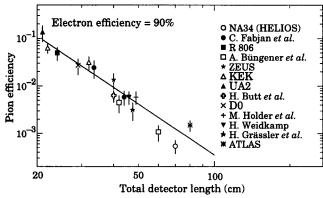


Figure 25.2: Pion efficiency measured (or predicted) for different TRDs as a function of the detector length for a fixed electron efficiency of 90%. The experimental data are directly taken or extrapolated from references [33-45] (top to bottom).

The major factor in the performance of any TRD is its overall length. This is illustrated in Fig. 25.2, which shows, for a variety of detectors, the measured (or predicted) pion efficiency at a fixed electron efficiency of 90% as a function of the overall detector length. The experimental data cover too wide a range of particle energies (from a few GeV to 40 GeV) to allow for a quantitative fit to a universal curve. Fig. 25.2 shows that an order of magnitude in rejection power against pions is gained each time the detector length is increased by \sim 20 cm.

25.5. Silicon photodiodes and particle detectors

Written October 1993 by H.F.W. Sadrozinski (UCSC) and H.G. Spieler (LBNL).

Silicon detectors are p-n junction diodes operated at reverse bias. This forms a sensitive region depleted of mobile charge and sets up an electric field that sweeps charge liberated by radiation to the electrodes. The thickness of the depleted region is

$$W = \sqrt{\frac{2\epsilon \left(V + V_{bi}\right)}{ne}} = \sqrt{2\rho\mu\epsilon(V + V_{bi})}, \qquad (25.7)$$

where V = external bias voltage

 $V_{bi}=$ "built-in" voltage ($\approx 0.8~{
m V}$ for resistivities typically used in detectors

n =doping concentration

e = electron charge

 $\epsilon = \text{dielectric constant} = 11.9 \ \epsilon_0 \approx 1 \ \text{pF/cm}$

 $\rho = \text{resistivity (typically 1-10 k}\Omega \text{ cm)}$

 $\mu = \text{charge carrier mobility}$

= 1350 cm² V⁻¹ s⁻¹ for electrons (n-type material)

= $450 \text{ cm}^2 \text{ V}^{-1} \text{ s}^{-1}$ for holes (p-type material)

or

$$W = 0.5 \ \mu \text{m} \times \sqrt{\rho (V + V_{bi})}$$
 for n-type material, (25.8)

and

$$W = 0.3 \ \mu \text{m} \times \sqrt{\rho(V + V_{bi})}$$
 for p-type material, (25.9)

where V is in volts and ρ is in Ω cm.

The corresponding capacitance per unit area is

$$C = \frac{\epsilon}{W} \approx 1 \,[\text{pF/cm}] \,\frac{1}{W} \,. \tag{25.10}$$

In strip detectors the capacitance is dominated by the strip-to-strip fringing capacitance of $\sim 1\text{--}1.5~\mathrm{pF}~\mathrm{cm}^{-1}$ of strip length at a strip pitch of 25–50 $\mu\mathrm{m}$.

About 3.6 eV is required to create an electron-hole pair. For minimum-ionizing particles, the most probable charge deposition in a 300 μ m thick silicon detector is about 4 fC (25000 electrons). Readily available photodiodes have quantum efficiences > 70% for wavelengths between 600 nm and 1 μ m. UV extended photodiodes have useful efficiency down to 200 nm. In applications in which photodiodes detect light from scintillators, care must be taken so that signal from the scintillator is larger than that produced by particles going through the photodiode.

Collection time decreases with increased depletion voltage, and can be reduced further by operating the detector with "overbias," i.e., a bias voltage exceeding the value required to fully deplete the device. The collection time is limited by velocity saturation at high fields; at an average field of 10^4 V/cm, the collection times is about 15 ps/ μ m for electrons and 30 ps/ μ m for holes. In typical strip detectors of 300 μ m thickness, electrons are collected within about 8 ns, and holes within about 25 ns.

Position resolution is limited by transverse diffusion during charge collection (typically 5 μ m for 300 μ m thickness) and by knock-on electrons. Resolutions of 3–4 μ m (rms) have been obtained in beam tests. In magnetic fields, the Lorentz drift can increase the spatial spread appreciably (see "Hall effect" in semiconductor textbooks).

Radiation damage occurs through two basic mechanisms:

- Bulk damage due to displacement of atoms from their lattice sites.
 This leads to increased leakage current, carrier trapping, and changes in doping concentration. Displacement damage depends on the nonionizing energy loss, i.e., particle type and energy. The dose should be specified as a fluence of particles of a specific type and energy.
- 2. Surface damage due to charge build-up in surface layers, which leads to increased surface leakage currents. In strip detectors the inter-strip isolation is affected. The effects of charge build-up are strongly dependent on the device structure and on fabrication details. Since the damage is determined directly by the absorbed energy, the dose should be specified in these units (rad or Gray).

The increase in leakage current due to bulk damage is $\Delta i = \alpha \phi$ per unit volume, where ϕ is the particle fluence and α the damage coefficient ($\alpha \approx 2 \times 10^{-17}$ A/cm for minimum ionizing protons and pions after long-term annealing; roughly the same value applies for 1 MeV neutrons). The doping concentration in n-type silicon changes as $n = n_0 \exp(-\delta \phi) - \beta \phi$, where n_0 is the initial donor concentration,

 $\delta \approx 6 \times 10^{14}~{\rm cm}^2$ determines donor removal, and $\beta \approx 0.03~{\rm cm}^{-1}$ describes acceptor creation. This leads to an initial increase in resisitivity until type-inversion changes the net doping from n to p. At this point the resistivity decreases, with a corresponding increase in depletion voltage. The safe operating limit of depletion voltage ultimately limits the detector lifetime. Strip detectors have remained functional at fluences beyond $10^{14}~{\rm cm}^{-2}$ for minimum ionizing protons. At this damage level, charge loss due to recombination and trapping also seems to become significant.

25.6. Proportional and drift chambers

<u>Proportional chamber wire instability</u>: The limit on the voltage V for a wire tension T, due to mechanical effects when the electrostatic repulsion of adjacent wires exceeds the restoring force of wire tension, is given by (SI units) [46]

$$V \le \frac{s}{\ell C} \sqrt{4\pi\epsilon_0 T} , \qquad (25.11)$$

where s, ℓ , and C are the wire spacing, length, and capacitance per unit length. An approximation to C for chamber half-gap t and wire diameter d (good for $s \lesssim t$) gives [47]

$$V \lesssim 59T^{1/2} \left[\frac{t}{\ell} + \frac{s}{\pi \ell} \ln \left(\frac{s}{\pi d} \right) \right] ,$$
 (25.12)

where V is in kV, and T is in grams-weight equivalent.

<u>Proportional and drift chamber potentials</u>: The potential distributions and fields in a proportional or drift chamber can usually be calculated with good accuracy from the exact formula for the potential around an array of parallel line charges q (coul/m) along z and located at $y = 0, \ z = 0, \ \pm s, \ \pm 2s, \ldots$,

$$V(x,y) = -\frac{q}{4\pi \epsilon_0} \ln \left\{ 4 \left[\sin^2 \left(\frac{\pi x}{s} \right) + \sinh^2 \left(\frac{\pi y}{s} \right) \right] \right\} . \tag{25.13}$$

Errors from the presence of cathodes, mechanical defects, TPC-type edge effects, etc., are usually small and are beyond the scope of this review.

25.7. Time-projection chambers

Written November 1997 by M.T. Ronan (LBNL).

Detectors with long drift distances perpendicular to a multi-anode proportional plane provide three-dimensional information, with one being the time projection. A (typically strong) magnetic field parallel to the drift direction suppresses transverse diffusion ($\sigma=\sqrt{2Dt}$) by a factor

$$D(B)/D(0) = \frac{1}{1 + \omega^2 \tau^2}$$
, (25.14)

where D is the diffusion coefficient, $\omega=eB/mc$ is the cyclotron frequency, and τ is the mean time between collisions. Multiple measurements of dE/dx along the particle trajectory combined with the measurement of momentum in the magnetic field allows excellent particle identification [48], as can be seen in Fig. 25.3.

A typical gas-filled TPC consists of a long uniform drift region (1–2 m) generated by a central high-voltage membrane and precision concentric cylindrical field cages within a uniform, parallel magnetic field [49]. Details of construction and electron trajectories near the anode end are shown in Fig. 25.4. Signal shaping and processing using analog storage devices or FADC's allows excellent pattern recognition, track reconstruction, and particle identification within the same detector.

Typical values:

 $\begin{array}{ll} {\rm Gas \cdot Ar \, + \, (10\text{--}20\%) \, \, CH_4} & {\rm Pressure}(P) = 1\text{--}8.5 \, \, {\rm atm.} \\ E/P = 100\text{--}200 \, V/{\rm cm/atm} & B = 1\text{--}1.5 \, \, {\rm Tesla} \\ v_{\rm drift} = 5\text{--}7 \, \, {\rm cm/}\mu {\rm s} & \omega \tau = 1\text{--}8 \\ \sigma_{x \, \, {\rm or} \, \, y} = 100\text{--}200 \, \, \mu {\rm m} & \sigma_{z} = 0.2\text{--}1 \, \, {\rm mm} \\ \sigma_{dE/dx} = 2.5\text{--}5.5 \, \% \end{array}$

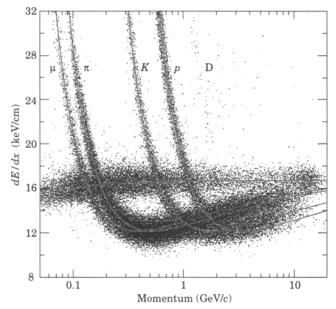


Figure 25.3: PEP4/9-TPC dE/dx measurements (185 samples @8.5 atm Ar-CH₄ 80–20%) in multihadron events. The electrons reach a Fermi plateau value of 1.4 times minimum. Muons from pion decays are separated from pions at low momentum; π/K are separated over all momenta except in the cross-over region. (Low-momentum protons and deuterons originate from hadron-nucleus collisions in inner materials such as the beam pipe.)

Truncated mean dE/dx resolution depends on the number and size of samples, and gas pressure:

$$\sigma_{dE/dx} \propto N^{-0.43} \times (P\ell)^{-0.32}$$
 (25.15)

Here N is the number of samples, ℓ is the sample size, and P is the pressure. Typical dE/dx distributions are shown in Fig. 25.3. Good three-dimensional two-track resolutions of about 1–1.5 cm are routinely achieved.

 $E \times B$ distortions arise from nonparallel E and B fields (see Eq. 2.6 in Ref. 49), and from the curved drift of electrons to the anode wires in the amplification region. Position measurement errors include contributions from the anode-cathode geometry, the track crossing angle (α) , $E \times B$ distortions, and from the drift diffusion of electrons

$$\sigma_{x \text{ or } y}^2 = \sigma_0^2 + \sigma_D^2 (1 + \tan^2 \alpha) L / L_{\text{max}} + \sigma_0^2 (\tan \alpha - \tan \psi)^2$$
 (25.16) .

where σ is the coordinate resolution, σ_0 includes the anode-cathode geometry contribution, ψ is the Lorentz angle, and L is the drift distance.

Space-charge distortions arise in high-rate environments, especially for low values of $\omega \tau$. However, they are mitigated by an effective gating grid (Fig. 25.4). Field uniformities of

$$\int (E_{\perp}/E) \, dz \lesssim 0.5-1 \text{ mm} , \qquad (25.17)$$

over 10-40 m³ volumes have been obtained. Laser tracks and calibration events allow mapping of any remnant drift non-uniformities.

25.8. Calorimeters

Electromagnetic calorimeters: The development of electromagnetic showers is discussed in the "Passage of Particles Through Matter" section (Sec. 23 of this Review). Formulae are given for the approximate description of average showers, but since the physics of electromagnetic showers is well understood, detailed and reliable Monte Carlo simulation is possible. EGS4 has emerged as the standard [50].

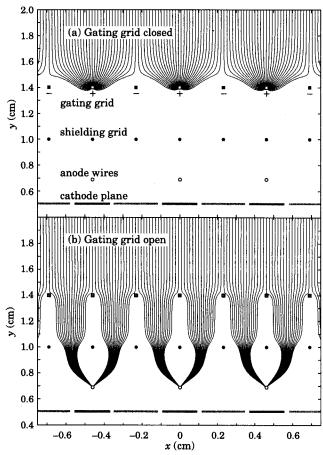


Figure 25.4: (a) Drifting electrons are collected on the gating grid until gated open by a triggering event. A shielding grid at ground potential is used to terminate the drift region. Electrons drifting through an open gating grid (b) pass through to the amplification region around the anode wires. Positive ions generated in the avalanche are detected on segmented cathode pads to provide precise measurements along the wire. The slow positive ions are blocked from entering the drift region by closing the gating grid after the electrons have drifted through.

The resolution of sampling calorimeters (hadronic and electromagnetic) is usually dominated by sampling fluctuations, leading to fractional resolution σ/E scaling inversely as the square root of the incident energy. Homogenous calorimeters, such as solid NaI(Tl), will in general not have resolution varying as $1/\sqrt{E}$. At high energies deviations from $1/\sqrt{E}$ occur because of noise, pedestal fluctuations, nonuniformities, calibration errors, and incomplete shower containment. Such effects are usually included by adding a constant term to σ/E , either in quadrature or (incorrectly) directly. In the case of the hadronic cascades discussed below, noncompensation also contributes to the constant term.

In Table 25.4 we give resolution as measured in detectors using typical EM calorimeter technologies. In almost all cases the installed calorimeters yield worse resolution than test beam prototypes for a variety of practical reasons. Where possible actual detector performance is given. For a fixed number of radiation lengths, the FWHM in sandwich detectors would be expected to be proportional to \sqrt{t} for t (= plate thickness) \geq 0.2 radiation lengths [51].

Given sufficient transverse granularity early in the calorimeter, position resolution of the order of a millimeter can be obtained.

<u>Hadronic calorimeters</u> [59,60]: The length scale appropriate for hadronic cascades is the nuclear interaction length, given very roughly by

$$\lambda_I \approx 35 \text{ g cm}^{-2} A^{1/3}$$
 (25.18)

Table 25.4: Resolution of typical electromagnetic calorimeters. E is in GeV.

Detector	Resolution
NaI(Tl) (Crystal Ball [52]; 20 X ₀)	$2.7\%/E^{1/4}$
Lead glass (OPAL [53])	$5\%/\sqrt{E}$
Lead-liquid argon (NA31 [54]; 80 cells: 27 X_0 , 1.5 mm Pb + 0.6 mm Al + 0.8 mm G10 + 4 mm LA)	$7.5\%/\sqrt{E}$
Lead-scintillator sandwich (ARGUS [55], LAPP-LAL [56])	$9\%/\sqrt{E}$
Lead-scintillator spaghetti (CERN test module) [57]	$13\%/\sqrt{E}$
Proportional wire chamber (MAC; 32 cells: 13 X_0 , 2.5 mm typemetal + 1.6 mm Al) [58]	$23\%/\sqrt{E}$

Longitudinal energy deposition profiles are characterized by a sharp peak near the first interaction point (from the fairly local deposition of EM energy resulting from π^0 's produced in the first interaction), followed by a more gradual development with a maximum at

$$x/\lambda_I \equiv t_{\text{max}} \approx 0.2 \ln(E/1 \text{ GeV}) + 0.7 \tag{25.19}$$

as measured from the front of the detector.

The depth required for containment of a fixed fraction of the energy also increases logarithmically with incident particle energy. The thickness of iron required for 95% (99%) containment of cascades induced by single hadrons is shown in Fig. 25.5 [61]. Two of the sets of data are from large neutrino experiments, while the third is from a commonly used parametrization. Depths as measured in nuclear interaction lengths presumably scale to other materials. From the same data it can be concluded that the requirement that 95% of the energy in 95% of the showers be contained requires 40 to 50 cm (2.4 to $3.0~\lambda_I$) more material material than for an average 95% containment.

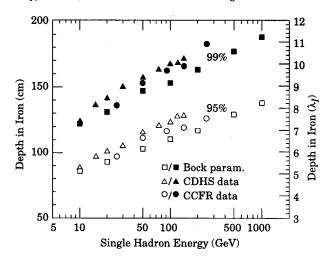


Figure 25.5: Required calorimeter thickness for 95% and 99% hadronic cascade containment in iron, on the basis of data from two large neutrino detectors and the parametrization of Bock et al. [61].

The transverse dimensions of hadronic showers also scale as λ_I , although most of the energy is contained in a narrow core.

The energy deposit in a hadronic cascade consists of a prompt EM component due to π^0 production and a slower component mainly due to low-energy hadronic activity. In general, these energy depositions are converted to electrical signals with different efficiencies [62]. The ratio of the conversion efficiencies is usually called the intrinsic e/h ratio. If e/h=1.0 the calorimeter is said to be compensating. If it differs from unity by more than 5% or 10%, detector performance is compromised because of fluctuations in the π^0 content of the cascades. Problems include:

- a) A skewed signal distribution;
- b) A response ratio for electrons and hadrons (the " e/π ratio") which is different from unity and depends upon energy;
- c) A nonlinear response to hadrons (the response per GeV is proportional to the reciprocal of e/π);
- d) A constant contribution to detector resolution, almost proportional to the degree of noncompensation. The coefficient relating the constant term to |1 e/h| is 14% according to FLUKA simulations, and 21% according to Wigman's calculations [59].

In most cases e/h is greater than unity, particularly if little hydrogen is present or if the gate time is short. This is because much of the low-energy hadronic energy is "hidden" in nuclear binding energy release, low-energy spallation products, etc. Partial correction for these losses occurs in a sampling calorimeter with thick plates, because a disproportionate fraction of electromagnetic energy is deposited in the inactive region. For this reason, a fully sensitive detector such as BGO or glass cannot be made compensating.

Compensation has been demonstrated in calorimeters with 2.5 mm scintillator sheets sandwiched between 3 mm depleted uranium plates [64] or 10 mm lead plates [65]; resolutions σ/E of $0.34/\sqrt{E}$ and $0.44/\sqrt{E}$ were obtained for these cases (E in GeV). The former was shown to be linear to within 2% over three orders of magnitude in energy, with approximately Gaussian signal distributions.

25.9. Measurement of particle momenta in a uniform magnetic field [71,72]

The trajectory of a particle with momentum p (in GeV/c) and charge ze in a constant magnetic field \overrightarrow{B} is a helix, with radius of curvature R and pitch angle λ . The radius of curvature and momentum component perpendicular to \overrightarrow{B} are related by

$$p\cos\lambda = 0.3zBR, \qquad (25.20)$$

where B is in tesla and R is in meters.

The distribution of measurements of the curvature $k \equiv 1/R$ is approximately Gaussian. The curvature error for a large number of uniformly spaced measurements on the trajectory of a charged particle in a uniform magnetic field can be approximated by

$$(\delta k)^2 = (\delta k_{\rm res})^2 + (\delta k_{\rm ms})^2$$
, (25.21)

where $\delta k = \text{curvature error}$

 $\delta k_{\rm res} =$ curvature error due to finite measurement resolution

 $\delta k_{\rm ms} =$ curvature error due to multiple scattering.

If many (≥ 10) uniformly spaced position measurements are made along a trajectory in a uniform medium,

$$\delta k_{\rm res} = \frac{\epsilon}{L'^2} \sqrt{\frac{720}{N+4}} , \qquad (25.22)$$

where N = number of points measured along track

L' = the projected length of the track onto the bending plane

 $\epsilon=$ measurement error for each point, perpendicular to the trajectory.

If a vertex constraint is applied at the origin of the track, the coefficient under the radical becomes 320.

For arbitrary spacing of coordinates s_i measured along the projected trajectory and with variable measurement errors ϵ_i the curvature error $\delta k_{\rm res}$ is calculated from:

$$(\delta k_{\rm res})^2 = \frac{4}{w} \frac{V_{ss}}{V_{ss}V_{s^2s^2} - (V_{ss^2})^2}, \qquad (25.23)$$

where V are covariances defined as $V_{s^ms^n}=\langle s^ms^n\rangle-\langle s^m\rangle\langle s^n\rangle$ with $\langle s^m\rangle=w^{-1}\sum(s_i^m/\epsilon_i^{\ 2})$ and $w=\sum\epsilon_i^{-2}$.

The contribution due to multiple Coulomb scattering is approximately

$$\delta k_{\rm ms} \approx \frac{(0.016)({\rm GeV}/c)z}{Lp\beta\cos^2\lambda}\sqrt{\frac{L}{X_0}} \ , \eqno(25.24)$$

where p = momentum (GeV/c)

z = charge of incident particle in units of e

L = the total track length

 X_0 = radiation length of the scattering medium (in units of length; the X_0 defined elsewhere must be multiplied by density)

 β = the kinematic variable v/c.

More accurate approximations for multiple scattering may be found in the section on Passage of Particles Through Matter (Sec. 23 of this *Review*). The contribution to the curvature error is given approximately by $\delta k_{\rm ms} \approx 8 s_{\rm plane}^{\rm rms}/L^2$, where $s_{\rm plane}^{\rm rms}$ is defined there.

25.10. Superconducting solenoids for collider detectors

Revised October 1997 by R.D. Kephart (FNAL).

25.10.1. Basic (approximate) equations: In all cases SI units are assumed, so that B is in tesla, E is in joules, dimensions are in meters, and $\mu_0 = 4\pi \times 10^{-7}$.

Magnetic field: The magnetic field at the center of a solenoid of length L and radius R, having N total turns and a current I is

$$B(0,0) = \frac{\mu_0 NI}{\sqrt{L^2 + 4R^2}} \,. \tag{25.25}$$

Stored energy: The energy stored in the magnetic field of any magnet is calculated by integrating B^2 over all space:

$$E = \frac{1}{2\mu_0} \int B^2 dV \ . \tag{25.26}$$

For a solenoid with an iron flux return in which the magnetic field is < 2T, the field in the aperture is approximately uniform and equal to $\mu_0 NI/L$. If the thickness of the coil is small, (which is the case if it is superconducting), then

$$E \approx (\pi/2\mu_0)B^2R^2L$$
 (25.27)

Cost of a superconducting solenoid [73]:

Cost (in M\$) =
$$0.523[(E/(1 \text{ MJ})]^{0.662}$$
 (25.28)

Magnetostatic computer programs: It is too difficult to solve the Biot-Savart equation for a magnetic circuit which includes iron components and so iterative computer programs are used. These include POISSON, TOSCA [74], and ANSYS [75].

25.10.2. Scaling laws for thin solenoids: For a detector in which the calorimetry is outside the aperture of the solenoid, the coil must be thin in terms of radiation and absorption lengths. This usually means that the coil is superconducting and that the vacuum vessel encasing it is of minimum real thickness and fabricated of a material with long radiation length. There are two major contributers to the thickness of a thin solenoid:

- 1. The conductor, consisting of the current-carrying superconducting material (usually Cu/Nb-Ti) and the quench protecting stabilizer (usually aluminum), is wound on the inside of a structural support cylinder (usually aluminum also). This package typically represents about 60% of the total thickness in radiation lengths. The thickness scales approximately as B^2R .
- 2. Approximately another 25% of the thickness of the magnet comes from the outer cylindrical shell of the vacuum vessel. Since this shell is susceptible to buckling collapse, its thickness is determined by the diameter, length, and the modulus of the material of which it is fabricated. When designing this shell to a typical standard, the real thickness is

$$t = P_c D^{2.5} [(L/D) - 0.45(t/D)^{0.5}] / 2.6Y^{0.4}, \qquad (25.29)$$

where t = shell thickness (in), D = shell diameter (in), L = shell length (in), Y = modulus of elasticity (psi), and $P_c =$ design collapse pressure (= 30 psi). For most large-diameter detector solenoids, the thickness to within a few percent is given by [76]

$$t = P_c D^{2.5} (L/D) / 2.6 Y^{0.4} . (25.30)$$

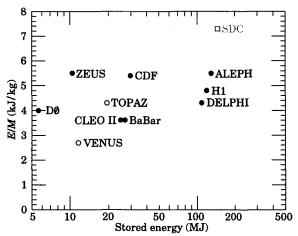


Figure 25.6: Ratio of stored energy to cold mass for existing thin detector solenoids. Solenoids in decommissioned detectors are indicated by open circles.

25.10.3. Properties of collider detector solenoids: The physical dimensions, central field, stored energy and thickness in radiation lengths normal to the beam line of the superconducting solenoids associated with the major colliders are given in Table 25.5.

Table 25.5: Properties of superconducting collider detector solenoids.

Experiment-Lab	Field (T)	Bore Dia (m)	Length (m)	Energy (MJ)	Thickness (X_0)
CDF-Fermilab	1.5	2.86	5.07	30	0.86
DØ -Fermilab	2.0	1.06	2.73	5.6	0.87
BaBar-SLAC	1.5	2.80	3.46	27.0	< 1.4
Topaz-KEK	1.2	2.72	5.4	19.5	0.70
Venus-KEK	0.75	3.4	5.64	12	0.52
Cleo II-Cornell	1.5	2.9	3.8	25	2.5
Aleph-CERN	1.5	5.0	7.0	130	1.7
Delphi-CERN	1.2	5.2	7.4	109	4.0
H1-DESY	1.2	5.2	5.75	120	1.2
Zeus-DESY	1.8	1.72	2.85	10.5	0.9

The ratio of stored energy to cold mass (E/M) is a useful performance measure. One would like the cold mass to be as small as possible to minimize the thickness, but temperature rise during a quench must also be minimized. Ratios as large as 8 kJ/kg may be possible (final temperature of 80 K after a fast quench with homogenous energy dump), but some contingency is desirable. This quantity is shown as a function of total stored energy for some major collider detectors in Fig. 25.6.

25.11. Other observations

dE/dx resolution in argon: Particle identification by dE/dx is dependent on the width of the distribution. For relativistic incident particles with charge e in a multiple-sample Ar gas counter with no lead [66],

$$\frac{dE}{dx}\Big|_{\text{FWHM}} / \frac{dE}{dx}\Big|_{\text{most probable}} = 0.96 N^{-0.46} (xp)^{-0.32} , \quad (25.31)$$

where N = number of samples, x = thickness per sample (cm), p = pressure (atm.). Most commonly used chamber gases (except Xe) give approximately the same resolution.

<u>Free electron drift velocities in liquid ionization chambers</u> [67–70]: Velocity as a function of electric field strength is given in

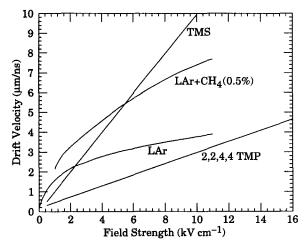


Figure 25.7: Electron drift velocity as a function of field strength for commonly used liquids.

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26. RADIOACTIVITY AND RADIATION PROTECTION

Revised March 1998 by R.J. Donahue (LBNL) and A. Fassò (SLAC).

26.1. Definitions

The International Commission on Radiation Units and Measurements (ICRU) recommends the use of SI units. Therefore we list SI units first, followed by cgs (or other common) units in parentheses, where they differ.

- Unit of activity = becquerel (curie):
 - $1~\mathrm{Bq}=1~\mathrm{disintegration~s^{-1}}~[=1/(3.7\times10^{10})~\mathrm{Ci}]$
- Unit of absorbed dose = gray (rad):

$$1 \text{ Gy} = 1 \text{ joule kg}^{-1} \ (= 10^4 \text{ erg g}^{-1} = 100 \text{ rad})$$

$$= 6.24 \times 10^{12} \text{ MeV kg}^{-1} \text{ deposited energy}$$

- Unit of exposure, the quantity of x- or γ radiation at a point in space integrated over time, in terms of charge of either sign produced by showering electrons in a small volume of air about the point:
 - = 1 coul kg $^{-1}$ of air (roentgen; 1 $R = 2.58 \times 10^{-4}$ coul kg $^{-1}$)
 - $= 1 \text{ esu cm}^{-3} (= 87.8 \text{ erg released energy per g of air})$

Implicit in the definition is the assumption that the small test volume is embedded in a sufficiently large uniformly irradiated volume that the number of secondary electrons entering the volume equals the number leaving. This unit is somewhat historical, but appears on many measuring instruments.

• Unit of equivalent dose (for biological damage) = sievert [= 100 rem (roentgen equivalent for man)]: Equivalent dose in Sv = absorbed dose in grays $\times w_R$, where w_R (radiation weighting factor, formerly the quality factor Q) expresses long-term risk (primarily cancer and leukemia) from low-level chronic exposure. It depends upon the type of radiation and other factors, as follows [2]:

Table 26.1: Radiation weighting factors.

Radiation	w_R
X- and γ -rays, all energies	1
Electrons and muons, all energies	1
Neutrons < 10 keV	5
10–100 keV	10
> 100 keV to 2 MeV	20
2-20 MeV	10
> 20 MeV	5
Protons (other than recoils) > 2 MeV	5
Alphas, fission fragments, & heavy nuclei	20

26.2. Radiation levels [3]

- Natural annual background, all sources: Most world areas, whole-body equivalent dose rate ≈ (0.4-4) mSv (40-400 millirems). Can range up to 50 mSv (5 rems) in certain areas. U.S. average ≈ 3.6 mSv, including ≈ 2 mSv (≈ 200 mrem) from inhaled natural radioactivity, mostly radon and radon daughters (0.1-0.2 mSv in open areas. Average is for a typical house and varies by more than an order of magnitude. It can be more than two orders of magnitude higher in poorly ventilated mines).
- Cosmic ray background in counters (Earth's surface): $\sim 1 \text{ min}^{-1} \text{ cm}^{-2} \text{ sr.}$ For more accurate estimates and details, see the Cosmic Rays section (Sec. 20 of this *Review*).
- Fluxes (per cm²) to deposit one Gy, assuming uniform irradiation: $\approx (\text{charged particles}) 6.24 \times 10^9/(dE/dx)$, where dE/dx (MeV g⁻¹ cm²), the energy loss per unit length, may be obtained from the Mean Range and Energy Loss figures.
- $\approx 3.5 \times 10^9~\text{cm}^{-2}$ minimum-ionizing singly-charged particles in carbon.

 \approx (photons) $6.24\times10^9/[Ef/\lambda]$, for photons of energy E (MeV), attenuation length λ (g cm⁻²) (see Photon Attenuation Length figure), and fraction $f\lesssim 1$ expressing the fraction of the photon's energy deposited in a small volume of thickness $\ll \lambda$ but large enough to contain the secondary electrons.

 $\approx 2 \times 10^{11} \text{ photons cm}^{-2} \text{ for 1 MeV photons on carbon } (f \approx 1/2).$ (Quoted fluxes are good to about a factor of 2 for all materials.)

 Recommended limits to exposure of radiation workers (whole-body dose):*

CERN: 15 mSv yr^{-1}

U.K.: 15 mSv yr⁻¹

U.S.: 50 mSv yr⁻¹ (5 rem yr⁻¹) †

• Lethal dose: Whole-body dose from penetrating ionizing radiation resulting in 50% mortality in 30 days (assuming no medical treatment) 2.5-3.0 Gy (250-300 rads), as measured internally on body longitudinal center line. Surface dose varies due to variable body attenuation and may be a strong function of energy.

26.3. Prompt neutrons at accelerators

26.3.1. Electron beams: At electron accelerators neutrons are generated via photonuclear reactions from bremsstrahlung photons. Neutron yields from semi-infinite targets per unit electron beam power are plotted in Fig. 26.1 as a function of electron beam energy [4]. In the photon energy range 10–30 MeV neutron production results from the giant photonuclear resonance mechanism. Neutrons are produced roughly isotropically (within a factor of 2) and with a Maxwellian energy distribution described as:

$$\frac{dN}{dE_n} = \frac{E_n}{T^2} e^{-E_n/T} , \qquad (26.1)$$

where T is the nuclear temperature characteristic of the target nucleus, generally in the range of T=0.5-1.0 MeV. For higher energy photons the quasi-deuteron and photopion production mechanisms become important.

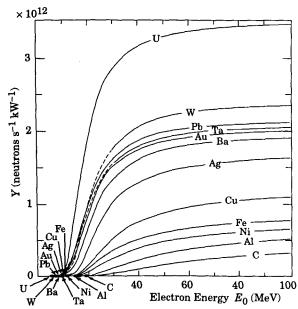


Figure 26.1: Neutron yields from semi-infinite targets, per kW of electron beam power, as a function of electron beam energy, disregarding target self-shielding.

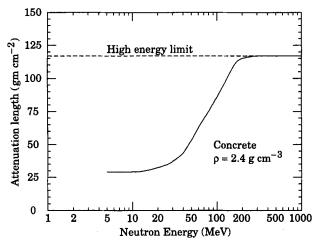


Figure 26.3: The variation of the attenuation length for monoenergetic neutrons in concrete as a function of neutron energy [5].

26.3.2. Proton beams: At proton accelerators neutron yields emitted per incident proton by different target materials are roughly independent [5] of proton energy between 20 MeV and 1 GeV and are given by the ratio C:Al:Cu-Fe:Sn:Ta-Pb = 0.3:0.6:1.0:1.5:1.7. Above 1 GeV neutron yield [6] is proportional to E^m , where $0.80 \le m \le 0.85$.

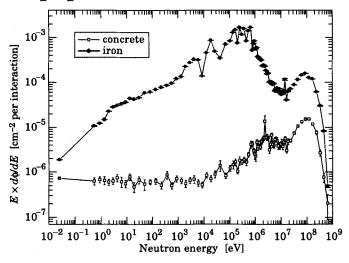


Figure 26.2: Calculated neutron spectrum from 205 GeV/c hadrons (2/3 protons and 1/3 π^+) on a thick copper target. Spectra are evaluated at 90° to beam and through 80 cm of normal density concrete or 40 cm of iron.

A typical neutron spectrum [7] outside a proton accelerator concrete shield is shown in Fig. 26.2. The shape of these spectra are generally characterized as having a thermal-energy peak which is very dependent on geometry and the presence of hydrogenic material, a low-energy evaporation peak around 2 MeV, and a high-energy spallation shoulder.

Letaw's [8] formula for the energy dependence of the inelastic proton cross-section (asymptotic values given in Table 6.1) for E < 2 GeV is:

$$\sigma(E) = \sigma_{\text{asympt}} \left[1 - 0.62e^{-E/200} \sin(10.9E^{-0.28}) \right] , \qquad (26.2)$$

and for E > 2 GeV:

$$\sigma_{\text{asympt}} = 45A^{0.7} [1 + 0.016 \sin(5.3 - 2.63 \ln A)],$$
 (26.3)

where σ is in mb, E is the proton energy in MeV and A is the mass number.

The neutron-attenuation length, λ , is shown in Fig. 26.3 for monoenergetic broad-beam conditions. These values give a satisfactory representation at depths greater than 1 m in concrete.

26.4. Dose conversion factors

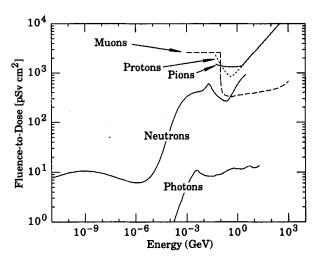


Figure 26.4: Fluence to dose equivalent conversion factors for various particles.

Fluence to dose equivalent factors are given in Fig. 26.4 for photons [9], neutrons [10], muons [11], protons and pions [12]. These factors can be used for converting particle fluence to dose for personnel protection purposes.

26.5. Accelerator-induced activity

The dose rate at 1 m due to spallation-induced activity by high energy hadrons in a 1 g medium atomic weight target can be estimated [13] from the following expression:

$$D = D_0 \Phi \ln[(T+t)/t] , \qquad (26.4)$$

where T is the irradiation time, t is the decay time since irradiation, Φ is the flux of irradiating hadrons (hadrons cm⁻² s⁻¹) and D_0 has a value of 5.2×10^{-17} [(Sv hr⁻¹)/(hadron cm⁻² s⁻¹)]. This relation is essentially independent of hadron energy above 200 MeV.

Dose due to accelerator-produced induced activity can also be estimated with the use of " ω factors" [5]. These factors give the dose rate per unit star density (inelastic reaction for E>50 MeV) after a 30-day irradiation and 1-day decay. The ω factor for steel or iron is $\simeq 3\times 10^{-12}$ (Sv cm³/star). This does not include possible contributions from thermal-neutron activation. Induced activity in concrete can vary widely depending on concrete composition, particularly with the concentration of trace quantities such as sodium. Additional information can be found in Barbier [14].

26.6. Photon sources

The dose rate from a gamma point source of C Curies emitting one photon of energy 0.07 < E < 4 MeV per disintegration at a distance of 30 cm is 6CE (rem/hr), or 60CE (mSv/hr), $\pm 20\%$.

The dose rate from a semi-infinite uniform photon source of specific activity C (μ Ci/g) and gamma energy E (MeV) is 1.07CE (rem/hr), or 10.7CE (mSv/hr).

26.7. Radiation levels in detectors at hadron colliders

An SSC Central Design Group task force studied the radiation levels to be expected in SSC detectors [15]. The study focused on scaling with energy, distance, and angle. As such, it is applicable to future detectors such as those at the LHC. Although superior detector-specific calculations have since been made, the scaling is in most cases not evident, and so the SSC results have some relevance. The SSC/CDG model assumed

- The machine luminosity at $\sqrt{s} = 40$ TeV is $\mathcal{L} = 10^{33}$ cm⁻²s⁻¹, and the pp inelastic cross section is $\sigma_{\rm inel} = 100$ mb. This luminosity is effectively achieved for 10^7 s yr⁻¹. The interaction rate is thus 10^8 s⁻¹, or 10^{15} yr⁻¹;
- All radiation comes from pp collisions at the interaction point:
- The charged particle distribution is (a) flat in pseudorapidity for $|\eta| < 6$ and (b) has a momentum distribution whose perpendicular component is independent of rapidity, which is taken as independent of pseudorapidity:

$$\frac{d^2N_{\rm ch}}{d\eta dp_{\perp}} = H f(p_{\perp}) \tag{26.5}$$

(where $p_{\perp} = p \sin \theta$). Integrals involving $f(p_{\perp})$ are simplified by replacing $f(p_{\perp})$ by $\delta(p_{\perp} - \langle p_{\perp} \rangle)$; in the worst case this approximation introduces an error of less than 10%;

- Gamma rays from π^0 decay are as abundant as charged particles. They have approximately the same η distribution, but half the mean momentum;
- At the SSC ($\sqrt{s}=40$ TeV), $H\approx 7.5$ and $\langle p_{\perp}\rangle\approx 0.6$ GeV/c; assumed values at other energies are given in Table 26.3. Together with the model discussed above, these values are thought to describe particle production to within a factor of two or better.

It then follows that the flux of charged particles from the interaction point passing through a normal area da located a distance r_{\perp} from the beam line is given by

$$\frac{dN_{\rm ch}}{da} = \frac{1.2 \times 10^8 \,\mathrm{s}^{-1}}{r_{\perp}^2} \ . \tag{26.6}$$

In a typical organic material, a relativistic charged particle flux of 3×10^9 cm⁻² produces an ionizing radiation dose of 1 Gy, where 1 Gy \equiv 1 joule kg⁻¹ (= 100 rads). The above result may thus be rewritten as dose rate,

$$\dot{D} = \frac{0.4 \text{ MGy yr}^{-1}}{(r_{\perp}/1 \text{ cm})^2} . \tag{26.7}$$

If a magnetic field is present, "loopers" may increase this dose rate by a factor of two ore more.

In a medium in which cascades can develop, the ionizing dose or neutron fluence is proportional to $dN_{\rm ch}/da$ multiplied by $\langle E \rangle^{\alpha}$, where $\langle E \rangle$ is the mean energy of the particles going through da and the power α is slightly less than unity. Since $E \approx p = p_{\perp}/\sin\theta$ and $r_{\perp} = r\sin\theta$, the above expression for $dN_{\rm ch}/da$ becomes

Dose or fluence[†] =
$$\frac{A}{r^2} \cosh^{2+\alpha} \eta = \frac{A}{r^2 \sin^{2+\alpha} \theta}$$
. (26.8)

The constant A contains the total number of interactions $\sigma_{\text{inel}} \int \mathcal{L} dt$, so the ionizing dose or neutron fluence at another accelerator scales as $\sigma_{\text{inel}} \int \mathcal{L} dt \, H \, \langle p_{\perp} \rangle^{\alpha}$.

The dose or fluence in a calorimeter scales as $1/r^2$, as does the neutron fluence inside a central cavity with characteristic dimension r.

Under all conditions so far studied, the neutron spectrum shows a broad log-normal distribution peaking at just under 1 MeV. In a 2 m radius central cavity of a detector with coverage down to $|\eta|=3$, the average neutron flux is $2\times 10^{12}~{\rm cm}^{-2}{\rm yr}^{-1}$, including secondary scattering contributions.

Values of A and α are given in Table 26.2 for several relevant situations. Examples of scaling to other accelerators are given in Table 26.3. It should be noted that the assumption that all radiation comes from the interaction point does not apply to the present generation of accelerators.

The constant A includes factors evaluated with cascade simulation programs as well as constants describing particle production at the interaction point. It is felt that each could introduce an error as large as a factor of two in the results.

Table 26.2: Coefficients $A/(100 \text{ cm})^2$ and α for the evaluation of calorimeter radiation levels at cascade maxima under SSC nominal operating conditions. At a distance r and angle θ from the interaction point the annual fluence or dose is $A/(r^2 \sin^{2+\alpha} \theta)$.

Quantity	$A/(100 \mathrm{~cm})^2$	Units	$\langle p_{\perp} angle$	α
Neutron flux	1.5×10^{12}	$\mathrm{cm^{-2}yr^{-1}}$	0.6 GeV/c	0.67
Dose rate from photons	124	$\rm Gy~\rm yr^{-1}$	$0.3~{ m GeV}/c$	0.93
Dose rate from hadrons	29	$\rm Gy~\rm yr^{-1}$	$0.6~{ m GeV}/c$	0.89

Table 26.3: A rough comparison of beam-collision induced radiation levels at the Tevatron, high-luminosity LHC, SSC, and a possible 100 TeV machine [16].

	Tevatron	LHC	SSC	100 TeV
\sqrt{s} (TeV)	1.8	15.4	40	100
$\mathscr{L}_{\text{nom}} \ (\text{cm}^{-2}\text{s}^{-1})$	2×10^{30}	$1.7\times10^{34^a}$	1×10^{33}	1×10^{34}
$\sigma_{ m inel}$	56 mb	84 mb	$100 \; \mathrm{mb}$	134 mb
H	3.9	6.2	7.5	10.6
$\langle p_{\perp} angle \; ({ m GeV}/c)$	0.46	0.55	0.60	0.70
Relative dose rate b	5×10^{-4}	11	1	20

- ^a High-luminosity option.
- ^b Proportional to $\mathcal{L}_{\text{nom }\sigma_{\text{inel}}} H \langle p_{\perp} \rangle^{0.7}$

Footnotes:

- * The ICRP recomendation [2] is 20 mSv yr⁻¹ averaged over 5 years, with the dose in any one year ≤ 50 mSv.
- † Many laboratories in the U.S. and elsewhere set lower limits.
- [‡] Dose is the time integral of dose rate, and fluence is the time integral of flux.

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27. COMMONLY USED RADIOACTIVE SOURCES

Table 27.1. Revised November 1993 by E. Browne (LBNL).

			Part	icle	Pho	oton
Nuclide	Half-life	Type of decay		Emission prob.		y Emission prob.
²² Na	2.603 y	β^+ , EC	0.545	90%	0.511	Annih.
					1.275	100%
Mn 5	0.855 у	EC			0.835	
						rays 26%
5Fe	2.73 y	EC			Mn K	
						24.4%
7.0	- 					2.86%
7Co	0.744 y	EC			0.014 0.122	9%
					0.122	1.7
						rays 58%
30 Co	5 271 v	β-	0.316	100%	1.173	100%
2700	0.211 y	ρ	0.510	10070	1.333	2.1
⁸ Ge	0.742 y	EC				rays 44%
→ ⁶⁸ ₃₁ Ga		β^+ , EC	1.899	90%	0.511	Annih.
10					1.077	3%
90 38 Sr	28.5 у	β^-	0.546	100%		
→ ⁹⁰ Y		β-	2.283	100%		
106Ru	1.020 v	$\frac{\beta^-}{\beta^-}$	0.039	100%		
$ ightarrow ^{106}_{45} Rl$	h	β^-	3.541	79%	0.512	21%
					0.622	10%
$^{109}_{48}\mathrm{Cd}$	1.267 y	EC	0.063~e		0.088	
			0.084 e		AgKa	rays 100%
			0.087 e			
^{l 13} 5n	0.315 у	EC	0.364 e		0.392	65%
			0.388 e		In K x	rays 97%
¹³⁷ Cs	30.2 у	β^-	0.514 e		0.662	85%
			1.176 e	- 6%		
¹³³ Ba	10.54 y	EC	0.045 e	- 50%	0.081	34%
			0.075~e	- 6%	0.356	62%
					Cs K x	rays 121%
²⁰⁷ 83Bi	31.8 у	EC	0.481 e	- 2%	0.569	98%
			0.975 e		1.063	75%
			1.047 e	- 2%	1.770	7%
					PbK	c rays 78%
$^{228}_{90}$ Th	1.912 y		5.341 to		0.239	44%
		3 <i>β</i> −:	0.334 to	o 2.246	0.583	31%
(→ ²²⁴ ₈₈ Ra	. 2201	D	216n.	. 212mL	2.614 . 212p:	36%
241 .		KII →	² 16 ₈₄ Po		→ ²¹² ₈₃ Bi	→ ²¹² ₈₄ Po)
² 1 Am	432.7 y	α	5.443 5.486	13% 85%	0.060 Np L 2	36% : rays 38%
²⁴¹ ₉₅ Am/Be	432.2 у		-5 neut	rons (4–8 Me	V) and	
		4 × 10) ⁻⁵ γ's (4	4.43 MeV) pe	r Am dec	ay
²⁴⁴ ₉₆ Cm	18.11 y	α	5.763	24% 76%	Pu L x	rays ~ 9%
252 cre	0.04-	/a=~:	5.805	76%		
²⁵² 0f	2.645 y	α (97%)		15%		
		Fission	6.118	82%		
				sion; 80% < 1	l MeV	
				$_{1}^{1}$ s/fission; $\langle E_{r} \rangle$		

"Emission probability" is the probability per decay of a given emission; because of cascades these may total more than 100%. Only principal emissions are listed. EC means electron capture, and e^- means monoenergetic internal conversion (Auger) electron. The intensity of 0.511 MeV e^+e^- annihilation photons depends upon the number of stopped positrons. Endpoint β^\pm energies are listed. In some cases when energies are closely spaced, the γ -ray values are approximate weighted averages. Radiation from short-lived daughter isotopes is included where relevant.

Half-lives, energies, and intensities are from E. Browne and R.B. Firestone, Table of Radioactive Isotopes (John Wiley & Sons, New York, 1986), recent Nuclear Data Sheets, and X-ray and Gamma-ray Standards for Detector Calibration, IAEA-TECDOC-619 (1991)

Neutron data are from Neutron Sources for Basic Physics and Applications (Pergamon Press, 1983).

28. PROBABILITY

Revised May 1996 by D.E. Groom (LBNL) and F. James (CERN).

28.1. General [1-5]

Let x be a possible outcome of an observation. The probability of x is the relative frequency with which that outcome occurs out of a (possibly hypothetical) large set of similar observations. If x can take any value from a continuous range, we write $f(x;\theta) dx$ as the probability of observing x between x and x + dx. The function $f(x; \theta)$ is the probability density function (p.d.f.) for the random variable x, which may depend upon one or more parameters θ . If x can take on only discrete values (e.g., the non-negative integers), then $f(x;\theta)$ is itself a probability, but we shall still call it a p.d.f. The p.d.f. is always normalized to unit area (unit sum, if discrete). Both x and θ may have multiple components and are then often written as column vectors. If θ is unknown and we wish to estimate its value from a given set of data measuring x, we may use statistics (see Sec. 29).

The cumulative distribution function F(a) is the probability that $x \leq a$:

$$F(a) = \int_{-\infty}^{a} f(x) dx . \qquad (28.1)$$

Here and below, if x is discrete-valued, the integral is replaced by a sum. The endpoint a is expressly included in the integral or sum. Then $0 \le F(x) \le 1$, F(x) is nondecreasing, and $Prob(a < x \le b) =$ F(b) - F(a). If x is discrete, F(x) is flat except at allowed values of x, where it has discontinuous jumps equal to f(x).

Any function of random variables is itself a random variable, with (in general) a different p.d.f. The expectation value of any function

$$E[u(x)] = \int_{-\infty}^{\infty} u(x) f(x) dx, \qquad (28.2)$$

assuming the integral is finite. For u(x) and v(x) any two functions of x, E(u+v) = E(u) + E(v). For c and k constants, E(cu+k) =

The nth moment of a distribution is

$$\alpha_n \equiv E(x^n) = \int_{-\infty}^{\infty} x^n f(x) dx$$
, (28.3a)

and the nth moment about the mean of x, α_1 , is

$$m_n \equiv E[(x-\alpha_1)^n] = \int_{-\infty}^{\infty} (x-\alpha_1)^n f(x) dx. \qquad (28.3b)$$

The most commonly used moments are the mean μ and variance σ^2 :

$$\mu \equiv \alpha_1 \tag{28.4a}$$

$$\mu \equiv \alpha_1 \qquad (28.4a)$$

$$\sigma^2 \equiv \operatorname{Var}(x) \equiv m_2 = \alpha_2 - \mu^2 . \qquad (28.4b)$$

The mean is the location of the "center of mass" of the probability density function, and the variance is a measure of the square of its width. Note that $Var(cx + k) = c^2 Var(x)$.

Any odd moment about the mean is a measure of the skewness of the p.d.f. The simplest of these is the dimensionless coefficient of skewness $\gamma_1 \equiv m_3/\sigma^3$.

Besides the mean, another useful indicator of the "middle" of the probability distribution is the median x_{med} , defined by $F(x_{\rm med}) = 1/2$; i.e., half the probability lies above and half lies below x_{med} . For a given sample of events, x_{med} is the value such that half the events have larger x and half have smaller x (not counting any that have the same x as the median). If the sample median lies between two observed x values, it is set by convention halfway between them. If the p.d.f. for x has the form $f(x - \mu)$ and μ is both mean and median, then for a large number of events N, the variance of the median approaches $1/[4Nf^2(0)]$, provided f(0) > 0.

Let x and y be two random variables with a joint p.d.f. f(x, y). The marginal p.d.f. of x (the distribution of x with y unobserved) is

$$f_1(x) = \int_{-\infty}^{\infty} f(x, y) dy$$
, (28.5)

and similarly for the marginal p.d.f. $f_2(y)$. We define the conditional p.d.f. of x, given fixed y, by

$$f_3(y|x) f_1(x) = f(x,y)$$
. (28.6a)

Similarly, the conditional p.d.f. of y, given fixed x, is

$$f_4(x|y) f_2(y) = f(x,y)$$
. (28.6b)

From these definitions we immediately obtain Bayes' theorem [2]:

$$f_4(x|y) = \frac{f_3(y|x) f_1(x)}{f_2(y)} = \frac{f_3(y|x) f_1(x)}{\int f_3(y|x) f_1(x) dx}.$$
 (28.7)

The mean of x is

$$\mu_x = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} x \ f(x, y) \ dx \ dy = \int_{-\infty}^{\infty} x \ f_1(x) \ dx \ , \tag{28.8}$$

and similarly for y. The correlation between x and y is a measure of the dependence of one on the other:

$$\rho_{xy} = E\left[(x - \mu_x)(y - \mu_y) \right] / \sigma_x \, \sigma_y = \operatorname{Cov}(x, y) / \sigma_x \, \sigma_y , \qquad (28.9)$$

where σ_x and σ_y are defined in analogy with Eq. (28.4b). It can be shown that $-1 \le \rho_{xy} \le 1$. Here "Cov" is the covariance of x and y, a 2-dimensional analogue of the variance.

Two random variables are independent if and only if

$$f(x,y) = f_1(x) f_2(y)$$
. (28.10)

If x and y are independent then $\rho_{xy} = 0$; the converse is not necessarily true except for Gaussian-distributed x and y. If x and y are independent, $E[u(x)\ v(y)] = E[u(x)]\ E[v(y)],$ and $\mathrm{Var}(x+y)$ = Var(x)+Var(y); otherwise, Var(x+y) = Var(x)+Var(y)+2Cov(x, y), and E(u v) does not factor.

In a change of continuous random variables from $x \equiv (x_1, \ldots, x_n)$, with p.d.f. $f(x) = f(x_1, ..., x_n)$, to $y \equiv (y_1, ..., y_n)$, a one-to-one function of the x_i 's, the p.d.f. $g(y) = g(y_1, \ldots, y_n)$ is found by substitution for (x_1, \ldots, x_n) in f followed by multiplication by the absolute value of the Jacobian of the transformation; that is,

$$g(y) = f[w_1(y), \dots, w_n(y)] |J|$$
 (28.11)

The functions w_i express the inverse transformation, $x_i = w_i(y)$ for $i=1,\ldots,n,$ and |J| is the absolute value of the determinant of the square matrix $J_{ij} = \partial x_i/\partial y_j$. If the transformation from x to y is not one-to-one, the situation is more complex and a unique solution . may not exist. For example, if the change is to m < n variables, then a given y may correspond to more than one x, leading to multiple integrals over the contributions [1].

To change variables for discrete random variables simply substitute; no Jacobian is necessary because now f is a probability rather than a

If f depends upon a parameter set α , a change to a different parameter set $\phi_i = \phi_i(\alpha)$ is made by simple substitution; no Jacobian is used.

28.2. Characteristic functions

The characteristic function $\phi(u)$ associated with the p.d.f. f(x) is essentially its (inverse) Fourier transform, or the expectation value of

$$\phi(u) = E(e^{iux}) = \int_{-\infty}^{\infty} e^{iux} f(x) dx . \qquad (28.12)$$

It is often useful, and several of its properties follow [1].

It follows from Eqs. (28.3a) and (28.12) that the *n*th moment of the distribution f(x) is given by

$$i^{-n}\frac{d^n\phi}{du^n}\bigg|_{u=0} = \int_{-\infty}^{\infty} x^n f(x) dx = \alpha_n . \tag{28.13}$$

Thus it is often easy to calculate all the moments of a distribution defined by $\phi(u)$, even when f(x) is difficult to obtain.

If $f_1(x)$ and $f_2(y)$ have characteristic functions $\phi_1(u)$ and $\phi_2(u)$, then the characteristic function of the weighted sum ax + by is $\phi_1(au)\phi_2(bu)$. The addition rules for common distributions (e.g., that the sum of two numbers from Gaussian distributions also has a Gaussian distribution) easily follow from this observation.

Let the (partial) characteristic function corresponding to the conditional p.d.f. $f_2(x|z)$ be $\phi_2(u|z)$, and the p.d.f. of z be $f_1(z)$. The characteristic function after integration over the conditional value is

$$\phi(u) = \int \phi_2(u|z) f_1(z) dz . \qquad (28.14)$$

Suppose we can write ϕ_2 in the form

$$\phi_2(u|z) = A(u)e^{ig(u)z}$$
 (28.15)

Then

$$\phi(u) = A(u)\phi_1(g(u)) . (28.16)$$

The semi-invariants κ_n are defined by

$$\phi(u) = \exp\left(\sum_{1}^{\infty} \frac{\kappa_n}{n!} (iu)^n\right) = \exp\left(i\kappa_1 u - \frac{1}{2}\kappa_2 u^2 + \ldots\right) . \quad (28.17)$$

The κ_n 's are related to the moments α_n and m_n . The first few relations are

$$\kappa_1 = \alpha_1 \ (= \mu, \text{ the mean})$$

$$\kappa_2 = m_2 = \alpha_2 - \alpha_1^2 \ (= \sigma^2, \text{ the variance})$$

$$\kappa_3 = m_3 = \alpha_3 - 3\alpha_1\alpha_2 + 2\alpha_1^2 \ . \tag{28.18}$$

28.3. Some probability distributions

Table 28.1 gives a number of common probability density functions and corresponding characteristic functions, means, and variances. Further information may be found in Refs. 1-6; Ref. 6 has particularly detailed tables. Monte Carlo techniques for generating each of them may be found in our Sec. 30.4. We comment below on all except the trivial uniform distribution.

28.3.1. Binomial distribution: A random process with exactly two possible outcomes is called a Bernoulli process. If the probability of obtaining a certain outcome (a "success") in each trial is p, then the probability of obtaining exactly r successes $(r=0,1,2,\ldots,n)$ in n trials, without regard to the order of the successes and failures, is given by the binomial distribution f(r;n,p) in Table 28.1. If r successes are observed in n_r trials with probability p of a success, and if s successes are observed in n_s similar trials, then t=r+s is also binomial with $n_t=n_r+n_s$.

28.3.2. Poisson distribution: The Poisson distribution $f(r;\mu)$ gives the probability of finding exactly r events in a given interval of x (e.g., space and time) when the events occur independently of one another and of x at an average rate of μ per the given interval. The variance σ^2 equals μ . It is the limiting case $p \to 0$, $n \to \infty$, $np = \mu$ of the binomial distribution. The Poisson distribution approaches the Gaussian distribution for large μ .

Two or more Poisson processes (e.g., signal + background, with parameters μ_s and μ_b) that independently contribute amounts n_s and n_b to a given measurement will produce an observed number $n=n_s+n_b$, which is distributed according to a new Poisson distribution with parameter $\mu=\mu_s+\mu_b$.

28.3.3. Normal or Gaussian distribution: The normal (or Gaussian) probability density function $f(x; \mu, \sigma^2)$ given in Table 28.1 has mean $\overline{x} = \mu$ and variance σ^2 . Comparison of the characteristic function $\phi(u)$ given in Table 28.1 with Eq. (28.17) shows that all semi-invariants κ_n beyond κ_2 vanish; this is a unique property of the Gaussian distribution. Some properties of the distribution are:

rms deviation = σ probability x in the range $\mu \pm \sigma = 0.6827$ probability x in the range $\mu \pm 0.6745\sigma = 0.5$ expection value of $|x - \mu|$, $E(|x - \mu|) = (2/\pi)^{1/2}\sigma = 0.7979\sigma$ half-width at half maximum = $(2 \ln 2)^{1/2}\sigma = 1.177\sigma$

The cumulative distribution, Eq. (28.1), for a Gaussian with $\mu=0$ and $\sigma^2=1$ is related to the error function $\mathrm{erf}(y)$ by

$$F(x;0,1) = \frac{1}{2} \left[1 + \operatorname{erf}(x/\sqrt{2}) \right] . \tag{28.19}$$

The error function is tabulated in Ref. 6 and is available in computer math libraries and personel computer spreadsheets. For a mean μ and variance σ^2 , replace x by $(x - \mu)/\sigma$. The probability of x in a given range can be calculated with Eq. (29.36).

For x and y independent and normally distributed, z = ax + by obeys $f(z; a\mu_x + b\mu_y, a^2\sigma_x^2 + b^2\sigma_y^2)$; that is, the weighted means and variances add.

The Gaussian gets its importance in large part from the central limit theorem: If a continuous random variable x is distributed according to any p.d.f. with finite mean and variance, then the sample mean, \overline{x}_n , of n observations of x will have a p.d.f. that approaches a Gaussian as n increases. Therefore the end result $\sum^n x_i \equiv n\overline{x}_n$ of a large number of small fluctuations x_i will be distributed as a Gaussian, even if the x_i themselves are not.

For a set of n Gaussian random variables x with means μ and corresponding Fourier variables u, the characteristic function for a one-dimensional Gaussian is generalized to

$$\phi(\mathbf{x}; \boldsymbol{\mu}, S) = \exp\left[i\boldsymbol{\mu} \cdot \mathbf{u} - \frac{1}{2}\mathbf{u}^T S \mathbf{u}\right] . \tag{28.20}$$

From Eq. (28.13), the covariance about the mean is

$$E[(x_j - \mu_j)(x_k - \mu_k)] = S_{jk}. (28.21)$$

If the x are independent, then $S_{jk} = \delta_{jk}\sigma_j^2$, and Eq. (28.20) is the product of the c.f.'s of n Gaussians.

The covariance matrix S can be related to the correlation matrix defined by Eq. (28.9) (a sort of normalized covariance matrix). With the definition $\sigma_k^2 \equiv S_{kk}$, we have $\rho_{jk} = S_{jk}/\sigma_j \sigma_k$.

The characteristic function may be inverted to find the corresponding p.d.f.

$$f(x; \mu, S) = \frac{1}{(2\pi)^{n/2} \sqrt{|S|}} \exp\left[-\frac{1}{2}(x - \mu)^T S^{-1}(x - \mu)\right] (28.22)$$

where the determinant |S| must be greater than 0. For diagonal S (independent variables), $f(x; \mu, S)$ is the product of the p.d.f.'s of n Gaussian distributions.

Table 28.1. Some common probability density functions, with corresponding characteristic functions and	
means and variances. In the Table, $\Gamma(k)$ is the gamma function, equal to $(k-1)!$ when k is an integer.	
	=

Distribution	Probability density function f (variable; parameters)	Characteristic function $\phi(u)$	Mean	Variance σ^2
Uniform	$f(x;a,b) = \left\{egin{array}{ll} 1/(b-a) & a \leq x \leq b \ 0 & ext{otherwise} \end{array} ight.$	$\frac{e^{ibu}-e^{iau}}{(b-a)iu}$	$\overline{x} = \frac{\overline{a+b}}{2}$	$\frac{(b-a)^2}{12}$
Binomial	$f(r;n,p) = rac{n!}{r!(n-r)!} p^r q^{n-r} \ r = 0,1,2,\ldots,n \; ; 0 \leq p \leq 1 \; ; q = 1-p$	$(q+pe^{iu})^n$	$\overline{r}=np$	npq
Poisson	$f(r;\mu) = \frac{\mu^r e^{-\mu}}{r!} \; ; r = 0, 1, 2, \dots \; ; \mu > 0$	$\exp[\mu(e^{iu}-1)]$	$\overline{r}=\mu$	μ
Normal (Gaussian)	$f(x; \mu, \sigma^2) = \frac{1}{\sigma \sqrt{2\pi}} \exp(-(x - \mu)^2 / 2\sigma^2)$ $-\infty < x < \infty \; ; -\infty < \mu < \infty \; ; \sigma > 0$	$\exp(i\mu u - \frac{1}{2}\sigma^2 u^2)$	$\overline{x} = \mu$	σ^2
Multivariate Gaussian	$f(oldsymbol{x};oldsymbol{\mu},S) = rac{1}{(2\pi)^{n/2}\sqrt{ S }} \ imes \exp\left[-rac{1}{2}(oldsymbol{x}-oldsymbol{\mu})^TS^{-1}(oldsymbol{x}-oldsymbol{\mu}) ight] \ -\infty < oldsymbol{x}_j < \infty; -\infty < oldsymbol{\mu}_j < \infty; \det S > 0$	$\exp\left[i\boldsymbol{\mu}\cdot\boldsymbol{u}-rac{1}{2}\boldsymbol{u}^TS\boldsymbol{u} ight]$	μ	S_{jk}
χ^2	$f(z;n) = \frac{z^{n/2-1}e^{-z/2}}{2^{n/2}\Gamma(n/2)}$; $z \ge 0$	$(1-2iu)^{-n/2}$	$\overline{z} = n$	2n
Student's t	$f(t;n) = rac{1}{\sqrt{n\pi}} \; rac{\Gamma[(n+1)/2]}{\Gamma(n/2)} \left(1 + rac{t^2}{n} ight)^{-(n+1)/2} onumber \ -\infty < t < \infty \; ; \qquad n ext{ not required to be integer}$. - .	$ar{t}=0 \ ext{for } n\geq 2$	$n/(n-2)$ for $n \ge 3$
Gamma	$f(x;\lambda,k) = rac{x^{k-1}\lambda^k e^{-\lambda x}}{\Gamma(k)}\;; 0 < x < \infty\;;$ k not required to be integer	$(1-iu/\lambda)^{-k}$	$\overline{x} = k/\lambda$	k/λ^2

For n=2, $f(x; \mu, S)$ is

$$f(x_1, x_2; \ \mu_1, \mu_2, \sigma_1, \sigma_2, \rho) = \frac{1}{2\pi\sigma_1\sigma_2\sqrt{1-\rho^2}}$$

$$\times \exp\left\{\frac{-1}{2(1-\rho^2)} \left[\frac{(x_1 - \mu_1)^2}{\sigma_1^2} - \frac{2\rho(x_1 - \mu_1)(x_2 - \mu_2)}{\sigma_1\sigma_2} + \frac{(x_2 - \mu_2)^2}{\sigma_2^2} \right] \right\}. \tag{28.23}$$

The marginal distribution of any x_i is a Gaussian with mean μ_i and variance S_{ii} . S is $n \times n$, symmetric, and positive definite. Therefore for any vector \mathbf{X} , the quadratic form $\mathbf{X}^T S^{-1} \mathbf{X} = C$, where C is any positive number, traces an n-dimensional ellipsoid as \mathbf{X} varies. If $X_i = (x_i - \mu_i)/\sigma_i$, then C is a random variable obeying the $\chi^2(n)$ distribution, discussed in the following section. The probability that \mathbf{X} corresponding to a set of Gaussian random variables x_i lies outside the ellipsoid characterized by a given value of $C = \chi^2$ is given by Eq. (28.24) and may be read from Fig. 28.1. For example, the "s-standard-deviation ellipsoid" occurs at $C = s^2$. For the two-variable case (n = 2), the point \mathbf{X} lies outside the one-standard-deviation ellipsoid with 61% probability. (This assumes that μ_i and σ_i are correct.) For $X_i = x_i/\sigma_i$, the ellipsoids of constant χ^2 have the same size and orientation but are centered at μ . The use of these ellipsoids as indicators of probable error is described in Sec. 29.6.4.

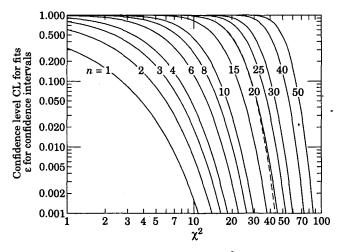


Figure 28.1: The confidence level versus χ^2 for n degrees of freedom, as defined in Eq. (28.24). The curve for a given n gives the probability that a value at least as large as χ^2 will be obtained in an experiment; e.g., for n=10, a value $\chi^2\gtrsim 18$ will occur in 5% of a large number of experiments. For a fit, the CL is a measure of goodness-of-fit, in that a good fit to a correct model is expected to yield a low χ^2 (see Sec. 29.5.0). For a confidence interval, α measures the probability that the interval does not cover the true value of the quantity being estimated (see Sec. 29.6). The dashed curve for n=20 is calculated using the approximation of Eq. (28.25).

28.3.4. χ^2 distribution: If x_1, \ldots, x_n are independent Gaussian distributed random variables, the sum $z = \sum^n (x_i - \mu_i)^2 / \sigma_i^2$ is distributed as a χ^2 with n degrees of freedom, $\chi^2(n)$. Under a linear transformation to n dependent Gaussian variables x_i' , the χ^2 at each transformed point retains its value; then $z = X'^T V^{-1}X'$ as in the previous section. For a set of z_i , each of which is $\chi^2(n_i)$, $\sum z_i$ is a new random variable which is $\chi^2(\sum n_i)$.

Fig. 28.1 shows the confidence level (CL) obtained by integrating the tail of f(z;n):

$$CL(\chi^2) = \int_{\chi^2}^{\infty} f(z; n) dz$$
. (28.24)

This is shown for a special case in Fig. 28.2, and is equal to 1.0 minus the cumulative distribution function $F(z=\chi^2;n)$. It is useful in evaluating the consistency of data with a model (see Sec. 29): The CL is the probability that a random repeat of the given experiment would observe a greater χ^2 , assuming the model is correct. It is also useful for confidence intervals for statistical estimators (see Sec. 29.6), in which case one is interested in the unshaded area of Fig. 28.2.

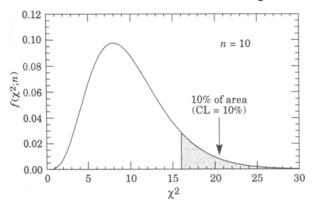


Figure 28.2: Illustration of the confidence level integral given in Eq. (28.24). This particlar example is for n = 10, where the area above 15.99 is 0.1.

Since the mean of the χ^2 distribution is equal to n, one expects in a "reasonable" experiment to obtain $\chi^2 \approx n$. While caution is necessary because of the width and skewness of the distribution, the "reduced χ^2 " $\equiv \chi^2/n$ is a sometimes useful quantity. Figure 28.3 shows χ^2/n for useful CL's as a function of n.

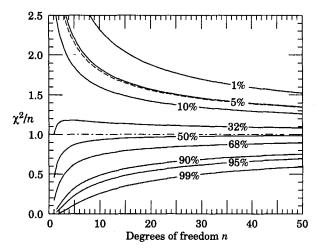


Figure 28.3: Confidence levels as a function of the "reduced χ^2 " $\equiv \chi^2/n$ and the number of degrees of freedom n. Curves are labeled by the probability that a measurement will give a value of χ^2/n greater than that given on the y axis; e.g., for n=10, a value $\chi^2/n \gtrsim 1.8$ can be expected 5% of the time.

For large n, the CL is approximately given by [1,7]

$$CL(\chi^2) \approx \frac{1}{\sqrt{2\pi}} \int_y^\infty e^{-x^2/2} dx$$
, (28.25)

where $y = \sqrt{2\chi^2} - \sqrt{2n-1}$. This approximation was used to draw the dashed curves in Fig. 28.1 (for n=20) and Fig. 28.3 (for CL = 5%). Since all the functions and their inverses are now readily available in standard mathematical libraries (such as IMSL, used to generate these figures, and personal computer spreadsheets, such as Microsoft \mathbb{R} Excel [8]), the approximation (and even figures and tables) are seldom needed.

28.3.5. Student's t distribution: Suppose that x and x_1, \ldots, x_n are independent and Gaussian distributed with mean 0 and variance 1. We then define

$$z = \sum_{i=1}^{n} x_i^2$$
, and $t = \frac{x}{\sqrt{z/n}}$. (28.26)

The variable z thus belongs to a $\chi^2(n)$ distribution. Then t is distributed according to a Student's t distribution with n degrees of freedom, f(t;n), given in Table 28.1.

The Student's t distribution resembles a Gaussian distribution with wide tails. As $n \to \infty$, the distribution approaches a Gaussian. If n=1, the distribution is a *Cauchy* or *Breit-Wigner* distribution. The mean is finite only for n>1 and the variance is finite only for n>2, so for n=1 or n=2, t does not obey the central limit theorem.

As an example, consider the sample mean $\overline{x} = \sum x_i/n$ and the sample variance $s^2 = \sum (x_i - \overline{x})^2/(n-1)$ for normally distributed random variables x_i with unknown mean μ and variance σ^2 . The sample mean has a Gaussian distribution with a variance σ^2/n , so the variable $(\overline{x} - \mu)/\sqrt{\sigma^2/n}$ is normal with mean 0 and variance 1. Similarly, $(n-1) s^2/\sigma^2$ is independent of this and is χ^2 distributed with n-1 degrees of freedom. The ratio

$$t = \frac{(\overline{x} - \mu)/\sqrt{\sigma^2/n}}{\sqrt{(n-1) s^2/\sigma^2 (n-1)}} = \frac{\overline{x} - \mu}{\sqrt{s^2/n}}$$
 (28.27)

is distributed as f(t; n-1). The unknown true variance σ^2 cancels, and t can be used to test the probability that the true mean is some particular value μ .

In Table 28.1, n in f(t;n) is not required to be an integer. A Student's t distribution with nonintegral n > 0 is useful in certain applications.

28.3.6. Gamma distribution: For a process that generates events as a function of x (e.g., space or time) according to a Poisson distribution, the distance in x from an arbitrary starting point (which may be some particular event) to the k^{th} event belongs to a gamma distribution, $f(x; \lambda, k)$. The Poisson parameter μ is λ per unit x. The special case k = 1 (i.e., $f(x; \lambda, 1) = \lambda e^{-\lambda x}$) is called the exponential distribution. A sum of k' exponential random variables x_i is distributed as $f(\sum x_i; \lambda, k')$.

The parameter k is not required to be an integer. For $\lambda = 1/2$ and k = n/2, the gamma distribution reduces to the $\chi^2(n)$ distribution.

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- 8. Microsoft® is a registered trademark of Microsoft corporation.

29. STATISTICS

Revised April 1998 by F. James (CERN).

29.1. Parameter estimation [1-4]

A probability density function $f(x;\alpha)$ with known parameters α enables us to predict the frequency with which random data x will take on a particular value (if discrete) or lie in a given range (if continuous). In *parametric* statistics we have the opposite problem of estimating the parameters α from a set of actual observations.

A statistic is any function of the data, plus known constants, which does not depend upon any of the unknown parameters. A statistic is a random variable if the data have random errors. An estimator is any statistic whose value (the estimate $\widehat{\alpha}$) is intended as a meaningful guess for the value of the parameter α , or the vector α if there is more than one parameter.

Since we are free to choose any function of the data as an estimator of the parameter α , we will try to choose that estimator which has the best properties. The most important properties are (a) consistency, (b) bias, (c) efficiency, and (d) robustness.

- (a) An estimator is said to be *consistent* if the estimate $\hat{\alpha}$ converges to the true value α as the amount of data increases. This property is so important that it is possessed by all commonly used estimators.
- (b) The bias, $b = E(\widehat{\alpha}) \widehat{\alpha}$, is the difference between the true value and the expectation of the estimates, where the expectation value is taken over a hypothetical set of similar experiments in which $\widehat{\alpha}$ is constructed the same way. When b=0 the estimator is said to be unbiased. The bias may be due to statistical properties of the estimator or to systematic errors in the experiment. If we can estimate the b we can subtract it from $\widehat{\alpha}$ to obtain a new $\widehat{\alpha}' \equiv \widehat{\alpha} b$. However, b may depend upon α or other unknowns, in which case we usually try to choose an estimator which minimizes its average size.
- (c) Efficiency is the inverse of the ratio between the variance of the estimates $Var(\widehat{\alpha})$ and the minimum possible value of the variance. Under rather general conditions, the minimum variance is given by the Rao-Cramér-Frechet bound:

$$Var_{min} = [1 + \partial b/\partial \alpha]^2/I(\alpha);$$
 (29.1)

$$I(\alpha) = E \left\{ \left[\frac{\partial}{\partial \alpha} \sum_{i=1}^{n} \ln f(x_i; \alpha) \right]^2 \right\} .$$

(Compare with Eq. (29.6) below.) The sum is over all data and b is the bias, if any; the x_i are assumed independent and distributed as $f(x_i; \alpha)$, and the allowed range of x must not depend upon α . Mean-squared error, $\operatorname{mse} = E[(\widehat{\alpha} - \alpha)^2] = V(\widehat{\alpha}) + b^2$ is a convenient quantity which combines in the appropriate way the errors due to bias and efficiency.

(d) Robustness; is the property of being insensitive to departures from assumptions in the p.d.f. due to such factors as noise.

For some common estimators the above properties are known exactly. More generally, it is always possible to evaluate them by Monte Carlo simulation. Note that they will often depend on the unknown α .

29.2. Data with a common mean

Suppose we have a set of N independent measurements y_i assumed to be unbiased measurements of the same unknown quantity μ with a common, but unknown, variance σ^2 resulting from measurement error. Then

$$\widehat{\mu} = \frac{1}{N} \sum_{i=1}^{N} y_i = E(y)$$
 (29.2)

$$\widehat{\sigma}^2 = \frac{1}{N-1} \sum_{i=1}^{N} (y_i - \widehat{\mu})^2 = \frac{N}{N-1} \left(E(y^2) - \widehat{\mu}^2 \right)$$
 (29.3)

are unbiased estimators of μ and σ^2 . The variance of $\hat{\mu}$ is σ^2/N . If the common p.d.f. of the y_i is Gaussian, these estimates are uncorrelated. Then, for large N, the standard deviation of $\hat{\sigma}$ (the "error of the

error") is $\sigma/\sqrt{2N}$. Again if the y_i are Gaussian, $\widehat{\mu}$ is an efficient estimator for μ . Otherwise the mean is in general not the most efficient estimator. For example, if the y follow a double-exponential distribution, the most efficient estimator of the mean is the sample median (the value for which half the y_i lie above and half below). This is discussed in more detail in Ref. 2, section 8.7.

If σ^2 is known, it does not improve the estimate $\widehat{\mu}$, as can be seen from Eq. (29.2); however, if μ is known, substitute it for $\widehat{\mu}$ in Eq. (29.3) and replace N-1 by N, to obtain a somewhat better estimator of σ^2 .

If the y_i have different, known, variances σ_i^2 , then the weighted average

$$\widehat{\mu} = \frac{1}{m} \sum_{i}^{N} w_i \ y_i \ , \tag{29.4}$$

is an unbiased estimator for μ with smaller variance than Eq. (29.2), where $w_i = 1/\sigma_i^2$ and $w = \sum w_i$. The standard deviation of $\widehat{\mu}$ is $1/\sqrt{w}$.

29.3. The method of maximum likelihood

29.3.1. Parameter estimation by maximum likelihood:

"From a theoretical point of view, the most important general method of estimation so far known is the *method of maximum likelihood*" [3]. We suppose that a set of independently measured quantities x_i came from a p.d.f. $f(x;\alpha)$, where α is an unknown set of parameters. The method of maximum likelihood consists of finding the set of values, $\hat{\alpha}$, which maximizes the joint probability density for all the data, given by

$$\mathscr{L}(\alpha) = \prod_{i} f(x_i; \alpha) , \qquad (29.5)$$

where \mathcal{L} is called the likelihood. It is usually easier to work with $\ln \mathcal{L}$, and since both are maximized for the same set of α , it is sufficient to solve the *likelihood equation*

$$\frac{\partial \ln \mathcal{L}}{\partial \alpha_n} = 0 \ . \tag{29.6}$$

When the solution to Eq. (29.6) is a maximum, it is called the maximum likelihood estimate of α . The importance of the approach is shown by the following proposition, proved in Ref. 1:

If an efficient estimate $\hat{\alpha}$ of α exists, the likelihood equation will have a unique solution equal to $\hat{\alpha}$.

In evaluating \mathcal{L} , it is important that any normalization factors in the f's which involve α be included. However, we will only be interested in the maximum of \mathcal{L} and in ratios of \mathcal{L} at different α 's; hence any multiplicative factors which do not involve the parameters we want to estimate may be dropped; this includes factors which depend on the data but not on α . The results of two or more independent experiments may be combined by forming the product of the \mathcal{L} 's, or the sum of the $\ln \mathcal{L}$'s.

Most commonly the solution to Eq. (29.6) will be found using a general numerical minimization program such as the CERN program MINUIT [8] which contains considerable code to take account of the many special cases and problems which can arise.

Under a one-to-one change of parameters from α to $\beta = \beta(\alpha)$, the maximum likelihood estimate $\widehat{\alpha}$ transforms to $\beta(\widehat{\alpha})$. That is, the maximum likelihood solution is invariant under change of parameter. However, many properties of $\widehat{\alpha}$, in particular the bias, are not invariant under change of parameter.

29.3.2. Confidence intervals from the likelihood function:

The covariance matrix V may be estimated from

$$V_{nm} = \left(E \left[-\frac{\partial^2 \ln \mathcal{L}}{\partial \alpha_n \partial \alpha_m} \Big|_{\widehat{\alpha}} \right] \right)^{-1} . \tag{29.7}$$

In the asymptotic case (or a linear model with Gaussian errors), $\mathscr L$ is Gaussian, $\ln \mathscr L$ is a (multidimensional) parabola, and the second derivative in Eq. (29.7) is constant, so the "expectation" operation has no effect. This leads to the usual approximation of calculating the error matrix of the parameters by inverting the second derivative matrix of $\ln \mathscr L$. In this asymptotic case, it can be seen that a numerically equivalent way of determining s-standard-deviation errors is from the contour given by the α' such that

$$\ln \mathcal{L}(\alpha') = \ln \mathcal{L}_{\text{max}} - s^2/2 , \qquad (29.8)$$

where $\ln \mathcal{L}_{\text{max}}$ is the value of $\ln \mathcal{L}$ at the solution point (compare with Eq. (29.32), below). The extreme limits of this contour parallel to the α_n axis give an approximate s-standard-deviation confidence interval in α_n . These intervals may not be symmetric and in pathological cases they may even consist of two or more disjoint intervals.

Although asymptotically Eq. (29.7) is equivalent to Eq. (29.8) with s=1, the latter is a better approximation when the model deviates from linearity. This is because Eq. (29.8) is invariant with respect to even a non-linear transformation of parameters α , whereas Eq. (29.7) is not. Still, when the model is non-linear or errors are not Gaussian, confidence intervals obtained with both these formulas are only approximate. The true coverage of these confidence intervals can always be determined by a Monte Carlo simulation, or exact confidence intervals can be determined as in Sec. 29.6.3.

29.3.3. Application to Poisson-distributed data:

In the case of Poisson-distributed data in a counting experiment, the unbinned maximum likelihood method (where the index i in Eq. (29.5) labels events) is preferred if the total number of events is very small. If there are enough events to justify binning them in a histogram, then one may alternatively maximize the likelihood function for the contents of the bins (so i labels bins). This is equivalent to minimizing [5]

$$\chi^2 = \sum_{i} \left[2(N_i^{\rm th} - N_i^{\rm obs}) + 2N_i^{\rm obs} \ln(N_i^{\rm obs}/N_i^{\rm th}) \right]. \tag{29.9}$$

where N_i^{obs} and N_i^{th} are the observed and theoretical (from f) contents of the ith bin. In bins where $N_i^{\text{obs}} = 0$, the second term is zero. This function asymptotically behaves like a classical χ^2 for purposes of point estimation, interval estimation, and goodness-of-fit. It also guarantees that the area under the fitted function f is equal to the sum of the histogram contents (as long as the overall normalization of f is effectively left unconstrained during the fit), which is not the case for χ^2 statistics based on a least-squares procedure with traditional weights.

29.4. Propagation of errors

Suppose that $F(x;\alpha)$ is some function of variable(s) x and the fitted parameters α , with a value \widehat{F} at $\widehat{\alpha}$. The variance matrix of the parameters is V_{mn} . To first order in $\alpha_m - \widehat{\alpha}_m$, F is given by

$$F = \widehat{F} + \sum_{m} \frac{\partial F}{\partial \alpha_{m}} (\alpha_{m} - \widehat{\alpha}_{m}) , \qquad (29.10)$$

and the variance of F about its estimator is given by

$$(\Delta F)^2 = E[(F - \widehat{F})^2] = \sum_{mn} \frac{\partial F}{\partial \alpha_m} \frac{\partial F}{\partial \alpha_n} V_{mn} , \qquad (29.11)$$

evaluated at the x of interest. For different functions F_j and F_k , the covariance is

$$E[(F_j - \widehat{F}_j)(F_k - \widehat{F}_k)] = \sum_{mn} \frac{\partial F_j}{\partial \alpha_m} \frac{\partial F_k}{\partial \alpha_n} V_{mn} . \tag{29.12}$$

If the first-order approximation is in serious error, the above results may be very approximate. \widehat{F} may be a biased estimator of F even if the $\widehat{\alpha}$ are unbiased estimators of α . Inclusion of higher-order terms or direct evaluation of F in the vicinity of $\widehat{\alpha}$ will help to reduce the bias.

29.5. Method of least squares

The method of least squares can be derived from the maximum likelihood theorem. We suppose a set of N measurements at points x_i . The *i*th measurement y_i is assumed to be chosen from a Gaussian distribution with mean $F(x_i; \alpha)$ and variance σ_i^2 . Then

$$\chi^2 = -2\ln \mathcal{L} + \text{constant} = \sum_{i=1}^{N} \frac{[y_i - F(x_i; \alpha)]^2}{\sigma_i^2} . \qquad (29.13)$$

Finding the set of parameters α which maximizes \mathcal{L} is the same as finding the set which minimizes χ^2 .

In many practical cases one further restricts the problem to the situation in which $F(x_i; \alpha)$ is a linear function of the α_m 's,

$$F(x_i;\alpha) = \sum_n \alpha_n f_n(x) , \qquad (29.14)$$

where the f_n are k linearly independent functions (e.g., 1, x, x^2 , ..., or Legendre polynomials) which are single-valued over the allowed range of x. We require $k \leq N$, and at least k of the x_i must be distinct. We wish to estimate the linear coefficients α_n . Later we will discuss the nonlinear case.

If the point errors $\epsilon_i=y_i-F(x_i;\alpha)$ are Gaussian, then the minimum χ^2 will be distributed as a χ^2 random variable with n = N - k degrees of freedom. We can then evaluate the goodnessof-fit (confidence level) from Figs. 28.1 or 28.3, as per the earlier discussion. The confidence level expresses the probability that a worse fit would be obtained in a large number of similar experiments under the assumptions that: (a) the model $y = \sum \alpha_n f_n$ is correct and (b) the errors ϵ_i are Gaussian and unbiased with variance σ_i^2 . If this probability is larger than an agreed-upon value (0.001, 0.01, or 0.05 are common choices), the data are consistent with the assumptions; otherwise we may want to find improved assumptions. As for the converse, most people do not regard a model as being truly inconsistent unless the probability is as low as that corresponding to four or five standard deviations for a Gaussian $(6\times10^{-3}~{\rm or}~6\times10^{-5};{\rm see~Sec.}~29.6.4)$. If the ϵ_i are not Gaussian, the method of least squares still gives an answer, but the goodness-of-fit test would have to be done using the correct distribution of the random variable which is still called " χ^2 ."

Finding the minimum of χ^2 in the linear case is straightforward:

$$-\frac{1}{2}\frac{\partial \chi^2}{\partial \alpha_m} = \sum_{i} f_m(x_i) \left(\frac{y_i - \sum_{n} \alpha_n f_n(x_i)}{\sigma_i^2} \right)$$
$$= \sum_{i} \frac{y_i f_m(x_i)}{\sigma_i^2} - \sum_{n} \alpha_n \sum_{i} \frac{f_n(x_i) f_m(x_i)}{\sigma_i^2} . \tag{29.15}$$

With the definitions

$$g_m = \sum_{i} y_i f_m(x_i) / \sigma_i^2$$
 (29.16)

and

$$V_{mn}^{-1} = \sum_{i} f_n(x_i) f_m(x_i) / \sigma_i^2 , \qquad (29.17)$$

the k-element column vector of solutions $\hat{\alpha}$, for which $\partial \chi^2/\partial \alpha_m=0$ for all m, is given by

$$\widehat{\boldsymbol{\alpha}} = \boldsymbol{V} \, \boldsymbol{g} \, . \tag{29.18}$$

With this notation, χ^2 for the special case of a linear fitting function (Eq. (29.14)) can be rewritten in the compact form

$$\chi^2 = \chi_{\min}^2 + (\alpha - \widehat{\alpha})^T V^{-1} (\alpha - \widehat{\alpha}) . \qquad (29.19)$$

Nonindependent y_i 's

Eq. (29.13) is based on the assumption that the likelihood function is the product of independent Gaussian distributions. More generally, the measured y_i's are not independent, and we must consider them as

coming from a multivariate distribution with nondiagonal covariance matrix S, as described in Sec. 28.3.3. The generalization of Eq. (29.13) is

$$\chi^2 = \sum_{jk} [y_j - F(x_j; \alpha)] S_{jk}^{-1} [y_k - F(x_k; \alpha)] . \qquad (29.20)$$

In the case of a fitting function that is linear in the parameters, one may differentiate χ^2 to find the generalization of Eq. (29.15), and with the extended definitions

$$g_m = \sum_{jk} y_j \ f_m(x_k) S_{jk}^{-1}$$

$$V_{mn}^{-1} = \sum_{jk} f_n(x_j) \ f_m(x_k) S_{jk}^{-1}$$
(29.21)

solve Eq. (29.18) for the estimators $\hat{\alpha}$.

The problem of constructing the covariance matrix S is simplified by the fact that contributions to S (not to its inverse) are additive. For example, suppose that we have three variables, all of which have independent statistical errors. The first two also have a common error resulting in a positive correlation, perhaps because a common baseline with its own statistical error (variance s^2) was subtracted from each. In addition, the second two have a common error (variance a^2), but this time the values are anticorrelated. This might happen, for example, if the sum of the two variables is a constant. Then

$$S = \begin{pmatrix} \sigma_1^2 & 0 & 0 \\ 0 & \sigma_2^2 & 0 \\ 0 & 0 & \sigma_3^2 \end{pmatrix} + \begin{pmatrix} s^2 & s^2 & 0 \\ s^2 & s^2 & 0 \\ 0 & 0 & 0 \end{pmatrix} + \begin{pmatrix} 0 & 0 & 0 \\ 0 & a^2 & -a^2 \\ 0 & -a^2 & a^2 \end{pmatrix} . \tag{29.22}$$

If unequal amounts of the common baseline were subtracted from variables 1, 2, and 3—e.g., fractions f_1 , f_2 , and f_3 , then we would have

$$S = \begin{pmatrix} \sigma_1^2 & 0 & 0 \\ 0 & \sigma_2^2 & 0 \\ 0 & 0 & \sigma_3^2 \end{pmatrix} + \begin{pmatrix} f_1^2 s^2 & f_1 f_2 s^2 & f_1 f_3 s^2 \\ f_1 f_2 s^2 & f_2^2 s^2 & f_2 f_3 s^2 \\ f_1 f_3 s^2 & f_2 f_3 s^2 & f_3^2 s^2 \end{pmatrix} .$$
 (29.23)

While in general this "two-vector" representation is not possible, it underscores the procedure: Add zero-determinant correlation matrices to the matrix expressing the independent variation.

Care must be taken when fitting to correlated data, since off-diagonal contributions to χ^2 are not necessarily positive. It is even possible for all of the residuals to have the same sign.

Example: straight-line fit

For the case of a straight-line fit, $y(x) = \alpha_1 + \alpha_2 x$, one obtains, for independent measurements y_i , the following estimates of α_1 and α_2 ,

$$\widehat{\alpha}_1 = (g_1 \ \Lambda_{22} - g_2 \ \Lambda_{12})/D \ ,$$
 (29.24)

$$\widehat{\alpha}_2 = (g_2 \ \Lambda_{11} - g_1 \ \Lambda_{12})/D \ , \tag{29.25}$$

where

$$(\Lambda_{11}, \Lambda_{12}, \Lambda_{22}) = \sum_{i=1}^{n} (1, x_i, x_i^2) / \sigma_i^2 , \qquad (29.26a)$$

$$(g_1, g_2) = \sum_{i} (1, x_i) y_i / \sigma_i^2 . \qquad (29.26b)$$

respectively, and

$$D = \Lambda_{11} \Lambda_{22} - (\Lambda_{12})^{2} . \tag{29.27}$$

The covariance matrix of the fitted parameters is:

$$\begin{pmatrix} V_{11} & V_{12} \\ V_{12} & V_{22} \end{pmatrix} = \frac{1}{D} \begin{pmatrix} \Lambda_{22} & -\Lambda_{12} \\ -\Lambda_{12} & \Lambda_{11} \end{pmatrix} . \tag{29.28}$$

The estimated variance of an interpolated or extrapolated value of y at point x is:

$$(\widehat{y} - y_{\text{true}})^2 \Big|_{\text{est}} = \frac{1}{\Lambda_{11}} + \frac{\Lambda_{11}}{D} \left(x - \frac{\Lambda_{12}}{\Lambda_{11}} \right)^2$$
 (29.29)

29.5.1. Confidence intervals from the chisquare function:

If y is not linear in the fitting parameters α , the solution vector may have to be found by iteration. If we have a first guess α_0 , then we may expand to obtain

$$\left. \frac{\partial \chi^2}{\partial \alpha} \right|_{\alpha} = \left. \frac{\partial \chi^2}{\partial \alpha} \right|_{\alpha_0} + V_{\alpha_0}^{-1} \cdot (\alpha - \alpha_0) + \dots , \qquad (29.30)$$

where $\partial \chi^2/\partial \alpha$ is a vector whose mth component is $\partial \chi^2/\partial \alpha_m$, and $(V_{mn}^{-1})=\frac{1}{2}\partial^2\chi^2/\partial \alpha_m\partial \alpha_n$. (See Eqns. 29.7 and 29.17. When evaluated at $\widehat{\alpha}$, V^{-1} is the inverse of the covariance matrix.) The next iteration toward $\widehat{\alpha}$ can be obtained by setting $\partial \chi^2/\partial \alpha_m|_{\alpha}=0$ and neglecting higher-order terms:

$$\alpha = \alpha_0 - V_{\alpha_0} \cdot \partial \chi^2 / \partial \alpha|_{\alpha_0} . \tag{29.31}$$

If V is constant in the vicinity of the minimum, as it is when the model function is linear in the parameters, then χ^2 is parabolic as a function of α and Eq. (29.31) gives the solution immediately. Otherwise, further iteration is necessary. If the problem is highly nonlinear, considerable difficulty may be encountered. There may be secondary minima, and χ^2 may be decreasing at physical boundaries. Numerical methods have been devised to find such solutions without divergence [7,8]. In particular, the CERN program MINUIT [8] offers several iteration schemes for solving such problems.

Note that minimizing any function proportional to χ^2 (or maximizing any function proportional $\ln \mathcal{L}$) will result in the same parameter set $\widehat{\alpha}$. Hence, for example, if the variances σ_j^2 are known only up to a common constant, one can still solve for $\widehat{\alpha}$. One cannot, however, evaluate goodness-of-fit, and the covariance matrix is known only to within the constant multiplier. The scale can be estimated at least roughly from the value of χ^2 compared to its expected value.

Additional information can be extracted from the behavior of the (normalized) residuals, $r_j = (y_j - F(x_j; \alpha)/\sigma_j)$, which should themselves distribute normally with a mean of 0.

If the data covariance matrix S has been correctly evaluated (or, equivalently, the σ_j 's, if the data are independent), then the s-standard deviation limits on the parameters are given by a set α'

$$\chi^2(\alpha') = \chi^2_{\min} + s^2 . {(29.32)}$$

This equation gives confidence intervals in the same sense as 29.8, and all the discussion of Sec. 29.3.2 applies as well here, substituting $-\chi^2/2$ for $\ln \mathcal{L}$.

29.6. Exact confidence intervals

29.6.1. Two methodologies:

There are two different approaches to statistical inference, which we may call Frequentist and Bayesian. For the cases considered up to now, both approaches give the same numerical answers, even though they are based on fundamentally different assumptions. However, for exact results for small samples and for measurements near a physical boundary, the different approaches may yield very different confidence limits, so we are forced to make a choice. There is an enormous amount of literature devoted to the question of Bayesian vs non-Bayesian methods, most of it written by people who are fervent advocates of one or the other methodology, which often leads to exaggerated conclusions. For a reasonably balanced discussion, we recommend the following articles: by a statistician [9], and by a physicist [6].

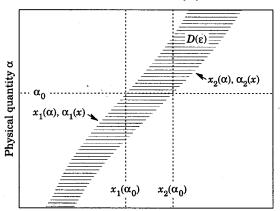
29.6.2. Bayesian: The Bayesian concept of probability is not based on limiting frequencies, but is more general and includes degrees of belief. It can therefore be used for experiments which cannot be repeated, where a frequency definition of probability would not be applicable (for example, one can consider the probability that it will rain tomorrow). Bayesian methods also allow for a natural way to input additional information such as physical boundaries and subjective information; in fact they require as input the prior distribution for any parameter to be estimated.

The Bayesian methodology, while well adapted to decision-making situations, is not in general appropriate for the objective presentation of experimental data. This can be seen from the following example.

An experiment sets out to measure the value of a parameter whose true value cannot be negative (such as the neutrino mass squared), but let us assume that the true value is in fact zero. We should then expect that about half of the time, an unbiased experimental measurement should yield a negative (unphysical) result. Now if our experiment produces a negative result, the question arises what value to report. If we wish to make a decision concerning the most likely value of this parameter, we would use a Bayesian approach which would assure that the reported value is positive, since it would be nonsense to assert that the most likely value is one which cannot be true. On the other hand, if we wish to report an unbiased result which can be combined with other measurements, it is better to report the unphysical result. Everyone understands what it means to quote a result of, for example, $m^2 = -1.2 \pm 2.0$ eV². This result could then be averaged with other results, half of which would be positive, and the average would eventually converge toward zero, the true value. If Bayesian estimates are averaged, they do not converge to the true value, since they have all been forced to be positive.

29.6.3. Frequentist, or classical confidence intervals: As the name implies, the Frequentist concept of probability is based entirely on the limiting frequency, so it only makes sense in situations where experiments are repeatable, at least in principle. This is clearly the case for the kind of data we are concerned with, and the methods we present here are based on the Frequentist point of view.

The classical construction of exact confidence intervals which we describe here was first proposed by Neyman [10].



Possible experimental values x

Figure 29.1: Confidence intervals for a single unknown parameter α . One might think of the p.d.f. $f(x;\alpha)$ as being plotted out of the paper as a function of x along each horizontal line of constant α . The domain $D(\varepsilon)$ contains a fraction $1-\varepsilon$ of the area under each of these functions.

We wish to set limits on the parameter α whose true value is fixed but unknown. The properties of our experimental apparatus are expressed in the function $f(x;\alpha)$ which gives the probability of observing data x if the true value of the parameter is α . This function must be known, otherwise it is impossible to interpret the results of an experiment. For a large complex experiment, this function is usually determined numerically using Monte Carlo simulation.

Given the function $f(x; \alpha)$, we can find for every value of α , two values $x_1(\alpha, \varepsilon)$ and $x_2(\alpha, \varepsilon)$ such that repeated experiments would produce results x in the interval $x_1 < x < x_2$ a fraction $1 - \varepsilon$ of the time, where

$$P(x_1 < x < x_2) = 1 - \varepsilon = \int_{x_1}^{x_2} f(x; \alpha) dx . \qquad (29.33)$$

This situation is shown in Fig. 29.1, where the region between the curves $x_1(\alpha, \varepsilon)$ and $x_2(\alpha, \varepsilon)$ is indicated by the domain $D(\varepsilon)$. We require that the curves $x_1(\alpha, \varepsilon)$ and $x_2(\alpha, \varepsilon)$ be monotonic functions of α , so they can be labeled either as functions of x or of α . Dropping the argument ε for simplicity, we may then label the curve $x_1(\alpha)$ as $\alpha_1(x)$ and $x_2(\alpha)$ as $\alpha_2(x)$. Now consider some arbitrary particular value of α , say α_0 , as indicated in the figure. We notice from the figure that for all values of x between $x_1(\alpha_0)$ and $x_2(\alpha_0)$, it happens that α_0 lies between $\alpha_1(x)$ and $\alpha_2(x)$. Thus we can write:

$$P[x_1(\alpha_0) < x < x_2(\alpha_0)] = 1 - \varepsilon = P[\alpha_2(x) < \alpha_0 < \alpha_1(x)].$$
 (29.34)

And since, by construction, this is true for any value α_0 , we can drop the subscript 0 and obtain the relationship we wanted to establish for the probability that the confidence limits will contain the true value of α :

$$P[\alpha_2(x) < \alpha < \alpha_1(x)] = 1 - \varepsilon. \tag{29.35}$$

In this probability statement, α_1 and α_2 are the random variables (not α), and we can verify that the statement is true, as a limiting ratio of frequencies in random experiments, for any assumed value of α . In a particular real experiment, the numerical values α_1 and α_2 are determined by applying the algorithm to the real data, and the probability statement appears to be a statement about the true value α since this is the only unknown remaining in the equation. It should however be understood that it gives only the probability of obtaining values α_1 and α_2 which include the true value of α , in an ensemble of identical experiments. Any method which gives confidence intervals that contain the true value with probability $1-\varepsilon$ (no matter what the true value of α is) is said to have coverage. The frequentist intervals as constructed above have coverage by construction. Coverage is considered the most important property of confidence intervals [6].

The condition of coverage Eq. (29.33) does not determine x_1 and x_2 completely, since any range which gives the desired value of the integral would give the same coverage. Additional criteria are needed to determine the intervals uniquely. The most common criterion is to choose central intervals such that the area of the excluded tail on either side is $\varepsilon/2$. This criterion is sufficient in most cases, but there is a more general ordering principle which reduces to centrality in the usual cases and produces confidence intervals with better properties when in the neighborhood of a physical limit. This ordering principle, which consists of taking the interval which includes the largest values of a likelihood ratio, is described by Feldman and Cousins [11].

29.6.4. Gaussian errors:

If the data are such that the distribution of the estimator(s) satisfies the central limit theorem discussed in Sec. 28.3.3, the function $f(x;\alpha)$ is the Gaussian distribution. If there is more than one parameter being estimated, the multivariate Gaussian is used. For the univariate case with known σ ,

$$1 - \varepsilon = \int_{\mu - \delta}^{\mu + \delta} e^{\frac{-(x - \mu)^2}{2\sigma^2}} dx = \operatorname{erf}\left(\frac{\delta}{\sqrt{2}\sigma}\right)$$
 (29.36)

is the probability that the measured value x will fall within $\pm \delta$ of the true value μ . From the symmetry of the Gaussian with respect to x and μ , this is also the probability that the true value will be within $\pm \delta$ of the measured value. Fig. 29.2 shows a $\delta = 1.64\sigma$ confidence interval unshaded. The choice $\delta = \sqrt{\text{Var}(\mu)} \equiv \sigma$ gives an interval called the *standard error* which has $1 - \varepsilon = 68.27\%$ if σ is known. Confidence coefficients ε for other frequently used choices of δ are given in Table 29.1. For other δ , find ε as the ordinate of Fig. 28.1 on the n=1 curve at $\chi^2=(\delta/\sigma)^2$. We can set a one-sided (upper or lower) limit by excluding above $\mu+\delta$ (or below $\mu-\delta$); ε 's for such limits are 1/2 the values in Table 29.1.

For multivariate α the scalar $\text{Var}(\mu)$ becomes a full variance-covariance matrix. Assuming a multivariate Gaussian, Eq. (28.22), and subsequent discussion the standard error ellipse for the pair $(\widehat{\alpha}_m, \widehat{\alpha}_n)$ may be drawn as in Fig. 29.3.

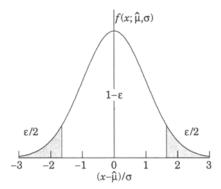


Figure 29.2: Illustration of a symmetric 90% confidence interval (unshaded) for a measurement of a single quantity with Gaussian errors. Integrated probabilities, defined by ε , are as shown.

Table 29.1: Area of the tails ε outside $\pm \delta$ from the mean of a Gaussian distribution.

$\varepsilon~(\%)$	δ	ϵ (%)	δ
31.73	1σ	20	1.28σ
4.55	2σ	10	1.64σ
0.27	3σ	5	1.96σ
6.3×10^{-3}	4σ	1	2.58σ
5.7×10^{-5}	5σ	0.1	3.29σ
2.0×10^{-7}	6σ	0.01	3.89σ

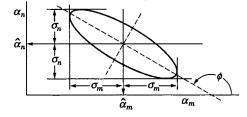


Figure 29.3: Standard error ellipse for the estimators $\widehat{\alpha}_m$ and $\widehat{\alpha}_n$. In this case the correlation is negative.

The minimum χ^2 or maximum likelihood solution is at $(\widehat{\alpha}_m, \widehat{\alpha}_n)$. The standard errors σ_m and σ_n are defined as shown, where the ellipse is at a constant value of $\chi^2 = \chi^2_{\min} + 1$ or $\ln \mathscr{L} = \ln \mathscr{L}_{\max} - 1/2$. The angle of the major axis of the ellipse is given by

$$\tan 2\phi = \frac{2\rho_{mn} \ \sigma_m \ \sigma_n}{\sigma_m^2 - \sigma_n^2} \ . \tag{29.37}$$

For non-Gaussian or nonlinear cases, one may construct an analogous contour from the same χ^2 or $\ln \mathcal{L}$ relations. Any other parameters $\hat{\alpha}_\ell, \ell \neq m, n$ must be allowed freely to find their optimum values for every trial point.

For any unbiased procedure (e.g., least squares or maximum likelihood) being used to estimate k parameters α_i , $i=1,\ldots,k$, the probability $1-\varepsilon$ that the true values of all k lie within the s-standard deviation ellipsoid may be found from Fig. 28.1. Read the ordinate as ε ; the correct value of ε occurs on the n=k curve at $\chi^2=s^2$. For example, for k=2, the probability that the true values of α_1 and α_2 simultaneously lie within the one-standard-deviation error ellipse (s=1), centered on $\widehat{\alpha}_1$ and $\widehat{\alpha}_2$, is 39%. This probability only assumes Gaussian errors, unbiased estimators, and that the model describing the data in terms of the α_i is correct.

29.6.5. Upper limits and two-sided intervals:

When a measured value is close to a physical boundary, it is natural to report a one-sided confidence interval (usually an upper limit). It is straightforward to force the procedure of Sec. 29.6.3 to produce only an upper limit, by setting $x_2 = \infty$ in Eq. (29.33). Then x_1 is uniquely determined. Clearly this procedure will have the desired coverage, but only if we always choose to set an upper limit. In practice one might decide after seeing the data whether to set an upper limit or a two-sided limit. In this case the upper limits calculated by Eq. (29.33) will not give exact coverage, as has been noted in Ref. 11.

In order to correct this problem and assure coverage in all circumstances, it is necessary to adopt a *unified procedure*, that is, a single ordering principle which will provide coverage globally. Then it is the *ordering principle* which decides whether a one-sided or two-sided interval will be reported for any given set of data. The appropriate unified procedure and ordering principle are given in Ref. 11. We reproduce below the main results.

29.6.6. Gaussian data close to a boundary:

One of the most controversial statistical questions in physics is how to report a measurement which is close to the edge or even outside of the allowed physical region. This is because there are several admissible possibilities depending on how the result is to be used or interpreted. Normally one or more of the following should be reported:

- (a) In any case, the actual measurement should be reported, even if it is outside the physical region. As with any other measurement, it is best to report the value of a quantity which is nearly Gaussian distributed if possible. Thus one may choose to report mass squared rather than mass, or $\cos\theta$ rather than θ . For a complex quantity z close to zero, report Re(z) and Im(z) rather than amplitude and phase of z. Data carefully reported in this way can be unbiased, objective, easily interpreted and combined (averaged) with other data in a straightforward way, even if it lies partly or wholly outside the physical region. The reported error is a direct measure of the intrinsic accuracy of the result, which cannot always be inferred from the upper limits proposed below.
- (b) If the data are to be used to make a decision, for example to determine the dimensions of a new experimental apparatus for an improved measurement, it may be appropriate to report a Bayesian upper limit, which must necessarily contain subjective feelings about the possible values of the parameter, as well as containing information about the physical boundary. Its interpretation requires knowledge of the prior distribution which was necessarily used to obtain it.
- (c) If it is desired to report an upper limit in an objective way such that it has a well-defined statistical meaning in terms of a limiting frequency, then report the Frequentist confidence bound(s) as given by the unified Feldman-Cousins approach. This algorithm always gives a non-null interval (that is, the confidence limits are always inside the physical region, even for a measurement well outside the physical region), and still has correct global coverage. These confidence limits for a Gaussian measurement close to a non-physical boundary are summarized in Fig. 29.4. Additional tables are given in Ref. 11.

29.6.7. Poisson data for small samples:

When the observable is restricted to integer values (as in the case of Poisson and binomial distributions), it is not generally possible to construct confidence intervals with exact coverage for all values of α . In these cases the integral in Eq. (29.33) becomes a sum of finite contributions and it is no longer possible (in general) to find consecutive terms which add up exactly to the required confidence level $1-\varepsilon$ for all values of α . Thus one constructs intervals which happen to have exact coverage for a few values of α , and unavoidable over-coverage for all other values. This is the best that can be done and still guarantee coverage for any true value.

In addition to the problem posed by the discreteness of the data, we usually have to contend with possible background whose expectation must be evaluated separately and may not be known precisely. For these reasons, the reporting of this kind of data is even more controversial than the Gaussian data near a boundary as discussed above. This is especially true when the number of observed counts is

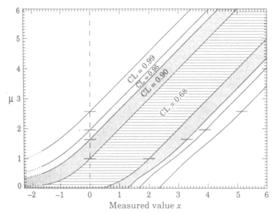


Figure 29.4: Plot of 99%, 95%, 90%, and 68.27% ("one σ ") confidence intervals for a physical quantity μ based on a Gaussian measurement x (in units of standard deviations), for the case where the true value of μ cannot be negative. The curves become straight lines above the horizontal tick marks. The probability of obtaining an experimental value at least as negative as the left edge of the graph (x=-2.33) is less than 1%. Values of x more negative than -1.64 (dotted segments) are less than 5% probable, no matter what the true value of μ .

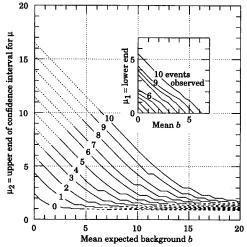


Figure 29.5: 90% confidence intervals $[\mu_1, \mu_2]$ on the number of signal events as a function of the expected number of background events b. For example, if the expected background is 8 events and 5 events are observed, then the signal is 2.60 or less with 90% confidence. Dotted portions of the μ_2 curves on the upper left indicate regions where μ_1 is non-zero (as shown by the inset). Dashed portions in the lower right indicate regions where the probability of obtaining the number of events observed or fewer is less than 1%, even if $\mu = 0$. Horizontal curve sections occur because of discrete number statistics. Tables showing these data as well as the CL = 68.27%, 95%, and 99% results are given in Ref. 11.

greater than the expected background. As for the Gaussian case, there are at least three possibilities for reporting such results depending on how the result is to be used:

- (a) In any case, the actual measurements should be reported, which means (1) the number of recorded counts, (2) the expected background, possibly with its error, and (3) normalization factor which turns the number of counts into a cross section, decay rate, etc. As with Gaussian data, this data can be combined with that of other experiments, to make improved upper limits for example.
- (b) A Bayesian upper limit may be reported. This has the advantages and disadvantages of any Bayesian result as discussed above. It is especially difficult to find an acceptable prior probability distribution for this case.

Table 29.2: Poisson limits $[\mu_1, \mu_2]$ for n_0 observed events in the absence of background.

CI = 90%			CI = 95%		
n_0	μ_1	μ_2	μ_1	μ_2	
0	0.00	2.44	0.00	3.09	
1	0.11	4.36	0.05	5.14	
2	0.53	5.91	0.36	6.72	
3	1.10	7.42	0.82	8.25	
4	1.47	8.60	1.37	9.76	
5	1.84	9.99	1.84	11.26	
6	2.21	11.47	2.21	12.75	
7	3.56	12.53	2.58	13.81	
8	3.96	13.99	2.94	15.29	
9	4.36	15.30	4.36	16.77	
10	5.50	16.50	4.75	17.82	

(c) An upper limit (or confidence region) with optimal coverage can be reported using the unified approach of Ref. 11. At the moment these confidence limits have been calculated only for the case of exactly known background expectation. The main results can be read from Fig. 29.5 or from Table 29.2; more extensive tables can be found in Ref. 11.

None of the above gives a single number which quantifies the quality or sensitivity of the experiment. This is a serious shortcoming of most upper limits including those of method (c), since it is impossible to distinguish, from the upper limit alone, between a clean experiment with no background and a lucky experiment with fewer observed counts than expected background. For this reason, we suggest that in addition to (a) and (c) above, a measure of the sensitivity should be reported whenever expected background is larger or comparable to the number of observed counts. The best such measure we know of is that proposed and tabulated in Ref. 11, defined as the average upper limit that would be attained by an ensemble of experiments with the expected background and no true signal.

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30. MONTE CARLO TECHNIQUES

Revised July 1995 by S. Youssef (SCRI, Florida State University).

Monte Carlo techniques are often the only practical way to evaluate difficult integrals or to sample random variables governed by complicated probability density functions. Here we describe an assortment of methods for sampling some commonly occurring probability density functions.

30.1. Sampling the uniform distribution

Most Monte Carlo sampling or integration techniques assume a "random number generator" which generates uniform statistically independent values on the half open interval [0, 1). Although such a generator is, strictly speaking, impossible on a finite digital computer, generators are nevertheless available which pass extensive batteries of tests for statistical independence and which have periods which are so long that, for practical purposes, values from these generators can be considered to be uniform and statistically independent. In particular, the lagged-Fibonacci based generator introduced by Marsaglia, Zaman, and Tsang [1] is efficient, has a period of approximately 10^{43} , produces identical sequences on a wide variety of computers and, passes the extensive "DIEHARD" battery of tests [2]. Many commonly available congruential generators fail these tests and often have sequences (typically with periods less than 2^{32}) which can be easily exhausted on modern computers and should therefore be avoided [3].

30.2. Inverse transform method

If the desired probability density function is f(x) on the range $-\infty < x < \infty$, its cumulative distribution function (expressing the probability that $x \le a$) is given by Eq. (28.1). If a is chosen with probability density f(a), then the integrated probability up to point a, F(a), is itself a random variable which will occur with uniform probability density on [0,1]. If x can take on any value, and ignoring the endpoints, we can then find a unique x chosen from the p.d.f. f(s) for a given x if we set

$$u = F(x) , (30.1)$$

provided we can find an inverse of F, defined by

$$x = F^{-1}(u) . (30.2)$$

This method is shown in Fig. 30.1a.

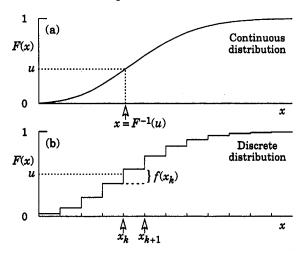


Figure 30.1: Use of a random number u chosen from a uniform distribution (0,1) to find a random number x from a distribution with cumulative distribution function F(x).

For a discrete distribution, F(x) will have a discontinuous jump of size $f(x_k)$ at each allowed $x_k, k = 1, 2, \cdots$. Choose u from a uniform distribution on (0,1) as before. Find x_k such that

$$F(x_{k-1}) < u \le F(x_k) \equiv \text{Prob}(x \le x_k) = \sum_{i=1}^k f(x_i);$$
 (30.3)

then x_k is the value we seek (note: $F(x_0) \equiv 0$). This algorithm is illustrated in Fig. 30.1b.

30.3. Acceptance-rejection method (Von Neumann)

Very commonly an analytic form for F(x) is unknown or too complex to work with, so that obtaining an inverse as in Eq. (30.2) is impractical. We suppose that for any given value of x the probability density function f(x) can be computed and further that enough is known about f(x) that we can enclose it entirely inside a shape which is C times an easily generated distribution h(x) as illustrated in Fig. 30.2.

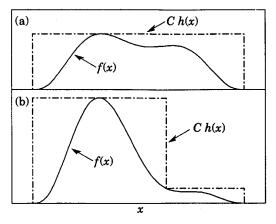


Figure 30.2: Illustration of the acceptance-rejection method. Random points are chosen inside the upper bounding figure, and rejected if the ordinate exceeds f(x). Lower figure illustrates importance sampling.

Frequently h(x) is uniform or is a normalized sum of uniform distributions. Note that both f(x) and h(x) must be normalized to unit area and therefore the proportionality constant C>1. To generate f(x), first generate a candidate x according to h(x). Calculate f(x) and the height of the envelope Ch(x); generate u and test if $uCh(x) \leq f(x)$. If so, accept x; if not reject x and try again. If we regard x and uCh(x) as the abscissa and ordinate of a point in a two-dimensional plot, these points will populate the entire area Ch(x) in a smooth manner; then we accept those which fall under f(x). The efficiency is the ratio of areas, which must equal 1/C; therefore we must keep C as close as possible to 1.0. Therefore we try to choose Ch(x) to be as close to f(x) as convenience dictates, as in the lower part of Fig. 30.2. This practice is called importance sampling, because we generate more trial values of x in the region where f(x) is most important.

30.4. Algorithms

Algorithms for generating random numbers belonging to many different distributions are given by Press [4], Ahrens and Dieter [5], Rubinstein [6], Everett and Cashwell [7], Devroye [8], and Walck [9]. For many distributions alternative algorithms exist, varying in complexity, speed, and accuracy. For time-critical applications, these algorithms may be coded in-line to remove the significant overhead often encountered in making function calls. Variables named "u" are assumed to be independent and uniform on (0,1).

In the examples given below, we use the notation for the variables and parameters given in Table 28.1.

30.4.1. Sine and cosine of random angle:

Generate u_1 and u_2 . Then $v_1 = 2u_1 - 1$ is uniform on (-1,1), and $v_2 = u_2$ is uniform on (0,1). Calculate $r^2 = v_1^2 + v_2^2$. If $r^2 > 1$, start over. Otherwise, the sine (S) and cosine (C) of a random angle are given by

$$S = 2v_1v_2/r^2$$
 and $C = (v_1^2 - v_2^2)/r^2$. (30.4)

30.4.2. Gaussian distribution:

If u_1 and u_2 are uniform on (0,1), then

$$z_1 = \sin 2\pi u_1 \sqrt{-2 \ln u_2}$$
 and $z_2 = \cos 2\pi u_1 \sqrt{-2 \ln u_2}$ (30.5)

are independent and Gaussian distributed with mean 0 and $\sigma = 1$.

There are many faster variants of this basic algorithm. For example, construct $v_1=2u_1-1$ and $v_2=2u_2-1$, which are uniform on (-1,1). Calculate $r^2=v_1^2+v_2^2$, and if $r^2>1$ start over. If $r^2<1$, it is uniform on (0,1). Then

$$z_1 = v_1 \sqrt{\frac{-2 \ln r^2}{r^2}}$$
 and $z_2 = v_2 \sqrt{\frac{-2 \ln r^2}{r^2}}$ (30.6)

are independent numbers chosen from a normal distribution with mean 0 and variance 1. $z_i' = \mu + \sigma z_i$ distributes with mean μ and variance σ^2 .

For a multivariate Gaussian, see the algorithm in Ref. 10.

30.4.3. $\chi^2(n)$ distribution:

For n even, generate n/2 uniform numbers u_i ; then

$$y = -2\ln\left(\prod_{i=1}^{n/2} u_i\right) \quad \text{is} \quad \chi^2(n) \ . \tag{30.7}$$

For n odd, generate (n-1)/2 uniform numbers u_i and one Gaussian z as in Sec. 30.4.2; then

$$y = -2 \ln \left(\prod_{i=1}^{(n-1)/2} u_i \right) + z^2 \quad \text{is} \quad \chi^2(n) . \tag{30.8}$$

For $n \gtrsim 30$ the much faster Gaussian approximation for the χ^2 may be preferable: generate z as in Sec. 30.4.2 and use $y = \left[z + \sqrt{2n-1}\right]^2/2$; if $z < -\sqrt{2n-1}$ reject and start over.

30.4.4. Gamma distribution:

All of the following algorithms are given for $\lambda=1$. For $\lambda\neq 1$, divide the resulting random number x by λ .

- If k = 1 (the exponential distribution), accept $x = -(\ln u)$.
- If 0 < k < 1, initialize with $v_1 = (e + k)/e$ (with e = 2.71828... being the natural log base). Generate u_1 , u_2 . Define $v_2 = v_1u_1$.

Case 1: $v_2 \le 1$. Define $x = v_2^{1/k}$. If $u_2 \le e^{-x}$, accept x and stop, else restart by generating new u_1, u_2 .

Case 2: $v_2 > 1$. Define $x = -\ln([v_1 - v_2]/k)$. If $u_2 \le x^{k-1}$, accept x and stop, else restart by generating new u_1, u_2 . Note that, for k < 1, the probability density has a pole at x = 0, so that return values of zero due to underflow must be accepted or otherwise dealt with.

• Otherwise, if k > 1, initialize with c = 3k - 0.75. Generate u_1 and compute $v_1 = u_1(1 - u_1)$ and $v_2 = (u_1 - 0.5)\sqrt{c/v_1}$. If $x = k + v_2 - 1 \le 0$, go back and generate new u_1 ; otherwise generate u_2 and compute $v_3 = 64v_1^3u_2^2$. If $v_3 \le 1 - 2v_2^2/x$ or if $\ln v_3 \le 2\{[k-1]\ln[x/(k-1)] - v_2\}$, accept x and stop; otherwise go back and generate new u_1 .

30.4.5. Binomial distribution:

If $p \le 1/2$, iterate until a successful choice is made: begin with k=1; compute $P_k=q^n$ [for $k \ne 1$ use $P_k \equiv f(r_k;n,p)$, and store P_k into B; generate u. If $u \le B$ accept $r_k=k-1$ and stop; otherwise increment k by 1 and compute next P_k and add to B; generate a new u and repeat. If we arrive at k=n+1, stop and accept $r_{n+1}=n$. If p>1/2 it will be more efficient to generate r from f(r;n,q), i.e., with p and q interchanged, and then set $r_k=n-r$.

30.4.6. Poisson distribution:

Iterate until a successful choice is made: Begin with k=1 and set A=1 to start. Generate u. Replace A with uA; if now $A<\exp(-\mu)$, where μ is the Poisson parameter, accept $n_k=k-1$ and stop. Otherwise increment k by 1, generate a new u and repeat, always starting with the value of A left from the previous try. For large $\mu(\gtrsim 10)$ it may be satisfactory (and much faster) to approximate the Poisson distribution by a Gaussian distribution (see our Probability chapter, Sec. 28.3.3) and generate z from f(z;0,1); then accept $x=\max(0,[\mu+z\sqrt{\mu}+0.5])$ where $[\]$ signifies the greatest integer \le the expression.

30.4.7. Student's t distribution:

For n>0 degrees of freedom (n not necessarily integer), generate x from a Gaussian with mean 0 and $\sigma^2=1$ according to the method of 30.4.2. Next generate y, an independent gamma random variate with k=n/2 degrees of freedom. Then $z=x\sqrt{2n}/\sqrt{y}$ is distributed as a t with n degrees of freedom.

For the special case n=1, the Breit-Wigner distribution, generate u_1 and u_2 ; set $v_1=2u_1-1$ and $v_2=2u_2-1$. If $v_1^2+v_2^2\leq 1$ accept $z=v_1/v_2$ as a Breit-Wigner distribution with unit area, center at 0.0, and FWHM 2.0. Otherwise start over. For center M_0 and FWHM Γ , use $W=z\Gamma/2+M_0$.

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31. MONTE CARLO PARTICLE NUMBERING SCHEME

Revised April 1998 by L. Garren (Fermilab), I.G. Knowles (Edinburgh U.), T. Sjöstrand (Lund U.), and T. Trippe (LBNL).

The PDG particle numbering scheme [1] is designed to facilitate interfacing between the event generator and analysis packages used in particle physics. It is used in several generators, e.g. HERWIG and PYTHIA/JETSET, and in the /HEPEVT/ [2] standard interface. After consultation [3], the scheme has been revised to better match the practice of program authors. The revised scheme includes numbering of states by orbital and radial quantum numbers to allow systematic inclusion of quark model states which are as yet undiscovered, and also includes numbering for hypothetical particles such as SUSY particles. The general form is a 7-digit number:

$$\pm n \, n_r \, n_L \, n_{q_1} \, n_{q_2} \, n_{q_3} \, n_J$$
.

This encodes information about the particle's spin, flavor content, and internal quantum numbers. The details are as follows:

- 1. Particles are given positive numbers, antiparticles negative numbers. The PDG convention for mesons is used, so that K^+ and B^+ are particles.
- 2. Quarks and leptons are numbered consecutively starting from 1 and 11 respectively; to do this they are first ordered by family and within families by weak isospin.
- 3. In composite quark systems (diquarks, mesons, and baryons) $n_{q_{1-3}}$ are quark numbers used to specify the quark content, while the rightmost digit $n_J = 2J + 1$ gives the system's spin (except for the K_S^0 and K_L^0). The scheme does not cover particles of spin
- 4. Diquarks have 4-digit numbers with $n_{q_1} \ge n_{q_2}$ and $n_{q_3} = 0$.
- 5. The numbering of mesons is guided by the nonrelativistic (L-Sdecoupled) quark model, as listed in Table 13.2. This leads to several differences with the earlier numbering [4] for excited mesons.
 - a. The numbers specifying the meson's quark content conform to the convention $n_{q_1}=0$ and $n_{q_2}\geq n_{q_3}.$ The special case K_I^0 is the sole exception to this rule.
 - b. The quark numbers of flavorless, light (u, d, s) mesons are: 11 for the member of the isotriplet (π^0, ρ^0, \ldots) , 22 for the lighter isosinglet (η, ω, \ldots) , and 33 for the heavier isosinglet (η', ϕ, \ldots) . Since isosinglet mesons are often large mixtures of $u\overline{u} + d\overline{d}$ and $s\overline{s}$ states, 22 and 33 are assigned by mass and do not necessarily specify the dominant quark composition.
 - c. The special numbers 310 and 130 are given to the K_S^0 and K_L^0 respectively.
 - d. The fifth digit n_L is reserved to distinguish mesons of the same total (J) but different spin (S) and orbital (L) angular momentum quantum numbers. For J > 0 the numbers are: $(L,S) = (J-1,1) n_L = 0, (J,0) n_L = 1, (J,1) n_L = 2$ and (J+1,1) $n_L=3$. For the exceptional case J=0 the numbers are (0,0) $n_L = 0$ and (1,1) $n_L = 1$ (i.e. $n_L = L$). See Table 31.1.

Table 31.1: Meson numbering logic. Here qq stands for $n_{q2} n_{q3}$

	L = J	- 1, <i>S</i>	= 1	L = J	, S =	0	L = J	, <i>S</i> =	1	L = J	7 + 1,	S=1
J	code	J^{PC}	L	code	$J^{\overline{PC}}$	L	code	J^{PC}	L	code	J^{PC}	\overline{L}
0	_	_	_	00qq1	0-+	0			_	10qq1	0++	1
1	00qq3	1	0	10qq3	1+-	1	20qq3	1++	1	30qq3	1	2
2	00qq5	2++	1 .	10 <i>qq</i> 5	2-+	2	20qq5	2	2	30qq5	2++	3
3	00qq7	3	2	10qq7	3+-	3	20qq7	3++	3	30qq7	3	4
4	00qq9	4++					20qq9					5

e. If a set of physical mesons correspond to a (non-negligible) mixture of basis states, differing in their internal quantum numbers, then the lightest physical state gets the smallest

- basis state number. For example the $K_1(1270)$ is numbered 10313 $(1^1P_1 K_{1B})$ and the $K_1(1400)$ is numbered 20313 $(1^3P_1\ K_{1A}).$
- f. The sixth digit n_r is used to label mesons radially excited above the ground state.
- g. Numbers have been assigned for complete $n_r = 0$ S- and P-wave multiplets, even where states remain to be identified.
- h. In some instances assignments within the $q\bar{q}$ meson model are only tentative; here best guess assignments are made.
- i. Many states appearing in the Meson Listings are not yet assigned within the $q\bar{q}$ model. Here $n_{q_{2-3}}$ and n_J are assigned according to the state's likely flavors and spin; all such unassigned light isoscalar states are given the flavor code 22. Within these groups $n_L = 0, 1, 2, \ldots$ is used to distinguish states of increasing mass. These states are flagged using n = 9. It is to be expected that these numbers will evolve as the nature of the states are elucidated.
- 6. The numbering of baryons is again guided by the nonrelativistic quark model, see Table 13.4.
 - a. The numbers specifying a baryon's quark content are such
 - that in general $n_{q_1} \ge n_{q_2} \ge n_{q_3}$. b. Two states exist for J=1/2 baryons containing 3 different types of quarks. In the lighter baryon $(\Lambda, \Xi, \Omega, \ldots)$ the light quarks are in an antisymmetric (J = 0) state while for the heavier baryon $(\mathfrak{L}^0, \mathfrak{T}', \Omega', \ldots)$ they are in a symmetric (J=1) state. In this situation n_{q_2} and n_{q_3} are reversed for the lighter state, so that the smaller number corresponds to the lighter baryon.
 - c. At present most Monte Carlos do not include excited baryons and no systematic scheme has been developed to denote them, though one is foreseen. In the meantime, use of the PDG 96 [4] numbers for excited baryons is recommended.
- 7. The gluon, when considered as a gauge boson, has official number 21. In codes for glueballs, however, 9 is used to allow a notation in close analogy with that of hadrons.
- 8. The pomeron and odderon trajectories and a generic reggeon trajectory of states in QCD are assigned codes 990, 9990, and 110 respectively, where the final 0 indicates the indeterminate nature of the spin, and the other digits reflect the expected "valence" flavor content. We do not attempt a complete classification of all reggeon trajectories, since there is currently no need to distinguish a specific such trajectory from its lowest-lying member.
- Two-digit numbers in the range 21-30 are provided for the Standard Model gauge bosons and Higgs.
- 10. Codes 81-100 are reserved for generator-specific pseudoparticles and concepts.
- 11. The search for physics beyond the Standard Model is an active area, so these codes are also standardized as far as possible.
 - a. A standard fourth generation of fermions is included by analogy with the first three.
 - b. The graviton and the boson content of a two-Higgs-doublet scenario and of additional SU(2)×U(1) groups are found in the range 31-40.
 - c. "One-of-a-kind" exotic particles are assigned numbers in the range 41-80.
 - d. Fundamental supersymmetric particles are identified by adding a nonzero n to the particle number. The superpartner of a boson or a left-handed fermion has n = 1 while the superpartner of a right-handed fermion has n = 2. When mixing occurs, such as between the winos and charged Higgsinos to give charginos, or between left and right sfermions, the lighter physical state is given the smaller basis state number.
 - e. Technicolor states have n = 3. In the absence of a unique theory we only number generic states whose digits reflect the techniquark content.
 - f. Excited (composite) quarks and leptons are identified by setting n=4.

- 12. Occasionally program authors add their own states. To avoid confusion, these should be flagged by setting $nn_r = 99$.
- 13. Concerning the non-99 numbers, it may be noted that only quarks, excited quarks, squarks, and diquarks have $n_{q_3}=0$; only diquarks, baryons, and the odderon have $n_{q_1}\neq 0$; and only mesons, the reggeon, and the pomeron have $n_{q_1}=0$ and $n_{q_2}\neq 0$. Concerning mesons (not antimesons), if n_{q_1} is odd then it labels a quark and an antiquark if even.

This text and lists of particle numbers can be found on the WWW [5]. The StdHep Monte Carlo standardization project [6] maintains the list of PDG particle numbers, as well as numbering schemes from most event generators and software to convert between the different schemes.

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				sus	Y		LIGHT I =	1 MESONS	LIGHT $I = 0$	MESONS
QUARKS	3	DIQU	ARKS		TICLES		π^0	111	$(u\overline{u}, d\overline{d}, \text{ and } s\overline{s})$	Admixtures)
	1	$(dd)_1$	1103	\widetilde{d}_L	1000001		π^+	211	η	221
	2	$(ud)_0$	2101	\widetilde{u}_L	1000002		$a_0(980)^0$	9000111*	$\eta'(958)$	331
	3	$(ud)_1$	2103	\widetilde{s}_L	1000003		$a_0(980)^+$	9000211*	$f_0(400-1200)$	9000221*
	4 5	$(uu)_1$	2203	\widetilde{c}_L	1000004		$\pi(1300)^0$	100111*	$f_0(980)$	9010221*
	5 6	$(sd)_0$	3101	$\widetilde{\widetilde{b}_1}$ $\widetilde{\widetilde{t}_1}$	1000005	a	$\pi(1300)^{+}$	100211*	$\eta(1295)$	100221*
	7	$(sd)_1$	3103	\widetilde{t}_1	1000006		$a_0(1450)^0$	10111*	$f_0(1370)$	10221*
	8	$(su)_0$	3201	$\widetilde{e_L}$	1000011		$a_0(1450)^+$	10211*	$\eta(1440)$	100331*
LEPTON	10	$(su)_1$	3203	$\widetilde{ u}_{eL}$	1000012		$\pi(1800)^{0}$	200111	$f_0(1500)$	9020221*
	11	$(ss)_1$	3303	$\widetilde{\mu}_L^-$	1000013		$\pi(1800)^{+}$	200211	$f_J(1710)$	9030221*
	12	$(cd)_0$	4101	$\widetilde{ u}_{\mu L}$	1000014		$ ho(770)^{0}$	113	$\eta(1760)$	200221
-	13	$(cd)_1$	4103	$ ilde{ au_1}$	1000015	a	$\rho(770)^{+}$	213	$f_0(2020)$	9040221
	14	$(cu)_0$	4201	$\widetilde{ u}_{ au L}$	1000016		$b_1(1235)^0$	10113	$f_0(2060)$	9050221
•	15	$(cu)_1$	4203	\widetilde{d}_R	2000001		$b_1(1235)^+$	10213	$f_0(2200)$	9060221*
	16	$(cs)_0$	4301	\widetilde{u}_R	2000002		$a_1(1260)^0$	20113	$\eta(2225)$	9070221*
	17	$(cs)_0$ $(cs)_1$	4303	\widetilde{s}_R	2000003		$a_1(1260)^+$	20213	$\omega(782)$	223
$\nu_{\tau'}$	18	$(cc)_1$	4403	\tilde{c}_R	2000004		$\hat{\rho}(1405)^0$	9000113	$\phi(1020)$	333
				\widetilde{b}_2	2000005		$\hat{ ho}(1405)^{+}$	9000213	$h_1(1170)$	10223
EXCITE		$(bd)_0$	5101	\widetilde{t}_2	2000006		$\rho(1450)^{0}$	100113*		
PARTIC d* 400	L ES 0001	$(bd)_1$	5103	\tilde{e}_R^-	2000011		$\rho(1450)^{+}$	100213*	$f_1(1285)$	20223
	0001 0002 .	$(bu)_0$	5201	$\widetilde{\mu}_R^-$	2000013		$\rho(1700)^0$	30113	$h_1(1380)$	10333
	0001	$(bu)_1$	5203	₽ _R ≈-	2000015		$\rho(1700)^{+}$	30213	$f_1(1420)$	20333*
	0012	$(bs)_0$	5301	$ ilde{ au}_2^-$			$\rho(2150)^0$	9010113	$\omega(1420)$	100223*
		$(bs)_1$	5303	$\widetilde{g}_{\sim 0}$	1000021	_	$\rho(2150)^{+}$	9010213	$f_1(1510)$	9000223*
GAUGE		$(bc)_0$	5401	$\widetilde{\chi}_1^0$	1000022	_	$a_2(1320)^0$	9010213	$\omega(1600)$	30223*
HIGGS I		$(bc)_1$	5403	$\widetilde{\chi}_2^0$	1000023		$a_2(1320)^+$ $a_2(1320)^+$		$\phi(1680)$	100333*
g	(9) 21	$(bb)_1$	5503	$\tilde{\chi}_1^+$	1000024			215	$f_2(1270)$	225
Z^0	22			$egin{array}{c} \widetilde{\chi}_3^0 \ \widetilde{\chi}_4^0 \ \widetilde{\chi}_2^+ \ \widetilde{G} \end{array}$	1000025		$\pi_2(1670)^0$	10115	$f_2(1430)$	9000225
W^+	23 24		NICOLOR ICLES	$\widetilde{\chi}_{4}^{0}$	1000035	b	$\pi_2(1670)^+$	10215	$f_2'(1525)$	335
h^0/H_1^0	24 25	π_{tech}^{0}	3000111	$\tilde{\chi}_2^+$	1000037	·b	$\pi_2(2100)^0$	9000115	$f_2(1565)$	9010225
Z'/Z_2^0	32			\widetilde{G}	1000039)	$\pi_2(2100)^+$	9000215	$f_2(1640)$	9020225
-		π_{tech}^+	3000211				$ ho_3(1690)^0$	117	$\eta_2(1645)$	10225
Z''/Z_3^0	33	$\eta_{ m tech}^0$	3000221		CIAL		$\rho_3(1690)^+$	217	$f_2(1810)$	100225
W'/W_2^+	34	$ ho_{ m tech}^0$	3000113		RTICLES raviton)	39	$\rho_3(2250)^0$	9000117	$\eta_2(1870)$	10335*
H^0/H_2^0	35	$ ho_{ m tech}^+$	3000213	R^0	iaviton)	41	$ ho_{3}(2250)^{+}$	9000217	$f_2(1950)$	9030225*
A^0/H_3^0	36	$\omega_{ m tech}^0$	3000223	LQ^c		42	$a_4(2040)^0$	119	$f_2(2010)$	100335*
H^+	37			regge	eon.	110	$a_4(2040)^+$	219	$f_2(2150)$	9040225*
				pome		990			$f_2(2300)$	9050225*
				odde		9990			$f_2(2340)$	9060225*
				Just					$\omega_3(1670)$	227
										337
				for N	IC interna	al use	81-100		$\phi_3(1850)$	229
									$f_4(2050)$	
									$f_J(2220)$	9000339
									$f_4(2300)$	9000229

STRANGE	:	CHARMED		LIGHT	воттом
MESONS		MESONS	cc MESONS	BARYONS	BARYONS
K_L^0	130	D^+ 411 D^0 421	$\eta_c(1S)$ 441	p 2212	A_b^0 5122
K_S^0	310	$D^0 421 \ D_0^{*+} 10411$	$\chi_{c0}(1P)$ 10441	n 2112	Σ_b^- 5112
K^0	311		$\eta_c(2S)$ 100441	$egin{array}{cccc} \Delta^{++} & 2224 \ \Delta^{+} & 2214 \end{array}$	$arSigma_b^0$ 5212
K ⁺	321	D_0^{*0} 10421	$J/\psi(1S)$ 443	Δ^0 2114	Σ_b^+ 5222
$K_0^*(1430)^0$	10311	$D^*(2010)^+$ 413	$h_c(1P)$ 10443	Δ^- 1114	Σ_b^{*-} 5114
$K_0^*(1430)^+$	10321	$D^*(2007)^0$ 423	$\chi_{c1}(1P)$ 20443*		Σ_b^{*0} 5214
$K(1460)^0$	100311	$D_1(2420)^+$ 10413	$\psi(2S)$ 100443*	STRANGE	<i>2</i> _b 3214
$K(1460)^+$	100321	$D_1(2420)^0$ 10423	$\psi(3770)$ 30443	BARYONS	Σ_b^{*+} 5224
$K(1830)^0$	200311	$D_1(H)^+$ 20413	$\psi(4040)$ 9000443*	$oldsymbol{\Lambda}$ 3122 $oldsymbol{arSigma}^+$ 3222	$\mathcal{\Xi}_{b}^{-}$ 5132
$K(1830)^{+}$	200321	$D_1(H)^0$ 20423	$\psi(4160)$ 9010443*	Σ^0 3212	\varXi_b^0 5232
$K_0^*(1950)^0$	9000311	$D_2^*(2460)^+$ 415	$\psi(4415)$ 9020443*	Σ^- 3112	$\Xi_b^{\prime-}$ 5312
$K_0^*(1950)^+$	9000321	$D_2^*(2460)^0$ 425	$\chi_{c2}(1P)$ 445	Σ^{*+} 3224 d	$\varXi_b^{\prime 0}$ 5322
$K^*(892)^0$	313	D_s^+ 431	XEZ(11) 110	\varSigma^{*0} 3214 d	Ξ_b^{*-} 5314
$K^*(892)^+$	323	D_{s0}^{*+} 10431	$b\overline{b}$ MESONS	Σ^{*-} 3114 ^d	Ξ_b^{*0} 5324
$K_1(1270)^0$	10313	D_s^{*+} 433	$\eta_b(1S)$ 551	$\mathcal{\Xi}^0$ 3322	
$K_1(1270)^+$		$D_{s1}(2536)^{+}$ 10433	$\chi_{b0}(1P)$ 10551*	$egin{array}{ccc} \Xi^{+} & 3312 \ \Xi^{*0} & 3324^d \end{array}$	Ω_b^- 5332
	10323		$\eta_b(2S)$ 100551	<i>⊆</i> ** 3314	Ω_b^{*-} 5334
$K_1(1400)^0$	20313		$\chi_{b0}(2P)$ 110551*	Ω^- 3334 d	\varXi_{bc}^0 5142
$K_1(1400)^+$	20323	D_{s2}^{*+} 435	$\eta_b(3S)$ 200551		$\mathcal{\Xi}_{bc}^{+}$ 5242
$K^*(1410)^0$	100313*	воттом	$\chi_{b0}(3P)$ 210551	CHARMED	$\mathcal{Z}_{bc}^{\prime 0}$ 5412
$K^*(1410)^+$	100323*	MESONS		BARYONS	$\mathcal{Z}_{bc}^{\prime 0}$ 5412 $\mathcal{Z}_{bc}^{\prime +}$ 5422
$K_1(1650)^0$	9000313	B^0 511	$\Upsilon(1S)$ 553	Λ_c^+ 4122	Ξ_{bc}^{*0} 5414
$K_1(1650)^+$	9000323	B^{+} 521	$h_b(1P)$ 10553	\varSigma_c^{++} 4222	Ξ_{bc}^{*+} 5424
$K^*(1680)^0$	30313*	B_0^{*0} 10511	$\chi_{b1}(1P)$ 20553*	\varSigma_c^+ 4212	00
$K^*(1680)^+$	30323*	B_0^{*+} 10521	$\Upsilon_1(1D)$ 30553	\varSigma_c^0 4112	Ω_{bc}^{0} 5342
$K_2^*(1430)^0$	315	B^{*0} 513	$\Upsilon(2S)$ 100553*	\varSigma_c^{*++} 4224	$\Omega_{bc}^{\prime 0}$ 5432
$K_2^*(1430)^+$	325	B*+ 523	$h_b(2P)$ 110553	Σ_c^{*+} 4214	Ω_{bc}^{*0} 5434
$K_2(1580)^0$	9000315	$B_1(L)^0$ 10513	$\chi_{b1}(2P)$ 120553*	$arSigma_c^{*0}$ 4114	Ω_{bcc}^{+} 5442
$K_2(1580)^+$	9000325	$B_1(L)^+$ 10523	$\Upsilon_1(2D)$ 130553	Ξ_c^+ 4232*	Ω_{bcc}^{*+} 5444
$K_2(1770)^0$	10315	$B_1(H)^0$ 20513	$\Upsilon(3S)$ 200553*	\varXi_c^0 4132*	\mathcal{Z}_{bb}^{-} 5512
$K_2(1770)^+$	10325	$B_1(H)^+$ 20523	$h_b(3P)$ 210553	$\varXi_c^{\prime+}$ 4322	Ξ_{bb}^{0} 5522
$K_2(1820)^0$	20315	B_2^{*0} 515	$\chi_{b1}(3P)$ 220553	$\Xi_c^{\prime 0}$ 4312	
$K_2(1820)^+$	20325	B_2^{*+} 525	$\Upsilon(4S)$ 300553*	$\mathcal{\Xi}_{c}^{*+}$ 4324	VV
$K_2^*(1980)^0$	100315	B_s^{0} 531	Y(10860) 9000553*	\varXi_c^{*0} 4314	\mathcal{Z}_{bb}^{*0} 5524
$K_2^*(1980)^+$	100325	B_{s0}^{*0} 10531	Υ(11020) 9010553*	Ω_c^0 4332	Ω_{bb}^{-} 5532
		B_s^{*0} 533	$\chi_{b2}(1P)$ 555	Ω_c^{*0} 4334	Ω_{bb}^{*-} 5534
$K_2(2250)^0$	9010315	$B_{s1}(L)^0$ 10533	$\eta_{b2}(1D)$ 10555	\mathcal{Z}_{cc}^{+} 4412	$arOmega_{bbc}^0$ 5542
$K_2(2250)^+$	9010325	$B_{s1}(H)^0$ 20533	$\Upsilon_2(1D)$ 20555	\mathcal{Z}_{cc}^{++} 4422	Ω_{bbc}^{*0} 5544
$K_3^*(1780)^0$	317		$\chi_{b2}(2P)$ 100555*	\mathcal{Z}_{cc}^{*+} 4414	Ω_{bbb}^{-} 5554
$K_3^*(1780)^+$	327		$\eta_{b2}(2D)$ 110555	\mathcal{Z}_{cc}^{*++} 4424	000
$K_3(2320)^0$	9010317	B_c^+ 541	$\Upsilon_2(2D)$ 120555	Ω_{cc}^{+} 4432	•
$K_3(2320)^+$	9010327	B_{c0}^{*+} 10541	$\chi_{b2}(3P)$ 120005 $\chi_{b2}(3P)$ 200555		
$K_4^*(2045)^0$	319	B_c^{*+} 543			
$K_4^*(2045)^+$	329	$B_{c1}(L)^+$ 10543		$arOmega_{ccc}^{++}$ 4444	
$K_4(2500)^0$	9000319	$B_{c1}(H)^+$ 20543	$\Upsilon_3(2D)$ 100557		
$K_4(2500)^+$	9000329	B_{c2}^{*+} 545			
**>					

Footnotes to the Tables:

- *) Numbers which have changed since the 1996 Review [4] are in bold face. Numbers which were not assigned in the 1996 Review [4] are in regular type.
- a) Particulary in the third generation, the left and right sfermion states may mix, as shown. The lighter mixed state is given the smaller number.
- b) The physical $\widetilde{\chi}$ states are admixtures of the pure $\widetilde{\gamma}$, \widetilde{Z}^0 , \widetilde{W}^+ , \widetilde{H}^0_1 , \widetilde{H}^0_2 , and \widetilde{H}^+ states. c) In this draft we have only provided one generic leptoquark code. More general classifications according to spin, weak isospin and flavor content would lead to a host of states, that could be added as the need arises.
- d) Σ^* and Ξ^* are alternate names for $\Sigma(1385)$ and $\Xi(1530)$.

32. CLEBSCH-GORDAN COEFFICIENTS, SPHERICAL HARMONICS,

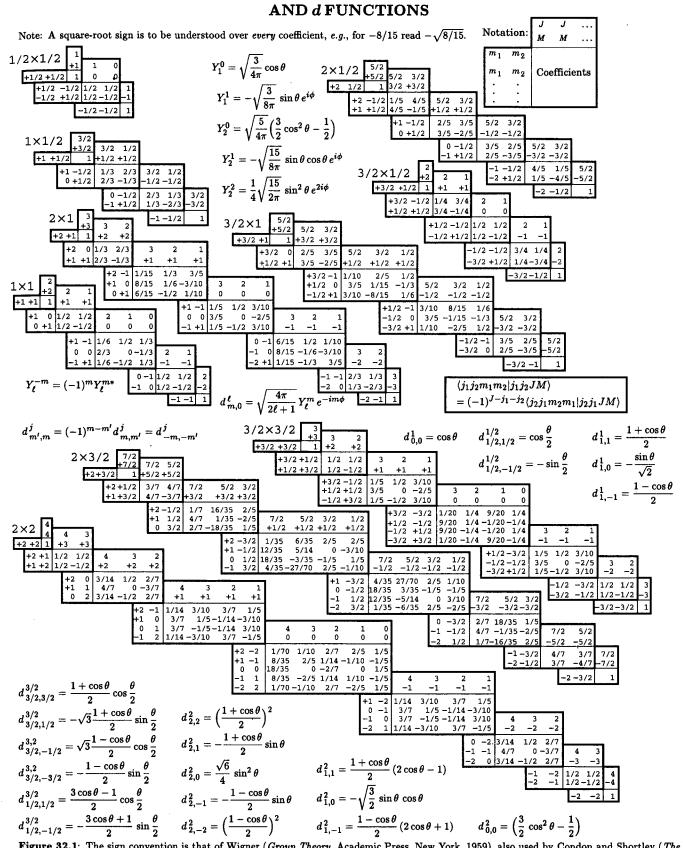


Figure 32.1: The sign convention is that of Wigner (*Group Theory*, Academic Press, New York, 1959), also used by Condon and Shortley (*The Theory of Atomic Spectra*, Cambridge Univ. Press, New York, 1953), Rose (*Elementary Theory of Angular Momentum*, Wiley, New York, 1957), and Cohen (*Tables of the Clebsch-Gordan Coefficients*, North American Rockwell Science Center, Thousand Oaks, Calif., 1974). The coefficients here have been calculated using computer programs written independently by Cohen and at LBNL.

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33. SU(3) ISOSCALAR FACTORS AND REPRESENTATION MATRICES

Written by R.L. Kelly (LBNL).

The most commonly used SU(3) isoscalar factors, corresponding to the singlet, octet, and decuplet content of $8\otimes 8$ and $10\otimes 8$, are shown at the right. The notation uses particle names to identify the coefficients, so that the pattern of relative couplings may be seen at a glance. We illustrate the use of the coefficients below. See J.J de Swart, Rev. Mod. Phys. 35, 916 (1963) for detailed explanations and phase conventions.

 $A \sqrt{\ }$ is to be understood over every integer in the matrices; the exponent 1/2 on each matrix is a reminder of this. For example, the $\Xi \to \Omega K$ element of the $10 \to 10 \otimes 8$ matrix is $-\sqrt{6}/\sqrt{24} = -1/2$.

Intramultiplet relative decay strengths may be read directly from the matrices. For example, in decuplet \to octet + octet decays, the ratio of $\Omega^* \to \varXi \overline{K}$ and $\Delta \to N\pi$ partial widths is, from the $10 \to 8 \times 8$ matrix.

$$\frac{\Gamma(\Omega^* \to \Xi \overline{K})}{\Gamma(\Delta \to N\pi)} = \frac{12}{6} \times \text{ (phase space factors)}. \tag{33.1}$$

Including isospin Clebsch-Gordan coefficients, we obtain, e.g.,

$$\frac{\Gamma(\Omega^{*-} \to \Xi^0 K^-)}{\Gamma(\Delta^+ \to p \pi^0)} = \frac{1/2}{2/3} \times \frac{12}{6} \times p.s.f. = \frac{3}{2} \times p.s.f.$$
 (33.2)

Partial widths for $8 \to 8 \otimes 8$ involve a linear superposition of 8_1 (symmetric) and 8_2 (antisymmetric) couplings. For example,

$$\Gamma(\Xi^* \to \Xi \pi) \sim \left(-\sqrt{\frac{9}{20}} g_1 + \sqrt{\frac{3}{12}} g_2\right)^2$$
 (33.3)

The relations between g_1 and g_2 (with de Swart's normalization) and the standard D and F couplings that appear in the interaction Lagrangian,

$$\mathcal{L} = -\sqrt{2} D \operatorname{Tr} (\{\overline{B}, B\}M) + \sqrt{2} F \operatorname{Tr} ([\overline{B}, B] M) , \qquad (33.4)$$

where $[\overline{B}, B] \equiv \overline{B}B - B\overline{B}$ and $\{\overline{B}, B\} \equiv \overline{B}B + B\overline{B}$, are

$$D = \frac{\sqrt{30}}{40} g_1 , \qquad F = \frac{\sqrt{6}}{24} g_2 . \qquad (33.5)$$

Thus, for example,

$$\Gamma(\Xi^* \to \Xi \pi) \sim (F - D)^2 \sim (1 - 2\alpha)^2$$
, (33.6)

where $\alpha \equiv F/(D+F)$. (This definition of α is de Swart's. The alternative D/(D+F), due to Gell-Mann, is also used.)

The generators of SU(3) transformations, λ_a (a=1,8), are 3×3 matrices that obey the following commutation and anticommutation relationships:

$$[\lambda_a, \lambda_b] \equiv \lambda_a \lambda_b - \lambda_b \lambda_a = 2i f_{abc} \lambda_c \tag{33.7}$$

$$\{\lambda_a,\ \lambda_b\} \equiv \lambda_a \lambda_b + \lambda_b \lambda_a = \frac{4}{3} \delta_{ab} I + 2 d_{abc} \lambda_c \ , \eqno(33.8)$$

where I is the 3×3 identity matrix, and δ_{ab} is the Kronecker delta symbol. The f_{abc} are odd under the permutation of any pair of indices, while the d_{abc} are even. The nonzero values are

1 -- 8 -- 8

$$(\Lambda) \rightarrow (N\overline{K} \ \Sigma \pi \ \Lambda \eta \ \Xi K) = \frac{1}{\sqrt{8}} (2 \ 3 \ -1 \ -2)^{1/2}$$

 $8_1 \rightarrow 8 \otimes 8$

$$\begin{pmatrix} N \\ \Sigma \\ \Lambda \\ \Xi \end{pmatrix} \rightarrow \begin{pmatrix} N\pi & N\eta & \Sigma K & \Lambda K \\ N\overline{K} & \Sigma\pi & \Lambda\pi & \Sigma\eta & \Xi K \\ N\overline{K} & \Sigma\pi & \Lambda\eta & \Xi K \\ \Sigma\overline{K} & \Lambda\overline{K} & \Xi\pi & \Xi\eta \end{pmatrix} = \frac{1}{\sqrt{20}} \begin{pmatrix} 9 & -1 & -9 & -1 \\ -6 & 0 & 4 & 4 & -6 \\ 2 & -12 & -4 & -2 \\ 9 & -1 & -9 & -1 \end{pmatrix}^{1/2}$$

 $8_2 \rightarrow 8 \otimes 8$

$$\begin{pmatrix} N \\ \Sigma \\ \Lambda \\ \Xi \end{pmatrix} \rightarrow \begin{pmatrix} N\pi & N\eta & \Sigma K & \Lambda K \\ N\overline{K} & \Sigma\pi & \Lambda\pi & \Sigma\eta & \Xi K \\ N\overline{K} & \Sigma\pi & \Lambda\eta & \Xi K \\ \Sigma \overline{K} & \Lambda \overline{K} & \Xi\pi & \Xi\eta \end{pmatrix} = \frac{1}{\sqrt{12}} \begin{pmatrix} 3 & 3 & 3 & -3 \\ 2 & 8 & 0 & 0 & -2 \\ 6 & 0 & 0 & 6 \\ 3 & 3 & 3 & -3 \end{pmatrix}^{1/2}$$

 $10 \rightarrow 8 \otimes 8$

$$\begin{pmatrix} \Delta \\ \Sigma \\ \Xi \\ \Omega \end{pmatrix} \rightarrow \begin{pmatrix} N\overline{K} & \Sigma\pi & \Lambda\pi & \Sigma\eta & \Xi K \\ \Sigma\overline{K} & \Lambda\overline{K} & \Xi\pi & \Xi\eta \\ \Xi\overline{K} \end{pmatrix} = \frac{1}{\sqrt{12}} \begin{pmatrix} -6 & 6 & \\ -2 & 2 & -3 & 3 & 2 \\ 3 & -3 & 3 & 3 & \\ 12 & & & 12 \end{pmatrix}^{1/2}$$

 $8 \rightarrow 10 \otimes 8$

$$\begin{pmatrix} N \\ \Sigma \\ \Lambda \\ \Xi \end{pmatrix} \rightarrow \begin{pmatrix} \Delta\pi & \Sigma K \\ \Sigma \pi & \Sigma \eta & \Xi K \\ \Sigma \pi & \Xi K \\ \Sigma \overline{K} & \Xi \pi & \Xi \eta & \Omega K \end{pmatrix} \qquad = \frac{1}{\sqrt{15}} \begin{pmatrix} -12 & 3 \\ 8 & -2 & -3 & 2 \\ -9 & 6 \\ 3 & -3 & -3 & 6 \end{pmatrix}^{1/2}$$

 $10 \rightarrow 10 \otimes 8$

$$\begin{pmatrix} \Delta \\ \Sigma \\ \Xi \\ \Omega \end{pmatrix} \rightarrow \begin{pmatrix} \Delta \pi & \Delta \eta & \Sigma K \\ \Delta \overline{K} & \Sigma \pi & \Sigma \eta & \Xi K \\ \Sigma \overline{K} & \Xi \pi & \Xi \eta & \Omega K \\ \Xi \overline{K} & \Omega \eta \end{pmatrix} \qquad = \frac{1}{\sqrt{24}} \begin{pmatrix} 15 & 3 & -6 \\ 8 & 8 & 0 & -8 \\ 12 & 3 & -3 & -6 \\ 12 & -12 \end{pmatrix}^{1/2}$$

abc	f_{abc}	\underline{abc}	d_{abc}	abc	d_{abc}
123	1	118	$1/\sqrt{3}$	355	1/2
147	1/2	146	1/2	366	-1/2
156	-1/2	157	1/2	377	-1/2
246	1/2	228	$1/\sqrt{3}$	448	$-1/(2\sqrt{3})$
257	1/2	247	-1/2	558	$-1/(2\sqrt{3})$
345	1/2	256	1/2	668	$-1/(2\sqrt{3})$
367	-1/2	338	$1/\sqrt{3}$	778	$-1/(2\sqrt{3})$
458	$\sqrt{3}/2$	344	1/2	888	$-1/\sqrt{3}$
678	$\sqrt{3}/2$		•	•	

The λ_{α} 's are

$$\lambda_1 = \begin{pmatrix} 0 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix} \ \lambda_2 = \begin{pmatrix} 0 & -i & 0 \\ i & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix} \ \lambda_3 = \begin{pmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 0 \end{pmatrix}$$

$$\lambda_4 = \begin{pmatrix} 0 & 0 & 1 \\ 0 & 0 & 0 \\ 1 & 0 & 0 \end{pmatrix} \lambda_5 = \begin{pmatrix} 0 & 0 & -i \\ 0 & 0 & 0 \\ i & 0 & 0 \end{pmatrix} \lambda_6 = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 1 \\ 0 & 1 & 0 \end{pmatrix}$$

$$\lambda_7 = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & -i \\ 0 & i & 0 \end{pmatrix} \quad \lambda_8 = \frac{1}{\sqrt{3}} \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & -2 \end{pmatrix}$$

Equation (33.7) defines the Lie algebra of SU(3). A general d-dimensional representation is given by a set of $d \times d$ matrices satisfying Eq. (33.7) with the f_{abc} given above. Equation (33.8) is specific to the defining 3-dimensional representation.

34. SU(n) MULTIPLETS AND YOUNG DIAGRAMS

Written by C.G. Wohl (LBNL).

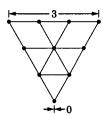
This note tells (1) how SU(n) particle multiplets are identified or labeled, (2) how to find the number of particles in a multiplet from its label, (3) how to draw the Young diagram for a multiplet, and (4) how to use Young diagrams to determine the overall multiplet structure of a composite system, such as a 3-quark or a meson-baryon system.

In much of the literature, the word "representation" is used where we use "multiplet," and "tableau" is used where we use "diagram."

34.1. Multiplet labels

An SU(n) multiplet is uniquely identified by a string of (n-1) nonnegative integers: $(\alpha, \beta, \gamma, \ldots)$. Any such set of integers specifies a multiplet. For an SU(2) multiplet such as an isospin multiplet, the single integer α is the number of *steps* from one end of the multiplet to the other (i.e., it is one fewer than the number of particles in the multiplet). In SU(3), the two integers α and β are the numbers of steps across the top and bottom levels of the multiplet diagram. Thus the labels for the SU(3) octet and decuplet





are (1,1) and (3,0). For larger n, the interpretation of the integers in terms of the geometry of the multiplets, which exist in an (n-1)-dimensional space, is not so readily apparent.

The label for the SU(n) singlet is $(0,0,\ldots,0)$. In a flavor SU(n), the n quarks together form a $(1,0,\ldots,0)$ multiplet, and the n antiquarks belong to a $(0,\ldots,0,1)$ multiplet. These two multiplets are *conjugate* to one another, which means their labels are related by $(\alpha,\beta,\ldots) \leftrightarrow (\ldots,\beta,\alpha)$.

34.2. Number of particles

The number of particles in a multiplet, $N=N(\alpha,\beta,\ldots)$, is given as follows (note the pattern of the equations).

In SU(2), $N = N(\alpha)$ is

$$N = \frac{(\alpha + 1)}{1} . \tag{34.1}$$

In SU(3), $N = N(\alpha, \beta)$ is

$$N = \frac{(\alpha+1)}{1} \cdot \frac{(\beta+1)}{1} \cdot \frac{(\alpha+\beta+2)}{2} . \tag{34.2}$$

In SU(4), $N = N(\alpha, \beta, \gamma)$ is

$$N = \frac{(\alpha+1)}{1} \cdot \frac{(\beta+1)}{1} \cdot \frac{(\gamma+1)}{1} \cdot \frac{(\alpha+\beta+2)}{2} \cdot \frac{(\beta+\gamma+2)}{2} \cdot \frac{(\alpha+\beta+\gamma+3)}{3}.$$
(34.3)

Note that in Eq. (34.3) there is no factor with $(\alpha + \gamma + 2)$: only a consecutive sequence of the label integers appears in any factor. One more example should make the pattern clear for any SU(n). In SU(5), $N = N(\alpha, \beta, \gamma, \delta)$ is

$$N = \frac{(\alpha+1)}{1} \cdot \frac{(\beta+1)}{1} \cdot \frac{(\gamma+1)}{1} \cdot \frac{(\delta+1)}{1} \cdot \frac{(\alpha+\beta+2)}{2} \cdot \frac{(\beta+\gamma+2)}{2} \times \frac{(\gamma+\delta+2)}{2} \cdot \frac{(\alpha+\beta+\gamma+3)}{3} \cdot \frac{(\beta+\gamma+\delta+3)}{3} \cdot \frac{(\alpha+\beta+\gamma+\delta+4)}{4} (34.4)$$

From the symmetry of these equations, it is clear that multiplets that are conjugate to one another have the same number of particles, but so can other multiplets. For example, the SU(4) multiplets (3,0,0) and (1,1,0) each have 20 particles. Try the equations and see.

34.3. Young diagrams

A Young diagram consists of an array of boxes (or some other symbol) arranged in one or more left-justified rows, with each row being at least as long as the row beneath. The correspondence between a diagram and a multiplet label is: The top row juts out α boxes to the right past the end of the second row, the second row juts out β boxes to the right past the end of the third row, etc. A diagram in SU(n) has at most n rows. There can be any number of "completed" columns of n boxes buttressing the left of a diagram; these don't affect the label. Thus in SU(3) the diagrams



represent the multiplets (1,0), (0,1), (0,0), (1,1), and (3,0). In any SU(n), the quark multiplet is represented by a single box, the antiquark multiplet by a column of (n-1) boxes, and a singlet by a completed column of n boxes.

34.4. Coupling multiplets together

The following recipe tells how to find the multiplets that occur in coupling two multiplets together. To couple together more than two multiplets, first couple two, then couple a third with each of the multiplets obtained from the first two, etc.

First a definition: A sequence of the letters a, b, c, \ldots is admissible if at any point in the sequence at least as many a's have occurred as b's, at least as many b's have occurred as c's, etc. Thus abcd and aabcb are admissible sequences and abb and acb are not. Now the recipe:

- (a) Draw the Young diagrams for the two multiplets, but in one of the diagrams replace the boxes in the first row with a's, the boxes in the second row with b's, etc. Thus, to couple two SU(3) octets (such as the π -meson octet and the baryon octet), we start with \square and
- ^{a a} . The unlettered diagram forms the upper left-hand corner of all the enlarged diagrams constructed below.
- (b) Add the a's from the lettered diagram to the right-hand ends of the rows of the unlettered diagram to form all possible legitimate Young diagrams that have no more than one a per column. In general, there will be several distinct diagrams, and all the a's appear in each diagram. At this stage, for the coupling of the two SU(3) octets, we have:

- (c) Use the b's to further enlarge the diagrams already obtained, subject to the same rules. Then throw away any diagram in which the full sequence of letters formed by reading right to left in the first row, then the second row, etc., is not admissible.
 - (d) Proceed as in (c) with the c's (if any), etc.

The final result of the coupling of the two SU(3) octets is:

Here only the diagrams with admissible sequences of a's and b's and with fewer than four rows (since n=3) have been kept. In terms of multiplet labels, the above may be written

$$(1,1)\otimes(1,1)=(2,2)\oplus(3,0)\oplus(0,3)\oplus(1,1)\oplus(1,1)\oplus(0,0)$$
.

In terms of numbers of particles, it may be written

$$\mathbf{8} \otimes \mathbf{8} = \mathbf{27} \oplus \mathbf{10} \oplus \mathbf{\overline{10}} \oplus \mathbf{8} \oplus \mathbf{8} \oplus \mathbf{1} .$$

The product of the numbers on the left here is equal to the sum on the right, a useful check. (See also Sec. 13 on the Quark Model.)

35. KINEMATICS

Revised May 1996 by J.D. Jackson (LBNL),

Throughout this section units are used in which $\hbar = c = 1$. The following conversions are useful: $\hbar c = 197.3 \text{ MeV fm}, (\hbar c)^2 = 0.3894$ $(GeV)^2$ mb.

35.1. Lorentz transformations

The energy E and 3-momentum p of a particle of mass m form a 4-vector p=(E,p) whose square $p^2\equiv E^2-|p|^2=m^2$. The velocity of the particle is $\beta = p/E$. The energy and momentum (E^*, p^*) viewed from a frame moving with velocity β_f are given by

$$\begin{pmatrix} E^* \\ p_{\parallel}^* \end{pmatrix} = \begin{pmatrix} \gamma_f & -\gamma_f \beta_f \\ -\gamma_f \beta_f & \gamma_f \end{pmatrix} \begin{pmatrix} E \\ p_{\parallel} \end{pmatrix} , \quad p_T^* = p_T , \quad (35.1)$$

where $\gamma_f=(1-\beta_f^2)^{-1/2}$ and p_T (p_\parallel) are the components of p perpendicular (parallel) to β_f . Other 4-vectors, such as the spacetime coordinates of events, of course transform in the same way. The scalar product of two 4-momenta $p_1 \cdot p_2 = E_1 E_2 - p_1 \cdot p_2$ is invariant (frame independent).

35.2. Center-of-mass energy and momentum

In the collision of two particles of masses m_1 and m_2 the total center-of-mass energy can be expressed in the Lorentz-invariant form

$$E_{\rm cm} = \left[(E_1 + E_2)^2 - (\mathbf{p}_1 + \mathbf{p}_2)^2 \right]^{1/2} ,$$

= $\left[m_1^2 + m_2^2 + 2E_1E_2(1 - \beta_1\beta_2\cos\theta) \right]^{1/2} ,$ (35.2)

where θ is the angle between the particles. In the frame where one particle (of mass m_2) is at rest (lab frame),

$$E_{\rm cm} = (m_1^2 + m_2^2 + 2E_{1\,{\rm lab}}\,m_2)^{1/2}$$
 (35.3)

The velocity of the center-of-mass in the lab frame is

$$\beta_{\rm cm} = p_{\rm lab}/(E_{\rm 1\,lab} + m_2)$$
, (35.4)

where $p_{lab} \equiv p_{l \, lab}$ and

$$\gamma_{\rm cm} = (E_{1\,\rm lab} + m_2)/E_{\rm cm}$$
 (35.5)

The c.m. momenta of particles 1 and 2 are of magnitude

$$p_{\rm cm} = p_{\rm lab} \frac{m_2}{E_{\rm cm}} . \tag{35.6}$$

For example, if a $0.80~{\rm GeV}/c$ kaon beam is incident on a proton target, the center of mass energy is 1.699 GeV and the center of mass momentum of either particle is 0.442 GeV/c. It is also useful to note that

$$E_{\rm cm} dE_{\rm cm} = m_2 dE_{1\,\rm lab} = m_2 \beta_{1\,\rm lab} dp_{\rm lab}$$
 (35.7)

35.3. Lorentz-invariant amplitudes

The matrix elements for a scattering or decay process are written in terms of an invariant amplitude $-i\mathcal{M}$. As an example, the S-matrix for $2 \rightarrow 2$ scattering is related to \mathcal{M} by

$$\langle p'_{1}p'_{2} | S | p_{1}p_{2} \rangle = I - i(2\pi)^{4} \delta^{4}(p_{1} + p_{2} - p'_{1} - p'_{2}) \times \frac{\mathscr{M}(p_{1}, p_{2}; p'_{1}, p'_{2})}{(2E_{1})^{1/2} (2E_{2})^{1/2} (2E'_{1})^{1/2} (2E'_{2})^{1/2}} . (35.8)$$

The state normalization is such that

$$\langle p'|p\rangle = (2\pi)^3 \delta^3(p-p') . \qquad (35.9)$$

35.4. Particle decays

The partial decay rate of a particle of mass M into n bodies in its rest frame is given in terms of the Lorentz-invariant matrix element ₩ bv

$$d\Gamma = \frac{(2\pi)^4}{2M} |\mathcal{M}|^2 d\Phi_n (P; p_1, \dots, p_n), \qquad (35.10)$$

where $d\Phi_n$ is an element of n-body phase space given by

$$d\Phi_n(P; p_1, \ldots, p_n) = \delta^4 \left(P - \sum_{i=1}^n p_i \right) \prod_{i=1}^n \frac{d^3 p_i}{(2\pi)^3 2E_i} . \tag{35.11}$$

This phase space can be generated recursively, viz.

$$d\Phi_n(P; p_1, \ldots, p_n) = d\Phi_i(q; p_1, \ldots, p_i)$$

$$\times d\Phi_{n-j+1}(P; q, p_{i+1}, \ldots, p_n)(2\pi)^3 dq^2,$$
 (35.12)

where $q^2 = (\sum_{i=1}^j E_i)^2 - \left|\sum_{i=1}^j p_i\right|^2$. This form is particularly useful in the case where a particle decays into another particle that subsequently decays.

35.4.1. Survival probability: If a particle of mass M has mean proper lifetime τ (= 1/ Γ) and has momentum (E, p), then the probability that it lives for a time to or greater before decaying is given by

$$P(t_0) = e^{-t_0 \Gamma/\gamma} = e^{-Mt_0 \Gamma/E} , \qquad (35.13)$$

and the probability that it travels a distance x_0 or greater is

$$P(x_0) = e^{-Mx_0 \Gamma/|p|}. (35.14)$$

35.4.2. Two-body decays:

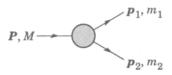


Figure 35.1: Definitions of variables for two-body decays.

In the rest frame of a particle of mass M, decaying into 2 particles labeled 1 and 2,

$$E_1 = \frac{M^2 - m_2^2 + m_1^2}{2M} , \qquad (35.15)$$

$$|p_1| = |p_2|$$

$$=\frac{\left[\left(M^2-(m_1+m_2)^2\right)\left(M^2-(m_1-m_2)^2\right)\right]^{1/2}}{2M},\qquad(35.16)$$

and

$$d\Gamma = \frac{1}{32\pi^2} |\mathcal{M}|^2 \frac{|p_1|}{M^2} d\Omega , \qquad (35.17)$$

where $d\Omega = d\phi_1 d(\cos \theta_1)$ is the solid angle of particle 1.

35.4.3. Three-body decays:

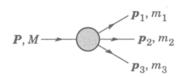


Figure 35.2: Definitions of variables for three-body decays.

Defining $p_{ij}=p_i+p_j$ and $m_{ij}^2=p_{ij}^2$, then $m_{12}^2+m_{23}^2+m_{13}^2=M^2+m_1^2+m_2^2+m_3^2$ and $m_{12}^2=(P-p_3)^2=M^2+m_3^2-2ME_3$, where E_3 is the energy of particle 3 in the rest frame of M. In that frame, the momenta of the three decay particles lie in a plane. The relative orientation of these three momenta is fixed if their energies are known. The momenta can therefore be specified in space by giving three Euler angles (α,β,γ) that specify the orientation of the final system relative to the initial particle. Then

$$d\Gamma = \frac{1}{(2\pi)^5} \frac{1}{16M} |\mathcal{M}|^2 dE_1 dE_2 d\alpha d(\cos \beta) d\gamma. \qquad (35.18)$$

Alternatively

$$d\Gamma = \frac{1}{(2\pi)^5} \frac{1}{16M^2} |\mathcal{M}|^2 |p_1^*| |p_3| dm_{12} d\Omega_1^* d\Omega_3 , \qquad (35.19)$$

where $(|p_1^*|, \Omega_1^*)$ is the momentum of particle 1 in the rest frame of 1 and 2, and Ω_3 is the angle of particle 3 in the rest frame of the decaying particle. $|p_1^*|$ and $|p_3|$ are given by

$$|\mathbf{p}_1^*| = \frac{\left[\left(m_{12}^2 - (m_1 + m_2)^2\right)\left(m_{12}^2 - (m_1 - m_2)^2\right)\right]^{1/2}}{2m_{12}},$$
 (35.20a)

and

$$|\mathbf{p}_3| = \frac{\left[\left(M^2 - (m_{12} + m_3)^2\right)\left(M^2 - (m_{12} - m_3)^2\right)\right]^{1/2}}{2M}$$
 (35.20b)

[Compare with Eq. (35.16).]

If the decaying particle is a scalar or we average over its spin states, then integration over the angles in Eq. (35.18) gives

$$d\Gamma = \frac{1}{(2\pi)^3} \frac{1}{8M} |\mathcal{M}|^2 dE_1 dE_2$$

$$= \frac{1}{(2\pi)^3} \frac{1}{32M^3} |\mathcal{M}|^2 dm_{12}^2 dm_{23}^2 . \tag{35.21}$$

This is the standard form for the Dalitz plot.

35.4.3.1. Dalitz plot: For a given value of m_{12}^2 , the range of m_{23}^2 is determined by its values when p_2 is parallel or antiparallel to p_3 :

$$(m_{23}^2)_{\text{max}} =$$

$$(E_2^* + E_3^*)^2 - \left(\sqrt{E_2^{*2} - m_2^2} - \sqrt{E_3^{*2} - m_3^2}\right)^2 , \qquad (35.22a)$$

$$(m_{23}^2)_{\text{min}} =$$

$$(E_2^* + E_3^*)^2 - \left(\sqrt{E_2^{*2} - m_2^2} + \sqrt{E_3^{*2} - m_3^2}\right)^2$$
 (35.22b)

Here $E_2^*=(m_{12}^2-m_1^2+m_2^2)/2m_{12}$ and $E_3^*=(M^2-m_{12}^2-m_3^2)/2m_{12}$ are the energies of particles 2 and 3 in the m_{12} rest frame. The scatter plot in m_{12}^2 and m_{23}^2 is called a Dalitz plot. If $|\mathcal{M}|^2$ is constant, the allowed region of the plot will be uniformly populated with events [see Eq. (35.21)]. A nonuniformity in the plot gives immediate information on $|\mathcal{M}|^2$. For example, in the case of $D\to K\pi\pi$, bands appear when $m_{(K\pi)}=m_{K^*(892)}$, reflecting the appearance of the decay chain $D\to K^*(892)\pi\to K\pi\pi$.

35.4.4. Kinematic limits: In a three-body decay the maximum of $|p_3|$, [given by Eq. (35.20)], is achieved when $m_{12} = m_1 + m_2$, i.e., particles 1 and 2 have the same vector velocity in the rest frame of the decaying particle. If, in addition, $m_3 > m_1, m_2$, then $|p_3|_{\max} > |p_1|_{\max}$, $|p_2|_{\max}$.

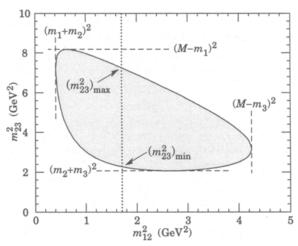


Figure 35.3: Dalitz plot for a three-body final state. In this example, the state is $\pi^+\overline{K}^0p$ at 3 GeV. Four-momentum conservation restricts events to the shaded region.

35.4.5. Multibody decays: The above results may be generalized to final states containing any number of particles by combining some of the particles into "effective particles" and treating the final states as 2 or 3 "effective particle" states. Thus, if $p_{ijk...} = p_i + p_j + p_k + \ldots$, then

$$m_{ijk...} = \sqrt{p^2_{ijk...}}, \qquad (35.23)$$

and $m_{ijk...}$ may be used in place of e.g., m_{12} in the relations in Sec. 35.4.3 or 35.4.3.1 above.

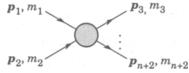


Figure 35.4: Definitions of variables for production of an *n*-body final state.

35.5. Cross sections

The differential cross section is given by

$$d\sigma = \frac{(2\pi)^4 |\mathcal{M}|^2}{4\sqrt{(p_1 \cdot p_2)^2 - m_1^2 m_2^2}}$$

$$\times d\Phi_n(p_1 + p_2; p_3, \dots, p_{n+2}). \tag{35.24}$$

[See Eq. (35.11).] In the rest frame of $m_2(lab)$,

$$\sqrt{(p_1 \cdot p_2)^2 - m_1^2 m_2^2} = m_2 p_{1 \, \text{lab}} ; \qquad (35.25a)$$

while in the center-of-mass frame

$$\sqrt{(p_1 \cdot p_2)^2 - m_1^2 m_2^2} = p_{1\text{cm}} \sqrt{s} . \tag{35.25b}$$

35.5.1. Two-body reactions:

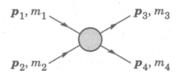


Figure 35.5: Definitions of variables for a two-body final state.

Two particles of momenta p_1 and p_2 and masses m_1 and m_2 scatter to particles of momenta p_3 and p_4 and masses m_3 and m_4 ; the Lorentz-invariant Mandelstam variables are defined by

$$s = (p_1 + p_2)^2 = (p_3 + p_4)^2$$

= $m_1^2 + 2E_{\underline{1}}E_2 - 2p_1 \cdot p_2 + m_2^2$, (35.26)

$$t = (p_1 - p_3)^2 = (p_2 - p_4)^2$$

= $m_1^2 - 2E_1E_3 + 2p_1 \cdot p_3 + m_3^2$, (35.27)

$$u = (p_1 - p_4)^2 = (p_2 - p_3)^2$$

= $m_1^2 - 2E_1E_4 + 2p_1 \cdot p_4 + m_4^2$, (35.28)

and they satisfy

$$s + t + u = m_1^2 + m_2^2 + m_3^2 + m_4^2 . (35.29)$$

The two-body cross section may be written as

$$\frac{d\sigma}{dt} = \frac{1}{64\pi s} \frac{1}{|\mathbf{p}_{1cm}|^2} |\mathcal{M}|^2 . \tag{35.30}$$

In the center-of-mass frame

$$t = (E_{1\text{cm}} - E_{3\text{cm}})^2 - (p_{1\text{cm}} - p_{3\text{cm}})^2 - 4p_{1\text{cm}} p_{3\text{cm}} \sin^2(\theta_{\text{cm}}/2)$$

$$= t_0 - 4p_{1cm} p_{3cm} \sin^2(\theta_{cm}/2) , \qquad (35.31)$$

where $\theta_{\rm cm}$ is the angle between particle 1 and 3. The limiting values t_0 ($\theta_{\rm cm}=0$) and t_1 ($\theta_{\rm cm}=\pi$) for $2\to 2$ scattering are

$$t_0(t_1) = \left[\frac{m_1^2 - m_3^2 - m_2^2 + m_4^2}{2\sqrt{s}} \right]^2 - (p_{1\,\text{cm}} \mp p_{3\,\text{cm}})^2 . \tag{35.32}$$

In the literature the notation t_{\min} (t_{\max}) for t_0 (t_1) is sometimes used, which should be discouraged since $t_0 > t_1$. The center-of-mass energies and momenta of the incoming particles are

$$E_{1\text{cm}} = \frac{s + m_1^2 - m_2^2}{2\sqrt{s}}$$
, $E_{2\text{cm}} = \frac{s + m_2^2 - m_1^2}{2\sqrt{s}}$, (35.33)

For $E_{3\rm cm}$ and $E_{4\rm cm}$, change m_1 to m_3 and m_2 to m_4 . Then

$$p_{i \text{ cm}} = \sqrt{E_{i \text{ cm}}^2 - m_i^2} \text{ and } p_{1 \text{ cm}} = \frac{p_{1 \text{ lab}} m_2}{\sqrt{s}}$$
 (35.34)

Here the subscript lab refers to the frame where particle 2 is at rest. [For other relations see Eqs. (35.2)–(35.4).]

35.5.2. Inclusive reactions: Choose some direction (usually the beam direction) for the z-axis; then the energy and momentum of a particle can be written as

$$E = m_T \cosh y \,, \, p_x \,, \, p_y \,, \, p_z = m_T \sinh y \,,$$
 (35.35)

where m_T is the transverse mass

$$m_T^2 = m^2 + p_x^2 + p_y^2 , (35.36)$$

and the rapidity y is defined by

$$y = \frac{1}{2} \ln \left(\frac{E + p_z}{E - p_z} \right)$$

$$= \ln \left(\frac{E + p_z}{m_x} \right) = \tanh^{-1} \left(\frac{p_z}{E} \right) . \tag{35.37}$$

Under a boost in the z-direction to a frame with velocity β , $y \to y - \tanh^{-1} \beta$. Hence the shape of the rapidity distribution dN/dy is invariant. The invariant cross section may also be rewritten

$$E\frac{d^3\sigma}{d^3p} = \frac{d^3\sigma}{d\phi \, dy \, p_T dp_T} \Longrightarrow \frac{d^2\sigma}{\pi \, dy \, d(p_T^2)} \,. \tag{35.38}$$

The second form is obtained using the identity $dy/dp_z = 1/E$, and the third form represents the average over ϕ .

Feynman's x variable is given by

$$x = \frac{p_z}{p_{z \max}} \approx \frac{E + p_z}{(E + p_z)_{\max}} \quad (p_T \ll |p_z|) .$$
 (35.39)

In the c.m. frame,

$$x \approx \frac{2p_{z\,\mathrm{cm}}}{\sqrt{s}} = \frac{2m_T \sinh y_{\mathrm{cm}}}{\sqrt{s}} \tag{35.40}$$

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$$=(y_{\rm cm})_{\rm max} = \ln(\sqrt{s}/m)$$
. (35.41)

For $p \gg m$, the rapidity [Eq. (35.37)] may be expanded to obtain

$$y = \frac{1}{2} \ln \frac{\cos^2(\theta/2) + m^2/4p^2 + \dots}{\sin^2(\theta/2) + m^2/4p^2 + \dots}$$
$$\approx -\ln \tan(\theta/2) \equiv \eta$$
 (35.42)

where $\cos \theta = p_x/p$. The pseudorapidity η defined by the second line is approximately equal to the rapidity y for $p \gg m$ and $\theta \gg 1/\gamma$, and in any case can be measured when the mass and momentum of the particle is unknown. From the definition one can obtain the identities

$$\sinh \eta = \cot \theta$$
, $\cosh \eta = 1/\sin \theta$, $\tanh \eta = \cos \theta$. (35.43)

35.5.3. Partial waves: The amplitude in the center of mass for elastic scattering of spinless particles may be expanded in Legendre polynomials

$$f(k,\theta) = \frac{1}{k} \sum_{\ell} (2\ell + 1) a_{\ell} P_{\ell}(\cos \theta) , \qquad (35.44)$$

where k is the c.m. momentum, θ is the c.m. scattering angle, $a_{\ell} = (\eta_{\ell}e^{2i\delta_{\ell}} - 1)/2i$, $0 \le \eta_{\ell} \le 1$, and δ_{ℓ} is the phase shift of the ℓ^{th} partial wave. For purely elastic scattering, $\eta_{\ell} = 1$. The differential cross section is

$$\frac{d\sigma}{d\Omega} = |f(k,\theta)|^2 . {(35.45)}$$

The optical theorem states that

$$\sigma_{\text{tot}} = \frac{4\pi}{k} \text{Im} f(k,0) , \qquad (35.46)$$

and the cross section in the ℓ^{th} partial wave is therefore bounded:

$$\sigma_{\ell} = \frac{4\pi}{k^2} (2\ell + 1) |a_{\ell}|^2 \le \frac{4\pi (2\ell + 1)}{k^2} . \tag{35.47}$$

The evolution with energy of a partial-wave amplitude a_{ℓ} can be displayed as a trajectory in an Argand plot, as shown in Fig. 35.6.

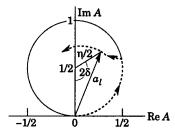


Figure 35.6: Argand plot showing a partial-wave amplitude a_{ℓ} as a function of energy. The amplitude leaves the unitary circle where inelasticity sets in $(\eta_{\ell} < 1)$.

The usual Lorentz-invariant matrix element \mathcal{M} (see Sec. 35.3 above) for the elastic process is related to $f(k,\theta)$ by

$$\mathscr{M} = -8\pi\sqrt{s} f(k,\theta) , \qquad (35.48)$$

so

$$\sigma_{\rm tot} = -\frac{1}{2p_{\rm lab} m_2} \, {\rm Im} \, \mathcal{M}(t=0) \; ,$$
 (35.49)

where s and t are the center-of-mass energy squared and momentum transfer squared, respectively (see Sec. 35.4.1).

35.5.3.1. Resonances: The Breit-Wigner (nonrelativistic) form for an elastic amplitude a_ℓ with a resonance at c.m. energy E_R , elastic width $\Gamma_{\rm el}$, and total width $\Gamma_{\rm tot}$ is

$$a_{\ell} = \frac{\Gamma_{\rm el}/2}{E_R - E - i\Gamma_{\rm tot}/2} , \qquad (35.50)$$

where E is the c.m. energy. As shown in Fig. 35.7, in the absence of background the elastic amplitude traces a counterclockwise circle with center $ix_{\rm el}/2$ and radius $x_{\rm el}/2$, where the elasticity $x_{\rm el}=\Gamma_{\rm el}/\Gamma_{\rm tot}$. The amplitude has a pole at $E=E_R-i\Gamma_{\rm tot}/2$.

The spin-averaged Breit-Wigner cross section for a spin-J resonance produced in the collision of particles of spin S_1 and S_2 is

$$\sigma_{BW}(E) = \frac{(2J+1)}{(2S_1+1)(2S_2+1)} \frac{\pi}{k^2} \frac{B_{\rm in} B_{\rm out} \Gamma_{\rm tot}^2}{(E-E_R)^2 + \Gamma_{\rm tot}^2/4} , \quad (35.51)$$

where k is the c.m. momentum, E is the c.m. energy, and $B_{\rm in}$ and $B_{\rm out}$ are the branching fractions of the resonance into the entrance and exit channels. The 2S+1 factors are the multiplicities of the incident spin states, and are replaced by 2 for photons. This expression is valid only for an isolated state. If the width is not small, $\Gamma_{\rm tot}$ cannot be treated as a constant independent of E. There are many other forms for σ_{BW} , all of which are equivalent to the one given here in the narrow-width case. Some of these forms may be more appropriate if the resonance is broad.

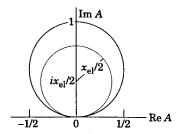


Figure 35.7: Argand plot for a resonance.

The relativistic Breit-Wigner form corresponding to Eq. (35.50) is:

$$a_{\ell} = \frac{-m\Gamma_{\rm el}}{s - m^2 + im\Gamma_{\rm tot}} \ . \tag{35.52}$$

A better form incorporates the known kinematic dependences, replacing $m\Gamma_{\rm tot}$ by $\sqrt{s}\,\Gamma_{\rm tot}(s)$, where $\Gamma_{\rm tot}(s)$ is the width the resonance particle would have if its mass were \sqrt{s} , and correspondingly $m\Gamma_{\rm el}$ by $\sqrt{s}\,\Gamma_{\rm el}(s)$ where $\Gamma_{\rm el}(s)$ is the partial width in the incident channel for a mass \sqrt{s} :

$$a_{\ell} = \frac{-\sqrt{s}\,\Gamma_{\rm el}(s)}{s - m^2 + i\sqrt{s}\,\Gamma_{\rm tot}(s)} \,. \tag{35.53}$$

For the Z boson, all the decays are to particles whose masses are small enough to be ignored, so on dimensional grounds $\Gamma_{\rm tot}(s) = \sqrt{s}\,\Gamma_0/m_Z$, where Γ_0 defines the width of the Z, and $\Gamma_{\rm el}(s)/\Gamma_{\rm tot}(s)$ is constant. A full treatment of the line shape requires consideration of dynamics, not just kinematics. For the Z this is done by calculating the radiative corrections in the Standard Model.

36. CROSS-SECTION FORMULAE FOR SPECIFIC PROCESSES

Revised April 1998 by R.N. Cahn (LBNL).

36.1. Leptoproduction

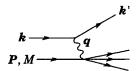


Figure 36.1: Kinematic quantities for description of lepton-nucleon scattering. k and k' are the four-momenta of incoming and outgoing leptons, P is the four-momentum of a nucleon with mass M. The exchanged particle is a γ , W^{\pm} , or Z^0 ; it transfers four-momentum q = k - k' to the target.

Invariant quantities:

 $\nu = \frac{q \cdot P}{M} = E - E' \text{ is the lepton's energy loss in the lab (in earlier literature sometimes } \nu = q \cdot P). \text{ Here, } E \text{ and } E' \text{ are the initial and final lepton energies in the lab.}$

 $Q^2 = -q^2 = 2(EE' - \overrightarrow{k} \cdot \overrightarrow{k}') - m_\ell^2 - m_{\ell'}^2 \text{ where } m_\ell(m_{\ell'}) \text{ is the initial}$ (final) lepton mass. If $EE' \sin^2(\theta/2) \gg m_\ell^2$, $m_{\ell'}^2$, then

 $pprox 4EE'\sin^2(\theta/2)$, where θ is the lepton's scattering angle in the lab.

 $x=rac{Q^2}{2M
u}$ In the parton model, x is the fraction of the target nucleon's momentum carried by the struck quark. [See section on Quantum Chromodynamics (Sec. 9 of this *Review*.)]

 $y = rac{q \cdot P}{k \cdot P} = rac{
u}{E}$ is the fraction of the lepton's energy lost in the lab.

 $W^2 = (P+q)^2 = M^2 + 2M\nu - Q^2$ is the mass squared of the system recoiling against the lepton.

$$s = (k+P)^2 = \frac{Q^2}{xy} + M^2$$

36.1.1. Leptoproduction cross sections:

$$\frac{d^{2}\sigma}{dx\,dy} = \nu (s - M^{2}) \, \frac{d^{2}\sigma}{d\nu\,dQ^{2}} = \frac{2\pi\,M\nu}{E^{I}} \frac{d^{2}\sigma}{d\Omega_{\text{lab}}\,dE^{I}}$$

$$= x(s - M^{2}) \, \frac{d^{2}\sigma}{dx\,d\Omega^{2}} \, . \tag{36.1}$$

36.1.2. Leptoproduction structure functions: The neutral-current process, $eN \to eX$, at low Q^2 is just electromagnetic and parity conserving. It can be written in terms of two structure functions $F_1^{\rm em}(x,Q^2)$ and $F_2^{\rm em}(x,Q^2)$:

$$\frac{d^2\sigma}{dx\,dy} = \frac{4\pi\,\alpha^2(s-M^2)}{Q^4} \times \left[(1-y)\,F_2^{\rm em} + y^2\,xF_1^{\rm em} - \frac{M^2}{(s-M^2)}\,xy\,F_2^{\rm em} \right] . (36.2)$$

The charged-current processes, $e^-N \to \nu X$, $\nu N \to e^-X$, and $\overline{\nu}N \to e^+X$, are parity violating and can be written in terms of three structure functions $F_1^{\rm CC}(x,Q^2)$, $F_2^{\rm CC}(x,Q^2)$, and $F_3^{\rm CC}(x,Q^2)$:

$$\frac{d^2\dot{\sigma}}{dx\;dy} = \frac{G_F^2\;(s-M^2)}{2\pi} \frac{M_W^4}{(Q^2+M_W^2)^2} \eqno(36.3)$$

$$\times \; \left\{ \left[1 - y - \frac{M^2 x y}{(s - M^2)} \right] F_2^{\rm CC} + \frac{y^2}{2} \; 2x \, F_1^{\rm CC} \pm (y - \frac{y^2}{2}) \; x \, F_3^{\rm CC} \right\} \, ,$$

where the last term is positive for the e^- and ν reactions and negative for $\overline{\nu}N \to e^+ X$. As explained below there are different structure functions for charge-raising and charge-lowering currents.

36.1.3. Structure functions in the QCD parton model: In the QCD parton model, the structure functions defined above can be expressed in terms of parton distribution functions. The quantity $f_i(x,Q^2)dx$ is the probability that a parton of type i (quark, antiquark, or gluon), carries a momentum fraction between x and x+dx of the nucleon's momentum in a frame where the nucleon's momentum is large. For the cross section corresponding to the neutral-current process $ep \to eX$, we have for $s \gg M^2$ (in the case where the incoming electron is either left- (L) or right- (R) handed):

$$\frac{d^{2}\sigma}{dx\ dy} = \frac{\pi\alpha^{2}}{sx^{2}\ y^{2}} \left[\sum_{q} \left(x f_{q} \left(x, Q^{2} \right) + x f_{\overline{q}} \left(x, Q^{2} \right) \right) \right] \times \left[A_{q} + (1 - y)^{2} B_{q} \right]. \tag{36.4}$$

Here the index q refers to a quark flavor (i.e., u, d, s, c, b, or t), and

$$\begin{split} A_q &= \left(-q_q + g_{Lq} \; g_{Le} \; \frac{Q^2}{Q^2 + M_Z^2} \right)^2 + \left(-q_q + g_{Rq} \; g_{Re} \; \frac{Q^2}{Q^2 + M_Z^2} \right)^2, \\ B_q &= \left(-q_q + g_{Rq} \; g_{Le} \; \frac{Q^2}{Q^2 + M_Z^2} \right)^2 + \left(-q_q + g_{Lq} \; g_{Re} \; \frac{Q^2}{Q^2 + M_Z^2} \right)^2. \end{split}$$

Here q_q is the charge of flavor q. For a left-handed electron, $g_{Re}=0$ and $g_{Le}=(-1/2+\sin^2\theta_W)/(\sin\theta_W\cos\theta_W)$, while for a right-handed electron, $g_{Le}=0$ and $g_{Re}=(\sin^2\theta_W)/(\sin\theta_W\cos\theta_W)$. For the quarks, $g_{Lq}=(T_3-q_q\sin^2\theta_W)/(\sin\theta_W\cos\theta_W)$, and $g_{Rq}=(-q_q\sin^2\theta_W)$ / $(\sin\theta_W\cos\theta_W)$.

For neutral-current neutrino (antineutrino) scattering, the same formula applies with g_{Le} replaced by $g_{L\nu}=1/(2\sin\theta_W\cos\theta_W)$ ($g_{L\overline{\nu}}=0$) and g_{Re} replaced by $g_{R\nu}=0$ [$g_{R\overline{\nu}}=-1/(2\sin\theta_W\cos\theta_W)$].

In the case of the charged-current processes $e_L^-p\to \nu X$ and $\overline{\nu}p\to e^+X$, Eq. (36.3) applies with

$$F_{2} = 2xF_{1} = 2x \Big[f_{u}(x, Q^{2}) + f_{c}(x, Q^{2}) + f_{t}(x, Q^{2}) + f_{\overline{d}}(x, Q^{2}) + f_{\overline{b}}(x, Q^{2}) + f_{\overline{b}}(x, Q^{2}) \Big] , \qquad (36.7)$$

$$F_{3} = 2 \Big[f_{u}(x, Q^{2}) + f_{c}(x, Q^{2}) + f_{t}(x, Q^{2}) - f_{\overline{d}}(x, Q^{2}) - f_{\overline{b}}(x, Q^{2}) \Big] . \qquad (36.8)$$

For the process $\nu p \to e^- X$:

$$F_{2} = 2xF_{1} = 2x \left[f_{d}(x,Q^{2}) + f_{s}(x,Q^{2}) + f_{b}(x,Q^{2}) + f_{\overline{u}}(x,Q^{2}) + f_{\overline{c}}(x,Q^{2}) + f_{\overline{c}}(x,Q^{2}) + f_{\overline{t}}(x,Q^{2}) \right],$$
(36.9)

$$F_{3} = 2 \left[f_{d}(x,Q^{2}) + f_{s}(x,Q^{2}) + f_{b}(x,Q^{2}) - f_{\overline{u}}(x,Q^{2}) - f_{\overline{c}}(x,Q^{2}) - f_{\overline{c}}(x,Q^{2}) \right].$$
(36.10)

36.2. e^+e^- annihilation

For pointlike, spin-1/2 fermions, the differential cross section in the c.m. for $e^+e^- \to f\bar{f}$ via single photon annihilation is (θ is the angle between the incident electron and the produced fermion; $N_c=1$ if f is a lepton and $N_c=3$ if f is a quark).

$$\frac{d\sigma}{d\Omega} = N_c \frac{\alpha^2}{4s} \beta \left[1 + \cos^2 \theta + (1 - \beta^2) \sin^2 \theta \right] Q_f^2 , \qquad (36.11)$$

where β is the velocity of the final state fermion in the c.m. and Q_f is the charge of the fermion in units of the proton charge. For $\beta \to 1$,

$$\sigma = N_c \frac{4\pi\alpha^2}{3s} Q_f^2 = N_c \frac{86.8 Q_f^2 \ nb}{s(GeV/c^2)} \ . \tag{36.12}$$

At higher energies, the Z^0 (mass M_Z and width Γ_Z) must be included. If the mass of a fermion f is much less than the mass of the Z^0 , then the differential cross section for $e^+e^- \to f\bar{f}$ is

$$\frac{d\sigma}{d\Omega} = N_c \frac{\alpha^2}{4s} \left\{ (1 + \cos^2 \theta) \left[Q_f^2 - 2\chi_1 v_e v_f Q_f + \chi_2 (a_e^2 + v_e^2) (a_f^2 + v_f^2) \right] + 2\cos \theta \left[-2\chi_1 a_e a_f Q_f + 4\chi_2 a_e a_f v_e v_f \right] \right\}$$
(36.13)

where

$$\chi_{1} = \frac{1}{16 \sin^{2} \theta_{W} \cos^{2} \theta_{W}} \frac{s(s - M_{Z}^{2})}{(s - M_{Z}^{2})^{2} + M_{Z}^{2} \Gamma_{Z}^{2}},$$

$$\chi_{2} = \frac{1}{256 \sin^{4} \theta_{W} \cos^{4} \theta_{W}} \frac{s^{2}}{(s - M_{Z}^{2})^{2} + M_{Z}^{2} \Gamma_{Z}^{2}},$$

$$a_{e} = -1,$$

$$v_{e} = -1 + 4 \sin^{2} \theta_{W},$$

$$a_{f} = 2T_{3f},$$

$$v_{f} = 2T_{3f} - 4Q_{f} \sin^{2} \theta_{W},$$
(36.14)

where $T_{3f}=1/2$ for $u,\ c$ and neutrinos, while $T_{3f}=-1/2$ for $d,\ s,\ b,$ and negatively charged leptons.

At LEP II it may be possible to produce the orthodox Higgs boson, H, (see the mini-review on Higgs bosons) in the reaction $e^+e^- \to HZ^0$, which proceeds dominantly through a virtual Z^0 . The Standard Model prediction for the cross section [3] is

$$\sigma(e^{+}e^{-} \to HZ^{0}) = \frac{\pi\alpha^{2}}{24} \cdot \frac{2K}{\sqrt{s}} \cdot \frac{K^{2} + 3M_{Z}^{2}}{(s - M_{Z}^{2})^{2}} \cdot \frac{1 - 4\sin^{2}\theta_{W} + 8\sin^{4}\theta_{W}}{\sin^{4}\theta_{W}\cos^{4}\theta_{W}}.$$
(36.15)

where K is the c.m. momentum of the produced H or Z^0 . Near the production threshold, this formula needs to be corrected for the finite width of the Z^0 .

36.3. Two-photon process at e^+e^- colliders

When an e^+ and an e^- collide with energies E_1 and E_2 , they emit dn_1 and dn_2 virtual photons with energies ω_1 and ω_2 and 4-momenta q_1 and q_2 . In the equivalent photon approximation, the cross section for $e^+e^- \to e^+e^-X$ is related to the cross section for $\gamma\gamma \to X$ by (Ref. 1)

$$d\sigma_{e^{+}e^{-}\rightarrow e^{+}e^{-}X}\left(s\right) = dn_{1} dn_{2} d\sigma_{\gamma\gamma\rightarrow X}\left(W^{2}\right) \tag{36.16}$$

where $s = 4E_1E_2$, $W^2 = 4\omega_1\omega_2$ and

$$dn_{i} = \frac{\alpha}{\pi} \left[1 - \frac{\omega_{i}}{E_{i}} + \frac{\omega_{i}^{2}}{2E_{i}^{2}} - \frac{m_{e}^{2}\omega_{i}^{2}}{(-q_{i}^{2})E_{i}^{2}} \right] \frac{d\omega_{i}}{\omega_{i}} \frac{d(-q_{i}^{2})}{(-q_{i}^{2})} \ . \eqno(36.17)$$

After integration (including that over q_i^2 in the region $m_e^2 \omega_i^2 / E_i(E_i - \omega_i) \le -q_i^2 \le (-q^2)_{\text{max}}$), the cross section is

$$\sigma_{e^{+}e^{-} \to e^{+}e^{-}X}(s) = \frac{\alpha^{2}}{\pi^{2}} \int_{z_{th}}^{1} \frac{dz}{z} \left[f(z) \left(\ln \frac{(-q^{2})_{\text{max}}}{m_{e}^{2}z} - 1 \right)^{2} - \frac{1}{3} \left(\ln \frac{1}{z} \right)^{3} \right] \sigma_{\gamma\gamma \to X}(zs) ;$$

$$f(z) = \left(1 + \frac{1}{2}z \right)^{2} \ln \frac{1}{z} - \frac{1}{2} (1 - z)(3 + z) ;$$

$$z = \frac{W^{2}}{s} . \tag{36.18}$$

The quantity $(-q^2)_{\max}$ depends on properties of the produced system X, in particular, $(-q^2)_{\max} \sim m_{\rho}^2$ for hadron production (X=h) and $(-q^2)_{\max} \sim W^2$ for lepton pair production $(X=\ell^+\ell^-,\ell^-,\ell^-,\ell^-)$

For production of a resonance of mass m_R and spin $J \neq 1$

$$\begin{split} \sigma_{e^{+}e^{-}\to e^{+}e^{-}R}(s) &= (2J+1)\frac{8\alpha^{2}\Gamma_{R\to\gamma\gamma}}{m_{R}^{3}} \\ &\times \left[f(m_{R}^{2}/s) \left(\ln \frac{sm_{V}^{2}}{m_{2}^{2}m_{P}^{2}} - 1 \right)^{2} - \frac{1}{3} \left(\ln \frac{s}{m_{P}^{2}} \right)^{3} \right] \end{split} \tag{36.19}$$

where m_V is the mass that enters into the form factor of the $\gamma\gamma \to R$ transition: $m_V \sim m_\rho$ for $R=\pi^0,~\rho^0,~\omega,~\phi,~\dots,~m_V \sim m_R$ for $R=c\bar{c}$ or $b\bar{b}$ resonances.

36.4. Inclusive hadronic reactions

One-particle inclusive cross sections $Ed^3\sigma/d^3p$ for the production of a particle of momentum p are conveniently expressed in terms of rapidity (see above) and the momentum p_T transverse to the beam direction (defined in the center-of-mass frame)

$$E\frac{d^3\sigma}{d^3p} = \frac{d^3\sigma}{d\phi\,dy\,p_T dp_T} \ . \tag{36.20}$$

In the case of processes where p_T is large or the mass of the produced particle is large (here large means greater than 10 GeV), the parton model can be used to calculate the rate. Symbolically

$$\sigma_{\text{hadronic}} = \sum_{ij} \int f_i(x_1, Q^2) f_j(x_2, Q^2) dx_1 dx_2 \, \hat{\sigma}_{\text{partonic}} , \quad (36.21)$$

where $f_i(x, Q^2)$ is the parton distribution introduced above and Q is a typical momentum transfer in the partonic process and $\hat{\sigma}$ is the partonic cross section. Some examples will help to clarify. The production of a W^+ in pp reactions at rapidity y in the center-of-mass frame is given by

$$\begin{split} \frac{d\sigma}{dy} &= \frac{G_F \, \pi \sqrt{2}}{3} \\ &\times \tau \bigg[\cos^2 \theta_c \bigg(u(x_1 \; , \; M_W^2) \; \overline{d} \; (x_2, M_W^2) \\ &\quad + \; u(x_2 \; , \; M_W^2) \; \overline{d} \; (x_1, M_W^2) \bigg) \\ &\quad + \; \sin^2 \theta_c \bigg(u(x_1 \; , \; M_W^2) \; \overline{s} \; (x_2 \; , \; M_W^2) \\ &\quad + \; s(x_2, M_W^2) \; \overline{u} \; (x_1, M_W^2) \bigg) \bigg] \; , \; (36.22) \end{split}$$

where $x_1 = \sqrt{\tau} \ e^y$, $x_2 = \sqrt{\tau} \ e^{-y}$, and $\tau = M_W^2/s$. Similarly the production of a jet in pp (or $p\bar{p}$) collisions is given by

$$\frac{d^3\sigma}{d^2p_T dy} = \sum_{ij} \int f_i(x_1, p_T^2) f_j(x_2, p_T^2) \times \left[\widehat{s} \frac{d\widehat{\sigma}}{d\widehat{t}} \right]_{ij} dx_1 dx_2 \delta(\widehat{s} + \widehat{t} + \widehat{u}), \quad (36.23)$$

where the summation is over quarks, gluons, and antiquarks. Here

$$s = (p_1 + p_2)^2 , (36.24)$$

$$t = (p_1 - p_{\text{iet}})^2 , \qquad (36.25)$$

$$u = (p_2 - p_{\text{jet}})^2 , (36.26)$$

 p_1 and p_2 are the momenta of the incoming p and p (or \overline{p}) and \widehat{s} , \widehat{t} , and \widehat{u} are s, t, and u with $p_1 \to x_1 p_1$ and $p_2 \to x_2 p_2$. The partonic cross section $\widehat{s}[(d\widehat{\sigma})/(d\widehat{t})]$ can be found in Ref. 2. Example: for the process $gg \to q\overline{q}$,

$$\widehat{s} \frac{d\sigma}{dt} = 3\alpha_s^2 \frac{(\widehat{t}^2 + \widehat{u}^2)}{8\widehat{s}} \left[\frac{4}{9\,\widehat{t}\,\widehat{u}} - \frac{1}{\widehat{s}^2} \right] . \tag{36.27}$$

The prediction of Eq. (36.23) is compared to data from the UA1 and UA2 collaborations in Fig. 38.8 in the Plots of Cross Sections and Related Quantities section of this *Review*.

The associated production of a Higgs boson and a gauge boson is analogous to the process $e^+e^- \to HZ^0$ in Sec. 36.2. The required parton-level cross sections [4], averaged over initial quark colors, are

$$\begin{split} \sigma(q_i \overline{q}_j \to W^\pm H) &= \frac{\pi \alpha^2 |V_{ij}|^2}{36 \sin^4 \theta_W} \cdot \frac{2K}{\sqrt{s}} \cdot \frac{K^2 + 3M_W^2}{(s - M_W^2)^2} \\ \sigma(q \overline{q} \to Z^0 H) &= \frac{\pi \alpha^2 (a_q^2 + v_q^2)}{144 \sin^4 \theta_W \cos^4 \theta_W} \cdot \frac{2K}{\sqrt{s}} \cdot \frac{K^2 + 3M_Z^2}{(s - M_Z^2)^2} \end{split}$$

Here V_{ij} is the appropriate element of the Kobayashi-Maskawa matrix and K is the c.m. momentum of the produced H. The axial and vector couplings are defined as in Sec. 36.2.

36.5. One-particle inclusive distributions

In order to describe one-particle inclusive production in e^+e^- annihilation or deep inelastic scattering, it is convenient to introduce a fragmentation function $D_i^h\left(z,Q^2\right)$ where $D_i^h\left(z,Q^2\right)$ is the number of hadrons of type h and momentum between zp and (z+dz)p produced in the fragmentation of a parton of type i. The Q^2 evolution is predicted by QCD and is similar to that of the parton distribution functions [see section on Quantum Chromodynamics (Sec. 9 of this Review)]. The $D_i^h(z,Q^2)$ are normalized so that

$$\sum_{h} \int z D_i^h (z, Q^2) dz = 1.$$
 (36.28)

If the contributions of the Z boson and three-jet events are neglected, the cross section for producing a hadron h in e^+e^- annihilation is given by

$$\frac{1}{\sigma_{\rm had}} \frac{d\sigma}{dz} = \frac{\sum_{i} e_{i}^{2} D_{i}^{h} (z, Q^{2})}{\sum_{i} e_{i}^{2}} , \qquad (36.29)$$

where e_i is the charge of quark-type i, $\sigma_{\rm had}$ is the total hadronic cross section, and the momentum of the hadron is $zE_{\rm cm}/2$.

In the case of deep inelastic muon scattering, the cross section for producing a hadron of energy E_h is given by

$$\frac{1}{\sigma_{\rm tot}} \frac{d\sigma}{dz} = \frac{\sum_{i} e_{i}^{2} q_{i}(x, Q^{2}) D_{i}^{h}(z, Q^{2})}{\sum_{i} e_{i}^{2} q_{i}(x, Q^{2})} , \qquad (36.30)$$

where $E_h = \nu z$. (For the kinematics of deep inelastic scattering, see Sec. 35.4.2 of the Kinematics section of this *Review*.) The fragmentation functions for light and heavy quarks have a different z dependence; the former peak near z=0. They are illustrated in Figs. 37.1 and 37.2 in the section on "Heavy Quark Fragmentation in e^+e^- Annihilation" (Sec. 37 of this *Review*).

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37. HEAVY-QUARK FRAGMENTATION IN e^+e^- ANNIHILATION

Written January 1998 by D. Besson (University of Kansas).

Measurement of the fragmentation functions of heavy quarks provides information about non-perturbative particle production in a variety of experimental environments. The CDF observation of high p_T $J/\psi(1S)$ production rates far in excess of the extant theoretical predictions prompted the development of the color octet model $(e.g.,\ p\overline{p}\to gg\to \chi_c\to \psi+{\rm X})$ and highlighted the role of gluon fragmentation in charmonium production. Recent results from both LEP and HERA have also helped elucidate the gluonic contribution to charmed meson production. Current estimates from LEP are that gluon fragmentation accounts for approximately half of the D^* production in the lowest momentum region (the lowest quarter of the allowed kinematic region).

Many functional forms have been suggested to describe these momentum spectra for heavy quarks produced in e^+e^- annihilations. The functional form given by Peterson et al. [1] in terms of just one free parameter ϵ_P has found widespread use; other parameterizations are also given in the literature [2]. The earliest Peterson form was a function of one variable z, defined for a heavy-quark Q, light-quark \overline{q} system as the ratio of the energy plus the longitudinal momentum of the hadron $Q\overline{q}$ to the sum of the energy and momentum of the heavy quark after accounting for initial state radiation, gluon bremsstrahlung, and final state radiation: $z = (E + p_{\parallel})_{Q\overline{q}}/(E + p_{Q})$. The main advantage of this variable is that it is relativistically invariant with respect to boosts in the direction of the primary quark. Unfortunately, as this quantity is not directly accessible, experiments typically use other scaling variables which are close approximations to z—either $x^+ = (p_{||} + E)_{hadron}/(p_{||} + E)_{max}$, $x_p = p/p_{max}$, or $x_E = E_{\rm hadron}/E_{\rm beam}$

The Peterson functional form is:

$$\frac{dN}{dz} = \frac{1}{z[1 - (1/z) - \epsilon_P/(1-z)]^2}$$
(37.1)

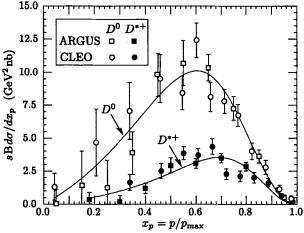


Figure 37.1: Efficiency-corrected inclusive cross section measurements for the production of D^0 and D^{*+} in e^+e^- measurements at $\sqrt{s}\approx 10$ GeV. The variable x_p is related to the Peterson variable z, but is not identical to it.

The bulk of the available fragmentation function data on charmed mesons (excluding $J/\psi(1S)$) is from measurements at $\sqrt{s}=10$ GeV. Shown in Fig. 37.1 are the efficiency-corrected (but not branching ratio corrected) CLEO [3] and ARGUS [4] inclusive cross sections $(s\cdot Bd\sigma/dx_p)$ in units of GeV²-nb, with $x_p=p/p_{\rm max}$) for the production of pseudoscalar D^0 and vector D^{*+} in e^+e^- annihilations at $\sqrt{s}\approx 10$ GeV. For the D^0 , B represents the branching fraction for $D^0\to K^-\pi^+$; for the D^{*+} , B represents the product branching fraction: $D^{*+}\to D^0\pi^+$; $D^0\to K^-\pi^+$. These inclusive spectra have not been corrected for cascades from higher states, nor for radiative effects. Note that since the momentum spectra are sensitive to

radiative corrections, comparison of charm spectra at $\sqrt{s}=10$ GeV cannot be compared directly with spectra at higher center-of-mass energies, and must be appropriately evolved.

Fits to the combined CLEO and ARGUS D^0 and D^{*+} data give $\epsilon_P(D^0)=0.135\pm0.01$ and $\epsilon_P(D^*)=0.078\pm0.008$; these are indicated in the solid curves. Measurement of the fragmentation functions for a variety of particles has allowed comparisons between mesons and baryons, and particles of different spin structure, as shown in Table 37.1

Table 37.1: The Peterson momentum hardness parameter ϵ_P as obtained from $e^+e^- \rightarrow (\text{particle}) + X$ measurements.

Particle	L	\sqrt{s}	ϵ_P	Reference
D^0	0	10 GeV	0.135 ± 0.01	[3]
D^{*+}	0	10 GeV	0.078 ± 0.008	[3]
D_s^*	0	10 GeV	$0.04^{+0.03}_{-0.01}$	[5]
$D_1^0(2420)$	1	10 GeV	$0.034^{+0.018}_{-0.012}$	[6]
$D_2^0(2460)$	1	10 GeV	0.015 ± 0.004	[6]
$D_1^+(2420)$	1	10 GeV	$0.020^{+0.011}_{-0.006}$	[7]
$D_2^+(2460)$	1	10 GeV	0.013 ± 0.007	[7]
$D_{s1}(2536)$	1	10 GeV	$0.06^{+0.035}_{-0.03}$	[8]
$D_{s2}(2573)$	1	10 GeV	$0.027^{+0.043}_{-0.016}$	[9]
Λ_c	0	10 GeV	0.25 ± 0.03	[10,11]
$arvarepsilon_c$	0	10 GeV	0.23 ± 0.05	[12,13]
Σ_c	0	10 GeV	0.29 ± 0.06	[14,15]
\varSigma_c^*	0	10 GeV	$0.30^{+0.10}_{-0.07}$	[16]
\mathcal{Z}_{c}^{*+}	0	10 GeV	$0.24^{+0.22}_{-0.10}$	[17]
\varXi_c^{*0}	0	10 GeV	$0.22^{+0.15}_{-0.08}$	[18]
$\overline{\Lambda_{c,1}}$	1	10 GeV	0.059 ± 0.028	[19,20]
$A_{c,2}$	1	10 GeV	0.053 ± 0.012	[19,21]
$arphi_{c,2}$	1	10 GeV	$0.058^{+0.037}_{-0.021}$	[22]
b hadrons	_	90 GeV	$0.0047^{+0.0010}_{-0.0008}$	[23]

We note from Table 37.1 that the mass dependence of ϵ_P is less marked than the dependence on the orbital angular momentum structure of the charmed hadron being measured. Orbitally excited L=1 charmed hadrons $(D_J, D_{s,J}, \text{and } \Lambda_{c,J})$ show consistently harder spectra (i.e., smaller values of ϵ_P) than the L=0 ground states, whereas the data for the ground state charmed baryons Λ_c and Ξ_c show agreement with the lighter (by ≈ 400 –600 MeV) ground-state D and D_s charmed mesons. To some extent, the harder spectra of L=1 hadrons can be attributed to the fact that all the L=1 charmed hadrons will eventually decay into L=0 hadrons.

Bottom-flavored hadrons at LEP have been measured to have an even harder momentum spectrum than charmed hadrons at lower energies [23-25]. Qualitatively, whereas charm spectra peak at $x_p \approx 0.6$, the spectra of bottom hadrons peak at $x_p \approx 0.8$. This is as expected in the Peterson model, where the value ϵ_P is expected to vary as the ratio of the effective light quark mass to the heavy quark mass in a heavy quark + light (di)quark hadron. In the case of charm, the Peterson functional form provides an acceptable description of the shape of the x_p distribution, provided the appropriate ϵ_P value is independently determined for each separate species of charmed particle. However, unlike charm, the numbers of fully reconstructed b-flavored hadrons is too small to allow a statistically compelling measure of ϵ_P for each separate bottom hadron. Consequently, a b-enriched sample is isolated kinematically, using, e.g., a high p_T lepton and/or a displaced vertex to tag a primary b quark. The x_p distribution therefore includes all b-flavored hadrons in the sample, and does not yet allow a straightforward species-by-species ϵ_P extraction. Additional uncertainties in the case of bottom arise from the sensitivity of ϵ_P to the fragmentation model used to non-perturbatively evolve the initial $q\overline{q}$ system into final state hadrons.

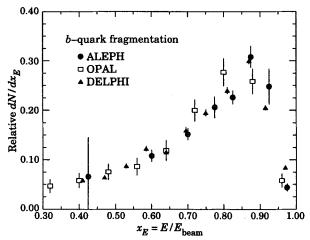


Figure 37.2: Fractional energy distribution for b-quark fragmentation for inclusive b production at LEP.

In general, the b-quark fragmentation function distribution is found to be somewhat narrower than the shape of the Peterson function; this may be due to a systematic underestimate of soft gluon emission in event generators, and/or uncertainties in the appropriate mix of b-flavored hadrons. The match of a single Peterson function to data is therefore much more difficult for bottom than charm at this time, although there is relatively good agreement from experiment to experiment, as seen in Fig. 37.2, which displays the fragmentation function data from OPAL [23], ALEPH [24], and DELPHI [25].

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38. PLOTS OF CROSS SECTIONS AND RELATED QUANTITIES

NOTE: THE FIGURES IN THIS SECTION ARE INTENDED TO SHOW THE REPRESENTATIVE DATA.
THEY ARE NOT MEANT TO BE COMPLETE COMPILATIONS OF ALL THE WORLD'S RELIABLE DATA.

Structure Functions

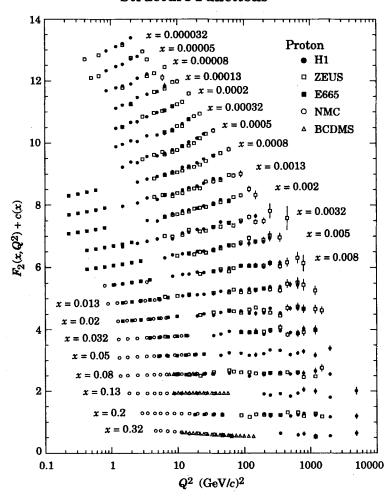


Figure 38.1: The proton structure function F_2^p measured in electromagnetic scattering of electrons (H1, ZEUS) and muons (BCDMS, E665, NMC), in the kinematic domain of the HERA data, for x > 0.00003; cf. Fig. 38.2 for data at smaller x. Only statistical errors are shown. The data are plotted as a function of Q^2 in bins of fixed x. The H1 binning in x is used in this plot; the ZEUS, BCDMS, E665 and NMC data are rebinned to the x values of the H1 data using a phenomenological parametrization. For the purpose of plotting, a constant $c(x) = 0.6(i_x - 0.4)$ is added to F_2^p , where i_x is the number of the x bin ranging from $i_x = 1$ (x = 0.32) to $i_x = 21$ (x = 0.000032). References: H1—S. Aid et al., Nucl. Phys. B470, 3 (1996); C. Adloff et al., Nucl. Phys. B497, 3 (1997); ZEUS—M. Derrick et al., Z. Phys. C72, 399 (1996); J. Breitweg et al., Phys. Lett. B407, 432 (1997); BCDMS—A.C. Benvenuti et al., Phys. Lett. B223, 485 (1989); E665—M.R. Adams et al., Phys. Rev. D54, 3006 (1996); NMC—M. Arneodo et al., Phys. Lett. B364, 107 (1995). (Courtesy of R. Voss, 1997.)

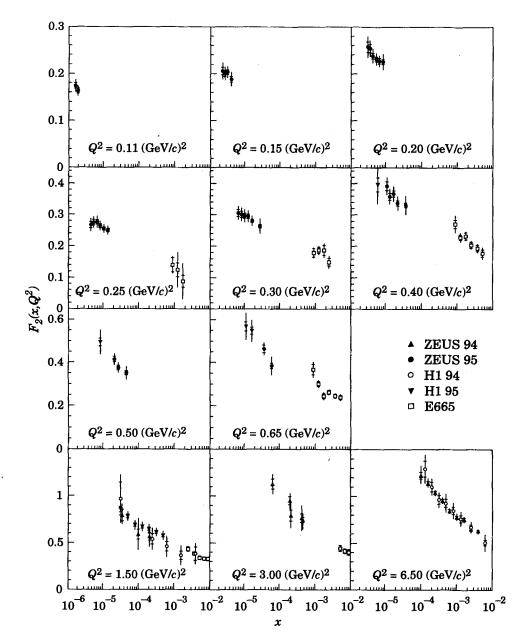


Figure 38.2: The proton structure function F_2^p at small x and Q^2 , measured in electromagnetic scattering of electrons (H1, ZEUS) and muons (E665). The data are plotted as a function of x in bins of fixed Q^2 . References: **ZEUS 94**—M. Derrick *et al.*, Z. Phys. **C72**, 399 (1996); **ZEUS 95**—J. Breitweg *et al.*, Phys. Lett. **B407**, 432 (1997); **H1 94**—S. Aid *et al.*, Nucl. Phys. **B470**, 3 (1996); **H1 95**—C. Adloff *et al.*, Nucl. Phys. **B497**, 3 (1997); **E665**—M.R. Adams *et al.*, Phys. Rev. **D54**, 3006 (1996). (Courtesy of R. Voss, 1997.)

Structure Functions

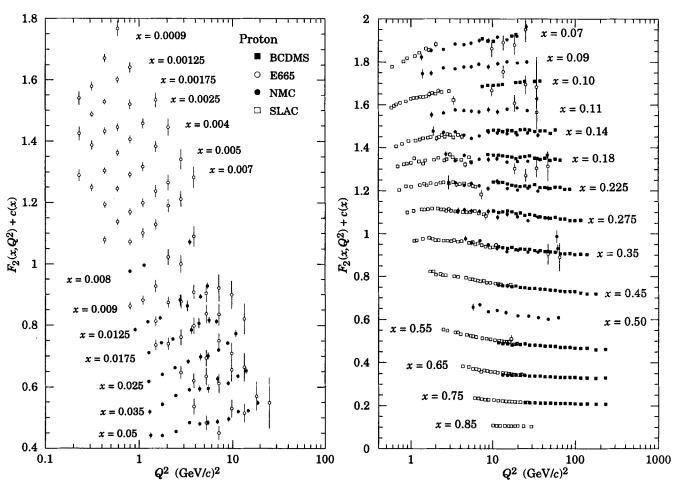


Figure 38.3: The proton structure function F_2^p measured in electromagnetic scattering of electrons (SLAC) and muons (BCDMS, E665, NMC), shown as a function of Q^2 for bins of fixed x. Only statistical errors are shown. For the purpose of plotting, a constant $c(x) = 0.1i_x$ is added to F_2^p where i_x is the number of the x bin, ranging from 1 (x = 0.05) to 14 (x = 0.0009) on the left-hand figure, and from 1 (x = 0.85) to 15 (x = 0.07) on the right-hand figure. For HERA data in the kinematic range of this figure, see Fig. 38.1. References: BCDMS—A.C. Benvenuti et al., Phys. Lett. B223, 485 (1989); E665—M.R. Adams et al., Phys. Rev. D54, 3006 (1996); NMC—M. Arneodo et al., Phys. Lett. B364, 107 (1995). SLAC—L.W. Whitlow et al., Phys. Lett. B282, 475 (1992). (Courtesy of R. Voss, 1996.)

Structure Functions

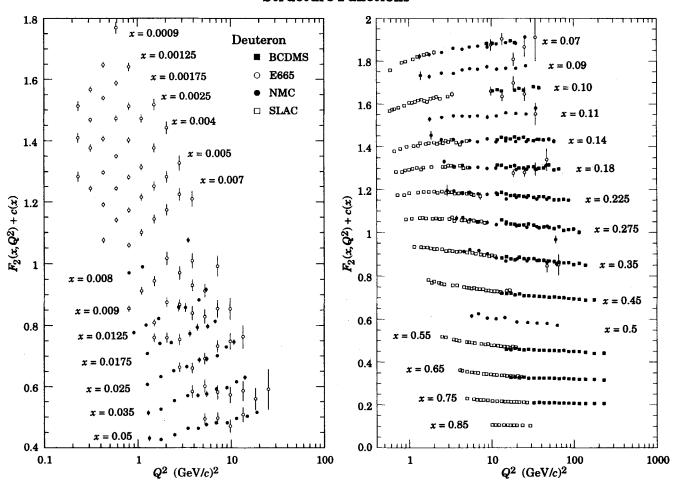


Figure 38.4: As Fig. 38.3, for the deuteron structure function F_2^d . References: BCDMS—A.C. Benvenuti *et al.*, Phys. Lett. B237, 592 (1990). E665, NMC, SLAC—same references as Fig. 38.3. (Courtesy of R. Voss, 1996.)

Structure Functions

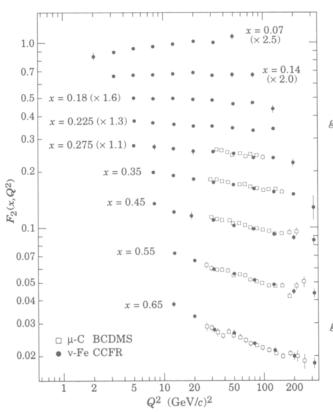


Figure 38.5: The nucleon structure function F_2 measured in deep inelastic scattering of muons on carbon (BCDMS) and neutrinos on iron (CCFR). The data are shown versus Q^2 , for bins of fixed x, and have been scaled by the factors shown in parentheses. References: BCDMS—A.C. Benvenuti et al., Phys. Lett. B195, 91 (1987); CCFR—S.R. Mishra et al., NEVIS-1465 (1992). (Courtesy of R. Voss, 1996.)

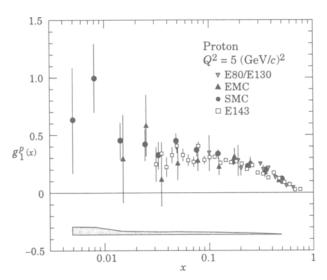


Figure 38.6: The spin-dependent structure function $g_1(x)$ of the proton measured in deep inelastic scattering of polarized electrons (E80, E130, E143) and muons (EMC, SMC), shown at $Q^2 = 5 \, GeV^2$. Only statistical errors are shown with the data points. As an example, the SMC systematic error is indicated by the shaded

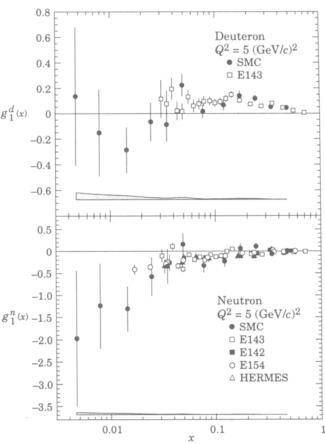


Figure 38.7: The spin-dependent structure function $g_1(x)$ of the deuteron (top) and the neutron (bottom) measured in deep inelastic scattering of polarized electrons (E142, E143, E154, HERMES) and muons (SMC). The SMC and E143 results for the neutron are evaluated from the difference of deuteron and proton data; the E142, E154, and HERMES results were obtained with polarized ³He targets. Only statistical errors are shown with the data points. As an example, the SMC systematic error is indicated by the shaded area. All results except the HERMES data are shown at $Q^2 = 5$ GeV²; the HERMES results are shown at the average Q^2 of the respective data point which varies from $Q^2 = 1.22$ GeV² at x = 0.033 to $Q^2 = 5.25$ GeV² at x = 0.464. References: E142—P.L. Anthony et al., Phys. Rev. Lett. 71, 959 (1993); E143-K. Abe et al., Phys. Rev. Lett. 75, 25 (1995); E154-K. Abe et al., Phys. Lett. B405, 180 (1997) and hep-ph/9705344 v2 (1997); HERMES-K. Ackerstaff et al., Phys. Lett. B404, 383 (1997); SMC-D. Adams et al., Phys. Lett. **B396**, 338 (1997). (Courtesy of R. Voss, 1997.)

area. References: **E80**—M.J. Alguard *et al.*, Phys. Rev. Lett. **37**, 1261 (1976); ibid. **41**, 70 (1978); **E130**—G. Baum *et al.*, Phys. Rev. Lett. **51**, 1135 (1983); **E143**—K. Abe *et al.*, Phys. Rev. Lett. **74**, 346 (1995); **EMC**—J. Ashman *et al.*, Nucl. Phys. **B328**, 1 (1989); **SMC**—B. Adeva *et al.*, Phys. Lett. **B412**, 414 (1997). In this plot, the E80, E130 and EMC data have been reevaluated using up-to-date parametrizations of F_2^p and $R = \sigma_L/\sigma_T$. (Courtesy of R. Voss, 1997.)

Jet Production in pp and $\bar{p}p$ Interactions

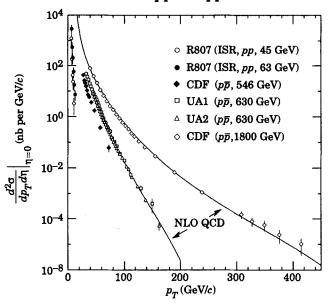


Figure 38.8: Differential cross sections for observation of a single jet of pseudorapidity $\eta=0$ as a function of the jet transverse momentum. CDF—F. Abe et al., Phys. Rev. Lett. 70, 1376 (1993); UA1—G. Arnison et al., Phys. Lett. B172, 461 (1986); UA2—J. Alitti et al., Phys. Lett. B257, 232 (1991); R807—T. Akesson et al., Phys. Lett. B123, 133 (1983). Next-to-leading order QCD curves are shown for 630 GeV and 1800 GeV. (Courtesy of S. Geer, FNAL, 1995.)

Direct γ Production in $\overline{p}p$ Interactions

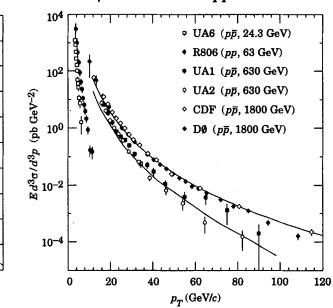


Figure 38.9: Differential cross sections for observation of a single photon of pseudorapidity $\eta=0$ as a function of the photon transverse momentum R806—E. Anassontzis et al., Z. Phys. C13, 277 (1982); UA6—A. Bernasconi et al., Phys. Lett. B206, 163 (1988); UA1—C. Albajar et al., Phys. Lett. B209, 385 (1988); UA2—J. Alitti et al., Phys. Lett. B288, 386 (1992); CDF—F. Abe et al., Phys. Rev. Lett. 73, 2662 (1994); \mathcal{DO} —S. Abachi et al., Phys. Rev. Lett. 77, 5011 (1996). Next-to-leading order QCD curves are shown for 630 GeV and 1800 GeV. (Courtesy of S. Geer, FNAL, 1995.)

Pseudorapidity Distributions in $\bar{p}p$ Interactions

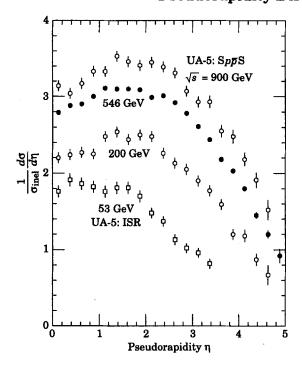


Figure 38.10: Charge particle pseudorapidity distributions in $p\bar{p}$ collisions for 53 GeV $\leq \sqrt{s} \leq$ 900 GeV. The number per pseudorapidity interval is about 10% higher if the rate is normalized excluding singly diffractive events rather than to the total inelastic rate. $Sp\bar{p}S$ data are from G.J. Alner et al., Z. Phys. C33, 1 (1986), and ISR data are from K. Alpgård et al., Phys. Lett. 112B, 193 (1982). CDF nonsingle-diffractive results at $\sqrt{s}=630$ and 1800 GeV are given in F. Abe et al., Phys. Rev. D41, 2330 (1990). (Courtesy of D.R. Ward, Cambridge Univ., 1991.)

Average Hadron Multiplicities in Hadronic e^+e^- Annihilation Events

Table 38.1: Average hadronic multiplicities per hadronic e^+e^- annihilation event at $\sqrt{s}\approx 10$, 29–35, and 91 GeV. The rates given include decay products from resonances with $c\tau<10$ cm, and include charge conjugated states. (Updated September 1997 by O. Biebel.)

Particle	$\sqrt{s} \approx$	10 GeV	$\sqrt{s} =$	29–35 GeV	\sqrt{s}	= 91 GeV
Pseudoscala						
π^+	6.6	± 0.2	10.3	± 0.4	17.1	± 0.4
π^0	3.2	± 0.3	5.83	± 0.28	9.42	± 0.56
K+	0.90	± 0.04	1.48	± 0.09	2.39	± 0.12
K^0	0.91	± 0.05	1.48	± 0.07	2.013	± 0.033
η	0.20	± 0.04	0.61	± 0.07	0.97	± 0.10
$\eta \prime (958)$	0.03	± 0.01	0.26	± 0.10	0.222	± 0.040
D^+	0.16	± 0.03	0.17	± 0.03	0.175	± 0.016
D^0	0.37	± 0.06	0.45	± 0.07	0.454	± 0.030
D_s^+	0.13	± 0.02	0.45	$\pm 0.20^{(a)}$	0.131	± 0.021
B^+, B_d^0		_		_	0.165	$\pm 0.026^{(b)}$
B_s^0					0.057	$\pm 0.013^{(b)}$
Scalar meso $f_0(980)$	ns: 0.024	± 0.006	0.05	$\pm~0.02^{(c)}$	0.14	$\pm 0.06^{(d)}$
Vector meso			0.01			
$\rho(770)^{0}$	0.35	± 0.04	0.81	± 0.08	1.28	± 0.14
$\omega(782)$	0.30	± 0.08			1.10	± 0.13
$K^*(892)^+$	0.27	± 0.03	0.64	± 0.05	0.715	± 0.059
$K^*(892)^0$	0.29	± 0.03	0.56	± 0.06	0.747	± 0.028
$\phi(1020)$	0.044	± 0.003	0.085	± 0.011	0.109	± 0.007
$D^*(2010)^+$	0.22	± 0.04	0.43	± 0.07	0.183	± 0.010
$D^*(2007)^0$	0.23	± 0.06	0.27	± 0.11		_
B^{*} $^{(e)}$				_	0.288	± 0.026
$J/\psi(1S)$		_		· 		$\pm 0.0004^{(f)}$
$\psi(2S)$		-				$\pm 0.0004^{(f)}$
$\Upsilon(1S)$		_			0.00014	4 ± 0.00007 (.
Pseudovecto $\chi_{c1}(1P)$	or meso	ons:	-		0.0041	$\pm 0.0011^{(f)}$
Tensor meso	ons:					
$f_2(1270)$	0.09	± 0.02	0.14	± 0.04	0.31	± 0.12
$f_2'(1525)$		_		_	0.020	± 0.008
$K_2^*(1430)^+$		_	0.09	± 0.03		
$K_2^*(1430)^0$		_	0.12	± 0.06	0.19	$\pm~0.07^{(g)}$
B** (h)				_	0.118	± 0.024
Baryons:		_				
p	0.253	± 0.016	0.640	± 0.050	0.964	± 0.102
Λ	0.080	± 0.007	0.205	$\pm \ 0.010$	0.372	± 0.009
$oldsymbol{arSigma^0}$	0.023	± 0.008		_	0.070	$\pm \ 0.012$
Σ^-		_			0.071	± 0.018
$arSigma^+$		_			0.099	± 0.015
$arSigma^\pm$				_	0.174	± 0.009
Ξ -	0.0059	± 0.0007	0.0176	$\pm~0.0027$	0.0258	$\pm~0.0010$
$\Delta(1232)^{++}$	0.040	± 0.010		_	0.085	± 0.014
$\Sigma(1385)^-$	0.006	± 0.002	0.017	± 0.004	0.0240	± 0.0017
$\Sigma(1385)^+$	0.005	± 0.001	0.017	± 0.004	0.0239	$\pm~0.0015$
$\Sigma(1385)^{\pm}$	0.0106	$\pm~0.0020$	0.033	± 0.008	0.0462	$\pm~0.0028$
$\Xi(1530)^0$	0.0015	± 0.0006			0.0055	± 0.0005
n- ´	0.0007		0.014	± 0.007	0.0016	± 0.0003
Λ_c^+	0.100	$\pm 0.030^{(i)}$		± 0.050	0.078	± 0.017
Λ_b^0		_		_	0.031	± 0.016
$\Sigma_c^{++}, \Sigma_c^0$	0.014	± 0.007			J.001	
$\Lambda(1520)$	0.008	± 0.007 ± 0.002		_		
11(1040)	0.000	⊥ 0.002		_		

- (a) $B(D_s \to \eta \pi, \eta' \pi)$ has been used (RPP 1994).
- (b) The Standard Model $B(Z \to b\bar{b}) = 0.217$ was used.
- (c) $x_p = p/p_{\text{beam}} > 0.1$ only.
- (d) Extrapolation to the unobserved region using the shape predicted by JETSET.
- (e) Any charge state (i.e., B_d^* , B_u^* , or B_s^*).
- (f) $B(Z \rightarrow hadrons) = 0.699$ has been used (RPP 1994).
- (g) $x_E = E[K_2^*(1430)^0]/E_{\text{beam}} < 0.3 \text{ only.}$
- (h) Any charge state (i.e., B_d^{**} , B_u^{**} , or B_s^{**}).
- (i) The value was taken from the cross section of the $\Lambda_c^+ \to p\pi K$, assuming the branching fraction to be $(3.2 \pm 0.7)\%$ (RPP 1992).

References:

RPP92: Phys. Rev. D45 (1992) and references therein

RPP94: Phys. Rev. D50, 1173 (1994) and references therein

 $\boldsymbol{RPP96}:\ Phys.\ Rev.\ \boldsymbol{D54},\ 1\ (1996)$ and references therein

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Phys. Rep. 276, 223 (1996)

CELLO: H.J. Behrend et al.: Z. Phys. C46, 397 (1990); Z. Phys. C47, 1 (1990)

CLEO: D. Bortoletto et al., Phys. Rev. D37, 1719 (1988)

Crystal Ball: Ch. Bieler et al., Z. Phys. C49, 225 (1991)

DELPHI: P. Abreu et al.: Z. Phys. C57, 181 (1993); Z. Phys. C59, 533 (1993); Z. Phys. C61, 407 (1994); Phys. Lett. B341, 109 (1994); Phys. Lett. B345, 598 (1995); Z. Phys. C65, 587 (1995); Nucl. Phys. B444, 3 (1995); Phys. Lett. B361, 207 (1995); Z. Phys. C67, 543 (1995); Z. Phys. C68, 353 (1995); Phys. Lett. B372, 172 (1996); Phys. Lett. B379, 309 (1996); Z. Phys. C, CERN-PPE/97-108; and W. Adam et al.: Z. Phys. C69, 561 (1996); Z. Phys. C70, 371 (1996)

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L3: M. Acciarri et al.: Phys. Lett. B328, 223 (1994); Phys. Lett. B345, 589 (1995); Phys. Lett. B371, 126 (1996); Phys. Lett. B371, 137 (1996); Phys. Lett. B393, 465 (1997); Phys. Lett. B404, 390 (1997); Phys. Lett. B407, 351 (1997); Phys. Lett. B407, 389 (1997)

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TASSO: H. Aihara et al., Z. Phys. C27, 27 (1985)

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Fragmentation in e^+e^- Annihilation

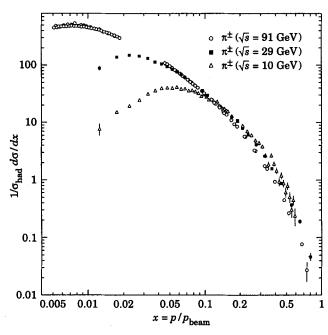
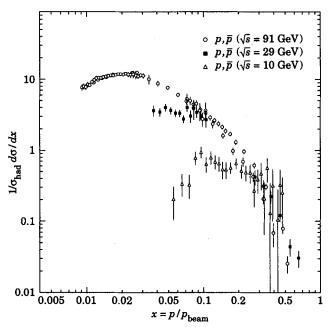


Figure 38.11: Fragmentation into π^{\pm} in e^+e^- annihilations: Inclusive cross sections $(1/\sigma_{\rm had})(d\sigma/dx)$, with $x=p/p_{\rm beam}$. The indicated errors are statistical and systematic errors added in quadrature.

 \triangle : rate at $\sqrt{s} = 9.98$ GeV; an overall uncertainty of 1.8%: **ARGUS**—H. Albrecht et al., Z. Phys. C44, 547 (1989).

\blacksquare: rate at $\sqrt{s} = 29$ GeV **TPC**—H. Aihara *et al.*, Phys. Rev. Lett. **61**, 1263 (1988).

 \bigcirc : rate for hadronic decays of the Z at $\sqrt{s} = 91.2$ GeV **ALEPH**—D. Buskulic *et al.*, Z. Phys. C66, 355 (1995); **OPAL**—R. Akers *et al.*, Z. Phys. C63, 181 (1994). (Courtesy of O. Biebel, S. Bethke, and D. Lanske, RWTH, Aachen, 1995.)



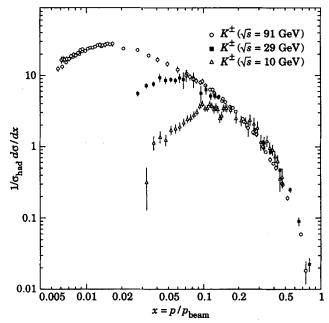


Figure 38.12: Fragmentation into K^{\pm} in e^+e^- annihilations: Inclusive cross sections $(1/\sigma_{\rm had})(d\sigma/dx)$, with $x=p/p_{\rm beam}$. The indicated errors are statistical and systematic errors added in quadrature.

 \triangle : rate at $\sqrt{s} = 9.98$ GeV; an overall uncertainty of 1.8%: **ARGUS**—H. Albrecht *et al.*, Z. Phys. C44, 547 (1989).

E: rate at $\sqrt{s} = 29$ GeV **TPC**—H. Aihara *et al.*, Phys. Rev. Lett. **61**, 1263 (1988).

 \bigcirc : rate for hadronic decays of the Z at $\sqrt{s} = 91.2$ GeV ALEPH—D. Buskulic et al., Z. Phys. C66, 355 (1995); DELPHI—P. Abreu et al., Nucl. Phys. B444, 3 (1995); OPAL—R. Akers et al., Z. Phys. C63, 181 (1994). (Courtesy of O. Biebel, S. Bethke, and D. Lanske, RWTH, Aachen, 1995.)

Figure 38.13: Fragmentation into $p\overline{p}$ in e^+e^- annihilations: Inclusive cross sections $(1/\sigma_{\rm had})(d\sigma/dx)$, with $x=p/p_{\rm beam}$. The indicated errors are statistical and systematic errors added in quadrature

 \triangle : rate at $\sqrt{s} = 9.98$ GeV; an overall uncertainty of 1.8%. This rate is obtained from the measured \bar{p} rate by scaling with a factor of two: **ARGUS**—H. Albrecht *et al.*, Z. Phys. C44, 547 (1989).

■: rate at $\sqrt{s} = 29$ GeV: **TPC**—H. Aihara *et al.*, Phys. Rev. Lett. **61**, 1263 (1988).

O: rate for hadronic decays of the Z at $\sqrt{s} = 91.2$ GeV: **ALEPH**—D. Buskulic et al., Z. Phys. C66, 355 (1995). **DELPHI**—P. Abreu et al., Nucl. Phys. **B444**, 3 (1995). **OPAL**—R. Akers et al., Z. Phys. C63, 181 (1994). (Courtesy of O. Biebel, S. Bethke, and D. Lanske, RWTH, Aachen, 1995.)

Annihilation Cross Section Near M_Z

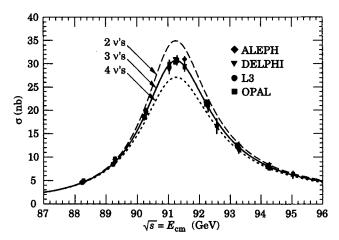


Figure 38.14: Data from the ALEPH, DELPHI, L3, and OPAL Collaborations for the cross section in e^+e^- annihilation into hadronic final states as a function of c.m. energy near the Z. LEP detectors obtained data at the same energies; some of the points are obscured by overlap. The curves show the predictions of the Standard Model with three species (solid curve) and four species (dashed curve) of light neutrinos. The asymmetry of the curves is produced by initial-state radiation. References:

ALEPH: D. Decamp et al., Z. Phys. C53, 1 (1992). **DEPHI**: P. Abreu et al., Nucl. Phys. **B367**, 511 (1992). **L3**: B. Adeva et al., Z. Phys. C51, 179 (1991). **OPAL**: G. Alexander et al., Z. Phys. C52, 175 (1991).

Average e^+e^- , pp, and $\overline{p}p$ Multiplicity

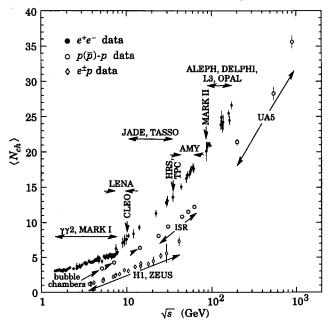


Figure 38.15: Average multiplicity as a function of \sqrt{s} for e^+e^- and $p\bar{p}$ annihilations, and pp and ep collisions. The indicated errors are statistical and systematic errors added in quadrature, except when no systematic errors are given. Files of the data shown in this figure are given in http://wwwinfo.cern.ch/b/biebel/www/RPP98/.

 e^+e^- : All e^+e^- measurements include contributions from K_s^0 and Λ decays with the exception of the L3 measurements. The $\gamma\gamma2$ and MARK I measurements contain a systematic 5% error. The five points at the Z resonance have been spread horizontally for clarity: **OPAL**: P.D. Acton et al., Z. Phys. **C53**, 539 (1992) and references therein, **OPAL**: R. Akers et al., Z. Phys. **C68**, 203 (1995), **ALEPH**: D. Buskulic et al., Z. Phys. **C69**, 15 (1995), **ALEPH**: D. Buskulic et al., Z. Phys. **C73**, 409 (1997), **DELPHI**: P. Abreu et al., Z. Phys. C, CERN-PPE/97-108, **DELPHI**: P. Abreu et al., Phys. Lett. **B372**, 172 (1996), **L3**: M. Acciarri et al., Phys. Lett. **B371**, 137 (1996), **L3**: M. Acciarri et al., Phys. Lett. **B404**, 390 (1997), **OPAL**: K. Ackerstaff et al., Z. Phys. **C75**, 193 (1997).

 $e^{\pm}p$: Multiplicities have been measured in the current fragmentation region of the Breit frame: **H1**: C. Adloff *et al.*, Nucl. Phys. **B**, DESY 97-108, **ZEUS**: M. Derrick *et al.*, Z. Phys. **C67**, 93 (1995).

 $p(\bar{p})$: The errors of the $p(\bar{p})$ measurements are the quadratically added statistical and systematic errors, except for the bubble chamber measurements for which only statistical errors are given in the references. The values measured by UA5 exclude single diffractive dissociation: bubble chamber: J. Benecke *et al.*, Nucl. Phys. B76, 29 (1976), bubble chamber: W.M. Morse *et al.*, Phys. Rev. D15, 66 (1977), ISR: A. Breakstone *et al.*, Phys. Rev. D30, 528 (1984), UA5: G.J. Alner *et al.*, Phys. Lett. B, 476 (1986), UA5: R.E. Ansorge *et al.*, Z. Phys. C43, 357 (1989).

(Courtesy of O. Biebel, RWTH, Aachen, 1997.)

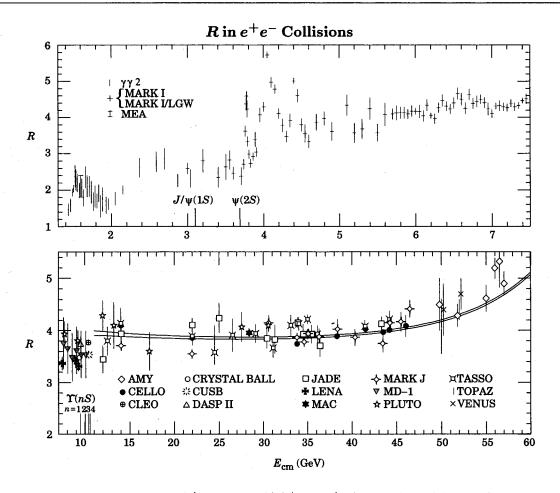


Figure 38.16: Selected measurements of $R \equiv \sigma(e^+e^- \to \text{hadrons})/\sigma(e^+e^- \to \mu^+\mu^-)$, where the annihilation in the numerator proceeds via one photon or via the Z. Measurements in the vicinity of the Z mass are shown in the following figure. The denominator is the calculated QED single-photon process; see the section on Cross-Section Formulae for Specific Processes. Radiative corrections and, where important, corrections for two-photon processes and τ production have been made. Note that the ADONE data $(\gamma\gamma^2)$ and MEA is for ≥ 3 hadrons. The points in the $\psi(3770)$ region are from the MARK I—Lead Glass Wall experiment. To preserve clarity only a representative subset of the available measurements is shown—references to additional data are included below. Also for clarity, some points have been combined or shifted slightly (<4%) in $E_{\rm cm}$, and some points with low statistical significance have been omitted. Systematic normalization errors are not included; they range from $\sim 5-20\%$, depending on experiment. We caution that especially the older experiments tend to have large normalization uncertainties. Note the suppressed zero. The horizontal extent of the plot symbols has no significance. The positions of the $J/\psi(1S)$, $\psi(2S)$, and the four lowest T vector-meson resonances are indicated. Two curves are overlaid for $E_{\rm cm} > 11$ GeV, showing the theoretical prediction for R, including higher order QCD [M. Dine and J. Sapirstein, Phys. Rev. Lett. 43, 668 (1979)] and electroweak corrections. The Λ values are for 5 flavors in the $\overline{\rm MS}$ scheme and are $\Lambda_{\rm MS}^{(5)} = 60$ MeV (lower curve) and $\Lambda_{\rm MS}^{(5)} = 250$ MeV (upper curve). (Courtesy of F. Porter, 1992.) References (including-several references to data not appearing in the figure and some references to preliminary data):

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CLEO: R. Giles et al., Phys. Rev. D29, 1285 (1984);
  and D. Besson et al., Phys. Rev. Lett. 54, 381 (1985);
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DASP II: Phys. Lett. 116B, 383 (1982);
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DHHM: P. Bock et al. (DESY-Hamburg-Heidelberg-
  MPI München Collab.), Z. Phys. C6, 125 (1980);
\gamma\gamma2: C. Bacci et al., Phys. Lett. 86B, 234 (1979);
HRS: D. Bender et al., Phys. Rev. D31, 1 (1985);
JADE: W. Bartel et al., Phys. Lett. 129B, 145 (1983);
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LENA: B. Niczyporuk et al., Z. Phys. C15, 299 (1982).
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MAC: E. Fernandez et al., Phys. Rev. D31, 1537 (1985);
MARK J: B. Adeva et al., Phys. Rev. Lett. 50, 799 (1983);
  and B. Adeva et al., Phys. Rev. D34, 681 (1986);
MARK I: J.L. Siegrist et al., Phys. Rev. D26, 969 (1982);
MARK I + Lead Glass Wall: P.A. Rapidis et al.,
  Phys. Rev. Lett. 39, 526 (1977); and P.A. Rapidis, thesis,
  SLAC-Report-220 (1979);
MARK II: J. Patrick, Ph.D. thesis, LBL-14585 (1982);
MD-1: A.E. Blinov et al., Z. Phys. C70, 31 (1996);
MEA: B. Esposito et al., Lett. Nuovo Cimento 19, 21 (1977);
PLUTO: A. Bäcker, thesis Gesamthochschule Siegen,
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  and M. Althoff et al., Phys. Lett. 138B, 441 (1984);
TOPAZ: I. Adachi et al., Phys. Rev. Lett. 60, 97 (1988); and
VENUS: H. Yoshida et al., Phys. Lett. 198B, 570 (1987).
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Table 38.2: Total hadronic cross section. Regge theory suggests a parameterization of total cross sections as

$$\begin{split} \sigma_{AB} &= X_{AB} s^{\epsilon} + Y_{1AB} s^{-\eta_1} + Y_{2AB} s^{-\eta_2} \\ \sigma_{\overline{A}B} &= X_{AB} s^{\epsilon} + Y_{1AB} s^{-\eta_1} - Y_{2AB} s^{-\eta_2} \end{split}$$

where X_{AB}, Y_{iAB} are in mb and s is in GeV². The exponents ϵ, η_1 , and η_2 are independent of the particles A, \overline{A} , and B and represent the pomeron, and lower-lying C-even and C-odd exchanges, respectively. Requiring $\eta_1 = \eta_2$ results in much poorer fits. In addition to total cross section, the measured ratio of the real to the imaginary part of the forward scattering amplitude can be included in the fits by assuming that the C-even and C-odd amplitudes have the simple behavior $(-s)^{\alpha} \pm s^{\alpha}$, where $\alpha = 1 + \epsilon, 1 + \eta_1, 1 + \eta_2$. Fits were made to the data for $p^{\pm}p, \pi^{\pm}p, K^{\pm}p, \gamma p$, and $\gamma \gamma$. The exponents $\epsilon = 0.095(2), \eta_1 = 0.34(2)$, and $\eta_2 = 0.55(2)$ thus obtained were then fixed and used as inputs to a fit to a larger data sample that included cross sections on deuterons and neutrons. In the initial fit only data above $\sqrt{s_{\min}} = 12$ GeV were used. In the subsequent fit, data above $p_{\text{lab}} = 10$ GeV (hadronic collisions) and $\sqrt{s_{\min}} = 4$ GeV (γp and $\gamma \gamma$) collisions were used.

Fits to \bar{p}	$(p) p, \pi^{\pm} p, K^{\pm} p$	$, \gamma p, \gamma \gamma$	Colliding]	χ^2/dof		
X	Y_1	Y_1 Y_2 particles		X	Y_1	Y_2	by groups
18.304(28)	60.12(24)	32.84(33)	$\overline{p}(p)p$	18.256(22)	60.19(21)	33.43(31)	
			$ar{p}(p)n$	18.256(22)	61.14(58)	29.80(58)	1.17
11.594(22)	27.52(14)	5.53(11)	$\pi^{\pm}p$	11.568(25)	27.55(15)	5.62(13)	1.65
10.353(28)	15.83(20)	12.98(17)	K [±] p	10.376(23)	15.57(16)	13.19(17)	
			$K^{\pm}n$	10.376(23)	14.29(37)	7.38(37)	1.26
0.0579(4)	0.1170(26)		γp	0.0577(3)	0.1171(17)		
1.56(18)E-4	0.32(13)E-3		77	1.56(11)E-4	0.32(8)E-3		0.75
$\chi^2/dof=1$	$\chi^2/dof = 1.28$ with fixed $\epsilon = 0.095(2)$, $\eta_1 = 0.34(2)$, $\eta_2 = 0.55(2)$ at their			32.357(47)	143.7(7)	85.95(99)	1.57
l '- `				21.015(39)	64.88(51)	1.36(63)	1.91
central valı	ies		$K^{\pm}d$	18.935(40)	35.74(48)	28.80(59)	1.56

The fitted functions are shown in the following figures, along with one-standard-deviation error bands. When the reduced χ^2 is greater than one, a scale factor has been included. Where appropriate, statistical and systematic errors were combined quadratically. Vertical arrows indicate lower limits on the p_{lab} or E_{cm} range used in the fits. The user may decide on the range of applicability of the extrapolated curves. The data were extracted from the PPDS accessible at http://wwwppds.ihep.su:8001/ppds.html or http://pdg.lbl.gov Computer-readable data files are also available at http://pdg.lbl.gov. (Courtesy of V.V. Ezhela, S.B. Lugovsky, and N.P. Tkachenko, COMPAS group, IHEP, Protvino, Russia, April 1998.)

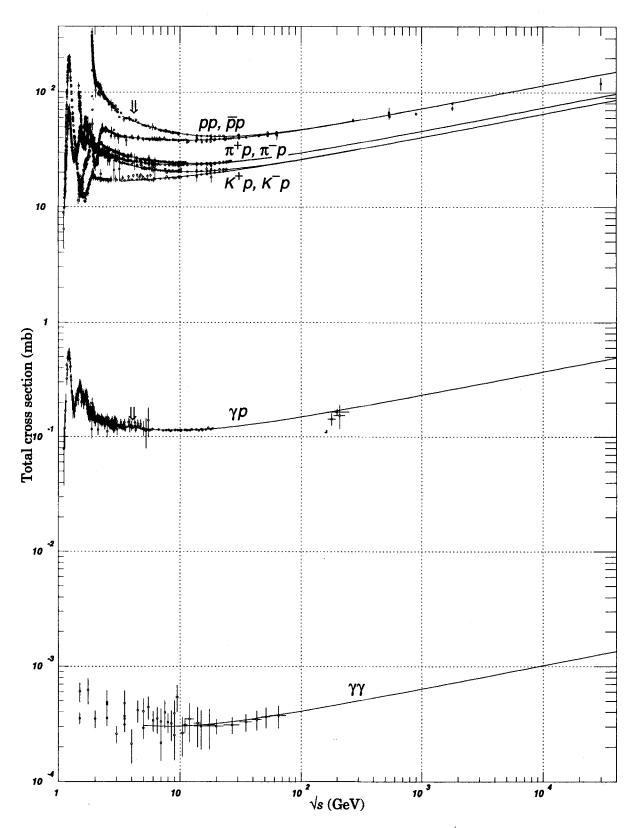


Figure 38.17: Summary of hadronic, γp , and $\gamma \gamma$ total cross sections. Corresponding computer-readable data files may be found at http://pdg.lbl.gov/xsect/contents.html (Courtesy of the COMPAS group, IHEP, Protvino, Russia, April 1998.)

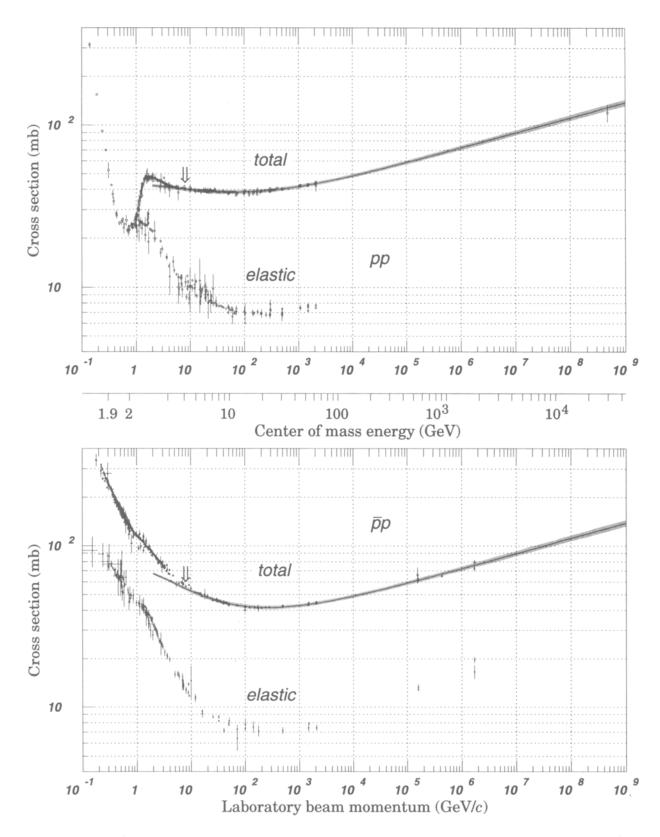


Figure 38.18: Total and elastic cross sections for pp and $\bar{p}p$ collisions as a function of laboratory beam momentum and total center-of-mass energy. Corresponding computer-readable data files may be found at http://pdg.lbl.gov/xsect/contents.html (Courtesy of the COMPAS Group, IHEP, Protvino, Russia, April 1998.)

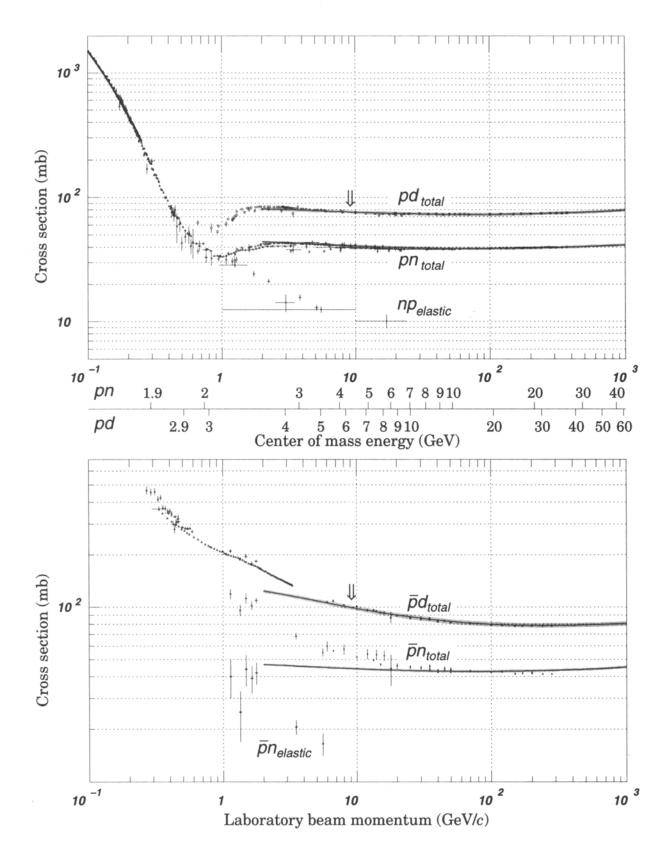


Figure 38.19: Total and elastic cross sections for pd (total only), np, $\bar{p}d$ (total only), and $\bar{p}n$ collisions as a function of laboratory beam momentum and total center-of-mass energy. Corresponding computer-readable data files may be found at http://pdg.lbl.gov/xsect/contents.html (Courtesy of the COMPAS Group, IHEP, Protvino, Russia, April 1998.)

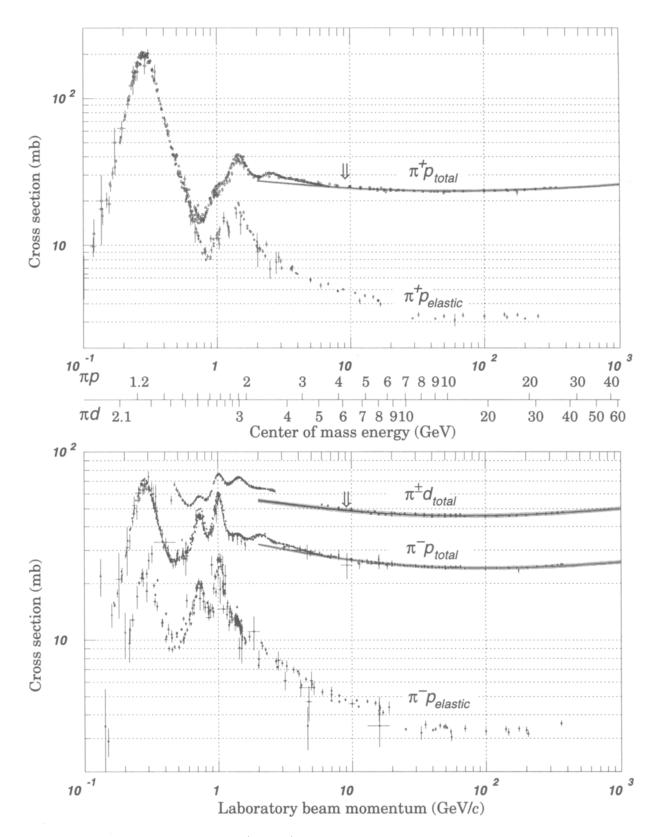


Figure 38.20: Total and elastic cross sections for $\pi^{\pm}p$ and $\pi^{\pm}d$ (total only) collisions as a function of laboratory beam momentum and total center-of-mass energy. Corresponding computer-readable data files may be found at http://pdg.lbl.gov/xsect/contents.html (Courtesy of the COMPAS Group, IHEP, Protvino, Russia, April 1998.)

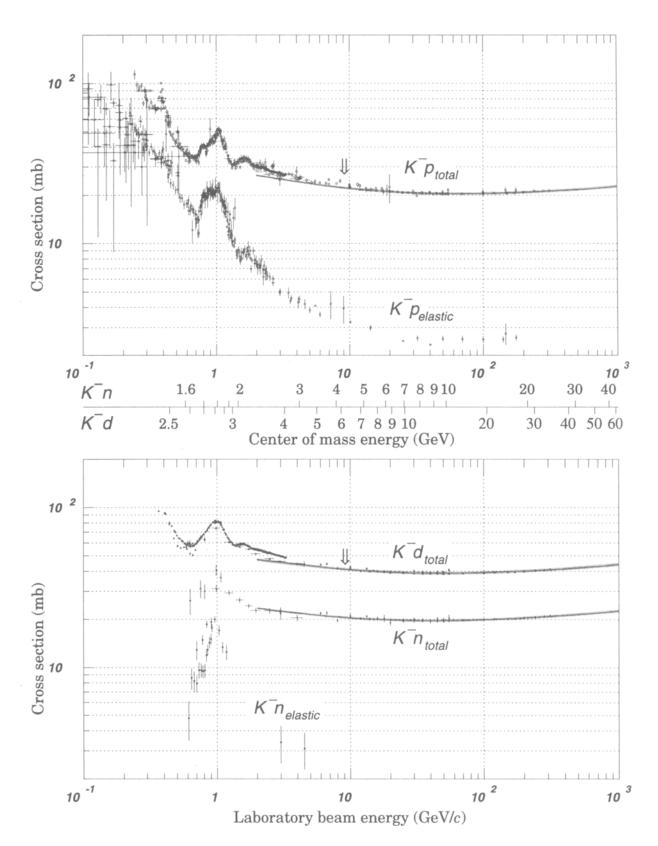


Figure 38.21: Total and elastic cross sections for K^-p and K^-d (total only), and K^-n collisions as a function of laboratory beam momentum and total center-of-mass energy. Corresponding computer-readable data files may be found at http://pdg.lbl.gov/xsect/contents.html (Courtesy of the COMPAS Group, IHEP, Protvino, Russia, April 1998.)

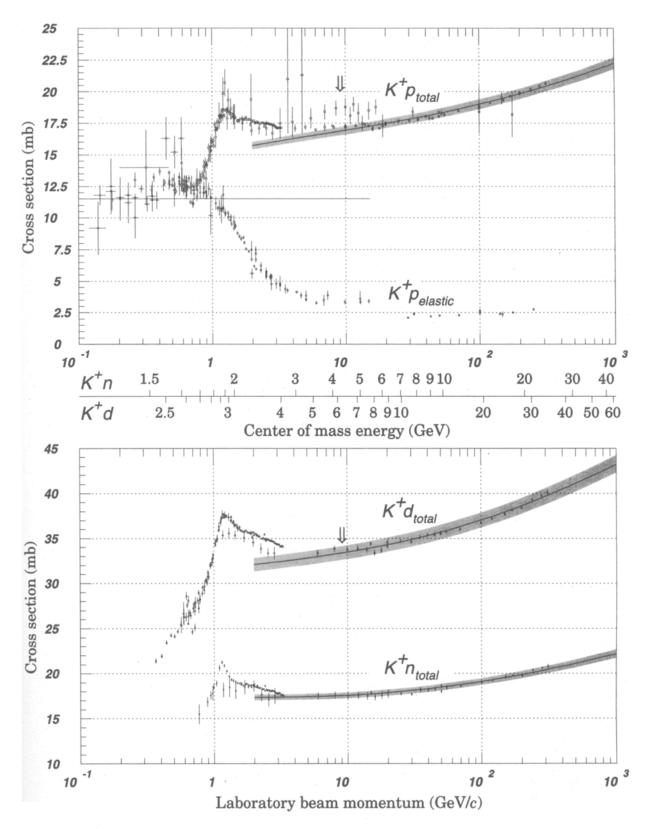


Figure 38.22: Total and elastic cross sections for K^+p and total cross sections for K^+d and K^+n collisions as a function of laboratory beam momentum and total center-of-mass energy. Corresponding computer-readable data files may be found at http://pdg.lbl.gov/xsect/contents.html (Courtesy of the COMPAS Group, IHEP, Protvino, Russia, April 1998.)

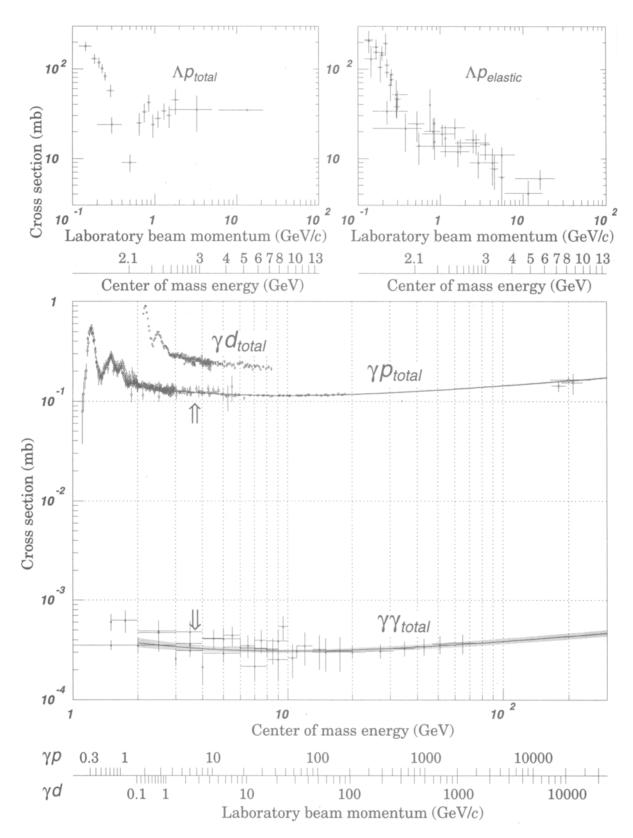
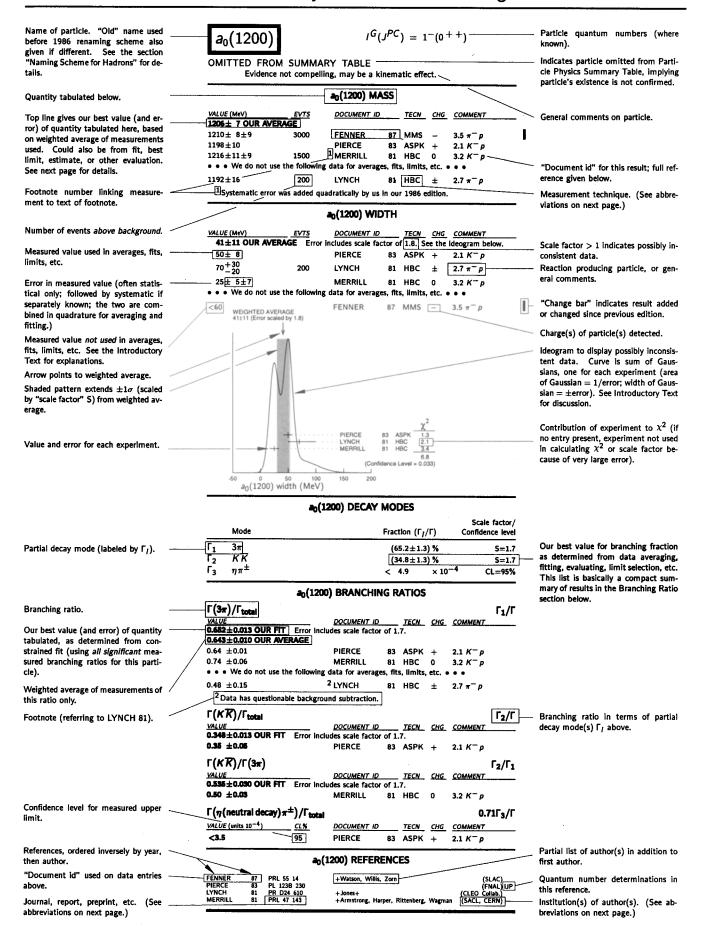


Figure 38.23: Total and elastic cross sections for Λp and total hadronic cross sections for γd , γp , and $\gamma \gamma$ collisions as a function of laboratory beam momentum and the total center-of-mass energy. Corresponding computer-readable data files may be found at http://pdg.lbl.gov/xsect/contents.html (Courtesy of the COMPAS group, IHEP, Protvino, Russia, April 1998.)

INTRODUCTION TO THE PARTICLE LISTINGS

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Illustrative Key to the Particle Listings



Indicat	or of Proc	edure Used to Obtain Our Result	E761	Fermilab E761 detector
OUR AV	ERAGE	From a weighted average of selected data.	E771 E773	Fermilab E771 detector Fermilab E773 Spectrometer-Calorimeter
OUR FIT	1	From a constrained or overdetermined multipa-	E789	Fermilab E789 detector
		rameter fit of selected data.	E791	Fermilab E791 detector
OUR EVA	ALUATION	Not from a direct measurement, but evaluated	E799	Fermilab E799 Spectrometer-Calorimeter
		from measurements of other quantities.	EHS	Four-pi detector at CERN
OUR EST	TIMATE	Based on the observed range of the data. Not	ELEC	Electronic combination
		from a formal statistical procedure.	EMC	European muon collaboration detector at CERN
OUR LIM	ΛIT	For special cases where the limit is evaluated by	EMUL	Emulsions
		us from measured ratios or other data. Not from	FBC	Freon bubble chamber
		a direct measurement.	FIT	Fit to previously existing data
			FMPS	Fermilab Multiparticle Spectrometer
	rement Te		FRAB	ADONE $B\overline{B}$ group detector
(i.e.,	Detectors	and Methods of Analysis)		ADONE $\gamma\gamma$ group detector
OOM .	ACCRACE C			ADONE MEA group detector
	ACCMOR Co		FREJ	FREJUS Collaboration - modular flash chamber detector
	-	tive mass spectrometer		(calorimeter)
		RN LEP detector	GA24	Hodoscope Cherenkov γ calorimeter (IHEP GAMS-2000)
		r at KEK-TRISTAN ctor at DORIS		(CERN GAMS-4000)
			CALY	GALLEX solar neutrino detector in the Gran Sasso Under-
		cular amplitude path on Argand diagram	GALA	ground Lab.
		ngle-photon detector	CAMO	-
		ark chambers		IHEP hodoscope Cherenkov γ calorimeter GAMS-2000
		tector at LEAR		CERN hodoscope Cherenkov γ calorimeter GAMS-4000
	Astronomy		GOLI	•
	BNL experim	ent 787 detector	H1	H1 detector at DESY/HERA
	BNL experim	ent 791 detector	HBC	Hydrogen bubble chamber
845 I	BNL experim	ent 845 detector	HDBC	Hydrogen and deuterium bubble chambers
AKS I	Baksan under	ground scintillation telescope	HEBC	Helium bubble chamber
	Bubble chaml	·	HEPT	
	Beam dump	- 	HLBC	Heavy-liquid bubble chamber
		RICE Collab.	HOME	
		bubble chamber at CERN	HPW	Harvard-Pennsylvania-Wisconsin detector
		Spectrometer at Beijing Electron-Positron Collider		-
		meter at Serpukhov	HRS	SLAC high-resolution spectrometer
			HYBR	Hybrid: bubble chamber + electronics
	-	ctrometer system at KEK Proton Synchroton	IMB	Irvine-Michigan-Brookhaven underground Cherenkov detector
		magnetic detector at DORIS	IMB3	Irvine-Michigan-Brookhaven underground Cherenkov detector
		partial-wave analysis	INDU	Magnetic induction
	Calorimeter		IPWA	Energy-independent partial-wave analysis
	-	detector at SLAC-SPEAR or DORIS	JADE	JADE detector at DESY
		detector at CERN-LEAR	KAM2	KAMIOKANDE-II underground Cherenkov detector
BOX (Crystal Box a	at LAMPF	KAMI	KAMIOKANDE underground Cherenkov detector
CC (Cloud chamb	er	KARM	KARMEN calorimeter at the ISIS neutron spallation source a
CFR (Columbia-Ch	icago-Fermilab-Rochester detector		Rutherford
DF (Collider detec	ctor at Fermilab	KOLR	Kolar Gold Field underground detector
DHS	CDHS neutri	no detector at CERN	KTEV	KTeV Collaboration
		ctor at DESY	L3	L3 detector at LEP
	Cherenkov de		LASS	Large-angle superconducting solenoid spectrometer at SLAC
		eutrino detector (glass) at CERN	LATT	Lattice calculations
		r Station near Chooz, France	LEBC	Little European bubble chamber at CERN
HRM (CHARM neu	trino detector (marble) at CERN	LENA	Nonmagnetic lead-glass NaI detector at DORIS
IBS (CERN-IHEP	boson spectrometer	LEPS	Low-Energy Pion Spectrometer at the Paul Scherrer Institute
	CLEO II dete	ector at CESR	LSND	Liquid Scintillator Neutrino Detector
		etic detector at CESR	MAC	MAC detector at PEP/SLAC
		agnetic detector at VEPP-2M, Novosibirsk	MBR	Molecular beam resonance technique
		agnetic detector 2 at VEPP-2M, Novosibirsk	MCRO	MACRO detector in Gran Sasso
	Counters	Garage and a series and a serie	MD1	Magnetic detector at VEEP-4, Novosibirsk
		nd astrophysics		T
	CPLEAR Co		MDRP	Millikan drop measurement
		- Stony Brook BGO calorimeter inserted in NaI	MICA	Underground mica deposits
	array	- Stony Brook BGO calorimeter inserted in Trai	MIRA	MIRABELLE Liquid-hydrogen bubble chamber
	•	Stony Brook segmented NaI detector at CESB	MLEV	Magnetic levitation
		- Stony Brook segmented NaI detector at CESR	MMS	Missing mass spectrometer
		at Fermilab Tevatron Collider	MPS	Multiparticle spectrometer at BNL
		matter detector at Gran Sasso National Lab.	MPS2	Multiparticle spectrometer upgrade at BNL
		e-arm spectrometer	MPSF	Multiparticle spectrometer at Fermilab
		ibble chamber		Model-dependent partial-wave analysis
		ctor at SLAC-SPEAR or SLAC-PEP	MRK1	SLAC Mark-I detector
	DELPHI dete Magnetia det		MRK2	SLAC Mark-II detector
	-	ector no. 1 at Orsay DCI collider	MRK3	
	-	ector no. 2 at Orsay DCI collider	MRKJ	Mark-J detector at DESY
		ident partial-wave analysis	MRS	Magnetic resonance spectrometer
	Fermilab E62			Multi-Wire Proportional Chamber
	Fermilab E65		NA14	CERN
	Fermilab E66		NA31	CERN NA31 Spectrometer-Calorimeter
	Fermilab E68		NA32	. 7
	Fermilab E69			CERN NA32 Spectrometer
2 705]		5 Spectrometer-Calorimeter	NA48 ND	CERN NA48 Collaboration Nat detector at VEPP-2M Navosibirsk
	Fermilab E73	1 Spectrometer-Calorimeter	ND NICE	NaI detector at VEPP-2M, Novosibirsk Serpukhov nonmagnetic precision spectrometer
	Fermilab E76			

NMR.	Nuclear magnetic resonance	JAP	Journal of Applied Physics	
NUSX	Mont Blanc NUSEX underground detector	JETP	English Translation of Soviet P	hysics ZETF
	OBELIX detector at LEAR	JETPL	English Translation of Soviet P	hysics ZETF Letters
	Detector at VEPP-2M and VEPP-4, Novosibirsk	JINR	Joint Inst. for Nuclear Research	h
	CERN OMEGA spectrometer		JINR Rapid Communications	
OPAL OSPK	OPAL detector at LEP Optical spark chamber	JPA	Journal of Physics, A	
PLAS	Plastic detector	JPB	Journal of Physics, B	anl Reference Date
	DESY PLUTO detector	JPG	Journal of Physical and Chemi	cal Reference Data
PWA	Partial-wave analysis	JPSJ	Journal of Physics, G Journal of the Physical Society	of Japan
REDE	Resonance depolarization	LNC	Lettere Nuovo Cimento	or Sapan
RVUE	Review of previous data	MNRA	Monthly Notices of the Royal	Astronomical Society
SAGE	US - Russian Gallium Experiment	MPL	Modern Physics Letters	•
SFM	CERN split-field magnet	NAT	Nature	
SHF	SLAC Hybrid Facility Photon Collaboration	NC	Nuovo Cimento	
SIGM	Serpukhov CERN-IHEP magnetic spectrometer (SIGMA)	NIM NP	Nuclear Instruments and Meth- Nuclear Physics	ods
SILI SLD	Silicon detector SLC Large Detector for e^+e^- colliding beams at SLAC		Nuclear Physics B Proceedings	Supplement
SOU2	Soudan 2 underground detector	PAN	Physics of Atomic Nuclei (form	
SOUD	Soudan underground detector	PD	Physics Doklady (Magazine)	,,
SPEC	Spectrometer	PDAT	Physik Daten	
SPED	From maximum of speed plot or resonant amplitude	PL	Physics Letters	
SPRK	Spark chamber	PN	Particles and Nuclei	
SQID	SQUID device	PPN	Physics of Particles and Nuclei	(formerly SJPN)
STRC	Streamer chamber	PPNP	Progress in Particles and Nucle	ear Physics
TASS	DESY TASSO detector	PPSL	Proc. of the Physical Society of	f London
THEO	Theoretical or heavily model-dependent result	\mathbf{PR}	Physical Review	•
TOF	Time-of-flight		Pramana	
TOPZ TPC	TOPAZ detector at KEK-TRISTAN	PRL	Physical Review Letters	G)
TPS	TPC detector at PEP/SLAC Tagged photon spectrometer at Fermilab	PRPL	Physics Reports (Physics Lette	-
TRAP	Penning trap	PRSE	Proc. of the Royal Society of I	
UA1	UA1 detector at CERN	PRSL	Proc. of the Royal Society of I	ondon, Section A
UA2	UA2 detector at CERN	PS	Physica Scripta	
UA5	UA5 detector at CERN	PTP	Progress of Theoretical Physics Phil. Trans. Royal Society of I	
VES	Vertex Spectrometer Facility at 70 GeV IHEP accelerator	RA	Radiochimica Acta	ondon
VNS	VENUS detector at KEK-TRISTAN	RMP	Reviews of Modern Physics	
WA75	CERN WA75 experiment	RNC	La Rivista del Nuovo Cimento	
WA82	CERN WA82 experiment	RPP	Reports on Progress in Physics	
WA89	CERN WA89 experiment	RRP	Revue Roumaine de Physique	
WIRE XEBC	Wire chamber Xenon bubble chamber	SCI	Science	
ZEUS	ZEUS detector at DESY/HERA	SJNP	Soviet Journal of Nuclear Phys	
		SJPN	Soviet Journal of Particles and	
Confe	rences	SPD SPU	Soviet Physics Doklady (Maga Soviet Physics - Uspekhi	zme <i>j</i>
Confere	nces are generally referred to by the location at which they were	UFN	Usp. Fiz. Nauk – Russian vers	ion of SPII
	g., HAMBURG, TORONTO, CORNELL, BRIGHTON, etc.).	YAF	Yadernaya Fizika	
	6 ,, , , , , , , , , , , , , , , ,	ZETF	Zhurnal Eksperimental'noi i Te	eoreticheskoi Fiziki
Journ	als	ZETFP	Zhurnal Eksperimental'noi i Te	
			Redakts	,,
AA ADVP	Astronomy and Astrophysics Advances in Physics	ZNAT		
AFIS	Anales de Fisica	ZPHY	Zeitschrift fur Physik	
AJP	American Journal of Physics			
ANP	Annals of Physics	Institu	itions	
ANPL	Annals of Physics (Leipzig)	AACH	Phys. Inst. der Techn.	Aachen, Germany
ANYAS	S Annals of the New York Academy of Sciences		Hochschule Aachen (His-	
AP	Atomic Physics		torical, use for general Inst.	
APAH	Acta Physica Academiae Scientiarum Hungaricae	4.4.0771	der Techn. Hochschule)	4) G
APJ	Astrophysical Journal	AACHI	I Phys. Inst. der Techn. Hochschule Aachen	Aachen, Germany
APJS	Astrophysical Journal Suppl.	AACH3	III Phys. Inst. der Techn.	Aachen, Germany
APP	Acta Physica Polonica		Hochschule Aachen	, -
	Annual Review of Nuclear and Particle Science	AACHT	Institut für Theoretische	Aachen, Germany
ARNS	Annual Review of Nuclear Science		Physik	
ASP BAPS	Astroparticle Physics Rulletin of the American Physical Society		Univ. of Aarhus	Aarhus C, Denmark
	Bulletin of the American Physical Society Bulletin of the Academy of Science, USSR (Physics)	ABO	Abo Akademi University	Abo (Turku), Finland
CJNP	Chinese Journal of Nuclear Physics	ADEL	-	Garden City, NY, USA
COLLE	Canadian Journal of Physics	ADLD	The Univ. of Adelaide	Adelaide, SA, Australia
CJP	·	AERE	Atomic Energy Research Estab.	Didcot, United Kingdom
CJP CNPP			Armed Forces Radiobiology	Bethesda, MD, USA
CNPP	· · · · · · · · · · · · · · · · · · ·	AFRR		
CNPP CZJP	Czechoslovak Journal of Physics		Res. Inst.	
CNPP	Czechoslovak Journal of Physics	AHMEI	Res. Inst. Physical Research Lab.	Ahmedabad, Gujarat, India
CNPP CZJP DANS	Czechoslovak Journal of Physics Dokłady Akademii nauk SSSR	AHMEI AICH	Res. Inst. OPhysical Research Lab. Aichi Univ. of Education	Ahmedabad, Gujarat, India Aichi, Japan
CNPP CZJP DANS EPJ EPL	Czechoslovak Journal of Physics Dokłady Akademii nauk SSSR European Physical Journal	AHMEI AICH AKIT	Res. Inst. DPhysical Research Lab. Aichi Univ. of Education Akita Univ.	Ahmedabad, Gujarat, India Aichi, Japan Akita, Japan
CNPP CZJP DANS EPJ EPL	Czechoslovak Journal of Physics Dokłady Akademii nauk SSSR European Physical Journal Europhysics Letters	AHMEI AICH	Res. Inst. OPhysical Research Lab. Aichi Univ. of Education	Ahmedabad, Gujarat, India Aichi, Japan

ALAT	Univ. of Alabama (Tuscaloosa)	Tuscaloosa, AL, USA		Brown Univ. Brunel Univ.	Providence, RI, USA Uxbridge, Middlesex, United
ALBA	· ·	Albany, NY, USA			Kingdom
ALBE	Univ. of Alberta	Edmonton, AB, Canada	BRUX	Univ. Libre de Bruxelles;	Bruxelles, Belgium
	Ames Lab.	Ames, IA, USA		Service de Physique des Par-	
THM	Amherst College	Amherst, MA, USA	DDIIV	ticules Elémentaires	D
MST	Univ. van Amsterdam	Amsterdam, The Netherlands	BRUXT	'Univ. Libre de Bruxelles;	Bruxelles, Belgium
NIK	NIKHEF	Amsterdam, The Netherlands	Ditoit	Physique Théorique	D 1 . 1 . 1 . D
ANKA	Middle East Technical	Ankara, Turkey		Univ. of Bucharest	Bucharest-Magurele, Romani
	Univ.; Dept. of Physics; Experimental HEP Lab	,,	RODA	KFKI Research Inst. for Par- ticle & Nuclear Physics	Budapest, Hungary
ANL	Argonne National Lab.; High	Argonne, IL, USA	BUFF	SUNY at Buffalo	Buffalo, NY, USA
1111	Energy Physics Division,	Argoine, i.i., USA	BURE	Inst. des Hautes Etudes Scien- tifiques	Bures-sur-Yvette, France
	Bldg. 362; Physics Division,		CAEN	•	Caen, France
NON	Bldg. 203	Manager and August 110 A	4.12.	laire, ISMRA	Oubli, Transc
	St. Anselm Coll.	Manchester, NH, USA	CAGL	Univ. degli Studi di Cagliari	Cagliari, Italy
	Arecibo Observatory	Arecibo, PR, USA	CAIR	Cairo University	Orman, Giza, Cairo, Egypt
ARIZ	Univ. of Arizona	Tucson, AZ, USA	CAIW	-	Washington, DC, USA
RZS	Arizona State Univ.	Tempe, AZ, USA	CAIW	ton	Washington, DC, C3A
SCI	Russian Academy of Sciences	Moscow, Russian Federation	CALC		Calcutta, India
AST	Inst. of Phys.	Nankang, Taipei, The Republic		Univ. of Cambridge	Cambridge, United Kingdom
		of China (Taiwan)		•	<u> </u>
TEN	NCSR "Demokritos"	Aghia Paraskevi Attikis,		Univ. de Campinas	Campinas, SP, Brasil
		Greece		Australian National Univ.	Canberra, ACT, Australia
THU	Univ. of Athens	Athens, Greece	CAPE	University of Capetown	Rondebosch, Cape, South
AUCK	Univ. of Auckland	Auckland, New Zealand	A15.	The Control of the Co	Africa
	Azerbaijian Academy of	Baku, Azerbaijan		Univ. Central de Venezuela	Caracas, Venezuela
	Sciences, Inst. of Physics	, 		Carleton Univ.	Ottawa, ON, Canada
BANG	B Bangabasi College	Calcutta, India		Carleton College	Northfield, MN, USA
	Univ. Autónoma de	Bellaterra (Barcelona), Spain	CASE	Case Western Reserve Univ.	Cleveland, OH, USA
	Barcelona	(was outone), open	CAST		Beijing, The People's Republ
BARI	Univ. di Bari	Bari, Italy		Science and Technology	of China
3ART		Newark, DE, USA	CATA	Univ. di Catania	Catania, Italy
	Research Inst.		CATH	Catholic Univ. of America	Washington, DC, USA
BASL	Inst. für Physik der Univ.	Basel, Switzerland	CAVE		Cambridge, United Kingdom
	Basel	•	CBNM		Geel, Belgium
BAYR	Univ. Bayreuth	Bayreuth, Germany	CCAC		Meadville, PA, USA
BCEN	Centre d'Etudes Nucleaires de	Gradignan, France	CDEF		
	Bordeaux-Gradignan	,		Collège de France	Paris, France
BEIJ	Beijing Univ.	Beijing, The People's Republic of China	CEA	Cambridge Electron Accelera- tor (Historical in Review)	Cambridge, MA, USA
зеіјт	Inst. of Theoretical Physics	Beijing, The People's Repub- lic of China	CEBAF	JLab—Thomas Jefferson National Accelerator Facil-	Newport News, VA, USA
BELG	Inter-University Inst. for High Energies (ULB-VUB)	Brussel, Belgium	CENG		Grenoble, France
BELL	AT & T Bell Labs	Murray Hill, NJ, USA	CERN		Genève, Switzerland
	Univ. of Bergen	Bergen, Norway		for Particle Physics	
BERL	DESY	Zeuthen, Germany	CFPA	Univ. of California, (Berke-	Berkeley, CA, USA
BERN	Univ. of Berne	Berne, Switzerland		ley)	
			CHIC	Univ. of Chicago	Chicago, IL, USA
GNA	Univ. di Bologna, & INFN, Sezione di Bologna; Viale C.	Bologna, Italy	CIAE	China Institute of Atomic Energy	Beijing, The People's Republ of China
	Berti Pichat, n. 6/2; Via Irne-		CINC	Univ. of Cincinnati	Cincinnati, OH, USA
	rio, 46, I-40126 Bologna		CINV	CINVESTAV-IPN, Centro de	México, DF, Mexico
знав	Bhabha Atomic Research Center	Trombay, Bombay, India	OT 1.4	Investigacion y de Estudios	ATTORNEOUS DES INTERICO
BHEP		Dailing The Poople's Popul		Avanzados del IPN	
1	Inst. of High Energy Physics	Beijing, The People's Repub- lic of China	CIT	California Inst. of Tech.	Pasadena, CA, USA
BIEL	Univ. Bielefeld		CLER	Univ. de Clermont-Ferrand	Aubière, France
		Bielefeld, Germany	CLEV	Cleveland State Univ.	Cleveland, OH, USA
BING.	SUNY at Binghamton	Binghamton, NY, USA	CMNS	Comenius Univ.	Bratislava, Slovakia
BIRK	Birkbeck College, Univ. of	London, United Kingdom	CMU	Carnegie Mellon Univ.	Pittsburgh, PA, USA
BIRM	London Univ. of Birmingham	Edgbaston, Birmingham,	CNEA	Comisión Nacional de En-	Buenos Aires, Argentina
NT CT-	D1 1 ***	United Kingdom	are.	ergía Atómica	044 034 0
BLSU	Bloomsburg Univ.	Bloomsburg, PA, USA	CNRC	Centre for Research in Parti-	Ottawa, ON, Canada
BNL	Brookhaven National Lab.	Upton, NY, USA	~ ~~-	cle Physics	
BOCH		Bochum, Germany	COLO	Univ. of Colorado	Boulder, CO, USA
OHR	Niels Bohr Inst.	Copenhagen Ø, Denmark	COLU		New York, NY, USA
BOIS	Boise State Univ.	Boise, ID, USA	CONC	Concordia University	Montreal, PQ, Canada
BOMB	Univ. of Bombay	Bombay, India	CORN	Cornell Univ.	Ithaca, NY, USA
	Rheinische Friedr	Bonn, Germany	COSU	Colorado State Univ.	Fort Collins, CO, USA
	Wilhelms-Univ. Bonn		CPPM	Centre National de la	Marseille, France
BORD	Univ. de Bordeaux I	Gradignan, France		Recherche Scientifique, Lu-	•
BOSE	S.N. Bose National Centre	Calcutta, India		miny	
	for Basis Sciences		CRAC	Kraków Inst. of Nuclear	Kraków, Poland
OSK	"Rudjer Bošković" Inst.	Zagreb, Croatia		Physics	,
BOST	Boston Univ.	Boston, MA, USA	CRNL	Chalk River Labs.	Chalk River, ON, Canada
RAN	Brandeis Univ.	Waltham, MA, USA	CSOK	Oklahoma Central State	Edmond, OK, USA
	VM1.	•	COOK	Univ.	
	Univ of British Columbia	Vancouver BC Canada			
BRCO	Univ. of British Columbia Univ. of Bristol	Vancouver, BC, Canada Bristol, United Kingdom	CST	Univ. of Science and Tech-	Hefei, Anhui 230027, The

	California State Univ. City College of New York	Long Beach, CA, USA New York, NY, USA	HEID	Univ. Heidelberg ; (unspecified division) (Historical in	Heidelberg, Germany
CURIN	Univ. Pierre et Marie Curie (Paris VI), LPNHE	Paris, France	HEIDH	Review) Univ. Heidelberg; Inst. für	Heidelberg, Germany
CURIT	Univ. Pierre et Marie Curie (Paris VI), LPTHE	Paris, France	HEIDP	Hochenergiephysik Univ. Heidelberg ; Physik	Heidelberg, Germany
DALH DARE	Dalhousie Univ. Daresbury Lab	Halifax, NS, Canada Cheshire, United Kingdom	HEIDT	Inst. Univ. Heidelberg ; Inst. für	Heidelberg, Germany
DARM	${\bf Tech.\ Hochschule\ Darmstadt}$	Darmstadt, Germany	HELS	Theoretische Physik Univ. of Helsinki ; Dept. of	University of Helsinki, Finland
DELA	Univ. of Delaware ; Dept. of Physics & Astronomy	Newark, DE, USA		Physics, High Energy Physics Division (SEFO); Dept. of	
DESY	Univ. of Delhi DESY, Deutsches Elektronen-Synchrotron	Delhi, India Hamburg, Germany		Physics, Theoretical Physics Division (TFO); Helsinki In-	
DFAB	Escuela de Ingenieros	Bilbao, Spain	HIRO	stitute of Physics (HIP) Hiroshima Univ.	Higashi-Hiroshima, Japan
DOE	Department of Energy	Germantown, MD, USA	HOUS	Univ. of Houston	Houston, TX, USA
DORT	Univ. Dortmund	Dortmund, Germany	HPC	Hewlett-Packard Corp.	Cupertino, CA, USA
DUKE	Duke Univ. Univ. of Durham	Durham, NC, USA Durham City, United Kingdom	HSCA	Harvard-Smithsonian Cen-	Cambridge, MA, USA
DUUC	University College	Dublin, Ireland	IAS	ter for Astrophysics Inst. for Advanced Study	Princeton, NJ, USA
EDIN	Univ. of Edinburgh	Edinburgh, United Kingdom	IASD	Dublin Inst. for Advanced	Dublin, Ireland
EFI	Enrico Fermi Inst.	Chicago, IL, USA		Studies	
ELMT	Elmhurst College	Elmhurst, IL, USA	IBAR IBM	Ibaraki Univ.	Ibaraki, Japan Palo Alto, CA, USA
ENSP	l'Ecole Normale Supérieure	Paris, France	IBMY	IBM Corp. IBM	Yorktown Heights, NY, USA
EOTV	Eötvös University	Budapest, Hungary	IBS	Inst. for Boson Studies	Pasadena, CA, USA
EPOL	École Polytechnique	Palaiseau, France	ICEPP	Univ. of Tokyo; Int. Cen-	Tokyo, Japan
ERLA ETH	Univ. Erlangen-Nurnberg Univ. Zürich	Erlangen, Germany Zürich, Switzerland		ter for Elementary Particle Physics (ICEPP)	
FERR	Univ. di Ferrara	Ferrara, Italy	ICRR	Univ. of Tokyo; Inst. for Cosmic Ray Research	Tokyo, Japan
FIRZ FISK	Univ. di Firenze Fisk Univ.	Firenze, Italy Nashville, TN, USA	ICTP	Abdus Salam International Centre for Theoretical Physics	Trieste, Italy
FLOR FNAL	Univ. of Florida Fermilab	Gainesville, FL, USA Batavia, IL, USA	IFIC	IFIC (Instituto de Física Corpuscular)	Burjassot, Valencia, Spain
FOM	FOM, Stichting voor Funda- menteel Onderzoek der Ma-	JP Utrecht, The Netherlands	IFRJ	Univ. Federal do Rio de Janeiro	Rio de Janeiro, RJ, Brasil
DD 437	terie	B 16 / W: G	IIT	Illinois Inst. of Tech.	Chicago, IL, USA
FRAN FRAS	Univ. Frankfurt Lab. Nazionali di Frascati	Frankfurt am Main, Germany Frascati (Roma), Italy	ILL	Univ. of Illinois at Urbana- Champaign	Urbana, IL, USA
EDEID	dell'INFN	Freiburg, Germany	ILLC	Univ. of Illinois at Chicago	Chicago, IL, USA
	Albert-Ludwigs Univ. Freie Univ. Berlin	Berlin, Germany	ILLG	Inst. Laue-Langevin	Grenoble, France
FRIB	Univ. de Fribourg	Fribourg, Switzerland	IND	Indiana Univ.	Bloomington, IN, USA
FSU	Florida State University	Tallahassee, FL, USA	INEL INFN	E G and G Idaho, Inc. Ist. Nazionale di Fisica Nu-	Idaho Falls, ID, USA Various places, Italy
	Florida State Univ.	Tallahassee, FL, USA	INFIN	clear (Generic INFN, un-	various places, leary
FUKI FUKU	Fukui Univ. Fukushima Univ.	Fukushima Japan		known location)	
GENO	Univ. di Genova	Fukushima, Japan Genova, Italy	INNS	Leopold-Franzens Univ.	Innsbruck, Austria
	Georgian Academy of Sci-	Tbilisi, Republic of Georgia	INPK	Inst. of Nuclear Physics	Kraków, Poland
	ences		INRM INUS	INR, Inst. for Nucl. Research Univ. of Tokyo; Inst. for	Moscow, Russian Federation Tokyo, Japan
GESC	General Electric Co.	Schenectady, NY, USA Genève, Switzerland	11105	Nuclear Study	Tokyo, Japan
GEVA GIES	Univ. de Genève Univ. Giessen	Giessen, Germany	IOAN	Univ. of Ioannina	Ioannina, Greece
GIFU	Gifu Univ.	Gifu, Japan	IOFF	A.F. Ioffe Phys. Tech. Inst.	St. Petersburg, Russian Fed-
GLAS	Univ. of Glasgow	Glasgow, United Kingdom	IOWA	Univ. of Iowa	eration Iowa City, IA, USA
GMAS	-	Fairfax, VA, USA	IPN	IPN, Inst. de Phys. Nucl.	Orsay, France
GOET	Univ. Göttingen	Göttingen, Germany	IPNP	Univ. Pierre et Marie Curie	Paris, France
GRAN	Univ. de Granada Univ. Graz	Granada, Spain Graz, Austria	713 4 75	(Paris VI)	Danie Fue
	Univ. of Groningen	Groningen, The Netherlands	IRAD ISNG	Inst. du Radium (Historical) Inst. des Sciences Nucleaires	Paris, France Grenoble, France
GSCO	Geological Survey of	Ottawa, ON, Canada	1914G	(ISN)	Grenous, France
GSI	Canada Darmstadt Gesellschaft für	Darmstadt, Germany	ISU	Iowa State Univ., Dept. of Physics & Astronomy; Al-	Ames, IA, USA
GUEL	Schwerionenforschung Univ. of Guelph	Guelph, ON, Canada		pha HEP Group; Ames High Energy Physics	
HAHN	Hahn-Meitner Inst. Berlin GmbH	Berlin, Germany	ITEP	ITEP, Inst. of Theor. and Exp. Physics	Moscow, Russian Federation
HAIF	Technion – Israel Inst. of Tech.	Technion, Haifa, Israel	ITHA	Ithaca College	Ithaca, NY, USA
HAMB	Univ. Hamburg ; I Inst. für Experimentalphysik; II Inst.	Hamburg, Germany	IUPU	Indiana Univ., Purdue Univ. Indianapolis	Indianapolis, IN, USA
	für Experimentalphysik		JADA	Jadavpur Univ.	Calcutta, India
	Univ. Hannover	Hannover, Germany	JAGL JHU	Jagiellonian Univ. Johns Hopkins Univ.	Kraków, Poland Baltimore, MD, USA
HARC	search Ctr.	The Woodlands, TX, USA Cambridge, MA, USA	JINR	JINR, Joint Inst. for Nucl. Research	Dubna, Russian Federation
HARV HAWA	Harvard Univ. Univ. of Hawai'i	Honolulu, HI, USA	JULI	Julich, Forschungszentrum	Julich, Germany
	Hebrew Univ.	Jerusalem, Israel	JYV	Univ. of Jyväskylä	Jyväskylä, Finland
		, 		•	

	Univ. of Kagoshima	Kagoshima-shi, Japan		Univ. Catholique de Louvain	Louvain-la-Neuve, Belgium
KANS KARL	Univ. of Kansas Univ. Karlsruhe; (unspec-	Lawrence, KS, USA Karlsruhe, Germany	LOWC	see LOQM (Queen Mary and	London, United Kingdom
	ified division) (Historical in Review)		LRL	Westfield joined)) U.C. Lawrence Radiation Lab.	Berkeley, CA, USA
CARLE	Univ. Karlsruhe; Inst. für Experimentelle Kernphysik	Karlsruhe, Germany	LSU	(Old name for LBL) Louisiana State Univ.	Baton Rouge, LA, USA
CARLK	Forschungszentrum Karl-	Karlsruhe, Germany	LUND	Univ. of Lund	Lund, Sweden
ADIT	sruhe	Varlanda Common.	LUND	Fysiska Institutionen	Lund, Sweden
	Univ. Karlsruhe; Inst. für Theoretische Teilchenphysik	Karlsruhe, Germany	LYON	Institute de Physique Nucléaire de Lyon (IPN)	Villeurbanne, France
	Kazakh Inst. of High Energy Physics	Alma Ata, Kazakhstan		Inst. de Estructura de la Ma- teria	Madrid, Spain
EK	KEK, National Lab. for High Energy Phys.	Ibaraki-ken, Japan		C.I.E.M.A.T	Madrid, Spain
ENT	Univ. of Kent	Canterbury, United Kingdom		Univ. Autónoma de Madrid Univ. of Manitoba	Madrid, Spain Winnipeg, MB, Canada
EYN	Open Univ.	Milton Keynes, United King-		Johannes-Gutenberg-Univ.	Mainz, Germany
FTI	Kharkov Inst. of Physics and	dom Kharkov, Ukraine		Univ. Marburg	Marburg, Germany
	Tech. (KFTI)	Time Rov, On time	MARS	Centre de Physique des Par-	Marseille, France
IAE	The Russian Research Center, Kurchatov Inst.	Moscow, Russian Federation	MASA	ticules de Marseille Univ. of Massachusetts Amherst	Amherst, MA, USA
MAI	Keldysh Inst. of Applied Math., Acad. Sci., Russia	Moscow, Russian Federation	MASB		Boston, MA, USA
KIDR	Vinča Inst. of Nuclear Sciences (Formerly Boris Kidrič	Belgrade, Yugoslavia	MASD	Univ. of Massachusetts Dartmouth	N. Dartmouth, MA, USA
	Inst.)		MCGI	McGill Univ.	Montreal, QC, Canada
KIEV	Institute for Nuclear Re- search	Kiev, Ukraine		Univ. of Manchester	Manchester, United Kingdon
CINK	Kinki Univ.	Osaka, Japan		McMaster Univ.	Hamilton, ON, Canada
NTY	Univ. of Kentucky	Lexington, KY, USA	MEHI	A Mehta Research Inst. of Mathematics & Mathemati-	Allahabad, India
	Kobe Univ.	Kobe, Japan		cal Physics	
	BUniv. of Tokyo, Komaba	Tokyo, Japan	MEIS	Meisei Univ.	Tokyo, Japan
CONAN	Konan Univ. Inst. of Experimental Physics	Kobe, Japan Košice, Slovakia	MELB	Univ. of Melbourne	Parkville, Victoria, Australia
	Kyoto Univ.	Kyoto, Japan	MEUD MICH		Meudon, France Ann Arbor, MI, USA
	Kyoto Univ.	Kyoto 606-01, Japan	MILA	Univ. di Milano	Milano, Italy
	Kyungpook National Univ.	Taegu, Republic of Korea		INFN, Sez. di Milano	Milano, Italy
	Kyushu Univ.	Fukuoka, Japan	MINN	Univ. of Minnesota	Minneapolis, MN, USA
ALU	LAL, Laboratoire de l'Accélérateur Linéaire	Orsay, France	MISS	Univ. of Mississippi	University, MS, USA
	Lancaster Univ.	Lancaster, United Kingdom	MIT	Univ. of Missouri MIT Massachusetts Inst.	Rolla, MO, USA Cambridge, MA, USA
ANL	Los Alamos National Lab. (LANL)	Los Alamos, NM, USA	MIU	of Technology Maharishi International	Fairfield, IA, USA
APP	LAPP, Lab. d'Annecy-le- Vieux de Phys. des Particules	Annecy-le-Vieux, France	MIYA	Univ. Miyazaki Univ.	Miyazaki-shi, Japan
LASL	U.C. Los Alamos Scientific	Los Alamos, NM, USA	MONP	•	Montpellier, France
ATINE	Lab. (Old name for LANL)	Disc. Lateria	MONS	Univ. de Mons-Hainaut	Mons, Belgium
LATV LAUS	Latvian State Univ. Univ. de Lausanne	Riga, Latvia Lausanne, Switzerland	MONT	Univ. de Montréal; Labora-	Montréal, PQ, Canada
LAVL	Univ. Laval	Quebec, PQ, Canada	MONT	toire René-JALévesque CUniv. de Montréal; Centre	Montréal, PQ, Canada
LBL	Lawrence Berkeley National Lab.	Berkeley, CA, USA		de recherches mathématiques Skobeltsyn Inst. of Nuclear	Moscow, Russian Federation
CGT	Univ. di Torino	Turin, Italy	MOSO	Physics, Moscow State Univ.	Wioscow, Russian rederatio
EBD	Lebedev Physical Inst.	Moscow, Russian Federation	MPCM	Max Planck Inst. fur Chemie	Mainz, Germany
ECE EED	Univ. di Lecce Univ. of Leeds	Lecce, Italy Leeds, United Kingdom	MPEI	Moscow Physical Engi-	Moscow, Russian Federation
EHI	Lehigh Univ.	Bethlehem, PA, USA	MPIA	neering Inst. Max-Planck-Institute für	Garching, Germany
	Lehman College of CUNY	Bronx, NY, USA	1411 121	Astrophysik	Outcome, Octmany
EID	Univ. of Leiden	Leiden, The Netherlands	MPIH	Max-Planck-Inst. für Kern-	Heidelberg, Germany
EMO	Le Moyne Coll.	Syracuse, NY, USA	MDIM	physik Max-Planck-Inst, für	Minches Comment
EUV INZ	Katholieke Univ. Leuven Univ. Linz	Leuven, Belgium Linz, Austria	MPIM	Physik	München, Germany
ISB	Inst. Nacional de Investigacion	Lisboa CODEX, Portugal	MSU	Michigan State Univ. Mount Holyoke College	East Lansing, MI, USA South Hadley, MA, USA
ISBT	Cientifica Univ. Técnica de Lisboa, Inst.	Lisboa, Portugal		Centre Univ. du Haut-Rhin	Mulhouse, France
	Superior Técnico	, 3		Ludwig-Maximilians-Univ.	Garching, Germany
IVP	Univ. of Liverpool	Liverpool, United Kingdom		München	- ·
LL	(Old name for LLNL)	Livermore, CA, USA		Tech. Univ. München Midwestern Univ. Research	Garching, Germany Stroughton, WI, USA
LLNL	Lawrence Livermore Na-	Livermore, CA, USA	NAAC	Assoc. (Historical in Review)	Thousand Oaks OA 1704
OCK		Palo Alto, CA, USA	NAAS	ence Center (Historical in	Thousand Oaks, CA, USA
OIC	Lab Imperial College of Science	London, United Kingdom		Review) Nagoya Univ.	Nagoya, Japan
LOIC	Tech & Medicine				
LOIC LOQM	Tech. & Medicine Univ. of London, Queen	London, United Kingdom		Univ. di Napoli NASA	Napoli, Italy Greenbelt, MD, USA

NBS	U.S National Bureau of Standards (Old name for	Gaithersburg, MD, USA	PPA	Princeton-Penn. Proton Accelerator (Historical in Review)	Princeton, NJ, USA
	NIST)		PRAG	Inst. of Physics, ASCR	Prague, Czech Republic
NBSB	National Inst. Standards	Boulder, CO, USA	PRIN	Princeton Univ.	Princeton, NJ, USA
	Tech.		PSI	Paul Scherrer Inst.	Villigen PSI, Switzerland
NCAR	National Center for Atmo-	Boulder, CO, USA	PSLL	Physical Science Lab	Las Cruces, NM, USA
	spheric Research		PSU	Penn State Univ.	University Park, PA, USA
	North Carolina State Univ.	Raleigh, NC, USA	PUCB	Pontifícia Univ. Católica	Rio de Janeiro, RJ, Brasil
IDAM	Univ. of Notre Dame	Notre Dame, IN, USA	1005	do Rio de Janeiro	Tuo de Baneiro, 100, Diam
NEAS	Northeastern Univ.	Boston, MA, USA	PUEB		Puebla, Pue, Mexico
NEUC	Univ. de Neuchâtel	Neuchâtel, Switzerland		FCFM - BUAP	,,
NICEA	Univ. de Nice	Nice, France	PURD		West Lafayette, IN, USA
IICEO	Observatoire de Nice	Nice, France	QUKI	Queen's Univ.	Kingston, ON, Canada
NIHO	Nihon Univ.	Tokyo, Japan	RAL	Rutherford Appleton Lab.	Chilton, Didcot, Oxon., Unit
IIIG	Niigata Univ.		10.11	reduction Appleton Lab.	Kingdom
		Niigata, Japan	REGE	Univ. Paganshung	
NIJM	Univ. of Nijmegen	Nijmegen, The Netherlands		• •	Regensburg, Germany
VIRS	Nat. Inst. Radiological Sci-	Chiba, Japan	REHO		Rehovot, Israel
TOTAL	ences	0.01 1 10 101	RHBL		Egham, Surrey, United King-
UST	National Institute of Stan-	Gaithersburg, MD, USA		New College	dom
	dards & Technology		RHEL	Rutherford High Energy	Chilton, Didcot, Oxon., Unit
IIU	Northern Illinois Univ.	De Kalb, IL, USA		Lab (Old name for RAL)	Kingdom
IMSU	New Mexico State Univ.	Las Cruces, NM, USA	RICE	Rice Univ.	Houston, TX, USA
ORD	Nordita	Copenhagen Ø, Denmark		Riken Accelerator Research	Saitama, Japan
	Univ. of Nottingham	Nottingham, United Kingdom	***********	Facility (RARF)	Jupun
	_	- · · · · · · · · · · · · · · · · · · ·	риии	- , ,	Tokus Japan
OVM	Inst. of Mathematics	Novosibirsk, Russian Federa- tion	RIKK	Rikkyo Univ.	Tokyo, Japan
OVO	BINP, Budker Inst. of Nu-		RIS	Rowland Inst. for Science	Cambridge, MA, USA
	clear Physics	Novosibirsk, Russian Federa- tion	RISC	Rockwell International	Thousand Oaks, CA, USA
IDO:	•		RISL	Universities Research Re-	Risley, Warrington, United
IPOL	Polytechnic of North Lon-	London, United Kingdom		actor	Kingdom
TDT	don	Washington DO 1104	RISO	Riso National Laboratory	Roskilde, Denmark
IRL	Naval Research Lab	Washington, DC, USA	RL	Rutherford High Energy	Chilton, Didcot, Oxon., Unit
ISF	National Science Founda-	Arlington, VA, USA		Lab (Old name for RAL)	Kingdom
	tion		RMCS	,	Swindon, Wilts., United Kin
THU	National Tsing Hua Univ.	Hsinchu, The Republic of	ItiviOS	ence	dom
		China (Taiwan)	ROCH	Univ. of Rochester	Rochester, NY, USA
TUA	National Tech. Univ. of	Athens, Greece			
	Athens			Rockefeller Univ.	New York, NY, USA
WES	Northwestern Univ.	Evanston, IL, USA		Univ. di Roma (Historical)	Roma, Italy
IYU	New York Univ.	New York, NY, USA	ROMA	2 Univ. di Roma , "Tor Ver-	Roma, Italy
BER	Oberlin College	Oberlin, OH, USA		gata"	
OCH	Ochanomizu Univ.	Tokyo, Japan	ROMA:	3 Univ. di Roma	Roma, Italy
OHIO				INFN, Sez. di Roma	Roma, Italy
	Ohio Univ.	Athens, OH, USA	ROSE		Terre Haute IN, USA
	Okayama Univ.	Okayama, Japan	HODE	nology	Terre Haute III, COA
	Univ. of Oklahoma	Norman, OK, USA	RPI	Rensselaer Polytechnic	There MV IICA
KSU	Oklahoma State Univ.	Stillwater, OK, USA	ILI I	Inst.	Troy, NY, USA
REG	Univ. of Oregon	Eugene, OR, USA	סדוות	Rutgers Univ.	Piscataway, NJ, USA
RNL	Oak Ridge National Labora-	Oak Ridge, TN, USA		-	
	tory		SACL	CE Saclay, DAPNIA	Gif-sur-Yvette, France
RSAY	Univ. de Paris Sud	Orsay CEDEX, France	SACL	CEA Saclay	Gif-sur-Yvette, France
	Oregon State Univ.	Corvallis, OR, USA	SACLD	CE Saclay, DAPNIA; Direc-	Gif-sur-Yvette, France
	_			tion	
	Osaka Univ.	Osaka, Japan	SAGA	Saga Univ.	Saga-shi, Japan
SKC	Osaka City Univ.	Osaka-shi, Japan	SANG	Kyoto Sangyo Univ.	Kyoto-shi, Japan
SLO	Univ. of Oslo	Oslo, Norway	SANI	Physics Lab., Ist. Superiore di	Roma, Italy
SU	Ohio State Univ.	Columbus, OH, USA		Sanità	. •
TTA	Univ. of Ottawa	Ottawa, ON, Canada	SASK	Univ. of Saskatchewan	Saskatoon, SK, Canada
XF	University of Oxford	Oxford, United Kingdom		Lab. Naz. del Gran Sasso	Assergi (L'Aquila), Italy
	Univ. of Oxford	Oxford, United Kingdom		dell'INFN	, 3 , 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1
			SAVO	Univ. de Savoie	Chambery, France
ADO	•	Padova, Italy	SBER	California State Univ.	San Bernardino, CA, USA
AKIN	Univ. Paris VI et Paris	Paris, France		W.J. Schafer Assoc.	Livermore, DA, USA
	VII, IN ² P ³ /CNRS				
	Univ. de Paris (Historical)	Paris, France	SCIT	Science Univ. of Tokyo	Tokyo, Japan
ARIT	Univ. Paris VI et Paris	Paris, France	SCOT	Scottish Univ. Research and	Glasgow, United Kingdom
	VII, LPTHE		COTTO	Reactor Ctr.	Galambia agg 1104
ARM		Parma, Italy	SCUC	Univ. of South Carolina	Columbia, SC, USA
AST	Institut Pasteur	Paris, France	SEAT	Seattle Pacific Coll.	Seattle, WA, USA
ATR	Univ. of Patras		SEIB	Austrian Research Center,	Seibersdorf, Austria
		Patras, Greece	_	Seibersdorf LTD.	
AVI	Univ. di Pavia	Pavia, Italy	SEOU	Korea Univ.; Dept. of	Seoul, Republic of Korea
PENN	Univ. of Pennsylvania	Philadelphia, PA, USA		Physics; HEP Group	
GIA	Univ. di Perugia	Perugia, Italy	SEOUL	Seoul National Univ.; Dept.	Seoul, Republic of Korea
ISA	Univ. di Pisa	Pisa, Italy		of Physics, Coll. of Natural	•
ISAI	INFN, Sez. di Pisa	Pisa, Italy		Sciences; Center for Theoreti-	
ITT	Univ. of Pittsburgh			cal Physics	
		Pittsburgh, PA, USA	SERP	IHEP, Inst. for High Energy	Protvino, Russian Federation
LAT	SUNY at Plattsburgh	Plattsburgh, NY, USA	Juli	Physics (Also known as Ser-	*
LRM	Univ. di Palermo	Palermo, Italy		pukhov)	
NL	Battelle Memorial Inst.	Richland, WA, USA	, and	- ,	Court Occup. NI TICA
111		Catabina Bussian Endoration	SETO	Seton Hall Univ.	South Orange, NJ, USA
	Petersburg Nuclear Physics	Gatchina, Russian Federation	OTST A	TT C C 1 TO ! ! !	(D
NPI	Petersburg Nuclear Physics Inst. of Russian Academy of	Gatchina, Russian rederation	SFLA SFRA	Univ. of South Florida Simon Fraser University	Tampa, FL, USA Burnaby, BC, Canada

FSU HAMS	California State Univ. Ain Shams University	San Francisco, CA, USA Kasr-El-Zaafran, Asbasiyah,	TPTI	Lab. of High Energy Phys.	Tashkent, Republic of Uzbe istan
	•	Cairo, Egypt	TRIN	Univ. of Dublin , Trinity College	Dublin, Ireland
HEF	Univ. of Sheffield	Sheffield, United Kingdom	TRIU	TRIUMF	Vancouver, BC, Canada
HMP	Univ. of Southampton	Southampton, United Kingdom		Univ. di Trieste	Trieste, Italy
ŒG	UnivGesamthochschule-	Siegen, Germany		INFN, Sez. di Trieste	Trieste, Italy
	Siegen			Univ. di Trieste	
LES	Univ. of Silesia	Katowice, Poland			Trieste, Italy
ΙN	Swiss Inst. of Nuclear Re-	Villigen, Switzerland		Univ. of Tsukuba	Ibaraki-ken, Japan
	search (Old name for VILL)		TTAM	Tamagawa Univ.	Tokyo, Japan
ING ISSA	National Univ. of Singapore Scuola Internazionale Superi-	Kent Ridge, Singapore Trieste, Italy	TUAT	Tokyo Univ. of Agriculture Tech.	Tokyo, Japan
	ore di Studi Avanzati	Tricsve, wary	TUBIN	Univ. Tübingen	Tübingen, Germany
LAC	Stanford Linear Accelera-	Stanford, CA, USA	TUFTS	Tufts Univ.	Medford, MA, USA
	tor Center		TUW	Technische Univ. Wien	Vienna, Austria
LOV	Inst. of Physics, Slovak Acad. of Sciences	Bratislava, Slovakia	UCB	Univ. of California (Berke-	Berkeley, CA, USA
MU	Southern Methodist Univ.	Dallas, TX, USA		ley); Dept. of Physics	
NSP			UCD	Univ. of California (Davis)	Davis, CA, USA
	Scuola Normale Superiore	Pisa, Italy	UCI	Univ. of California (Irvine)	Irvine, CA, USA
OFI	Inst. for Nuclear Research and Nuclear Energy	Sofia, Bulgaria	UCLA	Univ. of California (Los	Los Angeles, CA, USA
OFU	Univ. of Sofia	Sofia, Bulgaria	***	Angeles)	0 1 D:1 my 1104
	Univ. de São Paulo	São Paulo, SP, Brasil	UCND	Union Carbide Corp.	Oak Ridge, TN, USA
	Inst. de Física Teórica (IFT)	São Paulo, SP, Brasil	UCR	Univ. of California (River-	Riverside, CA, USA
SL	Univ. of California (Berke-	Berkeley, CA, USA	HOOD	side)	Camas Dankana CA 110A
	ley); Space Sciences Lab		UCSB	Univ. of California (Santa Barbara)	Santa Barbara, CA, USA
TAN	Stanford Univ.	Stanford, CA, USA	UCSBT	Inst. for Theoretical	Santa Barbara, CA, USA
TEV TLO	Stevens Inst. of Tech. St. Louis Univ.	Hoboken, NJ, USA St. Louis, MO, USA		Physics	
	Stockholm Univ.		UCSC	Univ. of California (Santa	Santa Cruz, CA, USA
ron		Stockholm, Sweden		Cruz)	
	SUNY at Stony Brook	Stony Brook, NY, USA	UCSD	Univ. of California (San	La Jolla, CA, USA
RB	IReS, Inst. de Recherches Subatomiques	Strasbourg, France	UMD	Diego)	College Book MD 1184
TUT	Univ. Stuttgart	Stuttgart, Germany		Univ. of Maryland	College Park, MD, USA
	I Max-Planck-Inst.	Stuttgart, Germany	UNC	Univ. of North Carolina	Greensboro, NC, USA
			UNCCH	Univ. of North Carolina at	Chapel Hill, NC, USA
JGI	Sugiyama Jogakuen Univ.	Aichi, Japan		Chapel Hill	
JRR	Univ. of Surrey	Guildford, Surrey, United	UNCS	Union College	Schenectady, NY, USA
		Kingdom	UNH	Univ. of New Hampshire	Durham, NH, USA
JSS	Univ. of Sussex	Brighton, United Kingdom	UNM	Univ. of New Mexico	Albuquerque, NM, USA
/R	Savannah River Labs.	Aiken, SC, USA	UOEH	Univ. of Occupational and	Kitakyushu, Japan
YDN	Univ. of Sydney	Sydney, NSW, Australia		Environmental Health	, ,
YRA	Syracuse Univ.	Syracuse, NY, USA	UPNJ	Upsala College	East Orange, NJ, USA
AJK	Acad. Sci., Tadzhik SSR	Dushanbe, Tadzhikstan	UPPS	Uppsala Univ.	Uppsala, Sweden
AMU	· · · · · · · · · · · · · · · · · · ·	College Station, TX, USA	UPR	Univ. of Puerto Rico	Rio Piedras, PR, USA
ATA	Tata Inst. of Fundamental	Bombay, India	URI	Univ. of Rhode Island	Kingston, RI, USA
	Research	Domouy, mana	USC	Univ. of Southern Califor-	Los Angeles, CA, USA
\mathbf{BIL}	Tbilisi State University	Tbilisi, Republic of Georgia	050	nia	Los Augeres, OA, OOA
ELA	Tel-Aviv Univ.	Tel Aviv, Israel	USF	Univ. of San Francisco	San Francisco, CA, USA
ELE	Teledyne Brown Engineer-	Huntsville, AL, USA	UTAH	Univ. of Utah; Dept. of	Salt Lake City, UT, USA
	ing		OIMI	Physics; High-Energy Astro-	balt bake Oity, 01, 05A
EMP	_	Philadelphia, PA, USA		physics Inst.	
ENN	Univ. of Tennessee	Knoxville, TN, USA		Univ. of Utrecht	Utrecht, The Netherlands
EXA	Univ. of Texas at Austin	Austin, TX, USA	UTRO	Norwegian Univ. of Sci-	Trondheim, Norway
GAK	Tokyo Gakugei Univ.	Tokyo, Japan		ence & Technology	
GU	Tohoku Gakuin Univ.	Miyagi, Japan	UZINR	Acad. Sci., Ukrainian SSR	Uzhgorod, Ukraine
HES	Aristotle Univ. of Thessa-	Thessaloniki, Greece	VALE	Univ. de Valencia	Burjassot, Valencia, Spain
-200	loniki		VALP	Valparaiso Univ.	Valparaiso, IN, USA
NT	Tokyo Inst. of Technology	Tokyo, Japan	VAND	Vanderbilt Univ.	Nashville, TN, USA
SA	Sagamihara Inst. of Space &	Kanagawa, Japan	VASS	Vassar College	Poughkeepsie, NY, USA
	Astronautical Sci.	Barray valuati	VICT	Univ. of Victoria	Victoria, BC, Canada
MSK		Tomsk, Russian Federation			
MTC	Tokyo Metropolitan Coll.	Tokyo, Japan	VIEN	Inst. für Hochenergiephysik (HEPHY)	Vienna, Austria
ΜU	Tech. Tokyo Metropolitan Univ.	Tokyo, Japan	VILL	Inst. for Particle Physics of	Villigen PSI, Switzerland
	Univ. of Toronto	Toronto, ON, Canada	MIDA	ETH Zürich Univ. of Virginia	Charlotte:11- 374 TIGA
ОНО		Chiba, Japan	VIRG	•	Charlottesville, VA, USA
			VPI	Virginia Tech.	Blacksburg, VA, USA
	(Tohoku Univ.	Sendai, Japan	VRIJ	Vrije Univ.	HV Amsterdam, The Net
	Tokai Univ.	Shimizu, Japan	TITA DES	ATDIA A A A A	lands
	HTokai Univ, SUniv. of Tokyo; Meson Sci-	Hiratsuka, Japan Tokyo, Japan	WABRI	NEidgenossisches Amt für Mess- wesen	Waber, Switzerland
	ence Laboratory	Joy Vorpost		Warsaw Univ.	Warsaw, Poland
OKU	Univ. of Tokushima	Tokushima-shi, Japan	WASCE	R Waseda Univ.; Cosmic Ray	Tokyo, Japan
OKY	Univ. of Tokyo ; High-Energy Physics Group	Tokyo, Japan	WASH	Division Univ. of Washington; Elem.	Seattle, WA, USA
^***	CUniv. of Tokyo; Dept. of	Tokyo, Japan		Particle Experiment (EPE); Particle Astrophysics (PA)	
OKYC				· · · · · · · · · · · · · · · · · · ·	
OKYC ORI	Chemistry Univ. degli Studi di Torino	Torino, Italy	WASU	Waseda Univ.; Dept. of	Tokyo, Japan

WESL WIEN WILL WINR WISC WITW WMIU WONT	Wayne State Univ. Wesleyan Univ. Univ. Wien Coll. of William and Mary Inst. for Nuclear Studies Univ. of Wisconsin Univ. of the Witwatersrand Western Michigan Univ. The Univ. of Western Ontario Woodstock College (No longer in existence)	Detroit, MI, USA Middletown, CT, USA Vienna, Austria Williamsburg, VA, USA Warsaw, Poland Madison, WI, USA Wits, South Africa Kalamazoo, MI, USA London, ON, Canada Woodstock, MD, USA	WUSL Washington Univ. WYOM Univ. of Wyoming YALE Yale Univ. YARO Yaroslav! State Univ. YCC Yokohama Coll. of Commerce YERE Yerevan Physics Inst. YOKO Yokohama National Univ YORKC York Univ. ZAGR Zagreb Univ. ZARA Univ. de Zaragoza Univ. van Amsterdam	Toronto, Canada Zagreb, Croatia Zaragoza, Spain TV Amsterdam, The Nether-
WUPP	Bergische Univ.	Wuppertal, Germany	ZURI Univ. Zürich	lands
WURZ	Univ. Würzburg	Würzburg, Germany		Zürich, Switzerland

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GAUGE AND HIGGS BOSONS



 $I(J^{PC}) = 0.1(1^{--})$

γ MASS

For a review of the photon mass, see BYRNE 77.

VALUE (eV)		CL%	DOCUMENT ID		TECN	COMMENT
< 2	× 10 ⁻¹⁶		1 LAKES	98		Torque on torold bal- ance
• • • We do	not use the	following	data for averages,	fits,	limits, e	tc. • • •
< 9	× 10 ⁻¹⁶	90	² FISCHBACH	94		Earth magnetic field
<(4.73±0.4	5) × 10 ⁻¹²		³ CHERNIKOV	92	SQID	Ampere-law null test
<(9.0 ±8.1) × 10 ⁻¹⁰		⁴ RYAN	85		Coulomb-law null test
< 3	× 10 ⁻²⁷		⁵ CHIBISOV	76		Galactic magnetic field
< 6	× 10 ⁻¹⁶	99.7	DAVIS	75		Jupiter magnetic field
< 7.3	× 10 ⁻¹⁶		HOLLWEG	74		Alfven waves
< 6	× 10 ⁻¹⁷		⁶ FRANKEN	71		Low freq. res. cir.
< 1	× 10 ⁻¹⁴		WILLIAMS	71	CNTR	Tests Gauss law
< 2.3	× 10 ⁻¹⁵		GOLDHABER	68		Satellite data
< 6	× 10 ⁻¹⁵		6 PATEL	65		Satellite data
< 6	× 10 ⁻¹⁵		GINTSBURG	64		Satellite data

¹LAKES 98 report limits on torque on a toroid Cavendish balance, obtaining a limit on $\mu^2 A$ via the Maxwell-Proca equations, where μ is the proton mass and A is the ambient vector potential in the Lorentz gauge. This is the most conservative limit reported, in which $\mathbf{A} \approx (1 \, \mu \, \mathbf{G}) \times (600 \, \mathrm{pc})$ is based on the Galactic field. 2 FISCHBACH 94 report $< 8 \times 10^{-16}$ with unknown CL. We report Baysian CL used elsewhere in these Listings and described in the Statistics section.

CHERNIKOV 92 measures the photon mass at 1.24 K, following a theoretical suggestion that electromagnetic gauge invariance might break down at some low critical temperature. See the erratum for a correction, included here, to the published result.

⁴ RYAN 85 measures the photon mass at 1.36 K (see the footnote to CHERNIKOV 92). ⁵ CHIBISOV 76 depends in critical way on assumptions such as applicability of virial theo-

rem. Some of the arguments given only in unpublished references.

6 See criticism questioning the validity of these results in KROLL 71 and GOLDHABER 71.

γ CHARGE

VALUE (e)	DOCUMENT ID	TECN	COMMENT
<5 × 10 ⁻³⁰	7 RAFFELT	94 TOF	Pulsar f ₁ - f ₂
• • • We do not use th	e following data for average	s, fits, limi	ts, etc. • • •
<2 × 10 ⁻²⁸	⁸ COCCONI	92	VLBA radio telescope
$< 2 \times 10^{-32}$	COCCONI	88 TOF	resolution Pulsar f ₁ — f ₂ TOF

7 RAFFELT 94 notes that COCCONI 88 neglects the fact that the time delay due to dispersion by free electrons in the interstellar medium has the same photon energy dependence as that due to bending of a charged photon in the magnetic field. His limit is based on the assumption that the entire observed dispersion is due to photon charge. It is a factor of 200 less stringent than the COCCONI 88 limit.

8 See COCCONI 92 for less stringent limits in other frequency ranges. Also see RAF-

~ REFERENCES

LAKES	98	PRL 80 1826	R. Lakes	(WISC)
FISCHBACH	94	PRL 73 514	+Kloor, Langel+	(PURD, JHU+)
RAFFELT	94	PR D50 7729	. •	(MPIM)
CHERNIKOV	92	PRL 68 3383	+Gerber, Ott, Gerber	`(ETH)
Also	92B	PRL 69 2999 (erratur	n) Chernikov, Gerber, Ott, Gerber	(ETH)
COCCON	92	AJP 60 750		(ČERN)
COCCONI	88	PL B206 705		(CERN)
RYAN	85	PR D32 802	+Accetta, Austin	(PRIN)
BYRNE	77	Ast.Sp.Sci. 46 115		(LOIC)
CHIBISOV	76	SPU 19 624		(LEBD)
DAVIS	75	PRL 35 1402	, +Goldhaber, Nieto	(CIT, STON, LASL)
HOLLWEG	74	PRL 32 961	,	(NCAR)
FRANKEN	71	PRL 26 115	+Ampulski	(MICH)
GOLDHABER	71	RMP 43 277	+Nieto	(STON, BOHR, UCSB)
KROLL	71	PRL 26 1395		(SLAC)
WILLIAMS	71	PRL 26 721	+Faller, Hill	(WESL)
GOLDHABER	68	PRL 21 567	+Nieto	(STON)
PATEL	65	PL 14 105		(DUKE)
GINTSBURG	64	Sov. Astr. AJ7 536	· ·	`(ASCI)



 $I(J^P) = 0(1^-)$

SU(3) color octet

Mass m=0. Theoretical value. A mass as large as a few MeV may not be precluded, see YNDURAIN 95.

	,			
VALUE	DOCUMENT ID	TECN	COMMENT	
• • • We do not use t	he following data for average:	s, fits, limits,	etc. • • •	
	ABREU	92E DLPH	Spin 1, not 0	
	ALEXANDER	91H OPAL	Spin 1, not 0	
	BEHREND	82D CELL	Spin 1, not 0	
	BERGER	80p PLUT	Spin 1, not 0	
	BRANDELIK	80C TASS	Spin 1, not 0	

gluon REFERENCES

YNDURAIN	95	PL B345 524		(MADU)
ABREU	92E	PL B274 498	+Adam, Adami, Adye, Akesson+	(DELPHI Collab.)
ALEXANDER	91H	ZPHY C52 543	+Allison, Allport, Anderson+	(OPAL Collab.)
BEHREND	82D	PL B110 329	+Chen, Field, Guempel, Schroeder+	(ČELLO Collab.)
BERGER	BOD	PL B97 459	+Genzel, Grigull, Lackas+	(PLUTO Collab.)
BRANDELIK	80C	PL B97 453	+Braunschweig, Gather, Kadansky+	(TASSO Collab.)

graviton

OMITTED FROM SUMMARY TABLE

gravitor MASS

All of the following limits are obtained assuming Yukawa potential in weak field limit. VANDAM 70 argue that a massive field cannot approach general relativity in the zero-mass limit; however, see GOLD-HABER 74 and references therein. h_0 is the Hubble constant in units of 100 km s $^{-1}$ Mpc $^{-1}$.

VALUE (eV)	DOCUMENT ID		COMMENT		
• • • We do not use the follo	owing data for average:	s, fit	s, limits, etc. • • •		
	¹ DAMOUR	91	Binary pulsar PSR 1913+16		
$< 2 \times 10^{-29} h_0^{-1}$ $< 7 \times 10^{-28}$	GOLDHABER	74	Rich clusters		
<7 × 10 ⁻²⁸	HARE	73	Galaxy		
<8 × 10 ⁴	HARE	73	2γ decay		

¹ DAMOUR 91 is an analysis of the orbital period change in binary pulsar PSR 1913+16, and confirms the general relativity prediction to 0.8%. "The theoretical importance of and confirms the general relativity prediction to 0.8%. "The theoretical importance of the [rate of orbital period decay] measurement has long been recognized as a direct confirmation that the gravitational interaction propagates with velocity \boldsymbol{c} (which is the immediate cause of the appearance of a damping force in the binary pulsar system) and thereby as a test of the existence of gravitational radiation and of its quadrupolar nature." TAYLOR 93 adds that orbital parameter studies now agree with general relativity to 0.5%, and set limits on the level of scalar contribution in the context of a family of tensor (spin 2)-biscalar theories

graviton REFERENCES

TAYLOR	93	Nature 355 132	+Wolszczan, Damour+	(PRIN, ARCBO, BURE, CARLC) J
DAMOUR	91	APJ 366 501	+ Taylor	(BURE, MEUD, PRIN)
GOLDHABER	74	PR D9 119	+Nieto	(LANL, STON)
HARE	73	CJP 51 431		(SASK)
VANDAM	70	NP B22 397	van Dam, Veltman	(UTRE)



J = 1

NOTE ON THE MASS OF THE W BOSON

Written March 1998 by C. Caso (Univ. of Genova) and A. Gurtu (Tata Inst.)

Till 1995 the production and study of the W boson was the exclusive domain of the $\bar{p}p$ colliders at CERN and FNAL. W production in these hadron colliders is tagged by a high p_T lepton from W decay. Owing to unknown parton-parton effective energy and missing energy in the longitudinal direction, the experiments reconstruct only the transverse mass of the Wand derive the W mass from comparing the transverse mass distribution with Monte Carlo predictions as a function of M_W .

In 1996 the energy of LEP was increased in two steps to 161 GeV and 172 GeV, allowing the production of pairs of W bosons. A precise knowledge of the e^+e^- centre of mass energy enables one to reconstruct the W mass even if one of them decays leptonically. At LEP two methods have been used to obtain the W mass. In the first method the measured W-pair production cross sections, $\sigma(e^+e^- \to W^+W^-)$, have been used to determine the W mass using the Standard Model based dependence of this cross section on M_W (see Fig. 1). At 161 GeV, which is just above the W-pair production threshold, this dependence is a much more sensitive function of the W mass than at higher energies.

W⁺W⁻ cross section at LEP

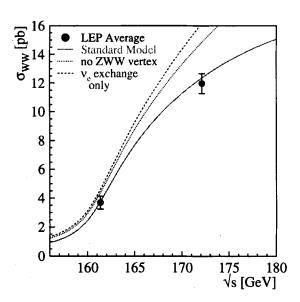


Figure 1: The W-pair cross section as a function of the center-of-mass energy. The data points are the LEP averages. The solid line is the Standard Model prediction. For comparison the figure contains also the cross section if the ZWW coupling did not exist (dotted line), or if only the t-channel ν_e exchange diagram existed (dashed line).

In the second method, which is used at the higher energies, the W mass has been determined by directly reconstructing the W from its decay products.

Each LEP experiment has combined their own mass values properly taking into account the common systematic errors. We have then combined their values into a LEP average leading to: $m_W = 80.49 \pm 0.14$ GeV. The error includes in the systematics a LEP energy uncertainty of ± 30 MeV and, in the case of the reconstruction method for the $q\bar{q}q\bar{q}$ channel, a possible effect of "color reconnection" and "Bose-Einstein correlations" between quarks from different W's. In our combination, the last two effects have been treated as 100% correlated between the experiments.

OUR AVERAGE is obtained by combining this LEP value with other measurements assuming no common systematics.

Combining published and unpublished preliminary Collider and LEP results (as of end of March 1998) yields an average W-boson mass of 80.375 ± 0.064 GeV (80.40 ± 0.09 GeV for p-pColliders and 80.35 ± 0.09 GeV for LEP).

The Standard Model prediction from the electroweak fit, excluding the direct W mass measurements from LEP and Tevatron, gives a W-boson mass of 80.364 ± 0.035 GeV.

W MASS

OUR FIT uses the W and Z mass, mass difference, and mass ratio measurements

VALUE				EVTS	DOCUMENT ID		TECN	COMMENT
	_		OUR FI	-				
	_		OUR AN ± 0.07	72	¹ ABREU	000	OLDU	Eee = 172.14 GeV
			±0.07	72 96	² ACKERSTAFF			Cita
					_			Citi
30.5	+	1.4 2.2	+0.5 -0.6	104	³ ACKERSTAFF	98D	OPAL	Ecm = 172.12 GeV
80.80	±	0.32	±0.114	95	4 BARATE	988	ALEP	Ecm = 172.09 GeV
30.40	±	0.44	± 0.095	29	⁵ ABREU	97	DLPH	Ecm = 161.3 GeV
30.80	+	0.48 0.42	±0.03	20	⁶ ACCIARRI	97	L3	Ecm = 161.3 GeV
		1.4 2.4	±0.3	94	⁷ ACCIARRI	97M	L3	Ecm = 172.13 GeV
80.71	+	0.34	±0.09	101	⁸ ACCIARRI	97 s	L3	Ecm= 172.13 GeV
			±0.095	32	9 BARATE	97	ALEP	Ecm = 161.3 GeV
1.17	+	1.15 1.62		106	10 BARATE	97 S	ALEP	Eee = 172.09 GeV
0.350	±	0.140	±0.230	5982	¹¹ ABACHI	96E	D0	$\mathcal{E}_{CM}^{p\overline{p}} = 1.8 \; TeV$
0.40	+	0.44 0.41	$^{+0.09}_{-0.10}$	23	12 ACKERSTAFF	96в	OPAL	Citi
0.410	ο±	0.180)	8986	¹³ ABE	95P	CDF	$E_{cm}^{p\overline{p}} = 1.8 \; TeV$
9.91	±	0.39		1722	14 ABE	90G	CDF	$E_{\rm CM}^{p\overline{p}} = 1.8 \text{ TeV}$
	W	e do n	ot use th	e followir	ig data for averages	, fits	, limits,	
4	+	10 7		13	15 AID	96 D	H1	$e^{\pm} p \rightarrow \nu_e(\overline{\nu}_e) + X$ $\sqrt{s} \approx 300 \text{ GeV}$
0.84	±	0.22	±0.83	2065	16 ALITTI	92B	UA2	See W/Z ratio below
0.79	±	0.31	±0.84		17 ALITTI	90B	UA2	<i>E</i> ^{<i>pp</i>} _{cm} = 546,630 GeV
0.0	+	3.3	±2.4	22	18 ABE	891	CDF	$E_{\rm cm}^{p\bar{p}} = 1.8 \text{ TeV}$
2.7		1.0	±2.7	149	19 ALBAJAR	89	UA1	$E_{cm}^{pp} = 546,630 \text{ GeV}$
1.8		6.0 5.3	±2.6	46	²⁰ ALBAJAR	89	UA1	E _{CM} = 546,630 GeV
9	±		±6	32	²¹ ALBAJAR	89	UA1	<i>E</i> _{cm} = 546,630 GeV
31.		5.		6	ARNISON	83	UA1	Ecm = 546 GeV
_	_	10.		•	,			Cili
Ю.		6.		4	BANNER	83B	UA2	Repl. by ALITTI 908

 $^{
m 1}$ ABREU 988 obtain this value from a fit to the reconstructed W mass distribution. The W width was taken as its Standard Model value at the fitted W mass. The systematic error includes ± 0.03 GeV due to the beam energy uncertainty and ± 0.05 GeV due to the possible color reconnection and Bose-Einstein effects in the purely hadronic final state. Combining with ABREU 97 authors find: $M(W)=80.33\pm0.30\pm0.06\pm0.03$ (LEP)

² ACKERSTAFF 980 obtain this value from a fit to the reconstructed W mass distribution. The W width was taken as its Standard Model value at the fitted W mass. When both W mass and width are varied they obtain $M(W)=80.30\pm0.27\pm0.095$ GeV. The systematic error includes ±0.03 GeV due to the beam energy uncertainty and ±0.05 GeV due to the possible color reconnection and Bose-Einstein effects in the purely hadronic fl-BD with ACKERSTAFF 96B authors find: $M(W) = 80.35 \pm 0.24 \pm 0.07 \pm 0.03$ (LEP) GeV.

3 ACKERSTAFF 98D derive this value from their measured W W production cross section σ_{WW} =12.3 \pm 1.3 \pm 0.4 pb using the Standard Model depen at the given c.m. energy.

⁴ BARATE 98B obtain this value from a fit to the reconstructed W mass distribution. The W width was taken as its Standard Model value at the fitted W mass. The systematic or willin was taken as its standard model value at the fitted W mass. The systematic error includes ± 0.03 GeV due to the beam energy uncertainty and ± 0.032 GeV due to the possible color reconnection and Bose-Einstein effects in the purely hadronic final state. Combining with the M_W values from cross section measurements at 161 and 172 GeV (BARATE 97 and BARATE 97s) authors find: $M(W) = 80.51 \pm 0.23 \pm 0.08$ GeV.

 5 ABREU 97 derive this value from their measured W-W production cross section σ_{WW} = 3.67 $^{+0.97}_{-0.85}$ \pm 0.19 pb using the Standard Model dependence of σ_{WW} on M_W at the given c.m. energy. The systematics include an error of ± 0.03 GeV arising from the beam energy uncertainty.

⁶ACCIARRI 97 derive this value from their measured W-W production cross section $\sigma_{WW} = 2.89^{+0.81}_{-0.70} \pm 0.14$ pb using the Standard Model dependence of σ_{WW} on M_W at the given c.m. energy. Statistical and systematic errors are added in quadrature and the last error of ± 0.03 GeV arises from the beam energy uncertainty. The same result is given by a fit of the production cross sections to the data.

⁷ACCIARRI 97M derive this value from their measured WW production cross section $\sigma_{WW}=12.27^{+1.41}_{-1.32}\pm0.23$ pb using the Standard Model dependence of σ_{WW} on M_W at the given c.m. energy. Combining with ACCIARRI 97 authors find M(W)=10.00 $80.78^{+0.45}_{-0.41}\pm0.03$ GeV where the last error is due to beam energy uncertainty.

⁸ ACCIARRI 975 obtain this value from a fit to the reconstructed W mass distribution. The Which was taken as its Standard Model value at the fitted W mass. When both W mass and width are varied they obtain $M(W) = 80.72 + 0.31 \pm 0.09$ GeV. The systematic error includes ± 0.03 GeV due to the beam energy uncertainty and ± 0.05 GeV due to the possible color reconnection and Bose-Einstein effects in the purely hadronic final state. Combining with ACCIARRI 97 and ACCIARRI 97M authors find: $M(W) = \pm 0.05$ GeV $80.75^{+0.26}_{-0.27}\pm0.03$ (LEP) GeV.

 9 BARATE 97 derive this value from their measured W-W production cross section σ_{WW} = 4.23 \pm 0.73 \pm 0.19 pb using the Standard Model dependence of σ_{WW} on M_W at the given c.m. energy. The systematics include an error of \pm 0.03 GeV arising from the beam energy uncertainty.

10 BARATE 975 derive this value from their measured W W production cross section σ_{WW}
= 11.71 \pm 1.23 \pm 0.28 pb using the Standard Model dependence of σ_{WW} on M_W at
the given c.m. energy. The errors quoted on the mass are statistical only. Combining
with BARATE 97 authors find: $M(W)=80.20\pm0.33\pm0.09\pm0.03$ (LEP) GeV.

¹¹ ABACHI 96E fit the transverse mass distribution of 5982 $W \rightarrow e \nu_e$ decays. An error of \pm 160 MeV due to the uncertainty in the absolute energy scale of the EM calorimeter is included in the total systematics.

12 ACKERSTAFF 968 derive this value from an analysis of the predicted M_W dependence of their accepted four-fermion cross section, explicitly taking into account interference effects. The systematics include an error of ±0.03 GeV arising from the beam energy uncertainty.

13 ABE 95P use 3268 $W\to \mu\nu_\mu$ events to find $M=80.310\pm0.205\pm0.130$ GeV and 5718 $W\to e\nu_e$ events to find $M=80.490\pm0.145\pm0.175$ GeV. The result given here combines these while accounting for correlated uncertainties.

¹⁴ ABE 90c result from $W\to e\nu$ is 79.91 \pm 0.35 \pm 0.24 \pm 0.19(scale) GeV and from $W\to \mu\nu$ is 79.90 \pm 0.53 \pm 0.32 \pm 0.08(scale) GeV.

¹⁵ AID 96D derive this value as a propagator mass using the Q^2 shape and magnitude of the e^{\pm} charged-current cross sections. $Q^2 > 5000 \, \text{GeV}^2$ events with p_T of the outgoing lepton $> 25 \, \text{GeV}/c$ are used.

 16 ALITTI 92B result has two contributions to the systematic error (± 0.83); one (± 0.81) cancels in m_W/m_Z and one (± 0.17) is noncancelling. These were added in quadrature. We choose the ALITTI 92B value without using the LEP m_Z value, because we perform our own combined fit.

17 There are two contributions to the systematic error (± 0.84) : one (± 0.81) which cancels in m_W/m_Z and one (± 0.21) which is non-cancelling. These were added in quadrature.

18 ABE 89I systematic error dominated by the uncertainty in the absolute energy scale.

 19 ALBAJAR 89 result is from a total sample of 299 $W \to e \nu$ events.

²⁰ ALBAJAR 89 result is from a total sample of 67 $W \to \mu \nu$ events.

²¹ ALBAJAR 89 result is from $W \to \tau \nu$ events.

W/Z MASS RATIO

The fit uses the W and Z mass, mass difference, and mass ratio measurements.

VALUE	EVTS	DOCUMENT I	D TECN	COMMENT
0.8818±0.0011 OUR FIT				
$0.8813 \pm 0.0036 \pm 0.0019$	156	²² ALITTI	92B UA2	$E_{\rm cm}^{p\overline{p}}$ = 630 GeV
• • • We do not use the fol	llowing	data for average	s, fits, limits, et	C. • • •
$0.8831 \pm 0.0048 \pm 0.0026$		22 ALITTI	90B UA2	$E_{\rm cm}^{{ar p}{\overline p}}=546,630~{\rm GeV}$
²² Scale error cancels in thi	s ratio			

1722

 -0.19 ± 0.58

$m_Z - m_W$

The fit uses the ${\it W}$ and ${\it Z}$ mass, mass difference, and mass ratio measurements.

VALUE (GeV)		DOCUMENT ID		TECN	COMMENT			
10.78±0.10 OUR	FIT							
10.4 ±1.4 ±0.8		ALBAJAR	89	UA1	E _{CM} = 546,630 GeV			
• • • We do not use the following data for averages, fits, limits, etc. • • •								
11.3 ±1.3 ±0.9		ANSARI	87	UA2	$E_{cm}^{p\overline{p}} = 546,630 \; GeV$			
		$m_{W^+} - m_V$	v -					
Test of C	PT invariance.							
VALUE (GeV)	EVTS	DOCUMENT ID		TECN	COMMENT			

W WIDTH

90G CDF

ARE

 $E_{\mathsf{CM}}^{ar{p}ar{p}} = 1.8 \; \mathsf{TeV}$

The CDF and DØ widths labelled "extracted value" are obtained by measuring $R=[\sigma(W)/\sigma(Z)]$ [$\Gamma(W\to e\nu_e)]/(B(Z\to ee)\Gamma(W))$ where the bracketed quantities can be calculated with plausible reliability. $\Gamma(W)$ is then extracted by using a value of $B(Z\to ee)$ measured at LEP. The UA1 and UA2 widths used $R=[\sigma(W)/\sigma(Z)]$ [$\Gamma(W\to e\nu_e)/\Gamma(Z\to ee)$] $\Gamma(Z)/\Gamma(W)$ and the measured value of $\Gamma(Z)$. The Standard Model prediction is 2.067 \pm 0.021 (ROSNER 94).

VALUE (GeV) 2.06 ±0.06 (EVTS AGE	DOCUMENT ID	TECN	COMMENT
$1.30 \begin{array}{l} +0.70 \\ -0.55 \end{array} \pm$	0.18	92	²³ ACKERSTAFF	98D OPAL	Ecm = 172.12 GeV
$1.74 \begin{array}{l} +0.88 \\ -0.78 \end{array}$	0.25	101	²⁴ ACCIARRI	975 L3	<i>E</i> _{CM} <i>ee</i> = 172.13 GeV
2.044 ± 0.093		13k	²⁵ ABACHI	95D D0	Extracted value
2.11 ±0.28 ±	0.16	58	²⁶ ABE	95C CDF	Direct meas.
$2.064 \pm 0.060 \pm$	0.059		²⁷ ABE	95w CDF	Extracted value
$2.10 \begin{array}{l} +0.14 \\ -0.13 \end{array} \pm$	0.09	3559	28 ALITTI	92 UA2	Extracted value
2.18 +0.26 ±	0.04	;	²⁹ ALBAJAR	91 UA1	Extracted value

• • • '	We do r	ot use	the fol	lowing o	lata	for averages,	fits, lin	nits, etc.	• • •
2.16	±0.17					ABE	921	CDF	Repl. by ABE 95W
2.12	± 0.20					ABE	90	CDF	Repl. by ABE 921
2.30	±0.19	± 0.06			32	ALITTI	90c	UA2	Extracted value
2.8	$+1.4 \\ -1.5$	±1.3		149	33	ALBAJAR	89	UA1	$E_{\rm CM}^{p\overline{p}}$ = 546,630 GeV
<7			90	251		ANSARI	87		<i>E</i> ^{<i>p</i><u>p</u>} = 546,630 GeV
<7			90	119		APPEL	86	UA2	E _{CM} = 546,630 GeV
<6.5			90	86	34	ARNISON	86	UA1	Repl. by

 23 ACKERSTAFF 980 obtain this value from a fit to the reconstructed $\it W$ mass distribution. 24 ACCIARRI 975 obtain this value from a fit to the reconstructed $\it W$ mass distribution.

²⁵ ABACHI 975 obtain this value from a fit to the reconstructed V mass section V mas

²⁶ ABE 95C use the tail of the transverse mass distribution of $W \to e \nu_e$ decays.

 27 ABE 95W measured $R=10.90\pm0.32\pm0.29$. They use $m_{W}\!=\!80.23\pm0.18$ GeV, $\sigma(W)/\sigma(Z)=3.35\pm0.03$, $\Gamma(W\to e\nu)=225.9\pm0.9$ MeV, $\Gamma(Z\to e^+e^-)=83.98\pm0.18$ MeV, and $\Gamma(Z)=2.4969\pm0.0038$ GeV. 28 ALITTI 92 measured $R=10.4^{+0.7}_{-0.6}\pm0.3$. The values of $\sigma(Z)$ and $\sigma(W)$ come from

²⁸ ALITTI 92 measured $R=10.4^{+0.7}_{-0.6}\pm0.3$. The values of $\sigma(Z)$ and $\sigma(W)$ come from $O(\alpha_S^2)$ calculations using $m_W=80.14\pm0.27$ GeV, and $m_Z=91.175\pm0.021$ GeV along with the corresponding value of $\sin^2\!\theta_W=0.2274$. They use $\sigma(W)/\sigma(Z)=3.26\pm0.07\pm0.05$ and $\Gamma(Z)=2.487\pm0.010$ GeV.

²⁹ ALBAJAR 91 measured $R=9.5^{+1.1}_{-1.0}$ (stat. + syst.). $\sigma(W)/\sigma(Z)$ is calculated in QCD at the parton level using $m_W=80.18\pm0.28$ GeV and $m_Z=91.172\pm0.031$ GeV along with $\sin^2\theta_W=0.2322\pm0.0014$. They use $\sigma(W)/\sigma(Z)=3.23\pm0.05$ and $\Gamma(Z)=2.498\pm0.020$ GeV.

30 ABE 92: report $1216\pm38^{+27}_{-31}W\to\mu\nu$ and $106\pm10^{+0.2}_{-1}Z\to\mu^+\mu^-$ events which are combined with 2426 $W\to e\nu$ events of ABE 91c to derive the ratio σ_W B($W\to \ell\nu$)/ σ_Z B($Z\to\ell^+\ell^-$)= $10.0\pm0.6\pm0.4$. Finally the value of $\Gamma(Z)$ measured by LEP 92 is used to extract $\Gamma(W)$.

31 ABE 90 extract $\Gamma(W)=2.19\pm0.20$ by using the value $\Gamma(Z)=2.57\pm0.07$ GeV. However, in ABE 91c they update their analysis with a new LEP value $\Gamma(Z)=2.496\pm0.016$; the value $\Gamma(W)=2.12\pm0.20$ above reflects this update. They measured $R=10.2\pm0.8\pm0.4$, assumed $\sin^2\theta_W=0.229\pm0.007$, and took predicted values $\sigma(W)/\sigma(Z)=3.23\pm0.03$ and $\Gamma(W\to e\nu)/\Gamma(Z\to ee)=2.70\pm0.02$. This yields $\Gamma(W)/\Gamma(Z)=0.85\pm0.08$. The quoted error for $\Gamma(W)$ includes systematic uncertainties. $E_{CM}^{\rm em}=1.8$ TeV.

³² ALITTI 90c used the same technique as described for ABE 90. They measured $R = 9.38^{+0.82}_{-0.72} \pm 0.25$, obtained $\Gamma(W)/\Gamma(Z) = 0.902 \pm 0.074 \pm 0.024$. Using $\Gamma(Z) = 2.546 \pm 0.032$ GeV, they obtained the $\Gamma(W)$ value quoted above and the limits $\Gamma(W) < 2.56$ (2.64) GeV at the 90% (95%) CL. $E_{\rm CM}^{p\bar{p}} = 546,630$ GeV.

³³ ALBAJAR 89 result is from a total sample of 299 $W \rightarrow e \nu$ events.

 34 If systematic error is neglected, result is $^{2.7}_{-1.5}^{+1.4}$ GeV. This is enhanced subsample of 172 total events.

W ANOMALOUS MAGNETIC MOMENT (△κ)

The full magnetic moment is given by $\mu_W=e(1+\kappa+\lambda)/2m_W$. In the Standard Model, at tree level, $\kappa=1$ and $\lambda=0$. Some papers have defined $\Delta\kappa=1-\kappa$ and assume that $\lambda=0$. Note that the electric quadrupole moment is given by $-e(\kappa-\lambda)/m_W^2$. A description of the parameterization of these moments and additional references can be found in HAGIWARA 87 and BAUR 88. The parameter Λ appearing in the theoretical limits below is a regularization cutoff which roughly corresponds to the energy scale where the structure of the W boson becomes manifest.

VALUE (e/2m _W)	DOCUMENT ID	TECN
• • • We do not use the fol	llowing data for average	es, fits, limits, etc. • • •
	35 ABE	95G
	36 ALITTI	92C UA2
	37 SAMUEL	92 THEO
	³⁸ SAMUEL	91 THEO
	39 GRIFOLS	88 THEO
	⁴⁰ GROTCH	87 THEO
	⁴¹ VANDERBIJ	87 THEO
	⁴² GRAU	85 THEO
	⁴³ SUZUKI	85 THEO
	44 HERZOG	84 THEO

 35 ABE 95G report $-1.3<\kappa<3.2$ for $\lambda=0$ and $-0.7<\lambda<0.7$ for $\kappa=1$ in $p\overline{p}\to e\nu_e\gamma X$ and $\mu\nu_\mu\gamma X$ at $\sqrt{s}=1.8$ TeV.

 36 ALITTI 92c measure $\kappa=1^{+2.6}_{-2.2}$ and $\lambda=0^{+1.7}_{-1.8}$ in $p\overline{p}\to e\nu\gamma+$ X at $\sqrt{s}=630$ GeV. At 95%CL they report $-3.5<\kappa<5.9$ and $-3.6<\lambda<3.5$. 37 SAMUEL 92 use preliminary CDF and UA2 data and find $-2.4<\kappa<3.7$ at 96%CL

 3 SAMUEL 92 use preliminary CDF and UA2 data and find $-2.4 < \kappa < 3.7$ at 96%CL and $-3.1 < \kappa < 4.2$ at 95%CL respectively. They use data for $W\gamma$ production and radiative W decay.

³⁸ SAMUEL 91 use preliminary CDF data for $p\overline{p}\to W\gamma X$ to obtain $-11.3 \le \Delta\kappa \le 10.9$. Note that their $\kappa=1-\Delta\kappa$.

 39 GRIFOLS 88 uses deviation from ρ parameter to set limit $\Delta\kappa\lesssim 65~(M_W^2/\Lambda^2)$.

 40 GROTCH 87 finds the limit $-37 < \Delta\kappa < 73.5$ (90% CL) from the experimental limits on $e^+e^- \to \nu \overline{\nu} \gamma$ assuming three neutrino generations and $-19.5 < \Delta\kappa < 56$ for four generations. Note their $\Delta\kappa$ has the opposite sign as our definition.

41 VANDERBIJ 87 uses existing limits to the photon structure to obtain $|\Delta\kappa|<33$ (m_W/Λ). In addition VANDERBIJ 87 discusses problems with using the ρ parameter of the Standard Model to determine $\Delta\kappa$.

Gauge & Higgs Boson Particle Listings

W

 42 GRAU 85 uses the muon anomaly to derive a coupled ilmit on the anomalous magnetic dipole and electric quadrupole (λ) moments 1.05 $> \Delta\kappa \ln(\Lambda/m_W) + \lambda/2 > -2.77$. In the Standard Model $\lambda=0$.

the Standard Model $\lambda=0$.

43 SUZUKI 85 uses partial-wave unitarity at high energies to obtain $|\Delta\kappa|\lesssim 190$ $(m_W/\Lambda)^2$. From the anomalous magnetic moment of the muon, SUZUKI 85 obtains $|\Delta\kappa|\lesssim 2.2/\ln(\Lambda/m_W)$. Finally SUZUKI 85 uses deviations from the ρ parameter and obtains a very qualitative, order-of-magnitude limit $|\Delta\kappa|\lesssim 150~(m_W/\Lambda)^4$ if $|\Delta\kappa|\ll 100$

44 HERZOG 84 consider the contribution of W-boson to muon magnetic moment including anomalous coupling of $WW\gamma$. Obtain a limit $-1 < \Delta\kappa < 3$ for $\Lambda \gtrsim 1$ TeV.

W+ DECAY MODES

W⁻ modes are charge conjugates of the modes below.

	Mode	Fraction (Γ_I/Γ)	Confidence level
Γ ₁	ℓ+ v	[a] (10.74±0.33) %	
Γ_2	$e^+ \nu$	(10.9 ±0.4) %	
Γ3	$\mu^+ \nu$	(10.2 ±0.5) %	
Γ4	$ au^+ u$	(11.3 ±0.8) %	1
Γ ₅	hadrons	(67.8 ±1.0) %	
Γ ₆	$\pi^+\gamma$	< 2.2 × 10)4 95%

[a] ℓ indicates each type of lepton (e, μ , and τ), not sum over them.

CONSTRAINED FIT INFORMATION

Overall fits are performed to determine the branching ratios of the W. For each LEP experiment the correlation matrix of the leptonic branching ratios is used. A first fit determines three individual leptonic branching ratios, $\mathsf{B}(W\to e\nu_e),\,\mathsf{B}(W\to \mu\nu_\mu),\,\mathsf{and}\,\mathsf{B}(W\to \tau\nu_\tau).$ This fit has a $\chi^2=9.0$ for 17 degrees of freedom. The second fit assumes lepton universality and determines the leptonic branching ratio $\mathsf{B}(W\to \ell\nu_\ell),\,\mathsf{from}$ which one also derives the hadronic branching ratio, assuming $\mathsf{B}(W\to hadrons)=1-3\cdot\mathsf{B}(W\to \ell\nu_\ell).$ This fit has a $\chi^2=10.9$ for 19 degrees of freedom.

W BRANCHING RATIOS

The LEP collaborations obtain the W branching ratios by a fit to their measured cross sections of the final states $e^+e^-\to W^+W^-\to q \overline{q} e \nu_e$, $q \overline{q} \mu \nu_\mu$, $q \overline{q} \tau \nu_\tau$, $q \overline{q} q \overline{q}$, $\ell \nu_\ell \ell \nu_\ell$. The leptonic branching ratios and $\sigma(e^+e^-\to W^+W^-)$ at the respective center-of-mass energies are the fitted parameters. Two fits are performed, one without and one assuming lepton universality. The hadronic branching ratio is derived from the second fit assuming $B(W\to hadrons)=1-3\cdot B(W\to \ell \nu_\ell)$.

$$\Gamma(\ell^+\nu)/\Gamma_{\rm total}$$
 ℓ indicates average over $e,\ \mu,\ {\rm and}\ \tau$ modes, not sum over modes.

Data marked "avg" are highly correlated with data appearing elsewhere in the Listings, and are therefore used for the average given below but not in the overall fits. "f&a" marks results used for the fit and the average.

VALUE		VTS	DOCUMENT ID	TECN	COMMENT
0.1074±0.0033 OUR FIT					
0.108 ±0.005 OUR AVE	RAGE				
0.113 ±0.012 ±0.003	avg	52	ABREU	98B DLPH	Ecm = 161.3 + 172.14 GeV
$0.101 \begin{array}{c} +0.011 \\ -0.010 \end{array} \pm 0.002$	avg	61	ACKERSTAFF	98D OPAL	Ecm = 161.3 + 172.12 GeV
$0.119 \begin{array}{l} +0.013 \\ -0.012 \end{array} \pm 0.002$	avg	51	ACCIARRI	97M L3	Ecm = 161.3 + 172.13 GeV
0.104 ±0.008	avg 36	542 ⁴⁵	ABE	921 CDF	$E_{\text{cm}}^{pp} = 1.8 \text{ TeV}$
45					

 45 1216 \pm 38 $^{+27}_{-31}$ W \rightarrow $\mu\nu$ events from ABE 92I and 2426W \rightarrow $e\nu$ events of ABE 91C. ABE 92I give the inverse quantity as 9.6 \pm 0.7 and we have inverted.

Γ(e⁺ν)/Γ_{total} Data marked "avg" are highly correlated with data appearing elsewhere in the Listings, and are therefore used for the average given below but not in the overall fits. "f&a" marks results used for the fit and the average.

VALUE			EVTS	DOCUMENT ID	TECN	COMMENT
0.109 ±0.004	OUR FIT					
0.109 ±0.004		RAGE				
0.102 +0.038 -0.032	±0.003	f&a	16	ABREU	988 DLPH	Ecm = 161.3 + 172.14 GeV
0.098 +0.022 -0.020	±0.003	f&a	21	ACKERSTAFF	98D OPAL	Ecm = 161.3 + 172.12 GeV
0.165 +0.037 -0.033	±0.005	f&a	23	ACCIARRI	97M L3	Ecm = 161.3 +
0.097 ±0.02	±0.005	f&a	21	BARATE	97S ALEP	172.13 GeV Ecm = 161.3 +
0.1094 ± 0.0033		f&a	4	6 ABE	95w CDF	172.09 GeV E _{CM} = 1.8 TeV
0.10 ±0.014	+0.02 -0.03	f&a	248 4	7 ANSARI	87C UA2	Ecm = 546,630

• • • We do not use the follow	ving data	for averages, fits, I	imits, etc. •	• •
0.106 ±0.0096	2426	⁴⁸ ABE	91c CDF	Repl. by
seen	299	⁴⁹ ALBAJAR	89 UA1	ABE 948 E _{CM} = 546,630 GeV
seen	119	APPEL	86 UA2	E _{cm} = 546,630 GeV
seen	172	ARNISON	86 UA1	Repl. by ALBA- JAR 89

⁴⁶ ABE 95w result is from a measurement of σ B($W \rightarrow e\nu$)/ σ B($Z \rightarrow e^+e^-$) = 10.90±0.32±0.29, the theoretical prediction for the cross section ratio, the experimental knowledge of $\Gamma(Z \rightarrow e^+e^-)$ = 83.98 ± 0.18 MeV, and $\Gamma(Z)$ = 2.4969 ± 0.0038.

47 The first error was obtained by adding the statistical and systematic experimental uncertainties in quadrature. The second error reflects the dependence on theoretical prediction of total W cross section: $\sigma(546 \text{ GeV}) = 4.7 + \frac{1}{0.7}$ nb and $\sigma(630 \text{ GeV}) = 5.8 + \frac{1}{1.0}$ nb.

See ALTARELLI 85. 48 ABE 91C result is from a measurement of $\sigma B(W \to e \nu)/\sigma B(Z \to e^+e^-)$, the theoretical prediction for the cross section ratio, and the experimental knowledge of $\Gamma(Z \to e^+e^-)/\Gamma(Z \to all)$.

⁴⁹ ALBAJAR 89 experiment determines values of branching ratio times production cross

 $\Gamma(\mu^+\nu)/\Gamma_{\text{total}}$ Γ_3/Γ Data marked "avg" are highly correlated with data appearing elsewhere in the Listings, and are therefore used for the average given below but not in the overall fits. "f&a" marks results used for the fit and the average.

VALUE 0.102±0.005 OUR FIT 0.097±0.007 OUR AVE	RAGE	<u>EVT\$</u>	DOCUMENT ID	<u>TECN</u>	COMMENT
$0.107^{+0.032}_{-0.027} \pm 0.003$	f&a	20	ABREU	98B DLPH	E ^{ee} _{CM} = 161.3 + 172.14 GeV
$0.073^{+0.019}_{-0.017} \pm 0.002$	f&a	16	ACKERSTAFF	98D OPAL	Ecm = 161.3 + 172.12 GeV
$0.084^{+0.028}_{-0.024} \pm 0.003$	f&a	13	ACCIARRI	97M L3	Ecm = 161.3 + 172.13 GeV
0.112±0.02 ±0.006	f&a	25	BARATE	97s ALEP	172.13 GeV Ecm = 161.3 + 172.09 GeV
0.10 ±0.01	f&∠a	1216	50 ABE	92i CDF	172.09 GeV E _{CM} ≃ 1.8 TeV
⁵⁰ ABE 921 quote the in	iverse q	uantity a	is 9.9 \pm 1.2 which w	e have inver	ted.

 $\Gamma(\tau^+ \nu)/\Gamma_{total}$ Data marked "avg" are highly correlated with data appearing elsewhere in the Listings, and are therefore used for the average given below but not in the overall fits. "f&a" marks results used for the fit and the average.

			-		
VALUE		EVTS	DOCUMENT ID	TECN	COMMENT
0.113±0.006 OUR FIT					
0.124±0.017 OUR AVE	RAGE				
$0.134^{+0.050}_{-0.048} \pm 0.007$	f&a	16	ABREU	988 DLPH	Ecm = 161.3 +
					172.14 GeV
$0.140^{+0.030}_{-0.028} \pm 0.005$	f&≀a	23	ACKERSTAFF	98D OPAL	Ecm = 161.3 +
±0 042					172.12 GeV
$0.109^{+0.042}_{-0.039} \pm 0.005$	f&ca	15	ACCIARRI	97M L3	Ecm = 161.3 +
					172.13 GeV
$0.113 \pm 0.027 \pm 0.006$	f&a	37	BARATE	97s ALEP	Ecm = 161.3 +
					172 AB C-1/

Γ(hadrons)/Γ_{total}
Data marked "avg" are highly correlated with data appearing elsewhere in the Listings, and are therefore used for the average given below but not in the overall fits. "f&a" marks results used for the fit and the average.

VALUE 0.678±0.010 OUR FIT		<u>EVT\$</u>	DOCUMENT ID	TECN_	COMMENT
0.672±0.017 OUR AVE	KAGE				
$0.660^{+0.036}_{-0.037} \pm 0.009$	avg	57	ABREU	98B DLPH	Ecm = 161.3 + 172.14 GeV
$0.698 + 0.030 \pm 0.007$	avg	52	ACKERSTAFF	98D OPAL	Ecm = 161.3 + 172.12 GeV
$0.642 + 0.037 \pm 0.005$	avg	70	ACCIARRI	97M L3	Ecm = 161.3 + 172.13 GeV
0.677 ± 0.031 ± 0.007	avg	65	BARATE	97s ALEP	Ecm = 161.3 + 172.09 GeV

 $\Gamma(\mu^+\nu)/\Gamma(e^+\nu)$ Γ_3/Γ_2 Data marked "avg" are highly correlated with data appearing elsewhere in the Listings, and are therefore used for the average given below but not in the overall fits. "f&a" marks results used for the fit and the average.

VALUE 0.94±0.05 OUR FIT 0.97±0.06 OUR AVERA		EVTS	DOCUMENT ID	_	TECN	COMMENT
O. 31 E O. OB CON AVEIG	-GL					
0.89 ± 0.10	f&∠a	13k	51 ABACHI	95D	D0	$E_{CM}^{p\overline{p}} = 1.8 \; TeV$
1.02 ± 0.08	f&a	1216	⁵² ABE	921	CDF	$E_{CM}^{p\overline{p}} = 1.8 \; TeV$
• • • We do not use the	ne followi	ng data	for averages, fits, I	imits,	etc. •	• •
1.00±0.14±0.08		67	ALBAJAR	89	UA1	<i>E</i> ^p = 546,630 GeV
$1.24^{+0.6}_{-0.4}$		14	ARNISON	84D	UA1	Repl. by ALBA- JAR 89

REU 98B EPJ C1 (accepted) CERN-PPE/97-160 KERSTAFF 98D EPJ C1 395 RATE 98B PL B422 384

ACKERSTAFF BARATE

 51 ABACHI 950 obtain this result from the measured σ_W B(W $\rightarrow~\mu\nu)=~2.09\pm0.23\pm0.11$ nb and σ_W B(W $\rightarrow~e\nu)=~2.36\pm0.07\pm0.13$ nb in which the first error is the combined statistical and systematic uncertainty, the second reflects the uncertainty in the luminosity.

the luminosity. 52 ABE 921 obtain σ_W B($W \rightarrow \mu\nu$) = 2.21 ± 0.07 ± 0.21 and combine with ABE 91c σ_W $B((W \rightarrow e \nu))$ to give a ratio of the couplings from which we derive this measure

 $\Gamma(\tau^+\nu)/\Gamma(e^+\nu)$ Data marked "avg" are highly correlated with data appearing elsewhere in the Listings and are therefore used for the average given below but not in the overall fits. "f&a" marks results used for the fit and the average.

VALUE	E1	V15	DOCUMENT ID		TECN	COMMENT
1.03 ±0.07 OUR FIT 1.00 ±0.08 OUR AVI						
0.94 ±0.14	f&a 1	179	53 ABE	92E	CDF	$\mathcal{E}_{CM}^{oldsymbol{p}oldsymbol{ar{p}}}$ = 1.8 TeV
$1.04 \pm 0.08 \pm 0.08$	f&a 7	754	⁵⁴ ALITTI	92F	UA2	$E_{\rm CM}^{p\overline{p}} = 630 \text{ GeV}$
1.02 ±0.20 ±0.12	f&a	32	ALBAJAR	89	UA1	E _{cm} = 546,630
• • • We do not use to	he following	data f	or averages, fits, i	lmits,	etc. •	GeV
$0.995 \pm 0.112 \pm 0.083$	1	198	ALITTI	91 C	UA2	Repl. by
1.02 ±0.20 ±0.10		32	ALBAJAR	87	UA1	ALITTI 92F Repl. by ALBA- JAR 89

 53 ABE 92E use two procedures for selecting $W\to \tau\nu_{\tau}$ events. The missing E $_{T}$ trigger leads to 132 \pm 14 \pm 8 events and the τ trigger to 47 \pm 9 \pm 4 events. Proper statistical and systematic correlations are taken into account to arrive at $\sigma B(W \to \tau \nu) = 2.05 \pm 0.27$ nb. Combined with ABE 91c result on $\sigma B(W \to e \nu)$, ABE 92E quote a ratio of the couplings from which we derive this measurement.

54 This measurement is derived by us from the ratio of the couplings of ALITTI 92F.

$\Gamma(\pi^+\gamma)/\Gamma(e^+\nu)$					Γ ₆ /Γ ₂	
VALUE	CL%	DOCUMENT ID	3	TECN	COMMENT	
$< 2.0 \times 10^{-3}$	95	ABE	961 (CDF	$E_{cm}^{p\bar{p}} = 1.8 \text{ TeV}$	ı
$< 4.9 \times 10^{-3}$	95	55 ALITTI	92D (UA2	<i>E</i> ^{pp} _{cm} = 630 GeV	
<58 × 10 ⁻³	95	⁵⁶ ALBAJAR	90 l	UA1	<i>E</i> ^{pp} = 546, 630 GeV	
55 ALITTI 920 limit 56 ALBAJAR 90 obta	is 3.8 × 10 in < 0.04	0 ^{—3} at 90%CL. 18 at 90%CL.				

W REFERENCES

(DELPHI Collab.)

ABREU	97	PL B397 158	+Adam, Adye, Adzic+	(DELPHI	Collab.)
ACCIARRI	97	PL B398 223	+Adriani, Aguilar-Benitez, Ahlen+		Collab.)
ACCIARRI	97M	PL B407 419	M. Acciarri+	(L3	Collab.)
ACCIARRI	97S	PL B413 176	M. Acciarri+		Collab.)
BARATE	97	PL B401 347	+Buskulic, Decamp, Ghez+	(ALEPH	Collab.)
BARATE	975	PL B415 435	R. Barate+	(ALEPH	Collab.
ABACHI	96E	PRL 77 3309	+Abbott, Abolins, Acharya+		Collab.)
ABE	961	PRL 76 2852	+Albrow, Amendolia, Amidei, Antos+		Collab.)
ACKER5TAFF	96B	PL B389 416	+Alexander, Allison, Altekamp+		Collab.)
AID	96D	PL B379 319	+Andreev, Andrieu, Appuhn+		Collab.)
ABACHI	95D	PRL 75 1456	+Abbott, Abolins, Acharya+	ÌDο	Collab.)
ABE	95C	PRL 74 341	+Albrow, Amidei, Antos, Anway-Wiese+	(CDF	Collab.)
ABE	95G	PRL 74 1936	+Albrow, Amidei, Antos+		Collab.)
ABE	95P	PRL 75 11	+Albrow, Amidei, Antos, Anway-Wiese+		Collab.)
Also	95Q	PR D52 4784	Abe, Albrow, Amidei, Antos, Anway-Wie	se+ (CDF	Collab.)
ABE	95W	PR D52: 2624	+Albrow, Amendolia, Amidei, Antos+	(CDF	Collab.)
Also	94B	PRL 73 220	Abe, Albrow, Amidei, Anway-Wiese+		Collab.)
ABE	94B	PRL 73 220	+ Albrow, Amidei, Anway-Wiese+	(CDF	Collab.)
ROSNER	94	PR D49 1363	+Worah, Takeuchi	`(EF)	, FNAL)
ABE	92E	PRL 68 3398	+Amidei, Apollinari, Atac+		Collab.)
ABE	921	PRL 69 28	+Amidei, Apollinari, Atac, Auchincloss+	(CDF	Collab.)
ALITTI	92	PL B276 365	+Ambrosini, Ansari, Autiero, Bareyre+		Collab.)
ALITTI	92B	PL B276 354	+Ambrosini, Ansari, Autlero, Bareyre+	(UA2	Collab.)
ALITTI	92C	PL B277 194	+Ambrosini, Ansari, Autiero, Bareyre+		Collab.)
ALITTI	92D	PL B277 203	+Ambrosini, Ansari, Autiero, Bareyre+	ἶUΑZ	Collab.)
ALITTI	92F	PL B280 137	+Ambrosini, Ansari, Autiero, Bareyre+		Collab.)
LEP	92	PL B276 247	+ALEPH, DELPHI, L3, OPAL	(LEP	Collabs.)
SAMUEL	92	PL B280 124	+Li, Sinha, Sinha, Sundaresan		, CARL)
ADE	916	DD D44 20	(Amidal Amelliani Assa Amelianiani		F-H-1 (

ABE	95W	PR D52 2624	+Albrow, Amendolia, Amidei, Antos+	(CDF Collab.)	
Also	94B	PRL 73 220	Abe, Albrow, Amidei, Anway-Wiese+	(CDF Collab.)	
ABE	94B	PRL 73 220	+Albrow, Amidei, Anway-Wiese+	(CDF Collab.)	
ROSNER	94	PR D49 1363	+Worah, Takeuchi	(EFI, FNAL)	
ABE	92E	PRL 68 3398	+Amidei, Apollinari, Atac+	(CDF Collab.)	
ABE	921	PRL 69 28	+Amidei, Apollinari, Atac, Auchincloss+	(CDF Collab.)	
ALITTI	92	PL B276 365	+Ambrosini, Ansari, Autiero, Bareyre+	(UA2 Collab.)	
ALITTI	92B	PL B276 354	+Ambrosini, Ansari, Autlero, Bareyre+	(UA2 Collab.)	
ALITTI	92C	PL B277 194	+Ambrosini, Ansari, Autiero, Bareyre+	(UA2 Collab.)	
ALITTI	92D	PL B277 203	+Ambrosini, Ansari, Autiero, Bareyre+	(UAZ Collab.)	
ALITTI	92F	PL B280 137	+Ambrosini, Ansari, Autiero, Barevre+	(UA2 Collab.)	
LEP	92	PL B276 247	+ALEPH, DELPHI, L3, OPAL	(LEP Collabs.)	
SAMUEL	92	PL B280 124	+Li, Sinha, Sinha, Sundaresan	(OKSU, CARL)	
ABE	91C	PR D44 29	+Amidei, Apollinari, Atac, Auchincloss+	(CDF Collab.)	
ALBAJAR	91	PL B253 503 ·	+Albrow, Altkofer, Ankoviak, Apsimon+	(UA1 Collab.)	
ALITTI	91C	ZPHY C52 209	+Ambrosini, Ansari, Autiero+	(UA2 Collab.)	
SAMUEL	91	PRL 67 9	+Li, Sinha, Sinha, Sundaresan	(OKSU, CARL)	
Also	91C	PRL 67 2920 erratum		(4,104, 4,114)	
ABE	90	PRL 64 152	+Amidei, Apollinari, Atac, Auchincloss+	(CDF Collab.)	
Also	91C	PR D44 29	Abe, Amidei, Apollinari, Atac, Auchincloss		
ABE	90G	PRL 65 2243	+Amidei, Apollinari, Atac+	(CDF Collab.)	
Also	91B	PR D43 2070	Abe, Amidei, Apollinari, Atac, Auchincloss		
ALBAJAR	90	PL B241 283	+Albrow, Allkofer+	(UA1 Collab.)	
ALITTI	908	PL B241 150	+Ansari, Ansorge, Autlero+	(UA2 Collab.)	
ALITTI	90C	ZPHY C47 11	+Ansari, Ansorge, Bagnaia+	(UA2 Collab.)	
ABE	891	PRL 62 1005	+Amidei, Apollinari, Ascoli, Atac+	(CDF Collab.)	
ALBAJAR	89	ZPHY C44 15	+Albrow, Allkofer, Arnison, Astbury+	(UA1 Collab.)	
BAUR	88	NP B308 127	+Zeppenfeld	(FSU, WISC)	
GRIFOL5	88	IJMP A3 225	+Peris, Sola	(BARC, DESY)	
Also	87	PL B197 437	Grifols, Peris, Sola	(BARC, DESY)	
ALBAJAR	87	PL B185 233	+Albrow, Allkofer, Arnison, Astbury+	(UA1 Collab.)	
ANSARI	87	PL B186 440	+Bagnaia, Banner, Battiston+	(UA2 Collab.)	
ANSARI	87C	PL B194 158	+Bagnaia, Banner, Battiston+	(UA2 Collab.)	
GROTCH	87	PR D36 2153	+ Robinett	(PSU)	
HAGIWARA	87	NP B2B2 253		EK, UCLA, FSU)	
VANDERBIJ	87	PR D35 1088	van der Bil	(FNAL)	
APPEL	86	ZPHY C30 1	+Bagnala, Banner, Battiston+	(UA2 Collab.)	
ARNISON	86	PL 166B 484	+Albrow, Allkofer, Astbury+	(UA1 Collab.)	ı
ALTARELLI	858	ZPHY C27 617		N, FNAL, FRAS)	
GRAU	BS	PL 1548 283	+ Grifols	(BARC)	
SUZUKI	85	PL 153B 289		(LBL)	
ARNISON	84D	PL 134B 469	+Astbury, Aubert, Bacci+	(UA1 Collab.)	
HERZOG	84	PL 148B 355		(WISC)	
Also	84B	PL 155B 468 erratum	Herzog	(WISC)	
ARNISON	83	PL 122B 103	+Astbury, Aubert, Bacci+	(UA1 Collab.)	
BANNER	83B	PL 122B 476	+Battiston, Bloch, Bonaudi+	(UA2 Collab.)	



J = 1

THE Z BOSON

Revised February 1998 by C. Caso (Univ. of Genova) and A. Gurtu (Tata Inst.)

Precision measurements at the Z-boson resonance using electron-positron colliding beams began in 1989 at the SLC and at LEP. During 1989-95, the four CERN experiments have made high-statistics studies of the Z. The availability of longitudinally polarized electron beams at the SLC since 1993 has enabled a precision determination of the effective electroweak mixing angle $\sin^2 \overline{\theta}_W$ that is competitive with the CERN results on this parameter.

The Z-boson properties reported in this section may broadly be categorized as:

- The standard 'lineshape' parameters of the Z consisting of its mass, M_Z , its total width, Γ_Z , and its partial decay widths, $\Gamma(\text{hadrons})$, and $\Gamma(\ell \bar{\ell})$ where $\ell = e, \mu, \tau, \nu$;
- Z asymmetries in leptonic decays and extraction of Z couplings to charged and neutral leptons;
- The b- and c-quark-related partial widths and charge asymmetries which require special techniques;
- Determination of Z decay modes and the search for modes that violate known conservation laws;
- Average particle multiplicities in hadronic Z decay.

For the lineshape-related Z properties there are no new published LEP results after those included in the 1994 edition of this compilation. The reason for this is the identification in mid 1995 of a new systematic effect which shifts the LEP energy by a few MeV. This is due to a drift of the dipole field in the LEP magnets caused by parasitic currents generated by electrically powered trains in the Geneva area. The LEP Energy Working Group has been studying the implications of this for the Z-lineshape properties which would be obtained after analysis of the high statistics 1993-95 data. The main consequence of this effect is expected to be in the determination of the Z mass.

Details on Z-parameter determination and the study of $Z \to b\bar{b}$, $c\bar{c}$ at LEP and SLC are given in this note.

The standard 'lineshape' parameters of the Z are determined with increasing precision from an analysis of the production cross sections of these final states in e^+e^- collisions. The $Z \to \nu \overline{\nu}(\gamma)$ state is identified directly by detecting single photon production and indirectly by subtracting the visible partial widths from the total width. Inclusion in this analysis of the forward-backward asymmetry of charged leptons, $A_{FB}^{(0,\ell)}$, of the τ polarization, $P(\tau)$, and its forward-backward asymmetry, $P(\tau)^{fb}$, enables the separate determination of the effective vector (\overline{g}_V) and axial vector (\overline{g}_A) couplings of the Z to these leptons and the ratio $(\overline{g}_V/\overline{g}_A)$ which is related to the effective electroweak mixing angle $\sin^2 \overline{\theta}_W$ (see the "Electroweak Model and Constraints on New Physics" Review).

Determination of the b- and c-quark-related partial widths and charge asymmetries involves tagging the b and c quarks. Traditionally this was done by requiring the presence of a prompt lepton in the event with high momentum and high transverse momentum (with respect to the accompanying jet). Precision vertex measurement with silicon detectors has enabled one to do impact parameter and lifetime tagging. Neuralnetwork techniques have also been used to classify events as b or non-b on a statistical basis using event-shape variables. Finally, the presence of a charmed meson (D/D^*) has been used to tag heavy quarks.

Z-parameter determination

LEP is run at a few energy points on and around the Z mass constituting an energy 'scan.' The shape of the cross-section variation around the Z peak can be described by a Breit-Wigner ansatz with an energy-dependent total width [1-3]. The three main properties of this distribution, viz., the position of the peak, the width of the distribution, and the height of the peak, determine respectively the values of M_Z , Γ_Z , and $\Gamma(e^+e^-) \times$ $\Gamma(f\overline{f})$, where $\Gamma(e^+e^-)$ and $\Gamma(f\overline{f})$ are the electron and fermion partial widths of the Z. The quantitative determination of these parameters is done by writing analytic expressions for these cross sections in terms of the parameters and fitting the calculated cross sections to the measured ones by varying these parameters, taking properly into account all the errors. Singlephoton exchange (σ_{γ}^0) and γ -Z interference $(\sigma_{\gamma Z}^0)$ are included, and the large (~25 %) initial-state radiation (ISR) effects are taken into account by convoluting the analytic expressions over a 'Radiator Function' [1-4] H(s,s'). Thus for the process

$$\sigma_f(s) = \int H(s, s') \, \sigma_f^0(s') \, ds' \tag{1}$$

$$\sigma_f^0(s) = \sigma_Z^0 + \sigma_{\gamma}^0 + \sigma_{\gamma Z}^0 \tag{2}$$

$$\sigma_{Z}^{0} = \frac{12\pi}{M_{Z}^{2}} \frac{\Gamma(e^{+}e^{-})\Gamma(f\overline{f})}{\Gamma_{Z}^{2}} \frac{s \Gamma_{Z}^{2}}{(s - M_{Z}^{2})^{2} + s^{2}\Gamma_{Z}^{2}/M_{Z}^{2}} (3)$$

$$\sigma_{\gamma}^{0} = \frac{4\pi\alpha^{2}(s)}{3s} Q_{f}^{2} N_{c}^{f} \tag{4}$$

$$\sigma_{\gamma Z}^{0} = -\frac{2\sqrt{2}\alpha(s)}{3} \left(Q_{f}G_{F}N_{c}^{f}g_{Ve}g_{Vf}\right) \times \frac{(s - M_{Z}^{2})M_{Z}^{2}}{(s - M_{Z}^{2})^{2} + s^{2}\Gamma_{Z}^{2}/M_{Z}^{2}}$$
(5)

where Q_f is the charge of the fermion, $N_c^f = 3(1)$ for quark (lepton) and g_{Vf} is the neutral vector coupling of the Z to the fermion-antifermion pair $f\bar{f}$.

· Since $\sigma_{\gamma Z}^0$ is expected to be much less than σ_Z^0 , the LEP Collaborations have generally calculated the interference term in the framework of the Standard Model using the best known values of g_V . This fixing of $\sigma_{\gamma Z}^0$ leads to a tighter constraint on M_Z and consequently a smaller error on its fitted value.

Defining

$$A_f = 2 \frac{g_{Vf} \cdot g_{Af}}{(g_{Vf}^2 + g_{Af}^2)} \tag{6}$$

where g_{Af} is the neutral axial-vector coupling of the Z to $f\overline{f}$, the lowest-order expressions for the various lepton-related asymmetries on the Z pole are [5–7] $A_{FB}^{(0,\ell)}=(3/4)A_eA_f$, $P(\tau)=-A_{\tau}$, $P(\tau)^{fb}=-(3/4)A_e$, $A_{LR}=A_e$. The full analysis takes into account the energy dependence of the asymmetries. Experimentally A_{LR} is defined as $(\sigma_L-\sigma_R)/(\sigma_L+\sigma_R)$ where $\sigma_{L(R)}$ are the $e^+e^-\to Z$ production cross sections with left- (right)-handed electrons.

In terms of g_A and g_V , the partial decay width of the Z to $f\overline{f}$ can be written as

$$\Gamma(f\overline{f}) = \frac{G_F M_Z^3}{6\sqrt{2}\pi} (g_{Vf}^2 + g_{Af}^2) N_c^f (1 + \delta_{\text{QED}}) (1 + \delta_{\text{QCD}})$$
 (7)

where $\delta_{\rm QED}=3\alpha Q_f^2/4\pi$ accounts for final-state photonic corrections and $\delta_{\rm QCD}=0$ for leptons and $\delta_{\rm QCD}=(\alpha_s/\pi)+1.409(\alpha_s/\pi)^2-12.77(\alpha_s/\pi)^3$ for quarks, α_s being the strong coupling constant at $\mu=M_Z$.

In the above framework, the QED radiative corrections have been explicitly taken into account by convoluting over the ISR and allowing the electromagnetic coupling constant to run [8]: $\alpha(s) = \alpha/(1-\Delta\alpha)$. On the other hand, weak radiative corrections that depend upon the assumptions of the electroweak theory and on the values of the unknown M_{top} and M_{Higgs} are accounted for by absorbing them into the couplings, which are then called the effective couplings \bar{g}_V and \bar{g}_A (or alternatively the effective parameters of the \star scheme of Kennedy and Lynn [9]).

S-matrix approach to the Z

While practically all experimental analyses of LEP/SLC data have followed the 'Breit-Wigner' approach described above, an alternative S-matrix-based analysis is also possible. The Z, like all unstable particles, is associated with a complex pole in the S matrix. The pole position is process independent and gauge invariant. The mass, \overline{M}_Z , and width, $\overline{\Gamma}_Z$, can be defined in terms of the pole in the energy plane via [10–13]

$$\overline{s} = \overline{M}_Z^2 - i\overline{M}_Z\overline{\Gamma}_Z \tag{8}$$

leading to the relations

$$\overline{M}_Z = M_Z / \sqrt{1 + \Gamma_Z^2 / M_Z^2}$$

$$\approx M_Z - 34.1 \text{ MeV}$$

$$\overline{\Gamma}_Z = \Gamma_Z / \sqrt{1 + \Gamma_Z^2 / M_Z^2}$$

$$\approx \Gamma_Z - 0.9 \text{ MeV} .$$
(10)

Some authors [14] choose to define the Z mass and width via

$$\overline{s} = (\overline{M}_Z - \frac{i}{2}\overline{\Gamma}_Z)^2 \tag{11}$$

which yields $\overline{M}_Z \approx M_Z - 26$ MeV, $\overline{\Gamma}_Z \approx \Gamma_Z - 1.2$ MeV.

The L3 and OPAL Collaborations at LEP (ACCIARRI 97K and ACKERSTAFF 97C) have analyzed their data using the S-matrix approach as defined in Eq. (8), in addition to

the conventional one. They observe a downward shift in the Z mass as expected.

Handling the large-angle e^+e^- final state

Unlike other $f\overline{f}$ decay final states of the Z, the e^+e^- final state has a contribution not only from the s-channel but also from the t-channel and s-t interference. The full amplitude is not amenable to fast calculation, which is essential if one has to carry out minimization fits within reasonable computer time. The usual procedure is to calculate the non-s channel part of the cross section separately using the Standard Model programs ALIBABA [15] or TOPAZO [16] with the measured value of $M_{\rm top}$, and the 'central' value of $M_{\rm Higgs}$ (300 GeV) and add it to the s-channel cross section calculated as for other channels. This leads to two additional sources of error in the analysis: firstly, the theoretical calculation in ALIBABA itself is known to be accurate to $\sim 0.5\%$, and secondly, there is uncertainty due to the error on M_{top} and the unknown value of M_{Higgs} (60-1000 GeV). These additional errors are propagated into the analysis by including them in the systematic error on the $e^+e^$ final state.

Errors due to uncertainty in LEP energy determination [17-21]

The systematic errors related to the LEP energy measurement can be classified as:

- The absolute energy scale error;
- Energy-point-to-energy-point errors due to the nonlinear response of the magnets to the exciting currents;
- Energy-point-to-energy-point errors due to possible higher-order effects in the relationship between the dipole field and beam energy;
- Energy reproducibility errors due to various unknown uncertainties in temperatures, tidal effects, corrector settings, RF status, etc. Since one groups together data taken at 'nominally same' energies in different fills, it can be assumed that these errors are uncorrelated and are reduced by $\sqrt{N_{\rm fill}}$ where $\overline{N}_{\rm fill}$ is the (luminosity weighted) effective number of fills at a particular energy point.

At each energy point the last two errors can be summed into one point-to-point error.

Choice of fit parameters

The LEP Collaborations have chosen the following primary set of parameters for fitting: M_Z , Γ_Z , $\sigma_{\rm hadron}^0$, $R({\rm lepton})$, $A_{FB}^{(0,\ell)}$, where $R({\rm lepton}) = \Gamma({\rm hadrons})/\Gamma({\rm lepton})$, $\sigma_{\rm hadron}^0 = 12\pi\Gamma(e^+e^-)\Gamma({\rm hadrons})/M_Z^2\Gamma_Z^2$. With a knowledge of these fitted parameters and their covariance matrix, any other parameter can be derived. The main advantage of these parameters

is that they form the **least correlated** set of parameters, so that it becomes easy to combine results from the different LEP experiments.

Thus, the most general fit carried out to cross section and asymmetry data determines the nine parameters: M_Z , Γ_Z , $\sigma_{\rm hadron}^0$, R(e), $R(\mu)$, $R(\tau)$, $A_{FB}^{(0,e)}$, $A_{FB}^{(0,\mu)}$, $A_{FB}^{(0,\tau)}$. Assumption of lepton universality leads to a five-parameter fit determining M_Z , Γ_Z , $\sigma_{\rm hadron}^0$, $R({\rm lepton})$, $A_{FB}^{(0,\ell)}$. The use of only cross-section data leads to six- or four-parameter fits if lepton universality is or is not assumed, *i.e.*, $A_{FB}^{(0,\ell)}$ values are not determined.

In order to determine the best values of the effective vector and axial vector couplings of the charged leptons to the Z, the above mentioned nine- and five-parameter fits are carried out with added constraints from the measured values of A_{τ} and A_{e} obtained from τ polarization studies at LEP and the determination of A_{LR} at SLC.

Combining results from the LEP and SLC experiments [22]

Each LEP experiment provides the values of the parameters mentioned above together with the full covariance matrix. The statistical and experimental systematic errors are assumed to be uncorrelated among the four experiments. The sources of common systematic errors are i) the LEP energy uncertainties, and ii) the effect of theoretical uncertainty in calculating the small-angle Bhabha cross section for luminosity determination and in estimating the non-s channel contribution to the large-angle Bhabha cross section. Using this information, a full covariance matrix, V, of all the input parameters is constructed and a combined parameter set is obtained by minimizing $\chi^2 = \Delta^T V^{-1} \Delta$, where Δ is the vector of residuals of the combined parameter set to the results of individual experiments.

Non-LEP measurement of a Z parameter, $(e.g., \Gamma(e^+e^-)$ from SLD) is included in the overall fit by calculating its value using the fit parameters and constraining it to the measurement.

Study of $Z \rightarrow b\overline{b}$ and $Z \rightarrow c\overline{c}$

In the sector of c- and b-physics the LEP experiments have measured the ratios of partial widths $R_b = \Gamma(Z \to b\bar{b})/\Gamma(Z \to \text{hadrons})$ and $R_c = \Gamma(Z \to c\bar{c})/\Gamma(Z \to \text{hadrons})$ and the forward-backward (charge) asymmetries $A_{FB}^{b\bar{b}}$ and $A_{FB}^{c\bar{c}}$. Several of the analyses have also determined other quantities, in particular the semileptonic branching ratios, $B(b \to \ell)$ and $B(b \to c \to \ell^+)$, the average $B^0\bar{B}^0$ mixing parameter $\bar{\chi}$ and the probabilities for a c-quark to fragment into a D^+ , a D_s , a D^{*+} , or a charmed baryon. The latter measurements do not concern properties of the Z boson and hence they are not covered in this section. However, they are correlated with the electroweak parameters, and since the mixture of b hadrons is different from the one at the $\Upsilon(4S)$, their values might differ from those measured at the $\Upsilon(4S)$.

All the above quantities are correlated to each other since:

- Several analyses (for example the lepton fits) determine more than one parameter simultaneously;
- Some of the electroweak parameters depend explicitly on the values of other parameters (for example R_b depends on R_c);
- Common tagging and analysis techniques produce common systematic uncertainties.

The LEP Electroweak Heavy Flavour Working Group has developed [23] a procedure for combining the measurements taking into account known sources of correlation. The combining procedure determines eleven parameters: the four parameters of interest in the electroweak sector, R_b , R_c , $A_{FB}^{b\bar{b}}$, and $A_{FB}^{c\bar{c}}$ and, in addition, $B(b \to \ell)$, $B(b \to c \to \ell^+)$, $\bar{\chi}$, $f(D^+)$, $f(D_s)$, $f(c_{\rm baryon})$ and $P(c \to D^{*+}) \times B(D^{*+} \to \pi^+ D^0)$, to take into account their correlations with the electroweak parameters. Before the fit both the peak and off-peak asymmetries are translated to $\sqrt{s} = 91.26$ GeV using the predicted dependence from ZFITTER [4].

Summary of the measurements and of the various kinds of analysis

The measurements of R_b and R_c fall into two classes. In the first, named single-tag measurement, a method for selecting b and c events is applied and the number of tagged events is counted. The second technique, named double-tag measurement, is based on the following principle: if the number of events with a single hemisphere tagged is N_t and with both hemispheres tagged is N_{tt} , then given a total number of N_{had} hadronic Z decays one has:

$$\frac{N_t}{2N_{had}} = \varepsilon_b R_b + \varepsilon_c R_c + \varepsilon_{uds} (1 - R_b - R_c) \tag{12}$$

$$\frac{N_{tt}}{N_{\text{had}}} = \mathcal{C}_b \varepsilon_b^2 R_b + \mathcal{C}_c \varepsilon_c^2 R_c + \mathcal{C}_{uds} \varepsilon_{uds}^2 (1 - R_b - R_c)$$
 (13)

where ε_b , ε_c , and ε_{uds} are the tagging efficiencies per hemisphere for b, c, and light quark events, and $C_q \neq 1$ accounts for the fact that the tagging efficiencies between the hemispheres may be correlated. In tagging the b one has $\varepsilon_b \gg \varepsilon_c \gg \varepsilon_{uds}$, $C_b \approx 1$. Neglecting the c and uds background and the hemisphere correlations, these equations give:

$$\varepsilon_b = 2N_{tt}/N_t \tag{14}$$

$$R_b = N_t^2 / (4N_{tt}N_{had}) . ag{15}$$

The double-tagging method has thus the great advantage that the tagging efficiency is directly derived from the data, reducing the systematic error of the measurement. The backgrounds, dominated by $c\bar{c}$ events, obviously complicate this simple picture, and their level must still be inferred by other means. The rate of charm background in these analyses depends explicitly on the value of R_c . The correlations in the

tagging efficiencies between the hemispheres (due for instance to correlations in momentum between the b hadrons in the two hemispheres) are small but nevertheless lead to further systematic uncertainties.

The measurements in the b- and c-sector can be grouped in the following categories:

- Lepton fits which use hadronic events with one or more leptons in the final state. Each analysis usually gives several electroweak parameters chosen among: R_b , R_c , $A_{FB}^{b\bar{b}}$, $A_{FB}^{c\bar{c}}$, $B(b \to \ell)$, $B(b \to c \to \ell^+)$ and $\overline{\chi}$. The output parameters are then correlated. The dominant sources of systematics are due to lepton identification, to other semileptonic branching ratios and to the modelling of the semileptonic decay;
- Event shape tag for R_h ;
- Lifetime (and lepton) double-tagging measurements
 of R_b. These are the most precise measurements
 of R_b and obviously dominate the combined result.
 The main sources of systematics come from the
 charm contamination and from estimating the hemisphere b-tagging efficiency correlation. The charm
 rejection has been improved (and hence the systematic errors reduced) by using either the information
 of the secondary vertex invariant mass or the information from the energy of all particles at the
 secondary vertex and their rapidity;
- Measurements of A^{bb}_{FB} using lifetime tagged events with a hemisphere charge measurement. Their contribution to the combined result has roughly the same weight as the lepton fits;
- Analyses with D/D*± to measure R_c. These measurements make use of several different tagging techniques (inclusive/exclusive double tag, inclusive single/double tag, exclusive double tag, reconstruction of all weakly decaying D states) and no assumptions are made on the energy dependence of charm fragmentation;
- Analyses with $D/D^{*\pm}$ to measure $A_{FB}^{c\bar{c}}$ or simultaneously $A_{FB}^{b\bar{b}}$ and $A_{FB}^{c\bar{c}}$;
- Measurements of A_b and A_c from SLD, using several tagging methods (lepton, D/D^* , and impact parameter). These quantities are directly extracted from a measurement of the left-right forward-backward asymmetry in $c\bar{c}$ and $b\bar{b}$ production using a polarized electron beam.

Averaging procedure

All the measurements are provided by the LEP Collaborations in the form of tables with a detailed breakdown of the systematic errors of each measurement and its dependence on other electroweak parameters. The averaging proceeds via the following steps:

- Define and propagate a consistent set of external inputs such as branching ratios, hadron lifetimes, fragmentation models etc. All the measurements are also consistently checked to ensure that all use a common set of assumptions (for instance since the QCD corrections for the forward-backward asymmetries are strongly dependent on the experimental conditions, the data are corrected before combining);
- Form the full (statistical and systematic) covariance matrix of the measurements. The systematic correlations between different analyses are calculated from the detailed error breakdown in the measurement tables. The correlations relating several measurements made by the same analysis are also used:
- Take into account any explicit dependence of a measurement on the other electroweak parameters. As an example of this dependence we illustrate the case of the double-tag measurement of R_b, where c-quarks constitute the main background. The normalization of the charm contribution is not usually fixed by the data and the measurement of R_b depends on the assumed value of R_c, which can be written as:

$$R_b = R_b^{\text{meas}} + a(R_c) \frac{(R_c - R_c^{\text{used}})}{R_c} , \qquad (16)$$

where R_b^{meas} is the result of the analysis which assumed a value of $R_c = R_c^{\text{used}}$ and $a(R_c)$ is the constant which gives the dependence on R_c ;

 Perform a X² minimization with respect to the combined electroweak parameters.

After the fit the average peak asymmetries $A_{FB}^{c\bar{c}}$ and A_{FB}^{bb} are corrected for the energy shift and for QED, γ exchange, and γZ interference effects to obtain the corresponding pole asymmetries $A_{FB}^{0,c}$ and $A_{FB}^{0,b}$. A small correction is also applied to both R_b and R_c to account for the contribution of γ exchange.

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Z MASS

The fit is performed using the Z mass and width, the Z hadronic pole cross section, the ratios of hadronic to leptonic partial widths, and the Z pole forward-backward lepton asymmetries. We believe that this set is the most free of correlations. Common systematic errors are taken into account. For more details, see the 'Note on the Z Boson.'

The Z-boson mass listed here corresponds to a Breit-Wigner resonance parameter. The value is 34 MeV greater than the real part of the position of the pole (in the energy-squared plane) in the Z-boson propagator. Also the LEP experiments have generally assumed a fixed value of the $\gamma-Z$ interferences term based on the standard model. Keeping this term as free parameter leads to a somewhat larger error on the fitted Z mass. See ACCIARRI 97K and ACKERSTAFF 97C for a detailed investigation of both these issues.

A new source of LEP energy variation was discovered in mid 1995: an energy change of a few MeV is correlated with the passage of a train on nearby railway tracks. The LEP energy working group is studying the implications of this effect for the high statistics data recorded since 1993. The main consequence of this is expected to be a shift in the overall LEP energy values leading to a corresponding shift in the value of m_Z . The LEP collaborations have consequently deferred publication of their results on Z lineshape and lepton forward-backward asymmetries based on 1993 and later data.

Because of the high current interest, we mention here the following preliminary results, but do not average them or include them in the Listings or Tables.

Combining published and unpublished preliminary LEP results (as of end of February 1998) yields an average Z-boson mass of 91.1867 \pm 0.0020 GeV, with a total width of 2.4948 \pm 0.0025 GeV.

VALUE (GeV)	EVTS	DOCUMENT ID		TECN	COMMENT
91.187±0.007 OUR F					
91.188±0.007 OUR A	WERAGE				
91.187±0.007±0.006	1.16M	¹ ABREU	94	DLPH	<i>E</i> ^{ee} _{cm} = 88-94 GeV
91.195±0.006±0.007	1.19M	¹ ACCIARRI	94	L3	Ecm = 88-94 GeV
$91.182 \pm 0.007 \pm 0.006$	1.33M	¹ AKERS	94	OPAL	<i>E</i> ^{ee} cm≃ 88-94 GeV
91.187±0.007±0.006	1.27M	¹ BUSKULIC	94	ALEP	<i>Ec</i> m= 88-94 GeV

93.1 ±1.0 ±3.0

91.193±0.010	1.2M	² ACCIARRI	97K L3	Ecm = LEP1 + 130-136			
				GeV + 161-172 GeV			
91.185 ± 0.010		³ ACKERSTAFF	97c OPAL	Citi			
		4		GeV + 161 GeV			
91.162 ± 0.011	1.2M		96B L3	Repl. by ACCIARRI 97K			
91.192±0.011	1.33M	⁵ ALEXANDER	96x OPAL	Repl. by ACKER- STAFF 97C			
91.151 ± 0.008		⁶ MIYABAYASHI	95 TOPZ	Ecm = 57.8 GeV			
$91.181 \pm 0.007 \pm 0.006$	512k		93D OPAL	Repl. by AKERS 94			
91.195 ± 0.009	460k	⁸ ADRIANI	93F L3	Repl. by ACCIARRI 94			
91.187 ± 0.009	520k	⁹ BUSKULIC	93J ALEP	Repl. by BUSKULIC 94			
$91.74 \pm 0.28 \pm 0.93$	156	10 ALITTI	92B UA2	<i>E</i> _{CM} = 630 GeV			
89.2 +2.1 -1.8		11 ADACHI	90F RVUE				
90.9 ±0.3 ±0.2	188	12 ABE	89c CDF	$E_{cm}^{ hoar{p}}$ = 1.8 TeV			
91.14 +0.12	480	13 ABRAMS	898 MRK2	F66 - 89-93 GeV			

- ¹ The second error of 6.3 MeV is due to a common LEP energy uncertainty.
- ACCIARRI 97k interpret the s-dependence of the cross sections and lepton forward-backward asymmetries in the framework of the S-matrix formalism with a combined fit to their cross section and asymmetry data at the Z peak (ACCIARRI 94) and their data at 130, 136, 161, and 172 GeV. The authors have corrected the measurement for the 34.1 MeV shift with respect to the Breit-Wigner fits. The error contains a contribution

24 14,15 ALBAJAR 89 UA1 $E_{\text{Cm}}^{\overline{p}\overline{p}}$ 546,630 GeV

- of ± 3 MeV due to the uncertainty on the γZ interference.

 3 ACKERSTAFF 97C obtain this using the S-matrix formalism for a combined fit to their cross-section and asymmetry data at the Z peak (AKERS 94) and their data at 130, 136, and 161 GeV. The authors have corrected the measurement for the 34 MeV shift with respect to the Breit-Wigner fits.
- ACCIARRI 968 interpret the s-dependence of the cross sections and lepton forward-backward asymmetries in the framework of the S-matrix ansatz. The 130–136 GeV data constrains the γZ interference terms. As expected, this result is below the mass values obtained with a standard Breit-Wigner parametrization.
- 5 ALEXANDER 96x obtain this using the S-matrix formalism for a combined fit to their cross-section and asymmetry data at the Z peak (AKERS 94) and their data at 130 and 136 GeV. The authors have corrected the measurement for the 34 MeV shift with respect to the Breit-Wigner fits.
- ⁶ MIYABAYASHI 95 combine their low energy total hadronic cross-section measurement with the ACTON 93D data and perform a fit using an S-matrix formalism. As expected, this result is below the mass values obtained with the standard Breit-Wigner parametriza-
- tion.
 7 The systematic error in ACTON 93D is from the uncertainty in the LEP energy calibration. ⁸ The error in ADRIANI 93F includes 6 MeV due to the uncertainty in LEP energy calibra-
- 9 BUSKULIC 93J supersedes DECAMP 92B. The error includes 6 MeV due to the uncertainty in LEP energy calibration.
- 10 Enters fit through W/Z mass ratio given in the W Particle Listings. The ALITTI 928 systematic error (± 0.93) has two contributions: one (± 0.92) cancels in m_W/m_Z and one (± 0.12) is noncancelling. These were added in quadrature.
- 11 ADACHI 90F use a Breit-Wigner resonance shape fit and combine their results with published data of PEP and PETRA.
- 12 First error of ABE 89 is combination of statistical and systematic contributions; second is mass scale uncertainty.
- 13 ABRAMS 89B uncertainty includes 35 MeV due to the absolute energy measurement.
- 14 Enters fit through Z-W mass difference given in the W Particle Listings.
- 15 ALBAJAR 89 result is from a total sample of 33 $Z \rightarrow e^+e^-$ events.

Z WIDTH

VALUE (GeV)	EVTS	DOCUMENT ID		TECN	COMMENT	
2.490±0.007 OUR FIT	•					
2.491±0.007 OUR AV	ERAGE					
$2.50 \pm 0.21 \pm 0.06$		¹⁶ ABREU	96R	DLPH	Ecm = 91.2 GeV	
$2.483 \pm 0.011 \pm 0.0045$	1.16M	17 ABREU	94	DLPH	Ecm = 88-94 GeV	
2.494±0.009±0.0045	1.19M	¹⁷ ACCIARRI	94	L3	Ecm = 88-94 GeV	
$2.483 \pm 0.011 \pm 0.0045$	1.33M	¹⁷ AKERS	94	OPAL	Ecm = 88-94 GeV	
$2.501 \pm 0.011 \pm 0.0045$	1.27M	¹⁷ BUSKULIC	94	ALEP	Ecm = 88-94 GeV	
• • • We do not use t	he followi	ng data for average	s, flts,	limits,	etc. • • •	
2.494±0.010	1.2M	¹⁸ ACCIARRI	97K	L3	Eee = LEP1 + 130-136	
		10			GeV + 161-172 GeV	
2.492±0.010	1.2M	19 ACCIARRI	96B		Repl. by ACCIARRI 97K	
$2.483 \pm 0.011 \pm 0.004$	512k	²⁰ ACTON		OPAL	Repl. by AKERS 94	
2.490 ± 0.011	460k	²¹ ADRIANI	93F I	L3	Repl. by ACCIARRI 94	
2.501 ± 0.012 -	520k	²² BUSKULIC	93.	ALEP	Repl. by BUSKULIC 94	
$3.8 \pm 0.8 \pm 1.0$	188	ABE	89C	CDF	'E ^{pp} _{cm} = 1.8 TeV	
2.42 +0.45 -0.35	480	²³ ABRAMS	89B	MRK2	Eee = 89-93 GeV	
$2.7 \begin{array}{c} +1.2 \\ -1.0 \end{array} \pm 1.3$	24	²⁴ ALBAJAR	89	UA1	$E_{\text{cm}}^{p\overline{p}}$ = 546,630 GeV	
2.7 ±2.0 ±1.0	25	²⁵ ANSARI	87	UA2	<i>E</i> ^{pp} _{cm} = 546,630 GeV	

- $^{16}\hspace{0.05cm}\mathsf{ABREU}$ 96R obtain this value from a study of the interference between initial and final
- state radiation in the process $e^+e^- \to Z \to \mu^+\mu^-$. 17 The second error of 4.5 MeV is due to a common LEP energy uncertainty.
- 18 ACCIARRI 97k Interpret the s-dependence of the cross sections and lepton forward-backward asymmetries in the framework of the 5-matrix formalism with a combined fit to their cross section and asymmetry data at the Z peak (ACCIARRI 94) and their data at 130, 136, 161, and 172 GeV. The authors have corrected the measurement for the 0.9 MeV shift with respect to the Breit-Wigner fits.

- 19 ACCIARRI 96B Interpret the s-dependence of the cross sections and lepton forward-backward asymmetries in the framework of the S-matrix ansatz. The 130–136 GeV data constrains the γZ interference terms. The fitted width is expected to be 0.9 MeV less than that obtained using the standard Breit-Wigner parametrization (see 'Note on the
- ²⁰The systematic error is from the uncertainty in the LEP energy calibration.
- ²¹ The error in ADRIANI 93F includes 4 MeV due to the uncertainty in LEP energy calibra-
- 22 The error in BUSKULIC 93J includes 4 MeV due to the uncertainty in LEP energy
- calibration.

 23 ABRAM5 89B uncertainty includes 50 MeV due to the miniSAM background subtraction
- error. 24 ALBAJAR 89 result is from a total sample of 33 $Z \rightarrow e^+e^-$ events.
- 25 Quoted values of ANSARI 87 are from direct fit. Ratio of Z and W production gives either $\Gamma(Z) < (1.09 \pm 0.07) \times \Gamma(W)$, CL = 90% or $\Gamma(Z) = (0.82 \stackrel{+}{_{-}}0.14 \pm 0.06) \times \Gamma(W)$. Assuming Standard-Model value $\Gamma(W) = 2.65$ GeV then gives $\Gamma(Z) < 2.89 \pm 0.19$ or = $2.17 \stackrel{+}{_{-}}0.37 \pm 0.16$.

Z DECAY MODES

	Mode		Fraction (Γ_I/Γ)	Confidence level
Γ ₁	e+e-		(3.366±0.008)	%
Γ ₂	$\mu^+\mu^-$		(3.367±0.013)	
Γ3	$\tau^+\tau^-$		(3.360±0.015)	%
Γ_4	l+l-		[a] (3.366±0.006)	%
Γ ₅	invisible		(20.01 ±0.16)	%
Γ ₆	hadrons		(69.90 ±0.15)	1 %
Γ7	$(u\overline{u}+c\overline{c})/2$		(10.1 ± 1.1)) %
Гв	$(d\overline{d} + s\overline{s} + b\overline{b})/3$		(16.6 ± 0.6)	%
Γg	c₹		(12.4 ± 0.6)	%
Γ ₁₀	bБ		(15.16 ±0.09)	%
Γ_{11}	g g g		< 1.1	% 95%
Γ ₁₂	$\pi^{0}\gamma$		< 5.2	× 10 ⁻⁵ 95%
Γ ₁₃	$\eta \gamma$		< 5.1	× 10 ⁻⁵ 95%
□ 14	$\omega\gamma$		< 6.5	× 10 ⁻⁴ 95%
[₁₅	$\eta'(958)\gamma$		< 4.2	× 10 ⁻⁵ 95%
Γ ₁₆	$\gamma\gamma$		< 5.2	× 10 ⁻⁵ 95%
Γ ₁₇	777		< 1.0	× 10 ⁻⁵ 95%
_18	$\pi^{\pm}W^{\mp}$		[b] < 7	× 10 ⁻⁵ 95%
[₁₉	ρ± W [∓]		[b] < 8.3	× 10 ⁻⁵ 95%
[₂₀	$J/\psi(15)X$		(3.66 ±0.23	
r ₂₁	ψ(25)X		(1.60 ±0.29)	
F ₂₂	$\chi_{c1}(1P)X$,) × 10 ⁻³
Γ ₂₃	$\chi_{c2}(1P)X$		< 3.2	× 10 ⁻³ 90%
Γ ₂₄	$\Upsilon(1S) \times + \Upsilon(2S) \times + \Upsilon(3S) \times$		(1.0 ±0.5)	× 10 ⁻⁴
Γ ₂₅	T(1S)X		< 5.5 .	× 10 ⁻⁵ 95%
Γ ₂₆	T(25)X		< 1.39	× 10 ⁻⁴ 95%
Γ ₂₇	T(35)X		< 9.4	× 10 ⁻⁵ 95%
Γ28	(D^0/\overline{D}^0) X		(20.7 ± 2.0)	%
Γ ₂₉	D [±] X		(12.2 ± 1.7)	%
Γ ₃₀	D*(2010)±X		[b] (11.4 ± 1.3)	%
Γ31	BX			
Γ32	<i>B</i> *X			
Γ ₃₃	$B_s^0 X$		seen	
Γ ₃₄	anomalous $\gamma+$ hadrons		[c] < 3.2	× 10 ⁻³ 95%
Γ ₃₅	$e^+e^-\gamma$		[c] < 5.2	×10 ⁻⁴ 95%
Γ ₃₆	$\mu^+\mu^-\gamma$		[c] < 5.6	× 10 ⁻⁴ 95%
Γ ₃₇	$\tau^+\tau^-\gamma$		[c] < 7.3	× 10 ⁻⁴ 95%
F38	$\ell^+\ell^-\gamma\gamma$		[d] < 6.8	× 10 ⁻⁶ 95%
۲ ₃₉	q <u>q</u> γγ		[d] < 5.5	× 10 ⁻⁶ 95%
F40	$\nu \overline{\nu} \gamma \gamma$		[d] < 3.1	× 10 ⁻⁶ 95%
Γ ₄₁	$e^{\pm}\mu^{\mp}$	LF	[b] < 1.7	× 10 ⁻⁶ 95%
Γ ₄₂	$e^{\pm} au^{\mp}$ $\mu^{\pm} au^{\mp}$	LF	[b] < 9.8	× 10 ⁻⁶ 95%
Γ ₄₃	$\mu^+ \tau^{r}$	LF	[b] < 1.2	× 10 ⁻⁵ 95%

- [a] ℓ indicates each type of lepton $(e, \mu, \text{ and } \tau)$, not sum over them.
- [b] The value is for the sum of the charge states of particle/antiparticle states
- [c] See the Particle Listings below for the γ energy range used in this measurement.
- [d] For $m_{\gamma\gamma} = (60 \pm 5)$ GeV.

Z PARTIAL WIDTHS

Γ(e ⁺ e ⁻)	P experiments, this parameter is not directly used in the overall fing the fit results; see the 'Note on the Z Boson.'	Γ1
` For the LE	P experiments, this parameter is not directly used in the overall fi	t but is
derived usi	ng the fit results; see the 'Note on the Z Boson.'	

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
83.82±0.30 OUR FIT	Г				
82.89±1.20±0.89		²⁶ ABE	95J	SLD	Ecm = 91.31 GeV
• • • We do not use	the following	ig data for averag	es, fit	s, limits,	etc. • • •
83.31 ± 0.54	31.4k	ABREU	94	DLPH	Ecm = 88-94 GeV
83.43±0.52	38k	ACCIARRI	94	L3	Ecm = 88-94 GeV
83.63±0.53	42k	AKERS	94	OPAL	Ecm = 88-94 GeV
84.61±0.49	45.8k	BUSKULIC	94	ALEP	Eee = 88-94 GeV
					- ····

 26 ABE 95J obtain this measurement from Bhabha events in a restricted fiducial region to improve systematics. They use the values 91.187 and 2.489 GeV for the Z mass and total decay width to extract this partial width.

 $\Gamma(\mu^+\mu^-)$ Γ_2 This parameter is not directly used in the overall fit but is derived using the fit results; see the 'Note on the Z Boson.'

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
83.83±0.39 OUR • • • We do not		or data for averag	ac fit	c limite	etc
		-			
84.15±0.77	45.6k	ABREU			Ecm = 88-94 GeV
83.20±0.79	34k	ACCIARRI	94	L3	<i>E</i> ^{ee} _{CM} = 88−94 GeV
83.83±0.65	57k	AKERS	94	OPAL	Ecm = 88-94 GeV
83.62±0.75	46.4k	BUSKULIC	94	ALEP	Ecm = 88-94 GeV

 $\Gamma(\tau^+\tau^-)$ This parameter is not directly used in the overall fit but is derived using the fit results; see the 'Note on the Z Roson.'

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT	
83.67±0.44 OUR	FIT				_	
• • • We do not	use the followin	ig data for averag	es, fit	s, limits,	etc. • • •	
83.55 ± 0.91	25k	ABREU	94	DLPH	Ecm = 88-94 GeV	
84.04 ± 0.94	25k	ACCIARRI	94	L3	Ecm = 88-94 GeV	
82.90±0.77	47k	AKERS	94	OPAL	Ecm = 88-94 GeV	
84.18±0.79	45.1k	BUSKULIC	94	ALEP	<i>E</i> cm = 88–94 GeV	
F/#+#~\						_

In our fit $\Gamma(\ell^+\ell^-)$ is defined as the partial Z width for the decay into a pair of massless charged leptons. This parameter is not directly used in the 5-parameter fit assuming lepton universality but is derived using the fit results. See the 'Note on the Z Boson.'

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT	
83.83±0.27 OUR I	FIT					
• • • We do not u	ise the following	g data for averag	es, fit	s, limits,	etc. • • •	
83.56 ± 0.45	102k	ABREU	94	DLPH	Eee = 88-94 GeV	
83.49±0.46	97k	ACCIARRI	94	L3	Eee = 88-94 GeV	
83.55 ± 0.44	146k	AKERS	94	OPAL	Eee = 88-94 GeV	
84.40±0.43	137.3k	BUSKULIC	94	ALEP	Ecm = 88-94 GeV	
Γ(invisible)						Г

We use only direct measurements of the invisible partial width to obtain the average value quoted below. The fit value is obtained as a difference between the total and the observed partial widths assuming lepton universality.

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
498.3± 4.2 OUR FIT				
517 ±22 OUR AV	ERAGE			
$539 \pm 26 \pm 17$	410	AKERS	95c OPAL	Eee = 88-94 GeV
450 ±34 ±34	258	BUSKULIC	93L ALEP	<i>E</i> ee = 88−94 GeV
540 ±80 ±40	52	ADEVA	92 L3	<i>Ec</i> m = 88-94 GeV
524 ±40 ±20	172	²⁷ ADRIANI	92E L3	<i>E</i> ee = 88−94 GeV
• • • We do not use	the following	ng data for averag	es, fits, limits	, etc. • • •
509.4± 7.0		ABREU	94 DLPH	Ecm = 88-94 GeV
496.5 ± 7.9		ACCIARRI	94 L3	Eee = 88-94 GeV
490.3 ± 7.3		AKERS	94 OPAL	Ecm = 88-94 GeV
501 ± 6		BUSKULIC	94 ALEP	Eee = 88-94 GeV
27				

27 ADRIANI 92E improves but does not supersede ADEVA 92, obtained with 1990 data only.

Γ(hadrons)

This parameter is not directly used in the 5-parameter fit assuming lepton universality, but is derived using the fit results. See the 'Note on the Z Boson.'

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
1740.7± 5.9 OU	R FIT				
• • • We do not	use the following	ng data for averag	es, fit	s, limits,	etc. • • •
1723 ±10	1.05M	ABREU	94	DLPH	Ecm = 88-94 GeV
1748 ±10	1.09M	ACCIARRI	94	L3	Ecm = 88-94 GeV
1741 ±10	1.19M	²⁸ AKERS	94	OPAL	Ecm = 88-94 GeV
1746 ±10	1.27M	BUSKULIC	94	ALEP	Ecm = 88-94 GeV
²⁸ AKERŞ 94 ası MeV.	sumes lepton ur	alversality. Withou	t this	assumpt	ilon, It becomes 1742 ±

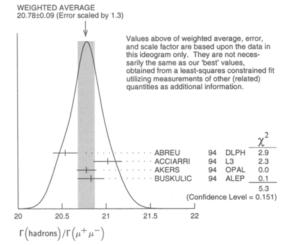
Z BRANCHING RATIOS

$\Gamma(\text{hadrons})/\Gamma(e^+)$	e~)					Γ_6/Γ_1
VALUE	EVTS	DOCUMENT ID	1	TECN	COMMENT	
20.77± 0.08 OUR FI	T					
20.74 ± 0.18	31.4k	ABREU	94	DLPH	Ecm = 88-94	GeV
20.96 ± 0.15	38k	ACCIARRI	94	L3	Eee = 88-94	GeV
20.83 ± 0.16	42k	AKERS	94	OPAL	Ecm = 88-94	GeV
20.59± 0.15	45.8k	BUSKULIC	94	ALEP	Ecm = 88-94	GeV
• • • We do not use	the following da	ata for averages,	fits, li	mits, etc		
20.99 ± 0.25	17k	ACTON	930	OPAL	Repl. by AKI	ERS 94
20.69± 0.21		BUSKULIC	93.	ALEP	Repl. by BUSKULI	C 94
27.0 +11.7 - 8.8	12	²⁹ ABRAMS	890	MRK2		

29 ABRAMS 89D have included both statistical and systematic uncertainties in their quoted errors.

$\Gamma(\text{hadrons})/\Gamma(\mu^+\mu^-)$	Ξ)			Γ_6/Γ_2
VALUE	<u>EVTS</u>	DOCUMENT ID	TECN	COMMENT
20.76±0.07 OUR FIT				
20.78±0.09 OUR AVE	RAGE Error	includes scale fact	tor of 1.3. See	the Ideogram below.
20.54±0.14	45.6k	ABREU	94 DLPH	Ecm = 88-94 GeV
21.02 ± 0.16	34k	ACCIARRI	94 L3	Ecm = 88-94 GeV
20.78 ± 0.11	57k	AKERS	94 OPAL	Ecm = 88-94 GeV
20.83 ± 0.15	46.4k	BUSKULIC	94 ALEP	Eco = 88-94 GeV
• • • We do not use t	he following d	ita for averages, f	its, limits, etc	. • • •
20.65 ± 0.17	23k	ACTON	93D OPAL	Repl. by AKERS 94
20.88±0.20		BUSKULIC	93J ALEP	Repl. by BUSKULIC 94
18.9 ^{+7.1} -5.3	13	30 ABRAMS	89D MRK2	<i>E</i> ee = 89−93 GeV

30 ABRAMS 89D have included both statistical and systematic uncertainties in their quoted errors.



$\Gamma(\text{hadrons})/\Gamma(\tau^+)$	r)				Γ ₆ /Γ ₃
VALUE	<u>EVTS</u>	DOCUMENT ID		TECN	COMMENT
20.90±0.08 OUR FIT 20.81±0.08 OUR AV					
20.81 ± 0.08 OUR AV	EKAGE				
20.68±0.18	25k	ABREU	94	DLPH	<i>E</i> cm = 88-94 GeV
20.80 ± 0.20	25k	ACCIARRI	94	L3	<i>E</i> ee = 88-94 GeV
21.01±0.15	47k	AKERS	94	OPAL	Ecm = 88-94 GeV
20.70±0.16	45.1k	BUSKULIC	94	ALEP	Ecm = 88-94 GeV
• • *• We do not use	the following d	ata for averages,	fits, li	mits, etc	. • • •
21.22±0.25	18k	ACTON	930	OPAL	Repl. by AKERS 94
20.77±0.23		BUSKULIC	93.	ALEP	Repl. by
					BUSKULIC 94
15.2 +4.8	21	31 ABRAMS	890	MRK2	Eee = 89-93 GeV

31 ABRAMS 890 have included both statistical and systematic uncertainties in their quoted errors.

 Γ_6/Γ_4

$\frac{\Gamma(\text{hadrons})/\Gamma(\ell^+\ell^-)}{\ell \text{ indicates each type of lepton } (e, \mu, \text{ and } \tau), \text{ not sum over them.} }$

 ϵ indicates each type of lepton (e, μ , and τ), not sum over then

Our fit result is obtained requiring lepton universality.

	oute to obtained .	-4 P 1-P 1-0			
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
20.76 ±0.05	OUR FIT				
20.77 ±0.07	OUR AVERAGE	Error includes below.	scale 1	factor of	1.4. See the ideogram
20.62 ±0.10	102k	ABREU	94	DLPH	Ecm = 88-94 GeV
20.93 ±0.10	97k	ACCIARRI	94	L3	Ecm = 88-94 GeV
20.835 ± 0.086	146k	AKERS	94	OPAL	Ecm = 88-94 GeV
20.69 ±0.09	137.3k	BUSKULIC	94	ALEP	Ecm = 88-94 GeV

	we do not	use the tollow	ving data tor ave	rages, fits, lim	ilts, etc.		
0.88	±0.13	58k	ACTON	93D OPAL		by AKERS	94
	±0.15	40k	ADRIANI	93M L3		by ACCIAR	
	± 0.13		BUSKULIC	93J ALEP	Repl.	by BUSKU	LIC 94
8.9	+3.6 -3.2	46	ABRAMS	898 MRK2	Ecm=	= 89-93 Ge ¹	V
		HTED AVERA :0.07 (Error so					
			and this sari obtr utili	ues above of was acade factor and ideogram only by the same as a dined from a le zing measuren intities as additional control of the control	re based t. They a our 'bes ast-squa nents of	d upon the d are not nece st' values, ares constra other (relate	ata in es- ined fit
		J -+		ABREU ACCIARF AKERS BUSKULI	C 9	4 L3 4 OPAL	2.2 2.6 0.6 0.8 6.2 0.104)
		1		\			
		20.4 20.6		21.2 21.4	21.6		
	Γ(had	drons $)/\Gamma(\ell^+$	· (-)				
.6990	±0.0015 O	UR FIT		MENT ID			
. 6990 .6983	We do not ± 0.0023	UR FIT use the follow		erages, fits, lim			
.6990 .6983 (e+	We do not ± 0.0023 $e^-)/\Gamma_{tota}$ This parame	UR FIT use the follow	ving data for ave 4M BUSK ectly used in the	erages, fits, lim ULIC 94	nits, etc. ALEP	• • • <i>Ecm</i> = 88-	Γ1/
.6990 .6983 (e+	We do not ± 0.0023 $e^-)/\Gamma_{tota}$ This parame	UR FIT use the follow 1.1 Il eter is not directe on the Z B	ving data for ave 4M BUSK ectly used in the	erages, fits, lim ULIC 94 overall fit but	nits, etc. ALEP is derive	• • • <i>Ecm</i> = 88-	Γ1/
.6990 .6983 (e+	We do not ±0.0023 e ⁻)/\(\Gamma_{\text{tota}}\) This parameter the 'Not 6±0.00008	UR FIT use the follow 1.1 use the follow ter is not directed to the Z B	ving data for ave 4M BUSK ectly used in the	erages, fits, lim ULIC 94 overall fit but MENT ID erages, fits, lim	nits, etc. ALEP is derive <u>TECN</u> nits, etc.	ECC = 88-	Γ ₁ /: fit result
.6990 .6983 (e+ .0336	We do not ±0.0023 e ⁻)/\(\Gamma_{\text{tota}}\) This parameter the 'Not 6±0.00008	use the follow 1.1 If the second of the sec	ving data for ave 4M BUSK ectly used in the loson.' TS DOCUM ving data for ave	erages, fits, lim ULIC 94 overall fit but MENT ID erages, fits, lim	nits, etc. ALEP is derive <u>TECN</u> nits, etc.	Ecm = 88- ed using the	Γ ₁ /: fit result
.6990 .6983 (e+ .0336 .0338	We do not ± 0.0023 e ⁻)/ Γ total This parameter the 'Not 6 ± 0.00008 We do not 3 ± 0.00013 μ^-)/ Γ total	use the follow 1.1 If the control of the control	ving data for ave 4M BUSK BUSK BUSK BUSK BUSK BUSK BUSK BUSK BUSK	erages, fits, lim ULIC 94 overall fit but MENT ID erages, fits, lim ULIC 94	nits, etc. ALEP is derive <u>TECN</u> nits, etc. ALEP	Ecm = 88-	Γ ₁ /: fit result
.6990 .6983 (e ⁺ .0336 .0338 (μ ⁺	We do not ± 0.0023 e ⁻)/ Γ tota This parameter the 'Not 6 ± 0.00008 We do not 3 ± 0.00013 μ^-)/ Γ tota This parameter this parameter the 'Not	use the follow 1.1 If the follow the follo	ving data for ave 4M BUSK ectly used in the loson. TS DOCUM ving data for ave 8k BUSK	erages, fits, lim ULIC 94 overall fit but MENT ID erages, fits, lim ULIC 94	nits, etc. ALEP is derive <u>TECN</u> nits, etc. ALEP	Ecm = 88-	Γ ₁ /: fit result
6990 6983 (e+ 0336 0338 (µ+	We do not ± 0.0023 e ⁻)/ Γ_{total} This parameters we the 'Not 6 ± 0.00008 We do not 3 ± 0.00013 μ^{-})/ Γ_{total} This parameter the 'Not see the 'Not π	use the follow 1.1 If the control of the control o	ving data for ave 4M BUSK ectly used in the loson. 7S DOCUM ving data for ave 8k BUSK ectly used in the loson.	erages, fits, lim ULIC 94 overall fit but dENT ID erages, fits, lim ULIC 94 overall fit but	nits, etc. ALEP is derive TECN nits, etc. ALEP	Ecm = 88-	Γ ₁ /: fit result
.6990 .6983 .(e+ .0336 .0338 .μ+	We do not ± 0.0023 e^-)/ Γ_{total} This parameter the 'Not 6 ± 0.0008 We do not 3 ± 0.00013 μ^-)/ Γ_{total} This parameter the 'Not π^+	use the follow 1.1 If the term is not directed to the Z B EV OUR FIT use the follow 45. If the term is not directed to the Z B EV OUR FIT OUR FIT OUR FIT	ving data for ave 4M BUSK ectly used in the loson. DOCUM ving data for ave 8k BUSK ectly used in the	erages, fits, lim ULIC 94 overall fit but MENT ID erages, fits, lim ULIC 94 overall fit but	nits, etc. ALEP is derive TECN nits, etc. ALEP Is derive TECN	ESS = 88- ed using the COMMENT ESS = 88- ed using the	Γ ₁ /: fit result
.6990 .6983 .(e+ .0336 .0338 .0338	We do not ± 0.0023 $e^-)/\Gamma_{tota}$ This parameter the 'Not 6 ± 0.00008 We do not 3 ± 0.00013 $\mu^-)/\Gamma_{tota}$ This parameter the 'Not π^+ This parameter the 'Not π^+ We do not π^+ We do not π^+	use the follow 1.1 If the term is not directed to the Z B OUR FIT use the follow 45. If the term is not directed to the Z B EV OUR FIT use the Z B EV OUR FIT use the follow OUR FIT use the follow	ving data for ave 4M BUSK ectly used in the closon. DOCUM ving data for ave 8k BUSK ectly used in the coson. DOCUM pocum poc	erages, fits, lim ULIC 94 overall fit but ###################################	nits, etc. ALEP is derive TECN nits, etc. ALEP Is derive TECN	ECM = 88- ed using the COMMENT ECM = 88- ed using the	Γ ₁ /. fit result
.6990 .6983 .(e+ .0336 .0338 .(\(\mu^+\)	We do not ± 0.0023 e^-)/ Γ_{total} This parameter the 'Not of 6 ± 0.00008 We do not 3 ± 0.00013 μ^-)/ Γ_{total} This parameter the 'Not of π^+ We do not 4 ± 0.00026	use the follow 1.1 If the control of the control	ving data for ave 4M BUSK ectly used in the closon. DOCUM ving data for ave 8k BUSK ectly used in the coson. DOCUM pocum poc	erages, fits, lim ULIC 94 overall fit but ###################################	nits, etc. ALEP is derive TECN nits, etc. ALEP Is derive TECN	ESS = 88- ed using the COMMENT ESS = 88- ed using the	Γ ₁ /. fit result
.6990 .6983 (e+ .0336 .0338 (μ+ .0334 (r+	We do not ± 0.0023 $e^-)/\Gamma_{\text{total}}$ This parameter the 'Not 6 ± 0.00008 We do not 3 ± 0.00013 $\mu^-)/\Gamma_{\text{total}}$ This parameter the 'Not 7 ± 0.00013 We do not 4 ± 0.00026 $\tau^-)/\Gamma_{\text{total}}$ This parameter this parameter than the 'Not π^+	use the follow 1.1 If the term is not directed to the Z B OUR FIT use the follow 45. OUR FIT use the follow 46. If the follow 46. If the follow 46.	ving data for ave 4M BUSK ectly used in the loson.* DOCUM ving data for ave loson.* DOCUM cuty used in the loson.* DOCUM ving data for ave 4k BUSK ectly used in the	erages, fits, lim ULIC 94 overall fit but MENT ID erages, fits, lim ULIC 94 overall fit but MENT ID erages, fits, lim ULIC 94	nits, etc. ALEP is derive TECN nits, etc. ALEP TECN nits, etc. ALEP	EEE 88- ECM = 88- COMMENT EEE 88- ECM = 88- COMMENT EEE 88-	Γ ₁ /. fit result 94 GeV Γ ₂ /. fit result
.6990 .6983 (e+ .0336 .0338 (μ+ .0336 .0334 (r+	We do not ± 0.0023 $e^-)/\Gamma_{\text{total}}$ This parametes the 'Not 6 ± 0.00008 We do not 3 ± 0.00013 $\mu^-)/\Gamma_{\text{total}}$ This parametes the 'Not 4 ± 0.00013 We do not 4 ± 0.00026 $\tau^-)/\Gamma_{\text{total}}$ This parametes the 'Not see the 'Not	use the follow 1.1 If the term is not directly a server is not direct	ving data for ave 4M BUSK ectly used In the loson. TS DOCUM ving data for ave 8k BUSK ectly used In the loson. TS DOCUM ving data for ave 4k BUSK ectly used In the loson.	erages, fits, lim ULIC 94 overall fit but MENT ID erages, fits, lim ULIC 94 overall fit but MENT ID erages, fits, lim ULIC 94	its, etc. ALEP is derive TECN Its, etc. ALEP is derive TECN Its, etc. ALEP	EEE 88- ed using the COMMENT EEE 88- ed using the COMMENT EEE 88- ed using the COMMENT EEE 88- ed using the	Γ ₁ /. fit result 94 GeV Γ ₂ /. fit result
.6990 .6983 .6983 .6983 .0338 .0338 .0338 .0336 .0336 .0336 .0336 .0336	We do not ± 0.0023 e^-)/ Γ_{total} This parameter the 'Not 6 ± 0.00008 We do not 3 ± 0.00013 μ^-)/ Γ_{total} This parameter the 'Not 7 ± 0.00013 We do not 4 ± 0.00026 τ^-)/ Γ_{total} This parameter the 'Not 0.00015	use the follow 1.1 If the term is not directly the term is not directly the follow 45. OUR FIT use the follow 46. OUR FIT use the follow 46. If the follow 47. If the follow 48. If the follow 49. If the follow 49. If the follow 40. If the follow 40	ving data for ave 4M BUSK ectly used in the loson. TS DOCUM ving data for ave 8k BUSK ectly used in the loson. DOCUM ving data for ave 4k BUSK ectly used in the loson. DOCUM	erages, fits, lim ULIC 94 overall fit but ###################################	is derive TECN Is derive TECN Is derive TECN Is derive TECN ALEP	ESS 88- ed using the COMMENT ESS 88- ed using the COMMENT ESS 88- ed using the COMMENT ESS 88- ed using the	Γ ₁ /. fit result 94 GeV Γ ₂ /. fit result
.6983 (e+ .0336 .0338 (µ+ .0336 .0334 (r+	We do not ± 0.0023 e^-)/ Γ_{total} This parameter the 'Not 6 ± 0.00008 We do not 3 ± 0.00013 μ^-)/ Γ_{total} This parameter the 'Not 7 ± 0.00013 We do not 4 ± 0.00026 τ^-)/ Γ_{total} This parameter the 'Not 0.00015	use the follow 1.1 If the term is not directed in the Z B OUR FIT use the follow 45. OUR FIT use the follow OUR FIT use the follow 46. If the term is not directed in the Z B OUR FIT use the follow	ving data for ave 4M BUSK ectly used in the loson. TS DOCUM ving data for ave 4k BUSK ectly used in the loson. DOCUM ving data for ave 4k BUSK ectly used in the loson. DOCUM ving data for ave 4k BUSK	erages, fits, lim ULIC 94 overall fit but ###################################	is derive TECN ALEP	ECM = 88- ed using the COMMENT ECM = 88- ed using the COMMENT ECM = 88- ed using the COMMENT ECM = 88- ed using the	F1/ fit result 94 GeV F2/ fit result 94 GeV F3/
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This parameter is not directly used in the overall fit but is derived using the fit results;

 $\Gamma(\mu^+\mu^-)/\Gamma(e^+e^-)$

1.000±0.005 OUR FIT

see the 'Note on the Z Boson

DOCUMENT ID

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\Gamma(\tau^+\tau^-)/\Gamma(e^+e^-)
                                                                                                                       \Gamma_3/\Gamma_1
         This parameter is not directly used in the overall fit but is derived using the fit results;
         see the 'Note on the Z Boson
                                                     DOCUMENT ID
0.998±0.005 OUR FIT
\Gamma((u\overline{u}+c\overline{c})/2)/\Gamma(\text{hadrons})
         This quantity is the branching ratio of Z \rightarrow "up-type" quarks to Z \rightarrow hadrons. Except
         ACKERSTAFF 97T the values of Z \to "up-type" and Z \to "down-type" branchings are extracted from measurements of \Gamma(\text{hadrons}), and \Gamma(Z \to \gamma + \text{jets}) where \gamma is a
         high-energy (>5 GeV) isolated photon. As the experiments use different procedures and slightly different values of M_Z, \Gamma(hadrons) and \alpha_S in their extraction procedures, our average has to be taken with caution.
                                                     DOCUMENT ID
                                                                                 TECN COMMENT
0.145±0.015 OUR AVERAGE
                                                 32 ACKERSTAFF 97T OPAL Ecm = 88-94 GeV
0.160 \pm 0.019 \pm 0.019
0.137 + 0.038 \\ -0.054
                                                 33 ABREU
                                                                            95x DLPH Ecm = 88-94 GeV
                                                 34 ACTON
0.139 \pm 0.026
                                                                            93F OPAL Ecm = 88-94 GeV
                                                 35 ADRIANI
0.137 \pm 0.033
                                                                            93 L3
                                                                                             Ecm = 91.2 GeV
 ^{32} ACKERSTAFF 97T measure \Gamma_{u\,\overline{u}}/(\Gamma_{d\,\overline{d}}+\Gamma_{u\,\overline{u}}+\Gamma_{s\,\overline{s}})=0.258\pm0.031\pm0.032. To obtain this branching ratio authors use R_c+R_b=0.380\pm0.010. This measurement is fully negatively correlated with the measurement of \Gamma_{d\,\overline{d},s\,\overline{s}}/(\Gamma_{d\,\overline{d}}+\Gamma_{u\,\overline{u}}+\Gamma_{s\,\overline{s}}) given
 in the next data block. 33 ABREU 95x use M_Z=91.187\pm0.009 GeV, \Gamma({\rm hadrons})=1725\pm12 MeV and \alpha_S=0.123\pm0.005. To obtain this branching ratio we divide their value of C_{2/3}=0.91_{-}^{+0.25}.
     by their value of (3C_{1/3} + 2C_{2/3}) = 6.66 \pm 0.05.
  ^{34}ACTON 93F use the LEP 92 value of \Gamma({
m hadrons}) = 1740 \pm 12 MeV and \alpha_{S} =
     0.122^{+0.006}_{-0.005}
  ^{-0.009} 35 ADRIANI 93 use M_Z=91.181\pm0.022 GeV, \Gamma({\rm hadrons})=1742\pm19 MeV and \alpha_S=0.125\pm0.009. To obtain this branching ratio we divide their value of C_{2/3}=0.92\pm0.22
      by their value of (3C_{1/3} + 2C_{2/3}) = 6.720 \pm 0.076.
\Gamma((d\overline{d}+s\overline{s}+b\overline{b})/3)/\Gamma(\text{hadrons})
         This quantity is the branching ratio of Z \to "down-type" quarks to Z \to hadrons. Except ACKERSTAFF 97T the values of Z \to "up-type" and Z \to "down-type" branchings are extracted from measurements of \Gamma(\text{hadrons}), and \Gamma(Z \to \gamma + \text{jets})
         where \gamma is a high-energy (>5 GeV) isolated photon. As the experiments use different
         procedures and slightly different values of M_Z, \Gamma({
m hadrons}) and lpha_S in their extraction
         procedures, our average has to be taken with caution.
                                                     DOCUMENT ID
                                                                             TECN COMMENT
0.237 ± 0.009 OUR AVERAGE
                                                 36 ACKERSTAFF 97T OPAL Ecm = 88-94 GeV
0.230 \pm 0.010 \pm 0.010
0.243^{+0.036}_{-0.026}
                                                 37 ABREU
                                                                            95X DLPH Ecm = 88-94 GeV
                                                 38 ACTON
0.241 \pm 0.017
                                                                            93F OPAL Ecm = 88-94 GeV
0.243 \pm 0.022
                                                 39 ADRIANI
                                                                            93 L3
                                                                                            Ecm = 91.2 GeV
  ^{36} ACKERSTAFF 97T measure \Gamma_{d\overline{d},s\overline{s}}/(\Gamma_{d\overline{d}}+\Gamma_{u\overline{u}}+\Gamma_{s\overline{s}})=0.371\pm0.016\pm0.016. To
     obtain this branching ratio authors use R_c + R_b = 0.380 \pm 0.010. This measurement is fully negatively correlated with the measurement of \Gamma_{u\overline{u}}/(\Gamma_{d\overline{d}} + \Gamma_{u\overline{u}} + \Gamma_{S\overline{s}}) presented
      in the previous data block.
  ^{37} ABREU 95x use M_Z=91.187\pm0.009 GeV, \Gamma({
m hadrons})=1725\pm12 MeV and lpha_S
     ABREU 95x use M_Z=91.187\pm0.009 GeV, \Gamma({\rm hadrons})=1725\pm12 MeV and \alpha_S=0.123\pm0.005. To obtain this branching ratio we divide their value of C_{1/3}=1.62^{+0.24}_{-0.24}
     by their value of (3C_{1/3} + 2C_{2/3}) = 6.66 \pm 0.05.
  <sup>38</sup> ACTON 93F use the LEP 92 value of \Gamma(\text{hadrons}) = 1740 \pm 12 MeV and \alpha_s =
     0.122^{+0.006}_{-0.005}
  ^{39} ADRIANI 93 use M_7=91.181\pm0.022 GeV, \Gamma({\rm hadrons})=1742\pm19 MeV and \alpha_5=0.125\pm0.009. To obtain this branching ratio we divide their value of C_{1/3}=1.63\pm0.15
      by their value of (3C_{1/3} + 2C_{2/3}) = 6.720 \pm 0.076.
 as explained in the Note on the 2 boson. As a class check we now easy performed a weighted average of the R_C measurements taking into account the various common systematic errors. Assuming that the smallest common systematic error is fully
         correlated, we obtain R_{c}=0.171\pm0.009.
         Because of the high current interest, we mention the following preliminary results
         here, but do not average them or include them in the Listings or Tables. Combining
         published and unpublished preliminary LEP and SLD electroweak results (as of end of February 1998) yields R_{\rm C}=0.1734\pm0.0048. The Standard Model predicts R_{\rm C}=0.1734\pm0.0048.
         0.1723 for m_t=175~{\rm GeV} and M_H=300~{\rm GeV}.
                                           DOCUMENT ID
                                                                  TECN COMMENT
0.177 ±0.008 OUR FIT
                                      40 ACKERSTAFF 98E OPAL Ecm = 88-94 GeV
0.180 ±0.011 ±0.013
                                      41 ALEXANDER 96R OPAL Ecm = 88-94 GeV
0.167 ±0.011 ±0.012
                                      42 ABREU
0.1623 \pm 0.0085 \pm 0.0209
                                                                  950 DLPH Ecm = 88-94 GeV
0.165 ±0.005 ±0.020
                                      <sup>43</sup> BUSKULIC
                                                                  94G ALEP ECM = 88-94 GeV
                                       44 ABREU
                                                                  931 DLPH Ecm = 88-94 GeV
0.187 ±0.031 ±0.023
\bullet \bullet \bullet We do not use the following data for averages, fits, limits, etc. \bullet \bullet
                                       45 AKERS
0.142 ±0.008 ±0.014
                                                                  950 OPAL Repl. by ACKERSTAFF 98E
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 Γ_2/Γ_1

0.151 ±0.008 ±0.041

⁴⁶ ABREU 920 DLPH E = 88-94 GeV 40 ACKERSTAFF 98E use an inclusive/exclusive double tag. In one jet $D^{*\pm}$ mesons are exclusively reconstruced in several decay channels and in the opposite jet a slow plon

(opposite charge inclusive $D^{\bullet\pm}$) tag is used. The b content of this sample is measured by the simultaneous detection of a lepton in one jet and an inclusively reconstructed $D^{\star\pm}$ meson in the opposite jet. The systematic error includes an uncertainty of ± 0.006 due to the external branching ratios.

41 ALEXANDER 96R obtain this value via direct charm counting, summing the partial contributions from D^0 , D^+ , D^+_s , and Λ^+_c , and assuming that strange-charmed baryons account for the 15% of the Λ_c^+ production. An uncertainty of ± 0.005 due to the uncertainties in the charm hadron branching ratios is included in the overall systematics.

42 ABREU 950 perform a maximum likelihood fit to the combined p and p_{T} distributions of single and dilepton samples. The second error includes an uncertainty of ± 0.0124 models and branching ratios.

43 BUSKULIC 94G perform a simultaneous fit to the p and p_T spectra of both single and dilepton events.

 44 ABREU 931 assume that the $D_{
m S}$ and charmed baryons are equally produced at LEP and CLEO (10 GeV) energies.

45 AKERS 950 use the presence of a $D^{*\pm}$ to tag $Z \to c\overline{c}$ with $D^* \to D^0\pi$ and $D^0 \to c\overline{c}$ $K\pi$. They measure $P_C * \Gamma(c\overline{c})/\Gamma(\text{hadrons})$ to be $(1.006 \pm 0.055 \pm 0.061) \times 10^{-3}$, where P_c is the product branching ratio B($c \to D^*$)B($D^* \to D^0 \pi$)B($D^0 \to K \pi$). Assuming that P_c remains unchanged with energy, they use its value $(7.1\pm0.5)\times10^{-3}$ determined at CESR/PETRA to obtain $\Gamma(c\overline{c})/\Gamma$ (hadrons). The second error of AKERS 950 includes an uncertainty of ±0.011 from the uncertainty on P_c .

46 ABREU 920 use the neural network techinque to tag heavy flavour events among a sample of 123k selected hadronic events. The systematic error consists of three due to Monte Carlo (MC) parametrization (0.023), choice of MC model (0.033) and detector effects (0.009) added in quadrature.

 $R_b = \Gamma(b\overline{b})/\Gamma(\text{hadrons})$

EVTS

OUR FIT is obtained by a simultaneous fit to several c- and b-quark measurements as explained in the "Note on the Z boson." As a cross check we have also performed a weighted average of the R_b measurements taking into account the various common systematic errors. We have assumed that the smallest common systematic error is fully correlated. For $R_C=0.177$ (as given by OUR FIT above), we obtain $R_b=0.2169\pm0.0012$. For an expected Standard Model value of $R_C=0.1723$, our weighted average gives $R_b = 0.2172 \pm 0.0012$.

Because of the high current interest, we mention the following preliminary results here, but do not average them or include them in the Listings or Tables. Combining published and unpublished preliminary LEP and SLD electroweak results (as of end of February 1998) yields $R_b=$ 0.2170 \pm 0.0009. The Standard Model predicts $R_b=$ 0.2158 for $m_t=$ 175 GeV and $M_H=$ 300 GeV.

DOCUMENT ID TECN COMMENT

0.2169±0.0012 OUR FIT			
$0.2142 \pm 0.0034 \pm 0.0015$	⁴⁷ ABE	98D SLD	Ecm = 91.2 GeV
$0.2175 \pm 0.0014 \pm 0.0017$	⁴⁸ ACKERSTAFF	97K OPAL	Eee = 88-94 GeV
$0.2159 \pm 0.0009 \pm 0.0011$	⁴⁹ BARATE	97F ALEP	Eee = 88-94 GeV
$0.2216 \pm 0.0016 \pm 0.0021$	⁵⁰ ABREU	96 DLPH	Ecm = 88-94 GeV
$0.2145 \pm 0.0089 \pm 0.0067$	⁵¹ ABREU	950 DLPH	Ecm = 88-94 GeV
$0.219 \pm 0.006 \pm 0.005$	⁵² BUSKULIC	94G ALEP	Ecm = 88-94 GeV
0.222 ±0.003 ±0.007	⁵³ ADRIANI	93E L3	Ecm = 88-94 GeV
0.222 ±0.011 ±0.007	⁵⁴ AKERS	93B OPAL	Ecm = 88-94 GeV
0.251 ±0.049 ±0.030 32	⁵⁵ JACOBSEN	91 MRK2	Ecm = 91 GeV
• • • We do not use the following	ng data for average:	s, fits, limits,	etc. • • •
$0.2167 \pm 0.0011 \pm 0.0013$	⁵⁶ BARATE	97E ALEP	Ecm = 88-94 GeV
0.229 ±0.011	⁵⁷ ABE	96E SLD	Repl. by ABE 980
$0.2217 \pm 0.0020 \pm 0.0033$	58 ABREU	950 DLPH	Repl. by ABREU 96
$0.2241 \pm 0.0063 \pm 0.0046$	59 ABREU	95」DLPH	Repl. by ABREU 96
$0.2171 \pm 0.0021 \pm 0.0021$	60 AKERS	95B OPAL	Repl. by ACKER-

						-CIII - 22 2. 22.
0.229 ±0.	011			⁵⁷ ABE	96E SLD	Repl. by ABE 980
$0.2217 \pm 0.$	002	0 ± 0.0033		⁵⁸ ABREU	950 DLPI	H Repl. by ABREU 96
$0.2241 \pm 0.$	006	3 ± 0.0046		⁵⁹ ABREU	95J DLPI	H Repl. by ABREU 96
$0.2171 \pm 0.$	002	1±0.0021		60 AKERS	95B OPAI	Repl. by ACKER- STAFF 97K
0.228 ±0.	005	± 0.005		⁶¹ BUSKULIC	93N ALEF	
0.222 +0.	033 031	± 0.017		62 ABREU	92 DLPI	H <i>E</i> ee = 88-94 GeV
0.219 ±0.	014	± 0.019		63 ABREU	92K DLPI	H Eee = 88-94 GeV
0.232 ±0.	005	± 0.017		64 ABREU	920 DLPI	1 Ecm = 88-94 GeV
0.23 +0.	10 08	+0.05 -0.04	15	65 KRAL	90 MRK	2 <i>E</i> _{CM} = 89–93 GeV

47 ABE 98D use a double tag based on 3D impact parameter with reconstruction of secondary vertices. The charm background is reduced by requiring the invariant mass at the secondary vertex to be above 2 GeV. The systematic error includes an uncertainty of ± 0.0002 due to the uncertainty on R_C .

48 ACKERSTAFF 97K use lepton and/or separated decay vertex to tag independently each hemisphere. Comparing the numbers of single- and double-tagged events, they determine the b-tagging efficiency directly from the data.

49 BARATE 97F combine the lifetime-mass hemisphere tag (BARATE 97E) with event shape information and lepton tag to identify $Z \rightarrow b\bar{b}$ candidates. They further use cand uds-selection tags to identify the background. For R_c different from its Standard Model value of 0.172, R_b varies as $-0.019 \times (R_c - 0.172)$.

50 ABREU 96 obtain this result combining several analyses (double lifetime tag, mixed tag and multivariate analysis). This value is obtained assuming $R_c = \Gamma(c\overline{c})/\Gamma(\text{hadrons}) = 0.172$. For a value of R_C different from this by an amount ΔR_C the change in the value is given by -0.087 ΔR_C .

 51 ABREU 95D perform a maximum likelihood fit to the combined p and p_{T} distributions of single and dilepton samples. The second error includes an uncertainty of ± 0.0023 due to models and branching ratios.

 52 BUSKULIC 94G perform a simultaneous fit to the ho and ho_{T} spectra of both single and

53 ADRIANI 93E use a multidimensional analysis based on a neural network approach.

54 AKERS 93B use a simultaneous fit to single and dilepton events (electrons and muons) to tag $Z \rightarrow b\overline{b}$.

 55 JACOBSEN 91 tagged $b\overline{b}$ events by requiring coincidence of \geq 3 tracks with significant Impact parameters using vertex detector. Systematic error includes lifetime and decay uncertainties (± 0.014).

56 BARATE 97E combine a lifetime tag with a mass cut based on the mass difference between c hadrons and b hadrons.

57 Detween C nations and D nations.

57 ABE 966 obtain this value by combining results from three different b-tagging methods (2D impact parameter, 3D impact parameter, and 3D displaced vertex).

58 ABREU 950 obtain this result combining several analyses (double-lifetime tag and mixed ABREU 950 obtain this result containing several analyses (account metrific tag and mixed tags). The second error contains an uncertainty of ± 0.0029 due to the total systematics and an uncertainty of ± 0.0016 due to an 8% variation of $\Gamma(c\overline{c})/\Gamma(\text{hadrons})$ around its Standard Model value (0.171 \pm 0.014). Combining with their own lepton analysis, ABREU 950 obtain 0.2210 \pm 0.0033 \pm 0.0003 (models) \pm 0.0014 [$\Gamma(c\overline{c})/\Gamma(\text{hadrons})$].

⁵⁹ABREU 95J obtain this value with a multivariate analysis based on event shape and particle trajectories near the interaction point. The second error contains an uncertainty of ± 0.0012 due to an 8% variation of $\Gamma(c\overline{c})/\Gamma(\text{hadrons})$ around its Standard Model value (0.171 + 0.014).

60 AKERS 95B select events based on the lepton and/or vertex tag independently in each hemisphere. Comparing the numbers of single- and double-tagged events, they determine the b-tagging efficiency directly from data.

61 BUSKULIC 93N use event shape and high p_T lepton discriminators applied to both

 62 ABREU 92 result is from an indirect technique. They measure the lifetime $au_{\mathcal{B}}$, but use a world average of τ_B independent of $\Gamma(b\overline{b})$ and compare to their $\Gamma(b\overline{b})$ dependent lifetime from a hadron sample.

63 ABREU 92K use boosted—sphericity technique to tag and enrich the b-b content with a sample of 50k hadronic events. Most of the systematic error is from hadronization uncertainty.

64 ABREU 920 use the neural network technique to tag heavy flavour events among a sample of 123k selected hadronic events. The systematic error consists of three parts: due to Monte Carlo (MC) parametrization (0.010), choice of MC model (0.008), and detector effects (0.011) added in quadrature.

⁶⁵ KRAL 90 used isolated leptons and found $\Gamma(b\overline{b})/\Gamma(\text{total}) = 0.17^{+0.07}_{-0.06} + 0.03^{+0.03}_{-0.03}$

$\Gamma(ggg)/\Gamma(hadrons)$ Γ_{11}/Γ_{6} CL% DOCUMENT ID VALUE TECN COMMENT <1.6 × 10⁻² 66 ABREU 95 965 DLPH Ecm = 88-94 GeV

66 This branching ratio is slightly dependent on the jet-finder algorithm. The value we quote is obtained using the JADE algorithm, while using the DURHAM algorithm ABREU 96S obtain an upper limit of 1.5×10^{-2} .

$\Gamma(\pi^0\gamma)/\Gamma_{ ext{total}}$					Γ ₁₂ /Γ
VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<5.2 × 10 ⁻⁵	95	67 ACCIARRI	95G	L3	Eee = 88-94 GeV
$< 5.5 \times 10^{-5}$	95	ABREU	948	DLPH	Ecm = 88-94 GeV
$< 2.1 \times 10^{-4}$	95	DECAMP	92	ALEP	Ecm = 88-94 GeV
$<1.4 \times 10^{-4}$	95	AKRAWY	91F	OPAL	Eee = 88-94 GeV
• • We do not use	the follow	ing data for average	s, fits,	limits,	etc. • • •
$<1.2 \times 10^{-4}$	95	68 ADRIANI	92 B	L3	Repl. by ACCIARRI 95G
67 This limit is for b	oth decay r	nodes $Z \to \pi^0 \gamma/\gamma$	γ which	ch are i	ndistinguishable in ACCIA-

⁶⁸ This limit is for both decay modes $Z
ightarrow \pi^0 \gamma/\gamma \gamma$ which are indistinguishable in ADRI-

$\Gamma(\eta \gamma)/\Gamma_{\text{total}}$						Γ_{13}/Γ
VALUE	<u>CL%</u>	DOCUMENT ID		<u>TECN</u>	COMMENT	
$< 7.6 \times 10^{-5}$	95	ACCIARRI	95G	L3	Ecm= 88-94 Ge	V
$< 8.0 \times 10^{-5}$	95	ABREU	94B	DLPH	Ecm = 88-94 Ge	V
<5.1 × 10 ⁻⁵	95	DECAMP	92	ALEP	Ecm = 88-94 Ge	V
$< 2.0 \times 10^{-4}$	95	AKRAWY	91F	OPAL	Ecm = 88-94 Ge	v
• • We do not use	the followin	g data for average	s, fits	, Ilmits,	etc. • • •	
$<1.8 \times 10^{-4}$	95	ADRIANI	92B	L3	Repl. by ACCIA	RRI 95G
$\Gamma(\omega\gamma)/\Gamma_{ m total}$						Γ ₁₄ /Γ
VALUE	CL%	DOCUMENT ID		TECN	COMMENT	
<6.5 × 10 ⁻⁴	95	ABREU	94B	DLPH	<i>E</i> ee = 88−94 Ge	٧
$\Gamma(\eta'(958)\gamma)/\Gamma_{\text{total}}$						Γ ₁₅ /Γ
	CL%	DOCUMENT ID		TECN	COMMENT	
<4.2 × 10 ⁻⁵	95	DECAMP	92	ALEP	Ecm= 88-94 Ge	V
Γ(γγ)/Γ _{total}	4 . 4 . 4 . 4 . 4 .					Γ ₁₆ /Γ
-		e Landau-Yang the	eorem	TECN	COMMENT	

i nis decay wo	onio violate ti	ie Landau-Yang tr	ieorem.	
VALUE	<u>CL%</u>	DOCUMENT ID	TECN	COMMENT
<5.2 × 10 ⁻⁵	95	⁶⁹ ACCIARRI	95G L3	Eee = 88-94 GeV
<5.5 × 10 ⁻⁵	95	ABREU	94B DLPH	<i>Ec</i> m = 88-94 GeV
$<1.4 \times 10^{-4}$	95	AKRAWY		Ecm = 88-94 GeV
• • • We do not us	e the following	ng data for average	es, fits, limits,	, etc. • • •

 $< 1.2 \times 10^{-4}$ ⁷⁰ ADRIANI 95 92B L3

 69 This limit is for both decay modes $Z
ightarrow ~\pi^0 \gamma/\gamma\gamma$ which are indistinguishable in ACCIA-

RRI 95G. 70 This limit is for both decay modes $Z \to \pi^0 \gamma/\gamma \gamma$ which are indistinguishable in ADRI-

⁸² ACCIARRI 97R search for $\, T(15)$ through its decay into $\, \ell^+ \, \ell^- \,$ ($\ell = e \,$ or $\, \mu$).

$\lceil (\gamma \gamma \gamma) / \lceil_{\text{total}} \rceil$				Γ ₁₇ /	/୮	$\Gamma(T(2S)X)/\Gamma_{\text{total}}$				Γ ₂₆ /Γ
VALUE	<u> </u>	DOCUMENT ID	TECN	COMMENT		VALUE CL%	DOCUMENT ID	TECN_	COMMENT	
<1.0 × 10 ⁻⁵	95 os	71 ACCIARRI 71 ARREII	95C L3	Ecm = 88-94 GeV		<13.9 × 10 ⁻⁵ 95	83 ACCIARRI	97R L3	Ecm = 88-94	
<1.7 × 10 ⁻⁵ <6.6 × 10 ⁻⁵	95 95	71 ABREU AKRAWY		Ecm = 88-94 GeV Ecm = 88-94 GeV		83 ACCIARRI 97R search for 1	(25) through its de	cay into $\ell^+\ell^-$	$(\ell = e \text{ or } \mu).$	•
• • We do not use						$\Gamma(\Upsilon(3S)X)/\Gamma_{\text{total}}$				Γ_{27}/Γ
<3.3 × 10 ⁻⁵	95	ADRIANI	92B L3			VALUE CL%	DOCUMENT ID	TECN	COMMENT	
71 Limit derived in th				Repl. by ACCIARRI 95	ic.	<9.4 × 10 ⁻⁵ 95	⁸⁴ ACCIARRI	97R L3	<i>E</i> cm= 88-94	GeV
	ie Context	or composite 2 mo	uei.	-	<i>.</i>	84 ACCIARRI 97R search for 1	$\Upsilon(35)$ through its de	cay into $\ell^+\ell^-$	$\tilde{\ell} = e \text{ or } \mu$	
$\Gamma(\pi^{\pm}W^{\mp})/\Gamma_{\text{total}}$ The value is for	the sum o	of the charge states	indicated.	Γ ₁₈ /	/I	$\Gamma((D^0/\overline{D}^0)X)/\Gamma(\text{hadrons})$	s)			Γ_{28}/Γ_{6}
VALUE	<u>C1%</u>	DOCUMENT ID	TECN	COMMENT		VALUE EVTS	DOCUMENT ID		COMMENT	
<7 × 10 ⁻⁵	95	DECAMP	92 ALEP	Ecm = 88-94 GeV		0.296±0.019±0.021 369	85 ABREU	931 DLPH	Ecm = 88-94	GeV
$\Gamma(\rho^{\pm}W^{\mp})/\Gamma_{\text{total}}$				Г19/	/r	⁸⁵ The (D^0/\overline{D}^0) states in A	BREU 931 are detec	ted by the K	π decay mode	. This is a
	the sum o	of the charge states	indicated.	119/	' •	corrected result (see the err	ratum of ABREU 931).		
ALUE	<u>CL%</u>	DOCUMENT ID	<u>TECN</u>		_	$\Gamma(D^{\pm}X)/\Gamma(\text{hadrons})$				Γ ₂₉ /Γ ₆
<8.3 × 10 ⁵	95	DECAMP	92 ALEP	<i>E</i> ^{ee} _{CM} = 88–94 GeV		VALUE EVTS	DOCUMENT ID			
$(J/\psi(1S)X)/\Gamma_{tot}$				Γ ₂₀ /	/ r	0.174±0.016±0.018 539	⁸⁶ ABREU		Ecm = 88-94	
VALUE (units 10 ⁻³)	EVTS	DOCUMENT ID	TECN	COMMENT	′•	⁸⁶ The D [±] states in ABREU seresult (see the erratum of A		ie $K\pi\pi$ decay	mode. This is	a corrected
3.66±0.23 OUR AVE		DOCUMENT ID	TECH	COMMENT	_					
3.40 ± 0.23 ± 0.27	441	72 ACCIARRI	97J L3	Ecm= 88-94 GeV	ı	$\Gamma(D^*(2010)^{\pm}X)/\Gamma(hadron)$ The value is for the sum		indicated		Γ ₃₀ /Γ ₆
$3.9 \pm 0.2 \pm 0.3$	511			Ecm = 88-94 GeV		VALUE EVTS	DOCUMENT ID	TECN	COMMENT	
3.73±0.39±0.36	153	74 ABREU		E ^{ee} = 88-94 GeV		0.163±0.019 OUR AVERAGE	Error Includes scale	factor of 1.3		
• • We do not use						0.155±0.010±0.013 358	87 ABREU		Ecm = 88-94	
3.6 ±0.5 ±0.4	121	⁷⁴ ADRIANI	931 L3	Repl. by ACCIARRI 97		0.21 ±0.04 362	88 DECAMP		Ecm = 88-94	
72 ACCIARRI 971 coi	mbine μ^+	μ^- and $e^+e^ J/\epsilon$	$\psi(15)$ decay	channels and take into a	ac-	87 D*(2010) in ABREU 931				
73 ALEYANDED OF	n systema:	ic error.	ecave into len	ton pairs. $(4.8 \pm 2.4)\%$	χ, I	new CLEO II measurement corrected result (see the en			£ 1.6) % is use	d. This is a
this branching rati	io is due t	prompt $J/\psi(1S)$	production (A	LEXANDER 96N).	OI .	88 DECAMP 911 report B(D*			K ⁻ π ⁺) Γ(D*	(2010)±X
74 Combining $\mu^+\mu^-$	and e^+e	— channels and take	ing into accou	int the common systema	tic	$/ \Gamma(hadrons) = (5.11 \pm 0)$	$(0.34) \times 10^{-3}$. They	obtained the	e above numbe	er assumin
errors. $(7.7^{+6.3}_{-5.4})$	% of this !	oranching ratio is du	ie to prompt	$J/\psi(1S)$ production.		$B(D^0 \to K^-\pi^+) = (3.62)$	$\pm 0.34 \pm 0.44)\%$ and	B(D*(2010)	$\rightarrow D^0\pi^+) =$	= (55 ± 4)%
/_//ne\v\ /F				-	/r	We have rescaled their orig				new CLEC
(ψ(25)X)/Γ _{total}				Γ ₂₁ /	/1	Il branching ratio B(D*(20	$(10)^{+} \rightarrow \mathcal{D}^{\vee} \pi^{+}) =$	(08.1 ± 1.6)	70.	
<u>/ALUE (units 10⁻³)</u> 60±0.29 OUR AVE	<u>EVTS</u>	DOCUMENT ID	TECN	COMMENT	_	$\Gamma(B_s^0X)/\Gamma(hadrons)$				Γ ₃₃ /Γ ₆
.6 ±0.5 ±0.3	39	75 ACCIARRI	97」L3	Eee = 88-94 GeV	1	VALUE	DOCUMENT ID		COMMENT	
.6 ±0.3 ±0.2	46.9			Eee = 88-94 GeV	•	seen	89 ABREU		Eee = 88-94	
		,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,							GeV
$.60 \pm 0.73 \pm 0.33$	5.4	77 ABREU	94P DLPH	Eee = 88-94 GeV		seen	90 ACTON	92N OPAL	Ecm = 88-94	
	5.4	77 ABREU		<i>E</i> cm = 88−94 GeV	(a 1	seen	⁹¹ BUSKULIC	92E ALEP	Ecm = 88-94	GeV
				$\mathcal{E}_{\text{CM}}^{\text{ee}} = 88-94 \text{ GeV}$ nannel $\psi(2S) \rightarrow \ell^+\ell^-$	(<i>t</i>	seen ⁸⁹ ABREU 92м reported value	⁹¹ BUSKULIC	92E ALEP	Ecm = 88-94	GeV
75 ACCIARRI 97 J me = μ, e). 76 ALEXANDER 96	easure this B measur	branching ratio via	the decay ch	<i>E</i> cm = 88−94 GeV	-	seen $^{89}ABREU 92M reported value$ $= (18 \pm 8) \times 10^{-5}.$	⁹¹ BUSKULIC : is $\Gamma(B_s^0 X) * B(B_s^0 \rightarrow$	92E ALEP <i>D_S μν_μ</i> X) *	$E_{\text{cm}}^{\text{ee}} = 88-94$ $B(D_{\text{S}} \rightarrow \phi \pi)/$	GeV /F(hadrons)
75 ACCIARRI 971 me = μ , e). 76 ALEXANDER 961 $J/\psi \pi^+ \pi^-$, with	easure this B measure $J/\psi ightarrow \mathcal{L}$	branching ratio via this branching ra $+\ell^-$.	the decay chatio via the	$E_{ m cm}^{ m ee}=88-94~{ m GeV}$ nannel $\psi(25) ightarrow \ell^+\ell^-$ decay channel $\psi(25)$	→	seen 89 ABREU 92M reported value $= (18 \pm 8) \times 10^{-5}$. 90 ACTON 92N find evidence to	91 BUSKULIC : is $\Gamma(B^0_SX)*B(B^0_S\to B^0_S)$	92E ALEP $D_S \mu u_{\mu} X$) $*$	$E_{ m CM}^{ m ee}=88-94$ ${ m B}(D_{ m S} ightarrow \phi \pi)/{ m Blations}$, with D	GeV $/\Gamma(\text{hadrons})$ $\rho_S^+ \to \phi \pi^+$
75 ACCIARRI 97J me = μ , e). 76 ALEXANDER 96I $J/\psi \pi^+\pi^-$, with 77 ABREU 94P meas	easure this B measure $J/\psi ightarrow \mathcal{L}$	branching ratio via this branching ra $+\ell^-$.	the decay chatio via the	$\mathcal{E}_{\text{CM}}^{\text{ee}} = 88-94 \text{ GeV}$ nannel $\psi(25) \rightarrow \ell^+\ell^-$	→	seen 89 ABREU 92M reported value $= (18 \pm 8) \times 10^{-5}$. 90 ACTON 92N find evidence 10 and $K^*(892)K^+$. Assumin	91 BUSKULIC : is $\Gamma(B_S^0 \times) *B(B_S^0 \to B_S^0)$ for B_S^0 production using R_b from the Stand	92E ALEP $D_S \mu \nu_{\mu} X$) * ing D_S - ℓ correlated Model and	$E_{\text{CM}}^{\text{ee}} = 88-94$ $B(D_S \rightarrow \phi \pi)/2$ Plations, with D d averaging over	GeV $/\Gamma(\text{hadrons})$ $r_s^+ o \phi \pi^+$ er the e and
75 ACCIARRI 97J me = μ . e). 76 ALEXANDER 96I 3 4 4 4 77 ABREU 94P meass 3 4 4 4 4 $^{-}$.	easure this B measure $J/\psi ightarrow \ell$ ure this br	branching ratio via this branching ra $+\ell^-$.	the decay chatio via the	$E_{ m cm}^{ m ee}=88-94~{ m GeV}$ nannel $\psi(25) ightarrow \ell^+\ell^-$ decay channel $\psi(25)$	→	seen 89 ABREU 92M reported value $= (18 \pm 8) \times 10^{-5}$. 90 ACTON 92N find evidence 10 and $K^*(892)K^+$. Assuming $^{10}\mu$ channels, authors measure	91 BUSKULIC is $\Gamma(B_S^0X)*B(B_S^0 \rightarrow B_S^0)*B(B_S^0)$ for B_S^0 production using R_D from the Standre the product branch	92E ALEP $D_S \mu \nu_{\mu} X$) * ing D_S - ℓ correlard Model and ing fraction to	$E_{\text{CM}}^{\text{EC}} = 88-94$ $B(D_S \rightarrow \phi \pi)/D$ Alations, with D d averaging over D	GeV $/\Gamma$ (hadrons) $r_s^+ o \phi \pi^+$ er the e and
75 ACCIARRI 971 me $= \mu$, e). 76 ALEXANDER 961 $J/\psi \pi^+ \pi^-$, with 77 ABREU 94P meass $J/\psi \rightarrow \mu^+ \mu^-$.	easure this B measure $J/\psi ightarrow \ell$ ure this br	branching ratio via this branching ra $+\ell^-$.	the decay chatio via the	$E_{ m cm}^{ m ee}=88-94~{ m GeV}$ nannel $\psi(25) ightarrow \ell^+\ell^-$ decay channel $\psi(25)$	→ ith	seen 89 ABREU 92M reported value $= (18 \pm 8) \times 10^{-5}$. 90 ACTON 92N find evidence 10 and $K^*(892)K^+$. Assumin 10 channels, authors measur $D_s^- \ell^+ \nu_\ell X) \times B(D_s^- \rightarrow \phi$	91 BUSKULIC is $\Gamma(B_S^0 X) * B(B_S^0 \rightarrow B_S^0) * B(B_S^0 \rightarrow B_S^0)$ from the Standre the product branch $\pi^-) = (3.9 \pm 1.1 \pm 0.00)$	92E ALEP $D_S \mu \nu_{\mu} X$) * ling D_S - ℓ correlated Model and ing fraction to: 1.0.8) × 10 ⁻⁴	$E_{\rm cm}^{\rm eq}=88-94$ $B(D_{\rm S} \to \phi \pi)/$ elations, with D d averaging over the $E_{\rm S}$ $E_{\rm S}$ $E_{\rm S}$	GeV / Γ (hadrons) $\rho_s^+ \rightarrow \phi \pi^+$ er the e and $\rho_s^+ \rightarrow \phi \pi^+$ $\rho_s^+ \rightarrow \phi \pi^+$
75 ACCIARRI 97J me = μ , e). 76 ALEXANDER 96I $J/\psi \pi^+\pi^-$, with 77 ABREU 94P meas: $J/\psi \rightarrow \mu^+\mu^-$ ($\chi_{c1}(1P)\chi$)/ Γ_{tot}	easure this B measure $J/\psi \rightarrow \ell$ ure this br ℓ ℓ ℓ ℓ ℓ ℓ ℓ ℓ	branching ratio via this branching ra $+\ell^-$.	the decay chatio via the	$E_{\rm CM}^{\rm eq}=88-94~{ m GeV}$ nannel $\psi(2S) ightarrow \ell^+\ell^-$ decay channel $\psi(2S)$ $\psi(2S) ightarrow J/\psi \pi^+\pi^-$, wi	→ ith	seen 89 ABREU 92M reported value $=(18\pm8)\times10^{-5}.$ 90 ACTON 92N find evidence that $K^*(892)K^+$. Assuming that the channels, authors measur $D_s^-\ell^+\nu_\ell X)\times B(D_s^-\to\phi$ 91 BUSKULIC 92E find eviden	91 BUSKULIC is $\Gamma(B_s^0X)*B(B_s^0 \rightarrow B_s^0)$ production using R_b from the Standre the product branch $\pi^-) = (3.9 \pm 1.1 \pm 0.00)$ for B_s^0 production for B_s^0 production	92E ALEP $D_S \mu \nu_{\mu} X$) * sing D_S - ℓ correlated Model and Ing fraction to: 0.8) \times 10 ⁻⁴ on using D_S - ℓ	$E_{\rm cm}^{\rm eq}=88-94$ $E_{\rm cm}^{\rm eq}=88-94$ $E_{\rm cm}^{\rm eq}=80$ $E_{\rm cm}^{\rm eq}=90$	GeV / Γ (hadrons) $S^+_S \to \phi \pi^+$ er the e and $S^0_S \to S^0_S \to S^0_S$ with $D^+_S \to S^0_S \to S^0_S$
75 ACCIARRI 97J me = μ , e). 76 ALEXANDER 96I $J/\psi \pi^+\pi^-$, with 77 ABREU 94P meas: $J/\psi \rightarrow \mu^+\mu^-$ $\Gamma(\chi_{c1}(1P)\chi)/\Gamma_{tot}$ VALUE (units 10^{-3}) 2.9±0.7 OUR AVERA	easure this B measure $J/\psi \rightarrow \ell$ ure this br ℓ ℓ ℓ ℓ ℓ ℓ ℓ ℓ	branching ratio via this branching ratio ℓ this branching ratio ℓ anching ratio via decomposition ℓ bocument ideals.	the decay cl atlo via the cay channel ψ	$E_{\rm CM}^{\rm eq}=88-94~{ m GeV}$ nannel $\psi(2S)\to\ell^+\ell^-$ decay channel $\psi(2S)$ $\psi(2S)\to J/\psi\pi^+\pi^-$, where $\chi(2S)\to J/\psi\pi^+\pi^-$	→ ith	seen 89 ABREU 92M reported value $=(18\pm8)\times10^{-5}.$ 90 ACTON 92N find evidence 10 and 10 10 Assumin 10 channels, authors measur 10 10 BUSKULIC 92E find evider 10 10 ABREU 10 10 BUSKULIC 92E find evider 10 10 ABREU 10	91 BUSKULIC is $\Gamma(B_S^0 X) * B(B_S^0 \rightarrow B_S^0) * B(B_S^0 \rightarrow B_S^0)$ from the Standre the product branch $\pi^-) = (3.9 \pm 1.1 \pm 1.0 \pm 1$	92E ALEP $D_S \mu \nu_\mu X$) * ing D_S - ℓ correlard Model an ing fraction to 0.8) \times 10 ⁻⁴ on using D_S - ℓ	$E_{\rm cm}^{\rm eq}=88-94$ $E(D_S \to \phi \pi)/2$ Hations, with D d averaging over D	GeV / Γ (hadrons) $\phi_S^+ \rightarrow \phi \pi^+$ er the e and $\phi_S^+ \rightarrow \phi \pi^+$ with $D_S^+ \rightarrow \phi$ with $D_S^+ \rightarrow \phi$
75 ACCIARRI 97J me $= \mu$, e). 76 ALEXANDER 96I $J/\psi \pi^+ \pi^-$, with 77 ABREU 94P meass $J/\psi \rightarrow \mu^+ \mu^-$ ($X_{c1}(1P)X$)/ Γ_{tot} ALUE (units 10^{-3}) .9±0.7 OUR AVERA	easure this B measure $J/\psi \rightarrow \ell$ ure this br ℓ ℓ ℓ ℓ ℓ ℓ ℓ ℓ	branching ratio via this branching ratio $+ \ell^-$, anching ratio via decomposition of $-\frac{DOCUMENT\ ID}{2}$	the decay charled via the cay channel via the	$E_{\rm CM}^{\rm ee} = 88-94 \; {\rm GeV}$ nannel $\psi(2S) \rightarrow \ell^+\ell^-$ decay channel $\psi(2S)$ $\Rightarrow J/\psi \pi^+\pi^-$, where $\ell^+\ell^ \ell^ \ell^-$	→ ith	seen 89 ABREU 92M reported value $= (18 \pm 8) \times 10^{-5}$. 90 ACTON 92N find evidence 10 and $K^*(892)K^+$. Assumin 10 channels, authors measur $D_s^- \ell^+ \nu_\ell \chi) \times B(D_s^- \to \phi$ 91 BUSKULIC 92E find evider 10 $\phi \pi^+$ and $K^*(892)K^+$. Use 10 and 10 channels, the weight	91 BUSKULIC is $\Gamma(B_S^0 \times) *B(B_S^0 \to B_S^0)$ production using R_D from the Standie the product branch $\pi^-) = (3.9 \pm 1.1 \pm 1.0 \pm 0.0 $	92E ALEP $D_S \mu \nu_{\mu} X) *$ $Ing D_S \cdot \ell \text{ correlated Model and ing fraction to } 0.8) \times 10^{-4}$ on using $D_S \cdot \ell$ $1 = (2.7 \pm 0.6) \times 10^{-4}$ of the translating	$E_{\rm cm}^{\rm ex} = 88-94$ $B(D_S \rightarrow \phi \pi)/$ dations, with D d averaging over the E_S	GeV / Γ (hadrons) $\phi_S^+ \rightarrow \phi \pi^+$ er the e and $\phi_S^+ \rightarrow \phi \pi^+$ with $D_S^+ \rightarrow \phi$ with $D_S^+ \rightarrow \phi$
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75 ACCIARRI 97J me $= \mu$, e). 76 ALEXANDER 96I $J/\psi \pi^+\pi^-$, with 77 ABREU 94P measi $J/\psi \rightarrow \mu^+\mu^-$. ($\chi_{c1}(1P)\chi$)/ Γ_{tot} ALUE (units 10^{-3}). 9 \pm 0.7 OUR AVERA .7 \pm 0.6 \pm 0.5 .0 \pm 2.1 \pm 1.5 .0 \pm 0.7 OUR AVERA with $J/\psi \rightarrow \ell^+\ell$ is fitted with two ℓ 79 This branching rat ℓ 4 ℓ 7. (ℓ 2 \pm 2 \pm 4). 80 ACCIARRI 97J det ℓ 7 ℓ 7 (ℓ 2 \pm 4). We cause ℓ 8 ACCIARRI 97J det ℓ 8 ACCIARRI 97J det ℓ 9 This branching rat ℓ 1 ℓ 1 ℓ 2 ℓ 3.2 ℓ 3.2 ℓ 4.0 ℓ 5. 4 ℓ 6.4 ℓ 6.6 ACCIARRI 97J det ℓ 7 (ℓ 6 ℓ 7 ℓ 7 ℓ 8 ACCIARRI 97J det ℓ 7 ℓ 7 (ℓ 8 ACCIARRI 97J det ℓ 8 ACCIARRI 97J det ℓ 8 ACCIARRI 97J det ℓ 9 ACCIARRI 97J det ℓ 9 ACCIARRI 97J det ℓ 9 ACCIARRI 97J det ℓ 1 ACCIARRI 97J det ℓ 1 ℓ 1 ℓ 2 ACCIARRI 97J det ℓ 3 ACCIARRI 97J det ℓ 4 ℓ 7 (ℓ 8 ACCIARRI 97J det ℓ 8 ACCIARRI 97J det ℓ 9 ACCI	easure this B measure $J/\psi \rightarrow \ell$ ure this brune this Br	branching ratio via to this branching ratio via to the property of the proper	the decay of atto via the cay channel \sqrt{tECN} 97J L3 94P DLPH es, fits, limits 93J L3 1 the decay of γ)- $M(\ell^+\ell^-)$ χ^2 -channel χ^2	$E_{\rm CM}^{\rm eq}=88-94~{\rm GeV}$ nannel $\psi(2S)\to\ell^+\ell^-$ decay channel $\psi(2S)$ $\psi(2S)\to J/\psi\pi^+\pi^-$, with $(2S)\to J/\psi\pi^ (2S)\to J/\psi\pi^+\pi^-$, with $(2S)\to J/\psi\pi^ (2S)\to J/\psi\pi^-$	→ ith //	89 ABREU 92M reported value $= (18 \pm 8) \times 10^{-5}.$ 90 ACTON 92N find evidence 1 and $K^*(892)K^+$. Assumin μ channels, authors measur $D_s^- \ell^+ \nu_\ell \chi) \times B(D_s^- \to \phi$ 91 BUSKULIC 92E find evider $\phi \pi^+$ and $K^*(892)K^+$. Use $\theta = \theta = \theta = \theta$. As the experiments assum should be taken with cau $= (13.2 \pm 4.1)\%$ as given 0.77 \pm 0.04. VALUE VALUE VALUE EVTS 0.75 \pm 0.04 OUR AVERAGE 0.760 \pm 0.036 \pm 0.083 0.771 \pm 0.026 \pm 0.070 0.72 \pm 0.03 \pm 0.06 0.76 \pm 0.08 \pm 0.06 1378 92 ACKERSTAFF 97M use ar 4.1)% θ -baryon contributio and θ_s . 93 BUSKULIC 96D use an in-4.3)% θ -baryon contribution θ_s . 94 ABREU 95R use an inclusive contribution. The value reference and θ -such that the value reference is an inclusive contribution.	91 BUSKULIC Is $\Gamma(B_S^0X)*B(B_S^0\to B_S^0)$ production using R_b from the Standier the product branch $\pi^-) = (3.9 \pm 1.1 \pm 1.0 \pm $	92E ALEP $D_S \mu \nu_\mu X$) * Ing D_S - ℓ correlated Model and Ing fraction to $(0.8) \times 10^{-4}$ cm using D_S - ℓ The ing the ing ing fraction to $(0.8) \times 10^{-4}$ cm using D_S - ℓ The ing ing fraction to $(0.8) \times 10^{-4}$ cm using D_S - ℓ The ing ing fraction in $(0.8) \times 10^{-4}$ cm of $(0.8) \times 10^{-4}$ cm	$E_{\rm cm}^{\rm ex} = 88-94$ $B(D_S \to \phi \pi)/b$ dations, with D d averaging over D d averaging over D d be $f(\overline{D} \to B_S^0)$. Correlations, with D d averaging over D d averaging D	GeV /F (hadrons, $+^*S \rightarrow \phi \pi^+$ er the e and $+^*S \rightarrow \phi \pi^+$ er the e and $+^*S \rightarrow \phi \pi^+$ with $D_S^+ - \Phi$ ming up the soured to be (F31+F32) our average fraction f_{A_1} GE become GeV GeV GeV GeV GeV GeV GeV G
75 ACCIARRI 97J me = μ , e). 76 ALEXANDER 96I $J/\psi \pi^+ \pi^-$, with 77 ABREU 94P meass $J/\psi \to \mu^+ \mu^-$. ($X_{c1}(1P)X$)/ Γ_{tot} ALUE (units 10^{-3}). 9±0.7 OUR AVERA. 7.±0.6±0.5 .0±2.1±1.5 .0±2.1±0.9 • We do not use .5±2.9±0.6 78 ACCIARRI 97J me with $J/\psi \to \ell^+ \ell$ is fitted with two [79 This branching rat $\mu^+ \mu^-$. ($X_{c2}(1P)X$)/ Γ_{tot} ALUE (3.2 × 10^{-3} 80 ACCIARRI 97J del $\ell^+ \ell^- (\ell = \mu, e)$. two gaussian shap ($T_{c1}(T_{c1}$	easure this B measure $J/\psi \rightarrow \ell$ ure this brune this Br	branching ratio via to this branching ratio via to the property of the proper	the decay of atto via the cay channel \sqrt{tECN} 97J L3 94P DLPH es, fits, limits 93J L3 1 the decay of γ)- $M(\ell^+\ell^-)$ χ^2 -channel χ^2	$E_{\rm cm}^{\rm ee}=88-94~{\rm GeV}$ nannel $\psi(2S)\to \ell^+\ell^-$ decay channel $\psi(2S)$ $\psi(2S)\to J/\psi\pi^+\pi^-$, with J/ψ $E_{\rm cm}^{\rm ee}=88-94~{\rm GeV}$ three lowest bound state	→ ith //	89 ABREU 92M reported value $= (18 \pm 8) \times 10^{-5}.$ 90 ACTON 92N find evidence to and $K^*(892)K^+$. Assuming the channels, authors measure $D_s^- \ell^+ \nu_\ell X) \times B(D_s^- \to \phi$ 91 BUSKULIC 92E find evider $\phi \pi^+$ and $K^*(892)K^+$. Use $\theta = \theta = \theta = \theta = \theta$. From the content of t	91 BUSKULIC Is $\Gamma(B_S^0 \times) *B(B_S^0 \to B_S^0) *$	92E ALEP $D_S \mu \nu_\mu X$) * Ing D_S - ℓ correlated Model an ling fraction to ℓ (0.8) × 10 ⁻⁴ The second of t	$E_{\rm cm}^{\rm ex}=88-94$ $B(D_S\to\phi\pi)/b$ Halations, with D d averaging over the E_D	GeV /F (hadrons $ \begin{array}{cccccccccccccccccccccccccccccccccc$
75 ACCIARRI 97J me = μ , e). 76 ALEXANDER 96I $J/\psi \pi^+ \pi^-$, with 77 ABREU 94P measis $J/\psi \rightarrow \mu^+ \mu^-$. 76 ($\chi_{c1}(1P)\chi$)/Ftota (μ) 40 Measis 19. 79 ±0.7 OUR AVERA (7. ±0.6 ±0.5). 79 ±0.7 OUR AVERA (7. ±0.6 ±0.5). 78 ACCIARRI 97J me with $J/\psi \rightarrow \ell^+ \ell^-$ ($\chi_{c2}(1P)\chi$)/Ftota (7. ±1.5). 80 ACCIARRI 97J det $\ell^+ \ell^-$ ($\ell = \mu$, e). two gaussian shape $\ell^+ \ell^-$ ($\ell = \mu$, e). two gaussian shape $\ell^+ \ell^-$ ($\ell^- \chi_{c2}(1P)\chi$) $\ell^- \chi_{c2}(1P)\chi$ ($\chi_{c3}(1P)\chi$) $\chi_{c3}(1P)\chi$ ($\chi_{c4}(1P)\chi$) $\chi_{c4}(1P)\chi$) $\chi_{c4}(1P)\chi$) $\chi_{c4}(1P)\chi$ ($\chi_{c4}(1P)\chi$) $\chi_{c4}(1P)\chi$) $\chi_{c4}(1P)\chi$) $\chi_{c4}(1P)\chi$ ($\chi_{c4}(1P)\chi$) $\chi_{c4}(1P)\chi$) $\chi_{c4}(1P)\chi$ ($\chi_{c4}(1P)\chi$) $\chi_{c4}(1P)\chi$) $\chi_{c4}(1P)\chi$ ($\chi_{c4}(1P$	easure this brown as $J/\psi \rightarrow \ell$ ure this brown as $I/\psi \rightarrow \ell$ ure this brown as $I/\psi \rightarrow \ell$ as $I/\psi $	branching ratio via to this branching ratio via to the property of the proper	the decay of atto via the cay channel \sqrt{tECN} 97J L3 94P DLPH es, fits, limits 93J L3 1 the decay of γ)- $M(\ell^+\ell^-)$ χ^2 -channel χ^2	$E_{\rm cm}^{\rm ee}=88-94~{\rm GeV}$ nannel $\psi(2S)\to \ell^+\ell^-$ decay channel $\psi(2S)$ $\psi(2S)\to J/\psi\pi^+\pi^-$, with J/ψ $E_{\rm cm}^{\rm ee}=88-94~{\rm GeV}$ three lowest bound state	ith // // // // // // // // ess)	89 ABREU 92M reported value $= (18 \pm 8) \times 10^{-5}.$ 90 ACTON 92N find evidence to and $K^*(892)K^+$. Assuming the channels, authors measure $D_s^- \ell^+ \ell_\ell X \times B(D_s^- \to \phi)$ 91 BUSKULIC 92E find evider $\phi \pi^+$ and $K^*(892)K^+$. Using the ending the ending $B(\overline{b} \to B_s^0) \times B(B_s^0 \to B_s^0) \times B(B$	91 BUSKULIC Is $\Gamma(B_S^0 \times) *B(B_S^0 \to B_S^0) *$	92E ALEP $D_S \mu \nu_\mu X$) * Ing D_S - ℓ correlated Model an ling fraction to ℓ (0.8) × 10 ⁻⁴ The second of t	$E_{\rm cm}^{\rm ex}=88-94$ $B(D_S\to\phi\pi)/b$ Halations, with D d averaging over the E_D	GeV /F (hadrons $ \begin{array}{cccccccccccccccccccccccccccccccccc$
75 ACCIARRI 97J me $= \mu$, e). 76 ALEXANDER 96I $J/\psi \pi^+ \pi^-$, with 77 ABREU 94P meass $J/\psi \rightarrow \mu^+ \mu^-$. ($X_{c1}(1P)X$)/ Γ_{tot} ALUE (units 10^{-3}). 9±0.7 OUR AVERA. 7±0.6±0.5 0.0±2.1±1.5 0.0±2.1±0.9 • We do not use 5.5±2.9±0.6 78 ACCIARRI 97J me with $J/\psi \rightarrow \ell^+ \ell$ is fitted with two in 79 This branching rat $\mu^+ \mu^-$. ($X_{c2}(1P)X$)/ Γ_{tot} ALUE (units 10^{-3}) 80 ACCIARRI 97J dei $\ell^+ \ell^- (\ell = \mu, e)$, two gaussian shap if $(T(1S)X + T(2S))$ 81 ALEXANDER 96F through its decay of ±0.2 due to the state of the s	easure this brown as $J/\psi \rightarrow \ell$ ure this brown as $I/\psi \rightarrow \ell$ ure this brown as $I/\psi \rightarrow \ell$ as $I/\psi $	branching ratio via to this branching ratio via to the property of the proper	the decay of atto via the cay channel $$ TECN 97J L3 94P DLPH es, fits, limits 93J L3 1 the decay of γ)- $M(\ell^+\ell^-)$ χ^2 - χ^2 -channel χ^2 - $\chi^$	$E_{\rm CM}^{\rm eq}=88-94~{\rm GeV}$ nannel $\psi(2S)\to \ell^+\ell^-$ decay channel $\psi(2S)\to \ell^+\ell^-$ decay channel $\psi(2S)\to J/\psi\pi^+\pi^-$, with J/ψ $E_{\rm CM}^{\rm eq}=88-94~{\rm GeV}$ three lowest bound state fror includes an uncertain	ith // // // // // // // // ess)	89 ABREU 92M reported value $= (18 \pm 8) \times 10^{-5}.$ 90 ACTON 92N find evidence to and $K^*(892)K^+$. Assuming the channels, authors measure $D_s^- \ell^+ \nu_\ell X) \times B(D_s^- \to \phi$ 91 BUSKULIC 92E find evider $\phi \pi^+$ and $K^*(892)K^+$. Use $\theta = \theta = \theta = \theta = \theta$. For $\theta = \theta = \theta = \theta = \theta = \theta$. For $\theta = \theta = \theta = \theta = \theta$. For $\theta = \theta = \theta = \theta = \theta$. For $\theta = \theta = \theta = \theta$. For $\theta = \theta = \theta = \theta$. For $\theta = \theta = \theta = \theta$. For $\theta = \theta$	91 BUSKULIC Is Is $\Gamma(B_S^0 \times) *B(B_S^0 \to B_S^0) *B(B_S^0 \to B_S^0$	92E ALEP $D_S \mu \nu_\mu X) *$ $Ing D_S \cdot \ell \text{ correlated Model and Ing fraction to } \{0.8\} \times 10^{-4} \text{ cm} \text{ using } D_S \cdot \ell \text{ cm} \}$ $Ing D_S \cdot \ell \text{ correlated Model and Ing fraction to } \{0.8\} \times 10^{-4} \text{ cm} \text{ using } D_S \cdot \ell \text{ cm} \}$ $Ing D_S \cdot \ell correlated Model Mo$	$E_{\rm cm}^{\rm ex}=88-94$ $B(D_S\to\phi\pi)/b$ Halations, with D d averaging over the E_D	GeV / (hadrons

 96 AKRAWY 90J report $\Gamma(\gamma \rm X)<8.2$ MeV at 95%CL. They assume a three-body $\gamma\,q\,\overline{q}$ distribution and use E($\gamma)>10$ GeV.

 $9.63 \pm 0.13 \pm 0.63$

 $9.90 \pm 0.02 \pm 0.33$

9.2 ±0.2 ±1.0

 $9.18 \pm 0.03 \pm 0.73$

BARATE

ACCIARRI

ACCIARRI

ADAM

• • • We do not use the following data for averages, fits, limits, etc. • • •

97J ALEP $E_{\text{CM}}^{\text{ee}}$ = 91.2 GeV

96 L3 $E_{\text{CM}}^{\text{ee}} = 91.2 \text{ GeV}$

96 DLPH Eee = 91.2 GeV

Repl. by ACCIARRI 96

94B L3

$\Gamma(e^+e^-\gamma)/\Gamma_{\mathrm{total}}$					Г ₃₅ /Г	$\langle N_{\eta} \rangle$	
VALUE 4	<u>CL%</u>	DOCUMENT ID		COMMENT		VALUE	DOCU
97 ACTON 918 look	95 ed for Isola			<i>E</i> cm = 91.2 GeV n energy (> 0.9 Ge	·V).	0.93 ±0.01 ±0.09 • • • We do not use the following	ACCIA data for
$\Gamma(\mu^+\mu^-\gamma)/\Gamma_{\text{total}}$					Г ₃₆ /Г	$0.91 \pm 0.02 \pm 0.11$ $0.298 \pm 0.023 \pm 0.021$ 103	ACCIA BUSK
VALUE	<u>CL%</u>	DOCUMENT ID		COMMENT		103 BUSKULIC 920 obtain this valu	
<5.6 x 10 ⁻⁴ 98 ACTON 918 look	95 ed for isola	⁹⁸ ACTON		Ecm = 91.2 GeV	M)	$\langle N_{\rho^0} \rangle$	
		The process and a	-> -> -> -	, c.i.e.g, (> 0. > 0.		VALUE	DOCUN
$\Gamma(\tau^+\tau^-\gamma)/\Gamma_{\text{total}}$	CL%	DOCUMENT ID	TECH	COMMENT	Γ ₃₇ /Γ	1.30±0.12 OUR AVERAGE 1.45±0.06±0.20	DUEV
<7.3 × 10 ⁻⁴	95	99 ACTON		Ecm = 91.2 GeV		1.45±0.06±0.20 1.21±0.04±0.15	BUSK
99 ACTON 918 look	ed for isola				·V).	• • We do not use the following	
$\Gamma(\ell^+\ell^-\gamma\gamma)/\Gamma_{ m tota}$					Γ ₃₈ /Γ	$1.43 \pm 0.12 \pm 0.22$	ABRE
The value is the	l e sum over	$\ell = e, \mu, \tau.$			138/1	$\langle N_{\omega} \rangle$	
VALUE	<u>CL%</u>	DOCUMENT ID		COMMENT		VALUE	DOCU
<6.8 × 10 ⁻⁶	95	100 ACTON	93E OPAL	Ecm = 88-94 Ge	V	1.11±0.11 OUR AVERAGE	
¹⁰⁰ For $m_{\gamma\gamma} = 60 \pm$	5 GeV.					$1.17 \pm 0.09 \pm 0.15$ $1.07 \pm 0.06 \pm 0.13$	ACCIA BUSK
$\lceil (q \overline{q} \gamma \gamma) / \lceil_{\text{total}} \rceil$					Г39/Г		2030
VALUE	CL%		TECN_			⟨N _n '⟩	
<5.5 × 10 ⁻⁶	95	¹⁰¹ ACTON	93E OPAL	Ecm = 88-94 Ge	v	VALUE 10	DOCUM 4 ACCUM
¹⁰¹ For $m_{\gamma\gamma}=60 \pm$	5 GeV.					0.25 ±0.04 10.4 • • • We do not use the following of	⁴ ACCI/
Γ(ν⊽γγ)/Γ _{total}					Γ ₄₀ /Γ	•	uata 101 5 BUSK
VALUE	<u>CL%</u>	DOCUMENT ID	TECN	COMMENT	- 	104 ACCIARRI 970 obtain this value	
<3.1 × 10 ⁶	95	102 ACTON		Eee = 88-94 Ge	v	and $n' \rightarrow \rho^0 \gamma$.	
102 For $m_{\gamma\gamma} = 60 \pm$	5 GeV.					105 BUSKULIC 92D obtain this valu	e for x>
Γ(e [±] μ [∓])/Γ(e ⁺ e ⁻	-)			1	Γ ₄₁ /Γ ₁	$\langle N_{f_0(980)} \rangle$	
Test of lepton	family nun	ber conservation.	The value is	for the sum of the	charge	VALUE	DOCUI
states Indicated VALUE	<u>CL%</u>	DOCUMENT ID	TECN CO	DMMENT		• • We do not use the following and the fol	data for ⁶ ABRE
<0.07	90	ALBAJAR 8	89 UA1 E	$p\widetilde{p} = 546,630 \text{ GeV}$			7 ABRE
c/_+ x \ /c			`		- /-		
$\Gamma(e^{\pm}\mu^{\mp})/\Gamma_{\text{total}}$ Test of lepton states indicated		nber conservation.	The value is	for the sum of the	Γ ₄₁ /Γ e charge	106 ABREU 95L obtain this value for ABREU 93 obtain this value for	x> 0.0
VALUE	. <u>crx</u>	DOCUMENT ID		COMMENT		⟨N∳⟩ VALUE	DOCUM
<2.5 × 10 ⁻⁶	95	ABREU		Ecm = 88-94 Ge		0.108±0.006 OUR AVERAGE Erro	
<1.7 x 10 ⁶	95 05	AKERS		Ecm = 88-94 Ge		$0.104 \pm 0.003 \pm 0.007$	ABRE
<0.6 × 10 ⁻⁵ <2.6 × 10 ⁻⁵	95 95	ADRIANI DECAMP	931 L3 92 ALED	$E_{\rm cm}^{\rm ee} = 88-94 {\rm Ge}^2$ $E_{\rm cm}^{\rm ee} = 88-94 {\rm Ge}^2$		$0.122 \pm 0.004 \pm 0.008$	BUSK
	,,,	- Cardill	MEET	-cm- 00-34 G6	•	0.100 ± 0.004 ± 0.007	AKER
$\Gamma(e^{\pm}\tau^{\mp})/\Gamma_{\text{total}}$	fa	.ha ·'	The :!	f 4b	Γ ₄₂ /Γ	 • • • We do not use the following of 0.086 ± 0.015 ± 0.010 	ACTO
states indicated		ber conservation.	i ne value is	ror the sum of the	cnarge		
VALUE	CL%	DOCUMENT ID		COMMENT		WEIGHTED AVERAGE 0.108±0.006 (Error sca	E aled by
<2.2 × 10 ⁻⁵	95 95	ABREU		Ecm = 88-94 Ge			
<1.3 × 10 ⁻⁵	95 95	AKERS ADRIANI		Ecm = 88-94 Ge		¥	
<1.2 × 10 ⁻⁴	95 95	DECAMP	931 L3 92 ALEP	$E_{cm}^{ee} = 88-94 \text{ Ge}$ $E_{cm}^{ee} = 88-94 \text{ Ge}$			
			/100/	-cm 35 37 00			
$\Gamma(\mu^{\pm}\tau^{\mp})/\Gamma_{\text{total}}$	familu nu-	nber conservation.	The value t-	for the even of AL.	Γ ₄₃ /Γ		
states indicated					charge		1
VALUE <1.2 × 10 ⁻⁵	<u>CL%</u>	DOCUMENT ID		COMMENT			1
< 1.2 x 10 - 0	95 05	ABREU AKERS		Ecm = 88-94 Ge			
			95W OPAL 931 L3	Ecm = 88-94 Ge Ecm = 88-94 Ge			
<1.7 × 10 ⁻⁵	95 95	ADRIANI		-cm- 30-34 GE	•	· [· / [= \
	95 95	ADRIANI DECAMP		Ecm = 88-94 Ge	V		1 /
<1.7 × 10 ⁻⁵ <1.9 × 10 ⁻⁵ <1.0 × 10 ⁻⁴	95 95	DECAMP	92 ALEP				
<1.7 × 10 ⁻⁵ <1.9 × 10 ⁻⁵ <1.0 × 10 ⁻⁴	95 95		92 ALEP			\ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \	\
<1.7 × 10 ⁻⁵ <1.9 × 10 ⁻⁵ <1.0 × 10 ⁻⁴ AVERAGE PA	95 95 RTICLE	DECAMP	92 ALEP	RONIC Z DECA			
<1.7 × 10 ⁻⁵ <1.9 × 10 ⁻⁵ <1.0 × 10 ⁻⁴ AVERAGE PA Summed ove	95 95 RTICLE	DECAMP MULTIPLICITI	92 ALEP	RONIC Z DECA		0.06 0.08 0.1	0.12
<1.7 × 10 ⁻⁵ <1.9 × 10 ⁻⁵ <1.0 × 10 ⁻⁴ AVERAGE PA Summed ove	95 95 RTICLE	DECAMP MULTIPLICITII and antiparticle, where the procument in the procum	92 ALEP ES IN HADE nen appropriate	RONIC Z DECA			0.12
<1.7 × 10 ⁻⁵ <1.9 × 10 ⁻⁵ <1.0 × 10 ⁻⁴ AVERAGE PA	95 95 RTICLE	DECAMP MULTIPLICITII and antiparticle, wh	92 ALEP ES IN HADE nen appropriate	RONIC Z DECA		0.06 0.08 0.1 $\langle N_{\phi} \rangle$	0.12
<1.7 × 10 ⁻⁵ <1.9 × 10 ⁻⁵ <1.0 × 10 ⁻⁴ AVERAGE PA Summed ove (N _{x±}) YALUE 17.05±0.43	95 95 RTICLE	MULTIPLICITII and antiparticle, wh DOCUMENT ID AKERS	92 ALEP ES IN HADE nen appropriate TECN 94P OPAL	RONIC Z DECA		$\left< N_{\phi} ight> \$	
<1.7 × 10 ⁻⁵ <1.9 × 10 ⁻⁵ <1.0 × 10 ⁻⁴ AVERAGE PA Summed ove (N _m ±) VALUE 17.05±0.43	95 95 ARTICLE r particle a	DECAMP MULTIPLICITII and antiparticle, where the procument in the procum	92 ALEP ES IN HADE nen appropriate TECN 94P OPAL	RONIC Z DECA		$\left\langle N_{\phi}\right angle$	DOCUM

	owing data for averag	es fits limits	etc. e.e.
(N ₅₍₁₂₇₀₎)	DOCUMENT ID	TECN	COMMENT
$\langle N_{\phi} \rangle$			
	0.1 0.12 0.14	0.16	0.18
			(Confidence Level = 0.157
/-	+-	· · AKERS	95X OPAL 0.9 3.7
		· · ABREU · · BUSKULI	96U DLPH 0.2 C 96H ALEP 2.6
			γ^2
	\bigwedge		
U. 10010.000 (EI	V 1.4)		
WEIGHTED AVE 0.108±0.006 (Er	ERAGE ror scaled by 1.4)		
• • • We do not use the folk 0.086 \pm 0.015 \pm 0.010			Repl. by AKERS 95X
$0.100 \pm 0.004 \pm 0.007$	AKERS	95x OPAL	Ecm = 91.2 GeV
0.104±0.003±0.007 0.122±0.004±0.008	ABREU BUSKULIC		Ecm = 91.2 GeV Ecm = 91.2 GeV
0.108±0.006 OUR AVERAGE	Error includes scal	e factor of 1.	4. See the ideogram below
⟨N_♠⟩ VALUE	DOCUMENT ID	TECN	COMMENT
O' ABREU 93 obtain this val	ue for x> 0.05.	-	
$0.10 \pm 0.03 \pm 0.019$ 0.06 ABREU 95L obtain this value	¹⁰⁷ ABREU alue for 0.05 < x< 0.6		Repl. by ABREU 95L
0.098±0.016	106 ABREU	95L DLPH	Ecm = 91.2 GeV
ALUE ◆ • We do not use the folk	DOCUMENT ID Dowing data for averag		
(N _{fg(980)})			
05 BUSKULIC 92D obtain th	is value for $x>0.1$.		
⁰⁴ ACCIARRI 97D obtain this and $\eta' \rightarrow \rho^0 \gamma$.	s value averaging over	the two dec	ay channels $\eta' o \pi^+\pi^-$
0.068±0.018±0.016	¹⁰⁵ BUSKULIC		Ecm = 91.2 GeV
• • We do not use the follo	owing data for averag		•
<i>VALUE</i> 0.25 ±0.04	DOCUMENT ID 104 ACCIARRI		COMMENT Ecm = 91.2 GeV
(N_y)	000000000000000000000000000000000000000		COMMENT
1.07±0.06±0.13	BUSKULIC	96H ALEP	<i>E</i> ^{ee} _{cm} = 91.2 GeV
$1.17 \pm 0.09 \pm 0.15$	ACCIARRI	970 L3	
VALUE 1.11±0.11 OUR AVERAGE	DOCUMENT ID	TECN	COMMENT
⟨N _w ⟩			
1.43 ± 0.12 ± 0.22	ABREU	93 DLPH	Repl. by ABREU 95L
• • • We do not use the folk			
1.45±0.06±0.20 1.21±0.04±0.15	BUSKULIC ABREU		Ecm = 91.2 GeV Ecm = 91.2 GeV
1.30±0.12 OUR AVERAGE	<u>DOCUMENT ID</u>	TECN	COMMENT
(N _p p)			
103 BUSKULIC 92D obtain th	is value for $x > 0.1$.		
$0.298 \pm 0.023 \pm 0.021$	¹⁰³ BUSKULIC		Repl. by ACCIARRI 96 Eee = 91.2 GeV
 • • We do not use the folion 0.91 ±0.02 ±0.11 	owing data for averag ACCIARRI	es, fits, limits 948 L3	
	ACCIARRI	96 L3	Ecm = 91.2 GeV
• • We do not use the following the fol			

93 DLPH Repl. by ABREU 951

 $0.11 \pm 0.04 \pm 0.03$

108 ABREU 95L obtain this value for x>0.05. 109 ABREU 93 obtain this value for x>0.1.

Gauge & Higgs Boson Particle Listings

Ζ

<u>Z</u>								
⟨ <i>N_{r'2}</i> (1525)⟩					⟨N _D ₀⟩			
VALUE	DOCUMENT ID	TECN	COMMENT		VALUE 0.462±0.026 OUR AVERAGE	DOCUMENT ID	<u>TECN</u>	COMMENT
0.020±0.005±0.006	ABREU	96c DLPH	Ecm = 91.2 GeV		0.465 ± 0.017 ± 0.027	AI FXANDER	96R OPAI	Ecm = 91.2 GeV
4					0.518±0.052±0.035	BUSKULIC		Ecm = 91.2 GeV
⟨N _{K±} ⟩					0.403 ± 0.038 ± 0.044	112 ABREU		Ecm = 91.2 GeV
VALUE	DOCUMENT ID	<u>TECN</u>	COMMENT			ADICEO	331 DET 11	-cm- 71.2 GCV
2.37±0.11 OUR AVERAGE 2.26±0.01±0.18	ABREU	AET DI DU	Eee = 91.2 GeV		¹¹² See ABREU 95 (erratum).			
	AKERS		Ecm = 91.2 GeV		$\langle N_{D_a^{\pm}} \rangle$			
2.42±0.13	AVEKS	94P OPAL	Ecm= 91.2 GeV		VALUE	DOCUMENT ID	TECN	COMMENT
$\langle N_{K^0} \rangle$					0.131±0.010±0.018			Eee = 91.2 GeV
VALUE	DOCUMENT ID	TECN	COMMENT		0.131±0.010±0.016	ALEXANDER	JOK OPAL	Ecm = 91.2 GeV
2.013±0.023 OUR AVERAGE					$\langle N_{D^{\bullet}(2010)^{\pm}} \rangle$			
2.024±0.006±0.042	ACCIARRI	97L L3	Ecm = 91.2 GeV	1	\'`*D*(2010)*/ VALUE	DOCUMENT ID	TECN	COMMENT
1.962±0.022±0.056	ABREU	95L DLPH	Ecm = 91.2 GeV		0.183 ±0.008 OUR AVERAGE		TECH	COMMENT
1.99 ±0.01 ±0.04	AKERS		Ecm = 91.2 GeV		$0.1854 \pm 0.0041 \pm 0.0091$	113 ACKERSTAFF	98E OPAL	Eco = 91.2 GeV
2.061±0.047	BUSKULIC		Eee = 91.2 GeV		0.187 ±0.015 ±0.013			Ecm = 91.2 GeV
• • We do not use the following					0.171 ±0.012 ±0.016	114 ABREU		Eee = 91.2 GeV
					• • We do not use the following			
2.04 ±0.02 ±0.14 2.12 ±0.05 ±0.04	ACCIARRI ABREU	94B L3 92G DLPH	Repl. by ACCIARRI 97L Repl. by ABREU 95L		0.183 ±0.009 ±0.011	115 AKERS		Repl. by ACKER- STAFF 98E
⟨N _{K*(892)±} ⟩					¹¹³ ACKERSTAFF 98E systema	tic error includes a	n uncertaint	
	DOCUMENT (T	TF.C.	COMMENT		branching ratios B(D*+ →	$D^0\pi^+) = 0.683 + 0$.014 and R/	$0^0 \rightarrow K^-\pi^+1 = 0.0383 +$
VALUE 0.72 ±0.05 OUR AVERAGE	DOCUMENT ID	<u> </u>	COMMENT	•	0.0012	, , _ 0.000 ± 0		, = 0.0000 1.
0.712±0.031±0.059	ABREU	951 DIDH	<i>E</i> ee 91.2 GeV		114 See ABREU 95 (erratum).			
	ACTON		Ecm = 91.2 GeV Ecm = 91.2 GeV		115 AKERS 950 systematic erro	r includes an uncert	tainty of ± 0	.008 due to the $D^{*\pm}$ and
0.72 ±0.02 ±0.08					D ⁰ branching ratios [they us	$e B(D^* \rightarrow D^U \pi) =$	$= 0.681 \pm 0$	016 and B($D^{U} \rightarrow K\pi$) =
• • We do not use the following					0.0401 ± 0.0014 to obtain t	nis measurement].		
$1.33 \pm 0.11 \pm 0.24$	ABREU	92G DLPH	Repl. by ABREU 95L		$\langle N_{D_{s1}(2536)^+} angle$			
/au \								
⟨N _{K*(892)0} ⟩					VALUE (units 10 ⁻³)	DOCUMENT ID		COMMENT
VALUE 0.752±0.025 OUR AVERAGE	DOCUMENT ID	TECN	COMMENT	-		ing data for average	s, fits, limits	, etc. • • •
	ACKEDSTAFE	076 ODAL	Eee = 91.2 GeV		$2.9^{+0.7}_{-0.6}\pm0.2$	116 ACKERSTAFF	97W OPAL	Ecm = 91.2 GeV
0.74 ±0.02 ±0.02				•	***			
0.77 ±0.02 ±0.07	ABREU	960 DLPH	Ecm = 91.2 GeV	• .	116 ACKERSTAFF 97W obtain t		and with the	assumption that its decay
0.83 ±0.01 ±0.09	BUSKULIC		Ecm = 91.2 GeV		width is saturated by the D^*	A final states.		
0.97 ±0.18 ±0.31	ABREU	93 DLPH	Ecm = 91.2 GeV		$\langle N_{B^*} \rangle$			
• • We do not use the following	g data for average:	s, fits, limits	, etc. • • •		VALUE	DOCUMENT ID.	TECN	COMMENT
0.74 ±0.03 ±0.03	AKERS	95x OPAL	Repl. by ACKER-		0.28 ±0.01 ±0.03	117 ABREU	95R DI PH	Eee = 91.2 GeV
			STAFF 97s					
$\langle N_{K_2^*(1430)} \rangle$					117 ABREU 95R quote this value	e tor a tiavor-average	ea excitea st	ate.
\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\					$\langle N_{J/\psi(1S)} \rangle$			
VALUE	DOCUMENT ID		COMMENT		VALUE	DOCUMENT ID	TECN	COMMENT
$0.079 \pm 0.026 \pm 0.031$	ABREU		<i>E</i> cm= 91.2 GeV	•	0.0056±0.0003±0.0004	118 ALEXANDER		
• • We do not use the following	g data for average:							
0.19 ±0.04 ±0.06 1	10 AKERS	95x OPAL	$E_{\rm cm}^{\rm ee}$ = 91.2 GeV		118 ALEXANDER 96B identify	$\eta/\psi(15)$ from the de	ecays into iep	oton pairs.
110 AKERS 95x obtain this value	for x< 0.3.				$\langle N_{\psi(2S)} \rangle$			
AITERO JOX ODIAM EMS VAIGE	IOI X \ 0.5.				VALUE	DOCUMENT ID	TECN	COMMENT
$\langle N_{D^{\pm}} \rangle$					0.0023±0.0004±0.0003			Eee = 91.2 GeV
VALUE	DOCUMENT ID	TECN	COMMENT	_	0.0023 1 0.0007 1 0.0003	ALLAANULN	700 OI AL	-cm- 31.1 GCV
0.187±0.020 OUR AVERAGE E	rror includes scale	factor of 1.5	i. See the ideogram below		$\langle N_{p} \rangle$			
$0.170 \pm 0.009 \pm 0.014$			<i>E</i> cm = 91.2 GeV	ŀ	VALUE	DOCUMENT ID	TECN	COMMENT
$0.251 \pm 0.026 \pm 0.025$	BUSKULIC	94J ALEP	<i>Ec</i> m= 91.2 GeV		0.98±0.09 OUR AVERAGE			
0.199±0.019±0.024 1	11 ABREU		Eee = 91.2 GeV		$1.07 \pm 0.01 \pm 0.14$	ABREU	95F DLPH	Ecm = 91.2 GeV
111 See ABREU 95 (erratum).					0.92±0.11	AKERS	94P OPAL	Ecm = 91.2 GeV
See Abrico 33 (citatom).								
WEIGHTED AVERAGE					$\langle N_{\Delta(1232)^{++}} angle$			
0.187±0.020 (Error scale	d by 1.5)				VALUE	DOCUMENT ID	TECN	COMMENT
1					0.087±0.033 OUR AVERAGE	Error includes scale		
Ψ					$0.079 \pm 0.009 \pm 0.011$	ABREU	95W DLPH	Ecm = 91.2 GeV
					$0.22 \pm 0.04 \pm 0.04$	ALEXANDER		Ecm = 91.2 GeV
					$\langle N_A \rangle$			
					VALUE	DOCUMENT ID	<u>TECN</u>	COMMENT
					0.372±0.007 OUR AVERAGE			
					$0.364 \pm 0.004 \pm 0.017$	ACCIARRI	97L L3	Ecm = 91.2 GeV
					$0.374 \pm 0.002 \pm 0.010$	ALEXANDER		Ecm = 91.2 GeV
					0.386 ± 0.016	BUSKULIC	94K ALEP	Ecm = 91.2 GeV
					$0.357 \pm 0.003 \pm 0.017$	ABREU		Eee = 91.2 GeV
			~2		• • We do not use the follow			
		EVANDES	OSD OBAL A		0.37 ±0.01 ±0.04	ACCIARRI		Repl. by ACCIARRI 97L
		LEXANDER USKULIC	96R OPAL 1.1 94J ALEP 3.1		0.351±0.019	ACTON		Repl. by ALEXAN-
		BREU	931 DLPH					DER 97D
/	\ "		4.3		/M \			
		(Con	fidence Level = 0.114)		⟨ <i>N_A</i> (1520)⟩			
					VALUE	DOCUMENT ID	TECN	COMMENT
0.1 0.15 0.2	0.25 0.3 (0.35 0.4			$0.0213 \pm 0.0021 \pm 0.0019$	ALEXANDER	97D OPAL	Ecm = 91.2 GeV
$\langle N_{D^{\pm}} \rangle$					$\langle N_{\Sigma^+} \rangle$			
/'*D±/					/ 14 4 + }			
(0-7					VALUE	DOCUMENT ID		COMMENT

0.099±0.008±0.013

ALEXANDER 97E OPAL FEE = 91.2 GeV

20.85 ± 0.02 ± 0.24

⟨N _Σ -⟩ VALUE	DOCUMENT ID	TECN	COMMENT
0.083±0.006±0.009	DOCUMENT ID ALEXANDER		COMMENT Ecm = 91.2 GeV
$\langle N_{\Sigma^{+}+\Sigma^{-}} \rangle$			
ALUE	DOCUMENT ID	TECN	COMMENT
0.181±0.018 OUR AVERAGE			•
			Ecm = 91.2 GeV
0.170±0.014±0.061	ABREU		E _{CM} = 91.2 GeV
19 We have combined the value the statistical and systematic isospin symmetry is assumed in	errors of the two	final states :	separately in quadrature.
N _{Σ0} ⟩ ALUE	DOCUMENT ID	TECN	COMMENT
0.070±0.011 OUR AVERAGE	DOCUMENT 10	, JECN	COMMENT
$0.071 \pm 0.012 \pm 0.013$	ALEXANDER		$E_{\rm cm}^{\rm ee}$ = 91.2 GeV
$0.070 \pm 0.010 \pm 0.010$	ADAM	96B DLPH	Ecm = 91.2 GeV
$\langle N_{(\Sigma^+ + \Sigma^- + \Sigma^0)/3} angle$			
ALUE	DOCUMENT ID		
0.084±0.005±0.008	ALEXANDER	97E OPAL	Ecm = 91.2 GeV
(N _{E(1385)+})	DOCUMENT IS	TECH	COMMENT
0.0239±0.0009±0.0012	DOCUMENT ID ALEXANDER		Eee = 91.2 GeV
	TELTHIDER	J.J OFAL	-cm- 31.2 GeV
(N _{E(1385)} -)	DOCUMENT ID	TECN	COMMENT
.0240±0.0010±0.0014			Eee = 91.2 GeV
$\langle N_{\Sigma(1385)^{+}+\Sigma(1385)^{-}} \rangle$			
ALUE	DOCUMENT ID Error includes sca	TECN ale factor of	1.6.
0.0479±0.0013±0.0026	ALEXANDER		
$0.0382 \pm 0.0028 \pm 0.0045$	ABREU		Eee = 91.2 GeV
• We do not use the following			•
0.0380±0.0062	ACTON	92J OPAL	Repl. by ALEXAN- DER 970
(N ₌ -)	005/4/5/7 /-		country.
0.0258±0.0009 OUR AVERAGE	DOCUMENT ID	<u>TECN</u>	COMMENT
.0259±0.0004±0.0009	ALEXANDER	970 OPAL	Eee = 91.2 GeV
$0.0250 \pm 0.0009 \pm 0.0021$	ABREU	950 DLPH	<i>E</i> cm = 91.2 GeV
• We do not use the following			
0.020 ±0.004 ±0.003	ABREU	92G DLPH 92J OPAL	Repl. by ABREU 950
0.0206 ± 0.0021	ACTON	921 OPAL	Repl. by ALEXAN- DER 97D
⟨N _{≡(1530)°} ⟩			
^-' ='(1530)"/ /ALUE	DOCUMENT ID	TECN	COMMENT
0.0053±0.0013 OUR AVERAGE	Error includes sca	ale factor of	3.2.
0.0068±0.0005±0.0004			Ecm = 91.2 GeV
0.0041±0.0004±0.0004	ABREU		Ecm = 91.2 GeV
 ● ● We do not use the followir 0.0063±0.0014 	ACTON		Repl. by ALEXAN-
		JEJ OFAL	DER 97D
$\langle N_{\Omega^{-}} \rangle$			
VALUE	DOCUMENT ID	<u>TECN</u>	COMMENT
0.00164±0.00028 OUR AVERAG		97n OD41	E66 _ 01 0 C-14
0.0018 ±0.0003 ±0.0002	ALEXANDER		Ecm = 91.2 GeV
0.0014 ±0.0002 ±0.0004 • • • We do not use the following			Ecm = 91.2 GeV
0.0050 ±0.0015	ACTON		Repl. by ALEXAN-
/N .\			DER 97D
$\langle N_{A_c^+} \rangle$			
ALUE	DOCUMENT ID		
0.078±0.012±0.012	ALEXANDER	96R OPAL	<i>E</i> cm = 91.2 GeV
(Ncharged)	DOCUMENT ID	TECN	COMMENT
1.00±0.13 OUR AVERAGE	goodani ib	, con	
21.05±0.20	AKERS		Ecm = 91.2 GeV
20.91±0.03±0.22	BUSKULIC		E _{CM} = 91.2 GeV
21.40±0.43	ACTON		Ecm = 91.2 GeV
20.71±0.04±0.77	ABREU		Ecm = 91.2 GeV
20.7 ±0.7	ADEVA	91: L3	<i>E</i> cm = 91.2 GeV
20.1 ±1.0 ±0.9	ABRAMS		2 Ecm = 91.1 GeV

DECAMP

91K ALEP Repl. by BUSKULIC 95R

Z HADRONIC POLE CROSS SECTION

This quantity is defined as

$$\sigma_h^0 = \frac{12\pi}{M_Z^2} \frac{\Gamma(e^+e^-)\Gamma(hadrons)}{\Gamma_Z^2}$$

It is one of the parameters used in the Z lineshape fit. (See the 'Note on

VALUE (nb)	EVTS	DOCUMENT ID		TECN	COMMENT
41.54±0.14 OUR FI 41.49±0.10 OUR A					
41.23 ± 0.20	1.05M	ABREU	94	DLPH	Ecm = 88-94 GeV
41.39 ± 0.26	1.09M	ACCIARRI	94	L3	Ecm = 88-94 GeV
41.70 ± 0.23	1.19M	AKERS	94	OPAL	Ecm = 88-94 GeV
41.60 ± 0.16	1.27M	BUSKULIC	94	ALEP	Ecm = 88-94 GeV
• • • We do not us	e the followin	g data for average	es, fits	s, Ilmits,	etc. • • •
41.45 ± 0.31	512k	ACTON	93D	OPAL	Repl. by AKERS 94
41.34 ± 0.28	460k	ADRIANI	93M	1 L.3	Repl. by ACCIARRI 94
41.60 ± 0.27	520k	BUSKULIC	93.	ALEP	Repl. by BUSKULIC 94
42 ±4	450	ABRAMS	8 9 8	MRK2	Eee = 89.2-93.0 GeV

Z VECTOR COUPLINGS TO CHARGED LEPTONS

These quantities are the effective vector couplings of the Z to charged leptons. Their magnitude is derived from a measurement of the Z lineshape and the forward-backward lepton asymmetries as a function of energy around the Z mass. The relative sign among the vector to axial-vector couplings is obtained from a measurement of the ${\cal Z}$ asymmetry parameters, $A_{\rm e}$ and $A_{\rm T}$, or $\nu_{\rm e}$ scattering. The fit values quoted below correspond to global nine- or five-parameter fits to lineshape, lepton forward-backward asymmetry, and $A_{\rm e}$ and $A_{\rm T}$ measurements. See "Note on the Z boson"

Within the current data set, the reason for the smallness of $g_{1\ell}^{tt}$ compared to $\mathbf{g}_{V}^{\mathbf{e}}$ and $\mathbf{g}_{V}^{ au}$ is due to the large value of $A_{\mathbf{e}}$ which is heavily weighted by the SLD result. This large value of $A_{\mathcal{C}}$ leads to a large value of $g_{\mathcal{V}}^{\mathcal{C}}$. Since $m{g}_{m{V}}^{\mu}$ is obtained using the relation $A_{FB}^{\mu}=0.75{ imes}A_{e}{ imes}A_{\mu}$, a large value of g_V^e leads to a SMALL value of g_V^e . Concerning the τ , its g_V gets mainly determined directly from A_τ which is obtained from a measurement of the τ polarization (see "Note on the Z boson").

EVTS	DOCUMENT ID	TECN	COMMENT
IR FIT			
the follow	ing data for average	s, fits, limits	s, etc. • • •
	120 ABE	95J SLD	Ecm = 91.31 GeV
38k	¹²¹ ACCIARRI	94 L3	<i>Ecm</i> = 88-94 GeV
45.8k	¹²² BUSKULIC	94 ALEP	Eee = 88-94 GeV
	123 ADRIANI	93M L3	Repl. by ACCIARRI 94
	121 BUSKULIC	93J ALEP	Repl. by BUSKULIC 94
	the follow	THE FIT the following data for average 120 ABE 38k 121 ACCIARRI 45.8k 122 BUSKULIC 123 ADRIANI	THE FIT the following data for averages, fits, limits 120 ABE 95J SLD 38k 121 ACCIARRI 94 L3 45.8k 122 BUSKULIC 94 ALEP 123 ADRIANI 93M L3

--- ABL 93) optial trils result combining polarized Bhabha results with the A_{LR} measurement of ABE 94C. The Bhabha results alone give $-0.0507 \pm 0.0096 \pm 0.0020$. 121 The τ polarization result has been included. 122 BUSKULIC 94 use the added constraint of τ polarization. 123 ADRIANI 93M use their measurement of the τ polarization in addition to forward-backward lepton asymmetries.

VALUE -0.0274±0.0047 OL	JR FIT	DOCUMENT ID	<u>TECN</u>	COMMENT
• • We do not use	the follow	ing data for averag	es, fits, limit	s, etc. • • •
$-0.0402^{+0.0153}_{-0.0211}$	34k	124 ACCIARRI	94 L3	Ecm = 88-94 GeV
-0.034 ± 0.013	46.4k	¹²⁵ BUSKULIC	94 ALEP	Ecm = 88-94 GeV
$-0.048 \begin{array}{l} +0.021 \\ -0.033 \end{array}$		126 ADRIANI	93M L3	Repl. by ACCIARRI 94
-0.019 +0.018 -0.019		¹²⁴ BUSKULIC	931 ALEP	Repl. by BUSKULIC 9

126 ADRIANI 93M use their measurement of the au polarization in addition to forwardbackward lepton asymmetries.

$\mathbf{\mathcal{E}}_{V}^{T}$				
VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
-0.0378±0.0020 OI	JR FIT			
• • • We do not use	e the follow	ing data for averag	es, fits, limits	, etc. • • •
-0.0384 ± 0.0078	25k	127 ACCIARRI	94 L3	Ecm = 88-94 GeV
-0.038 ± 0.005	45.1k	¹²⁸ BUSKULIC	94 ALEP	Ecm = 88-94 GeV
-0.037 ± 0.008	7441	129 ADRIANI	93M L3	Repl. by ACCIARRI 94
-0.039 ± 0.006		127 BUSKULIC	93J ALEP	Repl. by BUSKULIC 94
127 The τ polarization	n result has	s been Included.		

128 BUSKULIC 94 use the added constraint of au polarization. 129 ADRIANI 93M use their measurement of the au polarization in addition to forward-

backward lepton asymmetries.

VALUE	<u>EVTS</u>	DOCUMENT ID		TECN	COMMENT
-0.0377±0.0007 OU	JR FIT				
• • • We do not use	the follow	Ing data for average	s, fits	, limits,	etc. • • •
-0.039 ±0.004	50.3k	130 ABREU	94	DLPH	Ecm = 88-94 GeV
- 0.0378 ^{+ 0.0045} - 0.0042	97k	¹³¹ ACCIARRI	94	L3	Ecm = 88-94 GeV
~0.034 ±0.004	146k	130 AKERS	94	OPAL	Ecm = 88-94 GeV
-0.038 ±0.004	137.3k	¹³⁰ BUSKULIC	94	ALEP	Ecm = 88-94 GeV
-0.027 ± 0.008	58k	130 ACTON	93D	OPAL	Repl. by AKERS 94
-0.040 +0.006 -0.005		¹³¹ ADRIANI	93м	L3	Repl. by ACCIARRI 94
$-0.034 \begin{array}{l} +0.004 \\ -0.003 \end{array}$		131 BUSKULIC	93 J	ALEP	Repl. by BUSKULIC 94
130 Using forward-ba	ckward lent	on asymmetries			

Z AXIAL-VECTOR COUPLINGS TO CHARGED LEPTONS

These quantities are the effective axial-vector couplings of the Z to charged leptons. Their magnitude is derived from a measurement of the Z lineshape and the forward-backward lepton asymmetries as a function of energy around the Z mass. The relative sign among the vector to axial-vector couplings is obtained from a measurement of the Z asymmetry parameters, A_e and A_τ , or ν_e scattering. The fit values quoted below correspond to global nine- or five-parameter fits to lineshape, lepton forward-backward asymmetry, and A_e and $A_ au$ measurements. See "Note on the Z boson" for details.

E ^e A						
<u>VALUE</u> 0.5007 ± 0.0009 OI	ID EIT		DOCUMENT ID		<u>TECN</u>	COMMENT
• • We do not use		ina d	ata for average	c fits	limits	etc a a a
	,0110111	-	ABE			
-0.4977±0.0045					SLD	Ecm = 91.31 GeV
-0.4998 ± 0.0016	38k		ACCIARRI	94		Ecm = 88-94 GeV
-0.503 ± 0.002	45.8k		BUSKULIC		ALEP	Cili
-0.4980±0.0021			ADRIANI	93M		Repl. by ACCIARRI 94
-0.5029 ± 0.0018			BUSKULIC		ALEP	
¹³² ABE 95J obtain this result combining polarized Bhabha results with the A_{LR} measure ment of ABE 94C. The Bhabha results alone give $-0.4968 \pm 0.0039 \pm 0.0027$. ¹³³ The τ -polarization constraint has been included.						
VALUE	EVTS		DOCUMENT ID		TECN	COMMENT
-0.5015±0.0012 Ol			BOCOMENT ID	_	120.1	LOMME!!
$-0.4987 + 0.0030 \\ -0.0026$	34k	134	ACCIARRI	94	L3	<i>E</i> ee = 88−94 GeV
-0.501 ± 0.002	46.4k		BUSKULIC	94	ALEP	Eee = 88-94 GeV
-0.4968 +0.0050 -0.0037			ADRIANI	93M	L3	Repl. by ACCIARRI 94
-0.5014 ± 0.0029		134	BUSKULIC	93 J	ALEP	Repl. by BUSKULIC 94
134 The $ au$ -polarizatio	n constrain	t has	been included.			
$\mathcal{E}_{A}^{ au}$	E1 4EC					
<u>VALUE</u> 0.5009±0.0013 Ol	<u>EVTS</u>		DOCUMENT ID	—	TECN	COMMENT
• • We do not use		ing da	ata for average	s. fits	. limits.	etc. • • •
-0.5014±0.0029	25k	•	ACCIARRI		L3	Ecm = 88-94 GeV
-0.502 ±0.003	45.1k		BUSKULIC	94	ALEP	Eee = 88-94 GeV
-0.5032 ± 0.0038	7441		ADRIANI	93M	L3	Repl. by ACCIARRI 94
-0.5016 ± 0.0033		135	BUSKULIC	931	ALEP	
135 The $ au$ -polarizatio	ก constrain	t has	been included.			
ml.						
6 A	FICTO				TECH	CO
VALUE	EVIS		DOCUMENT ID		<u>TECN</u>	COMMENT

• • We do not use the following data for averages, fits, limits, etc. • • •

ABREU

AKERS

ACTON

136 ADRIANI

136 BUSKULIC

BUSKULIC

136 ACCIARRI

94 DLPH Ecm = 88-94 GeV

94 L3 Eee 88-94 GeV

94 OPAL Ecm = 88-94 GeV

94 ALEP Eee = 88-94 GeV

93M L3

93D OPAL Repl. by AKERS 94

93J ALEP Repl. by BUSKULIC 94

Repl. by ACCIARRI 94

71k

97k

146k

137k

58k

 $^{136}\,\text{The }\tau\text{-polarization}$ constraint has been included.

-0.5008 ±0.0008 OUR FIT

 -0.4999 ± 0.0014

 -0.4998 ± 0.0014

 -0.500 ± 0.001

-0.502 ±0.001

 -0.4998 ± 0.0016

 -0.4986 ± 0.0015

 -0.5022 ± 0.0015

Z COUPLINGS TO NEUTRAL LEPTONS

These quantities are the effective couplings of the \boldsymbol{Z} to neutral leptons. $u_e\,e$ and $u_\mu\,e$ scattering results are combined with g_A^e and g_V^e measurements at the Z mass to obtain $\mathbf{g}^{\nu}\mathbf{e}$ and $\mathbf{g}^{\nu}\mathbf{\mu}$ following NOVIKOV 93c.

g ^v •	T .			
VALUE	DOCUMENT ID			COMMENT
0.528±0.065	137 VILAIN	94	CHM2	From $\nu_{\mu}e$ and $\nu_{e}e$ scattering
137 VILAIN 94 derive 1 1.05 + 0.15 - 0.18.	this value from their value	of	g ^V µ and	d their ratio $g^{ u_e}/g^{ u_\mu} =$
پرس VALUE	DOCUMENT ID		TECN	COMMENT
0.502±0.017	138 VILAIN	94	CHM2	From $\nu_{\mu}e$ scattering
138 VILAIN 94 derive thi	is value from their measurem	ent	of the co	uplings $g_{A}^{e u_{\mu}}=-0.503\pm$
0.017 and ${m g}_{m V}^{m e u_{m \mu}} = -$	-0.035 ± 0.017 obtained from	$^{ u}\mu$	e scatter	ring. We have re-evaluated
	current PDG values for $g_{\mathcal{A}}^{e}$ a			

Z ASYMMETRY PARAMETERS

For each fermion-antifermion pair coupling to the Z these quantities are

$$A_f = \frac{2g_V^f g_A^f}{(g_V^f)^2 + (g_A^f)^2}$$

where g_V^f and g_A^f are the effective vector and axial-vector couplings. For their relation to the various lepton asymmetries see the 'Note on the Z

Using polarized beams, this quantity can also be measured as $(\sigma_L - \sigma_R)/(\sigma_L + \sigma_R)$, where σ_L and σ_R are the $e^+\,e^-$ production cross sections for Z bosons produced with left-handed and right-handed electrons respectively.

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
0.1519±0.0034 OUR AVE	RAGE			
0.162 ±0.041 ±0.014	89838	¹³⁹ ABE	97 SLD	Ecm = 91.27 GeV
0.1543 ± 0.0039	93644	¹⁴⁰ ABE	97E SLD	Ecm = 91.27 GeV
0.152 ±0.012		¹⁴¹ ABE	97N SLD	Ecm = 91.27 GeV
0.129 ±0.014 ±0.005	89075	¹⁴² ALEXANDER	960 OPAL	Ecm = 88-94 GeV
0.202 ±0.038 ±0.008		¹⁴³ ABE	95J SLD	Eee = 91.31 GeV
0.136 ±0.027 ±0.003		144 ABREU	951 DLPH	Ecm = 88-94 GeV
0.129 ±0.016 ±0.005	33000	¹⁴⁵ BUSKULIC	95Q ALEP	Eee = 88-94 GeV
0.157 ±0.020 ±0.005	86000	144 ACCIARRI	94E L3	Ecm = 88-94 GeV
• • • We do not use the	following	data for averages, fi	ts, limits, etc	. • • •
0.122 ±0.030 ±0.012	30663	144 AKERS	95 OPAL	Repl. by ALEXAN- DER 960
$0.1656 \pm 0.0071 \pm 0.0028$	49392	¹⁴⁶ ABE	94c SLD	Repl. by ABE 97E
0.097 ±0.044 ±0.004	10224	¹⁴⁷ ABE	93 SLD	Repl. by ABE 97E
0.120 ± 0.026		144 BUSKULIC	93P ALEP	Repl. by
				BUSKULIC 950

139 ABE 97 obtain this result from a measurement of the observed left-right charge asymmetry, $A_Q^{
m obs}=0.225\pm0.056\pm0.019$, in hadronic Z decays. If they combine this value of $A_{\rm C}^{\rm Obs}$ with their earlier measurement of $A_{LR}^{\rm Obs}$ they determine $A_{\rm e}$ to be 0.1574 \pm 0.0197 \pm 0.0067 independent of the beam polarization.

140 ABE 97E measure the left-right asymmetry in hadronic Z production. This value (statistical and systematic errors added in quadrature) leads to $\sin^2\!\theta_W^{\rm eff} = 0.23060 \pm$

141 ABE 97N obtain this direct measurement using the lef-right cross section asymmetry and the left-right forward-backward asymmetry in leptonic decays of the Z boson obtained with a polarized electron beam.

 142 ALEXANDER 960 measure the au-lepton polarization and the forward-backward polarization asymmetry.

143 ABE 95J obtain this result from polarized Bhabha scattering.

¹⁴⁴Derived from the measurement of forward-backward au polarization asymmetry.

 145 BUSKULIC 95Q obtain this result fitting the au polarization as a function of the polar auproduction angle.

146 ABE 94C measured the left-right asymmetry in Z production. This value leads to $\sin^2\!\theta_W = 0.2292 \pm 0.0009 \pm 0.0004$. 147 ABE 93 measured the left-right asymmetry in Z production.

Ap.

This quantity is directly extracted from a measurement of the left-right forwardbackward asymmetry in $\mu^+\mu^-$ production at SLC using a polarized electron beam. This double asymmetry eliminates the dependence on the Z-e-e coupling parameter

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
0.102±0.034	3788	¹⁴⁸ ABE	97N SLD	Ecm = 91.27 GeV

 $^{^{148} \}mbox{ABE}$ 97N obtain this direct measurement using the lef-right cross section asymmetry and the left-right forward-backward asymmetry in $\mu^+\mu^-$ decays of the Z boson obtained with a polarized electron beam.

The LEP Collaborations derive this quantity from the measurement of the average τ polarization in $Z\to \tau^+\tau^-$. The SLD Collaboration directly extracts this quantity from its measured left-right forward-backward asymmetry in $Z\to \tau^+\tau^-$ produced using a polarized e beam. This double asymmetry eliminates the dependence on the Z-e-e coupling parameter A.

- 0 0 000piiii 6 p		''e'		
VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
0.143±0.008 OUR AV	ERAGE			
0.195 ± 0.034		¹⁴⁹ ABE	97N SLD	Ecm = 91.27 GeV
$0.134 \pm 0.009 \pm 0.010$	89075	150 ALEXANDER	960 OPAL	Ecm = 88-94 GeV
$0.148 \pm 0.017 \pm 0.014$		ABREU	951 DLPH	Ecm = 88-94 GeV
$0.136 \pm 0.012 \pm 0.009$	33000	¹⁵¹ BUSKULIC	95Q ALEP	Ecm = 88-94 GeV
$0.150 \pm 0.013 \pm 0.009$	86000	ACCIARRI	94E L3	<i>E</i> ee = 88-94 GeV
• • • We do not use t	he follow	ing data for average	s, fits, limits,	etc. • • •
$0.153 \pm 0.019 \pm 0.013$	30663	AKERS	95 OPAL	Repl. by ALEXAN- DER 96u
0.132 ± 0.033	10732	ADRIANI	93M L3	Repl. by ACCIARRI 94E
0.143±0.023		BUSKULIC	93P ALEP	Repl. by BUSKULIC 950
0.24 ±0.07	2021	ABREU	92N DLPH	Repl. by ABREU 951
149				

ABE 97N obtain this direct measurement using the left-right cross section asymmetry and the left-right forward-backward asymmetry in $\tau^+\tau^-$ decays of the Z boson obtained with a polarized electron beam.

 $150\,\mathrm{ALEXANDER}$ 960 measure the au-lepton polarization and the forward-backward polarization asymmetry.

 151 BUSKULIC 95Q obtain this result fitting the au polarization as a function of the polar auproduction angle.

This quantity is directly extracted from a measurement of the left-right forwardbackward asymmetry in $c\overline{c}$ production at SLC using polarized electron beam. This double asymmetry eliminates the dependence on the Z-e-e coupling parameter A_e .

VALUE	DOCUMENT ID	TECN	COMMENT
0.59±0.19 OUR AVERAGE			
$0.37 \pm 0.23 \pm 0.21$	¹⁵² ABE	95L SLD	Eee = 91.26 GeV
$0.73 \pm 0.22 \pm 0.10$	¹⁵³ ABE,K	95 SLD	Ecm = 91.26 GeV

152 ABE 95. tag b and c quarks through their semileptonic decays into electrons and muons. A maximum likelihood fit is performed to extract A_b and A_c .

153 ABE,K 95 tag $Z \to c\overline{c}$ events using D^{*+} and D^{+} meson production. To take care

of the $b\bar{b}$ contamination in their analysis they use $A_b^D=0.64\pm0.11$ (which is A_b from D^*/D tagging). This is obtained by starting with a Standard Model value of 0.935, assigning it an estimated error of ± 0.105 to cover LEP and SLD measurements, and finally taking into account $B \cdot \overline{B}$ mixing $(1-2x_{\rm mix}=0.72\pm0.09)$. Combining with APE OF the review of $B \cdot \overline{B}$ in the sum of $B \cdot \overline{B}$ mixing $(1-2x_{\rm mix}=0.72\pm0.09)$. ABE 95L they quote 0.59 ± 0.19 .

This quantity is directly extracted from a measurement of the left-right forwardbackward asymmetry in $b\overline{b}$ production at SLC using polarized electron beam. This double asymmetry eliminates the dependence on the Z-e-e coupling parameter A_e .

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
0.89±0.11 OUR AVE	RAGE			
$0.87 \pm 0.11 \pm 0.09$	4032	154 ABE	95K SLD	Ecm = 91.26 GeV
$0.91 \pm 0.14 \pm 0.07$		155 ABE	95L SLD	Ecm = 91.26 GeV

 154 ABE 95K obtain an enriched sample of $b\,\overline{b}$ events tagging with the impact parameter. A momentum-weighted charge sum is used to identify the charge of the underlying b quark. 155 ABE 95L tag b and c quarks through their semileptonic decays into electrons and muons. A maximum likelihood fit is performed to extract A_b and A_c . Combining with ABE 95K, they quote 0.89 \pm 0.09 \pm 0.06.

TRANSVERSE SPIN CORRELATIONS IN $Z \rightarrow \tau^+\tau^-$

The correlations between the transverse spin components of $\tau^+\tau^-$ produced in \boldsymbol{Z} decays may be expressed in terms of the vector and axial-vector couplings:

$$\begin{split} C_{TT} &= \frac{|\boldsymbol{g}_{A}^{T}|^{2} - |\boldsymbol{g}_{V}^{T}|^{2}}{|\boldsymbol{g}_{A}^{T}|^{2} + |\boldsymbol{g}_{V}^{T}|^{2}} \\ C_{TN} &= -2 \frac{|\boldsymbol{g}_{A}^{T}| |\boldsymbol{g}_{V}^{T}|}{|\boldsymbol{g}_{A}^{T}|^{2} + |\boldsymbol{g}_{V}^{T}|^{2}} \sin(\boldsymbol{\Phi}_{\boldsymbol{g}_{V}^{T}} - \boldsymbol{\Phi}_{\boldsymbol{g}_{A}^{T}}) \end{split}$$

 C_{TT} refers to the transverse-transverse (within the collision plane) spin correlation and C_{TN} refers to the transverse-normal (to the collision plane)

The longitudinal au polarization $P_{ au}$ (= $-A_{ au}$) is given by:

$$P_{\tau} = -2\frac{|\mathbf{g}_{A}^{\tau}||\mathbf{g}_{V}^{\tau}|}{|\mathbf{g}_{A}^{\tau}|^{2} + |\mathbf{g}_{V}^{\tau}|^{2}}\cos(\Phi_{\mathbf{g}_{V}^{\tau}} - \Phi_{\mathbf{g}_{A}^{\tau}})$$

Here Φ is the phase and the phase difference $\Phi_{{\cal g}_{V}^{T}}-\Phi_{{\cal g}_{A}^{T}}$ can be obtained using both the measurements of C_{TN} and $P_{ au}$.

C _{TT} VALUE 1.01±0.12 OUR AVE	<u>EVTS</u>	DOCUMENT ID	<u>TECN</u>	COMMENT	
$0.87 \pm 0.20 ^{+0.10}_{-0.12}$	9.1K	ABREU	97G DLPH	Ecm = 91.2 GeV	
$1.06 \pm 0.13 \pm 0.05$	120K	BARATE	97D ALEP	<i>E</i> ee 91.2 GeV	

C _{TN}				
VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
$0.08 \pm 0.13 \pm 0.04$	120K	156 BARATE	970 ALEP	Ecm = 91.2 GeV
156 BARATE 97D con to obtain tan(Φ_g	mbine their $\tau - \Phi_{\mathbf{g}_{\mathbf{A}}^{T}}$	value of C_{TN} with t = -0.57 ± 0.97 .	he world ave	rage $P_{ au}=-0.140\pm0.007$

$A_{FR}^{(0,e)}$ CHARGE ASYMMETRY IN $e^+e^- \rightarrow e^+e^-$

For the Z peak, we report the pole asymmetry defined by $(3/4)A_{\rm C}^2$ as determined by the nine-parameter fit to cross-section and lepton forwardbackward asymmetry data. For details see the "Note on the ${\it Z}$ boson."

ASYMMETRY (%)	STD. MODEL	√s (GeV)	DOCUMENT ID		TECN
1.51±0.40 OUR FIT					
1.5 ±0.4 OUR AVERAGE					
2.5 ±0.9		91.2	ABREU	94	DLPH
1.04±0.92		91.2	ACCIARRI	94	L3
0.62 ± 0.80		91.2	AKERS	94	OPAL
1.85 ± 0.66		91.2	BUSKULIC	94	ALEP

$A_{FB}^{(0,\mu)}$ CHARGE ASYMMETRY IN $e^+e^ightarrow \ \mu^+\mu^-$

For the Z peak, we report the pole asymmetry defined by (3/4)A_eA_ μ as determined by the nine-parameter fit to cross-section and lepton forward backward asymmetry data. For details see the "Note on the ${\it Z}$ boson."

	STD. MODEL	(GeV)				
ASYMMETRY (%)	MODEL	(GeV)		DOCUMENT ID		<u>TECN</u>
1.33 ± 0.26 OUR FIT	_					
1.34± 0.24 OUR AVERAG	E					
1.4 ± 0.5		91.2		ABREU	94	DLPH
1.79± 0.61		91.2		ACCIARRI	94	L3
0.99± 0.42		91.2		AKERS	94	OPAL
1.46± 0.48		91.2		BUSKULIC	94	ALEP
• • We do not use the follow	wing data for	averages	, fits	, limits, etc. 🔹 🤄	•	
9 ±30	-2	20		ABREU	95M	DLPH
7 ± 26	-10	40		ABREU	95M	DLPH
-11 ±33	- 25	57		ABREU	95M	DLPH
-62 ± 17	45	69		ABREU	95M	DLPH
-56 ±10	-58	79	157	ABREU	95M	DLPH
-13 ± 5	-23	87.5	157	ABREU	95M	DLPH
$-29.0 {}^{+}_{-} {}^{5.0}_{4.8} \pm 0.5$	- 32.1	56.9	158	ABE	901	VN\$
$-9.9 \pm 1.5 \pm 0.5$	-9.2	35		HEGNER	90	JADE
0.05 ± 0.22	0.026	91.14		ABRAMS	89D	MRK2
-43.4 ± 17.0	- 24.9	52.0		BACALA	89	AMY
-11.0 ± 16.5	-29.4	55.0	160	BACALA	89	AMY
-30.0 ± 12.4	-31.2	56.0	160	BACALA	89	AMY
-46.2 ±14.9	- 33.0	57.0	160	BACALA	89	AMY
-29 ±13	- 25.9	53.3		ADACHI	88c	TOPZ
$+$ 5.3 \pm 5.0 \pm 0.5	-1.2	14.0		ADEVA	88	MRKJ
$-10.4 \pm 1.3 \pm 0.5$	-8.6	34.8		ADEVA	88	MRKJ
$-12.3 \pm 5.3 \pm 0.5$	-10.7	38.3		ADEVA	88	MRKJ
$-15.6 \pm 3.0 \pm 0.5$	-14.9	43.8		ADEVA	88	MRKJ
-1.0 ± 6.0	-1.2	13.9		BRAUNSCH	88D	TASS
$-9.1 \pm 2.3 \pm 0.5$	-8.6	34.5		BRAUNSCH	88D	TASS
$-10.6 \begin{array}{c} + & 2.2 \\ - & 2.3 \end{array} \pm 0.5$	-8.9	35.0		BRAUNSCH	88D	TASS
$-17.6 \begin{array}{c} + & 4.4 \\ - & 4.3 \end{array} \pm 0.5$	15.2	43.6		BRAUNSCH	88D	TASS
$-4.8 \pm 6.5 \pm 1.0$	-11.5	39		BEHREND	87C	CELL
$-18.8 \pm 4.5 \pm 1.0$	~ 15.5	44		BEHREND	87C	CELL
$+$ 2.7 \pm 4.9	-1.2	13.9		BARTEL	86C	JADE
$-11.1 \pm 1.8 \pm 1.0$	-8.6	34.4		BARTEL		JADE
$-17.3 \pm 4.8 \pm 1.0$	-13.7	41.5		BARTEL	86C	JADE
$-22.8 \pm 5.1 \pm 1.0$	-16.6	44.8		BARTEL	86C	JADE
$-6.3 \pm 0.8 \pm 0.2$	-6.3	29		ASH	85	MAC
$-4.9 \pm 1.5 \pm 0.5$	-5.9	29		DERRICK	85	HRS
- 7.1 ± 1.7	-5.7	29		LEVI	83	MRK2
-16.1 ± 3.2	- 9.2	34.2		BRANDELIK	82C	TASS

 157 ABREU 95M perform this measurement using radiative muon-pair events associated with high-energy isolated photons.

158 ABE 901 measurements in the range 50 $\leq \sqrt{5} \leq$ 60.8 GeV. 159 ABRAMS 89D asymmetry includes both 9 $\mu^+\mu^-$ and 15 $\tau^+\tau^-$ events.

160 BACALA 89 systematic error is about 5%.

$A_{FR}^{(0,\tau)}$ CHARGE ASYMMETRY IN $e^+e^- \rightarrow \tau^+\tau^-$

For the Z peak, we report the pole asymmetry defined by $(3/4)A_eA_{\tau}$ as determined by the nine-parameter fit to cross-section and lepton forward-backward asymmetry data. For details see the "Note on the ${\it Z}$ boson."

ASYMMETRY (%)	STD. MODEL	(GeV)	DOCUMENT ID		TECN
2.12± 0.32 OUR FIT				-	
2.13± 0.31 OUR AVERA	GE				
2.2 ± 0.7		91.2	ABREU	94	DLPH
2.65 ± 0.88		91.2	ACCIARRI	94	L3
2.05 ± 0.52		91.2	AKERS	94	OPAL
1.97 ± 0.56		91.2	BUSKULIC	94	ALEP
• • We do not use the foll	owing data fo	or averages, f	its, limits, etc. •	• •	
$-32.8 \begin{array}{l} + 6.4 \\ - 6.2 \end{array} \pm 1.5$	- 32.1	56.9 ¹	⁵¹ ABE	901	VNS
- 8.1 ± 2.0 ±0.6	- 9.2	35	HEGNER	90	JADE
-18.4 ±19.2	-24.9	52.0	⁶² BAÇALA	89	AMY
-17.7 ±26.1	-29.4	55.0 ¹	⁶² BACALA	89	AMY
-45.9 ±16.6	-31.2	56.0 1º	⁶² BACALA	89	AMY
-49.5 ±18.0	-33.0	57.0	⁶² BACALA	89	AMY
-20 ±14	- 25.9	53.3	ADACHI	880	TOPZ
-10.6 ± 3.1 ±1.5	-8.5	34.7	ADEVA	88	MRKJ
$-8.5 \pm 6.6 \pm 1.5$	- 15.4	43.8	ADEVA	88	MRKJ
$-6.0 \pm 2.5 \pm 1.0$	8.8	34.6	BARTEL	85F	JADE
$-11.8 \pm 4.6 \pm 1.0$	14.8	43.0	BARTEL	85F	JADE
- 5.5 ± 1.2 ±0.5	-0.063	29.0	FERNANDEZ	85	MAC
- 4.2 ± 2.0	0.057	29	LEVI	83	MRK2
-10.3 ± 5.2	-9.2	34.2	BEHREND	82	CELL
- 0.4 ± 6.6	-9.1	34.2	BRANDELIK	820	TASS
161 ABE 901 measurements in ¹⁶² BACALA 89 systematic e	the range 50 rror is about	$0 \le \sqrt{s} \le 5\%$.	60.8 GeV.		

$A_{FR}^{(0,\ell)}$ CHARGE ASYMMETRY IN $e^+e^- \rightarrow \ell^+\ell^-$

For the Z peak, we report the pole asymmetry defined by $(3/4)A_I^2$ as determined by the five-parameter fit to cross-section and lep backward asymmetry data assuming lepton universality. For details see the "Note on the Z boson."

ASYMMETRY (%)	STD. MODEL	(GeV)	DOCUMENT ID		TECN
1.59±0.18 OUR FIT					
1.60±0.18 OUR AVERAGE					
1.77±0.37		91.2	ABREU	94	DLPH
1.84±0.45		91.2	ACCIARRI	94	L3
1.28±0.30		91.2	AKERS	94	OPAL
1.71±0.33		91.2	BUSKULIC	94	ALEP

$A_{FR}^{(0,u)}$ CHARGE ASYMMETRY IN $e^+e^- \rightarrow u\overline{u}$

ASYMMETRY (%)	STD. MODEL	(GeV)	DOCUMENT ID TECN
4.0 ± 6.7 ± 2.8	6	91.2	163 ACKERSTAFF 97T OPAL

¹⁶³ ACKERSTAFF 97T measure the forward-backward asymmetry of various fast hadrons made of light quarks. Then using SU(2) isospin symmetry and flavor independence for down and strange quarks authors solve for the different quark types.

$A_{FB}^{(0,s)}$ CHARGE ASYMMETRY IN $e^+e^- \rightarrow s\bar{s}$

The s-quark asymmetry is derived from measurements of the forwardbackward asymmetry of fast hadrons containing an s quark.

ASYMMETRY (%)	STD. MODEL	(GeV)	DOCUMENT ID TECN	
9.9±3.1 OUR AVERAGE	Error Includes			_
$6.8 \pm 3.5 \pm 1.1$	10	91.2	164 ACKERSTAFF 97T OPAI	L
$13.1 \pm 3.5 \pm 1.3$		91.2	165 ABREU 95G DLPI	н

¹⁶⁴ ACKERSTAFF 97T measure the forward-backward asymmetry of various fast hadrons made of light quarks. Then using SU(2) isospin symmetry and flavor independence for down and strange quarks authors solve for the different quark types. The value reported here corresponds then to the forward-backward asymmetry for "down-type" quarks.

165 ABREU 95G require the presence of a high-momentum charged kaon or Λ⁰ to tag the s quark. An unresolved s- and d-quark asymmetry of (11.2 ± 3.1 ± 5.4)% is obtained by tagging the presence of a high-energy neutron or neutral kaon in the hadron calorimeter.

A(0,c) CHARGE ASYMMETRY IN e+e- → cc

OUR FIT, which is obtained by a simultaneous fit to several c- and bquark measurements as explained in the "Note on the Z boson," refers to the Z pole asymmetry. As a cross check we have also performed a weighted average of the "near peak" measurements taking into account the various common systematic errors. We have assumed that the smallest common systematic error is fully correlated. Applying to this combined "peak" measurement QCD, QED, and energy-dependence corrections, our weighted average gives a pole asymmetry of $(7.20 \pm 0.64)\%$.

ASYMMETRY (%)	STD. MODEL	(GeV)	DOCUMENT ID	TECN
7.32± 0.58 OUR	FIT			
$6.3 \pm 1.2 \pm 0.6$		91.22	166 ALEXANDER	97c OPAL
6.00 ± 0.67 ± 0.52		91.24	167 ALEXANDER	96 OPAL
$7.7 \pm 2.9 \pm 1.2$		91.27	168 ABREU	95E DLPH
$8.3 \pm 2.2 \pm 1.6$		91.27	169 ABREU	95K DLPH
6.99± 2.05±1.02		91.24	170 BUSKULIC	951 ALEP
$9.9 \pm 2.0 \pm 1.7$		91.24	171 BUSKULIC	94G ALEP
8.3 ± 3.8 ± 2.7	5.6	91.24	172 ADRIANI	920 L3
			or averages, fits, limit	
		-	- · · · ·	-
$3.9 \pm 5.1 \pm 0.9$		89.45	166 ALEXANDER	97c OPAL
$15.8 \pm 4.1 \pm 1.1$		93.00	166 ALEXANDER	97c OPAL
$-7.5 \pm 3.4 \pm 0.6$	- 3.5	89.52	167 ALEXANDER	96 OPAL
$14.1 \pm 2.8 \pm 0.9$	12.0	92.94	167 ALEXANDER	96 OPAL
6.8 ± 4.2 ±0.9		91.25	173 BUSKULIC	94J ALEP
1.4 ± 3.0 ±2.0	5.6	91.24	174 ACTON	93K OPAL
3.8 ± 4.4 ±1.0	5.4	91.28	175 AKERS	93D OPAL
$-12.9 \pm 7.8 \pm 5.5$	13.6	35	BEHREND	90D CELL
7.7 ±13.4 ±5.0	-22.1	43	BEHREND	90D CELL
	- 13.6	35	ELSEN	90 JADE
	- 23.2	44	ELSEN	90 JADE
$-10.9 \pm 12.9 \pm 4.6$				
-14.9 ± 6.7	– 13.3	35	OULD-SAADA	89 JADE
166				

- ¹⁶⁶ ALEXANDER 97C identify the b and c events using a D/D^* tag.
- 167 ALEXANDER 96 tag heavy flavors using one or two identified leptons. This allows the simultaneous fitting of the b and c quark forward-backward asymmetries as well as the average $B^0 - \overline{B}{}^0$ mixing.
- ¹⁶⁸ ABREU 95E require the presence of a $D^{*\pm}$ to identify c and b quarks.
- 169 ABREU 95K Identify c and b quarks using both electron and muon semileptonic decays.
- 170 BUSKULIC 951 require the presence of a high momentum $D^{*\pm}$ to have an enriched sample of $Z \rightarrow c\overline{c}$ events.
- 171 BUSKULIC 94G perform a simultaneous fit to the p and p_T spectra of both single and
- 172 ADRIANI 92D use both electron and muon semileptonic decays.
- $173\,\mathrm{BUSKULIC}$ 94J Identify the b and c decays using D^* . Replaced by BUSKULIC 95I.
- 174 ACTON 93K use the lepton tagging technique. Replaced by ALEXANDER 96.
- 175 AKERS 93D identify the b and c decays using D^* . Replaced by ALEXANDER 97C.

A(0,b) CHARGE ASYMMETRY IN e+e- → bb

OUR FIT, which is obtained by a simultaneous fit to several c- and bquark measurements as explained in the "Note on the Z boson," refers to the Z pole asymmetry. As a cross check we have also performed a weighted average of the "near peak" measurements taking into account the various common systematic errors. We have assumed that the smallest common systematic error is fully correlated. Applying to this combined "peak" measurement QCD, QED, and energy-dependence corrections, our weighted average gives a pole asymmetry of $(10.07\pm0.32)\%$. For the jetcharge measurements (where the QCD corrections are already included since they represent an inherent part of the analysis), we subtract the QCD correction before combining.

ASYMMETRY (%)	STD. MODEL	(GeV)	DOCUMENT ID	TECN
10.02± 0.28 OUR FIT			176	
9.94± 0.52± 0.44		91.21	176 ACKERSTAFF	97P OPAL
$9.4 \pm 2.7 \pm 2.2$		91.22	177 ALEXANDER	97c OPAL
$9.06 \pm 0.51 \pm 0.23$		91.24	¹⁷⁸ ALEXANDER	96 OPAL
9.65 ± 0.44 ± 0.26		91.21	179 BUSKULIC	96Q ALEP
$5.9 \pm 6.2 \pm 2.4$		91.27	¹⁸⁰ ABREU	95E DLPH
$10.4 \pm 1.3 \pm 0.5$		91.27	¹⁸¹ ABREU	95K DLPH
$11.5 \pm 1.7 \pm 1.0$		91.27	182 ABREU	95K DLPH
$8.7 \pm 1.1 \pm 0.4$		91.3	183 ACCIARRI	94D L3 .
9.92± 0.84± 0.46		91.19	¹⁸⁴ BUSKULIC	94I ALEP
ullet $ullet$ $ullet$ We do not use the	following da	ta for ave	erages, fits, limits, et	C. • • •
$4.1 \pm 2.1 \pm 0.2$		89.44	176 ACKERSTAFF	
$14.5 \pm 1.7 \pm 0.7$		92.91	176 ACKERSTAFF	97P OPAL
$-8.6 \pm 10.8 \pm 2.9$		89.45	177 ALEXANDER	97C OPAL
$-2.1 \pm 9.0 \pm 2.6$		93.00	177 ALEXANDER	97C OPAL
$5.5 \pm 2.4 \pm 0.3$	5.5	89.52	178 ALEXANDER	96 OPAL
$11.7 \pm 2.0 \pm 0.3$	11.4	92.94	178 ALEXANDER	96 OPAL
$-3.4 \pm 11.2 \pm 0.7$		88.38	179 BUSKULIC	960 ALEP
$5.3 \pm 2.0 \pm 0.2$		89.38	179 BUSKULIC	960 ALEP
8.9 ± 5.9 ± 0.4		90.21	179 BUSKULIC	96Q ALEP
3.8 ± 5.1 ± 0.2		92.05	179 BUSKULIC	96Q ALEP
10.3 ± 1.6 ± 0.4		92.94	179 BUSKULIC	96Q ALEP
10.3 ± 1.6 ± 0.4		72.74	- BOSKOLIC	JUQ ALEP

$8.8 \pm 7.5 \pm 0.5$		93.90	179 BUSKULIC	96Q ALEP
$6.2 \pm 3.4 \pm 0.2$		89.52	185 AKERS	95s OPAL
9.63 ± 0.67 ± 0.38		91.25	185 AKERS	95s OPAL
$17.2 \pm 2.8 \pm 0.7$		92.94	¹⁸⁵ AKERS	95s OPAL
$8.7 \pm 1.4 \pm 0.2$		91.24	¹⁸⁶ BUSKULIC	94G ALEP
$7.1 \pm 5.4 \pm 0.7$	5.2	89.66	187 ACTON	93K OPAL
$9.2 \pm 1.8 \pm 0.8$	8.5	91.24	187 ACTON	93K OPAL
$13.1 \pm 4.7 \pm 1.3$	10.8	92.75	187 ACTON	93K OPAL
$13.9 \pm 9.7 \pm 4.9$	9.4	91.28	188 AKERS	93D OPAL
$16.1 \pm 6.0 \pm 2.1$		91.2	189 ABREU	92H DLPH
$8.6 \pm 1.5 \pm 0.7$	8.2	91.24	¹⁹⁰ ADRIANI	92D L3
$2.5 \pm 5.1 \pm 0.7$	5.3	89.67	¹⁹¹ ADRIANI	92D L3
$9.7 \pm 1.7 \pm 0.7$	8.2	91.24	¹⁹¹ ADRIANI	920 L3
$6.2 \pm 4.2 \pm 0.7$	10.8	92.81	¹⁹¹ ADRIANI	920 L3
$-71 \pm 34 + 7 \\ -8$	-58	58.3	SHIMONAKA	91 TOPZ
$-22.2 \pm 7.7 \pm 3.5$	-26.0	35	BEHREND	90D CELL
$-49.1 \pm 16.0 \pm 5.0$	-39.7	43	BEHREND	90D CELL
-28 ±11	-23	35	BRAUNSCH	90 TASS
$-16.6 \pm 7.7 \pm 4.8$	24.3	35	ELSEN	90 JADE
$-33.6 \pm 22.2 \pm 5.2$	- 39.9	44	ELSEN	90 JADE
$3.4 \pm 7.0 \pm 3.5$	-16.0	29.0	BAND	89 MAC
$-72 \pm 28 \pm 13$	-56	55.2	SAGAWA	89 AMY

- 176 ACKERSTAFF 97P tag b quarks using lifetime. The quark charge is measured using both jet charge and vertex charge, a weighted sum of the charges of tracks in a jet which contains a tagged secondary vertex.
- 177 ALEXANDER 97C identify the b and c events using a D/D^* tag.
- 178 ALEXANDER 96 tag heavy flavors using one or two identified leptons. This allows the simultaneous fitting of the b and c quark forward-backward asymmetries as well as the average $B^0-\overline{B}^0$ mixing.
- 179 BUSKULIC 960 tag b-quark flavor and charge using high transverse momentum leptons. The asymmetry value at the Z peak is obtained using a charm charge asymmetry of 6.17%.

 180 ABREU 95E require the presence of a $D^{*\pm}$ to identify c and b quarks.
- 181 ABREU 95K Identify c and b quarks using both electron and muon semileptonic decays. The systematic error includes an uncertainty of ± 0.3 due to the mixing correction ($X=0.115\pm0.011$).
- 182 ABREU 95K tag b quarks using lifetime; the quark charge is identified using jet charge. The systematic error includes an uncertainty of ± 0.3 due to the mixing correction (X = 0.115 ± 0.011).
- 183 ACCIARRI 94D use both electron and muon semileptonic decays.
- 184 BUSKULIC 941 use the lifetime tag method to obtain a high purity sample of $Z \to b \bar{b}$ events and the hemisphere charge technique to obtain the jet charge.
- events and the nemisphere charge technique to obtain the jet charge. 185 AKERS 95s tag b quarks using lifetime; the quark charge is measured using jet charge. These asymmetry values are obtained using $R_b = \lceil (bb) \rceil \lceil (\text{hadrons}) = 0.216$. For a value of R_b different from this by an amount ΔR_b , the change in the asymmetry values is given by $-K\Delta R_b$, where K = 0.082, 0.471, and 0.855 for \sqrt{s} values of 89.52, 91.25, and 92.94 GeV respectively. Replaced by ACKERSTAFF 97P.
- and 92.94 GeV respectively. Replaced by ACKERSTAFF 97P.

 186 BUSKULIC 94c perform a simultaneous fit to the p and p_T spectra of both single and dilepton events. Replaced by BUSKULIC 96q.

 187 ACTON 93K use the lepton tagging technique. The systematic error includes the uncertainty on the mixing parameter. Replaced by ALEXANDER 96.

 188 AKERS 93D Identify the b and c decays using D*. Replaced by ALEXANDER 97C.

 189 B tagging via its semimuonic decay. Experimental value corrected using average LEP

- B^0 - \overline{B}^0 mixing parameter $\chi = 0.143 \pm 0.023$.
- 190 ADRIANI 92D use both electron and muon semileptonic decays. For this measurement ADRIANI 92D average over all √s values to obtain a single result.
- 191 ADRIANI 92D use both electron and muon semileptonic decays. The quoted systematic error is common to all measurements. The peak value is superseded by ACCIARRI 94D.

CHARGE ASYMMETRY IN e+e- → qq

Summed over five lighter flavors

Experimental and Standard Model values are somewhat event-selection endent. Standard Model expectations contain some assumptions on B^0 - \overline{B}^0 mixing and on other electroweak parameters.

ASYMMETRY (%)	STD. MODEL	√5 (GeV)	DOCUMENT ID	TECN
• • • We do not use the	following data t	for average	s, fits, limits, etc. •	• •
$-0.76\pm0.12\pm0.15$		91.2	192 ABREU	92i DLPH
$4.0 \pm 0.4 \pm 0.63$	4.0	91.3	¹⁹³ ACTON	92L OPAL
$9.1 \pm 1.4 \pm 1.6$	9.0	57. 9	ADACHI	91 TOPZ
$-0.84\pm0.15\pm0.04$		91	DECAMP	91B ALEP
$8.3 \pm 2.9 \pm 1.9$	8.7	56.6	STUART	90 AMY
$11.4 \pm 2.2 \pm 2.1$	8.7	57.6	ABE	89L VNS
6.0 ±1.3	5.0	34.8	GREENSHAW	89 JADE
8.2 ±2.9	8.5	43.6	GREENSHAW	89 JADE

192 ABREU 921 has 0.14 systematic error due to uncertainty of quark fragmentation.

193 ACTON 921 use the weight function method on 259k selected Z → hadrons events. The systematic error includes a contribution of 0.2 due to B⁰-B⁰ mixing effect, 0.4 due to Monte Carlo (MC) fragmentation uncertainties and 0.3 due to MC statistics. ACTON 92L derive a value of $\sin^2\!\theta_W^{\rm eff}$ to be 0.2321 \pm 0.0017 \pm 0.0028.

CHARGE ASYMMETRY IN $p\bar{p} \rightarrow Z \rightarrow e^+e^-$

ASYMMETRY (%)	STD. MODEL	(GeV)	DOCUMENT	D TECN
• • • We do not use the fo	llowing data f	or averages	, fits, limits, etc.	• • •
$5.2 \pm 5.9 \pm 0.4$		91	ABE	91E CDF

Z REFERENCES

ABE ACKERSTAFF	98D	PRL 80 660 EPJ C1 439	K. Abe+	(SLD	Collab.) Collab.)
ABE	98E 97	PRL 78 17	K. Ackerstaff+ +Abe, Abt, Akagi, Allen+	(OPAL	Collab.)
ABE	97E	PRL 78 2075	+Abe, Abt, Akagi, Allen+		Collab.)
ABE	97N	PRL 79 804 ZPHY C73 243	K. Abe+	(SLD (DELPHI	Collab.)
ABREU	97C	ZPHY C73 243	+Adam, Adye, Ajinenko+	(DELPHI	Collab.)
ABREU	97G	PL B404 194	P. Abreu+	(DELPHI	Collab.)
ACCIARRI ACCIARRI	97D 97J	PL B393 465 PL B407 351	+Adriani, Aguilar-Benitez, Ahlen+ M. Acciarri+		Collab.) Collab.)
ACCIARRI	97K	PL B407 361	M. Acciarri+		Collab.)
ACCIARRI	97L	PL B407 361 PL B407 389	M. Acciarri+	(L3	Collab.)
ACCIARRI	97R	PL B413 167	M. Acciarri+	(L3	Collab.)
ACKERSTAFF	97C	PL B391 221	+Alexander, Allison, Altekamp, Ametewee		Collab.)
ACKERSTAFF ACKERSTAFF	97K 97M	ZPHY C74 1 ZPHY C74 413	K. Ackerstaff+ K. Ackerstaff+	(OPAL	Collab.)
ACKERSTAFF	97P	ZPHY C75 385	K. Ackerstaff+	(OPAL	Collab.) Collab.)
ACKERSTAFF	975	PL B412 210	K. Ackerstaff+	(OPAL	Collab.)
	97T	ZPHY C76 387	K. Ackerstaff+	(OPAL	Collab.)
ACKERSTAFF	97W	ZPHY C76 425	K. Ackerstaff+	(OPAL	Collab.)
ALEXANDER ALEXANDER	97C	ZPHY C76 387 ZPHY C76 425 ZPHY C73 379 ZPHY C73 569	+Allison, Altekamp, Ametewee+	(OPAL	Collab.) Collab.)
ALEXANDER	97E	ZPHY C73 587	+Allison, Altekamp, Ametewee+ +Allison, Altekamp, Ametewee+	(OPAL	Collab.)
BARATE		PL B405 191	R. Barate+	(ALEPH	
BARATE	97E	PL B401 150	R. Barate+	(ALEPH	Collab.)
BARATE	97F	PL B401 163	R. Barate+	(ALEPH	Collab.)
BARATE	97 J	ZPHY C74 451	R. Barate+	(ALEPH	
ABE	96E	PR D53 1023	+Abt, Ahn, Akagi, Allen+		Collab.)
ABREU ABREU	96 96C	ZPHY C70 531 PL B379 309	+Adam, Adye+ +Adam, Adye+	(DELPHI	Collab.)
ABREU	96R	ZPHY C72 31	+Adam, Adye+	(DELPHI	Collab.)
ABREU	96S	PL B389 405	+Adam, Adye, Ajinenko+	(DELPHI	Collab.)
ABREU	96U	ZPHY C73 61	+Adam, Adye, Agasi, Ajinenko+	(DELPHI	Collab.)
ACCIARRI	96	PL B371 126	+Adam, Adriani+	(L3	Collab.)
ACCIARRI	96B	PL B370 195	+Adam, Adriani+	(L3	Collab.)
ADAM	96 06 D	ZPHY C69 561 ZPHY C70 371	+Adye, Agasi, Ajinenko+	(DELPHI	Collab.)
ADAM ALEXANDER	96B 96	ZPHY C70 371 ZPHY C70 357	+Adye, Agasi+ +Allison, Altekamp+	(DELPHI (OPAL	Collab.)
ALEXANDER	96B	ZPHY C70 197	+Allison, Altekamp+	(OPAL	Collab.)
ALEXANDER	96F	PL B370 185	+Allison, Altekamp+	OPAL	Collab.)
ALEXANDER	96N	PL B384 343	+Allison, Altekamp, Ametewee+	(OPAL	Collab.) Collab.)
ALEXANDER	96R	ZPHY C72 1	+Allison, Altekamp+	(OPAL	Collab.)
ALEXANDER	96U	ZPHY C72 365	+Allison, Altekamp, Ametewee+	(OPAL	Collab.)
ALEXANDER	96X	PL B376 232	G. Alexander+	(OPAL	Collab.)
BUSKULIC BUSKULIC	96D 96H	ZPHY C69 393 ZPHY C69 379	+Casper, De Bonis, Decamp+ +Casper, De Bonis+	(ALEPH (ALEPH	Collab.)
BUSKULIC	96Q	PL B384 414	+De Bonis, Decamp, Ghez+		
ABE	95 J	PRL 74 2880	+Abt, Ahn, Akagi+	(SLD	Collab.) Collab.) Collab.)
ABE	95K	PRL 74 2890	+Abt, Ahn, Akagi+	(SLD	Collab.)
ABE	95L	PRL 74 2890 PRL 74 2895	+Abt, Ahn, Akagi+	(SLD	Collab.) Collab.)
ABE,K	95	PRL 75 3609	K. Abe, Abt, Ahn, Akagi+	(SLD	Collab.)
ABREU	95	ZPHY C65 709	erratum+Adam, Adye, Agasi+	(DELPHI	Collab.)
ABREU ABREU	95D 95E	ZPHY C66 323 ZPHY C66 341	+Adam, Adye, Agasi+	(DELPHI (DELPHI	Collab.)
ABREU	95F	NP B444 3	+Adam, Adye, Agasi+ +Adam, Adye, Agasi+	(DELPHI	
ABREU	95G	7PHY C67 1	+Adam, Adye, Agasi+	(DELPHI	Collab.)
ABREU	951	ZPHY C67 183 ZPHY C65 555 ZPHY C65 569	+Adam, Adye, Agasi+	(DELPHI	
ABREU	95J	ZPHY C65 555	+Adam, Adye, Agasi+	(DELPHI	Collab.)
ABREU	95K	ZPHY C65 569	+Adam, Adye, Agasi+	(DELPHI	Collab.)
ABREU	95L	ZPHY C65 587	+Adam, Adye, Agasi+	(DELPHI	
ABREU ABREU	95M 95O	ZPHY C65 603	+Adam, Adye, Agasi, Ajinenko+ +Adam, Adye, Agasi+	(DELPHI	Collab.)
ABREU	95R	ZPHY C67 543 ZPHY C68 353	+Adam, Adye, Agasi+	(DELPHI	Collab.)
ABREU	95W	PL B361 207	+Adam, Adye, Agasi+	(DELPHI	Collab.)
ABREU	95X	ZPHY C69 1	+Adam, Adye, Agasi+	(DELPHI	Collab.)
ACCIARRI	95B	PL B345 589	+Adam, Adriani, Aguilar-Benitez+	(L3	Collab.)
ACCIARRI	95C	PL B345 609	+Adam, Adriani, Aguilar-Benitez+	{L3	Collab.)
ACCIARRI AKERS	95G 95	PL B353 136 ZPHY C65 1	+Adam, Adriani, Aguilar-Benitez, Ahlen+ +Alexander, Allison+	(CPAI	Collab.) Collab.)
AKER5	95B	ZPHY C65 17	+Alexander, Allison+	(OPAL	Collab.)
AKERS	95C	ZPHY C65 47 ZPHY C67 27 ZPHY C67 365	+Alexander, Allison+		Collab.)
AKERS	950	ZPHY C67 27	+Alexander, Allison+ +Alexander, Allison+	(OPAL	Collab.)
AKERS	95S	ZPHY C67 365	+Alexander, Allison+	(OPAL	Collab.)
AKERS	95U	ZPHY C67 389	+Alexander, Allison+	(OPAL	Collab.)
AKERS AKERS	95W 95X	ZPHY C67 555 ZPHY C68 1	+Alexander, Allison+ +Alexander, Allison+		Collab.)
AKERS	95Z	ZPHY C68 203	+Alexander, Allison+	(OPAI	Collab.) Collab.)
ALEXANDER	95D	PL B358 162	+Allison, Altekamp+	(OPAL	Collab.) Collab.)
BUSKULIC	951	PL B352 479	+Casper, De Bonis+	(ALEPH	Collab.)
BUSKULIC	95Q	ZPHY C69 183	+Casper, De Bonis+	(ALEPH	Collab.)
BUSKULIC	95R	ZPHY C69 15	+Casper, De Bonis, Decamp+	(ALEPH	Collab.)
MIYABAYASHI ABE	94C	PL B347 171 PRL 73 25	+Adachi, Fujii+ +Abt, Ash, Aston, Bacchetta, Baird+	(TOPAZ	Collab.)
ABREU	94	NP B418 403	+Adam, Adve. Agasi+	(DELPHI	Collab.)
ABREU	94B	PL B327 386	+Adam, Adye, Agasi+	(DELPHI	
ABREU	94P	PL B341 109	+Adam, Adye, Agasi, Ajinenko+	(DELPHI	Collab.
ACCIARRI	94	ZPHY C62 551	+Adam, Adriani, Aguilar-Benitez+	(L3	Collab.)
ACCIARRI ACCIARRI	94B 94D	PL B328 223 PL B335 542	+Adam, Adriani, Aguilar-Benitez+ +Adam, Adriani, Aguilar-Benitez, Ahlen+	(L3	Collab.)
ACCIARRI	94E	PL B335 542 PL B341 245	+Adam, Adriani+		Collab.) Collab.)
AKERS	94	ZPHY C61 19	+Alexander, Allison+	(OPAL	Collab.)
AKERS	94P	ZPHY C63 181	+ Alexander, Allison+	(OPAL	Collab.)
BUSKULIC	94	ZPHY C62 539	+Casper, De Bonis, Decamp, Ghez, Goy+	- (ALEPH	Collab.)
BUSKULIC	94G	ZPHY C62 179	+Casper, De Bonis, Decamp, Ghez+	(ALEPH	
BUSKULIC BUSKULIC	941 94 J	PL B335 99 ZPHY C62 1	+Casper, De Bonis+	(ALEPH (ALEPH	Collab.)
BUSKULIC	94 J 94 K	ZPHY C62 1 ZPHY C64 361	+De Bonis, Decamp+ +De Bonis, Decamp+	(ALEPH	
VILAIN	94	PL B320 203		CHARM II	
ABE	93	PRL 70 2515	+Abt, Acton+	(SLD	Collab.)
ABREU	93	PL B298 236	+Adam, Adye, Agasi+	(DELPHI	Collab.)
ABREU	931	ZPHY C59 533	+Adam, Adye, Agasi+	(DELPHI	Collab.)
Also	95	ZPHY C65 709	erratum Abreu, Adam, Adye, Agasi+	(DELPHI	Collab.)
ABREU ACTON	93L 93	PL B318 249 PL B305 407	+Adam, Adami, Adye+ +Alexander, Allison+	(DELPHI	
ACTON	93D	ZPHY C58 219	+ Alexander, Allison+ + Alexander, Allison+	(OPAL	Collab.) Collab.)
ACTON	93E	PL B311 391	+Akers, Alexander+	(OPAL	Collab.)
ACTON	93F	ZPHY C58 405	+ Alexander, Allison +	(OPAL	Collab.)
ACTON	93K	ZPHY C60 19	+Akers, Alexander+	(OPAL	Collab.)

Gauge & Higgs Boson Particle Listings

Z, Higgs Bosons — H^0 and H^{\pm}

ADRIANI 93 P. L. 8307 237 Aguilar-Benitez, Alben+ (L3 Collab.) ADRIANI 93 P. L. 8307 237 Aguilar-Benitez, Alben+ (L3 Collab.) ADRIANI 93 P. D. 8318 427 Aguilar-Benitez, Alben+ (L3 Collab.) ADRIANI 93 P. D. 8318 427 Aguilar-Benitez, Alben, Albent- (L3 Collab.) ADRIANI 93 P. D. 8318 427 Aguilar-Benitez, Alben, Albent- (L3 Collab.) ADRIANI 93 P. P. B317 461 + Aguilar-Benitez, Alben, Albent- (L3 Collab.) ADRIANI 93 P. P. B317 461 + Albeander, Alison- (Laberta) AKERS 930 ZPHY C60 199 + Albeander, Alison- (Laberta) AKERS 930 ZPHY C60 191 + Albeander, Alison- (Laberta) AKERS 930 ZPHY C60 191 + Albeander, Alison- (Laberta) AKERS 930 ZPHY C60 191 + Albeander, Alison- (Laberta) AKERS 930 ZPHY C80 501 + De Bonis, Decamp+ (ALEPH Collab.) BUSKULIC 93 P. L. B313 549 + Decamp, Goy, Lees, Minard+ (ALEPH Collab.) BUSKULIC 93 P. L. B313 549 + Decamp, Goy+ (ALEPH Collab.) ALEPH Collab. (ALEPH Collab.) ALBERGU 93 P. L. B236 557 + Decamp- (May Collab.) Alberta 92 P. L. B276 535 + Adam, Adami, Adami, Age+ (DELPHI Collab.) ABREU 92 P. L. B276 535 + Adam, Adami, Adami, Age+ (DELPHI Collab.) ABREU 92 P. L. B236 536 + Adam, Adami, Adami, Age+ (DELPHI Collab.) ABREU 920 P. L. B236 333 + Adam, Adami, Age+ (DELPHI Collab.) ABREU 920 P. L. B236 333 + Adam, Adami, Age+ (DELPHI Collab.) ABREU 920 P. L. B236 333 + Adam, Adami, Age+ (DELPHI Collab.) ABREU 920 P. L. B236 333 + Adam, Adami, Age+ (DELPHI Collab.) ABREU 920 P. L. B236 333 + Adam, Adami, Age+ (DELPHI Collab.) ABREU 920 P. L. B236 339 + Adam, Adami, Age+ (DELPHI Collab.) ABREU 920 P. L. B236 339 + Adam, Adami, Age+ (DELPHI Collab.) AGAMIN 920 P. L. B236 435 + Adam, Adami, Age+ (DELPHI Collab.) AGAMIN 920 P. L. B236 339 + Adamin, Adamin Age+ (DELPHI Collab.) AGAMIN 920 P. L. B236 339 + Adamin, Adamin Age+ (DELPHI Collab.) AGAMIN 920 P. L. B236 339 + Adamin, Adamin, Adamin Age+ (DELPHI Collab.) AGAMIN 920 P. L. B236 339 + Adamin, Adamin, Adamin Age+ (DELPHI Collab.) AGAMIN 920 P. L. B236 339 + Adamin, Adami						
ADRIANI 93F PL 8309 452 ADRIANI 93I PL 8314 427 ADRIANI 93I PL 8316 427 ADRIANI 93I PL 8317 436 1 AKERS 938 ZPHY C50 199 AKERS 938 ZPHY C50 190 AKERS 938 ZPHY C50 190 BUSKULIC 931 ZPHY C50 91 BUSKULIC 931 ZPHY C50 71 BUSKULIC 93P ZPHY C50 71 BUSKULIC 93P ZPHY C50 71 BUSKULIC 93P ZPHY C50 73 BUSKULIC 93P ZPHY C50 73 BUSKULIC 93P ZPHY C50 801 BUSKULIC 92P L B270 301 ABREU 92H PL B270 536 AACTON 92D PL B290 507 ACTON 92D PL B290			PL B301 136		(L3	Collab.)
ADRIANI 93.J PF B317 467 ADRIANI 93.M PRPL 236 1 AKERS 930 ZPHY C50 19 AKERS 930 ZPHY C50 19 AKERS 930 ZPHY C50 19 BUSKULIC 33.P B313 520 BUSKULIC 33.P CANNON CONTROL STAND CONTR			PL B307 237	+Aguilar-Benitez, Ahlen+	(L3	Collab.)
ADRIANI 93.J PF B317 467 ADRIANI 93.M PRPL 236 1 AKERS 930 ZPHY C50 19 AKERS 930 ZPHY C50 19 AKERS 930 ZPHY C50 19 BUSKULIC 33.P B313 520 BUSKULIC 33.P CANNON CONTROL STAND CONTR				+Aguilar-Benitez, Anien+	(13	Collab.)
ADRIAN 93M PRPL 236 1	ADRIANI		PL D310 427	+Aguilar-Benitez, Anien+	(L3	Collab.)
AKERS 938 ZPHY C60 191 AKERS 930 ZPHY C60 601 BUSKULIC 931 ZPHY C60 71 BUSKULIC 931 PL 8313 520 BUSKULIC 931 PL 8313 520 BUSKULIC 931 PL 8313 520 BUSKULIC 932 PL 8294 635 ABREU 932 PL 8277 635 ABREU 922 PL 8277 317 ABREU 924 PL 8277 317 ABREU 926 PL 8296 938 ACTON 920 PL 8296 938 ACTON 921 PL 8291 99 ACTON 921 PL 8294 436 ACTON 921 PL 8295 939 ACTON 920 PL 8298 436 ACTON				+Aguilar-Benitez, Allen Alcaraz Aloisio.	(13	Collab.)
BUSKULIC 931			7PHY C60 199	+Alexander Allison Anderson Arcelli+	(OPAI	Collab
BUSKULIC 931			ZPHY C60 601	+Alexander, Allison+	(OPAL	Collab.)
BUSKULIC 931 PL B313 529			ZPHY C60 71	+Decamp, Gov. Lees, Minard+	(ALEPH	Collab.)
BUSKULIC 93P PL 8313 549 BUSKULIC 93P PLPTY C59 369 NOVIKOV 93C PL 8298 453 NOVIKOV 93C PL 8298 453 ABREU 92 PL 8275 231 ABREU 92 PL 8275 231 ABREU 93P PL 8276 536 ABREU 92P PL 8276 536 ABREU 92N PL 8289 199 ABREU 92N PL 8289 199 AGRINA AGMI, Adye+ (DELPHI Collab.) ABREU 92N PL 8298 193 AGRINA 92N PL 8298 193 ACTON 92D PL 8295 333 ACTON 92D PL 8295 337 ACTON 92D PL 8295 367 ACTON 92D PL 8296 364 ADRIANI 92B PL 8288 404 ADRIANI 92B PL 8288 404 ADRIANI 92D PL 8292 454 ADRIANI 92D PL 8292 451 ADRIANI 92P PL 8276 534 ADRIANI 92P PL 8276 534 BUSKULIC 92D PL 8292 101 BUSKULIC 92D PL 8292 210 BUSKULIC 92D PL 8292 310 BUSKULIC 92D PL 8292 210 BUSKULIC 92P PL 8276 534 ADRAM 91P PL 8276 537 ADRAM 91P PL 8275 311 ARABER 91B PL 8278 313 ADRAM 91P PL 8275 313 ADRAM 91P PL 8275 313 ADRAM 91P PL 8275 313 ADRAM 91P PL 8276 547 ARABAM 91P PL 8278 547 ARABAM 91P PL 8278 557 ARABAM 91P PL 8	BUSKULIC	93L	PL B313 520	+De Bonis, Decamo+	(ALEPH	Collab.)
ABREU 92 PL 277 521 ABREU 92 PL 277 521 ABREU 93 PL 277 371 ABREU 92 PL 277 371 AAGTON 92 PL 277 371 AAGTON 92 PL 277 371 ACTON 92 PL 277 371 ADRIANI 92 PL 277 371 ADRIANI 92 PL 277 371 ABREU 93 PL 277 371 ABREU 93 PL 277 371 ABREU 94 PL 277 371 ABREU 95 PL 277 371 ABREU 97 AARTHANA AVARANA AVAR			PL B313 549	+De Bonis, Decamp+		
ABREU 92 PL 277 521 ABREU 92 PL 277 521 ABREU 93 PL 277 371 ABREU 92 PL 277 371 AAGTON 92 PL 277 371 AAGTON 92 PL 277 371 ACTON 92 PL 277 371 ADRIANI 92 PL 277 371 ADRIANI 92 PL 277 371 ABREU 93 PL 277 371 ABREU 93 PL 277 371 ABREU 94 PL 277 371 ABREU 95 PL 277 371 ABREU 97 AARTHANA AVARANA AVAR			ZPHY C59 369	+Decamp, Goy+	(ALEPH	
ABREU 92 PL 277 521 ABREU 92 PL 277 521 ABREU 93 PL 277 371 ABREU 92 PL 277 371 AAGTON 92 PL 277 371 AAGTON 92 PL 277 371 ACTON 92 PL 277 371 ADRIANI 92 PL 277 371 ADRIANI 92 PL 277 371 ABREU 93 PL 277 371 ABREU 93 PL 277 371 ABREU 94 PL 277 371 ABREU 95 PL 277 371 ABREU 97 AARTHANA AVARANA AVAR				+Okun, Vysotsky		
ABREU 924 PL B281 383 + Adam, Adye, Agasi, Aickseev+ (DELPHI Collab.) ABREU 928 PL B289 1985 + Adam, Adye, Agasi, Aickseev+ (DELPHI Collab.) ABREU 920 PL B293 1981 + Adam, Adye, Agasi, Aickseev+ (DELPHI Collab.) ACTON 928 PLPHY CS3 339 + Adam, Adye, Agasi, Aickseev+ (DELPHI Collab.) ACTON 921 PL B291 501 + Adexander, Allson, Allport+ (DPAI Collab.) ACTON 921 PL B291 501 + Alexander, Allson, Allport+ (DPAI Collab.) ACTON 921 PL B294 436 + Alexander, Allson, Allport, Anderson+ (DPAI Collab.) ACTON 920 PL B292 436 + Adexander, Allson, Allport, Anderson+ (DPAI Collab.) ACTON 920 PL B292 446 + Aguilar-Benitze, Alhen, Akbari, Alcaraz+ (L3 Collab.) ADRIANI 920 PL B292 444 + Aguilar-Benitze, Alhen, Akbari, Alcaraz+ (L3 Collab.) ADRIANI 920 PL B292 445 + Aguilar-Benitze, Alhen, Akbari, Alcaraz+ (L3 Collab.) ADRIANI 920 PL B292 445 + Aguilar-Benitze, Alhen, Akbari, Alcaraz+ (L3 Collab.) ADRIANI 920 PL B292 445 + Aguilar-Benitze, Alhen, Akbari, Alcaraz+ (L3 Collab.) ADRIANI 920 PL B292 445 + Aguilar-Benitze, Alhen, Akbari, Alcaraz+ (L3 Collab.) BUSKULIC 926 PL B293 437 + Aguilar-Benitze, Alhen, Akbari, Alcaraz+ (L3 Collab.) DECAMP 92 PRPY 215 253 + Decamp, Goy, Lees, Minard+ (ALEPHI Collab.) DECAMP 920 PRPY 215 253 + Decamp, Goy, Lees, Minard+ (ALEPHI Collab.) DECAMP 921 PL B293 437 + Alexander, Allson, Allport, Anderson+ (ALEPHI Collab.) ADEVA 911 PL B295 193 + Adam, Adami, Adye+ (ALEPHI Collab.) ADEVA 912 PL B293 193 + Adam, Alaport, Anderson+ (CPC Collab.) ADEVA 913 PL B293 193 + Adam, Alaport, Anderson+ (CPC Collab.) ANARAWY 914 PL B295 194 + Alexander, Allson, Allport, Anderson+ (CPC Collab.) ADEVA 915 PL B293 193 + Adam, Alaport, Anderson+ (CPC Collab.) ADEVA 916 PL B293 193 + Adam, Alaport, Anderson+ (CPC Collab.) ADEVA 917 PL G4 1334 + Alexander, Allson, Allport, Anderson+ (CPC Collab.) ADEVA 918 PL B293 193 + Adam, Alaport, Anderson+ (CPC Collab.) ADACHI 919 PL B266 218 + Adam, Alaport, Alexander, Allson, Allport, Anderson+ (CPC Collab.) ADACHI 910 PR B246 225 + Adam, Alaport, Anderson+ (CPC Collab.) ADACHI 910 P			ZPHY C53 567		(DELPHI	Collab.)
ABREU 924 PL B281 383 + Adam, Adye, Agasi, Aickseev+ (DELPHI Collab.) ABREU 928 PL B289 1985 + Adam, Adye, Agasi, Aickseev+ (DELPHI Collab.) ABREU 920 PL B293 1981 + Adam, Adye, Agasi, Aickseev+ (DELPHI Collab.) ACTON 928 PLPHY CS3 339 + Adam, Adye, Agasi, Aickseev+ (DELPHI Collab.) ACTON 921 PL B291 501 + Adexander, Allson, Allport+ (DPAI Collab.) ACTON 921 PL B291 501 + Alexander, Allson, Allport+ (DPAI Collab.) ACTON 921 PL B294 436 + Alexander, Allson, Allport, Anderson+ (DPAI Collab.) ACTON 920 PL B292 436 + Adexander, Allson, Allport, Anderson+ (DPAI Collab.) ACTON 920 PL B292 446 + Aguilar-Benitze, Alhen, Akbari, Alcaraz+ (L3 Collab.) ADRIANI 920 PL B292 444 + Aguilar-Benitze, Alhen, Akbari, Alcaraz+ (L3 Collab.) ADRIANI 920 PL B292 445 + Aguilar-Benitze, Alhen, Akbari, Alcaraz+ (L3 Collab.) ADRIANI 920 PL B292 445 + Aguilar-Benitze, Alhen, Akbari, Alcaraz+ (L3 Collab.) ADRIANI 920 PL B292 445 + Aguilar-Benitze, Alhen, Akbari, Alcaraz+ (L3 Collab.) ADRIANI 920 PL B292 445 + Aguilar-Benitze, Alhen, Akbari, Alcaraz+ (L3 Collab.) BUSKULIC 926 PL B293 437 + Aguilar-Benitze, Alhen, Akbari, Alcaraz+ (L3 Collab.) DECAMP 92 PRPY 215 253 + Decamp, Goy, Lees, Minard+ (ALEPHI Collab.) DECAMP 920 PRPY 215 253 + Decamp, Goy, Lees, Minard+ (ALEPHI Collab.) DECAMP 921 PL B293 437 + Alexander, Allson, Allport, Anderson+ (ALEPHI Collab.) ADEVA 911 PL B295 193 + Adam, Adami, Adye+ (ALEPHI Collab.) ADEVA 912 PL B293 193 + Adam, Alaport, Anderson+ (CPC Collab.) ADEVA 913 PL B293 193 + Adam, Alaport, Anderson+ (CPC Collab.) ANARAWY 914 PL B295 194 + Alexander, Allson, Allport, Anderson+ (CPC Collab.) ADEVA 915 PL B293 193 + Adam, Alaport, Anderson+ (CPC Collab.) ADEVA 916 PL B293 193 + Adam, Alaport, Anderson+ (CPC Collab.) ADEVA 917 PL G4 1334 + Alexander, Allson, Allport, Anderson+ (CPC Collab.) ADEVA 918 PL B293 193 + Adam, Alaport, Anderson+ (CPC Collab.) ADACHI 919 PL B266 218 + Adam, Alaport, Alexander, Allson, Allport, Anderson+ (CPC Collab.) ADACHI 910 PR B246 225 + Adam, Alaport, Anderson+ (CPC Collab.) ADACHI 910 P			PL B275 231	+Adam, Adami, Adye+	(DELPHI	Collab.)
ABREU 924 PL B281 383 + Adam, Adye, Agasi, Aickseev+ (DELPHI Collab.) ABREU 928 PL B289 1985 + Adam, Adye, Agasi, Aickseev+ (DELPHI Collab.) ABREU 920 PL B293 1981 + Adam, Adye, Agasi, Aickseev+ (DELPHI Collab.) ACTON 928 PLPHY CS3 339 + Adam, Adye, Agasi, Aickseev+ (DELPHI Collab.) ACTON 921 PL B291 501 + Adexander, Allson, Allport+ (DPAI Collab.) ACTON 921 PL B291 501 + Alexander, Allson, Allport+ (DPAI Collab.) ACTON 921 PL B294 436 + Alexander, Allson, Allport, Anderson+ (DPAI Collab.) ACTON 920 PL B292 436 + Adexander, Allson, Allport, Anderson+ (DPAI Collab.) ACTON 920 PL B292 446 + Aguilar-Benitze, Alhen, Akbari, Alcaraz+ (L3 Collab.) ADRIANI 920 PL B292 444 + Aguilar-Benitze, Alhen, Akbari, Alcaraz+ (L3 Collab.) ADRIANI 920 PL B292 445 + Aguilar-Benitze, Alhen, Akbari, Alcaraz+ (L3 Collab.) ADRIANI 920 PL B292 445 + Aguilar-Benitze, Alhen, Akbari, Alcaraz+ (L3 Collab.) ADRIANI 920 PL B292 445 + Aguilar-Benitze, Alhen, Akbari, Alcaraz+ (L3 Collab.) ADRIANI 920 PL B292 445 + Aguilar-Benitze, Alhen, Akbari, Alcaraz+ (L3 Collab.) BUSKULIC 926 PL B293 437 + Aguilar-Benitze, Alhen, Akbari, Alcaraz+ (L3 Collab.) DECAMP 92 PRPY 215 253 + Decamp, Goy, Lees, Minard+ (ALEPHI Collab.) DECAMP 920 PRPY 215 253 + Decamp, Goy, Lees, Minard+ (ALEPHI Collab.) DECAMP 921 PL B293 437 + Alexander, Allson, Allport, Anderson+ (ALEPHI Collab.) ADEVA 911 PL B295 193 + Adam, Adami, Adye+ (ALEPHI Collab.) ADEVA 912 PL B293 193 + Adam, Alaport, Anderson+ (CPC Collab.) ADEVA 913 PL B293 193 + Adam, Alaport, Anderson+ (CPC Collab.) ANARAWY 914 PL B295 194 + Alexander, Allson, Allport, Anderson+ (CPC Collab.) ADEVA 915 PL B293 193 + Adam, Alaport, Anderson+ (CPC Collab.) ADEVA 916 PL B293 193 + Adam, Alaport, Anderson+ (CPC Collab.) ADEVA 917 PL G4 1334 + Alexander, Allson, Allport, Anderson+ (CPC Collab.) ADEVA 918 PL B293 193 + Adam, Alaport, Anderson+ (CPC Collab.) ADACHI 919 PL B266 218 + Adam, Alaport, Alexander, Allson, Allport, Anderson+ (CPC Collab.) ADACHI 910 PR B246 225 + Adam, Alaport, Anderson+ (CPC Collab.) ADACHI 910 P				+Adam, Adami, Adye+		
ABREU 92M ZPHY C55 555 ABREU 920 PL B295 383 ARCTON 92B ZPHY C53 539 ACTON 92L PL B291 503 ACTON 92L PL B291 503 ACTON 92L PL B294 436 ACTON 92L PL B294 436 ACTON 92L PL B294 436 ACTON 92L PL B295 357 ACTON 92L PL B295 357 ACTON 92L PL B295 357 ACTON 92D ZPHY C56 521 ADEVA 92 PL B275 209 ADRIANI 92B PL B295 436 ADRIANI 92B PL B298 404 ADRIANI 92B PL B292 454 ADRIANI 92C PL B292 454 ADRIANI 92D PL B292 454 ADRIANI 92C PL B292 415 BUSKULIC 92C PL B294 145 DECAMP 92 PRPL 26 253 DECAMP 92 PRPL 26 253 DECAMP 92 PRPL 276 274 ABE 91E PRL 67 1502 ABREU 91H ZPHY C50 185 ACTON 91B PL B273 318 ADACHI 91 PL B259 317 ACRAMP 91F PL B259 313 ADRIANI 91F PL B293 317 ARRAWY 91F PL B293 317 ARRAWY 91F PL B293 317 ARRAWAY 91F PL B293 317 ARRAWAYAYA 91F PL B266 4518 ARRAWAY 91F PL B234 454 ABBE 91F PL B234 454				+Adam, Adami, Adye+	(DELPHI	Collab.)
ABREU 920 PL 925 383 ARREU 920 PL 9255 383 ACTON 921 PL 9295 383 ACTON 921 PL 9291 503 ACTON 921 PL 9291 503 ACTON 921 PL 9295 357 ACTON 920 PL 9275 209 ADRIANI 928 PL 9288 404 ADRIANI 920 PL 9292 454 BUSKULLC 920 PL 9292 210 BUSKULLC 920 PL 9292 310 BUSKULLC 930 PRU 26 253 BUSKULC 930 PRU 26 253 BUSKULLC 930 PRU 26 253 BUSKULC 930 PRU 26			PL D281 353	+Adam, Adami, Adye+	(DELPHI	Collab.)
ACTON 921 PL 8291 503 ACTON 921 PL 8291 503 ACTON 921 PL 8294 346 ACTON 920 PL 8295 357 ACTON 920 PL 8275 209 ADRIANN 928 PL 8288 404 ADRIANN 920 PL 8276 521 ADRIANN 920 PL 8292 454 ADRIANN 920 PL 8292 459 BUSKULIC 920 PL 8292 210 BUSKULIC 920 PL 8292 210 BUSKULIC 920 PL 8292 210 BUSKULIC 920 PL 8292 120 BUSKULIC 920 PL 8292 120 BUSKULIC 920 PRPV C33 1 LEP 92 PRPV C31 1 LEP 92 PL 8276 347 ADRCH 91 PL 8279 338 ACTON 918 PL 8273 318 ADECAMP 911 PL 8259 919 ACRAMP 911 PL 8259 919 ACRAMP 911 PL 8259 919 DECAMP 911 PL 8259 131 ACOBSON 91 PRL 67 3347 - ABEC 90 ZPHY C48 33 SHIMONAKA 91 PRL 64 1334 ADACHI 90 PR PL 824 525 ARRAWY 901 PR 8246 285 BEHREND 90 ZPHY C48 33 BHAINSCH 90 PRL 64 93 HEGNER 90 ZPHY C48 33 BRAUNSCH 90 PRL 64 913 BRAUNSCH 90 PRL 62 911 ABE 89 PRL 63 2170 ABE 89 PRL 63 2170 ABE 89 PRL 63 2170 ABE 89 PRL 63 2173 BRAUNSCH 90 PRL 64 918 BRAPEL 89 PRL 63 2173 BRAUNSCH 90 PRL 64 918 BRAPEL 89 PRL 63 2173 BABCAIA 89 PRL 63 2173 BABCAIA 89 PRL 63 2173 BABCAIA 89 PRL 63 2176 BABCAI			7DHV CSS SSS	+Adam Adva Agasis	(DEL DAI	Collab.)
ACTON 921 PL 8291 503 ACTON 921 PL 8291 503 ACTON 921 PL 8294 346 ACTON 920 PL 8295 357 ACTON 920 PL 8275 209 ADRIANN 928 PL 8288 404 ADRIANN 920 PL 8276 521 ADRIANN 920 PL 8292 454 ADRIANN 920 PL 8292 459 BUSKULIC 920 PL 8292 210 BUSKULIC 920 PL 8292 210 BUSKULIC 920 PL 8292 210 BUSKULIC 920 PL 8292 120 BUSKULIC 920 PL 8292 120 BUSKULIC 920 PRPV C33 1 LEP 92 PRPV C31 1 LEP 92 PL 8276 347 ADRCH 91 PL 8279 338 ACTON 918 PL 8273 318 ADECAMP 911 PL 8259 919 ACRAMP 911 PL 8259 919 ACRAMP 911 PL 8259 919 DECAMP 911 PL 8259 131 ACOBSON 91 PRL 67 3347 - ABEC 90 ZPHY C48 33 SHIMONAKA 91 PRL 64 1334 ADACHI 90 PR PL 824 525 ARRAWY 901 PR 8246 285 BEHREND 90 ZPHY C48 33 BHAINSCH 90 PRL 64 93 HEGNER 90 ZPHY C48 33 BRAUNSCH 90 PRL 64 913 BRAUNSCH 90 PRL 62 911 ABE 89 PRL 63 2170 ABE 89 PRL 63 2170 ABE 89 PRL 63 2170 ABE 89 PRL 63 2173 BRAUNSCH 90 PRL 64 918 BRAPEL 89 PRL 63 2173 BRAUNSCH 90 PRL 64 918 BRAPEL 89 PRL 63 2173 BABCAIA 89 PRL 63 2173 BABCAIA 89 PRL 63 2173 BABCAIA 89 PRL 63 2176 BABCAI		920	PI R295 383	±Adam Adami Adve±	(DEL PHI	Collab.)
ACTON 921 Pl. B294 436				±Alexander Allisson Allnort±	(OPAI	Collab)
ACTON 92N PL B295 357 ACTON 92N PL B295 357 ACTON 92N PL B295 357 ACTON 920 PL B275 209 ADRIANN 92B PL B285 404 ADRIANN 92B PL B288 404 ADRIANN 92D PL B276 354 ADRIANN 92D PL B292 453 ADRIANN 92D PL B292 453 ALITTI 92B PL B292 453 ALITTI 92B PL B293 454 BUSKULIC 92D PL B292 210 BUSKULIC 92D PL B293 210 BUSKULIC 92D PL B294 145 DECAMP 92 PRPV C33 1 LEP Collab. DECAMP 92 PRPV C33 1 LEP 82P PRL 87 1502 ABREU 911 PR PV S0 185 ACTON 91B PL B273 338 AARAANY 91 PL B259 919 DECAMP 911 PL B259 919 DECAMP 911 PL B259 919 DECAMP 911 PL B259 131 ACRBEND 91 PL B66 218 DECAMP 911 PL B259 131 ACRBEND 91 PL B273 131 BARRAMS 90 PRL 64 1334 ABRAMS 90 PRL 64 1314 ABRE 90 C PRPY C48 33 BELISEN 90 ZPHY C48 33 BELISEN 90 ZPHY C48 435 BELISEN 90 ZPHY C48 437 BELISEN 90 ZPHY C48 437 BELISEN 90 PRL 64 1921 STUART 90 PRL 64 993 BRAUNSCH 90 ZPHY C44 567 ABB 90 PRL 63 270 ABB 90 PRL 64 1814 ABB 90 PRL 64 1814 ABB 90 PRL 65 1814 ABB 90 PRL 66 181 ABB 90 PRL 66 1814 ABB 90 PRL 66 1814 ABB 90 PRL 66 1814 ABB 90				+Alexander, Allison, Allnort+	(OPAL	Collab.)
ADEVA 92 PL B275 209 ADRIANI 926 PL B275 209 ADRIANI 927 PL B275 209 ADRIANI 920 PL B288 404 ADRIANI 920 PL B292 454 ADRIANI 926 PL B292 454 ADRIANI 927 PL B292 453 ALITTI 928 PL B276 354 BUSKULIC 920 PL B292 210 BUSKULIC 920 PRPL 215 253 DECAMP 92 PRPV C31 1 LEP 92 PRPV C31 1 LEP 92 PL B276 247 ABE 91E PRL 67 1502 ABREU 91H ZPHY C50 185 ACTON 91B PL B273 338 ADACHI 91 PL B225 313 ADACHI 91 PL B225 313 ADACHI 91 PL B259 319 ACRAWY 911 PL B259 319 ACRAWY 911 PL B259 319 BCCAMP 911 PL B259 317 DECAMP 911 PL B276 314 ADEVA 911 PL B276 314 ADEVA 911 PL B278 318 ADACHI 91 PL B278 318 ADACHI 91 PL B278 317 DECAMP 911 PL B278 317 DECAMP 911 PL B286 218 DECAMP 911 PL B286 218 DECAMP 911 PL B286 218 DECAMP 912 PL B276 314 ADACHI 91 PL B278 317 DECAMP 913 PL B289 377 DECAMP 914 PL B278 317 DECAMP 915 PL B278 317 ABE 90 ZPHY C48 33 SHIMONAKA 91 PL B284 457 SHIMONAKA 91 PL B284 457 ABE 90 ZPHY C48 33 BARAMS 90 PRL 64 1334 ABRAMS 90 PRL 64 1314 ABR 89 PRL 63 2170 ABE 89 PRL 62 613 ABRAMS 89 PRL 63 2173 ABRAMS 89 PRL 63 2173 ABRAMS 89 PRL 64 121 STUART 90 PRL 64 98 BEHERD 90 ZPHY C46 347 KRAL 90 PRL 64 193 BRAUNSCH 90 PRL 64 98 BEHERD 90 ZPHY C46 347 KRAL 90 PRL 64 121 STUART 90 PRL 64 98 PRL 62 218 ABRAMS 89 PRL 63 2173 ABRAMS 89 PRL 63 2178 ABRAMS 89 PR	ACTON		PL B294 436	+Alexander, Allison, Allport+	(OPAL	Collab.)
ADEVA 92 PL B275 209 ADRIANI 926 PL B275 209 ADRIANI 927 PL B275 209 ADRIANI 920 PL B288 404 ADRIANI 920 PL B292 454 ADRIANI 926 PL B292 454 ADRIANI 927 PL B292 453 ALITTI 928 PL B276 354 BUSKULIC 920 PL B292 210 BUSKULIC 920 PRPL 215 253 DECAMP 92 PRPV C31 1 LEP 92 PRPV C31 1 LEP 92 PL B276 247 ABE 91E PRL 67 1502 ABREU 91H ZPHY C50 185 ACTON 91B PL B273 338 ADACHI 91 PL B225 313 ADACHI 91 PL B225 313 ADACHI 91 PL B259 319 ACRAWY 911 PL B259 319 ACRAWY 911 PL B259 319 BCCAMP 911 PL B259 317 DECAMP 911 PL B276 314 ADEVA 911 PL B276 314 ADEVA 911 PL B278 318 ADACHI 91 PL B278 318 ADACHI 91 PL B278 317 DECAMP 911 PL B278 317 DECAMP 911 PL B286 218 DECAMP 911 PL B286 218 DECAMP 911 PL B286 218 DECAMP 912 PL B276 314 ADACHI 91 PL B278 317 DECAMP 913 PL B289 377 DECAMP 914 PL B278 317 DECAMP 915 PL B278 317 ABE 90 ZPHY C48 33 SHIMONAKA 91 PL B284 457 SHIMONAKA 91 PL B284 457 ABE 90 ZPHY C48 33 BARAMS 90 PRL 64 1334 ABRAMS 90 PRL 64 1314 ABR 89 PRL 63 2170 ABE 89 PRL 62 613 ABRAMS 89 PRL 63 2173 ABRAMS 89 PRL 63 2173 ABRAMS 89 PRL 64 121 STUART 90 PRL 64 98 BEHERD 90 ZPHY C46 347 KRAL 90 PRL 64 193 BRAUNSCH 90 PRL 64 98 BEHERD 90 ZPHY C46 347 KRAL 90 PRL 64 121 STUART 90 PRL 64 98 PRL 62 218 ABRAMS 89 PRL 63 2173 ABRAMS 89 PRL 63 2178 ABRAMS 89 PR	ACTON	92N	PL B295 357	+Alexander, Allison, Allport, Anderson+	(OPAL	Collab.)
ADEVAN 92 PL B275 209 ADRIANN 92B PL B288 404 ADRIANN 92D PL B292 454 ADRIANN 92C PL B292 454 ADRIANN 92C PL B292 454 ADRIANN 92C PL B292 455 ADRIANN 92C PL B292 456 ALTTI 92B PL B276 354 BUSKULLC 92C PL B292 115 BUSKULLC 92C PL B294 145 BUSKULLC 92C PL B294 PL B296 185 BUSKULLC 92C PL B294 145	ACTON	920	ZPHY C56 521	+Alexander, Allison+	(OPAL	Collab.
ADRIAN 926 PL B276 354 ASKULIC 927 PL B292 210 BUSKULIC 928 PL B276 354 +Ambrosini, Ansari, Auter, Barryer+ (UAZ Collab.) ACCAMP 92 PRPL 215 253 DECAMP 92 PRPL 215 253 DECAMP 92 PRPY CS3 1 LEP 92 PL B276 247 +AEE PL PRY CS3 1 LEP 92 PL B276 247 +AEE PL PRY CS3 1 LEP 93 PL PRY CS3 185 ACTON 91 PL B273 338 ADACHI 91 PL B273 338 ADACHI 91 PL B255 613 ADEVA 91 PL B257 531 DECAMP 91 PL B257 531 ACCOMP DECAMP 91 PL B257 531 DECAMP 91 PL B257 531 DECAMP 91 PL B257 531 DECAMP 91 PL B266 218 DECAMP 91 PRL 67 3347 CAGNPIC Collab.) ABRAMS 90 PRL 64 1334 CESSEN BEHREND 90 ZPHY C46 349 HEGNER 90 PRL 64 1211 STUART 90 PRL 64 121 STUART 90 PRL 63 270 ABRE 91 PR 163 270 ABRE ABCALA 91 PR 163 270 ABRAMS 92 PRY C41 15 BACALA BRAMS 93 PRL 63 271 ABRAMS 94 PRL 63 278 ABRAMS 95 PRL 63 270 ABRAMS 96 PRL 63 270 ABRAMS 97 PRL 63 278 ABRAMS 98 PRL 63 278 ABRAMS 99 PRL 63 270 ABRAMS 90 PRL 63 278 AB			PL B275 209	+Adriani, Aguitar-Benitez+		
ADRIAN 926 PL B276 354 ASKULIC 927 PL B292 210 BUSKULIC 928 PL B276 354 +Ambrosini, Ansari, Auter, Barryer+ (UAZ Collab.) ACCAMP 92 PRPL 215 253 DECAMP 92 PRPL 215 253 DECAMP 92 PRPY CS3 1 LEP 92 PL B276 247 +AEE PL PRY CS3 1 LEP 92 PL B276 247 +AEE PL PRY CS3 1 LEP 93 PL PRY CS3 185 ACTON 91 PL B273 338 ADACHI 91 PL B273 338 ADACHI 91 PL B255 613 ADEVA 91 PL B257 531 DECAMP 91 PL B257 531 ACCOMP DECAMP 91 PL B257 531 DECAMP 91 PL B257 531 DECAMP 91 PL B257 531 DECAMP 91 PL B266 218 DECAMP 91 PRL 67 3347 CAGNPIC Collab.) ABRAMS 90 PRL 64 1334 CESSEN BEHREND 90 ZPHY C46 349 HEGNER 90 PRL 64 1211 STUART 90 PRL 64 121 STUART 90 PRL 63 270 ABRE 91 PR 163 270 ABRE ABCALA 91 PR 163 270 ABRAMS 92 PRY C41 15 BACALA BRAMS 93 PRL 63 271 ABRAMS 94 PRL 63 278 ABRAMS 95 PRL 63 270 ABRAMS 96 PRL 63 270 ABRAMS 97 PRL 63 278 ABRAMS 98 PRL 63 278 ABRAMS 99 PRL 63 270 ABRAMS 90 PRL 63 278 AB	ADRIANI		PL B288 404	+Aguilar-Benitez, Ahlen, Akbari, Alcaraz+	(L3	Collab.)
ADRIAN 926 PL B276 354 ASKULIC 927 PL B292 210 BUSKULIC 928 PL B276 354 +Ambrosini, Ansari, Auter, Barryer+ (UAZ Collab.) ACCAMP 92 PRPL 215 253 DECAMP 92 PRPL 215 253 DECAMP 92 PRPY CS3 1 LEP 92 PL B276 247 +AEE PL PRY CS3 1 LEP 92 PL B276 247 +AEE PL PRY CS3 1 LEP 93 PL PRY CS3 185 ACTON 91 PL B273 338 ADACHI 91 PL B273 338 ADACHI 91 PL B255 613 ADEVA 91 PL B257 531 DECAMP 91 PL B257 531 ACCOMP DECAMP 91 PL B257 531 DECAMP 91 PL B257 531 DECAMP 91 PL B257 531 DECAMP 91 PL B266 218 DECAMP 91 PRL 67 3347 CAGNPIC Collab.) ABRAMS 90 PRL 64 1334 CESSEN BEHREND 90 ZPHY C46 349 HEGNER 90 PRL 64 1211 STUART 90 PRL 64 121 STUART 90 PRL 63 270 ABRE 91 PR 163 270 ABRE ABCALA 91 PR 163 270 ABRAMS 92 PRY C41 15 BACALA BRAMS 93 PRL 63 271 ABRAMS 94 PRL 63 278 ABRAMS 95 PRL 63 270 ABRAMS 96 PRL 63 270 ABRAMS 97 PRL 63 278 ABRAMS 98 PRL 63 278 ABRAMS 99 PRL 63 270 ABRAMS 90 PRL 63 278 AB				+Aguilar-Benitez, Ahlen, Akbari+	(L3	Collab.)
BUSKULIC 926 Pl. B394 145 DECAMP 92 PRPL 215 253 LEP 92 Pl. B276 247 ABE 91E PRL 67 1502 ABREU 91H ZPHY CS0 185 ACTON 91B PL B273 338 ADACHI 91 PL B273 318 ADEVA 911 PL B275 413 ADEVA 911 PL B275 413 ADEVA 911 PL B275 919 ARRAWY 91F PL B275 737 DECAMP 918 PL B275 937 DECAMP 919 PL B275 937 DECAMP 910 PL B275 918 ACRAWY 91F PL B275 918 ACRAWY 91F PL B275 917 DECAMP 917 PL B275 918 ACRAWY 91 PL B275 918 ACRAWY 91 PL B275 918 ACRAWY 91 PL B275 917 DECAMP 918 PL B275 917 DECAMP 917 PL B275 918 ACRAWY 910 PL B286 218 DECAMP 917 PL B275 917 DECAMP 918 PL B275 917 DECAMP 917 PL B286 418 DECAMP 918 PL B289 919 ACRAWY 910 PL B286 918 DECAMP 917 PL B275 917 DECAMP 918 PL B288 457 SHIMONAKA 91 PL B286 457 SHIMONAKA 91 PL B286 487 SHIMONAKA 91 PL B286 48				+Aguitar-Benitez, Ahlen, Akbari, Alcaraz+	(L3	Collab.)
DECAMP 92 PRPL 215 253 +Deschizeaux, Goy, Lees, Minard+ (ALEPH Collab.) (ALEPH Collab.) DECAMP 928 ZPHY CS3 1 +Deschizeaux, Goy, Lees, Minard+ (ALEPH Collab.) (ALEPH Collab.) ABE 91E PRL 67 1502 +Amidel, Apollinari+ (ALEPH Collab.) (CDF Collab.) ABREU 91E PRL 67 1502 +Amidel, Apollinari+ (ALEPH Collab.) (CDF Collab.) AACTON 91B PL 8273 381 +Alexander, Allison, Allport, Anderson+ (JOPAL Collab.) (DPAL Collab.) ADEVA 911 PL 8293 193 +Adrain, Aguilar-Benitze, Abbari+ (JOPAL Collab.) (ALEPH Collab.) DECAMP 911 PL 8266 218 +Deschizeaux, Goy, Lees, Minard+ (ALEPH Collab.) (ALEPH Collab.) DECAMP 911 PL 8266 218 +Deschizeaux, Goy, Lees, Minard+ (ALEPH Collab.) (ALEPH Collab.) DECAMP 911 PL 8266 218 +Deschizeaux, Goy, Lees, Minard+ (ALEPH Collab.) (ALEPH Collab.) ABRAMS 90 PPL 67 334 +Acotex, Adolphsen, Fujino+ (Mark II Collab.) (ALEPH Collab.) ABRAMS 90 PPLY C48 13 +Amabo, Arai, Asano, Chiba+ (VENUS Collab.) (PL B276 354	+Ambrosini, Ansari, Autiero, Bareyre+	(UA2	Collab.)
DECAMP 92 PRPL 215 253 +Deschizeaux, Goy, Lees, Minard+ (ALEPH Collab.) (ALEPH Collab.) DECAMP 928 ZPHY CS3 1 +Deschizeaux, Goy, Lees, Minard+ (ALEPH Collab.) (ALEPH Collab.) ABE 91E PRL 67 1502 +Amidel, Apollinari+ (ALEPH Collab.) (CDF Collab.) ABREU 91E PRL 67 1502 +Amidel, Apollinari+ (ALEPH Collab.) (CDF Collab.) AACTON 91B PL 8273 381 +Alexander, Allison, Allport, Anderson+ (JOPAL Collab.) (DPAL Collab.) ADEVA 911 PL 8293 193 +Adrain, Aguilar-Benitze, Abbari+ (JOPAL Collab.) (ALEPH Collab.) DECAMP 911 PL 8266 218 +Deschizeaux, Goy, Lees, Minard+ (ALEPH Collab.) (ALEPH Collab.) DECAMP 911 PL 8266 218 +Deschizeaux, Goy, Lees, Minard+ (ALEPH Collab.) (ALEPH Collab.) DECAMP 911 PL 8266 218 +Deschizeaux, Goy, Lees, Minard+ (ALEPH Collab.) (ALEPH Collab.) ABRAMS 90 PPL 67 334 +Acotex, Adolphsen, Fujino+ (Mark II Collab.) (ALEPH Collab.) ABRAMS 90 PPLY C48 13 +Amabo, Arai, Asano, Chiba+ (VENUS Collab.) (PL B292 210	+Decamp, Goy, Lees+		
DECAMP 928 ZPHY CS3 1				+Decamp, Goy, Lees, Minard+	(ALEPH	Collab.
ACTON 91B PL B273 338 ACTON 91B PL B273 338 ADEVA 91 PL B255 613 ADEVA 91 PL B259 199 AKRANY 91F PL B257 531 DECAMP 91B PL B273 131 DECAMP 91B PL B273 131 DECAMP 91C P			PRPL 216 253	+Deschizeaux, Goy, Lees, Minard+		
ACTON 91B PL B273 338 ACTON 91B PL B273 338 ADEVA 91 PL B255 613 ADEVA 91 PL B259 199 AKRANY 91F PL B257 531 DECAMP 91B PL B273 131 DECAMP 91B PL B273 131 DECAMP 91C P				+Descrizeaux, Goy, Lees, Minard+	(ALEPH	Conab.)
ACTON 91B PL B273 338 ACTON 91B PL B273 338 ADEVA 91 PL B255 613 ADEVA 91 PL B259 199 AKRANY 91F PL B257 531 DECAMP 91B PL B273 131 DECAMP 91B PL B273 131 DECAMP 91C P				HALEPH, DELPHI, LS, UPAL	(CDF	COHECT
ACTON 91B PL B273 338 + Alexander, Allison, Allport, Anderson+ (OPAL Collab.) ADEVA 91 PL B255 613 + Anazawa, Doser, Enomoto+ (TOPAZ Collab.) ADEVA 91 PL B257 531 + Anazawa, Doser, Enomoto+ (L3 Collab.) ADEVA 91 PL B257 531 + Anazawa, Doser, Enomoto+ (L3 Collab.) ACEVA 91 PL B257 531 + Anazawa, Deser, Enomoto+ (L3 Collab.) ACEVA 91 PL B257 531 + Deschizeaux, Goy, Lees + (L6 Collab.) ACEVA 91 PL B266 218 + Deschizeaux, Goy, Lees + (ALEPH Collab.) ACEVA 91 PL B268 457 + ADEVA 14 PL B273 181 + Deschizeaux, Goy, Lees + (ALEPH Collab.) ACEVA 91 PL B273 181 + Deschizeaux, Goy, Lees + (ALEPH Collab.) ACEVA 91 PL B268 457 + Fujii, Miyamoto+ (ALEPH Collab.) ASHIMONAKA 91 PL B268 457 + Fujii, Miyamoto+ (ALEPH Collab.) ACEVA 90 PL C48 134 + Adolphsen, Averill, Ballam+ (Mark II Collab.) ACEVA 90 PRL 64 1334 + Adolphsen, Averill, Ballam+ (CELLO Collab.) ACEVA 90 PRL 64 1334 + Adolphsen, Averill, Ballam+ (CELLO Collab.) BEARINSCH 90 ZPHY C46 439 HAGWA 14 PL STORM 14 PL STORM 14 PL STORM 15 PRL 64 1211 + Alisson, Ambrus, Bardwa, ACEVA 14 PL STORM 15 PRL 64 1211 + Alisson, Ambrus, Bardwa, ACEVA 14 PL STORM 15 PRL 64 1211 + Alisson, Ambrus, Bardwa, ACEVA 14 PL STORM 15 PRL 64 1211 + Alisson, Ambrus, Bardwa, ACEVA 15 PRL 64 1211 + Alisson, Ambrus, Bardwa, ACEVA 15 PRL 64 1211 + Alisson, Ambrus, Bardwa, ACEVA 15 PRL 64 1211 + Alisson, Ambrus, Bardwa, ACEVA 15 PRL 64 1211 + Alisson, Ambrus, Bardwa, ACEVA 15 PRL 64 1211 + Adolphsen, Averill, Ballam, Barish+ Adolph			7DUV CEN 100	+Amster, Apolinari+	(COF	Collab.)
ADCHI 91 PL B255 613 ADEVA 91 PL B259 199 ARRAWY 91F PL B259 131 ARRAWY 91F PL B257 531 DECAMP 91B PL B259 317 DECAMP 91B PL B259 317 DECAMP 91C PL B256 4218 DECAMP 91C PL B256 421 DECAMP 91C PL B256 4218 DECAMP 90C PL B256 457 DECAMP 91C PL B256 4218 DECAMP 90C PL B256 457 DECAMP 91C PL B256 421 DECAMP 91C PL B256 421 DECAMP 91C PL B256 421 DECAMP 91C PL B256 4218 DECAMP 91C PL B256 421 DECAMP 91C PL B256 4218 DECAMP 90C PL B256 457 DECAMP 91C PL B256 4218 DECAMP 90C PL B256 457 DECAMP 91C PL B256 4218 DECAMP 90C PL B256 457 DECAMP 91C PL B256 4218 DECAMP 90C PL B256 457 DECAMP 91C PL B256 4218 DECAMP 91C PL B256 457 DECAMP 91C PL B2				+Additi, Additi, Adye+		
ARRAWY 90 PR L 625 1334 ADACHU 90 PR L 64 1349 ADACHU 90 PR L 64 1349 ABE 80 PR L 63 2178 ABE 80 PR L 63 2178 ABE 80 PR L 63 2178 ABE 80 PR L 65 2173 ABE 80 PR L 65 2173 ABRAMS 80 PR L 65 2173 ABRAMS 80 PR L 65 2173 ABRAMS 80 PR L 63 2180 ABRAMS 80 PR L 63 2214 ABRAMS 80 PR L 63 2241 ABRAMS 80 PR L 63 2278 ABRAMS 80 PR L 63 2278 ADACHU 80 PR L 63 2274 ADACHU 80 PR L 63 2278 ADACHU 80 PR			PI R255 413	+Anazana Doser Enomoto+		
DECAMP 918 Pl. B259 377 +Deschizeaux, Goy, Lees, Minard+ (ALEPH Collab.) DECAMP 911 Pl. B266 218 +Deschizeaux, Goy, Lees, Minard+ (ALEPH Collab.) DECAMP 91 Pl. B273 181 +Deschizeaux, Goy, Lees, Minard+ (ALEPH Collab.) JACOBSEN 91 PRI 67 3347 +Koetke, Adolphsen, Fujino+ (Mark It Collab.) SHIMONAKA 91 PRI 67 3344 +Holphy Callab. (TOPAZ Collab.) ABRAMS 90 PRI 64 1334 +Adolphsen, Averill, Ballam+ (Mark It Collab.) ADACHI 90 PL B244 525 +Alexander, Alison, Allpont, Anderson+ (CPL Collab.) BEHREND 90 ZPHY C48 433 +Criegee, Field, Franke, Jung+ (TASSC Collab.) ELSEN 90 ZPHY C46 547 +Allson, Adolphsen, Averill, Ballam+ (ALEPH Collab.) KRAL 91 PRL 64 1211 STUJART 90 PRL 64 1211 -Abrams, Adolphsen, Averill, Ballam+ (AMAY Collab.) ABE 89 PRL 52 613 +Amidel, Apollinari, Ascori, Atac+ (AMY Collab.) ABE 89				+Adriani Aguilar-Benitez Akbari+	(10172	Collab)
DECAMP 918 Pl. B259 377 +Deschizeaux, Goy, Lees, Minard+ (ALEPH Collab.) DECAMP 911 Pl. B266 218 +Deschizeaux, Goy, Lees, Minard+ (ALEPH Collab.) DECAMP 91 Pl. B273 181 +Deschizeaux, Goy, Lees, Minard+ (ALEPH Collab.) JACOBSEN 91 PRI 67 3347 +Koetke, Adolphsen, Fujino+ (Mark It Collab.) SHIMONAKA 91 PRI 67 3344 +Holphy Callab. (TOPAZ Collab.) ABRAMS 90 PRI 64 1334 +Adolphsen, Averill, Ballam+ (Mark It Collab.) ADACHI 90 PL B244 525 +Alexander, Alison, Allpont, Anderson+ (CPL Collab.) BEHREND 90 ZPHY C48 433 +Criegee, Field, Franke, Jung+ (TASSC Collab.) ELSEN 90 ZPHY C46 547 +Allson, Adolphsen, Averill, Ballam+ (ALEPH Collab.) KRAL 91 PRL 64 1211 STUJART 90 PRL 64 1211 -Abrams, Adolphsen, Averill, Ballam+ (AMAY Collab.) ABE 89 PRL 52 613 +Amidel, Apollinari, Ascori, Atac+ (AMY Collab.) ABE 89			PL B257 531	+Alexander, Allison, Allnort, Anderson+	(OPAL	Cotlab.)
SHIMONAK 91		91B		+Deschizeaux, Goy+	(ALEPH	Collab.)
SHIMONAK 91	DECAMP	91J	PL B266 218	+Deschizeaux, Goy, Lees+	(ALEPH	Collab.)
SHIMONAK 91	DECAMP	91K		+Deschizeaux, Goy, Lees, Minard+	(ALEPH	Collab.)
ABE 901 ZPHY C48 13 + Adolphsen, Averill, Ballam + (VENUS Collab.) ABACHI 90F PL B234 525 + Doser, Enomoto, Fujii + Adolphsen, Averill, Ballam + (TOPAZ Collab.) BEHREND 90D ZPHY C47 333 BERAUNSCH 90 ZPHY C48 433 + Criegee, Field, Franke, Jung+ (CPAL Collab.) ELSEN 90 ZPHY C46 439 + Allson, Ambrus, Barlow, Barzlet (JADE Collab.) ELSEN 90 ZPHY C46 547 + Narcoka, Schroth, Alison+, Allson, Allother, Allson, Allson, Allother, Allson, Alls				+Koetke, Adolphsen, Fujino+	(Mark H	Collab.)
ABRAMS 90 PRL 64 1334 ADACHI 90F PL B234 525 ARRAWY 90 PL B246 285 BEHREND 900 ZPHY C47 333 BRAUNSCH 90 ZPHY C48 433 ELSEN 90 ZPHY C48 433 BESSEN 90 ZPHY C48 434 BESSEN 90 ZPHY C46 547 KRAL 90 PRL 64 1231 STUART 90 PRL 64 1231 STUART 90 PRL 64 1231 STUART 90 PRL 64 1231 ABE B9 PRL 63 2780 ABBAMS 890 PRL 63 2780 ABBAMS 890 PRL 63 2780 AGAINGMAN, APRILL BAILBIN, BAITSH, ABINGMAN, ABINGMAN, APRILL BAILBIN, BAITSH, ABINGMAN,	SHIMONAKA		PL B268 457			
ADACHI 90F P. B.234 525 +Doser, Enomoto, Fujii+ Africander, Alison, Allport, Anderson+ (PAZ Collab.) BEHREND 90			ZPHY C48 13	+Amako, Arai, Asano, Chiba+	(VENUS	Collab.)
ARRAWY 90.0 PR. 8246 285 BEHREND 900 ZPHY C47 333 BRAUNSCH 90 ZPHY C48 433 ELSEN 90 ZPHY C46 434 HEGNER 90 ZPHY C46 547 KRAL 90 PRL 64 1211 STUART 90 PRL 64 1211 ABE 89 PRL 52 613 ABE 89 C PRL 63 720 ABE 89 PRL 63 2173 ABE 89 PRL 63 2173 ABE 89 PRL 63 2173 ABRAMS 89B PRL 63 2173 ABRAMS 89B PRL 63 2173 ABRAMS 89D PRL 63 2174 ALBAJAR 89 ZPHY C44 15 BACALA 89 PL 8218 112 BARD 89 PL 8218 169 ABRAMS 89D PRL 63 2814 BARTEL 86C PRHY C40 163 BARTEL 86C PRHY C30 371 BARTEL 86C PRHY C30 371 BARTEL 86C PRHY C30 371 BARTEL 86F PRL 51 1831 BARTEL 85F PRL 54 1624 FERNANDEZ 85 PRL 54 1624 FERNA			PRL 64 1334		(Mark II	Collab.)
BEHREND 900 ZPHY C47 333 BRAUNSCH. 90 ZPHY C48 433 ELSEN 90 ZPHY C46 439 HAGNEY GAPTAGE KITSCHRINK CAPACH				+Doser, Enomoto, Fujii+	(TOPAZ	Collab.)
ELSEN 90			7DUV C47 322	+Alexander, Allison, Allport, Anderson+		
ELSEN 90			7DHV C48 433	Braunechumie Cashaede Kisechfink	TASSO	Collab.)
HEGNER 90 ZPHY C46 547 Narosia, Schroth, Alison+ (AlaC Collab.) STUART 90 PRL 64 981 Harrosia, Adolphsen, Averill, Ballam+ (AMY Collab.) ABE 89 PRL 62 613 Harrison, Alison+ (Amy Collab.) (CDF Collab.) ABE 89 PRL 63 720 Harrison, Arai, Asano, Chiba+ (CDF Collab.)			7PHY C46 349	Allison Ambrus Radow Rartel	(IADE	Collab)
STUART 90	HEGNER		ZPHY C46 547	+Naroska, Schroth, Allison+	HADE	Collab)
STUART 90 PRI 64 983 +Breedon, Kim, Ko, Lander, Masshima+ (AMC Collab.) ABE 89 PRI 62 613 +Amidel, Apollinari, Ascor, Atac+ (CDF Collab.) ABE 89 PRI 63 2170 +Amidel, Apollinari, Atac, Auchincloss+ (CDF Collab.) ABE 89 PRI 63 2173 +Adolphsen, Averill, Ballam, Barish+ (Mark II Collab.) ABRAMS 898 PRI 63 2173 +Adolphsen, Averill, Ballam, Barish+ (Mark II Collab.) ABAJAR 89 PRI 8218 112 +Albrow, Allkofer, Arnison, Astbury+ (Mark II Collab.) ABACALA 89 PL 8218 112 +Alarhow, Sparts, Imlay, Kirk+ (Mark II Collab.) GREENSHAW 89 PRI 8218 369 +Campores, Chadwick, Dellino, Desangro+ (MAC Collab.) Collab.) COLLD-SAADA 89 ZPHY C44 557 +Advanting, Allison, Ambrus, Barlow+ (AMC Collab.) ADEVIA 88 PRI 63 2341 +Lim, Abe, Fujii, Higashi+ (AMW Collab.) ADEVIA 88 PRI 62 8319 +Ahlara, Dijlstra, Enometo, Fujii+ (AMW Collab.) ANDACHI 88 PRI 58 819 +Ahlara, Dijlstra, Enometo, Fujii+ (TASSO Collab.) ARSTEL 86C ZPHY C36 371 +Backer, Cords, Felst, Haldt+ (JADE Collab.) Barrel, Cords, Distinann, Eichler+ (JADE Collab.) ASH 85 PRI 55 1831 +Barde, Burne, Camporesi+ (JADE Collab.) Alao 82 PI 1088 140 Bartel, Cords, Ditmann, Eichler+ (JADE Collab.) ASH 85 PRI 51 831 +Barde, Burne, Camporesi+ (JADE Collab.) AMRA Collab.) Cords, Ditmann, Eichler+ (JADE Collab.)				+Abrams, Adolphsen, Averill, Ballam+	(Mark II	Collab.)
ABE 89C PRL 63 720 ABE 89L PL B232 425 ABRAMS 89B PRL 63 2173 ABRAMS 89D PRL 63 2173 ABRAMS 89 PR B218 112 BAND 89 PL B218 112 BAND 89 PL B218 119 BAND 89 PL B218 139 AGEENSHAW 89 ZPHY C42 1 OULD-SAADA 89 ZPHY C42 1 AULD-SAADA 89 PRL 812 8369 GREENSHAW 89 ZPHY C42 1 AULD-SAADA 89 PRL 812 8369 AGREENSHAW 89 ZPHY C42 1 AULD-SAADA 89 PRL 812 8369 AGREENSHAW 89 ZPHY C42 1 AULD-SAADA 89 PRL 82 2341 ADACHI 88C PL B208 319 ADEVA 89 PRL 82 2341 ADACHI 88C PL B208 319 ADEVA 88 PRL 82 2341 ADACHI 88C PL B208 319 ADEVA 88 PRL 82 2341 ADACHI 88C PL B208 319 ADEVA 88 PRL 819 209 BARTEL 86C PL B208 319 BARTEL 86F PL 1618 188 BARTEL 86F PRL 54 1624 FFRNANDEZ 85 PRL 55 1931 FFRNANDEZ 85 PRL 55 1931 BARTEL 86F PRL 55 1891 BARTEL 86F PRL 56 1891 BARTEL 86F PRL 56 1891 BARTEL 86F PRL 56 1891 BARTEL 86F PRL	STUART		PRL 64 983	+Breedon, Kim, Ko, Lander, Maeshima+	(AMY	Collab.)
ABE 89C PRL 63 720 ABE 89L PL B232 425 ABRAMS 89B PRL 63 2173 ABRAMS 89D PRL 63 2173 ABRAMS 89 PR B218 112 BAND 89 PL B218 112 BAND 89 PL B218 119 BAND 89 PL B218 139 AGEENSHAW 89 ZPHY C42 1 OULD-SAADA 89 ZPHY C42 1 AULD-SAADA 89 PRL 812 8369 GREENSHAW 89 ZPHY C42 1 AULD-SAADA 89 PRL 812 8369 AGREENSHAW 89 ZPHY C42 1 AULD-SAADA 89 PRL 812 8369 AGREENSHAW 89 ZPHY C42 1 AULD-SAADA 89 PRL 82 2341 ADACHI 88C PL B208 319 ADEVA 89 PRL 82 2341 ADACHI 88C PL B208 319 ADEVA 88 PRL 82 2341 ADACHI 88C PL B208 319 ADEVA 88 PRL 82 2341 ADACHI 88C PL B208 319 ADEVA 88 PRL 819 209 BARTEL 86C PL B208 319 BARTEL 86F PL 1618 188 BARTEL 86F PRL 54 1624 FFRNANDEZ 85 PRL 55 1931 FFRNANDEZ 85 PRL 55 1931 BARTEL 86F PRL 55 1891 BARTEL 86F PRL 56 1891 BARTEL 86F PRL 56 1891 BARTEL 86F PRL 56 1891 BARTEL 86F PRL		89	PRL 62 613	+Amidei, Apollinari, Ascori, Atac+	(CDF	Collab.)
ABE 89 P. B. 232 425 ABRAMS 890 PRI. 63 22780 ALBAJAR 89 PRI. 63 2780 ALBAJAR 89 PRI. 64 2178 ABRAMS 890 PRI. 63 2780 ALBAJAR 89 PRI. 64 28112 BAND 89 PRI. 8218 819 GREENSHAW 89 PRI. 82 2841 ADACHI 880 PRI. 62 2341 ADACHI 880 PRI. 62 2341 ADACHI 880 PRI. 63 2541 ADACHI 880 PRI. 64 404 BEHREND 870 PRI. 64 507 AISO 850 ZPHY C46 507 BARTEL 860 ZPHY C30 371 AISO 850 ZPHY C36 507 BARTEL 860 ZPHY C36 507 BARTEL 860 ZPHY C36 507 BARTEL 860 PRI. 55 1831 BARTEL 850 P	ABE	89C	PRL 63 720	+Amidel, Apollinari, Atac, Auchincloss+	(CDF	Collab.)
ALBAJAR 89 7EHY C44 15 BACALA 89 PL B218 112 BAND 89 PL B218 139 HAIstoney, Sparts, Imlay, Kirk+ HAIstoney, Sparts, Imlay, Rirk+ HAIstoney, Bartoney, Bartet+ HAIstoney, Bartoney, Bartoney, HAIstoney, HAIstoney, HAIstoney, HAIstoney, Bartoney, HAIstoney, HAIstone			PL B232 425	+Amako, Arai, Asano, Chiba+	(VENUS	Collab.)
ALBAJAR 89 7EHY C44 15 BACALA 89 PL B218 112 BAND 89 PL B218 139 HAIstoney, Sparts, Imlay, Kirk+ HAIstoney, Sparts, Imlay, Rirk+ HAIstoney, Bartoney, Bartet+ HAIstoney, Bartoney, Bartoney, HAIstoney, HAIstoney, HAIstoney, HAIstoney, Bartoney, HAIstoney, HAIstone			PRL 63 2173	+Adolphsen, Averill, Ballam, Barish+	(Mark II	Collab.)
BACALA 89 PL B218 112 Halchow, Sparks, Imbay, Kirk+ AMY Collab. BAND 89 PL B218 369 CREENSHAW 89 ZPHY C42 1 Harmon Charley Collab. Chadwick, Delfino, Desangro+ CALLEY Collab. CALLEY CALLEY COLLAB. CALLEY CALLEY COLLAB. CALLEY CALLEY COLLAB. CALLEY CALLEY COLLAB. CALLEY CA			PRL 63 2780	+Adolphsen, Averill, Ballam, Barish+	(Mark II	Collab.)
BAND 89				+Albrow, Allkofer, Arnison, Astbury+	(UA1	Collab.)
SAGAWA 89 PRI. 63 2241 +Lim, Abe, Fujii, Higashi+ (AMY Collab.) ADACHI 88C Pl. B208 319 +Aihara, Dijistra, Ennomic, Fujii+ (TOPAZ Collab.) ATOPA Collab.) ADEVA 88 PR. D33 2665 +Anderhub, Ansari, Becker-t Braunschweig, Gerhardx, Kirschfink+ (TASSO Collab.) ANSARI 87 Pl. B186 440 +Bagnala, Banner, Battiston+ 4Bagnala, Banner, Cords, Felst, Haldt+ (JADE Collab.) Also 85 ZPHY C36 371 +Becker, Cords, Felst, Haldt+ (JADE Collab.) ASH ASH Bartel, Cords, Ditmann, Eichler+ ASH ASH Bartel, Bume, Camporeity (JADE Collab.) ABAC Collab.) CERIOC (Bassante See Pri. 1618 188 +Becker, Cords, Felst+ (JADE Collab.) CERIOC (Bassante See Pri. 1618 188 +Becker, Cords, Felst+ (JADE Collab.) CERIOC (Bassante See Pri. 1618 184 +Becker, Cords, Felst+ (JADE Collab.) CERIOC (Bassante See Pri. 1618 185 +Becker, Cords, Felst+ (JADE Collab.) CHRS Collab.) CHRS Collab.) CHRS Collab. CHRS Co			PL B218 112		(AMY	Collab.)
SAGAWA 89 PRI. 63 2241 +Lim, Abe, Fujii, Higashi+ (AMY Collab.) ADACHI 88C Pl. B208 319 +Aihara, Dijistra, Ennomic, Fujii+ (TOPAZ Collab.) ATOPA Collab.) ADEVA 88 PR. D33 2665 +Anderhub, Ansari, Becker-t Braunschweig, Gerhardx, Kirschfink+ (TASSO Collab.) ANSARI 87 Pl. B186 440 +Bagnala, Banner, Battiston+ 4Bagnala, Banner, Cords, Felst, Haldt+ (JADE Collab.) Also 85 ZPHY C36 371 +Becker, Cords, Felst, Haldt+ (JADE Collab.) ASH ASH Bartel, Cords, Ditmann, Eichler+ ASH ASH Bartel, Bume, Camporeity (JADE Collab.) ABAC Collab.) CERIOC (Bassante See Pri. 1618 188 +Becker, Cords, Felst+ (JADE Collab.) CERIOC (Bassante See Pri. 1618 188 +Becker, Cords, Felst+ (JADE Collab.) CERIOC (Bassante See Pri. 1618 184 +Becker, Cords, Felst+ (JADE Collab.) CERIOC (Bassante See Pri. 1618 185 +Becker, Cords, Felst+ (JADE Collab.) CHRS Collab.) CHRS Collab.) CHRS Collab. CHRS Co			PL 8218 369	+Camporesi, Chadwick, Delfino, Desangro-	+ (MAC	Collab.)
SAGAWA 89 PRI. 63 2241 +Lim, Abe, Fujii, Higashi+ (AMY Collab.) ADACHI 88C Pl. B208 319 +Aihara, Dijistra, Ennomic, Fujii+ (TOPAZ Collab.) ATOPA Collab.) ADEVA 88 PR. D33 2665 +Anderhub, Ansari, Becker-t Braunschweig, Gerhardx, Kirschfink+ (TASSO Collab.) ANSARI 87 Pl. B186 440 +Bagnala, Banner, Battiston+ 4Bagnala, Banner, Cords, Felst, Haldt+ (JADE Collab.) Also 85 ZPHY C36 371 +Becker, Cords, Felst, Haldt+ (JADE Collab.) ASH ASH Bartel, Cords, Ditmann, Eichler+ ASH ASH Bartel, Bume, Camporeity (JADE Collab.) ABAC Collab.) CERIOC (Bassante See Pri. 1618 188 +Becker, Cords, Felst+ (JADE Collab.) CERIOC (Bassante See Pri. 1618 188 +Becker, Cords, Felst+ (JADE Collab.) CERIOC (Bassante See Pri. 1618 184 +Becker, Cords, Felst+ (JADE Collab.) CERIOC (Bassante See Pri. 1618 185 +Becker, Cords, Felst+ (JADE Collab.) CHRS Collab.) CHRS Collab.) CHRS Collab. CHRS Co	GREENSHAW	99	ZPRY C42 1	+vvarming, Allison, Ambrus, Barlow+	JADE	COHAD.)
ADACH 88C Pl. 8208 319	EAC MAN		2PRT C44 307	+Allison, Amorus, Danow, Barter+	(JAUE	Collab.)
ADEVA		880		+Aibera Dilketra Enomoto Sulli-	(TODA7	Collab.)
BRAINSCH 88D ZPHY C40 163 Braunschweig, Gerhards, Kirschfink+ (TASSO Collab.) ANSARI 87 Pl. B186 440 +Bagmala, Banner, Battiston+ (UAZ Collab.) BARTEL 86C ZPHY C30 371 +Buerger, Criegee, Dainton+ (CELLO Collab.) Also 85B ZPHY C36 507 Bartel, Becker, Bowdery, Cords+ (JADE Collab.) Also 82 PL 108B 140 Bartel, Cords, Dittmann, Eichler+ (JADE Collab.) ASH 85 PRL 55 1831 +Band, Blume, Camporesl+ (MAC Collab.) DERRICK 85 PR D31 2352 +Fernandez, Fries, Hyman+ (HRS Collab.) FERNANDEZ 85 PRL 54 1624 +Ford, Qi, Read+ (MAC Collab.) LEVI 83 PRL 51 1941 +Blocker, Strait+ (Mark II Collab.)			PR D38 2665	+Anderhub, Ansari, Recker+	(Mark-)	Collab.)
ANSARI 87 Pl. 8186 440 +Bagmala, Banner, Battiston+ (UAZ Collab.) BARTEL 86C ZPHY C30 371 +Becker, Cords, Felst, Halet+ (JADE Collab.) Also 85B ZPHY C36 507 Bartel, Becker, Bowdery, Cords+ (JADE Collab.) Also 82 Pl. 108B 140 Bartel, Ords, Dittaman, Eichler+ (JADE Collab.) ASH 85 PRI 55 1831 +Band, Blume, Camporesi+ (JADE Collab.) ASH 85 PRI 161B 188 +Becker, Cords, Felst+ (JADE Collab.) DERRICK 85 PR D31 2352 +Fernandez, Fries, Hyman+ (HRS Collab.) FERNANDEZ 85 PRI 54 1624 +Ford, Qi, Read+ (MAC Collab.)	BRAUNSCH			Braunschweig, Gerhards, Kirschfink+	(TASSO	Collab.
BEHREND 87C PL 8191 209	ANSARI			+Bagnaia, Banner, Battiston+	(UA2	Collab.
BARTEL 86C ZPHY (30 371 ABcker, Cords, Felst, Haldt+ JADE Collab.)	BEHREND	87C	PL B191 209	+Buerger, Criegee, Dainton+	CELLO	Callah
Also 82 Pt 108B 140 Bartel, Decker, Dowlery, Corch (JADE Collab.) ASH 85 PRI 55 1831 Bartel, Decker, Dords, Dittmann, Eichler+ JADE Collab.) ASH 85 PRI 55 1831 Band, Blume, Camporesi+ MAC Collab.) DERRICK 85 PR D31 2352 +Fernandez, Fries, Hyman+ FERNANDEZ 85 PRI 54 1624 +Ford, Qi, Read+ HORS Collab.) LEVI 85 PRI 51 1941 +Blocker, Strait+ (MAR til Collab.) (Mark II Collab.)			ZPHY C30 371	+Becker, Cords, Felst, Haidt+	(JADE	Collab.)
Also 82 Pl. 108B 140 Bartel, Cords, Dittmann, Eichler+ (JADE Collab.) ASH 85 PRL 155 1831 + Band, Blume, Camporeits (MAC Collab.) BARTEL 85F Pl. 1618 188 + Becker, Cords, Felst+ (JADE Collab.) DERRICK 85 PR D31 2352 + Fernandez, Fries, Hyman+ (HRS Collab.) FERNANDEZ 85 PRL 54 1624 + Ford, Qi, Read+ (MAC Collab.) LEVI 83 PRL 51 1941 + Blocker, Strait+ (Mark II Collab.)			ZPHY C26 507	Bartel, Becker, Bowdery, Cords+	(JAUE	COHED.)
DERRICK 85 PR D31 2352 +Fernandez, Fries, Hyman+ (HRS Collab.) FERNANDEZ 85 PRL 54 1624 +Ford, QI, Read+ (MAC Collab.) LEVI 83 PRL 51 1941 +Biocker, Strait+ (Mark II Collab.)			PL 108B 140	Bartel, Cords, Dittmann, Eichler+		
DERRICK 85 PR D31 2352 +Fernandez, Fries, Hyman+ (HRS Collab.) FERNANDEZ 85 PRL 54 1624 +Ford, QI, Read+ (MAC Collab.) LEVI 83 PRL 51 1941 +Biocker, Strait+ (Mark II Collab.)				+Band, Blume, Camporesi+	(MAC	Collab.)
LEVI 83 PRL 51 1941 +Flord, QI, Read+ (MAC Collab.) LEVI 83 PRL 51 1941 +Blocker, Strait+ (Mark II Collab.)			PL 1618 188	+Becker, Cords, Felst+	(JADE	Collab.)
LEVI 83 PRL 51 1941 +Flord, QI, Read+ (MAC Collab.) LEVI 83 PRL 51 1941 +Blocker, Strait+ (Mark II Collab.)				+remandez, Fries, Hyman+	(HRS	Collab.)
BEHREND 82 PL 114B 282 + Chen, Fener, Field+ (CELLO Collab.) BRANDELIK 82C PL 110B 173 + Braunschweig, Gather (TASSO Collab.)			PRL 34 1024			
BRANDELIK 82C PL 110B 173 +Braunschweig, Gather (CELLO Collab.)			PI 114R 292	+Chen Fenner Field+	(CELLO	Collab.)
(1700 COMB)		B2C	PL 110B 173	+Braunschweig, Gather	(TASSO	Collab
					,	

Higgs Bosons — H^0 and H^{\pm} , Searches for

THE HIGGS BOSON

Revised October 1997 by I. Hinchliffe (LBNL).

The Standard Model [1] contains one neutral scalar Higgs boson, which is a remnant of the mechanism that breaks the $SU(2) \times U(1)$ symmetry and generates the W and Z boson masses. The Higgs couples to quarks and leptons of mass m_f with a strength $gm_f/2M_W$. Its coupling to W and Z bosons is of strength g, where g is the coupling constant of the SU(2) gauge theory. The branching ratio of the Higgs boson into various final states is shown in Fig. 1.

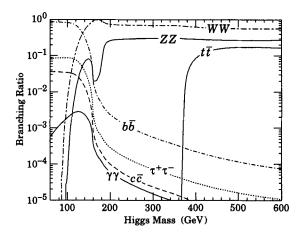


Figure 1: The branching ratio of the Higgs boson into $\gamma\gamma$, $\tau\bar{\tau}$, $b\bar{b}$, $t\bar{t}$, $c\bar{c}$, ZZ, and WW as a function of the Higgs mass. For ZZ and WW, if $M_H < 2M_Z$ (or $M_H < 2M_W$), the value indicated is the rate to ZZ^* (or WW^*) where Z^* (W^*) denotes a virtual Z (W). The $c\bar{c}$ rate depends sensitively on the poorly-determined charmed quark mass.

The Higgs coupling to stable matter is very small while its coupling to the top quark and to W and Z bosons is substantial. Hence its production is often characterized by a low rate and a poor signal to background ratio. A notable exception would be its production in the decay of the Z boson (for example $Z \to Hq\overline{q}$). Since large numbers of Z's can be produced and the coupling of the Z to the Higgs is unsuppressed, experiments at LEP are now able to rule out a significant range of Higgs masses.

If the Higgs mass is very large, the couplings of the Higgs to itself and to longitudinally polarized gauge bosons become large. Requiring that these couplings remain weak enough so that perturbation theory is applicable implies that $M_H \lesssim 1$ TeV [2]. While this is not an absolute bound, it is an indication of the mass scale at which one can no longer speak of an elementary Higgs boson. This fact is made more clear if one notes that the width of the Higgs boson is proportional to the cube of its mass (for $M_H > 2M_Z$) and that a boson of mass 1 TeV has a width of 500 GeV.

A scalar field theory of the type that is used to describe Higgs self-interactions can only be an effective theory (valid over a limited range of energies) if the Higgs self-coupling and hence the Higgs mass is finite. An upper bound on the Higgs mass can then be determined by requiring that the coupling has a finite value at all scales up to the Higgs mass [3]. Nonperturbative calculations using lattice [4] gauge theory that compute at arbitrary values of the Higgs coupling indicate that $M_H \lesssim 770$ GeV.

Gauge & Higgs Boson Particle Listings Higgs Bosons — H^0 and H^{\pm}

If the Higgs mass were small, then the vacuum (ground) state with the correct value of M_W would cease to be the true ground state of the theory [5]. A theoretical constraint can then be obtained from the requirement that our universe is in the true minimum of the Higgs potential [6]. The constraint depends upon the top quark mass and upon the scale (Λ) up to which the Standard Model remains valid. This scale must be at least 1 TeV, resulting in the constraint [7] $M_H > 52 \text{ GeV} +$ 0.64 ($M_{\rm top}$ -175 GeV). This constraint is weaker than that from the failure to directly observe the Higgs boson. The bound increases monotonically with the scale, for $\Lambda = 10^{19} \text{ GeV}$, $M_H > 135 \text{ GeV} + 1.9 (M_{\text{top}} - 175 \text{ GeV}) - 680 (\alpha_s(M_Z) - 0.117).$ This constraint may be too restrictive. Strictly speaking we can only require that the predicted lifetime of our universe, if it is not at the true minimum of the Higgs potential, be longer than its observed age [8,9]. For $\Lambda = 1$ TeV there is no meaningful constraint; and for $\Lambda = 10^{19} \text{ GeV } M_H > 130 \text{ GeV} +$ $2.3 (M_{\text{top}} - 175 \text{ GeV}) - 815(\alpha_s(M_Z) - 0.117)$ [10].

Experiments at LEP are able to exclude a large range of Higgs masses. They search for the decay $Z \to HZ^*$ or $e^+e^- \to ZH$. Here Z^* refers to a virtual Z boson that can appear in the detector as e^+e^- , $\mu^+\mu^-$, $\tau^+\tau^-$, $\nu\bar{\nu}$ (i.e., missing energy) or hadrons. The experimental searches have considered both $H \to$ hadrons and $H \to \tau^+\tau^-$. The best limits are shown in the Particle Listings below.

Precision measurement of electroweak parameters such as M_W , $M_{\rm top}$, and the various asymmetries at LEP and SLC are sensitive enough that they can constrain the Higgs mass through its effect in radiative corrections. The current unpublished limit is $M_H < 450$ GeV, at 95% CL with a central value of $M_H = 127^{+127}_{-72}$ GeV [11]. See also the article in this Review on the "Electroweak Model and Constraints on New Physics."

The process $e^+e^- \rightarrow ZH$ [12] should enable neutral Higgs bosons of masses up to 95 GeV to be discovered at LEP at a center-of-mass energy of 190 GeV [13]. The current unpublished limits corresponding to the failure to observe this process at LEP imply $M_H > 77.5$ GeV at 95% CL [14]. If the Higgs is too heavy to be observed at LEP, there is a possibility that it could be observed at the Tevatron via the processes $p\bar{p} \to HZX$ [15] and $p\bar{p} \to WHX$ [16]. Failing this, its discovery will have to wait until experiments at the LHC. If the neutral Higgs boson has mass greater than $2M_Z$, it will likely be discovered via its decay to ZZ and the subsequent decay of the Z's to charged leptons (electrons or muons) or of one Z to charged leptons and the other to neutrinos. A challenging region is that between the ultimate limit of LEP and $2M_Z$. At the upper end of this range the decay to a real and a virtual Z, followed by the decay to charged leptons is available. The decay rate of the Higgs boson into this channel falls rapidly as M_H is reduced and becomes too small for $M_H \lesssim 140$ GeV. For masses below this, the decays $H \to \gamma \gamma$ and possibly $H \to b\bar{b}$ [17] are expected to be used. The former has a small branching ratio and large background, the latter has a large branching ratio, larger background and a final state that is difficult to fully reconstruct [18].

Extensions of the Standard Model, such as those based on supersymmetry [19], can have more complicated spectra of Higgs bosons. The simplest extension has two Higgs doublets whose neutral components have vacuum expectation values v_1 and v_2 , both of which contribute to the W and Z masses. The physical particle spectrum contains one charged Higgs boson (H^{\pm}) , two neutral scalars (H_1^0, H_2^0) ,* and one pseudoscalar (A) [20]. See also the articles in this Review on Supersymmetry.

In the simplest version of the supersymmetric model (see the *Reviews* on Supersymmetry), the mass of the lightest of these scalars depends upon the top quark mass, the ratio v_2/v_1 ($\equiv \tan \beta$), and the masses of the other supersymmetric particles. For $M_{\rm top}=174$ GeV, there is a bound $M_{H_1^0}\lesssim 130$ GeV [21,22] at large $\tan \beta$. The bound reduces as $\tan \beta$ is lowered.

The H_1^0 , H_2^0 , and A couplings to fermions depend on v_2/v_1 and are either enhanced or suppressed relative to the couplings in the Standard Model. As the masses of H_2^0 and A increase, the mass of H_1^0 approaches the bound, and the properties of this lightest state become indistinguishable from those a Standard Model Higgs boson of the same mass. This observation is important since the discovery of a single Higgs boson at LEP with Standard Model couplings would not be evidence either for or against the minimal supersymmetric model. However the failure to find a Higgs boson of mass less than 130 GeV would be definite evidence against the minimal supersymmetric Standard Model. In more complicated supersymmetric models, there is always a Higgs boson of mass less than 160 GeV.

Experiments at LEP are able to exclude ranges of masses for neutral Higgs particles in these models. Production processes that are exploited are $e^+e^- \to ZH_1^0$ and $e^+e^- \to AH_1^0$. No signal is seen; the mass limits are (weakly) dependent upon the masses of other supersymmetric particles and upon $\tan \beta$. Currently $M_{H_1^0}$, $M_A > 62$ GeV. See the Particle Listings below on H_1^0 , Mass Limits in Supersymmetric Models.

Charged Higgs bosons can be pair-produced in e^+e^- annihilation. Searches for charged Higgs bosons depend on the assumed branching fractions to $\nu\tau$, $c\bar{s}$, and $c\bar{b}$. Data from LEP now exclude charged Higgs bosons of mass less than 54.5 GeV [23]. See the Particle Listings for details of the H^\pm Mass Limit.

A charged Higgs boson could also be produced in the decay of a top quark, $t \to H^+b$. A search at CDF excludes $M_{H^+} < 147$ GeV for $\tan \beta > 100$ where the branching ratio $H^+ \to \tau \nu$ is large and at $\tan \beta < 1$ where the BR $(t \to H^+b)$ is large [24]. The region at intermediate values of $\tan \beta$ will be probed as the number of produced top quarks increases. Searches for these non-standard Higgs bosons will be continued at LEP [13] and at LHC [25]

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H⁰ (Higgs Boson) MASS LIMITS

These limits apply to the Higgs boson of the three-generation Standard Model with the minimal Higgs sector. Limits that depend on the $Ht\bar{t}$ coupling may also apply to a Higgs boson of an extended Higgs sector whose couplings to up-type quarks are comparable to or larger than those of the standard one-doublet model H^0 couplings.

For comprehensive reviews, see Gunion, Haber, Kane, and Dawson, "The Higgs Hunter's Guide," (Addison-Wesley, Menio Park, CA, 1990) and R.N. Cahn, Reports on Progress in Physics 52 389 (1989). For a review of theoretical bounds on the Higgs mass, see M. Sher, Physics Reports (Physics Letters C) 179 273 (1989).

Limits from Coupling to Z/W^{\pm}

'OUR LIMIT' is taken from the LEP Higgs Boson Searches Working group (BOCK 97), where the combination of the results of ACCIARRI 970, BARATE 970, ACKER-STAFF 98H, and ABREU 98E was performed.

VALUE (Ge	v)	CL%		DOCUMENT ID		<u>TECN</u>	COMMENT
>77.5	(CL = 95%) O	UR LIMIT	Г				
>66.2		95	1	ABREU	98E	DLPH	$e^+e^- \rightarrow ZH^0$
>69.4		95	1	ACKERSTAFF	98H	OPAL	$e^+e^- \rightarrow ZH^0$
>69.5		95	1	ACCIARRI	970	L3	$e^+e^- \rightarrow ZH^0$
>70.7		95	1	BARATE	970	ALEP	$e^+e^- \rightarrow ZH^0$
• • • W	e do not use the	following	ξd	lata for averages	, fits	, limits,	etc. • • •
			2	ABE	97W	CDF	$p\overline{p} \rightarrow WH^0$
>65.0		95	3	ACKERSTAFF	97E	OPAL	$e^+e^- \rightarrow ZH^0$
>59.6		95	4	ALEXANDER	97	OPAL	$Z \rightarrow H^0 Z^*$
>60.2		95	5	ACCIARRI	961	L3	$Z \rightarrow H^0 Z^*$
			6	ACCIARRI	96J	L3	$Z \rightarrow H^0 \gamma$
			7	ALEXANDER	96H	OPAL	$Z \rightarrow H^0 \gamma$
>60.6		95		ALEXANDER	96L	OPAL	$Z \rightarrow H^0 Z^*$
>63.9		95		BUSKULIC	96R	ALEP	$Z \rightarrow H^0 Z^*$
>55.7				ABREU	94G	DLPH	
>56.9		95	11	AKERS	94B	OPAL	$Z \rightarrow H^0 Z^*$
>57.7		95	12	ADRIANI	93 C		$Z \rightarrow H^0 Z^*$
>58.4		95	13	BUSKULIC		ALEP	$Z \rightarrow H^0Z^*$
>60				GROSS		RVUE	
				ABREU		DLPH	$Z \rightarrow H^0 \gamma$
>38				ABREU		DLPH	$Z \rightarrow H^0Z^*$
>52		95	11	ADEVA	92B		$Z \rightarrow H^0Z^*$
			10	ADRIANI	92F		$Z \rightarrow H^0 \gamma$
>48		95	20	DECAMP		ALEP	$Z \rightarrow H^0 Z^*$
> 0.21				ABREU			$Z \rightarrow H^0 Z^*$
>11.3		95	21	ACTON		OPAL	H ⁰ → anything
>41.8		95	22	ADEVA	91		$Z \rightarrow H^0 Z^*$ $Z \rightarrow H^0 \gamma$
			24	ADEVA	91D		$Z \rightarrow H^0 \gamma$ $Z \rightarrow H^0 Z^*$
лопе 3-4-		95	27 25	AKRAWY		OPAL	
none 3-2		95	26	AKRAWY ABE		OPAL	$Z \rightarrow H^0 Z^*$ $p\overline{p} \rightarrow (W^{\pm}, Z) +$
попе 0.21	1-0.818	90		ARE	90E	CDF	$pp \rightarrow (W^{\perp}, Z) + H^0 + X$
none 0.84	16O 097	90	26	ABE	OUE	CDF	$\rho \overline{\rho} \rightarrow (W^{\pm}, Z) +$
HOHE U.U-	0.507	50		AUL	30L	COI	$H^0 + X$
none 0.21	L-14	95	27	ABREU	90c	DLPH	$z \rightarrow H^0 \hat{z}^*$
none 2-3				ADEVA	90H	L3	$Z \rightarrow H^0 Z^*$
> 2				ADEVA	90N	L3	$Z \rightarrow H^0 Z^*$
none 3.0-	-19.3	95	30	AKRAWY	90c	OPAL	$Z \rightarrow H^0 Z^*$
> 0.21		95	31	AKRAWY	90P	OPAL	$Z \rightarrow H^0 Z^*$
none 0.03	32-15			DECAMP	90	ALEP	$Z \rightarrow H^0 Z^*$
none 11-	24			DECAMP	90H	ALEP	
> 0.057				DECAMP	90M	ALEP	$Z \rightarrow H^0 ee, H^0 \mu\mu$
none 11-	41.6	95	35	DECAMP	90N	ALEP	$Z \rightarrow H^0 Z^*$
_		_					_

¹ Search for $e^+e^- \to ZH^0$ at $E_{\rm cm}=161$, 170, and 172 GeV in the final states $H^0 \to q \overline{q}$ with $Z \to \ell^+\ell^-$, $\nu \overline{\nu}$, $q \overline{q}$, and $\tau^+\tau^-$, and $H^0 \to \tau^+\tau^-$ with $Z \to \ell^+\ell^-$ and $q \overline{q}$. The limits also includes the data from Z decay by each experiment.

24. The limits associated WH^0 production in $p\overline{p}$ collisions at $\sqrt{s}=1.8$ TeV with $W\to t\nu_1$, $H^0\to b\overline{b}$ and find the cross-section limit $\sigma\cdot B(H^0\to b\overline{b})<(14-19)$ pb (95% CL) for $m_H=70-120$ GeV. This limit is one to two orders of magnitude larger than the expected cross section in the Standard Model.

³ ACKERSTAFF 97E searched for $e^+e^- \to ZH^0$ at $E_{\rm cm}=$ 161 GeV for the final states $(q\overline{q})(b\overline{b}),\ (\nu p)(q\overline{q}),\ (\tau^+\tau^-)(q\overline{q}),\ (q\overline{q})(\tau^+\tau^-),\ (e^+e^-)(q\overline{q}),\ {\rm and}\ (\mu^+\mu^-)(q\overline{q})$ [the $Z(H^0)$ decay products are in the first (second) parentheses]. The limit includes the results of ALEXANDER 97. Two additional low-mass candidate events are seen, consistent with expected backgrounds.

⁴ ALEXANDER 97 complements the study in ALEXANDER 96. With the inclusion of the search for $Z \to H^0 + (e^+e^-, \mu^+\mu^-)$, with $H^0 \to q\bar{q}$. One additional candidate event is found in the $\mu\mu$ channel, consistent with expected backgrounds.

⁵ ACCIARRI 96i searched for $Z \to H^0 + (e^+e^-, \mu^+\mu^-, \nu p)$ with $H^0 \to q \overline{q}$. Two $e^+e^-H^0$ candidate events with large recoiling mass (above 30 GeV) were found consistent with the background expectations.

 6 ACCIARRI 961 give B(Z $\rightarrow H^0\gamma)\times$ B(H^0 $\rightarrow q\overline{q})<6.9–22.9 <math display="inline">\times$ 10 $^{-6}$ (95%CL) for 20 < m_{H^0} <80 GeV.

7 ALEXANDER 96H give B($Z \to H^0 \gamma$)×B($H^0 \to q \overline{q}$) < 1–4 × 10⁻⁵ (95%CL) and B($Z \to H^0 \gamma$)×B($H^0 \to b \overline{b}$) < 0.7–2 × 10⁻⁵ (95%CL) in the range 20 < m_{H^0} <80

- ⁸ALEXANDER 96L searched for final states with monojets or acoplanar dijets. Two observed candidate events are consistent with expected backgrounds.
- 9 BUSKULIC 96R searched for $Z \to H^0 + (e^+e^-, \mu^+\mu^-, \nu\bar{\nu})$ with $H^0 \to q\bar{q}$. Three candidate events in the $\mu\mu$ channel are consistent with expected backgrounds. ¹⁰ ABREU 94G searched for $Z \to H^0 + (e^+e^-, \mu^+\mu^-, \tau^+\tau^-, \nu\bar{\nu})$ with $H^0 \to q\bar{q}$.
- Four $\ell^+\ell^-$ candidates were found (all yielding low mass) consistent with expected back-
- 11 AKERS 94B searched for $Z \rightarrow H^0 + (e^+e^-, \mu^+\mu^-, \nu\overline{\nu})$ with $H^0 \rightarrow q\overline{q}$. One $\nu\overline{\nu}$ and one $\mu^+\mu^-$ candidate were found consistent with expected backgrounds. ¹² ADRIANI 93C searched for $Z\to H^0+(\nu\overline{\nu},e^+e^-,\mu^+\mu^-)$ with H^0 decaying hadroni-
- cally or to $\tau \bar{\tau}$. Two e^+e^- and one $\mu^+\mu^-$ candidates are found consistent with expected background.
- ¹³ BUSKULIC 93H searched for $Z \rightarrow H^0 \nu \overline{\nu}$ (acoplanar jets) and $Z \rightarrow H^0 + (e^+e^-, e^-)$ $\mu^{+}\mu^{-}$) (lepton pairs in hadronic events).
- 14 GROSS 93 combine data taken by four LEP experiments through 1991.
 15 ABREU 92D give $\sigma(e^+e^-\to Z\to H^0\gamma)$ -B($H^0\to$ hadrons) <8 pb (95% CL) for m_{H^0} <75 GeV and E_{γ} >8 GeV.
- ¹⁶ ABREU 92J searched for $Z \rightarrow H^0 + (ee, \mu\mu, \tau\tau, \nu\overline{\nu})$ with $H^0 \rightarrow q\overline{q}$. Only one candidate was found, in the channel ee + 2jets, with a dijet mass 35.4 ± 5 GeV/ c^2 , consistent with the expected background of 1.0 \pm 0.2 events in the 3 channels $e^+e^ \mu^+\mu^-$, $\tau^+\tau^-$, and of 2.8 \pm 1.3 events in all 4 channels. This paper excludes 12–38 GeV. The range 0–12 GeV is eliminated by combining with the analyses of ABREU 90C and ABREU 918.
- and ABREU 91B. 17 ADEVA 92B searched for $Z \to H^0 + (\nu \overline{\nu}, ee, \mu \mu, \tau \tau)$ with $H^0 \to$ anything, $Z \to H^0 + \tau \tau$ with $H^0 \to q \overline{q}$, and $Z \to H^0 + q \overline{q}$ with $H^0 \to \tau \tau$. The analysis excludes the range $30 < m_{H^0} < 52$ GeV.
- ¹⁸ ADRIANI 92F give $\sigma(e^+e^- \rightarrow Z \rightarrow H^0\gamma) \cdot B(H^0 \rightarrow hadrons) < (2-10) pb (95% CL)$ hadrons) $<(0.7-3) \times 10^{-4}$ (95% CL).
- ¹⁹ DECAMP 92 searched for most possible final states for $Z \rightarrow H^0 Z^*$.
- ²⁰ ABREU 91B searched for $Z \rightarrow H^0 + \ell \bar{\ell}$ with missing H^0 and $Z \rightarrow H^0 + (\nu \bar{\nu}, \ell \bar{\ell}, \ell \bar{\ell})$ $q\overline{q}$) with $H^0 \rightarrow ee$.
- ²¹ ACTON 91 searched for $e^+e^- \rightarrow Z^*H^0$ where $Z^* \rightarrow e^+e^-$, $\mu^+\mu^-$, or $\nu\overline{\nu}$ and H^0 anything. Without assuming the minimal Standard Model mass-lifetime relationship, the limit is $m_{H^0} > 9.5 \,\mathrm{GeV}$.
- ²² ADEVA 91 searched for $Z \rightarrow H^0 + (\mu\mu, ee, \nu\overline{\nu})$. This paper only excludes 15 < $m_{H^0} <$ 41.8 GeV. The 0–15 GeV range is excluded by combining with the analyses of previous L3 papers.
- ²³ ADEVA 91D obtain a limit B($Z \rightarrow H^0 \gamma$)·B($H^0 \rightarrow \text{hadrons}$) < 4.7 × 10⁻⁴ (95%CL) for $m_{H^0} = 30-86$ GeV. The limit is not sensitive enough to exclude a standard H^0
- ²⁴ AKRAWY 91 searched for the channels $Z \to H^0 + (\nu \overline{\nu}, ee, \mu \mu, \tau \tau)$ with $H^0 \to$
- $q\overline{q}$, $\tau\tau$, and $Z\to H^0q\overline{q}$ with $H^0\to \tau\tau$. qq, $\tau\tau$, and $z\to H^-qq$ with $H^0\to \tau\tau$. 25 AKRAWY 91c searched the decay channels $Z\to H^0+(\nu\overline{\nu},\,ee,\,\mu\mu)$ with $H^0\to q\overline{q}$. 26 ABE 90E looked for associated production of H^0 with W^\pm or Z in $p\overline{p}$ collisions at \sqrt{s}
- = 1.8 TeV. Searched for H^0 decays into $\mu^+\mu^-$, $\pi^+\pi^-$, and K^+K^- . Most of the excluded region is also excluded at 95% CL.
- ²⁷ ABREU 90C searched for the channels $Z \to H^0 + (\nu \overline{\nu}, ee, \mu \mu)$ and $H^0 + q \overline{q}$ for m_H < 1 GeV.
- $m_H < 1$ GeV. 28 ADEVA 90H searched for $Z \to H^0 + (\mu \mu, \ ee, \ \nu \overline{\nu})$. 29 ADEVA 90N looked for $Z \to H^0 + (ee, \ \mu \mu)$ with missing H^0 and with $H^0 \to ee$. uu. π⁺π⁻. K⁺K⁻.
- 30 AKRAWY 90C based on 825 nb $^{-1}$. The decay $Z \rightarrow H^0 \nu \bar{\nu}$ with $H^0 \rightarrow \tau \bar{\tau}$ or $q \bar{q}$ provides the most powerful search means, but the quoted results sum all channels.
- ³¹ AKRAWY 90P looked for $Z \to H^0 + (ee, \mu\mu)$ (H^0 missing) and $Z \to H^0 \nu \overline{\nu}$, $H^0 \to H^0 \nu \overline{\nu}$
- 32 DECAMP 90 limits based on 11,550 Z events. They searched for Z \rightarrow $H^0+(\nu\overline{\nu},\,e\,e,$ $\mu\mu$, $\tau\tau$, (\overline{q}) . The decay $Z\to H^0\nu\overline{\nu}$ provides the most powerful search means, but the quoted results sum all channels. Different analysis methods are used for $m_{H^0} < 2m_{\mu}$ where Higgs would be long-lived. The 99% confidence limits exclude $m_{H^0}=0.040-12$
- GeV. 33 DECAMP 90H limits based on 25,000 $Z \rightarrow$ hadron events.
- ³⁴ DECAMP 90M looked for $Z \to H^0\ell\ell$, where H^0 decays outside the detector. ³⁵ DECAMP 90N searched for the channels $Z \to H^0 + (\nu \bar{\nu}, \ e e, \ \mu \mu, \ \tau \tau)$ with $H^0 \to H^0$

H⁰ Indirect Mass Limits from Electroweak Analysis

For limits obtained before the direct measurement of the top quark mass, see the 1996 (Physical Review D54 1 (1996)) Edition of this Review. For indirect limits obtained from other considerations of theoretical nature, see the review on "The Higgs boson."

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not u	se the following	ig data for average	s, fits	, ilmits,	etc. • • •
		36 CHANOWITZ	98	RVUE	
$141 + 140 \\ -77$		37 DEBOER	97B	RVUE	
$127 + 143 \\ -71$		38 DEGRASSI	97	RVUE	$\sin^2 \! heta_W (ext{eff,lept})$
158 ^{+ 148} - 84		39 DITTMAIER	97	RVUE	
149 ⁺¹⁴⁸ - 82		⁴⁰ RENTON	97	RVUE	
≲550	90	41 DITTMAIER	96	RVUE	
145+164 77		⁴² ELLIS	96 C	RVUE	

185^{+251}_{-134}		⁴³ GURTU	96	RVUE
63 ^{+ 97}		44 CHANKOWSKI	95	RVUE
<730	95	⁴⁵ ERLER	95	RVUE
<740	95	⁴⁶ MATSUMOTO	95	RVUE
45 ⁺ 95 - 28		⁴⁷ ELLIS	94B	RVUE
69 + 188 - 9		⁴⁸ GURTU	94	RVUE
•		⁴⁹ MONTAGNA	94	RVUE

36 CHANOWITZ 98 fits LEP and SLD Z-decay-asymmetry data (as reported in ABBA-NEO 97), and explores the sensitivity of the fit to the weight ascribed to measurements that are individually in significant contradiction with the direct-search limits. Various prescriptions are discussed, and significant variations of the 95%CL Higgs-mass upper limits are found. The Higgs-mass central value varies from 100 to 250 GeV and the 95%CL upper limit from 340 GeV to the TeV scale.

37 DEBOER 978 fit to LEP and SLD data (as reported in ALCARAZ 96), as well as m_W and m_t from CDF/DØ and CLEO $b \to s \gamma$ data (ALAM 95). $1/\alpha(m_Z) = 128.90 \pm 0.09$ is used.

- ³⁸ DEGRASSI 97 is a two-loop calculation of M_W and $\sin^2\theta_{
 m eff}^{
 m lept}$ as a function of m_H , using $\sin^2\! heta_{
 m aff}^{
 m lept}$ 0.23165(24) as reported in ALCARAZ 96, $m_t=$ 175 \pm 6 GeV, and $\Deltalpha_{
 m had}=$ 0.0280(9).
- 39 DITTMAIER 97 flt to m_W and LEP/SLC data as reported in ALCARAZ 96, with m_t = 175 \pm 6 GeV, $1/\alpha(m_Z^2)$ = 128.89 \pm 0.09. Exclusion of the SLD data gives m_H = 261^{+224}_{-128} GeV. Taking only the data on m_t , m_W , $\sin^2\theta$ eff., and Γ^{lept}_Z , the authors get $m_H=190^{+174}_{-102}$ GeV and $m_H=296^{+243}_{-143}$ GeV, with and without SLD data, respectively. The 95% CL upper limit is given by 550 GeV (800 GeV removing the SLD
- ⁴⁰ RENTON 97 fit to LEP and SLD data (as reported in ALCARAZ 96), as well as m_W and m_t from $p\overline{p}$, and low-energy νN data available in early 1997. $1/\alpha(m_Z)=128.90\pm0.09$
- 41 DITTMAIER 96 fit to m_W , LEP, and SLD data available in the Summer of 1995 (with and without m_t =180 \pm 12 GeV from CDF/DØ), leaving out R_b and R_C . They argue that the low Higgs mass obtained in some electroweak analyses is an artifact of including the observed value of R_b , which is incompatible with the rest of the data. Exclusion of the SLD data pushes the 90%CL limit on m_{H^0} above 1 TeV.
- 42 ELLIS 96c fit to LEP, SLD, m_{W_i} neutral-current data available in the summer of 1996, plus $m_t=175\pm 6$ GeV from CDF/DØ . The fit yields $m_t=172\pm 6$ GeV.
- 43 GURTU 96 studies the effect of the mutually incompatible SLD and LEP asymmetry data on the determination of m_{H} . Use is made of data available in the Summer of 1996. The quoted value is obtained by increasing the errors à la PDG. A fit ignoring the SLD data yields 267^{+242}_{-135} GeV.
- ⁴⁴ CHANKOWSKI 95 fit to LEP, SLD, and W mass data available in the spring of 1995 plus $m_t=176\pm13$ GeV. Exclusion of the SLD data increases the mass to $m_H=121-58$ GeV (m_H <800 GeV at 95% CL).
- 45 ERLER 95 fit to LEP, SLC, W mass, and various low-energy data available in the summer of 1994 plus m_t =174 \pm 16 GeV from CDF. The limit without m_t is 880 GeV. However, the preference for lighter m_H is due to R_b and A_{LR} , both of which do not agree well with the Standard Model prediction.
- 46 MATSUMOTO 95 fit to LEP, SLD, W mass, and various neutral current data available In the summer of 1994 plus m_t =180 \pm 13 GeV from CDF/DØ , and the LEP direct limit m_H >63 GeV. $\alpha_s(m_Z)$ = 0.124 is used. Fixing $\alpha_s(m_Z)$ = 0.116 lowers the upper limit to 440 GeV. Dependence on $\alpha(m_Z)$ is given in the paper.
- 47 ELLIS 94B fit to LEP, SLD, W mass, neutral current data available in the spring of 1994 plus $m_t=167\pm12$ GeV determined from CDF/DØ $t\bar{t}$ direct searches. $\alpha_g(m_Z)=0.118\pm0.007$ is used. The fit yields $m_{\bar{t}}=162\pm9$ GeV. A fit without the SLD data gives $m_H = 130^{+320}_{-90}$ GeV.
- 48 GURTU 94 fit to LEP, SLD, W mass, neutral current data available in the spring of 1994 as well as $m_t = 174 \pm 16$ GeV. A fit without $\Gamma(Z \rightarrow b \, \overline{b})/\Gamma(Z \rightarrow hadrons)$ gives $m_H = 120^{+364}_{-60}$ GeV.
- ⁴⁹ MONTAGNA 94 flt to LEP and SLD, W-mass data together with $m_t=174\pm17$ GeV. Although the data favor smaller Higgs masses, the authors do not regard it significant.

${\it H}^{0}$ (Higgs Boson) MASS LIMITS in Extended Higgs Models

The parameter x denotes the Higgs coupling to charge -1/3 quarks and charged leptons relative to the value in the standard one-Higgs-doublet model.

In order to prevent flavor-changing neutral currents in models with more than one Higgs doublet, only one of the Higgs doublets can couple to quarks of charge 2/3. The same requirement applies independently to charge -1/3 quarks and to leptons. Higgs couplings can be enhanced or suppressed.

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do not	use the following	ng data for averages	s, fits, limits	, etc. • • •
>69.6	95	50 ACCIARRI	98B L3	Invisible H ⁰
		⁵¹ ACKERSTAFF	988 OPAL	$e^+e^- \rightarrow H^0Z^{(*)},$ $H^0 \rightarrow \gamma\gamma$
		52 KRAWCZYK	97 RVUE	
		53 ACCIARRI	961 L3	$Z \rightarrow H^0 Z^*$
>66.7	95	54 ACCIARRI	961 L3	Invisible H ⁰
		⁵⁵ ACCIARRI	96J L3	$Z \rightarrow H^0 Z^*, H^0 \rightarrow$

Gauge & Higgs Boson Particle Listings

Higgs Bosons — H^0 and H^{\pm}

					$Z \rightarrow H^0 Z^*, H^0 \rightarrow$
		57 ABREU 58 BRAHMACH	95H D	LPH	$Z \stackrel{\gamma\gamma}{\rightarrow} H^0 Z^*, H^0 A^0$
					$Z \rightarrow H^0Z^*$
>65	95		931 A		Invisible H ⁰
		60 LOPEZ-FERN	.93 R	VUE	
		61 ADRIANI		3	$Z \rightarrow H^0 Z^*$
		62 PICH			Very light Higgs
> 3.57	95	63 ACTON	91 0	PAL	$Z \rightarrow H^0Z^*$
		64 DECAMP	91F A	LEP	$Z \rightarrow H^0 \ell^+ \ell^-$
		65 DECAMP	911 A	LEP	Z decay
> 0.21	95		90P O	PAL	$Z \rightarrow H^0 Z^*$
			89 B	DMP	$e^- Z \rightarrow e H^0 Z$ $(H^0 \rightarrow e^+ e^-)$
		⁶⁸ SNYDER	89 M	IRK2	$ \begin{array}{ccc} (H^0 \rightarrow e^+e^-) \\ B \rightarrow H^0 X \\ (H^0 \rightarrow e^+e^-) \end{array} $
none 0.6-6.2	90	⁶⁹ FRANZINI	87 C	USB	$\Upsilon(1S) \rightarrow \gamma H^0, x=2$
none 0.6-7.9	90	⁶⁹ FRANZINI	87 C		$\Upsilon(15) \rightarrow \gamma H^0, x=4$
none 3.7-5.6	90		85J A	RG	$T(15) \rightarrow \gamma H^0, x=2$
none 3.7-8.2	90		85J A		$T(15) \rightarrow \gamma H^0, x=4$
50 ACCIARRI SER	searches for e				hadrons and HO decayl

 $ightarrow ZH^0$ events, with Zlearches for e Invisibly. The limit assumes SM production cross section, and $B(Z \rightarrow \text{Invisible})=100\%$. For limits under other assumptions, see their Fig. 5b.

 51 ACKERSTAFF 988 search for associate production of a $\gamma\gamma$ resonance and a $q\,\overline{q}$, $\nu\overline{
u}$, or $\ell^+\ell^-$ pair in e^+e^- annihilation at $\sqrt{s}\simeq 91$, 130–140, and 161–172 GeV. The cross-section limit $\sigma(e^+e^-\to H^0Z^{(*)})$ B($H^0\to\gamma\gamma$) < 0.29–0.83 pb (95%CL) is obtained for $m_H=40$ –160 GeV at $\sqrt{s}=161$ –172 GeV, σ -B<0.09 pb for $m_H=40$ –80 GeV at $\sqrt{s} \simeq 91$ GeV. See also their Fig. 9 for the limit on $\sigma(H^0)$ B($H^0 \to \gamma \gamma$)/ $\sigma(H^0_{SM})$.

52 KRAWCZYK 97 analyse the muon anomalous magnetic moment in a two-doublet Higgs model (with type II Yukawa couplings) assuming no H_1^0 Z Z coupling and obtain $m_{H_1^0}$ \gtrsim

5 GeV or $m_{A^0} \gtrsim$ 5 GeV for $an\!eta >$ 50. Other Higgs bosons are assumed to be much

heavler. Sae Figs. 5 and 6 of ACCIARRI 961 for the excluded region in the $(m_{H^0}, \Gamma(Z \to Z^*H^0))$ plane (normalized to the Standard Model Higgs) for a general Higgs having a similar decay signature to Standard Model Higgs boson or decaying invisibly.

54 These limits are for H^0 with the standard coupling to Z but decaying to weakly interacting

⁵⁵ ACCIARRI 96J give B($Z \rightarrow H^0 + \text{hadrons}) \times B(H^0 \rightarrow \gamma \gamma) < 2.3-6.9 \times 10^{-6}$ for 20 <m_H⁰ <70 GeV.

⁵⁶ ALEXANDER 96H give B($Z \rightarrow H^0 + q\bar{q}$)×B($H^0 \rightarrow \gamma\gamma$) < 2 × 10⁻⁶ in the range $40 < m_{H^0} < 80 \text{ GeV}.$

 57 See Fig. 4 of ABREU 95H for the excluded region in the $m_{H^0}-m_{A^0}$ plane for general two-doublet models. For $an\!eta>\!1$, the region $m_{H^0}\!+\!m_{A^0}\!\lesssim\!87$ GeV, $m_{H^0}<\!47$ GeV is

58 BRAHMACHARI 93 consider Higgs limit from Z decay when the Higgs decays to invisible modes. If H^0 coupling to Z is at least $1/\sqrt{2}$ of the Standard Model H^0 , the DECAMP 92 limit of 48 GeV changes within ± 6 GeV for arbitrary $B(H^0 \rightarrow SM-like)+B(H^0 \rightarrow SM-like)$ invisible)=1.

59 See Fig. 1 of BUSKULIC 931 for the limit on ZZH^O coupling for a general Higgs having a similar decay signature to Standard Model Higgs boson or decaying invisibly. If the decay rate for $Z \rightarrow H^0 Z^*$ is >10% of the minimal Standard Model rate, then m_{H^0} >40

GeV. For the standard rate the limit is 58 GeV.

60 LOPEZ-FERNANDEZ 93 consider Higgs limit from Z decay when the Higgs decays to invisible modes. See Fig. 2 for excluded region in m_{H0}-ZZH coupling plane with arbitrary B($H^0 \rightarrow \text{SM-like}$)+B($H^0 \rightarrow \text{invisible}$)=1. m_H >50 GeV is obtained if the

H^O coupling strength to the Z is greater than 0.2 times the Standard Model rate.

61 See Fig. 1 of ADRIANI 92G for the limit on ZZH^O coupling for a general Higgs having a similar decay signature to Standard Model Higgs boson. For most masses below 30 GeV, the rate for $Z \rightarrow H_1^0 Z^*$ is less than 10% of the Standard Model rate.

 62 PICH 92 analyse H^0 with m_{H^0} <2 m_μ in general two-doublet models. Excluded regions in the space of mass-mixing angles from LEP, beam dump, and π^\pm , η rare decays are

 64 DECAMP 91F search for $Z \to H^0 \ell^+ \ell^-$ where H^0 escapes before decaying. Combining this with DECAMP 90M and DECAMP 90N, they obtain B(Z \rightarrow H⁰ $\ell^+\ell^-$)/B(Z \rightarrow $\ell^+\ell^-) < 2.5 \times 10^{-3} (95\% \text{CL}) \text{ for } m_{H^0} < 60 \text{ GeV}.$

65 See Figs. 1, 3, 4, 5 of DECAMP 911 for excluded regions for the masses and mixing angles in general two-doublet models.

⁶⁶ AKRAWY 90P limit is valid for any H^0 having $\Gamma(Z \rightarrow H^0 Z^*)$ more than 0.57 times that for the Standard Higgs boson

 67 DAVIER 89 give excluded region in m_{H^0} -x plane for m_{H^0} ranging from 1.2 MeV to 50

 68 SNYDER 89 give limits on B(B $\rightarrow~H^0$ X)-B(H^0 $\rightarrow~e^+e^-)$ for 100 $<~m_{H^0}~<$ 200 MeV, cτ < 24 mm.

⁶⁹ First order QCD correction included with $\alpha_s \approx 0.2$. Their figure 4 shows the limits vs.

 70 ALBRECHT 85.1 found no mono-energetic photons in both arphi(1S) and arphi(2S) radiative decays in the range 0.5 GeV $< E(\gamma) <$ 4.0 GeV with typically BR< 0.01 for $\Upsilon(1S)$ and BR< 0.02 for $\Upsilon(2S)$ at 90% CL. These upper limits are 5–10 times the prediction of the standard Higgs-doublet model. The quoted 90% limit B($\Upsilon(1S) \to H^0 \gamma$) $< 1.5 \times 10^{-3}$ at $E(\gamma)=1.07$ GeV contradicts previous Crystal Ball observation of $(4.7\pm1.1)\times10^{-3}$; see their reference 3. Their figure 8a shows the upper limits of x^2 as a function of $E(\gamma)$ by assuming no QCD corrections. We used $m_{H^0} = m_{\Upsilon} (1 - 2E(\gamma)/m_{\Upsilon})^{1/2}$.

H₁ (Higgs Boson) MASS LIMITS In Supersymmetric Models

The minimal supersymmetric model has two complex doublets of Higgs bosons. The resulting physical states are two scalars $[H_1^0$ and H_2^0 , where we define $m_{H_1^0} < m_{H_2^0}^{0}$.

a pseudoscalar (A^0) , and a charged Higgs pair (H^\pm) . H_1^0 and H_2^0 are also called h and H in the literature. There are two free parameters in the theory which can be chosen to be m_{A0} and $\tan \beta = \nu_2/\nu_1$, the ratio of vacuum expectation values of the two Higgs doublets. Tree-level Higgs masses are constrained by the model to be $m_{H_1^0} \le$

 m_Z , $m_{H_2^0} \ge m_Z$, $m_{A^0} \ge m_{H_1^0}$, and $m_{H^{\pm}} \ge m_W$. However, as described in the "Note on Supersymmetry," recent calculations of one-loop radiative corrections show that these relations may be violated. Many experimental analyses have not taken into account these corrections; footnotes indicate when these corrections are included. The results assume no invisible H^0 or A^0 decays.

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>59.5	95	71 ABREU	98E DLPH	
>62.5	95	72 BARATE	97P ALEP	
• • • We do not u	se the followi	ng data for average		etc. • • •
		73 ACCIARRI	97N L3	
>44.3	95	74 ALEXANDER	97 OPAL	any $tan B$
>44	95	75 ABREU	95H DLPH	
		76 ROSIEK	95 RVUE	•
>44.4	95	77 ABREU	940 DLPH	$m_{H_1^0}=m_{A^0}$, any $\tan \beta$
>44.5	95	78 AKERS	94i OPAL	$tan \hat{\beta} > 1$
>44	95	79 BUSKULIC	93i ALEP	$tan \beta > 1$
>34	95	⁸⁰ ABREU	92J DLPH	$tan\beta > 0.6$
>29	95	80 ABREU	92) DLPH	any tan $oldsymbol{eta}$
>42	95	81 ADRIANI	92G L3	1 <tanβ <50<="" td=""></tanβ>
> 0.21	95	82 ABREU	918 DLPH	any tan $oldsymbol{eta}$
>28	95	83 ABREU	918 DLPH	any tan $oldsymbol{eta}$
none 3-38	95	84 AKRAWY	91c OPAL	$tan\beta > 6$
none 3-22	95	84 AKRAWY	91c OPAL	$tan \beta > 0.5$
		85 BLUEMLEIN	91 BDMP	$pN \rightarrow H_1^0X$
				$(H_1^0 \rightarrow e^+e^-, 2\gamma)$
>41	95	86 DECAMP	911 ALEP	$\tan \beta > 1$
> 9	95	87 ABREU	90E DLPH	any tan $oldsymbol{eta}$
>13	95	87 ABREU	90E DLPH	taneta > 1
>26	95	88 ADEVA	90R L3	taneta > 1
none 0.05-3.1	95	89 DECAMP	90E ALEP	any tan $oldsymbol{eta}$
none 0.05-13	95	89 DECAMP	90E ALEP	$tan\beta > 0.6$
none 0.006-20	95	89 DECAMP	90E ALEP	tan eta > 2
>37.1	95	89 DECAMP	90E ALEP	$tan \beta > 6$
none 0.05-20	95	90 DECAMP	90H ALEP	$tan\beta > 0.6$
попе 0.006-21.4	95	90 DECAMP	90H ALEP	tan eta > 2
> 3.1	95	91 DECAMP	90M ALEP	any $ anoldsymbol{eta}$
71				

 71 ABREU 98E search for $e^+e^- oup H_0^1$ A^0 in the final state $b\bar{b}b\bar{b}$ and $q\bar{q}\tau^+\tau^-$ at $\sqrt{s}=161$ –172 GeV. The results from the SM Higgs search described in the same paper are also used to set these limits. Two-loop radiative corrections are included with $m_{\mathrm{top}}=1$ 175 GeV, $M_{SUSY} = 1$ TeV, and maximal scalar top mixings.

⁷²BARATE 97P search for $e^+e^- o H_1^0 A^0$ in the final state $b\overline{b}b\overline{b}$ and $b\overline{b}\tau^+\tau^-$ at \sqrt{s} = 130-172 GeV and combine with BARATE 970 limit on $e^+e^- \rightarrow H_1^0 Z$. Two-loop radiative corrections are included with $m_{\mathrm{top}} = 175$ GeV and $M_{\mathrm{SUSY}} = 1$ TeV, and maximal scalar top mixings. The invisible decays $H_1^0 \to \tilde{\chi}^0 \tilde{\chi}^0$ are not allowed in the analysis, as ruled out in the relevant kinematic region by BUSKULIC 96K.

73 ACCIARRI 97N search for $e^+e^- \rightarrow H_1^0 A^0$ in four-jet final states at $\sqrt{s}=130$ –172 GeV. Cross-section limits are obtained for $|m_{H_1^0}-m_{A^0}|\approx$ 0, 10, and 20 GeV.

 74 ALEXANDER 97 search for $Z \rightarrow H_1^0\,Z^*$ and $Z \rightarrow H_1^0\,A^0$ and use Γ_Z (nonstandard) < 13.9 MeV. Radiative corrections using two-loop renormalization group equations are included with $m_{\tilde{t}} <$ 195 GeV and the MSSM parameter space is widely scanned. Possible Invisible decay mode $H_1^0 \to \widetilde{\chi}^0 \widetilde{\chi}^0$ is included in the analysis.

75 ABREU 95H search for $\hat{Z} \rightarrow H_1^0 Z^*$ and $Z \rightarrow H_1^0 A^0$. Two-loop corrections are included with m_t =170 GeV, $m_{\widetilde{t}}$ =1 TeV. Including only one-loop corrections does not change the

 76 ROSIEK 95 study the dependence of $m_{H_1^0}$ limit on various supersymmetry parameters.

They argue that H_1^0 as light as 25 GeV is not excluded by ADRIANI 92G data in the region $m_{A^0}\sim 60$ GeV if $m_{\widetilde{t}}\lesssim 200$ GeV and $\widetilde{t}_L\cdot\widetilde{t}_R$ mixing is large. 77 ABREU 940 study $H_1^0A^0\to$ four Jets and combine with ABREU 94G analysis. The

limit applies if the H_1^0 A^0 mass difference is <4 GeV.

⁷⁸ AKERS 94I search for $Z \to H_1^0 Z^*$ and $Z \to H_1^0 A^0$. One-loop corrections are included with $m_t <$ 200 GeV, $m_{\widetilde{t}} <$ 1 TeV. See Fig. 10 for limits for $\tan \beta <$ 1.

⁷⁹BUSKULIC 93I search for $Z \rightarrow H_1^0 Z^*$ and $Z \rightarrow H_1^0 A^0$. One-loop corrections are Included with any m_t , $m_{\tilde{t}} > m_t$;

⁸⁰ ABREU 92J searched for $Z \to H_1^0 Z^*$ and $Z \to H_1^0 A^0$ with H_1^0 , $A^0 \to \tau \tau$ or jet-jet.

Small mass values are excluded by ABREU 91B. 81 ADRIANI 92G search for $Z \rightarrow H_1^0 Z^*$, $Z \rightarrow H_1^0 A^0 \rightarrow 4b$, $bb\tau\tau$, 4τ , 6b (via $H^0 \rightarrow H_1^0 A^0 \rightarrow H_1^0 A$ A^0A^0), and include constraints from $\Gamma(Z)$. One-loop corrections to the Higgs potential are included with 90< m_{t} <250 GeV, m_{t} < $m_{\widetilde{t}}$ <1 TeV.

⁸² ABREU 91B result is based on negative search for $Z \rightarrow H_1^0 f \overline{f}$ and the limit on invisible Z width $\Gamma(Z \rightarrow H_1^0 A^0) < 39$ MeV (95%CL), assuming $m_{A^0} < m_{H_1^0}$.

83 ABREU 91B result obtained by combining with analysis of ABREU 901.

- ⁸⁴ AKRAWY 91C result from $Z \rightarrow H_1^0 A^0 \rightarrow 4$ jet or $\tau^+ \tau^- JJ$ or 4τ and $Z \rightarrow H_1^0 Z^*$ $(H_0^0 \to q\bar{q}, Z^* \to \nu\bar{\nu}\, \sigma\, r\, e^+e^-\, \sigma\, \mu^+\mu^-)$. See paper for the excluded region for the case $\tan \beta < 1$. Although these limits do not take into account the one-loop radiative corrections, the authors have reported unpublished results including these corrections and showed that the excluded region becomes larger.
- 85 BLUEMLEIN 91 excluded certain range of $an\!eta$ for $m_{H_1^0} <$ 120 MeV, $m_{\mathcal{A}^0} <$ 80 MeV.
- ⁸⁶ DECAMP 911 searched for $Z \to H_1^0 Z^*$, and $Z \to H_1^0 A^0 \to 4$ jets or $\tau \tau j j$ or $3A^0$. Their limits take into account the one-loop radiative corrections to the Higgs potential with varied top and squark masses.
- 87 ABREU 90E searched for $Z \rightarrow H_1^0 A^0$ and $Z \rightarrow H_1^0 Z^*$. $m_{H_1^0} < 210$ MeV is not excluded by this analysis.
- ⁸⁸ ADEVA 90R result is from $Z \to H_1^0 A^0 \to 4$ jet or $\tau \tau j j$ or 4τ and $Z \to H_1^0 Z^*$. Some region of $m_{H_1^0} < 4$ GeV is not excluded by this analysis.
- ⁸⁹ DECAMP 90E look for $Z \to H_1^0 A^0$ as well as $Z \to H_1^0 \ell^+ \ell^-$, $Z \to H_1^0 \nu \overline{\nu}$ with 18610 Z decays. Their search includes signatures in which H_1^0 and A^0 decay to $\gamma\gamma$, e^+e^- , $\mu^+\mu^-$, $\tau^+\tau^-$, or $q\overline{q}$. See their figures of $m_{H_1^0}$ vs. $\tan\!eta$.
- 90 DECAMP 90H is similar to DECAMP 90E but with 25,000 Z decays. 91 DECAMP 90M looked for $Z \rightarrow H^0\ell\ell$, where H_1^0 decays outside the detector. This excludes a region in the $(m_{H^0}, \tan\beta)$ plane centered at $m_{H^0}=50$ MeV, $\tan\beta=0.5$. This limit together with DECAMP 90E result excludes $m_{H^0_1}<3$ GeV for any $\tan\beta$.

A⁰ (Pseudoscalar Higgs Boson) MASS LIMITS in Supersymmetric Models

Limits on the A^0 mass from e^+e^- collisions arise from direct searches in the $e^+e^-\to A^0\,H_1^0$ channel and indirectly from the relations valid in the minimal supersymmetric model between m_{A^0} and $m_{H_1^0}$. As discussed in the "Note on Supersymmetry," at the one-loop level and in the simplest cases, these relations depend on the masses of the t quark and \tilde{t} squarks. The limits are weaker for larger t and \tilde{t} masses, while they increase with the inclusion of two-loop radiative corrections. Some specific examples of these dependences are provided in the footnotes to the listed papers.

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>51.0	95	92 ABREU	98E DLPH	$ \tan \beta > 1$
>62.5	95	93 BARATE	97P ALEP	taneta>1
• • • We do not u	ise the follow	ving data for average	s, fits, limit	s, etc. • • •
		94 ACCIARRI	97N L3	
>23.5	95	95 ALEXANDER		$\tan \beta > 1$, $m_t < 195$ GeV
>60	95	96 KEITH	97 RVUE	,,,
>27	95	97 ABREU	95H DLPH	
>44.4	95	⁹⁸ ABREU	940 DLPH	GeV $m_{H_0^0=m_{A^0}}$, any tan eta
>24.3	95	⁹⁹ AKERS	941 OPAL	$\tan \beta > 1$, $m_t < 200 \text{ GeV}$
>44.5	95	⁹⁹ AKERS	941 OPAL	
>21	95	¹⁰⁰ BUSKULIC	931 ALEP	
		101 ELLIS	93 RVUE	
>34	95	102 ABREU	92J DLPH	$1 \tan \beta > 3$
>22	95	¹⁰³ ADRIANI	92G L3	$1 < \tan \beta < 50, m_{t} < 250$ GeV
> 0.21	95	104 BUSKULIC	92 ALEP	
none 3-40.5	95	105 AKRAWY	91c OPAL	$tan \beta > 1$, if 3 GeV <
				$m_{H_1^0} < m_{A^0}$
>20	95	106 DECAMP	911 ALEP	
>34	95	107 ABREU	90E DLPH	· · · · · -
				$m_{H_1^0} < m_{A^0}$
>12	95	107 ABREU	90E DLPH	
>39	95	108 ADEVA	90R L3	$tan\beta > 1$,
				$m_{H_1^0} < m_{A^0}$

- 92 ABREU 98E search for $e^+\,e^-\to\,H_1^0\,A^0$ in the final state $b\,\overline{b}\,b\,\overline{b}$ and $q\,\overline{q}\,\tau^+\tau^-$ at $\sqrt{s}=161-172$ GeV. The results from the SM Higgs search described in the same paper are also used to set these limits. Two-loop radiative corrections are included with $m_{\rm top}=$ 175 GeV, $M_{\mbox{SUSY}}=1\,\mbox{TeV}$, and maximal scalar top mixings.
- 93 BARATE 97P search for $e^+e^- \rightarrow H_1^0 A^0$ in the final state $b \overline{b} b \overline{b}$ and $b \overline{b} \tau^+ \tau^-$ at \sqrt{s} = 130–172 GeV and combine with BARATE 970 limit on e⁺ e⁻ \rightarrow $H_{0}^{0}Z$. Two-loop radiative corrections are included with $m_{\mathrm{top}}=$ 175 GeV and $M_{\mathrm{SUSY}}=$ 1 TeV, and maximal scalar top mixings. The invisible decays $H_1^0 \to \widetilde{\chi}^0 \widetilde{\chi}^0$ are not allowed in the analysis, as ruled out in the relevant kinematic region by BUSKULIC 96K.
- 94 ACCIARRI 97N search for $e^+e^- \rightarrow H_1^0 A^0$ in four-jet final states at $\sqrt{s}=130$ –172 GeV. Cross-section limits are obtained for $|m_{H_1^0} - m_{A^0}| = 0$, 10, and 20 GeV.
- 95 ALEXANDER 97 search for $Z\to H_1^0Z^*$ and $Z\to H_1^0A^0$ and use Γ_Z (nonstandard) < 13.9 MeV. Radiative corrections using two-loop renormalization group equations are included with $m_{\tilde{t}}<$ 195 GeV and the MSSM parameter space is widely scanned. Possible invisible decay mode $H_1^0 \to \widetilde{\chi}^0 \widetilde{\chi}^0$ is included in the analysis. The limit improves to 44 GeV for $\tan\!\beta \gtrsim$ 1.5, but goes to 0 for $\tan\!\beta <$ 0.9 and $m_t >$ 195 GeV.
- 44 GeV for tanh \lesssim 1.5, but goes to 0 for tanh < 0.9 and m_t > 195 GeV.

 96 KEITH 97 uses Tevatron data on $t\bar{t}$ production to estimate $B(t \rightarrow H^+b) < 0.3$ at 95%CL. The resulting constraints on m_{H^+} and the one-loop MSSM relation between m_{H^+} and m_{A^0} give rise to the limit shown on m_{A^0} .

 97 ABREU 95H search for $Z \rightarrow H_1^0 Z^*$ and $Z \rightarrow H_1^0 A^0$. One-loop corrections are included with $m_t = 170$ GeV, $m_{\tilde{t}} = 1$ TeV. The limit becomes weak for larger m_t : at $m_t = 190$ GeV, the limit is 14 GeV. The limit at $m_t = 170$ GeV would increase to 39 GeV

- If two-loop radiative corrections were included. $m_{\widetilde{t}}$ and $m_{\widetilde{\widetilde{t}}}$ dependences are shown in
- 98 ABREU 940 study $H_1^0A^0 \rightarrow$ four jets and combine with ABREU 94G analysis. The limit applies if the H_1^{0} - A^{0} mass difference is <4 GeV.
- ⁹⁹ AKERS 94I search for $Z \rightarrow H_1^0 Z^*$ and $Z \rightarrow H_1^0 A^0$. One-loop corrections are included with $m_t < 200$ GeV, $m_{\tilde{t}} < 1$ TeV. See Fig. 10 for limits for $\tan \beta < 1$.
- 100 BUSKULIC 931 search for $Z \to H_1^0 Z^*$ and $Z \to H_1^0 A^0$. One-loop corrections to the Higgs potential are included with any $m_{\tilde{t}}, m_{\tilde{t}} > m_{\tilde{t}}$. For $m_{\tilde{t}} = 140$ GeV and $m_{\tilde{t}} = 1$ TeV, the limit is $m_{A0} > 45$ GeV. Assumes no invisible H^0 or A^0 decays.

- 101 ELLIS 93 analyze possible constraints on the MSSM Higgs sector by electroweak precision measurements and find that m_{A0} is not constrained by the electroweak data.

 102 ABREU 921 searched for $Z \rightarrow H_0^1 Z^*$ and $Z \rightarrow H_1^0 A^0$ with $H_1^0 A^0 \rightarrow \tau \tau$ or jet-jet. Small mass values are excluded by ABREU 91B.

 103 ADRIANI 926 search for $Z \rightarrow H_1^0 Z^*$, $Z \rightarrow H_1^0 A^0 \rightarrow 4b$, $bb\tau \tau$, 4τ , 6b (via $H^0 \to A^0 A^0$), and include constraints from $\Gamma(Z)$. One-loop corrections are included with $90 < m_t < 250$ GeV, $m_t < m_{\widetilde t} < 1$ TeV. The region $m_{A^0} < 11$ GeV is allowed if $42 < m_{\widetilde H^0} < 62$ GeV, but is excluded by other experiments.
- 104 BUSKULIC 92 limit is from $\Gamma(Z)$, $Z\to H_1^0Z^*$, and $Z\to H_1^0A^0$. The limit is valid for any $m_{H_1^0}$ below the the theoretical limit $m_{H_1^0}<64$ GeV which holds for $m_{A^0}\sim 0$ in
- the minimal supersymmetric model. One-loop radiative corrections are included. 105 AKRAWY 91C result from $Z \to H_1^0 A^0 \to 4$ jet or $\tau^+ \tau^- jj$ or 4τ . See paper for the excluded region for the case $\tan \beta < 1$. 106 DECAMP 91I searched for $Z \to H_1^0 Z^*$, and $Z \to H_1^0 A^0 \to 4$ jets or $\tau \tau jj$ or $3A^0$. Their limits take into account the one-loop radiative corrections to the Higgs potential with varied top and squark masses. For $m_t = 140$ GeV and $m_{\widetilde{q}} = 1$ TeV, the limit is $m_t = 21$ GeV. $m_{A^0} > 31 \text{ GeV}.$
- 107 ABREU 90E searched $Z \rightarrow H_1^0 A^0$ and $Z \rightarrow H_1^0 Z^*$. $m_{A^0} <$ 210 MeV is not excluded
- 108 ADEVA 90R result is from $Z \to H_1^0 A^0 \to 4$ jet or $\tau \tau j j$ or 4τ and $Z \to H_1^0 Z^*$. Some region of $m_{A^0} < 5$ GeV is not excluded by this analysis.

MASS LIMITS for Associated Higgs Production in e^+e^- Interactions

In multi-Higgs models, associated production of Higgs via virtual or real Z in e^+e^- annihilation, $e^+e^-\to H_1^0H_2^0$, is possible if H_1^0 and H_2^0 have opposite CP eigenvalues. Limits are for the mass of the heavier Higgs H_2^0 in two-doublet models.

			4	
VALUE (GeV)	<u>CL%</u>	DOCUMENT ID	TECN	COMMENT
• • • We do not u	se the follow	ing data for average	s, fits, limit	s, etc. • • •
>53	95	¹⁰⁹ AKERS	94ı OPAL	m _{H1} < 12 GeV
		110 ADRIANI	92G L3	1
>45	95	111 DECAMP	90H ALEP	$m_{H_1^0} < 20 \text{ GeV}$
>37.5	95	111 DECAMP	90H ALEP	$m_{H_1^0}^{1} < m_{H_2^0}$
none 5-45	95	112 KOMAMIYA	90 MRK	$m_{H_1^0}^1 < 0.5 \text{ GeV},$
				$H_2^0 \rightarrow q\bar{q} \text{ or } \tau^+\tau^-$
> 8	90	113 KOMAMIYA	89 MRK	$H_1^0 \to \mu^+\mu^-,$
>28	95	114 LOW	90 AMV	$H_2^0 \rightarrow q \overline{q}, \tau^+ \tau^-$
, ,	73	LOW	O7 ANIT	$m_{H_1^0} \lesssim 20 \text{ MeV},$
none 2 -9	90	115 AKERLOF	85 HRS	$H_2^0 \rightarrow q\overline{q}$
	,,	ANENEO	05 71113	$m_{H_1^0} = 0,$
none 4-10	90	¹¹⁶ ASH	85c MAC	$H_2^0 \to f\overline{f}$ $m_{H_1^0} = 0.2 \text{ GeV},$
			000 111110	H ₁ 0 - 0.2 dev,
none 1.3-24.7	95	115 BARTEL	851 IADE	$H_2^0 \rightarrow \tau^+ \tau^-, c\overline{c}$ $m_{H_1^0} = 0.2 \text{ GeV}, H_2^0 \rightarrow$
10110 1.0 14.1	,,	DARTE	OUL JADE	
none 1.2-13.6	95	115 BEHREND	85 CFU	$f\overline{7}$ or $f\overline{7}H_1^0$
1000 112 1000	,,	BEIIILI		$m_{H_1^0} = 0,$
none 1-11	90	115 FELDMAN	85 MRK	$\begin{array}{c} \hat{H_2^0} \rightarrow f\bar{f} \\ P m_{H_1^0} = 0, H_2^0 \rightarrow f\bar{f} \end{array}$
none 1–9	90	115 FELDMAN	85 MRK	$H_1^0 = \pi + \pi$
none 1-7	90	LEDWAN	oo MIKK	$m_{H_1^0} = m_{H_2^0}$
				$H_2^0 \rightarrow f \overline{f}$

109 AKERS 94I search for $Z \to H_1^0 H_2^0$ with various decay modes. See Fig. 11 for the full excluded mass region in the general two-doublet model, from which the limit above is taken. In particular, for $m_{H_1^0} = m_{H_2^0}$ the limit becomes >38 GeV.

110 ADRIANI 92G excluded regions of the $m_{H_1^0}-m_{A^0}$ plane for various decay modes with limits B($Z \to H_1^0 H_2^0$) <(2–20) × 10⁻⁴ are shown in Figs. 2–5.

- 111 DECAMP 90H search for $Z\to H_1^0e^+e^-$, $H_1^0\mu^+\mu^-$, $H_1^0\tau^+\tau^-$, $H_1\,q\bar{q}$, low multiplicity final states, τ - τ -jet-jet final states and 4-jet final states.
- ¹¹² KOMAMIYA 90 limits valid for $\cos^2(\alpha-\beta)\approx 1$. They also search for the cases $H_1^0\to$ $\mu^+\mu^-$, $\tau^+\tau^-$, and $H^0_2 \to H^0_1 H^0_1$. See their Fig. 2 for limits for these cases.
- 113 KOMAMIYA 89 assume B($H_1^0 \to \mu^+ \mu^-$) = 100 %, $2m_{\mu} < m_{H_1^0} < m_{\tau}$. The limit is for maximal mixing. A limit of $m_{H_2^0} > 18$ GeV for the case $H_2^0 \to H_1^0 H_1^0$ ($H_1^0 \to H_2^0 H_1^0$) $\mu^+\mu^-$) is also given. From PEP at $E_{\rm CM}=29$ GeV.

VALUE (GeV)

> 19

> 18

> 17

Gauge & Higgs Boson Particle Listings

Higgs Bosons — H^0 and H^{\pm}

- ^{114}LOW 89 assume that H_1^0 escapes the detector. The limit is for maximal mixing. A reduced limit of 24 GeV is obtained for the case $H_2^0 \rightarrow H_1^0 f \overline{f}$. Limits for a Higgs-triplet model are also discussed. $E_{\text{CM}}^{\text{ee}} = 50\text{--}60.8 \text{ GeV}.$
- $^{115}\,\mathrm{The}$ limit assumes maximal mixing and that H_{1}^{0} escapes the detector.
- 116 ASH 85 assumes that H_1^0 escapes undetected. The bound applies up to a mixing sup-

H[±] (Charged Higgs) MASS LIMITS

Most of the following limits assume $B(H^+ \rightarrow \tau^+ \nu) + B(H^+ \rightarrow c\overline{s}) = 1$. DE-CAMP 901, BEHREND 87, and BARTEL 86 assume $B(H^+ \rightarrow \tau^+ \nu) + B(H^+ \rightarrow \tau^+ \nu)$ $c\overline{s}$) + B($H^+ \rightarrow c\overline{b}$) = 1. All limits from Z decays as well as ADACHI 90B assume that H^+ has weak isospin $T_3 = +1/2$.

For limits obtained in hadronic collisions before the observation of the top quark, and based on the top mass values inconsistent with the current measurements, see the 1996 (Physical Review D54 1 (1996)) Edition of this Review.

The limits are also applicable to pointlike techni-pions. For a discussion of techniparticles, see EICHTEN 86.

In the following tan eta is the ratio of the two vacuum expectation values in the twodoublet model

TECN COMMENT

87 CELL $B(\tau \nu) = 0-1$

JADE $B(\tau \nu) = 0.1-1.0$

MRKJ B $(\tau \nu)$ =0.25-1.0

DOCUMENT ID

VALUE (GEV)	_ <u>CL%</u>	DOCUMENT ID	<u>TECN</u>	COMMENT
> 54.5	95	117 ABREU	98F DLPH	$B(\tau\nu)=01$
> 52.0	95	117 ACKERSTAFF	981 RVUE	$B(\tau \nu) = 0-1$
• • • We do not use to	he follow	ing data for average	s, fits, limits	, etc. • • •
		118 ABE	97L CDF	$t \rightarrow bH^+, H \rightarrow \tau \nu$
		119 ACCIARRI	97F L3	$B \rightarrow \tau \nu_{\tau}$
		120 AMMAR	97B CLEO	$\tau \rightarrow \mu \nu \nu$
		121 COARASA	97 RVUE	B → τν X
		122 GUCHAIT	97 RVUE	$t \rightarrow bH^+, H \rightarrow \tau \nu$
		123 MANGANO	97 RVUE	$B_{u(c)} \rightarrow \tau \nu_{\tau}$
		124 STAHL	97 RVUE	
		125 ABE	96G CDF	
			700 CD1	$\tau^+ u_{ au}$
> 44.1	95	126 ALEXANDER	961 OPAL	$B(\tau \nu) = 0-1$
>244	95	127 ALAM	95 CLE2	
		128 BUSKULIC	95 ALEP	$b \rightarrow \tau \nu_{\tau} X$
> 43.5	95	129 ABREU		$B(\tau\nu)=0-1$
		130 BARGER	93 RVUE	$b \rightarrow s \gamma$
		131 BELANGER	93 RVUE	$b \rightarrow s\gamma$
		130 HEWETT	93 RVUE	
> 41	95	132 ADRIANI	92G L3	$B(\tau\nu)=01$
> 41.7	95 133	3,134 DECAMP	92 ALEP	
none 8.0-20.2	95	135 YUZUKI	91 VNS	$B(\ell\nu)=0-1$
> 29	₉₅ 133	3,136 ABREU	90B DLPH	$B(\tau\nu)=01$
> 19	95 133	3,137 ADACHI	90B TOPZ	
> 36.5	95 133	3,138 ADEVA	90M L3	$B(\tau\nu)=0-1$
> 35	95 133	3,139 AKRAWY	90K OPAL	$B(\tau\nu)=0-1$
> 35.4		1,140 DECAMP	901 ALEP	$B(\tau\nu)=01$
none 10-20	95	141 SMITH	90B AMY	$B(\tau \nu) > 0.7$

- 142 ADEVA 95 ¹¹⁷ Search for $e^+e^- \rightarrow H^+H^-$ at \sqrt{s} =130–172 GeV.
- ¹¹⁸ABE 97L search for a charged Higgs boson in top decays in $p\overline{p}$ collisions at $E_{\rm cm}=1.8$ TeV, with $H^+ \to \tau^+ \nu_\tau$, τ decaying hadronically. The limits depend on the choice of the $t\bar{t}$ cross section. See Fig. 3 for the excluded region. The excluded mass region extends to over 140 GeV for $\tan\beta$ values above 100.

85

140 BEHREND

142 BARTEL

- 119 ACCIARRI 97F give a limit $m_{H^+}>2.6$ taneta GeV (90%CL) from their limit on the exclusive $B \rightarrow \tau \nu_{\tau}$ branching ratio.
- 120 AMMAR 978 measure the Michel parameter ρ from $\tau \to e \nu \nu$ decays and assmes e/μ universality to extract the Michel η parameter from $\tau \to \mu \nu \nu$ decays. The measurement is translated to a lower limit on m_{H^+} in a two-doublet model $m_{H^+} > 0.97$ tan β GeV (90% CL).
- 121 COARASA 97 reanalyzed the constraint on the $(m_{H^\pm}, \tan\beta)$ plane derived from the inclusive $B \to \tau \nu_\tau X$ branching ratio in GROSSMAN 95B and BUSKULIC 95. They show that the constraint is quite sensitive to supersymmetric one-loop effects.
- 122 GUCHAIT 97 studies the constraints on $m_{H^{\pm}}$ set by Tevatron data on $\ell \tau$ final states in $t\bar{t} \rightarrow (Wb)(Hb), W \rightarrow \ell\nu, H \rightarrow \tau\nu_{\tau}$. See Fig. 2 for the excluded region.
- 123 MANGANO 97 reconsiders the limit in ACCIARRI 97F including the effect of the potentially large $B_{\rm C} \to \tau \nu_{\tau}$ background to $B_{\rm U} \to \tau \nu_{\tau}$ decays. Stronger limits are obtained.
- 124 STAHL 97 fit τ lifetime, leptonic branching ratios, and the Michel parameters and derive limit $m_{H^+} > 1.5 \tan\beta$ GeV (90% CL) for a two-doublet model. See also STAHL 94. 125 ABE 96G search for a charged Higgs boson in top decays in $p\overline{p}$ collisions at $E_{\rm c}$
- 1.8 TeV. For the currently observed value of the top mass, the search is not sensitive enough to exclude a charged Higgs boson of any mass. 126 ALEXANDER 961 search for the final states $H^+H^- \to \tau \nu_{\tau} \tau \nu_{\tau}$, $\tau \nu_{\tau} c\bar{s}$, $c\bar{s}\bar{c}s$. Limit for $B(\tau \nu_{\tau}) = 1 \text{ is 45.5 GeV}.$
- 127 ALAM 95 measure the inclusive $b \to s \gamma$ branching ratio at $\Upsilon(4S)$ and give B(b s_{γ})< 4.2 × 10⁻⁴ (95% CL), which translates to the limit m_{H^+} >[244 + 63/(tan β)^{1.3}] GeV in the Type II two-doublet model. Light supersymmetric particles can invalidate this
- 128 BUSKULIC 95 give a limit $m_{H^+} > 1.9 \tan \beta$ GeV (90%CL) for Type-II models from $b \rightarrow$ $\tau \nu_{\tau} X$ branching ratio, as proposed in GROSSMAN 94.

- 129 ABREU 940 study $H^+H^-\to c\bar s\bar s\bar s\bar s$ (four-jet final states) and $H^+H^-\to \tau\nu_\tau\tau\nu_\tau$. Limit for B $(\tau\nu_\tau)$ = 1 is 45.4 GeV.
- 130 HEWETT 93 and BARGER 93 analyze charged Higgs contribution to $b
 ightarrow s \gamma$ in twodoublet models with the CLEO limit $B(b\to s\gamma)<8.4\times10^{-4}$ (90% CL) and find lower limits on m_{H^\pm} in the type of model (model II) in which different Higgs are responsible for up-type and down-type quark masses. HEWETT 93 give $m_{H^\pm}>110$ (70) GeV for m_t >150 (120) GeV using m_b = 5 GeV. BARGER 93 give m_{H^+} >155 GeV for m_t = 150 GeV using m_b = 4.25 GeV. The authors employ leading logarithmic QCD corrections and emphasize that the limits are quite sensitive to m_b .
- 131 BELANGER 93 make an analysis similar to BARGER 93 and HEWETT 93 with an improved CLEO limit $B(b\to s\gamma)<5.4\times10^{-4}$ (95%CL). For the Type II model, the limit $m_{H^+}>540$ (300) GeV for $m_t>150$ (120) GeV is obtained. The authors employ leading logarithmic QCD corrections.
- 132 ADRIANI 92G limit improves to 44 GeV if B($au
 u_{ au}$) > 0.4.
- 133 Studled $H^+H^- \rightarrow (\tau \nu) + (\tau \nu)$, $H^+H^- \rightarrow (\tau \nu) + \text{hadrons}$, $H^+H^- \rightarrow \text{hadrons}$.
- ¹³⁴DECAMP 92 limit improves to 45.3 GeV for B($\tau\nu$)=1.
- 135 YUZUKI 91 assume photon exchange. The limit is valid for any decay mode $H^+
 ightarrow e
 u_{
 m s}$ $\mu\nu$, $\tau\nu$, $q\overline{q}$ with five flavors. For B($\ell\nu$) = 1, the limit improves to 25.0 GeV.
- $^{136}\,\mathrm{ABREU}$ 908 limit improves to 36 GeV for $\mathrm{B}(\tau\nu)=1.$
- $137\,\mathrm{ADACHI}$ 908 limit improves to 22 GeV for B(au
 u) = 0.6.
- $^{138} \, \mathrm{ADEVA}$ 90M limit improves to 42.5 GeV for $\mathrm{B}(\tau \nu) = 1.$
- $^{139}\,\mathrm{AKRAWY}$ 90K limit improves to 43 GeV for $\mathrm{B}(\tau\,\nu)=$ 1.
- 140 If B(H+ $\rightarrow \tau^+ \nu$) = 100%, the DECAMP 901 limit improves to 43 GeV.
- 141 SMITH 90B limit applies for $v_2/v_1 > 2$ in a model in which H_2 couples to u-type quarks
- 142 Studied $H^+H^- \rightarrow (\tau \nu) + (\tau \nu), H^+H^- \rightarrow (\tau \nu) + \text{hadrons.}$ Search for muon opposite hadronic shower.

MASS LIMITS for H±± (doubly-charged Higgs boson)

VALUE (GeV)	CL%	DOCUMENT ID		TECN	<u>COMMENT</u>
>45.6	95	143 ACTON	92M	OPAL	
• • • We do not use	the follow	ving data for averag	es, fits	, limits,	etc. • • •
		144 GORDEEV	97	SPEC	muonium conversion
		¹⁴⁵ ASAKA	95	THEO	
>30.4	95	146 ACTON	92M	OPAL	$T_3(H^{++})=+1$
>25.5	95	146 ACTON			$T_3(H^{++})=0$
none 6.5-36.6	95	¹⁴⁷ SWARTZ	90	MRK2	$T_3(H^{++}) = +1$
none 7.3-34.3	95	147 SWARTZ			$T_3(H^{++}) = 0$

- ¹⁴³ACTON 92M limit assumes $H^{\pm\pm} \rightarrow \ell^{\pm}\ell^{\pm}$ or $H^{\pm\pm}$ does not decay in the detector. Thus the region $g_{\ell\ell} \approx 10^{-7}$ is not excluded.
- 144 GORDEEV 97 search for muonium-antimuonium conversion and find $G_{M\overline{M}}/G_F < 0.14$ (90% CL), where $G_{M\overline{M}}$ is the lepton-flavor violating effective four-fermion coupling. This limit may be converted to $m_{H^{++}}>210$ GeV if the Yukawa copulings of H^{++} to ee and $\mu\mu$ are as large as the weak gauge coupling. For similar limits on muonium-antimuonium conversion, see the muon Particle Listings.
- 145 ASAKA 95 point out that H++ decays dominantly to four fermions in a large region of parameter space where the limit of ACTON 92M from the search of dilepton modes does
- 146 ACTON 92M from $\Delta\Gamma_Z$ <40 MeV.

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ARREII

147 SWARTZ 90 assume $H^{\pm\pm} \rightarrow \ell^{\pm}\ell^{\pm}$ (any flavor). The limits are valid for the Higgs-lepton coupling $g(H\ell\ell) \gtrsim 7.4 \times 10^{-7}/[m_H/\text{GeV}]^{1/2}$. The limits improve somewhat for ee and $\mu\mu$ decay modes.

Ho and H± REFERENCES

ADREU .	90C	ELI CS I	P. Abreu+	(DELPHI	Collab.)	
ABREU	98F	PL B420 140	P. Abreu+	(DELPHI		
ACCIARRI	98B	Pl. 8418 389	M. Acciarri+		Collab.)	
ACKERSTAFF	98B	EPJ C1 31	K. Ackerstaff+	(OPAL		
ACKERSTAFF	98H	EPJ C1 425	K. Ackerstaff+	OPAL	Collab.)	
ACKERSTAFF	981	PL B426 180	K. Ackerstaff+	(OPAL		
CHANOWITZ	98	PRL 80 2521	M. Chanowitz		,	
ABBANEO	97	CERN-PPE/97-154	D. Abbaneo+			
ALEPH, D	ELPHI	, L3, OPAL, and SLD Co	liaborations, and the LEP Electroweak Wo	orking Grou	up.	
ABE	97L	PRL 79 357	F. Abe+		Collab.)	
ABE	97W	PRL 79 3819	F. Abe+		Collab.)	
ACCIARRI	97F	PL B396 327	M. Acciarri+		Collab.	
ACCIARRI	97N	PL B411 330	M. Acciarri+	(L3	Collab.	
ACCIARRI	970	PL B411 373	M. Acciarri+	(L3	Collab.)	
ACKERSTAFF		PL B393 231	K. Ackerstaff+	(OPAL		
ALEXANDER	97	ZPHY C73 189	G. Alexander+	(OPAL	Collab.	
AMMAR	97B	PRL 78 4686	R. Ammar+	(CLEO	Collab.)	
BARATE	970	PL 8412 155	R. Barate+	(ALEPH		
BARATE	97P	PL B412 173	R. Barate+	(ALEPH		
BOCK	97	CERN-EP/98-046	P. Bock+	•	•	
ALEPH, D	ELPHI	, L3, and OPAL Collabora	ations, and the LEP Higgs Boson Searches	Working	Group	
COARASA	97	Pl. B406 337	J.A. Coarasa, R.A. Jirnenez, J. Sola	-		
DEBOER	97B	ZPHY C75 627	W. de Boer, A. Dabelstein, W. Hollik+			
DEGRASSI	97	PL B394 188	G. Degrassi, P. Gambino, A. Sirtin	(MPIM	, NYU)	
DITTMAIER	97	PL B391 420	S. Dittmaier, D. Schildknecht	,	(BIEL)	
GORDEEV	97	PAN 60 1164	V.A. Gordeev+		(PNPI)	
		Translated from YAF 60	1291.		,	

Higgs Bosons — H^0 and H^{\pm} , Heavy Bosons Other than Higgs Bosons

GUCHAIT	97	PR D55 7263	M. Guchait, D.P. Roy	(TATA)
KEITH KRAWCZYK	97 97	PR D56 R5306 PR D55 6968	E. Keith, E. Ma, D.P. Roy M. Krawczyk, J. Zochowski M. Mangano, S. Slabospitsky	(WARS)
MANGANO	97	PL B410 299	M. Mangano, S. Slabospitsky	(++(1/2)
RENTON STAHL	97 97	IJMP A12 4109 ZPHY C74 73	P.B. Renton A. Stahl, H. Voss	(BONN)
ABE ACCIARRI	96G 96J	PR D54 735 PL B385 454	<u>+</u>	(CDF Collab.)
ACCIARRI	96J	PL B388 409	÷	(L3 Collab.) (L3 Collab.)
ALCARAZ The ALEF	96 'H, Di	CERN-PPE/96-183 LPHI, L3, OPAL, a	J. Alcaraz+ nd SLD Collaborations and the LEP Electrow	weak Working Group
ALEXANDER ALEXANDER	96H 96I	ZPHY C71 1 PL B370 174	+	(OPAL Collab.)
ALEXANDER	96L	PL B377 273	+Allison, Altekamp, Ametewee+	(OPAL Collab.) (OPAL Collab.)
BUSKULIC BUSKULIC	96K 96R	PL B373 246 PL B384 427	+De Bonis, Decamp, Ghez+	(ALEPH Collab.) (ALEPH Collab.)
DITTMAIER	96	PL B386 247	+Schildknecht, Weiglein	(BIEL, KARL)
ELLIS GURTU	96C 96	PL B389 321 PL B385 415	+Fogli, Lisi	(CERN, BARI) (TATA)
PDG ABREU	96 95H	PR D54 1 ZPHY C67 69	±Adam Adus Asasi Alinaska Alakesa	
ALAM	95	PRL 74 2885	+Adam, Adye, Agasi, Ajinenko, Aleksar +Kim, Ling, Mahmood+	(CLEO Collab.)
ASAKA BUSKULIC	95 95	PL B345 36 PL B343 444	+Hikasa +Casper, De Bonis, Decamp, Ghez, Go	(TOHOK)
CHANKOWSK	95 95	PL B356 307	+ Pokorski	(WARS, MPIM)
ERLER GROSSMAN	95B	PR D52 441 PL B357 630	+Langacker Y. Grossman, H. Haber, Y. Nir	(PENN)
MATSUMOTO ROSIEK	95 95	MPL A10 2553 PL B341 419	+Sopczak	(KEK)
ABREU	94G	NP B421 3	+Adam, Adye, Agasi, Ajinenko+	(IFIC, CERN) (DELPHI Collab.)
ABREU AKERS	94O 94B	ZPHY C64 183 PL B327 397	+Adam, Adye, Agasi, Ajinenko, Aleksar +Alexander, Allison, Anderson, Arceili+	1+ (DELPHI Collab.) (OPAL Collab.)
AKERS ELLIS	941 948	ZPHY C64 1	+Alexander, Allison, Anderson, Arcelli,	Asai+(OPAL Collab.)
GROSSMAN	94	PL B333 118 PL B332 373 MPL A9 3301	+Fogli, Lisi Y. Grossman, Z. Ligeti	(CERN, BARI)
GURTU MONTAGNA	94 94	MPL A9 3301 PL B335 484	+Nicrosini, Passarino, Piccinini (INFN,	PAVIL CERN TORIN
STAHL	94	PL B324 121	A. Stahi	(BONN)
ADRIANI BARGER	93C 93	PL B303 391 PRL 70 1368	+Aguilar-Benitez, Ahlen, Alcaraz, Aloiso	+ (L3 Collab.)
BELANGER	93	PR D48 5419	+Berger, Philifips +Geng, Turcotte Brahmachari, Joshipura, Rindani+(AH	MONT, ISU, AMES)
BRAHMACH BUSKULIC	. 93 93H	PR D48 4224 PL B313 299	Brahmachari, Joshipura, Rindani+(AH +De Bonis, Decamp, Ghez, Goy+	MED, TATA, CERN) (ALEPH Collab.)
BUSKULIC	931	PL B313 312	+De Bonis, Decamp, Ghez, Goy, Lees+	(ALEPH Collab.)
ELLIS GROSS	93 93	NP 8393 3 IJMP A8 407	+Fogli, Lisi +Yepes	(CERN, BARI) (CERN)
HEWETT	93	IJMP A8 407 PRL 70 1045		(ANL, OREG)
LOPEZ-FERN, ABREU	92D	PL B312 240 ZPHY C53 555	Lopez-Fernandez, Romao+ (+Adam, Adami, Adye, Akesson, Aleksee	CERN, LISB, VALE)
ABREU	92J 92M	NP B373 3 PL B295 347	+Adam, Adami, Adye, Akesson+	(DELPHI Collab.)
ACTON ADEVA	92B	PL B293 347 PL B283 454	+Alexander, Allison, Allport, Anderson+ +Adriani, Aguilar-Benitez, Ahlen, Akbar	- (OPAL Collab.) i+ (L3 Collab.)
ADRIANI ADRIANI	92F 92G	PL B292 472 PL B294 457	+Aguilar-Benitez, Ahlen, Akbari, Alcare: +Aguilar-Benitez, Ahlen, Akbari, Alcara:	z+ (L3 Collab.)
Also	93B	ZPHY C57 355	Adriani, Aguilar-Benitez, Ahlen, Alcara	sz+ (L3 Collab.)
BUSKULIC DECAMP	92 92	PL B285 309 PRPL 216 253	+Decamp, Goy, Lees, Minard+ +Deschizeaux, Goy, Lees, Minard+	(ALEPH Collab.) (ALEPH Collab.)
PICH	92	NP B388 31	+Prades, Yepes +Adam, Adami, Adye, Akesson+	(CERN, CPPM)
ABREU ACTON	91B 91	ZPHY C51 25 PL B268 122	+Adam, Adami, Adye, Akesson+ +Alexander, Allison, Aliport+	(DELPHI Collab.) (OPAL Collab.)
ADEVA ADEVA	91 91D	PL B257 450 PL B262 155	+Adriani, Aguilar-Benitez, Akbari, Alcar	az+ (L3 Collab.)
AKRAWY	91	PL B253 511	+Adriani, Aguilar-Benitez, Akbari, Alcar +Alexander, Allison, Allport, Anderson+ +Alexander, Allison, Allport, Anderson+	(OPAL Collab.)
AKRAWY BLUEMLEIN	91C 91	ZPHY C49 1 ZPHY C51 341	+Alexander, Allison, Allport, Anderson+ +Brunner, Grabosch+ (BERL, I	 (OPAL Collab.)
DECAMP	91F	PL B262 139	+Deschizeaux, Goy, Lees, Minard+	BUDA, JINR, SERP) (ALEPH Collab.)
DECAMP YUZUKI	911 91	PL B265 475 PL B267 309	+Deschizeaux, Goy, Lees, Minard+ +Haba, Abe, Amako, Arai, Asano+	(ALEPH Collab.) (VENUS Collab.)
ABE ABREU	90E 90B	PR D41 1717 PL B241 449	+Amidei, Appollinari, Atac, Auchincloss	+ (CDF Collab.)
ABREU	90C	NP B342 1	+Adam, Adami, Adye, Alekseev+ +Adam, Adami, Adye, Alekseev+	(DELPHI Collab.) (DELPHI Collab.)
ABREU ABREU	90E 901	PL B245 276 HEP-90 Singapore	+Adam, Adami, Adye, Alekseev+ unpub-Adam, Adami, Adye, Alekseev+	(DELPHI Collab.) (DELPHI Collab.)
CERN-PPE	E/90-1	63		
ADACHI ADEVA	90B 90H	PL B240 513 PL B248 203	+Aihara, Doeser, Enomoto+ +Adriani, Aguilar-Benitez, Akbari, Alcar	(TOPAZ Collab.) az+ (L3 Collab.)
ADEVA	90M	PL B252 511	+Adriani, Aguitar-Benitez, Akbari, Alcar	az+ (L3 Collab.)
ADEVA ADEVA	90N 90R	PL B252 518 PL B251 311	+Adriani, Aguilar-Benitez, Akbari, Alcar +Adriani, Aguilar-Benitez, Akbari, Alcar	az+ (L3 Collab.) az+ (L3 Collab.)
AKRAWY AKRAWY	90C 90K	PL B236 224 PL B242 299	+Alexander, Allison, Allport+	(OPAL Collab.)
AKRAWY	90P	PL B251 211	+Alexander, Allison, Allport, Anderson+ +Alexander, Allison, Allport, Anderson+	(OPAL Collab.)
DECAMP DECAMP	90 90E	PL B236 233 PL B237 291	+Alexander, Allison, Allport, Anderson+ +Deschizeaux, Lees, Minard, Crespo+ +Deschizeaux, Lees, Minard+	(ALEPH Collab.) (ALEPH Collab.)
DECAMP	90H	PL B241 141	+Deschizeaux, Lees, Minard+	(ALEPH Collab.)
DECAMP DECAMP	901 90M	PL B241 623 PL B245 289	+Deschizeaux, Goy, Lees, Minard+ +Deschizeaux, Goy, Lees, Minard+	(ALEPH Collab.) (ALEPH Collab.)
DECAMP KOMAMIYA	90N 90	PL B245 289 PL B246 306 PRL 64 2881	+Deschizeaux, Goy, Lees, Minard+	(ALEPH Collab.)
SMITH	90B	PR D42 949	+Abrams, Adolphsen, Averill, Ballam+ +McNell, Breedon, Kim, Ko+	(Mark II Collab.) (AMY Collab.)
SWARTZ CAHN	90 89	PRL 64 2877 RPP 52 389	+Abrams, Adolphsen, Averill, Ballam+	(Mark II Collab.)
DAVIER	89	PL B229 150	+Nguyen Ngoc	(LALO)
KOMAMIYA LOW	89 89	PR D40 721 PL B228 548	+Fordham, Abrams, Adolphsen, Akeriof- +Xu, Abashian, Gotow, Hu, Mattson+	+ (Mark II Čollab.) (AMY Collab.)
SHER	89	PRPL 179 273		
SNYDER BEHREND	89 87	PL B229 169 PL B193 376	+Murray, Abrams, Adolphsen, Akerlof+ +Buerger, Criegee, Dainton+	(Mark II Collab.) (CELLO Collab.)
FRANZINI BARTEL	87	PR D35 2883	+Son, Tuts, Youssef, Zhao+	(CUSB Collab.)
EICHTEN	86 86	ZPHY C31 359 PR D34 1547	+Becker, Felst, Haidt+ +Hinchliffe, Lane, Quigg+	(JADE Collab.) (FNAL, LBL, OSU)
ADEVA AKERLOF	85 85	PL 152B 439 PL 156B 271	+Becker, Becker-Szendy+ +Bonvicini, Chapman, Errede+	(Mark-J Collab.) (HRS Collab.)
ALBRECHT	85J	ZPHY C29 167	+Binder, Harder+	(ARGUS Collab.)
ASH ASH	85 85C	PRL 55 1831 PRL 54 2477	+Band, Blume, Camporesi+ +Band, Blume, Camporesi+	(MAC Collab.) (MAC Collab.)
BARTEL	85L	PL 155B 288	+Becker, Cords, Felst, Hagiwara+	(JADE Collab.)
BEHREND FELDMAN	85 85	PL 161B 182 PRL 54 2289	+Burger, Criegee, Fenner+ +Abrams, Amidei, Baden+	(ČELLO Collab.) (Mark II Collab.)

Heavy Bosons Other Than Higgs Bosons, Searches for

We list here various limits on charged and neutral heavy vector bosons (other than W's and Z's), heavy scalar bosons (other than Higgs bosons), vector or scalar leptoquarks, and axigluons.

WR (Right-Handed W Boson) MASS LIMITS

Assuming a light right-handed neutrino, except for BEALL 82, LANGACKER 898, and COLANGELO 91. $g_R=g_L$ assumed. [Limits in the section MASS LIMITS for W' below are also valid for W_R if $m_{\nu_R} \ll m_{W_R}$.] Some limits assume manifest left-right symmetry, i.e., the equality of left- and right Cabibbo-Kobayashi-Maskawa matrices. For a comprehensive review, see LANGACKER 898. Limits on the W_L - W_R mixing angle ζ are found in the next section. Values in brackets are from cosmological and astrophysical considerations and assume a light right-handed neutrino.

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
> 549		¹ BARENBOIM	97	RVUE	μ decay
• • • We do not use	the follo	wing data for avera	ges,	fits, lim	its, etc. • • •
> 220	95	² STAHL	97	RVUE	au decay
> 220	90	3 ALLET	96	CNTR	β ⁺ decay
> 281	90	4 KUZNETSOV	95	CNTR	Polarized neutron decay
> 282	90	5 KUZNETSOV	94B	CNTR	Polarized neutron decay
> 439	90	6 BHATTACH	93	RVUE	Z-Z' mixing
> 250	90	7 SEVERIJNS	93	CNTR	β ⁺ decay
		⁸ IMAZATO	92	CNTR	K+, decay
> 475	90	⁹ POLAK	92B	RVUE	μ decay
> 240	90	¹⁰ AQUINO	91	RVUE	Neutron decay
> 496	90	¹⁰ AQUINO	91	RVUE	Neutron and muon decay
> 700		11 COLANGELO	91	THEO	
> 477	90	¹² POLAK	91	RVUE	μ decay
none 540-23000]		13 BARBIERI		ASTR	SN 1987A; light vR
> 300	90	14 LANGACKER	898	RVUE	General
> 160	90	15 BALKE	88	CNTR	$\mu \rightarrow e \nu \overline{\nu}$
> 406	90	16 JODIDIO	86	ELEC	Апу 🤇
> 482	90	16 JODIDIO		ELEC	
> 800		_ MOHAPATRA	86		$SU(2)_L \times SU(2)_R \times U(1)$
> 400	95	17 STOKER	85		
> 475	95	17 STOKER	85	ELEC	ζ <0.041
		¹⁸ BERGSMA	83	CHRM	$\nu_{\mu}e \rightarrow \mu\nu_{e}$
> 380	90	¹⁹ CARR	83		μ^+ decay
>1600		²⁰ BEALL	82	THEO	$m_{K_1^0} - m_{K_2^0}$
> 4000]		STEIGMAN	79	COSM	Nucleosynthesis; light VR

- 1 The quoted limit is from μ decay parameters. BARENBOIM 97 also evaluate limit from KI-Kg mass difference.
- 2 STAHL 97 limit is from fit to au-decay parameters.
- 3 ALLET 96 measured polarization-asymmetry correlaton in $^{12}{\rm N}\beta^+$ decay. The listed limit assumes zero $\it L-R$ mixing.
- KUZNETSOV 95 limit is from measurements of the asymmetry $\langle \vec{p}_{\nu} \cdot \sigma_{\rho} \rangle$ in the β decay of polarized neutrons. Zero mixing assumed. See also KUZNETSOV 94B.
- of polarized neutrons. Zero mixing assumed. See any nozine 1307 775. KUZNETSOV 948 limit is from measurements of the asymmetry $\langle \vec{p}\nu \cdot \sigma_n \rangle$ in the β decay of polarized neutrons. Zero mixing assumed. 6 BHATTACHARYYA 93 uses Z-Z' mixing limit from LEP '90 data, assuming a specific Higgs sector of $SU(2)_L \times SU(2)_R \times U(1)$ gauge model. The limit is for m_t =200 GeV and slightly improves for smaller m_t .
- 7 SEVERIJNS 93 measured polarization-asymmetry correlation in $^{107} \ln \beta^+$ decay. The listed limit assumes zero L-R mixing. Value quoted here is from SEVERIJNS 94 erratum. §IMAZATO 92 measure positron asymmetry in $K^+ \to \mu^+ \nu_\mu$ decay and obtain ξP_{μ} > 0.990 (90%CL). If W_R couples to $u\bar{s}$ with full weak strength ($V_{u\bar{s}}^R$ =1), the result corresponds to m_{W_R} >653 GeV. See their Fig. 4 for m_{W_R} limits for general
- $|V_{us}^R|^2=1-|V_{ud}^R|^2$. 9 POLAK 928 limit is from fit to muon decay parameters and is essentially determined by JODIDIO 86 data assuming C=0. Supersedes POLAK 91.
- 10 AQUINO 91 limits obtained from neutron lifetime and asymmetries together with unitarity of the CKM matrix. Manifest left-right symmetry assumed. Stronger of the two limits also includes muon decay results.
- 11 COLANGELO 91 limit uses hadronic matrix elements evaluated by QCD sum rule and is less restrictive than BEALL 82 limit which uses vacuum saturation approximation. Manifest left-right symmetry assumed.
- 12 POLAK 91 limit is from fit to muon decay parameters and is essentially determined by JODIDIO 86 data assuming 5=0. Superseded by POLAK 92B.
- 13 BARBIERI 898 limit holds for $m_{
 u_R} \le 10$ MeV
- 14 LANGACKER 898 limit is for any $_{PR}^{}$ mass (either Dirac or Majorana) and for a general class of right-handed quark mixing matrices.
- class or right-handed quark mixing matrices. 15 BALKE 88 limit is for $m_{\nu_e R} = 0$ and $m_{\nu_{\mu R}} \leq 50$ MeV. Limits come from precise measurements of the muon decay asymmetry as a function of the positron energy. 16 JODIDIO 86 is the same TRIUMF experiment as STOKER 85 (and CARR 83); however, it uses a different technique. The results given here are combined results of the two techniques. The technique here involves precise measurement of the end-point e^+ spectrum in the decay of the highly polarized μ^+
- 17 STOKER 85 is same TRIUMF experiment as CARR 83. Here they measure the decay e⁺ spectrum asymmetry above 46 MeV/c using a muon-spin-rotation technique. Assumed a light right-handed neutrino. Quoted limits are from combining with CARR 83.
- ¹⁸ BERGSMA 83 set limit m_{W_2}/m_{W_1} >1.9 at CL = 90%.

 19 CARR 83 is TRIUMF experiment with a highly polarized μ^+ beam. Looked for deviation from V-A at the high momentum end of the decay ${
m e^+}$ energy spectrum. Limit from previous world-average muon polarization parameter is $m_{W_R}~>$ 240 GeV. Assumes a light right-handed neutrino.

²⁰BEALL 82 limit is obtained assuming that W_R contribution to $K_I^0 - K_S^0$ mass difference is smaller than the standard one, neglecting the top quark contributions. Manifest left-right symmetry assumed.

Limit on W_L - W_R Mixing Angle ζ Lighter mass eigenstate $W_1 = W_L \cos \zeta - W_R \sin \zeta$. Light ν_R assumed unless noted. Values in brackets are from cosmological and astrophysical considerations.

VALUE CL% **DOCUMENT ID** TECN COMMENT • • • We do not use the following data for averages, fits, limits, etc. • • • ²¹ BARENBOIM 97 < 0.0333 RVUE μ decay ²² MISHRA < 0.04 CCFR VN scattering 92 -0.0006 to 0.0028 ²³ AQUINO RVUE 90 24 BARBIERI [none 0.00001-0.02] 89B ASTR SN 1987A 25 JODIDIO < 0.040 ELEC ²⁵ JODIDIO -0.056 to 0.040 86 ELEC

 21 The quoted limit is from μ decay parameters. BARENBOIM 97 also evaluate limit from

²²MISHRA 92 limit is from the absence of extra large-x, large-y $\overline{\nu}_{\mu}$ N ightarrow $\overline{\nu}_{\mu}$ X events at Tevatron, assuming left-handed ν and right-handed $\overline{\nu}$ in the neutrino beam. The result gives $\zeta^2(1-2m_{W_1}^2/m_{W_2}^2)$ < 0.0015. The limit is independent of ν_R mass.

23 AQUINO 91 limits obtained from neutron lifetime and asymmetries together with unitarity of the CKM matrix. Manifest left-right asymmetry is assumed 24 BARBIERI 898 limit holds for $m_{\nu_R} \leq$ 10 MeV.

²⁵ First JODIDIO 86 result assumes $m_{W_R} = \infty$, second is for unconstrained m_{W_R} .

THE W' SEARCHES

Written October 1997 by K.S. Babu, C. Kolda, and J. March-Russell (IAS/Princeton).

Any electrically charged gauge boson outside of the Standard Model is generically denoted W'. A W' always couples to two different flavors of fermions, similar to the W boson. In particular, if a W' couples quarks to leptons it is a leptoquark

The most attractive candidate for W' is the W_R gauge boson associated with the left-right symmetric models [1]. These models seek to provide a spontaneous origin for parity violation in weak interactions. Here the gauge group is extended to $SU(3)_C \times SU(2)_L \times SU(2)_R \times U(1)_{B-L}$ with the Standard Model hypercharge identified as $Y = T_{3R} + (B-L)/2$, T_{3R} being the third component of $SU(2)_R$. The fermions transform under the gauge group in a left-right symmetric fashion: $q_L(3, 2, 1, 1/3) +$ $q_R(3,1,2,1/3)$ for quarks and $\ell_L(1,2,1,-1) + \ell_R(1,1,2,-1)$ for leptons. Note that the model requires the introduction of right-handed neutrinos, which can facilitate the see-saw mechanism for explaining the smallness of the ordinary neutrino masses. A Higgs bidoublet $\Phi(1,2,2,0)$ is usually employed to generate quark and lepton masses and to participate in the electroweak symmetry breaking. Under left-right (or parity) symmetry, $q_L \leftrightarrow q_R$, $\ell_L \leftrightarrow \ell_R$, $W_L \leftrightarrow W_R$ and $\Phi \leftrightarrow \Phi^{\dagger}$.

After spontaneous symmetry breaking, the two W bosons of the model, W_L and W_R , will mix. The physical mass eigenstates are denoted as

$$W_1 = \cos \zeta W_L + \sin \zeta W_R, \qquad W_2 = -\sin \zeta W_L + \cos \zeta W_R$$
 (1)

with W_1 identified as the observed W boson. The most general Lagrangian that describes the interactions of the $W_{1,2}$ with the quarks can be written as [2]

$$\mathcal{L} = -\frac{1}{\sqrt{2}} \overline{u} \gamma_{\mu} \left[\left(g_L \cos \zeta \, V^L P_L - g_R e^{i\omega} \sin \zeta \, V^R P_R \right) W_1^{\mu} \right.$$
$$+ \left. \left(g_L \sin \zeta \, V^L P_L + g_R e^{i\omega} \cos \zeta \, V^R P_R \right) W_2^{\mu} \right] d + h.c.(2)$$

where $g_{L,R}$ are the SU(2)_{L,R} gauge couplings, $P_{L,R} = (1 \mp \gamma_5)/2$ and $V^{L,R}$ are the left- and right-handed CKM matrices in the quark sector. The phase ω reflects a possible complex mixing parameter in the W_L - W_R mass-squared matrix. Note that there is CP violation in the model arising from the right-handed currents even with only two generations. The Lagrangian for leptons is identical to that for quarks, with the replacements $u \to \nu$, $d \to e$ and the identification of $V^{L,R}$ with the CKM matrices in the leptonic sector.

If parity invariance is imposed on the Lagrangian, then $g_L = g_R$. Furthermore, the Yukawa coupling matrices that arise from coupling to the Higgs bidoublet Φ will be Hermitian. If in addition the vacuum expectation values of Φ are assumed to be real, the quark and lepton mass matrices will also be Hermitian, leading to the relation $V^L = V^R$. Such models are called manifest left-right symmetric models and are approximately realized with a minimal Higgs sector [3]. If instead parity and CP are both imposed on the Lagrangian, then the Yukawa coupling matrices will be real symmetric and, after spontaneous CP violation, the mass matrices will be complex symmetric. In this case, which is known in the literature as pseudo-manifest left-right symmetry, $V^L = (V^R)^*$.

Indirect constraints: In minimal version of manifest or pseudo-manifest left-right symmetric models with $\omega = 0$ or π , there are only two free parameters, ζ and M_{W_2} , and they can be constrained from low energy processes. In the large M_{W_2} limit, stringent bounds on the angle ζ arise from three processes. (i) Nonleptonic K decays: The decays $K \to 3\pi$ and $K \rightarrow 2\pi$ are sensitive to small admixtures of right-handed currents. Assuming the validity of PCAC relations in the Standard Model it has been argued in Ref. 4 that the success in the $K \to 3\pi$ prediction will be spoiled unless $|\zeta| < 4 \times 10^{-3}$. (ii) $b \rightarrow s\gamma$: The amplitude for this process has an enhancement factor m_t/m_h relative to the Standard Model and thus can be used to constrain ζ yielding the limit $-0.01 \le \zeta \le 0.003$ [5]. (iii) Universality in weak decays: If the right-handed neutrinos are heavy, the right-handed admixture in the charged current will contribute to β decay and K decay, but not to the μ decay. This will modify the extracted values of V_{ud}^L and V_{us}^L . Demanding that the difference not upset the three generation unitarity of the CKM matrix, a bound $|\zeta| \leq 10^{-3}$ has been

If the ν_R are heavy, leptonic and semileptonic processes do not constrain ζ since the emission of ν_R will not be kinematically allowed. However, if the ν_R is light enough to be emitted in μ decay and β decay, stringent limits on ζ do arise. For example, $|\zeta| \leq 0.039$ can be obtained from polarized μ decay [7] in the large M_{W_2} limit of the manifest left-right model. Alternatively, in the $\zeta = 0$ limit, there is a constraint $M_{W_2} \geq 484$ GeV from direct W_2 exchange. For the constraint on the case in which M_{W_2} is not taken to be heavy, see Ref. 2. There are also cosmological and astrophysical constraints on M_{W_2} and ζ in scenarios with a light ν_R . During nucleosynthesis the

process $e^+e^- \to \nu_R \overline{\nu}_R$, proceeding via W_2 exchange, will keep the ν_R in equilibrium leading to an overproduction of ⁴He unless M_{W_2} is greater than about 1 TeV [8]. Likewise the ν_{eR} produced via $e_R^- p \rightarrow n \nu_R$ inside a supernova must not drain too much of its energy, leading to limits $M_{W_2} > 16$ TeV and $|\zeta| \leq 3 \times 10^{-5}$ [9]. Note that models with light ν_R do not have a see-saw mechanism for explaining the smallness of the neutrino masses, though other mechanisms may arise in variant models [10].

The mass of W_2 is severely constrained (independent of the value of ζ) from K_L - K_S mass-splitting. The box diagram with exchange of one W_L and one W_R has an anomalous enhancement and yields the bound $M_{W_2} \geq 1.6$ TeV [11] for the case of manifest or pseudo-manifest left-right symmetry. If the ν_R have Majorana masses, another constraint arises from neutrinoless double β decay. Combining the experimental limit from $^{76}\mathrm{Ge}$ decay with arguments of vacuum stability, a limit of $M_{W_2} \ge 1.1 \text{ TeV has been obtained [12]}.$

Direct search limits: Limits on M_{W_2} from direct searches depend on the available decay channels of W_2 . If ν_R is heavier than W_2 , the decay $W_2^+ \to \ell_R^+ \nu_R$ will be forbidden kinematically. Assuming that ζ is small, the dominant decay of W_2 will be into dijets. UA2 [13] has excluded a W_2 in the mass range of 100 to 251 GeV in this channel. $D \varnothing$ excludes the mass range of 340 to 680 GeV [14], while CDF excludes the mass range of 300 to 420 GeV for such a W_2 [15]. If ν_R is lighter than W_2 , the decay $W_2^+ \to e_R^+ \nu_R$ is allowed. The ν_R can then decay into $e_RW_R^*$, leading to an eejj signature. DØ has a limit of $M_{W_2} > 720$ GeV if $m_{\nu_R} \ll M_{W_2}$; the bound weakens, for example, to 650 GeV for $m_{\nu_R} = M_{W_2}/2$ [16]. CDF finds $M_{W_2} > 652$ GeV if ν_R is stable and much lighter than W_2 [17]. All of these limits assume manifest or pseudo-manifest left-right symmetry. See [16] for some variations in the limits if the assumption of left-right symmetry is relaxed.

•Alternative models: W' gauge bosons can also arise in other models. We shall briefly mention some such popular models, but for details we refer the reader to the original literature. The alternate left-right model [18] is based on the same gauge group as the left-right model, but arises in the following way: In E_6 unification, there is an option to identify the righthanded down quarks as $SU(2)_R$ singlets or doublets. If they are $SU(2)_R$ doublets, one recovers the conventional left-right model; if they are singlets it leads to the alternate left-right model. A similar ambiguity exists in the assignment of lefthanded leptons; the alternate left-right model assigns them to a (1,2,2,0) multiplet. As a consequence, the ordinary neutrino remains exactly massless in the model. One important difference from the usual left-right model is that the limit from the K_L - K_S mass difference is no longer applicable, since the d_R do not couple to the W_R . There is also no limit from polarized μ decay, since the $SU(2)_R$ partner of e_R can receive a large Majorana mass. Other W' models include the un-unified Standard Model of Ref. 19 where there are two different SU(2) gauge groups,

one each for the quarks and leptons; models with separate SU(2) gauge factors for each generation [20]; and the SU(3)_C \times $SU(3)_L \times U(1)$ model of Ref. 21.

Leptoquark gauge bosons: The $SU(3)_C \times U(1)_{B-L}$ part of the gauge symmetry discussed above can be embedded into a simple $SU(4)_C$ gauge group [22]. The model then will contain leptoquark gauge boson as well, with couplings of the type $\{(\overline{e}_L\gamma_\mu d_L + \overline{\nu}_L\gamma_\mu u_L)W'^\mu + (L \to R)\}$. The best limit on such leptoquark W' comes from nonobservation of $K_L \to \mu e$, which requires $M_{W'} \geq 1400$ TeV; for the corresponding limits on less conventional leptoquark flavor structures, see Ref. 23. Thus such a W' is inaccessible to direct searches with present machines which are sensitive to vector leptoquark masses of order 300 GeV only.

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MASS LIMITS for W' (A Heavy-Charged Vector Boson Other Than W) in Hadron Collider Experiments

Couplings of W' to quarks and leptons are taken to be identical with those of W. The following limits are obtained from $p\bar{p} \to W'X$ with W' decaying to the mode indicated in the comments. New decay channels $(e.g., W' \to WZ)$ are assumed to be suppressed. UA1 and UA2 experiments assume that the $t\,\overline{b}$ channel is not open.

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>720	95	²⁶ ABACHI 96	c D0	$W' \rightarrow e \nu_e$
• • • We do not use the	following	ig data for averages, fl	ts, limits,	etc. • • •
none 300-420	95	²⁷ ABE 97	G CDF	$W' \rightarrow q \overline{q}$
>610	95	²⁸ ABACHI 95	E D0	$W' \rightarrow e \nu_e$ and $W' \rightarrow$
				$\tau \nu_{\tau} \rightarrow e \nu \overline{\nu}$
>652	95		M CDF	$W' \rightarrow e \nu_e$
>251	90	30 ALITTI 93	UA2	$W' \rightarrow q \overline{q}$
none 260-600	95	31 RIZZO 93	RVUE	$W' \rightarrow q \overline{q}$
>520	95		F CDF	$W' \rightarrow e \nu, \mu \nu$
none 101-158	90		UA2	$W' \rightarrow q \overline{q}$
>220	90		UA1	$W' \rightarrow e \nu$
>209	90		D UA2	$W' \rightarrow e \nu$
>210	90		B UA1	$W' \rightarrow e \nu$
>170	90	37 ARNISON 83	D UA1	$W' \rightarrow e \nu$

- 26 For bounds on W_R with nonzero right-handed mass, see Fig. 5 from ABACHI 96C.
- 27 ABE 97G search for new particle decaying to dijets.
- ²⁸ ABACHI 95E assume that the decay $W' \rightarrow WZ$ is suppressed and that the neutrino from W' decay is stable and has a mass significantly less $m_{W'}$.
- 29 ABE 95M assume that the decay $W'\to WZ$ is suppressed and the (right-handed) neutrino is light, noninteracting, and stable. If $m_{\nu}{=}60$ GeV, for example, the effect on the mass limit is neglibible.
- 30 ALITTI 93 search for resonances in the two-jet invariant mass. The limit assumes $\Gamma(W')/m_{W'} = \Gamma(W)/m_W$ and $B(W' \rightarrow JJ) = 2/3$. This corresponds to W_R with $m_{\nu_R} > m_{W_R}$ (no leptonic decay) and $W_R \to t \, \overline{b}$ allowed. See their Fig. 4 for limits in the $m_{W'} - \hat{B}(q\overline{q})$ plane.
- 31 RIZZO 93 analyses CDF limit on possible two-jet resonances. The limit is sensitive to
- the inclusion of the assumed K factor.

 32 ABE 91F assume leptonic branching ratio of 1/12 for each lepton flavor. The limit from the $e\nu$ ($\mu\nu$) mode alone is 490 (435) GeV. These limits apply to W_R if $m_{\nu_R}\lesssim 15$ GeV and ν_R does not decay in the detector. Cross section limit $\sigma\cdot {\rm B}<(1$ –10) pb is given for $m_{W'}=100$ –550 GeV; see Fig. 2.
- 33 ALITTI 91 search is based on two-jet invariant mass spectrum, assuming B($W' \to q \overline{q}$) = 67.6%. Limit on σ · B as a function of two-jet mass is given in Fig. 7.
- 34 ALBAJAR 89 cross section limit at 630 GeV is $\sigma(W')$ B(e ν) < 4.1 pb (90% CL). 35 See Fig. 5 of ANSARI 87D for the excluded region in the $m_{W'}^{-}[(g_{W'q})^2 \; {\rm B}(W' \to W')]$ $e\overline{\nu}$)] plane. Note that the quantity $(g_{W'g})^2$ B($W' \rightarrow e\overline{\nu}$) is normalized to unity for
- the standard W couplings.
- the standard w couplings.

 36 ARNISON 868 find no excess at large p_T in 148 $W \rightarrow e \nu$ events. Set limit $\sigma \times B(e \nu)$ <10 pb at CL = 90% at $E_{\rm CM}$ = 546 and 630 GeV.

 37 ARNISON 830 find among 47 $W \rightarrow e \nu$ candidates no event with excess p_T . Also set $\sigma \times B(e \nu)$ <30 pb with CL = 90% at $E_{\rm CM}$ = 540 GeV.

THE Z' SEARCHES

Written October 1997 by K.S. Babu, C. Kolda, and J. March-Russell (IAS/Princeton).

If the Standard Model is enhanced by additional gauge symmetries or embedded into a larger gauge group, there will arise new heavy gauge bosons, some of which generically are electrically neutral. Such a gauge boson is called a Z'. Consider the most general renormalizable Lagrangian describing the complete set of interactions of the neutral gauge bosons among themselves and with fermions, which is that of the Standard Model plus the following new pieces [1,2,3]:

$$\begin{split} \mathcal{L}_{Z'} &= -\frac{1}{4} \widehat{F}'_{\mu\nu} \widehat{F}'^{\mu\nu} - \frac{\sin \chi}{2} \widehat{F}'_{\mu\nu} \widehat{F}^{\mu\nu} + \frac{1}{2} \widehat{M}_{Z'}^2 \widehat{Z}'_{\mu} \widehat{Z}'^{\mu} \\ &+ \delta \widehat{M}^2 \, \widehat{Z}'_{\mu} \widehat{Z}^{\mu} - \frac{\widehat{g}'}{2} \sum_{i} \overline{\psi}_{i} \gamma^{\mu} (f_{V}^{i} - f_{A}^{i} \gamma^{5}) \psi_{i} \widehat{Z}'_{\mu} \end{split} \tag{1}$$

where $\widehat{F}_{\mu\nu}, \widehat{F}'_{\mu\nu}$ are the field strength tensors for the hypercharge \hat{B}_{μ} gauge boson and the Z' respectively before any diagonalizations are performed, ψ_i are the matter fields with Z'vector and axial charges f_V^i and f_A^i , and \widehat{Z}_μ is the electroweak Z boson in this basis. (See the Review on "Electroweak Model and Constraints on New Physics" for the Standard Model pieces of the Lagrangian.) The mass terms are assumed to come from spontaneous symmetry breaking via scalar expectation values. The above Lagrangian is general to all abelian and non-abelian extensions, except that $\chi = 0$ for the non-abelian case since then $\widehat{F}'_{\mu\nu}$ is not gauge invariant. Most analyses take $\chi=0$ even for the abelian case.

Going to the physical eigenbasis requires diagonalizing both the gauge kinetic and mass terms, with mass eigenstates denoted Z_1 and Z_2 , where we choose Z_1 to be the observed Z boson. The interaction Lagrangian for Z_1 has the form, to leading order in the mixing angle ξ ($s_W \equiv \sin \theta_W$, etc.):

$$\mathcal{L}_{Z_{1}} = -\frac{e}{2s_{W}c_{W}} \left(1 + \frac{\alpha T}{2} \right) \overline{\psi}_{i} \gamma^{\mu} \left\{ \left(g_{V}^{i} + \xi \tilde{f}_{V}^{i} \right) - \left(g_{A}^{i} + \xi \tilde{f}_{A}^{i} \right) \gamma^{5} \right\} \psi_{i} Z_{1\mu}$$

$$(2)$$

where

$$\xi \simeq \frac{-\cos \chi (\delta \widehat{M}^2 + \widehat{M}_Z^2 s_W \sin \chi)}{\widehat{M}_{Z'}^2 - \widehat{M}_Z^2 \cos^2 \chi + \widehat{M}_Z^2 s_W^2 \sin^2 \chi + 2 \delta \widehat{M}^2 s_W \sin \chi} . \quad (3)$$

We have made the identifications $g_A^i = T_3^i$, $g_V^i = T_3^i - 2Q^i s_*^2$, $\tilde{f}^i_{V,A} = (\widehat{g}' s_W c_W / e \cos \chi) f^i_{V,A}, \text{ and } s^2_W \text{ is identified to be the}$ $s_{M_Z}^2$ defined in the "Electroweak Model and Constraints on New Physics" review. Note that the value of the weak angle that appears in the vector coupling is shifted by the S and Toblique parameters:

$$s_*^2 = s_W^2 + \frac{1}{s_W^2 - c_W^2} \left(\frac{1}{4} \alpha S - c_W^2 s_W^2 \alpha T \right) . \tag{4}$$

Recall that $\rho = 1 + \alpha T$ defines the usual ρ parameter. In the presence of Z-Z' mixing, the oblique parameters receive contributions [4]:

$$\alpha S = 4\xi c_W^2 s_W \tan \chi$$

$$\alpha T = \xi^2 \left(\frac{M_{Z_2}^2}{M_{Z_1}^2} - 1 \right) + 2\xi s_W \tan \chi$$

$$\alpha U = 0$$
(5)

to leading order in small ξ . These contributions are in addition to those coming from top quark and Higgs boson loops in the Standard Model. (This is in contrast to the "Electroweak

Model and Constraints on New Physics" Review in which oblique parameters are defined to be zeró for reference values of m_t and M_H .) Note that nonzero Z-Z' contributions to S arise only in the presence of kinetic mixing.

The corresponding $Z_2\overline{\psi}\psi$ interaction Lagrangian is:

$$\mathcal{L}_{Z_2} = -\frac{e}{2s_W c_W} \overline{\psi}_i \gamma^{\mu} \left\{ \left(h_V^i - g_V^i \xi \right) - \left(h_A^i - g_A^i \xi \right) \gamma^5 \right\} \psi_i Z_{2\mu}$$
(6)

with the following definitions:

$$\begin{split} h_V^i &= \tilde{f}_V^i + \widetilde{s}(T_3^i - 2Q^i) \tan \chi \\ h_A^i &= \tilde{f}_A^i + \widetilde{s}T_3^i \tan \chi \\ \widetilde{s} &= s_W + \frac{s_W^3}{c_W^2 - s_W^2} \left(\frac{1}{4c_W^2} \alpha S - \frac{1}{2} \alpha T\right) \end{split} \tag{7}$$

where the last equation defines a weak angle appropriate for the \mathbb{Z}_2 interactions.

If the Z' charges are generation-dependent, there exist severe constraints in the first two generations coming from precision measurements such as the K_L - K_S mass splitting and $B(\mu \to 3e)$ owing to the lack of GIM suppression in the Z' interactions; however, constraints on a Z' which couples differently only to the third generation are somewhat weaker. (It will be assumed in the Z-pole constraint section that the Z' couples identically to all three generations of matter; all other results are general.) If the new Z' interactions commute with the Standard Model gauge group, then per generation, there are only five independent $Z'\bar{\psi}\psi$ couplings; we can choose them to be \tilde{f}_V^u , \tilde{f}_A^u , \tilde{f}_V^d , \tilde{f}_V^e , and \tilde{f}_A^e . All other couplings can be determined in terms of these, e.g., $\tilde{f}_V^v = (\tilde{f}_V^e + \tilde{f}_A^e)/2$.

Canonical models: One of the prime motivations for an additional Z' has come from string theory in which certain compactifications lead naturally to an E_6 gauge group, or one of its subgroups. E_6 contains two U(1) factors beyond the Standard Model, a basis for which is formed by the two groups U(1) χ and U(1) $_{\psi}$, defined via the decompositions $E_6 \to SO(10) \times U(1)_{\psi}$ and $SO(10) \to SU(5) \times U(1)_{\chi}$; one special case often encountered is U(1) $_{\eta}$ where $Z_{\eta} = \sqrt{\frac{3}{8}}Z_{\chi} + \sqrt{\frac{5}{8}}Z_{\psi}$. The charges of the SM fermions under these U(1)'s, and a discussion of their experimental signals, can be found in Ref. 5.

It is also common to express experimental bounds in terms of a toy Z' usually denoted $Z_{\rm SM}$. This $Z_{\rm SM}$, of arbitrary mass, couples to the SM fermions identically to the usual Z.

Almost all analyses of Z' physics have worked with one of these canonical models and have assumed zero kinetic mixing at the weak scale.

Experimental constraints: There are three primary sets of constraints on the existence of a Z' which will be considered here: precision measurements of neutral-current processes at low energies, Z-pole constraints on Z-Z' mixing, and direct search constraints from production at very high energies. In principle, one usually expects other new states to appear at the same scale as the Z', including its symmetry-breaking sector

and any additional fermions necessary for anomaly cancellation. However, because these states are highly model-dependent, we will not include searches for them, or Z^\prime decays to them, in the bounds that follow.

Low-energy constraints: After the breaking of the new gauge group and the usual electroweak breaking, the Z of the Standard Model can mix with the Z', with mixing angle ξ defined above. As already discussed, this Z-Z' mixing implies a shift in the usual oblique parameters [S,T,U] defined in Eq. (5). Current bounds on S and T translate into stringent constraints on the mixing angle, ξ , requiring $\xi \ll 1$; similar constraints on ξ arise from the LEP Z-pole data. Thus we will only consider the small- ξ limit henceforth.

Whether or not the new gauge interactions are parity violating, stringent constraints can arise from atomic parity violation (APV) and polarized electron-nucleon scattering experiments [6]. At low energies, the effective neutral-current Lagrangian is conventionally written:

$$\mathcal{L}_{\text{NC}} = \frac{G_F}{\sqrt{2}} \sum_{q=u,d} \left\{ C_{1q} (\bar{e} \gamma_\mu \gamma^5 e) (\bar{q} \gamma^\mu q) + C_{2q} (\bar{e} \gamma_\mu e) (\bar{q} \gamma^\mu \gamma^5 q) \right\} . \tag{8}$$

APV experiments are sensitive only to C_{1u} and C_{1d} (see the "Electroweak Model and Constraints on New Physics" Review for the nuclear weak charge, Q_W , in terms of the C_{1q}) where in the presence of the Z and Z':

$$C_{1q} = 2(1 + \alpha T)(g_A^e + \xi \tilde{f}_A^e)(g_V^q + \xi \tilde{f}_V^q) + 2r(h_A^e - \xi g_A^e)(h_V^q - \xi g_V^q)$$
(9)

where $r=(M_{Z_1}/M_{Z_2})^2$. The r-dependent terms arise from Z_2 exchange and can interfere constructively or destructively with the Z_1 contribution. In the limit $\xi=r=0$, this reduces to the Standard Model expression. Polarized electron scattering is sensitive to both the C_{1q} and C_{2q} couplings, again as discussed in the "Electroweak Model and Constraints on New Physics" Review. The C_{2q} can be derived from the expression for C_{1q} with the complete interchange $V \leftrightarrow A$.

Stringent limits also arise from neutrino-hadron scattering. One usually expresses experimental results in terms of the effective 4-fermion operators $(\overline{\nu}\gamma_{\mu}\nu)(\overline{q}_{L,R}\gamma^{\mu}q_{L,R})$ with coefficients $(2\sqrt{2}G_F)\epsilon_{L,R}(q)$. (Again, see the "Electroweak Model and Constraints on New Physics" Review.) In the presence of the Z and Z', the $\epsilon_{L,R}(q)$ are given by:

$$\begin{split} \epsilon_{L,R}(q) = & \frac{1 + \alpha T}{2} \left\{ (g_V^q \pm g_A^q) [1 + \xi (\tilde{f}_V^\nu \pm \tilde{f}_A^\nu)] + \xi (\tilde{f}_V^q \pm \tilde{f}_A^q) \right\} \\ & + \frac{r}{2} \left\{ (h_V^q \pm h_A^q) (h_V^\nu \pm h_A^\nu) - \xi (g_V^q \pm g_A^q) (h_V^\nu \pm h_A^\nu) - \xi (h_V^q \pm h_A^q) \right\} \; . \end{split}$$

$$(10)$$

Again, the r-dependent terms arise from Z_2 -exchange.

Z-pole constraints: Electroweak measurements made at LEP and SLC while sitting on the Z resonance are generally sensitive to Z' physics only through the mixing with the Z unless the Z and Z' are very nearly degenerate, a possibility we ignore.

Constraints on the allowed mixing angle and Z couplings arise by fitting all data simultaneously to the ansatz of Z-Z' mixing. For any observable, \mathcal{O} , the shift in that observable, $\Delta \mathcal{O}$, can be expressed (following the procedure of Ref. 7) as:

$$\frac{\Delta \mathcal{O}}{\mathcal{O}} = \mathcal{A}_{\mathcal{O}}^{S} \alpha S + \mathcal{A}_{\mathcal{O}}^{T} \alpha T + \xi \sum_{i} \mathcal{B}_{\mathcal{O}}^{(i)} \tilde{f}^{i}$$
 (11)

where i runs over the 5 independent $Z'\overline{\psi}\psi$ couplings listed earlier (assuming a Z' couplings commute with the generation and gauge symmetries of the Standard Model; this is the only place where we enforce such a restriction). The coefficients $\mathcal{A}_{\mathcal{O}}^{S,T}$ and $\mathcal{B}_{\mathcal{O}}^{(i)}$, which are functions only of the Standard Model parameters, are given in Table 1. The first 5 observables are directly measured at LEP and SLC, while \overline{A}_e , \overline{A}_b and \overline{A}_c are measured via the asymmetries $\overline{A}_{FB}^{(0,f)} = \frac{3}{4}\overline{A}_e\overline{A}_f$ and $A_{LR}^0 = \overline{A}_e$ as defined in the "Electroweak Model and Constraints on New Physics" Review. As an example, the shift in \overline{A}_e due to Z' physics is given by

$$\frac{\Delta \overline{A}_e}{\overline{A}_e} = -24.9 \,\alpha S + 17.7 \,\alpha T - 26.7 \,\xi \,\tilde{f}_V^e + 2.0 \,\xi \,\tilde{f}_A^e \ . \tag{12}$$

Table 1: Expansion coefficients for shifts in Z-pole observables normalized to the Standard Model value of the observable [7,3].

O	$\mathcal{A}_{\mathcal{O}}^{S}$	$\mathcal{A}_{\mathcal{O}}^{T}$	$\mathcal{B}^{Vu}_{\mathcal{O}}$	$\mathcal{B}^{Au}_{\mathcal{O}}$	$\mathcal{B}^{Vd}_{\mathcal{O}}$	$\mathcal{B}^{Ve}_{\mathcal{O}}$	$\mathcal{B}^{Ae}_{\mathcal{O}}$
Γ_Z	-0.49	1.35	-0.89	-0.40	0.37	0.37	0
$R_{\boldsymbol{\ell}}$	-0.39	0.28	-1.3	-0.56	0.52	0.30	4.0
σ_h	0.046	-0.033	0.50	0.22	-0.21	-1.0	-4.0
R_b	0.085	-0.061	-1.4	-2.1	0.29	0	0
R_c	-0.16	0.12	2.7	4.1	-0.59	0	0
\overline{A}_e	-24.9	17.7	0	0	0	-26.7	2.0
\overline{A}_b	-0.32	0.23	0.71	0.71	-1.73	0	0
\overline{A}_c	-2.42	1.72	3.89	-1.49	0	0	0
M_W^2	-0.93	1.43	0	0	0	0	0

High-energy indirect constraints: At $\sqrt{s} < M_{Z_2}$, but off the Z_1 pole, strong constraints on new Z' physics arise from measurements of deviations of asymmetries and leptonic and hadronic cross sections from their Standard Model predictions. These processes are sensitive not only to Z-Z' mixing but also to direct Z_2 exchange primarily through $\gamma-Z_2$ and Z_1-Z_2 interference; therefore information on the Z_2 couplings and mass can be extracted that is not accessible via Z-Z' mixing alone.

Far below the Z_2 mass scale, experiment is only sensitive to the scaled Z_2 couplings $(\sqrt{s}/M_{Z_2}) \cdot h_{V,A}^i$ so the Z_2 mass and overall magnitude of the couplings cannot both be extracted. However as \sqrt{s} approaches M_{Z_2} the Z_2 exchange can no longer be approximated by a contact interaction and the mass and couplings can be simultaneously extracted.

Z' studies done before LEP relied heavily on this approach; see, e.g., Ref. 8. LEP has also done similar work using data

collected above the Z peak; see, e.g., Ref. 9. For indirect Z' searches at future facilities, see, e.g. Refs. 10 and 11.

Direct-search constraints: Finally, high-energy experiments have searched for on-shell Z' (here Z_2) production and decay. Searches can be classified by the initial state off of which the Z' is produced, and the final state into which the Z' decays; we will not include here exotic decays of a Z'. Experiments to date have been sensitive to Z' production via their coupling to quarks $(p\bar{p}$ colliders), to electrons (e^+e^-) or to both (ep).

For a heavy Z' ($M_{Z_2}\gg M_{Z_1}$), the best limits come from $p\overline{p}$ machines via Drell-Yan production and subsequent decay to charged leptons. For $M_{Z_2}>600\,\mathrm{GeV}$, CDF [12] quotes limits on $\sigma(p\overline{p}\to Z_2X)\cdot B(Z_2\to \ell^+\ell^-)<0.04\,\mathrm{pb}$ at 95% C.L. for $\ell=e+\mu$ combined; DØ [13] quotes $\sigma\cdot B<0.025\,\mathrm{pb}$ for $\ell=e$. For $M_{Z_2}<600\,\mathrm{GeV}$, the mass dependence is complicated and one should refer to the original literature. For studies of the search capabilities of future facilities, see e.g. Ref. 10.

If the Z' has suppressed, or no, couplings to leptons (i.e., it is leptophobic) then experimental sensitivities are much weaker. In particular, searches for a Z' via hadronic decays at DØ [14] are able to rule out a Z' with quark couplings identical to those of the Z only in the mass range 365 GeV $< M_{Z_2} < 615$ GeV; CDF [15] cannot exclude even this range. Additionally, UA2 [16] finds $\sigma \cdot B(Z' \to jj) < 11.7$ pb at 90% C.L. for $M_{Z'} > 200$ GeV and more complicated bounds in the range 130 GeV $< M_{Z'} < 200$ GeV.

For a light Z' $(M_{Z'} < M_Z)$ direct searches in e^+e^- colliders have ruled out any Z' unless it has extremely weak couplings to leptons. For a combined analysis of the various pre-LEP experiments see Ref. 8.

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MASS LIMITS for Z' (Heavy Neutral Vector Boson Other Than Z)

Limits for Z_{SM}

Z'_M is assumed to have couplings with quarks and leptons which are identical to those of Z.

VALUE (SAV)

CLIS DOCUMENT ID TECH COMMENT

VALUE (GeV)	<u>CL%</u>	DOCUMENT ID		TECN	COMMENT
>690	95	³⁸ ABE	975	CDF	$p\overline{p}; Z'_{SM} \rightarrow e^+e^-,$
>779		39,40 LANGACKER			μ ⁺ μ ⁻ Electroweak
• • • We do not use t	he follow	ing data for average:	s, fits		
>490	95	ABACHI	96D	D0	$ \rho \overline{\rho}; Z'_{SM} \rightarrow e^+e^- $ $ \rho \overline{\rho}; Z'_{SM} \rightarrow e^+e^- $
>505	95	⁴¹ ABE	95	CDF	$\rho \overline{\rho}; Z_{SM}^{-} \rightarrow e^{+}e^{-}$
>398	95	⁴² VILAIN	94B	CHM2	$\nu_{\mu} e \rightarrow \nu_{\mu} e$ and
					$\bar{\nu}_{\mu}e \rightarrow \bar{\nu}_{\mu}e$
>237	90	43 ALITTI	93	UA2	pp; Z' _{SM} → qq
>119	90	44 ALLEN	93	CALO	νe → νe
none 490-560	95	⁴⁵ RIZZO	93	RVUE	$p\overline{p}; Z'_{SM} \rightarrow q\overline{q}$
>412	95	ABE	92B	CDF	$p\overline{p}; Z'_{SM} \rightarrow e^+e^-,$
					$\mu^+\mu^-$
>387	95	⁴⁶ ABE	91D	CDF	$p\overline{p}; Z'_{SM} \rightarrow e^+e^-$
>307	90	47 GEIREGAT	91	CHM2	
					$\bar{\nu}_{\mu}e \rightarrow \bar{\nu}_{\mu}e$
>426	90	⁴⁸ ABE	90F	VNS	e+e-
>208	90	⁴⁹ HAGIWARA	90	RVUE	e+ e-
>173	90	⁵⁰ ALBAJAR	89	UA1	$p\overline{p}$; $Z'_{SM} \rightarrow e^+e^-$
>180	90	⁵¹ ANSARI	87 D	UA2	$p\overline{p}; Z'_{SM} \rightarrow e^+e^-$ $p\overline{p}; Z'_{SM} \rightarrow e^+e^-$ $p\overline{p}; Z'_{SM} \rightarrow e^+e^-$
>160	90	⁵² ARNISON	86B	UA1	$p\bar{p}$; $Z_{SM}^{r} \rightarrow e^{+}e^{-}$

 38 ABE 97s limit is obtained assuming that Z' decays to known fermions only.

³⁹ LANGACKER 92B fit to a wide range of electroweak data including LEP results available early '91. $m_t >$ 89 GeV used.

 40 LANGACKER 92B give 95%CL limits on the Z-Z' mixing $-0.0086 < \theta < 0.0005$.

41 ABE 95 limit is obtained assuming that Z^\prime decays to known fermions only.

 42 VILAIN 94B assume $m_t=150$ GeV.

 43 ALITTI 93 search for resonances in the two-jet invariant mass. The limit assumes B($Z^{\prime}
ightarrow q\overline{q}$)=0.7. See their Fig. 5 for ilmits in the $m_{Z^{\prime}}$ -B($q\overline{q}$) plane.

⁴⁴ ALLEN 93 limit is from total cross section for $\nu e \rightarrow \nu e$, where $\nu = \nu_e$, ν_μ , $\overline{\nu}_\mu$.

 $^{
m 45}\,{\rm RIZZO}$ 93 analyses CDF limit on possible two-jet resonances. The limit is sensitive to

the inclusion of the assumed K factor. ^46 ABE 910 give $\sigma(Z')$ B(e⁺ e⁻) < 1.31 pb (95%CL) for $m_{Z'}>$ 200 GeV at $E_{\rm CM}=1.8$ TeV. Limits ranging from 2 to 30 pb are given for $m_{Z'} = 100-200$ GeV.

⁴⁷GEIREGAT 91 limit is from comparison of g_V^e from $\nu_\mu e$ scattering with $\Gamma(Z
ightharpoonup ee)$ from LEP. Zero mixing assumed.

⁴⁸ ABE 90F use data for R, $R_{\ell\ell}$, and $A_{\ell\ell}$. They fix $m_W=80.49\pm0.43\pm0.24$ GeV and $m_7 = 91.13 \pm 0.03 \text{ GeV}.$

 49 HAGIWARA 90 perform a fit to e^+e^- data at PEP, PETRA, and TRISTAN including

 $\mu^+\mu^-$, $au^+ au^-$, and hadron cross sections and asymmetries. ⁵⁰ ALBAJAR 89 cross section limit at 630 GeV is $\sigma(Z')$ B(ee) < 4.2 pb (90% CL).

⁵¹ See Fig. 5 of ANSARI 87D for the excluded region in the $m_{Z^{\prime}}$ [$(g_{Z^{\prime}g})^2$ B(Z^{\prime} \rightarrow $e^+e^-)]$ plane. Note that the quantity $(g_{Z'q})^2$ B $(Z' \rightarrow e^+e^-)$ is normalized to unity for the standard Z couplings.

 52 ARNISON 86B find no excess e^+e^- pairs among 13 pairs from Z. Set limit $\sigma \times B(e^+e^-)$ <13 pb at CL = 90% at $E_{\rm cm}$ = 546 and 630 GeV.

Limits for Z_{LR} Z_{LR} is the extra neutral boson in left-right symmetric models. $g_L = g_R$ is assumed unless noted. Values in parentheses assume stronger constraint on the Higgs sector, usually motivated by superstring models. Values in brackets are from cosmological and astrophysical considerations and assume a light right-handed neutrino.

VALUE (GeV)	CL%	DOCUMENT ID TECN COMMENT
>630	95	53 ABE 97S CDF $p\overline{p}$; $Z'_{LR} \rightarrow e^+e^-$, $\mu^+\mu^-$
>389	95 5	4,55 LANGACKER 92B RVUE Electroweak
• • • We do not us	e the foll	owing data for averages, fits, limits, etc. • • •
>190	95	⁵⁶ BARATE 97B ALEP $e^+e^- \rightarrow \mu^+\mu^-$ and hadronic cross section
>445	95	⁵⁷ ABE 95 CDF $p\bar{p}$; $Z'_{1P} \rightarrow e^+e^-$
>253	95	58 VILAIN 94B CHM2 $\nu_{\mu}e \xrightarrow{\nu_{\mu}} \nu_{\mu}e$ and $\overline{\nu}_{\mu}e $
>130	95	⁵⁹ ADRIANI 930 L3 Z parameters
(> 1500)	90	60 ALTARELLI 93B RVUE Z parameters
none 490-560	95	⁶¹ RIZZO 93 RVUE $\rho \overline{\rho}$; $Z_{IR} \rightarrow q \overline{q}$
>310	95	62 ABE 92B CDF PP
>230	95	63 ABE 92B CDF ρ p
(> 900)	90	64 DELAGUILA 92 RVUE
(> 1400)		65 LAYSSAC 928 RVUE Z parameters
(> 564)	90	66 POLAK 92 RVUE 4 decay
>474	90	67 POLAK 92B RVUE Electroweak
(> 1340)		68 RENTON 92 RVUE
(> 800)	90	69 ALTARELLI 918 RVUE Z parameters
(> 795)	90	⁷⁰ DELAGUILA 91 RVUE
>382	90	71 POLAK 91 RVUE Electroweak
[> 2000]		WALKER 91 COSM Nucleosynthesis; light ν_R
[> 500]		72 GRIFOLS 90 ASTR SN 1987A; light ν_R
(> 460)	90	73 HE 90B RVUE
[> 2400-6800]		74 BARBIERI 898 ASTR SN 1987A; light ν_R
>189		75 DELAGUILA 89 RVUE PP
[> 10000]		RAFFELT 88 ASTR SN 1987A; light vR
>325	90	76 AMALDI 87 RVUE
>278	90	77 DURKIN 86 RVUE
>150	95	⁷⁸ ADEVA 85B MRKJ $e^+e^- \rightarrow \mu^+\mu^-$

 53 ABE 97s limit is obtained assuming that Z' decays to known fermions only. 54 LANGACKER 92B fit to a wide range of electroweak data including LEP results available

early '91. $m_t > 89$ GeV used.

 55 LANGACKER 92B give 95%CL limits on the Z-Z' mixing -0.0025 $< \theta < 0.0083$. 56 BARATE 97B gives 95% CL limits on Z-Z' mixing $-0.0017 < \theta < 0.0035$. The bounds are computed with $\alpha_s=0.120\pm0.003$, $m_t=175\pm6$ GeV, and $M_H=150^{+120}_{-90}$ GeV. See their Fig. 4 for the limit contour in the mass-mixing plane.

 57 ABE 95 limit is obtained assuming that Z^\prime decays to known fermions only. See their Fig. 3 for the mass bound of Z^\prime decaying to all allowed fermions and supersymmetric

58 VILAIN 94B assume $m_{
m f}=$ 150 GeV and $\theta=$ 0. See Fig. 2 for limit contours in the

mass-mixing plane. See rig. 2 for limit contours in the mass-mixing plane. So ADRIANI 93D give limits on the Z-Z' mixing $-0.002 < \theta < 0.015$ assuming the ABE 92B mass limit. So The LEP data available in summer '93 and is for $m_{\tilde{t}} = 110$

GeV. $m_H=$ 100 GeV and $lpha_{\it S}=$ 0.118 assumed. The limit improves for larger m_t (see their Fig. 5). The 90%CL limit on the Z- Z^\prime mixing angle is in Table 4.

61 RIZZO 93 analyses CDF limit on possible two-jet resonances. The limit is sensitive to the inclusion of the assumed K factor.
62 These limits assume that Z' decays to known fermions only.

 63 These limits assume that Z' decays to all E_6 fermions and their superpartners.

⁶⁴ See Fig. 7b and 8 in DELAGUILA 92 for the allowed region in $m_{Z^{\prime}}$ -mixing plane and $m_{Z'} - m_t$ plane from electroweak fit including '90 LEP data.

65 LAYSSAC 928 limit is from LEP data available spring '92. Specific Higgs sector is

assumed. See also LAYSSAC 92. 66 POLAK 92 limit is from m_{W_R} >477 GeV, which is derived from muon decay parameters assuming light ν_R . Specific Higgs sector is assumed.

⁶⁷ POLAK 928 limit is from a simultaneous fit to charged and neutral sector in $SU(2)_L \times SU(2)_R \times U(1)$ model using Z parameters, m_W , and low-energy neutral current data as of 1991. Light ν_R assumed and $m_t = m_H = 100$ GeV used. Supersedes

POLAK 91.

68 RENTON 92 limits use LEP data taken up to '90 as well as m_W , νN , and atomic parity violation data. Specific Higgs structure is assumed.

69 ALTARELLI 918 is based on Z mass, widths, and A_{FB} . The limits are for superstring motivated models with extra assumption on the Higgs sector. $m_t > 90$ GeV and $m_{H^0} < 1$ TeV assumed. For large m_t , the bound improves drastically. Bounds for Z-Z' mixing angle and Z mass shift without this model assumption are also given in the

70 DELAGUILA 91 bounds have extra assumption of superstring motivated Higgs sector. From ν N neutral current data with $m_Z=91.10\pm0.04$ GeV, $m_t>77$ GeV, $m_{H^0}<1$

From νN neutral current data with $m_Z = 2$. TeV assumed. 71 POLAK 91 limit is from a simultaneous fit to charged and neutral sector in SU(2)_L×SU(2)_R×U(1) model using m_W , m_Z , and low-energy neutral current data as of 1990. Light ν_R assumed and $m_t = m_H = 100$ GeV used. Superseded by POLAK 928. 72 GRIFOLS 90 limit holds for $m_{\nu_R} \lesssim 1$ MeV. See also GRIFOLS 90D, RIZZO 91. 73 HE 90B model assumes a specific Higgs sector. Neutral current data of COSTA 88 as well as m_Z is used. g_R is left free in the fit. 74 BARBIERI 89B limit holds for $m_{\nu_R} \leq 10$ MeV. 75 DCLACIULA 90 limit is based on $\sigma(n_D \to Z')$ B($Z' \to e^+e^-$) < 1.8 pb at CERN p_D

⁷⁵ DELAGUILA 89 limit is based on $\sigma(p\bar{p}\to Z')$ ·B($Z'\to e^+e^-$) < 1.8 pb at CERN $p\bar{p}$ collider. 76 A wide range of neutral current data as of 1986 are used in the fit.

77 A wide range of neutral current data as of 1985 are used in the fit.

 78 ADEVA 858 measure asymmetry of μ -pair production, following formalism of RIZZO 81.

Gauge & Higgs Boson Particle Listings

Heavy Bosons Other than Higgs Bosons

Limits for Z_χ Z_χ is the extra neutral boson in SO(10) \to SU(5) \times U(1) χ . $g_\chi = e/\cos^2 W$ is assumed unless otherwise stated. We list limits with the assumption $\rho = 1$ but with no further constraints on the Higgs sector. Values in parentheses assume stronger constraint on the Higgs sector motivated by superstring models. Values in brackets are from cosmological and astrophysical considerations and assume a light right-handed neutrino. VALUE (GeV) CL% DOCUMENT ID TECN COMMENT

VALUE (GeV)	<u>CL%</u>		DOCUMENT ID		TECN	COMMENT
>595	95	79	ABE	97s	CDF	$p\overline{p}$; $Z_{\chi}' \rightarrow e^+e^-$, $\mu^+\mu^-$
>321	95 8	0,81	LANGACKER	92B	RVUE	Electroweak
• • • We do not use	the folk	owin	g data for avera	ges,	fits, lim	its, etc. • • •
>190	95		ARIMA	97	VNS	Bhabha scattering
>236	95	83	BARATE	97B	ALEP	$e^+e^- ightarrow \mu^+\mu^-$ and
>196	95	84	BUSKULIC	96N	ALEP	hadronic cross section Hadronic cross section
>425	95		ABE		CDF	$p\overline{p}$; $Z'_{\chi} \rightarrow e^+e^-$
>147	95		ABREU		DLPH	Z parameters and
	,,		7.5.1.20	,,,,,	02. 11	$e^+e^- \rightarrow \mu^+\mu^-(n\gamma)$
		87	NARDI	95	RVUE	Z parameters
		88	BUSKULIC	94	ALEP	Z parameters
>262	95	89	VILAIN	94B	CHM2	$ u_{\mu} e ightarrow u_{\mu} e \text{and} \overline{ u}_{\mu} e ightarrow$
		-				v_{μ} e
>117	95	90	ADRIANI	93D		Z parameters
(>900)	90	47	ALTARELLI ABE		RVUE	Z parameters
>340	95		ABE		CDF	P P
>280	95				CDF	₽₽
(>650) (>760)	90	95	DELAGUILA LAYSSAC		RVUE	7
>148	95	96	LEIKE	92B		Z parameters Z parameters
(>700)	73		RENTON	92	RVUE	2 parameters
(> 500)	90	98	ALTARELLI		RVUE	Z parameters
(> 570)	,0	99	BUCHMUEL			Z parameters
(> 555)	90		DELAGUILA		RVUE	_ •
[>1470]		101	FARAGGI	91	соѕм	Nucleosynthesis; light ν_R
>320	90		GONZALEZ-G.	.91	RVUE	
>221		103	MAHANTHAP.	.91	RVUE	Cs
>231	90 104	,105	ABE	90F	VNS	e+ e-
>206	90 105			9 0F	RVUE	e^+e^- , $\nu_{\mu}e$
>335		107	BARGER	908	RVUE	PP̈́
(> 650)	90	108	GLASHOW	90		
[> 1140]		109	GONZALEZ-G.	. 90 D	COSM	Nucleosynthesis; light ν_R
[> 2100]			GRIFOLS	90	ASTR	SN 1987A; light ν_R
none <150 or > 363	90	111	HAGIWARA	90	RVUE	e+ e-
>177		112	DELAGUILA	89	RVUE	₽₽
>280	95	113	DORENBOS		CHRM	$g_{\chi} = g_{Z}$
>352	90	114	COSTA	88	RVUE	
>170	90	115	ELLIS	88		₽Ē
>273	90	116	AMALDI	87	RVUE	
>266	90	117	MARCIANO	87	RVUE	
>283	90	***	DURKIN	86	RVUE	

- $79\,\mathrm{ABE}$ 975 limit is obtained assuming that Z' decays to known fermions only.
- 80 LANGACKER 928 flt to a wide range of electroweak data including LEP results available early '91. m, >89 GeV used.
- 81 LANGACKER 92B give 95%CL limits on the Z-Z' mixing $-0.0048~<~\theta<~0.0097$.
- $^{82}Z Z'$ mixing is assumed to be zero.
- 83 BARATE 978 gives 95% CL limits on Z-Z' mixing $-0.0016 < \theta < 0.0036$. The bounds are computed with $\alpha_s=0.120\pm0.003$, $m_t=175\pm6$ GeV, and $M_H=150^{+120}_{-90}$ GeV. See their Fig. 4 for the limit contour in the mass-mixing plane.
- 84 BUSKULIC 96N limit is from a combined fit to the hadronic cross sections measured at √s=130, 136 GeV (ALEPH) and √s=58 GeV (TOPAZ). Zero mixing is assumed.
- 85 ABE 95 limit is obtained assuming that Z^\prime decays to known fermions only. See their Fig. 3 for the mass bound of Z' decaying to all allowed fermions and supersymmetric
- fermions. 86 ABREU 95M limit is for α_s =0.123, m_t =150 GeV, and m_H =300 GeV. For the limit contour in the mass-mixing plane, see their Fig. 13.
- 87 NARDI 95 give 90%CL ilmits on $\it Z$ -Z $^{\prime}$ mixing $-0.0032 < \theta < 0.0031$ for $M_{Z^{\prime}} >$ 500 GeV, m_t =170 GeV, m_H =250 GeV, α_s =0.12. The bound is relaxed under the simultaneous presence of the mixing of the known fermions with new heavy states, $-0.0032 < \theta <$
- ⁸⁸ BUSKULIC 94 give 95%CL limits on the Z-Z' mixing $-0.0091 < \theta < 0.0023$.
- 89 VILAIN 948 assume $m_t=150$ GeV and $\theta=0$. See Fig. 2 for limit contours in the mass-mixing plane.
- 90 ADRIANI 93D give limits on the Z-Z' mixing $-0.004~<~\theta~<~0.015$ assuming the ABE 928 mass limit.
- 91 ALTARELLI 93B limit is from LEP data available in summer '93 and is for $m_{\tilde{t}}=110$ GeV. $m_H=100$ GeV and $\alpha_S=0.118$ assumed. The limit improves for larger m_t (see their Fig. 5). The 90%CL limit on the Z- Z^\prime mixing angle is in their Fig. 2.
- 92 These limits assume that Z^{\prime} decays to known fermions only.
- 93 These limits assume that Z^\prime decays to all E $_6$ fermions and their superpartners.
- 94 See Fig. 7a and 8 in DELAGUILA 92 for the allowed region in $m_{Z^{\rm I}}$ -mixing plane and $m_{Z'}-m_t$ plane from electroweak fit including '90 LEP data.
- 95 LAYSSAC 928 limit is from LEP data available spring '92. Specific Higgs sector is assumed. See also LAYSSAC 92. 96 LEIKE 92 is based on '90 LEP-data published in LEP 92.
- 97 RENTON 92 limits use LEP data taken up to '90 as well as m_W , ν N, and atomic parity
- violation data. Specific Higgs structure is assumed.
 98 ALTARELLI 918 is based on Z mass, widths, and A_{FB} . The limits are for superstring motivated models with extra assumption on the Higgs sector. $m_{t} > 90$ GeV and

- $m_{H^0} \, < \, 1$ TeV assumed. For large $m_{\, t^{*}}$ the bound improves drastically. Bounds for Z-Z' mixing angle and Z mass shift without this model assumption are also given in the paper.
- ⁹⁹BUCHMUELLER 91 limit is from LEP data. Specific assumption is made for the Higgs
- 100 Sector. DELAGUILA 91 bounds have extra assumption of superstring motivated Higgs sector. From νN neutral current data with $m_Z=91.10\pm0.04$ GeV, $m_t>77$ GeV, $m_{H^0}<1$ TeV assumed.
- 101 FARAGGG 91 limit assumes the nucleosynthesis bound on the effective number of neutrinos $\Delta N_{\nu}~<~0.5$ and is valid for $m_{\nu_R}~<~1$ MeV.
- 102 GONZALEZ-GARCIA 91 limit is based on low-energy neutral current data, Z mass and widths, m_W from ABE 906, 100 $<\!m_t<$ 200 GeV, $m_{H^0}=$ 100 GeV assumed. Dependence on m_t is shown in Fig. 7.
- $^{103}\,\mathrm{MAHANTHAPPA}$ 91 limit is from atomic parity violation in Cs with $m_W,\,m_Z$
- 104 ABE 90F use data for R, $R_{\ell\ell}$, and $A_{\ell\ell}$.
- 105 ABE 90F fix $m_W = 80.49 \pm 0.43 \pm 0.24$ GeV and $m_Z = 91.13 \pm 0.03$ GeV.
- $106\,e^+\,e^-$ data for R, $R_{\ell\ell}$, $A_{\ell\ell}$, and $A_{c\overline{c}}$ below Z as well as ν_μ e scattering data of GEIREGAT 89 is used in the fit.
- 107 BARGER 908 limit is based on CDF limit $\sigma(p\bar{p}\to Z')$ B($Z'\to e^+e^-$) < 1 pb (Nodulman, EPS Conf. '89). Assumes no new threshold is open for Z^{\prime} decay.
- 108 GLASHOW 90 model assumes a specific Higgs sector. See GLASHOW 90B.
- These authors claim that the nucleosynthesis bound on the effective number of light neutrinos ($\delta N_{\nu} < 1$) constrains Z' masses if ν_R is light ($\lesssim 1$ MeV).
- 110 GRIFOLS 90 limit holds for $m_{\nu_R}\lesssim 1$ MeV. See also GRIFOLS 90D, RIZZO 91. 111 HAGIWARA 90 perform a fit to $e^+\,e^-$ data at PEP, PETRA, and TRISTAN including $\mu^+\,\mu^-,\,\tau^+\,\tau^-,$ and hadron cross sections and asymmetries. The upper mass limit disappears at 2.7 s.d.
- ¹¹²DELAGUILA 89 limit is based on $\sigma(p\overline{p}\to Z')\cdot B(Z'\to e^+e^-)<1.8$ pb at CERN $p\overline{p}$
- 113 DORENBOSCH 89 obtain the limit $(g_\chi/g_Z)^2 \cdot (m_Z/m_{Z\chi})^2 < 0.11$ at 95% CL from the processes $\overline{\nu}_{\mu} \, e \to \ \overline{\nu}_{\mu} \, e$ and $\nu_{\mu} \, e \to \ \overline{\nu}_{\mu} \, e$.
- $^{114}\mbox{A}$ wide range of neutral current data as of 1986 are used in the fit.
- $^{115}Z'$ mass limits from non-observation of an excess of $\ell^+\ell^-$ pairs at the CERN $p\overline{p}$ collider [based on ANSARI 87D and GEER Uppsala Conf. 87]. The limits apply when Z^{\prime} decays only into light quarks and leptons.
- 116 MARCIANO 87 limit from unitarity of Cabibbo-Kobayashi-Maskawa matrix.
- $^{117}\,\mathrm{A}$ wide range of neutral current data as of 1985 are used in the fit.

Limits for Z

 Z_{ψ} is the extra neutral boson in $E_6 \to SO(10) \times U(1)_{\psi}$. $g_{\psi} = e/\cos\theta_{W}$ is assumed unless otherwise stated. We list limits with the assumption $\rho = 1$ but with no further constraints on the Higgs sector. Values in brackets are from cosmological and astrophysical considerations and assume a light right-handed neutrino.

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>590	95	¹¹⁸ ABE	97s CDF	$p\overline{p}; Z'_{sb} \rightarrow e^+e^-, \mu^+\mu^-$
>160	95 119	,120 LANGACKER	92B RVUE	Electroweak
• • • We do not us	se the foll	lowing data for avera	iges, fits, lim	its, etc. • • •
>160	95	121 BARATE	97B ALEP	$e^+e^- \rightarrow \mu^+\mu^-$ and hadronic cross section
>148	95	122 BUSKULIC	96N ALEP	Hadronic cross section
>415	95	123 ABE	95 CDF	$p\overline{p}; Z'_{sb} \rightarrow e^+e^-$
>105	95	124 ABREU	95M DLPH	Z parameters and $e^+e^- \rightarrow \mu^+\mu^-(n\gamma)$
		125 NARDI	95 RVUE	Z parameters
>135	95	126 VILAIN		$ u_{\mu} e \rightarrow \nu_{\mu} e \text{ and } \overline{\nu}_{\mu} e \rightarrow \overline{\nu}_{\mu} e $
>118	95	127 ADRIANI	93D L3	Z parameters
>320	95	128 ABE	928 CDF	pp̄
>180	95	¹²⁹ ABE	928 CDF	
>122	95	130 LEIKE	92 RVUE	Z parameters
>105	90 131	1,132 ABE	90F VNS	e+e-
>146	90 132	2,133 ABE	90F RVUE	e^+e^- , $\nu_{\mu}e$
>320		134 BARGER	90B RVUE	ρ Τ
[> 160]		135 GONZALEZ-G	900 COSM	Nucleosynthesis; light ν_R
[> 2000]		136 GRIFOLS	90D ASTR	SN 1987A; light ν_R
>136	90	¹³⁷ HAGIWARA	90 RVUE	e+e "
>154	90	138 AMALDI	87 RVUE	
>146	90	¹³⁹ DURKIN	86 RVUE	
		_		

- 118 ABE 975 limit is obtained assuming that Z^\prime decays to known fermions only.
- 119 LANGACKER 92B fit to a wide range of electroweak data including LEP results available early '91. $m_t > 89$ GeV used.
- 120 LANGACKER 92B give 95%CL limits on the Z-Z $^\prime$ mixing -0.0025 < heta < 0.013.
- 121 BARATE 978 gives 95% CL limits on Z-Z' mixing $-0.0020 < \theta < 0.0038$. The bounds are computed with $\alpha_5 = 0.120 \pm 0.003$, $m_t = 175 \pm 6$ GeV, and $M_H = 150 + \frac{120}{90}$ GeV. See their Fig. 4 for the limit contour in the mass-mixing plane.
- 122 BUSKULIC 96N limit is from a combined fit to the hadronic cross sections measured at √s=130, 136 GeV (ALEPH) and √s=58 GeV (TOPAZ). Zero mixing is assumed.
- 123 ABE 95 limit is obtained assuming that Z^\prime decays to known fermions only. See their Fig. 3 for the mass bound of Z' decaying to all allowed fermions and supersymmetric
- 124 ABREU 95M limit is for α_s =0.123, m_t =150 GeV, and m_H =300 GeV. For the limit contour in the mass-mixing plane, see their Fig. 13. 125 NARDI 95 give 90%CL limits on Z-Z' mixing $-0.0056 < \theta < 0.0055$ for $M_{Z'}$ >500 GeV,
- m_t =170 GeV, m_H =250 GeV, α_s =0.12. The bound is relaxed under the simultaneous presence of the mixing of the known fermions with new heavy states, $-0.0066 < \theta <$

- 126 VILAIN 94B assume $m_{t}=$ 150 GeV and $\theta=$ 0. See Fig. 2 for limit contours in the mass-mixing plane.
- 127 ADRIANI 93D give limits on the Z-Z' mixing $-0.003 < \theta < 0.020$ assuming the ABE 928 mass limit.

 128 These limits assume that Z^I decays to known fermions only.
- 129 These limits assume that Z' decays to all E_6 fermions and their superpartners.
- 130 LEIKE 92 is based on '90 LEP data published in LEP 92.
- 131 ABE 90F use data for R, $R_{\ell\ell}$, and $A_{\ell\ell}$.
- $^{132} \rm{ABE}$ 90F ffx $m_{W} = 80.49 \pm 0.43 \pm 0.24$ GeV and $m_{Z} = 91.13 \pm 0.03$ GeV.
- 133 e^+e^- data for R, $R_{\ell\ell}$, $A_{\ell\ell}$, and $A_{C\overline{C}}$ below Z as well as $\nu_{\mu}e$ scattering data of GEIREGAT 89 is used in the fit.
- 134 BARGER 908 limit is based on CDF limit $\sigma(p\overline{p}\to Z')$ B($Z'\to e^+e^-$) < 1 pb (Nodulman, EPS Conf. '89). Assumes no new threshold is open for Z^\prime decay.
- 135 These authors claim that the nucleosynthesis bound on the effective number of light neutrinos ($\delta N_{\nu} < 1$) constrains Z' masses if ν_R is light ($\lesssim 1$ MeV).
- 136 GRIFOLS 90D limit holds for $m_{\nu_R}\lesssim 1$ MeV. See also RIZZO 91. 137 HAGIWARA 90 perform a fit to ${\rm e^+\,e^-}$ data at PEP, PETRA, and TRISTAN including $\mu^+\mu^-$, $\tau^+\tau^-$, and hadron cross sections and asymmetries.
- 138 A wide range of neutral current data as of 1986 are used in the fit.
- $^{139}\,\mathrm{A}$ wide range of neutral current data as of 1985 are used in the fit.

Limits for Z_n

 Z_{η} is the extra neutral boson in E6 models, corresponding to $Q_{\eta}=\sqrt{3/8}~Q_{\chi}~ \sqrt{5/8}~Q_{\psi}.~g_{\eta}=e/\cos\! heta_{W}$ is assumed unless otherwise stated. We list limits with the assumption $\rho=1$ but with no further constraints on the Higgs sector. Values in parentheses assume stronger constraint on the Higgs sector motivated by superstring models. Values in brackets are from cosmological and astrophysical considerations and assume a light right-handed neutrino.

VALUE (GeV)	CL%		DOCUMENT ID		TECN	COMMENT
>620	95		ABE		CDF	$p\overline{p}$; $Z'_{p} \rightarrow e^{+}e^{-}$, $\mu^{+}\mu^{-}$
>182	95 141	,142	LANGACKER	92B	RVUE	Electroweak
 ● ● We do not use 	the foll	owin	g data for avera	ges,	fits, lim	its, etc. • • •
,>173	95		BARATE	97B	ALEP	$e^+e^- \rightarrow \mu^+\mu^-$ and hadronic cross section
>167	95	144	BUSKULIC	96N	ALEP	Hadronic cross section
>440	95		ABE	95	CDF	$p\bar{p}; Z'_{\eta} \rightarrow e^+e^-$
>109	95	146	ABREU	95M	DLPH	
		147	NARDI	95	RVUE	
>100	95	148	VILAIN			$ u_{\mu}{ m e} ightarrow u_{\mu}{ m e} { m and} \overline{ u}_{\mu}{ m e} ightarrow$
						$v_{\mu}e^{\mu}$
>100	95	149	ADRIANI	93 D	L3	Z parameters
(>500)	90	150	ALTARELLI		RVUE	Z parameters
>340	95	151	ABE		CDF	₽₽
>230	95	152	ABE		CDF	₽₽
(>450)	90	155	DELAGUILA		RVUE	
(>315)		154	LAYSSAC		RVUE	Z parameters
>118	95	155	LEIKE		RVUE	Z parameters
(>470)		150	RENTON	92		
(> 300)	90	150	ALTARELLI		RVUE	Z parameters
>120	90	150	GONZALEZ-G.			
>125	90 159	,160	ABE		VNS	e+ e-
>115	90 160			90F	RVUE	e^+e^- , $\nu_{\mu}e$
>340		162	BARGER		RVUE	₽₽
[> 820]		163	GONZALEZ-G.	. 90 D	COSM	Nucleosynthesis; light ν_R
[> 3300]		164	GRIFOLS	90	ASTR	SN 1987A; light VR
>100	90	165	HAGIWARA	90	RVUE	e+e-
[> 1040]		163	LOPEZ	90	COSM	Nucleosynthesis; light ν_R
>173		166	DELAGUILA	89	RVUE	PP̄
>129	90	167	COSTA	88	RVUE	
>156	90	168	ELLIS	88	RVUE	
>167	90	169	ELLIS	88	RVUE	ρP̄
>111	90	167	AMALDI	87	RVUE	
>143	90	170	BARGER	86B		ρÞ
>130	90	1/1	DURKIN	86		
[> 760]		163	ELLIS	86		Nucleosynthesis; light ν_R
[> 500]		163	STEIGMAN	86	COSM	Nucleosynthesis; light ν_R

- 140 ABE 97s limit is obtained assuming that Z' decays to known fermions only.
- 141 LANGACKER 92B fit to a wide range of electroweak data including LEP results available early '91. $m_t >$ 89 GeV used.
- 142 LANGACKER 92B give 95%CL limits on the Z-Z' mixing $-0.038 < \theta < 0.002$.
- 143 BARATE 978 gives 95% CL limits on Z-Z' mixing $-0.021 < \theta < 0.012$. The bounds are computed with $\alpha_s = 0.120 \pm 0.003$, $m_t = 175 \pm 6$ GeV, and $M_H = 150 ^{+120}_{-90}$ GeV. See their Fig. 4 for the limit contour in the mass-mixing plane.
- 144 BUSKULIC 96N limit is from a combined fit to the hadronic cross sections measured at √s=130, 136 GeV (ALEPH) and √s=58 GeV (TOPAZ). Zero mixing is assumed.
- 145 ABE 95 limit is obtained assuming that Z^\prime decays to known fermions only. See their Fig. 3 for the mass bound of Z' decaying to all allowed fermions and supersymmetric
- 146 ABREU 95M limit is for $\alpha_{\rm S}$ =0.123, m_t =150 GeV, and m_H =300 GeV. For the limit contour in the mass-mixing plane, see their Fig. 13.

- 147 NARDI 95 give 90%CL limits on Z-Z' mixing $-0.0087 < \theta < 0.0075$ for $M_{Z^{I}} > 500$ GeV, m_t =170 GeV, m_H =250 GeV, α_s =0.12. The bound is relaxed under the simultaneous presence of the mixing of the known fermions with new heavy states, $-0.0087 < \theta <$
- 148 VILAIN 94B assume $m_f=150$ GeV and $\theta=0$. See Fig. 2 for limit contours in the
- 149 ADRIANI 93D give limits on the Z-Z $^\prime$ mixing $-0.029~<~\theta~<~0.010$ assuming the
- ABE 928 mass limit. 150 ALTARELLI 938 limit is from LEP data available in summer '93 and is for $m_{\tilde{t}}=110$ GeV. $m_H=100$ GeV and $\alpha_{\rm S}=0.118$ assumed. The 90%CL limit on the Z-Z $^{\prime}$ mixing angle is in Fig. 2.
- $^{151}\mathrm{These}$ limits assume that Z' decays to known fermions only.
- $^{152}\mathrm{These}$ limits assume that Z^\prime decays to all E_6 fermions and their superpartners.
- 153 See Fig. 7d in DELAGUILA 92 for the allowed region in $m_{\gamma l}$ -mixing plane from electroweak fit including '90 LEP data.
- 154 LAYSSAC 928 limit is from LEP data available spring '92. Specific Higgs sector is assumed. See also LAYSSAC 92.
- 155 LEIKE 92 is based on '90 LEP data published in LEP 92.
- 156 RENTON 92 limits use LEP data taken up to '90 as well as m_W, νN, and atomic parity violation data. Specific Higgs structure is assumed.
 157 ALTARELLI 918 is based on Z mass, widths, and A_{FB}. The limits are for superstring motivated models with extra assumption on the Higgs sector. m_t > 90 GeV and m_{HO} < 1 TeV assumed. For large m_t, the bound improves drastically. Bounds for Z-Z' mixing angle and Z mass shift without this model assumption are also given in the
- 158 GONZALEZ-GARCIA 91 limit is based on low-energy neutral current data, LEP Z mass and widths, m_W from ABE 90G. 100 $< m_t < 200$ GeV, $m_{H^0} = 100$ GeV assumed. Dependence on m_t is shown in Fig. 8.
- 159 ABE 90F use data for R, $R_{\ell\ell}$, and $A_{\ell\ell}$.
- ¹⁶⁰ABE 90F fix $m_W = 80.49 \pm 0.43 \pm 0.24$ GeV and $m_Z = 91.13 \pm 0.03$ GeV.
- 161 e^+e^- data for R, $R_{\ell\ell}$, $A_{\ell\ell}$, and $A_{C\overline{C}}$ below Z as well as $\nu_{\mu}e$ scattering data of GEIREGAT 89 is used in the fit,
- 162 BARGER 908 limit is based on CDF limit $\sigma(p\bar{p}\to Z')\cdot B(Z'\to e^+e^-)<1$ pb (Nodulman, EPS Conf. '89). Assumes no new threshold is open for Z' decay.
- 163 These authors claim that the nucleosynthesis bound on the effective number of light neutrinos ($\delta N_{\nu} < 1$) constrains Z' masses if ν_R is light ($\lesssim 1$ MeV). 164 GRIFOLS 90 limit holds for $m_{\nu_R} \lesssim 1$ MeV. See also GRIFOLS 90D, RIZZO 91.
- 165 HAGIWARA 90 perform a fit to e+e- data at PEP, PETRA, and TRISTAN including $\mu^+\mu^-$, $\tau^+\tau^-$, and hadron cross sections and asymmetries.
- 166 DELAGUILA 89 limit is based on $\sigma(p\vec{p}\to Z')$ -B($Z'\to e^+e^-$) < 1.8 pb at CERN $p\overline{p}$
- collider.
 167 A wide range of neutral current data as of 1986 are used in the fit.
- $^{168}Z_{\eta}$ mass limits obtained by combining constraints from non-observation of an excess of $t^+ t^-$ pairs at the CERN ho p collider and the global analysis of neutral current data by COSTA 88. Least favorable spectrum of three (E_6 27) generations of particles and their superpartners are assumed.
- ¹⁶⁹ Z' mass limits from non-observation of an excess of $\ell^+\ell^-$ pairs at the CERN $p\,\overline{p}$ collider [based on ANSARI 87D and GEER Uppsala Conf. 87]. The limits apply when Z^\prime decays only into light quarks and leptons.
- 170 BARGER 868 limit is based on UA1/UA2 limit on $p\bar{p} \to Z'$, $Z' \to e^+e^-$ (Lepton Photon Symp., Kyoto, '85). Extra decay channels for Z' are assumed not be open.
- $^{171}\mathrm{A}$ wide range of neutral current data as of 1985 are used in the flt.

Limits for other Z'

 $Z_{\beta} = Z_{\chi} \cos \beta + Z_{\psi} \sin \beta$ VALUE (GeV) CL% DOCUMENT ID TECN COMMENT 172 DELAGUILA 92 RVUE >360 >190 175 GRIFOLS 90c RVUE 89 RVUE $p\bar{p}$ 88 RVUE Z_{β} with $tan\beta = \sqrt{15}$ 176 DELAGUILA 90 177,178 COSTA >180 179 ELLIS 90 88 RVUE Z_{β} (tan $\beta = \sqrt{15}$), $p\overline{p}$ >158

- 172 Fig. 7c and 7e In DELAGUILA 92 give limits for $an\!\beta = -1/\sqrt{15}$ and $\sqrt{15}$ from electroweak fit including '90 LEP data.
- 173 ALTARELLI 91 limit is from atomic parity violation in Cs together with LEP, CDF data. Z-Z' mixing is assumed to be zero to set the limit.
- 174 MAHANTHAPPA 91 limit is from atomic parity violation in Cs with $m_W,\,m_Z$. See Table III of MAHANTHAPPA 91 (corrected in erratum) for limits on various Z' models.
- 175 GRIFOLS 90C obtains a limit for Z' mass as a function of mixing angle β (his $\theta=\beta-\pi/2$), which is derived from a LAMPF experiment on $\sigma(\nu_{\varrho}\,e)$ (ALLEN 90). The result is shown in Fig. 1.
- $\frac{176}{5}$ See Table I of DELAGUILA 89 for limits on various Z' models.
- 177 g $_{eta}=e/{\cos} heta_{W}$ and ho=1 assumed.
- $^{178}\,\mathrm{A}$ wide range of neutral current data as of 1986 are used in the fit.
- 179 Z' mass limits from non-observation of an excess of $\ell^+\ell^-$ pairs at the CERN $p \bar{p}$ collider [based on ANSARI 870 and GEER Uppsala Conf. 87]. The limits apply when Z' decays only into light quarks and leptons.

LEPTOQUARK QUANTUM NUMBERS

Written December 1997 by M. Tanabashi (Tohoku U.).

Leptoquarks are particles carrying both baryon number (B)and lepton number (L). They are expected to exist in various extensions of the Standard Model (SM). The possible quantum numbers of leptoquark states can be restricted by assuming that their direct interactions with the ordinary SM fermions are dimensionless and invariant under the SM gauge group. Table 1 shows the list of all possible quantum numbers with this assumption [1]. The columns of $SU(3)_C$, $SU(2)_W$, and $U(1)_Y$ in Table 1 indicate the QCD representation, the weak isospin representation, and the weak hypercharge, respectively. Naming conventions of leptoquark states are taken from Ref. 1. The spin of a leptoquark state is taken to be 1 (vector leptoquark) or 0 (scalar leptoquark).

Table 1: Possible leptoquarks and their quantum numbers.

Leptoquarks	Spin	3B + L	$SU(3)_c$	$\mathrm{SU}(2)_W$	$\mathrm{U}(1)_Y$
$\overline{S_1}$	0	-2	3	1	1/3
$ ilde{S}_1$	0	-2	$\bar{3}$	1	4/3
S_3	0	-2	3	3	1/3
V_2	`1	-2	3	2	5/6
$ ilde{V}_2$	1	- 2	3	2	-1/6
R_2	0	0	3	2	7/6
$ ilde{R}_2$	0	0	3	2	1/6
U_1	1	0	3	1	2/3
$ ilde{U}_1$	1	0	3	1	5/3
U_3	1	0	3	3	2/3

If we do not require leptoquark states to couple directly with SM fermions, different assignments of quantum numbers become possible.

The Pati-Salam model [2] is an example predicting the existence of a leptoquark state. In this model a vector leptoquark appears at the scale where the Pati-Salam SU(4) "color" gauge group breaks into the familiar QCD $SU(3)_C$ group (or $SU(3)_C \times U(1)_{B-L}$). The Pati-Salam leptoquark is a weak isosinglet and its hypercharge is 2/3 (U₁ leptoquark in Table 1). The coupling strength of the Pati-Salam leptoquark is given by the QCD coupling at the Pati-Salam symmetry breaking scale.

Bounds on leptoquark states are obtained both directly and indirectly. Direct limits are from their production cross sections at colliders, while indirect limits are calculated from the bounds on the leptoquark induced four-fermion interactions which are obtained from low energy experiments.

The pair production cross sections of leptoquarks are evaluated from their interactions with gauge bosons. The gauge couplings of a scalar leptoquark are determined uniquely according to its quantum numbers in Table 1. The magneticdipole-type and the electric-quadrupole-type interactions of a vector leptoquark are, however, not determined even if we fix its gauge quantum numbers as listed in the table [3]. We need extra assumptions about these interactions to evaluate the pair production cross section for a vector leptoquark.

If a leptoquark couples to fermions of more than a single generation in the mass eigenbasis of the SM fermions, it can induce four-fermion interactions causing flavor-changing-neutralcurrents and lepton-family-number violations. Non-chiral leptoquarks, which couple simultaneously to both left- and righthanded quarks, cause four-fermion interactions affecting the $(\pi \to e\nu)/(\pi \to \mu\nu)$ ratio [4]. Indirect limits provide stringent constraints on these leptoquarks. Since the Pati-Salam leptoquark has non-chiral coupling with both e and μ , indirect limits from the bounds on $K_L \to \mu e$ lead to severe bounds on the Pati-Salam leptoquark mass. For detailed bounds obtained in this way, see the Boson Particle Listings for "Indirect Limits for Leptoquarks" and its references.

It is therefore often assumed that a leptoquark state couples only to a single generation in a chiral interaction, where indirect limits become much weaker. This assumption gives strong constraints on concrete models of leptoquarks, however. Leptoquark states which couple only to left- or right-handed quarks are called chiral leptoquarks. Leptoquark states which couple only to the first (second, third) generation are referred as the first (second, third) generation leptoquarks in this section.

Reference

- 1. W. Buchmüller, R. Rückl, and D. Wyler, Phys. Lett. B191, 442 (1987).
- J.C. Pati and A. Salam, Phys. Rev. D10, 275 (1974).
- J. Blümlein, E. Boos, and A. Kryukov, Z. Phys. C76, 137
- O. Shanker, Nucl. Phys. **B204**, 375 (1982).

MASS LIMITS for Leptoquarks from Pair Production

				eak c		the leptoquark.
VALUE (GeV)	<u>CL%</u>	EVTS	DOCUMENT ID		<u>TECN</u>	COMMENT
>225	95	180	D ABBOTT	98E	D0	First generation
> 99	95	18:	l ABE	97F	CDF	Third generation
>131	95	18:	2 ARF	95U	CDF	Second generation
> 45.5	95	183,18	⁴ ABREU	931	DLPH	First + second genera-
> 44.4	95	18	5 ADRIANI	93M	L3	First generation
> 44.6	95	18	6 ADRIANI	93M	L3	Third generation
> 44	95	18	5 DECAMP	92	ALEP	First or second generation
> 45	95	18	DECAMP	92	ALEP	Third generation
> 44.2	95	18	5 ALEXANDER	91	OPAL	First or second generation
> 41.4	95	18	5 ALEXANDER	91	OPAL	Third generation
• • We do not	t use th	e following	data for average	s, fits	, limits,	
>225	95		ABBOTT	97B	D0	Result included in AB- BOTT 98E
>213	95	18	⁷ ABE	97x	CDF	First generation
>119	95	18	^B ABACHI	95G	D0	Second generation
>116	95	18	9 ABACHI	94B	D0	First generation
> 80	95	19	DABE	931	CDF	First generation
> 44.5	95	18	5 ADRIANI	93M	L3	Second generation
> 42.1	95	19:	¹ ABREU	92f	DLPH	Second generation
> 74	95	19:	² ALITTI	92E	UA2	First generation
> 43.2	95	18	5 ADEVA	91B	L3	First generation
> 43.4	95	18	5 ADEVA	91B	L3	Second generation
none 8.9–22.6	95	193	3 KIM	90	AMY	First generation
none 10.2-23.2	95	19:	3 KIM	90	AMY	Second generation
none 5-20.8	95	19	⁴ BARTEL		JADE	
none 7-20.5	95	2 19	5 BEHREND	86B	CELL	

180 ABBOTT 98E search for scalar leptoquarks using $e\nu jj$, eejj, and $\nu\nu jj$ events in $p\overline{p}$ collisions at $E_{\rm cm}=1.8$ TeV. The limit above assumes B(eq)=1. For B(eq)=0.5 and 0, the bound becomes 204 and 79 GeV, respectively.

¹⁸¹ABE 97F search for third generation scalar and vector leptoquarks in $p\overline{p}$ collisions at $E_{\rm cm}=1.8$ TeV. The quoted limit is for scalar leptoquark with $B(\tau b)=1$.

182 ABE 95U search for scalar leptoquarks of charge $Q\!\!=\!\!2/3$ and $-1/3$ using $\mu\mu JJ$ events
in $p\bar{p}$ collisions at $E_{cm}=1.8$ TeV. The limit is for $B(\mu q)=1$. For $B(\mu q)=B(\nu q)=1$
0.5, the limit is > 96 GeV.

183 Limit is for charge -1/3 isospin-0 leptoquark with $B(\ell q)=2/3$.

184 First and second generation leptoquarks are assumed to be degenerate. The limit is slightly lower for each generation.

185 Limits are for charge -1/3, isospin-0 scalar leptoquarks decaying to $\ell^- q$ or νq with any branching ratio. See paper for limits for other charge-isospin assignments of leptoquarks. 186 ADRIANI 93M limit for charge -1/3, isospin-0 leptoquark decaying to au b.

187 ABBOTT 97B, ABE 97x search for scalar leptoquarks using eejj events in $p\overline{p}$ collisions at E_{cm} =1.8 TeV. The limit is for B(eq)=1.

188 ABACHI 95G search for scalar leptoquarks using $\mu\mu$ +jets and $\mu\nu_{\mu}$ +jets events in $p\overline{p}$

collisions at $E_{\rm Cm}=1.8$ TeV. The limit is for B(μq) = 1. For B(μq) = 0.5, the limit is > 97 GeV. 189 ABACHI 948 search for ee[j] and $e\nu[j]$ events in $p\bar{p}$ collisions at $E_{\rm Cm}=1.8$ TeV. ABACHI 948 obtain the limit >120 GeV for B(eq)=B(νq)=0.5 and >133 GeV for B(eq)=1. A change in the DØ luminosity monitor constant reduces the first bound to >116 GeV quoted above (see FERMILAB-TM-1911). This limit does not depend on the electroweak quantum numbers of the leptoquark.

190 ABE 93) search for $\ell\ell j j$ events in $p \bar p$ collisions at $E_{\rm CM} = 1.8$ TeV. The limit is for B(eq) = B(νq) = 0.5 and improves to >113 GeV for B(eq) = 1. This limit does not depend on electroweak quantum numbers of the leptoquark.

191 ABREU 92F limit is for charge -1/3 isosin-0 leptoquark with $B(\mu q) = 2/3$. If first and second generation leptoquarks are degenerate, the limit is 43.0 GeV, and for a charge 2/3 second generation leptoquark 43.4 GeV. Cross-section limit for pair production of tates decaying to ℓq is given in the paper.

192 ALITTI 92E search for $\ell\ell j j$ and $\ell\nu j j$ events in $\rho \bar{\rho}$ collisions at $E_{\rm cm}=$ 630 GeV. The limit is for ${\rm B}(eq)=1$ and is reduced to 67 GeV for ${\rm B}(eq)={\rm B}(\nu q)=0.5$. This limit does not depend on electroweak quantum numbers of the leptoquark.

193 KIM 90 assume pair production of charge 2/3 scalar-leptoquark via photon exchange.

The decay of the first (second) generation leptoquark is assumed to be any mixture of $d\,e^+$ and $u\overline{
u}$ ($s\,\mu^+$ and $c\,\overline{
u}$). See paper for limits for specific branching ratios.

 194 BARTEL 878 limit is valid when a pair of charge 2/3 spinless leptoquarks X is produced with point coupling, and when they decay under the constraint $B(X \to c \overline{\nu}_{\mu}) + B(X \to c \overline{\nu}_{\mu})$

 195 BEHREND 86B assumed that a charge 2/3 spinless leptoquark, χ , decays either into $s\mu^+$ or $c\overline{\nu}$: $B(X \to s\mu^+) + B(X \to c\overline{\nu}) = 1$.

MASS LIMITS for Leptoquarks from Single Production

These limits depend on the q- ℓ -leptoquark coupling g_{LQ} . It is often assumed that $g_{LQ}^2/4\pi$ =1/137. Limits shown are for a scalar, weak isoscalar, charge -1/3 lepto-

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
>237	95	196 AID	96B	H1	First generation
> 73	95	197 ABREU	93 J	DLPH	Second generation
• • • We do not	use the follow	ving data for averag	ges, fits	, limits,	etc. • • •
		198 DERRICK	97	ZEUS	Lepton-flavor violation
>230	95	¹⁹⁹ AHMED	94B	H1	Sup. by AID 968
> 65	95	¹⁹⁷ ABREU	93 J	DLPH	First generation
>181	95	²⁰⁰ ABT	93	H1	First generation
>168	95	²⁰¹ DERRICK	93	ZEUS	First generation

 $^{196}\mathrm{The}$ quoted limit is for a left-handed scalar leptoquark which solely couples to the first generation with electromagnetic strength. AID 96B also search for leptoquarks with lepton-flavor violating couplings. For limits on states with different quantum numbers and the limits in the coupling-mass plane, see their Fig. 2, Fig. 3, and Table 2. AID 96B

197 Limit from single production in Z decay. The limit is for a leptoquark coupling of electromagnetic strength and assumes $B(\ell q)=2/3$. The limit is 77 GeV if first and cond leptoquarks are degenerate.

198 DERRICK 97 search for various leptoquarks with lepton-flavor violating couplings. See their Figs. 5–8 and Table 1 for detailed limits.

their Figs. 3-8 and Table 1 for detailed limits.

199 AHMED 94B limit is for the left-handed leptoquark decaying to eq and νq with B(eq)

= B(νq)=1/2. Electromagnetic coupling strength is assumed for the scalar leptoquark interaction. For limits on states with different quantum numbers and the limits in the coupling-mass plane, see their Table 2 and Fig. 6.

 $^{200}\,\mathrm{ABT}$ 93 search for single leptoquark production in ep collisions with the decays eq and

 νq . The limit is for a leptoquark coupling of electromagnetic strength and assumes $B(eq) = B(\nu q) = 1/2$. The limit is for a leptoquark coupling of electromagnetic strength and assumes $B(eq) = B(\nu q) = 1/2$. The limit for B(eq) = 1 is 178 GeV. For limits on states with different quantum numbers, see their Fig. 2. ABT 93 superseded by AHMED 94B. 2^{01} DERRICK 93 search for single leptoquark production in ep collisions with the decay eq and νq . The limit is for leptoquark coupling of electromagnetic strength and assumes $B(eq) = B(\nu q) = 1/2$. The limit for B(eq) = 1 is 176 GeV. For limits on states with different quantum numbers, see their Table 3.

Indirect Limits for Leptoquarks

VALUE (TeV)	CL%	DOCUMENT ID	TE	CN	COMMENT
• • • We do not use t	the follow	ving data for average	s, fits, li	mits,	etc. • • •
> 0.76	95	²⁰² DEANDREA	97 R\	VUE	\tilde{R}_2 leptoquark
		²⁰³ DERRICK	97 ZE	EUS	Lepton-flavor violation
		²⁰⁴ GROSSMAN	97 R\	/UE	$B \rightarrow \tau^+ \tau^-(X)$
		²⁰⁵ JADACH			e ⁺ e ⁻ → qq̄
> 0.31	95	206 AID	95 H		
>1200		207 KUZNETSOV	958 R\	VUE	Pati-Salam type
		²⁰⁸ MIZUKOSHI			Third generation scalar leptoquark

> 0.3	95	²⁰⁹ ВНАТТАСН	94 RVU	E Spin-0 leptoquark cou- pled to $\overline{e}_R t_I$
		²¹⁰ DAVIDSON	94 RVU	
> 18		211 KUZNETSOV	94 RVU	E Pati-Salam type
> 0.4	3 95	²¹² LEURER		E First generation spin-1 leptoquark
> 0.4	4 95	²¹² LEURER	94B RVU	E First generation spin-0
		²¹³ MAHANTA	94 RVU	E P and T violation
> 350		²¹⁴ DESHPANDE	83 RVU	E Sup. by KUZNETSOV 95B
> 1		²¹⁵ SHANKER	82 RVU	E Nonchiral spin-0 lepto- quark
> 125		²¹⁵ SHANKER	82 RVU	

 202 DEANDREA 97 limit is for \tilde{R}_2 leptoquark obtained from atomic parity violation (APV). The coupling of leptoquark is assumed to be electromagnetic strength. See Table 2 for limits of the four-fermion interactions induced by various scalar leptoquark exchange. DEANDREA 97 combines APV limit and limits from Tevatron and HERA. See Fig. 1–4 for combined limits of leptoquark in mass-coupling plane.

²⁰³ DERRICK 97 search for lepton-flavor violation in ep collision. See their Tables 2-5 for limits on lepton-flavor violating four-fermion interactions induced by various leptoquarks.

204 GROSSMAN 97 estimate the upper bounds on the branching fraction $B\to \tau^+\tau^-({\rm X})$ from the absence of the B decay with large missing energy. These bounds can be used to constrain leptoquark induced four-fermion interactions.

205 JADACH 97 limit is from $e^+e^- \to q\bar{q}$ cross section at \sqrt{s} =172.3 GeV which can be affected by the t- and u-channel exchanges of leptoquarks. See their Fig. 1 for limits on vector leptoquarks in mass-coupling plane.

206 AID 95 limit is for the weak isotriplet spin-1 leptoquark with the electromagnetic coupling strength. For the limits of leptoquarks with different quantum number, see their Table 2. AID 95 limits are from the measurements of the Q^2 spectrum measurement of ep

207 E/X.

207 E/X.

207 E/X.

E/X. quoted limit is from $K_L \to \mu e$ decay assuming zero mixing. See also KUZNETSOV 94, DESHPANDE 83, and DIMOPOULOS 81.

208 MIZUKOSHI 95 calculate the one-loop radiative correction to the Z-physics parameters in various scalar leptoquark models. See their Fig. 4 for the exclusion plot of third generation leptoquark models in mass-coupling plane.

²⁰⁹BHATTACHARYYA 94 limit is from one-loop radiative correction to the leptonic decay width of the Z. m_H =250 GeV, $\alpha_S(m_Z)$ =0.12, m_t =180 GeV, and the electroweak strength of leptoquark coupling are assumed. For leptoquark coupled to $\overline{e}_L t_R$, $\overline{\mu} t$, and $\overline{\tau} t$, see Fig. 2 in BHATTACHARYYA 94B erratum and Fig. 3.

210 DAVIDSON 94 gives an extensive list of the bounds on leptoquark-induced four-fermion insteractions from π , K, D, B, μ , τ decays and meson mixings, etc. See Table 15 of

DAVIDSON 94 for detail.
211 KUZNETSOV 94 gives mixing independent bound of the Patl-Salam leptoquark from the cosmological limit on $\pi^0 \to \overline{\nu}\nu$.

212 LEURER 94, LEURER 94B limits are obtained from atomic parity violation and apply to any chiral leptoquark which couples to the first generation with electromagnetic strength. For a nonchiral leptoquark, universality in $\pi_{\ell 2}$ decay provides a much more stringent bound. See also SHANKER 82. 213 MAHANTA 94 gives bounds of P- and T-violating scalar-leptoquark couplings from

atomic and molecular experiments.

214 DESHPANDE 83 used upper limit on $K_L^0 \rightarrow \mu e$ decay with renormalization-group equations to estimate coupling at the heavy boson mass. See also DIMOPOULOS 81.

215 From $(\pi \to e\nu)/(\pi \to \mu\nu)$ ratio. SHANKER 82 assumes the leptoquark induced four-fermion coupling $4g^2/M^2$ (\overline{v}_{eL} u_R) ($\overline{d}_L e_R$)with g=0.004 for spin-0 leptoquark and g^2/M^2 ($\overline{\nu}_{eL} \ \gamma_{\mu} u_L$) ($\overline{d}_R \ \gamma^{\mu} e_R$) with $g \simeq 0.6$ for spin-1 leptoquark.

MASS LIMITS for Diquarks

• • • We do not use the following data for averages, fits, limits, etc. • • • none 290–420 95 216 ABE 97G CDF E ₆ diquark	VALUE (GeV)	CL%	DOCUMENT	ID TECN	COMMENT	
	• • • We do not use to	he follo	wing data for avera	ages, fits, limits,	etc. • • •	
	none 290-420	95		97G CDF	E ₆ diquark	
none 15–31.7 95 ²¹⁷ ABREU 940 DLPH SÚSY <i>E</i> ₆ diquark	none 15-31.7	95	²¹⁷ ABREU	940 DLPH	SÚSY <i>E</i> ₆ diquark	

216 ABE 97G search for new particle decaying to dijets.

217 ABREU 940 limit is from $e^+e^-
ightarrow \overline{cs} cs$. Range extends up to 43 GeV if diquarks are degenerate in mass.

MASS LIMITS for g_A (axigluon)

Axigluons are massive color-octet gauge bosons in chiral color models and have axialvector coupling to quarks with the same coupling strength as gluons DOCUMENT ID

• • We do not use the	ne follow	ing data for averages	i, fits, limits,	etc. • • •
none 200-980	95	²¹⁸ ABE	97G CDF	$p\overline{p} \rightarrow g_A X, X \rightarrow 2 \text{ jets}$
none 200-870	95	²¹⁹ ABE		$p\overline{p} \rightarrow g_A X, g_A \rightarrow q\overline{q}$
none 240-640	95	²²⁰ ABE	93G CDF	$p\overline{p} \to g_A X, g_A \to$
>50	95	221 CUYPERS	91 RVUE	2jets $\sigma(e^+e^- \rightarrow hadrons)$
none 120-210	95	²²² ABE	90H CDF	pp→ gAX. gA →
>29		223 ROBINETT	89 THEO	Partial-wave unitarity
none 150-310	95	²²⁴ ALBAJAR	88B UA1	$p\overline{p} \rightarrow g_A \times, g_A \rightarrow$ 2 iets
>20		BERGSTROM	88 RVUE	ρ p → ΥΧ via g _A g
> 9		225 CUYPERS	88 RVUE	γ decay
>25		²²⁶ DONCHESKI	88B RVUE	γ decay

Gauge & Higgs Boson Particle Listings

Heavy Bosons Other than Higgs Bosons

- 218 ABE 97G search for new particle decaying to dijets.
- 219 ABE 95N assume axigluons decaying to quarks in the Standard Model only.
- 220 ABE 93G assume $\Gamma(g_A) = N\alpha_S m_{g_A}/6$ with N=10.
- ²²¹CUYPERS 91 compare $lpha_{\mathcal{S}}$ measured in \mathcal{T} decay and that from R at PEP/PETRA
- ²²² ABE 90H assumes $\Gamma(g_A) = N\alpha_S m_{g_A}/6$ with N = 5 ($\Gamma(g_A) = 0.09 m_{g_A}$). For N = 10, the excluded region is reduced to 120–150 GeV.
- 223 ROBINETT 89 result demands partial-wave unitarity of J=0 $t\bar{t}\to t\bar{t}$ scattering amplitude and derives a limit $m_{g_A}>0.5$ m_t . Assumes $m_t>56$ GeV.
- $^{\rm O,A}$ ALBAJAR 88B result is from the nonobservation of a peak in two-jet invariant mass distribution. $\Gamma(g_A)<0.4~m_{g_A}$ assumed. See also BAGGER 88.
- 225 CUYPERS 88 requires $\Gamma(\Upsilon \to gg_A) < \Gamma(\Upsilon \to ggg)$. A similar result is obtained by DONCHESKI 88.
- 226 DONCHESKI 88 requires $\Gamma(T \to g q \overline{q})/\Gamma(T \to g g g) < 0.25$, where the former decay proceeds via axigluon exchange. A more conservative estimate of < 0.5 leads to mg_A > 21 GeV.

X^0 (Heavy Boson) Searches In Z Decays

Searches for radiative transition of Z to a lighter spin-0 state X^0 decaying to hadrons, a lepton pair, a photon pair, or invisible particles as shown in the comments. The limits are for the product of branching ratios.

CL% DOCUMENT ID TECN COMMENT

• •	•	We	do	not	use	the	following	data	for	averages,	fits	limits,	etc.	•	•	•

		²²⁷ ACCIARRI	97Q L3	X ⁰ → invisible parti- cle(s)
		228 ACTON	93E OPAL	$X^0 \rightarrow \gamma \gamma$
		²²⁹ ABREU	92D DLPH	$X^0 \rightarrow hadrons$
		²³⁰ ADRIANI	92F L3	$X^0 \rightarrow \text{hadrons}$
		²³¹ ACTON	91 OPAL	$X^0 \rightarrow \text{anything}$
<1.1 × 10 ⁻⁴	95	232 ACTON	918 OPAL	$X^0 \rightarrow e^+e^-$
<9 × 10 ⁻⁵	95	232 ACTON	91B OPAL	$\chi^0 \rightarrow \mu^+\mu^-$
$<1.1 \times 10^{-4}$	95	²³² ACTON	918 OPAL	$\chi^0 \rightarrow \tau^+ \tau^-$
$< 2.8 \times 10^{-4}$	95	²³³ ADEVA	910 L3	$X^0 \rightarrow e^+e^-$
$< 2.3 \times 10^{-4}$	95	233 ADEVA	91D L3	$X^0 \rightarrow \mu^+\mu^-$
$< 4.7 \times 10^{-4}$	95	²³⁴ ADEVA	91D L3	$X^0 \rightarrow hadrons$
<8 × 10 ⁻⁴	95	235 AKRAWY	90J OPAL	$X^0 \rightarrow \text{hadrons}$

- ²²⁷ See Fig. 4 of ACCIARRI 97Q for the upper limit on B(Z $\rightarrow \gamma X^0$; $E_{\gamma} > E_{\min}$) as a function of E_{min} .
- ²²⁸ ACTON 93E give $\sigma(e^+e^- \rightarrow X^0\gamma)$ -B($X^0 \rightarrow \gamma\gamma$)< 0.4 pb (95%CL) for m_{X^0} =60 ± 2.5 GeV. If the process occurs via s-channel γ exchange, the limit translates to $\Gamma(X^0)$ -B($X^0\to\gamma\gamma$)² <20 MeV for $m_{X^0}=60\pm 1$ GeV.
- ²²⁹ABREU 92D give σ_Z · B($Z \rightarrow \gamma X^0$) · B($X^0 \rightarrow$ hadrons) <(3–10) pb for m_{X^0} = 10–78 GeV. A very similar limit is obtained for spin-1 X^0 .
- ²³⁰ ADRIANI 92F search for isolated γ in hadronic Z decays. The limit $\sigma_Z + \mathsf{B}(Z \to \gamma X^0)$ \cdot B($X^0 \rightarrow \text{ hadrons}$) <(2–10) pb (95%CL) is given for $m_{X^0} = 25-85$ GeV.
- 231 ACTON 91 searches for $Z \to Z^* X^0$, $Z^* \to e^+ e^-$, $\mu^+ \mu^-$, or $\nu \overline{\nu}$. Excludes any new scalar X^0 with $m_{X^0} < 9.5$ GeV/c if it has the same coupling to ZZ^* as the MSM ... Higgs boson.
- ²³² ACTON 918 limits are for $m_{\chi^0}=$ 60–85 GeV.
- ²³³ ADEVA 91D limits are for $m_{\chi^0} = 30$ -89 GeV.
- ²³⁴ADEVA 91D limits are for $m_{\chi^0}=$ 30–86 GeV.
- 235 AKRAWY 901 give $\Gamma(Z \to \gamma X^0)$ -B($X^0 \to \text{hadrons}) < 1.9 \text{ MeV } (95\%\text{CL}) \text{ for } m_{\chi^0} = 32\text{-80 GeV}$. We divide by $\Gamma(Z) = 2.5 \text{ GeV}$ to get product of branching ratios. For nonresonant transitions, the limit is $B(Z \to \gamma q \bar{q}) < 8.2 \text{ MeV}$ assuming three-body phase space distribution.

MASS LIMITS for a Heavy Neutral Boson Coupling to e^+e^- VALUE (GeV) CL% DOCUMENT ID TECN COMMENT

• • • We do not	use the fo	ollowing data for ave	erages,	fits, lim	its, etc. • • •
none 55-61		²³⁶ ODAKA	89	VNS	$ \Gamma(X^0 \to e^+ e^-) \\ \cdot B(X^0 \to \text{hadrons}) \gtrsim $
>45	95	237 DERRICK	86	HRS	$\Gamma(X^0 \rightarrow e^+e^-)=6 \text{ MeV}$
>46.6	95	²³⁸ ADEVA	85	MRKJ	$\Gamma(X^0 \rightarrow e^+e^-)=10 \text{ keV}$
>48	95	²³⁸ ADEVA ²³⁹ BERGER		MRKJ PLUT	$\Gamma(X^0 \rightarrow e^+e^-)=4 \text{ MeV}$
none 39.8-45.5		²⁴⁰ ADEVA	84	MRKJ	$\Gamma(X^0 \rightarrow e^+e^-)=10 \text{ keV}$
>47.8	95	²⁴⁰ ADEVA	84	MRKJ	$\Gamma(X^0 \rightarrow e^+e^-)=4 \text{ MeV}$
none 39.8-45.2		²⁴⁰ BEHREND		CELL	
>47	95	²⁴⁰ BEHREND	84 C	CELL	$\Gamma(X^0 \rightarrow e^+e^-)=4 \text{ MeV}$

- 236 ODAKA 89 looked for a narrow or wide scalar resonance in $e^+e^- \rightarrow \text{hadrons}$ at E_{cm} = 55.0-60.8 GeV.
- 237 DERRICK 86 found no deviation from the Standard Model Bhabha scattering at E_{cm} = 29 GeV and set limits on the possible scalar boson e^+e^- coupling. See their figure 4 for excluded region in the $\Gamma(X^0 o e^+ e^-)$ - m_{X^0} plane. Electronic chiral invariance requires a parity doublet of X^0 , in which case the limit applies for $\Gamma(X^0 \to e^+e^-) =$
- 238 ADEVA 85 first limit is from 2γ , $\mu^+\mu^-$, hadrons assuming X^0 is a scalar. Second limit is from e^+e^- channel. $E_{\rm cm}=40$ –47 GeV. Supersedes ADEVA 84.
- 239 BERGER 85B looked for effect of spin-0 boson exchange in $e^+e^- \rightarrow e^+e^-$ and $\mu^+\mu^$ at $E_{\rm cm}=34.7$ GeV. See Fig. 5 for excluded region in the $m_{\chi 0}-\Gamma(\chi^0)$ plane.

 240 ADEVA 84 and BEHREND 84C have $E_{\rm cm}=39.8$ –45.5 GeV. MARK-J searched X^0 in $e^+e^- \rightarrow \text{ hadrons, } 2\gamma, \ \mu^+\mu^-, \ e^+e^- \text{ and CELLO in the same channels plus } \tau \text{ pair.}$ No narrow or broad X^0 is found in the energy range. They also searched for the effect of χ^0 with $m_{\chi} > E_{\rm cm}$. The second limits are from Bhabha data and for spin-0 singlet. The same limits apply for $\Gamma(X^0\to e^+e^-)=2$ MeV if X^0 is a spin-0 doublet. The second limit of BEHREND 84C was read off from their figure 2. The original papers also list limits in other channels.

Search for X^0 Resonance in e^+e^- Collisions

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The limit is for $\Gamma(X^0 \to e^+e^-) \cdot \mathsf{B}(X^0 \to f)$, where f is the specified final state. Spin 0 is assumed for X^0 .

VALUE (keV)	CL%	DOCUMENT ID	TECN COMMENT
• • We do not	use the following	ig data for averag	es, fits, limits, etc. • • •
<10 ³		²⁴¹ ABE	93C VNS Γ(ee)
<(0.4-10)		²⁴² ABE	93c VNS $f = \gamma \gamma$
<(0.3-5)		²⁴⁴ ABE	93D TOPZ $f = \gamma \gamma$
<(2-12)		²⁴⁴ ABE	93D TOPZ $f = hadrons$
<(4-200)		²⁴⁵ ABE	93D TOPZ $f = ee$
<(0.1-6)		²⁴⁵ ABE	93D TOPZ $f = \mu\mu$
<(0.5-8)	90	²⁴⁶ STERNER	93 AMY $f = \gamma \gamma$
			_

- 241 Limit is for $\Gamma(X^0 \to e^+ e^-) \ m_{X^0} = 56\text{--}63.5 \text{ GeV}$ for $\Gamma(X^0) = 0.5 \text{ GeV}$.
- 242 Limit is for $m_{\chi 0}=56-61.5$ GeV and is valid for $\Gamma(\chi^0)\ll 100$ MeV. See their Fig. 5 for limits for $\Gamma=1.2$ GeV.
- 243 Limit is for $m_{\chi^0} = 57.2-60$ GeV.
- ²⁴⁴Limit is valid for $\Gamma(X^0) \ll 100$ MeV. See paper for limits for $\Gamma=1$ GeV and those for I = 2 resonances.
- 245 Limit is for $m_{\chi 0} = 56.6$ -60 GeV.
- 246 STERNER 93 limit is for $m_{\chi^0}=$ 57–59.6 GeV and is valid for $\Gamma(\chi^0)<$ 100 MeV. See their Fig. 2 for limits for $\Gamma=$ 1,3 GeV.

Search for X⁰ Resonance in Two-Photon Process

The limit is for $\Gamma(X^0) \cdot B(X^0 \to \gamma \gamma)^2$. Spin 0 is assumed for X^0 . <u> ci%</u> DOCUMENT ID VALUE (MeV) TECN COMMENT • • • We do not use the following data for averages, fits, limits, etc. • • • <2.6 247 ACTON 93E OPAL $m_{\chi 0} = 60 \pm 1 \text{ GeV}$ 93F ALEP $m_{\chi^0} \sim 60 \text{ GeV}$ BUSKULIC <2.9 95 247 ACTON 93E limit for a J=2 resonance is 0.8 MeV.

Search for X^0 Resonance in $e^+e^- \rightarrow X^0\gamma$

VALUE (GeV) DOCUMENT ID TECN COMMENT

248 ADAM 96C DLPH X⁰ decaying invisibly

²⁴⁸ ADAM 96C is from the single photon production cross at \sqrt{s} =130, 136 GeV. The upper bound is less than 3 pb for X^0 masses between 60 and 130 GeV. See their Fig. 5 for the exact bound on the cross section $\sigma(e^+e^- \rightarrow \gamma X^0)$.

CL%

VALUE (MeV)

Search for X^0 Resonance in $Z \to f\overline{f}X^0$ The limit is for $B(Z \to f\overline{f}X^0) \cdot B(X^0 \to F)$ where f is a fermion and F is the specified final state. Spin 0 is assumed for X^0 .

TECN COMMENT

DOCUMENT ID

• • • We do not us	se the follow	ving data for averag	es, fits, limits,	etc. • • •
		²⁴⁹ ABREU	96T DLPH	$f=e,\mu,\tau; F=\gamma\gamma$
$< 3.7 \times 10^{-6}$	95	²⁵⁰ ABREU	96T DLPH	f=v; F=γγ
		²⁵¹ ABREU	96⊤ DLPH	$f=q$; $F=\gamma\gamma$
<6.8 × 10 ⁻⁶	95	²⁵⁰ ACTON	93E OPAL	$f=e,\mu,\tau; F=\gamma\gamma$
<5.5 × 10 ⁻⁶	95	²⁵⁰ ACTON	93E OPAL	$f=q$; $F=\gamma\gamma$
<3.1 × 10 ⁻⁶	95	²⁵⁰ ACTON	93E OPAL	$f=\nu$; $F=\gamma\gamma$
$< 6.5 \times 10^{-6}$	95	²⁵⁰ ACTON	93E OPAL	$f=e,\mu; F=\ell \overline{\ell}, q \overline{q}, \nu \overline{\nu}$
$< 7.1 \times 10^{-6}$	95	250 BUSKULIC	93F ALEP	$f=e,\mu$; $F=\ell \overline{\ell}$, $q \overline{q}$, $\nu \overline{\nu}$
		²⁵² ADRIANI	92F L3	$f=q$; $F=\gamma\gamma$

- ²⁴⁹ABREU 967 obtain limit as a function of $m_{\chi 0}$. See their Fig. 6.
- $^{250}\mathrm{Limit}$ is for m_{χ^0} around 60 GeV.
- $^{251} \, \mathrm{ABREU}$ 96T obtain limit as a function of $m_{\chi^0}.$ See their Fig. 15.
- ²⁵² ADRIANI 92F give σ_Z · B($Z \to q \overline{q} \, X^0$) · B($X^0 \to \gamma \gamma$)<(0.75–1.5) pb (95%CL) for $m_{X^0} = 10$ –70 GeV. The limit is 1 pb at 60 GeV.

Search for X^0 Resonance in $p\bar{p} \rightarrow WX^0$

DOCUMENT ID TECN COMMENT 253 ABE 97W CDF $X^0 \rightarrow b\bar{b}$

²⁵³ ABE 97w search for X^0 production associated with W in $p\overline{p}$ collisions at $E_{\rm cm}$ =1.8 TeV. The 95%CL upper limit on the production cross section times the branching ratio for $X^0 \to b\bar b$ ranges from 14 to 19 pb for X^0 mass between 70 and 120 GeV. See their Fig. 3 for upper limits of the production cross section as a function of m_{X^0} .

Search for Resonance X, Y in $e^+e^- \rightarrow XY$ DOCUMENT ID TECN COMMENT ²⁵⁴ ALEXANDER 978 OPAL $X \rightarrow 2$ jets, $Y \rightarrow 2$ jets 255 BUSKULIC,D 96 ALEP $X \rightarrow 2$ Jets, $Y \rightarrow 2$ Jets ²⁵⁴ ALEXANDER 97B search for the associated production of two massive particles decaying into quarks in e^+e^- collisions at \sqrt{s} =130-136 GeV. The 95%CL upper limits on $\sigma(e^+e^-\to XY)$ range from 2.7 to 4.5 pb for 95< $m_X+m_Y<$ 120 GeV. 255 BUSKULIC,D 96 observed an excess of four-jet production cross section in e⁺e⁻ collisions at \sqrt{s} =130–136 GeV and find an enhancement in the sum of two dijet masses around 105 GeV.

Heavy Particle Production in Quarkonium Decays

Limits are for plan	icianig.	I B LIOS LO III OUES SIIOWI	١,		
VALUE	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use th	e follov	wing data for averages	, fit	s, limits,	etc. • • •
$<1.5 \times 10^{-5}$	90	256 BALEST	95	CLE2	$T(15) \rightarrow X^0 \gamma$, $m_{X^0} < 5 \text{ GeV}$
$< 3 \times 10^{-5} - 6 \times 10^{-3}$	90	257 BALEST	95	CLE2	$\Upsilon(15) \rightarrow X^0 \overline{X}^0 \gamma$, $m_{X^0} < 3.9 \text{ GeV}$
$< 5.6 \times 10^{-5}$	90	²⁵⁸ ANTREASYAN	900	CBAL	
		259 ALBRECHT	89	ARG	^ -

- 256 BALEST 95 two-body limit is for pseudoscalar $\rm X^0$. The limit becomes $\rm < 10^{-4}$ for $\rm m_{\rm X^0} < 7.7$ GeV.
- 257 BALEST 95 three-body limit is for phase-space photon energy distribution and angular distribution same as for $\Upsilon \to gg\gamma$. 258 ANTREASYAN 90c assume that X^0 does not decay in the detector.
- 259 ALBRECHT 89 give limits for B($\Upsilon(15)$, $\Upsilon(2S) \rightarrow X^0 \gamma$)·B($X^0 \rightarrow \pi^+\pi^-$, K^+K^- , $p\bar{p}$) for $m_{X^0} < 3.5$ GeV.

REFERENCES FOR Searches for Heavy Bosons Other Than Higgs Bosons

ABBOTT	98E	PRL 80 2051	B. Abbott+ (D0 Collab.)
ABBOTT	97B	PRL 79 4321	+Abolins, Acharya+ (D0 Collab.)
ABE	97F	PRL 78 2906	+Akimoto, Akopian, Albrow, Amendolia+ (CDF Collab.)
ABE	97G	PR DSS RS263	+Akimoto, Akopian, Albrow, Amendolia+ (CDF Collab.)
ABE	975	PRL 79 2192	+Akimoto, Akopian, Albrow, Amendolia+ (CDF Collab.)
ABE	97W	PRL 79 3819	F. Abe+ (CDF Collab.)
ABE	97X	PRL 79 4327	+Akimoto, Akopian, Albrow, Amadon+ (CDF Collab.)
ACCIARRI	970	PL B412 201	M. Acciarri+ (L3 Collab.)
ALEXANDER	97B	ZPHY C73 201	
ARIMA	97	PR D55 19	+Odaka, Ogawa, Shirai, Tsuboyama+ (VENUS Collab.)
BARATE	97B	PL B399 329	+Buskulic, Decamp, Ghez, Goy, Lees+ (ALEPH Collab.)
BARENBOIM	97	PR D55 4213	+Bernabeu, Prades, Raidal (VALE, IFIC)
DEANDREA	97	PL B409 277	(MARS)
DERRICK	97	ZPHY C73 613	
GROSSMAN	97	PR D55 2768	+Ligeti, Nardi (REHO, CIT)
JADACH	97	PL B408 281	+Ward, Was (CERN, INPK, TENN, SLAC)
STAHL	97	ZPHY C74 73	A. Stahl, H. Voss (BONN)
ABACHI	96C	PRL 76 3271	+Abbott, Abolins, Acharya, Adam+ (D0 Collab.)
ABACHI	96D	PL B385 471	
			+Abbott, Abolins, Acharya, Adam+ (D0 Collab.)
ABREU	96T	ZPHY C72 179	+Adam, Adye, Agasi, Ajinenko, Aleksan+ (DELPHI Collab.)
ADAM	96C	PL B380 471	+Adye, Agasi, Alinenko, Aleksan+ (DELPHI Collab.)
AID	96B	PL B369 173	+Andreev, Andrieu, Appuhn, Arpagaus+ (H1 Coilab.)
ALLET	96	PL B383 139	+Bodek, Camps, Deutsch+ (VILL, LEUV, LOUV, WISC)
BUSKULIC	96N		
		PL B378 373	+De Bonis, Decamp, Ghez, Goy, Lees+ (ALEPH Collab.)
BUSKULIC,D	96	ZPHY C71 179	D. Buskulic+ (ALEPH Collab.)
ABACHI	95E	PL B358 405	+Abbott, Abolins, Acharya, Adam, Adams+ (D0 Collab.)
ABACHI	95G	PRL 75 3618	+Abbott, Abolins, Acharya, Adam, Adams+ (D0 Collab.)
ABE	95	PR D51 R949	+Albrow, Amidei, Antos, Anway-Wiese+ (CDF Collab.)
ABE	95M	PRL 74 2900	Albron Amidel Autos Annou Miles
			+Albrow, Amidel, Antos, Anway-Wiese+ (CDF Collab.)
ABE	95N	PRL 74 3538	+Albrow, Amendolla, Amidei, Antos+ (CDF Collab.)
ABE	95U	PRL 75 1012	+Albrow, Amendolia, Amidel, Antos+ (CDF Collab.)
ABREU	95M	ZPHY C65 603	+Adam, Adye, Agasi, Ajinenko+ (DELPHi Collab.)
AID	95	PL B353 578	+Andreev, Andrieu, Appuhn, Arpagaus+ (H1 Collab.)
BALEST	95	PR D51 2053	+Cho, Ford, Johnson+ (CLEO Collab.)
	95		Company Common (CECO COMMON)
KUZNETSOV		PRL 75 794	+Serebrov, Stepanenko+ (PNPI, KIAE, HARV, NIST)
KUZNET\$OV	95B	PAN 58 2113	+Mikheev (YARO)
		Translated from YAF 58	
MIZUKOSHI	95	NP B443 20	+Eboli, Gonzalez-Garcia (SPAUL, CERN)
NARDI	95	PL 8344 225	+Roulet, Tommasini (MICH, CERN)
ABACHI	94B	PRL 72 965	+Abbott, Abolins, Acharya, Adam+ (D0 Collab.)
ABREU	940	ZPHY C64 183	
			+Adam, Adye, Agasi, Alinenko, Aleksan+ (DELPHI Collab.)
AHMED	94B	ZPHY C64 545	+Aid, Andreev, Andrieu, Appuhn, Arpagaus+ (H1 Collab.)
BHATTACH	94	PL B336 100	Bhattacharyya, Eilis, Sridhar (CERN)
Also	948	PL B338 522 (erratum)	Bhattacharyya, Ellis, Sridhar (CERN)
BHATTACH	94B	PL 8338 522 (erratum)	Bhattacharyya, Ellis, Sridhar (CERN)
BUSKULIC	94		
		ZPHY C62 539	+Casper, De Bonis, Decamp, Ghez, Goy+ (ALEPH Collab.)
DAVIDSON	94	ZPHY C61 613	+Bailey, Campbell (CFPA, TNTO, ALBE)
KUZNETSOV	94	PL B329 295	+Mikheev (YARO)
KUZNETSOV	94B	JETPL 60 315	+Serebrov, Stepanenko+ (PNPI, KIAE, HARV, NIST)
		Translated from ZETFP	60 311.
LEURER	94	PR D50 536	(REHO)
LEURER			
	94R	PR D49 333	(PEHO)
	94B	PR D49 333	(REHO)
Also	93	PRL 71 1324	Leurer (REHO)
Also MAHANTA	93 94	PRL 71 1324 PL B337 128	Leurer (REHO) (MEHTA)
Also MAHANTA SEVERILINS	93 94 94	PRL 71 1324 PL B337 128 PRL 73 611 (erratum)	Leurer (REHO) (MEHTA) + (LOUV, WISC, LEUV, ETH, MASA)
Also MAHANTA	93 94	PRL 71 1324 PL B337 128 PRL 73 611 (erratum)	Leurer (REHO) (MEHTA) + (LOUV, WISC, LEUV, ETH, MASA)
Also MAHANTA SEVERIJNS VILAIN	93 94 94 94	PRL 71 1324 PL B337 128 PRL 73 611 (erratum) PL B332 465	Leurer (REHO) + (LOUV, WISC, LEUV, ETH, MASA) +Wilquet, Beyer, Fiegel, Grote+ (CHARM II Collab.)
Also MAHANTA SEVERIINS VILAIN ABE	93 94 94 94B 93C	PRL 71 1324 PL B337 128 PRL 73 611 (erratum) PL B332 465 PL B302 119	(REHO) (MEHTA) + (LOUV, WISC, LEUV, ETH, MASA) +Wilquet, Beyer, Fiegel, Grote+ (CHARM II Collab.) +Amako, Arai, Arlma, Asano, Chiba+ (VENUS Collab.)
Also MAHANTA SEVERILINS VILAIN ABE ABE	93 94 94 94B 93C 93D	PRL 71 1324 PL B337 128 PRL 73 611 (erratum) PL B332 465 PL B302 119 PL B304 373	Leurer (REHO) + (LOUV, WISC, LEUV, ETH, MASA) +Wiliquet, Beyer, Fiegel, Grote+ (CHARM II Collab,) +Amako, Arai, Arima, Asano, Chiba+ (VENUS Collab,) +Adachi, Awa, Aoki, Belusevic, Emi+ (TOPAZ Collab,)
Also MAHANTA SEVERIJNS VILAIN ABE ABE ABE	93 94 94 94B 93C 93D 93G	PRL 71 1324 PL B337 128 PRL 73 611 (erratum) PL B332 465 PL B302 119 PL B304 373 PRL 71 2542	REHO) (REHA) + (LOUV, WISC, LEUV, ETH, MASA) + Wilquet, Beyer, Fiegel, Grote+ (CHARM II Collab.) +Amako, Atai, Arima, Asano, Chiba+ (VENUS Collab.) +Adachi, Awa, Aoki, Belusevic, Emi+ (TOPAZ Collab.) +Albrow, Almoto, Amidel, Anway-Wiese+ (CDF Collab.)
Also MAHANTA SEVERIINS VILAIN ABE ABE ABE ABE	93 94 94 94B 93C 93D 93G 93I	PRL 71 1324 PL 8337 128 PRL 73 611 (erratum) PL 8302 465 PL 8302 119 PL 8304 373 PRL 71 2542 PR D48 R3939	Leurer (REHO) + (LOUV, WISC, LEUV, ETH, MASA) +Wiliquet, Beyer, Fiegel, Grote+ (CHARM II Collab,) +Amako, Arai, Arima, Asano, Chiba+ (VENUS Collab,) +Adachi, Awa, Aoki, Belusevic, Emi+ (TOPAZ Collab,)
Also MAHANTA SEVERIJNS VILAIN ABE ABE ABE	93 94 94 94B 93C 93D 93G	PRL 71 1324 PL 8337 128 PRL 73 611 (erratum) PL 8302 465 PL 8302 119 PL 8304 373 PRL 71 2542 PR D48 R3939	Leurer (REHO) (MEHTA) + (LOUV, WISC, LEUV, ETH, MASA) +Wilquet, Beyer, Fiegel, Grote+ (CHARM II Collab,) +Amako, Arai, Arima, Asano, Chiba+ (VENUS Collab,) +Adachi, Awa, Aoki, Belusevic, Emi+ (TOPAZ Collab,) +Albrow, Aklmoto, Amidel, Anway-Wiese+ (CDF Collab,) +Albrow, Amidel, Anway-Wiese, Apollinari+ (CDF Collab,)
Also MAHANTA SEVERIJNS VILAIN ABE ABE ABE ABE ABE ABE	93 94 94 94B 93C 93D 93G 93I 93J	PRL 71 1324 PL 8337 128 PRL 73 611 (erratum) PL 8302 465 PL 8302 119 PL 8304 373 PRL 71 2542 PR D48 R3939 PL 8316 620	REHO] (REHTA) + (LOUV, WISC, LEUV, ETH, MASA) + (*Wilquet, Beyer, Fiegel, Grote+ (*CHARM II Collab.) +Amako, Arai, Arima, Asano, Chiba+ (*VERUS Collab.) +Adison, Alminot, Amidel, Anway-Wiese+ Albrow, Almidei, Anway-Wiese, Apollinari+ (*CDF Collab.) +Almow, Amidei, Anway-Wiese, Apollinari+ (*CDF Collab.) +Adam, Adye, Agasi, Aleksan, Alekseev+ (*DELPHI Collab.)
Also MAHANTA SEVERLINS VILAIN ABE ABE ABE ABE ABE ABREU ABT	93 94 94 94B 93C 93D 93G 93I 93J 93	PRL 71 1324 PL B337 128 PRL 73 611 (erratum) PL B332 465 PL B302 119 PL B304 373 PRL 71 2542 PR D48 R3939 PL B316 620 NP B396 3	Leurer (REHO) + (LOUV, WISC, LEUV, ETH, MASA) + Wilquet, Beyer, Fiegel, Grote+ (CHARM II Collab.) + Amako, Arai, Arima, Asano, Chiba+ (VENUS Collab.) + Adachi, Awa, Aoki, Belusevic, Emil+ (TOPAZ Collab.) + Albrow, Almoto, Amidei, Anway-Wiese+ (CDF Collab.) + Albrow, Amidei, Anway-Wiese, Apollinari+ (CDF Collab.) + Addrew, Admidei, Anway-Wiese, Apollinari+ (CDF Collab.) + Addrew, Admidei, Appala, Aleksan, Aragaass+ (H1 Collab.)
Also MAHANTA SEVERIINS VILAIN ABE ABE ABE ABE ABE ABREU ABT ACTON	93 94 94 94B 93C 93D 93G 93I 93J 93 93	PRL 71 1324 PL B337 128 PRL 73 611 (erratum) PL B332 465 PL B302 119 PL B304 373 PRL 71 2542 PR D48 R3939 PL B316 620 NP B396 3 PL B311 391	Leurer (REHO) (MEHTA) + (LOUV, WISC, LEUV, ETH, MASA) +Wilquet, Beyer, Fiegel, Grote+ (CHARM II Collab.) +Adam, Ava, Arak, Asano, Chiba+ (CPNUS Collab.) +Adam, Alawa, Arak, Belusevic, Emit (TOPAZ Collab.) +Albrow, Almidet, Anway-Wiess+ (CDF Collab.) +Albrow, Andrieu, Appuhn, Arbagaus+ (CDF Collab.) +Adam, Adye, Agasi, Aleksan, Alekseev (DELPHI Collab.) +Andrew, Andrieu, Appuhn, Arpagaus+ (H1 Collab.)
Also MAHANTA SEVERLINS VILAIN ABE ABE ABE ABE ABREU ABT ACTON ADRIANI	93 94 94 94B 93C 93D 93G 93I 93J 93 93E 93D	PRL 71 1324 PL B337 128 PRL 73 611 (erratum) PL B332 465 PRL 73 619 (erratum) PL B304 373 PRL 71 2542 PR D48 R3939 PL B316 620 NP B396 3 PL B311 391 PL B306 187	Leurer (REHO) (MEHTA) + (LOUV, WISC, LEUV, ETH, MASA) +Wilquet, Beyer, Fiegel, Grote+ (CHARM II Collab.) +Adach, Arai, Arima, Asano, Chiba+ (VENUS Collab.) +Adach, Awa, Aoki, Belusevic, Emi+ (TOPAZ Collab.) +Albrow, Almitoto, Amidei, Anway-Wiese+ +Albrow, Amidei, Anway-Wiese, Apolinari+ (CDF Collab.) +Aldam, Adye, Agasi, Aleksan, Alekseev+ (DELPHI Collab.) +Andreev, Andrieu, Appuhn, Arpagaus+ +Akers, Alexanderr+ +Aguilar-Benitzer, Ahlen, Alcaraz, Aloisio+ (L3 Collab.)
Also MAHANTA SEVERIINS VILAIN ABE ABE ABE ABE ABREU ABT ACTON ADRIANI ADRIANI	93 94 94 94B 93C 93D 93G 93I 93J 93E 93D 93M	PRL 71 1324 PL B337 128 PRL 73 611 (erratum) PL B332 645 PL B302 119 PL B304 372 PRL 71 2542 PR D48 R3939 PL B316 620 NP B396 3 PL B311 391 PL B306 187 PRPL 236 1	REHOI (MEHTA) + (LOUV, WISC, LEUV, ETH, MASA) +Wilquet, Beyer, Fiegel, Grote+ (Charm II Collab.) +Adam, Ava, Araki, Arima, Asano, Chiba+ +Adam, Ava, Araki, Belusevic, Emil (TOPAZ Collab.) +Albrow, Almidot, Amidel, Anway-Wiess+ +Albrow, Amidel, Anway-Wiess+ +Albrow, Amidel, Anway-Wiess- +Albrow, Amidel, Anway-Wiess- +Albrow, Amidel, Anway-Wiess- +Albrow, Amidel, Anway-Wiess- +Adam, Adye, Agasi, Aleksan, Alekseev- (DELPHI Collab.) +Andrew, Andrieu, Appuhn, Arpagaus+ -Aguilar-Benitez, Ahlen, Alcaraz, Aloislo+ -Aguilar-Benitez, Ahlen, Alcaraz, Aloislo+ - (Li Collab.) - (Li Collab.)
Also MAHANTA SEVERLINS VILAIN ABE ABE ABE ABE ABREU ABT ACTON ADRIANI	93 94 94 94B 93C 93D 93G 93I 93J 93 93E 93D	PRL 71 1324 PL B337 128 PRL 73 611 (erratum) PL B332 465 PRL 73 610 (erratum) PL B304 373 PRL 71 2542 PR D48 R3939 PL B316 620 NP B396 3 PL B311 391 PL B306 187	REHOI (MEHTA) + (LOUV, WISC, LEUV, ETH, MASA) +Wilquet, Beyer, Fiegel, Grote+ (Charm II Collab.) +Adam, Ava, Araki, Arima, Asano, Chiba+ +Adam, Ava, Araki, Belusevic, Emil (TOPAZ Collab.) +Albrow, Almidot, Amidel, Anway-Wiess+ +Albrow, Amidel, Anway-Wiess+ +Albrow, Amidel, Anway-Wiess- +Albrow, Amidel, Anway-Wiess- +Albrow, Amidel, Anway-Wiess- +Albrow, Amidel, Anway-Wiess- +Adam, Adye, Agasi, Aleksan, Alekseev- (DELPHI Collab.) +Andrew, Andrieu, Appuhn, Arpagaus+ -Aguilar-Benitez, Ahlen, Alcaraz, Aloislo+ -Aguilar-Benitez, Ahlen, Alcaraz, Aloislo+ - (Li Collab.) - (Li Collab.)
Also MAHANTA SEVERIJINS VILAIN ABE ABE ABE ABE ABREU ABT ACTON ADRIANI ADRIANI ALITTI	93 94 94 94B 93C 93D 93G 93I 93J 93E 93D 93M 93	PRL 71 1324 PLL 8337 128 PRL 73 611 (erratum) PL 8302 465 PL 8302 119 PL 8304 373 PRL 71 2542 PR D48 R3939 PL 8316 620 NP 8396 3 PL 8311 391 PL 8306 187 PRPL 236 1 NP B400 3	Leurer (REHO) (MEHTA) + (LOUV, WISC, LEUV, ETH, MASA) + Wilquet, Beyer, Fiegel, Grote+ (CHARM II Collab.) + Admako, Atai, Arima, Asano, Chiba+ (VENUS Collab.) + Adaschi, Awa, Aoki, Belusevic, Emil+ (TOPAZ Collab.) + Albrow, Almitoto, Amidel, Anway-Wiese, Apolinari+ (CDF Collab.) + Albrow, Amidei, Anway-Wiese, Apolinari+ (CDF Collab.) + Adam, Adv., Agasi, Aleksan, Alekseev+ (DELPHI Collab.) + Andreev, Andrieu, Appuhn, Arpagaus+ (PIL Collab.) + Akers, Alexanderi+ Aguilar-Benitzz, Ahlen, Alcaraz, Aloisio+ (L3 Collab.) + Aguilar-Benitzz, Ahlen, Alcaraz, Aloisio+ (UA2 Collab.)
Also MAHANTA SEVERIJINS VILAIN ABE ABE ABE ABE ACTON ACTON ADRIANI ADRIANI ALITTI ALLEN	93 94 94 94B 93C 93D 93G 93I 93J 93E 93D 93M 93 93	PRL 71 1324 PL 8337 128 PRL 73 611 (erratum) PL 8322 465 PL 8302 119 PL 8302 119 PL 8304 373 PRL 71 2542 PR 048 R3939 PL 8316 620 NP 8396 3 PL 8316 1391 PL 8316 187 PL 8306 187 PRPL 236 1 NP 8400 3 PR D47 11	Leurer (REHO) (MEHTA) + (LOUV, WISC, LEUV, ETH, MASA) +Wilquet, Beyer, Fiegel, Grote+ (CHARM II Collab.) +Amako, Arai, Arima, Asano, Chiba+ (VENUS Collab.) +Alachi, Awa, Aoki, Belusevic, Emi+ (TOPAZ Collab.) +Albrow, Akimoto, Amidei, Anway-Wiese+ (CDF Collab.) +Albrow, Andrieu, Anyay-Wiese, Apolilarid+ (CDF Collab.) +Albrow, Andrieu, Appuhn, Arpagaus+ (CDF Collab.) +Andrew, Andrieu, Appuhn, Arpagaus+ (HI Collab.) +Andrew, Andrieu, Appuhn, Arpagaus+ (HI Collab.) (HA Collab.) +Aguilar-Benitez, Ahlen, Alcaraz, Aloislo+ +Aguilar-Benitez, Ahlen, Alcaraz, Aloislo+ (L3 Collab.) +Ambrosini, Ansari, Autiero, Bareyre+ (UA2 Collab.)
Also MAHANTA SEVERIJINS VILAIN ABE ABE ABE ABE AREU ABT ACTON ADRIANI ALITTI ALLEN ALTARELLI	93 94 94 94B 93C 93D 93G 93J 93E 93D 93B 93B	PRL 71 1324 PL 8337 128 PRL 73 611 (erratum) PL 8302 465 PL 8302 119 PL 8304 373 PRL 71 2542 PR D48 R3939 PL 8316 620 NP 8396 3 PL 8311 391 PL 8306 187 PRPL 236 1 NP 8400 3 PR D47 11 PL 8318 139	Leurer (REHO) (MEHTA) + (LOUV, WISC, LEUV, ETH, MASA) + (KIUV, WISC, LEUV, ETH, MASA) + (Wilquet, Beyer, Fiegel, Grote+ (CHARM II Collab.) + Admako, Atai, Arima, Asano, Chiba+ (VENUS Collab.) + Adarok, Awa, Aoki, Belusevic, Emil- + Albrow, Almidot, Amidel, Anway-Wiese- + Albrow, Amidei, Anway-Wiese, Apollinarl+ (CDF Collab.) + Adam, Adye, Agasi, Aleksan, Alekseev+ (DELPHI Collab.) + Adam, Adye, Agasi, Aleksan, Alekseev+ (MI Collab.) + Aguilar-Benitez, Ahlen, Alcaraz, Aloisio+ + Aguilar-Benitez, Ahlen, Alcaraz, Aloisio+ + Aguilar-Benitez, Albran, Alcaraz, Aloisio+ + Chen, Doc, Hausartmann+ (UA, LANL, ANL, UMD) + (CEN, Firz, GEVA, PADO)
Also MAHANTA SEVERIJINS VILAIN ABE ABE ABE ABE ABE ABT ACTON ADRIANI ADRIANI ADRIANI ALIEN ALLEN ALTARELLI BHATTACH	93 94 94 94B 93C 93D 93G 93I 93J 93E 93D 93M 93 93 93B 93B	PRL 71 1324 PL 8337 128 PRL 73 611 (erratum) PL 8322 465 PL 8302 119 PL 8304 373 PRL 71 2542 PR 048 R3939 PL 8316 620 NP 8396 3 PL 8316 1391 PL 8316 1391 PL 8306 187 PRPL 236 1 NP 8400 3 PR D47 11 PL 8318 139 PR 047 R3693	Leurer (REHO) (MEHTA) + (LOUV, WISC, LEUV, ETH, MASA) + Wilquet, Beyer, Fiegel, Grote+ (CHAM II Calab.) + Amako, Arai, Arima, Asano, Chiba+ (VENUS Collab.) + Alachi, Awa, Aoki, Belusevic, Emi+ (TOPAZ Callab.) + Albrow, Almoto, Amidel, Anway-Wiese+ (CDF Collab.) + Albrow, Amidei, Anway-Wiese, Apollinari+ (CDF Collab.) + Adam, Adye, Agasi, Aleksan, Alekseev+ (DELPHI Collab.) + Androev, Andrieu, Appuhn, Arpagaus+ (HI Collab.) + Arer, Alexander+ (DELPHI Collab.) + Aguilar-Benitez, Ahlen, Alcaraz, Aloisio+ (L3 Collab.) + Ambrosini, Ansari, Autero, Bareyre+ (UAZ Collab.) + Casalbuoni+ (CERN, FIRZ, GEVA, PADO) **Bhattacharyya+ (CALC, JADA, ICTP, AMMED, BOSE)
Also MAHANTA SEVERIJINS VILAIN ABE ABE ABE ABE AREU ABT ACTON ADRIANI ALITTI ALLEN ALTARELLI	93 94 94 94B 93C 93D 93G 93J 93E 93D 93B 93B	PRL 71 1324 PL 8337 128 PRL 73 611 (erratum) PL 8302 465 PL 8302 119 PL 8304 373 PRL 71 2542 PR D48 R3939 PL 8316 620 NP 8396 3 PL 8311 391 PL 8306 187 PRPL 236 1 NP 8400 3 PR D47 11 PL 8318 139	Leurer (REHO) (MEHTA) + (LOUV, WISC, LEUV, ETH, MASA) + (KIUV, WISC, LEUV, ETH, MASA) + (Wilquet, Beyer, Fiegel, Grote+ (CHARM II Collab.) + Admako, Atai, Arima, Asano, Chiba+ (VENUS Collab.) + Adarok, Awa, Aoki, Belusevic, Emil- + Albrow, Almidot, Amidel, Anway-Wiese- + Albrow, Amidei, Anway-Wiese, Apollinarl+ (CDF Collab.) + Adam, Adye, Agasi, Aleksan, Alekseev+ (DELPHI Collab.) + Adam, Adye, Agasi, Aleksan, Alekseev+ (MI Collab.) + Aguilar-Benitez, Ahlen, Alcaraz, Aloisio+ + Aguilar-Benitez, Ahlen, Alcaraz, Aloisio+ + Aguilar-Benitez, Albran, Alcaraz, Aloisio+ + Chen, Doc, Hausartmann+ (UA, LANL, ANL, UMD) + (CEN, Firz, GEVA, PADO)

			
DERRICK	93	PL B306 173	+Krakauer, Magill, Musgrave, Repond+ (ZEUS Collab.)
RIZZO	93	PR D48 4470	(ANL)
SEVERIJNS	93	PRL 70 4047	+Gimeno-Nogues+ (LOUV, WISC, LEUV, ETH, MASA)
Also STERNER	94 93	PRL 73 611 (erratum) PL B303 385	Severijns+ (LOUV, WISC, LEUV, ETH, MASA) +Abashian, Gotow, Haim, Mattson, Morgan+(AMY Collab.)
ABE	92B	PRL 68 1463	+Amidel, Apollinari, Atac, Auchincloss+ (CDF Collab.)
ABREU	92D	ZPHY C53 555	+Adam, Adami, Adye, Akesson, Alekseev+(DELPHI Collab.)
ABREU ADRIANI	92F 92F	PL B275 222 PL B292 472	+Adam, Adami, Adye, Akesson, Alekseev+(DELPHI Collab.) +Aguilar-Benitez, Ahlen, Akbari, Alcarez+ (13 Collab.)
ALITTI	92E	PL B274 507	+Ambrosini, Ansari, Autiero, Bareyre+ (UA2 Collab.)
DECAMP	92	PRPL 216 253	+Deschizeaux, Gov. Lees, Minard+ (ALEPH Collab.)
DELAGUILA	92	NP B372 3	del Aguila+ (CERN, GRAN, MPIM, BRUXT, MADE)
Also IMAZATO	91C 92	NP B361 45 PRL 69 877	del Aguila, Moreno, Quiros (BARC, MADE)
LANGACKER	92B	PR D45 278	+Kawashima, Tanaka+ (KEK, INUS, TOKY, TOKMS) +Luo (PENN)
LAYSSAC	92	ZPHY C53 97	+Renard, Verzegnassi (MONP, LAPP)
LAYSSAC	92B	PL B287 267	+Renard, Verzegnassi (MONP, TRSTT)
LEIKE .	92	PL B291 187	+Riemann, Riemann (BERL, CERN)
LEP MISHRA	92 92	PL B276 247 PRL 68 3499	+ALEPH, DELPHI, L3, OPAL (LEP Collabs.) +Leung, Arroyo+ (COLU, CHIC, FNAL, ROCH, WISC)
POLAK	92	PL 8276 492	+Zralek (SILES)
POLAK	92B	PR D46 3871	+Zralek (SILES)
RENTON	92	ZPHY C56 355	(OXF)
ABE ABE	91D 91F	PRL 67 2418 PRL 67 2609	+Amidei, Apollinari, Atac, Auchincloss+ (CDF Collab.) +Amidei, Apollinari, Atac, Auchincloss+ (CDF Collab.)
ACTON	91	PL B268 122	+Alexander, Allison, Allport+ (OPAL Collab.)
ACTON	918	PL B268 122 PL B273 338	+Alexander, Allison, Allport, Anderson+ (OPAL Collab.)
ADEVA	91B	PL B261 169	+Adriani, Aguilar-Benitez, Akbari, Alcaraz+ (L3 Collab.)
ADEVA ALEXANDER	91 D 91	PL B262 155 PL B263 123	+Adriani, Aguilar-Benitez, Akbari, Alcaraz+ (L3 Collab.) +Allison, Allport, Anderson, Arcelli+ (OPAL Collab.)
ALITTI	91	ZPHY C49 17	+Allison, Allport, Anderson, Arcelli+ +Ansari, Ansorge, Autiero, Bareyre+ (UA2 Collab.)
ALTARELLI	91	PL B261 146	+Casalbuoni, De Curtis+ (CERN, FIRZ, GEVA)
ALTARELLI	91B	PL B263 459	+Casalbuoni, De Curtis+ (CERN, FIRZ, GEVA) +Casalbuoni, De Curtis+ (CERN, FIRZ, GEVA)
Also	90	PL B245 669	Altarelli, Casalbuoni, Feruglio, Gatto(CERN, LECE, GEVA)
AQUINO BUCHMUEL	91 91	PL B261 280 PL B267 395	+Fernandez, Garcia (CINV, PUEB) Buchmueller, Greub, Minkowski (DESY, BERN)
COLANGELO	91	PL B253 154	+Nardulli (BARI)
CUYPERS	91	PL B259 173	+Falk, Frampton (DURH, HARV, UNCCH)
DELAGUILA	91	PL B254 497	del Aguila, Moreno, Quiros (BARC, MADE, CERN)
FARAGGI GEIREGAT	91 91	MPL A6 61 PL B259 499	+Nanopoulos (TAMU) +Vilain, Wilquet, Binder, Burkard+ (CHARM II Collab.)
GONZALEZ-G.		PL B259 365	+Vilain, Wilquet, Binder, Burkard+ (CHARM II Collab.) Gonzalez-Garcia, Valle (VALE)
Also	90C	NP B345 312	Gonzalez-Garcia, Valle (VALE)
MAHANTHAP.		PR D43 3093	Mahanthappa, Mohapatra (COLO)
Also POLAK	91B 91	PR D44 1616 erratum	Mahanthappa, Mohapatra (COLO)
RIZZO	91	NP B363 385 PR D44 202	+Zralek (SILES) (WISC, ISU)
WALKER	91	APJ 376 51	+Steigman, Schramm, Olive+ (HSCA, OSU, CHIC, MINN)
ABE	90F	PL B246 297	+Amako, Arai, Asano, Chiba+ (VENUS Collab.)
ABE ABE	90G	PRL 65 2243	+Amidei, Apollinari, Atac+ (CDF Collab.)
AKRAWY	90H	PR D41 1722 PL B246 285	+Amidei, Apollinari, Ascoli, Atac+ (CDF Collab.) +Alexander, Allison, Allport, Anderson+ (OPAL Collab.)
ALLEN	90	PRL 64 1330	+Chen, Doe+ (UCI, LASL, UMD)
ANTREASYAN	90C	PL B251 204	+Bartels, Besset, Bieler, Bienlein+ (Crystal Ball Collab.)
BARGER	90B	PR D42 152	+ Hewett, Rizzo (WISC, ISU)
GLASHOW	90 90B	PR D42 3224 PRL 64 725	+Sarid (HARV) +Sarid (HARV)
GONZALEZ-G.		PL B240 163	Gonzalez-Garcia, Valle (VALE)
GRIFOL5	90	NP B331 244	+Masso (BARC)
GRIFOLS	90C	MPL A5 2657	(BARC)
GRIFOLS HAGIWARA	90D 90	PR D42 3293 PR D41 815	+Masso, Rizzo (BARC, CERN, WISC, ISU) +Najima, Sakuda, Terunuma (KEK, DURH, YCC, HIRO)
HE	90B	PL B240 441	+Joshi, Volkas (MELB)
Also	90C	PL B244 580 erratum	He, Joshi, Volkas (MELB)
KIM	90	PL B240 243	+Breedon, Ko, Lander, Maeshima, Malchow+(AMY Collab.)
LOPEZ ALBAJAR	90 89	PL B241 392 ZPHY C44 15	+Nanopoulos (TAMU) +Albrow, Alikofer, Arnison, Astbury+ (UA1 Collab.)
ALBRECHT	89	ZPHY C42 349	+Albrow, Alikofer, Arnison, Astbury+ +Boeckmann, Glaeser, Harder+ (ARGUS Collab.)
BARBIERI	89B	PR D39 1229	+Mohapatra (PISA, UMD)
DELAGUILA	89	PR D40 2481	del Aguila, Moreno, Quiros (BARC, MADE)
Also Also	90B 90C	PR D41 134 PR D42 262 erratum	del Aguila, Moreno, Quiros (BARC, MADE)
DORENBOS	89	ZPHY C41 567	del Aguila, Moreno, Quiros (BARC, MADE) Dorenbosch, Lldo, Allaby, Amaldi+ (CHARM Collab.)
GEIREGAT	89	PL B232 539	+Vilain, Wilquet, Bergsma, Binder+ (CHARM II Collab.)
LANGACKER	89B	PR D40 1569	+Uma Sankar (PENN)
ODAKA ROBINETT	89 89	JPSJ 58 3037 PR D39 834	+Kondo, Abe, Amako+ (VENUS Collab.)
ALBAJAR	88B	PL B209 127	+Albrow, Allkofer, Astbury, Aubert+ (UA1 Collab.)
BAGGER	88	PR D37 1188	+Schmidt, King (HARV, BOST)
BALKE	88	PR D37 587	+Gidal, Jodidio+ (LBL, UCB, COLO, NWES, TRIU)
BERGSTROM COSTA	88 88	PL B212 386 NP B297 244	(STOH) +Ellis, Fogli+ (PADO, CERN, BARI, WISC, LBL)
CUYPERS	85	PRL 60 1237	+Frampton (PADO, CERN, BARI, WISC, LBL)
DONCHESKI	88	PL 8206 137	+Grotch, Robinett (PSU)
DONCHESKI	868	PR D38 412 PL B202 417	+Grotch, Robinett (PSU)
ELLIS RAFFELT	86 88	PRL 60 1793	Ellis, Franzini, Zwirner (CERN, UCB, LBL) +Seckel (UCB, LLL, UCSC)
AMALDI	87	PR D36 1385	+Bohm, Durkin, Langacker+ (CERN, AACH3, OSU+)
ANSARI	87D	PL B195 613	+Bagnaia, Banner+ (UA2 Collab.)
BARTEL MARCIANO	87B	ZPHY C36 15	+Becker, Feist+ (JADE Collab.)
ARNISON	87 86B	PR D35 1672 EPL 1 327	+Sirlin (BNL, NYU) +Albrow, Alikofer+ (UAI Collab.) +Deshpande, Whisnant (WISC, OREG, FSU)
BARGER	86B	PRL 56 30	+Deshpande, Whisnant (WISC, OREG, FSU)
BEHREND	868	PL B178 452	+Duerger, Criegee, Fenner, Field+ (CELLO COMBO.)
DERRICK	86	PL 166B 463	+Gan, Kool)man, Loos+ (HRS Collab.)
Also DURKIN	86B 86	PR D34 3286 PL 166B 436	Derrick, Gan, Kooljman, Loos, Musgrave+ (HRS Collab.) +Langacker (PENN)
ELLIS	86	PL 167B 457	+Enqvist, Nanopoulos, Sarkar (CERN, OXFTP)
JODIDIO	86	PR D34 1967	+Balke, Carr, Gidal, Shinsky+ (LBL, NWES, TRIU)
Also MOHAPATRA	88 86	PR D37 237 erratum PR D34 909	Jodidio, Balke, Carr+ (LBL, NWES, TRIU)
STEIGMAN	B6	PL B176 33	+Olive, Schramm, Turner (BART, MINN+)
ADEVA	85	PL 152B 439	+ Becker, Becker-Szendy+ (Mark-J Collab.)
ADEVA	85B	PRL 55 665	+Becker, Becker-Szendy+ (Mark-J Coliab.)
BERGER STOKER	85B 85	ZPHY C27 341 PRL 54 1887	+Deuter, Genzel, Lackas, Pielorz+ +Balke, Carr, Gidal+ (LBL, NWES, TRIU)
ADEVA	84	PRL 53 134	+Balke, Carr, Gidal+ (LBL, NWES, TRIU) +Barber, Becker, Berdugo+ (Mark-J Collab.)
BEHREND	84C	PL 140B 130	+Burger, Criegee, Fenner+ (CELLO Collab.)
		PL 129B 273	+Astbury, Aubert, Bacci+ (UA1 Collab.)
ARNISON	83D	DI 122P 445	Describer balance
BERGSMA	83	PL 122B 465	+Dorenbosch, Jonker+ (CHARM Collab.)
BERGSMA CARR DESHPANDE		PL 1228 465 PRL 51 627 PR D27 1193	+Dorenbosch, Jonker+ (CHARM Collab.) +Gidal, Gobbi, Jodidio, Oram+ (LBL, NWES, TRIU) +Johnson (OREG)
BERGSMA CARR DESHPANDE BEALL	83 83 83 82	PL 122B 465 PRL 51 627 PR D27 1193 PRL 48 848	+Dorenbosch, Jonker+ (CHARM Collab.) +Gidal, Gobbi, Jodidio, Oram+ (LBL, NWES, TRIU) +Johnson (OREG) +Bander, Soni (UCI, UCLA)
BERGSMA CARR DESHPANDE BEALL SHANKER	83 83 83 82 82	PL 122B 465 PRL 51 627 PR D27 1193 PRL 48 848 NP B204 375	+Dorenbosch, Jonker+ +Gidal, Gobbi, Jodidio, Oram+ +Johnson +Bander, Soni (UCI, UCLA) (TRIU)
BERGSMA CARR DESHPANDE BEALL SHANKER DIMOPOUL	83 83 82 82 81	PL 122B 465 PRL 51 627 PR D27 1193 PRL 48 848 NP B204 375 NP B182 77	+ Dorenbosch, Jonker+ (CHARM Collab.) + Gidal, Gobbi, Jodidio, Oram+ (LBL, NWES, TRIU) + Johnson (OREG) + Bander, Soni (UCI, UCLA) CTRIU Dimopoulos, Raby, Kane (STAN, MICH)
BERGSMA CARR DESHPANDE BEALL SHANKER	83 83 83 82 82	PL 122B 465 PRL 51 627 PR D27 1193 PRL 48 848 NP B204 375	+Dorenbosch, Jonker+ +Gidal, Gobbi, Jodidio, Oram+ +Johnson +Bander, Soni (UCI, UCLA) (TRIU)

Gauge & Higgs Boson Particle Listings Axions (A^0) and Other Very Light Bosons

Axions (A^0) and Other Very Light Bosons, Searches for

AXIONS AND OTHER VERY LIGHT BOSONS

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This review is divided into three parts:

Part I (Theory)

Part II (Astrophysical Constraints)

Part III (Experimental Limits)

AXIONS AND OTHER VERY LIGHT BOSONS, PART I (THEORY)

(by H. Murayama)

In this section we list limits for very light neutral (pseudo) scalar bosons that couple weakly to stable matter. They arise if there is a global continuous symmetry in the theory that is spontaneously broken in the vacuum. If the symmetry is exact, it results in a massless Nambu–Goldstone (NG) boson. If there is a small explicit breaking of the symmetry, either already in the Lagrangian or due to quantum mechanical effects such as anomalies, the would-be NG boson acquires a finite mass; then it is called a pseudo-NG boson. Typical examples are axions (A^0) [1], familons [2], and Majorons [3,4], associated, respectively, with spontaneously broken Peccei-Quinn [5], family, and lepton-number symmetries. This Review provides brief descriptions of each of them and their motivations.

One common characteristic for all these particles is that their coupling to the Standard Model particles are suppressed by the energy scale of symmetry breaking, *i.e.* the decay constant f, where the interaction is described by the Lagrangian

$$\mathcal{L} = \frac{1}{f} (\partial_{\mu} \phi) J^{\mu}, \tag{1}$$

where J^{μ} is the Noether current of the spontaneously broken global symmetry.

An axion gives a natural solution to the strong CP problem: why the effective θ -parameter in the QCD Lagrangian $\mathcal{L}_{\theta} = \theta_{eff} \frac{\alpha_s}{8\pi} F^{\mu\nu a} \widetilde{F}^a_{\mu\nu}$ is so small $(\theta_{eff} \lesssim 10^{-9})$ as required by the current limits on the neutron electric dipole moment, even though $\theta_{eff} \sim O(1)$ is perfectly allowed by the QCD gauge invariance. Here, θ_{eff} is the effective θ parameter after the diagonalization of the quark masses, and $F^{\mu\nu a}$ is the gluon field strength and $\widetilde{F}^a_{\mu\nu} = \frac{1}{2} \epsilon_{\mu\nu\rho\sigma} F^{\rho\sigma a}$. An axion is a pseudo-NG boson of a spontaneously broken Peccei–Quinn symmetry, which is an exact symmetry at the classical level, but is broken quantum mechanically due to the triangle anomaly with the gluons. The definition of the Peccei–Quinn symmetry is model dependent. As a result of the triangle anomaly, the axion acquires an effective coupling to gluons

$$\mathcal{L} = \left(\theta_{eff} - \frac{\phi_A}{f_A}\right) \frac{\alpha_s}{8\pi} F^{\mu\nu a} \widetilde{F}^a_{\mu\nu} , \qquad (2)$$

where ϕ_A is the axion field. It is often convenient to define the axion decay constant f_A with this Lagrangian [6]. The QCD nonperturbative effect induces a potential for ϕ_A whose minimum is at $\phi_A = \theta_{\it eff} f_A$ cancelling $\theta_{\it eff}$ and solving the strong $\it CP$ problem. The mass of the axion is inversely proportional to f_A as

$$m_A = 0.62 \times 10^{-3} \text{eV} \times (10^{10} \text{GeV}/f_A)$$
. (3)

The original axion model [1,5] assumes $f_A \sim v$, where $v = (\sqrt{2}G_F)^{-1/2} = 247$ GeV is the scale of the electroweak symmetry breaking, and has two Higgs doublets as minimal ingredients. By requiring tree-level flavor conservation, the axion mass and its couplings are completely fixed in terms of one parameter $(\tan \beta)$: the ratio of the vacuum expectation values of two Higgs fields. This model is excluded after extensive experimental searches for such an axion [7]. Observation of a narrow-peak structure in positron spectra from heavy ion collisions [8] suggested a particle of mass 1.8 MeV that decays into e^+e^- . Variants of the original axion model, which keep $f_A \sim v$, but drop the constraints of tree-level flavor conservation, were proposed [9]. Extensive searches for this particle, $A^0(1.8 \text{ MeV})$, ended up with another negative result [10].

The popular way to save the Peccei-Quinn idea is to introduce a new scale $f_A \gg v$. Then the A^0 coupling becomes weaker, thus one can easily avoid all the existing experimental limits; such models are called invisible axion models [11,12]. Two classes of models are discussed commonly in the literature. One introduces new heavy quarks which carry Peccei-Quinn charge while the usual quarks and leptons do not (KSVZ axion or "hadronic axion") [11]. The other does not need additional quarks but requires two Higgs doublets, and all quarks and leptons carry Peccei-Quinn charges (DFSZ axion or "GUTaxion") [12]. All models contain at least one electroweak singlet scalar boson which acquires an expectation value and breaks Peccei-Quinn symmetry. The invisible axion with a large decay constant $f_A \sim 10^{12}$ GeV was found to be a good candidate of the cold dark matter component of the Universe [13](see Dark Matter review). The energy density is stored in the lowmomentum modes of the axion field which are highly occupied and thus represent essentially classical field oscillations.

The constraints on the invisible axion from astrophysics are derived from interactions of the axion with either photons, electrons or nucleons. The strengths of the interactions are model dependent (i.e., not a function of f_A only), and hence one needs to specify a model in order to place lower bounds on f_A . Such constraints will be discussed in Part II. Serious experimental searches for an invisible axion are underway; they typically rely on axion-photon coupling, and some of them assume that the axion is the dominant component of our galactic halo density. Part III will discuss experimental techniques and limits.

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Familons arise when there is a global family symmetry broken spontaneously. A family symmetry interchanges generations or acts on different generations differently. Such a symmetry may explain the structure of quark and lepton masses and their mixings. A familon could be either a scalar or a pseudoscalar. For instance, an SU(3) family symmetry among three generations is non-anomalous and hence the familons are exactly massless. In this case, familons are scalars. If one has larger family symmetries with separate groups of left-handed and right-handed fields, one also has pseudoscalar familons. Some of them have flavor-off-diagonal couplings such as $\partial_{\mu}\phi_{F}\bar{d}\gamma^{\mu}s/F_{ds}$ or $\partial_{\mu}\phi_{F}\bar{e}\gamma^{\mu}\mu/F_{\mu e}$, and the decay constant F can be different for individual operators. The decay constants have lower bounds constrained by flavor-changing processes. For instance, $B(K^+ \to \pi^+ \phi_F) < 3 \times 10^{-10}$ [14] gives $F_{ds} > 3.4 \times 10^{11} \text{ GeV } [15]$. The constraints on familous primarily coupled to third generation are quite weak [15].

If there is a global lepton-number symmetry and if it breaks spontaneously, there is a Majoron. The triplet Majoron model [4] has a weak-triplet Higgs boson, and Majoron couples to Z. It is now excluded by the Z invisible-decay width. The model is viable if there is an additional singlet Higgs boson and if the Majoron is mainly a singlet [16]. In the singlet Majoron model [3], lepton-number symmetry is broken by a weak-singlet scalar field, and there are right-handed neutrinos which acquire Majorana masses. The left-handed neutrino masses are generated by a "seesaw" mechanism [17]. The scale of lepton number breaking can be much higher than the electroweak scale in this case. Astrophysical constraints require the decay constant to be $\gtrsim 10^9$ GeV [18].

There is revived interest in a long-lived neutrino, to improve Big-Bang Nucleosynthesis [19] or large scale structure formation theories [20]. Since a decay of neutrinos into electrons or photons is severely constrained, these scenarios require a familion (Majoron) mode $\nu_1 \rightarrow \nu_2 \phi_F$ (see, e.g., Ref. 15 and references therein).

Other light bosons (scalar, pseudoscalar, or vector) are constrained by "fifth force" experiments. For a compilation of constraints, see Ref. 21.

It has been widely argued that a fundamental theory will not possess global symmetries; gravity, for example, is expected to violate them. Global symmetries such as baryon number arise by accident, typically as a consequence of gauge symmetries. It has been noted [22] that the Peccei-Quinn symmetry, from this perspective, must also arise by accident and must hold to an extraordinary degree of accuracy in order to solve the strong CP problem. Possible resolutions to this problem, however, have been discussed [22,23]. String theory also provides sufficiently good symmetries, especially using a large compactification radius motivated by recent developments in M-theory [24].

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AXIONS AND OTHER VERY LIGHT BOSONS: PART II (ASTROPHYSICAL CONSTRAINTS)

(by G.G. Raffelt)

Low-mass weakly-interacting particles (neutrinos, gravitons, axions, baryonic or leptonic gauge bosons, etc.) are produced in hot plasmas and thus represent an energy-loss channel for stars. The strength of the interaction with photons, electrons, and nucleons can be constrained from the requirement that stellar-evolution time scales are not modified beyond observational limits. For detailed reviews see Refs. [1,2].

The energy-loss rates are steeply increasing functions of temperature T and density ρ . Because the new channel has to compete with the standard neutrino losses which tend to increase even faster, the best limits arise from low-mass stars, notably from horizontal-branch (HB) stars which have a helium-burning core of about 0.5 solar masses at $\langle \rho \rangle \approx 0.6 \times 10^4 \, \mathrm{g \ cm^{-3}}$ and $\langle T \rangle \approx 0.7 \times 10^8 \, \mathrm{K}$. The new energy-loss rate must not exceed about 10 ergs $\mathrm{g^{-1} \, s^{-1}}$ to avoid a conflict with the observed number ratio of HB stars in globular clusters. Likewise the ignition of helium in the degenerate cores of the preceding red-giant phase is delayed too much unless the same constraint holds at $\langle \rho \rangle \approx 2 \times 10^5 \, \mathrm{g \ cm^{-3}}$ and $\langle T \rangle \approx 1 \times 10^8 \, \mathrm{K}$. The white-dwarf luminosity function also yields useful bounds.

The new bosons X^0 interact with electrons and nucleons with a dimensionless strength g. For scalars it is a Yukawa coupling, for new gauge bosons (e.g., from a baryonic or leptonic gauge symmetry) a gauge coupling. Axion-like pseudoscalars couple derivatively as $f^{-1}\bar{\psi}\gamma_{\mu}\gamma_{5}\psi$ $\partial^{\mu}\phi_{X}$ with f an energy scale. Usually this is equivalent to $(2m/f)\bar{\psi}\gamma_{5}\psi$ ϕ_{X} with m the mass of the fermion ψ so that g=2m/f. For the coupling to electrons, globular-cluster stars yield the constraint

$$g_{Xe} \lesssim \begin{cases} 0.5 \times 10^{-12} & \text{for pseudoscalars [3]} \\ 1.3 \times 10^{-14} & \text{for scalars [4]} \end{cases}, \tag{1}$$

if $m_X \lesssim 10 \, \text{keV}$. The Compton process $\gamma + {}^4\text{He} \to {}^4\text{He} + X^0$ limits the coupling to nucleons to $g_{XN} \lesssim 0.4 \times 10^{-10}$ [4].

Scalar and vector bosons mediate long-range forces which are severely constrained by "fifth-force" experiments [5]. In the massless case the best limits come from tests of the equivalence principle in the solar system, leading to

$$g_{B,L} \lesssim 10^{-23} \tag{2}$$

for a baryonic or leptonic gauge coupling [6].

In analogy to neutral pions, axions A^0 couple to photons as $g_{A\gamma}\mathbf{E}\cdot\mathbf{B}\,\phi_A$ which allows for the Primakoff conversion $\gamma\leftrightarrow A^0$ in external electromagnetic fields. The most restrictive limit arises from globular-cluster stars [2]

$$g_{A\gamma} \lesssim 0.6 \times 10^{-10} \,\text{GeV}^{-1}$$
 (3)

The often-quoted "red-giant limit" [7] is slightly weaker.

The duration of the SN 1987A neutrino signal of a few seconds proves that the newborn neutron star cooled mostly by neutrinos rather than through an "invisible channel" such as right-handed (sterile) neutrinos or axions [8]. Therefore,

$$3 \times 10^{-10} \lesssim g_{AN} \lesssim 3 \times 10^{-7} \tag{4}$$

is excluded for the pseudoscalar Yukawa coupling to nucleons [2]. The "strong" coupling side is allowed because axions then escape only by diffusion, quenching their efficiency as an energy-loss channel [9]. Even then the range

$$10^{-6} \lesssim g_{AN} \lesssim 10^{-3} \tag{5}$$

is excluded to avoid excess counts in the water Cherenkov detectors which registered the SN 1987A neutrino signal [11].

In terms of the Peccei-Quinn scale f_A , the axion couplings to nucleons and photons are $g_{AN} = C_N m_N/f_A$ (N=n or p) and $g_{A\gamma} = (\alpha/2\pi f_A) (E/N-1.92)$ where C_N and E/N are model-dependent numerical parameters of order unity. With $m_A = 0.62 \, \mathrm{eV} \, (10^7 \, \mathrm{GeV}/f_A)$, Eq. (3) yields $m_A \lesssim 0.4 \, \mathrm{eV}$ for E/N = 8/3 as in GUT models or the DFSZ model. The SN 1987A limit is $m_A \lesssim 0.008 \, \mathrm{eV}$ for KSVZ axions while it varies between about 0.004 and 0.012 eV for DFSZ axions, depending on the angle β which measures the ratio of two Higgs vacuum expectation values [10]. In view of the large uncertainties it is good enough to remember $m_A \lesssim 0.01 \, \mathrm{eV}$ as a generic limit (Fig. 1).

In the early universe, axions come into thermal equilibrium only if $f_A \lesssim 10^8 \, {\rm GeV}$ [12]. Some fraction of the relic axions end up in galaxies and galaxy clusters. Their decay $a \to 2\gamma$ contributes to the cosmic extragalactic background light and to line emissions from galactic dark-matter haloes and galaxy clusters. An unsuccessful "telescope search" for such features yields $m_a < 3.5 \, {\rm eV}$ [13]. For $m_a \gtrsim 30 \, {\rm eV}$, the axion lifetime is shorter than the age of the universe.

For $f_A \gtrsim 10^8\,\mathrm{GeV}$ cosmic axions are produced nonthermally. If inflation occurred after the Peccei-Quinn symmetry breaking or if $T_{\mathrm{reheat}} < f_A$, the "misalignment mechanism" [14] leads to a contribution to the cosmic critical density of

$$\Omega_A h^2 \approx 1.9 \times 3^{\pm 1} (1 \,\mu\text{eV}/m_A)^{1.175} \,\Theta_i^2 F(\Theta_i)$$
 (6)

where h is the Hubble constant in units of $100\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$. The stated range reflects recognized uncertainties of the cosmic conditions at the QCD phase transition and of the temperature-dependent axion mass. The function $F(\Theta)$ with F(0)=1 and $F(\pi)=\infty$ accounts for anharmonic corrections to the axion

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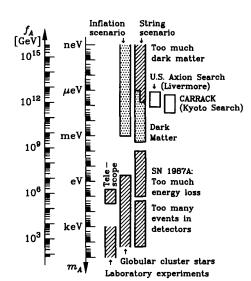


Figure 1: Astrophysical and cosmological exclusion regions (hatched) for the axion mass m_A or equivalently, the Peccei-Quinn scale f_A . An "open end" of an exclusion bar means that it represents a rough estimate; its exact location has not been established or it depends on detailed model assumptions. The globular cluster limit depends on the axion-photon coupling; it was assumed that E/N = 8/3 as in GUT models or the DFSZ model. The SN 1987A limits depend on the axion-nucleon couplings; the shown case corresponds to the KSVZ model and approximately to the DFSZ model. The dotted "inclusion regions" indicate where axions could plausibly be the cosmic dark matter. Most of the allowed range in the inflation scenario requires fine-tuned initial conditions. In the string scenario the plausible dark-matter range is controversial as indicated by the step in the low-mass end of the "inclusion bar" (see main text for a discussion). Also shown is the projected sensitivity range of the search experiments for galactic dark-matter axions.

potential. Because the initial misalignment angle Θ_i can be very small or very close to π , there is no real prediction for the mass of dark-matter axions even though one would expect $\Theta_i^2 F(\Theta_i) \sim 1$ to avoid fine-tuning the initial conditions.

A possible fine-tuning of Θ_i is limited by inflation-induced quantum fluctuations which in turn lead to temperature fluctuations of the cosmic microwave background [15,16]. In a broad class of inflationary models one thus finds an upper limit to m_A where axions could be the dark matter. According to the most recent discussion [16] it is about 10^{-3} eV (Fig. 1).

If inflation did not occur at all or if it occurred before the Peccei-Quinn symmetry breaking with $T_{\rm reheat} > f_A$, cosmic axion strings form by the Kibble mechanism [17]. Their motion is damped primarily by axion emission rather than gravitational waves. After axions acquire a mass at the QCD phase transition they quickly become nonrelativistic and thus form a cold dark

matter component. Battye and Shellard [18] found that the dominant source of axion radiation are string loops rather than long strings. At a cosmic time t the average loop creation size is parametrized as $\langle \ell \rangle = \alpha t$ while the radiation power is $P = \kappa \mu$ with μ the renormalized string tension. The loop contribution to the cosmic axion density is [18]

$$\Omega_A h^2 \approx 88 \times 3^{\pm 1} \left[(1 + \alpha/\kappa)^{3/2} - 1 \right] (1 \,\mu\text{eV}/m_A)^{1.175} ,$$
 (7)

where the stated nominal uncertainty has the same source as in Eq. (6). The values of α and κ are not known, but probably $0.1 < \alpha/\kappa < 1.0$ [18], taking the expression in square brackets to 0.15–1.83. If axions are the dark matter, we have

$$0.05 \lesssim \Omega_A h^2 \lesssim 0.50 , \qquad (8)$$

where it was assumed that the universe is older than 10 Gyr, that the dark-matter density is dominated by axions with $\Omega_A \gtrsim 0.2$, and that $h \gtrsim 0.5$. This implies $m_A = 6-2500~\mu\text{eV}$ for the plausible mass range of dark-matter axions (Fig. 1).

Contrary to Ref. 18, Sikivie et al. [19] find that the motion of global strings is strongly damped, leading to a flat axion spectrum. In Battye and Shellard's treatment the axion radiation is strongly peaked at wavelengths of order the loop size. In Sikivie et al.'s picture more of the string radiation goes into kinetic axion energy which is redshifted so that ultimately there are fewer axions. In this scenario the contributions from string decay and vacuum realignment are of the same order of magnitude; they are both given by Eq. (6) with Θ_i of order one. As a consequence, Sikivie et al. allow for a plausible range of dark-matter axions which reaches to smaller masses as indicated in Fig. 1.

The work of both groups implies that the low-mass end of the plausible mass interval in the string scenario overlaps with the projected sensitivity range of the U.S. search experiment for galactic dark-matter axions (Livermore) [20] and of the Kyoto search experiment CARRACK [21] as indicated in Fig. 1. (See also Part III of this Review by Hagmann, van Bibber, and Rosenberg.)

In summary, a variety of robust astrophysical arguments and laboratory experiments (Fig. 1) indicate that $m_A \lesssim 10^{-2}$ eV. The exact value of this limit may change with a more sophisticated treatment of supernova physics and/or the observation of the neutrino signal from a future galactic supernova, but a dramatic modification is not expected unless someone puts forth a completely new argument. The stellar-evolution limits shown in Fig. 1 depend on the axion couplings to various particles and thus can be irrelevant in fine-tuned models where, for example, the axion-photon coupling strictly vanishes. For nearly any m_A in the range generically allowed by stellar evolution, axions could be the cosmic dark matter, depending on the cosmological scenario realized in nature. It appears that our only practical chance to discover these "invisible" particles rests with the ongoing or future search experiments for galactic dark-matter.

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AXIONS AND OTHER VERY LIGHT BOSONS, PART III (EXPERIMENTAL LIMITS)

(by C. Hagmann, K. van Bibber, and L.J. Rosenberg)

In this section we review the experimental methodology and limits on light axions and light pseudoscalars in general. (A comprehensive overview of axion theory is given by H. Murayama in the Part I of this Review, whose notation we follow [1].) Within its scope are searches where the axion is assumed to be dark matter, searches where the Sun is presumed to be a source of axions, and purely laboratory experiments. We restrict the discussion to axions of mass $m_A < O(eV)$, as the allowed range for the axion mass is nominally $10^{-6} < m_A < 10^{-2}$ eV. Experimental work in this range predominantly has been through the axion-photon coupling $g_{A\gamma}$, to which the present review is confined. As discussed in Part II of this Review by G. Raffelt, the lower bound derives from a cosmological overclosure argument, and the upper bound from SN1987A [2]. Limits from stellar evolution overlap seamlessly above that, connecting with accelerator-based limits which ruled out the original axion. There it was assumed that the Peccei-Quinn symmetry-breaking scale was the electroweak scale, i.e., $f_A \sim 250$ GeV, implying axions of mass $m_A \sim O(100\,\mathrm{keV})$. These earlier limits from nuclear transitions, particle decays, etc., while not discussed here, are included in the Listings.

While the axion mass is well determined by the Peccei-Quinn scale, i.e., $m_A = 0.62$ eV $(10^7 \text{ GeV}/f_A)$, the axionphoton coupling $g_{A\gamma}$ is not: $g_{A\gamma} = (\alpha/\pi f_A) g_{\gamma}$, with $g_{\gamma} =$ (E/N-1.92)/2, where E/N is a model-dependent number. It is noteworthy however, that two quite distinct models lead to axion-photon couplings which are not very different. For the case of axions imbedded in Grand Unified Theories, the DFSZ axion [3], $g_{\gamma} = 0.37$, whereas in one popular implementation of the "hadronic" class of axions, the KSVZ axion [4], $g_{\gamma} = -0.96$. The Lagrangian $L = g_{A\gamma} \mathbf{E} \cdot \mathbf{B} \phi_A$, with ϕ_A the axion field, permits the conversion of an axion into a single real photon in an external electromagnetic field, i.e., a Primakoff interaction. In the case of relativistic axions, $k_{\gamma} - k_{A} \sim m_{A}^{2}/2\omega \ll \omega$, pertinent to several experiments below, coherent axion-photon mixing in long magnetic fields results in significant conversion probability even for very weakly coupled axions [5].

Below are discussed several experimental techniques constraining $g_{A\gamma}$, and their results. Also included are recent but yet-unpublished results, and projected sensitivities for experiments soon to be upgraded.

III.1. Microwave cavity experiments: Possibly the most promising avenue to the discovery of the axion presumes that axions constitute a significant fraction of the dark matter halo of our galaxy. The maximum likelihood density for the Cold Dark Matter (CDM) component of our galactic halo is $\rho_{\text{CDM}} = 7.5 \times 10^{-25} \text{g/cm}^3 (450 \, \text{MeV/cm}^3)$ [6]. That the CDM halo is in fact made of axions (rather than e.g. WIMPs) is in principle an independent assumption, however should very light axions exist they would almost necessarily be cosmologically

abundant [2]. As shown by Sikivie [7], halo axions may be detected by their resonant conversion into a quasi-monochromatic microwave signal in a high-Q cavity permeated by a strong magnetic field. The cavity is tunable and the signal is maximum when the frequency $\nu = m_A(1 + O(10^{-6}))$, the width of the peak representing the virial distribution of thermalized axions in the galactic gravitational potential. The signal may possess ultra-fine structure due to axions recently fallen into the galaxy and not yet thermalized [8]. The feasibility of the technique was established in early experiments of small sensitive volume, V = O(1 liter) [9,10] with High Electron Mobility Transistor (HEMT) amplifiers, which set limits on axions in the mass range $4.5 < m_A < 16.3 \,\mu\text{eV}$, but at power sensitivity levels 2-3 orders of magnitude too high to see KSVZ and DFSZ axions (the conversion power $P_{A\to\gamma}\propto g_{A\gamma}^2$). A recent large-scale experiment ($B \sim 7.5 \, \mathrm{T}, V \sim 200 \, \mathrm{liter}$) has achieved sensitivity to KSVZ axions over a narrow mass range $2.77 < m_A < 3.3 \,\mu\text{eV}$, and continues to take data [11]. The exclusion regions shown in Fig. 1 for Refs. [9-12] are all normalized to the best-fit Cold Dark Matter density $\rho_{\rm CDM} = 7.5 \times 10^{-25} {\rm g/cm^3 (450 \, MeV/cm^3)}$, and 90% CL. Recent developments in DC SQUID amplifiers [12] and Rydberg atom single-quantum detectors [13] promise dramatic improvements in noise temperature, which will enable rapid scanning of the axion mass range at or below the DFSZ limit. The region of the microwave cavity experiments is shown in detail in Fig. 2.

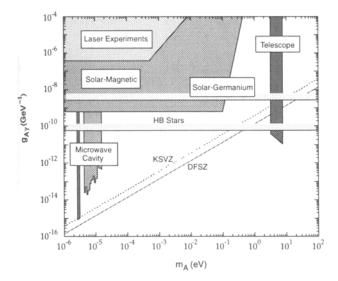


Figure 1: Exclusion region in mass vs. axion-photon coupling $(m_A, g_{A\gamma})$ for various experiments. The limit set by globular cluster Horizontal Branch Stars ("HB Stars") is shown for Ref. 2.

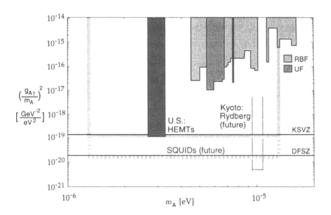


Figure 2: Exclusion region from the microwave cavity experiments, where the plot is flattened by presenting $(g_{A\gamma}/m_A)^2$ vs. m_A . The first-generation experiments (Rochester-BNL-FNAL, "RBF" [9]; University of Florida, "UF" [10]) and the US large-scale experiment in progress ("US" [11]) are all HEMT-based. Shown also is the full mass range to be covered by the latter experiment (shaded line), and the improved sensitivity when upgraded with DC SQUID amplifiers [12] (shaded dashed line). The expected performance of the Kyoto experiment based on a Rydberg atom single-quantum receiver (dotted line) is also shown [13].

III.2. Telescope search for eV axions: For axions of mass greater than about 10^{-1} eV, their cosmological abundance is no longer dominated by vacuum misalignment or string radiation mechanisms, but rather by thermal production. Their contribution to the critical density is small, $\Omega \sim 0.01 \, (m_A/\text{eV})$. However, the spontaneous-decay lifetime of axions, $\tau(A \rightarrow$ $(2\gamma) \sim 10^{25} \text{sec}(m_A/\text{eV})^{-5}$ while irrelevant for μeV axions, is short enough to afford a powerful constraint on such thermally produced axions in the eV range, by looking for a quasimonochromatic photon line from galactic clusters. This line, corrected for Doppler shift, would be at half the axion mass and its width would be consistent with the observed virial motion, typically $\Delta \lambda/\lambda \sim 10^{-2}$. The expected line intensity would be of the order $I_A \sim 10^{-17} (m_A/3 \, \text{eV})^7 \text{erg cm}^{-2} \text{arcsec}^{-2} \text{Å}^{-1} \text{sec}^{-1}$ for DFSZ axions, comparable to the continuum night emission. The conservative assumption is made that the relative density of thermal axions fallen into the cluster gravitational potential reflects their overall cosmological abundance. A search for thermal axions in three rich Abell clusters was carried out at Kitt Peak National Laboratory [14]; no such line was observed between 3100-8300 Å ($m_A = 3-8$ eV) after "on-off field" subtraction of the atmospheric molecular background spectra. A limit everywhere stronger than $g_{A\gamma} < 10^{-10} \text{GeV}^{-1}$ is set, which is seen from Fig. 1 to easily exclude DFSZ axions throughout the mass range.

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III.3. A search for solar axions: As with the telescope search for thermally produced axions above, the search for solar axions was stimulated by the possibility of there being a "1 eV window" for hadronic axions (i.e., axions with no treelevel coupling to leptons), a "window" subsequently closed by an improved understanding of the evolution of globular cluster stars and SN1987A [2]. Hadronic axions would be copiously produced within our Sun's interior by a Primakoff process. Their flux at the Earth of $\sim 10^{12} \text{cm}^{-2} \text{sec}^{-1} (m_A/\text{eV})^2$, which is independent of the details of the solar model, is sufficient for a definitive test via the axion reconversion to photons in a large magnetic field. However, their average energy is ~ 4 keV, implying an oscillation length in the vacuum of $2\pi (m_A^2/2\omega)^{-1} \sim O(\text{mm})$, precluding the mixing from achieving its theoretically maximum value in any practical magnet. It was recognized that one could endow the photon with an effective mass in a gas, $m_{\gamma} = \omega_{\rm ph}$ thus permitting the axion and photon dispersion relationships to be matched [15]. A first simple implementation of this proposal was carried out using a conventional dipole magnet with a conversion volume of variable-pressure helium gas and a xenon proportional chamber as the x-ray detector [16]. The magnet was fixed in orientation to take data for $\sim 1000 \sec/day$. Axions were excluded for $g_{A\gamma} < 3.6 \times 10^{-9} {\rm GeV^{-1}}$ for $m_A <$ $0.03\,\mathrm{eV}, \ \mathrm{and} \ g_{A\gamma} < 7.7 \times 10^{-9} \mathrm{GeV}^{-1} \ \mathrm{for} \ 0.03\,\mathrm{eV} < m_A < 0.11$ eV (95% CL). A more ambitious experiment has recently been commissioned, using a superconducting magnet on a telescope mount to track the Sun continuously. A preliminary exclusion limit of $g_{A\gamma} < 6 \times 10^{-10} \text{GeV}^{-1}$ (95% CL) has been set for $m_A < 0.03 \text{ eV } [17].$

Another search for solar axions has been carried out, using a single crystal germanium detector. It exploits the coherent conversion of axions into photons when their angle of incidence satisfies a Bragg condition with a crystalline plane. Analysis of 1.94 kg-yr of data from a 1 kg germanium detector yields a bound of $g_{A\gamma} < 2.7 \times 10^{-9} {\rm GeV}^{-1}$ (95% CL), independent of mass up to $m_A \sim 1$ keV [18].

III.4. Photon regeneration ("invisible light shining

through walls"): Photons propagating through a transverse field (with E||B) may convert into axions. For light axions with $m_A^2 l/2\omega \ll 2\pi$, where l is the length of the magnetic field, the axion beam produced is colinear and coherent with the photon beam, and the conversion probability Π is given by $\Pi \sim (1/4)(g_{A\gamma}Bl)^2$. An ideal implementation for this limit is a laser beam propagating down a long, superconducting dipole magnet like those for high-energy physics accelerators. If another such dipole magnet is set up in line with the first, with an optical barrier interposed between them, then photons may be regenerated from the pure axion beam in the second magnet and detected [19]. The overall probability $P(\gamma \to A \to \gamma) = \Pi^2$. Such an experiment has been carried

out, utilizing two magnets of length l=4.4 m and B=3.7 T.

Axions with mass $m_A < 10^{-3}$ eV, and $g_{A\gamma} > 6.7 \times 10^{-7} \text{GeV}^{-1}$

were excluded at 95% CL [20,21]. With sufficient effort, limits

comparable to those from stellar evolution would be achievable. Due to the $g_{A\gamma}^4$ rate suppression however, it does not seem feasible to reach standard axion couplings.

III.5. Polarization experiments: The existence of axions can affect the polarization of light propagating through a transverse magnetic field in two ways [22]. First, as the E_{\parallel} component, but not the E_{\perp} component will be depleted by the production of real axions, there will be in general a small rotation of the polarization vector of linearly polarized light. This effect will be a constant for all sufficiently light m_A such that the oscillation length is much longer than the magnet $(m_A^2 l/2\omega \ll 2\pi)$. For heavier axions, the effect oscillates and diminishes with increasing m_A , and vanishes for $m_A > \omega$. The second effect is birefringence of the vacuum, again because there can be a mixing of virtual axions in the E_{\parallel} state, but not for the E_{\perp} state. This will lead to light which is initially linearly polarized becoming elliptically polarized. Higher-order QED also induces vacuum birefringence, and is much stronger than the contribution due to axions. A search for both polarizationrotation and induced ellipticity has been carried out with the same magnets described in Sec. (III.4) above [21,23]. As in the case of photon regeneration, the observables are boosted linearly by the number of passes the laser beam makes in an optical cavity within the magnet. The polarization-rotation resulted in a stronger limit than that from ellipticity, $g_{A\gamma}$ < $3.6 \times 10^{-7} {\rm GeV^{-1}}$ (95% CL) for $m_A < 5 \times 10^{-4}$ eV. The limits from ellipticity are better at higher masses, as they fall off smoothly and do not terminate at m_A . There are two experiments in construction with greatly improved sensitivity which while still far from being able to detect standard axions, should measure the QED "light-by-light" contribution for the first time [24,25]. The overall envelope for limits from the laser-based experiments in Sec. (III.4) and Sec. (III.5) is shown schematically in Fig. 1.

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A⁰ (Axion) MASS LIMITS from Astrophysics and Cosmology

These bounds depend on model-dependent assumptions (i.e. — on a combination of axion parameters).

VALUE (MeV)	DOCUMENT ID	TEC	N COMMENT
• • • We do not use t	he following data for average	s, fits, lim	its, etc. • • •
>0.2	BARROSO	82 A5	FR Standard Axion
>0.25	¹ RAFFELT	82 AS	FR Standard Axion
>0.2	² DICUS	78C AS	TR Standard Axion
	MIKAELIAN	78 AS	TR Stellar emission
>0.3	² SATO	78 AS	TR Standard Axion
>0.2	VYSOTSKII	78 AS	TR Standard Axlon

Lower bound from 5.5 MeV γ -ray line from the sun.

A^0 (Axion) and Other Light Boson (X^0) Searches in Stable Particle Decays

imits are for D	ranching ratios.			
	CL% EVTS	DOCUMENT ID	TECN	COMMENT
We do not use	the following da	ta for averages, fits	i, limits, etc.	• • •
× 10 ⁻¹⁰	90	3 ADLER	97 B787	$K^+ \rightarrow \pi^+ A^0$
× 10 ⁻⁸	90	4 KITCHING	97 B787	$K^+ \rightarrow \pi^+ A^0$
× 10 ⁻¹⁰	90	5 ADLER	96 B787	$\begin{array}{c} (A^0 \rightarrow \gamma \gamma) \\ K^+ \rightarrow \pi^+ A^0 \end{array}$
× 10 ⁻⁴	90	⁶ AMSLER	96B CBAR	$m_{\chi^0}^0 \rightarrow \gamma \chi^0$, $m_{\chi^0}^{} < 65 \text{ MeV}$
× 10 ⁻⁴	90	6 AMSLER		$\eta \rightarrow \gamma X^0, m_{X^0} =$
× 10 ⁻⁵	90	⁶ AMSLER	96B CBAR	$\eta' \xrightarrow{50-200} \text{MeV}$ $\eta' \xrightarrow{\gamma} \gamma X^0$, $m_{X^0} = 50-925$
× 10 ⁻⁵	90	⁶ AMSLER	94B CBAR	$\pi^0 \xrightarrow{\text{MeV}} \gamma X^0$, $m_{X^0} = 65 - 125$
× 10 ⁻⁵	90	6 AMSLER	94B CBAR	$ \begin{array}{c} \text{MeV} \\ \eta \to \gamma X^0, \\ m_{X^0} = 200 - 525 \end{array} $
7	90	⁷ MEIJERDREE	S94 CNTR	
2	90	⁷ MEIJERDREE	594 CNTR	$\pi^0 \xrightarrow{\gamma} {\gamma}^{0},$ $m_{\chi^0} = 100 \text{ MeV}$
× 10 ⁻⁷ × 10 ⁻¹³	90	8 ATIYA 9 NG	938 B787 93 COSM	$K^+ \rightarrow \pi^+ A^0$
	We do not use × 10 ⁻¹⁰ × 10 ⁻⁸ × 10 ⁻¹⁰ × 10 ⁻⁴ × 10 ⁻⁵ × 10 ⁻⁵ × 10 ⁻⁵ × 10 ⁻⁵	We do not use the following da $\times 10^{-10}$ 90 $\times 10^{-8}$ 90 $\times 10^{-10}$ 90 $\times 10^{-4}$ 90 $\times 10^{-4}$ 90 $\times 10^{-5}$ 90 $\times 10^{-5}$ 90 $\times 10^{-5}$ 90 $\times 10^{-5}$ 90 $\times 10^{-7}$ 90	CL% EVTS DOCUMENT ID We do not use the following data for averages, fits x 10−10 90 3 ADLER 4 KITCHING x 10−10 90 5 ADLER 6 AMSLER x 10−4 90 6 AMSLER x 10−5 90 7 MEIJERDREE x 10−7 90 8 ATIYA	CL% EVTS DOCUMENT ID TECN We do not use the following data for averages, fits, limits, etc. x 10 ⁻¹⁰ 90 3 ADLER 97 B787 x 10 ⁻⁸ 90 4 KITCHING 97 B787 x 10 ⁻¹⁰ 90 5 ADLER 96 B787 x 10 ⁻⁴ 90 6 AMSLER 968 CBAR x 10 ⁻⁵ 90 6 AMSLER 968 CBAR x 10 ⁻⁵ 90 6 AMSLER 948 CBAR x 10 ⁻⁵ 90 6 AMSLER 948 CBAR x 10 ⁻⁵ 90 6 AMSLER 948 CBAR y 10 ⁻⁵ 90 7 MEIJERDREES 94 CNTR 2 90 7 MEIJERDREES 94 CNTR 2 90 7 MEIJERDREES 94 CNTR 38 ATIYA 938 B787

<1.1	× 10 ⁻⁸	90		¹⁰ ALLIEGRO	92	SPEC	$ \begin{array}{c} K^{+} \overrightarrow{\rightarrow} \pi^{+} A^{0} \\ (A^{0} \rightarrow e^{+} e^{-}) \\ \pi^{0} \rightarrow \gamma X^{0} \end{array} $
<5	× 10 ⁻⁴	90		11 ATIYA		B787	$\pi^0 \rightarrow \gamma X^0$
<4	× 10 ⁻⁶	90		12 MEIJERDREES	92	SPEC	$\pi^0 \rightarrow \gamma X^0$,
							$X^0 \rightarrow e^+e^-,$ $m_{\chi^0} = 100 \text{ MeV}$
<1	× 10 ⁻⁷	90		13 ATIYA	90B	B787	Sup. by KITCH-
<1.3	× 10 ⁻⁸	90		14 KORENCHE	87	SPEC	$ \begin{array}{c} \text{ING 97} \\ \pi^{+} \xrightarrow{\rightarrow} e^{+} \nu A^{0} \\ (A^{0} \xrightarrow{\rightarrow} e^{+} e^{-}) \end{array} $
<1	× 10 ⁻⁹	90	0	15 EICHLER	86	SPEC	Stopped $\pi^+ \rightarrow$
<2	× 10 ⁻⁵	90		16 YAMAZAKI	0.4	CDEC	e ⁺ νA ⁰ For 160< <i>m</i> <260
		90					MeV
<(1.5-	4) × 10 ⁻⁶	90		¹⁶ YAMAZAKI	84	SPEC	K decay, m _{A0} ≪
			0	17 ASANO	82	CNTR	100 MeV Stopped K ⁺ →
			•				π^+A^0
			0	18 ASANO	81B	CNTR	Stopped $K^+ \rightarrow \pi^+ A^0$
				¹⁹ ZHITNITSKII	79		π [™] A ^o Heavy axion

 3 ADLER 97 bound is for massless $A^0.$ 4 KITCHING 97 limit is for B(K+ $\rightarrow \ \pi^+A^0$)·B($A^0 \rightarrow \gamma\gamma$) and applies for $m_{A^0} \simeq 50$ MeV, $\tau_{A^0} < 10^{-10}\,\mathrm{s}$. Limits are provided for $0 < m_{A^0} < 100$ MeV, $\tau_{A^0} < 10^{-8}\,\mathrm{s}$.

⁵ ADLER 96 looked for a peak in missing-mass distribution. This work is an update of ATIYA 93. The limit is for massless stable A^0 particles and extends to m_{A^0} =80 MeV at the same level. See paper for dependence on finite lifetime.

⁶ AMSLER 94B and AMSLER 96B looked for a peak in missing-mass distribution.

⁷ The MEIJERDREES 94 limit is based on inclusive photon spectrum and is independent of X^0 decay modes. It applies to $\tau(X^0) > 10^{-23}$ sec.

 8 ATIYA 93B looked for a peak in missing mass distribution. The bound applies for stable 40 of m_{A^0} =150-250 MeV, and the limit becomes stronger (10⁻⁸) for m_{A^0} =180-240 MeV.

MeV. 9 NG 93 studled the production of X^0 via $\gamma\gamma \to \pi^0 \to \gamma X^0$ in the early universe at $T \simeq 1$ MeV. The bound on extra neutrinos from nucleosyntheis $\Delta N_{\nu} < 0.3$ (WALKER 91) is employed. It applies to $m_{X^0} \ll 1$ MeV in order to be relativistic down to nucleosynthesis temperature. See paper for heavier X^0 .

10 ALLIEGRO 92 limit applies for m_{A^0} =150-340 MeV and is the branching ratio times the decay ptobability. Limit is < 1.5 × 10⁻⁸ at 99%CL.

11 ATIYA 92 looked for a peak in missing mass distribution. The limit applies to $m_{\chi 0}$ =0-130 MeV in the narrow resonance limit. See paper for the dependence on

lifetime. Covariance requires X^0 to be a vector particle.

12 MEIJERDREES 92 limit applies for $\tau_{X^0} = 10^{-23}$ – 10^{-11} sec. Limits between 2×10^{-4} and 4×10^{-6} are obtained for $m_{X^0} = 25$ –120 MeV. Angular momentum conservation requires that X^0 has snin > 1.

requires that X^0 has spin ≥ 1 . 13 ATIYA 90B limit is for B($K^+ \to \pi^+ A^0$)·B($A^0 \to \gamma \gamma$) and applies for $m_{A^0} = 50$ MeV, $\tau_{A^0} < 10^{-10}$ s. Limits are also provided for $0 < m_{A^0} < 100$ MeV, $\tau_{A^0} < 10^{-8}$ s.

¹⁴ KORENCHENKO 87 limit assumes $m_{A^0} = 1.7$ MeV, $\tau_{A^0} \lesssim 10^{-12}$ s, and B($A^0 \rightarrow a^+a^-$) = 1

15 EICHLER 86 looked for $\pi^+ \to e^+ \nu A^0$ followed by $A^0 \to e^+ e^-$. Limits on the branching fraction depend on the mass and and lifetime of A^0 . The quoted limits are valid when $\tau(A^0) \gtrsim 3. \times 10^{-10} \mathrm{s}$ if the decays are kinematically allowed.

16 YAMAZAKI 84 looked for a discrete line in $K^+ \to \pi^+ X$. Sensitive to wide mass range (5–300 MeV), independent of whether X decays promptly or not.

 17 ASANO 82 at KEK set limits for B(K+ $\to ~\pi^+ A^0$) for $m_{A^0} <$ <100 MeV as BR $< 4. \times 10^{-8}$ for $\tau (A^0 \to ~n\gamma$'s) $> 1. \times 10^{-9}$ s, BR $< 1.4 \times 10^{-6}$ for $\tau < 1. \times 10^{-9}$ s.

¹⁸ ASANO 81B is KEK experiment. Set B($K^+ \to \pi^+ A^0$) < 3.8 × 10⁻⁸ at CL = 90%. ¹⁹ ZHITNITSKII 79 argue that a heavy axion predicted by YANG 78 (3 < m <40 MeV) contradicts experimental muon anomalous magnetic moments.

A⁰ (Axion) Searches in Quarkonium Decays

Decay or transition of quarkonium. Limits are for branching ratio.

VALUE	CL% EVTS	DOCUMENT ID		<u>TECN</u>	COMMENT
• • • We do not	use the following	ng data for averages	, fits	, limits,	etc. • • •
$< 1.3 \times 10^{-5}$	90	20 BALEST	95	CLEO	$\Upsilon(1S) \rightarrow A^0 \gamma$
$< 4.0 \times 10^{-5}$	90	ANTREASYAN			$\Upsilon(1S) \rightarrow A^0 \gamma$
		21 ANTREASYAN	90C	RVUE	
$< 5 \times 10^{-5}$	90	²² DRUZHININ	87	ND	$\phi \rightarrow A^0 \gamma$
					$(A^0 \rightarrow e^+e^-)$
<2 × 10 ⁻³	90	²³ DRUZHININ	87	ND	$(A^0 \to e^+e^-)$ $\phi \to A^0 \gamma (A^0 \to \gamma \gamma)$
$< 7 \times 10^{-6}$	90	²⁴ DRUZHININ	87	ND	$\phi \rightarrow A^0 \gamma$
					$(A^0 \rightarrow mlssing)$
$< 3.1 \times 10^{-4}$	90 0	²⁵ ALBRECHT	86D	ARG	$\gamma(1S) \rightarrow A^0 \gamma$ $(A^0 \rightarrow e^+e^-)$
					$(A^0 \rightarrow e^+e^-)$

² Lower bound from requiring the red glants' stellar evolution not be disrupted by axion emission.

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$<4 \times 10^{-4}$	90	0	25 ALBRECHT	86D AF	RG T	$r(1S) \rightarrow (A^0 \rightarrow$	$A^0\gamma$
						$(A^0 \rightarrow$	$\mu^{+}\mu^{-}$,
							K^+K^-
<8 × 10 ⁻⁴	90	1	²⁶ ALBRECHT	860 AF	RG 1	r(15) →	$A^0\gamma$
$< 1.3 \times 10^{-3}$	90	0	27 ALBRECHT	86D AF	RG T	r(1 <i>s</i>) →	$A^0\gamma$
						$(A^0 \rightarrow$	$e^+e^-, \gamma\gamma)$
$<2. \times 10^{-3}$	90		²⁸ BOWCOCK	86 CL	LEO T	r(25) →	γ(15) →
_						⊿ 0	_
<5. × 10 ⁻³	90		²⁹ MAGERAS	86 CL	JSB 1	r(15) →	$A^0\gamma$
$< 3. \times 10^{-4}$	90		³⁰ ALAM	83 CL	LEO 1	r(15) →	$A^0\gamma$
$< 9.1 \times 10^{-4}$	90		31 NICZYPORUK	83 LE	ENA 1	r(15) →	$A^0\gamma$
$< 1.4 \times 10^{-5}$	90		32 EDWARDS	82 CE	BAL J	$I/\psi \rightarrow A^0$	$^{\circ}\gamma$
$< 3.5 \times 10^{-4}$	90		33 SIVERTZ	82 CL	USB 1	r(15) →	$A^0\gamma$
$< 1.2 \times 10^{-4}$	90		33 SIVERTZ	82 CL	USB 1	r(35) →	$A^0\gamma$
20							

²⁰ BALEST 95 tooked for a monochromatic γ from T(1.5) decay. The bound is for $m_{A0} < 5.0$ GeV. See Fig. 7 in the paper for bounds for heavier m_{A0} . They also quote a bound on branching ratios 10⁻³-10⁻⁵ of three-body decay $\gamma X \overline{X}$ for $0 < m_X < 3.1$ GeV.

²¹ The combined limit of ANTREASYAN 90c and EDWARDS 82 excludes standard axion with $m_{A^0} < 2m_e$ at 90% CL as long as $C_T C_{J/\psi} > 0.09$, where $C_V \ (V = T, J/\psi)$ Is the reduction factor for $\Gamma(V \to A^0 \gamma)$ due to QCD and/or relativistic corrections. The same data excludes 0.02 < x < 260 (90% CL) if $C_T = C_{J/\psi} = 0.5$, and further combining with ALBRECHT 86D result excludes $5 \times 10^{-5} < x < 260$. x is the ratio of the vacuum expectation values of the two Higgs fields. These limits use conventional assumption $\Gamma(A^0 \to ee) \propto x^{-2}$. The alternative assumption $\Gamma(A^0 \to ee) \propto x^2$ gives a somewhat different excluded region 0.00075 < x < 44. 22 The first DRIZHININ 87 limit is valid when $\tau_{A^0}/m_{A^0} < 3 \times 10^{-13}$ s/MeV and

 m_{A^0} < 20 MeV.

²³ The second DRUZHININ 87 limit is valid when au_{A0}/m_{A^0} < 5 × 10 $^{-13}$ s/MeV and m_{A^0} < 20 MeV.

²⁴ The third DRUZHININ 87 limit is valid when $au_{A^0}/m_{A^0} > 7 imes 10^{-12}$ s/MeV and m_{A^0} < 200 MeV.

 $^{25}\tau_{A^0}<1\times10^{-13}{\rm s}$ and $m_{A^0}<1.5$ GeV. Applies for $A^0\to\gamma\gamma$ when $m_{A^0}<100$ MeV. $^{26}\tau_{A^0}>1\times10^{-7}{\rm s}.$

27 Independent of TAO.

²⁸ BOWCOCK 86 looked for A^0 that decays into e^+e^- in the cascade decay $\Upsilon(25) \rightarrow$ $\Upsilon(1S)\pi^+\pi^-$ followed by $\Upsilon(1S)\to A^0\gamma$. The limit for B($\Upsilon(1S)\to A^0\gamma$)B($A^0\to$ e^+e^-) depends on m_{A^0} and τ_{A^0} . The quoted limit for m_{A^0} =1.8 MeV is at $\tau_{A^0}\sim$ 2. \times 10⁻¹²s, where the limit is the worst. The same limit 2. \times 10⁻³ applies for all lifetimes for masses $2m_e < m_{A^0} < 2m_{\mu}$ when the results of this experiment are combined with the results of ALAM 83.
29 MAGERAS 86 looked for $\mathcal{T}(15) \to \gamma A^0$ ($A^0 \to e^+e^-$). The quoted branching fraction limit is for $m_{A^0} = 1.7$ MeV, at $\tau(A^0) \sim 4. \times 10^{-13}$ s where the limit is the worst

worst. 30 ALAM 83 is at CESR. This limit combined with limit for B($J/\psi \to A^0\gamma$) (EDWARDS 82)

excludes standard axion. 31 NICZYPORUK 83 is DESY-DORIS experiment. This limit together with lower limit 9.2×10^{-4} of B($\Upsilon \to A^0 \gamma$) derived from B($J/\psi(15) \to A^0 \gamma$) limit (EDWARDS 82) excludes standard axion

³² EDWARDS 82 looked for $J/\psi \rightarrow \gamma A^0$ decays by looking for events with a single γ [of energy \sim 1/2 the $J/\psi(15)$ mass], plus nothing else in the detector. The limit is inconsistent with the axion interpretation of the FAISSNER 81B result.

³³ SIVERTZ 82 is CESR experiment. Looked for $au o \gamma A^0$, A^0 undetected. Limit for 15 (35) is valid for $m_{A^0} < 7$ GeV (4 GeV).

A⁰ (Axion) Searches in Positronium Decays

Decay or transition of positronium. Limits are for branching ratio.

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not us	e the followi	ng data for average	es, fit	s, limits,	etc. • • •
<2 × 10 ⁻⁴	90	MAENO	95	CNTR	$o - Ps \rightarrow A^0 \gamma$ $m_{A^0} = 850 - 1013 \text{ keV}$
$< 3.0 \times 10^{-3}$	90	³⁴ ASAI	94	CNTR	$o\text{-Ps} \xrightarrow{A^0} A^0 \gamma$ $m_{\Delta 0} = 30 - 500 \text{ keV}$
$< 2.8 \times 10^{-5}$	90	³⁵ AKOPYAN	91	CNTR	o-Ps $\xrightarrow{A^0}$ $A^0 \gamma$ $(A^0 \rightarrow \gamma \gamma),$ $m_{A^0} < 30 \text{ keV}$
<1.1 × 10 ⁻⁶	90	36 ASAI	91	CNTR	$m_{A^0} < 30 \text{ keV}$ $o\text{-Ps} \rightarrow A^0 \gamma$, $m_{A^0} < 800 \text{ keV}$
$< 3.8 \times 10^{-4}$	90	GNINENKO	90	CNTR	$o\text{-Ps} \xrightarrow{\alpha} A^0 \gamma, m_{A^0} <$
<(1~5) × 10 ⁻⁴	95	37 TSUCHIAKI	90	CNTR	30 keV o-Ps $\rightarrow A^0 \gamma$, $m_{A^0} = 300-900 \text{ keV}$
<6.4 × 10 ⁻⁵	90	³⁸ ORITO	89	CNTR	0.900 + 900 keV $0.95 \rightarrow A^{0} \gamma$, $m_{A^{0}} < 30 \text{ keV}$
		39 AMALDI 40 CARRONI	85	CNTR	

 $^{^{34}}$ The ASAI 94 limit is based on inclusive photon spectrum and is independent of ${\it A}^{0}$ decay

- 38 ORITO 89 limit translates to $g_{A^0\,e\,e}^2/4\pi~<6.2 imes10^{-10}$. Somewhat more sensitive limits are obtained for larger m_{A^0} : $B < 7.6 \times 10^{-6}$ at 100 keV. ³⁹ AMALDI 85 set limits $B(A^0\gamma) / B(\gamma\gamma\gamma) < (1-5) \times 10^{-6}$ for $m_{A^0} = 900$ –100 keV
- which are about 1/10 of the CARBONI 83 limits.
- 40 CARBONI 83 looked for orthopositronium $\rightarrow A^0 \gamma$. Set limit for A^0 electron coupling squared, $g(e e A^0)^2/(4\pi) < 6 \times 10^{-10} 7 \times 10^{-9}$ for m_{A^0} from 150–900 keV (CL = 99.7%). This is about 1/10 of the bound from g-2 experiments.

A⁰ (Axion) Search in Photoproduction

DOCUMENT ID COMMENT

⁴¹ BASSOMPIE... 95 $m_{A^0} = 1.8 \pm 0.2 \text{ MeV}$

TECN COMMENT

41 BASSOMPIERRE 95 is an extension of BASSOMPIERRE 93. They looked for a peak in the invariant mass of e^+e^- pairs in the region $m_{e^+e^-}=1.8\pm0.2$ MeV. They obtained bounds on the production rate A^0 for $\tau(A^0)=10^{-18}-10^{-9}$ sec. They also found an excess of events in the range $m_{e^+e^-}=2.1$ -3.5 MeV.

DOCUMENT ID

A⁰ (Axion) Production in Hadron Collisions Limits are for $\sigma(A^0)$ / $\sigma(\pi^0)$. CL% EVTS

VALUE		<u> CL% _</u>	<u>EVTS</u>	DOCUMENT ID		<u>TECN</u>	COMMENT
• • • ٧	Ve do not	use the	followin	ng data for average	s, fits	, ilmits,	etc. • • •
				⁴² AHMAD	97	SPEC	e ⁺ production
				43 LEINBERGER		SPEC	
				44 GANZ	96	SPEC	$A^0 \rightarrow e^+e^-$
				45 KAMEL	96	EMUL	32S emulsion, A ⁰ → e ⁺ e ⁻
				46 BLUEMLEIN	92	BDMP	
				47 MEIJERDREE	S 92	SPEC	$\pi^- p \rightarrow nA^0, A^0 \rightarrow$
				48 BLUEMLEIN	91	BDMP	$A^0 \rightarrow e^+e^-, 2\gamma$
				⁴⁹ FAISSNER	89	OSPK	
				⁵⁰ DEBOER	88	RVUE	$A^0 \xrightarrow{e^+e^-} e^-$
				51 EL-NADI	88	EMUL	$A^0 \rightarrow e^+e^-$
				52 FAISSNER	88	OSPK	Beam dump, $A^0 \rightarrow 2\gamma$
				53 BADIER	86	BDMP	$A^0 \rightarrow e^+e^-$
<2. ×	10-11	90	0	54 BERGSMA	85	CHRM	CERN beam dump
<1. ×	10-13	90	0	54 BERGSMA	85	CHRM	CERN beam dump
			24	55 FAISSNER	83	OSPK	Beam dump, $A^0 \rightarrow 2^{\circ}$
				⁵⁶ FAISSNER	83B	RVUE	LAMPF beam dump
				⁵⁷ FRANK	83B	RVUE	LAMPF beam dump
				⁵⁸ HOFFMAN	83	CNTR	$\pi p \rightarrow nA^0$ $(A^0 \rightarrow e^+e^-)$
				⁵⁹ FETSCHER	82	RVUE	See FAISSNER 818
			12	⁶⁰ FAISSNER	81	OSPK	CERN PS ν wideband
			15	⁶¹ FAISSNER	81B	OSPK	Beam dump, $A^0 \rightarrow 2$
			8	⁶² KIM	81	OSPK	26 GeV $pN \rightarrow A^0X$
			0	⁶³ FAISSNER	80	OSPK	Beam dump, $A^0 \rightarrow e^+e^-$
<1. ×	10-8	90		64 JACQUES	80	HLBC	28 GeV protons
<1. ×	10^{-14}	90		64 JACQUES	80	HLBC	Beam dump
				65 SOUKAS	80	CALO	28 GeV p beam dump
	_			66 BECHIS	79	CNTR	
<1. ×		90		67 COTEUS	79	OSPK	Beam dump
<1. ×		95		68 DISHAW	79	CALO	400 GeV pp
<1. ×		90		ALIBRAN	78		Beam dump
<6. ×		95		ASRATYAN		CALO	
<1.5 ×		90		69 BELLOTTI	78	HLBC	Beam dump
<5.4 ×		90		69 BELLOTTI	78	HLBC	m _{A0} =1.5 MeV
<4.1 ×		90		69 BELLOTTI	78	HLBC	m _{A0} =1 MeV
<1. ×	10-8	90		70 BOSETTI	78 8	HYBR	Beam dump

73 VYSOTSKII 78 42 AHMAD 97 reports a result of APEX Collaboration which studied positron production in $^{238} \rm U + ^{232} \rm Ta$ and $^{238} \rm U + ^{181} \rm Ta$ collisions, without requiring a coincident electron. No narrow lines were found for 250 <E $_{e^+}$ < 750 keV.

⁷² MICELMAC... 78

78

780 WIRE Beam dump

71 DONNELLY

HANSL

 $< 0.5 \times 10^{-8}$

- 43 LEINBERGER 97 (ORANGE Collaboration) at GSI looked for a narrow sum-energy e^+e^- -line at \sim 635 keV in 238 U+ 181 Ta collision. Limits on the production probability bility for a narrow sum-energy e^+e^- line are set. See their Table 2.
- 44 GANZ 96 (EPos II Collaboration) has placed upper bounds on the production cross section of e^+e^- pairs from 238 U+ 181 Ta and 238 U+ 232 Th collisions at GSI. See Table 2 for limits both for back-to-back and isotropic configurations of ${\it e^+\,e^-}$ pairs. These limits rule out the existence of peaks in the e^+e^- sum-energy distribution, reported by an earlier version of this experiment.
- earlier version of this experiment. 45 KAMEL 96 looked for e^+e^- pairs from the collison of 32 5 (200 GeV/nucleon) and emulsion. No evidence of mass peaks is found in the region of sensitivity $m_{ee} > 2$ MeV.
- ⁴⁶ BLUEMLEIN 92 is a proton beam dump experiment at Serpukhov with a secondary target to induce Bethe-Heitler production of e^+e^- or $\mu^+\mu^-$ from the produce A^0 target to induce x. See Fig. 5 for the excluded region in m_{A0} -x plane. For the standard axion, 0.3 < x<25 is excluded at 95% CL. If combined with BLUEMLEIN 91, 0.008 < x<32 is excluded.

³⁵ The AKOPYAN 91 limit applies for a short-lived A^0 with $\tau_{A^0} < 10^{-13}~m_{A^0}$ [keV] s. 36 ASAI 91 limit translates to $g_{A^0}^2 e^+ e^-/4\pi < 1.1 \times 10^{-11}$ (90%CL) for $m_{A^0} < 800$

 $^{^{37}\,\}text{The TSUCHIAKI 90 limit is based on inclusive photon spectrum and is independent of$ A⁰ decay modes.

- 47 MEIJERDREES 92 give $\Gamma(\pi^- p \rightarrow nA^0)$ B($A^0 \rightarrow e^+ e^-$)/ $\Gamma(\pi^- p \rightarrow all)$ < 10^{-5} (90% CL) for $m_{A^0} = 100$ MeV, $\tau_{A^0} = 10^{-11} - 10^{-23}$ sec. Limits ranging from 2.5 × 10^{-3} to 10^{-7} are given for $m_{A^0} = 25$ -136 MeV.
- 48 BLUEMLEIN 91 Is a proton beam dump experiment at Serpukhov. No candidate event for $A^0 \rightarrow e^+e^-$, 2γ are found. Fig. 6 gives the excluded region in m_{A^0} -x plane (x= $\tan \beta = v_2/v_1$). Standard axion is excluded for 0.2 $< m_{A^0} < 3.2$ MeV for most
- x>1, 0.2–11 MeV for most x<1. ⁴⁹ FAISSNER 89 searched for $A^0\to e^+e^-$ in a proton beam dump experiment at SIN. No excess of events was observed over the background. A standard axion with mass 2m-20 MeV is excluded. Lower limit on f_{A0} of $\simeq 10^4$ GeV is given for $m_{A0} = 2m_e$ -20 MeV.
- 50 DEBOER 88 reanalyze EL-NADI 88 data and claim evidence for three distinct states with mass \sim 1.1, \sim 2.1, and \sim 9 MeV, lifetimes 10^{-16} - 10^{-15} s decaying to $e^+e^$ and note the similarity of the data with those of a cosmic-ray experiment by Bristol group (B.M. Anand, Proc. of the Royal Society of London, Section A A22 183 (1953)). For a criticism see PERKINS 89, who suggests that the events are compatible with π^0 Dalitz decay. DEBOER 89B Is a reply which contests the criticism.
- 51 EL-NADI 88 claim the existence of a neutral particle decaying into e^+e^- with mass 1.60 \pm 0.59 MeV, lifetime (0.15 \pm 0.01) \times 10⁻¹⁴ s, which is produced in heavy ion interactions with emulsion nuclei at \sim 4 GeV/c/nucleon.
- 52 FAISSNER 88 is a proton beam dump experiment at SIN. They found no candidate event for $A^0 \to \gamma \gamma$. A standard axion decaying to 2γ is excluded except for a region $x\!\!\simeq 1$. Lower limit on f_{A^0} of 10^2 – 10^3 GeV is given for $m_{A^0}=0.1$ –1 MeV.
- 53 BADIER 86 did not find long-lived A^0 in 300 GeV π^- Beam Dump Experiment that decays into e^+e^- in the mass range $m_{A^0}=$ (20–200) MeV, which excludes the A^0 decay constant $f(A^0)$ in the interval (60-600) GeV. See their figure 6 for excluded region on $f(A^0)$ - m_{Δ^0} plane.
- ⁵⁴BERGSMA 85 look for $A^0 \rightarrow 2\gamma$, e^+e^- , $\mu^+\mu^-$. First limit above is for $m_{A^0}=1$ MeV; second is for 200 MeV. See their figure 4 for excluded region on $f_{A0} - m_{A0}^{(1)}$ plane, where t_{A0} is A^0 decay constant. For Peccel-Quinn PECCEI 77 A^0 , m_{A0} <180 keV and τ >0.037 s. (CL = 90%). For the axion of FAISSNER 81B at 250 keV, BERGSMA 85 expect 15 events but observe zero.
- 55 FAISSNER 83 observed 19 1-7 and 12 2-7 events where a background of 4.8 and 2.3 respectively is expected. A small-angle peak is observed even if Iron wall is set in front of the decay region.
- 56 FAISSNER 838 extrapolate SIN γ signal to LAMPF ν experimental condition. Resulting 370 γ 's are not at variance with LAMPF upper limit of 450 γ 's. Derived from LAMPF limit that $\left[d\sigma(A^0)/d\omega$ at 90° $M_{A^0}/\tau_{A^0} < 14 \times 10^{-35} \text{ cm}^2 \text{ sr}^{-1} \text{ MeV ms}^{-1}$. See comment on FRANK 83B.
- 57 FRANK 838 stress the importance of LAMPF data bins with negative net signal. By statistical analysis say that LAMPF and SIN-AO are at variance when extrapolation by phase-space model is done. They find LAMPF upper limit is 248 not 450 γ 's. See comment on FAISSNER 838. 58 HOFFMAN 83 set CL = 90% limit $d\sigma/dt$ B(e^+e^-) < 3.5 × 10⁻³² cm²/GeV² for 140
- < m_{A^0} < 160 MeV. Limit assumes $\tau(A^0) < 10^{-9}$ s.
- 59 FTSCHER 82 reanalyzes SIN beam-dump data of FAISSNER 81. Claims no evidence for axion since 2-γ peak rate remarkably decreases if iron wall is set in front of the decay
- 60 FAISSNER 81 see excess μe events. Suggest axion interactions.
- 61 FAISSNER 81B is SIN 590 MeV proton beam dump. Observed 14.5 \pm 5.0 events of 2 γ decay of long-lived neutral penetrating particle with $m_{2\gamma} \lesssim$ 1 MeV. Axion interpretation with η - A^0 mixing gives $m_{A^0}=250\pm25$ keV, $\tau_{\{2\gamma\}}=(7.3\pm3.7)\times10^{-3}$ s from above rate. See critical remarks below in comments of FETSCHER 82, FAISSNER 83, FAISSNER 83B, FRANK 83B, and BERGSMA 85. Also see in the next subsection ALEK-SEEV 82, CAVAIGNAC 83, and ANANEV 85. 62 KIM 81 analyzed 8 candidates for $A^0\to 2\gamma$ obtained by Aachen-Padova experiment at CERN with 26 GeV protons on Be. Estimated axion mass is about 300 keV and lifetime is $(0.86\sim5.6)\times10^{-3}$ s depending on models. Faissner (private communication), says axion production underestimated and mass overestimated. Correct value around 200 keV.
- 63 FAISSNER 80 Is SIN beam dump experiment with 590 MeV protons looking for $A^0 \rightarrow e^+e^-$ decay. Assuming $A^0/\pi^0=5.5\times 10^{-7}$, obtained decay rate limit $20/(A^0$ mass) MeV/s (CL = 90%), which is about 10^{-7} below theory and interpreted as upper limit to m_{A0} <2m_e-
- 64 JACQUES 80 is a BNL beam dump experiment. First limit above comes from nonobserva tion of excess neutral-current-type events $[\sigma({
 m production})\sigma({
 m interactaction}) < 7. imes 10^{-68}$ cm⁴, CL = 90%]. Second limit is from nonobservation of axion decays into 2γ 's or e+e-, and for axion mass a few MeV.
- 65 SOUKAS 80 at BNL observed no excess of neutral-current-type events in beam dump.
- ⁶⁶BECHIS 79 looked for the axion production in low energy electron Bremsstrahlung and the subsequent decay into either 2γ or e^+e^- . No signal found. CL = 90% limits for model parameter(s) are given.
- 67 COTEUS 79 is a beam dump experiment at BNL.
- 68 DISHAW 79 is a calorimetric experiment and looks for low energy tall of energy distri-
- butions due to energy lost to weakly interacting particles.

 69 BELLOTTI 78 first value comes from search for $A^0 \rightarrow e^+e^-$. Second value comes from search for $A^0 \rightarrow e^+e^-$. For any mass satisfying this, limit is above value × (mass - 4). Third value uses data of PL 60B 401 and quotes $\sigma(\text{production})\sigma(\text{Interaction}) < 10^{-67} \text{ cm}^4.$
- ⁷⁰ BOSETTI 78B quotes σ(production)σ(interaction) $< 2. \times 10^{-67}$ cm⁴.
- 71 DONNELLY 78 examines data from reactor neutrino experiments of REINES 76 and GURR 74 as well as SLAC beam dump experiment. Evidence is negative.
- 72 MICELMACHER 78 finds no evidence of axion existence in reactor experiments of REINES 76 and GURR 74. (See reference under DONNELLY 78 below).
- 73 VYSOTSKII 78 derived lower limit for the axion mass 25 keV from luminosity of the sun and 200 keV from red superglants.

A⁰ (Axion) Searches in Reactor Experiments

VALUE	DOCUMENT ID		TECN	COMMENT
• • • We do not use th	e following data for averag	es, fit	s, limits,	etc. • • •
	74 ALTMANN	95	CNTR	Reactor; $A^0 \rightarrow e^+e^-$
	⁷⁵ KETOV	86	SPEC	Reactor, $A^0 \rightarrow \gamma \gamma$
	⁷⁶ косн	86	SPEC	Reactor; $A^0 \rightarrow \gamma \gamma$
	77 DATAR	82	CNTR	Light water reactor
	78 VUILLEUMIE	R 81	CNTR	Reactor, $A^0 \rightarrow 2\gamma$

- ⁷⁴ ALTMANN 95 looked for A^0 decaying into e^+e^- from the Bugey 5 nuclear reactor. They obtain an upper limit on the A^0 production rate of $\omega(A^0)/\omega(\gamma) \times \mathbb{B}(A^0 \to 0)$ e^+e^-)< 10^{-16} for $m_{A^0}=1.5$ MeV at 90% CL. The limit is weaker for heavier A^0 . In the case of a standard axion, this limit excludes a mass in the range $2m_e < m_{A^0} < 4.8$ MeV at 90% CL. See Fig. 5 of their paper for exclusion limits of axion-like resonances Z^0 in the (m_{X^0}, f_{X^0}) plane.
- 75 KETOV 86 searched for A^0 at the Rovno nuclear power plant. They found an upper limit on the A^0 production probability of 0.8 [100 keV/ m_{A^0}] $^6\times 10^{-6}$ per fission. In the standard axion model, this corresponds to $m_{A^0} > 150$ keV. Not valid for $m_{A^0} \gtrsim$
- 76 1 MeV. 76 KOCH 86 searched for $A^0 \rightarrow \gamma \gamma$ at nuclear power reactor Biblis A. They found an upper limit on the A^0 production rate of $\omega(A^0)/\omega(\gamma(M1)) < 1.5 \times 10^{-10}$ (CL=95%). Standard axion with $m_{A^0} = 250$ keV gives 10^{-5} for the ratio. Not valid for $m_{A^0} > 1022$
- 77 Rev. DATAR 82 looked for $A^0 \to 2\gamma$ in neutron capture $(np \to dA^0)$ at Tarapur 500 MW reactor. Sensitive to sum of I=0 and I=1 amplitudes. With ZEHNDER 81 [(I=0)]- (I = 1)] result, assert nonexistence of standard A^0 .
- 78 VUILLEUMIER 81 is at Grenoble reactor. Set limit $m_{A^0} <$ 280 keV.

A^0 (Axion) and Other Light Boson (X^0) Searches in Nuclear Transitions

Li	mits are fo	or brand	hing ratio.				
VALUE		CL%	EVTS	DOCUMENT ID		TECN	COMMENT
• • • V	Ve do not	use the		data for average	es, fits	, limits,	etc. • • •
			79	DEBOER	97 C	RVUE	M1 transitions
< 5.5	$\times 10^{-10}$	95	80	TSUNODA	95	CNTR	252 Cf fission, A ⁰ → e
< 1.2	× 10 ⁻⁶	95	81	MINOWA	93	CNTR	139 _{La} * → 139 _{La} A0
< 2	$\times 10^{-4}$		82	HICKS	92	CNTR	³⁵ S decay, $A^0 \rightarrow \gamma \gamma$
< 1.5			83	3 ASANUMA	90	CNTR	241 Am decay
<(0.4–1	0)×10 ⁻³	95	84	DEBOER	90	CNTR	8 Be* $\rightarrow ^{8}$ Be A0 , $A^{0} \rightarrow ^{e^{+}}e^{-}$
<(0.2-1) × 10 ⁻³	90	8!	BINI	89	CNTR	$^{16}O^* \rightarrow ^{16}OX^0$
			86	AVIGNONE	88	CNTR	$X^{0} \rightarrow e^{+}e^{-}$ $Cu^{*} \rightarrow CuA^{0} (A^{0} \rightarrow 2\gamma, A^{0}e \rightarrow \gamma e,$
< 1.5	× 10 ⁻⁴	90	87	DATAR	88	CNTR	$ \begin{array}{c} A^{0}Z \to \gamma Z) \\ 12C^{*} \to 12CA^{0} \end{array} $
< 5	× 10 ⁻³	90	88	DEBOER	88 C	CNTR	$16_{O^*}^{A^0} \rightarrow f_{O_X^0}^{+e^-}$
< 3.4	× 10 ⁻⁵		89	DOEHNER	88	SPEC	$2^{X^0}_{H^*, A^0} \xrightarrow{e^+e^-} e^+e^-$
< 4	× 10 ⁻⁴	95		SAVAGE	88	CNTR	Nuclear decay (isovec- tor)
< 3	× 10 ⁻³	95	90	SAVAGE	88	CNTR	
< 0.10	6	90	91	L HALLIN .	86	SPEC	⁶ Li Isovector decay
<10.8		90	91	L HALLIN	86	SPEC	¹⁰ B isoscalar decays
< 2.2		90	91	L HALLIN	86	SPEC	14 N isoscalar decays
< 4	× 10 ⁻⁴	90	0 92	SAVAGE	86B	CNTR	14 _{N*}
			93	ANANEV	85	CNTR	Li*, deut* $A^0 \rightarrow 2\gamma$
			94	CAVAIGNAC	83	CNTR	97 Nb*, deut* transitio $A^0 \rightarrow 2\gamma$
			95	ALEKSEEV	828	CNTR	Li*, deut* transition $A^0 \rightarrow 2\gamma$
			96	LEHMANN	82	CNTR	$Cu^* \rightarrow CuA^0$ $(A^0 \rightarrow 2\gamma)$
			0 97	ZEHNDER	82	CNTR	Li* Nb* decay, n-capt.
			0 98	ZEHNDER	81		$\begin{array}{c} Ba^* \rightarrow BaA^0 \\ (A^0 \rightarrow 2\gamma) \end{array}$
			99	CALAPRICE	79		Carbon

- $^{79}\, extsf{DEBOER}$ 97C reanalyzed the existent data on Nuclear M1 transitions and find that a 9 MeV boson decaying into e^+e^- would explain the excess of events with large opening
- 80 TSUNODA 95 looked for axion emission when ²⁵²Cf undergoes a spontaneous fission, with the axion decaying into e^+e^- . The bound is for $m_{A0}=40$ MeV. It improves to 2.5×10^{-5} for $m_{\ensuremath{A^0}}{=}200$ MeV.
- 81 MINOWA 93 studied chain process, 139 Ce \rightarrow 139 La* by electron capture and M1 transition of 139 La* to the ground state. It does not assume decay modes of A^0 . The bound applies for $m_{A^0}<$ 166 keV.
- ⁸² HICKS 92 bound is applicable for au_{χ^0} < 4 × 10⁻¹¹ sec.
- 83 The ASANUMA 90 limit is for the branching fraction of 20 emission per 241 Am $_{lpha}$ decay and valid for τ_{χ^0} < 3 × 10⁻¹¹ s.
- ⁸⁴ The DEBOER 90 limit is for the branching ratio 8 Be* (18.15 MeV, $^{1+}$) \rightarrow 8 Be 40 , $A^0 \rightarrow e^+ e^-$ for the mass range $m_{A^0} = 4$ –15 MeV.
- ⁸⁵The BINI 89 limit is for the branching fraction of $^{16}O^*(6.05 \text{ MeV}, 0^+) \rightarrow ^{16}OX^0$, $X^0
 ightharpoonup e^+ e^-$ for $m_X = 1.5$ -3.1 MeV. $au_{X^0} \lesssim 10^{-11} \, \mathrm{s}$ is assumed. The spin-parity of X is restricted to 0+ or 1-.

Gauge & Higgs Boson Particle Listings

Axions (A^0) and Other Very Light Bosons

- ⁸⁶ AVIGNONE 88 looked for the 1115 keV transition C* \rightarrow Cu A^0 , either from $A^0 \rightarrow$ 2γ in-flight decay or from the secondary A^0 interactions by Compton and by Primakoff processes. Limits for axion parameters are obtained for $m_{A^0}\,<\,1.1$ MeV.
- 87 DATAR 88 rule out light pseudoscalar particle emission through its decay $A^0 \rightarrow e^+e^$ in the mass range 1.02-2.5 MeV and lifetime range 10^{-13} - 10^{-8} s. The above limit is for $\tau=5\times 10^{-13}$ s and m=1.7 MeV; see the paper for the τ -m dependence of the
- ⁸⁸The limit is for the branching fraction of $^{16}\text{O}^*$ (6.05 MeV, $^{+}$) \rightarrow ^{16}O 0 , 0 \rightarrow ${
 m e^+e^-}$ against internal pair conversion for $m_{\chi 0}=1.7$ MeV and $au_{\chi 0}~<~10^{-11}\,{
 m s}.$ Similar limits are obtained for $m_{\chi 0} = 1.3-3.2$ MeV. The spin parity of X^0 must be either 0+ or 1-. The limit at 1.7 MeV is translated into a limit for the X^0 -nucleon coupling constant: $g_{X^0NN}^2/4\pi < 2.3\times 10^{-9}$.
- ⁸⁹The DOEHNER 88 limit is for $m_{A^0}=1.7$ MeV, $\tau(A^0)<10^{-10}$ s. Limits less than
- 90 SAVAGE 88 looked for 0 40 that decays into e⁺ e⁻ in the decay of the 9.17 MeV P = 2 + state in 14 N, 17.64 MeV state J = 1 + in 8 Be, and the 18.15 MeV state J = 2 1+ In $^8\mathrm{Be}$. This experiment constrains the isovector coupling of A^0 to hadrons, if m_{A^0} = (1.1 \rightarrow 2.2) MeV and the isoscalar coupling of A^0 to hadrons, if m_{A^0} = (1.1 \rightarrow 2.6) MeV. Both limits are valid only if $au(A^0) \lesssim 1 imes 10^{-11}$ s.
- 91 Limits are for $\Gamma(A^0(1.8~\text{MeV}))/\Gamma(\pi M1);$ i.e., for 1.8 MeV axion emission normalized to the rate for internal emission of e^+e^- pairs. Valid for $\tau_{A^0}~<~2\times 10^{-11}\text{s.}^{~6}\text{Li}$ Isovector decay data strongly disfavor PECCEI 86 model I, whereas the 10B and 14N
- isoscalar decay data strongly reject PECCEI 86 model II and III. 92 SAVAGE 868 looked for 40 that decays into e^+e^- in the decay of the 9.17 MeV $J^P=$ 2^+ state in 14 N. Limit on the branching fraction is valid if $au_{A^0}\lesssim 1. imes 10^{-11} {
 m s}$ for m_{A^0} = (1.1-1.7) MeV. This experiment constrains the iso-vector coupling of A^0 to hadrons.
- 93 ANANEV 85 with IBR-2 pulsed reactor exclude standard A^0 at CL = 95% masses below 470 keV (LI* decay) and below $2m_e$ for deuteron* decay.
- 94 CAVAIGNAC 83 at Bugey reactor exclude axion at any m_{97} Nb*decay and axion with $m_{\Delta0}$ between 275 and 288 keV (deuteron* decay).
- 95 ALEKSEEV 82 with IBR-2 pulsed reactor exclude standard A^0 at CL = 95% mass-ranges m_{A^0} <400 keV (LI* decay) and 330 keV < m_{A^0} <2.2 MeV. (deuteron* decay).
- 96 LEHMANN 82 obtained $A^0 \rightarrow 2\gamma$ rate $< 6.2 \times 10^{-5}/\text{s}$ (CL = 95%) excluding m_{A^0}
- between 100 and 1000 keV.

 97 ZEHNDER 82 used Goesgen 2.8GW light-water reactor to check A^0 production. No 2γ peak in Li*, Nb* decay (both single p transition) nor in n capture (combined with previous Ba* negative result) rules out standard A^0 . Set limit m_{A^0} <60 keV for any
- 98 ZEHNDER 81 looked for Ba* \rightarrow A⁰ Ba transition with A⁰ \rightarrow 2 γ . Obtained 2 γ coincidence rate $< 2.2 \times 10^{-5}/s$ (CL = 95%) excluding $m_{A^0} >$ 160 keV (or 200 keV depending on Higgs mixing). However, see BARROSO 81.
- ⁹⁹ CALAPRICE 79 saw no axion emission from excited states of carbon. Sensitive to axion mass between 1 and 15 MeV.

A⁰ (Axion) Limits from its Electron Coupling

VALUE (s)	CL%	DOCUMENT ID		TECN	COMMENT
 • • We do not use the follow 	wing d	ata for averages, fits	i, limi	ts, etc. •	• •
none $4 \times 10^{-16} - 4.5 \times 10^{-12}$	90	100 BROSS	91	8DMP	$eN \rightarrow eA^0N$ $(A^0 \rightarrow ee)$
		¹⁰¹ GUO	90	BDMP	$eN \rightarrow eA^0N$ $(A^0 \rightarrow ee)$
		102 BJORKEN	88		$A \rightarrow e^+e^-$ or 2γ
		¹⁰³ BLINOV	88	MD1	$\begin{array}{ccc} ee \rightarrow & ee A^0 \\ (A^0 \rightarrow & ee) \end{array}$
none $1 \times 10^{-14} - 1 \times 10^{-10}$	90	¹⁰⁴ RIORDAN	87	BDMP	$eN \rightarrow eA^0N$ $(A^0 \rightarrow ee)$
none $1 \times 10^{-14} - 1 \times 10^{-11}$	90	105 BROWN	86	BDMP	$eN \rightarrow eA^0N$ $(A^0 \rightarrow ee)$
none $6 \times 10^{-14} - 9 \times 10^{-11}$	95	106 DAVIER	86		$eN \rightarrow eA^0N$ $(A^0 \rightarrow ee)$
none $3 \times 10^{-13} - 1 \times 10^{-7}$	90	107 KONAKA	86	вомр	$eN \rightarrow eA^0N$ $(A^0 \rightarrow ee)$

- ¹⁰⁰ The listed BROSS 91 limit is for $m_{A^0}=1.14$ MeV. B($A^0\to e^+e^-$) = 1 assumed. Excluded domain in the τ_{A^0} - m_{A^0} plane extends up to $m_{A^0}\approx 7$ MeV (see Fig. 5). Combining with electron g-2 constraint, axions coupling only to e^+e^- ruled out for $m_{A^0}<4.8$ MeV (90%CL).
- $101\,\mathrm{GUO}$ 90 use the same apparatus as BROWN 86 and improve the previous limit in the shorter lifetime region. Combined with g – 2 constraint, axions coupling only to e^+e^- are ruled out for $m_{A^0}~<~2.7$ MeV (90% CL).
- 102 BJORKEN 88 reports limits on axion parameters (f_A , m_A , τ_A) for $m_{A^0} < 200$ MeV from electron beam-dump experiment with production via Primakoff photoproduction, bremsstrahlung from electrons, and resonant annihilation of positrons on atomic electrons.
- tors. 103 BLINOV 88 assume zero spin, m=1.8 MeV and lifetime $<5\times10^{-12}$ s and find $\Gamma(A^0\to\gamma\gamma)\mathrm{B}(A^0\to e^+e^-)<2$ eV (CL=90%). 104 Assumes $A^0\gamma\gamma$ coupling is small and hence Primakoff production is small. Their figure 2 shows limits on axions for $m_{A^0}<15$ MeV.
- 105 Uses electrons in hadronic showers from an incident 800 GeV proton beam. Limits for $m_{A^0} < 15$ MeV are shown in their figure 3.
- $106\,m_{A^0}^2=1.8$ MeV assumed. The excluded domain in the $au_{A^0}-m_{A^0}$ plane extends up to $m_{A0}^{\gamma} \approx 14$ MeV, see their figure 4.

 $107\,\mathrm{The}$ limits are obtained from their figure 3. Also given is the limit on the $A^0\gamma\gamma-A^0\,\mathrm{e}^+\,\mathrm{e}^-$ coupling plane by assuming Primakoff production.

Search for A⁰ (Axion) Resonance in Bhabha Scattering

The limit is for $\Gamma(A^0)[B(A^0 \rightarrow e^+e^-)]^2$.

VALUE (10 ⁻³ eV)	CL%		DOCUMENT ID		TECN	COMMENT
• • • We do not use the	followin	g d	ata for averages	, flts	, limits,	etc. • • •
< 1.3	97	108	HALLIN	92	CNTR	$m_{\Delta 0} = 1.75 - 1.88 \text{ MeV}$
none 0.0016-0.47			HENDERSON	92C	CNTR	m ₄₀ = 1.5-1.86 MeV
< 2.0	90	110	WU	92	CNTR	m ₄₀ = 1.56-1.86 MeV
< 0.013	95		TSERTOS	91	CNTR	$m_{A0} = 1.832 \text{ MeV}$
none 0.19-3.3	95	111	WIDMANN	91	CNTR	m _{A0} = 1.78-1.92 MeV
< 5	97		BAUER	90	CNTR	$m_{A0} = 1.832 \text{ MeV}$
none 0.09-1.5	95	112	JUDGE	90	CNTR	$m_{A0} = 1.832 \text{ MeV},$
< 1.9	97	113	TSERTOS	89	CNTR	elastic m _{A0} = 1.82 MeV
<(10-40)	97	113	TSERTOS	89		$m_{\Delta 0}^{\prime\prime} = 1.51-1.65 \text{ MeV}$
<(1-2.5)	97	113	TSERTOS	89	CNTR	$m_{A0} = 1.80-1.86 \text{ MeV}$
< 31	95		LORENZ	88	CNTR	$m_{A0} = 1.646 \text{ MeV}$
< 94	95		LORENZ	88	CNTR	$m_{A0} = 1.726 \text{ MeV}$
< 23	95		LORENZ	88	CNTR	$m_{A^0} = 1.782 \text{ MeV}$
< 19	95		LORENZ	88	CNTR	$m_{A^0} = 1.837 \text{ MeV}$
< 3.8			TSERTOS	88	CNTR	$m_{A^0} = 1.832 \text{ MeV}$
	:	116	VANKLINKEN MAIER	87	CNTR	
<2500	90		MILLS VONWIMMER.			$m_{A^0} = 1.8 \text{ MeV}$

- 108 HALLIN 92 quote limits on lifetime, 8×10^{-14} 5×10^{-13} sec depending on mass, assuming B($A^0 \rightarrow e^+e^-$) = 100%. They say that TSERTOS 91 overstated their sensitivity by a factor of 3.
- 109 HENDERSON 92C exclude axion with lifetime au_{A0} =1.4 imes 10 $^{-12}$ -4.0 imes 10 $^{-10}$ s, as- $\rightarrow e^+e^-)=100\%$. HENDERSON 92C also exclude a vector boson with $r=1.4 \times 10^{-12} - 6.0 \times 10^{-10}$ s.
- 110 WU 92 quote limits on lifetime $> 3.3 \times 10^{-13}$ s assuming B($A^0 \rightarrow e^+e^-$)=100%. They say that TSERTOS 89 overestimate the limit by a factor of $\pi/2$. WU 92 also quote a bound for vector boson, $\tau > 8.2 \times 10^{-13}$ s.
- ¹¹¹WIDMANN 91 bound applies exclusively to the case B($A^0 \rightarrow e^+e^-$)=1, since the detection efficiency varies substantially as $\Gamma(A^0)_{total}$ changes. See their Fig. 6.
- ¹¹² JUDGE 90 excludes an elastic pseudoscalar e^+e^- resonance for 4.5×10^{-13} s $< \tau(A^0)$ $< 7.5 \times 10^{-12} \, \mathrm{s}$ (95% CL) at $m_{A^0} = 1.832$ MeV. Comparable limits can be set for m_{A0} = 1.776-1.856 MeV.
- 113 See also TSERTOS 88B in references.
 114 The upper limit listed in TSERTOS 88 is too large by a factor of 4. See TSERTOS 88B,
- ¹¹⁵ VANKLINKEN 88 looked for relatively long-lived resonance ($\tau = 10^{-10}$ – 10^{-12} s). The sensitivity is not sufficient to exclude such a narrow resonance.
- 116 MAIER 87 obtained limits $R\Gamma\lesssim 60$ eV (100 eV) at $m_{A^0}\simeq 1.64$ MeV (1.83 MeV) for energy resolution $\Delta E_{\rm Cm}\simeq 3$ keV, where R is the resonance cross section normalized to that of Bhabha scattering, and $\Gamma = \Gamma_{ee}^2/\Gamma_{total}$. For a discussion implying that $\Delta E_{\rm cm} \simeq 10 \, {\rm keV}$, see TSERTOS 89.
- 117 VONWIMMERSPERG 87 measured Bhabha scattering for $E_{\rm cm}=1.37$ –1.86 MeV and found a possible peak at 1.73 with $\int \sigma dE_{\rm cm}=14.5\pm6.8$ keV-b. For a comment and a reply, see VANKLINKEN 888 and VONWIMMERSPERG 88. Also see CONNELL 88.

Search for A^0 (Axion) Resonance in $e^+e^- \rightarrow \gamma\gamma$

The limit is for $\Gamma(A^0 \to e^+e^-) \cdot \Gamma(A^0 \to \gamma\gamma)/\Gamma_{\text{total}}$

VALUE (10 ⁻³ eV)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use th	e follow	ing data for average	s, fit	s, limits,	etc. • • •
< 0.18	95	vo			m _{_40} =1.1 MeV
< 1.5	95	vo	94.	CNTR	m _{A0} =1.4 MeV
<12	95	VO	94	CNTR	m _{A0} =1.7 MeV
< 6.6	95	118 TRZASKA	91	CNTR	$m_{A^0} = 1.8 \text{ MeV}$
< 4.4	95	WIDMANN	91		m _{Δ0} = 1.78-1.92 MeV
		¹¹⁹ FOX	89	CNTR	.,
< 0.11	95	¹²⁰ MINOWA	89	CNTR	$m_{A^0} = 1.062 \text{ MeV}$
<33	97	CONNELL	88	CNTR	$m_{\Delta^0} = 1.580 \text{ MeV}$
<42	97	CONNELL	88	CNTR	$m_{\Delta 0} = 1.642 \text{ MeV}$
<73	97	CONNELL	88	CNTR	$m_{A^0} = 1.782 \text{ MeV}$
<79	97	CONNELL	88		$m_{A0}^{7} = 1.832 \text{ MeV}$

- ¹¹⁸TRZASKA 91 also give limits in the range (6.6–30) \times 10⁻³ eV (95%CL) for m_{A0} = 1.6-2.0 MeV
- 119 FOX 89 measured positron annihilation with an electron in the source material into two photons and found no signal at 1.062 MeV ($< 9 \times 10^{-5}$ of two-photon annihilation at
- $^{120}\,\mathrm{Similar}$ limits are obtained for $m_{A^0}=1.045\text{--}1.085$ MeV.

Gauge & Higgs Boson Particle Listings Axions (A^0) and Other Very Light Bosons

Search for X^0 (Light Boson) Resonance in $e^+e^- o \gamma\gamma\gamma$

The limit is for $\Gamma(X^0 o e^+e^-)\cdot\Gamma(X^0 o \gamma\gamma\gamma)/\Gamma_{ ext{total}}\cdot C$ invariance forbids spin-0 X^0 coupling to both e^+e^- and $\gamma\gamma\gamma$.

VALUE (10 ⁻³ eV)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not us	e the followi	ng data for averag	ges, fit	s, limits,	etc. • • •
< 0.2	95	¹²¹ VO	94	CNTR	m x0=1.1-1.9 MeV
< 1.0	95	¹²² VO			m _{X0} =1.1 MeV
< 2.5	95	122 VO			m _{X0} =1.4 MeV
<120	95	¹²² VO			$m_{\chi^0}^2 = 1.7 \text{ MeV}$
< 3.8	95	¹²³ SKALSEY			$m_{\chi^0}^2 = 1.5 \text{ MeV}$

- ¹²¹VO 94 looked for $X^0 \to \gamma \gamma \gamma$ decaying at rest. The precise limits depend on m_{X^0} . See
- ¹²²VO 94 looked for $X^0 \rightarrow \gamma \gamma \gamma$ decaying in flight.
- 123 SKALSEY 92 also give limits 4.3 for $m_{\chi 0}=$ 1.54 and 7.5 for 1.64 MeV. The spin of χ^0 is assumed to be one.

Light Boson (X^0) Search in Nonresonant e^+e^- Annihilation at Rest

Limits are for the ratio of $n\gamma + X^0$ production relative to $\gamma\gamma$.

VALUE (units 10 ⁻⁶)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use	the follow	ing data for averag	es, fit	s, limits,	etc. • • •
< 4.2	90	124 MITSUI	96	CNTR	γX^0
< 4	68	¹²⁵ SKALSEY	95	CNTR	γX^0
<40	68	¹²⁶ SKALSEY		RVUE	
< 0.18	90	¹²⁷ AÐACHI	94	CNTR	$\gamma\gamma X^0, X^0 \rightarrow \gamma\gamma$
< 0.26	90	128 ADACHI			$\gamma\gamma X^0, X^0 \rightarrow \gamma\gamma$
< 0.33	90	¹²⁹ ADACHI	94	CNTR	$\gamma X^0, X^0 \rightarrow \gamma \gamma \gamma$
					_

- 124 MITSUI 96 looked for a monochromatic γ . The bound applies for a vector X^0 with C=-1 and m_{χ^0} <200 keV. They derive an upper bound on eeX^0 coupling and hence on the branching ratio B(o-Ps $\rightarrow \gamma \gamma X^0$)< 6.2 × 10⁻⁶. The bounds weaken for heavier
- χ^0 . 125 SKALSEY 95 looked for a monochromatic γ without an accompanying γ in e^+e^- annihilation. The bound applies for scalar and vector χ^0 with C=-1 and $m_{\chi^0}=$
- 126 SKALSEY 95 reinterpreted the bound on γA^0 decay of o-Ps by ASAI 91 where 3% of delayed annihilations are not from 3S1 states. The bound applies for scalar and vector X^0 with C=-1 and $m_{X^0}=0$ -800 keV.
- 127 ADACHI 94 looked for a peak in the $\gamma\gamma$ invariant mass distribution in $\gamma\gamma\gamma\gamma$ production from e^+e^- annihilation. The bound applies for $m_{\chi^0}=$ 70–800 keV.
- 128 ADACHI 94 looked for a peak in the missing-mass mass distribution in $\gamma\gamma$ channel, using $\gamma\gamma\gamma\gamma$ production from e^+e^- annihilation. The bound applies for $m_{\chi 0}$ <800 keV.
- 129 ADACHI 94 looked for a peak in the missing mass distribution in $\gamma\gamma\gamma$ channel, using $\gamma\gamma\gamma\gamma$ production from e^+e^- annihilation. The bound applies for $m_{\chi 0}=200$ –900

Searches for Goldstone Bosons (X^0)

(Including Horizontal Bosons and Majorons.) Limits are for branching ratios. CL% EVTS DOCUMENT ID TECN COMMENT

• • • We do not	use the	follow	ing data for average	s, fits	, Ilmits,	etc. • • •
			130 BOBRAKOV	91		Electron quasi-magnetic Interaction
$< 3.3 \times 10^{-2}$	95		131 ALBRECHT	90E	ARG	$\tau \to \mu X^0$. Familion
$<1.8 \times 10^{-2}$	95		131 ALBRECHT	90E	ARG	$\tau \rightarrow eX^0$. Familion
$< 6.4 \times 10^{-9}$	90		132 ATIYA	90	B787	$K^+ \rightarrow \pi^+ X^0$.
$< 1.1 \times 10^{-9}$	90		133 BOLTON	88	свох	Familion $\mu^{+} \rightarrow e^{+} \gamma X^{0}.$ Familion
			134 CHANDA	88	ASTR	Sun, Majoron
			¹³⁵ CHOI	88	ASTR	
<5 × 10 ⁻⁶	90		136 PICCIOTTO	88	CNTR	$\pi \to e \nu X^0$, Majoron
<1.3 × 10 ⁻⁹	90		137 GOLDMAN	87	CNTR	$\mu \rightarrow e \gamma X^0$. Familion
<3 × 10 ⁻⁴	90		138 BRYMAN	86B	RVUE	$\mu \rightarrow eX^0$. Familion
<1. × 10 ⁻¹⁰	90	0	139 EICHLER	86	SPEC	$\mu^+ \rightarrow e^+ X^0$. Familion
$< 2.6 \times 10^{-6}$	90		140 JODIDIO	86	SPEC	$\mu^+ \rightarrow e^+ X^0$. Familion
			141 BALTRUSAIT	85	MRK3	$\tau \to \ell X^0$. Familion
			142 DICUS	83	COSM	$\nu(\text{hvy}) \rightarrow \nu(\text{light})X^0$
						- (), (B),

- 130 BOBRAKOV 91 searched for anomalous magnetic interactions between polarized electrons expected from the exchange of a massless pseudoscalar boson (arion). A limit $x_e^2 < 2 \times 10^{-4}$ (95%CL) is found for the effective anomalous magneton parametrized as $x_e (G_F/8\pi\sqrt{2})^{1/2}$.
- ¹³¹ALBRECHT 90E limits are for B($au o \ell X^0$)/B($au o \ell
 u \overline{
 u}$). Valid for $m_{\chi 0} < 100$
- MeV. The limits rise to 7.1% (for μ), 5.0% (for e) for $m_{\chi^0}=500$ MeV. ¹³² ATIYA 90 limit is for $m_{\chi^0}=0$. The limit B < 1 × 10⁻⁸ holds for $m_{\chi^0}<95$ MeV. For the reduction of the limit due to finite lifetime of x^0 , see their Fig. 3.
- 133 BOLTON 88 limit corresponds to $F>3.1\times10^9$ GeV, which does not depend on the chirality property of the coupling.
- 134 CHANDA 88 find $v_{\mathcal{T}}~<$ 10 MeV for the weak-triplet Higgs vev. in Gelmini-Roncadelli model, and $v_{\rm S}~>~5.8\times10^6$ GeV in the singlet Majoron model.
- 135 CHOI 88 used the observed neutrino flux from the supernova SN 1987A to exclude the neutrino Majoron Yukawa coupling h in the range $2\times 10^{-5} < h < 3\times 10^{-4}$ for the

- interaction $L_{\rm int}=\frac{1}{2}lh\overline{\psi}_{\nu}^{c}\gamma_{5}\psi_{\nu}\phi_{\rm X}.$ For several families of neutrinos, the limit applies for $(\Sigma h_I^4)^{1/4}$.
- 136 PICCIOTTO 88 limit applies when $m_{\chi 0}~<$ 55 MeV and $au_{\chi 0}~>$ 2ns, and it decreases to 4×10^{-7} at $m_{\chi^0} = 125$ MeV, beyond which no limit is obtained.
- 137 GOLDMAN 87 limit corresponds to $F > 2.9 \times 10^9$ GeV for the family symmetry breaking scale from the Lagrangian $L_{\rm int}=(1/F)\overline{\psi}_{\mu}\gamma^{\mu}$ $(a+b\gamma_5)$ $\psi_e\partial_{\mu}\phi_{\chi^0}$ with $a^2+b^2=1$. This is not as sensitive as the limit $F > 9.9 \times 10^9$ GeV derived from the search for $\mu^+ \rightarrow$ $e^+ \, \chi^0$ by JODIDIO 86, but does not depend on the chirality property of the coupling.
- 138 Limits are for $\Gamma(\mu \to e X^0)/\Gamma(\mu \to e \nu \overline{\nu})$. Valid when $m_{\chi^0}=0$ –93.4, 98.1–103.5
- 139 EICHLER 86 looked for $\mu^+ \to e^+ X^0$ followed by $X^0 \to e^+ e^-$. Limits on the branching fraction depend on the mass and and lifetime of X^0 . The quoted limits are valid when $\tau_{X^0} \lesssim 3. \times 10^{-10}$ s if the decays are kinematically allowed.
- ¹⁴⁰ JODIDIO 86 corresponds to $F > 9.9 \times 10^9$ GeV for the family symmetry breaking scale with the parity-conserving effective Lagrangian $L_{\rm int}=(1/F)~\overline{\psi}_{\mu}\gamma^{\mu}\psi_{e}\partial^{\mu}\phi_{\chi^{0}}$
- ¹⁴¹BALTRUSAITIS 85 search for light Goldstone boson(X^0) of broken U(1). CL = 95%
- limits are $B(\tau \to \mu^+ X^0)/B(\tau \to \mu^+ \nu \nu)$ < 0.125 and $B(\tau \to e^+ X^0)/B(\tau \to e^+ \nu \nu)$ < 0.04. Inferred limit for the symmetry breaking scale is m > 3000 TeV.

 142 The primordial heavy neutrino must decay into ν and familion, f_A , early so that the red-shifted decay products are below critical density, see their table. In addition, $K \to \infty$ πf_A and $\mu \to -e f_A$ are unseen. Combining these excludes $m_{
 m heavy}
 u$ between 5 imes 10 $^{-5}$ and 5 \times 10 $^{-4}$ MeV (μ decay) and $m_{\rm heavy}\nu$ between 5 \times 10 $^{-5}$ and 0.1 MeV (K-decay).

Majoron Searches in Neutrinoless Double β Decay

Limits are for the half-life of neutrinoless $\beta\beta$ decay with a Majoron emission. Previous Indications for neutrinoless double beta decay with majoron emission have been superseded. No experiment currently claims any such evidence. For a review, see

VALUE (year	rs)	CL%	DOCUMENT ID		TECN	COMMENT
> 7.2	× 10 ²⁴	90	143 BERNATOW	. 9 2	CNTR	128 _{Te}
• • • We	do not use 1	the follow	ving data for average	s, fit	s, limits,	etc. • • •
> 7.91	× 10 ²¹	90	144 GUENTHER	96	SPEC	76 _{Ge}
> 1.7	× 10 ²²	90	BECK	93	CNTR	⁷⁶ Ge
> 7.9	× 10 ²⁰	68	¹⁴⁵ TANAKA	93	SPEC	¹⁰⁰ Mo
> 1.9	× 10 ²⁰	68	BARABASH	89	CNTR	
> 1.0	× 10 ²¹	90	FISHER	89	CNTR	⁷⁶ Ge
> 3.3	× 10 ²⁰	90	ALSTON	88	CNTR	100 _{Mo}
(6 ±	1) × 10 ²⁰		AVIGNONE	87	CNTR	76 _{Ge}
> 1.4	× 10 ²¹	90	CALDWELL	87	CNTR	76 _{Ge}
> 4.4	× 10 ²⁰	90	ELLIOTT	87	SPEC	82 _{Se}
> 1.2	× 10 ²¹	90	FISHER	87	CNTR	⁷⁶ Ge
			146 VERGADOS	82	CNTR	

- 143 BERNATOWICZ 92 studied double-eta decays of 128 Te and 130 Te, and found the ratio $(1^{30}\text{Te})/r(1^{20}\text{Te}) = (3.52 \pm 0.11) \times 10^{-4}$ in agreement with relatively stable theoretical predictions. The bound is based on the requirement that Majoron-emitting decay cannot be larger than the observed double-beta rate of 128 Te of $(7.7\pm0.4)\times10^{24}$ year. We calculated 90% CL limit as $(7.7-1.28 \times 0.4=7.2) \times 10^{24}$.

- 144 See Table 1 in GUENTHER 96 for limits on the Majoron coupling in different models. 145 TANAKA 93 also quote limit 5.3 \times 10¹⁹ years on two Majoron emission. 146 VERGADOS 82 sets limit $g_H < 4 \times 10^{-3}$ for (dimensionless) lepton-number violating coupling, g_H , of scalar boson (Majoron) to neutrinos, from analysis of data on double β decay of ⁴⁸Ca.

Invisible A^0 (Axion) MASS LIMITS from Astrophysics and Cosmology

 $v_1=v_2$ is usually assumed ($v_i=$ vacuum expectation values). For a review of these limits, see RAFFELT 90C and TURNER 90. In the comment lines below, D and K refer to DFSZ and KSVZ axion types, discussed in the above minireview.

VALUE (eV)	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following	data for averages	, fits	, limits,	etc. • • •
< 0.007	47 BORISOV	97	ASTR	D, neutron star
< 4	48 KACHELRIESS	97	ASTR	D, neutron star cooling
$<(0.5-6)\times10^{-3}$	⁴⁹ KEIL	97	ASTR	SN 1987A
< 0.018	⁵⁰ RAFFELT	95	ASTR	D, red giant
< 0.010	⁵¹ ALTHERR	94	ASTR	D, red giants, white dwarfs
< 0.01	WANG	92	ASTR	D, white dwarf
< 0.03	WANG	92C	A5TR	D, C-O burning
	⁵² BERSHADY	91	ASTR	D, K, Intergalactic light
<10 1	⁵³ KIM	91 C	COSM	
1	54 RAFFELT	91B	ASTR	D.K. SN 1987A
< 1 × 10 ⁻³	⁵⁵ RESSELL	91	ASTR	K, intergalactic light
none 10 ⁻³ -3	BURROWS	90	ASTR	D.K. SN 1987A
1	⁵⁶ ENGEL	90	ASTR	D.K. SN 1987A
< 0.02	57 RAFFELT	90D	ASTR	D, red glant
< 1 × 10 ⁻³	58 BURROWS	89	ASTR	D,K, SN 1987A
<(1.4-10) × 10 ⁻³	⁵⁹ ERICSON	89	ASTR	D.K. SN 1987A
< 3.6 × 10 ⁻⁴	60 MAYLE	89	ASTR	D.K. SN 1987A
<12	CHANDA	88	ASTR	D, Sun

Gauge & Higgs Boson Particle Listings

Axions (A^0) and Other Very Light Bosons

< 1 × 10 ⁻³	RAFFELT	88 ASTR	D,K, SN 1987A
	161 RAFFELT	88B ASTR	red giant
< 0.07	FRIEMAN	87 ASTR	D, red glant
< 0.7	162 RAFFELT	87 ASTR	K, red glant
< 2-5	TURNER	87 COSM	K, thermal production
< 0.01	163 DEARBORN	86 ASTR	D, red giant
< 0.06	RAFFELT	86 ASTR	D, red glant
< 0.7	164 RAFFELT	86 ASTR	K, red glant
< 0.03	RAFFELT	86B ASTR	D, white dwarf
< 1	¹⁶⁵ KAPLAN	85 ASTR	K, red glant
< 0.003-0.02	IWAMOTO	84 ASTR	D, K, neutron star
> 1 × 10 ⁻⁵	ABBOTT	83 COSM	D,K, mass density of the
			universe
> 1 × 10 ⁻⁵	DINE	83 COSM	D,K, mass density of the universe
< 0.04	ELLIS	83B ASTR	D, red glant
$> 1 \times 10^{-5}$	PRESKILL	83 COSM	D,K, mass density of the universe
< 0.1	BARROSO	82 ASTR	D, red giant
< 1	¹⁶⁶ FUKUGITA	82 ASTR	D, stellar cooling
< 0.07	FUKUGITA	82B ASTR	D, red giant
147			13

147 BORISOV 97 bound is on the axion-electron coupling $g_{ae} < 1 \times 10^{-13}$ from the photoproduction of axions off of electric fields in the outer layers of neutron stars. 148 KACHELRIESS 97 bound is on the axion-electron coupling $g_{ae} < 1 \times 10^{-10}$ from the production of axions in strongly magnetized neutron stars. The authors also quote a stronger limit, $g_{ae} < 9 \times 10^{-13}$ which is strongly dependent on the strength of the magnetic field in white dwarfs.

149 KEIL 97 uses new measurements of the axial-vector coupling strength of nucleons, as well as a reanalysis of many-body effects and plon-emission processes in the core of the neutron star, to update limits on the invisible-axion mass.

150 RAFFELT 95 reexamined the constraints on axion emission from red giants due to the axion-electron coupling. They improve on DEARBORN 86 by taking into proper account degeneracy effects in the bremsstrahlung rate. The limit comes from requiring the red glant core mass at helium ignition not to exceed its standard value by more than 5% (0.025 solar masses).

151 ALTHERR 94 bound is on the axion-electron coupling $g_{ae} < 1.5 \times 10^{-13}$, from energy

loss via axion emission.

152 BERSHADY 91 searched for a line at wave length from 3100–8300 Å expected from 2 γ decays of relic thermal axions in intergalactic light of three rich clusters of galaxies.

153 KIM 91C argues that the bound from the mass density of the universe will change drastically for the supersymmetric models due to the entropy production of saxion (scalar component in the axionic chiral multiplet) decay. Note that it is an upperbound rather than a lowerbound.

154 RAFFELT 91B argue that previous SN 1987A bounds must be relaxed due to corrections to nucleon bremsstrahlung process

155 RESSELL 91 uses absence of any Intracluster line emission to set limit.

 156 ENGEL 90 rule out $10^{-10}\lesssim g_{AN}\lesssim 10^{-3}$, which for a hadronic axion with EMC motivated axion-nucleon couplings corresponds to 2.5 \times 10⁻³ eV $\lesssim m_{A^0} \lesssim$ 2.5 \times 10⁴ eV. The constraint is loose in the middle of the range, i.e. for $g_{AN} \sim 10^{-6}$.

157 RAFFELT 90D is a re-analysis of DEARBORN 86.

 158 The region $m_{A^0} \gtrsim 2$ eV is also allowed.

159 ERICSON 89 considered various nuclear corrections to axion emission in a supernova core, and found a reduction of the previous limit (MAYLE 88) by a large factor.

160 MAYLE 89 limit based on naive quark model couplings of axion to nucleons. Limit based on couplings motivated by EMC measurements is 2-4 times weaker. The limit from axion-electron coupling is weak: see HATSUDA 888.

161 RAFFELT 88B derives a limit for the energy generation rate by exotic processes in helium burning stars $\epsilon <$ 100 erg g $^{-1}$ s $^{-1}$, which gives a firmer basis for the axion limits based on red glant cooling.

 162 RAFFELT 87 also gives a limit $g_{A\gamma}~<~1\times 10^{-10}~{\rm GeV}^{-1}.$

 163 DEARBORN 86 also gives a limit $g_{A\gamma}~<~1.4 \times 10^{-11}~{\rm GeV}^{-1}.$

 164 RAFFELT 86 gives a limit $g_{A\gamma} < 1.1 \times 10^{-10}~{\rm GeV}^{-1}$ from red glants and $< 2.4 \times 10^{-9}$

GeV $^{-1}$ from the sun. 165 KAPLAN 85 says $m_{A^0} <$ 23 eV is allowed for a special choice of model parameters.

 $^{166}\,\mathrm{FUKUGITA}$ 82 gives a limit $g_{A\gamma}~<~2.3\times10^{-10}~\mathrm{GeV}^{-1}.$

Search for Relic Invisible Axions

Limits are for $[G_{A\gamma\gamma}/m_{A^0}]^2
ho_A$ where $G_{A\gamma\gamma}$ denotes the axion two-photon coupling, $L_{
m int}=rac{G_{A\gamma\gamma}}{4}\phi_AF_{\mu
u}\widetilde{F}^{\mu
u}=G_{A\gamma\gamma}\phi_A{f E.B.}$ and ho_A is the axion energy density near

VALUE T	e earth.	CL%	DOCUMENT ID		TECN	COMMENT
• • • V	Ve do not use the	follow	ing data for average	es, fit:	s, limits,	etc. • • •
<2 ×	10-41		¹⁶⁷ HAGMANN	90	CNTR	$m_{A^0} =$
<1.3 ×	10-42	95	168 WUENSCH	89	CNTR	$(5.4-5.9)10^{-6} \text{ eV}$ $m_{A_0}^0 = (4.5-10.2)10^{-6}$
<2 ×	10-41	95	168 WUENSCH	89	CNTR	eV m _{A0} =

167 HAGMANN 90 experiment is based on the proposal of SIKIVIE 83.

168 WUENSCH 89 looks for condensed axions near the earth that could be converted to photons in the presence of an intense electromagetic field via the Primakoff effect, following the proposal of SIKIVIE 83. The theoretical prediction with $[G_{A\gamma\gamma}/m_{A0}]^2$ = 2×10^{-14} MeV $^{-4}$ (the three generation DFSZ model) and $\rho_A=300$ MeV/cm 3 that makes up galactic halos gives $(G_{A\gamma\gamma}/m_{A^0})^2\,\rho_A=4\times 10^{-44}.$ Note that our definition of $G_{A\gamma\gamma}$ is $(1/4\pi)$ smaller than that of WUENSCH 89.

Invisible A⁰ (Axion) Limits from Photon Coupling

Limits are for the axion-two-photon coupling $G_{A\gamma\gamma}$ defined by $L=G_{A\gamma\gamma}\phi_A {\bf E}\cdot {\bf B}$. Related limits from astrophysics can be found in the "Invisible A⁰ (Axion) Mass Limits from Astrophysics and Cosmology" section.

VALUE (GeV-1)	CL%	DOCUMENT ID		COMMENT
• • • We do not use the	ne follov	ving data for averages	, fit	s, limits, etc. • • •
$< 3.6 \times 10^{-7}$	95	169 CAMERON	93	$m_{A^0} < 10^{-3} \text{ eV},$ optical rotation
$<6.7 \times 10^{-7}$	95	170 CAMERON	93	$m_{A^0} < 10^{-3} \text{ eV},$ photon regeneration
<3.6 × 10 ⁻⁹	99.7	¹⁷¹ LAZARUS	92	m _{A0} < 0.03 eV
$< 7.7 \times 10^{-9}$	99.7	¹⁷¹ LAZARUS	92	$m_{A0} = 0.03 - 0.11 \text{ eV}$
$< 7.7 \times 10^{-7}$	99	¹⁷² RUOSO	92	$m_{A0}^{A^{\circ}} < 10^{-3} \text{ eV}$
$< 2.5 \times 10^{-6}$		173 SEMERTZIDIS	90	$m_{A0} = 0.03 - 0.11 \text{ eV}$ $m_{A0} < 10^{-3} \text{ eV}$ $m_{A0} < 7 \times 10^{-4} \text{ eV}$
169 Experiment based of	n nrono			•••

169 Experiment based on proposal by MAIANI 86.
170 Experiment based on proposal by VANBIBBER 87.

171 LAZARUS 92 experiment is based on proposal found in VANBIBBER 89.

172 RUOSO 92 experiment is based on the proposal by VANBIBBER 87.

173 SEMERTZIDIS 90 experiment is based on the proposal of MAIANI 86. The limit is obtained by taking the noise amplitude as the upper limit. Limits extend to m_{A0} = 4×10^{-3} where $G_{A\gamma\gamma}$ < 1×10^{-4} GeV $^{-1}$.

Limit on invisible A⁰ (Axion) Electron Coupling

The limit is for $G_{Aee}\partial_{\mu}\phi_{A}\overline{e}\gamma^{\mu}\gamma_{5}e$ in GeV $^{-1}$, or equivalenty, the dipole-dipole potential $\frac{G_{AEE}^2}{4\pi}$ $((\sigma_1 \cdot \sigma_2) - 3(\sigma_1 \cdot n) (\sigma_2 \cdot n))/r^3$ where n = r/r.

The limits below apply to invisible axion of $m_A \le 10^{-6}$ eV.

VALUE (GeV ⁻¹)	CL%	DOCUMENT ID	TEC	COMMENT
• • • We do not u	se the follow	ing data for average	s, fits, ilmi	its, etc. • • •
$< 5.3 \times 10^{-5}$	66	¹⁷⁴ NI	94	Induced magnetism
$< 6.7 \times 10^{-5}$	、66	¹⁷⁴ CHUI	93	Induced magnetism
$< 3.6 \times 10^{-4}$	66	175 PAN	92	Torsion pendulum
$< 2.7 \times 10^{-5}$	95	174 BOBRAKOV	91	Induced magnetism
$<1.9 \times 10^{-3}$	66	176 WINELAND	91 NMI	२
<8.9 × 10 ⁻⁴	66	175 RITTER	90	Torsion pendulum
<6.6 × 10 ⁻⁵	95	174 VOROBYOV	88	Induced magnetism

174 These experiments measured induced magnetization of a bulk material by the spindependent potential generated from other bulk material with aligned electron spins, where the magnetic field is shielded with superconductor.

These experiments used a torsion pendulum to measure the potential between two bulk matter objects where the spins are polarized but without a net magnetic field in either

176 WINELAND 91 looked for an effect of bulk matter with aligned electron spins on atomic hyperfine splitting using nuclear magnetic resonance.

Axion Limits from T-violating Medium-Range Forces

The limit is for the coupling g in a T-violating potential between nucleons or nucleon and electron of the form $V = \frac{g\hbar^2}{8\pi m_g} (\sigma \dot{\Phi}) \left(\frac{1}{f^2} + \frac{m_A c}{\hbar r} \right) e^{-m_A c r/\hbar}$

DOCUMENT ID

 • • We do not use the following data for averages, fits, limits, etc. 177 YOUDIN

177 YOUDIN 96 compared the precession frequencies of atomic ¹⁹⁹ Hg and Cs when a large mass is positioned near the cells, relative to an applied magnetic field. See Fig. 3 for

REFERENCES FOR Searches for Axions (A0) and Other Very Light Bosons

ADLER	97	PRL 79 2204	S. Adler+	(DAIL TOT Collet)
AHMAD	97	PRL 78 618	I. Ahmad+	(BNL 787 Collab.)
BORISOV	97	JETP 83 868		(APEX Collab.)
DEBOER	97C	JP G23 L85	+Grishinia F.W.N. de Boer+	(MOSU)
KACHELRIESS		PR D56 1313		(2051))
KEN	97	PR D56 2419	+Wilke, Wunner	(BOCH)
			W. Keil+	
KITCHING	97	PRL 79 4079	P. Kitching+	(BNL 787 Collab.)
LEINBERGER	97	PL B394 16	U. Leinberger+	(ORANGE Collab.)
ADLER	96	PRL 76 1421	+Atiya, Chiang, Frank, Haggerty, Ky	
AMSLER	96B	ZPHY C70 219		(Crystal Barrel Collab.)
GANZ	96	PL B389 4		, FRAN, JAGL, MPIH)
GUENTHER	96	PR D54 3641	+Hellmig, Heusser, Hirsch+	(MPIH, SASSO)
KAMEL	96	PL B368 291		(SHAMS)
MITSUI	96	EPL 33 111	+Maki, Asai, Ishisaki+	(TOKY)
YOUDIN	96	PRL 77 2170	+Krause, Jagannathan, Hunter+	(AMHT, WASH)
ALTMANN	95	ZPHY C68 221		MUNT, LAPP, CPPM)
BALEST	95	PR D51 2053	+Cho, Ford, Johnson+	(CLEO Collab.)
BASSOMPIE	95	PL B355 584	Bassompierre, Bologna+	(LAPP, LCGT, LYON)
MAENO	95	PL B351 574	+Fujikawa, Kataoka, Nishihara+	(TOKY)
RAFFELT	95	PR D51 1495	+Weiss	(MPIM, MPIA)
SKALSEY	95	PR D51 6292	+Conti	(MICH)
TSUNODA	95	EPL 30 273	+Nakamura, Orito, Minowa	(TOKY)
ADACHI	94	PR A49 3201	+Chiba, Hirose, Nagayama+	(TMU)
ALTHERR	94	ASP 2 175	+Petitgirard, del Rio Gaztelurrutia	(CERN, LAPP, DFAB)
AMSLER	94B	PL B333 271		(Crystal Barrel Collab.)
ASAI	94	PL B323 90	+Shigekuni, Sanuki, Orito	(TOKY)
MEIJERDREES	94	PR D49 4937		(BRCO, OREG. TRIU)
NI	94	Physica B194 153	+Chui, Pan, Cheng	(NTHU)
vo	94	PR C49 1551		SU, LBL, LLNL, UCD)
ATIYA	93	PRL 70 2521	+Chiang, Frank, Haggerty, Ito+	(BNL 787 Collab.)
Also	93C	PRL 71 305 (erratum)	Atiya, Chiang, Frank, Haggerty, Ito-	
ATIYA	93B	PR D48 R1	+Chiang, Frank, Haggerty, Ito+	(BNL 787 Collab.)
BASSOMPIE		EPL 22 239	Bassompierre, Bologna+	(LAPP, TORI, LYON)
BECK	93	PRI. 70 2853	+Bensch, Bockholt, Heusser, Hirsch+	
DECK	73	FIL 10 2003	Toensen, oocknoit, neusser, misch+	(MFIN, NIAE, SASSO)

Gauge & Higgs Boson Particle Listings Axions (A^0) and Other Very Light Bosons

CAMERON 93 PR D47 3707 +Cantatore, Melissinos+		N, FNAL, EFI)
CHUI 93 PRL 71 3247 +Ni MINOWA 93 PRL 71 4120 +Inoue, Asanuma, Imam	(NTHU) GOLDMAN 87 PR D36 1543 +Hallin, Hoffman+ (LANL, CHIC, nura (TOKY) KORENCHE 87 SJNP 46 192 Korenchenko, Kostin, Mzhaviya+	STAN, TEMP)
NG 93 PR D48 2941	(AST) Translated from YAF 46 313.	(SMIL)
TANAKA 93 PR D48 5412 +Ejiri	(OSAK) MAIER 87 ZPHY A326 527 +Bauer, Briggmann, Carstanjen+	(STUT, GSI)
ALLIEGRO 92 PRL 68 278 + Campagnari+ ATIYA 92 PRL 69 733 + Chiang, Frank, Haggert	(BNL, FNAL, PSI, WASH, YALE) MILLS 87 PR D36 707 +Levy ty, Ito+ (BNL, LANL, PRIN, TRIU) RAFFELT 87 PR D36 2211 +Dearborn	(BELL) (LLL, UCB)
		(ROCH, CIT+)
BLUEMLEIN 92 IJMP A7 3835 +Brunner, Grabosch+	(BERL, BUDA, JINR, SERP) TURNER 87 PRL 59 2489	(FNAL. EFI)
HALLIN 92 PR D45 3955 +Calaprice, McPherson, HENDERSON 92C PRL 69 1733 +Asoka-Kumar, Greenber	Saettler {PRIN} VANBIBBER 87 PRL 59 759 Van Bibber, Dagdeviren, Koonin+(LLL, Cl'	r, MIT, STAN)
HENDERSON 92C PRL 69 1733 +Asoka-Kumar, Greenber HICKS 92 PL B276 423 +Alburger		-Haddad(WITW) ARGUS Collab.}
LAZARUS 92 PRL 69 2333 +Smith, Cameron, Melis	ssinos+ (BNL, ROCH, FNAL) BADIER 86 ZPHY C31 21 +Bemporad, Boucrot, Callot+	(NA3 Collab.)
MEIJERDREES 92 PRL 68 3845 Meijer Drees, Waltham	n+ (SINDRUM Collab.) BOWCOCK 86 PRL 56 2676 +Giles, Hassard, Kinoshita+	(CLEO Collab.)
PAN 92 MPL 7 1287 +Ni, Chen RUOSO 92 ZPHY C56 505 +Cameron, Cantatore+	(NTHU) BROWN 86 PRL 57 2101 + (FNAL, WASH, KYOT, KEK, COLU, (ROCH, BNL, FNAL, TRST) BRYMAN 86B PRL 57 2787 +Clifford	STON, SACL) (TRIU)
SKALSEY 92 PRL 68 456 +Kolata	(MICH, NDAM) DAVIER 86 PL B180 295 + Jeanjean, Nguyen Ngoc	(LALO)
WANG 92 MPL A7 1497	(ILL) DEARBORN 86 PRL 56 26 +Schramm, Steigman (LLL, CHIC,	FNAL, BART)
WANG 92C PL 8291 97	(ILL) EICHLER 86 PL B175 101 +Felawka, Kraus, Niebuhr+ (SIN	DRUM Collab.)
WU 92 PRL 69 1729 +Asoka-Kumar, Greenber, AKOPYAN 91 PL B272 443 +Atoyan, Gninenko, Suki	rg, Henderson+(BNL, YALE, CÙNÝ) HALLIN 86 PRL 57 2105 +Calparice, Dunford, McDonald (hov {INRM}) JODIDIO 86 PR D34 1967 +Balke, Carr, Gidal, Shinsky+ {LBL,	(PRIN) NWES, TRIU)
ASAI 91 PRL 66 2440 +Orito, Yoshimura, Haga		NWES, TRIU)
BERSHADY 91 PRL 66 1398 +Ressell, Turner	(CHIC, FNAL, EFI) KETOV 86 JETPL 44 146 +Klimov, Nikolaev, Mikaelyan+	(KIAE)
BLUEMLEIN 91 ZPHY C51 341 +Brunner, Grabosch+ BOBRAKOV 91 JETPL 53 294 +Borisov, Lasakov, Sereb	(BERL, BUDA, JINR, SERP) Translated from ZETFP 44 114. KOCH 86 NC 96A 182 +Schult	(JULI)
Translated from ZETFP 53 283.	KONAKA 86 PRL 57 659 +Imai, Kobayashi, Masaike, Miyake+	(KYOT, KEK)
BROSS 91 PRL 67 2942 +Crisier, Pordes, Volk, E		COLU, STON)
KIM 91C PRL 67 3465 RAFFELT 91B PRL 67 2605 +Seckel	(SEOUL) MAIANI 86 PL B175 359 + Petronzio, Zavattini (MPIM, BART) PECCEI 86 PL B172 435 + Wu, Yanagida	(CERN) (DESY)
RESSELL 91 PR D44 3001	(MPIM, BART) PECCEI 86 PL B172 435 +Wu, Yanagida (CHIC, FNAL) RAFFELT 86 PR D33 897	(MPIM)
TRZASKA 91 PL B269 54 + Dejbakhsh, Dutta, Li,	Cormier (TAMU) RAFFELT 86B PL 166B 402	(MPIM)
TSERTOS 91 PL B266 259 +Kienle, Judge, Schrecke		(CIT)
WALKER 91 APJ 376 51 +Steigman, Schramm, O WIDMANN 91 ZPHY A340 209 +Bauer, Connell, Maier,	Diive+ (HSCA, OSU, CHIC, MINN) AMALDI 85 PL 153B 444 +Carboni, Jonson, Thun Major+ (STUT, GSI, STUTM) ANANEV 85 SJNP 41 585 +Kalinina, Lushchikov, Olshevskii+	(CERN) (JINR)
WINELAND 91 PRL 67 1735 +Bollinger, Heinzen, Itan	no, Raizen (NBSB) Translated from YAF 41 912.	• •
ALBRECHT 90E Pl. B246 278 +Ehrlichmann, Harder, K	Krueger+ (ARGUS Collab.) BALTRUSAIT 85 PRL 55 1842 Baltrusaitis, Becker, Blaylock, Brown+ (N	lark III Collab.)
ANTREASYAN 90C PL B251 204 +Bartels, Besset, Bieler, ASANUMA 90 PL B237 588 +Minowa, Tsukamoto, O		HARM Collab.) (HARV)
ASANUMA 90 PL B237 588 + Minowa, Tsukamoto, O ATIYA 90 PRL 64 21 + Chiang, Frank, Haggert	ty. Ito. Kycia+ (BNI 787 Coliab.) IWAMOTO 84 PRL 53 1198	(UCSB, WUSL)
ATIYA 908 PRL 65 1188 +Chiang, Frank, Haggert	YAMAZAKI 84 PRL 52 1089 +Ishikawa, Taniguchi, Yamanaka+	(INUS, KEK)
BAUER 90 NIM B50 300 + Briggmann, Carstanjen,	, Connell+ (STUT, VILL, GSI) ABBOTT 83 PL 120B 133 +Sikivie	(BRAN, FLOR)
BURROWS 90 PR D42 3297 +Ressell, Turner DEBOER 90 JPG 16 L1 de Boer, Lehmann, Ste	(Allie, Circ, Tital)	(CERN, MUNI)
DEBOER 90 JPG 16 L1 de Boer, Lehmann, Ste ENGEL 90 PRL 65 960 +Seckel, Hayes	(BART LANI) CAVAIGNAC 83 PL 121B 193 +Hoummada, Koang, Ost+	(ISNG, LAPP)
GNINENKO 90 PL B237 287 +Klubakov, Poblaguev, F	Postoev (INRM) DICUS 83 PR D28 1778 + Teplitz	(TEXA, UMD)
GUO 90 PR D41 2924 +Kaplan, Alde+	(NIU, LANL, FNAL, CASE, TEXA) UNE 83 PL 1208 137 +FISCHIEF	(IAS, PENN) (CERN)
HAGMANN 90 PR D42 1297 +Sikivie, Sullivan, Tanne JUDGE 90 PRL 65 972 +Krusche, Schreckenbach		(AACH)
RAFFELT 90C PRPL 198 1	(MPIM) FAISSNER 83B PR D28 1787 +Frenzel, Heinrigs, Preussger+	(AACH3)
RAFFELT 90D PR D41 1324	(MPIM) FRANK 83B PR D28 1790 + (LANL, YALE, LBL, MIT, SACL, SIN,	
RITTER 90 PR D42 977 +Goldblum, Ni, Gillies, S SEMERTZIDIS 90 PRL 64 2988 +Cameron, Cantatore+		(LANL, ARZS) (LENA Collab.)
TSUCHIAKI 90 PL B236 81 +Orito, Yoshida, Minowa		IARV, UCSBT)
TURNER 90 PRPL 197 67	(FNAL) SIKIVIE 83 PRL 51 1415	(FLOR)
BARABASH 89 PL B223 273 +Kuzminov, Lobashev, N	Novikov+ (ITEP, INRM) Also 84 PRL 52 695 erratum Sikivie Poggi Sona+(FIR2 CERN AARH) ALEKSEEV 82 JETP 55 591 +Kartamyshev, Makarin+	(FLOR)
	(ABIZ CHIC FAIAL BOCK) Translated from ZETF 82 1007.	(KIAE)
BURROWS 89 PR D39 1020 +Turner, Brinkmann Also 88 PRL 60 1797 Turner	ALEKSEEV 82B JETPL 36 116 +Kalinina, Kruglov, Kulikov+	(MOSU, JINR)
DEBOER 89B PRL 62 2639 de Boer, van Dantzig	(ANIK) ASANO 82 PL 113B 195 +Kikutani, Kurokawa, Miyachi+(KEK, TOKY	INITIS OF AIC)
ERICSON 89 PL B219 507 + Mathiot	(CERN, IPN) BARROSO 82 PL 116B 247 +Branco	
	eltz, Samm+ (AACH3, BERL, PSI) DATAR 82 PL 114B 63 +Baba, Betigeri, Singh	(LISB) (BHAB)
FISHER 89 PL B218 257 +Boehm, Bovet, Egger+	eltz, Samm+ (AACH3, BERL, PSI) DATAR 82 PL 114B 63 +Baba, Betigeri, Singh - (CIT, NEUC, PSI) EDWARDS 82 PRL 48 903 +Partridge, Peck, Porter+ (Cryst	(BHAB) al Ball Collab.)
FISHER 89 PL B218 257 +Boehm, Bovet, Egger+ FISHER 89 PR C39 288 +Kemper, Cottle, Zingan MAYLE 89 PL B219 515 +Wilson, Ellis+ (LLL,	eltz, Samm+ (AACH3, BERL, PSI) DATAR 82 PL 114B 63 + Baba, Betigeri, Singh - (CIT, NEUC, PSI) EDWARDS 82 PRL 48 903 + Partridge, Peck, Porter+ (Cryst (FSU) FETSCHER 82 JPG 8 LL47 (CERN, MINN, FNAL, CHIC, OSU) FINKLIGITA 89 PBL 48 1522 AWARDS WAY STRIMMER	(BHAB) al Ball Collab.) (ETH)
FISHER 89 PL B218 257 + Boehm, Bovet, Egger+ FOX 89 PR C39 288 + Kemper, Cottle, Zingan MAYLE 89 PL B219 515 + Wilson, Eilis+ (LLL, Also 88 PL B203 188 Mayle, Wilson+ (LLL,	BEIZ, Samm+ (AACH3, BERL, PSI) DATAR 82 PL 114B 63 + Baba, Betigeri, Singh CIT, NEUC, PSI) EDWARDS 82 PRL 48 903 + Partridge, Pek, Porter+ (Cryst Petroscher) relli (FSU) FETSCHER 82 JPG 8 LL47 CERN, MINN, FNAL, CHIC, OSU) FUKUGITA 82 PRL 48 1522 + Watamura, Yoshimura CERN, MINN, FNAL, CHIC, OSU) FUKUGITA 82 PR D26 1840 + Watamura, Yoshimura	(BHAB) al Ball Collab.)
FISHER 89 PL 8218 257 + Boehm, Bovet, Egger+ FOX 89 PR 629 288 + Kemper, Cottle, Zingan MAYLE 89 PL 8219 515 + Wilson, Elis+ (LLL, MINOWA 89 PRL 62 1091 + Orito, Tisuchiaki, Tsub	Betz, Samm+ (AACH3, BERL, PSI) DATAR 82 PL 114B 63 + Baba, Betigeri, Singh H (CIT, NEUC, PSI) EDWARDS 82 PRL 48 903 + Partridge, Peck, Porter+ (Cryst relli (FSU) FETSCHER 82 JPG 8 LL47 CERN, MINN, FNAL, CHIC, OSU) FUKUGITA 82 PRL 48 1522 + Watamura, Yoshimura CERN, MINN, FNAL, CHIC, OSU) FUKUGITA 82B PR D26 1840 + Watamura, Yoshimura kamoto (ICEPP) LEHMANN 82 PL 115B 270 + Lesquoy, Muller, Zylberajch	(BHAB) al Ball Collab.) (ETH) (KEK) (KEK) (SACL)
FISHER 89 PL B218 257 + Boehm, Bovet, Egger+ FOX 89 PR C39 288 + Kemper, Cottle, Zingan MAYLE 89 PL B219 515 + Wilson, Eilis+ (LLL, Also 88 PL B203 188 Mayle, Wilson+ (LLL,	### ### ##############################	(BHAB) al Ball Collab.) (ETH) (KEK) (KEK) (SACL) (MPIM)
FISHER 89 PL B218 257 + Bochm, Bovet, Egger+ FOX 89 PR C39 288 + Kemper, Cottle, Zingan MAYLE 89 PL B219 515 + Wilson, Ellis+ (LLL, Also 88 PL B203 188 Mayle, Wilson+ (LLL, MINOWA 89 PRL 62 1091 + Orito, Tsuchiaki, Tsuch ORITO 89 PRL 63 597 + Yoshimura, Haga, Minc PERKINS 89 PRL 62 6238 TSERTOS 89 PR 640 1397 + Kozhuharov, Armbruste	### ### ##############################	(BHAB) al Ball Collab.) (ETH) (KEK) (KEK) (SACL) (MPIM) (CUSB Collab.)
FISHER 89 PL 8218 257 + Bochm, Bovet, Egger+ FOX 89 PR 629 288 + Kemper, Cottle, Zingan MAYLE 89 PL 8219 515 + Wilson, Elilis+ (LLL, Also 88 PL 8203 188 Mayle, Wilson, Elilis+ (LLL, Also 99 PRL 62 1091 + Orito, Tisuchiak), Tisuchiak), Tisuchiak), Tisuchiak, Tisuch	DATAR 82 PL 114B 63 +Baba, Betigeri, Singh	(BHAB) al Ball Collab.) (ETH) (KEK) (KEK) (SACL) (MPIM) (CUSB Collab.) (CERN) (TH, SIN, CIT)
FISHER	DATAR 148 14	(BHAB) al Ball Collab.) (ETH) (KEK) (KEK) (SACL) (MPIM) (CUSB Collab.) (CERN) (TH, SIN, CIT) , INUS, OSAK)
FISHER	## ## ## ## ## ## ## ## ## ## ## ## ##	(BHAB) al Ball Collab.) (ETH) (KEK) (KEK) (SACL) (MPIM) (CUSB Collab.) (CERN) TH, SIN, CIT) , INUS, OSAK) (SIN)
FISHER 89 PL 8218 257 + Bochm, Bovet, Egger+ FOX 89 PR C39 288 + Kemper, Cottle, Zingan MAYLE 89 PL 8219 515 + Wilson, Ellis+ (LLL, MINOWA 89 PL 8203 188 + Warper, Wilson- (LLL, MINOWA 89 PRL 62 1091 + Orito, Tsuchiaki, Tsu/ ORITO 89 PRL 62 553 + Yoshimura, Haga, Mino TSERTOS 89 PR D40 1397 + Kozhuharov, Armbruste VANBIBBER 89 PR D39 2089 Van Bibber, Michtyer, Also 87 PRL 58 839 + De Panfilis-Wiensch, S ALSTON 88 PRL 60 1928 Aiston-Garnjost, Dough AVIGNONE 88 PR D37 618 + Baktash, Barker, Calapa	DATAR SERL, PSI	(BHAB) al Ball Collab.) (ETH) (KEK) (KEK) (SACL) (MPIM) (CUSB Collab.) (CERN) (TH, SIN, CIT) , INUS, OSAK)
FISHER 89 PL 8218 257 + Bochm, Bovet, Egger+ FOX	### ### ### ### ### ### ### ### ### ##	(BHAB) al Ball Collab.) (ETH) (KEK) (KEK) (SACL) (MPIM) (CUSB Collab.) (TH, SIN, CIT) , INUS, OSAN, (AACH3) (AACH3)
FISHER 89 PL 8218 257 + Bochm, Bovet, Egger+ FOX	DATAR SERL, PSI	(BHAB) al Ball Collab.) (ETH) (KEK) (KEK) (SACL) (MPIM) (CUSB Collab.) (CERN) (TH, SIN, CIT) INUS, OSAK) (SIN) (AACH3) (AACH3) (AACH3) (CTT, MUNI)
FISHER 69 PL 8218 257 +Bochm, Bovet, Egger+ FOX	### ### ### #### #### #### #### #### ####	(BHAB) al Ball Collab.) (ETH) (KEK) (KEK) (SACL) (MPIM) (CUSB Collab.) ETH, SIN, CIT) (INUS, OSAK) (AACH3) (AACH3) (AACH3) (CUT, MUNI) (ETH)
FISHER 69 PL 8218 257 + Bochm, Bovet, Egger+ FOX	Batts Berley Be	(BI-AB) al Ball Collab. (ETH) (KEK) (KEK) (SACL) (MPIM) (CUSB Collab.) (CLEN) (TH, SIN, CIT) (INUS, OSAK) (AACH3) (AACH3) (AACH3) (ACH3) (ACH3) (ACH3) (ACH3) (SIN) (ACH3)
FISHER 69 PL 8218 257 +Bochm, Bovet, Egger+FOX	BILL, Samm (AACH3, BERL, PSI) Property	(BHAB) al Ball Collab. (ETH) (KEK) (KEK) (KEK) (SACL) (SACL) (CUSB Collab.) (CUSB Collab.) (CHN) (TH, SIN, CIT) (INUS, OSAK) (AACH3) (AACH3) (AACH3) (CIT, MUNI) (AACH3) (CACH3) (CACH3) (CORN, PENN) (AACH3) (CORN, PENN)
FISHER 69 Pl. 8218 257 +Bochm, Bovet, Egger+FOX 89 PR. 629 288 +Kemper, Cottle, Zingan MAYLE 89 Pl. 8239 515 +Wilson, Ellis+ (LLL, MINOWA 89 PRL 62 0991 +Orito, Tsuchiaki, TsudoRITO 89 PRL 62 5638 +Yoshimura, Haga, Minc TSERTOS 89 PR. 62 5638 +Yoshimura, Haga, Minc TSERTOS 89 PR. 60 1397 +Kozhuharov, Armbruste Van Bibber, McIntyre, +Dr. 10 + North March McIntyre, +Dr. 10 + North March McIntyre, +Dr. 10 + North March McIntyre, +Dr. 10	Bit, Samm (AACH3, BERL, PSI) Property DATAR 82 PL 148 63 +Baba, Betigeri, Singh Property CIT, NEUC, PSI EDWARDS SI PRL 48 903 PRL 48 90	(BI-AB) al Ball Collab. (ETH) (KEK) (KEK) (KEK) (SACL) (MPIM) (CUSB Collab.) (CERN) (TH, SIN, CIT) (INUS, OSAK) (AACH3) (AACH3) (AACH3) (AACH3) (ETH) (AACH3) STEV, COLU) ORNL, PENN)
FISHER 69 PL 8218 257 + Bochm, Bovet, Egger+ FOX	### ### ##############################	(BHAB) al Ball Collab. (ETH) (KEK) (KEK) (KEK) (KEK) (CUSB Collab.) (CUSB Collab.) (CERN) (TH, SIN, CIT) (INUS, OSAK) (AACH3) (AACH3) (AACH3) (CT, MUNI) (AACH3) (CT, MUNI) (CACH3) (CORNL, PENN) COLU, AFRR) (PRIN)
FISHER 89 PL 8218 257 + Bochm, Bovet, Egger+ FOX 89 PR 629 288 + Kemper, Cottle, Zingan MAYLE 89 PL 8219 515 + Wilson, Ellis+ (LLL, MINOWA 89 PRL 62 1091 + Orito, Tsuchiaki, Tsul ORITO 89 PRL 62 1091 + Orito, Tsuchiaki, Tsul ORITO 89 PRL 63 597 + Koshimura, Haga, Mine TSERTOS 89 PR D40 1397 + Koshimura, Haga, Mine TSERTOS 89 PR D40 1397 Van Bibber, McIntyre, VANBIBBER 89 PR D39 2009 + Van Bibber, McIntyre, VANBIBBER 89 PR D39 2009 + Van Bibber, McIntyre, Van	### ### ### ### ### ### ### ### ### ##	(BI-AB) al Ball Collab. (ETH) (KEK) (KEK) (KEK) (SACL) (MPIM) (CUSB Collab.) (CERN) :TH, SIN, CIT) (INUS, OSAK) (AACH3) (AACH3) (AACH3) (ACH3) (CUT, MUNI) STEV, COLU (PRIN) LU, ILL, BNL) (SLAC, CIT)
FISHER 89 PL 8218 257 + Bochm, Bovet, Egger+ FOX 89 PR 629 288 + Kemper, Cottle, Zingan MAYLE 89 PL 8219 515 + Wilson, Ellis+ Also 88 PL 18203 188 + Warper, Wilson, Ellis+ ORITO 89 PRL 62 1991 + Orito, Tsuchiaki, Tsul ORITO 89 PRL 63 597 + Vorito, Tsuchiaki, Tsul ORITO 89 PRL 63 597 + Vorito, Tsuchiaki, Tsul ORITO 89 PRL 63 593 + Voshimura, Haga, Mine TSERTOS 89 PR DA0 1397 Van Bibber, McIntyre, VANBIBBER 89 PR D39 2099 Van Bibber, McIntyre, Also 87 PRL 59 839 De Panfilis, Melisiono, A ALSTON— 89 PRL 60 1928 Alston-Garnjost, Dough AVIGNONE 88 PR D37 618 + Bohdar, Nelson, Abash BLINOV 88 SINP 47 563 Translated from YaF 47 889. BOLTON 88 PR D38 2077 Also 86 PRL 57 3241 Bolton, Bowman, Coop Also 86 PRL 57 3241 Bolton, Bowman, Coop Cronsick, Wright, Bolto CHOI 88 PR D37 2725 + Kim, Lam LTM 189 PR C37 250 Grosnick, Wright, Bolto DATAR 89 PR C37 250 Ge Bock, van Dantzig Also 89 PRL 61 1274 Also 89 PRL 61 1274 Also 89 PRL 62 2644 erratum de Boer, van Dantzig	### ### ### ### ### ### ### ### ### ##	(BI-AB) al Ball Collab. (ETH) (KEK) (KEK) (KEK) (SACL) (MPIM) (CUSB Collab.) (CERN) (TH, SIN, CIT) (INUS, OSAN) (AACH3) (AACH3) (AACH3) (AACH3) (ETH) (AACH3) STEV, COLU) ORNL, PENN) LU, ILL, BNL)
FISHER 69 Pl. 8218 257 +Bochm, Bovet, Egger+ FOX	### ### ### ### ### ### ### ### ### ##	(BI-AB) al Ball Collab. (ETH) (KEK) (KEK) (SACL) (MPIM) (CUSB Collab.) (CERN) (TH, SIN, CIT) (INUS, OSAK) (AACH3) (AACH3) (AACH3) (AACH3) (ACH3) (ACH3) (ACH3) (ACH3) (CUT, MUNI) ORNL, PENN) COLU, AFRR) (PRIN) LU, ILL, BNL) (SLAC, CIT) (NOVO)
FISHER 89 PL 8218 257 + Bochm, Bovet, Egger+ FOX 89 PR 629 288 + Kemper, Cottle, Zingan MAYLE 89 PL 8219 515 + Wilson, Ellis+ Also 88 PL 18203 188 + Waryer, Wilson, Ellis+ MINOWA 89 PRL 62 1091 + Orito, Tsuchiaki, Tsu ORITO 89 PRL 63 597 + Yoshimura, Haga, Minc TSERTOS 89 PR D40 1397 + Kozhuharov, Armbruste VANBIBBER 89 PR D39 2089 Van Bibber, McIntyre, WUENSCH 89 PR D40 3153 + De Panfilis, Melissinos, Also 87 PRL 59 339 De Panfilis, Melissinos, ALSTON 88 PRL 60 1928 + Battasis, Barter, Calpe BURNEN 88 PR D37 518 + Battasis, Barter, Calpe BURNEN 89 PR D39 3375 + Ecklund, Nelson, Abash BURNOV 81 SINP 47 563 + Ecklund, Nelson, Abash BURNOV 88 PR D38 3375 + Ecklund, Nelson, Abash BURNOV 88 PR D38 3277 + Footag, Bukin, Voroby Also 86 PRL 59 2461 Bolton, Bowman, Coop Also 86 PRL 59 2461 Bolton, Bowman, Coop Also 86 PRL 59 2461 Bolton, Bowman, Coop Also 87 PRL 59 23714 + Hinvex, Pal HINOW Right, Bolton Also 89 PRL 62 2644 erratum Also 89 PRL 62 2644 erratum Also 89 PRL 62 2644 erratum Also 89 PRL 62 2643 de Boer, van Dantzig Also 89 PRL 62 2643 de Boer, van Dantzig Also 89 PRL 62 2633 de Boer, van Dantzig Also 89 PRL 62 2631 de Boer, van Dantzig Also 89 PRL 62 2631 de Boer, van Dantzig Also 89 PRL 62 2631 de Boer, van Dantzig Also 89 PRL 62 2631 de Boer, van Dantzig Also 690 PRL 62 2631 de Boer, van Dantzig Also 690 PRL 62 2631 de Boer, van Dantzig Also 690 PRL 62 2631 de Boer, van Dantzig Also 690 PRL 62 2631 de Boer, van Dantzig Also 690 PRL 62 2634 de Boer, van Dantzig Also 690 PRL 62 2631 de Boer, van Dantzig Also 690 PRL 62 2631 de Boer, van Dantzig Also 690 PRL 62 2631 de Boer, van Dantzig Also 690 PRL 62 2631 de Boer, van Dantzig Also 690 PRL 62 2631 de Boer, van Dantzig Also 690 PRL 62 2631 de Boer, van Dantzig Also 690 PRL 62 2631 de Boer, van Dantzig Also 690 PRL 62 2631 de Boer, van Dantzig Also 690 PRL 62 2631 de Boer, van Dantzig	DATAR SEPIL, PSI	(BHAB) al Ball Collab. (ETH) (KEK) (KEK) (KEK) (KEK) (SACL) (MPIM) (CUSB Collab.) (CERN) :TH, SIN, CIT) (INUS, OSAK) (AACH3) (AACH3) (AACH3) (AACH3) (AACH3) (SIN) (SIN) (SIN) (SIN) (SIN) (SACH) (ETH) (ETH) (ETH) (ETH) (FRIN) (IL, BILL, BNL) (SLAC, CIT) (NOVO) (AMORIO) (MOVO) (AMORIO) (AMORIO) (AMORIO) (MOVO) (AMORIO)
FISHER 69 PL 8218 257	DATAR SERIL, PSI P	(BI-AB) al Ball Collab. (ETH) (ETH) (KEK) (KEK) (KEK) (SACL) (MPIM) (CUSB Collab.) (CERN) (TH, SIN, CIT) (INUS, OSAK) (AACH3) (AACH3) (AACH3) (AACH3) (AACH3) (ETH) (AACH3) STEV, COLU) ORNL, PENN) LU, ILL, BNL) (SLC, CIT) ((NOVO) (MILA)
FISHER 69 PL 8218 257	### Patridge, Peck, Potrer + (Cryst (FSU)	(BHAB) al Ball Collab. (ETH) (KEK) (KEK) (KEK) (SACL) (CUSH Collab.) (CUSH Collab.) (CUSH Collab.) (CUSH Collab.) (AACH3) (AACH3) (AACH3) (AACH3) (AACH3) (SIN) (STN) (SIN) (STN) (OU) (PRIN) (PRIN) (SLAC, CIT) (NOVO) (SAME Collab.) (GTEP, SERP) (MILA) (BEBC Collab.)
FISHER 69 PL 8218 257 +Bochm, Bovet, Egger+ FOX 89 PR C39 288 +Kemper, Cottle, Zingan MAYLE 89 PL 8219 515 +Wilson, Ellis+ (LLL, MINOWA 89 PR 18203 188 +Wemper, Cottle, Zingan Mayle, Wilson+ (LLL, MINOWA 89 PR 163 597 +Orito, Tsuchiaki, Tsul ORITO 89 PR 163 597 +Yoshimura, Haga, Minc TSERTOS 89 PR D40 1397 +Xoshimura, Haga, Minc TSERTOS 89 PR D40 3153 +Xoshimura, Haga, Minc Wuensch 89 PR D39 2009 Van Bibber, McIntyre, WUENSCH 89 PR D40 3153 +De Panfilis, Melissinos, Also 87 PR 158 339 De Panfilis, Melissinos, Also 80 PR 158 3375 +Ccoper, Translated from YAF 78 +De Panfilis, Melissinos, Absol BLINOV 88 PR D37 618 +Baktasis, Barker, Calap BLINOV 89 PR D38 2375 +Ccoper, Frank, Hallin+ Blinov 158 PR D38 2771 +Hondar, Busin, Voroby Chol Blinov 89 PR 157 3241 +Hincy, Pal +Hincy, Pal +Hincy, Might, Bolto Also 89 PR 162 2644 erratum Also 89 PR 162 2644 errat	DATAR SEPIL, PSI	(BI-AB) al Ball Collab. (ETH) (ETH) (KEK) (KEK) (KACL) (MPIM) (CUSB Collab. (CERN) (TH, SIN, CIT) (INUS, OSAN) (AACH3) (AACH3) (AACH3) (AACH3) (AACH3) (ETH) (AACH3) STEV, COLU) ORNL, PENN) LU, ILL, BNL) (SLAC, CIT) ((NOVO) (AMEL) (CITER) (COLU, AFRR) (PRIN) (COLU, AFRR) (PRIN) (COLU, AFRR) (PRIN) (SLAC, CIT) (NOVO) (AMEL) (MILA)
FISHER 69 PL 8218 257 + Bochm, Bovet, Egger+ FOX	### ### ### ### ### ### ### ### ### ##	(BHAB) al Ball Collab. (ETH) (EXEK) (KEK) (KEK) (KEK) (KEK) (SACL) (MPIM) (CUSB Collab.) (CERN) (TH, SIN, CIT) (INUS, OSAK) (AACH3) (AACH3) (AACH3) (AACH3) (AACH3) (AACH3) (ETH) (AACH3) STEV, COLU ORNL, PENN) (UI, ILL, BNL) (SLAC, CIT) (NOVO) (SAMELIE COLLAB, CHEN) (SEEC COLLAB, VPI, STAN) (UCI) (STAN) (UCI) (STAN) (UCI)
FISHER 69 PL 8218 257 +Bochm, Bovet, Egger+ FOX 89 PR C39 288 +Kemper, Cottle, Zingan MAYLE 89 PL 8219 515 +Wilson, Ellis+ (LLL, MINOWA 89 PR 18203 188 +Wemper, Cottle, Zingan Mayle, Wilson+ (LLL, MINOWA 89 PR 163 597 +Orito, Tsuchiaki, Tsul ORITO 89 PR 163 597 +Yoshimura, Haga, Minc TSERTOS 89 PR D40 1397 +Xoshimura, Haga, Minc TSERTOS 89 PR D40 3153 +Xoshimura, Haga, Minc Wuensch 89 PR D39 2009 Van Bibber, McIntyre, WUENSCH 89 PR D40 3153 +De Panfilis, Melissinos, Also 87 PR 158 339 De Panfilis, Melissinos, Also 80 PR 158 3375 +Ccoper, Translated from YAF 78 +De Panfilis, Melissinos, Absol BLINOV 88 PR D37 618 +Baktasis, Barker, Calap BLINOV 89 PR D38 2375 +Ccoper, Frank, Hallin+ Blinov 158 PR D38 2771 +Hondar, Busin, Voroby Chol Blinov 89 PR 157 3241 +Hincy, Pal +Hincy, Pal +Hincy, Might, Bolto Also 89 PR 162 2644 erratum Also 89 PR 162 2644 errat	Bit, Samm (AACH3, BERL, PSI)	(BHAB) al Ball Collab. (ETH) (KEK) (KEK) (KEK) (KEK) (SACL) (MPIM) (CUSB Collab.) TH, SIN, CIT) TH, SIN, CIT) (AACH3) (AACH3) (AACH3) (AACH3) (AACH3) (CUT, MUNI) (ETH) (ACH3) STEV, COLU) GRNL, FENN) (OLU, AFRR) (PRIN) (ULI, BNL) (UTEP, SERP) (MILA) (BEBC Collab.) (VCI) (STAN) (STAN) (STAN) (UCI) (UCI)
FISHER 89 PL 8218 257 + Bochm, Bovet, Egger+ FOX 89 PR 629 288 + Kemper, Cottle, Zingan MAYLE 89 PL 8219 515 + Wilson, Ellis+ LLL, MINOWA 89 PR 162 1091 + Orito, Tsuchiaki, Tsul ORITO 89 PRI, 62 1091 + Orito, Tsuchiaki, Tsul ORITO 89 PRI, 63 597 + Voximura, Haga, Mine TSERTOS 69 PR D40 1397 + Kozhuharov, Armbruste WUENSCH 89 PR D39 2089 Van Bibber, McIntyre, BOLTON 88 PR D39 2089 Van Bibber, McIntyre, BUINOV 88 PR D37 518 + Baktash, Barker, Calap BUINOV 88 PR D37 518 + Baktash, Barker, Calap BUINOV 88 PR D38 2072 BUINOV 88 PR D37 2214 + Hivers, Pal CHANDA 89 PR D37 2214 + Kim, Kim, Lam CHOL 88 PR D37 3225 + Foritic, Gales, Houraria Also 89 PRI, 62 2644 erratum Also 89 PRI, 62 2643 ed Boer, van Dantzig Also 89 PRI, 62 2643 ed Boer, van Dantzig DEBOER 80 PR D38 2722 + Foritic, Gales, Houraria Also 89 PRI, 62 2651 ed Boer, van Dantzig DEBOER 80 PR D38 2722 + Heinrigs, Preussger, Re HATSUDA 888 PR B203 469 + Voskimura HATSUDA 888 PR B203 469 + Voskimura HATSUDA 888 PR B203 188 + Heinrigs, Preussger, Re HATSUDA 888 PR B203 188 + Heinrigs, Preussger, Re HVOSKIMURA HVIEN PR D30 188 PR B203 189 + Vision PR UNIVER PR B30 308 + Vision PR UNIVER B30 308 + Vision PR B30 308 + Vi	Bit, Samm (AACH3, BERL, PSI) CIT, NEUC, PSI CIT,	(BHAB) al Ball Collab. (ETH) (KEK) (KEK) (KEK) (KEK) (KEK) (SACL) (MPIM) (CUSB Collab.) (CERN) (SACL) (AACH3) (AACH3) (AACH3) (AACH3) (AACH3) (AACH3) (ACH3) (ACH3) (ACH3) (ACH3) (ACH3) (ACH3) (ACH3) (CIT, MUNI) (ETH) (SLAC, CIT) (NOVO) (TER, SERP) (UCI) (STAN) (UCI) (UCI) (UCI) (UCI) (CDHS Collab.)
FISHER 69 Pl. 8218 257 + Bochm, Bovet, Egger+ FOX 89 PR C39 288 + Kemper, Cottle, Zingan MAYLE 89 Pl. 8219 515 + Wilson, Ellis+ (LLL, MINOWA 89 Pl. 8203 188 + Kemper, Cottle, Zingan MAYLE 89 Pl. 8203 188 + Kemper, Cottle, Zingan Mayle	## ## ## ## ## ## ## ## ## ## ## ## ##	(BHAB) al Ball Collab. (ETH) (KEK) (KEK) (KEK) (KEK) (KEK) (SACL) (MPIM) (CUSB Collab.) (CERN) (ACH3) (AACH3) (AACH3) (AACH3) (AACH3) (AACH3) (AACH3) (ACH3) (ACH3) (ACH3) (ACH3) (ACH3) (ACH3) (ACH3) (ACH3) (ACH3) (CIT, MUNI) (ETH) (ACH3) (JETH) (SLAC, CIT) (NOVO) (TER, SERP) (UCI) (JERC Collab.) (UCI) (UCI) (CITS Collab.) (UCI) (COLS Collab.) (INR)
FISHER 89 PL 8218 257 + Bochm, Bovet, Egger+ FOX 89 PR 629 288 + Kemper, Cottle, Zingan MAYLE 89 PL 8219 515 + Wilson, Ellis+ LLL, MINOWA 89 PR 162 1091 + Orito, Tsuchiaki, Tsul ORITO 89 PRI, 62 1091 + Orito, Tsuchiaki, Tsul ORITO 89 PRI, 63 597 + Voximura, Haga, Mine TSERTOS 69 PR D40 1397 + Kozhuharov, Armbruste WUENSCH 89 PR D39 2089 Vas Bibber, McIntyre, WUENSCH 89 PR D39 397 Learn State Control Also 89 PR D37 518 + Baktash, Barker, Calap BJORKEN 89 PR D38 2072 Also 86 PR 57 3261 Healtash, Barker, Calap Also 86 PR 57 3261 Grosnick, Wright, Bolto, CONNELL 88 PR D37 3225 + Kotan, Also 89 PR D37 2214 + Kim, Kim, Lam Also 89 PR D37 2214 + Kim, Kim, Lam Also 89 PR D37 2214 + Kim, Kim, Lam Also 89 PR D37 2259 Heinis, Kim, Lam Also 89 PR D37 2515 Heinis, Preussger, Re HATSUDA 888 PL B203 469 Heinis, Preussger, Re HATSUDA 889 PL B203 489 Heinings, Preussger, Re HYOShimura ANYLE 89 PL B203 188 Heinings, Preussger, Re HYOShimura Eggert Scholer, Latt, Ammad, Britton, Bryma ARFELT 88 PL B203 188 Heinings, Preussger, Re HYOShimura Eggert Scholer, Latt, Ammad, Britton, Bryma ASFERTOS SCHOLER SCH	### ### ### ### ### ### ### ### ### ##	(BHAB) al Ball Collab. (ETH) (KEK) (KEK) (KEK) (KACL) (MPIM) (CUSB Collab.) TH, SINCTI T
FISHER 89 PL 8218 257 + Bochm, Bovet, Egger+ FOX 89 PR 629 288 + Kemper, Cottle, Zingan MAYLE 89 PL 8219 515 + Wilson, Ellis+ LLL, MINOWA 89 PR 162 1091 + Orito, Tsuchiaki, Tsul ORITO 89 PRI, 62 1091 + Orito, Tsuchiaki, Tsul ORITO 89 PRI, 63 597 + Voxisimura, Haga, Mine TSERTOS 89 PR D40 3197 + Kozhuharov, Armbruste WUENSCH 89 PR D39 2089 Vas Bibber, McIntyre, BOLTON 88 PR D39 218 + De Panfilis, Welskinson, ALSTON 88 PR 160 1928 AVIGNONE BUINOV 88 PR D37 618 + Baktash, Barker, Calap BUINOV 88 PR D37 618 + Baktash, Barker, Calap BUINOV 88 PR D37 631 + Ccounty, Malton BUINOV 88 PR D38 2077 Also 86 PRI, 55 2461 Grosnick, Wright, Bolte CHANDA 88 PR D37 2214 + Kim, Kim, Lam CONNELL 88 PR D37 3225 + Fortier, Gales, Houraria Also 89 PRI, 62 2644 erratum Also 89 PRI, 62 2644 erratum Also 89 PRI, 62 2644 erratum Also 89 PRI, 62 2643 de Boer, van Dantzig Also 89 PRI, 62 2643 de Boer, van Dantzig DEBOER 80 PR D38 2722 + Heinrigs, Preussger, Re HATSUDA 88 PR D37 321 + Heinrigs, Preussger, Re HATSUDA 88 PR D33 49 + PRI- AND 40 40 1131 + Handrigs, Preussger, Re HATSUDA 88 PR D33 49 + Voskimura PRI- RAFFELT 88 PR D37 1314 + Wilson- Hilling, Preussger, Re HVOShimura PRO37 1311 + Ahmad, Britton, Bryma RAFFELT 88 PR D37 1314 + Secket POSTONIA 1111 + Handrigs, Preussger, Re HVOSHIMURA PRO37 1311 + HANDRIGH Fredman PRO37 1311 + HANDRIGH FR	### ### ### ### ### ### ### ### ### ##	(BHAB) al Ball Collab. (ETH) (KEK) (KEK) (KEK) (KEK) (KEK) (SACL) (MPIM) (CUSB Collab.) (CERN) (ACH3) (AACH3) (AACH3) (AACH3) (AACH3) (AACH3) (AACH3) (ACH3) (ACH3) (ACH3) (ACH3) (ACH3) (ACH3) (ACH3) (ACH3) (ACH3) (CIT, MUNI) (ETH) (ACH3) (JETH) (SLAC, CIT) (NOVO) (TER, SERP) (UCI) (JERC Collab.) (UCI) (UCI) (CITS Collab.) (UCI) (COLS Collab.) (INR)
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FISHER 99 P. B.218 257 + Bochm, Bovet, Egger+ FOX 89 PR C39 288 + Kemper, Cottle, Zingan MAYLE 89 PL B239 158 + Kemper, Cottle, Zingan MAYLE 89 PL B203 158 + Kemper, Cottle, Zingan Mayle Mayle, Wilson, LLL, MINOWA 89 PRL 62 991 + Orito, Tsuchiaki, Tsul ORITO 89 PRL 63 597 + Yoshimura, Haga, Minc TSERTOS 89 PR D40 1397 + Yoshimura, Haga, Minc TSERTOS 89 PR D40 1397 + Kozhuharov, Armbruste Mayle, Mayle, Wilson, LLL, Mayle, Wilson, Mayle, Minc Mayle, M	Bill, Jamm+ (AACH3, BERL, PSI) DATAR	(BI-AB) al Ball Collab.] (ETH) (KEK) (KEK) (KEK) (KEK) (KEK) (SACL) (MPIM) (CUSB Collab.) (ITH, SIN, CIT) (INUS, OSAK) (AACH3) (AACH3) (AACH3) (AACH3) (AACH3) (AACH3) (SIN) (SIN) (ITH, SIN, CIT) (ITH, SIN
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FISHER 89 PL 8218 257 + Bochm, Bovet, Egger+ FOX 89 PR 629 288	DATAR 82 PL 1148 63	(BHAB) al Ball Collab. (ETH) (KEK) (KEK) (KEK) (KEK) (KEK) (KEK) (SACL) (MPIM) (CUSB Collab.) (CUSB Collab.) (CH, SIN, CIT) (INUS, OSAK) (AACH3) (AACH3) (AACH3) (AACH3) (AACH3) (AACH3) (ACH3) (FETH) (AACH3) (CIT, MUNI) (ETH) (AACH3) (FEND, (PRIN) (JUL) (JEAC, CIT) (MOVO) (JIEP, SERP) (MILA) (BEBC Collab.) (JUT) (CDHS COLL) (JUR) (COHS COLL) (JUR) (MASA) (STAN, SLAC) (STAN, SLAC) (STAN, SLAC) (STAN, SLAC) (UCI) (UCI)
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LEPTONS

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LEPTONS

 $J = \frac{1}{2}$

e MASS

The mass is known much more precisely in u (atomic mass units) than in MeV (see the footnote). The conversion from u to MeV, $1\,u=931.49432\pm0.00028$ MeV, involves the relatively poorly known electronic

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
0.51099907±0.00000015	¹ FARNHAM	95	CNTR	Penning
• • • We do not use the follow	ving data for averag	es, fit	s, limits,	etc. • • •
$0.51099906 \pm 0.00000015$	² COHEN	87	RVUE	1986 CODATA value
0.5110034 ± 0.0000014	COHEN	73	RVUE	1973 CODATA value

 $^{1}\,\mbox{FARNHAM}$ 95 compares cyclotron frequency of trapped electrons with that of a single trapped $^{12}\text{C}^{+6}$ Ion. The result is $m_e=0.0005485799111(12)$ u, where the figure in parenthesis is the $^{1}\sigma$ uncertainty in the last digit. The uncertainty after conversion to MeV is dominated by the uncertainty in the electron charge.

² COHEN 87 (1986 CODATA) value in atomic mass units is 0.000548579903(13). See footnote on FARNHAM 95.

$(m_{e^+}-m_{e^-})\ /\ m_{ m average}$

A test of CPT invariance.

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<4 × 10 ⁻⁸	90	сни	84	CNTR	Positronium spec- troscopy

$|q_{e^+} + q_{e^-}|/e$

A test of CPT invariance. See also similar tests involving the proton.

VALUE	DOCUMENT ID		TECN	COMMENT
<4 × 10 ⁻⁸	3 HUGHES	92	RVUE	
• • • We do not use the	following data for average	es, fit	s, limits,	etc. • • •
$< 2 \times 10^{-18}$				Vacuum polarization
$<1 \times 10^{-18}$	⁵ MUELLER	92	THEO	Vacuum polarization
tios. ⁴ SCHAEFER 95 remov	es model dependency of N	MUEL	LER 92.	nd cyclotron-frequency ra-
order vacuum polariza	tion, contribute to the ne	t cha	rge of at	oms.

e MAGNETIC MOMENT ANOMALY

 $\mu_e/\mu_B - 1 = (g-2)/2$ For the most accurate theoretical calculation, see KINOSHITA 81.

Some older results have been omitted.

OHEN	_			
OHEN	87	RVUE		1986 CODATA value
a for average	s, fits	, limits,	etc. •	• •
ANDYCK	87	MRS	_	Single electron
ANDYCK	87	MRS	+	Single positron
'ANDYCK	86	MRS	-	Single electron
CHWINBERG	S 81	MRS	+	Single positron
	ANDYCK ANDYCK ANDYCK CHWINBERG	ANDYCK 87 ANDYCK 87 ANDYCK 86 CHWINBERG 81	YANDYCK 87 MRS YANDYCK 87 MRS YANDYCK 86 MRS CHWINBERG 81 MRS	YANDYCK 87 MRS + YANDYCK 86 MRS -

$(g_{e^+} - g_{e^-}) / g_{average}$

A test of CPT invariance.

VALUE (units 10 ⁻¹²)	CL%	DOCUMENT ID	TECN	COMMENT
-0.5 ± 2.1		7 VANDYCK 87	MRS	Penning trap
• • • We do not use	the follow	ing data for averages, fit	s, limits	, etc. • • •
< 12	95	8 VASSERMAN 87	CNTR	Assumes $m_{a^+} = m_{a^-}$
22 ±64		SCHWINBERG 81	MRS	Penning trap
7 VANDYCK 87 me	asured (g	$_{-}/g_{+})-1$ and we conve	rted it.	
8 VASSERMAN 87	measured	$(g_{\perp} - g_{\perp})/(g-2)$. W	/e multij	olied by $(g-2)/g = 1.2 \times$
10-3		- // -		

e ELECTRIC DIPOLE MOMENT

A nonzero value is forbidden by both T invariance and P invariance.

VALUE (10 ⁻²⁶ ecm) CL%	DOCUMENT ID		TECN	COMMENT	_
0.18± 0.12±0.10	9 COMMINS	94	MRS	²⁰⁵ Tl beams	
 We do not use the following 	g data for averages,	fits,	limits,	etc. • • •	
- 0.27± 0.83	⁹ ABDULLAH	90	MRS	205 Ti beams	
- 14 ± 24	СНО	89	NMR	TI F molecules	
$-$ 1.5 \pm 5.5 \pm 1.5	MURTHY	89		Cesium, no B field	
- 50 ±110	LAMOREAUX	87	NMR	¹⁹⁹ Hg	
190 ±340 90	SANDARS	75	MRS	Thallium	
70 ±220 90	PLAYER	70	MRS	Xenon	
< 300 90	WEISSKOPF	68	MRS	Ceslum	

the relativistic enhancement of a valence electron's electric dipole moment in a high-Z atom.

e MEAN LIFE / BRANCHING FRACTION

A test of charge conservation. See the "Note on Testing Charge Conservation and the Pauli Exclusion Principle" following this section in our 1992 edition (Physical Review **D45**, 1 June, Part II (1992), p. VI.10). We use the best "disappearance" limit for the Summary Tables. The best limit for the specific channel $e^- \to \nu \gamma$ is much better.

Note that we use the mean life rather than what is often reported, the

VALUE (yr)	CL%	DOCUMENT ID	TECN	COMMENT
>4.3 × 10 ²³	68	AHARONOV	95B CNTR	Ge K-shil disappearance
• • • We do no	t use the	following data for a	verages, fits,	limits, etc. • • •
$> 3.7 \times 10^{25}$	68	AHARONOV	95B CNTR	$e^- \rightarrow \nu \gamma$
>2.35 × 10 ²⁵	68	BALYSH	93 CNTR	$e^- \rightarrow \nu \gamma$, ⁷⁶ Ge detector
$>2.7 \times 10^{23}$	68	REUSSER	91 CNTR	Ge K-shell disappearance
$>1.5 \times 10^{25}$	68	AVIGNONE	86 CNTR	$e^- \rightarrow \nu \gamma$
>1 × 10 ³⁹		¹⁰ ORITO	85 ASTR	Astrophysical argument
>3 × 10 ²³	68	BELLOTTI	83B CNTR	e ⁻ → νγ
>2 × 10 ²²	68	BELLOTTI	83B CNTR	Ge K-shell disappearance

 $^{^{10}\,\}textsc{ORITO}$ 85 assumes that electromagnetic forces extend out to large enough distances and that the age of our galaxy is $10^{10}\,$ years.

e REFERENCES

AHARONOV	95B	PR D52 3785	+Avignon, Brodzinski, Collar+ (SCU)	C, PNL, ZAGR, TELA)
Also	95	PL B353 168	Aharonov, Avignone+ (SCU)	C, PNL, ZAGR, TELA)
FARNHAM	95	PRL 75 3598	+Van Dyck, Schwinberg	(WASH)
SCHAEFER	95	PR A51 838	A. Schaefer, J. Reinhardt	(FRAN)
COMMINS	94	PR A50 2960	E.D. Commins, S.B. Ross, D. DeM	ille, B.C. Regan
BALYSH	93	PL B298 278	+Beck, Belyaev, Bensch+	(KIAE, MPIH, SASSO)
HUGHES	92	PRL 69 578	+ Deutch	(LANL, AARH)
MUELLER	92	PRL 69 3432	+Thoma	(DUKE)
PDG	92	PR D45, 1 June,	Part II Hikasa, Barnett, Stone+	(KEK, LBL, BOST+)
REUSSER	91	PL B255 143	+Treichel, Boehm, Broggini+	(NEUC, CIT, PSI)
ABDULLAH	90	PRL 65 2347	+Carlberg, Commins, Gould, Ross	` (LBL, UCB)
CHO	89	PRL 63 2559	+Sangster, Hinds	(YALE)
MURTHY	89	PRL 63 965	+Krause, Li, Hunter	(ÀMHT)
COHEN	87	RMP 59 1121	+Taylor	(RISČ. NBS)
LAMOREAUX	87	PRL 59 2275	+Jacobs, Heckel, Raab, Fortson	` (WASH)
VANDYCK	87	PRL 59 26	Van Dyck, Schwinberg, Dehmelt	(WASH)
VASSERMAN	87	PL B198 302	+Vorobyov, Gluskin+	(NOVO)
Also	87B	PL B187 172	Vasserman, Vorobyov, Gluskin+	(NOVO)
AVIGNONE	86	PR D34 97	+Brodzinski, Hensley, Miley, Reeves+	(PNL, SCUC)
VANDYCK	86	PR D34 722	Van Dyck, Schwinberg, Dehmelt	(WASH)
ORITO	85	PRL 54 2457	+Yoshimura	(TOKÝ, KEK)
CHU	84	PRL 52 1689	+Mills. Hall	(BELL, NBS, COLO)
BELLOTTI	83B	PL 124B 435	+Corti, Fiorini, Liguori, Pullia+	(MILA)
KINOSHITA	81	PRL 47 1573	+Lindquist	(CORN)
SCHWINBERG	81	PRL 47 1679	+Van Dyck, Dehmelt	(WASH)
SANDARS	75	PR A11 473	+Sternheimer	(OXÈ, BNL)
COHEN	73	JPCRD 2 663	+ Taylor	(RISC, NBS)
PLAYER	70	JPB 3 1620	+ Sandars	` (OXF)
WEISSKOPF	68	PRL 21 1645	+Carrico, Gould, Lipworth+	(BRAN)

 $J=\frac{1}{2}$

μ MASS

The mass is known more precisely in u (atomic mass units) than in MeV (see the footnote to COHEN 87). The conversion from u to MeV, $1\,u=931.49432\pm0.00028$ MeV, involves the relatively poorly known electronic

Where $m_{\mu}/m_{\rm e}$ was measured, we have used the 1986 CODATA value for $m_{\rm e}=0.51099906\pm0.00000015$ MeV.

VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT
108.658389±0.000034	1 COHEN	87	RVUE		1986 CODATA value
• • We do not use the follow	ving data for average	s, flt	s, ilmits,	etc. e	
105.65841 ±0.00033	² BELTRAMI	86	SPEC	_	Muonic atoms
105.658432±0.000064	³ KLEMPT	82	CNTR	+	Incl. in MARIAM 82
105.658386±0.000044	4 MARIAM	82	CNTR	+	MARIAN 02
105.65856 ±0.00015	5 CASPERSON	77	CNTR	+	
105.65836 ±0.00026	⁶ CROWE	72	CNTR		
105.65865 ±0.00044	7 CRANE	71	CNTR		
¹ The mass is known more pr makes use of the other entr ² BELTRAMI 86 gives m_{μ}/m_{μ}	ries helow		8913 ± 0	0.0000	00017 u. COHEN 87
³ KLEMPT 82 gives m _μ /m _e	= 206.76835(11).				
4 MARIAM 82 gives m _u /m _e	= 206.768259(62).				

μ MEAN LIFE τ Measurements with an error $> 0.001 \times 10^{-6}$ s have been omitted.

VALUE (10 ⁻⁶ s)	DOCUMENT ID		TECN	CHG
2.19703 ±0.00004 OUR AVERAG	SE .			
2.197078±0.000073	BARDIN	84	CNTR	+
2.197025±0.000155	BARDIN	84	CNTR	_
2.19695 ±0.00006	GIOVANETTI	84	CNTR	+
2.19711 ±0.00008	BALANDIN	74	CNTR	+
2.1973 ±0.0003	DUCLOS	73	CNTR	+

au_{μ^+}/ au_{μ^-} MEAN LIFE RATIO

A test of CPT Invariance.

VALUE	DOCUMENT II		TECN	COMMENT
1.000024±0.000078	BARDIN	84	CNTR	
• • We do not use the following	ing data for avera	ges, fits	s, limits,	etc. • • •
1.0008 ±0.0010	BAILEY	79	CNTR	Storage ring
1.000 ±0.001	MEYER	63	CNTR	Mean life μ^+/μ^-

$$(au_{\mu^+} - au_{\mu^-}) / au_{ ext{average}}$$

A test of CPT invariance. Calculated from the mean-life ratio, above.

VALUE	DOCUMENT ID
$(2\pm8)\times10^{-5}$ OUR EVALUATION	

μ MAGNETIC MOMENT ANOMALY

 $\mu_\mu/(e\hbar/2m_\mu)-1=(g_\mu-2)/2$ For reviews of theory and experiments, see HUGHES 85, KINOSHITA 84, COMBLEY 81, FARLEY 79, and CALMET 77.

VALUE (units 10 ⁻⁶)	DOCUMENT ID		TECN	CHG	COMMENT
1165.9230±0.0084	COHEN	87	RVUE		1986 CODATA value
• • We do not use the following the following the following that the following the following that the following the followi	llowing data for averag	es, fit	s, limits,	etc.	• • •
1165.910 ±0.011	8 BAILEY	79	CNTR	+	Storage ring
1165.937 ±0.012	8 BAILEY	79	CNTR	_	Storage ring
1165.923 ±0.0085	8 BAILEY	79	CNTR	±	Storage ring
1165.922 ±0.009	8 BAILEY	77	CNTR	±	Storage ring
1166.16 ±0.31	BAILEY	68	CNTR	±	Storage rings
11620 +50	CHARPAK	62	CNTR	_	

 8 BAILEY 79 is final result. Includes BAILEY 77 data. We use μ/p magnetic moment ratio = 3.1833452 and recalculate the BAILEY 79 values. Third BAILEY 79 result is first two combined.

$(g_{\mu^+}-g_{\mu^-})$ / $g_{ m average}$

A test of CPT Invariance

VALUE (units	

DOCUMENT ID BAILEY

µ **ELECTRIC DIPOLE MOMENT**

A nonzero value is forbidden by both T invariance and P invariance.

VALUE (10 ⁻¹⁹ ecm)	DOCUMENT ID		TECN	CHG	COMMENT
3.7±3.4	9 BAILEY	78	CNTR	±	Storage ring
• • • We do not use the fo	ollowing data for averag	es, fits	i, limits,	etc. •	• •
8.6±4.5	BAILEY	78	CNTR	+	Storage rings
0.8±4.3	BAILEY	78	CNTR	_	Storage rings
⁹ This is the combination	of the two BAILEY 78	result	s given t	elow.	

μ/p MAGNETIC MOMENT RATIO

This ratio is used to obtain a precise value of the muon mass. Measurements with an error > 0.00001 have been omitted.

<u>VALUE</u> 3.18334547±0.00000047	10 COHEN	87	<u>TECN</u> RVUE	CHG	1986 CODATA value
• • • We do not use the followi	ng data for average	s, fit:	s, limits,	etc. •	• •
3.1833441 ±0.0000017	KLEMPT	82	CNTR	+	Precession strob
3.1833461 ±0.0000011	MARIAM	82	CNTR	+	HFS splitting
3.1833448 ±0.0000029	CAMANI	78	CNTR	+	See KLEMPT 82
3.1833403 ±0.0000044	CASPERSON	77	CNTR	+	HFS splitting
3.1833402 ±0.0000072	COHEN	73	RVUE		1973 CODATA value
3.1833467 ±0.0000082	CROWE	72	CNTR	+	Precession phase

10 COHEN 87 (1986 CODATA) value was fitted using their own selection of the following data. Because their value is from a multiparameter fit, correlations with other quantities may be important and one cannot arrive at this result by any average of these data alone.

μ^- DECAY MODES

 μ^+ modes are charge conjugates of the modes below.

Mode		Fraction (Γ ₁ /Γ)	Confidence level
$e^-\overline{\nu}_e \nu_\mu$		≈ 100%		
$e^- \overline{\nu}_e \nu_\mu \gamma$		[a] (1.4±0	.4) %	
$e^-\overline{ u}_e u_\mu e^+ e^-$		[b] (3.4±0	.4) × 10 ⁻⁵	
Lepton Fa	mily number (<i>i</i>	.F) violatin	g modes	
$e^- \nu_e \overline{\nu}_{\mu}$	LF	[c] < 1.2	%	90%
e ⁻ γ ΄	LF	< 4.9	× 10 ⁻¹¹	90%
e ⁻ e ⁺ e ⁻	LF	< 1.0	× 10 ⁻¹²	90%
$e^-2\gamma$	LF	< 7.2	× 10 ⁻¹¹	90%
	$e^-\overline{\nu}_e \nu_\mu$ $e^-\overline{\nu}_e \nu_\mu \gamma$ $e^-\overline{\nu}_e \nu_\mu e^+e^-$ Lepton Fall $e^-\nu_e\overline{\nu}_\mu$ $e^-\gamma$ $e^-e^+e^-$	$e^-\overline{ u}_e u_\mu$ $e^-\overline{ u}_e u_\mu\gamma$ $e^-\overline{ u}_e u_\mu e^+e^-$ Lepton Family number (ℓ $e^- u_e u_\mu$ ℓ	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$

- [a] This only includes events with the γ energy > 10 MeV. Since the $e^-\,\overline{\nu}_e\,\nu_\mu$ and $e^- \overline{\nu}_e \nu_\mu \gamma$ modes cannot be clearly separated, we regard the latter mode as a subset of the former.
- [b] See the Particle Listings below for the energy limits used in this measure-
- [c] A test of additive vs. multiplicative lepton family number conservation.

μ~ BRANCHING RATIOS

$\Gamma(e^- \overline{\nu}_e \nu_\mu \gamma) / \Gamma_{\text{total}}$				•			Γ ₂ /Ι
VALUE	EVTS	DOCUMENT ID		TECN	COMA	MENT	
0.014 ±0.004		CRITTENDEN	61	CNTR	γKE	> 10 MeV	
• • • We do not use the	e follow	ng data for average:	i, fit	s, limits,	etc. •	• •	
	862	BOGART	67	CNTR	γ ΚΕ	> 14.5 Me\	,
0.0033±0.0013		CRITTENDEN	61	CNTR	γKE	> 20 MeV	
	27	ASHKIN	59	CNTR			
$\Gamma(e^- \nu_e \nu_\mu e^+ e^-)/\Gamma_e$ VALUE (units 10^{-5})	EVTS	DOCUMENT ID			_		Гз/
3.4±0.2±0.3	7443	11 BERTL	85	SPEC	+	SINDRUM	
 • • We do not use the 	e follow	ng data for averages	i, fit	s, limits,	etc. •		
2.2±1.5	7	12 CRITTENDEN	61	HLBC	+	E(e+e-)> MeV	10
2	1	13 GUREVICH	60	EMUL	+	1110.4	
1.5±1.0	3	¹⁴ LEE	59	HBC	+		
11 BERTL 85 has trans Increased by us.		nomentum cut p_T					

- 12 CRITTENDEN 61 count only those decays where total energy of either (e^+ , e^-) comblaation is >10 MeV. ¹³ GUREVICH 60 interpret their event as either virtual or real photon conversion. e⁺ and
- e energies not measured. ¹⁴ In the three LEE 59 events, the sum of energies $E(e^+) + E(e^-) + E(e^+)$ was 51 MeV, 55 MeV, and 33 MeV.

⁵ CASPERSON 77 gives $m_{\mu}/m_{e} = 206.76859(29)$.

⁶ CROWE 72 gives $m_{\mu}/m_e = 206.7682(5)$. ⁷CRANE 71 gives $m_{\mu}/m_e = 206.76878(85)$.

		conservation law fo					
•		g ratio to be 1/2. F					
.UE	<u>CLN</u>	15 FREEDMAN				COMMENT	
0.012	90	FREEDMAN	93	CNTR	+	ν oscillation search	1
• We do not u	se the follow	ing data for average	es, fit	s, limits,	etc. •		
0.018	90	KRAKAUER	91E	CALO	+		
0.05	90	¹⁶ BERGSMA	83	CALO		$\overline{\nu}_{\mu}e \rightarrow \mu$	- v ,
0.09	90	JONKER	80	CALO		See BERGS	
-0.001 ± 0.061		WILLIS	80	CNTR	+		
0.13 ± 0.15		BLIETSCHAL	78	HLBC	±	Avg. of 4 v	alues
0.25	90	EICHTEN	73	HLBC	+		
FREEDMAN 93	B limit on ワ,	observation is here	e inte	rpreted a	as a lir	nit on leptor	family
number violatio BERGSMA 83	n. gives a limit	on the inverse muc ,), which is essentia	on de	cay cross	-sectio	on ratio $\sigma(\overline{ u}_{\mu})$,e
small values like			ну сч	PIAGICIIL	101 (6	' e μ)/ ' t	otal
e ⁻ γ)/Γ _{total}	lenton famil	y number conservat	ion				Γ ₅ /Γ
UE (units 10 ⁻¹¹)	CL%	DOCUMENT ID		TECN	CHG	COMMENT	
4.9	90	BOLTON	88		+	LAMPF	
		ing data for averag					
100	90 90	AZUELOS KINNISON	83 82	CNTR SPEC	++	TRIUMF LAMPF	
17 100	90 90	SCHAAF	80	ELEC	+	SIN	
	30	SCHAAF	OU		7	J.114	
e ⁻ e ⁺ e ⁻)/Γtc	otal						Γ ₆ /Ι
Forbidden by	lepton faml	ly number conservat	ion.				
UE (units 10 ⁻¹²)	<u>CL%</u>	DOCUMENT ID		TECN		COMMENT	
1.0	90	17 BELLGARDT		SPEC	+	SINDRUM	
• We do not u	se the follow	Ing data for averag	es, fit	s, limits,	etc. •	• • •	
36	90	BARANOV	91	SPEC	+	ARES	
35	90	BOLTON	88	CBOX	+	LAMPF	
2.4	90	17 BERTL	85	SPEC	+	SINDRUM	
160	90	17 BERTL	84	SPEC	+	SINDRUM	
130	9 0	17 BOLTON	84	CNTR		LAMPF	
These experime	nts assume	a constant matrix e	emer	t.			
e ⁻ 2γ)/Γ _{total} Forbidden by	lepton fami	ly number conservat	ion.				Γ ₇ /Ι
		-				COMMENT	
LUE (units 10 ⁻¹¹)	CL%	DOCUMENT ID		TECN	CHG	COMMENT	
7.2	<u>CL%</u> 90	DOCUMENT ID		CBOX	+	LAMPF	
7.2	90		88	свох	+	LAMPF	
7.2 • • We do not u	90	BOLTON ving data for averag	88	свох	+	LAMPF	
7.2 • • We do not u 840	90 ise the follow	BOLTON ving data for averag	88 es, fil	CBOX s, limits	+ etc.	LAMPF TRIUMF DEPOMM	IER 77
• • We do not u 840 5000 ⁸ AZUELOS 83 u	90 90 90 90 90 uses the phase	BOLTON ving data for averag 18 AZUELOS 19 BOWMAN se space distribution	88 es, fli 83 78 of B	CBOX s, limits CNTR CNTR	+ , etc. (+	LAMPF TRIUMF DEPOMM data	
7.2 • • We do not u 840 5000 8 AZUELOS 83 1	90 90 90 90 uses the phase assumes an	BOLTON ving data for averag 18 AZUELOS 19 BOWMAN se space distribution interaction Lagran	88 es, fit 83 78 of B gian I	CBOX is, limits CNTR CNTR OWMAI	+ , etc. • + N 78.	LAMPF TRIUMF DEPOMM data	
7.2 • • We do not u 840 5000 8 AZUELOS 83 u 9 BOWMAN 78 mass.	90 90 90 90 ses the phase assumes an	BOLTON ving data for averag 18 AZUELOS 19 BOWMAN se space distribution	88 es, fli 83 78 of B gian I	CBOX ss, limits CNTR CNTR OWMAI ocal on	+ , etc. • + N 78.	LAMPF TRIUMF DEPOMM data	
7.2 • We do not used to the second of the s	90 90 90 90 ses the phase assumes an LIMIT by lepton fa	BOLTON ving data for average 18 AZUELOS 19 BOWMAN se space distribution interaction Lagran, ON $\mu^- \rightarrow e^-$ imily number consein $(\mu^{-32}S \rightarrow \nu_{\mu}^{32})$	88 es, fit 83 78 of B gian I	CBOX s, limits CNTR CNTR CNTR OWMAI ocal on VERSI	+ + N 78. the sc	LAMPF TRIUMF DEPOMM data	
7.2 • We do not u 840 85000 3 AZUELOS 83 a 9 BOWMAN 78 mass. Forbidden	90 uses the follow 90 90 uses the pha: assumes an LIMIT by lepton fa	BOLTON 18 AZUELOS 19 BOWMAN se space distribution interaction Lagran ON $\mu^- \rightarrow e^-$ Imily number conseinable of the process of the proc	88 es, fil 83 78 of B gian I	CBOX s, limits CNTR CNTR OWMAI ocal on VERSIO	+ + + + + + + + + + + + + + + + + + +	LAMPF TRIUMF DEPOMM data	
7.2 ■ • We do not u 840 840 BAZUELOS 83 u BOWMAN 78 mass. Forbidden	90 90 90 90 ses the follow 90 90 LIMIT by lepton fa -32S) / $\sigma(\frac{CLX}{90})$	BOLTON 18 AZUELOS 19 BOWMAN se space distribution interaction Lagran ON $\mu^- \rightarrow e^-$ Imily number consei $\mu^{-32} = \nu_{\mu}^{32}$ BADERT	88 es, fill 83 78 of B gian I CON vatio	CBOX s, ilmits CNTR CNTR OWMAI ocal on VERSIO n. IECN STRC	+ + etc. + + N 78. the sc	TRIUMF DEPOMM data cale of the in	
7.2 • • We do not u 840 840 BOWMAN 78 Forbidden p-325 → e-4 LUE 7 × 10-11 • • We do not u	90 90 90 90 ses the follow 90 90 LIMIT by lepton fa -32S) / $\sigma(\frac{CLX}{90})$	BOLTON ving data for average 18 AZUELOS 19 BOWMAN se space distribution interaction Lagran ON $\mu^- \rightarrow e^-$ imily number consei $(\mu^{-32}S \rightarrow \nu_{\mu}^{32})$ $\frac{DOCUMENT IC}{BADERT}$ ving data for average	88 es, fill 83 78 of Biglan I	CBOX s, ilmits CNTR CNTR CNTR OWMAI ocal on VERSI n TECN STRC ts, ilmits	+ + + + + + + + + + + + + + + + + + +	LAMPF TRIUMF DEPOMM data cale of the in	
7.2 • • We do not u 840 840 BOWMAN 78 Forbidden p-325 → e-4 LUE 7 × 10-11 • • We do not u	90 90 90 90 ses the follow 90 90 LIMIT by lepton fa -32S) / $\sigma(\frac{CLX}{90})$	BOLTON 18 AZUELOS 19 BOWMAN se space distribution interaction Lagran ON $\mu^- \rightarrow e^-$ Imily number consei $\mu^{-32} = \nu_{\mu}^{32}$ BADERT	88 es, fill 83 78 of Biglan I	CBOX s, ilmits CNTR CNTR CNTR OWMAI ocal on VERSI n TECN STRC ts, ilmits	+ + + + + + + + + + + + + + + + + + +	LAMPF TRIUMF DEPOMM data cale of the in	
7.2 • • We do not u 840 8AZUELOS 83 a 8 BOWMAN 78 mass. Forbidden	90 90 90 90 ses the follow 90 90 LIMIT by lepton fa -32S) / σ (21% 90 90	BOLTON 18 AZUELOS 19 BOWMAN se space distribution Interaction Lagran ON $\mu^- \rightarrow e^-$ imily number consei μ^- 325 $\rightarrow \nu_\mu$ 32 μ^- BADERT ving data for average BADERT μ^- Cu \rightarrow captum	88 88 es, fill 83 78 of B glan I CON vatio P*) 80 es, fil 77	CBOX s, limits CNTR CNTR OWMAI ocal on VERSIO TECN STRC STRC	+ etc. + + N 78. The scoon SIN etc. SIN	LAMPF TRIUMF DEPOMM data cale of the in	
7.2 • • We do not u 840 840 9 BOWMAN 78 mass. Forbidden p-32 S → e ⁻ LUE 7 × 10 ⁻¹¹ • • We do not u 4 × 10 ⁻¹⁰ p-Cu → e ⁻ LUE	90 90 90 90 see the follow 90 90 LIMIT by lepton fa -32S) / σ (21½ 90 cu) / σ (μ)	BOLTON 18 AZUELOS 19 BOWMAN se space distribution Interaction Lagran ON $\mu^- \rightarrow e^-$ imily number consei μ^- 325 $\rightarrow \nu_\mu$ 32 μ^- BADERT ving data for average BADERT μ^- Cu \rightarrow captum	88 88 es, fil 83 78 of B glan I CON vatio P*) 80 es, fil 77	CBOX s, limits CNTR CNTR OWMAI ocal on VERSI n. IECN STRC ts, limits STRC	+ etc. + + N 78. the sc	TRIUMF DEPOMM data cale of the in	
7.2 • • We do not u 840 840 8 AZUELOS 83 a 9 BOWMAN 78 mass. Forbidden (µ-325 → e-1) (UE 7 × 10-11 • • We do not u 4 × 10-10 (µ-Cu → e-1) (UE • • We do not u	90 90 90 90 see the follow 90 90 LIMIT by lepton fa -32S) / σ (21½ 90 Cu) / σ (μ see the follow 90 Cu) / σ (μ see the follow 90	BOLTON BOLTON 18 AZUELOS 19 BOWMAN se space distribution interaction Lagran ON $\mu^- \rightarrow e^-$ Imily number conseination BADERT BADERT CU \rightarrow Captur DOCUMENT IS BOUGHT IS BADERT CU \rightarrow Captur DOCUMENT IS OCUMENT I	88 88 es, fli 83 78 re 1 of Biglan I CON vatio (P*) 80 res, fli res, fli res, fli	CBOX s, limits CNTR CNTR OWMAI ocal on VERSI n. IECN STRC ts, limits STRC	+ etc. + + N 78. the sc	TRIUMF DEPOMM data cale of the in	
7.2 • • We do not u 840 • BAZUELOS 83 1 • BOWMAN 78 mass. Forbidden	90 90 90 90 90 ses the follow 90 90 LIMIT by lepton fa -32S) / σ ($\frac{CLX}{90}$ 90 Cu) / σ (μ ses the follow 90	BOLTON 18 AZUELOS 19 BOWMAN se space distribution Interaction Lagran, ON $\mu^- \rightarrow e^-$ Imily number conseint and the second state of the second sta	88 88 es, fli 83 78 re 1 of Biglan I CON vatio (P*) 80 res, fli res, fli res, fli	CBOX s, limits CNTR CNTR OWMAI ocal on VERSI n. IECN STRC ts, limits STRC	+ etc. + + N 78. the sc	TRIUMF DEPOMM data cale of the in	
7.2 • • We do not use the way of the way o	90 90 90 90 90 ses the follow 90 90 LIMIT by lepton fa -32S) / σ ($\frac{CLX}{90}$ 90 Cu) / σ (μ ses the follow 90	BOLTON 18 AZUELOS 19 BOWMAN se space distribution Interaction Lagran, ON μ → e - (1) smilly number consect μ - 325 → ν μ 32 DOCUMENT IS BADERT TOU → Capture DOCUMENT IS BRYMAN TI → Capture) DOCUMENT IS	88 es, fil 83 78 res, fil 98 res, fil 77 res, fil 72	CBOX s, limits cNTR CNTR OWMAI ocal on n.	+ + etc. + + + N 78. The scoon SIN SIN etc. SIN etc.	TRIUMF DEPOMM data ale of the in	
7.2 • • We do not use the way of the way o	90 90 90 90 see the follow 90 90 LIMIT by lepton fa -32S) $/ \sigma ($ 90 use the follow 90 Cu) $/ \sigma (\mu $ Size the follow 90 Ti) $/ \sigma (\mu $	BOLTON 18 AZUELOS 19 BOWMAN se space distribution Interaction Lagran ON μ → e − i Imily number consei μ − 325 → ν μ 32 DOCUMENT IC BADERT S − Cu → capture DOCUMENT IC BRYMAN ¬TI → capture)	88 es, fil 83 78 res, fil 98 res, fil 77 res, fil 72	CBOX s, limits cNTR CNTR OWMAI ocal on n.	+ + etc. + + + N 78. The scoon SIN SIN etc. SIN etc.	TRIUMF DEPOMM data ale of the in	
7.2 • • We do not u 840 840 8AZUELOS 83 a 9 BOWMAN 78 mass. Forbidden (µ-325 → e- (µ-10-11 • • We do not u 4 × 10-10 (µ-Cu → e- (µ-Cu → e- (µ-Cu → e- (µ-Tu → e-	90 90 90 90 10 10 10 10 10 10 10 10 10 10 10 10 10	BOLTON 18 AZUELOS 19 BOWMAN se space distribution Interaction Lagran, ON μ → e - (1) smilly number consect μ - 325 → ν μ 32 DOCUMENT IS BADERT TOU → Capture DOCUMENT IS BRYMAN TI → Capture) DOCUMENT IS	88 es, fili 83 78 res, fili 93 res, fili 72 res, fili 72	CBOX s, limits cNTR CNTR OWMAI ocal on n. - TECN STRC TECN TECN SPEC - TECN SPEC	+ etc. + + N 78. The scoon SINI	LAMPF TRIUMF DEPOMM data cale of the in	
7.2 • • We do not u 840 5000 8 AZUELOS 83 19 9 BOWMAN 78 mass. Forbidden (µ-32S → e ⁻¹ LUE • • We do not u 4 × 10 ⁻¹⁰ (µ-Cu → e ⁻¹ LUE • • We do not u 1.6 × 10 ⁻⁸ (µ-Π → e ⁻¹ LUE 4.3 × 10 ⁻¹² • • We do not u	90 90 90 90 10 10 10 10 10 10 10 10 10 10 10 10 10	BOLTON 18 AZUELOS 19 BOWMAN se space distribution Interaction Lagran, ON $\mu^- \rightarrow e^-$ Imilio number consee Imilio number consee Imilio number consee BADERT Cu — capture DOCUMENT IC BRYMAN TI — capture) DOCUMENT IC DOCUMENT	88 es, fili 83 78 83 78 93 93 es, fili 93 93 es, fili 93 es, fili 72	CBOX s, limits cNTR CNTR OWMAI ocal on n. - TECN STRC TECN TECN SPEC - TECN SPEC	+ etc. + + N 78. The scoon SINI	LAMPF TRIUMF DEPOMM data cale of the in	
7.2 • • We do not u 840 840 AZUELOS 83 a 9 BOWMAN 78 mass. Forbidden [µ-32S → e ⁻ LUE 7 × 10-11 • • We do not u 4 × 10-10 [µ-Cu → e ⁻ LUE 4.3 × 10-12 • • We do not u 4.6 × 10-12	90 90 90 90 see the follow 90 90 LIMIT by lepton fa 90 90 Cu) / $\sigma(\mu$ 90 TI) / $\sigma(\mu$ 90 use the follow 90 TI) / $\sigma(\mu$ 90 see the follow 90 See the follow 90 TI) / $\sigma(\mu$ 90 see the follow 90 TI) / $\sigma(\mu$ 90 see the follow 90 see the follow	BOLTON In azuelos 18 Azuelos 19 BOWMAN se space distribution Interaction Lagran ON μ → e → e Imilio number consee Iμ → 325 → νμ 32 DOCUMENT IC BADERT ICu → captum DOCUMENT IC BRYMAN TI → capture) POCUMENT IC 20 DOHMEN Wing data for average BRYMAN	88 es, fil 83 78 83 78 93 es, fil 88	CBOX s, ilmits cNTR CNTR OWMAI ocal on TECN STRC TECN TECN SPEC T	+ etc. + + N 78. The scommon sin etc. Sin etc. COM Sini etc.	LAMPF TRIUMF DEPOMM data cale of the in	
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7.2 • • We do not u 840 • BAZUELOS 83 19 • BOWMAN 78 mass. Forbidden	90 90 90 90 90 see the follow 90 90 LIMIT by lepton fa -32S) $/ \sigma (\mu$ 90 90 Cu) $/ \sigma (\mu \mu$ CL% use the follow 90 TI) $/ \sigma (\mu$ 90 90 90 90 assumes μ ed by cohern	BOLTON 18 AZUELOS 19 BOWMAN se space distribution Interaction Lagran, ON μ → e − i Imily number consei (μ − 325 → νμ 32 DOCUMENT IC BADERT S Cu → capture DOCUMENT IC DOCUMENT IC AUTHORITY CONSEINED POCUMENT IC OOUMENT IC AUTHORITY CAPTURE A	88 es, fli 83 78 es, fli 80 P*) 80 es, fli 72 93 es, fli 88 85 leave o don	CBOX s, limits cNTR CNTR OWMAI ocal on n.	+ etc. + + N 78. the scoon SIN etc. SIN SINII etc. TRIII TRIII	LAMPF TRIUMF DEPOMM data ale of the in MENT DRUM II ONLY UMF	iverse ,
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LIMIT ON $\mu^- \rightarrow e^+$ CONVERSION

Forbidden by total lepton number conservation.

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$\sigma(\mu^{-127} \to e^{+127}S) \to e^{+127}S$ $<3 \times 10^{-10}$	CLX	DOCUMENT ID		TECN	COMMENT Radiochemical tech.
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 $< 2.6 \times 10^{-8}$ BRYMAN 72 SPEC <2.2 × 10⁻⁷ CONFORTO 62 OSPK $\sigma(\mu^-\Pi \to e^+Ca) \ / \ \sigma(\mu^-\Pi \to capture)$ CL% DOCUMENT ID 15CH 22 DOHMEN 93 SPEC SINDRUM II <8.9 × 10⁻¹¹ ● We do not use the following data for averages, fits, limits, etc. <4.3 \times 10⁻¹² 23 DOHMEN 93 SPEC SINDRUM II 90 <1.7 × 10⁻¹⁰ 24 AHMAD 90 88 TPC TRIUMF

• • • We do not use the following data for averages, fits, limits, etc. • •

22 This DOHMEN 93 limit assumes a glant resonance excitation of the daughter Ca nucleus (mean energy and width both 20 MeV).

23 This DOHMEN 93 limit assumes the daughter Ca nucleus is left in the ground state. However, the probability of this is unknown.

²⁴ Assuming a giant-resonance-excitation model.

LIMIT ON MUONIUM -> ANTIMUONIUM CONVERSION

Forbidden by lepton family number conservation.

$R_{\rm g} = G_{\rm C} / G_{\rm F}$

The effective Lagrangian for the $\mu^+e^-
ightarrow \mu^-e^+$ conversion is assumed to be

$$\mathcal{L} = 2^{-1/2} \; \textit{G}_{\textit{C}} \; [\overline{\psi}_{\mu} \gamma_{\lambda} \; (1 \, - \, \gamma_{5}) \; \psi_{e}] \; [\overline{\psi}_{\mu} \gamma_{\lambda} \; (1 \, - \, \gamma_{5}) \; \psi_{e}] \; + \; \text{h.c.}$$

The experimental result is then an upper limit on $G_{\mathcal{C}}/G_{\mathcal{F}}$, where $G_{\mathcal{F}}$ is the Fermi coupling constant.

VALUE	CL%	EVTS	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT
< 0.018	90	0	²⁵ ABELA	96	SPEC	+	μ^+ at 24 MeV
• • We do	not use the	follow	ng data for average	s, fits	, limits,	etc. •	• •
< 0.14	90	1	²⁶ GORDEEV	97	SPEC	+	JINR phasotron
< 6.9	90		NI	93	CBOX		LAMPF
< 0.16	90		MATTHIAS	91	SPEC		LAMPF
< 0.29	90		HUBER	90B	CNTR		TRIUMF
<20	95		BEER	86	CNTR		TRIUMF
<42	95		MARSHALL	82	CNTR		

 $^{25}\,\mathrm{ABELA}$ 96 quote both probability $P_{\mbox{$M\overline{M}$}}$ $< 8 \times 10^{-9}$ at 90% CL and $R_{\mbox{\it g}} = G_{\mbox{\it C}}/G_{\mbox{\it F}}.$ ²⁶ GORDEEV 97 quote limits on both $f=G_{MM}/GF$ and the probability W_{MM} < 4.7 × 10⁻⁷ (90%CL).

MUON DECAY PARAMETERS

Revised October 1997 by W. Fetscher and H.-J. Gerber (ETH Zürich).

Introduction: All measurements in direct muon decay, $\mu^- \to e^- + 2$ neutrals, and its inverse, $\nu_\mu + e^- \to \mu^- + \text{neutral}$, are successfully described by the "V-A interaction", which is a particular case of a local, derivative-free, lepton-number-conserving, four fermion interaction [1]. As shown below, within this framework, the Standard Model assumptions, such as the V-A form and the nature of the neutrals $(\nu_\mu \text{ and } \bar{\nu}_e)$, and hence the doublet assignments $(\nu_e \ e^-)_L$ and $(\nu_\mu \ \mu^-)_L$, have been determined from experiments [2,3]. All considerations on muon decay are valid for the leptonic tau decays $\tau \to \ell + \nu_\tau + \bar{\nu}_e$ with the replacements $m_\mu \to m_\tau$, $m_e \to m_\ell$.

Parameters: The differential decay probability to obtain an e^{\pm} with (reduced) energy between x and x+dx, emitted in the direction \widehat{z} at an angle between ϑ and $\vartheta+d\vartheta$ with respect to the muon polarization vector \vec{P}_{μ} , and with its spin pointing in the arbitrary direction $\widehat{\zeta}$, neglecting radiative corrections, is given by

$$\begin{split} \frac{d^2\Gamma}{dx\ d\cos\vartheta} &= \frac{m_\mu}{4\pi^3} \ W_{e\mu}^4 \ G_F^2 \ \sqrt{x^2 - x_0^2} \\ &\quad \times (F_{IS}(x) \pm P_\mu \cos\vartheta \ F_{AS}(x)) \\ &\quad \times \left[1 + \vec{P}_e(x,\vartheta) \cdot \hat{\zeta} \right] \ . \end{split} \tag{1}$$

Here, $W_{e\mu}=\max(E_e)=(m_{\mu}^2+m_e^2)/2m_{\mu}$ is the maximum e^\pm energy, $x=E_e/W_{e\mu}$ is the reduced energy, $x_0=m_e/W_{e\mu}=9.67\times 10^{-3}$, and $P_{\mu}=|\vec{P}_{\mu}|$ is the degree of muon polarization. $\hat{\zeta}$ is the direction in which a perfect polarization-sensitive electron detector is most sensitive. The isotropic part of the spectrum, $F_{IS}(x)$, the anisotropic part $F_{AS}(x)$ and the electron polarization, $\vec{P}_e(x,\vartheta)$, may be parametrized by the Michel parameters [1,4] ρ , η , ξ , δ , etc. These are bilinear combinations of the coupling constants $g_{\epsilon\mu}^{\gamma}$, which occur in the matrix element (given below).

If the masses of the neutrinos as well as x_0^2 are neglected, the energy and angular distribution of the electron in the rest frame of a muon (μ^{\pm}) measured by a polarization insensitive detector, is given by

$$\begin{split} \frac{d^2\Gamma}{dx\ d\cos\vartheta} \sim x^2 \cdot \left\{ 3(1-x) + \frac{2\rho}{3}(4x-3) + 3\eta\ x_0(1-x)/x \right. \\ \left. \pm P_\mu \cdot \xi \cdot \cos\vartheta \left[1 - x + \frac{2\delta}{3}(4x-3) \right] \right\} \ . \end{split}$$

Here, ϑ is the angle between the electron momentum and the muon spin, and $x\equiv 2E_e/m_\mu$. For the Standard Model coupling, we obtain $\rho=\xi\delta=3/4,\,\xi=1,\,\eta=0$ and the differential decay rate is

$$\frac{d^2 \Gamma}{dx \ d\cos\vartheta} \ = \ \frac{G_F^2 m_\mu^5}{192 \pi^3} \ \left[3 - 2 x \pm P_\mu \cos\vartheta (2x-1) \right] \ x^2 \quad . \label{eq:delta}$$

The coefficient in front of the square bracket is the total decay rate.

If only the neutrino masses are neglected, and if the e^{\pm} polarization is detected, then the functions in Eq. (1) become

$$\begin{split} F_{IS}(x) &= x(1-x) + \frac{2}{9} \, \rho (4x^2 - 3x - x_0^2) + \eta \cdot x_0 (1-x) \\ F_{AS}(x) &= \frac{1}{3} \xi \, \sqrt{x^2 - x_0^2} \\ &\qquad \times \left[1 - x + \frac{2}{3} \delta \left(4x - 3 + \left(\sqrt{1 - x_0^2} - 1 \right) \right) \right] \\ \vec{P}_e(x, \vartheta) &= P_{T_1} \, \hat{x} + P_{T_2} \hat{y} + P_L \, \hat{z} \, . \end{split}$$

Here \hat{x} , \hat{y} , and \hat{z} are orthogonal unit vectors defined as follows:

 \hat{z} is along the e momentum

 $\widehat{y} = [\widehat{z} \times \vec{P_{\mu}}]/|[\widehat{z} \times \vec{P_{\mu}}]|$ is transverse to the e momentum and perpendicular to the "decay plane" $\widehat{x} = \widehat{y} \times \widehat{z}$ is transverse to the e momentum and in the "decay plane."

The components of $\vec{P_e}$ then are given by

$$\begin{split} P_{T_1}(x,\vartheta) &= P_{\mu}\sin\vartheta \; F_{T_1}(x)/\left(F_{IS}(x) \pm P_{\mu}\cos\vartheta \; F_{AS}(x)\right) \\ P_{T_2}(x,\vartheta) &= P_{\mu}\sin\vartheta \; F_{T_2}(x)/\left(F_{IS}(x) \pm P_{\mu}\cos\vartheta \; F_{AS}(x)\right) \\ P_{L}(x,\vartheta) &= \pm F_{IP}(x) + P_{\mu}\cos\vartheta \\ &\qquad \times F_{AP}(x)/\left(F_{IS}(x) \pm P_{\mu}\cos\vartheta \; F_{AS}(x)\right) \; , \end{split}$$

where

$$\begin{split} F_{T_1}(x) &= \frac{1}{12} \left\{ -2 \left[\xi'' + 12(\rho - \frac{3}{4}) \right] (1 - x) x_0 \\ &- 3\eta(x^2 - x_0^2) + \eta''(-3x^2 + 4x - x_0^2) \right\} \\ F_{T_2}(x) &= \frac{1}{3} \sqrt{x^2 - x_0^2} \left\{ 3 \frac{\alpha'}{A} (1 - x) + 2 \frac{\beta'}{A} \sqrt{1 - x_0^2} \right\} \\ F_{IP}(x) &= \frac{1}{54} \sqrt{x^2 - x_0^2} \left\{ 9 \xi' \left(-2x + 2 + \sqrt{1 - x_0^2} \right) \right. \\ &+ 4 \xi (\delta - \frac{3}{4}) (4x - 4 + \sqrt{1 - x_0^2}) \right\} \\ F_{AP}(x) &= \frac{1}{6} \left\{ \xi''(2x^2 - x - x_0^2) + 4(\rho - \frac{3}{4}) \left(4x^2 - 3x - x_0^2 \right) \right. \\ &+ 2 \eta'' (1 - x) x_0 \right\} . \end{split}$$

For the experimental values of the parameters ρ , ξ , ξ' , ξ' , δ , η , η' , α/A , β/A , α'/A , β'/A , which are not all independent, see the Data Listings below. Experiments in the past have also been analyzed using the parameters a, b, c, a', b', c', α/A , β/A , α'/A , β'/A (and $\eta = (\alpha - 2\beta)/2A$), as defined by Kinoshita and Sirlin [5]. They serve as a model-independent summary of all possible measurements on the decay electron (see Listings below). The relations between the two sets of parameters are

$$\begin{split} \rho - \frac{3}{4} &= \frac{3}{4}(-a+2c)/A \;, \\ \eta &= (\alpha - 2\beta)/A \;, \\ \eta'' &= (3\alpha + 2\beta)/A \;, \\ \delta - \frac{3}{4} &= \frac{9}{4} \;\cdot \; \frac{(a'-2c')/A}{1 - [a+3a'+4(b+b')+6c-14c']/A} \;, \\ 1 - \xi \frac{\delta}{\rho} &= 4 \; \frac{[(b+b')+2(c-c')]/A}{1 - (a-2c)/A} \;, \\ 1 - \xi' &= \; [(a+a')+4(b+b')+6(c+c')]/A \;, \\ 1 - \xi'' &= \; (-2a+20c)/A \;, \end{split}$$

where

$$A = a + 4b + 6c.$$

The differential decay probability to obtain a *left-handed* ν_e with (reduced) energy between y and y + dy, neglecting radiative corrections as well as the masses of the electron and of the neutrinos, is given by [6]

$$\frac{d\Gamma}{dy} \; = \; \frac{m_{\mu}^5 \; G_F}{16\pi^3} \; \cdot \; Q_L^{\nu_e} \; \cdot y^2 \Big\{ (1-y) - \omega_L \cdot (y-\tfrac{3}{4}) \Big\} \; .$$

Here, y=2 E_{ν_e}/m_{μ} . $Q_L^{\nu_e}$ and ω_L are parameters. ω_L is the neutrino analog of the spectral shape parameter ρ of Michel. Since in the Standard Model, $Q_L^{\nu_e}=1$, $\omega_L=0$, the measurement of $d\Gamma/dy$ has allowed a null-test of the Standard Model (see Listings below).

Matrix element: All results in direct muon decay (energy spectra of the electron and of the neutrinos, polarizations, and angular distributions) and in inverse muon decay (the reaction cross section) at energies well below $m_W c^2$ may be parametrized in terms of amplitudes $g_{e\mu}^{\gamma}$ and the Fermi coupling constant G_F , using the matrix element

$$\frac{4G_F}{\sqrt{2}} \sum_{\substack{\gamma = S, V, T\\ e, \mu = R, L}} g_{\varepsilon\mu}^{\gamma} \langle \bar{e}_{\varepsilon} | \Gamma^{\gamma} | (\nu_e)_n \rangle \langle \bar{\nu}_{\mu})_m | \Gamma_{\gamma} | \mu_{\mu} \rangle. \tag{2}$$

We use the notation of Fetscher et al. [2], who in turn use the sign conventions and definitions of Scheck [7]. Here, $\gamma=S,V,T$ indicates a scalar, vector, or tensor interaction; and $\varepsilon,\mu=R,L$ indicate a right- or left-handed chirality of the electron or muon. The chiralities n and m of the ν_e and $\bar{\nu}_\mu$ are then determined by the values of γ, ε and μ . The particles are represented by fields of definite chirality [8].

As shown by Langacker and London [9], explicit lepton-number nonconservation still leads to a matrix element equivalent to Eq. (2). They conclude that it is not possible, even in principle, to test lepton-number conservation in (leptonic) muon decay if the final neutrinos are massless and are not observed.

The ten complex amplitudes $g_{\varepsilon\mu}^{\gamma}$ (g_{RR}^{T} and g_{LL}^{T} are identically zero) and G_{F} constitute 19 independent (real) parameters to be determined by experiment. The Standard Model interaction corresponds to one single amplitude g_{LL}^{V} being unity and all the others being zero.

The (direct) muon decay experiments are compatible with an arbitrary mix of the scalar and vector amplitudes g_{LL}^S and g_{LL}^V – in the extreme even with purely scalar $g_{LL}^S = 2$, $g_{LL}^V = 0$. The decision in favour of the Standard Model comes from the quantitative observation of inverse muon decay, which would be forbidden for pure g_{LL}^S [2].

Experimental determination of V-A: In order to determine the amplitudes $g_{\varepsilon\mu}^{\gamma}$ uniquely from experiment, the following set of equations, where the left-hand sides represent experimental results, has to be solved.

$$\begin{split} a &= 16(|g_{RL}^V|^2 + |g_{LR}^V|^2) + |g_{RL}^S + 6g_{RL}^T|^2 + |g_{LR}^S + 6g_{LR}^T|^2 \\ a' &= 16(|g_{RL}^V|^2 - |g_{LR}^V|^2) + |g_{RL}^S + 6g_{RL}^T|^2 - |g_{LR}^S + 6g_{LR}^T|^2 \\ \alpha &= 8\text{Re}\left\{g_{RL}^V(g_{LR}^{S*} + 6g_{LR}^{T*}) + g_{LR}^V(g_{RL}^{S*} + 6g_{RL}^{T*})\right\} \\ \alpha' &= 8\text{Im}\left\{g_{LR}^V(g_{RL}^{S*} + 6g_{RL}^{T*}) - g_{RL}^V(g_{LR}^{S*} + 6g_{LR}^{T*})\right\} \\ b' &= 4(|g_{RR}^V|^2 + |g_{LL}^V|^2) + |g_{RR}^S|^2 + |g_{LL}^S|^2 \\ b' &= 4(|g_{RR}^V|^2 - |g_{LL}^V|^2) + |g_{RR}^S|^2 - |g_{LL}^S|^2 \\ \beta &= -4\text{Re}\left\{g_{RR}^Vg_{LL}^{S*} + g_{LL}^Vg_{RR}^{S*}\right\} \\ \beta' &= 4\text{Im}\left\{g_{RR}^Vg_{LL}^{S*} - g_{LL}^Vg_{RR}^{S*}\right\} \\ c &= \frac{1}{2}\left\{|g_{RL}^S - 2g_{RL}^T|^2 + |g_{LR}^S - 2g_{LR}^T|^2\right\} \\ c' &= \frac{1}{2}\left\{|g_{RL}^S - 2g_{RL}^T|^2 - |g_{LR}^S - 2g_{LR}^T|^2\right\} \\ \text{ad} \\ Q_L^{\nu e} &= 1 - \left\{\frac{1}{4}|g_{LR}^S|^2 + \frac{1}{4}|g_{LL}^S|^2 + |g_{RR}^V|^2 + |g_{RL}^V|^2 + 3|g_{LR}^T|^2\right\} \end{split}$$

$$\begin{split} Q_L^{\nu_e} &= 1 - \left\{ \frac{1}{4} |g_{LR}^S|^2 + \frac{1}{4} |g_{LL}^S|^2 + |g_{RR}^V|^2 + |g_{RL}^V|^2 + 3|g_{LR}^T|^2 \right\} \\ \omega_L &= \frac{3}{4} \, \frac{\{|g_{RR}^S|^2 + 4|g_{LR}^V|^2 + |g_{RL}^S + 2g_{RL}^T|^2\}}{|g_{RL}^S|^2 + |g_{RR}^S|^2 + 4|g_{LL}^V|^2 + 4|g_{LR}^V|^2 + 12|g_{RL}^T|^2\}} \;. \end{split}$$

It has been noted earlier by C. Jarlskog [10], that certain experiments observing the decay electron are especially informative if the yield the V-A values. The complete solution is now found as follows. Fetscher et al. [2] introduced four probabilities $Q_{\varepsilon\mu}(\varepsilon,\mu=R,L)$ for the decay of a μ -handed muon into an ε -handed electron and showed that there exist upper bounds on Q_{RR} , Q_{LR} , and Q_{RL} , and a lower bound on Q_{LL} . These probabilities are given in terms of the $g_{\tau\mu}^{2}$'s by

$$Q_{\varepsilon\mu} = \frac{1}{4}|g_{\varepsilon\mu}^S|^2 + |g_{\varepsilon\mu}^V|^2 + 3(1 - \delta_{\varepsilon\mu})|g_{\varepsilon\mu}^T|^2 , \qquad (3)$$

where $\delta_{\varepsilon\mu}=1$ for $\varepsilon=\mu$, and $\delta_{\varepsilon\mu}=0$ for $\varepsilon\neq\mu$. They are related to the parameters $a,\ b,\ c,\ a',b',$ and c' by

$$egin{aligned} Q_{RR} &= 2(b+b')/A \;, \ Q_{LR} &= [(a-a')+6(c-c')]/2A \;, \ Q_{RL} &= [(a+a')+6(c+c')]/2A \;, \ Q_{LL} &= 2(b-b')/A \;, \end{aligned}$$

with A=16. In the Standard Model, $Q_{LL}=1$ and the others are zero.

Since the upper bounds on Q_{RR} , Q_{LR} , and Q_{RL} are found to be small, and since the helicity of the ν_{μ} in pion decay is known from experiment [11,12] to very high precision to be -1 [13], the cross section S of *inverse* muon decay, normalized to the V-A value, yields [2]

$$|g_{LL}^S|^2 \le 4(1-S) \tag{4}$$

and

$$|g_{LL}^V|^2 = S. (5)$$

Thus the Standard Model assumption of a pure V-A leptonic charged weak interaction of e and μ is derived (within errors)

Lepton Particle Listings

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from experiments at energies far below mass of the W^{\pm} : Eq. (5) gives a lower limit for V-A, and Eqs. (3) and (4) give upper limits for the other four-fermion interactions. The existence of such upper limits may also be seen from $Q_{RR}+Q_{RL}=(1-\xi')/2$ and $Q_{RR}+Q_{LR}=\frac{1}{2}(1+\xi/3-16\ \xi\delta/9)$. Table 1 gives the current experimental limits on the magnitudes of the $g_{\tau\mu}^{\epsilon}$'s.

Limits on the "charge retention" coordinates, as used in the older literature (e.g., Ref. 16), are given by Burkard et al. [17].

Table 1. Coupling constants $g_{e\mu}^{\gamma}$. Ninety-percent confidence level experimental limits. The limits on $|g_{LL}^{S}|$ and $|g_{LL}^{V}|$ are from Ref. 14, and the others are from Ref. 15. The experimental uncertainty on the muon polarization in pion decay is included.

$\overline{ g_{RR}^S } < 0.066$	$ g_{RR}^V < 0.033$	$ g_{RR}^T \equiv 0$
$ g_{LR}^S <0.125$	$ g_{LR}^V <0.060$	$ g_{LR}^T <0.036$
$\left g_{RL}^S\right <0.424$	$\left g_{RL}^{V}\right <0.110$	$\left g_{RL}^{T}\right <0.122$
$ g_{LL}^S <0.550$	$ g_{LL}^V >0.960$	$ g_{LL}^T \equiv 0$

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μ DECAY PARAMETERS

ρ PARAMETER

(V-A) theory predicts $\rho = 0.75$.

TALUL		DOCUMENT ID		7201		
0.7518±0.0026		DERENZO	69	RVUE		
• • • We do not use	the following	ng data for average	s, fit	s, limits,	etc.	• •
0.762 ±0.008	170k	27 FRYBERGER	68	ASPK	+	25-53 MeV e+
0.760 ±0.009	280k	²⁷ SHERWOOD	67	ASPK	+	25-53 MeV e+
0.7503 ± 0.0026	800k	27 PEOPLES	66	ASPK	+	20-53 MeV e ⁺

 $^{{\}bf 27}_{\eta}$ constrained = 0. These values incorporated into a two parameter fit to ρ and η by DERENZO 69.

η PARAMETER

(V-A) theory	η predicts $\eta = 0$.	
ΙE	EVTS	DOCUMENT ID

-0.007±0.013 OUR AVERAGE -0.007±0.013 5.3M ²⁸ BURKARD 858 FIT + 9-53 MeV e⁺ -0.12 ±0.21 6346 DERENZO 69 HBC + 1.6-6.8 MeV e⁺

TECN CHG COMMENT

• • We do not use the following data for averages, fits, limits, etc. • • •

29 BURKARD -0.012 ± 0.015 ± 0.003 5.3M 85B CNTR 9-53 MeV e+ $0.011 \pm 0.081 \pm 0.026$ 5.3M BURKARD 85B CNTR 9-53 MeV e+ 30 FRYBERGER 170k 68 ASPK 25-53 MeV e+ -0.7 ± 0.5 ³⁰ SHERWOOD ASPK -0.7 ±0.6 280k 67 25-53 MeV e+ 30 PEOPLES 0.05 ± 0.5 800k **ASPK** 20-53 MeV e+ 31 PLANO Whole spec- -2.0 ± 0.9 9213 60 HBC trum

28 Global fit to all measured parameters. Correlation coefficients are given in BURKARD 85B.

 $^{29}\alpha = \alpha' = 0$ assumed.

δ PARAMETER

0.97 ±0.05

(V-A) theory predicts $\delta = 0.75$.

VALUE	<u>EVTS</u>	DOCUMENT ID		TECN	CHG	COMMENT
0.7486±0.0026±0.00	28	32 BALKE	88	SPEC	+	Surface μ^+ 's
• • • We do not use	the following o	data for averages, t	fits, I	imits, et	C. • •	•
		33 VOSSLER	69			
0.752 ±0.009	490k	FRYBERGER	68	ASPK	+	25-53 MeV e+
0.782 ± 0.031		KRUGER	61			
0.78 ±0.05	8354	PLANO	60	HBC	+	Whole spec-

 32 BALKE 88 uses $\rho = 0.752 \pm 0.003$.

|(ξ PARAMETER)×(μ LONGITUDINAL POLARIZATION)| (V-A) theory predicts $\xi = 1$, longitudinal polarization = 1.

VALUE	EVTS	DOCUMENT ID		<u>TEÇN</u>	CHG	COMMENT
1.0027±0.0079±0.0030		BELTRAMI	87	CNTR		SIN, π decay in flight
• • We do not use the	following	data for averages,	fits,	limits, et	C. • •	•
$1.0013 \pm 0.0030 \pm 0.0053$		34 IMAZATO	92	SPEC	+	$K^+ \rightarrow \mu^+ \nu_{\mu}$
0.975 ±0.015		AKHMANOV	68	EMUL		140 kG
0.975 ±0.030	66k	GUREVICH	64	EMUL		See AKHMA- NOV 68
0.903 ±0.027		35 ALI-ZADE	61	EMUL	+	27 kG
0.93 +0.06	8354	PLANO	60	HRC	+	8 8 kG

 $^{^{34}}$ The corresponding 90% confidence limit from IMAZATO 92 is $|\xi P_{\mu}|>0.990$. This measurement is of K^+ decay, not π^+ decay, so we do not include it in an average, nor do we yet set up a separate data block for K results.

BARDON

59 CNTR

Bromoform target

$\xi \times (\mu \text{ LONGITUDINAL POLARIZATION}) \times \delta / \rho$

VALUE	<u>CL%</u>	<u>DOCUMENT I</u>	<u> </u>	TECN	CHG	COMMENT
>0.99682	90	36 TODIDIO	86	SPEC	+	TRIUMF
• • • We do not	use the follow	ing data for avera	ges, fit:	s, limits,	etc.	• •
>0.9966	90	37 STOKER	85	SPEC	+	μ -spin rotation
>0.9959	90	CARR	83	SPEC	+	11 kG
26						

³⁶ JODIDIO 86 Includes data from CARR 83 and STOKER 85. The value here is from the creatum.

$\xi' = LONGITUDINAL POLARIZATION OF e^+$

(V-A) theory predicts the longitudinal polarization $=\pm 1$ for e^{\pm} , respectively. We have flipped the sign for e^{-} so our programs can average.

VALUE	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
1.00 ±0.04 OUR AV	ERAGE					
0.998 ± 0.045	1M	BURKARD	85	CNTR	+	Bhabha + annihil
0.89 ±0.28	29k	SCHWARTZ	67	OSPK	-	Moller scattering
0.94 ±0.33		BLOOM	64	CNTR	+	Brems. transmiss.
1.04 ±0.18		DUCLOS	64	CNTR	+	Bhabha scattering
1.05 ± 0.30		BUHLER	63	CNTR	+	Annihilation
ξ" PARAMETER						
MALCIE	CLATE	DOCUMENT ID		TECN	CHC	COMMENT

ALUE EY

0.65 ± 0.36 326k 38 BURKARD 85 CNTR + Bhabha + annihil 38 BURKARD 85 measure $(\xi'' \cdot \xi \xi')/\xi$ and ξ' and set $\xi = 1$.

TRANSVERSE e+ POLARIZATION IN PLANE OF μ SPIN, e+ MOMEN-

TUM					
VALUE	EVTS	DOCUMENT ID	<u>TECN</u>	<u>CHG</u>	COMMENT
• • • We do not use	the followin	g data for averages	, fits, limits,	etc. •	• •
0.016 + 0.021 + 0.01	5.3M	RURKARD	85B CNTR	+	Annihil 9-53 MeV

 $^{^{30}}ho$ constrained = 0.75, 31 Two parameter fit to ho and η ; PLANO 60 discounts value for η .

³³ VOSSLER 69 has measured the asymmetry below 10 MeV. See comments about radiative corrections in VOSSLER 69.

³⁵ Depolarization by medium not known sufficiently well.

³⁷ STOKER 85 find $(\xi P_{\mu} \delta/\rho) > 0.9955$ and >0.9966, where the first limit is from new μ spin-rotation data and the second is from combination with CARR 83 data. In V-A theory, $(\delta/\rho) = 1.0$.

TRANSVERSE e^+ POLARIZATION NORMAL TO PLANE OF μ SPIN, e^+ MOMENTUM Zero If T Invariance holds. DOCUMENT ID TECN CHG COMMENT 0.007±0.022±0.007 5.3M BURKARD 858 CNTR + Annihil 9-53 MeV 39 BURKARD 8 VALUE (units 10⁻³) EVTS TECN CHG COMMENT 85B FIT • • • We do not use the following data for averages, fits, limits, etc. • • • 15 ±50 ±14 5.3M BURKARD 85B CNTR + 9-53 MeV e+ ³⁹ Global fit to all measured parameters. Correlation coefficients are given in BURKARD 85B. Zero if T invariance holds. VALUE (units 10⁻³) EVTS DOCUMENT ID TECN CHG COMMENT 40 BURKARD 858 FIT • • • We do not use the following data for averages, fits, limits, etc. • • • -47 ±50 ±14 5.3M 41 BURKARD 858 CNTR + 9-53 MeV e+ 40 Global fit to all measured parameters. Correlation coefficients are given in BURKARD 85B. 41 BURKARD 85B measure e^+ polarizations ${\rm P}_{T_1}$ and ${\rm P}_{T_2}$ versus e^+ energy. VALUE (units 10⁻³) EVTS DOCUMENT ID TECN CHG COMMENT 42 BURKARD 858 FIT • • • We do not use the following data for averages, fits, limits, etc. • • • 2 ±17 ±6 5.3M BURKARD 858 CNTR + 9-53 MeV e+ $^{\rm 42}\,\text{Global}$ fit to all measured parameters. Correlation coefficients are given in BURKARD 85B. Zero If T invariance holds. DOCUMENT ID TECN CHG COMMENT 43 BURKARD 858 FIT VALUE (units 10⁻³) EVTS 5.3M 44 BURKARD 858 CNTR + 9-53 MeV e+ 43 Global fit to all measured parameters. Correlation coefficients are given in BURKARD 85B. measure e^+ polarizations ${\sf P}_{T_1}$ and ${\sf P}_{T_2}$ versus e^+ energy. This comes from an alternative parameterization to that used in the Summary Table (see the "Note on Muon Decay Parameters" above). VALUE (units 10⁻³) CL% DOCUMENT ID TECN • • • We do not use the following data for averages, fits, limits, etc. • • • 90 ⁴⁵ BURKARD 85B FIT 45 Global fit to all measured parameters. Correlation coefficients are given in BURKARD 85B. This comes from an alternative parameterization to that used in the Summary Table (see the "Note on Muon Decay Parameters" above). VALUE (units 10⁻³) DOCUMENT ID TECN • • • We do not use the following data for averages, fits, limits, etc. • • • 46 BURKARD 858 FIT 46 Global fit to all measured parameters. Correlation coefficients are given in BURKARD 85B. (b'+b)/AThis comes from an alternative parameterization to that used in the Summary Table (see the "Note on Muon Decay Parameters" above). VALUE (units 10⁻³) CL% DOCUMENT ID TECN • • • We do not use the following data for averages, fits, limits, etc. • • • 90 47 BURKARD 858 FIT 47 Global fit to all measured parameters. Correlation coefficients are given in BURKARD 858. This comes from an alternative parameterization to that used in the Summary Table (see the "Note on Muon Decay Parameters" above). VALUE (units 10⁻³) CL% DOCUMENT ID TECN • • • We do not use the following data for averages, fits, limits, etc. • • • 90 48 BURKARD 858 FIT 48 Global fit to all measured parameters. Correlation coefficients are given in

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This comes from an alternative parameterization to that used in the Summary Table
     (see the "Note on Muon Decay Parameters" above).
VALUE (units 10<sup>-3</sup>)
                                 DOCUMENT ID
                                                  TECN
• • • We do not use the following data for averages, fits, limits, etc. • • •
                              49 BURKARD 858 FIT
 <sup>49</sup>Global fit to all measured parameters. Correlation coefficients are given in
77 PARAMETER
     (V-A) theory predicts \overline{\eta}=0. \overline{\eta} affects spectrum of radiative muon decay.
                                  DOCUMENT ID TECN CHG COMMENT
 0.02 ±0.08 OUR AVERAGE
-0.014 \pm 0.090
                                  EICHENBER... 84 ELEC +
                                  BOGART 67 CNTR +
+0.09 ±0.14

    • • • We do not use the following data for averages, fits, limits, etc. • • •
                                  EICHENBER... 84 ELEC + \rho=0.75 assumed
-0.035±0.098
                                # REFERENCES
GORDEEV
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PAN 60 1164
Translated from YAF
PRL 77 1950
PRL 76 200
PL 8317 631
PR D48 1976
PRL 69 877
SIMP 53 802
Translated from YAF
PL B263 534
PRL 66 2716
PRL 67 932 erratum
PR D41 2709
PR D38 2102
PRL 59 970
PR D38 2102
PRL 59 970
PR D37 587
NP B299 1 V.A. Gordeev+ (PNPI)
0 1291.
+Bagaturia+ (PSI, ZURI, HEIDH, TBIL, YALE+)
+Dohmen, Haan, Junker+ (SINDRUM II Collab.)
+Groth, Heer+ (PSI SINDRUM-II Collab.)
+Arnold, Chmely+ (LAMPF E4SS Collab.)
+Arnold, Chmely+ (KEK, INUS, TOKY, TOKN)
+Vanko, Glazov, Evtukhovich+ (JINR)
3 1302. ABELA HONECKER DOHMEN FREEDMAN NI IMAZATO +Kawashima, Ianaka+
+Kawashima, Ianaka+
+Kawashima, Ianaka+
+Kawashima, Ianaka+
+Kawashima, Ianaka+
+Kawashima, Ianaka+
+Kale, Kale, KRAKAUER MATTHIAS Also BALKE NP B299 1 PR D38 2077 PRL 56 2461 PRL 57 3241 BOLTON PL B194 326 RMP 59 1121 PRL 57 671 COHEN BEER NP A451 679 PR D34 1967 PR D37 237 erratum NP B260 1 BELTRAMI JODIDIO Also BERTI. PRL 158 465
PL 150B 242
PL 150B 343
PR D24 2004
PR D25 204
PR D26 204 BRYMAN BRCU, LANL, CHIC, CARL+)
(ETH, SIN, MANZ)
(ETH, SIN, MANZ)
(ETH, SIN, MANZ)
(ETH, SIN, MANZ)
(YALE, CORN)
(LBL, NWES, TRIU)
(SACL, CERN, BGNA, FIRM BURKARD BURKARD Also Also HUGHES Corriveau, Egger, Fetscher+
Kinoshita

Halake, Carr, Gidal+

Halake, Carr, Gidal+

Helcher, Felawka+

Helcher, Felawka+

Helcher, Felawka+

How, Carr, Gidal
Helcher, Felawka+

Helcher, Felawka+

How, Carrini+

How, Eckawa, Hart
Hore, Eckawa, Hart
Hore, Eckawa, Hart
Hore, Corn, Martin
Depommler, Leroy, Martin
Depommler, Leroy, Martin
Depommler, Leroy, Martin
Depommler, Leroy, Martin
Horenbosch, Jonkert
Horenbosch, Jonkert
Horenbosch, Jonkert
Horenbosch, Matts, Wright
Horenbosch, Matts, Wright
How, Charm, Kell

How, Camani, Gygax
Handerson, Matts, Wright
How, Camani, Gygax
Handerson, Matts, Wright
How, Camani, Gygax
Harten, Botton, Egan, Gardner
Haren, Oram, Kiefl

Harten, Picasso

Hughes

Ger, Capek, Flueckiger
Hadertscher, Borer, Capek, Flueckiger
Handerson, Matter, Pfeiffer
How, Les, Matter, Horenbosch, Horekiger
Horenbosch, Dey, Water, Pfeiffer
Willis
Hughes

(CHARM Collab,

Helgher, Powel, Dey+

(CHARM Collab,

(CHARM HUGHES STOKER BARDIN BERTL BOLTON EICHENBER... GIOVANETTI KINOSHITA AZUELOS Also +Raike. Carr. Gidal+ Also BERGSMA CARR KINNISON Also KLEMPT MARIAM MARSHALL COMBLEY NEMETHY ABELA BADERT... Also JONKER SCHAAF Also WILLIS PL 72B 183 PRL 44 522 PRL 45 1370 NP B150 1 ARNPS 29 243 PL 79B 371 IPG 4 345 NP B150 1 NP B133 205 PRL 41 442 PL 77B 326 PRL 39 1385 BAILEY FARLEY BADERT Badertscher, Buter, MANZ, RMCS, CERN, BIRM, Bailey
(DARE, BERN, SHEF, MANZ, RMCS, CERN, BIRM, Bailey
+ Deden, Hasert, Krenx+ (Gargamelle Collab, +Cheng, Li, Matis
+ Cheng, Li, Matis
+ Cheng, Li, Matis
+ CERN, Mang, Schenck, Schulze+ (ETH, MANZ, Badertscher, Borer, Czapek, Flueckiger+

- (CERN, Mono Storage Ring Collab, Bird)
+ Bailey+ (CERN, DARE, BERN, SHEF, MANZ+Balley+ (CERN, DARE, BERN, SHEF, MANZ+H, Bailey+ (CERN, Mono Storage Ring Collab, Bird)
+ Harison, Perrottet+ (MONT, BRCO, TRIU, VICT, MELB)
+ Cranet (MONT, BRCO, TRIU, VICT, MELB)
+ Grebenyuk, Zinov, Konin, Ponomarev
(7 1631, Magnon, Picard (SACL)
+ Deden, Hasert, Krenz+ (Gargamelle Collab, Bird)
+ Hagier, Rothberg, Schenck+ (LB, WASH)
+ Casperson, Crane, Egan, Hughes+ (KALE)
(EFI) BADERT...
BAILEY
Also
BLIETSCHAU
BOWMAN
CAMANI PL 77B 326
PRL 39 1385
PL 58B 295
PL 58B 420
RIMP 49 21
PRL 39 956
PRL 39 1113
JETP 40 811
JETP 40 811
JETP 40 811
JETP 40 814
JETP 40 814
JETP 40 815
JETP 40 815
JETP 40 816
JETP 40 817
JETP 40 81
JETP CAMANI BADERT... BAILEY. Also Also CALMET CASPERSON DEPOMMIER BALANDIN COHEN

μ , τ

BAILEY	68	PL 28B 287	+Bartl, VonBochmann, Brown, Farley+	(CERN)
Also	72	NC 9A 369	Bailey, Barti, VonBochmann, Brown+	(CERN)
FRYBERGER	68	PR 166 1379		` (EFI)
BOGART	67	PR 156 1405	+Dicapua, Nemethy, Stretzoff	(CÒLU)
SCHWARTZ	67	PR 162 1306	•	` (EFI)
SHERWOOD	67	PR 156 1475		(EFI)
PEOPLES	66	Nevis 147 unpub.		(còluí
BLOOM	64	PL 8 87	+Dick, Feuvrais, Henry, Macq, Spighel	(CERN)
DUCLOS	64	PL 9 62	+Heintze, DeRujula, Soergel	(CERN)
GUREVICH	64	PL 11 185	+Makarina+	`(KIAE)
BUHLER	63	PL 7 368	+Cabibbo, Fidecaro, Massam, Muller+	(ČERN)
MEYER	63	PR 132 2693	+Anderson, Bleser, Lederman+	(COLU)
CHARPAK	62	PL 1 16	+Farley, Garwin+	(CERN)
CONFORTO	62	NC 26 261	+Conversi, Dilelia+ (INFN.	ROMA, CERN)
ALI-ZADE	61	JETP 13 313	+Gurevich, Nikolski	
		Translated from ZETF	40 452.	
CRITTENDEN	61	PR 121 1823	+Walker, Ballam	(WISC, MSU)
KRUGER	61	UCRL 9322 unpub.		(LRL)
GUREVICH	60	JETP 10 225	+Nikolski, Surkova	(ITEP)
		Translated from ZETF	37 318.	
PLANO	60	PR 119 1400		(COLU)
ASHKIN	59	NC 14 1266	+Fazzini, Fidecaro, Lipman, Merrison+	(CERN)
BARDON	59	PRL 2 56	+Berley, Lederman	(corn)
LEE	59	PRL 3 55	+Samios	(COLU)

au discovery paper was PERL 75. $e^+e^- \rightarrow \tau^+\tau^-$ cross-section threshold behavior and magnitude are consistent with pointlike spin-1/2 Dirac particle. BRANDELIK 78 ruled out pointlike spin-0 or spin-1 particle. FELDMAN 78 ruled out J=3/2. KIRKBY 79 also ruled out J=integer, J = 3/2.

τ MASS

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT	
1777.06 +0.29 OL						
1778.2 ±0.8 ±1	.2	ANASTASSOV	97	CLEO	Eee = 10.6 GeV	
1776.96 + 0.18 + 0 $-0.21 - 0$.25 .17 65	¹ BAI	96	BES	Ecm = 3.54-3.57 GeV	
1777.8 ±0.7 ±1	.7 35k	² BALEST	93	CLEO	Ecm = 10.6 GeV	
1776.3 $\pm 2.4 \pm 1$.4 11k	3 ALBRECHT	92M	ARG	Ecm = 9.4-10.6 GeV	
1783 +3	692	⁴ BACINO	78B	DLCO	Ecm = 3.1-7.4 GeV	
• • • We do not	use the following	data for averages	, fits	, limits,	etc. • • •	
1776.9 $^{+0.4}_{-0.5}$ ± 0	.2 14	⁵ BAI	92	BES	Repl. by BAI 96	
¹ BAI 96 fit $\sigma(e^+e^-\to \tau^+\tau^-)$ at different energies near threshold. ² BALEST 93 fit spectra of minimum kinematically allowed τ mass in events of the type $e^+e^-\to \tau^+\tau^-\to (\pi^+\pi\pi^0\nu_\tau)(\pi^-m\pi^0\nu_\tau)$ $n\leq 2,\ m\leq 2,\ 1\leq n+m\leq 3$. If $m_{\nu_\tau}\neq 0$, result increases by $(m_{\nu_\tau}^2/1100\ \text{MeV})$.						

 $^{^3}$ ALBRECHT 92M fit au pseudomass spectrum in $au^- o 2\pi^-\pi^+
u_ au$ decays. Result assumes $m_{
u_{ au}} =$ 0.

τ MEAN LIFE

VALUE (10		EVTS	DOCUMENT ID	TECN	COMMENT
290.0±	I.2 OUR AV	ERAGE			
290.1±	l.5 ± 1.1		BARATE	97R ALEP	1989~1994 LEP runs
291.4±	3.0		ABREU	96B DLPH	1991~1993 LEP runs
290.1±	1.0	34k	ACCIARRI	96K L3	1994 LEP run
289.2±	.7± 1.2		ALEXANDER	96E OPAL	1990~1994 LEP runs
289.0± :	2.8± 4.0	57.4k	BALEST	96 CLEO	Ecm= 10.6 GeV
• • • We	do not use	the following	data for averag	es, fits, limi	s, etc. • • •
291.2±	2.0± 1.2		BARATE	971 ALEP	Repl. by BARATE 97R
297 ±	+ 5	1671	ABE	95Y SLD	1992~1993 SLC runs
293 ± 9	±12	5743	ADRIANI	93M L3	1991 LEP run
304 ± 1	± 7	4100	BATTLE	92 CLEO	Ecm= 10.6 GeV
309 ± 2	±30	2817	ADEVA	91F L3	1990 LEP run
301 ± 2)	3780	KLEINWORT	89 JADE	Ecm = 35-46 GeV
288 ± 10	±17	807	AMIDEI	88 MRK2	Ecm= 29 GeV
306 ± 2	±14	695	BRAUNSCH	88c TASS	Ecm= 36 GeV
299 ± 1	±10	1311	ABACHI	87c HRS	<i>E</i> ee = 29 GeV
295 ± 1	±11	5696	ALBRECHT	87P ARG	Ecm= 9.3-10.6 GeV
309 ± 1	± 7	3788	BAND	87B MAC	<i>E</i> cm= 29 GeV
325 ± 1	±18	8470	BEBEK	87c CLEO	Ecm= 10.5 GeV
460 ±19)	102	FELDMAN	82 MRK2	Ecm= 29 GeV

τ MAGNETIC MOMENT ANOMALY

$\mu_{\tau}/(e\hbar/2m_{\tau})-1=(g_{\tau}-2)/2$ For a theoretical calculation [($g_{\tau}-2$)/2 = 11773(3) \times 10 $^{-7}$], see SAMUEL 91B. <u>VALUE</u> <u>CL%</u> <u>DOCUMENT ID</u> > −0.052 and < 0.058 (CL = 95%) OUR LIMIT TECN COMMENT > -0.052 and < 0.058 95 ACCIARRI 98E L3 1991-1995 LEP runs • • • We do not use the following data for averages, fits, limits, etc. • • • > -0.068 and < 0.065 95 6 ACKERSTAFF 98N OPAL 1990-1995 LEP runs > -0.004 and < 0.006 95 7 ESCRIBANO 97 RVUE $Z ightarrow au^{+} au^{-}$ at LEP 8 ESCRIBANO 93 RVUE $Z \rightarrow \tau^{+}\tau^{-}$ at LEP <0.12 90 GRIFOLS 91 RVUE $Z \rightarrow \tau \tau \gamma$ at LEP 9 SILVERMAN 83 RVUE $e^+e^- \rightarrow \tau^+\tau^-$ at PETRA < 0.023 95 6 ACKERSTAFF 98N use $Z \to \tau^+ \tau^- \gamma$ events. The limit applies to an average of the form factor for off-shell τ 's having p^2 ranging from m_{τ}^2 to $(M_Z - m_{\tau})^2$. ⁷ ESCRIBANO 97 use preliminary experimental results. 8 ESCRIBANO 93 limit derived from $\Gamma(Z o au^+ au^-)$, and is on the absolute value of the

τ ELECTRIC DIPOLE MOMENT (d_{τ})

A nonzero value is forbidden by both T invariance and P invariance.

VALUE (10 ⁻¹⁶ ecm)	CL%	DOCUMENT ID	TECN	COMMENT
> -3.1 and < 3.1 (CL = 9	95%) OUR	LIMIT		
> -3.1 and < 3.1	95	ACCIARRI	98E L3	1991-1995 LEP runs
• • We do not use the f	ollowing da	ita for averages, fits, li	imits, etc. •	• •
> -3.8 and < 3.6	95	¹⁰ ACKERSTAFF		
<0.11	95	11,12 ESCRIBANO	97 RVUE	$Z \rightarrow \tau^+ \tau^-$ at LEP
<0.5	95	13 ESCRIBANO	93 RVUE	$Z \rightarrow \tau^+ \tau^-$ at LEP
<7	90	GRIFOLS	91 RVUE	$Z \rightarrow \tau \tau \gamma$ at
<1.6	90	DELAGUILA	90 RVUE	$e^+e^{\tau^+\tau^-}$ $E^{ee}_{cm} = 35 \text{ GeV}$

 $^{^{10}}$ ACKERSTAFF 98N use $Z \to \tau^+ \tau^- \gamma$ events. The limit applies to an average of the form factor for off-shell τ 's having p^2 ranging from m_{τ}^2 to $(M_Z - m_{\tau})^2$.

τ WEAK DIPOLE MOMENT (d_{τ}^{w})

A nonzero value is forbidden by CP invariance.

$Re(d_{\tau}^{w})$

VALUE (10 ⁻¹⁷ ecm)	CL%	DOCUMENT ID	TECN	COMMENT	
<0.56	95	ACKERSTAF	F 97L OPAL	1991-1995 LEP runs	
• • • We do not u	se the followi	ng data for averag	es, fits, limits,	, etc. • • •	Ī
<3.0	90	14 ACCIARRI	98C L3	1991-1995 LEP runs	ı
<0.78	95	¹⁵ AKERS	95F OPAL		
<1.5	95	15 BUSKULIC	95C ALEP	STAFF 97L 1990–1992 LEP runs	
<7.0	95	15 ACTON	92F OPAL	$Z \rightarrow \tau^+ \tau^-$ at LEP	
<3.7	95	¹⁵ BUSKULIC	921 ALEP	Repl. by BUSKULIC 950	

⁴ ACCIARRI 98C limit is on the absolute value of the real part of the weak dipole moment. $^{15}\mathrm{Limit}$ is on the absolute value of the real part of the weak dipole moment, and applies for $q^2 = m_7^2$.

$im(d_{\pm}^{w})$

<i>VALUE</i> (10 ⁻¹⁷ ecm)	CL%	DOCUMENT ID	TECI	COMMENT			
<1.5	95	ACKERSTAFF	97L OPA	L 1991-1995 LEP runs			
● ● We do not use the following data for averages, fits, limits, etc. ● ●							
<4.5	95	¹⁶ AKERS	95F OPA	L Repl. by ACKER- STAFF 97L			
¹⁶ Limit is on the a	bsolute valu	e of the Imaginary	part of the	ne weak dipole moment, and			

applies for $q^2 = m_Z^2$.

τ WEAK ANOMALOUS MAGNETIC DIPOLE MOMENT (α_{τ}^{W})

$Re(\alpha_{-}^{W})$

·(
VALUE	CL%	DOCUMENT ID	TECN	COMMENT	
<4.5 × 10 ⁻³	90	17 ACCIARRI	98c L3	1991-1995 LEP runs	

 $^{^{17}}$ ACCIARRI 98C limit is on the absolute value of the real part of the weak anomalous magnetic dipole moment.

⁴ BACINO 78B value comes from e^{\pm} X $^{\mp}$ threshold. Published mass 1782 MeV increased by 1 MeV using the high precision $\psi(25)$ mass measurement of ZHOLENTZ 80 to eliminate the absolute SPEAR energy calibration uncertainty.

⁵BAI 92 fit $\sigma(e^+e^- \rightarrow \tau^+\tau^-)$ near threshold using $e\mu$ events.

⁹ SILVERMAN 83 limit is derived from $e^+e^- \rightarrow \tau^+\tau^-$ total cross-section measurements for q^2 up to (37 GeV)².

¹¹ESCRIBANO 97 derive the relationship $|d_{\tau}| = \cot \theta_W |d_{\tau}^W|$ using effective Lagrangian methods, and use a conference result $|d_{\tau}^W| < 5.8 \times 10^{-18}$ ecm at 95% CL (L. Silvestris, ICHEP96) to obtain this result.

 $^{^{12}\,\}mbox{ESCRIBANO}$ 97 use preliminary experimental results.

 $^{^{13}}$ ESCRIBANO 93 limit derived from $\Gamma(Z \to \tau^+ \tau^-)$, and is on the absolute value of the electric dipole moment.

lm(α	")					Modes with three o	harge	ed particles	
ALUE	CL% DOCUMEN		TECN COMMENT		Γ ₄₉	$h^-h^-h^+ \ge 0$ neut. ν_{τ} ("3-prong")	(15.18± 0.13) %	S=1.
	< 10⁻³ 90 ¹⁸ ACCIARR		98c L3 1991-1995 LE	-	Γ ₅₀	$h^-h^-h^+ \ge 0$ neutrals ν_{τ}		(14.60± 0.13) %	S=1
	CIARRI 98C limit is on the absolute value	of th	e imaginary part of the weak	canomalous		$(ex.K_{S}^{0}\to\pi^{+}\pi^{-})$			
ma	gnetic dipole moment.				Γ ₅₁	$\pi^-\pi^+\pi^- \geq 0$ neutrals ν_{τ}		$(14.60 \pm 0.14) \%$	
	DECAY		DEC		Γ ₅₂	$h^-h^-h^+\nu_{\tau}$		(9.96± 0.10) %	S=1
	$ au^-$ DECAY	мО	DES		Γ ₅₃	$h^- h^- h^+ \nu_{\tau} (\text{ex.} K^0)$		(9.62± 0.10) %	S=1
	$ au^+$ modes are charge conjugates of t				Γ ₅₄	$h^-h^-h^+\nu_{\tau}(ex.K^0,\omega)$		(9.57± 0.10) %	S=1
	π^{\pm} or K^{\pm} . " ℓ " stands for e or μ . "Ne		' means neutral hadron who	ose	Γ ₅₅	$\pi^-\pi^+\pi^-\nu_{\tau}$		(9.56± 0.11) %	S=1
	decay products include γ 's and/or π^0	S.			Γ ₅₆	$\pi^{-}\pi^{+}\pi^{-}\nu_{\tau}(ex.K^{0})$		(9.52± 0.11) %	S=1
		_		cale factor/	۲ ₅₇	$\pi^-\pi^+\pi^-\nu_{\tau}(\text{ex.}K^0,\omega)$	[a]	(9.23± 0.11) %	S=1
	Mode		Fraction (Γ_I/Γ) Conf	fidence level	Г ₅₈	$h^-h^-h^+ \ge 1$ neutrals ν_{τ} $h^-h^-h^+ \ge 1$ neutrals ν_{τ} (ex.		(5.18± 0.11) % (4.98± 0.11) %	S=1
	Modes with one of	haro	ed narticle		Γ ₅₉	$K_S^0 o \pi^+\pi^-)$		(4.90 ± 0.11) %	S=1
1	particle ≥ 0 neutrals $\geq 0K_I^0\nu_{\tau}$	0	(84.71± 0.13) %	S=1.2	Γ	$h^-h^-h^+\pi^0\nu_{\tau}$		(4.50± 0.09) %	S=1
•	("1-prong")		(0		Γ ₆₀ Γ ₆₁	$h^{-}h^{-}h^{+}\pi^{0}\nu_{\tau}$ (ex. K^{0})		(4.31± 0.09) %	S=1
2	particle ≥ 0 neutrals $\geq 0K^0\nu_{\tau}$		(85.30± 0.13) %	S=1.2	Γ ₆₂	$h^-h^-h^+\pi^0\nu_{\tau}(\mathrm{ex.}\ K^0,\omega)$		(2.59± 0.09) %	3_1
3	$\mu^-\overline{\nu}_\mu\nu_{\tau}$	[a]	(17.37± 0.09) %		Γ ₆₃	$\pi^-\pi^+\pi^-\pi^0\nu_{\tau}$		(4.35± 0.10) %	
4	$\mu^- \overline{\nu}_\mu \nu_\tau \gamma$	[b]			Γ ₆₄	$\pi^{-}\pi^{+}\pi^{-}\pi^{0}\nu_{\tau}$ (ex. K^{0})		(4.22± 0.10) %	
5	$e^{-\overline{\nu}_{e}\nu_{\tau}}$	[a]	, ,		Γ ₆₅	$\pi^-\pi^+\pi^-\pi^0\nu_{\tau}(ex.K^0,\omega)$	[a]	(2.49± 0.10) %	
6	$h^- \ge 0$ neutrals $\ge 0K_L^0 \nu_{\tau}$	[-]	(49.52± 0.16)%	S=1.2	Γ ₆₆	$h^-(\rho\pi)^0\nu_{\tau}$	[-]	(2.88± 0.35) %	
7	$h^- \ge 0 K_L^0 \nu_{\tau}$		(12.32± 0.12) %	S=1.5	Γ ₆₇	$(a_1(1260)h)^-\nu_{\tau}$		< 2.00 ± 0.33) %	CL=95
			,		Γ ₆₈	$h^-\rho\pi^0\nu_{\tau}$	•	(1.35± 0.20) %	
8 9	$rac{h^- u_ au}{\pi^- u_ au}$	[-3	(11.79± 0.12) % (11.08± 0.13) %	S=1.5 S=1.4	Γ ₆₉	$h^-\rho^+h^-\nu_{\tau}$		$(4.5 \pm 2.2) \times 10^{-3}$	
9 10	$K^- u_{ au}$		$(7.1 \pm 0.5) \times 10^{-3}$	3=1.4	Γ ₇₀	$h^-\rho^-h^+\nu_{\tau}$		(1.17± 0.23) %	
-10 11	$h^- \geq 1$ neutrals ν_{τ}	(e)	(36.91± 0.17) %	S=1.2	Γ ₇₁	$h^- h^- h^+ 2\pi^0 \nu_{\tau}$		$(5.4 \pm 0.4) \times 10^{-3}$	
12	$h^{-}\pi^{0}\nu_{\tau}$		(25.84± 0.14) %	S=1.1	Γ ₇₂	$h^-h^-h^+2\pi^0\nu_{\tau}(ex.K^0)$		$(5.3 \pm 0.4) \times 10^{-3}$	
13	$\pi^-\pi^0\nu_{\tau}$	[a]	(25.32± 0.15) %	S=1.1	Γ ₇₃	$h^{-}h^{-}h^{+}2\pi^{0}\nu_{\tau}(ex.K^{0},\omega,\eta)$	[a]	$(1.1 \pm 0.4) \times 10^{-3}$	
.13	$\pi^-\pi^0$ non- ρ (770) $\nu_{ au}$	[-]	$(3.0 \pm 3.2) \times 10^{-3}$		Γ ₇₄	$h^-h^-h^+ \geq 3\pi^0\nu_{\tau}$		$(1.4 + 0.9 \atop -0.7) \times 10^{-3}$	S=1
15	$K^-\pi^0\nu_{\tau}$	[a]	$(5.2 \pm 0.5) \times 10^{-3}$			- · · · · · · · · · · · · · · · · · · ·	[a]	_	3_1
16	$h^- \geq 2\pi^0 \nu_{\tau}$	[-]	(10.79± 0.16) %	S=1.2	Γ ₇₅	$h^-h^-h^+3\pi^0\nu_{\tau}$		$(2.9 \pm 0.8) \times 10^{-4}$	
17	$h^{-}2\pi^{0}\nu_{\tau}$		(9.39± 0.14)%	S=1.2	Γ ₇₆	$K^-h^+h^- \ge 0$ neutrals ν_{τ}		$(5.4 \pm 0.7) \times 10^{-3}$	S=:
18	$h^-2\pi^0\nu_{\tau}$ (ex. K^0)		(9.23 ± 0.14) %	5=1.2	Γ ₇₇	$K^-\pi^+\pi^- \geq 0$ neutrals $\nu_{ au}$		$(3.1 \pm 0.6) \times 10^{-3}$	S=1
19	$\pi^- 2\pi^0 \nu_{\tau} (\text{ex.} K^0)$	[a]	(9.15± 0.15) %	S=1.2	Γ ₇₈	$K^-\pi^+\pi^-\nu_{\tau}$		$(2.3 \pm 0.4) \times 10^{-3}$	
20	$K^{-}2\pi^{0}\nu_{\tau}(\text{ex}.K^{0})$		$(8.0 \pm 2.7) \times 10^{-4}$	U-2.L	Γ ₇₉	$K^-\pi^+\pi^-\nu_{\tau}({\rm ex}.K^0)$	[a]	$(1.8 \pm 0.5) \times 10^{-3}$	
21	$h^- \geq 3\pi^0 \nu_\tau$	[P]	(1.40± 0.11) %	S=1.1	Γ ₈₀	$\mathcal{K}^-\pi^+\pi^-\pi^0 u_{ au}$		$(8 \pm 4) \times 10^{-4}$	
22	$h^{-3\pi^0}\nu_{\tau}$		(1.23± 0.10) %	S=1.1	Γ ₈₁	$K^-\pi^+\pi^-\pi^0\nu_{\tau}({ m ex}.K^0)$	[a]	$(2.4 + 4.3 \times 10^{-4}) \times 10^{-4}$	
23	$\pi^{-}3\pi^{0}\nu_{\tau}$ (ex. K^{0})	[a]	(1.11± 0.14) %	0-2.2	Γ ₈₂	$K^-\pi^+K^- \geq 0$ neut. ν_{τ}		< 9 × 10 ⁻⁴	CL=95
					Γ ₈₃	$K^-K^+\pi^- \ge 0$ neut. ν_{τ}		$(2.3 \pm 0.4) \times 10^{-3}$	CL-70
24	$K^{-}3\pi^{0}\nu_{\tau}(\text{ex}.K^{0})$		$(4.3 \begin{array}{c} +10.0 \\ -2.9 \end{array}) \times 10^{-4}$		Γ ₈₄	$K^-K^+\pi^-\nu_{\tau}$	[a]	$(1.61 \pm 0.26) \times 10^{-3}$	
25	$h^{-}4\pi^{0}\nu_{\tau}(\text{ex}.K^{0})$		$(1.7 \pm 0.6) \times 10^{-3}$		Γ ₈₅	$\kappa^-\kappa^+\pi^-\pi^0\nu_{ au}$		$(6.9 \pm 3.0) \times 10^{-4}$	
26	$h^-4\pi^0\nu_{\tau}(ex.K^0,\eta)$	[a]	$(1.1 \pm 0.6) \times 10^{-3}$		Γ ₈₆	$K^-K^+K^- \ge 0$ neut. ν_{τ}		< 2.1 × 10 ^{−3}	CL=95
27	$K^- \geq 0\pi^0 \geq 0K^0 \nu_{\tau}$		(1.66 ± 0.10) %		Г87	$K^-K^+K^-\nu_{\tau}$		< 1.9 × 10 ⁻⁴	CL=90
28	$\mathcal{K}^- \geq 1 \; (\pi^0 \; ext{or} \; \mathcal{K}^0) \; u_ au$		$(9.5 \pm 1.0) \times 10^{-3}$		Г ₈₈	$\pi^- K^+ \pi^- \geq 0$ neut. $\nu_{ au}$		< 2.5 × 10 ⁻³	CL=95
	Modes wi	th K	0'e		Г89	$e^-e^-e^+\overline{\nu}_e\overline{\nu}_{\tau}$		$(2.8 \pm 1.5) \times 10^{-5}$	
29	K^0 (particles) $^-\nu_{ au}$	LII /\	(1.66± 0.09)%	S=1.4	Γ ₉₀	$\mu^-e^-e^+\overline{\nu}_\mu\overline{\nu}_\tau$		< 3.6 × 10 ⁻⁵	CL=90
30	$h^{-}\overline{K}^{0} \geq 0$ neutrals $\geq 0K_{L}^{0}\nu_{T}$		(1.62± 0.09) %	S=1.4		·		4	
31	$h^-\overline{K^0}\nu_{\tau}$		$(9.9 \pm 0.8) \times 10^{-3}$	S=1.5	_	Modes with five c	narge	•	
31	$\pi^{-\frac{\nu_{\tau}}{K^0}}\nu_{\tau}$	[a]	$(8.3 \pm 0.8) \times 10^{-3}$	S=1.4	Γ ₉₁	$3h^-2h^+ \ge 0$ neutrals ν_{τ}		$(9.7 \pm 0.7) \times 10^{-4}$	
33	$\frac{\kappa}{\pi} - \frac{\kappa}{\kappa}$		< 1.7 × 10 ⁻³	CL=95%		$(\text{ex. } K_S^0 \to \pi^-\pi^+)$			
JJ	(non- $K^*(892)^-)\nu_{ au}$			3576	-	("5-prong")		/ = = 1 = = > ·== A	
34	$K^-K^0\nu_{\tau}$	[a]	$(1.59 \pm 0.24) \times 10^{-3}$		Г ₉₂	$3h^{-}2h^{+}\nu_{\tau}(ex.K^{0})$		$(7.5 \pm 0.7) \times 10^{-4}$	
35	$h^{-}\overline{K}^{0}\pi^{0}\nu_{\tau}$	1	$(5.5 \pm 0.5) \times 10^{-3}$		Г ₉₃	$3h^{-}2h^{+}\pi^{0}\nu_{\tau}(ex.K^{0})$		$(2.2 \pm 0.5) \times 10^{-4}$	C1 ^-
36	$\pi^-\overline{\mathcal{K}}{}^0\pi^0 u_{ au}$	[a]	$(3.9 \pm 0.5) \times 10^{-3}$		Г ₉₄	$3h^-2h^+2\pi^0\nu_{ au}$	•	< 1.1 × 10 ⁻⁴	CL=90
37	$\overline{K}^0 \rho^- \nu$		$(1.9 \pm 0.7) \times 10^{-3}$			Miscellaneous othe	r allo	wed modes	
38	$K^-K^0\pi^0 u_{ au}$	[a]	$(1.51 \pm 0.29) \times 10^{-3}$		Γ ₉₅	$(5\pi)^-\nu_{\tau}$		$(7.4 \pm 0.7) \times 10^{-3}$	
39	$\pi^-\overline{\mathcal{K}}{}^0\pi^0\pi^0 u_{ au}$	• •	$(6 \pm 4) \times 10^{-4}$		Γ ₉₆	$4h^-3h^+ \ge 0$ neutrals $\nu_{ au}$		$< 2.4 \times 10^{-6}$	CL=90
	$K^{-}K^{0}\pi^{0}\pi^{0}\nu_{\tau}$		< 3.9 × 10 ⁻⁴	CL=95%		("7-prong")			
40	0 770	[a]	$(1.21 \pm 0.21) \times 10^{-3}$	S=1.2	Γ ₉₇	$K^*(892)^- \ge 0(h^0 \ne K_S^0)\nu_{\tau}$		(1.94± 0.31) %	
40 41	$\pi^- K^0 \overline{K}{}^0 u_{ au}$		$(3.0 \pm 0.5) \times 10^{-4}$	S=1.2		$K^*(892)^- \geq 0$ neutrals ν_{τ}		(1.33± 0.13) %	
41	$\pi^- K_S^0 K_S^0 \nu_{\tau}$		(0.0 + 0.0) / 20		Г99	$K^*(892)^-\nu_{\tau}$		(1.28± 0.08) %	
41 42	$\pi^- K_S^0 K_S^0 \nu_{\tau}$		$(6.0 \pm 1.0) \times 10^{-4}$	S=1.2	. 22				
41 42 43	$\pi^- K^0_S K^0_S u_ au$ $\pi^- K^0_S K^0_L u_ au$ $\pi^- K^0_S K^0_L u_ au$			S=1.2 CL=95%	Γ ₁₀₀	$K^*(892)^0 K^- \ge 0$ neutrals ν_{τ}		$(3.2 \pm 1.4) \times 10^{-3}$	
41 42 43 44	$\pi^- K^0_S K^0_S u_ au$ $\pi^- K^0_S K^0_L u_ au$ $\pi^- K^0_S K^0_L u_ au$		$(6.0 \pm 1.0) \times 10^{-4}$ < 2.0×10^{-4}		Γ ₁₀₀ Γ ₁₀₁	$K^*(892)^0 K^- \nu_{\tau}$		$(2.1 \pm 0.4) \times 10^{-3}$	
40 41 42 43 44 45	$\pi^{-}K_{S}^{0}K_{S}^{0} u_{ au}$ $\pi^{-}K_{S}^{0}K_{L}^{0} u_{ au}$ $\pi^{-}K_{S}^{0}K_{S}^{0}\pi^{0} u_{ au}$ $\pi^{-}K_{S}^{0}K_{L}^{0}\pi^{0} u_{ au}$		$(6.0 \pm 1.0) \times 10^{-4}$ < 2.0×10^{-4} $(3.1 \pm 1.2) \times 10^{-4}$		Γ ₁₀₀ Γ ₁₀₁	$K^*(892)^0 K^- \nu_{\tau}$ $K^*(892)^0 \pi^- \ge 0$ neutrals ν_{τ}		$(3.2 \pm 1.4) \times 10^{-3}$ $(2.1 \pm 0.4) \times 10^{-3}$ $(3.8 \pm 1.7) \times 10^{-3}$	
41 42 43 44 45	$\begin{array}{l} \pi^- K_S^0 K_S^0 \nu_\tau \\ \pi^- K_S^0 K_L^0 \nu_\tau \\ \pi^- K_S^0 K_S^0 \pi^0 \nu_\tau \\ \pi^- K_S^0 K_L^0 \pi^0 \nu_\tau \\ K^- K_S^0 \geq 0 \text{ neutrals } \nu_\tau \end{array}$		$(6.0 \pm 1.0) \times 10^{-4}$ $< 2.0 \times 10^{-4}$ $(3.1 \pm 1.2) \times 10^{-4}$ $(3.1 \pm 0.4) \times 10^{-3}$	CL=95%	Γ ₁₀₀ Γ ₁₀₁ Γ ₁₀₂ Γ ₁₀₃	$K^*(892)^0 K^- \nu_{\tau}$ $\overline{K}^*(892)^0 \pi^- \ge 0$ neutrals ν_{τ} $\overline{K}^*(892)^0 \pi^- \nu_{\tau}$		$(2.1 \pm 0.4) \times 10^{-3}$	
41 42 43 44 45 46 47	$\begin{array}{c} \pi^-K_S^0K_S^0\nu_\tau \\ \pi^-K_S^0K_L^0\nu_\tau \\ \pi^-K_S^0K_S^0\pi^0\nu_\tau \\ \pi^-K_S^0K_L^0\pi^0\nu_\tau \\ K^-K_S^0 & \geq 0 \text{ neutrals } \nu_\tau \\ K^0h^+h^-h^- \geq 0 \text{ neutrals } \nu_\tau \end{array}$		$ \begin{array}{cccccccccccccccccccccccccccccccccccc$		Γ ₁₀₀ Γ ₁₀₁ Γ ₁₀₂ Γ ₁₀₃	$\begin{array}{l} K^*(892)^0 K^- \nu_{\tau} \\ \overline{K}^*(892)^0 \pi^- \geq 0 \text{ neutrals } \nu_{\tau} \\ \overline{K}^*(892)^0 \pi^- \nu_{\tau} \\ (\overline{K}^*(892) \pi)^- \nu_{\tau} \to \end{array}$		$(2.1 \pm 0.4) \times 10^{-3}$ $(3.8 \pm 1.7) \times 10^{-3}$	
41 42 43 44 45 46 47	$\begin{array}{l} \pi^- K_S^0 K_S^0 \nu_\tau \\ \pi^- K_S^0 K_L^0 \nu_\tau \\ \pi^- K_S^0 K_S^0 \pi^0 \nu_\tau \\ \pi^- K_S^0 K_L^0 \pi^0 \nu_\tau \\ K^- K_S^0 \geq 0 \text{ neutrals } \nu_\tau \end{array}$		$(6.0 \pm 1.0) \times 10^{-4}$ $< 2.0 \times 10^{-4}$ $(3.1 \pm 1.2) \times 10^{-4}$ $(3.1 \pm 0.4) \times 10^{-3}$	CL=95%	Γ ₁₀₀ Γ ₁₀₁ Γ ₁₀₂ Γ ₁₀₃ Γ ₁₀₄	$K^*(892)^0 K^- \nu_{\tau}$ $\overline{K}^*(892)^0 \pi^- \ge 0$ neutrals ν_{τ} $\overline{K}^*(892)^0 \pi^- \nu_{\tau}$ $(\overline{K}^*(892) \pi)^- \nu_{\tau} \rightarrow \pi^- \overline{K}^0 \pi^0 \nu_{\tau}$		$(2.1 \pm 0.4) \times 10^{-3}$ $(3.8 \pm 1.7) \times 10^{-3}$ $(2.2 \pm 0.5) \times 10^{-3}$ $(1.1 \pm 0.5) \times 10^{-3}$	
41 42 43 44 45 46 47	$\begin{array}{c} \pi^-K_S^0K_S^0\nu_\tau \\ \pi^-K_S^0K_L^0\nu_\tau \\ \pi^-K_S^0K_S^0\pi^0\nu_\tau \\ \pi^-K_S^0K_L^0\pi^0\nu_\tau \\ K^-K_S^0 & \geq 0 \text{ neutrals } \nu_\tau \\ K^0h^+h^-h^- \geq 0 \text{ neutrals } \nu_\tau \end{array}$		$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	CL=95%	Γ ₁₀₀ Γ ₁₀₁ Γ ₁₀₂ Γ ₁₀₃ Γ ₁₀₄	$K^*(892)^0 K^- \nu_{\tau}$ $\overline{K}^*(892)^0 \pi^- \ge 0$ neutrals ν_{τ} $\overline{K}^*(892)^0 \pi^- \nu_{\tau}$ $(\overline{K}^*(892)^0 \pi^- \nu_{\tau} \rightarrow \pi^- \overline{K}^0 \pi^0 \nu_{\tau}$ $K_1(1270)^- \nu_{\tau}$		$(2.1 \pm 0.4) \times 10^{-3}$ $(3.8 \pm 1.7) \times 10^{-3}$ $(2.2 \pm 0.5) \times 10^{-3}$ $(1.1 \pm 0.5) \times 10^{-3}$ $(4 \pm 4) \times 10^{-3}$	
41 42 43 44 45 46 47	$\begin{array}{c} \pi^-K_S^0K_S^0\nu_\tau \\ \pi^-K_S^0K_L^0\nu_\tau \\ \pi^-K_S^0K_S^0\pi^0\nu_\tau \\ \pi^-K_S^0K_L^0\pi^0\nu_\tau \\ K^-K_S^0 & \geq 0 \text{ neutrals } \nu_\tau \\ K^0h^+h^-h^- \geq 0 \text{ neutrals } \nu_\tau \end{array}$		$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	CL=95%	Γ ₁₀₀ Γ ₁₀₁ Γ ₁₀₂ Γ ₁₀₃ Γ ₁₀₄	$K^*(892)^0 K^- \nu_{\tau}$ $\overline{K}^*(892)^0 \pi^- \ge 0$ neutrals ν_{τ} $\overline{K}^*(892)^0 \pi^- \nu_{\tau}$ $(\overline{K}^*(892)^0 \pi^- \nu_{\tau} \rightarrow \pi^- \overline{K}^0 \pi^0 \nu_{\tau}$ $K_1(1270)^- \nu_{\tau}$		$(2.1 \pm 0.4) \times 10^{-3}$ $(3.8 \pm 1.7) \times 10^{-3}$ $(2.2 \pm 0.5) \times 10^{-3}$ $(1.1 \pm 0.5) \times 10^{-3}$	
41 42 43 44 45 46 47	$\begin{array}{c} \pi^-K_S^0K_S^0\nu_\tau \\ \pi^-K_S^0K_L^0\nu_\tau \\ \pi^-K_S^0K_S^0\pi^0\nu_\tau \\ \pi^-K_S^0K_L^0\pi^0\nu_\tau \\ K^-K_S^0 & \geq 0 \text{ neutrals } \nu_\tau \\ K^0h^+h^-h^- \geq 0 \text{ neutrals } \nu_\tau \end{array}$		$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	CL=95%	F ₁₀₀ F ₁₀₁ F ₁₀₂ F ₁₀₃ F ₁₀₄ F ₁₀₅ F ₁₀₆ F ₁₀₇	$K^*(892)^0 K^- \nu_{\tau}$ $\overline{K}^*(892)^0 \pi^- \ge 0$ neutrals ν_{τ} $\overline{K}^*(892)^0 \pi^- \nu_{\tau}$ $(\overline{K}^*(892)^0 \pi^- \nu_{\tau} \rightarrow \pi^- \overline{K}^0 \pi^0 \nu_{\tau}$ $K_1(1270)^- \nu_{\tau}$ $K_1(1400)^- \nu_{\tau}$ $K_2^*(1430)^- \nu_{\tau}$		$(2.1 \pm 0.4) \times 10^{-3}$ $(3.8 \pm 1.7) \times 10^{-3}$ $(2.2 \pm 0.5) \times 10^{-3}$ $(1.1 \pm 0.5) \times 10^{-3}$ $(4 \pm 4) \times 10^{-3}$	CL=9!
41 42 43 44 45	$\begin{array}{c} \pi^-K_S^0K_S^0\nu_\tau \\ \pi^-K_S^0K_L^0\nu_\tau \\ \pi^-K_S^0K_S^0\pi^0\nu_\tau \\ \pi^-K_S^0K_L^0\pi^0\nu_\tau \\ K^-K_S^0 & \geq 0 \text{ neutrals } \nu_\tau \\ K^0h^+h^-h^- \geq 0 \text{ neutrals } \nu_\tau \end{array}$		$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	CL=95%	F ₁₀₀ F ₁₀₁ F ₁₀₂ F ₁₀₃ F ₁₀₄ F ₁₀₅ F ₁₀₆ F ₁₀₇	$K^*(892)^0 K^- \nu_{\tau}$ $\overline{K}^*(892)^0 \pi^- \ge 0$ neutrals ν_{τ} $\overline{K}^*(892)^0 \pi^- \nu_{\tau}$ $(\overline{K}^*(892)^0 \pi^- \nu_{\tau} \rightarrow \pi^- \overline{K}^0 \pi^0 \nu_{\tau}$ $K_1(1270)^- \nu_{\tau}$ $K_1(1400)^- \nu_{\tau}$ $K_2^*(1430)^- \nu_{\tau}$		$(2.1 \pm 0.4) \times 10^{-3}$ $(3.8 \pm 1.7) \times 10^{-3}$ $(2.2 \pm 0.5) \times 10^{-3}$ $(1.1 \pm 0.5) \times 10^{-3}$ $(4 \pm 4) \times 10^{-3}$ $(8 \pm 4) \times 10^{-3}$	CL=95
41 42 43 44 45 46 47	$\begin{array}{c} \pi^-K_S^0K_S^0\nu_\tau \\ \pi^-K_S^0K_L^0\nu_\tau \\ \pi^-K_S^0K_S^0\pi^0\nu_\tau \\ \pi^-K_S^0K_L^0\pi^0\nu_\tau \\ K^-K_S^0 & \geq 0 \text{ neutrals } \nu_\tau \\ K^0h^+h^-h^- \geq 0 \text{ neutrals } \nu_\tau \end{array}$		$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	CL=95%	F100 F101 F102 F103 F104 F105 F106 F107 F108	$K^*(892)^0 K^- \nu_{\tau}$ $\overline{K}^*(892)^0 \pi^- \ge 0$ neutrals ν_{τ} $\overline{K}^*(892)^0 \pi^- \nu_{\tau}$ $(\overline{K}^*(892)^{\pi})^- \nu_{\tau} \rightarrow \pi^- \overline{K}^0 \pi^0 \nu_{\tau}$ $K_1(1270)^- \nu_{\tau}$ $K_1(1400)^- \nu_{\tau}$		$(2.1 \pm 0.4) \times 10^{-3}$ $(3.8 \pm 1.7) \times 10^{-3}$ $(2.2 \pm 0.5) \times 10^{-3}$ $(1.1 \pm 0.5) \times 10^{-3}$ $(4 \pm 4) \times 10^{-3}$ $(8 \pm 4) \times 10^{-3}$	CL=95 CL=95

au

```
\Gamma_{111} \ \eta \pi^- \pi^0 \pi^0 \nu_\tau
                                                                                       (1.4 \pm 0.7) \times 10^{-4}
\begin{array}{ll}
111 & \eta K & \nu_{\tau} \\
112 & \eta K^{-} \nu_{\tau} \\
113 & \eta \pi^{+} \pi^{-} \pi^{-} \geq 0 \text{ neutrals } \nu_{\tau} \\
\Gamma_{114} & \eta \pi^{-} \pi^{+} \pi^{-} \nu_{\tau} \\
115 & \eta a_{1}(1260)^{-} \nu_{\tau} \rightarrow \eta \pi^{-} \rho^{0} \nu_{\tau}
\end{array}
                                                                                       ( 2.7 \pm 0.6 ) \times 10<sup>-4</sup>
                                                                                                                × 10<sup>-3</sup>
                                                                                     < 3
                                                                                                                                    CL=90%
                                                                                      (3.4 \pm 0.8) \times 10^{-4}
                                                                                                                × 10<sup>-4</sup>
r<sub>115</sub>
                                                                                                                                    CL=90%
                                                                                     < 3.9
× 10<sup>-4</sup>
                                                                                     < 1.1
                                                                                                                                    CL=95%
                                                                                                                 × 10<sup>-4</sup>
                                                                                     < 2.0
                                                                                                                                    CL=95%
                                                                                                                 × 10<sup>-5</sup>
\Gamma_{118} \eta'(958)\pi^-\nu
                                                                                     < 7.4
                                                                                                                                    CL=90%
\Gamma_{119} \eta'(958)\pi^-\pi^0\nu_{\tau}
                                                                                     < 8.0
                                                                                                                 × 10~5
                                                                                                                                    CL=90%
                                                                                                                 × 10~4
\Gamma_{120} \ \phi \pi^- \nu_\tau
                                                                                                                                    CL=90%
                                                                                     < 2.0
\Gamma_{121} \phi K^{-\nu}
                                                                                                                 × 10~5
                                                                                     < 6.7
                                                                                                                                    CL=90%
                                                                                       (5.8 \pm 2.3) \times 10^{-4}
\Gamma_{122} f_1(1285) \pi^- \nu_{\tau}
              f_1(1285)\pi^-\nu_{\tau} \rightarrow
                                                                                       ( 1.9 \pm 0.7 ) \times 10<sup>-4</sup>
Γ<sub>123</sub>
                       \eta \pi^- \pi^+ \pi^- \nu_{\tau}
\Gamma_{124} h^-\omega \geq 0 neutrals \nu_{\tau}
                                                                                       ( 2.36 ± 0.08) %
           h^-\omega\nu_{\tau}
h^-\omega\pi^0\nu_{\tau}
Γ125
                                                                               [a] ( 1.93 ± 0.06) %
                                                                               [a] (4.3 \pm 0.5) \times 10^{-3}
Γ<sub>126</sub>
                h^-\omega 2\pi^0\nu_{\tau}
                                                                                       (1.9 \pm 0.8) \times 10^{-4}
Γ<sub>127</sub>
```

Lepton Family number (LF), Lepton number (L), or Baryon number (B) violating modes (in the modes below, ℓ means a sum over e and μ modes)

L means lepton number violation (e.g. $\tau^- \to e^+\pi^-\pi^-$). Following common usage, LF means lepton family violation and not lepton number violation (e.g. $\tau^- \to e^-\pi^+\pi^-$). B means baryon number violation.

	violation (e.g. $\tau^- \rightarrow e^- \pi^+ \tau$	r [—]). <i>B</i> mea	ıns t	paryon numbe	r violation.	•
Γ ₁₂₈	$e^-\gamma$	LF	<	2.7	× 10 ⁻⁶	CL=90%
Γ ₁₂₉	$\mu^-\gamma$	LF	<		× 10 ⁻⁶	CL=90%
Γ ₁₃₀	$e^{-\frac{1}{\pi}0}$	LF	<		× 10 ⁻⁶	CL=90%
Γ ₁₃₁	$\mu^-\pi^0$	LF	<		× 10 ⁻⁶	CL=90%
Γ ₁₃₂	e-Ko	LF	<		× 10 ⁻³	CL=90%
Γ ₁₃₃	$\mu^- K^0$	LF	<		× 10 ⁻³	CL=90%
Γ ₁₃₄	e-η	LF	~		× 10 ⁻⁶	CL=90%
Γ ₁₃₅	$\mu^-\eta$	LF	~		× 10 ⁻⁶	CL=90%
Γ ₁₃₆	$e^{-\frac{\eta}{\rho}0}$	LF	<		× 10 ⁻⁶	CL=90%
Γ ₁₃₇	$\mu^- \rho^0$	LF	<		× 10 ⁻⁶	CL=90%
Γ ₁₃₈	e K*(892)0	LF	~		× 10 ⁻⁶	CL=90%
	$\mu^- K^*(892)^0$	LF			× 10 ⁻⁶	CL=90%
Γ ₁₃₉	$e^{-\frac{K}{K}}$ *(892)0	LF	<		× 10 ⁻⁶	CL=90%
F ₁₄₀	$\mu^{-} \overline{K}^{*} (892)^{0}$		<		× 10 -6	CL=90% CL=90%
Γ ₁₄₁		LF LF	<		× 10 -6	CL=90% CL=90%
「142	e ⁻ φ	LF	<		× 10 -6	CL=90% CL=90%
[143	$\mu^-\phi$	LF	<		× 10 •	CL=90% CL=90%
「144 「	$\frac{\pi^- \gamma}{\pi^- \pi^0}$	L	<		× 10 ⁻⁴ × 10 ⁻⁴	CL=90% CL=90%
Γ ₁₄₅	π π- e-e+e-	L 	<		× 10 ·	
[146	e e e	LF	<		× 10 ⁻⁶	CL=90%
Γ ₁₄₇	$e^- \mu^+ \mu^-$	LF	<		× 10 ⁻⁶	CL=90%
「148	$e^{+}\mu^{-}\mu^{-}$ $\mu^{-}e^{+}e^{-}$	LF	<		× 10 ⁻⁶	CL=90%
Γ ₁₄₉	μ e e	LF	<		× 10 ⁻⁶	CL=90%
F ₁₅₀	μ ⁺ e ⁻ e ⁻	LF	<		× 10 ⁻⁶	CL=90%
Γ ₁₅₁	$\mu^- \mu^+ \mu^- e^- \pi^+ \pi^-$	LF	<		× 10 ⁻⁶	CL=90% CL=90%
Γ ₁₅₂	e π π	LF	<		× 10 ⁻⁶	
Γ ₁₅₃	$e^{+}\pi^{-}\pi^{-}$ $\mu^{-}\pi^{+}\pi^{-}$	L	<	1.9	× 10 ⁻⁶	CL=90%
「 ₁₅₄	μ π π	LF	<		× 10 ⁻⁶	CL=90%
「 ₁₅₅	$\mu^{+}\pi^{-}\pi^{-}$ $e^{-}\pi^{+}K^{-}$	L	<		× 10 ⁻⁶	CL=90%
[156		LF 	<		× 10 ⁻⁶	CL=90%
Γ ₁₅₇	e ⁻ π ⁻ Κ ⁺	LF .	<		× 10 ⁻⁶	CL=90%
Γ ₁₅₈	e ⁺ π ⁻ K ⁻	L	<		× 10 ⁻⁶	CL=90%
Γ ₁₅₉	e- K+ K-	LF	<		× 10 ⁻⁶	CL=90%
L ₁₆₀	e+ K- K-	L	<		× 10 ⁻⁶	CL=90%
[161	$\mu^{-}\pi^{+}K^{-}$	LF	<	7.5	× 10 ⁻⁶	CL=90%
Γ ₁₆₂	$\mu^{-}\pi^{-}K^{+}$	LF	<	7.4	× 10 ⁶	CL=90%
L ₁₆₃	$\mu^{+}\pi^{-}K^{-}$	L	<	7.0	× 10 ⁻⁶	CL=90%
Γ ₁₆₄	μ- Κ+ Κ-	LF	<	1.5	× 10 ⁻⁵	CL=90%
「 ₁₆₅	$\mu^{+} K^{-} K^{-}$	L	<	6.0	× 10 ⁻⁶	CL=90%
Γ ₁₆₆	$e^{-}\pi^{0}\pi^{0}$	LF	<		× 10 ⁻⁶	CL=90%
Γ ₁₆₇	$\mu^-\pi^0\pi^0$	LF	<	1.4	× 10 ⁻⁵	CL=90%
Γ ₁₆₈	$e^-\eta\eta$	LF	<	3.5	× 10 ⁻⁵	CL=90%
Γ ₁₆₉	$\mu^- \eta \eta$	LF	<	6.0	× 10 ⁻⁵	CL=90%
[₁₇₀	$e^{-\pi^0\eta}$	LF	<		× 10 ⁻⁵	CL=90%
Γ ₁₇₁	$\mu^-\pi^0\eta$	LF	<	2.2	× 10 ⁻⁵	CL=90%
Γ ₁₇₂	$\overline{p}\gamma_0$	L,B	<		× 10 ⁻⁴	CL=90%
Γ ₁₇₃	$\overline{p}\pi^0$	L,B	<		× 10 ⁻⁴	CL=90%
[₁₇₄	$\overline{p}\eta$	L,B	<	1.30	× 10 ⁻³	CL=90%
Γ ₁₇₅	e light boson	LF	<	2.7	× 10 ⁻³	CL=95%

LF

< 5

× 10⁻³

CL=95%

 Γ_{176} μ^- light boson

- [a] Basis mode for the τ .
- [b] See the Particle Listings below for the energy limits used in this measurement.

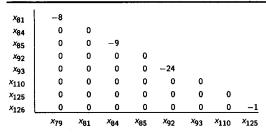
CONSTRAINED FIT INFORMATION

An overall fit to 65 branching ratios uses 141 measurements and one constraint to determine 29 parameters. The overall fit has a $\chi^2=$ 94.2 for 113 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\langle \delta x_i \delta x_j \rangle / (\delta x_i \cdot \delta x_j)$, in percent, from the fit to the branching fractions, $x_i \equiv \Gamma_i / \Gamma_{\rm total}$. The fit constrains the x_i whose labels appear in this array to sum to one.

<i>x</i> ₅	11									
X9	-11	-10								
×10	0	0	-34							
<i>x</i> ₁₃	-15	-13	-17	3						
X ₁₅	0	0	2	-7	-37					
x ₁₉	-16	-14	-15	1	-24	1				
X ₂₀	0	0	1	-3	1	-4	-18			
x ₂₃	-7	-6	-13	14	-14	17	-14	8		
×24	0	0	7	-19	9	-23	2	~11	-72	
X ₂₆	-5	-4	-5	0	-7	0	-9	0	-4	0
×32	-2	-2	-24	0	-3	0	-12	0	-2	1
X34	0	0	-4	-3	1	-3	-2	-2	7	~9
X36	-2	-2	-1	1	-4	1	-3	1	-8	3
X38	-1	-1	1	-3	0	-4	-1	-2	6	-11
X41	-1	-1	-3	0	-2	0	-2	0	-1	0
X57	-7	-6	-4	0	-10	0	-9	0	-4	0
X ₆₅	-3	-3	-4	0	-5	0	5	0	-1	-1
X73	-1	-1	-2	0	-2	0	-2	0	-1	0
X74	6	-5	-7	0	-9	. 0	-9	0	-4	0
X79	0	0	1	0	0	1	0	0	-1	2
<i>x</i> ₈₁	0	0	0	1	0	1	0	0	-1	3
X84	0	0	0	0	0	0	0	0	0	0
X ₈₅	0	0	0	0	0	0	0	0	0	0
X92	0	. 0	-1	0	-1	0	-1	0	0	0
X93	0	0	0	0	0	0	0	0	0	0
X ₁₁₀	-1	-1	-1	0	-1	0	-1	0	-1	0
X ₁₂₅	-2	-2	-3	0	-3	0	4	0	-1	. 0
×126	_2	-2	-3	0	-3	0	4	0	-2	0
	<i>x</i> ₃	X5	Χg	<i>x</i> ₁₀	×13	<i>x</i> ₁₅	X ₁₉	<i>x</i> ₂₀	×23	X ₂₄

	1									
x ₃₂	-1									
X34	0	-10								
×36	-1	-8	-1							
X38	0	-3	-2	-29						
x ₄₁	-1	-4	-1	-2	-1					
×57	-3	-17	4	0	0	0				
×65	-2	1	0	-10	7	0	-10			
×73	1	0	0	0	0	0	-1	-2		
×74	-3	0	0	0	0	-1	-13	15	-3	
X79	0	2	-18	0	0	0	-40	3	0	0
×81	0	1	1	7	-23	0	3	-41	0	0
x ₈₄	0	0	0	0	0	0	-23	3	0	0
×85	0	0	0	0	0	0	2	_30	0	. 0
X92	0	0	0	0	0	0	0	0	0	0
<i>X</i> 93	0	0	0	0	0	0	0	0	0	0
<i>x</i> ₁₁₀	-14	0	0	0	0	0	-1	0	-14	-1
×125	-1	0	0	-4	-1	0	-6	~28	-1	-8
×126	-1	0	0	0	0	0	-1	-4	-42	4
	×26	x ₃₂	×34	×36	×38	×41	×57	×65	<i>x</i> 73	×74



au BRANCHING FRACTIONS

Revised April 1998 by K.G. Hayes (Hillsdale College).

For the last six years, the rate of publication of new experimental results on the τ lepton has been high. The 30 new experimental papers listed in the τ References for this edition have produced significant changes in the τ Listings. The new results are made possible by the large τ data sets accumulated by the LEP experiments and by CLEO. Measurements of new τ -decay modes with small (< 10^{-3}) branching fractions have been published, and stringent upper limits on other new allowed τ decays have also been published. Significant improvements in branching fraction upper limits for forbidden τ decays have been made including the determination of upper limits for 12 new forbidden decay modes. The great majority of branching fraction upper limits for forbidden modes are now in the range of 10^{-5} to 10^{-6} .

Relatively precise branching fractions for 3-prong exclusive τ -decay modes containing charged kaons have finally been published [1]. This allows the determination of branching fractions for the decay modes $\tau^- \to \pi^- \pi^+ \pi^- \nu_{\tau}$ and $\tau^- \to \pi^- \pi^+ \pi^- \pi^0 \nu_{\tau}$, the last exclusive τ -decay modes with large branching fractions to be measured. The new measurements have resulted in a 30% increase in the number of τ -decay modes in the Listings; 176 decay modes are listed in the current edition, although many are not mutually independent.

There have also been many new measurements of τ -decay parameters. For most parameters, the uncertainty on the world average has decreased by a factor of 2.5 or more. Finally, new experimental limits have been published for the various τ -dipole moments. However, there have been few new measurements of τ -decay modes with large branching fractions, and the world average values for most of these branching fractions have changed little since the last edition.

The constrained fit to \u03c4 branching fractions: The Lepton Summary Table and the List of τ -Decay Modes contain branching fractions for 105 conventional τ -decay modes and upper limits on the branching fractions for 22 other conventional τ -decay modes. Of the 105 modes with branching fractions, 76 are derived from a constrained fit to τ branching fraction data. The goal of the constrained fit is to make optimal use of the experimental data to determine τ branching fractions. For example, the new branching fractions for the decay modes $\tau^- \to \pi^- \pi^+ \pi^- \nu_\tau$ and $\tau^- \to \pi^- \pi^+ \pi^- \pi^0 \nu_\tau$ are determined mostly from experimental measurements of the branching fractions for modes $\tau^- \to h^- h^- h^+ \nu_{\tau}$ and $\tau^- \to h^- h^- h^+ \pi^0 \nu_{\tau}$

and the new measurements of exclusive branching fractions for 3-prong modes containing charged kaons and 0 or 1 π^{0} 's.

Branching fractions from the constrained fit are derived from a set of basis modes. The basis modes form an exclusive set whose branching fractions are constrained to sum exactly to one. The list of 29 basis modes selected for the 1998 fit are listed in Table 1. The only change for the 1996 basis set is that the two modes $\tau \to h^-h^-h^+\nu_{\tau}$ (ex. K^0,ω) and $\tau \to h^- h^- h^+ \pi^0 \nu_{\tau}$ (ex. K^0, ω) have been replaced by the six new modes:

$$\begin{split} \tau &\to \pi^- \pi^+ \pi^- \nu_\tau \ \, (\text{ex.} \ \, K^0, \omega), \\ \tau &\to \pi^- \pi^+ \pi^- \pi^0 \nu_\tau \ \, (\text{ex.} \ \, K^0, \omega), \\ \tau &\to K^- \pi^+ \pi^- \nu_\tau \ \, (\text{ex.} \ \, K^0), \\ \tau &\to K^- \pi^+ \pi^- \pi^0 \nu_\tau \ \, (\text{ex.} \ \, K^0), \\ \tau &\to K^- K^+ \pi^- \nu_\tau, \text{ and } \\ \tau &\to K^- K^+ \pi^- \pi^0 \nu_\tau. \end{split}$$

Table 1: Basis modes for the 1998 fit to τ branching fraction data.

$e^-\overline{ u}_e u_ au$	$K^-K^0 u_ au$
$\mu^-\overline{ u}_\mu u_ au$	$K^-K^0\pi^0 u_ au$
$\pi^- u_{ au}$	$\pi^-\pi^+\pi^- u_ au$ (ex. K^0,ω)
$\pi^-\pi^0 u_ au$	$\pi^-\pi^+\pi^-\pi^0 u_ au$ (ex. K^0,ω)
$\pi^- 2 \pi^0 u_{ au} \; (ext{ex. } K^0)$	$K^-\pi^+\pi^- u_{ au} \; ({ m ex.} \; K^0)$
$\pi^- 3 \pi^0 u_{ au} \ ({ m ex.} \ K^0)$	$K^-\pi^+\pi^-\pi^0 u_{ au} \ ({ m ex.} \ K^0)$
$h^-4\pi^0 u_ au$ (ex. K^0)	$K^-K^+\pi^- u_ au$
$K^- u_ au$	$K^-K^+\pi^-\pi^0 u_ au$
$K^-\pi^0 u_ au$	$h^-h^-h^+2\pi^0\nu_{ au}~({ m ex.}~K^0,\omega,\eta)$
$K^{-}2\pi^{0}\nu_{ au}~({ m ex.}~K^{0})$	$h^-h^-h^+ \geq 3\pi^0 u_ au$
$K^{-}3\pi^{0}\nu_{\tau} \ ({\rm ex.}\ K^{0})$	$3h^-2h^+ u_{ au} \; ({ m ex.} \; K^0)$
$\pi^-\overline{K}^0 u_ au$	$3h^-2h^+\pi^0 u_{ au}~({ m ex.}~K^0)$
$\pi^-\overline{K}^0\pi^0 u_ au$	$h^-\omega u_ au$
$\pi^- K^0 \overline{K}^0 u_ au$	$h^-\omega\pi^0 u_ au$
	$\pi^-\eta\pi^0 u_ au$

In selecting the basis modes, assumptions and choices must be made. Factors pertaining to the selection of the 1996 basis modes are described in the 1996 edition. Additional assumptions have been made in selecting the six new modes for the 1998 basis set. We assume the decays $au^- o \pi^- K^+ \pi^- \ge 0 \pi^0
u_{ au}$ and $au^- o \pi^+ K^- K^- \ge 0 \pi^0
u_{ au}$ have negligible branching fractions. This is consistent with Standard Model predictions for τ decay, although the experimental limits for these branching fractions are not very stringent. The 95% CL upper limits for these branching fractions in the current Listings are B($\tau^- \to \pi^- K^+ \pi^- \ge 0 \pi^0 \nu_{\tau}$) < 0.25% and $B(\pi^+K^-K^- \ge 0\pi^0\nu_{\tau}) < 0.09\%$, values not so different from measured branching fractions for allowed 3-prong modes containing charged kaons. Although our usual goal is to impose as few theoretical constraints as possible so that the world averages and fit results can be used to test the theoretical constraints (i.e., we do not make use of the theoretical constraint from lepton universality on the ratio of the τ -leptonic branching fractions $B(\tau^- \to \mu^- \overline{\nu}_\mu \nu_\tau)/B(\tau^- \to e^- \overline{\nu}_e \nu_\tau) = 0.9728)$, the experimental challenge to identify charged prongs in 3-prong τ decays is sufficiently difficult that experimenters have been forced to make these assumptions when measuring the branching fractions of the allowed decays.

We also assume the branching fraction for the allowed decay $\tau^- \to K^- K^+ K^- \ge 0 \pi^0 \nu_\tau$ is negligible. This decay has limited phase space, and the branching fraction is expected to be very small. The branching fraction upper limit for this decay in the current Listings is $B(\tau^- \to K^- K^+ K^- \ge 0 \pi^0 \nu_\tau) < 0.21\%$ at 95% CL, and the ALEPH Collaboration [1] has determined a much more stringent limit on the branching fraction $B(\tau^- \to K^- K^+ K^- \nu_\tau) < 0.019\%$ at 90% CL.

Recent measurements of several new decay modes having very small branching fractions have raised two other issues regarding the choice of basis modes. The ALEPH Collaboration has recently measured new branching fractions for 1-prong τ decays containing two neutral kaons [2]. The basis set has just one τ -decay mode containing two neutral kaons: $\tau^- \to \pi^- K^0 \overline{K}^0 \nu_{\tau}$. In calculating the contribution of this decay to other measured τ -decay modes, we assume the two neutral kaons decay independently:

$$\begin{split} \mathbf{B}(\tau^- \to \pi^- K_S^0 K_S^0 \nu_\tau) &= \mathbf{B}(\tau^- \to \pi^- K_L^0 K_L^0 \nu_\tau) \\ &= \frac{1}{4} \mathbf{B}(\pi^- K^0 \overline{K}^0 \nu_\tau). \\ \mathbf{B}(\tau^- \to \pi^- K_S^0 K_L^0 \nu_\tau) &= \frac{1}{2} \mathbf{B}(\pi^- K^0 \overline{K}^0 \nu_\tau). \end{split}$$

This assumption may be incorrect. For example, Bose-Einstein correlations between the two neutral kaons can in principle alter these branching fractions. The ratio of the ALEPH measurement of B ($\tau^- \to \pi^- K_S^0 K_L^0 \nu_\tau$) = (0.101 ± 0.023 ± 0.013)% to the average of the CLEO [3] and ALEPH [2] measurements of B($\tau^- \to \pi^- K_S^0 K_S^0 \nu_\tau$) = (0.024 ± 0.005)% is not inconsistent with our assumed value for this ratio of 2. For the sake of simplicity, we retain in this edition the assumption of independent K^0 decay.

There are several newly measured modes with small branching fractions [4] which cannot be expressed in terms of the selected basis modes and are therefore left out of the fit:

$$\begin{split} \mathrm{B}(K^0h^+h^-h^-\nu_\tau) &= (2.3\pm 2.0)\times 10^{-4},\\ \mathrm{B}(\pi^-K_S^0K_L^0\pi^0\nu_\tau) &= (3.1\pm 1.2)\times 10^{-4},\\ \mathrm{B}(\tau^-\to\pi^-\overline{K}^0\pi^0\pi^0\nu_\tau) &= (6\pm 4)\times 10^{-4},\\ \mathrm{plus\ the}\ \eta\to\gamma\gamma\ \mathrm{component\ of\ the\ branching\ fractions}\\ \mathrm{B}(\eta\pi^-\pi^+\pi^-\nu_\tau) &= (3.4\pm 0.8)\times 10^{-4},\\ \mathrm{B}(\eta\pi^-\pi^0\pi^0\nu_\tau) &= (1.4\pm 0.7)\times 10^{-4},\ \mathrm{and}\\ \mathrm{B}(\eta K^-\nu_\tau) &= (2.7\pm 0.6)\times 10^{-4}. \end{split}$$

The sum of these excluded branching fractions is $(0.15\pm0.05)\%$. This is near our goal of 0.1% for the internal consistency of the τ Listings for this edition, and thus for simplicity we do not include these small branching fraction decay modes in the basis set.

The only significant difference between the world average value and the constrained fit value for branching fractions in the 1996 edition was for the 1-prong and 3-prong topological branching fractions. The average values for the topological

branching fractions were dominated by old measurements from the pre-LEP era. Some of these old experiments had significantly underestimated their experimental uncertainties, with the result that, in the period between 1986 and 1990, the uncertainty in the world averages for the 1-prong and 3-prong topological branching fractions were considerably smaller than the uncertainty in the world averages of the very well-measured leptonic branching fractions [5]. Also, several of these old topological branching fraction measurements made the largest contributions the the constrained χ^2 fit. These measurement are now very old and have been retired.

The constrained fit has a χ^2 of 94 for 113 degrees of freedom. The only basis mode branching fraction which shifted more than 1σ from its 1996 value is $B(\tau^- \to \pi^- \nu_\tau)$ which changed from $(11.31 \pm 0.15)\%$ to $(11.08 \pm 0.11)\%$ due mainly to the new measurement of $B(\tau^- \to h^- \nu_\tau)$ by the CLEO Collaboration [6]. The fit and average values for the topological branching fractions are consistent. Table 2 compares the current fit and average values for

$${\rm B_1}\equiv {\rm B(particle}^-\geq 0 \ {\rm neutrals} \ \geq 0 K_L^0 \nu_{\tau}) \ {\rm and} \ {\rm B_3}\equiv {\rm B}(h^-h^-h^+\geq 0 \ {\rm neutrals} \ \nu_{\tau})$$
 with the values from the 1996 edition.

Table 2: Fit and average values for B₁ and B₃.

Branching fraction		1996 Fit	1998 Fit		
B ₁ B ₁	Fit: Ave:	84.96 ± 0.17 85.91 ± 0.30	84.71 ± 0.13 85.1 ± 0.4		
B ₃	Fit:	14.92 ± 0.17 14.01 ± 0.29	15.18 ± 0.13 14.8 ± 0.4		

Another measure of the overall consistency of the τ branching fraction data with the fit constraint is a comparison of the fit and average values for the leptonic branching fractions. Table 3 compares the current fit and average values for $B_e \equiv B(\tau^- \to e^- \overline{\nu}_e \nu_\tau)$ and $B_\mu \equiv B(\tau^- \to \mu^- \overline{\nu}_\mu \nu_\tau)$ with the values from the 1996 edition.

Table 3: Fit and average values for $\tau^- \to e^- \overline{\nu}_e \nu_\tau$ and $\tau^- \to \mu^- \overline{\nu}_\mu \nu_\tau$.

Branching fraction		1996 Fit	1998 Fit
B_e B_e	Fit:	17.83 ± 0.08 17.80 ± 0.08	17.81 ± 0.07 17.78 ± 0.08
B_{μ} B_{μ}	Fit:	17.35 ± 0.10 17.30 ± 0.10	17.37 ± 0.09 17.32 ± 0.09

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Conclusions: Many new measurements of τ -lepton properties have been made in the last two years. Experimenters have exploited the availability of large data sets to measure τ decay modes with either small branching fractions or low detection efficiencies. Charged particle identification in 3-prong decays has finally allowed the experimental determination of the branching fraction for the decay modes $\tau^- \to \pi^- \pi^+ \pi^- \nu_{\tau}$ and $\tau^- \to \pi^- \pi^+ \pi^- \pi^0 \nu_{\tau}$, the last exclusive τ -decay modes with large branching fractions to be measured. The basis set of τ -decay modes used in the constrained fit to branching fractions has been expanded to include the new measurements of exclusive 3-prong decays with identified charged prongs and 0 or 1 π^{0} 's. There is no significant evidence of any inconsistency in the branching fraction data used in the constrained fit or to calculate world average values.

References

- 1. ALEPH Collaboration, R. Barate et al., Eur. Phys. J. C1, 65 (1998).
- ALEPH Collaboration, R. Barate et al., Eur. Phys. J. (to be published), CERN-PPE/97-167.
- CLEO Collaboration, T.E. Coan et al., Phys. Rev. D53, 6037 (1996).
- See the τ Listings for references.
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- CLEO Collaboration, A. Anastassov et al., Phys. Rev. D55, 2559 (1997).

τ - BRANCHING RATIOS

 $\begin{array}{l} \Gamma \text{(particle}^- \geq 0 \text{ neutrals } \geq 0 \\ K_0^D \nu_{\tau} \text{("1-prong"))} / \Gamma_{\text{total}} \\ \Gamma_1 / \Gamma = (\Gamma_3 + \Gamma_5 + \Gamma_9 + \Gamma_{10} + \Gamma_{13} + \Gamma_{15} + \Gamma_{19} + \Gamma_{20} + \Gamma_{23} + \Gamma_{24} + \Gamma_{26} + 0.6569 \Gamma_{32} + 0.6569 \Gamma_{36} + 0.6569 \Gamma_{38} + 0.4316 \Gamma_{41} + 0.708 \Gamma_{110} + 0.09 \Gamma_{125} + 0.6569 \Gamma_{36} + 0.6569 \Gamma_{38} + 0.4316 \Gamma_{41} + 0.708 \Gamma_{110} + 0.09 \Gamma_{125} + 0.6569 \Gamma_{36} + 0.6569 \Gamma_{36}$ $0.09\Gamma_{126})/\Gamma$

The charged particle here can be e, μ , or hadron. In many analyses, the sum of the topological branching fractions (1, 3, and 5 prongs) is constrained to be unity. Since the 5-prong fraction is very small, the measured 1-prong and 3-prong fractions are highly correlated and cannot be treated as independent quantities in our overall fit. We arbitrarily choose to use the 3-prong fraction in our fit, and leave the 1-prong fraction out. We do, however, use these 1-prong measurements in our average below The measurements used only for the average are marked "avg," whereas "f&a" marks a result used for the fit and the average.

VALUE (%)	<u>EVTS</u>	DOCUMENT ID	TECN	COMMENT
84.71 ± 0.13 OUR FIT	Error include	es scale factor of	1.2.	
85.1 ±0.4 OUR AVER	AGE			
$85.6 \pm 0.6 \pm 0.3$ avg	3300 ¹⁹	9 ADEVA	91F L3	Ecm= 88.3~94.3 GeV
84.9 ±0.4 ±0.3 avg		BEHREND		Ecm= 14-47 GeV
84.7 ±0.8 ±0.6 avg	20	DAIHARA	87B TPC	Ecm= 29 GeV
• • • We do not use the	ie following d	ata for averages,	fits, limits	etc. • • •
86.4 ±0.3 ±0.3		ABACHI	89B HRS	Ecm= 29 GeV
87.1 ±1.0 ±0.7	2:	¹ BURCHAT	87 MRK	2 Ecm = 29 GeV
87.2 ±0.5 ±0.8		SCHMIDKE	86 MRK	2 Ecm = 29 GeV
84.7 $\pm 1.1 \begin{array}{c} +1.6 \\ -1.3 \end{array}$	169 2	² ALTHOFF	85 TASS	Ecm = 34.5 GeV
86.1 ±0.5 ±0.9		BARTEL	85F JADE	Ecm = 34.6 GeV
87.8 ±1.3 ±3.9	2:	³ BERGER	85 PLUT	Ecm = 34.6 GeV
86.7 ±0.3 ±0.6		FERNANDEZ	85 MAC	Ecm = 29 GeV

¹⁹ Not independent of ADEVA 91F $\Gamma(h^-h^-h^+ \geq 0$ neut, ν_{τ} ("3-prong"))/ $\Gamma_{\rm total}$ value. ²⁰Not independent of AIHARA 87B $\Gamma(\mu^-\overline{\nu}_\mu\nu_ au)/\Gamma_{
m total}$, $\Gamma(e^-\overline{\nu}_e\nu_ au)/\Gamma_{
m total}$, and $\Gamma(h^- \ge 0 \text{ neutrals } \ge 0 K_L^0 \ \nu_{ au})/\Gamma_{ ext{total}} \text{ values.}$

```
\Gamma(\text{particle}^- \ge 0 \text{ neutrals } \ge 0K^0\nu_{\tau})/\Gamma_{\text{total}}
                                                                                              \Gamma_2/\Gamma
      +「<sub>20</sub>+「<sub>23</sub>+「<sub>24</sub>+「<sub>26</sub>+「<sub>32</sub>+「<sub>34</sub>+「<sub>36</sub>+
                                     DOCUMENT ID
                                                           TECN COMMENT
VALUE (%)
85.30±0.13 OUR FIT Error includes scale factor of 1.2.
84.59±0.33 OUR AVERAGE
84.48 ± 0.27 ± 0.23
                                     ACTON
                                                       92H OPAL 1990-1991 LEP runs
85.45^{+0.69}_{-0.73}\pm0.65
                        f&∠a
                                     DECAMP
                                                       92C ALEP 1989~1990 LEP runs
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 $\Gamma(\mu^- \overline{\nu}_\mu \nu_ au)/\Gamma_{ ext{total}}$ Data marked "avg" are highly correlated with data appearing elsewhere in the Listings. and are therefore used for the average given below but not in the overall fits. "f&a' marks results used for the fit and the average.

To minimize the effect of experiments with large systematic errors, we exclude experiments which together would contribute 5% of the weight in the average.

VALUE (%) 17.37±0.09 OUR I	-TT	EVTS		DOCUMENT ID	_	TECN	COMMENT
17.32±0.09 OUR /	WER/						
$17.37 \pm 0.08 \pm 0.18$	avg		24	ANASTASSOV	97	CLEO	Ecm = 10.6 GeV
$17.31 \pm 0.11 \pm 0.05$	f&a	20.7k		BUSKULIC	96C	ALEP	1991-1993 LEP runs
$17.02 \pm 0.19 \pm 0.24$	f&≀a	6586		ABREU	95T	DLPH	1991-1992 LEP runs
17.36 ± 0.27	f&a	7941		AKERS	951	OPAL	1990-1992 LEP runs
17.6 ± 0.4 ± 0.4	f&a	2148		ADRIANI	93M	L3	Ecm = 88-94 GeV
$17.4 \pm 0.3 \pm 0.5$	avg		25	ALBRECHT	93 G	ARG	Ecm = 9.4-10.6 GeV
$17.35 \pm 0.41 \pm 0.37$	f&a			DECAMP	92 C	ALEP	1989-1990 LEP runs
17.7 $\pm 0.8 \pm 0.4$	f&≀a	568		BEHREND	90	CELL	Ecm = 35 GeV
17.4 ±1.0	f&a	2197		ADEVA	88	MRKJ	Ecm = 14-16 GeV
● ● We do not u	se the	following	da	ita for averages,	flts,	limits, e	etc. • • •
$17.7 \pm 1.2 \pm 0.7$				AIHARA	87B	TPC	Ecm = 29 GeV
$18.3 \pm 0.9 \pm 0.8$				BURCHAT	87	MRK2	Ecm = 29 GeV
$18.6 \pm 0.8 \pm 0.7$		558	26	BARTEL	86 D	JADE	Ecm = 34.6 GeV
$12.9 \pm 1.7 ^{+0.7}_{-0.5}$				ALTHOFF	85	TASS	Eee = 34.5 GeV
18.0 ±0.9 ±0.5		473	26	ASH	858	MAC	Ecm = 29 GeV
$18.0 \pm 1.0 \pm 0.6$			27	BALTRUSAIT.	.85	MRK3	Ecm = 3.77 GeV
19.4 ±1.6 ±1.7		153		BERGER			Ecm = 34.6 GeV
17.6 ±2.6 ±2.1		47		BEHREND	83C	CELL	Ecm = 34 GeV
17.8 $\pm 2.0 \pm 1.8$				BERGER	81B	PLUT	Ecm = 9-32 GeV
24 This ANASTAS	ssov	97 result	k	not independe	nt o	f Γ(μ ⁻	$\overline{\nu}_{\mu} \nu_{\tau}) / \Gamma(e^{-} \overline{\nu}_{e} \nu_{\tau})$ and

is not independent of $\Gamma(\mu^-\overline{\nu}_\mu\nu_ au)/\Gamma(e^-\overline{\nu}_e\nu_ au)$ and

 $\Gamma(e^-\overline{\nu}_e\,\nu_{ au})/\Gamma_{ ext{total}}$ values. ²⁵ Not Independent of ALBRECHT 92D $\Gamma(\mu^- \overline{\nu}_\mu \nu_\tau)/\Gamma(e^- \overline{\nu}_e \nu_\tau)$ and ALBRECHT 93G $\Gamma(\mu^- \overline{\nu}_{\mu} \nu_{\tau}) \times \Gamma(e^- \overline{\nu}_{e} \nu_{\tau}) / \Gamma_{\text{total}}^2$ values.

²⁶ Modified using B($e^-\bar{\nu}_e\nu_{\tau}$)/B("1 prong") and B("1 prong") .= 0.855.

 $^{27}\,\text{Error}$ correlated with BALTRUSAITIS 85 $e\,\nu\,\overline{\nu}$ value.

VALUE EVTS DOCUMENT ID

0.2051 ± 0.0010 OUR FIT Error includes scale factor of 1.1.

10

 $\begin{array}{l} \Gamma \big(\mu^- \overline{\nu}_\mu \nu_\tau \big) / \Gamma \big(\text{particle}^- \geq 0 \text{ neutrals } \geq 0 K_L^0 \nu_\tau \big(\text{`$^-$1-prong"} \big) \big) \\ \Gamma_3 / \Gamma_1 = \Gamma_3 / (\Gamma_3 + \Gamma_5 + \Gamma_9 + \Gamma_{10} + \Gamma_{13} + \Gamma_{15} + \Gamma_{19} + \Gamma_{20} + \Gamma_{23} + \Gamma_{24} + \Gamma_{26} + \\ 0.6569 \Gamma_{32} + 0.6569 \Gamma_{34} + 0.6569 \Gamma_{36} + 0.6569 \Gamma_{38} + 0.4316 \Gamma_{41} + 0.708 \Gamma_{110} + 0.09 \Gamma_{125} + \\ \end{array}$

TECN COMMENT

• • • We do not use the following data for averages, fits, limits, etc. • • • 0.217 ±0.009 ±0.008 BARTEL 86D JADE Ecm = 34.6 GeV 0.211 + 0.010 + 0.006ASH 858 MAC Ecm = 29 GeV $\Gamma(\mu^- \overline{\nu}_\mu \nu_\tau \gamma) / \Gamma_{\text{total}}$ Γ_4/Γ VALUE (%) EVTS DOCUMENT ID TECN COMMENT 28 ALEXANDER 965 OPAL 1991-1994 LEP runs 0.30±0.04±0.05 116 ²⁹ WU

90 MRK2 EC = 29 GeV 28 ALEXANDER 96s impose requirements on detected γ 's corresponding to a au-rest-frame energy cutoff $E_{\gamma} > 20$ MeV.

²⁹WU 90 reports $\Gamma(\mu^- \overline{\nu}_\mu \nu_\tau \gamma)/\Gamma(\mu^- \overline{\nu}_\mu \nu_\tau) = 0.013 \pm 0.006$, which is converted to $\Gamma(\mu^-\overline{\nu}_\mu\nu_\tau\gamma)/\Gamma_{\rm total} \text{ using } \Gamma(\mu^-\overline{\nu}_\mu\nu_\tau\gamma)/\Gamma_{\rm total} = 17.35\%. \text{ Requirements on detected}$ γ 's correspond to a au rest frame energy cutoff $E_{\gamma} > 37$ MeV.

 $\Gamma(e^- v_e v_r)/\Gamma_{
m total}$ Data marked "avg" are highly correlated with data appearing elsewhere in the Listings, and are therefore used for the average given below but not in the overall fits. "f&a" marks results used for the fit and the average.

To minimize the effect of experiments with large systematic errors, we exclude experiments which together would contribute 5% of the weight in the average.

VALUE (%) EVTS 17.81±0.07 OUR FIT	DOCUMENT ID TECN	COMMENT
17.78±0.08 OUR AVERAGE		
17.76±0.06±0.17 f&a	ANASTASSOV 97 CLEO	Ecm = 10.6 GeV
17.78 ± 0.10 ± 0.09 f&a 25.3k	ALEXANDER 96D OPAL	1991-1994 LEP runs
17.79±0.12±0.06 f&a 20.6k	BUSKULIC 96c ALEP	1991-1993 LEP runs
17.51 ± 0.23 ± 0.31 f&a 5059	ABREU 95T DLPH	1991-1992 LEP runs
17.9 ±0.4 ±0.4 f&a 2892	ADRIANI 93M L3	Ecm = 88-94 GeV

²¹Not independent of SCHMIDKE 86 value (also not independent of BURCHAT 87 value for $\Gamma(h^-h^-h^+ \geq 0$ neut. ν_{τ} ("3-prong"))/ $\Gamma_{\rm total}$.

²² Not independent of ALTHOFF 85 $\Gamma(\mu^-\overline{\nu}_{\mu}\nu_{\tau})/\Gamma_{\rm total}$, $\Gamma(e^-\overline{\nu}_{e}\nu_{\tau})/\Gamma_{\rm total}$, $\Gamma(h^-\geq 0)$ neutrals $\geq 0K_L^0 \nu_{\tau})/\Gamma_{\rm total}$, and $\Gamma(h^-h^-h^+ \geq 0$ neut. ν_{τ} ("3-prong"))/ $\Gamma_{\rm total}$ values.

²³ Not independent of (1-prong $+ 0\pi^0$) and (1-prong $+ \ge 1\pi^0$) values.

12.1 ±0.7 ±0.5

12.3 ±0.9 ±0.5

 $11.3 \pm 0.5 \pm 0.8$

 $12.3 \pm 0.6 \pm 1.1$

f&a 309

avg

f&a 1338

798

328

ALEXANDER

BEHREND

⁴⁰ FORD

⁴¹ BARTEL

91D OPAL

87 MAC

1990 LEP run

Ecm = 29 GeV

90 CELL Ecm = 35 GeV

86D JADE Ecm = 34.6 GeV

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    •    • We do not use the following data for averages, fits, limits, etc.    •    •    •

                                           30 ALBRECHT
17.5 ±0.3 ±0.5 avg
                                                                  93G ARG
                                                                                  Ecm = 9.4-10.6 GeV
                                                                                                                                                                            <sup>42</sup> BURCHAT
                                                                                                                              11.1 +1.1 +1.4
                                                                                                                                                                                                 87 MRK2 Ecm = 29 GeV
19.1 ±0.4 ±0.6 avg 2960
                                           31 AMMAR
                                                                  92 CLEO Eee = 10.5-10.9 GeV
                                                                                                                              13.0 ±2.0 ±4.0
                                                                                                                                                                                BERGER . 85 PLUT ECM = 34.6 GeV
                                               DECAMP
18.09±0.45±0.45 f&a
                                                                  92C ALEP 1989-1990 LEP runs
                                                                                                                              11.2 \pm 1.7 \pm 1.2
                                                                                                                                                                            43 BEHREND 83C CELL Ecm = 34 GeV
17.0 ±0.5 ±0.6 f&a
                                               ABACHI
                                                                  90 HRS
                                                                               Ecm= 29 GeV
                               1.7k
                                                                                                                               ^{35} BUSKULIC 96 quote 11.78 \pm 0.11 \pm 0.13 We add 0.66 to undo their correction for
• • • We do not use the following data for averages, fits, limits, etc. • • •
                                                                                                                                  unseen K_1^0 and modify the systematic error accordingly.
                                                                  92 CLEO Repl. by ANAS-
TASSOV 97
90 CELL Ecm = 35 GeV
17.97 \pm 0.14 \pm 0.23
                                               AKERIB
                                3970
                                                                                                                                ^{36} ACCIARRI 95 with 0.65% added to remove their correction for \pi^- K_L^0 backgrounds.
18.4 ±0.8 ±0.4
                                               BEHREND
                                                                                                                                <sup>37</sup> ABREU 92N with 0.5% added to remove their correction for K*(892) backgrounds.
                                                                  89 CBAL Ecm = 9.4-10.6 GeV
16.3 \pm 0.3 \pm 3.2
                                               JANSSEN
                                                                                                                                <sup>38</sup> Not independent of ALBRECHT 92D \Gamma(\mu^-\overline{\nu}_\mu\nu_\tau)/\Gamma(e^-\overline{\nu}_e\nu_\tau), \Gamma(\mu^-\overline{\nu}_\mu\nu_\tau) ×
                                                                  878 TPC Eee = 29 GeV
18.4 \pm 1.2 \pm 1.0
                                               AIHARA
                                                                                                                                   \Gamma(e^-\overline{\nu}_e\nu_\tau), \text{ and } \Gamma(h^-\geq 0\,K_L^0\nu_\tau)/\Gamma(e^-\overline{\nu}_e\nu_\tau) \text{ values}.
19.1 \pm 0.8 \pm 1.1
                                               BURCHAT
                                                                  87 MRK2 Ecm = 29 GeV
                                                                                                                                ^{39} DECAMP 92c quote B(h^- \geq 0 K_L^0 \geq 0 (K_S^0 \to \pi^+\pi^-) \nu_{\tau}) = 13.32 \pm 0.44 \pm 0.33.
                                           31 BARTEL
16.8 ±0.7 ±0.9
                                                                  86D JADE Ecm = 34.6 GeV
                                                                                                                                   We subtract 0.35 to correct for their inclusion of the K_S^0 decays.
20.4 ±3.0 +1.4
-0.9
                                               ALTHOFF
                                                                  85 TASS EC = 34.5 GeV
                                                                                                                                ^{40} FORD 87 result for B( \pi^-\nu_{\tau} ) with 0.67% added to remove their K^- correction and adjusted for 1992 B("1 prong").
17.8 \pm 0.9 \pm 0.6
                                           31 ASH
                                                                  85B MAC Ecm = 29 GeV
                                                                                                                                ^{41} BARTEL 860 result for B(\pi^-\nu_r) with 0.59% added to remove their K^- correction and adjusted for 1992 B("1 prong").
                                           32 BALTRUSAIT...85 MRK3 Ecm = 3.77 GeV
18.2 \pm 0.7 \pm 0.5
                                                                  85 PLUT Eee = 34.6 GeV
13.0 \pm 1.9 \pm 2.9
                                               BERGER
                                                                                                                                ^{42} BURCHAT 87 with 1.1% added to remove their correction for K^- and K^*(892)^- back-
                                               BEHREND
                                                                  83C CELL Ecm = 34 GeV
18.3 ±2.4 ±1.9
                                   60
                                          33 BACINO
16.0 ±1.3
                                  459
                                                                  788 DLCO Ecm = 3.1-7.4 GeV
                                                                                                                                ^{43} BEHREND 83c quote B(\pi^- 
u_{	au}) = 9.9 \pm 1.7 \pm 1.3 after subtracting 1.3 \pm 0.5 to correct
 ^{30}\,\rm Not independent of ALBRECHT 92D \Gamma(\mu^-\,\overline{\nu}_\mu\nu_\tau)/\Gamma(e^-\,\overline{\nu}_e\nu_\tau) and ALBRECHT 93G |
                                                                                                                                  for B(K = v_).
     \Gamma(\mu^- \overline{\nu}_{\mu} \nu_{\tau}) \times \Gamma(e^- \overline{\nu}_{e} \nu_{\tau}) / \Gamma_{\text{total}}^2 values.
                                                                                                                              \Gamma(h^- \ge 0K_L^0 \nu_\tau)/\Gamma(\text{particle}^- \ge 0 \text{ neutrals } \ge 0K_L^0 \nu_\tau(\text{"1-prong"}))
 <sup>31</sup> Modified using B(e^-\overline{\nu}_e\nu_{	au})/B("1 prong") and B("1 prong") ,= 0.855.
                                                                                                                                     32 Error correlated with BALTRUSAITIS 85 \Gamma(\mu^- \overline{\nu}_\mu \nu_	au)/\Gamma_{
m total}
 ^{33} BACINO 78B value comes from fit to events with e^\pm and one other nonelectron charged
                                                                                                                                      0.708\(\text{1}_{110} + 0.09\(\text{1}_{125} + 0.09\(\text{1}_{126}\)
                                                                                                                              <u>VALUE</u> <u>EVTS</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u>

0.1455±0.0014 OUR FIT Error includes scale factor of 1.4.
\begin{array}{l} \Gamma\left(e^{-}\overline{\nu_{e}}\nu_{\tau}\right)/\Gamma\left(\text{particle}^{-}\geq0\text{ neutrals }\geq0K_{0}^{0}\nu_{\tau}\left(\text{"1-prong"}\right)\right) & \Gamma_{5}/\Gamma_{1}\\ \Gamma_{5}/\Gamma_{1}=\Gamma_{5}/(\Gamma_{3}+\Gamma_{5}+\Gamma_{9}+\Gamma_{10}+\Gamma_{13}+\Gamma_{15}+\Gamma_{19}+\Gamma_{20}+\Gamma_{23}+\Gamma_{24}+\Gamma_{26}+\\ 0.6569\Gamma_{32}+0.6569\Gamma_{34}+0.6569\Gamma_{36}+0.6569\Gamma_{38}+0.4316\Gamma_{41}+0.708\Gamma_{110}+0.09\Gamma_{125}+\\ \end{array}
                                                                                                                              0.135 ±0.009 OUR AVERAGE
                                                                                                                                                                       44 FORD
                                                                                                                              0.131 ±0.006 ±0.009 798
                                                                                                                                                                                               87 MAC Em = 29 GeV
       0.09[126]
                                                                                                                                                                      45 BARTEL
                                                                                                                              0.143 ±0.007 ±0.013 328
                                                                                                                                                                                               86D JADE Em = 34.6 GeV
VALUE EVTS DOCUMENT ID 1.1.

0.2102±0.0009 OUR FIT Error includes scale factor of 1.1.
                                                                         TECN COMMENT
                                                                                                                                44 FORD 87 result divided by 0.865, their assumed value for B("1 prong").
                                                                                                                                45 BARTEL 86p result with 0.6% added to remove their K<sup>-</sup> correction and then divided
by 0.866, their assumed value for B("1 prong").
0.2231 ± 0.0044 ± 0.0073 2856
                                                 AMMAR
                                                                    92 CLEO Em = 10.5-10.9 GeV
• • • We do not use the following data for averages, fits, limits, etc. • •
                                                                                                                               \Gamma(h^- \geq 0K_L^0 \nu_{\tau})/\Gamma(e^- \overline{\nu}_e \nu_{\tau})
                                                 BARTEL
                                                                    86D JADE EC = 34.6 GeV
                                                                                                                                                                                                                                    \Gamma_7/\Gamma_5
0.196 \pm 0.008 \pm 0.010
0.208 ±0.010 ±0.007
                                                  ASH
                                                                     85B MAC Ecm = 29 GeV
                                                                                                                                      \Gamma_7/\Gamma_5 = (\Gamma_9 + \Gamma_{10} + \frac{1}{2}\Gamma_{32} + \frac{1}{2}\Gamma_{34} + \frac{1}{4}\Gamma_{41})/\Gamma_5
                                                                                                                                                                             DOCUMENT ID
\Gamma(\mu^- \overline{\nu}_\mu \nu_	au) \times \Gamma(e^- \overline{\nu}_e \nu_	au) / \Gamma_{	ext{total}}^2
                                                                                                   \Gamma_3\Gamma_5/\Gamma^2
                                                                                                                                                                                                     TECN COMMENT
                                                                                                                               0.692±0.006 OUR FIT Error includes scale factor of 1.4.
<u>VALUE</u> <u>EVTS</u> <u>DOCUMENT ID</u> <u>TEC</u>
0.03094±0.00021 OUR FIT Error includes scale factor of 1.1.
                                                                          TECN COMMENT
                                                                                                                                                                            ALBRECHT 92D ARG Ecm = 9.4-10.6 GeV
                                                                                                                               0.678±0.037±0.044
0.0306 ±0.0005 ±0.0013 3230
                                                 ALBRECHT 93G ARG
                                                                                  Ecm ≈ 9.4-10.6 GeV

    • • We do not use the following data for averages, fits, limits, etc.

• • • We do not use the following data for averages, fits, limits, etc. • • •
                                                                                                                                                                         46 BARTEL
                                                                                                                              0.647 \pm 0.039 \pm 0.061
                                                                                                                                                                                               86D JADE E = 34.6 GeV
0.0288 \pm 0.0017 \pm 0.0019
                                                 ASH
                                                                     85B MAC Ecm = 29 GeV
                                                                                                                                <sup>46</sup> Combined result of BARTEL 86D e\nu\overline{\nu}, \mu\nu\overline{\nu}, and \pi^-\nu assuming B(\mu\nu\overline{\nu})/B(e\nu\overline{\nu})\approx
                                                                                                                                   0.973.
 \Gamma(\mu^- \overline{\nu}_\mu \nu_\tau) / \Gamma(e^- \overline{\nu}_e \nu_\tau) \\ \text{Predicted to be 1 for sequential lepton, 1/2 for para-electron, and 2 for para-mu-
                                                                                                       \Gamma_3/\Gamma_5
                                                                                                                              \Gamma(h^-\nu_{\tau})/\Gamma_{\text{total}} \Gamma_{\text{B}}/\Gamma=(\Gamma_{\text{9}}+\Gamma_{\text{10}})/\Gamma_{\text{Data marked "avg"}} are highly correlated with data appearing elsewhere in the Listings,
       Para-electron also ruled out by HEILE 78.
                                                                                                                                      and are therefore used for the average given below but not in the overall fits. "f&a"
       Data marked "avg" are highly correlated with data appearing elsewhere in the Listings,
                                                                                                                                      marks results used for the fit and the average.
       and are therefore used for the average given below but not in the overall fits. "f&a"
        marks results used for the fit and the average.
                                                                                                                                                                              DOCUMENT ID
                                                                                                                                                                                                     TECN COMMENT
                                                                                                                               11.79±0.12 OUR FIT Error includes scale factor of 1.5.
VALUE
0.976 ±0.006 OUR FIT
0.978 ±0.011 OUR AVERAGE
                                                DOCUMENT ID
                                                                   TECN COMMENT
                                                                                                                               11.65 ± 0.21 OUR AVERAGE Error includes scale factor of 1.9.
                                                                                                                                                                              ACKERSTAFF 98M OPAL 1991-1995 LEP runs
                                                                                                                               11.98 \pm 0.13 \pm 0.16
                                                                                                                                                               f&a
                                                                                                                                                                              ANASTASSOV 97 CLEO E_{\rm cm}^{\rm ee} = 10.6~{\rm GeV}
0.9777±0.0063±0.0087 f&a
                                                ANASTASSOV 97 CLEO Ecm = 10.6 GeV
                                                                                                                               11.52 \pm 0.05 \pm 0.12
                                                                                                                                                                f&a
                                                ALBRECHT 92D ARG Ecm = 9.4-10.6 GeV
 0.997 ±0.035 ±0.040
                                                                                                                               \Gamma(h^-\nu_{\tau})/\Gamma(e^-\overline{\nu}_e\nu_{\tau})
                                                                                                                                                                                                              \Gamma_6/\Gamma_5 = (\Gamma_9 + \Gamma_{10})/\Gamma_5
 \begin{array}{l} \Gamma\left(h^{-} \geq 0 \text{ neutrals } \geq 0K_{1}^{0} \nu_{\tau}\right) / \Gamma_{\text{total}} & \Gamma_{6}/\Gamma \\ \Gamma_{6}/\Gamma = (\Gamma_{9} + \Gamma_{10} + \Gamma_{13} + \Gamma_{19} + \Gamma_{20} + \Gamma_{23} + \Gamma_{24} + \Gamma_{26} + 0.6569\Gamma_{32} + 0.6569\Gamma_{34} + 0.6569\Gamma_{36} + 0.6569\Gamma_{38} + 0.4316\Gamma_{41} + 0.708\Gamma_{110} + 0.09\Gamma_{125} + 0.09\Gamma_{126})/\Gamma \end{array} 
                                                                                                                                      Data marked "avg" are highly correlated with data appearing elsewhere in the Listings,
                                                                                                                                      and are therefore used for the average given below but not in the overall fits. "f&a"
                                                                                                                                      marks results used for the fit and the average.
 VALUE (%) DOCUMENT ID TECN

49.52±0.16 OUR FIT Error includes scale factor of 1.2.
                                                                                                                                                                             DOCUMENT ID
                                                                                                                                                                                                      TECN COMMENT
                                                              TECN COMMENT
                                                                                                                               0.662 ±0.008 OUR FIT Error includes scale factor of 1.4.
                                                                                                                                                                        47 ANASTASSOV 97 CLEO Ecm = 10.6 GeV
 48.6 ±1.2 ±0.9 avg 34 AIHARA
                                                     87B TPC Ecm = 29 GeV
                                                                                                                               0.6484±0.0041±0.0060 avg
                                                                                                                                ^{47} Not independent of ANASTASSOV 97 \Gamma(h^-\nu_{	au})/\Gamma_{	ext{total}} value.
 <sup>34</sup> Not independent of AIHARA 878 e\nu\overline{\nu}, \mu\nu\overline{\nu}, and \pi^+2\pi^-(\geq 0\pi^0)\nu values.
 \Gamma(h^- \geq 0K_L^0 \nu_\tau)/\Gamma_{\text{total}}
                                                                                                                               \Gamma(\pi^-\nu_{\tau})/\Gamma_{\text{total}} 19/1
Data marked "avg" are highly correlated with data appearing elsewhere in the Listings,
        \Gamma_7/\Gamma = (\Gamma_9 + \Gamma_{10} + \frac{1}{2}\Gamma_{32} + \frac{1}{2}\Gamma_{34} + \frac{1}{4}\Gamma_{41})/\Gamma
                                                                                                                                      and are therefore used for the average given below but not in the overall fits. "f&a"
        Data marked "avg" are highly correlated with data appearing elsewhere in the Listings,
                                                                                                                                      marks results used for the fit and the average.
        and are therefore used for the average given below but not in the overall fits. "f&a"
                                                                                                                               VALUE (%) EVTS DOCUMENT ID

11.08±0.13 OUR FIT Error includes scale factor of 1.4.
                                                                                                                                                                                                         TECN COMMENT
        marks results used for the fit and the average.
VALUE (%)

12.32 ± 0.12 OUR FIT Error includes scale factor of 1.5.

12.42 ± 0.14 OUR AVERAGE
                                                                           TECN COMMENT
                                                                                                                               11.07±0.18 OUR AVERAGE
                                                                                                                                                       avg
                                                                                                                                                                            48 BUSKULIC
                                                                                                                                                                                                   96 ALEP LEP 1991-1993 data
                                                                                                                               11.06 ± 0.11 ± 0.14
                                                                                                                                                                                                   820 MRK2 Ecm = 3.5-6.7 GeV
                                                                                                                                                                                BLOCKER
                                                                                                                               11.7 ±0.4 ±1.8 f&a 1138
 12.44±0.11±0.11
                           f&a 15k
                                               35 BUSKULIC
                                                                      96 ALEP 1991-1993 LEP run
                                               36 ACCIARRI
 12.47 ± 0.26 ± 0.43
                            f&a 2967
                                                                      95 L3
                                                                                      1992 LEP run
                                                                                                                                <sup>48</sup> Not independent of BUSKULIC 96 B(h^-\nu_{\tau}) and B(K^-\nu_{\tau}) values.
 12.4 ±0.7 ±0.7
                                               37 ABREU
                                                                      92N DLPH 1990 LEP run
                            f&a
                                     283
 11.7 ±0.6 ±0.8
                                               38 ALBRECHT
                                                                      920 ARG
                                                                                      Ecm = 9.4-10.6 GeV
                            avg
 12.98±0.44±0.33
                                               39 DECAMP
                                                                      92C ALEP
                                                                                      1989-1990 LEP runs
                            f&∠a
```

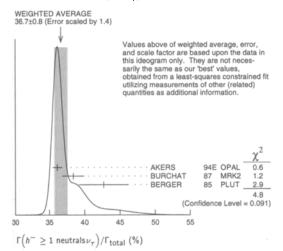
TECN COMMENT

$\Gamma(K^-\nu_{\tau})/\Gamma_{\text{total}}$					Γ ₁₀ /Γ
VALUE (%)	EVTS	DOCUMENT ID		TECN	COMMENT
0.71±0.05 OUR FIT					
0.71±0.05 OUR AVER	LAGE				
$0.72 \pm 0.04 \pm 0.04$	728	BUSKULIC	96	ALEP	LEP 1991-1993 data
0.85 ± 0.18	27	ABREU	94K	DLPH	LEP 1992 Z data
$0.66 \pm 0.07 \pm 0.09$	99	BATTLE	94	CLEO	Ecm ≈ 10.6 GeV
0.59 ± 0.18	16	MILLS	84	DLCO	Ecm≃ 29 GeV
1.3 ±0.5	15	BLOCKER	82B	MRK2	Ecm = 3.9-6.7 GeV
• • • We do not use t	the following (data for averages,	fits, li	mits, et	C. • • •
$0.64 \pm 0.05 \pm 0.05$	336	BUSKULIC	94E	ALEP	Repl. by BUSKULIC 96

 $\Gamma(h^- \ge 1 \text{ neutrals } \nu_{\tau})/\Gamma_{\text{total}}$ Γ_{11}/Γ $\Gamma_{11}/\Gamma = (\Gamma_{13} + \Gamma_{15} + \Gamma_{19} + \Gamma_{20} + \Gamma_{23} + \Gamma_{24} + \Gamma_{26} + 0.157\Gamma_{32} + 0.157\Gamma_{34} + 0.157\Gamma_{36} + 0.157\Gamma_{38} + 0.0246\Gamma_{41} + 0.708\Gamma_{110} + 0.09\Gamma_{125} + 0.09\Gamma_{126})/\Gamma$

DOCUMENT ID TECN COMMENT 36.91±0.17 OUR FIT Error includes scale factor of 1.2. 36.7 ±0.8 OUR AVERAGE Error includes scale factor of 1.4. See the ideogram below. 36.14±0.33±0.58 **AKERS** 94E OPAL 1991-1992 LEP runs ⁴⁹ BURCHAT 38.4 ±1.2 ±1.0 87 MRK2 Eee = 29 GeV 85 PLUT *E*ee = 34.6 GeV 42.7 +2.0 +2.9 BERGER

 49 BURCHAT 87 quote for B($\pi^{\pm} \geq$ 1 neutral $\nu_{\tau}) = 0.378 \pm 0.012 \pm 0.010$. We add 0.006 to account for contribution from $(K^{*-}\nu_{\tau})$ which they fixed at BR = 0.013.



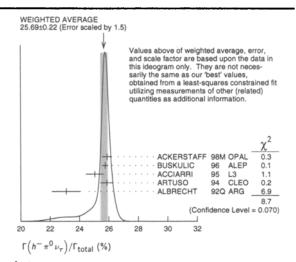
$\Gamma(h^-\pi^0\nu_\tau)/\Gamma_{\text{total}}$				$\Gamma_{12}/\Gamma = (\Gamma_{13} + \Gamma_{15})/\Gamma$
VALUE (%)	EVTS	DOCUMENT ID	TECN	COMMENT
25.84±0.14 OUR FIT	Error In	cludes scale factor o	f 1.1.	
25.69±0.22 OUR AVE	RAGE E	rror includes scale fa	actor of 1.	5. See the ideogram below.
25.89±0.17±0.29		ACKERSTAFF	98M OPA	1991-1995 LEP runs
$25.76 \pm 0.15 \pm 0.13$	31k	BUSKULIC	96 ALER	P LEP 1991-1993 data
$25.05 \pm 0.35 \pm 0.50$	6613	ACCIARRI	95 L3	1992 LEP run
$25.87 \pm 0.12 \pm 0.42$	51k	⁵⁰ ARTUSO	94 CLEC) Ecm = 10.6 GeV
23.1 ±0.4 ±0.9	1249	51 ALBRECHT	92Q ARG	Ecm = 10 GeV
• • • We do not use t	he followi	ing data for averages	, fits, limit	s, etc. • • •
$25.98 \pm 0.36 \pm 0.52$		⁵² AKERS	94E OPA	
22.9 ±0.8 ±1.3	283	⁵³ ABREU	92N DLPI	STAFF 98M H Ecm = 88.2-94.2 GeV
25.02 ± 0.64 ± 0.88	1849	DECAMP	92C ALE	1989-1990 LEP runs
22.0 ±0.8 ±1.9	779	ANTREASYAN	91 CBA	L Ecm = 9.4-10.6 GeV
22.6 ±1.5 ±0.7	1101	BEHREND	90 CELI	. Ecm = 35 GeV
23.1 ±1.9 ±1.6		BEHREND	84 CELL	. Ecm = 14,22 GeV
EO				

50 ARTUSO 94 reports the combined result from three independent methods, one of which (23% of the $\tau^- \to h^- \pi^0 \nu_{\tau}$) is normalized to the inclusive one-prong branching fraction, taken as 0.854 \pm 0.004. Renormalization to the present value causes negligible change.

⁵¹ ALBRECHT 920 with 0.5% added to remove their correction for $au^- o imes au^*$ (892) $^-
u_{ au}$ background.

 52 AKERS 94E quote (26.25 \pm 0.36 \pm 0.52) \times 10 $^{-2}$; we subtract 0.27% from their number to correct for $\tau^- \to h^- K^0_L \nu_{\tau}$.

 53 ABREU 92N with 0.5% added to remove their correction for $K^*(892)^-$ backgrounds.



and are therefore used for the average given below but not in the overall fits. "f&a" marks results used for the fit and the average. DOCUMENT ID

25.30±	0.15 ± 0.13	avg	34 BUSKULIC	96	ALEP	LEP 1991-1993
25.36±	0.44	avg	⁵⁵ ARTUSO	94	CLEO	eee 10.6 GeV
• • • ٧	We do not use the	following dat	a for averages, fits,	limits,	etc. • •	•
21.5 ±	0.4 ±1.9	4400	56,57 ALBRECHT	88L	ARG	Ecm = 10 GeV
23.0 ±	1.3 ±1.7	582	ADLER	87B	MRK3	Ecm = 3.77 GeV
25.8 ±	1.7 ±2.5		⁵⁸ BURCHAT	87	MRK2	Ecm = 29 GeV
22.3 +	06 +14	629	57 YELTON	86	MRK2	Fee = 29 GeV

 $^{54}\,\mathrm{Not}$ Independent of BUSKULIC 96 B($h^-\,\pi^0\,\nu_{\tau})$ and B($K^-\,\pi^0\,\nu_{\tau})$ values.

EVTS

25.32±0.15 OUR FIT Error includes scale factor of 1.1.

25.31 ±0.18 OUR AVERAGE

⁵⁵ Not independent of ARTUSO 94 B($h^-\pi^0\nu_{\tau}$) and BATTLE 94 B($K^-\pi^0\nu_{\tau}$) values.

⁵⁶ The authors divide by ($\Gamma_3 + \Gamma_5 + \Gamma_9 + \Gamma_{10}$)/ Γ = 0.467 to obtain this result. ⁵⁷ Experiment had no hadron identification. Kaon corrections were made, but insufficient Information is given to permit their removal.

58 BURCHAT 87 value is not independent of YELTON 86 value. Nonresonant decays included.

$\Gamma(\pi^-\pi^0\operatorname{non-}\rho(770)\nu_{ au})/\Gamma_{\operatorname{total}}$							
VALUE (%)	DOCUMENT ID		TECN	COMMENT			
0.3 ±0.1 ±0.3	59 BEHREND	84	CELL	Eee = 14,22 GeV			

⁵⁹BEHREND 84 assume a flat nonresonant mass distribution down to the ho(770) mass, using events with mass above 1300 to set the level.

$\Gamma(K^-\pi^0\nu_{\tau})/\Gamma_{\text{tota}}$	ı				Γ_{15}/Γ
VALUE (%)	EVTS	DOCUMENT ID	TEC	N COMMENT	
0.52±0.05 OUR FIT					-
0.52±0.06 OUR AVE	RAGE				
$0.52\pm0.04\pm0.05$	395	BUSKULIC	96 ALE	P LEP 1991-1993	data
$0.51 \pm 0.10 \pm 0.07$	37	BATTLE	94 CLE	O Ecm ≈ 10.6 Ge\	/
• • • We do not use	the followin	ng data for averag	es, fits, lim	lts, etc. • • •	
$0.53 \pm 0.05 \pm 0.07$	220	BUSKULIC	94E ALE	P Repl. by BUSKU	LIC 96

 $\begin{array}{l} \Gamma\left(h^{-} \geq 2\pi^{0}\nu_{\tau}\right)/\Gamma_{total} & \Gamma_{16}/$ Γ_{16}/Γ

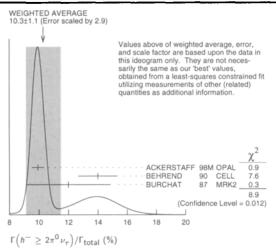
Data marked "avg" are highly correlated with data appearing elsewhere in the Listings, and are therefore used for the average given below but not in the overall fits. "f&a" marks results used for the fit and the average.

DOCUMENT ID EVTS TECN COMMENT 10.79±0.16 OUR FIT Error includes scale factor of 1.2. 10.3 ±1.1 OUR AVERAGE Error includes scale factor of 2.9. See the ideogram below. 9.91±0.31±0.27 f&a ACKERSTAFF 98M OPAL 1991-1995 LEP runs 60 BEHREND 90 CELL Eee = 35 GeV 14.0 ±1.2 ±0.6 avg ⁶¹ BURCHAT 87 MRK2 Ecm = 29 GeV 12.0 ±1.4 ±2.5 f&a • • • We do not use the following data for averages, fits, limits, etc. • • • 62 AKERS 94E OPAL Repl. by ACKER-STAFF 98M $9.89 \pm 0.34 \pm 0.55$ 63 AIHARA $13.9 \pm 2.0 \begin{array}{c} +1.9 \\ -2.2 \end{array}$

 60 No Independent of BEHREND 90 $\Gamma(h^-\,2\pi^0\,\nu_\tau\,({\rm exp.}~K^0))$ and $\Gamma(h^-\geq 3\,\pi^0\,\nu_\tau).$

 61 Error correlated with BURCHAT 87 $\Gamma(
ho^-
u_e)/\Gamma({
m total})$ value.

 62 AKERS 94E not independent of AKERS 94E B($h^- \geq 1\pi^0 \nu_{ au}$) and B($h^-\pi^0 \nu_{ au}$) mea surements. 63 AIHARA 86E (TPC) quote B(2 $\pi^0\pi^-\nu_{ au}$) + 1.6B(3 $\pi^0\pi^-\nu_{ au}$) + 1.1B($\pi^0\eta\pi^-\nu_{ au}$).



 $\begin{array}{ll} \Gamma \left(h^{-} 2 \pi^{0} \nu_{r} \right) / \Gamma_{total} & \Gamma_{17} / \Gamma \\ \Gamma_{17} / \Gamma = (\Gamma_{19} + \Gamma_{20} + 0.157 \Gamma_{32} + 0.157 \Gamma_{34}) / \Gamma \end{array}$

 VALUE (%)
 EVTS
 DOCUMENT ID
 TECN
 COMMENT

 9.39±0.14 QUR FIT
 Error includes scale factor of 1.2.
 VEX. (Company of 1.2)
 EVEX. (Company of 1.2)

 9.48±0.13±0.10
 12k
 64 BUSKULIC
 96
 ALEP
 LEP 1991–1993 data

 64 BUSKULIC 96 quote 9.29 \pm 0.13 \pm 0.10. We add 0.19 to undo their correction for $\tau^- \to h^- K^0 \nu_\tau$

$$\begin{array}{ll} \Gamma\left(h^{-}2\pi^{0}\nu_{\tau}\left(\mathbf{ex}.K^{0}\right)\right)/\Gamma_{total} \\ \Gamma_{18}/\Gamma=(\Gamma_{19}+\Gamma_{20})/\Gamma \end{array}$$

Data marked "avg" are highly correlated with data appearing elsewhere in the Listings, and are therefore used for the average given below but not in the overall fits. f&a marks results used for the fit and the average.

VALUE (%)		EVTS	DOCUMENT ID		TECN	COMMENT
			udes scale factor of			
8.95±0.33 OUR	AVER/	AGE Er	ror includes scale fac	tor o	of 1.1.	
$8.88 \pm 0.37 \pm 0.42$	f&a	1060				1992 LEP run
$8.96 \pm 0.16 \pm 0.44$	avg		⁶⁵ PROCARIO	93	CLEO	Ecm ≈ 10.6 GeV
$10.38 \pm 0.66 \pm 0.82$	f&ca	809	66 DECAMP	92 C	ALEP	1989-1990 LEP runs
$5.7 \pm 0.5 \stackrel{+1.7}{-1.0}$	f&a	133	67 ANTREASYAN	91	CBAL	<i>E</i> ee = 9.4–10.6 GeV
$10.0 \pm 1.5 \pm 1.1$	f&a	333	68 BEHREND	90	CELL	Eee = 35 GeV
$8.7 \pm 0.4 \pm 1.1$	f&≀a	815	69 BAND	87	MAC	<i>E</i> cm ≈ 29 GeV
$6.0 \pm 3.0 \pm 1.8$	f&∠a		BEHREND	84	CELL	Ecm= 14,22 GeV
• • • We do not u	use the	followin	g data for averages,	fits,	Ilmits, e	tc. • • •
$6.2 \pm 0.6 \pm 1.2$			⁷⁰ GAN	87	MRK2	<i>E</i> ee ≈ 29 GeV
65 0000 000 00		le obtol	ned from B/h- 2-0	\	D/h	O., Vusing ARTHEO

 65 PROCARIO 93 entry is obtained from B($h^-\,2\pi^0\,\nu_{\tau}$)/B($h^-\,\pi^0\,\nu_{\tau}$) using ARTUSO 94 result for B($h^-\,\pi^0\,\nu_{\tau}$).

66 We subtract 0.0015 to account for $\tau^- \to K^*(892)^- \nu_{\tau}$ contribution.

 67 ANTREASYAN 91 subtract 0.001 to account for the $au^- o extit{ } au^*(892)^- extit{$
u_{ au}$}$ contribution.

⁶⁸ BEHREND 90 subtract 0.002 to account for the $\tau^- \rightarrow K^*(892)^- \nu_{\tau}$ contribution.

⁶⁹ BAND 87 assume B($\pi^- 3\pi^0 \nu_{ au}$) = 0.01 and B($\pi^- \pi^0 \eta \nu_{ au}$) = 0.005.

 70 GAN 87 analysis use photon multiplicity distribution.

$$\Gamma(h^{-}2\pi^{0}\nu_{\tau}(ex.K^{0}))/\Gamma(h^{-}\pi^{0}\nu_{\tau})$$

$$\Gamma_{18}/\Gamma_{12} = (\Gamma_{19}+\Gamma_{20})/(\Gamma_{13}+\Gamma_{15})$$

$$\Gamma_{18}/\Gamma_{12}$$

 VALUE
 DOCUMENT ID
 TECN
 COMMENT

 0.357±0.006 OUR FIT
 Error includes scale factor of 1.2.

 0.342±0.006±0.016
 71 PROCARIO
 93 CLEO
 Eec cm ≈ 10.6 GeV

71 PROCARIO 93 quote $0.345\pm0.006\pm0.016$ after correction for 2 kaon backgrounds assuming B($K^{*-}\nu_{\tau}$)=1.42 \pm 0.18% and B($h^-K^0\pi^0\nu_{\tau}$)=0.48 \pm 0.48%. We multiply by 0.990 \pm 0.010 to remove these corrections to B($h^-\pi^0\nu_{\tau}$).

 $\Gamma(\pi^- 2\pi^0 \nu_\tau (\text{ex.} K^0))/\Gamma_{\text{total}}$ Data marked "avg" are highly correlated with data appearing elsewhere in the Listings, and are therefore used for the average given below but not in the overall fits. "4&a" marks results used for the fit and the average.

 VALUE (%)
 DOCUMENT ID
 TECN
 COMMENT

 9.15±0.15 OUR FIT
 Error includes scale factor of 1.2.

 9.21±0.13±0.11
 avg
 72 BUSKULIC
 96 ALEP
 LEP 1991–1993 data

72 Not independent of BUSKULIC 96 B($h^-2\pi^0\nu_{\tau}$ (ex. K^0)) and B($K^-2\pi^0\nu_{\tau}$ (ex. K^0))

VALUE (%)	EVTS	DOCUMENT ID		TECN	COMMENT	
0.080±0.027 OUR FI	ř —					
0.081±0.027 OUR AV	ERAGE					
0.08 ±0.02 ±0.02	59				LEP 1991-1993	
0.09 ±0.10 ±0.03	3	73 BATTLE	94	CLEO	Ecm ≈ 10.6 Ge	٠V
• • We do not use	the follow	ing data for average	s, fit	s, limits,	etc. • • •	
0.04 ±0.03 ±0.02	11	BUSKULIC	94E	ALEP	Repl. by BUSKI	JLIC 96
73 BATTLE 94 quote to account for $ au^-$		$0 \pm 0.03 \text{ or } < 0.3\%$ $K^0 \rightarrow \pi^0 \pi^0) \nu_{\tau} \text{ b}$			Ve subtract (0.05 :	± 0.02)%
$\Gamma(h^- \ge 3\pi^0 \nu_\tau)/\Gamma$ $\Gamma_{21}/\Gamma = (\Gamma_{23} +$	total Γ ₂₄ +Γ ₂₆ -	+0.157Г ₃₆ +0.157Г	38+0	.0246Г ₄	1+0.319Г ₁₁₀)/Г	Γ ₂₁ /Γ

Data marked "avg" are highly correlated with data appearing elsewhere in the Listings, and are therefore used for the average given below but not in the overall fits. "f&a" marks results used for the fit and the average.

 VALUE (%)
 EVTS
 DOCUMENT ID
 TECN
 COMMENT

 1.40 ± 0.11 OUR FIT
 Error includes scale factor of 1.1.
 1.8 ± 0.6 OUR AVERAGE
 Error includes scale factor of 1.1.
 1.53 ± 0.40 ± 0.46
 f&a 186 DECAMP 92 ALEP runs
 ALEP 1899-1990 LEP runs

 3.2 ± 1.0 ± 1.0
 f&a BEHREND 90 CELL Ecm 35 GEV
 Eee 25 CEM 25 CEM

 $\begin{array}{ll} \Gamma \left(h^{-} 3 \pi^{0} \nu_{r} \right) / \Gamma_{total} & \Gamma_{22} / \Gamma \\ \Gamma_{22} / \Gamma = (\Gamma_{23} + \Gamma_{24} + 0.157 \Gamma_{36} + 0.157 \Gamma_{38}) / \Gamma \end{array}$

Data marked "avg" are highly correlated with data appearing elsewhere in the Listings, and are therefore used for the average given below but not in the overall fits. "f&a" marks results used for the fit and the average.

VALUE (%) EVTS DOCUMENT ID

1.23±0.10 OUR FIT Error includes scale factor of 1.1. TECN COMMENT 1.22±0.10 OUR AVERAGE 1.24±0.09±0.11 f&a 2.3k 74 BUSKULIC 96 ALEP LEP 1991-1993 data 1.70±0.24±0.38 f&a 293 ACCIARRI 95 L3 1992 LEP run 75 PROCARIO 1.15 ± 0.08 ± 0.13 avg 93 CLEO $E_{\mathrm{CM}}^{\mathrm{ee}} \approx$ 10.6 GeV $0.0 \begin{array}{c} +1.4 \\ -0.1 \end{array} \begin{array}{c} +1.1 \\ -0.1 \end{array}$ 76 GAN 87 MRK2 Eee ≈ 29 GeV

 74 BUSKULIC 96 quote B($h^ 3\pi^0\,\nu_{\tau}$ (ex. $\,K^0))=$ 1.17 \pm 0.09 \pm 0.11. We add 0.07 to remove their correction for K^0 backgrounds.

 75 PROCARIO 93 entry is obtained from B($h^ 3\pi^0$ ν_{τ})/B($h^ \pi^0$ ν_{τ}) using ARTUSO 94 result for B($h^ \pi^0$ ν_{τ}).

⁷⁶ Highly correlated with GAN 87 $\Gamma(\eta \pi^- \pi^0 \nu_\tau)/\Gamma_{\rm total}$ value. Authors quot ${\rm B}(\pi^\pm 3\pi^0 \nu_\tau) + 0.67 {\rm B}(\pi^\pm \eta \pi^0 \nu_\tau) = 0.047 \pm 0.010 \pm 0.011.$

$$\begin{array}{l} \Gamma \left(h^{-} 3 \pi^{0} \nu_{\tau} \right) / \Gamma \left(h^{-} \pi^{0} \nu_{\tau} \right) \\ \Gamma_{22} / \Gamma_{12} = \left(\Gamma_{23} + \Gamma_{24} + 0.157 \Gamma_{36} + 0.157 \Gamma_{38} \right) / \left(\Gamma_{13} + \Gamma_{15} \right) \end{array}$$

 VALUE
 DOCUMENT ID
 TECN
 COMMENT

 0.048±0.004 OUR FIT
 Error includes scale factor of 1.1.

 0.044±0.003±0.005
 77 PROCARIO
 93 CLEO
 $E_{CR}^{em} \approx 10.6 \text{ GeV}$

77 PROCARIO 93 quote $0.041\pm0.003\pm0.005$ after correction for 2 kaon backgrounds assuming B($K^{*-}\nu_{\tau}$)=1.42 \pm 0.18% and B($h^{-}K^{0}\pi^{0}\nu_{\tau}$)=0.48 \pm 0.48%. We add 0.003 \pm 0.003 and multiply the sum by 0.990 \pm 0.010 to remove these corrections.

$$\Gamma(\pi^{-3}\pi^{0}\nu_{\tau}(ex.K^{0}))/\Gamma_{total}$$

VALUE (%)

DOCUMENT ID

DOCUMENT ID

VALUE (%) DOC 1.11±0.14 OUR FIT

 $\Gamma(K^-3\pi^0
u_{ au}(ex.K^0))/\Gamma_{ ext{total}}$ $\Gamma_{24}/\Gamma_{ ext{VALUE}(\%)}$ DOCUMENT ID TECN COMMENT

0.043^{+0.100}_{-0.029} OUR FIT

0.05 ±0.13 78 BUSKULIC 94E ALEP 1991-1992 LEP runs

 78 BUSKULIC 94E quote B($K^- \geq 0\pi^0 \geq 0K^0\nu_{\tau}) - [B(K^-\nu_{\tau}) + B(K^-\pi^0\nu_{\tau}) + B(K^-\pi^0\nu_{\tau}) + B(K^-\pi^0\kappa^0\nu_{\tau}) + B(K^-\pi^0K^0\nu_{\tau})] = 0.05 \pm 0.13\%$ accounting for common systematic errors in BUSKULIC 94E and BUSKULIC 94E measurements of these modes. We assume B($K^- \geq 2K^0\nu_{\tau})$ and B($K^- \geq 4\pi^0\nu_{\tau})$ are negligible.

$$\begin{array}{ll} \Gamma\left(h^{-}4\pi^{0}\nu_{\tau}\left(\text{ex.}K^{0}\right)\right)/\Gamma_{\text{total}} & \Gamma_{25}/\Gamma \\ \Gamma_{25}/\Gamma = (\Gamma_{26}+0.319\Gamma_{110})/\Gamma \end{array}$$

⁷⁹ BUSKULIC 96 quote result for $\tau^- \to h^- \ge 4\pi^0 \nu_\tau$. We assume B($h^- \ge 5\pi^0 \nu_\tau$) Is negligible.

⁸⁰ PROCARIO 93 quotes $B(h^-4\pi^0\nu_{\tau})/B(h^-\pi^0\nu_{\tau}) = 0.006 \pm 0.002 \pm 0.002$. We multiply by the ARTUSO 94 result for $B(h^-\pi^0\nu_{\tau})$ to obtain $B(h^-4\pi^0\nu_{\tau})$. PROCARIO 93 assume $B(h^- \ge 5\pi^0\nu_{\tau})$ is small and do not correct for it.

$$\Gamma(h^-4\pi^0\nu_{\tau}(\text{ex.}K^0,\eta))/\Gamma_{\text{total}}$$
 $\Gamma_{26}/\Gamma_{0.11\pm0.06 \text{ OUR FIT}}$ DOCUMENT ID 0.11 $\pm0.06 \text{ OUR FIT}$

 90 Not Independent of COAN 96 B($h^-K^0\nu_{ au}$) and B($K^-K^0\nu_{ au}$) measurements. 91 ACCIARRI 95F do not identify π^-/K^- and assume B($K^-K^0\nu_{ au}$) = (0.29 \pm 0.12)%.

```
\Gamma_{27}/\Gamma
                                                                                                                                                                                    \Gamma(\pi^-\overline{K}^0(\text{non-}K^*(892)^-)\nu_{\tau})/\Gamma_{\text{total}}
                                                                                                                                                                                                                                                                                                                                      \Gamma_{33}/\Gamma
                                                                                                                                                                                    VALUE (%)
                                                                                                                                                                                                                                                    DOCUMENT ID
                                                                                                                                                                                                                              CL%
                                                                                                                                                                                                                                                                                       TECN COMMENT
           Data marked "avg" are highly correlated with data appearing elsewhere in the Listings,
                                                                                                                                                                                                                                                                                95F L3
                                                                                                                                                                                      < 0.17
                                                                                                                                                                                                                                                     ACCIARRI
                                                                                                                                                                                                                                                                                                      1991-1993 LEP runs
           and are therefore used for the average given below but not in the overall fits. "f&a
                                                                                                                                                                                    \Gamma(K^-K^0\nu_{\tau})/\Gamma_{\text{total}}
           marks results used for the fit and the average.
                                                                                                                                                                                                                                                                                                                                      \Gamma_{34}/\Gamma
VALUE (%) ______ EVTS ______
                                                                       DOCUMENT ID
                                                                                                       TECN COMMENT
                                                                                                                                                                                     VALUE (%)
                                                                                                                                                                                                                                  EVTS
                                                                                                                                                                                                                                                       DOCUMENT ID
                                                                                                                                                                                                                                                                                          TECN COMMENT
                                                                                                                                                                                    0.159±0.024 OUR FIT
1.69±0.07 OUR AVERAGE
                                                                                                                                                                                    0.161±0.024 OUR AVERAGE
                                                                   81 BUSKULIC
1.70 \pm 0.05 \pm 0.06
                                                                                                   96 ALEP LEP 1991-1993 data
                                                                                                                                                                                                                                                  92 BARATE
                                        avg
                                                1610
                                                                                                                                                                                    0.158 \pm 0.042 \pm 0.017
                                                                                                                                                                                                                                                                                    98E ALEP 1991-1995 LEP runs
                                                                                                                                                                                                                                      46
1.54 \pm 0.24
                                        f&∠a
                                                                        ABREU
                                                                                                   94K DLPH LEP 1992 Z data
                                                                                                                                                                                                                                                  93 BUSKULIC
                                                                                                                                                                                                                                                                                   96 ALEP LEP 1991-1993 data
                                                                                                                                                                                    0.26 \pm 0.09 \pm 0.02
                                                                                                                                                                                                                                      13
                                                                   82 BATTLE
1.70 \pm 0.12 \pm 0.19
                                       f& a
                                                    202
                                                                                                   94 CLEO E_{\mathrm{Cm}}^{ee} \approx 10.6 \ \mathrm{GeV}
                                                                                                                                                                                    0.151 \pm 0.021 \pm 0.022
                                                                                                                                                                                                                                     111
                                                                                                                                                                                                                                                       COAN
                                                                                                                                                                                                                                                                                   96 CLEO E € ≈ 10.6 GeV
1.6 \pm 0.4 \pm 0.2
                                        f&a
                                                      35
                                                                        AIHARA
                                                                                                   87B TPC Ecm = 29 GeV
                                                                                                                                                                                     • • • We do not use the following data for averages, fits, limits, etc. • • •
                                                                                                   84 DLCO Eee = 29 GeV
1.71±0.29
                                       f&∠a
                                                      53
                                                                        MILLS
                                                                                                                                                                                                                                                                                 94F ALEP Repl. by
BUSKULIC 96
                                                                                                                                                                                                                                                       BUSKULIC
                                                                                                                                                                                    0.29 \pm 0.12 \pm 0.03
                                                                                                                                                                                                                                        8
• • • We do not use the following data for averages, fits, limits, etc. • • •
                                                                                                 94E ALEP Repl. by
BUSKULIC 96
                                                                 <sup>83</sup> BUSKULIC
                                                                                                                                                                                      <sup>92</sup>BARATE 98E reconstruct K^0's using K^0_s \rightarrow \pi^+\pi^- decays.
                                                    967
                                                                                                                                                                                      ^{93} BUSKULIC 96 measure K^0's by detecting K^0_I's in their hadron calorimeter.
  <sup>81</sup> Not independent of BUSKULIC 96 B(K^-\nu_{	au}), B(K^-\pi^0\nu_{	au}), B(K^-2\pi^0\nu_{	au}),
       B(K^-K^0\nu_{\tau}), and B(K^-K^0\pi^0\nu_{\tau}) values.
                                                                                                                                                                                     \Gamma \left(h^-\overline{K^0}\pi^0\nu_\tau\right)/\Gamma_{\text{total}}  Data marked "avg" are highly correlated with data appearing elsewhere in the Listings,
  ^{82} BATTLE 94 quote 1.60\pm0.12\pm0.19. We add 0.10\pm0.02 to correct for their rejection
      of K_S^0 \to \pi^+\pi^- decays.
                                                                                                                                                                                               and are therefore used for the average given below but not in the overall fits. "f&a"
  83 Not independent of BUSKULIC 94E B(K^-\nu_{	au}), B(K^-\pi^0\nu_{	au}), B(K^-2\pi^0\nu_{	au}),
                                                                                                                                                                                               marks results used for the fit and the average.
       B(K^-K^0\nu_{\tau}), and B(K^-K^0\pi^0\nu_{\tau}) values.
                                                                                                                                                                                                                                EVTS
                                                                                                                                                                                                                                                          DOCUMENT ID
                                                                                                                                                                                                                                                                                             TECN COMMENT
                                                                                                                                                                                     0.55 ±0.05 OUR FIT
 \Gamma \Big( \textit{K}^- \geq 1 \, \big( \pi^0 \, \text{or} \, \textit{K}^0 \big) \, \nu_\tau \Big) / \Gamma_{\text{total}} \\ \Gamma_{28} / \Gamma = (\Gamma_{15} + \Gamma_{20} + \Gamma_{24} + \Gamma_{34} + \Gamma_{38}) / \Gamma_{\text{total}} \\
                                                                                                                                                                                    0.50 ±0.06 OUR AVERAGE Error includes scale factor of 1.2. 
0.446±0.052±0.046 avg 157 94 BARATE 98E ALE
                                                                                                                                                   \Gamma_{28}/\Gamma
                                                                                                                                                                                    0.446 ± 0.052 ± 0.046 avg 157
                                                                                                                                                                                                                                                                                       98E ALEP 1991-1995 LEP runs
                                                                                                                                                                                    0.562±0.050±0.048 f&a 264
                                                                                                                                                                                                                                                           COAN
                                                                                                                                                                                                                                                                                       96 CLEO E cm ≈ 10.6 GeV
            Data marked "avg" are highly correlated with data appearing elsewhere in the Listings,
                                                                                                                                                                                      <sup>94</sup> Not independent of BARATE 98E B(	au^- 	o \pi^- \overline{K}{}^0 \pi^0 	au) and B(	au^- 	o K^- K^0 \pi^0 
u_	au)
            and are therefore used for the average given below but not in the overall fits. "f&a"
           marks results used for the fit and the average.
                                             <u>EVTS</u>
                                                                       DOCUMENT ID
                                                                                                        TECN COMMENT
                                                                                                                                                                                    \Gamma(\pi^-\overline{K}^0\pi^0\nu_{\tau})/\Gamma_{	ext{total}} Data marked "avg" are highly correlated with data appearing elsewhere in the Listings. "[&a"]
 0.95±0.10 OUR FIT
0.76±0.23 OUR AVERAGE
                                                                   84 ABREU
0.69 \pm 0.25
                                                                                                    94K DLPH LEP 1992 Z data
                                       avg
                                                                                                                                                                                               marks results used for the fit and the average.
1.2 \pm 0.5 ^{+0.2}_{-0.4}
                                       f&a
                                                        9
                                                                        AIHARA
                                                                                                   878 TPC Ecm = 29 GeV
                                                                                                                                                                                                                                    EVTS
                                                                                                                                                                                                                                                            DOCUMENT ID
                                                                                                                                                                                                                                                                                                TECN COMMENT
                                                                                                                                                                                    0.39 ±0.05 OUR FIT
  ^{84} Not independent of ABREU 94K B(K^-
u_{	au}) and B(K^-\geq 0 neutrals 
u_{	au}) measurements.
                                                                                                                                                                                    0.36 ±0.05 OUR AVERAGE
 \begin{array}{l} \Gamma \big( \textit{K}^0 \big( \text{particles} \big)^- \nu_\tau \big) / \Gamma_{\text{total}} \\ \Gamma_{29} / \Gamma = (\Gamma_{32} + \Gamma_{34} + \Gamma_{36} + \Gamma_{38} + \Gamma_{41}) / \Gamma_{\text{total}} \end{array} 
                                                                                                                                                   \Gamma_{29}/\Gamma
                                                                                                                                                                                    0.294 ± 0.073 ± 0.037 f&a
                                                                                                                                                                                                                                         142
                                                                                                                                                                                                                                                       95 BARATE
                                                                                                                                                                                                                                                                                        98E ALEP 1991-1995 LEP
                                                                                                                                                                                                                                                        <sup>96</sup> BUSKULIC
                                                                                                                                                                                                                                                                                                ALEP LEP 1991-1993
                                                                                                                                                                                    0.32 \pm 0.11 \pm 0.05
                                                                                                                                                                                                                            f&∠a
                                                                                                                                                                                                                                                                                                             data
Eee ≈ 10.6 GeV
                                             EVTS
                                                                 DOCUMENT ID
                                                                                                    TECN COMMENT
                                                                                                                                                                                                                                                        97 COAN
                                                                                                                                                                                    0.417 ± 0.058 ± 0.044 avg
                                                                                                                                                                                                                                                                                        96
                                                                                                                                                                                                                                                                                                CLEO
 1.66±0.09 OUR FIT Error includes scale factor of 1.4.
                                                                                                                                                                                                                                                        <sup>98</sup> ACCIARRI
                                                                                                                                                                                                                                                                                                              1991-1993 LEP
1.94 ± 0.13 OUR AVERAGE
                                                                                                                                                                                    0.41 ±0.12 ±0.03 f&a
                                                                                                                                                                                                                                                                                        95F L3
                                                            85 BARATE
1.94 \pm 0.12 \pm 0.12
                                              929
                                                                                              98E ALEP 1991-1995 LEP runs
                                                                                                                                                                                     86 AKERS
1.94 \pm 0.18 \pm 0.12
                                               141
                                                                                             94G OPAL Ecm = 88-94 GeV
                                                                                                                                                                                                                                                                                       94F ALEP Repl. by
BUSKULIC 96
                                                                                                                                                                                                                                                            BUSKULIC
                                                                                                                                                                                    0.33 \pm 0.14 \pm 0.07
  <sup>85</sup> BARATE 98E measure \Gamma(K_S^0(\text{particles})^-\nu_{	au})/\Gamma_{\text{total}} = (0.970 \pm 0.058 \pm 0.062)\%. We
       multiply this by 2 to obtain the listed value.
                                                                                                                                                                                      <sup>95</sup>BARATE 98E reconstruct K^0's using K^0_S \to \pi^+\pi^- decays.
  <sup>86</sup> AKERS 94G measure \Gamma(K_5^0 (\text{particles})^- \nu_\tau)/\Gamma_{\text{total}} = 0.97 \pm 0.09 \pm 0.06.
                                                                                                                                                                                       ^{96} BUSKULIC 96 measure K^0's by detecting K_L^0's in their hadron calorimeter.
                                                                                                                                                                                      ^{97} Not independent of COAN 96 B( h^- K^0 \pi^0 \nu_\tau ) and B( K^- K^0 \pi^0 \nu_\tau ) measurements.
\begin{array}{l} \Gamma \Big( h^- \overline{K^0} \geq 0 \text{ neutrals } \geq 0 K_L^0 \nu_\tau \Big) / \Gamma_{\text{total}} \\ \Gamma_{30} / \Gamma = (\Gamma_{32} + \Gamma_{34} + \Gamma_{36} + \Gamma_{38} + 0.657 \Gamma_{41}) / \Gamma_{36} + \Gamma_{36} + \Gamma_{36} + \Gamma_{36} + \Gamma_{36} + 0.657 \Gamma_{41} \Big) / \Gamma_{10} + \Gamma_{10}
                                                                                                                                                   \Gamma_{30}/\Gamma
                                                                                                                                                                                       <sup>98</sup> ACCIARRI 95F do not identify \pi^-/K^- and assume B(K^-K^0\pi^0\nu_{\tau}) = (0.05 ± 0.05)%.
EVTS DOCUMENT ID TECN COMMENT

1.62±0.09 OUR FIT Error includes scale factor of 1.4.
                                                                                                                                                                                    \Gamma(\overline{K^0}\rho^-\nu_{\tau})/\Gamma_{\text{total}}
                                                                                                                                                                                                                                                                                                                                      \Gamma_{37}/\Gamma
                                                                                                                                                                                     VALUE (%)
                                                                                                                                                                                                                                                    DOCUMENT ID
                                                                                                                                                                                                                                                                                     TECN COMMENT
1.3 ±0.3
                                                44
                                                                TSCHIRHART 88 HRS
                                                                                                                Ecm = 29 GeV
                                                                                                                                                                                                                                              99 BARATE
                                                                                                                                                                                    0.188 \pm 0.054 \pm 0.038
                                                                                                                                                                                                                                                                                98E ALEP 1991-1995 LEP runs
\Gamma(h^-\overline{K}^0\nu_{	au})/\Gamma_{	ext{total}} Data marked "avg" are highly correlated with data appearing the state of the state 
                                                                                                                                                                                       ^{99} BARATE 98E determine the \overline{K}{}^0
ho^- fraction in 	au^-	o\pi^-\overline{K}{}^0\pi^0
u_{	au} decays to be (0.64 \pm
                                                                                                                  \Gamma_{31}/\Gamma = (\Gamma_{32} + \Gamma_{34})/\Gamma
                                                                                                                                                                                           0.09 \pm 0.10) and multiply their B(\pi^-\overline{K}^0\pi^0
u_{	au}) measurement by this fraction to obtain
           and are therefore used for the average given below but not in the overall fits. "f&a"
                                                                                                                                                                                           the quoted result.
           marks results used for the fit and the average.
                                                                                                                                                                                    \Gamma(K^-K^0\pi^0\nu_{	au})/\Gamma_{	ext{total}}
                                                  EVTS
                                                                       DOCUMENT ID
                                                                                                                                                                                                                                                                                                                                      Γ<sub>38</sub>/Γ
                                                                                                        TECN COMMENT
 0.99 ±0.08 OUR FIT Error includes scale factor of 1.5.
                                                                                                                                                                                    VALUE (%)
                                                                                                                                                                                                                                                    DOCUMENT ID TECN COMMENT
0.90 ±0.07 OUR AVERAGE
                                                                                                                                                                                    0.151±0.029 OUR FIT
1.01 ±0.11 ±0.07 avg 555
                                                                  87 BARATE
                                                                                                    98E ALEP 1991-1995 LEP runs
                                                                                                                                                                                    0.133±0.031 OUR AVERAGE
0.855±0.036±0.073 f&a 1242
                                                                        COAN
                                                                                                   96 CLEO E_{
m cm}^{\it ee} pprox 10.6 GeV
                                                                                                                                                                                    0.152 \pm 0.076 \pm 0.021
                                                                                                                                                                                                                                   15
                                                                                                                                                                                                                                             100 BARATE
                                                                                                                                                                                                                                                                                 98E ALEP 1991-1995 LEP runs
  <sup>87</sup> Not Independent of BARATE 98E B(	au^- 	o \pi^- \overline{K}{}^0 
u_	au) and B(	au^- 	o K^- K^0 
u_	au) values.
                                                                                                                                                                                                                                             101 BUSKULIC
                                                                                                                                                                                                                                                                                 96 ALEP LEP 1991-1993 data
                                                                                                                                                                                    0.10 \pm 0.05 \pm 0.03
                                                                                                                                                                                                                                                                                 96 CLEO E_{\rm cm}^{\rm ee} \approx 10.6~{\rm GeV}
                                                                                                                                                                                    0.145 \pm 0.036 \pm 0.020
                                                                                                                                                                                                                                    32
                                                                                                                                                                                                                                                    COAN
\Gamma(\pi^-\overline{K}^0
u_{	au})/\Gamma_{	ext{total}}
                                                                                                                                                                                     "avg" are highly correlated with data appearing elsewhere in the Listings,
                                                                                                                                                                                    0.05 \pm 0.05 \pm 0.01
                                                                                                                                                                                                                                    1
                                                                                                                                                                                                                                                    BUSKULIC 94F ALEP Repl. by BUSKULIC 96
           and are therefore used for the average given below but not in the overall fits. "f&a"
                                                                                                                                                                                     <sup>100</sup>BARATE 98E reconstruct K^0's using K^0_S \rightarrow \pi^+\pi^- decays.
           marks results used for the fit and the average.
                                                   EVTS
                                                                         DOCUMENT ID
                                                                                                            TECN COMMENT
                                                                                                                                                                                     ^{101}BUSKULIC 96 measure K^0's by detecting K^0_I's in their hadron calorimeter.
 0.83 ±0.06 OUR FIT Error includes scale factor of 1.4.
0.78 ±0.06 OUR AVERAGE
                                                                                                                                                                                    \Gamma(\pi^-\overline{K}{}^0\pi^0\pi^0\nu_{\tau})/\Gamma_{\text{total}}
                                                                                                                                                                                                                                                                                                                                      T39/F
                                                                    88 BARATE
0.855 ± 0.117 ± 0.066 avg
                                                     509
                                                                                                     98E ALEP 1991-1995 LEP
                                                                                                     runs
96 ALEP LEP 1991-1993
                                                                                                                                                                                                                             EVTS
                                                                                                                                                                                                                                                     DOCUMENT ID
                                                                                                                                                                                                                                                                                      TECN COMMENT
                                                                    <sup>89</sup> BUSKULIC
0.79 \pm 0.10 \pm 0.09
                                        f&∠a
                                                                                                                                                                                                                                           102 BARATE
                                                                                                                                                                                     0.58 ± 0.33 ± 0.14
                                                                                                                                                                                                                                                                                 98E ALEP 1991-1995 LEP runs
                                                                                                     data
96 CLEO Ecm ≈ 10.6 GeV
                                                                     90 COAN
0.704 ± 0.041 ± 0.072 avg
                                                                                                                                                                                    ^{102} BARATE 98E reconstruct K^0's using K^0_S \rightarrow \pi^+\pi^- decays.
                                                                     91 ACCIARRI
0.95 ±0.15 ±0.06 f&a
                                                                                                     95F L3
                                                                                                                           1991-1993 LEP
                                                                                                                                                                                    \Gamma(K^-K^0\pi^0\pi^0\nu_{\tau})/\Gamma_{\text{total}}
                                                                                                                                                                                                                                                                                                                                       \Gamma_{40}/\Gamma
 • • • We do not use the following data for averages, fits, limits, etc. • •
                                                                                                                                                                                    VALUE
                                                                                                                                                                                                                                                     DOCUMENT ID
                                                                                                                                                                                                                                                                                       TECN COMMENT
                                                                                                                                                                                                                                CL%
                                                        53
                                                                         BUSKULIC
                                                                                                  94F ALEP Repl. by
                                                                                                                                                                                     < 0.39 \times 10^{-3}
                                                                                                                                BUSKULIC 96
                                                                                                                                                                                                                                                     BARATE
                                                                                                                                                                                                                                                                                 98E ALEP 1991-1995 LEP runs
                                                                                                                                                                                                                                 95
  <sup>88</sup>BARATE 98E reconstruct K^0's using K^0_S \to \pi^+\pi^- decays. Not independent of
        BARATE 98E B(K^0 particles \nu_{\tau}) value.
  <sup>89</sup> BUSKULIC 96 measure K^0's by detecting K_I^0's in their hadron calorimeter.
```

 τ

 $\Gamma(\pi^-K^0\overline{K}^0\nu_{\tau})/\Gamma_{\rm total}$ $\Gamma_{\rm 41}/\Gamma$ Data marked "avg" are highly correlated with data appearing elsewhere in the Listings, and are therefore used for the average given below but not in the overall fits. "f&a" marks results used for the fit and the average.

 VALUE (%)
 EVTS
 DOCUMENT ID
 TECN
 COMMENT

 0.12±0.021 OUR FIT
 Error Includes scale factor of 1.2.
 COMMENT

 0.16±0.028 OUR AVERAGE
 Error Includes scale factor of 1.5. See the Ideogram below.

 0.153±0.030±0.016
 f&a
 74
 103 BARATE
 98E ALEP
 1991–1995 LEP runs

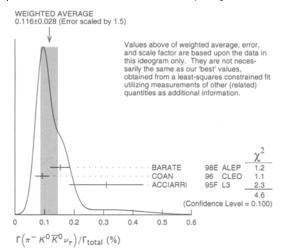
 0.092±0.020±0.012
 avg
 42
 104 COAN
 96
 CLEO
 Ecm
 ≈ 10.6 GeV

 0.31 ±0.12 ±0.04
 f&a
 ACCIARRI
 95F L3
 1991–1993 LEP runs

 103 BARATE 98E obtain this value by adding twice their $R(\pi^- K^0 K^0 L^0)$ value to their

¹⁰³BARATE 98E obtain this value by adding twice their $B(\pi^- K_S^0 K_S^0 \nu_{\tau})$ value to their $B(\pi^- K_S^0 K_L^0 \nu_{\tau})$ value.

104 We multiply the COAN 96 measurement B($h^ K_S^0$ K_S^0 $\nu_{ au}$) = (0.023 \pm 0.005 \pm 0.003)% by 4 to obtain the listed value. This factor of 1/4 is uncertain, and might be as large as 1/2, due to Bose-Einstein correlations and the resonant parentage of this state.



 $\Gamma(\pi^- K_S^0 K_S^0 \nu_T)/\Gamma_{total}$ Bose-Einstein correlations might make the mixing fraction different than 1/4.

VALUE (%)

EVTS

DOCUMENT ID

TECN

COMMENT

0.030 ± 0.005 OUR FIT

Error includes scale factor of 1.2.

0.030±0.005 OUR FIT Error Includes scale factor of 1.2.
0.024±0.005 OUR AVERAGE
0.026±0.010±0.005 6 BARATE 98F ALEP

0.026±0.010±0.005 6 0.023±0.005±0.003 42

42 COAN

98E ALEP 1991–1995 LEP runs 96 CLEO $E_{cm}^{ee} \approx 10.6 \text{ GeV}$

 $\Gamma(\pi^- K_5^0 K_0^0 \nu_\tau) / \Gamma_{total}$ Data marked "avg" are highly correlated with data appearing elsewhere in the Listings, and are therefore used for the average given below but not in the overall fits. "f&a" marks results used for the fit and the average.

 VALUE (%)
 EVTS
 DOCUMENT ID
 TECN
 COMMENT

 0.060±0.010 OUR FIT
 Error includes scale factor of 1.2.
 0.101±0.023±0.013
 avg
 68
 BARATE
 98E
 ALEP
 1991-1995 LEP

 FURS
 FURS
 1991-1995 LEP
 1991-1995 LEP
 1991-1995 LEP
 1991-1995 LEP

 $\Gamma(K^-K^0 \ge 0 \text{ neutrals } \nu_{\tau})/\Gamma_{\text{total}}$ $\Gamma_{46}/\Gamma = (\Gamma_{34}+\Gamma_{38})/\Gamma_{46}/\Gamma = (\Gamma_{34}+\Gamma_{38$

 $\Gamma(K^0h^+h^-h^-\nu_\tau)/\Gamma_{total}$ VALUE (%)

EVTS

DOCUMENT 10

BARATE

98ε

ALEP

105 BARATE

98ε

ALEP

1991–1995 LEP runs

105 BARATE

98ε

40 comment

105 BARATE

98ε

40 comment

4

 $\begin{array}{l} \Gamma \big(h^- \, h^- \, h^+ \geq 0 \text{ neut. } \nu_\tau \big(\text{"3-prong"} \big) \big) / \Gamma_{\text{total}} \\ \Gamma_{49} / \Gamma = (0.3431\Gamma_{32} + 0.3431\Gamma_{34} + 0.3431\Gamma_{36} + 0.3431\Gamma_{38} + 0.4508\Gamma_{41} + \Gamma_{57} + \Gamma_{65} + \Gamma_{73} + \Gamma_{79} + \Gamma_{81} + \Gamma_{84} + \Gamma_{85} + 0.285\Gamma_{110} + 0.9101\Gamma_{125} + 0.9101\Gamma_{126} \big) / \Gamma_{126} \\ \end{array}$

Data marked "avg" are highly correlated with data appearing elsewhere in the Listings, and are therefore used for the average given below but not in the overall fits. "f&a" marks results used for the fit and the average.

VALUE (%)	EVTS	DOCUMENT ID	TECN	COMMENT
15.18± 0.13 OUR FIT	Error Includ	es scale factor of 1.2	?.	
14.8 ± 0.4 OUR AV	ERAGE			
$14.4 \pm 0.6 \pm 0.3$	f&a	ADEVA	91F L3	Ecm = 88.3-94.3 GeV
$15.0 \pm 0.4 \pm 0.3$	f&∠a	BEHREND	89B CELL	
$15.1 \pm 0.8 \pm 0.6$	f&∠a	AIHARA	87B TPC	Ecm= 29 GeV
• • • We do not use t	he following da	ata for averages, fits.	limits, etc.	• • •
$13.5 \pm 0.3 \pm 0.3$		ABACHI	898 HRS	Ecm= 29 GeV
$12.8 \pm 1.0 \pm 0.7$		106 BURCHAT	87 MRK2	Eee = 29 GeV
$12.1 \pm 0.5 \pm 1.2$		RUCKSTUHL	86 DLCO	Ecm = 29 GeV
$12.8 \pm 0.5 \pm 0.8$	1420	SCHMIDKE	86 MRK2	Ecm= 29 GeV
$15.3 \pm 1.1 {+1.3 \atop -1.6}$	367	ALTHOFF	85 TASS	<i>E</i> ^{<i>ee</i>} _{CM} = 34.5 GeV
$13.6 \pm 0.5 \pm 0.8$		BARTEL	85F JADE	<i>Ec</i> m = 34.6 GeV
$12.2 \pm 1.3 \pm 3.9$		107 BERGER	85 PLUT	<i>Ec</i> m = 34.6 GeV
$13.3 \pm 0.3 \pm 0.6$		FERNANDEZ	85 MAC	Ecm= 29 GeV
24 ± 6	35	BRANDELIK	80 TASS	Ecm= 30 GeV
32 ± 5	692	108 BACINO	78B DLCO	Ecm = 3.1-7.4 GeV
35 ±11		¹⁰⁸ BRANDELIK	78 DASP	Assumes V – A de- cay
18 ± 6.5	33	108 JAROS	78 MRK1	Ecm > 6 GeV

106 BURCHAT 87 value is not independent of SCHMIDKE 86 value.

107 Not independent of BERGER 85 $\Gamma(\mu^-\overline{\nu}_\mu\nu_ au)/\Gamma_{ ext{total}}$, $\Gamma(e^-\overline{\nu}_e\nu_ au)/\Gamma_{ ext{total}}$, $\Gamma(h^-\geq 1$ neutrals $\nu_ au)/\Gamma_{ ext{total}}$, and $\Gamma(h^-\geq 0K_L^0\ \nu_ au)/\Gamma_{ ext{total}}$, and therefore not used in the fit.

108 Low energy experiments are not in average or fit because the systematic errors in background subtraction are judged to be large.

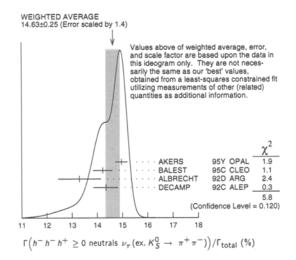
$$\begin{array}{l} \Gamma \big(h^- \, h^- \, h^+ \geq 0 \text{ neutrals } \nu_\tau \, (\text{ex. } K_5^0 \to \pi^+ \pi^-) \big) / \Gamma_{\text{total}} & \Gamma_{50} / \Gamma \\ \Gamma_{50} / \Gamma = (\Gamma_{57} + \Gamma_{65} + \Gamma_{73} + \Gamma_{74} + \Gamma_{79} + \Gamma_{81} + \Gamma_{84} + \Gamma_{85} + 0.285 \Gamma_{110} + 0.9101 \Gamma_{125} + 0.9101 \Gamma_{126} \big) / \Gamma \\ 0.9101 \Gamma_{126} \big) / \Gamma \end{array}$$

Data marked "avg" are highly correlated with data appearing elsewhere in the Listings, and are therefore used for the average given below but not in the overall fits. "fa" marks results used for the fit and the average.

EVTS DOCUMENT ID TECN COMMENT 14.60±0.13 OUR FIT Error includes scale factor of 1.2. 14.63 ± 0.25 OUR AVERAGE Error includes scale factor of 1.4. See the ideogram below. f&a 10.4k AKERS 95Y OPAL 1991-1994 LEP runs 14.96 ± 0.09 ± 0.22 109 BALEST 95C CLEO Ecm ≈ 10.6 GeV 14.22 ± 0.10 ± 0.37 avg 110 ALBRECHT 13.3 ±0.3 ±0.8 f&∠a 14.35 + 0.40 ± 0.24 f&a DECAMP 92C ALEP 1989-1990 LEP runs ACTON 92H OPAL Repl. by AKERS 95Y

109 Not independent of BALEST 95c B($h^-h^-h^+\nu_{ au}$) and B($h^-h^-h^+\pi^0\nu_{ au}$) values, and BORTOLETTO 93 B($h^-h^-h^+2\pi^0\nu_{ au}$)/B($h^-h^-h^+\geq 0$ neutrals $\nu_{ au}$) value.

110 This ALBRECHT 92D value is not independent of their $\Gamma(\mu^-\overline{\nu}_\mu\nu_\tau)\Gamma(e^-\overline{\nu}_e\nu_\tau)/\Gamma_{\rm total}^2$ value.



 Γ_{53}/Γ

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\Gamma(\pi^-\pi^+\pi^- \ge 0 \text{ neutrals } \nu_\tau)/\Gamma(h^-h^-h^+ \ge 0 \text{neut. } \nu_\tau ("3-prong"))
```

 Γ_{51}/Γ_{49} $\begin{matrix} \Gamma_{51}/\Gamma_{49} = (0.3431\Gamma_{32} + 0.3431\Gamma_{36} + 0.1078\Gamma_{41} + \Gamma_{57} + \Gamma_{65} + \Gamma_{73} + \Gamma_{74} + 0.285\Gamma_{110} + 0.9101\Gamma_{125} + 0.9101\Gamma_{126})/(0.3431\Gamma_{32} + 0.3431\Gamma_{34} + 0.3431\Gamma_{36} + 0.3431\Gamma_{38} + 0.4508\Gamma_{41} + \Gamma_{57} + \Gamma_{65} + \Gamma_{73} + \Gamma_{74} + \Gamma_{79} + \Gamma_{81} + \Gamma_{84} + \Gamma_{85} + 0.285\Gamma_{110} + 0.9101\Gamma_{125} + 0.3231\Gamma_{36} + 0.3431\Gamma_{36} + 0.3431\Gamma_$

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
0.962±0.005 OUR FIT	Error i	ncludes scale factor of 1	.1.	
0.945±0.019	490	¹¹¹ BAUER 94	TPC	Ecm= 29 GeV

 111 BAUER 94 quote B($\pi^-\pi^+\pi^- \ge 0$ neutrals $\nu_\tau)=0.1329\pm 0.0027.$ We divide by 0.1406, their assumed value for B("3prong").

$$\begin{array}{l} \Gamma\left(h^-h^-h^+\nu_{\tau}\right)/\Gamma_{\text{total}} \\ \Gamma_{52}/\Gamma = (0.3431\Gamma_{32} + 0.3431\Gamma_{34} + \Gamma_{57} + \Gamma_{79} + \Gamma_{84} + 0.0221\Gamma_{125})/\Gamma \end{array}$$

Data marked "avg" are highly correlated with data appearing elsewhere in the Listings, and are therefore used for the average given below but not in the overall fits. "f&a" marks results used for the fit and the average.

DOCUMENT ID VALUE (%) EVTS TECN COMMENT 9.96±0.10 OUR FIT Error includes scale factor of 1.1. 9.7 ±0.4 OUR AVERAGE Error includes scale factor of 3.1. See the ideogram below. 7.6 $\pm 0.1 \pm 0.5$ avg 7.5k 112 ALBRECHT 96E ARG $E_{\rm cm}^{\rm ee} = 9.4 - 10.6 \; {\rm GeV}$ $9.92\pm0.10\pm0.09$ f&a 11.2k 113 BUSKULIC 96 ALEP LEP 1991-1993 data 9.49±0.36±0.63 f&a DECAMP 92C ALEP 1989-1990 LEP runs 114 BEHREND 90 CELL Eee = 35 GeV 8.7 ±0.7 ±0.3 f&a 694 \bullet \bullet \bullet We do not use the following data for averages, fits, limits, etc. \bullet \bullet 115 BAND 87 MAC Ecm = 29 GeV $7.0 \pm 0.3 \pm 0.7$ 116 BURCHAT 6.7 ±0.8 ±0.9 87 MRK2 Ecm = 29 GeV 117 RUCKSTUHL 86 DLCO Ecm = 29 GeV 6.4 ±0.4 ±0.9 SCHMIDKE 86 MRK2 Eee 29 GeV $7.8 \pm 0.5 \pm 0.8$ 890 117 FERNANDEZ 85 MAC Eee = 29 GeV 8.4 ±0.4 ±0.7 1255 BEHREND 84 CELL Eee = 14,22 GeV 9.7 ±2.0 ±1.3

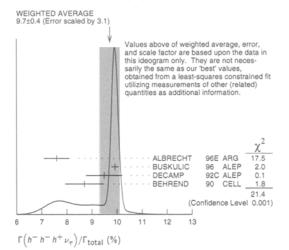
 $^{112} {\rm ALBRECHT}$ 96E not independent of ALBRECHT 93C $\Gamma(h^-\,h^-\,h^+\,\nu_{\tau}\,({\rm ex.}~~K^0)\,\times~$ $\Gamma(\text{particle}^- \ge 0 \text{ neutrals } \ge 0 \kappa_L^0 \nu_\tau) / \Gamma_{\text{total}}^2 \text{ value.}$

¹¹³BUSKULIC 96 quote B($h^-h^-h^+\nu_{\tau}$ (ex. K^0)) = 9.50 \pm 0.10 \pm 0.11. We add 0.42 to remove their K^0 correction and reduce the systematic error accordingly.

 $^{114} \rm BEHREND$ 90 subtract 0.3% to account for the $\tau^- \rightarrow ~K^*(892)^- \nu_\tau$ contribution to measured events.
115 BAND 87 subtract for charged kaon modes; not independent of FERNANDEZ 85 value.

116 BURCHAT 87 value is not independent of SCHMIDKE 86 value.

 117 Value obtained by multiplying paper's R= B($h^-\,h^-\,h^+\,
u_{ au}$)/B(3-prong) by B(3-prong) = 0.143 and subtracting 0.3% for $K^*(892)$ background.



 Γ_{52}/Γ_{49} $\Gamma_{84} + \Gamma_{85} + 0.285\Gamma_{110} + 0.9101\Gamma_{125} + 0.9101\Gamma_{126}$

This branching fractions is not independent of values for $\Gamma(h^-\,h^-\,h^+\,
u_{ au})/\Gamma_{ ext{total}}$ and $\Gamma(h^-h^-h^+ \ge 0$ neut. $\nu_{\tau}("3-prong"))/\Gamma_{total}$.

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<u>VALUE</u> <u>DOCUMENT ID</u> <u>TECN</u>
0.656±0.006 OUR FIT Error Includes scale factor of 1.1.
                                                                           TECN COMMENT
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• • • We do not use the following data for averages, fits, limits, etc. • •

RUCKSTUHL 86 DLCO Ecm = 29 GeV FERNANDEZ 85 MAC Ecm = 29 GeV 0.61 ±0.03 ±0.05

```
\Gamma(h^-h^-h^+\nu_{\tau}(ex.K^0))/\Gamma_{total}
           \Gamma_{53}/\Gamma = (\Gamma_{57} + \Gamma_{79} + \Gamma_{84} + 0.0221\Gamma_{125})/\Gamma
```

Data marked "avg" are highly correlated with data appearing elsewhere in the Listings, and are therefore used for the average given below but not in the overall fits. "f&a" marks results used for the fit and the average.

EVTS DOCUMENT ID VALUE (%) TECN COMMENT 9.62±0.10 OUR FIT Error includes scale factor of 1.1. 9.57±0.11 OUR AVERAGE avg 11.2k 118 BUSKULIC 96 ALEP LEP 1991-1993 data 9.50 + 0.10 + 0.11 119 AKERS 95Y OPAL 1991-1994 LEP runs $9.87 \pm 0.10 \pm 0.24$ avg 95c CLEO $E_{\mathrm{cm}}^{\mathrm{ee}} \approx 10.6 \,\mathrm{GeV}$ $9.51 \pm 0.07 \pm 0.20$ f&a 37.7k BALEST 118 Not independent of BUSKULIC 96 B($\it h^- \it h^- \it h^+ \it
u_{r}$) value.

¹¹⁹ Not independent of AKERS 95Y B($h^-h^-h^+ \ge 0$ neutrals ν_{τ} (ex. $K_S^0 \to \pi^+\pi^-$)) and $B(h^-h^-h^+\nu_{\tau}(ex. K^0))/B(h^-h^-h^+ \ge 0 \text{ neutrals } \nu_{\tau}(ex. K_S^0 \to \pi^+\pi^-)) \text{ values.}$

 $\Gamma\big(h^-\,h^-\,h^+\,\nu_\tau\,(\text{ex}.K^0)\big)/\Gamma\big(h^-\,h^-\,h^+\,\geq\,0\text{ neutrals }\nu_\tau\,(\text{ex}.\,K^0_S\to\,\pi^+\pi^-)\big)$ $\Gamma_{53}/\Gamma_{50} = (\Gamma_{57} + \Gamma_{79} + \Gamma_{84} + 0.0221\Gamma_{125})/(\Gamma_{57} + \Gamma_{65} + \Gamma_{73} + \Gamma_{74} + \Gamma_{79} + \Gamma_{81} + \Gamma_{84} + \Gamma_{85} + 0.285\Gamma_{110} + 0.9101\Gamma_{125} + 0.9101\Gamma_{126})$

DOCUMENT ID TECN COMMENT 0.659±0.006 OUR FIT Error includes scale factor of 1.1. $0.660 \pm 0.004 \pm 0.014$ **AKERS** 95Y OPAL 1991-1994 LEP runs

 $\Gamma(h^-h^-h^+\nu_{\tau}(ex.K^0,\omega))/\Gamma_{total}$ $\Gamma_{54}/\Gamma = (\Gamma_{57} + \Gamma_{79} + \Gamma_{84})/\Gamma$ DOCUMENT ID 9.57±0.10 OUR FIT Error includes scale factor of 1.1.

 $\Gamma(\pi^-\pi^+\pi^-\nu_{ au})/\Gamma_{ ext{total}}$ $\Gamma_{55}/\Gamma = (0.3431\Gamma_{32} + \Gamma_{57} + 0.0221\Gamma_{125})/\Gamma$ DOCUMENT ID

9.56±0.11 OUR FIT Error includes scale factor of 1.1.

 $\Gamma(\pi^-\pi^+\pi^-\nu_{\tau}(ex.K^0))/\Gamma_{total}$ $\Gamma_{56}/\Gamma = (0.3431\Gamma_{32} + \Gamma_{57})/\Gamma$ VALUE (%) DOCUMENT ID

9.52±0.11 OUR FIT Error includes scale factor of 1.1.

 $\Gamma(\pi^-\pi^+\pi^-\nu_{\tau}(ec.K^0,\omega))/\Gamma_{total}$ Γ₅₇/Γ DOCUMENT ID

9.23±0.11 OUR FIT Error includes scale factor of 1.1.

$$\begin{split} \Gamma \left(h^- \, h^- \, h^+ \geq 1 \, \text{neutrals} \, \nu_\tau \right) / \Gamma_{\text{total}} \\ \Gamma_{58} / \Gamma &= \left(0.3431 \Gamma_{36} + 0.3431 \Gamma_{38} + 0.1077 \Gamma_{41} + \Gamma_{65} + \Gamma_{73} + \Gamma_{74} + \Gamma_{81} + \Gamma_{85} + 0.285 \Gamma_{110} + 0.888 \Gamma_{125} + 0.9101 \Gamma_{126} \right) / \Gamma \end{split}$$
 Γ_{58}/Γ

Data marked "avg" are highly correlated with data appearing elsewhere in the Listings, and are therefore used for the average given below but not in the overall fits. "f&a" marks results used for the fit and the average.

EVTS DOCUMENT ID TECN COMMENT 5.18±0.11 OUR FIT Error includes scale factor of 1.2. 5.2 ±0.6 OUR AVERAGE 352 120 BEHREND 5.6 ±0.7 ±0.3 avg 90 CELL Eee = 35 GeV 121 ALBRECHT 87L ARG Ecm = 10 GeV 203 $4.2 \pm 0.5 \pm 0.9$ f&a $6.2 \pm 2.3 \pm 1.7$ f& a **BEHREND** 84 CELL Eee 14,22 GeV • • • We do not use the following data for averages, fits, limits, etc. • • • 87 MRK2 Ecm = 29 GeV 122 BURCHAT $6.1 \pm 0.8 \pm 0.9$ 123,124 RUCKSTUHL 86 DLCO Ecm = 29 GeV 7.6 ±0.4 ±0.9 530 125 SCHMIDKE 86 MRK2 Eee = 29 GeV 4.7 ±0.5 ±0.8 124 FERNANDEZ 85 MAC $E_{
m cm}^{
m ee} = 29~{
m GeV}$ 5.6 ±0.4 ±0.7 120 BEHREND 90 value is not independent of BEHREND 90 B(3 $h
u_{ au}~\ge~1$ neutrals) + B(5-prong). 121 ALBRECHT the product measure ACENTECT 10 II ((e $\bar{\nu}\sigma\mu\bar{\nu}\sigma\pi\sigma K\sigma\rho)\nu_{\tau}$) = 0.029 and use the PDG 86 values for the second branching ratio which sum to 0.69 \pm 0.03 to get the quoted value. 122 BURCHAT 87 value is not independent of SCHMIDKE 86 value.

123 Contributions from kaons and from $>1\pi^0$ are subtracted. Not independent of (3-prong $+ 0\pi^{0}$) and (3-prong $+ \ge 0\pi^{0}$) values.

124 Value obtained using paper's $R=\mathrm{B}(h^-h^-h^+\nu_{ au})/\mathrm{B}(3\text{-prong})$ and current B(3-prong)

125 Not independent of SCHMIDKE 86 $h^-h^-h^+\nu_{ au}$ and $h^-h^-h^+(\ge 0\pi^0)\nu_{ au}$ values.

$\Gamma(h^-h^-h^+ \ge 1 \text{ neutrals } \nu_{\tau}(\text{ex. } K_S^0 \to \pi^+\pi^-))/\Gamma_{\text{total}}$ $\Gamma_{59}/\Gamma = (\Gamma_{65} + \Gamma_{73} + \Gamma_{74} + \Gamma_{81} + \Gamma_{85} + 0.285\Gamma_{110} + 0.888\Gamma_{125} + 0.9101\Gamma_{126})/\Gamma_{126}$

Data marked "avg" are highly correlated with data appearing elsewhere in the Listings, and are therefore used for the average given below but not in the overall fits. "f&a" marks results used for the fit and the average.

DOCUMENT ID VALUE (%) EVTS TECN COMMENT 4.98±0.11 OUR FIT Error includes scale factor of 1.2. 5.07±0.24 OUR AVERAGE 126 AKERS $5.09 \pm 0.10 \pm 0.23$ 95Y OPAL 1991-1994 LEP runs f&a 570 DECAMP 92C ALEP 1989-1990 LEP runs $4.95 \pm 0.29 \pm 0.65$ 126 Not independent of AKERS 95Y B($h^-h^-h^+ \ge 0$ neutrals ν_{τ} (ex. $\kappa_{S}^0 \rightarrow \pi^+\pi^-$)) and B($h^-h^-h^+ \ge 0$ neutrals ν_{τ} (ex. K^0))/B($h^-h^-h^+ \ge 0$ neutrals ν_{τ} (ex. $K^0_S \to 0$ $\pi^+\pi^-$)) values.

 τ

	• • • • • • • • • • • • • • • • • • • •	Γ ₇₃ /Γ
VALUE (%) EVTS DOCUMENT ID TECH COMMENT	VALUE (%) DOCUMENT ID 0.11±0.04 OUR FIT	
4.50±0.09 OUR FIT Error includes scale factor of 1.1.	$\Gamma(h^-h^-h^+ \ge 3\pi^0\nu_T)/\Gamma_{\text{total}}$	Γ ₇₄ /Γ
4.45\pm0.09\pm0.07 6.1k ¹² / BUSKULIC 96 ALEP LEP 1991–1993 data 127 BUSKULIC 96 quote B($h^-h^-h^+\pi^0\nu_\tau$ (ex. K^0)) = 4.30 \pm 0.09 \pm 0.09. We add 0.15	VALUE (%) EVTS DOCUMENT ID TECN COMMENT	
to remove their K^0 correction and reduce the systematic error accordingly.	0.14+0.09 OUR FIT Error includes scale factor of 1.5.	
$ \Gamma(h^-h^-h^+\pi^0\nu_{\tau}(\text{ex.}K^0))/\Gamma_{\text{total}} \Gamma_{61}/\Gamma = (\Gamma_{65} + \Gamma_{81} + \Gamma_{85} + 0.888\Gamma_{125} + 0.0221\Gamma_{126})/\Gamma $	0.11±0.04±0.06 440 BUSKULIC 96 ALEP LEP 1991-1993 da	ta
$\Gamma_{61}/\Gamma = (\Gamma_{65} + \Gamma_{81} + \Gamma_{85} + 0.888\Gamma_{125} + 0.0221\Gamma_{126})/\Gamma$	$\Gamma(h^-h^-h^+3\pi^0\nu_{\tau})/\Gamma_{\text{total}}$	75/r
<u>VALUE (%)</u> <u>EVTS</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u> 4.31±0.09 OUR FIT Error includes scale factor of 1.1.	VALUE (units 10 ⁻⁴) EVTS DOCUMENT ID TECN COMMENT	
1.23 ± 0.06 ± 0.22 7.2k BALEST 95C CLEO E cm ≈ 10.6 GeV	2.85 ± 0.56 ± 0.51 57 ANDERSON 97 CLEO $E_{\text{CM}}^{\text{pe}} = 10.6 \text{ GeV}$	
$\Gamma(h^-h^-h^+\pi^0\nu_{\tau}(\textbf{ex. }K^0,\omega))/\Gamma_{\textbf{total}} \qquad \qquad \Gamma_{62}/\Gamma = (\Gamma_{65}+\Gamma_{81}+\Gamma_{85})/\Gamma_{\textbf{DOCUMENT ID}}$	$\Gamma(K^-h^+h^- \ge 0 \text{ neutrals } \nu_{\tau})/\Gamma_{\text{total}}$ $\Gamma_{76}/\Gamma = (0.3431\Gamma_{34} + 0.3431\Gamma_{38} + \Gamma_{79} + \Gamma_{81} + \Gamma_{84} + \Gamma_{85})/\Gamma_{38}$	
2.59±0.09 OUR FIT	VALUE (%) O.54±0.07 OUR FIT Error includes scale factor of 1.1.	
$\Gamma(\pi^-\pi^+\pi^-\pi^0 u_{ au})/\Gamma_{ ext{total}}$	<0.6 90 AIHARA 84c TPC $E_{\text{cm}}^{\text{ee}} = 29 \text{ GeV}$	
$\Gamma_{63}/\Gamma = (0.3431\Gamma_{36} + \Gamma_{65} + 0.888\Gamma_{125} + 0.0221\Gamma_{126})/\Gamma$ ALUE (%) DOCUMENT ID	$\Gamma(K^-\pi^+\pi^-\geq 0 \text{ neutrals } \nu_{ au})/\Gamma_{ ext{total}}$	
4.35±0.10 OUR FIT	$\Gamma_{77}/\Gamma = (0.3431\Gamma_{34} + 0.3431\Gamma_{38} + \Gamma_{79} + \Gamma_{81})/\Gamma$ Data marked "avg" are highly correlated with data appearing elsewhere in the Li	ictings
$\Gamma(\pi^-\pi^+\pi^-\pi^0\nu_{\tau}(\text{ex.}K^0))/\Gamma_{\text{total}}$ $\Gamma_{64}/\Gamma = (\Gamma_{65}+0.888\Gamma_{125}+0.0221\Gamma_{126})/\Gamma_{\text{DOCUMENT ID}}$	and are therefore used for the average given below but not in the overall fits, marks results used for the fit and the average.	
4.22±0.10 OUR FIT	VALUE (%) EVTS DOCUMENT ID TECN COMMENT 0.31 ±0.06 OUR FIT Error includes scale factor of 1.1.	
$\Gamma(\pi^-\pi^+\pi^-\pi^0\nu_{\tau}(ex.K^0,\omega))/\Gamma_{total}$ Γ_{65}/Γ	0.30 ±0.07 OUR AVERAGE Error includes scale factor of 1.2. 0.275±0.064 avg ¹³¹ BARATE 98 ALEP 1991–1995	IED [
VALUE (%) DOCUMENT ID	runs	
2.49±0.10 OUR FIT	$0.58 + 0.15 \pm 0.12$ f&a 20 132 BAUER 94 TPC $E_{cm}^{ee} = 29$	
$\frac{\Gamma(h^-(\rho\pi)^0\nu_\tau)/\Gamma(h^-h^-h^+\pi^0\nu_\tau)}{\Gamma_{66}/\Gamma_{60} = (\Gamma_{68}+\Gamma_{69}+\Gamma_{70})/\Gamma_{60}}$	$0.22 ^{+0.16}_{-0.13} \pm 0.05$ f&a 9 133 MILLS 85 DLCO $E_{\rm cm}^{\rm ee} = 29$	
'66' 60 - ('68 + '69 + '70)' 60 <u>ALUE</u>	131 Not independent of BARATE 98 $\Gamma(\tau^- \rightarrow K^-\pi^+\pi^-\nu_\tau)/\Gamma_{\text{total}}$ and $\Gamma(\tau^- \rightarrow K^-\pi^+\pi^-\nu_\tau)/\Gamma_{\text{total}}$	- →
0.64±0.07±0.03 128 ALBRECHT 91D ARG ECC = 9.4-10.6 GeV	$K^-\pi^+\pi^-\pi^0\nu_{\tau})/\Gamma_{\rm total}$ values. ¹³² We multiply 0.58% by 0.20, the relative systematic error quoted by BAUER 94, to	obtain
128 ALBRECHT 91D not independent of their $\Gamma(h^-\rho^+h^-\nu_{\tau})/\Gamma(h^-h^-h^+\pi^0\nu_{\tau})$, $\Gamma(h^-\rho^-h^+\nu_{\tau})/\Gamma(h^-h^-h^+\pi^0\nu_{\tau})$, and $\Gamma(h^-\rho\pi^0\nu_{\tau})/\Gamma(h^-h^-h^+\pi^0\nu_{\tau})$	the systematic error. 133 Error correlated with MILLS 85 ($KK\pi\nu$) value. We multiply 0.22% by 0.23, the systematic error quoted by MILLS 85, to obtain obtain the systematic error.	
values. $\Gamma((a_1(1260)h)^-\nu_\tau)/\Gamma(h^-h^-h^+\pi^0\nu_\tau)$ Γ_{67}/Γ_{60}	$\Gamma(K^-\pi^+\pi^-\nu_\tau)/\Gamma_{\text{total}} \qquad \qquad \Gamma_{78}/\Gamma = (0.3431\Gamma_{34} + \Gamma_{78})$	79)/Г
VALUE CL% DOCUMENT ID TECH COMMENT	VALUE (%) DOCUMENT ID TECN COMMENT 0.23 ±0.04 OUR FIT	
<0.44 95 129 ALBRECHT 910 ARG ECT = 9.4-10.6 GeV	0.214±0.037±0.029 BARATE 98 ALEP 1991-1995 LEP ru	ns
²⁹ ALBRECHT 91D not independent of their $\Gamma(h^-\omega\nu_{\tau})/\Gamma(h^-h^-h^+\pi^0\nu_{\tau}(\mathbf{ex}.K^0))$, $\Gamma(h^-\rho\pi^0\nu_{\tau})/\Gamma(h^-h^-h^+\pi^0\nu_{\tau})$, $\Gamma(h^-\rho^+h^-\nu_{\tau})/\Gamma(h^-h^-h^+\pi^0\nu_{\tau})$, and $\Gamma(h^-\rho^-h^+\nu_{\tau})/\Gamma(h^-h^-h^+\pi^0\nu_{\tau})$ values.	$\Gamma(K^-\pi^+\pi^-\nu_{\tau}(ex.K^0))/\Gamma_{total}$ $VALUE(\%)$ 0.18±0.05 OUR FIT	Г 79 /Г
$\Gamma(h^-\rho\pi^0\nu_{\tau})/\Gamma(h^-h^-h^+\pi^0\nu_{\tau})$ Γ_{68}/Γ_{60}		\ (F
VALUE EVTS DOCUMENT ID TECN COMMENT	$\Gamma(K^-\pi^+\pi^-\pi^0\nu_{\tau})/\Gamma_{\text{total}}$ $\Gamma_{80}/\Gamma=(0.3431\Gamma_{38}+\Gamma_{10})$ VALUE (%) DOCUMENT ID TECH COMMENT	81//
0.30±0.04±0.02 393 ALBRECHT 91D ARG $E_{\text{Cm}}^{\text{ee}} = 9.4$ -10.6 GeV	0.08 ±0.04 OUR FIT	
$\Gamma(h^-\rho^+h^-\nu_\tau)/\Gamma(h^-h^-h^+\pi^0\nu_\tau) \qquad \qquad \Gamma_{69}/\Gamma_{60}$		
<u>VALUE EVTS DOCUMENT ID TECN COMMENT</u> 0.10±0.03±0.04 142 ALBRECHT 91D ARG E ^{CC} _{CTT} = 9.4−10.6 GeV	$\Gamma(K^-\pi^+\pi^-\pi^0\nu_{\tau}(\mathbf{ex}.K^0))/\Gamma_{\mathbf{total}}$	Γ ₈₁ /Γ
$\Gamma(h^-\rho^-h^+\nu_{ au})/\Gamma(h^-h^-h^+\pi^0\nu_{ au})$ Γ_{70}/Γ_{60}	(2.4 ^{+4.3}) × 10 ⁻⁴ OUR FIT	
<u>VALUE EVTS DOCUMENT ID TECN COMMENT</u> 0.26±0.05±0.01 370 ALBRECHT 91D ARG E ^{®®} _{CH} = 9.4−10.6 GeV	$\Gamma(K^-\pi^+K^- \ge 0 \text{ neut. } \nu_{\tau})/\Gamma_{\text{total}}$	Γ ₈₂ /Γ
	VALUE (%) CL% DOCUMENT ID TECN COMMENT	
$ \frac{\Gamma(h^-\rho^+h^-\nu_\tau) + \Gamma(h^-\rho^-h^+\nu_\tau)}{\Gamma(h^-\rho^-h^+\nu_\tau)} \frac{\Gamma(h^-h^-h^+\pi^0\nu_\tau)}{\Gamma(h^-h^-h^+\pi^0\nu_\tau)} \frac{\Gamma(h^-\rho^-h^+\nu_\tau)}{\Gamma(h^-\rho^-h^+\nu_\tau)} $	<0.09 95 BAUER 94 TPC <i>E</i> _{CM} ^{ee} = 29 GeV	
ALUE <u>EVTS</u> <u>DOCUMENT ID TECN COMMENT</u> 233 ± 0.06 ± 0.01 475 130 ALBRECHT 91D ARG E ^{CC} _{CTD} = 9.4-10.6 GeV	$\Gamma(K^-K^+\pi^- \ge 0 \text{ neut. } \nu_{\tau})/\Gamma_{\text{total}}$ $\Gamma_{83}/\Gamma = (\Gamma_{84}+\Gamma_{1})$	
30 ALBRECHT 910 not independent of their $\Gamma(h^-\rho^+h^-\nu_\tau)/\Gamma(h^-h^-h^+\pi^0\nu_\tau)$ and $\Gamma(h^-\rho^-h^+\nu_\tau)/\Gamma(h^-h^-h^+\pi^0\nu_\tau)$ values.	Data marked "avg" are highly correlated with data appearing elsewhere in the Li- and are therefore used for the average given below but not in the overall fits. marks results used for the fit and the average.	
$\Gamma(h^-h^-h^+2\pi^0\nu_{\tau})/\Gamma_{\text{total}}$ Γ_{71}/Γ	VALUE (%) EVTS DOCUMENT ID TECN COMMENT 0.23 ±0.04 OUR FIT	
$\Gamma_{71}/\Gamma = (0.1077\Gamma_{41} + \Gamma_{73} + 0.236\Gamma_{110} + 0.888\Gamma_{126})/\Gamma$	0.22 ±0.04 OUR AVERAGE 0.238±0.042 avg 134 BARATE 98 ALEP 1991-1995	uen f
ALUE (%) DOCUMENT ID .54±0.04 OUR FIT	0.238±0.042 avg 134 BARATE 98 ALEP 1991-1995 runs 0.15 +0.09 ±0.03 f&a 4 135 BAUER 94 TPC Ecm = 29	
	134 Not Independent of BARATE 98 $\Gamma(\tau^- \to K^- K^+ \pi^- \nu_{ au})/\Gamma_{ ext{total}}$ and $\Gamma(\tau^- \to K^- K^+ \pi^- \nu_{ au})/\Gamma_{ ext{total}}$	
172/1 = (173+0.2361 ₁₁₀ +0.8881 ₁₂₆)/f <u>ALUE(%)</u> <u>EVTS</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u>	$K^-K^+\pi^-\pi^0\nu_{\tau})/\Gamma_{\rm total}$ values. ¹³⁵ We multiply 0.15% by 0.20, the relative systematic error quoted by BAUER 94, to	
.83±0.04 OUR FIT	the systematic error.	
	• • • • • • • • • • • • • • • • • • • •	T84/F
$ \begin{array}{l} -(h^-h^-h^+2\pi^0\nu_{\tau}(\text{ex.}K^0))/\Gamma(h^-h^-h^+ \geq 0 \text{neut. } \nu_{\tau}(\text{"3-prong"})) \Gamma_{72}/\Gamma_{49} \\ \Gamma_{72}/\Gamma_{49} = (\Gamma_{73} + 0.236\Gamma_{110} + 0.888\Gamma_{126})/(0.3431\Gamma_{32} + 0.3431\Gamma_{34} + 0.3431\Gamma_{36} + 0.3431\Gamma_{36}) \end{array} $	0.161±0.026 OUR FIT	
$\begin{array}{c} 72/749 = (73+6.236) 110+6.0001 126/(0.34511 32+0.34511 34+6.34511 36+0.34511 38+0.4508\Gamma_{41}+\Gamma_{57}+\Gamma_{65}+\Gamma_{73}+\Gamma_{74}+\Gamma_{79}+\Gamma_{81}+\Gamma_{84}+\Gamma_{85}+0.285\Gamma_{110}+0.9101\Gamma_{125}+0.9101\Gamma_{126}) \end{array}$	0.165±0.027 OUR AVERAGE 0.163±0.021±0.017 BARATE 98 ALEP 1991-1995 LEP 0.22 +0.17 ±0.05 9 136 MILLS 85 DLCO ESS = 29 GeV	runs
ALUE EYTS DOCUMENT ID TECN COMMENT 1.0348±0.0028 OUR FTT	-0.11	
0.034 ±0.002 ±0.003 668 BORTOLETTO93 CLEO E ^{ee} _{Cm} ≈ 10.6 GeV	136 Error correlated with MILLS 85 $(K\pi\pi\pi^0\nu)$ value. We multiply 0.22% by 0.2 relative systematic error quoted by MILLS 85, to obtain obtain the systematic error	

VALUE (%)	/F _{total}	DOCUMENT ID	TECN	COMMENT	Г ₈₅ /Г	$\Gamma((5\pi)^{-}\nu_{\tau})/\Gamma_{\text{total}}$ $\Gamma_{\text{or}}/\Gamma = (\Gamma_{\text{or}} + \frac{1}{2})$	Г _{F41} +Г ₇₃ +Г ₉₂ +0.236Г ₁₁₀ +0.888Г ₁₂₆)/Г
0.069±0.030 OUR FIT 0.075±0.029±0.015	r	BARATE	98 ALEP	1991-1995 LEP	runs	Data marked "avg	" are highly correlated with data appearing elsewhere in the Li- used for the average given below but not in the overall fits.
$(K^-K^+K^- \ge 0)$			T 5411		Г ₈₆ /Г		for the fit and the average. DOCUMENT ID TECN COMMENT
ALUE (%) <0.21	95	DOCUMENT ID BAUER	94 TPC	COMMENT Ecm = 29 GeV	~	0.74±0.07 OUR FIT 0.61±0.06±0.08 a	vg ¹⁴⁰ GIBAUT 948 CLEO E∰ = 10.6 GeV
(K-K+K-v _t)/1	total				Γ ₈₇ /Γ		GIBAUT 948 B(3 h^- 2 h^+ $\nu_ au$), PROCARIO 93 B(h^- 4 π^0 $\nu_ au$
4LUE (1.9 × 10 ⁻⁴	<u>CL%</u> 90	DOCUMENT ID	98 ALEP	COMMENT 1991-1995 LEP	runs	for η contributions.	B($2h^-h^+2\pi^0 u_{ au}$)/B("3prong") measurements. Result is cor
$(\pi^-K^+\pi^- \ge 0 \text{ ns}$	eut. v_)/	Ttotal			Γ ₈₈ /Γ		trais ν_{τ} ("7-prong"))/ Γ_{total}
ALUE (%)	CL%	DOCUMENT ID		COMMENT		<u>∨ALUE</u> <2.4 × 10 ⁻⁶	<u>CL%</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u> 90 EDWARDS 978 CLEO E ^{co} _{cm} = 10.6 GeV
(0.25	95	BAUER	94 TPC	Ecm= 29 GeV		_	ne following data for averages, fits, limits, etc. • • •
$(e^-e^-e^+\overline{ u}_e u_ au)/$	r _{total}				Γ ₈₉ /Γ	$<1.8 \times 10^{-5}$ $<2.9 \times 10^{-4}$	95 ACKERSTAFF 97J OPAL 1990-1995 LEP r 90 BYLSMA 87 HRS Ecm = 29 GeV
4 <i>LUE</i> (units 10 ⁻⁵)	EVTS	DOCUMENT ID		COMMENT			· · · · · · · · · · · · · · · · · · ·
8±1.4±0.4	5	ALAM	96 CLEO	Ecm = 10.6 GeV	/	$\Gamma(K^*(892)^- \ge 0(h^0$	$0 eq K_S^0) u_ au) / \Gamma_{ ext{total}}$
$(\mu^- e^- e^+ \overline{\nu}_\mu \nu_\tau)$	/Faces				Γ ₉₀ /Γ	VALUE (%)	EVTS DOCUMENT ID TECN COMMENT
ALUE (units 10 ⁻⁵)	CL%	DOCUMENT ID	TECN	COMMENT	. 30/	1.94±0.27±0.15	74 AKERS 94G OPAL <i>Eee</i> = 88–94 GeV
(3.6	90	ALAM		Eee = 10.6 Ge\	, 	$\Gamma(K^{*}(892)^{-} \geq 0 \text{ ne}$	• •
$(3h^-2h^+ \ge 0 \text{ net}$	utrals $ u_{-}(\epsilon$	ex. K ⁰ → π ⁻ 1	r+)(#5-pror	ng"))/F _{total}	Γ ₉₁ /Γ	VALUE (%) 1.33±0.13 OUR AVER/	EVTS DOCUMENT ID TECN COMMENT
$\Gamma_{91}/\Gamma = (\Gamma_{92} + \Gamma_{91})$. Дори	-6 /// · Wuai	. 92/	$1.19 \pm 0.15 + 0.13 \\ -0.18$	104 ALBRECHT 95H ARG Ecc = 9.4-10.6
ALUE (%)	EVTS	DOCUMENT ID	TECN	COMMENT		1.43±0.11±0.13	475 141 GOLDBERG 90 CLEO Eee 9.4-10.9
097±0.007 OUR FI7 102±0.011 OUR AV						141 GOLDBERG 90 esti	mates that 10% of observed $K^*(892)$ are accompanied by a
097±0.005±0.011	419	GIBAUT	948 CLEO	Eee = 10.6 Ge\	V	$\Gamma(K^{\bullet}(892)^{-}\nu_{\tau})/\Gamma_{tc}$	
26 ±0.06 ±0.05		ACTON		Ecm = 88.2-94.		VALUE (%)	INTERPORT IN TECH COMMENT
10 +0.05 ±0.03		DECAMP	92C ALEP	1989-1990 LEP	runs	1.28±0.08 OUR AVER	
-0.04 102±0.029	13	BYLSMA	87 HRS	Ecm = 29 GeV		$1.39 \pm 0.09 \pm 0.10$	142 BUSKULIC 96 ALEP LEP 1991-1993 d
6 ±0.08 ±0.04	4	BURCHAT		Eee = 29 GeV		1.11 ± 0.12	143 COAN 96 CLEO E cm ≈ 10.6 GeV
• We do not use 1	the following					$1.42 \pm 0.22 \pm 0.09$	144 ACCIARRI 95F L3 1991-1993 LEP ri
6 ±0.13 ±0.04		BEHREND		Ecm = 14-47 G	ieV	$1.23 \pm 0.21 ^{+0.11}_{-0.21}$	54 145 ALBRECHT 88L ARG Ecm = 10 GeV
3 ±0.1 ±0.2		BARTEL		Ecm = 34.6 Ge\		$1.9 \pm 0.3 \pm 0.4$	44 146 TSCHIRHART 88 HRS Ecm = 29 GeV
13 ±0.04	10	BELTRAMI	85 HRS	Repl. by BYLSN		$1.5 \pm 0.4 \pm 0.4$	15 147 AIHARA 87C TPC Ecm = 29 GeV
0 ±0.4	10	BEHREND		Repl. by BEHRI		$1.3 \pm 0.3 \pm 0.3$	31 YELTON 86 MRK2 $E_{\text{CM}}^{\text{dd}} = 29 \text{ GeV}$
-/		\ . F/24-24d		-l:			ne following data for averages, fits, limits, etc. • • •
$\Gamma(h^-h^-h^+ \ge 1 \text{ n}$			≥ o neutra		/-	$1.45 \pm 0.13 \pm 0.11$	273 148 BUSKULIC 94F ALEP Repl. by BUSKUL
ex. $K_S^0 o \pi^- \pi^+$) $(\Gamma_{58} + \Gamma_{91})/\Gamma =$)(⁻5-prong :(0.3431Г ₃₆	「))]/ total ,+0.3431Γ ₃₈ +0.1	1077F ₄₁ +F ₆₅	(Ι 58 + -173+Γ ₇₄ +Γ ₈₁ +	+Γ ₉₁)/Γ +Γ ₈₅ +	1.7 ±0.7 142 Not independent of	11 DORFAN 81 MRK2 $E_{\rm cm}^{\rm ee}=$ 4.2–6.7 Ge BUSKULIC 96 B $(\pi^-\overline{K}^0\nu_{ au})$ and B $(K^-\pi^0\nu_{ au})$ measurement
Foo+Foo+0.28F		8Г ₁₂₅ +0.9101Г ₁				143 Not independent of	COAN 96 B($\pi^-\overline{K}^0\nu_{\tau}$) and BATTLE 94 B($K^-\pi^0\nu_{\tau}$) me
				COMMENT			ates are consistent with and assumed to originate from K*(
ALUE (%)	<u>EVTS</u>	DOCUMENT ID				production.	,
4LUE (%) .28±0.11 OUR FIT	Error Includ		f 1.2.			144 This result is obtain	
ALUE (%) .28±0.11 OUR FIT .4 ±0.5 OUR AVER	Error Includ			1989-1990 LEP	runs		ned from their B $(\pi^-\overline{K}{}^0 u_{ au})$ assuming all those decays origin
4 <i>LUE</i> (%) 1.28±0.11 OUR FIT 1.4 ±0.5 OUR AVER 1.05±0.29±0.65	Error Includ RAGE 570	des scale factor o	92C ALEP	1989–1990 LEP <i>Ee</i> e = 35 GeV	' runs	K*(892) decays.	, ,, ,
ALUE (%) 28±0.11 OUR FIT 4 ±0.5 OUR AVER 05±0.29±0.65 8 ±0.7 ±0.2 37 BEHREND 90 not	Error Includ RAGE 570 352 1	des scale factor of DECAMP L37 BEHREND	92c ALEP 90 CELL	Eee = 35 GeV		K*(892) decays. 145 The authors divide to the lindependent decays.	by $\Gamma_1/\Gamma=0.865$ to obtain this result.
ALUE (%) .28±0.11 OUR FIT .4 ±0.5 OUR AVEF .05±0.29±0.65 .8 ±0.7 ±0.2 37 BEHREND 90 not ment.	Error Includ RAGE 570 352 ¹ Independen	des scale factor of DECAMP 137 BEHREND of their $\Gamma(h^-h^-)$	92c ALEP 90 CELL	Eee = 35 GeV	measure-	$K^*(892)^-$ decays. 145 The authors divide to 146 Not independ $h^-\overline{K}^0 \ge 0$ neutrals	by $\Gamma_1/\Gamma=0.865$ to obtain this result. lent of TSCHIRHART 88 $\Gamma(\tau^-)$ $(5 \ge 0K_1^0 \nu_{\tau})/\Gamma(\text{total})$.
ALUE (%) 28±0.11 OUR FIT $A \pm 0.5$ OUR AVER .05±0.29±0.65 .8 ±0.7 ±0.2 37 BEHREND 90 not ment. : $(3h^-2h^+\nu_{\tau})$ (ex. K	Error Includ RAGE 570 352 1 Independen	des scale factor of DECAMP 137 BEHREND at of their $\Gamma(h^-h^-)$	92c ALEP 90 CELL $n^{-}h^{+} \ge 1 \text{ ne}$	$E_{ m cm}^{ m ee}=35~{ m GeV}$ eutrals $ u_{ au})/\Gamma_{ m total}$		$K^*(892)^-$ decays. 145 The authors divide the second of the second o	by $\Gamma_1/\Gamma=0.865$ to obtain this result. lent of TSCHIRHART 88 $\Gamma(\tau^-)=0$ (total). In this experiment, is assumed in the others.
ALUE (%) 28±0.11 OUR FIT A ±0.5 OUR AVER 05±0.29±0.65 8 ±0.7 ±0.2 37 BEHREND 90 not ment. (3h-2h+ν _T (ex.K ALUE (%) .075±0.007 OUR FIT	Error Include RAGE 570 352 Independen (O))/\(\Gamma\) EVTS T	des scale factor of DECAMP 137 BEHREND of their $\Gamma(h^-h^-)$	92c ALEP 90 CELL $n^{-}h^{+} \ge 1 \text{ ne}$	$E_{ m cm}^{ m ee}=35~{ m GeV}$ eutrals $ u_{ au})/\Gamma_{ m total}$	measure-	$K^*(892)^-$ decays. 145 The authors divide 146 Not independ $h^-\overline{K}^0 \geq 0$ neutrals 147 Decay π^- identified 148 BUSKULIC 94F obta	by $\Gamma_1/\Gamma=0.865$ to obtain this result. lent of TSCHIRHART 88 $\Gamma(\tau^-)$ $(5 \ge 0K_1^0 \nu_{\tau})/\Gamma(\text{total})$.
ALUE (%) 2.28 ± 0.11 OUR FIT 4. ± 0.5 OUR AVER 0.05 ± 0.29 ± 0.65 8. ± 0.7 ± 0.2 37 BEHREND 90 not ment. (3h - 2h + ν_{τ} (ex. K ALUE (%) 0.075 ± 0.007 OUR FIT 0.073 ± 0.008 OUR AV	Error Include RAGE 570 352 Independen (O))/\(\Gamma\) \(\frac{EVTS}{T}\) /ERAGE	des scale factor of DECAMP 137 BEHREND at of their F(h h h	92c ALEP 90 CELL 1 h ⁺ ≥ 1 ne	$E_{ m cm}^{ m eq}=$ 35 GeV cutrals $ u_{ au}/\Gamma_{ m total}$	теаѕите- Г ₉₂ /Г	$K^*(892)^-$ decays. 145 The authors divide a 146 Not independ $h^-\overline{K}^0 \geq 0$ neutrals 147 Decay π^- identified 148 BUSKULIC 94F obta B $(K^-\pi^0 \nu_T)$ assum	by $\Gamma_1/\Gamma=0.865$ to obtain this result. lent of TSCHIRHART 88 $\Gamma(\tau^-)$ is $\geq 0K_0^0 \nu_{\tau}$)/ $\Gamma(\text{total})$. In this experiment, is assumed in the others, ain this result from BUSKULIC 94F B($\overline{K}^0 \pi^- \nu_{\tau}$) and BUSKULing all of those decays originate in $K^*(892)^-$ decays.
4LUE (%) 28±0.11 OUR FIT $A \pm 0.5$ OUR AVER $0.5 \pm 0.29 \pm 0.65$ $8 \pm 0.7 \pm 0.2$ 37 BEHREND 90 not ment. $(3h^-2h^+\nu_T$ (ex. KALUE (%) .073±0.007 OUR FIT .073±0.008 OUR AV .080±0.011±0.013	Error Include RAGE 570 352 Independen (O))/\(\Gamma\) EVTS T	DECAMP 137 BEHREND It of their $\Gamma(h^-h)$ DOCUMENT ID BUSKULIC	92C ALEP 90 CELL 1 h ≥ 1 ne TECN 96 ALEP	$E_{ m cm}^{ m eq}=35~{ m GeV}$ eutrals $ u_{ m T}$)/ $\Gamma_{ m total}$ $ \underline{COMMENT} $ LEP 1991–1993	F92/F	$K^*(892)^-$ decays. 145 The authors divide 8 146 Not independ $h^-\overline{K}^0 \geq 0$ neutrals 147 Decay π^- identifies 148 BUSKULIC 94F obta B($K^-\pi^0\nu_T$) assum $\Gamma(K^*(892)^-\nu_T)/\Gamma($	by $\Gamma_1/\Gamma=0.865$ to obtain this result. lent of TSCHIRHART 88 $\Gamma(\tau^-)$ is $\geq 0K_0^0 \nu_{\tau}$)/ $\Gamma(\text{total})$. I in this experiment, is assumed in the others, ain this result from BUSKULIC 94F $\mathrm{B}(\overline{K}^0\pi^-\nu_{\tau})$ and BUSKULing all of those decays originate in $K^*(892)^-$ decays. $\pi^-\pi^0\nu_{\tau}$)
#4UE (%) 28±0.11 OUR FIT A ±0.5 OUR AVER 05±0.29±0.65 8 ±0.7 ±0.2 37 BEHREND 90 not ment. (3 $h^-2h^+\nu_T$ (ex. K #4UE (%) 0.775±0.007 OUR FIT 0.008 OUR AV 0.80±0.011±0.013	Error Include RAGE 570 352 Independen (O))/\(\Gamma\) EVTS T /ERAGE 58	des scale factor of DECAMP 137 BEHREND at of their F(h h h	92c ALEP 90 CELL 1 h ⁺ ≥ 1 ne	$E_{\rm cm}^{\rm ee}=35~{ m GeV}$ eutrals $ u_{T}$)/ $\Gamma_{ m total}$ $ \underline{COMMENT} $ LEP 1991–1993 $ \underline{E_{ m cm}^{\rm ee}}=10.6~{ m GeV} $	F92/F	$K^*(892)^-$ decays. 145 The authors divide a 146 Not independ $h^-\overline{K}^0 \geq 0$ neutrals 147 Decay π^- identified 148 BUSKULIC 94F obta B $(K^-\pi^0 \nu_T)$ assum	by $\Gamma_1/\Gamma=0.865$ to obtain this result. lent of TSCHIRHART 88 $\Gamma(\tau^-)$ is $\geq 0K_0^0 \nu_{\tau}$)/ $\Gamma(\text{total})$. In this experiment, is assumed in the others, ain this result from BUSKULIC 94F B($\overline{K}^0 \pi^- \nu_{\tau}$) and BUSKULing all of those decays originate in $K^*(892)^-$ decays.
ALUE (%) 28±0.11 OUR FIT 4 ±0.5 OUR AVER 05±0.29±0.65 8 ±0.7 ±0.2 37 BEHREND 90 not ment. (3h-2h+ν _T (ex. K ALUE (%) 075±0.007 OUR FIT 075±0.006 OUR AV 080±0.011±0.013 077±0.009 064±0.023±0.01	Error Include RAGE 570 352 Independen (O))/\(\Gamma\) EVTS T/ERAGE 58 295	DECAMP 137 BEHREND Int of their \(\Gamma(h^- h) \) \[\frac{DOCUMENT ID}{GIBAUT} \]	92C ALEP 90 CELL 1 h ⁺ ≥ 1 ne TECN 96 ALEP 948 CLEO	$E_{ m cm}^{ m eq}=35~{ m GeV}$ eutrals $ u_{ m T}$)/ $\Gamma_{ m total}$ $ \underline{COMMENT} $ LEP 1991–1993	F92/F	K^* (892) decays. 145 The authors divide it 146 Not independ $h^-\overline{K}^0 \ge 0$ neutrals 147 Decay π^- identified 148 BUSKULIC 94F obta B($K^-\pi^0\nu_T$) assum Γ(K^* (892) ν_T)/Γ($\frac{VALUE}{2}$ 0.075±0.027	by $\Gamma_1/\Gamma=0.865$ to obtain this result. lent of TSCHIRHART 88 $\Gamma(\tau^-)$ ($\tau>0.86$,
ALUE (%) 28±0.11 OUR FIT 4 ±0.5 OUR AVER 05±0.29±0.65 8 ±0.7 ±0.2 37 BEHREND 90 not ment. (3h-2h+ ν_{τ} (ex. K ALUE (%) 075±0.007 OUR FIT 075±0.005 OUR AV 080±0.011±0.013 077±0.005±0.009 064±0.023±0.01	Error Include RAGE 570 352 1: Independen (O))// total EVTS T /ERAGE 58 295 12 7	DECAMP 137 BEHREND Int of their Γ(h - h DOCUMENT ID BUSKULIC GIBAUT ALBRECHT BYLSMA	92c ALEP 90 CELL 7 h ⁺ ≥ 1 ne TECN 96 ALEP 94B CLEO 88B ARG 87 HRS	$E_{\rm cm}^{\rm em}=35~{\rm GeV}$ entrals ν_{τ})/ $\Gamma_{ m total}$ $COMMENT$ LEP 1991–1993 $E_{ m cm}^{\rm em}=10.6~{\rm GeV}$ $E_{ m cm}^{\rm em}=10~{\rm GeV}$ $E_{ m cm}^{\rm em}=29~{\rm GeV}$	F92/F	$K^*(892)^-$ decays. 145 The authors divide the second of the second o	by $\Gamma_1/\Gamma=0.865$ to obtain this result. lent of TSCHIRHART 88 $\Gamma(\tau^-)$ (τ^-) and BUSKUL 1 his result from BUSKULIC 94F B(τ^-) τ^-) and BUSKUL 1 hing all of those decays originate in τ^- (892) decays. τ^-
ALUE (%) 28 \pm 0.11 OUR FIT 4 \pm 0.5 OUR AVER 05 \pm 0.29 \pm 0.65 8 \pm 0.7 \pm 0.2 37 BEHREND 90 not ment. (3h $-$ 2h $+$ ν_{T} (ex. K ALUE (%) 0.075 \pm 0.007 OUR FIT 0.073 \pm 0.008 OUR AV 0.80 \pm 0.011 \pm 0.013 0.77 \pm 0.005 \pm 0.009 0.64 \pm 0.023 \pm 0.01 0.51 \pm 0.020 • We do not use to 0.67 \pm 0.030	Error Include RAGE 570 352 1 Independen (O))// total EVTS T /ERAGE 58 295 12 7 the following 5 1	DECAMP 137 BEHREND 1st of their Γ(h - h DOCUMENT ID BUSKULIC GIBAUT ALBRECHT BYLSMA g data for average 138 BELTRAMI	92c ALEP 90 CELL 7 h ⁺ ≥ 1 ne TECN 96 ALEP 94B CLEO 88B ARG 87 HRS	$E_{\rm cm}^{\rm em}=35~{\rm GeV}$ entrals ν_{τ})/ $\Gamma_{ m total}$ $COMMENT$ LEP 1991–1993 $E_{ m cm}^{\rm em}=10.6~{\rm GeV}$ $E_{ m cm}^{\rm em}=10~{\rm GeV}$ $E_{ m cm}^{\rm em}=29~{\rm GeV}$	F92/F	K^* (892) decays. 145 The authors divide to 146 Not independ $h^-\overline{K}^0 \ge 0$ neutrals 147 Decay π^- identified 148 BUSKULIC 94F obta B($K^-\pi^0 \nu_{\tau}$) assum $\Gamma(K^*(892)^-\nu_{\tau})/\Gamma(VALUE)$ 0.075 ± 0.027	by $\Gamma_1/\Gamma=0.865$ to obtain this result. lent of TSCHIRHART 88 $\Gamma(\tau^-)$ is $\geq 0K_0^0 \nu_{\tau}$)/ $\Gamma(\text{total})$. In this experiment, is assumed in the others. lain this result from BUSKULIC 94F B($\overline{K}^0 \pi^- \nu_{\tau}$) and BUSKUL ling all of those decays originate in $K^*(892)^-$ decays. $\frac{\pi^- \pi^0 \nu_{\tau}}{149 \text{ ABREU}} \frac{DOCUMENT \ ID}{94K \ DLPH} \frac{TECN}{\text{LEP 1992 } Z \ \text{data}} \frac{COMMENT}{3(\tau^- \to K^*(892)^- \nu_{\tau})B(K^*(892)^- \to K^- \pi^0)/B(\tau^- \to K^-)} \text{Ve divide by } B(K^*(892)^- \to K^- \pi^0) = 0.333 \text{ to obtain this}$
ALUE (%) 28±0.11 OUR FIT 4 ±0.5 OUR AVER 05±0.29±0.65 8 ±0.7 ±0.2 37 BEHREND 90 not ment. (3h-2h+ ν_{τ} (ex. K ALUE (%) 075±0.007 OUR FIT 075±0.005 OUR AV 080±0.011±0.013 077±0.005±0.009 064±0.023±0.01 051±0.020 • • We do not use to 067±0.030 38 The error quoted is	Error Include RAGE 570 352 1 Independent 600) // Total EVTS T // FRAGE 58 295 12 7 the following 5 1 is statistical	DECAMP 137 BEHREND Int of their Γ(h - h DOCUMENT ID BUSKULIC GIBAUT ALBRECHT BYLSMA g data for average 138 BELTRAMI only.	92c ALEP 90 CELL 7 h ⁺ ≥ 1 ne 7ECN 96 ALEP 94B CLEO 88B ARG 87 HRS es, fits, limits	$E_{\rm cm}^{\rm em}=35~{\rm GeV}$ entrals ν_{τ})/ $\Gamma_{\rm total}$ $\frac{COMMENT}{E_{\rm cm}^{\rm em}=10.6~{\rm GeV}}$ $E_{\rm cm}^{\rm em}=10.6~{\rm GeV}$ $E_{\rm cm}^{\rm em}=10~{\rm GeV}$ $E_{\rm cm}^{\rm em}=29~{\rm GeV}$, etc. • • •	F92/F	$K^*(892)^-$ decays. 145 The authors divide the second of the second o	by $\Gamma_1/\Gamma=0.865$ to obtain this result. lent of TSCHIRHART 88 $\Gamma(\tau^-)$ is $\geq 0K_0^0 \nu_{\tau}$)/ $\Gamma(\text{total})$. In this experiment, is assumed in the others. lain this result from BUSKULIC 94F B($\overline{K}^0 \pi^- \nu_{\tau}$) and BUSKUL ling all of those decays originate in $K^*(892)^-$ decays. $\frac{\pi^- \pi^0 \nu_{\tau}}{149 \text{ ABREU}} \frac{DOCUMENT \ ID}{94K \ DLPH} \frac{TECN}{\text{LEP 1992 } Z \ \text{data}} \frac{COMMENT}{3(\tau^- \to K^*(892)^- \nu_{\tau})B(K^*(892)^- \to K^- \pi^0)/B(\tau^- \to K^-)} \text{Ve divide by } B(K^*(892)^- \to K^- \pi^0) = 0.333 \text{ to obtain this}$
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ALUE (%) 28±0.11 OUR FIT 4 ±0.5 OUR AVER 05±0.29±0.65 8 ±0.7 ±0.2 37 BEHREND 90 not ment. (3 h^- 2 h^+ ν_T (ex. K 4LUE (%) .075±0.007 OUR FIT .073±0.006 OUR AV .080±0.011±0.013 .077±0.005±0.009 .064±0.023±0.01 .051±0.020 .064±0.023±0.01 .067±0.030 .070±0.005	Error Include RAGE 570 352 1 Independen (*O*))/\[\int \text{total} \] \[\frac{\xi\text{EVTS}}{\xi\text{T}} \] the following 5 1 is statistical \(\text{x.KO*} \) \\ /\[\text{T} \) \[\frac{\xi\text{EVTS}}{\xi\text{EVTS}} \] the following 5 1 is statistical \(\text{total} \) is statistical \(\text{total} \) is statistical \(\text{total} \) is statistical \(\text{total} \)	des scale factor of DECAMP 137 BEHREND Int of their F(h-h) BUSKULIC GIBAUT ALBRECHT BYLSMA g data for average 138 BELTRAMI DOCUMENT BUSKULIC GIBAUT BUSKULIC GIBAUT BUSKULIC GIBAUT BUSKULIC GIBAUT BYLSMA g data for average 139 BELTRAMI	92c ALEP 90 CELL 17 h ⁺ ≥ 1 ne TECN 96 ALEP 94B CLEO 88B ARG 87 HRS es, fits, limits, 85 HRS 1D TEC 96 ALE 94B CLE 87 HRS	ECM = 35 GeV cutrals ν _T)/Γtotal COMMENT LEP 1991–1993 ECM = 10.6 GeV ECM = 10 GeV ECM = 29 GeV etc. • • • Repl. by BYLSN N COMMENT EP LEP 1991–19 EO ECM = 10.6 GeV ECM = 29 GeV etc. • • • •	MA 87 F92/F 993 data GeV	$K^*(892)^-$ decays. 145 The authors divide 146 Not independ $h^-K^0 \ge 0$ neutrals 147 Decay π^- identified 148 BUSKULIC 94F obta B($K^-\pi^0 \nu_{\tau}$) assum $\Gamma(K^*(892)^-\nu_{\tau})/\Gamma(\frac{VALUE}{2}$ 0.075 ± 0.009. V $\Gamma(K^*(892)^0K^- \ge 0$ $VALUE(\%)$ 0.32 ± 0.00 ± 0.12 $\Gamma(K^*(892)^0K^-\nu_{\tau})$ $VALUE(\%)$ 0.21 ± 0.04 OUR AVE 0.213 ± 0.048 0.20 ± 0.05 ± 0.04 150 BARATE 98 measurals to be (35 ± 0.05) $N^ N^ N^-$	by $\Gamma_1/\Gamma=0.865$ to obtain this result. lent of TSCHIRHART 88 $\Gamma(\tau^-)$ (τ^-) $(\tau^-$

 τ

$(\overline{K}^{*}(892)^{0}\pi^{-}\nu_{\tau})/\Gamma_{\text{total}}$	DOCUMENT ID	TECN COMM	Γ ₁₀₃ /Γ	$\Gamma(\eta\pi^-\pi^0\pi^0\nu$	•				Γ ₁₁₁ /
.22 ±0.05 OUR AVERAGE	DOCUMENT ID	TECH COMMI		VALUE (units 10-4)				CN COMMEN	
.209±0.058		ALEP 1991-		1.4±0.6±0		5 BERGFEL ig data for average.		EO Ecm = 1	.0.6 GeV
25 ±0.10 ±0.05 27			9.4-10.6 GeV		95	ARTUSO			10 (5-1/
1 BARATE 98 measure the cays to be (87 \pm 13)% an				£120	95 95	ALBRECH		EO E∰ ≈ KG E∰ ≈	
$K^-K^+\pi^-\nu_{\tau})/\Gamma_{\text{total}}$.				$\Gamma(\eta K^- \nu_{\tau})/\Gamma_t$	otal				Γ ₁₁₂ /
$((\overline{K}^*(892)\pi)^- u_{ au} o\pi^-)$			Γ ₁₀₄ /Γ	VALUE (units 10 ⁻⁴) 2.7±0.6 OUR	CL% EVTS	DOCUMENT ID	<u>TECN</u>	COMMENT	
LUE (%) 106±0.037±0.032	152 BARATE 98E	ALEP 1991-		2.7±0.6 OOR 2.9+1.3±0.7	VAEKVAGE	BUSKULIC	O7C ALED	1991-1994 L	ED
² BARATE 98E determine the					85	BARTELT			
0.09 ± 0.10) and multiply the to obtain the quoted result.	elr B $(\pi^- \overline{K}{}^0 \pi^0 \nu_T)$ measi	urement by one	minus this fraction	• • • We do not		ng data for average	s, fits, limits,	$E_{\text{CM}}^{\text{ee}} \approx 10.6$ etc. • • • $E_{\text{CM}}^{\text{ee}} \approx 10.6$	
$(K_1(1270)^- u_{ au})/\Gamma_{ ext{total}}$			Γ ₁₀₅ /Γ	r/ +				-ciii	
LUE (%) EVTS	DOCUMENT ID	TECN COMM	ENT	$\Gamma(\eta \pi^+ \pi^- \pi^-)$		• .			Γ ₁₁₃ /
41 ^{+0.41} ±0.10 5	¹⁵³ BAUER 94	TPC Eee =	= 29 GeV	<u>VALUE (%)</u> <0.3	<u>CL%</u> 90	DOCUMENT ID	878 HRS	Eee = 29 C	
³ We multiply 0.41% by 0.25, the systematic error.	the relative systematic erro	or quoted by BA	AUER 94, to obtain	Γ(ηπ ⁻ π ⁺ π ⁻ ι		ABACIII	orb into	2cm= 29 (Γ ₁₁₄ /
			- /-	VALUE (units 10-4)	•	DOCUMENT ID	TECN	COMMENT	
(K ₁ (1400) ⁻ ν _τ)/Γ _{total}	DOCUMENT ID	TECN COMM		3.4 ^{+0.6} _{-0.5} ±0.6	89	BERGFELD		Eee = 10.6	GeV
		•	29 GeV	$\Gamma(\eta a_1(1260)^{-1})$	$\nu_{\tau} \rightarrow \eta \pi^{-} \rho^{0}$	$\nu_{\tau})/\Gamma_{trest}$			Γ115/
We multiply 0.76% by 0.25, i	the relative systematic erro	or quoted by BA	AUER 94, to obtain	VALUE	<u>cl%</u>	DOCUMENT ID		COMMENT	
the systematic error.				<3.9 × 10 ⁻⁴	90	BERGFELD	97 CLEO	Ecm = 10.6	GeV
$\frac{\left(K_1(1270)^-\nu_{\tau}\right)+\Gamma\left(K_1(1270)^-\nu_{\tau}\right)}{\frac{EVTS}{2}}$	· •	TECN COMMI	(Γ ₁₀₅ +Γ ₁₀₆)/Γ	$\Gamma(\eta\eta\pi^- u_{ au})/\Gamma$					Γ ₁₁₆ /
7 ^{+0.41} ±0.29 16	155 BAUER 94	TPC E	29 GeV	<u>VALUE (units 10⁻⁴)</u> < 1.1	<u>CL%</u>	DOCUMENT ID		COMMENT	
We multiply 1.17% by 0.25, 1				- ·	95 t use the followin	ARTUSO og data for averages		Ecm ≈ 10.6	GeV
the systematic error. Not inc $B(K_1(1400)^- \nu_T)$ measurem	dependent of BAUER 94 I	$B(K_1(1270)^{-1}\nu$	γ_{τ}) and BAUER 94	<83	95	ALBRECHT		Ecm ≈ 10	GeV
-				$\Gamma(\eta\eta\pi^-\pi^0\nu_{\tau})$	1/[1				Γ117
$K_2^*(1430)^-\nu_\tau)/\Gamma_{total}$			Γ ₁₀₇ /Γ						
	S DOCUMENT ID	TECN CON	Γ ₁₀₇ /Γ <u>ΜΕΝΤ</u>	VALUE (units 10-4)	CL%	DOCUMENT ID	TECN CLEO	COMMENT	
UE (%) CL% EVTS	S DOCUMENT ID TSCHIRHART 8		MENT	VALUE (units 10 ⁻⁴) < 2.0	CL% 95	ARTUSO	92 CLEO	E ^{ee} _{cm} ≈ 10.6	
UE (%) CL% EVTS	TSCHIRHART 8	B HRS E	ment n= 29 GeV	<u>VALUE {units 10⁻⁴}</u> < 2.0 • • • We do not	95 t use the followin	ARTUSO g data for averages	92 CLEO s, fits, limits,	Eee ≈ 10.6 etc. • • •	GeV
3 95 • We do not use the following 95	TSCHIRHART 81 ing data for averages, fits, 156 ACCIARRI 91	8 HRS <i>E</i> ^{ee} , limits, etc. • 5F L3 199	###ENT = 29 GeV • • • 01–1993 LEP runs	<u>VALUE {units 10⁻⁴}</u> < 2.0 • • • We do not < 90	95 t use the followin 95	ARTUSO	92 CLEO s, fits, limits,	E ^{ee} _{cm} ≈ 10.6	GeV
UE (%) CL% EVTS ■ We do not use the followid .33 95 .9 95 0	TSCHIRHART 81 ing data for averages, fits, 156 ACCIARRI 91 D DORFAN 81	8 HRS <i>E</i> ec. , limits, etc. • 5F L3 199 1 MRK2 <i>E</i> ec.	######################################	<u>VALUE {units 10⁻⁴}</u> < 2.0 • • • We do not	95 t use the followin 95	ARTUSO g data for averages	92 CLEO s, fits, limits,	Eee ≈ 10.6 etc. • • •	GeV GeV
UE (%) Output Outpu	TSCHIRHART 81 ing data for averages, fits, 156 ACCIARRI 91 DORFAN 81 \rightarrow $K^*(1430)^- \rightarrow \pi^-$	8 HRS $E_{\text{ch}}^{\text{eq}}$, limits, etc. • 5F L3 199 1 MRK2 $E_{\text{ch}}^{\text{eq}}$	######################################	VALUE (units 10 ⁻⁴) < 2.0 • • • We do not < 90 Γ(η' (958) π − ν VALUE	CL% 95 t use the followin, 95 'r)/\(\Gamma\)	ARTUSO g data for averages ALBRECHT DOCUMENT ID	92 CLEO s, fits, limits, 88M ARG	$E_{\text{CM}}^{\text{ee}} \approx 10.6$ etc. • • • $E_{\text{CM}}^{\text{ee}} \approx 10$	GeV GeV F 118,
UE (%) • We do not use the following the f	TSCHIRHART 81 ling data for averages, fits. 156 ACCIARRI 91 DORFAN 8: $\rightarrow \kappa^* (1430)^- \rightarrow \pi^- = 0.33$ to obtain the limit	8 HRS $E_{\rm CR}^{\rm ee}$, limits, etc. • 5F L3 199 1 MRK2 $E_{\rm CR}^{\rm ee}$ $\overline{K}^0 \nu_{ au}$) $<$ 0.1 shown.	######################################	$VALUE$ (units 10 ⁻⁴) < 2.0 • • • We do not < 90 Γ(τ /(958) π ⁻ ν $VALUE$ < 7.4 × 10 ⁻⁵	21% 95 t use the following 95 (r)/\(\Gamma\) \(\frac{CL%}{2}} 90	ARTUSO g data for averages ALBRECHT	92 CLEO s, fits, limits, 88M ARG	$E_{\text{CM}}^{\text{ee}} \approx 10.6$ etc. • • • $E_{\text{CM}}^{\text{ee}} \approx 10$	GeV GeV F 118,
UE (%) 1.3 95 • We do not use the following the follow	TSCHIRHART 81 ing data for averages, fits. 156 ACCIARRI 91 DORFAN 8: $\rightarrow K^*(1430)^- \rightarrow \pi^- = 0.33$ to obtain the limit $\rightarrow //\Gamma_{\text{total}} \times B(a_0(980))$	8 HRS E_{CR}^{ee} , limits, etc. • 5F L3 199 1 MRK2 E_{CR}^{ee} $\overline{K}^{0}\nu_{\tau}$) < 0.1 shown.	### 29 GeV 11-1993 LEP runs 12-4.2-6.7 GeV 1%. We divide by	VALUE (units 10 ⁻⁴) < 2.0 • • • We do not < 90 Γ(η' (958) π − ν VALUE	21% 95 t use the following 95 (r)/\(\Gamma\) \(\frac{CL%}{2}} 90	ARTUSO g data for averages ALBRECHT DOCUMENT ID	92 CLEO s, flts, limits, 88M ARG TECN 97 CLEO	$E_{\text{cm}}^{\text{ee}} \approx 10.6$ etc. • • • $E_{\text{cm}}^{\text{ee}} \approx 10$ $COMMENT$ $E_{\text{cm}}^{\text{ee}} = 10.6$	GeV GeV F 118,
UE (%) Output LS PVTS 95 Output We do not use the following the fo	TSCHIRHART 81 Ing data for averages, fits, 156 ACCIARRI 91 DORFAN 81 → K*(1430) → π = 0.33 to obtain the limit -)/\(\Gamma_{\text{total}}\times \text{B}(a_0(980)) \(\text{DOCUMENT ID}\)	8 HRS $E_{\rm col}^{\rm col}$, limits, etc. • 5F L3 199 1 MRK2 $E_{\rm col}^{\rm col}$ $\overline{K}^0 \nu_{\tau}$) < 0.1 c shown. $\rightarrow K^0 K^-$)	mment n = 29 GeV • • • • • • • • • • • • • • • • • • •	$VALUE (units 10^{-4})$ < 2.0 • • • We do not < 90 $\Gamma(\eta'(958)\pi^{-}\nu)$ $VALUE$ < 7.4 × 10 ⁻⁵ $\Gamma(\eta'(958)\pi^{-}\pi)$ $VALUE$	t use the following 95 $(\tau)/\Gamma_{\text{total}}$ $CL\%$ 0 0 0 0 0 0 0 0 0 0	ARTUSO Ig data for average: ALBRECHT DOCUMENT ID BERGFELD	92 CLEO s, fits, limits, 88M ARG TECN 97 CLEO	$E_{\text{CM}}^{\text{ee}} \approx 10.6$ etc. • • • $E_{\text{CM}}^{\text{ee}} \approx 10$ $C_{\text{CMMENT}}^{\text{COMMENT}}$ $E_{\text{CM}}^{\text{ee}} = 10.6$ $C_{\text{CMMENT}}^{\text{COMMENT}}$	GeV GeV F118, GeV
2.8 \times 1.04 \times 1.05 \times 1.0	TSCHIRHART 81 ing data for averages, fits. 156 ACCIARRI 91 DORFAN 8: $\rightarrow K^*(1430)^- \rightarrow \pi^- = 0.33$ to obtain the limit $\rightarrow //\Gamma_{\text{total}} \times B(a_0(980))$	8 HRS $E_{\rm col}^{\rm col}$, limits, etc. • 5F L3 199 1 MRK2 $E_{\rm col}^{\rm col}$ $\overline{K}^0 \nu_{\tau}$) < 0.1 c shown. $\rightarrow K^0 K^-$)	mment n = 29 GeV 11-1993 LEP runs n = 4.2-6.7 GeV 1%. We divide by F106/Γ × B ENT 9.4-10.9 GeV	$VALUE$ (units 10 ⁻⁴) < 2.0 • • • We do not < 90 Γ(τ /(958) π ⁻ ν $VALUE$ < 7.4 × 10 ⁻⁵	t use the following 95 $ \frac{c_{LN}}{95} $ t use the following 95 $ \frac{c_{LN}}{90} $ $ \frac{c_{LN}}{90} $	ARTUSO Ig data for average: ALBRECHT DOCUMENT ID BERGFELD	92 CLEO s, fits, limits, 88M ARG TECN 97 CLEO	$E_{\text{cm}}^{\text{ee}} \approx 10.6$ etc. • • • $E_{\text{cm}}^{\text{ee}} \approx 10$ $COMMENT$ $E_{\text{cm}}^{\text{ee}} = 10.6$	GeV GeV F118, GeV F119,
UE (%) Output LY (%) Output Outpu	TSCHIRHART 81 ing data for averages, fits, 156 ACCIARRI 91 D DORFAN 81 → K*(1430) → π ⁻ = 0.33 to obtain the limit -)/\(\Gamma_{\text{total}}\times \text{B}(\frac{a_0(980)}{bOCUMENT ID})\) GOLDBERG 90	8 HRS $E_{\rm col}^{\rm ext}$, limits, etc. • 5F L3 199 1 MRK2 $E_{\rm col}^{\rm ext}$ $\overline{K}^0\nu_{\tau}$) < 0.1 1 shown. $\rightarrow K^0K^-$ TECN COMMITCALE OF $E_{\rm col}^{\rm ext}$	mment n = 29 GeV • • • • • • • • • • • • • • • • • • •	VALUE (units 10-4) < 2.0 • • • We do not < 90 Γ (η' (958) π - ν VALUE < 7.4 × 10-5 Γ (η' (958) π - π VALUE < 8.0 × 10-5	2L% 95 t use the followin, 95 (τ)/Γτοταί — <u>CL%</u> 90 - <u>CL%</u> 90 - <u>CL%</u> 90	ARTUSO Ig data for average: ALBRECHT DOCUMENT ID BERGFELD	92 CLEO s, fits, limits, 88M ARG TECN 97 CLEO	$E_{\text{CM}}^{\text{ee}} \approx 10.6$ etc. • • • $E_{\text{CM}}^{\text{ee}} \approx 10$ $C_{\text{CMMENT}}^{\text{COMMENT}}$ $E_{\text{CM}}^{\text{ee}} = 10.6$ $C_{\text{CMMENT}}^{\text{COMMENT}}$	GeV F118, GeV F119,
UE (%) CL% EVTS 95 • We do not use the following of t	TSCHIRHART 81 Ing data for averages, fits, 156 ACCIARRI 91 DORFAN 81 → K*(1430) → π ⁻ = 0.33 to obtain the limit -)/\(\tau_{\text{total}}\) × B(a_0(980) \(\text{DOCUMENT ID}\) BOCUMENT ID EVTS DOCUMENT ID	8 HRS $E_{\rm col}^{\rm eq}$, limits, etc. • 5F L3 199 1 MR42 $E_{\rm col}^{\rm eq}$ $\overline{K}^0 \nu_{\tau}$) < 0.1 shown. $\rightarrow K^0 K^-$) \underline{TECN} \underline{COM}	###ENT 29 GeV 1-1993 LEP runs 1-1993 LEP runs 1-1995 LEP	$VALUE (units 10^{-4})$ < 2.0 • • • We do not < 90 $\Gamma(\eta'(958)\pi^{-}\nu)$ $VALUE$ < 7.4 × 10 ⁻⁵ $\Gamma(\eta'(958)\pi^{-}\pi)$ $VALUE$	2L% 95 t use the followin, 95 (τ)/Γτοταί — <u>CL%</u> 90 - <u>CL%</u> 90 - <u>CL%</u> 90	ARTUSO Ig data for average: ALBRECHT DOCUMENT ID BERGFELD	92 CLEO s, fits, limits, 88M ARG TECN 97 CLEO TECN 97 CLEO	$E_{\text{CM}}^{\text{ee}} \approx 10.6$ etc. • • • $E_{\text{CM}}^{\text{ee}} \approx 10$ $C_{\text{CMMENT}}^{\text{COMMENT}}$ $E_{\text{CM}}^{\text{ee}} = 10.6$ $C_{\text{CMMENT}}^{\text{COMMENT}}$	GeV F118 GeV F119 GeV
$\frac{VE}{3}$ 95 • We do not use the following of the fo	TSCHIRHART 81 Ing data for averages, fits. 156 ACCIARRI 91 DORFAN 83 → K*(1430) → π = 0.33 to obtain the limit -)/\(\text{Total}\) × B(a0(980) \(\text{DOCUMENT ID}\) GOLDBERG 90 EVTS DOCUMENT ID BARTELT	8 HRS $E_{\rm col}^{\rm CR}$, limits, etc. • 5F L3 199 1 MRK2 $E_{\rm col}^{\rm CR}$ 0 $\nu_{\rm T}$) < 0.1 shown. \rightarrow K^0 K^-) $T_{\rm COL}$ $T_{\rm $	###ENT \$\frac{1}{2} = 29 \text{ GeV}\$ \$\frac{1}{2} = 4.2 - 6.7 \text{ GeV}\$ \$\frac{1}{2} = 6.7 \text{ GeV}\$ \$\frac{1}{2} = 6.7 \text{ GeV}\$ \$\frac{1}{2} = 6.6 \text{ GeV}\$	$VALUE$ (units 10-4) < 2.0 • • • We do not < 90 $\Gamma(\eta'(958)\pi^{-}\nu)$ $VALUE$ < 7.4 × 10-5 $\Gamma(\eta'(958)\pi^{-}\pi)$ $VALUE$ < 8.0 × 10-5 $\Gamma(\phi\pi^{-}\nu_{\tau})/\Gamma_{tx}$ $VALUE$ < 2.0 × 10-4	CLN 95 t use the followin, 95 (γ) / Γ total CLN 90 (σ) (ν _τ) / Γ total CLN 90 (σ)	ARTUSO Ig data for average: ALBRECHT DOCUMENT ID BERGFELD DOCUMENT ID BERGFELD DOCUMENT ID AVERY	92 CLEO 5, flts, limits, 88M ARG 7ECN 97 CLEO 7ECN 97 CLEO 7ECN 97 CLEO	$E_{\text{CM}}^{\text{CM}} \approx 10.6$ etc. • • • $E_{\text{CM}}^{\text{CM}} \approx 10$ $C_{\text{CMMENT}}^{\text{CMMENT}}$ $E_{\text{CM}}^{\text{CM}} = 10.6$ $C_{\text{CMMENT}}^{\text{CMMENT}}$ $E_{\text{CM}}^{\text{CM}} = 10.6$ $C_{\text{CMMENT}}^{\text{CMMENT}}$ $E_{\text{CM}}^{\text{CM}} = 10.6$	GeV F118 GeV F119 GeV F120
UE (%) CL% EVTS 95 • We do not use the following of t	TSCHIRHART 81 Ing data for averages, fits, 156 ACCIARRI 91 DORFAN 8: → K*(1430) → π = 0.33 to obtain the limit -)/\(\text{Total}\) × B(a0(980) \(\text{DOCUMENT ID}\) GOLDBERG 90 EVTS \(\text{DOCUMENT ID}\) 0 \(\text{BARTELT}\) Ing data for averages, fits,	8 HRS $E_{\rm cen}^{\rm CR}$, limits, etc. • SF L3 199 1 MRK2 $E_{\rm cen}^{\rm CR}$ $E_{\rm cen}^$	###ENT \$\frac{1}{2} = 29 \text{ GeV} \$\text{1} = 4.2-6.7 \text{ GeV} \$1%. We divide by \[\begin{align*} \Gamma_{100} / \Gamma \text{ B} \\ \text{ENT} \\ \text{2} = 9.4-10.9 \text{ GeV} \] \$\frac{COMMENT}{ECC} \text{ \$\text{106} \text{ GeV}} \$\text{ \$\text{106} \text{ GeV}}	$VALUE$ (units 10 ⁻⁴) < 2.0 • • • • We do not < 90 $\Gamma(\eta'(958)\pi^{-}\nu)$ $VALUE$ < 7.4 × 10 ⁻⁵ $\Gamma(\eta'(958)\pi^{-}\pi)$ $VALUE$ < 8.0 × 10 ⁻⁵ $\Gamma(\phi\pi^{-}\nu_{\tau})/\Gamma_{tx}$ $VALUE$ < 2.0 × 10 ⁻⁴ • • • We do not	t use the following $\frac{cL\%}{95}$ t use the following $\frac{cL\%}{90}$ $\frac{O}{V_T}$ $\frac{O}{V_T}$ $\frac{CL\%}{90}$ $\frac{O}{V_T}$ $\frac{CL\%}{90}$ t use the following tuse the following $\frac{CL\%}{90}$	ARTUSO Ig data for average: ALBRECHT DOCUMENT ID BERGFELD DOCUMENT ID BERGFELD DOCUMENT ID SERGFELD DOCUMENT ID AND SER	92 CLEO s, flts, limits, 88M ARG 7ECN 97 CLEO 7ECN 97 CLEO 7ECN 97 CLEO	$E_{\text{CM}}^{\text{ex}} \approx 10.6$ etc. • • • $E_{\text{CM}}^{\text{ex}} \approx 10$ $C_{\text{CMMENT}}^{\text{ex}} = 10.6$ etc. • • •	GeV F118 GeV F119 GeV F120
2. $\frac{(K)}{3}$ 95 • We do not use the following of the	TSCHIRHART 81 Ing data for averages, fits, 156 ACCIARRI 91 DORFAN 83 → K*(1430) → π = 0.33 to obtain the limit -)/\(\text{Total} \times \text{B}(\text{a}0(980)) \(\text{DOCUMENT ID}\) GOLDBERG 90 EVTS \(\text{DOCUMENT ID}\) 0 \(\text{BARTELT}\) Ing data for averages, fits, BUSKULIC	8 HRS $E_{\rm col}^{\rm CR}$, limits, etc. • 5F L3 199 1 MRK2 $E_{\rm col}^{\rm CR}$ $V_{\rm T}$) < 0.1 shown. \rightarrow K^0 K^-) $TECN$ $COMMS$ CLEO $E_{\rm col}^{\rm CR}$ $TECN$ 96 CLEO, limits, etc. • 97C ALEP	######################################	$VALUE$ (units 10 ⁻⁴) < 2.0 • • • • We do not <90 Γ (η' (958) $\pi^- \nu$ $VALUE$ <7.4 × 10 ⁻⁵ Γ (η' (958) $\pi^- \pi$ $VALUE$ <8.0 × 10 ⁻⁵ Γ ($\phi \pi^- \nu_\tau$) / Γ χ $VALUE$ <2.0 × 10 ⁻⁴ • • • We do not <3.5 × 10 ⁻⁴	t use the following 95 t use the following 95 $(\tau)/\Gamma_{\text{total}}$ $CL\%$ 90 $CL\%$ 90 otal $CL\%$ 90 t use the following 90	ARTUSO Ig data for average: ALBRECHT DOCUMENT ID BERGFELD DOCUMENT ID BERGFELD DOCUMENT ID SERGFELD ALBRECHT ALBRECHT	92 CLEO s, flts, limits, 88M ARG 7ECN 97 CLEO 7ECN 97 CLEO 7ECN 97 CLEO 5, flts, limits, 95H ARG	$E_{\text{CM}}^{\text{CM}} \approx 10.6$ etc. • • • $E_{\text{CM}}^{\text{CM}} \approx 10$ $C_{\text{CMMENT}}^{\text{CMMENT}}$ $E_{\text{CM}}^{\text{CM}} = 10.6$ $C_{\text{CMMENT}}^{\text{CMMENT}}$ $E_{\text{CM}}^{\text{CM}} = 10.6$ etc. • • • $E_{\text{CM}}^{\text{CM}} = 9.4-1$	GeV F118 GeV F119 GeV F120 GeV F0.6 GeV
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E (%) CL% EVTS S S S S S S S S S	TSCHIRHART 81 Ing data for averages, fits. 156 ACCIARRI 91 DORFAN 8: → K*(1430) → π = 0.33 to obtain the limit -)/Ftotal × B(a0(980) DOCUMENT ID GOLDBERG 90 EVTS DOCUMENT ID 0 BARTELT Ing data for averages, fits, BUSKULIC ARTUSO ALBRECHT	8 HRS $E_{\rm col}^{\rm CR}$, limits, etc. • 5F L3 199 1 MRK2 $E_{\rm col}^{\rm CR}$ $V_{\rm T}$) < 0.1 shown. \rightarrow K^0 K^-) $TECN$ COMMIC CLEO $E_{\rm col}^{\rm CR}$ = $TECN$ 96 CLEO, limits, etc. • 97C ALEP 92 CLEO 88M ARG	"n= 29 GeV "1= 4.2-6.7 GeV 1%. We divide by F108 F × B ENT 9.4-10.9 GeV F206 F207 F208 F207 F208 F208 F208 F208 F208 F208 F208 F208 F208 F208 F208 F208 F208 F208 F208 F208 F208 F208 F208	$ \begin{array}{c} VALUE (\text{units } 10^{-4}) \\ < 2.0 \\ \bullet \bullet \bullet \text{ We do not} \\ < 90 \\ \hline \Gamma \left(\eta' \left(958 \right) \pi^{-} \nu \right. \\ VALUE \\ < 7.4 \times 10^{-5} \\ \hline \Gamma \left(\eta' \left(958 \right) \pi^{-} \pi \right. \\ VALUE \\ < 8.0 \times 10^{-5} \\ \hline \Gamma \left(\phi \pi^{-} \nu_{\tau} \right) / \Gamma_{\text{tx}} \\ VALUE \\ < 2.0 \times 10^{-4} \\ \bullet \bullet \bullet \text{ We do not} \\ < 3.5 \times 10^{-4} \\ \hline 158 \text{AVERY } 97 \text{lin} \end{array} $	t use the following $(r_{\tau})/\Gamma_{\text{total}}$ $\frac{CLN}{95}$ $\frac{CLN}{90}$ $\frac{CLN}{90}$ otal $\frac{CLN}{90}$ t use the following $\frac{CLN}{90}$ mit varies from (1)	ARTUSO Ig data for average: ALBRECHT DOCUMENT ID BERGFELD DOCUMENT ID BERGFELD DOCUMENT ID SERGFELD ALBRECHT ALBRECHT	92 CLEO s, flts, limits, 88M ARG 7ECN 97 CLEO 7ECN 97 CLEO 7ECN 97 CLEO 5, flts, limits, 95H ARG	$E_{\text{CM}}^{\text{CM}} \approx 10.6$ etc. • • • $E_{\text{CM}}^{\text{CM}} \approx 10$ $C_{\text{CMMENT}}^{\text{CMMENT}}$ $E_{\text{CM}}^{\text{CM}} = 10.6$ $C_{\text{CMMENT}}^{\text{CMMENT}}$ $E_{\text{CM}}^{\text{CM}} = 10.6$ etc. • • • $E_{\text{CM}}^{\text{CM}} = 9.4-1$	GeV F118 GeV F119 GeV F120 GeV 0.6 GeV ssumptio
	TSCHIRHART 81 Ing data for averages, fits. 156 ACCIARRI 91 DORFAN 83 → K*(1430) → π = 0.33 to obtain the limit -)/\(\text{Total} \times \text{B}(\text{a}0(980)) \(\text{DOCUMENT ID}\) GOLDBERG 90 EVTS \(\text{DOCUMENT ID}\) 0 BARTELT Ing data for averages, fits, BUSKULIC ARTUSO ALBRECHT BEHREND	8 HRS $E_{\rm col}^{\rm CR}$, limits, etc. • 5F L3 199 1 MRK2 $E_{\rm col}^{\rm CR}$ $V_{\rm T}$) < 0.1 shown. \rightarrow K^0 K^-) $TECN$ COMMIC CLEO $E_{\rm col}^{\rm CR}$ = $TECN$ 96 CLEO, limits, etc. • 97C ALEP 92 CLEO 88M ARG 88 CELL	"n= 29 GeV 1-1-1993 LEP runs 1-1-1993 LEP runs 1-1-1993 LEP runs 1-1-1994 LEP 1-10-1994 LEP 1-1994 LEP 1-1994 LEP 1-1994 LEP 1-1995 10.6 GeV 1-1991-1994 LEP 1-1995 10.6 GeV 1-1995 10.6 GeV 1-1995 10.6 GeV	$VALUE$ (units 10 ⁻⁴) < 2.0 • • • • We do not <90 Γ (η' (958) $\pi^- \nu$ $VALUE$ <7.4 × 10 ⁻⁵ Γ (η' (958) $\pi^- \pi$ $VALUE$ <8.0 × 10 ⁻⁵ Γ ($\phi \pi^- \nu_\tau$) / Γ _{tx} $VALUE$ <2.0 × 10 ⁻⁴ • • • We do not <3.5 × 10 ⁻⁴ 158 AVERY 97 III Γ ($\phi K^- \nu_\tau$) / Γ _{tx} $VALUE$	t use the following $(r_{\tau})/\Gamma_{\text{total}}$ $\frac{CLN}{95}$ $\frac{CLN}{90}$ $\frac{CLN}{90}$ otal $\frac{CLN}{90}$ t use the following 90 mit varies from (1)	ARTUSO Ig data for average: ALBRECHT DOCUMENT ID BERGFELD DOCUMENT ID BERGFELD 158 AVERY Ig data for average: ALBRECHT 1.2-2.0) × 10 ⁻⁴ do	92 CLEO s, flts, limits, 88M ARG 7ECN 97 CLEO 7ECN 97 CLEO 7ECN 97 CLEO 5, flts, limits, 95H ARG epending on	Ecm ≈ 10.6 etc. • • • Ecm ≈ 10.6 etc. • • • Ecm ≈ 10 comment Ecm = 10.6 comment	GeV F118 GeV F119 GeV F120 GeV F121 F121
$\frac{UE}{N}$ CL% EVT3 3 95 • We do not use the followid 33 95 99 95 C ACCIARRI 95F quote B(τ − B(K*(1430) − → π − \overline{K}^0) = $\frac{CL}{N}$ 8 × 10 − 4 90 1.4 95 • We do not use the followid 6.2 95 3.4 95 90 95 40 90 95	TSCHIRHART 81 Ing data for averages, fits. 156 ACCIARRI 91 DORFAN 8: → K*(1430) → π = 0.33 to obtain the limit -)/Total × B(a0(980) DOCUMENT ID GOLDBERG 90 EVTS DOCUMENT ID 0 BARTELT Ing data for averages, fits, BUSKULIC ARTUSO ALBRECHT BEHREND BARINGER	8 HRS $E_{\rm ce}^{\rm CR}$, limits, etc. • 5F L3 199 1 MRK2 $E_{\rm ce}^{\rm CR}$ $^{\rm O}\nu_{\rm T}$) < 0.1 shown. \rightarrow $K^{\rm O}$ K^{-}) $T_{\rm ECN}$ $C_{\rm COMMI}$ CLEO $E_{\rm ce}^{\rm CR}$ $=$ $T_{\rm ECN}$ 96 CLEO, limits, etc. • 97C ALEP 92 CLEO 88M ARG 88 CELL 87 CLEO	#####################################	$VALUE$ (units 10-4) < 2.0 • • • • We do not <90 Γ (η' (958) $\pi^- \nu$ $VALUE$ <7.4 × 10 ⁻⁵ Γ (η' (958) $\pi^- \pi$ $VALUE$ <8.0 × 10 ⁻⁵ Γ ($\phi \pi^- \nu_\tau$) / Γ _t $VALUE$ <2.0 × 10 ⁻⁴ • • • We do not <3.5 × 10 ⁻⁴ 158 AVERY 97 III Γ ($\phi K^- \nu_\tau$) / Γ _t $VALUE$ <6.7 × 10 ⁻⁵	CL 95 t use the following 95 (-) / Γ total CL 90 (-) ν _τ) / Γ total CL 90 t use the following 90 mit varies from (1) (-) (-) (-) (-) (-) (-) (-) (-) (-) (-)	ARTUSO Ig data for average: ALBRECHT DOCUMENT ID BERGFELD DOCUMENT ID 158 AVERY Ig data for average: ALBRECHT 1.2-2.0) × 10 ⁻⁴ document ID	92 CLEO s, flts, limits, 88M ARG 97 CLEO TECN 97 CLEO TECN 97 CLEO s, flts, limits, 95H ARG epending on TECN 97 CLEO	Ecm ≈ 10.6 etc. • • • • • • • • • • • • • • • • • • •	GeV F118 GeV F119 GeV F120 GeV SeV F121 GeV
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s,	Test of lepton 1	-				Γ ₁₂₉ ,
"		<u>CL%</u>				COMMENT
						etc a a a
-		_	-			
_						1990-1993 LEP runs
l	_					
	_					Ecm = 10 GeV
	<55 × 10 °	90	HAYES	82	MKK2	E ^{ee} _{Cm} = 3.8-6.8 GeV
	$\Gamma(e^-\pi^0)/\Gamma_{\text{total}}$					r ₁₃₀
		family number	conservation.			
	VALUE	<u> </u>	DOCUMENT ID			COMMENT
		90	BONVICINI			Ecm = 10.6 GeV
v	• • We do not use	the following	data for averages	s, fits,	łimits, e	etc. • • •
-	$< 17 \times 10^{-5}$	90	ALBRECHT	92K	ARG	<i>E</i> em == 10 GeV
	$< 14 \times 10^{-5}$	90	KEH	88	CBAL	Ecm= 10 GeV
	<210 × 10 ⁻⁵	90	HAYES	82	MRK2	Ecm = 3.8-6.8 GeV
	Γ/υ- σ ⁰ \ /Γ					Г ₁₃₁
		family number	conservation.			' 131
1	VALUE	CL%_	DOCUMENT ID		TECN	COMMENT
	$< 4.0 \times 10^{-6}$	90	BONVICINI	97	CLEO	Ecm = 10.6 GeV
	• • • We do not use	the following	data for averages			
						<i>Ee</i> e = 10 GeV
						Ecm = 3.8-6.8 GeV
	V02 × 10	,,,	114123	-		-cm- 5.5 5.5 GET
	F(e-K0)/Fmail					Γ ₁₃₂
	Test of lepton	family number	conservation.			
,	VALUE	<u>CL%</u>	DOCUMENT ID			COMMENT
:h	$<1.3 \times 10^{-3}$	90	HAYES	82	MRK2	Ecm = 3.8-6.8 GeV
→	E/ - 1/0\ /E					-
		6				F ₁₃₃
:h		*			TECN	COMMENT
ne				82		Ecm = 3.8-6.8 GeV
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	$\Gamma(e^-\eta)/\Gamma_{\text{total}}$					Γ ₁₃₄
.0		family number	conservation.			
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Έ	< 8.2 × 10 ⁻⁶	90	BONVICINI	97	CLEO	$E_{\text{cm}}^{\text{ee}} = 10.6 \text{ GeV}$
	• • • We do not use	the following	data for averages	s, fits,	llmits,	etc. • • •
	$< 6.3 \times 10^{-5}$	90	ALBRECHT	92K	ARG	Ecm = 10 GeV
	$< 24 \times 10^{-5}$	90	KEH	88	CBAL	Ecm= 10 GeV
·r	m/ - \/m					_
	$(\mu^-\eta)/1$ total	e 11				Γ ₁₃₅
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ı						Eee = 10.6 GeV
19	_					Ecm = 10 GeV
	(1.3 × 10	30	ALDRECITI	72K	-1110	-cm- 10 0cv
,	$\Gamma(e^-\rho^0)/\Gamma_{total}$					Γ ₁₃₆
(S,	Test of lepton					
3"	VALUE	<u>CL%</u>	DOCUMENT ID			COMMENT
_		90	BLISS			<i>E</i> cm= 10.6 GeV
				s, fits,	limits,	etc. • • •
	< 0.42 × 10 ⁻⁵	90 1				Repl. by BLISS 98
	< 1.9 × 10 ⁻⁵	90	ALBRECHT			$E_{\rm cm}^{\rm ee}$ = 10 GeV
→	<37 × 10 ⁻⁵	90	HAYES	82	MRK2	Ecm = 3.8-6.8 GeV
	1		ace decays			
	166 BARTELT 94 as	sume phase so:	ace uccays.			
		sume phase sp	ace uccays.			Γ ₁₃₇
72 .	$\Gamma(\mu^-\rho^0)/\Gamma_{\text{total}}$		•			
	$\Gamma(\mu^-\rho^0)/\Gamma_{\text{total}}$ Test of lepton	family number	conservation.		TECN	COMMENT
	$\Gamma(\mu^-\rho^0)/\Gamma_{\text{total}}$ Test of lepton VALUE	family number	conservation. <u>DOCUMENT ID</u>			COMMENT
	$\Gamma(\mu^{-}\rho^{0})/\Gamma_{\text{total}}$ Test of lepton $\frac{VALUE}{< 6.3 \times 10^{-6}}$	family number	conservation. <u>DOCUMENT ID</u> BLISS	98	CLEO	Ecm = 10.6 GeV
	$\Gamma(\mu^{-}\rho^{0})/\Gamma_{\text{total}}$ Test of lepton $\frac{VALUE}{< 6.3 \times 10^{-6}}$ • • • We do not use	family number <u>CL%</u> 90 the following	conservation. <u>DOCUMENT ID</u> BLISS data for average:	98 s, fits,	CLEO limits,	Ecm = 10.6 GeV etc. • • •
72	$\Gamma(\mu^-\rho^0)/\Gamma_{\rm total}$ Test of lepton $\frac{VALUE}{< 6.3 \times 10^{-6}}$ • • • We do not use $< 0.57 \times 10^{-5}$	family number CL% 90 the following	conservation. <u>DOCUMENT ID</u> BLISS data for average: 167 BARTELT	98 s, fits, 94	CLEO limits, CLEO	E ^{ee} _{CM} = 10.6 GeV etc. • • • Repl. by BLISS 98
	$\Gamma(\mu^-\rho^0)/\Gamma_{\text{total}}$ Test of lepton YALUE < 6.3 × 10 ⁻⁶ • • • We do not use < 0.57 × 10 ⁻⁵ < 2.9 × 10 ⁻⁵	family number CL% 90 e the following 90 90	conservation. <u>DOCUMENT ID</u> BLISS data for average: 167 BARTELT ALBRECHT	98 s, fits, 94 924	CLEO limits, CLEO ARG	Ecm = 10.6 GeV etc. • • • Repi. by BLISS 98 Ecm = 10 GeV
72	$\Gamma(\mu^-\rho^0)/\Gamma_{\text{total}}$ Test of lepton YALUE < 6.3 × 10 ⁻⁶ • • • We do not use < 0.57 × 10 ⁻⁵ < 2.9 × 10 ⁻⁵ < 44 × 10 ⁻⁵	family number CL% 90 e the following 90 90 90	r conservation. <u>POCUMENT ID</u> BLISS data for average: 167 BARTELT ALBRECHT HAYES	98 s, fits, 94 924	CLEO limits, CLEO ARG	Ecm = 10.6 GeV etc. • • • Repi. by BLISS 98 Ecm = 10 GeV
72	$\Gamma(\mu^-\rho^0)/\Gamma_{\text{total}}$ Test of lepton YALUE < 6.3 × 10 ⁻⁶ • • • We do not use < 0.57 × 10 ⁻⁵ < 2.9 × 10 ⁻⁵	family number CL% 90 e the following 90 90 90	r conservation. <u>POCUMENT ID</u> BLISS data for average: 167 BARTELT ALBRECHT HAYES	98 s, fits, 94 924	CLEO limits, CLEO ARG	Ecm = 10.6 GeV etc. • • • Repi. by BLISS 98 Ecm = 10 GeV
72	$\Gamma(\mu^-\rho^0)/\Gamma_{\text{total}}$ Test of lepton YALUE < 6.3 × 10 ⁻⁶ • • • We do not use < 0.57 × 10 ⁻⁵ < 2.9 × 10 ⁻⁵ < 2.4 × 10 ⁻⁵ 167 BARTELT 94 as	family number CLX 90 e the following 90 90 90 sume phase sp	r conservation. <u>POCUMENT ID</u> BLISS data for average: 167 BARTELT ALBRECHT HAYES	98 s, fits, 94 924	CLEO limits, CLEO ARG	E ^{©E} = 10.6 GeV etc. • • • Repi. by BLISS 98 E ^{©E} = 10 GeV E ^{©E} = 3.8-6.8 GeV
72	$\Gamma(\mu^-\rho^0)/\Gamma_{\text{total}}$ Test of lepton YALVE < 6.3 × 10 ⁻⁶ • • • We do not use < 0.57 × 10 ⁻⁵ < 2.9 × 10 ⁻⁵ < 44 × 10 ⁻⁵ 167 BARTELT 94 ass $\Gamma(e^-K^*(892)^0)/\Gamma_{\text{total}}$	family number 21% 90 e the following 90 90 90 sume phase sp	conservation. <u>DOCUMENT ID</u> BLISS data for average: 167 BARTELT ALBRECHT HAYES ace decays.	98 s, fits, 94 924	CLEO limits, CLEO ARG	E ^{SE} = 10.6 GeV etc. • • • Repl. by BLISS 98 E ^{SE} = 10 GeV E ^{SE} = 3.8-6.8 GeV
72	$\Gamma(\mu^-\rho^0)/\Gamma_{\text{total}}$ Test of lepton YALUE < 6.3 × 10 ⁻⁶ • • • We do not use < 0.57 × 10 ⁻⁵ < 2.9 × 10 ⁻⁵ < 2.4 × 10 ⁻⁵ 167 BARTELT 94 as	family number 21% 90 e the following 90 90 90 sume phase sp	conservation. <u>DOCUMENT ID</u> BLISS data for average: 167 BARTELT ALBRECHT HAYES ace decays.	98 s, fits, 94 924 82	CLEO limits, CLEO ARG MRK2	E ^{ee} _{CM} = 10.6 GeV etc. • • • Repl. by BLISS 98
72	Γ(μ - ρ 0)/Γ _{total} Test of lepton YALVE < 6.3 × 10 ⁻⁶ • • • We do not use < 0.57 × 10 ⁻⁵ < 2.9 × 10 ⁻⁵ < 44 × 10 ⁻⁵ 167 BARTELT 94 as: Γ(e - K *(892)0)/Test of lepton	family number CLX 90 e the following 90 90 sume phase sp. Footal family number	r conservation. DOCUMENT ID BLISS data for average: 167 BARTELT ALBRECHT HAYES ace decays. r conservation.	98 s, fits, 94 92k 82	CLEO limits, CLEO ARG MRK2	E ^{cc} m = 10.6 GeV etc. • • • Repl. by BLISS 98 E ^{cc} m = 10 GeV E ^{cc} m = 3.8-6.8 GeV
72	$\Gamma(\mu^-\rho^0)/\Gamma_{\text{total}}$ Test of lepton YALUE < 6.3 × 10 ⁻⁶ • • • We do not use < 0.57 × 10 ⁻⁵ < 2.9 × 10 ⁻⁵ < 2.9 × 10 ⁻⁵ 167 BARTELT 94 as: $\Gamma(e^-K^*(892)^0)/\Gamma_{\text{Test of lepton}}$	family number CLX 90 the following 90 90 90 sume phase sp. Frotal family number CLX 90	r conservation. DOCUMENT ID BLISS data for average: 167 BARTELT ALBRECHT HAYES ace decays. r conservation. DOCUMENT ID BLISS	98 s, fits, 94 92k 82	CLEO limits, CLEO ARG MRK2	E ^{cc} _{Cm} = 10.6 GeV etc. • • • Repl. by BLISS 98 E ^{cc} _{Cm} = 10 GeV E ^{cc} _{Cm} = 3.8-6.8 GeV - COMMENT E ^{cc} _{Cm} = 10.6 GeV
72	$\Gamma(\mu^-\rho^0)/\Gamma_{\text{total}}$ Test of lepton YALUE < 6.3 × 10 ⁻⁶ • • • We do not use < 0.57 × 10 ⁻⁵ < 2.9 × 10 ⁻⁵ < 44 × 10 ⁻⁵ 167 BARTELT 94 as: $\Gamma(e^-K^*(892)^0)/\Gamma_{\text{Test of lepton}}$ YALUE <5.1 × 10 ⁻⁶	family number 20% 90 e the following 90 90 90 sume phase sp. Footal family number 20% 90 e the following	r conservation. DOCUMENT ID BLISS data for average: 167 BARTELT ALBRECHT HAYES ace decays. r conservation. DOCUMENT ID BLISS	98 s, fits, 94 92H 82 98	CLEO limits, CLEO ARG MRK2	E ^{cc} _{Cm} = 10.6 GeV etc. • • • Repl. by BLISS 98 E ^{cc} _{Cm} = 10 GeV E ^{cc} _{Cm} = 3.8-6.8 GeV - COMMENT E ^{cc} _{Cm} = 10.6 GeV
		Test of lepton to the property of lepton to	Test of lepton family number VALUE 2.3.0 × 10 ⁻⁶ 90 ••• We do not use the following $< 6.2 \times 10^{-5}$ 90 $< 0.42 \times 10^{-5}$ 90 $< 3.4 \times 10^{-5}$ 90 $< 3.4 \times 10^{-5}$ 90 $< 3.5 \times 10^{-5}$ 90 ••• We do not use the following $< 10^{-5} \times 10^{-5}$ 90 ••• We do not use the following $< 10^{-5} \times 10^{-5}$ 90 $< 10^{-5} \times$	Test of lepton family number conservation. VALUE 2.3.0 × 10 ⁻⁶ 90 EDWARDS • • • We do not use the following data for averages: $< 6.2 \times 10^{-5}$ 90 ABREU $< 0.42 \times 10^{-5}$ 90 BEAN $< 3.4 \times 10^{-5}$ 90 ALBRECHT $< 55 \times 10^{-5}$ 90 HAYES	Trist of lepton family number conservation. YALUE 2.3.0 × 10^-6 90 EDWARDS 97 • • • We do not use the following data for averages, fits, $< 6.2 \times 10^{-5}$ 90 BEAN 93 $< 3.4 \times 10^{-5}$ 90 BEAN 93 $< 3.4 \times 10^{-5}$ 90 ALBRECHT 92× $< 55 \times 10^{-5}$ 90 HAYES 82	Test of lepton family number conservation. VALUE 3.0 × 10^-6 90 EDWARDS 97 CLEO • • • We do not use the following data for averages, fits, limits, 6 < 6.2 × 10^-5 90 BEAN 93 CLEO < 3.4 × 10^-5 90 ALBRECHT 72× ARG <55 × 10^-5 90 ALBRECHT Test of lepton family number conservation. VALUE 3.7 × 10^-5 90 ALBRECHT Test of lepton family number conservation. VALUE 3.7 × 10^-5 90 ALBRECHT 70 • • • We do not use the following data for averages, fits, limits, 6 < 17 × 10^-5 90 ALBRECHT 72× ARG < 14 × 10^-5 90 ALBRECHT 72× ARG < 14 × 10^-5 90 BONVICINI 75 76 77 76 78 79 ALBRECHT 79 78 78 79 ALBRECHT 79 78 78 78 79 ALBRECHT 79 78 78 78 78 79 ALBRECHT 78 78 78 78 78 78 78 78 78 7

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(µ ⁻ K*(892) ⁰)/(Test of lepton f	family numbe			F ₁₃₉ /[Γ(μ ⁻ e ⁺ e ⁻)/Γ _{total} Test of lepton fa	mily number				Γ ₁₄₉
ALUE	<u>cr</u> #	DOCUMENT ID		COMMENT		< 1.7 × 10 ⁻⁶	<u>CL%</u> _	DOCUMENT ID			COMMENT
<7.5 × 10 ⁻⁶	90	BLISS		D Ecm = 10.6 GeV		< 1.7 × 10 • • • • We do not use t	90 the following (BLISS			Ecm = 10.6 GeV
We do not use		-				$< 0.34 \times 10^{-5}$		75 BARTELT			Repl. by BLISS 98
<0.94 × 10 ⁻⁵ <4.5 × 10 ⁻⁵	90 90	169 BARTELT ALBRECHT		Repl. by BLISS 98 Ecc = 10 GeV		$< 1.4 \times 10^{-5}$	90	ALBRECHT			Ecm = 10 GeV
			JZN ANG	rem= 10 GeV		< 2.7 × 10 ⁻⁵	90	BOWCOCK			Ecm = 10.4-10.9
⁶⁹ BARTELT 94 ass	iume phase sp	sace decays.				$<44 \times 10^{-5}$	90	HAYES			Ecm = 3.8-6.8 GeV
$(e^{-}\overline{K}^{*}(892)^{0})/[$	F _{total}			Γ ₁₄₀ /ί	Γ	¹⁷⁵ BARTELT 94 assu	me phase spac	ce decays.			Ciii
Test of lepton f			TF 614	CO111517							-
<7.4 × 10 ⁻⁶	<u>CL%</u> 90	DOCUMENT ID BLISS		COMMENT	- ₁	$\Gamma(\mu^+e^-e^-)/\Gamma_{ ext{total}}$ Test of lepton fa	mily number	conservation			Γ ₁₅₀
				Ecm = 10.6 GeV	•	VALUE	CL%	DOCUMENT ID		TECN	COMMENT
We do not use						<1.5 × 10 ⁻⁶	90	BLISS	98		Ecm = 10.6 GeV
<1.1 × 10 ^{−5}		¹⁷⁰ BARTELT	94 CLEO	Repl. by BLISS 98		• • We do not use to					
⁷⁰ BARTELT 94 ass	sume phase sp	pace decays.				$< 0.34 \times 10^{-5}$		76 BARTELT			Repl. by BLISS 98
$(\mu^- \overline{K}^* (892)^0) / I$	Гана			Γ ₁₄₁ /Ι		$<1.4 \times 10^{-5}$	90	ALBRECHT		ARG	Ecm = 10 GeV
Test of lepton 1		er conservation.		. 1411 .	•	$<1.6 \times 10^{-5}$	90	BOWCOCK	90	CLEO	ECT = 10.4-10.9
ALUE	CL%	DOCUMENT ID	TECN	COMMENT		¹⁷⁶ BARTELT 94 assu	me ohase soa	ce decays.			•
(7.5 × 10 ^{—6}	90	BLISS	98 CLEO	$E_{cm}^{ee} = 10.6 \text{ GeV}$				ce accays.			_
 We do not use 	e the following	g data for average	es, fits, limits	, etc. • • •		$\Gamma(\mu^-\mu^+\mu^-)/\Gamma_{\text{tota}}$	1				Γ ₁₅₁
0.87 × 10 ⁵	90 1	¹⁷¹ BARTELT	94 CLEO	Repl. by BLISS 98		Test of lepton fa	mily number	CONSERVATION, DOCUMENT ID		TECN	COMMENT
¹ BARTELT 94 ass	sume phase si	pace decays.			-	< 1.9 × 10 ⁻⁶	90	BLISS	98		Ecm = 10.6 GeV
		• •			-	• • • We do not use t					
(e φ)/Γ _{total}	familia	ar annaar:+!		Γ ₁₄₂ /ί	i '	< 0.43 × 10 ⁻⁵		77 BARTELT			Repl. by BLISS 98
Test of lepton t	tamily numbe	er conservation. <u>DOCUMENT ID</u>	TECN	COMMENT		< 1.9 × 10 ⁻⁵	90	ALBRECHT		ARG	Ecm ≈ 10 GeV
6.9 × 10 ⁻⁶	90	BLISS		Ecm = 10.6 GeV	⁻ 1	< 1.7 × 10 ⁻⁵	90	BOWCOCK			Ecm ≈ 10.4-10.9
	,,,	J-100	CLLO	-cm- 10:0 GeA	•	<49 × 10 ⁻⁵	90	HAYES			Ecm = 3.8-6.8 GeV
$\mu^- \phi) / \Gamma_{\text{total}}$				Γ ₁₄₃ /Ι	Γ	177 BARTELT 94 assu					um =========
Test of lepton i	family number	er conservation.		,				ce decays.		,	
LUE	<u> </u>	DOCUMENT ID		COMMENT		$\Gamma(e^-\pi^+\pi^-)/\Gamma_{tota}$	1 .				۲ ₁₅₃
7.0 × 10 ^{—6}	90	BLISS	98 CLEO	Ecm = 10.6 GeV	ı	Test of lepton fa					40144 TUT
				F //		<2.2 × 10 ⁻⁶	CL%_	DOCUMENT ID			COMMENT
π [−] γ)/Γ _{total} Test of lepton :	number cons	en atlan		Γ ₁₄₄ /Ι			90	BLISS			Ecm≈ 10.6 GeV
UE	CL%	DOCUMENT ID	TECN	COMMENT		• • We do not use 1					
28 × 10 ⁻⁵	90	ALBRECHT	92K ARG	Eee = 10 GeV	_	<0.44 × 10 ⁻⁵		78 BARTELT			Repl. by BLISS 98
				-cm		<2.7 × 10 ⁻⁵	90	ALBRECHT		ARG	E cm = 10 GeV
$(\pi^-\pi^0)/\Gamma_{ ext{total}}$				Γ ₁₄₅ /Ι	Γ	<6.0 × 10 ⁻⁵	90	BOWCOCK	90	CLEO	Ecm = 10.4-10.9
Test of lepton	number cons					¹⁷⁸ BARTELT 94 assu	me phase spa	ce decays.			
LUE	CL%	DOCUMENT ID			-	$\Gamma(e^+\pi^-\pi^-)/\Gamma_{\text{tota}}$					Γ ₁₅₃
37 × 10 ⁻⁵	90	ALBRECHT	92K ARG	Ecm= 10 GeV		Test of lepton n	umber conserv	vation.			- 200
(e ⁻ e ⁺ e ⁻)/Γ _{tota}				Γ ₁₄₆ /	г	VALUE	<u>CL%</u>	DOCUMENT ID			COMMENT
		er conservation.		146/		<1.9 × 10 ⁻⁶	90	BLISS			$E_{\rm CM}^{\rm ee}$ = 10.6 GeV
LUE	CL%	DOCUMENT IL	D TECH	COMMENT	_	• • We do not use					
2.9×10^{-6}	90	BLISS	98 CLE	O Ecm = 10.6 GeV	ı	<0.44 × 10 ⁻⁵		⁷⁹ BARTELT			Repl. by BLISS 98
• We do not use	e the followin	g data for average	es, fits, limit:	s, etc. • • •		<1.8 × 10 ⁻⁵	90	ALBRECHT		ARG	Ecm = 10 GeV
0.33×10^{-5}	90	172 BARTELT		O Repl. by BLISS 98		<1.7 × 10 ⁻⁵	90	BOWCOCK	90	CLEO	Ecm = 10.4-10.9
1.3×10^{-5}	90	ALBRECHT				¹⁷⁹ BARTELT 94 assu	me phase spa	ce decays.			
2.7×10^{-5}	90	вомсоск		O Ecm = 10.4-10.9		$\Gamma(\mu^-\pi^+\pi^-)/\Gamma_{\text{tota}}$					Γ ₁₅₄
40 × 10 ⁻⁵	90	HAYES		(2 Ecm = 3.8-6.8 GeV		Test of lepton fa		conservation.			154
BARTELT 94 ass				-		VALUE	CL%_	DOCUMENT ID		TECN	COMMENT
		per mentage.				<8.2 × 10 ⁻⁶	90	BLISS	98	CLEO	Ecm = 10.6 GeV
$e^-\mu^+\mu^-)/\Gamma_{ m tot}$				Γ ₁₄₇ /	Г	• • We do not use					
		er conservation.	n			$< 0.74 \times 10^{-5}$	90 1	⁸⁰ BARTELT	94	CLEO	Repl. by BLISS 98
.UE	<u> </u>	DOCUMENT IL		COMMENT	- ,	<3.6 × 10 ⁻⁵	90	ALBRECHT	92K	ARG	Ecm = 10 GeV
1.8 × 10 ⁻⁶	90	BLISS		O Ecm = 10.6 GeV	•	<3.9 × 10 ⁻⁵	90	BOWCOCK			Ecm = 10.4-10.9
• We do not use						¹⁸⁰ BARTELT 94 assu	ime phase spa	ce decays.			
0.36×10^{-5}	90	173 BARTELT		O Repl. by BLISS 98				•			-
1.9 × 10 ⁻⁵	90	ALBRECHT		Ecm = 10 GeV		$\Gamma(\mu^+\pi^-\pi^-)/\Gamma_{\text{tota}}$ Test of lepton n	il umber conson	vation			Γ ₁₅₄
2.7 × 10 ⁻⁵	90	BOWCOCK	90 CLE	O Ecm = 10.4-10.9		VALUE	CL%	DOCUMENT ID	_	TECN	COMMENT
33 × 10 ⁻⁵	90	HAYES	82 MRH	$E_{cm}^{ee} = 3.8 - 6.8 \text{ GeV}$		<3.4 × 10 ⁻⁶	90	BLISS	98		Ecm = 10.6 GeV
BARTELT 94 ass	sume phase s	pace decays.				• • We do not use:					
				r ₁₄₈ /		<0.69 × 10 ⁻⁵		81 BARTELT			Repl. by BLISS 98
e+ μ~ μ=\ /Γ		er conservation.		' 148/	•	<6.3 × 10 ⁻⁵	90	ALBRECHT			Ecm = 10 GeV
	CL%	DOCUMENT IL	D TECI	COMMENT		<3.9 × 10 ⁻⁵	90	вомсоск			Ecm = 10.4~10.9
Test of lepton		BLISS		O Ecm = 10.6 GeV	1	181 BARTELT 94 assu			-		
Test of lepton	90	g data for averag									
Test of lepton 1.5 × 10 ⁻⁶		•		O Repl. by BLISS 98		$\Gamma(e^-\pi^+K^-)/\Gamma_{\text{total}}$	ol	-4			Γ ₁₅₆
Test of lepton LUE 1.5 × 10 ⁻⁶ • • We do not use		174 BARTELT				Test of lepton fa				TEC	COMMENT
Test of lepton LUE 1.5 × 10 ⁻⁶ • • We do not use 0.35 × 10 ⁻⁵	e the followin	174 BARTELT ALBRECHT	92K ARG	Ečm= 10 Gev		VALUE	CL%	DOCUMENT ID			COMMENT
Test of lepton LUE 1.5 × 10 ⁻⁶ • • We do not use 0.35 × 10 ⁻⁵ 1.8 × 10 ⁻⁵	e the followin 90			Ecm = 10 GeV O Ecm = 10.4-10.9		-64 - 40-6	00	DIFC	00	CIFC	E66 _ 10 4 C-1/
Test of lepton LUE 1.5 × 10 ⁻⁶ • • We do not use 0.35 × 10 ⁻⁵ 1.8 × 10 ⁻⁵ 1.6 × 10 ⁻⁵	e the followin 90 90 90	ALBRECHT BOWCOCK		O Ecm = 10.4-10.9		<6.4 × 10 ⁻⁶	90 the following	BLISS			Ecm = 10.6 GeV
Test of lepton UE 1.5 × 10-6 • We do not use 0.35 × 10-5 1.8 × 10-5 1.6 × 10-5	e the followin 90 90 90	ALBRECHT BOWCOCK				• • • We do not use	the following	data for averages	, fits,	, limits,	etc. • • •
Test of lepton LUE 1.5 × 10 ⁻⁶ • • We do not use 0.35 × 10 ⁻⁵ 1.8 × 10 ⁻⁵ 1.6 × 10 ⁻⁵	e the followin 90 90 90	ALBRECHT BOWCOCK				• • • We do not use $< 0.77 \times 10^{-5}$	the following 90 1	data for averages ⁸² BARTELT	, fits, 94	, limits, CLEO	etc. • • • Repl. by BLISS 98
Test of lepton LUE 1.5 × 10 ⁻⁶ • • We do not use 0.35 × 10 ⁻⁵ 1.8 × 10 ⁻⁵ 1.6 × 10 ⁻⁵	e the followin 90 90 90	ALBRECHT BOWCOCK				• • • We do not use $<0.77 \times 10^{-5}$ $<2.9 \times 10^{-5}$	the following 90 1 90	data for averages ⁸² BARTELT ALBRECHT	, fits, 94 92H	, limits, CLEO k ARG	etc. • • • Repl. by BLISS 98 Eee = 10 GeV
(e ⁺ $\mu^-\mu^-$)/ Γ_{tot} Test of lepton MUE 1.1.5 × 10 ⁻⁶ • • We do not use 10.35 × 10 ⁻⁵ 1.8 × 10 ⁻⁵ 1.6 × 10 ⁻⁵ 1.6 × 10 ⁻⁵ 1.4 BARTELT 94 ass	e the followin 90 90 90	ALBRECHT BOWCOCK				• • • We do not use $< 0.77 \times 10^{-5}$	the following 90 1 90 90	data for averages 82 BARTELT ALBRECHT BOWCOCK	, fits, 94 92H	, limits, CLEO k ARG	etc. • • • Repl. by BLISS 98

$(e^-\pi^-K^+)/\Gamma_{to}$	tal .				Γ ₁₅₇ /Γ
	family number				
ALUE		DOCUMENT ID			
<3.8 × 10 ⁻⁶	90	BLISS	98 CLEO		eV
• • We do not use					
(0.46 × 10 ⁻⁵		3 BARTELT	94 CLEO		
(5.8 × 10 ⁻⁵	90	BOWCOCK	90 CLEO	Ecm = 10.4-16	0.9
⁸³ BARTELT 94 as:	ume phase spa	ce decays.			
$(e^+\pi^-K^-)/\Gamma_{tc}$					Γ ₁₅₈ /Γ
	Cai number conser	vation			156/
ALUE	<u>CL%</u>	DOCUMENT ID	TECN	COMMENT	
2.1 × 10 ⁻⁶	90	BLISS		Eee = 10.6 (GeV
We do not us					
0.45 × 10 ⁻⁵		84 BARTELT		Repl. by BLI	CC 00
2.0 × 10 ⁻⁵	90	ALBRECHT		$E_{\text{Cm}}^{\text{ee}} = 10 \text{ Ge}$	
4.9 × 10 ⁻⁵	90	BOWCOCK		Ecm = 10.4-	
			30 CLL.	2 -cm - 10.4	10.7
³⁴ BARTELT 94 as	iume phase spa	ice decays.			
(e ⁻ K ⁺ K ⁻)/Γ _t	-4-1				Γ ₁₅₉ /Γ
Test of lepton	mai family number	conservation.			. 194/ .
LUE		DOCUMENT ID	TECN	COMMENT	
6.0 × 10 ⁻⁶	90	BLISS		Ecm = 10.6 G	
				CIII	
$(e^+K^-K^-)/\Gamma_t$	otal				Γ ₁₆₀ /Γ
Test of lepton	number conser	vation.			
NLUE	<u> </u>	DOCUMENT ID			
3.8 × 10 ^{—6}	90	BLISS	98 CLEO	Ecm = 10.6 G	eV
/+ ~-\ /-					F /F
$(\mu^-\pi^+K^-)/\Gamma_{tr}$	tal				Γ ₁₆₁ /Γ
LUE Test of lepton	family number 	DOCUMENT IS	TECA	COMMENT	
7.5 × 10 ⁻⁶	90	DITE	00 (15)	D Ecm = 10.6	CoV
					ue v
We do not us					
0.87 × 10 ⁻⁵		85 BARTELT		Repl. by BLI	
11 × 10 ⁻⁵	90	ALBRECHT		Ecm = 10 Ge	
7.7×10^{-5}	90	BOWCOCK	90 CLE) Ecm = 10.4-	10.9
³⁵ BARTELT 94 as	sume phase spa	ice decays.			
	famlly number	conservation.	TFG.		Γ ₁₆₂ /Γ
ILUE 6		DOCUMENT ID			
7.4 × 10 ⁻⁶	90	BLISS		Ecm = 10.6 G	ev
We do not us					
(1.5 × 10 ⁻⁵		6 BARTELT	94 CLEO	Repl. by BLIS	S 98
(7.7 × 10 ⁻⁵	90	BOWCOCK	90 CLEO	Ecm = 10.4-1	0.9
³⁶ BARTELT 94 as	sume phase spa	ice decays.			
/+ W-\ /C					- /-
$(\mu^+\pi^-K^-)/\Gamma_{ti}$	ital number senser	untlan			Г ₁₆₃ /Г
LUE	number conser	DOCUMENT IL) TECN	COMMENT	
7.0 × 10 ⁻⁶	90			$E_{\rm cm}^{\rm ee} = 10.6$	
. r.u x 40 -		data for average	عاسات مخاصم	2 Ecm= 10.6	GCV
• • We do not us					
(2.0 × 10 ⁻⁵		87 BARTELT			
(5.8 × 10 ⁻⁵	90	ALBRECHT		Ecm = 10 Ge	
(4.0 × 10 ⁻⁵	90	BOWCOCK	90 CLE	D Ecm = 10.4-	10.9
¹⁷ BARTELT 94 as	sume phase spa	ice decays.			
		-			
$(\mu^- K^+ K^-)/\Gamma_1$	otal				Γ ₁₆₄ /Γ
	family number	conservation.	TF. C.	COMMENT	
15 × 10 ⁻⁶	<u> </u>	DOCUMENT ID			
.13 X 1U =	90	BLISS	98 CLEO	Ecm = 10.6 G	ev
(μ ⁺ K ⁻ K ⁻)/Γ ₁					Far. /F
	otal number conser	vation			Γ ₁₆₅ /Γ
	CL%		TECN	COMMENT	
6.0 × 10 ⁻⁶	90	BLISS		Ecm = 10.6 G	
,			,,	-cm = 10.0 G	
	.1				Γ ₁₆₆ /Γ
(e- 2 0 2 0) /[conservation.			. 100/
$(e^-\pi^0\pi^0)/\Gamma_{\text{total}}$ Test of lepton	famlly number		TECN	COMMENT	
NEUE	family number	DOCUMENT ID			
4LUE	family number CL% 90	DOCUMENT ID	97 CLEO	Ecm = 10.6 G	eV
(6.5 × 10 ⁻⁶	90	BONVICINI	97 CLEO	Ecm = 10.6 G	eV
(6.5 × 10 ⁻⁶	90	BONVICINI	97 CLEO	Ecm = 10.6 G	eV Γ ₁₆₇ /Γ
$\frac{4UE}{(6.5 \times 10^{-6})} / \Gamma_{\text{tot}}$ Test of lepton	90 family number	BONVICINI conservation.			••
$(e^-\pi^0\pi^0)/\Gamma_{\text{total}}$ Test of lepton ALUE (6.5 × 10 ⁻⁶ $(\mu^-\pi^0\pi^0)/\Gamma_{\text{total}}$ Test of lepton ALUE	90 family number	BONVICINI conservation. DOCUMENT ID	TECN	COMMENT	Γ ₁₆₇ /Γ
(6.5 × 10 ⁻⁶) $(\mu^- \pi^0 \pi^0) / \Gamma_{\text{tot}}$ Test of lepton	90 family number	BONVICINI conservation. DOCUMENT ID	TECN		Γ ₁₆₇ /Γ
$\frac{410E}{(6.5 \times 10^{-6})}/\Gamma_{\text{bot}}$ Test of lepton $\frac{410E}{(14 \times 10^{-6})}$	90 ai family number	BONVICINI conservation. DOCUMENT ID	TECN	COMMENT	Γ ₁₆₇ /Γ
(6.5 × 10 ⁻⁶ $(\mu - \pi^0 \pi^0) / \Gamma_{\text{tot}}$ Test of lepton $\frac{3LUE}{(14 \times 10^{-6})}$ $(e^- \eta \eta) / \Gamma_{\text{total}}$	90 at family number CL% 90	BONVICINI conservation. DOCUMENT ID BONVICINI	TECN	COMMENT	Γ ₁₆₇ /Γ
($\mu = \frac{1}{2}$ ($\mu = \frac{1}{2}$ π^0) Γ total Test of lepton ($\mu = \frac{1}{2}$ π^0) Γ total Test of lepton	90 ai family number CL% 90 family number	BONVICINI conservation. <u>DOCUMENT ID</u> BONVICINI conservation.	97 CLEO	COMMENT Ecm = 10.6 G	Γ ₁₆₇ /Γ
4.0E (6.5×10^{-6}) / $(\mu - \pi^0 \pi^0)$ / Γ test of lepton 4.0E (14×10^{-6}) (e- $\eta \eta$) / Γ total Test of lepton	90 at family number CL% 90	DOCUMENT ID BONVICINI conservation. DOCUMENT ID BONVICINI conservation. DOCUMENT ID	TECN 97 CLEO	COMMENT Ecm = 10.6 G	Γ ₁₆₇ /Γ eV Γ ₁₆₈ /Γ

rear or repro-	family numb	er conservation.			Γ ₁₆₉ ,
ALUE	CL%	DOCUMENT ID		TECN	COMMENT
< 6 0 × 10 ^{—6}	90	BONVICINI	97	CLEO	Ecm = 10.6 GeV
-/0_\ /r					-
(e ⁻ π ⁰ η)/Γ _{total}	family numb	er conservation.			Γ ₁₇₀ ,
ALUE	CL%	DOCUMENT ID		TECN	COMMENT
<24 × 10 ⁻⁶	90	BONVICINI	97	CLEO	Ecm = 10.6 GeV
$(\mu^-\pi^0\eta)/\Gamma_{ m total}$	1				Γ _{171/}
Test of lepton ALUE	-	per conservation. <u>DOCUMENT ID</u>		TECN	COMMENT
<22 × 10 ⁻⁶	<u>CL%</u>	BONVICINI			Eee = 10.6 GeV
~ 10	70	BOITTICHT	,,	CLLO	-cm- 10:0 de4
-(p γ)/Γ _{total}					Γ ₁₇₂ ,
		baryon number co			
<i>∕ALUE</i> <29 × 10 ^{—5}	<u>CL%</u> 90	DOCUMENT ID ALBRECHT		ARG	Eem = 10 GeV
<29 X 10 °	90	ALBRECHI	92K	AKG	Ecm= 10 GeV
$(\overline{p}\pi^0)/\Gamma_{\text{total}}$					Γ ₁₇₃ ,
Test of lepton	number and	baryon number co	nserva	ation.	
ALUE	<u>CL%</u>	DOCUMENT ID			
<66 × 10 ^{—5}	90	ALBRECHT	92K	ARG	Ecm = 10 GeV
「ρη)/Γ _{total}					Γ ₁₇₄ ,
Test of lepton	number and	baryon number co	nserva	ation.	174
ALUE	CL%	DOCUMENT ID			COMMENT
<130 × 10 ⁻⁵	90	ALBRECHT	92K	ARG	Eee = 10 GeV
-/ n_L · `					F . //
Test of lepton)/「(e ̄ジ _e ッ family numb	er conservation.			Γ ₁₇₅ /
Test of lepton ALUE	family numb	per conservation. <u>DOCUMENT ID</u>			COMMENT
Test of lepton /ALUE <0.015	family numb <u>CL%</u> 95	per conservation. <u>DOCUMENT ID</u> 188 ALBRECHT	95 G	ARG	<u>COMMENT</u> Eee = 9.4-10.6 GeV
Test of lepton /ALUE <0.015	family numb <u>CL%</u> 95	per conservation. <u>DOCUMENT ID</u> 188 ALBRECHT Ing data for average	95G es, fits	ARG , limits,	<u>COMMENT</u> Eee = 9.4–10.6 GeV etc. • • •
Test of lepton /ALUE <0.015 • • We do not us	family numb <u>CL%</u> 95	per conservation. DOCUMENT ID 188 ALBRECHT ng data for average 189 ALBRECHT	95G es, fits 90E	ARG , limits, ARG	COMMENT Eee = 9.4-10.6 GeV etc. • • • Eee = 9.4-10.6 GeV
Test of lepton /ALUE <0.015 • • • We do not us <0.018 <0.040	of family number 15 (15 (15 (15 (15 (15 (15 (15 (15 (15	per conservation. <u>DOCUMENT ID</u> 188 ALBRECHT ng data for average 189 ALBRECHT 190 BALTRUSAIT	95G es, fits 90E 85	ARG , limits, ARG MRK3	COMMENT E ^{CC} _{CM} = 9.4-10.6 GeV etc. • • • E ^{CC} _{CM} = 9.4-10.6 GeV E ^{CC} _{CM} = 3.77 GeV
Test of lepton (ALUE (0.015) • • • We do not us (0.018 (0.040) 188 ALBRECHT 95 for a mass of 1.0 9.050 for mass s	95 se the followin 95 96 G limit holds D GeV, then fe E limit applie	DOCUMENT ID 188 ALBRECHT 189 ALBRECHT 190 BALTRUSAIT for bosons with malls to 0.006 at the s for spinless bosons	95G es, fits 90E 85 ass < e uppe on wit	ARG I, limits, ARG MRK3 0.4 Geter mass h mass	COMMENT E ^{ce} _{CM} = 9.4-10.6 GeV etc. • • • E ^{ce} _{CM} = 9.4-10.6 GeV E ^{ce} _{CM} = 3.77 GeV V. The limit rises to 0.0 limit of 1.6 GeV. < 100 MeV, and rises
Test of lepton ALUE <0.015 • • • We do not us <0.018 <0.040 88 ALBRECHT 950 for a mass of 1.1 89 ALBRECHT 900 0.050 for mass = 90 BALTRUSAITIS -(µ- light boson)	95 se the followin 95 se the followin 95 G limit holds D GeV, then 6 E limit applie 500 MeV. 85 limit app	DOCUMENT ID 188 ALBRECHT 189 ALBRECHT 190 BALTRUSAIT for bosons with mails to 0.006 at th s for spinless boso ties for spinless bo	95G es, fits 90E 85 ass < e uppe on wit	ARG I, limits, ARG MRK3 0.4 Geter mass h mass	COMMENT E ^{ce} _{CM} = 9.4-10.6 GeV etc. • • • E ^{ce} _{CM} = 9.4-10.6 GeV E ^{ce} _{CM} = 3.77 GeV V. The limit rises to 0.0 limit of 1.6 GeV. < 100 MeV, and rises
Test of lepton ALUE <0.015 • • • We do not us <0.018 <0.040 .88 ALBRECHT 95 for a mass of 1.0 .89 ALBRECHT 90 .0.050 for mass = 90 BALTRUSAITIS -(μ — light boson) Test of lepton	95 se the followin 95 se the followin 95 G limit holds D GeV, then 6 E limit applie 500 MeV. 85 limit app	DOCUMENT ID DOS STATES DOS S	95G es, fits 90E 85 ass < e uppe on wit	ARG i, limits, ARG MRK3 0.4 Geter mass h mass	COMMENT $E_{CM}^{ee} = 9.4-10.6 \text{ GeV}$ etc. • • • $E_{CM}^{ee} = 9.4-10.6 \text{ GeV}$ $E_{CM}^{ee} = 9.4-10.6 \text{ GeV}$ V. The limit rises to 0.0 limit of 1.6 GeV. < 100 MeV, and rises $i < 100 \text{ MeV}$.
Test of lepton (ALUE (-0.015) • • • We do not us <0.040 (-0.040 (-0.040 (-0.040 (-0.040 (-0.050 for a mass of 1.0 (-0.050 for mass = 9.0 (-0.050 for mass = 9.0	95 se the followin 95 se the followin 95 G limit holds D GeV, then fe E limit applie 500 MeV. 85 limit apple	DOCUMENT ID. 188 ALBRECHT 189 ALBRECHT 190 BALTRUSAIT for bosons with malls to 0.006 at the s for spinless boso tiles for spinless boso tr) per conservation.	95G es, fits 90E 85 ass < e uppe on wit	ARG i, limits, ARG MRK3 0.4 Geter mass h mass	COMMENT E ^{ce} _{Cm} = 9.4-10.6 GeV etc. • • • E ^{ce} _{Cm} = 9.4-10.6 GeV E ^{ce} _{Cm} = 3.77 GeV V. The limit rises to 0.0 limit of 1.6 GeV. < 100 MeV, and rises s < 100 MeV.
Test of lepton ALUE <0.015 • • • We do not us <0.018 <0.040	s family number of the control of th	DOCUMENT ID 188 ALBRECHT 189 ALBRECHT 190 BALTRUSAIT for bosons with m rails to 0.006 at th s for spinless boso the state of the state of the state of the state DOCUMENT ID 191 ALBRECHT	95G es, fits 90E 85 ass < e uppe on wit son wi	ARG , limits, ARG MRK3 0.4 Geter mass th mass th mass	COMMENT E ^{ce} _{Cm} = 9.4-10.6 GeV etc. • • • etc. • • • E ^{ce} _{Cm} = 9.4-10.6 GeV etc. • • • E ^{ce} _{Cm} = 3.77 GeV v. The limit rises to 0.0 limit of 1.6 GeV. < 100 MeV, and rises s < 100 MeV. COMMENT E ^{ce} _{Cm} = 9.4-10.6 GeV
Test of lepton ALUE <0.015 • • • We do not us <0.018 <0.040 188 ALBRECHT 956 for a mass of 17 0.050 for mass 190 BALTRUSAITIS (μ' light boson) Test of lepton ALUE <0.026 • • • We do not us	s family number of the control of th	DOCUMENT ID 188 ALBRECHT 189 ALBRECHT 190 BALTRUSAIT for bosons with m rails to 0.006 at th s for spinless boso the state of the state of the state of the state DOCUMENT ID 191 ALBRECHT	95G es, fits 90E85 ass < e uppe on wit son wi 95G es, fits	ARG i, limits, ARG MRK3 0.4 Geter mass in mass ith mass TECN ARG i, limits,	COMMENT E ^{ce} _{Cm} = 9.4-10.6 GeV etc. • • • etc. • • • E ^{ce} _{Cm} = 9.4-10.6 GeV etc. • • • E ^{ce} _{Cm} = 3.77 GeV v. The limit rises to 0.0 limit of 1.6 GeV. < 100 MeV, and rises s < 100 MeV. COMMENT E ^{ce} _{Cm} = 9.4-10.6 GeV
Test of lepton ALUE <0.015 • • • We do not us <0.040 188 ALBRECHT 950 for a mass of 1.1 9.050 for mass = 190 BALTRUSAITIS (μ = light boson) Test of lepton ALUE <0.026 • • We do not us <0.033	s family number of the control of th	DOCUMENT ID 188 ALBRECHT 190 BALTRUSAIT for bosons with m alls to 0.006 at th s for spinless boso (1) 2) 2) 2) 2) 2) 2) 2) 2) 2)	95G 90E85 ass < e upper on with son	ARG i, limits, ARG MRK3 0.4 Geter mass in mass ith mass ARG ARG i, limits, ARG	COMMENT E ^{ce} _{CM} = 9.4-10.6 GeV etc. • • • E ^{ce} _{CM} = 9.4-10.6 GeV E ^{ce} _{CM} = 3.77 GeV V. The limit rises to 0.0 Ilmit of 1.6 GeV. < 100 MeV, and rises is < 100 MeV. COMMENT E ^{ce} _{CM} = 9.4-10.6 GeV E ^{ce} _{CM} = 9.4-10.6 GeV E ^{ce} _{CM} = 9.4-10.6 GeV
ALUE	s family number 12.5% 95 se the following 95 se the following 95 G limit holds 0 GeV, then for the second of the s	per conservation. DOCUMENT ID 188 ALBRECHT 190 BALTRUSAIT for bosons with mails to 0.006 at the for spinless bosons iles for spinless bosons per conservation. DOCUMENT ID 191 ALBRECHT 193 BALTRUSAIT for bosons with mails to 0.003 at the for spinless bosons 192 ALBRECHT 193 BALTRUSAIT for bosons with mails to 0.003 at the for spinless bosons	95G 90E 85 ass < e upper on wit 95G es, fits 90E 85 < e upper on wit	ARG i, limits, ARG MRK3 0.4 Geter mass h mass ith mass ith mass ARG i, limits, ARG MRK3 1.3 Geter mass h mass	COMMENT E ^{ce} _{Cm} = 9.4-10.6 GeV etc. • • • E ^{ce} _{Cm} = 9.4-10.6 GeV E ^{ce} _{Cm} = 3.77 GeV V. The limit rises to 0.0 limit of 1.6 GeV. < 100 MeV, and rises is < 100 MeV. COMMENT E ^{ce} _{Cm} = 9.4-10.6 GeV E ^{ce} _{Cm} = 9.4-10.6 GeV E ^{ce} _{Cm} = 9.4-10.6 GeV Imit of 1.6 GeV. V. The limit rises to 0.0 limit of 1.6 GeV. < 100 MeV, and rises
Test of lepton ALUE <0.015 • • • We do not us <0.040 188 ALBRECHT 95c for a mass of 1.1. 199 ALBRECHT 90 0.050 for mass = 190 BALTRUSAITIS (μ = light boson) Test of lepton ALUE <0.026 • • • We do not us <0.033 <0.125 191 ALBRECHT 95c for a mass of 1.1 192 ALBRECHT 90 94 ALBRECHT 90 194 ALBRECHT 90	s family number of the control of th	per conservation. DOCUMENT ID 188 ALBRECHT 190 BALTRUSAIT for bosons with mails to 0.006 at the for spinless bosons iles for spinless bosons per conservation. DOCUMENT ID 191 ALBRECHT 193 BALTRUSAIT for bosons with mails to 0.003 at the for spinless bosons 192 ALBRECHT 193 BALTRUSAIT for bosons with mails to 0.003 at the for spinless bosons	95G 90E 95G	ARG i, limits, ARG MRK3 0.4 Geter mass th mass th mass TECN ARG ARG ARG 1.3 Geter mass	COMMENT E ^{ce} _{Cm} = 9.4-10.6 GeV etc. • • • E ^{ce} _{Cm} = 9.4-10.6 GeV E ^{ce} _{Cm} = 3.77 GeV V. The limit rises to 0.0 limit of 1.6 GeV. < 100 MeV, and rises is < 100 MeV. COMMENT E ^{ce} _{Cm} = 9.4-10.6 GeV E ^{ce} _{Cm} = 9.4-10.6 GeV E ^{ce} _{Cm} = 9.4-10.6 GeV Imit of 1.6 GeV. V. The limit rises to 0.0 limit of 1.6 GeV. < 100 MeV, and rises

Neglecting radiative corrections and terms proportional to m_ℓ^2/m_τ^2 , the energy spectrum of the charged decay lepton ℓ in the τ rest frame is given by

$$\frac{d^2\Gamma_{\tau \to \ell \nu \overline{\nu}}}{d\Omega \, dx} \propto x^2
\times \left\{ 12(1-x) + \rho_{\tau} \left(\frac{32}{3} x - 8 \right) + 24 \eta_{\tau} \, \frac{m_{\ell}}{m_{\tau}} \, \frac{(1-x)}{x} \right.
\left. - P_{\tau} \, \xi_{\tau} \cos \theta \, \left[4(1-x) + \delta_{\tau} \left(\frac{32}{3} x - 8 \right) \right] \right\}.$$
(1)

Here $x=2E_{\ell}/m_{\tau}$ is the scaled lepton energy, P_{τ} is the τ polarization, and θ is the angle between the τ spin and the lepton momentum. With unpolarized τ 's or integrating over the full θ range, the spectrum depends only on ρ_{τ} and η_{τ} . Measurements of the other two Michel parameters, ξ_{τ} and $\delta_{ au}$, require polarized au's. The Standard Model predicitions for $\rho_{\tau}, \, \eta_{\tau}, \, \xi_{\tau}$ and δ_{τ} are $\frac{3}{4}, \, 0, \, 1$ and $\frac{3}{4}$. Where possible, we give separately the parameters for $\tau^- \to e^- \nu_\tau \overline{\nu}_e$ and $\tau^- \to \mu^- \nu_\tau \overline{\nu}_\mu$, to avoid assumptions about universality. Listings labelled "(eor μ)" contain either the results assuming lepton universality if quoted by the experiments or repeat the results from the "e" or " μ " section.

Hadronic two-body decays $\tau \to \nu_{\tau} h$, $h = \pi$, ρ , a_1, \ldots , can under minimal assumptions be written

$$\frac{1}{\Gamma} \frac{d\Gamma}{dz} = f_h(z) + P_\tau \, \xi_h \, g_h(z) \; , \qquad (2)$$

where the kinematic functions f_h , g_h and the definition of the variable z depend on the spin of the hadron h. For the simple case $h = \pi$, one has $z = E_{\pi}/E_{\tau}$, f(z) = 1, and g(z) = 2z - 1. The parameter ξ_h is predicted to be unity and can be identified with twice the negative ν_{τ} helicity. Again ξ_h is listed, when available, separately for each hadron and averaged over all hadronic decays modes.

 ρ^{T} (e or μ) PARAMETER (V-A) theory predicts $\rho = 0.75$.

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT	
0.748±0.010 OUR AVE					
0.72 ±0.09 ±0.03		194 ABE	970 SLD	1993-1995 SLC runs	ı
$0.747 \pm 0.010 \pm 0.006$	55k	ALEXANDER	97F CLEO	Ecm = 10.6 GeV	1
$0.794 \pm 0.039 \pm 0.031$	18k	ACCIARRI	96H L3	1991-1993 LEP runs	ı
0.738±0.038		195 ALBRECHT	95c ARG	Ecm = 9.5-10.6 GeV	-
$0.751 \pm 0.039 \pm 0.022$		BUSKULIC	95D ALEP	1990-1992 LEP runs	
0.79 ±0.10 ±0.10	3732	FORD	87B MAC	Ecm= 29 GeV	
0.71 ±0.09 ±0.03	1426	BEHRENDS	85 CLEO	e^+e^- near $\Upsilon(45)$	
• • • We do not use the	he followi	ng data for average	s, fits, limits,	etc. • • •	
$0.735 \pm 0.013 \pm 0.008$	31k	AMMAR	97B CLEO	Repl. by ALEXAN- DER 97F	Į
$0.732 \pm 0.034 \pm 0.020$	8.2k	196 ALBRECHT	95 ARG	Ecm = 9.5-10.6 GeV	
$0.742 \pm 0.035 \pm 0.020$	8000	ALBRECHT	90E ARG	Ecm = 9.4-10.6 GeV	
194 ABE 970 assume 7	$r^{\tau}=0$ in	their fit. Letting	$\eta^{\mathcal{T}}$ vary in t	he fit gives a $ ho^T$ value of	j

 $0.69\pm0.13\pm0.05$. On the first Ecting η vary in the fit gives a p value of 195 Combined fit to ARGUS tau decay parameter measurements in ALBRECHT 95C, ALBRECHT 93C, and ALBRECHT 94E. 196 Value is from a simultaneous fit for the ρ^T and η^T decay parameters to the lepton energy

spectrum. Not independent of ALBRECHT 90E $\rho^{\tau}(e \text{ or } \mu)$ value which assumes η^{τ} =0. Result is strongly correlated with ALBRECHT 95c.

 $\rho^{\tau}(e)$ PARAMETER

(V-A) theory predicts $\rho = 0.75$.

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VALUE	EVTS	DOCUMENT ID	TECN	COMMENT	
0.745±0.012 OUR A	/ERAGE				
$0.71 \pm 0.14 \pm 0.05$		ABE	970 SLD	1993-1995 SLC runs	
$0.747 \pm 0.012 \pm 0.004$	34k	ALEXANDER	97F CLEO	Ecm = 10.6 GeV	
$0.735 \pm 0.036 \pm 0.020$	4.7k	¹⁹⁷ ALBRECHT	95 ARG	Ecm = 9.5~10.6 GeV	
$0.793 \pm 0.050 \pm 0.025$		BUSKULIC	95D ALEP	1990-1992 LEP runs	
$0.79 \pm 0.08 \pm 0.06$	3230	¹⁹⁸ ALBRECHT	93G ARG	Eee = 9.4-10.6 GeV	
0.64 ±0.06 ±0.07	2753	JANSSEN	89 CBAL	Ecm = 9.4-10.6 GeV	
0.62 ±0.17 ±0.14	1823	FORD	878 MAC	Ecm ≈ 29 GeV	
0.60 ±0.13	699	BEHRENDS	85 CLEO	e^+e^- near $\Upsilon(4S)$	
$0.72 \pm 0.10 \pm 0.11$	594	BACINO	79B DLCO	$E_{\text{CM}}^{\text{ee}} \approx 3.5-7.4 \text{ GeV}$	
• • • We do not use	the following	ng data for average	s, fits, limits,	etc. • • •	
0.732±0.014±0.009	19k	AMMAR	978 CLEO	Repl. by ALEXAN- DER 97F	
$0.747 \pm 0.045 \pm 0.028$	5106	ALBRECHT	90E ARG	Repl. by ALBRECHT 95	
197 ALBRECHT 95	use tau	pair events of	the type 1	$r^-\tau^+ \rightarrow (\ell^- \overline{\nu}_{\ell} \nu_{\tau})$	ì
$(h^+h^-h^+(\pi^0)\bar{\nu}$	_) and the	ir charged conjugat	es.		
198 ALBRECHT 936 u	se tau nair	events of the type	r = τ+ → (u	$(\overline{} \overline{}_{\mu} u_{ au}) (e^+ u_e \overline{}_{ au}) $ and	
their shared and				μ_{μ}	

 $\rho^{\tau}(\mu)$ PARAMETER

their charged conjugates.

(V-A) theory predicts $\rho = 0.75$.

VALUE	EVTS:	DOCUMENT ID	TECN	COMMENT
0.741±0.030 OUR AV	ERAGE			
$0.54 \pm 0.28 \pm 0.14$		ABE	970 SLD	1993-1995 SLC runs
$0.750 \pm 0.017 \pm 0.045$	22k	ALEXANDER	97F CLEO	$E_{Cm}^{ee} = 10.6 \text{ GeV}$
$0.693 \pm 0.057 \pm 0.028$		BUSKULIC	95D ALEP	1990-1992 LEP runs
$0.76 \pm 0.07 \pm 0.08$	3230	ALBRECHT	93G ARG	Ecm = 9.4-10.6 GeV
$0.734 \pm 0.055 \pm 0.027$	3041	ALBRECHT	90E ARG	Ecm = 9.4-10.6 GeV
0.89 ±0.14 ±0.08	1909	FORD	878 MAC	Ecm= 29 GeV
0.81 ±0.13	727	BEHRENDS		e+e- near T(45)
 ◆ ◆ We do not use t 	he followin	g data for average	s, fits, limits,	etc. • • •
0.747±0.048±0.044	13k	AMMAR	978 CLEO	Repl. by ALEXAN- DER 97F

ξ ^T (e or μ) PARAMI	ETER			· · · · · · · · · · · · · · · · · · ·
(V-A) theory pr				
VALUE 1.01 ±0.04 OUR AVI	EVTS FRAGE	DOCUMENT ID	<u>TECN</u>	COMMENT
1.05 ±0.35 ±0.04		¹⁹⁹ ABE	970 SLD	1993-1995 SLC runs
$1.007 \pm 0.040 \pm 0.015$	55k	ALEXANDER		Ecm = 10.6 GeV
0.94 ±0.21 ±0.07	18k	ACCIARRI	96H L3	1991-1993 LEP runs
0.97 ±0.14	:	200 ALBRECHT	95C ARG	Ecm = 9.5-10.6 GeV
$1.18 \pm 0.15 \pm 0.16$		BUSKULIC	950 ALEP	1990-1992 LEP runs
• • • We do not use the	he followin	g data for averag	es, fits, limits	, etc. • • •
0.90 ±0.15 ±0.10	3230	O1 ALBRECHT	93G ARG	Ecm = 9.4-10.6 GeV
199 ARE 970 PEUMA			T van in t	the fit gives a ξ^T value o
$1.02 \pm 0.36 \pm 0.05$ Combined fit to AF BRECHT 93G, and $(\ell^- V_\ell \nu_\tau) (h^+ h^-$ 201 ALBRECHT 93G m	RGUS tau ALBRECH カ ⁺ _{アァ}) ar neasuremer	decay parameter T 94E. ALBRECH of their charged continues ξ^T	measurement IT 95C uses en onjugates. I for the case	s in ALBRECHT 95C, AL- vents of the type $\tau^-\tau^+$ — e. $\xi^T(e) = \xi^T(\mu)$, but the sign to be positive.
€ ^T (e) PARAMETER		,		
(V-A) theory pr		1.		
VALUE	EVTS	DOCUMENT ID	TECN_	COMMENT
0.98 ±0.05 OUR AVE	ERAGE			
1.16 ±0.52 ±0.06		ABE	970 SLD	1993-1995 SLC runs
0.979±0.048±0.016	34k	ALEXANDER		Ecm≈ 10.6 GeV
1.03 ±0.23 ±0.09		BUSKULIC	95D ALEP	1990-1992 LEP runs
ξ [*] (μ) PARAMETER (V-A) theory pro	edicts $\xi =$			
VALUE 1.07 ±0.08 QUR AVE	EVTS	DOCUMENT ID	TECN_	COMMENT
0.75 ±0.50 ±0.14	:rowie	ABE	970 SLD	1993~1995 SLC runs
1.054±0.069±0.047	22k	ALEXANDER		E ^{ee} _{cm} ≈ 10.6 GeV
1.23 ±0.22 ±0.10		BUSKULIC	95D ALEP	1990~1992 LEP runs
1.23 TO.22 TO.10		BOSKOLIC	73D ALEF	1330-1335 FEB (0)12
η^{T} (e or μ) PARAMI (V-A) theory provalue		0. <u>DOCUMENT</u>	ID TEC	NCOMMENT
0.01 ±0.07 OUR A				
$-0.13 \pm 0.47 \pm 0.15$		ABE	970 SLD	1993-1995 SLC runs
$-0.015\pm0.061\pm0.062$	31k	AMMAR		
		VINIMIAL	97B CLE	O Ecm = 10.6 GeV
$0.25 \pm 0.17 \pm 0.11$	18k	ACCIARRI	978 CLE 96H L3	O Ecm = 10.6 GeV 1991-1993 LEP runs
0.25 ±0.17 ±0.11 0.03 ±0.18 ±0.12	18k 8.2k		96H L3	1991-1993 LEP runs
		ACCIARRI	96H L3 T 95 ARC	1991-1993 LEP runs Ecm = 9.5-10.6 GeV
0.03 ±0.18 ±0.12 -0.04 ±0.15 ±0.11 $\eta^{T}(\mu)$ PARAMETER (V-A) theory pro-	8.2k ₹ edicts η =	ACCIARRI ALBRECH BUSKULIO 0.	96H L3 T 95 ARC	1991–1993 LEP runs 5
0.03 ±0.18 ±0.12 -0.04 ±0.15 ±0.11 $\eta^{T}(\mu)$ PARAMETER (V-A) theory provature	8.2k R edicts η = <u>EVTS</u>	ACCIARRI ALBRECH BUSKULIC	96H L3 T 95 ARC	1991-1993 LEP runs Ecm = 9.5-10.6 GeV
0.03 ±0.18 ±0.12 -0.04 ±0.15 ±0.11 η ^T (μ) PARAMETER (V-A) theory parameters -0.10 ±0.18 OUR A	8.2k Redicts η = <u>EVTS</u> VERAGE	ACCIARRI ALBRECH' BUSKULIO 0. <u>DOCUMENT ID</u>	96H L3 T 95 ARC 95D ALE	1991–1993 LEP runs 5 ECM = 9.5–10.6 GeV P 1990–1992 LEP runs
0.03 ±0.18 ±0.12 -0.04 ±0.15 ±0.11 $\eta^T(\mu)$ PARAMETER (V-A) theory provided -0.10 ±0.18 OUR AI -0.59 ±0.82 ±0.45	8.2k R edicts $\eta = \frac{EVTS}{VERAGE}$	ACCIARRI ALBRECH BUSKULIO 0. <u>DOCUMENT IO</u>	96H L3 T 95 ARC 95D ALE TECN 970 SLD	1991–1993 LEP runs 5 Ecm = 9.5–10.6 GeV P 1990–1992 LEP runs COMMENT 1993–1995 SLC runs
0.03 \pm 0.18 \pm 0.12 $-$ 0.04 \pm 0.15 \pm 0.11 $\eta^{T}(\mu)$ PARAMETER $(V-A)$ theory pn VALUE $-$ 0.10 \pm 0.18 OUR W $-$ 0.59 \pm 0.82 \pm 0.45 \pm 0.10 \pm 0.149 \pm 0.171	8.2k R edicts $\eta = \frac{EVTS}{VERAGE}$	ACCIARRI ALBRECH BUSKULIO 0. <u>DOCUMENT ID</u> 102 ABE 103 AMMAR	96H L3 T 95 ARC : 95D ALE	1991–1993 LEP runs ECC = 9.5–10.6 GeV P 1990–1992 LEP runs COMMENT 1993–1995 SLC runs ECC = 10.6 GeV
0.03 \pm 0.18 \pm 0.12 $-$ 0.04 \pm 0.15 \pm 0.11 $\eta^{T}(\mu)$ PARAMETER ($V-A$) theory provided Ψ^{LUE} = 0.10 \pm 0.18 OUR Φ^{LUE} 0.010 \pm 0.18 \pm 0.42 \pm 0.45 \pm 0.010 \pm 0.149 \pm 0.171 $-$ 0.24 \pm 0.23 \pm 0.18	8.2k R edicts η = <u>EVTS</u> VERAGE213k2	ACCIARRI ALBRECH BUSKULIO 0. DOCUMENT ID 102 ABE 103 AMMAR BUSKULIC	96H L3 T 95 ARC 95D ALE 7ECN 970 SLD 978 CLEO 95D ALEP	1991–1993 LEP runs 5
0.03 ±0.18 ±0.12 -0.04 ±0.15 ±0.11 $\eta^T(\mu)$ PARAMETER (V-A) theory provature -0.10 ±0.18 OUR A -0.59 ±0.82 ±0.45 0.010±0.149±0.171 -0.24 ±0.23 ±0.18 202 Highly correlated (c	8.2k Redicts $\eta = \frac{EVTS}{2}$ VERAGE 13k 2 13r 2	ACCIARRI ALBRECH BUSKULIO DOCUMENT IO DOCUMENT IO AMMAR BUSKULIC With ABE 970	96H L3 T 95 ARC 95D ALE 970 SLD 978 CLEO 95D ALEP ρ ^T (μ) measu	1991–1993 LEP runs 6 E ^{cc} _{Cm} = 9.5–10.6 GeV P 1990–1992 LEP runs COMMENT 1993–1995 SLC runs E ^{cc} _{Cm} = 10.6 GeV 1990–1992 LEP runs rement.
0.03 ±0.18 ±0.12 -0.04 ±0.15 ±0.11 $\eta^{T}(\mu)$ PARAMETER (V-A) theory pn -0.10 ±0.18 OUR A -0.59 ±0.82 ±0.45 0.010±0.149±0.171 -0.24 ±0.23 ±0.18 202 Highly correlated (c 203 Highly correlated (c	8.2k Redicts η =	ACCIARRI ALBRECH BUSKULIO DOCUMENT IO DOCUMENT IO AMMAR BUSKULIC With ABE 970	96H L3 T 95 ARC 95D ALE 970 SLD 978 CLEO 95D ALEP ρ ^T (μ) measu	1991–1993 LEP runs 6 E ^{cc} _{Cm} = 9.5–10.6 GeV P 1990–1992 LEP runs COMMENT 1993–1995 SLC runs E ^{cc} _{Cm} = 10.6 GeV 1990–1992 LEP runs rement.
0.03 ±0.18 ±0.12 -0.04 ±0.15 ±0.11 η [*] (μ) PARAMETER (V-A) theory produced by the control of	8.2k R edicts η =	ACCIARRI ALBRECH BUSKULIO 0. DOCUMENT ID 102 ABE 103 AMMAR BUSKULIC 2) with ABE 970 49) with AMMAR	96H L3 T 95 ARC 95D ALE 970 SLD 978 CLEO 95D ALEP ρ ^T (μ) measu	1991–1993 LEP runs 6 E ^{cc} _{Cm} = 9.5–10.6 GeV P 1990–1992 LEP runs COMMENT 1993–1995 SLC runs E ^{cc} _{Cm} = 10.6 GeV 1990–1992 LEP runs rement.
0.03 ±0.18 ±0.12 -0.04 ±0.15 ±0.11 $\eta^{T}(\mu)$ PARAMETER (V-A) theory pn -0.10 ±0.18 OUR A -0.59 ±0.82 ±0.45 0.010±0.149±0.171 -0.24 ±0.23 ±0.18 202 Highly correlated (c 203 Highly correlated (c	8.2k R edicts η =	ACCIARRI ALBRECH' BUSKULIC 0. DOCUMENT ID 102 ABE 103 AMMAR BUSKULIC 2) With ABE 970 49) with AMMAR = 0.75.	96H L3 T 95 ARC 95D ALE 970 SLD 978 CLEO 95D ALEP ρ ^τ (μ) measu 8 97B ρ ^τ (μ) v	1991–1993 LEP runs 5
0.03 ±0.18 ±0.12 -0.04 ±0.15 ±0.11 η [*] (μ) PARAMETER (V-A) theory provature -0.10 ±0.18 OUR A -0.59 ±0.82 ±0.45 0.010±0.149±0.171 -0.24 ±0.23 ±0.18 202 Highly correlated (c 203 Highly correlated (c (δξ)*(e or μ) PARA (V-A) theory provations (c)	8.2k Redicts $\eta = \frac{EVTS}{2}$ VERAGE 13k 2 13r 2 METER edicts ($\delta \xi$) EVTS	ACCIARRI ALBRECH BUSKULIC O. DOCUMENT ID OZ ABE OZ AMMAR BUSKULIC OZ WITH ABE 970 HO WITH AMMAR DOCUMENT ID OZ ABE	96H L3 T 95 ARC 95D ALE 970 SLD 978 CLEO 95D ALEP ρ ^τ (μ) measu 8 978 ρ ^τ (μ) v	1991–1993 LEP runs 6
0.03 ±0.18 ±0.12 -0.04 ±0.15 ±0.11 η [*] (μ) PARAMETER (V-A) theory produced -0.10 ±0.18 OUR M -0.59 ±0.82 ±0.45 0.010±0.149±0.171 -0.24 ±0.23 ±0.18 202 Highly correlated (c 203 Highly correlated (c (δξ)*(e or μ) PARA (V-A) theory produced 0.749±0.026 OUR AVE 0.88 ±0.27 ±0.04	8.2k Redicts $\eta = \frac{EVTS}{2}$ VERAGE 13k 2 13r 2 METER edicts ($\delta \xi$) EVTS	ACCIARRI ALBRECH BUSKULIC 0. DOCUMENT ID 102 ABE 103 AMMAR BUSKULIC 2) with ABE 970 49) with AMMAR = 0.75. DOCUMENT ID 104 ABE	96H L3 T 95 ARC 95D ALE 970 SLD 978 CLEO 95D ALEP $ ho^{T}(\mu)$ measu R 978 $ ho^{T}(\mu)$ v	1991–1993 LEP runs 6
0.03 ±0.18 ±0.12 -0.04 ±0.15 ±0.11 η [*] (μ) PARAMETER (V-A) theory pn -0.10 ±0.18 OUR A -0.59 ±0.82 ±0.45 0.010±0.149±0.171 -0.24 ±0.23 ±0.18 202 Highly correlated (c 203 Highly correlated (c (δξ)*(e or μ) PARA (V-A) theory pn -0.44 ±0.026 OUR AVE	8.2k Redicts $\eta = \frac{EVTS}{2}$ VERAGE 13k 2 13r 2 METER edicts ($\delta \xi$) EVTS	ACCIARRI ALBRECH BUSKULIC O. DOCUMENT ID OZ ABE OZ AMMAR BUSKULIC OZ WITH ABE 970 HO WITH AMMAR DOCUMENT ID OZ ABE	96H L3 T 95 ARC 95D ALE 970 SLD 978 CLEO 95D ALEP $ ho^{T}(\mu)$ measu R 978 $ ho^{T}(\mu)$ v	1991–1993 LEP runs 6
0.03 ±0.18 ±0.12 -0.04 ±0.15 ±0.11 η ^T (μ) PARAMETER (V-A) theory produce -0.10 ±0.18 OUR Algorithms -0.59 ±0.82 ±0.45 0.010 ±0.149 ±0.171 -0.24 ±0.23 ±0.18 202 Highly correlated (constitution of the constitution of th	8.2k R edicts η = _EVTS VERAGE 13k 2 13k 2 corr. = 0.9: METER edicts (δε) _EVTS ENAGE 2 18k	ACCIARRI ALBRECH' BUSKULIC 0. DOCUMENT ID. 102 ABE 103 AMMAR BUSKULIC 2) With ABE 970 49) With AMMAR = 0.75. DOCUMENT ID. 104 ABE ALEXANDER ACCIARRI	96H L3 T 95 ARC 95D ALE 970 SLD 978 CLEO 950 ALEP ρ ^τ (μ) measus 8 978 ρ ^τ (μ) v <u>TECN</u> 970 SLD 976 CLEO 96H L3	1991–1993 LEP runs 5
0.03 ±0.18 ±0.12 -0.04 ±0.15 ±0.11 η ^T (μ) PARAMETER (V-A) theory pn -0.10 ±0.18 OUR AI -0.59 ±0.82 ±0.45 0.010±0.149±0.171 -0.24 ±0.23 ±0.18 202 Highly correlated (c 203 Highly correlated (c (δε) ^T (e or μ) PARA (V-A) theory pn -0.10 ±0.18 ±0.27 ±0.04 0.749±0.026 OUR AVE 0.749±0.026 OUR AVE 0.745±0.026±0.009 0.81 ±0.14 ±0.06 0.65 ±0.12	8.2k R edicts η = _EVTS VERAGE 13k 2 13k 2 corr. = 0.9: METER edicts (δε) _EVTS ENAGE 2 18k	ACCIARRI ALBRECH' BUSKULIC 0. DOCUMENT ID 102 ABE 103 AMMAR BUSKULIC 2) With ABE 970 49) With AMMAR = 0.75. DOCUMENT ID 104 ABE ALEXANDER ACCIARRI 105 ALBRECHT	96H L3 T 95 ARC 95D ALE 970 SLD 978 CLEO 95D ALEP $\rho^{\tau}(\mu)$ measu R 978 $\rho^{\tau}(\mu)$ v 7ECN 970 SLD 976 CLEO 96H L3 95C ARG	1991–1993 LEP runs 6 Ecm = 9.5–10.6 GeV P 1990–1992 LEP runs COMMENT 1993–1995 SLC runs Ecm = 10.6 GeV 1990–1992 LEP runs rement. afue. COMMENT 1993–1995 SLC runs Ecm = 10.6 GeV
0.03 ±0.18 ±0.12 -0.04 ±0.15 ±0.11 η [*] (μ) PARAMETER (V-A) theory pn -0.10 ±0.18 OUR AV -0.59 ±0.82 ±0.45 0.010±0.149±0.171 -0.24 ±0.23 ±0.18 202 Highly correlated (c 203 Highly correlated (c (V-A) theory pn -0.10 ±0.10 ±0.10 -0.10 ±0.10 ±0.10 ±0.10 -0.10 ±0.10 ±0.10 ±0.10 -0.10 ±0.10 ±0.10 ±0.10 ±0.10 -0.10 ±0.10	8.2k Redicts $\eta = \underbrace{EVTS}$ VERAGE 13k 2 13k 2 METER edicts ($\delta \xi$) EXTS EXTS EXTS EXTS 2 55k 18k	ACCIARRI ALBRECH' BUSKULIC 0. DOCUMENT ID 102 ABE 103 AMMAR BUSKULIC 2) With ABE 970 49) With AMMAR = 0.75. DOCUMENT ID 104 ABE ALEXANDER ACCIARRI ALBRECHT BUSKULIC	96H L3 T 95 ARC 95D ALE 970 SLD 978 CLEO 95D ALEP ρ ^τ (μ) measu 8 978 ρ ^τ (μ) v <u>TECN</u> 970 SLD 976 CLEO 96H L3 95C ARG 95D ALEP	1991–1993 LEP runs 6 ECM = 9.5–10.6 GeV P 1990–1992 LEP runs COMMENT 1993–1995 SLC runs ECM = 10.6 GeV 1990–1992 LEP runs rement. alue. COMMENT 1993–1995 SLC runs ECM = 10.6 GeV 1991–1993 LEP runs ECM = 10.6 GeV 1991–1993 LEP runs ECM = 9.5–10.6 GeV 1990–1992 LEP runs
0.03 ±0.18 ±0.12 -0.04 ±0.15 ±0.11 η [*] (μ) PARAMETER (V-A) theory pn -0.10 ±0.18 OUR AV -0.59 ±0.82 ±0.45 0.010±0.149±0.171 -0.24 ±0.23 ±0.18 202 Highly correlated (c 203 Highly correlated (c (V-A) theory pn -0.10 ±0.14 ±0.04 (V-A) theory pn -0.149±0.026 OUR AVE 0.745±0.026±0.009 0.81 ±0.14 ±0.06 0.65 ±0.12 0.88 ±0.11 ±0.07	8.2k Redicts $\eta = \underbrace{EVTS}$ VERAGE 13k 2 13k 2 METER edicts ($\delta \xi$) EXTS EXTS EXTS EXTS 2 55k 18k	ACCIARRI ALBRECH' BUSKULIC 0. DOCUMENT ID 102 ABE 103 AMMAR BUSKULIC 2) With ABE 970 49) With AMMAR = 0.75. DOCUMENT ID 104 ABE ALEXANDER ACCIARRI ALBRECHT BUSKULIC	96H L3 T 95 ARC 95D ALE 970 SLD 978 CLEO 95D ALEP ρ ^τ (μ) measu 8 978 ρ ^τ (μ) v <u>TECN</u> 970 SLD 976 CLEO 96H L3 95C ARG 95D ALEP	1991–1993 LEP runs 6 ECM = 9.5–10.6 GeV P 1990–1992 LEP runs COMMENT 1993–1995 SLC runs ECM = 10.6 GeV 1990–1992 LEP runs rement. alue. COMMENT 1993–1995 SLC runs ECM = 10.6 GeV 1991–1993 LEP runs ECM = 10.6 GeV 1991–1993 LEP runs ECM = 9.5–10.6 GeV 1990–1992 LEP runs
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0.03 ±0.18 ±0.12 -0.04 ±0.15 ±0.11 η [*] (μ) PARAMETER (V-A) theory property of the control of	8.2k Redicts $\eta = \frac{EVTS}{2}$ VERAGE 13k OOT. = 0.9: METER edicts ($\delta \xi$) EVTS EVTS EXTS 55k 18k 2 T = 0 In t. RGUS tau tALBRECH	ACCIARRI ALBRECH' BUSKULIC DOCUMENT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID ACCIARRI ACCIARRI ACCIARRI ACCIARRI ACCIARRI ALEXANDER ALEXANDER ALEXANDER ALEXANDER ALEXANDER ALEXANDER ALEXANDER ACCIARRI DOCUMENT ID DOCUMENT	96H L3 T 95 ARC 95D ALE 970 SLD 978 CLEO 95D ALEP ρ ^τ (μ) measu 8 978 ρ ^τ (μ) v TECN 970 SLD 976 CLEO 96H L3 95C ARG 95D ALEP η ^τ vary in the measurement: T 95C uses ev	1991–1993 LEP runs 5 E ^{cc} _{Cm} = 9.5–10.6 GeV P 1990–1992 LEP runs COMMENT 1993–1995 SLC runs E ^{cc} _{Cm} = 10.6 GeV 1990–1992 LEP runs rement. alue. COMMENT 1993–1995 SLC runs E ^{cc} _{Cm} = 10.6 GeV 1991–1993 LEP runs E ^{cc} _{Cm} = 9.5–10.6 GeV 1991–1993 LEP runs E ^{cc} _{Cm} = 9.5–10.6 GeV 1990–1992 LEP runs ift gives a (ρξ) ^T value of sin ALBRECHT 95c, AL
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0.03 ± 0.18 ±0.12 -0.04 ±0.15 ±0.11 η ^T (μ) PARAMETER (V-A) theory produced -0.10 ±0.18 OUR AV -0.59 ±0.82 ±0.45 0.010±0.149±0.171 -0.24 ±0.23 ±0.18 202 Highly correlated (co 203 Highly correlated (co (δε) ^T (e or μ) PARA (V-A) theory produced 0.745±0.026 OUR AVE 0.745±0.026 OUR AVE 0.88 ±0.27 ±0.04 0.88 ±0.17 ±0.06 0.55 ±0.12 0.88 ±0.11 ±0.07 204 ABE 970 assume η 0.87 ± 0.27 ± 0.04 205 Combined fit to AR BRECHT 93G, and M (ℓ ⁻ V _ℓ ν _T) (h ⁺ h ⁻ (δε) ^T (e) PARAMET (V-A) theory produced	8.2k R edicts $\eta = \frac{EVTS}{2}$ VERAGE 13k 2 13k 14k 15k 18k 2 7 15k 16k 18k 2 7 16k 17k 17k 17k 17k 17k 17k	ACCIARRI ALBRECH' BUSKULIC DOCUMENT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID ACCIARRI ACCIARRI ACCIARRI SACCIARRI LOS ALEXANDER ALEXANDER ALEXANDER ALEXANDER ACCIARRI ACCIARRI ACCIARRI ACCIARRI DOCUMENT ID DOCUMENT	96H L3 T 95 ARC 95D ALE 970 SLD 978 CLEO 95D ALEP ρ ^τ (μ) measu 8 978 ρ ^τ (μ) v TECN 970 SLD 976 CLEO 96H L3 95C ARG 95D ALEP η ^τ vary in the measurement IT 95C uses evonjugates.	1991–1993 LEP runs 5
0.03 ± 0.18 ± 0.12 -0.04 ± 0.15 ± 0.11 η [*] (μ) PARAMETER (V-A) theory properties of the control of the cont	8.2k R edicts $\eta = \frac{EVTS}{2}$ VERAGE 13k 2 13k 14k 15k 18k 2 7 15k 16k 18k 2 7 16k 17k 17k 17k 17k 17k 17k	ACCIARRI ALBRECH' BUSKULIC O. DOCUMENT ID. OZ ABE BUSKULIC OZ ABE OZ AMMAR BUSKULIC OZ WITH ABE 970 ALEXANDER ALEXANDER ALEXANDER ACCIARRI BUSKULIC THE OZ ABE ALEXANDER ACCIARRI ACCIARRI ACCIARRI ACCIARRI ACCIARRI ACCIARRI ACCIARRI ACCIARRI ACCIARRI	96H L3 T 95 ARC 95D ALE 970 SLD 978 CLEO 95D ALEP $\rho^{\tau}(\mu)$ measu R 978 $\rho^{\tau}(\mu)$ v TECN 970 SLD 976 CLEO 96H L3 95C ARG 95D ALEP η^{τ} vary in the measurement IT 95C uses exonjugates.	1991–1993 LEP runs 5 E ^{cc} _{Cm} = 9.5–10.6 GeV P 1990–1992 LEP runs COMMENT 1993–1995 SLC runs E ^{cc} _{Cm} = 10.6 GeV 1990–1992 LEP runs rement. alue. COMMENT 1993–1995 SLC runs E ^{cc} _{Cm} = 10.6 GeV 1991–1993 LEP runs E ^{cc} _{Cm} = 9.5–10.6 GeV 1990–1992 LEP runs efft gives a (ρξ) ^T value of sin ALBRECHT 95C, AL rents of the type τ τ τ + — COMMENT 1993–1995 SLC runs
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0.03 ± 0.18 ±0.12 -0.04 ±0.15 ±0.11 η [*] (μ) PARAMETER (V-A) theory property of the control o	8.2k Redicts $\eta = EVTS$ VERAGE 13k 2 13k 2 13k 2 OOFF. = 0.9: METER ddicts $(\delta \xi)$ 55k 18k 2 55k 18k 2 T = 0 in t GUS tau $(\delta \xi)$ ALBRECH $(\delta \xi)$ ERAGE ERAGE 2 34k	ACCIARRI ALBRECH' BUSKULIC DOCUMENT IO DOCUMENT IO DOCUMENT IO DOCUMENT IO DOCUMENT IO ACCIARRI ACC	96H L3 T 95 ARC 95D ALE 970 SLD 978 CLEO 976 P (μ) w 770 SLD 976 CLEO 977 CLEO 96H L3 95C ARG 95D ALEP 97 vary in the measurement T 95C uses exonjugates.	1991–1993 LEP runs 5 E ^{cc} _{CM} = 9.5–10.6 GeV P 1990–1992 LEP runs COMMENT 1993–1995 SLC runs E ^{cc} _{CM} = 10.6 GeV 1990–1992 LEP runs rement. afue. COMMENT 1993–1995 SLC runs E ^{cc} _{CM} = 10.6 GeV 1991–1993 LEP runs E ^{cc} _{CM} = 9.5–10.6 GeV 1991–1992 LEP runs of the gives a (ρξ) ^T value of sin ALBRECHT 95c, AL rents of the type τ τ τ +
0.03 ± 0.18 ±0.12 -0.04 ±0.15 ±0.11 η ^T (μ) PARAMETER (V-A) theory provided to the control of the control o	8.2k Redicts $\eta = \frac{EVTS}{2}$ VERAGE 13k Orr. = 0.9: METER edicts $(\delta \xi)$ EVAGE 55k 18k 2 55k 18k 2 T = 0 in t GUS tau $(\delta \xi)$ ALBRECH $(\delta \xi)$ EVAGE 34k	ACCIARRI ALBRECH' BUSKULIC DOCUMENT IO DOCUMENT IO DOCUMENT IO DOCUMENT IO DOCUMENT IO ABE ALEXANDER ACCIARRI ACCIARRI ACCIARRI ACCIARRI ACCIARRI ACCIARRI LETT BUSKULIC Detting 1 decay parameter T 94E. ALBRECH T 194E. ALBRECH DOCUMENT IO ABE ALEXANDER BUSKULIC ABE ALEXANDER BUSKULIC	96H L3 T 95 ARC 95D ALE 970 SLD 978 CLEO 975 SLD 976 CLEO 977 CLEO 96H L3 95C ARG 95D ALEP 7 vary in the measurement IT 95C uses exonjugates. 1ECN 970 SLD 977 CLEO 95D ALEP	1991–1993 LEP runs 5 E ^{cc} _{CM} = 9.5–10.6 GeV P 1990–1992 LEP runs COMMENT 1993–1995 SLC runs E ^{cc} _{CM} = 10.6 GeV 1990–1992 LEP runs rement. afue. COMMENT 1993–1995 SLC runs E ^{cc} _{CM} = 10.6 GeV 1991–1993 LEP runs E ^{cc} _{CM} = 9.5–10.6 GeV 1991–1992 LEP runs of the gives a (ρξ) ^T value of sin ALBRECHT 95c, AL rents of the type τ τ τ +

970 SLD

ALEXANDER 97F CLEO Ecm = 10.6 GeV

1993-1995 SLC runs

950 ALEP 1990-1992 LEP runs

0.78 ±0.05 OUR AVERAGE $0.82 \pm 0.32 \pm 0.07$

 $0.786 \pm 0.041 \pm 0.032$

0.71 ±0.14 ±0.06

(*) PARAMETER							τ	REFERENCES	
(V-A) theory pr	edicts ξ' (_ <i>EVTS</i>	π) = 1. <u>DOCUMENT ID</u>	TECN	COMMENT	ACCIARRI CERN-EP/9		PL B (to be publ.)	M. Acclarri+	(L3 C
99 ±0.05 OUR AVI	ERAGE				ACCIARRI	98E F	Pl. B (to be publ.)	M. Aciarri+	(L3 C
81 ±0.17 ±0.02		ABE	970 SLD	1993-1995 SLC runs		98M E	EPJ C (to be publ.)	K. Ackerstaff+	(OPAL C
03 ±0.06 ±0.04 987±0.057±0.027	2.0k	COAN BUSKULIC		Ecm = 10.6 GeV 1990-1992 LEP runs	CERN-PPE, ACKERSTAFF		PL B (to be publ.)	K. Ackerstaff+	(OPAL C
● We do not use t	he followir				CERN-EP/9 BARATE	98-033	EPJ C1 65	R. Barate+	(ALEPH C
95 ±0.11 ±0.05		206 BUSKULIC		1990+1991 LEP run	BARATE CERN-PPE	98E E	EPJ C (to be publ.)	R. Barate+	(ALEPH C
6 Superseded by BUS					BLISS	98 F	PR D57 5903	D.W. Bliss+	(CLEO C
						97J F	PRL 78 4691 Pl. 8404 213	+Akagi, Allen, Ash+ +Alexander, Allison, Altekamp+	(SLD C
PARAMETER (α)		-1 1			ACKERSTAFF		ZPHY C74 403 ZPHY C75 593	+Alexander, Allison, Altekamp+ K. Ackerstaff+	(OPAL C
(V – A) theory pr	EVTS	ρ) = 1. <u>DOCUMENT ID</u>	TECN	COMMENT	ALEXANDER AMMAR		PR D56 5320 PRL 78 4686	+Bebek, Berger, Berkelman, Bloom+ R. Ammar+	(CLEO C
996±0.010 OUR AV					ANASTASSOV	97 F	PR D55 2559	+Blinov, Duboscq, Fisher, Fujino+ +Kubota, Lee, O'Neill, Patton+	(CLEO C
99 ±0.12 ±0.04	661.	ABE	970 SLD	1993-1995 SLC runs	AVERY	97 F	PR D55 R1119	+Prescott, Yang, Yelton+ +Buskulic, Decamp, Ghez, Goy+	(CLEO C
995±0.010±0.003 045±0.058±0.032	66k	BUSKULIC		Ecm = 10.6 GeV 1990-1992 LEP runs	BARATE	97R F	ZPHY C74 387 PL B414 362	R. Barate+	(ALEPH C
 We do not use t 	he followir				BONVICINI	97 F	PRL 79 2406 PRL 79 1221	+Eisenstein, Ernst, Gladding+ +Cinabro, Green, Perera+	(CLEO C
03 ±0.11 ±0.05		207 BUŞKULIC		1990+1991 LEP run	BUSKULIC COAN	97C 7	ZPHY C74 263 PR D55 7291	+De Bonis, Decamp, Ghez, Goy+ +Fadeyev, Korolkov, Maravin+	(ALEPH C
⁷ Superseded by BUS					EDWARDS EDWARDS	97 F	PR D55 R3919 PR D56 R5297	+ Bellerive, Janicek, MacFarlane+ + Bellerive, Janicek, MacFarlane+	(CLEO C
					ESCRIBANO	97 F	PL B395 369	+ Masso	(BARC, P
(a) PARAMETE	_				ABREU ACCIARRI	96H F	PL B365 448 PL B377 313	+Adam, Adye, Agasi+ +Adam, Adriani, Aguilar-Benitez+	(DELPHI C (L3 C
(V – A) theory pr	redicts ξ' (<i>EVTS</i>	$(a_1) = 1.$ $DOCUMENT ID$	TECN	COMMENT	ACCIARRI ALAM	96 F	PL B389 187 PRL 76 2637	+Adriani, Aguilar-Benitez, Ahlen+ +Kim, Ling, Mahmood, O'Neill+	(L3 C (CLEO C
2 ±0.04 OUR AV	ERAGE				ALBRECHT ALEXANDER	96E F	PRPL 276 223 PL B369 163	+Andam, Binder, Bockmann+ +Allison, Altekamp, Ametewee+	(ARGUS C
9 ±0.26 ±0.11				1992-1994 LEP runs	ALEXANDER	96E !	Pl. 8374 341	+Allison, Altekamp, Ametewee+	(OPAL C
17±0.039		ALBRECHT	95c ARG	Ecm = 9.5-10.6 GeV	ALEXANDER BAI	96 I	PL B388 437 PR D53 20	+Allison, Altekamp, Ametewee+ +Bardon, Becker-Szendy, Blum+	(OPAL C (BES C
37±0.116±0.064	ha fallows	BUSKULIC		1990-1992 LEP runs	BALEST BARTELT		PL B388 402 PRL 76 4119	+Behrens, Cho, Daoudi, Ford+ +Csorna, Jain, Marka+	(CLEO C
• We do not use t		_	s, rits, limits,	etc. • • •	BUSKULIC BUSKULIC	96	ZPHY C70 579 ZPHY C70 561	+Casper, De Bonis, Decamp+ +Casper, De Bonis, Decamp+	(ALEPH C
8 +0.46 +0.14 -0.41 -0.25	2.6k	²⁰⁹ AKERS	95P OPAL	Repl. by ACKER-	COAN	96 I	PR D53 6037	+Dominick, Fadeyev, Korolkov+	(CLEO C
22±0.028±0.030	1.7k	210 ALBRECHT	94E ARG	STAFF 97R Ecm = 9.4-10.6 GeV	ABE ABREU	95T (PR D52 4828 PL B357 715	+Abt, Ahn, Akagi, Allen+ +Adam, Adye, Agasi, Ajinenko+	(SLD C (DELPHI C
5 ±0.23 +0.15 -0.08	7.5k	ALBRECHT	93c ARG	Ecm = 9.4-10.6 GeV	ABREU ACCIARRI		PL 8359 411 PL 8345 93	+Adam, Adye, Agasi, Ajinenko+ +Adam, Adriani, Aguilar-Benitez+	(DELPHI C
				****	ACCIARRI	95F (PL B352 487 ZPHY C66 31	+Adam, Adriani, Aguilar-Benitez+ +Alexander, Allison, Ametewee+	(L3 C
ACKERSTAFF 97R	obtain thi Ing with ti	s result with a mod-	ei Independe Id Santamari	nt fit to the hadronic struc- a (ZPHY C48 , 445 (1990))		951	ZPHY C66 543	+Alexander, Allison, Ametewee+	(OPAL C
				al. (PR D39 ,1357 (1989))		95P 7	ZPHY C67 45 ZPHY C68 555	+Alexander, Allison, Ametewee+ +Alexander, Allison, Altekamp+	(OPAL C
they obtain 1.20 ±	$0.21 \pm 0.$	14.			ALBRECHT ALBRECHT		Pl. B341 441 Pl. B349 576	+Hamacher, Hofmann, Kirchhoff+ +Hamacher, Hofmann, Kirchoff+	(ARGUS C
functions. Fitting	this resul	it with a modeling model of Kuhn and	iependent tit Santamaria	to the hadronic structure (ZPHY C48, 445 (1990))		95G :	ZPHY C68 25	+Hamacher, Hofmann, Kirchhoff+	(ARGUS C
gives 0.87 ± 0.27	-0.05 and	i with the model of	f of Isgur et	al. (PR D39 ,1357 (1989))	BALEST	95C I	ZPHY C68 215 PRL 75 3809	+Hamacher, Hofmann, Kirchhoff+ +Cho, Ford, Lohner+	(CLEO C
they obtain 1.10 ±	0.31 +0.1	.3	•		BUSKULIC BUSKULIC	95C I	PL B346 371 PL B346 379	+Casper, De Bonis, Decamp+ +Casper, De Bonis, Decamp+	(ALEPH C
OALBRECHT 94F n	easure th	4' e square of this ou	antity and u	se the sign determined by	Alen		PL B363 265 erratum PL B334 435	+Adam, Adye, Agasi+	(DELPHI C
ALBRECHT 90i to	obtain the	e quoted result. Re	placed by Al	BRECHT 95C.	AKERS AKERS	94E	PL B328 207 PL B339 278	+Alexander, Allison, Anderson+ +Alexander, Allison, Anderson+	(OPAL C
(all hadronic mod	des) PAR	AMETER			ALBRECHT	94E	PL B337 383	+Hamacher, Hofmann+	(ARGUS C
(V-A) theory p					ARTUSO BARTELT	94	PRL 72 3762 PRL 73 1890	+Goldberg, He, Horwitz+ +Csorna, Egyed, Jain+	(CLEO C
LUE	EVTS	DOCUMENT ID	TECN	COMMENT	BATTLE BAUER		PRL 73 1079 PR D50 R13		CLEO C) PC/2gamma C
97±0.009 OUR AV	ERAGE	485	070 CLD	1002 1005 CL C	BUSKULIC BUSKULIC	94D	PL B321 168 PL B332 209	+De Bonis, Decamp, Ghez+ +Casper, De Bonis, Decamp+	(ALEPH C
93 ±0.10 ±0.04 29 ±0.26 ±0.11	7.4k	ABE 211 ACKERSTAFE	970 SLD 978 OPAI	1993–1995 SLC runs 1992–1994 LEP runs	BUSKULIC	94F	PL B332 219	+Casper, De Bonis, Decamp+ +Kinoshita, Barish, Chadha+	(ALEPH C
95±0.010±0.003	66k	212 ALEXANDER	97F CLEO	E = 10.6 GeV	GIBAUT ADRIANI	93M	PRL 73 934 PRPL 236 1	+Aguilar-Benitez, Ahlen, Alcaraz, Aloisie	
3 ±0.06 ±0.04	2.0k	213 COAN		Ecm = 10.6 GeV	ALBRECHT ALBRECHT		ZPHY C58 61 PL B316 608	+Ehrlichmann, Hamacher+ +Ehrlichmann, Hamacher+	(ARGUS C
70±0.053±0.011	14k	²¹⁴ ACCIARRI	96H L3	1991-1993 LEP runs	BALEST BEAN	93	PR D47 R3671 PRL 70 138	+Daoudi, Ford, Johnson+ +Gronberg, Kutschke+	(CLEO C
17±0.039		215 ALBRECHT	95c ARG	Ecm = 9.5-10.6 GeV	BORTOLETTO	93	PRL 71 1791	+Brown, Fast, Mcliwain+	(CLEO C
06±0.032±0.019		²¹⁶ BUSKULIC		1990-1992 LEP runs	ESCRIBANO PROCARIO	93	PL B301 419 PRL 70 1207	+Masso +Yang, Balest, Cho+	(CLEO C
• We do not use t	he following	ng data for average	s, fits, limits	, etc. • • •	ABREU ACTON		ZPHY CS5 555 PL B281 405	+Adam, Adye, Agasi+ +Alexander, Allison, Allport+	(DELPHI C
8 +0.46 +0.14 -0.41 -0.25	2.6k	²¹⁷ AKERS	95P OPAL	Repl. by ACKER-	ACTON AKERIB	92H	PL B288 373 PRL 69 3610	+Allison, Allport+	(OPAL C
22±0.028±0.030	1.7k	218 ALBRECHT	94E ARG	STAFF 97R Ecm = 9.4-10.6 GeV	Also	938	PRL 71 3395 (erratum)	+Barish, Chadha, Cowen+ Akerib, Barish, Chadha, Cowen+	(CLEO C
9 ±0.07 ±0.04		219 BUSKULIC		1990+1991 LEP run	ALBRECHT ALBRECHT		ZPHY C53 367 ZPHY C55 179	+Ehrlichmann, Hamacher+ +Ehrlichmann, Hamacher, Krueger+	(ARGUS C
5 ±0.23 +0.15 -0.08		220 ALBRECHT	93c ARG	Ecm = 9.4-10.6 GeV	ALBRECHT ALBRECHT	92M	PL B292 221 ZPHY C56 339	+Ehrlichmann, Hamacher, Hofmann+ +Ehrlichmann, Hamacher+	(ARGUS C
			,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	ocm - M Iolo Cot	AMMAR	92	PR D45 3976	+Baringer, Coppage, Davis+	(CLEO C
ACKERSTAFF 97	use $\tau \rightarrow$	$a_1 \nu_{ au}$ decays.			ARTUSO BAI	92	PRL 69 3278 PRL 69 3021	+Goldberg, Horwitz, Kennett+ +Bardon, Becker-Szendy, Burnett+	(CLEO C
² ALEXANDER 97F ³ COAN 97 use h ⁺ /	use $\tau \rightarrow$	$\rho \nu_{\tau}$ decays.			BATTLE BUSKULIC	92	PL B291 488 PL B297 459	+Ernst, Kroha, Roberts+ +Decamp, Goy, Lees+	(CLEO C
ACCIARRI 96H use	energy	correlations.	τ → 02 d	ecavs	DECAMP ADEVA	92C	ZPHY C54 211 PL B265 451	+Deschizeaux, Goy, Lees+ +Adriani, Aguilar-Benitez, Akbari+	(ALEPH C
	RGUS tau	decay parameter r	neasurement	s in ALBRECHT 95C, AL-	ALBRECHT	91D	PL B260 259	+Ehrlichmann, Hamacher, Krueger+	(ARGUS C
Combined fit to A	ALBREC	HT 94E.			ANTREASYAN	91	PL B266 201 PL B259 216	+Allison, Allport, Anderson+ +Bartels, Besset, Bieler+	OPAL () Crystal Ball ()
⁵ Combined fit to A BRECHT 93G, and	$e \tau \rightarrow \pi r$	$\nu_{\tau}, \tau \rightarrow \rho \nu_{\tau}$, and	$ au ightarrow a_1 u_{ au}$	decays.	GRIFOLS SAMUEL	91	PL B255 611 PRL 67 668	+Mendez +Li, Mendel	OKSU, V
⁵ Combined fit to A BRECHT 93G, and ⁶ BUSKULIC 95D us	$\rightarrow a_1 \nu_{\pi}$	decays.	.anele	the elem d-t1-: 11	Alea		PRL 69 995	Samuel, Li, Mendel	(OKSU, V
⁵ Combined fit to A BRECHT 93G, and ⁶ BUSKULIC 95D us ⁷ AKERS 95P use τ		e square of this quality in the proofer of the square of t	iantity and the Uses $\tau \to -1$	use the sign determined by $a_1 u_{ au}$ decays. Replaced by	, ABACHI		PR D41 1414	+Derrick, Kooljman, Musgrave+	(HRS C
⁵ Combined fit to A BRECHT 93G, and 6 BUSKULIC 95D us ⁷ AKERS 95P use τ ⁸ ALBRECHT 94E r	neasure th	4 100011.		- /	ALBRECHT	90E	PL B246 278 PL B250 164	+Ehrlichmann, Harder, Krueger+ +Ehrlichmann, Harder, Krueger+	(ARGUS (
⁵ Combined fit to A BRECHT 93G, and 6 BUSKULIC 95D us ⁷ AKERS 95P use τ 8 ALBRECHT 94E r ALBRECHT 95C	neasure th o obtain ti			readed by DUSKING OFF	BEHREND	90	ZPHY C46 537	+Criegee, Field, Franke+	(CELLO C
⁵ Combined fit to A BRECHT 93G, and ⁶ BUSKULIC 95D us ⁷ AKERS 95P use τ ⁸ ALBRECHT 94E r ALBRECHT 90I to ALBRECHT 95C. ⁹ BUSKULIC 94D us	neasure the obtain the $\tau \rightarrow \pi i$	$\nu_{ au}$ and $ au ightarrow ho u_{ au}$ c	lecays. Supe	iseded by BOSKOLIC 950.					
⁵ Combined fit to A BRECHT 93C, and ⁶ BUSKULIC 95D us ⁷ AKERS 95P use τ ⁸ ALBRECHT 94E r ALBRECHT 90I to ALBRECHT 95C. ⁹ BUSKULIC 94D us	neasure the obtain the $\tau \rightarrow \pi i$	$\nu_{ au}$ and $ au ightarrow ho u_{ au}$ c	lecays. Supe HT 95C.	iseded by BOSKOLIC 450.	BOWCOCK DELAGUILA	90	PR D41 805 PL B252 116	+Kinoshita, Pipkin, Procario+ +Sher	(CLEO C (BARC,
⁵ Combined fit to A BRECHT 93G, and ⁶ BUSKULIC 95D us ⁷ AKERS 95P use τ ⁸ ALBRECHT 94E r ALBRECHT 90I to ALBRECHT 95C. ⁹ BUSKULIC 94D us	neasure the obtain the $\tau \rightarrow \pi i$	$\nu_{ au}$ and $ au ightarrow ho u_{ au}$ c	decays. Supe HT 95C.	sected by BUSKULIC 930.	DELAGUILA GOLDBERG WU	90 90		+Sher +Haupt, Horwitz, Jain+	
⁵ Combined fit to A BRECHT 93G, and 6 BUSKULIC 95D us 7 AKERS 95P use τ 8 ALBRECHT 94E r ALBRECHT 901 to	neasure the obtain the $\tau \rightarrow \pi i$	$\nu_{ au}$ and $ au ightarrow ho u_{ au}$ c	lecays. Supe HT 95C.		DELAGUILA GOLDBERG WU ABACHI	90 90 90 898	PL B252 116 PL B251 223 PR O41 2339 PR D40 902	+Sher +Haupt, Horwitz, Jain+ +Hayes, Perl, Barklow+ +Derrick, Kooljman, Musgrave+	(BARC, (CLEO ((Mark II ((HRS (
5 Combined fit to A BRECHT 93c, and 6 BUSKULIC 95D us 7 AKERS 95P use t 8 ALBRECHT 94E r ALBRECHT 90I to ALBRECHT 95C. 9 BUSKULIC 94D us	neasure the obtain the $\tau \rightarrow \pi i$	$\nu_{ au}$ and $ au ightarrow ho u_{ au}$ c	lecays. Supe HT 95C.	sector by Boskotic 450.	DELAGUILA GOLDBERG WU	90 90 90 89B 89B 89	PL B252 116 PL B251 223 PR D41 2339	+Sher +Haupt, Horwitz, Jain+ +Hayes, Perl, Barklow+ +Derrick, Kooljman, Musgrave+ +Criegee, Dainton, Field, Franke+	(BARC, (CLEO ((Mark II (

au, Heavy Charged Lepton Searches

ALBRECHT	88B	PL B202 149	+Binder, Boeckmann+	(ARGUS Collab.)
ALBRECHT	88L		+Boeckmann, Glaeser, Harder+	(ARGUS Collab.)
		ZPHY C41 1		
ALBRECHT		ZPHY C41 405	+Boeckmann, Glaeser, Harder+	(ARGUS Collab.)
AMIDEI	88	PR D37 1750	+Trilling, Abrams, Baden+	(Mark II Collab.)
BEHREND	88	PL B200 226	+Criegee, Dainton, Field+	(CELLO Collab.)
BRAUNSCH		ZPHY C39 331	Braunschweig, Kirschfink, Martyn+	(TASSO Collab.)
		DI BO10 122	Antonomia Bontola Bontola	(C-mal Ball Callab.)
KEH	88	PL B212 123	+Antreasyan, Bartels, Besset+	(Crystal Ball Collab.)
TSCHIRHART	88	Pl. B205 407	+Abachi, Akerlof, Baringer+	(HRS Collab.)
ABACHI	87B	PL B197 291	+Baringer, Bylsma, De Bonte+	(HRS Collab.)
ABACHI	87C	PRL 59 2519	+Akerlof, Baringer, Blockus+	(HR5 Collab.)
		PRL 59 1527	+Becker, Blaylock, Bolton+	
ADLER	87B			(Mark III Collab.)
AIHARA	87B	PR D35 1553	+Alston-Garnjost, Avery+	(TPC Collab.)
AIHARA	87C	PRL 59 751	+Alston-Garnjost, Avery+	(TPC Collab.) (TPC Collab.)
AI RDECHT	271	PL B185 223	+Binder, Boeckmann, Glaser+	(ARGUS Collab.)
ALBRECHT ALBRECHT	011			
	811	PL 8199 580	+Andam, Binder, Boeckmann+	(ARGUS Collab.)
BAND	87	PL B198 297	+Camporesi, Chadwick, Delfino+	(MAC Collab.)
BAND	87B	PRL 59 415	+Bosman, Camporesi, Chadwick+	(MAC Collab.)
RARINGER	87	PRL 59 1993	+McIlwain, Miller, Shibata+	(CLEO Collab.)
BARINGER BEBEK	076	DD DOC (00	+Berkelman, Blucher, Cassel+	
DEDEN	6/4	PR 036 690		(CLEO Collab.)
	87	PR D35 27	+Feldman, Barklow, Boyarski+	(Mark II Collab.)
BYLSMA	87	PR D35 2269	+Abachi, Baringer, DeBonte+	(HRS Collab.)
COFFMAN		PR D36 2185	+Dubois, Eigen, Hauser+	(Mark III Collab.)
DERRICK		PL B189 260	+Kooijman, Loos, Musgrave+	(HRS Collab.)
FORD	87	PR D35 408	+Qi, Read, Smith+	(MAC Collab.)
FORD	87B	PR D36 1971	+Qi, Read, Smith+	(MAC Collab.)
GAN	87	PRL 59 411	+Abrams, Amidei, Baden+	(Mark II Collab.)
GAN				
		PL B197 561	+Abrams, Amidei, Baden+	(Mark II Collab.)
Alhara	86E	PRL 57 1836	+Alston-Garnjost, Avery+	(TPC Collab.)
BARTEL	86D	PL B182 216	+Becker, Felst, Haidt, Knies+	(JADE Collab.)
PDG	86	PL 170B	Aguilar-Benitez, Porter+	(CERN, CIT+)
				(DELCO Collab.)
RUCKSTUHL		PRL 56 2132	+Stroynowski, Atwood, Barish+	
SCHMIDKE	86	PRL 57 527	+Abrams, Matteuzzi, Amidei+	(Mark II Collab.)
YELTON	86	PRL 56 812	+Dorfan, Abrams, Amidei+	(Mark II Collab.)
ALTHOFF	85	ZPHY C26 521	+Braunschweig, Kirschfink+	(TASSO Collab.)
ASH		PRL 55 2118	+Band, Blume, Camporesi+	(MAC Collab.)
BALTRUSAIT.		PRL 55 1842	Baltrusaitis, Becker, Blaylock, Brown 4	
BARTEL	85F	PL 161B 188	+Becker, Cords, Felst+	(JADE Collab.)
BEHRENDS	85	PR D32 2468	+Gentile, Guida, Guida, Morrow+	(CLEO Collab.)
	85	PRL 54 1775	+Bylsma, DeBonte, Gan+	(HRS Collab.)
DELIKAMI	02			
BERGER	85	ZPHY C28 1	+Genzel, Lackas, Pielorz+	(PLUTO Collab.)
BURCHAT	85	PRL 54 2489	+Schmidke, Yelton, Abrams+	(Mark If Collab.)
FERNANDEZ	85	PRL 54 1624	+Ford, Qi, Read+	(MAC Collab.)
MILLS	oE.	PRL 54 624	+Pal, Atwood, Baillon+	(DELCO Collab.)
MILLS	85 84C	FRL 34 024		
AIHARA	84C	PR D30 2436	+Alston-Garnjost, Badtke, Bakken+	(TPC Collab.)
BEHREND	84	ZPHY C23 103	+Fenner, Schachter, Schroder+	(CÉLLO Collab.)
MILLS	84	PRL 52 1944	+Ruckstuhl, Atwood, Baillon+	(DELCO Collab.)
AIHARA BEHREND MILLS BEHREND	830	PL 127B 270	+Chen, Fenner, Gumpel+	(CELLO Collab.)
O4.11(E110	050			
SILVERMAN	83	PR D27 1196	+Shaw	(UCI)
BEHREND	82	PL 114B 282	TCHEA, FEIMEI, FIEIGT	(CELLO Collab.)
BLOCKER	82B	PRL 48 1586	+Abrams, Alam, Blondel+	(Mark II Collab.)
BLOCKER		PL 109B 119	+Dorfan, Abrams, Alam+	(Mark II Collab.) J
FELDMAN	82	PRL 48 66	+Trilling, Abrams, Amidei+	(Mark II Collab.)
HAYES	82_	PR D25 2869	+Perl, Alam, Boyarski+	(Mark II Collab.)
BERGER	81B	PL 99B 489	+Genzel, Grigull, Lackas+	(PLUTO Collab.)
DORFAN	81	PRL 46 215	+Blocker, Abrams, Alam+	(Mark II Collab.)
BRANDELIK	80	PL 92B 199	+Braunschweig, Gather+	(TASSO Collab.)
			+Kurdadze, Lelchuk, Mishnev+	
ZHOLENTZ	80	PL 96B 214		(NOVO)
Also	81	SJNP 34 814	Zholentz, Kurdadze, Leichuk+	(NOVO)
		Translated from YAF	34 1471.	•
BACINO	79B	PRL 42 749	+Ferguson, Nodulman, Slater+	(DELCO Collab.)
KIRKBY	79	SLAC-PUB-2419		(SLAC) J
		Photon Conference.		(SEAC) 3
			Francis Notition Class	(DELCO C-8.1.)
BACINO		PRL 41 13	+Ferguson, Nodulman, Slater+	(DELCO Collab.) J
Also	78	Tokyo Conf. 249	Kirz	(STON)
	80	PL 96B 214	Zholentz, Kurdadze, Leichuk, Mishney	
		PL 73B 109	+Braunschweig, Martyn, Sander+	(DASP Collab.) J
Also RPANDELIK			TOTAL STREET, MAILYN, JANGELT	(PMSE CONDITION
BRANDELIK	78			
Brandelik Feldman	76	Tokyo Conf. 777		(SLAC) J
BRANDELIK	76 78		+Perl, Abrams, Alam, Boyarski+	(SLAC, LBL)
Brandelik Feldman	76	Tokyo Conf. 777	+Perl, Abrams, Alam, Boyarski+ +Abrams, Alam+ (SLAC, I	(SLAC, LBL)
BRANDELIK FELDMAN HEILE JAROS	76 78 78	Tokyo Conf. 777 NP B138 189 PRL 40 1120	+Abrams, Alam+ (SLAC,	(SLAC, LBL) LBL, NWES, HAWA)
Brandelik Feldman Heile	76 78	Tokyo Conf. 777 NP B138 189	+Perl, Abrams, Alam, Boyarski+ +Abrams, Alam+ (SLAC, I +Abrams, Boyarski, Breidenbach+	(SLAC, LBL)
BRANDELIK FELDMAN HEILE JAROS	76 78 78	Tokyo Conf. 777 NP B13B 189 PRL 40 1120 PRL 35 1489	+Abrams, Alam+ (SLAC,	(SLAC, LBL) LBL, NWES, HAWA)

OTHER RELATED PAPERS -

GENTILE	96	PRPL 274 287	+Pohl	(ROMAI, ETH)
WEINSTEIN	93	ARNPS 43 457	+Stroynowski	(CIT, SMU)
PERL	92	RPP 55 653	•	` (SLAC)
PICH	90	MPL AS 1995		(VALE)
BARISH	88	PRPL 157 1	+Stroynowski	(CIT)
GAN	88	IJMP A3 531	+Perl	(SLAC)
HAYES	88	PR D38 3351	+Perl	(SLAC)
PERL	80	ARNPS 30 299		. (SLAC)

Heavy Charged Lepton Searches

Charged Heavy Lepton MASS LIMITS

Sequential Charged Heavy Lepton (L±) MASS LIMITS

These experiments assumed that a fourth generation L^\pm decayed to a fourth generation ν_L (or L^0) where ν_L was stable, or that L^\pm decays to a light ν_L via mixing.

See the "Quark and Lepton Compositeness, Searches for" Listings for limits on radiatively decaying excited leptons, i.e. $\ell^* \to \ell \gamma$. See the "WIMPs and other Particle Searches" section for heavy charged particle search limits in which the charged particle could be a lepton.

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT	
>81.5	95	ACKERSTAFF	98c OPAL	Assumed $m_{L^{\pm}} - m_{L^0} > 8.4$	
>80.2	95	ACKERSTAFF	98c OPAL	GeV $m_{L^0} > m_{L^\pm}$ and $L^\pm \to \nu W$	
>72	95	ACCIARRI	97P L3	Assumed $m_{I\pm} - m_{\nu_I} > 10 \text{ GeV}$	
>81	95	ACCIARRI	97P L3	Assumed $m_{I\pm} - m_{\nu_I} > 20 \text{ GeV}$	
>78.7	95	ACCIARRI	97P L3	Light ν , $\sqrt{s} = 161$, 172 GeV	
< 48 or > 61	95	¹ ACCIARRI	96G L3		
>64.5	95	ALEXANDER	96P OPAL	$m_{L} - m_{I0} > 10 \text{ GeV}$	
>63.5	95	BUSKULIC	96s ALEP	$m_L - m_{10} > 7 \text{ GeV}$	
>42.8	95	ADEVA	90s L3	Decay to Dirac ν_I	
>44.3	95	AKRAWY	90G OPAL	~	

• • • We do no	t use t	he following data for	averages, fit	is, limits, etc. • •
>73.5	95	ACKERSTAFF	-	Assumed $m_{L^{\pm}} - m_{\nu_L} > 13 \text{ GeV}$
>76.7	95	ACKERSTAFF	97D OPAL	$m_{\nu_L} > m_{L^{\pm}}$ and $L^{\pm} \rightarrow \nu W^*$
>63.9	95	ALEXANDER	96P OPAL	Decay to massless ν's
>65	95	BUSKULIC	96S ALEP	Decay to massless v's
none 10-225		² AHMED	94 CNTR	H1 Collab. at HERA
none 12.6-29.6	95	KIM	918 AMY	Massless ν assumed
>42.7	95	DECAMP	90F ALEP	
none 0.5-10	95	3 RILES	90 MRK2	For (m ₁₀ -m ₁₀)> 0.25-0.4GeV
> 8		4 STOKER	89 MRK2	
>12		⁴ STOKER	89 MRK2	For m ₁₀ =0.9 GeV
none 18.4-27.6	95 .	⁵ ABE	88 VNS	
>25.5	95	⁶ ADACHI	888 TOPZ	
none 1.5-22.0	95	BEHREND	88C CELL	
>41	90	⁷ ALBAJAR	87B UA1	
>22.5	95	8 ADEVA	85 MRKJ	
>18.0	95	9 BARTEL	83 JADE	
none 4-14.5	95	10 BERGER	81B PLUT	
>15.5	95	11 BRANDELIK	81 TASS	
>13.		12 AZIMOV	80	
>16.	95	13 BARBER	80B CNTR	
> 0.490		14 ROTHE	69 RVUE	
GeV. ² The AHMEI at HERA via	94 lin	nits are from a search ecay channels $L^- \rightarrow$	for neutral a $e\gamma$, $L^- \rightarrow$	ted neutral heavy lepton mass $>$ 40 nd charged sequential heavy leptons νW^- , $L^- \to eZ$; and $L^0 \to \nu \gamma$, to $\ell \nu_\ell$, or to jets, and Z decays to
$\ell^+\ell^-$ or jet	s.			-
³ RILES 90 lin difference <i>m</i> Into which t	L- he seq	m _{L0} was allowed to uential charged lepto	be quite sm n decays. V	the data in the case where the mass rall, where \mathcal{L}^0 denotes the neutrino vith a slightly reduced m_{I^\pm} range,
4 STOKER 89	(Mar	extends to about 4 of k II at PEP) gives b	ounds on ch	narged heavy lepton (L+) mass for
doublet is no	ot of n	egligible mass.	_	tral heavy lepton (L^0) in the SU(2)
valid for m_{ν}	, < 10	GeV.		g for acoplanar jets. The bound is
6 ADACHI 88	searci	for hadronic decays	riving acopia	nar events with large missing energy.

⁶ ADACHI 88B search for hadronic decays giving acoplanar events with large missing energy. $E_{cm}^{ee} = 52 \text{ GeV}.$

7 Assumes associated neutrino is approximately massless. 8 ADEVA 85 analyze one-isolated-muon data and sensitive to au <10 nanosec. Assume B(lepton) = 0.30. $E_{cm} = 40-47$ GeV.

⁹ BARTEL 83 limit is from PETRA e⁺ e⁻ experiment with average $E_{cm} = 34.2$ GeV.

¹⁰ BERGER B1B is DESY DORIS and PETRA experiment. Looking for $e^+e^- \rightarrow L^+L^-$.

11 BRANDELIK 81 Is DESY-PETRA experiment. Looking for $e^+e^- \rightarrow L^+L^-$.

12 AZIMOV 80 estimated probabilities for M+N type events in $e^+e^- \rightarrow L^+L^-$ deducing semi-hadronic decay multiplicities of L from e^+e^- annihilation data at $\mathcal{E}_{cm}=(2/3)m_L$. Obtained above limit comparing these with e^+e^- data (BRANDELIK 80).

 13 BARBER 808 looked for e⁺ e⁻ \rightarrow L⁺ L⁻ , L \rightarrow ν_L^+ X with MARK-J at DESY-PETRA.

 14 ROTHE 69 examines previous data on μ pair production and π and K decays.

Stable Charged Heavy Lepton (L±) MASS LIMITS

VALUE (GeV)	CL%	DOCUMENT ID		TECN	
>84.2	95	ACCIARRI	97P	L3	
• • • We do not us	e the follow	ing data for averag	es, fits	, limits, e	łc. • • •
>28.2	95	15 ADACHI	90c	TOPZ	
none 18.5~42.8	95	AKRAWY	900	OPAL	
>26.5	95	DECAMP	90F	ALEP	
none m ₁₁ -36.3	95	SODERSTRO	M90	MRK2	

 15 ADACHI 90c put lower limits on the mass of stable charged particles with electric charge Q satisying 2/3 < Q/e < 4/3 and with spin 0 or 1/2. We list here the special case for a stable charged heavy lepton.

Charged Long-Lived Heavy Lepton MASS LIMITS

VALUE (GeV)	EVTS	DOCUMENT ID		TECN_	CHG	COMMENT .
• • • We do not use	the followin	g data for averag	es, fits	, ilmits,	etc. •	• •
>0.1	0	16 ANSORGE	73B	HBC	_	Long-Ilved
none 0.55-4.5		17 BUSHNIN	73	CNTR	_	Long-lived
none 0.2-0.92		18 BARNA	68	CNTR	-	Long-lived
none 0.97-1.03		18 BARNA	68	CNTR	-	Long-lived

 $^{16}\,\text{ANSORGE}$ 73B looks for electron pair production and electron-like Bremsstrahlung.

17 BUSHNIN 73 Is SERPUKOV 70 GeV p experiment. Masses assume mean life above 7 x 10⁻¹⁰ and 3 x 10⁻⁸ respectively. Calculated from cross section (see "Charged Quasi-Stable Lepton Production Differential Cross Section" below) and 30 GeV muon pair production data.

18 BARNA 68 is SLAC photoproduction experiment.

Doubly-Charged Heavy Lepton MASS LIMITS

VALUE (GeV)		DOCUMENT	ID	TECN	<u>CHG</u>		
• • • We do not use t	he follow	ling data for avera	ges, fit	s, Ilmits,	etc.	•	•
none 1-9 GeV	90	19 CLARK	81	SPEC	++		

 19 CLARK 81 is FNAL experiment with 209 GeV muons. Bounds apply to μ_P which couples with full weak strength to muon. See also section on "Doubly-Charged Lepton Produciton Cross Section."

Heavy Charged Lepton Searches, Neutrinos

Doubly-Charged Lepton Production Cross Section $(\mu N \text{ Scattering})$

VALUE (cm ²)	EVTS	DOCUMENT I	0	TECN	CHG	
• • • We do not use th	e followin	g data for avera	ges, fits	, limits,	etc. •	• •
<6. × 10 ⁻³⁸	0	²⁰ CLARK	81	SPEC	++	

²⁰CLARK 81 is FNAL/experiment with 209 GeV muon. Looked for μ^+ nucleon $\to \overline{\mu}_P^0 \times$, $\overline{\mu}_P^0 \to \mu^+ \mu^- \overline{\nu}_\mu$ and $\mu^+ n \to \mu_P^+ \times$, $\mu_P^+ \to 2\mu^+ \nu_\mu$. Above limits are for $\sigma \times BR$ taken from their mass-dependence plot figure 2.

REFERENCES FOR Heavy Charged Lepton Searches

ACKERSTAFF		EPJ C1 45	K. Ackerstaff+	(OPAL Collab.)
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BUSKULIC	965	PL B384 439	+De Bonis, Decamp, Ghez+	(ALEPH Collab.)
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NEUTRINO MASS

Written February 1998 by B. Kayser (NSF).

While there is no unequivocal evidence for neutrino mass, it is natural to suspect that the neutrinos, like the charged leptons and the quarks, have nonzero masses. Evidence of these masses is being sought through experiments on neutrinos created astrophysically, in the earth's atmosphere, by accelerators, by reactors, and by nuclear decays, and in studies of reactions where neutrinos appear only as virtual particles.

In the decay

$$W^+ \to \ell^+ \nu_{\ell} \tag{1}$$

(SLAC)

of a W boson into a charged lepton of "flavor" $\ell(e, \mu, \text{ or } \tau)$, the accompanying neutrino is referred to as ν_{ℓ} , the neutrino of flavor ℓ . Neutrinos of different flavor are different objects. When an energetic ν_{ℓ} undergoes a charged-current weak interaction, it produces a charged lepton ℓ of the same flavor as the neutrino [1].

If neutrinos have masses, then a neutrino of definite flavor, ν_{ℓ} , need not be a mass eigenstate. Indeed, if leptons behave like quarks, the ν_{ℓ} is a coherent linear superposition of mass eigenstates, given by

$$|\nu_{\ell}\rangle = \sum_{m} U_{\ell m} |\nu_{m}\rangle . \qquad (2)$$

Here, the ν_m are the mass eigenstates, and the coefficients $U_{\ell m}$ form a matrix U known as the leptonic mixing matrix.

There are at least three ν_m , and perhaps more. However, it is usually assumed that no more than three ν_m make significant contributions to Eq. (2). Then U is a 3×3 matrix, and according to the electroweak Standard Model (SM), extended to include neutrino masses, it is unitary.

The relation (2) means that when, for example, a W^+ decays to an e^+ and a neutrino, the neutrino with probability $|U_{e1}|^2$ is a ν_1 , with probability $|U_{e2}|^2$ is a ν_2 , and so on. This behavior is an exact leptonic analogue of what is known to occur when a W^+ decays to quarks.

If each neutrino of definite flavor is a coherent superposition of mass eigenstates, then we will have neutrino oscillation [2]. This is the spontaneous metamorphosis of a neutrino of one flavor into one of another flavor as the neutrino propagates.

To understand neutrino oscillation, let us consider how a neutrino born as the ν_{ℓ} of Eq. (2) evolves in time. First, we apply Schrödinger's equation to the ν_m component of ν_{ℓ} in the rest frame of that component. This tells us that [3]

$$|\nu_m(\tau_m)\rangle = e^{-iM_m\tau_m}|\nu_m(0)\rangle , \qquad (3)$$

where M_m is the mass of ν_m , and τ_m is time in the ν_m frame. In terms of the time t and position L in the laboratory frame, the Lorentz-invariant phase factor in Eq. (3) may be written

$$e^{-iM_m\tau_m} = e^{-i(E_mt - p_mL)} . (4)$$

Here, E_m and p_m are respectively the energy and momentum of ν_m in the laboratory frame. In practice, our neutrino will be extremely relativistic, so we will be interested in evaluating the phase factor of Eq. (4) where $t \approx L$, where it becomes $\exp[-i(E_m - p_m)L]$.

Imagine now that our ν_ℓ has been produced with a definite momentum p, so that all of its mass-eigenstate components have this common momentum. Then the ν_m component has $E_m = \sqrt{p^2 + M_m^2} \approx p + M_m^2/2p$, assuming that all neutrino masses M_m are small compared to the neutrino momentum. The phase factor of Eq. (4) is then approximately

$$e^{-i(M_m^2/2p)L} (5)$$

Alternatively, suppose that our ν_ℓ has been produced with a definite energy E, so that all of its mass-eigenstate components have this common energy [4]. Then the ν_m component has $p_m = \sqrt{E^2 - M_m^2} \approx E - M_m^2/2E$. The phase factor of Eq. (4) is then approximately

$$e^{-i(M_m^2/2E)L} (6)$$

Since highly relativistic neutrinos have $E \approx p$, the phase factors (5) and (6) are approximately equal. Thus, it doesn't matter whether our ν_{ℓ} is created with definite momentum or definite energy.

From Eq. (2) and either Eq. (5) or Eq. (6), it follows that after a neutrino born as a ν_{ℓ} has propagated a distance L, its state vector has become

$$|\nu_{\ell}(L)\rangle \approx \sum_{m} U_{\ell m} e^{-i(M_{m}^{2}/2E)L} |\nu_{m}\rangle$$
 (7)

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Using the unitarity of U to invert Eq. (2), and inserting the result in Eq. (7), we find that

$$|\nu_{\ell}(L)\rangle pprox \sum_{\ell'} \left[\sum_{m} U_{\ell m} e^{-i(M_m^2/2E)L} U_{\ell'm}^* \right] |\nu_{\ell'}\rangle .$$
 (8)

We see that our ν_{ℓ} , in traveling the distance L, has turned into a superposition of all the flavors. The probability that it has flavor ℓ' , $P(\nu_{\ell} \to \nu_{\ell'}; L)$, is obviously given by

$$P(\nu_{\ell} \to \nu_{\ell'}; L) = |\langle \nu_{\ell'} | \nu_{\ell}(L) \rangle|^2 = \left| \sum_{m} U_{\ell m} e^{-i(M_m^2/2E)L} U_{\ell'm}^* \right|^2.$$
(9)

The quantum mechanics of neutrino oscillation leading to the result Eq. (9) is somewhat subtle. It has been analyzed using wave packets [5], treating a propagating neutrino as a virtual particle [6], evaluating the phase acquired by a propagating mass eigenstate in terms of the proper time of propagation [3], requiring that a neutrino's flavor cannot change unless the neutrino travels [4], and taking different neutrino mass eigenstates to have both different momenta and different energies [7]. The subtleties of oscillation are still being explored and discussed.

Frequently, a neutrino oscillation experiment is analyzed assuming that only two neutrino flavors, ν_e and ν_μ for example, mix appreciably. Then the mixing matrix U takes the form

$$U = \begin{pmatrix} \cos \theta_{e\mu} & \sin \theta_{e\mu} \\ -\sin \theta_{e\mu} & \cos \theta_{e\mu} \end{pmatrix} , \qquad (10)$$

where $\theta_{e\mu}$ is the ν_e - ν_μ mixing angle. Inserting this matrix into Eq. (9), we find that

$$P(\nu_e \to \nu_\mu; L) = \sin^2 2\theta_{e\mu} \sin^2 \left(\Delta M_{12}^2 L/4E\right)$$
 (11)

Here, $\Delta M_{12}^2 \equiv M_1^2 - M_2^2$, where ν_1 and ν_2 are the mass eigenstates which make up ν_e and ν_μ . If the omitted factors of \hbar and c are inserted into the argument $\Delta M_{12}^2 L/4E$ of the oscillatory sine function, it becomes 1.27 ΔM_{12}^2 (eV²)L (km)/E (GeV). The probability that a ν_e will retain its original flavor during propagation over a distance L is simply

$$P(\nu_e \to \nu_e; L) = 1 - P(\nu_e \to \nu_\mu; L) . \tag{12}$$

Under some important circumstances, a "two-neutrino" formula virtually identical to that of Eq. (11) accurately describes neutrino oscillation even when all three neutrino flavors mix. One of these circumstances is when all mixing angles are small. That is, each neutrino of definite flavor is dominantly one mass eigenstate, plus only small amounts of the other two. In this circumstance, let us refer to the dominant mass eigenstate component of ν_e as ν_1 , that of ν_μ as ν_2 , and that of ν_τ as ν_3 . Then the mixing matrix U is approximately

$$U \approx \begin{pmatrix} 1 & \theta_{e\mu} & \theta_{e\tau} \\ -\theta_{e\mu} & 1 & \theta_{\mu\tau} \\ -\theta_{e\tau} & -\theta_{\mu\tau} & 1 \end{pmatrix} , \qquad (13)$$

where θ_{ab} is the (small) ν_{ℓ_a} – ν_{ℓ_b} mixing angle. Inserting this mixing matrix in Eq. (9), we find that through second order in the mixing angles,

$$P(\nu_{\ell_a} \to \nu_{\ell_b \neq \ell_a}; L) \approx (2\theta_{ab})^2 \sin^2(\Delta M_{ij}^2 L/4E)$$
 (14)

Here, $\Delta M_{ij}^2 \equiv M_i^2 - M_j^2$, where ν_i and ν_j are, respectively, the dominant mass eigenstate components of ν_{ℓ_a} and ν_{ℓ_b} . We see that when all mixing angles are small, the oscillation between any pair of neutrino flavors is indeed described by a two-neutrino formula just like Eq. (11), but for each pair of flavors, there is a different mixing angle and a different ΔM^2 . In addition, in contrast to Eq. (12), the probability that a neutrino (say, a ν_e) retains its original flavor is now given by

$$P(\nu_e \to \nu_e; L) = 1 - P(\nu_e \to \nu_\mu; L) - P(\nu_e \to \nu_\tau; L)$$
. (15)

Another interesting situation occurs when there is a neutrino mass hierarchy, $M_3 \gg M_2 \gg M_1$, so that $\Delta M_{32}^2 \approx \Delta M_{31}^2 \gg \Delta M_{21}^2$. Then there is a region of L/E in which $\Delta M_{21}^2 L/E$ is negligible compared to unity, but $\Delta M_{32}^2 L/E$ is not. For L/E in this region, it follows from Eq. (9) and the unitarity of U that [8]

$$P(\nu_{\ell_a} \to \nu_{\ell_b \neq \ell_a}; L) \approx |2U_{a3}U_{b3}|^2 \sin^2(\Delta M_{32}^2 L/4E)$$
 (16)

Once again, the oscillation probability has the same form as when just two neutrinos mix. Furthermore, Eq. (16) holds whether the mixing angles are large or small. However, the parameters in Eq. (16) have a different meaning from those in the true two-neutrino formula, Eq. (11). In Eq. (16), the coefficient $|2U_{a3}U_{b3}|^2$ is, in general, $not \sin^2 2\theta_{ab}$, as it would be in the two-neutrino case. (To be sure, $|2U_{a3}U_{b3}|^2$ never exceeds unity, anymore than $\sin^2 2\theta_{ab}$ does.) In addition, in Eq. (16), the mass splitting which appears is always the same one— ΔM_{32}^2 —regardless of which neutrino flavors are being considered.

In a beam of neutrinos born with flavor ℓ_a , neutrino oscillation can be sought in two ways: First, one may seek the appearance in the beam of neutrinos of a different flavor, ℓ_b . Secondly, one may seek a disappearance of some of the original ν_{ℓ_a} flux, or an L-dependence of this flux.

Clearly, no oscillation is expected unless L/E of the experiment is sufficiently large that the phase factors $\exp(-iM_m^2 L/2E)$ in Eq. (9) differ appreciably from one another. Otherwise, $P(\nu_\ell \to \nu_{\ell'}; L) = |\sum_m U_{\ell m} U_{\ell'm}^*|^2 = \delta_{\ell\ell'}$. Now, with omitted factors of \hbar and c inserted, the relative phase of $\exp(-iM_i^2L/2E)$ and $\exp(-iM_j^2L/2E)$ is 2.54 $\Delta M_{ij}^2({\rm eV}^2)$ $L({\rm km})/E({\rm GeV})$. Thus, for example, an experiment in which neutrinos with $E \approx 1$ GeV travel 1 km between production and detection will be sensitive to $\Delta M^2 \gtrsim 1$ eV².

A more direct way than neutrino oscillation experiments to search for neutrino mass is to look for its kinematical effects in decays which produce a neutrino. In the decay $X \to Y\ell^+\nu_\ell$, where X is a hadron and Y is zero or more hadrons, the momenta of ℓ^+ and the particles in Y will obviously be modified if ν_ℓ has a mass. If ν_ℓ is a superposition of mass eigenstates ν_m , then $X \to Y\ell^+\nu_\ell$ is actually the sum of the

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decays $X \to Y \ell^+ \nu_m$ yielding every ν_m light enough to be emitted. Thus, if, for example, one ν_m is much heavier than the others, the energy spectrum of ℓ^+ may show a threshold rise where the ℓ^+ energy becomes low enough for the heavy ν_m to be emitted [9]. However, if neutrino mixing is small, then the decays $X \to Y \ell^+ \nu_m$ yield almost always the neutrino mass eigenstate which is the dominant component of ν_ℓ . The kinematics of ℓ^+ and Y then reflect the mass of this mass eigenstate.

From kinematical studies of the particles produced in ${}^3{\rm H} \to {}^3{\rm He}\ e^-\overline{\nu}_e, \pi \to \mu\nu_\mu, \ {\rm and}\ \tau \to n\pi\nu_\tau, \ {\rm upper}\ {\rm limits}\ {\rm have}\ {\rm been}\ {\rm derived}\ {\rm for}\ M_1, M_2, \ {\rm and}\ M_3, \ {\rm respectively.}$ Here, we assume mixing to be small, and, as before, call the dominant masseigenstate components of $\nu_e, \nu_\mu, \ {\rm and}\ \nu_\tau, \ {\rm respectively}, \nu_1, \nu_2, \ {\rm and}\ \nu_3.$ In the case of the decay ${}^3{\rm H} \to {}^3{\rm He}\ e^-\overline{\nu}_e, \ {\rm the}\ {\rm upper}\ {\rm bound}\ {\rm on}\ {\rm the}\ {\rm neutrino}\ {\rm mass}\ {\rm is}\ {\rm derived}\ {\rm from}\ {\rm study}\ {\rm of}\ {\rm the}\ e^-\ {\rm energy}\ {\rm spectrum}.$ It should be noted that in several experiments, the theoretical expression used to describe this spectrum does not produce a good fit, either for $M_1=0$ or for $M_1>0$ [10]. Indeed, the best fit is achieved for an unphysical, negative value of M_1^2 . Thus, the quoted limits on M_1 must be interpreted with caution.

Neutrinos carry neither electric charge nor, as far as we know, any other charge-like quantum numbers. To be sure, it may be that the reason an interacting "neutrino" creates an ℓ^- , while an "antineutrino" creates an ℓ^+ , is that neutrinos and antineutrinos carry opposite values of a conserved "lepton number." However, there may be no lepton number. Even then, the fact that "neutrinos" and "antineutrinos" interact differently can be easily understood. One need only note that, in practice, the particles we call "neutrinos" are always left-handed, while the ones we call "antineutrinos" are right-handed. Since the weak interactions are not invariant under parity, it is then possible to attribute the difference between the interactions of "neutrinos" and "antineutrinos" to the fact that these particles are oppositely polarized.

If the neutrino mass eigenstates do not carry any chargelike attributes, they may be their own antiparticles. A neutrino which is its own antiparticle is called a Majorana neutrino, while one which is not is called a Dirac neutrino.

If neutrinos are of Majorana character, we can have neutrinoless double beta-decay $(\beta\beta_{0\nu})$, in which one nucleus decays to another by emitting two electrons and nothing else. This process can be initiated through the emission of two virtual W bosons by the parent nucleus. One of these W bosons then emits an electron and an accompanying virtual "antineutrino." In the Majorana case, this "antineutrino" is no different from a "neutrino," except for its right-handed helicity. If the virtual neutrino has a mass, then (like the e^+ in nuclear β -decay), it is not fully right-handed, but has a small amplitude, proportional to its mass, for being left-handed. Its left-handed component is precisely what we call a "neutrino," and can be absorbed by the second virtual W boson to create the second outgoing

electron. This mechanism yields for $\beta\beta_{0\nu}$ an amplitude proportional to an effective neutrino mass $\langle M \rangle$, given in a common phase convention by [11]

$$\langle M \rangle = \sum_{m} U_{em}^2 M_m \ . \tag{17}$$

Experimental upper bounds on the $\beta\beta_{0\nu}$ rate are used to derive upper bounds on $\langle M \rangle$. Note that, owing to possible phases in the mixing matrix elements U_{em} , the relation between $\langle M \rangle$ and the actual masses M_m of the neutrino mass eigenstates can be somewhat complicated. The process $\beta\beta_{0\nu}$ is discussed further by P. Vogel in this Review.

If neutrinos are their own antiparticles, then their magnetic and electric dipole moments must vanish. To see why, recall that CPT invariance requires that the dipole moments of the electron and its antiparticle be equal and opposite. Similarly, CPT invariance would require that the dipole moments of a neutrino and its antiparticle be equal and opposite. But, if the antiparticle of the neutrino is the neutrino itself, this means that the dipole moments must vanish [12].

If neutrinos are not their own antiparticles, then they can have dipole moments. However, for a Dirac neutrino mass eigenstate ν_m , the magnetic dipole moment μ_m predicted by the Standard Model (extended to include neutrino masses) is only [13]

$$\mu_m = 3.2 \times 10^{-19} M_m (\text{eV}) \mu_B ,$$
 (18)

where μ_B is the Bohr magneton.

Whether neutrinos are their own antiparticles or not, there may be transition magnetic and electric dipole moments. These induce the transitions $\nu_m \to \nu_{m' \neq m} \gamma$.

A Majorana neutrino, being its own antiparticle, obviously consists of just two states: spin up and spin down. In contrast, a Dirac neutrino, together with its antiparticle, consists of four states: the spin-up and spin-down neutrino states, plus the spin-up and spin-down antineutrino states. A four-state Dirac neutrino may be pictured as comprised of two degenerate two-state Majorana neutrinos. Conversely, in the field-theory description of neutrinos, by introducing so-called Majorana mass terms, one can split a Dirac neutrino, D, into two nondegenerate Majorana neutrinos, ν and N. In some extensions of the SM, it is natural for the D, ν , and N masses, M_D , M_{ν} , and M_N , to be related by

$$M_{\nu}M_{N}\approx M_{D}^{2}. \tag{19}$$

In these extensions, it is also natural for M_D to be of the order of $M_{\ell \text{ or } q}$, the mass of a typical charged lepton or quark. Then we have [14]

$$M_{\nu}M_N \sim M_{\ell \, \text{or} \, a}^2 \ . \tag{20}$$

Suppose now that $M_N\gg M_{\ell \text{ or }q}$, so that N is a very heavy neutrino which has not yet been observed. Then relation (20), known as the seesaw relation, implies that $M_\nu\ll M_{\ell \text{ or }q}$. Thus, ν is a candidate for one of the light neutrino mass eigenstates which make up ν_e , ν_μ , and ν_τ . So long as N is heavy, the seesaw

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relation explains, without fine tuning, why a mass eigenstate component of ν_e , ν_{μ} , or ν_{τ} will be light. Interestingly, the picture from which the seesaw relation arises predicts that the mass eigenstate components of ν_e , ν_{μ} , and ν_{τ} are Majorana neutrinos.

In early 1998, there are three observed hints of neutrino oscillation, and thus of neutrino mass. These hints are the behavior of solar neutrinos, the behavior of atmospheric neutrinos, and the results of the LSND experiment.

The flux of solar neutrinos has been detected on earth by several experiments [15] with different neutrino energy thresholds. In every experiment, the flux is found to be below the corresponding prediction of the Standard Solar Model (SSM) [16]. The discrepancies between the observed fluxes and the SSM predictions have proven very difficult to explain by simply modifying the SSM, without invoking neutrino mass [17]. Indeed, we know of no attempt which has succeeded. By contrast, all the existing observations can successfully and elegantly be explained if one does invoke neutrino mass. The most popular explanation of this type is based on the Mikheyev-Smirnov-Wolfenstein (MSW) effect—a matter-enhanced neutrino oscillation [18].

The neutrinos produced by the nuclear processes that power the sun are electron neutrinos ν_e . With some probability, the MSW effect converts a ν_e into a neutrino ν_x of another flavor. Depending on the specific version of the effect, ν_x is a ν_μ , a ν_τ , a ν_μ - ν_τ mixture, or perhaps a sterile neutrino ν_s . Since present solar neutrino detectors are sensitive to a ν_e , but wholly, or at least largely, insensitive to a ν_μ , ν_τ , or ν_s , the flavor conversion accounts for the low observed fluxes.

The MSW $\nu_e \to \nu_x$ conversion results from interaction between neutrinos and solar electrons as the neutrinos travel outward from the solar core, where they were produced. The conversion requires that, somewhere in the sun, the total energy of a ν_e of given momentum, including the energy of its interaction with the solar electrons, equal the total energy of the ν_x of the same momentum, so that we have an energy level crossing. Given the typical density of solar electrons, and the typical momenta of solar neutrinos, the condition that there be a level crossing requires that

$$M_{\nu_{\tau}}^2 - M_{\nu_{e}}^2 \equiv \Delta M_{\nu_{\tau}\nu_{e}}^2 \sim 10^{-5} \text{eV}^2 \,,$$
 (21)

where M_{ν_e} is the mass of the dominant mass eigenstate component of ν_e , and M_{ν_x} is the mass of ν_x .

The solar neutrino observations can also be explained by supposing that on their way from the sun to the earth, the electron neutrinos produced in the solar core undergo vacuum oscillation into neutrinos of another flavor [19]. Assuming that only two neutrino flavors are important to this oscillation, the oscillation probability is described by an expression of the form given by Eq. (11). To explain the observed suppression of the solar ν_e flux to less than half the predicted value at some energies, and to accommodate the observation that the suppression is energy-dependent, the argument $[1.27\Delta M^2(\text{eV}^2)L(\text{km})/E(\text{GeV})]$ of

the oscillatory factor in Eq. (11) must be of order unity when L is the distance from the sun to the earth, and $E \simeq 1$ MeV is the typical energy of a solar neutrino. Perhaps this apparent coincidence makes the vacuum oscillation explanation of the solar neutrino observations less likely than the MSW explanation. To have $[1.27\Delta M^2(\text{eV}^2)L(\text{km})/E(\text{GeV})] \sim 1$, we require that $\Delta M^2 \sim 10^{-10} \text{ eV}^2$.

The solar neutrino experiments, and the comparison between their results and theoretical predictions, are discussed in some detail by K. Nakamura in this *Review*.

Neutrinos created in the earth's atmosphere by cosmic rays result largely from the cosmic-ray-induced production of pions, which then decay via the chain $\pi \to \mu \nu_{\mu}$, $\mu \to e \nu_e \nu_{\mu}$. As we see, this chain produces neutrinos in the ratio $\nu_{\mu}: \nu_e = 2:1$. Since the various neutrinos from the chain have different energy spectra, this 2:1 ratio does not hold at a given neutrino energy, but it is believed that the actual $\nu_{\mu}: \nu_e$ ratio is known to 5% [20]. However, measurements of this ratio in underground detectors yield [21]

$$R \equiv \frac{(\nu_{\mu} : \nu_{e})_{\text{Data}}}{(\nu_{\mu} : \nu_{e})_{\text{MC}}} \approx 0.6 \pm 0.1 , \qquad (22)$$

where $(\nu_{\mu}:\nu_{e})_{\rm MC}$ is the $\nu_{\mu}:\nu_{e}$ ratio expected on the basis of a Monte Carlo simulation. In addition, it is found that the quantity R depends on the direction from which the neutrinos are coming: For upward-going neutrinos, which must have been produced in the atmosphere on the side of the earth opposite to where the detector is located, and then traveled $\sim 10^4$ km, the diameter of the earth, to reach the detector, R has an anomalously low value. But for downward-going neutrinos, which must have been produced in the atmosphere just above the detector and traveled only ~ 10 km to reach it, R is consistent with unity [22].

The atmospheric neutrino results have been interpreted as $\nu_{\mu} \rightarrow \nu_{\tau}$ or $\nu_{\mu} \rightarrow \nu_{e}$ oscillation, described by an expression like that of Eq. (11). To accommodate the fact that the upward-going neutrinos oscillate, making R anomalously low, we must have $[1.27\Delta M^{2}(\mathrm{eV^{2}})L(\mathrm{km})/E(\mathrm{GeV})]\gtrsim 1$ when $L\sim 10^{4}$ km and $E\sim 1$ GeV, a typical energy for the neutrinos studied. This requires $\Delta M^{2}\gtrsim 10^{-4}$ eV². To accommodate the fact that the downward-going neutrinos do not oscillate (since for them R is not anomalous), we must have $[1.27\Delta M^{2}(\mathrm{eV^{2}})L(\mathrm{km})/E(\mathrm{GeV})]\ll 1$ when $L\sim 10$ km and $E\sim 1$ GeV. This requires $\Delta M^{2}\lesssim 10^{-2}$ eV². Thus, the favored ΔM^{2} range is

$$10^{-4} \lesssim \Delta M^2 \lesssim 10^{-2} \text{ eV}^2$$
 (23)

The size of the observed effect implies that the mixing angle is near maximal:

$$\sin^2 2\theta \approx 1. \tag{24}$$

In view of a recent bound on $\nu_e \leftrightarrow \nu_\mu$ oscillation from the CHOOZ reactor experiment [23], the $\nu_\mu \to \nu_\tau$ interpretation of

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the atmospheric neutrino data is more likely than the $\nu_{\mu} \rightarrow \nu_{e}$ interpretation.

The LSND experiment [24] has studied neutrinos from stopped positively-charged pions, which decay via the chain

$$\pi^{+} \to \mu^{+} \nu_{\mu}$$

$$\longrightarrow e^{+} \nu_{e} \overline{\nu}_{\mu} \tag{25}$$

We note that this chain does not produce $\overline{\nu}_e$, but an excess of $\overline{\nu}_e$ over expected background is reported by the experiment. This excess is interpreted as arising from oscillation of the $\overline{\nu}_{\mu}$ which the chain does produce into $\overline{\nu}_e$. Since the experiment has $L(\mathrm{km})/E(\mathrm{GeV}) \sim 1$, the implied mass splitting is $\Delta M^2 \gtrsim 1 \mathrm{~eV}^2$.

More recently, the same experiment has studied the neutrinos from the decay

$$\pi^+ \to \mu^+ \nu_{\mu} \tag{26}$$

of positively-charged pions in flight. This decay does not produce ν_e , but the experiment reports a ν_e signal above background [25]. This signal is interpreted as coming from $\nu_{\mu} \rightarrow \nu_{e}$ oscillation. The regions of ΔM^2 and $\sin^2 2\theta$ favored by the stopped pion and decay-in-flight data are consistent [25,26].

Suppose we assume that the behavior of the solar, atmospheric, and LSND neutrinos are all to be understood in terms of neutrino oscillation. What neutrino masses are then suggested?

If there are only three neutrinos of definite flavor, ν_e , ν_μ , and ν_τ , made up out of just three neutrinos of definite mass, ν_1 , ν_2 , and ν_3 , then there are only three mass splittings ΔM_{ij}^2 , and they obviously satisfy

$$\Delta M_{12}^2 + \Delta M_{23}^2 + \Delta M_{31}^2 = (M_1^2 - M_2^2) + (M_2^2 - M_3^2) + (M_3^2 - M_1^2) = 0.$$
 (27)

Now, the ΔM^2 required by the MSW explanation of the solar neutrino data is $\sim 10^{-5}$ eV², Eq. (21), and that required by the vacuum oscillation explanation is only 10^{-10} eV². The ΔM^2 required by the vacuum oscillation interpretation of the atmospheric neutrino anomaly is $\sim 10^{-(2-4)} {\rm eV^2}$, Eq. (23). Finally, the ΔM^2 favored by the vacuum oscillation explanation of the LSND data is $\gtrsim 1$ eV². Since the ΔM^2 values required to explain the solar, atmospheric, and LSND effects are of three different orders of magnitude, there is no way these three ΔM^2 values can add up to zero, as demanded by Eq. (27). Thus, it appears that one cannot explain all three of the existing hints of neutrino oscillation without introducing a fourth neutrino. Since this neutrino is known to make no contribution to the width of the Z^0 [27], it must be a neutrino which does not participate in the normal weak interactions—a "sterile" neutrino.

Despite this argument, interesting attempts have been made to make do with just three neutrinos. In one of these [28], there is a neutrino mass hierarchy of the sort described before Eq. (16), with $\Delta M_{32}^2 \approx \Delta M_{31}^2 \gg \Delta M_{21}^2$. The large mass splitting, ΔM_{32}^2 , is taken to be $\sim 0.4~{\rm eV^2}$, and the small one, ΔM_{21}^2 , to be $\sim (3\text{--}10) \times 10^{-5} {\rm eV^2}$. The LSND results are interpreted as $\langle \overline{\nu}_{\mu}^{\rangle} \rightarrow \langle \overline{\nu}_{e}^{\rangle} \rangle$ oscillation governed by the large mass splitting. The solar neutrino observations are explained in terms of an MSW $\nu_{e} \rightarrow \nu_{\mu}$ conversion governed by the small mass splitting. The atmospheric neutrino anomaly, which appears naively to require an intermediate ΔM^2 , is explained as a combination of oscillation effects involving both the large ΔM_{32}^2 and the small ΔM_{21}^2 . This scheme does not quite fit all the data, but it is intriguingly close.

If one assumes that a sterile neutrino cannot be avoided, then all three hints of neutrino oscillation can be accommodated, for example, with the following four neutrinos: A nearly degenerate pair, ν_3 , ν_2 , with $M_3\approx M_2\sim 1$ eV, a lighter neutrino ν_1 , with $M_1\sim 3\times 10^{-3}$ eV, and a sterile neutrino ν_s much lighter than ν_1 [29]. The flavor neutrinos ν_τ and ν_μ are each 50–50 mixtures of ν_3 and ν_2 , in accord with the suggestion from the atmospheric neutrino data that ν_τ and ν_μ are maximally mixed. The ν_e is dominantly ν_1 . The mass splitting $M_3^2-M_2^2$ is chosen to be $\lesssim 10^{-2} {\rm eV}^2$ to facilitate the $\nu_\mu \to \nu_\tau$ oscillation interpretation of the atmospheric anomaly. The splitting $M_1^2-M_s^2\approx M_1^2\sim 10^{-5}~{\rm eV}^2$ allows us to interpret the solar neutrino observations as reflecting MSW conversion of ν_e to the sterile ν_s . The splitting $M_3^2-M_1^2\approx M_2^2-M_1^2\sim 1~{\rm eV}^2$ enables us to explain the $\overline{\nu}_\mu \to \overline{\nu}_e$ oscillation.

The existing hints of neutrino oscillation, and the possible neutrino-mass scenarios which they suggest, will be probed in future neutrino experiments.

In addition to the ν_e , ν_μ , and ν_τ sections, the Review of Particle Physics includes sections on "Number of Light Neutrino Types," "Heavy Lepton Searches," and "Searches for Massive Neutrinos and Lepton Mixing."

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 $J = \frac{1}{2}$

Not in general a mass eigenstate. See note on neutrino properties above.

Written April 1996 by D.E. Groom (LBNL).

These limits apply to ν_1 , the primary mass eigenstate in ν_e . They would also apply to any other ν_j which mixes strongly in ν_e and has sufficiently small mass that it can occur in the respective decay. The neutrino mass may be of a Dirac or Majorana type; the former conserves total lepton number while the latter violates it. Either would violate lepton family number, since nothing forces the neutrino mass eigenstates to coincide with the neutrino interaction eigenstates. For limits on a Majorana ν_e mass, see the section on "Searches for Massive Neutrinos and Lepton Mixing," part (C), entitled "Searches for Neutrinoless Double- β Decay."

The square of the neutrino mass $m_{\nu_e}^2$ is measured in tritium beta decay experiments by fitting the shape of the beta spectrum near the endpoint; results are given in one of the tables in this section. In many experiments, it has been found to be significantly negative. In the 1994 edition of this *Review*, it was noted that the combined probability of a positive result was 3.5%. The problem has been exacerbated by the precise and careful experiments reported in two new papers (BELESEV 95 and STOEFFL 95). Both groups conclude that unknown effects cause the accumulation of events in the electron spectrum near its end point. If the fitting hypothesis does not account for this, unphysical values for $m_{\nu_e}^2$ are obtained. BELESEV 95 obtain their value for $m_{\nu_e}^2$ and limit for m_{ν_e} (4.35 eV at 95% CL) under the assumption that a certain narrow region is free of both high-energy and low-energy anomalies. Including the endpoint

accumulation (they find no low-energy anomaly), STOEFFL 95 find a value for $m_{\nu_e}^2$ which is more than 5 standard deviations negative, and report a Bayesian limit of 7 eV for m_{ν_e} which is obtained by setting $m_{\nu_e}^2 = 0$. Given the status of the tritium results, we find no clear way to set a meaningful limit on m_{ν_e} . On the other hand, a mass as large as 10-15 eV would probably cause detectable spectrum distortions near the endpoint.

The spread of arrival times of the neutrinos from SN 1987A, coupled with the measured neutrino energies, should provide a simple time-of-flight limit on m_{ν_e} . This statement, clothed in various degrees of sophistication, has been the basis for a very large number of papers. The LOREDO 89 limit (23 eV) is among the most conservative and involves few assumptions; as such, it is probably a safe limit. We list this limit below as "used," but conclude that a limit about half this size is justified by the tritium decay experiments.

ν_e MASS

Most of the data from which these limits are derived are from β^{-} decay experiments in which a $\overline{
u}_e$ is produced, so that they really apply to $m_{\overline{
u}_1}$ Assuming CPT invariance, a limit on $m_{\overline{\nu}_1}$ is the same as a limit on $m_{\nu_1}^{-1}$. Results from studies of electron capture transitions, given below " m_{ν_1} " $m_{\overline{
u}_1}$ ", give limits on $m_{
u_1}$ itself. OUR EVALUATION of the present status of the tritium decay experiments is discussed in the above minireview.

VALUE (eV)	CL%	DOCUMENT ID	TECN	COMMENT
< 15 OUR EVALUA	TION			
< 23		LOREDO 89	ASTR	SN 1987A
• • • We do not use th	e following	data for averages, fi	ts, limits,	etc. • • •
< 4.35	95	1 BELESEV 95	SPEC	³ H β decay
< 12.4	95	² CHING 95	SPEC	3 H $^{\beta}$ decay
< 92	95	³ HIDDEMANN 95	SPEC	3 H β decay
15 +32 -15		HIDDEMANN 95	SPEC	3 H eta decay
< 19.6	95	KERNAN 95	ASTR	SN 1987A
< 7.0	95	4 STOEFFL 95	SPEC	³ H β decay
<460	68	⁵ YASUMI 94	CNTR	e capture in ¹⁶³ Ho
< 7.2	95	⁶ WEINHEIMER 93	SPEC	3 H β decay
< 11.7	95	7 HOLZSCHUH 92	B SPEC	3 H β decay
< 13.1	95	8 KAWAKAMI 91	SPEC	3 H β decay
< 9.3	95	9 ROBERTSON 91	5PEC	³ H β decay
< 14	95	AVIGNONE 90	ASTR	SN 1987A
< 16		SPERGEL 88	ASTR	SN 1987A
17 to 40		10 BORIS 87	SPEC	⊽ 3H β decay

- ¹ BELESEV 95 (Moscow) use an integral electrostatic spectrometer with adiabatic magnetic collimation and a gaseous tritium sources. A fit to a normal Kurle plot above 18300–18350 eV (to avoid a low-energy anomaly) plus a monochromatic line 7–15 eV below the endpoint yields $m_{\nu}^2=-4.1\pm 10.9 \, {\rm eV}^2$, leading to this Bayesian limit.
- ²CHING 95 quotes results previously given by SUN 93; no experimental details are given. A possible explanation for consistently negative values of m_{ν}^2 is given.
- ³ HIDDEMANN 95 (Munich) experiment uses atomic tritium embedded in a metal-dioxide lattice. Bayesian limit calculated from the weighted mean $m_{\nu}^2 = 221 \pm 4244 \text{ eV}^2$ from he two runs listed below.
- 4 STOEFFL 95 (LLNL) result is the Bayesian limit obtained from the m_{ν}^2 errors given below but with m_{ij}^2 set equal to 0. The anomalous endpoint accumulation leads to a value of m_{ij}^2 which is negative by more than 5 standard deviations.
- 5 The YASUMI 94 (KEK) limit results from their measurement $m_{\nu}{=}110^{+350}_{-110}~{\rm eV}.$
- 6 WEINHEIMER 93 (Mainz) is a measurement of the endpoint of the tritlum β spectrum using an electrostatic spectrometer with a magnetic guiding field. The source is molecular tritium frozen onto an aluminum substrate.
- ⁷ HOLZSCHUH 92B (Zurich) result is obtained from the measurement $m_{\nu}^2 = -24 \pm 48 \pm 61$ (1 σ errors), in eV², using the PDG prescription for conversion to a limit in m_{ν} .
- ⁸ KAWAKAMI 91 (Tokyo) experiment uses tritium-labeled arachidic acid. This result is the Bayesian limit obtained from the $m_{
 u}^2$ limit with the errors combined in quadrature. This was also done in ROBERTSON 91, although the authors report a different procedure.
- 9 ROBERTSON 91 (LANL) experiment uses gaseous molecular tritium. The result is in strong disagreement with the earlier claims by the ITEP group [LUBIMOV 80, BORIS 87 (+ BORIS 88 erratum)] that m_{ν} lies between 17 and 40 eV. However, the probability of a positive m^2 is only 3% if statistical and systematic error are combined in quadrature.
- ¹⁰See also comment in BORIS 87B and erratum in BORIS 88.

v. MASS SQUARED

The tritium experiments actually measure mass squared. A combined limit on mass must therefore be obtained from the weighted average of the results shown here. The recent results are in strong disagreement with the earlier claims by the ITEP group [LUBIMOV 80, BORIS 87 (+ BORIS 88, erratum)] that m_{ν_1} lies between 17 and 40 eV. The BORIS 87 result is excluded because of the controversy over the possibly large unreported systematic errors; see BERGKVIST 85B, BERGKVIST 86, SIMPSON 84, and REDONDO 89. However, the average for the new experiments given below Implies only a 3.5% probability that m^2 is positive. See HOLZSCHUH 92 for a review of the recent direct $m_{
u_1}$ measurements.

VALUE (eV	2)		CL%	DOCUMENT ID		TECN	COMMENT
– 27±	20	OUR	AVERAGE	Error Includes scale below.	fac	tor of 4.	2. See the ideogram
- 22±	4.1	8		11 BELESEV	95	SPEC	3 H β decay
-130±	20	±15	95	12 STOEFFL	95	SPEC	³ H β decay
- 31±	75	±48		¹³ SUN	93	SPEC	3 H β decay
- 39±	34	± 15		14 WEINHEIMER	93	SPEC	³ H β decay
- 24±	48	±61		¹⁵ HOLZSCHUH	92B	SPEC	³ H β decay
- 65±	85	±65		¹⁶ KAWAKAMI	91	SPEC	3 H β decay
-147±	68	±41		¹⁷ ROBERTSON	91	SPEC	3 H β decay
• • • W	e do	not use	the following	ng data for averages	, fits	, limits,	etc. • • •
.129±6	010			18 HIDDEMANN	95	SPEC	³ H β decay
313±5	994			18 HIDDEMANN			

11 BELESEV 95 (Moscow) use an integral electrostatic spectrometer with adiabatic magnetic collimation and a gaseous tritium sources. This value comes from a fit to a normal Kurie plot above 18300–18350 eV (to avoid a low-energy anomaly), including the effects of an apparent peak 7-15 eV below the endpoint.

 12 STOEFFL 95 (LLNL) uses a gaseous source of molecular tritium. An anomalous pileup of events at the endpoint leads to the negative value for m_{ν}^2 . The authors acknowledge that "the negative value for the best fit of m_{ν}^2 has no physical meaning" and discuss possible explanations for this effect.

13 SUN 93 uses a tritlated hydrocarbon source. See also CHING 95.

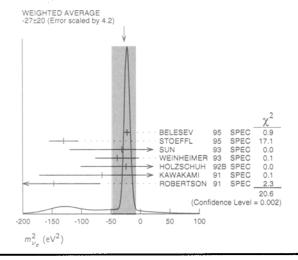
 14 WEINHEIMER 93 (Mainz) is a measurement of the endpoint of the tritium eta spectrum ng an electrostatic spectrometer with a magnetic guiding field. The source is molecular tritium frozen onto an aluminum substrate.

15 HOLZSCHUH 92B (Zurich) source is a monolayer of tritlated hydrocarbon.

16 KAWAKAMI 91 (Tokyo) experiment uses tritium-labeled arachidic acid.

 17 ROBERTSON 91 (LANL) experiment uses gaseous molecular tritium. The result is in strong disagreement with the earlier claims by the ITEP group [LUBIMOV 80, BORIS 87 (+ BORIS 88 erratum)] that m_{ν} lies between 17 and 40 eV. However, the probability of a positive m_{ν}^2 is only 3% if statistical and systematic error are combined in quadrature.

18 HIDDEMANN 95 (Munich) experiment uses atomic tritium embedded in a metal-dioxide lattice. They quote measurements from two data sets.



m_{P1} $-m_{\overline{\nu}_1}$

These are measurement of m_{ν_1} (in contrast to $m_{\overline{\nu}_1}$, given above). The masses can be different for a Dirac neutrino in the absense of CPT invariance. ance. The test is not very strong.

VALUE (eV)	CL%	DOCUMENT ID		TECN	COMMENT
< 225	95	SPRINGER	87	CNTR	ν, ¹⁶³ Ho
< 550	68	YASUMI	86	CNTR	ν, ¹⁶³ Ho
• • • We do not use the	following	data for average	s, fit	s, limits,	etc. • • •
$< 4.5 \times 10^5$	90	CLARK	74	ASPK	K _{e3} decay ν, ²² Na
<4100	67	BECK	68	CNTR	ν, ⁻²² Na

12 CHARGE

VALUE (units: electron charge)	DOCUMENT ID		TECN	COMMENT
• • • We do not use the follow	Ing data for average	s, fits	s, limits,	etc. • • •
<2 × 10 ⁻¹⁵	¹⁹ BARBIELLINI	87	ASTR	SN 1987A
<1 × 10 ⁻¹³	BERNSTEIN	63	ASTR	Solar energy losses
19 Precise limit depends on ass	sumptions about the	inter	galactic	or galactic magnetic fields

and about the direct distance and time through the field.

MEAN LIFE

VALUE (s)	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do not us	e the followin	g data for averag	es, fits, limi	ts, etc. • • •
		²⁰ COWSIK	89 AST	R m _v = 1-50 MeV
		21 RAFFELT		E ₽ (Dirac, Majorana)
		22 RAFFELT	89B AST	R
>278	90	²³ LOSECCO	878 IMB	
> 1.1 × 10 ²⁵		²⁴ HENRY	81 AST	$R m_{\nu} = 16-20 \text{ eV}$
> 10 ²² -10 ²³		25 KIMBLE	81 AST	R m = 10-100 eV

²⁰ COWSIK 89 use observations of supernova SN 1987A to set the limit for the lifetime of a neutrino with 1 < m < 50 MeV decaying through ν_H \rightarrow $~\nu_1\,ee$ to be τ > 4 imes 10¹⁵ exp(-m/5 MeV) s.

²¹RAFFELT 89 uses KYULDJIEV 84 to obtain $\tau m^3 > 3 \times 10^{18}$ s eV³ (based on $\overline{\nu}_e$ e⁻⁻ cross sections). The bound is not valid if electric and magnetic transition moments are equal for Dirac neutrinos.

 22 RAFFELT 89B analyze stellar evolution and exclude the region 3 imes 10 12 < $au m^3$

 $3 < 3 \times 10^{21} \text{ seV}^3$.

23 LOSECCO 87B assumes observed rate of 2.1 SNU (solar neutrino units) comes from sun nile 7.0 \pm 3.0 is theory.

24 HENRY 81 uses UV flux from clusters of galaxies to find limit for radiative decay.

²⁵ KIMBLE 81 uses extreme UV flux limits.

1 (MEAN LIFE) / MASS

VALUE (s/eV)	<u>CL%</u>	DOCUMENT ID		TECN	COMMENT
> 7 × 10 ⁹		26 RAFFELT	85	ASTR	
>300	90	²⁷ REINES	74	CNTR	$\overline{\nu}$
• • • We do not use	the follow	ving data for average:	s, fits	, limits,	etc. • • •
$> 2.8 \times 10^{15}$		^{28,29} BLUDMAN	92	ASTR	$m_{\nu} < 50 \text{ eV}$
> 6.4	90	³⁰ KRAKAUER	91		⊽ at LAMPF
> 6.3 × 10 ¹⁵		^{29,31} CHUPP	89	ASTR	$m_{\nu} < 20 \text{ eV}$
> 1.7 × 10 ¹⁵		²⁹ KOLB	89		m, < 20 eV
> 8.3 × 10 ¹⁴		32 VONFEILIT	88	ASTR	•
> 22	68	33 OBERAUER	87		$\overline{\nu}_R$ (Dirac)
> 38	68	33 OBERAUER	87		ァ (Majorana)
> 59	68	33 OBERAUER	87		v₁ (Dirac)
> 30	68	KETOV	86	CNTR	⊽ (Dirac)
> 20	68	KETOV	86	CNTR	ァ (Majorana)
$> 2 \times 10^{21}$		34 STECKER	80	ASTR	m.,= 10-100 eV

26 RAFFELT 85 limit is from solar x- and γ -ray fluxes. Limit depends on ν flux from pp, now established from GALLEX and SAGE to be > 0.5 of expectation.

²⁷ REINES 74 looked for ν_e of nonzero mass decaying to a neutral of lesser mass + γ . Used liquid scintillator detector near fission reactor. Finds lab lifetime $6. \times 10^7$ s or more. Above value of (mean life)/mass assumes average effective neutrino energy of 0.2 MeV. To obtain the limit 6. \times 10⁷ s REINES 74 assumed that the full $\overline{\nu}_e$ reactor flux could be responsible for yielding decays with photon energies in the interval 0.1 MeV – 0.5 MeV. This represents some overestimate so their lower limit is an over-estimate of the ab lifetime (VOGEL 84). If so, OBERAUER 87 may be comparable or better.

28 BLUDMAN 92 sets additional limits by this method for higher mass ranges. Cosmological

Ilmits are also obtained. 29 Nonobservation of γ' 's in coincidence with ν 's from SN 1987A. 30 KRAKAUER 91 quotes the limit $\tau/m_{\nu_1} > (0.3a^2 + 9.8a + 15.9)$ s/eV, where a is a parameter describing the asymmetry in the neutrino decay defined as $dN_{\gamma}/d\cos\theta =$ $(1/2)(1+a\cos\theta)$ a=0 for a Majorana neutrino, but can vary from -1 to 1 for a Dirac neutrino. The bound given by the authors is the most conservative (which applies for

31 CHUPP 89 should be multiplied by a branching ratio (about 1) and a detection efficiency (about 1/4), and pertains to radiative decay of any neutrino to a lighter or sterile neutrino.

32 Model-dependent theoretical analysis of SN 1987A neutrinos.

33 OBERAUER 87 bounds are from comparison of observed and expected rate of reactor

34 seutrinos. 35 STECKER 80 limit based on UV background; result given is $au>4\times10^{22}$ s at $m_{
u}=20$

$|(v-c)/d|(v \equiv \nu_1 \text{ VELOCITY})$

Expected to be zero for massless neutrino, but tests also whether photons and neutrinos have the same limiting velocity in vacuum.

VALUE (units 10 ⁻⁸)	EVTS	DOCUMENT ID	TECN	COMMENT
<1	17	35 STODOLSKY 88	ASTR	SN 1987A
<0.2				SN 1987A

35 STODOLSKY 88 result based on <10 hr between $\overline{\nu}_e$ detection in IMB and KAMI detectors and beginning of light signal. Inclusion of the problematic 5 neutrino events from FREJ (four hours later) does not change the result.

 $36\,\text{LONGO}$ 87 argues that uncertainty between light and neutrino transit times is $\pm 3\,\text{hr}$, ignoring FREJUS events.

1/2 MAGNETIC MOMENT

Must vanish for Majorana neutrino or purely chiral massless Dirac neutrino. The value of the magnetic moment for the standard SU(2)×U(1) electroweak theory extended to include massive neutrinos (see FUJIKAWA 80) Is $\mu_{\nu} = 3eG_F m_{\nu}/(8\pi^2\sqrt{2}) = (3.20 \times 10^{-19}) m_{\nu} \mu_B$ where m_{ν} is in eV and $\mu_B = e\hbar/2m_e$ is the Bohr magneton. Given the upper bound m_{ν_1} < 7.3 eV, it follows that for the extended standard electroweak theory, $\mu(\nu_1) < 2.3 \times 10^{-18}~\mu_B$. Current experiments are not yet challenging this limit. There is considerable controversy over the validity of many of the claimed upper limits on the magnetic moment from the astrophysical data. For example, VOLOSHIN 90 states that "in connection with the astrophysical limits on $\mu_{\nu_{\tau}}$, ... there is by now a general consensus that contrary to the initial claims (BARBIERI 88, LATTIMER 88, GOLD-MAN 88, NOTZOLD 88), essentially no better than quoted limits (from previous constraints) can be derived from detection of the neutrino flux from the supernova SN1987A." See VOLOSHIN 88 and VOLOSHIN 88C.

$VALUE (10^{-10} \mu_B)$	CL%		DOCUMENT ID		TECN	COMMENT
< 1.8	90	37	DERBIN	94	CNTR	Reactor $\overline{\nu}_e e \rightarrow \overline{\nu}_e e$
• • • We do not use the	followin	g d	ata for averages	, fits	, limits,	etc. • • •
< 0.62		38	ELMFORS	97	COSM	Depolarization in early universe plasma
< 3.2	90	39	GOVAERTS	96		
< 0.003-0.0005		40	GOYAL	95		SN 1987A
< 7.7	95		MOURAO	92	AŞTR	HOME/KAM2 ν rates
< 2.4	90	41	VIDYAKIN	92	CNTR	Reactor V _e e → V _e e
<10.8	90	42	KRAKAUER	90	CNTR	LAMPF vee - vee
< 0.02		43	RAFFELT	90	ASTR	Red giant luminosity
< 0.1		44	RAFFFIT	89B	ASTR	Cooling helium stars
< 0.02-0.08	44,45	,46	BARBIERI	88	ASTR	SN 1987A
		47	FUKUGITA	88	COSM	Primordial magn. fleids
< 0.01	45,46	,48	GOLDMAN	88	ASTR	SN 1987A
< 0.005	44	,46	LATTIMER	88	ASTR	SN 1987A
≤ 0.015	44	,46	NOETZOLD	88	ASTR	SN 1987A
≤ .3		44	RAFFELT	888	ASTR	He burning stars
< 0.11		44	FUKUGITA	87	ASTR	Cooling helium stars
< 0.4			LYNN	81	ASTR	
< 0.1-0.2			MORGAN	81	COSM	⁴ He abundance
< 0.85			BEG	78	ASTR	Stellar plasmons
< 0.6		49	SUTHERLAND	76	ASTR	Red glants + degen. dwarfs
< 1			BERNSTEIN	63	ASTR	Solar cooling
<14			COWAN	57	CNTR	Reactor $\overline{\nu}_e$
						-

37 DERBIN 94 supersedes DERBIN 93.

38 ELMFORS 97 calculate the rate of depolarization in a plasma for neutrinos with a magnetic moment and use the constraints from a big-bang nucleosynthesis on additional

³⁹ GOVAERTS 96 limit is on $\sqrt{\Sigma \mu \nu_\ell^2}$, based on limits on 2ν decay of ortho-positronium.

 40 GOYAL 95 assume that helicity flip via μ_{ν} would result in faster cooling and hence shorter burst from SN1987A. Limit is based on the assumed presence of a pion condensate or

quark core in the remanant. 41 VIDYAKIN 92 limit is from a $e \overline{\nu}_e$ elastic scattering experiment. No experimental details are given except for the cross section from which this limit is derived. Signal/noise was 1/10. The limit uses $\sin^2 \theta_W = 0.23$ as input.

42 KRAKAUER 90 experiment fully reported in ALLEN 93.

ARAFACET 90 limit applies for a diagonal magnetic moment of a Dirac neutrino, or for a transition magnetic moment of a Majorana neutrino. In the latter case, the same analysis gives $< 1.4 \times 10^{-12}$. Limit at 95%CL obtained from δM_C .

 44 Significant dependence on details of stellar models. 45 A limit of 10^{-13} is obtained with even more model-dependence.

These papers have assumed that the right-handed neutrino is inert; see BARBIERI 888.

47 FUKUGITA 88 find magnetic dipole moments of any two neutrino species are bounded by $\mu < 10^{-16} \, [10^{-9} \, G/B_0]$ where B_0 is the present-day intergalactic field strength.

⁴⁸ Some dependence on details of stellar models.

⁴⁹We obtain above limit from SUTHERLAND 76 using their limit f < 1/3.

NONSTANDARD CONTRIBUTIONS TO NEUTRINO SCATTERING

We report limits on the so-called neutrino charge radius squared in this section. This quantity is not an observable, physical quantity and this is reflected in the fact that it is gauge dependent (see LEE 77C). It is not necessarily positive. A more general interpretation of the experimental results is that they are limits on certain nonstandard contributions to neutrino scattering.

VALUE (10-32 cm ²)	CL%	DOCUMENT ID		TECN_	COMMENT
0.9±2.7		ALLEN	93	CNTR	LAMPF vee - vee
• • • We do not	use the follow	ing data for averag	ges, fits	, iimits,	etc. • • •
<2.3	95	MOURAO	92	ASTR	HOME/KAM2 ν rates
<7.3	90	50 VIDYAKIN	92	CNTR	Reactor $\overline{\nu}_e e \rightarrow \overline{\nu}_e e$
1.1 ± 2.3		ALLEN	91	CNTR	Repl. by ALLEN 93
		51 GRIFOLS	898	ASTR	SN 1987A

 50 VIDYAKIN 92 limit is from a $e \nu_e$ elastic scattering experiment. No experimental details are given except for the cross section from which this limit is derived. Signal/noise was 1/10. The limit uses $\sin^2 \theta_W = 0.23$ as input.

 51 GRIFOLS 89B sets a limit of $\langle r^2 \rangle < 0.2 \times 10^{-32}$ cm 2 for right-handed neutrinos.

ν_e REFERENCES

FLUEODE		tin ness s	
ELMFORS GOVAERTS	97 96	NP B503 3 PL B381 451	P. Elmfors, K. Enqvist, G. Raffelt, G. Sigl +Van Caillie (LOUV)
BELESEV	95	PL B350 263	+Bleule, Geraskin, Golubev+ (INRM, KIAE) +Ho, Liang, Mao, Chen, Sun (CST, BEIJT, CIAE)
CHING GOYAL	95 95	IJMP A10 2841	+Ho, Liang, Mao, Chen, Sun (CST, BEIJT, CIAE)
HIDDEMANN	95	PL B346 312 JP G21 639	+Dutta, Choudhury (DELH) +Daniel, Schwentker (MUNT)
KERNAN	95	NP B437 243	+Krauss (CASE)
STOEFFL DERBIN	95 94	PRL 75 3237 PAN 57 222	+Decman (LLNL) (PNPI)
	-	Translated from YAF 5 PL B334 229	7 236
YASUMI ALLEN	94 93	PR D47 11	+Maezawa, Shima, Inagaki+ +Chen, Doe, Hausammann+ (UCI, LANL, ANL, UMD)
DERBIN	93	JETPL 57 768 Translated from ZETFF	+Chernyi, Popeko, Muratova+ (PNPI)
SUN	93	CJNP 15 261	+Liang, Chen, Si+ (CIAE, CST, BEIJT)
WEINHEIMER			+Przyrembel, Backe+ (MANZ)
BLUDMAN HOLZSCHUH	92 92	PR D45 4720 RPP 55 1035	(CFPA) (ZURI)
HOLZSCHUH	92B	PL B287 381	+Fritschi, Kuendig (ZURI)
MOURAO	92	PL B285 364	+Pulido, Raiston (LISB, LISBT, CERN, KANS)
VIDYAKIN	92	Translated from ZETFF	+Fritschi, Kuendig (ZURI) +Pulido, Raiston (LISB, LISBT, CERN, KANS) +Vyrodov, Gurevich, Koslov+ (KIAE) 55 212Chen, Doe, Hausammann (UCI, LANL, UMD) +Kato, Ohshima+ (INUS, TOHOK, TINT, KOBE, KEK) +Talaga, Allen, Chen+ (LAMPF E225 Collab.) +Bowles, Stephenson, Wark, Wilkerson, Knapp (LASL, LLL)
ALLEN	91	PR D43 R1	+Chen, Doe, Hausammann (UCI, LANL, UMD)
KAWAKAMI KRAKAUER	91 91	PR D44 R6	+Kato, Onshima+ (INUS, TOHOK, TINT, KOBE, KEK) +Talaga, Allen, Chen+ (LAMPE F225, Collab.)
ROBERTSON	91	PRL 67 957 PR D41 682	+Bowles, Stephenson, Wark, Wilkerson, Knapp (LASL, LLL)
AVIGNONE	90	PR D41 682	+Collar (SCUC)
KRAKAUER RAFFELT	90 90	PL B252 177 PRL 64 2856	+Talaga, Allen, Chen+ (LAMPF E225 Čollab.) (MPIM)
VOLOSHIN	90	NP B (Proc. Suppl) 1	9 433 (ITEP)
Neutrino 9 CHUPP	0 Con	ference PRL 62 505	
COWSIK	89	PKE 62 505 PI B218 91	+Vestrand, Reppin +Schramm, Hoflich (WUSL, TATA, CHIC, MPIM)
GRIFOLS	89B	Pl. B218 91 PR D40 3819	+Masso (BARC)
KOLB	89	PRL 62 509	+Masso (BARC) +Turner (CHIC, FNAL)
LOREDO RAFFELT	89 89	ANYAS 571 601 PR D39 2066	+Lamb (CHIC) (PRIN, UCB)
RAFFELT	89B	APJ 336 61	+Dearborn, Suk (UCB, ELLI
REDONDO	89	PR C40 368	+Robertson (LANL)
BARBIERI BARBIERI	88 88B	PRL 61 27 PL B213 69	+Mohapatra (PISA, UMD) +Mohapatra, Yanagida (PISA, UMD, MICH)
BORIS	88	PRL 61 245 erratum	+Golutvin, Laptin+ (ITEP, ASCI)
FUKUGITA	88	PRL 60 879	Notrold Doffels Cilk (MYOTH AADIM HCD)
GOLDMAN LATTIMER	88 88	PRL 60 1789	+Aharanov, Alexander, Nussinov (TELA) +Cooperstein (STON, BNL) Lattimer, Cooperstein (STON, BNL)
Also	88B	PRL 61 23 PRL 61 2633 erratum	Lattimer, Cooperstein (STON, BNL)
NOETZOLD	88	PR D38 1658	(MPIM) (MPIM)
NOTZOLD RAFFELT	88 88B	PR D38 1658 PR D37 549	+Dearborn (MPIM)
SPERGEL	88	PL B200 366	+Bahcall (IAS)
STODOLSKY	88	PL B201 353	(MPIM)
VOLOSHIN Also	88 88B	PL B209 360 JETPL 47 501	(ITEP) Voloshin (ITEP)
		JETPL 47 501 Translated from ZETFF JETPL 68 690	47 421.
VOLOSHIN VONFEILIT	88C 88	JETPL 68 690 PL B200 580	(ITEP) Von Feilitzsch, Oberauer (MUNT)
BARBIELLINI	87	Nature 329 21	+Cocconi (CERN)
BORIS	87	PRL 58 2019 PRL 61 245 erratum	+Golutvin, Laptin+ (ITEP, ASCI)
Aiso BORIS	88 87B	PRL 61 245 erratum	Boris, Golutvin, Laptin+ (ITEP, ASCI) +Golutvin, Laptin+ (ITEP)
		JETPL 45 333 Translated from ZETFF	2 45 267.
FUKUGITA	87	PR D36 3817 PR D36 3276 PR D35 2073	+Yazaki (KYOTU, TOKY)
LONGO LOSECCO	87 87B	PR D36 32/6 PR D35 2073	M.J. Longo (MICH) +Bionta, Blewitt, Bratton+ (IMB Collab.)
OBERAUER	87	PL B198 113	+von Feilitzsch, Mossbauer (MUNT)
SPRINGER BERGKVIST	87 86	PR A35 679	⊥Rennet Raisden⊥ (IINI)
KETOV	86	JETPL 44 146	HKlimov, Nikolaev, Mikaelyan+ 4 114. Andre (KEK, OSAK, TOHOK, TSHK, KYOT, INHS)
		Translated from ZETFF	44 114.
YASUMI BERGKVIST	86 85B		TAILOT (KEK, OJAK, TOTIOK, TJOK, KTOT, 11037)
RAFFELT	85	PL 159B 408 PR D31 3002	(STOH) (MPIM)
KYULDJIEV SIMPSON	84 84	NP B243 387	(SOFI)
VOGEL	84	PR D30 1110 PR D30 1505	P. Vogel
HENRY	81	PRL 47 618	+Feldman (JHU)
KIMBLE LYNN	81 81	PRL 46 80	+Bowyer, Jakobsen (UCB)
MORGAN	81	PR D23 2151 PL 102B 247	Morgan (SUSS)
FUJIKAWA	80	PRL 45 963 PL 94B 266	+Shrock (STON)
LUBIMOV Also	80 80	PL 94B 266 SJNP 32 154	+Novikov, Nozik, Tretyakov, Kosik (ITEP) Kozik, Lubimov, Novikov+ (ITEP)
Also	81	JETP 54 616	Lubimov, Novikov, Nozik+ (ITEP)
STECKER	80	PRL 45 1460	11130. (NASA)
BEG	78	PRL 45 1460 PR D17 1395	(NASA) + Marciano, Ruderman (ROCK, COLU) + Shrock (STON)
LEE SUTHERLAND	77C	PR D16 1444 PR D13 2700	+Shrock (STON) +Ng, Flowers+ (PENN, COLU, NYU)
CLARK	74	PR D9 533	+Ng, Flowers+ (PENN, COLU, NYU) +Elioff, Frisch, Johnson, Kerth, Shen+ (LBL)
REINES	74	PRL 32 180	+Elioff, Frisch, Johnson, Kerth, Shen+ (LBL) +Sobel, Gurr (UCI)
Also			
RECK	78 68	Private Comm. 7PHY 216 229	Barnes (PURD)
BECK BERNSTEIN COWAN	78 68 63 57	Private Comm. ZPHY 216 229 PR 132 1227 PR 107 528	Barnes (PURD) + Daniel (MPIH) + Ruderman, Feinberg (NYU, COLU) + Reines (LANL)

$J = \frac{1}{2}$

Not in general a mass eigenstate. See note on neutrinos in the u_{e} section above.

u_{μ} MASS

Applies to ν_2 , the primary mass eigenstate in ν_μ . Would also apply to any other ν_J which mixes strongly in ν_μ and has sufficiently small mass that it can occur in the respective decays. (This would be nontrivial only for $j\geq 3$, given the ν_e mass limit above.) Results based upon an obselete pion mass are no longer shown; they were in any cass less restrive than ASSAMAGAN 96.

VALUE (MeV)	CL%	DOCUMENT ID		TECN	COMMENT
<0.17	90	¹ ASSAMAGAN	96	SPEC	$m^2 = -0.016 \pm 0.023$
• • • We do not use the	follow	ing data for averages	, fits	i, limits,	etc. • • •
< 0.15		² DOLGOV	95	COSM	Nucleosynthesis
< 0.48		3 ENQVIST	93	COSM	Nucleosynthesis
< 0.003		4,5 MAYLE	93	ASTR	SN 1987A cooling
< 0.025-0.030		5,6 BURROWS	92	ASTR	SN 1987A cooling
< 0.3		⁷ FULLER	91	COSM	Nucleosynthesis
< 0.42		⁷ LAM	91	COSM	Nucleosynthesis
< 0.028-0.15		⁸ NATALE	91	ASTR	SN 1987A
< 0.028		⁵ GANDHI	90	ASTR	SN 1987A
< 0.014		^{5,9} GRIFOLS	90B	ASTR	SN 1987A
< 0.06		5,10 GAEMERS	89		SN 1987A
< 0.50	90	¹¹ ANDERHUB	82	SPEC	$m^2 = -0.14 \pm 0.20$
< 0.65	90	CLARK	74	ASPK	K _{u3} decay
					r:-

 1 ASSAMAGAN 96 measurement of ρ_μ from $\pi^+\to \mu^+\nu_\mu$ at rest combined with JECK-ELMANN 94 Solution B pion mass yields $m_\nu^2=-0.016\pm0.023$ with corresponding Bayesian limit listed above. If Solution A is used, $m_2=-0.143\pm0.024~{\rm MeV}^2$. Replaces ASSAMAGAN 94.

places ASSAMAGAN 94.

2 DOLGOV 95 removes earlier assumptions (DOLGOV 93) about thermal equilibrium below TQCD for wrong-helicity Dirac neutrinos (ENQVIST 93, FULLER 91) to set more stringent limits.

3 ENQVIST 93 bases limit on the fact that thermalized wrong-helicity Dirac neutrinos would speed up expansion of early universe, thus reducing the primordial abundance. FULLER 91 exploits the same mechanism but in the older calculation obtains a larger production rate for these states, and hence a lower limit. Neutrino lifetime assumed to exceed nucleosynthesis time a.1.5

exceed nucleosynthesis time, ~ 1 s.

*MAYLE 93 recalculates cooling rate enhancement by escape of wrong-helicity Dirac neutrinos using the Livermore Supernova Explosion Code, obtains more restrictive result than the "very conservative" BURROWS 92 limit because of higher core temperature.

⁵ There would be an increased cooling rate if Dirac neutrino mass is included; this does not apply for Majorana neutrinos. Limit is on $\sqrt{m^2_{\nu\mu}+m^2_{\nu\tau}}$, and error becomes very large if ν_{τ} is nonrelativistic, which occurs near the lab limit of 31 MeV. RAJPOOT 93 notes that limit could be evaded with new physics.

8 BURROWS 92 limit for Dirac neutrinos only.

7 Assumes neutrino lifetime 51s. For Dirac neutrinos only.

⁷ Assumes neutrino lifetime >1 s. For Dirac neutrinos only. See also ENQVIST 93.

⁸ NATALE 91 published result multiplied by $\sqrt{8}\sqrt{4}$ at the advice of the author.

9 GRIFOLS 90B estimated error is a factor of 3. 10 GAEMERS 89 published result (< 0.03) corrected via the GANDHI 91 erratum.

11 ANDERHUB 82 kinematics is insensitive to the pion mass.

$m_{\nu_2} - m_{\overline{\nu}_2}$

Test of CPT for a Dirac neutrino. (Not a very strong test.)

VALUE (MeV)	CL%	DOCUMENT ID	TECN	COMMENT
	e following	data for averages,	fits, limits,	etc. • • •
<0.45	90	CLARK 7	4 ASPK	$\kappa_{\mu3}$ decay

1/2 (MEAN LIFE) / MASS

These limits often apply to ν_{τ} (ν_{3}) also.

VALUE (s/eV)	CL%	EVTS	DOCUMENT ID		TECN	
>15.4	90		12 KRAKAUER	91	CNTR	$ u_{\mu}$, $\overline{ u}_{\mu}$ at LAMPF
• • • We do not us	e the follo		iata for averages, fit:	s, Iln	nits, etc.	• • •
> 2.8 × 10 ¹⁵		:	13,14 BLUDMAN	92	ASTR	$m_{_{12}} < 50 \text{ eV}$
none 10 ⁻¹² - 5 ×	104		15 DODELSON	92	ASTR	m _v =1-300 keV
$> 6.3 \times 10^{15}$			14,16 CHUPP	89	ASTR	$m_{\nu} < 20 \text{ eV}$
$> 1.7 \times 10^{15}$			14 KOLB	89	ASTR	$m_{\nu} < 20 \text{ eV}$
$> 3.3 \times 10^{14}$			17,18 VONFEILIT	88	ASTR	•
> 0.11	90	0	19 FRANK	81	CNTR	ν⊽ LAMPF
			20 HENRY	81	ASTR	$m_{\nu} = 16-20 \text{ eV}$
•			21 KIMBLE	81	ASTR	$m_{\nu} = 10-100 \text{ eV}$
			22 REPHAELI	81	ASTR	$m_{\nu} = 30-150 \text{ eV}$
			²³ DERUJULA	80	ASTR	$m_{\nu} = 10-100 \text{ eV}$
> 2 × 10 ²¹			24 STECKER	80	ASTR	$m_{\nu} = 10-100 \text{ eV}$
$> 1.0 \times 10^{-2}$	90	0	¹⁹ BLIETSCHAU	78	HLBC	ν_{μ} , CERN GGM
$> 1.7 \times 10^{-2}$	90	0	¹⁹ BLIETSCHAU	78	HLBC	$\bar{\nu}_{\mu}$, CERN GGM
$> 2.2 \times 10^{-3}$	90	0	¹⁹ BARNES	77	DBC	ν, ANL 12-ft
$> 3. \times 10^{-3}$	90	0	19 BELLOTTI	76	HLBC	ν, CERN GGM
$> 1.3 \times 10^{-2}$	90	1	19 BELLOTTI	76	HLBC	₽, CERN GGM

 $\nu_{\mu}, \nu_{ au}$

 12 KRAKAUER 91 quotes the limit $\tau/m_{\nu_1}~>~(0.75a^2~+~21.65a~+~26.3)~\text{s/eV},$ where ais a parameter describing the asymmetry in the neutrino decay defined as $dN_{rev}/d\cos\theta$ $\approx (1/2)(1 + a\cos\theta)$ The parameter a=0 for a Majorana neutrino, but can vary from -1 to 1 for a Dirac neutrino. The bound given by the authors is the most conservative (which applies for a=-1).

(which applies for a ≈ -1).

13 BLUDMAN 92 sets additional limits by this method for higher mass ranges. Cosmological limits are also obtained.

14 Nonobservation of γ 's in coincidence with ν 's from SN 1987A. Results should be divided by the $\tau_{\nu} \rightarrow \gamma X$ branching ratio.

15 DODELSON 92 range is for wrong-helicity keV mass Dirac ν 's from the core of neutron star in SN 1987A decaying to v's that would have interacted in KAM2 or IMB detectors.

16 CHUPP 99 should be multiplied by a branching ratio (about 1) and a detection efficiency (about 1/4), and pertains to radiative decay of any neutrino to a lighter or sterile neutrino.

17 Model-dependent theoretical analysis of SN 1987A neutrinos.

 18 Limit applies to ν_{τ} also.

 19 These experiments look for $\nu_{\mu} \to \ \nu_{e} \gamma$ or $\overline{\nu}_{\mu} \to \ \overline{\nu}_{e} \gamma.$

 $^{20}\,\text{HENRY}$ 81 uses UV flux from clusters of galaxies to find $\tau>~1.1\times10^{25}\,\text{s}$ for radiative

²¹ KIMBLE 81 uses extreme UV flux limits to find $\tau > 10^{22}$ – 10^{23} s.

²² REPHAELI 81 consider ν decay γ effect on neutral H in early universe; based on M31 HI concludes $\tau > 10^{24}$ s. ²³ DERUJULA 80 finds $\tau > 3 \times 10^{23}$ s based on CDM neutrino decay contribution to UV

background.

²⁴ STECKER 80 limit based on UV background; result given is $\tau > 4 \times 10^{22}$ s at $m_{\nu} = 20$

$|(v-c)/c| (v \equiv \nu_2 \text{ VELOCITY})$

Expected to be zero for massless neutrino, but also tests whether photons and neutrinos have the same limiting velocity in vacuum.

VALUE (units 1			DOCUMENT ID				_
<0.4	95	9800	KALBFLEISCH 79	SPEC			
<2.0	99	77	ALSPECTOR 76	SPEC	0	>5 GeV v	
<4.0	99	26	ALSPECTOR 76	SPEC	0	<5 GeV ν	

1/2 MAGNETIC MOMENT

Must vanish for Majorana neutrino or purely chiral massless Dirac neutrino. The value of the magnetic moment for the standard SU(2)×U(1) electroweak theory extended to include massive neutrinos (see FUJIKAWA 80) troweak theory extended to include massive neutrinos (see FUJIKAWA 80) is $\mu_{\nu} = 3 \text{eG}_F m_{\nu} / (8\pi^2 \sqrt{2}) = (3.2 \times 10^{-19}) m_{\nu} \mu_B$ where m_{ν} is in eV and $\mu_B = \text{e}\hbar / 2m_e$ is the Bohr magneton. Given the upper bound $m_{\nu_2} < 0.17$ MeV, it follows that for the extended standard electroweak theory, $\mu(\nu_2) < 0.51 \times 10^{-13} \ \mu_B$.

ALUE $(10^{-10} \mu_B)$	CL%		DOCUMENT ID		TECN	COMMENT
< 8.5	90		AHRENS	90	CNTR	$\nu_{\mu}e \rightarrow \nu_{\mu}e$
< 7.A	90	25	KRAKAUER			LAMPF $(\nu_{\mu}, \overline{\nu}_{\mu})e$
• • • We do not use the	following	g d	ata for averages	, fits	, ilmits,	
< 0.62		26	ELMFORS	97	COSM	Depolarization in early universe plasma
< 3.2	90	27	GOVAERTS	96		
< 30	90		VILAIN	95B	CHM2	$\nu_{\mu}e \rightarrow \nu_{\mu}e$
<100	95	28	DORENBOS	91	CHRM	$\nu_{\mu}e \rightarrow \nu_{\mu}e$
< 0.02		29	RAFFELT			Red giant luminosity
< 0.1		30	RAFFELT	89B	ASTR	Cooling helium stars
< 0.11	30	,31	FUKUGITA	87	ASTR	Cooling helium stars
< 0.0006		32	NUSSINOV	87	ASTR	Cosmic EM backgrounds
< 0.4			LYNN	81	ASTR	_
< 0.85		31	BEG	78	ASTR	Stellar plasmons
< 81		33	KIM	74	RVUE	$\overline{\nu}_{\mu}e \rightarrow \overline{\nu}_{\mu}e$
< 1		34	BERNSTEIN	63		Solar cooling

25 KRAKAUER 90 experiment fully reported in ALLEN 93.

26 ELMFORS 97 calculate the rate of depolarization in a plasma for neutrinos with a magnetic moment and use the constraints from a big-bang nucleosynthesis on additional

²⁷ GOVAERTS 96 limit is on $\sqrt{\Sigma \mu \nu_\ell^2}$, based on limits on 2ν decay of ortho-positronium.

 28 DORENBOSCH 91 corrects an incorrect statement in DORENBOSCH 89 that the ν_2 magnetic moment is $< 1 \times 10^{-9}$ at the 95%CL. DORENBOSCH 89 measures both $\nu_{\mu}e^{-2}$ and $\overline{\nu}_{\mu}$ e elastic scattering and assume $\mu(\nu_{\mu})=\mu(\overline{\nu}_{\mu}).$

 29 RAFFELT 90 limit applies for a diagonal magnetic moment of a Dirac neutrino, or for a transition magnetic moment of a Majorana neutrino. In the latter case, the same analysis gives $<1.4\times10^{-12}$. Limit at 95%CL obtained from $\delta M_{\rm C}$.

30 Significant dependence on details of stellar properties.

 31 if m_{ν_2} < 10 keV.

 32 For $m_{
u_2}=$ 8–200 eV. NUSSINOV 87 examines transition magnetic moments for u_{μ} ightarrow $\nu_{\rm e}$ and obtain < 3 \times 10⁻¹⁵ for $m_{\nu_{\rm 2}}$ > 16 eV and < 6 \times 10⁻¹⁴ for $m_{\nu_{\rm 2}}$ > 4 eV.

 $^{33}\,\text{KIM}$ 74 is a theoretical analysis of $\bar{\nu_{\mu}}$ reaction data.

 34 If m_{ν_2} < 1 keV.

NONSTANDARD CONTRIBUTIONS TO NEUTRING SCATTERING

We report limits on the so-called neutrino charge radius squared in this section. This quantity is not an observable, physical quantity and this is reflected in the fact that it is gauge dependent (see LEE 77C). It is not necessarily positive. A more general interpretation of the experimental results is that they are limits on certain nonstandard contributions to neutrino

VALUE (10-32 cm ²)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the	he followir	ng data for averages	s, fits	, limits,	etc. • • •
< 0.6	90	VILAIN	95B	CHM2	ν_{ii} e elas scat
-1.1 ± 1.0		35 AHRENS			ν _μ e elas scat
-0.3 ± 1.5		35 DORENBOS	89	CHRM	ν, e elas scat
**					,

³⁵ Result is obtained from reanalysis given in ALLEN 91, followed by our reduction to obtain

ν, REFERENCES

ELMFORS	97	NP 8503 3	P. Elmfors, K. Engvist, G. Raffelt, G. Sigi
ASSAMAGAN	96	PR D53 6065	+Broennimann, Daum+ (PSI, ZÜRI, VILL, VIRG)
GOVAERTS	96	PL B381 451	+Van Caillie (LOUV)
DOLGOV	95	PR D51 4129	+Kainulainen, Rothstein (MICH, MINN, CERN)
VILAIN		PL 8345 115	+Wilquet, Beyer+ (CHARM II Collab.)
ASSAMAGAN	94	PL B335 231	+Broennimann, Daum+ (PSI, ZURI, VILL, VIRG)
JECKELMANN		PL B335 326	+Goudsmit, Leisi (WABRN, VILL)
ALLEN	93	PR D47 11	+Chen, Doe, Hausammann+ (UCI, LANL, ANL, UMD)
DOLGOV	93	PRL 71 476	+Rothstein (MICH)
ENQVIST	93	PL B301 376	+Uibo (NORD)
MAYLE	93	PL B317 119	+Schramm, Turner, Wilson (LLNL, CHIC)
RAJPOOT	93	MPL A8 1179	(CSULB)
BLUDMAN	92	PR D45 4720	(CFPA)
BURROWS	92	PRL 68 3834	+Gandhi, Turner (ARIZ, CHIC)
DODELSON	92	PRL 68 2572	+Frieman, Turner (FNAL, CHIC)
ALLEN	91	PR D43 R1	+Chen, Doe, Hausammann (UCI, LANL, UMD)
DORENBOS	91	ZPHY C51 142	Dorenbosch, Udo, Aliaby, Amaldi+ (CHARM Collab.)
FULLER	91	PR D43 3136	+Malaney (UCSD)
GANDHI	91	PL B261 519E	(erratum) Burrows (ARIZ)
KRAKAUER	91	PR D44 R6	+Talaga, Allen, Chen+ (LAMPF E225 Collab.)
LAM	91	PR D44 3345	+Ng (AST)
NATALE	91	PL B258 227	(SPIFT)
AHRENS	90	PR D41 3297	+ (BNL, BROW, HIRO, KEK, OSAK, PENN, STON)
GANDHI	90	PL B246 149	+Burrows (ARIZ)
Also	91	PL B261 519E	(erratum) Gandhi, Burrows (ARIZ)
GRIFOLS	90B	PL B242 77	+Masso (BARC, ČERN)
KRAKAUER	90	PL B252 177	+Talaga, Allen, Chen+ (LAMPF E225 Collab.)
RAFFELT	90	PRL 64 2856	(MPIM)
CHUPP	89	PRL 62 505	+Vestrand, Reppin (UNH, MPIM)
DORENBOS	89	ZPHY C41 567	Dorenbosch, Udo, Allaby, Amaldi+ (CHARM Collab.)
GAEMERS	89	PR D40 309	+Gandhi, Lattimer (ANIK, STON)
KOLB	89	PRL 62 509	+Turner (CHIC, FNAL)
RAFFELT	89B	APJ 336 61	+Dearborn, Silk (UCB, LLL)
VONFEILIT	88	PL B200 \$80	Von Feilitzsch, Oberauer (MUNT)
FUKUGITA	87	PR D36 3817	+Yazaki (KYOTU, TOKY)
NUSSINOV	87	PR D36 2278	+Rephaeli (TELA)
ANDERHUB	82	PL 114B 76	+Boecklin, Hofer, Kottmann+ (ETH, SIN)
FRANK	81	PR D24 2001	+Burman+ (LASL, YALE, MIT, SACL, SIN+)
HENRY	81	PRL 47 618	+Feldman (JHU)
KIMBLE	81	PRL 46 80	+Bowyer, Jakobsen (UCB)
LYNN	81	PR D23 2151	(COLU)
REPHAELI	81	PL 106B 73	+Szalay (UCSB, CHIC)
DERUJULA	80	PRL 45 942	+Glashow (MIT, HARV)
FUJIKAWA	60	PRL 45 963	+Shrock (STON)
STECKER	80	PRL 45 1460	(NASA)
KALBFLEISCH		PRL 43 1361	+Baggett, Fowler+ (FNAL, PURO, BELL)
BEG	78	PR D17 1395	+Marciano, Ruderman (ROCK, COLU)
BLIETSCHAU	78	NP B133 205	+Deden, Hasert, Krenz+ (Gargamelle Collab.)
BARNES	77	PRL 38 1049	+Carmony, Dauwe, Fernandez+ (PURD, ANL)
LEE	77C	PR D16 1444	+Shrock (STON)
ALSPECTOR	76	PRL 36 837	+ (BNL, PURD, CIT, FNAL, ROCK)
BELLOTTI	76	LNC 17 553	+Cavalli, Florini, Rollier (MILA)
CLARK	74	PR D9 533	+Elioff, Frisch, Johnson, Kerth, Shen+ (LBL)
KIM	74	PR D9 3050	+Mather, Okubo (ROCH)
BERNSTEIN	63	PR 132 1227	+Ruderman, Feinberg (NYU, COLU)
DEKINS I EIN	63	PK 132 1221	+Ruderman, Feinberg (NYO, COLO)



Existence indirectly established from au decay data combined with u reaction data. See for example FELDMAN 81. ALBRECHT 92Q rules out J=3/2 by establishing that the ρ^{-} is not in a pure $H_0=-1$ helicity state in $\tau^- \rightarrow \rho^- \nu_\tau$.

Not in general a mass eigenstate. See note on neutrinos in the $\nu_{\rm e}$ section above.

VT MASS

Applies to ν_3 , the primary mass eigenstate in ν_τ . Would also apply to any other ν_f which mixes strongly in ν_τ and has sufficiently small mass that It can occur in the respective decays. (This would be nontrivial only for a hypothetical $j \ge 4$, given the ν_e and ν_μ mass limits above.) See also the Listings in the Neutrino Bounds from Astrophysics and Cosmology section.

VALUE (MeV)	CLX EVTS	DOCUMENT ID	TECN	COMMENT
< 18.2	95	1 BARATE 98F	ALEP	1991-1995 LEP runs

< 0.42

< 0.028-0.15

< 0.014 or > 34

< 0.028

< 0.06

• • • We do	not use the	followi	ing data for averages	, fits	, ilmits,	etc. • • •
< 60	95		² ANASTASSOV	97	CLEO	Ecm = 10.6 GeV
< 0.37 or >2	22		3 FIELDS	97	COSM	Nucleosynthesis
< 68	95		4 SWAIN	97	THEO	m_{τ} , τ_{τ} , τ partial widths
< 29.9	95			96M	OPAL	1990-1994 LEP runs
<149						π , μ , τ leptonic decays
<1 or >25			7 HANNESTAD	96 C	COSM	Nucleosynthesis
< 71	95		⁸ SOBIE	96	THEO	m_{τ} , τ_{τ} , $B(\tau^{-} \rightarrow$
						$e^- \overline{\nu}_e \nu_{\tau})$
< 74	95		9 AKERS	95D	OPAL	$Z \rightarrow \tau^+ \tau^-$ at LEP
< 24	95	25	¹⁰ BUSKULIC	95H	ALEP	1991-1993 LEP runs
< 0.19			11 DOLGOV	95	COSM	Nucleosynthesis
< 3			12 SIGL	95	ASTR	SN 1987A
< 0.4 or > 3	0		13 DODELSON	94	COSM	Nucleosynthesis
< 0.1 or > 5	0		14 KAWASAKI	94	COSM	
155-225			15 PERES	94		π , K , μ , τ weak decays
< 75	95		16 BALEST	93	CLEO	<i>E</i> €m = 10.6 GeV
< 32.6	95	113	¹⁷ CINABRO	93	CLEO	E ⁶⁶ _{Cm} ≈ 10.6 GeV
< 0.3 or >	35		18 DOLGOV	93	COSM	Nucleosynthesis
< 0.74			19 ENQVIST	93	COSM	Nucleosynthesis
< 0.003		2	0,21 MAYLE	93	ASTR	SN 1987A cooling
< 31	95	19	22 ALBRECHT	92M	ARG	Ecm = 9.4-10.6 GeV
< 0.025-0.03	30	2	^{21,23} BURROWS	92	ASTR	SN 1987A cooling
< 0.3			²⁴ FULLER ²⁵ KOLB	91	COSM	Nucleosynthesis
< 0.5 or >				91		Nucleosynthesis

 1 BARATE 98F result based on kinematics of 2939 $au^{-}
ightarrow 2\pi^{-}\pi^{+}
u_{ au}$ and 52 au^{-} - $3\pi^-2\pi^+(\pi^0)\nu_{\tau}$ decays. If possible 2.5% excited a_1 decay is included in 3-prong sample analysis, limit increases to 19.2 MeV.

91 COSM Nucleosynthesis

SN 1987A

SN 1987A

91 ASTR 5N 1987A

90 ASTR SN 1987A

908 ASTR

89

24 LAM

26 NATALE

21 GANDHI

^{21,27} GRIFOLS

21,28 GAEMERS

- 2 ANASTASSOV 97 derive limit by comparing their m_τ measurement (which depends on m_{ν_τ}) to BAI 96 m_τ threshold measurement.
- 3 FIELDS 97 limit for a Dirac neutrino. For a Majorana neutrino the mass region < 0.93or >31 MeV is excluded. These bounds assume N_{ν} <4 from nucleosynthesis; a wider excluded region occurs with a smaller N_{ν} upper limit.
- ⁴ SWAIN 97 derive their limit from the Standard Model relationships between the tau mass, lifetime, branching fractions for $\tau^- \to e^- \overline{\nu}_e \nu_{ au}, \, \tau^- \to \mu^- \overline{\nu}_{\mu} \nu_{ au}, \, \tau^- \to \pi^- \nu_{ au}$, and $au^- o K^-
 u_{_T}$, and the muon mass and lifetime by assuming lepton universality and using world average values. Limit is reduced to 48 MeV when the CLEO au mass measurement (BALEST 93) is included; see CLEO's more recent $m_{_{V_T}}$ limit (ANASTASSOV 97). Consideration of mixing with a fourth generation heavy neutrino yields $\sin^2 \theta_L < 0.016$
- 5 ALEXANDER 96M bound comes from analyses of $au^- o 3\pi^- 2\pi^+
 u_{ au}$ and $au^- o 1$ $h^-\,h^-\,h^+\,\nu_\tau$ decays.
- ⁶ BOTTINO 96 assumes three generations of neutrinos with mixing, finds consistency with massless neutrinos with no mixing based on 1995 data for masses, lifetimes, and leptonic partial widths.
- THANNESTAD 96C limit is on the mass of a Majorana neutrino. This bound assumes $N_{\nu} < 4$ from nucleosynthesis. A wider excluded region occurs with a smaller N_{ν} upper limit. This paper is the corrected version of HANNESTAD 96; see the erratum:
- 8 SOBIE 96 derive their limit from the Standard Model relationship between the tau mass, lifetime, and leptonic branching fraction, and the muon mass and lifetime, by assuming lepton universality and using world average values.
- ⁹ AKERS 95D bound comes from analysis of $au^- o 3\pi^- 2\pi^+
 u_{ au}$ decay mode.
- 10 BUSKULIC 95H bound comes from a two-dimensional fit of the visible energy and invariant mass distribution of $au o 5\pi(\pi^0)
 u_{ au}$ decays. Replaced by BARATE 98F.
- 11 DOLGOV 95 removes earlier assumptions (DOLGOV 93) about thermal equilibrium below TQCD for wrong-helicity Dirac neutrinos (ENQVIST 93, FULLER 91) to set more strinent limits. DOLGOV 96 argues that a possible window near 20 MeV is excluded.
- 12 SiGL 95 exclude massive Dirac or Majorana neutrinos with lifetimes between 10^{-3} and
- 10⁸ seconds if the decay products are predominantly γ or e^+e^- .

 13 DODELSON 94 calculate constraints on ν_{τ} mass and lifetime from nucleosynthesis for 4 generic decay modes. Limits depend strongly on decay mode. Quoted limit is valid for all decay modes of Majorana neutrinos with lifetime greater than about 300 s. For Dirac neutrinos limits change to < 0.3 or > 33.
- 14 KAWASAKI 94 excluded region is for Majorana neutrino with lifetime >1000 s. Other limits are given as a function of ν_{τ} lifetime for decays of the type $\nu_{\tau} \rightarrow \ \nu_{\mu} \phi$ where ϕ
- is a Nambu-Goldstone boson. 15 PERES 94 used PDG 92 values for parameters to obtain a value consistent with mixing. Reexamination by BOTTINO 96 which included radiative corrections and 1995 PDG parameters resulted in two allowed regions, $m_3 < 70$ MeV and 140 MeV $m_3 < 149$
- 16 BALEST 93 derive limit by comparing their $m_{ au}$ measurement (which depends on $m_{
 u_{ au}}$) to BAI 92 and BACINO 788 m., threshold measurements.
- ¹⁷CINABRO 93 bound comes from analysis of $\tau^- \rightarrow 3\pi^- 2\pi^+ \nu_{\tau}$ and $\tau^- \rightarrow$ $2\pi^-\pi^+2\pi^0\nu_{ au}$ decay modes.
- 18 DOLGOV 93 assumes neutrino lifetime >100 s. For Majorana neutrinos, the low mass limit is 0.5 MeV. KAWANO 92 points out that these bounds can be overcome for a Dirac neutrino if it possesses a magnetic moment. See also DOLGOV 96.
- 19 ENQVIST 93 bases limit on the fact that thermalized wrong-helicity Dirac neutrinos would speed up expansion of early universe, thus reducing the primordial abundance. FULLER 91 exploits the same mechanism but in the older calculation obtains a larger production rate for these states, and hence a lower limit. Neutrino lifetime assumed to exceed nucleosynthesis time, \sim 1 s.

- ²⁰ MAYLE 93 recalculates cooling rate enhancement by escape of wrong-helicity Dirac neutrinos using the Livermore Supernova Explosion Code, obtains more restrictive result than the "very conservative" BURROWS 92 limit because of higher core temperature.
- ²¹ There would be an increased SN 1987A cooling rate if Dirac neutrino mass is included; this does not apply for Majorana neutrinos. Limit is on $\sqrt{m^2_{\ \nu_\mu} + m^2_{\ \nu_\tau}}$, and error becomes very large if ν_τ is nonrelativistic, which occurs near the lab limit of 31 MeV. RAJPOOT 93 notes that limit could be evaded with new physics.
- 22 ALBRECHT 92M reports measurement of a slightly lower au mass, which has the effect of reducing the $u_{ au}$ mass reported in ALBRECHT 88B. Bound is from analysis of $au^-
 ightarrow$ $3\pi^+2\pi^+\nu_{\tau}$ mode.
- 23 BURROWS 92 limit for Dirac neutrinos only.
- 24 Assumes neutrino lifetime >1 s. For Dirac neutrinos. See also ENQVIST 93.
- 25 KOLB 91 exclusion region is for Dirac neutrino with lifetime >1 s; other limits are given.
- $^{26}\,\text{NATALE}$ 91 published result multiplied by $\sqrt{8}\sqrt{4}$ at the advice of the author.
- GRIFOLS 90B estimated error is a factor of 3. ²⁸ GAEMERS 89 published result (< 0.03) corrected via the GANDHI 91 erratum.

以 (MEAN LIFE) / MASS

These limits often apply to $\nu_{\mu}~(\nu_{2})$ also.

VALUE (s/eV)	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following	owing data for average	s, fit:	s, Ilmits,	etc. • • •
>1 × 10 ¹⁴	²⁹ SIGL	95	ASTR	m_{ν} > few MeV
>2.8 × 10 ¹⁵	30,31 BLUDMAN	92	ASTR	m,, < 50 eV
$< 10^{-12} \text{ or } > 5 \times 10^4$	32 DODELSON	92	ASTR	m _v =1-300 keV
	³³ GRANEK	91	COSM	Decaying L ⁰
	³⁴ WALKER	90	ASTR	$m_{\nu} = 0.03 - \sim 2 \text{ MeV}$
$>6.3 \times 10^{15}$	31,35 CHUPP	89	ASTR	$m_{\nu} < 20 \text{ eV}$
>1.7 × 10 ¹⁵	31 KOLB	89	ASTR	$m_{\nu} < 20 \text{ eV}$
	³⁶ TERASAWA	88	COSM	m ₁₁ = 30-70 MeV
	37 KAWASAKI	86	COSM	m, >10 MeV
	38 LINDLEY	85	COSM	m _v > 10 MeV
	39 BINETRUY	84	COSM	$m_{\nu} \sim 1 \text{ MeV}$
	⁴⁰ SARKAR	84	COSM	$m_{\nu} = 10-100 \text{ MeV}$
	41 HENRY	81	ASTR	$m_{\nu} = 16-20 \text{ eV}$
	42 KIMBLE	81	ASTR	$m_{\nu} = 10 - 100 \text{ eV}$
	43 REPHAELI	81	ASTR	$m_{\nu} = 30-150 \text{ eV}$
	44 DERUJULA	80	ASTR	<i>V</i>
>2 × 10 ²¹	45 STECKER	80	ASTR	$m_{\nu} = 10-100 \text{ eV}$
	46 DICUS	78	COSM	$m_{\nu} = 0.5 - 30 \text{ MeV}$
$< 3 \times 10^{-11}$	47 FALK	78	ASTR	$m_{\nu} < 10 \text{ MeV}$
	48 COWSIK	77	ASTR	

- 29 SIGL 95 exclude 1 s $\lesssim \tau \lesssim 10^8$ s for MeV-mass τ nuetrinos from SN 1987A decaying radiatively, and eliminates the lower limit using other published results.
- 30 BLUDMAN 92 sets additional limits by this method for higher mass ranges. Cosmological
- limits are also obtained. 31 Nonobservation of γ 's in coincidence with ν 's from SN 1987A. Results should be divided by the $\tau_{\nu} \rightarrow \ \gamma$ X branching ratio.
- 32 DODELSON 92 range is for wrong-helicity keV mass Dirac u's from the core of neutron star in SN 1987A decaying to u's that would have interacted in KAM2 or IMB detectors.
- 33 GRANEK 91 considers heavy neutrino decays to $\gamma \nu_L$ and $3 \nu_L$, where m_{ν_L} <100 keV. Lifetime is calculated as a function of heavy neutrino mass, branching ratio into $\gamma \nu_L$,
- 34 WALKER 90 uses SN 1987A $_{\gamma}$ flux limits after 289 days to find $m_{_{T}}~>~1.1 \times 10^{15}$ eV s.
- 35 CHUPP 89 should be multiplied by a branching ratio (about 1) and a detection efficiency (about 1/4), and pertains to radiative decay of any neutrino to a lighter or sterile neutrino.
- 36 TERASAWA 88 finds only $10^2 < au < 10^4$ allowed for 30–70 MeV u's from primordal
- 37 KAWASAKI 86 concludes that light elements in primordal nucleosynthesis would be destroyed by radiative decay of neutrinos with 10 MeV < m_{ν} <1 GeV unless $\tau \lesssim 10^4$ s.
- 38 LINDLEY 85 considers destruction of cosmologically-produced light elements, and finds $au < 2 imes 10^3 \, \mathrm{s}$ for 10 MeV $< m_{
 u} <$ 100 MeV. See also LINDLEY 79.
- ³⁹ BINETRUY 84 finds $\tau < 10^8$ s for neutrinos in a radiation-dominated universe. ⁴⁰ SARKAR 84 finds $\tau < 20$ s at $m_{\nu} = 10$ MeV, with higher limits for other m_{ν} , and claims that all masses between 1 MeV and 50 MeV are ruled out.
- ⁴¹ HENRY 81 uses UV flux from clusters of galaxies to find $au > 1.1 imes 10^{25} \, \mathrm{s}$ for radiative
- decay. 42 KIMBLE 81 uses extreme UV flux limits to find $\tau > 10^{22} 10^{23}$ s. 43 REPHAELI 81 consider ν decay γ effect on neutral H in early universe; based on M31 Hi concludes $\tau > 10^{24}$ s. 44 DERUJULA 80 finds $\tau > 3 \times 10^{23}$ s based on CDM neutrino decay contribution to UV
- 45 STECKER 80 limit based on UV background; result given is $au > 4 imes 10^{22}\,\mathrm{s}$ at $m_{
 m p} = 20\,$ eV.

 6 DICUS 78 considers effect of ν decay photons on light-element production, and finds lifetime must be less than "hours." See also DICUS 77.

 7 FALK 78 finds lifetime constraints based on supernova energetics.
- 48 COWSIK 77 considers varity of scenarios. For neutrinos produced in the big bang, present limits on optical photon flux require $\tau>10^{23}\,\mathrm{s}$ for $m_{\nu}\sim 1$ eV. See also COWSIK 79 and GOLDMAN 79.

№ MAGNETIC MOMENT

Must vanish for Majorana neutrino or purely chiral massless Dirac neutrino. The value of the magnetic moment for the standard SU(2)×U(1) electroweak theory extended to include massive neutrinos (see FUJIKAWA 80) is $\mu_{\nu}=3eG_Fm_{\nu}/(8\pi^2\sqrt{2})=(3.20\times 10^{-19})m_{\nu}\mu_B$ where m_{ν} is in eV and $\mu_B=e\hbar/2m_e$ is the Bohr magneton. Given the upper bound $m_{\nu_3}<35$ MeV, it follows that for the extended standard electroweak theory, $\mu(\nu_3)<1.1\times10^{-11}~\mu_B$.

VALUE (µB)	CL%	DOCUMENT ID		TECN	COMMENT
<5.4 × 10 ⁷	90	49 COOPER	92	BEBC	$\nu_{\tau} e^{-} \rightarrow \nu_{\tau} e^{-}$
• • • We do not us	e the follow	wing data for average			
<4.4 × 10 ⁻⁶	90	ABREU	97J	DLPH	$e^+e^- \rightarrow \nu \overline{\nu} \gamma$ at LEP
<3.3 × 10 ⁻⁶	90	⁵⁰ ACCIARRI	97Q	L3	$e^+e^- \rightarrow \nu \overline{\nu} \gamma$ at LEP
<6.2 × 10 ⁻¹¹		⁵¹ ELMFORS	97	COSM	Depolarization in early universe plasma
<2.7 × 10 ⁻⁶	95	52 ESCRIBANO	97	RVUE	$\Gamma(Z \rightarrow \nu \nu)$ at LEP
<3.2 × 10 ⁻¹⁰	90	53 GOVAERTS	96		,
<5.5 × 10 ^{~6}	90	GOULD	94	RVUE	$e^+e^- \rightarrow \nu \overline{\nu} \gamma$ at LEP
≥10-8		⁵⁴ KAWANO	92	ASTR	Primodial ⁴ He abun- dance
<5.6 × 10 ⁻⁶	90	DESHPANDE	91	RVUE	$e^+e^- \rightarrow \nu \overline{\nu} \gamma$
<2 × 10 ⁻¹²		55 RAFFELT	90	ASTR	Red giant luminosity
<1 × 10 ⁻¹¹		⁵⁶ RAFFELT	89B	ASTR	Cooling hellum stars
<4. × 10 ⁻⁶	90	57 GROTCH	88	RVUE	$e^+e^- \rightarrow \nu \overline{\nu} \gamma$
<1.1 × 10 ⁻¹¹		56,58 FUKUGITA	87	ASTR	Cooling helium stars
<6 × 10 ⁻¹⁴		⁵⁹ NUSSINOV	87	ASTR	Cosmic EM backgrounds
$< 8.5 \times 10^{-11}$		⁵⁸ BEG	78		Stellar plasmons
49	. 			=	

- 49 COOPER-SARKAR 92 assume $f_{D_s}/f_\pi=2$ and $D_s,\ \overline{D}_s$ production cross section =2.6 $\mu{\rm b}$ to calculate ν_{τ} flux.
- 50 ACCIARRI 97Q result applies to both direct and transition magnetic moments and for $a^2 = 0$.
- 51 ELMFORS 97 calculate the rate of depolarization in a plasma for neutrinos with a magnetic moment and use the constraints from a big-bang nucleosynthesis on additional degrees of freedom.
- ⁵² Applies to absolute value of magnetic moment.
- 53 GOVAERTS 96 limit is on $\sqrt{\Sigma\,\mu\nu_\ell^2}$, based on limits on 2ν decay of ortho-positronium.
- ⁵⁴ KAWANO 92 lower limit is that needed to circumvent ⁴He production if $m_{
 u_{\tau}}$ is between 5 and \sim 30 MeV/ c^2 .
- 53 and \sim 30 MeV/c⁻. 55 RAFFELT 90 limit valid if $m_{\nu_3} < 5$ keV. It applies for a diagonal magnetic moment of a Dirac neutrino, or for a transition magnetic moment of a Majorana neutrino. In the latter case, the same analysis gives $< 1.4 \times 10^{-12}$. Limit at 95%CL obtained from δM_C .
- ⁵⁶ Significant dependence on details of stellar properties. 57 GROTCH 88 combined data from MAC, ASP, CELLO, and Mark J.
- $^{58}\,\mathrm{if}\;m_{\nu_3}\;<$ 10 keV.
- $^{59}\,\mathrm{For}~m_{\nu_3}^{}=$ 8–200 eV. NUSSINOV 87 examines transition magnetic moments for ν_{τ} \rightarrow $\nu_{\rm e}$ and obtain < 3 \times 10 $^{-15}$ for m_{ν_3} < 16 eV and < 6 \times 10 $^{-14}$ for m_{ν_3} > 4 eV.

13 ELECTRIC DIPOLE MOMENT

VALUE (ecm)	CL%	DOCUMENT ID		TECN	COMMENT
<5.2 × 10 ⁻¹⁷	95	60 ESCRIBANO	97	RVUE	$\Gamma(Z \rightarrow \nu \nu)$ at LEP
60 Applies to absolut	te value of o	electric dipole mom	ent.		

A CHARGE

		_		
VALUE (units: electron charge)	DOCUMENT ID		TECN	COMMENT
• • • We do not use the follow	owing data for averag	es, fit	s, limits,	etc. • • •
<4 × 10 ⁻⁴	61 BABU	94	RVUE	BEBC beam dump
<3 × 10 ⁻⁴	62 DAVIDSON	91	RVUE	SLAC electron beam dump

- 61 BABU 94 use COOPER-SARKAR 92 limit on ν_3 magnetic moment to derive quoted
- result.

 62 DAVIDSON 91 use data from early SLAC electron beam dump experiment to derive charge limit as a function of neutrino mass.

LIMIT ON ν_{τ} PRODUCTION IN BEAM DUMP EXPERIMENT

VALUE	DOCUMENT ID		TECN
• • • We do not use the following	ng data for averages	, fits	, limits, etc. • • •
	63 DORENBOS	88	CHRM
•		87	
	65 TALEBZADEH	87	BEBC `
	66 USHIDA		EMUL
	67 ASRATYAN	81	HLBC
	68 FRITZE	80	BEBC

- 63 DORENBOSCH 88 is CERN SPS beam dump experiment with the CHARM detector. $\nu_{\tau}+\nu_{\tau}$ flux is <21% of the total prompt flux at 90% CL. 64 BOFILL 87 is a Fermilab narrow-band ν beam with a fine-grained neutrino detector.
- 65 TALEBZADEH 87 is a CERN SPS beam dump experiment with the BEBC detector. Mixing probability $P(\nu_e \to \nu_\tau)$ <18% at 90% CL.
- 66 USHIDA 86c is a Fermilab wide-band ν beam with a hybrid emulsion spectrometer. Mixing probabilities $P(\nu_e \rightarrow \nu_\tau) < 7.3\%$ and $P(\nu_\mu \rightarrow \nu_\tau) < 0.2\%$ at 90% CL.

- 67 ASRATYAN 81 is a Fermilab wide-band $\overline{\nu}$ beam with a 15 foot bubble chamber. Mixing probability $P(\overline{\nu}_{\mu}\to\ \overline{\nu}_{\tau})<2.2\%$ at 90% CL.
- 68 FRITZE 80 is CERN SPS experiment with BEBC. Neutral-current/charged-current ratio corresponds to R= (prompt- ν_T -induced events)/(all prompt- ν events) <0.1. Mixing probability $P(\nu_e \to \nu_T)$ <0.35 at CL = 90%.

ν_{τ} REFERENCES

BARATE			
	98F	EPJ C2 395	R. Barate+ (ALEPH Collab.) P. Abreu+ (DELPHI Collab.)
ABREU	97J	ZPHY C74 577	P. Abreu+ (DELPHI Collab.)
ACCIARRI	97Q	PL B412 201	M. Acciarri+ (L3 Collab.)
ANASTASSOV		PR D55 2559	+Blinov, Duboscq, Fisher, Fujino+ (CLEO Collab.)
ELMFORS	97	NP B503 3	P. Elmfors, K. Enqvist, G. Raffelt, G. Sigi
		NP 0303 3	F. Elmiors, K. Endvist, G. Karrett, G. Sigi
ESCRIBANO	97	PL B395 369	+Masso (BARC, PARIT)
FIELDS	97	ASP 6 169	→Kainulainen Olive (NDAM MINN)
SWAIN	97	PR D55 R1	+Taylor (NEAS)
ALEXANDER	96M	ZPHY C72 231	+Taylor (NEAS) +Allison, Altekamp, Ametewee+ +Bardon, Becker-Szendy, Blum+ (BES Collab.)
BAI	96	PR D53 20	Pardon Backer Crendy Blum (DEC Callab.)
			+Bardon, Becker-Szendy, Blum+ (BES Collab.)
BOTTINO	96	PR D53 6361	A. Bottino+
DOLGOV	96	PL B383 193	+Pastor, Valle (IFIC, VALE) +Van Caillie (LOUV)
GOVAERTS	96	PI R3R1 451	+Van Caillie (LOUV) +Madsen (AARH)
HANNESTAD	96	DDI 76 2848	Madren (AADU)
HANNESTAD		DD1 77 5148 /	(AADU)
	96B	PRL 76 2848 PRL 77 5148 (erratum)	+Madsen (AARH)
HANNESTAD	96C	PK D54 /894	+Madsen (AAKH)
SOBIE	96	ZPHY C70 383 ZPHY C65 183	+Keeler, Lawson (VICT) +Alexander, Attison, Anderson+ (OPAL Collab.)
AKERS	95D	ZPHY C65 183	+Alexander, Allison, Anderson+ (OPAL Collab.)
BUSKULIC	95H	PL B349 585	+Casper, De Bonis, Decamp+ (ALEPH Collab.)
		DD DE1 4100	Maintelland Determine (ACCT) CORD.)
DOLGOV	95	PR D51 4129	+Kainulainen, Rothstein (MICH, MINN, CERN)
SIGL	95	PR D51 1499	+Kainulainen, Rothstein (MICH, MINN, CERN) +Turner (FNAL, EFI) +Gould, Rothstein (BART, JHU, MICH)
BABU	94	PL B321 140	+Gould, Rothstein (BART, JHU, MICH) +Gyuk, Turner (FNAL, CHIC, EFI)
DODELSON	94	PR D49 5068	+Gunk Turner (ENAL CHIC EEL)
GOULD	94	PL B333 545	+Gyuk, Turner (FNAL, CHIC, EFI) +Rothstein (JHU, MICH)
GOOLD		FL 0333 343	+ROLISCEII (JRO, MICH)
KAWASAKI	94	NP B419 105	+Kernan, Kang+ (OSU) O.L.G. Peres, V. Pleitez, Funchal
PERES	94	PR D50 513	O.L.G. Peres, V. Pleitez, Funchal
BALEST	93	PR D47 R3671	+Dagudi, Ford. Johnson+ (CLEO Collab.)
CINABRO	93	PRI 70 3700	+Henderson, Kinoshita+ (CLEO Collab.)
DOI GOV	93	PRL 70 3700 PRL 71 476	+Rothstein (MICH)
		LKT 11 410	
ENQVIST	93	PL B301 376	+Uibo (NORD)
MAYLE	93	PL B301 376 PL B317 119	+Schramm, Turner, Wilson (LLNL, CHIC) (CSULB)
RAJPOOT	93	MPL A8 1179	(CSULB)
ALBRECHT	92M	PL B292 221	+ Ehrlichmann, Hamacher, Hofmann+ (ARGUS Collab.) + Ehrlichmann, Hamacher+ (ARGUS Collab.)
		TD 0272 221	+Ehrlichmann, Hamacher, Hofmann+ (ARGUS Collab.) +Ehrlichmann, Hamacher+ (ARGUS Collab.)
ALBRECHT	92Q	ZPHY C56 339	+Enrichmann, Hamacher+ (ARGUS Collab.)
BAI	92	PRL 69 3021	
BLUDMAN	92	PR D45 4720	(CFPA)
BURROWS	92	PRL 68 3834	+Gandhi, Turner (ARIZ, CHIC)
COOPER			Constant Portion Forting Com. Manual (PEDC MACC Collect)
	92	PL B280 153	(CFPA) +Gandhi, Turner (ARIZ, CHIC) Cooper-Sarkar, Sarkar, Guy, Venus+(BEBC WA66 Collab.)
DODELSON	92	PRL 68 2572	
KAWANO	92	PL B275 487	+Fuller, Malaney, Savage II Hikasa, Barnett, Stone+ +Campbell, Bailey (CIT, UCSD, LLL, RUTG) (KEK, LBL, 80ST+) (ALBE, TNTO)
PDG	92	PR D45, 1 June, Part	II Hikasa, Barnett, Stone+ (KEK, LBL, BOST+) +Campbell, Bailey (ALBE, TNTO)
DAVIDSON	91	PR D43 2314	+Campbell Bailey (ALRE TNTO)
		DD D43 043	(ODEC TATA)
DESHPANDE	91	PR D43 943	+Sarma (OREG, TATA)
FULLER	91	PR D43 3136	+Malaney (UCSD)
GANDHI	91	PL B261 519E (erratum	n)-Burrows (ARIZ)
GRANEK	91	IJMP A6 2387	+McKellar (MELB)
KOLB	91	PRL 67 533	+Turner, Chakravorty, Schramm (FNAL, CHIC)
KOLD		PR D44 3345	Tiumer, Charlestory, Schrammi (Final, Critc)
LAM	91	PR D44 3345	+Ng (AST)
NATALE	91	PL B258 227 PL B246 149	(SPIFT)
GANDHI	90	PL B246 149	+Rurrows (ARI7)
	91	DL B061 E105 (
Also		PL B261 519E (erratum	n) Gandhi, Burrows (ARIZ)
GRIFOLS	90B	PL B242 77	+ Masso (ARIZ) + Masso (BARC, CERN)
GRIFOLS RAFFELT	90B 90	PL B242 77 PRL 64 2856	
GRIFOLS RAFFELT WALKER	90B 90 90	PL B242 77 PRL 64 2856 PR D41 689	n) Gandhi, Burrows (ARIZ) +Masso (BARC, CERN) (MPIM) (HARV)
GRIFOLS RAFFELT WALKER	90B 90 90	PL B242 77 PRL 64 2856 PR D41 689	n) Gandhi, Burrows (ARIZ) +Masso (BARC, CERN) (MPIM) (HARV) +Vestrand Rennin (INIM, MPIM)
GRIFOLS RAFFELT WALKER CHUPP	90B 90 90 89	PL B242 77 PRL 64 2856 PR D41 689 PRL 62 505 PR D40 309	(MARV) +Vestrand, Reppin (UNH, MPIM)
GRIFOLS RAFFELT WALKER CHUPP GAEMERS	90B 90 90 89 89	PL B242 77 PRL 64 2856 PR D41 689 PRL 62 505 PR D40 309	+Vestrand, Reppin (UNH, MPIM) +Gandhi, Lattimer (ANIK, STON)
GRIFOLS RAFFELT WALKER CHUPP GAEMERS KOLB	90B 90 90 89 89	PL B242 77 PRL 64 2856 PR D41 689 PRL 62 505 PR D40 309	+Vestrand, Reppin (UNH, MPIM) +Gandhi, Lattimer (ANIK, STON) +Turner (CHIC, FNAL)
GRIFOLS RAFFELT WALKER CHUPP GAEMERS KOLB RAFFELT	90B 90 90 89 89 89	PL B242 77 PRL 64 2856 PR D41 689 PRL 62 505 PR D40 309 PRL 62 509 APJ 336 61	Vestrand, Reppin
GRIFOLS RAFFELT WALKER CHUPP GAEMERS KOLB	90B 90 90 89 89	PL 8242 77 PRL 64 2856 PR D41 689 PRL 62 505 PR D40 309 PRL 62 509 APJ 336 61 PL 8202 149	+Vestrand, Reppin (UNH, MPIM) +Gandhi, Lattimer (ANIK, STON) +Turner (CHIC, FNAL) +Dearborn, Silk (UCB, LLL) +Bilder, Boeckmann+ (ARGUS Collab)
GRIFOLS RAFFELT WALKER CHUPP GAEMERS KOLB RAFFELT ALBRECHT	90B 90 90 89 89 89 89B 88B	PL 8242 77 PRL 64 2856 PR D41 689 PRL 62 505 PR D40 309 PRL 62 509 APJ 336 61 PL 8202 149	+Vestrand, Reppin (UNH, MPIM) +Gandhi, Lattimer (ANIK, STON) +Turner (CHIC, FNAL) +Dearborn, Silk (UCB, LLL) +Bilder, Boeckmann+ (ARGUS Collab)
GRIFOLS RAFFELT WALKER CHUPP GAEMERS KOLB RAFFELT ALBRECHT DORENBOS	90B 90 90 89 89 89 89 88B 88B	PL 8242 77 PRL 64 2856 PR D41 689 PRL 62 505 PR D40 309 PRL 62 509 APJ 336 61 PL 8202 149	Vestrand, Reppin (UNH, MPIM) + Gandhi, Lattimer (ANIK, STON) + Turner (CHIC, FNAL LL) + Dearborn, Silk (UCB, LLL) + Bilder, Boeckmann+ (ARGUS Collab.) Dorenbosch, Allaby, Amaldi, Barbellini+ (CHARM Collab.)
GRIFOLS RAFFELT WALKER CHUPP GAEMERS KOLB RAFFELT ALBRECHT DORENBOS GROTCH	90B 90 90 89 89 89 89B 88B 88B	PL 8242 77 PRL 64 2856 PR D41 669 PRL 62 505 PR D40 309 PRL 62 509 APJ 336 61 PL 8202 149 ZPHY C40 497 ZPHY C40 39 553	Vestrand, Reppin (UNH, MPIM) + Gandhi, Lattimer (ANIK, STON) + Turner (CHIC, FNAL) + Dearborn, Silk (UCB, LLL) - Binder, Boeckmann + (ARGUS Collab.) - Dorenbosch, Allaby, Amaldi, Barbiellini+ (CHAR (Collab.) - Robinett
GRIFOLS RAFFELT WALKER CHUPP GAEMERS KOLB RAFFELT ALBRECHT DORENBOS GROTCH TERASAWA	90B 90 90 89 89 89 89B 88B 88B 88	PL 8242 77 PRL 64 2856 PR D41 689 PR L62 505 PR D40 309 PRL 62 509 APJ 336 61 PL 8202 149 ZPHY C40 497 ZPHY C39 553 NP B302 697	Vestrand, Reppin (UNH, MPIM) + Gandhi, Lattimer (ANIK, STON) + Turner (CHIC, FNAL) + Dearborn, Silk (UCB, LL) + Bilder, Boeckmann+ (ARGUS Collab.) Dorenbosch, Allaby, Amaldi, Barbiellini+ (CHARM Collab.) + Robinett (FSU)
GRIFOLS RAFFELT WALKER CHUPP GAEMERS KOLB RAFFELT ALBRECHT DORENBOS GROTCH TERASAWA BOFILL	90B 90 90 89 89 89 89B 88B 88B 88	PL 8242 77 PRL 64 2856 PR D41 689 PRL 62 505 PR D40 309 PRL 62 509 APJ 336 61 PL 8202 149 ZPHY C30 497 ZPHY C39 553 NP 8302 697 PR D36 3309	Vestrand, Reppin (UNH, MPIM) + Gandhi, Lattimer (ANIK, STON) + Turner (CHIC, FNAL) + Dearborn, Silk (UCB, LL) + Bilder, Boeckmann+ (ARGUS Collab.) Dorenbosch, Allaby, Amaldi, Barbiellini+ (CHARM Collab.) + Robinett (FSU)
GRIFOLS RAFFELT WALKER CHUPP GAEMERS KOLB RAFFELT ALBRECHT DORENBOS GROTCH TERASAWA BOFILL FUKUGITA	90B 90 90 89 89 89 89B 88B 88B 88	PL 8242 77 PRL 64 2856 PR D41 689 PRL 62 505 PR D40 309 PRL 62 509 APJ 336 61 PL 8202 149 ZPHY C39 553 NP B302 697 PR D36 3309 PR D36 3309 PR D36 3317	Vestrand, Reppin (UNH, MPIM) + Gandhi, Lattimer (ANIK, STON) + Turner (CHIC, FNAL) + Dearborn, Silk (UCB, LIL) + Bilder, Boeckmann+ (ARGUS Collab.) Dorenbosch, Allaby, Amaldi, Barbiellini+ (CHARM Collab.) + Robinett (PSU) + Kawasaki, Sato (RIT, FNAL, MSU) + Busza, Eldridge+ (MIT, FNAL, MSU) + Yazaki (KYOTU, TOKY)
GRIFOLS RAFFELT WALKER CHUPP GAEMERS KOLB RAFFELT ALBRECHT DORENBOS GROTCH TERASAWA BOFILL	90B 90 90 89 89 89 89B 88B 88B 88	PL 8242 77 PRL 64 2856 PR D41 689 PRL 62 505 PR D40 309 PRL 62 509 APJ 336 61 PL 8202 149 ZPHY C39 553 NP B302 697 PR D36 3309 PR D36 3309 PR D36 3317	Vestrand, Reppin (UNH, MPIM) + Gandhi, Lattimer (ANIK, STON) + Turner (CHIC, FNAL) + Dearborn, Silk (UCB, LIL) + Bilder, Boeckmann+ (ARGUS Collab.) Dorenbosch, Allaby, Amaldi, Barbiellini+ (CHARM Collab.) + Robinett (PSU) + Kawasaki, Sato (RIT, FNAL, MSU) + Busza, Eldridge+ (MIT, FNAL, MSU) + Yazaki (KYOTU, TOKY)
GRIFOLS RAFFELT WALKER CHUPP GAEMERS KOLB RAFFELT ALBRECHT DORENBOS GROTCH TERASANVA BOFILL FUKUGITA NUSSINOV	90B 90 90 89 89 89 88B 88B 88 88 88	PL 8242 77 PRL 64 2856 PR D41 689 PRL 62 505 PR D40 309 PRL 62 509 APJ 336 61 PL 8202 149 ZPHY C39 553 NP B302 697 PR D36 3309 PR D36 3309 PR D36 3317	Vestrand, Reppin (UNH, MPIM) + Gandhi, Lattimer (ANIK, STON) + Turner (CHIC, FNAL) + Dearborn, Silk (UCB, LIL) + Bilder, Boeckmann+ (ARGUS Collab.) Dorenbosch, Allaby, Amaldi, Barbiellini+ (CHARM Collab.) + Robinett (PSU) + Kawasaki, Sato (RIT, FNAL, MSU) + Busza, Eldridge+ (MIT, FNAL, MSU) + Yazaki (KYOTU, TOKY)
GRIFOLS RAFFELT WALKER CHUPP GAEMERS KOLB RAFFELT ALBRECHT DORENBOS GROTCH TERASAWA BOFILL FUKUGITA NUSSINOV TALEBZADEH	90B 90 90 89 89 89B 88B 88 88 88 87 87	PL B242 77 PRL 64 2856 PR D41 689 PRL 62 505 PR D40 309 PRL 62 509 APJ 336 61 PL B302 149 ZPHY C40 497 ZPHY C59 533 NP B302 697 PR D36 3309 PR D36 3317 PR D36 2276 NP B291 503	Vestrand, Reppin (UNH, MPIM) + Gandhi, Lattimer (ANIK, STON) + Turner (CHIC, FNAL) + Dearborn, Silk (UCB, LIL) + Bilder, Boeckmann+ (ARGUS Collab.) Dorenbosch, Allaby, Amaldi, Barbiellini+ (CHARM Collab.) + Robinett (PSU) + Kawasaki, Sato (RIT, FNAL, MSU) + Busza, Eldridge+ (MIT, FNAL, MSU) + Yazaki (KYOTU, TON) + Rephael (TELA) + Gow, Yenus+ (BEBC WA66 Collab.)
GRIFOLS RAFFELT WALKER CHUPP GAEMERS KOLB RAFFELT ALBRECHT DORENBOS GROTCH TERASAWA BOFILL FUKUGITA NUSSINOV TALEBZADEH KAWASAKI	90B 90 90 89 89 89 88B 88 88 88 87 87 87	PL B242 77 PRL 64 2856 PR D41 699 PRL 62 505 PR D40 505 PR D40 396 APJ 336 61 PL B202 149 ZPHY C40 497 ZPHY C40 497 ZPHY C40 497 ZPHY C30 533 NP B302 697 PR D36 3317 PR D36 3319 PR D36 3217 PR D36 3217	Vestrand, Reppin (UNH, MPIM) + Gandhi, Lattimer (ANIK, STON) + Turner (CHIC, FNAL) + Dearborn, Silk (UCB, LIL) + Bilder, Boeckmann+ (ARGUS Collab.) Dorenbosch, Allaby, Amaldi, Barbiellini+ (CHARM Collab.) + Robinett (PSU) + Kawasaki, Sato (RIT, FNAL, MSU) + Busza, Eldridge+ (MIT, FNAL, MSU) + Yazaki (KYOTU, TON) + Rephael (TELA) + Gow, Yenus+ (BEBC WA66 Collab.)
GRIFOLS RAFFELT WALKER CHUPP GAEMERS KOLB RAFFELT AL BRECHT DORENBOS GROTCH TERASAWA BOFILL FUKUGITA NUSSINOV TALEBZADEH KAWASAKI USHIDA	90B 90 90 89 89 89 88B 88 88 87 87 87 87 86 86C	PL B242 77 PRL 64 2856 PR D41 699 PRL 62 505 PR D40 505 PR D40 396 APJ 336 61 PL B202 149 ZPHY C40 497 ZPHY C40 497 ZPHY C40 497 ZPHY C30 533 NP B302 697 PR D36 3317 PR D36 3319 PR D36 3217 PR D36 3217	Vestrand, Reppin (UNH, MPIM) + Vestrand, Reppin (UNH, MPIM) + Gandhi, Lattimer (ANIK, STON) + Turner (CHIC, FNAL) + Dearborn, Silk (UCB, LL) + Bilder, Boeckmann+ (UCB, LL) - Binder, Boeckmann+ (UCB, LL) - Robinett (PSU) - Kawasaki, Sato (FUSY) - Hausza, Eldridge+ (MIT, FNAL, MSU) - Hyazaki (KYOTU, TOKY) - Rephaeil (TELA) - Terasawa, Sato (FNAL ES31 Collab) - Terasawa, Sato (FNAL ES31 Collab) - Terasawa, Sato (FNAL ES31 Collab)
GRIFOLS RAFFELT WALKER CALWEP GAEMERS KOLB RAFFELT ALBRECHT DORENBOS GROTCH TERASAWA BOFILL FUKUGITA NUSSINOV TALEBZADEH KAWASAKI USHIDA LINDLEY	90B 90 90 89 89 89 88B 88 88 87 87 87 87 86 86C 85	PL B242 77 PRL 64 2856 PR D41 689 PR D41 689 PRL 62 505 PR D40 309 PRL 62 509 APJ 336 61 PL B302 149 ZPHY C40 497 ZPHY C39 553 VPH 236 5309 PR D36 3309 PR D36 3317 PR D36 2278 NP B302 539 PL B317 71 PR D37 2897 PR D36 4	Vestrand, Reppin (HARV) + Vestrand, Reppin (UNH, MPIM) + Gandhi, Lattimer (ANIK, STON) + Turner (CHIC, FNAL) + Dearborn, Silk (UCB, LLL) + Bilder, Boeckmann+ (ARGUS Collab.) Dorenbosch, Allaby, Amaldi, Barbiellini+ (CHARM Collab.) + Robinett (PSU) + Kawasaki, Sato (TOKY) + Busze, Eldridge+ (MIT, FNAL, MSU) + Yazaki (KYOTU, TOKY) + Rephael (BEBC W466 Collab.) + Terraswa, Sato (TOKY) + Kondo, Tasaka, Park, Song+ (FNAL ESI) Collab.)
GRIFOLS RAFFELT WALKER CALWEP GAEMERS KOLB RAFFELT ALBRECHT DORENBOS GROTCH TERASAWA BOFILL FUKUGITA NUSSINOV TALEBZADEH KAWASAKI USHIDA LINDLEY	90B 90 90 89 89 89 88B 88 88 87 87 87 87 86 86C	PL B242 77 PRL 64 2856 PR D41 689 PR D41 689 PRL 62 505 PR D40 309 PRL 62 509 APJ 336 61 PL B302 149 ZPHY C40 497 ZPHY C39 553 VPH 236 5309 PR D36 3309 PR D36 3317 PR D36 2278 NP B302 539 PL B317 71 PR D37 2897 PR D36 4	Vestrand, Reppin (UNH, MPIM) + Gandhi, Lattimer (ANIK, STON) + Turner (CHIC, FNAL) + Dearborn, Silk (UCB, LIL) + Bilder, Boeckmann+ (LRGUS Collab.) - Dorenbosch, Allaby, Amaldi, Barbiellini+ (CHARM Collab.) - Robinett (PSU) + Kawasaki, Sato (RIT, FNAL, MSU) + Havasaki, Sato (KYOTU, TON) + Pususa, Eldridge+ (MIT, FNAL, MSU) + Yazaki (KYOTU, TON) + Rephael (TELA) + Giuy, Venus+ (BEBC WA66 Collab.) + Teranawa, Sato (FNAL ES31 Collab.) - Heranawa, Sato (FNAL ES31 Collab.) - Glazni Sabati (1 ADD)
GRIFOLS RAFFELT WALKER CHUPP GAEMERS KOLB RAFFELT AL BRECHT DORENBOS GROTCH TERASAWA BOFILL FUKUGITA NUSSINOV TALEBZADEH KAWASAKI USHIDA LINDLEY BINETRUY	90B 90 90 89 89 89 88 88 88 87 87 87 87 86 86 85	PL B242 77 PRI. 64 2856 PR D41 62 505 PR D40 309 PRI. 62 509 APJ 336 61 PL B202 149 ZPHY C40 497 ZPHY C40 497 ZPHY C40 497 PR D36 3307 PR D36 3307 PR D36 3307 PR D36 3307 PR D36 3307 PR D36 3209 PR D36 3209 PR D36 3209 PR D36 3209 PR D36 3209 PR D37 2897 APJ 294 1 PL 1348 174	Vestrand, Reppin (UNH, MPIM) + Gandhi, Lattimer (ANIK, STON) + Turner (CHIC, FNAL) + Dearborn, Silk (UCB, LIL) + Bilder, Boeckmann+ (LRGUS Collab.) - Dorenbosch, Allaby, Amaldi, Barbiellini+ (CHARM Collab.) - Robinett (PSU) + Kawasaki, Sato (RIT, FNAL, MSU) + Havasaki, Sato (KYOTU, TON) + Pususa, Eldridge+ (MIT, FNAL, MSU) + Yazaki (KYOTU, TON) + Rephael (TELA) + Giuy, Venus+ (BEBC WA66 Collab.) + Teranawa, Sato (FNAL ES31 Collab.) - Heranawa, Sato (FNAL ES31 Collab.) - Glazni Sabati (1 ADD)
GRIFOLS RAFFELT WALKER CHUPP GAEMERS KOLB RAFFELT ALBRECHT DORENBOS GROTCH TERASAWA BOFILL FUKUGITA NUSSINOV TALEBZADEH KAWASAKI USHIDA LINDLEY BINETRUY SARKAR	90B 90 90 89 89 89 89 88 88 88 87 87 87 87 86 86 86 84	PL B242 77 PRI. 64 2856 PR D41 689 PR D41 689 PRI. 62 505 PR D40 309 PRI. 62 509 APJ 336 61 PL B202 149 ZPHY C40 497 ZPHY C39 553 VPH 230 697 PR D36 3309 PR D36 3309 PR D36 3317 PR D36 2278 NP B392 503 PL B378 71 PR D57 2897 APJ 294 1 PL B178 71 PRI. 57 2897 APJ 294 1 PL 148B 174 PL 148B 347	Vestrand, Reppin (UNH, MPIM) + Gandhi, Lattimer (ANIK, STON) + Turner (CHIC, FNAL) + Dearborn, Silk (UCB, LIL) + Bilder, Boeckmann+ (LRGUS Collab.) - Dorenbosch, Allaby, Amaldi, Barbiellini+ (CHARM Collab.) - Robinett (PSU) + Kawasaki, Sato (RIT, FNAL, MSU) + Havasaki, Sato (KYOTU, TON) + Pususa, Eldridge+ (MIT, FNAL, MSU) + Yazaki (KYOTU, TON) + Rephael (TELA) + Giuy, Venus+ (BEBC WA66 Collab.) + Teranawa, Sato (FNAL ES31 Collab.) - Heranawa, Sato (FNAL ES31 Collab.) - Glazni Sabati (1 ADD)
GRIFOLS RAFFELT WALKER CHUPP GAEMERS KOLB RAFFELT AL BRECHT DORENBOS GROTCH TERASAWA BOFILL FUKUGITA NUSSINOV TALEBZADEH KAWASAKI USHIDA LINDLEY BINETRUY SARKAR ASRATYAN	90B 90 90 89 89 89 89 88 88 87 87 87 87 87 86 86 86 84 84	PL B242 77 PRI. 64 2856 PR D41 62 505 PR D40 309 PRI. 62 509 APJ 336 61 PL B202 149 ZPHY C40 497 ZPHY C40 497 ZPHY C40 497 PR D36 3307 PR D36 3307 PR D36 3307 PR D36 2769 NP B291 5703 PL B178 71 PR D36 2789 APJ 294 1 PL 1348 174 PL 148B 347 PL 105B 301	Vestrand, Reppin (UNH, MPIM) + Gandhi, Lattimer (ANIK, STON) + Turner (CHIC, FNAL) + Dearborn, Silk (UCB, LIL) + Bilder, Boeckmann+ (LRGUS Collab.) - Dorenbosch, Allaby, Amaldi, Barbiellini+ (CHARM Collab.) - Robinett (PSU) + Kawasaki, Sato (RIT, FNAL, MSU) + Havasaki, Sato (KYOTU, TON) + Pususa, Eldridge+ (MIT, FNAL, MSU) + Yazaki (KYOTU, TON) + Rephael (TELA) + Giuy, Venus+ (BEBC WA66 Collab.) + Teranawa, Sato (FNAL ES31 Collab.) - Heranawa, Sato (FNAL ES31 Collab.) - Glazni Sabati (1 ADD)
GRIFOLS RAFFELT WALKER CHUPP GAEMERS KOLB RAFFELT AL BRECHT DORENBOS GROTCH TERASAWA BOFILL FUKUGITA NUSSINOV TALEBZADEH KAWASAKI USHIDA LINDLEY BINETRUY SARKAR ASRATYAN FELDMAN	90B 90 90 89 89 89 88 88 88 87 87 87 86 86 85 84 84 84	PL 8242 77 PRI. 64 2856 PR D41 689 PR D41 689 PRI. 62 505 PR D40 309 PRI. 62 509 APJ 336 61 PL B202 149 ZPHY C40 487 ZPHY C40 487 ZPHY C40 487 ZPHY C40 487 PR D36 3309 PR D36 3317 PR D36 2278 NP 8302 697 PR D36 3317 PR D36 2278 NP 8291 503 APJ 2841 PL 1148 371 PL 1488 347 PL 148B 347 PL 158B 301	Vestrand, Reppin (UNH, MPIM) + Gandhi, Lattimer (ANIK, STON) + Turner (CHIC, FNAL) + Dearborn, Silk (UCB, LIL) + Bilder, Boeckmann+ (LRGUS Collab.) - Dorenbosch, Allaby, Amaldi, Barbiellini+ (CHARM Collab.) - Robinett (PSU) + Kawasaki, Sato (RIT, FNAL, MSU) + Havasaki, Sato (KYOTU, TON) + Pususa, Eldridge+ (MIT, FNAL, MSU) + Yazaki (KYOTU, TON) + Rephael (TELA) + Giuy, Venus+ (BEBC WA66 Collab.) + Teranawa, Sato (FNAL ES31 Collab.) - Heranawa, Sato (FNAL ES31 Collab.) - Glazni Sabati (1 ADD)
GRIFOLS RAFFELT WALKER CHUPP GAEMERS KOLB RAFFELT AL BRECHT DORENBOS GROTCH TERASAWA BOFILL TERASAWA BOFILL TUKUGITA NUSSINOV TALEBZADEH KAWASAKI USHIDA LINDLEY BINETRUY SARKAR ASRATYAN FELDMAN Santa Cru;	90B 90 90 89 89 89 89 88 88 88 87 87 86 86 85 84 84 81 81 81	PL B242 77 PRI. 64 2856 PR D41 689 PR D41 689 PRI. 62 505 PR D40 309 PRI. 62 509 APJ 336 61 PL B202 149 ZPHY C40 487 ZPHY C40 487 ZPHY C40 487 ZPHY C40 53309 PR D36 3217 PR D36 3217 PR D36 3217 PR D36 2278 NP B291 503 PL B187 71 PRI. 57 2897 APJ 294 1 PL 134B 174 PL 148B 347 PL 105B 301 SLAC-PUB-2839	Vestrand, Reppin Vestrand, R
GRIFOLS RAFFELT WALKER CHUPP GAEMERS KOLB RAFFELT AL BRECHT DORENBOS GROTCH TERASAWA BOFILL FUKUGITA NUSSINOV TALEBZADEH KAWASAKI USHIDA LINDLEY BINETRUY SARKAR ASRATYAN FELDMAN	90B 90 90 89 89 89 88 88 88 87 87 87 86 86 85 84 84 84	PL B242 77 PRI. 64 2856 PR D41 689 PR D41 689 PRI. 62 505 PR D40 309 PRI. 62 509 APJ 336 61 PL B202 149 ZPHY C40 487 ZPHY C40 487 ZPHY C40 487 ZPHY C40 53309 PR D36 3217 PR D36 3217 PR D36 3217 PR D36 2278 NP B291 503 PL B187 71 PRI. 57 2897 APJ 294 1 PL 134B 174 PL 148B 347 PL 105B 301 SLAC-PUB-2839	Vestrand, Reppin Vestrand, R
GRIFOLS RAFFELT WALKER CHUPP GAEMERS KOLB RAFFELT ALBRECHT DORENBOS GROTCH TERASAWA BOFILL FUKUGITA NUSSING TALEBZADEH KAWASAKI USHIDA LINDLEY BINETRY SARKAR ASRATYAN FELDMAN Santa Cru: HENRY	908 90 90 89 89 89 89 88 88 87 87 87 87 86 85 84 84 81 7	PL B242 77 PRI. 64 2856 PR D41 689 PR D41 689 PRI. 62 505 PR D40 309 PRI. 62 509 APJ 336 61 PL B202 149 ZPHY C40 487 ZPHY C40 487 ZPHY C40 487 ZPHY C40 53309 PR D36 3217 PR D36 3217 PR D36 3217 PR D36 2278 NP B291 503 PL B187 71 PRI. 57 2897 APJ 294 1 PL 134B 174 PL 148B 347 PL 105B 301 SLAC-PUB-2839	Vestrand, Reppin
GRIFOLS RAFFELT WALKER CHUPP GAEMERS KOLB RAFFELT AL BRECHT DORENBOS GROTCH TERASAWA BOFILL TUKUGITA NUSSINOV TALEBZADEH KAWASAKI USHIDA LINDLEY BINETRUY SARKAR ASRATYAN FELDMAN Santa Cru: HENRY KIMBLE	90B 90 90 89 89 89 89 88 88 88 87 87 87 86 86 85 84 81 81 81	PL B242 77 PRI. 64 2856 PR D41 689 PR D41 689 PR D41 689 PR D40 309 PRI. 62 509 APJ 336 61 PL B202 149 ZPHY C40 497 ZPHY C40 497 ZPHY C40 497 PR D36 3309 PR D36 3817 PR D36 3817 PR D36 2278 NP 8302 697 PR D36 3817 PR D36 3817 PR D36 2278 PR D36 3817 PR D36 2278 PR D36 3817 PR D36 2278 PR D37 2	Vestrand, Reppin (HARV) + Vestrand, Reppin (UNH, MPIM) + Gandhi, Lattimer (ANIK, STON) + Turner (CHIC, FNAL) + Dearborn, Silk (UCB, LL) + Bilder, Boeckmann+ (ARGUS Collab.) - Dorenbosch, Allaby, Amaldi, Barbiellini+ (CHARM Collab.) + Robinett (PSU) + Kawasaki, Sato (FSU) + Kawasaki, Sato (MIT, FNAL, MSU) + Yazaki (KYOTU, TOKY) + Bussa, Eldridge+ (MIT, FNAL, MSU) + Yazaki (KYOTU, TOKY) + Hesphael (TELA) + Guy, Venus+ (BEBC WA66 Collab.) + Terasawa, Sato (TOKY) + Kondo, Tasaka, Park, Song+ (FNAL ES31 Collab.) - Grandi, Salati (LAPP) - Cooper (OXF, CERN) + Efremenko, Fedotov+ (ITEP, FNAL, SERP, MICH) - Feldman (JHU) + Feldman (UCB)
GRIFOLS RAFFELT WALKER CHUPP GAEMERS KOLB RAFFELT ALBRECHT DORENBOS GROTCH TERASAWA BOFILL FUKUGITA NUSSINOV TALEBZADEH KAWASAKI USHIDA LINDLEY BINETRUY SARKAR ASRATYAN FELDMAN Santa Cru: HENRY KIMBLE REPHAELI	90B 90 90 89 89 89 89 89 88 88 87 87 87 86 86 85 84 81 81 81 81	PIL 8242 77 PRIL 64 2856 PR D41 689 PR D41 689 PRIL 62 505 PR D40 309 PRIL 62 509 APJ 336 61 PL B202 149 ZPHY C40 487 ZPHY C40 487 ZPHY C40 487 ZPHY C40 5309 PR D36 33109 PR D36 33109 PR D36 33109 PR D36 3317 PR D36 2278 NP 8292 697 PR D36 3817 PR D36 2278 NP 8291 503 PR D36 3817 PR D36 2278 PR D36 3817 PR D36 2278 PR D36 3817 PR D36 2278 PR D36 3817 PR D37 3817 P	Vestrand, Reppin (HARV) + Vestrand, Reppin (UNH, MPIM) + Gandhi, Lattimer (ANIK, STON) + Turner (CHIC, FNAL) + Dearborn, Silk (UCB, LL) + Bilder, Boeckmann+ (ARGUS Collab.) - Dorenbosch, Allaby, Amaldi, Barbiellini+ (CHARM Collab.) + Robinett (PSU) + Kawasaki, Sato (FSU) + Kawasaki, Sato (MIT, FNAL, MSU) + Yazaki (KYOTU, TOKY) + Bussa, Eldridge+ (MIT, FNAL, MSU) + Yazaki (KYOTU, TOKY) + Hesphael (TELA) + Guy, Venus+ (BEBC WA66 Collab.) + Terasawa, Sato (TOKY) + Kondo, Tasaka, Park, Song+ (FNAL ES31 Collab.) - Grandi, Salati (LAPP) - Cooper (OXF, CERN) + Efremenko, Fedotov+ (ITEP, FNAL, SERP, MICH) - Feldman (JHU) + Feldman (UCB)
GRIFOLS RAFFELT WALKER CHUPP GAEMERS KOLB RAFFELT AL BRECHT DORENBOS GROTCH TERASAWA BOFILL TORSINOV TALEBZADEH KAWASAKI USHIDA LINDLEY BINETRUY SARKAR ASRATYAN FELDMAN Santa Cru; HENRY KIMBLE REPHAELI DERUJULA	908 90 90 89 89 89 89 88 88 88 87 87 87 86 86 81 81 81 81 80	PIL 8242 77 PRIL 64 2856 PR D41 689 PR D41 689 PRIL 62 505 PR D40 309 PRIL 62 509 APJ 336 61 PL B202 149 ZPHY C40 487 ZPHY C40 487 ZPHY C40 487 ZPHY C40 5309 PR D36 33109 PR D36 33109 PR D36 33109 PR D36 3317 PR D36 2278 NP 8292 697 PR D36 3817 PR D36 2278 NP 8291 503 PR D36 3817 PR D36 2278 PR D36 3817 PR D36 2278 PR D36 3817 PR D36 2278 PR D36 3817 PR D37 3817 P	Vestrand, Reppin (HARV) + Vestrand, Reppin (UNH, MPIM) + Gandhi, Lattimer (ANIK, STON) + Turner (CHIC, FNAL) + Dearborn, Silk (UCB, LL) + Bilder, Boeckmann+ (ARGUS Collab.) - Dorenbosch, Allaby, Amaldi, Barbiellini+ (CHARM Collab.) + Robinett (PSU) + Kawasaki, Sato (FSU) + Kawasaki, Sato (MIT, FNAL, MSU) + Yazaki (KYOTU, TOKY) + Bussa, Eldridge+ (MIT, FNAL, MSU) + Yazaki (KYOTU, TOKY) + Hesphael (TELA) + Guy, Venus+ (BEBC WA66 Collab.) + Terasawa, Sato (TOKY) + Kondo, Tasaka, Park, Song+ (FNAL ES31 Collab.) - Grandi, Salati (LAPP) - Cooper (OXF, CERN) + Efremenko, Fedotov+ (ITEP, FNAL, SERP, MICH) - Feldman (JHU) + Feldman (UCB)
GRIFOLS RAFFELT WALKER CHUPP GAEMERS KOLB RAFFELT ALBRECHT DORENBOS GROTCH TERASAWA BOFILL FUKUGITA NUSSINOV TALEBZADEH KAWASAKI USHIDA LINDLEY BINETRUY SARKAR ASRATYAN FELDMAN Santa Cru: HENRY KIMBLE REPHAELI DERUJULA	90B 90 89 89 89 88 88 88 87 87 87 87 86 86C 85 84 81 81 81 81 80 80	PL B242 77 PRI. 64 2856 PR D41 689 PR D41 689 PR D41 689 PR D40 309 PRI. 62 505 PR D40 309 PRI. 62 509 APJ 336 61 PL B302 149 ZPHY C40 497 ZPHY C59 553 NP B302 697 PR D36 3309 PR D36 3307 PR D36 3307 PR D36 2278 PR D36 3317 PR D36 2278 PR D36 2278 PR D36 3117 PR D36 2278 PR D36 3217 PR D36 2278 PR D36 3217 PR D36 2278 PR D36 3217 PR D36 2278 PR D36 2278 PR D37 2897 APJ 294 1 PL 148B 347 PL 148B 347 PL 148B 347 PL 148B 347 PL 168 07 PL 108B 73 PRI. 47 618 PRI. 46 80 PL 108B 73 PRI. 45 942 PL 1946 73 PRI. 45 942	Vestrand, Reppin (HARV) + Vestrand, Reppin (UNH, MPIM) + Gandhi, Lattimer (ANIK, STON) + Turner (CHIC, FNAL) + Dearborn, Silk (UCB, LL) + Bilder, Boeckmann+ (ARGUS Collab.) - Dorenbosch, Allaby, Amaldi, Barbiellini+ (CHARM Collab.) + Robinett (PSU) + Kawasaki, Sato (FSU) + Kawasaki, Sato (MIT, FNAL, MSU) + Yazaki (KYOTU, TOKY) + Bussa, Eldridge+ (MIT, FNAL, MSU) + Yazaki (KYOTU, TOKY) + Hesphael (TELA) + Guy, Venus+ (BEBC WA66 Collab.) + Terasawa, Sato (TOKY) + Kondo, Tasaka, Park, Song+ (FNAL ES31 Collab.) - Grandi, Salati (LAPP) - Cooper (OXF, CERN) + Efremenko, Fedotov+ (ITEP, FNAL, SERP, MICH) - Feldman (JHU) + Feldman (UCB)
GRIFOLS RAFFELT WALKER CHUPP GAEMERS KOLB RAFFELT AL BRECHT DORENBOS GROTCH TERASAWA BOFILL TANDISINOV TALEBZADEH KAWASAKI USHIDA LINDLEY BINETRUY SARKAR ASRATYAN FELDMAN Santa Cru; HENRY KIMBLE REPHAELI DERUJULA FRITZE FUJIKAWA	90B 90 90 89 89 89 89 88 88 88 88 87 87 87 87 81 81 81 81 80 80 80 80	PL B242 77 PRI. 64 2856 PR D41 689 PR D41 689 PR D41 689 PR D42 505 PR D40 309 PRI. 62 509 APJ 336 61 PL B202 149 ZPHY C40 487 PR D36 3309 PR D36 3319 PR D36 3319 PR D36 3278 NP B202 697 PR D36 2278 NP B202 697 PR D36 2278 NP B291 503 PL B187 71 PL 1948 347 PL 1948 347 PL 148B 348 PL 148B	Vestrand, Reppin (UNH, MPIM) + Gandhi, Lattimer (ANIK, STON) + Turner (CHIC, FNAL) + Binder, Boeckmann+ (UCB, LLL) + Binder, Boeckmann+ (UCB, LLL) + Binder, Boeckmann+ (UCB, LLL) + Binder, Boeckmann+ (CHIC, FNAL) + Robinett (FSU) + Kawasaki, Sato (FNU) + Hausza, Eldridge+ (MIT, FNAL, MSU) + Rephaeil (KYOTU, TOKY) + Rephaeil (KYOTU, TOKY) + Rephaeil (KYOTU, TOKY) + Rephaeil (TELA) + Terraswa, Sato (KYOTU, TOKY) + Rephaeil (TOKY) + Kondo, Tasaka, Park, Song+ (FNAL E531 Collab.) + Girardi, Salati (LNAL) + Girardi, Salati (LNAL) + Efermenko, Fedotov+ (ITEP, FNAL SERP, MICH) + Efermenko, Fedotov+ (ITEP, FNAL SERP, MICH) + Efermenko, Fedotov+ (USB, CHIC, STAN) + Feldman (JHU) + Bowyer, Jakobsen (USB, CHIC, GSB, CHIC, GIsakhou (MIT, HARV) - Glashou (AACH3, BONN, CERN, LOIC, OXF, SACL) + Shock (TOK)
GRIFOLS RAFFELT WALKER CHUPP GAEMERS KOLB RAFFELT AL BRECHT DORENBOS GROTCH TERASAWA BOFILL TANDISINOV TALEBZADEH KAWASAKI USHIDA LINDLEY BINETRUY SARKAR ASRATYAN FELDMAN Santa Cru; HENRY KIMBLE REPHAELI DERUJULA FRITZE FUJIKAWA	90B 90 90 89 89 89 89 88 88 88 88 87 87 87 87 81 81 81 81 80 80 80 80	PL B242 77 PRI. 64 2856 PR D41 689 PR D41 689 PR D41 689 PR D42 505 PR D40 309 PRI. 62 509 APJ 336 61 PL B202 149 ZPHY C40 487 PR D36 3309 PR D36 3319 PR D36 3319 PR D36 3278 NP B202 697 PR D36 2278 NP B202 697 PR D36 2278 NP B291 503 PL B187 71 PL 1948 347 PL 1948 347 PL 148B 348 PL 148B	Vestrand, Reppin (UNH, MPIM) + Gandhi, Lattimer (ANIK, STON) + Turner (CHIC, FNAL) + Binder, Boeckmann+ (UCB, LLL) + Binder, Boeckmann+ (UCB, LLL) + Binder, Boeckmann+ (UCB, LLL) + Binder, Boeckmann+ (CHIC, FNAL) + Robinett (FSU) + Kawasaki, Sato (FNU) + Hausza, Eldridge+ (MIT, FNAL, MSU) + Rephaeil (KYOTU, TOKY) + Rephaeil (KYOTU, TOKY) + Rephaeil (KYOTU, TOKY) + Rephaeil (TELA) + Terraswa, Sato (KYOTU, TOKY) + Rephaeil (TOKY) + Kondo, Tasaka, Park, Song+ (FNAL E531 Collab.) + Girardi, Salati (LNAL) + Girardi, Salati (LNAL) + Efermenko, Fedotov+ (ITEP, FNAL SERP, MICH) + Efermenko, Fedotov+ (ITEP, FNAL SERP, MICH) + Efermenko, Fedotov+ (USB, CHIC, STAN) + Feldman (JHU) + Bowyer, Jakobsen (USB, CHIC, GSB, CHIC, GIsakhou (MIT, HARV) - Glashou (AACH3, BONN, CERN, LOIC, OXF, SACL) + Shock (TOK)
GRIFOLS RAFFELT WALKER CHUPP GAEMERS KOLB RAFFELT ALBRECHT DORENBOS GROTCH TERASAWA BOFILL FUKUGITA NUSSINOV TALEBZADEH KAWASAKI USHIDA LINDLEY BINETRUY SARKAR ASRATYAN FELDMAN SARKAR ASRATYAN FELDMAN LINDLEY KIMBLE REPHAELI DERUJULA FRITZE FUJIKAWA STECKER	90B 90 89 89 89 88 88 88 87 87 86 6C 85 84 84 81 80 80 80 80	PIL 8242 77 PRIL 64 2856 PR D41 689 PR D41 689 PR D41 689 PR D40 309 PRIL 62 509 APJ 336 61 PL B402 149 ZPHY C40 497 ZPHY C40 497 PR D36 3019 PR D36 3017 PR D36 3017 PR D36 2276 PR D36 3017 PR D36 2276 PR D36 3017 PR D36 2276 PR D36 2276 PR D36 3017 PR D36 2276 PR D37 2876 PR D37 2	Vestrand, Reppin (HARV) + Vestrand, Reppin (UNH, MPIM) + Gandhi, Lattimer (ANIK, STON) + Turner (CHIC, FNAL) + Dearborn, Silk (UCB, LL) + Bilder, Boeckmann+ (LGHC, FNAL) + Bilder, Boeckmann+ (ARGUS Collab.) - Dorenbosch, Allaby, Amaldi, Barbiellini+ (CHARM Collab.) + Robinett (PSU) + Kawasaki, Sato (FNAL, MSU) + Yazaki (KYOTU, TON) + Vazaki (KYOTU, TON) + Rephaeli (TELA) + Yazaki (KYOTU, TON) + Rephaeli (TELA) + Gily, Venus+ (BBEC WA66 Collab.) + Teratawa, Sato (TOKY) + Kondo, Tasaka, Park, Song+ (FNAL ES31 Collab.) - Teratawa, Sato (TOKY) + Kondo, Tasaka, Park, Song+ (FNAL ES31 Collab.) - Cligrand, Salati (LAPP) - Cooper (OXF, CERN) + Efremenko, Fedotov+ (ITEP, FNAL, SERP, MICH) + Eddman (JHU) + Bowyer, Jakobsen (UCB) + Szalay (UCSS, CHIC) + Glashow (MACH3, BONN, CERN, LOIC, OXF, SACL,
GRIFOLS RAFFELT WALKER CHUPP GAEMERS KOLB RAFFELT AL BRECHT DORENBOS GROTCH TERASAWA BOFILI TERASAWA SANTA SANTA SANTA SANTA SANTA SANTA FELDMAN SANTA CFU HENRY KIMBLE REPHAELI DERUJULA FRITZE FUJIKAWA STECKER COWSIK	90B 90 89 89 89 88 88 88 88 87 87 87 86 6C 85 484 81 81 81 80 80 80 80 79	PL B242 77 PRI. 64 2856 PR D41 689 PR D41 689 PR D41 689 PR D42 505 PR D40 309 APJ 336 61 PL B202 149 ZPHY C40 497 ZPHY C40 497 ZPHY C40 497 PR D36 3817 PR D36 2278 NP B391 503 PL B178 71 PR D36 2278 APJ 294 1 PL 134B 174 PL 14BB 347 PL 16B 301 SLAC-PUB-2839 PRI. 47 618 PRI. 46 80 PL 106B 73 PRI. 45 942 PL 96B 447 PRI. 45 963 PRI. 45 1460	Vestrand, Reppin (UNH, MPIM) + Gandhi, Lattimer (ANIK, STON) + Turner (CHIC, FNAL) + Dearborn, Silk (UCB, LLL) + Binder, Boeckmann+ (UCB, LLL) - Robinett (FSU) - Rowsell, Sato (FNAL) - Robinett (FNAL) - Robinett (FNAL) - Robinett (KYOTU, TOKY) - Rephaeil - Teraswa, Sato (KYOTU, TOKY) - Rephaeil - Teraswa, Sato (KYOTU, TOKY) - Rephaeil - Teraswa, Sato (KYOTU, TOKY) - Rephaeil - Felding, Salati - CIAPP - Cooper - CIGRON (FNAL E531 Collab.) - Feldman - Bowyer, Jakobsen - Feldman - Bowyer, Jakobsen - Scalay - CACH3, BONN, CERN, LOIC, OXF, SACL, - Glashow - (MIT, HARV) - KINER - MIT, HARV - (MIT, HARV) - KINER - MIT, HARV - (MIT, HARV) - (MASA) - (MASA) - (MASA) - (MASA) - (TASA)
GRIFOLS RAFFELT WALKER CHUPP GAEMERS KOLB RAFFELT ALBRECHT DORENBOS GROTCH TERASAWA BOFILL FUKUGITA NUSSINOV TALEBZADEH KAWASAKI USHIDA LINDLEY BINETRUY SARKAR ASRATYAN FELDMAN SARKAR ASRATYAN FELDMAN SARKAR ASRATYAN FELDMAN REPHAELI DERUJULA FRITZE FUJIKAWA STECKER COWSIK GOLDMAN	90B 90 89 89 89 88 88 87 87 87 86 C 81 81 81 80 80 80 80 87 79 79	PL B242 77 PRI. 64 2856 PR D41 689 PR D41 689 PR D41 689 PR D42 505 PR D40 309 APJ 336 61 PL B202 149 ZPHY C40 497 ZPHY C40 497 ZPHY C40 497 PR D36 3817 PR D36 2278 NP B391 503 PL B178 71 PR D36 2278 APJ 294 1 PL 134B 174 PL 14BB 347 PL 16B 301 SLAC-PUB-2839 PRI. 47 618 PRI. 46 80 PL 106B 73 PRI. 45 942 PL 96B 447 PRI. 45 963 PRI. 45 1460	Vestrand, Reppin (HARV) + Vestrand, Reppin (UNH, MPIM) + Gandhi, Lattimer (ANIK, STON) + Turner (CHIC, FNAL) + Dearborn, Silk (UCB, LIL) + Bilder, Boeckmann+ (ARGUS Collab.) - Dorenbosch, Allaby, Amaldi, Barbiellini+ (CHARM Collab.) + Robinett (PSU) + Kawasaki, Sato (FNAL STALL) + Wassa, Eldridge+ (MIT, FNAL, MSU) + Yazaki (KYOTU, TONY) + Rephaeli (TELA) + Gign, Venus+ (BEBC WA66 Collab.) + Terratawa, Sato (TOKY) + Kondo, Tasaka, Park, Song+ (FNAL ES31 Collab.) + Terratawa, Sato (TOKY) + Cooper (OXF, CERN) + Cooper (OXF, CERN) + Efremenko, Fedotov+ (ITEP, FNAL, SERP, MICH) + Eddman (JHU) + Bowyer, Jakobsen (UCB) + Szalay (UCSS, CHIC) + Glashow (MACH3, BONN, CERN, LOIC, OXF, SCC) + Shrock (NASA) - (TATA) + Stephenson (LSL)
GRIFOLS RAFFELT WALKER CHUPP GAEMERS KOLB RAFFELT AL BRECHT DORENBOS GROTCH TERASAWA BOFILL THERASAWA BOFILL USHIDA LINDLEY BINETRUY SARKAR ASRATYAN FELDMAN Santa Cruz HENRY KIMBLE REPHAELI DERUJULA FRITZE FUJIKAWA STECKER COWSIK GOLDMAN LINDLEY	90B 90 89 89 89 89 88 88 88 87 87 87 86 6C 85 84 81 81 80 80 80 79 779	PL B242 77 PRI. 64 2856 PR D41 699 PRI. 62 505 PR D40 309 PRI. 62 509 APJ 336 61 PL B202 149 ZPHY C40 497 ZPHY C40 497 PR D36 3309 PR D36 3317 PR D36 2278 NP B392 697 PR D36 2278 NP B391 503 PR D36 2278 PR D36 2278 PR D36 2278 PR D36 2378 PR D36 2378 PR D36 2378 PR D36 2378 PR D36 3817 PR D47 587	
GRIFOLS RAFFELT WALKER CHUPP GAEMERS KOLB RAFFELT ALBRECHT DORENBOS GROTCH TERASAWA BOFILL FUKUGITA NUSSINOV TALEBZADEH KAWASAKI USHIDA LINDLEY BINETRUY SARKAR ASRATYAN FELDMAN Santa Cru; HENRY KIMBLE REPHAELI DERUJULA FRITZE FUJIKAWA STECKER COWSIK GOLDMAN LINDLEY BACINO	90B 90 89 89 89 88 88 88 88 87 87 87 86 86 85 81 81 81 81 81 81 80 80 80 87 79 79 78	PL B242 77 PRI. 64 2856 PR D41 689 PR D41 689 PR D41 689 PR D41 689 PR D40 309 PRI. 62 509 APJ 336 61 PL B302 149 ZPHY C40 487 ZPHY C40 487 PR D36 3309 PR D36 3307 PR D36 276 PR D36 276 PR D36 276 PR D37 2897 APJ 294 1 PL 134B 147 PL 148B 347 PL 148B 347 PL 148B 347 PL 148 347 PL 148 542 PR 145 942 PR 145 943 PRI. 45 963 PRI. 45 963 PRI. 45 1460 PR D19 2215 MNRA5 188 15P PR D14 2115 MNRA5 188 15P PRI. 41 131	Vestrand, Reppin (HARV) + Vestrand, Reppin (UNH, MPIM) + Gandhi, Lattimer (ANIK, STON) + Turner (CHIC, FNAL) + Dearborn, Silk (UCB, LIL) + Bilder, Boeckmann+ (ARGUS Collab.) - Dorenbosch, Allaby, Amaldi, Barbiellini+ (CHARM Collab.) + Robinett (PSU) + Kawasaki, Sato (FNAL STAN, STON) + Wasza, Eldridge+ (MIT, FNAL, MSU) + Yazaki (KYOTU, TON) + Vazaki (KYOTU, TON) + Gligv, Venus+ (BEBC WA66 Collab.) + Terratawa, Sato (TOKY) + Kephaeli (TELA) + Foratawa, Sato (TOKY) + Kephaeli (TELA) + Foratawa, Sato (TOKY) + Kondo, Tasaka, Park, Song+ (FNAL ES31 Collab.) + Cooper (OXF, CERN) + Cooper (OXF, CERN) + Efremenko, Fedotov+ (ITEP, FNAL, SERP, MICH) + Bowyer, Jakobsen (UCB) + Szalay (UCSS, CHIC) + Shrock (NASA) - Stephenson (LSL) + Stephenson (LSL) + Stephenson (LSL) + Stephenson (SUS) + Ferrusson, Nodulman, Slater+ (DELCO Collab.)
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Number of Light Neutrino Types

The neutrinos referred to in this section are those of the Standard SU(2)×U(1) Electroweak Model possibly extended to allow nonzero neutrino masses. Light neutrinos are those with $m_{\nu} < m_{Z}/2$. The limits are on the number of neutrino families or species, including $\nu_{\rm e},\,\nu_{\mu},\,\nu_{\tau}$

THE NUMBER OF LIGHT NEUTRINO TYPES FROM COLLIDER EXPERIMENTS

Revised April 1998 by D. Karlen (Carleton University).

The most precise measurements of the number of light neutrino types, N_{ν} , come from studies of Z production in e^+e^- collisions. At the time of this report, the most recent (preliminary) combined analysis of the four LEP experiments [1] included over 16 million visible Z decays. The invisible partial width, $\Gamma_{\rm inv}$, is determined from these data by subtracting the measured visible partial widths, corresponding to Z decays into quarks and charged leptons, from the total Z width. The invisible width is assumed to be due to N_{ν} light neutrino species each contributing the neutrino partial width Γ_{ν} as given by the Standard Model. In order to reduce the model dependence, the Standard Model value for the ratio of the neutrino to charged leptonic partial widths, $(\Gamma_{\nu}/\Gamma_{\ell})_{\rm SM}=1.991\pm0.001$, is used instead of $(\Gamma_{\nu})_{\rm SM}$ to determine the number of light neutrino types:

$$N_{\nu} = \frac{\Gamma_{\rm inv}}{\Gamma_{\ell}} \left(\frac{\Gamma_{\ell}}{\Gamma_{\nu}}\right)_{\rm SM}$$

The combined LEP result is $N_{\nu} = 2.993 \pm 0.011$.

In the past, when only small samples of Z decays had been recorded by the LEP experiments and by the Mark II at SLC, the uncertainty in N_{ν} was reduced by using Standard Model fits to the measured hadronic cross sections at several center-of-mass energies near the Z resonance. Since this method is much more dependent on the Standard Model, the approach described above is favored.

Before the advent of the SLC and LEP, limits on the number of neutrino generations were placed by experiments at lower-energy e^+e^- colliders by measuring the cross section of the process $e^+e^- \to \nu \bar{\nu} \gamma$. The ASP, CELLO, MAC, MARK J, and VENUS experiments observed a total of 3.9 events above background [2], leading to a 95% CL limit of $N_{\nu} < 4.8$. This process has a much larger cross section at center-of-mass energies near the Z mass and has been measured at LEP by the ALEPH, DELPHI, L3, and OPAL experiments [3]. These experiments have observed several thousand such events, and the combined result is $N_{\nu} = 3.00 \pm 0.09$.

Experiments at $p\overline{p}$ colliders also placed limits on N_{ν} by determining the total Z width from the observed ratio of $W^{\pm} \to \ell^{\pm} \nu$ to $Z \to \ell^{+} \ell^{-}$ events [4]. This involved a calculation that assumed Standard Model values for the total W width and the ratio of W and Z leptonic partial widths, and used an estimate of the ratio of Z to W production cross sections. Now that the Z width is very precisely known from the LEP experiments, the approach is now one of those used to determine the W width.

References

- The LEP Collaborations, the LEP Electroweak Working Group, and the SLD Heavy Flavor Group, CERN/PPE/97-154. (Based upon published and preliminary electroweak results).
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- L3: M. Acciarri et al., CERN/PPE/98-25 (submitted to Phys. Lett. B);
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 ALEPH: D. Buskulic et al., Phys. Lett. B313, 520 (1993).
- UA1: C. Albajar et al., Phys. Lett. B198, 271 (1987);
 UA2: R. Ansari et al., Phys. Lett. B186, 440 (1987).

Number from e+e- Colliders

Number of Light ν Types

Our evaluation uses the invisible and leptonic widths of the Z boson from our combined fit shown in the Particle Listings for the Z Boson, and the Standard Model value $\Gamma_{\nu}/\Gamma_{\ell} = 1.9908 \pm 0.0015$.

VALUE DOCUMENT ID TECN

2.994 \pm 0.012 OUR EVALUATION Combined fit to all LEP data.

• • We do not use the following data for averages, fits, limits, etc. • • •

3.00 \pm 0.05 1LEP 92 RVUE

Number of Light ν Types from Direct Measurement of Invisible Z Width

In the following, the invisible Z width is obtained from studies of single-photon events from the reaction $e^+e^- \rightarrow \nu \bar{\nu} \gamma$. All are obtained from LEP runs in the $E_{\rm CM}^{\rm ep}$ range 89.94 GeV.

VALUE	DOCUMENT ID	TECN	COMMENT			
3.07±0.12 OUR AVERAGE						
2.89±0.32±0.19	ABREU	97J DLPH	1993~1994 LEP runs			
3.23 ± 0.16 ± 0.10	AKERS	95c OPAL	1990-1992 LEP runs			
2.68 ± 0.20 ± 0.20	BUSKULIC	93L ALEP	1990-1991 LEP runs			
3.24 ± 0.46 ± 0.22	ADEVA	92 L3	1990 LEP run			
$3.14 \pm 0.24 \pm 0.12$	ADRIANI	92E L3	1991 LEP run			
● ● We do not use the following data for averages, fits, limits, etc. ● ●						
$3.1 \pm 0.6 \pm 0.1$	ADAM	96C DLPH	$\sqrt{s}=$ 130, 136 GeV			

Limits from Astrophysics and Cosmology

Number of Light ν Types

("light" means < about 1 MeV). See also OLIVE 81. For a review of limits based on Nucleosynthesis, Supernovae, and also on terrestial experiments, see DENEGRI 90. Also see "Big-Bang Nucleosynthesis" in this *Review*.

DOCUMENT ID TECN VALUE • • • We do not use the following data for averages, fits, limits, etc. • • • < 4.9 COPI 97 COSM ² HATA < 3.6 < 4.0 97B COSM 3 OLIVE COSM 97 ² CARDALL < 4.7 96B COSM 3 FIELDS < 3.9 COSM ² KERNAN < 4.5 96 COSM 4 OLIVE < 3.6 95 COSM WALKER 91 COSM < 3.3 < 3.4 OLIVE COSM YANG COSM YANG 79 COSM < 7 STEIGMAN 77 COSM PEEBLES COSM 71 <16 5 SHVARTSMAN69 COSM HOYLE

⁵ SHVARTSMAN 69 limit inferred from his equations.

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VALUE	DOCUMENT ID	TECN
• • • We do not us	e the following data for average	es, fits, limits, etc. • • •
<20	⁶ OLIVE	81c COSM
<20	⁶ STEIGMAN	79 COSM
6 Limit varies with	strength of coupling. See also	WALKER 91.

¹Simultaneous fits to all measured cross section data from all four LEP experiments.

²Limit based on high D/H from quasar absorption systems.

³ Limit based on high ⁴He and ⁷Li.

⁴OLIVE 95 limit assumes the existence of at least three (massless) neutrinos.

Number of Light Neutrino Types, Massive Neutrinos and Lepton Mixing

REFERENCES FOR Limits on Number of Light Neutrino Types

ABREU	97.J	ZPHY C74 577	P. Abreu+	(DELPHI Collab.)
COPI	97	PR D55 3389	C.J. Copi, D.N. Schramm, M.S. Turner	(CHIC)
HATA	97B	PR D55 540	N. Hata, G. Steigman, S. Bludman+	(OSU, PENN)
OLIVE	97	ASP 7 27	+Thomas	(MINN, FLOR)
ADAM	96C	PL B380 471	+Adye, Agasi, Ajinenko, Aleksan+	(DELPHI Collab.)
CARDALL	96B	APJ 472 435	+Fuller	(UCSD)
FIELDS	96	New Ast 1 77	+Kainulainen, Olive+ (NDAM, CEF	RN, MINN, FLOR)
KERNAN	96	PR D54 3681	P.S. Kernan, S. Sarkar	(CASE, OXFTP)
AKERS	95C	ZPHY C65 47	+Alexander, Allison+	(OPAL Collab.)
OLIVE	95	PL B354 357	+Steigman	(MINN, OSU)
BUSKULIC	93L	PL B313 520	+De Bonis, Decamp+	(ALEPH Collab.)
ADÉVA	92	PL B275 209	+Adriani, Aguilar-Benitez+	(L3 Collab.)
ADRIANI	92E	PL B292 463	+Aguilar-Benitez, Ahlen, Akbari, Alcaraz+	
LEP	92	PL B276 247	+ALEPH, DELPHI, L3, OPAL	(LEP Collabs.)
WALKER	91	APJ 376 51	+Steigman, Schramm, Olive+ (HSCA, O	SU, CHIC, MINN)
DENEGRI	90	RMP 62 1		ERN, UCB, SACL)
OLIVE	90	PL B236 454	+Schramm, Steigman, Walker (MINN, CI	HIC, OSU, HARV)
YANG	84	APJ 281 493	+Turner, Steigman, Schramm, Olive	(CHIC, BART)
OLIVE	81	APJ 246 557	+Schramm, Steigman, Turner, Yang+	(CHIC, BART)
OLIVE	81C	NP B180 497	+Schramm, Steigman	(EFI, BART)
STEIGMAN	79	PRL 43 239	+Olive, Schramm	(BART, EFI)
YANG	79	APJ 227 697		HIC, YALE, VIRG)
STEIGMAN	77	PL 66B 202	+Schramm, Gunn (YALE, CHIC, CIT)
PEEBLES	71	Physical Cosmology		(PRIN)
Princeton		Press (1971)		
SHVARTSMA	N 69	JETPL 9 184		(MOSU)
		Translated from ZETFP		(
HOYLE	64	Nature 203 1108	+ Tayler	(CAMB)

Massive Neutrinos and Lepton Mixing, Searches for

SEARCHES FOR MASSIVE NEUTRINOS

Revised April 1998 by D.E. Groom (LBNL).

Searches for massive neutral leptons and the effects of nonzero neutrino masses are listed here. These results are divided into the following main sections:

- A. Heavy neutral lepton mass limits;
- B. Sum of neutrino masses;
- C. Searches for neutrinoless double- β decay (see the note by P. Vogel on "Searches for neutrinoless double- β decay" preceding this section);
- D. Other bounds from nuclear and particle decays;
- E. Bounds from particle decays;
- F. Solar ν experiments (see the note on "Solar Neutrinos" by K. Nakamura preceding this section);
- G. Astrophysical neutrino observations;
- H. Reactor $\overline{\nu}_e$ disappearance experiments;
- I. Accelerator neutrino appearance experiments;
- Disappearance experiments with accelerator and radioactive source neutrinos.

Direct searches for masses of dominantly coupled neutrinos are listed in the appropriate section on ν_e , ν_μ , or ν_τ . Searches for massive charged leptons are given elsewhere, and searches for the mixing of (μ^-e^+) and (μ^+e^-) are given in the muon Listings.

Discussion of the current neutrino mass limits and the theory of mixing are given in the note on "Neutrino Mass" by Boris Kayser just before the ν_e Listings.

In many of the following Listings (e.g. neutrino disappearance and appearance experiments), results are presented assuming that mixing occurs only between two neutrino species, such as $\nu_{\tau} \leftrightarrow \nu_{e}$. This assumption is also made for lepton-number violating mixing between two states, such as $\nu_{e} \leftrightarrow \overline{\nu}_{\mu}$ or $\nu_{\mu} \leftrightarrow \overline{\nu}_{\mu}$. As discussed in Kayser's review, the assumption of mixing between only two states is valid if (a) all mixing angles are small or (b) there is a mass hierarchy such that one ΔM_{ij}^{2} ,

e.g. $\Delta M_{21}^2 = M_{\nu_2}^2 - M_{\nu_1}^2$, is small compared with the others, so that there is a region in L/E (the ratio of the distance L that the neutrino travels to its energy E) where $\Delta M_{21}^2 L/E$ is negligible, but $\Delta M_{32}^2 L/E$ is not.

In this case limits or results can be shown as allowed regions on a plot of $|\Delta M^2|$ as a function of $\sin^2 2\theta$. The simplest situation occurs in an "appearance" experiment, where one searches for interactions by neutrinos of a variety not expected in the beam. An example is the search for ν_e interactions in a detector in a ν_μ beam. For oscillation between two states, the probability that the "wrong" state will appear is given by Eq. 11 in Kayser's review, which may be written as

$$P = \sin^2 2\theta \, \sin^2(1.27\Delta M^2 L/E) \,, \tag{1}$$

where $|\Delta M^2|$ is in eV² and L/E is in km/GeV or m/MeV. In a real experiment L and E have some spread, so that one must average P over the distribution of L/E. As an example, let us make the somewhat unrealistic assumption that $b \equiv 1.27L/E$ has a Gaussian distribution with standard deviation σ_b about a central value b_0 . Then:

$$\langle P \rangle = \frac{1}{2} \sin^2 2\theta [1 - \cos(2b_0 \Delta M^2) \exp(-2\sigma_b^2 (\Delta M^2)^2)]$$
 (2)

The value of $\langle P \rangle$ is set by the experiment. For example, if 230 interactions of the expected flavor are detected and none of the wrong flavor are seen, then P=0.010 at the 90% CL. *A superior statistical analysis of confidence limits in the $\sin^2 2\theta - |\Delta M^2|$ plane is given in Ref. 1. We can then solve the above expression for $\sin^2 2\theta$ as a function of $|\Delta M^2|$. This function is shown in Fig. 1. † Curve generated with $\langle P \rangle = 0.005$, $\langle L/E \rangle = 1.11$, and $\sigma_b/b_0 = 0.08$. Note that:

- (a) since the fast oscillations are completely washed out by the resolution for large $|\Delta M^2|$, $\sin^2 2\theta = 2 \langle P \rangle$ in this region;
- (b) the maximum excursion of the curve to the left is to $\sin^2 2\theta = \langle P \rangle$ with good resolution, with smaller excursion for worse resolution. This "bump" occurs at $|\Delta M^2| = \pi/2b_0 \text{ eV}^2$;
- (c) for large $\sin^2 2\theta$, $\Delta M^2 \approx (\langle P \rangle / \sin^2 2\theta)^{1/2}/b_0$; and, consequently,
- (d) the intercept at $\sin^2 2\theta = 1$ is at $\Delta M^2 = \sqrt{\langle P \rangle}/b_0$.

The intercept for large $|\Delta M^2|$ is a measure of running time and backgrounds, while the intercept at $\sin^2 2\theta = 1$ depends also on the mean value of L/E. The wiggles depend on experimental features such as the size of the source, the neutrino energy distribution, and detector and analysis features. Aside from such details, the two intercepts completely describe the exclusion region: For large $|\Delta M^2|$, $\sin^2 2\theta$ is constant and equal to $2\langle P \rangle$, and for large $\sin^2 2\theta$ the slope is known from the intercept. For these reasons, it is (nearly) sufficient to summarize the results of an experiment by stating the two intercepts, as is done in the following tables. The reader is referred to the original papers for the two-dimensional plots expressing the actual limits.

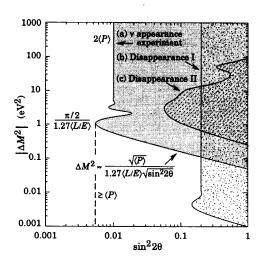


Figure 1: Neutrino oscillation parameter ranges excluded by two hypothetical experiments

(a and b) described by Eq. (2) and one real one (c). Parameters for the first two cases are given in the footnotes. In case (a) one searches for the appearance of neutrinos not expected in the beam. The probability of appearance, in this case 0.5% at some specified CL, is set by the number of right-flavor events observed and/or information about the flux and cross sections. Case (b) represents a disappearance experiment in which the flux is known in the absence of mixing. In case (c), the information comes from measured fluxes at two distances from the target [4].

If a positive effect is claimed, then the excluded region is replaced by an allowed band or allowed regions. This is the case for the LSND experiment [2] and the SuperKamiokande analysis of $R(\mu/e)$ for atmospheric neutrinos [3].

In a "disappearance" experiment, one looks for the attenuation of the beam neutrinos (for example, ν_k) by mixing with at least one other neutrino eigenstate. (We label such experiments as $\nu_k \not\rightarrow \nu_k$.) The probability that a neutrino remains the same neutrino from the production point to detector is given by

$$P(\nu_k \to \nu_k) = 1 - P(\nu_k \to \nu_j) , \qquad (3)$$

where mixing occurs between the kth and jth species with $P(\nu_k \to \nu_j)$ given by Eq. (1) or Eq. (2).

In contrast to the detection of even a few "wrong-flavor" neutrinos establishing mixing in an appearance experiment, the disappearance of a few "right-flavor" neutrinos in a disappearance experiment goes unobserved because of statistical fluctuations. For this reason, disappearance experiments usually cannot establish small-probability (small $\sin^2 2\theta$) mixing.

Disappearance experiments fall into two general classes:

- I. Those in which the beam neutrino flux is known, from theory or from other measurements. Examples are reactor $\overline{\nu}_e$ experiments and certain accelerator experiments. Although such experiments cannot establish very small- $\sin^2 2\theta$ mixing, they can establish small limits on ΔM^2 for large $\sin^2 2\theta$ because L/E can be very large. An example, based on the Chooz reactor measurements [5], is labeled "Disappearance I" in Fig. 1. [†]Curve parameters $\langle P \rangle = 0.1$, $\langle L/E \rangle = 237$, and $\sigma_b/b_0 = 0.5$. For the actual Chooz experiment [5], $\langle L/E \rangle \approx 300$ and the limit on $\langle P \rangle$ is 0.09.
- II. Those in which attenuation or oscillation of the beam neutrino flux is measured in the apparatus itself (two detectors, or a "long" detector). Above some minimum $|\Delta M^2|$ the equilibrium is established upstream, and there is no change in intensity over the length of the apparatus. As a result, sensitivity is lost at high $|\Delta M^2|$, as can be seen by the curve labeled "Disappearance II" in Fig. 1 [4]. Such experiments have not been competititive for a long time. However, a new generation of long-baseline experiments with a "near" detector and a "far" detector with very large L, e.g., MINOS, will be able to use this strategy to advantage.

Finally, there are more complicated cases, such as analyses of solar neutrino data in terms of the MSW parameters [6]. For a variety of physical reasons, an irregular region in the $|\Delta M^2|$ vs $\sin^2 2\theta$ plane is allowed. It is difficult to represent these graphical data adequately within the strictures of our tables.

References

- 1. G.J. Feldman and R.D. Cousins, Phys. Rev. D3873 (1998).
- 2. C. Athanassopoulos et al., Phys. Rev. C54 (1996).
- 3. Y. Fukuda et al., eprint hep-ex/9803005.
- F. Dydak et al., Phys. Lett. 134B (1984).
- 5. M. Apollonio et al., Phys. Lett. **B420**, 397 (1998).
- 6. N. Hata and P. Langacker, Phys. Rev. D56, 6107 (1997).

(A) Heavy neutral leptons

--- Stable Neutral Heavy Lepton MASS LIMITS ----

Note that LEP results in combination with REUSSER 91 exclude a fourth stable neutrino with m < 2400 GeV.

VALUE (GeV)	<u> </u>	DOCUMENT ID		TECN	COMMENT
>45.0	95	ABREU	92B	DLPH	Dirac
>39.5	95	ABREU	92B	DLPH	Majorana
>44.1	95	ALEXANDER	91F	OPAL	
>37.2	95	ALEXANDER	91F	OPAL	Majorana
none 3-100	90	SATO	91	KAM2	Kamiokande II
>42.8	95	1 ADEVA	90s	L3	Dirac
>34.8	95	¹ ADEVA	90\$	L3	Majorana
>42.7	95	DECAMP	90F	ALEP	Dirac

 1 ADEVA 90s limits for the heavy neutrino apply if the mixing with the charged leptons satisfies $|U_1j|^2+|U_2j|^2+|U_3j|^2>6.2\times10^{-8}$ at $m_{L^0}=20$ GeV and $>5.1\times10^{-10}$ for $m_{L^0}=40$ GeV.

- Neutral Heavy Lepton MASS LIMITS ----

Limits apply only to heavy lepton type given in comment at right of data Listings. See review above for description of types.

See the "Quark and Lepton Compositeness, Searches for" Listings for limits on radiatively decaying excited neutral leptons, i.e. $\nu^* \to \nu \gamma$.

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>69.8	95	² ACKERSTAFF 98c	OPAL	Majorana, coupling to e
>79.1	95	² ACKERSTAFF 98c		
>68.7	95			Majorana, coupling to μ
>78.5	95	² ACKERSTAFF 98c	OPAL	Dirac, coupling to μ

Massive Neutrinos and Lepton Mixing

		2		
>54.4	95	2 ACKERSTAFF		
>69,0	95	2 ACKERSTAFF		
>78.0 >66.7	95 95	² ACCIARRI ² ACCIARRI	97P L3 97P L3	Dirac coupling to e
>78.0	95	² ACCIARRI	97P L3	Majorana coupling to e Dirac coupling to μ
>66.7	95	² ACCIARRI	97P L3	Majorana coupling to μ
>72.2	95	² ACCIARRI	97P L3	Dirac coupling to τ
>58.2	95	² ACCIARRI	97P L3	Majorana coupling to $ au$
>63	95	3,4 BUSKULIC	96S ALEP	
>54.3	95	3,5 BUSKULIC	96S ALEP	
• • • We do not use the	e folio		s, fits, limits	s, etc. • • •
>59.3	95	ACCIARRI	96G L3	Dirac coupling to e
>57.9	95	ACCIARRI	96G L3	Dirac coupling to μ
>48.6	95	ACCIARRI	96G L3	Majorana coupling to e
>47.2	95	ACCIARRI	96G L3	Majorana coupling to μ
>62.5	95	ALEXANDER	96P OPAL	, •
>63.0	95	ALEXANDER	96P OPAL	. • .
>57.4	95	ALEXANDER	96P OPAL	
>51.4 >52.2	95	ALEXANDER	96P OPAL	
>44.2	95 95	ALEXANDER ALEXANDER	96P OPAL	
>44.5	95	6 ABREU	928 DLPH	
>39.0	95	6 ABREU	928 DLPH	
none 2.5-50	95	7 ADRIANI	921 L3	
none 4-50	95			$ U_{\tau \text{ or } \mu} ^2 < 3 \times 10^{-4}$ $ U_{\tau} ^2 < 3 \times 10^{-4}$
>46.4	95	⁷ ADRIANI ⁸ ADEVA	921 L3	
>45.1	95	8 ADEVA	90s L3 90s L3	Dirac
>46.5	95	9 AKRAWY	901 OPAL	Majorana
>45.7	95	9 AKRAWY	90L OPAL	, •
>41	95	10,11 BURCHAT	90 MRK2	
71.	,,	DONCHAI	30 WINK	10-10
>19.6	95	10,11 BURCHAT	90 MRK2	Dirac, all $ U_{\ell j} ^2$
none 25-45.7	95	10,12 DECAMP	90F ALEP	
		13 SHAW		Dirac $ \mathcal{O}_{\ell,j} ^2 > 10^{-12}$
none 8.2–26.5	95	- SHAW	89 AMY	$ U_{ej} ^2 > 10^{-6}$
		13		$ U_{ej} ^2 > 10^{-6}$
none 8.3-22.4	95	13 SHAW	89 AMY	Majorana L ⁰ ,
		19		$ U_{ej} ^2 > 10^{-6}$
none 8.1-24.9	95	¹³ SHAW	89 AMY	Majorana L ^O .
				$ U_{\mu j} ^2 > 10^{-6}$
none 1.8-6.7	90	14 AKERLOF	88 HR5	$ U_{ej} ^2=1$
none 1.8-6.4	90	14 AKERLOF	88 HRS	$ U_{\mu I} ^2 = 1$
none 2.5-6.3	80	14 AKERLOF	88 HRS	$ U_{\tau J} ^2=1$
none 0.25-14	90	¹⁵ MISHRA	87 CNTR	
none 0.25-10	90	15 MISHRA	87 CNTR	
		15 MISHRA		$ u_{\mu f} ^2 = 0.1$
none 0.25-7.7	90		87 CNTR	$ U_{\mu j} ^2 = 0.03$
none 12.	90	16 WENDT	87 MRK2	$ U_{e \text{ or } \mu j} ^2 = 0.1$
none 2.2-4.	90	16 WENDT	87 MRK2	$ U_{e \text{ or } \mu j} ^2 = 0.001$
none 2.3-3.	90	16 WENDT	87 MRK2	$ U_{\tau j} ^{2=0.1}$
none 3.2-4.8	90	16 WENDT	87 MRK2	$ U_{\tau j} ^2 = 0.001$
none 0.3-0.9	90	17 BADIER	86 CNTR	
none 0.33-2.0	90	17 BADIER	86 CNTR	
none 0.6-0.7	90	17 BADIER	86 CNTR	
none 0.6-2.0	90	¹⁷ BADIER	86 CNTR	, prj.
> 1.2		MEYER	77 MRK1	. Neutral

 $^{^2}$ The decay length of the heavy lepton is assumed to be < 1 cm, limiting the square of the mixing angle $|U_{\ell j}|^2$ to $10^{-12}.$

 16 WENDT 87 is MARK-II search at PEP for heavy u with decay length 1–20 cm (hence

iong-ived). The ADIER 86 is a search for a long-lived penetrating sequential lepton produced in π^- nucleon collisions with lifetimes in the range from 5×10^{-7} – 5×10^{-11} s and decaying into at least two charged particles. U_{ej} and $U_{m,j}$ are mixing angles to ν_e and ν_μ . See also the BADIER 86 entry in the section "Searches for Massive Neutrinos and Lepton Mixing".

Astrophysical Limits on Neutrino MASS for $m_{\nu} > 1$ GeV -

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
• • We do not use	the folk	owing data for average	s, fits	, limits,	etc. • • •
none 60-115		18 FARGION	95	ASTR	Dirac
none 9.2-2000		19 GARCIA	95	COSM	Nucleosynthesis
none 26-4700		¹⁹ ВЕСК	94	COSM	Dirac
none 6 – hundreds		^{20,21} MORI	92B	KAM2	Dirac neutrino
none 24 – hundreds		^{20,21} MORI	92B	KAM2	Majorana neutrino
none 10-2400	90	²² REUSSER	91	CNTR	HPGe search
none 3-100	90	SATO	91	KAM2	Kamiokande II
		²³ ENQVIST	89	COSM	
none 12-1400		¹⁹ CALDWELL	88	COSM	Dirac v
none 4-16	90	19,20 OLIVE	88	COSM	Dirac v
none 4-35	90	OLIVE	88	COSM	Majorana ν
>4.2 to 4.7		SREDNICKI	88	COSM	Dirac v
>5.3 to 7.4		SREDNICKI	88	COSM	Majorana ν
none 20-1000	95	19 AHLEN	87	COSM	Dirac v
>4.1		GRIEST	87	COSM	Dirac v

23 ENQVIST 89 argue that there is no cosmological upper bound on heavy neutrinos.

(B) Sum of neutrino masses

Revised April 1998 by K.A. Olive (University of Minnesota).

The limits on low mass $(m_{\nu} \lesssim 1 \text{ MeV})$ neutrinos apply to $m_{\rm tot}$ given by

$$m_{
m tot} = \sum_
u (g_
u/2) m_
u$$
 ,

where g_{ν} is the number of spin degrees of freedom for ν plus $\overline{\nu}$: $g_{\nu} = 4$ for neutrinos with Dirac masses; $g_{\nu} = 2$ for Majorana neutrinos. Stable neutrinos in this mass range make a contribution to the total energy density of the Universe which is given by

$$\rho_{\nu} = m_{\text{tot}} n_{\nu} = m_{\text{tot}} (3/11) n_{\gamma} ,$$

where the factor 3/11 is the ratio of (light) neutrinos to photons. Writing $\Omega_{\nu} = \rho_{\nu}/\rho_c$, where ρ_c is the critical energy density of the Universe, and using $n_{\gamma} = 412 \text{ cm}^{-3}$, we have

$$\Omega_{\nu}h^2 = m_{\rm tot}/(94 \text{ eV})$$
.

Therefore, a limit on $\Omega_{\nu}h^2$ such as $\Omega_{\nu}h^2 < 0.25$ gives the limit

$$m_{\mathrm{tot}} < 24 \mathrm{~eV}$$
 .

The limits on high mass $(m_{\nu} > 1 \text{ MeV})$ neutrinos apply separately to each neutrino type.

Limit on Total ν MASS, m_{tot} (Defined in the above note), of effectively stable neutrinos (i.e., those with mean lives greater than or equal to the age of the universe). These papers assumed Dirac neutrinos. When necessary, we have generalized the results reported so they apply to $m_{
m tot}$. For other limits, see SZALAY 76, VYSOTSKY 77, BERNSTEIN 81, FREESE 84. SCHRAMM 84, and COWSIK 85.

VALUE (eV)	DOCUMENT ID		TECN
• • • We do not use the	e following data for average	es, flt	s, Ilmits, etc. • • •
<180	SZALAY	74	COSM
<132	COWSIK	72	COSM
<280	MARX	72	COSM
<400	GERSHTEIN	66	COSM

 $^{^3\,\}mathrm{BUSKULIC}$ 96S requires the decay length of the heavy lepton to be < 1 cm, limiting the square of the mixing angle $|U_{\ell j}|^2$ to 10^{-10} .

 $^{^4}$ BUSKULIC 96s ilmit for mixing with au. Mass is > 63.6 GeV for mixing with e or μ .

⁵ BUSKULIC 965 limit for mixing with au. Mass is > 55.2 GeV for mixing with e or μ . 6 ABREU 928 limit is for mixing matrix element pprox 1 for coupling to e or μ . Reduced Somewhat for coupling to τ , increased somewhat for smaller mixing matrix element. Replaces ABREU 91F.

⁷ ADRIANI 921 is a search for isosinglet heavy lepton N_ℓ which might be produced from $Z \to \nu_\ell N_\ell$, then decay via a number of different channels. Limits are weaker for decay lengths longer than about 1 m.

ADEVA 90s limits for the heavy neutrino apply if the mixing with the charged leptons satisfies $|U_1j|^2 + |U_2j|^2 + |U_3j|^2 > 6.2 \times 10^{-8}$ at $m_{L^0} = 20$ GeV and $> 5.1 \times 10^{-10}$ for $m_{L0} = 40$ GeV.

⁹ AKRAWY 90L limits valid if coupling strength is greater than a mass-dependent value, e.g., 4.9×10^{-7} at $m_{L^0} = 20$ GeV, 3.5×10^{-8} at 30 GeV, 4×10^{-9} at 40 GeV.

¹⁰ Limits apply for $\ell=e, \mu$, or τ and for V-A decays of Dirac neutrinos. 11 BURCHAT 90 searched for Z decay to unstable L^0 pairs at SLC. It includes the analyses reported in JUNG 90, ABRAMS 89c, and WENDT 87. 12 For 25 $< m_{L^0} < 42.7$ GeV, DECAMP 90F exclude an L^0 for all values of $|U_{\ell f}|^2$.

 $^{^{13}}$ SHAW 89 also excludes the mass region from 8.0 to 27.2 GeV for Dirac L^0 and from 8.1 to 23.6 GeV for Majorana L^0 with equal full-strength couplings to e and μ . SHAW 89 also gives correlated bounds on lepton mixing.

¹⁴ AKERLOF 88 is PEP e^+e^- experiment at $E_{\rm cm}=$ 29 GeV. The L^0 is assumed to decay via V-A to e or μ or τ plus a virtual W.

¹⁵ MISHRA 87 is Fermilab neutrino experiment looking for either dimuon or double vertex events (hence long-lived).

 $^{^{18}}$ FARGION 95 bound is sensitive to assumed ν concentration in the Galaxy. See also KONOPLICH 94. 19 These results assume that neutrinos make up dark matter in the galactic halo. 20 Limits based on annihilations in the sun and are due to an absence of high energy eutrinos detected in underground experiments.

²¹ MORI 92B results assume that neutrinos make up dark matter in the galactic halo. Limits

based on annihilations in earth are also given. ²² REUSSER 91 uses existing $\beta\beta$ detector (see FISHER 89) to search for CDM Dirac

Limits on MASSES of Light Stable Right-Handed ν (with necessarily suppressed interaction strengths)

VALUE (eV)	DOCUMENT	ID.	TECN	COMMENT
• • • We do not use	the following data for avera	ges, fit	s, limits,	etc. • • •
<100-200	²⁴ OLIVE	82	COSM	Dirac ν
<200-2000	²⁴ OLIVE	82	COSM	Majorana $ u$

²⁴ Depending on interaction strength G_R where $G_R < G_F$.

Limits on MASSES of Heavy Stable Right-Handed ν (with necessarily suppressed interaction strengths)

<u> </u>					
• • • We do not use the follo	wing data for avera	ages, fits	s, limits,	etc. • • •	
> 10	²⁵ OLIVE	82	COSM	GR/GF <	0.1
>100	²⁵ OLIVE	82	COSM	GR/GF <	0.01

²⁵ These results apply to heavy Majorana neutrinos and are summarized by the equation: $m_{\nu} > 1.2$ GeV (G_F/G_R) . The bound saturates, and if G_R is too small no mass range is allowed.

(C) Searches for neutrinoless double- β decay

LIMITS FROM NEUTRINOLESS $\beta\beta$ DECAY

Revised 1995 by P. Vogel (Caltech).

Limits on an effective Majorana neutrino mass and a leptonnumber violating current admixture can be obtained from lifetime limits on $0\nu\beta\beta$ nuclear decay. The derived quantities are model-dependent, so the half-life measurements are given first. Where possible we list the references for the matrix elements used in the subsequent analysis. Since rates for the more conventional $2\nu\beta\beta$ decay serve to calibrate the theory, results for this process are also given. As an indication of the spread among different ways of evaluating the matrix elements, we show in Fig. 1 some representative examples for the most popular nuclei. For further calculations, see, e.g., Ref. 1

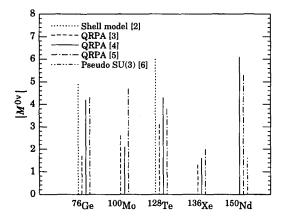


Figure 1: Nuclear matrix elements for $0\nu\beta\beta$ decay calculated by a subset of different methods and different authors for the most popular double-beta decay candidate nuclei. Recalculated from the published half-lives using consistent phase-space factors and $g_A=1.25$. The QRPA [3] value is for $\alpha'=-390$ MeV fm³.

To define the limits on lepton-number violating right-handed current admixtures, we display the relevant part of a phenomenological current-current weak interaction Hamiltonian:

$$\begin{split} H_W = & (G_F/\sqrt{2}) \\ \times & (J_L \cdot j_L^{\dagger} + \kappa J_R \cdot j_L^{\dagger} + \eta J_L \cdot j_R^{\dagger} + \lambda J_R \cdot j_R^{\dagger}) + \text{h.c.} \end{split}$$

where $j_L^\mu = \bar{e}_L \gamma^\mu \nu_{eL}, \ j_R^\mu = \bar{e}_R \gamma^\mu \nu_{eR}$, and J_L^μ and J_R^μ are lefthanded and right-handed hadronic weak currents. Experiments are not sensitive to κ , but quote limits on quantities proportional to η and λ .* In analogy to $\langle m_{\nu} \rangle$ (see Eq. 11 in the "Note on Neutrinos" at the beginning of the Neutrino Particle Listings), the quantities extracted from experiments are $\langle \eta \rangle = \eta \sum U_{1j} V_{1j}$ and $\langle \lambda \rangle = \lambda \sum U_{1j} V_{1j}$, where V_{ij} is a matrix analogous to U_{ij} (see Eq. 2 in the "Note on Neutrinos"), but describing the mixing among right-handed neutrinos. The quantities $\langle \eta \rangle$ and $\langle \lambda \rangle$ therefore vanish for massless or unmixed neutrinos. Also, as in the case of $\langle m_{\nu} \rangle$, cancellations are possible in $\langle \eta \rangle$ and $\langle \lambda \rangle$. The limits on $\langle \eta \rangle$ are of order 10^{-8} while the limits on $\langle \lambda \rangle$ are of order 10^{-6} . The reader is warned that a number of earlier experiments did not distinguish between η and λ . Because of evolving reporting conventions and matrix element calculations, we have not tabulated the admixture parameters for experiments published earlier than 1989.

See the section on Majoron searches for additional limits set by these experiments.

Footnotes and References

- * We have previously used a less accepted but more explicit notation in which $\eta_{RL} \equiv \kappa$, $\eta_{LR} \equiv \eta$, and $\eta_{RR} \equiv \lambda$.
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Half-life Measurements and Limits for Double β Decay

In all cases of double beta decay, $(Z,A) \rightarrow (Z+2,A) + 2\beta^- + (0 \text{ or } 2)\overline{\nu}_e$. In the following Listings, only best or comparable limits or lifetimes for each isotope are reported.

t _{1/2} (10 ²¹ yr)	CL%	ISOTOPE	TR	RANSITION	METHOD	DOCUMENT ID	
• • • We do not i	use th	e follow	ing data	for average	s, fits, limits, etc.		
(7.6 ^{+2.2} _{-1.4})E18		100 _{Mo}	2ν		Si(LI)	²⁶ ALSTON	97
> 0.19	90	92 _{Mo}	0ν+2ν	$0^+ \rightarrow 0^+$	γ In HPGe	27 BARABASH	97
> 0.81	90	92 Mo	$0\nu+2\nu$	$0^+ \to 0_1^+$	γ in HPGe	²⁷ BARABASH	97
> 0.89	90	92 _{Mo}	0ν+2ν	$0^+ \to 2^{\frac{1}{1}}$	γ in HPGe	27 BARABASH	97
>11000	90	76 _{Ge}	0ν	$0^{+} \rightarrow 0^{+}$	Enriched HPGe	28 BAUDIS	97
$(6.82^{+0.38}_{-0.53} \pm 0.68$	3)E18	100 _{Mo}	2ν		TPC	²⁹ DESILVA	97
>11000 $(6.82^{+0.38}_{-0.53} \pm 0.68)$ $(6.75^{+0.37}_{-0.42} \pm 0.68)$	3)E18	150 _{Nd}	2ν		TPC	30 DESILVA	97
> 1.2	90	150 _{Nd}			TPC	31 DESILVA	97
$1.77 \pm 0.01^{+0.13}_{-0.11}$		76 _{Ge}	2ν		Enriched HPGe	32 GUENTHER	97
> 32.5	90	130 _{Te}	0ν		Bolometer	33 ALESSAND	96B
$(3.75 \pm 0.35 \pm 0.2$	1)E1	9116 _{Cd}	2ν	$0^{+} \rightarrow 0^{+}$	NEMO 2	34 ARNOLD	96
$0.043^{+0.024}_{-0.011}\pm0.0$	014	⁴⁸ Ca	2ν		TPC	35 BALYSH	96
> 52	68	100 _{Mo}	0ν , $\langle in_{\nu}$,)o+ → o+	ELEGANT V	36 EJIRI	96
> 39	68	100 _{Mo}	$0\nu,\langle\lambda\rangle$	0 ⁺ → 0 ⁺	ELEGANT V	36 EJIRI	96

Massive Neutrinos and Lepton Mixing

> 51 68	100 _{Mo}	$0 u,\langle\eta angle$	$0^+ \rightarrow 0^+$	ELEGANT V	36 EJIRI	96
0.79 ± 0.10	130 Te	$0\nu+2\nu$		Geochem	37 TAKAOKA	96
$0.61^{+0.18}_{-0.11}$	100 Mo	$0\nu+2\nu$	$0^+ \to 0_1^+$	γ In HPGe	38 BARABASH	95
> 0.00013 99	160 _{Gd}	2ν	0 ⁺ → 0 ⁺	Gd2SIO5:Ce scint	t ³⁹ BURACHAS	95
> 0.00012 99	160 _{Gd}	2ν	0+ → 2+	Gd2SiO5:Ce scint	t ³⁹ BURACHAS	95
> 0.014 90	160 _{Gd}	Đν	$0^{+} \rightarrow 0^{+}$	Gd ₂ SiO ₅ :Ce scint	t ³⁹ BURACHAS	95
> 0.013 90	160 _{Gd}	0ν	0 ⁺ → 2 ⁺	Gd ₂ SlO ₅ :Ce scint	t ³⁹ BURACHAS	95
$(9.5 \pm 0.4 \pm 0.9)$ E18	100 _{Mo}	2ν	=	NEMO 2	DASSIE	95
> 0.6 90	100 _{Mo}	0ν	$0^+ \to 0_1^+$	NEMO 2	DASSIE	95
0.026 + 0.009	116 _{Cd}	2ν	0 ⁺ → 0 ⁺	ELEGANT IV	EJIRI	95
> 29 90	116 _{Cd}	Oν	$0^+ \rightarrow 0^+$		40 GEORGADZE	95
> 0.3 68	160 _{Gd}	0ν		Gd ₂ SiO ₅ : Ce scir		95 95
> 2.37 90	116 _{Cd}	0ν+2ν	$0^+ \rightarrow 2^+$		41 PIEPKE	94
> 2.05 90	116 _{Cd}	0v+2v	$0^+ \rightarrow 0_1^+$	γ in HPGe	41 PIEPKE	94
> 2.05 90	116 _{Cd}	0v+2v	$0^+ \to 0^+_2$	γ in HPGe	41 PIEPKE	94
$0.017^{+0.010}_{-0.005} \pm 0.0035$	¹⁵⁰ Nd	2ν	$0^{+} \rightarrow 0^{+}$	TPC	ARTEMEV	93
0.039 ± 0.009	96 Mo	0ν+2ν		Geochem	KAWASHIMA	93
> 340 90	136 _{Xe}	0ν (2ν	$0^{+} \rightarrow 0^{+}$	TPC	⁴² VUILLEUMIER	₹ 93
> 260 90	136 _{Xe}	0ν	0+ → 0+	TPC	43 VUILLEUMIER	₹ 93
> 0.21 90	136 Xe	2ν	0+ → 0+	TPC	VUILLEUMIER	
> 430 90	76 Ge	0ν	0 ⁺ → 2 ⁺	Enriched HPGe	BALYSH	92
2.7 ± 0.1	130 Te			Geochem	BERNATOW	. 92
7200 ± 400	128 _{Te}		•		44 BERNATOW	. 92
> 27 68	82 _{Se}	0ν	$0^+ \rightarrow 0^+$	TPC	ELLIOTT	92
0.108 + 0.026	82 _{Se}	2ν	$0^+ \rightarrow 0^+$	TPC	ELLIOTT	92
0.92 + 0.07	⁷⁶ Ge	2ν	$0^+ \rightarrow 0^+$		⁴⁵ AVIGNONE	91
> 3.3 95	136 _{Xe}	0ν	0 ⁺ → 2 ⁺		46 BELLOTTI	91
> 0.16 95	136 Xe	2ν		Prop cntr	BELLOTTI	91
2.0 ± 0.6	238 _U			Radiochem	47 TURKEVICH	91
> 9.5 76	⁴⁸ Ca	0ν		CaF ₂ scint.	YOU	91
1.12+0.48	⁷⁶ Ge	2ν	$0^{+} \rightarrow 0^{+}$	HPGe	⁴⁸ MILEY	90
0.9 ± 0.1	76 Ge	2ν		Enriched Ge(LI)	VASENKO	90
> 4.7 68	128 Te		0 ⁺ -> 2 ⁺	Ge(LI)	39 BELLOTTI	87
> 4.5 68	130 _{Te}		0 ⁺ → 2 ⁺	Ge(Li)	39 BELLOTTI	87
> 800 95	128 Te			Geochem '	49 KIRSTEN	83
2.60 ± 0.28	130 _{Te}			Geochem	49 KIRSTEN	83
26 ALSTON-GARNIOS	T 07 ***	hort and	lanca for 2	deens of 100s4-	This deares has t	

 26 ALSTON-GARNJOST 97 report evidence for $^{2\nu}$ decay of 100 Mo. This decay has been also observed by EJIRI 91, DASSIE 95, and DESILVA 97. 27 BARABASH 97 measure limits for β^+ , EC, and ECEC decay of 92 Mo to the ground and excited states of 92 Ru, respectively. Limits are not competive compared to $\beta^-\beta^$ searches as far as sensitivity to $\langle m_{
u}
angle$ or RHC admixtures is concerned.

28 BAUDIS 97 limit for 0\u03c4 decay of enriched 76 Ge using Ge calorimeters supersedes GUENTHER 97.

GUENT HER 97. 29 DESILVA 97 result for 2ν decay of 100 Mo is in agreement with ALSTON-GARNJOST 97 and DASSIE 95. This measurement has the smallest errors.

30 DESILVA 97 result for 2 ν decay of 150 Nd is in marginal agreement with ARTEMEV 93.

It has smaller errors.

31 DESILVA 97 do not explain whether their efficiency for 0 ν decay of ¹⁵⁰Nd was calculated under the assumption of a $\langle m_{\nu} \rangle$, $\langle \lambda \rangle$, or $\langle \eta \rangle$ driven decay. ³² GUENTHER 97 half-life for the 2 ν decay of ⁷⁶Ge is not in good agreement with the

previous measurements of BALYSH 94, AVIGNONE 91, and MILEY 90.

 33 ALESSANDRELLO 96B experiment can distinguish the 0
u and 2
u modes; it shows that the geochemical observation of ¹³⁰Te decay (BERNATOWICZ 92, KIRSTEN 83,

TAKAOKA 96) is dominanted by the 2 ν decay. Supersedes ALESSANDRELLO 94.

34 ARNOLD 96 measure the 2 ν decay of 116Cd. This result is in agreement with EJIRI 95, but has smaller errors. Supersedes ARNOLD 95.

 35 BALYSH 96 measure the $^{2
u}$ decay of 48 Ca, using a passive source of enriched 48 Ca in

36 EJIRI 96 use energy and angular correlations of the 2 β -rays in efficiency estimate to give limits for the 0ν decay modes associated with $\langle m_{\nu} \rangle$, $\langle \lambda \rangle$, and $\langle \eta \rangle$, respectively. Enriched $^{100}\mathrm{Mo}$ source is used in tracking calorimeter. These are the best limits for

100 Mo. Limit is more stringent than ALSTON-GARNJOST 97.

37 TAKAOKA 96 measure the geochemical half-life of ¹³⁰Te. Their value is in disagreemnt with the quoted values of BERNATOWICZ 92 and KIRSTEN 83; but agrees with several

other unquoted determinations, e.g., MANUEL 91.

38 BARABASH 95 cannot distinguish 0» and 2ν, but it is inferred indirectly that the 0» mode accounts for less than 0.026% of their event sample. They also note that their result disagrees with the previous experiment by the NEMO group (BLUM 92).

 39 BELLOTTI 87 searches for γ rays for 2^+ state decays in corresponding Xe isotopes. Limit for 130 Te case argues for dominant $0^+ \rightarrow 0^+$ transition in known decay of this

40 GEORGADZE 95 result for this and other modes are also give in DANEVICH 95. Result

for 2ν decay omitted because of authors' caveats. ⁴¹ In PIEPKE 94, the studied excited states of 116 Sn have energies above the ground state of 1.2935 MeV for the 2^+ state, 1.7568 MeV for the 0^+_1 state, and 2.0273 for the 0^+_2

state.
42 Limit In the case of a transition induced by a Majorana mass.

43 Limit for lepton-number violating right-handed current-induced (RHC) decay.

44 BERNATOWICZ 92 finds 128 Te/130 Te activity ratio from slope of 128 Xe/132 Xe vs 130Xe/132Xe ratios during extraction, and normalizes to lead-dated ages for the ¹³⁰Te lifetime. The authors state that their results imply that "(a) the double beta decay of ¹²⁸Te has been firmly established and its half-life has been determined ... without any ambiguity due to trapped Xe interferences... (b) Theoretical calculations ... underestimate the [long half-lives of ^{128}Te ^{130}Te] by 1 or 2 orders of magnitude, pointing to a real supression in the $^{2\nu}$ decay rate of these isotopes. (c) Despite [this], most $^{69}\text{-models}$

predict a ratio of 2 ν decay widths ... in fair agreement with observation." Further details of the experiment are given in BERNATOWICZ 93. Our listed half-life has been revised downward from the published value by the authors, on the basis of reevaluated cosmic-ray 128Xe production corrections.

45 AVIGNONE 91 reports confirmation of the MILEY 90 and VASENKO 90 observations of $2\nu\beta\beta$ decay of 76 Ge. Error is 2σ .

 46 BELLOTTI 91 uses difference between natural and enriched 136 Xe runs to obtain etaeta0ulimits, leading to "less stringent, but safer limits."

limits, leading to "less stringent, but safer limits."

47 TURKEVICH 91 observes activity in old U sample. The authors compare their results with theoretical calculations. They state "Using the phase-space factors of Boehm and Vogel (BOEHM 87) leads to matrix element values for the ²³⁸U transition in the same range as deduced for ¹³⁰Te and ⁷⁶Ge. On the other hand, the latest theoretical estimates (STAUDT 90) give an upper limit that is 10 times lower. This large discrepancy implies either a defect in the calculations or the presence of a faster path than the standard wo-neutrino mode in this case." See BOEHM 87 and STAUDT 90.

48 MILEY NO claims only "surgestive evidence" for the decay. Error is 2a.

two-neutrino mode in this case." See BUEHM 87 and STAUDI 30.

48 MILEY 90 claims only "suggestive evidence" for the decay. Error is 2\sigma.

49 KIRSTEN 83 reports "2\sigma" error. References are given to earlier determinations of the 130 Te lifetime.

$\langle m_{ u} \rangle$, The Effective Weighted Sum of Majorana Neutrino Masses Contributing to Neutrinoless Double β Decay

 $\langle m_{\nu} \rangle = |\Sigma| U_{1}^{2} |m_{\nu_{i}}|$, where the sum goes from 1 to n and where n= number of neutrino generations, and ν_j is a Majorana neutrino. Note that U_{1j}^2 , not $|U_{1j}|^2$, occurs in the sum. The possibility of cancellations has been stressed. In the following Listings, only best or comparable limits or lifetimes for each isotope are reported.

VALUE (eV)	CL9	SOTOPE	TRANSITION	METHOD	DOCUMENT ID	
 ◆ ◆ We do 	not us	e the followir	ng data for aver	ages, fits, limits, etc	. • • •	
<9.3	68	100 _{Mo 0ν}		Si(LI)	50 ALSTON	97
<0.46	90	⁷⁶ Ge 0ν		Enriched HPGe	51 BAUDIS	97
<2.2	68	100 Mo Ov	$0^+ \rightarrow 0^+$	ELEGANT V	52 EJIRI	96
<4.1	90	116 _{Cd} 0 _v		116CdWO ₄ scint	53 DANEVICH	95
< 2.8-4.3	90	136Xe 0ν	o ⁺ → o ⁺	TPC	54 VUILLEUMIER	93
< 1.1-1.5		128 _{Te}		Geochem	55 BERNATOW	
<5	68	82 _{Se}		TPC	56 ELLIOTT	92
<8.3	76	⁴⁸ Ca 0ν		CaF ₂ scint.	YOU	91
< 5.6	95	128 _{Te}		Geochem	KIRSTEN	83
70						

⁵⁰ ALSTON-GARNJOST 97 obtain the limit for $\langle m_{\nu} \rangle$ using the matrix elements of ENGEL 88. The limit supersedes ALSTON-GARNJOST 93.

51 BAUDIS 97 limit for $\langle m_{
u}
angle$ is based on the matrix elements of STAUDT 90. This is the most stringent bound on $\langle m_{\nu} \rangle.$ It supersedes the limit of GUENTHER 97.

 52 EJIRI 96 obtain the limit for $\langle m_{
u}
angle$ using the matrix elements of TOMODA 91.

53 DANEVICH 95 is identical to GEORGADZE 95.

55 DANEVICH 99 is identical to GEORGADZE 99.

45 VUILLEUMIER 93 mass range from parameter range in the Caltech calculations (ENGEL 88). On the basis of these calculations, the BALYSH 92 mass range would be <2.2-4.4 eV.

55 BERNATOWICZ 92 finds these majoron mass limits assuming that the measured geochemical decay width is a limit on the 0ν decay width. The range is the range found using matrix elements from HAXTON 84, TOMODA 87, and SUHONEN 91. Further details of the experiment are given in BERNATOWICZ 93.

56 ELLIOTT 92 uses the matrix elements of HAXTON 84.

Limits on Lepton-Number Violating (V+A) Current Admixture

For reasons given in the discussion at the beginning of this section, we list only results from 1989 and later. $\langle \lambda \rangle = \lambda \sum U_{IJ} V_{IJ}$ and $\langle \eta \rangle = \eta \sum U_{IJ} V_{IJ}$, where the sum is over the number of neutrino generations. This sum vanishes for massless or unmixed neutrinos. In the following Listings, only best or comparable limits or lifetimes for each isotope are reported.

$\langle \lambda \rangle$ (10 ⁻	6) CL%	$\langle \eta \rangle$ (10	8) CL%	ISOTOPE	METHOD	DOCUMENT ID	
• • • V	Ve do n	ot use the	followir	ng data for	averages, fits, limit	s, etc. • • •	
<1.1	90	< 0.64	90	76 _{Ge}	Enriched HPGe	57 GUENTHER	97
<3.7	68	<2.5	68	100 _{Mo}	Elegant V	⁵⁸ EJIRI	96
<5.3	90	< 5.9	90	116 _{Cd}	116CdWO ₄ scint	⁵⁹ DANEVICH	95
<4.4	90	<2.3	90	136 Xe	TPC	60 VUILLEUMIER	₹ 93
		< 5.3		128 _{Te}	Geochem	61 BERNATOW	. 92
67							

GUENTHER 97 limits use the matrix elements of STAUDT 90. Supersedes BALYSH 95

⁵⁸ EJIRI 96 obtain limits for $\langle \lambda \rangle$ and $\langle \eta \rangle$ using the matrix elements of TOMODA 91.

59 DANEVICH 96 is identical to GEORGADZE 95.
60 VUILLEUMIER 93 uses the matrix elements of MUTO 89.
61 BERNATOWICZ 92 takes the measured geochemical decay width as a limit on the 0ν width, and uses the SUHONEN 91 coefficients to obtain the least restrictive limit on η. Further details of the experiment are given in BERNATOWICZ 93.

(D) Other bounds from nuclear and particle decays

– Limits on $|U_{1j}|^2$ as Function of $m_{
u_j}$

Peak and kink search tests

Limits on $|U_{1i}|^2$ as function of m_{ν_i}

			- 1			
VALUE	<u> </u>	CL%	DOCUMENT ID	TECN	COMMENT	
<1	× 10 ⁻⁷	90	62 BRITTON	928 CNTR	50 MeV < m _{νj} <	130
					Ma\/	

Lepton Particle Listings Massive Neutrinos and Lepton Mixing

	• We do not use the	following	а	ata for averages	fits	limits	etc. e e e
<5	× 10 ⁻⁶	90	Ī	DELEENER		,	$m_{\nu_i} = 20 \text{ MeV}$
<5	× 10 ⁻⁷	90		DELEENER	91		$m_{\nu_i} = 40 \text{ MeV}$
<3	× 10 ⁻⁷	90		DELEENER	91		$m_{\nu_j} = 60 \text{ MeV}$
<1	× 10 ⁻⁶	90		DELEENER	91		$m_{\nu_i} = 80 \text{ MeV}$
<1	× 10 ⁻⁶	90		DELEENER	91		$m_{\nu_i} = 100 \text{ MeV}$
<5	× 10 ⁻⁷	90		AZUELOS	86	CNTR	,
<2	× 10 ⁻⁷	90		AZUELOS	86	CNTR	$m_{\nu_i} = 80 \text{ MeV}$
<3	× 10 ⁻⁷	90		AZUELOS	86	CNTR	$m_{\nu_i} = 100 \text{ MeV}$
<1	× 10 ⁻⁶	90		AZUELOS	86	CNTR	,
<2	× 10 ⁻⁷	90		AZUELOS	86	CNTR	,
<8	× 10 ⁻⁶			DELEENER	86		ຫ _{ນ:} =20 MeV
<4	× 10 ⁻⁷			DELEENER			,
<2	× 10 ⁻⁶						$m_{\nu_i} = 100 \text{ MeV}$
<7	× 10 ⁻⁶						m _{ν;} =120 MeV
<1	× 10 ⁻⁴	90	3	BRYMAN			$m_{\nu_i} = 5 \text{ MeV}$
<1.5	5 × 10 ⁻⁶	90		BRYMAN			_{vi} =53 MeV
<1	× 10 ⁻⁵	90		BRYMAN			m _{ν;} =70 MeV
<1	× 10 ⁻⁴	90		BRYMAN			$m_{\nu_i} = 130 \text{ MeV}$
<1	× 10 ⁻⁴	68	4	SHROCK			$m_{\nu_i} = 10 \text{ MeV}$
<5	× 10 ⁻⁶			SHROCK	81		m _{ν1} =60 MeV
<1	× 10 ⁻⁵	68	55	SHROCK	80		m_{ν_i} =80 MeV
<3	× 10 ⁻⁶			SHROCK	80		m _{ν;} =160 MeV
62 -	DITTON OOD IS 600						

 62 BRITTON 92B is from a search for additional peaks in the e^+ spectrum from $\pi^+
ightarrow$ $e^+ \nu_e$ decay at TRIUMF. See also BRITTON 92. 63 BRYMAN 838 obtain upper limits from both direct peak search and analysis of B($\pi \to$

 $e\nu$)/B($\pi \to \mu\nu$). Latter limits are not listed, except for this entry (i.e. — we list the most stringent limits for given mass). ⁶⁴ Analysis of $(\pi^+ \to e^+\nu_e)/(\pi^+ \to \mu^+\nu_\mu)$ and $(K^+ \to e^+\nu_e)/(K^+ \to \mu^+\nu_\mu)$

decay ratios. 65 Analysis of $(K^+ \rightarrow e^+ \nu_e)$ spectrum.

Kink search in nuclear β decay

High-sensitivity follow-up experiments show that indications for a neutrino with mass 17 keV (Simpson, Hime, and others) were not valid. Accordingly, we no longer list the experiments by these authors and some others which made positive claims of 17 keV neutrino emission. Complete listings are given in the 1994 edition (Physical Review **D80** 1173 (1994)). Limits on $|U_{1j}|^2$ as a function of $m_{\nu j}$. See WIETFELDT 96 for a comprehensive review

	ehensive	review.			
<i>VALUE</i> (units 10 ⁻³)	CL%	m _{νį} (keV)	ISOTO	PE METHOD	DOCUMENT ID
• • • We do	not use t	he following data		es, fits, limits, etc	
$< 1 \times 10^{-2}$	95	1	3 _H	SPEC	66 HIDDEMANN 95
$< 6 \times 10^{-3}$	95	2	3 _H	SPEC	66 HIDDEMANN 95
< 2 × 10 ⁻³	95	3	³ H	SPEC	66 HIDDEMANN 95
< 2 × 10 ⁻³	95	4	3 _H	SPEC	66 HIDDEMANN 95
0.3 ± 1.5	±0.8	17	35 _S	Mag spect	67 BERMAN 93
< 2.8	99	17	3 _H	Prop chamber	68 KALBFLEISCH 93
< 1	99	14.4-15.2	3 _H	Prop chamber	68 KALBFLEISCH 93
< 0.7	99	16.3-16.6	3 _H	Prop chamber	68 KALBFLEISCH 93
< 2	95	13-40	³⁵ S	SI(LI)	69 MORTARA 93
< 0.73	95	17	63 _{Ni}	Mag spect	OHSHIMA 93
< 1.5	95	10.5-25.0	63NI	Mag spect	70 OHSHIMA 93
< 6	95	5-25	22 E	IBEC in Ge	71 WIETFELDT 93
< 2	90	17	35 _S	Mag spect.	⁷² CHEN 92
< 0.95	95	17	63 _{NI}	Mag spect	73 KAWAKAMI 92
< 1.0	95	10-24	63N1	Mag spect	KAWAKAMI 92
< 10	90	16-35	125	IBEC; γ det	74 BORGE 86
< 7.5	99	5-50	35 _S	Mag spect	ALTZITZOG 85
< 8	90	80	35 _S	Mag spect	75 APALIKOV 85
< 1.5	90	60	35 _S	Mag spect	APALIKOV 85
< 8	90	30	35 _S	Mag spect	APALIKOV 85
< 3	90	17	35 _S	Mag spect	APALIKOV 85
< 45	90	4	35 _S	Mag spect	APALIKOV 85
< 10	90	5-30	35 _S	Si(LI)	DATAR 85
< 3.0	90	550		Mag spect	MARKEY 85
< 0.62	90	48	35 _S	SI(LI)	OHI 85
< 0.90	90	30	35 _S	SI(Li)	OHI 85
< 1.30	90	20	35 _S	SI(LI)	OHI 85
< 1.50	90	17	35 _S	SI(LI)	OHI 85
< 3.30	90	10	35 _S	Si(L1)	OHI 85
< 25	90	30	64Cu	Mag spect	76 SCHRECK 83
< 4	90	140	64Cu	Mag spect	76 SCHRECK 83
< 8	90	440	64Cu	Mag spect	76 SCHRECK 83
< 1	95	0.1			77 SIMPSON BI
<4E-3	95	10			77 SIMPSON 81
<100	90	0.1-3000		THEO	78 SHROCK 80
< 0.1	68	80		THEO	⁷⁹ SHROCK 80

 $^{66}\,\mathrm{ln}$ the beta spectrum from tritium β decay nonvanishing or mixed $m_{\overline{\nu}_1}$ state in the mass region 0.01–4 keV. For $m_{
u_{ar{j}}}$ <1 keV, their upper limit on $|U_{ar{j}}|^2$ becomes less

⁶⁷BERMAN 93 uses an iron-free intermediate-image magnetic spectrometer to measure 35 S β decay over a large portion of the spectrum. Paper reports (0.01 \pm 0.15)%; above result revised by author on basis of analysis refinements.

68 KALBFLEISCH 93 extends the 17 keV neutrino search of BAHRAN 92, using an improved proportional chamber to which a small amount of $^3\mathrm{H}$ is added. Systematics are significantly reduced, allowing for an improved upper limit. The authors give a 99% confidence limit on $|u_{1j}|^2$ as a function of m_{ν_j} in the range from 13.5 keV to 17.5 keV. Typical upper limits are listed above. They report that this experiment in combination with BAHRAN 92 gives an upper limit of 2.4×10^{-3} at the 99% CL. See also the related papers BAHRAN 93, BAHRAN 93B, and BAHRAN 95 on theoretical aspects of beta spectra and fitting methods for heavy neutrinos.

⁶⁹MORTARA 93 limit is from study using a high-resolution solid-state detector with a superconducting solenoid. The authors note that "The sensitivity to neutrino mass is verified by measurement with a mixed source of $^{35}\mathrm{S}$ and $^{14}\mathrm{C}$, which artificially produces a distortion in the beta spectrum similar to that expected from the massive neutrino."

 $^{70}\,\text{OHSHIMA}$ 93 is the full data analysis from this experiment. The above limit on the mixing strength for a 17 keV neutrino is obtained from the measurement $|U_{1j}|^2 =$ $(-0.11\pm0.33\pm0.30)\times10^{-3}$ by taking zero as the best estimate and ignoring physical boundaries; see discussion in HOLZSCHUH 92B for a comparison of methods. An earlier report of this experiment was given in KAWAKAMI 92.

71 WIETFELDT 93 is an extension of the NORMAN 91 experiment. However, whereas NORMAN 91 reported indications for the emission of a neutrino with mass $m_{\nu j}=$ 21 ± 2 keV and coupling strength = 0.0085 \pm 0.0045, the present experiment states that "We find no evidence for emission of a neutrino in the mass range 5–25 keV. In particular, a 17 keV neutrino with $\sin^2\theta \left(|U_{1j}|^2 \text{ in our notation}\right) = 0.008$ is excluded at the 7σ level." The listed limits can be obtained from the paper's Fig. 4. The authors acknowledge that this conclusion contradicts the one reported in NORMAN 91, based on a smaller data sample. In further tests, WIETFELDT 95 have shown that "the observed distortion was most likely caused by systematic effects... A new measurement with a smaller data sample shows no sign of this distortion."

72 CHEN 92 is a continuation and improvement of the Boehm et al. Caltech iron-free magnetic spectrometer experiment searching for emission of massive neutrinos in 35S decay (MARKEY 85). The upper limit on $|U_{1j}|^2$ for $m_{\nu_i}=17$ keV comes from the measurement $|U_{1j}|^2 = (-0.5 \pm 1.4) \times 10^{-3}$. The authors state that their results "rule out, at the 6σ level, a 17 keV neutrino admixed at 0.85% (i.e. with $|U_{1j}|^2$ 0.85×10^{-2} ," the level claimed by Hime and Jelly in HIME 91. They also state that "our data show no evidence for a heavy neutrino with a mass between 12 and 22 keV" with substantial admixture in the weak admixture in the weak eigenstate ν_{e} ; see their Fig. 4 for a graphical set of measured values of $|U_{1,i}|^2$ for various hypothetical values of

73 KAWAKAMI 92 experiment final results are given in OHSHIMA 93. The upper limit is improved to 0.73×10^{-3} , based on $|U_{1j}|^2 = (-0.11 \pm 0.33 \pm 0.30) \times 10^{-3}$. Ohshima notes that the result is 22σ away from the value $|U_{1j}|^2=1\%$.

 74 BORGE 86 results originally presented as evidence against the SIMPSON 85 claim of a 17 keV antineutrino emitted with $|U_{1J}|^2=0.03$ in $^3\mathrm{H}$ decay.

75 This limit was taken from the figure 3 of APALIKOV 85; the text gives a more restrictive limit of 1.7×10^{-3} at CL = 90%.

76 SCHRECKENBACH 83 is a combined measurement of the β^+ and β^- spectrum.

77 Application of kink search test to tritium β decay Kurie plot.

78 SHROCK 80 was a retroactive analysis of data on several superallowed eta decays to search for kinks in the Kurie plot.

79 Application of test to search for kinks in β decay Kurie plots.

Searches for Decays of Massive ν

Limits on $|U_{1,l}|^2$ as function of m_{ν} .

1 1/1		ν_{j}
VALUE	<u>CL%</u>	DOCUMENT ID TECN COMMENT
• • • We do not use th	e followi	ing data for averages, fits, limits, etc. • • •
$<2 \times 10^{-5}$	95	⁸⁰ ABREU 971 DLPH m_{ν_i} =6 GeV
$<3 \times 10^{-5}$	95	80 ABREU 97ι DLPH m _{ν1} =50 GeV
$<1.8 \times 10^{-3}$	90	⁸¹ HAGNER 95 MWPC $m_{\nu_h} = 1.5 \text{ MeV}$
$< 2.5 \times 10^{-4}$	90	⁸¹ HAGNER 95 MWPC $m_{\nu_h}^{"} = 4 \text{ MeV}$
$<4.2 \times 10^{-3}$	90	⁸¹ HAGNER 95 MWPC $m_{\nu_h}^{"} = 9 \text{ MeV}$
<1 × 10 ⁻⁵	90	⁸² BARANOV 93 $m_{\nu_i}^{"}$ = 100 MeV
$<1 \times 10^{-6}$	90	⁸² BARANOV 93 $m_{\nu_i} = 200 \text{ MeV}$
$< 3 \times 10^{-7}$	90	⁸² BARANOV 93 $m_{\nu_i} = 300 \text{ MeV}$
<2 × 10 ⁻⁷	90	⁸² BARANOV 93 $m_{\nu_i}^{\prime}$ = 400 MeV
<6.2 × 10 ⁻⁸	95	ADEVA 90s L3 $m_{\nu_l} = 20 \text{ GeV}$
$< 5.1 \times 10^{-10}$	95	ADEVA 90s L3 $m_{\nu_i} = 40 \text{ GeV}$
all values ruled out	95	⁸³ BURCHAT 90 MRK2 $m_{\nu_j}^{\ \ \ \ \ \ } < 19.6 \text{ GeV}$
<1 × 10 ⁻¹⁰	95	⁸³ BURCHAT 90 MRK2 $m_{\nu_i}^{J} = 22 \text{ GeV}$
<1 × 10 ⁻¹¹	95	⁸³ BURCHAT 90 MRK2 $m_{\nu_i} = 41 \text{ GeV}$
all values ruled out	95	DECAMP 90F ALEP $m_{\nu_i}^{\ \ j} = 25.0-42.7 \text{ GeV}$
<1 × 10 ⁻¹³	95	DECAMP 90F ALEP $m_{\nu_i} = 42.7-45.7 \text{ GeV}$
<5 × 10 ⁻³	90	AKERLOF 88 HRS $m_{\nu_i}^{I} = 1.8 \text{ GeV}$
$< 2 \times 10^{-5}$	90	AKERLOF 88 HRS $m_{\nu_i}^{J}$ =4 GeV
<3 × 10 ⁻⁶	90	AKERLOF 88 HRS $m_{ u_i}^{j} = 6$ GeV
		- 7

Massive Neutrinos and Lepton Mixing

<1.2	2 × 10 ⁻⁷	90		BERNARDI	88	CNTR	m _{ν,} =100 MeV
<1	× 10 ⁻⁸	90		BERNARDI	88	CNTR	m _{νj} ≈200 MeV
<2.4	× 10 ⁻⁹	90		BERNARDI	88		m _{νi} =300 MeV
<2.1	× 10 ⁻⁹	90		BERNARDI	88	CNTR	,
<2	× 10 ⁻²	68	84	OBERAUER	87		$m_{\nu_j}^{\prime}$ =1.5 MeV
<8	× 10 ⁻⁴	68	84	OBERAUER	87		$m_{\nu_i}^{\prime}$ =4.0 MeV
<8	$\times 10^{-3}$	90		BADIER	86	CNTR	m _{ν1} =400 MeV
<8	× 10 ⁻⁵	90		BADIER	86	CNTR	$m_{\nu_i} = 1.7 \text{ GeV}$
<8	× 10 ⁻⁸	90		BERNARDI	86	CNTR	$m_{\nu_i} = 100 \text{ MeV}$
<4	× 10 ⁻⁸	90		BERNARDI	86	CNTR	$m_{\nu_i}^{j}$ =200 MeV
<6	× 10 ⁻⁹	90		BERNARDI	86	CNTR	$m_{\nu_i} = 400 \text{ MeV}$
<3	× 10 ⁻⁵	90		DORENBOS	86	CNTR	$m_{\nu_i}^{J}$ =150 MeV
<1	× 10 ⁻⁶	90		DORENBOS	86	CNTR	m _{ν1} =500 MeV
<1	× 10 ⁻⁷	90		DORENBOS	86	CNTR	m _{ν;} =1.6 GeV
<7	× 10 ⁻⁷	90	85	COOPER	85	HLBC	$m_{\nu_j} = 0.4 \text{ GeV}$
<8	× 10 ⁻⁸	90	85	COOPER	85	HLBC	$m_{\nu_i}^{J}$ =1.5 GeV
<1	$\times 10^{-2}$	90	86	BERGSMA	83B	CNTR	$m_{\nu_j}^{J}$ =10 MeV
<1	× 10 ⁻⁵	90	86	BERGSMA	838	CNTR	$m_{\nu_j} = 110 \text{ MeV}$
<6	× 10 ⁻⁷	90	86	BERGSMA	83B	CNTR	•
<1	× 10 ⁻⁵	90		GRONAU	83		$m_{\nu_i}^{J}$ =160 MeV
<1	× 10 ⁻⁶	90		GRONAU	83		$m_{\nu_i}^{J}$ =480 MeV
							,

 $^{^{80}}$ ABREU 971 long-lived u_i analysis. Short-lived analysis extends limit to lower masses with decreasing sensitivity except at 3.5 GeV, where the limit is the same as at 6 GeV.

- Limits on $|U_{2j}|^2$ as Function of m_{ν_j}

Peak search test

Limits on $|U_{2j}|^2$ as function of m_{ν_i}

VALUE	CL%	DOCUMENT ID		CN COMMENT	
• • • We do not use	e the follow	ing data for average	s, fits, li	mits, etc. • • •	
< 1-10 × 10 ⁻⁴		87 BRYMAN	96 CI	NTR $m_{\nu_{\nu}} = 30-33.91 \text{ MeV}$	J
>10 -16		88 ARMBRUSTE		ARM $m_{\nu_{\nu}} = 33.9 \text{ MeV}$	
$< 4 \times 10^{-7}$	95	89 BILGER	95 LE	$PS m_{\overline{\nu}_{x}} = 33.9 \text{ MeV}$	
$< 7 \times 10^{-8}$	95	89 BILGER	95 LE	EPS $m_{\nu_{\nu}} = 33.9 \text{ MeV}$	
$< 2.6 \times 10^{-8}$	95	⁸⁹ DAUM	95B T	OF $m_{\nu_x} = 33.9 \text{ MeV}$	
$< 2 \times 10^{-2}$	90	DAUM	87	$\hat{m_{\nu_i}}=1$ MeV	
$< 1 \times 10^{-3}$	90	DAUM	87	$m_{\nu_i}^{J}$ =2 MeV	
$< 6 \times 10^{-5}$	90	DAUM	87	3 MeV $< m_{ u_j} < 19.5$	
< 3 × 10 ⁻²	90	90 MINEHART	84	MeV m _{ν,} =2 MeV	
< 1 × 10 ⁻³	90	90 MINEHART	84	$m_{\nu_j}^{\gamma}$ =4 MeV	
< 3 × 10 ⁻⁴	90	90 MINEHART	84	$m_{\nu_i} = 10 \text{ MeV}$	
< 5 × 10 ⁻⁶	90	91 HAYANO	82	m _{\nu_1} =330 MeV	
$< 1 \times 10^{-4}$	90	91 HAYANO	82	$m_{\nu_l} = 70 \text{ MeV}$	
$< 9 \times 10^{-7}$	90	91 HAYANO	82	$m_{\nu_i}^{J}$ =250 MeV	
$< 1 \times 10^{-1}$	90	90 ABELA	81	$m_{\nu_i} = 4 \text{ MeV}$	
< 7 × 10 ⁻⁵	90	90 ABELA	81	$m_{\nu_j} = 10.5 \text{ MeV}$	
$< 2 \times 10^{-4}$	90	90 ABELA	81	$m_{\nu_j}^{J} = 11.5 \text{ MeV}$	
$< 2 \times 10^{-5}$	90	90 ABELA	81	m _{vi} =16-30 MeV	
< 2 × 10 ⁻⁵	95	⁹¹ ASANO	81	$m_{\nu_i} = 170 \text{ MeV}$	

	6		91			
	× 10 ⁻⁶	95	⁹¹ ASANO	81		m_{ν_j} =210 MeV
< 3	× 10 ⁻⁶	95	⁹¹ ASANO	81		m _{νj} =230 MeV
< 6	× 10 ⁻⁶	95	92 ASANO	81		m _{νi} =240 MeV
< 5	× 10 ⁻⁷	95	⁹² ASANO	81		$m_{\nu_j} = 280 \text{ MeV}$
< 6	× 10 ⁻⁶	95	⁹² ASANO	81		m _{ν1} =300 MeV
< 1	× 10 ⁻²	95	90 CALAPRICE	81		$m_{\nu_i} = 7 \text{ MeV}$
	× 10 ⁻³	95	90 CALAPRICE	81		m _{ν;} =33 MeV
< 1.	× 10 ⁻⁴	68	93 SHROCK	81	THEO	m _{νi} ≈13 MeV
< 3	× 10 ⁻⁵	68	⁹³ SHROCK			m _{νj} ≈33 MeV
	× 10 ⁻³	68	94 SHROCK			m _{ν1} =80 MeV
< 5	× 10 ⁻³	68	94 SHROCK			m _{ν:} =120 MeV

⁸⁷ BRYMAN 96 search for massive unconventional neutrinos of mass m_{ν_χ} in π^+ decay. The reported value is the upper limit for the branching ratio, $<4-6\times10^{-5}$ (90%CL). They interpret the result as an upper limit for the admixture of a heavy sterile or otherwise

Peak Search in Muon Capture

Limits on $|U_{2j}|^2$ as function of m_{ν_1}

VALUE	DOCUMENT ID		COMMENT
• • • We do not use the following	data for averages	, fits	, limits, etc. • • •
<1 × 10 ⁻¹	DEUTSCH	83	m_{ν_i} =45 MeV
$< 7 \times 10^{-3}$	DEUTSCH	83	$m_{\nu_i} = 70 \text{ MeV}$
<1 × 10 ⁻¹	DEUTSCH	83	m _{\nui} =85 MeV

Searches for Decays of Massive ν Limits on $|U_{2j}|^2$ as function of m_{ν_l}

			. 1			
VALUE	CLX		DOCUMENT ID		TECN	COMMENT
• • • We do not use the	followin			, fits	, limits,	etc. • • •
<2 × 10 ⁻⁵	95		ABREU	9 71	DLPH	m_{ν_i} =6 GeV
<3 × 10 ⁻⁵	95	95	ABREU	971	DLPH	$m_{\nu_j} = 50 \text{ GeV}$
<3 × 10 ⁻⁶	90		GALLAS	95	CNTR	$m_{\nu_i} = 1 \text{ GeV}$
$<3 \times 10^{-5}$	90	96	VILAIN	95 C	CHM2	$m_{\nu_i} = 2 \text{ GeV}$
$< 6.2 \times 10^{-8}$	95		ADEVA	9 0s	L3	$m_{\nu_i} = 20 \text{ GeV}$
$< 5.1 \times 10^{-10}$	95		ADEVA	905	L3	$m_{\nu_i} = 40 \text{ GeV}$
all values ruled out	95	97	BURCHAT	90	MRK2	,
<1 × 10 ⁻¹⁰	95	97	BURCHAT	90	MRK2	$m_{\nu_j} = 22 \text{ GeV}$
<1 × 10 ⁻¹¹	95	97	BURCHAT	90	MRK2	$m_{\nu_i} = 41 \text{ GeV}$
all values ruled out	95		DECAMP	90F	ALEP	$m_{\nu_i} = 25.0-42.7 \text{ GeV}$
<1 × 10 ⁻¹³	95		DECAMP	90F	ALEP	$m_{\nu_i} = 42.7 - 45.7 \text{ GeV}$
<5 × 10 ⁻⁴	90	98	KOPEIKIN	90	CNTR	$m_{\nu_j} = 5.2 \text{ MeV}$
<5 × 10 ⁻³	90		AKERLOF	88	HRS	$m_{\nu_i} = 1.8 \text{ GeV}$
<2 × 10 ⁻⁵	90		AKERLOF	88	HRS	$m_{\nu_i} = 4 \text{ GeV}$
<3 × 10 ⁻⁶	90		AKERLOF	88	HRS	$m_{\nu_i} = 6 \text{ GeV}$
<1 × 10 ⁻⁷	90		BERNARDI	88	CNTR	$m_{\nu_l} = 200 \text{ MeV}$
<3 × 10 ⁻⁹	90		BERNARDI	88	CNTR	m_{ν_i} =300 MeV
<4 × 10 ⁻⁴	90	99	MISHRA	87	CNTR	$m_{\nu_i} = 1.5 \text{ GeV}$
<4 × 10 ⁻³	90	99	MISHRA	87	CNTR	m _{\nu1} =2.5 GeV
<0.9 × 10 ⁻²	90	99	MISHRA	87	CNTR	$m_{\nu_i} = 5 \text{ GeV}$
<0.1	90	99	MISHRA	87	CNTR	$m_{\nu_I} = 10 \text{ GeV}$
<8 × 10 ⁻⁴	90		BADIER	86	CNTR	$m_{\nu_i} = 600 \text{ MeV}$
$<1.2 \times 10^{-5}$	90		BADIER	86	CNTR	$m_{\nu_i} = 1.7 \text{ GeV}$
<3 × 10 ⁻⁸	90		BERNARDI	86	CNTR	m _{ν;} =200 MeV
<6 × 10 ⁻⁹	90		BERNARDI	86	CNTR	m_{ν_i} =350 MeV
<1 × 10 ⁻⁶	90		DORENBOS	86	CNTR	m _{νi} =500 MeV
<1 × 10 ⁻⁷	90		DORENBOS	86	CNTR	m_{ν_i} =1600 MeV
$< 0.8 \times 10^{-5}$	90	100	COOPER	85	HLBC	$m_{\nu_i} = 0.4 \text{ GeV}$
<1.0 × 10 ⁻⁷			COOPER	85	HLBC	$m_{\nu_j} = 1.5 \text{ GeV}$
						7)

⁸¹ HAGNER 95 obtain limits on heavy neutrino admixture from the decay $\nu_h \rightarrow \nu_e \, e^+ \, e^-$ at a nuclear reactor for the ν_h mass range 2–9 MeV.

 ⁸² BARANOV 93 is a search for neutrino decays into e⁺e⁻ν_e using a beam dump experiment at the 70 GeV Serpukhov proton synchrotron. The limits are not as good as those achieved earlier by BERGSMA 83 and BERNARDI 86, BERNARDI 88.
 83 BURCHAT 90 Includes the analyses reported in JUNG 90, ABRAMS 89C, and MENDEL 97.

WENDT 87.

WEND 1 67. 84 OBERAUER 87 bounds from search for $\nu \rightarrow \nu' ee$ decay mode using reactor

⁽anti)neutrinos. 85 COOPER-SARKAR 85 also give limits based on model-dependent assumptions for ν_{τ} flux. We do not list these. Note that for this bound to be nontrivial, j is not equal to 3, i.e. ν_J cannot be the dominant mass eigenstate in ν_τ since $m_{\nu_3} < 70$ MeV (ALBRECHT 85i). Also, of course, J is not equal to 1 or 2, so a fourth generation would be required for this bound to be nontrivial. 86 BERGSMA 83B also quote limits on $|U_{13}|^2$ where the index 3 refers to the mass eigenstate dominantly coupled to the τ . Those limits were based on assumptions about the D_S mass and $D_S \rightarrow \tau \nu_T$ branching ratio which are no longer valid. See COOPERSABLAR BE

 D_s mass and $D_s \rightarrow$ SARKAR 85.

⁸⁸ ARMBRUSTER 95 study the reactions 12 C(ν_e,e^-) 12 N and 12 C(ν,ν') 12 C* induced by neutrinos from π^+ and μ^+ decay at the ISIS neutron spallation source at the Rutherford-Appleton laboratory. An anomaly in the time distribution can be interpreted as the decay $\pi^+ \to \mu^+ \nu_X$, where ν_X is a neutral weakly interacting particle with mass ≈ 33.9 MeV and spin 1/2. The lower limit to the branching ratio is a function of the lifetime of the new massive neutral particle, and reaches a minimum of a few \times 10⁻¹⁶ for $\tau_{\chi}\sim$ 5 s.

⁸⁹ From experiments of π^+ and π^- decay in flight at PSI, to check the claim of the KARMEN Collaboration quoted above (ARMBRUSTER 95).

⁹⁰ $\pi^+ \rightarrow \mu^+ \nu_\mu$ peak search experiment.

 $^{^{91}}$ K $^+$ $\rightarrow~\mu^+ \nu_\mu$ peak search experiment.

⁹² Analysis of experiment on $K^+ \to \mu^+ \nu_\mu \nu_\chi \overline{\nu}_\chi$ decay.

⁹³ Analysis of magnetic spectrometer experiment, bubble chamber experiment, and emulsion experiment on $\pi^+
ightarrow \mu^+
u_\mu$ decay.

⁹⁴ Analysis of magnetic spectrometer experiment on $K \to \mu, \nu_{\mu}$ decay.

 95 ABREU 971 long-lived u_{i} analysis. Short-lived analysis extends limit to lower masses with decreasing sensitivity except at 3.5 GeV, where the limit is the same as at 6 GeV.

Limits on $|U_{3j}|^2$ as a Function of m_{ν_j}

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use	the follow	ing data for average	s, fits	, limits,	etc. • • •
$< 2 \times 10^{-5}$	95	101 ABREU	97t	DLPH	m_{ν_i} =6 GeV
<3 × 10 ⁻⁵	95	101 ABREU	971	DLPH	$m_{\nu_l}^{J}$ =50 GeV
$< 6.2 \times 10^{-8}$	95	ADEVA		L3	$m_{\nu_i}^{\ \ j}=20~{ m GeV}$
$< 5.1 \times 10^{-10}$	95	ADEVA	90 s	L3	$m_{\nu_i}^{\ \ j}=40~{ m GeV}$
all values ruled out	95	102 BURCHAT	90	MRK2	$m_{\nu_i}^{\ \ j} < 19.6 \text{ GeV}$
$<1 \times 10^{-10}$	95	102 BURCHAT	90		$m_{\nu_l} = 22 \text{ GeV}$
<1 × 10 ⁻¹¹	95	¹⁰² BURCHAT	90		$m_{\nu_i} = 41 \text{ GeV}$
all values ruled out	95	DECAMP	90F	ALEP	$m_{\nu_i} = 25.0-42.7 \text{ GeV}$
<1 × 10 ⁻¹³	95	DECAMP	90F	ALEP	$m_{\nu_i} = 42.7-45.7 \text{ GeV}$
<5 × 10 ⁻²	80	AKERLOF	88	HRS	$m_{\nu_i}^{J}$ =2.5 GeV
<9 × 10 ⁻⁵	80	AKERLOF	88	HRS	$m_{\nu_i}^{\ \ j}$ =4.5 GeV
					,

 $^{^{101}}$ ABREU 97I long-lived u_{l} analysis. Short-lived analysis extends limit to lower masses with decreasing sensitivity.

Limits on $|U_{aj}|^2$

Where a=1, 2 from ρ parameter in μ decay.

VALUE	CL%	DOCUMENT ID	<u>TECN</u>	COMMENT
• • • We do not use the	following d	ata for averages	, fits, limits,	etc. • • •
<1 × 10 ⁻²	68	SHROCK	81B THEO	m_{ν_l} =10 MeV
<2 × 10 ⁻³	68	SHROCK	81B THEO	$m_{\nu_i} = 40 \text{ MeV}$
<4 × 10 ⁻²	68	SHROCK	81B THEO	$m_{\nu_j} = 70 \text{ MeV}$

Limits on $|U_{1i} \times U_{2i}|$ as Function of m_{ν_1}

	1 -2 -21		-,		
VALUE		CL%	DOCUMENT ID	TECN	COMMENT
• • • We	do not use the	following	lata for averages	, fits, limits	i, etc. • • •
<3 × 10	₎ –5	90 103	BARANOV	93	$m_{ u_i}$ = 80 MeV
<3 × 10	₎ –6	90 103	BARANOV	93	$m_{\nu_i} = 160 \text{ MeV}$
<6 × 10	₎ –7	90 103	BARANOV	93	m _{vi} = 240 MeV
<2 × 10	₎ 7	90 103	BARANOV	93	$m_{\nu_i} = 320 \text{ MeV}$
<9 × 10	₎ –5	90	BERNARDI	86 CNTR	: m _{vj} =25 MeV
<3.6 × 10	₎ –7	90	BERNARDI		m _{vi} =100 MeV
<3 × 10	₎ –8	90	BERNARDI		$m_{\nu_i}^{\prime}$ =200 MeV
<6 × 10	₎ —9	90	BERNARDI		m _{v1} =350 MeV
<1 × 10	₎ –2	90	BERGSMA	83B CNTF	$m_{\nu_i} = 10 \text{ MeV}$
<1 × 10	₎ –5	90	BERGSMA		$m_{\nu_i}^{\prime}$ =140 MeV
<7 × 10	₎ –7	90	BERGSMA		R m _{v;} =370 MeV

¹⁰³ BARANOV 93 is a search for neutrino decays into $e^+e^-\nu_e$ using a beam dump experiment at the 70 GeV Serpukhov proton synchrotron.

(E) Solar ν Experiments

SOLAR NEUTRINOS

Revised February 1998 by K. Nakamura (KEK, High Energy Accelerator Research Organization, Japan).

The Sun is a main-sequence star at a stage of stable hydrogen burning. It produces an intense flux of electron neutrinos as a consequence of nuclear fusion reactions which generate solar energy, and whose combined effect is

$$4p + 2e^- \rightarrow {}^4\text{He} + 2\nu_e + 26.73 \text{ MeV} - E_{\nu}$$
, (1)

where E_{ν} represents the energy taken away by neutrinos, with an average value being $\langle E_{\nu} \rangle \sim 0.6$ MeV. Each neutrinoproducing reaction, the resulting flux, and contributions to the event rates in chlorine and gallium solar-neutrino experiments predicted by the recent Bahcall and Pinsonneault standard solar model (SSM) calculation [1] are listed in Table 1. This SSM is regarded as the best with helium and heavy-element diffusion. Figure 1 shows the energy spectra of solar neutrinos from these reactions quoted from the SSM calculation by Bahcall and Ulrich [2]. Recently, the SSM has been shown to predict accurately the helioseismological sound velocities with a precision of 0.1% rms throughout essentially the entire Sun, greatly strengthening the confidence in the solar model [3].

Table 1: Neutrino-producing reactions in the Sun (the first column) and their abbreviations (second column). The neutrino fluxes and event rates in chlorine and gallium solar-neutrino expreiments predicted by Bahcall and Pinsonneault [1] are listed in the third, fourth, and fifth columns respectively.

		BAHCALL 95B [1]						
Reaction	Abbr.	Flux (cm ⁻² s ⁻¹)	Cl (SNU*)	Ga (SNU*)				
$pp \rightarrow d e^+ \nu$	pp	$5.91(1.00^{+0.01}_{-0.01}) \times 10^{10}$	_	69.7				
$pe^-p o d u$	pep	$1.40(1.00^{+0.01}_{-0.02})\times10^{8}$	0.22	3.0				
$^3{ m He}~p ightarrow{}^4{ m He}~e^+ u$	hep	1.21×10^3						
$^7\mathrm{Be}\;e^- \to {}^7\mathrm{Li}\;\nu + (\gamma)$	⁷ Be	$5.15(1.00^{+0.06}_{-0.07}) \times 10^9$	1.24	37.7				
$^8\mathrm{B} \rightarrow {}^8\mathrm{Be^*} \; e^+\nu$	8B	$6.62(1.00^{+0.14}_{-0.17}) \times 10^6$	7.36	16.1				
$^{13}\mathrm{N} \rightarrow ^{13}\mathrm{C}~e^{+}\nu$	^{13}N	$6.18(1.00^{+0.17}_{-0.20}) \times 10^8$	0.11	3.8				
$^{15}\mathrm{O} \rightarrow ^{15}\mathrm{N}~e^{+}\nu$	¹⁵ O	$5.45(1.00^{+0.19}_{-0.22}) \times 10^{8}$	0.37	6.3				
$^{17}\mathrm{F} \rightarrow ^{17}\mathrm{O}~e^+ \nu$	^{17}F	$6.48(1.00^{+0.15}_{-0.19}) \times 10^6$						
Total			$9.3^{+1.2}_{-1.4}$	137+8				

^{* 1} SNU (Solar Neutrino Unit) = 10^{-36} captures per atom per second.

Observation of solar neutrinos directly addresses the SSM and, more generally, the theory of stellar structure and evolution which is the basis of the SSM. The Sun as a well-defined neutrino source also provides extremely important opportunities to investigate nontrivial neutrino properties such as nonzero mass and mixing, because of the wide range of matter density and the very long distance from the Sun to the Earth. In fact, the currently available solar-neutrino data seem to require such neutrino properties, if one tries to understand them consistently.

So far, four solar-neutrino experiments published the results. In addition, a new solar-neutrino experiment (Super-Kamiokande) started observation in 1996. Three of them are radiochemical experiments using ³⁷Cl (Homestake in USA) or ⁷¹Ga (GALLEX at Gran Sasso in Italy and SAGE at Baksan in Russia) to capture neutrinos: $^{37}{\rm Cl}~\nu_e \rightarrow ^{37}{\rm Ar}~e^-$ (threshold 814 keV) or $^{71}{\rm Ga}~\nu_e \rightarrow ^{71}{\rm Ge}~e^-$ (threshold 233 keV). The produced ³⁷Ar and ⁷¹Ge are both radioactive nuclei, with half lives $(\tau_{1/2})$ of 34.8 days and 11.43 days, respectively. After an exposure of the detector for two to three times $\tau_{1/2}$, the reaction products are extracted and introduced into a low-background proportional counter, and are counted for a sufficiently long period to determine the exponentially decaying signal and a

⁹⁶ VILAIN 95C is a search for the decays of heavy isosinglet neutrinos produced by neutral current neutrino interactions. Limits were quoted for masses in the range from 0.3 to 24 GeV. The best limit is listed above.

⁹⁷ BURCHAT 90 includes the analyses reported in JUNG 90, ABRAMS 89c, and WENDT 87. 98 KOPEIKIN 90 find no m_{ν_j} in the interval 1–6.3 MeV at 90%CL for maximal mixing.

⁹⁹ See also limits on $|U_{3j}|$ from WENDT 87.

 $^{^{100}}$ COOPER-SARKAR 85 also give limits based on model-dependent assumptions for ν_{τ} flux. We do not list these. Note that for this bound to be nontrivial, J is not equal to 3, i.e. ν_{j} cannot be the dominant mass eigenstate in ν_{τ} since $m_{\nu_{3}}$ <70 MeV (ALBRECHT 85i). Also, of course, J is not equal to 1 or 2, so a fourth generation would be required for this bound to be nontrivial.

¹⁰² BURCHAT 90 includes the analyses reported in JUNG 90, ABRAMS 89C, and WENDT 87.

Massive Neutrinos and Lepton Mixing

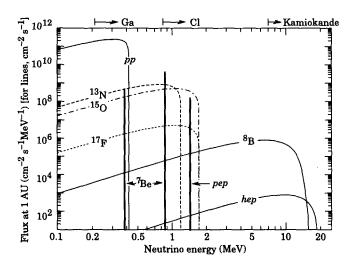


Figure 1: The solar neutrino spectrum predicted by the standard solar model. The neutrino fluxes from continuum sources are given in units of number cm⁻²s⁻¹MeV⁻¹ at one astronomical unit, and the line fluxes are given in number cm⁻²s⁻¹. Spectra for the *pp* chain are shown by solid lines, and those for the CNO chain by dotted or dashed lines. (Courtesy of J.N. Bahcall, 1995.)

constant background. In the chlorine experiment, the dominant contribution comes from ⁸B neutrinos, but ⁷Be, *pep*, ¹³N, and ¹⁵O neutrinos also contribute. At present, the most abundant *pp* neutrinos can be detected only in gallium experiments. Even so, almost half of the capture rate in the gallium experiments is due to other solar neutrinos.

The other experiments are real-time experiments utilizing νe scattering in a large water-Čerenkov detector (Kamiokande and Super-Kamiokande in Japan). These experiments take advantage of the directional correlation between the incoming neutrino and the recoil electron. This feature greatly helps the clear separation of the solar-neutrino signal from the background. Due to the high thresholds (7 MeV in Kamiokande and 6.5 MeV at present in Super-Kamiokande) the experiments observe pure $^8{\rm B}$ solar neutrinos (hep neutrinos contribute negligibly).

Solar neutrinos were first observed in the Homestake chlorine experiment in the late 1960's. From the very beginning, it was recognized that the observed capture rate was significantly smaller than the SSM prediction provided nothing happens to the electron neutrinos after they are created in the solar interior. This deficit has been called "the solar-neutrino problem."

The Kamiokande-II Collaboration started observing the 8 B solar neutrinos at the beginning of 1987. Because of the strong directional correlation of νe scattering, this result gave the

first direct evidence that the Sun emits neutrinos (no directional information is available in radiochemical solar-neutrino experiments.) The observed solar-neutrino flux was also significantly less than the SSM prediction. In addition, Kamiokande-II obtained the energy spectrum of recoil electrons and the fluxes separately measured in the day time and nighttime. The Kamiokande-II experiment came to an end at the beginning of 1995, and a 50-kton second-generation solar-neutrino detector Super-Kamiokande started observation in April, 1996.

GALLEX presented the first evidence of pp solar-neutrino observation in 1992. Here also, the observed capture rate is significantly less than the SSM prediction. SAGE, after the initial confusion which is ascribed to statistics by the group, observed a similar capture rate to that of GALLEX. Both GALLEX and SAGE groups tested the overall detector response with intense man-made 51 Cr neutrino sources, and observed good agreement between the measured 71 Ge production rate and that predicted from the source activity, demonstrating the reliability of these experiments.

The most recent published results on the average capture rates or flux from these experiments are listed in Table 2 and compared to the results from SSM calculations which are taken from "Lepton Particle Listings (E) Solar ν Experiments" in this edition of "Review of Particle Physics." In these calculations, BAHCALL 95B [1] and DAR 96 [9] take into account helium and heavy-element diffusion, but other calculations do not. SSM calculations give essentially the same results for the same input parameters and physics. The BAHCALL 95B [1] model and the TURCK-CHIEZE 93B [10] model differ primarily in that BAHCALL 95B [1] includes element diffusion. DAR 96 [9] model differs significantly from the BAHCALL 95B [1] model mostly due to the use of nonstandard reaction rates, the different treatments of diffusion and the equation of state.

There was a controversy whether the ³⁷Cl capture rate showed possible time variation, anticorrelated with the sunspot numbers which represent the 11-year solar-activity cycle. However, Walther recently argued that the claimed significant anticorrelation is due to a statistical fallacy [7]. Also, eight years of Kamiokande-II solar-neutrino observations covering an entire period of solar cycle 22 [8] does not show evidence for a statistically significant correlation or anticorrelation between the solar-neutrino flux and sunspot number.

All results from the present solar-neutrino experiments indicate significantly less flux than expected from the SSM calculations except DAR 96 [9]. The DAR 96 [9] model predicts the ⁸B solar-neutrino flux which is consistent with the Kamiokande-II result, but even this model predicts ³⁷Cl and ⁷¹Ga capture rates significantly larger than the Homestake, GALLEX, and SAGE results. Is there any possible consistent explanation of all the results of solar-neutrino observations in the framework of the standard solar model? This is difficult because the Homestake result and the Kamiokande result, taken at face value, are mutually inconsistent if one assumes standard neutrino spectra. That is, with the reduction factor of the ⁸B solar-neutrino flux

Table 2: Recent results from the four solar-neutrino experiments and a comparison with theoretical solar-model predictions. Solar model calculations are also presented. The evolution of these results over the years gives some feeling for their robustness as the models have become more sophisticated and complete.

	$^{37}\text{Cl}\rightarrow^{37}\text{Ar}$ (SNU)	71 Ga \rightarrow 71 Ge (SNU)	8 B ν flux $(10^{6}$ cm $^{-2}$ s $^{-1})$
Homestake			<u> </u>
(DAVIS 89)[4]	2.33 ± 0.25	_	_
GALLEX			
(HAMPEL 96)[5]	_	$69.7 \pm 6.7^{+3.9}_{-4.5}$	_
SAGE		•	
(ABDURASHI94)[6]	_	73^{+18+5}_{-16-7}	
Kamiokande			
(FUKUKDA 96)[8]		_	$2.80 \pm 0.19 \pm 0.33$
(DAR 96)[9]	4.1 ± 1.2	115 ± 6	2.49
(BAHCALL 95B)[1]	$9.3^{+1.2}_{-1.4}$	137^{+8}_{-7}	$6.6(1.00^{+0.14}_{-0.17})$
(TURCK-CHIEZE 93B)[10]	6.4 ± 1.4	123 ± 7	4.4 ± 1.1
(BAHCALL 92)[11]	$8.0 \pm 3.0^{\dagger}$	132^{+21}_{-17} †	$5.69(1.00\pm0.43)^{\dagger}$
(BAHCALL 88)[2]	$7.9 \pm 2.6^{\dagger}$	132^{+20}_{-17} †	$5.8(1.00\pm0.37)^{\dagger}$
(TURCK-CHIEZE 88)[12]	5.8 ± 1.3	125 ± 5	$3.8(1.00\pm0.29)$
(FILIPPONE 83)[13]	5.6	_	_
(BAHCALL 82)[14]	$7.6\pm3.3^{\dagger}$	106^{+13}_{-8} †	5.6
(FILIPPONE 82)[15]	7.0 ± 3.0	111 ± 13	4.8
(FOWLER 82)[16]	6.9 ± 1.0	-	_
(BAHCALL 80)[17]	7.3	_	_

^{* 1} SNU (Solar Neutrino Unit) = 10^{-36} captures per atom per second.

as determined from the Kamiokande result, the Homestake ³⁷Cl capture rate would be oversaturated, and there would be no room to accommodate the ⁷Be solar neutrinos. This makes astrophysical solutions untenable because ⁸B nuclei are produced from ⁷Be nuclei in the Sun.

Several authors made more elaborate analyses using the constraint of observed solar luminosity, and found (see for example, Refs. 18–20)

- that both the comparison of the Kamiokande and gallium results and the comparison of the gallium and chlorine results also indicate strong suppression of the ⁷Be solar-neutrino flux, and
- that not only the SSM but also nonstandard solar models are incompatible with the observed data.

In view of the above situation, it is attractive to invoke nontrivial neutrino properties. Neutrino oscillation in matter (MSW mechanism) is particularly attractive in explaining all the experimental data on the average solar-neutrino flux consistently, without any a priori assumptions or fine tuning. Several authors made extensive MSW analyses using all the existing data and ended up with similar results. For example, Hata and Langacker [19] analyzed the solar-neutrino data as of 1996 in terms of two-flavor oscillations, including the preliminary result from Super-Kamiokande [21]

on the average ⁸B solar-neutrino flux which is consistent with the Kamiokande-II result. They obtained viable solutions for the BAHCALL 95B [1] SSM: the small-mixing solution $(\Delta m^2 \sim 5 \times 10^{-6} \text{ eV}^2 \text{ and } \sin^2 2\theta \sim 8 \times 10^{-3})$ and the large-mixing solution $(\Delta m^2 \sim 1.6 \times 10^{-5} \text{ eV}^2 \text{ and } \sin^2 2\theta \sim 0.6)$. Vacuum oscillations also provide solutions $(\Delta m^2 = (5-8) \times 10^{-11} \text{ eV}^2 \text{ and } \sin^2 2\theta = 0.65 - 1)$.

Assuming that the solution to the solar-neutrino problem be provided by some nontrivial neutrino properties, how can one discriminate various scenarios? The measurements of energy spectrum of the solar neutrinos and the day-night flux difference, and the measurement of solar-neutrino flux by utilizing neutral-current reactions are key issues. The MSW small-mixing solution causes the energy-spectrum distortion, while the MSW large-angle solution causes the day-night flux difference. If the flux measured by neutral-current reactions is consistent with the SSM prediction, and larger than that measured by charged-current reactions, it is a clear indication of neutrino oscillations.

Two high-statistics solar-neutrino experiments, Sudbury Neutrino Observatory (SNO) and Super-Kamiokande are expected to provide such results within a few years. Super-Kamiokande is sensitive to the solar-neutrino spectrum through measurement of recoil electron energy. SNO, which is expected to be completed in 1998, will use 1,000 tons of heavy water (D₂O) to measure solar neutrinos through both inverse beta decay $(\nu_e d \rightarrow e^- pp)$ and neutral current interactions $(\nu_x d \rightarrow \nu_x pn)$. In addition, νe scattering events will also be measured. The Borexino experiment with 300 tons of ultrapure liquid scintillator is approved for the Gran Sasso. The primary purpose of this experiment is the measurement of the ⁷Be solar neutrino flux, whose possible deficit is now a key question, by lowering the detection threshold for the recoil electrons to 250 keV. Also, the vacuum-oscillations cause seasonal variation of the ⁷Be solar neutrino flux. It is hoped that these new experiments will finally provide the key to solving the different solar-neutrino problems raised by the first-generation experiments.

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1 SNU (Solar Neutrino Unit) = 10^{-36} captures per atom per second.

2 4.10 (2010) 110211112 01111) = 20 Captaido par 210111 por 20001121							
VALUE	DOCUMENT ID		TECN	COMMENT			
$(2.80 \pm 0.19 \pm 0.33) \times 10^6 \text{cm}^{-2} \text{s}^{-2}$	-1104 FUKUDA	96	KAMI	⁸ B <i>v</i> flux			
$(2.70 \pm 0.27) \times 10^6 \text{cm}^{-2} \text{s}^{-1}$	¹⁰⁴ FUKUDA	96	KAMI	⁸ B $ u$ flux (day)			
$(2.87^{+0.27}_{-0.26}) \times 10^6 \text{cm}^{-2} \text{s}^{-1}$	¹⁰⁴ FUKUDA	96	KAMI	⁸ Βν flux (night)			
$69.7 \pm 6.7 ^{+3.9}_{-4.5}$ SNU	105 HAMPEL	96	GALX	$^{71}\text{Ga} \rightarrow ^{71}\text{Ge}$			
73+18+5 SNU	106 ABDURASHI	94	SAGE	71 Ga \rightarrow 71 Ge			
2.33 ± 0.25 SNU	107 DAVIS	89	HOME	³⁷ Cl radiochemical			

104 FUKUDA 96 results are for a total of 2079 live days with Kamiokandell and Ill from January 1987 through February 1995, covering the entire solar cycle 22, with threshold $\rm E_e > 9.3$ MeV (first 449 days), > 7.5 MeV (middle 794 days), and > 7.0 MeV (last 836 days). These results update the HIRATA 90 result for the average $^8\rm B$ solar-neutrino flux and HIRATA 91 result for the day-night variation in the $^8\rm B$ solar-neutrino flux. The total data sample was also analyzed for short-term variations: within experimental errors, no strong correlation of the solar-neutrino flux with the sunspot numbers was found.

105 HAMPEL 96 reports the combined result for GALLEX I+II+III (53 runs in total), which updates the ANSELMANN 958 result. The GALLEX III result (14 runs) is 53.9 ± 10.6 ± 3.1 SNU, which is "15.8 SNU below but statistically compatible with the new combined result." The total run data, covering the period 14 May 1991 through 4 October 1995, are consistent with a ⁷¹Ge production rate constant in time, but "the confidence with which some kind of periodic or sporadic variability may be excluded has decreased as a result of the statistical departure of GALLEX III." HAMPEL 96 also reports the second calibration run using a strong ⁵¹Cr source. The result combined with the ANSELMANN 95 data was found to be 92 ± 8 for the (measured)/(expected) Cr induced ⁷¹Ge rate.

106 ABDURASHITOV 94 result is for a total of 15 runs from January 1990 through May 1992, using 30 tons of metallic gallium for the first 7 runs, increased to 57 tons for the rest of 8 runs. The first 5 runs in 1990 yielded 40+31+5 SNU which updates the ABAZOV 918 result

ABAZOV 918 result.

107 DAVIS 89 is the average from the ³⁷CL experiment at the Homestake Mine (HOME) from 1970–1988. Earlier averages are given in the references therein.

(F) Astrophysical neutrino observations

Neutrinos and antineutrinos produced in the atmosphere induce μ -like and e-like events in underground detectors. The ratio of the numbers of the two kinds of events is defined as μ/e . It has the advantage that that systematic effects, such as flux uncertainty, tend to cancel, for both experimental and theoretical values of the ratio. The "ratio of the ratios" of experimental to theoretical μ/e , $R(\mu/e)$, or that of experimental to theoretical μ/t total, $R(\mu/t)$ total = $\mu+e$, is reported below. If the actual value is not unity, the value obtained in a given experiment may depend on the experimental conditions.

$R(\mu/e) = (Measured Ratio \mu/e) / (Expected Ratio \mu/e)$

<u>VALUE</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u>

• • • • We do not use the following data for averages, fits, limits, etc. • • •

$0.72\pm0.19^{+0.05}_{-0.07}$	108 ALLISON	97 5OU2	Calorimeter
•.•.	109 FUKUDA	968 KAMI	Water Cerenkov
$1.00 \pm 0.15 \pm 0.08$	110 DAUM	95 FREJ	Calorimeter
$0.60^{+0.06}_{-0.05}\pm0.05$	111 FUKUDA	94 KAMI	sub-GeV
$0.57^{+0.08}_{-0.07} \pm 0.07$	112 FUKUDA	94 KAMI	multi-Gev
0.0.	113 RECKER ST	928 IMR	Water Cerenkov

 108 ALLISON 97 result is based on an exposure of 1.52 kton yr. ALLISON 97 also studied the background due to interaction of neutrons or photons produced by muon interactions in the rock surrounding the detector. This background is shown not to produce the low values of $R(\mu/e)$.

109 FUKUDA 968 studied neutron background in the atmospheric neutrino sample observed in the Kamlokande detector. No evidence for the background contamination was found.

110 DAUM 95 results are based on an exposure of 2.0 kton yr which includes the data used by BERGER 908. This ratio is for the contained and semicontained events. DAUM 95 also report $R(\mu/e) = 0.99 \pm 0.13 \pm 0.08$ for the total neutrino induced data sample which includes upward going stopping muons and horizontal muons in addition to the contained and semicontained events.

111 FUKUDA 94 result is based on an exposure of 7.7 kton yr and updates the HIRATA 92

111 FUKUDA 94 result is based on an exposure of 7.7 kton yr and updates the HIRATA 92 result. The analyzed data sample consists of fully contained e-like events with 0.1 $< p_e < 1.33 \text{ GeV/}c$ and fully-contained μ -like events with 0.2 $< p_{\mu} < 1.5 \text{ GeV/}c$.

112 FUKUDA 94 analyzed the data sample consisting of fully contained events with visible energy > 1.33 GeV and partially contained μ-like events.

113 BECKER-SZENDY 928 reports the fraction of nonshowering events (mostly muons from atomospheric neutrinos) as $0.36 \pm 0.02 \pm 0.02$, as compared with expected fraction $0.51 \pm 0.01 \pm 0.05$. After cutting the energy range to the Kamiokande limits, BEIER 92 finds $R(\mu/e)$ very close to the Kamiokande value.

$R(\nu_{\mu}) = (Measured Flux of \nu_{\mu}) / (Expected Flux of \nu_{\mu})$

	• • • •			
VALUE			<u>TECN</u>	COMMENT
• • • We do not use the	following data for averag	es, fit:	s, limits,	etc. • • •
$0.73 \pm 0.09 \pm 0.06$	114 AHLEN	95	MCRO	Streamer tubes
	¹¹⁵ CASPER	91	IMB	Water Cherenkov
	116 AGLIETTA	89	NUSX	
0.95 ± 0.22	117 BOLIEV	81		Baksan
0.62 ± 0.17	CROUCH	78		Case Western/UCI

 114 AHLEN 95 result is for all nadir angles. The lower cutoff on the muon energy is 1 GeV. The errors are statistical / systematic. The Monte Carlo flux error is ± 0.12 .

115 CASPER 91 correlates showering/nonshowering signature of single-ring events with parent atmospheric-neutrino flavor. They find nonshowering ($\approx \nu_{\mu}$ induced) fraction is $0.41 \pm 0.03 \pm 0.02$, as compared with expected 0.51 ± 0.05 (syst).

116 AGLIETTA 89 finds no evidence for any anomaly in the neutrino flux. They define $\rho=$ (measured number of ν_e 's)/(measured number of ν_μ 's). They report ρ (measured)= ρ (expected) = $0.96^{+}0.32^{-}0.28^{+}$

117 From this data BOLIEV 81 obtain the limit $\Delta(m^2) \le 6 \times 10^{-3} \ {\rm eV^2}$ for maximal mixing, $\nu_\mu \not\to \nu_\mu$ type oscillation.

$R(\mu/total) = (Measured Ratio \mu/total) / (Expected Ratio \mu/total)$

VALUE	DOCUMENT	ID TECN		
• • • We do not use th	e following data for aver-	ages, fits, limits	, etc. • • •	
$1.1^{+0.07}_{-0.12}\pm0.11$	118 CLARK	97 IMB	multi-GeV	
110				

118 CLARK 97 obtained this result by an analysis of fully contained and partially contained events in the IMB water-Cerenkov detector with visible energy > 0.95 GeV.

$\sin^2(2\theta)$ for given $\Delta(m^2)$ $(\nu_e \leftrightarrow \nu_\mu)$

For a review	v see BAHC	ALL 89.			
VALUE	CLX	DOCUMENT ID		<u>TECN</u>	COMMENT
• • • We do not	use the foll	owing data for	avera	ges, fits,	limits, etc. • • •
<0.5		CLARK			$\Delta(m^2) > 0.1 \text{ eV}^2$
>0.55	90 120	FUKUDA	94	KAMI	$\Delta(m^2) = 0.007 - 0.08 \text{ ev}^2$
<0.47	90 121	BERGER			$\Delta(m^2) > 1 \text{ eV}^2$
< 0.14	90	LOSECCO	87	IMB	$\Delta(m^2) = 0.00011 \text{ eV}^2$

119 CLARK 97 obtained this result by an analysis of fully contained and partially contained events in the IMB water-Cerenkov detector with visible energy > 0.95 GeV.

120 FUKUDA 94 obtained this result by a combined analysis of sub- and multi-GeV atmospheric neutrino events in Kamlokande.

121 BERGER 908 uses the Frejus detector to search for oscillations of atmospheric neutrinos. Bounds are for both neutrino and antinuetrino oscillations.

$\Delta(m^2)$ for $\sin^2(2\theta) = 1 (\nu_e \leftrightarrow \nu_\mu)$

VALUE (10-5 eV2)	CL%	DOCUMENT IL	<u> </u>	TECN
• • • We do not use th	e follow	ving data for avera	ges, fits	, limits, etc. • • •
<980		122 CLARK	97	IMB
$700 < \Delta(m^2) < 7000$	90	¹²³ FUKUDA	94	KAMI
<150	90	124 BERGER	90B	FREJ

122 CLARK 97 obtained this result by an analysis of fully contained and partially contained events in the IMB water-Cerenkov detector with visible energy > 0.95 GeV.

123 FUKUDA 94 obtained this result by a combined analysis of sub- and multi-GeV atmospheric neutrino events in Kamiokande.

124 BERGER 90B uses the Frejus detector to search for oscillations of atmospheric neutrinos. Bounds are for both neutrino and antinuetrino oscillations.

$\sin^2(2\theta)$ for given $\Delta(m^2)$ ($\overline{\nu}_e \leftrightarrow \overline{\nu}_\mu$)

VALUE (10^{-5} eV^2)	<u>CL%</u>	DOCUMENT ID		TECN	COMMENT
• • • We do not	use the follow	ing data for averag	es, fits	, limits,	etc. • • •
<0.9	99	125 SMIRNOV			$\Delta(m^2) > 3 \times 10^{-4} \text{ eV}^2$
<0.7	99	¹²⁵ SMIRNOV	94	THEO	$\Delta(m^2) < 10^{-11} \text{ eV}^2$

125 SMIRNOV 94 analyzed the data from SN 1987A using stellar-collapse models. They also give less stringent upper limits on $\sin^2 2\theta$ for $10^{-11} < \Delta(m^2) < 3 \times 10^{-7}$ eV² and $10^{-5} < \Delta(m^2) < 3 \times 10^{-4}$ eV². The same results apply to $\overline{\nu}_e \leftrightarrow \overline{\nu}_\tau$, ν_μ , and ν_τ .

$\sin^2(2\theta)$ for given $\Delta(m^2)$ $(\nu_{\mu} \leftrightarrow \nu_{\tau})$

VALUE	<u>CL%</u>	DOCUMENT ID	TECN	COMMENT
• • • We do	not use the	following data for	averages, flt	s, Ilmits, etc. • • •
<0.7		126 CLARK	97 IMB	$\Delta(m^2) > 0.1 \text{ eV}^2$
>0.65	90	¹²⁷ FUKUDA	94 KAMI	$\Delta(m^2) = 0.005 - 0.03 \text{ ev}^2$
>0.5				$\Delta(m^2) = 1-2 \times 10^{-4} \text{ eV}^2$
< 0.6	90	129 BERGER	90B FREJ	$\Delta(m^2) > 1 \text{ eV}^2$

126 CLARK 97 obtained this result by an analysis of fully contained and partially contained events in the IMB water-Cerenkov detector with visible energy > 0.95 GeV.

127 FUKUDA 94 obtained this result by a combined analysis of sub-and multi-GeV atmospheric neutrino events in Kamiokande.

128 BECKER-SZENDY 92 uses upward-going muons to search for atomospheric ν_{μ} oscillations. The fraction of muons which stop in the detector is used to search for deviations in the expected spectrum. No evidence for oscillations is found.

129 BERGER 90B uses the Frejus detector to search for oscillations of atmospheric neutrinos. Bounds are for both neutrino and antinuetrino oscillations.

$\Delta(m^2)$ for $\sin^2(2\theta) = 1 (\nu_{\mu} \leftrightarrow \nu_{\tau})$

VALUE (10-5 eV2)	CL%	DOCUMENT IL)	TECN
• • • We do not use the	ne follow	ving data for averag	ges, fits	, limits, etc. • •
<1500		130 CLARK	97	IMB
$500 < \Delta(m^2) < 2500$	90	¹³¹ FUKUDA	94	KAMI
< 350	90	132 BERGER	90R	FRE.t

- 130 CLARK 97 obtained this result by an analysis of fully contained and partially contained events in the IMB water-Cerenkov detector with visible energy > 0.95 GeV.
 131 FUKUDA 94 obtained this result by a combined analysis of sub-and multi-GeV atmos-
- oheric neutrino events in Kamiokande.
- 132 BERGER 908 uses the Frejus detector to search for oscillations of atmospheric neutrinos. Bounds are for both neutrino and antinuetrino oscillations.

$\Delta(\textit{m}^2) \text{ for } \sin^2(2\theta) = 1 \; (\nu_{\mu} \; \rightarrow \; \nu_{\text{S}}) \\ \nu_{\text{S}} \; \text{means} \; \nu_{\tau} \; \text{or any sterile (noninteracting)} \; \nu.$

VALUE (10 ⁻⁵ eV ²)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use	the followin	ng data for averag	ges, fits	, limits,	etc. • • •
<3000 (or <550)	90	133 OYAMA	89	KAMI	Water Cerenkov
< 4.2 or > 54.	90	BIONTA	88	IMB	Flux has ν_{μ} , $\overline{\nu}_{\mu}$, ν_{e} ,
					and 77

133 OYAMA 89 gives a range of limits, depending on assumptions in their analysis. They argue that the region $\Delta(m^2)=(100\text{--}1000)\times 10^{-5}~\text{eV}^2$ is not ruled out by any data for large mixing.

(G) Reactor $\overline{\nu}_e$ disappearance experiments

In most cases, the reaction $\overline{\nu}_e p \rightarrow e^+ n$ is observed at different distances from one or more reactors in a complex.

Events (Observed/Expected) from Reactor V. Experiments

VALUE	DOCUMENT ID		<u>TECN</u>	COMMENT
• • • We do not use th	e following data for average	s, fit	s, limits,	etc. • • •
$0.98 \pm 0.04 \pm 0.04$	134 APOLLONIO	98	CHOZ	Chooz reactors 1.1 km
$0.987 \pm 0.006 \pm 0.037$	135 GREENWOOD	96		Savannah River, 18.2 m
$1.055 \pm 0.010 \pm 0.037$	135 GREENWOOD	96		Savannah River, 23.8 m
$0.988 \pm 0.004 \pm 0.05$	ACHKAR	95	CNTR	Bugey reactor, 15 m
$0.994 \pm 0.010 \pm 0.05$	ACHKAR	95	CNTR	Bugey reactor, 40 m
$0.915 \pm 0.132 \pm 0.05$, ACHKAR	95	CNTR	Bugey reactor, 95 m
$0.987 \pm 0.014 \pm 0.027$	136 DECLAIS	94	CNTR	Bugey reactor, 15 m
$0.985 \pm 0.018 \pm 0.034$	KUVSHINN	91	CNTR	Rovno reactor
$1.05 \pm 0.02 \pm 0.05$	VUILLEUMIER	82		Gösgen reactor
$0.955 \pm 0.035 \pm 0.110$	137 KWON	81		$\overline{\nu}_e p \rightarrow e^+ n$
0.89 ±0.15	137 BOEHM	80		$\overline{\nu}_{e}p \rightarrow e^{+}n$
0.38 ±0.21	138,139 REINES	80		
0.40 ±0.22	138,139 REINES	80		
124				

- 134 APOLLONIO 98 search for neutrino oscillations at 1.1 km fixed distance from Chooz reactors. They use $\overline{\nu}_e \, \rho \to e^+ \, n$ in Gd-loaded scintillator target.
- 135 GREENWOOD 96 search for neutrino oscillations at 18 m and 24 m from the reactor at
- Savannah River.

 136 DECLAIS 94 result based on integral measurement of neutrons only. Result is ratio of measured cross section to that expected in standard V-A theory. Replaced by ACHKAR 95.

 137 KWON 81 represents an analysis of a larger set of data from the same experiment as
- 138 REINES 80 involves comparison of neutral- and charged-current reactions $\overline{\nu}_e d \rightarrow n p \overline{\nu}_e$ and $\overline{v}_e d \rightarrow nne^+$ respectively. Combined analysis of reactor \overline{v}_e experiments was
- performed by SILVERMAN 81. he two REINES 80 values correspond to the calculated $\overline{
 u}_e$ fluxes of AVIGNONE 80 and DAVIS 79 respectively.

$- \overline{\nu}_e \not\rightarrow \overline{\nu}_e -$

$\Delta(m^2)$ for $\sin^2(2\theta) = 1$

VALUE (eV ²)	CL%	DOCUMENT ID		TECN	COMMENT
< 0.0009	90	¹⁴⁰ APOLLONIO	98		Chooz reactors 1.1 km
• • • We do not	use the follow	ing data for average	s, fits	, limits,	etc. • • •
< 0.06	90	141 GREENWOOD	96		Savannah River
< 0.01	90	¹⁴² ACHKAR	95	CNTR	Bugey reactor
< 0.0075	90	¹⁴³ VIDYAKIN	94		Krasnoyark reactors
< 0.0083	90	¹⁴³ VIDYAKIN	90		Krasnoyark reactors
< 0.04	90	144 AFONIN	88	CNTR	Rovno reactor
< 0.014	68	145 VIDYAKIN	87		$\overline{\nu}_e p \rightarrow e^+ n$
< 0.019	90	146 ZACEK	86		Gösgen reactor
< 0.02	90	¹⁴⁷ ZACEK	85		Gösgen reactor
< 0.016	90	148 GABATHULEI	R 84		Gösgen reactor

- 140 APOLLONIO 98 search for neutrino oscillations at 1.1 km fixed distance from Chooz reactors. They use $\overline{\nu}_e p \rightarrow e^+ n$ in Gd-loaded scintillator target. This is the most sensitive search in terms of $\Delta(m^2)$ for $\overline{\nu}_e$ disappearance.
- 141 GREENWOOD 96 search for neutrino oscillations at 18 m and 24 m from the reactor at Savannah River by observing $\overline{\nu}_e p \to e^+ n$ in a Gd loaded scintillator target. Their
- region of sensitivity in $\Delta(m^2)$ and $\sin^2 2\theta$ is already excluded by ACHKAR 95. 142 ACHKAR 95 bound is for L=15, 40, and 95 m. 143 VIDYAKIN 94 bound is for L=57.0 m, 57.6 m, and 231.4 m. Supersedes VIDYAKIN 90. 144 AFONIN 86 and AFONIN 87 also give limits on $\sin^2(2\theta)$ for intermediate values of
- $\Delta(m^2)$. (See also KETOV 92). Supersedes AFONIN 87, AFONIN 86, AFONIN 85, AFONIN 83, and BELENKII 83.

 145 VIDYAKIN 87 bound is for L=32.8 and 92.3 m distance from two reactors.

 146 This bound is from data for L=37.9 m, 45.9 m, and 64.7 m.

 147 See the comment for ZACEK 85 in the section on $\sin^2(2\theta)$ below.

- 148 This bound comes from a combination of the VUILLEUMIER 82 data at distance 37.9 m and new data at 45.9 m.

$sin^2(2\theta)$ for "Large" $\Delta(m^2)$

VALUE	<u> </u>	DOCUMENT ID		TECN	COMMENT
<0.02	90	¹⁴⁹ ACHKAR	95	CNTR	For $\Delta(m^2) = 0.6 \text{ eV}^2$
	t use the follow	ing data for averages	, fit	s, limits,	etc. • • •
< 0.18	90	150 APOLLONIO	98	CHOZ	Chooz reactors 1.1 km
< 0.24	90	151 GREENWOOD	96		
< 0.04	90	151 GREENWOOD	96		For $\Delta(m^2) = 1.0 \text{ eV}^2$
< 0.087	68	152 VYRODOV	95	CNTR	For $\Delta(m^2) > 2 \text{ eV}^2$
< 0.15	90	¹⁵³ VIDYAKIN	94		For $\Delta(m^2) > 5.0 \times 10^{-2}$
<0.2	90	154 AFONIN	88	CNTR	eV^2 $\overline{\nu}_P p \to e^+ n$
< 0.14	68	¹⁵⁵ VIDYAKIN	87		$\overline{\nu}_e p \rightarrow e^+ n$
< 0.21	90	156 ZACEK	86		$\overline{\nu}_e p \rightarrow e^+ n$
< 0.19	90	¹⁵⁷ ZACEK	85		Gösgen reactor
< 0.16	90	158 GABATHULER	84		$\overline{\nu}_e p \rightarrow e^+ n$
					C.

- 149 ACHKAR 95 bound is from data for L=15, 40, and 95 m distance from the Bugey reactor. 150 APOLLONIO 98 search for neutrino oscillations at 1.1 km fixed distance from Chooz
- 151 GREENWOOD 96 search for neutrino oscillations at 18 m and 24 m from the reactor at Savannah River by observing $\overline{v}_e p \to e^+ n$ in a Gd loaded scintillator target. Their region of sensitivity in $\Delta(m^2)$ and $\sin^2 2\theta$ is already excluded by ACHKAR 95.
- 152 The VYRODOV 95 bound is from data for L=15 m distance from the Bugey-5 reactor.
- 153 The VIDYAKIN 94 bound is from data for L=57.0 m, 57.6 m, and 231.4 m from three reactors in the Krasnoyark Reactor complex.
- 154 Several different methods of data analysis are used in AFONIN 88. We quote the most stringent limits. Different upper limits on $\sin^2 2\theta$ apply at intermediate values of $\Delta(m^2)$. Supersedes AFONIN 87, AFONIN 85, and BELENKII 83.
- 155 VIDYAKIN 87 bound is for L = 32.8 and 92.3 m distance from two reactors.

 156 This bound is from data for L = 37.9 m, 45.9 m, and 64.7 m distance from Gosgen reactor. 157 ZACEK 85 gives two sets of bounds depending on what assumptions are used in the data analysis. The bounds in figure 3(a) of ZACEK 85 are progressively poorer for large $\Delta(m^2)$ whereas those of figure 3(b) approach a constant. We list the latter. Both sets of bounds use combination of data from 37.9, 45.9, and 64.7m distance from reactor. ZACEK 85 states "Our experiment excludes this area (the oscillation parameter region allowed by the Bugey data, CAVAIGNAC 84) almost completely, thus disproving the indications of neutrino oscillations of CAVAIGNAC 84 with a high degree of confidence."
- 158 This bound comes from a combination of the VUILLEUMIER 82 data at distance 37.9m from Gosgen reactor and new data at 45.9m.

(H) Accelerator neutrino appearance experiments

 $\nu_e \rightarrow \nu_\tau$ -

90

 $\Delta(m^2)$ for $\sin^2(2\theta) = 1$ VALUE (eV²) CL% DOCUMENT ID TECN COMMENT

USHIDA 86C EMUL FNAL 90 • • • We do not use the following data for averages, fits, limits, etc. • • • <44 90 TALEBZADEH 87 HLBC BEBC

$\sin^2(2\theta)$ for "Large" $\Delta(m^2)$

< 0.36

 SIN-[20] IG
 CL%
 DOCUMENT

 90
 159 USHIDA
 DOCUMENT ID TECN COMMENT 86C EMUL FNAL • • We do not use the following data for averages, fits, limits, etc. • • •

 159 USHIDA 86C published result is $\sin^2\!2 heta < 0.12$. The quoted result is corrected for a numerical mistake incurred in calculating the expected number of ν_e CC events, normalized to the total number of neutrino interactions (3886) rather than to the total number of u_{μ} CC events (1870).

TALEBZADEH 87 HLBC BEBC

$-\overline{\nu}_e \rightarrow \overline{\nu}_\tau -$

$\sin^2(2\theta)$ for "Large" $\Delta(m^2)$

20% DUC.... 160 FRITZE VALUE DOCUMENT ID TECN COMMENT 80 HYBR BEBC CERN SPS

 160 Authors give P($\nu_e \rightarrow ~ \nu_{ au}$) <0.35, equivalent to above limit.

$u_{\mu} \rightarrow \nu_{e}$

$\Delta(m^2) \text{ for } \sin^2(2\theta) = 1$

VALUE (eV ²)	CL%	DOCUMENT ID		TECN	COMMENT
< 0.09	90	ANGELINI	86	HLBC	BEBC CERN PS
• • • We do not		data for averages	, fits	, limits,	etc. • • •
<2.3	90 1	⁶¹ LOVERRE	96		CHARM/CDHS
< 0.9	90	VILAIN	94C	CHM2	CERN SPS
< 0.1	90	BLUMENFELD	89	CNTR	
<1.3	90	AMMOSOV	88	HLBC	SKAT at Serpukhov
< 0.19	90	BERGSMA	88	CHRM	
	1	⁶² LOVERRE	88	RVUE	
<2.4	90	AHRENS	87	CNTR	BNL AGS
<1.8	90	BOFILL	87	CNTR	FNAL
<2.2	90 1	⁶³ BRUCKER	86	HLBC	15-ft FNAL
< 0.43	90	AHRENS	85	CNTR	BNL AGS E734
< 0.20	90	BERGSMA	84	CHRM	
<1.7	90	ARMENISE	81	HLBC	GGM CERN PS
< 0.6	90	BAKER	81	HLBC	15-ft FNAL
<1.7	90	ERRIQUEZ	81	HLBC	BEBC CERN P\$
<1.2	95	BLIETSCHAU	78	HLBC	GGM CERN PS
<1.2	95	BELLOTTI	76	HLBC	GGM CERN PS

Massive Neutrinos and Lepton Mixing

161 LOVERRE 96 uses the charged-current to neutral-current ratio from the combined CHARM (ALLABY 86) and CDHS (ABRAMOWICZ 86) data from 1986.

162 LOVERRE 88 reports a less stringent, indirect limit based on theoretical analysis of neutral to charged current ratios.

163 15ft bubble chamber at FNAL.

$sin^2(2\theta)$	for	"Large"	Δ((m²))
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VALUE (units 10 ⁻³)	CL%		DOCUMENT ID		TECN	COMMENT
< 3.0	90	164	LOVERRE	96		CHARM/CDHS
< 2.5	90		AMMOSOV	88	HLBC	SKAT at Serpukhov
• • • We do not use the	following	g d	ata for averages	, fits	, limits,	etc. • • •
< 9.4	90		VILAIN	94C	CHM2	CERN SPS
< 5.6	90	165	VILAIN	94c	CHM2	CERN SPS
< 16	90		BLUMENFELD	89	CNTR	
< 8	90		BERGSMA	88	CHRM	$\Delta(m^2) \geq 30 \text{ eV}^2$
		166	LOVERRE	88	RVUE	, , –
< 10	90		AHRENS	87	CNTR	BNL AGS
< 15	90			87	CNTR	FNAL
< 20	90	167				BEBC CERN PS
20 to 40		168		86B	CNTR	$\Delta(m^2)\approx 5-10$
< 11	90	169	BRUCKER	86	HLBC	15-ft FNAL
< 3.4	90		AHRENS	85	CNTR	BNL AGS E734
<240	90		BERGSMA	84	CHRM	
< 10	90		ARMENISE	81	HLBC	GGM CERN PS
< 6	90		BAKER	81	HLBC	15-ft FNAL
< 10	90		ERRIQUEZ	81	HLBC	BEBC CERN PS
< 4	95		BLIETSCHAU	78	HLBC	GGM CERN PS
< 10	95		BELLOTTI	76	HLBC	GGM CERN PS

164 LOVERRE 96 uses the charged-current to neutral-current ratio from the combined CHARM (ALLABY 86) and CDHS (ABRAMOWICZ 86) data from 1986.

165 VILAIN 94c limit derived by combining the u_{μ} and $\overline{
u}_{\mu}$ data assuming CP conservation.

166 LOVERRE 88 reports a less stringent, Indirect limit based on theoretical analysis of neutral to charged current ratios.

¹⁶⁷ ANGELINI 86 limit reaches 13×10^{-3} at $\Delta(m^2) \approx 2 \text{ eV}^2$.

168 BERNARDI 86B is a typical fit to the data, assuming mixing between two species. As the authors state, this result is in conflict with earlier upper bounds on this type of neutrino oscillations.

169 15ft bubble chamber at FNAL.

$$- \overline{\nu}_{\mu} \rightarrow \overline{\nu}_{e} - - - - -$$

$\Delta(m^2)$ for $\sin^2(2\theta) = 1$

VALUE (eV ²)	CL%	DOCUMENT ID		TECN	COMMENT
<0.14	90	170 FREEDMAN	93	CNTR	LAMPF
• • • We do not	use the follow	ing data for average	s, fits	i, limits,	etc. • • •
0.05-0.08	90	171 ATHANASSO.	96	LSND	LAMPF
0.048-0.090	80	172 ATHANASSO.	95		
< 0.07	90	173 HILL	95		
<0.9	90	VILAIN	94C	CHM ₂	CERN SPS
<3.1	90	BOFILL	87	CNTR	FNAL
<2.4	90	TAYLOR	83	HLBC	15-ft FNAL
< 0.91	90	174 NEMETHY	81B	CNTR	LAMPF
<1	95	BLIETSCHAU	78	HLBC	GGM CERN PS

170 FREEDMAN 93 is a search at LAMPF for $\overline{\nu}_e$ generated from any of the three neutrino types ν_μ , $\overline{\nu}_\mu$, and ν_e which come from the beam stop. The $\overline{\nu}_e$'s would be detected by the reaction $v_e p \rightarrow e^+ n$. FREEDMAN 93 replaces DURKIN 88.

 171 ATHANASSOPOULOS 96 is a search for $\overline{
u}_e$ 30 m from LAMPF beam stop. Neutrinos originate mainly from π^+ decay at rest. $\overline{\nu}_e$ could come from either $\overline{\nu}_\mu \to \overline{\nu}_e$ or $\nu_e \to \overline{\nu}_e$; our entry assumes the first interpretation. They are detected through $\overline{\nu}_e p \to 0$ e⁺n (20 MeV <E_{e+} <60 MeV) in delayed coincidence with $np \rightarrow d\gamma$. Authors observe 51 \pm 20 \pm 8 total excess events over an estimated background 12.5 \pm 2.9. ATHANASSOPOULOS 96B is a shorter version of this paper.

ATHANASSOPOULOS 968 is a shorter version of this paper.

172 ATHANASSOPOULOS 95 error corresponds to the 1.6 σ band in the plot. The expected background is 2.7 ± 0.4 events. Corresponds to an oscillation probability of $(0.34 + 0.20 \pm 0.07)\%$. For a different interpretation, see HILL 95. Replaced by ATHANASSOPOULOS 96.

173 HILL 95 is a report by one member of the LSND Collaboration, reporting a different conclusion from the analysis of the data of this experiment (see ATHANASSOPOULOS 95). Contrary to the rest of the LSND Collaboration, Hill finds no evidence for the neutrino oscillation.

oscillation $\overline{\nu}_{\mu} \rightarrow \ \overline{\nu}_{e}$ and obtains only upper limits.

¹⁷⁴ In reaction $\vec{\nu}_e p \rightarrow e^+ n$.

$\sin^2(2\theta)$ for "Large" $\Delta(m^2)$

VALUE	<u>ci%</u>	DOCUMENT ID		<u>TECN</u>	COMMENT
<0.004	95	BLIETSCHAU	78	HLBC	GGM CERN PS
• • We do not use the	ne folloy	ving data for average	s, fits	, limits,	etc. • • •
0.0062 ± 0.0024 ± 0.001	.0	175 ATHANASSO.	96	LSND	LAMPF
0.003-0.012	80	176 ATHANASSO.	95		
< 0.006	90	¹⁷⁷ HILL	95		
<4.8	90	VILAIN	94C	CHM ₂	CERN SPS
<5.6	90	178 VILAIN	94C	CHM ₂	CERN SPS
<0.024	90	¹⁷⁹ FREEDMAN	93	CNTR	LAMPF
<0.04	90	BOFILL	87	CNTR	FNAL
<0.013	90	TAYLOR	83	HLBC	15-ft FNAL
<0.2	90	180 NEMETHY	81B	CNTR	LAMPF

 175 ATHANASSOPOULOS 96 reports (0.31 \pm 0.12 \pm 0.05)% for the oscillation probability; the value of $\sin^2 2\theta$ for large $\Delta(m^2)$ should be twice this probability. See footnote in preceeding table for further details, and see the paper for a plot showing allowed regions.

 176 ATHANASSOPOULOS 95 error corresponds to the 1.6σ band in the plot. The ex-

pected background is 2.7 ± 0.4 events. Corresponds to an oscillation probability of (0.34 + 0.20 -0.18 ± 0.07)%. For a different interpretation, see HILL 95. Replaced by ATHANASSOPOULOS 96.

177 HILL 95 is a report by one member of the LSND Collaboration, reporting a different conclusion from the analysis of the data of this experiment (see ATHANASSOPOULOS 95). Contrary to the rest of the LSND Collaboration, Hill finds no evidence for the neutrino oscillation 31. — 32. and obtains only limite. oscillation $\overline{
u}_{\mu}
ightarrow \overline{
u}_{e}$ and obtains only upper limits.

178 VILAIN 94C limit derived by combining the u_{μ} and $\overline{\nu}_{\mu}$ data assuming CP conservation.

179 FREEDMAN 93 is a search at LAMPF for $\overline{\nu}_e$ generated from any of the three neutrino types $\nu_\mu, \, \overline{\nu}_\mu$, and ν_e which come from the beam stop. The $\overline{\nu}_e$'s would be detected by the reaction $\overline{\nu}_e p \rightarrow e^+ n$. FREEDMAN 93 replaces DURKIN 88.

180 in reaction $\vec{v}_e p \rightarrow e^+ n$.

$$- \nu_{\mu}(\overline{\nu}_{\mu}) \rightarrow \nu_{e}(\overline{\nu}_{e})$$
 $---$

$\Delta(m^2) \text{ for } \sin^2(2\theta) = 1$

VALUE (eV ²)	CL%	DOCUMENT ID		TECN	COMMENT
<0.075	90	BORODOV	92	CNTR	BNL E776
• • • We do not use the	following	data for averages	i, fits	i, limits,	etc. • • •
<1.6	90 18	¹ ROMOSAN	97	CCFR	FNAL

 181 ROMOSAN 97 uses wideband beam with a 0.5 km decay region.

$\sin^2(2\theta)$ for "Large" $\Delta(m^2)$

VALUE (units 10-3)	CL%	DOCUMENT ID		TECN	COMMENT
<1.8	90	182 ROMOSAN	97	CCFR	FNAL
• • • We do not use	e the follow	ving data for averages	i, fit	s, limits,	etc. • • •
<3.8	90	183 MCFARLAND	95	CCFR	FNAL
<3	90	BORODOV	92	CNTR	BNL E776

182 ROMOSAN 97 uses wideband beam with a 0.5 km decay region.

183 MCFARLAND 95 state that "This result is the most stringent to date for 250< $\Delta(m^2)$ <450 ev² and also excludes at 90%CL much of the high $\Delta(m^2)$ region favored by the recent LSND observation." See ATHANASSOPOULOS 95 and ATHANASSOPOUL

 $-\nu_{\mu} \rightarrow \nu_{\tau}$

$\Delta(m^2)$ for $\sin^2(2\theta) = 1$

VALUE (eV2)	CL%	DOCUMENT ID		TECN	COMMENT	
< 0.9	90	USHIDA	86C	EMUL	FNAL	
• • • We do not	t use the following	g data for average	s, fits	, limits,	etc. • • •	
< 3.3	90 ¹	84 LOVERRE	96		CHARM/CDHS	
< 1.4	90	MCFARLAND	95	CCFR	FNAL	
< 4.5	90	BATUSOV	90B	EMUL	FNAL	
<10.2	90	BOFILL	87	CNTR	FNAL	
< 6.3	90	BRUCKER	86	HLBC	15-ft FNAL	
< 4.6	90	ARMENISE	81	HLBC	GGM CERN SPS	
< 3	90	BAKER	81	HLBC	15-ft FNAL	
< 6	90	ERRIQUEZ	81	HLBC	BEBC CERN SPS	
< 3	90	USHIDA	81	EMUL	FNAL	

184 LOVERRE 96 uses the charged-current to neutral-current ratio from the combined CHARM (ALLABY 86) and CDHS (ABRAMOWICZ 86) data from 1986.

$\sin^2(2\theta)$ for "Large" $\Delta(m^2)$

VALUE	<u>CL%</u>	DOCUMENT ID		TECN	COMMENT
<0.004	90	USHIDA	86C	EMUL	FNAL
	use the followi	ng data for average	s, fits	, Ilmits,	etc. • • •
< 0.006	90	185 LOVERRE	96		CHARM/CDHS
<0.0081	90	MCFARLAND	95	CCFR	FNAL
<0.06	90	BATUSOV	90B	EMUL	FNAL
<0.34	90	BOFILL	87	CNTR	FNAL
<0.088	90	BRUCKER	86	HLBC	15-ft FNAL
<0.11	90	BALLAGH	84	HLBC	15-ft FNAL
<0.017	90	ARMENISE	81	HLBC	GGM CERN SPS
<0.06	90	BAKER	81	HLBC	15-ft FNAL
<0.05	90	ERRIQUEZ	81	HLBC	BEBC CERN SPS
<0.013	90	IISHIDA	81	FMUI	FNAI

185 LOVERRE 96 uses the charged-current to neutral-current ratio from the combined CHARM (ALLABY 86) and CDHS (ABRAMOWICZ 86) data from 1986.

$- \overline{\nu}_{\mu} \rightarrow \overline{\nu}_{\tau} -$ A (-2) 6-- -1-2(00) 1

W(m_) for su	-(20) = 1					
VALUE (eV2)	CL%	DOCUMENT ID		TECN	COMMENT	
<2.2	90	ASRATYAN	81	HLBC	FNAL	
• • • We do no	ot use the following	g data for average	s, fit	s, Ilmits,	etc. • • •	
<1.4	90	MCFARLAND	95	CCFR	FNAL	
<6.5	90	BOFILL	87	CNTR	FNAL	
<7.4	90	TAYLOR	83	HLBC	15-ft FNAL	

$\sin^2(2\theta)$ for "Large" $\Delta(m^2)$ DOCUMENT ID TECN COMMENT ASRATYAN 81 HLBC FNAL VALUE CL% × 10⁻² <4.4 90 • • • We do not use the following data for averages, fits, limits, etc. • • < 0.0081 MCFARLAND 95 CCFR FNAL < 0.15 90 BOFILL 87 CNTR FNAL × 10⁻² 90 **TAYLOR** 83 HLBC 15-ft FNAL <8.8 $\nu_{\mu}(\overline{\nu}_{\mu}) \rightarrow \nu_{\tau}(\overline{\nu}_{\tau})$ $\Delta(m^2)$ for $\sin^2(2\theta) = 1$ DOCUMENT ID TECN COMMENT VALUE (eV2) CL% 186 GRUWE 93 CHM2 CERN SPS <1.5 90

186 GRUWE 93 is a search using the CHARM II detector in the CERN SPS wide-band neutrino beam for $\nu_{\mu} \rightarrow \nu_{\tau}$ and $\overline{\nu}_{\mu} \rightarrow \overline{\nu}_{\tau}$ oscillations signalled by quasi-elastic ν_{τ} and $\overline{\nu}_{\tau}$ interactions followed by the decay $\tau \rightarrow \nu_{\tau} \pi$. The maximum sensitivity in $\sin^2 2\theta$ (< 6.4 × 10⁻³ at the 90% CL) is reached for $\Delta(m^2) \simeq 50 \text{ eV}^2$.

$\sin^2(2\theta)$ for "Large" $\Delta(m^2)$

VALUE (units 10 ⁻³)	CL%	DOCUMENT ID		TECN	COMMENT	
<8	90	187 GRUWE	93	CHM2	CERN SPS	

187 GRUWE 93 is a search using the CHARM II detector in the CERN SPS wide-band neutrino beam for $\nu_{\mu} \rightarrow \nu_{\tau}$ and $\overline{\nu}_{\mu} \rightarrow \overline{\nu}_{\tau}$ oscillations signalled by quasi-elastic ν_{τ} and $\overline{\nu}_{\tau}$ interactions followed by the decay $\tau \rightarrow \nu_{\tau}\pi$. The maximum sensitivity in $\sin^2 2\theta$ (< 6.4 × 10⁻³ at the 90% CL) is reached for $\Delta(m^2) \simeq 50 \text{ eV}^2$.

$$-- \nu_e \rightarrow (\bar{\nu}_e)_L$$
 $---$

This is a limit on lepton family-number violation and total lepton-number violation. $(\overline{\nu}_e)_L$ denotes a hypothetical left-handed $\overline{\nu}_e$. The bound is quoted in terms of Δ (m^2) , $\sin(2\theta)$, and α , where α denotes the fractional admixture of (V+A) charged current.

$\alpha\Delta(m^2)$ for $\sin^2(2\theta)=1$

VALUE (eV ²)	CL%	DOCUMENT ID	TECN	COMMENT
<0.14	90	188 FREEDMAN 9	3 CNTR	LAMPF
• • • We do not use the	follow	ing data for averages, f	its, limits	etc. • • •
<7	90	189 COOPER 8	2 HLBC	BEBC CERN SPS

188 FREEDMAN 93 is a search at LAMPF for $\overline{\nu}_e$ generated from any of the three neutrino types $\nu_\mu, \overline{\nu}_\mu$, and ν_e which come from the beam stop. The $\overline{\nu}_e$'s would be detected by the reaction $\overline{\nu}_e p \to e^+ n$.

 189 COOPER 82 states that existing bounds on V+A currents require lpha to be small.

$\alpha^2 \sin^2(2\theta)$ for "Large" $\Delta(m^2)$

VALUE	CLZ	DUCUMENT ID		TELN	COMMENT	
<0.032	90	¹⁹⁰ FREEDMAN	93	CNTR	LAMPF	
• • • We do not use the	follow	ing data for averages	, fits	s, limits,	etc. • • •	
< 0.05	90	191 COOPER	82	HLBC	BEBC CERN SPS	í

¹⁹⁰ FREEDMAN 93 is a search at LAMPF for $\overline{\nu}_e$ generated from any of the three neutrino types ν_μ , $\overline{\nu}_\mu$, and ν_e which come from the beam stop. The $\overline{\nu}_e$'s would be detected by the reaction $\overline{\nu}_e p \rightarrow e^+ n$.

¹⁹¹COOPER 82 states that existing bounds on V+A currents require α to be small.

$$--- \nu_{\mu} \rightarrow (\overline{\nu}_{e})_{L}$$
 $----$

See note above for $u_e
ightarrow (\overline{
u}_e)_L$ limit

$\alpha\Delta(m^2)$ for $\sin^2(2\theta)=1$

VALUE (eV2)	<u>CL%</u>	DOCUMENT ID		TECN	COMMENT
<0.16	· 90	¹⁹² FREEDMAN	93	CNTR	LAMPF
• • • We do not i	use the follow	ing data for average	es, fits	, limits,	etc. • • •
<0.7	90	193 COOPER	82	HLBC	BEBC CERN SPS

¹⁹² FREEDMAN 93 is a search at LAMPF for $\overline{\nu}_e$ generated from any of the three neutrino types ν_μ , $\overline{\nu}_\mu$, and ν_e which come from the beam stop. The $\overline{\nu}_e$'s would be detected by the reaction $\overline{\nu}_e p \rightarrow e^+ n$. The limit on $\Delta(m^2)$ is better than the CERN BEBC experiment, but the limit on $\sin^2\theta$ is almost a factor of 100 less sensitive.

 193 COOPER 82 states that existing bounds on V+A currents require lpha to be small.

$\alpha^2 \sin^2(2\theta)$ for "Large" $\Delta(m^2)$

VALUE	CL%	DOCUMENT ID	TECN	COMMENT	
< 0.001	90	194 COOPER	82 HLBC	BEBC CERN SPS	
• • • We do not u	ise the follow	ing data for averag	es, fits, limits	, etc. • • •	
< 0.07	90	195 FREEDMAN	93 CNTR	LAMPE	

194 COOPER 82 states that existing bounds on V+A currents require α to be small. 195 FREEDMAN 93 is a search at LAMPF for $\overline{\nu}_e$ generated from any of the three neutrino types ν_μ , $\overline{\nu}_\mu$, and ν_e which come from the beam stop. The $\overline{\nu}_e$'s would be detected by the reaction $\overline{\nu}_e \, p \to e^+ \, n$. The limit on $\Delta (m^2)$ is better than the CERN BEBC experiment, but the limit on $\sin^2\theta$

(i) Disappearance experiments with accelerator & radioactive source neutrinos $\nu_e \not\rightarrow \nu_e - \nu_e$

$\Delta(m^2)$ for $\sin^2(2\theta) =$	= 1				
VALUE (eV ²)	CL%	DOCUMENT ID		TECN	COMMENT
< 0.17	90	196 BAHCALL	95	THEO	

V 0.21	. 70	DATICALL	73	THEO	
 • • We do not ι 	ise the follow	ving data for averag	es, fits	, limits,	etc. • • •
<40	90	197 BORISOV	96	CNTR	IHEP-JINR detector
<14.9	90	BRUCKER	86	HLBC	15-ft FNAL
< 8	90	BAKER	81	HLBC	15-ft FNAL
<56	90	DEDEN	81	HLBC	BEBC CERN SPS
<10	90	ERRIQUEZ	81	HLBC	BEBC CERN SPS
<2.3 OR >8	90	NEMETHY	818	CNTR	LAMPE

 196 BAHCALL 95 analyzed the GALLEX 51 Cr calibration source experiment (ANSELMANN 95). They also gave a 95% CL limit of $<0.19\ eV^2.$

197 BORISOV 96 exclusion curve extrapolated to obtain this value; however, it does not have the right curvature in this region.

$\sin^2(2\theta)$ for "Large" $\Delta(m^2)$

VALUE <7 × 10 ^{−2}	<u>CL%</u> 90	DOCUMENT ID		TECN HI RC	COMMENT BEBC CERN SPS
		wing data for averag			
<0.115	90	199 BORISOV	96	CNTR	$\Delta(m^2) = 175 \text{ eV}^2$
<0.38	90	200 BAHCALL	95	THEO	51 Cr source
<0.54	90	BRUCKER	86	HLBC	15-ft FNAL
<0.6	90	BAKER	81	HLBC	15-ft FNAL
<0.3	90	198 DEDEN	81	HLBC	BEBC CERN SPS

198 Obtained from a Gaussian centered in the unphysical region.

 199 BORISOV 96 sets less stringent limits at large $\Delta(m^2)$, but exclusion curve does not have clear asymptotic behavior.

200 BAHCALL 95 analyzed the GALLEX ⁵¹Cr calibration source experiment (ANSEL-MANN 95). They also gave a 95% CL limit of < 0.45.</p>

___ ν_μ μ ν_μ ____

$\Delta(m^2) \text{ for } \sin^2(2\theta) = 1$

These experiments also allow sufficiently large $\Delta(m^2)$.

VALUE (eV2)	CL%	DOCUMENT ID		TECN	COMMENT	
<0.23 OR >1500 Ol	JR LIMIT					
<0.23 OR >100	90	DYDAK	84	CNTR		
<13 OR >1500	90	STOCKDALE	84	CNTR		
 • We do not use 	the following	ng data for average	s, fit	s, limits,	etc. • • •	
< 0.29 OR >22	90	BERGSMA	88	CHRM		
<7	90	BELIKOV	85	CNTR	Serpukhov	
<8.0 OR >1250	90	STOCKDALE	85	CNTR		
<0.29 OR >22	90	BERGSMA	84	CHRM		
<8.0	90	BELIKOV	83	CNTR		

$\sin^2(2\theta)$ for $\Delta(m^2) = 100 \mathrm{eV}^2$

VALUE	<u>CL%</u>	DOCUMENT ID		TECN	COMMENT
< 0.02	90	²⁰¹ STOCKDALE	85	CNTR	FNAL
• • • We do not	use the follow	ing data for average	s, fit	s, limits,	etc. • • •
< 0.17	90	²⁰² BERGSMA	88	CHRM	
< 0.07	90	²⁰³ BELIKOV		CNTR	Serpukhov
<0.27	90	²⁰² BERGSMA	84	CHRM	CERN PS
<0.1	90	²⁰⁴ DYDAK			CERN PS
< 0.02	90	²⁰⁵ STOCKDALE	84	CNTR	FNAL
< 0.1	90	²⁰⁶ BELIKOV	83	CNTR	Serpukhov

²⁰¹ This bound applies for $\Delta(m^2) = 100 \text{ eV}^2$. Less stringent bounds apply for other $\Delta(m^2)$; these are nontrivial for $8 < \Delta(m^2) < 1250 \text{ eV}^2$.

these are nontrivial for $8 < \Delta(m^2) < 1250 \text{ eV}^2$.

202 This bound applies for $\Delta(m^2) = 0.7-9$. eV². Less stringent bounds apply for other $\Delta(m^2)$: these are nontrivial for $0.28 < \Delta(m^2) < 22 \text{ eV}^2$.

 $\Delta(m^2)$, these are nontrivial for $0.28 < \Delta(m^2) < 22 \text{ eV}^2$.

203 This bound applies for a wide range of $\Delta(m^2) > 7 \text{ eV}^2$. For some values of $\Delta(m^2)$, the value is less stringent; the least restrictive, nontrivial bound occurs approximately at $\Delta(m^2) = 300 \text{ eV}^2$ where $\sin^2(7\theta) < 0.13$ at C = 90%.

 $\Delta(m^2) = 300 \text{ eV}^2$ where $\sin^2(2\theta) < 0.13$ at CL = 90%. 204 This bound applies for $\Delta(m^2) = 1.-10$. eV². Less stringent bounds apply for other $\Delta(m^2)$; these are nontrivial for $0.23 < \Delta(m^2) < 90 \text{ eV}^2$

 $\Delta(m^2)$; these are nontrivial for 0.23 $< \Delta(m^2) < 90 \text{ eV}^2$. 205 This bound applies for $\Delta(m^2) = 110 \text{ eV}^2$. Less stringent bounds apply for other $\Delta(m^2)$; these are nontrivial for 13 $< \Delta(m^2) < 1500 \text{ eV}^2$.

206 Bound holds for $\Delta(m^2) = 20$ –1000 eV².

—— ν_μ ≁ ν_μ ——

$\Delta(m^2) \text{ for } \sin^2(2\theta) = 1$

VALUE (eV ²)	CL%		TECN		
<7 OR >1200 OUR	LIMIT				
<7 OR >1200	90	STOCKDALE	85	CNTR	

$\sin^2(2\theta)$ for 190 eV² $< \Delta(m^2) < 320$ eV²

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
<0.02	90	207 STOCKDALE 85	CNTR	FNAL

207 This bound applies for $\Delta(m^2)$ between 190 and 320 or = 530 eV². Less stringent bounds apply for other $\Delta(m^2)$; these are nontrivial for $7 < \Delta(m^2) < 1200 \text{ eV}^2$.

Massive Neutrinos and Lepton Mixing

REFEREN	NCI	ES FOR Searches	for Massive Neutrinos and Lepton Mixing	MORI ABAZOV	92B 91B	PL B289 463 PRL 67 3332	+Hikasa, Nojiri, Oyama+ (KAM2 Collab.) +Anosov, Faizov+ (SAGE Collab.)
ACKERSTAFF 98	8C	EPJ C1 45	K. Ackerstaff+ (OPAL Collab.)	ABREU ALEXANDER	91F	NP B367 511	+Adam, Adami, Adye, Akesson+ (DELPHI Collab.)
APOLLONIO 98	8	PL B420 397	M. Apollonio+ (CHOOZ Collab.)	ALEXANDER AVIGNONE	91F 91	ZPHY C52 175 PL B256 559	+Allison, Allport, Anderson, Arcelli+ (OPAL Collab.) +Brodzinski, Guerard+ (SCUC, PNL, ITEP, YERE)
ABREU 97 Also 97	71 7L	ZPHY C74 57 ZPHY C75 580 erratum	+Adam, Adye, Ajinenko, Alekseev+ (DELPHI Collab.) Abreu, Adam, Adye, Ajinenko+ (DELPHI Collab.)	BELLOTTI	91	PL B266 193	+Cremonesi, Fiorini, Gervasio+ (MILA, INFN)
	7P	PL B412 189	+Adriani, Aguilar-Benitez, Ahlen+ (L3 Collab.)	CASPER DELEENER	91 91	PRL 66 2561 PR D43 3611	+Becker-Szendy, Bratton, Cady+ De Leener-Rosier, Deutsch+ (LOUV, ZURI, LAUS)
ALLISON 97 ALSTON 97		PL B391 491 - PR C55 474	+Ainer, Ayres, Barrett+ (Soudan 2 Collab.) Alston-Garnjost, Dougherty+ (LBL, MTHO, UNM, INEL)	EJIRI	91	PL B258 17	+Fushimi, Kamada, Kinoshita+ (OSAK) +Jelley (OXF)
BARABASH 97	7	ZPHY A357 351	+Gurriaran, Hubert, Hubert, Umatov (ITEP, BCEN)	HIME HIRATA	91 91	PL B257 441 PRL 66 9	+Inoue, Kajita, Kihara+ (Kamiokande II Collab.)
BAUDIS 97 CLARK 97		PL B407 219 PRL 79 345 -	L. Baudis+ (MPIH, KIAE, SASSO) +Becker-Szendy, Bratton, Brealt+ (IMB Collab.)	KUVSHINN	91 91	JETPL 54 253	A.A. Kuvshinnikov+ (KIAE) (MISSR)
DESILVA 97	7	PR C56 2451	De Silva, Moe, Nelson, Vient (UCI)	MANUEL NORMAN	91	JP G17 5221 JPG 17 5291	+Sur, Lesko+ (LBL)
GUENTHER 97 ROMOSAN 97			+Hellmig+ (MPIH, KIAE, SASSO) +Arroyo, de Barbaro, de Barbaro+ (CCFR Collab.)	REUSSER SATO	91 91	PL B255 143 PR D44 2220	+Treichel, Boehm, Broggini+ (NEUC, CIT, PSI) +Hirata, Kajita, Kifune, Kihara+ (Kamioka Collab.)
		PL B377 304 NPBPS 48 238	+Adam, Adriani, Aguilar-Benitez+ (L3 Collab.) Alessandrello, Brofferio, Bucci+ (MILA, SASSO)	SUHONEN	91	NP A535 509	+Khadkikar, Faessler (JYV, AHMED, TUBIN)
ALEXANDER 96	6P	PL B385 433 -	+Allison, Altekamp, Ametewee+ (OPAL Collab.)	TOMODA TURKEVICH	91 91	RPP 54 53 PRL 67 3211	T. Tomoda +Economou, Cowan (CHIC, LANL)
ARNOLD 96 ATHANASSO 96		ZPHY C72 239 PR C54 2685	R. Arnold+ (BCEN, CAEN, JINR+) Athanassopoulos, Auerbach, Burman+ (LSND Collab.)	YOU	91	PL B265 53	+Zhu, Lu+ (BHEP, CAST+)
ATHANASSO 96	16B	PRL 77 3082	Athanassopoulos, Auerbach, Burman+ (LSND Collab.)	ADEVA AKRAWY	90S 90L	PL B251 321 PL B247 448	+Adriani, Aguilar-Benitez, Akbari+ (L3 Collab.) +Alexander, Allison, Aliport+ (OPAL Collab.)
BALYSH 96 BORISOV 96	16 16		+De Silva, Lebedev, Lou, Moe+ (KIAE, UCI, CIT) +Chernichenko, Chukin, Goryachev+ (SERP, JINR)	BATUSOV	90B	ZPHY C48 209	+Bunyatov, Kuznetsov, Pozharova+ (JINR, ITEP, SERP)
BRYMAN 96	16	PR D53 558 -	+Numao (TRIU)	BERGER BURCHAT	90B 90	PL B245 305 PR D41 3542	+Froehlich, Moench, Nisius+ (FREJUS Collab.) +King, Abrams, Adolphsen+ (Mark II Collab.)
BUSKULIC 96 EJIRI 96		PL B384 439 NP A611 85	+De Bonis, Decamp, Ghez+ (ALEPH Collab.) H. Ejiri+ (OSAK)	DECAMP	90F 90	PL B236 511 PRL 65 1297	+Deschizeaux, Lees, Minard+ +Inoue, Kajita+ (ALEPH Collab.) (Kamiokande II Collab.)
FUKUDA 96 FUKUDA 96	96	PRL 77 1683	+Hayakawa, Inoue, Ishihara+ (Kamiokande Collab.) +Hayakawa, Inoue, Ishihara+ (Kamiokande Collab.)	HIRATA JUNG	90	PRL 64 1091	+Van Kooten, Abrams, Adolphsen+ (Mark II Collab.)
GREENWOOD 96	96	PR D53 6054	+Kropp, Mandelkern, Nakamura+ (UCI, SVR, SCUC)	KOPEIKIN	90	JETPL 51 86 Translated from ZETFF	+Mikaziyan, Fayans (KIAE)
HAMPEL 96 LOVERRE 96		PL B388 384 PL B370 156	+Heusser, Kiko, Kirsten+ (GALLEX Collab.) P.F. Loverre	MILEY	90	PRL 65 3092	+Avignone, Brodzinski, Collar, Reeves (SCUC, PNL)
TAKAOKA 96	96	PR C53 1557 -	+Motomura, Nagao (KYUSH, OKAY)	STAUDT VASENKO	90 90	EPL 13 31 MPL A5 1299	+Kirpichnikov, Kuznetsov, Starostin (ITEP, YERE)
WIETFELDT 96 ACHKAR 95			+Norman (LBL) +Aleksan+ (SING, SACLD, CPPM, CDEF, LAPP)	VIDYAKIN	90	JETP 71 424 Translated from ZETF	+Vyrodov, Gurevich, Koslov+ (KIAE)
AHLEN 95	95	PL B357 481	+Ambrosio, Antolini, Auriemma+ (MACRO Collab.)	ABRAMS	89C	PRL 63 2447	+Adolphsen, Averill, Ballam+ (Mark II Collab.)
ANSELMANN 95 ANSELMANN 95			+Fockenbrock, Hampel, Heusser+ (GALLEX Collab.) +Hampel, Heusser, Kike+ (GALLEX Collab.)	AGLIETTA BAHCALL	89 89	EPL 8 611 Neutrino Astrophysics,	+Battistoni, Bellotti+ (FREJUS Collab.) Cambridge Univ. Press (IAS)
ARMBRUSTER 95 ARNOLD 95			+Blair, Bodmann, Booth+ (KARMEN Collab.) +Caurier, Guyonnet, Linck+ (NEMO Collab.)	BLUMENFELD		PRL 62 2237	+Chi, Čhichura, Chien+ (COLU, ILL, JHU) +Mann, Wolfenstein (BNL, PENN, CMU)
		Translated from ZETFP	61 168.	DAVIS ENQVIST	89 89	ARNPS 39 467 NP B317 647	+Kainulainen, Maalampi (HELS)
ATHANASSO 99 BAHCALL 99		PRL 75 2650 PL B348 121	Athanassopoulos, Auerbach+ (LSND Collab.) +Krastev, Lisi (IAS)	FISHER MUTO	89 89	PL B218 257 ZPHY A334 187	+Boehm, Bovet, Egger+ (CIT, NEUC, PSI) +Bender, Klapdor (TINT, MPIH)
BAHRAN 95	95	PL B354 481	+Kalbfleisch (OKLA)	OYAMA	89	PR D39 1481	+Hirata, Kajita, Kifune+ (Kamiokande II Collab.)
BALYSH 99 BARABASH 99		PL B345 408	+Avignone+ (ITEP, SCUC, PNL, MINN, LEBD)	SHAW AFONIN	89 88	PRL 63 1342 JETP 67 213	+Blanis, Bodek, Budd+ (AMY Collab.) +Ketov, Kopeikin, Mikaelyan+ (KIAE)
BILGER 99 BURACHAS 99		PL B363 41 PAN 58 153	+Clement, Denig, Fohl+ (TUBIN, KARLE, PSI) +Danevich, Zdesenko, Kobychev+ (KIEV)	AKERLOF	88	Translated from ZETF	94 1, issue 2.
		Translated from YAF 58	195.	AMMOSOV	88	PR D37 577 ZPHY C40 487	+Chapman, Errede, Ken+ (HRS Collab.) +Belikov+ (SKAT Collab.)
		PR D51 2090	+Georgadze, Kobychev, Kropivyansky+ (KIEV) +Eschbach, Hubert, Isaac, Isac+ (NEMO Collab.)	BERGSMA BERNARDI	88 88	ZPHY C40 171 PL B203 332	+Dorenbosch, Nieuwenhuis+ (CHARM Collab.) +Carugno, Chauveau+ (PARIN, CERN, INFN, ATEN)
			+Rhode, Bareyre, Barloutaud+ (FREJUS Collab.) +Frosch, Hajdas, Janousch+ (PSI, VIRG)	BIONTA	88	PR D38 768	+Biewitt, Bratton, Casper+ (IMB Collab.)
EJIRI 9	95	JPSJ 64 339	+Fushmii, Hazama, Kawasaki+ (OSAK, KIEV)	CALDWELL DURKIN	88 88	PRL 61 510 PRL 61 1811	+Eisberg, Grumm, Witherell+ (UCSB, UCB, LBL) +Harper, Ling+ (OSU, ANL, CIT, LBL, LSU, LANL)
			+Khlopov, Konplich, Mignani (ROMA, KIAM, MPEI) +Abolins, Brock, Cobau+ (MSU, FNAL, MIT, FLOR)	ENGEL LOVERRE	88 88	PR C37 731 PL B206 711	+Vogel, Zimbene (INFN)
	95	PR D51 1458 PAN 58 1093	+Morales, Morales, Sarsa+ (ZARA, SCUC, PNL)	OLIVE	88	PL B205 553	+Srednicki (MINN, UCSB)
		Translated from YAF 58	1170.	SREDNICKI AFONIN	88 87	NP B310 693 JETPL 45 257	+Watkins, Olive (MINN, UCSB) +Bogatov, Vershinskii+ (KIAE)
HAGNER 99 HIDDEMANN 99			+Altmann, Feilitzsch, Oberauer+ (MUNT, LAPP, CPPM) +Daniel, Schwentker (MUNT)	AHLEN	87	Translated from ZETFI PL B195 603	> 45 201. +Avignone, Brodzinski+ (BOST, SCUC, HARV, CHIC)
		PRL 75 2654 NP A586 457	(PENN) +Kobayashi (KEK, SAGA)	AHRENS	87	PR D36 702	+ (BNL, BROW, UCI, HIRO, KEK, OSAK, PENN, STON)
MCFARLAND 9	95	PRL 75 3993	+Naples, Arroyo, Auchinchloss+ (CCFR Collab.)	BELLOTTI BOEHM	87 87	EPL 3 889 Massive Neutrinos	+Cattadori, Cremonesi, Florini+ (MILA) +Vogel (CIT)
		PL B351 387 PL B343 453	+Wilquet, Petrak+ (CHARM II Collab.) Vilain, Wilquet+ (CHARM II Collab.)	Cambridge BOFILL		Press, Cambridge PR D36 3309	+Busza, Eldridge+ (MIT, FNAL, MSU)
VYRODOV 9	95	JETPL 61 163 Translated from ZETFP	+Kozlov, Martem'yanov, Machulin+ (KIAE, LAPP, CDEF)	DAUM	87	PR D36 2624	+Kettle, Jost+ (SIN, VIRG)
WIETFELDT 9		PR C52 1028	+Norman+ (LBL, UCB, SPAUL, IND, TENN)	GRIEST Also	87 88	NP B283 681 NP B296 1034 erratun	+Seckel (UCSC, CERN) Griest, Seckel (UCSC, CERN)
ABDURASHI 9- ALESSAND 9-		PL B328 234 PL B335 519	Abdurashitov, Faizov, Gavrin, Gusev+ (SAGE Collab.) Alessandrello, Brofferio,, Fiorini+ (MILA)	LOSECCO	87	PL B184 305	+Bionta, Blewitt, Bratton+ (IMB Collab.)
BALYSH 9-	94	PL B322 176	+Beck, Belyaev, Bensch+ (MPIH, KIAE, SASSO)	MISHRA OBERAUER	87 87	PRL 59 1397 PL B198 113	+Auchincloss+ (COLU, CIT, FNAL, CHIC, ROCH) +von Feilitzsch, Mossbauer (MUNT)
DECLAIS 9	94	PL B338 383	Y. Declais+	TALEBZADEH TOMODA	1 87 87	NP B291 503 PL B199 475	+Gıry, Venus+ (BEBC WA66 Collab.) +Faessler (TUBIN)
FUKUDA 9 KONOPLICH 9			+Hayakawa, Inoue, Ishida+ (Kamiokande Collab.) +Khlopov (MPEI)	VIDYAKIN	87	JETP 66 243	+Vyrodov, Gurevich, Kozlov+ (KIAE)
PDG 9	94	PR D50 1173	Montanet+ (CERN, LBL, BOST, IFIC+)	WENDT	87	Translated from ZETF PRL 58 1810	+Abrams, Amidei, Baden+ (Mark II Collab.)
		PR D49 1389	+, Klapdor-Kleingrothaus+ (MPIH, ITEP) +Spergel, Bahcall (IAS, ICTP, INRM, PRIN)	ABRAMOWIC AFONIN	Z 86 86	PRL 57 298 JETPL 44 142	H. Abramowicz+ (CDHS Collab.) +Bogatov, Borovoi, Vershinskii+ (KIAE)
VIDYAKIN 9	94	JETPL 59 390 Translated from ZETFP	+Vyrodov, Kozlov+ (KIAE)	ALLABY	86	Translated from ZETF	P 44 iii. J.V. Allaby+ (CHARM Collab.)
		ZPHY C64 539	+Wilquet, Beyer+ (CHARM II Collab.)	ANGELINI	86	PL B177 446 PL B179 307	+Apostolakis, Baldini+ (PISA, ATHU, PADO, WISC)
	93 93	PRL 71 831 JETPL 58 262	+Brakhman, Zeldofich, Karelin+ (ITEP, INRM)	AZUELOS BADIER	86 86	PRL 56 2241 ZPHY C31 21	+Britton, Bryman+ (TRIU, CNRC) +Bemporad, Boucrot, Callot+ (NA3 Collab.)
BAHRAN 9	93	Translated from ZETFP PR D47 R754	58 256. +Kaibfleisch (OKLA)	BERNARDI	86	PL 166B 479	+Carugno+ (CURIN, INFN, CDEF, ATEN, CERN)
BAHRAN 9		PR D47 R759	+Kalbfleisch (OKLA)	BERNARDI BORGE	86B 86	PL B181 173 PS 34 591	+Carugno+ (CURIN, INFN, CDEF, ATEN, CERN) +DeRujula, Hansen, Jonson+ (ISOLDE Collab.)
BERMAN 9	93	PR C48 R1	+Pitt, Calaprice, Lowry (PRIN)	BRUCKER DELEENER	86	PR D34 2183 PL B177 228	+ Jacques, Kalelkar, Koller+ (RUTG, BNL, COLU) DeLeener-Rosier, Deutsch+ (LOUV, ZURI, LAUS)
BERNATOW 9 FREEDMAN 9		PR C47 806 PR D47 811	Bernatowicz, Brazzle, Cowsik+ (WUSL, TATA) +Fujikawa, Napolitano, Nelson+ (LAMPF E645 Collab.)	DORENBOS		PL 166B 473	Dorenbosch, Allaby, Amaldi+ (CHARM Coffab.)
GRUWE 9	93	PL B309 463	+Mommaert, Vilain, Wilquet+ (CHARM II Collab.)	USHIDA ZACEK	86C 86	PRL 57 2897 PR D34 2621	+Kondo, Tasaka, Park, Song+ (FNAL E531 Collab.) +Feilitzsch+ (CIT-SIN-TUM Collab.)
KALBFLEISCH 9 KAWASHIMA 9	93 93		+Bahran (OKLA) +Takahashi, Masuda (TOKYC, RIKEN)	AFONIN	85	JETPL 41 435	+Borovoi, Dobrynin+ (KIAE)
MORTARA 9	93	PRL 70 394	+Ahmad, Coulter, Freedman+ (ANL, LBL, UCB)	Also	85B	Translated from ZETF JETPL 42 285	Afonin, Bogatov, Borovoi, Dobrynin+ (KIAE)
OHSHIMA 9 VUILLEUMIER 9	93 93		+ (KEK, TUAT, RIKEN, SCUC, ROCH, TSUK, INUS) +Busto, Farine, Jorgens+ (NEUC, CIT, VILL)	AHRENS	85	Translated from ZETF PR D31 2732	P 42 230. +Aronson+ (BNL, BROW, KEK, OSAK, PENN+)
	93 92B		+Chan, da Cruz, Gārcia+ (LBL, UCB, SPAUL) +Adams, Adami, Adye+ (DELPHI Collab.)	ALBRECHT ALTZITZOG	851	PL 163B 404 PRL 55 799	+Binder, Drescher, Schubert+ (ARGUS Collab.) Altzitzoglou, Calaprice, Dewey+ (PRIN)
ADRIANI 9	92I	PL B295 371	+Aguilar-Benitez, Ahlen, Akbari, Alcaraz+ (L3 Collab.)	APALIKOV	. 65 85	JETPL 42 289	+Boris, Golutvin, Laptin, Lubimov+ (ITEP)
	92 9 2	PL B291 336 PL B283 32	+Kalbfleisch (OKLA) +Belyaev, Bockholt, Demehin+ (MPIH, KIAE, SASSO)	BELIKOV	85	Translated from ZETF SJNP 41 589	+Volkov, Kochetkov, Mukhin+ (SERP)
BECKER-SZ 9 BECKER-SZ 9	92 02B	PRL 69 1010 PR D46 3720	Becker-Szendy, Bratton, Casper, Dyè+ (IMB Collab.) Becker-Szendy, Bratton, Casper, Dye+ (IMB Collab.)	COOPER	85	Translated from YAF - PL 160B 207	1 919. Cooper-Sarkar+ (CERN, LOIC, OXF, SACL+)
BEIER 9	92	PL B283 446	+Frank, Frati, Kim, Mann+ (KAM2 Collab.)	COWSIK	85	PL 151B 62	(TATA)
	94 92	PTRSL A346 63 PRL 69 2341	Beier, Frank (PENN) Bernatowicz, Brannon, Brazzle, Cowsik+ (WUSL, TATA)	DATAR MARKEY	85 85	Nature 318 547 PR C32 2215	+Baba, Bhattacherjee, Bhuinya, Roy (BHAB, TATA) +Boehm (CIT)
BLUM 9	92		+Busto, Campagne, Dassie, Hubert+ (NEMO Collab.) Borodovsky, Chi, Ho, Kondakis, Lee+ (COLU, JHU, ILL)	OHI SIMPSON	85 85	PL 160B 322 PRL 54 1891	+Nakajima, Tamura+ (TOKY, INUS, ŘEK) (GUEL)
BRITTON 9	92 92	PRL 68 3000	+Ahmad, Bryman, Burnham+ (TRIU, CARL)	STOCKDALE	85	ZPHY C27 53	+Bodek+ (ROCH, CHIC, COLU, FNAL)
BRITTON 9	94 92B	PR D49 28 PR D46 R885	Britton, Ahmad, Bryman+ (TRIU, CARL) +Ahmad, Bryman+ (TRIU, CARL)	ZACEK BALLAGH	85 84	PL 164B 193 PR D30 2271	+Zacek, Boehm+ (MUNI, CIT, SIN) +Bingham+ (UCB, LBL, FNAL, HAWA, WASH, WISC)
CHEN 9	92 92	PRL 69 3151	+Imel, Radcliffe, Henrickson, Boehm (CIT)	BERGSMA CAVAIGNAC	84 84	PL 142B 103 PL 148B 387	+Dorenbosch, Allaby, Abt+ (CHARM Collab.) +Hoummada, Koang+ (ISNG, LAPP)
ELLIOTT 9			+Hahn, Moe+ (UCI)	DYDAK	84	PL 134B 281	+Feldman+ (CERN, DORT, HEIDH, SACL, WARS)
HIRATA 9	92		+Inoue, Ishida+ (Kamiokande II Collab.)				C-barren (Service Control Francis Control
HIRATA 9 HOLZSCHUH 9	92 92B	PL B287 381	+Fritschi, Kuendig (ZURI)	FREESE GABATHULEI	84 R 84	NP B233 167 PL 138B 449	+Schramm (CHIC, FNAL) +Boehm+ (CIT, SIN, MUNI)
HIRATA 9 HOLZSCHUH 9 KAWAKAMI 9	92	PL B287 381 PL B287 45 JETPL 55 564	+Fritschi, Kuendig (ZURI) + (INUS, KEK, SCUC, TUAT, RIKEN, ROCH, TSUK) +Machulin, Mikaelyan+ (KIAE)	GABATHULEI HAXTON	R 84 84	PL 138B 449 PPNP 12 409	+Schramm (CHIC, FNAL) +Boehm+ (CIT, SIN, MUNI) +Stevenson
HIRATA 9 HOLZSCHUH 9 KAWAKAMI 9	92 92B 92	PL B287 381 PL B287 45	+Fritschi, Kuendig (ZURI) + (INUS, KEK, SCUC, TUAT, RIKEN, ROCH, TSUK) +Machulin, Mikaelyan+ (KIAE)	GABATHULEI HAXTON MINEHART SCHRAMM	R 84 84 84 84	PL 138B 449 PPNP 12 409 PRL 52 804 PL 141B 337	+Schramm (CHIC, FNAL) +Boehm+ (CIT, SIN, MUNI) +Stevenson +Zlock, Marshall, Stephens, Daum+ +Steigman (VIRG, SIN) (FNAL, BART)
HIRATA 9 HOLZSCHUH 9 KAWAKAMI 9	92 92B 92	PL B287 381 PL B287 45 JETPL 55 564	+Fritschi, Kuendig (ZURI) + (INUS, KEK, SCUC, TUAT, RIKEN, ROCH, TSUK) +Machulin, Mikaelyan+ (KIAE)	GABATHULEI HAXTON MINEHART	R 84 84 84 84	PL 138B 449 PPNP 12 409 PRL 52 804	+Schramm (CRIC, FMAL) +Boehm+ (CIT, SIN, MUNI) +Stevenson +Ziock, Marshall, Stephens, Daum+ (VIRG, SIN) +Steigman (FNAL, BART) +Bogatov, Borovoi, Vershinskii+ (KIAE)

Lepton Particle Listings Massive Neutrinos and Lepton Mixing

BELENKII	83	JETPL 38 493	+Dobrynin, Zemlyakov, Mikaelyan+		(KIAE)	ERRIQUEZ	81	PL 102B 73		EPOL, RHEL, SACL+) (CIT, ISNG, MUNI)
BELIKOV	83	Translated from ZETFF JETPL 38 661	+Volkov, Kochetkov, Mukhin, Sviridov	v.L	(SERP)	KWON NEMETHY	81 81B	PR D24 1097 PR D23 262	+Boehm, Hahn, Henrikson+ + (YALE, LBL, LASL, MIT, SA	
DELINOT	03	Translated from ZETER	38 547.		(Seria)	SHROCK	81	PR D24 1232	+ (17.1.1, 101, 17.1, 17.1	(STON)
BERGSMA	83	PL 122B 465	+Dorenbosch, Jonker+	(CHARM	Collab.)	SHROCK	81B	PR D24 1275		(STON)
BERGSMA	83B	PL 128B 361	+Dorenbosch+	(CHARM	Collab.)	SILVERMAN	81	PRL 46 467	+Soni	(UCI, UCLA)
BRYMAN	83B	PRL 50 1546	+Dubois, Numao, Olaniya, Olin+	` (TRIU,	, CNRC)	SIMPSON	81B	PR D24 2971	1 30111	(GUEL)
Also	83	PRL 50 7	Bryman, Dubois, Numao, Olaniya+	(TRIU,	, CNRC)	USHIDA	81	PRL 47 1694	+ (AICH, FNAL, KOBE, SEOU	
DEUTSCH	83	PR D27 1644	+Lebrun, Prieels	•	(LOUV)	AVIGNONE	80	PR C22 594	+Greenwood	(SCUC)
GRONAU	83	PR D28 2762			(HAIF)	BOEHM	80	PL 97B 310		LLG, CIT, ISNG, MUNI)
KIRSTEN	83	PRL 50 474	+Richter, Jessberger		(MPIH)	FRITZE	80	PL 96B 427		RN, LOIC, OXF, SACL)
Also	83B	ZPHY 16 189	Kirsten, Richter, Jessberger		(MPIH)	REINES	80	PRL 45 1307	+Sobel, Pasierb	(UCI)
SCHRECK	83	PL 129B 265	Schreckenbach, Colvin+		G, ILLG)	Also	59	PR 113 273	Reines, Cowan	(LASL)
TAYLOR	83	PR D28 2705	+Cence, Harris, Jones+	(HAWA, LBL		Also	66	PR 142 852	Nezrick, Reines	(CASE)
COOPER	82	PL 112B 97	+Guy, Michette, Tyndel, Venus		(RL)	Also	76	PRL 37 315	Reines, Gurr, Sobel	` (UCI)
HAYANO	82	PRL 49 1305		(TOKY, KEK		SHROCK	80	PL 96B 159		(SŤON)
OLIVE	82	PR D25 213	+Turner		, UCSB)	DAVIS	79	PR C19 2259	+Vogel, Mann, Schenter	` (CIT)
VUILLEUMIER	82	PL 114B 298	+Boehm, Egger+	(CIT, SIN		BLIETSCHAU	78	NP B133 205	+Deden, Hasert, Krenz+	(Gargamelle Collab.)
ABELA	81	PL 105B 263	+Daum, Eaton, Frosch, Jost, Kettle,		(SIN)	CROUCH	78	PR D18 2239	+Landecker, Lathrop, Reines+	(ČASĚ, UCI, WITW)
ARMENISE	81	PL 100B 182		, CERN, MILA		MEYER	77	PL 70B 469	+Nguyen, Abrams+ (SLA	C. LBL. NWES, HAWA)
ASANO	81	PL 104B 84	+Hayano, Kikutani, Kurokawa+(KEK,	TOKY, INUS	, OSAK)	VYSOTSKY	77	JETPL 26 188	+Dolgov, Zeldovich	(ITEP)
Also	81	PR D24 1232	Shrock		(STON)			Translated from ZETFF	26 200.	, ,
ASRATYAN	81	PL 105B 301		, FNAL, SERP		BELLOTTI	76	LNC 17 553	+Cavalli, Fiorini, Rollier	(MILA)
BAKER	81	PRL 47 1576	+Connolly, Kahn, Kirk, Murtagh+		, COLU)	SZALAY	76	AA 49 437	+Marx	(EOTV)
Also	78	PRL 40 144	Cnops, Connolly, Kahn, Kirk+		, COLU)	SZALAY	74	APAH 35 8	+Marx	(EOTV)
BERNSTEIN	81	PL 101B 39	+Feinberg	(STEV	, COLU)	COWSIK	72	PRL 29 669	+McClelland	(UCB)
BOLIEV	81	SJNP 34 787	+Butkevich, Zakidyshev, Makoev+		(INRM)	MARX	72	Nu Conf. Budapest	+Szalay	(EOTV)
		Translated from YAF 3		(0.0		GERSHTEIN	66	JETPL 4 120	+Zeldovich	(KIAM)
CALAPRICE	81	PL 106B 175	+Schreiber, Schneider+		IN, IND)			Translated from ZETFF	9 4 189.	
DEDEN	81	PL 98B 310	+Grassler, Boeckmann, Mermikides+	(BFBC	Collab.)					

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Quark Particle Listings

Quarks

independent of the renormalization scheme used. It is known that the on-shell quark propagator has no infrared divergences in perturbation theory [1], so this provides a perturbative definition of the quark mass. The pole mass cannot be used to arbitrarily high accuracy because of nonperturbative infrared effects in QCD. The full quark propagator has no pole because the quarks are confined, so that the pole mass cannot be defined outside of perturbation theory.

The $\overline{\rm MS}$ running mass $\overline{m}(\mu)$ is defined by regulating the QCD theory using dimensional regularization, and subtracting the divergences using the modified minimal subtraction scheme. The $\overline{\rm MS}$ scheme is particularly convenient for Feynman diagram computations, and is the most commonly used subtraction scheme.

The Georgi-Politzer mass \widehat{m} is defined using the momentum space subtraction scheme at the spacelike point $-p^2 = \widehat{m}^2$ [2]. A generalization of the Georgi-Politzer mass that is often used in computations involving QCD sum rules [3] is $\widehat{m}(\xi)$, defined at the subtraction point $p^2 = -(\xi+1)m_P^2$. QCD sum rules are discussed in more detail in the next section on light quark masses.

Lattice gauge theory calculations can be used to obtain heavy quark masses from ψ and Υ spectroscopy. The quark masses are obtained by comparing a nonperturbative computation of the meson spectrum with the experimental data. The lattice quark mass values can then be converted into quark mass values in the continuum QCD Lagrangian Eq. (1) using lattice perturbation theory at a scale given by the inverse lattice spacing. A recent computation determines the *b*-quark pole mass to be 5.0 ± 0.2 GeV, and the $\overline{\rm MS}$ mass to be 4.0 ± 0.1 GeV [4].

Potential model calculations of the hadron spectrum also involve the heavy quark mass. There is no way to relate the quark mass as defined in a potential model to the quark mass parameter of the QCD Lagrangian, or to the pole mass. Even in the heavy quark limit, the two masses can differ by nonperturbative effects of order $\Lambda_{\rm QCD}$. There is also no reason why the potential model quark mass should be independent of the particular form of the potential used.

Recent work on the heavy quark effective theory [5-9] has provided a definition of the quark mass for a heavy quark that is valid when one includes nonperturbative effects and will be called the HQET mass m_Q . The HQET mass is particularly useful in the analysis of the $1/m_Q$ corrections in HQET. The HQET mass agrees with the pole mass to all orders in perturbation theory when only one quark flavor is present, but differs from the pole mass at order α_s^2 when there are additional flavors [10]. Physical quantities such as hadron masses can in principle be computed in the heavy quark effective theory in terms of the HQET mass m_Q . The computations cannot be done analytically in practice because of nonperturbative effects in QCD, which also prevent a direct extraction of the quark masses from the original QCD Lagrangian, Eq. (1). Nevertheless, for heavy quarks, it is possible to parametrize the nonperturbative effects to a given order in the $1/m_Q$ expansion in terms of a few unknown constants that can be obtained from experiment. For example, the B and D meson masses in the heavy quark effective theory are given in terms of a single nonperturbative parameter $\overline{\Lambda}$,

$$M(B) = m_b + \overline{\Lambda} + \mathcal{O}\left(\frac{\overline{\Lambda}^2}{m_b}\right) ,$$

$$M(D) = m_c + \overline{\Lambda} + \mathcal{O}\left(\frac{\overline{\Lambda}^2}{m_c}\right) . \tag{2}$$

This allows one to determine the mass difference $m_b - m_c =$ M(B) - M(D) = 3.4 GeV up to corrections of order $\overline{\Lambda}^2/m_b$ $\overline{\Lambda}^2/m_c$. The extraction of the individual quark masses m_b and m_c requires some knowledge of $\overline{\Lambda}$. An estimate of $\overline{\Lambda}$ using QCD sum rules gives $\overline{\Lambda} = 0.57 \pm 0.07$ GeV [11]. The HQET masses with this value of $\overline{\Lambda}$ are $m_b = 4.74 \pm 0.14$ GeV and $m_c = 1.4 \pm 0.2$ GeV, where the spin averaged meson masses $(3M(B^*) + M(B))/4$ and $(3M(D^*) + M(D))/4$ have been used to eliminate the spin-dependent $\mathcal{O}(\overline{\Lambda}^2/m_Q)$ correction terms. The errors reflect the uncertainty in $\overline{\Lambda}$ and the unknown spinaveraged $\mathcal{O}(\overline{\Lambda}^2/m_Q)$ correction. The errors do not include any theoretical uncertainty in the QCD sum rules, which could be large. A quark model estimate suggests that $\overline{\Lambda}$ is the constituent quark mass (≈ 350 MeV), which differs significantly from the sum rule estimate. In HQET, the $1/m_Q$ corrections to heavy meson decay form-factors are also given in terms of $\overline{\Lambda}$. Thus an accurate enough measurement of these form-factors could be used to extract $\overline{\Lambda}$ directly from experiment, which then determines the quark masses up to corrections of order

The quark mass m_Q of HQET can be related to other quark mass parameters using QCD perturbation theory at the scale m_Q . The relation between m_Q and $\widehat{m}(\xi)$ at one loop is [12]

$$m_Q = \widehat{m}(\xi) \left[1 + \frac{\widehat{\alpha}_s(\xi)}{\pi} \frac{\xi + 2}{\xi + 1} \log(\xi + 2) \right], \tag{3}$$

where $\widehat{\alpha}_s(\xi)$ is the strong interaction coupling constant in the momentum space subtraction scheme. The relation between m_Q and the $\overline{\text{MS}}$ mass \overline{m} is known to two loops [13],

$$\begin{split} m_Q &= \overline{m}(m_Q) \left[1 + \frac{4\overline{\alpha}_s(m_Q)}{3\pi} \right. \\ &+ \left(16.11 - 1.04 \sum_k \left(1 - \frac{m_{Q_k}}{m_Q} \right) \right) \left(\frac{\overline{\alpha}_s(m_Q)}{\pi} \right)^2 \right] , \quad (4) \end{split}$$

where $\overline{\alpha}_s(\mu)$ is the strong interaction coupling constants in the $\overline{\text{MS}}$ scheme, and the sum on k extends over all flavors Q_k lighter than Q. For the b-quark, Eq. (4) reads

$$m_b = \overline{m}_b (m_b) [1 + 0.09 + 0.06],$$
 (5)

where the contributions from the different orders in α_s are shown explicitly. The two loop correction is comparable in size and has the same sign as the one loop term. There is

presumably an error of order 0.05 in the relation between m_b and $\overline{m}_b(m_b)$ from the uncalculated higher order terms.

D. Light quarks

For light quarks, one can use the techniques of chiral perturbation theory to extract quark mass ratios. The light quark part of the QCD Lagrangian Eq. (1) has a chiral symmetry in the limit that the light quark masses are set to zero, under which left- and right-handed quarks transform independently. The mass term explicitly breaks the chiral symmetry, since it couples the left- and right-handed quarks to each other. A systematic analysis of this explicit chiral symmetry breaking provides some information on the light quark masses.

It is convenient to think of the three light quarks u, d and s as a three component column vector Ψ , and to write the mass term for the light quarks as

$$\overline{\Psi}M\Psi = \overline{\Psi}_L M\Psi_R + \overline{\Psi}_R M\Psi_L, \tag{6}$$

where M is the quark mass matrix M,

$$M = \begin{pmatrix} m_u & 0 & 0 \\ 0 & m_d & 0 \\ 0 & 0 & m_s \end{pmatrix}. \tag{7}$$

The mass term $\overline{\Psi}M\Psi$ is the only term in the QCD Lagrangian that mixes left- and right-handed quarks. In the limit that $M \to 0$, there is an independent SU(3) flavor symmetry for the left- and right-handed quarks. This $G_{\chi} = \mathrm{SU}(3)_L \times \mathrm{SU}(3)_R$ chiral symmetry of the QCD Lagrangian is spontaneously broken, which leads to eight massless Goldstone bosons, the π 's, K's, and η , in the limit $M \to 0$. The symmetry G_{χ} is only an approximate symmetry, since it is explicitly broken by the quark mass matrix M. The Goldstone bosons acquire masses which can be computed in a systematic expansion in M in terms of certain unknown nonperturbative parameters of the theory. For example, to first order in M one finds that [14,15]

$$m_{\pi^0}^2 = B (m_u + m_d) ,$$

$$m_{\pi^{\pm}}^2 = B (m_u + m_d) + \Delta_{em} ,$$

$$m_{K^0}^2 = m_{\overline{K}^0}^2 = B (m_d + m_s) ,$$

$$m_{K^{\pm}}^2 = B (m_u + m_s) + \Delta_{em} ,$$

$$m_{\eta}^2 = \frac{1}{3} B (m_u + m_d + 4m_s) ,$$
(8)

with two unknown parameters B and Δ_{em} , the electromagnetic mass difference. From Eq. (8), one can determine the quark mass ratios [14]

$$\frac{m_u}{m_d} = \frac{2m_{\pi^0}^2 - m_{\pi^+}^2 + m_{K^+}^2 - m_{K^0}^2}{m_{K^0}^2 - m_{K^+}^2 + m_{\pi^+}^2} = 0.56 ,$$

$$\frac{m_s}{m_d} = \frac{m_{K^0}^2 + m_{K^+}^2 - m_{\pi^+}^2}{m_{K^0}^2 + m_{\pi^+}^2 - m_{K^+}^2} = 20.1 ,$$
(9)

to lowest order in chiral perturbation theory. The error on these numbers is the size of the second-order corrections, which are discussed at the end of this section. Chiral perturbation theory cannot determine the overall scale of the quark masses, since it uses only the symmetry properties of M, and any multiple of M has the same G_{χ} transformation law as M. This can be seen from Eq. (8), where all quark masses occur only in the form Bm, so that B and m cannot be determined separately.

The mass parameters in the QCD Lagrangian have a scale dependence due to radiative corrections, and are renormalization scheme dependent. Since the mass ratios extracted using chiral perturbation theory use the symmetry transformation property of M under the chiral symmetry G_{χ} , it is important to use a renormalization scheme for QCD that does not change this transformation law. Any quark mass independent subtraction scheme such as $\overline{\rm MS}$ is suitable. The ratios of quark masses are scale independent in such a scheme.

The absolute normalization of the quark masses can be determined by using methods that go beyond chiral perturbation theory, such as QCD sum rules [3]. Typically, one writes a sum rule for a quantity such as B in terms of a spectral integral over all states with certain quantum numbers. This spectral integral is then evaluated by assuming it is dominated by one (or two) of the lowest resonances, and using the experimentally measured resonance parameters [16]. There are many subtleties involved, which cannot be discussed here [16].

Another method for determining the absolute normalization of the quark masses, is to assume that the strange quark mass is equal to the SU(3) mass splitting in the baryon multiplets [14,16]. There is an uncertainty in this method since in the baryon octet one can use either the Σ -N or the Λ -N mass difference, which differ by about 75 MeV, to estimate the strange quark mass. But more importantly, there is no way to relate this normalization to any more fundamental definition of quark masses.

One can extend the chiral perturbation expansion Eq. (8) to second order in the quark masses M to get a more accurate determination of the quark mass ratios. There is a subtlety that arises at second order [17], because

$$M\left(M^{\dagger}M\right)^{-1}\det M^{\dagger} \tag{10}$$

transforms in the same way under $G\chi$ as M. One can make the replacement $M\to M(\lambda)=M+\lambda M\left(M^\dagger M\right)^{-1}\det M^\dagger$ in all formulæ,

$$M(\lambda) = \operatorname{diag}(m_u(\lambda), m_d(\lambda), m_s(\lambda))$$

$$= \operatorname{diag}(m_u + \lambda m_d m_s, m_d + \lambda m_u m_s, m_s + \lambda m_u m_d)$$
, (11)

so it is not possible to determine λ by fitting to data. One can only determine the ratios $m_i(\lambda)/m_j(\lambda)$ using second-order chiral perturbation theory, not the desired ratios $m_i/m_j = m_i(\lambda = 0)/m_j(\lambda = 0)$.

Dimensional analysis can be used to estimate [18] that second-order corrections in chiral perturbation theory due to the

Quark Particle Listings

Quarks

strange quark mass are of order $\lambda m_s \sim 0.25$. The ambiguity due to the redefinition Eq. (11) (which corresponds to a second-order correction) can produce a sizeable uncertainty in the ratio m_u/m_d . The lowest-order value $m_u/m_d = 0.56$ gets corrections of order $\lambda m_s(m_d/m_u - m_u/m_d) \sim 30\%$, whereas m_s/m_d gets a smaller correction of order $\lambda m_s(m_u/m_d - m_u m_d/m_s^2) \sim 15\%$. A more quantitative discussion of second-order effects can be found in Refs. 17,19,20. Since the second-order terms have a single parameter ambiguity, the value of m_u/m_d is related to the value of m_s/m_d .

The ratio m_u/m_d is of great interest since there is no strong CP problem if $m_u=0$. To determine m_u/m_d requires fixing λ in the mass redefinition Eq. (11). There has been considerable effort to determine the chiral Lagrangian parameters accurately enough to determine m_u/m_d , for example from the analysis of the decays $\psi' \to \psi + \pi^0, \eta$, the decay $\eta \to 3\pi$, using sum rules, and from the heavy meson mass spectrum [16,21–24]. A recent paper giving a critique of these estimates is Ref. 25.

Eventually, lattice gauge theory methods will be accurate enough to be able to compute meson masses directly from the QCD Lagrangian Eq. (1), and thus determine the light quark masses. For a reliable determination of quark masses, these computations will have to be done with dynamical fermions, and with a small enough lattice spacing that one can accurately compute the relation between lattice and continuum Lagrangians.

The quark masses for light quarks discussed so far are often referred to as current quark masses. Nonrelativistic quark models use constituent quark masses, which are of order 350 MeV for the u and d quarks. Constituent quark masses model the effects of dynamical chiral symmetry breaking, and are not related to the quark mass parameters m_k of the QCD Lagrangian Eq. (1). Constituent masses are only defined in the context of a particular hadronic model.

E. Numerical values and caveats

The quark masses in the particle data listings have been obtained by using the wide variety of theoretical methods outlined above. Each method involves its own set of approximations and errors. In most cases, the errors are a best guess at the size of neglected higher-order corrections. The expansion parameter for the approximations is not much smaller than unity (for example it is $m_K^2/\Lambda_\chi^2 \approx 0.25$ for the chiral expansion), so an unexpectedly large coefficient in a neglected higher-order term could significantly alter the results. It is also important to note that the quark mass values can be significantly different in the different schemes. For example, assuming that the b-quark pole mass is 5.0 GeV, and $\overline{\alpha}_s(m_b) \approx 0.22$ gives the $\overline{\rm MS}$ b-quark mass $\overline{m}_b(\mu=m_b)=4.6$ GeV using the one-loop term in Eq. (4), and $\overline{m}_b(\mu = m_b) = 4.3$ GeV including the one-loop and two-loop terms. The heavy quark masses obtained using HQET, QCD sum rules, or lattice gauge theory are consistent with each other if they are all converted into the same scheme. When using the data listings, it is important to remember that

the numerical value for a quark mass is meaningless without specifying the particular scheme in which it was obtained. All non- $\overline{\rm MS}$ quark masses have been converted to $\overline{\rm MS}$ values in the data listings using one-loop formulæ, unless an explicit two-loop conversion is given by the authors in the original article.

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u

$$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$$

Mass m = 1.5 to 5 MeV $m_u/m_d = 0.20$ to 0.70

$$Charge = \frac{2}{3} e I_Z = +\frac{1}{2}$$

$$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$$

Mass m=3 to 9 MeV

Charge =
$$-\frac{1}{3}e$$
 $I_Z = -\frac{1}{2}$

 $m_s/m_d = 17 \text{ to } 25$

$$\overline{m} = (m_u + m_d)/2 = 2 \text{ to 6 MeV}$$

$$I(J^P) = 0(\frac{1}{2}^+)$$

Charge = $-\frac{1}{3}e$ Mass m = 60 to 170 MeV Strangeness = -1 $(m_s - (m_u + m_d)/2)/(m_d - m_u) = 34 \text{ to } 51$

LIGHT QUARKS (u, d, s)

OMITTED FROM SUMMARY TABLE

u-QUARK MASS

The u-, d-, and s-quark masses are estimates of so-called "current-quark masses," in a mass- independent subtraction scheme such as MS. The ratios $m_{\it U}/m_{\it d}$ and $m_{\it s}/m_{\it d}$ are extracted from pion and kaon masses using chiral symmetry. The estimates of $\it d$ and $\it u$ masses are not without controversy and remain under active investigation. Within the literature there are even suggestions that the u quark could be essentially massless. The s-quark mass is estimated from SU(3) splittings in hadron masses.

Starting with this edition of the Review, we have normalized the MS masses at a renormalization scale of $\mu=2$ GeV. Results quoted in the literature at $\mu = 1$ GeV have been rescaled by dividing by 1.35.

VALUE (MeV) 1.5 to 5 OUR EVALUATION • • • We do not use the following data for averages, fits, limits, etc. • • • 3.9 ± 1.1 1 JAMIN 95 THEO MS scheme ² NARISON 95C THEO MS scheme 3.0 ± 0.7 ³ CHOI 92B THEO ⁴ BARDUCCI 88 THEO 5 GASSER 82 THEO 3.8 ± 1.1

- $^{1}\,\mathrm{JAMIN}$ 95 uses QCD sum rules at next-to-leading order. We have rescaled $m_{y}(\mathrm{1\,GeV})$
- = 5.3 \pm 1.5 to μ = 2 GeV. 2 For NARISON 95c, we have rescaled m_y (1 GeV) = 4 \pm 1 to μ = 2 GeV. 3 CHOI 928 argues that m_y = 0 is okay based on instanton contributions to the chiral coefficients. Disagrees with DONOGHUE 92 and DONOGHUE 92B.
- 4 BARDUCCI 88 uses a calculation of the effective potential for $\bar{\psi}\psi$ in QCD, and estimates for $\Sigma(p^2)$. We have rescaled $m_{\nu}(1 \, \text{GeV}) = 5.8$ to $\mu = 2 \, \text{GeV}$.
- To extract the absolute values. We have rescaled $m_{u}(1 \text{ GeV}) = 5.0 \pm 1.5$ and uses QCD sum rules to extract the absolute values. We have rescaled $m_{u}(1 \text{ GeV}) = 5.1 \pm 1.5$ to $\mu = 2 \text{ GeV}$.

d-QUARK MASS

See the comment for the u quark above.

Starting with this edition of the Review, we have normalized the MS masses at a renormalization scale of $\mu=2$ GeV. Results quoted in the literature at $\mu=1$ GeV have been rescaled by dividing by 1.35.

VALUE (MeV)	DOCUMENT ID		TECN_	COMMENT
to 9 OUR EVALUA • • We do not use t	ITION he following data for average	s, fits	ilmits,	etc. • • •
7.0±1.1	NIMAL ⁹	95	THEO	MS scheme
7.4 ± 0.7	⁷ NARISON	95C	THEO	MS scheme
	8 ADAMI	93	THEO	
	⁹ NEFKENS	92	THEO	
6.2	¹⁰ BARDUCCI	88	THEO	
	11 DOMINGUEZ	87	THEO	
	12 KREMER	84	THEO	
6.6±1.9	13 GASSER	82	THEO	

- 6 JAMIN 95 uses QCD sum rules at next-to-leading order. We have rescaled $m_d(1~{\rm GeV})$
- = 9.4 \pm 1.5 to μ = 2 GeV.

 For NARISON 95c, we have rescaled $m_d(1 \text{ GeV}) = 10 \pm 1$ to μ = 2 GeV.

 8 ADAMI 93 obtain $m_d m_u$ =3 \pm 1 MeV at μ =0.5 GeV using isospin-violating effects in OCD sum rules.
- 9 NEFKENS 92 results for m_d-m_u are 3.1 \pm 0.4 MeV from meson masses and 3.6 \pm 0.4
- MeV from baryon masses. ^10 BARDUCCI 88 uses a calculation of the effective potential for $\overline{\psi}\psi$ in QCD, and estimates for $\Sigma(p^2)$. We have rescaled $m_d(1\,{
 m GeV})=8.4$ to $\mu=2\,{
 m GeV}$.
- 11 DOMINGUEZ 87 uses QCD sum rules to obtain $m_u + m_d = 15.5 \pm 2.0$ MeV and $m_d -$
- 12 KREMER 84 obtain $m_u + m_d = 21 \pm 2$ MeV at $Q^2 = 1$ GeV 2 using SVZ values for quark condensates; they obtain $m_u+m_d=35\pm3$ MeV at $Q^2=1$ GeV 2 using factorization values for quark condensates.
 ¹³ GASSER 82 uses chiral perturbation theory for the mass ratios, and uses QCD sum rules
- to extract the absolute values. We have rescaled $m_d(1~{\rm GeV})=8.9\pm2.6$ to $\mu=2~{\rm GeV}.$

$Tilde{m} = (m_u + m_d)/2$

See the comments for the u quark above.

Starting with this edition of the Review, we have normalized the MS masses at a renormalization scale of $\mu=2$ GeV. Results quoted in the literature at $\mu = 1$ GeV have been rescaled by dividing by 1.35.

VALUE (MeV) 2 to 6 OUR EVALUA	DOCUMENT IS	'	TECN	COMMENT
	the following data for averag	ges, fit	s, limits.	, etc. • • •
2.7±0.2	14 EICKER	97	LATT	MS scheme
3.6±0.6	¹⁵ GOUGH	97	LATT	MS scheme
3.4±0.4±0.3	¹⁶ GUPTA	97	LATT	MS scheme
4.5 ± 1.0	17 BIJNENS	95		

- 15 GOUGH 97 use lattice gauge computations in the quenched approximation. Correcting for quenching gives $2.1 < \overline{m} < 3.5$ MeV at $\mu{=}2$ GeV. 16 GUPTA 97 use Lattice Monte Carlo computations in the quenched approximation. The
- value for two light dynamic flavors at $\mu=$ 2 GeV is 2.7 \pm 0.3 \pm 0.3 MeV.
- 17 BIJNENS 95 determines m_u+m_d (1 GeV) = 12 \pm 2.5 MeV using finite energy sum rules. We have rescaled this to 2 GeV.

5-QUARK MASS

See the comment for the u quark above

Starting with this edition of the Review, we have normalized the MS masses ormalization scale of $\mu=2$ GeV. Results quoted in the literature at $\mu=1~{\rm GeV}$ have been rescaled by dividing by 1.35.

VALUE (MeV)	DOCUMENT ID TECN COMMENT	
60 to 170 OUR EVALU • • We do not use the	JATION following data for averages, fits, limits, etc. • • •	
152.4±14.1	18 CHETYRKIN 97 THEO MS scheme	e
≥ 89	19 COLANGELO 97 THEO MS scheme	e
140 ±20	20 EICKER 97 LATT MS scheme	2
95 ±16	21 GOUGH 97 LATT MS scheme	e
100 ±21 ±10	22 GUPTA 97 LATT MS scheme	e
127 ±11	23 CHETYRKIN 95 THEO MS scheme	=
140 ±24	24 JAMIN 95 THEO MS scheme	е
146 ±22	25 NARISON 95C THEO MS scheme	e
	²⁶ NEFKENS 92 THEO	
144 ± 3	27 DOMINGUEZ 91 THEO	
88	28 BARDUCCI 88 THEO	
	²⁹ KREMER 84 THEO	
130 +41	30 GASSER 82 THEO	

- 18 CHETYRKIN 97 obtains 205.5 \pm 19.1 MeV at μ =1 GeV from QCD sum rules including fourth-order QCD corrections. We have rescaled the result to 2 GeV.
- 19 COLANGELO 97 is QCD sum rule computation. We have rescaled $m_{\rm 5}(1\,{\rm GeV})>$ 120 to
- 20 EICKER 97 use lattice gauge computations with two dynamical light flavors
- 21 GOUGH 97 use lattice gauge computations in the quenched approximation. Correcting for quenching gives 54 < m_S < 92 MeV at μ =2 GeV.
- ²²GUPTA 97 use Lattice Monte Carlo computations in the quenched approximation. The value for two light dynamical flavors at μ = 2 GeV is 68 \pm 12 \pm 7 MeV.
- 23 CHETYRKIN 95 uses QCD sum rules at next-to-leading order. We have rescaled $m_{\rm S}(1~{\rm GeV})=171\pm15$ to $\mu=2~{\rm GeV}.$
- ²⁴ JAMIN 95 uses QCD sum rules at next-to-leading order. We have rescaled $m_{\rm S}({
 m 1~GeV})$ $= 189 \pm 32 \text{ to } \mu = 2 \text{ GeV}.$
- ²⁵ For NARISON 95c, we have rescaled $m_S(1~{\rm GeV})=197\pm29~{\rm to}~\mu=2~{\rm GeV}.$
- 26 NEFKENS 92 results for $m_s-(m_0+m_d)/2$ are 111 \pm 10 MeV from meson masses and 163 \pm 15 MeV from baryon masses.
- 27 DOMINGUEZ 91 uses QCD sum rules with $\Lambda_{QCD}=100$ –200 MeV and the SVZ value for the gluon condensate. We have rescaled $m_s(1\,{
 m GeV})=194\pm 9$ to $\mu=2\,{
 m GeV}$.
- ²⁸ BARDUCCI 88 uses a calculation of the effective potential for $\overline{\psi}\psi$ in QCD, and estimates for $\Sigma(p^2)$. We have rescaled $m_s(1 \text{ GeV}) = 118$ to $\mu = 2 \text{ GeV}$.
- 29 KREMER 84 obtain $m_u + m_s = 245 \pm 10$ MeV at $Q^2 = 1$ GeV 2 using SVZ values for quark condensates; they obtain m_u+m_s =270 \pm 10 MeV at $Q^2=1$ GeV 2 using factorization values for quark condensates.
- Values for quark concensates. 30 GASSER 82 uses chiral perturbation theory for the mass ratios, and uses QCD sum rules to extract the absolute values. We have rescaled $m_{\rm S}(1~{\rm GeV})=175\pm55$ to $\mu=2~{\rm GeV}$.

Quark Particle Listings

Light Quarks (u, d, s), c

LIGHT QUARK MASS RATIOS

u/d MASS RATIO

VALUE	DOCUMENT ID TECN COMMENT
0.2 to 0.7 OUR EVA	
• • • We do not use the	following data for averages, fits, limits, etc. • • •
0.44	31 GAO 97 THEO MS scheme
0.553 ± 0.043	32 LEUTWYLER 96 THEO Compliation
<0.3	³³ CHOI 92 THEO
0.26	34 DONOGHUE 92 THEO
0.30 ±0.07	35 DONOGHUE 928 THEO
0.66	³⁶ GERARD 90 THEO
0.4 to 0.65	37 LEUTWYLER 90B THEO
0.05 to 0.78	³⁸ MALTMAN 90 THEO
0.0 to 0.56	³⁹ CHOI 898 THEO
0.0 to 0.8	⁴⁰ KAPLAN 86 THEO
0.57 ±0.04	⁴¹ GASSER 82 THEO
0.38 ±0.13	⁴² LANGACKER 79 THEO
0.47 ±0.11	43 LANGACKER 798 THEO
0.56	44 WEINBERG 77 THEO

- $^{31}\,\mathrm{GAO}$ 97 uses electromagnetic mass splittings of light mesons.
- 33 CHOI 92 result obtained from the decays $\psi(2S) \to J/\psi(1S)\pi$ and $\psi(2S) \to J/\psi(1S)\eta$, and a dilute instanton gas estimate of some unknown matrix elements.
- ³⁴ DONOGHUE 92 result is from a combined analysis of meson masses, $\eta \to 3\pi$ using second-order chiral perturbation theory including nonanalytic terms, and $(\psi(2S) \to J/\psi(1S)\pi)/(\psi(2S) \to J/\psi(1S)\eta)$.
- 35 DONOGHUE 928 computes quark mass ratios using $(\psi(2S) \to J/\psi(1S)\pi)/(\psi(2S) \to J/\psi(1S)\eta)$, and an estimate of L_{14} using Weinberg sum rules. ³⁶ GERARD 90 uses large N and η - η' mixing.
- ³⁷ LEUTWYLER 90B determines quark mass ratios using second-order chiral perturbation theory for the meson and baryon masses, including nonanalytic corrections. Also uses Weinberg sum rules to determine L_7 .
- 38 MALTMAN 90 uses second-order chiral perturbation theory including nonanalytic terms for the meson masses. Uses a criterion of "maximum reasonableness" that certain coefficients which are expected to be of order one are ≤ 3.
- 39 CHOI 89 uses second-order chiral perturbation theory and a dilute instanton gas estimate of second-order coefficients in the chiral lagrangian.
- 40 KAPLAN 86 uses second-order chiral perturbation theory including nonanalytic terms for the meson masses. Assumes that less than 30% of the mass squared of the pion is due to second-order corrections.
- 41 GASSER 82 uses chiral perturbation theory for the meson and baryon masses.
- 42 LANGACKER 79 result is from a fit to the meson and baryon mass spectrum, and the decay $\eta \to 3\pi$. The electromagnetic contribution is taken from Socolow rather than from Dashen's formula.
- 43 LANGACKER 79B result uses LANGACKER 79 and also ρ - ω mixing.
- 44 WEINBERG 77 uses lowest-order chiral perturbation theory for the meson and baryon masses and Dashen's formula for the electromagnetic mass differences.

DOCUMENT ID TECN COMMENT

s/d MASS RATIO

VALUE

17	to 25 OUR EVALUATION		
	AAA A A A A A A A A A A A A A A A A A	dia II-la	

• • • vve do not use the to	nowing data for average	5, TIT:	s, umits,	etc. • • •
20.0	⁴⁵ GAO	97	THEO	MS scheme
18.9±0.8	46 LEUTWYLER	96	THEO	Compilation
21	47 DONOGHUE			
18	⁴⁸ GERARD	90	THEO	
18 to 23	⁴⁹ LEUTWYLER	908	THEO	
15 to 26	⁵⁰ KAPLAN	86	THEO	
19.6 ± 1.5	⁵¹ GASSER	82	THEO	
22 ±5	52 LANGACKER	79	THEO	
24 ±4	53 LANGACKER	79E	THEO	
20	54 WEINBERG			

- 45 GAO 97 uses electromagnetic mass splittings of light mesons.
- 46 LEUTWYLER 96 uses a combined fit to $\eta\to 3\pi$ and $\psi'\to J/\psi$ (π,η) decay rates, and the electromagnetic mass differences of the π and K.
- 47 DONOGHUE 92 result is from a combined analysis of meson masses, $\eta \to 3\pi$ using second-order chiral perturbation theory including nonanalytic terms, and $(\psi(2S) \to J/\psi(1S)\pi)/(\psi(2S) \to J/\psi(1S)\eta)$.
- ⁴⁸ GERARD 90 uses large N and η - η' mixing.
- 49 LEUTWYLER 90B determines quark mass ratios using second-order chiral perturbation theory for the meson and baryon masses, including nonanalytic corrections. Also uses Weinberg sum rules to determine L_7 .
- $^{50}\,\mathrm{KAPLAN}$ 86 uses second-order chiral perturbation theory including nonanalytic terms for the meson masses. Assumes that less than 30% of the mass squared of the pion is due to second-order corrections.
- 51 GASSER 82 uses chiral perturbation theory for the meson and baryon masses.
- 52 LANGACKER 79 result is from a fit to the meson and baryon mass spectrum, and the decay $\eta\to 3\pi$. The electromagnetic contribution is taken from Socolow rather than from Dashen's formula.
- 53 LANGACKER 79B result uses LANGACKER 79 and also ρ - ω mixing.
- 54 WEINBERG 77 uses lowest-order chiral perturbation theory for the meson and baryon masses and Dashen's formula for the electromagnetic mass differences.

$(m_s - m)/(m_d - m_u)$ MASS RATIO $\overline{m} \equiv (m_u + m_d)/2$

34 to 51 OUR EVALUATION ■ ● ● We do not use the following data for averages, fits, limits, etc. ● ● 55 ANISOVICH 96 THEO	
55 ANISOVICH 96 THEO 36 ±5 56 NEFKENS 92 THEO 45 ±3 57 NEFKENS 92 THEO 38 ±9 58 AMETLLER 84 THEO	
36 ±5	
45 ±3 57 NEFKENS 92 THEO 38 ±9 58 AMETLLER 84 THEO	
38 ±9 ⁵⁸ AMETLLER 84 THEO	
43.5±2.2 GASSER 82 THEO	
34 to 51 GASSER 81 THEO	
48 ±7 MINKOWSKI 80 THEO	
⁵⁵ ANISOVICH 96 find $Q=22.7 \pm 0.8$ with $Q^2 \equiv (m_s^2 - m^2)/(m_d^2 - m_s^2)$ from	η →
$\pi^+\pi^-\pi^0$ decay using dispersion relations and chiral perturbation theory.	
56 NEFKENS 92 result is from an analysis of meson masses, mixing, and decay.	
57 NEFKENS 92 result is from an analysis of of baryon masses.	
⁵⁸ AMETLLER 84 uses $\eta \to \pi^+\pi^-\pi^0$ and ρ dominance.	

LIGHT QUARKS (u, d, s) REFERENCES

CHETYRKIN	97	PL B404 337	K.G. Chetyrkin, D. Pirjol, K.	Schilcher
COLANGELO	97	PL B408 340	P. Colangelo+	
EICKER	97	PL B407 290	N. Eicker+	(SESAM Collab.)
GAO	97	PR D56 4115	DN. Gao, B.A. Li, ML. Ya	
GOUGH	97	PRL 79 1622	B. Gough+	
GUPTA	97	PR D55 7203	R. Gupta, T. Bhattacharya	
ANISOVICH	96	PL B375 335	A.V. Anisovich, H. Leutwyler	
LEUTWYLER	96	PL B378 313	H. Leutwyler	
BIJNENS	95	PL B348 226	+Prades, de Rafael	(NORD, BOHR, CPPM)
CHETYRKIN	95	PR D51 5090	+Dominguez, Pirjol, Schilcher	(INRM, CAPE, MANZ)
JAMIN	95	ZPHY C66 633	+ Munz	(HEIDT, MUNT)
NARISON	95C	PL B35B 113	·	(MONP)
ADAMI	93	PR D48 2304	+Drukarey, loffe	(CIT, ITEP, PNPI)
CHOI	92	PL B292 159	•	(UCSD)
CHOI	92B	NP B383 58		(UCSD)
DONOGHUE	92	PRL 69 3444	+Holstein, Wyler	(MASA, ZURI)
DONOGHUE	92B	PR D45 892	+Wyler	(MASA, ŽURI, UCSBT)
NEFKENS	92	CNPP 20 221	+Miller, Slaus	(UCLA, WASH, ZAGR)
DOMINGUEZ	91	PL B253 241	+van Gend, Paver	(CAPE, TRST, INFN)
GERARD	90	MPL A5 391		(MPIM)
LEUTWYLER	90B	NP B337 108		(BERN)
MALTMAN	90	PL B234 158	+Goldman, Stephenson Jr.	(YORKC, LANL)
CHOI	89	PRL 62 849		
CHOI	89B	PR D40 890	+Kim	(CMU, JHU)
BARDUCCI	88	PR D38 238	+Casalbuoni, De Curtis+	(FIRZ, INFN, LECE, GEVA)
Also	87	PL B193 305	Barducci, Casalbuoni+	(FIRZ, INFN, LECE, GEVA)
DOMINGUEZ	87	ANP 174 372	+de Rafael	(ICTP, MARS, WIEN)
KAPLAN	86	PRL 56 2004	+ Manohar	(HARV)
AMETLLER	84	PR D30 674	+Ayala, Bramon	(BARC)
KREMER	84	PL 143B 476	+Papadopoulos, Schilcher	(MANZ)
GASSER	82	PRPL 87 77	+Leutwyler	(BERN)
GASSER	81	ANP 136 62		(BERN)
MINKOWSKI	80	NP B164 25	+Zepeda	(BERN)
LANGACKER	79	PR D19 2070	+Pagels	(DESY, PRIN)
LANGACKER	79B	PR D20 2983		(PENN)
WEINBERG	77	ANYAS 38 185		(HARV)



 $I(J^P) = 0(\frac{1}{2}^+)$ Charge $=\frac{2}{3}e$ Charm = +1

c-QUARK MASS

The c-quark mass is estimated from charmonium and D masses. It corresponds to the "running" mass m_C ($\mu=m_C$) in the $\overline{\rm MS}$ scheme. We have converted masses in other schemes to the $\overline{\rm MS}$ scheme using one-loop QCD pertubation theory with $\alpha_s(\mu=m_c)=0.39$. The range 1.0–1.6 GeV for the $\overline{\text{MS}}$ mass corresponds to 1.2–1.9 GeV for the pole mass (see the "Note on Quark Masses").

VALUE (GeV)	DOCUMENT ID		TECN	COMMENT
1.1 to 1.4 OUR EVALUATION				
• • We do not use the following	data for average	s, fit	s, limits,	etc. • • •
1.22±0.06	¹ DOMINGUEZ	94	THEO	MS scheme
≥ 1.23	² LIGETI	94	THEO	MS scheme
≥ 1.25	3 LUKE	94	THEO	MS scheme
1.23 ± 0.04	4 NARISON	94	THEO	MS scheme
1.31 ± 0.03	⁵ TITARD	94	THEO	MS scheme
$1.5 \begin{array}{c} +0.2 \\ -0.1 \end{array} \pm 0.2$	⁶ ALVAREZ	93	THEO	
1.27 ± 0.02	7 NARISON	89	THEO	
1.25 ± 0.05	⁸ NARISON	87	THEO	
1.27 ± 0.05	⁹ GASSER	82	THEO	

- 1 DOMINGUEZ 94 uses QCD sum rules for $J/\psi(15)$ system and finds a pole mass of 1.46 ± 0.07 GeV. 2 LIGETI 94 computes lower bound of 1.43 GeV on pole mass using HQET, and experi-
- mental data on inclusive B and D decays.
- 3 LUKE 94 computes lower bound of 1.46 GeV on pole mass using HQET, and experimental data on inclusive B and D decays. ANARISON 94 uses spectral sum rules to two loops, and $J/\psi(15)$ and Υ systems.
- TITARD 44 uses one-loop computation of the quark potential with nonperturbative gluon condensate effects to fit $J/\psi(1S)$ and T states.
- ALVAREZ 93 method is to fit the measured x_F and p_T^2 charm photoproduction distributions to the theoretical predictions of ELLIS 89c. 7 NARISON 89 determines the Georgi-Politzer mass at $p^2 = -m^2$ to be 1.26 \pm 0.02 GeV
- using QCD sum rules. 8 NARISON 87 computes pole mass of 1.46 \pm 0.05 GeV using QCD sum rules, with $\Lambda(\overline{MS})$
- $_{9}$ = 180 \pm 80 MeV. $_{9}$ GASSER 82 uses SVZ sum rules. The renormalization point is $\mu=$ quark mass.

6-QUARK REFERENCES

DOMINGUEZ	94	PL B333 184	+Gluckman, Paver	(CAPE, TRST, INFN)
LIGETI	94	PR D49 R4331	+Nir	(REHO)
LUKE	94	PL B321 88	+Savage .	(TNTO, UCSD, CMU)
NARISON	94	PL B341 73	•	(CERN, MONP)
TITARD	94	PR D49 6007	+Yndurain	(MICH, MADU)
ALVAREZ	93	ZPHY C60 53	+Barate, Bloch, Bonamy+	(CERN NA14/2 Collab.)
ELLIS	89C	NP B312 551	+Nason	(FNAL, ETH)
NARISON	89	PL B216 191		` (ICTP)
NARISON	87	PL B197 405		(ČERN)
GASSER	82	PRPL 87 77	+Leutwyler	(BERN)

b

$$I(J^P) = 0(\frac{1}{2}^+)$$

Charge = $-\frac{1}{3}e$

Bottom = -1

b-QUARK MASS

The b-quark mass is estimated from bottomonium and B masses. It corresponds to the "running" mass $m_{B}~(\mu=m_{B})$ in the $\overline{\rm MS}$ scheme. We have converted masses in other schemes to the $\overline{\rm MS}$ scheme using one-loop QCD pertubation theory with $\alpha_S(\mu=m_b)=0.22$. The range 4.1–4.5 GeV for the $\overline{\rm MS}$ mass corresponds to 4.5–4.9 GeV for the pole mass (see the "Note on Quark Masses").

VALUE (GeV)	DOCUMENT ID		TECN	COMMENT
4.1 to 4.4 OUR EVALUATION • • • We do not use the follow		s. fits	. limits.	etc. • • •
3.91 ±0.67	1 ABREU		DLPH	
4.15 ±0.05 ±0.20	² GIMENEZ	97	LATT	MS scheme
4.13 ±0.06	3 JAMIN	97	THEO	MS scheme
4.16 ±0.32 ±0.60	⁴ RODRIGO	97	THEO	MS scheme
4.22 ±0.05	⁵ NARISON	95B	THEO	M5 scheme
4.415±0.006	6 VOLOSHIN	95	THEO	MS scheme
4.0 ±0.1	7 DAVIES	94	THEO	
≥ 4.26	8 LIGETI	94	THEO	
≥ 4.2	9 LUKE	94	THEO	MS scheme
4.23 ±0.04	10 NARISON	94		MS scheme
4.397±0.025	11 TITARD	94	THEO	MS scheme
4.32 ±0.05	12 DOMINGUEZ	92	THEO	
4.24 ±0.05	13 NARISON	89	THEO	
4.18 ±0.02	14 REINDERS	88	THEO	
4.30 ±0.13	· 15 NARISON	87	THEO	
4.25 ±0.1	16 GASSER	82	THEO	

¹ ABREU 981 determines the $\overline{\rm MS}$ mass $m_b=2.67\pm0.25\pm0.34\pm0.27$ GeV at $\mu={\rm M}_Z$ from three jet heavy quark production at LEP. ABREU 981 have rescaled the result to $\mu=m_b$ using α_s =0.118 \pm 0.003.

 2 GIMENEZ 97 uses lattice computations of the B-meson propagator and the B-meson binding energy \overline{A} in the HQET. Their systematic (second) error for the $\overline{\rm MS}$ mass is an estimate of the effects of higher-order corrections in the matching of the HQET operators

 3 JAMIN 97 apply the QCD moment method to the au system. They also find a pole mass

of 4.60 \pm 0.02. ⁴ RODRIGO 97 determines the $\overline{\rm M5}$ mass $m_b \approx 2.85 \pm 0.22 \pm 0.20 \pm 0.36$ GeV at $\mu=M_Z$ from three jet heavy quark production at LEP. We have rescaled the result.

5 NARISON 958 uses finite energy sum rules to two-loop accuracy to determine a b-quark pole mass of 4.61 ± 0.05 GeV.

 6 VOLOSHIN 95 result was converted from a pole mass of 4827 \pm 7 MeV using the oneloop formula. Pole mass was extracted using moments of the total cross section for → bhadrons

 7 DAVIES 94 uses lattice computation of au spectroscopy. They also quote a value of 5.0 ± 0.2 GeV for the *b*-quark pole mass. The numerical computation includes quark vacuum polarization (unquenched); they find that the masses are independent of n_f to within their errors. Their error for the pole mass is larger than the error for the $\overline{\rm MS}$ mass, because both are computed from the bare lattice quark mass, and the conversion for the pole mass is less accurate.

B LIGETI 94 computes lower bound of 4.66 GeV on pole mass using HQET, and experimental data on inclusive B and D decays.

9LUKE 94 computes lower bound of 4.60 GeV on pole mass using HQET, and experimental data on inclusive B and D decays.

 10 NARISON 94 uses spectral sum rules to two loops, and $J/\psi(15)$ and ${\cal T}$ systems.

 11 TITARD 94 uses one-loop computation of the quark potential with nonperturbative gluon condensate effects to fit $J/\psi(1S)$ and Υ states.

 $^{12}\,\text{DOMINGUEZ}$ 92 determines pole mass to be 4.72 \pm 0.05 using next-to-leading order in 1/m in moment sum rule.

13 NARISON 89 determines the Georgi-Politzer mass at $p^2 = -m^2$ to be 4.23 \pm 0.05 GeV using QCD sum rules.

¹⁴ REINDERS 88 determines the Georgi-Politzer mass at $p^2 = -m^2$ to be 4.17 \pm 0.02 using moments of $\overline{b}\gamma^{\mu}b$. This technique leads to a value for the mass of the B meson of 5.25 ± 0.15 GeV.

 15 NARISON 87 determines the pole mass to be 4.70 \pm 0.14 using QCD sum rules, with $\Lambda(\overline{MS}) = 180 \pm 80 \text{ MeV}.$

 16 GASSER 82 uses SVZ sum rules. The renormalization point is $\mu=$ quark mass.

mb - mc MASS DIFFERENCE

The mass difference m_b-m_c in the HQET scheme is 3.4 \pm 0.2 GeV (see the "Note on Quark Masses").

VALUE (GeV) DOCUMENT ID 17 GROSSE > 3.29 78

 17 GROSSE 78 obtain (m_b-m_c) $\,\geq$ 3.29 GeV based on elgenvalue inequalities in potential

b-QUARK REFERENCES

ABREU	981	PL B418 430	P. Abreu+	(DELPHI Collab.)
GIMENEZ	97	PL B393 124	V. Gimenez, G	. Martinelli, C.T. Sachrajdà
JAMIN	97	NP B507 334	M. Jamin, A. I	Pich
RODRIGO	97	PRL 79 193	G. Rodrigo, A.	Santamaria, M. Bilenky
NARISON	95B	PL B352 122	=	(MONP)
VOLOSHIN	95	IJMP A10 2865		`(MINN)
DAVIES	94	PRL 73 2654	+Hornbostel+	(GLAS, SMU, CORN, EDIN, OSÚ, FSÚ)
LIGETI	94	PR D49 R4331	+Nir	(REHO)
LUKE	94	PL B321 88	+Savage	(TNTO, UCSD, CMU)
NARISON	94	PL B341 73		(CERN, MONP)
TITARD	94	PR D49 6007	+Yndurain	(MICH, MADU)
DOMINGUEZ	92	PL B293 197	+Paver	(CAPE, TRST, INFN)
NARISON	89	PL B216 191		(ICTP)
REINDERS	88	PR D38 947		(BONN)
NARISON	87	PL B197 405		(CERN)
GASSER	82	PRPL 87 77	+Leutwyler	(BERN)
GROSSE	78	PL 79B 103	+ Martin	(CERN)

t

models.

$$I(J^P) = 0(\frac{1}{2}^+)$$

Charge $\approx \frac{2}{3} e$ Top = +1

THE TOP QUARK

Revised April 1998 by M. Mangano (CERN) and T. Trippe (LBNL).

A. Introduction: The top quark is the Q = 2/3, $T_3 = +1/2$ member of the weak-isospin doublet containing the bottom quark (see our review on the "Standard Model of Electroweak Interactions" for more information). This note collects a summary of its currently measured properties, in addition to a discussion of the experimental and theoretical issues involved in the determination of its parameters (mass, production cross section, decay branching ratios, etc.) and some comments on of the prospects for future improvements.

B. Top quark production at the Tevatron: At the Tevatron energy, 1.8 TeV, top quarks are dominantly produced in pairs from pure QCD processes: $q\bar{q} \rightarrow t\bar{t}$ and $gg \rightarrow t\bar{t}$. The production cross section through these channels is expected to be approximately 5 pb at $m_t = 175 \text{ GeV/c}^2$, with a dominant 90% contribution from the $q\overline{q}$ annihilation process. Smaller contributions come from the single-top production mechanisms, namely $q\overline{q}' \to W^* \to t\overline{b}$ and $qg \to q't\overline{b}$, this last mediated by a t-channel virtual-W exchange. The combined rate from these processes is approximately 2.5 pb at $m_t = 175 \text{ GeV}$ (see Ref. 1 and references therein). The actual contribution of these channels to the detected final states is further reduced relative to the dominant pair-production mechanisms, due to the lower experimental acceptances.

With a mass above the Wb threshold, the top quark decay width is dominated by the two-body decay $t \to Wb$. Neglecting terms of order m_b^2/m_t^2 and of order $(\alpha_s/\pi)m_W^2/m_t^2$, this is predicted in the Standard Model to be [2]:

$$\Gamma_{t} = \frac{G_{F}m_{t}^{3}}{8\pi\sqrt{2}} \left(1 - \frac{M_{W}^{2}}{m_{t}^{2}}\right)^{2} \left(1 + 2\frac{M_{W}^{2}}{m_{t}^{2}}\right) \left[1 - \frac{2\alpha_{s}}{3\pi} \left(\frac{2\pi^{2}}{3} - \frac{5}{2}\right)\right]. \tag{1}$$

Quark Particle Listings

t

The use of G_F in this equation accounts for the largest part of the one-loop electroweak radiative corrections, providing an expression accurate to better than 2%. The width values increase with mass, going for example from 1.02 GeV at $m_t = 160$ GeV to 1.56 GeV at $m_t = 180$ GeV (we used $\alpha_S(\rm M_Z) = 0.118$). With such a correspondingly short lifetime, the top quark is expected to decay before top-flavored hadrons or $t\bar{t}$ -quarkonium bound states can form.

In top decay, the Ws and Wd final states are expected to be suppressed relative to Wb by the square of the CKM matrix elements V_{ts} and V_{td} , whose values can be estimated under the assumption of unitarity of the three-generation CKM matrix to be less than 0.042 and 0.013, respectively (see our review "The Cabibbo-Kobayashi-Maskawa Mixing Matrix" in the current edition for more information).

Typical final states for the leading pair-production process therefore belong to three classes:

- A. $t\overline{t} \to W b W \overline{b} \to q \overline{q}' b q'' \overline{q}''' \overline{b}$,
- B. $t\overline{t} \to W b W \overline{b} \to q \overline{q}' b \ell \overline{\nu}_{\ell} \overline{b} + \overline{\ell} \nu_{\ell} b q \overline{q}' \overline{b}$,
- C. $t\overline{t} \to W b W \overline{b} \to \overline{\ell} \nu_{\ell} b \ell' \overline{\nu}_{\ell'} \overline{b}$,

where A, B, and C are referred to as the all-jets, lepton + jets, and dilepton channels, respectively.

The final state quarks emit radiation and evolve into jets of hadrons. The precise number of jets reconstructed by the detectors varies event by event, as it depends on the decay kinematics, as well as on the precise definition of jet used in the analysis. The neutrinos are reconstructed via the large imbalance in detected transverse momentum of the event (missing E_T).

The observation of $t\bar{t}$ pairs has been reported in all of the above decay modes. As discussed in detail below, the top quark production and decay properties extracted from the three different decay channels above are all consistent with each other, within the present experimental sensitivity. In particular, the $t \to Wb$ decay mode has been confirmed by the reconstruction of the $W \to jj$ invariant mass in the $\ell \bar{\nu}_\ell b \bar{b} jj$ final state [3].

The extraction of the top-quark properties from the Tevatron data requires a good understanding of the production and decay mechanisms of the top itself, as well as of the large background processes. The theoretical estimates of the physics backgrounds have large uncertainties, since only leading order QCD calculations are available for most of the relevant processes (W+3 and 4 jets, or WW+2 jets). While this limitation is known to affect the estimates of the overall production rates, it is believed that the LO determination of the event kinematics and of the fraction of W plus multi-jet events containing b quarks is rather accurate. In particular, one expects the E_T spectrum of these jets to fall rather steeply, the jet direction to point preferentially at small angles from the beams, and the fraction of events with b quarks to be of the order of few percent. In the case of the top signal, vice versa, the b fraction is $\sim 100\%$ and the jets are rather energetic, since they come from the decay of a massive object. It is therefore possible to improve the S/B ratio by either requiring the presence of a b quark, or by selecting very energetic and central kinematical configurations.

A detailed study of control samples with features similar to those of the relevant backgrounds, but free from possible top contamination is required to provide a reliable check on the background estimates.

C. Measured top properties: All direct measurements of top quark production and decay have been made by the CDF and DØ experiments at the Fermilab Tevatron collider in $p\overline{p}$ collisions at $\sqrt{s}=1.8$ TeV. Since the first direct experimental evidence for the top quark in 1994 [4] by CDF (a 2.8 σ effect. See this review in our 1996 edition [5] for more details) and the conclusive observation by both CDF and DØ in 1995 [6,7], the integrated luminosity has increased to 109 pb⁻¹ for CDF and 125 pb⁻¹ for DØ, allowing significant improvements in the measurement of the top production cross section, mass, and decay properties.

DØ and CDF determine the $t\bar{t}$ cross section $\sigma_{t\bar{t}}$ from their numbers of top candidates, their estimated background, their $t\bar{t}$ acceptance, and their integrated luminosity, assuming Standard Model decays $t\to Wb$ with unity branching ratio. Table 1 shows the measured cross sections from DØ and CDF along with the range of theoretical expectations, evaluated at the m_t values used by the experiments in calculating their acceptances. There is fairly good agreement between the experiments and the theoretical expectations, although the CDF values are somewhat higher than the theory values. This agreement supports the hypothesis that the excess of events over background in all of these channels is due to $t\bar{t}$ production. A joint CDF/DØ working group is expected to produce a combined cross section for the two experiments in the near future.

Future precise determinations of the top production cross section will test the current theoretical understanding of the production mechanisms [8–11]. A precise understanding of top production at the Tevatron is important for the extrapolation to the higher energies of future colliders, like the LHC, where the expected large cross section will enable more extensive studies. Discrepancies in rate between theory and data, on the other hand, would be more exciting and might indicate the presence of exotic production channels, as predicted in some models. In this case, one should also expect a modification of kinematical distributions such as the invariant mass of the top pair or the top quark transverse momentum.

The top mass has been measured in the lepton + jets and dilepton channels by both DØ and CDF, and in the all-jets channel by CDF. At present, the most precise measurements come from the lepton + jets channel with four or more jets and large missing E_T . In this channel, each event is subjected to a two-constraint kinematic fit to the hypothesis $t\bar{t} \to W^+ b W^- \bar{b} \to \ell \nu_\ell q \bar{q}' b \bar{b}$, assuming that the four highest E_T jets are the $t\bar{t}$ daughters. The shape of the distribution of fitted top masses from these events is compared to templates

Table 1: Cross section for $t\bar{t}$ production in $p\bar{p}$ collisions at $\sqrt{s} = 1.8$ TeV from DØ $(m_t = 173.3 \text{ GeV/c}^2)$, CDF $(m_t = 175 \text{ GeV/c}^2)$, and theory.

$t\overline{t}$ cross section	Source	Ref.	Method
$4.1 \pm 2.0 \text{ pb}$	DØ	[12]	lepton + jets
$8.2 \pm 3.5~\mathrm{pb}$	DØ	[12]	lepton + jets/ μ
$6.3 \pm 3.3~\mathrm{pb}$	DØ	[12]	dileptons $+ e \nu$
$5.5 \pm 1.8 \text{ pb}$	DØ	[12]	Ref. 12 combined
5.0 – 5.8 pb	Theory	[8-11]	at $m_t = 173.3 \text{ GeV/c}^2$
6.7 ^{+2.0} _{-1.7} pb	CDF	[13]	lepton + jet
$8.2^{+4.4}_{-3.4}$ pb	CDF	[14]	dileptons
$10.1^{+4.5}_{-3.6} \text{ pb}$	CDF	[15]	all jets
7.6 ^{+1.8} _{-1.5} pb	CDF	[13]	Refs. 13–15 combined
4.75 - 5.5 pb	Theory	[8-11]	at $m_t = 175 \text{ GeV/c}^2$

expected from a mixture of background and signal distributions for a series of assumed top masses. This comparison yields values of the likelihood as a function of top mass, from which a best value of the top mass and its error are obtained. The results are shown in Table 2. The systematic error, the second error shown, is comparable to the statistical error and is primarily due to uncertainties in the jet energy scale and the Monte Carlo modeling.

Less precise determinations of the top mass come from the dilepton channel with two or more jets and large missing E_T , and from the all-jets channel. In the dilepton channel a kinematically constrained fit is not possible because there are two missing neutrinos, so experiments must use other mass estimators than the reconstructed top mass. Any quantity which is correlated with top mass can be used as a mass estimator. DØ uses the fact that if m_t is assumed, the $t\bar{t}$ system can be reconstructed (up to a four-fold ambiguity). They compare the resulting kinematic configurations to expectations from $t\bar{t}$ production and obtain a weight vs m_t curve for each event, which they coarsely histogram to obtain four shapesensitive quantities as their multidimensional mass estimator. Their method yields a significant increase in precision over onedimensional estimators. CDF does two analyses, one using the b quark jet energy and the other using the ℓ b-jet invariant mass. Both DØ and CDF obtain the top mass and error from these mass estimators using the same template likelihood method as for the lepton + jets channel. CDF also measures the mass in the all-jets channel using events with six or more jets, at least one of which is tagged as a b jet by the presence of a secondary vertex.

As seen in Table 2, all top mass results are in good agreement, giving further support to the hypothesis that these events are due to $t\bar{t}$ production. A joint CDF/DØ working group is expected to produce a combined CDF/DØ average top mass in the near future, taking into account correlations

Table 2: Top mass measurements from $D\emptyset$ and CDF.

$m_t \; ({ m GeV/c^2})$	Source	Ref.	Method
$\overline{173.3 \pm 5.6 \pm 5.5}$	DØ	[16]	lepton + jets
$168.4 \pm 12.3 \pm 3.6$	DØ	[17]	dileptons
$172.1 \pm 5.2 \pm 4.9$	DØ	[16]	DØ combined
$175.9 \pm 4.8 \pm 4.9$	CDF	[18]	lepton + jet
$161\pm17\pm10$	CDF	[14]	dileptons
$186 \pm 10 \pm 12$	CDF	[15]	all jets
$173.8 \pm 3.5 \pm 3.9$ *	PDG		PDG Average

^{*} Average does not include CDF all jets. See text.

between the systematic errors in the different measurements. In the meantime, the PDG obtains an average top mass as follows. Using DØ's approach to combining their own results [16], we assume a 100% correlation between the DØ lepton + jets and dilepton systematic errors for jet energy scale, signal model, and multiple interactions, and 0% correlation between their other systematic errors. CDF have not published their combined results, but we can include CDF results for lepton + jets [18] and dileptons [14] by assuming 100% correlation between the signal model errors in all four results and 100% correlation between the jet energy scale errors of the two CDF results. In addition, in a given channel, lepton + jets or dileptons, we assume a 100% correlation between systematic errors in the CDF and DØ background shapes. All other correlations are assumed to be zero. We do not include the CDF all jets channel because we do not know what correlation to assume for its signal model error. These assumptions yield a PDG average top mass of $m_t = 173.8 \pm 3.5 \pm 3.9 \text{ GeV}/c^2 = 173.8 \pm 5.2 \text{ GeV}/c^2$.

Given the experimental technique used to extract the top mass, the top mass values should be taken as representing the top *pole mass* (see our review "Note on Quark Masses" in the current edition).

The extraction of the value of the top mass from the analyses described requires, in addition to an understanding of the absolute energy calibration and resolution of the detectors, also an a priori knowledge of the structure of the final state. Given the hardness of a $t\bar{t}$ production process, jets can in fact arise not only from the top decays, but also from the initial state gluon radiation. Furthermore, quarks from the top decays can radiate additional jets. The presence of these additional jets will affect the shape of the mass spectrum, depending on the details of how the samples used for the mass determination were defined. QCD calculations used to model top production and decay are expected to be rather reliable, but residual uncertainties remain and are accounted for in the overall systematic error on the top mass. The larger samples that will become available in the future will allow more strict selection criteria, leading to purer samples of top quarks. For example, requesting the presence of four and only four jets in the event, two of which are b tagged jets and the other two of which are central jets of high- E_T , should largely reduce the possibility of erroneously including jets not coming from the top decays into the mass reconstruction. This will significantly improve the mass resolution and will make it less sensitive to the theoretical uncertainties. With a smaller error on the top mass, and with yet improved measurements of the electroweak parameters, it will be possible to get important constraints on the value of the Higgs mass. Current global fits performed within the Standard Model and its minimal supersymmetric extension provide indications for a relatively light Higgs (see the " H^0 Indirect Mass Limits from Electroweak Analysis" in the Particle Listings of the current edition), possibly within the range of the upcoming LEP2 experiments.

Measurements of other properties of top decays are underway. CDF reports a direct measurement of the $t \to Wb$ branching ratio [19]. Their preliminary result, obtained by comparing the number of events with 0, 1 and 2 tagged b jets and using the known tagging efficiency, is: $R = B(t \rightarrow Wb) / \sum_{q=d,s,b} B(t \rightarrow Wb) / \sum_{q=d$ $Wq) = 0.99 \pm 0.29$ where the error includes statistical and systematic uncertainties, or as a lower limit, R > 0.58 at 95% CL. Assuming that non-W decays of top can be neglected, that only three generations exist, and assuming the unitarity of the CKM matrix, they extract a CKM matrix-element $|V_{th}| = 0.99 \pm 0.15$ or $|V_{tb}| > 0.76$ at 95% CL. A more direct measurement of the Wtb coupling constant will be possible when enough data have been accumulated to detect the less frequent single-top production processes, such as $q\tilde{q}' \to W^* \to t\tilde{b}$ and $qb \to q't$ via W exchange. The cross-sections for these processes are proportional to $|V_{tb}|^2$, and no assumption on the number of families or the unitarity of the CKM matrix needs to be made to extract

Both CDF and DØ are searching for non-Standard Model top decays, particularly those expected in supersymmetric models. CDF [20] has published a direct search for top decay to a charged Higgs and a b quark followed by $H^+ \to \tau \nu_{\tau}$ with τ decaying to hadrons. This search focuses on large $\tan \beta$, the ratio of the vacuum expectation values for the two Higgs doublets. As $\tan \beta$ increases, the $t \to H^+ b$ and $H^+ \to \tau \nu_{\tau}$ branching fractions are both expected to approach one, maximizing sensitivity to this mode. CDF sees no excess of events over the expected background, giving an exclusion region in the $m_{H^+} vs \tan \beta$ plane (see their Fig. 3) which extends to m_{H^+} values higher than existing LEP limits for $\tan \beta$ above 100, assuming $m_t = 175 \text{ GeV}/c^2$ and $\sigma_{t\bar{t}} = 5.0 \text{ pb}$.

DØ and CDF are looking for top disappearance via $t \to H^+b$, $H^+ \to \tau \nu$ or $c\bar{s}$. These charged Higgs decays would not be detected in the lepton + jets or dilepton cross section analyses as efficiently as $t \to W^\pm b$, primarily because of the absence of energetic isolated leptons in the Higgs decays. This would give rise to measured cross sections lower than the Standard Model prediction, assuming that non-Standard Model $t\bar{t}$ production is negligible. The H^+ is expected to decay to $\tau \nu$ at high $\tan \beta$ and to $c\bar{s}$ or $Wb\bar{b}$ at low $\tan \beta$. The $\tau \nu$ and

 $c\overline{s}$ modes lead to disagreement with the observed cross section and thus to exclusion regions at both low and high $\tan \beta$. At high $\tan \beta$ these experiments can potentially probe m_{H^+} up to the top decay kinematic limit, while at low $\tan \beta$ the m_{H^+} reach is expected to be weakened to perhaps 140 GeV. This is because at higher m_{H^+} and low $\tan \beta$ the $H^+ \to W b \bar{b}$ decay mode dominates [21] and cannot easily be distinguished from Standard Model top decay.

Searches for other possible new particles such as a supersymmetric scalar top quark (\tilde{t}) via $t \to \tilde{t} \tilde{\chi}^0$, are under way both at CDF and DØ.

CDF reports a search for flavor changing neutral current (FCNC) decays of the top quark $t \to q\gamma$ and $t \to qZ$ [22], for which the Standard Model predicts such small rates that their observation here would indicate new physics. They assume that one top decays via FCNC while the other decays via Wb. For the $t \to q\gamma$ search, they search for two signatures, depending on whether the W decays leptonically or hadronically. For leptonic W decay, the signature is $\gamma \ell$ plus missing E_T and two or more jets, while for hadronic W decay, it is γ plus four or more jets, one with a secondary vertex b tag. They observe one event $(\mu\gamma)$ with an expected background of less than half an event, giving an upper limit on the top branching ratio of $B(t \to q\gamma) < 3.2\%$ at 95% CL.

For the $t\to qZ$ FCNC search, they look for $Z\to \mu\mu$ or ee and $W\to$ hadrons, giving a Z plus four jet signature. They observe one $\mu\mu$ event with an expected background of 1.2 events, giving an upper limit on the top branching ratio of $B(t\to qZ)<33\%$ at 95% CL. Both the γ and Z limits are non-background subtracted (i.e. conservative) estimates.

Studies of the decay angular distributions are also in progress using the current data sets. They will allow a first direct analysis of the V-A nature of the Wtb coupling, as well as providing direct information on the relative coupling of longitudinal and transverse W bosons to the top. In the Standard Model, the fraction of decays to transversely polarized W bosons is expected to be $1/(1+m_t^2/2M_W^2)$ (30% for $m_t=175~{\rm GeV}$. Deviations from this value would challenge the Higgs mechanism of spontaneous symmetry breaking.

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t-Quark Mass in pp Collisions

The t quark has now been observed, Its mass is sufficiently high that decay is expected to occur before hadronization. OUR EVALUATION is an AVERAGE which incorporates correlations as described in the note "The Top Quark" above.

For earlier search limits see the Review of Particle Physics, Phys. Rev. D54.1 (1996).

VALUE (GeV)	DOCUMENT ID	TECN	COMMENT
173.8± 5.2 OUR EVALUAT	ION		
168.4±12.3± 3.6	1 ABBOTT	98D D0	ll + jets
173.3± 5.6± 5.5	¹ ABBOTT	98F D0	ℓ + jets
175.9± 4.8± 4.9	² ABE	98E CDF	ℓ + jets
161 ±17 ±10	² ABE	98F CDF	ll + jets
• • • We do not use the foll	lowing data for averag	es, fits, limits	, etc. • • •
173.3± 5.6± 6.2	¹ ABACHi	97E D0	ℓ + jets
186 ±10 ±12	^{2,3} ABE	97R CDF	6 or more jets
199 $^{+19}_{-21}$ ± 22	ABACHI	95 D0	ℓ + Jets
$176 \pm 8 \pm 10$	ABE	95F CDF	l + b-jet
174 ±10 +13	ABE	94E CDF	ℓ + b-jet

¹ Result is based on 125 pb⁻¹ of data at $\sqrt{s} = 1.8$ TeV.

t-Quark Decay Branching Fractions

VALUE (%)	DOCUMENT ID	TECN	COMMENT
• • • We do not use the followin	g data for averages	, fits, limits,	etc. • • •
	4 ARE	97V CDF	I + lets

⁴ ABE 97v searched for $t\bar{t} \to (\ell\nu_\ell) (\tau\nu_\tau) b\bar{b}$ events in 109 pb⁻¹ of $p\bar{p}$ collisions at $\sqrt{s}=1.8$ TeV. They observed 4 candidate events where one expects ~ 1 signal and ~ 2 background events. Three of the four observed events have jets identified as b candidates.

Indirect t-Quark Mass from Standard Model Electroweak Fit

VALUE (GeV)

"OUR EVALUATION" below is from the fit to electroweak data described in the "Electroweak Model and Constraints on New Physics" section of this Review. This fit result does not include direct measurements of m_t . The central value and first uncertainty are for $M_H=M_Z$. The second uncertainty is the shift from changing M_H to 300 GeV.

The RVUE values are based on the data described in the footnotes. RVUE's published before 1994 and superseded analyses are now omitted. For more complete listings of earlier results, see the 1994 edition (Physical Review **D50** 1173 (1994)).

DOCUMENT ID

170 ± 7 (+14) OUR EVALUATION								
• • We do not use the follo	wing data for average	s, fits, limits	, etc. • • •					
172.0^{+}_{-} $\begin{array}{c} 5.8 \\ 5.7 \end{array}$	⁵ DEBOER	978 RVUE	Electroweak + Direct					
157 ⁺¹⁶ ₋₁₂	⁶ ELLIS	96c RVUE	Z parameters, m _W , low energy					
175 $\pm 11 \begin{array}{c} +17 \\ -19 \end{array}$	⁷ ERLER	95 RVUE	Z parameters, m _W , low energy					
$180 \pm 9^{+19}_{-21} \mp 2.6 \pm 4.8$	⁸ MATSUMOTO	95 RVUE	-					
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	⁹ ABREU	94 DLPH	Z parameters					
158 $^{+32}_{-40}$ ±19	¹⁰ ACCIARRI	94 L3	Z parameters					
132 +41 +24 -48 -18	11 AKERS	94 OPAL	Z parameters					
$190 \begin{array}{c} +39 \\ -48 \end{array} \begin{array}{c} +12 \\ -14 \end{array}$	12 ARROYO	94 CCFR	$ u_{\mu}$ iron scattering					
$184 \begin{array}{ccc} +25 & +17 \\ -29 & -18 \end{array}$	¹³ BUSKULIC	94 ALEP	Z parameters					
153 ±15	¹⁴ ELLIS	94B RVUE	Electroweak					
$177 \pm 9 \begin{array}{l} +16 \\ -20 \end{array}$	¹⁵ GURTU	94 RVUE	Electroweak					
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	¹⁶ MONTAGNA	94 RVUE	Electroweak					
171 $\pm 12 \begin{array}{c} +15 \\ -21 \end{array}$	¹⁷ NOVIKOV	94B RVUE	Electroweak					
160 +50 -60	18 ALITTI	92B UA2	m _W , m _Z					

⁵ DEBOER 97B result is from the five-parameter fit which varies m_Z , m_t , m_H , α_S , and $\alpha(m_Z)$ under the contraints: m_t =175 ± 6 GeV, $1/\alpha(m_Z)$ =128.896 ± 0.09. They found m_H =141 $^{+140}_{-77}$ GeV and $\alpha_S(m_Z)$ =0.1197 ± 0.0031.

⁶ ELLIS 96C result is a the two-parameter fit with free m_t and m_{H^+} yielding also m_H =65 $^+_-$ 17 GeV.

⁷ ERLER 95 result is from fit with free m_t and $\alpha_s(m_Z)$, yielding $\alpha_s(m_Z) = 0.127(5)(2)$.

⁸ MATSUMOTO 95 result is from fit with free m_t to Z parameters, M_W , and low-energy neutral-current data. The second error is for $m_H = 300 {+ 700 \atop 240}$ GeV, the third error is for $\alpha_s(m_Z) = 0.116 \pm 0.005$, the fourth error is for $\delta \alpha_{\rm had} = 0.0283 \pm 0.0007$.

⁹ ABREU 94 value is for $\alpha_s(m_Z)$ constrained to 0.123 \pm 0.005. The second error corresponds to $m_H = 300^{+700}_{-240}$ GeV.

 10 ACCIARRI 94 value is for $\alpha_s(m_Z)$ constrained to 0.124 \pm 0.006. The second error corresponds to $m_H=300^{+700}_{-240}$ GeV.

 11 AKERS 94 result is from fit with free α_5 . The second error corresponds to $m_H{=}300 {\,}^{+}700$ GeV. The 95%CL limit is m_t <210 GeV.

12 ARROYO 94 measures the ratio of the neutral-current and charged-current deep inelastic scattering of ν_{μ} on an iron target. By assuming the SM electroweak correction, they obtain $1-m_W^2/m_Z^2=0.2218\pm0.0059$, yielding the quoted $m_{\hat{t}}$ value. The second error corresponds to $m_H=300^{+700}_{-240}$ GeV.

 13 BUSKULIC 94 result is from fit with free $\alpha_{\rm S}.$ The second error is from $m_{H}{=}300^{+700}_{-240}$ GeV.

14 ELLIS 94B result is fit to electroweak data available in spring 1994, including the 1994 A_{LR} data from SLD. m_t and m_H are two free parameters of the fit for $\alpha_s(m_Z) = 0.118 \pm 0.007$ yielding m_t above, and $m_H = 35 {+}^{+}70_{-}$ GeV. ELLIS 94B also give results for fits including constraints from CDF's direct measurement of m_t and CDF's and DØ 's production cross-section measurements. Fits excluding the A_{LR} data from SLD are also given.

BYPCH.

15 GURTU 94 result is from fit with free m_t and $\alpha_s(m_Z)$, yielding m_t above and $\alpha_s(m_Z)$ $= 0.125 \pm 0.005 ^{+0.003}_{-0.001}$. The second errors correspond to $m_H = 300 ^{+700}_{-240}$ GeV. Uses LEP, M_W , νN , and SLD electroweak data available in spring 1994.

16 MONTAGNA 94 result is from fit with free m_t and $\alpha_s(m_Z)$, yielding m_t above and $\alpha_s(m_Z)=0.124$. The second errors correspond to $m_H=300^{+700}_{-240}$ GeV. Errors in $\alpha(m_Z)$ and m_D are taken into account in the fit. Uses LEP, SLC, and M_W/M_Z data available in spring 1994.

¹⁷ NOVIKOV 94B result is from fit with free m_t and $\alpha_s(m_Z)$, yielding m_t above and $\alpha_s(m_Z) = 0.125 \pm 0.005 \pm 0.002$. The second errors correspond to $m_H = 300^{+700}_{-240}$ GeV. Uses LEP and CDF electroweak data available in spring 1994.

 18 ALITTI 92B assume $m_H=$ 100 GeV. The 95%CL limit is $m_{\mbox{\it t}}<$ 250 GeV for $m_H<$ 1 TeV.

² Result is based on 109 \pm 7 pb⁻¹ of data at \sqrt{s} = 1.8 TeV.

 $^{^3}$ ABE 97R result is based on the first observation of all hadronic decays of $t\bar{t}$ pairs. Single b-quark tagging with jet-shape variable constraints was used to select signal enriched multi-jet events. Not used in OUR EVALUATION because of unknown correlations in the systematic errors. A joint CDF-DØ working group is considering how to include these results.

Quark Particle Listings

t, b' (Fourth Generation) Quark

		r-Q	uark REFERENCES	
ABBOTT	98D	PRI. 80 2063	B. Abbott+	(D0 Collab.)
ABBOTT	98F	PR D (to be publ.)	B. Abbott+	(D0 Collab.)
FERMILAE	-Pub-	98/031-E		
ABE	98E	PRL 80 2767	F. Abe+	(CDF Collab.)
ABE	98F	PRL 80 2779	F. Abe+	(CDF Collab.)
ABACHI		PRL 79 1197	S. Abachi+	(D0 Collab.)
ABE		PRL 79 1992	F. Abe+	(CDF Collab.)
ABE	97V	PRL 79 3585	F. Abe+	(CDF Collab.)
DEBOER	97B	ZPHY C75 627	W. de Boer, A. Dabelstein, W. Hollik+	
EŁLIS		PL B389 321	+Fogli, Lisi	(CERN, BARI)
ABACHI	95	PRL 74 2632	+Abbott, Abolins, Acharya, Adam+	(DO Collab.)
ABE	95F	PRL 74 2626	+Akimoto, Akopian, Albrow, Amendolia+	(CDF Collab.)
ERLER	95	PR D\$2 441	+Langacker	(PENN)
MATSUMOTO		MPL A10 2553		(KEK)
ABE	94E	PR D50 2966	+Albrow, Amendolia, Amidei, Antos+	(CDF Collab.)
Also	94F	PRL 73 225	Abe, Albrow, Amidei, Antos, Anway-Weis	e+ (CDF Collab.)
ABREU	94	NP B418 403		(DELPHI Collab.)
ACCIARRI	94	ZPHY C62 551	+Adam, Adriani, Aguilar-Benitez+	(L3 Collab.)
AKERS	94	ZPHY C61 19	+ Alexander, Allison+	(OPAL Collab.)
ARROYO	94	PRL 72 3452	+King, Bachman+ (COLU, CHIC, FNA	
BUSKULIC	94	ZPHY C62 539	+Casper, De Bonis, Decamp, Ghez, Goy+	(ALEPH Collab.)
ELLIS	94B	PL B333 118	+Fogli, Lisi	(CERN, BARI)
GURTU	94	MPL A9 3301		(TATA)
MONTAGNA	94	PL B335 484	+Nicrosini, Passarino, Piccinini (INFN, PA)	/I, CERN, TORI)
NOVIKOV	94B	MPL A9 2641	+Okun, Rozanov, Vysotsky (GUE	L, CERN, ITEP)
PDG	94	PR D50 1173		L, BOST, IFIC+)
ALITTI	92B	PL B276 354	+Ambrosini, Ansari, Autiero, Bareyre+	(UA2 Collab.)

b' (4th Generation) Quark, Searches for

MASS LIMITS for b' (4th Generation) Quark or Hadron in $p\bar{p}$ Collisions

These experiments (except for MUKHOPADHYAYA 93 and ABACHI 97D) assume that no two-body modes such as $b' \rightarrow b\gamma$, $b' \rightarrow bg$, or $b' \rightarrow cH^+$ are available.

VALUE (GeV)	CL%	DOCUMENTID		IECN	COMMENT	
>128	95	¹ ABACHI	95F	D0	$\ell\ell$ + jets, ℓ + jets	
• • We do not use the	following	data for averages	, fits	, limits,	etc. • • •	
> 96	95	² ABACHI	97D	D0	FCNC $(b' \rightarrow b\gamma)$	
> 75	95	3 MUKHOPAD	93	RVUE	FCNC $(b' \rightarrow b\ell^+\ell^-)$	
> 85			92	CDF	$\ell\ell$	
> 72			90B	CDF	$e + \mu$	
> 54			90	UA2	$e + jets + missing E_T$	
> 43			90B	UA1	μ + jets	
> 34	95	⁸ ALBAJAR	88	UA1	e or μ + jets	

- ¹ ABACHI 95F bound on the top-quark also applies to b' and t' quarks that decay predominantly into W. See FROGGATT 97.
- ² ABACHI 97D searched for b' that decays mainly via FCNC. They obtained 95%CL upper bounds on B($b'\overline{b}' \rightarrow \gamma + 3$ jets) and B($b'\overline{b}' \rightarrow 2\gamma + 2$ jets), which can be interpreted as the lower mass bound $m_{b'} > m_Z + m_b$.
- 3 MUKHOPADHYAYA 93 analyze CDF dilepton data of ABE 92G in terms of a new quark decaying via flavor-changing neutral current. The above limit assumes $\mathsf{B}(b' \to$ $b\ell^+\ell^-$)=1%. For an exotic quark decaying only via virtual Z [B($b\ell^+\ell^-$) = 3%], the limit is 85 GeV.
- ⁴ ABE 92 dilepton analysis limit of >85 GeV at CL≈95% also applies to b' quarks, as discussed in ABE 908.

 ABE 908 exclude the region 28-72 GeV.
- 6 AKESSON 90 searched for events having an electron with $p_T > 12$ GeV, missing momentum > 15 GeV, and a jet with $E_{T}>$ 10 GeV, $|\eta|$ < 2.2, and excluded $m_{b'}$ between 30 and 69 GeV.
- 7 For the reduction of the limit due to non-charged-current decay modes, see Fig. 19 of
- ALBAJAR 908.

 8 ALBAJAR 88 study events at $E_{\rm cm}$ = 546 and 630 GeV with a muon or isolated electron, accompanied by one or more jets and find agreement with Monte Carlo predictions for the production of charm and bottom, without the need for a new quark. The lower mass limit is obtained by using a conservative estimate for the $b'\overline{b}'$ production cross section and by assuming that it cannot be produced in W decays. The value quoted here is revised using the full $O(\alpha_s^3)$ cross section of ALTARELLI 88.

MASS LIMITS for b^\prime (4th Generation) Quark or Hadron in e^+e^- Collisions

Search for hadrons containing a fourth-generation -1/3 quark denoted b'.

The last column specifies the assumption for the decay mode (CC denotes the conventional charged-current decay) and the event signature which is looked for.

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>46.0	95	⁹ DECAMP	90F ALEP	any decay
• • • We do not us	e the followi	ng data for averag	es, fits, limits,	etc. • • •
		10 ADRIANI	93G L3	Quarkonium
>44.7	95 .	ADRIANI	93M L3	, Γ(<i>Z</i>)
>45	95	ABREU	91F DLPH	Γ(<i>Ž</i>)
none 19.4-28.2	95	ABE	90D VNS	Any decay; event shape
>45.0	95	ABREU	900 DLPH	B(CC) = 1; event shape
>44.5	95	¹¹ ABREU	90D DLPH	b' → cH-, H- →
>40.5	95	12 ABREU	90D DLPH	$\overline{c}s$, $\tau^-\nu$ $\Gamma(Z \rightarrow \text{hadrons})$
>28.3	95	ADACHI		B(FCNC)=100%; isol. γ or 4 jets
>41.4	95	13 AKRAWY	90B OPAL	Any decay; acoplanarity

>45.2	95	¹³ AKRAWY	90B OPAL	B(CC) = 1; acopla- narity
>46	95	14 AKRAWY	90」OPAL	$b' \rightarrow \gamma + any$
>27.5	95	¹⁵ ABE	89E VNS	$B(CC) = 1; \mu, e$
none 11.4-27.3	95	16 ABE	89G VNS	$B(b' \rightarrow b\gamma) > 10\%;$ isolated γ
>44.7	95	17 ABRAMS	89c MRK2	B(CC)= 100%; isol. track
>42.7	95	¹⁷ ABRAMS	89C MRK2	B(bg) = 100%; event shape
>42.0	95	17 ABRAMS	89c MRK2	Any decay; event shape
>28.4	95	^{18,19} ADACHI	89c TOPZ	$B(CC) = 1; \mu$
>28.8	95	²⁰ ENO	89 AMY	$B(C C) \gtrsim 90\%; \mu, e$
>27.2	95	20,21 ENO	89 AMY	any decay; event shape
>29.0	95	²⁰ ENO	89 AMY	$B(b' \rightarrow bg) \gtrsim 85\%$; event shape
>24.4	95	²² IGARASHI	88 AMY	μ,e
>23.8	95	²³ SAGAWA	88 AMY	event shape
>22.7	95	²⁴ ADEVA	86 MRKJ	μ
>21		²⁵ ALTHOFF	84c TASS	R, event shape
>19		²⁶ ALTHOFF	84L TASS	Aplanarity

- ⁹ DECAMP 90F looked for isolated charged particles, for isolated photons, and for four-jet final states. The modes $b'\to bg$ for B($b'\to bg$) > 65% $b'\to b\gamma$ for B($b'\to b\gamma$) > 5% are excluded. Charged Higgs decay were not discussed. ¹⁰ ADRIANI 93G search for vector quarkonium states near Z and give limit on quarkonium.
- Z mixing parameter $\delta m^2 < (10-30) \text{ GeV}^2$ (95%CL) for the mass 88-94.5 GeV. Using Richardson potential, a 1S $(b'\bar{b}')$ state is excluded for the mass range 87.7-94.7 GeV. This range depends on the potential choice.
- $^{11} \, \mathrm{ABREU}$ 90D assumed $m_{\ensuremath{H^-}} \, < m_{\ensuremath{b^+}} 3$ GeV.
- $^{12}\,\mathrm{Superseded}$ by ABREU 91F.
- 13 AKRAWY 90B search was restricted to data near the Z peak at $E_{
 m cm}=$ 91.26 GeV at LEP. The excluded region is between 23.6 and 41.4 GeV if no H^{+} decays exist. For charged Higgs decays the excluded regions are between ($m_{H^+}\,+1.5$ GeV) and 45.5
- GeV.

 14 AKRAWY 90J search for isolated photons in hadronic Z decay and derive $B(Z \to b' \bar{b}') \cdot B(b' \to \gamma X)/B(Z \to hadrons) < 2.2 \times 10^{-3}$. Mass limit assumes $B(b' \rightarrow \gamma X) > 10\%$.
- $^{15}\,\mathrm{ABE}$ 89E search at $E_{cm}=$ 56-57 GeV at TRISTAN for multihadron events with a spherical shape (using thrust and acoplanarity) or containing isolated leptons.
- 16 ABE 89G search was at $E_{cm} =$ 55–60.8 GeV at TRISTAN.
- 17 if the photonic decay mode is large (B($b'\to b\gamma$) > 25%), the ABRAMS 89c limit is 45.4 GeV. The limit for for Higgs decay ($b'\to cH^-,H^-\to \bar cs$) is 45.2 GeV.
- 18 ADACHI 89c search was at $E_{\it cm}=56.5$ –60.8 GeV at TRISTAN using multi-hadron events accompanying muons.
- ¹⁹ ADACHI 89C also gives limits for any mixture of C C and bg decays.
- 20 ENO 89 search at $E_{cm} = 50-60.8$ at TRISTAN.
- ²¹ ENO 89 considers arbitrary mixture of the charged current, bg, and $b\gamma$ decays.
- 22 IGARASHI 88 searches for leptons in low-thrust events and gives $\Delta R(b')<0.26$ (95% CL) assuming charged current decay, which translates to $m_{b'}>24.4$ GeV.
- ²³ SAGAWA 88 set limit $\sigma(top) < 6.1$ pb at CL=95% for top-flavored hadron production from event shape analyses at $E_{CM} = 52$ GeV. By using the quark parton model cross-section formula near threshold, the above limit leads to lower mass bounds of 23.8 GeV for charge -1/3 quarks.
- 24 ADEVA 86 give 95%CL upper bound on an excess of the normalized cross section, $\Delta R_{\rm i}$ as a function of the minimum c.m. energy (see their figure 3). Production of a pair of 1/3 charge quarks is excluded up to $E_{\rm cm}=45.4$ GeV.
- ²⁵ ALTHOFF 84C narrow state search sets limit $\Gamma(e^+e^-)$ B(hadrons) <2.4 keV CL = 95% and heavy charge 1/3 quark pair production m>21 GeV, CL = 95%.
- 26 ALTHOFF 84: exclude heavy quark pair production for 7 < m < 19 GeV (1/3 charge) using aplanarity distributions (CL = 95%).

REFERENCES FOR Searches for (Fourth Generation) b' Quark

ABACHI	97D	PRL 78 3818	S. Abachi+ (D0 Collab	
FROGGATT	970	ZPHY C73 333		
ABACHI	95F	PR D52 4877		
ADRIANI	93G	PL B313 326		
ADRIANI		PRPI 236 1	+Aguilar-Benitez, Ahlen, Alcaraz, Aloisio+ (L3 Collab	
	93M		+Aguilar-Benitez, Ahlen, Alcaraz, Aloisio+ (L3 Collab	
MUKHOPAD		PR D48 2105	Mukhopadhyaya, Roy (TAT/	
ABE	92	PRL 68 447	+Amidei, Apollinari, Atac, Auchincloss+ (CDF Collab	
Also	92G	PR D45 3921	Abe, Amidei, Apollinari, Atac, Auchincloss+ (CDF Collab	
ABE	92G	PR D45 3921	+Amidei, Apollinari, Atac, Auchincloss+ (CDF Collab	
ABREU	91F	NP B367 511	+Adam, Adami, Adye, Akesson+ (DELPHI Collab	
ABE	90B	PRL 64 147	+Amidei, Apollinari, Atac, Auchincloss+ (CDF Collab	
ABE	90D	PL B234 382	+Amako, Arai, Asano+ (VENUS Collab	
ABREU	90D	PL B242 536	+Adam, Adami, Adye, Alekseev, Allaby+ (DELPHI Collab	
ADACHI	90	PL B234 197	+Aihara, Doser, Enomoto+ (TOPAZ Collab	
AKESSON	90	ZPHY C46 179	+Alitti, Ansari, Ansorge, Bagnaia+ (UA2 Collab	
AKRAWY	90B	PL B236 364	+Alexander, Allison, Allport, Anderson+ (OPAL Collab	
AKRAWY	9 01	PL B246 285	+Alexander, Allison, Allport, Anderson+ (OPAL Collab	ر.د
ALBAJAR	90B	ZPHY C48 1	+Albrow, Allkofer, Andrieu, Ankoviak+ (UA1 Collab	(.د
DECAMP	90F	PL B236 511	+Deschizeaux, Lees, Minard+ (ALEPH Collab).)
ABE	89E	PR D39 3524	+Amako, Arai, Asano, Chiba, Chiba+ (VENUS Collat	(.د
ABE	89G	PRL 63 1776	+Amako, Arai, Asano, Chiba+ (VENUS Collab	J.)
ABRAMS	89C	PRL 63 2447	+Adolphsen, Averill, Ballam+ (Mark II Collab).)
ADACHI	89C	PL B229 427	+Aihara, Doser, Enomoto, Fujii+ (TOPAZ Collab	١.١
ENO	89	PRL 63 1910	+Auchincloss, Blanis, Bodek, Budd+ (AMY Collab).)
ALBAJAR	88	ZPHY C37 505	+Albrow, Allkofer+ (UA1 Collab	ı.j
ALTARELLI	88	NP B308 724	+Diemoz, Martinelli, Nason (CERN, ROMA, ETI	d)
IGARASHI	88	PRL 60 2359	+Myung, Chiba, Hanaoka+ (AMY Collab	a.)
SAGAWA	88	PRL 60 93	+Mori, Abe+ (AMY Collab	ı.)
ADEVA	86	PR D34 681	+Ansari, Becker, Becker-Szendy+ (Mark-J Collab	i.)
ALTHOFF	84C	PL 138B 441	+Braunschweig, Kirschfink+ (TASSO Collab	ı.)
ALTHOFF	841	ZPHY C22 307	+Braunschweig, Kirschfink+ (TASSO Collab	ı.)
			-	•

Free Quark Searches

FREE QUARK SEARCHES

The basis for much of the theory of particle scattering and hadron spectroscopy is the construction of the hadrons from a set of fractionally charged constituents (quarks). A central but unproven hypothesis of this theory, Quantum Chromodynamics, is that quarks cannot be observed as free particles but are confined to mesons and baryons.

Experiments show that it is at best difficult to "unglue" quarks. Accelerator searches at increasing energies have produced no evidence for free quarks, while only a few cosmic-ray and matter searches have produced uncorroborated events.

This compilation is only a guide to the literature, since the quoted experimental limits are often only indicative. Reviews can be found in Refs. 1-3.

References

- 1. P.F. Smith, Ann. Rev. Nucl. and Part. Sci. 39, 73 (1989).
- 2. L. Lyons, Phys. Reports 129, 225 (1985).
- 3. M. Marinelli and G. Morpurgo, Phys. Reports 85, 161 (1982).

	Quark Production Cross Section — Accelerator Searches								
X-SECT	CHG		ENERGY						
(cm ²)	(e/3)	(GeV)	(GeV)		EVTS	DOCUMENT ID		TECN	
<1.3E-36	±2	45-84	130-172	e+ e-	0	ABREU	97 D	DLPH	
<2.E-35	+2	250	1800	PΨ	0	¹ ABE	92J	CDF	
<1.E-35	+4	250	1800	$P\overline{P}$	0	¹ ABE	92J	CDF	
<3.8E-28			14.5A	28SI-P	ь о	² HE	91	PLAS	
<3.2E-28			14.5A	²⁸ Si-C	u O	² HE	91	PLAS	
<1.E-40	$\pm 1,2$	<10		$p, \nu, \overline{\nu}$	0	BERGSMA	84B	CHRM	
<1.E-36	$\pm 1,2$	<9	200	μ	0	AUBERT	83C	SPEC	
<2.E-10	± 2.4	1-3	200	p	0	3 BUSSIERE	80	CNTR	
<5.E-38	+1,2	. >5	300	p	0	4,5 STEVENSON	79	CNTR	
<1.E-33	± 1	<20	52	PP	0	BASILE	78	SPEC	
<9.E-39	$\pm 1,2$	<6	400	P	0	4 ANTREASYAN	77	SPEC	
<8.E-35	+1,2	<20	52	PР	0	⁶ FABJAN	75	CNTR	
<5.E-38	-1,2	4~9	200	P	0	NASH	74	CNTR	
<1.E-32	+2,4	4-24	52	PP	0	ALPER	73	SPEC	
<5.E-31	+1,2,4	<12	300	P	0	LEIPUNER	73	CNTR	
<6.E-34	$\pm 1,2$	<13	52	pр	0	BOTT	72	CNTR	
<1.E-36	-4	4	* 70	p	0	ANTIPOV	71	CNTR	
<1.E-35	$\pm 1,2$	2	28	P	0	7 ALLABY	69B	CNTR	
<4.E-37	-2	<5	70	P	0	³ ANTIPOV	69	CNTR	
<3.E-37	-1,2	25	70	P	0	⁷ ANTIPOV	69 B	CNTR	
<1.E-35	+1,2	<7	30	p	0	DORFAN	65	CNTR	
<2.E-35	-2	< 2.5-5	30	P	0	⁸ FRANZINI	65 B	CNTR	
<5.E-35	+1,2	<2.2	21	P	0	BINGHAM	64	HLBC	
<1.E-32	+1,2	<4.0	28	P	0	BLUM	64	HBC	
<1.E-35	+1,2	<2.5	31	p	0	8 HAGOPIAN	64	HBC	
<1.E-34	+1	<2	28	P	0	LEIPUNER	64	CNTR	
<1.E-33	+1,2	<2.4	24	P	0	MORRISON	64	HBC	

 $^{^1}$ ABE 92.1 flux limits decrease as the mass increases from 50 to 500 GeV. 2 HE 91 limits are for charges of the form $\it N\pm 1/3$ from 23/3 to 38/3.

Quark Diff	ferential	Producti	on Cros	s Secti	on — Ad	ccelerator Search	ies	
X-SECT (cm ² sr ⁻¹ GeV	CHG -1) e/3	MASS (GeV)	ENERGY (GeV)	BEAM	EVTS	DOCUMENT ID		TECN
								CNTR
<4.E-36	- 2,4	1.5 -6	70	р	0	BALDIN	76	
<2.E-33	±4	5-20	52	pр	0	ALBROW	75	SPEC
<5.E-34	<7	7-15	44	pр	0	JOVANOV	75	CNTR
<5.E 35			20	γ	0	⁹ GALIK	74	CNTR
<9.E-35	-1,2		200	p	0	NASH	74	CNTR
<4.E-36	-4	2.3-2.7	70	p	0	ANTIPOV	71	CNTR
<3.E-35	±1,2	<2.7	27	p	0	ALLABY	69 B	CNTR
<7.E-38	-1,2	<2.5	70	p	0	ANTIPOV	69B	CNTR
⁹ Cross se	ction in c	:m ² /sr/equ	ılvalent q	uanta.				

Quark Flux — Accelerator Searches

The definition of FLUX depends on the experiment

- (a) is the ratio of measured free quarks to predicted free quarks if there is no "con-
- (b) is the probability of fractional charge on nuclear fragments. Energy is in GeV/nucleon
- (c) is the 90%CL upper limit on fractionally-charged particles produced per interac-
- (d) is quarks per collision.
- (e) is inclusive quark-production cross-section ratio to $\sigma(e^+e^- \to \mu^+\mu^-)$.
- (f) is quark flux per charged particle.
- (g) is the flux per ν -event.
- (h) is quark yield per π^- yield.
- (i) is 2-body exclusive quark-production cross-section ratio to $\sigma(e^+e^-
 ightarrow$

	$\mu \cdot \mu$),							
FLUX	CHG (e/3)	MASS (GeV)	(GeV)	BEAM E	√TS	DOCUMENT ID		TECN
<1.6E-3 t	see note		200	32 _{S-Pb}	0	¹⁰ HUENTRUP	96	PLAS
<6.2E-4 b	see note		10.6	32 _{S-Pb}	0	¹⁰ HUENTRUP	96	PLAS
<0.94E-4	±2	2-30	88-94	e^+e^-	0	AKERS	95R	OPAL
<1.7E-4	±2	30-40	88-94	e^+e^-	0	AKERS	95R	OPAL
	±4	5-30	88-94	e^+e^-	0	AKERS	95R	OPAL
	±4	30-45		e^+e^-	0	AKERS	95R	OPAL
<2.E-3	e +1	5-40	88-94	e+ e-	0	¹¹ BUSKULIC	93C	ALEP
<6.E-4	e +2	5-30	88- 9 4	e+ e-	0	¹¹ BUSKULIC	93C	ALEP
<1.2E-3	e +4	15-40	88-94	e^+e^-	0	11 BUSKULIC	93C	ALEP
<3.6E-4	1 +4	5.0~10.2	88-94	e^+e^-	0	BUSKULIC	93C	ALEP
<3.6E-4	i +4	16.5-26.0		e+ e~	0	BUSKULIC		ALEP
<6:9E-4	i +4	26.0-33.3	88-94	e^+e^-	0	BUSKULIC	93C	ALEP
	i +4	33.3-38.6	88-94	e^+e^-	0	BUSKULIC	93C	ALEP
	i +4	38.6-44.9	88-94	e+ e-	0	BUSKULIC	93C	ALEP
<1.7E-4 t			e note		0	12 CECCHINI	93	PLAS
ı	4,5,7,8		2.1A	16 _{O 0,2}	2,0,6	13 GHOSH	92	EMUL
<6.4E-5	χ 1			$\nu,\overline{\nu}$	1	14 BASILE	91	CNTR
`	ž 2			$\nu,\overline{\nu}$	0	14 BASILE	91	CNTR
	ž 1			$\nu_{i}\overline{\nu}$	1	¹⁵ BASILE	91	CNTR
<2.8E-5	2			$ u,\overline{\nu}$	0	15 BASILE	91	CNTR
<1.9E-4	C		14.5A	28SI-Pb	0	¹⁶ HE	91	PLAS
<3.9E-4	С		14.5A	²⁸ SI-Cu	0	¹⁶ HE	91	PLAS
	±1,2,4		14.5A	16 _{O-Ar}	0	MATIS	91	MDRP
<5.1E-10			14.5A	16 _{O-Hg}	0	MATIS	91	MDRP
	±1,2,4		14.5A	-	0	MATIS	91	MDRP
	±1,2,4		60A	160-Hg	0	MATIS	91	MDRP
	c ±1,2,4		200A	¹⁶ O-Hg	0	MATIS	91	MDRP
<1.3E-6	c ±1,2,4		200A	S-Hg	0	MATIS	91	MDRP
<5E-2	e 2	19-27	52-60	e+ e-	0	ADACHI	90c	TOPZ
<5E-2	e 4	<24	52-60	e+ e-	0	ADACHI	90c	TOPZ
<1.E-4	e +2	<3.5	10	e^+e^-	0	BOWCOCK	89B	CLEO
	±1,2		60	16 _{O-Hg}	0	CALLOWAY	89	MDRP
	±1,2		200	16 _{O-Hg}	Ó	CALLOWAY	89	MDRP
	±1,2		200	S-Hg	ō	CALLOWAY	89	MDRP
<1.2E-10		1	800	p-Hg	0	MATIS	89	MDRP
<1.1E-10		1	800	p-Hg	0	MATIS	89	MDRP
<1.2E-10	d ±1	1	800	p-N ₂	0	MATIS	89	MDRP
<7.7E-11	d ±2	1	800	p-N ₂	0	MATIS	89	MDRP
<6.E-9	h5	0.9-2.3	12	P _	0	NAKAMURA	89	SPEC
<5.E-5	g 1,2	<0.5		ν. ν d	0	ALLASIA	88	BEBC
<3.E-4	b See note		14.5	16 _{O-Pb}	0	¹⁷ HOFFMANN	88	PLAS
<2.E-4	b See note		200	16 _{O-Pb}	0	18 HOFFMANN	88	PLAS
	19,20,22,23		200A			GERBIER	87	PLAS
	a ±1,2	<300	320	ĪΡ	0	LYONS	87	MLEV
	c ±1,2,4,5		14.5	16 _{O-Hg}	0	SHAW	87	MDRP
	d -1,2,3,4,6	<5	2	Si-Si	0	¹⁹ ABACHI	86C	CNTR
<1.E-4	e ±1,2,4	<4	10	e^+e^-	0	ALBRECHT	85 G	ARG

³ Hadronic or leptonic quarks.

⁴ Cross section cm²/GeV².

 $^{^5}$ 3 \times 10⁻⁵ < lifetime < 1 \times 10⁻³ s.

⁶ Includes BOTT 72 results.

7 Assumes isotropic cm production.

⁸ Cross section inferred from flux.

Quark Particle Listings

Free Quark Searches

<6.E-5	b	±1,2	1	540	₽₽	0	BANNER	85	UA2
<5.E-3	е	-4	1-8	29	e+ e-	0	AIHARA	84	TPC
<1.E-2	е	±1,2	1-13	29	e^+e^-	0	AIHARA	84B	TPC
<2.E-4	b	. ±1		72	⁴⁰ Ar	0	²⁰ BARWICK	84	CNTR
<1.E-4	е	±2	< 0.4	1.4	e+ e-	0	BONDAR	84	OLYA
<5.E-1	e	±1,2	<13	29	e+e-	0	GURYN	84	CNTR
<3.E-3	b	±1,2	<2	540	$p\overline{p}$	0	BANNER	83	CNTR
<1.E-4	b	±1,2		106	56 _{Fe}	0	LINDGREN	83	CNTR
<3.E-3	b	> ± 0.1		74	40 _{Ar}	0	²⁰ PRICE	83	PLAS
<1.E-2	e	±1,2	<14	29	e^+e^-	0	MARINI	82B	CNTR
<8.E-2	е	±1,2	<12	29	e+ e-	0	ROSS	82	CNTR
<3.E-4	е	±2	1.8-2	7	e+ e~	0	WEISS	81	MRK2
<5.E-2	е	+1,2,4,5	2-12	27	e+ e-	0	BARTEL	80	JADE
<2.E-5	g	1,2			ν	0	14,15 BASILE	80	CNTR
<3.E-10	f	±2,4	1-3	200	P	0	²¹ BOZZOLI	79	CNTR
<6.E-11	f	±1	<21	52	PΡ	0	BASILE	78	SPEC
<5.E-3	g				ν_{μ}	0	BASILE	7 8 8	CNTR
<2.E-9	f	±1	<26	62	pр	0	BASILE	77	SPEC
<7.E-10	f	+1,2	<20	52	p	0	22 FABJAN	75	CNTR
		+1,2	>4.5		γ	0	14,15 GALIK	74	CNTR
		+1,2	>1.5	12	e ⁻	0	14,15 BELLAMY	68	CNTR
		+1,2	>0.9		γ	0	15 BATHOW	67	CNTR
		+1,2	>0.9	6	γ	0	15 FOSS	67	CNTR

 $^{^{10}}$ HUENTRUP 96 quote 95% CL limits for production of fragments with charge differing by as much as $\pm 1/3$ (in units of e) for charge 6 \leq Z \leq 10. 11 BUSKULIC 93C limits for inclusive quark production are more conservative if the ALEPH hadronic fragmentation function is assumed.

Quark Flux — Cosmic Ray Searches

Shielding values followed with an asterisk indicate altitude in km. Shielding values not followed with an asterisk indicate sea level in kg/cm².

FLUX	CHG	MASS		. 0,			
(cm ⁻² sr ⁻¹ s ⁻¹		(GeV)	SHIELDING	EVTS	DOCUMENT ID		TECN
<2.1E-15	±1			G	MORI	91	KAM2
<2.3E-15	±2			0	MORI	91	KAM2
<2.E-10	±1,2		0.3	0	WADA	88	CNTR
	±4		0.3	12	23 WADA	88	CNTR
	±4		0.3	9	24 WADA	86	CNTR
<1.E-12	$\pm 2,3/2$		–70.	0	25 KAWAGOE	84B	PLA\$
<9.E-10	±1,2		0.3	0	WADA	84B	CNTR
<4.E-9	±4		0.3	7	WADA	84B	CNTR
<2.E-12	\pm 1,2,3		-0.3 *	0	MASHIMO	83	CNTR
<3.E-10	$\pm 1,2$		0.3	0	MARINI	82	CNTR
<2.E-11	±1,2			0	MASHIMO	82	CNTR
<8.E 10	$\pm 1,2$		0.3	0	²⁵ NAPOLITANO	82	CNTR
				3	²⁶ YOCK	78	CNTR
<1.E-9				0	²⁷ BRIATORE	76	ELEC
<2.E-11	+1			0	28 HAZEN	75	CC
<2.E-10	+1,2			0	KRISOR	75	CNTR
<1.E-7	+1,2			0	28,29 CLARK	74B	CC
<3.E-10	+1	>20		0	KIFUNE	74	CNTR
<8.E-11	+1			0	²⁸ ASHTON	73	CNTR
<2.E~8	+1,2			0	HICKS	73B	CNTR
<5.E-10	+4		2.8 *	0	BEAUCHAMP	72	CNTR
<1.E-10	+1,2			0	²⁸ вонм	72B	CNTR
<1.E-10	+1,2		2.8 *	0	COX	72	ELEC
<3.E-10	+2			0	CROUCH	72	CNTR
<3.E-8			7	0	²⁷ DARDO	72	CNTR
<4.E-9	+1			0	²⁸ EVANS	72	CC
<2.E-9		>10		0	²⁷ TONWAR	72	CNTR
<2.E-10	+1		2.8 *	0	CHIN	71	CNTR
<3.E-10	+1,2			0	²⁸ CLARK	71B	cc
<1.E-10	+1.2			0	²⁸ HAZEN	71	cc
<5.E-10	+1,2		3.5 *	0	BOSIA	70	CNTR
	+1,2	< 6.5		1	²⁸ СНU	70	HLBC
<2.E-9	+1			0	FAISSNER	70B	CNTR
<2.E-10	+1,2		0.8 *	0	KRIDER	70	CNTR
<5.E-11	+2			4	CAIRNS	69	CC
<8.E-10	+1,2	<10		0	FUKUSHIMA	69	CNTR
	+2			1	28,30 MCCUSKER	69	cc
<1.E-10		>5	1.7,3.6	0	27 BJORNBOE	68	CNTR

<1.E-8	$\pm 1,2,4$		6.3,.2 *	0	²⁵ BRIATORE	68	CNTR
<3.E-8		>2		0	FRANZINI	68	CNTR
<9.E-11	±1,2			0	GARMIRE	68	CNTR
<4.E-10	±1			0	HANAYAMA	68	CNTR
<3.E-8		>15		0	KASHA	68	OSPK
<2.E-10	+2			0	KASHA	688	CNTR
<2.E-10	+4			0	KASHA	68C	CNTR
<2.E-10	+2		6	0	BARTON	67	CNTR
<2.E-7	+4		0.008,0.5 *	0	BUHLER	67	CNTR
<5.E-10	1,2		0.008,0.5 *	0	BUHLER	67B	CNTR
<4.E-10	+1,2			0	GOMEZ	67	CNTR
<2.E-9	+2			0	KASHA	67	CNTR
<2.E-10	+2		220	0	BARTON	66	CNTR
<2.E-9	+1.2		0.5 *	0	BUHLER	66	CNTR
<3.E-9	+1,2			0	KASHA	66	CNTR
<2.E-9	+1,2			0	LAMB	66	CNTR
<2.E-8	+1,2	>7	2.8 +	0	DELISÉ	65	CNTR
<5.E~8	+2	>2.5	0.5 *	0	MASSAM	65	CNTR
<2.E-8	+1		2.5 *	0	BOWEN	64	CNTR
<2.E~7	+1		8.0	0	SUNYAR	64	CNTR

 $^{^{23}\}mbox{Distribution}$ in celestial sphere was described as anisotropic.

DOCUMENT ID

Quark Density - Matter Searches

For a review, see SMITH 89. QUARKS/ CHG MASS

NUCLEON	(e/3)	(GeV)	MATERIAL/METHOD	EV75	DOCUMENT ID
<4.7E-21	±1,2		silicone oil drops	0	MAR 96
<8.E-22	+2		SI/Infrared photoionization	on O	PERERA 93
<5.E-27	±1,2		sea water/levitation	0	HOMER 92
<4.E-20	±1,2		meteorites/mag. levitation	on O	JONES 89
<1.E-19	±1,2		various/spectrometer	0	MILNER 87
<5.E-22	±1,2		W/levitation	0	SMITH 87
<3.E-20	+1,2		org liq/droplet tower	0	VANPOLEN 87
<6.E-20	-1,2		org liq/droplet tower	0	VANPOLEN 87
<3.E-21	±1		Hg drops-untreated	0	SAVAGE 86
<3.E-22	±1,2		levitated niobium	0	SMITH 86
<2.E-26	±1,2		⁴ He/levitation	0	SMITH 86B
<2.E-20	>±1	0.2-250		0	MILNER 85
<1.E-21	±1		levitated nioblum	0	SMITH 85
	+1,2	<100	niobium/mass spec	0	KUTSCHERA 84
<5.E-22			levitated steel	0	MARINELLI 84
<9.E-20	± <13		water/oil drop	0	JOYCE 83
<2.E-21 >	, , ,		levitated steel	0	LIEBOWITZ 83
<1.E-19	±1,2		photo ion spec	0	VANDESTEEG 83
<2.E-20			mercury/oil drop	0	31 HODGES 81
1.E-20	+1		levitated niobium	4	32 LARUE 81
1.E-20	-1		levitated niobium	4	32 LARUE 81
<1.E-21			levitated steel	0	MARINELLI 80B
<6.E-16			hellum/mass spec	0	BOYD 79
1.E~20	+1		levitated niobium	2	³² LARUE 79
<4.E-28			earth+/ion beam	0	OGOROD 79
<5.E-15	+1		tungs./mass spec	0	BOYD 78
<5.E-16	+3	<1.7	hydrogen/mass spec	0	BOYD 78B
<1.E-21	±2,4		water/ion beam	0	LUND 78 PUTT 78
<6.E-15	>1/2		levitated tungsten	0	SCHIFFER 78
<1.E-22 <5.E-15			metals/mass spec levitated tungsten ox	0	BLAND 77
<3.E-21			levitated iron	0	GALLINARO 77
2.E~21	-1		levitated nioblum	1	32 LARUE 77
4.E~21	+1		levitated niobium	2	32 LARUE 77
<1.E-13	+3	<7.7		0	MULLER 77
<5.E-27	, 3	Ç	water+/ion beam	0	OGOROD 77
<1.E-21			funar+/ion spec	ō	STEVENS 76
<1.E-15	+1	<60	oxygen+/ion spec	ő	ELBERT 70
<5.E-19		~~~	levitated graphite	ŏ	MORPURGO 70
<5.E-23			water+/atom beam	ō	COOK 69
<1.E-17	±1,2		levitated graphite	ō	BRAGINSK 68
<1.E-17	- •		water+/uv spec	0	RANK 68
<3.E-19	±1		levitated iron	0	STOVER 67
<1.E-10			sun/uv spec	0	33 BENNETT 66
<1.E-17	+1,2		meteorites+/ion beam	0	CHUPKA 66
<1.E-16	±1		levitated graphite	0	GALLINARO 66
<1.E-22			argon/electrometer	0	HILLAS 59
	-2		levitated oil	0	MILLIKAN 10

³¹ Also set limits for $Q = \pm e/6$.

nadronic fragmentation function is assumed. 12 CECCHINI 93 limit at 90%CL for $23/3 \le Z \le 40/3$, for 16A GeV O, 14.5A SI, and 200A S incident on Cu target. Other limits are 2.3×10^{-4} for $17/3 \le Z \le 20/3$ and $1.2 \times 10^{-4} \le Z \le 23/3$.

¹³ GHOSH 92 reports measurement of spallation fragment charge based on ionization in emulsion. Out of 650 measured tracks, 2 were consistent with charge 5e/3, and 4 with 7e/3.

¹⁴ Hadronic quark.

¹⁶ HE 91 limits are for charges of the form $N\pm1/3$ from 23/3 to 38/3, and correspond to

¹⁷ The limits apply to projectile fragment charges of 17, 19, 20, 22, 23 in units of e/3.

¹⁸ The limits apply to projectile fragment charges of 16, 17, 19, 20, 22, 23 in units of e/3.

¹⁹ Flux limits and mass range depend on charge.

²⁰ Bound to nuclei. 21 Quark lifetimes > 1 × 10⁻⁸ s. ²² One candidate m < 0.17 GeV.

²⁴ With telescope axis at zenith angle 40° to the south.

²⁵ Leptonic quarks. 25 Leptonic quarks. 26 Lifetime $> 10^{-8}$ s; charge ± 0.70 , 0.68, 0.42; and mass > 4.4, 4.8, and 20 GeV, respectively. tively.

27 Time delayed air shower search.

²⁸ Prompt air shower search.

²⁹ Also e/4 and e/6 charges.

³⁰ No events in subsequent experiments.

³² Note that in PHILLIPS 88 these authors report a subtle magnetic effect which could account for the apparent fractional charges.

³³ Limit inferred by JONES 77B.

Quark Particle Listings Free Quark Searches

		REFERENCES	FOR Free Quark Searches			77	Science 521	+Alvarez, Holley, Stephenson	(LBL)
ABREU	070	DI B207 215	D. Abresia		OGOROD	77	JETP 45 857 Translated from ZETF	Ogorodnikov, Samollov, Solntsev 72 1633.	(KIAE)
HUENTRUP	97D 96	PL B396 315 PR C53 358	P. Abreu+ (DELPHI Collab.) +Weidmann, Hirzebruch, Winkel, Heiarich (SIEG)	;} •	BALDIN	76	S INP 22 264	+Vertogradov Vichneysky Grichkevich+	(JINR)
MAR	96	PR D53 6017	+Lee, Fleming, Case+ (SLAC, SCHAF, LANL, UCI)	i) e	BRIATORE	76	Translated from YAF 2: NC 31A 553	2 512. +Dardo, Piazzoli, Mannocchi+ (LCGT, FRAS,	. FRFIB)
AKERS BUSKULIC	95R 93C	ZPHY C67 203 PL B303 198	+Alexander, Allison, Ametewee, Anderson+ (OPAL Collab.) +Decamp, Goy, Lees, Minard+ (ALEPH Collab.)	·} s	TEVENS	76	PR D14 716	+Schiffer, Chupka	(ANL)
CECCHINI	93	ASP 1 369	5. Cecchini+			75 75	NP B97 189 NP B101 349	+Barber+ (CERN, DARE, FOM, LANC, MCHS +Gruhn, Peak, Sauli, Caldwell+ (CERN	i, UTRE) i, MPIM)
PERERA ABE	93 92J	PRL 70 1053 PR D46 R1889	+Betarbet, Byungsung, Coon (PITT) +Amidei, Anway-Weiss+ (CDF Collab.)	'} ⊦	AZEN	75	NP B95 189	+Hodson, Winterstein, Green, Kass+ (MICH	I, LEED)
GHOSH	92	NC 105A 99	+Roy, Ghosh, Ghosh, Bass (JADA, BANGB)	ń :		75 75	PL 56B 105 NC 27A 132	Jovanovich+ (MANI, AACH, CERN, GÈNO,	
HOMER BASILE	92 91	ZPHY C55 549	+Smith, Lewin, Robertson+ (RAL, SHMP, LOQM)	()	LARK	748	PR D10 2721	+Finn, Hansen, Smith	(AACH3) (LLL)
HE	91	NC 104A 405 PR C44 1672	+Berbiers, Cara Romeo+ (BGNA, INFN, CERN, PLRM+) +Price (UCB)			74 74	PR D9 1856 JPSJ 36 629	+Jordan, Richter, Seppi, Siemann+ (SLAC	, FNAL)
MATIS	91	NP A525 513c	+Pugh, Alba, Bland, Calloway+ (LBL, SFSU, UCI, LANL)	.)		74	PRL 32 858	+Yamanouchi, Nease, Sculli (FNAL, COR)	Y, KEK) N. NYU)
MORI ADACHI	91 90C	PR D43 2843 PL B244 352	+Oyama, Suzuki, Takahashi+ (Kamlokande II Collab.) +Alhara, Doser, Enomoto+ (TOPAZ Collab.)			73	PL 46B 265	+ (CERN, LIVP, LUND, BOHR, RHEL, STOH,	BERG+)
BOWCOCK	89B	PR D40 263	+Kinoshita, Mauskoof, Pinkin+ (CLEO Collab.)	.) :		73 738	JPA 6 577 NC 14A 65	+Cooper, Parvaresh, Saleh +Flint, Standil	(DURH) (MANI)
CALLOWAY JONES	89 89	PL B232 549 ZPHY C43 349	+Alba, Bland, Dickson, Hodges+ (SFSU, UCI, LBL, LANL) +Smith, Homer, Lewin, Walford (LOIC, RAL)			73	PRL 31 1226	+Larsen, Sessoms, Smith, Williams+ (BNI	L, YALE)
MATIS	89	PR D39 1851	+Pugh, Bland, Calloway+ (LBL, SFSU, UCI, FNAL, LANL)	.)	BEAUCHAMP BOHM	72 72B	PR D6 1211 PRL 28 326	+Bowen, Cox, Kalbach +Diemont, Faissner, Fasold, Krisor+	(ARIZ) (AACH)
NAKAMURA SMITH	89 89	PR D39 1261 ARNPS 39 73	+Kobayashi, Konaka, Imai, Masaike+ (KYOT, TMTC) (RAL)	·}	BOTT	72	PL 40B 693	+Caldwell, Fabjan, Gruhn, Peak+ (CERN	, MPIM)
ALLASIA	86	PR D37 219	+Angelini, Baldini+ (WA25 Collab.)	.) .		72 72	PR D6 1203 PR D5 2667	+Beauchamp, Bowen, Kalbach +Mori, Smith	(ARIZ) (CASE)
HOFFMANN PHILLIPS	88 88	PL B200 583 NIM A264 125	+Brechtmann, Heinrich, Benton (SIEG, USF) +Fairbank, Navarro (STAN)	:) r	DARDO	72	NC 9A 319	+Navarra, Penengo, Sitte	(TORI)
WADA	88	NC 11C 229	+Fairbank, Navarro (STAN) +Yamashita, Yamamoto (OKAY)			72 72	PRSE A70 143 JPA 5 569	+Fancey, Muir, Watson (EDIN +Naranan, Sreekantan	I, LEED) (TATA)
GERBIER LYONS	87 87	PRL 59 2535 ZPHY C36 363	G. Gerbier+ (UCB, CERN)	i) i		71	NP B27 374	+Kachanov, Kutjin, Landsberg, Lebedev+	(SERP)
MILNER	87	PR D36 37	+Cooper, Chang, Wilson, Labrenz, McKeown (CIT)	i		71 71 B	NC 2A 419	+Hanayama, Hara, Higashi, Tsuji	(OSAK)
SHAW	87	PR D36 3533	+Matis, Pugh, Slansky+ (UCI, LBL, LANE, SFSU)	l) i		71 5	PRL 27 51 PRL 26 582	+Ernst, Finn, Griffin, Hansen, Smith+ (LI	LĹ, LBL) (M∤CH)
SMITH VANPOLEN	87 87	PL B197 447 PR D36 1983	+Homer, Lewin, Walford, Jones (RAL, LOIC) +Hagstrom, Hirsch (ANL, LBL)			70	NC 66A 167	+Briatore	(TORI)
ABACHI		PR D33 2733	+Shor, Barasch, Carroll+ (UCLA, LBL, UCD)))	HU Also	70 708	PRL 24 917 PRL 25 550	+Kim, Beam, Kwak (OSU, ROSE Allison, Derrick, Hunt, Simpson, Voyvodic	(ANL)
SAVAGE SMITH	86 86	PL 167B 481 PL B171 129	+Bland, Hodges, Huntington, Joyce+ (SFSU) +Homer, Lewin, Walford, Jones (RAL, LOIC)		LBERT	70	NP B20 217	+Erwin, Herb, Nielsen, Petrilak, Weinberg	(WISC)
SMITH	86B	PL B181 407	+Homer, Lewin, Walford, Jones (RAL, LOIC)	:) i		70B 70	PRL 24 1357 PR D1 835	+Holder, Krisor, Mason, Sawaf, Umbach +Bowen, Kalbach	(AACH3) (ARIZ)
WADA ALBRECHT	86 85G	NC 9C 358 PL 156B 134	+Binder, Harder, Hasemann+ (ARGUS Collab.)	'} • •	MORPURGO	70	NIM 79 95	+Gallinaro, Palmieri	(ĠENO)
BANNER	85	PL 156B 129	+Bioch, Borer, Borghini+ (UA2 Collab.)	,	ALLABY ANTIPOV	69B 69	NC 64A 75 PL 29B 245	+Bianchini, Diddens, Dobinson, Hartung+	(CERN)
MILNER SMITH	85	PRL 54 1472 PL 1538 188	+Cooper, Chang, Wilson, Labrenz, McKeown (CIT)	·) ;		69B	PL 30B 576	+Karpov, Khromov, Landsberg, Lapshin+ +Bolotov, Devishev, Devisheva, Isakov+	(SERP) (SERP)
AIHARA	85 84	PRL 52 168	+Homer, Lewin, Walford, Jones (RAL, LOIC) +Alston-Garnjost, Badtke, Bakker+ (TPC Collab.)	,		69 69	PR 186 1394	+McCkusker, Peak, Woolcott	(SYDN)
AIHARA		PRL 52 2332	+Alston-Garnjost, Badtke, Bakker+ (TPC Collab.)	.) .	OOK UKUSHIMA	69	PR 188 2092 PR 178 2058	+Depasquali, Frauenfelder, Peacock+ +Kifune, Kondo, Koshiba+	(ILL) (TOKY)
BARWICK BERGSMA	84 84B	PR D30 691 ZPHY C24 217	+Musser, Stevenson (UCB) +Allaby, Abt, Gemanov+ (CHARM Collab.)	()	MCCUSKER	69	PRL 23 658	+Cairns	(SYDN)
BONDAR	84	JETPL 40 1265	+Kurdadze, Lelchuk, Panin, Sidorov+ (NOVO)		BELLAMY BJORNBOE	68 68	PR 166 1391 NC B53 241	+Hofstadter, Lakin, Perl, Toner (STAN+Damgard, Hansen+ (BOHR, TATA, BERN	N, SLAC) I. BERG)
GURYN	84	Translated from ZETFP PL 139B 313	+Parker, Fries+ (FRAS, LBL, NWES, STAN, HAWA)		BRAGINSK	68	JETP 27 51	+Zeldovich, Martynov, Migulin 54 91.	(MOSU)
KAWAGOE KUTSCHERA	84B 84	LNC 41 604 PR D29 791	+Mashimo, Nakamura, Nozaki, Orito (TOKY)	΄) ε		68	NC 57A 850	+Castagnoli, Bollini, Massam+ (TORI, CERN	, BGNA)
MARINELLI	84	PL 137B 439	+Schiffer, Frekers+ (ANL, FNAL) +Morpurgo (GENO)	: <i>{</i> }	RANZINI SARMIRE	68 68	PRL 21 1013 PR 166 166	+Shulman +Leong, Sreekantan	(COLU) (MIT)
WADA AUBERT	84B 83C	LNC 40 329	+Yamashita, Yamamoto (OKAY)	') i	HANAYAMA	68	CJP 46 S734	+Hara, Higashi, Kitamura, Miono+	(OSAK)
BANNER	83C	PL 133B 461 PL 121B 187	+Bassomplerre, Becks, Best+ +Bloch, Bonaudi, Borer+ (UA2 Collab.)	((ASHA (ASHA	68 68B	PR 172 1297 PRL 20 217		L, YALE) L. YALE)
JOYCE LIEBOWITZ	83 83	PRL 51 731 PRL 50 1640	+Abrams, Bland, Johnson, Lindgren+ (SFSU)) j	(ASHA	68C	CJP 46 S730		L, YALE)
LINDGREN	83	PRL 50 1640 PRL 51 1621	+Binder, Ziock +Joyce+ (SFSU, UCR, UCI, SLAC, LBL, LANL)	·	RANK BARTON	68 67	PR 176 1635 PRSL 90 87	•	(MICH)
MASHIMO PRICE	83 83	PL 128B 327	+Orito, Kawagoe, Nakamura, Nozaki (ICEPP)) :	BATHOW	67	PL 25B 163	+Freytag, Schulz, Tesch	(DESY)
VANDESTEEG		PRL 50 566 PRL 50 1234	+Tincknell, Tarle, Ahlen, Frankel+ (UCB) +Jongbloets, Wyder (NIJM)			67 67B	NC 49A 209	+Fortunato, Massam, Zichichi (CERN	, BGNA)
MARINI	82	PR D26 1777	+Peruzzi, Piccolo+ (FRAS, LBL, NWES, STAN, HAWA)	() i		67	NC 51A 837 PL 25B 166	+Dałpiaz, Massam, Zichichi (CERN, BGNA +Garelick, Homma, Lobar, Osborne, Uglum	(MIT)
MARINI MASHIMO	82B 82	PRL 48 1649 JPSJ 51 3067	+Peruzzi, Piccolo+ +Kawagoe, Koshiba (FRAS, LBL, NWES, STAN, HAWA)			67	PRL 18 1022	+Kobrak, Moline, Mullins, Orth, VanPutten+	(CIT)
NAPOLITANO	82	PR D25 2837	+Besset+ (STAN, FRAS, LBL, NWES, HAWA)	i i	KASHA STOVER	67 67	PR 154 1263 PR 164 1599	+Leipuner, Wangler, Alspector, Adair +Moran, Trischka (BNI	L, YALE) (SYRA)
ROSS HODGES	82 81	PL 118B 199 PRL 47 1651	+Ronga, Besset+ (FRAS, LBL, NWES, STAN, HAWA) +Abrams, Baden, Bland, Joyce+ (UCR, SFSU)	<u>()</u>	BARTON	66	PL 21 360	+Stockel	(NPOL)
LARUE	81	PRL 46 967	+Phillips, Fairbank (STAN)	រ ំ	BENNETT BUHLER	66 66	PRL 17 1196 NC 45A 520	+Fortunato, Massam, Muller+ (CERN, BGNA	(YALE)
WEISS BARTEL	81 80	PL 101B 439 ZPHY C6 295	+Abrams, Alam, Blocker+ (SLAC, LBL, UCB) +Canzler, Lords, Drumm+ (JADE Collab.)) (CHUPKA	66	PRL 17 60	+Schiffer, Stevens	(ANL)
BASILE	80	LNC 29 251	+Berbiers+ (BGNA, CERN, FRAS, ROMA, BARI)	i)	GALLINARO KASHA	66 66	PL 23 609 PR 150 1140	+Morpurgo +Leipuner, Adair (BNI	(GENO) L, YALE)
BUSSIERE MARINELLI	80 80B	NP B174 1 PL 94B 433	+Giacomelli, Lesquoy+ (BGNA, SACL, LAPP)	<u>'</u> } i	.AMB	66	PRL 17 1068	+Lundy, Novey, Yovanovitch	(ANL)
Also	80	PL 94B 427	+Morpurgo (GENO) Marinelli, Morpurgo (GENO)		DELISE DORFAN	65 65	PR 140B 458 PRL 14 999	+Bowen +Eades, Lederman, Lee, Ting	(ÀRIZ) (COLU)
BOYD BOZZOLI	79 79	PRL 43 1288 NP B159 363	+Blatt, Donoghue, Dries, Hausman, Suiter (OSU) +Bussiere, Giacomelii+ (BGNA, LAPP, SACL, CERN)	<u>}</u>	RANZINI	65B	PRL 14 196	+Leontic, Rahm, Samios, Schwartz (BNL	, COLU)
LARUE	79	PRL 42 142	+Fairbank, Phillips (STAN)		MASSAM BINGHAM	65 64	NC 40A 589 PL 9 201	+Muller, Zichichi +Dickinson, Diebold, Koch, Leith+ (CERN	(CERN) I, EPOL)
Also OGOROD	79B	PRL 42 1019	Larue, Fairbank, Phillips		BLUM	64	PRL 13 353A	+Brandt, Cocconi, Czyzewski, Danysz+	(CERN)
	79	JETP 49 953 Translated from ZETF	Ogorodnikov, Samoilov, Solntsev (KIAE) 76 1881.		BOWEN HAGOPIAN	64 64	PRL 13 728 PRL 13 280	+Delise, Kalbach, Mortara	(ARIZ)
STEVENSON BASILE	7 9 78	PR D20 82 NC 45A 171	(LBL)	:{	.EIPUNER	64	PRL 13 280 PRL 12 423	+Selove, Ehrlich, Leboy, Lanza+ +Chu, Larsen, Adair (BNI	IN, BNL) L, YALE)
BASILE	78B	NC 45A 281	+Cara-Romeo, Cifarelli, Contin+ (CERN, BGNA)	3	MORRISON	64 64	PL 9 199	,	(CERN)
BOYD BOYD	78 78R	PRL 40 216	+Elmore, Melissinos, Sugarbaker (ROCH)	()	SUNYAR HILLAS	64 59	PR 136B 1157 Nature 184 B92	+Schwarzschild, Connors +Cranshaw	(BNL) (AERE)
LUND	78	PL 72B 484 RA 25 75	+Elmore, Nitz, Olsen, Sugarbaker, Warren+ +Brandt, Fares (MARB)			10	Phil Mag 19 209		(CHIC)
PUTT	78	PR D17 1466	+Yock (AUCK)	()			OT: :=:	DELATED DADEDE	
SCHIFFER YOCK	78 78	PR D17 2241 PR D18 641	+Renner, Gemmell, Mooring (CHIC, ANL) (AUCK)	3			OTHER	R RELATED PAPERS	
ANTREASYAN	77	PRL 39 513	+Cocconi, Cronin, Frisch+ (EFI, PRIN)	i) i	YONS	85	PRPL C129 225		(OXF)
BASILE BLAND	77 77	NC 40A 41 PRL 39 369	+Romeo, Cifarelli, Giusti+ (CERN, BGNA) +Bocobo, Eubank, Royer (SFSU)	١)	Review	82	PRPL 85 161	1 Marausa	
GALLINARO	77	PRL 38 1255	+Marinelli, Morpurgo (GENO)		Review	04	LVLF 92 191	+ Morpurgo	(GENO)
JONES LARUE	77B 77	RMP 69 717 PRL 38 1011	+Fairbank, Hebard (STAN)	α -					
			(31AN)	• •					

LIGHT UNFLAVORED MESONS ($S = C = B = 0$)	• $f_2(2010)$
\bullet π^{\pm}	$f_0(2020)$
\bullet π^0	• $a_4(2040)$
• η	• $f_4(2050)$
• $f_0(400-1200)$	$f_0(2060)$
• ρ(770)	$\pi_2(2100)$
• $\omega(782)$	$f_2(2150)$ 427
• η'(958)	$\rho(2150)$ 429
• $f_0(980)$	$f_0(2200)$
• $a_0(980)$	$f_J(2220)$
• $\phi(1020)$	$\eta(2225)$
	$\rho_3(2250)$
• h ₁ (1170)	• $f_2(2300)$
• $b_1(1235)$	$f_4(2300)$
• $a_1(1260)$	• $f_2(2340)$
• f ₂ (1270)	$\rho_5(2350)$
• $f_1(1285)$	
• $\eta(1295)$	$a_6(2450)$
• $\pi(1300)$	$f_6(2510)$
• $a_2(1320)$	X(3250)
• $f_0(1370)$	OTHER LICHT LINELAYORED (C. C. D. O)
$h_1(1380)$	OTHER LIGHT UNFLAVORED $(S = C = B = 0)$
$\hat{ ho}(1405)$	$e^{+}e^{-}(1100-2200)$ 435
• $f_1(1420)$	$\overline{N}N(1100-3600)$ 435
• $\omega(1420)$	X(1900-3600) 437
$f_2(1430)$	
• $\eta(1440)$	STRANGE MESONS $(S = \pm 1, C = B = 0)$
• $\eta(1110)$	
• $a_0(1450)$	• K^{\pm}
• $a_0(1450)$	• K^{\pm}
• $a_0(1450)$	• K^{\pm}
$ullet a_0(1450)$	 K[±] K⁰ K⁰ K⁰ 455
$egin{array}{cccccccccccccccccccccccccccccccccccc$	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$
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(continued on the next page)

[•] Indicates the particle is in the Meson Summary Table

CHARMED MESONS ($C = \pm 1$)	$ ext{NON-}q\overline{q}$ CANDIDATES
• D [±]	Non- $q\overline{q}$ Candidates 609
• D ⁰	
• $D^*(2007)^0$	Notes in the Meson Listings
• $D^*(2010)^{\pm}$	Pseudoscalar-Meson Decay Constants (rev.) 353
$D_1(2420)^{\pm}$	$\pi^{\pm} \to \ell^{\pm} \nu \gamma$ and $K^{\pm} \to \ell^{\pm} \nu \gamma$ Form Factors 356
• $D_2^*(2460)^0$	The $\rho(770)$ (rev.)
• $D_2^*(2460)^+$	The $a_1(1260)$ (rev.)
	Scalar Mesons (rev.)
CHARMED, STRANGE MESONS ($C = S = \pm 1$)	The $\rho(1450)$ and the $\rho(1700)$ (rev.)
• D_s^{\pm}	The $f_J(1710)$ (rev.)
• $D_s^{*\pm}$	The $f_J(2220)$ (new)
• $D_{sJ}(2573)^{\pm}$	The $X(1900-3600)$ Region
·	The Charged Kaon Mass 439
BOTTOM MESONS $(B = \pm 1)$	Rare Kaon Decays (rev.)
$\bullet B^{\pm} $	Dalitz Plot Parameters for $K \to 3\pi$ Decays 449 K_{P3}^{\pm} and K_{P3}^{0} Form Factors 450
• B ⁰	$K_{\ell 3}^{\pm}$ and $K_{\ell 3}^{0}$ Form Factors
• B^{\pm}/B^0 admixture	Fits for K_L^0 CP -Violation Parameters (rev.) 465
• $B^{\pm}/B^{0}/B_{s}^{0}/b$ -baryon admixture	$\Delta S = \Delta Q$ in K^0 Decays
• $B_J^*(5732)$	$K^*(892)$ Masses and Mass Differences 472
• •	$K_2(1770)$ and the $K_2(1820)$ 480
BOTTOM, STRANGE MESONS $(B = \pm 1, S = \mp 1)$	D Mesons (rev.)
\bullet B_s^0	Production and Decay of b-flavored Hadrons (rev.) 522
B_s^*	$B^0-\overline{B}^0$ Mixing (rev.)
$B_{sJ}^*(5850)$	CP Violation in B Decay (rev.)
BOTTOM, CHARMED MESONS ($B = C = \pm 1$)	Non- $q\bar{q}$ Mesons (rev.) 609
B_c^\pm	1101 44 1100010 (2011)
= MEGONG	
cē MESONS	
• $\eta_c(1S) = \eta_c(2980)$	
• $J/\psi(1S) = J/\psi(3097)$	
• $\chi_{c1}(1P) = \chi_{c1}(3510)$	
$h_c(1P)$	
• $\chi_{c2}(1P) = \chi_{c2}(3555)$	
$\eta_c(2S) = \eta_c(3590) $	
$\bullet \psi(2S) = \psi(3685) \dots \dots \dots \dots \dots \dots \dots \dots \dots $	
• $\psi(3770)$	
• $\psi(4040)$	
• $\psi(4415)$	
$b\overline{b}$ MESONS	
$\bullet \Upsilon(1S) = \Upsilon(9460) $	
• $\chi_{b0}(1P) = \chi_{b0}(9860)$	
• $\chi_{b1}(1P) = \chi_{b1}(9890)$ 602	
• $\chi_{b2}(1P) = \chi_{b2}(9915)$	
• $T(2S) = T(10023)$	
• $\chi_{b1}(2P) = \chi_{b1}(10255)$ 605	
• $\chi_{b2}(2P) = \chi_{b2}(10270)$	
$\bullet \Upsilon(3S) = \Upsilon(10355) \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots \qquad \ldots$	
$\bullet \Upsilon(4S) = \Upsilon(10580) \qquad . \qquad 607$	
• \(\gamma(10860) \) 608	
• $\Upsilon(11020)$ 608	
• Indicates the particle is in the Meson Summary Table	

LIGHT UNFLAVORED MESONS (S = C = B = 0)

For I=1 (π, b, ρ, a) : $u\overline{d}$, $(u\overline{u}-d\overline{d})/\sqrt{2}$, $d\overline{u}$; for I=0 $(\eta, \eta', h, h', \omega, \phi, f, f')$: $c_1(u\overline{u}+d\overline{d})+c_2(s\overline{s})$

PSEUDOSCALAR-MESON DECAY CONSTANTS Revised March 1998 by M. Suzuki (LBNL).

Charged mesons

The decay constant f_P for a charged pseudoscalar meson P is defined by

$$\langle 0|A_{\mu}(0)|P(\mathbf{q})\rangle = if_P q_{\mu} , \qquad (1)$$

where A_{μ} is the axial-vector part of the charged weak current after a Cabibbo-Kobayashi-Maskawa mixing-matrix element $V_{qq'}$ has been removed. The state vector is normalized by $\langle P(\mathbf{q})|P(\mathbf{q'})\rangle=(2\pi)^3$ $2E_q$ $\delta(\mathbf{q}-\mathbf{q'})$, and its phase is chosen to make f_P real and positive. Note, however, that in many theoretical papers our $f_P/\sqrt{2}$ is denoted by f_P .

In determining f_P experimentally, radiative corrections must be taken into account. Since the photon-loop correction introduces an infrared divergence that is canceled by soft-photon emission, we can determine f_P only from the combined rate for $P^\pm \to \ell^\pm \nu_\ell$ and $P^\pm \to \ell^\pm \nu_\ell \gamma$. This rate is given by

$$\Gamma(P \to \ell \nu_{\ell} + \ell \nu_{\ell} \gamma) =$$

$$\frac{G_F^2 |V_{qq'}|^2}{8\pi} f_P^2 m_\ell^2 m_P \left(1 - \frac{m_\ell^2}{m_P^2}\right)^2 [1 + \mathscr{O}(\alpha)] . \tag{2}$$

Here m_{ℓ} and m_P are the masses of the lepton and meson. Radiative corrections include inner bremsstrahlung, which is independent of the structure of the meson [1-3], and also a structure-dependent term [4,5]. After radiative corrections are made, there are ambiguities in extracting f_P from experimental measurements. In fact, the definition of f_P is no longer unique.

It is desirable to define f_P such that it depends only on the properties of the pseudoscalar meson, not on the final decay products. The short-distance corrections to the fundamental electroweak constants like $G_F|V_{qq'}|$ should be separated out. Following Marciano and Sirlin [6], we define f_P with the following form for the $\mathcal{O}(\alpha)$ corrections:

$$1 + \mathcal{O}(\alpha) = \left[1 + \frac{2\alpha}{\pi} \ln\left(\frac{m_Z}{m_\rho}\right)\right] \left[1 + \frac{\alpha}{\pi} F(x)\right]$$

$$\times \left\{1 - \frac{\alpha}{\pi} \left[\frac{3}{2} \ln\left(\frac{m_\rho}{m_P}\right) + C_1 + C_2 \frac{m_\ell^2}{m_\rho^2} \ln\left(\frac{m_\rho^2}{m_\ell^2}\right) + C_3 \frac{m_\ell^2}{m_\rho^2} + \dots\right]\right\},$$
(3)

where m_{ρ} and m_{Z} are the masses of the ρ meson and Z boson. Here

$$\begin{split} F(x) &= 3 \ln x + \frac{13 - 19x^2}{8(1 - x^2)} - \frac{8 - 5x^2}{2(1 - x^2)^2} \, x^2 \ln x \\ &- 2 \Big(\frac{1 + x^2}{1 - x^2} \ln x + 1 \Big) \ln(1 - x^2) + 2 \Big(\frac{1 + x^2}{1 - x^2} \Big) L(1 - x^2) \ , \end{split}$$

with

$$x \equiv m_{\ell}/m_P$$
, $L(z) \equiv \int_0^z \frac{\ln(1-t)}{t} dt$. (4)

The first bracket in the expression for $1 + \mathcal{O}(\alpha)$ is the short-distance electroweak correction. A quarter of $(2\alpha/\pi) \ln(m_Z/m_\rho)$ is subject to the QCD correction $(1-\alpha_s/\pi)$, which leads to a reduction of the total short-distance correction of 0.00033 from the electroweak contribution alone [6]. The second bracket together with the term $-(3\alpha/2\pi) \ln(m_\rho/m_P)$ in the third bracket corresponds to the radiative corrections to the point-like pion decay $(\Lambda_{\text{cutoff}} \approx m_\rho)$ [2]. The rest of the corrections in the third bracket are expanded in powers of m_ℓ/m_ρ . The expansion coefficients C_1 , C_2 , and C_3 depend on the hadronic structure of the pseudoscalar meson and in most cases cannot be computed accurately. In particular, C_1 absorbs the uncertainty in the matching energy scale between short- and long-distance strong interactions and thus is the main source of uncertainty in determining f_{π^+} accurately.

With the experimental value for the decay $\pi^+ \to \mu^+ \nu_\mu + \mu^+ \nu_\mu \gamma$, one obtains

$$f_{\pi^{+}} = 130.7 \pm 0.1 \pm 0.36 \text{ MeV}$$
 (5)

where the first error comes from the experimental uncertainty on $|V_{ud}|$ and the second comes from the uncertainty on C_1 (= 0 ± 0.24) [6]. Similarly, one obtains from the decay $K^+ \rightarrow \mu^+\nu_\mu + \mu^+\nu_\mu\gamma$ the decay constant

$$f_{K^+} = 159.8 \pm 1.4 \pm 0.44 \text{ MeV}$$
, (6)

where the first error is due to the uncertainty on $|V_{us}|$.

For the heavy pseudoscalar mesons, uncertainties in the experimental values for the decay rates are much larger than the radiative corrections. For the D^+ , only an upper bound can be obtained from the published data:

$$f_{D^+} < 310 \text{ MeV (CL} = 90\%)$$
 (7)

For the D_s^+ , the decay constant has been extracted from both the $D_s^+ \to \mu^+\nu_\mu$ and the $D_s^+ \to \tau^+\nu_\tau$ branching fractions. Two values have been reported since the last edition [7,8]:

$$\begin{split} f_{D_s^+} &= 194 \pm 35 \pm 20 \pm 14 \text{ MeV from } D_s^+ \to \mu^+ \nu_\mu \ , \\ f_{D_s^+} &= 309 \pm 58 \pm 33 \pm 38 \text{ MeV from } D_s^+ \to \tau^+ \nu_\tau \ . \end{split}$$
 There are now altogether five reported values for $f_{D_s^+}$ spread over a wide range,

$$f_{D^{+}} = 194 \text{ MeV} \sim 430 \text{ MeV}$$
 (8)

with large uncertainties attached. We must wait for better data before giving a meaningful value for $f_{D_s^+}$. (See the measurements of the $D_s^+ \to \ell^+ \nu_\ell$ modes in the Particle Listings for the numbers quoted by individual experiments.)

There have been many attempts to extract f_P from spectroscopy and nonleptonic decays using theoretical models. Since it is difficult to estimate uncertainties for them, we have listed here only values of decay constants that are obtained directly from the observation of $P^\pm \to \ell^\pm \nu_\ell$.

Meson Particle Listings

 π^{\pm}

Light neutral mesons

The decay constants for the light neutral pseudoscalar mesons π^0 , η , and η' are defined by

$$\langle 0|A_{\mu}(0)|P^{0}(\mathbf{q})\rangle = i(f_{P}/\sqrt{2})q_{\mu} ,$$
 (9)

where A_{μ} is a neutral axial-vector current of octet or singlet. However f_p for the neutral mesons cannot be extracted directly from the data.

In the limit of $m_P \to 0$, the Adler-Bell-Jackiw anomaly determines f_P through the matrix element of the two-photon decay $P^0 \to \gamma \gamma$ [9,10]. The extrapolation to the mass shell is needed to extract the physical value of f_P . In the case of f_{π^0} , the extrapolation is small and the experimental uncertainty in the π^0 lifetime dominates in the uncertainty of f_{π^0} :

$$f_{\pi^0} = 130 \pm 5 \text{ MeV} ,$$
 (10)

which is consistent with isospin symmetry.

For the η and η' , the extrapolation to the mass shell is larger and therefore the dominance of the anomaly on the mass shell is questionable, particularly for the η' ; and η - η' mixing adds to the uncertainty. If the corrections are computed for the octet with the chiral Lagrangian [11], one obtains $f_8 \approx 1.3 f_\pi$ for the decay constant of the I=0 octet state. For the singlet state, if the $\eta \to \gamma \gamma$ and $\eta' \to \gamma \gamma$ decay rates are fitted with the same form as the anomaly indicates, $f_1 \approx f_\pi$ would give a viable fit for $f_8 \approx 1.3 f_\pi$ and the η - η' mixing angle of $\theta_P \approx -20^\circ$. However, because of the arbitrariness even in defining the decay constants, we do not quote numbers for f_η or $f_{\eta'}$ here.

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$$I^{G}(J^{P}) = 1^{-}(0^{-})$$

We have omitted some results that have been superseded by later experiments. The omitted results may be found in our 1988 edition Physics Letters **B204** (1988).

π[±] MASS

The most accurate charged pion mass measurements are based upon x-ray wavelength measurements for transitions in π^- -mesonic atoms. The observed line is the blend of three components, corresponding to different K-shell occupancies. JECKELMANN 94 revisits the occupancy question, with the conclusion that two sets of occupancy ratios, resulting in two different pion masses (Solutions A and B), are equally probable. We choose the higher Solution B since only this solution is consistent with a positive mass-squared for the muon neutrino, given the precise muon momentum measurements now available (DAUM 91, ASSAMAGAN 94, and ASSAMAGAN 96) for the decay of pions at rest. Earlier mass determinations with pi-mesonic atoms may have used incorrect K-shell screening corrections.

Measurements with an error of > 0.005 MeV have been omitted from this Listing.

VALUE (MeV)	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT
139.56995 ± 0.00035 OUR FIT					
139.56995±0.00035	1 JECKELMANN	94	CNTR	_	π^- atom, Soln. B
• • • We do not use the following	data for averages	, flts	, limits,	etc. •	• •
139.57022±0.00014	² ASSAMAGAN	96	SPEC	+	$\pi^+ \rightarrow \mu^+ \nu_{\mu}$
139.56782±0.00037	3 JECKELMANN	94	CNTR	_	π^- atom, Soln. A
139.56996±0.00067			SPEC		$\pi^+ \rightarrow \mu^+ \nu$
139.56752±0.00037	5 JECKELMANN	86B	CNTR	-	Mesonic atoms
139.5704 ±0.0011		84	SPEC	+	See DAUM 91
139.5664 ±0.0009	⁶ LU	80	CNTR	-	Mesonic atoms
139.5686 ±0.0020		76	CNTR	_	Mesonic atoms
139.5660 ±0.0024	^{5,7} MARUSHEN	76	CNTR	-	Mesonic atoms

- 1 JECKELMANN 94 Solution B (dominant 2-electron K-shell occupancy), chosen for consistency with positive $m_{\nu_-}^2$.
- ²ASSAMAGAN 96 measures the μ^+ momentum p_μ in $\pi^+ \to \mu^+ \nu_\mu$ decay at rest to be 29.79200 \pm 0.00011 MeV/c. Combined with the μ^+ mass and the assumption m_{ν_μ} = 0, this gives the π^+ mass above: if $m_{\nu_\mu} > 0$, m_{π^+} given above is a lower limit. Combined instead with m_μ and (assuming *CPT*) the π^- mass of JECKELMANN 94, p_μ gives an upper limit on m_{ν_μ} (see the ν_μ).
- ³ JECKELMANN 94 Solution A (small 2-electron K-shell occupancy) in combination with either the DAUM 91 or ASSAMAGAN 94 pion decay muon momentum measurement yields a significantly negative $m_{\nu_{\mu}}^2$. It is accordingly not used in our fits.
- ⁴ The DAUM 91 value includes the ABELA 84 result. The value is based on a measurement of the μ^+ momentum for π^+ decay at rest, $p_\mu=29.79179\pm0.00053$ MeV, uses $m_\mu=105.658389\pm0.000034$ MeV, and assumes that $m_{\nu_\mu}=0$. The last assumption means
- that in fact the value is a lower limit. ⁵ JECKELMANN 868 gives $m_\pi/m_e=273.12677(71)$. We use $m_e=0.51099906(15)$ MeV from COHEN 87. The authors note that two solutions for the probability distribution of K-shell occupancy fit equally well, and use other data to choose the lower of the two possible π^\pm masses.
- 6 These values are scaled with a new wavelength-energy conversion factor V\ = 1.23984244(37) \times 10^{-6} eV m from COHEN 87. The LU 80 screening correction relies upon a theoretical calculation of inner-shell refilling rates.
- 7 This MARUSHENKO 76 value used at the authors' request to use the accepted set of calibration γ energies. Error increased from 0.0017 MeV to include QED calculation error of 0.0017 MeV (12 ppm).

$$m_{\pi^+}-m_{\mu^+}$$

Measurements with an error > 0.05 MeV have been omitted from this Listing.

VALUE (MeV)	EVTS	DOCUMENT I	0	TECN	CHG	COMMENT
• • • We do not use	the followin	ng data for avera	ges, fit	s, limits,	etc. •	• •
33.91157±0.00067		8 DAUM	91	SPEC	+	$\pi^+ \rightarrow \mu^+ \nu$
33.9111 ±0.0011		ABELA	84	SPEC		See DAUM 91
33.925 ±0.025		воотн	70	CNTR	+	Magnetic spect.
33.881 ±0.035	145	HYMAN	67	HEBC	+	K⁻ He
8 The DALIM OF US		that m = 0 a	nd uses		_ 105	. ceosoo ⊥ n nnnns.

$$(m_{\pi^+}-m_{\pi^-})/m_{average}$$

A test of CPT invariance.

VALUE (units 10 ⁻⁴)	DOCUMENT I		TECN
2±5	AYRES	71	CNTR

π[±] MEAN LIFE

Measurements with an error $> 0.02 \times 10^{-8}$ s have been omitted.

VALUE (1	10 ⁻⁸ s)		DOCUMENT ID		TECN	CHG	COMMENT
2.6033	±0.0005	OUR AVERAGE	Error includes	scale	factor o	f 1.2.	
2.60361	±0.00052	,	⁹ KOPTEV	95	SPEC	+	Surface μ^+ 's
2.60231	±0.00050	±0.00084	NUMAO	95	SPEC	+	Surface μ^+ 's
2.609	± 0.008		DUNAITSEV	73	CNTR	+	
2.602	± 0.004		AYRES	71	CNTR	±	
2.604	± 0.005		NORDBERG	67	CNTR	+	
2.602	± 0.004		ECKHAUSE	65	CNTR	+	
	We do not	use the following	data for average	es, fits	s, limits,	etc. e	• •
2.640	±0.008	10	KINSEY	66	CNTR	+	

⁹ KOPTEV 95 combines the statistical and systematic errors; the statistical error domi-

nates.

Systematic errors in the calibration of this experiment are discussed by NORDBERG 67.

$(\tau_{\pi^+} - \tau_{\pi^-}) / \tau_{\text{average}}$

A test of CPT invariance.

VALUE	(units 10 ⁻⁴)	DOCUMENT ID		TECN
5.5	± 7.1	AYRES	71	CNTR
• • •	We do not use the fol	lowing data for average	s, fit	s, limits, etc. • • •
-14	±29	PETRUKHIN	68	CNTR
40	±70	BARDON	66	CNTR
23	±40	11 LOBKOWICZ	66	CNTR
		ative value given by LO		

π^+ DECAY MODES

 π^- modes are charge conjugates of the modes below.

	Mode	Fraction (Γ_I/Γ) Confidence leve	ı
Γ ₁	$\mu^+ u_\mu$	[a] (99.98770±0.00004) %	-
Γ_2	$\mu^{+}\nu_{\mu}\gamma$	[b] $(1.24 \pm 0.25) \times 10^{-4}$	
Гз	$e^+ u_e$	[a] $(1.230 \pm 0.004) \times 10^{-4}$	
Γ_4	$e^+ u_e\gamma$	[b] (1.61 ± 0.23) $\times 10^{-7}$	
Γ ₅	$e^+ u_e\pi^0$	$(1.025 \pm 0.034) \times 10^{-8}$	
Γ ₆	$e^+ u_e e^+ e^-$	$(3.2 \pm 0.5) \times 10^{-9}$	
Γ7	$e^+ u_e u \overline{ u}$	$< 5 \times 10^{-6} 90\%$	ó
	Lepton Family number	(LF) or Lepton number (L) violating modes	

$\Gamma_8 \quad \mu^+ \overline{\nu}_e$. ×10⁻³ 90% L [c] < 1.5 $\mu^+ \nu_e$ × 10⁻³ LF 90% [c] < 8.0× 10⁻⁶ $\Gamma_{10} \mu^{-}e^{+}e^{+}\nu$ LF

- [a] Measurements of $\Gamma(e^+\nu_e)/\Gamma(\mu^+\nu_\mu)$ always include decays with γ 's, and measurements of $\Gamma(e^+\nu_e\gamma)$ and $\Gamma(\mu^+\nu_\mu\gamma)$ never include low-energy γ 's. Therefore, since no clean separation is possible, we consider the modes with γ 's to be subreactions of the modes without them, and let $[\Gamma(e^+\nu_e)]$ + $\Gamma(\mu^+\nu_\mu)]/\Gamma_{\text{total}} = 100\%$.
- [b] See the Particle Listings below for the energy limits used in this measurement; low-energy γ 's are not included.
- [c] Derived from an analysis of neutrino-oscillation experiments.

π⁺ BRANCHING RATIOS

 $\Gamma(e^+\nu_e)/\Gamma_{\text{total}}$ See note [a] in the list of π^+ decay modes just above, and see also the next block of

DOCUMENT ID

VALUE (units 10⁻⁴) 1.230±0.004 OUR EVALUATION

 $\left[\Gamma(e^+\nu_e) + \Gamma(e^+\nu_e\gamma)\right] / \left[\Gamma(\mu^+\nu_\mu) + \Gamma(\mu^+\nu_\mu\gamma)\right]$

See note [a] in the list of π^+ decay modes above. See NUMAO 92 for a discussion of e-u universality.

VALUE (units 10-4)	EVTS	DOCUMENT ID		TECN	COMMENT
1.230 ±0.004 OUR AV	ERAGE			_	
$1.2346 \pm 0.0035 \pm 0.0036$	120k	CZAPEK			Stopping π^+
$1.2265 \pm 0.0034 \pm 0.0044$	190k	BRITTON			Stopping π^+
1.218 ±0.014	32k	BRYMAN	86	CNTR	Stopping π^+
• • • We do not use the	following	g data for averages,	fits,	, limits,	etc. • • •
1.273 ±0.028	11k	12 DICAPUA	64	CNTR	
1.21 ± 0.07		ANDERSON	60	SPEC	

12 DICAPUA 64 has been updated using the current mean life.

		ere do not cover the		•	
VALUE (units 10 ⁻⁴)					
1.24±0.25	26	CASTAGNOLI	58 EML	IL KE $_{\mu}$ $<$ 3.38 MeV	
$\Gamma(e^+ u_e\gamma)/\Gamma_{ ext{total}}$ Note that meass	urements h	ere do not cover the	e full kiner		Γ4/Γ
VALUE (units 10 ⁻⁸)	EVTS	DOCUMENT ID	TECN	COMMENT	
6.1±2.3				C 17 GeV $\pi^- \rightarrow e^-$	$\overline{\nu}_{\mu}\gamma$
• • We do not use	the followir	ng data for averages	, fits, limi	ts, etc. • • •	
5.6 ± 0.7	226	14 STETZ	78 SPE	C P _e > 56 MeV/c	
3.0	143	DEPOMMIER	63B CNT	R (KE) _{e+7} > 48 Me	V
13 BOLOTOV 90B is	for E _~ >	21 MeV, Ea > 70	0.8 E	- '	
14 STETZ 78 is for a	ne ⁻ γope	ning angle > 132°	. Obtains	3.7 when using same c	utoff
as DEPOMMIER	JJB,				

'(~ "e" //'total						'8/'
VALUE (units 10-8)	EVTS	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT
1.025 ± 0.034 OUR AV	/ERAGE					
1.026 ± 0.039	1224	¹⁵ MCFARLANE	85	CNTR	+	Decay in flight
1.00 +0.08	332	DEPOMMIER	68	CNTR	+	
1.07 ±0.21	38	¹⁶ BACASTOW		O5PK		
1.10 ±0.26		16 BERTRAM				
1.1 ±0.2	43	16 DUNAITSEV	65	CNTR	+	
0.97 ±0.20	36	16 BARTLETT	64	OSPK	+	
• • • We do not use	the follow	ing data for average	s, fit	s, limits,	etc. •	• •
1.15 ±0.22	52	¹⁶ DEPOMMIER	63	CNTR	+	See DEPOM- MIER 68

 $^{15}\,\mathrm{MCFARLANE}$ 85 combines a measured rate (0.394 \pm 0.015)/s with 1982 PDG mean

life.

16 DEPOMMIER 68 says the result of DEPOMMIER 63 is at least 10% too large because of a systematic error in the π^0 detection efficiency, and that this may be precise previous measurements (also V. Soergel, private communication, 1972).

$\Gamma(e^+\nu_ee^+e^-)/\Gamma$	$(\mu^+ \nu_\mu)$			Γ_6/Γ_1
VALUE (units 10 ⁻⁹)	CL% EVTS	DOCUMENT ID	TECN	COMMENT
3.2 ±0.5 ±0.2	98	EGLI 8	9 SPEC	Uses R _{PCAC} = 0.068 ± 0.004
• • We do not use	the following	g data for averages, fits	, limits, et	:c, • • •
$0.46 \pm 0.16 \pm 0.07$	7	17 BARANOV 9	2 SPEC	Stopped π^+
< 4.8	90	KORENCHE 7	6B SPEC	
<34	90	KORENCHE 7	1 OSPK	

17 This measurement by BARANOV 92 is of the structure-dependent part of the decay. The value depends on values assumed for ratios of form factors.

$\Gamma(e^+\nu_e\nu\overline{\nu})/\Gamma_{\rm tota}$	ıl		Γ ₇ /Γ
VALUE (units 10 ⁻⁶)	CL%	DOCUMENT ID T	ECN_
<5	90	PICCIOTTO 88 S	PEC
$\Gamma(\mu^+\overline{\nu}_e)/\Gamma_{\text{total}}$			Г _в /Г

Forbidden by total lepton number conservation. VALUE (units 10⁻³)
 CL%
 DOCUMENT ID
 TECN
 COMMENT

 90
 18 COOPER
 82
 HLBC
 Wideband \(\nu\) beam
 CL%

 18 COOPER 82 limit on $\overline{\nu}_e$ observation is here interpreted as a limit on lepton number

 $\Gamma(\mu^+\nu_e)/\Gamma_{\text{total}}$ Г9/Г Forbidden by lepton family number conservation. DOCUMENT ID TECN COMMENT 82 HLBC Wideband v beam 19 COOPER 82 limit on u_e observation is here interpreted as a limit on lepton family number

 $\Gamma(\mu^- e^+ e^+ \nu)/\Gamma_{\text{total}}$ Γ₁₀/Γ Forbidden by lepton family number conservation. VALUE (units 10⁻⁶) CL% DOCUMENT ID TECN CHG <1.6 90 ' BARANOV 918 SPEC + . . . We do not use the following data for averages, fits, limits, etc. . . . KORENCHE... 87 SPEC + 90 <7.7

π^+ — POLARIZATION OF EMITTED μ^+

 $\pi^+ \rightarrow \mu^+ \nu$ Tests the Lorentz structure of leptonic charged weak interactions. DOCUMENT ID TECN CHG COMMENT VALUE CL% • • • We do not use the following data for averages, fits, limits, etc. • • • <(-0.9959) 90 ²⁰ FETSCHER 84 RVUE + 21 ABELA -0.99 ± 0.16 $^{20}\,\mbox{FETSCHER}$ 84 uses only the measurement of CARR 83. 21 Sign of measurement reversed in ABELA 83 to compare with μ^+ measurements. $\pi^{\pm} \to \ell^{\pm} \nu \gamma$ AND $K^{\pm} \to \ell^{\pm} \nu \gamma$ FORM FACTORS

Written by H.S. Pruys (Zürich University).

In the radiative decays $\pi^{\pm} \to \ell^{\pm} \nu \gamma$ and $K^{\pm} \to \ell^{\pm} \nu \gamma$, where ℓ is an e or a μ and γ is a real or virtual photon $(e^+e^-$ pair), both the vector and the axial-vector weak hadronic currents contribute to the decay amplitude. Each current gives a structure-dependent term (SD_V and SD_A) from virtual hadronic states, and the axial-vector current also gives a contribution from inner bremsstrahlung (IB) from the lepton and meson. The IB amplitudes are determined by the meson decay constants f_{π} and f_K [1]. The SD_V and SD_A amplitudes are parameterized in terms of the vector form factor F_V and the axial-vector form factors F_A and R [1-4]:

$$M(\mathrm{SD}_V) = rac{-eG_F V_{qq'}}{\sqrt{2} \ m_P} \epsilon^\mu \ \ell^
u \ F_V \ \epsilon_{\mu
u\sigma au} \ k^\sigma \ q^ au \ ,$$

$$M({\rm SD}_A) = \frac{-ie\,G_F V_{qq'}}{\sqrt{2}\,\,m_P}\,\epsilon^\mu\,\ell^\nu\,\big\{F_A\,[(s\,-\,t)g_{\mu\nu}\,-\,q_\mu\,k_\nu]\,+\,R\,t\,g_{\mu\nu}\big\}\ .$$

Here $V_{qq'}$ is the Cabibbo-Kobayashi-Maskawa mixing-matrix element; ϵ^{μ} is the polarization vector of the photon (or the effective vertex, $\epsilon^{\mu} = (e/t)\overline{u}(p_{-})\gamma^{\mu}v(p_{+})$, of the $e^{+}e^{-}$ pair); $\ell^{\nu} = \overline{u}(p_{\nu})\gamma^{\nu}(1-\gamma_5)v(p_{\ell})$ is the lepton-neutrino current; q and k are the meson and photon four-momenta, with $s = q \cdot k$ and $t = k^2 (= (p_+ + p_-)^2)$; and P stands for π or K. In the analysis of data, the s and t dependence of the form factors is neglected, which is a good approximation for pions [2] but not for kaons [4]. The pion vector form factor F_V^{π} is related via CVC to the π^0 lifetime, $|F_V^{\pi}| = (1/\alpha)\sqrt{2\Gamma_{\pi^0}/\pi m_{\pi^0}}$ [1]. PCAC relates R to the electromagnetic radius of the meson [2,4], $R^P = \frac{1}{3} m_P f_P \langle r_P^2 \rangle$. The calculation of the other form factors, F_A^{π} , F_V^K , and F_A^K , is model dependent [1,4].

When the photon is real, the partial decay rate can be given analytically [1,5]:

$$\frac{d^2\Gamma_{P\to\ell\nu\gamma}}{dxdy} = \frac{d^2\left(\Gamma_{\rm IB} + \Gamma_{\rm SD} + \Gamma_{\rm INT}\right)}{dxdy} \; , \label{eq:continuous}$$

where Γ_{IB} , Γ_{SD} , and Γ_{INT} are the contributions from inner bremsstrahlung, structure-dependent radiation, and their interference, and the Γ_{SD} term is given by

$$\frac{d^2\Gamma_{\rm SD}}{dxdy} = \frac{\alpha}{8\pi} \Gamma_{P \to \ell\nu} \frac{1}{r(1-r)^2} \left(\frac{m_P}{f_P}\right)^2 \times \left[(F_V + F_A)^2 \, \text{SD}^+ + (F_V - F_A)^2 \, \text{SD}^- \right] .$$

Here

$$SD^+ = (x + y - 1 - r)[(x + y - 1)(1 - x) - r]$$
,

$$SD^- = (1 - y + r)[(1 - x)(1 - y) + r]$$
,

where $x = 2E_{\gamma}/m_P$, $y = 2E_{\ell}/m_P$, and $r = (m_{\ell}/m_P)^2$.

In $\pi^{\pm} \to e^{\pm}\nu\gamma$ and $K^{\pm} \to e^{\pm}\nu\gamma$ decays, the interference terms are small, and thus only the absolute values $|F_A + F_V|$ and $|F_A - F_V|$ can be obtained. In $K^{\pm} \to \mu^{\pm} \nu \gamma$ decay, the interference term is important, and thus the signs of F_V and F_A can be obtained. In $\pi^{\pm} \to \mu^{\pm} \nu \gamma$ decay, bremsstrahlung completely dominates. In $\pi^{\pm} \to e^{\pm} \nu e^{+} e^{-}$ and $K^{\pm} \to \ell^{\pm} \nu e^{+} e^{-}$ decays, all three form factors, F_V , F_A , and R, can be determined.

We give the π^{\pm} form factors F_V , F_A , and R in the Listings below. In the K^{\pm} Listings, we give the sum $F_A + F_V$ and difference $F_A - F_V$.

The electroweak decays of the pseudoscalar mesons are investigated to learn something about the unknown hadronic structure of these mesons, assuming a standard V-A structure of the weak leptonic current. The experiments are quite difficult, and it is not meaningful to analyse the results using parameters for both the hadronic structure (decay constants, form factors) and the leptonic weak current (e.g., to add pseudoscalar or tensor couplings to the V-A coupling). Deviations from the V-A interactions are much better studied in purely leptonic systems such as muon decay.

References

- D.A. Bryman et al., Phys. Reports 88, 151 (1982). See also our note on "Pseudoscalar-Meson Decay Constants,"
- A. Kersch and F. Scheck, Nucl. Phys. B263, 475 (1986).
- W.T. Chu et al., Phys. Rev. 166, 1577 (1968).
- D.Yu. Bardin and E.A. Ivanov, Sov. J. Part. Nucl. 7, 286 (1976).
- S.G. Brown and S.A. Bludman, Phys. Rev. 136, B1160 (1964).

** FORM FACTORS

Fv, VECTOR FORM FACTOR

VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
0.017±0.008 OUR	AVERAGE			
0.014 ± 0.009		²² BOLOTOV	908 SPEC	17 GeV $\pi^- \rightarrow e^- \overline{\nu}_e \gamma$
0.023 + 0.015	98	EGLI	89 SPEC	$\pi^+ \rightarrow e^+ \nu_e e^+ e^-$

²²BOLOTOV 90B only determines the absolute value.

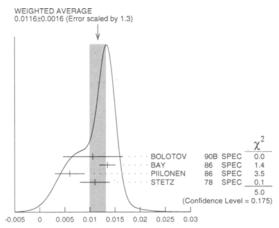
FA, AXIAL-VECTOR FORM FACTOR

VALUE EVTS	DOCUMENT ID	TECN COMMENT	
0.0116±0.0016 OUR AVERAGE	Error includes so	cale factor of 1.3. See the ideogram	
	below.	, –	
0.0106 ± 0.0060	23 BOLOTOV	908 SPEC 17 GeV $\pi^- \rightarrow e^- \overline{\nu}_e$	7
0.0135 ± 0.0016	²³ BAY	86 SPEC $\pi^+ \rightarrow e^+ \nu \gamma$	
0.006 ±0.003	23 PIILONEN	86 SPEC $\pi^+ \rightarrow e^+ \nu \gamma$	
0.011 ±0.003	3,24 STETZ	78 SPEC $\pi^+ \rightarrow e^+ \nu \gamma$	
• • • We do not use the followi	ng data for averag	ges, fits, limits, etc. • • •	
$0.021 \begin{array}{l} +0.011 \\ -0.013 \end{array}$ 98	EGLI	89 SPEC $\pi^+ \rightarrow e^+ \nu_e e^+ e^-$	

²³Using the vector form factor from CVC prediction $F_V = 0.0259 \pm 0.0005$. Only the

absolute value of F_A is determined.

24 The result of STETZ 78 has a two-fold ambiguity. We take the solution compatible with later determinations.



 π^{\pm} axial-vector form factor

R, SECOND AXI	AL-VECTOR	R FORM FAC	TOR	
VALUE	EVTS	DOCUMENT IC	TEC!	COMMENT
900.0+ 900.0+ 900.0	98	EGLI	89 SPE	$C \pi^+ \rightarrow e^+ \nu_e e^+ e^-$

π[±] REFERENCES

We have omitted some papers that have been superseded by later experiments. The omitted papers may be found in our 1988 edition Physics Letters **B204** (1988).

	96	PR D53 6065		RI, VILL, VIRG)
KOPTEV	95	JETPL 61 877	+Mikirtych yants, Shcherbakov+	(PNPI)
NUMAO	95	Translated from ZETFP	+ Macdonald, Marshall, Olin, Fujiwara	(TON) DOCO)
	94	PR D52 4855 PL B335 231		(TRIU, BRCO) RI, VILL, VIRG)
		PL B335 326		(WABRN, VILL)
	93	PRL 70 17	+Federspiel, Flueckiger, Frei+	(BERN, VILL)
BARANOV	92	SJNP 55 1644	+Vanko, Glazov, Evtukhovich+	(JINR)
		Translated from YAF 55	2940.	
	92	PRL 68 3000	+Ahmad, Bryman, Burnham+	(TRIU, CARL)
	94	PR D49 28	Britton, Ahmad, Bryman+	(TRIU, CARL)
	92 91B	MPL A7 3357 SJNP 54 790	Wied Massachanta Masshinstal	(TRIU)
DARAHOV	410	Translated from YAF 54	+Kisel, Korenchenko, Kuchinskii+ 1298	(JINR)
DAUM	91		+Frosch, Herter, Janousch, Kettle	(VILL)
BOLOTOV	90B	PL B243 308	+Gninenko, Djilkibaev, Isakov+	(INRM)
	89	PL B222 533		IDRUM Čollab.)
	86	PL B175 97		TH, SIN, ZURI)
	88	PL B204	Yost, Barnett+	(LBL+)
	88	PR D37 1131	+Ahmad, Britton, Bryman, Clifford+	(TRIU, CNRC)
	87	RMP 59 1121	+Taylor	(RISC, NBS)
KORENCHE	87	SJNP 46 192 Translated from YAF 46	Korenchenko, Kostin, Mzhaviya+	(JINR)
BAY	86	PL B174 445	+Ruegger, Gabioud, Joseph, Loude+	(LAUS, ZURI)
	86	PR D33 1211	+Dubois, Macdonald, Numao+	(TRIU, CNRC)
	83	PRL 50 7	Bryman, Dubois, Numao, Olaniya+	(TRIU, CNRC)
JECKELMANN		NP A457 709	+Beer, Chambrier, Elsenhans+	(ETH, FRIB)
	86	PRL 56 1444	Jeckelmann, Nakada, Beer+	(ETH, FRIB)
PIILONEN	86	PRL 57 1402	+Bolton, Cooper, Frank+ (LANL	, TEMP, CHIC)
MCFARLANE	85	PR D32 547	+Auerbach, Gaille+	(TEMP, LANL)
ABELA	84	PL 146B 431	+Daum, Eaton, Frosch, Jost, Kettle+	` (SIN)
	78	PL 74B 126	Daum, Eaton, Frosch, Hirschmann+	(SIN)
	79	PR D20 2692	Daum, Eaton, Frosch, Hirschmann+	(SIN)
	84	PL 140B 117		(ETH)
	83	NP A395 413	+Backenstoss, Kunold, Simons+ (BASL, K	ARLK, KARLE)
	83	PRL 51 627	+Gidal, Gobbi, Jodidio, Oram+ (LBL	., NWES, TRIU)
	82	PL 112B 97	+Guy, Michette, Tyndel, Venus	(RL)
	80	PRL 45 1066	+Delker, Dugan, Wu, Caffrey+ (YAL	.E, COLU, JHU)
STETZ	78	NP B138 285	+Delker, Dugan, Wu, Caffrey+ (YAL +Carroll, Ortendahl, Perez-Mendez+	.E, COLU, JHU) (LBL, UCLA)
STETZ CARTER	78 76	NP B138 285 PRL 37 1380	+Delker, Dugan, Wu, Caffrey+ (YAL +Carroli, Ortendahl, Perez-Mendez+ +Dixit, Sundaresan+ (CARL, CN	.E, COLU, JHU) (LBL, UCLA) iRC, CHIC, CIT)
STETZ CARTER	78	NP B138 285 PRL 37 1380 JETP 44 35	+ Delker, Dugan, Wu, Caffrey+ (YAL + Carroll, Ortendahl, Perez-Mendez+ + Dixit, Sundaresan+ (CARL, CN Korenchenko, Kostin, Micelmacher+	.E, COLU, JHU) (LBL, UCLA)
STETZ CARTER	78 76 76B	NP B138 285 PRL 37 1380 JETP 44 35 Translated from ZETF 7	+Delker, Dugan, Wu, Caffrey+ (YAL +Carroll, Ortendahl, Perez-Mendez+ +Dixit, Sundaresan+ (CARL, CN Korenchenko, Kostin, Micelmacher+ 1 69.	.E, COLU, JHU) (LBL, UCLA) IRC, CHIC, CIT) (JINR)
STETZ CARTER KORENCHE MARUSHEN	78 76 76B 76	NP B138 285 PRL 37 1380 JETP 44 35 Translated from ZETF 7 JETPL 23 72 Translated from ZETFP	+ Delker, Dugan, Wu, Caffrey+ (YAL + Carroll, Ortendahl, Perez-Mendez+ + Dixit, Sundaresan+ (CARL, CN Korenchenko, Kostin, Micelmacher+ 1 69. Marushenko, Mezentsev, Petrunin+ 23 80.	.E, COLU, JHU) (LBL, UCLA) (RC, CHIC, CIT) (JINR) (PNPI)
STETZ CARTER KORENCHE MARUSHEN	78 76 76B 76	NP B138 285 PRL 37 1380 JETP 44 35 Translated from ZETF 7 JETPL 23 72 Translated from ZETFP Private Comm.	+ Delker, Dugan, Wu, Caffrey+ (YAL + Carroll, Ortendahl, Perez-Mendez+ + Dixit, Sundaresan+ Korenchenko, Kostin, Micelmacher+ 1 69. Marushenko, Mezentsev, Petrunin+ 23 80. Shafer	.E, COLU, JHU) (LBL, UCLA) (RC, CHIC, CIT) (JINR) (PNPI) (FNAL)
STETZ CARTER KORENCHE MARUSHEN Also Also	78 76 76B 76 76 76	NP B138 285 PRL 37 1380 JETP 44 35 Translated from ZETF 7 JETPL 23 72 Translated from ZETFP Private Comm. Private Comm.	+ Delker, Dugan, Wu, Caffrey+ (YAL - Carroll, Ordendah, Perez-Mendez+ + Dickt, Sundaresan+ (CARL, CN Korenchenko, Kostin, Micelmacher+ 169. Marushenko, Mezentsev, Petrunin+ 23 80. Shafer Smirnov	.E, COLU, JHU) (LBL, UCLA) (RC, CHIC, CIT) (JINR) (PNPI) (FNAL) (PNPI)
STETZ CARTER KORENCHE MARUSHEN Also Also	78 76 76B 76	NP B138 285 PRL 37 1380 JETP 44 35 Translated from ZETF 7 JETPL 23 72 Translated from ZETFP Private Comm. SJNP 16 292	+ Delker, Dugan, Wu, Caffrey+ (YAI - Karroll, Ortenz-Mendez+ + Lözik, Sundaresan+ (CARL, CN Korenchenko, Kostin, Micelmacher+ 1 69. Marushenko, Mezentsev, Petrunin+ 23 80. Shafer Smirnov + Prokoshkin, Razuvaev+	.E, COLU, JHU) (LBL, UCLA) (RC, CHIC, CIT) (JINR) (PNPI) (FNAL)
STETZ CARTER KORENCHE MARUSHEN Also Also DUNAITSEV	78 76 76B 76 76 76 78 73	NP B138 285 PRL 37 1380 JETP 44 35 Translated from ZETF 7 JETPL 23 72 Translated from ZETFP Private Comm. Private Comm. SJNP 16 292 Translated from YAF 16	+ Delker, Dugan, Wu, Caffrey+ (YAL - Carroll, Ordendah, Perez-Mendez+ + Dizid, Sundaresan+ (CARL, CN Korenchenko, Kostin, MiccImacher+ 1 99. Marushenko, Mezentsev, Petrunin+ 23 80. Shafer Smirnov + Prokopikin, Razuvaev+ 524.	.E, COLU, JHU) (LBL, UCLA) (RC, CHIC, CIT) (JINR) (PNPI) (FNAL) (PNPI) (SERP)
STETZ CARTER KORENCHE MARUSHEN Also Also DUNAITSEV AYRES	78 76 76B 76 76 76 78 73	NP B138 285 PRL 37 1380 JETP 44 35 Translated from ZETF 7 JETPL 23 72 Translated from ZETFP Private Comm. SJNP 16 292 Translated from YAF 16 PR D3 1051	+ Delker, Dugan, Wu, Caffrey+ (YAI - Karroll, Ortenz-Mendez, - AIL, CN - Korenchenko, Kostin, Micelmacher+ 1 69. Marushenko, Mezentsev, Petrunin+ 23 80. Shafer Smirnov + Prokoshkin, Razuvaev+ 524. + Cormack, Greenberg, Kenney+	.E, COLU, JHU) (LBL, UCLA) (RC, CHIC, CIT) (JINR) (PNPI) (FNAL) (PNPI) (SERP) (LRL, UCSB)
STETZ CARTER KORENCHE MARUSHEN Also Also DUNAITSEV AYRES Also	78 76 76B 76 76 76 78 73	NP B138 285 PRL 37 1380 JETP 44 35 Translated from ZETF 7 JETPL 23 72 Translated from ZETF Private Comm. Private Comm. Private Comm. SJNP 16 292 Translated from YAF 16 PR D3 1051 PR 157 1288	+ Delker, Dugan, Wu, Caffrey+ (YAL - Carroll, Ortendahl, Perez-Mendez+ + Dizik, Sundaresan+ (CARL, CN Korenchenko, Kostin, Micelmacher+ 1 69. Marushenko, Mezentsev, Petrunin+ 23 80. Shafer Smirnov + Prokoshkin, Razuvaev+ 524. + Cormack, Greenberg, Kenney+ Ayres, Caldwell, Greenberg, Kenney, Kurz+ Ayres, Caldwell, Greenberg, Kenney, Kurz+	.E, COLU, JHU) (LBL, UCLA) (RC, CHIC, CIT) (JINR) (PNPI) (FNAL) (PRPI) (SERP) (LRL, UCSB) (LRL, UCSB)
STETZ CARTER KORENCHE MARUSHEN Also Also DUNAITSEV AYRES Also Also	78 76 76B 76 76 78 73 71 67 68	NP B138 285 PRL 37 1380 JETP 44 35 Translated from ZETF 7 JETPL 23 72 Translated from ZETFP Private Comm. Private Comm. Private Comm. SIMP 16 292 Translated from YAF 16 PR D3 1051 PR 157 1288 PRL 21 261	+ Delker, Dugan, Wu, Caffrey+ (YAI - Karroll, Ortenz-Mendez + ALC, N. CAIR, C.N. Korenchenko, Kostin, Micelmacher+ 1 69. Marushenko, Mezentsev, Petrunin+ 23 80. Shafer Smirnov + Prokoshkin, Razuvaev+ 524. + Vcormack, Greenberg, Kenney, Kurz+ Ayres, Caldwell, Greenberg, Kenney, Kurz+ Ayres, Cadwell, Greenberg, Kenney, Kurz+ Ayres, Comack, Greenberg	.E, COLU, JHU) (LBL, UCLA) (RC, CHIC, CIT) (JINR) (PNPI) (FNAL) (PNPI) (SERP) (LRL, UCSB) (LRL, UCSB)
STETZ CARTER KORENCHE MARUSHEN Also Also DUNAITSEV AYRES Also Also Also Also	78 76 76B 76 76 76 78 73 71 67	NP B138 285 PRL 37 1380 JETP 44 35 Translated from ZETF 7 JETPL 23 72 Translated from ZETF Private Comm. Private Comm. Private Comm. SJNP 16 292 Translated from YAF 16 PR D3 1051 PR 157 1288	+ Delker, Dugan, Wu, Caffrey+ (YAL - Carroll, Ortendah), Perez-Mendez+ + Dizik, Sundaresan+ (CARL, CN Korenchenko, Kostin, Micelmacher+ 1 69. Marushenko, Mezentsev, Petrunin+ 23 80. Shafer Smirnov + States + Sources + Sources - Smirnov	.E, COLU, JHU) (LBL, UCLA) (RC, CHIC, CIT) (JINR) (PNPI) (FNAL) (PRPI) (SERP) (LRL, UCSB) (LRL, UCSB) (LRL, UCSB) (LRL, UCSB)
STETZ CARTER KORENCHE MARUSHEN Also Also DUNAITSEV AYRES Also Also Also	78 76 76B 76 76 76 78 73 71 67 68 69	NP B138 285 PRI. 37 1380 JETP 44 35 Translated from ZETF 7 JETPL 23 72 Translated from ZETFP Private Comm. Private Comm. SJNP 16 292 Translated from YAF 16 PR D3 1051 PR 157 1288 PRI. 21 261 Thesis UCRI. 18369 PRI. 23 1267 SJNP 13 189	+ Delker, Dugan, Wu, Caffrey+ (YAL -Carroll, Ortenath), Perez-Mendez+ + Dizik, Sundaresan+ (CARL, CN Korenchenko, Kostin, Micelmacher+ 1 69. Marushenko, Mezentsev, Petrunin+ 23 80. Shafer Smirnov + Prokoshkin, Razuvaev+ 524. + Cormack, Greenberg, Kenney, Kurz+ Ayres, Caldwell, Greenberg, Kenney, Kurz+ Ayres, Cormack, Greenberg- Ayres Greenberg, Ayres, Cormack- Greenberg, Ayres, Cormack- Greenberg, Ayres, Cormack- Greenberg, Ayres, Cormack- Korenchenko, Kostin, Micelmacher+	.E, COLU, JHU) (LBL, UCLA) (RC, CHIC, CIT) (JINR) (PNPI) (FNAL) (PNPI) (SERP) (LRL, UCSB) (LRL, UCSB)
STETZ CARTER CARTER KORENCHE AISO AISO DUNAITSEV AYRES AISO AISO AISO AISO AISO AISO KORENCHE	78 76 76B 76 76 78 73 71 67 68 69 69 71	NP B138 285 PRI. 37 1380 JETP 44 35 Translated from ZETF 7 JETPL 23 72 Translated from ZETFP Private Comm. SINP 16 292 Translated from YAF 16 PR D3 1051 PR 157 1288 PRI. 21 267 SINP 13 189 Translated from YAF 16 PRI. 21 267 SINP 13 189 Translated from YAF 13	+ Delker, Dugan, Wu, Caffrey+ (YAI - Karroll, Ortenz-Mendez, + AL Korenchenko, Kostin, Micelmacher+ 1 69. Marushenko, Mezentsev, Petrunin+ 23 80. Shafer Smirnov + Prokoshkin, Razuvaev+ 524. + Vecmack, Greenberg, Kenney, Kurz+ Ayres, Caldwell, Greenberg, Kenney, Kurz+ Ayres, Cardon, Greenberg, Kenney, Kurz+ Ayres, Comack, Greenberg, Kenney, Kurz- Ayres, Comack, Greenberg, Kenney, Kurz- Ayres, Comack, Greenberg, Myres, Cormack+ Korenchenko, Kostin, Micelmacher+ 339.	LE, COLU, JHUJ (LBL, UCLA) (RC, CHIC, CIT) (JINR) (PNPI) (FNAL) (PNPI) (SERP) (LRL, UCSB) (LRL, UCSB) (LRL, UCSB) (JINR)
STETZ CARTER KORENCHE MARUSHEN Also DUNAITSEV AYRES Also Also Also KORENCHE BOOTH	78 76 76B 76 76 78 73 71 67 68 69 69 71	NP B138 285 PRI. 37 1380 JETP 44 35 Translated from ZETF 7 JETPL 23 72 Translated from ZETFP Private Comm. Private Comm. SJNP 16 292 Translated from YAF 16 PR D3 1051 PR 157 1288 PRI. 21 261 Thesis UCRI. 18369 PRI. 23 1267 SJNP 13 189 Translated from YAF 13 PL 328 F23	+ Delker, Dugan, Wu, Caffrey+ (YAL -Carroll, Ortendahl, Perez-Mendez+ + Dizik, Sandaresan+ (CARL, CN Korenchenko, Kostin, Micelmacher+ 1 69. Marushenko, Mezentsev, Petrunin+ 23 80. Shafer -Smirnov + Prokoshkin, Razuvaev+ 524. + Cormack, Greenberg, Kenney+ Ayres, Caldwell, Greenberg, Kenney, Kurz+ Ayres, Cormack, Greenberg- Ayres Greenberg, Ayres, Cormack+ Korenchenko, Kostin, Micelmacher+ 339, + Johnson, Williams, Wormald	LE, COLU, JHUJ (LBL, UCLA) (RC, CHIC, CIT) (JINR) (PNPI) (FNAL) (PNPI) (SERP) (LRL, UCSB) (LRL, UCSB)
STETZ CARTER KORENCHE MARUSHEN Also Also Also Also Also Also Also Also	78 76 76B 76 76 78 73 71 67 68 69 69 71 70	NP B138 285 PRI. 37 1380 JETP 44 35 Translated from ZETF 7 JETPL 23 72 Translated from ZETFP Private Comm. SINP 16 292 Translated from YAF 16 PR 03 1051 PR 157 1288 PR 157 1288 PR 157 1286 PR 152 1287 SINP 13 189 Translated from YAF 13 PL 28 267 SINP 13 189 Translated from YAF 13 PL 32 872 NP B4 189	+ Delker, Dugan, Wu, Caffrey+ (YAI, - Caroli, Ortendah, Perez-Mendez+ + Dixit, Sundaresan+ (CARL, CN Korenchenko, Kostin, Micelmacher+ 1 69. Marushenko, Mezentsev, Petrunin+ 23 80. Shafer Smirnov + Prokoshkin, Razuvaev+ 524. + Yerokankin, Razuvaev+ 524. + Ayers, Candwell, Greenberg, Kenney, Kurz+ Ayres, Candwell, Greenberg- Ayres, Comack, Greenberg- 4 Ayers, Comack, Greenberg- 5 Ayers, Comack+ Korenchenko, Kostin, Micelmacher+ 5 39. 4 Johnson, Williams, Wormald- 4 Duckos, Helntze, Kleinknecht+	LE, COLU, JHUJ (LBL, UCLA) (RC, CHIC, CIT) (PNPI) (FNAL) (PNPI) (SERP) (LRL, UCSB) (LRL, UCSB) (LRL, UCSB) (LRL, UCSB) (LRL, UCSB) (LRL, UCSB) (LRL) (LRL, UCSB) (LRL) (LRL) (LRL, UCSB) (LRL)
STETZ CARTER KORENCHE MARUSHEN Also Also DUNAITSEV AYRES Also Also Also KORENCHE BOOTH DEPOMMIER PETRUKHIN	78 76 76B 76 76 78 73 71 67 68 69 69 71 70 68 68	NP B138 285 PRI. 37 1380 JETP 44 35 Translated from ZETF 7 JETPL 23 72 Translated from ZETFP Private Comm. SINP 16 292 Translated from YAF 16 PR D3 1051 PR 157 1288 PRI. 21 261 Thesis UCRI. 18369 PRI. 23 1267 SINP 13 189 Translated from YAF 13 PL 328 723 NP B4 189 JINR P1 3862	+ Delker, Dugan, Wu, Caffrey+ (YAI - Carroll, Ortenath), Perez-Mendez+ + Dizik, Sandaresan+ (CARL, CN Korenchenko, Kostin, Micelmacher+ 1 69. Marushenko, Mezentsev, Petrunin+ 23 80. Shafer Smirnov + Prokoshkin, Razuvaev+ 524. + Cormack, Greenberg, Kenney+ Ayres, Caldwell, Greenberg, Kenney, Kurz+ Ayres, Cormack, Greenberg- Ayres Greenberg, Ayres, Cormack+ Korenchenko, Kostin, Micelmacher+ 339, + Johnson, Williams, Wormald + Duclos, Heintze, Kleinknecht+ + Hykalin, Khazins, Cisek	LE, COLU, JHUJ (IBL, UCLA) (ICC, CHIC, CIT) (JINR) (PNPI) (FNAL) (PNPI) (SERP) (LRL, UCSB) (LRL, UCSB) (LRL, UCSB) (JINR) (LIVP) (CERN) (JINR) (JINR)
STETZ CARTER KORENCHE MARUSHEN Also Also DUNAITSEV AYRES Also Also Also Also KORENCHE BOOTH BOOTH BOOTH MIER PETRUKHIN NYMAN	78 76 76B 76 778 73 71 67 68 69 69 71 70 68 68 68 67	NP B138 285 PRI. 37 1380 JETP 44 35 Translated from ZETF 7 JETPL 23 72 Translated from ZETFP Private Comm. SINP 16 292 Translated from VAF 16 PR D3 1051 PR 157 1288 PRI. 21 261 Thesis UCRL 18369 PRI. 23 1267 SINP 13 189 Translated from VAF 13 PI 258 723 NP B4 189 JINR PI 3862 JINR PI 3862 JINR PI 3862	+ Delker, Dugan, Wu, Caffrey+ (YAI - Karroll, Ortenath, Perez-Mendez (+ ARL, CN Korenchenko, Kostin, Micelmacher+ 1 69. Marushenko, Mezentsev, Petrunin+ 23 80. Shafer Smirnov + Prokoshkin, Razuvaev+ 524. + Vcormack, Greenberg, Kenney, Kurz+ Ayres, Caldwell, Greenberg, Kenney, Kurz+ Ayres, Candex, Greenberg- Ayres, Commack, Greenberg- Ayres, Commack- Korenchenko, Kostin, Micelmacher+ 399. + Johnson, Williams, Wormald + Duckos, Helnitze, Kleinknecht+ + Rykalin, Khazins, Gisek + Loken, Pewith, McKenzie+ (ANI	LE, COLU, JHUJ (IBL, UCLA) (IRC, CHIC, CIT) (PNPI) (FNAL) (PNPI) (FNAL) (FNAL) (FNAL) (ERL, UCSB) (LRL, UCSB) (LRL
STETZ CARTER KORENCHE MARUSHEN Also Also DUNAITSEV AYRES Also Also Also KORENCHE BOOTH DEPOMMIER PETRUKHIN HYMAN NORDBERG	78 76 76B 76 78 73 71 67 68 69 69 71 70 68 68 67 67	NP B138 285 PRI. 37 1380 JETP 44 35 Translated from ZETF 7 JETPL 23 72 Translated from ZETFP Private Comm. Private Comm. SJNP 16 292 Translated from YAF 16 PR D3 1051 PR 157 1288 PRI. 21 261 Thesis UCRI. 18369 PRI. 23 1267 SJNP 13 189 Translated from YAF 13 PL 326 723 NP B4 189 JINR P1 3862 PL 258 376 PL 248 594	+ Delker, Dugan, Wu, Caffrey+ (YAI - Carroll, Ortenath), Perez-Mendez+ + Dizik, Sundaresan+ (CARL, CN Korenchenko, Kostin, Micelmacher+ 1 69. Marushenko, Mezentsev, Petrunin+ 23 80. Shafer 5mirnov + Prokoshkin, Razuvaev+ 524. + Vcormack, Greenberg, Kenney+ Ayres, Cadwell, Greenberg+ Ayres, Cormack, Greenberg+ Ayres, Cormack, Greenberg+ Ayres Greenberg, Ayres, Cormack+ Korenchenko, Kostin, Micelmacher+ 339. + Johnson, Williams, Wormald + Duclox, Heintze, Kleinknecht+ + Rykalin, Khazins, Cisek + Loken, Pewitt, McKenzie+ + Lokokowicz, Burman	LE, COLU, JHUJ (LBL, UCLA) (RC, CHIC, CIT) (PNPI) (FNAL) (PNPI) (SERP) (LRL, UCSB) (LRL, UCSB) (LRL, UCSB) (LRL, UCSB) (LRL, UCSB) (LINI) (LRL, UCSB) (LINI) (LRL, UCSB) (LINI) (LRL, UCSB) (LRL, UCSB) (LINI) (LRL, UCSB) (LINI) (LRL, UCSB) (LRL, UCSB) (LRL, UCSB) (RCCH) (RCCH)
STETZ CARTER KORENCHE MARUSHEN Also Also DUNAITSEV AYRES Also Also Also KORENCHE BOPPOMMIER PETRUKHIN HYMAN NORDBERG BARDON	78 76 76B 76 78 73 71 668 69 69 71 70 688 687 67 67 667	NP B138 285 PRI. 37 1380 JETP 44 35 Translated from ZETF 7 JETPL 23 72 Translated from ZETFP Private Comm. SJNP 16 292 Translated from VAF 16 PR D3 1051 PR 157 128 PRI. 27 128 PRI. 27 128 PRI. 28 1267 SJNP 13 189 PRI. 29 1267 Translated from VAF 13 PL 258 723 NP B4 189 JINNR PI. 3862 PII. 258 737 PL 258 574 PL 258 575 PL 258 575 PL 258 576 PL 258 576 PL 258 576 PL 258 576	+ Delker, Dugan, Wu, Caffrey+ (YAI - Karroll, Ortenath, Perez-Mendez (- ARL, CN Korenchenko, Kostin, Micelmacher+ 1 69. Marushenko, Mezentsev, Petrunin+ 23 80. Shafer Smirnov + Prokoshkin, Razuvaev+ 524. + Vecomack, Greenberg, Kenney, Kurz+ Ayres, Caldwell, Greenberg, Kenney, Kurz+ Ayres, Candek, Greenberg, Ayres, Commack, Greenberg- Ayres, Commack- Korenchenko, Kostin, Micelmacher+ 399. + Johnson, Williams, Wormald + Duckos, Heintze, Kleinknecht+ + Rykalin, Khazins, Cisek + Loken, Pewit, McKenzle+ + Loken, Pewit, McKenzle+ + Loken, Pewit, McKenzle+	LE, COLU, JHUJ (IBL, UCLA) (IRC, CHIC, CIT) (PNPI) (FNAL) (PNPI) (FNAL) (FNAL) (FNAL) (ERL, UCSB) (LRL, UCSB) (CRN) (COLU) (COLU)
STETZ CARTER KORENCHE MARUSHEN Also Also DUNAITSEV AYRES Also Also Also KORENCHE BOOTH DEPOMMIER PETRUKHIN HYMAN NORDBERG BARDON KINSEY	78 76 76 76 76 76 77 71 67 68 69 69 71 70 68 68 67 67 66 67 66 67 66 67 66 67 66 67 67	NP B138 285 PRI. 37 1380 JETP 44 35 Translated from ZETF 7 JETPL 23 72 Translated from ZETFP Private Comm. SINP 16 292 Translated from YAF 16 PR D3 1051 PR 157 1288 PRI. 21 261 Thesis UCRI. 18369 PRI. 23 1267 SINP 13 189 Translated from YAF 13 PL 226 123 NP B4 189 JINR P1 3862 PL 246 894 PRI. 47 775 PRI. 44 132	+ Delker, Dugan, Wu, Caffrey+ (YAI - Carroll, Ortenath), Perez-Mendez+ + Dizik, Sundaresan+ (CARL, CN Korenchenko, Kostin, Micelmacher+ 1 69. Marushenko, Mezentsev, Petrunin+ 23 80. Shafer Smirnov + Prokoshkin, Razuvaev+ 524. + Veromack, Greenberg, Kenney, Kurz+ Ayres, Cormack, Greenberg, Kenney, Kurz+ Ayres, Cormack, Greenberg, Hongon, Williams, Wormald + Ducloa, Heintze, Kleinknecht+ + Rykalin, Khazins, Cisek + Lokew, Pewitt, McKenzie+ + Lokew, Pewitt, McKenzie+ + Lokew, Pewitt, McKenzie+ + Lokowicz, Burman + Dore, Dorfan, Krieger+ + Lokowicz, Korodberg	LE, COLU, JHUJ (LBL, UCLA) (RC, CHIC, CIT) (PNPI) (FNAL) (PNPI) (FNAL) (FNPI) (LRL, UCSB) (LRL, UCSB) (LRL, UCSB) (LRL, UCSB) (LRL, UCSB) (LINI) (LRL, UCSB) (LINI) (LIVP) (CERN) (CERN) (COLU) (ROCH) (ROCH)
STETZ CARTER KORENCHE MARUSHEN Also Also DUNAITSEV AYRES Also Also Also KORENCHE BOPOMMIER PETRUKHIN HYMAN NORDBERG BARDON KINSEY LOBKOWICZ	78 76 76B 76 78 73 71 668 69 69 71 70 688 687 67 67 667	NP B138 285 PRI. 37 1380 JETP 44 35 Translated from ZETF 7 JETPL 23 72 Translated from ZETFP Private Comm. SJNP 16 292 Translated from VAF 16 PR D3 1051 PR 157 1288 PRI. 21 261 Thesis UCRL 18369 PRI. 23 1267 SJNP 13 189 PRI. 25 127 JINN PI 3 189 JINN PI 3 189 JINN PI 3 189 PI 258 723 NP B4 189 PRI. 25 876 PI 248 594 PRII. 15 775 PR 144 1132 PRII. 17 7548	+ Delker, Dugan, Wu, Caffrey+ (YAI - Karroll, Ortenath, Perez-Mendez (- ARL, CN Korenchenko, Kostin, Micelmacher+ 1 69. Marushenko, Mezentsev, Petrunin+ 23 80. Shafer Smirnov + Prokoshkin, Razuvaev+ 524. + Vecomack, Greenberg, Kenney, Kurz+ Ayres, Caldwell, Greenberg, Kenney, Kurz+ Ayres, Candek, Greenberg, Kenney, Kurz+ Ayres, Comack, Greenberg, Ayres, Comack, Greenberg, Ayres, Comack+ Korenchenko, Kostin, Micelmacher+ 339. + Johnson, Williams, Wormald + Duckos, Helntze, Kleinknecht+ + Rykalin, Khazins, Cisek + Loken, Pewit, McKenzle+ + Lokokowicz, Burman + Dove, Dorfan, Krieger+ + Lokowowicz, Nordberg + Mellissinos, Nigagshima+	LE, COLU, JHUJ (IBL, UCLA) (IRC, CHIC, CIT) (PNPI) (FNAL) (PNPI) (FNAL) (PNPI) (SERP) (LRL, UCSB) (CRU, WWSS) (CCU) (ROCH, GROCH, BNL)
STETZ CARTER KORENCHE MARUSHEN Also Also Also Also Also Also Also Also	78 76 76 76 76 77 71 67 68 69 69 71 70 68 68 67 67 66 66 66 66 66 66	NP B138 285 PRI. 37 1380 JETP 44 35 Translated from ZETF 7 JETPL 23 72 Translated from ZETFP Private Comm. Private Comm. Private Comm. SINP 16 292 Translated from YAF 16 PR 03 1051 PR 157 1289 PRI. 21 261 Thesis UCRL 18369 PRI. 21 267 SINP 13 189 Translated from YAF 13 PL 228 723 NP B4 189 JINR PI 3862 JINR PI 3862 PRI 17 548 PRI 144 1132 PRI 17 548 PRI 1396 407	+ Delker, Dugan, Wu, Caffrey+ (YAI - Carroll, Ortenath), Perez-Mendez+ + Dizik, Sundaresan+ (CARL, CN Korenchenko, Kostin, Micelmacher+ 1 69. Marushenko, Mezentsev, Petrunin+ 23 80. Shafer Smirnov + Prokoshkin, Razuvaev+ 524. + Cormack, Greenberg, Kenney+ Ayres, Caddwell, Greenberg, Kenney, Kurz+ Ayres, Cormack, Greenberg, Kenney, Kurz+ Ayres, Cormack, Greenberg, Kenney, Kurz+ Ayres, Cormack, Greenberg, Hongon, Micelmacher+ 339. + Johnson, Williams, Wormald + Duclos, Heintze, Kleinknecht + Pkylalin, Khazins, Cisek + Loken, Pewitt, McKenzie+ + Lokewicz, Surman + Dore, Dorfan, Krieger+ + Holkowicz, Koroberg + Melissinos, Nagashima+ + Melssinos, Nagashima+ + Melssinos, Nagashima+ + Melssinos, Nagashima+ + Melssinos, Nagashima+	LE, COLU, JHUJ (BL, UCLA) (ICL, CHIC, CIT) (PNPI) (FNAL) (PNPI) (SERP) (LRL, UCSB) (LRL, UCSB) (LRL, UCSB) (LRL, UCSB) (LINR) (LIVP) (LERL) (LIVP) (CERN) (LIVP) (COLU) (ROCH, BNL) (LRL, SLAC)
STETZ CARTER KORENCHE MARUSHEN Also Also DUNAITSEV AYRES Also Also Also Also Also Also Also Also	78 76 76 76 76 77 71 71 67 68 69 69 71 70 68 68 67 67 66 66 66 66 66 66 66 66 66 66 66	NP B138 285 PRI. 37 1380 JETP 44 35 Translated from ZETF 7 JETPL 23 72 Translated from ZETFP Private Comm. Private Comm. SJNP 16 292 Translated from YAF 16 PR D3 1051 PR 157 1288 PRI. 21 261 Thesis UCRI. 18369 PRI. 23 1267 SJNP 13 189 Translated from YAF 13 PL 32B 723 NP B4 189 JINR P1 3862 PL 24B 594 PRI. 16 775 PR 144 1132 PRI. 17 548 PRI. 198 617 PR 1398 617 PR 1398 617 PR 1398 617 JETP 20 58	+ Delker, Dugan, Wu, Caffrey+ (YAI - Carroll, Ortenath, Perez-Mendez+ + Dizik, Sundaresan+ (CARL, CN Korenchenko, Kostin, Micelmacher+ 1 69. Marushenko, Mezentsev, Petrunin+ 23 80. Shafer Smirnov + Prokoshkin, Razuvaev+ 524. + Veromack, Greenberg, Kenney+ Ayres, Cormack, Greenberg, Kenney, Kurz+ Ayres, Cormack, Greenberg, Hongon, Williams, Wormald + Outlook, Heintze, Kleinknecht+ Hyklalin, Khazins, Cisek + Lokew, Pewitt, McKenzie+ + Lokew, Pewitt, McKenzie+ + Lokew, Pewitt, McKenzie+ + Lokowick, Surman + Dore, Dorfan, Krieger+ + Holbkowick, Norodberg + Melissinos, Nagashima+ + Meyer, Carrigan+ + Meyer, Carrigan+ + Metyer, Carrigan+ + Petrukhin, Photososhkin-	LE, COLU, JIHUJ (IBL, UCLA) (ICL, CHIC, CIT) (JINR) (PNPI) (FNAL) (PNPI) (SERP) (LRL, UCSB) (LRL, UCSB) (LRL, UCSB) (LRL, UCSB) (JINR) (CERN) (JINR) (CERN) (COLU) (ROCH) (ROCH, BNL) (LRL, SLAC) (MICH, CMU)
STETZ CARTER KORENCHE MARUSHEN Also Also DUNAITSEV AYRES Also Also Also Also BOOTH DEPOMMIER PETRUKHIN HYMAN NORDBERG BARDON KINSEY LOBKOWICZ BACASTOW BERTRAM DUNAITSEV	78 76 76 76 76 77 77 71 67 68 69 69 71 70 68 68 67 67 66 66 66 66 66 65 65 65	NP B138 285 PRI. 37 1380 JETP 44 35 Translated from ZETF 7 JETPL 23 72 Translated from ZETFP Private Comm. SINP 16 292 Translated from YAF 16 PR D3 1051 PR 157 1288 PRI. 21 261 Thesis UCFIL 18369 PRI. 23 1267 SINP 13 189 Translated from YAF 13 PL 256 272 NP B4 189 PL 256 375 PR 144 1132 PRI. 157 75 PR 144 1132 PRI. 157 75 PR 144 1132 PRI. 157 75 PR 144 1132 PRI. 157 548 PR 1398 407 PR 1398 407 PR 1398 617 JETP 20 58 Translated from ZETF 4	+ Delker, Dugan, Wu, Caffrey+ (YAI, Carroll, Ortenath, Perez-Mendez, + H Laroll, Ortenath, Perez-Mendez, + H Los, Sandaresan+ (CARL, CN Korenchenko, Kostin, Micclamacher+ 1 69. Marushenko, Mezentsev, Petrunin+ 23 80. Shafer Smirnov + Prokoshkin, Razuvaev+ 524. + Prokoshkin, Razuvaev+ 524. + Ayres, Candwell, Greenberg, Kenney, Kurz+ Ayres, Candwell, Greenberg, Kenney, Kurz+ Ayres, Comack, Greenberg- Ayres, Comack, Greenberg- Ayres, Comack, Greenberg- Ayres, Comack, Greenberg- Ayres, Comack- Korenchenko, Kostin, Micclamacher+ 339. + Johnson, Williams, Wormald + Duckos, Helitze, Kleinknecht+ + Rykalin, Khazins, Cisek + Loken, Pewit, McKenzle+ + Loken, Pewit, McKenzle+ + Loken, Pewit, McKenzle+ + Loken, Micris, Krieger+ + Loken, Micris, Krieger+ + Loken, Micris, Krieger+ + Loken, Micris, Krieger+ + Holssinon, Nagashima+ + Ghesquiere, Wiegand, Larsen + Meyer, Carrigan+ + Petrukhin, Prokoshkin+ 7 84.	LE, COLU, JHUJ (IBL, UCLA) (IRC, CHIC, CIT) (PNPI) (PNRI) (PNRI) (FNAL) (PNRI) (SERP) (LRL, UCSB) (LIVP, UCSB) (COLU) (ROCH, GROCH, BNL) (LRL, SLAC) (MICH, CMU) (JINR)
STETZ CARTER KORENCHE MARUSHEN Also Also DUNAITSEV AYRES Also Also Also Also KORENCHE BOOTH DEPOMMIER PETRUKHIN HYMAN NORDBERG BARDON KINSEY LOBKOWICZ BACASTOW BERTRAM DUNAITSEV ECKHAUSE	78 76 76B 76 778 73 71 67 68 69 69 71 70 68 68 68 67 67 66 66 66 65 65 65 65 65	NP B138 285 PRI. 37 1380 JETP 44 35 Translated from ZETF 7 JETPL 23 72 Translated from ZETFP Private Comm. SINP 16 292 Translated from YAF 16 PR D3 1051 PR 157 1288 PRI. 21 261 Thesis UCRI. 18369 PRI. 23 1267 SINP 13 189 Translated from YAF 13 PL 226 123 NP B4 189 JINR P1 3862 PL 246 894 PRI. 47 175 PRI. 47 186 PRI. 47 187 PRI.	+ Delker, Dugan, Wu, Caffrey+ - (CARL, CN	LE, COLU, JHUJ (IBL, UCLA) (ICL, CHIC, CIT) (INR) (PNPI) (FNAL) (PNPI) (SERP) (LRL, UCSB) (LRL, UCSB) (LRL, UCSB) (LRL, UCSB) (LIVP) (CERN) (LIVP) (CERN) (CERN) (COLU) (ROCH, SNLL) (LRL, SLAC) (MICH, CMU) (MICH, CMU) (MICH, CMU) (WILL)
STETZ CARTER KORENCHE MARUSHEN Also Also DUNAITSEV AYRES Also Also Also Also Also Also Also Also	78 76 76B 76 778 73 71 67 68 69 69 71 70 68 68 67 66 66 66 66 65 65 65 65 65	NP B138 285 PRI. 37 1380 JETP 44 35 Translated from ZETF 7 JETPL 23 72 Translated from ZETFP Private Comm. SINP 16 292 Translated from YAF 16 PR D3 1051 PR 157 1288 PRI. 21 261 Thesis UCFIL 18369 PRI. 23 1267 SINP 13 189 Translated from YAF 13 PR 157 1288 PRI. 21 1362 PRI 258 376 PR 148 199 JRI. 157 75 PR 144 1132 PRI. 157 75 PR 144 1132 PRI. 157 548 PR 1398 407 PRI 1398 617 JETP 20 58 Translated from ZETF 4 PL 1348	+ Delker, Dugan, Wu, Caffrey+ - (YAL - Acroll, Ortendahl, Perez-Mendez (+ ACR, CN Korenchenko, Kostin, Micclamacher+ 1 69. Marushenko, Mezentsev, Petrunin+ 23 80. Shafer Smirnov + Prokoshkin, Razuvaev+ 524. + Prokoshkin, Razuvaev+ 524. + Ayres, Candwell, Greenberg, Kenney, Kurz+ Ayres, Candwell, Greenberg, Kenney, Kurz+ Ayres, Comack, Greenberg- Ayres Greenberg, Ayres, Cormack+ Korenchenko, Kostin, Micclamacher+ 339. + Johnson, Williams, Wormald + Duckos, Heintze, Kleinknecht+ + Rykalin, Khazins, Cisek + Loken, Pewit, McKenzle+ + Loken, Pewit, McKenzle+ + Lokowkiz, Burman + Dove, Dorfan, Krieger+ + Lokowkiz, Nordberg + Melissianos, Nagashima+ + Ghesquiere, Wiegand, Larsen + Meyer, Carrigan+ + Petrukhin, Prokoshkin+ 7 84. + Harris, Shuler+	LE, COLU, JHUJ (IBL, UCLA) (IRC, CHIC, CIT) (PNPI) (FNAL) (PNPI) (FNAL) (PNPI) (SERP) (LRL, UCSB) (LIVP) (CERN) (COLU) (ROCH, GNUL) (LRL, SLAC) (MICH, CMU) (WILL) (COLU) (COLU) (COLU) (COLU)
STETZ CARTER KORENCHE MARUSHEN Also Also DUNAITSEV AYRES Also Also Also Also KORENCHE BOOTH DEPOMMIER PETRUKHIN HYMAN NORDBERG BARDON KINSEY LOBKOWICZ BACASTOW BERTRAM DUNAITSEV ECKHAUSE BARTLETT DICAPUA	78 76 76B 76 76 78 73 71 67 68 69 69 71 70 68 667 666 666 665 665 665 664 664	NP B138 285 PRI. 37 1380 JETP 44 35 Translated from ZETF 7 JETPL 23 72 Translated from ZETFP Private Comm. SINP 16 292 Translated from YAF 16 PR D3 1051 PR 157 1288 PRI. 21 261 Thesis UCRI. 18369 PRI. 23 1267 SINP 13 189 Translated from YAF 13 PL 226 723 NP B4 189 JINR P1 3862 PL 246 894 PRI. 47 175 PRI. 47 185 PRI. 47 185 PRI. 48 187 PRI. 48 188 PRI. 48 183 PRI. 48 183 PRI. 48 183	+ Delker, Dugan, Wu, Caffrey+ - (CARL, CN	LE, COLU, JHUJ (BL, UCLA) (ICL, CHIC, CITT) (PNPI) (FNAL) (PNPI) (SERP) (LRL, UCSB) (LRL, UCSB) (LRL, UCSB) (LRL, UCSB) (LINP) (LIVP) (CERN) (LIVP) (CERN) (LIVP) (CERN) (COLU) (ROCH, BNL) (LRL, SLAC) (MICH, CMU) (COLU) (COLU) (COLU) (COLU) (COLU) (COLU)
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$$I^{G}(J^{PC}) = 1^{-}(0^{-+})$$

We have omitted some results that have been superseded by later experiments. The omitted results may be found in our 1988 edition Physics Letters **8204** (1988).

x⁰ MASS

The value is calculated from m_{π^\pm} and $(m_{\pi^\pm}-m_{\pi^0})$. See notes under the π^\pm Mass Listings concerning recent revision of the charged pion mass.

 VALUE (MeV)
 DOCUMENT ID

 134.9764±0.0006 OUR FIT
 ■

$m_{\pi^\pm}-m_{\pi^0}$

Measurements with an error > 0.01 MeV have been omitted.

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
4.5936 ±0.0006 OUR FIT			
4.5936 ±0.0005 OUR AVERAGE			
4.59364±0.00048	CRAWFORD	91 CNTR	$\pi^- p \rightarrow \pi^0 n, n \text{TOF}$
4.5930 ±0.0013	CRAWFORD	86 CNTR	$\pi^- p \rightarrow \pi^0 n$, n TOF
• • • We do not use the following	data for average	s, fits, limits	, etc. • • •
4.59366±0.00048	CRAWFORD	888 CNTR	See CRAWFORD 91
4.6034 ±0.0052	VASILEVSKY	66 CNTR	
4.6056 ±0.0055	CZIRR	63 CNTR	

π⁰ MEAN LIFE

Measurements with an error $> 1 \times 10^{-17}$ s have been omitted.

VALUE (10 ⁻¹⁷ s)	EVTS	DOCUMENT ID			COMMENT
B.4 ±0.6 OUR AVI	ERAGE En	ror includes scale fa	ctor	of 3.0. S	See the Ideogram below.
8.97±0.22±0.17		ATHERTON	85	CNTR	
8.2 ±0.4		¹ BROWMAN	74	CNTR	Primakoff effect
5.6 ±0.6		BELLETTINI	70	CNTR	Primakoff effect
9 ±0.68		KRYSHKIN	70	CNTR	Primakoff effect
• • We do not use	the following	ng data for average	s, fit	s, ilmits,	etc. • • •
8.4 ±0.5 ±0.5	1182	² WILLIAMS	88	CBAL	$e^{+}e^{-} \rightarrow e^{+}e^{-}\pi^{0}$

² WILLIAMS 88 gives $\Gamma(\gamma\gamma) = 7.7 \pm 0.5 \pm 0.5$ eV. We give here $\tau = \hbar/\Gamma(\text{total})$.

WEIGHTED AVERAGE
8.4±0.6 (Error scaled by 3.0)

ATHERTON 85 CNTR 4.4

BROWMAN 74 CNTR 0.2

BELLETTINI 70 CNTR 21.5

KRYSHKIN 70 CNTR 0.8

27.0

(Confidence Level 0.001)

4 6 8 10 12 14

π⁰ mean life (10⁻¹⁷ s)

₹0 DECAY MODES

	Mode 2γ	Fraction (Γ_I/Γ)	Scale factor/ Confidence level	
Γ ₁		(98.798±0.032) %	S=1.1	
Γ_2	e ⁺ e ⁻ γ	(1.198±0.032) %	S=1.1	
Гз	γ positronium	(1.82 ±0.29)×1	.o ^{_9}	
Γ4	e+ e+ e- e-	(3.14 ±0.30) × 1	.o ^{—5}	
Γ ₅	e+ e-	(7.5 ±2.0)×1	.0-8	
Γ6	4γ	< 2 ×1	.0 ⁻⁸ CL=90%	
Γ7	$ u \overline{\nu}$	[a] < 8.3 × 1	.0 ⁻⁷ CL=90%	
Гв	$ u_e \overline{\nu}_e$	< 1.7 × 1	.0 ⁻⁶ CL=90%	
و٦	$ u_{m{\mu}} \overline{ u}_{m{\mu}}$	< 3.1 × 1	.0 ⁻⁶ CL≔90%	
Γ10	$\nu_{\tau} \overline{\nu}_{\tau}$	< 2.1 × 1	0-6 CL=90%	

Charge conjugation (C) or Lepton Family number (LF) violating modes

Г11	3γ	c	< 3.1	× 10 ⁻⁸	CL=90%
Γ12	μ^+e^-				
Γ13	$\mu^{+} e^{-} + e^{-} \mu^{+}$	LF	< 1.72	× 10 ⁻⁸	CL=90%

[a] Astrophysical and cosmological arguments give limits of order 10^{-13} ; see the Particle Listings below.

 π^0

CONSTRAINED FIT INFORMATION

An overall fit to 2 branching ratios uses 4 measurements and one constraint to determine 3 parameters. The overall fit has a χ^2 = 1.9 for 2 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\langle \delta x_i \delta x_j \rangle / (\delta x_i \cdot \delta x_j)$, in percent, from the fit to the branching fractions, $x_i \equiv$ Γ_i/Γ_{total} . The fit constrains the x_i whose labels appear in this array to sum to one.

$$\begin{array}{c|cccc} x_2 & -100 & & \\ x_4 & -1 & 0 & \\ \hline & x_1 & x_2 & & \end{array}$$

x⁰ BRANCHING RATIOS

$\Gamma(e^+e^-\gamma)/\Gamma(2$	γ)				Γ_2/Γ_1
VALUE (%)	EVTS	DOCUMENT ID		COMMENT	
1.213±0.033 OUR	FIT Error in	icludes scale facto	r of 1.1.		
1.213±0.030 OUR	AVERAGE				
1.25 ±0.04		SCHARDT	81 SPEC	$\begin{array}{ccc} \pi^- p \to n \pi^0 \\ \pi^- p \to n \pi^0 \end{array}$	
1.166 ± 0.047	3071	3 SAMIOS	61 HBC	$\pi^- p \rightarrow n \pi^0$	
1.17 ± 0.15	27	BUDAGOV	60 HBC		
• • • We do not a	ise the followi	ng data for averag	es, fits, limi	ts, etc. • • •	
1.196		JOSEPH	60 THE	O QED calculation	n

³SAMIOS 61 value uses a Panofsky ratio = 1.62.

Γ(γ positronium)/	Γ(2γ)	•				Γ ₃ /Γ ₁
VALUE (units 10-9)	EVTS	DOCUMENT ID		TECN	COMMENT	
1.84±0.29	277	AFANASYEV	90	CNTR	pC 70 GeV	
Γ(e ⁺ e ⁺ e ⁻ e ⁻)/i	-(2γ)					Γ_4/Γ_1
VALUE (units 10 ⁻⁵) 3.18±0.30 OUR FIT	EVTS	DOCUMENT ID		TECN		
3.18±0.30	146	4 SAMIOS	62B	нвс		
⁴ SAMIOS 62B val	ue uses a Pa	nofsky ratio = 1.6	2.			

$\Gamma(e^+e^-)/\Gamma_{ m total}$			Г ₅ /Г
VALUE (units 10 ⁻⁸) 7.5±2.0 OUR AVERA	EVTS	DOCUMENT ID TECH	COMMENT
$6.9 \pm 2.3 \pm 0.6$	21	⁵ DESHPANDE 93 SPE	$C K^+ \rightarrow \pi^+ \pi^0$
$8.8^{+4.5}_{-3.2}\pm0.6$	8	⁶ MCFARLAND 93 SPE	C $K_L^0 o 3\pi^0$ in flight

 $^5\,\text{The DESHPANDE 93}$ result with bremsstrahlung radiative corrections is (8.0 \pm 2.6 \pm

0.6) \times 10⁻⁸.
⁶ The MCFARLAND 93 result with radiative corrections and excluding $[m_{ee}/m_{\pi^0}]^2$ < 0.95 is $(7.6^{+3.9}_{-2.8} \pm 0.5) \times 10^{-8}$.

Γ(e ⁺ e ⁻)/Γ((2γ)			Γ ₅ /Γ ₁
VALUE (units 10	7) CL% EVTS	DOCUMENT ID	TECN	COMMENT
• • • We do r	ot use the following d	ata for averages, fits, I	imits, etc	. • • •
<1.3	90	NIEBUHR 89	SPEC	$\pi^- p \rightarrow \pi^0 n$ at rest

<1.3	90		NIEBUHR	89 SPEC	$\pi^- p \rightarrow \pi^0 n$ at re
<5.3	90		ZEPHAT	87 SPEC	$\pi^- p \rightarrow \pi^0 n$
					0.3 GeV/ <i>c</i>
$1.7 \pm 0.6 \pm 0.3$		59	FRANK	83 SPEC	$\pi^- \rho \rightarrow n \pi^0$
1.8 ± 0.6		58	MISCHKE	82 SPEC	See FRANK 83
$2.23 + 2.40 \\ -1.10$	90	8	FISCHER	788 SPRK	$K^+ \rightarrow \pi^+ \pi^0$

$\Gamma(4\gamma)/\Gamma_{tot}$	tal					` Γ ₆ /Γ
VALUE (units 1	0 ⁻⁸) <u>CL%</u>	EVTS	DOCUMENT ID	TECN	COMMENT	
< 2	90		MCDONOUG	188 CBOX	$\pi^- p$ at rest	
• • • We do	o not use the	followin	g data for average	s, fits, limits	, etc. • • •	
<160	90		BOLOTOV	86c CALO		
<440	90	0	AUERBACH	80 CNTR		

 $\Gamma(\nu \overline{\nu})/\Gamma_{total}$ The astrophysical and cosmological limits are many orders of magnitude lower, but we use the best laboratory limit for the Summary Tables

asc the best in	COIBLO	y	i the Jummary 10	DICS.		
VALUE (units 10 ⁻⁶)	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
< 0.83	90		7 ATIYA	91	B787	$K^+ \rightarrow \pi^+ \nu \nu'$
• • • We do not us	e the fo	llowing d	ata for averages, fi	its, li	mits, etc	. • • •
$< 2.9 \times 10^{-7}$			⁸ LAM	91		Cosmological limit
$< 3.2 \times 10^{-7}$			⁹ NATALE	91		SN 1987A
< 6.5	90		DORENBOS	. 88	CHRM	Beam dump, prompt
<24	90	0	7 HERCZEG	81	RVUE	$\kappa^{+}_{+} \rightarrow \pi^{+} \nu \nu'$
-						

 7 This limit applies to all possible u
u' states as well as to other massless, weakly interacting

states. 8 LAM 91 considers the production of right-handed neutrinos produced from the cosmic thermal background at the temperature of about the pion mass through the reaction $\gamma\gamma \to \pi^0 \to \nu\bar{\nu}$. 9 NATALE 91 considers the excess energy-loss rate from SN 1987A if the process $\gamma\gamma \to 0$

 $\pi^0 \to \nu \overline{\nu}$ occurs, permitted if the neutrinos have a right-handed component. As pointed out in LAM 91 (and confirmed by Natale), there is a factor 4 error in the NATALE 91 published result (0.8×10^{-7}) .

<1.7		90				Beam dump, prompt ν
• • • We do r	ot use th	e followi	ing data for average			
<3.1		90	¹⁰ HOFFMAN	88	RVUE	Beam dump, prompt ν
¹⁰ HOFFMAN	l 88 analy	zes data	from a 400-GeV B	BEBC	beam-d	ump experiment.
$\Gamma(u_{\mu}\overline{ u}_{\mu})/\Gamma_{\mathrm{tr}}$	otal					Г9/Г
VALUE (units 10-	6)	CL%	DOCUMENT ID		TECN	COMMENT
<3.1		90				Beam dump, prompt ν
• • • We do r	ot use th	e followi	ing data for average			
<7.8		90	DORENBOS	. 88	CHRM	Beam dump, prompt $ u$
¹¹ HOFFMAN	l 88 analy	zes data	from a 400-GeV B	BEBC	beam-d	ump experiment.
$\Gamma(\nu_{\tau}\overline{\nu}_{\tau})/\Gamma_{tc}$	tal					Γ ₁₀ /Γ
VALUE (units 10	6}	CL%	DOCUMENT ID		TECN	COMMENT Beam dump, prompt ν
<2.1		90	¹² HOFFMAN	88	RVUE	Beam dump, prompt ν
• • • We do i	not use th	e follow	ing data for average	es, fit	s, limits,	etc. • • •
<4.1		90	DORENBOS	. 88	CHRM	Beam dump, prompt ν
12 HOFFMAN	l 88 analy	zes data	from a 400-GeV E	BEBC	beam-d	ump experiment.
Γ(3γ)/Γ _{total} Forbidde	n by <i>C</i> in	variance				Г11/Г
VALUE (units 10	8) CL%	EVTS	DOCUMENT ID		TECN	COMMENT
< 3.1	90		MCDONOUG	H 88	свох	$\pi^- p$ at rest
● ● ● We do i	not use th	e follow	ing data for average	es, fit	s, limits,	etc. • • •
< 38	90	0	HIGHLAND	80	CNTR	
<150	90	0	AUERBACH			
<490	90	0	13 DUCLOS		CNTR	
<490	90		13 KUTIN	65	CNTR	

DOCUMENT ID TECN COMMENT

 Γ_B/Γ

 $\Gamma(\nu_e \overline{\nu}_e)/\Gamma_{\text{total}}$

VALUE (units 10-6)

CL%

 $^{13}\,\text{These}$ experiments give B(3 $\gamma/2\gamma)<~5.0\times10^{-6}.$

$\Gamma(\mu^+e^-)/\Gamma_{\text{total}}$ Forbidden by I	epton family	number conservation			Γ1	2/Г
VALUE (units 10 ⁻⁹)	CL%	DOCUMENT ID	TECN	COMMENT		
• • • We do not us	e the followin	ng data for averages,	fits, limits	, etc. • • •		
<16	90	LEE 9	0 SPEC	$K^+ \rightarrow \pi^+ \mu^+ \epsilon$	-	
<78	90	CAMPAGNARI 8	8 SPEC	See LEE 90		
[c/ + -=\ . c/-	_ +\1/-				_	,-

Forbidden by	μ'/]/ˈtɑ lepton family	ital number conserva	tion.		1 13/1
VALUE (units 10 ⁻⁹)	CL%	DOCUMENT ID		TECN	COMMENT
< 17.2	90	KROLAK	94	E799	In $K_I^0 \rightarrow 3\pi^0$
• • • We do not us	e the followin				
<140		HERCZEG	84	RVUE	$K^+ \rightarrow \pi^+ \mu e$
$< 2 \times 10^{-6}$		HERCZEG			$\mu^- \rightarrow e^-$ conversion
< 70	90	BRYMAN	82	RVUE	$K^+ \rightarrow \pi^+ \mu e$

π^0 ELECTROMAGNETIC FORM FACTOR

The amplitude for the process $\pi^0 \rightarrow e^+ e^- \gamma$ contains a form factor F(x) at the $\pi^0\gamma\gamma$ vertex, where $x=[m_{e^+e^-}/m_{\pi^0}]^2$. The parameter s in the linear expansion F(x)=1+sx is listed below.

All the measurements except that of BEHREND 91 are in the time-like region of momentum transfer.

LINEAR COEFFICIENT OF π^0 ELECTROMAGNETIC FORM FACTOR VALUE EVTS 0.032 ±0.004 OUR AVERAGE DOCUMENT ID TECN COMMENT

+0.026	± 0.024	± 0.048	7548					$\pi^- p \rightarrow \pi^0 n$ at rest
+0.025	± 0.014	± 0.026	54k			92B	SPEC	$\pi^- p \rightarrow \pi^0 n$ at rest
+0.032	6±0.0026	6±0.0026	127	14	BEHREND	91	CELL	$e^+e^- \rightarrow e^+e^-\pi^0$
-0.11	± 0.03	± 0.08	32k		FONVIEILLE	89	SPEC	Radiation corr.
• • • ١	Ve do not	t use the fo	llowing o	lata	for averages, fits	s, lìn	nits, etc.	
0.12	+0.05 -0.04			15	TUPPER	83	THEO	FISCHER 78 data
+0.10	± 0.03		31k	16	FISCHER	78	SPEC	Radiation corr.
+0.01	± 0.11		2200		DEVONS	69	OSPK	No radiation corr.
-0.15	± 0.10		7676		KOBRAK	61	HBC	No radiation corr.
-0.24	± 0.16		3071		SAMIOS	61	HBC	No radiation corr.

14 BEHREND 91 estimates that their systematic error is of the same order of magnitude as their statistical error, and so we have included a systematic error of this magnitude. The value of a is obtained by extrapolation from the region of large space-like momentum transfer assuming vector dominance.

15 TUPPER 83 is a theoretical analysis of FISCHER 78 including 2-photon exchange in the

corrections.

16 The FISCHER 78 error is statistical only. The result without radiation corrections is $+0.05 \pm 0.03$

CL=90%

CL=90%

× 10⁻⁶

× 10-6

₹0 REFERENCES

We have omitted some papers that have been superseded by later experiments. The omitted papers may be found in our 1988 edition Physics Letters **B204** (1988).

KROLAK	94	PL B320 407	+ (EFI, UCLA, COLO, ELMT, FNA	L. ILL. OSAK, RUTG)
DESHPANDE	93	PRL 71 27	+Alliegro, Chaloupka+	(BNL E851 Collab.)
MCFARLAND	93	PRL 71 31	+ (EFI, UCLA, COLO, ELMT, FNA	
FARZANPAY	92	PL B278 413	+ (ORST, TRIU, BRCO, QI	JKI, LBL, BIRM, OXF)
MEIJERDREES	92B	PR D45 1439		SI SINDRUM-I Collab.)
ATIYA	91	PRL 66 2189		L, LANL, PRIN, TRIU)
BEHREND	91	ZPHY C49 401	+Criegee, Field, Franke+	(CELLO Collab.)
CRAWFORD	91	PR D43 46	+Daum, Frosch, Jost, Kettle+	` (VILL, VIRG)
LAM	91	PR D44 3345	+Ng	(AST)
NATALE	91	PL B258 227	. •	(SPIFT)
AFANASYEV	90	PL B236 116	+Chvyrov, Karpukhin+	(JINR, MOSU, SERP)
Also	90B	SJNP 51 664	Afanasyev, Gorchakov, Karpukhin, Ko	marov+ (JINR)
		Translated from YAF 51	1040.	` '
LEE	90	PRL 64 165	+Alliegro, Campagnari+ (BNL, FNAI	., VILL, WASH, YALE)
FONVIEILLE	89	PL B233 65	+Bensayah, Berthot, Bertin+	(CLER, LYON, SACL)
NIEBUHR	89	PR D40 2796	+Eichler, Felawka, Kozlowski+	(SINDRUM Collab.)
CAMPAGNARI	88	PRL 61 2062	+Alliegro, Chaloupka+ (BNL, FNA	NL, PSI, WASH, YALE)
CRAWFORD	88B	PL B213 391	+Daum, Frosch, Jost, Kettle, Marshall-	⊦ (PSI, VIRG)
DORENBOS	88	ZPHY C40 497	Dorenbosch, Allaby, Amaldi, Barbiellin	i+ (CHARM Collab.)
HOFFMAN	88	PL B208 149		(LANL)
MCDONOUGH	88	PR D38 2121	+Highland, McFarlane, Bolton+	(TEMP, LANL, CHIC)
PDG	88	Pl. B204	Yost, Barnett+	(LBL+)
WILLIAMS	88	PR D38 1365	+Antreasyan, Bartels, Besset+	(Crystal Ball Collab.)
ZEPHAT	87	JPG 13 1375	+Playfer, van Doesburg, Bressani+	(OMICRON Collab.)
BOLOTOV	86C	JETPL 43 520	+Gninenko, Dzhilkibaev, Isakov	(INRM)
		Translated from ZETFP		, .
CRAWFORD	86	PRL 56 1043	+Daum, Frosch, Jost, Kettle+	(SIN, VIRG)
ATHERTON	85	PL 158B 81		J, LUND, CURIN, EFI)
HERCZEG	84	PR D29 1954	+Hoffman	(LANL)
FRANK	83	PR D28 423	+Hoffman, Mischke, Moir+	(LANL, ARZS)
TUPPER	83	PR D28 2905	+Grose, Samuel	(OKSU)
BRYMAN	82	PR D26 2538		(TRIU)
MISCHKE	82	PRL 48 1153	+Frank, Hoffman, Moir, Sarracino+	(LANL, ARZS)
HERCZEG	81	PL 100B 347	+Hoffman	(LANL)
SCHARDT	81	PR D23 639	+Frank, Hoffmann, Mischke, Moir+	(ARZS, LANL)
AUERBACH	80	PL 90B 317	+Haik, Highland, McFarlane, Macek+	(TEMP, LASL)
HIGHLAND	80	PRL 44 628	+Auerbach, Halk, McFarlane, Macek+	(TEMP, LASL)
AUERBACH	78	PRL 41 275	+Highland, Johnson+	(TEMP, LASL)
FISCHER	78	PL 73B 359	+Extermann, Guisan, Mermod+	(GEVA, SACL)
FISCHER	78B	PL 73B 364	+Extermann, Guisan, Mermod+	(GEVA, SACL)
BROWMAN	74	PRL 33 1400	+Dewire, Gittelman, Hanson+	(CORN, BING)
BELLETTINI	70	NC 66A 243	+Bemporad, Lubelsmey+	(PISA, BONN)
KRYSHKIN	70	JETP 30 1037	+Sterligov, Usov	(TMSK)
DEVONE	"	Translated from ZETF 5		(60111 00141)
DEVONS	69	PR 184 1356	+Nemethy, Nissim-Sabat, Capua+	(COLU, ROMA)
VASILEVSKY DUCLOS	66	PL 23 281	+Vishnyakov, Dunaitsev+	(JINR)
	65	PL 19 253	+Freytag, Heintze+	(CERN, HEID)
KUTIN	65	JETPL 2 243	+Petrukhin, Prokoshkin	(JINR)
CZIDD	40	Translated from unknow	m journal.	(18)
CZIRR SAMIOS	63 62B	PR 130 341 PR 126 1844	(Diana - Dec dell)	(LRL)
			+Plano, Prodell+	(COLU, BNL)
KOBRAK	61	NC 20 1115		(EFI)
SAMIOS BUDAGOV	61 60	PR 121 275 JETP 11 755	Without Debalance Familia	(COLU, BNL)
DUDAUUV	OU	Translated from ZETF 3	+Viktor, Dzhelepov, Ermolov+	(JINR)
JOSEPH	60	NC 16 997	N 4071.	(EFI)
				(=1.1)

$\overline{\eta}$

$$I^{G}(J^{PC}) = 0^{+}(0^{-})$$

We have omitted some results that have been superseded by later experiments. The omitted results may be found in our 1988 edition Physics Letters **B204** (1988).

η MASS

We no longer use the bubble-chamber measurements from the 1960's. which seem to have been systematically high by about 1 MeV. Some early results have been omitted altogether.

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT	_
547.30±0.12 OUR	AVERAGE					
$547.12 \pm 0.06 \pm 0.25$		KRUSCHE	95D	SPEC	$\gamma p \rightarrow \eta p$, threshold	
547.30±0.15		PLOUIN	92	SPEC	$dp \rightarrow \eta^3 He$	
547.45 ± 0.25		DUANE	74	SPEC	$\pi^- p \rightarrow n$ neutrals	
• • • We do not us	e the followin	g data for averag	es, fits	, limits	, etc. • • •	
548.2 ±0.65		FOSTER	65C	HBC		
549.0 ±0.7	148	FOELSCHE	64	HBC		
548.0 ±1.0	91	ALFF	62	HBC		
549.0 ±1.2	53	BASTIEN	62	HBC		

7 WIDTH

This is the partial decay rate $\Gamma(\eta \to \gamma \gamma)$ divided by the fitted branching fraction for that mode. See the "Note on the Decay Width $\Gamma(\eta \to \gamma \gamma)$ " in our 1994 edition, Phys. Rev. **D50**, 1 August 1994, Part I, p. 1451.

VALUE (keV)	_			_	DOCU	MENT I	D	
1.18 ± 0.11	OUR	FIT	Error	includes	scale	factor	of	1.8.

7 DECAY MODES

	Mode	Fraction (Γ_f/Γ)	Scale factor/ Confidence level						
		Neutral modes							
Г	neutral modes	(71.5 ±0.6)	% 5=1.4						
Γ_2	2γ	[a] (39.21±0.34)	% S=1.4						
Γ_3	$3\pi^0$	(32.2 ±0.4)							
Γ_4	$\pi^0 2\gamma$	(7.1 ±1.4)	× 10 ⁻⁴						
Γ ₅	other neutral modes	< 2.8	% CL=90%						
		Charged modes							
Γ ₆	charged modes	(28.5 ±0.6)	% S=1.4						
Γ7	$\pi^+\pi^-\pi^0$	(23.1 ±0.5)	% S=1.4						
Γ8	$\pi^+\pi^-\gamma$	(4.77±0.13)	% S=1.3						
Г9	e ⁺ e ⁻ γ	(4.9 ± 1.1)	× 10 ⁻³						
Γ ₁₀	$\mu^+\mu^-\gamma$	(3.1 ±0.4)	× 10 ⁻⁴						
Γ_{11}	e+e−	< 7.7	$\times 10^{-5}$ CL=90%						
Γ ₁₂	$\mu^+\mu^-$	(5.8 ±0.8)	× 10 ⁻⁶						
Γ ₁₃	$\pi^{+}\pi^{-}e^{+}e^{-}$	$(1.3 \begin{array}{c} +1.2 \\ -0.8 \end{array})$	× 10 ⁻³						
Γ ₁₄	$\pi^+\pi^-2\gamma$	< 2.1	× 10 ⁻³						
Γ ₁₅	$\pi^+\pi^-\pi^0\gamma$	< 6	× 10 ⁻⁴ CL=90%						
Γ ₁₆	$\pi^0\mu^+\mu^-\gamma$	< 3	× 10 ⁻⁶ CL=90%						
	Charge conjugation (C), Parity (P), Charge conjugation \times Parity (CP), or								
		number (<i>LF</i>) violating mo	des						
Γ ₁₇	$\pi^+\pi^-$	P.CP < 9	× 10 ⁻⁴ CL=90%						
Γ ₁₈	3γ	C < 5	× 10 ⁻⁴ CL=95%						
Γ19	$\pi^{0}e^{+}e^{-}$	C [b] < 4	× 10 ^{-\$} CL=90%						
۲,	_0+		10-6 61 000/						

[a] See the "Note on the Decay Width $\Gamma(\eta \to \gamma \gamma)$ " in our 1994 edition, Phys. Rev. **D50**, 1 August 1994, Part I, p. 1451.

С

LF

[b] < 5

[b] C parity forbids this to occur as a single-photon process.

 $\Gamma_{20} = \pi^0 \mu^+ \mu^-$

 Γ_{21} $\mu^{+}e^{-} + \mu^{-}e^{+}$

CONSTRAINED FIT INFORMATION

An overall fit to a decay rate and 15 branching ratios uses 40 measurements and one constraint to determine 9 parameters. The overall fit has a $\chi^2 = 31.0$ for 32 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\langle \delta x_i \delta x_j \rangle / (\delta x_i \cdot \delta x_j)$, in percent, from the fit to the branching fractions, $x_i \equiv$ $\Gamma_i/\Gamma_{\text{total}}$. The fit constrains the x_i whose labels appear in this array to sum to

	Mode	Rate (keV)	Scale factor
Γ ₂	2γ	[a] 0.46 ±0.04	1.8
Гз	$3\pi^{0}$	0.381 ±0.035	1,8
Γ ₃ Γ ₄	$\pi^0 2\gamma$	$(8.4 \pm 1.9) \times 10^{-4}$	1.1
Γ7	$\pi^+\pi^-\pi^0$	0.274 ±0.026	1.8
Г	$\pi^+\pi^-\gamma$	0.057 ±0.005	1.7
و٦	e+e-γ	0.0058 ± 0.0014	
Γ10	$\mu^+\mu^-\gamma$	$(3.7 \pm 0.6) \times 10^{-4}$	1.1
Γ_{13}	$\pi^{+}\pi^{-}e^{+}e^{-}$	$0.0015 ^{+0.0015}_{-0.0009}$	

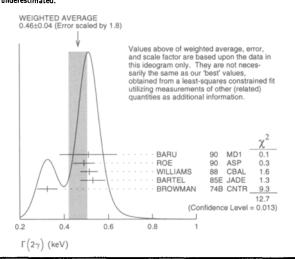
Γ(neutral modes)/Γ_{total}

7 DECAY RATES

	2
See the table immediately above giving the fitted decay rates. See also the "Note of	on
the Decay Width $\Gamma(\eta \to \gamma \gamma)$," in our 1994 edition, Phys. Rev. D50 , 1 August 199	4,
Part I, p. 1451.	

VALUE (keV)	EVTS	DOCUMENT ID	TECN	COMMENT
0.46 ±0.04 OUR FIT	Error In	cludes scale factor	of 1.8,	
0.46 ±0.04 OUR AVE	RAGE	Error includes scale	factor of 1.8	3. See the ideogram below.
$0.51 \pm 0.12 \pm 0.05$	36	BARU	90 MD1	$e^+e^- \rightarrow e^+e^-\eta$
$0.490 \pm 0.010 \pm 0.048$	2287	ROE	90 ASP	$e^+e^- \rightarrow e^+e^-\eta$
$0.514 \pm 0.017 \pm 0.035$	1295	WILLIAMS	88 CBAL	$e^+e^- \rightarrow e^+e^-\eta$
$0.53 \pm 0.04 \pm 0.04$		BARTEL	85E JADE	$e^+e^- \rightarrow e^+e^-\eta$
0.324 ± 0.046		BROWMAN	74B CNTR	Primakoff effect
• • • We do not use th	e followir	ng data for average	s, fits, limits	, etc. • • •
$0.64 \pm 0.14 \pm 0.13$		AIHARA	86 TPC	$e^+e^- \rightarrow e^+e^-\eta$
0.56 ±0.16	56	WEINSTEIN	83 CBAL	$e^+e^- \rightarrow e^+e^-\eta$
1.00 ±0.22		¹ BEMPORAD	67 CNTR	Primakoff effect
0.56 ±0.16	56	WEINSTEIN	83 CBAL	$e^+e^- \rightarrow e^+e^-\eta$

 $^{1}\,\text{BEMPORAD}$ 67 gives $\Gamma(2\gamma)\,=\,1.21\,\pm\,0.26$ keV assuming $\Gamma(2\gamma)/\Gamma(\text{total})\,=\,0.314.$ Bemporad private communication gives $\Gamma(2\gamma)^2/\Gamma(\text{total}) = 0.318$. Bemporad private communication gives $\Gamma(2\gamma)^2/\Gamma(\text{total}) = 0.380 \pm 0.01$. Not included in average because the uncertainty resulting from the separation of the coulomb and nuclear amplitudes has apparently been underestimated.



η BRANCHING RATIOS

- Neutral modes

 $\Gamma_1/\Gamma = (\Gamma_2 + \Gamma_3 + \Gamma_4)/\Gamma$

1.61±0.39

BAGLIN FOSTER

. (7/ (. 2 3 4)/.
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.715±0.006 OUR FIT	Error in	cludes scale factor	of 1.	4.	
0.705±0.008	16k	BASILE	71D	CNTR	MM spectrometer
• • • We do not use the	he followir	ng data for average:	s, fits	, limits,	etc. • • •
0.79 ±0.08		BUNIATOV	67	OSPK	
$\Gamma(2\gamma)/\Gamma_{\text{total}}$					Γ ₂ /Γ
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.3921 ± 0.0034 OUR F					
0.3949±0.0017±0.003	0 65k	ABEGG	96	SPEC	$pd \rightarrow {}^{3}He\eta$
$\Gamma(2\gamma)/\Gamma({ m neutral\ mod})$					$/\Gamma_1 = \Gamma_2/(\Gamma_2 + \Gamma_3 + \Gamma_4)$
VALUE 0.5485±0.0022 OUR F					COMMENT
		includes scale fact	or or	1.1.	
0.549 ±0.004 OUR A	VERAGE				
0.549 ±0.004		ALDE			
0.535 ±0.018		BUTTRAM			
0.59 ±0.033		BUNIATOV		OSPK	
• • We do not use the	he followir	ng data for average:	s, fits	, ilmits,	etc. • • •
0.52 ±0.09	88	ABROSIMOV	80	HLBC	
0.60 ±0.14	113	KENDALL	74	OSPK	
0.57 ±0.09		STRUGALSKI	71	HLBC	
0.579 ±0.052		FELDMAN	67	OSPK	
0.416 ±0.044		DIGIUGNO	66	CNTR	Error doubled
0.44 ±0.07		GRUNHAUS			
0.39 ±0.06		2 IONES			

² This result from	n combining cross	s sections from	two different	experiments.
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$\Gamma(3\pi^0)/\Gamma(\text{neutral modes})$)		Γ3/	$\Gamma_1 = \Gamma_3/(\Gamma_2 + \Gamma_3 + \Gamma_4)$
VALUE EVT.	S DOCUMENT ID			COMMENT
	Error Includes scale fact	tor of	1.1.	
0.450 ±0.004 OUR AVERA		0.4	CA142	
0.450 ±0.004	ALDE		GAM2	
0.439 ±0.024	BUTTRAM		OSPK	
• • We do not use the foli	•			etc. • • •
0.44 ±0.08 75				
0.32 ±0.09	STRUGALSKI			
0.41 ±0.033	BUNIATOV	67	OSPK	Not indep. of $\Gamma(2\gamma)$
				Γ(neutral modes)
0.177 ±0.035	FELDMAN		OSPK	
0.209 ±0.054	DIGIUGNO			Error doubled
0.29 ±0.10	GRUNHAUS	66	OSPK	
$\Gamma(3\pi^0)/\Gamma(2\gamma)$				Γ ₃ /Γ ₂
VALUE	DOCUMENT ID		TECH	
	or includes scale factor			COMMENT
0.833±0.012 OUR AVERAGE		· ·	•••	
0.832±0.005±0.012	KRUSCHE	95D	SPEC	$\gamma p \rightarrow \eta p$, threshold
0.841 ± 0.034	AMSLER			$\overline{p}p \rightarrow \pi^{+}\pi^{-}\eta$ at rest
• • • We do not use the foll				
	3 ALDE			.
0.822±0.009	COX		GAM2	
0.91 ±0.14 0.75 ±0.09	DEVONS		HBC OSPK	
0.88 ±0.16	BALTAY		DBC	
1.1 ±0.2	CENCE		OSPK	
1.25 ±0.39	BACCI			Inverse BR reported
_				•
³ This result is not independent from the fit and average.		resul	ts in this	s Listing, and so is omitted
nom the nt and average.				
$\Gamma(\pi^0 2\gamma)/\Gamma(\text{neutral mode})$	es)		ΓA	$/\Gamma_1 = \Gamma_4/(\Gamma_2 + \Gamma_3 + \Gamma_4)$
VALUE	DOCUMENT ID		TECN	- 4/(- 4/ 4/
(1.00 ±0.20)×10 ⁻³	OUR FIT			
0.0010 ±0.0002	ALDE	84	GAM2	
0.0010 10.0001	ALUE	04	GAIVIZ	
$\Gamma(\pi^0 2\gamma)/\Gamma_{\text{total}}$				Γ4/Γ
These results are sumn	narized in the review b	v LAN	IDSBER	
VALUE (units 10-4) CL% EVT				COMMENT
7.1±1.4 OUR FIT				
• • • We do not use the foll	lowing data for average	s. fits	. Ilmits.	etc. • • •
	O BINON	82		See ALDE 84
	0 DAVYDOV	81		$\pi^- p \rightarrow \eta \pi$
(30)0	U DAVIDOV	01	UAWI2	$\kappa p \rightarrow \ \eta n$
$\Gamma(\text{neutral modes})/[\Gamma(\pi^+$	· = - =0) + [(=+=-	~) 4	· r/e+	e= ~\]
(REMAINED HISBURS / (文)	/		. (-	- /4
· (ucertel linnes)\ [i (%,	Γ ₁ /(Γ ₂ +Γ ₀ 4	רב). ינים	= (Гэ∔	-[2+[4]/([2+[4+[4]
	Γ ₁ /(Γ ₇ +Γ ₈ +	(و۲-		-「3+「4)/(「7+「8+「9)
VALUE EVT	Γ ₁ /(Γ ₇ +Γ ₈ +	-Γ ₉)	= (Г ₂ + <u>теси</u>	-「3+「4)/(「7+「8+「9)
VALUE EVT	Γ ₁ /(Γ ₇ +Γ ₈ +	-Γ 9) f 1.5.		-Г3+Г4)/(Г7+Г8+Г9)
<u>VALUE</u> <u>EVT</u> 2.52±0.08 OUR FIT Error 2.64±0.23	F1/(F7+F8+ S <u>DOCUMENT ID</u> Includes scale factor of BALTAY	- Γ9) f 1.5. 67Β	TECN DBC	
<u>VALUE</u> <u>EVT</u> 2.52±0.08 OUR FIT Error 2.64±0.23 • • • We do not use the foll	F1/(F7+F8+ S <u>DOCUMENT ID</u> Includes scale factor of BALTAY Iowing data for average	- Γ 9) f 1.5. 67Β es, fits	TECN DBC i, limits,	
<u>VALUE</u> <u>EVT</u> 2.52±0.08 OUR FIT Error 2.64±0.23 • • • We do not use the foll 4.5 ±1.0 28	F1/(\(\Gamma\)7+\(\Gamma\)8 \[\text{DOCUMENT ID} \\ \text{Includes scale factor of BALTAY} \\ \text{lowing data for average} \\ \text{10} \] \[\text{4 JAMES} \]	f 1.5. 67B es, fits	TECN DBC i, limits, HBC	
<u>VALUE</u> <u>EVT</u> 2.52±0.08 OUR FIT Error 2.64±0.23 • • • We do not use the foll 4.5 ±1.0 28 3.20±1.26 5	F1/(F7+F8+ S <u>DOCUMENT ID</u> Includes scale factor of BALTAY Iowing data for average	f 1.5. 67Β es, fits 66 62	DBC i, limits, HBC HBC	
<u>VALUE</u> <u>EVT</u> 2.52 ± 0.08 OUR FIT Error 2.64 ± 0.23 • • • We do not use the foll 4.5 ± 1.0 28 3.20 ± 1.26 5 2.5 ± 1.0 1	F1/(F7+F8+ POCUMENT ID. Includes scale factor of BALTAY Iowing data for average A JAMES A BASTIEN PICKUP	f 1.5. 67Bes, fits 66 62 62	DBC i, limits, HBC HBC HBC	etc. • • •
VALUE 2.52 ± 0.08 OUR FIT 2.64 ± 0.23 • • • We do not use the foll 4.5 ± 1.0 2.02 ± 1.26 2.5 ± 1.0 4 These experiments are in	F1/([7+F8+] DOCUMENT ID Includes scale factor of BALTAY Iowing data for average 4 JAMES 4 BASTIEN 0 PICKUP out used in the average	f 1.5. 67Bes, filts 66 62 62 es as	DBC i, limits, HBC HBC HBC they do	etc. $ullet$ $ullet$ o $ullet$ not separate clearly η $ ightarrow$
VALUE EFVT 2.52 ±0.08 OUR FIT Error 2.64 ±0.23 • • • We do not use the foll 4.5 ±1.0 3.20 ±1.26 2.5 ±1.0 4 These experiments are $n + \pi - \pi^0$ and $η → \pi^-$	F1/([7+F8+] DOCUMENT ID Includes scale factor of BALTAY lowing data for average 4 JAMES 4 BASTIEN 0 PICKUP not used in the average + \(\pi^-\gamma\) from each oth	f 1.5. 67Bes, fits 66 62 62 es as er. T	DBC i, limits, HBC HBC HBC they do	etc. • • •
VALUEEVT2.52 \pm 0.08 OUR FITError2.64 \pm 0.23• • • We do not use the foll4.5 \pm 1.0283.20 \pm 1.2652.5 \pm 1.0114 These experiments are negative $\pi^+\pi^-\pi^0$ and $\eta \to \pi^-$ contain some unknown fr	$\Gamma_1/(\Gamma_7+\Gamma_8+\Gamma_0COMENT ID)$ Includes scale factor of BALTAY lowing data for average 0.4 JAMES 3.4 BASTIEN 0.4 PICKUP lot used in the average 1.4	f 1.5. 67Bes, fits 66 62 62 es as er. T	DBC i, limits, HBC HBC HBC they do	etc. $ullet$ $ullet$ o $ullet$ not separate clearly η $ ightarrow$
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2.52 ± 0.08 OUR FIT Error 2.64 ± 0.23 • • • We do not use the foll 4.5 ± 1.0 28 3.20 ± 1.26 5 2.5 ± 1.0 11 4 These experiments are $n_{\pi^+\pi^-\pi^0}$ and $η \to π^-$ contain some unknown fr (2γ)/[$\Gamma(\pi^+\pi^-\pi^0)$ + Γ VALUE EVT 1.38 ± 0.04 OUR FIT Error 1.1 ± 0.4 OUR AVERAGE 1.51 ± 0.93 7.0.99 ± 0.48	Γ ₁ /(Γ ₇ +Γ ₈ + DOCUMENT ID. Includes scale factor of BALTAY lowing data for average of JAMES 3 4 BASTIEN 4 PICKUP of used in the average $+\pi^-\gamma$ from each oth faction of $\eta \to \pi^+\pi^-$ Γ($\pi^+\pi^-\gamma$) + Γ(e^+ 5 DOCUMENT ID. includes scale factor of SENDALL CRAWFORD 3 CRAWFORD 4 CRAWFORD 4 CRAWFORD 4 CRAWFORD 5 DOCUMENT ID. 10 SBLOODWO 4 LATTE AGUILAR 5 BLOODWO 4 FLATTE ALFF 6 KRAEMER PAULI Illshed value 0.5 by Blo	f 1.5. 678 ess, fits 66 62 62 ess as er. 7 7 f 1.5. 74 63 71 f 1.4. 74 728 66 64 64 64 64 64	TECN DBC i, limits, HBC HBC HBC they do he repc OSPK HBC OSPK HBC OSPK HBC HBC DBC DBC DBC DBC DBC DBC DBC DBC DBC D	etc. • • • not separate clearly $\eta \to 0$ where $\eta = 0$
VALUE 2.52 ±0.08 OUR FIT Error 2.64 ±0.23 • • • We do not use the foll 4.5 ±1.0 28 3.20 ±1.26 5.5 ±1.0 11 4 These experiments are $n + \pi - \pi^0$ and $\eta \to \pi^-$ contain some unknown fr $\Gamma(2\gamma)/[\Gamma(\pi^+\pi^-\pi^0) + \Gamma V_{AUE}]$ VALUE 1.38 ±0.04 OUR FIT Error 1.1 ±0.4 OUR AVERAGE 1.51 ±0.93 0.99 ±0.48 $\Gamma(\text{neutral modes})/\Gamma(\pi^+\pi^+\pi^-\pi^0)$ 3.09 ±0.10 OUR FIT Error 3.26 ±0.30 OUR AVERAGE 2.54 ±1.89 3.4 ±1.1 2.83 ±0.80 3.6 ±0.6 2.89 ±0.56 3.6 ±0.6 3.8 ±1.1 5 Error increased from public increased increas	$\Gamma_1/(\Gamma_7 + \Gamma_8 + \frac{1}{DOCUMENT ID})$ Includes scale factor of BALTAY lowing data for average 0 4 JAMES 0 4 PICKUP of used in the average 0 7 0 4 PICKUP of used in the average 0 7 0 4 PICKUP of used in the average 0 7 0 7 0 7 0 9 PICKUP of used in the average 0 7 0 9 PICKUP of used in the average 0 9 PICKUP of used in the average 0 9 PICKUP of 0 9 PICKUP of 0 9 PICKUP includes scale factor of 0 9 PICKUP Includes scale factor of 0 9 PICKUP OF 0 9 PIC	F 1.5. 678 es, fits 66 62 62 es as er. 1 7. 67 74 63 74 63 74 728 666 64 64 64 64 64 65 95	TECN DBC i, limits, HBC HBC HBC they do he repc OSPK HBC OSPK HBC OSPK HBC HBC DBC DBC DBC DBC DBC DBC DBC DBC DBC D	etc. • • • not separate clearly $\eta \to 0$ where $\eta = 0$

69 HLBC 65 HBC

)) 5000	DOCUMENT (_	TECH CO		Γ_3/Γ_7	٠, ,	$/\Gamma(\pi^+\pi^-\pi^0)$					Γ_{15}/Γ_{7}
	_ <i>EVTS</i> Error includ	DOCUMENT ID des scale factor of		ECN COMM	WENT.		VALUE (units 10 ⁻²)		DOCUMENT ID		ECN		
34±0.10 OUK AVER		r includes scale fa		1.2.			<0.24	90 0	THALER		SPK		
.44±0.09±0.10	1627	AMSLER	95 C	BAR Pp -	$\rightarrow \pi^{+}\pi^{-}\eta$	at rest		t use the following	g data for averag	es, fits, I	imits, e	stc. • • •	
.50+0.15 -0.29	199	BAGLIN	69 H	II BC			<1.7	90	ARNOLD	68 H			
	•,,,	DATE		LDC			<1.6	95	BALTAY	67B D			
.47 ^{+0.20} -0.17		BULLOCK	68 H	ILBC			<7.0		FLATTE	67 H			
.3 ±0.4		BAGLIN	678 H	łLBC			<0.9		PRICE	67 H	IBC		
.90±0.24		FOSTER		IBC			$\Gamma(\pi^0\mu^+\mu^-\gamma)$	/Γ					F /
.0 ±1.0		FOELSCHE	64 H					-					Γ ₁₆ /Ι
0.83±0.32		CRAWFORD	63 H	IBC			VALUE (units 10-6)	CL%	DOCUMENT ID	<u>T</u>	ECN	COMMENT	
-/						_ ,_	<3	90	DZHELYADIN	∛ 81 S	PEC	$\pi^- p \rightarrow \eta n$	
(other neutral mode	es)/F _{total}					Γ ₅ /Γ		p,	ere or forbidder				
These are neutral	modes oth	her than $\gamma\gamma$, $3\pi^{0}$.	, and π	^U γγ; nearly	any such m	ode one		rva	we or iorbiduei	moue	5		
can think of woul			_				$\Gamma(\pi^+\pi^-)/\Gamma_{tx}$	d-si					Γ17/
ALUE	<u>CL%</u> _	DOCUMENT ID		ECN COMA				by Pand CP Inva	ariance.				217
<0.028	90	ABEGG	96 5	PEC pd -	→ Heη		VALUE (units 10-4)	CL% EVTS	DOCUMENT ID	T	ECN	COMMENT	
		- Charged mod	jes —				< 9	90	AKHMETSHI	N 97c C	MD2	$e^+e^- \rightarrow \pi^+$	π-γ.
	•						• •					0.99-1.04 Ge	
$\Gamma(\pi^+\pi^-\gamma)/\Gamma(\pi^+\pi^-\gamma)$	~ ≖⁰)					Γ ₈ /Γ ₇	• • • We do no	t use the following	g data for averag	es, fits, i	limits, e	etc. • • •	
ALUE	EVTS	DOCUMENT ID		TECN_			<15	0	THALER	73 A	SPK		
0.207±0.004 OUR FIT							-4- > 4-4						
0.207±0.004 OUR AVE		rror includes scale					$\Gamma(3\gamma)/\Gamma(\text{neut}$				18/	$\Gamma_1 = \Gamma_{18}/(\Gamma_2 +$	-13+14
0.209±0.004	18k	THALER	73 A					by C invariance.					
).201±0.006 • • • We do not use ti	7250 he following	GORMLEY	70 A s fits l				VALUE (units 10 ⁻⁴		DOCUMENT ID		ECN		
	" which	_			- 		<7	95	ALDE	84 G	AM2		
0.28 ±0.04		BALTAY	67B C				r/_0 _4> ·	c(_+ n\					
0.25 ±0.035 0.30 ±0.06		LITCHFIELD CRAWFORD	67 D				$\Gamma(\pi^0 e^+ e^-)$						Γ ₁₉ /Γ
).30 ±0.06).196±0.041		FOSTER	65C H					orbids this to occu					
.190 10.041		TOSTER	030 1	ibc.			VALUE (units 10-4		DOCUMENT ID		ECN		
$\Gamma(e^+e^-\gamma)/\Gamma(\pi^+\pi^-)$	− π 0)					Γ ₉ /Γ ₇	< 1.9	90	JANE	75 C			
ALUE (units 10 ⁻²)	EVTS	DOCUMENT ID	7	TECN COMI		•, •		t use the following	g data for averag	es, fits, i	limits,	etc. • • •	
2.1±0.5 OUR FIT		DOCUMENT ID	— <i>'</i>	ECN COMM	MEN I		< 42	90	BAGLIN	67 H	ILBC		
2.1±0.5	80	JANE	758 C	OSPK See t	the erratum		< 16	90 0	BILLING	67 H			
	••						< 77	0	FOSTER	65B H			
$(\mu^+\mu^-\gamma)/\Gamma_{\text{total}}$						Γ_{10}/Γ	<110		PRICE	65 H	łBC		
ALUE (units 10 ⁻⁴)	EVT5	DOCUMENT ID	7	TECN COM	MENT		r/_0 _+\ /	_					- /
1.1±0.4 OUR FIT		<u> </u>	— ÷				Γ(π ⁰ e ⁺ e ⁻)/						Γ ₁₉ /
3.1±0.4	600	DZHELYADIN	1 80 5	PEC # n)> n#			orbids this to occu					
• • We do not use ti							VALUE (units 10 ⁻²	CL% EVTS	DOCUMENT ID	7	ECN		
1.5±0.75	100	BUSHNIN			DZHELYADI	N 80	■ ■ ■ We do no	t use the followin	g data for averag	es, fits, i	limits,	etc. • • •	
1.5±0.75	100	BOSHIN	10 3	FEC Sec I	DZNELIAUI	14 60	< 0.016	90 0	MARTYNOV	76 H	ILBC		
Γ(e ⁺ e ⁻)/Γ _{total}						Γ_{11}/Γ	< 0.084	90	BAZIN	68 D	BC		
VALUE (units 10 ⁻⁴)	CL%	DOCUMENT ID	7	TECN COM	MENT		<0.7		RITTENBER	G 65 H	IBC		
<0.77	90	BROWDER			_ ≃ 10.5 G	201/	F/ 0 ±\	·-					
• • • We do not use to						iev 1	$\Gamma(\pi^0\mu^+\mu^-)$!!				Γ ₂₀ /
		-		-	_			orbids this to occu					
<2	90	WHITE DAVIES		SPEC pd – RVUE Uses			VALUE (units 10-4		DOCUMENT ID			COMMENT	
	90	DAVIES	/4 P	TACE OPER	E3 EN 0/		<0.06	90	DZHELYADI				
<3						- 1-	● ● ● We do no	ot use the following	g data for averag	es, fits, i	limits,	etc. • • •	
<3						[13/]							
$<$ 3 $\Gamma(\mu^+\mu^-)/\Gamma_{ ext{total}}$	FIOTE	DOCUMENT ID		TECH COM	MENT	Γ ₁₂ /Γ	<5		WEHMANN	68 C	SPK		
<3 $\Gamma(\mu^+\mu^-)/\Gamma_{\text{total}}$ VALUE (units 10^{-6}) CL%		DOCUMENT ID	1	TECN COM	MENT	12/1	<5	m4 131 m		68 C	SPK		
<3 Γ(μ ⁺ μ ⁻)/Γ _{total} <u>VALUE (units 10⁻⁶)</u> <u>CL%</u> 5.8±0.8 OUR AVE	RAGE				_	12/1	<5 [Γ(μ ⁺ e ⁻) +	Γ(μ ⁻ e ⁺)]/Γ _{to}	ital		OSPK		Γ ₂₁ /
<3 $\Gamma(\mu^{+}\mu^{-})/\Gamma_{\text{total}}$ VALUE (units 10^{-6}) CL % 5.8 ± 0.8 OUR AVE 5.7 ± 0.7 ± 0.5	RAGE 114	ABEGG	94 5	SPEC pd -	→ η ³ He	112/1	<5 $[\Gamma(\mu^+e^-) + Forbiden!]$	Γ (μ[—] e⁺)]/Γ_{to} by lepton family n	ital		DSPK		Γ ₂₁ /
<3 $\Gamma(\mu^+\mu^-)/\Gamma_{\text{total}}$ **Example 1.5 (a) **Example 2.5 (b) **Example 2.5 (c)	114 27	ABEGG DZHELYADIN	94 S	SPEC pd -	→ η ³ He > → ηπ	112/1	<5 [Γ(μ ⁺ e ⁻) +	Γ(μ [—] e ⁺)]/Γ _{to} by lepton family n	ital	on. <u>7</u>	ECN	COMMENT	Γ ₂₁ /
<3 (µ ⁺ µ ⁻)/\(\triangle^6\) 5.8±0.8 OUR AVEI 5.7±0.7±0.5 6.5±2.1 • • • We do not use to	RAGE 114 27 he following	ABEGG DZHELYADIN g data for average	94 S I 808 S es, fits,	SPEC pd - SPEC π ⁻ p limits, etc. e	→ η ³ He > → ηπ • • •	112/1	<5 $[\Gamma(\mu^+e^-) + Forbiden!]$	y lepton family n	ital umber conservati	on. <u>7</u>	ECN	$COMMENT$ $pd \rightarrow \eta^3$ He	Г ₂₁ /
<3 $\frac{(\mu^{+}\mu^{-})/\Gamma_{\text{total}}}{5.8 \pm 0.8 \text{ OUR AVEI}}$ 5.7 ± 0.7 ± 0.5 6.5 ± 2.1	114 27	ABEGG DZHELYADIN	94 S I 808 S es, fits,	SPEC pd -	→ η ³ He > → ηπ • • •	112/1	<5 $ \left[\Gamma(\mu^+ e^-) + Forbiden \right] $ VALUE (units 10 ⁻⁶	oy lepton family n	ntal number conservati DOCUMENT ID	on. <u>7</u>	ECN		Γ ₂₁ /
<3	RAGE 114 27 he following	ABEGG DZHELYADIN g data for average	94 S I 808 S es, fits,	SPEC pd - SPEC π ⁻ p limits, etc. 4	→ η ³ He > → ηπ • • •	112/1	<5 $ \left[\Gamma(\mu^+ e^-) + Forbiden \right] $ VALUE (units 10 ⁻⁶	oy lepton family n	otal number conservati <u>DOCUMENT ID</u> WHITE	on. 	<i>ECN</i> SPEC	$pd \rightarrow \eta^3 He$	Γ ₂₁ /
<3	RAGE 114 27 he following 100	ABEGG DZHELYADIN g data for average KESSLER	94 S I 808 S es, fits, I	SPEC pd - SPEC π ⁻ p limits, etc. 4	→ η ³ He ο → ηπ • • • ABEGG 94		<5 $ [\Gamma(\mu^+e^-) + Forbiden VALUE (units 10^{-6}) $	y lepton family n CL% 90 7 C-NONCON	Mai number conservati <u>DOCUMENT ID</u> WHITE	on. 96 S CAY PA	PECN SPEC	$pd \rightarrow \eta^3 He$	Γ ₂₁ /
<3	RAGE 114 27 he following 100	ABEGG DZHELYADIN g data for average KESSLER	94 S I 808 S es, fits, I	SPEC pd - SPEC π ⁻ p limits, etc. 4	→ η ³ He ο → ηπ • • • ABEGG 94	Γ ₁₂ /Γ ₂	<5 [Γ(μ+e ⁻) + Forbiden VALUE (units 10 ⁻⁶ <6 π+π-π ⁰ LEF	y lepton family n CL% 90 η C-NONCON T-RIGHT ASY	MAINTE DOCUMENT ID WHITE SERVING DEC	on. 96 S CAY PA	PECN SPEC ARAM TER	pd → η ³ He	Γ ₂₁ /
<3	RAGE 114 27 he following 100	ABEGG DZHELYADIN g data for average KESSLER	94 S I 808 S es, fits, I 93 S 68 C	SPEC pd - SPEC π ⁻ p limits, etc. 4	→ η ³ He ο → ηπ • • • ABEGG 94		<5 $ [\Gamma(\mu^+e^-) + Forbiden VALUE (units 10^{-6} < 6) $ $\pi^+\pi^-\pi^0 LEF $ Measurerr	γ C-NONCON T-RIGHT ASY ents with an error	MHITE SERVING DEC /MMETRY PA r > 1.0 × 10 ⁻²	on. 96 S CAY PA RAME have bee	PECN SPEC ARAM TER en omit	pd → η ³ He	Γ21/
<3	RAGE 114 27 he following 100 0	ABEGG DZHELYADIN g data for average KESSLER WEHMANN	94 S I 808 S es, fits, I 93 S 68 C	SPEC pd – SPEC π – p limits, etc. « SPEC See A DSPK	→ η ³ He → η η • • • ABEGG 94		<5 $[\Gamma(\mu^+e^-) + Forbiden VALUE (units 10^-6)$ <6 $\pi^+\pi^-\pi^0 LEF$ Measurem VALUE (units 10^-2)	y lepton family n CL% 90 7 C-NONCON T-RIGHT ASY ents with an error EVTS	MAINTE DOCUMENT ID WHITE SERVING DEC	on. 96 S CAY PA RAME have bee	PECN SPEC ARAM TER	pd → η ³ He	Γ ₂₁ /
<3	RAGE 114 27 he following 100 0	ABEGG DZHELYADIN g data for average KESSLER WEHMANN DOCUMENT ID g data for average	94 S I 80B S es, fits, I 93 S 68 C	SPEC pd – SPEC π – p limits, etc. « SPEC See A DSPK TECN limits, etc. «	→ η ³ He → η η • • • ABEGG 94		<5 [Γ(μ+e ⁻) + Forbiden	γ C-NONCON T-RIGHT ASY ents with an error EVTS UR AVERAGE	DOCUMENT ID WHITE SERVING DEC MMETRY PA r > 1.0 × 10 ⁻² DOCUMENT ID	on. 96 S CAY PA RAME have bee	PECN ARAM TER en omit	pd → η ³ He	Γ ₂₁ /
<3	RAGE 114 27 he following 100 0	ABEGG DZHELYADIN g data for average KESSLER WEHMANN DOCUMENT ID g data for average HYAMS	94 S I 808 S es, fits, I 93 S 68 C	SPEC pd – SPEC π – p limits, etc. « SPEC See A DSPK TECN limits, etc. «	→ η ³ He → η η • • • ABEGG 94		<5 [Γ(μ+e ⁻) + Forbiden	η C-NONCON T-RIGHT ASY ents with an error EVTS JR AVERAGE 165k	WHITE SERVING DEC (MMETRY PA r > 1.0 × 10 ⁻² DOCUMENT ID JANE	on. 96 S CAY PA RAME have bee	RAM TER en omit recn	pd → η ³ He	Γ21/
<3	RAGE 114 27 he following 100 0	ABEGG DZHELYADIN g data for average KESSLER WEHMANN DOCUMENT ID g data for average HYAMS	94 S I 80B S es, fits, I 93 S 68 C	SPEC pd – SPEC π – p limits, etc. « SPEC See A DSPK TECN limits, etc. «	→ η ³ He → η η • • • ABEGG 94	Γ12/Γ2	<5 [Γ(μ+e ⁻) + Forbiden VALUE (units 10 ⁻⁶ <6 π+π-π ⁰ LEF Measuren VALUE (units 10 ⁻² 0.09±0.17 OI 0.28±0.26 -0.05±0.22	7 C-NONCON T-RIGHT ASY tents with an error EVTS UR AVERAGE 165k 220k	WHITE SERVING DECUMENT ID WHITE SERVING DECUMENT ID TO 1.0 × 10 ⁻² DOCUMENT ID JANE LAYTER	On. 76 S CAY PA RAME have bee	TER en omit	$pd \rightarrow \eta^3 He$ ETERS	Γ ₂₁ /
$(4)^{-1}$ ($\mu^{+}\mu^{-}$)/ Γ_{total} ($\mu^{+}\mu^{-}$)/ Γ_{total} (μ^{-}) (μ^{-})/ μ^{-}) (μ^{-})/ μ^{-})/ μ^{-})/ μ^{-}) (μ^{-})/ μ^{-})	RAGE 114 27 he following 100 0	ABEGG DZHELYADIN g data for average KESSLER WEHMANN DOCUMENT ID g data for average HYAMS	94 S 1 808 S es, fits, 1 93 S 68 C	SPEC pd – SPEC π – p limits, etc. « SPEC See A DSPK TECN limits, etc. «	→ η ³ He → η η • • • ABEGG 94		<5 $[\Gamma(\mu^{+}e^{-}) + Forbiden VALUE (units 10^{-6}) <6 \pi^{+}\pi^{-}\pi^{0} LEF Measurerr VALUE (units 10^{-2}) 0.09±0.17 OI 0.28±0.26 -0.05±0.22 • • • We do not$	γ C-NONCON T-RIGHT ASY tents with an error EVTS UR AVERAGE 165k 220k at use the followin	MAIN WHITE SERVING DECUMENT ID WHITE SERVING DECUMENT ID JANE LAYTER In data for average with the serving data for average with the servi	On. 76 S CAY PA RAME have been 74 C 72 A ges, fits,	TER en omit recn OSPK ASPK Ilmits,	$pd \rightarrow \eta^3 He$ ETERS	Γ21/
<3	RAGE 114 27 he following 100 0 the following $(\pi^+\pi^-\gamma)$ EVTS	ABEGG DZHELYADIN g data for average KESSLER WEHMANN DOCUMENT ID g data for average HYAMS	94 S 1 808 S es, fits, 1 93 S 68 C	SPEC pd - SPEC x - SPEC x - SPEC See A DSPK SPECN SImits, etc. 4 DSPK	→ η ³ He → η η • • • ABEGG 94	Γ12/Γ2	<5 [Γ(μ+e ⁻) + Forbiden VALUE (units 10 ⁻⁶ <6 π+π-π ⁰ LEF Measuren VALUE (units 10 ⁻² 0.09±0.17 OI 0.28±0.26 -0.05±0.22	7 C-NONCON T-RIGHT ASY tents with an error EVTS UR AVERAGE 165k 220k	WHITE SERVING DECUMENT ID WHITE SERVING DECUMENT ID TO 1.0 × 10 ⁻² DOCUMENT ID JANE LAYTER	On. 76 S CAY PA RAME have bee	TER en omit recn OSPK ASPK Ilmits,	$pd \rightarrow \eta^3 He$ ETERS	Γ21/
(3) $\frac{\Gamma(\mu^{+}\mu^{-})/\Gamma_{\text{total}}}{5.8\pm0.8 \text{ OUR AVEI}}$ 5.8±0.8 OUR AVEI 5.7±0.7±0.5 6.5±2.1 • • We do not use the second sec	RAGE 114 27 he following 100 0 the following $(\pi^+\pi^-\gamma)$ EVTS	ABEGG DZHELYADIN g data for average KESSLER WEHMANN DOCUMENT ID g data for average HYAMS	94 S 1 808 S es, fits, 1 93 S 68 C	SPEC pd - SPEC x - SPEC x - SPEC See A DSPK SPECN SImits, etc. 4 DSPK	→ η ³ He → η η • • • ABEGG 94	Γ12/Γ2	<5 $[\Gamma(\mu^{+}e^{-}) + Forbiden]$ Forbiden in VALUE (units 10^{-6}) <6 $\pi^{+}\pi^{-}\pi^{0}$ LEF Measurer VALUE (units 10^{-2}) 0.09 ± 0.17 Oi 0.28 ± 0.26 -0.05 ± 0.22 • • • We do not 1.5 ± 0.5 6 The GORMin	7 C-NONCON T-RIGHT ASY ents with an error EVTS JR AVERAGE 165k 220k ot use the followin 37k LEY 68c asymmet	WHITE SERVING DECUMENT 10 WHOTE SERVING DECUMENT 10 TO 1.0 × 10 - 2 DOCUMENT 10 JANE LAYTER In data for average 6 GORMLEY Try is probably dur	on. 96 S CAY PA RAME have bee 74 C 72 A ges, fits, 1 68c A e to unm	TER en omit rECN OSPK ASPK Ilmits, ASPK	$pd \rightarrow \eta^3$ He ETERS tted. etc. • • •	k chamb
$(4) \frac{1}{2} \frac{1}{(\mu^{+}\mu^{-})} / \Gamma_{\text{total}} \frac{1}{(\mu^{+}\mu^{-})} / \Gamma_{\text{total}} \frac{1}{(\mu^{+}\mu^{-})} / \Gamma_{\text{total}} \frac{1}{(\mu^{+}\mu^{-})} \frac{CL\%}{6.5 \pm 0.8} \frac{CL\%}{6.5 \pm 2.1} \frac{1}{6.5 \pm 2.1} \frac{1}{6.5 \pm 2.1} \frac{1}{6.0 \pm 0.5} \frac{1}{6.0 \pm 0.05} \frac{1}{6.0 \pm 0$	RAGE 114 27 he following 100 0 the following $(\pi^+\pi^-\gamma)$ EVTS	ABEGG DZHELYADIN g data for average KESSLER WEHMANN DOCUMENT ID g data for average HYAMS	94 S 1 808 S es, fits, 1 93 S 68 C	SPEC pd - SPEC x - p limits, etc. e SPEC See A DSPK TECN Jimits, etc. e DSPK	→ η ³ He → η η • • • ABEGG 94	Γ12/Γ2	<5 $[\Gamma(\mu^{+}e^{-}) + Forbiden]$ Forbiden in VALUE (units 10^{-6}) <6 $\pi^{+}\pi^{-}\pi^{0}$ LEF Measurer VALUE (units 10^{-2}) 0.09 ± 0.17 Oi 0.28 ± 0.26 -0.05 ± 0.22 • • • We do not 1.5 ± 0.5 6 The GORMin	7 C-NONCON T-RIGHT ASY tents with an error EVTS UR AVERAGE 165k 220k to use the followin 37k	WHITE SERVING DECUMENT 10 WHOTE SERVING DECUMENT 10 TO 1.0 × 10 - 2 DOCUMENT 10 JANE LAYTER In data for average 6 GORMLEY Try is probably dur	on. 96 S CAY PA RAME have bee 74 C 72 A ges, fits, 1 68c A e to unm	TER en omit rECN OSPK ASPK Ilmits, ASPK	$pd \rightarrow \eta^3$ He ETERS tted. etc. • • •	k chamb
$(4) \frac{1}{2} \frac{1}{(\mu^{+}\mu^{-})} / \Gamma_{\text{total}} \frac{1}{(\mu^{+}\mu^{-})} / \Gamma_{\text{total}} \frac{1}{(\mu^{+}\mu^{-})} / \Gamma_{\text{total}} \frac{1}{(\mu^{+}\mu^{-})} / \Gamma_{\text{total}} \frac{1}{(\mu^{+}\mu^{-})} = \frac{CL\%}{6.5 \pm 2.1} \frac{1}{6.5 \pm 2.1} \frac{1}{6.5 \pm 2.1} \frac{1}{6.0 \pm 0.5} = \frac{6.5 \pm 2.1}{6.0 \pm 0.05} = \frac{6.5 \pm 2.1}{6.0.025} - \frac{6.5 \pm 2.1}{6.0.025} - \frac{6.5 \pm 2.1}{6.0.025} - \frac{6.0.025}{6.0.025} - \frac{6.0.025}{6.0.025} = \frac{CL\%}{6.0.025} - \frac{6.0.025}{6.0.025} = \frac{6.0.025}{6.0.025$	RAGE 114 27 the following 100 0 the following $(\pi^+\pi^-\gamma)$ EVTS	ABEGG DZHELYADIN g data for average KESSLER WEHMANN DOCUMENT ID g data for average HYAMS	94 S I 808 S es, fits, I 93 S 68 C 7 es, fits,	SPEC pd - SPEC x - p limits, etc. e SPEC See A DSPK TECN Jimits, etc. e DSPK	→ η ³ He → η η • • • ABEGG 94	Γ ₁₂ /Γ ₂ Γ ₁₃ /Γ ₈	<5 $[\Gamma(\mu^{+}e^{-}) + Forbiden]$ Forbiden is VALUE (units 10^{-6}) <6 $\pi^{+}\pi^{-}\pi^{0}$ LEF Measurerr VALUE (units 10^{-2}) 0.09 \pm 0.17 Oi 0.28 \pm 0.26 -0.05 \pm 0.22 • • We do not 1.5 \pm 0.5 6 The GORMI effects. New	7 C-NONCON T-RIGHT ASY tents with an error EVTS UR AVERAGE 165k 220k ot use the followin 37k LEY 68C asymmetr experiments with	MAINTE DOCUMENT ID WHITE SERVING DEC MMETRY PA T > 1.0 × 10 ⁻² DOCUMENT ID JANE LAYTER ag data for average GORMLEY try is probably due to (E × B) control	PAME TAY PA RAME 74 C 72 A res, fits, l 68C A e to unm is don't	TER en omit FECN OSPK ASPK Ilmits, ASPK Deasure observe	$pd \rightarrow \eta^3$ He ETERS tted. etc. • • •	k chamb
$(4) \frac{1}{2} \frac{1}{(\mu^{+}\mu^{-})} / \Gamma_{\text{total}} \frac{1}{(\mu^{+}\mu^{-})} / \Gamma_{\text{total}} \frac{1}{(\mu^{+}\mu^{-})} / \Gamma_{\text{total}} \frac{1}{(\mu^{+}\mu^{-})} / \Gamma_{\text{total}} \frac{1}{(\mu^{+}\mu^{-})} = \frac{CL\%}{6.5 \pm 2.1} \frac{1}{6.5 \pm 2.1} \frac{1}{6.5 \pm 2.1} \frac{1}{6.0 \pm 0.5} = \frac{6.5 \pm 2.1}{6.0 \pm 0.05} = \frac{6.5 \pm 2.1}{6.0.025} - \frac{6.5 \pm 2.1}{6.0.025} - \frac{6.5 \pm 2.1}{6.0.025} - \frac{6.0.025}{6.0.025} - \frac{6.0.025}{6.0.025} = \frac{CL\%}{6.0.025} - \frac{6.0.025}{6.0.025} = \frac{6.0.025}{6.0.025$	RAGE 114 27 the following 100 0 the following $(\pi^+\pi^-\gamma)$ EVTS	ABEGG DZHELYADIN g data for average KESSLER WEHMANN DOCUMENT ID g data for average HYAMS	94 S I 808 S es, fits, I 93 S 68 C 7 es, fits,	SPEC pd - SPEC x - p limits, etc. e SPEC See A DSPK TECN Jimits, etc. e DSPK	→ η ³ He → η η • • • ABEGG 94	Γ12/Γ2	(-5) [Γ(μ^+e^-) + Forbiden is VALUE (units 10 ⁻⁶) (-6) $\pi^+\pi^-\pi^0$ LEF Measurer VALUE (units 10 ⁻⁷) 0.09 ± 0.17 Of 0.28 ± 0.26 -0.05 ± 0.22 • • • We do not 1.5 ± 0.5 6 The GORMI effects. New $\pi^+\pi^-\pi^0$ SE	7 C-NONCON T-RIGHT ASY ents with an error EVTS UR AVERAGE 165k 220k ot use the followin 37k LEY 68c asymmet r experiments with	WHITE SERVING DECUMENT 10 WHITE SERVING DECUMENT 10 JANE LAYTER and data for average 6 GORMLEY try is probably due and (E × B) control METRY PARA	on. 96 S CAY PA RAME have been 74 C 72 A res, fits, 68C A e to unmis don't	TER en omit rECN OSPK ASPK Ilmits, ASPK neasure observe	pd → η ³ He ETERS tted. etc. • • • et (E × B) sparle an asymmetry.	k chamb
<3 $(4)^{+}\mu^{-})/\Gamma_{\text{total}}$ $(4)^{-}\mu^{-})/\Gamma_{\text{total}}$ $(4)^{-}\mu^{-})/\Gamma_{\text{total}}$ $(5)^{-}\mu^{-}$ $5.8\pm0.8 \text{ OUR}$ 5.7 ± 0.5 6.5 ± 2.1 6.5 ± 2.1 6.5 ± 2.1 6.5 ± 2.1 6.5 ± 2.1 6.5 ± 2.1 6.5 ± 2.1 6.5 ± 2.1 6.6 ± 2.0 95 $(4)^{-}\mu^{-})/\Gamma(2\gamma)$ 6.20 95 $(4)^{-}\mu^{-})/\Gamma(2\gamma)$ 6.9 ± 2.2 $(4)^{-}\mu^{-})/\Gamma(2\gamma)$ 6.9 ± 2.2 $(4)^{-}\mu^{-}$ 6.9 ± 2.2	RAGE 114 27 the following 100 0 the following $(\pi^+\pi^-\gamma)$ EVTS	ABEGG DZHELYADIN g data for average KESSLER WEHMANN DOCUMENT ID g data for average HYAMS	94 S 1 80B S es, fits, 93 S 68 C 7 es, fits, 69 C	SPEC pd - SPEC x - p limits, etc. e SPEC See A DSPK TECN Jimits, etc. e DSPK	→ η ³ He → η η • • • ABEGG 94	Γ ₁₂ /Γ ₂ Γ ₁₃ /Γ ₈	(5) [$\Gamma(\mu^+e^-)$ + Forbiden In MALUE (units 10 ⁻⁶) (6) $\pi^+\pi^-\pi^0$ LEF Measurem MALUE (units 10 ⁻²) 0.09±0.17 0.09±0.20 0.09±0.20 1.5 ±0.5 6 The GORMI effects. New Measurem Measurem	7 C-NONCON T-RIGHT ASY ents with an error EVTS UR AVERAGE 165k 220k ot use the followin 37k LEY 68C asymmet r experiments with CTANT ASYMI	MAINUMBER CONSERVATION WHITE ISERVING DECEMBER 10 WHETRY PA T > 1.0 × 10 - 2 DOCUMENT IO JANE LAYTER and data for average 6 GORMLEY try Is probably due to (E × B) contro METRY PARA T > 2.0 × 10 - 2	On. 96 S RAME RAME 74 C 72 A es fits, 68c A e to unm is don't	TER TECN DSPK SSPK SSPK Illimits, SSPK Resource Observer R en omit	pd → η ³ He ETERS tted. etc. • • • et (E × B) sparle an asymmetry.	k chamb
$(4) \frac{1}{2} \frac{1}{(\mu^{+}\mu^{-})} / \Gamma_{\text{total}} \frac{1}{(\mu^{+}\mu^{-})} / \Gamma_{\text{total}} \frac{1}{(\mu^{+}\mu^{-})} / \Gamma_{\text{total}} \frac{1}{(\mu^{-}\mu^{-})} \frac{CL\%}{6.5 \pm 0.8} \frac{CL\%}{6.5 \pm 2.1} \frac{1}{6.5 \pm 2.1} \frac{1}{6.5 \pm 2.1} \frac{1}{6.0.6 \pm 0.5} \frac{1}{6.0.7 \pm 0.00} \frac{1}{6.0$	RAGE 114 27 the following 100 0 The following $(\pi^+\pi^-\gamma)$ EVTS	ABEGG DZHELYADIN g data for average KESSLER WEHMANN DOCUMENT ID g data for average HYAMS DOCUMENT ID GROSSMAN	94 S 1 80B S es, fits, 93 S 68 C 7 es, fits, 69 C	SPEC pd - SPEC # p Ilmits, etc. 4 SPEC See # OSPK FECN Ilmits, etc. 4 DSPK HBC	→ η ³ He → η η • • • ABEGG 94	Γ ₁₂ /Γ ₂ Γ ₁₃ /Γ ₈	(5) $[\Gamma(\mu^{+}e^{-}) + Forbiden VALUE (wints 10^{-6}) < 6$ $\pi^{+}\pi^{-}\pi^{0} \text{ LEF}$ Measurem VALUE (wints 10^{-2}) 0.09 ± 0.17 0 0.28 ± 0.26 -0.05 ± 0.22 • • • We do not 1.5 ± 0.5 6 The GORMI effects. New π+π-π ⁰ SED Measurem VALUE (wints 10^{-2}) Measurem VALUE (wints 10^{-2})	7 C-NONCON T-RIGHT ASY tents with an error EVTS PR AVERAGE 165k 220k to use the followin 37k LEY 68c asymmet r experiments with tents with an error EVTS	WHITE SERVING DECUMENT 10 WHITE SERVING DECUMENT 10 JANE LAYTER and data for average 6 GORMLEY try is probably due and (E × B) control METRY PARA	On. 96 S RAME RAME 74 C 72 A es fits, 68c A e to unm is don't	TER en omit rECN OSPK ASPK Ilmits, ASPK neasure observe	pd → η ³ He ETERS tted. etc. • • • et (E × B) sparle an asymmetry.	k chamb
<3 $(4)^{+}\mu^{-})/\Gamma_{\text{total}}$ $(4)^{-}\mu^{-})/\Gamma_{\text{total}}$ $(4)^{-}\mu^{-})/\Gamma_{\text{total}}$ $(5)^{-}\mu^{-}$ $5.8\pm0.8 \text{ OUR}$ 5.7 ± 0.5 6.5 ± 2.1 6.5 ± 2.1 6.5 ± 2.1 6.5 ± 2.1 6.5 ± 2.1 6.5 ± 2.1 6.5 ± 2.1 6.5 ± 2.1 6.6 ± 2.0 95 $(4)^{-}\mu^{-})/\Gamma(2\gamma)$ 6.20 95 $(4)^{-}\mu^{-})/\Gamma(2\gamma)$ 6.9 ± 2.2 $(4)^{-}\mu^{-})/\Gamma(2\gamma)$ 6.9 ± 2.2 $(4)^{-}\mu^{-}$ 6.9 ± 2.2	RAGE 114 27 the following 100 0 The following $(\pi^+\pi^-\gamma)$ EVTS	ABEGG DZHELYADIN g data for average KESSLER WEHMANN DOCUMENT ID g data for average HYAMS DOCUMENT ID GROSSMAN	94 S 1 80B S es, fits, 93 S 68 C 7 es, fits, 69 C	SPEC pd - SPEC # p Ilmits, etc. 4 SPEC See # OSPK FECN Ilmits, etc. 4 DSPK HBC	→ η ³ He → η η • • • ABEGG 94	Γ ₁₂ /Γ ₂ Γ ₁₃ /Γ ₈	<5 $[\Gamma(\mu^{+}e^{-}) + Forbiden VALUE (writs 10^{-6}) < 6$ $\pi^{+}\pi^{-}\pi^{0} \text{ LEF}$ Measuren VALUE (writs 10^{-2}) 0.09 \pm 0.17 0.28 \pm 0.26 - 0.05 \pm 0.22 • • • We do not 1.5 \pm 0.5 6 The GORMI effects. New $\pi^{+}\pi^{-}\pi^{0} \text{ SE}$ Measuren VALUE (writs 10^{-2}) 0.18 \pm 0.16 OUF	7 C-NONCON T-RIGHT ASY ents with an error EVTS 165k 220k to use the followin 37k LEY 68c asymmet r experiments with (TANT ASYMI) ents with an error EVTS t AVERAGE	MMETRY PARA GORMLEY Ty probably due (E B) control METRY PARA	PAME TAY PA RAME TAY PA TA	TER TER TER TER TECN DSPK ASPK dilmits, ASPK Deasure observe R	pd → η ³ He ETERS tted. etc. • • • et (E × B) sparle an asymmetry.	k chamb
<3	RAGE 114 27 he following 100 0 he following $(\pi^+\pi^-\gamma)$ EVTS	ABEGG DZHELYADIN g data for average KESSLER WEHMANN DOCUMENT ID g data for average HYAMS DOCUMENT ID GROSSMAN	94 S I 808 S ess, fits, 93 S 68 C 7 7 Ess, fits, 69 C 66 F	SPEC pd - SPEC r - SPEC r - SPEC see A SPEC See A SPECN SPEC	→ η ³ He → η η • • • ABEGG 94	Γ ₁₂ /Γ ₂ Γ ₁₃ /Γ ₈	(-5) [Γ(μ^+e^-) + Forbiden	7 C-NONCON T-RIGHT ASY ents with an error 220k of use the followin 37k EY 68C asymmet experiments with CTANT ASYMI ents with an error EVTS EXPERIMENTS EVTS EXPERIMENTS EXPER	MAINUMBER CONSERVATION WHITE ISERVING DEC MMETRY PA T > 1.0 × 10 ⁻² DOCUMENT IO JANE LAYTER IN data for average 6 GORMLEY try is probably due 1 (E × B) contro METRY PARA T > 2.0 × 10 ⁻² DOCUMENT IO JANE JANE	on. 76 S RAME have bee 72 A es, fits, 68c A e to unm is don't METEI have bee	ARAM TER en omit rece OSPK ASPK Reasure Renobserve R R OSPK OSPK OSPK OSPK OSPK OSPK OSPK OSPK	pd → η ³ He ETERS tted. etc. • • • et (E × B) sparle an asymmetry.	k chamb
<3 $\Gamma(\mu^{+}\mu^{-})/\Gamma_{\text{total}}$ $F(\mu^{+}\mu^{-})/\Gamma_{\text{total}}$ $F(\mu^{+}\mu^{-$	RAGE 114 27 he following 100 0 he following $(\pi^+\pi^-\gamma)$ EVTS	ABEGG DZHELYADIN g data for average KESSLER WEHMANN DOCUMENT ID g data for average HYAMS DOCUMENT ID GROSSMAN	94 S 1 80B S 5 8 8 8 1 8 1 8 1 8 1 8 1 8 1 8 1 8 1 8	SPEC pd - SPEC rp limits, etc. e SPEC See A DSPK FECN limits, etc. e DSPK FECN HBC Ilmits, etc. e	→ η ³ He → η η • • • ABEGG 94	Γ ₁₂ /Γ ₂ Γ ₁₃ /Γ ₈	(5) [$\Gamma(\mu^+e^-)_+$ Forbiden is (3) (4)	7 C-NONCON T-RIGHT ASY ents with an error 220k ot use the followin 37k LEY 68c asymmet r experiments with (TANT ASYMI ents with an error) EVTS t AVERAGE 165k 220k	MAINUMBER CONSERVATION WHITE ISERVING DECEMBER 10 WHETRY PA T > 1.0 × 10 - 2 DOCUMENT ID JANE LAYTER G GORMLEY try Is probably due to (E × B) contro METRY PARA T > 2.0 × 10 - 2 DOCUMENT ID JANE LAYTER	PAME TA CATE TA CAT	TECN TER TO SPK ASPK ASPK ASPK ASPK ASPK ASPK ASPK A	pd → η ³ He ETERS tted. etc. • • • et (E × B) sparle an asymmetry.	k chamb
(3) $\frac{(\mu^{+}\mu^{-})/\Gamma_{\text{total}}}{5.8\pm0.8 \text{ OUR AVEI}}$ 5.8±0.8 OUR AVEI 5.7±0.5 6.5±2.1 • • We do not use the second of the s	PAGE 114 27 he following 100 0 $(\pi^+\pi^-\gamma)$ EVTS 1 ootal	ABEGG DZHELYADIN g data for average KESSLER WEHMANN DOCUMENT ID g data for average HYAMS DOCUMENT ID GROSSMAN DOCUMENT ID	94 S 1 80B S 5 8 8 8 1 8 1 8 1 8 1 8 1 8 1 8 1 8 1 8	SPEC pd - SPEC rp limits, etc. e SPEC See A DSPK FECN limits, etc. e DSPK FECN HBC Ilmits, etc. e	→ η ³ He → η η • • • ABEGG 94	Γ ₁₂ /Γ ₂ Γ ₁₃ /Γ ₈	(-5) [Γ(μ^+e^-) + Forbiden	7 C-NONCON T-RIGHT ASY ents with an error 220k of use the followin 37k EY 68C asymmet experiments with CTANT ASYMI ents with an error EVTS EXPERIMENTS EVTS EXPERIMENTS EXPER	MAINUMBER CONSERVATION WHITE ISERVING DEC MMETRY PA T > 1.0 × 10 ⁻² DOCUMENT IO JANE LAYTER IN data for average 6 GORMLEY try is probably due 1 (E × B) contro METRY PARA T > 2.0 × 10 ⁻² DOCUMENT IO JANE JANE	on. 76 S RAME have bee 72 A es, fits, 68c A e to unm is don't METEI have bee	TECN TER TO SPK ASPK ASPK ASPK ASPK ASPK ASPK ASPK A	pd → η ³ He ETERS tted. etc. • • • et (E × B) sparle an asymmetry.	k chamb
(3) $(\mu^{+}\mu^{-})/\Gamma_{\text{total}}$ $ALUE (units 10^{-6}) CL\% 5.8±0.8 OUR AVEI 5.7±0.5 6.5±2.1 • • We do not use the second of the second o$	PAGE 114 27 he following 100 0 $(\pi^+\pi^-\gamma)$ EVTS 1 ootal	ABEGG DZHELYADIN g data for average KESSLER WEHMANN DOCUMENT ID g data for average HYAMS DOCUMENT ID GROSSMAN DOCUMENT ID	94 S 1 80B S 5 8 8 8 1 8 1 8 1 8 1 8 1 8 1 8 1 8 1 8	SPEC pd - SPEC rp limits, etc. e SPEC See A DSPK FECN limits, etc. e DSPK FECN HBC Ilmits, etc. e	→ η ³ He → η η ABEGG 94	Γ ₁₂ /Γ ₂ Γ ₁₃ /Γ ₈	(5) [$\Gamma(\mu^+e^-)$ + Forbiden VALUE (units 10 ⁻⁶) (6) $\pi^+\pi^-\pi^0$ LEF Measurer VALUE (units 10 ⁻² 0.09 ± 0.17 0.28 ± 0.26 -0.05 ± 0.22 • • • We do not 1.5 ± 0.5 6 The GORMI effects. New $\pi^+\pi^-\pi^0$ SE) Measurer VALUE (units 10 ⁻² 0.18 ± 0.16 OUF 0.20 ± 0.25 0.10 ± 0.22 0.5 ± 0.5	7 C-NONCON T-RIGHT ASY ents with an error 220k of use the followin 37k EY 68C asymmet r experiments with CTANT ASYMI ents with an error EVTS 220k 37k AVERAGE 165k 220k 37k	MAINUMBER CONSERVATION WHITE ISERVING DECEMBER 10 WHETRY PA T > 1.0 × 10 ⁻² DOCUMENT 10 JANE LAYTER IS data for average 6 GORMLEY Try Is probably due 1 (E × B) contro METRY PARA T > 2.0 × 10 ⁻² DOCUMENT 10 JANE LAYTER GORMLEY	PAME have been for the part of	TECN TER TO OTHER TECN TER TO OTHER TO	pd → η ³ He ETERS tted. etc. • • • et (E × B) sparle an asymmetry.	k chamb
(3) $\frac{\Gamma(\mu^{+}\mu^{-})}{\Gamma \text{total}}$ $\frac{ALUE (\text{units }10^{-6})}{5.8 \pm 0.8 \text{ OUR AVEI}}$ $\frac{5.8 \pm 0.8 \text{ OUR AVEI}}{5.7 \pm 0.5}$ 6.5 ± 2.1 • • We do not use the second of the second o	PAGE 114 27 he following 100 0 $(\pi^+\pi^-\gamma)$ EVTS 1 ootal	ABEGG DZHELYADIN g data for average KESSLER WEHMANN DOCUMENT ID g data for average HYAMS DOCUMENT ID GROSSMAN DOCUMENT ID	94 S 1 808 S 5 1 808 S 68 C 7 7 Es, fits, 69 C 7 66 H	SPEC pd - SPEC rp limits, etc. e SPEC See A DSPK FECN limits, etc. e DSPK FECN HBC Ilmits, etc. e	→ η ³ He → η η ABEGG 94	Γ ₁₂ /Γ ₂ Γ ₁₃ /Γ ₈	(5) [$\Gamma(\mu^+e^-)_+$ Forbiden is problem in the problem is problem in the probl	7 C-NONCON T-RIGHT ASY ents with an error 220k of use the followin 37k LEY 68C asymmet r experiments with CTANT ASYMI lents with an error EVTS 165k 220k 37k ADRANT ASY	MAINUMBER CONSERVATION WHITE ISERVING DECEMBER 10 WHETRY PA T > 1.0 × 10 - 2 DOCUMENT 10 JANE LAYTER IN GARMLEY Try Is probably due The Example Comment 10 METRY PARA T > 2.0 × 10 - 2 DOCUMENT 10 JANE LAYTER GORMLEY METRY PARA T > 2.0 × 10 - 2 DOCUMENT 10 JANE LAYTER GORMLEY METRY PARA T > METRY PARA	PAME TAY PA RAME TAY PA TAY P	PEC ARAM TER en omit recov OSPK SSPK easure observe R en omit recov OSPK SSPK NSPK PEN omit RECOV OSPK SSPK TECOV OSPK TEC	pd → η ³ He ETERS tted. etc. • • • et (E × B) sparle an asymmetry.	k chamb
$\frac{(\mu^{+}\mu^{-})/\Gamma_{\text{total}}}{(\mu^{+}\mu^{-})/\Gamma_{\text{total}}}$ $\frac{ALUE (\text{units }10^{-6})}{5.8\pm0.8 \text{ OUR}}$ $\frac{CL\%}{5.7\pm0.7\pm0.5}$ 6.5 ± 2.1 $\cdot We do not use the standard of t$	PAGE 114 27 he following 100 0 ($\pi^+\pi^-\gamma$) 1 total The following $\pi^-\pi^0$)	ABEGG DZHELYADIN g data for average KESSLER WEHMANN DOCUMENT ID GROSSMAN DOCUMENT ID GROSSMAN DOCUMENT ID GROSSMAN	94 S 1 808 S 5 1 808 S 68 C 7 7 Es, fits, 69 C 7 66 H	SPEC pd = SPEC pd = SPEC r = p Ilimits, etc. e SPEC See A DSPK FECN Ilimits, etc. e DSPK HBC Ilimits, etc. e HBC	→ η ³ He → η η ABEGG 94	Γ ₁₂ /Γ ₂ Γ ₁₃ /Γ ₈	$(-1)^{4}$ (Forbiden is value (units 10 ⁻⁶) $(-1)^{4}$ (White 10 ⁻⁶) $(-1)^{4}$ (White 10 ⁻⁶) $(-1)^{4}$ (White 10 ⁻²)	7 C-NONCON T-RIGHT ASY ents with an error EVTS FOR AVERAGE 165k 220k ot use the followin 37k LEY 68c asymmet rexperiments with CTANT ASYMI ents with an error EVTS R AVERAGE 165k 220k 37k ADRANT ASY EVTS	MAINUMBER CONSERVATION WHITE ISERVING DECEMBER 10 WHETRY PA T > 1.0 × 10 ⁻² DOCUMENT 10 JANE LAYTER IS data for average 6 GORMLEY Try Is probably due 1 (E × B) contro METRY PARA T > 2.0 × 10 ⁻² DOCUMENT 10 JANE LAYTER GORMLEY	PAME TAY PA RAME TAY PA TAY P	TECN TER TO OTHER TECN TER TO OTHER TO	pd → η ³ He ETERS tted. etc. • • • et (E × B) sparle an asymmetry.	k chamb
<3 $(4) \frac{1}{4} \frac{1}{$	PAGE 114 27 the following 100 0 $(\pi^+\pi^-\gamma)$ EVTS 1 the following $\pi^-\pi^0$ SLX	ABEGG DZHELYADIN g data for average KESSLER WEHMANN DOCUMENT ID G data for average HYAMS DOCUMENT ID GROSSMAN DOCUMENT ID g data for average RITTENBERG	94 S S 180B S Ses, fits, 93 S 68 C 7 1 1 666 F 1 1 667 F 1 67 F 1	SPEC pd - SPEC pd - SPEC x - p limits, etc. e SPEC See A DSPK TECN Ilimits, etc. e HBC HBC TECN HBC TECN HBC	→ η ³ He → η η → Φ ABEGG 94	Γ ₁₂ /Γ ₂ Γ ₁₃ /Γ ₈	(5) [$\Gamma(\mu^+e^-)_+$ Forbiden is problem in the problem is problem in the probl	7 C-NONCON T-RIGHT ASY ents with an error EVTS FOR AVERAGE 165k 220k ot use the followin 37k LEY 68c asymmet rexperiments with CTANT ASYMI ents with an error EVTS R AVERAGE 165k 220k 37k ADRANT ASY EVTS	MAINUMBER CONSERVATION WHITE ISERVING DECEMBER 10 WHETRY PA T > 1.0 × 10 - 2 DOCUMENT 10 JANE LAYTER IN GARMLEY Try Is probably due The Example Comment 10 METRY PARA T > 2.0 × 10 - 2 DOCUMENT 10 JANE LAYTER GORMLEY WHETRY PARA T > 2.0 × 10 - 2 DOCUMENT 10 METRY PARA T > 2.0 × 10 - 2 DOCUMENT 10 METRY PARA T > METR	PAME TAY PA RAME TAY PA TAY P	TER OSPK Neasure OSPK Neasure OSPK Neasure OSPK Neasure OSSPK Neasure OSSPK Nessure OS	pd → η ³ He ETERS tted. etc. • • • et (E × B) sparle an asymmetry.	k chamb

$\pi^+\pi^-\gamma$ LEFT-RIGHT ASYMMETRY PARAMETER

Measurements with an error $> 2.0 \times 10^{-2}$ have been omitted.

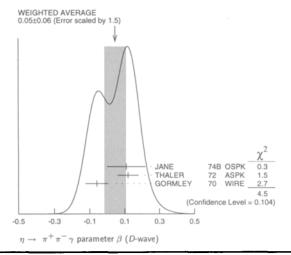
VALUE (units 10-2)	EVTS	DOCUMENT ID	TECN
0.9 ±0.4 OUR AV	ERAGE	-	
1.2 ± 0.6	35k	JANE	74B OSPK
0.5 ± 0.6	36k	THALER	72 ASPK
1.22 ± 1.56	7257	GORMLEY	70 ASPK

$\pi^+\pi^-\gamma$ PARAMETER β (*D*-wave)

Sensitive to a *D*-wave contribution: $dN/d\cos\theta = \sin^2\theta \ (1 + \beta \cos^2\theta)$ ALUE <u>EVTS</u> <u>DOCUMENT ID TECN</u>

0.05 ±0.06 OUR AVERAGE Error includes scale factor of 1.5. See the Ideogram 0.11 ±0.11 JANE 74B OSPK 7 THALER 0.12 ±0.06 72 ASPK -0.060 ± 0.065 7250 GORMLEY 70 WIRE

 $^7{\rm The}$ authors don't believe this indicates ${\it D}{\rm -wave}$ because the dependence of β on the γ energy is inconsistent with theoretical prediction. A $\cos^2\theta$ dependence may also come from P- and F-wave interference.



ENERGY DEPENDENCE OF $\eta \to 3\pi$ DALITZ PLOTS

PARAMETERS FOR $\eta \to \pi^+\pi^-\pi^0$

See the "Note on η Decay Parameters" in our 1994 edition, Phys. Rev. **D50**, 1 August 1994, Part I, p. 1454. The following experiments fit to one or more of the coefficients a, b, c, d, or e for $|\text{matrix element}|^2 = 1 + ay + by^2 + cx + dx^2 + exy$. DOCUMENT ID TECN COMMENT VALUE

VALUE	EVTS	DOCUMENT ID	<u>TECN</u>	COMMENT
• • • We do not use th	e following d	ata for averages, fit	s, limits,	etc. • • •

3230	8 ABELE	98D	CBAR	$\overline{p}p \rightarrow$	$\pi^0\pi^0\eta$ at rest
1077	⁹ AMSLER				$\pi^+\pi^-\eta$ at rest
81k	LAYTER	73	ASPK		
220k	LAYTER	72	ASPK		
1138	CARPENTER	70	HBC		
349	DANBURG	70	DBC		
7250	GORMLEY	70	WIRE		
526	BAGLIN	69	HLBC		
7170	CNOPS	68	OSPK		
37k	GORMLEY	68C	WIRE		
1300	CLPWY	66	HBC		
705	LARRIBE	66	HRC		

⁸ ABELE 98D obtain $a=-1.22\pm0.07$ and $b=0.22\pm0.11$ when c (our d) is fixed at 0.06. 9 AMSLER 95 fits to $(1+ay+by^2)$ and obtains $a=-0.94\pm0.15$ and $b=0.11\pm0.27$.

α PARAMETER FOR $\eta \to 3\pi^0$

See the "Note on η Decay Parameters" in our 1994 edition, Phys. Rev. **D50**, 1 August 1994, Part I, p. 1454. The value here is of α in $|\text{matrix element}|^2 = 1 + 2\alpha z$.

22211 aleit bi 210			~			
VALUE	EVTS	DOCUMENT II	D	TECN	COMMENT	_
-0.039±0.015 OUR AV	ERAGE					_
$-0.052\pm0.017\pm0.010$	98k	ABELE	98c	CBAR	$\overline{p}p \rightarrow 5\pi^0$	- 1
-0.022 ± 0.023	50k	ALDE	84	GAM2		
• • • We do not use the	following	data for avera	ges, fits	, limits,	etc. • • •	
-0.32 ±0.37	192	BAGLIN	70	HLBC		

η REFERENCES +Adomeit+

(CERN Crystal Barrel Collab.)

ABELE

98C PL B417 193

## ARCHAPE SIN 97 PL 9814 542 ## PR D55 3539 ## D55 3539 ## D55 3549 ## D55 35	ABELE ABELE	98C 98D	PL B417 193 PL B417 197		+Adomeit+ +Adomeit+	(CERN Crystal Barrel Collab.) (CERN Crystal Barrel Collab.)
WHITE 56 PR D33 4658 + Tippers, Abegg+ Sature SPES2 Collab.) 76 PR D31 4658 + Amazono, Hestin-the Corput Barra Collab. Amazono, Hestin-the Computation of the Computati	AKHMETSHIN	97C	Pl. B415 4\$2		+Aksenov+	(NOVO, BOST, PITT, YALE)
WHITE 56 PR D33 4658 + Tippers, Abegg+ Sature SPES2 Collab.) 76 PR D31 4658 + Amazono, Hestin-the Corput Barra Collab. Amazono, Hestin-the Computation of the Computati					+Li, Li, Kodriguez+ +Abela, Boudard+	(CLEO COllab.) (Saturne SPES2 Collab.)
KRUSCHE 950 ZPHY A53 237 ABCCC 97 PR D30 27 PR D30 28 PR	WHITE	96	PR D53 6658		+Tippens, Abegg+	(Saturne SPES2 Collab.)
ABECG ABSIGER ARSIGER ARSIG			ZPHY A351 237			(TAPS + A2 Collab.)
KESSLER 39 PRI. 70 9872 Holge	ABEGG		PR D50 92			(Saturne SPES2 Collab.)
SARU S0 ZPHY C46 S81 SHIROV, Billion,	KESSLER		PRL 70 892		+Abegg, Baldisseri+	(Saturne SPES2 Collab.)
ROE			PL B276 526		+Fleury+	(Saturne SPES4 Collab.)
AllAHARA 86 PR D33 844 AllAHARA 86 PR D33 844 AllAHARA 86 PR D33 844 AllAHARA 86 PT L308 847 All 86 PR D34 848 All 87 PR D34 858 All 87 PR D34 858 BINON 82 PR D34 858 BINON 84 PR D34 858 BINON 85 PR D34 858	ROE	90	PR D41 17		+Bartha, Burke, Garbincius+	(ASP Collab.)
BARTEL 85					+Antreasyan, Bartels, Besset+	
ALDE			PL 160B 421			(JADE Collab.)
ASS SAP 90 918			PRPL 128 310		⊥Rinon Bricman Donskov⊥	(SERP)
WEINSTEIN 3 PR D28 2996			SJNP 40 918		Alde, Binon, Bricman+	(SERP, BELG, LAPP)
BINON 22 S.N.P. 33 33 48 48 48 48 48 48	WEINSTEIN	83				(Crystal Ball Collab.)
Abo Abo Billon, Bilchman + (SERP, BELG, LAPP, CERN) Abo Billon, Bilchman + (SERP, BELG, LAPP, CERN) Davydow, Bilonh + (SERP) Davydow, Bilonh + (SERP, BELG, LAPP, CERN) Davydow, Bilonh + (SERP) Electron + (Serp) Davydow, Bilonh + (Serp) Davydow, Bilonh + (Serp) Electron + (Serp) Davydow, Bilonh + (Serp) Davydow, Bilonh + (Serp) Electron + (Serp) Electron + (Serp) Electron + (Serp) Ele	BINON	82	SJNP 36 391		+Bricman, Gouanere+	(SERP, BELG, LAPP, CERN)
Abso	Also	82B	NC 71A 497	IF 30	Binon, Bricman+	
DZHELYADIN SERP LIDSB 29 CoGovini, Konstantinov, Kubarovski+ (SERP)					+Donskov, Inyakin+	(SERP, BELG, LAPP, CERN)
ABROSIMOV 80 AB			Translated from YA	√F 33	1534,	
ABROSIMOV 5 SIMP 31 197 WAF 31 1529. DZHELYADIN 80 PL 988 549					+Golovkin, Konstantinov, Kut Dzhelvadin, Viktorov, Golovi	barovski+ (SERP) kin+ (SERP)
DZHELYADIN BOC SIMP 21 31 371.			Translated from YA	VF 33	3 152 9 .	
Also 80 C SIMP 32 516 Dzhelyadín, Golován, Kachanov+ (SERP) Franslated from VAF 32 39 Pl. Also 80 D. SIMP 2715 Translated from VAF 32 30 Pl. Also 78 SIMP 278 775 Translated from VAF 32 30 Pl. Also 78 SIMP 278 775 Translated from VAF 32 30 Pl. Also 78 Pl. 788 197 VAF 32 1967 VAF 32			Translated from YA	F 31	. 371.	
DZHELYADIN ABIO SIMP PL 998 471 Vikitorov, Golovkin, Critzuk SERP			PL 94B 548 S INP 32 516		+Viktorov, Golovkin+ Dzhelvadin, Golovkin Kacha	
BUSHNIN 78			Translated from YA	F 32	998.	• •
BUSHNIN 78			SJNP 32 518		Dzhelyadin, Golovkin, Kacha	
Also 78B S.JNP 28 775 Translated from YF 25 S.JNP 23 48 MARTYNOV 7 6 MARTYNOV 7 6 S.JNP 23 48 MARTYNOV 7 6 MARTY	RUSHMIN	79	Translated from Y/	\F 32	2 1002.	
ABARTYNOV 76 S.N.P. 23 48 +5altykov, Tarasov, Uzhinskii S.N.P. 23 ABART Tanalated from YAF 23 29 +5rannis, Jones, Lipman, Owen+ RHEL, LOWC) ABAD RT S.N.P. 23 +5rannis, Jones, Lipman, Owen+ RHEL, LOWC) Jane RT RT S.N.P. 24 PRI, 32 425 +6w, Zia Hinnie, Camileri, Carr+ LOCK, S.M.P. JANE 74 PRI, 32 425 +6w, Zia Hinnie, Camileri, Carr+ LowC, S.M.P. JANE 74 PRI, 32 425 +1anou, Massimo, Shapiro+ (BROW, BARI, MIT) LAYTER 73 PR D7 2565 +Appel, Kotlewski, Leyster, Tarlarer COLUJ ABAD RAGILIAR T.			SJNP 28 775		Bushnin, Golovkin, Gritsuk,	
JANE 75	MARTYNOV	76	SJNP 23 48		+Saltykov, Tarasov, Uzninskii	(JINR)
JANE 758 P, 1598 103 Also Forantis, Jones, Lipman, Owen+ COUNC) Jane Forantis, Janes, Lipman, Owen+ COUNC) Jane Forantis, Janes, Lipman, Owen+ COUNC) Jane Forantis, Janes, Lipman, Owen+ COUNC, BING) Also Forantis, Janes, Lipman, Owen+ COUNC, BING) Also Forantis, Janes, Lipman, Owen+ COUNC, BING) Also Forantis, Janes, Lipman, Owen+ RHEL, LOWC, SUSS) Jane Forantis, Janes, Lipman, Owen+ RHEL, LOWC, SUSS) Jane Forantis, Janes, Lipman, Owen+ RHEL, LOWC, SUSS) Also Forantis, Janes, Lipman, Owen+ RHEL, LOWC, SUSS Also Forantis, Janes, Lipm			Translated from YA	F 23	3 93 .	• •
## Apple Collegage ## App			PL 59B 103		+Grannis, Jones, Lipman, Ow	ren+ (RHEL, LOWC)
BROWMAN 748 PRI. 32 1067			PL 73B 503		Jane	
JANE 748 Pt. 488 265 + Jones, Lipman, Owen+ (RHEL, LOWC, SUSS) (KENDALL AYTER 73 PR 07 2559 + Janes, Massimo, Shapiro+ 1 Appel, Kotlewski, Layer, Lee, Stein, Chaler 1 Appel, Kotlewski, Layer, Lee, Stein (COLU) (C					+Dewire, Gittelman, Hanson,	Loh+ (CORN, BING)
JANE 748 Pt. 488 265 + Jones, Lipman, Owen+ (RHEL, LOWC, SUSS) (KENDALL AYTER 73 PR 07 2559 + Janes, Massimo, Shapiro+ 1 Appel, Kotlewski, Layer, Lee, Stein, Chaler 1 Appel, Kotlewski, Layer, Lee, Stein (COLU) (C			NC 24A 324		+Guy, Zia	(BIRM, RHEL, SHMP)
JANE 748 Pt. 488 265 + Jones, Lipman, Owen+ (RHEL, LOWC, SUSS) (KENDALL AYTER 73 PR 07 2559 + Janes, Massimo, Shapiro+ 1 Appel, Kotlewski, Layer, Lee, Stein, Chaler 1 Appel, Kotlewski, Layer, Lee, Stein (COLU) (C	JANE	74	PL 48B 260		+Jones, Lipman, Owen+	(RHEL, LOWC, SUSS)
LAYTER 73						(RHEL, LOWC, SUSS)
THALER 73 PR 07 2569 BLOODWO 72B PR 06 29 BLOODWO 72B PR 07 2569 BLOODWO 72B PR 06 29 BLOODWO 72B PR 29 316 LAYTER 72 PRL 29 315 THALER 72 PRL 29 315 THO NC AA 796 STRUGALSKI 71 NP B27 429 HAPPE, Kotlewski, Lee, Stein, Thaler (COLU) BAGLIN 70 NP B22 66 BUTTRAM 70 PRL 25 1358 COX 70B PRL 24 534 DEVONS 70 PR D1 1030 COX 70B PRL 24 534 DEVONS 70 PR D1 1936 COX 70B PRL 25 1358 HARDOLD 69 PR D1 1936 Thesis Nevis 181 BAGLIN 69 PL 29B 445 Also 70 NP B22 66 PR 12 102 BAGLIN 69 PL 29B 445 BAGLIN 69 PL 29B 45 BAGLIN 69 PL 29B 45 BAGLIN 69 PL 27B 466 FR 12 10 895 FROMBUT 660 PR 12 1569 FR 12 10 895 FROMBUT 67 PR D1 1596 FR 12 1569 FR 12 1569 FR 12 1569 BALTAY 67B PRL 19 1495 BEMPORAD 67 PL 28B 307 BALTAY 67B PRL 19 1495 BEMPORAD 67 PL 28B 307 BALTAY 67B PRL 19 1495 BEMPORAD 67 PR 12 159 560 BUILING 67 PR			PR D7 2565		+Appel, Kotlewski, Lee, Stein	n, Thaler (COLU)
BLOODWO			PR D7 2569		+Appel, Kotlewski, Layter, Lo	ee, Stein (COLU)
THALER 72 PRL 29 313	BLOODWO		NP B39 525		Bloodworth, Jackson, Prenti	ice, Yoon (TNTO)
BASILE 71D NC 3A 796	LAYTER		PRL 29 316		+Appel, Kotlewski, Lee, Stein	n, Thaler (COLU)
STRUGALSKI 71 NP B27 429	BASILE	71D	NC 3A 796		+Bollini, Dalpiaz, Frabetti+	(CERN, BGNA, STRB)
BUITRAM 70	STRUGALSKI				+Chuvilo, Gemesy, Ivanovskay	(JINR) + (JINR) (FPOL MADE STER)
CARPENTER 70 PR D1 1303 + Binkley, Chapman, Cox, Dagan+ (DUKE) COX 70B PRL 24 534 + Abolins, Dahl, Davies, Hoch, Kirz+ (LRL) COLU, SRL) Fortney, Golson (DUKE) COX 70 PR D2 2564 + Abolins, Dahl, Davies, Hoch, Kirz+ (COLU, BRL) Gormley Cox 70B Theiss levels 181 September 191 Septembe	BUTTRAM		PRL 25 1358		+Kreisler, Mischke	(PRIN)
DANBURG 70					+Binkley, Chapman, Cox, Da	gan+ (DUKE)
SORMLEY 70			PR D2 2564		+Abolins, Dahl, Davies, Hoch	n, Kirz+ (LRL)
Also 708 Thesis Nevis 181 Gormley GCOLU					+Grunhaus, Kozlowski, Neme	thy+ (COLU, SYRA)
Also 70 NP B22 66						(COLU)
HYAMS						(EPOL, UCB, MADR, STRB)
BULLOCK	HYAMS	69	PL 29B 128		+Koch, Potter, VonLindern+	(CERN, MPIM)
BULLOCK					+Paty, Baglin, Bingham+	(STRB, MADR, EPOL, UCB)
GORMLEY 68C PRL 21 402 +1syman, Lee, Nash, Peoples+ COLU, BNL)			PL 27B 402		+Esten, Fleming, Govan, Her	nderson+ (LOUC)
WEHMANN 68 PRL 20 748					+Hough, Cohn+ (BNL, +Hyman Lee, Nash Peoples	ORNL, UCND, TENN, PENN) + (COLU. BNL)
BAGLIN 678 BAPS 12 567 +Bezaguet, Degrange+ (EPOL, UCB) BALTAY 678 PRI 19 1498 +Franzini, Kim, Newman+ (COLU, BRAN) BEMPORAD 67 PL 258 380 +Franzini, Kim, Newman+ (COLU, BRAN) BILLING 67 PL 258 435 +Braccini, Foa, Lubelsmey+ (PISA, BONN) BUNIATOV 67 PL 258 435 +Peterson, Stenger, Chiu+ (LOUC, OXF) ESTEN 67 PL 258 550 +Zavattini, Deinet+ (CERN, KARI) CENCE 67 PRL 19 1393 +Peterson, Stenger, Chiu+ (HAWA, LRI) FELDMAN 67 PRL 18 1868 +Franzini, Kim, Newman+ (COU, OXF) FELDMAN 67 PRL 18 1868 +Peterson, Stenger, Chiu+ (HAWA, ERI) FLATTE 67 PRL 18 1868 +Franzini, Kim, Newman+ (COU, OXF) FLATTE 67 PRL 18 1866 +Franzini, Kim, Newman+ (COU, OXF) FLATTE 67 PRL 18 1807 (LNL) ALF 67 PRL 18 186 +Franzini, Kim, Newman+ (COU,	WEHMANN	68	PRL 20 748		+Engels+ (HARV	, CASE, SLAC, CORN, MCGI)
BALTAY 678 PRI. 19 1498	BAGLIN				+Bezaguet, Degrange+	(EPOL, UCB)
Also 67 Private Comm. 60 8 1 1 1 1 1 1 1 1 1	BALTAY	67B	PRL 19 1498		+Franzini, Kim, Newman+	(COLU, STON)
Also 67 Private Comm. 60 8 1 1 1 1 1 1 1 1 1			PKL 19 1495 PL 25B 380		+rranzini, Kim, Newman+ +Braccini, Foa. Lubeismev+	(COLU, BRAN) (PISA. BONN)
BUMATOV 67 PL 258 560 +2 avattini	Also	67	Private Comm.		ion	
CENCE 67 PR. 19 1393 +Peterson, Stenger, Chiu+ (HAWA, LRL) ESTEN 67 PL 24B 115 +Ferston, Green, Chiu+ (LOUC, OXP) FELDMAN 67 PR. 18 868 +Frati, Gleeson, Halpern+ (LOUC, OXP) FLATTE 67 PR. 18 976 (LRL) FLATTE 67 PR. 18 896 +Frati, Gleeson, Halpern+ (LRL) LITCHFIELD 67 PL 24B 846 +Wohl (LRL) PRICE 67 PR. 18 1027 +Crawford (LRL) ALEF 66 PR 145 1072 Aff-Steinberger, Berley+ (COLU, RLI, PURD, WISC, VALE) CRAWFORD 66 PR. 16 6 33 +Price, Crawford (NAPL, TRST, FRAS) GROSSMAN 66 PR. 146 793 +Frice, Crawford (COLU) JONES 66 PR. 148 896 +Frasis (COLU) JONES 66 PR. 142 896 +Kraybill (YALE, BML) POSTER 67 PR. 138 652 +Peters, Meet, Loeffler+ (WISC, PURD) FOSTER 65						(ČERN, KARL)
FELDMAN 67 PRL 18 868	CENCE	67	PRL 19 1393		+Peterson, Stenger, Chiu+	(HAWA, LRL)
FLATTE 67 PR. 18 976 FLATTE 678 PR 163 1441 LITCHFIELD 67 PL 248 486 FPRICE 67 PR 18 1207 ALFF 66 PR 145 1072 CLPW 66 PR 145 1072 CLPW 66 PR 145 1072 CLPW 66 PR 146 333 DIGIUGNO 66 PR. 16 767 GROSSMAN 66 PR 146 993 FPICE, Crawford (RLR) JAMES 66 PR 142 896 JONES 66 PL 23 597 LARRIBE 66 PL 23 597 LARRIBE 67 PR 1388 652 FPSTER 67 PR 1388 652 FPSTER 68 PR 1388 652 FPSTER 69 PR 1388 1138 FOSELSCHE 69 PR 1389 322 AlfF-Steinberger, Berley, Colley FOSTER 60 PR 18 10 506 FOSELSCHE 69 PR 145 10 506 FOSELSCHE 69 PR 138 932 AlfF-Steinberger, Berley, Colley FOSELSCHE 69 PR 145 100 506 FOSELSCHE 69 PR 145 907 AlfF-Steinberger, Berley, Colley FOSELSCHE (LRL, DUKE) FOSELSCHE 60 PR 145 100 506 FO					+Frati, Gleeson, Halpern+	(PENN)
LITCHFIELD 67 PL 248 486 +Rangan, Segar, Smith + (RHEL, SACL) PRICE 67 PRI 18 1207 AffS-Steinberger, Berley + (COLU, RUTG) CLPW 66 PR 145 1072 AffS-Steinberger, Berley + (COLU, RUTG) CLPW 66 PR 146 333 +Price (SCUC, LRL, PURD, WISC, YALE CROSSMAN 66 PRI 16 767 +Giorgi, Silvestri + (NAPL, TRST, FRAS COLU, NAMES COLU, NA	FLATTE	67	PRL 18 976			(LRL)
PRICE						(RHEL, SACL)
CLPWY	PRICE		PRL 18 1207		+Crawford	(LRL)
CRAWFORD 66 PRI 16 333 +Price (LRL) DIGIUGNO 66 PRI 16 767 +Ciorgi, Silvestri+ (NAPL, TRST, FRAS) GROSSMAN 66 PR 146 993 +Price, Crawford (LRL) GRUNHAUS 66 PR 142 896 +Frice, Crawford (COLU) JAMES 66 PR 142 896 +Kraybill (YALE, BNL) JONES 66 PL 23 597 +Binnie, Duane, Horsey, Mason+ (LOIC, RHEL) FOSTER 65 PR 138B 650 +Peters, Meer, Loeffler+ (WISC, PURD) FOSTER 65B Athens Conf. +Good, Meer (WISC) FOITER 65 PR 1 15 123 +Crawford (LRL) RITTENBERG 65 PR 184B 1138 +Kraybill (VALE) FOELSCHE 64 PR 136B 496 +Kalbfleisch (LRL) FRACE 64 PR 136B 496 +Madansky, Fields+ (JHU, NWES, WOOD) PAULI 64 PR 136B 496 +Madansky, Fields+ (ROMA, FRAS) CRAWFORD 63 PRI 10 576 +Crawford, Lloyd, Fowler (LRL, DUKE) Also 66B PR 16 697 Crawford, Lloyd, Fowler (LRL, DUKE) <t< td=""><td></td><td></td><td></td><td></td><td>AITI-Steinberger, Beney+ (SCU</td><td>JC, LRL, PURD, WISC, YALE)</td></t<>					AITI-Steinberger, Beney+ (SCU	JC, LRL, PURD, WISC, YALE)
GROSSMAN 66 PR 146 993 + Price, Crawford (LRL) GRUNHAUS 66 PR 142 896 + Kraybill (COLU) JAMES 66 PR 142 896 + Kraybill (YALE, BNL) JONES 66 PR 132 597 + Binnie, Duane, Horsey, Mason+ (LOIC, RHEL) FOSTER 65 PR 138B 652 + Peters, Meer, Loeffler+ (WISC, PURD) FOSTER 65 Thesis (WISC) FOSTER 65 PR 15 123 + Crawford (LRL) RITTENBERG 65 PR 15 556 + Kralbfleisch (LRL, BNL) FOELSCHE 64 PR 1348 1138 + Kraybill (YALE) KRAEMER 64 PR 136B 496 + Kraybill (YALE) KRAEMER 64 PR 136B 496 + HMadansky, Fields+ (JHU, NWES, WOOD) FAULI 64 PL 13 351 + HMuller (SACL) RACCIO 63 PRL 10 36 + HMuller (GAM, FRAS) CRAWFORD 64 PR 13 697 + Penso, Salvini+ (ROMA, FRAS) Also 66B PR 16 907 Alif-Steinberger, Berley, Colley (CIRL, DUKE) ALFF 62 PRL 9 322 Alif-Steinberger, Berley, Colley (CIRL, DUKE) BASTIEN 65 PR 114 + Penge, Dahl, Ferro-Luzzi+ (LRL)	CRAWFORD	66	PRL 16 333		+Price	(LRL)
GRUNHAUS 66 Thesis (COLU)	GROSSMAN		PR 146 993			(LRL)
JONES	GRUNHAUS		Thesis			(CÒLU)
FOSTER 65	JONES	66	PL 23 597		+Binnie, Duane, Horsey, Mas	son+ (LOIC, RHEL)
FOSTER 658 Athens Conf. +Good, Meer (WISC) FOSTER 65C Thesis +Crawford (LRL) RITTENBERG 65 PRL 15 123 +Crawford (LRL) RITTENBERG 65 PRL 15 556 +Kalbfielsch (LRL, BNL) FOELSCHE 64 PR 1348 1138 +Kraybill (YALE) RAGEMER 64 PR 1348 1138 +Kraybill (YALE) BACCI 63 PRL 13 351 +Muller (JHU, NWES, WOOD) BACCI 63 PRL 11 37 +Penso, Salvini+ (ROMA, FRAS) CRAWFORD 63 PRL 10 546 +Lloyd, Fowler (LRL, DUKE) ALFF 62 PRL 9 322 Allf-Steinberger, Berley, Colley+ (COLU, RUTG) BASTIEN 62 PRL 11 4 +Berge, Dalh, Ferro-Luzzi+ (LRL) EVALUATION FOR STATE FOR STATE FOR STATE (LRL) EVALUATION FOR STATE FOR			PL 23 600 PR 138R 452		+Leveque, Muller, Pauli+	(SACL, RHEL)
PRICE 65 PRI 15 123 +Crawford (LRL) RN	FOSTER	65B	Athens Conf.		+Good, Meer	(WISC)
RITTENBERG 65 PRL 15 556 **Kalbitesch (LRL, BNL)			Thesis		+Crawford	
FOELSCHE	RITTENBERG	65	PRL 15 556		+Kalbfleisch	(LRL, BNL)
PAULI 64 PL 13 351	FOELSCHE	64	PR 134B 1138		+Kraybill	(YALE)
BACCI CRAWFORD 63 63 PRI. 10 546 PRI. 16 907 +Penso, Salvinii- Lloyd, Fowler (ROMA, FRAS) (IRL, DUKE) Also 66B ALFF PRI. 9 307 Crawford, Lloyd, Fowler Crawford, Lloyd, Fowler Alf-Steinberger, Berley, Colley+ (BASTIEN) (LRL, DUKE) BASTIEN 62 PRI. 8 114 +Berge, Dahl, Ferro-Luzzi+ Alfress (COLU, RUTG)	PAULI	64	PL 13 351		+Muller	(SACL)
Also 66B PRL 16 907 Crawford, Lloyd, Fowler (LRL, DUKE) ALFF 62 PRL 9 322 Alff-Steinberger, Berley, Colley+ (COLU, RUTG) BASTIEN 62 PRL 8 114 +Berge, Dahl, Ferro-Luzzi+ (LRL)			PRL 11 37 PRL 10 546		+Penso, Salvini+ +Lloyd, Fowler	(ROMA, FRAS) (LRL. DUKF)
BASTIEN 62 PRL 8 114 +Berge, Dahl, Ferro-Luzzi+ (LRL)	Also	66B	PRL 16 907		Crawford, Lloyd, Fowler	(LRL, DUKE)
						(LRL)
			PRL 8 329			(CNRC, BNL)
		_		-		

(CANC C.U.L.)

Meson Particle Listings $f_0(400-1200)$

 $f_0(400-1200)$

$$I^{G}(J^{PC}) = 0^{+}(0^{+})$$

See "Note on scalar mesons" under $f_0(1370)$.

f_0 (400–1200) T-MATRIX POLE \sqrt{s}

Note that $\Gamma \approx 2 \text{ Im}(. \sqrt{s_{note}})$

Note tha	t $\Gamma \approx 2 \text{ Im}(\sqrt{s_{pole}})$.				
VALUE (MeV)		OCUMENT ID		TECN	COMMENT
	-500) OUR ESTIMA				
	use the following dat				_
469.5 - i178.6 470 - i250		LLER ORNQVIST			$\pi\pi \rightarrow \pi\pi$, $K\overline{K}$ $\pi\pi \rightarrow \pi\pi$, $K\overline{K}$, $K\pi$,
~ (1100 - i300)	А	MSLER	958	CBAR	$ \frac{\eta \pi}{\bar{p}\rho \rightarrow 3\pi^0} $
400 - i500		MSLER		CBAR	
1100 - i137	3,5 A	MSLER			$\bar{p}p \rightarrow 3\pi^0$
387 - i305	رر 3,6	ANSSEN	95		$\pi\pi \rightarrow \pi\pi, K\overline{K}$
525 — i269	7 A	CHASOV			$\pi \pi \rightarrow \pi \pi$
370 — i356	8 Z	OU			$\pi\pi \to \pi\pi$, $K\overline{K}$
408 - i342	3,8 Z ³ 3,9 A	อบ			$\pi\pi \to \pi\pi, KK$
$870 - i370 750 \pm 50 - i(450)$					$\pi\pi \rightarrow \pi\pi, K\overline{K}$ $\pi\pi \rightarrow \pi\pi, K\overline{K}$
$660 \pm 100 - i(320)$ $650 - i370$) ± 70) P	ROTOPOP ASDEVANT	. 73	HBC	$ \begin{array}{cccc} \pi\pi & \rightarrow & \pi\pi, & \overline{K} \\ \pi\pi & \rightarrow & \pi\pi, & \overline{K} \\ \pi\pi & \rightarrow & \pi\pi \end{array} $
symmetry and 3 Demonstrates 4 Coupled chann 5 Coupled chann 6 Analysis of da 7 Analysis of da 9 Analysis of da 10 Analysis of da and errors of 4	all light two-pseudos explicitly that $f_0(400$ explicitly that $f_0(400$ ele analysis of $\overline{p}p \rightarrow$ ta from FALVARD 88 ta from OCHS 73, ES ta from OCHS 73, GI ta from OCHS 73, GI ta from APEL 73, GR, a spuirloss, GR, a spuirloss.	calars system \leftarrow 1200) and $3\pi^0$, $\pi^0\eta\eta$ $3\pi^0$, $\pi^0\eta\eta$ \sim 5TABROOKS RAYER 74, a RAYER 74, CA	$f_0(137)$ and π^0 and π^0 $f_0(137)$ and π^0 $f_0(137)$ $f_0(137)$ $f_0(137)$ $f_0(137)$	0) are to 0 π 0 η 0 ο ο ο ο ο ο ο ο ο ο ο ο ο ο ο ο ο	n sheet II. n sheet III. ET 77, and MUKHIN 80 T 77.
f ₀ (400-1200) E <u>VALUE (MeV)</u> (400-1200) OUR	DOCUMENT IE			HRIX H	POLE PARAMETER
•	use the following dat	a for average	s, fits,	limits,	etc. • • •
780 ±30	ALDE				$p_{P}\pi^{0}\pi^{0}$
553.3± 0.5	12 ISHIDA			$\rightarrow \pi\pi$	
761 ±12	¹³ SVEC	96 RVU	E 6-1	7 π N pc	$_{olar} \rightarrow \pi^{+}\pi^{-}N$
~ 860	14 TORNQVIST	96 RVU			$K\overline{K}, K\pi, \eta\pi$
1165 ±50	15,16 ANISOVICH	95 RVU		$p \rightarrow \pi$	
	47			$\overline{p}p \rightarrow $	$\pi^0\pi^0\pi^0$, $\pi^0\pi^0\eta$, $\pi^0\eta$
~ 1000	17 ACHASOV	94 RVU		$\rightarrow \pi \pi$	
506 ±10	KAMINSKI	94 RVU		$\rightarrow \pi\pi$, <i>KK</i>
414 ±20	¹³ AUGUSTIN	89 DM2			
using the inter 13 Breit-Wigner of The fit does n 14 Uses data froic CASON 83, R metry and all 15 Uses π^0 π^0 da OCHS 73, GR	fering amplitude met it to S-wave intensity ot include f ₀ (980). n ASTON 88, OCHS OSSELET 77, and B light two-pseudoscala ta from ANISOVICH AYER 74 and ROSSI	thod. measured in 73, HYAMS EIER 72B. Colors systems. 94, AMSLEF ELET 77, and	1 π N - 5 73, A cupled R 94D, a d ηη d	→ π [−] π ARMST channe and ALE tata from	N 75, and ROSSELET 7. $^+$ N on polarized target RONG 91B, GRAYER 7 I analysis with flavor syn DE 95B, $\pi^+\pi^-$ data fro nANISOVICH 94. $^-$ 1200) and $f_0(1370)$ a
two different p	ooles.				
Analysis of da	ta from OCHS 73, ES	- ABROOK) /5, F	(USSEL	ET 77, and MUKHIN 8
	f ₀ (400–1200)	BREIT-WI	GNEF	R WID	ТН
VALUE (MeV)	DOCUMENT IL	TECN	col	MMENT	
(600–1000) OUR • • • We do not	ESTIMATE use the following dat	a for average	es, fits,	, limits,	etc. • • •
780 ±60	ALDE				$pp\pi^{0}\pi^{0}$
242.6± 1.2	18 ISHIDA			$\rightarrow \pi\pi$	
290 ±54	19 SVEC				olar $\rightarrow \pi^+\pi^-N$
~ 880	20 TORNQVIST	76 RVU			olar , K K , K π , η π
460 ±40	^{21,22} ANISOVICH	95 RVU	E π-	$p \rightarrow \pi$	
~ 3200	²³ ACHASOV	94 RVU		$\gamma \rightarrow \pi \pi$	
494 ± 5	KAMINSKI	94 RVU		$\rightarrow \pi\pi$	
494 ± 58	19 AUGUSTIN	89 DM2			

19 AUGUSTIN

89 DM2 ¹⁸ Reanalysis of data from HYAMS 73, GRAYER 74, SRINIVASAN 75, and ROSSELET 77 using the interfering amplitude method.

19 Breit-Wigner fit to S-wave intensity measured in $\pi N \to \pi^- \pi^+ N$ on polarized targets. The fit does not include $f_0(980)$.
20 Uses data from ASTON 88, OCHS 73, HYAMS 73, ARMSTRONG 918, GRAYER 74, CASON 83, ROSSELET 77, and BEIER 72B. Coupled channel analysis with flavor symmetry and all light two-pseudoscalars systems.
21 Uses $\pi^0 \pi^0$ data from ANISOVICH 94, AMSLER 94D, and ALDE 95B, $\pi^+ \pi^-$ data from OCHS 73, GRAYER 74 and ROSSELET 77, and $\eta \eta$ data fromANISOVICH 94.
22 The pole is on Sheet III. Demonstrates explicitly that $f_0(400-1200)$ and $f_0(1370)$ are two different poles.

23 Analysis of data from OCHS 73, ESTABROOKS 75, ROSSELET 77, and MUKHIN 80.

fo(400-1200) DECAY MODES

	Mode	 Fraction (Γ_i/Γ)	
Γ ₁	ππ	 dominant	
Γ_2	$\gamma\gamma$	seen	

fo(400-1200) PARTIAL WIDTHS

$\Gamma(\gamma\gamma)$			Г2
VALUE (keV)	DOCUMENT ID	TECN	COMMENT
seen	²⁴ MORGAN 9	O RVUE	$\gamma \gamma \rightarrow \pi^+ \pi^-, \pi^0 \pi^0$
	he following data for averages,	fits, limits	, etc. • • •
10±6	COURAU 8	6 DM1	$e^+e^{\pi^+\pi^-e^+e^-}$

²⁴ Analysis of data from BOYER 90 and MARSISKE 90.

fo(400-1200) REFERENCES

ALDE	97	PL B397 350	+Bellazzini, Binon+ (GAMS Collab.)	
OLLER	97	NP A620 438	J.A. Oller+ (VALE)	
ISHIDA	96	PTP 95 745	S. Ishida+ (TOKY, MIYA, KEK)	
SVEC	96	PR D53 2343	(MCGI)	
TORNQVIST	96	PRL 76 1575	+Roos (HELS)	
ALDE	95B	ZPHY C66 375	+Binon, Boutemeur+ (GAMS Collab.)	
AMSLER	95B	PL B342 433	+Armstrong, Brose+ (Crystal Barrel Collab.)	
AMSLER	95D	PL B355 425	+Armstrong, Spanier+ (Crystal Barrel Collab.)	
ANISOVICH	95	PL B355 363	+Kondashov+ (PNPI, SERP)	
JANSSEN	95	PR D52 2690	+Pearce, Holinde, Speth (STON, ADLD, JULI)	
ACHASOV	94	PR D49 5779	+Shestakov (NOVM)	
AMSLER	94D	PL B333 277	+Anisovich, Spanier+ (Crystal Barrel Collab.)	
ANISOVICH	94	PL B323 233	+Armstrong+ (Crystal Barrel Collab.)	
KAMINSKI	94	PR D50 3145	R. Kaminski+ (CRAC, IPN)	
ZOU	94B	PR D50 591	+Bugg (LOQM)	
ZOU	93	PR D48 R3948	+Bugg (LOQM)	
ARMSTRONG	91B	ZPHY C52 389	+Barnes+ (ATHU, BARI, BIRM, CERN, CDEF)	
BOYER	90	PR D42 1350	+Butler+ (Mark II Collab.)	
MARSISKE	90	PR D41 3324	+Antreasyan+ (Crystal Ball Collab.)	
MORGAN	90	ZPHY C48 623	+Pennington (RAL, DURH)	
AUGUSTIN	89	NP B320 1	+Cosme (DM2 Collab.)	
ASTON	88	NP B296 493	+Awaji, Bienz, Bird+ (SLAC, NAGO, CINC, INUS)	
FALVARD	88	PR D38 2706	+Ajaltouni+ (CLER, FRAS, LALO, PADO)	
AU	87	PR D35 1633	+Morgan, Pennington (DURH, RAL)	
COURAU	86	NP B271 1	+Falvard, Haissinski, Jousset, Michel+ (CLER, LALO)	
CASON	83	PR D28 1586	+Cannata, Baumbaugh, Bishop+ (NDAM, ANL)	
MUKHIN	80	JETPL 32 601	+Patarakin+ (KIAE)	
		Translated from ZETFP		
BECKER	79	NP B151 46	+Blanar, Blum+ (MPIM, CERN, ZEEM, CRAC)	
ESTABROOKS	79	PR D19 2678	(CARL)	
PAWLICKI	77	PR D15 3196	+Ayres, Cohen, Diebold, Kramer, Wicklund (ANL) IJ	
ROSSELET	77	PR D15 574	+Extermann, Fischer, Guisan+ (GEVA, SACL)	
CASON	76	PRL 36 1485	+Polychronakos, Bishop, Biswas+ (NDAM, ANL) IJ	
ESTABROOKS	75	NP B95 322	+ Martin (DURH)	
SRINIVASAN	75	PR D12 681	+Helland, Lennox, Klem+ (NDAM, ANL)	
GRAYER	74	NP B75 189	+Hyams, Blum, Dietl+ (ČERN, MPIM)	
APEL	73	PL 41B 542	+Auslander, Muller+ (KARL, PISA)	
HYAMS	73	NP B64 134	+ Jones, Weilhammer, Blum, Dietl+ (CERN, MPIM)	
OCHS	73	Thesis	(MPIM, MUNI)	
PROTOPOP	73	PR D7 1279	Protopopescu, Alston-Garnjost, Galtieri, Flatte+ (LBL)	
BAILLON	72	PL 38B 555	+Carnegie, Kluge, Leith, Lynch, Ratcliff+ (SLAC)	
BASDEVANT	72	PL 41B 178	+Froggatt, Petersen (CERN)	
BEIER	72B	PRL 29 511	+Buchholtz, Mann+ (PENN)	
BENSINGER	71	PL 36B 134	+Erwin, Thompson, Walker (WISC)	
COLTON	71	PR D3 2028	+Malamud, Schlein+ (LBL, FNAL, UCLA, HAWA)	
BATON	70	PL 33B 528	+Laurens, Reignier (SACL)	
WALKER	67	RMP 39 695	(WISC)	
			•	

- OTHER DELATER DADERS -

		отн	ER RELATED PAPERS	
ABELE ANISOVICH ANISOVICH	98 97 97B	PR D57 3860 PL B395 123 ZPHY A357 123	A. Abele, Adomeit, Amsler+ +Sarantsev A.V. Anisovich+	(Crystal Barrel Collab.) (PNPI) (PNPI)
ANISOVICH ANISOVICH CLOSE	97C 97D 97B	PL B413 137 ZPHY A359 173 PR D55 5749	F. Close+	(RAL, RUTG, BEIJT)
KAMINSKI MALTMAN OLLER	97 97 97	ZPHY C74 79 PL B393 19 NP A620 438	R. Kaminski+ K. Maltman, Wolfe J.A. Oller+	(CRAC) (YORKC) (VALE)
SVEC SVEC ABELE	97 97B 96	PR D55 4355 PR D55 5727 PL B380 453	M. Svec M. Svec +Adomeit, Amsler+	(MCGI) (Crystal Barrel Collab.)
AMSLER BIJNENS	96 96	PR D53 295 PL B374 210 PRL 77 603	+Close J. Bijnens, Colangelo, Ecker+	(ZURI, RAL) (NORD, BERN, WIEN, HELS)
BONUTTI BUGG HARADA	96 96 96	NP B471 59 PR D54 1991	+Amerini, Fragiacomo+ +Sarantsev, Zou M. Harasa+	(TRSTI, TRSTT, TRIU) (LOQM, PNPI) (SYRA)
ISHIDA AMSLER AMSLER	96 95C 95F	PTP 95 745 PL 8353 571 PL B358 389	S. Ishida+ +Armstrong, Hackman+ +Armstrong, Urner+	(TOKY, MIYA, KEK) (Crystal Barrel Collab.) (Crystal Barrel Collab.)
ANTINORI BUGG GASPERO	95 95 95	PL B353 589 PL B353 378 NP A588 861	+Barberis, Bayes+ (ATHU +Scott, Zoli+	, BARI, BIRM, CERN, JINR) (LOQM, PNPI, WASH) (ROMA)
TORNQVIST AMSLER BUGG KAMINSKI ADAMO	95 94 94 94 93	ZPHY C68 647 PL B322 431 PR D50 4412 PR D50 3145 NP A558 13C	+Armstrong, Meyer+ +Anisovich+ R. Kaminski+ +Agnello+	(HELS) (Crystal Barrel Collab.) (LOQM) (CRAC, IPN) (OBELIX Collab.)
				(,

 $f_0(400-1200), \rho(770)$

GASPERO ·	93	NP A562 407		(ROMAI)
MORGAN	93	PR D48 1185	+Pennington	(RAL, DURH)
Also	93C	NC A Conf. Suppl.	Morgan	(RAL)
BOLTON	92B	PRL 69 1328	+Brown, Bunnell+	(Mark III Collab.)
SVEC	92	PR D45 55	+de Lesquen, van Rossum	(MCGI, SACL)
SVEC	92B	PR D45 1518	+de Lesquen, van Rossum	(MCGI, SACL)
SVEC	92C	PR D46 949	+de Lesquen, van Rossum	(MCGI, SACL)
RIGGENBACH	91	PR D43 127	C. Riggenbach, Gasser+	(BERN, CERN, MASA)
BAI	90C	PRL 65 2507	+Blaylock+	(Mark III Collab.)
WEINSTEIN	90	PR D41 2236	+lsgur	(TNTO)
WEINSTEIN	89	UTPT 89 03	+lsgur	(TNTO)
ASTON	88D	NP B301 525	+Awaji, Bienz+	(SLAC, NAGO, CINC, INUS)
BEVEREN	86	ZPHY C30 615	E. van Beveren+	(NIJM, BIEL)
LONGACRE	86	PL B177 223		BRAN, CUNY, DÜKE, NDAM)
ACHASOV	84	ZPHY C22 53	+Devyanin, Shestakov	(NOVM)
GASSER	84	ANP 158 142	-	
BINON	83	NC 78A 313	+Donskov, Duteil+	(BELG, LAPP, SERP, CERN)
ETKIN	828	PR D25 1786	+Foley, Lai+	(BNL, CUNY, TUFTS, VAND)
TORNQVIST	82	PRL 49 624		(HELS)
COHEN	80	PR D22 2595	+Ayres, Diebold, Kramer, F	Pawlicki+ (ANL) IJP
COSTA	80	NP B175 402	G. Costa+(BARI, BONN, C	ERN, GLAS, LIVP, MILA, WIEN)
BECKER	79B	NP B150 301	+Blanar, Blum+	(MPIM, CERN, ZEEM, CRAC)
NAGELS	79	PR D20 1633	+Rijken, Deswart	(MUM)
POLYCHRO	79	PR D19 1317	Polychronakos, Cason, Bis	hop+ (NDAM, ANL) IJP
CORDEN	78	NP B144 253	+Corbett, Alexander+	(BIRM, RHEL, TELA, LOWC)
JAFFE	77	PR D15 267,281		(MIT)
FLATTE	76	PL 63B 224		(CERN)
WETZEL	76	NP B115 208	+Freudenreich, Beusch+	(ETH, CERN, LOIC)
DEFOIX	72	NP B44 125	+Nascimento, Bizzarri+	(CDEF, CERN)



$$I^{G}(J^{PC}) = 1^{+}(1^{-})$$

THE $\rho(770)$

Written February 1998 by S. Eidelman (Novosibirsk).

Determination of the parameters of the $\rho(770)$ is beset with many difficulties because of its large width. In physical region fits, the line shape does not correspond to a relativistic Breit-Wigner function with a P-wave width, but requires some additional shape parameter. This dependence on parametrization was demonstrated long ago by PISUT 68. Bose-Einstein correlations are another source of shifts in the $\rho(770)$ line shape, particularly in the multiparticle final state systems (LAFFERTY 93).

The same model dependence afflicts any other source of the resonance parameters, such as the energy dependence of the phase shift δ_1^1 or the pole position. It is therefore not surprising that a study of $\rho(770)$ dominance in the decays of the η and η' reveals the need for specific dynamical effects in addition to the $\rho(770)$ pole (BENAYOUN 93, ABELE 97B). Recently BENAYOUN 98 compared the predictions of different Vector Meson Dominance (VMD) based models with the data on the $e^+e^- \to \pi^+\pi^-$ cross section below 1 GeV as well as with the phase and near-threshold behaviour of the timelike pion form factor. They showed that only the model based on a hidden local symmetry (HLS) is able to account consistently for all lowenergy information, if one also requires a point-like coupling $\gamma \pi^+ \pi^-$ which is excluded by common VMD but predicted by HLS.

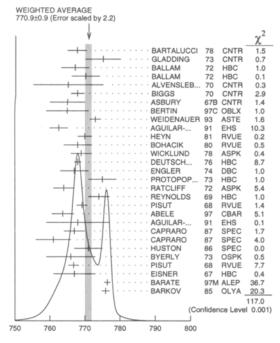
The cleanest determination of the $\rho(770)$ mass and width comes from the e^+e^- annihilation and τ -lepton decays. BARA-TE 97M showed that the charged $\rho(770)$ parameters measured from τ -lepton decays are consistent with those of the neutral one determined from e^+e^- data of BARKOV 85.

ρ(770) MASS

We no longer list 5-wave Brelt-Wigner fits, or data with high combinatorial

MIXED CHARGES

DOCUMENT ID 770.0±0.8 OUR AVERAGE Includes data from the 4 datablocks that follow this one. Error includes scale factor of 1.8. See the ideogram



ρ(770) MASS MIXED CHARGES

MIXED CHARGES, τ DECAYS and e^+e^-

<u>VALUE (MeV)</u> <u>DOCUMENT ID</u> <u>TECN</u>
The data in this block is included in the average printed for a pre TECN CHG COMMENT

776.0±0.9 OUR AVERA	GE			_
776.4±0.9±1.5	1 BARATE	97N	A ALEP	$ au^- ightarrow \pi^- \pi^0 u_{ au}$
775.9 ± 1.1	² BARKOV	85	OLYA 0	$e^+e^- \rightarrow \pi^+\pi^-$
• • • We do not use the	e following data for average	s, fit	s, limits, etc	. • • •
775.1±0.7	³ BENAYOUN	98	RVUE	$e^+e^{\pi^+\pi^-}$
764.1±0.7	4 O'CONNELL	97	RVUE	$e^{+}\stackrel{\mu^{+}\mu^{-}}{e^{-}\rightarrow\pi^{+}\pi^{-}}$
757.5±1.5	⁵ BERNICHA	94	RVUE	$e^+e^- \rightarrow \pi^+\pi^-$
768 ±1	⁶ GESHKEN	89	RVUE	$e^+e^- \rightarrow \pi^+\pi^-$

CHARGED ONLY, HADROPRODUCED

2430

140k

4000

770 ± 4

765 + 10

765 ± 5

 767.7 ± 1.9

ANT DE [WEA]	EVIS	DOCUMENT ID				
The data in this b	lock is included	in the average pri	nted	for a pre	vious	datablock.
766.5±1.1 OUR A	WERAGE					
763.7±3.2		ABELE	97	CBAR		$\bar{p}n \rightarrow \pi^-\pi^0\pi^0$
768 ±9		AGUILAR	91	EHS		400 pp
767 ±3	2935	⁷ CAPRARO	87	SPEC	-	200 π − Cu → π − π ⁰ Cu
761 ±5	967	7 CAPRARO	87	SPEC	-	200 π Pb → π − π Pb
771 ±4		HUSTON	86	SPEC	+	202 π ⁺ A → π ⁺ π ⁰ A
766 ±7	6500	8 BYERLY	73	OSPK	_	5 π ⁻ ρ
766.8±1.5	9650	⁹ PISUT	68	RVUE	_	1.7-3.2 π p, t <10
767 ±6	900	⁷ EISNER	67	HBC		4.2 π^{-} p, t < 10
NEUTRAL ON	LY. PHOTOI	PRODUCED				
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
The data in this b	lock is included	I in the average pri	nted	for a pre	vious	datablock.
768.1± 1.3 OUR	AVERAGE					
767.6± 2.7		BARTALUCCI	78	CNTR	0	$\gamma p \rightarrow e^+ e^- p$
775 ± 5		GLADDING	73	CNTR	0	2.9-4.7 yp
767 ± 4	1930	BALLAM	72	HBC	0	2.8 yp

BALLAM

BIGGS ASBURY

ALVENSLEB.

72 HBC

70

CNTR

67B CNTR 0

CNTR 0

0

4.7 yp

 $\gamma A, t < 0.01$

<4.1 γC →

1

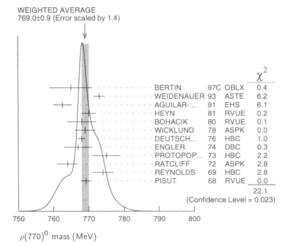
NEUTRAL ONLY, (JINEK F	KEAC HONS			
VALUE (MeV)	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
The data in this block	is included	in the average printer	d for a pre	evious	datablock

769.0±0.9 OUR AVE	RAGE Err	or includes scale fa	ctor	of 1.4.	See th	ne ideogram below.
765 ±6		BERTIN	970	OBLX		$\begin{array}{c} 0.0 \ \overline{p}p \rightarrow \\ \pi^{+}\pi^{-}\pi^{0} \end{array}$
773 ±1.6		WEIDENAUER	93	ASTE		$\overline{p}p \rightarrow \pi^{+}\pi^{-}\omega$
762.6±2.6		AGUILAR	91	EHS		400 pp
770 ±2		10 HEYN	81	RVUE		Pion form factor
768 ±4	11	1,12 BOHACIK	80	RVUE	0	
769 ±3		8 WICKLUND	78	ASPK	0	3,4,6 π^{\pm} N
768 ±1	76000	DEUTSCH	76	нвс	0	16 π ⁺ ρ
767 ±4	4100	ENGLER	74	DBC	0	$6 \pi^+ n \rightarrow$
						$\pi^+\pi^-p$
775 ±4	32000	11 PROTOPOP	73	HBC	0	7.1 $\pi^+ p$, $t < 0.4$
764 ±3	6800	RATCLIFF	72	ASPK	0	15 $\pi^- p$, $t < 0.3$
774 ±3	1700	REYNOLDS	69	HBC	0	2.26 π ⁻ p
769.2±1.5	13300	13 PISUT	68	RVUE	0	1.7-3.2 $\pi^- p$, t <10
• • We do not use	the followir	ng data for average	s, fit	s, limits,	etc.	• • •
777 ±2	4943	14 ADAMS	97	E665		$470 \mu p \rightarrow \mu XE$
770 ±2		15 BOGOLYUB	97	MIRA		32 p p →
						$\pi^+\pi^-X$
768 ±8		15 BOGOLYUB	97	MIRA		32 <i>pp</i> →
				. _		$\pi^+\pi^-X$
761.1±2.9		DUBNICKA	89			π form factor
777.4±2.0		16 CHABAUD	83		0	17 $\pi^- p$ polarized
769.5±0.7	1.	L,12 LANG	79		0	
770 ±9		12 ESTABROOKS	74	RVUE	0	17 $\pi^- p \rightarrow$
773.5±1.7	11200	7 JACOBS	72	нвс	0	π ⁺ π ⁻ n 2.8 π ⁻ p

HYAMS

68 OSPK 0

 $11.2 \pi^{-} D$



- ¹ From the Gounaris-Sakurai parametrization of the pion form factor. The second error is a model error taking into account different parametrizations of the pion form factor.
- ² From the Gounaris-Sakurai parametrization of the pion form factor.
- The data of BARKOV 85 and near-threshold behavior of the time-like pion form factor in the hidden local symmetry model. 4 A fit of BARKOV 85 data assuming the direct $\omega \pi \pi$ coupling.
- 5 Applying the S-matrix formalism to the BARKOV 85 data.
 6 Includes BARKOV 85 data. Model-dependent width definition.
- ⁷ Mass errors enlarged by us to Γ/\sqrt{N} ; see the note with the $K^*(892)$ mass.
- ⁸ Phase shift analysis. Systematic errors added corresponding to spread of different fits. ⁹ From fit of 3-parameter relativistic P-wave Breit-Wigner to total mass distribution. Includes BATON 68, MILLER 678, ALFF-STEINBERGER 66, HAGOPIAN 66, HAGOPIAN 668, JACOBS 668, JAMES 66, WEST 66, BLIEDEN 65 and CARMONY 64.
- 10 HEYN 81 includes all spacelike and timelike F_π values until 1978.
- ¹¹ From pole extrapolation.

775 ±3

2250

- 12 From phase shift analysis of GRAYER 74 data.
- 13 includes MALAMUD 69, ARMENISE 68, BACON 67, HUWE 67, MILLER 67B, ALFF-STEINBERGER 66, HAGOPIAN 66, HAGOPIAN 66B, JACOBS 66B, JAMES 66, WEST 66, GOLDHABER 64, ABOLINS 63. 14 Systematic errors not evaluated.
- 15 Systematic effects not studied.
- 16 From fit of 3-parameter relativistic Breit-Wigner to helicity-zero part of P-wave intensity. CHABAUD 83 includes data of GRAYER 74.

$m_{\rho(770)^0} - m_{\rho(770)^{\pm}}$

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT
0.1±0.9 OUR	WERAGE	_				
0.0 ± 1.0		17 BARATE	97N	ALEP		$\tau^- \rightarrow \pi^- \pi^0 \nu_{\tau}$
-4 ±4	3000	18 REYNOLDS	69	HBG	-0	2.26 x - p
-5 ±5	3600	18 FOSTER	68	HBC	±0	0.0 p p
2.4 ± 2.1	22950	¹⁹ PISUT	68	RVUE		$\pi N \rightarrow \rho N$
17 Using the com	pilation of e+	e [—] data from BAI	RKOV	85.		

¹⁸ From quoted masses of charged and neutral modes.

¹⁹ Includes MALAMUD 69, ARMENISE 68, BATON 68, BACON 67, HUWE 67, MILLER 67B, ALFF-STEINBERGER 66, HAGOPIAN 66, HAGOPIAN 66B, JACOBS 66B, JAMES 66, WEST 66, BLIEDEN 65, CARMONY 64, GOLDHABER 64, ABOLINS 63.

ρ(770) RANGE PARAMETER

The range parameter R enters an energy-dependent correction to the width, of the form $(1+q_f^2~R^2)/(1+q^2~R^2)$, where q is the momentum of one of the pions in the $\pi\pi$ rest system. At resonance, q=

VALUE (GeV ⁻¹)	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT
5.3 ^{+0.9} -0.7	CHABAUD	83	ASPK	0	17 $\pi^- p$ polarized

ρ(770) WIDTH

We no longer list S-wave Breit-Wigner fits, or data with high combinatorial background.

MIXED CHARGES

DOCUMENT ID

150.7±1.1 OUR AVERAGE Includes data from the 4 datablocks that follow this one.

MIXED CHARGES, + DECAYS and e+e-

TECN CHG COMMENT The data in this block is included in the average printed for a previous datablock.

150.5 ± 2.7 OUR AVERAGE

$150.5 \pm 1.6 \pm 6.3$	²⁰ BARATE	97M A	LEP	$\tau^- \rightarrow \pi^- \pi^0 \nu_{\tau}$
150.5 ± 3.0	²¹ BARKOV	85 O	LYA 0	$e^+e^- \rightarrow \pi^+\pi^-$
• • • We do not use th	e following data for averag	ges, fîts, i	lmits, etc.	
147.9±1.5	²² BENAYOUN	98 R	VUE	$e^+e^{\pi^+\pi^-}$
145.0±1.7	23 O'CONNELL	97 R	VUE	$\mu^+\mu^-$
142.5 ± 3.5	24 BERNICHA	94 R		$e^+e^- \rightarrow \pi^+\pi^-$
138 ±1	²⁵ GESHKEN	89 R	VUE	$e^+e^- \rightarrow \pi^+\pi^-$

CHARGED ONLY, HADROPRODUCED

DOCUMENT ID TECN CHG COMMENT The data in this block is included in the average printed for a previous datablock.

150.2± 2.4 OUR FIT

150.2± 2.4 OUR AVERAGE

152.8 ± 4.3		ABELE	97	CBAR		$\overline{p}n \rightarrow \pi^{-}\pi^{0}\pi^{0}$
155 ±11	2935	²⁶ CAPRARO	87	SPEC	-	200 π − Cu → π − π 0 Cu
154 ±20	967	²⁶ CAPRARO	87	SPEC	_	200 π Pb →
150 ± 5		HUSTON	86	SPEC	+	$\pi^- \pi^0 Pb$ 202 $\pi^+ A \rightarrow \pi^+ \pi^0 A$
146 ±12	6500	27 BYERLY	73	OSPK	_	5 π P
148.2± 4.1	9650	²⁸ PISUT	68	RVUE	-	1.7-3.2 π ⁻ p, t <10
146 +13	900	FISNER	67	HRC	_	42 7 n t < 10

NEUTRAL ONLY, PHOTOPRODUCED

DOCUMENT ID EVT5 TECN CHG COMMENT The data in this block is included in the average printed for a previous datablock.

150.9± 3.0		BARTALUCCI	78	CNTR	0	$\gamma p \rightarrow e^+e^-p$
• • • We do not	use the followin	g data for averages	s, fits	i, limits,	etc.	• • •
147 ±11		GLADDING	73	CNTR	0	2.9-4.7 γp
155 ±12	2430	BALLAM	72	HBC	0	4.7 yp
145 ±13	1930	BALLAM	72	HBC	0	2.8 γp
140 ± 5		ALVENSLEB	70	CNTR	0	γA , $t < 0.01$
146.1 ± 2.9	140k	BIGGS	70	CNTR	0	<4.1 γC →
						$\pi^+\pi^-$ C
160 ±10		LANZEROTTI	68	CNTR	0	γP
130 ± 5	4000	ASBURY	67B	CNTR	0	γ + Pb

$\rho(770)$

163 ±15

NEUTRAL ONLY, OTHER REACTIONS

VALUE (MeV)	EVTS	DOCUMENT ID	TECN.	CHG	COMMENT	
The data in this block	is included i	n the average printed	for a pre	vious o	atablock.	_

	i ne	data	a in this block	is includ	led in	the average prin	tea 1	or a pre	vious c	iatabiock.
						es scale factor of Includes scale fa				
				MAGE	EHOL					
-	122	±2	20			BERTIN	97 C	OBLX		0.0 p p →
	145.7	7+	5.3			WEIDENAUER	93	ASTE		$\pi^{+}\pi^{-}\pi^{0}$ $\bar{p}p \rightarrow \pi^{+}\pi^{-}\omega$
	144.9	_					89			π form factor
					29.30		07		_	A TOTAL INCLOS
	148	_			27,00	BUHACIK	80			
	152	±	9		21	WICKLUND	78	ASPK	0	$3,4,6 \pi^{\pm} pN$
:	154	±	2	76000		DEUTSCH	76	HBC	0	16 π ⁺ p
	157	±	8	6800		RATCLIFF	72	ASPK	0	15 $\pi^- p$, $t < 0.3$
1	143	±	8	1700		REYNOLDS	69	HBC	0	2.26 π ⁻ p
•	• •	• ٧	√e do πot use t	he follo	wing d	ata for averages	, fits	, limits,	etc. •	• •
1	146	±	3	4943	31	ADAMS	97	E665		470 $\mu p \rightarrow \mu XB$
:	160.0	<u>+</u>	4.1 4.0		32	CHABAUD	83	ASPK	0	17 $\pi^- p$ polarized
:	155	±	1		33	HEYN	81	RVUE	0	π form factor
:	148.0	θ±	1.3		29,30	LANG	79	RVUE	0	
:	146	±:	14	4100		ENGLER	74	DBC	0	$6 \pi^+ n \rightarrow \pi^+ \pi^- p$
;	143	#:	13		30	ESTABROOKS	74	RVUE	0	$ \begin{array}{c} \pi^- p \rightarrow \\ \pi^+ \pi^- n \end{array} $
	160	±:	10	32000	29	PROTOPOP	73	нвс	0	$7.1 \pi^{+} p$, $t < 0.4$
	145			2250		HYAMS		OSPK		11.2 π ρ
	143	Ŧ.		2230		1,1714/2	-0	OUTK	•	11.2 " P

 $^{\rm 20}\,{\rm From}$ the Gounarls-Sakural parametrization of the pion form factor. The second error is a model error taking into account different parametrizations of the pion form factor.

68 RVUE 0

 $1.7-3.2 \pi^{-} p, t$ <10

21 From the Gounaris-Sakural parametrization of the pion form factor.

34 PISUT

²² Using the data of BARKOV 85 and near-threshold behavior of the time-like pion form factor in the hidden local symmetry model.

 23 A fit of BARKOV 85 data assuming the direct $\omega\pi\pi$ coupling. 24 Applying the S-matrix formalism to the BARKOV 85 data.

25 Includes BARKOV 85 data. Model-dependent width definition.

 26 Width errors enlarged by us to $4\Gamma/\sqrt{N}$; see the note with the $K^*(892)$ mass.

Width errors enlarged by us to 41/y/r, see the most with the x (0.25) mass.
 Phase shift analysis. Systematic errors added corresponding to spread of different fits.
 From fit of 3-parameter relativistic P-wave Breit-Wigner to total mass distribution. Includes BATON 68, MILLER 67B, ALFF-STEINBERGER 66, HAGOPIAN 66, HAGO-PIAN 66B, JACOBS 66B, JAMES 66, WEST 66, BLIEDEN 65 and CARMONY 64.

²⁹ From pole extrapolation.

30 From phase shift analysis of GRAYER 74 data.

 $^{31}\,\mathrm{Systematic}$ errors not evaluated.

32 From fit of 3-parameter relativistic Breit-Wigner to helicity-zero part of P-wave intensity. CHABAUD 83 includes data of GRAYER 74.

 33 HEYN 81 Includes data of Grater 14. 34 HEYN 81 Includes all spacelike and timelike F_π values until 1978. 34 Includes MALAMUD 69, ARMENISE 68, BACON 67, HUWE 67, MILLER 678, ALFF-STEINBERGER 66, HAGOPIAN 66, HAGOPIAN 66B, JACOBS 66B, JAMES 66, WEST 66, GOLDHABER 64, ABOLINS 63.

$\Gamma_{\rho(770)^0} - \Gamma_{\rho(770)^{\pm}}$			
VALUE	DOCUMENT_ID	TECN	COMMENT
-0.1±1.9	35 BARATE	97M ALEP	$\tau^- \rightarrow \pi^- \pi^0 \nu_{\tau}$
35 Using the compilation of	e+e- data from BAR	KOV 85.	

p(770) DECAY MODES

	Mode		ale factor/ dence level
Γ ₁	$\pi\pi$	~ 100 %	
		$\rho(770)^{\pm}$ decays	
Γ_2	$\pi^{\pm}\pi^{0}$	~ 100 %	
Γ_3	$\pi^{\pm}\pi^{0}$ $\pi^{\pm}\gamma$	$(4.5 \pm 0.5) \times 10^{-4}$	S=2.2
Гд	$\pi^{\pm}\eta$	< 6 × 10 ⁻³	CL=84%
Γ ₅	$\pi^{\pm}\pi^{+}\pi^{-}\pi^{0}$	$< 2.0 \times 10^{-3}$	CL=84%
		$\rho(770)^0$ decays	
Γ ₆	$\pi^+\pi^-$	~ 100 %	
Γ ₇	$\pi^+\pi^-\gamma$	$(9.9 \pm 1.6) \times 10^{-3}$	
Γ_8	$\pi^{0}\gamma$	$(6.8 \pm 1.7) \times 10^{-4}$	
Γ۹	$\eta\gamma$	$(2.4 \begin{array}{c} +0.8 \\ -0.9 \end{array}) \times 10^{-4}$	S=1.6
Γ ₁₀	$\mu^+\mu^-$	[a] $(4.60\pm0.28)\times10^{-5}$	
Γ11	e+ e-	[a] $(4.49\pm0.22)\times10^{-5}$	
Γ12	$\pi^{+}\pi^{-}\pi^{0}$	< 1.2 × 10 ⁻⁴	CL=90%
Γ13	$\pi^{+}\pi^{-}\pi^{+}\pi^{-}$	< 2 × 10 ⁻⁴	CL=90%
Γ ₁₄	$\pi^{+}\pi^{-}\pi^{0}\pi^{0}$	< 4 × 10 ⁻⁵	CL=90%

[a] The $e^+\,e^-$ branching fraction is from $e^+\,e^- \to \pi^+\pi^-$ experiments only. The $\omega \rho$ interference is then due to $\omega \rho$ mixing only, and is expected to be small. If $e\mu$ universality holds, $\Gamma(\rho^0 \to \mu^+ \mu^-) = \Gamma(\rho^0 \to e^+ e^-)$ \times 0.99785.

CONSTRAINED FIT INFORMATION

An overall fit to the total width and a partial width uses 10 measurements and one constraint to determine 3 parameters. The overall fit has a $\chi^2 = 10.7$ for 8 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\left<\delta p_i \delta p_j \right>/(\delta p_i \cdot \delta p_j)$, in percent, from the fit to parameters p_i , including the branching fractions, $x_i \equiv \Gamma_i/\Gamma_{\text{total}}$. The fit constrains the x_i whose labels appear in this array to sum to one.

	Mode	Rate (MeV)	Scale factor
Γ ₂ Γ ₃	$\pi^{\pm}\pi^{0}$ $\pi^{\pm}\gamma$	150.2 ±2.4 0.068±0.007	2.3

CONSTRAINED FIT INFORMATION

An overall fit to the total width, a partial width, and a branching ratio uses 10 measurements and one constraint to determine 4 parameters. The overall fit has a $\chi^2 = 9.9$ for 7 degrees of freedom.

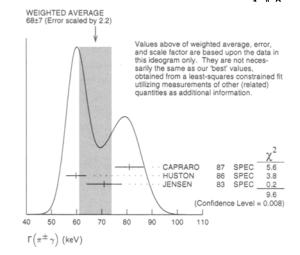
The following off-diagonal array elements are the correlation coefficients $\left<\delta p_i \delta p_j \right>/(\delta p_i \cdot \delta p_j)$, in percent, from the fit to parameters p_i , including the branching fractions, $x_i \equiv \Gamma_i/\Gamma_{\text{total}}$. The fit constrains the x_i whose labels appear in this array to sum to one.

$$\begin{array}{c|ccccc} x_{10} & -79 & & & \\ x_{11} & -61 & 0 & & \\ \hline \Gamma & 16 & 0 & -27 & & \\ \hline & x_6 & x_{10} & x_{11} & & & \end{array}$$

Mode		Rate (MeV)	Scale factor
Γ ₆	$\pi^+\pi^-$	150.8 ±2.0	1.3
Γ10	$\mu^+\mu^-$	[a] 0.0069 ± 0.0004	
Γ11	e+ e-	[a] 0.00677 ± 0.00032	

ρ(770) PARTIAL WIDTHS

Г(:	$\pi^{\pm}\gamma$)							Гз
VAL	UE (ke	V)		DOCUMENT ID		TECN	CHG	COMMENT	
68	±7	OUR F	T Error	includes scale factor of	f 2.3.				
68	±7	OUR A	VERAGE	Error includes scale fa	actor o	f 2.2. S	ee the	ideogram belov	√ .
81	±4	±4		CAPRARO	87	SPEC	-	$200 \pi^- A \rightarrow$	
59.	8±4.	0		HUSTON	86	SPEC	+ "	202 π+ A →	
71	±7			JENSEN	83	SPEC	-	156-260 7	٠ →



Meson Particle Listings $\rho(770)$

Γ(e+e-)				Г11
VALUE (keV)	DOCUMENT I	D TECN	COMMENT	
6.77±0.32 OUR FIT				_
6.77±0.10±0.30 • • • We do not use the fo	BARKOV		$e^+e^- \rightarrow \pi^+\pi^-$	•
6.3 ±0.1	36 BENAYOUN		$e^+e^- \rightarrow \pi^+\pi^-$	
0.3 ±0.1	BENATOON	70 KVOL	$\mu^+\mu^-$	•
³⁶ Using the data of BARI	KOV 85 and near-thre	shold behavior	of the time-like plo	n form
factor in the hidden loca	il symmetry model.			
$\Gamma(\pi^0\gamma)$				Га
VALUE (keV)	DOCUMENT I	D TECN	COMMENT	
• • • We do not use the fo	llowing data for avera	ges, fits, limits,	etc. • • •	
121±31	DOLINSKY	89 ND	$e^+e^- \rightarrow \pi^0 \gamma$	
[/=a\				Го
$\Gamma(\eta\gamma)$ VALUE (keV)	DOCUMENT I	D TECN	COMMENT	19
• • • We do not use the form				
62±17	37 DOLINSKY	89 ND	$e^+e^- \rightarrow n\gamma$	
37 Solution corresponding				
	ρ(770) BRANCHII	NG RATIOS		
r/_±_\ /r/\				Γ4/Γ1
$\Gamma(\pi^{\pm}\eta)/\Gamma(\pi\pi)$			6116 601 11 T	4/11
	<u>DOCUMENT I</u>		$\pm \pi^{\pm} \rho$ above	. 2 5
<60 8		66 HBC	$\pm \pi^{\pm} \rho$ above	: 2.5
$\Gamma(\pi^{\pm}\pi^{+}\pi^{-}\pi^{0})/\Gamma(\pi\pi)$)			Γ_5/Γ_1
•	L% DOCUMENT	ID TECN	CHG COMMENT	
<20 8		66 HBC	$\pm \pi^{\pm} p$ above	2.5
• • We do not use the fe	ollowing data for avera	=		
35 ± 40	JAMES	66 HBC	+ $2.1 \pi^{+} p$	
$\Gamma(\mu^+\mu^-)/\Gamma(\pi^+\pi^-)$			1	10/F ₆
VALUE (units 10 ⁻⁵)	DOCUMENT	ID TECN	COMMENT	
4.60±0.28 OUR FIT				
4.6 ±0.2 ±0.2	ANTIPOV		$\pi^- Cu \rightarrow \mu^+ \mu^-$	π Cu
• • We do not use the fe	ollowing data for avera	iges, fits, limits	, etc. • • •	
$8.2 \begin{array}{c} +1.6 \\ -3.6 \end{array}$	38 ROTHWEL	L 69 CNTR	Photoproduction	
5.6 ±1.5	39 WEHMANN	I 69 OSPK	12 π^- C, Fe	
$9.7 \begin{array}{l} +3.1 \\ -3.3 \end{array}$	⁴⁰ HYAMS	67 OSPK	11 π Li, Η	
-3.3 38 Possibly large ρ - ω Inter		reace the minu	e arror	
39 Result contains 11 ± 1				on the
correction takes accoun	t of possible $ ho ext{-}\omega$ interi	ference and the		
upper limit of $\omega \rightarrow \mu^{-1}$ 40 HYAMS 67's mass reso			voluded	
	acion is 20 MeV. The	w region was t		
$\Gamma(e^+e^-)/\Gamma(\pi\pi)$				Г11/Г1
VALUE (units 10 ⁻⁴)	DOCUMENT		COMMENT	11/ . 1
0.41 ± 0.05				
	BENAKSAS			
$\Gamma(n\gamma)/\Gamma_{n+1}$	BENAKSAS			
$\Gamma(\eta \gamma)/\Gamma_{\text{total}}$		72 OSPK	e+ e-	Г9/Г
VALUE (units 10-4)	DOCUMENT	5 72 OSPK		
VALUE (units 10 ⁻⁴) 2.4 ^{+0.8} / _{-0.9} OUR AVERAGE	DOCUMENT	5 72 OSPK	e+ e-	
VALUE (units 10 ⁻⁴) 2.4 ^{+0.8} / _{-0.9} OUR AVERAGE	DOCUMENT	5 72 OSPK ID <u>TECN</u> actor of 1.6.	e+e- CHG COMMENT 0.54-1.04	Г ₉ /Г
VALUE (units 10-4)	DOCUMENT Error includes scale for	5 72 OSPK ID TECN actor of 1.6. N 96 RVUE	e+e- CHG COMMENT 0.54-1.04 e+e-	Γ ₉ /Γ
2.4+0.8 OUR AVERAGE 1.9+0.6 0.8	DOCUMENT Error includes scale for 41 BENAYOUI 42 ANDREWS	5 72 OSPK ID TECN actor of 1.6. N 96 RVUE 77 CNTR	e+e- CHG COMMENT 0.54-1.04 e+e- 0 6.7-10 γ C	Γ ₉ /Γ
2.4+0.8 OUR AVERAGE 1.9+0.8 3.6±0.9	DOCUMENT Error includes scale for 41 BENAYOUI 42 ANDREWS	ID TECN TECN TECN TECN TECN TECN TECN TECN	e+e- CHG COMMENT 0.54-1.04 e+e- 0 6.7-10 γ C	Γ ₉ /Γ
VALUE (units 10 ⁻⁴) 2.4+0.8 OUR AVERAGE 1.9+0.6 3.6±0.9 ■ ■ We do not use the f 4.0±1.1 41 Reanalysis of DRUZHII	DOCUMENT Error includes scale for the scale	S 72 OSPK ID TECN actor of 1.6. N 96 RVUE 77 CNTR ages, fits, limits 89 ND 9, and DOLINS	e^+e^- CHG COMMENT 0.54-1.04 e^+e^- 0 6.7-10 γ C 1, etc. • • • $e^+e^- \rightarrow$ KY 91 taking into	Γ ₉ /Γ
2.4 + 0.8 OUR AVERAGE 1.9 + 0.6 1.9 + 0.6 3.6 ± 0.9 • • • We do not use the f 4.0 ± 1.1 41 Reanalysis of DRUZHII a triangle anomaly con	DOCUMENT Error includes scale for the scale	ID TECN actor of 1.6. N 96 RVUE 77 CNTR ages, fits, limits 8 ND 9, and DOLINS p, miterferen	e^+e^- CHG COMMENT 0.54-1.04 e^+e^- 0 6.7-10 γ C 1, etc. • • • $e^+e^- \rightarrow$ KY 91 taking into	Γ ₉ /Γ
2.4+0.8 OUR AVERAGE 1.9+0.6 1.9+0.6 3.6±0.9 • • • We do not use the f 4.0±1.1 41 Reanalysis of DRUZHII a triangle anomaly con 42 Solution corresponding	DOCUMENT Error includes scale for the scal	ID TECN actor of 1.6. N 96 RVUE 77 CNTR ages, fits, limits 8 ND 9, and DOLINS p, miterferen	e^+e^- CHG COMMENT 0.54-1.04 e^+e^- 0 6.7-10 γ C 1, etc. • • • $e^+e^- \rightarrow$ KY 91 taking into	Γ_9/Γ $\rightarrow \eta \gamma$ $\downarrow u$ $\eta \gamma$ account
2.4 + 0.8 OUR AVERAGE 1.9 + 0.6 1.9 + 0.6 3.6 ± 0.9 • • • We do not use the f 4.0 ± 1.1 41 Reanalysis of DRUZHII a triangle anomaly con	DOCUMENT Error includes scale for 41 BENAYOUI 42 ANDREWS ollowing data for average 42 DOLINSKY 817 BUTON CONSTRUCTIVE ω-ρ in 11 Included 15 Included	TECN TECN TECN TO TECN TO THE TO TO TH	e^+e^- CHG COMMENT 0.54-1.04 e^+e^- 0 6.7-10 γ C 1, etc. • • • $e^+e^- \rightarrow$ KY 91 taking into ce solution.	Γ ₉ /Γ
2.4+0.8 OUR AVERAGE 1.9+0.6 1.9+0.6 3.6±0.9 • • We do not use the f 4.0±1.1 41 Reanalysis of DRUZHII a triangle anomaly con 42 Solution corresponding $\Gamma(\pi^+\pi^-\pi^+\pi^-)/\Gamma_{\text{tota}}$ VALUE (units 10-4)	DOCUMENT Error includes scale fit 41 BENAYOUI 42 ANDREWS ollowing data for avert 42 DOLINSKY NIN 84, DOLINSKY 8 tribution. Constructive to constructive ω-ρ in 11.54 DOCUMENT	TECN	e^+e^- CHG COMMENT 0.54-1.04 e^+e^- 0 6.7-10 γ C, etc. • • • $e^+e^- \rightarrow$ GKY 91 taking into ce solution.	Γ_9/Γ $\rightarrow \eta \gamma$ $\downarrow u$ $\eta \gamma$ account
2.4+0.8 OUR AVERAGE 1.9+0.6 1.9+0.6 3.6±0.9 • • We do not use the f 4.0±1.1 41 Reanalysis of DRUZHII a triangle anomaly con 42 Solution corresponding $\Gamma(\pi^+\pi^-\pi^+\pi^-)/\Gamma_{\text{tota}}$ VALUE (units 10-4)	DOCUMENT Error includes scale for 41 BENAYOUI 42 ANDREWS ollowing data for average 42 DOLINSKY 817 BUTON CONSTRUCTIVE ω-ρ in 11 Included 15 Included	TECN	e^+e^- CHG COMMENT 0.54-1.04 e^+e^- 0 6.7-10 γ C, etc. • • • $e^+e^- \rightarrow$ GKY 91 taking into ce solution.	Γ_9/Γ $\rightarrow \eta \gamma$ $\downarrow u$ $\eta \gamma$ account
2.4 + 0.8 OUR AVERAGE 1.9 + 0.6 1.9 + 0.6 3.6 ± 0.9 • • • We do not use the f 4.0 ± 1.1 41 Reanalysis of DRUZHII a triangle anomaly con 42 Solution corresponding $\Gamma(\pi^+\pi^-\pi^+\pi^-)/\Gamma_{\text{total}}$ $\frac{VALUE \text{ (units } 10^{-4}\text{)}}{9}$	DOCUMENT Error includes scale fi 41 BENAYOUI 42 ANDREWS ollowing data for avera 42 DOLINSKY 8 tribution. Constructive to constructive ω-ρ in 14 DOCUMENT KURDADZ	TECN	$\begin{array}{c} e^+e^-\\ \hline CHG & \underline{COMMENT}\\ 0.54-1.04\\ e^+e^-\\ 0.6.7-10\ \gamma\mathrm{C}\\ \text{, etc.} \bullet \bullet\\ e^+e^-\to\\ \text{KY 91 taking into ce solution.} \\ \\ \hline \\ \underline{COMMENT}\\ e^+e^-\to\\ \pi^+\pi^-\pi^+\pi^-\\ \end{array}$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$
2.4 + 0.8 OUR AVERAGE 1.9 + 0.6 1.9 + 0.6 3.6 ± 0.9 • • • We do not use the f 4.0 ± 1.1 41 Reanalysis of DRUZHII a triangle anomaly con 42 Solution corresponding $\Gamma(\pi^{+}\pi^{-}\pi^{+}\pi^{-})/\Gamma_{\text{tota}}$ $\frac{VALUE \text{ (units }10^{-4}\text{)}}{2}$ $= \frac{VALUE \text{ (units }10^{-4}\text{)}}{2}$	DOCUMENT Error includes scale fi 41 BENAYOUI 42 ANDREWS ollowing data for avera 42 DOLINSKY 8 tribution. Constructive to constructive ω-ρ in 11 DOCUMENT 10 KURDADZ	TECN TECN TECN TECN TECN TO THE TO TECN TO TECN TECN TECN TECN TECN TECN TECN TECN	$\begin{array}{c} e^+e^-\\ \hline CHG & COMMENT\\ \hline 0.54-1.04\\ e^+e^-\\ 0 & 6.7-10\ \gamma C\\ c, etc. \bullet \bullet \\ e^+e^- \to \\ cKY 91 & taking into ce solution.\\ \hline \\ \frac{COMMENT}{e^+e^- \to \pi^+\pi^-} \\ \end{array}$	Γ_9/Γ $\rightarrow \eta \gamma$ $\downarrow u$ $\eta \gamma$ account
2.4 + 0.8 OUR AVERAGE 1.9 + 0.6 1.9 + 0.6 3.6 ± 0.9 • • • We do not use the f 4.0 ± 1.1 41 Reanalysis of DRUZHII a triangle anomaly con 42 Solution corresponding $\Gamma(\pi^{+}\pi^{-}\pi^{+}\pi^{-})/\Gamma_{\text{tota}}$ $\frac{VALUE}{2} \text{ (units } 10^{-4})$ $\frac{VALUE}{2} \text{ (units } 10^{-4})$	DOCUMENT Error includes scale fi 41 BENAYOUI 42 ANDREWS ollowing data for avera 42 DOLINSKY 84. DOLINSKY 84 inibution. Constructive to constructive to constructive ω-ρ in EX DOCUMENT O KURDADZ T) DOCUMENT	S 72 OSPK ID TECN actor of 1.6. N 96 RVUE 77 CNTR ages, fits, limits 89 ND 9, and DOLINS ε ρ-ω interferen teerference.	$\begin{array}{c} e^+e^-\\ \hline CHG & \underline{COMMENT}\\ 0.54-1.04\\ e^+e^-\\ 0.6.7-10\ \gamma\text{C}\\ \text{, etc.} \bullet \bullet\\ e^+e^-\to\\ \text{KY 91 taking into ce solution.} \\ \hline \\ \underline{COMMENT}\\ e^+e^-\to\\ \pi^+\pi^-\pi^+\pi^-\\ \underline{CHG} & \underline{COMMENT} \end{array}$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$
2.4 + 0.8 OUR AVERAGE 1.9 + 0.6 1.9 + 0.6 3.6 ± 0.9 • • • We do not use the factor of the strange anomaly conducted a riangle anomaly conducted for the strange for the stran	DOCUMENT Error includes scale f. 41 BENAYOUI 42 ANDREWS ollowing data for aver- 42 DOLINSKY NIN 84, DOLINSKY 8 tribution. Constructive to constructive ω-ρ in LES DOCUMENT O KURDADZ T) DOCUMENT ollowing data for aver-	S 72 OSPK ID TECN actor of 1.6. N 96 RVUE 77 CNTR ages, fits, limits 89 ND 9, and DOLINS 6 p-w interferen teerference. ID TECN E 88 OLYA ID TECN ages, fits, limits	$\begin{array}{c} e^+e^-\\ \hline CHG & \underline{COMMENT}\\ 0.54-1.04\\ e^+e^-\\ 0.6.7-10\ \gamma C\\ \text{, etc.} \bullet \bullet\\ e^+e^-\rightarrow\\ \text{GKY 91 taking into ce solution.} \\ \hline \\ \underline{COMMENT}\\ e^+e^-\rightarrow\\ \pi^+\pi^-\pi^+\pi^-\\ \underline{CHG} & \underline{COMMENT}\\ \text{i, etc.} \bullet \bullet \bullet \end{array}$	Γ ₉ /Γ ηγ αccount Γ ₁₃ /Γ
2.4 ± 0.8 OUR AVERAGE 1.9 ± 0.6 1.9 ± 0.6 3.6 ± 0.9 • • • We do not use the final	DOCUMENT Error includes scale fi 41 BENAYOUI 42 ANDREWS collowing data for avering the serving se	ID TECN 10 TECN 10 TECN 10 TECN 10 TECN 11 TECN 12 TECN 13 TECN 14 TECN 15 TECN 16 TECN 16 TECN 17 TECN 18 TECN 18 TECN 18 TECN 19 HBC	e^+e^- CHG COMMENT 0.54-1.04 e^+e^- 0.6.7-10 γ C 1.etc. • • • $e^+e^- \rightarrow$ SKY 91 taking into ce solution. COMMENT $e^+e^- \rightarrow \pi^+\pi^ \pi^+\pi^-$ CHG COMMENT 1.etc. • • • • • • • • • • • • • • • • • • •	Γ ₉ /Γ πγ αccount Γ ₁₃ /Γ
2.4 ± 0.8 OUR AVERAGE 1.9 ± 0.6 1.9 ± 0.6 3.6 ± 0.9 • • • We do not use the f 4.0 ± 1.1 41 Reanalysis of DRUZHII a triangle anomaly con 42 Solution corresponding $\Gamma(\pi^{+}\pi^{-}\pi^{+}\pi^{-})/\Gamma$ tota VALUE (units 10 ⁻⁴) • • • We do not use the f 4.0 ± 1.1 4.	DOCUMENT Error includes scale fi 41 BENAYOUI 42 ANDREWS ollowing data for aver- 42 DOLINSKY NIN 84, DOLINSKY 8 tribution. Constructive to constructive ω-ρ in 11.5 DOCUMENT TO KURDADZ T) OLING ERBE CHUNG	S 72 OSPK ID TECN actor of 1.6. N 96 RVUE 77 CNTR ages, fits, limits 89 ND 9, and DOLINS ε ρ-ω interferenterference. ID TECN E 88 OLYA ID TECN ages, fits, limits 69 HBC 68 HBC	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Γ ₉ /Γ πγ αccount Γ ₁₃ /Γ
2.4 ± 0.8 OUR AVERAGE 1.9 ± 0.6 1.9 ± 0.6 3.6 ± 0.9 • • • We do not use the f 4.0 ± 1.1 41 Reanalysis of DRUZHII a triangle anomaly con 42 Solution corresponding $\Gamma(\pi^{+}\pi^{-}\pi^{+}\pi^{-})/\Gamma$ tota VALUE (units 10 ⁻⁴) • • • We do not use the f 4.0 ± 1.1 4.	DOCUMENT Error includes scale fi 41 BENAYOUI 42 ANDREWS collowing data for avering the serving se	ID TECN 10 TECN 10 TECN 10 TECN 10 TECN 11 TECN 12 TECN 13 TECN 14 TECN 15 TECN 16 TECN 16 TECN 17 TECN 18 TECN 18 TECN 18 TECN 19 HBC	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Γ ₉ /Γ πγ αccount Γ ₁₃ /Γ
2.4 + 0.8 OUR AVERAGE 1.9 + 0.6 1.9 + 0.6 3.6 ± 0.9 • • • We do not use the f 4.0 ± 1.1 41 Reanalysis of DRUZHII a triangle anomaly con 42 Solution corresponding $\Gamma(\pi^{+}\pi^{-}\pi^{+}\pi^{-})/\Gamma$ tota VALUE (units 10^{-4}) • • • We do not use the f	DOCUMENT Error includes scale fi 41 BENAYOUI 42 ANDREWS collowing data for avering the scale for a vering the	ID TECN 10 TECN 10 TECN 10 TECN 10 TECN 10 TECN 11 TECN 12 TECN 13 TECN 14 TECN 15 TECN 16 HBC 16 HBC 18 HBC	e^+e^- CHG COMMENT 0.54-1.04 e^+e^- 0 6.7-10 γ C, etc. • • • $e^+e^- \rightarrow KY$ 91 taking into ce solution. COMMENT $e^+e^- \rightarrow \pi^+\pi^-\pi^+\pi^ CHG$ COMMENT $e^+e^- \rightarrow \pi^+\pi^-\pi^+\pi^-$ 0 2.5-5.8 γ 4 0 3.2,4.2 π^- 0 16.0 π^-p	Γ ₉ /Γ
2.4 ± 0.8 OUR AVERAGE 1.9 ± 0.6 1.9 ± 0.6 3.6 ± 0.9 • • • We do not use the f 4.0 ± 1.1 41 Reanalysis of DRUZHII a triangle anomaly con 42 Solution corresponding $\Gamma(\pi^{+}\pi^{-}\pi^{+}\pi^{-})/\Gamma$ tota VALUE (units 10 ⁻⁴) • • We do not use the f <15 <20 <20 <80 $\Gamma(\pi^{+}\pi^{-}\pi^{0})/\Gamma$ total	DOCUMENT Error includes scale fi 41 BENAYOUI 42 ANDREWS ollowing data for averi 42 DOLINSKY NIN 84, DOLINSKY 8 tribution. Constructive to constructive ω-ρ in KURDADZ TO DOCUMENT Ollowing data for averi CHUNG HUSON JAMES	S 72 OSPK ID TECN actor of 1.6. N 96 RVUE 77 CNTR ages, fits, limits 89 ND 9, and DOLINS p-w interferenterference. ID TECN B 88 OLYA ID TECN ages, fits, limits 69 HBC 68 HBC 68 HBC 66 HBC	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Γ ₉ /Γ πγ αccount Γ ₁₃ /Γ
2.4 ± 0.8 OUR AVERAGE 1.9 ± 0.6 1.9 ± 0.6 3.6 ± 0.9 • • • We do not use the following the following triangle anomaly conducted a triangle anomaly conducted for the following triangle anomaly conducted for the following triangle anomaly conducted for the following triangle for the fol	DOCUMENT Error includes scale fi 41 BENAYOUI 42 ANDREWS ollowing data for aver- 42 DOLINSKY NIN 84, DOLINSKY 8 tribution. Constructive to constructive ω-ρ in 11/2 DOCUMENT O KURDADZ T) OILOWING data for aver- 10 ERBE CHUNG 10 HUSON JAMES	S 72 OSPK ID TECN actor of 1.6. N 96 RVUE 77 CNTR ages, fits, limits 89 ND 9, and DOLINS ε ρ-ω interferenterference. ID TECN E 88 OLYA ID TECN 69 HBC 68 HBC 68 HBC 66 HBC	$\begin{array}{cccc} e^+e^- \\ \hline CHG & COMMENT \\ \hline 0.54-1.04 & e^+e^- \\ 0.6-7-10 \gamma C \\ e^+e^- \rightarrow e^+e^- \rightarrow KKY 91 taking into ce solution. \\ \hline \frac{COMMENT}{e^+e^- \rightarrow \pi^+\pi^-\pi^+\pi^-} \\ \frac{CHG}{0.3-2,4.2} & \frac{COMMENT}{0.3-2,4.2} & \frac{\pi^-}{0.2} \\ 0.3-2,4.2 & \pi^-\\ 0.16.0 & \pi^-p \\ 0.2.1 & \pi^+p \\ \hline \\ \frac{COMMENT}{0.2} & \frac{COMMENT}{0.2} & \frac{COMMENT}{0.2} & \frac{COMMENT}{0.2} & \frac{COMMENT}{0.2} \\ \hline \end{array}$	Γ ₉ /Γ
2.4 + 0.8 OUR AVERAGE 1.9 + 0.6 1.9 + 0.6 3.6 ± 0.9 • • • We do not use the f 4.0 ± 1.1 41 Reanalysis of DRUZHII a triangle anomaly con 42 Solution corresponding $\Gamma(\pi^+\pi^-\pi^+\pi^-)/\Gamma$ tota VALUE (units 10 ⁻⁴) • • We do not use the f <15 <20 <20 <20 <80 $\Gamma(\pi^+\pi^-\pi^0)/\Gamma$ total VALUE (units 10 ⁻⁴) • • We do not use the f <15 <20 <20 <20 <20 <20 <20 <20 <2	DOCUMENT Error includes scale fi 41 BENAYOUI 42 ANDREWS ollowing data for aver- 42 DOLINSKY NIN 84, DOLINSKY 8 tribution. Constructive to constructive ω-ρ in 11/2 DOCUMENT O KURDADZ T) OILOWING data for aver- 10 ERBE CHUNG 10 HUSON JAMES	S 72 OSPK ID TECN actor of 1.6. N 96 RVUE 77 CNTR ages, fits, limits 89 ND 9, and DOLINS p-w interferenterference. ID TECN B 88 OLYA ID TECN ages, fits, limits 69 HBC 68 HBC 68 HBC 66 HBC	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Γ ₉ /Γ

Γ(π ⁺ π π ⁰)/Γ(π π) _{VALUE}	CL%	DOCUMENT ID		TECN	CHC	Γ ₁₂ /Γ ₁
	ic ionow	BRAMON	•	RVUE		$J/\psi \rightarrow \omega \pi^0$
~ 0.01 <0.01	84	43 ABRAMS		HBC	0	$3/\psi \rightarrow \omega \pi^{-}$ $3.7 \pi^{+} \rho$
43 Model dependent, a					•	S " P
$\Gamma(\pi^+\pi^-\pi^0\pi^0)/\Gamma_{tot}$				•		Γ ₁₄ /Γ
VALUE (units 10 ⁻⁴)		DOCUMENT ID		TECN	снс	COMMENT
<0.4	90	AULCHENKO	87C	ND	0	$\frac{\overline{e^+e^-}}{\pi^+\pi^-\pi^0\pi^0}$
• • • We do not use the	ne follow	ing data for average	s, fits	, limits,	etc	π ⁻ π ⁻ π ⁰ π ⁰ •••
<2	90	KURDADZE		OLYA		$e^+e^{\pi^+\pi^-\pi^0\pi^0}$
$\Gamma(\pi^+\pi^-\gamma)/\Gamma_{ m total}$						л . л . л . Г ₇ /I
VALUE	CL%	DOCUMENT ID		TECN	сом	• • •
0.0099±0.0016	_ 5-71	44 DOLINSKY				$- \rightarrow \pi^+\pi^-\gamma$
• • We do not use the	ne follow			s, limits,	etc.	• • •
0.0111 ± 0.0014		⁴⁵ VASSERMAN	88	ND	e ⁺ e	$- \rightarrow \pi^{+}\pi^{-}\gamma$
< 0.005	90	⁴⁶ VASSERMAN	88	ND	e ⁺ e	$- \rightarrow \pi^+ \pi^- \gamma$
44 Bremsstrahlung from	n a deca	y pion and for photo	n en	ergy abo	ve 50	MeV.
45 Superseded by DOL						
46 Structure radiation	due to c	luark rearrangement	in th	e decay.		
$\Gamma(\pi^0\gamma)/\Gamma_{\text{total}}$						Γ ₈ /Ι
VALUE (units 10 ⁻⁴)		DOCUMENT ID				MENT
6.8±1.7		⁴⁷ BENAYOUN	96	RVUE	0.54· π	$_{\gamma}^{1.04~e^{+}e^{-}}\rightarrow$
• • We do not use t	he follov	ving data for average	s, fit	s, limits,	etc.	• • •
7.9 ± 2.0		DOLINSKY	89	ND	e ⁺ e	$- \rightarrow \pi^0 \gamma$
47 Reanalysis of DRUZ a triangle anomaly			and (OOLINS	KY 91	taking into accoun

ρ(770) REFERENCES

	, ,	•
BENAYOUN 98	EPJ C2 269	M. Benavoun+ (IPNP, NOVO, ADLD, KNTY)
ABELE 97	PL B391 191	A. Abele, Adomeit, Amsler+ (Crystal Barrel Collab.)
ADAMS 97	ZPHY C74 237	M.R. Adams+ (E665 Collab.)
	A ZPHY C76 15	R. Barate+ (ALEPH Collab.)
BERTIN 970		A. Bertin, Bruschi+ (OBELIX Collab.)
BOGOLYUB 97	PAN 60 46	Bogolyubsky, Bravina, Kiryunin+ (MOSU, SERP)
	Translated from YAF 6	
O'CONNELL 97	NP A623 559	H.B. O'Connell, Thomas, Williams+ (ADLD)
BENAYOUN 96	ZPHY C72 221	M. Benayoun+ (IPNP, NOVO)
BERNICHA 94	PR D50 4454	+Lopez Castro, Pestieau (LOUV, CINV)
WEIDENAUER 93	ZPHY C59 387	+Duch+ (ASTERIX Collab.)
AGUILAR 91	ZPHY C50 405	Aguilar-Benitez, Allison, Batalor+ (LEBC-EHS Collab.)
DOLINSKY 91	PRPL 202 99	+Druzhinin, Dubrovin+ (NOVO)
ANTIPOV 89	ZPHY C42 185	+Batarin+ (SERP, JINR, BGNA, MILA, TBIL)
DOLINSKY 89	ZPHY C42 511	+Druzhinin, Dubrovin, Golubev+ (NOVO)
DUBNICKA 89	JPG 15 1349	+Martinovic+ (JINR, SLOV)
GESHKEN 89	ZPHY 45 351	Geshkenbein (ITEP)
KURDADZE 88	JETPL 47 512	+Leltchouk, Pakhtusova, Sidorov+ (NOVO)
	Translated from ZETFF	
VASSERMAN 88	SJNP 47 1035	+Golubev, Dolinsky+ (NOVO)
	Translated from YAF 4	
VASSERMAN 88	3 SJNP 48 480 Translated from YAF 4	+Golubev, Dolinsky+ (NOVO)
AULCHENKO 87		+Dolinsky, Druzhinin+ (NOVO)
AULCHENKO 87 CAPRARO 87	C IYF 87-90 Preprint NP B288 659	+Levy+ (CLER, FRAS, MILA, PISA, LCGT, TRST+)
BRAMON 86	PL B173 97	+Casulleras (BARC)
HUSTON 86	PR 33 3199	+Berg, Collick, Jonckheere+ (ROCH, FNAL, MINN)
KURDADZE 86	JETPL 43 643	+Lelchuk, Pakhtusova, Sidorov, Skrinskii+ (NOVO)
KUKDADZE 00	Translated from ZETFF	
BARKOV 85	NP B256 365	+Chilingarov, Eidelman, Khazin, Leichuk+ (NOVO)
DRUZHININ 84	PL 144B 136	+Golubev, Ivanchenko, Peryshkin+ (NOVO)
CHABAUD 83	NP B223 1	+Gorlich, Cerrada+ (CERN, CRAC, MPIM)
JENSEN 83	PR D27 26	+Berg, Biel, Collick+ (ROCH, FNAL, MINN)
HEYN 81	ZPHY C7 169	+Lang (GRAZ)
BOHACIK 80	PR D21 1342	+Kuhnelt (SLOV, WIEN)
LANG 79	PR D19 956	+Mas-Parareda (GRAZ)
BARTALUCCI 78	NC 44A 587	+Basini, Bertolucci+ (DESY, FRAS)
WICKLUND 78	PR D17 1197	+Ayres, Diebold, Greene, Kramer, Pawlicki (ANL)
ANDREWS 77	PRL 38 198	+Fukushima, Harvey, Lobkowicz, May+ (ROCH)
DEUTSCH 76	NP B103 426	Deutschmann+ (AACH3, BERL, BONN, CERN+)
ENGLER 74	PR D10 2070	+Kraemer, Toaff, Weisser, Diaz+ (CMU, CASE)
ESTABROOKS 74	NP B79 301	+Martin (DURH)
GRAYER 74	NP B75 189	+Hyams, Blum, Dietl+ (CERN, MPIM)
BYERLY 73	PR D7 637	+Anthony, Coffin, Meanley, Meyer, Rice+ (MICH)
GLADDING 73	PR D8 3721	+Russell, Tannenbaum, Weiss, Thomson (HARV)
PROTOPOP 73	PR D7 1279	Protopopescu, Alston-Garnjost, Galtieri, Flatte+ (LBL)
BALLAM 72	PR D5 545	+Chadwick, Bingham, Milburn+ (SLAC, LBL, TUFTS)
BENAKSAS 72	PL 39B 289	+Cosme, Jean-Marie, Julian, Laplanche+ (ORSAY)
JACOBS 72	PR D6 1291	(SACL)
RATCLIFF 72	PL 38B 345	+Bulos, Carnegle, Kluge, Leith, Lynch+ (SLAC)
ABRAMS 71	PR D4 653	+Barnham, Butler, Coyne, Goldhaber, Hall+ (LBL)
ALVENSLEB 70	PRL 24 786	Alvensleben, Becker, Bertram, Chen, Cohen (DESY)
BIGGS 70	PRL 24 1197	+Braben, Clifft, Gabathuler, Kitching+ (DARE)
ERBE 69	PR 188 2060	+Hilpert+ (German Bubble Chamber Collab.)
MALAMUD 69	Argonne Conf. 93	+Schlein (UCLA)
REYNOLDS 69	PR 184 1424	+Albright, Bradley, Brucker, Harms+ (FSU)
ROTHWELL 69		+Chase, Earles, Gettner, Glass, Weinstein+ (NEAS)
WEHMANN 69		 (HARV, CASE, SLAC, CORN, MCGI)
ARMENISE 68		+Ghidini, Forino+ (BARI, BGNA, FIRZ, ORSAY)
BATON 68	PR 176 1574	+Laurens (SACL)

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CHUNG	68	PR 165 1491	+Dahl, Kirz, Miller (LRL)
FOSTER	68	NP B6 107	+Gavillet, Labrosse, Montanet+ (CERN, CDEF)
HUSON	68	PL 28B 208	+Lubatti, Six, Veillet+ (ORSAY, MILA, UCLA)
HYAMS	68	NP B7 1	+Koch, Potter, Wilson, VonLindern+ (CERN, MPIM)
LANZEROTTI	68	PR 166 1365	+Blumenthal, Ehn, Faissler+ (HARV)
PISUT	68	NP B6 325	+Roos (CERN)
ASBURY	67B	PRL 19 865	+Becker, Bertram, Joos, Jordan+ (DESY, COLU)
BACON	67	PR 157 1263	+Fickinger, Hill, Hopkins, Robinson+ (BNL)
EISNER	67	PR 164 1699	+ Johnson, Klein, Peters, Sahni, Yen+ (PURD)
HUWE	67	PL 24B 252	+Marquit, Oppenheimer, Schultz, Wilson (COLU)
HYAMS	67	PL 24B 634	+Koch, Pellett, Potter, VonLindern+ (CERN, MPIM)
MILLER	67B	PR 153 1423	+Gutay, Johnson, Loeffler+ (PURD)
ALFF	66	PR 145 1072	Alff-Steinberger, Berley+ (COLU, RUTG)
FERBEL	66	PL 21 111	(ROCH)
HAGOPIAN	66	PR 145 1128	+Selove, Alitti, Baton+ (PENN, SACL)
HAGOPIAN	66B	PR 152 1183	+Pan (PENN, LRL)
JACOBS	66B	UCRL 16877	(LRL)
JAMES	56	PR 142 896	+Kraybill (YALE, BNL)
WEST	66	PR 149 1089	+Boyd, Erwin, Walker (WISC)
BLIEDEN	65	PL 19 444	+Freytag, Geibel+ (CERN Missing Mass Spect. Collab.)
CARMONY	64	PRL 12 254	+Lander, Rindfleisch, Xuong, Yager (UCB)
GOLDHABER	64	PRL 12 336	+Brown, Kadyk, Shen+ (LRL, UCB)
ABOLINS	63	PRL 11 381	+Lander, Mehlhop, Nguyen, Yager (UCSD)

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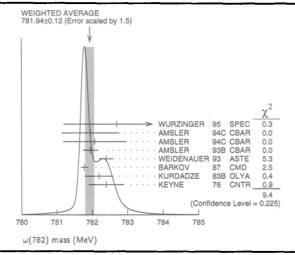
ABELE	97B	PL B402 195	A. Abele, Adomeit, Amsler-	(Crystal Barrel Collab.)
ABELE	97F	PL B411 354	A. Abele+	(Crystal Barrel Collab.)
BARATE	97M	ZPHY C76 15	R. Barate+	(ALEPH Collab.)
BENAYOUN	93	ZPHY 58 31	+Feindt, Girone+	(CDEF, CERN, BARI)
LAFFERTY	93	ZPHY C60 659		(MCHS)
KAMAL	92	PL B284 421	+Xu	(ALBE)
KUHN	90	ZPHY C48 445	J.H. Kuhn, Santamaria+	(MPIM)
ERKAL	85	ZPHY C29 485	+Oisson	(WISC)
RYBICKI	85	ZPHY C28 65	+Sakreida	(CRAC)
KURDADZE	83	JETPL 37 733	+Leichuk, Pakhtusova+	(NOVO)
		Translated from ZE		(11010)
ALEKSEEV	82	JETP 55 591	+Kartamyshev, Makarin+	(KIAE)
		Translated from ZE		(11112)
KENNEY	62	PR 126 736	+Shephard, Gall	(KNTY)
SAMIOS	62	PRL 9 139	+Bachman, Lea+	(BNL, CUNY, COLU, KNTY)
XUONG	62	PR 128 1849	+Lynch	(LRL)
ANDERSON	61	PRL 6 365	+Bang, Burke, Carmony, Schi	
ERWIN	61	PRL 6 628	+March, Walker, West	(WISC)
			,	(11100)



$$I^{G}(J^{PC}) = 0^{-(1--)}$$

ω(782) MASS

VALUE (MeV)	EVTS	DOCUMENT ID TECN COMMENT
781.94±0.12 OUR A	/ERAGE	Error includes scale factor of 1.5. See the ideogram below.
$782.7 \pm 0.1 \pm 1.5$.	19500	WURZINGER 95 SPEC 1.33 $pd \rightarrow {}^{3}He\omega$
$781.96 \pm 0.17 \pm 0.80$	11k	AMSLER 94C CBAR $0.0 \overline{p}p \rightarrow \omega \pi^0 \pi^0$
$782.08 \pm 0.36 \pm 0.82$	3463	AMSLER 94C CBAR $0.0 \overline{p}p \rightarrow \omega \eta \pi^0$
$781.96 \pm 0.13 \pm 0.17$	15k	AMSLER 93B CBAR $0.0 \overline{p}p \rightarrow \omega \pi^0 \pi^0$
782.4 ±0.2	270k	WEIDENAUER 93 ASTE $pp \rightarrow 2\pi^{+}2\pi^{-}\pi^{0}$
781.78 ± 0.10		BARKOV 87 CMD $e^+e^- \rightarrow \pi^+\pi^-\pi^0$
782.2 ±0.4	1488	KURDADZE 83B OLYA $e^+e^- \rightarrow \pi^+\pi^-\pi^0$
782.4 ±0.5	7000	¹ KEYNE 76 CNTR $\pi^- p \rightarrow \omega n$
• • • We do not use	the follow	ing data for averages, fits, limits, etc. • •
783.3 ±0.4		CORDIER 80 WIRE $e^+e^- \rightarrow \pi^+\pi^-\pi^0$
782.5 ±0.8	33260	ROOS 80 RVUE 0.0−3.6 pp
782.6 ±0.8	3000	BENKHEIRI 79 OMEG 9–12 π [±] p
781.8 ±0.6	1430	COOPER 788 HBC $0.7-0.8 \overline{p}p \rightarrow 5\pi$
782.7 ±0.9	535	VANAPEL 78 HBC 7.2 $\overline{p}p \rightarrow \overline{p}p\omega$
783.5 ±0.8	2100	GESSAROLI 77 HBC $11 \pi^- p \rightarrow \omega n$
782.5 ±0.8	418	AGUILAR 72B HBC 3.9,4.6 K-p
783.4 ±1.0	248	BIZZARRI 71 HBC $0.0 p\overline{p} \rightarrow K^+ K^- \omega$
781.0 ±0.6	510	BIZZARRI 71 HBC $0.0 p\overline{p} \rightarrow K_1 K_1 \omega$
783.7 ±1.0	3583	² COYNE 71 HBC 3.7 $\pi^+ \rho \rightarrow$
12.		$p\pi^+\pi^+\pi^-\pi^0$
784.1 ±1.2	750	ABRAMOVI 70 HBC 3.9 π ⁻ p
783.2 ±1.6		³ BIGGS 708 CNTR $<4.1 \gamma C \rightarrow \pi^+ \pi^- C$
782.4 ±0.5	2400	BIZZARRI 69 HBC 0.0 pp



ω(782)	WIDTH
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VALUE (MeV)	EVTS	DOCUMENT ID		ECN	COMMENT
8.41 ± 0.09 OUR AV	ERAGE				
8.2 ±0.3	19500	WURZINGER	95 S	PEC	1.33 $pd \rightarrow {}^{3}He\omega$
8.4 ±0.1		⁴ AULCHENKO	87 N	łD.	$e^+e^- \rightarrow \pi^+\pi^-\pi^0$
8.30 ± 0.40		BARKOV	87 C	MD	$e^+e^- \rightarrow \pi^+\pi^-\pi^0$
9.8 ±0.9	1488	KURDADZE	83B C	DLYA	$e^+e^- \rightarrow \pi^+\pi^-\pi^0$
9.0 ±0.8		CORDIER	80 V	VIRE	$e^+e^- \rightarrow \pi^+\pi^-\pi^0$
9.1 ±0.8		BENAKSAS	72B C	SPK	e ⁺ e ⁻
• • • We do not use	the following	ng data for averages	s, fits, I	limits,	etc. • • •
12 ±2	1430	COOPER	788 H	IBC	0.7-0.8 p̄ρ → 5π
9.4 ±2.5	2100	GESSAROLI	77 H	BC	$11 \pi^- \rho \rightarrow \omega n$
10.22 ± 0.43	20000	⁵ KEYNE	76 C	NTR	$\pi^- p \rightarrow \omega n$
13.3 ±2	418	AGUILAR	72B H	IBC	3.9,4.6 K ⁻ p
10.5 ±1.5		BORENSTEIN	72 H	IBC	2.18 K ⁻ p
$7.70\pm0.9\ \pm1.15$	940	BROWN	72 N	/MS	$2.5 \pi^- p \rightarrow nMM$
10.3 ±1.4	510	BIZZARRI	71 H	IBC	$0.0 \ p\overline{p} \rightarrow K_1 K_1 \omega$
12.8 ±3.0	248	BIZZARRI	71 H	IBC	$0.0 p\bar{p} \rightarrow K^+K^-\omega$
9.5 ±1.0	3583	COYNE	71 H	IBC	$3.7 \pi^+ p \rightarrow$
					n-+-+0

⁴ Relativistic Breit-Wigner includes radiative corrections.

ω (782) DECAY MODES

	Mode		Fraction	(Γ _I /Γ)		cale factor/ Idence level
Γ ₁	$\pi^{+}\pi^{-}\pi^{0}$		(88.8	±0.7)%		
Γ2	$\pi^0\gamma$		(8.5 :	±0.5)%		
Гз	$\pi^+\pi^-$		(2.21	±0.30) %		
Γ4	neutrals (excluding π^0	$\gamma)$	(5.3	+8.7 -3.5) × 1	0-3	
Γ_{5}	$\eta \gamma$		(6.5 :	±1.0)×1	₀ –4	
Γ6	$^{\eta\gamma}_{\pi^0e^+e^-}$			±1.9)×10		
Γ7	$\pi^{0}\mu^{+}\mu^{-}$ $e^{+}e^{-}$		(9.6 :	±2.3) × 10	ე–5	
Γ8	e ⁺ e ⁻		(7.07	±0.19) × 10	₀ –5	S=1.1
و۱	$\pi^{+}\pi^{-}\pi^{0}\pi^{0}$		< 2	%		CL≈90%
Γ ₁₀	$\pi^+\pi^-\gamma$		< 3.6	× 10	₎ –3	CL≈95%
Γ11	$\pi^{+}\pi^{-}\pi^{+}\pi^{-}$		< 1	× 10	₀ –3	CL≈90%
Γ ₁₂	$\pi^0\pi^0\gamma$		(7.2 :	±2.5) × 10	₎ –5	
Γ ₁₃	$\mu^+\mu^-$		< 1.8	× 10	₀ -4	CL≈90%
Γ_{14}	$\pi^0 \pi^0 \gamma$ $\mu^+ \mu^ 3\gamma$		< 1.9	× 10	₀ -4	CL≈95%
		onjugation (C)	violating	modes		
Γ ₁₅	$\eta\pi^0$	c	< 1	× 10	₀ –3	CL≃90%
Γ16	$3\pi^0$	c	< 3	x 10	₀ -4	CL=90%

 $^{^1}$ Qbserved by threshold-crossing technique. Mass resolution = 4.8 MeV FWHM. 2 From best-resolution sample of COYNE 71. 3 From $\omega\text{-}\rho$ interference in the $\pi^+\pi^-$ mass spectrum assuming ω width 12.6 MeV.

⁵Observed by threshold-crossing technique. Mass resolution = 4.8 MeV FWHM.

DOCUMENT ID TECN COMMENT

 $(\Gamma_2+\Gamma_4)/(\Gamma_1+\Gamma_3)$

CONSTRAINED FIT INFORMATION

An overall fit to 6 branching ratios uses 20 measurements and one constraint to determine 4 parameters. The overall fit has a $\chi^2=10.3$ for 17 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\langle \delta x_i \delta x_j \rangle / (\delta x_i \cdot \delta x_j)$, in percent, from the fit to the branching fractions, $x_i \equiv \Gamma_i / \Gamma_{\text{total}}$. The fit constrains the x_i whose labels appear in this array to sum to one.

<i>x</i> ₂	13		
<i>x</i> ₃	-39	-5	
<i>x</i> ₄	-74	-68	-1
	X1	Χa	X2

ω(782) PARTIAL WIDTHS

Γ(e ⁺ e ⁻)		Гв
VALUE (keV)	DOCUMENT ID	
0.60+0.02 OUR EVALUATION		

ω (782) BRANCHING RATIOS

$\Gamma(\text{neutrals})/\Gamma(\pi^{-1})$	⁺ π ⁻ π ⁰)				$(\Gamma_2+\Gamma_4)/\Gamma_1$
VALUE 0.102±0.008 OUR	<u>EVŤS</u> FIT	DOCUMENT ID		<u>TECN</u>	COMMENT
$0.103^{+0.011}_{-0.010}$ OUR	AVERAGE				
0.15 ±0.04	46	AGUILAR	72B	нвс	3.9,4.6 K-p
0.10 ±0.03	19	BARASH	67B	HBC	0.0 p p
0.134 ± 0.026	850	DIGIUGNO	66B	CNTR	1.4 $\pi^{-}p$
0.097 ± 0.016	348	FLATTE	66	нвс	1.4 - 1.7 K ⁻ p → ΛΜΜ
0.06 +0.05		JAMES	66	нвс	$2.1 \pi^{+} p$
0.08 ±0.03	35	KRAEMER	64	DBC	$1.2 \pi^{+} d$
• • • We do not us	se the followin	g data for average	s, fits	, limits,	, etc. • • •
0.11 ±0.02	20	BUSCHBECK	63	нвс	1.5 K p

$\Gamma(\pi^+\pi^-)/\Gamma(\pi^+\pi^-\pi^0)$					Γ_3/Γ_1
See also $\Gamma(\pi^+\pi^-)/\Gamma_{\text{total}}$.					
VALUE	DOCUMENT ID		TECN	COMMENT	
0.0249±0.0035 OUR FIT				•	
0.026 ±0.005 OUR AVERAGE					
0.021 +0.028 -0.009	⁶ RATCLIFF	72	ASPK	$15 \pi^- p \rightarrow n2\pi$	r
0.028 ±0.006	BEHREND	71	ASPK	Photoproduction	
0.022 +0.009	7 ROOS	70	RVUE		

 $^{^6}$ Significant interference effect observed. NB of $\omega\to 3\pi$ comes from an extrapolation. 7 ROOS 70 combines ABRAMOVICH 70 and BIZZARRI 70.

$\Gamma(\pi^0\gamma)/\Gamma(\pi^+\pi^-\pi^0)$	DOCUMENT ID		TECN	COMMENT	Γ_2/Γ_1
0.096±0.006 OUR FIT 0.096±0.006 OUR AVERAGE	DOCUMENT 10		TECH	COMMENT	
0.099 ± 0.007	DOLINSKY	89	ND	$e^+e^- \rightarrow \pi^0\gamma$	
0.084 ± 0.013	KEYNE	76	CNTR	$\pi^- p \rightarrow \omega n$	
0.109±0.025	BENAKSAS	72C	OSPK	e ⁺ e ⁻	
0.081 ± 0.020	BALDIN	71	HLBC	$2.9 \pi^{+} p$	
0.13 ±0.04	JACQUET	6 9 B	HLBC		
$\Gamma(\pi^{+}\pi^{-}\gamma)/\Gamma(\pi^{+}\pi^{-}\pi^{0})$					Γ10/Γ1

1 (* * 7)/1 (*	•	205111515		TC	CO. 111511T	. 10/
VALUE	<u>CL%</u>	DOCUMENT ID		TECN	COMMENT	
• • • We do not	use the following	g data for averag	es, fits	, limits,	etc. • • •	
< 0.066	90	KALBFLEISC	H 75	HBC	2.18 K ⁻ p →	
					$\Lambda \pi^+ \pi^- \gamma$	
< 0.05	90	FLATTE	66	HBC	1.2 - 1.7 K - p	-
					A++-~	

$\Gamma(\pi^+\pi^-\gamma)/\Gamma_{to}$	tal			Γ ₁₀ /Γ			
VALUE	CL%	DOCUMENT ID	TECN	COMMENT			
<0.0036	95	WEIDENAUEI	R 90 ASTE	$\rho \overline{\rho} \rightarrow \pi^+ \pi^- \pi^+ \pi^- \gamma$			
● ● We do not use the following data for averages, fits, limits, etc. ● ●							
<0.004	95	BITYUKOV	888 SPEC	$32 \pi^- \rho \rightarrow \pi^+ \pi^- \gamma X$			

$\Gamma(\pi^+\pi^-\pi^+\pi^-)$)/Γ _{total} :				Γ_{11}/Γ
VALUE	CL%	DOCUMENT ID	TECN	COMMENT	
<1 × 10 ⁻³	90	KURDADZE 8	B OLYA	$e^+e^{\pi^+\pi^-\pi^+\pi^-}$	
$\Gamma(\pi^{+}\pi^{-}\pi^{0}\pi^{0})$	/Γ _{total}				Г9/Г

' (A' A A A)/'1	total			19/1
VALUE (units 10 ⁻²)	CL%	DOCUMENT ID	TECN	COMMENT
~ 2	90	KURDADZE 86	OLYA	$e^{+}e^{-} \rightarrow \pi^{+}\pi^{-}\pi^{0}\pi^{0}$

$\Gamma(\mu^+\mu^-)/\Gamma(\pi^+\pi^-$	π^0)					Γ_{13}/Γ_1
VALUE (units 10 ⁻³)	CL%	DOCUMENT ID		TECN	COMMENT	
<0.2	90	WILSON	69	OSPK	12 π ⁻ C → Fe	
• • We do not use the	e following	data for average	s, fit	s, limits,	etc. • • •	
<1.7	74	FLATTE	66	нвс	$1.2 - 1.7 K^- p$ $\Lambda \mu^+ \mu^-$	→
<1.2		BARBARO	65	HBC	2.7 K ⁻ p	
$\Gamma(\pi^0\pi^0\gamma)/\Gamma(\pi^0\gamma)$						Γ_{12}/Γ_2

0.00085±0.00029	40 ± 14	ALDE	94B GAM2	$38\pi^{-} p \rightarrow \pi^{0} \pi^{0} \gamma n$
• • • We do not use the	ne following data fo	r averages, fits, li		
< 0.005	90	DOLINSKY	89 ND	$e^+e^{\pi^0\pi^0\gamma}$
< 0.18	95	KEYNE		$\pi^- p \rightarrow \omega n$
< 0.15	90	BENAKSAS	72c OSPK	e ⁺ e ⁻
< 0.14		BALDIN	71 HLBC	$2.9 \pi^{+} p$
< 0.1	90	BARMIN	64 HLBC	1.3-2.8 π ⁻ p

$\Gamma(\eta \pi^0)/\Gamma_{\text{total}}$ Violates C conserv	ation.				Γ ₁₅ /Γ
VALUE	CL%	DOCUMENT ID	TECN	COMMENT	
<0.001	90	ALDE	94B GAM2	38π ⁻ p →	$\eta \pi^0 n$

$$\frac{\left[\Gamma(\eta \gamma) + \Gamma(\eta \pi^{0})\right]/\Gamma(\pi^{+}\pi^{-}\pi^{0})}{\frac{CL\%}{0}} \frac{OCUMENT ID}{\frac{DOCUMENT ID}{1}} \frac{TECN}{1.2 - 1.7 K^{-}\rho \rightarrow} \frac{COMMENT}{1.2 - 1.7 K^{-}\rho \rightarrow}$$

• • • We do not use the following data for averages, fits, limits, etc. • • • < <0.045 95 JACQUET 698 HLBC

<0.045 95 JACQUET 698 HLB

8 Restated by us using B($\eta \rightarrow$ charged modes) = 29.2%.

CL% EVTS

VALUE

<0.08

VALUE		DOCUMENT ID	TECN	COMMENT	
0.099±0.008 OUR FIT	•				
0.124 ± 0.021		FELDMAN	67c OSPK	$1.2 \pi^{-} p$	
$\Gamma(\pi^0\pi^0\gamma)/\Gamma(\pi^+\pi^-)$	π0)				Γ_{12}/Γ_1
VALUE	CL%	DOCUMENT ID	TECN	COMMENT	
< 0.00045	90	DOLINSKY	89 ND	e ⁺ e ⁻ →	$\pi^0\pi^0\gamma$
• • • We do not use t	he followin	g data for average	s, fits, limits	, etc. • • •	

$\Gamma(\eta\gamma)/\Gamma(\pi^0\gamma)$					Γ_5/Γ_2
VALUE	DOCUMENT ID	3	TECN	COMMENT	
• • • We do not use the follow	ing data for averag	es, fits,	limits,	etc. • • •	
0.0098±0.0024	9 ALDE	93 (SAM2	$38\pi^- p \rightarrow \omega n$	
0.0082 ± 0.0033	¹⁰ DOLINSKY	89 ħ	ND	$e^+e^- \rightarrow \eta \gamma$	
0.010 ±0.045	APEL	72B (OSPK	$4-8 \pi^- p \rightarrow n3$	y

JACQUET

69B HLBC

Γ(neutrals)/Γ(charged particles)

¹⁰ Solution corresponding to constructive ω - ρ interference.

$\Gamma(\pi^0 \mu^+ \mu^-)/\Gamma_{\text{total}}$		Γ ₇ /Γ
VALUE (units 10 ⁻⁴)	DOCUMENT IDTECN	COMMENT
0.96±0.23	DZHELYADIN 818 CNTI	R 25-33 $\pi^- p \rightarrow \omega n$
$\Gamma(\pi^0 e^+ e^-)/\Gamma_{\text{total}}$		Г ₆ /Г
VALUE (units 10 ⁻⁴) EVTS	DOCUMENT ID TECN	COMMENT
5.9±1.9 43	DOLINSKY 88 ND	$e^+e^- \rightarrow \pi^0e^+e^-$
$\Gamma(e^+e^-)/\Gamma_{\text{total}}$		Г8/Г
VALUE (únits 10 ⁻⁴) EVTS	DOCUMENT ID TECN	COMMENT
0.707±0.019 OUR AVERAGE	Error includes scale factor of 1	1,
0.714±0.036	DOLINSKY 89 ND	
0.72 ±0.03	BARKOV 87 CMD	$e^+e^- \rightarrow \pi^+\pi^-\pi^0$
0.64 ±0.04 1488	KURDADZE 838 OLYA	$e^+e^- \rightarrow \pi^+\pi^-\pi^0$
0.675 ± 0.069	CORDIER 80 WIRE	$e^+e^- \rightarrow 3\pi$
0.83 ±0.10	BENAKSAS 728 OSPI	$\langle e^+e^- \rightarrow 3\pi$
0.77 ±0.06	11 AUGUSTIN 69D OSPI	$(e^+e^- \rightarrow 2\pi)$
• • • We do not use the follow	ving data for averages, fits, limit	s, etc. • • •
0.65 ±0.13 33	12 ASTVACAT 68 OSPI	(Assume SU(3)+mixing

 11 Rescaled by us to correspond to ω width 8.4 MeV. 12 Not resolved from ρ decay. Error statistical only.

	, ,		•		
Γ(neutrals)/Γ _{tota}	al				$(\Gamma_2+\Gamma_4)/\Gamma$
VALUE	EVTS	DOCUMENT IS	TECN	COMMENT	
0.090±0.006 OUR	FIT				
0.081 ± 0.011 OUR	AVERAGE				
0.075 ± 0.025		BIZZARRI	71 HBC	0.0 p p	
0.079 ± 0.019		DEINET	69B OSPH	(1.5 π ⁻ p	
0.084 ± 0.015		BOLLINI	68c CNTI	R 2.1 π p	
• • • We do not us	se the followin	g data for averag	ges, fits, limit	s, etc. • • •	
0.073 ± 0.018	42	BASILE	72B CNTI	R 1.67 π - p	

⁹ Model Independent determination.

• • • We do not use the following data for averages, fits, limits, etc. • • •

9975 22 BENAYOUN 96 RVUE $e^+e^- \rightarrow \pi^0 \gamma$

²²Reanalysis of DRUZHININ 84, DOLINSKY 89, DOLINSKY 91 taking into account the triangle anomaly contributions.

 ω (782)

$\Gamma(\pi^+\pi^-)/\Gamma_{\text{total}}$			Γ ₃ /Γ				ω(78:) REFERENCES	
See also $\Gamma(\pi^+\pi^-)/\Gamma(\pi^+\pi^-)$,— x ⁰). <u>DOCUMENT ID</u>	TECN	COMMENT		BENAYOUN ABELE	98 97E	EPJ C2 269 PL B411 361	M. Benzyoun+ (IPNP, NOVO, A. Abele+ (Crystal	DLD, KNTY) Barrel Collab.)
0.0221±0.0030 OUR FIT 0.021 ±0.004 OUR AVERAGE					BENAYOUN	96	ZPHY C72 221	M. Benayoun+ -Samolienko	IPNP, NOVO)
0.021 ±0.004 OUR AVERAGE 0.023 ±0.005	BARKOV	85 OLYA	e+e-			95	Translated from DANS 3 PR CE1 443	42 610. •Siebert+ /RONN, DRSAY, SACL, I	OUC. CRAC)
0.016 +0.009	QUENZER	78 CNTR			ALDE AMSLER	94B 94C	PL B340 122	+Binon, Boutemeur+ (SERP, BELG, LANL, L	APP, MONT) Barrel Collab.)
• • We do not use the following	-				ALDE	93	PAN 86 1229 -	+Binon+ (SERP, LAPP, LANL, BELG, I	BRUX, CERN)
0.023 ±0.004			$e^+e^- \rightarrow \pi^+\pi^-$,	ı	Also AMSLER	94 93B	ZPHY C61 35 PL B311 362	Aide, Binon+(SERP, LAPP, LANL, BELG, I +Armstrong, v.Dombrowski+ (Crystal	Barrel Collab.)
0.010 ±0.001	14 WICKLUND	78 ASPK	$\mu^{+}\mu^{-}$ 3.4.6 $\pi^{\pm}N$		WEIDENAUER DOLINSKY	91	PRPL 202 99	-Druzhinin, Dubrovin+	ERIX Collab.) (NOVO)
0.0122 ± 0.0030			Photoproduction		WEIDENAUER DOLINSKY	89	ZPHY C42 511 -	Druzhinin, Dubrovin, Golubev+	ERIX Collab.) (NOVO)
0.013 +0.012 -0.009	MOFFEIT	71 HBC	2.8,4.7 ~p		BITYUKOV	66B	Translated from YAF 47	Borisov, Viktorov, Golovkin+ 1258.	(SERP)
0.0080 + 0.0028	15 BIGGS	70B CNTR	$4.2\gamma C \rightarrow \pi^{+}\pi^{-}C$		DOLINSKY KURDADZE	81 M	Translated from VAE 48	+ Druzhinin, Dubrovin, Golubev+ 442. + Lettchouk, Pakhtusova, Sidorov+	(NOVO) (NOVO)
13 Not independent of BARKOV	85.			ı	AULCHENKO	87	PL B186 432 -	+Letchouk, Pakhtusova, Sidorov+ 47 432. +Dolinsky, Druzhinin, Dubrovin+	(NOVO)
14 From a model-dependent anal	vals assuming com	plete coheren	ice.	•	BARKOV	67	Translated from ZETFP		(NOVO)
¹⁵ Re-evaluated under $\Gamma(\pi^+\pi^-)$ ρ photoproduction cross-section	/Γ(π+π+π+)by l on ratko.	BEHREND 7	1 using more accurate ω →		KURDADZE	86	Translated from ZETFP	+Leichuk, Pakhtusova, Sidorov, Skrinskii+ 43 497.	(NOVO)
					BARKOV DRUZHININ	85 84	PL 1448 136 -	+Chilingarov, Eldelman, Khazin, Leichuk+ +Golubev, Ivanchenko, Peryshkin+	(NOVO)
$\Gamma(\pi^0\pi^0\gamma)/\Gamma(\text{neutrals})$ VALUE CLY	DOCUMENT ID	TECN	Γ ₁₂ /(Γ ₂ +Γ ₄)		KURDADZE	838	Translated from ZETFP	-Pakhtusova, Sidorov+ 36 221.	(NOVO)
• • We do not use the following					CORDIER	81B 80	NP 8172 13 -	+Golovkin, Konstantinov+ +Delcourt, Eschstruth, Fulda+	(SERP) (LALO)
0.22±0.07			1.4 π ⁻ p → nMM		ROOS BENKHEIRI	90 79	NP B150 268	+Pellinen +Elsenstein+ (EPOL, CERN,	
<0.19 90	DEINET	698 OSPK	•		DZHELYADIN COOPER	79 78B	NP B146 1 -	+Golovkin, Gritsuk+ +Ganguil+ (TATA, CERN, C	(SERP)
¹⁶ See $\Gamma(\pi^0\gamma)/\Gamma(\text{neutrals})$.					QUENZER VANAPEL	78 78	NP B133 248	+Ribes, Rumpf, Bertrand, Blact, Chase+ VanApeldoorn, Grundeman, Harting+	(LALO)
$\Gamma(\pi^0\gamma)/\Gamma(\text{neutrals})$			$\Gamma_2/(\Gamma_2+\Gamma_4)$		WICKLUND ANDREWS	78 77	PR D17 1197 PRL 38 198	+Ayres, Diebold, Greene, Kramer, Pawlicki +Fukushima, Harvey, Lobkowicz, May+ + (BGNA, FIRZ, GENO, MILA	(ANL) (ROCH)
VALUE CLN	DOCUMENT ID	<u>TECN</u>	COMMENT		GESSAROLI KEYNE	77 76	PR D14 28 -	+Binnie, Carr, Debenham, Garbutt+ (LOIC, SHMP)
• • We do not use the following	-	s, fits, limits,	etc. • • •		Also Kalbfleisch		PR D8 2789 PR D11 987	Binnie, Carr, Debenham, Duane+ (+Strand, Chapman	LOIC, SHMP) (BNL, MICH)
0.78±0.07			1.4 $\pi^- p \rightarrow nMM$		AGUILAR APEL	72B 72B	PR D6 29 PL 41B 234	- Aguilar-Benitez, Chung, Elsner, Ssmios + Auslander, Muller, Bertolucci+ - (KARLK, I	(BNL) (ARLE, PISA)
>0.81 90 17 Error statistical only. Author	DEINET	698 OSPK	-0- as the ask series		BASILE BENAKSAS	728 728	PMI. Conf. 153 PL 428 507	+Bollini, Broglin, Dalpiaz, Frabetti+ +Cosme, Jean-Marie, Julian	(CERN) (ORSAY)
decay.	outsin good tit a	med #sermini	5 π - γ as the only neutral		BENAKSAS BORENSTEIN	72C 72	PL 42B 511 PR DS 1559	+Cosme, Jean-Marie, Julian, Laplanche+ +Danburg, Kaibfielsch+	(ORSAY)
Γ(ηγ)/Γ _{total}			r _{\$} /r		BROWN DAKIN	72 72	PL 42B 117 PR D6 2321	+Downing, Holloway, Huld, Bernstein+ +Hauser, Kreisler, Mischke	(ILL, ILLC) (PRIN)
VALUE (units 10 ⁻⁴) EVTS	DOCUMENT ID	TECN	COMMENT		RATCLIFF ALVENSLEB	72	PL 38B 345 PRL 27 888	+Bulos, Carnegie, Kluge, Leith, Lynch+ Alvensleben, Becker, Busza, Chen, Cohen+	(SLAC) (DESY)
6.5 ±1.0 OUR AVERAGE					BALDIN	71	SJNP 13 758 Translated from YAF 13	+Yergakov, Trebukhovsky, Shishov 1316.	(ITEP)
6.6 ±1.7	ABELE		0.0 βp → 5γ	I	BEHREND BIZZARRI	71 71	PRL 27 61 NP B27 140	+Lee, Nordberg, Wehmann+ (ROCH, (+Montanet, Nilsson, D'Andlau+ (CORN, FNAL) CERN, CDEF)
8.3 ±2.1 7.3 ±2.9	ALDE 18 DOLINSKY	93 GAM2 89 ND	38π		COYNE MOFFEIT	71 71	NP 832 333 NP 829 349	+Butler, Fang-Landau, MacNaughton +Bingham, Fretter+ (LRL, UCB, S	(LRL) LAC, TUFTS)
3.0 +2.5	18 ANDREWS		6.7−10 γ Cu		ABRAMOVI: BIGGS	70 70B	NP B20 209	Abramovich, Blumenfeld, Bruyant+ +Clifft, Gabathuler, Kitching, Rand	(CERN)
• • • We do not use the following			•		BIZZARRI ROOS	70 70	PRL 25 1385 DNPL/R7 173	+Clapettl, Dore, Gaspero, Guidoni+ (F	OMA, SYRA)
	,19 BENAYOUN			1	Proc. Dan AUGUSTIN		Study Weekend No. 1.	+Bensksas, Buon, Gracco, Halssinski+	(ORSAY)
			יון די פיפ	•	BIZZARRI DEINET	69 69B	NP B14 169	+Foster, Gavillet, Montanet+ (CERN, CDEF) KARL, CERN)
¹⁸ Solution corresponding to con ¹⁹ Reanalysis of DRUZHININ 84	istructive ω-ρ interi L DOLINSKY 89. I	ference. DOLINSKY (91 taking into account the		JACQUET WILSON	69B 69		+Nguyen-Khac, Haatuft, Haisteinsiid	EPOL, BERG
triangle anomaly contribution			•	•	Also ASTVACAT	68	PR 178 2095 PL 27B 45	Wehmann+ (HARV, CASE, SLAC, Astvacaturov, Azimov, Baldin+	CORN, MCGI JINR, MOSU)
$\Gamma(\pi^0\mu^+\mu^-)/\Gamma(\mu^+\mu^-)$			Γ ₇ /Γ ₁₃		BOLLINI BARASH	68C 67B	NC 56A 531	+Buhler, Dalpiaz, Massam+ (CERN, +Kirsch, Miller, Tan	BGNA, STRB) (COLU)
VALUE EVTS	DOCUMENT ID	TECN_	COMMENT		FELDMAN DIGIUGNO	67C 66B	PR 159 1219	+Frati, Gleeson, Halpern, Nussbaum+	(PENN) FRAS, TRST)
• • We do not use the following					FLATTE	66 66	PR 145 1050	+Huwe, Murray, Button-Shafer, Solmitz+ +Kraybill	(LRL) (YALE, BNL)
1.2±0.6 30	20 DZHELYADIN	79 CNTR	25-33 π ⁻ p		BARBARO BARMIN	65 64	PRL 14 279	Barbaro-Galtieri, Tripp +Dolgolenko, Krestnikov+	(LRL) (ITEP)
²⁰ Superseded by DZHELYADIN	81B result above.				KRAEMER	64	Translated from ZETF 4	5 1879.	WES, WOOD)
$\Gamma(\pi^+\pi^-\pi^0)/\Gamma_{\text{total}}$			Γ ₁ /Γ		BUSCHBECK	63			CERN, ANIK)
YALUE	DOCUMENT ID	TECN_	COMMENT				OTHER	RELATED PAPERS	
0.8942±0.0062	DOLINSKY	89 ND	$e^+e^- \rightarrow \pi^+\pi^-\pi^0$		ABELE	97F	PL B411 354		Barrel Collab.)
$\Gamma(3\pi^0)/\Gamma_{\text{total}}$			Γ ₁₆ /Γ		DOLINSKY KURDADZE	86 83	PL B174 453 JETPL 37 733	+Druzhinin, Dubrovin, Eldelman+ +Lelchuk, Pakhtusova+	(NOVO)
Violates C conservation. VALUE CL%	DOCUMENT ID	TECN	COMMENT		ALFF	62B	Translated from ZETFP PRL 9 325	37 613. Alff-Steinberger, Berley, Colley+ (4	COLU, RUTG)
<0.0003 90			38 π ⁻ p → 3π ⁰ n		STEVENSON MAGLICH	62 61	PR 125 687	+Alvarez, Maglich, Rosenfeld +Alvarez, Rosenfeld, Stevenson	(LRL) (LRL)
$\Gamma(3\gamma)/\Gamma_{\text{total}}$			Γ ₁₄ /Γ		PEVSNER XUONG	61 61	PRL 7 421	+Kraemer, Nussbaum, Richardson+ +Lynch	(JHU) (LRL)
VALUE (units 10 ⁻⁴) CL%	DOCUMENT ID	TECN	COMMENT			_			
<1.9 95	21 ABELE		0.0 pp → 5γ	ı					
• • We do not use the following		s, fits, limits,	etc. • • •	-					
<2 90	²¹ PROKOSHKIN	95 GAM2	$38~\pi^-~p~\rightarrow~3\gamma~n$	_					
21 From direct 3γ decay search.				l					
$\Gamma(\pi^0\gamma)/\Gamma_{\text{total}}$			Γ ₂ /Γ						
VALUE (units 10 ⁻²) EVTS	DOCUMENT ID	TECN	COMMENT						

$\eta'(958)$	
--------------	--

$$I^{G}(J^{PC}) = 0^{+}(0^{-})$$

n/(958) MASS

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
957.78±0.14 OUR A	VERAGE				
957.9 ±0.2 ±0.6	4800	WURZINGER	96	SPEC	$1.68 \ pd \rightarrow {}^{3}He\eta'$
959 ±1	630	BELADIDZE	92 C	VES	36 π^- Be $\rightarrow \pi^- \eta' \eta$ Be
958 ±1	340	ARMSTRONG	91B	OMEG	300 pp $\rightarrow pp\eta \pi^+ \pi^-$
958.2 ±0.4	622	AUGUSTIN	90	DM2	$J/\psi \rightarrow \gamma \eta \pi^+ \pi^-$
957.8 ±0.2	2420	AUGUSTIN	90	DM2	$J/\psi \rightarrow \gamma \gamma \pi^+ \pi^-$
956.3 ±1.0	143	GIDAL	87	MRK2	$e^+e^1 \rightarrow$
					$e^+e^-\eta\pi^+\pi^-$
957.46 ± 0.33		DUANE	74	MMS	$\pi^- p \rightarrow nMM$
958.2 ±0.5	1414	DANBURG	73	HBC	$2.2 K^- p \rightarrow \Lambda X^0$
958 ±1	400	JACOBS	73	HBC	$2.9 K^- p \rightarrow \Lambda X^0$
956.1 ±1.1	3415	BASILE	71	CNTR	$1.6 \pi^- p \rightarrow nX^0$
957.4 ±1.4	535	BASILE	71	CNTR	$1.6 \pi^- p \rightarrow n X^0$
957 ±1		RITTENBERG	69	нвс	1.7-2.7 K ⁻ p

η/(958) WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT	
0.203±0.016 OUR FIT 0.30 ±0.09 OUR AVE		des scale factor	of 1.	3.			
0.40 ±0.22	4800	WURZINGER	96	SPEC		1.68 pd → 3Hen'	ı
0.28 ±0.10	1000	BINNIE	79	MMS	0	$\pi^- \rho \rightarrow nMM$	

7 (958) DECAY MODES

	Mode		Fraction (Γ_{I}	′Γ)	Scale factor/ Confidence level
Γ1	$\pi^+\pi^-\eta$		(43.8 ±1	5)%	S=1.1
Γ2	$ \rho^0 \gamma $ (including non-resonant $\pi^+\pi^-\gamma$)		(30.2 ±1	3)%	S=1.1
Γ_3	$\pi^0\pi^0\eta$		(20.7 ±1	3)%	5=1.2
Γ4	$\omega \gamma$		(3.01±0	30) %	
Γ ₅	$\gamma\gamma$		(2.11±0	13) %	S=1.2
Γ6	$3\pi^0$		(1.54±0	26) × 10	-3
Γ ₇	$\mu^+\mu^-\gamma$		(1.03±0	26) × 10	-4
Γ8	$\pi^+\pi^-\pi^0$		< 5	%	CL=90%
Γ٩	$\pi^{0} \rho^{0}$		< 4	%	CL=90%
Γ ₁₀	$\pi^{+}\pi^{+}\pi^{-}\pi^{-}$		< 1	%	CL=90%
Γ11	$\pi^+\pi^+\pi^-\pi^-$ neutrals		< 1	%	CL=95%
Γ12	$\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{0}$		< 1	%	CL=90%
Γ13	6π		< 1	%	CL=90%
Γ14	$\pi^{+}\pi^{-}e^{+}e^{-}$		< 6	× 10	-3 CL=90%
Γ ₁₅	$\pi^0 \gamma \gamma$		< 8	× 10	-4 CL=90%
Г16	$4\pi^{0}$		< 5	× 10	-4 CL=90%
Γ ₁₇	e ⁺ e ⁻		< 2.1	× 10	
	Charge conjugation (C)	or Pari	ty (<i>P</i>) viola	ting mo	des
Γ ₁₈	$\pi^+\pi^-$	P,CP	< 2	%	CL=90%
Γ10	$\pi^0\pi^0$	P.CP	< 9	× 10	-4 CL=90%

' 18	A A	F, CF	_	-	70	CL- 70 /0
	$\pi^{0}\pi^{0}$	P,CP	<	9	× 10 ⁻⁴	CL=90%
Γ20	$\pi^{0} e^{+} e^{-}$	c	[a] <	1.3	%	CL=90%
Γ21	$\eta e^+ e^-$	c	[a] <	1.1	%	CL=90%
	3γ	c	<	1.0	× 10 ⁻⁴	CL=90%
Γ23	$\mu^{+}\mu^{-}\pi^{0}$	c	[a] <	6.0	× 10 ⁻⁵	CL=90%
	$\mu^+\mu^-\eta$	c	[a] <	1.5	\times 10 ⁻⁵	CL=90%

 $[a]\ C$ parity forbids this to occur as a single-photon process.

CONSTRAINED FIT INFORMATION

An overall fit to the total width, a partial width, 2 combinations of partial widths obtained from integrated cross section, and 16 branching ratios uses 46 measurements and one constraint to determine $\bar{7}$ parameters. The overall fit has a $\chi^2=34.4$ for 40 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\left<\delta p_i \delta p_j\right>/(\delta p_i \cdot \delta p_j)$, in percent, from the fit to parameters p_i , including the branching fractions, $x_i \equiv \Gamma_i/\Gamma_{\text{total}}$. The fit constrains the x_i whose labels appear in this array to sum to one.

	Mode	Rate (MeV)	Scale factor
Γ ₁	$\pi^+\pi^-\eta$	0.089 ±0.009	1.2
Γ2	$ \rho^0 \gamma $ (including non-resonant $\pi^+\pi^-\gamma$)	0.061 ±0.005	1,3
Γ_3	$\pi^0\pi^0\eta$	0.042 ±0.004	1.5
Γ4	$\omega\gamma$.	0.0061 ±0.0008	1.2
Γ ₅	$\gamma\gamma$	0.00427 ± 0.00019	1.1
Γ ₆	$3\pi^0$	(3.1 ±0.6)×	10-4 1.1

1/(958) PARTIAL WIDTHS

$\Gamma(\gamma\gamma)$						Г5
VALUE (keV)	EVTS	DOCUMENT ID		TECN	COMMENT	_
4.27±0.19 OUR FIT	Error incl	udes scale factor of	f 1.1.			
4.37±0.25 OUR AVE	RAGE					
$4.53 \pm 0.29 \pm 0.51$	266	KARCH	92	CBAL	$e^+e^{e^+e^-\eta\pi^0\pi^0}$	
3.61±0.13±0.48		¹ BEHREND	91	CELL	$e^{+}e^{-}\eta\pi^{0}\pi^{0}$ $e^{+}e^{-}\rightarrow$ $e^{+}e^{-}\eta'(958)$	
4.6 ±1.1 ±0.6	23	BARU	90	MDI	$e' \stackrel{e}{e^+} \stackrel{\rightarrow}{e^-} \pi^+ \pi^- \gamma$	
4.57±0.25±0.44		BUTLER	90	MRK2	$e^{+}e^{-}_{e^{+}e^{-}\eta'(958)}$	
5.08±0.24±0.71	547	² ROE	90	ASP	$e^+e^- \rightarrow e^+e^-2\gamma$	
3.8 ±0.7 ±0.6	34	AIHARA	88 C	TPC	$e^+e^{e^+e^-\eta\pi^+\pi^-}$	
4.9 ±0.5 ±0.5	136	3 WILLIAMS	88	CBAL	$e^+e^- \rightarrow e^+e^-2\gamma$	
• • • We do not use	the following	ng data for averag	es, fits	s, ilmits,	etc. • • •	
4.7 ±0.6 ±0.9	143	4 GIDAL	87	MRK2	$e^+e^{e^+e^-\eta\pi^+\pi^-}$	
4.0 ±0.9		⁵ BARTEL	85E	JADE	$e^+e^- \rightarrow e^+e^- 2\gamma$	
¹ Revaluated by us	using B(n'	$\rightarrow \rho(770)\gamma) = ($	30.2 ±	1.3)%.		
² Revaluated by us						
³ Revaluated by us						
⁴ Superseded by B		. , , , = (2.22 .		.,		
5 Systematic error		vd.				

$\eta'(958) \Gamma(i)\Gamma(\gamma\gamma)/\Gamma(total)$

This combination of a partial width with the partial width into $\gamma\gamma$ and with the total width is obtained from the integrated cross section into channel(i) in the $\gamma\gamma$ annihilation.

$\Gamma(\gamma\gamma) \times \Gamma(\rho^0\gamma)$ (inc	-non gnibut	resonant $\pi^+\pi^-$	$(\gamma))/\Gamma_{\text{total}}$	Γ ₅ Γ _{2/} Γ
VALUE (keV)	EVTS	DOCUMENT ID		COMMENT
1.29±0.06 OUR FIT	Error includes	scale factor of 1.	2.	
1.26±0.07 OUR AVER	MGE Error in	icludes scale facti	or of 1.2.	
$1.09 \pm 0.04 \pm 0.13$		BEHREND	91 CELL	$e^{+}e^{-}_{e^{+}e^{-}\rho(770)^{0}\gamma}$
$1.35 \pm 0.09 \pm 0.21$		AIHARA	87 TPC	$e^+e^- \rightarrow e^+e^-\rho\gamma$
$1.13 \pm 0.04 \pm 0.13$	867	ALBRECHT	87B ARG	$e^+e^- \rightarrow e^+e^-\rho\gamma$
$1.53 \pm 0.09 \pm 0.21$		ALTHOFF	84E TASS	$e^+e^- \rightarrow e^+e^-\rho\gamma$
$1.14 \pm 0.08 \pm 0.11$	243	BERGER		$e^+e^- \rightarrow e^+e^-\rho\gamma$
$1.73 \pm 0.34 \pm 0.35$	95	JENNI		$e^+e^- \rightarrow e^+e^-\rho\gamma$
$1.49 \pm 0.13 \pm 0.027$	213	BARTEL	82B JADE	$e^+e^- \rightarrow e^+e^-\rho\gamma$
• • • We do not use the	e following d	ata for averages,	fits, limits, etc	. • • •
$1.85 \pm 0.31 \pm 0.24$	43	BEHREND	83B CELL	$e^+e^- \rightarrow e^+e^-\rho\gamma$

 $\eta'(958)$

$\Gamma(\gamma\gamma) \times \Gamma(\pi^0\pi^0\eta)$	/Γ _{total}			Γ ₅ Γ _{3/}	/r	$\Gamma(\pi^+\pi^-e^+e^-)/\Gamma_t$						Γ ₁₄ /Γ
/ALUE (keV) 0.88±0.07 OUR FIT		DOCUMENT ID		OMMENT		VALUE	<u>CL%</u> 90	DOCUMENT ID		TECN UBC	2.7 K p	
0.92±0.06±0.11 0 • • We do not use the	6	KARCH 9	2 CBAL e	$+e^- \rightarrow e^+e^-\eta\pi^0\pi^0$	•	<0.006 Γ(6π)/Γ _{total}	90	KILLENBERG	65	пвс	2.1 K p	Γ ₁₃ /
0.95±0.05±0.08				$+e^- \rightarrow e^+e^-\eta\pi^0\pi^0$	1	VALUE	_ CL%_	DOCUMENT ID		TECN	COMMENT	
.00±0.08±0.10				$+e^- \rightarrow e^+e^-\eta\pi^0\pi^0$		<0.01	90	LONDON	66	нвс	Compilation	
6 Revaluated by us us	$lng B(\eta \rightarrow$	$\gamma\gamma)=(39.21\pm$	0.34)%. Sup	ersedes ANTREASYAN	87	$\Gamma(\omega\gamma)/\Gamma(\pi^+\pi^-\eta)$						Γ_4/Γ_2
and KARCH 90. Superseded by KAR	CH 92.			•		VALUE	EVTS	DOCUMENT ID			COMMENT	
⁸ Using BR($\eta \rightarrow 2\gamma$)	=(38.9 ±	0.5)%.				0.069±0.008 OUR FIT 0.068±0.013	Error Inclu 68	ides scale factor ZANFINO			8.4 * p	
	.,	oro) - DADAI	ACTED		_						•	
	• •	958) α PARAI				$\Gamma(\rho^0\gamma)$ (including no	n-resonant	x+x-γ))/[Γ	(*T	r η) -		
MATRIX ELEMEN	$T ^2=(1$					$\Gamma(\omega\gamma)$]		DOCUMENT 10		TECH	Γ ₂ /(Γ ₁ -	H 3+14
VALUE		DOCUMENT ID		$\frac{COMMENT}{38 \pi^- p \rightarrow n\eta 2\pi^0}$	-	VALUE 0.448±0.028 OUR FIT	Error Incl	<u>DOCUMENT ID</u> Ides scale factor			COMMENT	
-0.058±0.013 • • • We do not use ti	he following	g data for average	es, fits, limits	etc. • • •		0.25 ±0.14		DAUBER	64	нвс	1.95 K ⁻ p	
-0.08 ±0.03				$\eta' \rightarrow \eta \pi^+ \pi^-$		$\Gamma(\gamma\gamma)/\Gamma_{\text{total}}$						Γ ₅ /!
⁹ May not necessarily	be the sar	ne for $\eta' o \eta \pi^{-}$	π^- and η'	$\rightarrow \eta \pi^0 \pi^0$.	_	VALUE 0.0211±0.0013 OUR I	_ <i>EVTS</i> FIT Error In	DOCUMENT ID cludes scale fact		<u>TECN</u> 1.2.	COMMENT	
	ط/(95)	B) BRANCHIN	G RATIOS			0.0196±0.0015 OUR	WERAGE					
-4.1		•	J.211100		/=	0.0200 ± 0.0018	1	⁰ STANTON	80	SPEC	$8.45 \pi^- p \rightarrow \pi^+ \pi^- 2\gamma$	
$\Gamma(\pi^+\pi^-\eta)$ (neutral d				0.714F ₁	/ 「	0.025 ±0.007		DUANE			$\pi^- p \rightarrow nMN$	A _
VALUE 0.313±0.011 OUR FIT	Error inc	<u>DOCUMENT ID</u> ludes scale facto		COMMENT		0.0171±0.0033	68	DALPIAZ			$1.6 \ \pi^- p \rightarrow \ n$	
0.314±0.026	281			1.7-2.7 K ⁻ p		0.020 +0.008 -0.006	31	HARVEY			$3.65 \pi^- p \rightarrow$	πX ^U
$\Gamma(\pi^+\pi^-$ neutrals)/I	Tenent		(0.714	1+0.286F3+0.89F4)	/ Γ	• • • We do not use	_					
VALUE	EVTS	DOCUMENT ID	TECN	COMMENT		0.018 ±0.002		1 APEL	79	NICE	15-40 π ⁻ p	· π2γ
0.399±0.009 OUR FIT 0.36 ±0.05 OUR AVI		cludes scale facto				¹⁰ includes APEL 79 ¹¹ Data is included in	result. STANTON	80 evaluation.				
0.4 ±0.1	39	LONDON	66 HBC	2.24 $K^- p \rightarrow \Lambda \pi^+ \pi^-$ neutrals		$\Gamma(e^+e^-)/\Gamma_{\text{total}}$						Γ ₁₇ /
0.35 ±0.06	33	BADIER	658 HBC	3 K p		VALUE (units 10 ⁻⁷)	CL%	DOCUMENT ID		TECN	COMMENT	
$\Gamma(\pi^+\pi^-\eta)$ (charged	decay))/	T _{total}		0.286Г₁	<u>/</u> /Γ	<2.1	90	VOROBYEV	88	ND	e+e- → π+	π - η
VALUE	<u>EVTS</u>	DOCUMENT ID		COMMENT		$\Gamma(\pi^+\pi^-)/\Gamma_{\text{total}}$						Γ ₁₈ /
0.125±0.004 OUR FIT 0.116±0.013 OUR AVI		cludes scale facto	r of 1.1.			VALUE	<u> CL%</u>	DOCUMENT ID		TECN		
0.123±0.014	107	RITTENBER	G 69 HBC	1.7-2.7 K ⁻ p		<0.02 • • • We do not use	90 the following	RITTENBERG			1.7-2.7 K p . etc. • • •	
0.10 ±0.04	10	LONDON	66 HBC	2.24 K ⁻ p \rightarrow $\Lambda \pi^{+} \pi^{-} \pi^{+} \pi^{-} \pi^{0}$)	<0.08	95	DANBURG		нвс	2.2 K p →	ΛX ⁰
0.07 ±0.04	7	BADIER	65B HBC	3 K p		r/_+0\/r						Г. /
Γ(π ⁰ π ⁰ η(charged	ا (المحمدا	- Flatcharmed	decaylarl	·r		$\Gamma(\pi^+\pi^-\pi^0)/\Gamma_{\text{tota}}$	<u>CL%</u>	DOCUMENT ID		TECN	COMMENT	Гв/
[i (x x y/ciiaigeu	uccay)) -	L I (m (citat Red	decay).////	(0.286\(\Gamma_3+0.89\(\Gamma_4\))/ r	<0.05	90	RITTENBERG			1.7-2.7 K ⁻ p	
VALUE	EVTS	DOCUMENT ID		COMMENT		• • • We do not use	the following	data for average	es, fits	, limits		_
0.086±0.005 OUR FIT 0.045±0.029	Error In			1.7-2.7 K ⁻ p		<0.09	95	DANBURG	73	HBC	2.2 K ⁻ p →	ΛX ⁰
	74	·	_			Γ(π ⁺ π ⁺ π ⁻ π ⁻ nei	rtrais)/ Γ_{tot}	ai e				Γ ₁₁ /
「(neutrals)/「total	E1 (TC	DACUMENT IS	•	.714[3+0.09[4+[5] COMMENT)/[VALUE	<u>ct%</u>	DOCUMENT ID			COMMENT	
VALUE 0.172±0.009 OUR FIT	EVTS Error in	<u>DOCUMENT ID</u> cludes scale facto		COMMENT		<0.01 • • • We do not use	95 the following	DANBURG			2.2 K ⁻ p →	ΛX ⁰
0.187±0.017 OUR AV		DACH F	TI CHTE	14		<0.01	90				1.7-2.7 K p	
0.185±0.022 0.189±0.026	535 123	BASILE RITTENBER		1.6 $\pi^- p \to nX^0$ 1.7-2.7 $K^- p$				WITTE TO LIN		1100	p	_ ,
_					. /F	Γ(π+π+π-π-π0		DOCUMENT IN		TECH	COMMENT	F ₁₂ /
$\Gamma(\rho^0 \gamma)$ (including no VALUE	n-resonar <i>EVTŞ</i>	Itπ™π™γ))/(DOCUMENT ID		COMMENT	2/Γ	<u>VALUE</u> <0.01	90	DOCUMENT ID			1.7-2.7 K ⁻ p	
0.302±0.013 OUR FIT	Error In										, p	
0.319±0.030 OUR AV		DITTENDED	C 60 HPC	17_27 V = -		Γ(π ⁺ π ⁺ π ⁻ π ⁻)/[DOCUMENT :-		TECH	COMMENT	Γ ₁₀ /
0.329±0.033 0.2 ±0.1	298 20	RITTENBER LONDON	66 HBC	1.7-2.7 K p 2.24 K p →		<u>VALUE</u> <0.01	<u>CL%</u> 90	DOCUMENT ID			1.7-2.7 K - p	
				$\Lambda \pi^+ \pi^- \gamma$		_					•	
0.34 ±0.09	35	BADIER	658 HBC	3 K p		Γ(π ⁰ π ⁰ η(3π ⁰ deca	y))/「total	DOCUMENT ID		TECH	<u>COMMENT</u>).321 ₃ /
$\Gamma(ho^0\gamma)$ (including no	n-resonal			$\Gamma_2/(\Gamma_1+$	Г ₃)	0.066±0.004 OUR FI	T Error Inc	ludes scale facto	r of 1.	2.		
VALUE 0.469±0.029 OUR FIT	Γ Frror In	<u>DOCUMENT ID</u>		COMMENT		0.11 ±0.06	4	BENSINGER	70	DBC	$2.2 \pi^{+} d$	
0.31 ±0.15		DAVIS		5.5 K ⁻ p		$\Gamma(ho^0\gamma)$ (including no	on-resonant	tπ ⁺ π ⁻ γ))/Γ	(π ⁺ π	r ⁻ η(n		
$\Gamma(\pi^0 e^+ e^-)/\Gamma_{\text{total}}$				Γ ₂₁	₀ /Γ	VALUE	EVTS	DOCUMENT ID		TECN	COMMENT	2/0.714[
VALUE	CL%	DOCUMENT IL		COMMENT		0.97±0.07 OUR FIT	Error includ					
<0.013	90	RITTENBER	G 65 HBC	2.7 K ⁻ p		1.01±0.09 OUR AVE	RAGE	DEL 401077	00-	vee	26 a= Da	/
$\Gamma(\eta e^+ e^-)/\Gamma_{\text{total}}$				Гэ	1/F	1.07±0.17 0.92±0.14	473	BELADIDZE DANBURG		VES	36 π^- Be \rightarrow 2.2 $K^- p \rightarrow$	
VALUE	<u>CL%_</u>	DOCUMENT IL	TECN	COMMENT		1.11±0.18	192	JACOBS			2.9 K ⁻ p →	
<0.011	90	RITTENBER	RG 65 HBC	2.7 K ⁻ p		$\Gamma(\gamma\gamma)/\Gamma(\pi^0\pi^0\eta)$	nautral dae	m))			F.	s/0.714ľ
$\Gamma(\pi^0 \rho^0)/\Gamma_{\text{total}}$				r.	9/۲	(γγ)/ (π°π°η(EVTS	DOCUMENT ID		<u>TECN</u>	COMMENT)/ V. 1 271
VALUE	CL%	DOCUMENT II	<u>TECN</u>	COMMENT		0.143±0.010 OUR F	1 Error Inc	ludes scale facto APEL			(3.8 π ⁻ p →	

Meson Particle Listings $\eta'(958)$, $f_0(980)$

						_
$\Gamma(\mu^+\mu^-\gamma)/\Gamma(\gamma\gamma)$					Γ ₇ /Γ	B
VALUE (units 10 ⁻³)	EVTS	DOCUMENT ID		TECN	COMMENT	_
4.9±1.2	33	VIKTOROV	80	CNTR	25,33 $\pi^- p \rightarrow 2\mu\gamma$	
$\Gamma(\mu^+\mu^-\eta)/\Gamma_{\text{total}}$					Γ ₂₄ /	' Γ
VALUE (units 10 ⁻⁵)	CL%	DOCUMENT ID		TECN	COMMENT	_
<1.5	90	DZHELYADIN	81	CNTR	$30 \pi^- p \rightarrow \eta' n$	
$\Gamma(\mu^+\mu^-\pi^0)/\Gamma_{ m total}$					Γ ₂₃ /	/ Γ
VALUE (units 10 ⁻⁵)	CL%	DOCUMENT ID		TECN	COMMENT	_
<6.0	90	DZHELYADIN	81	CNTR	$30 \pi^- p \rightarrow \eta' n$	
$\Gamma(3\pi^0)/\Gamma(\pi^0\pi^0\eta)$					Г ₆ /Г	3
VALUE (units 10 ⁻⁴)		DOCUMENT ID		TECN	COMMENT	_
74±12 OUR FIT						
74±12 OUR AVERAGE 74±15		ALDE	970	GAMO	38 π ⁻ p → n6γ	
75±18		BINON			$30-40 \pi^- p \rightarrow n6\gamma$	
		5	•		•	
$\Gamma(\gamma\gamma)/\Gamma(\pi^0\pi^0\eta)$					Γ ₅ /Ι	3
VALUE	Fara la alc	DOCUMENT ID			COMMENT	
0.102±0.007 OUR FIT 0.105±0.010 OUR AVER		des scale factor or includes scale				
0.091±0.009	ONGE CIT	AMSLER		CBAR		
$0.112 \pm 0.002 \pm 0.006$		ALDE			38 π ⁻ p → π2γ	
$\Gamma(\omega\gamma)/\Gamma(\pi^0\pi^0\eta)$					Γ4/Ι	Гз
VALUE		DOCUMENT ID		TECN	COMMENT	_
0.146±0.014 OUR FIT						
0.147±0.016		ALDE	878	GAM2	$38 \pi^- p \rightarrow n4\gamma$	
$\Gamma(3\gamma)/\Gamma(\pi^0\pi^0\eta)$					Γ ₂₂ /Ι	Г3
VALUE (units 10 ⁻⁴)	CL%	DOCUMENT ID			COMMENT	_
<4.6	90	ALDE	87B	GAM2	$38 \pi^- p \rightarrow n3\gamma$	
$\Gamma(\pi^0\gamma\gamma)/\Gamma(\pi^0\pi^0\eta)$					Γ ₁₅ /!	Γ3
VALUE (units 10 ⁻⁴)	CL%	DOCUMENT ID		TECN	COMMENT	_
<37	90	ALDE	87e	GAM2	38 π ⁻ p → π4γ	
$\Gamma(\pi^0\pi^0)/\Gamma(\pi^0\pi^0\eta)$					Γ ₁₉ /Ι	Г3
VALUE (units 10 ⁻⁴)	CL%	DOCUMENT ID		TECN	COMMENT	_
<45	90	ALDE	878	GAM2	$38 \pi^- p \rightarrow n4\gamma$	
$\Gamma(4\pi^0)/\Gamma(\pi^0\pi^0\eta)$					Γ ₁₆ /	Гз
VALUE (units 10 ⁻⁴)	CL%	DOCUMENT ID		TECN	COMMENT	
<23	90	ALDE	87 E	GAM2	38 π ⁻ p → n8γ	
			_			_

7/(958) C-NONCONSERVING DECAY PARAMETER

See the note on η decay parameters in the Stable Particle Particle Listings for definition of this parameter.

DECAY ASYMMETRY PARAMETER FOR $\pi^+\pi^-\gamma$

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
-0.01 ± 0.04	OUR AVERAGE				
-0.019 ± 0.056		AIHARA	87	TPC	$2\gamma \rightarrow \pi^{+}\pi^{-}\gamma$
-0.069 ± 0.078	295	GRIGORIAN	75	STRC	2.1 π ⁻ p
0.00 ± 0.10	103	KALBFLEISCH	75	HBC	
					$\Lambda \pi^+ \pi^- \gamma$
0.07 ± 0.08	152	RITTENBERG	65	HBC	2.1-2.7 K ⁻ p

η'(958) REFERENCES

WURZINGER	96	PL B374 283	+Siebert+ (BC	NN, ORSAY, SACL, CRAC)
AMSLER	93	ZPHY C58 175	+Armstrong, Merkel+	(Crystal Barrel Collab.)
BELADIDZE	92C	SJNP 55 1535	+Bityukov, Borisov	(SERP, TBIL)
		Translated from	YAF 55 2748.	,
KARCH	92	ZPHY C54 33	+Antreasyan, Bartels+	(Crystal Ball Collab.)
ARMSTRONG	91B	ZPHY C52 389	+Barnes+ (ATHU,	BARI, BÌRM, CERN, CDEF)
BEHREND	91	ZPHY C49 401	+Criegee, Field, Franke+	(CELLO Collab.)
AUGUSTIN	90	PR D42 10	+Cosme+	(DM2 Collab.)
BARU	90	ZPHY C48 581	+Blinov, Blinov+	(MD-1 Collab.)
BUTLER	90	PR D42 1368	+Boyer+	(Mark II Collab.)
KARCH	90	PL B249 353	+Antreasyan, Bartels+	(Crystal Ball Collab.)
ROE	90	PR D41 17	+Bartha, Burke, Garbincius+	(ASP Collab.)
AIHARA	88C	PR D38 1	+Alston-Garnjost+	(TPC-2γ Collab.)
VOROBYEV	88	SJNP 48 273	+Golubev, Dolinsky, Druzhinin+	(NOVO)
		Translated from	VAC 10 196	• •

WILLIAMS	88	PR D38 1365	+Antreasyan, Bartels, Besset+ (Crystal Ball Collab.)
AIHARA	87	PR D35 2650	+Alston-Garnjost+ (TPC-2 γ Collab.) JP
ALBRECHT	87B		+Andam, Binder+ (ARGUS Collab.)
ALDE	87B	ZPHY C36 603	+Binon, Bricman+ (LANL, BELG, SERP, LAPP)
ANTREASYAN	87	PR D36 2633	+Bartels, Besset+ (Crystal Ball Collab.)
GIDAL	87	PRL 59 2012	+Boyer, Butler, Cords, Abrams+ (LBL, SLAC, HARV)
ALDE	86	PL B177 115	+Binon, Bricman+ (SERP, BELG, LANL, LAPP)
BARTEL	85E	PL 160B 421	+Becker, Cords, Felst+ (JADE Collab.)
ALTHOFF	84E	PL 147B 487	+Braunschweig, Kirschfink, Luebelsmeyer+ (TASSO Collab.)
BERGER	84B	PL 142B 125	(PLUTO Collab.)
BINON	84	PL 140B 264	+Donskov, Duteil+ (SERP, BELG, LAPP, CERN)
BEHREND	83B	PL 125B 518	+D'Agostini+ (CELLO Collab.)
Also	82C	PL 114B 378	Behrend, Chen, Fenner, Field+ (CELLO Collab.)
JENNI	83	PR D27 1031	+Burke, Telnov, Abrams, Blocker+ (SLAC, LBL)
BARTEL		PL 113B 190	+Cords+ (JADE Collab.)
DZHELYADIN	81	PL 105B 239	
STANTON	80	PL 92 B 353	+Edwards, Legacey+ (OSU, CARL, MCGI, TNTO)
VIKTOROV	80	SJNP 32 520	+Golovkin, Dzhelyadin, Zaitsev, Mukhin+ (SERP)
ADEL	70	Translated from YAF 3:	Augustain Dantalussi/KADLK KADLE DICA CERD WIEN)
APEL	79	PL 83B 131	Augenstein, Bertolucci(KARLK, KARLE, PISA, SERP, WIEN)
BINNIE	79	PL 83B 141	+Carr, Debenham, Jones, Karami, Keyne+ (LOIC)
ZANFINO	77	PRL 38 930	+Brockman+ (CARL, MCGI, OHIO, TNTO)
GRIGORIAN	75	NP B91 232	+Ladage, Mellema, Rudnick+ (+)
KALBFLEISCH		PR D11 987	+Strand, Chapman (BNL, MICH)
DUANE	74	PRL 32 425	+Binnie, Camilleri, Carr+ (LOIC, SHMP)
KALBFLEISCH	74	PR D10 916	(BNL)
DANBURG	73	PR D8 3744	+Kalbfleisch, Borenstein, Chapman+ (BNL, MICH) JP
JACOBS	73	PR D8 18	+Chang, Gauthier+ (BRAN, UMD, SYRA, TUFTS) JP
APEL	72	PL 40B 680	+Auslander, Muller, Bertolucci+ (KARLK, KARLE, PISA)
DALPIAZ	72	PL 42B 377	+Frabetti, Massam, Navarria, Zichichi (CERN)
BASILE	71	NC 3A 371	+Bollini, Dalpiaz, Frabetti+ (CERN, BGNA, STRB)
HARVEY	71	PRL 27 885	+Marquit, Peterson, Rhoades+ (MINN, MICH)
BENSINGER	70	PL 33B 505	+Erwin, Thompson, Walker (WISC)
RITTENBERG		Thesis UCRL 18863	(LRL)
DAVIS	68	PL 27B 532	+Ammar, Mott, Dagan, Derrick+ (NWES, ANL)
LONDON	66	PR 143 1034	+Rau, Goldberg, Lichtman+ (BNL, SYRA) IJP
	65B		+Demoulin, Barloutaud+ (EPOL, SACL, AMST)
BADIER			
RITTENBERG		PRL 15 556	+Kalbfleisch (LRL, BNL)
DAUBER	64	PRL 13 449	+Siater, Smith, Stork, Ticho (UCLA) JP
			
		OTHER	R RELATED PAPERS
GRONBERG	98	PR D57 33	J. Gronberg, Hill, Kutschke+ (CLEO Collab.)
ABELE	97B	PL B402 195	A. Abele, Adomeit, Amsler+ (Crystal Barrel Collab.)
GENOVESE	94	ZPHY C61 425	+Lichtenberg, Pedrazzi (TORI, IND)
BENAYOUN	93	ZPHY 58 31	+Feindt, Girone+ (CDEF, CERN, BARI)
KAMAL	92	PL B284 421	+Xu (ALBE)
BICKERSTAFF		ZPHY C16 171	+ McKellar (MELB)
KIENZLE	65	PL 19 438	+Maglich, Levrat, Lefebvres+ (CERN)
TRILLING	65	PL 19 427	+Brown, Goldhaber, Kadyk, Scanlo (LRL)
GOLDBERG	64	PRL 12 546	+Gundzik, Lichtman, Connolly, Hart+ (SYRA, BNL)
GOLDBERG	64B		+Gundzik, Leitner, Connolly, Hart+ (SYRA, BNL)
		PRL 12 527	+Alvarez, Barbaro-Galtieri+ (LRL) JP
KALBFLEISCH		PRL 12 327	+Dahl, Rittenberg (LRL) JP
NALDELEISCH	040	LUT 13 343	+Dail, Kitteineiß (CKC) 15

$f_0(980)$

$$I^{G}(J^{PC}) = 0^{+}(0^{+})$$

See also the minireview on scalar mesons under $f_0(1370)$. (See the index for the page number.)

€(980) MASS

VALUE (M		EVTS	DOCUMENT ID		TECN	COMMENT
		ESTIMATE		St. 1	laaten ne	
		the following a	ata for averages, f			
955			¹ ALDE ² BERTIN	97	GAM2	$450 pp \rightarrow pp\pi^{0}\pi^{0}$ $0.0 \overline{p}p \rightarrow \pi^{+}\pi^{-}\pi^{0}$
994	± 9 ± 6.5±6.9				RVUE	
1006	± 0.5±0.9		TORNQVIST		RVUE	
1000			TORINGVIST	70	KVUL	$n\pi$
997	± 5	3k	4 ALDE	958	GAM2	$38 \pi^- p \rightarrow \pi^0 \pi^0 n$
960	±10	10k	⁵ ALDE	95B	GAM2	38 $\pi^- p \to \pi^0 \pi^0 n$
994	± 5		AMSLER	95B	CBAR	
~ 996			⁶ AMSLER	95D	CBAR	$0.0 \overline{\rho} \rho \rightarrow \pi^0 \pi^0 \pi^0, \\ \pi^0 \eta \eta, \pi^0 \pi^0 \eta$
987	+ 6		7 ANISOVICH	95	RVUE	<i>н үү, к к ү</i>
1015			JANSSEN			$\pi\pi \rightarrow \pi\pi, K\overline{K}$
983			⁸ BUGG		RVUE	
973	± 2		KAMINSKI	94	RVUE	$\pi\pi \rightarrow \pi\pi, K\overline{K}$
988			⁹ zou	94B	RVUE	
988	±10	1	^{LO} MORGAN	93	RVUE	
						$\pi\pi(K\overline{K}), J/\psi \rightarrow$
						$\phi\pi\pi(K\overline{K}), D_S \rightarrow$
			1			$\pi(\pi\pi)$
	± 4.0		1 AGUILAR	91		400 pp
979	± 4	•	11 ARMSTRONG	91	OMEG	300 $pp \rightarrow pp \pi \pi$, $pp K \overline{K}$
956	±12		BREAKSTONE	90	SFM	$pp \rightarrow pp\pi^{+}\pi^{-}$
959.4	1± 6.5		1 AUGUSTIN	89	DM2	$J/\psi \rightarrow \omega \pi^+ \pi^-$
978	± 9		¹ ABACHI	86B	HRS	$e^+e^- \rightarrow \pi^+\pi^-X$
985.0	9.0 -39.0		ETKIN	82B	MPS	$23~\pi^-\rho\to~n2K_S^0$
974	± 4	1	¹¹ GIDAL	81	MRK2	$J/\psi \rightarrow \pi^{+}\pi^{-}X$
975			¹² ACHASOV	80	RVUE	
986	±10	:	¹¹ AGUILAR	78	HBC	$0.7 \overline{p}_P \rightarrow K_S^0 K_S^0$
969	± 5	:	¹¹ LEEPER	77	ASPK	$2-2.4 \pi^{-} p \rightarrow \pi^{+} \pi^{-} n, K^{+} K^{-} n$
987	± 7	:	¹¹ BINNIE	73	CNTR	$\pi^- p \rightarrow nMM$
1012		:	13 GRAYER		ASPK	
1007			13 HYAMS	73	ASPK	
997			13 PROTOPOP		HBC	7 π ⁺ p →
,,,						$\pi^+p\pi^+\pi^-$

 $f_0(980)$

Erom	Invariant	marc	fit
Frioin	invariant	111455	m.

²On sheet II in a 2 pole solution. The other pole is found on sheet III at (963-29i) MeV. ³ Reanalysis of data from HYAMS 73, GRAYER 74, SRINIVASAN 75, and ROSSELET 77 using the Interfering amplitude method.

⁴ At high |t|.

⁵ At low |t|.

⁶ On sheet II in a 4-pole solution, the other poles are found on sheet III at (953–55/) MeV and on sheet IV at (938-35/) MeV.

7 Combined fit of ALDE 958, ANISOVICH 94, AMSLER 94D. 8 On sheet II in a 2 pole solution. The other pole is found on sheet III at (996 – 103/) MeV. ⁹ On sheet II in a 2 pole solution. The other pole is found on sheet III at (797–1851) MeV and can be interpreted as a shadow pole.

10 On sheet II in a 2 pole solution. The other pole is found on sheet III at (978–28/) MeV.

11 From coupled channel analysis.

12 Coupled channel analysis with finite width corrections.

13 Included In AGUILAR-BENITEZ 78 fit.

ჩ₀(980) WIDTH

Width determination very model dependent. Peak width in $\pi\pi$ is about 50 MeV, but decay width can be much larger.

VALUE (vrs	,	DOCUMENT ID		<u>TECN</u>	COMMENT
			OUR ESTIM						'
• • •	We	do n	ot use the fol	lowing	dat	a for averages,	fits, I	lmits, ei	tc. • • •
69	±	15			14	ALDE	97	GAM2	$450 pp \rightarrow pp\pi^0\pi^0$
38	±	20				BERTIN	97c	OBLX	$0.0 \; \overline{p} \rho \rightarrow \; \pi^+ \pi^- \pi^0$
~ 100					16	ISHIDA			$\pi\pi \to \pi\pi$, $K\overline{K}$
34						TORNQVIST	96	RVUE	$\pi\pi \to \pi\pi, K\overline{K}, K\pi, \eta\pi$
48	±	10		3k	17	ALDE	95B	GAM2	38 $\pi^- p \to \pi^0 \pi^0 n$
95	±	20		10k	18	ALDE	95B	GAM2	38 $\pi^- p \rightarrow \pi^0 \pi^0 n$
26	±	10				AMSLER	95B	CBAR	$0.0 \ \overline{p}p \rightarrow 3\pi^{0}$
~ 112					19	AMSLER	95D	CBAR	$\begin{array}{ccc} 0.0 \ \overline{p}p \to & \pi^0 \pi^0 \pi^0, \\ \pi^0 \eta \eta, \ \pi^0 \pi^0 \eta \end{array}$
80	±	12			20	ANISOVICH	95	RVUE	* 44, " * 4
30						JANSSEN	95	RVUE	$\pi\pi \rightarrow \pi\pi$, $K\overline{K}$
74					21	BUGG	94	RVUE	$\overline{p}p \rightarrow \eta 2\pi^0$
29	±	2				KAMIN5KI	94	RVUE	$\pi\pi \rightarrow \pi\pi, K\overline{K}$
46					22	ZOU	94B	RVUE	
48	±	12			23	MORGAN	93	RVUE	$\pi\pi(K\overline{K}) \to \\ \pi\pi(K\overline{K}), J/\psi \to \\ \phi\pi\pi(K\overline{K}), D_c \to$
									$\pi(\pi\pi)$
37.4	4 ±	10.6			14	AGUILAR	91	EHS	400 pp
72	±	8			24	ARMSTRONG	91	OMEG	300 $pp \rightarrow pp\pi\pi$, $ppK\overline{K}$
110	±	30				BREAKSTONE	90	SFM	$pp \rightarrow pp\pi^{+}\pi^{-}$
29	±	13			14	ABACHI	86B	HRS	$e^+e^- \rightarrow \pi^+\pi^-X$
120	±2	81	±20			ETKIN	828	MPS	$23 \pi^- p \rightarrow n2K_S^0$
28	±	10			24	GIDAL	81	MRK2	$J/\psi \rightarrow \pi^{+}\pi^{-}X$
70	to	300			25			RVUE	-/+
100	±	80			26	AGUILAR	78	HBC	$0.7 \overline{p}p \rightarrow K_S^0 K_S^0$
30	±	8			24	LEEPER	77	ASPK	2-2.4 π ⁻ p →
48	±	14			24	BINNIE	73	CNTP	$\pi^+\pi^-n$, K^+K^-n $\pi^-p \to nMM$
	+								$17 \pi^- p \rightarrow \pi^+ \pi^- n$
	±							ASPK	
54	±					PROTOPOP		HBC	$7\pi^+p \rightarrow$
-	_								$\pi^+p\pi^+\pi^-$

 $14\,{\rm From}$ invariant mass fit. $15\,{\rm On}$ sheet II in a 2 pole solution. The other pole is found on sheet III at (963-29I) MeV. 16 Reanalysis of data from HYAMS 73, GRAYER 74, SRINIVASAN 75, and ROSSELET 77 using the interfering amplitude method. $^{17}{\rm At~high~}|t|.$

 18 At low |t|.

19 On sheet II in a 4-pole solution, the other poles are found on sheet III at (953–55/) MeV and on sheet IV at (938–35/) MeV.

20 Combined fit of ALDE 95B, ANISOVICH 94, 21 On sheet II in a 2 pole solution. The other pole is found on sheet III at (996–103/) MeV. 22 On sheet II in a 2 pole solution. The other pole is found on sheet III at (797–185/) MeV and can be interpreted as a shadow pole.

23 On sheet II in a 2 pole solution. The other pole is found on sheet III at (978–28/) MeV.

²⁴ From coupled channel analysis.

²⁵ Coupled channel analysis with finite width corrections.

26 From coupled channel fit to the HYAMS 73 and PROTOPOPESCU 73 data. With a simultaneous fit to the $\pi\pi$ phase-shifts, inelasticity and to the $K^0_SK^0_S$ invariant mass.

27 Included in AGUILAR-BENITEZ 78 fit.

fo(980) DECAY MODES

	Mode	Fraction (Γ_I/Γ)	Confidence level
Γ1	ππ_	dominant	
Γ_2	KΚ	seen	
Гз	$\gamma\gamma$	(1.19±0.33)	
Γ_4	e ⁺ e ⁻	< 3	× 10 ⁻⁷ 90%

fo (980) PARTIAL WIDTHS

				Гз
EVTS	DOCUMENT ID		TECN	COMMENT
AGE				
	²⁸ MORGAN	90	RVUE	$\gamma \gamma \rightarrow \pi^{+}\pi^{-}, \pi^{0}\pi^{0}$
60	²⁹ OEST	90	JADE	$e^+e^- \rightarrow e^+e^-\pi^0\pi^0$
he followir	ng data for averag	es, fit	s, limits,	etc. • • •
30	,31 BOYER	90	MRK2	
30	^{),31} MARSISKE	90	CBAL	$e^{+}e^{-}\pi^{+}\pi^{-}$ $e^{+}e^{-}\to e^{+}e^{-}\pi^{0}\pi^{0}$
	AGE 60 he followin 30	AGE 28 MORGAN 60 29 OEST	AGE 28 MORGAN 90 60 29 OEST 90 he following data for averages, fit 30,31 BOYER 90	AGE

 28 From amplitude analysis of BOYER 90 and MARSISKE 90, data corresponds to resonance parameters m=989 MeV, $\Gamma=61$ MeV. 29 OEST 90 quote systematic errors $^{+0.08}_{-0.18}$. We use ± 0.18 .

 $^{
m 30}$ From analysis allowing arbitrary background unconstrained by unitarity.

31 Data included in MORGAN 90 analysis.

Γ(e+e-) Γ4 VALUE (eV) CL% DOCUMENT ID TECN COMMENT $e^+e^- \rightarrow \pi^{0}\pi^{0}$ <8.4 90 VOROBYEV 88 ND

€(980) BRANCHING RATIOS

$\Gamma(\pi\pi)/[\Gamma(\pi\pi)+\Gamma($	κ Ҡ)]		$\Gamma_1/(\Gamma_1+\Gamma_2)$
VALUE	DOCUMENT ID	TECN	COMMENT
• • • We do not use th	e following data for averag	es, fits, limit	s, etc. • • •
0.67 ± 0.09	32 LOVERRE	80 HBC	$4 \pi^- p \rightarrow n2K_S^0$
$0.81^{+0.09}_{-0.04}$	32 CASON	78 STR	$7\pi^-p \rightarrow n2K_5^0$
0.78 ± 0.03	32 WETZEL	76 OSPI	$\langle 8.9 \pi^- p \rightarrow \pi 2 K_S^0 \rangle$

³² Measure $\pi\pi$ elasticity assuming two resonances coupled to the $\pi\pi$ and $K\overline{K}$ channels

€(980) REFERENCES

	N.D.C		DI D207 454	. D. H I. I. Diversi	(61146 6 11 1 1
	ALDE	97	PL B397 350	+Bellazzini, Binon+	(GAMS Collab.)
	BERTIN	97C	PL B408 476	A. Bertin, Bruschi+	(OBELIX Collab.)
	ISHIDA	96	PTP 95 745		(TOKY, MIYA, KEK)
	TORNQVIST	96	PRL 76 1575	+Roos	(HELS)
	ALDE	95B	ZPHY C66 375	+Binon, Boutemeur+	(GAMS Collab.)
	AMSLER	95B	PL B342 433		Crystal Barrel Collab.)
	AMSLER	95D	PL B355 425		Crystal Barrel Collab.)
	ANISOVICH	95	PL B355 363	+Kondashov+	(PNPI, SERP)
	JANSSEN	95	PR D52 2690		(STON, ADLD, JULI)
	AMSLER	94D	PL B333 277		Crystal Barrel Collab.)
	ANISOVICH	94	PL B323 233		Crystal Barrel Collab.)
	BUGG	94	PR D50 4412	+Anisovich+	(LOQM)
	KAMINSKI	94	PR D50 3145	R. Kaminski+	(CRAC, IPN)
	ZOU	94B	PR D50 591	+Bugg	(LOQM)
	MORGAN	93	PR D48 1185	+Pennington	(RAL, DURH)
	AGUILAR	91	ZPHY C50 405	Aguilar-Benitez, Allison, Batalor+	(LEBC-EHS Collab.)
	ARMSTRONG	91	ZPHY C51 351	+Benayoun+ (ATHU, BARI,	BIRM, CERN, CDEF)
	BOYER	90	PR D42 1350	+Butler+	(Mark II Collab.)
	BREAKSTONE	90	ZPHY C48 569	+ (ISU, BGNA, CERN, D	ORT. HEIDH, WARS
	MARSISKE	90	PR D41 3324	+Antreasyan+	(Crystal Ball Collab.)
	MORGAN	90	ZPHY C48 623	+Pennington	(RAL, DURH)
	OEST	90	ZPHY C47 343	+Olsson+	(JADE Collab.)
	AUGUSTIN	89	NP B320 1	+Cosme	(DM2 Collab.)
	VOROBYEV	88	SJNP 48 273	+Golubev, Dolinsky, Druzhinin+	(NOVO)
			Translated from	YAF 48 436.	()
	ABACHI	86B	PRL 57 1990	+Derrick, Blockus+ (PURD, All	VL. IND. MICH, LBL)
	ETKIN	82B	PR D25 1786	+Foley, Lai+ (BNL, CI	UNY, TUFTS, VAND)
	GIDAL	81	PL 107B 153	+Goldhaber, Guy, Millikan, Abrams+	(SLAC, LBL)
	ACHASOV	80	SJNP 32 566	+Devyanin, Shestakov	(NOVM)
			Translated from		, ,
	LOVERRE	80	ZPHY C6 187	+Armenteros, Dionisi+ (CERN, C	DEF, MADR, STOH) IJP
	AGUILAR	78	NP B140 73	Aguilar-Benitez, Cerrada+ (MA	DR, BOMB, CERN+)
	CASON	78	PRL 41 271	+Baumbaugh, Bishop, Biswas+	(NDAM, ANL)
	LEEPER	77	PR D16 2054	+Buttram, Crawley, Duke, Lamb, Pete	erson (ISU)
•	ROSSELET	77	PR D15 574	+Extermann, Fischer, Guisan+	(GEVA, SÀCL)
	WETZEL	76	NP B115 208	+Freudenreich, Beusch+	(ETH, CERN, LOIC)
	SRINIVASAN	75	PR D12 681	+Helland, Lennox, Klem+	(NDAM, ANL)
	GRAYER	74	NP B75 189	+Hvams, Blum, DietI+	(CERN, MPIM)
	BINNIE	73	PRL 31 1534	+Carr, Debenham, Duane, Garbutt+	(LOIC, SHMP)
	GRAYER	73	Tallahassee	+Hyams, Jones, Blum, Dietl, Koch+	(CERN, MPIM)
	HYAMS	73	NP B64 134	+Jones, Weilhammer, Blum, Dieti+	(CERN, MPIM)
	PROTOPOP	73	PR D7 1279	Protopopescu, Alston-Garnjost, Galtie	
					,

OTHER RELATED PAPERS -

ACHASOV	97C	PR D56 4084	N.N. Achasov+	
ACHASOV	97D	PR D56 203	N.N. Achasov+	
PROKOSHKIN	97	SPD 42 117 Translated from DANS	+Kondashov, Sadovsky+ 353 323.	(SERP)
AU	87	PR D35 1633	+Morgan, Pennington	(DURH, RAL)
AKESSON	86	NP B264 154	+Albrow, Almehed+	(Axial Field Spec. Collab.)
MENNESSIER	83	ZPHY C16 241		(MONP)
BARBER	82	ZPHY C12 1	+Dainton, Brodbeck, Brookes+	(DARE, LANC, SHEF)
ETKIN	82C	PR D25 2446	+Foley, Lai+ (BN	IL, CUNY, TUFTS, VAND)
SRINIVASAN	75	PR D12 681	+Helland, Lennox, Klem+	(NDAM, ANL)
BIGI	62	CERN Conf. 247	+Brandt, Carrara+	(CERN)
BINGHAM	62	CERN Conf. 240	+Bloch+	(EPOL, CERN)
ERWIN	62	PRL 9 34	+Hover, March, Walker, Wangler	
WANG	61	JETP 13 323 Translated from ZETF	+Veksler, Vrana+ 40 464.	(JINR)

г		ı
ı	a ₀ (980)	
l	20(300)	

$I^{G}(J^{PC}) = 1^{-(0++)}$

See our minireview on scalar mesons under $f_0(1370)$. (See the index for the page number.)

a₀(980) MASS

DOCUMENT ID

983.4±0.9 OUR AVERAGE Includes data from the 2 datablocks that follow this one.

$\eta\pi$ FINAL STATE ONLY

WALUE (MeV) EVTS DOCUMENT ID TECN CHG COMMENT
The data in this block is included in the average printed for a previous datablock.

983.7	±	0.9	OUR AVERA	GE				
984.4	5 ±	1.23	±0.34	AMSLER	94C	CBAR		$0.0 \overline{\rho} p \rightarrow \omega \eta \pi^0$
982	±	2		¹ AMSLER	92	CBAR		$0.0 \overline{p}p \rightarrow \eta \eta \pi^0$
984	±	4	1040	¹ ARMSTRONG	918	OMEG	±	$300 pp \rightarrow pp\eta \pi^+\pi^-$
976	±	6		ATKINSON	84E	OMEG	±	$25-55 \gamma p \rightarrow \eta \pi n$
986	±	3	500	² EVANGELISTA	81	OMEG	±	12 π ⁻ p →
		_		² GURTU		unc		$\eta \pi^+ \pi^- \pi^- \rho$
990	±	-	145		79		#	
977	±	-		GRASSLER	77	HBC	-	
972	±:	10	150	DEFOIX	72	HBC	±	0.7 βp → 7π
• • •	W	e do	not use the fo	ilowing data for a	/erag	es, fits,	limit	s, etc. • • •
987				TORNQVIST	96	RVUE		$\pi\pi \rightarrow \pi\pi, K\overline{K}, K\pi, \eta\pi$
991				JANSSEN	95	RVUE		$ \eta \pi \xrightarrow{\eta} \eta \pi, KR, K\pi, \\ \eta \pi $
980	±:	11	47	CONFORTO	78	OSPK	_	$4.5 \pi^- \rho \rightarrow \rho X^-$
978	±:	16	50	CORDEN	78	OMEG	±	$12-15 \pi^- p \rightarrow n\eta 2\pi$
989	+	4	70	WELLS	75	HBC	_	3.1-6 K p → Λη2π
970	±:	15	20	BARNES	69C	HBC	_	$4-5 K^- p \rightarrow \Lambda \eta 2\pi$
980	±	10		CAMPBELL	69	DBC	±	$2.7 \pi^{+} d$
980	±	10	15	MILLER	69B	HBC	_	4.5 $K^- N \rightarrow \eta \pi \Lambda$
				_				

¹ From a single Breit-Wigner fit.

30

980 ±10

KR ONLY
VALUE (Mav)

The data in this block is included in the average printed for a previous datablock.

AMMAR

980.8± 2.7 OUR AVERAGE

700.03 2.7 00	K VAEVA	GE.					_
982 ± 3		3 ABELE	98	CBAR		$0.0 \overline{p}p \rightarrow K_1^0 K^{\pm} \pi^{\mp}$	ı
976 ± 6	316	DEBILLY	80	HBC	±	$1.2-2 \overline{p} p \rightarrow f_1(1285) \omega$	
• • • We do not	use the fe	ollowing data for a	verag	zes, fits,	limits	, etc. • • •	
1016 ±10	100	4 ASTIER	67	HBC	±	0.0 Bp	
1003.3 ± 7.0	143	5 ROSENFELD	65	RVUE	±		

68 HBC \pm 5.5 K⁻⁻p \rightarrow $\Lambda\eta 2\pi$

a₀(980) WIDTH

EVE (MeV)EVTSDOCUMENT IDTECNCHGCOMMENT80to 100 OUR ESTIMATEWidth determination very model dependent. Peak width in $\eta\pi$ is about 60 MeV, but decay width can be much larger. VALUE (MeV)

•	• • W	/e do not	use the f	ollo	wing data for av	erag	es, fits, i	limits,	etc. • • •
~	100				TORNQVIST	96	RVUE		$\pi\pi \rightarrow \pi\pi$, KR, K π ,
	202				JANSSEN	95	RVUE		$ \eta \pi $ $ \eta \pi \to \eta \pi, K\overline{K}, K\pi, $ $ \eta \pi $
	54.12	2± 0.34:	±0.12		AMSLER	94C	CBAR		$0.0 \overline{p}p \rightarrow \omega \eta \pi^0$
	54	±10		6	AMSLER	92	CBAR		$0.0 \overline{p}p \rightarrow \eta \eta \pi^0$
	95	±14	1040	6	ARMSTRONG	91B	OMEG	±	300 pp $\rightarrow pp\eta\pi^{+}\pi^{-}$
	62	±15	500	7	EVANGELISTA	81	OMEG	±	12 π ⁻ p →
	60	±20	145	7	GURTU	79	нвс	±	$\eta \pi^+ \pi^- \pi^- \rho$ $4.2 K^- \rho \rightarrow \Lambda \eta 2\pi$
	60	+50 -30	47		CONFORTO	78	OSPK	-	$4.5 \pi^- p \rightarrow pX^-$
	86.0	+60.0 -50.0	50		CORDEN	78	OMEG	±	$1215~\pi^-\rho\to~\eta\eta2\pi$
	44	±22			GRASSLER	77	HBC	-	$16 \pi^{\mp} \rho \rightarrow \rho \eta 3\pi$
	80	to 300		8	FLATTE	76	RVUE	-	$4.2 K^- p \rightarrow \Lambda \eta 2\pi$
	16.0	+25.0 -16.0	70		WELLS	75	нвс	-	$3.16~K^-\rho\rightarrow\Lambda\eta2\pi$
	30	± 5	150		DEFOIX	72	HBC	±	$0.7 \overline{p} p \rightarrow 7 \pi$
	40	±15			CAMPBELL	69	DBC	±	$2.7 \pi^{+}d$
	60	±30	15		MILLER	69B	HBC	-	$4.5 K^- N \rightarrow \eta \pi \Lambda$
	80	±30	30		AMMAR	68	HBC	±	$5.5 K^- p \rightarrow \Lambda \eta 2\pi$
	6		Dunia tari		. 44				

From a single Breit-Wigner fit.

KK ONLY	EVTS	DOCUMENT ID		TECN	CHG	COMMENT	_
92± 8		9 ABELE	98	CBAR		$0.0 \overline{p}p \rightarrow K^0 K^{\pm} \pi^{\mp}$	
• • • We do n	ot use the	following data for a	vera	ges, fits,	limits,	, etc. • • •	
~ 25 57±13	100 143	10 ASTIER 11 ROSENFELD		HBC RVUE	± ±		
	includes d	t II, the pole on she ata of BARLOW 67				MeV. ARMENTEROS 65.	1

a₀(980) DECAY MODES

	Mode	Fraction (Γ_I/Γ)
Γ ₁	ηπ	dominant
Γ ₁ Γ ₂	κR	seen
Гз	$ ho\pi$	
Γ4	$\gamma \gamma$	seen
Г5	e+e-	

$a_0(980) \Gamma(I)\Gamma(\gamma\gamma)/\Gamma(total)$

$\Gamma(\eta\pi)\times\Gamma(\gamma\gamma)/$	Γ _{total}					$\Gamma_1\Gamma_4/\Gamma$
VALUE (keV)	EVTS	DOCUMENT ID		TECN	COMMENT	· · · · · · · · · · · · · · · · · · ·
0.24 +0.00 OUR AVE	RAGE					
$0.28 \pm 0.04 \pm 0.10$	44	OEST	90	JADE	$e^+e^- \rightarrow$	$e^+e^-\pi^0\eta$
$0.19 \pm 0.07 ^{+0.10}_{-0.07}$		ANTREASYAN	86	CBAL	e ⁺ e ⁻ →	$e^+e^-\pi^0\eta$
$\Gamma(\eta\pi) \times \Gamma(e^+e^-$)/r _{total}					Γ ₁ Γ ₅ /Γ
VALUE (eV)	CL%	DOCUMENT ID		TECN	COMMENT	
<1.5	90	VOROBYEV	88	ND	e+ e- →	$\pi^0\eta$

40(980) BRANCHING RATIOS

98 CBAR 0.0 ₱ ₭ **rerages, flts, limits, etc. • • • • 94 RVUE ₱p —	β → βκ±π∓ 0
7	- 0
94 RVUE 750	0
	 ηηπ⁻
78 OMEG 12-1	5 π − p → η2π
	\rightarrow 7 π
	nı

 $^{^{14}}$ From the decay of $f_1(1285)$.

$\Gamma(\rho\pi)/\Gamma(\eta\pi)$ $\rho\pi$ forbidden.					Γ3/Γ1
VALUE	CL%	DOCUMENT IL	TECN	CHG	COMMENT
• • • We do not use	the following	ng data for avera	ges, fits, limits	, etc. •	• • •
<0.25	70	AMMAR	70 HBC	±	4.1,5.5 K p →

a₀(980) REFERENCES

ABELE	98	PR D57 3860	A. Abele, Adomeit, Amsler+ (Crystal Barre	
TORNQVIST	96	PRL 76 1575	+Roos	(HELS)
JANSSEN	95	PR D52 2690	+Pearce, Holinde, Speth (STON, AD	LD, JULI)
AMSLER	94C	PL B327 425	+Armstrong, Ravndal+ (Crystal Barn	el Collab.)
AMSLER	94D	PL B333 277	+Anisovich, Spanier+ (Crystal Barr	el Collab.)
BUGG	94	PR D50 4412	+Anisovich+	(LOQM)
AMSLER	92	PL B291 347	+Augustin, Baker+ (Crystal Barr	
ARMSTRONG	91B	ZPHY C52 389	+Barnes+ (ATHU, BARI, BIRM, CER	N, CDEF)
OEST	90	ZPHY C47 343	+Oisson+ (JAD	E Collab.)
VOROBYEV	88	SJNP 48 273	+Golubey, Dolinsky, Druzhinin+	(NOVO)
		Translated from YAF 48	3 436.	
ANTREASYAN		PR D33 1847	+Aschman, Besset, Bienlein+ (Crystal Ba	
ATKINSON	84E	PL 138B 459	+ (BONN, CERN, GLAS, LANC, MCHS,	CURIN+)
EVANGELISTA	81	NP B178 197	+ (BARI, BONN, CERN, DARI	
DEBILLY	80	NP B176 1	+Briand, Duboc, Levy+ (CURIN, LAUS, NEU	
GURTU	79	NP B151 181	+Gavillet, Blokzijl+ (CERN, ZEEM, NI	
CONFORTO	78	LNC 23 419	+Conforto, Key+ (RHEL, TNTO, CHIC	
CORDEN	78	NP B144 253	+Corbett, Alexander+ (BIRM, RHEL, TEL	
GRASSLER	77	NP B121 189	+ (AACH3, BERL, BONN, CERN, CRAC,	HEIDH+)
FLATTE	76	PL 63B 224	,	(CERN)
GAY	76B	PL 63B 220		ST, NIJM) JP .
WELLS	75	NP 8101 333	+Radojicic, Roscoe, Lyons	(OXF)
DEFOIX	72	NP B44 125		F, CERN)
AMMAR	70	PR D2 430	+Kropac, Davis+ (KANS, NWES, AN	IL, WISC)
BARNES	69C	PRL 23 610	+Chung, Eisner, Bassano, Goloberg+ (BN	IL, SYRA)
CAMPBELL	69	PRL 22 1204	+Lichtman, Loeffler+	(PURD)
MILLER	69B	PL 29B 255	+Kramer, Carmony+	(PURD)
Also	69	PR 188 2011	Yen, Ammann, Carmony, Elsner+	(PURD)
AMMAR	68	PRL 21 1832		/ES, ANL)
ASTIER	67	PL 25B 294	+Montanet, Baubillier, Duboc+ (CDEF, CEF	RN, IRAD)
Includes da	ta of		TO 67, and ARMENTEROS 65.	
BARLOW	67	NC 50A 701	+Lillestol, Montanet+ (CERN, CDEF, IR	
CONFORTO	67	NP B3 469	+Marechal+ (CERN, CDEF, IP	
ARMENTEROS		PL 17 344	+Edwards, Jacobsen+ (CER	N, CDEF)
ROSENFELD	65	Oxford Conf. 58		(LRL)

 $^{^{2}}$ From $f_{1}(1285)$ decay.

³ T-matrix pole on sheet II, the pole on sheet III is at 1006-i49 MeV.

⁴ASTIER 67 includes data of BARLOW 67, CONFORTO 67, ARMENTEROS 65.

⁵ Plus systematic errors.

⁷ From $f_1(1285)$ decay.

⁸ Using a two-channel resonance parametrization of GAY 76B data.

 $a_0(980)$, $\phi(1020)$

- OTHER RELATED PAPERS

ACHASOV	97C	PR D56 4084	N.N. Achasov+	
ACHASOV	97D	PR D56 203	N.N. Achasov+	
AMSLER	94D	PL B333 277	+Anisovich, Spanier+	(Crystal Barrel Collab.)
TORNQVIST	90	NPBPS 21 196		(HELS)
WEINSTEIN	89	UTPT 89 03	+lsgur	(ŤNTO)
ACHASOV	88B	ZPHY C41 309	+Shestakov	(NOVM)
WEINSTEIN	83B	PR D27 588	+lsgur	(TNTO)
TORNQVIST	82	PRL 49 624	•	(HELS)
BRAMON	80	PL 93B 65	+Masso	(BARC)
TURKOT	63	Siena Conf. 1 661	+Collins, Fujii, Kemp+	(BNL, PITT)

$\phi(1020)$

$$I^{G}(J^{PC}) = 0^{-}(1^{-})$$

φ(1020) MASS

We average mass and width values only when the systematic errors have been evaluated.

VALUE (N			EVTS	DOCUM	IENT ID	_	TECN	COMMENT
		B OUR AVE						
1019.42	±0.06		55600	AKHM	IETSHIN	95	CMD2	e+e- →
1019.7	±0.3		2012	DAVE	NPORT	86	MPSF	hadrons 400 pA → 4KX
1019.41		8	642k	1 DIJKS		86	SPEC	100-200 π^{\pm} , \vec{p} ,
								p, K±, on Be
1019.7	±0.1	±0.1	5079	ALBRE	ECHT	85 D	ARG	10 e ⁺ e ⁻ → K ⁺ K ⁻ X
1019.3	±0.1		1500	AREN'	TON	82	AEMS	11.8 polar. pp → KK
1019.67	±0.17		25080	² PELLII	NEN	82	RVUE	
1019.52	±0.13		3681	BUKIN	i	78 C	OLYA	e ⁺ e ⁻ →
	Vo do n	at usa tha fi	ollowing data fo		nc fite lie	m ite	ato a	hadrons
		ot use the h	onowing data it	_				4.
1019.8	±0.7			ARMS	TRONG	86	OMEG	85 π ⁺ /pp →
1000 4				3 ATKIN				π ⁺ /p4Kp
1020.1	±0.11		5526			86		20-70 γ p
1019.7	±1.0			BEBE	Α.	86	CLEO	$e^+e^- \rightarrow \Upsilon(4S)$
1020.9	±0.2			3 FRAM	E	86	OMEG	13 K+p →
								φK÷ρ
1021.0	±0.2			3 ARMS	TRONG	83B	OMEG	18.5 K ⁻ p →
				•				$K^-K^+\Lambda$
1020.0	±0.5			3 ARMS	TRONG	838	OMEG	18.5 K ⁻ p \rightarrow
1019.7	±0.3			3 BARA	TF	83	GOLI	$K^-K^+\Lambda$ 190 π^- Be \rightarrow
1017.1				D/ III			001.	2μΧ
1019.8	± 0.2	± 0.5	766	IVANO	V	81	OLYA	1-1.4 e ⁺ e ⁻ →
1019.4	±0.5		337	COOP	FR	78R	нвс	K+K− 0.7-0.8 pp →
2022.4	0.0		55.					κο κο π+ π-
1020	±1		383	3 BALDI	ı	77	CNTR	10 π p →
1020			303	DALD		• •	C14 1 11	$\pi^-\phi p$
1018.9	±0.6		800	COHE	N	77	ASPK	6 π [±] N →
								K+K-N
1019.7	±0.5		454	KALBI	FLEISCH	76	HBC	2.18 K ⁻ p → ΛK K
1019.4	±0.8		984	BESCH	1	74	CNTR	
								pK+K-
1020.3	±0.4		100	BALLA	AM	73	HBC	2.8−9.3 γp
1019.4	±0.7			BINNI	E	73B	CNTR	$\pi^- p \rightarrow \phi n$
1019.6	± 0.5		120	4 AGUIL	AR	728	HBC	3.9,4.6 $K^{-}p \rightarrow$
				4				1K+K-
1019.9	±0.5		100	4 AGUIL	AR	72B	HBC	3.9,4.6 K ⁻ p →
								K-pK+K-
1020.4	± 0.5		131	COLLE	- Y	72	HBC	10 K+p →
1010.0	+02		410	CTOT	T1 =	71	unc	K ⁺ pφ
1019.9	±0.3		410	STOT	1 LE	71	нвс	2.9 K ⁻ p → Σ/ΛΚΚ
								2////

Weighted and scaled average of 12 measurements of DIJKSTRA 86.
 PELLINEN 82 review includes AKERLOF 77, DAUM 81, BALDI 77, AYRES 74, DE-

φ(1020) WIDTH

We average mass and width values only when the systematic errors have

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
4.43±0.05 OUR A	VERAGE				
4.44 ± 0.09	55600	AKHMETSHI	N 95	CMD2	$e^+e^- \rightarrow hadrons$
4.45 ± 0.06	271k	DIJKSTRA	86	SPEC	100 π ⁻ Be
4.5 ±0.7	1500	ARENTON	82	AEMS	11.8 polar. $pp \rightarrow KK$
4.2 ±0.6	766	⁵ IVANOV	81	OLYA	$1-1.4 e^{+}e^{-} \rightarrow \kappa^{+}\kappa^{-}$
4.3 ±0.6		5 CORDIER	80	WIRE	$e^+e^- \rightarrow \pi^+\pi^-\pi^0$
4.36 ± 0.29	3681	⁵ BUKIN	78 C	OLYA	$e^+e^- \rightarrow hadrons$
4.4 ±0.6	984	⁵ BEŞCH	74	CNTR	$2 \gamma \rho \rightarrow \rho K^+ K^-$
4.67±0.72	681	⁵ BALAKIN	71	OSPK	e ⁺ e [−] → hadrons
4.09 ± 0.29		BIZOT	70	OSPK	$e^+e^- \rightarrow hadrons$

3.6 ±0.8	337	⁵ COOPER	78B	HBC	0.7–0.8 p p →
4.5 1.050	****	5,6 AKERLOF		CDEC	$K_{S}^{0}K_{L}^{0}\pi^{+}\pi^{-}$ 400 pA $\rightarrow K^{+}K^{-}X$
4.5 ±0.50	1300		"	SPEC	400 pA → K · K X
4.5 ±0.8	500	^{5,6} AYRES	74	ASPK	$3-6 \pi^- p \rightarrow$
					$K^+K^-n, K^-p \rightarrow$
					$K^+K^-\Lambda/\Sigma^0$
3.81±0.37		COSME	74B	OSPK	$e^+e^- \rightarrow K_I^0K_S^0$
3.8 ±0.7	454	5 BORENSTEIN	72	нвс	2.18 K ⁻ p → KKn

⁶ Systematic errors not evaluated.

$\phi(1020)$ DECAY MODES

	Mode	Fraction (Γ_I/Γ)	Scale factor/ Confidence level
$\overline{\Gamma_1}$	K+K-	(49.1 ±0.8) %	S=1.3
Γ_2^-	$\kappa_L^0 \kappa_S^0$	$(34.1 \pm 0.6)\%$	S=1.2
Γ_3	$\rho\pi$ + π + π - π 0	(15.5 ±0.7) %	S=1.5
Γ ₄ Γ ₅	$\frac{ ho\pi}{\pi^+\pi^-\pi^0}$		
Γ ₆	$\eta \gamma$	(1.26±0.06) %	5=1.1
Γ7	$\pi^0\gamma$	(1.31±0.13) × 10	
Γ8	e+ e~	(2.99±0.08) × 10°	
Γg	$\mu^+\mu^-$	$(2.5 \pm 0.4) \times 10^{\circ}$	
Γ ₁₀	$\eta e^+ e^-$	$(1.3 \begin{array}{c} +0.8 \\ -0.6 \end{array}) \times 10^{-1}$	-4
Γ ₁₁	$\pi^+\pi^-$	$(8 {+5 \atop -4}) \times 10$	-5 S=1.5
Γ_{12}	$\omega \gamma$	< 5 %	CL=84%
Γ ₁₃	$ ho\gamma$	< 7 × 10	
Γ ₁₄	$\pi^+\pi^-\gamma$	< 3 × 10	
Γ ₁₅	$f_0(980)\gamma$	< 1 × 10	
Γ ₁₆	$\pi^0\pi^0\gamma$	< 1 × 10	
Γ ₁₇	$\pi^{+}\pi^{-}\pi^{+}\pi^{-}$	< 8.7 × 10	-4 CL=90%
Γ ₁₈	$\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{0}$	< 1.5 × 10	
Γ ₁₉	$\pi^0 e^+ e^-$	< 1.2 × 10	-4 CL=90%
Γ ₂₀	$\pi^0\eta\gamma$	< 2.5 × 10	
Γ_{21}	a_0 (980) γ	< 5 × 10	⁻³ CL=90%
Γ22	$\eta'(958)\gamma$	$(1.2 \begin{array}{c} +0.7 \\ -0.5 \end{array}) \times 10^{-1}$	-4
Γ ₂₃	$\mu^+\mu^-\gamma$	(2.3 ±1.0) × 10	-5

CONSTRAINED FIT INFORMATION

An overall fit to 9 branching ratios uses 29 measurements and one constraint to determine 4 parameters. The overall fit has a χ^2 = 26.9 for 26 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\langle \delta x_i \delta x_j \rangle / (\delta x_i \cdot \delta x_j)$, in percent, from the fit to the branching fractions, $x_i \equiv$ Γ_i/Γ_{total} . The fit constrains the x_i whose labels appear in this array to sum to

ϕ (1020) BRANCHING RATIOS

$\Gamma(K^+K^-)/\Gamma_{\text{total}}$					Γ_1/Γ
VALUE	EVTS	DOCUMENT ID		<u>TECN</u>	COMMENT
0.491±0.008 OUR FIT	Error Inclu	des scale factor	of 1.	3.	
0.493±0.010 OUR AVE	RAGE				
0.492 ± 0.012	2913	AKHMETSHIN	95	CMD2	$e^+e^- \rightarrow K^+K^-$
0.44 ±0.05	321	KALBFLEISCH	76	HBC	$2.18 K^- p \rightarrow \Lambda K^+ K^-$
0.49 ±0.06	270	DEGROOT	74	нвс	$4.2 K^- p \rightarrow \Lambda \phi$
0.540 ± 0.034	565	BALAKIN	71	OSPK	$e^+e^- \rightarrow K^+K^-$
0.48 ±0.04	252	LINDSEY	66	HBC	2.1-2.7 K p →
					ΛK ⁺ K ⁻
$\Gamma(K_L^0 K_S^0)/\Gamma_{\text{total}}$					Γ ₂ /Γ
VALUE	<u>EVTS</u>	DOCUMENT ID		TECN	COMMENT
0.341 ± 0.006 OUR FIT	Error inclu	des scale factor	of 1.	2.	
0.331±0.009 OUR AVE	RAGE				
0.335 ± 0.010	40644	AKHMETSHIN	95	CMD2	$e^+e^- \rightarrow \kappa_1^0 \kappa_2^0$
0.326 ± 0.035		DOLINSKY	91	ND	e+e- → KOKO e+e- → KOKO
0.310 ± 0.024		DRUZHININ	84	ND	e+e-→ KČKŠ

³ Systematic errors not evaluated. 4 Mass errors enlarged by us to Γ/\sqrt{N} ; see the note with the $K^*(892)$ mass.

Meson Particle Listings ϕ (1020)

0.27 ±0.03		g data for average			$\Gamma(ho\gamma)/\Gamma_{ m total}$					Γ ₁₃ /Ι
_	133			$2.18 K^- p \rightarrow \Lambda K_L^0 K_S^0$	VALUE (units 10 ⁻⁴)	<u>CL%</u>	DOCUMENT ID		COMMENT	1
257±0.030	95	BALAKIN		$e^+e^- \rightarrow \kappa_L^0 \kappa_S^0$	< 7	90 se the followin	AKHMETSHIN 97 g data for averages, f			$r^+\pi^-\gamma$
0 ±0.04	167	LINDSEY	66 HBC	$2.1-2.7 K^{-} p \rightarrow \Lambda K_{1}^{0} K_{5}^{0}$	<200	84	=		2.1-2.7 K ⁻	p →
$(\rho\pi) + \Gamma(\pi^+\pi^-)$	0\1 /r	_		r. /r					$\Lambda \pi^+ \pi^-$	neutrals
(PX) TI(X X	")]/' to	<u>DOCUMENT ID</u>	TECN	Γ ₃ /Γ	$\Gamma(e^+e^-)/\Gamma_{\text{total}}$					Г8/
55±0.007 OUR F					VALUE (units 10 ⁻⁴)	EVTS	DOCUMENT ID or Includes scale facto	TECN	COMMENT	
51±0.009 OUR A 61±0.008	11761	rror includes scale AKHMETSHI		$\begin{array}{c} 7. \\ 2 e^+e^- \rightarrow \pi^+\pi^-\pi^0 \end{array}$	2.88±0.09	55600	AKHMETSHIN 9		e ⁺ e ⁻ → t	adrons
43±0.007		DOLINSKY	91 ND	$e^+e^- \rightarrow \pi^+\pi^-\pi^0$	3.00 ± 0.21	3681		BC OLYA		adrons
We do not use	the followin				3.10±0.14 3.3 ±0.3			OSPK	e+e- e+e- → t	adrons
139±0.007		⁷ PARROUR	768 OSPH	•	2 81 + 0 25	681			e+e- → 1	
' Using total width level.	4.1 MeV. Th	$e \rho \pi$ to 3π mode	is more than	80%. at the 90% confidence	3.30±0.27			I OSPK		
K ⁰ _S K ⁰ _S)/Γ(K K)			$\Gamma_2/(\Gamma_1+\Gamma_2)$			They detect 3π mode for in the result quot			interferenc
LUE	EVTS	DOCUMENT ID			$\Gamma(\pi^0\gamma)/\Gamma_{\text{total}}$					Γ7/
410±0.007 OUR F 45 ±0.04 OUR A		Judes scale lacto	1 01 1.2.		VALUE (units 10 ⁻³)	EVTS	DOCUMENT ID	TECN	COMMENT	
44 ±0.07		LONDON	66 HBC	2.24 $K^-p \rightarrow \Lambda K \overline{K}$	1.31±0.13 OUR A					
.48 ±0.07	52 - 34	BADIER SCHLEIN	65B HBC	3 K ⁻ p 1.95 K ⁻ p → ΛK K̄	1.30±0.13 1.4 ±0.5	32		4 ND 6 OSPK	$e^+e^- \rightarrow 3$	3γ
40 ±0.10			es HBC	•	• • • We do not u		g data for averages, 1			
$\Gamma(\rho\pi) + \Gamma(\pi^+\pi^-)$	⁻ ѫº)]/۲(<i>/</i>			$\Gamma_3/(\Gamma_1+\Gamma_2)$	1.26±0.17				0.54-1.04 e	+ e ⁻ →
NLUE 187±0.010 OUR F	T C !-	DOCUMENT ID		COMMENT	-				$\pi^{0}\gamma$	
187±0.010 OUR F 24 ±0.04 OUR A		PINOCO SCRIC IBCIO	, UI 1.3.		$\Gamma(\pi^+\pi^-)/\Gamma_{\text{total}}$	1				Γ ₁₁ /
237±0.039		CERRADA	77в НВС	$4.2~K^-p \rightarrow \Lambda 3\pi$	VALUE (units 10 ⁻⁴)	CL%	DOCUMENT ID	TECN	COMMENT	
30 ±0.15		LONDON	66 HBC	$2.24 K^- p \rightarrow \Lambda_{\pi} + {}_{\pi} - {}_{\pi}0$	0.8 +0.5 OUR	AVERAGE E	Error Includes scale fa	ctor of 1.5	5.	
$\Gamma(\rho\pi) + \Gamma(\pi^+\pi^-)$	0\1 /c/	0 KO1		г _з /г;	0.63+0.37		15 GOLUBEV 8	6 ND	e+e- → 1	π+π-
LUE	#)]/' (' EVTS	`L`S) <u>DOCUMENT ID</u>	TECN	COMMENT	- 1.94 + 1.03 - 0.81		15 VASSERMAN 8		a+ a-	
156±0.025 OUR F						95			e+e- → 1	_+
51 ±0.05 OUR A 56 ±0.07	WERAGE 3681	BUKIN	78C OLVA	e+e K0 K0	•••		ig data for averages, i			т - ж
50 ±0.07	3001	BOKIN	ISC OLIA	$e^+e^- \rightarrow \kappa_L^0 \kappa_S^0,$ $\pi^+\pi^-\pi^0$	<2.7	95	ALVENSLEB 7			$C_{\pi}^{+}\pi^{-}$
47 ±0.06	516	COSME	74 OSP	$(e^+e^- \rightarrow \pi^+\pi^-\pi^0)$	15 Using $\Gamma(e^+e^-$	$)/\Gamma_{\text{total}} = 3.1$				
$(\mu^+\mu^-)/\Gamma_{\text{total}}$				Г9/І						Γ2/Γ
ALUE (units 10 ⁻⁴)		DOCUMENT ID	TECN		VALUE	EVTS	DOCUMENT ID	TECN	COMMENT	12/1
5 ±0.4 OUR AVE	ERAGE				0.695±0.021 OUR		cludes scale factor of			
		8 HAYES		R 8.3,9.8 γ C $\rightarrow \mu^+\mu^-$ X		AVERAGE		0c OLVA	a+ a	۷0 ×0
17±0.60	erence between	8 EARLES	70 CNTI	R 8.3,9.8 γ C $\rightarrow \mu^+\mu^-$ X R 6.0 γ C $\rightarrow \mu^+\mu^-$ X	0.70 ±0.06		BUKIN 7		e ⁺ e ⁻ → 1	
17±0.60 ⁸ Neglecting interfe	erence betwe	8 EARLES	70 CNTI	$R 6.0 \gamma C \rightarrow \mu^{+}\mu^{-}X$	0.70 ±0.06 0.82 ±0.08 0.71 ±0.05	AVERAGE	BUKIN 7.	8C OLYA 8 HBC 7 HBC	$e^+e^- \rightarrow i$ 4.2 $K^-p \rightarrow i$ 10 $K^-p \rightarrow i$	ϕ hyperon
$^{17\pm0.60}$ Neglecting interfo $(\eta\gamma)/\Gamma_{ m total}$		⁸ EARLES on resonance and	70 CNTI continuum.	$\begin{array}{ccc} R & 6.0 \gamma C \rightarrow & \mu^{+}\mu^{-} X \end{array}$	$\begin{array}{c} 0.70 \pm 0.06 \\ 0.82 \pm 0.08 \\ 0.71 \pm 0.05 \\ 0.71 \pm 0.08 \end{array}$	AVERAGE 2732	BUKIN 7 LOSTY 7 LAVEN 7 LYONS 7	8 HBC 7 HBC 7 HBC	4.2 K ⁻ p → 10 K ⁻ p → 3-4 K ⁻ p →	φhyperon K ⁺ K ⁻ Λ → Λφ
69 ± 0.46 $.17\pm0.60$ ⁸ Neglecting interferment of the second of the	<u>EVTS</u>	⁸ EARLES en resonance and <u>DOCUMENT ID</u>	70 CNTI continuum.	$\begin{array}{ccc} R & 6.0 \gamma C \rightarrow & \mu^{+}\mu^{-} X \end{array}$	0.70 ±0.06 0.82 ±0.08 0.71 ±0.05	AVERAGE	BUKIN 7 LOSTY 7 LAVEN 7 LYONS 7	8 HBC 7 HBC	4.2 K ⁻ p → 10 K ⁻ p →	φhyperon K ⁺ K ⁻ Λ → Λφ
.17 \pm 0.60 ⁸ Neglecting interference ($(\gamma \gamma)/\Gamma_{\text{total}}$.0126 \pm 0.0006 OUR .0126 \pm 0.0005 OUR	EVTS R FIT Error R AVERAGE	8 EARLES en resonance and DOCUMENT ID Includes scale fac Error Includes sc	70 CNTI continuum. TECN tor of 1.1. cale factor of	$\begin{array}{c} R & 6.0 \gamma \text{C} \rightarrow \mu^+ \mu^- \text{X} \\ \hline & \Gamma_6 / \text{I} \\ \hline & COMMENT \end{array}$	$\begin{array}{c} 0.70 \pm 0.06 \\ 0.82 \pm 0.08 \\ 0.71 \pm 0.05 \\ 0.71 \pm 0.08 \end{array}$	2732 144	BUKIN 7 LOSTY 7 LAVEN 7 LYONS 7 AGUILAR 7	8 HBC 7 HBC 7 HBC	4.2 K ⁻ p → 10 K ⁻ p → 3-4 K ⁻ p →	φhyperon K ⁺ K ⁻ Λ → Λφ
17±0.60 ⁸ Neglecting interference (77)/\(\Gamma_{\text{total}}\) 4.0E .0126±0.0006 OUR .0126±0.0001	<u>EVTS</u> R FTT Error	8 EARLES en resonance and DOCUMENT ID includes scale fac Error includes s 9 AKHMETSHI	70 CNTI continuum. TECN ctor of 1.1. cale factor of IN 95 CMD	$\begin{array}{c} R & 6.0 \gamma \text{C} \rightarrow \mu^+ \mu^- \text{X} \\ \hline & \Gamma_6 / \text{I} \\ \hline & COMMENT \\ \hline & 1.1. \\ 2 & e^+ e^- \rightarrow \pi^+ \pi^- 3 \gamma \end{array}$	0.70 \pm 0.06 0.82 \pm 0.08 0.71 \pm 0.05 0.71 \pm 0.08 0.89 \pm 0.10 $\Gamma(\rho\pi) + \Gamma(\pi^{+})$ VALUE	2732 144 π-π ⁰)]/Γ(/	BUKIN 7 LOSTY 7 LAVEN 7 LYONS 7 AGUILAR 7 K+K-) DOCUMENT ID	8 HBC 7 HBC 7 HBC 2B HBC	4.2 $K^- p \rightarrow$ 10 $K^- p \rightarrow$ 3-4 $K^- p \rightarrow$ 3.9,4.6 K^-	φhyperon K ⁺ K ⁻ Λ → Λφ p
17±0.60 8 Neglecting Interference (77)/\(\Gamma_{\text{total}}\) 4.UE 0.126±0.0006 OUR 0.126±0.0005 OUR 0.118±0.0011 0.130±0.0006	EVTS R FIT Error R AVERAGE	8 EARLES en resonance and DOCUMENT ID includes scale fac Error includes s 9 AKHMETSHI 10 DRUZHININ	70 CNTI continuum. TECN ctor of 1.1. cale factor of IN 95 CMD 84 ND	$\begin{array}{c} R \ 6.0 \ \gamma C \rightarrow \ \mu^{+} \mu^{-} X \\ \hline \hline \Gamma_{6}/I \\ \hline - COMMENT \\ \hline 2 \ e^{+} e^{-} \rightarrow \ \pi^{+} \pi^{-} 3 \gamma \\ e^{+} e^{-} \rightarrow \ 3 \gamma \\ \end{array}$	0.70 \pm 0.06 0.82 \pm 0.08 0.71 \pm 0.05 0.71 \pm 0.08 0.89 \pm 0.10 $\Gamma(\rho\pi) + \Gamma(\pi^{+})$ VALUE 0.317 \pm 0.017 OUR	144 π-π ⁰)]/Γ(EVIS FIT Error in	BUKIN 7 LOSTY 7 LAVEN 7 LYONS 7 AGUILAR 7 K+K-) <u>DOCUMENT ID</u> cludes scale factor of	8 HBC 7 HBC 7 HBC 2B HBC <u>TECN</u> 1.5.	4.2 $K^-p \rightarrow 10 K^-p \rightarrow 3-4 K^-p \rightarrow 3.9,4.6 K^-$	ϕ hyperon $K^+K^-\Lambda$ $\rightarrow \Lambda \phi$ ρ Γ_3/Γ
17±0.60 ⁸ Neglecting Interfection (77)/\(\bar{\tau}\) total 4.0E 0126±0.0005 OUR 0126±0.0005 OUR 0130±0.0006 014 ±0.002 0088±0.0020	EVTS R FIT Error R AVERAGE	8 EARLES en resonance and DOCUMENT ID Includes scale fac Error Includes sc 9 AKHMETSHI 10 DRUZHININ 11 DRUZHININ KURDADZE	70 CNTI continuum. TECN ctor of 1.1. cale factor of IN 95 CMD 84 ND 84 ND 830 OLYA	R 6.0 γ C $\rightarrow \mu^{+}\mu^{-}$ X $ \begin{array}{c} \Gamma_{6}/I \\ \hline 1.1. \\ 2 e^{+}e^{-} \rightarrow 3\gamma \\ e^{+}e^{-} \rightarrow 6\gamma \\ e^{+}e^{-} \rightarrow 3\gamma \end{array} $	0.70 \pm 0.06 0.82 \pm 0.08 0.71 \pm 0.05 0.71 \pm 0.08 - 0.89 \pm 0.10 $\Gamma(\rho\pi) + \Gamma(\pi^{+})$ VALUE 0.317 \pm 0.017 OUR 0.28 \pm 0.09	2732 144 π ⁻ π ⁰)]/Γ(1 EVTS FIT Error in 34	BUKIN 7 LOSTY 7 LAVEN 7 LYONS 7 AGUILAR 7 K+K-) DOCUMENT ID	8 HBC 7 HBC 7 HBC 2B HBC <u>TECN</u> 1.5.	4.2 $K^-p \rightarrow 10 K^-p \rightarrow 3-4 K^-p \rightarrow 3.9,4.6 K^-$	φhyperon κ+κ-Λ γ Λφ γ Γ ₃ /Γ
17±0.60 ⁸ Neglecting interference (77)/\(\tau\) total 1026±0.0006 OUR 10126±0.0005 OUR 10130±0.0006 1014±0.002 10088±0.0020 1015±0.0029	EVTS R FIT Error R AVERAGE 279 290	8 EARLES en resonance and DOCUMENT ID Includes scale fac Error Includes s 9 AKHMETSHI 10 DRUZHININ 11 DRUZHININ KURDADZE ANDREWS	70 CNTI continuum. TECN ctor of 1.1. cale factor of IN 95 CMD 84 ND 84 ND 83C OLYA 77 CNTI	$\begin{array}{c} \textbf{COMMENT} \\ \textbf{1.1.} \\ \textbf{2} & e^+e^- \rightarrow \pi^+\pi^-3\gamma \\ e^+e^- \rightarrow 3\gamma \\ e^+e^- \rightarrow 3\gamma \\ \textbf{2} & e^+e^- \rightarrow 3\gamma \\ \textbf{3} & e^+e^- \rightarrow 3\gamma \\ \textbf{3} & \textbf{6.7-10} \ \gamma \textbf{Cu} \\ \end{array}$	0.70 \pm 0.06 0.82 \pm 0.08 0.71 \pm 0.05 0.71 \pm 0.08 0.89 \pm 0.10 $\begin{bmatrix} \Gamma(\rho\pi) + \Gamma(\pi^{+} \\ VALUE \end{bmatrix}$ 0.317 \pm 0.017 OUR 0.28 \pm 0.09	2732 144 π - π ⁰)]/Γ(I FIT Error in 34	BUKIN 7 LOSTY 7 LAVEN 7 LYONS 7 AGUILAR 7 K+K-) DOCUMENT ID Cludes scale factor of AGUILAR 7	8 HBC 7 HBC 7 HBC 2B HBC <u>TECN</u> 1.5.	4.2 $K^-p \rightarrow 10 K^-p \rightarrow 3-4 K^-p \rightarrow 3.9,4.6 K^-$	ϕ hyperon $K^+K^-\Lambda$ $\rightarrow \Lambda \phi$ ρ Γ_3/Γ
17±0.60 8 Neglecting interfective (77)/\(\Gamma\) 1016±0.0006 OUR 1016±0.0006 OUR 10130±0.0016 10130±0.0006 1014±0.002 10030±0.0020 10135±0.0029 1015±0.0029	EVTS R FIT Error R AVERAGE 279 290 54	8 EARLES en resonance and DOCUMENT ID Includes scale face Fror Includes s 9 AKHMETSHI 10 DRUZHININ 11 DRUZHININ KURDADZE ANDREWS 10 COSME	70 CNTI continuum. 7	$\begin{array}{c} \mathbf{R} \ 6.0 \ \gamma \mathbf{C} \rightarrow \ \mu^{+} \mu^{-} \mathbf{X} \\ \hline & \mathbf{\Gamma} 6 / \mathbf{I} \\ \hline & \mathbf{COMMENT} \\ \hline 1.1. \\ 2 \ e^{+} e^{-} \rightarrow \ 3 \gamma \\ e^{+} e^{-} \rightarrow \ 3 \gamma \\ e^{+} e^{-} \rightarrow \ 3 \gamma \\ 8 \ 6.7 - 10 \ \gamma \mathbf{Cu} \\ \mathbf{C} \ e^{+} e^{-} \end{array}$	0.70 \pm 0.06 0.82 \pm 0.08 0.71 \pm 0.05 0.71 \pm 0.08 0.89 \pm 0.10 $\begin{bmatrix} \Gamma(\rho\pi) + \Gamma(\pi^{+} \\ VALUE \\ 0.317 \pm 0.017 \text{ OUR} \\ 0.28 \pm 0.09 \end{bmatrix}$ $\Gamma(\eta e^{+}e^{-})/\Gamma_{\text{tot}}$ $VALUE (units 10^{-4})$	2732 144 π ⁻ π ⁰)]/Γ(1 EVTS FIT Error in 34	BUKIN 7 LOSTY 7 LAVEN 7 LYONS 7 AGUILAR 7 K+K-) <u>DOCUMENT ID</u> cludes scale factor of	8 HBC 7 HBC 7 HBC 2B HBC <u>TECN</u> 1.5.	4.2 K^-p — 10 K^-p \rightarrow 3-4 K^-p — 3.9,4.6 K^- . COMMENT 3.9,4.6 K^-	 φhyperon κ+ κ- Λ Λφ Γ₃/Γ
17±0.60 8 Neglecting interfet (177)/F total MUE 0126±0.0005 OUR 0118±0.0011 0130±0.0006 014±0.002 00088±0.0020 0135±0.0029 015 ±0.004 • We do not use	EVTS R FIT Error R AVERAGE 279 290 54	8 EARLES en resonance and DOCUMENT ID Includes scale fac Error includes 9 9 AKHMETSH 10 DRUZHININ 11 DRUZHININ KURDADZE ANDREWS 10 COSME g data for averag	70 CNTI continuum. TECN tor of 1.1. cale factor of IN 95 CMD 84 ND 84 ND 83 COLYA 77 CNTI 76 OSPI ges, fits, limit	$\begin{array}{c} \mathbf{R} \ 6.0 \ \gamma \mathbf{C} \rightarrow \ \mu^{+} \mu^{-} \mathbf{X} \\ \hline & \mathbf{\Gamma} 6 / \mathbf{I} \\ \hline & \mathbf{COMMENT} \\ \hline 1.1. \\ 2 \ e^{+} e^{-} \rightarrow \ 3 \gamma \\ e^{+} e^{-} \rightarrow \ 3 \gamma \\ e^{+} e^{-} \rightarrow \ 3 \gamma \\ 8 \ 6.7 - 10 \ \gamma \mathbf{Cu} \\ \mathbf{C} \ e^{+} e^{-} \end{array}$	0.70 \pm 0.06 0.82 \pm 0.08 0.71 \pm 0.05 0.71 \pm 0.08 0.89 \pm 0.10 $\begin{bmatrix} \Gamma(\rho\pi) + \Gamma(\pi^{+} \\ VALUE \\ 0.317 \pm 0.017 \text{ OUR} \\ 0.28 \pm 0.09 \end{bmatrix}$ $\Gamma(\eta e^{+}e^{-})/\Gamma_{\text{tot}}$ $VALUE (units 10^{-4})$ $+ 0.8$	2732 144 π - π ⁰)]/Γ(I FIT Error in 34	BUKIN 7 LOSTY 7 LAVEN 7 LYONS 7 AGUILAR 7 K+K-) DOCUMENT ID Cludes scale factor of AGUILAR 7	8 HBC 7 HBC 7 HBC 28 HBC 1.5.	4.2 $K^-p - 10 K^-p \rightarrow 3-4 K^-p - 3.9,4.6 K^-$	 φhyperon κ+ κ- Λ Λφ Γ₃/Γ
17±0.60 8 Neglecting interfet (77)/Γtotal ALUE0126±0.0006 OUR .0126±0.0005 OUR .0118±0.0001 .0130±0.0006 .014±0.002 .0088±0.0020 .0135±0.0029 .015±0.004• We do not use .0121±0.0007 9 From π+π-π0	EVTS R FIT Error R AVERAGE 279 290 54 e the followin	8 EARLES en resonance and DOCUMENT ID Includes scale fac Error Includes 9 AKHMETSHI 10 DRUZHININ 11 DRUZHININ KURDADZE ANDREWS 10 COSME g data for averag 12 BENAYOUN	70 CNTI continuum. TECN tor of 1.1. cale factor of IN 95 CMD 84 ND 84 ND 83 COLYA 77 CNTI 76 OSPI ges, fits, limit	$\begin{array}{c} \textbf{F6/I} \\ & \textbf{COMMENT} \\ & \textbf{COMMENT} \\ & \textbf{SOINT} \\ & \textbf{SOINT}$	0.70 \pm 0.06 0.82 \pm 0.08 0.71 \pm 0.05 0.71 \pm 0.08 0.89 \pm 0.10 $\Gamma(\rho\pi) + \Gamma(\pi^{+})$ VALUE 0.317 \pm 0.017 OUR 0.28 \pm 0.09 $\Gamma(\eta e^{+}e^{-})/\Gamma_{\text{tot}}$ VALUE (units 10^{-4}) 1.3 $^{+}$ 0.8	2732 144 π = π ⁰) / Γ (1 FIT Error in 34 al EVTS 7	BUKIN 7 LOSTY 7 LAVEN 7 LYONS 7 AGUILAR 7 K+K-) DOCUMENT ID Cludes scale factor of AGUILAR 7	8 HBC 7 HBC 7 HBC 2B HBC 1.5. 2B HBC	4.2 K^-p — 10 K^-p \rightarrow 3-4 K^-p — 3.9,4.6 K^- . COMMENT 3.9,4.6 K^-	φhyperon κ+κ-λ γγε+ε- γγε+ε-
17±0.60 8 Neglecting interfer (ηγ)/Γtotal 4.UE 0126±0.0006 OUR 0126±0.0005 OUR 0118±0.0011 0130±0.0006 014±0.002 0088±0.0020 0135±0.0029 0135±0.0029 01021±0.0007 9 From π+π-π-π 10 From 2γ decay m	EVTS R FIT Error R AVERAGE 279 290 54 e the followin decay mode node of η .	8 EARLES en resonance and DOCUMENT ID Includes scale fac Error Includes 9 AKHMETSHI 10 DRUZHININ 11 DRUZHININ KURDADZE ANDREWS 10 COSME g data for averag 12 BENAYOUN	70 CNTI continuum. TECN tor of 1.1. cale factor of IN 95 CMD 84 ND 84 ND 83 COLYA 77 CNTI 76 OSPI ges, fits, limit	$\begin{array}{c} \textbf{F6/I} \\ \textbf{COMMENT} \\ \textbf{1.1.} \\ \textbf{2} & e^+e^- \rightarrow \pi^+\pi^-3\gamma \\ e^+e^- \rightarrow 3\gamma \\ e^+e^- \rightarrow 5\gamma \\ e^-e^- \rightarrow 5\gamma \\ e^-e^$	0.70 \pm 0.06 0.82 \pm 0.08 0.71 \pm 0.05 0.71 \pm 0.08 0.89 \pm 0.10 $[\Gamma(\rho\pi) + \Gamma(\pi^+ \frac{VALUE}{0.317 \pm 0.017} \text{ OUR} \\ 0.28 \pm 0.09$ $\Gamma(\eta e^+ e^-)/\Gamma_{\text{tot}} \frac{VALUE}{0.13 \pm 0.6}$ $1.3 + 0.8$ $\Gamma(\eta'(958)\gamma)/\Gamma_{\text{b}}$	2732 144 (7 - 70) / (10) / (10) FIT Error in 34 al EVTS 7	BUKIN 7 LOSTY 7 LAVEN 7 LYONS 7 AGUILAR 7 K+K-) DOCUMENT ID Cludes scale factor of AGUILAR 7 DOCUMENT ID GOLUBEV 8	8 HBC 7 HBC 7 HBC 28 HBC 1.5. 28 HBC TECN 5 ND	4.2 $K^-p \rightarrow 10 K^-p \rightarrow 3-4 K^-p \rightarrow 3.9,4.6 K^-$ COMMENT 3.9,4.6 K^- COMMENT $e^+e^- \rightarrow e^- \rightarrow e^-$	φhyperon κ+κ-λ γγε+ε- γγε+ε-
17±0.60 8 Neglecting interfective (77)/Ftotal LLUE 10126±0.0006 OUR 10130±0.0006 1014±0.001 10130±0.0006 1014±0.002 10088±0.0029 1015±0.0029 1015±0.004 • We do not use 10121±0.0007 9 From π+π-π0 1 From 2γ decay m 1 From 3π ⁰ decay	EVTS R FIT Error R AVERAGE 279 290 54 e the followin decay mode node of η , mode of η ,	8 EARLES en resonance and DOCUMENT ID Includes scale fac Error Includes scale fac 9 AKHMETSHI 10 DRUZHININ 11 DRUZHININ KURDADZE ANDREWS 10 COSME g data for averag 12 BENAYOUN of η .	70 CNTI continuum. TECN tor of 1.1. cale factor of IN 95 CMD 84 ND 84 ND 83 OLYA 77 CNTI 76 OSPH ges, fits, limit	$\begin{array}{c} \mathbf{R} \ 6.0 \ \gamma \mathbf{C} \rightarrow \ \mu^{+} \mu^{-} \mathbf{X} \\ \hline & \mathbf{\Gamma_{6}/I} \\ \hline & \mathbf{COMMENT} \\ \hline & 1.1. \\ 2 \ e^{+} e^{-} \rightarrow \ \pi^{+} \pi^{-} 3 \gamma \\ e^{+} e^{-} \rightarrow \ 3 \gamma \\ e^{+} e^{-} \rightarrow \ 3 \gamma \\ \mathbf{R} \ 6.7-10 \ \gamma \mathbf{Cu} \\ \mathbf{C} \ e^{+} e^{-} \\ \mathbf{S}, \text{ etc.} \bullet \bullet \bullet \\ \hline = \ 0.54-1.04 \ e^{+} e^{-} \rightarrow \ \eta \gamma \\ \hline \end{array}$	0.70 \pm 0.06 0.82 \pm 0.08 0.71 \pm 0.05 0.71 \pm 0.08 0.89 \pm 0.10 $ \begin{bmatrix} \Gamma(\rho\pi) + \Gamma(\pi^+ \\ VALUE \\ 0.317 \pm 0.017 \text{ OUR} \\ 0.28 \pm 0.09 \end{bmatrix} $ $ \begin{bmatrix} \Gamma(\eta e^+e^-)/\Gamma_{\text{tot}} \\ VALUE (\text{units } 10^{-4}) \\ 1.3 + 0.8 \end{bmatrix} $ $ \begin{bmatrix} \Gamma(\eta'(958)\gamma)/\Gamma_{\text{tot}} \\ VALUE (\text{units } 10^{-4}) \end{bmatrix} $ $ \begin{bmatrix} VALUE (\text{units } 10^{-4}) \\ VALUE (\text{units } 10^{-4}) \end{bmatrix} $	2732 144 π - π ⁰) / Γ(1 FIT Error in 34 al EVTS 7 otal CL% EVTS	BUKIN 7 LOSTY 7 LAVEN 7 LYONS 7 AGUILAR 7 K+K-) DOCUMENT ID GOLUBEV 8	8 HBC 7 HBC 7 HBC 28 HBC 1.5. 28 HBC 7 TECN 5 ND	4.2 $K^-p - 10 K^-p \rightarrow 3-4 K^-p - 3.9,4.6 K^-$ COMMENT COMMENT $e^+e^- \rightarrow C$ COMMENT	γγe+e-
17±0.60 8 Neglecting interfet (77)/Γ total MUE 0126±0.0006 OUR 0126±0.0005 OUR 0118±0.0011 0130±0.0006 014±0.002 00088±0.0020 0135±0.0029 015±0.004 • We do not use 0121±0.0007 9 From π+π-π0 10 From 2γ decay m 11 From 3π ⁰ decay	EVTS R FIT Error R AVERAGE 279 290 54 e the followin decay mode node of η . MOZHININ 84	B EARLES en resonance and DOCUMENT ID Includes scale fac Error includes 9 9 AKHMETSHI 10 DRUZHININ 11 DRUZHININ KURDADZE ANDREWS 10 COSME g data for averag 12 BENAYOUN of η. , DOLINSKY 89,	70 CNTI continuum. TECN tor of 1.1. cale factor of IN 95 CMD 84 ND 84 ND 83 OLYA 77 CNTI 76 OSPH ges, fits, limit	$\begin{array}{c} \textbf{F6/I} \\ \textbf{COMMENT} \\ \textbf{1.1.} \\ \textbf{2} & e^+e^- \rightarrow \pi^+\pi^-3\gamma \\ e^+e^- \rightarrow 3\gamma \\ e^+e^- \rightarrow 5\gamma \\ e^-e^- \rightarrow 5\gamma \\ e^-e^$	0.70 \pm 0.06 0.82 \pm 0.08 0.71 \pm 0.05 0.71 \pm 0.08 0.89 \pm 0.10 $ \begin{bmatrix} \Gamma(\rho\pi) + \Gamma(\pi^+ \\ VALUE \\ 0.317 \pm 0.017 \text{ OUR} \\ 0.28 \pm 0.09 \end{bmatrix} $ $ \begin{bmatrix} \Gamma(\eta^+ e^+ e^-)/\Gamma_{\text{tot}} \\ VALUE (\text{units } 10^{-4}) \\ 1.3 + 0.8 \\ \Gamma(\eta'(958)\gamma)/\Gamma_{\text{tot}} \\ VALUE (\text{units } 10^{-4}) \\ 0.9 & \bullet & \text{We do not total} \end{bmatrix} $	2732 144 π - π ⁰) / Γ(1 FIT Error in 34 al EVTS 7 otal CL% EVTS	BUKIN 7 LOSTY 7 LAVEN 7 LYONS 7 AGUILAR 7 K+K-) DOCUMENT ID GOLUBEV 8 DOCUMENT ID GOLUBEV 8	8 HBC 7 HBC 7 HBC 28 HBC 1.5. 28 HBC TECN 5 ND	4.2 $K^-p \rightarrow$ 10 $K^-p \rightarrow$ 3-4 $K^-p \rightarrow$ 3.9,4.6 K^- COMMENT $e^+e^- \rightarrow$ $\frac{COMMENT}{e^+e^-} \leftrightarrow \frac{COMMENT}{e^+e^-} \leftrightarrow \frac{COMMENT}{e^-} \leftrightarrow COMME$	γγe+e- Γ22/
17 \pm 0.60 8 Neglecting interfet ($\eta \gamma$)/ Γ total 44.0 ϵ 0126 \pm 0.0006 OUR 0118 \pm 0.0011 0130 \pm 0.0016 014 \pm 0.0011 0130 \pm 0.002 0088 \pm 0.0020 0135 \pm 0.0029 015 \pm 0.004 • We do not use 0121 \pm 0.007 9 From $\pi^+\pi^-\pi^0$ 10 From 2γ decay in 11 From $3\pi^0$ decay in 11 From $3\pi^0$ decay a triangle anoma	EVTS R FIT Error R AVERAGE 279 290 54 e the followin decay mode ode of η , mode of η , RUZHININ 84 bly contribution	B EARLES en resonance and DOCUMENT ID Includes scale fac Error includes 9 9 AKHMETSHI 10 DRUZHININ 11 DRUZHININ KURDADZE ANDREWS 10 COSME g data for averag 12 BENAYOUN of η. , DOLINSKY 89,	70 CNTI continuum. TECN tor of 1.1. cale factor of IN 95 CMD 84 ND 84 ND 83 OLYA 77 CNTI 76 OSPH ges, fits, limit	$\begin{array}{c} \textbf{76/I} \\ \textbf{COMMENT} \\ \textbf{1.1.} \\ \textbf{2} & e^+e^- \rightarrow \pi^+\pi^-3\gamma \\ e^+e^- \rightarrow 3\gamma \\ e^+e^- \rightarrow 6\gamma \\ e^+e^- \rightarrow 3\gamma \\ \textbf{3} & \textbf{6.7-10 } \gamma \textbf{Cu} \\ \textbf{4} & \textbf{c} & \textbf{e} & \textbf{e} \\ \textbf{5.7-10 } \gamma \textbf{Cu} \\ \textbf{5.8-1.04 } & \textbf{e}^+e^- \rightarrow \eta \gamma \\ \textbf{5.8-1.04 } & \textbf{e}^+e^- \rightarrow \eta \gamma \\ \textbf{5.8-1.04 } & \textbf{6.8-1.04 } & \textbf{6.8-1.04 } \\ \textbf{6.8-1.04 } & \textbf{6.8-1.04 } \\ \textbf{6.8-1.04 } & \textbf{6.8-1.04 } & \textbf{6.8-1.04 } \\ \textbf{6.8-1.04 } & \textbf{6.8-1.04 } & \textbf{6.8-1.04 } \\ \textbf{6.8-1.04 } & \textbf{6.8-1.04 } & \textbf{6.8-1.04 } \\ \textbf{6.8-1.04 } & \textbf{6.8-1.04 } & \textbf{6.8-1.04 } \\ \textbf{6.8-1.04 } & \textbf{6.8-1.04 } & \textbf{6.8-1.04 } \\ \textbf{6.8-1.04 } & \textbf{6.8-1.04 } & \textbf{6.8-1.04 } \\ \textbf{6.8-1.04 } & \textbf{6.8-1.04 } & \textbf{6.8-1.04 } \\ \textbf{6.8-1.04 } & \textbf{6.8-1.04 } & \textbf{6.8-1.04 } \\ \textbf{6.8-1.04 } & \textbf{6.8-1.04 } & \textbf{6.8-1.04 } \\ \textbf{6.8-1.04 } & \textbf{6.8-1.04 } & \textbf{6.8-1.04 } \\ \textbf{6.8-1.04 } & \textbf{6.8-1.04 } & \textbf{6.8-1.04 } \\ \textbf{6.8-1.04 } & \textbf{6.8-1.04 } & \textbf{6.8-1.04 } \\ \textbf{6.8-1.04 } & \textbf{6.8-1.04 } & \textbf{6.8-1.04 } \\ \textbf{6.8-1.04 } & \textbf{6.8-1.04 } & \textbf{6.8-1.04 } \\ 6.8-1.0$	0.70 \pm 0.06 0.82 \pm 0.08 0.71 \pm 0.05 0.71 \pm 0.08 0.89 \pm 0.10 $\begin{bmatrix} \Gamma(\rho\pi) + \Gamma(\pi^+ \\ \frac{VALUE}{2} \end{bmatrix} \\ 0.317 \pm 0.017 \text{ OUR} \\ 0.28 \pm 0.09 \end{bmatrix}$ $\Gamma(\eta e^+ e^-)/\Gamma_{\text{tot}} \\ \frac{VALUE}{2} \text{ (units } 10^{-4}) \\ 1.3 + 0.8 \\ \Gamma(\eta'(958)\gamma)/\Gamma_{\text{tot}} \\ \frac{VALUE}{2} \text{ (units } 10^{-4}) \\ \bullet \bullet \text{ We do not } \text{ tot} \\ 1.2 + 0.7 \pm 0.2 \\ \end{bmatrix}$	2732 144 7 70)]/[(1/2 EVTS) FIT Error in 34 21 EVTS 7 Otal CL% EVTS use the followin 6	BUKIN 7 LOSTY 7 LAVEN 7 LYONS 7 AGUILAR 7 K+K-) DOCUMENT ID Cludes scale factor of AGUILAR 7 DOCUMENT ID GOLUBEV 8 DOCUMENT ID ag data for averages, 16 AKHMETSHIN 9	8 HBC 7 HBC 28 HBC 1.5. 28 HBC TECN 5 ND TECN fits, limits 78 CMD2	4.2 $K^-p \rightarrow$ 10 $K^-p \rightarrow$ 3-4 $K^-p \rightarrow$ 3.9,4.6 K^- COMMENT 3.9,4.6 K^- COMMENT $e^+e^- \rightarrow$ COMMENT i, etc. • • •	φ φ hyperon κ+ κ − Λ → Λ φ ρ Γ3/Γ ρ Γ10/ γγe+e- Γ22/ π+π-3γ
17 \pm 0.60 8 Neglecting interfer (77)/ Γ total 1.00E 10126 \pm 0.0006 OUR 10118 \pm 0.0011 10130 \pm 0.0016 1014 \pm 0.0011 10130 \pm 0.002 10088 \pm 0.0020 10135 \pm 0.0029 1015 \pm 0.004 • • We do not use 1.0020 1015 \pm 0.007 1017 From 2γ decay of 1.1 From $3\pi^0$ decay of 1.2 Trom $3\pi^0$ decay a triangle anoma $(\pi^+\pi^-\gamma)/\Gamma$ total $(\pi^+\pi^-\gamma)/\Gamma$ total	EVTS R FIT Error R AVERAGE 279 290 54 e the followin decay mode ode of η , mode of η , RUZHININ 84 bly contribution	B EARLES en resonance and DOCUMENT ID Includes scale fac Error includes 9 9 AKHMETSHI 10 DRUZHININ 11 DRUZHININ KURDADZE ANDREWS 10 COSME g data for averag 12 BENAYOUN of η. , DOLINSKY 89,	70 CNTI continuum. TECN tor of 1.1. cale factor of IN 95 CMD 84 ND 84 ND 83 COLYA 77 CNTI 76 OSPH ges, fits, limit 96 RVUI	$\begin{array}{c} \mathbf{R} \ 6.0 \ \gamma \mathbf{C} \rightarrow \ \mu^{+} \mu^{-} \mathbf{X} \\ \hline & \mathbf{\Gamma_{6}/I} \\ \hline & \mathbf{COMMENT} \\ \hline & 1.1. \\ 2 \ e^{+} e^{-} \rightarrow \ \pi^{+} \pi^{-} 3 \gamma \\ e^{+} e^{-} \rightarrow \ 3 \gamma \\ e^{+} e^{-} \rightarrow \ 3 \gamma \\ \mathbf{R} \ 6.7-10 \ \gamma \mathbf{Cu} \\ \mathbf{C} \ e^{+} e^{-} \\ \mathbf{S}, \text{ etc.} \bullet \bullet \bullet \\ \hline = \ 0.54-1.04 \ e^{+} e^{-} \rightarrow \ \eta \gamma \\ \hline \end{array}$	0.70 \pm 0.06 0.82 \pm 0.08 0.71 \pm 0.05 0.71 \pm 0.08 0.89 \pm 0.10 $\begin{bmatrix} \Gamma(\rho\pi) + \Gamma(\pi^+ \\ \frac{VALUE}{2} \end{bmatrix} \\ 0.317 \pm 0.017 \text{ OUR} \\ 0.28 \pm 0.09 \\ \end{bmatrix}$ $\begin{bmatrix} \Gamma(\eta e^+ e^-) / \Gamma_{\text{tot}} \\ \frac{VALUE}{2} (\text{units } 10^{-4}) \\ 1.3 + 0.8 \\ \end{bmatrix}$ $\begin{bmatrix} \Gamma(\eta'(958) \gamma) / \Gamma_{\text{tot}} \\ \frac{VALUE}{2} (\text{units } 10^{-4}) \\ \bullet \bullet \bullet \text{ We do not } t \\ 1.2 + 0.7 \pm 0.2 \\ < 4.1 \end{bmatrix}$	144 π π σ σ σ σ σ σ σ σ σ σ σ σ σ σ σ σ σ	BUKIN 7 LOSTY 7 LAVEN 7 LYONS 7 AGUILAR 7 K+K-) DOCUMENT ID Cludes scale factor of AGUILAR 7 DOCUMENT ID GOLUBEV 8 DOCUMENT ID GOLUBEV 8 DOCUMENT ID AGUILAR 16 AKHMETSHIN 9 DRUZHININ 8	8 HBC 7 HBC 28 HBC 21 HBC 1.5. 28 HBC TECN 5 ND TECN 76 CMD2 7 ND	4.2 $K^-p \rightarrow$ 10 $K^-p \rightarrow$ 3-4 $K^-p \rightarrow$ 3.9,4.6 K^- COMMENT $e^+e^- \rightarrow$ $\frac{COMMENT}{e^+e^-} \leftrightarrow \frac{COMMENT}{e^+e^-} \leftrightarrow \frac{COMMENT}{e^-} \leftrightarrow COMME$	φ φ hyperon κ+ κ − Λ → Λ φ ρ Γ3/Γ ρ Γ10/ γγe+e- Γ22/ π+π- 3γ
17±0.60 8 Neglecting interfer (77)/ Γtotal LUE 0126±0.0006 OUR 0126±0.0006 OUR 0126±0.0006 014±0.001 0130±0.0006 014±0.002 0088±0.0020 00135±0.0029 015±0.004 • We do not use 0121±0.0007 9 From π+π-π ⁰ .0 From 2γ decay m 1 From 3π ⁰ decay 2 Reanalysis of DR a triangle anoma (π+π-γ)/ Γtotal LUE (units 10-4)	EVTS R FIT Error R AVERAGE 279 290 54 e the followin decay mode node of η. RUZHININ 84 bity contribution CL% 90	8 EARLES en resonance and DOCUMENT ID Includes scale face Error Includes scale face 9 AKHMETSHI 10 DRUZHININ 11 DRUZHININ KURDADZE ANDREWS 10 COSME g data for averag 12 BENAYOUN of η. DOLINSKY 89, on. DOCUMENT ID 13 AKHMETSH	70 CNTI continuum. TECN tor of 1.1. cale factor of 18 4 ND 84 ND 84 ND 85 CUV 77 CNTI 76 OSPI (es, fits, limit 96 RVUI and DOLIN TECN	$\begin{array}{c} \textbf{76/1} \\ \textbf{COMMENT} \\ \textbf{1.1.} \\ \textbf{2} & e^+e^- \rightarrow \pi^+\pi^-3\gamma \\ e^+e^- \rightarrow 3\gamma \\ e^+e^- \rightarrow 3\gamma \\ e^+e^- \rightarrow 3\gamma \\ \textbf{3.6.7-10} \ \gamma \ \textbf{Cu} \\ \textbf{4.6.7-10} \ \gamma \ \textbf{Cu} \\ \textbf{4.6.7-10} \ \gamma \ \textbf{Cu} \\ \textbf{5.5.} \ \textbf{etc.} \ \bullet \bullet \bullet \\ \textbf{5.6.7-1.04} \ \textbf{e}^+e^- \rightarrow \eta \ \textbf{7.6.7-10} \\ \textbf{5.8.} \ \textbf{COMMENT} \\ \textbf{2.6.7-1.04} \ \textbf{1.04} \ \textbf{1.04} \ \textbf{1.04} \ \textbf{1.04} \\ \textbf{2.6.7-1.04} \ \textbf{1.04} \ \textbf{1.04} \ \textbf{1.04} \ \textbf{1.04} \\ \textbf{2.6.7-1.04} \ \textbf{1.04} \ \textbf{1.04} \ \textbf{1.04} \ \textbf{1.04} \\ \textbf{2.6.7-1.04} \ \textbf{1.04} \ \textbf{1.04} \ \textbf{1.04} \ \textbf{1.04} \\ \textbf{2.6.7-1.04} \ \textbf{1.04} \ \textbf{1.04} \ \textbf{1.04} \ \textbf{1.04} \\ \textbf{2.6.7-1.04} \ \textbf{1.04} \ \textbf{1.04} \ \textbf{1.04} \ \textbf{1.04} \\ \textbf{2.6.7-1.04} \ \textbf{1.04} \ \textbf{1.04} \ \textbf{1.04} \ \textbf{1.04} \\ \textbf{3.6.7-1.04} \ \textbf{1.04} \ \textbf{1.04} \ \textbf{1.04} \ \textbf{1.04} \\ \textbf{3.6.7-1.04} \ \textbf{1.04} \ \textbf{1.04} \ \textbf{1.04} \ \textbf{1.04} \\ \textbf{3.6.7-1.04} \ \textbf{1.04} \ \textbf{1.04} \ \textbf{1.04} \ \textbf{1.04} \\ \textbf{3.6.7-1.04} \ \textbf{1.04} \ \textbf{1.04} \ \textbf{1.04} \ \textbf{1.04} \\ \textbf{3.6.7-1.04} \ \textbf{1.04} \ \textbf{1.04} \ \textbf{1.04} \ \textbf{1.04} \\ \textbf{3.6.7-1.04} \ \textbf{1.04} \ \textbf{1.04} \ \textbf{1.04} \ \textbf{1.04} \\ \textbf{3.6.7-1.04} \ \textbf{1.04} \ \textbf{1.04} \ \textbf{1.04} \ \textbf{1.04} \\ \textbf{3.6.7-1.04} \ \textbf{1.04} \ \textbf{1.04} \ \textbf{1.04} \ \textbf{1.04} \ \textbf{1.04} \ \textbf{1.04} \\ \textbf{3.6.7-1.04} \ \textbf{1.04} \ 1.04$	0.70 \pm 0.06 0.82 \pm 0.08 0.71 \pm 0.05 0.71 \pm 0.08 0.89 \pm 0.10 $\begin{bmatrix} \Gamma(\rho\pi) + \Gamma(\pi^+ \\ VALUE \\ 0.317 \pm 0.017 \text{ OUR} \\ 0.28 \pm 0.09 \end{bmatrix}$ $\Gamma(\eta e^+ e^-)/\Gamma_{tot}$ $VALUE \text{ (units } 10^{-4})$ 1.3+0.8 $\Gamma(\eta'(958)\gamma)/\Gamma_{tot}$ $VALUE \text{ (units } 10^{-4})$ • • • We do not to 1.2+0.7 \pm 0.2 < 4.1 16 Using the value	average 2732 144 $\pi^-\pi^0$)]/ Γ ($\frac{EVTS}{TT}$ Error in 34 $\frac{EVTS}{T}$ 7 obtain $\frac{EVTS}{T}$ use the following 6 90 $\frac{E(\phi)}{T}$ $E($	BUKIN 7 LOSTY 7 LAVEN 7 LYONS 7 AGUILAR 7 K+K-) DOCUMENT ID Cludes scale factor of AGUILAR 7 DOCUMENT ID GOLUBEV 8 DOCUMENT ID ag data for averages, 16 AKHMETSHIN 9	8 HBC 7 HBC 28 HBC 21 HBC 1.5. 28 HBC TECN 5 ND TECN 76 CMD2 7 ND	4.2 $K^-p \rightarrow$ 10 $K^-p \rightarrow$ 3-4 $K^-p \rightarrow$ 3.9,4.6 K^- COMMENT 3.9,4.6 K^- COMMENT $e^+e^- \rightarrow$ COMMENT i, etc. • • •	γγ e ⁺ e ⁻ Γ22/ π ⁺ π ⁻ 3γ γγηπ ⁺ π ⁻
17±0.60 8 Neglecting interfer (77)/ Γtotal LUE 0126±0.0006 OUR 0126±0.0006 OUR 0126±0.0006 014±0.001 0130±0.0006 014±0.002 0088±0.0020 00135±0.0029 015±0.004 • We do not use 0121±0.0007 9 From π+π-π ⁰ .0 From 2γ decay m 1 From 3π ⁰ decay 2 Reanalysis of DR a triangle anoma (π+π-γ)/ Γtotal LUE (units 10-4)	EVTS R FIT Error R AVERAGE 279 290 54 e the followin decay mode node of η. RUZHININ 84 bity contribution CL% 90	8 EARLES en resonance and DOCUMENT ID Includes scale face Error Includes scale face 9 AKHMETSHI 10 DRUZHININ 11 DRUZHININ KURDADZE ANDREWS 10 COSME g data for averag 12 BENAYOUN of η. DOLINSKY 89, on. DOCUMENT ID 13 AKHMETSHI g data for averag	70 CNTI continuum. TECN tor of 1.1. cale factor of 18 4 ND 84 ND 84 ND 85 CUV 77 CNTI 76 OSPI res, fits, limit 96 RVUI 10 and DOLIN 11 TECN 1	$\begin{array}{c} \textbf{76/I} \\ \textbf{COMMENT} \\ \textbf{1.1.} \\ \textbf{2} & e^+e^- \rightarrow \pi^+\pi^-3\gamma \\ e^+e^- \rightarrow 3\gamma \\ e^+e^- \rightarrow 3\gamma \\ e^+e^- \rightarrow 3\gamma \\ \textbf{2} & e^+e^- \rightarrow 3\gamma \\ \textbf{3} & e^+e^- \rightarrow 3\gamma \\ \textbf{3} & e^+e^- \rightarrow 3\gamma \\ \textbf{4} & e^+e^- \rightarrow 3\gamma \\ \textbf{5} & e^+e^- \rightarrow \gamma \\ \textbf{5} & e^+e^- \rightarrow \gamma \\ \textbf{5} & e^+e^- \rightarrow \gamma \\ \textbf{5} & e^-e^- \rightarrow \gamma \\ \textbf{5} & e^-$	0.70 \pm 0.06 0.82 \pm 0.08 0.71 \pm 0.05 0.71 \pm 0.08 0.89 \pm 0.10 $\begin{bmatrix} \Gamma(\rho\pi) + \Gamma(\pi^+ \\ VALUE \\ 0.317 \pm 0.017 \text{ OUR} \\ 0.28 \pm 0.09 \end{bmatrix}$ $\Gamma(\eta e^+ e^-)/\Gamma_{\text{tot}}$ $VALUE (units 10^{-4})$ 1.3 \pm 0.8 $\Gamma(\eta'(958)\gamma)/\Gamma_{\text{tot}}$ $VALUE (units 10^{-4})$ 1.2 \pm 0.7 \pm 0.2 <4.1 1.6 Using the value $\Gamma(\pi^0\pi^0\gamma)/\Gamma_{\text{total}}$	AVERAGE 2732 144 $\pi^-\pi^0$)]/ Γ ($\frac{EVTS}{TT}$ Error in 34 al $\frac{EVTS}{T}$ 7 obtain $\frac{EVTS}{T}$ use the following 6 90 $\frac{EVTS}{T}$ 8 $\frac{EVTS}{T}$ 19 $EVTS$	BUKIN 7 LOSTY 7 LAVEN 7 LYONS 7 AGUILAR 7 K+K-) DOCUMENT ID Cludes scale factor of AGUILAR 7 DOCUMENT ID GOLUBEV 8 DOCUMENT ID ag data for averages, 16 AKHMETSHIN 9 DRUZHININ 8 = (1.26 ± 0.06) × 10	8 HBC 7 HBC 28 HBC 1.5. 28 HBC TECN 5 ND TECN 61ts, limits 78 CMD2 7 ND 1-2	4.2 K^-p — 10 K^-p \rightarrow 3-4 K^-p = 3.9,4.6 K^- . COMMENT $e^+e^ \rightarrow$. COMMENT $e^+e^ \rightarrow$. $e^+e^ \rightarrow$. $e^+e^ \rightarrow$. $e^+e^ \rightarrow$.	γγ e ⁺ e ⁻ Γ22/ π ⁺ π ⁻ 3γ γγηπ ⁺ π ⁻
17±0.60 8 Neglecting interfer (77)/\(^{\text{total}}\) \(\text{LUE}\) 0126±0.0006 OUR 0118±0.0016 OUR 0118±0.0011 0130±0.0006 014±0.002 00135±0.0029 015±0.0029 015±0.004 • We do not use 0121±0.0007 9 From \(\pi + \pi - \pi \) 0.0 From \(\pi \) decay in 1 From \(\pi \) decay in 2 Reanalysis of DR a triangle anoma (\(\pi + \pi - \pi \)/\(^{\text{total}}\) \(\text{LUE}\) (units 10 ⁻⁴) 1 0.3 • We do not use	EVTS R FIT Error R AVERAGE 279 290 54 e the followin decay mode node of η. RUZHININ 84 bity contribution CL% 90	8 EARLES en resonance and DOCUMENT ID Includes scale face Error Includes scale face 9 AKHMETSHI 10 DRUZHININ 11 DRUZHININ KURDADZE ANDREWS 10 COSME g data for averag 12 BENAYOUN of η. DOLINSKY 89, on. DOCUMENT ID 13 AKHMETSHI g data for averag	70 CNTI continuum. TECN tor of 1.1. cale factor of 18 4 ND 84 ND 84 ND 85 CUV 77 CNTI 76 OSPI res, fits, limit 96 RVUI 10 and DOLIN 11 TECN 1	$\begin{array}{c} \textbf{R} \ 6.0 \ \gamma \textbf{C} \rightarrow \ \mu^+\mu^-\textbf{X} \\ \hline & $	0.70 \pm 0.06 0.82 \pm 0.08 0.71 \pm 0.05 0.71 \pm 0.08 0.89 \pm 0.10 $\begin{bmatrix} \Gamma(\rho\pi) + \Gamma(\pi^+ \\ VALUE \\ 0.317 \pm 0.017 \text{ OUR} \\ 0.28 \pm 0.09 \end{bmatrix}$ $\Gamma(\eta e^+ e^-)/\Gamma_{\text{tot}}$ $VALUE (units 10^{-4})$ 1.3 \pm 0.8 $\Gamma(\eta'(958)\gamma)/\Gamma_{\text{tot}}$ $VALUE (units 10^{-4})$ 1.2 \pm 0.7 \pm 0.2 <4.1 16 Using the value $\Gamma(\pi^0 \pi^0 \gamma)/\Gamma_{\text{total}}$ $VALUE (units 10^{-3})$	average 2732 144 $\pi^-\pi^0$)]/ Γ ($\frac{EVTS}{T}$ Error in 34 21 $\frac{EVTS}{T}$ 7 obtain $\frac{EVTS}{T}$ use the following 6 90 $\exp(\phi \rightarrow \eta \gamma)$ at $\frac{EU}{T}$	BUKIN 7 LOSTY 7 LAVEN 7 LYONS 7 AGUILAR 7 K+K-) DOCUMENT ID Cludes scale factor of AGUILAR 7 DOCUMENT ID GOLUBEV 8 DOCUMENT ID ag data for averages, 16 AKHMETSHIN 9 DRUZHININ 8 = (1.26 ± 0.06) × 10	8 HBC 7 HBC 28 HBC 1.5. 28 HBC TECN 5 ND TECN 6fts, limits 76 CMD2 7 ND 1-2	4.2 K^-p — 10 K^-p \rightarrow 3-4 K^-p — 3.9,4.6 K^- . COMMENT $e^+e^ \rightarrow$. COMMENT $e^+e^ \rightarrow$.	γγe+e- Γ22/ π+π-3γγηπ+π- Γ16/
17 \pm 0.60 8 Neglecting interfer (77)/ Γ total 1.00E 10126 \pm 0.0006 OUR 10130 \pm 0.0006 OUR 10130 \pm 0.0016 10130 \pm 0.0006 1014 \pm 0.0011 10130 \pm 0.0020 1035 \pm 0.0029 1015 \pm 0.0029 1015 \pm 0.004 • We do not use 0.0121 \pm 0.0007 10 From 2γ decay m 1.1 From $3\pi^0$ decay of a triangle anoma ($\pi^+\pi^-\gamma$)/ Γ total 1.0007 10 From 2γ decay m 1.1 From $3\pi^0$ decay π 1.2 From 2γ decay m 1.3 From 2γ decay m 1.4 From 2γ decay m 2.5 Reanalysis of DR a triangle anoma ($\pi^+\pi^-\gamma$)/ Γ total 1.0006 10 Section 1.0007 11 Graph 1.0007 12 Graph 1.0007 13 Graph 1.0007 14 Graph 1.0007 15 Graph 1.0007 16 Graph 1.0007 17 Graph 1.0007 18 Graph 1.0007 19 Graph 1.0007 19 Graph 1.0007 10 Graph 1.0007	EVTS R FIT Error R AVERAGE 279 290 54 e the followin decay mode of η . RUZHININ 84 bity contribution CL% 90 e the followin	8 EARLES en resonance and DOCUMENT ID Includes scale face Error Includes scale face 9 AKHMETSHI 10 DRUZHININ 11 DRUZHININ KURDADZE ANDREWS 10 COSME g data for averag 12 BENAYOUN of η. DOLINSKY 89, on. DOCUMENT ID 13 AKHMETSHI g data for averag	70 CNTI continuum. TECN tor of 1.1. cale factor of 18 4 ND 84 ND 84 ND 84 ND 85 CUV 77 CNTI 76 OSPI (es, fits, limit 96 RVUI and DOLIN TECN IN 97C CMD (es, fits, limit	$\begin{array}{c} \textbf{R} & 6.0 \ \gamma \textbf{C} \rightarrow \ \mu^+\mu^-\textbf{X} \\ \hline & \textbf{\Gamma_6/I} \\ \hline & \textbf{COMMENT} \\ \hline & \textbf{1.1.} \\ \textbf{2} & \textbf{e}^+\textbf{e}^- \rightarrow \ \pi^+\pi^-3\gamma \\ \textbf{e}^+\textbf{e}^- \rightarrow \ 3\gamma \\ \textbf{e}^+\textbf{e}^- \rightarrow \ 3\gamma \\ \textbf{R} & \textbf{6.7-10} \ \gamma \textbf{Cu} \\ \textbf{(e}^+\textbf{e}^- \rightarrow \ 3\gamma \\ \textbf{S} & \textbf{6.7-10} \ \gamma \textbf{Cu} \\ \textbf{(e}^+\textbf{e}^- \rightarrow \ \gamma \textbf{Cu} \\ \textbf{S} & \textbf{etc.} \bullet \bullet \bullet \\ \hline \textbf{0.54-1.04} \ \textbf{e}^+\textbf{e}^- \rightarrow \ \eta \gamma \\ \hline & \textbf{SKY 91 taking into accoun} \\ \hline & \textbf{\Gamma_{14/I}} \\ \hline & \textbf{2} \\ \hline & \textbf{COMMENT} \\ \textbf{2} & \textbf{e}^+\textbf{e}^- \rightarrow \ \pi^+\pi^-\gamma \\ \textbf{S} & \textbf{stc.} \bullet \bullet \bullet \\ \hline \textbf{2.18} \ \textbf{K}^-\textbf{p} \rightarrow \ \Lambda\pi^+\pi^-\gamma \\ \hline \end{array}$	0.70 \pm 0.06 0.82 \pm 0.08 0.71 \pm 0.05 0.71 \pm 0.08 0.89 \pm 0.10 $\begin{bmatrix} \Gamma(\rho\pi) + \Gamma(\pi^+ \\ VALUE \\ 0.317 \pm 0.017 \text{ OUR} \\ 0.28 \pm 0.09 \end{bmatrix}$ $\Gamma(\eta e^+ e^-)/\Gamma_{\text{tot}}$ $VALUE (units 10^{-4})$ 1.3 \pm 0.8 $\Gamma(\eta'(958)\gamma)/\Gamma_{\text{tot}}$ $VALUE (units 10^{-4})$ 1.2 \pm 0.7 \pm 0.2 <4.1 1.6 Using the value $\Gamma(\pi^0\pi^0\gamma)/\Gamma_{\text{total}}$	AVERAGE 2732 144 $\pi^-\pi^0$)]/ Γ ($\frac{EVTS}{TT}$ Error in 34 al $\frac{EVTS}{T}$ 7 obtain $\frac{EVTS}{T}$ use the following 6 90 as $\mathbb{B}(\phi \to \eta \gamma)$ al	BUKIN 7 LOSTY 7 LAVEN 7 LYONS 7 AGUILAR 7 K+K-) DOCUMENT ID Cludes scale factor of AGUILAR 7 DOCUMENT ID GOLUBEV 8 DOCUMENT ID ag data for averages, 16 AKHMETSHIN 9 DRUZHININ 8 = (1.26 ± 0.06) × 16	8 HBC 7 HBC 28 HBC 1.5. 28 HBC TECN 5 ND TECN 61ts, limits 78 CMD2 7 ND 1-2	4.2 K^-p — 10 K^-p \rightarrow 3-4 K^-p = 3.9,4.6 K^- . COMMENT $e^+e^ \rightarrow$. COMMENT $e^+e^ \rightarrow$. $e^+e^ \rightarrow$. $e^+e^ \rightarrow$. $e^+e^ \rightarrow$.	γγe+e- Γ22/ π+π-3γγηπ+π- Γ16/
17±0.60 8 Neglecting interfer (177)/ total MUE 0126±0.0005 OUR 0118±0.0011 0130±0.0016 014±0.002 0088±0.0020 0135±0.0029 015±0.004 • We do not use 0121±0.0007 9 From π+π-π 10 From 2γ decay m 11 From 3π ⁰ decay 12 Reanalysis of DR	EVTS R FIT Error R AVERAGE 279 290 54 e the followin decay mode of η. mode of η. RUZHININ 84 lly contribution 11 CL% 90 e the followin	8 EARLES en resonance and DOCUMENT ID Includes scale fac Error Includes scale fac 9 AKHMETSHI 10 DRUZHININ 11 DRUZHININ KURDADZE ANDREWS 10 COSME g data for averag 12 BENAYOUN of η . DOLINSKY 89, on. DOCUMENT ID 13 AKHMETSHI g data for averag KALBFLEISC	70 CNTI continuum. TECN tor of 1.1. cale factor of 18 95 CMD 84 ND 84 ND 84 ND 86 COLYM 77 CNTI 76 OSPI res, fits, limit 96 RVUI 10 TECN IN 97C CMD res, fits, limit CH 75 HBC	$\begin{array}{c} \textbf{76/1} \\ \textbf{COMMENT} \\ \textbf{1.1.} \\ \textbf{2} & e^+e^- \rightarrow \pi^+\pi^-3\gamma \\ e^+e^- \rightarrow 3\gamma \\ e^+e^- \rightarrow 3\gamma \\ e^+e^- \rightarrow 3\gamma \\ \textbf{2} & e^+e^- \rightarrow 3\gamma \\ \textbf{3} & e^+e^- \rightarrow 3\gamma \\ \textbf{3} & e^+e^- \rightarrow 3\gamma \\ \textbf{4} & e^+e^- \rightarrow 3\gamma \\ \textbf{5} & e^+e^- \rightarrow 3\gamma \\ \textbf{5} & e^+e^- \rightarrow 3\gamma \\ \textbf{5} & e^+e^- \rightarrow \gamma \\ \textbf{5} & e^+e^- \rightarrow \gamma \\ \textbf{5} & e^+e^- \rightarrow \gamma \\ \textbf{5} & e^+e^- \rightarrow \pi^+\pi^-\gamma \\ \textbf{5} & e^+e^- \rightarrow \pi^-\gamma \\ \textbf{5} & e^+e^- \rightarrow \pi^-\gamma \\ \textbf{5} & e^+e^- \rightarrow \pi^-\gamma \\ \textbf{5} & e^+e^- \rightarrow \pi^$	0.70 \pm 0.06 0.82 \pm 0.08 0.71 \pm 0.05 0.71 \pm 0.08 0.89 \pm 0.10 $\begin{bmatrix} \Gamma(\rho\pi) + \Gamma(\pi^+ \\ VALUE \\ 0.317 \pm 0.017 \text{ OUR} \\ 0.28 \pm 0.09 \end{bmatrix}$ $\Gamma(\eta e^+ e^-)/\Gamma_{\text{tot}}$ $VALUE (units 10^{-4})$ 1.3 \pm 0.8 $\Gamma(\eta'(958)\gamma)/\Gamma_{\text{tot}}$ $VALUE (units 10^{-4})$ 1.2 \pm 0.7 \pm 0.2 <4.1 16 Using the value $\Gamma(\pi^0 \pi^0 \gamma)/\Gamma_{\text{total}}$ $VALUE (units 10^{-3})$	AVERAGE 2732 144 $\pi^-\pi^0$) $/\Gamma(I$ FIT Error in 34 al EVTS 7 Otal CL% EVTS Use the followin 6 90 e B($\phi \rightarrow \eta \gamma$) al CL% 90	BUKIN 7 LOSTY 7 LAVEN 7 LYONS 7 AGUILAR 7 K+K-) DOCUMENT ID Cludes scale factor of AGUILAR 7 DOCUMENT ID GOLUBEV 8 DOCUMENT ID ag data for averages, 16 AKHMETSHIN 9 DRUZHININ 8 = (1.26 ± 0.06) × 10	8 HBC 7 HBC 28 HBC 1.5. 28 HBC TECN 5 ND TECN 6fts, limits 76 CMD2 7 ND 1-2	4.2 K^-p — 10 K^-p \rightarrow 3-4 K^-p — 3.9,4.6 K^- . COMMENT $e^+e^ \rightarrow$. COMMENT $e^+e^ \rightarrow$.	γγe+e- Γ22/ π+π-3γ γηπ+π- Γ16/
17±0.60 8 Neglecting interfer (77)/Γtotal MUE 0126±0.0006 OUR 0126±0.0005 OUR 0118±0.0011 0130±0.0006 014±0.002 0088±0.0029 015±0.0029 015±0.0029 015±0.0029 016±0.0029 017±0.0007 017±0.0007 018±0.0029 018±0.0029 019±0.0029 019±0.0029 010 From 2γ decay must remain the promove of the pro	EVTS R FIT Error R AVERAGE 279 290 54 e the followin decay mode node of η. mode of η. EVZHININ 84 ely contribution ii CL% 90 e the followin 90 90	8 EARLES en resonance and DOCUMENT ID Includes scale fac Error Includes scale fac 9 AKHMETSHI 10 DRUZHININ 11 DRUZHININ KURDADZE ANDREWS 10 COSME g data for averag 12 BENAYOUN of η . DOCUMENT ID 13 AKHMETSHI g data for averag KALBFLEISC COSME LINDSEY	70 CNTI continuum. TECN tor of 1.1. cale factor of 1.8 ND 84 ND 83c OLYA 77 CNTI 76 OSPI ges, fits, limit 96 RVUI 10 TECN TECN TECN TECN TECN TECN TECN TECN	The second seco	0.70 \pm 0.06 0.82 \pm 0.08 0.71 \pm 0.05 0.71 \pm 0.08 0.89 \pm 0.10 $\begin{bmatrix} \Gamma(\rho\pi) + \Gamma(\pi^+ \\ VALUE \\ 0.317 \pm 0.017 \text{ OUR} \\ 0.28 \pm 0.09 \end{bmatrix}$ $\begin{bmatrix} \Gamma(\eta e^+e^-)/\Gamma_{\text{tot}} \\ VALUE (units 10^{-4}) \\ 1.3 + 0.6 \end{bmatrix} \begin{bmatrix} (\eta'(958)\gamma)/\Gamma_{\text{tot}} \\ VALUE (units 10^{-4}) \\ 1.2 + 0.7 \pm 0.2 \end{bmatrix} < 4.1 \begin{bmatrix} 1.2 + 0.7 \pm 0.2 \\ < 4.1 \end{bmatrix} VALUE (units 10^{-3}) VALUE (units 10^{-3})$	AVERAGE 2732 144 $\pi^-\pi^0$) $/\Gamma(I$ FIT Error in 34 al EVTS 7 Otal CL% EVTS Use the followin 6 90 e B($\phi \rightarrow \eta \gamma$) al CL% 90	BUKIN 7 LOSTY 7 LAVEN 7 LYONS 7 AGUILAR 7 K+K-) DOCUMENT ID Cludes scale factor of AGUILAR 7 DOCUMENT ID GOLUBEV 8 DOCUMENT ID ag data for averages, 16 AKHMETSHIN 9 DRUZHININ 8 = (1.26 ± 0.06) × 10	8 HBC 7 HBC 28 HBC 1.5. 28 HBC TECN 5 ND TECN 6fts, limits 76 CMD2 7 ND 1-2	4.2 K^-p — 10 K^-p \rightarrow 3-4 K^-p — 3.9,4.6 K^- . COMMENT $e^+e^ \rightarrow$. COMMENT $e^+e^ \rightarrow$.	γγ e ⁺ e ⁻ Γ22/ π ⁺ π ⁻ 3γ γγηπ ⁺ π ⁻
17 \pm 0.60 8 Neglecting interfectively below the following interfective interfectively below the following interfective inte	EVTS R FIT Error R AVERAGE 279 290 54 e the followin decay mode node of η. mode of η. EVZHININ 84 ely contribution ii CL% 90 e the followin 90 90	8 EARLES en resonance and DOCUMENT ID Includes scale fac Error Includes scale fac 9 AKHMETSHI 10 DRUZHININ 11 DRUZHININ KURDADZE ANDREWS 10 COSME g data for averag 12 BENAYOUN of η . DOCUMENT ID 13 AKHMETSHI g data for averag KALBFLEISC COSME LINDSEY	70 CNTI continuum. TECN tor of 1.1. cale factor of 1.8 ND 84 ND 83c OLYA 77 CNTI 76 OSPI ges, fits, limit 96 RVUI 10 TECN TECN TECN TECN TECN TECN TECN TECN	The second seco	0.70 \pm 0.06 0.82 \pm 0.08 0.71 \pm 0.05 0.71 \pm 0.08 0.89 \pm 0.10 $\begin{bmatrix} \Gamma(\rho\pi) + \Gamma(\pi^+ \\ \frac{VALUE}{2} \end{bmatrix} \\ 0.317 \pm 0.017 \text{ OUR} \\ 0.28 \pm 0.09 \\ \end{bmatrix} \\ \begin{bmatrix} (\eta e^+e^-)/\Gamma_{\text{tot}} \\ \frac{VALUE}{2} \end{bmatrix} \\ 1.3 \frac{+0.8}{-0.6} \\ \end{bmatrix} \\ \begin{bmatrix} (\eta'(958)\gamma)/\Gamma_{\text{tot}} \\ \frac{VALUE}{2} \end{bmatrix} \\ \cdot \cdot \cdot We do not total substitution of the substi$	AVERAGE 2732 144 $\pi^-\pi^0$)]/ Γ (I FIT Error in 34 al EVTS 7 otal $CL\%$ EVTS use the followin 6 90 $EB(\phi \rightarrow \eta \gamma)$ al $EVTS$ E	BUKIN 7 LOSTY 7 LAVEN 7 LYONS 7 AGUILAR 7 K+K-) DOCUMENT ID Cludes scale factor of AGUILAR 7 DOCUMENT ID GOLUBEV 8 DOCUMENT ID DRUZHININ 8 = (1.26 ± 0.06) × 10 DRUZHININ 8 DOCUMENT ID DRUZHININ 8	8 HBC 7 HBC 28 HBC 1.5. 28 HBC TECN 5 ND TECN 6 CMD2 7 ND 7 ND 7 ND 7 ND	4.2 K^-p — 10 K^-p \rightarrow 3-4 K^-p — 3.9,4.6 K^- . COMMENT $e^+e^ \rightarrow$. COMMENT $e^+e^ \rightarrow$. e^+ . $e^ \rightarrow$. e^+ . $e^ \rightarrow$. e^+ . $e^ \rightarrow$. e^-	γγε+ε- Γ22/ π+π-3γ γγπ+π- Γ16/
17 ± 0.60 8 Neglecting interfer (77) / Γ total 1.0E 10126 ± 0.0005 OUR 10136 ± 0.0005 OUR 10130 ± 0.0011 10130 ± 0.0016 1014 ± 0.002 10088 ± 0.0020 10135 ± 0.0029 1015 ± 0.004 • • We do not use 0.0121 ± 0.0007 9 From $\pi^+\pi^-\pi^0$ 0 From 2γ decay m 1 From $3\pi^0$ decay 2 Reanalysis of DR a triangle anoma ($\pi^+\pi^-\gamma$) / Γ total 1.0UE (units 10-4) 1 0.3 • • We do not use 0.600 1 70 1 400 3 For $E_{\gamma} > 20$ Me	EVTS R FIT Error R AVERAGE 279 290 54 e the followin decay mode node of η. mode of η. EVZHININ 84 ely contribution ii CL% 90 e the followin 90 90	8 EARLES en resonance and DOCUMENT ID Includes scale fac Error Includes scale fac 9 AKHMETSHI 10 DRUZHININ 11 DRUZHININ KURDADZE ANDREWS 10 COSME g data for averag 12 BENAYOUN of η . DOCUMENT ID 13 AKHMETSHI g data for averag KALBFLEISC COSME LINDSEY	70 CNTI continuum. TECN tor of 1.1. cale factor of 1.8 ND 84 ND 83c OLYA 77 CNTI 76 OSPI ges, fits, limit 96 RVUI 10 TECN TECN TECN TECN TECN TECN TECN TECN	The second seco	0.70 \pm 0.06 0.82 \pm 0.08 0.71 \pm 0.05 0.71 \pm 0.08 0.89 \pm 0.10 $ \begin{bmatrix} \Gamma(\rho\pi) + \Gamma(\pi^+ \\ VALUE \\ 0.317 \pm 0.017 \text{ OUR} \\ 0.28 \pm 0.09 \end{bmatrix} \begin{bmatrix} \gamma e^+ e^- \\ \Gamma(\eta'(958) \gamma) / \Gamma_{tot} \\ VALUE (units 10^{-4} \\ 0.5 \pm 0.09 \end{bmatrix} \end{bmatrix} \begin{bmatrix} \gamma (958) \gamma \\ VALUE (units 10^{-4} \\ 0.5 \pm 0.09 \end{bmatrix} \end{bmatrix} \begin{bmatrix} \gamma (958) \gamma \\ VALUE (units 10^{-4} \\ 0.5 \pm 0.2 \end{bmatrix} \end{bmatrix} \begin{bmatrix} \gamma (1958) \gamma \\ VALUE (units 10^{-4} \\ 0.5 \pm 0.2 \end{bmatrix} \end{bmatrix} \begin{bmatrix} \gamma (1958) \gamma \\ VALUE (units 10^{-4} \\ 0.5 \pm 0.2 \end{bmatrix} \end{bmatrix} \begin{bmatrix} \gamma (1958) \gamma \\ VALUE (units 10^{-3} \\ 0.5 \pm 0.2 \end{bmatrix} \end{bmatrix} \begin{bmatrix} \gamma (1958) \gamma \\ VALUE (units 10^{-3} \\ 0.5 \pm 0.2 \end{bmatrix} \end{bmatrix} \begin{bmatrix} \gamma (1958) \gamma \\ VALUE (units 10^{-3} \\ 0.5 \pm 0.2 \end{bmatrix} \end{bmatrix} \begin{bmatrix} \gamma (1958) \gamma \\ VALUE (units 10^{-3} \\ 0.5 \pm 0.2 \end{bmatrix} \end{bmatrix} \begin{bmatrix} \gamma (1958) \gamma \\ VALUE (units 10^{-3} \\ 0.5 \pm 0.2 \end{bmatrix} \end{bmatrix} \begin{bmatrix} \gamma (1958) \gamma \\ VALUE (units 10^{-3} \\ 0.5 \pm 0.2 \end{bmatrix} \end{bmatrix} \begin{bmatrix} \gamma (1958) \gamma \\ VALUE (units 10^{-3} \\ 0.5 \pm 0.2 \end{bmatrix} \end{bmatrix} \begin{bmatrix} \gamma (1958) \gamma \\ VALUE (units 10^{-3} \\ 0.5 \pm 0.2 \end{bmatrix} \end{bmatrix} \begin{bmatrix} \gamma (1958) \gamma \\ VALUE (units 10^{-3} \\ 0.5 \pm 0.2 \end{bmatrix} \end{bmatrix} \begin{bmatrix} \gamma (1958) \gamma \\ VALUE (units 10^{-3} \\ 0.5 \pm 0.2 \end{bmatrix} \end{bmatrix} \begin{bmatrix} \gamma (1958) \gamma \\ VALUE (units 10^{-3} \\ 0.5 \pm 0.2 \end{bmatrix} \end{bmatrix} \begin{bmatrix} \gamma (1958) \gamma \\ VALUE (units 10^{-3} \\ 0.5 \pm 0.2 \end{bmatrix}$	AVERAGE 2732 144 $\pi^-\pi^0$)]/ Γ (I FIT Error in 34 al EVTS 7 otal CLS EVTS see the followin 6 90 $EVTS$	BUKIN 7 LOSTY 7 LAVEN 7 LYONS 7 AGUILAR 7 K+K-) DOCUMENT ID Cludes scale factor of AGUILAR 7 DOCUMENT ID GOLUBEV 8 DOCUMENT ID DRUZHININ 8 = (1.26 ± 0.06) × 10 DRUZHININ 8 DOCUMENT ID DRUZHININ 8	8 HBC 7 HBC 28 HBC 1.5. 28 HBC TECN 5 ND TECN 7 ND 7 ND 7 TECN 7 ND 7 TECN 7 ND	4.2 K^-p — 10 K^-p \rightarrow 3-4 K^-p \rightarrow 3.9,4.6 K^- . COMMENT \rightarrow 4.6 \rightarrow 6. COMMENT \rightarrow 6. \rightarrow 7. \rightarrow 6. \rightarrow 7. \rightarrow 6. \rightarrow 7. \rightarrow 7. \rightarrow 8. \rightarrow 8. \rightarrow 9. \rightarrow	γγε+ε- Γ16/ π+π-3γ γγπ+π- Γ16/ Γ18/ Γ10/ Γ10/ Γ10/ Γ10/ Γ116/ Γ116/ Γ116/
17 \pm 0.60 8 Neglecting interfer (77)/ Γ total MUE 0126 \pm 0.0005 OUR 0126 \pm 0.0005 OUR 0118 \pm 0.0011 0130 \pm 0.0016 014 \pm 0.002 0088 \pm 0.0020 0135 \pm 0.0029 015 \pm 0.004 • We do not use 0121 \pm 0.007 9 From $\pi^+\pi^-\pi^0$ 10 From 2γ decay multiple 11 from $3\pi^0$ decay of 12 Reanalysis of DR a triangle anoma ($\pi^+\pi^-\gamma$)/ Γ total 40 UE (units 10^{-4}) • We do not use 0.30 • We do not use 0.600	EVTS R FIT Error R AVERAGE 279 290 54 e the followin decay mode node of η. mode of η. EVZHININ 84 ely contribution ii CL% 90 e the followin 90 90	8 EARLES en resonance and DOCUMENT ID Includes scale fac Error Includes scale fac 9 AKHMETSHI 10 DRUZHININ 11 DRUZHININ KURDADZE ANDREWS 10 COSME g data for averag 12 BENAYOUN of η . DOCUMENT ID 13 AKHMETSHI g data for averag KALBFLEISC COSME LINDSEY	70 CNTI continuum. TECN tor of 1.1. cale factor of 18 95 CMD 84 ND 84 ND 83c OLYA 77 CNTI 76 OSPI res, fits, limit 96 RVUI N 97C CMD res, fits, limit CH 75 HBC 74 OSPI 65 HBC	$\begin{array}{c} \textbf{R} \ 6.0 \ \gamma \textbf{C} \rightarrow \ \mu^+\mu^-\textbf{X} \\ \hline & \textbf{COMMENT} \\ \hline & \textbf{1.1.} \\ \textbf{2} \ e^+e^- \rightarrow \ \pi^+\pi^-3\gamma \\ e^+e^- \rightarrow 3\gamma \\ e^+e^- \rightarrow 3\gamma \\ e^+e^- \rightarrow 3\gamma \\ \textbf{3} \ e^+e^- \rightarrow 3\gamma \\ \textbf{4} \ e^+e^- \rightarrow 3\gamma \\ \textbf{5} \ e^+e^- \rightarrow 3\gamma \\ \textbf{5} \ e^+e^- \rightarrow 3\gamma \\ \textbf{5} \ e^+e^- \rightarrow \gamma \\ \textbf{5} \ e^+e^- \rightarrow \eta \\ \textbf{5} \ \textbf{5} \ \textbf{COMMENT} \\ \hline & \textbf{2.18} \ \textbf{K}^-p \rightarrow \Lambda\pi^+\pi^-\gamma \\ \textbf{5} \ \textbf{ctc.} \bullet \bullet \bullet \\ \textbf{2.18} \ \textbf{K}^-p \rightarrow \Lambda\pi^+\pi^-\gamma \\ \textbf{5} \ \textbf{ctc.} \bullet \bullet \bullet \\ \textbf{2.17} \ \textbf{K}^-p \rightarrow \Lambda\pi^+\pi^-\gamma \\ \textbf{6} \ e^+e^- \rightarrow \pi^+\pi^-\gamma \\ \textbf{2.1-2.7} \ \textbf{K}^-p \rightarrow \Lambda\pi^+\pi^-\eta \\ \textbf{2.1-2.7} \ \textbf{K}^-p \rightarrow \Lambda\pi^+\eta^-\eta \\ \textbf{2.1-2.7} \ \textbf{K}^-p \rightarrow \Lambda\pi^+\eta^-\eta \\ \textbf{2.1-2.7} \ \textbf{4.1-2.7} \ \textbf{4.1-2.7} \\ \textbf{2.1-2.7} \ \textbf{4.1-2.7} \ \textbf{4.1-2.7} \\ \textbf{2.1-2.7} \ \textbf{4.1-2.7} \ \textbf{4.1-2.7} \ \textbf{4.1-2.7} \\ \textbf{4.1-2.7} \ \textbf{4.1-2.7} \ \textbf{4.1-2.7} \\ \textbf{4.1-2.7} \ \textbf{4.1-2.7} \ \textbf{4.1-2.7} \\ \textbf{4.1-2.7} \ \textbf{4.1-2.7} \ \textbf{4.1-2.7} \ \textbf{4.1-2.7} \\ \textbf{4.1-2.7} \ \textbf{4.1-2.7} \ \textbf{4.1-2.7} \ \textbf{4.1-2.7} \ \textbf{4.1-2.7} \\ \textbf{4.1-2.7} \ \textbf{4.1-2.7} \ \textbf{4.1-2.7} \ \textbf{4.1-2.7} \ \textbf{4.1-2.7} \ \textbf{4.1-2.7} \\ \textbf{4.1-2.7} \ 4.$	0.70 \pm 0.06 0.82 \pm 0.08 0.71 \pm 0.05 0.71 \pm 0.08 0.89 \pm 0.10 $\begin{bmatrix} \Gamma(\rho\pi) + \Gamma(\pi^+ \\ \frac{VALUE}{2} \end{bmatrix} \\ 0.317 \pm 0.017 \text{ OUR} \\ 0.28 \pm 0.09 \\ \end{bmatrix} \\ \begin{bmatrix} (\eta e^+e^-)/\Gamma_{\text{tot}} \\ \frac{VALUE}{2} \end{bmatrix} \\ 1.3 \frac{+0.8}{-0.6} \\ \end{bmatrix} \\ \begin{bmatrix} (\eta'(958)\gamma)/\Gamma_{\text{tot}} \\ \frac{VALUE}{2} \end{bmatrix} \\ \cdot \bullet \bullet We do not total substitution of the subst$	AVERAGE 2732 144 $\pi^-\pi^0$)]/ Γ (I FIT Error in 34 al EVTS 7 otal CLS EVTS see the followin 6 90 $EVTS$	BUKIN 7 LOSTY 7 LAVEN 7 LYONS 7 AGUILAR 7 K+K-) DOCUMENT ID Cludes scale factor of AGUILAR 7 DOCUMENT ID GOLUBEV 8 DOCUMENT ID DRUZHININ 8 = (1.26 ± 0.06) × 10 DRUZHININ 8 DOCUMENT ID DRUZHININ 8	8 HBC 7 HBC 28 HBC 1.5. 28 HBC TECN 5 ND TECN 7 ND 7 ND 7 TECN 7 ND 7 TECN 7 ND	4.2 K^-p — 10 K^-p \rightarrow 3-4 K^-p \rightarrow 3.9,4.6 K^- COMMENT $e^+e^ \rightarrow$	γγε+ε- Γ22/ π+π-3γ γγπ+π- Γ16/

 ϕ (1020), h_1 (1170)

$\Gamma(f_0(980)\gamma)/\Gamma_{\text{total}}$							Γ ₁₅ /Γ
VALUE (units 10 ⁻⁴)	CL%		DOCUMENT ID		TECN	COMMENT	
< 1	90	17	AKHMETSHIN	97c	CMD2	$e^+e^- \rightarrow$	$\pi^+\pi^-\gamma$
 We do not use the 	ne followi	ng c	lata for averages	, fits	, Ilmits,	etc. • • •	
< 7	90	18	AKHMETSHIN	97c	CMD2	$e^+e^- \rightarrow$	$\pi^+\pi^-\gamma$
<20	90		DRUZHININ	87	ND	$e^+e^- \rightarrow$	$\pi^0\pi^0\gamma$
17 For destructive inter 18 For constructive inter	rference v erference	vith wit	the Bremsstrahl the Bremsstrah	ung ilung	process g process	i	
$\Gamma(\pi^0 e^+ e^-)/\Gamma_{\text{total}}$							Γ ₁₉ /[
ALUE	<u> CL%</u>		DOCUMENT ID		<u>TECN</u>	$e^+e^- \rightarrow$	
<1.2 × 10 ⁻⁴	90		DOLINSKY	88	ND	e+e- →	$\pi^0 e^+ e^-$
$\Gamma(\pi^0\eta\gamma)/\Gamma_{\text{total}}$							Γ ₂₀ /Ι
/ALUE (units 10 ⁻³)	<u>CL%_</u>		DOCUMENT ID		<u>TECN</u>	COMMENT	
<2.5 [*]	90		DOLINSKY	91	ND	$e^+e^-\to$	$\pi^{0}\eta\gamma$
$\Gamma(a_0(980)\gamma)/\Gamma_{\text{total}}$							Γ ₂₁ /Ι
VALUE (units 10 ⁻³)	CL%		DOCUMENT ID		TECN_	COMMENT	
<5	90		DOLINSKY	91	ND	$e^+e^- \rightarrow$	$\pi^0\eta\gamma$
Γ(η'(958)γ)/Γ(ηγ)						•	Γ ₂₂ /Γ ₀
VALUE (units 10 ⁻³)	EVTS		DOCUMENT ID		TECN	COMMENT	
$9.5^{+5.2}_{-4.0}\pm1.4$	6		AKHMETSHIN	97 B	CMD2	e ⁺ e ⁻ →	$\pi^+\pi^-3\gamma$
$\Gamma(\mu^+\mu^-\gamma)/\Gamma_{ m total}$							Γ ₂₃ /Ι
VALUE (units 10 ⁻⁵)	EVTS		DOCUMENT ID		<u>TECN</u>	COMMENT	
2.3±1.0	824±	19	AKHMETSHIN	97c	CMD2	$e^+e^- \rightarrow$	$\mu^+\mu^-\gamma$
10	33						
19 For $E_{\gamma} > 20$ MeV.							

ϕ (1020) REFERENCES

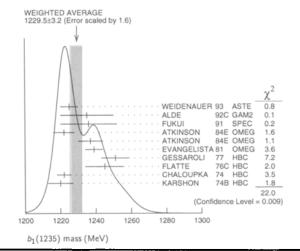
AKHMETSHIN		PL B415 445	R.R. Akhmetshin, Anashkin+(NOVO, BOST, PITT, YALE)
AKHMETSHIN	97C	PL B415 452	+Aksenov+ (NOVO, BOST, PITT, YALE)
BENAYOUN	96	ZPHY C72 221	M. Benayoun+ (IPNP, NOVO)
AKHMETSHIN	95	PL B364 199	+Akesnov+ (NOVO, BOST, PITT, MINN, YALE)
DOLINSKY	91	PRPL 202 99	+Druzhinin, Dubrovin+ (NOVO)
DOLINSKY	89	ZPHY C42 511	+Druzhinin, Dubrovin, Golubev+ (NOVO)
BARKOV	88	SJNP 47 248	+Vasserman, Vorobyev, Ivanov+ (NOVO)
		Translated from	
DOLINSKY	88	SJNP 48 277	+Druzhinin, Dubrovin, Golubev+ (NOVO)
		Translated from	
DRUZHININ	67	ZPHY C37 1	+Dubrovin, Eidelman, Golubev+ (NOVO)
ARMSTRONG	86	PL 166B 245	+Bloodworth, Carney+ (ATHU, BARI, BIRM, CERN)
ATKINSON	86	ZPHY C30 521	 + (BONN, CERN, GLAS, LANC, MCHS, CURIN+)
BEBEK	86	PRL 56 1893	+Berkelman, Blucher, Cassel+ (CLEO Collab.)
DAVENPORT	86	PR 33 2519	(TUFTS, ARIZ, FNAL, FSU, NDAM, VAND)
DIJKSTRA	86	ZPHY C31 375	+Bailey+ (ANIK, BRIS, CERN, CRAC, MPIM, RAL)
FRAME	86	NP B276 667	+Hughes, Lynch, Minto, McFadzean+ (GLAS)
GOLUBEV	86	SJNP 44 409	+Druzhinin, Ivanchenko, Perevedentsev+ (NOVO)
		Translated from	
ALBRECHT	85D	PL 153B 343	+Drescher, Binder, Drews+ (ARGUS Collab.)
GOLUBEV	85	SJNP 41 756	+Druzhinin, Ivanchenko, Peryshkin+ (NOVO)
BBUTUNE		Translated from	
DRUZHININ	84	PL 144B 136	+Golubev, Ivanchenko, Peryshkin+ (NOVO)
ARMSTRONG	83B	NP B224 193	+ (BARI, BIRM, CERN, MILA, CURIN+)
BARATE	83	PL 121B 449	+Bareyre, Bonamy+ (SACL, LOIC, SHMP, IND)
KURDADZE	83C	JETPL 38 366	+Leichuk, Root+ (NOVO)
ADENTON			ZETFP 38 306.
ARENTON	82	PR D25 2241	+Ayres, Diebold, May, Swallow+ (ANL, ILL)
PELLINEN	82	PS 25 599	+Roos (HELS)
DAUM	81	PL 100B 439	+Bardsley+ (AMST, BRIS, CERN, CRAC, MPIM+)
IVANOV	81	PL 107B 297	+Kurdadze, Lelchuk, Sidorov, Skrinsky+ (NOVO)
Also	82	Private Comm.	Eidelman (NOVO)
VASSERMAN	81	PL 99B 62	+Kurdadze, Sidorov, Skrinsky+ (NOVO)
CORDIER	80	NP B172 13	+Delcourt, Eschstruth, Fulda+ (LALO)
CORDIER	79	PL 818 389	+Delcourt, Eschstruth, Fulda+ (LALO)
BUKIN	78B	SJNP 27 521	+Kurdadze, Sidorov, Skrinsky+ (NOVO)
BUKIN	78C	Translated from SJNP 27 516	
DUNIN	100	Translated from	+Kurdadze, Serednyakov, Sidorov+ (NOVO)
COOPER	78B	NP B146 1	+Ganguli+ (TATA, CERN, CDEF, MADR)
LOSTY	78	NP B133 38	+Holmgren, Blokzijl+ (CERN, AMST, NIJM, OXF)
AKERLOF	77	PRL 39 861	+Alley, Bintinger, Ditzler+ (FNAL, MICH, PURD)
ANDREWS	77	PRL` 38 198	+Fukushima, Harvey, Lobkowicz, May+ (ROCH)
BALDI	77	PL 68B 381	+Bohringer, Dorsaz, Hungerbuhler+ (GEVA)
CERRADA	77B	NP B126 241	+Blockziji, Heinen+ (AMST, CERN, NIJM, OXF)
COHEN	77	PRL 38 269	+Ayres, Diebold, Kramer, Pawlicki, Wicklund (ANL)
LAVEN	77	NP B127 43	+Otter, Klein+ (AACH3, BERL, CERN, LOIC, WIEN)
LYONS	77	NP B125 207	
COSME	76	PL 63B 352	+Cooper, Clark (OXF)
			+Courau, Dudelzak, Grelaud, Jean-Marie+ (ORSAY)
KALBFLEISCH PARROUR	76 76	PR D13 22 PL 63B 357	+Strand, Chapman (BNL, MICH)
	76B		+Grelaud, Cosme, Courau, Dudelzak+ (ORSAY)
PARROUR		PL 63B 362	+Grelaud, Cosme, Courau, Dudelzak+ (ORSAY)
KALBFLEISCH		PR D11 987	+Strand, Chapman (BNL, MICH)
AYRES	74	PRL 32 1463	+Diebold, Greene, Kramer, Levine+ (ANL)
BESCH	74	NP B70 257	+Hartmann, Kose, Krautschneider, Paul+ (BONN)
COSME	74	PL 48B 155	+Jean-Marie, Jullian, Laplanche+ (ORSAY)
COSME	74B	PL 48B 159	+Jean-Marie, Jullian, Laplanche+ (ORSAY)
DEGROOT	74	NP B74 77	+Hoogland, Jongejans, Metzger+ (AMST, NIJM)
BALLAM	73	PR D7 3150	+Chadwick, Eisenberg, Bingham+ (SLAC, LBL)
BINNIE	73B	PR D8 2789	+Carr, Debenham, Duane+ (LOIC, SHMP)
AGUILAR	72B	PR D6 29	Aguilar-Benitez, Chung, Eisner, Samios (BNL)
ALVENSLEB	72	PRL 28 66	Alvensleben, Becker, Biggs, Binkley+ (MIT, DESY)

CHATELUS AISO AISO EARLES LINDSEY LONDON BADIER LINDSEY LINDSEY LINDSEY ACHASOV ACHASOV ACHASOV KAMAL GEORGIO	72 PR D5 1559 + Danburg, Kalbfeisch+ (BNL, MICI PL 348 328 + Ljobes, Riddford, Griffiths+ (BNR, GLA PL 1747 70 PL 32 416 + Bludker, Pakhtusova, Sidorov, Skrinsky+ (NOV GSTR 171 PR D4 899 + Himlay, Joseph, Keizer, Stein (CORSA PL 25 1312 + Faissler, Gettner, Lutz, Moy, Tang+ Peraz-y-Jorba PR 143 1034 + Faissler, Gettner, Lutz, Moy, Tang+ (SBN PR 143 1034 + Faissler, Gettner, Lutz, Moy, Tang+ (BNL, SYR 56 PR 147 913 + Faissler, Gettner, Lutz, Moy, Tang+ (BNL, SYR 56 PR 147 313 + Faissler, Gettner, Lutz, Moy, Tang+ (BNL, SYR 56 PR 147 337 + Demoulin, Barloutaud+ (EPOL, SACL, AMS 56 Adta included in LINDSEY 65. + Slater, Smith, Stork, Ticho (UCL) OTHER RELATED PAPERS 97C PR D56 4084 97D PR D56 203
GELFAND BERTANZA	63B PRL 11 438 + Miller, Nussbaum, Kirsch (COLU, RUT) 62 PRL 9 180 + Brisson, Connolly, Hart+ (BNL, 5YR)
$h_1(11)$	70) $I^{G}(J^{PC}) = 0^{-(1+-)}$
	h ₁ (1170) MASS
• • • We d	JR ESTIMATE DOCUMENT ID TECN CHG COMMENT On not use the following data for averages, fits, limits, etc. ANDO 92 SPEC $8\pi^-p \rightarrow \pi^+\pi^-\pi^0$
1166± 5±	$\pi^+\pi^-\pi^0$
	2 DANKOWY 81 SPEC 0 8 $\pi p \rightarrow 3\pi r$ and spread of values using 2 variants of the model of BOWLER 75. model of BOWLER 75.
	<i>h</i> 1(1170) WIDTH
	DOCUMENT ID TECN CHG COMMENT R ESTIMATE
● ● ● vve o 345 ± 6	o not use the following data for averages, fits, limits, etc. • • • ANDO 92 SPEC 8 $\pi^- p \rightarrow$
	$\pi^+\pi^-\pi^0$
375± 6±3	3 ANDO 92 SPEC $8 \pi^- p \rightarrow \pi^+ \pi^- \pi^0$
375± 6±3 320±50 ³ Average	³ ANDO 92 SPEC $8 \pi^- p \rightarrow$
375± 6±3 320±50 ³ Average	3 ANDO 92 SPEC $8 \pi^- p \rightarrow \pi^+ \pi^- \pi^0$ 4 DANKOWY 81 SPEC 0 $8 \pi p \rightarrow 3\pi \iota$ and spread of values using 2 variants of the model of BOWLER 75.
375± 6±3 320±50 ³ Average	3 ANDO 92 SPEC $8\pi^-p \rightarrow \pi^+\pi^-\pi^0$ 4 DANKOWY 81 SPEC 0 $8\pi p \rightarrow 3\pi r$ and spread of values using 2 variants of the model of BOWLER 75. model of BOWLER 75. h ₁ (1170) DECAY MODES
375± 6±3 320±50 3 Average 4 Uses the	3 ANDO 92 SPEC $8 \pi^- p \rightarrow \pi^+ \pi^- \pi^0$ 4 DANKOWY 81 SPEC 0 $8 \pi p \rightarrow 3\pi r$ and spread of values using 2 variants of the model of BOWLER 75. model of BOWLER 75. h ₁ (1170) DECAY MODES
375± 6±3 320±50 3 Average 4 Uses the	3 ANDO 92 SPEC $8\pi^-p \rightarrow \pi^+\pi^-\pi^0$ 4 DANKOWY 81 SPEC 0 $8\pi p \rightarrow 3\pi r$ and spread of values using 2 variants of the model of BOWLER 75. h ₁ (1170) DECAY MODES Fraction (Γ_1/Γ) seen
375± 6±3 320±50 3 Average 4 Uses the	3 ANDO 92 SPEC $8\pi^-p - \pi^0$ 4 DANKOWY 81 SPEC 0 $8\pi p \to 3\pi r$ and spread of values using 2 variants of the model of BOWLER 75. h ₁ (1170) DECAY MODES Fraction (Γ_i/Γ) seen h ₁ (1170) BRANCHING RATIOS
$375 \pm 6 \pm 3$ 320 ± 50 3 Average 4 Uses the $\frac{\text{Mod}}{\Gamma_1 \rho \pi}$ $\frac{\Gamma(\rho \pi)/\Gamma_{\text{th}}}{VALUE}$ ••• • We define the second state of	3 ANDO 92 SPEC $8\pi^-p \rightarrow \pi^+\pi^-\pi^0$ 4 DANKOWY 81 SPEC 0 $8\pi p \rightarrow 3\pi r$ and spread of values using 2 variants of the model of BOWLER 75. h1(1170) DECAY MODES Fraction (Γ_1/Γ) seen h1(1170) BRANCHING RATIOS tal DOCUMENT ID TECN COMMENT o not use the following data for averages, fits, limits, etc. • •
$375 \pm 6 \pm 3$ 320 ± 50 3 Average 4 Uses the $\frac{\text{Mod}}{\Gamma_1 \rho \pi}$ $\Gamma(\rho \pi)/\Gamma_{\text{tx}}$ $VALUE$	3 ANDO 92 SPEC $8\pi^-p \rightarrow \pi^+\pi^-$ 4 DANKOWY 81 SPEC 0 $8\pi p \rightarrow 3\pi r$ and spread of values using 2 variants of the model of BOWLER 75. h ₁ (1170) DECAY MODES Fraction (Γ_I/Γ) seen h ₁ (1170) BRANCHING RATIOS tal DOCUMENT ID TECN O not use the following data for averages, fits, limits, etc. • • • ANDO 92 SPEC $8\pi^-p \rightarrow \pi^+\pi^-$ ATKINSON 84 OMEG 20-70 $\gamma p \rightarrow$
$375 \pm 6 \pm 3$ 320 ± 50 3 Average 4 Uses the	3 ANDO 92 SPEC $8\pi^-p \rightarrow \pi^+\pi^-\pi^0$ 4 DANKOWY 81 SPEC 0 $8\pi p \rightarrow 3\pi I$ and spread of values using 2 variants of the model of BOWLER 75. h1(1170) DECAY MODES Fraction (Γ_I/Γ) seen h1(1170) BRANCHING RATIOS tal DOCUMENT ID TECN COMMENT On not use the following data for averages, fits, limits, etc. • • ANDO 92 SPEC $8\pi^-p \rightarrow \pi^+\pi^-$
$375 \pm 6 \pm 3$ 320 ± 50 3 Average 4 Uses the Mod $\Gamma_1 \rho \pi$ $\Gamma(\rho \pi)/\Gamma_{\text{th}}$ $VALUE$ • • • We disseen seen	3 ANDO 92 SPEC $8\pi^-p \rightarrow \pi^+\pi^-\pi^0$ 4 DANKOWY 81 SPEC 0 $8\pi p \rightarrow 3\pi r$ and spread of values using 2 variants of the model of BOWLER 75. h1(1170) DECAY MODES Fraction (Γ_I/Γ) seen h1(1170) BRANCHING RATIOS tal DOCUMENT ID DOCUMENT ID ANDO 92 SPEC $8\pi^-p \rightarrow \pi^+\pi^-r$ ANDO ATKINSON 84 OMEG 20-70 $\gamma p \rightarrow \pi^+\pi^-r^0 p$

h.	(1	235)
ν_1	1,	.233)

$$I^{G}(J^{PC}) = 1^{+}(1^{+})$$

		b ₁ (1235) MAS	SS			
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
1229.5± 3.2 OU	R AVERAGE Err	or Includes scale	facto	of 1.6.	See	the ideogram below
1225 ± 5		WEIDENAUER	93	ASTE		$\overline{p}p \rightarrow 2\pi^+ 2\pi^- \pi^0$
1235 ±15		ALDE	92 C	GAM2		$38,100 \pi^{-} \rho \rightarrow \omega \pi^{0} n$
1236 ±16		FUKUI	91	SPEC		8.95 π ⁻ ρ → ωπ ⁰ n
1222 ± 6		ATKINSON	84E	OMEG	Ŧ	25-55 γp → ωπΧ
1237 ± 7		ATKINSON	84E	OMEG	0	25-55 γp → ωπΧ
1239 ± 5		EVANGELISTA	81	OMEG	-	12 π ⁻ p → ω* p
1251 ± 8	450	GESSAROLI	77	нвс	-	11 π ⁻ p - · π ⁻ ω p
1245 ±11	890	FLATTE	76 C	нвс	-	$4.2 K^- p \rightarrow \pi^- \omega \Sigma^+$
1222 ± 4	1400	CHALOUPKA	74	HBC	_	3.9 π ⁻ p
1220 ± 7	600	KARSHON	748	HBC	+	$4.9 \pi^{+} p$
• • • We do not	use the following	data for average:	s, fits	, ilmits,	etc.	• •
1190 ±10		AUGUSTIN	89	DM2	±	$e^+e^- ightarrow 5\pi$
1213 ± 5		ATKINSON	840	OMEG	0	20-70 γp
1271 ±11		COLLICK	84	SPEC	-	200 π ⁺ Z →



b₁(1235) WIDTH

VALUE (MeV)	EVT5	DOCUMENT ID		TECN	CHG	COMMENT
142± 9 OUR AVERAGE	Error incl	udes scale facto	r of :	1.2.		
113±12		WEIDENAUER	93	ASTE		$\overline{p}p \rightarrow$
						$2\pi^{+}2\pi^{-}\pi^{0}$
160±30		ALDE	92 C	GAM2		38,100 $\pi^- \rho \rightarrow$
						$\omega \pi^0 \pi$
151 ± 31		FUKUI	91	SPEC		8.95 x - p →
						$\omega \pi^0 n$
170±15		EVANGELISTA	81	OMEG	_	$12 \pi^- p \rightarrow \omega \pi p$
170±50	225	BALTAY	788	HBC	+	$15 \pi^+ p \rightarrow p4\pi$
155±32	450	GESSAROLI	77	HBC	-	$11 \pi^- p \rightarrow$
						$\pi^-\omega p$
182±45	890	FLATTE	76 C	HBC	-	4.2 K ⁻ p →
						$\pi^-\omega\Sigma^+$
135 ± 20	1400	CHALOUPKA	74	HBC	-	3.9 π ⁻ p
156 ± 22	600	KARSHON	74B	HBC	+	4.9 π ⁺ p
• • • We do not use the	e following d	ata for averages	, fits	, iimits,	etc. •	• •
210±19		AUGUSTIN	89	DM2	±	$e^+e^- \rightarrow 5\pi$
231 ± 14		ATKINSON	84C	OMEG	0	20-70 γp
232 ± 29		COLLICK	84	SPEC	+	200 x+Z →
						Ζπω

b1(1235) DECAY MODES

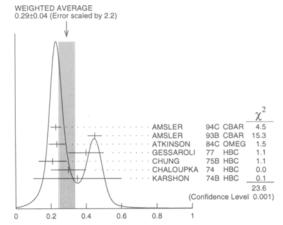
	Mode	Fraction (f	· _/ /Γ)	Confidence level
Γ ₁	$\omega \pi$ [D/5 amplitude ratio = 0.29 ± 0.04]	domina	nt	
Γ_2	$\pi^{\pm}\gamma$	(1.6±0	$(.4) \times 10^{-3}$	Į.
Γ3	$\eta \rho$	seen		
Γ_4	$\frac{\pi^+\pi^+\pi^-\pi^0}{(K\overline{K})^{\pm}\pi^0}$	< 50	%	84%
۲5	$(K\overline{K})^{\pm}\pi^{0}$	< 8	%	90%
Γ ₅ Γ ₆	$K_S^0 K_L^0 \pi^{\pm}$	< 6	%	90%
Γ7	$K_S^{ar{0}}K_S^{ar{0}}\pi^{\pm}$	< 2	%	90%
۲8	$\phi\pi$	< 1.5	%	84%

b1(1235) PARTIAL WIDTHS

				Γ ₂
DOCUMENT ID	TECN	CHG	COMMENT	
COLLICK 8	SPEC	+	200 π ⁺ Z →	

$b_1(1235)$ D-wave/S-wave AMPLITUDE RATIO IN DECAY OF $b_1(1235) ightarrow \omega \pi$

VALUE	EVTS	DOCUMENT ID	TECN_	CHG	COMMENT
0.29 ±0.04	OUR AVERAGE	Error includes scale	factor of 2.2	2. See	the ideogram below.
0.23 ± 0.03		AMSLER	94c CBAR		$0.0 \ \overline{p}p \rightarrow \omega \eta \pi^0$
0.45 ±0.04		AMSLER	93B CBAR		$0.0 \overline{p}p \rightarrow$
					_{ωπ} 0π0
0.235 ± 0.047	'	ATKINSON	84c OMEG	i	20-70 γp
$0.4 \begin{array}{c} +0.1 \\ -0.1 \end{array}$		GESSAROLI	77 HBC	-	11 π ⁻ ρ →
					$\pi^-\omega p$
0.21 ±0.08		CHUNG	75B HBC	+	$7.1 \pi^{+} \rho$
0.3 ± 0.1		CHALOUPKA	74 HBC	-	3.9-7.5 x - p
0.35 ±0.25	600	KARSHON	74B HBC	+	4.9 π ⁺ p



 b_1 (1235) *D*-wave/*S*-wave amplitude ratio in decay of b_1 (1235) $ightarrow \omega \pi$

b1(1235) BRANCHING RATIOS

$\Gamma(\eta \rho)/\Gamma(\omega \pi)$)						Γ_3/Γ_1
VALUE		DOCUMENT ID		TECN	COM	MENT.	
<0.10		ATKINSON	840	OMEG	20-7	0γρ	
Γ(π+π+π-π	$^{0})/\Gamma(\omega\pi)$						Γ_4/Γ_1
VALUE		DOCUMENT ID		TECN	CHG		
<0.5		ABOLINS	63	нвс	+	$3.5 \pi^{+} p$	
$\Gamma((K\overline{K})^{\pm}\pi^{0})$	/Γ(ωπ)						Γ_5/Γ_1
VALUE	CLN	DOCUMENT ID		TECN_	CHG	COMMENT	
<0.08	90	BALTAY	67	HBC	±	0.0 p p	
$\Gamma(K_S^0K_L^0\pi^{\pm})$	/Γ(ω π)						Γ ₆ /Γ ₁
VALUE	CLM	DOCUMENT ID		TECN	CHG	COMMENT	
<0.06	90	. BALTAY	67	HBC	±	0.0 Pp	
$\Gamma(K_S^0K_S^0\pi^{\pm})$	/Γ(ωπ)						Γ7/Γ1
VALUE	CL%	DOCUMENT ID		TECN	CHG	COMMENT	
<0.02	90	BALTAY	67	HBC	±	0.0 Pp	

 $b_1(1235), a_1(1260)$

$\Gamma(\phi\pi)/\Gamma(\omega\pi)$						Γ ₈ /Γ ₁
VALUE	<u>CL%</u>	DOCUMENT IL)	TECN	CHG	COMMENT
<0.004 • • • We do no	95 t use the followin	VIKTOROV				$32.5 \pi^- p \rightarrow K^+ K^- \pi^0 n$
<0.04 <0.015	95	BIZZARRI DAHL	69	НВС НВС		0.0 <i>p̄ p</i> 1.6-4.2 π ⁻ p
		(4005) DEFE				

b₁ (1235) REFERENCES

VIKTOROV	96	PAN 59 1184		
		Translated from		
AMSLER	94C	PL B327 425		
AMSLER	93B	PL B311 362	+Armstrong, v.Dombrowski+ (Crystal Barrel Collab.)	
WEIDENAUER	93	ZPHY C59 387		
ALDE	92C	ZPHY C54 553	+Bencheikh, Binon+ (BELG, SERP, KEK, LANL, LAPP)	
FUKUI	91	PL B257 241	+Horikawa+ (SUGI, NAGO, KEK, KYOT, MIYA)	
AUGUSTIN	89	NP B320 1	+Cosme (DM2 Collab.)	
ATKIN5ON	84C	NP B243 1	+ (BONN, CERN, GLAS, LANC, MCHS, CURIN+) JP	•
ATKINSON	84D	NP B242 269	+ (BONN, CERN, GLAS, LANC, MCHS, CURIN+)	
ATKINSON	84E	PL 138B 459	+ (BONN, CERN, GLAS, LANC, MCHS, CURIN+)	
COLLICK	84	PRL 53 2374	+Heppelmann, Berg+ (MINN, ROCH, FNAL)	
EVANGELISTA	81	NP B178 197	+ (BARI, BONN, CERN, DARE, LIVP+)	
	78B	PR D17 62	+Cautis, Cohen, Csorna+ (COLU, BING)	
GESSAROLI	77	NP B126 382	+ (BGNA, FIRZ, GENO, MILÀ, OXF, PAVI) JP	,
FLATTE	76C	PL 64B 225	+Gay, Blokziji, Metzger+ (CERN, AMST, NIJM, OXF) JP	,
CHUNG	75B	PR D11 2426	+Protopopescu, Lynch, Flatte+ (BNL, LBL, UCSC) JF	,
CHALOUPKA	74	PL 51B 407	+Ferrando, Losty, Montanet (CERN) JP	
KARSHON	74B	PR D10 3608	+Mikenberg, Eisenberg, Pitluck, Ronat+ (REHO) JF	
BIZZARRI	69	NP B14 169	+Foster, Gavillet, Montanet+ (CERN, CDEF)	
	67	PRL 18 93	+Franzini, Severiens, Yeh, Zanello (COLU)	
DAHL	67		+Hardy, Hess, Kirz, Miller (LRL)	
ABOLINS	63	PRL 11 381	+Lander, Mehlhop, Nguyen, Yager (UCSD)	

OTHER RELATED PAPERS

GOLOVKIN	97	ZPHY A359 4335	S.V. Golovkin, Kozhevnikov+	(SERP, ITEP)
BRAU	88	PR D37 2379	+Franek+ (SLAC Hybrid Facility	Photon Collab.) JP
ATKINSON	84C	NP B243 1	 + (BONN, CÉRN, GLÁS, LANC, M 	iCHS, CURIN+) JP
GOLDHABER	65	PRL 15 118	+Goldhaber, Kadyk, Shen	(LRL)
CARMONY	64	PRL 12 254	+Lander, Rindfleisch, Xuong, Yager	(UCB) JP
BONDAR	63B	PL 5 209	+Dodd+ (AACH, BIRM, HAMB	, LOIC, MPIM)

 $a_1(1260)$

$$I^G(J^{PC}) = 1^-(1^{++})$$

THE $a_1(1260)$

Written March 1998 by S. Eidelman (Novosibirsk).

The main experimental data on the $a_1(1260)$ may be grouped into two classes:

(1) Hadronic Production. This comprises diffractive production with incident π^- (DAUM 80, 81B) and chargeexchange production with low-energy π^- (DANKOWYCH 81, ANDO 92). The 1980's experiments explain the I^GLJ^P = 1+S0+ data using a phenomenological amplitude consisting of a rescattered Deck amplitude plus a direct resonance-production term. They agree on an $a_1(1260)$ mass of about 1270 MeV and a width of 300-380 MeV. ANDO 92 finds rather lower values for the mass (1121 MeV) and width (239 MeV) in a partial-wave analysis based on the isobar model of the $\pi^+\pi^-\pi^0$ system. However, in this analysis, only Breit-Wigner terms were considered.

(2) \(\tau \) decay. Five experiments reported good data on $\tau \rightarrow a_1(1260)\nu_{\tau} \rightarrow \rho\pi\nu_{\tau}$ (RUCKSTUHL 86, SCHMIDKE 86, ALBRECHT 86B, BAND 87, and ACKERSTAFF 97R). They are somewhat inconsistent concerning the $a_1(1260)$ mass, which can, however, be attributed to model-dependent systematic uncertainties (BOWLER 86, ALBRECHT 93C, ACKERSTAFF 97R). They all find a width greater than 400 MeV.

The discrepancies between the hadronic- and τ -decay results have stimulated several reanalyses. BASDEVANT 77, 78 used the early diffractive dissociation and τ decay data and showed that they could be well reproduced with an a_1 resonance mass of 1180 ± 50 MeV and width of 400 ± 50 MeV. Later, BOWLER 86, TORNQVIST 87, ISGUR 89, and IVANOV 91 have studied the process $\tau \to 3\pi\nu_{\tau}$. Despite quite different approaches, they all found a good overall description of the τ -decay data with an $a_1(1260)$ mass near 1230 MeV, consistent with the hadronic data. However, their widths remain significantly larger (400-600 MeV) than those extracted from diffractive-hadronic data. This is also the case with the later OPAL experiment (ACKERSTAFF 97R). In the high statistics analysis of ACKERSTAFF 97R the models of ISGUR 89 and KUHN 90 are used to fit distributions of the 3π invariant mass as well as the 2π invariant mass projections of the Dalitz plot and neither model is found to provide a completely satisfactory description of the data. Another recent high statistics analysis of ABREU 98G obtains good description of the $\tau \to 3\pi$ data using the model of FEINDT 90 which includes the a'_1 meson, a radial excitation of the $a_1(1260)$ meson, with a mass of 1700 MeV and a width of 300 MeV.

BOWLER 88 showed that good fits to both the hadronic and the τ -decay data could be obtained with a width of about 400 MeV. However, applying the same type of analysis to the ANDO 92 data, the low mass and narrow width they obtained with the Breit-Wigner PWA do not change appreciably.

CONDO 93 found no evidence for charge-exchange photoproduction of the $a_1(1260)$ (but found a clear signal of $a_2(1320)$ photoproduction). They show that it is consistent with either an extremely large $a_1(1260)$ hadronic width or with a small radiative width to $\pi\gamma$, which could be accommodated if the a_1 mass is somewhat below 1260 MeV.

21(1260) MASS

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VALUE (MeV)	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT
1230±40 OUR ESTIMATE			ti un léa	- - -	
• • We do not use the f				etc. •	
1262 ± 9 ± 7	1,2 ACKERSTAFF	97R	OPAL		Ecm = 88-94,
1210± 7± 2	2,3 ACKERSTAFF	97R	OPAL		$E_{CM}^{T} = 88-94,$ $\tau \rightarrow 3\pi\nu$
1211± 7	ALBRECHT	93 C	ARG		$\tau^{+} \xrightarrow{\sigma} 3\pi\nu$ $\tau^{+} \xrightarrow{\pi^{+}} \pi^{+} \pi^{-} \nu$
1121± 8	4 ANDO	92	SPEC		$ 8 \pi^{-} p \rightarrow \\ \pi^{+} \pi^{-} \pi^{0} p $
1242±37	5 IVANOV	91	RVUE		$\tau \rightarrow \pi^+\pi^+\pi^-\nu$
1260±14	6 IVANOV	91	RVUE		$\tau \rightarrow \pi^+\pi^+\pi^-\nu$
1250± 9	7 IVANOV	91	RVUE		$\tau \rightarrow \pi^{+}\pi^{+}\pi^{-}\nu$
1208±15	ARMSTRONG	90	OMEG	0	$\begin{array}{c} 300.0pp \rightarrow \\ pp\pi^{+}\pi^{-}\pi^{0} \end{array}$
1220±15	8 ISGUR	89	RVUE		$\tau^+ \stackrel{\rho\rho\pi}{\rightarrow} +$
1260±25	9 BOWLER	88	RVUE		π'π'π ν
1166±18±11	BAND	87	MAC		τ ⁺ →
1164±41±23	BAND	87	MAC		$\tau^{+} \xrightarrow{\pi^{+} \pi^{0} \pi^{0} \nu} \tau^{+}$
1250 ± 40	8 TORNQVIST	87	RVUE		# · # · # · D
1046 ± 11	ALBRECHT	86B	ARG		τ ⁺ →
1056±20±15	RUCKSTUHL	86	DLCO		7+ -+ ··
1194±14±10	SCHMIDKE	86	MRK2		τ ⁺ →
1240±80	10 DANKOWY	81	SPEC	0	$8.45 \pi^{-} p \rightarrow 0.3\pi$
1280±30	10 DAUM	818	CNTR		63,94 $\pi^- p \rightarrow$
1041±13	11 GAVILLET	77	нвс	+	$\begin{array}{c} p3\pi \\ 4.2 K^{-} p \rightarrow \end{array}$
					$\Sigma 3\pi$

Uses the model of KUHN 90. Supersedes AKERS 95P

Supersects ARERS 999'
Uses the model of ISGUR 89.
Average and spread of values using 2 variants of the model of BOWLER 75.
Reanalysis of RUCKSTUHL 86.
Reanalysis of SCHMIDKE 86.

Reanalysis of ALBRECHT 86B

From a combined reanalysis of ALBRECHT 86B, SCHMIDKE 86, and RUCKSTUHL 86.

From a combined reanalysis of ALBRECHT 868 and DAUM 818.

Uses the model of BOWLER 75.

Produced in K— backward scattering.

	a ₁ (1260) WID	TH			
VALUE (MeV)	DOCUMENT ID	TECH	<u>CHG</u>	COMMENT	_
250 to 600 OUR ESTIMATE • • • We do not use the foll	owing data for average	e fite limi	ts etc :		
621± 32±58	12,13 ACKERSTAFF			Ecm = 88-94,	1
457± 15±17	13,14 ACKERSTAFF			$\begin{array}{c} \tau \rightarrow 3\pi\nu \\ E_{CM}^{ee} = 88-94, \end{array}$	ī
446± 21	ALBRECHT	93C ARG		$\tau \to 3\pi \nu$ $\tau^+ \to$	Ī
239± 11	ANDO	92 SPE		$\pi^+\pi^+\pi^-\nu$ 8 $\pi^-\rho$ \rightarrow	
266± 13± 4	15 ANDO	92 SPE	c	$\pi^{+}\pi^{-}\pi^{0}\pi$ 8 $\pi^{-}\rho \rightarrow$	
				$\pi^{+}\pi^{-}\pi^{0}n$	
465 ⁺²²⁸ -143	16 IVANOV	91 RVL		$\tau \rightarrow \pi^{+}\pi^{+}\pi^{-}$	
298 + 40 - 34 488 ± 32	¹⁷ IVANOV ¹⁸ IVANOV	91 RVU		$\tau \to \pi^+ \pi^+ \pi^-$ $\tau \to \pi^+ \pi^+ \pi^-$	
430± 50	ARMSTRONG		EG 0	300.0 <i>pp</i> →	•
420± 40	¹⁹ ISGUR	89 RVI	JE	$\tau^+ \stackrel{pp\pi^+\pi^-\pi^0}{\rightarrow}$	
396± 43	²⁰ BOWLER	88 RVI		π ⁺ π ⁺ π ⁻ ν	
405± 75±25	BAND	87 MA		$\tau^+_{_{\perp}\pi^+\pi^+\pi^-\nu}$	
419±108±57	BAND	87 MA		$\overset{\tau^{\top}}{\underset{\perp}{\pi^{+}}}\overset{\rightarrow}{\pi^{0}}_{\pi^{0}}$	
521± 27	ALBRECHT	868 ARG	i	$\tau^+_{,\pi^+\pi^+\pi^-\nu}$	
476 + 132 + 54	RUCKSTUHL			$^{\tau^+}_{,\pi^+\pi^+\pi^-\nu}$	
462± 56±30	SCHMIDKE	86 MR		$\tau^+ \rightarrow \pi^+ \pi^- \nu$	
380±100	21 DANKOWY			8.45 π ⁻ p → π3π	
300± 50	²¹ DAUM	818 CN		63,94 π p → p3π	
230± 50 12 Uses the model of KUHN	²² GAVILLET	77 HB	C +	4.2 K ⁻ p → Σ3π	
13 Supersedes AKERS 95P 14 Uses the model of ISGUF 15 Average and spread of va 16 Page about of PUCKSTU	ilues using 2 variants o	f the mod	el of BO	WLER 75.	•
14 Uses the model of ISGUR	olues using 2 variants o HL 86. E 86. T 86B. rsis of ALBRECHT 868 ysis of ALBRECHT 868 LER 75.	, SCHMID	KE 86, a		16.
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14 Uses the model of ISGUI 15 Average and spread of va 16 Reanalysis of RUCKSTU 17 Reanalysis of SCHMIDK. 18 Reanalysis of ALBRECH 19 From a combined reanaly 20 From a combined reanaly 21 Uses the model of BOW 22 Produced in K^- backwa $\frac{\rho \pi}{\Gamma} \frac{\rho \pi}{D/S} \frac{\rho \pi}{\Delta m} \frac{\Gamma}{S-Wave}$		MODES Fraction dominant 28] seen possibly s WIDTH	KE 86, a M 818. (Γ _I /Γ) S S EC 200	and RUCKSTUHL 8 $ \frac{MENT}{\pi^+ Z \rightarrow Z 3\pi} $	-
14 Uses the model of ISGUE 15 Average and spread of va 16 Reanalysis of RUCKSTU 17 Reanalysis of SCHMIDKI 18 Reanalysis of ALBRECH ¹ 19 From a combined reanaly 20 From a combined reanaly 21 Uses the model of BOWI 22 Produced in K^- backwa Mode $\Gamma_1 \qquad \rho \pi \qquad [D/S \text{ amplitude rate} \\ \Gamma_2 \qquad \pi \gamma \qquad \Gamma_3 \qquad \pi (\pi\pi)_{S\text{-wave}}$ $\Gamma(\pi\gamma)$ VALUE (ω V) 440±246 D-wave/S-wave AMI		MODES Fraction dominant 228 seen possibly s WIDTH	KE 86, a M 818.	MMENT $\pi^+ Z \rightarrow Z 3\pi$ $(1260) \rightarrow \rho \pi$	-
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a1(1260) REFERENCES

ACKERSTAFF	97R	ZPHY C75 593	K. Ackerstaff+ (OPAL Collab.)
AKERS	95P	ZPHY C67 45	+Alexander, Allison, Ametewee+ (OPAL Collab.)
ALBRECHT	93C	ZPHY C58 61	+Ehrlichmann, Hamacher+ (ARGUS Collab.)
ANDO	92	PL B291 496	+lmai+ (KEK, KYOT, NIRS, SAGA, INUS, AKIT)
IVANOV	91	ZPHY C49 563	+Osipov, Volkov (JINR)
ARMSTRONG	90	ZPHY C48 213	+ Benayoun, Beusch (WA76 Collab.)
KUHN	90	ZPHY C48 445	J.H. Kuhn, Santamaria+ (MPIM)
ISGUR	89	PR D39 1357	+Morningstar, Reader (TNTO)
BOWLER	88	PL B209 99	(OXF)
BAND	87	PL B198 297	+Camporesi, Chadwick, Delfino+ (MAC Collab.)
TORNQVIST	87	ZPHY C36 695	(HELS)
ALBRECHT	86B	ZPHY C33 7	+ Donker, Gabriel, Edwards+ (ARGUS Collab.)
RUCKSTUHL	86	PRL 56 2132	+Stroynowski, Atwood, Barish+ (DELCO Collab.)
SCHMIDKE	86	PRL 57 527	+Abrams, Matteuzzi, Amidei+ (Mark II Collab.)
ZIELINSKI	84C	PRL 52 1195	+Berg, Chandlee, Cihangir+ (ROCH, MINN, FNAL)
LONGACRE	82	PR D26 83	(BNL)
DANKOWY	81	PRL 46 580	Dankowych+' (TNTO, BNL, CARL, MCGI, OHIO)
DAUM	81B	NP B182 269	+Henzberger+ (AMST, CERN, CRAC, MPIM, OXF+)
DAUM	80	PL 89B 281	+ Hertzberger + (AMST, CERN, CRAC, MPIM, OXF+) JP
GAVILLET	77	PL 69B 119	+Blockziji, Engelen+ (AMST, CERN, NIJM, OXF) JP
BOWLER	75	NP B97 227	+Game, Aitchison, Dainton (OXFTP, DARE)

- OTHER RELATED PAPERS -

ABREU	98G	PL B (to be publ.)	P. Abreu+	(DELPHI Collab.)
CERN-EP	/9B-14			
BOLONKIN	95	PAN 58 1535	+Vladimirskii, Erofeeva+	(ITEP)
		Translated from YAF	58 1628.	
WINGATE	95	PRL 74 4596	+De Grand	(COLO, FSU)
CONDO	93	PR D48 3045	+Handler, Bugg+	(SLAC Hybrid Collab.)
FEINDT	90	ZPHY C48 681	M. Feindt	(HAMB)
BZUKA	89	PR D39 3357	+Koibuchi, Masuda	(NAGO, IBAR, TSUK)
TORNOVIST	87	ZPHY C36 695		(HELS)
BOWLER	86	PL B182 400		`(OXF)
BASDEVANT	78	PRL 40 994	+ Berger	(FNAL, ANL) JP
BASDEVANT	77	PR D16 657	+ Berger	(FNAL, ANL) JP
ADERHOLZ	64	PL 10 226		M, BONN, DESY, HAMB+)
GOLDHABER	64	PRL 12 336	+Brown, Kadyk, Shen+	(LRL, UCB)
LANDER	64	PRL 13 346A	+ Abolins, Carmony, Hendricks,	
		NC 29 896	+Fiorini, Herz, Negri, Ratti	(MILA)
BELLINI	63	MC 53 838	+rionni, merz, negni, macu	(MILEY)

 $f_2(1270)$

VALUE (MeV)

 $I^{G}(J^{PC}) = 0^{+}(2^{+})$

DOCUMENT ID TECN COMMENT

£(1270) MASS

EVTS

1275.0± 1.2 OUR A	VERAGE	
1278 ± 5		¹ BERTIN 97C OBLX 0.0 $\bar{p}p \rightarrow \pi^+\pi^-\pi^0$
1272 ± 8	200k	PROKOSHKIN 94 GAM2 38 $\pi^- p \rightarrow \pi^0 \pi^0 \pi$
1269.7± 5.2	5730	AUGUSTIN 89 DM2 $e^+e^- \rightarrow 5\pi$
1283 ± 8	400	² ALDE 87 GAM4 100 $\pi^{-}p \rightarrow 4\pi^{0}n$
1274 ± 5		² AUGUSTIN 87 DM2 $J/\psi \rightarrow \gamma \pi^+ \pi^-$
1283 ± 6		³ LONGACRE 86 MPS $22 \pi^- p \rightarrow \pi^2 K_S^0$
1276 ± 7		COURAU 84 DLCO $e^+e^- \rightarrow e^+e^-\pi^+\pi^-$
1273.3± 2.3		⁴ CHABAUD 83 ASPK 17 π ⁻ p polarized
1280 ± 4		5 CASON 82 STRC 8 $\pi^{+} p \rightarrow \Delta^{++} \pi^{0} \pi^{0}$
1281 ± 7	11600	GIDAL 81 MRK2 J/ψ decay
1282 ± 5		⁶ CORDEN 79 OMEG 12–15 $\pi^- p \rightarrow n2\pi$
1269 ± 4	10k	APEL 75 NICE $40 \pi^- p \rightarrow n2\pi^0$
1272 ± 4	4600	ENGLER 74 DBC $6\pi^+\eta \rightarrow \pi^+\pi^-\rho$
1277 ± 4	5300	FLATTE 71 HBC 7.0 $\pi^+ p$
1273 ± 8		² STUNTEBECK 70 HBC $8\pi^-p$, 5.4 π^+d
1265 ± 8		BOESEBECK 68 HBC $8\pi^+\rho$
 We do not use 	the following	ng data for averages, fits, limits, etc. • • •
1260 ±10		⁷ ALDE 97 GAM2 450 $pp \rightarrow pp\pi^0\pi^0$
1278 ± 6		7 GRYGOREV 96 SPEC 40 + N → K K K X
1262 ±11		AGUILAR 91 EHS 400 pp
1275 ±10		AKER 91 CBAR $0.0 \overline{p}p \rightarrow 3\pi^0$
1220 ±10		BREAKSTONE 90 SFM $pp \rightarrow pp\pi^{+}\pi^{-}$
1288 ±12		ABACHI 868 HRS $e^+e^- \rightarrow \pi^+\pi^-X$
1284 ±30	3k	BINON 83 GAM2 38 $\pi^{}p \rightarrow \pi 2\eta$
1280 ±20	3k	APEL 82 CNTR $25 \pi^- p \rightarrow n2\pi^0$
1284 ±10	16000	DEUTSCH 76 HBC 16 π ⁺ ρ
1258 ±10	600	TAKAHASHI 72 HBC 8π p → π2π
1275 ±13		ARMENISE 70 HBC $9 \pi^+ n \rightarrow p \pi^+ \pi^-$
1261 ± 5	1960	² ARMENISE 68 DBC 5.1 $\pi^+ \pi \rightarrow p \pi^+ MM$
1270 ±10	360	² ARMENISE 68 DBC $5.1 \pi^+ n \rightarrow p \pi^0 MM$
1268 ± 6		⁸ JOHNSON 68 HBC 3.7-4.2 π ⁻ p
1		

- ¹ T-matrix pole.
- 1 T-matrix pole. 2 Mass errors enlarged by us to Γ/\sqrt{N} ; see the note with the $K^*(892)$ mass. 3 From a partial-wave analysis of data using a K-matrix formalism with 5 poles. 4 From an energy-independent partial-wave analysis. 5 From an amplitude analysis of the reaction $\pi^+\pi^-\to 2\pi^0$. 6 From an amplitude analysis of $\pi^+\pi^-\to \pi^+\pi^-$ scattering data. 7 Systematic uncertainties not estimated. 8 JOHNSON 68 includes BONDAR 63, LEE 64, DERADO 65, EISNER 67.

$f_2(1270)$

100

150

 $f_2(1270)$ width (MeV)

200

		∱(1270) WIDT	H		
VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT	
185.5 + 3.8 OUR FIT	Error in	cludes scale factor of	1.5.	•	
.84.6 + 4.2 OUR AVE	RAGE E	error includes scale fa	ctor of 1.7	. See the ideogram below	w.
04 ±20		9 BERTIN		$0.0 \overline{p}p \rightarrow \pi^{+}\pi^{-}\pi^{0}$	
92 ± 5	200k	PROKOSHKIN		$38 \pi^- p \to \pi^0 \pi^0 n$	
80 ±24 69 ± 9	5730	AGUILAR ¹⁰ AUGUSTIN	91 EHS 89 DM2	400 <i>pp</i> e ⁺ e [−] ⊶ 5π	
50 ±30	400	10 ALDE	87 GAM4		
86 + 9		11 LONGACRE	86 MPS	22 π ⁻ p → n2K ⁰ _S	
79.2 + 6.9 - 6.6		12 CHABAUD	83 ASPK	17 m p polarized	
60 ±11		DENNEY	83 LASS	10 π ⁺ N	
96 ±10	3k	APEL		$25 \pi^- p \rightarrow n2\pi^0$	_
52 ± 9 86 ±27	11600	¹³ CASON GIDAL	82 STRC		·U
16 ±13	11600	14 CORDEN		$\begin{array}{ccc} 2 & J/\psi & \text{decay} \\ 3 & 12-15 & \pi^- p \rightarrow & n2\pi \end{array}$	
90 ±10	10k	APEL	75 NICE		
92 ±16	4600	ENGLER	74 DBC	$6\pi^+n\rightarrow\pi^+\pi^-p$	
83 ±15	5300	FLATTE	71 HBC	$7\pi^+p \rightarrow \Delta^{++}f_2$	
96 ±30 16 ±20	1960	10 STUNTEBECK 10 ARMENISE	70 HBC 68 DBC	$8 \pi^- p$, 5.4 $\pi^+ d$ 5.1 $\pi^+ n \rightarrow p \pi^+ MN$	<u>.</u>
28 ±27		10 BOESEBECK	68 HBC	$8\pi^+p$	"
76 ±21	1	0,15 JOHNSON	68 HBC	3.7-4.2 π ⁻ p	
• We do not use to	the follow	-			
87 ±20 84 ±10		¹⁶ ALDE ¹⁶ GRYGOREV		1 450 $pp \rightarrow pp\pi^{0}\pi^{0}$ 40 $\pi^{-}N \rightarrow K_{0}^{0}K_{0}^{0}$,
00 ±10		AKER	96 SPEC 91 CBAR		`
40 ±40	3k	BINON	B3 GAM		
87 ±30	650	10 ANTIPOV	77 CIBS	$25 \pi^- p \rightarrow p3\pi$	
25 ±38	16000	DEUTSCH	76 HBC	16 π ⁺ p	
66 ±28 73 ±53	600	¹⁰ TAKAHASHI ¹⁰ ARMENISE	72 HBC 70 HBC	$8 \pi^- p \rightarrow n2\pi$ $9 \pi^+ n \rightarrow p\pi^+\pi^-$	
11 From a partial-wav 12 From an energy-ind 13 From an amplitude 14 From an amplitude 15 JOHNSON 68 Incl 16 Systematic uncerta	dependent e analysis e analysis udes BON iintles not	partial-wave analysi of the reaction $\pi^+\pi^-$ of $\pi^+\pi^-\to\pi^+\pi^-$ IDAR 63, LEE 64, D estimated.	s. − _{→ 2π} 0 _. - scattering	r data.	
WEIGHTED / 184.6+4.2-2.6					
1	V			and account of	
		and scale for this ideogra sarily the sa obtained fro utilizing me	actor are ba m only. Th ame as our om a least-s asurements	ted average, error, sed upon the data in ey are not neces- 'best' values, quares constrained fit of other (related) information.	
				χ^2	
	-		RTIN	97C OBLX 0.9	
_	-		OKOSHKIN UILAR	94 GAM2 2.2 91 EHS 0.0	
	+	AU	GUSTIN	89 DM2 3.0	
	—Ш:	AL	DE NGACRE	87 GAM4 1.3 86 MPS 0.3	
	+	CH	IABAUD	83 ASPK 0.6	
-	- []	DE	NNEY EL	83 LASS 5.0 82 CNTR 1.3	
+	- 4-1-	CA	SON	82 STRC 13.1	
'	//		DAL DRDEN	81 MRK2 0.0 79 OMEG 5.8	
	/	AP	EL	75 NICE 0.3	
	/		GLER ATTE	74 DBC 0.2 71 HBC 0.0	
	/ 80				
	/		UNTEBEC	(70 HBC 0.1 68 DBC 2.5	

BOESEBECK 68 HBC JOHNSON 68 HBC

350

300

(Confidence Level = 0.001)

5(1270) DECAY MODES

	Mode	Fraction (Γ_I/Γ)	Scale factor/ Confidence level
Γ1	ππ	$(84.6 \begin{array}{c} +2.5 \\ -1.3 \end{array}) \%$	S=1.3
Γ ₂	$\pi^{+}\pi^{-}2\pi^{0}$	$(7.2^{+1.5}_{-2.7})\%$	S=1.3
Гз	ĸĸ	(4.6 ±0.4)%	S=2.8
Γ4	$2\pi^{+}2\pi^{-}$	(2.8 ±0.4) %	S=1.2
Γ ₅ Γ ₆	$\eta \eta 4\pi^0$	(4.5 ±1.0) × 10 (3.0 ±1.0) × 10	
Γ7	$\gamma\gamma$	$(1.32^{+0.17}_{-0.16}) \times 10^{-0.16}$	₀ –5
Γ _β Γ ₉ Γ ₁₀	$\eta \pi \pi$ $K^{0}K^{-}\pi^{+} + \text{c.c.}$ $e^{+}e^{-}$	< 8 × 10 < 3.4 × 10 < 9 × 10	0 ⁻³ CL=95%

CONSTRAINED FIT INFORMATION

An overall fit to the total width, 4 partial widths, a combination of partial widths obtained from integrated cross sections, and 6 branching ratios uses 39 measurements and one constraint to determine 8 parameters. The overall fit has a $\chi^2 = 70.7$ for 32 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\langle \delta p_i \delta p_j \rangle / (\delta p_i \cdot \delta p_j)$, in percent, from the fit to parameters p_i , including the branching fractions, $x_i \equiv \Gamma_i/\Gamma_{\rm total}$. The fit constrains the x_i whose labels appear in this array to sum to one.

	<i>x</i> ₁	x ₂	<i>x</i> ₃	×4	×5	х6	Х7
Γ	-79	74	-12	-9	3_	0	-10
×6 ×7	8	~3	-15	1	0	0	
×6	0	-7	0	0	0		
X5	2	-9	0	0			
X ₄	11	-36	1				
x ₃	11	-38					
x ₂	-92						

	Mode	Rate (M	eV)	Scale factor
۲	ππ	156.9	+4.2 -1.2	
Γ2	$\pi^{+}\pi^{-}2\pi^{0}$	13.4	+3.1 -5.1	1.3
Гз	κ Κ	8.6	±0.8	2.9
Γ4	$2\pi^{+}2\pi^{-}$	5.2	±0.7	1.2
Γ ₅	$\eta\eta$	0.83	±0.18	2.4
Γ ₅ Γ ₆	$4\pi^0$	0.55	±0.19	
Γ ₇	77	0.0024	14 ^{+ 0.00032} - 0.00029	

5(1270) PARTIAL WIDTHS

Γ(ππ)				Γ1
VALUE (MeV)	DOCUMENT ID	TECN	COMMENT	
156.9 ^{+4.2} OUR FIT				
157.0 ^{+6.0} -1.0	17 LONGACRE 86	MPS	$22~\pi^-\rho\to~n2K_S^0$	
Γ(<i>κҠ</i>)				Гз
VALUE (MeV)	DOCUMENT ID	TECN	COMMENT	
8.6 ±0.8 OUR FIT	Error includes scale factor of 2.9.			
9.0 +0.7	17 LONGACRE 86	MPS	$22~\pi^-p\to~n2K_S^0$	
$\Gamma(\eta\eta)$				Г
VALUE (MeV)	DOCUMENT ID	TECN	COMMENT	
0.83±0.18 OUR FIT	Error includes scale factor of 2.4,			
1.0 ±0.1	17 LONGACRE 86	MPS	$22 \pi^- p \rightarrow n2K_S^0$	

 $\Gamma(\gamma\gamma)$ Γ_{γ} The value of this width depends on the theoretical model used. Unitarised models with scalars give values clustering around \simeq 2.6; without an S-wave contribution, values are systematically higher (typically around 3). Since it is used to average results obtained with variety of models, we prefer to quote our own estimate.

VALUE (keV) EVTS
2.8 ±0.4 OUR ESTIMATE DOCUMENT ID TECN COMMENT 2.44 +0.32 OUR FIT 92 CELL e+e-→ e+e-π+π-

18 BEHREND

2.50±0.13+0.36

 0.039 ± 0.008

LOVERRE

80 HBC 4 $\pi^- p \rightarrow K \overline{K} N$

• • We do not use the following data for averages, fits, limits, etc. • • •	◆ ◆ We do not use the following data for averages, fi	ts, limits, etc. • •
3.10 \pm 0.35 \pm 0.35 19 BLINOV 92 MD1 $e^+e^- \rightarrow$		OMEG 1-2.2 π ⁻ p →
$e^+e^-\pi^+\pi^-$ 2.27 ± 0.47 ± 0.11 ADACHI 90D TOPZ $e^+e^-\to$		K+K-n RVUE
$e^{+}e^{-}\pi^{+}\pi^{-}$ 3.15±0.04±0.39 BOYER 90 MRK2 $e^{+}e^{-}\to$		STRC $7\pi^-p \rightarrow n2K_S^0$
$e^+e^-\pi^+\pi^-$		D DBC $4\pi^+ n \rightarrow pf_2$
$0.19 \pm 0.16 \stackrel{+0.29}{_{-0.28}}$ MARSISKE 90 CBAL $e^+e^- \rightarrow e^+e^-\pi^0\pi^0$	0.031±0.012 20 ADERHOLZ 69	HBC $8\pi^+\rho \rightarrow K^+K^-\pi^+\rho$
.35 ± 0.65 20 MORGAN 90 RVUE $\gamma \gamma \rightarrow \pi^{+} \pi^{-}$, $\pi^{0} \pi^{0}$.19 + 0.09 + 0.22 2177 OEST 90 JADE $e^{+} e^{-} \rightarrow e^{+} e^{-} \pi^{0} \pi^{0}$	²⁸ Re-evaluated by CHABAUD 83.	·· · · · · · · · · · · · · · · · · · ·
-0.38	29 Includes PAWLICKI 77 data. 30 Takes into account the $f_2(1270)$ - $f_2'(1525)$ interfere	nce
$e^{+}e^{-}\pi^{+}\pi^{-}$	Takes into account the 12(1270)-72(1325) interiere	ice.
.5 \pm 0.1 \pm 0.5 BEHREND 848 CELL $e^+e^- \rightarrow e^+e^- \pi^+\pi^-$	$\Gamma(2\pi^+2\pi^-)/\Gamma(\pi\pi)$	Γ ₄ /Γ ₁
$85 \pm 0.25 \pm 0.5$	VALUE EVTS DOCUMENT ID 0.033±0.005 OUR FIT Error includes scale factor of :	TECN COMMENT
$e^+e^-\pi^+\pi^-$	0.033±0.004 OUR AVERAGE Error includes scale fac	tor of 1.1.
$52 \pm 0.13 \pm 0.38$ 23 SMITH 84C MRK2 $e^+e^- \rightarrow e^+e^- \pi^+\pi^-$		DDBC $4\pi^+ n \rightarrow pf_2$ HBC $4.9\pi^+ p \rightarrow \Delta^{++} f_2$
7 $\pm 0.2 \pm 0.6$ EDWARDS 82F CBAL $e^+e^- \rightarrow e^+e^- 2\pi^0$	0.043 +0.007 285 LOUIE 74	
9 + 0.6 ± 0.6 24 EDWARDS 82F CBAL $e^+e^- \rightarrow e^+e^- 2\pi^0$	0.043 <u>0.011</u> 255 CODE 74	
2 $\pm 0.2 \pm 0.6$ BRANDELIK 81B TASS $e^+e^- \rightarrow e^+e^-\pi^+\pi^-$	0.047±0.013 OH 70	
6 \pm 0.3 \pm 0.5 ROUSSARIE 81 MRK2 $e^+e^- \rightarrow e^+e^-\pi^+\pi^-$	$\Gamma(\eta\eta)/\Gamma_{ ext{total}}$	Γ ₆ /Γ
3 ± 0.8 25 BERGER 808 PLUT e^+e^-	VALUE (units 10 ⁻³) DOCUMENT ID	TECN COMMENT
(e ⁺ e ⁻)	4.5±1.0 OUR FIT Error Includes scale factor of 2.4.	1001
ALUE (eV) CL% DOCUMENT ID TECN COMMENT	3.1±0.8 OUR AVERAGE Error includes scale factor of	
21.7 90 VOROBYEV 88 ND $e^+e^- \rightarrow \pi^0\pi^0$		SO GAM4 100 $\pi^- p \rightarrow 2\eta n$ S GAM2 38 $\pi^- p \rightarrow 2\eta n$
⁷ From a partial-wave analysis of data using a K-matrix formalism with 5 poles. 8 Using a unitarized model with scalars.		
¹⁹ Using the unitarized model of LYTH 85.	Γ(ηη)/Γ(ππ) VALUE CL% DOCUMENT ID	Γ ₅ /Γ ₁ _ <u>TECN COMMENT</u>
²⁰ Error includes spread of different solutions. Data of MARK2 and CRYSTAL BALL used in the analysis. Authors report strong correlations with $\gamma\gamma$ width of $f_0(1370)$: $\Gamma(f_2)$ +	• • • We do not use the following data for averages, fi	
$1/4 \Gamma(f^0) = 3.6 \pm 0.3 \text{ KeV}.$	<0.05 95 EDWARDS 82	PF CBAL $e^+e^- \rightarrow e^+e^-2\eta$
21 Radiative corrections modify the partial widths; for instance the COURAU 84 value		50 DBC $4\pi^+ n \rightarrow pf_2$
becomes 2.66 \pm 0.21 in the calculation of LANDRO 86. Using the MENNESSIER 83 model.	<0.09 95 EISENBERG 74	HBC $4.9 \pi^+ p \rightarrow \Delta^{++} f_2$
²³ Superseded by BOYER 90. ²⁴ If helicity = 2 assumption is not made.	$\Gamma(4\pi^0)/\Gamma_{ m total}$	Γ ₆ /Γ
25 Using mass, width and B($f_2(1270) \rightarrow 2\pi$) from PDG 78.	<u>VALUE EVTS</u> <u>DOCUMENT ID</u> 0.0030 ± 0.0010 OUR FIT	TECN COMMENT
$f_2(1270) \Gamma(i)\Gamma(\gamma\gamma)/\Gamma(\text{total})$		7 GAM4 100 $\pi^- p \to 4\pi^0 n$
	50	
$\Gamma(K\overline{K}) imes \Gamma(\gamma\gamma)/\Gamma_{ ext{total}}$ (ALUE (keV) DOCUMENT ID TECN COMMENT	Γ(ηππ)/Γ(ππ) VALUE CL% DOCUMENT ID	Γ ₈ /Γ ₁
0.113+0.016 OUR FIT Error includes scale factor of 1.1.		SO DBC $4\pi^+ n \rightarrow pf_2$
26 ALBRECHT 90G ARG e ⁺ e ⁻ →	$\Gamma(K^0K^-\pi^+ + \text{c.c.})/\Gamma(\pi\pi)$	- r./r.
• • We do not use the following data for averages, fits, limits, etc. • •	VALUE CL% DOCUMENT ID	F9/F1
0.104 \pm 0.007 \pm 0.072 27 ALBRECHT 90G ARG $e^+e^- \rightarrow$		5D DBC $4\pi^+ n \rightarrow pf_2$
e ⁺ e ⁻ K ⁺ K ⁻		
²⁶ Using an incoherent background. ²⁷ Using a coherent background.	f ₂ (1270) REFEREN	CES
	ALDE 97 PL B397 350 +Bellazzini, Binan+ BERTIN 97C PL B408 476 A. Bertin, Bruschi-	(GAMS Collab.)* (OBELIX Collab.)
f ₂ (1270) BRANCHING RATIOS	BERTIN 97C PL B408 476 A. Bertin, Bruschi- GRYGOREV 96 PAN 59 2105 + Baloshin, Barkov Translated from YAF 59 2187.	
		(ITEP)
	PROKOSHKIN 94 SPD 39 420 +Kondashov Translated from DANS 336 613.	(SERP)
ALUE EVTS DOCUMENT ID TECN COMMENT	PROKOSHKIN 94 SPD 39 420 +Kondashov Translated from DANS 336 613. BEHREND 92 ZPHY C55 381 +Bondar, Bukin+	(SERP) (CELLO Collab.) (NOVO)
ALUE EVTS DOCUMENT. ID TECN COMMENT. 1.846 + 0.025 OUR FIT Error includes scale factor of 1.3.	PROKOSHKIN 94 SPD 39 420 + Kondashov Trianslated from DANS 336 613. BEHREND 92 ZPHY C56 381 BLINOV 92 ZPHY CS3 33 + Bondar, Bukin+ AGUILAR 91 ZPHY CS0 405 Aguilar-Benitez, All AKER 91 PL 8260 249 + Amsler, Peters+	(SERP) (CELLO Collab.) (NOVO) (Ison, Batalor+ (LEBC-EH5 Collab.) (Crystal Barrel Collab.)
### EVTS DOCUMENT.ID TECN COMMENT. ### 1.025 OUR FIT Error includes scale factor of 1.3. ##################################	PROKOSHKIN 94 SPD 39 420	(SERP) (CELLO Collab.) (NOVO) (Ison, Batalor+ (LEBC-EHS Collab.) (Crystal Barrel Collab.) (TOPAZ Collab.) tr+ (ARGUS Collab.)
ALUE EVTS DOCUMENT.ID TECN COMMENT. 1.846 \pm 0.025 OUR FIT Error includes scale factor of 1.3. 1.837 \pm 0.020 OUR AVERAGE 1.849 \pm 0.025 CHABAUD 83 ASPK 17 $\pi^- p$ polarized 1.85 \pm 0.05 250 BEAUPRE 71 HBC 8 $\pi^+ p \rightarrow \Delta^{++} f_2$	PROKOSHKIN 94 SPD 39 420	(SERP) (CELLO Collab.) (NOVO) (Ison, Batalor+ (LERC-EHS Collab.) (Crystal Barrel Collab.) (TOPAZ Collab.) (**TOPAZ Collab.) (**TOPAZ Collab.) (**ARGUS Collab.) (Mark II Collab.) BGNA, CERN, DORT, HEIDH, WARS)
ALUE EVTS DOCUMENT.ID TECN COMMENT. 1.846 \pm 0.025 OUR FIT Error includes scale factor of 1.3. 1.837 \pm 0.020 OUR AVERAGE 1.849 \pm 0.025 CHABAUD 83 ASPK 17 $\pi^- \rho$ polarized 1.85 \pm 0.05 250 BEAUPRE 71 HBC 8 $\pi^+ \rho \rightarrow \Delta^{++} f_2$	PROKOSHKIN 94 SPD 39 420	(SERP) (CELLO Collab.) (NOVO) (Ison, Batalor+ (LEBC-EHS Collab.) (Crystal Barrel Collab.) (TOPAZ Collab.) (ARGUS Collab.) (ARGUS Collab.) (BGNA, CERN, DORT, HEIDH, WARS) (Crystal Bail Collab.) (RAL, DURN)
SALUE EVTS DOCUMENT.ID TECN COMMENT	PROKOSHKIN 94 SPD 39 420	(SERP) (CELLO Collab.) (NOVO) (Ison, Batalor+ (LEBC-EHS Collab.) (Crystal Barrel Collab.) (Crystal Barrel Collab.) (HARGUS Collab.) (ARGUS Collab.) (Mark II Collab.) (GORT, HEIDH, WARS) (Crystal Bail Collab.) (ARGUS COllab.) (JADE Collab.) (OMZ Collab.)
2.846 $^{+}$ 0.025 OUR FIT Error includes scale factor of 1.3. 2.846 $^{+}$ 0.020 OUR AVERAGE 2.849 \pm 0.025 CHABAUD 83 ASPK 17 $\pi^- \rho$ polarized 2.869 \pm 0.05 250 BEAUPRE 71 HBC 8 $\pi^+ \rho \rightarrow \Delta^{++} f_2$ 2.8 \pm 0.04 600 OH 70 HBC 1.26 $\pi^- \rho \rightarrow \pi^+ \pi^- \rho$ Should be twice $\Gamma(2\pi^+ 2\pi^-)/\Gamma(\pi\pi)$ If decay is $\rho \rho$. (See ASCOLI 68D.)	PROKOSHKIN 94 SPD 39 420	(SERP) (CELLO Collab.) (NOVO) (Ison, Batalor+ (LEBC-EHS Collab.) (Crystal Barrel Collab.) (TOPAZ Collab.) (ARGUS Collab.) (Mark II Collab.) (BGNA, CERN, DORT, HEIDH, WARS) (Crystal Bail Collab.) (ARGUS Collab.) (JADE Collab.) (DMZ (JADE Collab.) (DMZ Collab.) (NOVO)
PALLUE EVTS DOCUMENT. D TECN COMMENT. 1.846 $\stackrel{+}{-}0.013$ OUR FIT Error includes scale factor of 1.3. 1.837 $\stackrel{+}{+}0.020$ OUR AVERAGE 1.849 $\stackrel{+}{+}0.025$ CHABAUD 83 ASPK 17 π^-p polarized 1.85 $\stackrel{+}{+}0.05$ 250 BEAUPRE 71 HBC 8 $\pi^+p \rightarrow \Delta^{++}f_2$ 1.86 $\stackrel{+}{+}0.05$ 0H 70 HBC 1.26 $\pi^-p \rightarrow \pi^+\pi^-n$ 1.86 $\stackrel{+}{+}\pi^-p \rightarrow \pi^+\pi^-n$ 1.87 $\stackrel{+}{+}\pi^-p \rightarrow \pi^-p \rightarrow \pi^+\pi^-n$ 1.88 $\stackrel{+}{+}\pi^-p \rightarrow \pi^+\pi^-n$ 1.89 Should be twice $\Gamma(2\pi^+2\pi^-)/\Gamma(\pi\pi)$ if decay is pp . (See ASCOLI 68D.) 1.80 $\stackrel{+}{+}\pi^-p \rightarrow \pi^-p \rightarrow \pi^+\pi^-n$ 1.80 $\stackrel{+}{+}\pi^-p \rightarrow \pi^+p \rightarrow \pi^-p$ 1.80 $\stackrel{+}{+}\pi^-p \rightarrow \pi^+p \rightarrow \pi^-p \rightarrow \pi^+p \rightarrow \pi^-p$ 1.81 $\stackrel{+}{+}\pi^-p \rightarrow \pi^+p \rightarrow \pi^-p \rightarrow \pi^+p \rightarrow \pi^-p$ 1.82 $\stackrel{+}{+}\pi^-p \rightarrow \pi^-p \rightarrow \pi^-$	PROKOSHKIN 94 SPD 39 420	(SERP) (CELLO Collab.) (NOVO) (Ison, Batalor+ (LEBC-EHS Collab.) (Crystal Barrel Collab.) (TOPAZ Collab.) (ARGUS Collab.) (ARGUS Collab.) (BGNA, CERN, DORT, HEIDH, WARS) (Crystal Bail Collab.) (JADE Collab.) (DMZ Collab.) (DMZ Collab.) (DMZ Collab.) (NOVO) (LANL, BRUX, SERP, LAPP) (LALO, CLER, FRAS, PADO)
2.846 $+ 0.025$ OUR FIT Error includes scale factor of 1.3. 2.846 $+ 0.025$ OUR FIT Error includes scale factor of 1.3. 2.837 $+ 0.020$ OUR AVERAGE 2.849 $+ 0.025$ CHABAUD 83 ASPK 17 $\pi^- p$ polarized 2.85 $+ 0.05$ 250 BEAUPRE 71 HBC 8 $\pi^+ p \rightarrow \Delta^{+++} f_2$ 2.8 $+ 0.04$ 600 OH 70 HBC 1.26 $\pi^- p \rightarrow \pi^+ \pi^- n$ Thould be twice $\Gamma(2\pi^+ 2\pi^-)/\Gamma(\pi\pi)$ if decay is $\rho \rho$. (See ASCOLI 68D.) 2.84 UE EVTS DOCUMENT ID TECN COMMENT 1.085 $+ 0.020$ OUR FIT Error includes scale factor of 1.3.	PROKOSHKIN 94 SPD 39 420	(SERP) (CELLO Collab.) (NOVO) (Ison, Batalor+ (LEBC-EHS Collab.) (Crystal Barrel Collab.) (Crystal Barrel Collab.) (Crystal Barrel Collab.) (Mark II Collab.) (MAL, DURH) (JADE Collab.) (DMZ Collab.) (DMZ Collab.) (DMZ Collab.) (LANL, BRUX, SERP, LAPP) (LALO, CLER, FRAS, PADO) (PURD, ANL, IND, MICH, LBL) (TPC-27 Collab.)
2.846 $+ 0.025$ OUR FIT Error includes scale factor of 1.3. 2.846 $+ 0.025$ OUR AVERAGE 2.849 ± 0.025 CHABAUD 83 ASPK 17 $\pi^- p$ polarized 2.85 ± 0.05 250 BEAUPRE 71 HBC 8 $\pi^+ p \rightarrow \Delta^{++} f_2$ 2.8 ± 0.04 600 OH 70 HBC 1.26 $\pi^- p \rightarrow \pi^+ \pi^- n$ Should be twice $\Gamma(2\pi^+ 2\pi^-)/\Gamma(\pi\pi)$ if decay is $\rho \rho$. (See ASCOLI 68D.) 2.44.UE EVTS DOCUMENT ID TECN COMMENT 2.0.085 $+ 0.020$ OUR FIT Error includes scale factor of 1.3. 2.15 ± 0.06 600 EISENBERG 74 HBC 4.9 $\pi^+ p \rightarrow \Delta^{++} f_2$	PROKOSHKIN 94 SPD 39 420	(SERP) (CELLO Collab.) (NOVO) (Ison, Batalor+ (LEBC-EHS Collab.) (Crystal Barrel Collab.) (Crystal Barrel Collab.) (Crystal Barrel Collab.) (Crystal Barrel Collab.) (Mark II Collab.) (Mark II Collab.) (Mark II Collab.) (Mark II Collab.) (Crystal Bail Collab.) (Mark II Collab.) (Mar
2.846 $+ 0.025$ OUR FIT Error includes scale factor of 1.3. 2.846 $+ 0.025$ OUR AVERAGE 2.849 ± 0.025 CHABAUD 83 ASPK 17 $\pi^- p$ polarized 2.849 ± 0.025 BEAUPRE 71 HBC 8 $\pi^+ p \rightarrow \Delta^{++} f_2$ 2.8 ± 0.04 600 OH 70 HBC 1.26 $\pi^- p \rightarrow \pi^+ \pi^- p$ Should be twice $\Gamma(2\pi^+ 2\pi^-)/\Gamma(\pi\pi)$ if decay is $\rho \rho$. (See ASCOLI 68D.) 2.940 EVTS DOCUMENT ID TECN COMMENT 2.15 ± 0.034 OUR FIT Error includes scale factor of 1.3. 2.15 ± 0.06 600 EISENBERG 74 HBC 4.9 $\pi^+ p \rightarrow \Delta^{++} f_2$ 2.16 ± 0.06 600 EISENBERG 74 HBC 4.9 $\pi^+ p \rightarrow \Delta^{++} f_2$	PROKOSHKIN 94 SPD 39 420	(SERP) (CELLO Collab.) (NOVO) (Ison, Batalor+ (LEBC-EHS Collab.) (TOPAZ Collab.) (Crystal Barrel Collab.) (TOPAZ Collab.) (Mark II Collab.) (RAL, DURH) (ADC Collab.) (RAL, DURH) (ADC Collab.) (DM2 Collab.) (DM2 Collab.) (DM2 Collab.) (DM2 Collab.) (DM2 Collab.) (PURD, ANL, IND, MICH, LBL) (TPCZ Collab.) (BELG, LAPP, SERP, CERN, LANL) (UTRO) (BNL, BRAN, CUNY, DUKE, NDAM)
2.846 $+ 0.025$ OUR FIT Error includes scale factor of 1.3. 2.837 ± 0.020 OUR AVERAGE 2.849 ± 0.025 CHABAUD 83 ASPK 17 $\pi^- p$ polarized 2.85 ± 0.05 250 BEAUPRE 71 HBC 8 $\pi^+ p \rightarrow \Delta^{++} f_2$ 2.8 ± 0.04 600 OH 70 HBC 1.26 $\pi^- p \rightarrow \pi^+ \pi^- n$ Should be twice $\Gamma(2\pi^+ 2\pi^-)/\Gamma(\pi\pi)$ if decay is $\rho \rho$. (See ASCOLI 68D.) 2.84.UE EVTS DOCUMENT ID TECN COMMENT 2.085 ± 0.020 OUR FIT Error includes scale factor of 1.3. 2.15 ± 0.06 600 EISENBERG 74 HBC 4.9 $\pi^+ p \rightarrow \Delta^{++} f_2$ 2.007 EMMS 75D DBC 4 $\pi^+ n \rightarrow p f_2$	PROKOSHKIN 94 SPD 39 420	(SERP) (CELLO Collab.) (NOVO) (Ison, Batalor+ (LEBC-EHS Collab.) (Crystal Barrel Collab.) (TOPAZ Collab.) (ARGUS Collab.) (Mark II Collab.) (Mark II Collab.) (ARGUS Collab.) (Mark II Collab.) (Mark II Collab.) (RAL, DURR) (LADC Collab.) (POVO) (LALD, CER, FRAS, PADO) (PURD, ANL, IND, MICH, LBL) (TPC-27 Collab.) (BELG, LAPP, SERP, CERN, LANL) (UTRO) (BNL, BRAN, CUNY, DUKE, NDAM) Schroeder+ (CELLO Collab.)
2.846 $\frac{10.025}{0.015}$ QUR FIT Error includes scale factor of 1.3. 2.837 \pm 0.020 QUR AVERAGE 2.849 \pm 0.025 CHABAUD 83 ASPK 17 π^-p polarized 2.849 \pm 0.05 250 BEAUPRE 71 HBC 8 $\pi^+p \rightarrow \Delta^{++}f_2$ 2.8 \pm 0.04 600 OH 70 HBC 1.26 $\pi^-p \rightarrow \pi^+\pi^-n$ Should be twice $\Gamma(2\pi^+2\pi^-)/\Gamma(\pi\pi)$ If decay is $\rho\rho$. (See ASCOLI 68D.) 2.84 $\times LUE$ EVTS DOCUMENT ID TECN COMMENT 2.0.08 \pm 0.034 QUR FIT Error includes scale factor of 1.3. 2.15 \pm 0.06 600 EISENBERG 74 HBC 4.9 $\pi^+p \rightarrow \Delta^{++}f_2$ 2.0.07 EMMS 75D DBC 4 $\pi^+n \rightarrow pf_2$	PROKOSHKIN 94 SPD 39 420	(SERP) (CELLO Collab.) (NOVO) (Ison, Batalor+ (LEBC-EHS Collab.) (TOPAZ Collab.) (TYPAZ Collab.) (TYPAZ Collab.) (Mark II Collab.) (Mark II Collab.) (Mark II Collab.) (RAL, DURR) (LADC Collab.) (DM2 Collab.) (DM2 Collab.) (DM2 Collab.) (DM2 Collab.) (DM2 Collab.) (PURD, ANL, IND, MICH, LBL) (TYPCZ Collab.) (BELG, LAPP, SERP, CERN, LANL) (UTRO) (BNL, BRAN, CUNY, DUKE, NDAM) Schroeder+ (CELLO Collab.) (PUTO Collab.) Atwood, Baillor+ (CIT, SLAC) coker, Levi+ (SLAC, LBL, HARV)
1.846 $+ 0.025$ OUR FIT Error includes scale factor of 1.3. 1.857 ± 0.020 OUR AVERAGE 1.849 ± 0.025 CHABAUD 83 ASPK 17 $\pi^- p$ polarized 1.85 ± 0.05 250 BEAUPRE 71 HBC 8 $\pi^+ p \rightarrow \Delta^{++} f_2$ 1.86 ± 0.04 600 OH 70 HBC 1.26 $\pi^- p \rightarrow \pi^+ \pi^- n$ Should be twice $\Gamma(2\pi^+ 2\pi^-)/\Gamma(\pi\pi)$ if decay is $\rho \rho$. (See ASCOLI 68D.) 2.15 ± 0.020 OUR FIT Error includes scale factor of 1.3. 1.15 ± 0.06 600 EISENBERG 74 HBC 4.9 $\pi^+ p \rightarrow \Delta^{++} f_2$ 1.005 ± 0.006 600 EISENBERG 74 HBC 4.9 $\pi^+ p \rightarrow \Delta^{++} f_2$ 1.015 ± 0.06 600 EISENBERG 75 DBC 4 $\pi^+ n \rightarrow p f_2$	PROKOSHKIN 94 SPD 39 420	(SERP) (CELLO Collab.) (NOVO) (Ison, Batalor+ (LEBC-EHS Collab.) (Crystal Barrel Collab.) (Crystal Barrel Collab.) (Crystal Barrel Collab.) (Part Collab.) (Mark II Collab.) (Mark II Collab.) (Mark II Collab.) (Mark II Collab.) (Crystal Bail Collab.) (DM2 Collab.) (DM2 Collab.) (DM2 Collab.) (DM2 Collab.) (Collab.) (Collab.) (Crystal Bail Collab.) (FUTO Collab.) (BRLG, LAPP, SERP, CERN, LANL) (Collab.) (Collab.) (CELLO Collab.) (CELLO Collab.) (Atwood, Baillon+ (CIT, SLAC)
1.846 $+ 0.025$ OUR FIT Error includes scale factor of 1.3. 1.837 $+ 0.020$ OUR AVERAGE 1.849 $+ 0.025$ CHABAUD 83 ASPK 17 $\pi^- p$ polarized 1.85 $+ 0.05$ 250 BEAUPRE 71 HBC 8 $\pi^+ p \rightarrow \Delta^{++} f_2$ 1.8 $+ 0.04$ 600 OH 70 HBC 1.26 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.27 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.26 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.27 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.26 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.27 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.26 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.27 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.26 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.27 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.26 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.27 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.26 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.27 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.26 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.27 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.26 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.27 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.28 $\pi^+ p \rightarrow \pi^- p \rightarrow \pi^+ \pi^- n$ 1.29 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.20 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.21 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.22 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.23 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.24 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.25 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.26 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.27 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.26 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.27 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.28 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.29 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.20 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.20 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.21 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.22 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.23 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.24 $\pi^- p \rightarrow \pi^- p \rightarrow \pi^+ \pi^- n$ 1.25 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.26 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.27 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.28 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.29 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.20 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.21 $\pi^- p \rightarrow \pi^- p \rightarrow \pi^+ \pi^- n$ 1.22 $\pi^- p \rightarrow \pi^- p \rightarrow \pi^- \pi^- n$ 1.23 $\pi^- p \rightarrow \pi^- p \rightarrow \pi^- \pi^- n$ 1.24 $\pi^- p \rightarrow \pi^- p \rightarrow \pi^- \pi^- n$ 1.25 $\pi^- p \rightarrow \pi^- \pi^- n$ 1.26 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.27 $\pi^- p \rightarrow \pi^- p \rightarrow \pi^- \pi^- n$ 1.29 $\pi^- p \rightarrow \pi^- p \rightarrow \pi^- p \rightarrow \pi^- \pi^- n$ 1.20 $\pi^- p \rightarrow \pi^- p$	PROKOSHKIN 94 SPD 39 420	(SERP) (CELLO Collab.) (NOVO) (Ison, Batalor+ (CELCO Collab.) (NOVO) (TOPAZ Collab.) (Crystal Barrel Collab.) (TOPAZ Collab.) (ARGUS Collab.) (Mark II Collab.) (Mark II Collab.) (Mark II Collab.) (ARAL, DURN) (AND Collab.) (DWZ Collab.) (PURD, ANL, IND, ACC, FRAS, PADO) (PURD, ANL, IND, ACC, FRAS, PADO) (PURD, ANL, IND, ACC, FRAS, PADO) (BUL, BRAN, CUNY, DUKE, NDAM) Schroeder+ (CELLO Collab.) (PUTO Collab.) (PUTO Collab.) (Atwood, Baillon+ (CELC) Collab.) (BELG, LAPP, SERP, CERN) (BELG, LAPP, SERP, CERN) (BELG, LAPP, SERP, CERN) (BELG, LAPP, SERP, CERN) (CERN, CRAC, MPIM)
1.846 $+ 0.025$ OUR FIT Error includes scale factor of 1.3. 1.837 $+ 0.020$ OUR AVERAGE 1.849 $+ 0.025$ CHABAUD 83 ASPK 17 $\pi^- p$ polarized 1.85 $+ 0.05$ 250 BEAUPRE 71 HBC 8 $\pi^+ p \rightarrow \Delta^{++} f_2$ 1.8 $+ 0.04$ 600 OH 70 HBC 1.26 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.27 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.26 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.27 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.26 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.27 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.26 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.27 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.26 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.27 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.26 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.27 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.26 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.27 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.26 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.27 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.26 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.27 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.28 $\pi^+ p \rightarrow \pi^- p \rightarrow \pi^+ \pi^- n$ 1.29 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.20 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.21 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.22 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.23 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.24 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.25 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.26 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.27 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.26 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.27 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.28 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.29 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.20 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.20 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.21 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.22 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.23 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.24 $\pi^- p \rightarrow \pi^- p \rightarrow \pi^+ \pi^- n$ 1.25 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.26 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.27 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.28 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.29 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.20 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.21 $\pi^- p \rightarrow \pi^- p \rightarrow \pi^+ \pi^- n$ 1.22 $\pi^- p \rightarrow \pi^- p \rightarrow \pi^- \pi^- n$ 1.23 $\pi^- p \rightarrow \pi^- p \rightarrow \pi^- \pi^- n$ 1.24 $\pi^- p \rightarrow \pi^- p \rightarrow \pi^- \pi^- n$ 1.25 $\pi^- p \rightarrow \pi^- \pi^- n$ 1.26 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.27 $\pi^- p \rightarrow \pi^- p \rightarrow \pi^- \pi^- n$ 1.29 $\pi^- p \rightarrow \pi^- p \rightarrow \pi^- p \rightarrow \pi^- \pi^- n$ 1.20 $\pi^- p \rightarrow \pi^- p$	PROKOSHKIN 94 SPD 39 420	(SERP) (CELLO Collab.) (NOVO) (Ison, Batalor+ (CELC Collab.) (NOVO) (TOPAZ Collab.) (Crystal Barrel Collab.) (TOPAZ Collab.) (Mark II Collab.) (ARAL, DURN) (BELG, LAPP, SERP, CERN) (CERN, CRAC, MPIM) (CHAPMAR) (CONNA, MICH) (MONP)
1.846 + 0.025 OUR FIT Error includes scale factor of 1.3. 1.837 + 0.020 OUR AVERAGE 1.849 ± 0.025 CHABAUD 83 ASPK 17 π^-p polarized 1.85 ± 0.05 250 BEAUPRE 71 HBC 8 $\pi^+p \rightarrow \Delta^{++}f_2$ 1.85 ± 0.04 600 OH 70 HBC 1.26 $\pi^-p \rightarrow \pi^+\pi^-n$ 1.86 ± 0.04 FIT Error includes scale factor of 1.3. 1.87 + 0.020 OUR FIT Error includes scale factor of 1.3. 1.88 ± 0.04 FIT Error includes scale factor of 1.3. 1.15 ± 0.06 600 EISENBERG 74 HBC 4.9 $\pi^+p \rightarrow \Delta^{++}f_2$ 1.005 + 0.020 OUR FIT Error includes scale factor of 1.3. 1.15 ± 0.06 600 EISENBERG 74 HBC 4.9 $\pi^+p \rightarrow \Delta^{++}f_2$ 1.07 EMMS 75D DBC $4\pi^+n \rightarrow pf_2$ 1.07 EMMS 75D DBC $4\pi^+n \rightarrow pf_2$ 1.085 + 0.020 OUR FIT Error includes scale factor of 1.3. 1.15 ± 0.06 6.00 EISENBERG 74 HBC 6.9 $\pi^+p \rightarrow \Delta^{++}f_2$ 1.16 • • We do not use the following data for averages, fits, limits, etc. • • • • • • • • • • • • • • • • • • •	PROKOSHKIN 94 SPD 39 420	(SERP) (CELLO Collab.) (NOVO) (Ison, Batalor+ (CELC Collab.) (NOVO) (TOPAZ Collab.) (TYPAZ Collab.) (TYPAZ Collab.) (Mark II Collab.) (Mark II Collab.) (Mark II Collab.) (ARQUS Collab.) (Mark II Collab.) (Mark II Collab.) (Mark II Collab.) (RAL, DURR) (IADC Collab.) (PURD Collab.) (DM2 Collab.) (DM2 Collab.) (DM2 Collab.) (PURD, ANL, IND, MICH, LBL) (TYPC-27 Collab.) (BELG, LAPP, SERP, CERN, LANL) (UTRO) (BNL, BRAN, CUNY, DUKE, NDAM) Schroeder+ (CELLO Collab.) (PUTO Collab.) (PUTO Collab.) (SELG, LAPP, SERP, CERN) (BELG, LAPP, SERP, CERN) (BELG, LAPP, SERP, CERN) (BELG, LAPP, SERP, CERN) (CERN, CRAC, MPIM) (Chapman+ (CORN, CRAC, MPIM) (KARLE, PISA, SERP, WIEN, CERN) (MONP) (K, KARLE, PISA, SERP, WIEN, CERN) (BBISON, BISHOP+ (NDAM, ANL) (BBISHOP+ (NDAM, MIL) (NOMP) (MONP) (MON
ALUE EVTS DOCUMENT.ID TECN COMMENT. 1.846 + 0.025 OUR FIT Error includes scale factor of 1.3. 1.837 + 0.020 OUR AVERAGE 1.849 ± 0.025 CHABAUD 83 ASPK 17 $\pi^- p$ polarized 1.85 ± 0.05 250 BEAUPRE 71 HBC $8\pi^+ p \rightarrow \Delta^{++} f_2$ 1.8 ± 0.04 600 OH 70 HBC 1.26 $\pi^- p \rightarrow \pi^+ \pi^- n$ 1.2 $f_1 = f_2 f_1$ 1.3 Should be twice $\Gamma(2\pi^+ 2\pi^-)/\Gamma(\pi\pi)$ if decay is $\rho \rho$. (See ASCOLI 68D.) 2.4 LUE EVTS DOCUMENT ID TECN COMMENT 1.0085 + 0.020 OUR FIT Error includes scale factor of 1.3. 1.15 ± 0.06 600 EISENBERG 74 HBC $4.9\pi^+ p \rightarrow \Delta^{++} f_2$ 1.0 • • We do not use the following data for averages, fits, limits, etc. • • • 1.0 - • We do not use the following data for averages, fits, limits, etc. • • • 1.0 - • We average only experiments which either take into account $f_2(1270) - a_2(1320)$ interference explicitly or demonstrate that $a_2(1320)$ production is negligible. 2.10 - 0.005 OUR FIT Error includes scale factor of 2.8. 2.11 - 0.005 OUR FIT Error includes scale factor of 2.8. 2.12 - 0.005 OUR AVERAGE	PROKOSHKIN 94 SPD 39 420	(SERP) (CELLO Collab.) (NOVO) (Ison, Batalor+ (LEBC-EHS Collab.) (TOPAZ Collab.) (Crystal Barrel Collab.) (TOPAZ Collab.) (Mark II Collab.) (Movo) (RAL, DURR) (JADC Collab.) (DMZ Collab.) (DMZ Collab.) (DMZ Collab.) (DMZ Collab.) (DMZ Collab.) (DMZ Collab.) (PURD, ANL, IND, MICH, LBL) (PURD, ANL, IND, MICH, LBL) (BELG, LAPP, SERP, CERN, LANL) (UTRO) (BNL, BRAN, CUNY, DUKE, NDAM) Schroeder+ (CELLO Collab.) (PUTO Collab.) (PUTO Collab.) (PUTO Collab.) (CEL, LAPP, SERP, CERN) (BELG, LAPP, SERP, CERN) (BELG, LAPP, SERP, CERN) (BELG, LAPP, SERP, CERN) (CERN, CRAC, MPIM) (CHAPMAR) (CIT, SLAC, CERN) (CERN, CRAC, MPIM) (CHAPMAR) (CIT, SLAC, CERN) (CERN, CRAC, MPIM) (CIT, HARY, PRIN, STAN, SLAC) (BNL, CUNY, TUFTS, VAND) (BISHOPH, PRIN, STAN, SLAC)
VALUE EVTS DOCUMENT. (D. TECN COMMENT. (D. 0.846 $^+$ 0.025 OUR FIT Error includes scale factor of 1.3. (D.837 $^+$ 0.020 OUR AVERAGE D.849 $^+$ 0.025 CHABAUD 83 ASPK 17 π^- p polarized 0.85 $^+$ 0.05 250 BEAUPRE 71 HBC 8 π^+ p $\rightarrow \Delta^{++}$ f ₂ 0.8 \pm 0.04 600 OH 70 HBC 1.26 π^- p $\rightarrow \pi^+$ π^- n F(π^+ π^- 2 π^0)/ $\Gamma(\pi\pi)$ Should be twice $\Gamma(2\pi^+$ 2 π^-)/ $\Gamma(\pi\pi)$ If decay is $\rho\rho$. (See ASCOLI 68D.) VALUE EVTS DOCUMENT ID TECN COMMENT 0.085 $^+$ 0.020 OUR FIT Error includes scale factor of 1.3. (0.95 $^+$ 0.024 OUR FIT Error includes scale factor of 1.3. (0.96 $^+$ 0.024 OUR FIT Error includes scale factor of 1.3. (0.96 $^+$ 0.025 OUR FIT Error includes scale factor of 1.3. (0.96 $^+$ 0.026 OUR FIT Error includes scale factor of 1.3. (0.97 $^+$ 0.095 $^+$ 0.096 $^+$ 0.097 OUR FIT Error includes scale factor of 1.3. (0.97 $^+$ 0.097 OUR FIT Error includes scale factor of 1.3. (0.97 $^+$ 0.097 OUR FIT Error includes scale factor of 1.3. (0.97 $^+$ 0.097 OUR FIT Error includes scale factor of 1.3. (0.97 $^+$ 0.098 $^+$ 0.098 OUR FIT Error includes scale factor of 1.3. (0.97 $^+$ 0.098 $^+$ 0.098 OUR FIT Error includes scale factor of 1.3. (0.98 $^+$ 0.098 $^+$ 0.098 OUR FIT Error includes scale factor of 1.3. (0.98 $^+$ 0.098 $^+$ 0.099 OUR FIT Error includes scale factor of 1.3. (0.98 $^+$ 0.099 OUR FIT Error includes scale factor of 1.3. (0.98 $^+$ 0.099 OUR FIT Error includes scale factor of 1.3. (0.98 $^+$ 0.099 OUR FIT Error includes scale factor of 1.3. (0.98 $^+$ 0.099 OUR FIT Error includes scale factor of 1.3. (0.98 $^+$ 0.099 OUR FIT Error includes scale factor of 1.3. (0.98 $^+$ 0.099 OUR FIT Error includes scale factor of 1.3. (0.98 $^+$ 0.099 OUR FIT Error includes scale factor of 1.3. (0.98 $^+$ 0.099 OUR FIT Error includes scale factor of 1.3. (0.98 $^+$ 0.099 OUR FIT Error includes scale factor of 1.3. (0.98 $^+$ 0.099 OUR FIT Error includes scale factor of 1.3. (0.98 $^+$ 0.099 OUR FIT Error includes scale factor of 1.3. (0.98 $^+$ 0.099 OUR FIT Error includes scale factor of 1.3. (0.98 $^+$ 0.099 OUR FIT Error includes scale fac	PROKOSHKIN 94 SPD 39 420	(SERP) (CELLO Collab.) (NOVO) (Ison, Batalor+ (LEBC-EHS Collab.) (TOTAL Barrel Collab.) (Crystal Barrel Collab.) (Crystal Barrel Collab.) (TOTAL Collab.) (Mark II Collab.) (Mark Collab.) (PURD ANIL, IND, MICH, LBL) (TFC-27 Collab.) (BELG, LAPP, SERP, CERN, LANL) (UTRO) (BNL, BRAN, CUNY, DUKE, NDAM) Schroeder+ (CELLO Collab.) (PLUTO

$f_2(1270), f_1(1285)$

GIDAL 8	31	PL 107B 153	+Goldhaber, Guy, Millikan, Abrams+ (SLAC, LBL)
ROUSSARIE 8	31	PL 105B 304	+Burke, Abrams, Alam+ (SLAC, LBL)
BERGER 8	30B	PL 94B 254	+Genzer+ (PLUTO Collab.)
COSTA 8	30	NP B175 402	Costa De Beauregard+ (BARI, BONN, CERN+)
LOVERRE 8	30	ZPHY C6 187	+Armenteros, Dionisi+ (CERN, CDEF, MADR, STOH)
CORDEN 7	79	NP B157 250	+Dowell, Garvey+ (BIRM, RHEL, TELA, LOWC)
MARTIN 7	79	NP B158 520	+Ozmutlu (DURH)
POLYCHRO 7	79	PR D19 1317	Polychronakos, Cason, Bishop+ (NDAM, ANL)
PDG 7	78	PL 75B	Bricman+
ANTIPOV 7	77	NP B119 45	+Busnello, Damgaard, Kienzle+ (SERP, GEVA)
PAWLICKI 7	77	PR D15 3196	+Ayres, Cohen, Diebold, Kramer, Wicklund (ANL)
DEUTSCH 7	76	NP B103 426	Deutschmann+ (AACH3, BERL, BONN, CERN+)
APEL 7	75	PL 57B 398	+Augenstein+(KARLK, KARLE, PISA, SERP, WIEN, CERN)
	75D	NP B96 155	+Kinson, Stacey, Votruba+ (BIRM, DURH, RHEL)
EISENBERG 7	74	PL 52B 239	+Engler, Haber, Karshon+ (REHO)
ENGLER 7	74	PR D10 2070	+Kraemer, Toaff, Weisser, Dlaz+ (CMU, CASE)
	74	PL 48B 385	+Alitti, Gandois, Chaloupka+ (SACL, CERN)
	73	PRL 31 562	+Engler, Kraemer, Toaff, Dlaz+ (CMU, CASE)
TAKAHASHI 7	72	PR D6 1266	+Barish+ (TOHOK, PENN, NDAM, ANL)
	71	NP B28 77	+Deutschmann, Graessler+ (AACH, BERL, CERN)
	71	PL 348 551	+Alston-Garniost, Barbaro-Galtieri+ (LBL)
ARMENISE 7	70	LNC 4 199	+Ghidini, Foring, Cartacci+ (BARI, BGNA, FIRZ)
	70	PR D1 2494	+Garfinkel, Morse, Walker, Prentice (WISC, TNTO) JP
STUNTEBECK 7		PL 32B 391	+Kenney, Deery, Biswas, Cason+ (NDAM)
	9	NP B11 259	+Bartsch+ (AACH3, BERL, CERN, JAGL, WARS)
ARMENISE 6	8	NC 54A 999	+Ghidini, Forino+ (BARI, BGNA, FIRZ, ORSAY)
	58D	PRL 21 1712	+Crawley, Mortara+ (ILL)
	18	NP B4 501	+Deutschmann+ (AACH, BERL, CERN)
	58	PR 176 1651	+Polrier, Biswas, Gutay+ (NDAM, PURD, SLAC)
	57	PR 164 1699	+Johnson, Klein, Peters, Sahni, Yen+ (PURD)
	55	PRL 14 872	+Kenney, Poirier, Shephard (NDAM)
	54	PRL 12 342	+Roe, Sinclair, VanderVelde (MICH)
	53	PL 5 153	+ (AACH, BIRM, BONN, DESY, LOIC, MPIM)
00,10,11			(concil print, politi, pest, core, mrim)

 $f_1(1285)$

$$I^{G}(J^{PC}) = 0^{+}(1^{+})$$

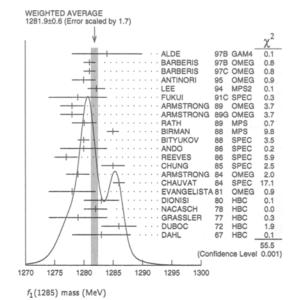
f1(1285) MASS

VALUE (N	let/)			EVTS	Dr	CUMENT ID		TECN	COMMENT
		0.6	OUR AV		_			$\overline{}$.7. See the ideogram
	_		•			low.			see me leesgram
1284	±	6		1400	ΑI	LDE	97B	GAM4	$100 \pi^+ p \rightarrow \eta \pi^0 \pi^0 n$
1281	±	1			B	ARBERIS	97B	OMEG	450 pp →
									pp2(π ⁺ π)
1281	±	1			B/	ARBERIS	97C	OMEG	450 pp →
									ρρKS K±π∓
1280	Ŧ	2			1 Al	NTINORI	95	OMEG	300,450 pp →
									pp2(π ⁺ π)
1282.3	2±	1.5	i		LE	E	94	MPS2	18 π ρ →
		_							$K^+\overline{K}^02\pi^-p$
1279	÷	**				JKUI		SPEC	$8.95 \pi^- p \rightarrow \eta \pi^+ \pi^- n$
1278	±	_		140		RMSTRONG			300 pp → KKπpp
1278	±	2			A	RMSTRONG	89G	OMEG	$85 \pi^+ p \rightarrow 4\pi\pi p,$ $pp \rightarrow 4\pi pp$
1280.:	1+	2.1		60	R/	ATH	89	MPS	$21.4 \pi^- p \rightarrow$
				•••	,		••		K 6 K 6 x 0 n
1285	±	1		4750	2 RI	RMAN	88	MPS	$8\pi^-p \rightarrow K^+\overline{K}^0\pi^-n$
1280	±	-		504			88	SPEC	32.5 π ⁻ ρ →
	_	-							$K^{+}K^{-}\pi^{0}n$
1280	±	4			Αſ	NDO	86	SPEC	$8\pi^- p \rightarrow \eta \pi^+ \pi^- n$
1277	±	2		420	R	EEVES	86	SPEC	6.6 pp̄ → KKπX
1285	±	2			CH	HUNG	85	SPEC	$8\pi^-\rho \rightarrow NK\overline{K}\pi$
1279	±	2		604	ΑI	RMSTRONG	84	OMEG	$85 \pi^+ p \rightarrow \underline{K} \overline{K} \pi \pi p,$
1000					٠.	1410/47		CDEC	$pp \rightarrow K\overline{K}\pi pp$
1286	±	-					84	SPEC	ISR 31.5 pp
1278	±	4			E	/ANGELISTA	81	OMEG	12 π ⁻ p →
1283	±	2		103	nı	ONISI	80	нвс	$\eta \pi^+ \pi^- \pi^- p$ $4 \pi^- p \rightarrow K \overline{K} \pi n$
1282	±			320			78	HBC	$0.7, 0.76 \ \overline{p}p \rightarrow K\overline{K}3\pi$
1279	±	-		210			77	HBC	16 π [∓] ρ
1286	±	-		180	-	UBOC	72	HBC	1.2 pp → 2K4π
1283	±	-					67	HBC	1.6-4.2 π ⁻ p
V	ve c	Ιοπ	ot use the	e following	data	for averages	. fits	. Ilmits.	,
1270	±:					-	95	VES	37 π N →
12,0	٠.				~	VILLIIA	93	VLS	$\pi^-\pi^+\pi^-\gamma N$
1280	±	2			ΑI	BATZIS	94	OMEG	450 pp →
									$pp2(\pi^+\pi^-)$
1282	±	4			ΑI	RMSTRONG	93 C	E760	$\bar{p}p \rightarrow \pi^0 \eta \eta \rightarrow 6\gamma$
1270	±	6	±10		ΑI	RMSTRONG	92 C	OMEG	300 pp $\rightarrow pp\pi^+\pi^-\gamma$
1264	±	8					90	DM2	$J/\psi \rightarrow \gamma \eta \pi^+ \pi^-$
1281	±	1			ΑI	RMSTRONG	89E	OMEG	
					_				$pp2(\pi^{+}\pi^{-})$
1279	±		±10	16			87	MRK3	$e^+e^- \rightarrow \phi K \overline{K} \pi$
1286	±	9			GI	DAL	87	MRK2	$e^+e^- \rightarrow e^+e^- \eta \pi^+ \pi^-$
1287	±	5		353	RI	TYUKOV	84p	SPEC	$32 \pi^- \rho \rightarrow$
2201		•					J70	J, L.	$K+K-\pi^0n$
~ 1279					3 T(ORNQVIST	828	RVUE	
1275	±	6		31	В	ROMBERG	80	SPEC	$100 \pi^- p \rightarrow K \overline{K} \pi X$

1288	±	9	20	00	GURTU	79	HBC	$4.2 K^- p \rightarrow n\eta 2\pi$
~ 1275.0	ł			16 4	STANTON	79	CNTR	$8.5 \pi^- p \rightarrow n2\gamma 2\pi$
1271	±	10	\$	34	CORDEN	78	OMEG	$12-15 \pi^{-} \rho \rightarrow K^{+} K^{-} \pi \rho$
1295	±	12		35	CORDEN	78	OMEG	12-15 x p → n5π
1292	±	10	19	50	DEFOIX	72	HBC	0.7 pp → 7π
1280	±	3	50	o 5	THUN	72	MMS	13.4 π ⁻ p
1303	±	8			BARDADIN	71	HBC	$8\pi^+p \rightarrow p6\pi$
1283	±	6			BOESEBECK	71	HBC	$16.0 \pi p \rightarrow p5\pi$
1270	±	10			CAMPBELL	69	DBC	$2.7 \pi^{+}d$
1285	Ŧ	7			LORSTAD	69	HBC	0.7 pp. 4,5-body
1290	±	7			D'ANDLAU	68	HBC	1.2 ₱p. 5-6 body

¹ Supersedes ABATZIS 94, ARMSTRONG 89E.

⁵ Seen in the missing mass spectrum.



f₁(1285) WIDTH

Only experiments giving width error less than 20 MeV are kept for averaging.

VALUE (MeV) EVTS	DOCUMENT ID	TECN	COMMENT
24.0± 1.2 OUR AVERAGE	Error includes scale	factor of 1.4	. See the ideogram below.
55 ±18 1400	ALDE	97B GAM4	$100 \pi^- p \rightarrow \eta \pi^0 \pi^0 n$
24 ± 3	BARBERIS	97B OMEG	
			$pp2(\pi^+\pi^-)$
20 ± 2	BARBERIS	97c OMEG	
			ppK ⁰ SK±π [∓]
36 ± 5	⁶ ANTINORI	95 OMEG	300,450 pp →
			$pp2(\pi^{+}\pi^{-})$
29.0± 4.1	LEE	94 MP52	18 π ⁻ p →
			$K + \overline{K}^0 2\pi^- p$
25 ± 4 140	ARMSTRONG		$300 pp \rightarrow K\overline{K}\pi pp$
22 ± 2 4750	⁷ BIRMAN	88 MPS	$8\pi^-p \rightarrow K^+\overline{K}^0\pi^-n$
25 ± 4 504	BITYUKOV	88 SPEC	32.5 π ¬ p →
			K+K-π ⁰ n
19 ± 5	ANDO	86 SPEC	$8\pi^- p \rightarrow \eta \pi^+ \pi^- n$
32 ± 8 420	REEVES	86 SPEC	6.6 pp → KKπX
22 ± 2	CHUNG	85 SPEC	$8\pi^-p \rightarrow NK\overline{K}\pi$
32 ± 3 604	ARMSTRONG	84 OMEG	85 $\pi^+ p \rightarrow K \overline{K} \pi \pi p$,
			$pp \rightarrow K \overline{K} \pi p p$
24 ± 3	CHAUVAT	84 SPEC	ISR 31.5 pp
29 ±10 103	DIONISI	80 HBC	4 π ⁻ p → KKπn
28.3 ± 6.7 320	NACASCH	78 HBC	$0.7,0.76 \overline{p}p \rightarrow K\overline{K}3\pi$
• • • We do not use the follow	ving data for averages	, fits, limits,	etc. • • •

² From partial wave analysis of $K^+\overline{K}{}^0\pi^-$ system.

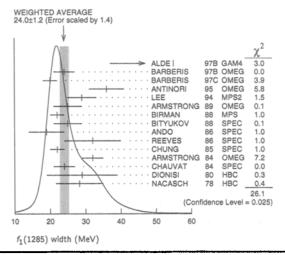
³ From a unitarized quark-model calculation.

From phase shift analysis of $\eta \pi^+ \pi^-$ system.

40	± 5			ABATZIS	94	OMEG	450 pp →
44	±20			AUGUSTIN			$p \rho 2(\pi^+\pi^-)$ $J/\psi \rightarrow \gamma \eta \pi^+\pi^-$
31	± 5			ARMSTRONG	89E	OMEG	300 $pp \rightarrow pp2(\pi^+\pi^-)$
41	±12			ARMSTRONG	89 G	OMEG	$85 \pi^{+} p \rightarrow 4\pi\pi p,$ $pp \rightarrow 4\pi pp$
17.9	± 10.9	•	60	RATH	89	MPS	
14	+20 -14	±10	16	BECKER	87	MRK3	$e^+e^- \rightarrow \phi K \overline{K} \pi$
26	±12			EVANGELISTA	81	OMEG	12 $\pi^{-} p \rightarrow \pi^{+} \pi^{-} \pi^{-} p$
25	± 15		200	GURTU			$4.2~K^-p\to~\eta\eta2\pi$
~ 10				8 STANTON	79	CNTR	$8.5 \pi^- p \rightarrow n2\gamma 2\pi$
24	±18		210	GRASSLER	77	HBC	16 π [∓] ρ
28	± 5		150	9 DEFOIX	72	HBC	$0.7 \ \overline{p}p \rightarrow 7\pi$
46	± 9		180	9 DUBOC	72	HBC	$1.2 \overline{p}p \rightarrow 2K4\pi$
37	± 5		500	¹⁰ THUN	72	MMS	13.4 π ⁻ p
10	±10			BOESEBECK	71	HBC	$16.0 \pi p \rightarrow p5\pi$
30	±15			CAMPBELL	69	DBC	$2.7 \pi^{+} d$
60	± 15			9 LORSTAD	69	HBC	0.7 pp, 4,5-body
35	±10			⁹ DAHL	67	HBC	1.6~4.2 π ⁻ p

⁶ Supersedes ABATZIS 94, ARMSTRONG 89E.

⁹ Resolution is not unfolded. 10 Seen in the missing mass spectrum.



f1(1285) DECAY MODES

 $(4\pi = \rho(\pi\pi)_{Pwave})$

	Mode	Fraction (Γ_I/Γ)	Scale factor/ Confidence level
$\overline{\Gamma_1}$	4π	(35 ± 4)%	S=1.6
Γ_2	$\pi^{0}\pi^{0}\pi^{+}\pi^{-}$	(23.5± 3.0) %	S=1.6
Γ3	$2\pi^{+}2\pi^{-}$	(11.7± 1.5) %	S=1.6
Γ4	$\int_{0}^{\pi} \rho^{0} \pi^{+} \pi^{-}$	(11.7± 1.5) %	S=1.6
Γ5	$4\pi^0$	< 7 × 10	·4 CL=90%
Γ ₆	$\eta \pi \pi$	(50 ±18)%	
Γ,	$a_0(980)\pi$ (ignoring $a_0(980) \rightarrow K\overline{K}$)	(34 ± 8)%	5=1.2
Г8	$\eta \pi \pi$ [excluding $a_0(980)\pi$]	(15 ± 7)%	S=1.1
Γğ	$K\overline{K}\pi$	(9.6± 1.2) %	S=1.5
Γ ₁₀	<i>Κ</i> K *(892)	not seen	
Γ11	$\gamma \rho^0$	(5.4± 1.2) %	5=2.3
Γ12	$\phi\gamma$	(7.9± 3.0) × 10 ⁻¹	-4
Γ ₁₃	$\dot{\gamma}\dot{\gamma}^*$		
Γ ₁₄	77		

CONSTRAINED FIT INFORMATION

An overall fit to 7 branching ratios uses 14 measurements and one constraint to determine 5 parameters. The overall fit has a χ^2 = 23.7 for 10 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\langle \delta x_i \delta x_j \rangle / (\delta x_i \cdot \delta x_j)$, in percent, from the fit to the branching fractions, $x_i \equiv$ Γ_i/Γ_{total} . The fit constrains the x_i whose labels appear in this array to sum to

$f_1(1285) \Gamma(I)\Gamma(\gamma\gamma)/\Gamma(total)$

$\Gamma(\eta\pi\pi)\times\Gamma(\gamma\gamma)/\Gamma$	total			Γ ₆ Γ	$\Gamma_{14}/\Gamma = (\Gamma_7 + \Gamma_8)\Gamma_{14}/\Gamma$
VALUE (keV)	CL%	DOCUMENT ID		TECN	COMMENT
<0.62	95	GIDAL	87	MRK2	e+e- → •+e-ma+a-

 $\Gamma_6\Gamma_{13}/\Gamma = (\Gamma_7 + \Gamma_8)\Gamma_{13}/\Gamma$ $\Gamma(\eta\pi\pi) \times \Gamma(\gamma\gamma^*)/\Gamma_{\text{total}}$ DOCUMENT ID TECN EVTS 1.4 ±0.4 OUR AVERAGE Error includes scale factor of 1.4. 1.18±0.25±0.20 26 11,12 AIHARA 88B TPC 11,13 GIDAL 2.30 ± 0.61 ± 0.42

¹¹ Assuming a ρ -pole form factor.

 12 Published value multiplied by $\eta\pi\pi$ branching ratio 0.49.

 13 Published value divided by 2 and multiplied by the $\eta\pi\pi$ branching ratio 0.49.

f₁(1285) BRANCHING RATIOS

Γ(ΚҠπ)/Γ(4π)				Γ9/Γ1
VALUE	DOCUMENT ID			COMMENT
0.274±0.018 OUR FIT Erro				
0.271±0.016 OUR AVERAGE				
0.265 ± 0.014	¹⁴ BARBERIS			$450 pp \rightarrow pp K_5^0 K^{\pm} \pi^{\mp}$
0.28 ±0.05	15 ARMSTRONG	89E	OMEG	300 $pp \to ppf_1(1285)$
0.37 ±0.03 ±0.05	16 ARMSTRONG	89G	OMEG	85 π p → 4π X
¹⁴ Using $2(\pi^+\pi^-)$ data from 15 Assuming $\rho\pi\pi$ and a_0 (98 16 4π consistent with being 6	$0)\pi$ intermediate state	ıs.		
$\Gamma(\pi^0\pi^0\pi^+\pi^-)/\Gamma_{\text{total}}$				$\Gamma_2/\Gamma = \frac{2}{3}\Gamma_1/\Gamma$
VALUE	DOCUMENT ID			_, , _,
0.235 ± 0.030 OUR FIT Erro	r includes scale factor	of 1.	6.	
$\Gamma(2\pi^+2\pi^-)/\Gamma_{\text{total}}$				$\Gamma_3/\Gamma = \frac{1}{3}\Gamma_1/\Gamma$
VALUE	DOCUMENT ID			·, 3 ·,
0.117±0.015 OUR FIT Erro	r includes scale factor	of 1.	6.	
$\Gamma(ho^0\pi^+\pi^-)/\Gamma_{ m total}$				$\Gamma_4/\Gamma = \frac{1}{4}\Gamma_1/\Gamma$
VALUE	DOCUMENT ID			
0.117±0.015 OUR FIT Erro	r includes scale factor	of 1.	6.	
$\Gamma(K\overline{K}\pi)/\Gamma(\eta\pi\pi)$				$\Gamma_9/\Gamma_6 = \Gamma_9/(\Gamma_7 + \Gamma_8)$
VALUE	DOCUMENT ID		TECN	COMMENT
	ncludes scale factor of			*
0.23±0.06 OUR AVERAGE				
0.42±0.15	GURTU		HBC	4.2 K ⁻ p
0.5 ±0.2	CORDEN			12-15 π ⁻ p
0.20±0.08	17 DEFOIX		HBC	
0.16±0.08	CAMPBELL		DBC	$2.7 \pi^+ d$
17 K K system characterized	by the $I = 1$ threshold	d ent	anceme	nt. (See under a ₀ (980)).

 $\Gamma(a_0(980)\pi \text{ [ignoring } a_0(980) \rightarrow K\overline{K}])/\Gamma(\eta\pi\pi)$ $\Gamma_7/\Gamma_6 = \Gamma_7/(\Gamma_7 + \Gamma_8)$ DOCUMENT ID TECN COMMENT. VALUE 0.69±0.13 OUR FIT

0.69 +0.13 OUR AVERAGE

0.72±0.15 **GURTU** 79 HBC 4.2 K-p $0.6 \begin{array}{c} +0.3 \\ -0.2 \end{array}$ CORDEN 78 OMEG 12-15 π⁻ p • • We do not use the following data for averages, fits, limits, etc. • •

978 GAM4 100 $\pi^- p \rightarrow \eta \pi^0 \pi^0 n$ 0.28 ± 0.07 1400 ALDE 77 HBC 16 π[∓] p GRASSLER 1.0 ± 0.3

⁷ From partial wave analysis of $K^+\overline{K}^0\pi^-$ system.

⁸ From phase shift analysis of $\eta \pi^+ \pi^-$ system.

 $f_1(1285), \eta(1295)$

$\Gamma(4\pi)/\Gamma(\eta\pi\pi) \qquad \qquad \Gamma_1/\Gamma_6 = \Gamma_1/(\Gamma_7 + \Gamma_8)$	ANDO 86 PRL 57 1296	+lmai+ (KEK, KYOT, NIRS, SAGA, INUS, TSUK+) IJF
VALUE DOCUMENT ID TECN COMMENT	REEVES 86 PR 34 1960 CHUNG 85 PRL 55 779	+Chung, Crittenden+ (FLOR, BNL, IND, MASD) JP +Fernow, Boehnlein+ (BNL, FLOR, IND, MASD) JP
1.71±0.15 OUR FIT Error includes scale factor of 1.5.	ARMSTRONG 84 PL 146B 273	+Bloodworth, Burns+ (ATHU, BARI, BIRM, CERN) JP
A1±0.14 OUR AVERAGE	BITYUKOV 848 PL 144B 133 CHAUVAT 84 PL 148B 382	Bitukov, Dorofeev, Dzhelyadin, Golovkin, Kulik+ (SERP) +Meritet, Bonino+ (CERN, CLER, UCLA, SACL)
.37 \pm 0.11 \pm 0.11 BOLTON 92 MRK3 $J/\psi \rightarrow \gamma f_1(1285)$.64 \pm 0.40 GURTU 79 HBC 4.2 $K^- p$	TORNQVIST 82B NP B203 268 EVANGELISTA 81 NP B178 197	(HELS) + (BARI, BONN, CERN, DARE, LIVP+)
.64±0.40 GURTU 79 HBC 4.2 K ⁻ p • • We do not use the following data for averages, fits, limits, etc. • • •	BROMBERG 80 PR D22 1513	+Haggerty, Abrams, Dzierba (CIT, FNAL, ILLC, IND)
1.93 ± 0.30 18 GRASSLER 77 HBC 16 $\pi^{\mp}p$	DIONISI 80 NP B169 1 GURTU 79 NP B151 181	+Gavillet+ (CERN, MADR, CDEF, STOH) +Gavillet, Blokzijl+ (CERN, ZEEM, NIJM, OXF)
18 Assuming $\rho\pi\pi$ and $a_0(980)\pi$ intermediate states.	STANTON 79 PRL 42 346 CORDEN 78 NP B144 253	+Brockman+ (OSU, CARL, MCGI, TNTO) JP +Corbett, Alexander+ (BIRM, RHEL, TELA, LOWC) JP
Assuming part and a0(300) intermediate states.	NACASCH 78 NP B135 203 GRASSLER 77 NP B121 189	+Defoix, Dobrzynski+ (PARIS, MADR, CERN) + (AACH3, BERL, BONN, CERN, CRAC, HEIDH+)
$\Gamma(K\overline{K}^{\bullet}(892))/\Gamma_{\text{total}}$ Γ_{10}/Γ	DEFOIX 72 NP B44 125	+Nascimento, Bizzarri+ (CDEF, CERN)
VALUE DOCUMENT ID TECN COMMENT	DUBOC 72 NP B46 429 THUN 72 PRL 28 1733	+Goldberg, Måkowski, Donald+ (PARIS, LIVP) +Blieden, Finocchiaro, Bowen+ (STON, NEAS)
of seen NACASCH 78 HBC $0.7, 0.76 \ \overline{p}p \rightarrow K\overline{K}3\pi$	BARDADIN 71 PR D4 2711 BOESEBECK 71 PL 34B 659	Bardadin-Otwinowska, Hofmokl+ (WARS) (AACH, BERL, BONN, CERN, CRAC, HEID, WARS)
$-(\rho^0\pi^+\pi^-)/\Gamma(2\pi^+2\pi^-)$ Γ_4/Γ_3	CAMPBELL 69 PRL 22 1204 LORSTAD 69 NP B14 63	+Lichtman, Loeffler+ (PURD) +D'Andlau, Astier+ (CDEF, CERN) JF
ALUE DOCUMENT ID TECH COMMENT	D'ANDLAU 68 NP B5 693	+Astier, Barlow+ (CDEF, CERN, IRAD, LIVP) IJ
• We do not use the following data for averages, fits, limits, etc. • • •	DAHL 67 PR 163 1377	+Hardy, Hess, Kirz, Miller (LRL) IJ
.0±0.4 GRASSLER 77 HBC 16 GeV $\pi^{\pm} \rho$	—— от	HER RELATED PAPERS ———
	AIHARA 88C PR D38 1	+Alston-Garnjost+ (TPC-2γ Collab.) Ji
$\Gamma(4\pi^0)/\Gamma_{\text{total}}$ Γ_5/Γ	ASTON 85 PR D32 2255 ATKINSON 84E PL 138B 459	+Carnegie, Dunwoodie+ (SLAC, CARL, CNRC) + (BONN, CERN, GLAS, LANC, MCHS, CURIN+)
/ALUE (units 10 ⁻⁴) CL% DOCUMENT ID TECN COMMENT	GAVILLET 82 ZPHY C16 119	+Armenteros+ (CERN, CDEF, PADO, ROMA)
<7 90 ALDE 87 GAM4 $100 \pi^- p \rightarrow 4\pi^0 n$	D'ANDLAU 65 PL 17 347 MILLER 65 PRL 14 1074	+Barlow, Adamson+ (CDEF, CERN, IRAD, LIVP) +Chung, Dahl, Hess, Hardy, Kirz+ (LRL, UCB)
$\Gamma(\phi\gamma)/\Gamma(K\overline{K}\pi)$ Γ_{12}/Γ_{9}		
	(100=)	$I^{G}(J^{PC}) = 0^{+}(0^{-})$
	$\eta(1295)$	$I^{G}(J^{r,C}) = 0^{+}(0^{-})$
0.82±0.21±0.20 19 BITYUKOV 88 SPEC 32.5 $\pi^- \rho \rightarrow \kappa^+ \kappa^- \pi^0 \eta$		
• • We do not use the following data for averages, fits, limits, etc. • •		ew under non- $q\overline{q}$ candidates. (See the index
<0.93 95 AMELIN 95 VES 37 $\pi^- N \rightarrow$	for the page number.)	
$\pi^-\pi^+\pi^-\gamma$ N		_(100E) MASS
$\Gamma(\gamma \rho^0)/\Gamma(K\overline{K}\pi)$ Γ_{11}/Γ_9		η(1295) MASS
ALUE CL% DOCUMENT ID TECN COMMENT	VALUE (MeV) EVTS	DOCUMENT ID TECN COMMENT
● ● We do not use the following data for averages, fits, limits, etc. ● ●	1297.0±2.8 OUR AVERAGE	
>0.035 90 19 COFFMAN 90 MRK3 $J/\psi \rightarrow \gamma\gamma\pi^{+}\pi^{-}$	1299 ±4 2100	ALDE 978 GAM4 $100 \pi^{-} p \rightarrow \eta \pi^{0} \pi^{0} t$
¹⁹ Using B($J/\psi \rightarrow \gamma f_1(1285) \rightarrow \gamma \gamma \rho^0$)=0.25 × 10 ⁻⁴ and B($J/\psi \rightarrow \gamma f_1(1285) \rightarrow$	1295 ±4	FUKUI 91C SPEC 8.95 $\pi^- p \rightarrow \eta \pi^+ \pi^-$
$\gamma \text{Using B}(J/\psi \to \gamma r_1(1285) \to \gamma \gamma \rho^*) = 0.25 \times 10^{-8} \text{ and B}(J/\psi \to \gamma r_1(1285) \to \gamma K \overline{K} \pi) = < 0.72 \times 10^{-3}.$	• • We do not use the followledge	ng data for averages, fits, limits, etc. • • •
• •	~ 1275	STANTON 79 CNTR 8.4 $\pi^- p \rightarrow n \eta 2\pi$
$\Gamma(\gamma \rho^0)/\Gamma(2\pi^+ 2\pi^-) \qquad \qquad \Gamma_{11}/\Gamma_3 = \Gamma_{11}/\frac{1}{3}\Gamma_1$		4\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \
VALUE DOCUMENT ID TECN COMMENT		η(1295) WIDTH
0.46 \pm 0.13 OUR FIT Error Includes scale factor of 1.9. 0.45 \pm 0.18 Position of the proof of the p	VALUE (MeV) EVTS	DOCUMENT ID TECN COMMENT
20 Using B($J/\psi \rightarrow \gamma f_1(1285) \rightarrow \gamma \gamma \rho^0$)=0.25 × 10 ⁻⁴ and B($J/\psi \rightarrow \gamma f_1(1285) \rightarrow$	53±6	FUKUI 91C SPEC 8.95 $\pi^- p \rightarrow \eta \pi^+ \pi^-$
Using B($J/\psi \rightarrow \gamma r_1(1285) \rightarrow \gamma \gamma \rho^*$)=0.25 x 10 · and B($J/\psi \rightarrow \gamma r_1(1285) \rightarrow \gamma 2\pi^+ 2\pi^-$)=0.55 x 10 · 4 given by MIR 88.		ng data for averages, fits, limits, etc. • • •
	<40 2100	ALDE 978 GAM4 100 $\pi^{-}p \rightarrow \eta \pi^{0} \pi^{0}$
$\Gamma(\gamma ho^0)/\Gamma_{ m total}$ Γ_{11}/Γ	~ 70	STANTON 79 CNTR 8.4 $\pi^- p \rightarrow n \eta 2\pi$
VALUE CL% DOCUMENT ID TECN COMMENT		
0.054±0.012 OUR FIT Error includes scale factor of 2.3.	ηl	(1295) DECAY MODES
0.028 ± 0.007 ± 0.006 AMELIN 95 VES 37 $\pi^- N \to \pi^- \pi^+ \pi^- \gamma N$		
$\pi^-\pi^+\pi^-\gamma N$	Mode	Fraction (Γ ₁ /Γ)
$\pi^-\pi^+\pi^-\gamma N$ • • We do not use the following data for averages, fits, limits, etc. • • •	$\frac{Mode}{\Gamma_1 \eta \pi^+ \pi^-}$	Fraction (Γ_{J}/Γ)
• • • We do not use the following data for averages, fits, limits, etc. • • • < 0.05 95 BITYUKOV 91B SPEC $32 \pi^- p \rightarrow \pi^+ \pi^- \gamma n$		
• • • We do not use the following data for averages, fits, limits, etc. • • • <0.05 95 BITYUKOV 918 SPEC $32 \pi^- p \rightarrow \pi^+ \pi^- \gamma n$ $\Gamma(\eta \pi \pi)/\Gamma(\gamma \rho^0) \qquad \qquad \Gamma_6/\Gamma_{11} = (\Gamma_7 + \Gamma_8)/\Gamma_{11}$		seen
$\pi^-\pi^+\pi^-\gamma N$ • • • We do not use the following data for averages, fits, limits, etc. • • • <0.05 95 BITYUKOV 91B SPEC 32 $\pi^-p \to \pi^+\pi^-\gamma N$ $\Gamma(\eta\pi\pi)/\Gamma(\gamma\rho^0)$ $\Gamma_6/\Gamma_{11} = (\Gamma_7 + \Gamma_8)/\Gamma_{11}$ WALUE DOCUMENT ID TECN COMMENT		seen
$\pi^-\pi^+\pi^-\gamma N$ • • • We do not use the following data for averages, fits, limits, etc. • • • <0.05 95 BITYUKOV 918 SPEC $32\pi^-\rho \to \pi^+\pi^-\gamma N$ $\Gamma(\eta\pi\pi)/\Gamma(\gamma\rho^0)$ $\Gamma_6/\Gamma_{11} = (\Gamma_7+\Gamma_8)/\Gamma_{11}$ VALUE DOCUMENT ID TECN COMMENT 9.2±2.6 OUR FIT Error includes scale factor of 3.0.		seen seen
$\pi^-\pi^+\pi^-\gamma N$ • • • We do not use the following data for averages, fits, limits, etc. • • • <0.05 95 BITYUKOV 918 SPEC $32\pi^-p \to \pi^+\pi^-\gamma N$ $\Gamma(\eta\pi\pi)/\Gamma(\gamma\rho^0)$ $\Gamma_6/\Gamma_{11} = (\Gamma_7+\Gamma_8)/\Gamma_{11}$ AND DOCUMENT ID TECK COMMENT 9.2±2.6 OUR FIT Error includes scale factor of 3.0.	$\Gamma_{1} \eta \pi^{+} \pi^{-}$ $\Gamma_{2} a_{0}(980) \pi$ $\Gamma_{3} \gamma \gamma$ $\Gamma_{4} \eta \pi^{0} \pi^{0}$ $\Gamma_{5} \eta (\pi \pi)_{S}$ -wave	seen seen seen seen
$\pi^-\pi^+\pi^-\gamma N$ $\pi^-\pi^-\pi^-\gamma N$ $\pi^-\pi^-\pi^-\gamma N$ $\pi^-\pi^-\pi^-\gamma N$ $\pi^-\pi^-\pi^-\gamma N$ $\pi^-\pi^-\gamma N$	$\Gamma_{1} \eta \pi^{+} \pi^{-}$ $\Gamma_{2} a_{0}(980) \pi$ $\Gamma_{3} \gamma \gamma$ $\Gamma_{4} \eta \pi^{0} \pi^{0}$ $\Gamma_{5} \eta (\pi \pi)_{S}$ -wave	seen seen seen
$\pi^-\pi^+\pi^-\gamma N$ $\pi^-\pi^-\pi^-\gamma N$ $\pi^-\pi^-\pi^-\gamma N$ $\pi^-\pi^-\pi^-\gamma N$ $\pi^-\pi^-\pi^-\gamma N$ $\pi^-\pi^-\pi^-\gamma N$ $\pi^-\pi^-\gamma N$	$\Gamma_{1} \eta \pi^{+} \pi^{-}$ $\Gamma_{2} a_{0}(980) \pi$ $\Gamma_{3} \gamma \gamma$ $\Gamma_{4} \eta \pi^{0} \pi^{0}$ $\Gamma_{5} \eta(\pi\pi)_{s\text{-wave}}$	seen seen seen 1295) Γ(Ι)Γ(γγ)/Γ(total)
• • • We do not use the following data for averages, fits, limits, etc. • • • • < < 0.05 95 BITYUKOV 91B SPEC $32\pi^-p \rightarrow \pi^+\pi^-\gamma n$ $\Gamma(\eta\pi\pi)/\Gamma(\gamma\rho^0) \qquad \qquad \Gamma_{6}/\Gamma_{11} = (\Gamma_7 + \Gamma_8)/\Gamma_{11}$ VALUE DOCUMENT ID TECN COMMENT 9.2±2.6 OUR FIT Error includes scale factor of 3.0. 21 ARMSTRONG 92C OMEG 300 $pp \rightarrow pp\pi^+\pi^-\gamma$, $pp\eta\pi^+\pi^-$	$ \Gamma_{1} \eta \pi^{+} \pi^{-} $ $ \Gamma_{2} a_{0}(980) \pi $ $ \Gamma_{3} \gamma \gamma $ $ \Gamma_{4} \eta \pi^{0} \pi^{0} $ $ \Gamma_{5} \eta(\pi\pi)_{\text{S-wave}} $ $ \Gamma(\eta \pi^{+} \pi^{-}) \times \Gamma(\gamma \gamma)/\Gamma_{\text{total}} $	seen seen seen seen seen $\Gamma(I)\Gamma(\gamma\gamma)/\Gamma(total)$
$\pi^-\pi^+\pi^-\gamma N$ \sim • • • We do not use the following data for averages, fits, limits, etc. • • • • • • • • • • • • • • • • • • •	$ \Gamma_{1} \eta \pi^{+} \pi^{-} $ $ \Gamma_{2} a_{0}(980) \pi $ $ \Gamma_{3} \gamma \gamma $ $ \Gamma_{4} \eta \pi^{0} \pi^{0} $ $ \Gamma_{5} \eta(\pi \pi)_{S\text{-wave}} $ $ \Gamma(\eta \pi^{+} \pi^{-}) \times \Gamma(\gamma \gamma)/\Gamma_{\text{bota}} $ VALUE (keV) $ CL\% $	seen seen seen seen 1295) Γ(i)Γ(γγ)/Γ(total) I DOCUMENT ID TECN COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • • • • • • • • • • • • • • • • • •	$ \Gamma_{1} \eta \pi^{+} \pi^{-} $ $ \Gamma_{2} a_{0}(980) \pi $ $ \Gamma_{3} \gamma \gamma $ $ \Gamma_{4} \eta \pi^{0} \pi^{0} $ $ \Gamma_{5} \eta (\pi \pi)_{S\text{-wave}} $ $ \Gamma(\eta \pi^{+} \pi^{-}) \times \Gamma(\gamma \gamma) / \Gamma_{\text{tota}} $ $ \frac{VALUE (\text{keV})}{< 0.3} $	seen seen seen seen seen seen seen seen
*** • • We do not use the following data for averages, fits, limits, etc. • • • • • • • • • • • • • • • • • • •	$ \Gamma_{1} \eta \pi^{+} \pi^{-} $ $ \Gamma_{2} a_{0}(980) \pi $ $ \Gamma_{3} \gamma \gamma $ $ \Gamma_{4} \eta \pi^{0} \pi^{0} $ $ \Gamma_{5} \eta(\pi\pi)_{S\text{-wave}} $ $ \Gamma(\eta \pi^{+} \pi^{-}) \times \Gamma(\gamma \gamma) / \Gamma_{\text{total}} $ $ \frac{VALUE (\text{keV})}{< 0.3} $ • • • We do not use the follows:	seen seen seen seen seen seen seen seen
*** • • We do not use the following data for averages, fits, limits, etc. • • • • • • • • • • • • • • • • • • •	$ \Gamma_{1} \eta \pi^{+} \pi^{-} $ $ \Gamma_{2} a_{0}(980) \pi $ $ \Gamma_{3} \gamma \gamma $ $ \Gamma_{4} \eta \pi^{0} \pi^{0} $ $ \Gamma_{5} \eta (\pi \pi)_{S\text{-wave}} $ $ \Gamma(\eta \pi^{+} \pi^{-}) \times \Gamma(\gamma \gamma) / \Gamma_{\text{tota}} $ $ \frac{VALUE (\text{keV})}{< 0.3} $	seen seen seen seen seen seen seen seen
$\pi^-\pi^+\pi^-\gamma N$ $\pi^-\pi^-\pi^-\gamma N$ $\pi^-\pi^-\gamma N$ $\pi^-\pi$	$ \Gamma_{1} \eta \pi^{+} \pi^{-} $ $ \Gamma_{2} a_{0}(980) \pi $ $ \Gamma_{3} \gamma \gamma $ $ \Gamma_{4} \eta \pi^{0} \pi^{0} $ $ \Gamma_{5} \eta(\pi\pi)_{S\text{-wave}} $ $ \Gamma(\eta \pi^{+} \pi^{-}) \times \Gamma(\gamma \gamma) / \Gamma_{\text{total}} $ $ VALUE (keV) \qquad CL \% $ $ <0.3 $ ••• We do not use the following conductions of the policy of the po	seen seen seen seen seen seen seen seen
$\pi^-\pi^+\pi^-\gamma N$ $\pi^-\pi^-\pi^-\gamma N$ $\pi^-\pi^-\pi^-\pi^-\gamma N$ $\pi^-\pi^-\pi^-\gamma N$ $\pi^-\pi^-\gamma N$	$ \Gamma_{1} \eta \pi^{+} \pi^{-} $ $ \Gamma_{2} a_{0}(980) \pi $ $ \Gamma_{3} \gamma \gamma $ $ \Gamma_{4} \eta \pi^{0} \pi^{0} $ $ \Gamma_{5} \eta(\pi\pi)_{S\text{-wave}} $ $ \Gamma(\eta \pi^{+} \pi^{-}) \times \Gamma(\gamma \gamma) / \Gamma_{\text{total}} $ $ VALUE (keV) \qquad CL \% $ $ <0.3 $ ••• We do not use the following conductions of the policy of the po	seen seen seen seen seen seen seen seen
$\pi^-\pi^+\pi^-\gamma N$	$ \Gamma_{1} \eta \pi^{+} \pi^{-} $ $ \Gamma_{2} a_{0}(980) \pi $ $ \Gamma_{3} \gamma \gamma $ $ \Gamma_{4} \eta \pi^{0} \pi^{0} $ $ \Gamma_{5} \eta (\pi \pi)_{S-\text{wave}} $ $ \Gamma(\eta \pi^{+} \pi^{-}) \times \Gamma(\gamma \gamma) / \Gamma_{\text{total}} $ $ VALUE (keV) \qquad CL \% $ $ < 0.3 $ • • • We do not use the following constant of the properties	seen seen seen seen seen seen seen seen
$\pi^-\pi^+\pi^-\gamma N$ $\pi^-\pi^-\pi^-\gamma N$ $\pi^-\pi^-\gamma $	$ \Gamma_{1} \eta \pi^{+} \pi^{-} $ $ \Gamma_{2} a_{0}(980) \pi $ $ \Gamma_{3} \gamma \gamma $ $ \Gamma_{4} \eta \pi^{0} \pi^{0} $ $ \Gamma_{5} \eta (\pi \pi)_{S-\text{wave}} $ $ \Gamma(\eta \pi^{+} \pi^{-}) \times \Gamma(\gamma \gamma) / \Gamma_{\text{total}} $ $ \bullet \bullet We do not use the following solution of the solution of$	seen seen seen seen seen seen seen seen
$\pi^-\pi^+\pi^-\gamma N$ $\pi^-\pi^-\pi^-\gamma $		seen seen seen seen seen seen seen seen
$\pi^-\pi^+\pi^-\gamma N$ • • • We do not use the following data for averages, fits, limits, etc. • • • • • • • • • • • • • • • • • • •	$ \Gamma_{1} \eta \pi^{+} \pi^{-} $ $ \Gamma_{2} a_{0}(980) \pi $ $ \Gamma_{3} \gamma \gamma $ $ \Gamma_{4} \eta \pi^{0} \pi^{0} $ $ \Gamma_{5} \eta (\pi \pi)_{S\text{-wave}} $ $ \Gamma(\eta \pi^{+} \pi^{-}) \times \Gamma(\gamma \gamma) / \Gamma_{\text{total}} $ $ <0.3 $ • • • We do not use the following the following that the following the following that the following that the following the following the following that the following that the following the	seen seen seen seen seen seen seen seen
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$\pi^-\pi^+\pi^-\gamma N$ $\pi^-\pi^-\pi^-\gamma $	$ \Gamma_{1} \eta \pi^{+} \pi^{-} $ $ \Gamma_{2} a_{0}(980) \pi $ $ \Gamma_{3} \gamma \gamma $ $ \Gamma_{4} \eta \pi^{0} \pi^{0} $ $ \Gamma_{5} \eta (\pi \pi)_{S\text{-wave}} $ $ \Gamma(\eta \pi^{+} \pi^{-}) \times \Gamma(\gamma \gamma) / \Gamma_{\text{total}} $ $ <0.3 $ • • • We do not use the following the following that the following the following that the following that the following the following the following that the following that the following the	seen seen seen seen seen seen seen seen
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	$\Gamma_{1} \eta \pi^{+} \pi^{-}$ $\Gamma_{2} a_{0}(980) \pi$ $\Gamma_{3} \gamma \gamma$ $\Gamma_{4} \eta \pi^{0} \pi^{0}$ $\Gamma_{5} \eta (\pi \pi)_{S\text{-wave}}$ $\Gamma(\eta \pi^{+} \pi^{-}) \times \Gamma(\gamma \gamma) / \Gamma_{\text{total}}$ < 0.3 • • • We do not use the following continuous to the following continuous co	seen seen seen seen seen seen seen seen
$\pi^-\pi^+\pi^-\gamma N$ $\pi^-\pi^-\pi^-\gamma N$ $\pi^-\pi^-\pi^-\gamma N$ $\pi^-\pi^-\pi^-\gamma N$ $\pi^-\pi^-\pi^-\gamma N$ $\pi^-\pi^-\pi^-\gamma N$ $\pi^-\pi^-\gamma N$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	seen seen seen seen seen seen seen seen
	Γ_1 $\eta \pi^+ \pi^ \Gamma_2$ $a_0(980) \pi$ Γ_3 $\gamma \gamma$ Γ_4 $\eta \pi^0 \pi^0$ Γ_5 $\eta(\pi\pi)_{S\text{-wave}}$ $\Gamma(\eta \pi^+ \pi^-) \times \Gamma(\gamma \gamma)/\Gamma_{\text{total}}$ <0.3 • • • We do not use the following constant V_{ALUE} • • • We do not use the following rot seen large large $\Gamma(a_0(980) \pi)/\Gamma(\eta \pi^0 \pi^0)$	seen seen seen seen seen seen seen seen
Section Sec	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	seen seen seen seen seen seen seen seen

 $^{1}\operatorname{Assuming}$ that $\textit{a}_{0}(980)$ decays only to $\eta\pi.$

$(\eta(\pi\pi)_{S\text{-wave}})/\Gamma(\eta\pi^0)$	π^0) Γ_5/Γ_4
ALUE	DOCUMENT ID TECN COMMENT
35±0.10	ALDE 978 GAM4 $100 \pi^{-} p \rightarrow \eta \pi^{0} \pi^{0} n$
	η(1295) REFERENCES
DE 97B PAN 60 386 Translated fro	D. Alde, Binon, Bricman+ (GAMS Collab.)
ERTIN 97 PL 8400 226 JKUI 91C PL 8267 293	+ (SUGI, NAGO, KEK, KYOT, MIYA, AKIT)
HARA 88C PR D38 1 RMAN 88 PRL 61 1557	+Alston-Garnjost+ (TPC-2γ Collab.) 7 +Chung, Peaslee+ (BNL, FSU, IND, MASD) JP
NTREASYAN 87 PR D36 2633	3 +Bartels Besset+ (Crystal Ball Collab.)
NDO 86 PRL 57 1296 FANTON 79 PRL 42 346	6 + mai+ (KEK, KYOT, NIRS, SAĞA, INUS, TSUK+) IJP +Brockman+ (OSU, CARL, MCGI, TNTO) JP
$\pi(1300)$	$I^{G}(J^{PC}) = 1^{-}(0^{-}+)$
· · · · · · · · · · · · · · · · · · ·	π(1300) MASS
ALUE (MeV)	DOCUMENT ID TECN COMMENT
1300±100 OUR ESTIMAT • • We do not use the following the	TE Nowing data for averages, fits, limits, etc. • • •
1275± 15	BERTIN 97D OBLX 0.05 $\overline{p}p \rightarrow 2\pi^+2\pi^-$
1114	ABELE 96 CBAR $0.0 \overline{p}p \rightarrow 5\pi^0$
1190± 30 1240± 30	ZIELINSKI 84 SPEC 200 $\pi^+Z \rightarrow Z3\pi$ BELLINI 82 SPEC 40 $\pi^-A \rightarrow A3\pi$
1273± 50	AARON 81 RVUE
1342± 20	BONESINI 81 OMEG $12 \pi^- p \rightarrow p 3\pi$
1400	DAUM 818 SPEC 63,94 $\pi^{-}p$
Uses multichannel Aitchi and DANKOWYCH 81.	ison-Bowler model (BOWLER 75). Uses data from DAUM 80
	π(1300) WIDTH
ALUE (MeV)	DOCUMENT ID TECN COMMENT
We do not use the following the second control of the second	ITE Ilowing data for averages, fits, limits, etc. • • •
218±100	BERTIN 97D OBLX 0.05 $\vec{p}p \rightarrow 2\pi^{+}2\pi^{-}$
340	ABELE 96 CBAR 0.0 $\overline{p}p \rightarrow 5\pi^0$
440 ± 80	ZIELINSKI 84 SPEC $200 \pi^+ Z \rightarrow Z3\pi$
360 ± 120 580 ± 100	BELLINI 82 SPEC $40 \pi^- A \rightarrow A3\pi$ ² AARON 81 RVUE
220± 70	BONESINI 81 OMEG 12 $\pi^- p \rightarrow p3\pi$
600	DAUM 818 SPEC 63,94 π ⁻ ρ
² Uses multichannel Aitchl and DANKOWYCH 81.	ilson-Bowler model (BOWLER 75). Uses data from DAUM 80
	π(1300) DECAY MODES
Mode	Fraction (Γ _f /Γ)
$\rho\pi$	
$\rho\pi$ $\pi(\pi\pi)s$ -wave	Fraction (Γ _I /Γ)
$\rho\pi$ $\pi(\pi\pi)s$ -wave	Fraction (Γ _f /Γ) seen seen
$\rho\pi$ $2 \pi(\pi\pi)s$ -wave $3 \gamma\gamma$	Fraction (Γ _I /Γ) seen
$ \begin{array}{ccc} 1 & \rho \pi \\ 2 & \pi(\pi\pi)_{\text{S-wave}} \\ 3 & \gamma \gamma \end{array} $ $ \frac{\Gamma(\rho \pi) \times \Gamma(\gamma \gamma)}{\Gamma(\rho \pi)} \times \Gamma(\gamma \gamma) = \frac{CL}{CL} $ (ALUE (keV) CL	Fraction (Γ_I/Γ) seen seen $\pi(1300) \; \Gamma(I)\Gamma(\gamma\gamma)/\Gamma(total)$ $\Gamma_1\Gamma_3/\Gamma$ LK DOCUMENT ID TECN COMMENT
$ \begin{array}{ccc} 1 & \rho \pi \\ 2 & \pi(\pi\pi)_{S\text{-wave}} \\ 3 & \gamma \gamma \end{array} $ $ \frac{\Gamma(\rho \pi) \times \Gamma(\gamma \gamma)}{\Gamma(\rho \pi)} \times \frac{\Gamma(\gamma \gamma)}{\Gamma(\rho \pi)} = \frac{CL}{CL} $	Fraction (Γ_I/Γ) seen seen $\pi(1300) \; \Gamma(I)\Gamma(\gamma\gamma)/\Gamma(total)$ $\Gamma_1\Gamma_3/\Gamma$ LK DOCUMENT ID TECN COMMENT
$ \begin{array}{ccc} 1 & \rho \pi \\ 2 & \pi (\pi \pi) \text{s-wave} \\ 3 & \gamma \gamma \end{array} $ $ \begin{array}{ccc} \Gamma(\rho \pi) \times \Gamma(\gamma \gamma) / \Gamma_{\text{total}} \\ ALUE (\text{keV}) & CL \\ < 0.085 & 90 \end{array} $	Fraction (Γ_I/Γ) seen seen $\pi(1300) \ \Gamma(I)\Gamma(\gamma\gamma)/\Gamma(total)$ $\Gamma_1\Gamma_3/\Gamma$ $\frac{LK}{DOCUMENT \ ID} \qquad \frac{TECN}{ACCIARRI} \qquad \begin{array}{c} COMMENT \\ e^+e^- \rightarrow \\ e^+e^- + \pi^- \pi^0 \end{array}$
$ \begin{array}{ccc} 1 & \rho \pi \\ 2 & \pi (\pi \pi)_{\text{5-wave}} \\ 3 & \gamma \gamma \end{array} $ $ \begin{array}{ccc} \Gamma(\rho \pi) \times \Gamma(\gamma \gamma) / \Gamma_{\text{total}} \\ ALUE (\text{keV}) & CL \\ < 0.085 & 90 \\ < 0.54 & 90 \end{array} $	Fraction (Γ_I/Γ) seen seen $\pi(1300) \ \Gamma(I)\Gamma(\gamma\gamma)/\Gamma(total)$ $\frac{1\%}{1} \frac{DOCUMENT \ ID}{1} \frac{TECN}{1} \frac{COMMENT}{1} \frac{TCOMMENT}{1} e^+e^- \rightarrow e^- \rightarrow e^-e^- \rightarrow e^- \rightarrow e^-$
$ \begin{array}{ccc} 1 & \rho \pi \\ 2 & \pi (\pi \pi)_{\text{S-wave}} \\ 3 & \gamma \gamma \end{array} $ $ \begin{array}{c} \Gamma(\rho \pi) \times \Gamma(\gamma \gamma)/\Gamma_{\text{total}} \\ ALUE (\text{keV}) & CL \\ < 0.085 & 90 \\ < 0.54 & 90 \end{array} $ $ \begin{array}{c} \Gamma(\pi(\pi \pi)_{\text{S-wave}})/\Gamma(\rho \pi) \\ \end{array} $	Fraction (Γ_i/Γ) seen seen $\pi(1300) \ \Gamma(i)\Gamma(\gamma\gamma)/\Gamma(total)$ $\Gamma_1\Gamma_3/\Gamma$ $\frac{DOCUMENT \ ID}{0} \qquad \frac{TECN}{ACCIARRI} \qquad 97T \ L3 \qquad e^+e^- \rightarrow e^- \rightarrow e$
$ \begin{array}{ccc} 1 & \rho \pi \\ 2 & \pi (\pi \pi)_{S\text{-wave}} \\ 3 & \gamma \gamma \end{array} $ $ \Gamma(\rho \pi) \times \Gamma(\gamma \gamma)/\Gamma_{\text{total}} $ $ \frac{CL}{<0.085} & 90 $ $ <0.54 & 90 $ $ \Gamma(\pi(\pi \pi)_{S\text{-wave}})/\Gamma(\rho \pi) $ WALUE	Fraction (Γ_I/Γ) seen seen $\pi(1300) \ \Gamma(I)\Gamma(\gamma\gamma)/\Gamma(total)$ $\frac{1\%}{1} \frac{DOCUMENT \ ID}{1} \frac{TECN}{1} \frac{COMMENT}{1} \frac{TCOMMENT}{1} e^+e^- \rightarrow e^- \rightarrow $
$ \begin{array}{ccc} 1 & \rho \pi \\ 2 & \pi (\pi \pi)_{S\text{-wave}} \\ 3 & \gamma \gamma \end{array} $ $ \begin{array}{ccc} \Gamma(\rho \pi) \times \Gamma(\gamma \gamma)/\Gamma_{\text{total}} \\ \frac{ALUE (\text{keV})}{<0.085} & 90 \\ <0.54 & 90 \end{array} $ $ \begin{array}{ccc} \Gamma(\pi(\pi \pi)_{S\text{-wave}})/\Gamma(\rho \pi) \\ \frac{ALUE}{<0.085} & 0 & \text{We do not use the fo} \end{array} $	Fraction (Γ_I/Γ) seen seen $\pi(1300) \ \Gamma(I)\Gamma(\gamma\gamma)/\Gamma(total)$ $\frac{\Gamma_1\Gamma_3/\Gamma}{\Gamma_1\Gamma_3/\Gamma}$ $\frac{I.\%}{O} \qquad \begin{array}{ccccccccccccccccccccccccccccccccccc$
$\begin{array}{ccc} 1 & \rho \pi \\ 2 & \pi (\pi \pi) \text{s-wave} \\ 3 & \gamma \gamma \end{array}$ $\Gamma(\rho \pi) \times \Gamma(\gamma \gamma) / \Gamma_{\text{total}}$ $\langle 0.085 & 90 \\ \langle 0.54 & 90 \end{array}$ $\langle 0.54 & 90 $ $\Gamma(\pi(\pi \pi) \text{s-wave}) / \Gamma(\rho \pi)$ χ_{LUE} $0 \bullet \bullet \text{We do not use the fo}$ 2.12 $\frac{3}{3} \text{Uses multichannel Altch}$	Fraction (Γ_I/Γ) seen seen $\pi(1300) \ \Gamma(i)\Gamma(\gamma\gamma)/\Gamma(total)$ $\frac{\Gamma_1\Gamma_3/\Gamma}{\Gamma_1}$ $\frac{\Gamma_1\Gamma_3/\Gamma}{\Gamma_2}$ $\frac{\Gamma_1\Gamma_3/\Gamma}{\Gamma_1}$ $\frac{\Gamma_1\Gamma_3/\Gamma}{\Gamma_2}$ $\frac{\Gamma_1\Gamma_3/\Gamma}{\Gamma_1}$ $\frac{\Gamma_1\Gamma_3/\Gamma}{\Gamma_2}$ $\frac{\Gamma_1\Gamma_3/\Gamma}{\Gamma_1}$ $\frac{\Gamma_1\Gamma_1}{\Gamma_1}$
$ \begin{array}{cccc} 1 & \rho \pi \\ 2 & \pi (\pi \pi) \text{s-wave} \\ 3 & \gamma \gamma \end{array} $ $ \begin{array}{cccc} \Gamma(\rho \pi) \times \Gamma(\gamma \gamma) / \Gamma_{\text{total}} \\ \text{ALUE (keV)} & \text{CL} \\ < 0.085 & 90 \\ < 0.54 & 90 \end{array} $ $ \begin{array}{cccc} \Gamma(\pi(\pi \pi) \text{s-wave}) / \Gamma(\rho \pi) \\ \text{ALUE} \\ \text{e. • • We do not use the fo} \\ 2.12 $	Fraction (Γ_I/Γ) seen seen $\pi(1300) \ \Gamma(i)\Gamma(\gamma\gamma)/\Gamma(total)$ $\frac{\Gamma_1\Gamma_3/\Gamma}{\Gamma_1\Gamma_3/\Gamma}$ $\frac{IX}{\Gamma_1\Gamma_3/\Gamma}$ O ACCIARRI 97T L3 $e^+e^- \rightarrow e^+e^- \rightarrow e^- \rightarrow$
1 $\rho\pi$ 2 $\pi(\pi\pi)s$ -wave 3 $\gamma\gamma$ 1 $(\rho\pi) \times \Gamma(\gamma\gamma)/\Gamma_{\text{total}}$ 2 (0.085) 3 (0.085) 4 (0.085) 5 (0.085) 6 (0.54) 7 $(\pi(\pi\pi)s$ -wave)/ $(\pi\rho\pi)$ 6 (0.085) 7 $(\pi(\pi\pi)s$ -wave)/ $(\pi\rho\pi)$ 7 $(\pi\pi\pi)s$ -wave) 8 (0.085) 8 (0.085) 8 (0.085) 9 (0.085) 8 (0.085) 9 (0.085) 8 (0.085) 9 (0.085) 8 (0.085) 9 (0.085) 8 (0.085) 9 (0.085) 8 (0.085) 9 (0.085) 8 (0.085) 9 (0.085) 8 (0.085) 8 (0.085) 9 (0.085) 8 (0.085) 9 (0.085) 8 (0.085) 9 (0.085) 8 (0.085) 9 $(0.08$	Fraction (Γ_I/Γ) seen seen $\pi(1300) \ \Gamma(i)\Gamma(\gamma\gamma)/\Gamma(total)$ $\Gamma_1\Gamma_3/\Gamma$ $\Gamma_1 \Gamma_3/\Gamma$ $\Gamma_2 \Gamma_3/\Gamma$ $\Gamma_3 \Gamma_4 \Gamma_5 \Gamma_5 \Gamma_5 \Gamma_5 \Gamma_5 \Gamma_5 \Gamma_5 \Gamma_5 \Gamma_5 \Gamma_5$
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Fraction (Γ_I/Γ) seen seen $\pi(1300) \Gamma(I)\Gamma(\gamma\gamma)/\Gamma(total)$ $\pi(1300) \Gamma(I)\Gamma(\gamma\gamma)/\Gamma(total)$ $\Gamma_I\Gamma_3/\Gamma$ Γ_I ACCIARRI 97T L3 $e^+e^- \rightarrow e^+e^- \pi^+\pi^-\pi^0$ ALBRECHT 97B ARG $e^+e^- \pi^+\pi^-\pi^0$ $e^+e^- \pi^+\pi^-\pi^0$ Poliowing data for averages, fits, limits, etc. • • • • • • • • • • • • • • • • • • •
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Fraction (Γ_I/Γ) seen seen $\pi(1300) \Gamma(I)\Gamma(\gamma\gamma)/\Gamma(total)$ $\Gamma_I\Gamma_3/\Gamma$ Γ_I
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Fraction (Γ_I/Γ) seen seen $\pi(1300) \ \Gamma(i)\Gamma(\gamma\gamma)/\Gamma(total)$ $T_1\Gamma_3/\Gamma$ $T_$
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Fraction (Γ_I/Γ) seen seen $\pi(1300) \Gamma(I)\Gamma(\gamma\gamma)/\Gamma(total)$ $T_1\Gamma_3/\Gamma$ $T_1\Gamma$
1 ρπ 2 π (ππ)s-wave 3 γγ Γ(ρπ) × Γ(γγ)/Γtotal (ALUE (keV) CL <0.085 90 <0.54 90 Γ(π(ππ)s-wave)/Γ(ρπ) (ALUE • • • We do not use the fo 2.12 3 Uses multichannel Altch and DANKOWYCH 81. ACCIARRI 97T PL B413 14 ALBRECHT 97B ZPHY C74 ALBRECHT 97B ZPHY C74 ABELE 96 PL 8380 48 BERTIN 97D PL 8414 22 BEELLIN 81 PR 7030 18 BELLIN 82 PRI. 48 166 BELLIN 82 PRI. 48 166 BELLIN 81 PR 2024 128 BELLIN 81 PR 2024 128	Fraction (Γ_I/Γ) seen seen $\pi(1300) \Gamma(I)\Gamma(\gamma\gamma)/\Gamma(total)$ $\Gamma_1\Gamma_3/\Gamma$ $\Gamma_1\Gamma_3/\Gamma$ COMMENT ID ACCIARRI 97T L3 $\Gamma_1\Gamma_3/\Gamma$ ACCIARRI 97T L3 Γ_2/Γ_1 DIGUMENT ID DOCUMENT ID TECN Γ_2/Γ_1 DIGUMING data for averages, fits, limits, etc. •• 3 AARON 81 RVUE AARON 81 RVUE AMBION-Bowler model (BOWLER 75). Uses data from DAUM 80 $\pi(1300) \text{ REFERENCES}$ 47 M. Acciari+ 469 + Hamacher, Hofmann+ 20 A. Bertin- 53 + Adomeit, Amsier+ 547 + Frabetti, Nanshin, Litkin+ 555 Berg, Chandlec, Chlangir+ Frabetti, Nanshin, Litkin+ (ROCH, MINN, FNAL) (REAS, BNL) 707 - Longacre 1007 - Longacre 1007 - Longacre - Dankowych+ (TNTO, BNL, CARL, MCGI, OHIO)

- OTHER RELATED PAPERS

K. Ackerstaff+ +Hamacher, Hofmann, Kirchoff+ (OPAL Collab.) (ARGUS Collab.)

ACKERSTAFF 97R ZPHY C75 593 ALBRECHT 95C PL B349 576 $a_2(1320)$

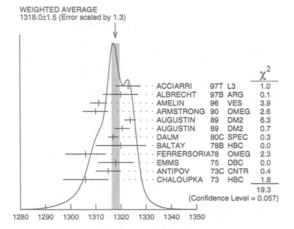
$$I^{G}(J^{PC}) = 1^{-(2++)}$$

a₂(1320) MASS

VALUE (MeV)

1318.1±0.6 OUR AVERAGE Includes data from the 4 datablocks that follow this one. Error includes scale factor of 1.1.

3π MOD								
VALUE (Me		EVT5		DOCUMENT ID				COMMENT
The data	in this blo	ck is include	ed	In the average p	orint	ed for a	previo	us datadiock.
1318.0±	1.5 OUR	AVERAGE	E	rror includes sc	ale fa	actor of	1.3. S	ee the ideogram below
1323 ±	4 ±3			ACCIARRI	97T	L3		$e^+e^-\rightarrow e^+e^-\pi^+\pi^-\pi^0$
1320 ±	7			ALBRECHT	97B	ARG		$e^{+}e^{-} \rightarrow \pi^{+}\pi^{-}\pi^{0}$
1311.3±	1.6 ± 3.0	72400		AMELIN	96	VES		$36 \pi^{-} p \rightarrow \pi^{+} \pi^{-} \pi^{0} n$
1310 ±	5			ARMSTRONG	90	OMEG	0	$ 300.0pp \rightarrow pp\pi^{+}\pi^{-}\pi^{0} $
1323.8±	2.3	4022		AUGUSTIN	89	DM2	±	$J/\psi \rightarrow \rho^{\pm} a_{2}^{\mp}$
1320.6±	3.1	3562		AUGUSTIN	89	DM2	0	$J/\psi \rightarrow \rho^0 a_2^0$
1317 ±	2	25000	1	DAUM	80C	SPEC	_	$63.94 \pi^- p \rightarrow 3\pi p$
320 ±1	10	1097	1	BALTAY	78B	нвс	+0	$15 \pi^+ p \rightarrow p4\pi$
1306 ±	8			FERRERSORIA	78	OMEG	_	$9 \pi^- p \rightarrow p 3\pi$
318 ±	7	1600	1	EMMS	75	DBC	0	$4 \pi^+ n \rightarrow \rho (3\pi)^0$
315 ±	5		1	ANTIPOV	73 C	CNTR	_	25,40 π ⁻ ρ →
								pηπ [—]
1306 ±		1580		CHALOUPKA			_	3.9 π ⁻ p
• • W	e do not u	se the follov	wir	g data for avera	iges,	fits, lim	its, et	c. • • •
1305 ±1	14			CONDO	93	SHF		$\gamma p \rightarrow \eta \pi^+ \pi^+ \pi^-$
1310 ±	2		1	EVANGELISTA	81	OMEG	-	$12 \pi^- p \rightarrow 3\pi p$
1343 ±1	11	490		BALTAY	78B	HBC	0	$15 \pi^+ p \rightarrow \Delta 3\pi$
1309 ±	5	5000		BINNIE	71	MMS	-	π ⁻ p near a ₂ thresh- old
1299 ±	6	28000		BOWEN	71	MMS	-	5 π ⁻ p
1300 ±	6	24000		BOWEN	71	MMS	+	5 π ⁺ p
1309 ±	4	17000		BOWEN	71	MMS	-	7 π ⁻ p
1306 ±	4	941		ALSTON	70	нвс	+	$7.0 \pi^+ p \rightarrow 3\pi p$
¹ From	a fit to J	$P=2^+ \rho \pi$	P	artial wave.				



 $a_2(1320)$ mass, 3π mode (MeV)

$K^{\pm}K_{S}^{0}$ MODE

VALUE	íMi	·V1	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
				ed in the average	print	ed for a	previo	us datablock.
		0.7 OUR /	WEDACE					
1319	±	5	4700	^{1,3} CLELAND	82B	SPEC	+	$50 \pi^{T} p \rightarrow K_{S}^{G} K^{T}$
1324	±	6	5200 ²	^{2,3} CLELAND	82B	SPEC	-	50 $\pi^+ p \to K_S^0 K^+$ 50 $\pi^- p \to K_S^0 K^-$
1320	±	2	4000	CHABAUD	80	SPEC	-	17 $\pi^- A \rightarrow K_S^0 K^- A$
1312	±	4	11000	CHABAUD	78	SPEC	-	$9.8 \pi^{-} p \rightarrow K^{-} K_{S}^{0} p$
1316	±	2	4730	CHABAUD	78	SPEC	-	$18.8 \pi^{-} p \rightarrow K^{-} K_{S}^{0} p$
1318	±	1	2	^{2,4} MARTIN	78 D	SPEC	_	$10 \pi^- p \rightarrow K_S^0 K^-$
1320	±	2	2724	MARGULIE	76	SPEC	-	$23 \pi^- p \rightarrow K^- K_S^0$
1313	±	4	730	FOLEY	72	CNTR	-	$20.3 \pi^{-} p \rightarrow K^{-} K_{S}^{0} p$
1319	±	3	1500	⁴ GRAYER	71	ASPK	-	17.2 π p → K K ⁰ p

126 ±11

11000

CHABAUD

78 SPEC -

• We do not us	se the folk	owing data for avera	iges,	fits, lim	lts, etc	. • • •
330 ±11	1000	2,3 CLELAND		SPEC	+	$30 \pi^+ p \rightarrow K_S^0 K^+ p$
324 ± 5	350	HYAMS			+	12.7 $\pi^+ p \rightarrow \kappa^+ \kappa^0_{cp}$
² From a fit to J ¹						3.
³ Number of even ⁴ Systematic error						
ηπ MODE						
VALUE (MeV) The data in this blo	<u>EVT5</u> ck is inclu	DOCUMENT ID Ided In the average				
1318.0±1.5 OUR A	VERAGE					
1317 ±1 ±2		THOMPSON	97	MPS		18 $\pi^- p \rightarrow \eta \pi^- p$
1315 ±5 ±2		5 AMSLER		CBAR		$0.0 \overline{p} p \to \pi^0 \pi^0 \eta$
1325.1 ± 5.1 1317.7 ± 1.4 ± 2.0		AOYAGI BELADIDZE		BKEI VES		$\pi^- p \rightarrow \eta \pi^- p$ $37\pi^- N \rightarrow \eta \pi^- N$
1323 ±8	1000	6 KEY		OSPK	_	$6\pi^-\rho \rightarrow \rho\pi^-\eta$
• • • We do not u	se the follo	owing data for avera	ages,	fits, lim	lts, et	2
1324 ±5		ARMSTRONG			0	$\overline{p} p \to \pi^0 \eta \eta \to 6\gamma$
1336.2±1.7 1330.7±2.4	2561 1653	DELFOSSE DELFOSSE	81 81	SPEC SPEC	+	$\pi^{\pm} p \rightarrow p \pi^{\pm} \eta$ $\pi^{\pm} p \rightarrow p \pi^{\pm} \eta$
1330.7 ± 2.4 1324 ±8	6200	6,7 CONFORTO			_	$\pi^- p \rightarrow p \pi^- \eta$ $6 \pi^- p \rightarrow p M M^-$
		MeV corresponds to				
6 Error Includes 5	MeV syst	ematic mass-scale e	rror.			
⁷ Missing mass w	ith enriche	ed MMS = $\eta \pi^-$, η	= 2	γ.		
η'π MODE						
VALUE (MeV)		DOCUMENT				DMMENT
ine data in this blo	ck is Inclu	ided in the average	print	ed for a	previo	us datablock.
1327.0±10.7		BELADIDZ	E 9	93 VES	3	$7\pi^- N \rightarrow \eta' \pi^- N$
		- (4000) 14			_	
*		a₂ (1320) W	ו טוי	п		
37 MODE VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
104.1± 2.0 OUR						
105 ±10 ±11		ACCIARRI	97T	L3		$e^{+}e^{-}_{e^{+}e^{-}\pi^{+}\pi^{-}\pi^{0}}$
120 ±10		ALBRECHT	97B	ARG		e+e- →
103.0± 6.0± 3.3	72400	AMELIN	96	VES		$\begin{array}{c} e^+e^-\pi^+\pi^-\pi^0 \\ 36 \pi^-\rho \rightarrow \end{array}$
					_	$\pi^+\pi^-\pi^0n$
120 ±10		ARMSTRONG	90	OMEG	U	$\begin{array}{c} 300.0pp \rightarrow \\ pp\pi^{+}\pi^{-}\pi^{0} \end{array}$
107.0± 9.7	4022	AUGUSTIN	89	DM2	±	$J/\psi \rightarrow \rho^{\pm} s_{2}^{\mp}$
118.5 ± 12.5	3562	AUGUSTIN	89	DM2	0	$J/\psi \rightarrow \rho^0 a_2^0$
97 ± 5		8 EVANGELISTA			-	$12 \pi^- p \rightarrow 3\pi p$
96 ± 9 110 ±15	25000 1097	⁸ DAUM ⁸ BALTAY		SPEC HBC	- +0	$63,94 \pi^- p \rightarrow 3\pi p$ $15 \pi^+ p \rightarrow p4\pi$
110 ±15	1600	B EMMS	75	DBC	0	$4 \pi^+ n \rightarrow p(3\pi)^0$
122 ±14	1200	8,9 WAGNER	75		0	$7 \pi^+ \rho \rightarrow$
115 ±15		8 ANTIPOV.	73C	CNTR	_	$\Delta^{++}(3\pi)^0$ 25,40 $\pi^- p \to$
~•			. 50			$p\eta\pi^-$
99 ±15	1580	CHALOUPKA			-	3.9 π ⁻ p
105 ± 5	28000	BOWEN		MMS	_	5 π ⁻ ρ 5 π ⁺ ρ
99 ± 5 103 ± 5	24000 17000	BOWEN BOWEN	71	MMS MMS	+	5π' P 7π ⁻ P
		lowing data for aver				
120 ±40		CONDO	93	SHF		$\gamma \rho \rightarrow \eta \pi^+ \pi^+ \pi^-$
115 ±14	490	BALTAY		нвс	0	$15 \pi^+ \rho \rightarrow \Delta 3\pi$
72 ±16	5000	BINNIË	71	MMS	-	π p near a ₂ thresh- old
	941	ALSTON	70	HBC	+	$7.0 \pi^+ \rho \rightarrow 3\pi \rho$
79 ±12	$P = 2 + \mu$					
8 From a fit to J		us to AF/. /All son t	he n	ote with	the K	(*(892) mass.
	larged by	us to 41 / V 14; see t				
⁸ From a fit to J ⁹ Width errors er K [±] K ⁰ ₅ AND η ₂		S				
⁸ From a fit to <i>J</i> ⁹ Width errors er K [±] K ⁰ ₅ AND 7 <u>VALUE (MeV)</u>	MODE	S DOCUMENT	ID	_		
⁸ From a fit to J ⁹ Width errors er $K^{\pm}K_{5}^{0}$ AND η_{7} <u>VALUE (MeV)</u> 107 \pm 5 OUR E	MODE	S DOCUMENT		 2 datab	locks 1	that follow this one.
8 From a fit to J 9 Width errors er $^{K\pm}$ K 5 AND 77 VALUE (MeV) 107 $^{\pm}$ 5 OUR E 110.3 $^{\pm}$ 1.7 OUR A	MODE	S DOCUMENT		 2 datab	locks 1	that follow this one.
8 From a fit to J 9 Width errors er $K^{\pm}K^0_5$ AND $\eta \tau$ $VALUE$ (MeV) 107 ± 5 OUR E 110.3 ± 1.7 OUR A $K^{\pm}K^0_5$ MODE	MODE	DOCUMENT Includes data from	the			
SFrom a fit to J Width errors er K± K°S AND 77 VALUE (MeV) 107 ±5 OUR E 110.3±1.7 OUR A K± K°S MODE VALUE (MeV)	STIMATE VERAGE	S DOCUMENT	the	TECN	<u>CHG</u>	COMMENT
⁸ From a fit to J ⁹ Width errors er K± K ⁹ _S AND η2 VALUE (MeV) 107 ±5 OUR E 110.3±1.7 OUR A K± K ⁹ _S MODE VALUE (MeV) The data in this bil	STIMATE VERAGE EVTS ock is incl	DOCUMENT ID Unded in the average	the print	<u>TECN</u> ted for a	<u>CHG</u>	<u>COMMENT</u> ous datablock,
8 From a fit to J 9 Width errors er K± K°S AND 77 VALUE (MeV) 107 ±5 OUR E 110.3±1.7 OUR A K± K°S MODE VALUE (MeV) The data in this bi 109.8± 2.4 OUR A 112 ±20	STIMATE VERAGE EVTS DCK IS INCI	DOCUMENT ID Includes data from DOCUMENT ID uded in the average 0,11 CLELAND	print 828	TECN ted for a	<u>сна</u> previo	<u>COMMENT</u> ous datablock,
SFrom a fit to J 9 Width errors er K± K°S AND 77 VALUE (MeV) 107 ±5 OUR E 110.3±1.7 OUR A K± K°S MODE VALUE (MeV)	STIMATE VERAGE EVTS DCK IS INCI	DOCUMENT ID Unded in the average	print 828 828	TECN ted for a	<u>CHG</u> previo	COMMENT Dus datablock. $50 \pi^+ p \rightarrow K_S^0 K^+ p$

	BELADID	ZE.	93 VE	S	$37\pi^-N \rightarrow n'\pi^-N$
	DOCUMEN	T ID	TE	<u> </u>	COMMENT
s not unfolded	d.				
					•
6200	15 CONFORTO				•• • • • •
				٥	
	14 THOMPSON	97	MPS		18 π ⁻ p → nπ ⁻ p
t use the foll	lowing data for ave	rages	, fits, lin	nits,	
1000	KEY				
1653	DELFOSSE	81	SPEC	_	$\pi^{\pm} p \rightarrow p \pi^{\pm} \eta$
2561		81	SPEC	+	$\pi^{\pm} p \rightarrow p \pi^{\pm} p$
					$37\pi^-N \rightarrow n\pi^-N$
HEIGH		941	CBAR		$0.0 \overline{p}p \rightarrow \pi^0 \pi^0 \eta$
R AVERAGE					
block is inclu	ded in the averag	e prin	ted for a	pre	vious datablock.
<u>EVT5</u>					
vents evaluat	ed by us.	the n	ote with	the	K*(892) mass.
					K+ K ⁰ P
350	HYAMS	78	ASPK	+	
1000 10	D,11 CLELAND	825	SPEC	+	$30 \pi^+ p \rightarrow K_S^0 K^+$
	_	rages	, fits, lin	ılts,	
			•		$17.2 \pi^{-} p \rightarrow K^{-} K_{5}^{0} p$
	12				K-K0 p
730	FOLEY	72	CNTR	_	20.3 π ⁻ p →
2724	12 MARGULIE	76	SPEC	_	23 π p → K K K 0
10	^{0,12} MARTIN	780	SPEC	_	10 π ⁻ ρ → K ⁰ _S K ⁻
					K-K0p
	2724 730 1500 It use the foll 1000 10 350 It is the foll 250 24 pevents evaluate enlarged by EVTS block is inclusive inclu	1500 FOLEY 1500 12 GRAYER at use the following data for ave 1000 10,11 CLELAND 350 HYAMS by $J^P = 2^+$ partial wave. Events evaluated by us. Is enlarged by us to $4\Gamma/\sqrt{N}$; see 1000 10,11 cleaning to I^0 and I^0 and I^0 block is included in the average 13 AMSLER BELADIDZE 2561 DELFOSSE 1653 DELFOSSE 1653 DELFOSSE 1000 KEY at use the following data for ave 14 THOMPSON ARMSTRON: 6200 15 CONFORTO atticerror of 2 NeV corresponds is not unfolded. Is with enriched MMS = $\eta \pi^-$.	2724 12 MARGULIE 76 730 FOLEY 72 1500 12 GRAYER 71 1500 10,11 CLELAND 82e 350 HYAMS 78 150 $J^P = 2^+$ partial wave. 150 Partial wave. 150 DOCUMENT 10	2724 12 MARGULIE 76 SPEC 730 FOLEY 72 CNTR 1500 12 GRAYER 71 ASPK of use the following data for averages, fits, lim 1000 10,11 CLELAND 828 SPEC 350 HYAMS 78 ASPK of $J^P = 2^+$ partial wave. Wents evaluated by us. is enlarged by us to $4\Gamma/\sqrt{N}$; see the note with block is included in the average printed for a RAVERAGE 13 AMSLER 94D CBAR BELADIDZE 93 VES 2561 DELFOSSE 81 SPEC 1000 KEY 73 OSPK of use the following data for averages, fits, lim 14 THOMPSON 97 MPS ARMSTRONG 93C E760 6200 15 CONFORTO 73 OSPK at lice error of 2 MeV corresponds to the spread is not unfolded. Is with enriched MMS = $\eta \pi^-$, $\eta = 2\gamma$.	2724 12 MARGULIE 76 SPEC $-$ 730 FOLEY 72 CNTR $-$ 1500 12 GRAYER 71 ASPK $-$ of use the following data for averages, fits, limits, 1000 10,11 CLELAND 828 SPEC $+$ 350 HYAMS 78 ASPK $+$ 0 $J^P = 2^+$ partial wave. 10 ASP SPEC $+$ 350 HYAMS 78 ASPK $+$ 10 ASP SPEC $+$ 350 HYAMS 78 ASPK $+$ 10 ASP SPEC $+$ 350 HYAMS 78 ASPK $+$ 10 ASP SPEC $+$ 350 BELADIDZE 93 VES 11 AMSLER 940 CBAR 12 BELADIDZE 93 VES 13 AMSLER 940 CBAR 14 BELADIDZE 93 VES 1551 DELFOSSE 81 SPEC $+$ 1653 DELFOSSE 81 SPEC $+$ 1654 DELFOSSE 81 SPEC $+$ 1655 DELFOSSE 81 SPEC $+$ 1656 DELFOSSE 81 SPEC $+$ 1657 DELFOSSE 81 SPEC $+$ 1658 DELFOSSE 81 SPEC $+$ 1659 DELFOSSE 81 SPEC $+$ 1650 OKEY 73 OSPK $-$ 17 THOMPSON 97 MPS ARMSTRONG 93C E760 0 18 CONFORTO 73 OSPK $-$ 28 ARMSTRONG 93C E760 0 18 CONFORTO 73 OSPK $-$ 28 ARMSTRONG 93C E760 0 18 CONFORTO 73 OSPK $-$ 28 ARMSTRONG 93C E760 0 18 CONFORTO 73 OSPK $-$ 28 ARMSTRONG 93C E760 0 18 CONFORTO 73 OSPK $-$ 28 ARMSTRONG 93C E760 0 18 CONFORTO 73 OSPK $-$ 29 ARMSTRONG 93C E760 0 19 COMMENT 10 TECN

	≥₂(1320) DECAY MODES						
	Mode	Fraction (Γ_I/Γ)	Scale factor/ Confidence level				
Γ ₁	ρπ	(70.1±2.7) %	S=1.2				
Γ_2^-	$\eta\pi$	(14.5±1.2) %					
$\overline{\Gamma_3}$	$\omega \pi \pi$	(10.6±3.2) %	S=1.3				
Γ ₄ Γ ₅	κ Κ	(4.9±0.8) %					
Γ5	$\eta'(958)\pi$	$(5.3\pm0.9)\times10^{-3}$	1				
Γ ₆	$\pi^{\pm}\gamma$	$(2.8\pm0.6)\times10^{-3}$	3				
Γ7	$\gamma \gamma$	$(9.4\pm0.7)\times10^{-6}$					

CONSTRAINED FIT INFORMATION

< 8

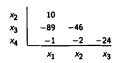
< 2.3

% $\times 10^{-7}$ CL=90%

CL=90%

An overall fit to 5 branching ratios uses 18 measurements and one constraint to determine 4 parameters. The overall fit has a χ^2 = 9.3 for 15 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\langle \delta x_i \delta x_j \rangle / (\delta x_i \cdot \delta x_j)$, in percent, from the fit to the branching fractions, $x_i \equiv \Gamma_i / \Gamma_{\text{total}}$. The fit constrains the x_i whose labels appear in this array to sum to one.

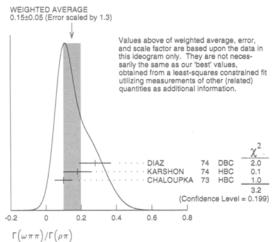


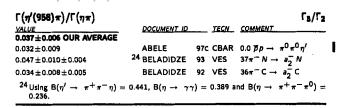
a2(1320) PARTIAL WIDTHS

Γ(π [±] γ) VALUE (keV)	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT	Γ ₆
295± 60	CIHANGIR	82	SPEC	+	200 π ⁺ A	
• • • We do not use the following	data for average	s, flt	s, limits,	etc. •	• •	
461±110	MAY	77	SPEC	±	9.7 γA	

$\Gamma(\gamma\gamma)$						Γ7
VALUE (keV)	EV/TE	DOCUMENT ID	TEC	N CUC	COMMENT	٠,
1.00±0.06 OUR AV	<u>EVTS</u> /FRAGE	DOCUMENT 10	<u> </u>	.n cno	COMMENT	
0.98±0.05±0.09		ACCIARRI	97⊤ L3		e+e- →	1
					$e^+e^-\pi^+$	$\pi^{-}\pi^{0}$
$0.96 \pm 0.03 \pm 0.13$		ALBRECHT	978 AR	G	$e^+e^- \rightarrow e^+e^-\pi^+$	0 I
$1.26 \pm 0.26 \pm 0.18$	36	BARU	90 MD	1	$e^+e^- \rightarrow$	" "
		OFLIDEND	00- 65		$e^{+}e^{-}\pi^{+}$	$\pi - \pi^0$
$1.00\pm0.07\pm0.15$	415	BEHREND	90c CEI	LL 0	$\begin{array}{c} e^+e^- \rightarrow \\ e^+e^-\pi^+ \end{array}$	- _π _π 0
$1.03 \pm 0.13 \pm 0.21$		BUTLER	90 MR	K2	e+e- → .	
101 0 14 0 00	oe.	OFCT	00 147	`E	e ⁺ e ⁻ π ⁻	$-\pi^{-}\pi^{0}$
$1.01 \pm 0.14 \pm 0.22$	85	OEST	90 JAI	<i>)</i> E	e+ e → π0	n
$0.90 \pm 0.27 \pm 0.15$	56 ¹	¹⁶ ALTHOFF	86 TA	SS 0		$^+e^-3\pi$
$1.14 \pm 0.20 \pm 0.26$	1	^{L7} ANTREASYAI	186 CB	AL O	e+e- → 0	
					$e^+e^-\pi^0$	
1.06 ± 0.18 ± 0.19		BERGER	84c PL1		_e+e- → e	1 e 3π
• • • We do not u			rages, iits	, nants, e	ас.	
$0.81 \pm 0.19 ^{+0.42}_{-0.11}$	35	¹⁶ BEHREND	83B CE	LL 0	$e^+e^- \rightarrow e$	$^{+}e^{-}3\pi$
0.77±0.18±0.27	22 1	17 EDWARDS	82F CB	AL 0	e+e- →	
					$e^+e^-\pi^0$	η
16 From $\rho\pi$ decay	mode.					
17 From $\eta\pi^0$ deca						
r(4\						-
Γ(e+e-)						Гэ
VALUE (eV)	<u>CL%</u>	DOCUMENT	· ID		COMMENT	
<25	90	VOROBYE	V 88	ND .	$e^+e^- \rightarrow \pi^0\tau$	7
	22	(1320) Γ(I)Γ(·	γγ)/Γ(tα	otal)		
F/V77 F/	\ /F					F . F . /F
$\Gamma(K\overline{K}) \times \Gamma(\gamma\gamma)$	/)/ [‡] total					$\Gamma_4\Gamma_7/\Gamma$
VALUE (keV)		DOCUMENT			COMMENT	
0.126±0.007±0.02	18	¹⁸ ALBRECH	T 90G	ARG	e+e- → ++ ×+ +	<u>-</u>
• • • We do not u	se the follow	ving data for ave	rages, fits	, limits, e	etc. • • •	`
		19 ALBRECH	_			
			1 700	ANG	e+e e+e- K+1	~ -
$0.081 \pm 0.006 \pm 0.02$	• •	ACOMEON			e e ^ /	
					e'e n'r	•
18 Using an incohe	erent backgr	ound.			e'e K'	•
¹⁸ Using an incohe	erent backgr	ound.			e'e x''	·
¹⁸ Using an incohe	erent backgr nt backgrou	ound. nd.	HING R	ATIOS		·
18 Using an incohe 19 Using a coherer	erent backgr nt backgrou	ound.	HING R	ATIOS		
¹⁸ Using an incohe	erent backgr nt backgrou	ound. nd.				Γ ₄ /Γ ₁
18 Using an incohe 19 Using a coherer Γ(ΚΚ)/Γ(ρπ)	erent background background background background background background background background background backgr	ound. nd.			CHG COMMEN	Γ ₄ /Γ ₁
18 Using an incohe 19 Using a coherer Γ(KK)/Γ(ρπ) VALUE 0.070±0.012 OUR	erent background background background background background background background background background backgr	DOCUMENT	ID	<u>TECN</u>		Γ ₄ /Γ ₁
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18 Using an incohe 19 Using a coherer Γ(KK)/Γ(ρπ) MALUE 0.070±0.012 OUR 0.078±0.017 • • We do not u 0.056±0.014 0.097±0.018 0.06±0.03	EVTS FIT see the follow	DOCUMENT CHABAUI Wing data for ave 20 CHALOUF 20 ALSTON- 20 ABRAMO	78 rages, fits PKA 73 71 VI 708	TECN RVUE i, limits, o HBC HBC HBC	CHG COMMEN etc. • • • - 3.9 π ⁻ μ + 7.0 π ⁺ μ - 3.93 π ⁻	Γ4/Γ1
18 Using an incohe 19 Using a coherer Γ(KK)/Γ(ρπ) VALUE 0.070±0.012 OUR 0.078±0.017 • • We do not u 0.056±0.014 0.097±0.018 0.06±0.03 0.054±0.022	FIT EVTS FIT 50 113	DOCUMENT CHABAUI Ming data for ave 20 CHALOUF 20 ALSTON- 20 ABRAMO 20 CHUNG	78 rages, fits PKA 73	TECN RVUE i, limits, o HBC HBC	<u>CHG</u> <u>COMMEN</u> etc. • • • - 3.9 π ⁻ μ + 7.0 π ⁺ μ	Γ4/Γ1
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18 Using an incohe 19 Using a coherer Γ(KK)/Γ(ρπ) MALUE 0.070±0.012 OUR 0.078±0.017 • • • We do not u 0.056±0.014 0.097±0.018 0.06±0.03 0.054±0.022 20 Included in CH/ Γ(ηπ)/[Γ(ρπ) -	erent background back	DOUMD. DOCUMENT CHABAUL Wing data for ave 20 CHALOUI 20 ALSTON- 20 ABRAMO 20 CHUNG review. - 「(KK)]	7 10 78 rages, fits PKA 73 71 VVI 708 68	TECN RVUE s, limits, s HBC HBC HBC HBC	CHG COMMEN etc. • • • - 3.9 π ⁻ μ + 7.0 π ⁺ μ - 3.93 π ⁻ - 3.2 π ⁻ μ Γ ₂ /(Γ ₁ -	Γ ₄ /Γ ₁
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18 Using an incohe 19 Using a coherer Γ(KK)/Γ(ρπ) <u>WALUE</u> 0.070±0.012 OUR 0.078±0.017 • • • We do not u 0.056±0.014 0.097±0.018 0.06 ±0.03 0.054±0.022 20 included in CH/Γ(ηπ)/[Γ(ρπ) -	erent background the	DOUMD. DOCUMENT CHABAUL Wing data for ave 20 CHALOUI 20 ALSTON- 20 ABRAMO 20 CHUNG review. - 「(KK)]	7 10 78 rages, fits PKA 73 71 VVI 708 68	TECN RVUE s, limits, s HBC HBC HBC HBC	CHG COMMEN etc. • • • - 3.9 π ⁻ μ + 7.0 π ⁺ μ - 3.93 π ⁻ - 3.2 π ⁻ μ Γ ₂ /(Γ ₁ -	Γ ₄ /Γ ₁ , , , , , , , , , , , , , , , , , , ,
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18 Using an incohe 19 Using a coherer 19 Using a coheren 19 Using 19	erent background the	DOCUMENT DOCUMENT CHABAUL Wing data for ave 20 CHALOUF 20 ALSTON- 20 ABRAMO 20 CHUNG review. - \(\(\kappa	7 1D 7 78 rages, fits PKA 73 71 VI 70B 68	RVUE i, limits, o HBC HBC HBC HBC HBC	chg COMMEN 3.9 π ⁻ μ 7.0 π ⁺ μ 3.93 π ⁻ 3.2 π ⁻ μ Γ ₂ /(Γ ₁ - Chg COMMEN	Γ4/Γ1 7 P P P P P
18 Using an incohe 19 Using a coherer 19 Using a coheren 19 Using a c	erent background back	DOCUMENT CHABAUL Wing data for ave 20 CHALOUF 20 ALSTON- 20 ABRAMO 20 CHUNG review. - \(\(\kappa \kap	7 1D 7 78 rages, fits PKA 73 71 VI 70B 68	TECN. RVUE i, limits, i HBC HBC HBC HBC HBC	CHG COMMEN ctc. • • • • - 3.9 π - μ - 7.0 π + μ - 3.93 π - 3.2 π - μ Γ2/(Γ1- CHG COMMEN ± 0.0 pp	Γ ₄ /Γ ₁ Τ
18 Using an incohe 19 Using a coheren 19 Using a c	erent background the	DOCUMENT CHABAUL Wing data for ave 20 CHALOUF ABRAMO 20 ABRAMO 20 CHUNG review. - 「(KK)] DOCUMENT BARNHAI	72 M 71	TECN RVUE , limits, (HBC HBC HBC HBC HBC HBC	etc. • • • - 3.9 $\pi^- \mu$ + 7.0 $\pi^+ \mu$ - 3.93 π^- - 3.2 $\pi^- \mu$ $\Gamma_2/(\Gamma_1$ - CHG COMMEN \pm 0.0 F_P + 3.7 $\pi^+ \mu$	Γ ₄ /Γ ₁ 7
18 Using an incohe 19 Using a coherer Γ(KK)/Γ(ρπ) MALUE 0.070±0.012 OUR 0.078±0.017 • • • We do not u 0.056±0.014 0.097±0.018 0.06±0.03 0.054±0.022 20 Included in CH. Γ(ηπ)/[Γ(ρπ)- MALUE 0.162±0.012 OUR 0.140±0.028 OUR 0.15 ±0.04 Γ(ηπ)/Γ(ρπ) MALUE	erent background the background for the background	DOCUMENT CHABAUL Wing data for ave 20 CHALOUF 20 ALSTON- 20 ABRAMO 20 CHUNG review. - \(\(\kappa \kap	72 M 71	TECN RVUE , limits, (HBC HBC HBC HBC HBC HBC	CHG COMMEN ctc. • • • • - 3.9 π - μ - 7.0 π + μ - 3.93 π - 3.2 π - μ Γ2/(Γ1- CHG COMMEN ± 0.0 pp	Γ ₄ /Γ ₁ 7
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18 Using an incohe 19 Using a coheren 19 Using a c	erent background the	DOCUMENT CHABAUL POCUMENT CHABAUL Wing data for ave 20 CHALOUS 20 ALSTON- 20 ABRAMO 20 CHUNG review. - \(\(\kappa \kappa	72 M 71	TECN RVUE ,, limits, of HBC HBC HBC HBC HBC TECN	CHG COMMEN - 3.9 π - μ + 7.0 π + μ - 3.93 π - μ - 3.2 π - μ Γ2/(Γ1+ CHG COMMEN ± 0.0 pp + 3.7 π + μ CHG COMMEN	Γ ₄ /Γ ₁ , , , , , , , , , , , , , , , , , , ,
18 Using an incohe 19 Using a coheren 19 Using a c	erent background the	DOCUMENT ESPIGAT BARNAI DOCUMENT CHABAUL VING data for ave 20 CHALOUI 20 ALSTON- 20 ABRAMO 20 CHUNG review. FORINO	72 Y 71 T /D 76	TECN RVUE i, limits, of HBC	CHG COMMEN ctc. • • • • - 3.9 π - μ - 3.93 π - 3.2 π - μ - 3.2 π - μ CHG COMMEN ± 0.0 pp + 3.7 π + μ CHG COMMEN	Γ ₄ /Γ ₁ , , , , , , , , , , , , , , , , , , ,
18 Using an incohe 19 Using a coherer 19 Using a coherer 19 Using a coherer 29 Using a coherer 29 Using a coherer 29 Using a coherer 29 Using a coherer 20 Using 20	erent background the background	DOCUMENT ESPIGAT BARNHAI DOCUMENT CHABAUL VING data for ave 20 CHALOUG 20 ALSTON- 20 ABRAMO 20 CHUNG review. - \(\(\epsilon \) \(\text{T} \) \(\text{T} \) DOCUMENT FORINO ANTIPOV	76 73	TECN RVUE i, limits, i HBC HBC HBC HBC HBC TECN HBC HBC HBC HBC HBC	CHG COMMEN - 3.9 π - μ + 7.0 π + μ - 3.93 π - μ - 3.2 π - μ Γ2/(Γ1+ CHG COMMEN ± 0.0 pp + 3.7 π + μ CHG COMMEN	Γ ₄ /Γ ₁ γ γ γ γ γ γ γ γ γ γ γ γ γ γ γ γ γ γ
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18 Using an incohe 19 Using a coherer 19 Using a coherer 19 Using a coherer 29 Using a coherer 29 Using a coherer 29 Using a coherer 29 Using a coherer 20 Using 20	erent background the background	DOCUMENT CHABAUL MING data for ave 20 CHALOUF 20 ABRAMO 20 CHUNG review. - \(\(\kappa	71 70 76 73 PKA 73 71	TECN RVUE I, limits, I HBC HBC HBC HBC TECN HBC HBC HBC HBC HBC HBC HBC H	CHG COMMEN etc. • • • - 3.9 $\pi^- \mu$ + 7.0 $\pi^+ \mu$ - 3.93 π^- - 3.2 $\pi^- \mu$ $\frac{\Gamma_2}{\Gamma_1} = \frac{\Gamma_2}{\Gamma_2} = \frac{\Gamma_2}{\Gamma_1} = \frac{\Gamma_2}{\Gamma_2} = \Gamma_$	Γ ₄ /Γ ₁
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18 Using an incohe 19 Using a coheren 19 Using a c	2(1) EVTS FIT EVTS see the follow 113 ABAUD 78 + Γ(ηπ) + EVTS AVERAGE 52 149 167 15	DOCUMENT ESPIGAT BARNHAI DOCUMENT CHABAUL 20 CHALOUI 20 ALSTON- 20 ABRAMO 20 CHUNG review. FORINO ANTIPOV CHALOUI ALSTON- BOECKM	72 Y 71 Y 72 Y 74 ANN 70 68	TECN RVUE i, limits, i HBC	CHG COMMEN etc. • • • • • • • • • • • • • • • • • • •	Γ ₄ /Γ ₁ , , , , , , , , , , , , , , , , , ,
18 Using an incohe 19 Using a coherer 19 Using a coherer 19 Using a coherer 29 Using a coherer 29 Using a coherer 29 Using a coherer 29 Using a coherer 20 Using a coheren 20 Using a c	2(1) EVTS FIT EVTS see the follow 113 ABAUD 78 + Γ(ηπ) + EVTS AVERAGE 52 149 167 15	DOCUMENT ESPIGAT BARNHAI DOCUMENT CHABAUL VING data for ave 20 CHALOUF 20 ALSTON- 20 ABRAMO 20 CHUNG review. FORINO ANTIPOV CHALOUF ALSTON- BOECKM ASCOLI	72 Y 71 Y 72 Y 74 ANN 70 68	TECN RVUE i, limits, i HBC	chc commen etc. • • • • $3.9 \pi^- \mu$ $- 3.93 \pi^-$ $- 3.2 \pi^- \mu$ $- 3.2 \pi^- \mu$ $- 3.7 \pi^+ \mu$ chg commen $\pm 0.0 pp$ $+ 3.7 \pi^+ \mu$ $- 40 \pi^- p$ $- 3.9 \pi^- \mu$ $+ 7.0 \pi^+ \mu$ $+ 5.0 \pi^+ \mu$	Γ ₄ /Γ ₁ 7
18 Using an incohe 19 Using a coherer 19 Using a coherer 19 Using a coherer 29 Using a coherer 29 Using a coherer 29 Using a coherer 20 Using a coherer 20 Using a coheren 20 Using a c	2(1) EVTS FIT AVERAGE 52 113 ABAUD 78 + Γ(ηπ) + EVTS FIT AVERAGE 52 149 167 155 22	DOCUMENT CHABAUL MING data for ave 20 CHALOUI 20 ALSTON- 20 ABRAMO 20 CHUNG review. - \(\(\kappa \ka	72 M 71 76 73 74 73 71 71 71 71 71 70 68 68 68 68	TECN RVUE i, limits, i HBC	CHG COMMEN 2. 3.9 $\pi^ \mu^-$ 2. 3.9 $\pi^ \mu^-$ 3.9 $\pi^ \mu^-$ 3.9 $\pi^ \mu^-$ 3.2 $\pi^ \mu^-$ 3.2 $\pi^ \mu^-$ 4. 0.0 μ^- 4. 0.0 μ^- 5. 0.0 π^- 7. 0.0 π^+ 4. 0.0 π^- 3.7 π^+ 4. 0.0 π^- 3.9 π^- 4. 0.0 π^- 3.9 π^- 4. 0.0 π^- 3.9 π^- 4. 0.0 π^- 5. 0.0 π^+ 5. 0.0 π^+ 5. 0.0 π^+ 5. 0.0 π^+ 7. 0.0 π^+ 7. 0.0 π^+ 7. 0.0 π^+ 9. 0.0 π^-	Γ ₄ /Γ ₁ Γ ₂ /Γ ₁ Γ ₂ /Γ ₁
18 Using an incohe 19 Using a coherer 19 Using a coherer 19 Using a coherer 29 Using a coherer 29 Using a coherer 29 Using a coherer 29 Using a coherer 20 Using 20	2(1) EVTS FIT AVERAGE 52 113 ABAUD 78 + Γ(ηπ) + EVTS FIT AVERAGE 52 149 167 155 22	DOCUMENT CHABAUL MING data for ave 20 CHALOUI 20 ALSTON- 20 ABRAMO 20 CHUNG review. - \(\(\kappa \ka	72 M 71 76 73 74 73 71 71 71 71 71 70 68 68 68 68	TECN RVUE i, limits, i HBC	CHG COMMEN 2. 3.9 $\pi^ \mu^-$ 2. 3.9 $\pi^ \mu^-$ 3.9 $\pi^ \mu^-$ 3.9 $\pi^ \mu^-$ 3.2 $\pi^ \mu^-$ 3.2 $\pi^ \mu^-$ 4. 0.0 μ^- 4. 0.0 μ^- 5. 0.0 π^- 7. 0.0 π^+ 4. 0.0 π^- 3.7 π^+ 4. 0.0 π^- 3.9 π^- 4. 0.0 π^- 3.9 π^- 4. 0.0 π^- 3.9 π^- 4. 0.0 π^- 5. 0.0 π^+ 5. 0.0 π^+ 5. 0.0 π^+ 5. 0.0 π^+ 7. 0.0 π^+ 7. 0.0 π^+ 7. 0.0 π^+ 9. 0.0 π^-	Γ ₄ /Γ ₁ 7
18 Using an incohe 19 Using a coherer 19 Using a coherer 19 Using a coherer 29 Using a coherer 29 Using a coherer 29 Using a coherer 20 Using a coherer 20 Using a coheren 20 Using a c	2(1) EVTS FIT AVERAGE 52 113 ABAUD 78 + Γ(ηπ) + EVTS FIT AVERAGE 52 149 167 155 22	DOCUMENT CHABAUL Wing data for ave 20 CHALOUF 20 ALSTON- 20 ABRAMO 20 CHUNG review. FORINO ANTIPOV CHALOUF ALSTON- BOECKM ASCOLI CHUNG CONTE	72 Y 71 Y 72 Y 74 ANN 70 68 68 67 77 78 68 68 67	TECN RVUE i, limits, i HBC	CHG COMMEN 2. 3.9 $\pi^ \mu^-$ 2. 3.9 $\pi^ \mu^-$ 3.9 $\pi^ \mu^-$ 3.9 $\pi^ \mu^-$ 3.2 $\pi^ \mu^-$ 3.2 $\pi^ \mu^-$ 4. 0.0 μ^- 4. 0.0 μ^- 5. 0.0 π^- 7. 0.0 π^+ 4. 0.0 π^- 3.7 π^+ 4. 0.0 π^- 3.9 π^- 4. 0.0 π^- 3.9 π^- 4. 0.0 π^- 3.9 π^- 4. 0.0 π^- 5. 0.0 π^+ 5. 0.0 π^+ 5. 0.0 π^+ 5. 0.0 π^+ 7. 0.0 π^+ 7. 0.0 π^+ 7. 0.0 π^+ 9. 0.0 π^-	Γ ₄ /Γ ₁ Γ ₂ /Γ ₁ Γ ₂ /Γ ₁ Γ ₃ /Γ ₂ Γ ₅ /Γ
18 Using an incohe 19 Using a coherer 19 Using a coherer 19 Using a coherer 29 Using a coherer 29 Using a coherer 29 Using a coherer 20 Using a coherer 20 Using a coheren 20 Using a c	### PAPERAGE Separate Paperage	DOCUMENT CHABAUL CHABAUL Wing data for ave 20 CHALOUF 20 ABRAMO 20 CHUNG review. - \(\(\kappa \kappa \) \) FORINO ANTIPOV CHALOUF ALSTON- BOCUMENT FORINO ANTIPOV CHALOUF ALSTON- BOCUMENT FORINO ANTIPOV CHALOUF ALSTON- BOECKM ASCOLI CHUNG CONTE	72 M 71 70 68 68 68 67 71 71 71 71 71 71 71 71 71 71 71 71 71	TECN RVUE i, limits, i, HBC	CHG COMMEN 2 tc. • • • 3.9 $\pi^- \mu$ 7.0 $\pi^+ \mu$ 7.0 $\pi^+ \mu$ 3.3 π^- 3.2 $\pi^- \mu$ 2 (F1- CHG COMMEN 11 $\pi^- p$ 40 $\pi^- p$ 3.7 $\pi^+ \mu$ CHG COMMEN 1.0 $\pi^+ \mu$ 5 $\pi^- p$ 1.10 π^-	Γ ₄ /Γ ₁ Γ ₂ /Γ ₁ Γ ₂ /Γ ₁ Γ ₃ /Γ ₂ Γ ₅ /Γ
18 Using an incohe 19 Using a coherer 19 Using a coherer 19 Using a coherer 29 Using a coherer 29 Using a coherer 29 Using a coherer 29 Using a coherer 20 Using 20	### PAPERAGE September Paperage	DOCUMENT CHABAUL CHABAUL Wing data for ave 20 CHALOUF 20 ABRAMO 20 CHUNG review. - \(\(\kappa \kappa \) \) FORINO ANTIPOV CHALOUF ALSTON- BOCUMENT FORINO ANTIPOV CHALOUF ALSTON- BOCUMENT FORINO ANTIPOV CHALOUF ALSTON- BOECKM ASCOLI CHUNG CONTE	72 Y 71 Y 70 68 68 68 67 71 P 10 68 68 67 F 10 68 68 68 68 68 68 68 68 68 68 68 68 68	TECN RVUE i, limits, i, HBC	CHG COMMEN 2 tc. • • • 3.9 $\pi^- \mu$ 7.0 $\pi^+ \mu$ 7.0 $\pi^+ \mu$ 3.3 π^- 3.2 $\pi^- \mu$ 2 (F1- CHG COMMEN 11 $\pi^- p$ 40 $\pi^- p$ 3.7 $\pi^+ \mu$ CHG COMMEN 1.0 $\pi^+ \mu$ 5 $\pi^- p$ 1.10 π^-	Γ ₄ /Γ ₁ Γ ₂ /Γ ₁ Γ ₂ /Γ ₁ Γ ₃ Γ ₄ /Γ ₁
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						$a_2(13)$	20)
Γ(η'(958)π)/Γ(ρπ)						Γ ₅ /Γ ₁
VALUE	<u>CL%</u>	DOCUMENT ID				COMMENT	
• • We do not use to		-			etc.		
<0.011	90	EISENSTEIN	73	HBC	-	5 π ⁻ p	
<0.04		ALSTON	71	нвс	+	7.0 π ⁺ p	
$0.04 \begin{array}{l} +0.03 \\ -0.04 \end{array}$		BOECKMANN	70	нвс	0	5.0 π ⁺ p	
$\Gamma(K\overline{K})/[\Gamma(\rho\pi)+$	$\Gamma(\eta\pi)$ +					$\Gamma_4/(\Gamma_1+\Gamma_1)$	₂ +Γ ₄)
VALUE 0.054±0.009 OUR FI	<u>EVTS</u>	DOCUMENT ID	—	<u>TECN</u>	<u>CHG</u>	COMMENT	
0.048±0.012 OUR AV	ERAGE						
0.05 ±0.02		TOET	73	нвс	+	5 π ⁺ p	
0.09 ±0.04		TOET	73	нвс	0	5 π ⁺ p	
0.03 ±0.02	8	DAMERI	72	нвс	_	11 π ⁻ p	
0.06 ±0.03	17	BARNHAM	71	HBC	+	3.7 $\pi^{+}p$	
• • We do not use	the follow	ng data for average:	s, fit:	, limits	, etc. e	• •	
0.020 ± 0.004		21 ESPIGAT	72	нвс	±	0.0 p p	
²¹ Not averaged beca	use of disc	repancy between m	asses	from #	(Kan	d ρπ modes.	
		•				•	
$\Gamma(\pi^+\pi^-\pi^-)/\Gamma(\rho)$	r)						Γ_8/Γ_1
VALUE	CL%	DOCUMENT ID			<u>CHG</u>	COMMENT	
<0.12	90	ABRAMOVI	70B	HBC	_	3.93 π p	
$\Gamma(\pi^{\pm}\gamma)/\Gamma_{\text{total}}$							Γ ₆ /Γ
VALUE		DOCUMENT ID		TECN	COM	MENT	. 6/ .
• • We do not use	the followi						
0.005 + 0.005		²² EISENBERG		нвс		.25,7.5 γp	
²² Plon-exchange mo	del used in	this estimation.					
$\Gamma(\omega\pi\pi)/\Gamma(\rho\pi)$							Γ3/Γ1
VALUE	EVT\$	DOCUMENT ID		TECN	CHG	COMMENT	. 3/ . 1
0.15±0.05 OUR FIT		ludes scale factor of					
0.15±0.05 OUR AVE		ror includes scale fa					elow.
0.28±0.09	60	DIAZ	74	DBC	0	6 π ⁺ π	
0.18±0.08		23 KARSHON	74	HBC		Avg. of ab	ove two
0.10±0.05	279	CHALOUPKA		HBC	-	3.9 π ⁻ ρ	
• • We do not use		•					
0.29 ± 0.08	140	23 KARSHON	74	HBC	0	4.9 π^{+} p	
0.10 ± 0.04	60	23 KARSHON	74	HBC	+	4.9 $\pi^{+}p$	
0.19±0.08		DEFOIX	73	нвс	0	0.7 Tp	
23 KARSHON 74 sug explain discrepand systematic spread.	les in bra	dditional $I = 0$ state number of real of real or rea	e stre	ongly co	use a	to ωππ whi central valu	ch could e and a
WEIGHTED	AVERAGE						
0.15±0.05 (E	Error scaled	d by 1.3)					
	٧	Values ab	ove	of weigh	ted ave	erage, error,	
		and scale	facto	r are he	ead un	on the data i	n
	10 1000	this ideogr	am o	only. Th	ey are	not neces- ralues,	





 $a_2(1320), f_0(1370)$

a2(1320) REFERENCES

ABELE	97C	PL B404 179	A. Abele, Adomeit, Amsler+ (Crystal Barrel Collab.)
ACCIARRI	97 T	PL B413 147	M. Acciarri+
ALBRECHT	97B	ZPHY C74 469	+Hamacher, Hofmann+ (ARGUS Collab.)
THOMPSON	97	PRL 79 1630	+Adams+ (E852 Collab.)
AMELIN	96	ZPHY C70 71	+Berdnikov, Bityukov+ (SERP, TBIL)
AMSLER	94D	PL B333 277	+Anisovich, Spanier+ (Crystal Barrel Collab.)
AOYAGI	93	PL B314 246	+Fukui, Hasegawa+ (BKEI Collab.)
ARMSTRONG	93C	PL B307 394	+Bettoni+ (FNAL, FERR, GENO, UCI, NWES+)
BELADIDZE	93	PL 313 276	+Berdnikov, Bityukov+ (VES Collab.)
CONDO	93	PR D48 3045	+Handler, Bugg+ (SLAC Hybrid Collab.)
ALDE	92B	ZPHY C54 549	+Binon+ (SERP, BELG, LANL, LAPP, PISA, KEK)
BELADIDZE	92	ZPHY C54 235	+Bityukov, Borisov+ (VES Collab.)
ALBRECHT	90G	ZPHY C48 183	+Ehrlichmann, Harder+ (ARGUS Collab.)
ARMSTRONG	90	ZPHY C48 213	+Benayoun, Beusch (WA76 Collab.)
BARU	90	ZPHY C48 581	+Blinov, Blinov+ (MD-1 Collab.)
BEHREND	90C	ZPHY C46 583	+Criegee+ (CELLO Collab.)
BUTLER	90	PR D42 1368	+Boyer+ (Mark II Collab.)
OEST	90	ZPHY C47 343	+Olsson+ (JADE Collab.)
AUGUSTIN	89	NP B320 1	+Cosme (DM2 Collab.)
VOROBYEV	88	SJNP 48 273 Translated from	
ALTHOFF	86	ZPHY C31 537	+Boch, Foster, Bernardi+ (TASSO Collab.)
ANTREASYAN		PR D33 1847	+Aschman, Besset, Bienlein+ (Crystal Bali Collab.)
	84C	PL 149B 427	
BERGER			
BEHREND	83B	PL 125B 518	+D'Agostini+ (CELLO Collab.)
CIHANGIR	82	PL 117B 123	+Berg, Biel, Chandlee+ (FNAL, MINN, ROCH)
CLELAND	82B	NP B208 228	+Delfosse, Dorsaz, Gioor (DURH, GEVA, LAUS, PITT)
EDWARDS	82F	PL 110B 82	+Partridge, Peck+ (CIT, HARV, PRIN, STAN, SLAC)
DELFOSSE	81	NP B183 349	+Guisan, Martin, Muhlemann, Weill+ (GEVA, LAUS)
EVANGELISTA		NP 8178 197	+ (BARI, BONN, CERN, DARE, LIVP+)
CHABAUD	80	NP B175 189	+Hyams, Papadopoulou+ (CERN, MPIM, AMST)
DAUM	BOC	PL 89B 276	+Hertzberger+ (AMST, CERN, CRAC, MPIM, OXF+) JP
BALTAY	78B	PR D17 62	+Cautis, Cohen, Csorna+ (COLU, BING)
CHABAUD	78	NP B145 349	+Hyams, Jones, Weilhammer, Blum+ (CERN, MPIM)
FERRERSORIA	78	PL 74B 287	+Treille+ (ORSAY, CERN, CDEF, EPOL)
HYAMS	78	NP B146 303	+Jones, Weilhammer, Blum+ (CERN, MPIM, ATEN)
MARTIN	78D	PL 74B 417	+Ozmutlu, Baldi, Bohringer, Dorsaz+ (DURH, GEVA) JP
MAY	77	PR D16 1983	+Abramson, Andrews, Busnello+ (ROCH, CORN)
FORINO	76	NC 35A 465	+Gessaroli+ (BGNA, FIRZ, GENO, MILA, OXF, PAVI)
MARGULIE	76	PR D14 667	+Kramer, Foley, Love, Lindenbaum+ (BNL, CUNY)
EMMS	75	PL 58B 117	+Jones, Kinson, Stacey, Bell+ (BIRM, DURH, RHEL) JP
WAGNER	75	PL 58B 201	+Tabak, Chew (LBL) JP
DIAZ	74	PRL 32 260	+Dibianca, Fickinger, Anderson+ (CASE, CMU)
KARSHON	74	PRL 32 852	+Mikenberg, Pitluck, Eisenberg, Ronat+ (REHO)
ANTIPOV	73	NP B63 175	+Ascoli, Busnello, Focacci+ (CERN, SERP) JP
ANTIPOV	73C	NP B63 153	+Ascoli, Busnello, Focacci+ (CERN, SERP) JP
CHALOUPKA	73	PL 44B 211	+Dobrzynski, Ferrando, Losty+ (CERN)
CONFORTO	73	PL 45B 154	+Mobley, Key+ (EFI, FNAL, TNTO, WISC)
DEFOIX	73	PL 43B 141	+Dobrzynski, Espigat, Nascimento+ (CDEF)
EISENSTEIN	73	PR D7 278	+Schultz, Ascoli, loffredo+ (ILL)
KEY	73	PRL 30 503	+Conforto, Mobley+ (TNTO, EFI, FNAL, WISC)
TOET	73	NP B63 248	+Thuan, Major+ (NIJM, BONN, DURH, TORI)
DAMERI	72	NC 9A 1	+Borzatta, Goussu+ (GENO, MILA, SACL)
EISENBERG	72	PR D5 15	
ESPIGAT	72	NP 836 93	+Ghesquiere, Lillestol, Montanet (CERN, CDEF)
FOLEY	72	PR D6 747	+Love, Ozaki, Platner, Lindenbaum+ (BNL, CUNY)
ALSTON	71	PL 34B 156	Alston-Garnjost, Barbaro, Buhl, Derenzo+ (LRL)
BARNHAM	71	PRL 26 1494	+Abrams, Butler, Coyne, Goldhaber, Hall+ (LBL)
BINNIE	71	PL 36B 257	+Camilleri, Duane, Faruqi, Burton+ (LOIC, SHMP)
BOWEN	71	PRL 26 1663	+Earles, Faissler, Blieden+ (NEAS, STON)
GRAYER	71	PL 34B 333	+Hyams, Jones, Schlein, Blum+ (CERN, MPIM)
ABRAMOVI	70B	NP B23 466	Abramovich, Blumenfeld, Bruyant+ (CERN) JP
ALSTON	70	PL 33B 607	Alston-Garnjost, Barbaro, Buhl, Derenzo+ (LRL)
BOECKMANN		NP B16 221	+Major+ (BONN, DURH, NIJM, EPOL, TORI)
ASCOLI	68	PRL 20 1321	+Crawley, Mortara, Shapiro, Bridges+ (ILL) JP
BOESEBECK	68	NP B4 501	+Deutschmann+ (AACH, BERL, CERN)
CHUNG	68	PR 165 1491	+Dahl, Kirz, Miller (LRL)
CONTE	67	NC 51A 175	+Tomasini, Cords+ (GENO, HAMB, MILA, SACL)
			•

OTHER RELATED PAPERS

JENNI	83	PR D27 1031	+Burke, Telnov, Abrams, Blocker+ (SLAC, LBL)
BEHREND	82C	PL 114B 378	+Chen, Fenner, Field+ (CELLO Collab.)
ADERHOLZ	65	PR 138B 897	(AACH3, BERL, BIRM, BONN, HAMB, LOIC, MPIM)
ALITTI	65	PL 15 69	+Baton, Deler, Crussard+ (SACL, BGNA) JF
CHUNG	65	PRL 15 325	+Dahl, Hardy, Hess, Jacobs, Kirz (LRL)
FORINO	65B	PL 19 68	+Gessaroli+ (BGNA, BARI, FIRZ, ORSAY, SACL)
LEFEBVRES	65	PL 19 434	+Levrat+ (CERN Missing Mass Spect. Collab.)
SEIDLITZ	65	PRL 15 217	+Dahl, Miller (LRL)
ADERHOLZ	64	PL 10 226	+ (AACH3, BERL, BIRM, BONN, DESY, HAMB+)
CHUNG	64	PRL 12 621	+Dahl, Hardy, Hess, Kalbfleisch, Kirz (LRL)
GOLDHABER	64	PRL 12 336	+Brown, Kadvk, Shen+ (LRL, UCB)
LANDER	64	PRL 13 346A	+Abolins, Carmony, Hendricks, Xuong+ (UCSD)

 $f_0(1370)$

$$I^{G}(J^{PC}) = 0^{+}(0^{+})$$

NOTE ON SCALAR MESONS

Written March 1998 by S. Spanier (Zürich) and N. Törnqvist (Helsinki).

In contrast to the vector and tensor mesons the identification of the scalar mesons is a long standing puzzle. The problem originates from their large decay widths causing a strong overlap of individual resonances within the same partial wave, and at the same time several decay channels open up within a short mass interval. In addition the $K\overline{K}$ and $\eta\eta$ thresholds produce sharp cusps in the energy dependence of the resonant amplitude. Furthermore, one expects non- $q\overline{q}$ scalar objects like glueballs and multiquark states in the mass range below 1800 MeV. In

spite of these problems the understanding of the scalars has improved considerably during the last few years, because we now have high statistics measurements of different production modes from: $p\bar{p}$ annihilation at rest, πN -scattering on polarized/unpolarized targets, central production, $J/\psi(1S)$ decays, D-meson decays, $\gamma\gamma$ -formation. Furthermore, we have had a strong development of better theoretical models for the reaction amplitudes, which are based on common fundamental principles. These allow direct comparison and interpretation of many different experimental results. Two-body unitarity, analyticity, Lorentz invariance, chiral- and flavor-symmetry constraints have been implemented into the transition amplitudes using different general methods (K-matrix formalism, N/D-method, Dalitz-Tuan ansatz, unitarized quark models with coupled channels, etc.). In general, mass and width parameters of a resonance are found from the position of the nearest pole in the T-matrix (or equivalently the S-matrix) at an unphysical sheet of the complex energy plane: $(E-i\frac{\Gamma}{2})$. It is important to realize, that only in the case of well separated resonances, far away from the opening of decay channels, does a naive Breit-Wigner parametrization (or K-matrix pole parametrization) agree approximately with the T-matrix pole position in the amplitude. Breit-Wigner parameters are sensitive to background, nearby thresholds etc., while T-matrix poles depend only on the limitations of the theoretical model.

In this note we discuss all light scalars organized in the listings under the entries (I=1/2) $K_0^{\star}(1430)$, (I=1) $a_0(980)$, $a_0(1450)$, and (I=0) σ or $f_0(400-1200)$, $f_0(980)$, $f_0(1370)$, and $f_0(1500)$. The list is minimal and does not necessarily exhaust the list of actual resonances.

The I=1/2 states

The $K_0^\star(1430)$ (ASTON 88) is the least controversial of the light scalar mesons. The phase shift rises smoothly from threshold, passes 90° at 1350 MeV, and then continues to rise to about 170° at 1600 MeV at the first important inelastic threshold $K\eta'(958)$. Thus it behaves like a single broad, nearly elastic resonance. ABELE 98 finds for the T-matrix pole parameters, $m\approx 1430$ MeV and $\Gamma\approx 290$ MeV, while the K-matrix pole of the same data is at about 1340 MeV using $K\overline{K}\pi$ in $p\overline{p}$ annihilation at rest. This agrees with the LASS (ASTON 88) determination. The scattering length near threshold is $a=2.56\pm0.20~({\rm GeV/c})^{-1}$ (ABELE 98).

The I=1 states

Two states are established, the well-known $a_0(980)$, and the $a_0(1450)$ found by Crystal Barrel (AMSLER 94D). Independently of any model about the nature of the $a_0(980)$ the $K\overline{K}$ component in the wave function of the state must be large: the $a_0(980)$ lies very close to the opening of the $K\overline{K}$ channel to which it couples strongly. This gives an important cusplike behaviour in the resonant amplitude. Hence, its mass and width parameters are strongly distorted. To reveal its true coupling constants a coupled channel model with energy-dependent

widths and mass shift contributions must be applied. A naive Breit-Wigner form is certainly inadequate.

The relative coupling $K\overline{K}/\pi\eta$ in previous editions was determined only indirectly from $f_1(1285)$ (CORDEN 78, DEFOIX 72) or $\eta(1410)$ decays (BAI 90C, BOLTON 92B, AMSLER 95F) or from the line shape observed in the $\pi\eta$ decay mode (FLATTE 76, AMSLER 94D, BUGG 94, JANSSEN 95). From analysis of $\pi\pi\eta$ and $K\overline{K}\pi$ final states of $\overline{p}p$ annihilation at rest a relative production ratio $B(\overline{p}p\to\pi a_0;a_0\to K\overline{K})/B(\overline{p}p\to\pi a_0;a_0\to\pi\eta)=0.23\pm0.05$ is obtained by ABELE 98. Tuning of the couplings in a coupled channel formula to reproduce the production ratio for the integrated mass distributions gives a relative branching ratio $\Gamma(K\overline{K})/\Gamma(\pi\eta)=1.03\pm0.14$. Analysis of $p\overline{p}$ annihilation data also found that the width determined from the T-matrix pole is 92 ± 8 MeV, while the observed width of the peak in the $\pi\eta$ mass spectrum is about 45 MeV.

In our table the mass position comes out very consistently near 980 MeV in all measurements, but the width takes values between 50 and 300 MeV, because of the differences in the models used in the analyses. Using the relative production ratio and the observed 2-photon generation of $a_0(980)$ one can calculate the 2-photon width of $a_0(980)$ to be $\Gamma_{\gamma\gamma}=(0.30\pm0.10)$ keV, which is similar to that of $f_0(980)$.

The $a_0(1450)$ is seen by the Crystal Barrel experiment in its $\pi\eta$, $K\overline{K}$, and $\pi\eta'(958)$ decay modes. The relative couplings to the different final states are found to be close to SU(3)-flavor predictions for an ordinary $q\overline{q}$ meson.

The I=0 states

The I=0 $J^{PC}=0^{++}$ sector is the most complex one both experimentally and theoretically. The data have been obtained from $\pi\pi$, $K\overline{K}$, $\eta\eta$, 4π , and $\eta\eta'(958)$ systems produced in S-waves by nonstrange initial states. From the high statistics data sets collected from $\overline{p}p$ annihilation at rest into $\pi^0 f_0$'s, where the f_0 decay into the above mentioned channels, one concludes that at least four poles are needed in the mass range from $\pi\pi$ threshold to about 1600 MeV. The claimed isoscalar resonances are found under the separate entries σ or $f_0(400-1200)$, $f_0(980)$, $f_0(1370)$, and $f_0(1500)$.

Below 1100 MeV the important data come from $\pi\pi$ and $K\overline{K}$ final states. Information on the $\pi\pi$ S-wave phase shift $\delta_J^I = \delta_0^0$ was extracted already 20 years ago from πN scattering with unpolarized (GRAYER 74) and polarized target (BECKER 79) and near threshold from K_{e4} -decay (ROSSELET 77). The $\pi\pi$ S-wave inelasticity is not accurately known, and the reported $\pi\pi \to K\overline{K}$ cross sections (WETZEL 76, POLYCHRONAKOS 79, COHEN 80, ETKIN 82B) may have large uncertainties. Recently, the πN data (GRAYER 74, BECKER 79) have been reevaluated in a combined partial-wave analysis (KAMINSKI 97). Out of four, two relevant solutions are found with the S-wave phase-shift rising slower than the P-wave $[\rho(770)]$, which is used as reference. One of these corresponds to the well known "down" solution of (GRAYER 74), the other "up"

solution shows a decrease of the modulus in the mass interval 800-980 MeV. Both solutions exhibit at 1 GeV a sudden drop in the modulus and in the inelasticity parameter η_0^0 , which is due to the appearance of $f_0(980)$ very close to the opening of the $K\overline{K}$ -threshold. The phase shift δ_0^0 rises smoothly up to this point where it jumps by 120° (in the "up") or 140° (in the "down"-solution) to reach 230°, from which point both continue to rise slowly.

SVEC 97 using data on πN (polarized) producing the $\pi\pi$ system from 600 to 900 MeV suggests that there exists a narrow state at 750 MeV with a small width of 100 to 200 MeV. Such a solution is also found by (KAMINSKI 97) using the CERN-Munich(-Cracow) data considering both π -and $a_1(1260)$ -exchange in the reaction amplitudes. However, they show that unitarity is violated for this solution; therefore a narrow light f_0 state below 900 MeV seems to be excluded. Also, the $2\pi^0$ invariant mass spectra of $p\bar{p}$ annihilation at rest (AMSLER 95B, ABELE 96) and central collision (ALDE 97) do not show a narrow resonance below 900 MeV, and these data are consistently described with the standard "down" solution (GRAYER 74, KAMINSKI 97), which allows for the existence of the broad ($\Gamma \approx 500$ MeV) σ listed under $f_0(400-1200)$.

For low-energy $\pi\pi$ scattering the predicted Weinberg scattering length for the isoscalar S-wave a_0^0 is 0.16, chiral perturbation theory including one-loop corrections increases this value to $a_0^0\approx 0.20$ while the slope parameter is $b_0^0\approx 0.18$ (GASSER 83, RIGGENBACH 91). With two-loop corrections one still gets a little larger value $a_0^0=0.217$ (BIJNENS 96), but electromagnetic corrections reduce this value to 0.208 (MALT-MAN 97). Experimentally the region near the $\pi\pi$ threshold is difficult to investigate. Current values of these quantities are $a_0^0=0.26\pm 0.05$ and $b_0^0=0.25\pm 0.03$ (NAGELS 79).

An experimentally very well studied meson resonance is the $f_0(1500)$ seen by the Crystal Barrel experiment in five decay modes: $\pi\pi$, $K\overline{K}$, $\eta\eta$, $\eta\eta'(958)$, and 4π (AMSLER 95D, ABELE 96, ABELE 98). Due to its interference with the $f_0(1370)$ the peak attributed to $f_0(1500)$ can appear shifted in mass to 1590 MeV, where it was observed by the GAMS collaboration (BINON 83) in the $\eta\eta$ mass spectrum. They applied a sum of Breit-Wigner functions for the dynamics in the resonant amplitude. In central production (ANTINORI 95) a peak at 1450 MeV having a width of 60 MeV can be interpreted as the coherent sum of $f_0(1370)$ and $f_0(1500)$. The $\overline{p}p$ and $\overline{n}p/\overline{p}n$ reactions show a single enhancement at 1400 MeV in the invariant 4π mass (GASPERO 93, ADAMO 93, AMSLER 94, ABELE 96). In the $5\pi^0$ channel (ABELE 96) this structure was resolved into $f_0(1500)$ and $f_0(1370)$, found at a somewhat lower mass around 1300 MeV. An additional scalar in mass above 1700 MeV had to be introduced in the re-analysis of the reaction $J/\psi(1S) \rightarrow \gamma 4\pi$ (BUGG 95). According to these investigations the $f_0(1500)$ decay proceeds dominantly via $\sigma\sigma \to 4\pi$ where σ denotes the $\pi\pi$ S-wave below $K\overline{K}$ threshold. The $K\overline{K}$ decay of $f_0(1500)$ is suppressed (ABELE 98).

 $f_0(1370)$

The determination of the $\pi\pi$ coupling of $f_0(1370)$ is inhibited by the strong overlap with the broad background from the $f_0(400-1200)$. Since it does not show up prominently in the 2π spectra its mass and width are difficult to fix. A resonance band in the $\pi^0\eta\eta$ final state of $p\bar{p}$ annihilation at rest (AM-SLER 95D) is attributed to it. Data on $\pi\pi \to K\overline{K}$ show an enhancement at around 1300 MeV in the scalar partial wave (WETZEL 76, COHEN 80, POLYCHRONAKOS 79, COSTA 80, LONGACRE 86). According to the phase shift the resonance is found around 1400 MeV (COHEN 80), while a recent re-analysis (BUGG 96) claims a trend to lower mass. Further information about the $K\overline{K}$ decay of the scalars are most welcome, in particular those which clearly distinguish between the I = 0 and the I = 1 system.

In the analysis of (ANISOVICH 97, 97C) using data of πN and $\bar{p}p$ annihilation reactions a fifth pole at 1530 MeV about 1 GeV off the physical region is added.

Interpretation

Almost every model on the scalar states agrees that the $K_0^*(1430)$ is the 1 3P_0 quark model $s\overline{u}$ or $s\overline{d}$ state, but the other scalars remain controversial.

The $f_0(980)$ and $a_0(980)$ are often interpreted as being multiquark states (JAFFE 77) or $K\overline{K}$ bound states (WEINSTEIN 90). This picture is supported by their 2-photon widths which are smaller than expected for $q\bar{q}$ mesons, if one neglects the $K\bar{K}$ component. Using a simple quark model one is led to put the $f_0(1370)$, $a_0(1450)$, and $K_0^*(1430)$ into the same SU(3) flavor nonet being the $(u\overline{u} + d\overline{d})$, $u\overline{d}$ and the $u\overline{s}$ state, respectively. In this picture the $s\overline{s}$ state is missing experimentally. Compared with these states the $f_0(1500)$ is too narrow to be the isoscalar partner, and too light to be the first radial excitation. A non- $q\bar{q}$ (gluonium) interpretation seems likely (CLOSE 97B). See our Note on Non- $q\bar{q}$ states. As to the light $f_0(400-1200)$ structure it is far from the physical region and its interpretation in terms of a $q\bar{q}$ state or cross channel effect remains open. Such a state is often referred to as the σ or $f_0(500)$ meson.

More detailed models exist, which include more theoretical input at least phenomenologically. One such unitarized quark model with coupled channels can understand 6 of the light scalars as different unitarized manifestations of bare quarks model ${}^{3}P_{0}$ $q\overline{q}$ states (TORNQVIST 82, 95, 96). The σ , f_{0} (980), $f_0(1370)$, $a_0(980)$, $a_0(1450)$, and $K_0^{\star}(1430)$ are described as unitarized remnants of strongly shifted and mixed $q\bar{q}$ 1 $^{3}P_{0}$ states using 6 parameters. Here the σ is the $(u\overline{u} + d\overline{d})$ state and at the same time also the chiral partner of the π . The $f_0(980)$ and $f_0(1370)$ as well as $a_0(980)$ and $a_0(1450)$ are two manifestations of the same $q\bar{q}$ state. The interpretation of $f_0(1500)$ in this scheme is an open question; it can be a glueball or a deuteron-like $\rho\rho + \omega\omega$ bound state. For other models and more details discussing the light scalar resonances see also (AU 87, MORGAN 93, ZOU 94B, JANSSEN 95, CLOSE 92, ANISOVICH 97, 97B, 97C, 97D, BEVEREN 86, KAMINSKI 94, 97B, OLLER 97, ISHIDA 96).

fo(1370) T-MATRIX POLE POSITION

Note that $\Gamma \approx 2 \text{ Im}(\sqrt{s_{pole}})$.

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
(1200-1500)-i(150-250) OUR	ESTIMATE		
• • • We do not use the follow	ng data for average	s, fits, limits,	etc. • • •
$(1290 \pm 15) - i(145 \pm 15)$	BARBERIS	97B OMEG	$450 pp \rightarrow pp2(\pi^{+}\pi^{-})$
$(1548 \pm 40) - i(560 \pm 40)$	BERTIN	97C OBLX	$0.0 \ \overline{\rho} \rho \rightarrow \pi^{+} \pi^{-} \pi^{0}$
$(1380 \pm 40) - i(180 \pm 25)$	ABELE	96B CBAR	$0.0 \overline{p}p \rightarrow \pi^0 K_I^0 K_I^0$
$(1300 \pm 15) - i(115 \pm 8)$	BUGG	96 RVUE	
$(1330 \pm 50) - i(150 \pm 40)$	¹ AMSLER	95B CBAR	$\bar{p}p \rightarrow 3\pi^0$
$(1360 \pm 35) - i(150 - 300)$	1 AMSLER		$\overline{p}p \rightarrow \pi^0 \eta \eta$
$(1390 \pm 30) - i(190 \pm 40)$	² AMSLER	95D CBAR	$\overline{p}p \to 3\pi^0, \pi^0\eta\eta,$
1346 i249	3,4 JANSSEN	95 RVUE	$\pi\pi \rightarrow \pi\pi, K\overline{K}$
1214 - i168	4,5 TORNQVIST		$\pi\pi \to \pi\pi$, $K\overline{K}$, $K\pi$,
1364 - i139	AMSLER	94D CBAR	$ \widetilde{p}_{P} \xrightarrow{\eta \pi} \pi^{0} \pi^{0} \eta $
(1365^{+20}_{-55}) - $i(134 \pm 35)$	ANISOVICH	94 CBAR	$\overline{p}p \rightarrow 3\pi^0, \pi^0\eta\eta$
$(1340 \pm 40) - i(127 + \frac{30}{20})$	⁶ BUGG	94 RVUE	$\overline{p}p \to 3\pi^0, \eta\eta\pi^0,$
1515 ~ i214	^{4,7} zou	93 RVUE	$\pi\pi \to \pi\pi, K\overline{K}$
1420 - i220	8 AU	87 RVUE	$\pi\pi \to \pi\pi, K\overline{K}$
16			

Supersedes ANISOVICH 94.

Supersectes Annother 1997. The supersection of $\bar{p}p \to 3\pi^0$, $\pi^0\eta\eta$, and $\pi^0\pi^0\eta$ on sheet IV. Demonstrates explicitly that $f_0(400-1200)$ and $f_0(1370)$ are two different poles.

3 Analysis of data from FALVARD 88.

⁴ The pole is on Sheet III. Demonstrates explicitly that $f_0(400-1200)$ and $f_0(1370)$ are

5 Lises data from BEIER 728, OCHS 73, HYAMS 73, GRAYER 74, ROSSELET 77, CA-SON 83, ASTON 88, and ARMSTRONG 91B. Coupled channel analysis with flavor symmetry and all light two-pseudoscalars systems.

⁶ Reanalysis of ANISOVICH 94 data.

VALUE (MeV)

1256

⁷ Analysis of data from OCHS 73, GRAYER 74, and ROSSELET 77.

8 Analysis of data from OCHS 73, GRAYER 74, BECKER 79, and CASON 83.

fo(1370) BREIT-WIGNER MASS OR K-MATRIX POLE PARAMETER DOCUMENT ID

1200 to 1500 OUR ESTIMATE ππ MODE DOCUMENT ID TECN COMMENT • • • We do not use the following data for averages, fits, limits, etc. • • BERTIN 98 OBLX 50-405 Trp 1280 ± 55 $\pi^+\pi^+\pi^ r \rightarrow \pi\pi, K\overline{K}, K\pi$ 9 TORNOVIST 95 RVUE ππ ηπ 94 RVUE $\pi\pi \to \pi\pi$, K \overline{K} 1430± 5 KAMINSKI 1472±12 ARMSTRONG 91 OMEG 300 $pp \rightarrow pp K\overline{K}$ 1275 ± 20 BREAKSTONE 90 SFM 62 pp → ppπ+π-86 SPEC $63 pp \rightarrow pp\pi^+\pi^-$ 77 RVUE $\pi^+\pi^-$ channel 1420 ± 20 AKESSON

FROGGATT

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9 Uses data from BEIER 728, OCHS 73, HYAMS 73, GRAYER 74, ROSSELET 77, CA-SON 83, ASTON 88, and ARMSTRONG 91B. Coupled channel analysis with flavor symmetry and all light two-pseudoscalars systems.

KK MODE	DOCUMENT ID		<u>TECN</u>	COMMENT
• • • We do not use the fo	ollowing data for average:	s, fits	, limits,	etc. • • •
1440 ± 50	BOLONKIN	88	SPEC	$40 \pi^- p \rightarrow K_5^0 K_5^0 n$
1463± 9	ETKIN	82B	MPS	23 π ⁻ p → n2K ₅ 0
1425±15	WICKLUND	80	SPEC	$6 \pi N \rightarrow K^+ K^- N$
~ 1300	POLYCHRO	79	STRC	$7\pi^-p \rightarrow n2K_S^0$
4π MODE 2(ππ) ₅ +ρρ	•			
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
• • • We do not use the fe	ollowing data for average:	, fits	, ilmits,	etc. • • •
1374±38	AMSLER	94	CBAR	$0.0 \ \overline{p}p \rightarrow \pi^{+}\pi^{-}3\pi^{0}$
1345±12	ADAMO	93	OBLX	$\pi \rho \rightarrow 3\pi^+ 2\pi^-$
1386±30	GASPERO	93	DBC	$0.0 \ \overline{\rho}n \rightarrow 2\pi^{+}3\pi^{-}$
nn MODE				
VALUE (MeV)	DOCUMENT ID	_	TECN	COMMENT
■ ■ We do not use the fe	ollowing data for average	s, fits	, limits,	etc. • • •
1430	AMSLER	92	CBAR	$0.0 \ \overline{p}p \rightarrow \pi^0 \eta \eta$
1220 ± 40	ALDE	86D	GAM4	$100 \pi^- p \rightarrow \pi 2 \eta$

 12 Using AMSLER 95B (3 π^0).

Meson Particle Listings $f_0(1370)$

	70) BREIT-WIGNER WIDTH	$ \Gamma(4\pi)/\Gamma_{\text{total}} \qquad \qquad \Gamma_2/\Gamma = (\Gamma_3 + \Gamma_4 + \Gamma_5)/\Gamma_{\text{ALUE}} \qquad \qquad \Gamma_{\text{COMMENT}} \qquad \Gamma_{\text{COMMENT}} $
ALUE (MeV)	DOCUMENT ID	
		0.80 ± 0.04 GASPERO 93 DBC $0.0\ pn \rightarrow hadrons$
π MODE ALUE (MeV)	DOCUMENT ID TECN COMMENT	$\Gamma(4\pi^0)/\Gamma_{ m total}$
	ving data for averages, fits, limits, etc. • • •	<u>VALUE</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u> ■ • • • We do not use the following data for averages, fits, limits, etc. • • •
323±13	BERTIN 98 OBLX 50-405 $\overline{n}p \rightarrow \pi^+\pi^+\pi^-$	seen ABELE 96 CBAR 0.0 $\overline{p}p \rightarrow 5\pi^0$
350	10 TORNQVIST 95 RVUE $\pi\pi \to \pi\pi, K\overline{K}, K\pi, \eta\pi$	$ \Gamma(2\pi^{+}2\pi^{-})/\Gamma(4\pi) $ $ \Gamma_{4}/\Gamma_{2} = \Gamma_{4}/(\Gamma_{3}+\Gamma_{4}+\Gamma_{4}) $
145±25 195±33	KAMINSKI 94 RVUE $\pi\pi \to \pi\pi$, $K\overline{K}$ ARMSTRONG 91 OMEG 300 $pp \to pp\pi\pi$,	VALUE DOCUMENT ID TECN COMMENT • • • • We do not use the following data for averages, fits, limits, etc. • • •
285±60	$ppK\overline{K}$ BREAKSTONE 90 SFM 62 $pp \rightarrow pp\pi^+\pi^-$	0.420 ± 0.014 13 GASPERO 93 DBC $0.0 \ \overline{p} n \rightarrow 2\pi^{+} 3\pi^{-}$
460±50	AKESSON 86 SPEC $63pp \rightarrow pp\pi^{+}\pi^{-}$	13 Model-dependent evaluation.
400	11 FROGGATT 77 RVUE $\pi^+\pi^-$ channel	$\Gamma(\pi^{+}\pi^{-}2\pi^{0})/\Gamma(4\pi) \qquad \qquad \Gamma_{5}/\Gamma_{2} = \Gamma_{5}/(\Gamma_{3}+\Gamma_{4}+\Gamma_{5})$
SON 83, ASTON 88, and	s, OCHS 73, HYAMS 73, GRAYER 74, ROSSELET 77, CA- I ARMSTRONG 91B. Coupled channel analysis with flavor	VALUE DOCUMENT ID TECH COMMENT
symmetry and all light two- 11 Width defined as distance I	-pseudoscalars systems. between 45 and 135° phase shift.	• • • We do not use the following data for averages, fits, limits, etc. • • • • 0.512+0.019 14 GASPERO 93 DBC 0.0 $\overline{p}n \rightarrow hadrons$
	F	0.512 ± 0.019 ¹⁴ GASPERO 93 DBC $0.0 \ \overline{p}n \rightarrow \text{ hadrons}$ 14 Model-dependent evaluation.
KK MODE VALUE (MeV)	DOCUMENT ID TECN COMMENT	
	wing data for averages, fits, limits, etc. • •	$\Gamma(\rho\rho)/\Gamma(2(\pi\pi)_{S-\text{wave}})$ VALUE DOCUMENT ID TECH COMMENT
250± 80	BOLONKIN 88 SPEC 40 $\pi^- p \rightarrow K_S^0 K_S^0 n$	<u>VALUE</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u> • • • We do not use the following data for averages, fits, limits, etc. • • •
118 ⁺¹³⁸ ₋₁₆	ETKIN 828 MPS $23 \pi^- p \rightarrow n2K_S^0$	1.6 ± 0.2 AMSLER 94 CBAR $\overline{p}p \rightarrow \pi^+\pi^-3\pi^0$
160± 30	WICKLUND 80 SPEC $6 \pi N \rightarrow K^+K^-N$	0.58 ± 0.16 GASPERO 93 DBC $0.0 \ \overline{p} n \rightarrow 2\pi^{+} 3\pi^{-}$
150	POLYCHRO 79 STRC $7 \pi^- p \rightarrow n2K_S^0$	Γ(KK)/Γ _{total} Γ _g
π MODE 2(ππ)s+ρρ	DOCUMENT ID TECN COMMENT	VALUE DOCUMENT ID TECH
ALUE (MeV)	DOCUMENT ID TECN COMMENT wing data for averages, fits, limits, etc. ● ●	• • • We do not use the following data for averages, fits, limits, etc. • • •
75±61	AMSLER 94 CBAR $0.0 \overline{p}p \rightarrow \pi^+\pi^-3\pi^0$	0.35±0.13 BUGG 96 RVUE
75±61 98±26	ADAMO 93 OBLX $\pi p \rightarrow 3\pi^+ 2\pi^-$	f ₀ (1370) REFERENCES
10±50	GASPERO 93 DBC $0.0 pn \rightarrow 2\pi^{+}3\pi^{-}$	· ,
77 MODE ALUE (MeV) • We do not use the follo	DOCUMENT ID TECN COMMENT wing data for averages, fits, limits, etc. • •	BERTIN 98 PR D57 55 A. Bertin, Bruschi, Capponi+ (OBELIX Collab.) BARBERIS 97B PL B413 217 D. Barberis+ (WA102 Collab.) BERTIN 97C PL B408 476 A. Bertin, Bruschi+ (OBELIX Collab.) ABELE 96 PL B380 453 + Adomeit, Amsler+ (Crystal Barrel Collab.) ABELE 96B PL B385 425 + Adomeit, Amsler+ (Crystal Barrel Collab.) BUGG 96 NP B471 59 + Sarantsey, Zou (LOQM, PNPT)
250	AMSLER 92 CBAR $0.0 \overline{p}p \rightarrow \pi^0 \eta \eta$	AMSLER 95B PL B342 433 +Armstrong, Brose+ (Crystal Barrel Collab.)
320±40	ALDE 860 GAM4 100 π ⁻ p → π2η	AMSLER 95D PL B355 425 +Armstrong, Spanler+ (Crystal Barrel Collab.)
	f ₀ (1370) DECAY MODES	TORNOVIST 95 ZPHY C68 647 (HELS)
	M(1910) DECAT MODES	AMSLER 94D PL B333 277 +Anisovich, Spanier+ (Crystal Barrel Collab.
Mode	Fraction (Γ_I/Γ)	AMSLER 94D PL 8333 277 +Anisovich, Spanier+ (Crystal Barrel Collab. ANISOVICH 94 PL 8323 233 +Armstrog+ (Crystal Barrel Collab. BUGG 94 PR D50 4412 +Anisovich+ (LOQM
$\Gamma_1 = \pi \pi$		AMSLER
$ \Gamma_1 \pi \pi $ $ \Gamma_2 4\pi $	Fraction (Γ _I /Γ) seen seen	AMSLER 94D PL B333 277 + Anisovich, Spanier + (Crystal Barrel Collab, NISOVICH 94 PL B323 233 + Armstrong+ (Crystal Barrel Collab, BUGG 94 PR D30 4412 + Anisovich+ (LOQM (LOQM KAMINSKI 94 PR D30 3145 R. Kaminski+ (CRAC, IPN ADAMO 93 NP AS58 13C + Agnelic+ (OBELIX Collab.) GASPERO 93 NP A552 407 ZOU 93 PR O48 R3948 + Bugg (LOQM
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Fraction (Γ _I /Γ) seen seen seen	AMSLER 94D PL 833 277 + Anisovich, Spanier + (Crystal Barrel Collab, NISOVICH 94 PL 832 233 + Armstrong + (Crystal Barrel Collab, BUG 94 PR D50 4412 + Anisovich + (LOQM CARAL PR) ADAMO 93 NP ASS 13C + Agnelo + (CRAC. PR) ADAMO 93 NP ASS 13C + Agnelo + (OBELIX Collab, GASPERO 93 NP ASS 2407 ZOU 93 PR O48 R9948 + Bugg (LOQM AMSLER 92 PL 8291 347 + Augustin, Baker + (Crystal Barrel Collab, RMSTRONG 91 ZPHY CS1 351 + Benayoun + (ATHU, BARI, BIRM, CERN, CDEF
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Fraction (Γ _I /Γ) seen seen	AMSLER 94D PL 833 277 + Anisovich, Spanier + (Crystal Barrel Collab. ANISOVICH 94 PL 832 233 + Armstrong-F (Crystal Barrel Collab. BUGG 94 PR D50 4412 + Anisovich + (COM. CAMINSKI 94 PR D50 3145 R. Kaminski + (CRAC., IPN. ADAMO 91 NP A558 13C + Agnello + (OBELIX Collab. GASPERO 93 NP A552 407 ZOU 93 PR O48 R9948 + Bugg + Augustin, Baker + (Crystal Barrel Collab. AMSLER 92 PL 8291 347 + Augustin, Baker + (Crystal Barrel Collab. ARMSTRONG 91 ZPHY C51 351 + Benayoun + (ATHU, BARI, BIRM, CERN. CDEF BREAKSTONE 90 ZPHY C48 569 + (ISU, BGNA, CERN, DOTR HEIDH, WARS) BREAKSTONE 90 ZPHY C48 569 + (ISU, BGNA, CERN, DOTR HEIDH, WARS)
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Fraction (Γ _I /Γ) seen seen seen seen	AMSLER 94D PL 833 277 + Anisovich, Spanier + (Crystal Barrel Collab, NISOVICH 94 PL 823 237 + Armstrong + (Crystal Barrel Collab, BUGG 94 PR D50 4412 + Anisovich + (LOQM (LOQM CAMINSKI) 94 PR D50 3145 + Anisovich + (CRAC, IPN) ADAMO 93 NP A558 13C + Agnello+ (OBELIX Collab, CASPERO 93 NP A552 407 ZOU 93 PR O48 R9948 + Augustin, Baker + (Crystal Barrel Collab, AMSLER 92 PL 8291 347 + Augustin, Baker + (Crystal Barrel Collab, ARMSTRONG 91 ZPHY C51 351 + Benayoun + (ATHU, BARI, BIRM, CERN, CDEF BREAKSTONE 90 ZPHY C48 562 + Pennington (RAL, DURH ASTON) 88 NP B296 493 + Awayl, Bienz, Bird (SLAC, NAG, CINC, INUS)
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Fraction (Γ _I /Γ) seen seen seen seen	AMSLER 94D PL 833 277 + Anisovich, Spanier + (Crystal Barrel Collab, NISOVICH) 94 PL 8232 233 + Armstrong + (Crystal Barrel Collab, BUGG 94 PR D50 4412 + Anisovich + (Crystal Barrel Collab, BUGG 94 PR D50 3445 + Anisovich + (CRAC, IPN) ADAMO 33 NP A558 13C + Agnello + (OBELIX Collab, GASPERO 93 NP A562 407 COU 93 PR D48 R3948 + Agnello + (OBELIX Collab, GROMAL) AMSLER 91 2PHY C51 351 + Benayoun + (ATHU, BARI, BIRM, CERN, CDEF ARMSTRONG 91 2PHY C51 351 + Benayoun + (ATHU, BARI, BIRM, CERN, CDEF BREAKSTONE 90 2PHY C48 623 + Barres + (ATHU, BARI, BIRM, CERN, CDEF HORIZONG ASTON 80 NP B296 493 + Pennington (RAL, DURH ASTON 80 NP B296 493 + Awayl, Bienz, Bird + (SLAC, NAGO, CINC, INUS) BOLONKIN 88 NP B308 426 + Bioshenko, Gorin + (CLER, FRAS, LALO, PAD)
$egin{array}{cccccccccccccccccccccccccccccccccccc$	Fraction (Γ _I /F) seen seen seen seen seen seen	AMSLER 94D PL 833 277 + Anisovich, Spanier+ (Crystal Barrel Collab, ANISOVICH 94 PL 832 233 + Armstrong+ (Crystal Barrel Collab, PL 822 233 + Armstrong+ (Crystal Barrel Collab, PL 824 224 + Anisovich+ (Crystal Barrel Collab, PL 824 224 + Anisovich+ (CRAC, IPN) (CRAC, IP
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Fraction (Γ _I /Γ) seen seen seen seen seen seen seen	AMSLER 94D PL 833 277 + Anisovich, Spanier+ (Crystal Barrel Collab, NISOVICHO 94 PL 823 237 + Armstrong+ (Crystal Barrel Collab, BUGG 94 PR D50 4412 + Anisovich+ (Crystal Barrel Collab, BUGG 94 PR D50 3445 + Armstrong+ (Crystal Barrel Collab, Property of the Crystal Barrel Crystal Barrel Collab, Property of the Crystal Barrel Co
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Fraction (Γ _I /F) seen seen seen seen seen seen	AMSLER 94D PL 833 277 + Anisovich, Spanier + (Crystal Barrel Collab, NISOVICH 94 PL 832 233 + Armstrong + (Crystal Barrel Collab, BUGG 94 PR D50 4412 + Anisovich + (Crystal Barrel Collab, BUGG 94 PR D50 3445 + Anisovich + (Crystal Barrel Collab, Anisovich + (Crystal Barrel Collab, Crystal Barrel Crystal Barrel Collab, Crystal Barrel Crystal Barrel Collab, Crystal Barrel Crystal Barrel Collab, Crystal Barrel Collab, Crystal Barrel Collab, Crystal Barrel Collab, Crystal Barrel Crystal Barrel Crystal Barrel Crystal Barrel Crystal Crystal Barrel Crystal Crystal Barrel Crystal Crystal Barrel Crystal Barrel Crystal Barrel Crystal Crystal Barrel Crystal Crystal Barrel Crystal Crystal Barrel Crystal Barrel Crystal Crystal Barrel Crystal Crystal Barrel Crystal Barrel Crystal Crystal Crystal Crystal Barrel Crystal Cryst
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Fraction (Γ _I /Γ) seen seen seen seen seen seen seen se	AMSLER 94D PL 833 277 + Anisovich, Spanier + (Crystal Barrel Collab, NISOVICH 94 PL 833 277 + Anisovich, Spanier + (Crystal Barrel Collab, BUGG 94 PR D50 4412 + Anisovich + (LOQM) (Crystal Barrel Collab, BUGG 94 PR D50 3145 + Anisovich + (LOQM) (CRAC, IPN) (
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Fraction (Γ _I /Γ) seen seen seen seen seen seen seen se	AMSLER 94D PL 833 277 + Anisovich, Spanier + (Crystal Barrel Collab.) ANISOVICH 94 PL 832 233 + Armstrons + (Crystal Barrel Collab.) BUGG 94 PR D50 4412 + Anisovich + (Crystal Barrel Collab.) BUGG 94 PR D50 3145 + Anisovich + (CRAC, IPN) ADAMO 93 NP A556 132 + Anisovich + (CRAC, IPN) ADAMO 93 NP A558 132 + Anisovich + (CRAC, IPN) ADAMO 93 NP A558 132 + Anisovich + (CRAC, IPN) ADAMO 93 NP A558 132 + Anisovich + (CRAC, IPN) ADAMO 94 PR D48 R3948 + Anisovich + (Anisovich + (CRAC, IPN) ADAMO 95 PL 8291 347 + Anisovich + (Anisovich + (Anisovich + Anisovich + (Anisovich + (Anisovich + Anisovich + (CRAC, IPN) ADAMO 93 NP A558 132 + Anisovich + Anisovich + (Anisovich + Anisovich + (Anisovich + Anisovich + Anisovich + (Anisovich + Anisovich + Anisovich + (CRAC, IPN) Anisovich + A
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Fraction (Γ _I /Γ) seen seen seen seen seen seen seen se	AMSLER 94D PL 833 277 + Anisovich, Spanier+ (Crystal Barrel Collab.) ANISOVICH 94 PL 832 233 + Armstrons+ (Crystal Barrel Collab.) BUGG 94 PR D50 4412 + Anisovich+ (Crystal Barrel Collab.) BUGG 94 PR D50 3445 + Anisovich+ (Crystal Barrel Collab.) ANISOVICH 94 PR D50 3145 + Anisovich+ (CRAC, IPN) ADIANO 33 NP A558 33C + Agnello+ (OBELIX Collab.) GASPERO 33 NP A558 33C + Agnello+ (OBELIX Collab.) GASPERO 33 NP A558 33C + Agnello+ (CRAC, IPN) AMSLER 97 PR D48 2949 + Bugg 1 Anisovich 1 Anisovich 1 Agnello+ (CRAC, IPN) AMSLER 97 PR D48 2949 + Anisovich 1 Agnello+ (COPM.) ANISOVICH 1 Anisovich 1 Agnello+ (CRAC, IPN) ANISOVICH 1 Agnello+ (COPM.) Anisovich 1 Agnello+ (CRAC, IPN) Anisovich 1 Agnello+ (CRAC, IPN) Anisovich 1 Agnello+ (COPM.) Agnello+ (COPM.) Anisovich 1 Agnello+ (Agnello+ (COPM.) Anisovich 1 Agnello+ (Agnello+ (Agnello+ (Agnello+ (Agnello+ (Agnello+ (Agnello+ (Agnell
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Fraction (Γ _I /F) seen seen seen seen seen seen seen se	AMSLER 94D PL 833 277 + Anisovich, Spanier + (Crystal Barrel Collab.) ANISOVICH 94 PL 832 233 + Armstrong + (Crystal Barrel Collab.) BUGG 94 PR D50 4412 + Anisovich + (Crystal Barrel Collab.) BUGG 94 PR D50 3445 + Anisovich + (Crystal Barrel Collab.) ADAMO 33 NP A558 13C + Agnello+ (OBELIX Collab.) GASPERO 33 NP A558 13C + Agnello+ (OBELIX Collab.) GASPERO 33 NP A552 407 (ROMAI) AMSLER 192 PR D48 2949 + Bugg 1 Anisovich + Agnello+ (COBELIX Collab.) GROMAID AMSLER 192 PR D48 2949 + Augustin, Baker + (ATHU, BARI, Birm, CERN, CDEF ARMSTRONG 91 2PHY C52 389 + Barrel + (ATHU, BARI, Birm, CERN, CDEF ARMSTRONG 91 2PHY C52 389 + Barrel + (ATHU, BARI, Birm, CERN, CDEF ARMSTRONG 90 2PHY C48 623 + Pennington (SMA, CERN, DORT, HEIDH, WARS) HEIDH WARS AND ASTON 80 NP B296 432 + Pennington (SMA, CERN, DORT, HEIDH, WARS) PR D35 1633 AKESSON 80 PR D38 2706 + Bioshenko, Gorin + (CLER, FRAS, LALD, PADO VOROBYEV 88 SINP 48 273 Translated from YAF 48 436. ALD PADO NP B269 485 ALD PADO NP B269 ALD PADO NP B269 ALD PADO NP
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Fraction (\(\Gamma_i/\Gamma\) seen seen seen seen seen seen seen se	AMSLER 94D PL 833 277 + Anisovich, Spanier+ (Crystal Barrel Collab.) ANISOVICH 94 PL 832 233 + Armstrong+ (Crystal Barrel Collab.) BUGG 94 PR D50 4412 + Anisovich+ (CQAC, IPK) ADAMO 93 NP ASS8 13C + Agnelo+ (OBELIX Collab.) GASPERO 93 NP ASS8 13C + Agnelo+ (OBELIX Collab.) GASPERO 93 NP ASS8 13C + Agnelo+ (OBELIX Collab.) AMSLER 92 PL 8291 347 + Augustin, Baker+ (Crystal Barrel Collab.) AMSLER 92 PL 8291 347 + Augustin, Baker+ (Crystal Barrel Collab.) ARMSTRONG 91 ZPHY C51 351 + Benayoun+ (ATHU, BARI, BIRM, CERN, CDEF.) ARMSTRONG 91 ZPHY C48 569 + (ISU, BGNA, CERN, DORF.) BREAKSTONE 90 ZPHY C48 623 + Bennington (RAL, DURH) ASTON 88 NP B296 493 + Awall, Blenz, Bird+ (SLAC, NAGO, CINC, INUS) BOLDINKIN 88 NP B309 426 + Bioshenko, Gorin+ (CLER, FRAS, LALO, PADO) VOROBYEV 88 SJNP 48 273 Translated from YAF 48 435. + Alaitouni+ (CLER, FRAS, LALO, PADO) VOROBYEV 88 SJNP 48 273 Translated from YAF 48 436. + Bioshenko, Gorin+ (Axial Field Spec. Collab.) ALDE 86D NP B264 154 + Alimon, Bricman+ (BELG, LAPP, SERP, CERN, LANL (NDV) TEXT OF THE COLLAB COLLA
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Fraction (\(\Gamma_I/\Gamma\) Seen Seen Seen Seen Seen Seen Seen Se	AMSLER 94D PL 833 277 + Anisovich, Spanier+ (Crystal Barrel Collab, Anisovich) 9 PL 833 277 + Anisovich, Spanier+ (Crystal Barrel Collab, Plant Collab, Plan
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Fraction (Γ_I/Γ) seen seen seen seen seen seen seen se	AMSLER 94D PL 833 277 ANISOVICH. 94 PL 833 277 ANISOVICH. 94 PL 832 233 HARMSTORY 64 PR D50 4412 AMSLER 94 PR D50 4412 AMSLER 94 PR D50 3445 ADAMO 33 NP A558 33C ASPERO 31 PR O48 R9948 AMSLER 94 PR D50 3145 AMSLER 94 PR
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Fraction (Γ_I/Γ) seen seen seen seen seen seen seen se	AMSLER 94D PL B333 277 ANISOVICH 97 B332 233 +Amstovich, Spanier+ (Crystal Barrel Collab.) ANISOVICH 97 B332 233 +Amstovich, Spanier+ (Crystal Barrel Collab.) ANISOVICH 97 B 205 2407 AMSLER 94P PR D50 3415 ARMSTRON 31 PA 558 313C AAMINSKI 94 PR D50 3145 ARMSTRON 31 NP A558 313C ASPERO 33 NP A552 407 ZOU 93 PR O48 R3948 +Bugg +Augustin, Baker+ (ATHU, BARI, BiRM, CERN, CDEF) ARMSTRONG 91 ZPHY C52 389 BREAKSTONE 90 ZPHY C48 569 MORGAN 90 ZPHY C48 522 ASTON 80 NP B256 433 ASTON 80 NP B256 435 FALVARD 88 PR D33 2706 VOROBYEV 88 SINP 48 273 Translated from YAF 48 436. AU 87 PR D35 1653 AKESSON 80 NP B256 435 AKESSON 80 NP B256 435 ALDE 66D NP B269 485 ALDE 66D NP B269 485 ALDE 66D NP B269 485 WICKLUND 80 PR D25 1786 WICKLUND 80 PR D25 1786 WICKLUND 80 PR D35 1543 AKESSON 80 PR D25 1786 WICKLUND 80 PR L54 1469 BECKER 79 NP B151 46 POLYCHRO 79 PR D19 1317 FROGGATT 77 NP B129 89 ROSSELET 77 PR D15 574 GRAYER 74 NP B75 189 HYAMS 73 NP 864 134 OCHS 73 Thesis BEIER 728 PR L29 511 ANISOVICH 978 ZPHY A357 123
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Fraction (Γ_I/Γ) seen seen seen seen seen seen seen se	AMSLER 94D PL 833 277 ANISOVICH 97 PL 833 277 ANISOVICH 97 PL 832 233 +Amstroni, Spanier+ (Crystal Barrel Collab.) ANISOVICH 97 PL 893 123 +Amstroni, Spanier+ (Crystal Barrel Collab.) Anisovich+ (LOQM) (LOQM) ANISOVICH 976 PR D50 3412 +Amstroni, Spanier+ (Crystal Barrel Collab.) Anisovich+ (LOQM) (LOQM) ANISOVICH 976 PN PL 893 123 +Amstroni, Spanier+ (Crystal Barrel Collab.) Anisovich+ (ROMA) R. Kaminskih (CRAC, IPN) R. Bugstin, Baker+ (ATHU, BARI, BIRM, CERN, CDEF) R. Harnes+ (ATHU, BARI, BIRM, CERN, CDEF) R. Harne
	Fraction (Γ_I/Γ) seen seen seen seen seen seen seen se	AMSLER 94D PL 833 277 ANISOVICH 97 B332 233 AMSLER 40 PR D50 4412 ANISOVICH 97 BD 3145 ANISOVICH 97 BD 3146 ANISOVICH 97 BD 3146 ANISOVICH 97 BD 3146 ANISOVICH 97 BD 3146 ANISOVICH 97 BD 3127 ANISOVICH 97 BD 3137 ANISOVICH 97 BD 313 ADIA ANISOVICH 97 BD 3137 AN
	Fraction (Γ_I/Γ) seen seen seen seen seen seen seen se	AMSLER 94D PL 833 277 ANISOVICH 97 PL 833 277 ANISOVICH 97 PL 833 277 AMISOVICH 97 PL 835 125 AMISOVICH 97 PL 835 127 AMISOVICH 97 PL 895 123 AMISOVICH 97 PL 895 124 AMISOVICH 97 PL 895 125 AMISOVIC
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Fraction (Γ_I/Γ) seen seen seen seen seen seen seen se	AMSLER 94D PL 833 277 ANISOVICH 94 PL 832 233 ANISOVICH 94 PL 832 233 AMSLER 94D PR DSD 4412 AMISOVICH 94 PL 832 233 AMSLER 94 PR DSD 4412 AMSLER 94 PR DSD 4412 AMSLER 95 PL 829 3145 ADAMO 93 NP A558 13C ASPERO 93 NP A558 13C ASPERO 93 NP A562 407 ZOU 93 PR O48 R3948 AMSLER 95 PL 8291 347 ARMSTRONG 91 ZPHY CS1 331 ARMSTRONG 91 ZPHY CS1 331 ARMSTRONG 91 ZPHY CS2 389 BREAKSTONE 90 ZPHY C48 569 MORGAN 90 ZPHY C48 562 ASTON 80 NP B296 493 ASTON 80 NP B296 493 ASTON 80 NP B296 493 ASTON 80 PB 2984 94 AW3I, Blenz, Bird+ (SLAC, NAG, CERN, DOTR, IEDH), WARS) BOLONKIN 88 NP B309 426 FALVARD 89 PR D38 2706 VOROBVEV 88 SJNP 48 273 Translated from YAF 48 436. ALDE 96D NP B269 485 ALDE
	Fraction (Γ_I/Γ) seen seen seen seen seen seen seen se	AMSLER 94D PL 833 277 ANISOVICH 94 PL 832 233 AMISOVICH 94 PL 832 233 AMISOVICH 94 PL 832 233 AMISOVICH 97 PR DSD 4412 AMISOVICH 97 PR DSD 4412 AMISOVICH 97 PL 835 13C ANISOVICH 97 PR DSD 4412 AMISOVICH 97 PL 835 123 ANISOVICH 97 PL 8368 861 LI 21 91 PR D43 2161 H- Cocket Admitstance And Anisovich H- CERN, CERN, CERN, CERN, PENDING BLIZZARRI BLITCH HORSE BATE Collab. Albrow Assistance H- Agmission
Γ_1 $\pi\pi$ Γ_2 4π Γ_3 $4\pi^0$ Γ_4 $2\pi^+2\pi^ \Gamma_5$ $\pi^+\pi^-2\pi^0$ Γ_6 $\rho\rho$ Γ_7 $2(\pi\pi)s$ -wave Γ_8 $\eta\eta$ Γ_{10} $\gamma\gamma$ Γ_{11} $e^+e^ VALUE$ (eV) • • • We do not use the folion of the	Fraction (Γ_I/Γ) seen seen seen seen seen seen seen se	AMSLER 94D PL 833 277 ANISOVICH 94 PL 832 233 AMISOVICH 94 PL 832 233 AMISOVICH 94 PL 832 233 AMISOVICH 97 PR DSD 4412 AMISOVICH 97 PR DSD 4412 AMISOVICH 97 PL 835 13C ANISOVICH 97 PR DSD 4412 AMISOVICH 97 PL 835 123 ANISOVICH 97 PL 8368 861 LI 21 91 PR D43 2161 FCOGGATT TON PL 836 861 LI 21 91 PR D43 2161 FCOGGATT TON PL 836 861 LI 272ARIB PL 20 20 20 20 20 20 20 20 20 20 20 20 20
Γ_1 $\pi\pi$ Γ_2 4π Γ_3 $4\pi^0$ Γ_4 $2\pi^+2\pi^ \Gamma_5$ $\pi^+\pi^-2\pi^0$ Γ_6 $\rho\rho$ Γ_7 $2(\pi\pi)s$ -wave Γ_8 $\eta\eta$ Γ_{10} $\gamma\gamma$ Γ_{11} $e^+e^ \Gamma_{11}$ $e^+e^ \Gamma_{11}$ $e^+e^ \Gamma_{12}$ Γ_{13} Γ_{14} Γ_{15} Γ_{15	Fraction (Γ_I/Γ) seen seen seen seen seen seen seen se	AMSLER 94D PL 833 277 ANISOVICH 94 PL 832 233 AMISOVICH 94 PL 832 233 AMISOVICH 94 PL 832 233 AMISOVICH 97 PR DSD 4412 AMISOVICH 97 PR DSD 4412 AMISOVICH 97 PL 835 13C ANISOVICH 97 PR DSD 4412 AMISOVICH 97 PL 835 123 ANISOVICH 97 PL 8368 861 LI 21 91 PR D43 2161 FCOGGATT TON PL 836 861 LI 21 91 PR D43 2161 FCOGGATT TON PL 836 861 LI 272ARIB PL 20 20 20 20 20 20 20 20 20 20 20 20 20

 $h_1(1380)$, $\hat{\rho}(1405)$, $f_1(1420)$

h_1	(1	380)	
-------	----	------	--

 $I^{G}(J^{PC}) = ?^{-}(1+-)$

OMITTED FROM SUMMARY TABLE

Seen in partial-wave analysis of the $KK\pi$ system. Needs confirma-

m	(1380)	I M	MDD.

VALUE (MeV) 1386 ± 19 OUR AVERAGE	DOCUMENT ID TECN COMMENT	_
1440±60	- ABELE 97H CBAR $\overline{p}p \rightarrow K_L^0 K_S^0 \pi^0 \pi^0$	
1380±20	ASTON · 88c LASS 11 K [−] p → K ⁰ _S K [±] π [∓] Λ	

h1 (1380) WIDTH

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
91±30 OUR AVERAGE			
170±80	ABELE	97H CBAR	$\overline{p}p \rightarrow K_L^0 K_S^0 \pi^0 \pi^0$
80±30	ASTON	88C LASS	11 K ⁻ p →
			$K_S^0 K^{\pm} \pi^{\mp} \Lambda$

h1(1380) DECAY MODES

	Mode		
Γ ₁	K K*(892) +	c.c.	
			h1(1380) REFERENCES

97H PL B415 280 88C PL B201 573

 $I^{G}(J^{PC}) = 1^{-}(1^{-+})$

(Crystal Barrel Collab.) (SLAC, NAGO, CINC, INUS)

$\hat{\rho}(1405)$

OMITTED FROM SUMMARY TABLE

See also the mini-review under non- $q\overline{q}$ candidates. (See the index for the page number.)

ρ(1405) MASS

VALUE	(MeV)		DOCUMENT ID	TECN CHG	COMMENT
1392	+25 -22	OUR AVERAGE			
1400	±20	±20	ABELE	98B CBAR	$0.0 \ \overline{\rho} \ n \xrightarrow[\pi^- \pi^0 \eta]{}$
1370	±16	+50 -30	¹ THOMPSON	97 MPS	$18 \pi^{-} p \rightarrow \eta \pi^{-} p$
• • •	We d	o not use the followin	g data for average	s, fits, limits, etc.	
1323.	1 ± 4.	6	² AOYAGI	93 BKEI	$\pi^- p \rightarrow \eta \pi^- p$
1406	± 20		3 ALDE	88B GAM4 0	$\begin{array}{c} 100 \ \pi^{-} \ \rho \rightarrow \\ \eta \pi^{0} \ n \end{array}$

¹ Natural parity exchange.

ρ(1405) WIDTH

VALUE (MeV)	DOCUMENT ID	TECN CHG	COMMENT
333 ±50 OUR AVERAGE			
310 ±50 + 50 - 30	ABELE	988 CBAR	$0.0 \overline{p} n \rightarrow \pi^{-} \pi^{0} \eta$
$385 \pm 40 \begin{array}{c} + 65 \\ -105 \end{array}$	⁴ THOMPSON	97 MPS	$18 \pi^- p \rightarrow \eta \pi^- p$
• • • We do not use the following	g data for averages,	fits, limits, etc.	• •
143.2±12.5	5 AOYAGI	93 BKEI	$\pi^- p \rightarrow \eta \pi^- p$
180 ±20	⁶ ALDE	88B GAM4 0	$100 \pi^- p \rightarrow \pi^0 n$

⁴ Resolution is not unfolded, natural parity exchange.

ô(1405) DECAY MODES

	Mode	Fraction (Γ_I/Γ)
Γ ₁	$\eta \pi^0$ $\eta \pi^-$	seen
Γ ₂ Γ ₃	$\eta \pi^-$	seen
Гз	$\eta'\pi$	possibly seen

β(1405) BRANCHING RATIOS

$\Gamma(\eta \pi^0)/\Gamma_{\text{total}}$					Γ ₁ /Γ
VALUE	DOCUMENT	D	TECN	<u>CHG</u>	COMMENT
• • • We do not use the	following data for avera	ges, fits	s, limits,	etc, e	• • •
not seen	PROKOSH	(IN 958	GAM4		$100 \pi^- \rho \rightarrow \pi^0 \eta$
not seen	⁷ BUGG	94	RVUE		$\eta \pi^0 n$ $\overline{p} p \rightarrow \eta 2 \pi^0$
not seen	8 APEL	81	NICE	0	$40 \pi^- p \rightarrow \pi^0 n$
7.1.1.2.0					<i>4.</i>

⁷ Using Crystal Barrel data.

 $\Gamma(\eta\pi^-)/\Gamma_{\text{total}}$

<0.80

** Osing Crystal Darrel data. 8 A general fit allowing S, D, and P waves (including m=0) is not done because of limited statistics.

 Γ_2/Γ

VALUE	DOCUMENT ID	<u>/EC</u>	N COMMENT	
• • We do not use the for	llowing data for average:	s, fits, lim	its, etc. • • •	
possibly seen	BELADIDZE	93 VES	37π ⁻ N →	$\eta\pi^-N$
$\Gamma(\eta'\pi)/\Gamma_{\text{total}}$				Г ₃ /Г
VALUE	DOCUMENT ID	IEC	N COMMENT	
 • • We do not use the fo 	llowing data for average	s, fits, lim	its, etc. • • •	
possibly seen	BELADIDZE	93 VE	37π ⁻ N →	$\eta \pi^- N$
$\Gamma(\eta'\pi)/\Gamma(\eta\pi^0)$				Γ_3/Γ_1
VALUE CL	% DOCUMENT ID	TEC	N COMMENT	
• • • We do not use the fo	llowing data for average	s, fits, lim	its, etc. • • •	

∂(1405) REFERENCES

ABELE	98B	PL B423 175	A. Abele, Adomeit, Ams	lez± (Covstal	Barrel Collab.)	
THOMPSON	97	PRL 79 1630	+Adams+	act (Crystan	(E852 Collab.)	
PROKOSHKIN	95B	PAN 58 606	+Sadovski		(SERP)	
BUGG	94	Translated from YAF PR D50 4412	58 662. +Anisovich+		(LOOM)	
AOYAGI	93	PL B314 246	+Fukui, Hasegawa+		(BKEI Collab.)	
BELADIDZE	93	PL 313 276	+Berdnikov, Bityukov+		(VES Collab.)	
BOUTEMEUR	90	Hadron 89 Conf. p 1		BELG, LANL, LAP		
ALDE	888	PL B205 397	+Binon, Boutemeur+		LANL, LAPP) IGJPO	•
APEL	81	NP B193 269	+Augenstein, Bertolucci, (Donskov+	(SERP, CERN)	

OTHER RELATED PAPERS -

		_	,,,_,,,,,,,	
LACOCK	97	PL B401 308	P. Lacock+	(EDIN, LIVP)
SVEC	97C	PR D56 4355	M. Svec	(MCGI)
PROKOSHKIN	95C	PAN 58 853 Translated from	+Sadovski YAF 58 921.	(SERP)
KALASHNIK	94	ZPHY C62 323	Kalashnikova	(ITEP)
IDDIR	88	PL B205 564	+Le Yaouanc, Ono+	(ORSAY, ŤOKY)
TUAN	88	PL B213 537	+Ferbel, Dalitz	(HAWA, ROCH, OXFTP)
ZIELINSKI	87	ZPHY C34 255		(ROCH)

 $f_1(1420)$

$$I^G(J^{PC}) = 0^+(1^{++})$$

BOUTEMEUR 90 GAM4 100 $\pi^- p \rightarrow 4 \gamma n$

See the minireview under $\eta(1440)$.

f1(1420) MASS

				,			
VALUE (M	eV)		EVT5	DOCUMENT_ID		TECN	COMMENT
1426.2	2± 1.	2 OUR	AVERAGE	Error includes sca below.	le fac	ctor of 1	.3. See the ideogram
. 1426	± 1			BARBERIS	97C	OMEG	450 pp → ppK ⁰ _S K [±] π [∓]
1425	± 8			BERTIN	97	OBLX	$0.0 \overline{p}p \rightarrow K^{\pm}(K^{0})\pi^{\mp}\pi^{+}\pi^{-}$
1430	± 4			¹ ARMSTRONG	92E	OMEG	85,300 $\pi^+ p$, $pp \rightarrow \pi^+ p$, $pp(K\overline{K}\pi)$
1462	±20			² AUGUSTIN	92	DM2	$J/\psi \rightarrow \gamma K \overline{K} \pi$
1443	+ 7	+ 3 - 2	1100	BAI	90c	MRK3	$J/\psi \rightarrow \gamma K_S^0 K^{\pm} \pi^{\mp}$
1425		_	17	BEHREND	89	CELL	$\gamma\gamma \rightarrow K_S^0 K^{\pm} \pi^{\mp}$
1442	± 5	+10 -17	111	BECKER	87	MRK3	e^+e^- , $\omega K\overline{K}\pi$
1423	± 4			GIDAL			$e^+e^- \rightarrow e^+e^- K \overline{K} \pi$
1417	±13		13	AIHARA	86C	TPC	$e^+e^- \rightarrow e^+e^- K \overline{K} \pi$
1422	± 3			CHAUVAT	84	SPEC	ISR 31.5 pp
1440	±10			3 BROMBERG	80	SPEC	$100 \pi^- p \rightarrow K \overline{K} \pi X$
1426	± 6		221	DIONISI	80	нвс	$4\pi^- p \rightarrow K\overline{K}\pi n$
1420	±20			DAHL	67	нвс	1.6-4.2 π ⁻ p
W	/e do	not use	the following	g data for averages	, fits	, limits,	etc. • • •
1429			389	-			$300 pp \rightarrow K\overline{K}\pi pp$
1425			1520				85 π ⁺ ρ, ρρ →
1423	- 4		2020	7111131110110	••	JI20	$(\pi^+, p)(K\overline{K}\pi)p$
~ 1420				BITYUKOV	84	SPEC	32 K ⁻ p →

¹ This result supersedes ARMSTRONG 84, ARMSTRONG 89.

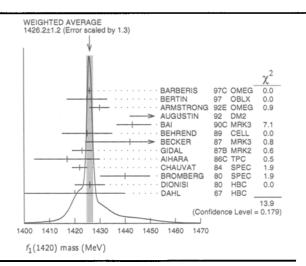
³ Seen in the P_0 -wave intensity of the $\eta\pi^0$ system, unnatural parity exchange.

⁵ Unnatural parity exchange.

⁶ Seen in the P_0 -wave intensity of the $\eta\pi^0$ system, unnatural parity exchange.

² From fit to the $K^*(892)K1^{++}$ partial wave.

³ Mass error increased to account for a₀(980) mass cut uncertainties.



f ₁ (1420) WIDTH							
VALUE (OUP A	EVTS VERAGE	DOCUMENT ID		TECN	COMMENT
	± 4	, 00K F	LIONGE	BARBERIS	97c	OMEG	450 pp → ppK ⁰ _S K±π [∓]
45	±10			BERTIN	97	OBLX	$0.0 \overline{p}p \rightarrow K^{\pm}(K^{0})\pi^{\mp}\pi^{+}\pi^{-}$
58	±10			⁴ ARMSTRONG	92E	OMEG	85,300 $\pi^+ p$, $pp \rightarrow \pi^+ p$, $pp(K\overline{K}\pi)$
129	±41			⁵ AUGUSTIN	92	DM2	$J/\psi \rightarrow \gamma K \overline{K} \pi$
68	+29 -18	+8 -9	1100	BAI	90 C	MRK3	$J/\psi ightarrow \gamma K_S^0 K^{\pm} \pi^{\mp}$
42	±22		17	BEHREND	89	CELL	$\gamma\gamma \rightarrow K_5^0 K^{\pm} \pi^{\mp}$
40	+17 -13	±5	111	BECKER	87	MRK3	$e^+e^- \rightarrow \omega K \overline{K} \pi$
35	+47 -20		13	AIHARA	86 C	TPC	$e^+e^-\to~e^+e^-\kappa\overline{\kappa}\pi$
47	±10			CHAUVAT	84	SPEC	ISR 31.5 pp
62	±14			BROMBERG	80	SPEC	100 $\pi^- p \rightarrow K \overline{K} \pi X$
40	±15		221	DIONISI	80	HBC	$4 \pi^- p \rightarrow K \overline{K} \pi n$
60	±20			DAHL	67	HBC	1.6-4.2 π ⁻ p
• • •	We do	not use	the followin	g data for averages	, fits	, limits,	etc. • • •
58	± 8		389	ARMSTRONG	89	OMEG	300 $pp \rightarrow K\overline{K}\pi pp$
62	± 5		1520	ARMSTRONG	84	OMEG	85 π ⁺ p, pp →
~ 50				ВІТУИКОУ	84	SPEC	$(\pi^{+},p)(K\overline{K}\pi)p$ 32 K ⁻ p \to K ⁺ K ⁻ \pi ⁰ Y
⁴ Th 5 Fro	is resul	t superso	edes ARMS (892) K 1	TRONG 84, ARMS + + partial wave.	TRO	NG 89.	

f1(1420) DECAY MODES

	Mode	Fraction (Γ_I/Γ)	
Γ ₁	KKπ	dominant	_
Γ_2	$K\overline{K}^*$ (892)+ c.c.	dominant	
Γ ₃ Γ ₄ Γ ₅	η π π a ₀ (980) π π π ρ	possibly seen	
Γ ₆	4π		
Γ ₇	γ γ*		
Γ8	$ ho^{G}\gamma$		

$f_1(1420) \Gamma(i)\Gamma(\gamma\gamma)/\Gamma(total)$

$\Gamma(K\overline{K}\pi) \times \Gamma(\gamma\gamma^*)/\Gamma_{\text{tot}}$			Γ ₁ Γ ₇ /Γ
VALUE (keV) CL%	DOCUMENT ID	TECN	COMMENT
1.7±0.4 OUR AVERAGE			
$3.0 \pm 0.9 \pm 0.7$	6,7 BEHREND	89 CELL	$e^+e^{e^+e^-} \overset{ ightarrow}{\kappa_S^0} \kappa_\pi$
$2.3^{+1.0}_{-0.9}\pm0.8$	HILL	89 JADE	$e^+e^-\rightarrow e^+e^-K^\pm K^0_S\pi^\mp$
$1.3 \pm 0.5 \pm 0.3$	AIHARA		$e^+e^- \rightarrow e^+e^- K^{\pm} K^0_{S} \pi^{\mp}$
$1.6 \pm 0.7 \pm 0.3$	6,8 GIDAL	878 MRK2	$e^+e^- \rightarrow e^+e^- K \overline{K} \pi$
• • • We do not use the follo	wing data for average	s, fits, limits	, etc. • • •
<8.0 95	JENNI	83 MRK2	$e^+e^- \rightarrow e^+e^- K \overline{K} \pi$
⁶ Assume a ρ -pole form fact ⁷ A ϕ - pole form factor give	s considerably smalle	widths.	

⁸ Published value divided by 2.

f₁(1420) BRANCHING RATIOS

	71(1420)	BRANCHIN	3 FV	41103		
Γ(<i>K K</i> *(892) + c.c.)/	'Γ(<i>ΚҠ</i> π)					Γ_2/Γ_1
VALUE • • • We do not use the	fallandar .	DOCUMENT ID			COMMENT	
	: IONOWINE I	_				
0.76±0.06 0.86±0.12		BROMBERG DIONISI	80 80	SPEC HBC	$100 \pi^{-} p \rightarrow K$ $4 \pi^{-} p \rightarrow K\overline{K}$	
$\Gamma(\pi\pi\rho)/\Gamma(K\overline{K}\pi)$						Γ_5/Γ_1
VALUE	CL%	DOCUMENT ID		TECN	COMMENT	
• • We do not use the	following	data for average	s, fits	s, limits,	etc. • • •	
< 0.3	95	CORDEN	78	OMEG	12-15 π - ρ	
<2.0	* *	DAHL	67	нвс	$1.6-4.2 \pi^- p$	
$\Gamma(\eta\pi\pi)/\Gamma(K\overline{K}\pi)$						Γ_3/Γ_1
VALUE	CL%	DOCUMENT ID				
<0.1 • • • We do not use the	95 Sollowing				300 pp → ppη	$\pi^+\pi^-$
	e tollowing	-				W W - \
1.35±0.75 <0.6	90	KOPKË GIDAL	89 87		$J/\psi \to \omega \eta \pi \pi (e^+e^- \to$	
					$e^+e^-\eta\pi^+\pi$	-
<0.5 1.5 ±0.8	95	CORDEN DEFOIX	78 72	OMEG HBC	12-15 π ρ 0.7 Ђρ	
		DEFOIX	12	пьс	0.7 μμ	
$\Gamma(a_0(980)\pi)/\Gamma(\eta\pi\pi$	·)					Γ_4/Γ_3
VALUE	 .	DOCUMENT ID				
• • We do not use the	e following	_				
not seen in either mode		ANDO	86	SPEC	8 π ⁻ ρ	
not seen in either mode 0.4±0.2		CORDEN DEFOIX	78 72	HBC	$12-15 \pi^{\infty} p$ $0.7 \overline{p}p \rightarrow 7\pi$	
U.4±U.2		DEFOIX	12	пвс	$0.1 pp \rightarrow 1\pi$	
$\Gamma(4\pi)/\Gamma(K\overline{K}^*(892))$	•					Γ_6/Γ_2
VALUE	<u>CL%</u>	DOCUMENT ID				
• • We do not use th	-	-				
<0.90	95	DIONISI	80	HBC	4 π ⁻ p	
Γ(<i>ΚҠ</i> π)/[Γ(<i>ΚҠ</i> *(8	392) + c.c.	$-) + \Gamma(a_0(980)$)#)]		Γ1/($\Gamma_2+\Gamma_4)$
VALUE	 .	DOCUMENT ID				
• • We do not use th	_					
0.65±0.27		⁹ DIONISI		HBC	4 π ⁻ p	
⁹ Calculated using Γ(<i>i</i>	$(K)/\Gamma(\eta\pi)$	$= 0.24 \pm 0.07$	for a	o(980) 1	fractions.	
$\Gamma(a_0(980)\pi)/\Gamma(K\overline{K})$	*(892)+	c.c.)				Γ_4/Γ_2
VALUE	CL%	DOCUMENT ID		TECN	COMMENT	
• • • We do not use th	e following	data for average	s, fit	s, limits,	etc. • • •	
<0.04	68	ARMSTRONG	84	OMEG	85 π ⁺ ρ	
$\Gamma(4\pi)/\Gamma(K\overline{K}\pi)$						Γ_6/Γ_1
VALUE	CL%	DOCUMENT ID		TECN	COMMENT	
<0.62	95	ARMSTRONG	890	OMEG	$85 \pi p \rightarrow 4\pi X$	
$\Gamma(\rho^0\gamma)/\Gamma_{\text{total}}$						Гв/Г
VALUE	CL%	DOCUMENT ID		TECN	COMMENT	. 6/ '
<0.08		O ARMSTRONG			300 pp → pp1	+ , - ~
10 Using the data on th					220 pp pp	,
- Osing the data on tr	ic ΛΛπ M	ode Holli AKIVIS	. NO	113 07.		

f1(1420) REFERENCES

	140.000							
BARBERIS	97C	PL B413 225	D. Barberis+ (WA102 Collab.)					
BERTIN	97	PL B400 226	+Bruschi, Capponi+ (ÒBELIX Collab.)					
ARMSTRONG	92C	ZPHY C54 371	+Barnes, Benayoun+ (ATHU, BARI, BIRM, CERN, CDEF)					
ARMSTRONG	92E	ZPHY 56 29	+Benayoun+ (ATHU, BARI, BIRM, CERN, CDEF) JPC					
AUGUSTIN	92	PR D46 1951	+Cosme (DM2 Collab.)					
ARMSTRONG	91B	ZPHY C52 389	+Barnes+ (ATHU, BARI, BIRM, CERN, CDEF)					
BAI	90C	PRL 65 2507	+Blaylock+ (Mark III Collab.)					
ARMSTRONG	89	PL B221 216	+Benayoun+(CERN, CDEF, BIRM, BARI, ATHU, CURIN+) JPC					
ARMSTRONG	89G	ZPHY C43 55	+Bloodworth+ (CERN, BIRM, BARI, ATHU, CURIN+)					
BEHREND	89	ZPHY C42 367	+Criegee+ (CELLO Collab.)					
HILL	89	ZPHY C42 355	+Olsson+ (JADE Collab.) JP					
KOPKE	89	PRPL 174 67	+Wermes+ (CERN)					
AIHARA	88B	PL B209 107	+Alston-Garnjost+ (TPC-2 γ Collab.)					
BECKER	87	PRL 59 186	+Blaylock, Bolton, Brown+ (Mark III Collab.) JP					
GIÐAL	87	PRL 59 2012	+Boyer, Butler, Cords, Abrams+ (LBL, SLAC, HARV)					
GIDAL	87B	PRL 59 2016	+Boyer, Butler, Cords, Abrams+ (LBL, SLAC, HARV)					
AIHARA	86C	PRL 57 2500	+Alston-Garnjost+ (TPC-2γ Collab.) JP					
ANDO	86	PRL 57 1296	 +Imai+ (KEK, KYOT, NIRS, SAGA, INUS, TSUK+) 					
ARMSTRONG	84	PL 146B 273	+Bloodworth, Burns+ (ATHU, BARI, BIRM, CERN) JP					
BITYUKOV	84	SJNP 39 735 Translated from	5. Bityukov+ YAF 39 1165. (SERP)					
CHAUVAT	84	PL 148B 382	+Meritet, Bonino+ (CERN, CLER, UCLA, SACL)					
JENNI	83	PR D27 1031	+Burke, Telnov, Abrams, Blocker+ (SLAC, LBL)					
BROMBERG	80	PR D22 1513	+Haggerty, Abrams, Dzierba (CIT, FNAL, ILLC, IND)					
DIONISI	80	NP B169 1	+Gavillet+ (CERN, MADR, CDEF, STOH) UP					
CORDEN	78	NP B144 253	+Corbett, Alexander+ (BIRM, RHEL, TELA, LOWC)					
DEFOIX	72	NP B44 125	+Nascimento, Bizzarri+ (CDEF, CERN)					
DAHL	67	PR 163 1377	+Hardy, Hess, Kirz, Miller (LRL) IJP					
Also	65	PRL 14 1074	Miller, Chung, Dahl, Hess, Hardy, Kirz+ (LRL, UCB)					
		or	THER RELATED PAPERS					

OTHER RELATED PAPERS

IIZUKA	91	PTP 86 885	+Koibuchi	(NAGO)
ISHIDA	89	PTP 82 119	+Oda, Sawazaki, Yamada	(NIHO)
AIHARA	88C	PR D38 1	+Alston-Garnjost+	(TPC-2γ Čollab.) JPC
BITYUKOV	88	PL B203 327	+Borisov, Dorofeev+	(SERP)
PROTOPOP	87B	Hadron 87 Conf.	Protopopescu, Chung	(BNL)

 $\omega(1420), f_2(1430), \eta(1440)$

$\omega(1420)$

$$I^{G}(J^{PC}) = 0^{-}(1^{-})$$

ω(1420) MASS

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
1419±31	315	1 ANTONELLI	92	DM2	$1.34-2.4e^{+}e^{-} \rightarrow \rho\pi$
• • • We do not u	ise the followin	ig data for averag	es, fit	s, limits,	etc. • • •
1440±70		² CLEGG	94	RVUE	

 $^{^{1}}$ From a fit to two Breit-Wigner functions interfering between them and with the ω,ϕ tails with fixed (+,-,+) phases.

ω(1420) WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID	<u> </u>	TECN	COMMENT
174±59	315	3 ANTONELLI	92	DM2	$1.34-2.4e^{+}e^{-} \rightarrow \rho\pi$
• • • We do not	use the followin	ng data for averag	es, fit	s, ilmits,	, etc. • • •
240±70		⁴ CLEGG	94	RVUE	
3 From a fit to to		er functions interfe	ring b	etween t	them and with the ω,ϕ tal

ω(1420) DECAY MODES

	Mode	Fraction (Γ_I/Γ)
Γ1	ρπ	dominant
Γ ₂ Γ ₃	ωππ e+e-	

$\omega(1420) \Gamma(l)\Gamma(e^+e^-)/\Gamma(total)$

$\Gamma(\rho\pi)\times\Gamma(e^+$	e-)/F _{total}				Γ ₁ Γ ₃ /Γ
VALUE (eV)		DOCUMENT ID	TECN	COMMENT	
81±31	315	5 ANTONELLI 92	DM2	1.34-2.4e+e-	→ ρπ
5					

From a fit to two Breit-Wigner functions interfering between them and with the ω , ϕ talks with fixed (+,-,+) phases.

		4	/(1420) R	EFERENCES	
CLEGG ANTONELLI	94 92	ZPHY C62 455 ZPHY C56 15	+Donna +Baldin		(LANC, MCHS) (DM2 Collab.)
		—— от	HER REL	ATED PAPERS -	
ACHASOV	97F	PAN 60 2029 Translated from Y		Achasov, Kozhevnikov	(NOVM)
ATKINSON	87	ZPHY C34 157	+	(BONN, CERN, GLAS,	LANC, MCHS, CURIN)
ATKINSON	84	NP B231 15	÷	(BONN, CERN, GLAS, L	
ATKINSON	83B	PL 127B 132	÷	(BONN, CERN, GLAS, L	



$$I^G(J^{PC}) = 0^+(2^{++})$$

OMITTED FROM SUMMARY TABLE

This entry lists nearby peaks observed in the D wave of the $K\overline{K}$ and $\pi^+\pi^-$ systems. Needs confirmation.

£(1430) MASS

LUE (MeV)	DOCUMENT ID		TECN	COMMENT
1430 OUR ESTIMATE				
 We do not use the 	following data for averag	es, fit	s, Ilmits,	etc. • • •
1421± 5	AUGUSTIN	87	DM2	$J/\psi \rightarrow \gamma \pi^+ \pi^-$
1480±50	AKESSON	86	SPEC	$pp \rightarrow pp\pi^{+}\pi^{-}$
1436 ⁺²⁶ -16	DAUM			17-18 π ⁻ p →
1412± 3	DAUM	84	CNTR	$63 \pi^{-} p \to K_{5}^{0} K_{5}^{0} n$ $K^{+} K^{-} n$
1439 + 5 6	1 BEUSCH	67	OSPK	$5.7.12 \pi^{-} p \rightarrow K_{0}^{0} K_{0}^{0} n$

6(1430) WIDTH

VALUE (MeV)	DOCUMENT ID		<u>TECN</u>	COMMENT
• • • We do not use the following	ng data for averag	es, fit	s, limits,	etc. • • •
30± 9	AUGUSTIN			$J/\psi \rightarrow \gamma \pi^+ \pi^-$
150±50	AKESSON	86	SPEC	$pp \rightarrow pp\pi^{+}\pi^{-}$
81 ^{+ 56} - 29	DAUM			17-18 $\pi^- p \rightarrow K^+ K^- p$
14± 6	DAUM	84	CNTR	$63 \pi^{-} p \rightarrow K_{S}^{0} K_{S}^{0} n,$ $K^{+} K^{-} n$
43 ⁺¹⁷ -18	² BEUSCH	67	OSPK	5,7,12 $\pi^- p \rightarrow K_S^0 K_S^0 n$
² Not seen by WETZEL 76.				

£(1430) DECAY MODES

	Mode	
1	κK	
2	$\pi\pi$	

%(1430) REFERENCES

AKESSON 86 NI DAUM 84 ZF WETZEL 76 NI		Imehed+ (Axial Fieler+ (AMST, CERN, CRAC	R, FRAS, PADO) Id Spec. Collab.) C, MPIM, OXF+) JP H, CERN, LOIC) (ETH, CERN)
---	--	--	---

 $\eta(1440)$

$$I^{G}(J^{PC}) = 0^{+}(0^{-})$$

See also the mini-review under non- $q\overline{q}$ candidates. (See the index for the page number.)

THE $\eta(1440)$, $f_1(1420)$, AND $f_1(1510)$

Written March 1998 by M. Aguilar-Benitez (CIEMAT, Madrid) and C. Amsler (Zürich).

The first observation of $\eta(1440)$ was made in $p\overline{p}$ annihilation at rest into $\eta(1440)\pi^+\pi^-$, $\eta(1440) \to K\overline{K}\pi$ (BAIL-LON 67). This state was reported to decay through $a_0(980)\pi$ and $K^*(892)\overline{K}$ with roughly equal contributions. The $\eta(1440)$ has also been observed in radiative $J/\psi(1S)$ decay to $K\overline{K}\pi$ (SCHARRE 80, EDWARDS 82E, AUGUSTIN 90).

The $f_i(1420)$, decaying to $K^*\overline{K}$ was reported in π^-p reactions at 4 GeV/c (DIONISI 80). However, later analyses found that the 1400-1500 MeV region is far more complex. In π^-p experiments (CHUNG 85, REEVES 86, BIRMAN 88) reported 0^{-+} with a dominant $a_0(980)\pi$ contribution to $K\overline{K}\pi$. The π^-p data of RATH 89 at 21 GeV/c suggest the presence of two pseudoscalars decaying to $K\overline{K}\pi$, one around 1410 MeV decaying through $a_0(980)\pi$ and the other around 1470 MeV, decaying to $K^*\overline{K}$. A reanalysis of the MARK III data in radiative $J/\psi(1S)$ decay to $K\overline{K}\pi$ (BAI 90C) also claims the existence of two pseudoscalars in the 1400-1500 MeV range, the lower mass state decaying through $a_0(980)\pi$ and the higher mass state decaying via $K^*\overline{K}$. In addition, $f_1(1420)$ is observed to decay into $K^*\overline{K}$.

In $\pi^- p \to \eta \pi \pi n$ charge-exchange reactions at 8-9 GeV/c the $\eta\pi\pi$ mass spectrum is dominated by $\eta(1440)$ and $\eta(1295)$ (ANDO 86, FUKUI 91C) and at 100 GeV ALDE 97B report $\eta(1295)$ and $\eta(1440)$ decaying to $\eta \pi^0 \pi^0$ with a weak $f_1(1285)$ and no evidence for $f_1(1420)$.

²Using data published by ANTONELLI 92.

⁴Using data published by ANTONELLI 92.

An experiment in $\overline{p}p$ annihilation at rest into $K\overline{K}3\pi$ (BERTIN 95) reports two pseudoscalars with decay properties similar to BAI 90C, although the lower state shows, apart from $a_0(980)\pi$, a large contribution from the direct decay $\eta(1440) \to K\overline{K}\pi$. We note that the data from AUGUSTIN 92 also suggest two states but their intermediate states, $a_0(980)\pi$ and $K^*\overline{K}$, are reversed relative to BAI 90C.

In $J/\psi(1S)$ radiative decay $\eta(1440)$ decays to $K\overline{K}\pi$ through $a_0(980)\pi$ and hence a signal is also expected in the $\eta\pi\pi$ mass spectrum. This has indeed been observed by MARK III in $\eta\pi^+\pi^-$ (BOLTON 92B) which report a mass of 1400 MeV, in line with the existence of a low mass pseudoscalar in the $\eta(1440)$ structure, decaying to $a_0(980)\pi$. This state is also observed in $\overline{p}p$ annihilation at rest into $\eta\pi^+\pi^-\pi^0\pi^0$ where it decays to $\eta\pi\pi$ (AMSLER 95F). The intermediate $a_0(980)\pi$ accounts for roughly half of the $\eta\pi\pi$ rate, in accord with MARK III (BOLTON 92B) and DM2 (AUGUSTIN 90). However, ALDE 97B reports only a very small contribution of $a_0(980)\pi$.

One of these two pseudoscalars could be the first radial excitation of the η' , with $\eta(1295)$ the first radial of the η . Ideal mixing suggested by the $\eta(1295)$ and $\pi(1300)$ mass degeneracy would then imply that the second isoscalar in the nonet is mainly $s\bar{s}$ and hence couples to $K^*\bar{K}$, in accord with observations for the upper $\eta(1440)$ state. This scheme then favors an exotic interpretation of the lower state, perhaps gluonium mixed with $q\bar{q}$ (CLOSE 97B) or a bound state of gluinos (FARRAR 96). The gluonium interpretation is, however, not favoured by lattice gauge theories, which predict the 0^{-+} state above 2 GeV (BALI 93).

Axial (1^{++}) mesons are not observed in $\overline{p}p$ annihilation at rest in liquid hydrogen which proceeds dominantly through S-wave annihilation. However, in gaseous hydrogen P-wave annihilation is enhanced and, indeed, BERTIN 97 report $f_1(1420)$ decaying to $K^*\overline{K}$ in gaseous hydrogen, while confirming their earlier evidence for two pseudoscalars (BERTIN 95).

In $\gamma\gamma$ fusion from e^+e^- annihilations, a signal around 1420 MeV is seen in single-tag events (GIDAL 87B, AIHARA 88B, BEHREND 89, HILL 89) where one of the two photons is off-shell. However, it is totally absent in the untagged events where both photons are real. This points to a spin 1 object which is not produced by two real (massless) photons (Yang-Landau theorem). The 2γ decays also implies C=+1. For the parity, AIHARA 88C and BEHREND 89 both find angular distributions with positive parity preferred, but negative parity cannot be excluded.

The $f_1(1420)$ is definitively observed in $K\overline{K}\pi$ in pp central production at 300 and 450 GeV, together with $f_1(1285)$. The latter decays via $a_0(980)\pi$ and the former only via $K^*\overline{K}$, while $\eta(1440)$ is absent (ARMSTRONG 89, BARBERIS 97C). The $K_SK_S\pi^0$ decay mode of $f_1(1420)$ establishes unambiguously that C=+1. On the other hand, there is no evidence for any state decaying to $\eta\pi\pi$ around 1400 MeV and hence the $\eta\pi\pi$ mode of $f_1(1420)$ is suppressed (ARMSTRONG 91B).

We now turn to the experimental evidence for $f_1(1510)$. Two states, $f_1(1420)$ and $f_1(1510)$, decaying to $K^*\overline{K}$, compete for the $s\overline{s}$ assignment in the 1^{++} nonet. The $f_1(1510)$ was seen in $K^-p \to \Lambda K\overline{K}\pi$ at 4 GeV/c (GAVILLET 82) and at 11 GeV/c (ASTON 88C). Evidence is also reported in π^-p at 8 GeV/c, based on the phase motion of the 1^{++} $K^*\overline{K}$ wave (BIRMAN 88).

The absence of $f_1(1420)$ in K^-p (ASTON 88C) argues against $f_1(1420)$ being the $s\bar{s}$ member of the 1⁺⁺ nonet. However, $f_1(1420)$ has been reported in K^-p but not in $\pi^- p$ (BITYUKOV 84) while two experiments do not observe $f_1(1510)$ in K^-p (BITYUKOV 84, KING 91). It is also not seen in radiative $J/\psi(1S)$ decay (BAI 90C, AUGUSTIN 92), central collisions (BARBERIS 97C), nor in $\gamma\gamma$ collisions (AI-HARA 88C), although and surprisingly for an ss state, a signal is reported in 4π decays (BAUER 93B). These facts led to the conclusion that $f_1(1510)$ is not well established and that its assignment as $s\bar{s}$ member of the 1⁺⁺ nonet is premature (CLOSE 97D). The Particle Data Group agrees and has removed this state from the Summary Table. Assigning instead $f_1(1420)$ to the 1⁺⁺ nonet one finds a nonet mixing angle of \sim 50° (CLOSE 97D). This is derived from the mass formula and from $f_1(1285)$ radiative decays to $\phi\gamma$ (BITYUKOV 88) and $\rho\gamma$ (AMELIN 95).

Arguments favoring $f_1(1420)$ being a hybrid $q\bar{q}g$ meson or a four-quark state are put forward by ISHIDA 89 and by CALDWELL 90, respectively, while LONGACRE 90 argues that this particle is a molecular state formed by the π orbiting in a P-wave around an S-wave $K\bar{K}$ state.

Summarizing, there is strong evidence for $f_1(1420)$, mostly produced in central collisions and decaying to $K^*\overline{K}$, and for $\eta(1440)$ mostly produced in radiative $J/\psi(1S)$ decay and $\overline{p}p$ annihilation at rest, decaying to $K^*\overline{K}$ and $a_0(980)\pi$. Confusion remains as to which states are observed in π^-p interactions. The $f_1(1510)$ is not well established. Furthermore, there are experimental indications for the presence of two pseudoscalars in the $\eta(1440)$ structure. Accordingly, the Particle Data Group has split the $K\overline{K}\pi$ entry for $\eta(1440)$ into $a_0(980)\pi$ and $K^*\overline{K}$.

η(1440) MASS

VALUE (MeV) DOCUMENT ID

1400 - 1470 OUR ESTIMATE Contains possibly two overlapping pseudoscalars.

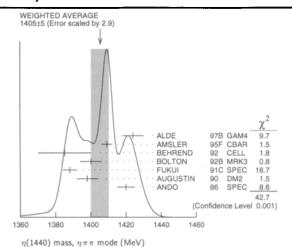
 $\eta\pi\pi$ MODE

VALUE (MeV)	EVTS	DOCUMENT ID	TE	N COMMENT	
				. See the ideogram below	·
1424± 6	2200	ALDE	978 GA	M4 100 $\pi^- p \rightarrow \eta \pi^0 \pi^0$	o _n
1409± 3		AMSLER	95F CB	AR $0 \overline{p} p \rightarrow \pi^+ \pi^- \pi^0$	π ⁰ η `
1385±15		1 BEHREND	92 CE	LL $J/\psi \rightarrow \gamma \eta \pi^+ \pi^-$	-
1400 ± 6		1 BOLTON	92B MF	K3 $J/\psi \rightarrow \gamma \eta \pi^+ \pi^-$	
1388 ± 4		FUKUI	91c SP	EC 8.95 $\pi^- p \rightarrow \eta \pi^+$	π ⁻ n
1398 ± 6	261	2 AUGUSTIN	90 DN	12 $J/\psi \rightarrow \gamma \eta \pi^+ \pi^-$	
1420 ± 5		ANDO	86 SP	EC $8\pi^-p \rightarrow \eta\pi^+\pi^-$	n

¹ From fit to the $a_0(980)\pi$ 0 ^{-- +} partial wave.

² Best fit with a single Breit Wigner.

$\eta(1440)$



ππγ MODE

VALUE (MEV)	DUCUMENTID		IELIA	COMMENT	
• • • We do not use the follow	wing data for average	s, fits	i, limits,	etc. • •	
1401 ± 18	3,4 AUGUSTIN	90	DM2	$J/\psi \rightarrow \pi^{+}\pi^{-}$	γγ
1440 ± 20	4 COFFMAN	90	MRK3	$J/\psi \rightarrow \pi^{+}\pi^{-}$	2γ

³ Best fit with a single Breit Wigner.

4π MODE

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMEN	<u>T</u>
• • • We do not use t	he following	data for averages	, fits	, limits,	etc. • •	•
1420±20						$\gamma \pi^{+} \pi^{-} \pi^{+} \pi^{-}$
1489±12	3270	⁵ BISELLO	89B	DM2	$J/\psi \rightarrow$	$4\pi\gamma$

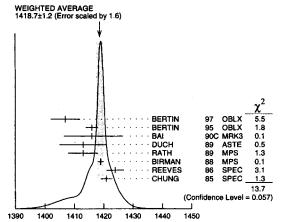
⁵ Estimated by us from various fits.

$K\overline{K}\pi$ MODE (a₀(980) π dominant)

VALUE	(MeV)		EVTS		DOCUMENT II	<u> </u>	TECN	COMMENT
1418.7	±1.2	OUR.	AVERAGE	Error	Includes scale	e factor	of 1.6.	See the ideogram below.
1407	±5			6	BERTIN	97	OBLX	0 p p →
								$\kappa^{\pm}(\kappa^{0})\pi^{\mp}\pi^{+}\pi^{-}$
1416	±2			ь	BERTIN	95	OBLX	$0 \overline{p} p \rightarrow K \overline{K} \pi \pi \pi$
1416	±8	+7 -5	700	7	BAI			$J/\psi \rightarrow \gamma K_S^0 K^{\pm} \pi^{\mp}$
1413	±8		500		DUCH	89	ASTE	$\bar{p}p \rightarrow \pi^{+}\pi^{-}K^{\pm}\pi^{\mp}K^{0}$
1413	±5			7	RATH	89	MPS	$21.4 \pi^{-} p \rightarrow nK_{S}^{0} K_{S}^{0} \pi^{0}$
1419	±1		8800		BIRMAN	88	MPS	$8\pi^-p \rightarrow K^+\overline{K}^0\pi^-n$
1424	±3		620		REEVES	86	SPEC	6.6 pp̄ → KKπX
1421	±2				CHUNG	85	SPEC	$8\pi^-p \rightarrow K\overline{K}\pi n$
• • •	We d	o not i	use the follow	wing d	ata for avera	ges, fits	, limits,	etc. • • •
145 9	±5			8	AUGUSTIN	92	DM2	$J/\psi \to \gamma K \overline{K} \pi$

wave.

8 Excluded from averaging because averaging would be meaningless.



 $\eta(1440)$ mass, $K\overline{K}\pi$ mode ($a_0(980)$ π dominant) (MeV)

K₹# MODE	(K*(892)	K dominant)
----------	----------	-------------

VALUE	<u> </u>	DOCUMENT ID	TEUN	COMMENT
1473± 4 OUR AV	ERAGE Error	includes scale fa	ctor of 1.1.	
1464±10		BERTIN	97 OBLX	$0 \overline{p}p \rightarrow K^{\pm}(K^{0})\pi^{\mp}\pi^{+}\pi^{-}$
1460±10		BERTIN	95 OBLX	0 pp → KKπππ
$1490^{+14}_{-8}^{+3}_{-16}$	1100	BAI	90c MRK3	$J/\psi \to \gamma K_S^0 K^{\pm} \pi^{\mp}$
1475± 4		RATH	89 MPS	$21.4 \pi^{-} p \rightarrow n K_{S}^{0} K_{S}^{0} \pi^{0}$
• • • We do not u	se the followin	g data for averag	es, fits, limits	, etc. • • •
1421±14		9 AUGUSTIN	92 DM2	$J/\psi ightarrow \gamma K \overline{K} \pi$

⁹ Excluded from averaging because averaging would be meaningless.

$K\overline{K}\pi$ MODE (unresolved)

VALUE	<u>EVTS</u>	DOCUMENT ID		<u>TECN</u>	COMMENT
 ● ● We do not 	use the following	ng data for averag	es, fits	, limits,	etc. • • •
1445± 8	693	AUGUSTIN	90	DM2	$J/\psi \rightarrow \gamma K_5^0 K^{\pm} \pi^{\mp}$ $J/\psi \rightarrow \gamma K^{+} K^{-} \pi^{0}$
1433± 8	296	AUGUSTIN	90	DM2	$J/\psi \rightarrow \gamma K^{+}K^{-}\pi^{0}$
1453± 7	170	RATH	89	MPS	21.4 $\pi^- p \rightarrow K_S^0 K_S^0 \pi^0 n$
1440 ^{+ 20} - 15	174	EDWARDS	82E	CBAL	$J/\psi \rightarrow \gamma K^+ K^- \pi^0$
1440 ^{+ 10} - 15		SCHARRE	80	MRK2	$J/\psi \rightarrow \gamma K_5^0 K^{\pm} \pi^{\mp}$
1425 ± 7	800	10 BAILLON	67	HBC	$0 \overline{p}p \rightarrow K \overline{K} \pi \pi \pi$

η(1440) WIDTH

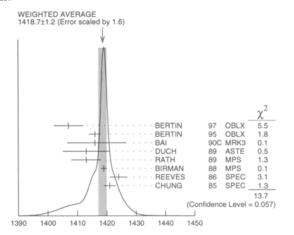
VALUE (MeV) DOCUMENT ID
50 - 80 OUR ESTIMATE Contains possibly two overlapping pseudoscalars.

ηππ MODE

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
56± 7 OUR	AVERAGE	Error Includes scal	le factor of 2.	3. See the ideogram below.
85 ± 18	2200	ALDE	97B GAM4	$100 \pi^- p \rightarrow \eta \pi^0 \pi^0 n$
86±10		AMSLER	95F CBAR	$0 \overline{p} p \rightarrow \pi^+ \pi^- \pi^0 \pi^0 \eta$
47±13		11 BOLTON	928 MRK3	$J/\psi \rightarrow \gamma \eta \pi^+ \pi^-$
59± 4		FUKUI	91c SPEC	$8.95 \pi^- \rho \rightarrow \eta \pi^+ \pi^- \eta$
53±11		¹² AUGUSTIN	90 DM2	$J/\psi \rightarrow \gamma \eta \pi^+ \pi^-$
31 ± 7		ANDO	86 SPEC	$8 \pi^- p \rightarrow \eta \pi^+ \pi^- n$
• • • We do no	t use the fo	ollowing data for av	erages, fits, li	mits, etc. • • •
~ 50		12 BEHREND	92 CELL	$J/\psi \rightarrow \gamma \eta \pi^+ \pi^-$

 $^{^{11}}$ From fit to the $a_0(980)\pi$ 0 $^-$ + partial wave.

¹² From $\eta \pi^+ \pi^-$ mass distribution - mainly $a_0(980)\pi$ - no spin-parity determination available.



 η (1440) mass, $K\overline{K}\pi$ mode (a_0 (980) π dominant) (MeV)

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
• • • We do not use t	he following data for average	es, fit	s, limits,	etc. • • •
174±44	AUGUSTIN	90	DM2	$J/\psi \rightarrow \pi^+\pi^-\gamma\gamma$
60±30	¹³ COFFMAN	90	MRK3	$J/\psi \rightarrow \pi^{+}\pi^{-}2\gamma$
13 This peak in the γ_i	channel may not be related	l to t	he η(144	10).

4π MODE VALUE (MeV)	EVTS	DOCUMENT II	D TECN	COMMEN	IT
• • • We do not					
• • • we do not	use the lollowi	ing data for avera	Res' urs' murs'	elc. • •	•
160±30		BUGG	95 MRK3	$J/\psi \rightarrow$	$\gamma \pi^+ \pi^- \pi^+ \pi^-$
144±13	3270	14 BISELLO	89B DM2	$J/\psi \rightarrow$	$4\pi\gamma$
14 Estimated by a	s from various	fits.			

⁴ This peak in the $\gamma \rho$ channel may not be related to the $\eta(1440)$.

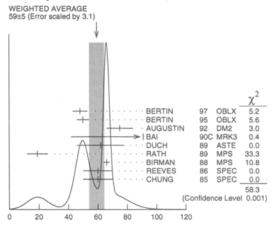
⁶ Decaying into $(K\overline{K})_S\pi$, $(K\pi)_S\overline{K}$, and $a_0(980)\pi$.

⁷ From fit to the $a_0(980)\pi$ 0 $^{-+}$ partial wave. Cannot rule out a $a_0(980)\pi$ 1 $^{++}$ partial

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
59± 5 OUR AVERAG	SE Error	includes scale facto	r of 3	.1. See	the ideogram below.
48± 5		15 BERTIN	97	OBLX	$0.0 \ \overline{\rho} p \rightarrow K^{\pm} (K^{0}) \pi^{\mp} \pi^{+} \pi^{-}$
50 ± 4		15 BERTIN	95	OBLX	$0 \overline{p} p \rightarrow K \overline{K} \pi \pi \pi$
75± 9		AUGUSTIN	92	DM2	$J/\psi \rightarrow \gamma K \overline{K} \pi$
91 + 67 + 15 - 31 - 38		¹⁶ BAI			$J/\psi \rightarrow \gamma K_S^0 K^{\pm} \pi^{\mp}$
62±16	500	DUCH	89	ASTE	$p_p \rightarrow K \overline{K} \pi \pi \pi$
19± 7		16 RATH			21.4 $\pi^- \rho \to \pi K_S^0 K_S^0 \pi^0$
66± 2	8800	BIRMAN	88	MPS	$8\pi^-p \rightarrow K^+\overline{K}^0\pi^-n$
60 ± 10	620	REEVES			6.6 pp → KK#X
60±10		CHUNG	85	SPEC	$8\pi^- p \rightarrow K\overline{K}\pi n$

¹⁵ Decaying into $(K\overline{K})_S\pi$, $(K\pi)_S\overline{K}$, and $a_0(980)\pi$.

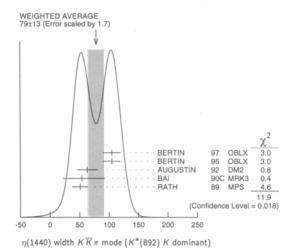
 16 From fit to the $a_0(980)\pi$ 0 $^{-+}$ partial wave , but $a_0(980)\pi$ 1 $^{++}$ cannot be excluded.



 η (1440) width $K\overline{K}\pi$ mode (a_0 (980) π dominant)

KKπ MODE (K*(892) K dominant)

VALUE	DOCUMENT ID		TECN	COMMENT
79±13 OUR AVERAGE	Error includes scale fact	or of	1.7. See	the ideogram below.
105±15	BERTIN	97	OBLX	$0.0 \ \overline{\rho}\rho \rightarrow K^{\pm}(K^{0})\pi^{\mp}\pi^{+}\pi^{-}$
105 ± 15	BERTIN			$0 \overline{p} p \rightarrow K \overline{K} \pi \pi \pi$
63±18	AUGUSTIN	92	DM2	$J/\psi \rightarrow \gamma K \overline{K} \pi$
54+37+13 -21-24	BAI	90 0	MRK3	$J/\psi \rightarrow \gamma K_S^0 K^{\pm} \pi^{\mp}$
51±13	RATH	89	MPS	$ \begin{array}{c} 21.4 \ \pi^{-} \ \rho \rightarrow \\ n K_{5}^{0} \ K_{5}^{0} \ \pi^{0} \end{array} $



$\eta(1440)$ KKπ MODE (unresolved) DOCUMENT ID . TECN COMMENT EVTS 296 AUGUSTIN 90 DM2 $J/\psi \rightarrow \gamma K^+ K^- \pi^0$ 93±14 90 DM2 $J/\psi \rightarrow \gamma K_S^0 K^{\pm} \pi^{\mp}$ **AUGUSTIN** 105 ± 10 693 21.4 $\pi^- p \to K_5^0 K_5^0 \pi^0 n$ 89 MPS RATH 100 ± 11 170 82E CBAL $J/\psi \rightarrow \gamma K^+ K^- \pi^0$ $55 + 20 \\ -30$ 174 **EDWARDS** 80 MRK2 $J/\psi \rightarrow \gamma K_5^0 K^{\pm} \pi^{\mp}$ 50⁺³⁰ SCHARRE 17 BAILLON 67 HBC 0.0 pp → KKπππ 80 ± 10 800 17 From best fit to 0 $^-$ + partial wave , 50% $K^*(892)K$, 50% $a_0(980)\pi$. η(1440) DECAY MODES Fraction (Γ_I/Γ) Γ_1 Γ_2 $K\overline{K}^*(892) + c.c.$ seen Γ₃ ηππ $a_0(980)\pi$ seen Γ5 $\eta(\pi\pi)_{S\text{-wave}}$ seen Γ₆ Γ₇ 4π $\rho^0 \gamma$ $\eta(1440) \Gamma(I)\Gamma(\gamma\gamma)/\Gamma(total)$ $\Gamma(K\overline{K}\pi) \times \Gamma(\gamma\gamma)/\Gamma_{\text{total}}$ $\Gamma_1\Gamma_7/\Gamma$ TECN COMMENT DOCUMENT_ID VALUE (keV) CL% BEHREND 89 CELL $\gamma\gamma \rightarrow K_S^0 K^{\pm} \pi^{\mp}$ 95 • • • We do not use the following data for averages, fits, limits, etc. • • 860 TPC $e^{+}e^{-} \rightarrow \kappa_{S}^{0} \kappa^{\pm} \pi^{\mp}$ 95 AIHARA 85B TASS e+e- → e+e-KKπ ALTHOFF <2.2 83 MRK2 $e^+e^- \rightarrow e^+e^- K \overline{K} \pi$ JENNI <8.0 $\Gamma_3\Gamma_7/\Gamma$ $\Gamma(\eta\pi\pi) \times \Gamma(\gamma\gamma)/\Gamma_{\text{total}}$ DOCUMENT ID TECN COMMENT VALUE (keV) • • • We do not use the following data for averages, fits, limits, etc. • • • ANTREASYAN 87 CBAL $e^+\,e^- ightarrow \, e^+\,e^-\,\eta\,\pi\,\pi$ $\Gamma(\rho^0\gamma) \times \Gamma(\gamma\gamma)/\Gamma_{\text{total}}$ $\Gamma_8\Gamma_7/\Gamma$ CL% DOCUMENT ID TECN COMMENT 84E TASS $e^+e^-_{e^+e^-\pi^+\pi^-\gamma}$ ALTHOFF η (1440) BRANCHING RATIOS $\Gamma(\eta\pi\pi)/\Gamma(K\overline{K}\pi)$ Γ_3/Γ_1 CL% DOCUMENT ID TECN COMMENT EDWARDS 83B CBAL $J/\psi \rightarrow \eta \pi \pi \gamma$ < 0.5 SCHARRE 80 MRK2 $J/\psi \rightarrow \eta \pi \pi \gamma$ <1.1 FOSTER 68B HBC 0.0 ₽p Γ_4/Γ_1 $\Gamma(a_0(980)\pi)/\Gamma(K\overline{K}\pi)$ DOCUMENT ID TECN COMMENT EVTS VALUE • • • We do not use the following data for averages, fits, limits, etc. • • • 95 OBLX $0 \, \overline{p} p \rightarrow K \overline{K} \pi \pi \pi$ 18 BERTIN ~ 0.15 18 DUCH 89 ASTE $\bar{p}p \rightarrow \pi^{+}\pi^{-}K^{\pm}\pi^{\mp}K^{0}$ 86 SPEC 6.6 $p\bar{p} \rightarrow KK\pi X$ ~ 0.8 18 REEVES 18 Assuming that the $\textit{a}_{0}(980)$ decays only into $\textit{K}\,\overline{\textit{K}}.$ Γ_4/Γ_3 $\Gamma(a_0(980)\pi)/\Gamma(\eta\pi\pi)$ EVTS DOCUMENT ID TECN COMMENT 2200 19 ALDE 97B GAM4 100 π⁻ p → ηπ⁰ π⁰ π 0.19±0.04 19 AMSLER 95F CBAR 0 pp → π+ $0.56 \pm 0.04 \pm 0.03$ ¹⁹ Assuming that the a_0 (980) decays only into $\eta \pi$. $\Gamma(K\overline{K}^*(892) + \text{c.c.})/\Gamma(K\overline{K}\pi)$ Γ_2/Γ_1 DOCUMENT ID TECN COMMENT

BAILLON

DOCUMENT ID

 $\Gamma(K\overline{K}^*(892) + c.c.)/[\Gamma(K\overline{K}^*(892) + c.c.) + \Gamma(a_0(980)\pi)]$

CLX

90

<0.25

67 HBC 0.0 pp → KKπππ

TECN COMMENT

EDWARDS 82E CBAL $J/\psi \rightarrow K^+K^-\pi^0\gamma$

 $\Gamma_2/(\Gamma_2+\Gamma_4)$

 $\eta(1440), a_0(1450), \rho(1450)$

$\Gamma(ho^0\gamma)/\Gamma(K\overline{K}\pi)$	Γ ₈ /Γ ₁	a ₀ (1450) DECAY MODES					
	DOCUMENT ID TECN COMMENT COFFMAN 90 MRK3 $J/\psi \rightarrow \gamma \gamma \pi^+ \pi^-$	Mode	Fraction (Γ_I/Γ)				
	$\gamma K \overline{K} \pi$)=4.2 × 10 ⁻³ and B($J/\psi \rightarrow \gamma \eta$ (1440) \rightarrow	$\Gamma_1 = \pi \eta$	seen				
$\gamma \gamma \rho^0)$ =6.4 × 10 ⁻⁵ and assuming	that the $\gamma \rho^0$ signal does not come from the $f_1(1420)$.	$\Gamma_{2}^{1} = \frac{\pi \eta'}{\pi \eta'} (958)$	seen				
Γ(η(ππ) _{S-wave})/Γ(ηππ)	Γ ₅ /Γ ₃	Γ₃ Kα̈́ ΄	seen				
VALUE EVTS	DOCUMENT ID TECN COMMENT						
•	ata for averages, fits, limits, etc. • • •	$\Gamma(\pi\eta'(958))/\Gamma(\pi\eta)$	Γ ₂ /Γ				
0.81±0.04 2200 /	ALDE 978 GAM4 $100 \pi^{-} p \rightarrow \eta \pi^{0} \pi^{0} n$	YALUE	DOCUMENT ID TECN COMMENT				
7/(14	40) REFERENCES	0.35±0.16	³ ABELE 98 CBAR $0.0 \ \overline{p}p \rightarrow K_L^0 K^{\pm} \pi^{\mp}$ Ving data for averages, fits, limits, etc. • • •				
ALDE 97B PAN 60 386	D. Alde, Binon, Bricman+ (GAMS Collab.)	0.43±0.19	ABELE 97C CBAR $0.0 \overline{p} p \rightarrow \pi^0 \pi^0 \eta'$				
Translated from YAF 60	3 458. + Bruschi, Capponi+ (OBELIX Collab.)	³ Using π ⁰ η from AMSLER 9	• • • • • • • • • • • • • • • • • • • •				
AMSLER 95F PL B358 389 BERTIN 95 PL B361 187	+Armstrong, Urner+ (Crystal Barrel Collab.) +Bruschi+ (OBELIX Collab.)	$\Gamma(K\overline{K})/\Gamma(\pi\eta)$	Г ₃ /Г				
BUGG 95 PL B3\$3 378 AUGUSTIN 92 PR D46 1951	+Scott, Zoli+ (LOQM, PNPI, WASH) +Cosme (DM2 Collab.)	YALUE	DOCUMENT ID TECN COMMENT				
BEHREND 92 ZPHY C56 381 BOLTON 928 PRL 69 1328	+Brown, Bunneli+ (CELLO Collab.)	0.88±0.23	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$				
FUKUI 91C PL B267 293 AUGUSTIN 90 PR D42 10	+ (SUGI, NAGO, KEK, KYOT, MIYA, AKIT) +Cosme+ (DM2 Collab.)		- (4.10) DEEDENGE				
BAI 90C PRL 6\$ 2507 COFFMAN 90 PR D41 1410	+Blaylock+ (Mark III Collab.) +De Jongh+ (Mark III Collab.)	•	a ₀ (1450) REFERENCES				
BEHREND 89 ZPHY C42 367 BISELLO 89B PR D39 701	+Criegee+ (CELLO Collab.) Busetto+ (DM2 Collab.)	ABELE 98 PR D57 3860 ABELE 97C PL B404 179	A. Abele, Adomeit, Amsler+ (Crystal Barrel Collab.) A. Abela, Adomeit, Amsler+ (Crystal Barrel Collab.)				
DUCH 89 ZPHY 45 223 RATH 89 PR D40 693	+Heel, Balley+ +Cason+ (NDAM, BRAN, BNL, CUNY, DUKE)	AMSLER 95B PL B342 433 AMSLER 95C PL B353 571	+Armstrong, Brose+ (Crystal Barrel Collab.) +Armstrong, Hackman+ (Crystal Barrel Collab.)				
BIRMAN 88 PRL 61 1557 ANTREASYAN 87 PR D36 2633	+Chung, Peaslee+ (BNL, FSU, IND, MASD) JP +Barrels, Besset+ (Crystal Ball Collab.)	AMSLER 95D PL B355 425 AMSLER 94D PL B333 277	+Armstrong, Spanier+ (Crystal Barrel Collab.) +Anisovich, Spanier+ (Crystal Barrel Collab.) IG.				
AIHARA 86D PRL 57 51 ANDO 86 PRL 57 1296	+Alston-Garnjost+ (TPC-2γ Collab.) +Imai+ (KEK, KYOT, NIRS, SAGA, INUS, TSUK+) IJP	BUGG 94 PR D50 4412	+Anisovich+ (LOQM)				
REEVES 86 PR 34 1960 ALTHOFF 858 ZPHY C29 189 CHUNG 85 PRL 55 779	+Chung, Crittenden+ +Braunschweig, Kirschfink+ +Fernow, Boehniein+ (FLOR, BNL, IND, MASD) JP (BNL, FLOR, IND, MASD) JP						
ALTHOFF 84E PL 147B 487 EDWARDS 83B PRL 51 859	+Braunschweig, Kirschfink, Luebeismeyer+ (TASSO Collab.)	$\rho(1450)$	$I^{G}(J^{PC}) = 1^{+}(1^{-})$				
JENNI 83 PR D27 1031 EDWARDS 82E PRL 49 259	+Partridge, Peck+ (CIT, HARV, PRIN, STAN, SLAC) +Burke, Telnov, Abrams, Blocker+ (SLAC, LBL) +Partridge, Peck+ (CIT, HARV, PRIN, STAN, SLAC)						
Also 83 PRL 50 219 SCHARRE 80 PL 97B 329	Edwards, Partridge+ (CIT, HARV, PRIN, STAN+) +Trilling, Abrams, Alam, Blocker+ (SLAC, LBL)	See the mini-review i	under the $\rho(1700)$.				
FOSTER 68B NP B8 174 BAILLON 67 NC 50A 393	+Gavillet, Labrosse, Montanet+ (CERN, CDEF) +Edwards, D'Andlaw, Astler+ (CERN, CDEF, IRAD)		ρ(1450) MASS				
			., ,				
	R RELATED PAPERS	VALUE (MeV) 1465±25 OUR ESTIMATE T	DOCUMENT ID his is only an educated guess; the error given is larger than				
CLOSE 97B PR D55 5749 BERTIN 96 PL B385 493	F. Close+ (RAL, RUTG, BEIJT) +Bruschi+ (Obelix Collab.)		the error on the average of the published values.				
FARRAR 96 PRL 76 4111 AMELIN 95 ZPHY C66 71	G.R. Farrar (RUTG) +Berdnikov+ (VES Collab.)	1482± 8 OUR AVERAGE Inc	dudes data from the 2 datablocks that follow this one.				
GENOVESE 94 ZPHY C61 425 BALI 93 PL B309 378	+Lichtenberg, Pedrazzi (TORI, IND) +Schilling, Hulsebo, Irving, Michael+ (LIVP)	ηρ ⁰ MODE					
LONGACRE 90 PR D42 874 AHMAD 89 NP B (PROC.)8 50	(BNL) +Amsler, Auld+ (ASTERIX Collab.)	VALUE (MeV) The data in this block is include	DOCUMENT ID TECN COMMENT ed In the average printed for a previous datablock.				
ARMSTRONG 89 PL B221 216 ARMSTRONG 87 ZPHY C34 23	+Benayoun+(CERN, CDEF, BIRM, BARI, ATHU, CURIN+) +Bloodworth+ (CERN, BIRM, BARI, ATHU, CURIN+)						
ASTON 87 NP B292 693 ARMSTRONG 84 PL 146B 273	+Avaji, D'Amore+ (SLAC, NAGO, CINC, INUS) +Bloodworth, Burm+ (ATHU, BARI, BIRM, CERN)	1470±20 1446±10	ANTONELLI 88 DM2 $e^+e^- \rightarrow \eta \pi^+\pi^-$ FUKUI 88 SPEC 8.95 $\pi^-p \rightarrow \eta \pi^+\pi^-$				
DIONISI 80 NP B169 1 DEFOIX 72 NP B44 125	+Gavillet+ (CERN, MADR, CDEF, STOH) +Nascimento, Bizzarri+ (CDEF, CERN)		, o				
DUBOC 72 NP B46 429 LORSTAD 69 NP B14 63	+Goldberg, Makowski, Donald+ (PARIS, LIVP) +D'Andlau, Astier+ (CDEF, CERN)	WA MODE	DOCUMENT ID TECN COMMENT .				
		The data in this block is include	ed in the average printed for a previous datablock.				
$a_0(1450)$	$I^{G}(J^{PC}) = 1^{-}(0^{+})$	1463 ± 25	1 CLEGG 94 RVUE				
40(1100)			ving data for averages, flts, limits, etc. • • •				
See minireview on scalar n	nesons under $f_0(1370)$.	1250 1290 ± 40	² ASTON 80C OMEG 20–70 $\gamma p \rightarrow \omega \pi^0 p$ ² BARBER 80C SPEC 3–5 $\gamma p \rightarrow \omega \pi^0 p$				
	b(1450) MASS	¹ Using data from BISELLO 9	918, DOLINSKY 86 and ALBRECHT 87L.				
•	6(1700) MP-55	² Not separated from $b_1(1235)$	5), not pure $J^P = 1^-$ effect.				
VALUE (MeV) 1474±19 OUR AVERAGE	DOCUMENT ID TECN COMMENT	ππ MODE					
	ABELE 98 CBAR 0.0 $p_p \rightarrow \kappa_p^0 K^{\pm} \pi^{\mp}$	VALUE (MeV)	DOCUMENT ID TECN COMMENT				
	AMSLER 950 CBAR 0.0 $\overline{p}p \rightarrow \pi^0 \pi^0 \pi^0$,		ving data for averages, fits, limits, etc. ● ● ● BERTIN 98 OBLX 50-405 πp →				
e e e We do not use the following do	$\pi^0\eta\eta, \pi^0\pi^0\eta$ ata for averages, fits, limits, etc. • • •		$\pi^{+}\pi^{+}\pi^{-}$				
	AMSLER 94D CBAR 0.0 $\overline{p}p \rightarrow \pi^0 \pi^0 \eta$	1411±14	3 ABELE 97 CBAR $pn \rightarrow \pi^-\pi^0\pi^0$				
	BUGG 94 RVUE $\overline{p}p \rightarrow \eta 2\pi^0$	1370 + 90 1390 + 34	ACHASOV 97 RVUE $e^+e^- \rightarrow \pi^+\pi^-$				
¹ Coupled-channel analysis of AMSi	LER 95B, AMSLER 95C, and AMSLER 94D.	1380 ± 24 1359 ± 40	⁴ BARATE 97M ALEP $\tau^- \rightarrow \pi^- \pi^0 \nu_{\tau}$ ⁵ BERTIN 97C OBLX 0.0 $\overline{p}_P \rightarrow \pi^+ \pi^- \pi^0$				
	(1450) MIDTU	1282 ± 37	BERTIN 97D OBLX 0.05 $\overline{p}p \rightarrow 2\pi^+2\pi^-$				
a ₀	(1450) WIDTH	1424±25	BISELLO 89 DM2 $e^+e^- \rightarrow \pi^+\pi^-$				
	DOCUMENT ID TECN COMMENT	³ T-matrix pole. ⁴ Fixing ρ (1450) width to 310	0 MeV and $ ho$ (1700) mass and width to 1700 MeV and 23				
265±13 OUR AVERAGE 265±15	ABELE 98 CBAR 0.0 pp → K ⁰ K± π [∓]	MeV respectively.	,				
	AMSLER 950 CBAR $0.0 p_D \rightarrow \pi^0 \pi^0 \pi^0$.	$^{3}\rho(1700)$ mass and width fix	ed at 1700 MeV and 235 MeV, respectively.				
	$\pi^0_{\eta\eta}$, $\pi^0_{\pi}^0_{\eta}$	π ⁺ π ⁻ π ⁺ π ⁻ MODE	DOCUMENT ID TECH COMMENT				
B B B VVE GO NOT USE the following da	ata for averages, fits, limits, etc. • • •	VALUE (MeV)	DOCUMENT ID TECN COMMENT				
	AMELED 042 CDAD 007 0 0	e e e vve do not use the tollow	ving data for averages, fits, limits, etc. • • •				
270±40	AMSLER 94D CBAR $0.0 \overline{p}p \rightarrow \pi^0 \pi^0 \eta$ BUGG 94 RVUE $\overline{p}p \rightarrow \eta 2\pi^0$	• • • We do not use the follow	ving data for averages, fits, limits, etc. $\bullet \bullet \bullet$ ACHASOV 97 RVUE $e^+e^- \rightarrow 2(\pi^+\pi^-)$				

⁶ Not clear whether this observation has t=1 or 0.

φ≈ MODE VALUE (MeV) DOCUMENT ID TECN CHG COMMENT			(e+	e)/Γ _{total}	DOCUMENT "	D TECN	COMMENT	Γ ₅ Γ ₄ /Ι
VALUE (MeV) DOCUMENT ID TECN CHG COMMENT • • • We do not use the following data for averages, fits, limits, etc. • • •	_	ALUE (eV)			ANTONELL		e ⁺ e ⁻ →	nπ+ π-
1480 \pm 40 7,8 BITYUKOV 87 SPEC 0 32.5 $\pi^- p \to \phi \pi^0 n$			Γ(e [†]	e ⁻)/F _{total}	ANTONECE	00 01112		/" " ΓεΓ4/!
7 DONNACHIE 91 suggests this is a different particle. 8 Not seen by ABELE 97H.	<u>. 1</u>	ALUE (eV)		CL%	DOCUMENT II		$\frac{COMMENT}{e^+e^-} \rightarrow$	κ ⁰ κ ⁰ π ⁰
·	•	16 Using m	ass 14	180 ± 40 MeV an				
MIXED MODES VALUE (MeV) DOCUMENT ID TECN COMMENT	-				\ DD44(C)	UC DATIO	<u>.</u>	
				ρ(1450) BRANCHI	NG KAIIOS	•	
1265.5 \pm 75.3 DUBNICKA 89 RVUE $e^+e^- \rightarrow \pi^+\pi^-$		$(\eta \rho)/\Gamma_{to}$	tal					Γ 5/ I
ρ(1450) WIDTH	_	<u><0.04</u>			<u>DOCUMENT II</u> DONNACHI	E 878 RVUI	_	
VALUE (MeV) DOCUMENT ID	J	(φπ)/Γ(ωπ)					Γ_6/Γ
310±60 OUR ESTIMATE This is only an educated guess; the error given is larger than the error on the average of the published values.	_	ALUE		<u>CL%</u>	DOCUMENT I			
ηho^0 MODE		>0.5		95	BITYUKOV	87 SPEC		$\pi^- p \rightarrow \pi^0 n$
VALUE (MeV) DOCUMENT ID TECN COMMENT		$\Gamma(\omega \pi)/\Gamma(\omega \pi)$	4m)					Г3/Г
• • • We do not use the following data for averages, fits, limits, etc. • •	_	ALUE			DOCUMENT I		_	
230 \pm 30 ANTONELLI 88 DM2 $e^+e^- \to \eta \pi^+ \pi^-$ 60 \pm 15 FUKUI 88 SPEC 8.95 $\pi^- p \to \eta \pi^+ \pi^- n$		<0.14			CLEGG	88 RVUI	=	
ωπ MODE		$\Gamma(\eta \rho)/\Gamma(c)$	vπ)		2001112		5014:15:1-	Γ ₅ /Γ
VALUE (MeV) DOCUMENT ID TECN COMMENT	_	<u>∕ALUE</u> ~ 0.24			<u>DOCUMENT /</u> DONNACHI			
The data in this block is included in the average printed for a previous datablock.			o not	use the following				
311 ± 62		>2			FUKUI	91 SPEC	8.95 π ⁻ p -	→ ωπ ⁰ n
• • We do not use the following data for averages, fits, limits, etc. • •	((wx)/F	ليج					Γ3/
300 10 ASTON 80C OMEG 20-70 $\gamma p \to \omega \pi^0 p$ 320±100 10 BARBER 80C SPEC 3-5 $\gamma p \to \omega \pi^0 p$	1	ALUE			DOCUMENT I		_	- 41
9 Using data from BISELLO 91B, DOLINSKY 86 and ALBRECHT 87L.	•	~ 0.21			CLEGG	94 RVU	E	
¹⁰ Not separated from $b_1(1235)$, not pure $J^P=1^-$ effect.	ĺ	[(ππ)/Γ(ωπ)					Г1/Г
ππ MODE		ALUE			DOCUMENT I			
VALUE (MeV) DOCUMENT ID TECN COMMENT	,	~ 0.32			CLEGG	94 RVU	Ē.	
• • • We do not use the following data for averages, fits, limits, etc. • • OTE 1.50 OPENTIAL OPEN		Γ(φπ)/Γ _{ti}	otal					Γ ₆ /
275±10 BERTIN 98 OBLX $50-405 \ \overline{n}p \rightarrow \pi^{+}\pi^{+}\pi^{-}$		VALUE			DOCUMENT I		COMMENT	
343±20 11 ABELE 97 CBAR $\overline{\rho}n \to \pi^- \pi^0 \pi^0$	1 .	<0.01 • • • We d	о пот	use the following	¹⁷ DONNACHI data for avera			
310 \pm 40	1	not seen			ABELE	•	R PP → K	κ ⁰ π ⁰ π ⁰
269±31 BISELLO 89 DM2 $e^+e^- \to \pi^+\pi^-$	-		, ,		=		· · · L	•
11 T-matrix pole. $^{12} ho(1700)$ mass and width fixed at 1700 MeV and 235 MeV, respectively.		r(KK)/F	(ωπ		DOCUMENT			Γ ₇ /Γ
óπ MODE	-	<0.08	-A- 4-		17 DONNACHI			
VALUE (MeV) DOCUMENT ID TECN CHG COMMENT		Using di	ata m	om BISELLO 918	, DOLINSKY C	D AND ALDRE	CHI BIL.	
• • We do not use the following data for averages, fits, limits, etc. • • •				ρ(1450) REFE	RENCES		
130 \pm 60 13,14 BITYUKOV 87 SPEC 0 32.5 $\pi^- p \rightarrow \phi \pi^0 n$	1	BERTIN	98	PR D57 55	A. Bertin, E	Bruschi, Capponi-	- (OBE	LIX Collab.)
13 DONNACHIE 91 suggests this is a different particle.	4	ABELE ABELE	97	PL B391 191 PL B415 280	A. Abele+	domeit, Amsler+		arrel Collab.) arrel Collab.)
¹⁴ Not seen by ABELE 97H.		ACHASOV BARATE	97 97 M	PR D55 2663 ZPHY C76 15	+Kozhevnikov R. Barate+	+	(ALI	(NOVM) EPH Collab.)
MIXED MODES		BERTIN BERTIN	97C 97D	PL 8408 476 PL 8414 220	A. Bertin, E A. Bertin+	Bru sc hi+	(OBE	LIX Collab.) LIX Collab.)
VALUE (MeV) DOCUMENT ID TECN COMMENT		CLEGG BISELLO	94 91 B	ZPHY C62 455 NP B21 111 (suppl			(0	NC, MCH5) M2 Collab.)
• • • We do not use the following data for averages, fits, limits, etc. • • • 391 \pm 70 DUBNICKA 89 RVUE $e^+e^- \rightarrow \pi^+\pi^-$		DONNACHIE FUKUI	91 91	ZPHY C51 689 PL B257 241	+Clegg +Horikawa+	(SUGI,	NAGO, KEK, K'	CHS, LANC) YOT, MIYA)
SPIETO DODITICA OF RECE OF A A A	•	ARMSTRONG BISELLO	89	PL B228 536 PL B220 321	+Busetto+	ATHU, BARI, BI		OM2 Collab.)
ρ(1450) DECAY MODES		DUBNICKA ANTONELLI	89 88	JPG 15 1349 PL B212 133	+Martinovic+ +Baldini+		(1	HNR, \$LOV) OM2 Collab.
Mode Fraction (Γ_1/Γ) Confidence level		CLEGG DIEKMAN	68 68	ZPHY C40 313 PRPL 159 101	+Donnachle	16110-		CHS, LANC) (BONN)
	•	FUKUI ALBRECHT	88 87L	PL 8202 441 PL 8185 223	+Horikawa+ +Binder, Boe	ckmann, Glaser+	NAGO, KEK, K (AR	GUS Collab.)
		AULCHENKO BITYUKOV	678 67	JETPL 45 145 Translated from ZE PL R188 383	TFP 45 118.	uzhinin, Dubrovi Dorofeev, Golovi		(NOVO) (SERP)
$\Gamma_3 \qquad \omega \pi \qquad \qquad <2.0\% \qquad \qquad 95\%$		DONNACHIE	87B	PL B188 383 ZPHY C34 257	+Clegg	Dubrovin, Eidelm:	(M:	CHS, LANC) (NOVO)
Γ ₄ e ⁺ e ⁻ seen		DOLINSKY ASTON BADRED		PL B174 453 PL 92B 211	(1	BONN, CERN, E odbeck, Brookes	POL. GLAS, LAN	
Γ ₅ ηρ <4 %		BARBER	80C	ZPHY C4 169				mile, afferj
				—— отн	ER RELATE	D PAPERS		
1		ABELE BARNES	97H 97	PL B415 280 PR D55 4157	A. Abele+ T. Barnes+		(ORNL. I	arrel Collab.) RAL, MCHS)
$\rho(1450) \Gamma(i)\Gamma(e^+e^-)/\Gamma(total)$		CLOSE URHEIM	97C 97	PR D56 1584 NPBPS 55C 359	F.E. Close+		. (1	RAL, MCHS) LEO Collab.)
		ACHASOV	96B	PAN 59 1262 Translated from YA	+Shestakov		(0	(NOVM)
$\Gamma(\pi\pi) \times \Gamma(e^+e^-)/\Gamma_{\text{total}}$		MURADOV LANDSBERG	94 92	PAN 57 864 SJNP 55 1051				(BAKU) (SERP)
<u>VALUE (keV)</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u> • • • We do not use the following data for averages, fits, limits, etc. • • •	•	BRAU	92 8B	Translated from YA PR D37 2379	F 55 1896. +Franck+	(SLAC I	lybrid Facility Ph	
		ASTON	87 86	NP B292 693 JETPL 43 643	+Awaji, D'Ar		(SLAC, NAGO,	
0.12 15 DIEKMAN 88 RVUE $e^+e^- \to \pi^+\pi^-$		KURDADZE						

 $\rho(1450)$, $f_0(1500)$

BARKOV BISELLO ABE ATKINSON CORDIER KILLIAN COSME BINGHAM FRENKIFI	85 84B 84C 82 80 76 72B	NP B256 365 ŁAL 85-15 PRL 53 751 NP B243 1 PL 1098 129 PR D21 3005 PL 63B 352 PL 41B 635 NP R47 61	+Chilingarov, Eidelman, Khazin, Leichuk+ +Augustin, Ajaitouni+ (PADO, LALO, CLER, FRAS) +Bacon, Ballam+ (SLAC Hybrid Facility Photon Collab.) + (BONN, CERN, GLAS, LANC, MCHS, CURIN+) +Bisello, Bizot, Buon, Delcourt +Treadwell, Ahrens, Berkelman, Cassel+ +Courau, Dudelzau, Grelaud, Jean-Marie+ (OSRAY) +Rabin, Rosenfeld, Smadja+ (Chemicke, Libert Collab.)
FRENKIEL	72	NP B47 61	+Ghesquiere, Lillestol, Chung+ (CDEF, CERN)
LAYSSAC	71	NC 6A 134	+Renard (MONP)

$f_0(1500)$

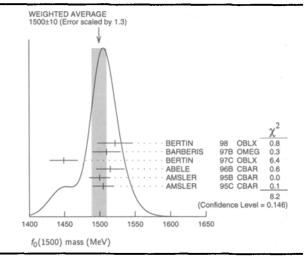
$$I^{G}(J^{PC}) = 0^{+}(0^{+})$$

See also the mini-reviews on scalar mesons under $f_0(1370)$ and on non-qq candidates. (See the index for the page number.)

f₀(1500) MASS

		,		
VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
1500±10 OUR /	WERAGE E	rror includes scale	factor of 1.3	. See the ideogram below.
1522±25		BERTIN	98 OBL	50-405 \(\overline{n} \rho \rightarrow\)
1510±20		1 BARBERIS	978 OMF	$\pi^+\pi^+\pi^-$ G 450 pp \rightarrow
		D. H.D.L	2.0 02	$pp2(\pi^{+}\pi^{-})$
1449±20		1 BERTIN	97c OBL	$\langle 0.0 \overline{p}p \rightarrow \pi^{+}\pi^{-}\pi^{0} \rangle$
1515±20		ABELE		$R = 0.0 \overline{p}p \rightarrow \pi^0 K_i^0 K_i^0$
1500±15		² AMSLER	958 CBAI	$30.0 \overline{p}p \rightarrow 3\pi^0$
1505 ± 15		3 AMSLER	95c CBAI	$R = 0.0 \overline{p}p \rightarrow \eta \eta \pi^0$
• • • We do not u	se the following	ng data for average	s, fits, limit	s, etc. • • •
~ 1475		FRABETTI	97D E687	$D_s^{\pm} \rightarrow \pi^{\mp}\pi^{\pm}\pi^{\pm}$
~ 1430		4 KAMINSKI	978 RVUI	
~ 1505		ABELE	96 CBAI	
1500 ± 8		1 ABELE	96c RVUI	Compliation
1460 ± 20	120	⁵ AMELIN	96B VES	$37 \pi^- A \rightarrow \eta \eta \pi^- A$
1500± 8		BUGG	96 RVU	
1500±10		⁶ AMSLER	95D CBAI	$\begin{array}{c} 3 0.0 \ \overline{p}p \rightarrow \pi^0 \pi^0 \pi^0, \\ \pi^0 np, \pi^0 \pi^0 n \end{array}$
1445± 5		⁷ ANTINORI	95 OME	G 300,450 $pp \rightarrow pp = pp = pp = pp = pp = pp = pp $
1497±30		⁵ ANTINORI	95 OME	$ \begin{array}{c} \rho p 2(\pi \cdot \pi) \\ G 300,450 pp \rightarrow \\ \rho p \pi^{+} \pi^{-} \end{array} $
~ 1505		BUGG	95 MRK	3 $J/\psi \rightarrow \gamma \pi^+ \pi^- \pi^+ \pi^-$
1446± 5		⁵ ABATZIS		G 450 pp →
		_		$pp2(\pi^+\pi^-)$
1545 ± 25		5 AMSLER		$R = 0.0 \overline{p} p \rightarrow \pi^0 \eta \eta'$
1520 ± 25		1,8 ANISOVICH	94 CBAI	
1505 ± 20		^{1,9} BUGG	94 RVU	$ \begin{array}{c} \overline{p}p \to 3\pi^0, \eta\eta\pi^0, \\ \eta\pi^0\pi^0 \end{array} $
1560 ± 25		5 AMSLER	92 CBAI	
$1550 \pm 45 \pm 30$		5 BELADIDZE	92C VES	36 π^- Be $\rightarrow \pi^- \eta' \eta$ Be
1449± 4		⁵ ARMSTRONG	89E OME	G 300 $pp \rightarrow pp2(\pi^+\pi^-)$
1610±20		⁵ ALDE	88 GAM	
~ 1525		ASTON	88D LASS	$11 K^- p \rightarrow K_S^0 K_S^0 \Lambda$
1570 ± 20	600	5 ALDE	87 GAM	
1575 ± 45		¹⁰ ALDE	86D GAM	4 100 π ⁻ p → 2η π
1568±33		⁵ BINON	84c GAM	
1592 ± 25		⁵ BINON	83 GAM	$2 38 \pi^- p \rightarrow 2\eta n$
1525± 5		⁵ GRAY	83 DBC	$0.0 \overline{p} N \rightarrow 3\pi$
¹ T-matrix pole.				
² T-matrix pole.	supersedes AN	IISOVICH 94.	•	

T-matrix pole, supersedes ANISOVICH 94.



f ₀ (1500) WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID	TEC	V COMMENT
112±10 OUR AVE	RAGE			
108±33		BERTIN	98 OBL	X 50~405 $\overline{n}p$ → $\pi^+\pi^+\pi^-$
120±35		11 BARBERIS	97B OM	EG 450 pp →
114±30		11 BERTIN		$PP2(\pi^{+}\pi^{-})$ $X 0.0 \overline{p}p \rightarrow \pi^{+}\pi^{-}\pi^{0}$
105 ± 15		ABELE	968 CBA	$R 0.0 \ \overline{p}p \rightarrow \pi^0 K_i^0 K_i^0$
120±25		12 AMSLER	95B CBA	$R 0.0 \ \overline{p}p \rightarrow 3\pi^0$
120±30		13 AMSLER	95C CBA	$R 0.0 \ \overline{p}p \rightarrow \eta \eta \pi^0$
• • • We do not use	the follow	wing data for average	s, fits, lim	its, etc. • • •
~ 100		FRABETTI	97D E68	$7 D_s^{\pm} \rightarrow \pi^{\mp} \pi^{\pm} \pi^{\pm}$
~ 135		14 KAMINSKI	978 RVL	
~ 169		ABELE	96 CBA	$R 0.0 \widetilde{p} p \rightarrow 5\pi^0$
100±30	120	15 AMELIN	96B VES	$37 \pi^- A \rightarrow \eta \eta \pi^- A$
132 ± 15		BUGG	96 RVL	
154±30		¹⁶ AMSLER	95D CBA	$ \begin{array}{ccc} & \text{RR} & 0.0 \ \bar{p}p \to & \pi^0 \pi^0 \pi^0, \\ & \pi^0 \eta \eta, \pi^0 \pi^0, \end{array} $
65 ± 10		17 ANTINORI	95 OM	EG 300,450 pp →
199±30		15 ANTINORI	95 OM	$\begin{array}{c} pp2(\pi^{+}\pi^{-}) \\ \text{EG 300,450} pp \rightarrow \end{array}$
56±12		15 ABATZIS	94 OM	$pp\pi^{+}\pi^{-}$ EG 450 $pp \rightarrow$
100±40		15 AMSLER	94E CBA	$p p 2(\pi^+\pi^-)$ AR 0.0 $\bar{p}p \rightarrow \pi^0 \eta \eta'$
148 ⁺²⁰ -25		11,18 ANISOVICH		$R 0.0 \ \overline{p}p \rightarrow 3\pi^0, \pi^0\eta\eta$
150±20		11,19 BUGG		$ \begin{array}{ccc} \text{JE} & \vec{p}p \rightarrow 3\pi^0, \eta\eta\pi^0, \\ \eta\pi^0\pi^0 \end{array} $
245±50		15 AMSLER	92 CBA	$R 0.0 \ \overline{p}p \rightarrow \pi^0 n\eta$
153 ± 67 ± 50		15 BELADIDZE	92c VES	
78±18		15 ARMSTRONG	89E OM	EG 300 $pp \rightarrow pp2(\pi^+\pi^-)$
170±40		15 ALDE	88 GAN	$\begin{array}{c} pp2(\pi^{+}\pi^{-})\\ 14 & 300 & \pi^{-}N \rightarrow \pi^{-}N2n \end{array}$
150±20	600	¹⁵ ALDE		A4 100 $\pi^- p \to 4\pi^0 n$
265 ± 65		²⁰ ALDE		A4 100 π p → 2ηn
260 ± 60		15 BINON		$12 38 \pi^- p \rightarrow \eta \eta^{\prime} n$
210±40		15 BINON		A2 38 $\pi^- p \rightarrow 2\eta n$
101±13	,	15 GRAY	83 DBC	
11				•

¹¹ T-matrix pole.

Therefore, pole, supersedes ANISOVICH 94 and AMSLER 92. Reanalysis of SRINIVASAN 75, ROSSELET 77, BECKER 79, and COHEN 80 using a three coupled channel analysis ($\pi\pi$, $K\overline{K}$, and $\sigma\sigma$).

⁵ Breit-Wigner mass.

⁶T-matrix pole. Coupled-channel analysis of AMSLER 95B, AMSLER 95C, and AM-SLER 94D. 7 Supersedes ABATZIS 94, ARMSTRONG 89E. Breit-Wigner mass,

⁸ From a simultaneous analysis of the annihilations $\overline{p}\rho \to 3\pi^0, \pi^0\eta\eta$. Reanalysis of ANISOVICH 94 data.

¹⁰ From central value and spread of two solutions. Breit-Wigner mass.

¹² T-matrix pole, supersedes ANISOVICH 94.

¹³ T-matrix pole, supersedes ANISOVICH 94 and AMSLER 92.

 $^{^{14}}$ Reanalysis of SRINIVASAN 75, ROSSELET 77, BECKER 79, and COHEN 80 using a three coupled channel analysis $(\pi\pi,\,K\overline{K},\,{\rm and}\,\sigma\sigma).$

¹⁵ Breit-Wigner mass.

¹⁶ T-matrix pole. Coupled-channel analysis of AMSLER 95B, AMSLER 95C, and AM-SLER 94D.

17 Supersedes ABATZIS 94, ARMSTRONG 89E. Breit-Wigner mass.

¹⁸ From a simultaneous analysis of the annihilations $\overline{p}p \to 3\pi^0$, $\pi^0\eta\eta$.

¹⁹ Reanalysis of ANISOVICH 94 data.

²⁰ From central value and spread of two solutions. Brelt-Wigner mass.

Meson Particle Listings $f_0(1500)$

	f ₀ (1500) DECAY	MODES		Γ(ΚΚ̄) /Γ() <u>VALUE</u>	2π)	DOCUMENT II) TECN	COMMENT	Γ ₉ /Γ
Mode		Fraction (Γ_i/Γ)		0.19±0.07		27 ABELE		$0.0 \ \overline{p}p \rightarrow K_I^0$) κ±π [∓]
$\eta \eta'(958)$		seen		• • • We do	not use the followi	ng data for avera			-
1 1/1 (356) 2 1/1		seen		0.20±0.08		²⁸ ABELE		$0.0 \ \overline{p}p \rightarrow \pi^0$	Kº Kº
$\frac{2}{3}$ 4π		seen		27 Heinα π0	π ⁰ from AMSLER	95e		•	L L
$-\frac{3}{4}$ $4\pi^{0}$		seen			4SLER 95B (3 π^0), /		0_{η}) and SU(3).	
$\frac{7}{5}$ $2\pi^{+}2\pi^{-}$		seen			, ,	\	',' '	•	
$6 2\pi$		seen		$\Gamma(2\pi)/\Gamma_{\text{tot}}$	al				Γ6/
$_{7}$ $_{\pi^{+}\pi^{-}}$		seen		VALUE		DOCUMENT II			
$\frac{1}{8}$ $2\pi^{0}$		seen			not use the followl		=	, etc. • • •	
, KK		seen		0.454 ± 0.104		BUGG	96 RVUE		
····				Γ(4π)/Γ(2:	π)				Γ3/Γ
f ₀	(1500) BRANCHII	NG RATIOS		VALUE	<u> </u>	DOCUMENT I	TECN	COMMENT	
$\Gamma(\eta\eta'(958))/\Gamma(\eta\eta)$			Γ_1/Γ_2	 ● ● We do 	not use the followi	ng data for avera	ges, fits, limits	, etc. • • •	
VALUE		TECN COMMENT	. 17 . 2	3.4 ± 0.8		²⁹ ABELE	96 CBAR	0.0 pp → 5π	.0
0.29±0.10	21 AMSLER	95c CBAR 0.0 pp →	$\eta\eta\pi^0$	29 Excluding	g ho ho contribution to	4π,			
• • We do not use the fol									_
0.84±0.23	ABELE	96C RVUE Compilation	on I	$\Gamma(\pi^+\pi^-)/$	1 total			co	Γ ₇ /
2.7 ±0.8	BINON	84c GAM2 38 π ⁻ p -		VALUE		DOCUMENT I		COMMENT	
21 Using AMSLER 94E ($\eta\eta$	(π^{0}) .				not use the followi	_	•		
	•			seen		BERTIN	98 OBLX	50-405 \(\bar{n} \rho \rightarrow \)	
Γ(ηη)/Γ _{total}			Γ ₂ /Γ	possibly seen		FRABETTI	97D E687	$D_{s}^{\pm} \rightarrow \pi^{\mp}\pi^{-}$	±π±
ALUE	DOCUMENT IS			<u> </u>					
• • We do not use the fol	_	-	- 44		1	6(1500) REFE	RENCES		
arge	ALDE BINON	88 GAM4 300 π N 83 GAM2 38 π p -				• ,			
arge	BINON	63 GAM2 38π P -	→ 2η <i>11</i>		98 PR D57 3860 98 PR D57 55	A. Abele, A. A. Restin, R	lomeit, Amsler+ ruschi, Capponi+	(Crystal Barrel (OBELIX	(Collab.)
$\Gamma(4\pi^0)/\Gamma(\eta\eta)$			Γ_4/Γ_2	BARBERIS	97B PL B413 217	D. Barberis+		{WA102	Collab.)
ALUE	DOCUMENT IL	TECN COMMENT			97C PL B408 476 97D PL B407 79	A. Bertin, B +Cheung, Cur	ruschi+ nalat+	(FNAL E687	(Collab.) 7 Collab.)
• • We do not use the fo	llowing data for averag	ges, fits, limits, etc. • • •		KAMINSKI	97B PL B413 130	R. Kaminski +Adomeit. An	+	CR.	AC, IPN)
0.8±0.3	ALDE	87 GAM4 100 π ⁻ ρ	$\rightarrow 4\pi^0 n$	ABELE ABELE	96B PL B385 425	+Adomeit, Ar	nsler+	(Crystal Barre	(Collab.)
		0. 0/M// 100 // p		ABELE AMELIN	96C NP A609 562 96B PAN 59 976	A. Abele, A +Berdnikov, E	domeit, Armstron; litviikov+	t+ (Crystal Barre)	l Collab.) RP, TBIL)
$\Gamma(2\pi^0)/\Gamma(\eta\eta)$			Γ_8/Γ_2		Translated from	YAF 59 1021.			M, PNPI)
VALUE	DOCUMENT IL	TECN COMMENT		AMSLER	95B PL B342 433	+Sarantsev, Z +Armstrong,	Brose+	(Crystal Barre	(Collab.)
1.45±0.61	²² AMSLER	95c CBAR 0.0 pp →	$\eta\eta\pi^0$		95C PL B353 571 95D PL B355 425	+Armstrong, l +Armstrong, l		(Crystal Barre (Crystal Barre	l Collab.) l Collab.)
• • We do not use the fo		ges, fits, limits, etc. • • •	_	ANTINORI	95 PL B353 589	+Barberis, Ba +Scott, Zoli+	yes+ (ATHU,	BARI, BIRM, CER	N, JINR)
4.29 ± 0.72	23 ABELE	96c RVUE Compilation		BUGG ABATZIS	94 PL B324 509	+Antinori, Ba	rberis+ (ATHU,	(LOQM, PNPI BARI, BIRM, CER	IN. JINR)
2.12±0.81	²⁴ AMSLER	950 CBAR 0.0 pp →	$\pi^{0}\pi^{0}\pi^{0}$.	AMSLER AMSLER	94C PL B327 425 94D PL B333 277	+Armstrong, +Anisovich, S	Ravndal+ nanier+	(Crystal Barre (Crystal Barre	d Collab.)
-0.0	BINON	π ⁰ ηη, 83 GAM2 38 π ⁻ p -	π ⁰ π ⁰ η	AMSLER	94E PL B340 259	+Armstrong,		(Crystal Barre	d Collab.)
<0.3		63 GANIZ 36 π p -	→ 2η <i>1</i> 1	BUGG	94 PL B323 233 94 PR D50 4412	+Armstrong+ +Anisovich+		(Crystal Barre	(LOQM)
22 Using AMSLER 958 (3π				AMSLER BELADIDZE	92 PL B291 347 92C SJNP 55 1535	+Augustin, B +Bityukov, B	aker+	(Crystal Barre	Collab.)
23 2π width determined to 24 Coupled-channel analysis	s of AMSLER 95B. AN	ASLER 95C. and AMSLER	94D.		Translated from	YAF 55 2748.		(GAM2, GAM4	-
•				PROKOSHKIN	Translated from	DANS 316 900.	B.O. DI	•	•
$\Gamma(K\overline{K})/\Gamma(\eta\eta)$			Γ_9/Γ_2	ARMSTRONG ALDE	89E PL B228 536 88 PL B201 160	+Benayoun (. +Bellazzini, B	inon+ (SERP,	RM, CERN, CDEF, BELG, LANL, LAF	P, PISA)
	% DOCUMENT II			ASTON ALDE	88D NP B301 525 87 PL B198 286	+Awaji, Bienz +Binon, Brice	·+	(SLAC, NAGO, CIN LANL, BRUX, SER	IC, INUS)
<0.6	²⁵ BINON	83 GAM2 38 π ⁻ p -	,	ALDE	86D NP B269 485	+Binon, Bricr	naπ+ (BELG,	LAPP, SERP, CERI	N. LANL)
• • We do not use the fo	-	=		BINON BINON	84C NC 80A 363 83 NC 78A 313	+Bricman, Do +Donskov, D	rteil+	BELG, LAPP, SERI BELG, LAPP, SERI	P. CERN)
<0.4 90		IN 91 GAM4 300 π ⁻ p	$\rightarrow \pi^- \rho \eta \eta$	Also	83B SJNP 38 561 Translated from	Binon, Goua	nere+	BELG, LAPP, SERI	P, CERN)
25 Using ETKIN 82B and C				GRAY	83 PR D27 307	+Kalogeropou	los, Nandy, Roy,		(SYRA)
²⁶ Combining results of GA	M4 with those of WA	76 on KK central product	tion.	ETKIN COHEN	82B PR D25 1786 80 PR D22 2595	+Foley, Lai+ +Ayres, Dieb	old, Kramer, Pawl	BNL, CUNY, TUFTS icki+	(ANL)
$\Gamma(K\overline{K})/\Gamma_{\text{total}}$			Г9/Г	BECKER ROSSELET	79 NP B151 46	+Blanar, Blur	n+ (M Fischer, Guisan+	APIM, CERN, ZEEN	M, ČRAC) (A, SACL)
VALUE	DOCUMENT I	DTECN	. 3/ .		77 PR D15 574 75 PR D12 681	+Helland, Ler	nox, Klem+		M, ANL)
• • We do not use the for			,			HER RELATE	D PAPEDS		
0.044±0.021	BUGG	96 RVUE	1			HER RELATE	D FAFEIG		
		·= ···· - •	•	ANISOVICH	97 PL B395 123	+Sarantsev A.V. Anisov	ich±		(PNPI) (PNPI)
				ANISOVICH ANISOVICH	97B ZPHY A357 123 97C PL B413 137				
				ANISOVICH	97E PAN 60 1892 Translated from	A.V. Anisov YAF 60 2065.	ich+		(PNPI)
				PROKOSHKIN	97 SPD 42 117 Translated from	+Kondashov,	Sadovsky+		(SERP)
				AMSLER	96 PR D53 295	+Close			JRI, RAL)
				AMSLER GASPERO	95E PL B353 385 95 NP A588 861	+Close		{Zt	URI, RAL) (ROMA)
				SLAUGHTER	88 MPL A3 1361				(LANL)

 $f_1(1510), f_2'(1525)$

 $f_1(1510)$

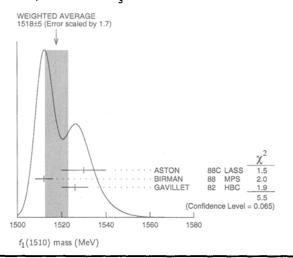
$$I^{G}(J^{PC}) = 0^{+}(1^{+})$$

OMITTED FROM SUMMARY TABLE See the minireview under $\eta(1440)$.

f₁(1510) MASS

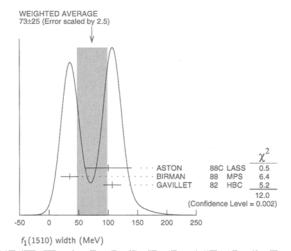
V	ALUE (Me	V)	EVTS	DOCUMENT ID		TECN	COMMENT
	1518±	5 OUR AVE	RAGE E	rror includes scale	factor	of 1.7.	See the ideogram below.
	1530±	10		ASTON	88 C	LAS5	11 $K^- p \rightarrow K_0^0 K^{\pm} \pi^{\mp} \Lambda$
	1512±	4	600	1 BIRMAN	88	MPS	$8\pi^-p \rightarrow K^+\overline{K}^0\pi^-n$
	$\textbf{1526} \pm$	6	271	GAVILLET	82	HBC	$4.2 K^- p \rightarrow \Lambda K K \pi$
•	• • We	do not use t	he followir	ng data for average	s, fits	, limits,	etc. • • •
~	1525			² BAUER	93B		$\gamma \gamma^* \rightarrow \pi^+ \pi^- \pi^0 \pi^0$
	1 Erom	nartal ways		v+ v 0			

 1 From partial wave analysis of $K^+\overline{K}{}^0\,\pi^-$ state. 2 Not seen by AIHARA 88C in the $K_S^0\,K^\pm\,\pi^\mp$ final state.



f1(1510) WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
73±25 OUR AVERAG	E Error	ncludes scale facto	or of	2.5. See	the ideogram below.
100 ± 40		ASTON	880	LASS	11 K ⁻ p →
					K ₀ K±π∓Λ
35 ± 15	600	³ BIRMAN	88	MPS	$8\pi^-p \rightarrow K^+\overline{K}^0\pi^-n$
107±15	271	GAVILLET	82	HBC	$4.2 K^- p \rightarrow \Lambda K K \pi$
³ From partial wave a	nalysis of	$K + \overline{K}^0 \pi^-$ state.			



f1(1510) DECAY MODES

Mode		Fraction (Γ _I /Γ)
Γ ₁	Κ ₹*(892)+ c.c.	seen

f1(1510) REFERENCES

BAUER	88C	PR D48 3976	+Belcinski, Berg, Bingham+	(SLAC)
AIHARA		PR D38 1	+Alston-Garnjost+	(TPC-2 γ Collab.)
ASTON		PL B201 573	+Awaji, Bienz+	(SLAC, NAGO, CINC, INUS) JP
BIRMAN		PRL 61 1557	+Chung, Peaslee+	(BNL, FSU, IND, MASD) JP
GAVILLET		ZPHY C16 119	+Armenteros+	(CERN, CDEF, PADO, ROMA)

OTHER RELATED PAPERS

		D. D		
ABELE	97G	PL B415 289	A. Abele+	
BARBERIS	97C	Pl. B413 225	D. Barberis+	(WA102 Collab.)
CLOSE	97D	ZPHY C76 469	F.E. Close+	• •
KING	91	NP B21 11 (suppl)	E. King+	(FSU, BNL+)
AIHARA	88C	PR D38 1	+Alston-Garniost+	(TPC-2 y Collab.)
BITYUKOV	84	SJNP 39 735	S. Bitvukov+	(SERP)
		Translated from YAF	39 1165.	(· /

 $f_{2}^{\prime}(1525)$

 $I^{G}(J^{PC}) = 0^{+}(2^{+})$

$f_2'(1525)$ MASS

VALUE (MeV) DOCUMENT ID 1525±5 OUR ESTIMATE This is only an educated guess; the error given is larger than the error on the average of the published values.

PRODUCED BY PION BEAM

VALUE (MeV)	EVT5	DOCUMENT ID		TECN	COMMENT
• • • We do not	use the followin	g data for average	es, fit	s, limits,	etc. • • •
1547^{+10}_{-2}		¹ LONGACRE	86	MPS	$22 \pi^- p \rightarrow K_S^0 K_S^0 n$
1496 + 9		² CHABAUD	81	ASPK	6 π ⁻ p → K ⁺ K ⁻ n
1497 + 8		CHABAUD	81	ASPK	18.4 π ⁻ p → K ⁺ K ⁻ n
1492±29		GORLICH	80	ASPK	17 $\pi^- p$ polarized \rightarrow
1502±25		³ CORDEN			K^+K^-n 12-15 $\pi^-p \rightarrow$
1480	14	CRENNELL	66	нвс	$\pi^{+}\pi^{-}n$ 6.0 $\pi^{-}p \to K_{5}^{0}K_{5}^{0}n$

 $^1\,\mbox{From a partial-wave analysis of data using a K-matrix formalism with 5 poles.}$ CHABAUD 81 is a reanalysis of PAWLICKI 77 data.

 3 From an amplitude analysis where the $t_2^\prime(1525)$ width and elasticity are in complete disagreement with the values obtained from $K\overline{K}$ channel, making the solution dubious.

PRODUCED BY K* BEAM

I NODGCED DI N O	- · · · · ·			
VALUE (MeV) EV	/TS	DOCUMENT ID	TECN	COMMENT
1524.6± 1.4 OUR AVERA		des data from t Error includes s		that follows this one. f 1.1.
1526.8± 4.3		ASTON	880 LASS	$11 K^- p \rightarrow K_5^0 K_5^0 \Lambda$
1504 ±12		BOLONKIN	86 SPEC	$40 K^- p \rightarrow K_S^{0} K_S^{0} Y$
1529 ± 3		ARMSTRONG	83B OMEG	18.5 K-p → K-K+A
1521 ± 6 6	50	AGUILAR	818 HBC	$4.2 K^- p \rightarrow \Lambda K^+ K^-$
1521 ± 3 5	72	ALHARRAN	81 HBC	8.25 K ⁻ p → ΛK K̄
1522 ± 6 1	23	BARREIRO	77 HBC	$4.15 K^-p \rightarrow \Lambda K_S^0 K_S^0$
1528 ± 7 1	.66	EVANGELISTA	77 OMEG	$ \begin{array}{c} 10 \ K^- \rho \rightarrow \\ K^+ K^- (\Lambda, \Sigma) \end{array} $
1527 ± 3 1	.20	BRANDENB	76c ASPK	13 $K^- p \rightarrow K^+ K^- (\Lambda, \Sigma)$
1519 ± 7	.00	AGUILAR	728 HBC	3.9,4.6 $K^-p \rightarrow K\overline{K}(\Lambda, \Sigma)$

PRODUCED IN e+e- ANNIHILATION

VALUE (MeV)

DOCUMENT ID

TECN

COMMENT

The data in this block is included in the average printed for a previous datablock.

1524 ± 4 OUR AVERAGE	Error includes scale	factor of 1.2	2.
1535 ± 5 ± 4	ABREU	96C DLPH	$\gamma \gamma \rightarrow K^+ K^- E_{CM}^{ee} =$ 91.2 GeV
1516 \pm 5 $^{+9}_{-15}$	BAI	96c BES	$J/\psi \rightarrow \gamma K^+ K^-$
1529 ±10	ACCIARRI	95J L3	$\gamma \gamma \rightarrow K_S^0 K_S^0 E_{CM}^{ee} = 88-94 \text{ GeV}$ $J/\psi \rightarrow \gamma K^+ K^-$
1531.6±10.0	AUGUSTIN	88 DM2	$J/\psi \rightarrow \gamma K^+ K^-$
1515 ± 5	4 FALVARD	88 DM2	$J/\psi \rightarrow \phi K^+ K^-$
1525 ±10 ±10	BALTRUSAIT	87 MRK3	$J/\psi \rightarrow \gamma K^+ K^-$
• • • We do not use the follow	ving data for average	s, fits, limits	, etc. • • •
1496 ± 2	5 FALVARD	88 DM2	$J/\psi \rightarrow \phi K^+ K^-$

⁴ From an analysis ignoring interference with $f_j(1710)$.

⁵ From an analysis including interference with f_J (1710).

f'2(1525) WIDTH

VALUE (MeV)	DOCUMENT ID	COMMENT				
76±10 OUR ESTIMATE	This is only an educated guess; the error given is larger than					
	the error on the av	erage of the published values.				
-+ 6						

73 + 8 OUR FIT

92 + 39

PDG

90 For fitting

PRODUCED BY F	PION BEAM		TECN	COMMENT
• • • We do not use	the following data for average	s, fit	s, Ilmits,	etc. • • •
108 + 5	⁶ LONGACRE	86	MPS	$22 \pi^- p \rightarrow K_S^0 K_S^0 n$
69 ⁺²² -16	7 CHABAUD	81	ASPK	$6\pi^-p \rightarrow K^+K^-n$
137+23	CHABAUD	81	ASPK	18.4 $\pi^- p \rightarrow K^+ K^- r$
150+83	GORLICH	80	ASPK	17 $\pi^- p$ polarized \rightarrow
165 ± 42	⁸ CORDEN	79	OMEG	$K^+ K^- n$ 12–15 $\pi^- p \rightarrow$

⁶ From a partial-wave analysis of data using a K-matrix formalism with 5 poles.

⁹ POLYCHRO... 79 STRC $7\pi^-p$

PRODUCED BY KE DEAM

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
76± 5 OUR AVERAGE				
18T 9 OUK MAEKWOE	incindez i			
90±12		ASTON	88D LASS	11 $K^- p \rightarrow K_S^0 K_S^0 \Lambda$
73±18		BOLONKIN	86 SPEC	11 $K^- p \to K_5^0 K_5^0 X$ 40 $K^- p \to K_5^0 K_5^0 Y$
83±15				$18.5 K^- p \rightarrow K^- K^+ \Lambda$
85 ± 16	650	AGUILAR	81B HBC	$4.2 K^- p \rightarrow \Lambda K^+ K^-$
80+14	572	ALHARRAN	81 HBC	8.25 $K^- p \rightarrow \Lambda K \overline{K}$
72±25	166	EVANGELISTA	77 OMEG	$\begin{array}{c} 10 \ K^- p \rightarrow \\ K^+ K^- (\Lambda, \Sigma) \end{array}$
69±22	100	AGUILAR	728 HBC	3.9,4.6 $K^-p \rightarrow K\overline{K}(\Lambda, \Sigma)$
• • • We do not use th	e following	data for average	s, fits, limits	, etc. • • •
62 ⁺¹⁹	123	BARREIRO	77 HBC	4.15 $K^-p \rightarrow \Lambda K^0_S K^0_S$
61 ± 8	120	BRANDENB	76c ASPK	13 $K^- p \rightarrow$

 $K^+K^-(\Lambda,\Sigma)$

PRODUCED IN e+e- ANNIHILATION

TECN COMMENT <u>VALUE (MeV)</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u>

The data in this block is included in the average printed for a previous datablock.

66± 8 OUR AVERAGE 96C DLPH $\gamma\gamma \rightarrow K^+K^-$ Ecm= ABREU 60±20±19 91.2 GeV $J/\psi \rightarrow \gamma K^+ K^-$ 60±23+13 BAI 96c B**ES**

 $J/\psi \rightarrow \gamma K^+ K^ J/\psi \rightarrow \phi K^+ K^-$ AUGUSTIN 88 DM2 103±30 10 FALVARD 88 DM2 62±10 BALTRUSAIT...87 MRK3 $J/\psi \rightarrow \gamma K^+ K^ 85 \pm 35$ data for averages, fits, limits, etc. • • •

• • • We do not use the following 95J L3 $\gamma\gamma \rightarrow K_SK_S E_{\rm Cm}^{\rm ee}=$ 88–94 GeV 88 DM2 $J/\psi \rightarrow \phi K^+ K^ 76 \pm 40$ **ACCIARRI** 11 FALVARD

f'2(1525) DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ,	κ κ	(88.8 ±3.1)%
Γ_2	ηη	(10.3 ±3.1)%
Γ₃	ππ	$(8.2 \pm 1.5) \times 10^{-3}$
ΓΔ	77	$(1.32\pm0.21)\times10^{-6}$
Γ ₅	$K\overline{K}^*$ (892) + c.c.	
Γ ₆	$\pi\pi\eta$	·
Γ ₇	$\pi K \overline{K}$	
Γ8	$\pi^{+}\pi^{+}\pi^{-}\pi^{-}$	*

CONSTRAINED FIT INFORMATION

An overall fit to the total width, 2 partial widths, a combination of partial widths obtained from integrated cross sections, and 3 branching ratios uses 14 measurements and one constraint to determine 5 parameters. The overall fit has a $\chi^2 = 11.4$ for 10

The following off-diagonal array elements are the correlation coefficients $\left<\delta p_i \delta p_j \right>/(\delta p_i \cdot \delta p_j)$, in percent, from the fit to parameters p_i , including the branching fractions, $x_i \equiv \Gamma_i/\Gamma_{\text{total}}$. The fit constrains the x_i whose labels appear in this

	Mode	Rate (MeV)
Γ ₁	κ κ	65 +5 -4
Γ_2	ηη	7.6 ±2.6
Γ3	$\pi\pi$	0.60 ± 0.12
Γ ₂ Γ ₃ Γ ₄	$\gamma\gamma$	$(9.7 \pm 1.4) \times 10^{-5}$

f'2(1525) PARTIAL WIDTHS

Γ(<i>KT</i> K)			Γ ₁
VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
65 ⁺⁵ OUR FIT			
63+6	12 LONGACRE 86	MPS	$22 \pi^- p \rightarrow K_S^0 K_S^0 n$
$\Gamma(\pi\pi)$			Γ ₃
VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
0.60±0.12 OUR FIT	12		00
1.4 +1.0 -0.5	12 LONGACRE 86	MP5	$22 \pi^- p \rightarrow K_S^0 K_S^0 n$
$\Gamma(\eta\eta)$			Γ ₂
VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
7.6±2.5 OUR FIT			
• • We do not use the folion	wing data for averages, f	its, limits	, etc. • • •
24 +3	¹² LONGACRE 86	MPS	22 $\pi^- p \to K_5^0 K_5^0 n$
12 From a partial-wave analys	sis of data using a K-mat	rix forma	lism with 5 poles.

$f_2'(1525) \Gamma(i)\Gamma(\gamma\gamma)/\Gamma(total)$

Γ(<i>K</i> 7	R) × r	$(\gamma \gamma)/\Gamma_{\text{total}}$			Γ ₁ Γ ₄ /Γ
VALUE	•		DOCUMENT ID	TECN	COMMENT
0.086	±0.012	OUR FIT			
0.086	± 0.012	OUR AVERAGE			
0.093	± 0.018	±0.022	¹³ ACCIARRI	95J L3	<i>E</i> cm = 88−94 GeV
0.067	±0.008	±0.015	13 ALBRECHT	90G ARG	e+e- → e+e-K+K-
0.11	+0.03 -0.02	±0.02	BEHREND	89C CEL	L e ⁺ e ⁻ → e ⁺ e ⁻ K ⁰ _S K ⁰ _S
0.10	$+0.04 \\ -0.03$	+0.03 -0.02	BERGER	88 PLU	T e+e- → e+e-K ⁰ K ⁰ S
0.12	±0.07	±0.04	¹³ AIHARA	86B TPC	
0.11	±0.02		¹³ ALTHOFF	83 TAS	
• • •	We do	not use the followi	ng data for average	s, fits, lim	ts, etc. • • •
0.031	4±0.005	0±0.0077	14 ALBRECHT	90G ARG	i e+e-→

¹³ Using an incoherent background.

f'2(1525) BRANCHING RATIOS

$\Gamma(\eta\eta)/\Gamma(K\overline{K})$			Γ_2/Γ_1
VALUE	DOCUMENT ID	TECN	COMMENT
0.12±0.04 OUR FIT			
0.11 ± 0.04	15 PROKOSHK	N 91 GAM4	$1300 \pi^- p \rightarrow \pi^- p \eta \eta$
• • • We do not use the	foilowing data for averag	es, fits, limit:	s, etc. • • •
<0.50	BARNES	67 HBC	4.6,5.0 K ⁻ p

 $^{^{15}}$ Combining results of GAM4 with those of WA76 on $K\overline{K}$ central production and results of CBAL, MRK3 and DM2 on $J/\psi\to~\gamma\eta\eta$.

⁷CHABAUD 81 is a reanalysis of PAWLICKI 77 data.

 $^{^8}$ From an amplitude analysis where the $f_2'(1525)$ width and elasticity are in complete disagreement with the values obtained from $K\overline{K}$ channel, making the solution dublous. 9 From a fit to the D with $f_2(1270)$ - $f_2'(1525)$ interference. Mass fixed at 1516 MeV.

 $^{^{10}\,\}mathrm{From}$ an analysis ignoring interference with $f_J(1710)$.

 $^{^{11}}$ From an analysis including interference with $f_{\it J}(1710)$

¹⁴ Using a coherent background.

 $f_2'(1525), f_2(1565)$

(ππ)/Γ _{total}						Г3/Г
0.0082±0.0016 O	ID EIT	DOCUMENT ID		<u>TECN</u>	COMMENT	
0.0075±0.0016 O		E				
0.007 ±0.002		COSTA	80	OMEG	10 π ⁻ p → K	+ K- n
$0.027 \begin{array}{l} +0.071 \\ -0.013 \end{array}$		16 GORLICH	80	ASPK	17,18 π ⁻ p	
0.0075±0.0025	16	,17 MARTIN	79	RVUE	,	
We do not use					etc. • • •	
<0.06	95	AGUILAR	•	нвс	4.2 K ⁻ p →	1K+K-
0.19 ±0.03		CORDEN	79		12-15 m p -	
-					$\pi^+\pi^-\pi$	
<0.045	95	BARREIRO	77	HBC	4.15 K p →	
0.012 ±0.004		16 PAWLICKI	77	SPEC	$6\pi N \rightarrow K^+$	K-N
<0.063	90	BRANDENB.	76c	ASPK	13 K~ p →	
<0.0086		16 BEUSCH	750	OSBK	$K^+K^-(\Lambda, 8.9 \pi^-p \rightarrow 1)$	
	- <i>el. (</i>					
16 Assuming that the	e 72(1525) is	produced by an o	ne-pioi	n exchar	ige production n	nechanish
17 MARTIN 79 uses		CKI 77 data With	dimere	nt input	value of the r	2(1525) -
KK branching ra	tio.					
(ππ)/Γ(K K)						Γ ₂ /Γ
ALUE		DOCUMENT ID		TECN	COMMENT	
.0092±0.0018 OUR	l FIT					
.075 ±0.035		AUGUSTIN	87	DM2	$J/\psi \rightarrow \gamma \pi^+$	π-
		AUGUSTIN	87	DM2	$J/\psi \rightarrow \gamma \pi^+$	
$(\pi\pi\eta)/\Gamma(K\overline{K})$	CL%_	AUGUSTIN			,, ,	
$(\pi\pi\eta)/\Gamma(K\overline{K})$ • • We do not use		DOCUMENT ID		<u>TECN</u>	COMMENT	
(ππη)/Γ(Κ Κ̈)		DOCUMENT ID	es, fits	<u>TECN</u>	COMMENT	
(ππη)/Γ(Κ K) ALUE • • We do not use	the followin	DOCUMENT ID	es, fits	TECN i, limits, HBC	COMMENT etc. ● ●	
(ππη)/Γ(ΚK) (Δ <i>LUE</i> • • We do not use <0.41 <0.3	the followin 95 67	<u>DOCUMENT ID</u> g data for averag AGUILAR AMMAR	es, fits	TECN i, limits, HBC	<u>COMMENT</u> etc. • • • 3.9,4.6 K p	Γ ₆ /Γ
$(\pi\pi\eta)/\Gamma(K\overline{K})$ • • We do not use <0.41 <0.3 $\Gamma(K\overline{K}^{\circ}(892)+c$	e the followin 95 67 .c.) + Γ(π	DOCUMENT ID g data for averag AGUILAR AMMAR KK)]/Γ(KK)	es, fits 728 67	TECN s, limits, HBC HBC	<u>COMMENT</u> etc. • • • 3.9,4.6 K ⁻ p	Γ ₆ /Γ
$(\pi\pi\eta)/\Gamma(K\overline{K})$ ALUE • We do not use (0.41) (0.3) $\Gamma(K\overline{K}^{\circ}(892) + C$ ALUE	95 67 .c.) + Γ(π)	DOCUMENT ID g data for averag AGUILAR AMMAR KK)]/((KK) DOCUMENT ID	es, fits 728 67	TECN s, limits, HBC HBC	COMMENT etc. • • • 3.9,4.6 K ⁻ p (Γ ₃	Γ ₆ /Γ
$(\pi \pi \eta)/\Gamma(K\overline{K})$ ALUE • • We do not use <0.41 <0.3 $\Gamma(K\overline{K}^{\circ}(892) + C$ ALUE • • We do not use	the following 95 67 $(C.) + \Gamma(\pi)$ the following the following states at the f	DOCUMENT ID g data for averag AGUILAR AMMAR KK)]/Г(KK) DOCUMENT ID g data for averag	es, fits 728 67 es, fits	TECN , limits, HBC HBC TECN , limits,	COMMENT etc. • • • 3.9,4.6 K ⁻ p (Γ ₃ COMMENT etc. • • •	Γ ₆ /Γ
(ππη)/Γ(ΚΚ) ALUE • • We do not use <0.41 <0.3 Γ(ΚΚ*(892) + c ALUE • • We do not use <0.35	the followin 95 67 (C.) + $\Gamma(\pi + \frac{CLS}{2})$ a the followin 95	DOCUMENT ID g data for average AGUILAR AMMAR (KK)]/ (KK) DOCUMENT ID g data for average AGUILAR	es, fits 728 67 es, fits 728	TECN i, limits, HBC HBC TECN i, limits,	COMMENT etc. • • • 3.9,4.6 K ⁻ p (Γ ₃	Γ ₆ /Γ
$(\pi \pi \eta)/\Gamma(K\overline{K})$ ALUE • • We do not use <0.41 <0.3 $\Gamma(K\overline{K}^{\circ}(892) + C$ ALUE • • We do not use	the following 95 67 $(C.) + \Gamma(\pi)$ the following the following states at the f	DOCUMENT ID g data for averag AGUILAR AMMAR KK)]/Г(KK) DOCUMENT ID g data for averag	es, fits 728 67 es, fits 728	TECN , limits, HBC HBC TECN , limits,	COMMENT etc. • • • 3.9,4.6 K ⁻ p (Γ ₃ COMMENT etc. • • •	Γ ₆ /Γ
$(\pi \pi \eta)/\Gamma(KK)$ ALUE • • We do not use <0.41 <0.3 $\Gamma(KK^{\circ}(892) + C)$ ALUE • • We do not use <0.35 <0.4	95 67 .c.) + \(\(\pi \) 2	DOCUMENT ID g data for average AGUILAR AMMAR (KK)]/ (KK) DOCUMENT ID g data for average AGUILAR	es, fits 728 67 es, fits 728	TECN i, limits, HBC HBC TECN i, limits,	COMMENT etc. • • • 3.9,4.6 K ⁻ p (Γ ₃ COMMENT etc. • • •	Γ ₆ /Γ +Γ ₇)/Γ
(ππη)/Γ(ΚΚ) ALUE • • We do not use <0.41 <0.3 Γ(ΚΚ*(892) + c ALUE • • We do not use <0.35	95 67 .c.) + \(\(\pi \) 2	DOCUMENT ID g data for average AGUILAR AMMAR (KK)]/ (KK) DOCUMENT ID g data for average AGUILAR	es, fits 728 67 es, fits 728 67	TECN HBC HBC TECN I limits, HBC HBC	COMMENT etc. • • • 3.9,4.6 K ⁻ p (Γ ₃ COMMENT etc. • • •	Γ ₆ /Γ +Γ ₇)/Γ
$(\pi \pi \eta)/\Gamma(KK)$ ALUE • • We do not use <0.41 <0.3 $\Gamma(KK^{\circ}(892) + C)$ ALUE • • We do not use <0.35 <0.4 $(\pi + \pi + \pi - \pi^{-})/C$	2 the following 95 67 .c.) + Γ(π/2 15 67 67 67 67 61 5 67 61 5 61 5 61 5 6	DOCUMENT ID g data for averag AGUILAR AMMAR KK)]/ (KK) DOCUMENT ID g data for averag AGUILAR AMMAR	es, fits 728 67 es, fits 728 67	TECN Inits, HBC HBC TECN Ilmits, HBC HBC	COMMENT etc. • • • 3.9,4.6 K - p (Fig. COMMENT etc. • • • 3.9,4.6 K - p	Γ ₆ /Γ +Γ ₇)/Γ
$(\pi \pi \eta)/\Gamma(KK)$ ALUE • • We do not use <0.41 <0.3 $\Gamma(KK^{\circ}(892) + c$ ALUE • • We do not use <0.35 <0.4 $(\pi + \pi + \pi - \pi^{-})/ALUE$	2 the following 95 67 .c.) + Γ(π/2 15 67 67 67 67 61 5 67 61 5 61 5 61 5 6	DOCUMENT ID g data for averag AGUILAR AMMAR KK)]/ (KK) DOCUMENT ID g data for averag AGUILAR AMMAR	es, fits 72B 67 es, fits 72B 67	TECN Inits, HBC HBC TECN Ilmits, HBC HBC	COMMENT etc. • • • 3.9,4.6 K - p (Fig. COMMENT etc. • • • 3.9,4.6 K - p	Γ ₆ /Γ +Γ ₇)/Γ
$(\pi \pi \eta)/\Gamma(KK)$ ALUE • • We do not use <0.41 <0.3 $\Gamma(KK^{\circ}(892) + C)$ ALUE • • We do not use <0.35 <0.4 $(\pi^{+}\pi^{+}\pi^{-}\pi^{-})/C$ ALUE • • We do not use <0.32	the following 95 67 .c.) + \(\Gamma_{\text{K}}\) the following 95 67 \(\Gamma_{\text{K}}\) the following 67	DOCUMENT ID g data for averag AGUILAR AMMAR KK)]/ (KK) DOCUMENT ID g data for averag AGUILAR AMMAR	es, fits 72B 67 es, fits 72B 67	TECN In limits, HBC HBC TECN Ilmits, HBC HBC TECN Ilmits,	COMMENT etc. • • • 3.9,4.6 K ⁻ p (Γ ₃ COMMENT etc. • • • 3.9,4.6 K ⁻ p	Γ ₆ /Γ, +Γ ₇)/Γ, Γ ₆ /Γ
$(\pi \pi \eta)/\Gamma(KK)$ ALUE • • We do not use <0.41 <0.3 $(\pi K)^{\circ}(892) + c$ ALUE • • We do not use <0.35 <0.4 • $(\pi + \pi + \pi - \pi)/\Gamma(K)$ • • We do not use <0.32 • $(\pi \eta)/\Gamma_{\text{total}}$	e the following 95 67 .c.) + \(\Gamma_{\text{K}}\) a the following 95 67 (\(\Gamma_{\text{K}}\)) at 100 (\(\Gamma_{\text{K}}\) at 100 (\(\Gamma_{\text{K}}\)) at 100 (\(\Gamma_{\text{K}}\)) at 100 (\(\Gamma_{\text{K}}\) at 100 (\(\Gamma_{\text{K}}\)) at 100 (\(\Gamma_{\text{K}}\)) at 100 (\(\Gamma_{\text{K}}\) at 100 (\(\Gamma_{\text{K}}\)) at 100 (\(\Gamma_{\text{K}}\)) at 100 (\(\Gamma_{\text{K}}\) at 100 (\(\Gamma_{\text{K}}\)) at 100 (\(\Gamma_{\text{K}}\) at 100 (\(\Gamma_{\text{K}}\) at 100 (\(\Gamma_{\text{K}}\)) at 100 (\(\Gamma_{\text{K}}\) at 100 (\(\Gamma_{\text{K}}\))	DOCUMENT ID g data for averag AGUILAR AMMAR KK)]/ (KK) DOCUMENT ID g data for averag AGUILAR AMMAR DOCUMENT ID g data for averag AGUILAR	728 67 728 67 728 728 67	TECN 3, limits, HBC HBC TECN 5, limits, HBC HBC TECN 5, limits,	COMMENT etc. • • • 3.9,4.6 K ⁻ p (Γ ₃ COMMENT etc. • • • 3.9,4.6 K ⁻ p COMMENT etc. • • • 3.9,4.6 K ⁻ p	Γ⊕/Γ +Γγ)/Γ Γ⊕/Γ
$(\pi \pi \eta)/\Gamma(KK)$ ALUE • • We do not use <0.41 <0.3 $(\pi K^{\bullet}(892) + c)$ ALUE • • We do not use <0.35 <0.4 $(\pi + \pi + \pi - \pi^{-})/C$ ALUE • • We do not use <0.32 $(\eta \eta)/\Gamma_{\text{total}}$ ALUE	the following 95 67 .c.) + \(\Gamma_{\text{K}}\) a the following 95 67 (\(\Gamma_{\text{K}}\)) a the following 95 at the following 95	DOCUMENT ID g data for averag AGUILAR AMMAR KK)]/ (KK) DOCUMENT ID g data for averag AGUILAR AMMAR DOCUMENT ID g data for averag AGUILAR	728 67 728 67 728 67 728	TECN. s, Ilmits, HBC HBC TECN. s, Ilmits, HBC HBC TECN. s, Ilmits, HBC	COMMENT etc. • • • 3.9,4.6 K - p (Find Comment etc. • • • 3.9,4.6 K - p COMMENT etc. • • • 3.9,4.6 K - p COMMENT etc. • • • 3.9,4.6 K - p	Γ⊕/Γ +Γγ)/Γ Γ⊕/Γ
$(\pi \pi \eta)/\Gamma(KK)$ ALUE • • We do not use <0.41 <0.3 $(\Gamma(KK^{\bullet}(892) + C)$ ALUE • • We do not use <0.35 <0.4 $(\pi^{+}\pi^{+}\pi^{-}\pi^{-})/ALUE$ • • We do not use <0.32 $(\eta \eta)/\Gamma_{\text{total}}$ ALUE • • We do not use	the following 95 67 .c.) + \(\Gamma\) (\Gamma\) a the following 95 67 (\(\Gamma\) (\Gamma\) a the following 95 e the following 95	DOCUMENT ID g data for averag AGUILAR AMMAR KK)]/Г(KK) DOCUMENT ID g data for averag AGUILAR AMMAR DOCUMENT ID g data for averag AGUILAR DOCUMENT ID g data for averag	728 67 728 67 728 728	TECN s, Ilmits, HBC HBC TECN s, Ilmits, HBC HBC TECN s, Ilmits, HBC	COMMENT etc. • • • 3.9,4.6 K - p COMMENT etc. • • • 3.9,4.6 K - p COMMENT etc. • • • 3.9,4.6 K - p	Γ ₆ /Γ: +Γ ₇)/Γ: Γ ₆ /Γ
$(\pi \pi \eta)/\Gamma(KK)$ ALUE • • We do not use <0.41 <0.3 $(\pi K^{\bullet}(892) + c)$ ALUE • • We do not use <0.35 <0.4 $(\pi + \pi + \pi - \pi^{-})/C$ ALUE • • We do not use <0.32 $(\eta \eta)/\Gamma_{\text{total}}$ ALUE	e the followings 67 1.C.) + \(\Gamma\) (\(\pi\) 1. the followings 67 1. (\(\K'\) 2. the followings 6 the followings	DOCUMENT ID g data for averag AGUILAR AMMAR KK)]/Г(KK) DOCUMENT ID g data for averag AGUILAR AMMAR DOCUMENT ID g data for averag AGUILAR DOCUMENT ID g data for averag AGUILAR	728 67 728 67 728 67 728 85, fits	TECN s, Ilmits, HBC HBC TECN s, Ilmits, HBC TECN s, Ilmits, HBC	COMMENT etc. • • • 3.9,4.6 K ⁻ p COMMENT etc. • • • 3.9,4.6 K ⁻ p COMMENT etc. • • • 3.9,4.6 K ⁻ p COMMENT etc. • • • 3.9,4.6 K ⁻ p	Γ ₆ /Γ ₁ +Γ ₇)/Γ ₁ Γ ₆ /Γ Γ ₂ /Γ

f'₂(1525) REFERENCES

ABREU	96C	PL 8379 309	+Adam, Adye+ (DELPHI Collab.)
BAI	96C	PRL 77 3959	J.Z. Bai+ (BES Collab.)
ACCIARRI	95J	PL B363 118	+Adam, Adriani, Aguilar-Benitez+ (L3 Collab.)
PROKOSHKIN	91	SPD 36 155	(GAM2, GAM4 Collab.)
ALBRECHT	90G	Translated from D/ ZPHY C48 183	ANS 316 900. +Ehriichmann, Harder+ (ARGUS Collab.)
PDG	90	PL B239	Hernandez, Stone, Porter+ (IFIC, BOST, CIT+)
BEHREND	89C	ZPHY C43 91	+Criegee, Dainton+ (CELLO Collab.)
ASTON	88D	NP B301 525	+Awaji, Bienz+ (SLAC, NAGO, CINC, INUS)
AUGUSTIN	88	PRL 60 2238	+Calcaterra+ (DM2 Collab.)
BERGER	88	ZPHY C37 329	+Genzel, Lackas+ (PLUTO Collab.)
FALVARD	88	PR D38 2706	+Ajaitouni+ (CLER, FRAS, LALO, PADO)
AUGUSTIN	87	ZPHY C36 369	+Cosme+ (LALO, CLER, FRAS, PADO)
BALTRUSAIT		PR D35 2077	Baltrusaltis, Coffman, Dubols+ (Mark III Collab.)
AIHARA	86B		+Aiston-Garnjost+ (TPC-2γ Collab.)
BOLONKIN	86	SJNP 43 776 Translated from YA	+Bloshenko+ (ITEP) JP
LONGACRE	86	PL B177 223	+Etkin+ (BNL, BRAN, CUNY, DUKE, NDAM)
ALTHOFF	83	PL 121B 216	+Brandelik, Boerner, Burkhardt+ (TASSO Collab.)
ARMSTRONG	83B		+ (BARI, BIRM, CERN, MILA, CURIN+)
AGUILAR	81B	ZPHY C8 313	Aguilar-Benitez, Albajar+ (CERN, CDEF, MADR+)
ALHARRAN	81	NP B191 26	+Baubiller+ (BIRM, CERN, GLAS, MICH, CURIN)
CHABAUD	81	APP B12 575	+Niczyporuk, Becker+ (CERN, CRAC, MPIM)
COSTA	80	NP B175 402	Costa De Beauregard+ (BARI, BONN, CERN+)
GORLICH	80	NP B174 16	+Niczyporuk+ (CRAC, MPIM, CERN, ZEEM)
CORDEN	79	NP B157 250	+Dowell, Garvey+ (BIRM, RHEL, TELA, LOWC) JP
MARTIN	79	NP B158 520	+Ozmutlu (DURH)
POLYCHRO	79	PR D19 1317	Polychronakos, Cason, Bishop+ (NDAM, ANL)
BARREIRO	77	NP B121 237	+Diaz, Gay, Hemingway+ (CERN, AMST, NIJM, OXF)
EVANGELISTA		NP B127 384	+ (BARI, BONN, CERN, DARE, GLAS+)
PAWLICKI	77 76C	PR D15 3196	+Ayres, Cohen, Diebold, Kramer, Wicklund (ANL) IJP
BRANDENB BEUSCH	75B	NP B104 413 PL 60B 101	Brandenburg, Carnegie, Cashmore+ (SLAC) +Birman, Websdale, Wetzel (CERN, ETH)
AGUILAR	728		+Birman, Websdale, Wetzel (CERN, ETH) Aguilar-Benitez, Chung, Eisner, Samios (BNL)
AMMAR	67	PRL 19 1071	+Davis, Hwang, Dagan, Derrick+ (NWES, ANL) JP
BARNES	67	PRL 19 964	+Dornan, Goldberg, Leitner+ (BNL, SYRA) IJPC
CRENNELL	66	PRL 16 1025	+Kalbfleisch, Lai, Scarr, Schumann+ (BNL) 1
CHEMICE	••	1110 10 1010	Attenditional Cast Scattle Senditional (District
		ОТН	HER RELATED PAPERS
JENNI	83	PR D27 1031	+Burke, Telnov, Abrams, Blocker+ (SLAC, LBL)
ARMSTRONG ETKIN	82B	PL 110B 77	+Baubilier+ (BARI, BIRM, CERN, MILA, CURIN+)
ABRAMS	67B		+Foley, Lai+ (BNL, CUNY, TUFTS, VAND)
BARNES	65	PRL 18 620 PRL 15 322	+Kehoe, Giasser, Sechl-Zorn, Wolsky (UMD) +Culwick, Guldoni, Kalbflelsch, Goz+ (BNL, SYRA)
PUNITES		FRE 13 322	+Curwick, Guidoni, Raidicisch, GOZ+ (BRL, STRA)

$f_2(1565)$

 $I^{G}(J^{PC}) = 0^{+}(2^{+})$

OMITTED FROM SUMMARY TABLE

Seen in antinucleon-nucleon annihilation at rest. See also minireview under non-qq candidates. (See the index for the page number.) Needs confirmation.

%(1565) MASS

VALUE (MeV)	DOCUMENT ID	TECN	
1542±22 OUR AVERA	SE Error includes scale fo	actor of 2.3.	See the Ideogram below.
1575 ± 18	BERTIN	98 OBLX	50—405 πp →
1507 ± 15	1 BERTIN	97c OBLX	$0.0 \overline{p}p \rightarrow \pi^{+}\pi^{-}\pi^{0}$
1565 ± 20	MAY	90 ASTE	$0.0 \overline{\rho} p \rightarrow \pi^+ \pi^- \pi^0$
• • • We do not use the	following data for average:	s, fits, limits	, etc. • • •
1534 ± 20	² ABELE	96¢ RVUE	Compliation
~ 1552	3 AMSLER	950 CBAR	$0.0 pp \rightarrow \pi^0 \pi^0 \pi^0$
			$\pi^0\eta\eta, \pi^0\pi^0\eta$
1598±72	BALOSHIN	95 SPEC	40 *- C → KO KO X
1566 +80 -50	4 ANISOVICH	94 CBAR	$0.0 \ \overline{p}p \rightarrow 3\pi^{0}, \eta \eta \pi^{0}$
1502 ± 9	ADAMO	93 OBLX	$\pi p \rightarrow \pi^+ \pi^+ \pi^-$
1488 ± 10	5 ARMSTRONG	93C E760	$\overline{p}p \rightarrow \pi^0 \eta \eta \rightarrow 6\gamma$
1508±10			$\overline{D}p \rightarrow 3\pi^{0} \rightarrow 6\gamma$
1525±10	5 ARMSTRONG	93D E760	$\overline{p}p \rightarrow \eta \pi^0 \pi^0 \rightarrow 6\gamma$
~ 1504	6 WEIDENAUER		0.0 βN → 3π ⁻ 2π ⁺
1540±15	5 ADAMO	92 OBLX	$\pi_P \rightarrow \pi^+\pi^+\pi^-$
1515±10	7 AKER	91 CBAR	$0.0 \overline{D}p \rightarrow 3\pi^0$
1477 ± 5	BRIDGES	86C DBC	0.0 pN → 3π ⁻ 2π ⁺
¹ T-matrix pole.			•

¹T-matrix pole, large coupling to ρ_P and ω_{ω} , could be f_2 (1640).

³Coupled-channel analysis of AMSLER 958, AMSLER 95c, and AMSLER 940.

⁴From a simultaneous analysis of the annihilations $\overline{\rho}p \to 3\pi^0, \pi^0\eta\eta$ including AKER 91 days.

⁵JP not determined, could be partly f_0 (1500).

⁶JP not determined.

⁷Superseded by AMSLER 958,

WEIGHTED AVERAGE 1542±22 (Error scaled by 2.3) BERTIN 97C OBLX 90 ASTE BERTIN (Confidence Level = 0.006) 1450 1500 1550 1600 1650 1700 f₂(1565) mass (MeV)

6(1565) WIDTH

VALUE (MeV) 131± 14 OUR AVERAGE	DOCUMENT ID	TECN	COMMENT
119± 24	BERTIN		50-405 πp →
130± 20	8 BERTIN		$ \begin{array}{c} \pi^{+}\pi^{+}\pi^{-}\\ 0.0 \ \overline{p}p \rightarrow \pi^{+}\pi^{-}\pi^{0}\\ 0.0 \ \overline{p}p \rightarrow \pi^{+}\pi^{-}\pi^{0} \end{array} $
170± 40 • • • We do not use the followin	MAY ig data for average:		
180± 60			Compliation
~ 142	10 AMSLER		$\begin{array}{c} 0.0 \ \overline{p}p \rightarrow \pi^0 \pi^0 \pi^0, \\ \pi^0 \eta \eta, \pi^0 \pi^0 \eta \end{array}$
263±101	BALOSHIN	95 SPEC	$40 \pi^{-}C \rightarrow K_{S}^{0} K_{S}^{0} X$
166 + 80 - 20	11 ANISOVICH	94 CBAR	$0.0 \ \overline{p}p \rightarrow 3\pi^{0}, \eta\eta\pi^{0}$
130± 10	12 ADAMO		$\pi \rho \rightarrow \pi^+ \pi^+ \pi^-$
148± 27			$\overline{\rho}p \rightarrow \pi^0\eta\eta \rightarrow 6\gamma$
103± 15			$\overline{p}p \rightarrow 3\pi^0 \rightarrow 6\gamma$
111 ± 10			$\overline{p}p \rightarrow \eta \pi^0 \pi^0 \rightarrow 6\gamma$
~ 206		93 ASTE	$0.0 \ \overline{p} N \rightarrow 3\pi^- 2\pi^+$
132± 37	13 ADAMO	92 OBLX	$\pi_P \rightarrow \pi^+ \pi^+ \pi^-$
120± 10	15 AKER	91 CBAR	$0.0 \overline{p}p \rightarrow 3\pi^{0}$
116± 9	BRIDGES	86C DBC	$0.0 \overline{p} N \rightarrow 3 \pi^- 2 \pi^+$

8T-ma	trix	pole.
0 —		

- 9T-matrix pole, large coupling to $\rho\rho$ and $\omega\omega$, could be f_2 (1640).

 10 Coupled-channel analysis of AMSLER 95B, AMSLER 95C, and AMSLER 94D.

 11 From a simultaneous analysis of the annihilations $\bar{\rho}\rho \to 3\pi^0, \pi^0\eta\eta$ including AKER 91 data.

 12 Supersedes ADAMO 92.

 13 J^P not determined, could be partly $f_0(1500)$.

- 14 JP not determined. 15 Superseded by AMSLER 958,

f2(1565) DECAY MODES

	Mode	Fraction (Γ_i/Γ)
[₁	$\pi^+\pi^ \pi^0\pi^0$	seen
Γ ₂ Γ ₃	$\rho^{0} \rho^{0} \rho^{0} = 2\pi^{+} 2\pi^{-}$	seen seen
Γ ₄ Γ ₅	$2\pi^+2\pi^ \eta\eta$	seen seen
	3.4	

f2(1565) BRANCHING RATIOS

$\Gamma(\pi^+\pi^-)/\Gamma_{\text{total}}$					Γ_1/Γ
VALUE	DOCUMENT ID		TECN	COMMENT	
• • We do not use the following	g data for average	s, fits	s, limits,	etc. • • •	
seen	BERTIN			50-405 n p →	
not seen	16 ANISOVICH	94B	RVUE	$\frac{\pi^+\pi^+\pi^-}{\overline{p}p\to\pi^+\pi^-\pi^0}$	0
seen	MAY	89	ASTE	$\overline{p}p \rightarrow \pi^{+}\pi^{-}\pi^{0}$	0
¹⁶ ANISOVICH 94B Is from a rea	analysis of MAY 90).			
$\Gamma(\pi^+\pi^-)/\Gamma(\rho^0\rho^0)$					Γ_1/Γ_3
VALUE	DOCUMENT ID		<u>TECN</u>	COMMENT	
• • • We do not use the following	g data for average	s, fits	s, limits,	etc. • • •	
0.042 ± 0.013	BRIDGES	86B	DBC	$\overline{p}N \rightarrow 3\pi^-2\pi^+$	+
$\Gamma(\pi^0\pi^0)/\Gamma_{\text{total}}$					Γ_2/Γ
VALUE	DOCUMENT ID		TECN	COMMENT	
seen	AMSLER	95B	CBAR	$0.0 \ \overline{p}p \rightarrow 3\pi^{0}$	
$\Gamma(\eta\eta)/\Gamma(\pi^0\pi^0)$					Γ_5/Γ_2
VALUE	DOCUMENT ID		TECN	COMMENT	
• • We do not use the following	g data for average	s, fit	s, limits,	etc. • • •	
$0.024\pm0.005\pm0.012$ $^{17}J^P$ not determined, could be		930	E760	$\overline{p}p \rightarrow \pi^0 \eta \eta \rightarrow$	6γ

f₂(1565) REFERENCES

BERTIN	98	PR D57 55	A. Bertin, Bruschi, Capponi+	(OBELIX Collab.)
BERTIN	97C	PL B408 476	A. Bertin, Bruschi+	(OBELIX Collab.)
ABELE	96C	NP A609 562	A. Abele, Adomeit, Armstrong+	(Crystal Barrel Collab.)
AMSLER	95B	PL B342 433	+Armstrong, Brose+	(Crystal Barrel Collab.)
AMSLER	95C	PL B353 571	+Armstrong, Hackman+	(Crystal Barrel Collab.)
AMSLER	95D	PL B355 425	+Armstrong, Spanier+	(Crystal Barrel Collab.)
BALOSHIN	95	PAN 58 46	+ Bolonkin, Vladimirskii+	(ITEP)
		Translated from	YAF 58 50.	` '
AMSLER	94D	PL B333 277	+Anisovich, Spanier+	(Crystal Barrel Collab.)
ANISOVICH	94	PL B323 233	+Armstrong+	(Crystal Barrel Collab.)
ANISOVICH	94B	PR D50 1972	+Bugg+	(LOQM)
ADAMO	93	NP A558 13C	+Agnello+	(OBELIX Collab.)
ARMSTRONG	93C	PL B307 394	+Bettoni+ (FNAL, FERR,	GENÒ, UCI, NWES+
ARMSTRONG	93D	PL B307 399	+Bettoni+ (FNAL, FERR,	GENO, UCI, NWES+)
WEIDENAUER	93	ZPHY C59 387	+Duch+	(ASTERIX Collab.)
ADAMO	92	PL B287 368	+Agnello, Balestra+	(OBELIX Collab.)
AKER	91	PL B260 249	+Amsler, Peters+	(Crystal Barrel Collab.)
MAY	90	ZPHY C46 203	+Duch, Heel+	(ASTERIX Collab.)
MAY	89	PL B225 450	+Duch, Heel+	(ASTERIX Collab.) IJP
BRIDGES	86B	PRL 56 215	+Daftari, Kalogeropoulos, Debbe+	(SYRA, CASE)
BRIDGES	B6C	PRL 57 1534	+Daftari, Kalogeropoulos+	(SYRA)
			, gerepenser,	(5)

 $\omega(1600)$

$$I^{G}(J^{PC}) = 0^{-}(1^{-})$$

ω (1600) MASS

VALUE (MeV)	EVTS	DOCUMENT ID		TECN CHG	COMMENT
1649 ± 24 OUR AVERA	GE Erro	r Includes scale fac	tor o	f 2.3.	
1609 ± 20	315	¹ ANTONELLI	92	DM2	1.34-2.4 $e^+e^- \to$
1663±12	435	² ANTONELLI	92	DM2	$ \begin{array}{c} \rho\pi\\ 1.34-2.4e^+e^- \rightarrow\\ \omega\pi\pi \end{array} $
• • • We do not use t	he followii	ng data for average	s, fits	s, limits, etc.	• • •
1600±30		¹ CLEGG	94	RVUE	$e^+e^- \rightarrow \rho\pi$
1607 ± 10		² CLEGG	94	RVUE	$e^+e^- \rightarrow \omega \pi \pi$
1635 ± 35		³ CLEGG	94	RVUE	$e^+e^- \rightarrow \rho\pi$
1625 ± 21		³ CLEGG	94	RVUE	$e^+e^- \rightarrow \omega \pi \pi$
1670 ± 20		ATKINSON	838	OMEG	$20-70 \gamma p \rightarrow$
1657±13		CORDIER	81	DM1	$e^{+\frac{3\pi}{e}X} \rightarrow \omega 2\pi$
1679±34	21	ESPOSITO	80	FRAM	$e^+e^- \rightarrow 3\pi$
1652 ± 17		COSME	79	OSPK 0	$e^+e^- \rightarrow 3\pi$

ω(1600) WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID		TECN CHG	COMMENT
220±35 OUR AVERAGE	Error in	cludes scale facto	r of :	1.6.	
159±43	315	4 ANTONELLI	92	DM2	$1.34-2.4e^{+}e^{-} \rightarrow$
		-			$ ho\pi$
240±25	435	⁵ ANTONELLI	92	DM2	$1.34-2.4e^{+}e^{-} \rightarrow$
• • • We do not use the	following	data for average	fite	limite etc e	$\omega \pi \pi$
• • • • vve do not use the	IOHOWING	data ioi aveiages	, 111.3	, minits, etc. •	••
140±50		⁴ CLEGG	94	RVUE	$e^+e^- \rightarrow \rho\pi$
86 ± 20		⁵ CLEGG	94	RVUE	$e^+e^- ightarrow \omega \pi \pi$
350 ± 80		⁶ CLEGG	94	RVUE	$e^+e^- \rightarrow \rho\pi$
401 ± 63		⁶ CLEGG	94	RVUE	$e^+e^- \rightarrow \omega \pi \pi$
160±20		ATKINSON	83B	OMEG	20-70 γp →
					3π X
136±46		CORDIER	81	DM1	$e^+e^- \rightarrow \omega 2\pi$
99±49	21	ESPOSITO	80	FRAM	$e^+e^- \rightarrow 3\pi$
42±17		COSME	79	OSPK 0	$e^+e^- \rightarrow 3\pi$

$\omega(1600)$ DECAY MODES

	Mode	Fraction (Γ_I/Γ)
Γ1	ρπ	seen
Γ_2	$\omega\pi\pi$ e^+e^-	seen
Γ ₃	e ⁺ e ⁻	seen

$\omega(1600) \Gamma(l)\Gamma(e^+e^-)/\Gamma(total)$

$\Gamma(\rho\pi) \times \Gamma(e^+e^-)$	·-)/Γ _{total}				Γ ₁ Γ ₃ /Γ
VALUE (eV)	EVTS	DOCUMENT ID		TECN	COMMENT
134±14	435				1.34-2.4e ⁺ e ⁻ → hadrons
• • • We do not u	se the following	ig data for average	5, 111	s, nmits,	, etc. • • •
93 ± 27	315	ANTONELLI	92	DM2	$1.34-2.4e^+e^-\rightarrow \rho\pi$
96 + 35		DONNACHIE	89	RVUE	e+e 0#

 $^{7}\,\mathrm{From}$ a coupled fit of $\rho\pi$ and $\omega\,\pi\,\pi$ channels.

Γ(ωππ) × Γ(e	+ e ⁻)/Γ _{total}	1 .			Γ ₂ Γ ₃ /Γ
VALUE (keV)	EVTS	DOCUMENT ID		TECN	COMMENT
170±17	435	⁸ ANTONELLI	92	DM2	1.34-2.4e ⁺ e ⁻ → hadrons
• • • We do not a	ise the followin	ng data for average	s, flt:	s, limits,	etc. • • •
135±16	435	9 ANTONELLI	92	DM2	$1.34-2.4e^{+}e^{-} \rightarrow \omega \pi \pi$
56 ± 31		DONNACHIE	89	RVUE	$e^+e^- \rightarrow \omega 2\pi$
8 From a coupled	ifit of $\rho\pi$ and	$\omega \pi \pi$ channels.			
⁹ From a single E	Breit-Wigner fi	t.			

$\omega(1600)$ REFERENCES

CLEGG	94	ZPHY C62 455	+Donnachie (LANC, MCHS
ANTONELLI	92	ZPHY C56 15	+Baldini+ (DM2 Collab
DONNACHIE	89	ZPHY C42 663	+Clegg (CERN, MCHS
ATKINSON	83B	PL 127B 132	+ (BONN, CERN, GLAS, LANC, MCHS, CURIN+
CORDIER	81	PL 106B 155	+Bisello, Bizot, Buon, Delcourt, Mane (ORSA)
ESPOSITO	80	LNC 28 195	+Marini, Patteri+ (FRAS, NAPL, PADO, ROMA
COSME	79	NP B152 215	+Dudelzak, Grelaud, Jean-Marie, Jullian+ (IPA

 $^{^1\,\}mathrm{From}$ a two Breit-Wigner fit. $^2\,\mathrm{From}$ a single Breit-Wigner plus background fit. $^3\,\mathrm{From}$ a single Breit-Wigner fit.

From a two Breit-Wigner fit.
 From a single Breit-Wigner plus background fit.
 From a single Breit-Wigner fit.

 $\omega(1600)$, X(1600), $f_2(1640)$, $\eta_2(1645)$, X(1650)

	HER RELATED PAPERS	f ₂	(1640) DECAY MODES
ACHASOV 97F PAN 60 2029 Translated from 'DOLINSKY 91 PRPL 202 99	N.N. Achasov, Kozhevnikov (NOVM) YAF 60 2212. + Druzhinin, Dubrovin+ (NOVO)	Mode	Fraction (Γ_f/Γ)
ATKINSON 87 ZPHY C34 157 ATKINSON 84 NP B231 15	+ (BONN, CERN, GLAS, LANC, MCHS, CURIN) + (BONN, CERN, GLAS, LANC, MCHS, CURIN+)	$\Gamma_1 \omega \omega$	seen
	(Solit, Colit, GEAS, EARC, Mells, Colity)	Γ_2 4π	seen .
X(1600)	$I^{G}(J^{PC}) = 2^{+}(2^{+})$,	2(1640) REFERENCES
	ARY TABLE ion $\gamma\gamma \to \rho\rho$ near threshold. See also minirendidates. (See the index for the page number.)	BUGG 95 PL B353 378 ADAMO 92 PL B287 368 BELADIDZE 92B ZPHY C54 367 ALDE 90 PL B241 600	+Scott, Zoll+ (LOQM, PNPI, WASH) JP +Agnello, Balestra+ (OBELIX Collab.) +Bityukov, Borisov+ (VES Collab.) +Binon+ (SERP, BELG, LANL, LAPP, PISA, KEK)
	X(1600) MASS	$\eta_2(1645)$	$J^{G}(J^{PC}) = 0^{+}(2^{-})$
VALUE (MeV)	DOCUMENT ID TECN CHG COMMENT		
1600±100 1	ALBRECHT 91F ARG 0 10.2 e+e-→	OMITTED FROM SUMM	ARY TABLE
¹ Our estimate.	$e^+e^-2(\pi^+\pi^-)$		72(1645) MASS
	V(1600) WIDTH	VALUE (MeV)	DOCUMENT ID TECN CHG COMMENT
	X(1600) WIDTH	1632±14 OUR AVERAGE 1620±20	BARBERIS 978 OMEG 450 pp →
	<u>DOCUMENT ID</u> <u>TECN CHG COMMENT</u> ALBRECHT 91F ARG 0 10.2 e ⁺ e ⁻ →		$\rho \rho 2(\pi^+\pi^-)$
	ALBRECHT 91F ARG 0 10.2 $e^+e^- \rightarrow e^+e^- 2(\pi^+\pi^-)$	1645±14±15	ADOMEIT 96 CBAR 0 1.94 $\vec{p} \vec{p} \rightarrow \eta 3 \hat{\pi}^0$
² Our estimate.			η ₂ (1645) WIDTH
,	((1600) REFERENCES	VALUE (MeV)	DOCUMENT ID TECN CHG COMMENT
LBRECHT 91F ZPHY C50 1	+Appuan, Paulini, Funk+ (ARGUS Collab.)	180+22 OUR AVERAGE	
	HER RELATED PAPERS	180±25	BARBERIS 978 OMEG 450 pp →
AJC 96 ZPHY A356 187 LBRECHT 89M PL B217 205	B. Bajc+ +Bockmann+ (ARGUS Collab.)	$180^{+40}_{-21}\pm 25$	$pp2(\pi^{+}\pi^{-})$ ADOMEIT 96 CBAR 0 1.94 $\overline{p}p \rightarrow \eta 3\pi^{0}$
EHREND 89D PL B218 494	+Criegee+ (CELLO Collab.)	70	(1645) DECAY MODES
$f_{5}(1640)$	$I^{G}(J^{PC}) = 0^{+}(2^{+})$		(10.0)
12(1040)	. (-) = - (-)	Mode	
MITTED FROM SUMMA	ARY TABLE	Γ ₁	
· · · · · · · · · · · · · · · · · · ·	6(1640) MASS	Γ ₂	
/ALUE (\$4-30)			(45) PDANCHING SATIOS
/ALUE (MeV) 1638± 6 OUR AVÉRAGE Erro	DOCUMENT ID TECN COMMENT or includes scale factor of 1.2.		45) BRANCHING RATIOS
620±16 647± 7	BUGG 95 MRK3 $J/\psi \rightarrow \gamma \pi^+ \pi^- \pi^+ \pi^-$	$\Gamma(K\overline{K}\pi)/\Gamma(a_2(1320)\pi)$	Γ ₂ /Γ ₁ DOCUMENT ID TECN COMMENT
590±30	ADAMO 92 OBLX $\overline{n}p \rightarrow 3\pi^+ 2\pi^-$ BELADIDZE 928 VES $36 \pi^- p \rightarrow \omega \omega n$	0.07 ±0.03	¹ BARBERIS 97C OMEG 450 $pp \rightarrow ppK\overline{K}\pi$
635± 7	ALDE 90 GAM2 $38 \pi^- p \rightarrow \omega \omega n$	1 Using 2 $(\pi^{+}\pi^{-})$ data from E	BARBERIS 97B.
		7	2(1645) REFERENCES
	€ (1640) WIDTH	4	2(10-5) NEI ENENCES
ALUE (MeV) CL%	6(1640) WIDTH DOCUMENT ID TECN COMMENT	BARBERIS 97B PL 8413 217	D. Barberis+ (WA102 Collab.)
			
99-28 OUR AVERAGE En	DOCUMENT ID TECN COMMENT ror includes scale factor of 2.1. See the ideogram below.	BARBERIS 97B PL B413 217 BARBERIS 97C PL B413 225 ADOMEIT 96 ZPHY C71 227	D. Barberis+ (WA102 Collab.) D. Barberis+ (WA102 Collab.) +Amsler, Armstrong+ (Crystal Barrel Collab.)
	DOCUMENT ID TECN COMMENT ror includes scale factor of 2.1. See the ideogram below.	BARBERIS 97B PL B413 217 BARBERIS 97C PL B413 225	D. Barberis+ (WA102 Collab.) D. Barberis+ (WA102 Collab.) +Amsler, Armstrong+ (Crystal Barrel Collab.) $I^G(J^{PC}) = 0^+(?^{?-})$
99+28 OUR AVERAGE Ent 140+60 140+20 58±20 100±20	DOCUMENT ID TECN COMMENT TO Includes scale factor of 2.1. See the ideogram below. BUGG 95 MRK3 $J/\psi \rightarrow \gamma \pi^+ \pi^- \pi^+ \pi^-$ ADAMO 92 OBLX $\overline{n}p \rightarrow 3\pi^+ 2\pi^-$ BELADIDZE 928 VES $36 \pi^- p \rightarrow \omega \omega n$	BARBERIS 97B PL 8413 217 BARBERIS 97C PL 8413 225 ADOMEIT 96 ZPHY C71 227 X(1650)	D. Barberis+ (WA102 Collab.) D. Barberis+ (WA102 Collab.) $+$ Amsler, Armstrong+ (Crystal Barrel Collab.) $I^G(J^{PC}) = 0^+(?^{?-})$ J , P need confirmation.
99+28 OUR AVERAGE End 140+60 58±20 100±20 • • We do not use the following	DOCUMENT ID TECN COMMENT ror includes scale factor of 2.1. See the ideogram below. BUGG 95 MRK3 $J/\psi \rightarrow \gamma \pi^+ \pi^- \pi^+ \pi^-$ ADAMO 92 OBLX $\overline{n}_P \rightarrow 3\pi^+ 2\pi^-$	BARBERIS 97B PL 8413 217 BARBERIS 97C PL 8413 225 ADOMEIT 96 ZPHY C71 227 X(1650) OMITTED FROM SUMMA	D. Barberis+ (WA102 Collab.) D. Barberis+ (WA102 Collab.) +Amsler, Armstrong+ (Crystal Barrel Collab.) $I^G(J^{PC}) = 0^+(?^{?-})$ J. P need confirmation.
99 _ 24 OUR AVERAGE End 140 _ 20 58 ± 20 100 ± 20 • • We do not use the following	DOCUMENT ID TECN COMMENT TO Includes scale factor of 2.1. See the ideogram below. BUGG 95 MRK3 $J/\psi \rightarrow \gamma \pi^+ \pi^- \pi^+ \pi^-$ ADAMO 92 OBLX $\overline{n}p \rightarrow 3\pi^+ 2\pi^-$ BELADIDZE 928 VES $36 \pi^- p \rightarrow \omega \omega n$ and data for averages, fits, limits, etc. • • • ALDE 90 GAM2 $38 \pi^- p \rightarrow \omega \omega n$	BARBERIS 97B PL B413 217 BARBERIS 97C PL B413 225 ADOMEIT 96 ZPHY C71 227 X(1650) OMITTED FROM SUMM, Observed in a study of	D. Barberis+ (WA102 Collab.) D. Barberis+ (WA102 Collab.) $(Crystal Barrel Collab.)$ $I^G(J^{PC}) = 0^+(?^{?-})$ J. P need confirmation. ARY TABLE
99-28 OUR AVERAGE End 140-20 58±20 100±20 • We do not use the following 70 90 WEIGHTED AVERAGE	DOCUMENT ID TECN COMMENT TO Includes scale factor of 2.1. See the ideogram below. BUGG 95 MRK3 $J/\psi \rightarrow \gamma \pi^+ \pi^- \pi^+ \pi^-$ ADAMO 92 OBLX $\overline{n}p \rightarrow 3\pi^+ 2\pi^-$ BELADIDZE 928 VES $36 \pi^- p \rightarrow \omega \omega n$ and data for averages, fits, limits, etc. • • • ALDE 90 GAM2 $38 \pi^- p \rightarrow \omega \omega n$	BARBERIS 97B PL B413 217 BARBERIS 97C PL B413 225 ADOMEIT 96 ZPHY C71 227 X(1650) OMITTED FROM SUMM, Observed in a study of confirmation.	D. Barberis+ (WA102 Collab.) D. Barberis+ (WA102 Collab.) P. Barberis+ (WA102 Collab.) (Crystal Barrel Collab.) $I^G(J^{PC}) = 0^+(?^{?-})$ J. P need confirmation. ARY TABLE of the $\omega\eta$ effective mass distribution. Needs X(1650) MASS
99-28 OUR AVERAGE End 140-20 58 ± 20 100 ± 20 • • We do not use the following 70 90 WEIGHTED AVERAGE	DOCUMENT ID TECN COMMENT TO Includes scale factor of 2.1. See the ideogram below. BUGG 95 MRK3 $J/\psi \rightarrow \gamma \pi^+ \pi^- \pi^+ \pi^-$ ADAMO 92 OBLX $\overline{n}p \rightarrow 3\pi^+ 2\pi^-$ BELADIDZE 928 VES $36 \pi^- p \rightarrow \omega \omega n$ and data for averages, fits, limits, etc. • • • ALDE 90 GAM2 $38 \pi^- p \rightarrow \omega \omega n$	BARBERIS 97B PL B413 217 BARBERIS 97C PL B413 225 ADOMEIT 96 ZPHY C71 227 X(1650) OMITTED FROM SUMM, Observed in a study of	D. Barberis+ D. Barberis+ $+$ Amsler, Armstrong+ $I^G(J^{PC}) = 0^+(?^{?-})$ J. P need confirmation. ARY TABLE of the $\omega\eta$ effective mass distribution. Needs $X(1650) \text{ MASS}$ $\frac{DOCUMENT\ ID}{1\ PROKOSHKIN\ 96} = \frac{TECN}{GAM2} = \frac{CHG}{0} = \frac{COMMENT}{32,38\ \pi P \rightarrow \omega\eta\eta}$
99-28 OUR AVERAGE End 140-20 58±20 100±20 • We do not use the following 70 90 WEIGHTED AVERAGE	DOCUMENT ID TECN COMMENT TO Includes scale factor of 2.1. See the ideogram below. BUGG 95 MRK3 $J/\psi \rightarrow \gamma \pi^+ \pi^- \pi^+ \pi^-$ ADAMO 92 OBLX $\overline{n}p \rightarrow 3\pi^+ 2\pi^-$ BELADIDZE 928 VES $36 \pi^- p \rightarrow \omega \omega n$ and data for averages, fits, limits, etc. • • • ALDE 90 GAM2 $38 \pi^- p \rightarrow \omega \omega n$	BARBERIS 97B PL 8413 217 BARBERIS 97C PL 8413 225 ADOMEIT 96 ZPHY C71 227 X(1650) OMITTED FROM SUMM, Observed in a study of confirmation.	D. Barberis+ (WA102 Collab.) D. Barberis+ (WA102 Collab.) P. Barberis+ (WA102 Collab.) $I^G(J^{PC}) = 0^+(?^{?-})$ J. P need confirmation. ARY TABLE of the $\omega\eta$ effective mass distribution. Needs $X(1650) \text{ MASS}$ $\frac{DOCUMENT\ ID}{1\ PROKOSHKIN\ 96} \frac{TECN}{GAM2} \frac{CHG}{0} \frac{COMMENT}{32,38\ \pi P \rightarrow \omega\eta\eta}$
99-28 OUR AVERAGE End 140-20 58 ± 20 100 ± 20 • • We do not use the following 70 90 WEIGHTED AVERAGE	DOCUMENT ID TECN COMMENT TO Includes scale factor of 2.1. See the ideogram below. BUGG 95 MRK3 $J/\psi \rightarrow \gamma \pi^+ \pi^- \pi^+ \pi^-$ ADAMO 92 OBLX $\overline{n}p \rightarrow 3\pi^+ 2\pi^-$ BELADIDZE 928 VES $36 \pi^- p \rightarrow \omega \omega n$ and data for averages, fits, limits, etc. • • • ALDE 90 GAM2 $38 \pi^- p \rightarrow \omega \omega n$	BARBERIS 97B PL 8413 217 BARBERIS 97C PL 8413 225 ADOMEIT 96 ZPHY C71 227 X(1650) OMITTED FROM SUMM Observed in a study of confirmation. VALUE (MeV) EVTS 1652±7 100 1 Supersedes SAMOILENKO 9	D. Barberis+ D. Barberis+ $+$ Cary Collab. $I^G(J^{PC}) = 0^+(?^{?-})$ J. P need confirmation. ARY TABLE of the $\omega\eta$ effective mass distribution. Needs $X(1650)$ MASS $\frac{DOCUMENT\ ID}{1\ PROKOSHKIN\ 96} \frac{TECN}{GAM2} \frac{CHG}{0} \frac{COMMENT}{32,38\ \pi P \rightarrow \omega\eta n}$ 1. $X(1650)$ WIDTH
99-28 OUR AVERAGE End 140-60 58 ± 20 100 ± 20 • We do not use the followin 70 90 WEIGHTED AVERAGE	DOCUMENT ID TECN COMMENT TO Includes scale factor of 2.1. See the ideogram below. BUGG 95 MRK3 $J/\psi \rightarrow \gamma \pi^+ \pi^- \pi^+ \pi^-$ ADAMO 92 OBLX $\overline{n}p \rightarrow 3\pi^+ 2\pi^-$ BELADIDZE 928 VES $36 \pi^- p \rightarrow \omega \omega n$ and data for averages, fits, limits, etc. • • • ALDE 90 GAM2 $38 \pi^- p \rightarrow \omega \omega n$	BARBERIS 97B PL 8413 217 BARBERIS 97C PL 8413 225 ADOMEIT 96 ZPHY C71 227 X(1650) OMITTED FROM SUMM, Observed in a study of confirmation.	D. Barberis+ D. Barberis+ $+$ C. WA102 Collab.) $I^G(J^{PC}) = 0 + (?^2 -)$ J. P need confirmation. ARY TABLE of the $\omega \eta$ effective mass distribution. Needs $X(1650) \text{ MASS}$ $\frac{DOCUMENT\ ID}{1\ PROKOSHKIN\ 96} \frac{TECN}{GAM2} \frac{CHG}{0} \frac{COMMENT}{32,38\ \pi p \to \omega \eta n}$ 1. $X(1650) \text{ WIDTH}$ $\frac{DOCUMENT\ ID}{1000000000000000000000000000000000000$
99-28 OUR AVERAGE End 140-60 58 ± 20 100 ± 20 • We do not use the followin 70 90 WEIGHTED AVERAGE	DOCUMENT ID TECN COMMENT TO Includes scale factor of 2.1. See the ideogram below. BUGG 95 MRK3 $J/\psi \rightarrow \gamma \pi^+ \pi^- \pi^+ \pi^-$ ADAMO 92 OBLX $\overline{n}p \rightarrow 3\pi^+ 2\pi^-$ BELADIDZE 928 VES $36 \pi^- p \rightarrow \omega \omega n$ and data for averages, fits, limits, etc. • • • ALDE 90 GAM2 $38 \pi^- p \rightarrow \omega \omega n$	BARBERIS 97B PL B413 217 BARBERIS 97C PL B413 215 ADOMEIT 97C PL B413 225 ADOMEIT 97C PL B413 225 ADOMEIT 97C PL B413 225 ADOMEIT 97C PL B413 217 PL B	D. Barberis+ (WA102 Collab.) D. Barberis+ (WA102 Collab.) D. Barberis+ (WA102 Collab.) $I^G(J^{PC}) = 0^+(?^?-)$ $J, P \text{ need confirmation.}$ ARY TABLE of the $\omega\eta$ effective mass distribution. Needs $\frac{X(1650) \text{ MASS}}{1 \text{ PROKOSHKIN 96}} \frac{DOCUMENT ID}{GAM2} \frac{TECN}{0} \frac{CHG}{32,38 \pi P \rightarrow \omega \eta n}$ 1. $\frac{DOCUMENT ID}{2 \text{ PROKOSHKIN 96}} \frac{TECN}{GAM2} \frac{CHG}{0} \frac{COMMENT}{32,38 \pi P \rightarrow \omega \eta n}$
99-28 OUR AVERAGE End 140-60 58±20 100±20 • We do not use the followin 70 90 WEIGHTED AVERAGE	DOCUMENT ID TECN COMMENT TO Includes scale factor of 2.1. See the ideogram below. BUGG 95 MRK3 $J/\psi \rightarrow \gamma \pi^+ \pi^- \pi^+ \pi^-$ ADAMO 92 OBLX $\overline{n}p \rightarrow 3\pi^+ 2\pi^-$ BELADIDZE 928 VES $36 \pi^- p \rightarrow \omega \omega n$ and data for averages, fits, limits, etc. • • • ALDE 90 GAM2 $38 \pi^- p \rightarrow \omega \omega n$	BARBERIS 97B PL 8413 217 BARBERIS 97C PL 8413 225 ADOMEIT 97C PL 8413 225 ADOMEIT 96 ZPHY C71 227 X(1650) OMITTED FROM SUMMA Observed in a study of confirmation. VALUE (MeV) EVTS 1652±7 100 1 Supersedes SAMOILENKO 9 VALUE (MeV) CL% 90 2 Supersedes SAMOILENKO 9	D. Barberis+ D. Barberis+ D. Barberis+ $+$ Amsler, Armstrong+ $I^G(J^{PC}) = 0 + (?^2 -)$ J. P need confirmation. ARY TABLE of the $\omega \eta$ effective mass distribution. Needs $X(1650) \text{ MASS}$ $\frac{DOCUMENT\ ID}{1\ PROKOSHKIN\ 96} \frac{TECN}{GAM2} \frac{CHG}{0} \frac{COMMENT}{32,38\ \pi p \to \omega \eta n}$ 1. $X(1650) \text{ WIDTH}$ $\frac{DOCUMENT\ ID}{2\ PROKOSHKIN\ 96} \frac{TECN}{GAM2} \frac{CHG}{0} \frac{COMMENT}{32,38\ \pi p \to \omega \eta n}$ 1.
99-28 OUR AVERAGE End 140-60 58 ± 20 100 ± 20 • • We do not use the followin: 70 90 WEIGHTED AVERAGE	TECN COMMENT ID TECN COMMENT TO Includes scale factor of 2.1. See the ideogram below. BUGG 95 MRK3 $J/\psi \to \gamma \pi^+ \pi^- \pi^+ \pi^-$ ADAMO 92 OBLX $\overline{n}p \to 3\pi^+ 2\pi^-$ BELADIDZE 928 VES $36\pi^- p \to \omega \omega n$ and ata for averages, fits, limits, etc. • • • ALDE 90 GAM2 $38\pi^- p \to \omega \omega n$	BARBERIS 97B PL 8413 217 BARBERIS 97C PL 8413 225 ADOMEIT 97C PL 8413 225 ADOMEIT 96 ZPHY C71 227 X(1650) OMITTED FROM SUMMA Observed in a study of confirmation. VALUE (MeV) EVTS 1652±7 100 1 Supersedes SAMOILENKO 9 VALUE (MeV) CL% 90 2 Supersedes SAMOILENKO 9	D. Barberis+ (WA102 Collab.) D. Barberis+ (WA102 Collab.) D. Barberis+ (WA102 Collab.) $I^G(J^{PC}) = 0^+(?^?-)$ $J, P \text{ need confirmation.}$ ARY TABLE of the $\omega\eta$ effective mass distribution. Needs $X(1650) \text{ MASS}$ $\frac{DOCUMENT \ ID}{1 \ PROKOSHKIN 96} \frac{TECN}{GAM2} \frac{CHG}{0} \frac{COMMENT}{32,38 \ \pi P \rightarrow \omega \eta n}$ 1. $X(1650) \text{ WIDTH}$ $\frac{DOCUMENT \ ID}{2 \ PROKOSHKIN 96} \frac{TECN}{GAM2} \frac{CHG}{0} \frac{COMMENT}{32,38 \ \pi P \rightarrow \omega \eta n}$
99-28 OUR AVERAGE End 140-60 58±20 100±20 • We do not use the followin 70 90 WEIGHTED AVERAGE	TOT INCLUDES SCALE FACTOR OF 2.1. See the ideogram below. BUGG 95 MRK3 $J/\psi \rightarrow \gamma \pi^+ \pi^- \pi^+ \pi^-$ ADAMO 92 OBLX $\overline{n}p \rightarrow 3\pi^+ 2\pi^-$ BELADIDZE 928 VES $36\pi^- p \rightarrow \omega \omega n$ ng data for averages, fits, limits, etc. • • • ALDE 90 GAM2 $38\pi^- p \rightarrow \omega \omega n$ by 2.1) BUGG 95 MRK3 4.1 ADAMO 92 OBLX 4.3	BARBERIS 97B PL 8413 217 BARBERIS 97C PL 8413 225 ADOMEIT 97C PL 8413 225 ADOMEIT 96 ZPHY C71 227 X(1650) OMITTED FROM SUMMA Observed in a study of confirmation. VALUE (MeV) EVTS 1652±7 100 1 Supersedes SAMOILENKO 9 VALUE (MeV) CL% 90 2 Supersedes SAMOILENKO 9	D. Barberis+ D. Barberis+ D. Barberis+ $+$ Amsler, Armstrong+ $I^G(J^{PC}) = 0 + (?^2 -)$ J. P need confirmation. ARY TABLE of the $\omega \eta$ effective mass distribution. Needs $X(1650) \text{ MASS}$ $\frac{DOCUMENT\ ID}{1\ PROKOSHKIN\ 96} \frac{TECN}{GAM2} \frac{CHG}{0} \frac{COMMENT}{32,38\ \pi p \to \omega \eta n}$ 1. $X(1650) \text{ WIDTH}$ $\frac{DOCUMENT\ ID}{2\ PROKOSHKIN\ 96} \frac{TECN}{GAM2} \frac{CHG}{0} \frac{COMMENT}{32,38\ \pi p \to \omega \eta n}$ 1.
99-28 OUR AVERAGE End 140-60 58±20 100±20 • We do not use the followin 70 90 WEIGHTED AVERAGE	TECN COMMENT ID TECN COMMENT TO Includes scale factor of 2.1. See the ideogram below. BUGG 95 MRK3 $J/\psi \to \gamma \pi^+ \pi^- \pi^+ \pi^-$ ADAMO 92 OBLX $\overline{n}p \to 3\pi^+ 2\pi^-$ BELADIDZE 928 VES $36\pi^- p \to \omega \omega n$ and a for averages, fits, limits, etc. • • • ALDE 90 GAM2 $38\pi^- p \to \omega \omega n$ by 2.1)	BARBERIS 97B PL B413 217 BARBERIS 97C PL B413 225 ADOMEIT 97C PL B413 217 PL B	D. Barberis+ (WA102 Collab.) D. Barberis+ (WA102 Collab.) P. Barberis+ (WA102 Collab.) $I^G(J^{PC}) = 0^+(?^2-)$ $J, P \text{ need confirmation.}$ ARY TABLE of the $\omega\eta$ effective mass distribution. Needs $X(1650) \text{ MASS}$ $\frac{DOCUMENT ID}{1 \text{ PROKOSHKIN 96}} \frac{\text{TECN}}{\text{GAM2}} \frac{\text{CHG}}{0} \frac{COMMENT}{32,38 \pi p \rightarrow \omega \eta n}$ 1. $X(1650) \text{ WIDTH}$ $\frac{DOCUMENT ID}{2 \text{ PROKOSHKIN 96}} \frac{\text{TECN}}{\text{GAM2}} \frac{\text{CHG}}{0} \frac{COMMENT}{32,38 \pi p \rightarrow \omega \eta n}$ 1. $(1650) \text{ DECAY MODES}$
99-28 OUR AVERAGE End 140-60 58±20 100±20 • We do not use the followin 70 90 WEIGHTED AVERAGE	TOT INCLUDES SCALE FACTOR OF 2.1. See the ideogram below. BUGG 95 MRK3 $J/\psi \rightarrow \gamma \pi^+ \pi^- \pi^+ \pi^-$ ADAMO 92 OBLX $\overline{n}p \rightarrow 3\pi^+ 2\pi^-$ BELADIDZE 928 VES $36\pi^- p \rightarrow \omega \omega n$ ng data for averages, fits, limits, etc. • • • ALDE 90 GAM2 $38\pi^- p \rightarrow \omega \omega n$ by 2.1) BUGG 95 MRK3 4.1 ADAMO 92 OBLX 4.3	BARBERIS 97B PL B413 217 BARBERIS 97C PL B413 225 ADOMEIT 96 ZPHY C71 227 X(1650) OMITTED FROM SUMM, Observed in a study of confirmation. VALUE (MeV) EVTS 1652±7 100 1 Supersedes SAMOILENKO 9 VALUE (MeV) CL% <80 90 2 Supersedes SAMOILENKO 9 Mode Γ ₁ ωη	D. Barberis+ D. Barberis+ D. Barberis+ P. Barberis+ D. Barberis+ D. Barberis+ P. WA102 Collab. (Crystal Barrel Collab.) $I^G(J^{PC}) = 0 + (?^2 -)$ J. P need confirmation. ARY TABLE of the $\omega \eta$ effective mass distribution. Needs $X(1650) \text{ MASS}$ $\frac{DOCUMENT ID}{1 \text{ PROKOSHKIN 96}} \frac{TECN}{GAM2} \frac{CHG}{0} \frac{COMMENT}{32,38 \pi p \rightarrow \omega \eta n}$ 1. $X(1650) \text{ WIDTH}$ $\frac{DOCUMENT ID}{2 \text{ PROKOSHKIN 96}} \frac{TECN}{GAM2} \frac{CHG}{0} \frac{COMMENT}{32,38 \pi p \rightarrow \omega \eta n}$ 1. $(1650) \text{ DECAY MODES}$ Fraction (Γ_I/Γ)
99-28 OUR AVERAGE End 140-20 58 ± 20 100 ± 20 • We do not use the following 70 90 WEIGHTED AVERAGE	TECN COMMENT ID TECN COMMENT ror includes scale factor of 2.1. See the ideogram below. BUGG 95 MRK3 $J/\psi \to \gamma \pi^+ \pi^- \pi^+ \pi^-$ ADAMO 92 OBLX $\overline{n}p \to 3\pi^+ 2\pi^-$ BELADIDZE 928 VES $36\pi^- p \to \omega \omega n$ and after averages, fits, limits, etc. • • • ALDE 90 GAM2 $38\pi^- p \to \omega \omega n$ by 2.1)	BARBERIS 97B PL B413 217 BARBERIS 97C PL B413 225 ADOMEIT 97C PL B413 217 PL	D. Barberis+ D. Barberis+ P. Barberis+ P. Barberis+ P. Barberis+ P. Barberis+ P. WA102 Collab. (Crystal Barrel Collab.) $I^G(J^{PC}) = 0^+(?^2 -)$ J. P need confirmation. ARY TABLE of the $\omega\eta$ effective mass distribution. Needs $X(1650) \text{ MASS}$ $\frac{DOCUMENT\ ID}{1\ PROKOSHKIN\ 96\ GAM2\ 0} \frac{TECN}{32.38\ \pi P} \rightarrow \omega\eta n$ 1. $X(1650) \text{ WIDTH}$ $\frac{DOCUMENT\ ID}{2\ PROKOSHKIN\ 96\ GAM2\ 0} \frac{TECN}{32.38\ \pi P} \rightarrow \omega\eta n$ 1. $(1650) \text{ DECAY MODES}$ Fraction (Γ_I/Γ) seen
99-28 OUR AVERAGE End 140+60 -20 58±20 100±20 • We do not use the following 70 90 WEIGHTED AVERAGE 99+28-24 (Error scaled	TO DOCUMENT ID TECN COMMENT ror includes scale factor of 2.1. See the ideogram below. BUGG 95 MRK3 $J/\psi \to \gamma \pi^+ \pi^- \pi^+ \pi^-$ ADAMO 92 OBLX $\overline{n}p \to 3\pi^+ 2\pi^-$ BELADIDZE 928 VES $36\pi^- p \to \omega \omega n$ and data for averages, fits, limits, etc. • • • ALDE 90 GAM2 $38\pi^- p \to \omega \omega n$ by 2.1) BUGG 95 MRK3 4.1 ADAMO 92 OBLX 4.3 BELADIDZE 928 VES 0.0 8.4 (Confidence Level = 0.015)	BARBERIS 97B PL B413 217 BARBERIS 97C PL B413 225 ADOMEIT 97C PL B413 217 PL	D. Barberis+ D. Barberis+ D. Barberis+ P. Barberis+ D. Barberis+ P. WA102 Collab. (Crystal Barrel Collab.) $I^G(J^{PC}) = 0^+(?^?-)$ $J, P \text{ need confirmation.}$ ARY TABLE of the $\omega\eta$ effective mass distribution. Needs $X(1650) \text{ MASS}$ $\frac{DOCUMENT ID}{1 \text{ PROKOSHKIN 96}} \frac{\text{TECN}}{\text{GAM2}} \frac{\text{CHG}}{0} \frac{COMMENT}{32,38 \pi p \rightarrow \omega \eta n}$ 1. $X(1650) \text{ WIDTH}$ $\frac{DOCUMENT ID}{2 \text{ PROKOSHKIN 96}} \frac{\text{TECN}}{\text{GAM2}} \frac{\text{CHG}}{0} \frac{COMMENT}{32,38 \pi p \rightarrow \omega \eta n}$ 1. $(1650) \text{ DECAY MODES}$ Fraction (Γ_I/Γ) seen $(1650) \text{ REFERENCES}$ $(1650) \text{ REFERENCES}$ $(1650) \text{ REFERENCES}$ $(1650) \text{ SAS 348 490lienko} (SERP)$

 $\omega_3(1670)$

$$I^{G}(J^{PC}) = 0^{-}(3^{-})$$

ω_3 (1670) MASS

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
1667 ± 4 OUR	WERAGE			
1665.3± 5.2±4.5	23400	AMELIN	96 VES	$36 \pi^- p \rightarrow \pi^+ \pi^- \pi^0 n$
1685 ±20	60	BAUBILLIER	79 HBC	8.2 K p backward
1673 ±12	430	1,2 BALTAY	78E HBC	$15 \pi^+ \rho \rightarrow \Delta 3\pi$
1650 ±12		CORDEN	788 OMEG	$8-12 \pi^- p \rightarrow N3\pi$
1669 ±11	600	² WAGNER	75 HBC	$7\pi^+p \rightarrow \Delta^{++}3\pi$
1678 ±14	500	DIAZ	74 DBC	$6 \pi^+ n \rightarrow p 3 \pi^0$
1660 ±13	200	DIAZ	74 DBC	$6\pi^+ n \rightarrow p\omega\pi^0\pi^0$
1679 ±17	200	MATTHEWS	71D DBC	$7.0 \pi^+ n \rightarrow p3\pi^0$
1670 ±20		KENYON	69 DBC	$8\pi^+ n \rightarrow p3\pi^0$
• • • We do not use t	he followi	ng data for average	s, fits, limits,	etc. • • •
~ 1700	110	¹ CERRADA	77в НВС	$4.2 K^- p \rightarrow \Lambda 3\pi$
1695 ±20		BARNES	698 HBC	$4.6 K^- p \rightarrow \omega 2\pi X$
1636 ±20		ARMENISE	68B DBC	$5.1~\pi^+~n\rightarrow~p3\pi^0$
¹ Phase rotation see	for JP =	: 3 ρπ wave.		
2 From a fit to $I(J^P)$				

$\omega_3(1670)$ WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
168±10 OUR AV	ERAGE				
149±19±7	23400	AMELIN	96	VES	$36 \pi^- p \rightarrow \pi^+ \pi^- \pi^0 n$
160±80	60	3 BAUBILLIER	79	HBC	8.2 K p backward
173±16	430	4,5 BALTAY	78E	HBC	$15 \pi^+ \rho \rightarrow \Delta 3\pi$
253±39		CORDEN	78B	OMEG	$8-12 \pi^- p \rightarrow N3\pi$
173±28	600	^{3,5} WAGNER	75	нвс	$7\pi^+p \rightarrow \Delta^{++}3\pi$
167 ± 40	500	DIAZ	74	DBC	$6\pi^+ n \rightarrow p3\pi^0$
122±39	200	DIAZ	74	DBC	$6\pi^+ n \rightarrow \rho \omega \pi^0 \pi^0$
155 ± 40	200	3 MATTHEWS	71D	DBC	$7.0 \pi^+ n \rightarrow p3\pi^0$
• • • We do not	use the follow	ing data for average	s, fits	, limits,	etc. • • •
90±20		BARNES	69B	HBC	4.6 $K^-p \rightarrow \omega 2\pi$
100±40		KENYON	69	DBC	$8\pi^+ n \rightarrow p3\pi^0$
112±60		ARMENISE	68B	DBC	$5.1 \pi^+ \eta \rightarrow p3\pi^0$
3 Width errors e	niarged by us	to $4\Gamma/\sqrt{N}$: see the	note	ulth the	K*(803) mass

Phase rotation seen for $J^P = 3^- \rho \pi$ wave. From a fit to $I(J^P) = 0(3^-) \rho \pi$ partial wave.

	Mode	Fraction (Γ_f/Γ)
Γ1	$\rho\pi$	seen
Γ_2	$\omega \pi \pi$	seen
Γ3	$b_1(1235)\pi$	possibly seen

 ω_3 (1670) DECAY MODES

ω_3 (1670) BRANCHING RATIOS

$\Gamma(\omega\pi\pi)/\Gamma(\rho\pi)$						Γ_2/Γ_1
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT	
• • • We do not use	the followin	g data for average	s, fit	s, limits	, etc. • • •	
0.71 ± 0.27	100	DIAZ	74	DBC	$6 \pi^+ n \rightarrow$	$\rho 5\pi^0$
$\Gamma(b_1(1235)\pi)/\Gamma(\mu$	r)					Γ_3/Γ_1
VALUE		DOCUMENT ID		TECN	COMMENT	
possibly seen		DIAZ	74	DBC	$6 \pi^+ n \rightarrow$	ρ5π ⁰
$\Gamma(b_1(1235)\pi)/\Gamma(a$	υππ)					Γ_3/Γ_2
VALUE	CL%	DOCUMENT ID		TECN	COMMENT	
• • • We do not use	the followin	g data for average	s, flt	s, ilmits	, etc. • • •	
>0.75	68	BAUBILLIER	79	HBC	8.2 K - p l	backward

ω₃(1670) REFERENCES

			,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,		
AMELIN BAUBILLIER BALTAY CORDEN CERRADA WAGNER DIAZ MATTHEWS BARNES KENYON ARMENISE	96 79 78E 78B 77B 75 74 71D 69B 69 68B	ZPHY C70 71 PL 89B 131 PRL 40 87 NP B138 235 NP B126 241 PL 58B 201 PRL 32 260 PR D3 2561 PRL 23 142 PRL 23 146 PL 26B 336	+Berdnikov, Bityukov+	(SERP, TBIL) 1, CERN, GLAS, MSU, ORSAY) (BIRM, RHEL, TELA, LOWC) (AMST, CERN, NIJM, OXF) (AMST, CERN, NIJM, OXF) (TNTO, WISC) (BNL, UCND, ORNL) (BARI, BGNA, FIRZ, ORSAY)	

OTHER RELATED PAPERS

MATTHEWS 71 LNC 1 361 ARMENISE 70 LNC 4 199

+Prentice, Yoon, Carroll+ +Ghidini, Foring, Cartacci+

(TNTO, WISC) (BARI, BGNA, FIRZ)

$\pi_2(1670)$

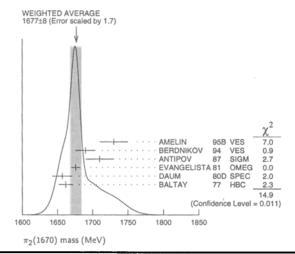
$$I^{G}(J^{PC}) = 1^{-}(2^{-+})$$

$\pi_2(1670)$ MASS

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
1670±20 OUR ES	TIMATE					or given is larger than published values.
1677± 8 OUR A	ERAGE	Error includes scale f	actor	of 1.7.	See th	e ideogram below.
1730±20		1 AMELIN	95B	VES		$36 \pi^{-} A \rightarrow \pi^{+} \pi^{-} \pi^{-} A$
1690±14		² BERDNIKOV	94	VES		$37 \pi^{-} A \rightarrow K^{+} K^{-} \pi^{-} A$
1710±20	700	ANTIPOV	87	SIGM	-	50 π ⁻ Cu → μ ⁺ μ ⁻ π ⁻ Cu
1676± 6		² EVANGELISTA	81	OMEG	_	$12 \pi^- p \rightarrow 3\pi p$
1657±14		2,3 DAUM	80D	SPEC	_	$63-94 \pi p \rightarrow 3\pi X$
1662±10	2000	² BALTAY	77	HBC	+	$15 \pi^+ p \rightarrow p 3\pi$
• • • We do not	use the folk	owing data for avera	ges,	fits, lim	its, etc	. • • •
1742±31±49		ANTREASYAN	90	CBAL		$e^{+}e^{-}_{e^{+}e^{-}\pi^{0}\pi^{0}\pi^{0}}$
1710 ± 20		⁴ DAUM	81B	SPEC	_	63,94 π ⁻ ρ
1660±10		² ASCOLI	73	HBC	_	$5-25 \pi^- p \rightarrow p\pi_2$
1 Erom 2 fft to	PC _ 2 -	+ 6 (1070) - 6 (10	70)_			· •

¹ From a fit to $J_{\alpha}^{PC} = 2^{-+} f_2(1270)\pi$, $f_0(1370)\pi$ waves.

single resonance fits.



π₂(1670) WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT
258 ± 18 OUR A	VERAGE Er	ror includes scale fa	ctor	of 1.7.	See the	ideogram below.
310±20		⁵ AMELIN	95B	VES		$\begin{array}{c} 36 \ \pi^- A \rightarrow \\ \pi^+ \pi^- \pi^- A \end{array}$
190±50		⁶ BERDNIKOV	94	VES		$37 \pi^{-} A \rightarrow K^{+} K^{-} \pi^{-} A$
170±80	700	ANTIPOV	87	SIGM	-	$ \begin{array}{c} 50 \ \pi^{-} \ Cu \rightarrow \\ \mu^{+} \ \mu^{-} \ \pi^{-} \ Cu \end{array} $
260±20		6 EVANGELISTA	81	OMEG	-	$12 \pi^- p \rightarrow 3\pi p$
219±20		6,7 DAUM	800	SPEC	_	63-94 πp → 3πX
285 ± 60	2000	6 BALTAY	77	HBC	+	$15 \pi^+ p \rightarrow p 3\pi$
• • • We do no	t use the follo	wing data for avera	ges,	fits, Ilmi	ts, etc	. • • •
236±49±36		ANTREASYAN	90	CBAL		$e^{+}e^{-}_{e^{+}e^{-}\pi^{0}\pi^{0}\pi^{0}}$
312±50		8 DAUM	81B	SPEC	_	63,94 π ⁻ p
270±60		⁶ ASCOLI	73	нвс	_	5-25 x p → pπ2
_	0.0					

⁵ From a fit to $J^{PC}=2^{-}+f_2(1270)\pi$, $f_0(1370)\pi$ waves. ⁶ From a fit to $J^P=2^{-}$ $f_2(1270)\pi$ partial wave.

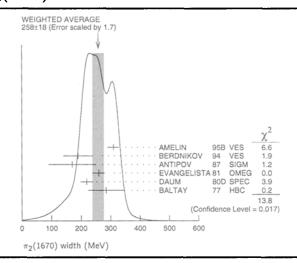
² From a fit to $J^P = 2^- S$ -wave $f_2(1270)\pi$ partial wave.

 $^{^3}$ Clear phase rotation seen in 2^-5 , 2^-P , 2^-D waves. We quote central value and spread of single-resonance fits to three channels. 4 From a two-resonance fit to four 2^-0^+ waves. This should not be averaged with all the

⁷ Clear phase rotation seen in 2^-S , 2^-D , 2^-D waves. We quote central value and spread of single-resonance fits to three channels.

⁸ From a two-resonance fit to four 2^{-0+} waves. This should not be averaged with all the single resonance fits.

$\pi_2(1670)$



$\pi_2(1670)$ DECAY MODES

	Mode	Fraction (Γ_I/Γ)	
$\overline{\Gamma_1}$	3π	(95.8±1.4) %	
Γ_2	$f_2(1270)\pi$	(56.2±3.2) %	
Γ_3	$ ho\pi$	(31 ±4)%	
Γ_4	$f_0(1370)\pi$	(8.7±3.4) %	
Γ_5	$K\vec{K}^*$ (892) $+$ c.c.	(4.2±1.4) %	
Γ6	$\gamma\gamma$	•	
Γ7	$\eta\pi$		
L ⁸	$\pi^{\pm} 2\pi^{+} 2\pi^{-}$		

CONSTRAINED FIT INFORMATION

An overall fit to 4 branching ratios uses 6 measurements and one constraint to determine 4 parameters. The overall fit has a $\chi^2 =$ 1.9 for 3 degrees of freedom.

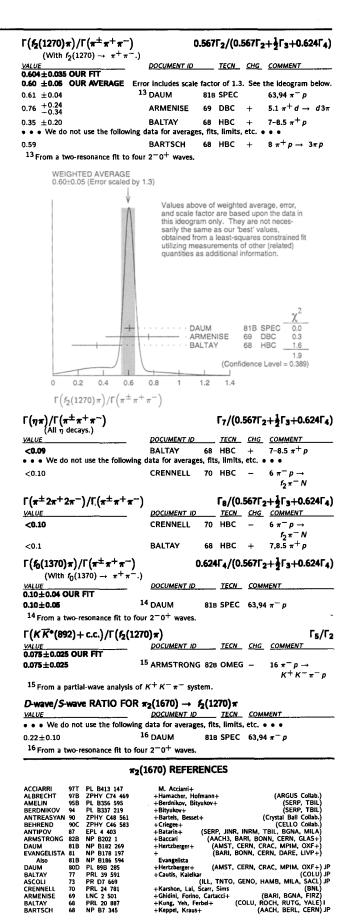
The following off-diagonal array elements are the correlation coefficients $\langle \delta x_i \delta x_j \rangle / (\delta x_i \cdot \delta x_j)$, in percent, from the fit to the branching fractions, $x_i \equiv$ $\Gamma_i/\Gamma_{\text{total}}$. The fit constrains the x_i whose labels appear in this array to sum to

π_2 (1670) PARTIAL WIDTHS

		,			
$\Gamma(\gamma\gamma)$					Γ ₆
VALUE (keV)	CL%	DOCUMENT ID	TECN	CHG	COMMENT
<0.072	90	⁹ ACCIARRI	97T L3		e+e_ →
<0.19	90	9 ALBRECHT	978 ARG		$e^{+}e^{-}e^{-}\pi^{+}\pi^{-}\pi^{0}$ $e^{+}e^{-}\pi^{+}\pi^{-}\pi^{0}$
• • • We do not use	the foli	owing data for aver-	ages, fits, lir	nits, el	tc. • • •
1.41 ±0.23±0.28		ANTREASYAN	90 CBAL	0	$e^+e^{\rho^+\rho^-\pi^0\pi^0\pi^0}$
0.8 ±0.3 ±0.12		10 BEHREND	90c CELL	0	e+e-→ ++0
1.3 $\pm 0.3 \pm 0.2$		11 BEHREND	90C CELL	0	$e^+e^- \rightarrow e^+e^- \pi^+\pi^-\pi^0$
⁹ Decaying into f ₂ (¹⁰ Constructive inte ¹¹ incoherent Ansat	rference		$ ho\pi$ and bac	kgrour	nd.

π₂(1670) BRANCHING RATIOS

$\Gamma(3\pi)/\Gamma_{\text{total}}$ VALUE 0.958 ± 0.014 OUR FIT	<u>DOCUMENT ID</u>	_	Г1/Г	$= (\Gamma_2 + \Gamma_3 + \Gamma_4)/\Gamma$
$\Gamma(\rho\pi)/\Gamma(\pi^{\pm}\pi^{+}\pi^{-})$	•] Γ3/(0.567Γ	$_{2}+\frac{1}{2}\Gamma_{3}+0.624\Gamma_{4})$
VALUE	DOCUMENT ID			COMMENT
0.29±0.04 OUR FIT				
0.29±0.05	12 DAUM	818 SPE	С	63,94 π ⁻ p
• • We do not use the following the following the following that the following the following that the following the followi	llowing data for average	s, fits, limi	ts, etc.	• • •
<0.3	BARTSCH	68 HBC	+	$8 \pi^+ p \rightarrow 3\pi p$
12 From a two-resonance fit	t to four 2 ⁻⁰⁺ waves.			



(AMST, CERN, CRAC, MPIM, OXF+) JP

++Hertzeerger+ (AMST, CENN, CRAC, MPIM, OXF+) JP
-(Cautis, Kaielkar (COLU) JP
-(Cautis, Kaielkar (COLU) JP
-(Cautis, Kaielkar (COLU) JP
-(Cautis, Kaielkar (COLU) JP
-(CAUTis) JP
-(CAUTIS)

HEN 83B PR	D28 2304		/ADIT ENAI	ELOD NOAM THETS+)
EEDOM 83 PR	D27 1426	+DeBonte, Gald	os, Key, Wong+	, FLOR, NDAM, TUFTS+) (PURD, TNTO)
DCACCI 66 PRL	B199 1 . 17 890	+ (CERN, I +Klenzie, Levrat	, Magilch, Marti	NA, HELS, PAVI, WARS+) n (CERN)
	22 714 21 579	+Toistrup+ +Guszavin, Kiige	(CERN M	issing Mass Spect. Collab.) (ITEP)
	19 68	+Gessaroli+	(BGNA, B	ARI, FIRZ, ORSAY, SACL)
ϕ (1680)		IG($J^{PC}) = 0$	-(1)
		φ(1680) MA	SS	
+e- PRODUCT	ION			
ALUE (MeV) 560±20 OUR ESTI	EVTS	DOCUMENT ID	<u>TECN</u>	COMMENT
SOL # 20 OUR ESTR				
700±20	V-14.00	¹ CLEGG	94 RVUE	$e^+e^- \rightarrow K^+K^-,$ $K^0_eK_\pi$
457.1.07	247	DISELLO	01.5 DM0	
657±27 680±10	367	BISELLO ² BUON	91c DM2 82 DM1	$e^+e^- \rightarrow K_5^0 K^{\pm} \pi^{\mp}$ $e^+e^- \rightarrow hadrons$
● ● We do not use	the following			
655±17		3 BISELLO	888 DM2	e+e- → K+K-
577±12		4 MANE	82 DM1	e+e− → K ⁰ _S Kπ
HOTOPRODUC	TION			_
ALUE (MeV)	Aba falland	DOCUMENT ID		
We do not use	the following	-	•	
726±22		BUSENITZ	89 TPS	$\gamma p \rightarrow K^+K^-X$
760±20 690±10 1 Using BISELLO 8 2 From global fit o K ⁰ ₂ K ⁰ ₁ K ⁰ ₂ K± 1 tlons, mass 1570	f $ρ$, $ω$, $φ$ and $π$ \mp . Assuming and width 5	ATKINSON ASTON NE 82 data. nd their radial exce e mass 1570 MeV 500 MeV for ω rad	85C OMEG 81F OMEG stations to ch and width 51 ial excitation.	20–70 $\gamma p \to K \overline{K} X$ 25–70 $\gamma p \to K^+ K^- X$ annels $\omega \pi^+ \pi^-$, $K^+ K^-$, 0 MeV for ρ radial excita-
760±20 690±10 1 Using BISELLO 8 2 From global fit o K ⁰ ₂ K ⁰ ₁ K ⁰ ₂ K± tions. mass 1570	of ρ , ω , ϕ and π^{\pm} . Assuming and width 5 including ρ , ϕ excitation.	ATKINSON ASTON NE 82 data. Ind their radial exce mass 1570 MeV for ω rad ω , ϕ and $\rho(1700)$	85C OMEG 81F OMEG itations to ch and width 51 ial excitation. assume mass	$20\text{-}70 \gamma \rho \rightarrow KRX$ $25\text{-}70 \gamma \rho \rightarrow K^+K^-X$ sannels $\omega \pi^+\pi^-$, K^+K^- 0 MeV for ρ radial excita-
760 ± 20 690 ± 10 ¹ Using BISELLO 8 ² From global fit o $K_S^0K_L^0$, $K_S^0K_T^0$, tions, mass 1570 ³ From global fit in MeV for ρ radial	of ρ , ω , ϕ and π^{\pm} . Assuming and width 5 including ρ , ϕ excitation.	ATKINSON ASTON NE 82 data. Ind their radial exce mass 1570 MeV for ω rad ω , ϕ and $\rho(1700)$	85c OMEG 81F OMEG itations to ch and width 51 ial excitation. assume mass with ω , $\rho(170$	$20\text{-}70 \gamma \rho \rightarrow KRX$ $25\text{-}70 \gamma \rho \rightarrow K^+K^-X$ sannels $\omega \pi^+\pi^-$, K^+K^- 0 MeV for ρ radial excita-
760±20 690±10 1 Using BISELLO 8 2 From global fit o \$\chi_0^2 \chi_0^0, \chi_0^0 \	of ρ , ω , ϕ as $\pi \pm$. Assume and width 5 occluding ρ , α excitation.	ATKINSON ASTON ASTON NE 82 data. nd their radial exce e mass 1570 MeV 600 MeV for ω rad ω , ϕ and ρ (1700) ecting interference	85c OMEG 81F OMEG itations to ch and width 51 ial excitation. assume mass with ω , $\rho(170$	$20\text{-}70 \gamma \rho \rightarrow KRX$ $25\text{-}70 \gamma \rho \rightarrow K^+K^-X$ sannels $\omega \pi^+\pi^-$, K^+K^- 0 MeV for ρ radial excita-
760±20 690±10 1 Using BISELLO 8 2 From global fit o KS KI, KS K±, tions, mass 1570 3 From global fit ir MeV for p radial 4 Fit to one channe	of ρ , ω , ϕ and π^{\pm} . Assuming and width 5 including ρ , ϵ excitation. Belonly, neglection $EVTS$	ATKINSON ASTON NE 82 data. nd their radial exce mass 1570 MeV 600 MeV for ω rad ω, φ and ρ(1700) ecting interference φ(1680) WID DOCUMENT 10	85c OMEG 81F OMEG ditations to ch and width 51 ial excitation. assume mass with ω , ρ (176 TH	$20\text{-}70 \gamma \rho \rightarrow KRX$ $25\text{-}70 \gamma \rho \rightarrow K^+K^-X$ sannels $\omega \pi^+\pi^-$, K^+K^- 0 MeV for ρ radial excita-
760±20 690±10 1 Using BISELLO 8 690±10 1 Using BISELLO 8 67 67 67 67 67 67 67 67 67 67 67 67 67	of ρ , ω , ϕ and π^{\pm} . Assuming and width 5 nocluding ρ , and excitation, all only, neglections $\frac{EVTS}{AATE}$. This	ATKINSON ASTON NE 82 data. Ind their radial exce mass 1570 MeV 600 MeV for ω rad ω, φ and ρ(1700) ecting interference φ(1680) WID DOCUMENT ID s is only an educat the error on t	85c OMEG 81F OMEG itations to ch and width 51 ial excitation. assume mass with ω , $\rho(170$ TH	$20-70 \gamma p \rightarrow KRX$ $25-70 \gamma p \rightarrow K^+K^-X$ sannels $\omega \pi^+\pi^-$, K^+K^- MeV for ρ radial excita- 1570 MeV and width 510 00). COMMENT error given is larger than the published values.
760±20 690±10 1 Using BISELLO 8 690±10 1 Using BISELLO 8 67 67 67 67 67 67 67 67 67 67 67 67 67	of ρ , ω , ϕ and π^{\pm} . Assuming and width 5 nocluding ρ , and excitation, all only, neglections $\frac{EVTS}{AATE}$. This	ATKINSON ASTON ASTON NE 82 data. nd their radial exce mass 1570 MeV 600 MeV for ω rad ω , ϕ and ρ (1700) excing interference ϕ (1680) WID By Is only an educat the error on the graduat for average data for average method.	85c OMEG 81F OMEG sitations to ch and width 51 lal excitation. assume mass with ω , $\rho(170)$ TH	$20-70 \gamma p \rightarrow KRX$ $25-70 \gamma p \rightarrow K^+K^-X$ sannels $\omega \pi^+\pi^-$, K^+K^- 0 MeV for ρ radial excita- 1570 MeV and width 510 00). COMMENT error given is larger than the published values.
760±20 690±10 1 Using BISELLO 8 690±10 1 Using BISELLO 8 67 67 67 67 67 67 67 67 67 67 67 67 67	of ρ , ω , ϕ and π^{\pm} . Assuming and width 5 nocluding ρ , and excitation, all only, neglections $\frac{EVTS}{AATE}$. This	ATKINSON ASTON NE 82 data. Ind their radial exce mass 1570 MeV 600 MeV for ω rad ω, φ and ρ(1700) ecting interference φ(1680) WID DOCUMENT ID s is only an educat the error on t	85c OMEG 81F OMEG itations to ch and width 51 ial excitation. assume mass with ω , $\rho(170$ TH	$\begin{array}{cccccccccccccccccccccccccccccccccccc$
760±20 690±10 1 Using BISELLO 8 2 From global fit o \(\cdot \cdo	of ρ, ω, φ air π∓. Assuming the Assuming t	ATKINSON ASTON NE 82 data. nd their radial exce mass 1570 MeV 600 MeV for ω rad ω , ϕ and ρ (1700) ecting interference ϕ (1680) WID DOCUMENT ID is is only an educat the error on the grade for average 5 CLEGG	85c OMEG 81F OMEG 81stations to ch and width 51 ial excitation. assume mass with ω , ρ (17t 9TH TECN ed guess; the he average of es, fits, limits 94 RVUE	$20-70 \gamma p \rightarrow K \overline{K} X$ $25-70 \gamma p \rightarrow K^+ K^- X$ Annels $\omega \pi^+ \pi^-$, $K^+ K^-$ $0. MeV for \rho radial excita- 1570 MeV and width 510 00). \frac{COMMENT}{error given is larger than the published values.} 00, etc. \bullet \bullet 00, etc. \bullet \bullet$
760±20 690±10 1 Using BISELLO 8 2 From global fit o	of ρ , ω , ϕ and π^{\pm} . Assuming and width 5 nocluding ρ , and excitation, all only, neglections $\frac{EVTS}{AATE}$. This	ATKINSON ASTON ASTON NE 82 data. nd their radial exce mass 1570 MeV 600 MeV for ω rad ω , ϕ and ρ (1700) excing interference ϕ (1680) WID By Is only an educat the error on the graduat for average data for average method.	85c OMEG 81F OMEG sitations to ch and width 51 lal excitation. assume mass with ω , $\rho(170)$ TH	$\begin{array}{cccccccccccccccccccccccccccccccccccc$
760±20 1 Using BISELLO 8 590±10 1 Using BISELLO 8 6 K ⁰ ₂ K ⁰ ₂ K ⁰ ₃ K ⁰ ₄ tions, mass 1570 3 From global fit or MeV for a ful in MeV for become channe 4 Fit to one channe 4 Fit to one channe • • PRODUCT ALUE (MeV) • • We do not use 00±60 46±55 07±45	of ρ, ω, φ air π∓. Assuming the Assuming t	ATKINSON ASTON NE 82 data. nd their radial exce mass 1570 MeV for ω rad ω, φ and ρ(1700) ecting interference φ(1680) WID DOCUMENT ID s is only an educat the error on t and data for average 5 CLEGG BISELLO	85c OMEG 81F OMEG itations to ch and width 51 ial excitation. assume mass with ω, ρ(176 TH TECN ed guess; the he average of es, fits, limits 94 RVUE 91c DM2	20-70 $\gamma p \rightarrow KRX$ 25-70 $\gamma p \rightarrow KRX$ annels $\omega \pi^+ \pi^-$, $K^+ K^-$ MeV for ρ radial excita- 1570 MeV and width 510 00). $\frac{COMMENT}{error given is larger than}$ the published values. etc. • • • • • • • • • • • • • • • • • • •
760±20 590±10 1 Using BISELLO 8 590±10 1 Using BISELLO 8 6 K ₀ K ₀ K ₂ K ₂ tions, mass 1570 3 From global fit to MeV for ρ radial 4 Fit to one channe + e PRODUCT 4LUE (MeV) 80±80 OUR ESTIN • • We do not use 00±60 46±55 07±45 85±22	of ρ, ω, φ air π∓. Assuming the Assuming t	ATKINSON ASTON NE 82 data. Ind their radial exce mass 1570 MeV 600 MeV for ω rad ω , ϕ and ρ (1700) ecting interference ϕ (1680) WID DOCUMENT ID To sis only an educat the error on tong data for average 5 CLEGG BISELLO 6 BISELLO	85c OMEG 81F OMEG 81F OMEG itations to ch and width 51 ial excitation. assume mass with ω, ρ(170 DTH TECN ed guess; the he average of es, fits, limits 94 RVUE 91c DM2 88B DM2	20-70 $\gamma p \rightarrow KRX$ 25-70 $\gamma p \rightarrow KRX$ 25-70 $\gamma p \rightarrow K^+K^-X$ sannels $\omega \pi^+\pi^-$, K^+K^- 0 MeV for ρ radial excita- 1570 MeV and width 510 00). $\frac{COMMENT}{error given is larger than}$ the published values. etc. • • • • $e^+e^- \rightarrow K^+K^ K^0_S K\pi$ $e^+e^- \rightarrow K^0_S K^\pm \pi^\mp$ $e^+e^- \rightarrow K^+K^-$
760±20 690±10 1 Using BISELLO 8 From global fit to K ⁰ ₂ K ⁰ ₂ , K ⁰ ₃ K [±] ₂ , tlons, mass 1570 3 From global fit in MeV for ρ radial 4 Fit to one channe + e PRODUCT ALUE (MAV) 80±80 OUR ESTIN • • We do not use 00±60 46±55 77±45 85±22 02±36 PHOTOPRODUC	if ρ, ω, φ air F. Assum and width 5 cluding ρ, α excitation. el only, negle TON EVTS AATE This the followin	ATKINSON ASTON NE 82 data. nd their radial exce e mass 1570 MeV 600 MeV for ω rad ω , ϕ and ρ (1700) exting interference ϕ (1680) WID s is only an education the error on the error on the error on the error on the data for average 5 CLEGG BISELLO 6 BISELLO 7 BUON 8 MANE	85c OMEG 81F OMEG 81F OMEG 81F OMEG 81F OMEG 91C PMC 91TH 91TH 91C PMC 91C PMC 88B DMC 82 DM1 82 DM1 82 DM1	$\begin{array}{c} 20\text{-}70\ \gamma\rho\rightarrow\ KRX\\ 25\text{-}70\ \gamma\rho\rightarrow\ K^+K^-X\\ \end{array}$ annels $\omega\pi^+\pi^-,\ K^+K^-$. O MeV for ρ radial excitations of the published values. $\begin{array}{c} COMMENT\\ error given is larger than the published values.\\ ,etc. \bullet \bullet \bullet\\ e^+e^-\rightarrow\ K^0+K^-,\ K^0_SK\pi\\ e^+e^-\rightarrow\ K^0+K^-+\\ e^+e^-\rightarrow\ K^0+K^-\\ e^+e^-\rightarrow\ K^0+K^-$
760±20 690±10 1 Using BISELLO 8 2 From global fit or	f ρ, ω, φ air = T. Assum: and width 5 cicluding ρ, ω excitation. el only, negle = TION	ATKINSON ASTON NE 82 data. nd their radial exce mass 1570 MeV 600 MeV for ω rad ω, φ and ρ(1700) ecting interference φ(1680) WID s is only an educat the error on the graduate for average 5 CLEGG BISELLO 6 BISELLO 7 BUON 8 MANE DOCUMENT ID	85c OMEG 81F OMEG 82F OMEG 84F OMEG 84F OMEG 85F OMEG 86F OMEG 87F OMEG 87	$20-70 \gamma p \rightarrow KRX$ $25-70 \gamma p \rightarrow K+K-X$ annels $\omega \pi^+\pi^-$, K^+K^- $0. MeV for \rho radial excita- 1570 MeV and width 510 00). \frac{COMMENT}{error given is larger than} the published values, etc. • • • e^+e^- \rightarrow K^+K^- K^0_S K\pi e^+e^- \rightarrow K^0_S K^\pm\pi^\mp e^+e^- \rightarrow K^+K^- e^+e^- \rightarrow K^0_S K\pi e^+e^- \rightarrow K^0_S K\pi e^+e^- \rightarrow K^0_S K\pi e^+e^- \rightarrow K^0_S K\pi$
760±20 690±10 1 Using BISELLO 8 2 From global fit o	f ρ, ω, φ air = T. Assum: and width 5 cicluding ρ, ω excitation. el only, negle = TION	ATKINSON ASTON NE 82 data. nd their radial exce mass 1570 MeV 600 MeV for ω rad ω, φ and ρ(1700) ecting interference φ(1680) WID DOCUMENT ID s is only an educat the error on the data for average 5 CLEGG BISELLO 7 BUON 8 MANE DOCUMENT ID ng data for average description.	85c OMEG 81F OMEG 82F OMEG 84F OMEG 86F OMEG 87F OMEG 87	$20-70 \gamma p \rightarrow K \overline{K} X$ $25-70 \gamma p \rightarrow K^+ K^- X$ annels $\omega \pi^+ \pi^-$, $K^+ K^-$, 0 MeV for ρ radial excita- 1570 MeV and width 510 00). $\frac{COMMENT}{error}$ error given is larger than the published values, etc. • • • • • • • • • • • • • • • • • • •
760±20 990±10 1 Using BISELLO 8 2 From global fit or	f ρ, ω, φ air = T. Assum: and width 5 cicluding ρ, ω excitation. el only, negle = TION	ATKINSON ASTON NE 82 data. nd their radial exce mass 1570 MeV 600 MeV for ω rad ω, φ and ρ(1700) ecting interference φ(1680) WID s is only an educat the error on the graduate for average 5 CLEGG BISELLO 6 BISELLO 7 BUON 8 MANE DOCUMENT ID	85c OMEG 81F OMEG 94 P(176) 97 P TECN 94 RVUE 91C DM2 88B DM2 82 DM1 82 DM1 82 DM1 82 DM1 82 DM1 83 DM1 84 RVUE 85 BM2 86 BM2 87 PS	$20-70 \gamma p \rightarrow KRX$ $25-70 \gamma p \rightarrow K+K-X$ annels $\omega \pi^+\pi^-$, K^+K^- $0. MeV for \rho radial excita- 1570 MeV and width 510 00). \frac{COMMENT}{error given is larger than} the published values, etc. • • • e^+e^- \rightarrow K^+K^- K^0_S K\pi e^+e^- \rightarrow K^0_S K^\pm\pi^\mp e^+e^- \rightarrow K^+K^- e^+e^- \rightarrow K^0_S K\pi e^+e^- \rightarrow K^0_S K\pi e^+e^- \rightarrow K^0_S K\pi e^+e^- \rightarrow K^0_S K\pi$
760±20 590±10 1 Using BISELLO 8 590±10 1 Using BISELLO 8 67 K ⁰ K ⁰ K ⁰ K ¹ to see the seed of t	f ρ, ω, φ air = T. Assum: and width 5 cicluding ρ, ω excitation. el only, negle = TION	ATKINSON ASTON NE 82 data. nd their radial exce mass 1570 MeV 600 MeV for ω rad ω, φ and ρ(1700) ecting interference φ(1680) WID s is only an educat the error on t and data for averag 5 CLEGG BISELLO 6 BISELLO 7 BUON 8 MANE DOCUMENT ID 10 DOCUMENT ID 10 DOCUMENT ID 11 DOCUMENT ID 12 DOCUMENT ID 13 DOCUMENT ID 14 DOCUMENT ID 15 DOCUMENT ID 16 DOCUMENT ID 17 DOCUMENT ID 18 DOCU	85c OMEG 81F OMEG 101 Excitation, assume mass with ω, ρ(170 TH TECN ed guess; the he average of es, fits, limits 94 RVUE 91c DM2 88B DM2 62 DM1 82 DM1 82 DM1 82 DM1 82 DM1 83 DM1 84 FPS 85c OMEG 85C OMEG	20-70 $\gamma p \rightarrow KRX$ 25-70 $\gamma p \rightarrow KRX$ 25-70 $\gamma p \rightarrow K^+K^-X$ sannels $\omega \pi^+\pi^-$, K^+K^- 0 MeV for ρ radial excita- 1570 MeV and width 510 00). $\frac{COMMENT}{error given is larger than}$ the published values. etc. • • • $e^+e^- \rightarrow K^+K^-$ $e^+e^- \rightarrow K^0S^+\pi^-$ $e^+e^- \rightarrow K^0S^+K^-$ $e^+e^- \rightarrow K^0S^-K^-$
760±20 690±10 1 Using BISELLO 8 2 From global fit to K ⁰ ₂ K ⁰ ₁ , K ⁰ ₃ K [±] + tlons, mass 1570 3 From global fit in MeV for ρ radial 4 Fit to one channe 4 Fit to one channe 4 Fit to one channe 6 We do not use 00±60 46±55 67±45 68±22 60±40 60±40 60±40 60±40 60±40 60±40 60±40 60±40 60±40	T ρ, ω, φ air F. Assum and width 5 cluding ρ, α excitation. el only, negle TION EVTS MATE This the followin 367	ATKINSON ASTON NE 82 data. nd their radial exce e mass 1570 MeV 600 MeV for ω rad ω , ϕ and ρ (1700) exting interference ϕ (1680) WID s is only an education the error on ting data for average 5 CLEGG BISELLO 6 BISELLO 7 BUON 8 MANE $\frac{DOCUMENT ID}{1000}$ ng data for average BUSENITZ ATKINSON ASTON NE 82 data.	85c OMEG 81F OMEG 101 Excitation, assume mass with ω, ρ(170 TH TECN ed guess; the he average of es, fits, limits 94 RVUE 91c DM2 88B DM2 62 DM1 82 DM1 82 DM1 82 DM1 82 DM1 83 DM1 84 FPS 85c OMEG 85C OMEG	20-70 $\gamma p \rightarrow K \overline{K} X$ 25-70 $\gamma p \rightarrow K \overline{K} X$ 25-70 $\gamma p \rightarrow K^+ K^- X$ sannels $\omega \pi^+ \pi^-$, $K^+ K^-$ 0 MeV for ρ radial excita- 1570 MeV and width 510 300). $\frac{COMMENT}{COMMENT}$ error given is larger than the published values. etc. • • • • • • • • • • • • • • • • • • •
760±20 690±10 1 Using BISELLO 8 2 From global fit to K. 6, K. 6, K. 5, K. 1. 1 Using BISELLO 8 7 From global fit to K. 6, K. 6, K. 6, K. 5, K. 1. 1 However the control of the control o	T ρ, ω, φ air F. Assum and width 5 cluding ρ, α excitation. el only, negle TION EVTS MATE This the followin 367	ATKINSON ASTON NE 82 data. nd their radial exce mass 1570 MeV 600 MeV for ω rad ω, φ and ρ(1700) ecting interference φ(1680) WID s is only an educat the error on the graduate of the service of BISELLO 6 BISELLO 7 BUDON 8 MANE DOCUMENT ID ng data for average BUSENITZ ATKINSON ASTON ASTON NE 82 data. υ, φ and ρ(1700)	85c OMEG 81F OMEG	20-70 $\gamma p \rightarrow K \overline{K} X$ 25-70 $\gamma p \rightarrow K \overline{K} X$ 25-70 $\gamma p \rightarrow K^+ K^- X$ annels $\omega \pi^+ \pi^-$, $K^+ K^-$.0 MeV for ρ radial excitation. 1570 MeV and width 510 00). $\frac{COMMENT}{error}$ error given is larger than the published values, etc. • • • • $e^+ e^- \rightarrow K^0 K^+ K^ K^0 K \pi$ $e^+ e^- \rightarrow K^0 K^\pm \pi^\mp$ $e^+ e^- \rightarrow K^0 K \pi$ $e^+ e^- \rightarrow K^0 K \pi$ $\frac{COMMENT}{e^+ e^- \rightarrow K^0 K \pi}$.etc. • • • • $\gamma p \rightarrow K^+ K^- X$ 320-70 $\gamma p \rightarrow K^+ K^- X$
760±20 690±10 1 Using BISELLO 8 690±10 1 Using BISELLO 8 670, K ⁰ , K ⁰ , K [±] , tions, mass 1570 3 From global fit to K ⁰ , K ⁰ , K ⁰ , K [±] , tions, mass 1570 3 From global fit in MeV for p radial 4 Fit to one channe 4 Fit to one channe 4 Fit to one channe 5 We do not use 60 46±55 607±45 65±22 602±36 60 6040 605 6040 605 605 605 605 605 605 605 605 605 60	If ρ, ω, φ air F. Assum and width 5 cicluding ρ, excitation. el only, negle and MATE. This is the following a f ρ, ω, φ at a cicluding ρ, ω of cicluding	ATKINSON ASTON NE 82 data. Ind their radial exce mass 1570 MeV 1000 MeV for ω radial ω, φ and ρ(1700) ecting interference POCCUMENT ID S is only an educat the error on ting data for average 5 CLEGG BISELLO BISELL	85c OMEG 81F OMEG 94 RVUE 94 RVUE 94 RVUE 95 DM1 82 DM1 82 DM1 82 DM1 82 DM1 83 DM2 84 DM2 85 DM1 86 DM2 86 DM2 86 DM1 86 DM1	20-70 $\gamma p \rightarrow K \overline{K} X$ 25-70 $\gamma p \rightarrow K \overline{K} X$ 25-70 $\gamma p \rightarrow K^+ K^- X$ sannels $\omega \pi^+ \pi^-$, $K^+ K^-$ 0 MeV for ρ radial excita- 1570 MeV and width 510 300). $\frac{COMMENT}{COMMENT}$ error given is larger than the published values. etc. • • • • • • • • • • • • • • • • • • •

	Mode	Fraction (Γ_I/Γ)
Γ ₁	Κ K *(892)+ c.c.	dominant
Γ_2	K ⁰ _S K ¹ π	seen
Гз	ĸΚ	seen
Γ4	e+ e-	seen
Γ ₅	$\omega \pi \pi$	not seen
Γ ₆	$K^+K^-\pi^0$	

$\phi(1680) \Gamma(l)\Gamma(e^+e^-)/\Gamma(total)$

This combination of a partial width with the partial width into $e^+\,e^$ and with the total width is obtained from the integrated cross section into channel (i) in e^+e^- annihilation. We list only data that have not been

Γ (ΚΚ*(8 VALUE (WV)		· c.c.) × Γ(e +	e⁻)/Γ _{total} DÖCUMENT II	2	<u>TECN</u>	COMMENT	Γ ₁ Γ ₄ /Γ
	do not	use the following		_			
0.48±0.14		367	BISELLO	910	DM2	e⊤e →	KSK± #∓
		φ(168	0) BRANCHI	NG RA	ATIOS		
Γ(<i>Κ'</i> ₹*(8	192) +	c.c.)/F(Kg K	π)				Γ_1/Γ_2
VALUE			DOCUMENT I	2	TECN		
dominant			MANE	82	DM1	e+ e- →	κ ₅ κ± π [∓]
Γ(<i>κ</i> ͳ)/Ι	(KT	⁷ (892) + c.c.)					Γ3/Γ1
VALUE	`		DOCUMENT I	0	TECN	COMMENT	-, -
0.07 ±0.0	1		BUON	82	DM1	e+ c-	
Γ(ωππ)/	T(K)	K*(892) + c.c.)	1				Γ_B/Γ_2
VALUE			DOCUMENT I	<u> </u>	TECN	COMMENT	-, -
<0.10			BUON	82	DM1	e ⁺ e ⁻	
	,	ø (1680) REFE	RENCE	ES .		
CLEGG BISELLO BUSENITZ BISELLO ATKINSON BUON MANE ASTON	85C 82 82	ZPHY C62 455 ZPHY C52 227 PR D40 1 ZPHY C39 13 ZPHY C27 233 PL 118B 221 PL 112B 178 PL 104B 231	+Bisello, Bizo +Bisello, Bizo	allahan+ ONN, CE t, Cordier t. Buon.	(F RN, GLA , Delcourt, Delcourt,	a+ PADO, CLER, S, LANC, MC rt+ (L Favard+	LANC, MCHS) (DM2 Collab.) (ILL, FNAL) FRAS, LALO) HS, CURIN+) LALO, MONP (LALO) LNC, MCHS+)
		отн	IER RELATE	D PAF	ERS ·		
ACHASOV ATKINSON ATKINSON ATKINSON ATKINSON CORDIER MANE ASTON	97F 86C 84 84B 83C 81 81 80F	PAN 60 2029 Translated from YA ZPHY CSD 541 NP B231 15 NP B231 1 NP B229 269 PL 106B 155 PL 99B 261 NP B174 269	+ (BC + (BC + (BC + Bisello, Bizo + Bisello, Bizo	ONN, CE ONN, CE ONN, CE ONN, CE t, Buon, t, Buon,	RN, GLA RN, GLA RN, GLA RN, GLA Delcourt, Cordier.	S, LANC, MC S, LANC, MC S, LANC, MC Mane Delcourt	(NOVM) HS, CURIN+) HS, CURIN+) HS, CURIN+) (ORSAY) (ORSAY) NC, MCHS+)
$\rho_3(1$	690)	IG	(J ^{PC}) = 1	1+(3)

$ho_{3}(1690) \text{ MASS}$

VALUE (MeV)

1691 ±5 OUR ESTIMATE

This is only an educated guess; the error given is larger than the error on the average of the published values. 1660.8 ± 2.1 OUR AVERAGE Includes data from the 5 datablocks that follow this one.

2π MODE VALUE (MeV)	EVT5	DOCUMENT ID		TECN	CHG	COMMENT
The data in this bid	ock is included	In the average prin	ted 1	or a pre	vious	datablock.
1686± 4 OUR AV	ERAGE					
1677±14		EVANGELISTA	81	OMEG	_	12 π ⁻ p → 2π p
1679±11	476	BALTAY	78B	нвс	0	15 π ⁺ ρ →
1678±12	175	1 ANTIPOV	77	CIBS	0	$\pi^+\pi^-n$ 25 $\pi^-p \rightarrow p3\pi$
1690± 7	600	¹ ENGLER	74	DBC	0	$\begin{array}{c} 6 \pi^+ n \rightarrow \\ \pi^+ \pi^- p \end{array}$
1693± 8		² GRAYER	74	ASPK	0	17 $\pi^- p \rightarrow$
1678±12		MATTHEWS	71c	DBC	0	π ⁺ π ⁻ η 7 π ⁺ Ν
• • • We do not u	se the followi	ng data for averages	, fits	, limits,	etc. (• • •
1734±10		3 CORDEN	79	OMEG		12-15 $\pi^- p \rightarrow$
1692±12		^{2,4} ESTABROOKS	75	RVUE		$17 \begin{array}{c} n2\pi \\ \pi^- p \rightarrow \\ \bot \end{array}$
1737±23		ARMENISE	70	DBC	0	π ⁺ π ⁻ η 9π ⁺ Ν
1650±35	122	BARTSCH	70B	HBC	+	$8\pi^+p \rightarrow N2\pi$
1687 ± 21		STUNTEBECK	70	HDBC	0	$8 \pi^- p$, 5.4 $\pi^+ d$
1683 ± 13		ARMENISE	68	DBC	0	$5.1 \pi^{+} d$
1670±30		GOLDBERG	65	HBC	0	$6 \pi^+ d$, $8 \pi^- p$

 $^{^{1}}$ Mass errors enlarged by us to $\Gamma/\sqrt{N};$ see the note with the $K^{*}(892)$ mass.

² Uses same data as HYAMS 75. ³ From a phase shift solution containing a $f_2'(1525)$ width two times larger than the $K\overline{K}$

result.

From phase-shift analysis. Error takes account of spread of different phase-shift solutions.

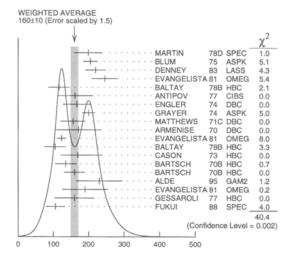
 $\rho_3(1690)$

1696± 4 OUR AVERAG	Ε	•		·		
699± 5		ALPER	80	CNTR	0	$\begin{array}{c} 62 \pi^- p \rightarrow \\ K^+ K^- n \end{array}$
698±12	6k	5,6 MARTIN	78D	SPEC		$ \begin{array}{c} 10 \pi p \rightarrow \\ K_S^0 K^- p \end{array} $
692± 6		BLUM		ASPK		$18.4 \pi^- p \rightarrow nK^+K^-$
690±16 • • We do not use the	followi	ADERHOLZ ing data for averag	69 es, fit:		+ etc.	$8 \pi^+ p \to K \overline{K} \pi$
694 ± 8 ⁵ From a fit to $J^P = 3$	t parti	⁷ COSTA	80	OMEG		$ \begin{array}{c} 10 \ \pi^- p \rightarrow \\ K^+ K^- n \end{array} $
⁶ Systematic error on n ⁷ They cannot distingu	nass sca	ale subtracted.	ω3(1	670).		
4π)± MODE		DOSMISHT ID				construct
ALUE (MeV) The data in this block is	EVTS include	DOCUMENT ID d in the average pr				
686± 5 OUR AVERAG	E Erro					
694± 6		8 EVANGELIST				$12 \pi^- p \rightarrow p4\pi$
665±15 670±10	177	BALTAY THOMPSON		HBC HBC	++	$15 \pi^+ p \rightarrow p4\pi$ $13 \pi^+ p$
.687±20		CASON		HBC	_	13 π · ρ 8,18.5 π ⁻ ρ
685±14		9 CASON		HBC	_	8,18.5 π ⁻ p
680±40	144	BARTSCH		HBC	+	$8\pi^+p \rightarrow N4\pi$
.689 ± 20	102	⁹ BARTSCH	70B	нвс	+	$8\pi^+p \rightarrow N2\rho$
705±21		CASO	70	HBC	-	11.2 $\pi^- p \rightarrow$
• We do not use the	follow	•				
718±10		10 EVANGELIST	TA 81	OMEG	_	$12 \pi^- p \rightarrow p4\pi$
673± 9		11 EVANGELIST	A 81	OMEG	-	$12 \pi^- \rho \rightarrow \rho 4\pi$
733± 9	66	9 KLIGER	74	HBC	_	$4.5~\pi^-~p\rightarrow~p4\pi$
1630 ± 15 1720 ± 15 8 From $ ho^{-} ho^{0}$ mode, n	ot inde	HOLMES BALTAY pendent of the oth	68	HBC HBC EVANG	+ ELIS	10–12 $K^+ p$ 7, 8.5 $\pi^+ p$ TA 81 entries.
630 ± 15 720 ± 15 8 From $\rho^- \rho^0$ mode, n 9 From $\rho^\pm \rho^0$ mode. 10 From a ₂ (1320) $^-\pi^0$ 11 From a ₂ (1320) $^0\pi^-$ was MODE MALUE (MeV)	mode, r mode, r	BALTAY pendent of the other not independent of not independent of DOCUMENT ID	68 er two the ot the ot	HBC EVANG her two her two	+ ELIS EVAN EVAN	7, 8.5 # p TA 81 entries. NGELISTA 81 entrie NGELISTA 81 entrie
630 ± 15 720 ± 15 ⁸ From $\rho^-\rho^0$ mode, n ⁹ From $\rho^\pm\rho^0$ mode. 10 From $a_2(1320)^-\pi^0$ 11 From $a_2(1320)^0\pi^-$ 27 MODE ALUE (MeV) The data in this block is	mode, r mode, r include	BALTAY pendent of the other not independent of not independent of DOCUMENT ID	68 er two the ot the ot	HBC EVANG her two her two	+ ELIS EVAN EVAN	7, 8.5 # p TA 81 entries. NGELISTA 81 entrie NGELISTA 81 entrie
1630 ± 15 1720 ± 15 8 From $\rho^- \rho^0$ mode, n 9 From $\rho^\pm \rho^0$ mode, 10 From $a_2(1320)^- \pi^0$ 11 From $a_2(1320)^0 \pi^ \mu\pi$ MODE **MUDE** **MUDE	mode, r mode, r include	BALTAY pendent of the other not independent of not independent of DOCUMENT ID	68 er two the ot the ot inted	HBC EVANG her two her two	+ ELIS EVAN EVAN	7, 8.5 $\pi^+ p$ TA 81 entries. RGELISTA 81 entries RGELISTA 81 entries COMMENT datablock. 38 $\pi^- p \rightarrow$
$^{1630\pm15}$ 8 From $\rho^{-}\rho^{0}$ mode, n 9 From $\rho^{\pm}\rho^{0}$ mode. 10 From 2 (1320) $^{-}\pi^{0}$ 11 From 2 (1320) $^{0}\pi^{-}$ 2	mode, r mode, r include	BALTAY pendent of the other not independent of not independent of <u>DOCUMENT ID</u> d in the average pi	68 er two the ot the ot inted	HBC EVANG her two her two TECN for a pre	+ EVAN EVAN <u>CHG</u>	7, 8.5 $\pi^+ p$ TA 81 entries. RGELISTA 81 entries RGELISTA 81 entries COMMENT datablock. 38 $\pi^- p \rightarrow \omega \pi^0 n$
630 ± 15 720 ± 15 8 From $\rho^- \rho^0$ mode, in 9 From $\rho^\pm \rho^0$ mode. $10 \text{ From a}_2(1320)^- \pi^0$ $11 \text{ From a}_2(1320)^0 \pi^-$ war MODE **ALUE (MeV) The data in this block is 1681 ± 7 OUR AVERAG 1670 ± 25 1690 ± 15	mode, r mode, r include	BALTAY pendent of the other not independent of not independent of DOCUMENT ID d in the average pi 12 ALDE EVANGELIST	68 er two the ot the ot rinted 95	HBC EVANG her two her two for a pre GAM2 OMEG	+ EVAN EVAN <u>CHG</u>	7, 8.5 $\pi^+ p$ TA 81 entries. RGELISTA 81 entries RGELISTA 81 entries COMMENT datablock. 38 $\pi^- p \rightarrow \omega \pi^0 n$ 12 $\pi^- p \rightarrow \omega \pi p$
630 ± 15 720 ± 15 8 From $\rho^- \rho^0$ mode, n 9 From $\rho^\pm \rho^0$ mode. n 10 From $a_2(1320)^- \pi^0$ 11 From $a_2(1320)^0 \pi^-$ 12 From $a_2(1320)^0 \pi^-$ 13 MODE ALUE (MeV) The data in this block is 681 ± 7 OUR AVERAG 670 ± 25 690 ± 15 666 ± 14	mode, r mode, r include	BALTAY pendent of the other not independent of not independent of <u>DOCUMENT ID</u> d in the average pi	68 er two the ot the ot inted 95 (A 81 77	HBC EVANG her two her two TECN for a pre	+ EVAN EVAN <u>CHG</u>	7, 8.5 $\pi^+ p$ TA 81 entries. RGELISTA 81 entries RGELISTA 81 entries COMMENT datablock. 38 $\pi^- p \rightarrow \omega \pi^0 n$ 12 $\pi^- p \rightarrow \omega \pi p$
630 \pm 15 720 \pm 15 8 From $\rho^- \rho^0$ mode, n 9 From $\rho^\pm \rho^0$ mode. 10 From $a_2(1320)^- \pi^0$ 11 From $a_2(1320)^0 \pi^-$ 12 M MODE MLUE (MeV) The data in this block is 661 \pm 7 OUR AVERAG 670 \pm 25 669 \pm 15 666 \pm 14 686 \pm 9	mode, r mode, r include	BALTAY pendent of the other not independent of not independent of DOCUMENT ID d in the average pi 12 ALDE EVANGELIST GESSAROLI THOMPSON	68 er two the ot the ot inted 95 77 74	HBC EVANG her two her two TECN for a pre GAM2 OMEG HBC HBC	+ SELIS EVAN EVAN <u>CHG</u> evious	7, 8.5 $\pi^+ p$ TA 81 entries. RGELISTA 81 entrie RGELISTA 81 entrie COMMENT datablock. 38 $\pi^- p \rightarrow \omega \pi p$ $12 \pi^- p \rightarrow \omega \pi p$ $13 \pi^+ p$
630 \pm 15 720 \pm 15 8 From $\rho^- \rho^0$ mode, n 9 From $\rho^\pm \rho^0$ mode. 10 From $a_2(1320)^- \pi^0$ 11 From $a_2(1320)^0 \pi^-$ 12 M MODE Material Mey The data in this block is 661 \pm 7 OUR AVERAG 670 \pm 25 669 \pm 15 666 \pm 14 686 \pm 9 • • We do not use the	mode, r mode, r include	BALTAY pendent of the other not independent of not independent of DOCUMENT ID d in the average pi 12 ALDE EVANGELIST GESSAROLI THOMPSON	68 er two the ot the ot rinted 95 TA 81 77 74 ges, fit	HBC EVANG her two her two TECN for a pre GAM2 OMEG HBC HBC	+ SELIS EVAN EVAN <u>CHG</u> evious	7, 8.5 $\pi^+ p$ TA 81 entries. RGELISTA 81 entrie RGELISTA 81 entrie COMMENT datablock. 38 $\pi^- p \rightarrow \omega \pi p$ $12 \pi^- p \rightarrow \omega \pi p$ $13 \pi^+ p$ • • •
630 ± 15 720 ± 15 8 From $\rho^- \rho^0$ mode, n 9 From $\rho^\pm \rho^0$ mode. 10 From $\rho^\pm \rho^0$ mode. 11 From $\rho^\pm \rho^0$ mode. 12 From $\rho^\pm \rho^0$ mode. 13 From $\rho^\pm \rho^0$ mode. 14 From $\rho^\pm \rho^0$ mode. 15 From $\rho^\pm \rho^0$ mode. 16 From $\rho^\pm \rho^0$ mode. 17 From $\rho^\pm \rho^0$ mode. 18 From $\rho^\pm \rho^0$ mode. 19 From $\rho^\pm \rho^0$ mode. 19 From $\rho^\pm \rho^0$ mode. 19 From $\rho^\pm \rho^0$ mode. 10 From $\rho^\pm \rho^0$ mode. 10 From $\rho^\pm \rho^0$ mode. 11 From $\rho^\pm \rho^0$ mode. 12 From $\rho^\pm \rho^0$ mode. 13 From $\rho^\pm \rho^0$ mode. 14 From $\rho^\pm \rho^0$ mode. 16 From $\rho^\pm \rho^0$ mode. 17 From $\rho^\pm \rho^0$ mode. 18 From $\rho^\pm \rho^0$ mode. 19 From $\rho^\pm \rho^0$ mode. 19 From $\rho^\pm \rho^0$ mode. 10 From $\rho^\pm \rho^0$ mode. 10 From $\rho^\pm \rho^0$ mode. 11 From $\rho^\pm \rho^0$ mode. 12 From $\rho^\pm \rho^0$ mode. 13 From $\rho^\pm \rho^0$ mode. 14 From $\rho^\pm \rho^0$ mode. 16 From $\rho^\pm \rho^0$ mode. 17 From $\rho^\pm \rho^0$ mode. 18 From $\rho^\pm \rho^0$ mode. 19 From $\rho^\pm \rho^0$ mode. 19 From $\rho^\pm \rho^0$ mode. 10 From $\rho^\pm \rho^0$ mode. 10 From $\rho^\pm \rho^0$ mode. 11 From $\rho^\pm \rho^0$ mode. 12 From $\rho^\pm \rho^0$ mode. 12 From $\rho^\pm \rho^0$ mode. 13 From $\rho^\pm \rho^0$ mode. 14 From $\rho^\pm \rho^0$ mode. 16 From $\rho^\pm \rho^0$ mode. 17 From $\rho^\pm \rho^0$ mode. 18 From $\rho^\pm \rho^0$ mode. 19 From $\rho^\pm \rho^0$ mode. 19 From $\rho^\pm \rho^0$ mode. 19 From $\rho^\pm \rho^0$ mode. 10 From $\rho^\pm \rho^0$ mode. 10 From $\rho^\pm \rho^0$ mode. 10 From $\rho^\pm \rho^0$ mode. 11 From $\rho^\pm \rho^0$ mode. 12 From $\rho^\pm \rho^0$ mode. 12 From $\rho^\pm \rho^0$ mode. 12 From $\rho^\pm \rho^0$ mode. 13 From $\rho^\pm \rho^0$ mode. 14 From $\rho^\pm \rho^0$ mode. 15 From $\rho^\pm \rho^0$ mode. 16 From $\rho^\pm \rho^0$ mode. 17 From $\rho^\pm \rho^0$ mode. 18 From $\rho^\pm \rho^0$ mode. 19 From $\rho^\pm \rho^0$ mode. 19 From $\rho^\pm \rho^0$ mode. 19 From ρ^0 mode. 19 From $\rho^\pm \rho^0$ mode. 19 From $\rho^\pm \rho$	mode, r mode, r include iE	BALTAY pendent of the other not independent of not independent of <u>DOCUMENT ID</u> d in the average pi 12 ALDE EVANGELIST GESSAROLI THOMPSON ing data for average	68 er two the ot the ot rinted 95 TA 81 77 74 ges, fit	HBC EVANG her two her two for a pre GAM2 OMEG HBC HBC s, limits,	+ EELIS EVAN EVAN CHG evlous	7, 8.5 $\pi^+ p$ TA 81 entries. RGELISTA 81 entrie RGELISTA 81 entrie COMMENT datablock. 38 $\pi^- p \rightarrow \omega \pi p$ $12 \pi^- p \rightarrow \omega \pi p$ $13 \pi^+ p$ • • •
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ρ₃(1690) WIDTH

2π, KK, AND KKπ MODES

160±10 OUR AVERAGE Includes data from the 5 datablocks that follow this one. Error Includes scale factor of 1.5. See the ideogram below.



 ho_3 (1690) width, 2π , $K\overline{K}$, and $K\overline{K}\pi$ modes (MeV)

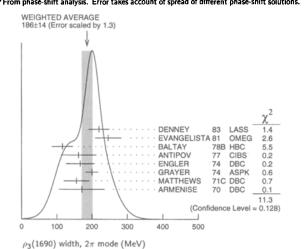
2x MODE						
VALUE (MeV)	EVTS	DOCUMENT ID	TECN	CHG	COMMENT	
The data in this b	lock is included in	the average printed	for a pre	vious	datablock.	

186±14 OUR AVERAGE	Erro	rincl	udes scale facto	r of :	1.3. See	the id	eogram below.
220±29			DENNEY	83	LASS		10 $\pi^+ N$
246 ± 37			EVANGELISTA	81	OMEG	-	$12~\pi^-p\to~2\pip$
116±30	476		BALTAY	78B	HBC	0	15 $\pi^+ p \rightarrow$
		15					$\pi^+\pi^-n$
162±50	175	15	ANTIPOV	77	CIBS	0	$25 \pi^- p \rightarrow p 3\pi$
167±40	600		ENGLER	74	DBC	0	$6 \pi^{+} \stackrel{n}{\pi^{+}} \stackrel{\rightarrow}{\pi^{-}} \stackrel{p}{\rho}$
200±18		16	GRAYER	74	ASPK	0	$17 \pi^- \rho \rightarrow$
156±36			MATTHEWS	71c	DBC	0	$\pi^{+}\pi^{-}n$ $7\pi^{+}N$
171±65			ARMENISE	70	DBC	0	$9\pi^+d$
• • • We do not use the	follow	ing d	ata for averages	, fits	, limits,	etc. •	• •
322±35		17	CORDEN	79	OMEG		$1215 \pi^- \rho \rightarrow n2\pi$
240±30	1	6,18	ESTABROOKS	75	RVUE		$17 \pi^- p \rightarrow$
180±30	122		BARTSCH	70B	нвс	+	$ \begin{array}{c} \pi^{+}\pi^{-}n\\ 8\pi^{+}p\rightarrow N2\pi \end{array} $
267 ⁺⁷² -46			STUNTEBECK	70	HDBC	0	$8 \pi^- \rho$, 5.4 $\pi^+ d$
188±49			ARMENISE	68	DBC	0	$5.1 \pi^{+} d$
180±40			GOLDBERG	65	HBC	0	6 π ⁺ d, 8 π ⁻ p

¹⁵ Width errors enlarged by us to $4\Gamma/\sqrt{N}$; see the note with the $K^*(892)$ mass. 16 Uses same data as HYAMS 75 and BECKER 79. 17 From a phase shift solution containing a $I_2'(1525)$ width two times larger than the $K\overline{K}$

result.

18 From phase-shift analysis. Error takes account of spread of different phase-shift solutions.



VALUE (MeV) The data in this bio	MODES EVTS ock is included	l in	DOCUMENT ID the average prin				COMMENT iatablock.
04±18 OUR AVE	RAGE						
99±40	6000	19	MARTIN	7 8 D	SPEC		$ \begin{array}{c} 10 \ \pi p \rightarrow \\ \kappa_S^0 \ \kappa^- p \end{array} $
05±20			BLUM	75	ASPK	0	18.4 π ⁻ p → ηK ⁺ K ⁻
• • We do not u	ise the followin	ng d	ata for averages	s, fits	, limits,	etc. •	
19± 4			ALPER	80	CNTR	0	62 π ⁻ p →
86±11		20	COSTA	80	OMEG		K ⁺ K [−] n 10π [−] p→
.12±60			ADERHOLZ	69	нвс	+	K^+K^-n 8 $\pi^+p \rightarrow K\overline{K}\pi$
19 From a fit to J^2 They cannot dis				<i>∪</i> 3(10	670).		
4π)± MODE				•			
ALUE (MeV)	EVTS		DOCUMENT ID		TECN	CHG	COMMENT
he data in this blo		l in					
29±10 OUR AVE	RAGE	•					
23±13		21	EVANGELISTA				
105±30	177		BALTAY		нвс	+	$15 \pi^+ \rho \to \rho 4\pi$
69+70 -48			CASON		нвс	-	
35±30	144		BARTSCH		HBC	+	$8 \pi^+ p \rightarrow N4\pi$
160±30	102		BARTSCH		HBC	+	$8\pi^+p \rightarrow N2\rho$
• • We do not u	ise the following	_	_				
30±28 .84±33			EVANGELISTA EVANGELISTA				$12 \pi^- p \rightarrow p4\pi$ $12 \pi^- p \rightarrow p4\pi$
184±33 150	66		KLIGER		HBC	_	$12 \pi^- p \rightarrow p4\pi$ $4.5 \pi^- p \rightarrow p4\pi$
106±25	•		THOMPSON		HBC	+	$13 \pi^+ p$
25+83		24	CASON	73	нвс	_	8,18.5 π ⁻ p
35						+	10-12 K+p
30±30			HOLMES	12	HBC		
	90	24	HOLMES BARTSCH		HBC HBC	+	
.80±30 .00±35 ²¹ From ρ ⁻ ρ ⁰ mo ²² From a ₂ (1320)	ode, not indep - π ⁰ mode, n	end ot ir	BARTSCH BALTAY ent of the other idependent of the	70B 68 two ne ot	HBC HBC EVANG her two	+ + ELIST EVAN	$8 \pi^+ p \rightarrow N a_2 \pi$ 7, 8.5 $\pi^+ p$ A 81 entries. GELISTA 81 entries.
180 ± 30 180 ± 35 $21 \text{ From } \rho^- \rho^0 \text{ mo}$ $22 \text{ From } a_2(1320)$ $23 \text{ From } a_2(1320)$ $24 \text{ From } \rho^{\pm} \rho^0 \text{ mo}$ $\omega \pi \text{ MODE}$	ode, not indep π ⁰ mode, n 0π mode, n	end ot ir	BARTSCH BALTAY ent of the other idependent of the	70B 68 two ne ot	HBC HBC EVANG her two	+ + ELIST EVAN	$8 \pi^+ p \rightarrow Na_2 \pi$ 7, $8.5 \pi^+ p$ A 81 entries. GELISTA 81 entries. GELISTA 81 entries.
80 ± 30 00 ± 35 $21 \text{ From } \rho^- \rho^0 \text{ mo}$ $22 \text{ From } a_2(1320)$ $23 \text{ From } a_2(1320)$ $24 \text{ From } \rho^{\pm} \rho^0 \text{ mo}$ $a_2 + a_2 + a_3 + a_4 + a_4 + a_5 $	ode, not indep π ⁰ mode, n 0 π mode, n ode.	end ot in	BARTSCH BALTAY ent of the other idependent of the	70B 68 two ne ot	HBC HBC EVANG her two	+ + ELIST EVAN	$8 \pi^+ p \rightarrow N a_2 \pi$ 7, 8.5 $\pi^+ p$ A 81 entries. GELISTA 81 entries. GELISTA 81 entries.
180 ± 30 100 ± 35 $21 \text{ From } \rho^- \rho^0 \text{ mo}$ $22 \text{ From } a_2(1320)$ $23 \text{ From } a_2(1320)$ $24 \text{ From } \rho^{\pm} \rho^0 \text{ mo}$ $a_2 + a_2 + a_3 + a_4 + a_4 + a_5 + a_$	ode, not indep π ⁰ mode, n 0 π mode, n ode.	end ot in	BARTSCH BALTAY ent of the other idependent of the	70B 68 two ne ot	HBC HBC EVANG her two	+ + ELIST EVAN	$8 \pi^+ p \rightarrow N a_2 \pi$ 7, 8.5 $\pi^+ p$ A 81 entries. GELISTA 81 entries. GELISTA 81 entries.
180 ± 30 100 ± 35 100 ± 35 100 ± 35 100 ± 36	ode, not indep - \(\pi^0 \) mode, n 0 \(\pi^- \) mode, n ode.	end ot in	BARTSCH BALTAY ent of the other idependent of the	70B 68 two ne ot	HBC HBC EVANG her two	+ + ELIST EVAN	$8 \pi^+ p \rightarrow N a_2 \pi$ 7, 8.5 $\pi^+ p$ A 81 entries. GELISTA 81 entries. GELISTA 81 entries. COMMENT datablock.
80 ± 30 00 ± 35 $21 \text{ From } \rho^- \rho^0 \text{ mo}$ $22 \text{ From } a_2 (1320)$ $23 \text{ From } \rho^{\pm} \rho^0 \text{ mo}$ $24 \text{ From } \rho^{\pm} \rho^0 \text{ mo}$ $\sqrt{\pi} \text{ MODE}$ $\sqrt{ALUE (\text{MeV})}$ The data in this bid $130 \pm 40 \text{ OUR AVE}$ 130 ± 65	ode, not indep - \(\pi^0 \) mode, n 0 \(\pi^- \) mode, n ode.	end ot in	BARTSCH BALTAY ent of the other idependent of th idependent of th DOCUMENT ID the average print ALDE	70B 68 two ne ot ne ot	HBC HBC EVANG her two her two	+ + ELIST EVAN: EVAN:	$8 \pi^+ p \rightarrow N a_2 \pi$ 7, 8.5 $\pi^+ p$ A 81 entries. GELISTA 81 entries. GELISTA 81 entries. COMMENT datablock. $38 \pi^- p \rightarrow \omega_\pi^0 n$
80 ± 30 00 ± 35 $21 \text{ From } \rho^- \rho^0 \text{ m}$ $22 \text{ From } a_2(1320)$ $24 \text{ From } \rho^{\pm} \rho^0 \text{ m}$ $24 \text{ From } \rho^{\pm} \rho^0 \text{ m}$	ode, not indep	end ot in ot in	BARTSCH BALTAY ent of the other idependent of the idependent of th	70B 68 two ne ot ne ot 95 81 77	HBC HBC EVANG her two for a pre GAM2 OMEG HBC	+ + ELISTEVANIEVANIEVANIEVANIEVANIEVANIEVANIEVANI	$8 \pi^+ p \rightarrow N a_2 \pi$ 7, 8.5 $\pi^+ p$ A 81 entries. GELISTA 81 entries. GELISTA 81 entries. COMMENT datablock. $38 \pi^- p \rightarrow \omega \pi p$ $12 \pi^- p \rightarrow \omega \pi p$ $11 \pi^- p \rightarrow \omega \pi p$
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80 \pm 30 00 \pm 35 21 From $\rho^- \rho^0$ mo 222 From a_2 (1320) 24 From $\rho^\pm \rho^0$ mo 24 From $\rho^\pm \rho^0$ mo 25 MODE ALUE (MeV) The data in this bit 90 \pm 40 OUR AVE 30 \pm 65 60 \pm 56 • • We do not us 89 \pm 25	ode, not indep	end ot in ot in	BARTSCH BALTAY ent of the other idependent of the idependent of th	70B 68 two ne oti ne oti 95 81 77 77 74	HBC HBC EVANG her two her two her two for a pre GAM2 OMEG HBC s, limits,	+ + + ELIST EVAN EVAN CHG vious	$8 \pi^+ p \rightarrow N a_2 \pi$ 7, 8.5 $\pi^+ p$ A 81 entries. GELISTA 81 entries. GELISTA 81 entries. COMMENT datablock. $38 \pi^- p \rightarrow \omega \pi p$ $11 \pi^- p \rightarrow \omega \pi p$
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180 ± 30 100 ± 35 $21 \text{ From } \rho^- \rho^0 \text{ m}$ $22 \text{ From } a_2(1320)$ $24 \text{ From } \rho^\pm \rho^0 \text{ m}$ $\sqrt{\pi} \text{ MODE}$ $\sqrt{4kUE (\text{MeV})}$ The data in this bk $190 \pm 40 \text{ OUR AVE}$ 190 ± 65 160 ± 56 190 ± 65	ode, not indep - \(\pi \) mode, n 0 \(\pi \) mode, n ode. ock is included cck is included crage	end ot in ot in	BARTSCH BALTAY ent of the other idependent of the idependent of th	70B 68 two ne oti ne oti 95 81 77 77 74	HBC HBC EVANG her two her two her two for a pre GAM2 OMEG HBC s, limits,	+ + + ELIST EVAN EVAN CHG vious	$8 \pi^+ p \rightarrow N a_2 \pi$ 7, 8.5 $\pi^+ p$ A 81 entries. GELISTA 81 entries. GELISTA 81 entries. COMMENT datablock. $38 \pi^- p \rightarrow \omega \pi p$ $11 \pi^- p \rightarrow \omega \pi p$
180 ± 30 100 ± 35 $21 \text{ From } \rho^- \rho^0 \text{ m}$ $22 \text{ From } a_2(1320)$ $23 \text{ From } \rho^\pm 2(1320)$ $24 \text{ From } \rho^\pm \rho^0 \text{ m}$ $24 \text{ From } \rho^\pm \rho^0 \text{ m}$ $24 \text{ From } \rho^\pm \rho^0 \text{ m}$ 25 MODE $24 \text{ From } \rho^\pm \rho^0 \text{ m}$ 25 MODE	ode, not indep - \(\pi^0 \) mode, n 0 \(\pi^- \) mode, n ock is included CRAGE use the followin DE 92c.	pend ot in ot in 25	BARTSCH BALTAY ent of the other idependent of th dependent of th DOCUMENT ID the average prin ALDE EVANGELISTA GESSAROLI lata for average THOMPSON BARNHAM	70B 68 two ne of the of two 95 A 81 77 75 fits 74	HBC HBC EVANG her two her two for a pre GAM2 OMEG HBC s, limits, HBC HBC	+ + + ELIST EVAN	$8 \pi^+ p \rightarrow N a_2 \pi$ 7, 8.5 $\pi^+ p$ A 81 entries. GELISTA 81 entries. GELISTA 81 entries. COMMENT datablock. $38 \pi^- p \rightarrow \omega \pi p$ $11 \pi^- p \rightarrow \omega \pi p$
80 ± 30 80 ± 30 80 ± 35 $21 \text{ From } \rho^- \rho^0 \text{ mos}$ $22 \text{ From } a_2(1320)$ $23 \text{ From } a_2(3320)$ $24 \text{ From } \rho^+ \rho^0 \text{ mos}$ $\rho^+ \rho^0 \text{ mos}$ $\rho^0 = \rho^$	ode, not indep \[\pi^0 \] mode, n 0 \[\pi^- \] mode, n ock is included cck is included cck as include	pend of in of in 25	BARTSCH BALTAY ent of the other idependent of th dependent of th DOCUMENT ID the average prin ALDE EVANGELISTA GESSAROLI lata for average: THOMPSON BARNHAM Experiments, see	70B 68 two ne oti 95 81 77 78, fits 70	HBC HBC EVANG her two of the two	+ + + + ELIST EVAN	$8 \pi^+ p \rightarrow N a_2 \pi$ 7, 8.5 $\pi^+ p$ A 81 entries. GELISTA 81 entries. GELISTA 81 entries. $\frac{COMMENT}{datablock}$ $38 \pi^- p \rightarrow \omega \pi p$ $12 \pi^- p \rightarrow \omega \pi p$ $11 \pi^- p \rightarrow \omega \pi p$ $10 K^+ p \rightarrow \omega \pi X$ -review in the 1973
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180 ± 30 180 ± 35 190 ± 35 190 ± 35 190 ± 36	ode, not indep \[\pi^0 \] mode, n 0 \[\pi^- \] mode, n ock is included cck is included cck as include	pend of in of in 25	BARTSCH BALTAY ent of the other idependent of th dependent of th DOCUMENT ID the average prin ALDE EVANGELISTA GESSAROLI lata for average: THOMPSON BARNHAM Experiments, see	70B 68 two ne of the of	HBC HBC EVANG her two of the two	+ + + + + ELIST EVAN CHG vious + + + + + + + + + + + + + + + CHG vious	$8 \pi^+ p \rightarrow N a_2 \pi$ 7, 8.5 $\pi^+ p$ A 81 entries. GELISTA 81 entries. GELISTA 81 entries. $\frac{COMMENT}{datablock}$ $38 \pi^- p \rightarrow \omega \pi p$ $12 \pi^- p \rightarrow \omega \pi p$ $11 \pi^- p \rightarrow \omega \pi p$ $10 K^+ p \rightarrow \omega \pi X$ -review in the 1973
180 ± 30 180 ± 35 101 ± 35 102 ± 35 $11 \text{ From } \rho^- \rho^0 \text{ mod}$ $122 \text{ From } a_2(1320)$ $123 \text{ From } a_2(1320)$ $124 \text{ From } \rho^\pm \rho^0 \text{ mod}$ $125 \text{ From } \rho^\pm \rho^0 \text{ mod}$ $126 \text{ From } \rho^0 \text{ mod}$ $126 \text{ From } \rho^\pm \rho^0 \text{ mod}$ $126 \text{ From } \rho^0 \text{ mod}$ $126 \text{ From } \rho^\pm \rho^0 \text{ mod}$ $126 \text$	ode, not indep	pend of irrot irro	BARTSCH BALTAY ent of the other dependent of the dependen	70B 68 two ne of the of	HBC HBC EVANG her two long TECN for a pre GAM2 OMEG HBC ,, limits, HBC HBC TECN TECN TECN TECN TO A PRE SPEC	+ + + + ELIST EVANN CHG etc. • + + +) mini CHG vlous 0	$8 \pi^+ p \rightarrow N a_2 \pi$ 7, 8.5 $\pi^+ p$ A 81 entries. GELISTA 81 entries. GELISTA 81 entries. $\frac{COMMENT}{datablock}$ $38 \pi^- p \rightarrow \omega \pi p$ $12 \pi^- p \rightarrow \omega \pi p$ $11 \pi^- p \rightarrow \omega \pi p$ $10 K^+ p \rightarrow \omega \pi X$ -review in the 1973 $\frac{COMMENT}{datablock}$ $\frac{COMMENT}{datablock}$ $\frac{COMMENT}{datablock}$
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180 ± 30 100 ± 35 $21 \text{ From } \rho - \rho^0 \text{ mis}$ $221 \text{ From } a_2(1320)$ $23 \text{ From } a_2(1320)$ $24 \text{ From } \rho^{\pm} \rho^0 \text{ mis}$ $\omega \pi \text{ MODE}$ $\omega \pi \text{ MODE}$ $\omega 100 \pm 40 \text{ OUR AVE}$ $\omega 100 \pm 40 \text{ OUR AVE}$ $\omega 100 \pm 65$ $\omega 100 \pm$	ode, not indep	pend of in other section of the sect	BARTSCH BALTAY ent of the other idependent of the idependent io the average print idea average in the idea average in	708 68 two ne of the of two ne of the of two ne of the of two ne o	HBC HBC EVANG her two long TECN for a pre GAM2 OMEG HBC ,, limits, HBC HBC TECN for a pre SPEC SPEC SPEC MMS MMS	+ + + + ELIST EVANN CHG etc. • + + +) mini CHG vlous 0	$8 \pi^+ p \rightarrow N a_2 \pi$ 7, $8.5 \pi^+ p$ A 81 entries. GELISTA 81 entries. GELISTA 81 entries. GELISTA 81 entries. $\frac{COMMENT}{datablock}$ $38 \pi^- p \rightarrow \omega \pi p$ $12 \pi^- p \rightarrow \omega \pi p$ $11 \pi^- p \rightarrow \omega \pi p$ $10 K^+ p \rightarrow \omega \pi X$ -review in the 1973 $\frac{COMMENT}{datablock}$ $\frac{COMMENT}{datablock}$ $\frac{COMMENT}{datablock}$ $\frac{COMMENT}{datablock}$ $\frac{COMMENT}{datablock}$
180 ± 30 100 ± 35 $21 \text{ From } \rho^- \rho^0 \text{ mod}$ $221 \text{ From } \rho^- \rho^0 \text{ mod}$ $222 \text{ From } \rho^2 \rho^0 \text{ mod}$ $224 \text{ From } \rho^+ \rho^0 \text{ mod}$ $23 \text{ From } \rho^+ \rho^0 \text{ mod}$ $24 \text{ From } \rho^+ \rho^0 \text{ mod}$ $25 \text{ Supersedes ALI}$ $25 \text{ Supersedes ALI}$ $25 \text{ Supersedes ALI}$ $25 \text{ Supersedes ALI}$ $25 \text{ From } \rho^+ \rho^0 \text{ mod}$ 2	ode, not indep	send of in o	BARTSCH BALTAY ent of the other dependent of the dependen	708 68 two ne of the of two ne of the of two ne of two n	HBC HBC EVANG her two long TECN for a pre GAM2 OMEG HBC is, limits, HBC HBC SPEC SPEC SPEC MMS MMS MMS	+ + + + ELIST EVANN CHG etc. • + + +) mini CHG vlous 0	$8 \pi^+ p \rightarrow N a_2 \pi$ $7, 8.5 \pi^+ p \rightarrow N a_2 \pi$ $7, 8.5 \pi^+ p$ A 81 entries. GELISTA 81 entries. GELISTA 81 entries. $\frac{comment}{datablock}$ $38 \pi^- p \rightarrow \omega \pi p$ $12 \pi^- p \rightarrow \omega \pi p$ $11 \pi^- p \rightarrow \omega \pi p$ $13 \pi^+ p$ $10 K^+ p \rightarrow \omega \pi X$ -review in the 1973 $\frac{comment}{datablock}$ $8.95 \pi^- p \rightarrow \eta \pi^+ \pi^- n$ $16 \pi^- p$ backward $7-12 \pi^- p \rightarrow p MM$ $7-12 \pi^- p \rightarrow p MM$ $7-12 \pi^- p \rightarrow p MM$
22 From a ₂ (1320) 23 From a ₂ (1320) 24 From ρ [±] ρ ⁰ me ωπ MODE WALUE (MeV) The data in this bid 190±40 OUR AVE 230±65 190±65 1	ode, not indep	send of in 25 sex d in ng 6 6,27 6,27 6,27	BARTSCH BALTAY ent of the other idependent of the idependent io the average print idependent io the average print idea of average idea of aver	708 68 1 two ne ot inted 1 95 81 77 74 70 the 1 66 66 66 66 66 66 68	HBC HBC EVANG her two long a pre GAM2 OMEG HBC i, limits, HBC SPEC SPEC s, limits, MMS MMS MMS	+ + + + ELIST EVANO EVANO EVANO EVANO EVANO EVANO EVANO EVANO ETC. •	$8 \pi^+ p \rightarrow N a_2 \pi$ 7, 8.5 $\pi^+ p$ A 81 entries. GELISTA 81 entries. GELISTA 81 entries. GELISTA 81 entries. $\frac{COMMENT}{datablock}$ $38 \pi^- p \rightarrow \omega \pi p$ $11 \pi^- p \rightarrow \omega \pi p$ $10 K^+ p \rightarrow \omega \pi p$ $10 K^+ p \rightarrow \omega \pi x$ Freview in the 1973 $\frac{COMMENT}{datablock}$ $8.95 \pi^- p \rightarrow \omega \pi p$ $10 K^+ p \rightarrow \omega \pi x$ $10 K^+ p \rightarrow \omega \pi x$ $10 K^+ p \rightarrow \omega \pi x$

$ho_3(1690)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)	Scale factor
Γ ₁ Γ ₂ Γ ₃	4π $\pi^{\pm}\pi^{+}\pi^{-}\pi^{0}$ $\omega\pi$	(71.1 ± 1.9) % (67 ±22) % (16 ± 6) %	
Γ ₄ Γ ₅ Γ ₆	ππ Κ <u>Κ</u> π	$(23.6 \pm 1.3)\%$ $(3.8 \pm 1.2)\%$	
Γ ₇ Γ ₈	Κ Κ ηπ ⁺ π ⁻ ππρ	(1.58± 0.26) % seen	1.2
_	Excluding 2ρ and $a_2(1320)\pi$.		
Γ ₉ Γ ₁₀	$a_2(1320)\pi$ $ ho ho$		
Γ ₁₁ Γ ₁₂	$\phi\pi$ $\eta\pi$		
Γ ₁₃	$\pi^{\pm} 2\pi^{+} 2\pi^{-} \pi^{0}$		

CONSTRAINED FIT INFORMATION

An overall fit to 5 branching ratios uses 10 measurements and one constraint to determine 4 parameters. The overall fit has a $\chi^2=$ 14.7 for 7 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\left\langle \delta x_i \delta x_j \right\rangle / (\delta x_i \cdot \delta x_j),$ in percent, from the fit to the branching fractions, $x_i \equiv \Gamma_i / \Gamma_{\rm total}.$ The fit constrains the x_i whose labels appear in this array to sum to one.

ρ_3 (1690) BRANCHING RATIOS

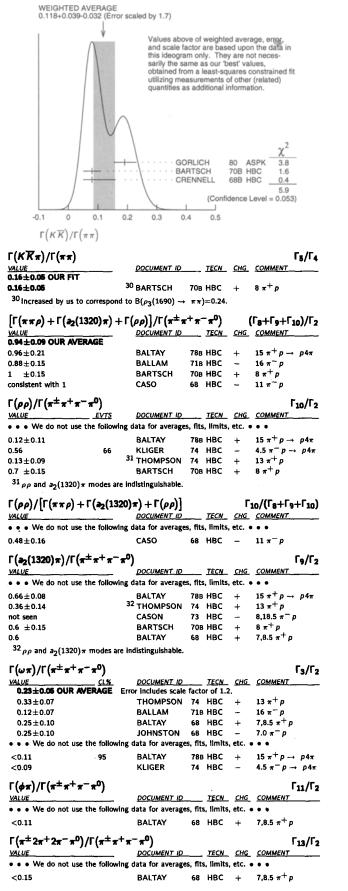
$\Gamma(\pi\pi)/\Gamma_{\text{total}}$					Γ ₄ /Γ
VALUE	DOCUMENT ID		<u>TECN</u>	<u>CHG</u>	COMMENT
0.236±0.013 OUR FIT 0.243±0.013 OUR AVE	RAGE				
$0.259 ^{+0.018}_{-0.019}$	BECKER	79	ASPK	0	17 $\pi^- p$ polarized
0.23 ±0.02	CORDEN	79	OMEG		$12-15 \pi^- p \rightarrow p^2 \pi$
0.22 ±0.04	²⁸ MATTHEWS	710	HDBC	0	$7\pi^{+}n \rightarrow \pi^{-}p$
• • • We do not use th	e following data for average	s, fit:	s, limits,	etc.	• •
0.245 ± 0.006	²⁹ ESTABROOKS	75	RVUE		$17 \pi^+ p \rightarrow \pi^+ \pi^- p$

²⁸ One-pion-exchange model used in this estimation.

²⁹ From phase-shift analysis of HYAMS 75 data.

$\Gamma(\pi\pi)/\Gamma(\pi^{\pm}\pi^{+}\pi^{-}\pi^{0})$					Γ ₄ /Γ ₂
VALUE	DOCUMENT ID		<u>TECN</u>	CHG	COMMENT
0.35 ± 0.11	CASON	73	HBC	_	8,18.5 π ⁻ p
 We do not use the following 	owing data for average	s, fits	, limits,	etc. •	• •
<0.2	HOLMES	72	нвс	+	10-12 K ⁺ p
<0.12	BALLAM	71B	HBC	_	16 π ⁻ p
$\Gamma(\pi\pi)/\Gamma(4\pi)$					Γ ₄ /Γ ₁
VALUE	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT
0.332 ± 0.026 OUR FIT Erro	or includes scale factor	of 1.			
0.30 ±0.10	BALTAY	78B	нвс	0	$15 \pi^+ \rho \rightarrow \rho 4\pi$
$\Gamma(K\overline{K})/\Gamma(\pi\pi)$					Γ_6/Γ_4
VALUE	DOCUMENT ID		<u>TECN</u>	CHG	COMMENT
0.067±0.011 OUR FIT Erro	or includes scale factor	of 1.	2.		
0.118 ^{+0.039} OUR AVERAGE		facto	or of 1.7	. See	the ideogram
	below.				
0.191 ^{+ 0.040} - 0.037	GORLICH	80	ASPK	0	17,18 π p polar- ized
0.08 ±0.03	BARTSCH	70B	HBC	+	8 π+ρ
0.08 +0.08 -0.03	CRENNELL	68B	нвс		6.0 $\pi^{-}p$

$\rho_3(1690)$



```
\Gamma(\eta\pi)/\Gamma(\pi^{\pm}\pi^{+}\pi^{-}\pi^{0})
                                                                                                                                                                                                                                                                                                                                    \Gamma_{12}/\Gamma_2
                                                                                                                                                 DOCUMENT ID
                                                                                                                                                                                                                        TECN CHG COMMENT
 • • • We do not use the following data for averages, fits, limits, etc. • •
                                                                                                                                                  THOMPSON 74 HBC +
   < 0.02
 \Gamma(K\overline{K})/\Gamma_{\text{total}}
                                                                                                                                                 DOCUMENT ID
                                                                                                                                                                                                                                TECN CHG COMMENT
 0.0158±0.0026 OUR FIT Error includes scale factor of 1.2.
 0.0130±0.0024 OUR AVERAGE
                                                                                                                                                  COSTA...
                                                                                                                                                                                                                80 OMEG 0
 0.013 \pm 0.003
                                                                                                                                                                                                                                                                                          10 π P →
                                                                                                                                                                                                                                                                                                       K+K-n
                                                                                                                                       33 MARTIN
                                                                                                                                                                                                                788 SPEC ~
 0.013 \pm 0.004
                                                                                                                                                                                                                                                                                          10 π n
                                                                                                                                                                                                                                                                                                       K 6 K - p
     ^{33}\, {\rm From}\; (\Gamma_4\Gamma_6)^{1/2} = 0.056 \pm 0.034 \; {\rm assuming}\; {\rm B}(\rho_3(1690) \to \; \pi\pi) = 0.24.
 \Gamma(\omega\pi)/[\Gamma(\omega\pi)+\Gamma(\rho\rho)]
                                                                                                                                                                                                                                                                                                      \Gamma_3/(\Gamma_3+\Gamma_{10})
                                                                                                                                                  DOCUMENT ID
                                                                                                                                                                                                                        TECN CHG COMMENT
  73 HBC - 8,18.5 π<sup>--</sup> ρ
 0.22 \pm 0.08
                                                                                                                                                  CASON
 \Gamma(\eta \pi^+ \pi^-)/\Gamma_{\text{total}}
                                                                                                                                                                                                                                                                                                                                              \Gamma_7/\Gamma
  VALUE
                                                                                                                                                  DOCUMENT ID
                                                                                                                                                                                                                              TECN COMMENT
                                                                                                                                                  FUKUL
                                                                                                                                                                                                                88 SPEC 8.95 \pi^- p \to \eta \pi^+ \pi^- n

ho_3(1690) REFERENCES
 ALDE 95
ALDE 92C
FUKUI 88
DENNEY 83
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ALPER 80
COSTA... 80
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CORDEN 79
BALTAY 78B
MARTIN 78B
MARTIN 78D
MARTIN 78D
ANTIPOV 77
BLUM 75
ESTABROOKS 75
HYAMS 75
ENGLER 74
KLIGER 74
KLIGER 74
                                                                                                                                                      + Binon, Bricman+
+ Bencheikh, Binon+
+ Hencheikh, Binon+
+ Horikawa+
- (SUGI, NAGO, KEK, KYOT, MIYA)
+ Cranley, Firestone, Chapman+
- (IOWA, MIGH)
+ Becker+
- (AMST, CERN, CRAC, MPIM, OXF+)
- Costa De Beauregard+
- Hiczyporuk+
- Hoizyporuk+
- Hoizyporuk+
- Hoisyporuk+
- Hoisyporuk+
- Howell, Garvey+
- Howell, Garvey-
- Howell, Garvey
                                                                    ZPHY C66 379
ZPHY C54 553
PL B202 441
PR D28 2726
NP B178 197
PL 94B 422
NP B175 402
NP B151 46
NP B151 46
NP B151 250
PR D17 62
PR D17 62
PR D17 64
NP B191 158
PL 74B 417
NP B119 45
                                                                       PL 74B 417
NP B119 45
NP B126 382
PL 57B 403
NP B95 322
NP B100 205
PR D10 2070
NP B75 189
                                                                                                                                                                                                                                                                                                    (CERN, MPIM)
(CMU, CASE)
(CERN, MPIM)
                                                                                                                                                          - Martin
+ Jones, Wellhammer, Blum, Dietl+
                                                                                                                                                        +Kraemer, Toaff, Weisser, Diaz+
+Hyams, Blum, Diet+
+Beketov, Grechko, Guzhavin, Dubovikov-
                                                                     NP B75 I89
SJNP 19 428
Translated from
NP B71 I89
NP B69 220
PR D7 1971
PRL 29 890
PR D6 3336
PR D3 2606
NP B33 1
LNC 4 199
PRL 24 1083
NP B22 109
LNC 3 707
PL 328 791
                                                                                                                                                                                                                                                                                                                                (ITEP)
                                                                                                                                                      9 Saccepts, Stellans, Sullivani, Bubothovit

4 Calogo, Koliwain, Miller, Mulera+

4 Biswas, Kenney, Madden+

4 Earles, Falsster, Bileden+

4 Chadwick, Sulragossian, Johnson+

4 Chadwick, Guiragossian, Johnson+

4 Chadwick, Guiragossian, Johnson+

4 Chadwick, Gring, Cartacch+

4 Childini, Foring, Cartacch+

4 Colley, Jobes, Kenyon, Pathak, Riddiford

4 Kraus, Tsanos, Grote+

4 Conte, Tomasini+

4 Cenev, Deern, Biswas, Cason+

4 Conte, Tomasini+

4 Cenev, Deern, Biswas, Cason+

(NDAM)

(NDAM)
   OREN
                                                   74
74
73
72
72
71B
71C
70
70
70B
    THOMPSON
   CASON
BOWEN
HOLMES
BALLAM
  MATTHEWS
ARMENISE
BARNHAM
BARTSCH
 CASO 70
STUNTEBECK 70
ADERHOLZ 69
ANDERSON 69
ARMENISE 68
BALTAY 68
                                                                                                                                                         +Conte, Tomasin+ (GENO, HAMB, MILA, SACL)
+Kenney, Deery, Biswas, Cason+ (NDAM)
+Bartsch+ (AACH3, BERL, CERN, JAGL, WARS)
                                                                         PL 32B 391
NP B11 259
                                                                                                                                                      + Battsch+ (AACH3, BERL, CERN, JAGL, WARS)
+ Collins+
+ Collins, Forino+ (BARI, BGNA, FIRZ, ORSAY)
+ Kung, Yeh, Ferbel+ (COLU, ROCH, RUTG, YALE)
+ Conte, Coxfo, Diaz+ (GENO, HAMB, MILA, SACH)
+ Harshon, Lai, Scarr, Skillicorn (BNL)
+ Prentice, Steenberg, Yoon (TNTO, WISC)
+ Kienzle, Levrat, Maglich, Martin (CERN)
+ (CERN, EPOL, ORSAY, MILA, CEA, SACL)
                                                                       NP B11 259
PRL 22 1390
NC 54A 999
PRL 20 887
NC 54A 983
PL 28B 136
PRL 20 1414
PRL 17 890
PL 17 354
   CASO
CRENNELL
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FOCACCI GOLDBERG

BARNETT

EHRLICH LEVRAT

BELLINI

FORING

SEGUINOT

DEUTSCH...

PL 120B 455 PR 152 1194 PL 22 714 PL 19 712 NC 40A 948 PL 18 351 PL 19 65

83B

(BNL) (TNTO, WISC) UP

(CERN Missing Mass Spect. Collab. (CERN Missing Mass Spect. Collab.

(AACH3, BERL, CERN) (BGNA, ORSAY, SACL)

 $\rho(1700)$

$$I^{G}(J^{PC}) = 1^{+}(1^{-})$$

THE $\rho(1450)$ AND THE $\rho(1700)$

Written March 1998 by S. Eidelman (Novosibirsk) and J. Hernandez (Valencia).

In our 1988 edition, we replaced the $\rho(1600)$ entry with two new ones, the $\rho(1450)$ and the $\rho(1700)$, because there was emerging evidence that the 1600-MeV region actually contains two ρ -like resonances. ERKAL 86 had pointed out this possibility with a theoretical analysis on the consistency of 2π and 4π electromagnetic form factors and the $\pi\pi$ scattering length. DONNACHIE 87, with a full analysis of data on the 2π and 4π final states in e^+e^- annihilation and photoproduction reactions, had also argued that in order to obtain a consistent picture two resonances were necessary. The existence of $\rho(1450)$ was supported by the analysis of $\eta\rho^0$ mass spectra obtained in photoproduction and e^+e^- annihilation (DONNACHIE 87B) as well as that of $e^+e^- \to \omega\pi$ (DONNACHIE 91).

The analysis of DONNACHIE 87 was further extended by CLEGG 88, 94 to include new data on 4π systems produced in e^+e^- annihilation and in τ decays (τ decays to 4π and e^+e^- annihilation to 4π can be related by the Conserved Vector Current assumption). These systems were successfully analyzed using interfering contributions from two ρ -like states, and from the tail of the $\rho(770)$ decaying into two-body states. While specific conclusions on $\rho(1450) \to 4\pi$ were obtained, little could be said about the $\rho(1700)$.

An analysis by CLEGG 90 of 6π mass spectra from e^+e^- annihilation and from diffractive photoproduction provides evidence for two ρ mesons at about 2.1 and 1.8 GeV that decay strongly into 6π states. While the former is a candidate for a new resonance ($\rho(2150)$), the latter could be a manifestation of the $\rho(1700)$ distorted by threshold effects.

Independent evidence for two 1⁻ states is provided by KILLIAN 80 in 4π electroproduction at $\langle Q^2 \rangle = 1$ (GeV/c)², and by FUKUI 88 in a high-statistics sample of the $\eta\pi\pi$ system in π^-p charge exchange.

This scenario with two overlapping resonances is supported by other data. BISELLO 89 measured the pion form factor in the interval 1.35–2.4 GeV and observed a deep minimum around 1.6 GeV. The best fit was obtained with the hypothesis of ρ -like resonances at 1420 and 1770 MeV with widths of about 250 MeV. ANTONELLI 88 found that the $e^+e^- \to \eta \pi^+ \pi^-$ cross section is better fitted with two fully interfering Breit-Wigners, with parameters in fair agreement with those of DONNACHIE 87 and BISELLO 89. These results can be considered as a confirmation of the $\rho(1450)$.

Decisive evidence for the $\pi\pi$ decay mode of both $\rho(1450)$ and $\rho(1700)$ came from recent results in $\overline{p}p$ annihilation at rest (ABELE 97). According to ABELE 98 these resonances also possess a $K\overline{K}$ decay mode. High statistics studies of the $\tau \to \pi\pi\nu_{\tau}$ decay also require the $\rho(1450)$ (BARATE 97M, URHEIM 97), but are not sensitive to the $\rho(1700)$ because it is too close to the τ mass.

The structure of these ρ states is not yet completely clear. BARNES 97 and CLOSE 97C claim that $\rho(1450)$ has a mass consistent with radial 2S, but its decays show characteristics of hybrids and suggest that this state may be a 2S-hybrid mixture.

We also list under the $\rho(1450)$ the $\phi\pi$ state with $J^{PC}=1^{--}$ or C(1480) observed by BITYUKOV 87. While ACHASOV 96B shows that it may be a threshold effect, CLEGG 88 and LANDSBERG 92 suggest two independent vector states with this decay mode. Note, however, that C(1480) in its $\phi\pi$ decay mode was not confirmed by e^+e^- (DOLINSKY 91, BISELLO 91C) and $\bar{p}p$ (ABELE 97H) experiments.

Several observations on the $\omega\pi$ system in the 1200-MeV region (FRENKIEL 72, COSME 76, BARBER 80C, ASTON 80C, ATKINSON 84C, BRAU 88, AMSLER 93B) may be interpreted in terms of either $J^P=1^ \rho(770)\to\omega\pi$ production (LAYSSAC 71) or $J^P=1^+$ $b_1(1235)$ production (BRAU 88, AMSLER 93B). We argue that no special entry for a $\rho(1250)$ is needed. The LASS amplitude analysis (ASTON 91B) showing evidence for $\rho(1270)$ is preliminary and needs confirmation. For completeness, the relevant observations are listed under the $\rho(1450)$.

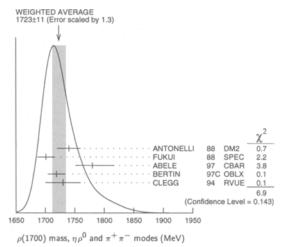
ρ(1700) MASS

 $\eta \rho^0$ AND $\pi^+\pi^-$ MODES

1700±20 OUR ESTIMATE

DOCUMENT ID

1723±11 OUR AVERAGE Includes data from the 2 datablocks that follow this one. Error includes scale factor of 1.3. See the ideogram below.



The data in this block is included in the average printed for a previous 1740 ± 20 ANTONELLI 88 DM2 e^{+}	
1740±20 ANTONELLI 88 DM2 e ⁺	
	$e^- \rightarrow \eta \pi^+ \pi^-$
1 FLIVER OF SPEC OF	
1701±15	$95 \pi^- p \rightarrow \eta \pi^+ \pi^- n$
ππ MODE	
VALUE (MeV) DOCUMENT ID TECN CO	MMENT
The data in this block is included in the average printed for a previous	us datablock.
1780 +37 2 ABELE 97 CBAR pr	$\eta \rightarrow \pi^- \pi^0 \pi^0$
1719 ±15 2 BERTIN 97C OBLX 0.0	$0 \bar{p} p \rightarrow \pi^+ \pi^- \pi^0$
1730 \pm 30 CLEGG 94 RVUE e^+	$e^- \rightarrow \pi^+\pi^-$

$\rho(1700)$

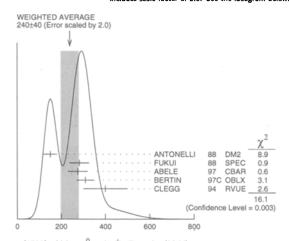
• • We do not us	the following	ng data for average	s fits	limits.	etc. • • •
		BISELLO			$e^+e^- \rightarrow \pi^+\pi^-$
.745.7±91.9		DUBNICKA	89 F	RVUE	$e^+e^- \rightarrow \pi^+\pi^-$
.546 ±26		GESHKEN	89 f	RVUE	**
650		³ ERKAL			
		ABE			
		4 ASTON			
		ATIYA	79B S	SPEC	$50 \gamma C \rightarrow C2\pi$
598 +24		BECKER	79 /	ASPK	17 $\pi^- p$ polarized
.659 ±25		³ LANG	79 F	RVUE	
.575		3 MARTIN			
.610 ±30			77 F	RVUE	$17 \pi^- p \rightarrow \pi^+ \pi^- n$
590 ±20		⁶ HYAMS	73	ASPK	$17 \pi^- p \rightarrow \pi^+ \pi^- n$
ru MODE					
		DOCUMENT ID		TECN	COMMENT
• • We do not use	e the followin	ng data for average	es, fits,	limits,	etc. • • •
710±90		ACHASOV	97 F	RVUE	$e^+e^- \rightarrow \omega \pi^0$
(T MODE					
	EVTS	DOCUMENT ID		TECN	CHG COMMENT
• • We do not us	e the followin	ng data for average	es, fits,	limits,	etc. • • •
582±36	1600	CLELAND	82B S	SPEC	\pm 50 $\pi p \rightarrow$
					K ⁰ S K± p
					Ū
•					
	EVTS				
• We do not use	e the followi	ng data for average	es, fits,	limits,	etc. • • •
851 + 27		ACHASOV	97 1	RVUE	$e^+e^- \to 2(\pi^+\pi^-)$
		7 CORDIER	82	DM1	a+a- \ 2(\pi+\pi-)
	34	KILLIAN			
.500		9 ATIYA	79B S	SPEC	
570± 60	65	¹⁰ ALEXANDER	75 I	HBC	$7.5 \gamma p \rightarrow p4\pi$
1550± 60		⁴ CONVERSI		OSPK	$e^+e^- \rightarrow 2(\pi^+\pi^-)$
.550 ± 50	160	SCHACHT	74 5	STRC	$5.5-9 \gamma p \rightarrow p4\pi$
430± 50	400	BINGHAM	72B i	HBC	$9.3 \gamma p \rightarrow p4\pi$
+ 	DE				
		DOCUMENT ID	:	TECN	COMMENT
• • We do not us	e the followi	ng data for average	es, fits,	limits,	etc. • • •
660±30		ATKINSON	85B (OMEG	20-70 γp
					.,
•	(x x x x x v				
• • We do not us	e the followi	ng data for averag	es, fits,	limits,	etc. • • •
1745.7±91.9 1546 ±26 1550 1550 1550 1550 1550 1550 1550 155					
two Brelt-Wigne ² T-matrix pole.	r fit.		with a ₁	(1260)	
⁵ From phase shift ⁴ Simple relativisti ⁵ An additional 40 choice of the bac	c Breit-Wign MeV uncer kground sha	er fit with constan rtainty in both the ope.	t width mass	n. and w	ldth is present due to the
Simple relativisti One peak fit resi	c Breit-Wign Jit.	er fit with model of	depende	ent wld	lth.
⁹ Parameters roug	hly estimate	d, not from a fit. ensated by Ross-S	todolsk	y facto	и.

ρ(1700) WIDTH

 $\eta \rho^0$ AND $\pi^+\pi^-$ MODES <u>VALUE (MeV)</u> **240±60 OUR ESTIMATE**

DOCUMENT ID

240±40 OUR AVERAGE Includes data from the 2 datablocks that follow this one. Error includes scale factor of 2.0. See the Ideogram below.



 $\rho (1700)$ width, $\eta \, \rho^0$ and $\pi^+ \, \pi^-$ modes (MeV)

$\eta \rho^0$	MODE
---------------	------

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
The data in this block is included	In the average pri	nted fo	r a pre	vious datablock.
150±30	ANTONELLI	88 C	DM2	$e^+e^- \rightarrow \eta \pi^+\pi^-$
282±44	¹¹ FUKUI	88 5	PEC	8.95 $\pi^- p \to \eta \pi^+ \pi^- n$

## MODE VALUE (MeV)		DOCUMENT ID		TECN	COMMENT
The data in this bloc	k is included				
275 ± 45		12 ABELE	97	CBAR	$\bar{p}n \rightarrow \pi^-\pi^0\pi^0$
310 ± 40		12 BERTIN	97C	OBLX	$0.0 \overline{p}_{P} \rightarrow \pi^{+}\pi^{-}\pi^{0}$
400 ±100		CLEGG	94	RVUE	$e^+e^- \rightarrow \pi^+\pi^-$
• • • We do not us	e the followi	ng data for average	s, fits,	limits,	etc. • • •
224 ± 22		BISELLO	89	DM2	$e^+e^- \rightarrow \pi^+\pi^-$
242.5 ± 163.0		DUBNICKA	89	RVUE	$e^+e^- \rightarrow \pi^+\pi^-$
620 ± 60		GESHKEN	89	RVUE	
<315		¹³ ERKAL	85	RVUE	$20-70 \gamma p \rightarrow \gamma \pi$
280 + 30 - 80		ABE	84B	HYBR	$20~\gamma p \rightarrow~\pi^+\pi^-p$
230 ± 80		¹⁴ ASTON	80	OMEG	$20-70 \gamma p \rightarrow p2\pi$
283 ± 14		15 ATIYA	79B	SPEC	$50 \gamma C \rightarrow C2\pi$
175 + 98 - 53		BECKER	79	ASPK	17 $\pi^- p$ polarized
232 ± 34		13 LANG	79	RVUE	
340		¹³ MARTIN		RVUE	$17 \pi^- p \to \pi^+ \pi^- n$
300 ±100		13 FROGGATT	77	RVUE	$17 \pi^- p \rightarrow \pi^+ \pi^- n$
180 ± 50		¹⁶ HYAMS		ASPK	$17 \pi^- p \rightarrow \pi^+ \pi^- n$
KK MODE					
VALUE (MeV)	EVT5	DOCUMENT ID		TECN	CHG COMMENT
• • • We do not us	e the followi	ng data for average	s, fits,	limits,	etc. • • •
265±120	1600	CLELAND	82B	SPEC	± 50 π p →
					K ⁰ K±p

$2(\pi^+\pi^-)$ MODE VALUE (MeV)

VALUE (MeV)	EVIS	DOCUMENT ID		TECN	COMMENT
• • We do not use th	e follow	ing data for average	s, fits	, limits,	etc. • • •
510± 40		17 CORDIER	82	DM1	$e^+e^- \rightarrow 2(\pi^+\pi^-)$
100± 50		¹⁴ ASTON	81E	OMEG	$20-70 \gamma p \rightarrow p4\pi$
100±146		¹⁸ DIBIANCA	81	DBC	$\pi^+ d \rightarrow pp2(\pi^+\pi^-)$
700±160		17 BACCI	80	FRAG	$e^+e^- \rightarrow 2(\pi^+\pi^-)$
100	34	KILLIAN	80	SPEC	$11 e^- p \rightarrow 2(\pi^+ \pi^-)$
500		19 ATIYA	79B	SPEC	$50 \gamma C \rightarrow C4\pi^{\pm}$
340±160	65	²⁰ ALEXANDER	75	HBC -	$7.5 \gamma p \rightarrow p4\pi$
360±100		14 CONVERSI	74	OSPK	$e^+e^- \rightarrow 2(\pi^+\pi^-)$
400±120	160	21 SCHACHT	74	STRC	$5.5-9 \gamma p \rightarrow p4\pi$
350±200	340	21 SCHACHT	74	STRC	$9-18 \gamma p \rightarrow p4\pi$
550±100	400	BINGHAM	72R	HBC	$9.3 \gamma p \rightarrow p4\pi$

VALUE (MeV)	DUCUMENT ID		IECN	COMME	<u>v/</u>
• • • We do not use the following	data for average	s, fits,	limits,	etc. • •	•
300±50	ATKINSON	85B (OMEG	20-70 -	γP

$3(\pi^{+}\pi^{-})$ AND $2(\pi^{+}\pi^{-})$	0\ MODES		
VALUE (MeV)	DOCUMENT	ID TECN	COMMENT
• • • We do not use the fe	ollowing data for a	verages, fits, lir	nits, etc. • • •
285 ± 20	CLEGG	90 RVUE	$e^+e^- \rightarrow 3(\pi^+\pi^-)2(\pi^+\pi^-\pi^0)$
two Breit-Wigner fit.	decay mode interf	eres with $a_1(1$	260) $^+\pi$ background. From a
12 T-matrix pole. 13 From phase shift analys	- of UVALAC 72 d	***	
¹⁴ Simple relativistic Breit			
	uncertainty in bot d shape.		d width is present due to the

- 16 Included in BECKER 79 analysis. 17 Simple relativistic Breit-Wigner fit with model-dependent width.
- 18 One peak fit result.

- 10 One peak fit result.

 19 Parameters roughly estimated, not from a fit.

 20 Skew mass distribution compensated by Ross-Stodolsky factor.

 21 Width errors enlarged by us to $4\Gamma/\sqrt{N}$; see the note with the $K^*(892)$ mass.

$\rho(1700)$ DECAY MODES

	Mode	Fraction (Γ_I/Γ)	
$\overline{\Gamma_1}$	ρππ	dominant	
Г2	$2(\pi^{+}\pi^{-})$	large	
Γ ₃	$\rho^0\pi^+\pi^-$	large	
Γ4	$\rho^0\pi^0\pi^0$		
Γ ₅	$\rho^{\pm}\pi^{\mp}\pi^{0}$	large	
Γ ₆	$\pi^+\pi^-$	seen	
Γ ₇	$\pi^-\pi^0$	seen	
Γ8	<i>K</i> K *(892) + c.c.	seen	
و۱	$\eta \rho$	seen	
Γ ₁₀	Ŕ Κ	seen	
Γ ₁₁	e^+e^-	seen	
Γ_{12}	$\pi^0\omega$	seen	

$\rho(1700) \Gamma(i)\Gamma(e^+e^-)/\Gamma(\text{total})$

This combination of a partial width with the partial width into $e^+\,e^-$ and with the total width is obtained from the cross-section into channel, in e^+e^- annihilation.

$\Gamma(2(\pi^+\pi^-)) \times \Gamma(e^+e^-)/$					$\Gamma_2\Gamma_{11}/\Gamma$
VALUE (keV)	DOCUMENT ID				
2.83±0.42	BACCI			e ⁺ e ⁻ →	$2(\pi^{+}\pi^{-})$
 We do not use the following 	-				
2.6 ±0.2	DELCOURT	818	DM1	e+ e- →	$2(\pi^{+}\pi^{-})$
$\Gamma(\pi^+\pi^-) \times \Gamma(e^+e^-)/\Gamma_{to}$					Γ ₆ Γ ₁₁ /Γ
VALUE (keV)	DOCUMENT ID		TECN		
• • We do not use the following					
0.13	²² DIEKMAN	88	RVUE	e+ e- →	$\pi^+\pi^-$
²² Using total width = 220 Me	v .				
$\Gamma(K\overline{K}^{\bullet}(892) + \text{c.c.}) \times \Gamma(e)$	+e-)/[Γ ₈ Γ ₁₁ /Γ
VALUE (keV)	DOCUMENT ID		TECN	COMMENT	0. 22/
• • • We do not use the followi			s, limits,	etc. • • •	
0.305±0.071	23 BIZOT		DM1		
$\Gamma(\eta \rho) \times \Gamma(e^+e^-)/\Gamma_{\text{total}}$					Γ ₉ Γ ₁₁ /Γ
VALUE (eV)	DOCUMENT ID		TECN	COMMENT	1 9: 11/1
7 ±3	ANTONELLI			e ⁺ e ⁻ →	$\eta \pi^+ \pi^-$
r(v7) ~ r(a+a-\/r					Γ ₁₀ Γ ₁₁ /Γ
$\Gamma(K\overline{K}) \times \Gamma(e^+e^-)/\Gamma_{\text{total}}$			TECH	COLUMENT	10111/1
VALUE (keV)	DOCUMENT ID			COMMENT	
• • We do not use the following	•				
0.035±0.029	²³ BIZOT	80	DM1	e ⁺ e ⁻	
$\Gamma(\rho\pi\pi) \times \Gamma(e^+e^-)/\Gamma_{\text{tota}}$	I				Γ ₁ Γ ₁₁ /Ι
	DOCUMENT ID		TECN	COMMENT	
VALUE (keV)		41+	e limite	. etc. • • •	
VALUE (keV) • • • We do not use the follow	ing data for averag	es, 11L	.5, 11111115	,	
	Ing data for averag ²³ BIZOT			e+e-	

/1700) DDANCUING DATIOS

ho(1700) BRANCHING RATIOS	
$\Gamma(\pi^+\pi^-)/\Gamma_{\text{total}}$	′Γ
VALUE DOCUMENT ID TECN COMMENT	
• • We do not use the following data for averages, fits, limits, etc. • • • • • • • • • • • • • • • • •	
0.287 + 0.043 BECKER 79 ASPK 17 π - p polarized	
0.15 to 0.30	
0.30 ±0.05	
<0.15 $ \begin{array}{ccccccccccccccccccccccccccccccccccc$	
 From phase shift analysis of HYAMS 73 data. Estimate using unitarity, time reversal invariance, Breit-Wigner. Estimated using one-pion-exchange model. Included in BECKER 79 analysis. 	
$\Gamma(\pi^+\pi^-)/\Gamma(2(\pi^+\pi^-))$ VALUE DOCUMENT ID TECH. COMMENT	2
• • • We do not use the following data for averages, fits, limits, etc. • • •	_
0.13 \pm 0.05 ASTON 80 OMEG 20–70 $\gamma p \rightarrow p2\pi$ <0.14 28 DAVIER 73 STRC 6–18 $\gamma p \rightarrow p4\pi$	
< 0.14 < 0 DAVIER 73 STRC 6-18 $γρ → ρ4π$ < 0.2 < 0.2 < 0.3 < 0.3 < 0.4 < 0.4 < 0.5 < 0.4 < 0.5 < 0.4 < 0.5 < 0.4 < 0.5 < 0.4 < 0.5 < 0.4 < 0.5 < 0.4 < 0.5 < 0.4 < 0.5 < 0.4 < 0.5 < 0.4 < 0.5 < 0.4 < 0.5 < 0.6 < 0.6 < 0.7 < 0.7 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8 < 0.8	
28 Upper limit is estimate. 29 $_{2\sigma}$ upper limit.	
$\Gamma(K\overline{K}^*(892) + c.c.)/\Gamma(2(\pi^+\pi^-))$ $\Gamma_8/$	2
• • • We do not use the following data for averages, fits, limits, etc. • • •	
0.15 \pm 0.03 30 DELCOURT 818 DM1 $e^+e^- \rightarrow \overline{K}K\pi$	
30 Assuming $ ho(1700)$ and ω radial excitations to be degenerate in mass.	
$\Gamma(\eta \rho)/\Gamma_{\text{total}}$	/Γ
VALUE CL% DOCUMENT ID TECN COMMENT <0.04 DONNACHIE 878 RVUE	
• • • We do not use the following data for averages, fits, limits, etc. • • •	
<0.02 58 ATKINSON 868 OMEG 20-70 γ p	
$\Gamma(\eta\rho)/\Gamma(2(\pi^+\pi^-))$ VALUE DOCUMENT ID TECN COMMENT	Γ ₂
0.123 \pm 0.027 DELCOURT 82 DM1 $e^+e^- \to \pi^+\pi^-$ MN \sim 0.1 ASTON 80 OMEG 20-70 γp	i
$\Gamma(\pi^+\pi^-\text{neutrals})/\Gamma(2(\pi^+\pi^-))$ $(\Gamma_4+\Gamma_5+0.714\Gamma_9)/\Gamma_4$	Γ ₂
2.6 \pm 0.4 31 BALLAM 74 HBC 9.3 γp	
31 Upper limit. Background not subtracted.	
$\Gamma(\pi^0\omega)/\Gamma_{\text{total}}$ VALUE DOCUMENT ID TECH COMMENT	/Γ
<u>VALUE</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u> • • • We do not use the following data for averages, fits, limits, etc. • •	_
seen ACHASOV 97 RVUE $e^+e^- ightarrow \omega \pi^0$	l
$\Gamma(K\overline{K})/\Gamma(2(\pi^+\pi^-))$	Γ,
VALUE CL% DOCUMENT ID TECN CHG COMMENT	_
• • • We do not use the following data for averages, fits, limits, etc. • •	
0.015 \pm 0.010 32 DELCOURT 81B DM1 $e^+e^- \rightarrow \overline{K}K$ <0.04 95 BINGHAM 72B HBC 0 9.3 γp	
³² Assuming ρ (1700) and ω radial excitations to be degenerate in mass. Γ($K\overline{K}$)/Γ($K\overline{K}$ *(892)+ c.c.)	Г
VALUE DOCUMENT ID TECH COMMENT	
• • • We do not use the following data for averages, fits, limits, etc. • • • 0.052 ± 0.026 BUON 82 DM1 $e^+e^- \rightarrow \text{hadrons}$	•
$\Gamma(\rho^0\pi^+\pi^-)/\Gamma(2(\pi^+\pi^-))$	г_
VALUE EVTS DOCUMENT ID TECN COMMENT • • • We do not use the following data for averages, fits, limits, etc. • • •	-
~ 1.0 DELCOURT 818 DM1 $e^+e^- \rightarrow 2(\pi^+\pi^-)$	
0.7 \pm 0.1 500 SCHACHT 74 STRC 5.5–18 $\gamma p \to p 4\pi$ 0.80 33 BINGHAM 72B HBC 9.3 $\gamma p \to p 4\pi$	
33 The $\pi\pi$ system is in <i>S</i> -wave.	
$\Gamma(\rho^0\pi^0\pi^0)/\Gamma(\rho^{\pm}\pi^{\mp}\pi^0)$ VALUE DOCUMENT ID TECH CHG COMMENT	Γ5
<0.10 ATKINSON 85B OMEG 20–70 γp <0.15	4π

Meson Particle Listings $\rho(1700)$, $f_J(1710)$

ρ(1700) REFERENCES

ABELE	97	PL B391 191	A. Abele, Adomeit, Amsler+ (Crystal Barrel Collab.)
ACHASOV	97	PR D55 2663	+Kozhevnikov+ (NOVM)
BERTIN	97C	PL B408 476	A. Bertin, Bruschi+ (OBELIX Collab.)
CLEGG	94	ZPHY C62 455	+Donnachie (LANC, MCHS)
CLEGG	90	ZPHY C45 677	+Donnachie (LANC, MCHS)
BISELLO	89	PL B220 321	+Busetto+ (DM2 Collab.)
DUBNICKA	89	JPG 15 1349	+Martinovic+ (JINR, SLOV)
GESHKEN	89	ZPHY 45 351	Geshkenbein (ITEP)
ANTONELLI	88	PL B212 133	+Baldini+ (DM2 Collab.)
DIEKMAN	88	PRPL 159 101	(BONN)
FUKUI	88	PL B202 441	+Horikawa+ (SUGI, NAGO, KEK, KYOT, MIYA)
DONNACHIE	87B	ZPHY C34 257	+Clegg (MCHS, LANC)
ATKINSON	86B	ZPHY C30 531	+ (BONN, CERN, GLAS, LANC, MCHS, CURIN+)
ATKINSON	85B	ZPHY C26 499	+ (BONN, CERN, GLAS, LANC, MCHS, CURIN+)
ERKAL	85	ZPHY C29 485	+Olsson (WISC)
ABE	84B		+Bacon, Ballam+ (SLAC Hybrid Facility Photon Collab.)
ATKINSON	82	PL 108B 55	+ (BONN, CERN, GLAS, LANC, MCHS, CURIN+)
BUON	82	PL 118B 221	+Bisello, Bizot, Cordier, Delcourt+ (LALO, MONP)
CLELAND	82B		+Delfosse, Dorsaz, Gloor (DURH, GEVA, LAUS, PITT)
CORDIER	82	PL 109B 129	+Bisello, Bizot, Buon, Delcourt (LALO)
DELCOURT	82	PL 113B 93	+Bisello, Bizot, Buon, Cordier, Mane (LALO)
ASTON	81E	NP B189 15	(BONN, CERN, EPOL, GLAS, LANC, MCHS+)
DELCOURT	81B		(ORSAY)
Also	82	PL 109B 129	Cordier, Bisello, Bizot, Buon, Delcourt (LALO)
DIBIANCA	81	PR D23 \$95	+Fickinger, Malko, Dado, Engler+ (CASE, CMU)
ASTON	80	PL 92B 215	(BONN, CERN, EPOL, GLAS, LANC, MCHS+)
BACCI	80	PL 95B 139	+DeZorzi, Penso, Baldini-Celio+ (ROMA, FRAS)
BIZOT	80	Madison Conf. 546	+Bisello, Buon, Cordier, Delcourt+ (LALO, MONP)
KILLIAN	80	PR D21 3005	+Treadwell, Ahrens, Berkelman, Cassel+ (CORN)
ATIYA	79B		+Holmes, Knapp, Lee, Seto+ (COLU, ILL, FNAL)
BECKER	79	NP B151 46	+Blanar, Blum+ (MPIM, CERN, ZEEM, CRAC)
LANG	79	PR D19 956	+Mas-Parareda (GRAZ)
MARTIN	78C	ANP 114 1	+Pennington (CERN)
COSTA	77B	PL 71B 345	Costa De Beauregard, Pire, Truong (EPOL)
FROGGATT	77	NP B129 89	
ALEXANDER	75	PL 57B 487	
BALLAM			
	74	NP B76 375	
CONVERSI	74	PL 52B 493	+Paoluzi, Ceradini, Grilli+ (ROMA, FRAS)
SCHACHT	74	NP B81 205	+Derado, Fries, Park, Yount (MPIM)
DAVIER	73	NP B58 31	+Derado, Fries, Liu, Mozley, Odian, Park+ (SLAC)
EISENBERG	73	PL 43B 149	+Karshon, Mikenberg, Pitluck+ (REHO)
HYAM5	73	NP B64 134	+Jones, Weilhammer, Blum, Dietl+ (CERN, MPIM)
BINGHAM	72B	PL 41B 635	+Rabin, Rosenfeld, Smadja+ (LBL, UCB, SLAC) IGJP

OTHER RELATED PAPERS -

BARNES	97	PR D55 4157	T. Barnes+	(ORNL, RAL, MCHS)
CLOSE	97C	PR D56 1584	F.E. Close+	(RAL, MCHS)
URHEIM	97	NPBPS 55C 359	J. Urheim	(CLEO Collab.)
ACHASOV	968	PAN 59 1262	+Shestakov	(NOVM)
7107111007	,,,,	Translated from YAF		(1104111)
AMSLER	93B	PL B311 362	+Armstrong, v.Dombre	owski+ (Crystal Barrel Collab.)
LANDSBERG	92	SJNP 55 1051	-	(SERP)
		Translated from YAF		
ASTON	91B		+Awaji, Bienz+	(LASS Collab.)
DONNACHIE	91	ZPHY C51 689	+Clegg	(MCHS, LANC)
ACHASOV	88C	PL B209 373	+Kozhevnikov	(NOVM)
BRAU	88	PR D37 2379	+Franek+	(SLAC Hybrid Facility Photon Collab.) JP
CLEGG	88	ZPHY C40 313	+Donnachie	(MCHS, LANC)
ASTON	87	NP B292 693	+Awaji, D'Amore+	(SLAC, NAGO, CINC, INUS)
ERKAL	86	ZPHY C31 615	+Olsson	(WISC)
BARKOV	85	NP B256 365	+Chilingarov, Eidelman	n, Khazin, Leichuk+ (NOVO)
ATKINSON	84C	NP B243 1	+ (BONN, CE	ERN, GLAS, LANC, MCHS, CURIN+) JP
ATKINSON	83B	PL 127B 132	+ (BONN, CI	ERN, GLAS, LANC, MCHS, CURIN+)
ATKINSON	83C	NP B229 269		ERN, GLAS, LANC, MCHS, CURIN+)
AUGUSTIN	83	LAL 83-21	+Ayach, Bisello, Baldi	
SHAMBROOM	82	PR D26 1	+Wilson, Anderson, Fr	
ASTON	BOC	PL 92B 211		ERN, EPOL, GLAS, LANC, MCHS+)
BARBER	80C	ZPHY C4 169	+Dainton, Brodbeck,	
KILLIAN	80	PR D21 3005	+Treadwell, Ahrens, B	
COSME	76	PL 63B 352		orelaud, Jean-Marie+ (ORSAY)
FRENKIEL	72	NP B47 61	+Ghesquiere, Lillestol,	
ALVENSLEB	71	PRL 26 273		Bertram, Chen+ (DESY, MIT) G
BRAUN	71	NP B30 213	+Fridman, Gerber, Giv	
BULOS	71	PRL 26 149	+Busza, Kehoe, Benis	
LAYSSAC	71	NC 6A 134	+Renard	(MONP)
				(

 $f_J(1710)$

 $I^G(J^{PC}) = 0^+(\text{even}^{++})$

THE $f_J(1710)$

Written March 1998 by M. Doser (CERN).

The $f_J(1710)$ is seen in the radiative decay $J/\psi(1S) \rightarrow \gamma f_J(1710)$; therefore C=+1. It decays into 2η and $K_S^0 K_S^0$, which implies $I^G J^{PC}=0^+(\text{even})^{++}$. The spin of the $f_J(1710)$ is controversial. Combined amplitude analyses of the K^+K^- , K_SK_S and $\pi^+\pi^-$ systems produced in $J/\psi(1S)$ radiative decay (in recent and some earlier unpublished analyses by the Mark III Collaboration) find a large spin-0 component, as well as reproducing known parameters of the $f_2(1270)$ and $f_2'(1525)$. A recent reanalysis (BUGG 95) of the 4π channel from MARK III, allowing both $\rho\rho$ and two $\pi\pi$ S waves, finds two states, a 0^{++} at ~ 1750 MeV and a 2^{++} at ~ 1620 MeV. Earlier analyses of the $\rho\rho$ final state (BISELLO 89B, BALTRU-SAITIS 86B) found only pseudoscalar activity in the $f_J(1710)$

region, but considered only the process $J/\psi(1S) \to \gamma\rho\rho$. In contrast, a spin 2 was found for the $f_J(1710)$ in earlier analyses of the $\eta\eta$ (BLOOM 83) or K^+K^- (BALTRUSAITIS 87) systems based on less statistics. More recently, an analysis of the K^+K^- channel finds indications for a lower mass tensor as well as a higher mass scalar state (BAI 96C).

In pp central production at 300 GeV/c in both K^+K^- and $K_S^0K_S^0$, $f_J(1710)$ is definitely spin 2 (ARMSTRONG 89D). More recent analyses with greater statistics (E690 Collaboration, unpublished) are, however, not able to differentiate between spin 0 and 2. Generally, analyses preferring spin 2 concentrate on angular distributions in the $f_J(1710)$ region, and do not include possible interferences or distortion due to the nearby $f_Z'(1525)$.

The $f_J(1710)$ is also observed in $K\overline{K}$ (FALVARD 88) in $J/\psi(1S) \to \omega K\overline{K}$ and $J/\psi(1S) \to \phi K\overline{K}$, but with no spin-parity analysis. ARMSTRONG 93C also sees a broad peak at 1747 MeV in $p\overline{p}$ annihilation into $\eta\eta$, which may be the $f_J(1710)$. This resonance is not observed in the hypercharge-exchange reactions $K^-p \to K_S^0K_S^0\Lambda$ (ASTON 88D) and $K^-p \to K_S^0K_S^0\Lambda^*$ (BOLONKIN 86).

A partial-wave analysis of the $K_S^0K_S^0$ system in $\pi^-p \to K_S^0K_S^0n$ (BOLONKIN 88) finds a D_0 -wave behavior ($J^{PC}=2^{++}$) near 1700 MeV, but the width (~ 30 MeV) is much smaller than those observed in $J/\psi(1S)$ decays and in hadroproduction. The 0^{++} wave shows, however a broad enhancement around 1720 MeV.

f_(1710) MASS

VALUE (MeV)	DOCUMENT ID		COMMENT
1712± 5 OUR AVERAGE	Error includes scale fa	ctor of 1.1.	
1713±10			300 pp → ppK+K-
1706±10	¹ ARMSTRONG	89D OMEG	$300 pp \rightarrow ppK_S^0K_S^0$
1707 ± 10	² AUGUSTIN	88 DM2	$J/\psi \rightarrow \gamma K^+ K^-$
			$J/\psi \to \gamma K^+ K^-, K_S^0 K_S^0$
1698±15	² AUGUSTIN		
$1720 \pm 10 \pm 10$			$J/\psi \rightarrow \gamma K^+ K^-$
1742±15	² WILLIAMS	84 MPSF	$200 \pi^{-} N \rightarrow 2K_{5}^{0} X$
1670±50	BLOOM	83 CBAL	
• • We do not use the follow	wing data for averages	i, fits, limits,	etc. • • •
1704^{+16}_{-23}	4 DUNWOODIE	97	$J/\psi \rightarrow K\overline{K}, \pi\pi$
1690±11	5 ABREU	96C DLPH	$\gamma \gamma \rightarrow K^+ K^- E_{cm}^{ee} =$
	_		91.2 GeV
1696± 5+9	³ BAI	96C BES	$J/\psi \rightarrow \gamma K^+ K^-$
$1781 \pm 8^{+10}_{-31}$	⁶ BAI	96C BES	• • •
1768 ± 14	BALOSHIN	95 SPEC	$40 \pi^- C \rightarrow K_S^0 K_S^0 X$
1750±15	7 BUGG	95 MRK3	$J/\psi \rightarrow \gamma \pi^+ \pi^- \pi^+ \pi^-$
1620±16	³ BUGG		$J/\psi \rightarrow \gamma \pi^+ \pi^- \pi^+ \pi^-$
1748 ± 10	² ARMSTRONG		
~ 1750	BREAKSTONE	93 SFM	PP →
	0		ppπ ⁺ π ⁻ π ⁺ π ⁻
1744 ± 15	8 ALDE	92D GAM2	
1700 ± 15	3 BOLONKIN	88 SPEC	
1720±60	6 BOLONKIN	88 SPEC	' 33
1638±10	⁹ FALVARD	88 DM2	$J/\psi \rightarrow \phi K^+ K^-$,
	10		Kg Kg
1690± 4	10 FALVARD	88 DM2	$J/\psi \rightarrow \phi K^+ K^-,$ $K_S^0 K_S^0$
1730 + 2	¹¹ LONGACRE	86 RVUE	22 π ⁻ p → n2K ⁰ _S
1650 ± 50	BURKE	82 MRK2	$J/\psi ightarrow \gamma 2 ho$
1640±50 ·	12,13 EDWARDS	820 CBAL	
1730±10±20	¹⁴ ETKIN	82c MPS	23 π p → π2K ⁰ _S
$^{1}J^{P}=2^{+}$, (0+ excluded).			
² No J^{PC} determination. ³ $J^{P} = 2^{+}$.			
$^{3}J^{P}=2^{+}.$			

	_
$^4J^P=0^+$, reanalysis of MARK III data. $^5No\ J^PC$ determination, width not determined. $^6J^P=0^+$.	
7 From a fit to the 0 ⁺ partial wave.	
8 ALDE 92D combines all the GAMS-2000 data, 9 From an analysis ignoring interference with f_{2}^{\prime} (1525).	
¹⁰ From an analysis including interference with $f_2'(1525)$.	
11 Uses MRK3 data. From a partial-wave analysis of data using a K-matrix formalism with 5 poles, but assuming spin 2. Fit with constrained inelasticity. $^{12}J^P=2^+$ preferred.	, j
13 From fit neglecting nearby f'_2 (1525). Replaced by BLOOM 83.	ı
14 Superseded by LONGACRE 86.	ı

				f	(1710) WID)ر	TH		
ALUE (CL%		DOCUMENT ID		TECN	COMMENT
133	±	14	OUR AVERAG		rror includes sca			
181	±			10	ARMSTRONG	89 D	OMEG	$300 pp \rightarrow ppK^{+}K^{-}$
104	Ŧ	30						$300 pp \rightarrow ppK_5^0K_5^0$
166.	1 ±	33.2	!		AUGUSTIN	88	DM2	$J/\psi \to \gamma K^+ K^-, K_S^0 K_S^0$
136	±	28			AUGUSTIN	87	DM2	$J/\psi \rightarrow \gamma \pi^+ \pi^-$
130	±	20			BALTRUSAIT.	.87	MRK3	$J/\psi \rightarrow \gamma K^+ K^-$
57	±	38		2	WILLIAMS	84	MPSF	$200 \pi^- N \rightarrow 2K_S^0 X$
160	ŧ				BLOOM	83	CBAL	$J/\psi o \gamma 2\eta$
• •	We		ot use the follow	ving c	ata for average	s, fits	, limits,	etc. • • •
124	+	52 44	+30		DUNWOODIE			$J/\psi \to K\overline{K}, \pi\pi$
103	±	18	-11	17	BAI	96 C	BES	$J/\psi \rightarrow \gamma K^+ K^-$
85		24	+22 -19	19	BAI		BES	$J/\psi \rightarrow \gamma K^+ K^-$
56	±				BALOSHIN	95	SPEC	$40 \pi^{-} C \rightarrow K_{5}^{0} K_{5}^{0} X$
160	±				BUGG	95	MRK3	, , , , , , , , , , , , , , , , , , , ,
160	+	60 20		17	BUGG	95	MRK3	$J/\psi \rightarrow \gamma \pi^+ \pi^- \pi^+ \pi^-$
264	±	25		16	ARMSTRONG	93C	E760	$\overline{p}p \rightarrow \pi^0 \eta \eta \rightarrow 6\gamma$
200	to	300			BREAKSTON		SFM	$\rho p \rightarrow$
								$pp\pi^{+}\pi^{-}\pi^{+}\pi^{-}$
< 80			90		ALDE		GAM2	$38 \pi^- p \rightarrow \eta \eta N^*$
30	±	20			BOLONKIN	88	SPEC	$40 \pi^- p \to K_5^0 K_5^0 n$
350	±:	150			BOLONKIN	88	SPEC	$40 \pi^- p \rightarrow K_S^0 K_S^0 n$
148	±	17		22	FALVARD	88	DM2	$J/\psi \to \phi K^+ K^-,$ $K_S^0 K_S^0$
184	±	6		23	FALVARD	88	DM2	$J/\psi \xrightarrow{3} \phi K^{+} K^{-},$ $K_{S}^{0} K_{S}^{0}$
122		74 15		24	LONGACRE	86	RVUE	$22 \pi^- p \rightarrow n2K_S^0$
200		100			BURKE	82	MRK2	$J/\psi \rightarrow \gamma 2\rho$
220	+1	100		25,26	EDWARDS		CBAL	$J/\psi \rightarrow \gamma 2\eta$
200.		70 156.0 9.0)		ETKIN		MPS	$23 \pi^{-} p \rightarrow n2K_{5}^{0}$
15 ,P	_	2+ 2	(O+ evoluded)					J
16 No	JΡ	C de	termination.					
17 JP 18 JP	=	2+.			11			
19 _I P	=	υ', n+	reanalysis of MA	AKK I	ii data.			
[∠] Fro	m a	ı fit 1	to the O⊤ partia	ıl wav	e.			
ZI AI	DE	92n	combines all the	GAN	45-2000 data			
Fro	m a	au st	ialysis ignoring i	nterfe	rence with f' ₂ (1	525)	•	
Fro	m a	in an	alysis including	interf	erence with f_2'	1525).	
5 r	oles	: hii	t assuming spin	artial 2. Fi	-wave analysis o with constrain	of dat ed in	a using elasticity	a K-matrix formalism wit
26 e	=	2 [™] [oreferred. glecting nearby	el (1=	(2E) Pontaged	DI	0014.9	2
		и пе					LICION H	

	f _J (1710) DECAY MODES
М	lode	Fraction (Γ_I/Γ)
ĸ	K	seen
η	η	seen
π	π	seen
ρ	ρ	
γ	γ	

	',	(*** ***) * (*)* (7 7);		,,,,		
$\Gamma(K\overline{K}) \times \Gamma(\gamma\gamma)/\Gamma_{\gamma}$	total					$\Gamma_1\Gamma_5/\Gamma$
VALUE (keV)	CL%	DOCUMENT ID		TECN	COMMENT	
<0.11	95	28 BEHREND	89c	CELL	YY - KOKO	
• • • We do not use th	e follov	ving data for average	s, fits	, limits,	etc. • • •	
< 0.48	95	ALBRECHT			$\gamma\gamma \rightarrow K^+K^-$	
<0.28	95	²⁸ ALTHOFF	85B	TASS	$\gamma\gamma \to K\overline{K}\pi$	
²⁸ Assuming helicity 2.						

	$f_J(1710)$ BRANCHING RATIOS	
Γ(KK)/Γ _{total}		Γ ₁ /Γ
VALUE ■ ■ We do no	DOCUMENT ID TECN COMME t use the following data for averages, fits, limits, etc. • •	
0.38 ^{+0.09} _{-0.19}		$p \rightarrow n2K_S^0$
$\Gamma(\eta\eta)/\Gamma_{\text{total}}$		Γ ₂ /Γ
VALUE	DOCUMENT ID TECN	
	et use the following data for averages, fits, limits, etc. • •	•
$0.18^{+0.03}_{-0.13}$	^{29,30} LONGACRE 86 RVUE	
Γ(ππ)/Γ _{total}	DOCUMENT ID TECN	Γ_3/Γ
	t use the following data for averages, fits, limits, etc. •	• •
$0.039^{+0.002}_{-0.024}$	^{29,30} LONGACRE 86 RVUE	
$\Gamma(\pi\pi)/\Gamma(K\overline{k})$		Γ_3/Γ_1
VALUE	DOCUMENT ID TECN COMME	
0.39±0.14	ARMSTRONG 91 OMEG 300 p.p.l p.p.l	
Γ(ηη)/Γ(KK	CL% DOCUMENT ID TECN COMME	Γ_2/Γ_1
	of use the following data for averages, fits, limits, etc.	
< 0.02	21	$p \rightarrow \pi^- p \eta \eta$
suming spin 30 Fit with con	ial-wave analysis of data using a K-matrix formalism wit	h 5 poles, but as-
	f _J (1710) REFERENCES	
DUNWOODIE 97	Hadron 97 Conf. W. Dunwoodie	(SLAC)
ABREU 960 BAI 960	PRL 77 3959 J.Z. Bai+	(DELPHI Collab.) (BES Collab.)
BALOSHIN 95	PAN 58 46 +Bolonkin, Vladimirskii+ Translated from YAF 58 50.	(ITEP)
BUGG 95 ARMSTRONG 930	PL B353 378 +Scott, Zoli+ (LOQ PL B307 394 +Bettoni+ (FNAL, FERR, GEN ZPHY C58 251 +Campanini+ (IOWA, CERN, DORT	M, PNPI, WASH) O. UCI. NWES+)
BREAKSTONE 93 ALDE 920	ZPHY C58 251 +Campanini+ (IOWA, CERN, DORT PL B284 457 +Binon, Bricman+	, HEIDH, WARS) (GAM2 Collab.)
Also 91	SJNP 54 451 Alde, Binon, Bricman+	(GAM2 Collab.)
ARMSTRONG 91 PROKOSHKIN 91	Translated from YAF 54 745. ZPHY C51 351 +Benayoun+ (ATHU, BARI, BIRI SPD 36 155 (GAM Translated from DANS 316 900.	M, CERN, CDEF) 2, GAM4 Collab.)
ALBRECHT 900	5 ZPHY C48 183 +Ehrlichmann, Harder+	(ARGUS Collab.)
BEHREND 890	ZPHY C43 91 +Criegee, Dainton+	(CELLO Collab.)
AUGUSTIN 88 BOLONKIN 88	PRL 60 2238 + Calcaterra+ NP B309 426 + Bioshenko, Gorin+	(DM2 Collab.) (ITEP, SERP)
FALVARD 88 AUGUSTIN 87	PR D38 2706	S, LALO, PADO) R, FRAS, PADO)
BALTRUSAIT 87	PR D35 2077 Baltrusaitis, Coffman, Dubois+	(Mark III Collab.)
LONGACRE 86 ALTHOFF 85E	PL B177 223 +Etkin+ (BNL, BRAN, CUNY ZPHY C29 189 +Braunschweig, Kirschfink+	(TASSO Collab.)
WILLIAMS 84 BLOOM 83	PR D30 877	S, ARIZ, FNAL+) (SLAC, CIT)
BURKE 82	PRL 49 632 + Trilling, Abrams, Alam, Blocker+	(LBL, SLAC)
EDWARDS 820 ETKIN 825	D PRL 48 458 +Partridge, Peck+ (CIT, HARV, PR B PR D25 1786 +Foley, Lai+ (BNL, CUNY)	IN, STAN, SLAC) , TUFTS, VAND) , TUFTS, VAND)
ETKIN 820	PR D25 2446 +Foley, Lai+ (BNL, CUNY) OTHER RELATED PAPERS	, (UF15, VAND)
ANISOVICH 97	PL B395 123 +Sarantsev	(PNPI)
BISELLO 89E ASTON 88E	B PR D39 701 Busetto+	(DM2 Čollab.) GO, CINC, INUS)
AKESSON 86	NP B264 154 +Albrow, Almehed+ (Axial Fig.	eld Spec. Collab.)
ARMSTRONG 866 BALTRUSAIT 866	B PR D33 1222 Baltrusaitis, Coffman, Hauser+	RI, BIRM, CERN) (Mark III Collab.)
ALTHOFF 83 BARNETT 83E	PL 121B 216 +Brandelik, Boerner, Burkhardt+	(TASSO Collab.) (JHU)
ALTHOFF 82	ZPHY C16 13 +Boerner, Burkhardt+	(TASSO Collab.)
BARNES 82 BARNES 828 TANIMOTO 82	PL B116 365 +Close 8 NP B198 360 +Close, Monaghan PL 116B 198	(RHEL) (RHEL, OXFTP) (BIEL)
		\ <i>)</i>

 $\eta(1760), X(1775), \pi(1800)$

 $\eta(1760)$

$$I^{G}(J^{PC}) = 0^{+}(0^{-})$$

OMITTED FROM SUMMARY TABLE

Seen by DM2 in the $\rho\rho$ system (BISELLO 89B). Structure in this region has been reported before in the same system (BALTRUSAITIS 86B) and in the $\omega\omega$ system (BALTRUSAITIS 85C, BISELLO 87). Needs confirmation.

n(1760)	MASS

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT	_
1760±11	320	1 BISELLO	898 DM2	$J/\psi \rightarrow 4\pi\gamma$	
1					

1 Estimated by us from various fits.

η(1760) WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID T	ECN	COMMENT
60±16	320	² BISELLO 89B D	M2	$J/\psi \rightarrow 4\pi\gamma$

² Estimated by us from various fits.

η(1760) REFERENCES

BISELLO	89B	PR D39 701
BISELLO	87	PL B192 239
BALTRUSAIT	86B	PR D33 1222
BALTRUSAIT	85C	PRL 55 1723

Busetto+
Ajaltouni, Baldini+
Ajaltouni, Baldini+
Baltrusaitis, Coffman, Hauser+
(CIT, UCSC, ILL, SLAC, WASH)

X(1775)

$$I^{G}(J^{PC}) = 1^{-}(?^{-})$$

OMITTED FROM SUMMARY TABLE Needs confirmation.

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1776±13 OUR AVERAGE				
1763±20	COŃDO	91	SHF	$\gamma p \rightarrow$
1787±18	CONDO	91	SHF	$\gamma \rho \to n \pi^+ \pi^+ \pi^-$

X(1775) WIDTH

VALUE (MeV) 155±40 OUR AVERAGE	DOCUMENT ID		TECN	COMMENT
192±60	CONDO	91	SHF	$\gamma p \rightarrow (-+)(-+)$
118±60	CONDO	91	SHF	$\begin{array}{c} (p\pi^+)(\pi^+\pi^-\pi^-) \\ \gamma p \to n\pi^+\pi^+\pi^- \end{array}$

X(1775) DECAY MODES

	Mode	
Γ ₁ Γ ₂	$\rho \pi f_2(1270) \pi$	

X(1775) BRANCHING RATIOS

$\Gamma(\rho\pi)/\Gamma(f_2(1270)\pi)$				Γ1,	/Γ2
VALUE	DOCUMENT ID		TECN	COMMENT	
1.43±0.26 OUR AVERAGE					
1.3 ±0.3	CONDO	91	SHF	$\gamma p \rightarrow$	•
				$(p\pi^+)(\pi^+\pi^-\pi^-$)
1.8 ±0.5	CONDO	91	SHF	$(p\pi^+)(\pi^+\pi^-\pi^-$ $\gamma p \rightarrow n\pi^+\pi^+\pi^-$	•

X(1775) REFERENCES

CONDO	91	PR D43 2787	+Handler+	(SLAC Hybrid Collab.)

 $\pi(1800)$

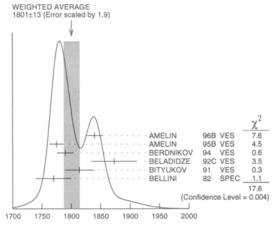
$$I^G(J^{PC}) = 1^-(0^{-+})$$

See also minireview under non- $q\overline{q}$ candidates. (See the index for the page number.)

π (1800) MASS

,					
VALUE (MeV)	EVTS	DOCUMENT ID	TE	CN CHG	COMMENT
1801 ± 13 OUR AVER	AGE Erro	r includes scale fac	tor of 1.	9. See the	ideogram below.
1840±10±10	1200	AMELIN	96B V	S -	$\begin{array}{c} 37 \ \pi^- A \rightarrow \\ \eta \eta \pi^- A \end{array}$
1775± 7±10		¹ AMELIN	958 VE	:S –	$\begin{array}{c} 36 \pi^{-} A \rightarrow \\ \pi^{+} \pi^{-} \pi^{-} A \end{array}$
1790±14		² BERDNIKOV	94 VI	S –	$\begin{array}{c} 37 \ \pi^- A \rightarrow \\ K^+ K^- \pi^- A \end{array}$
1873±33±20		BELADIDZE	92C V	:s -	36 π^- Be $\rightarrow \pi^- \eta' \eta$ Be
1814±10±23	426± 57	BITYUKOV	91 VI	S –	$ \begin{array}{c} 36 \ \pi^{-} C \rightarrow \\ \pi^{-} \eta \eta C \end{array} $
1770±30	1100	BELLINI	82 SF	EC -	$40 \pi^- A \rightarrow 3\pi A$

 1 From a fit to $J^{PC}=0$ $^{-}+$ $f_0(980)\pi,$ $f_0(1370)\pi$ waves. 2 From a fit to $J^{PC}=0$ $^{-}+$ $K_0^*(1430)K^-$ and $f_0(980)\pi^-$ waves.



 π (1800) mass (MeV)

310±50

π(1800) WIDTH							
VALUE (MeV) 210±15 OUR AVERAGE	_ <u>ΕὐΤ\$</u> Ι Ε	DOCUMENT ID	TECN	CHG	COMMENT		
210±30±30	1200	AMELIN	96B VES	-	$\begin{array}{c} 37 \ \pi^- A \rightarrow \\ \eta \eta \pi^- A \end{array}$		
190±15±15		3 AMELIN	958 VES	-	$36 \pi^{-} A \rightarrow \pi^{+} \pi^{-} \pi^{-} A$		
210±70		⁴ BERDNIKOV	94 VES		$37 \pi^{-} A \rightarrow K^{+} K^{-} \pi^{-} A.$		
225±35±20		BELADIDZE	92C VE6	-	$36 \pi^- Be \rightarrow$		
205±18±32	426± 57	BITYUKOV	91 VES	-	$\pi^- \eta' \eta \text{ Be}$ 36 $\pi^- C \rightarrow \pi^- \eta \eta C$		

82 SPEC -

³ From a fit to $J_{--}^{PC} = 0^{-+} f_0(980)\pi$, $f_0(1370)\pi$ waves.

1100

4 From a fit to $J^{PC} = 0^{-} + K_0^*(1430)K^-$ and $f_0(980)\pi^-$ waves.

π (1800) DECAY MODES

BELLINI

	Mode	Fraction (Γ_I/Γ)
$\overline{\Gamma_1}$	π+π-π-	seen
Γ_2	$f_0(980)\pi^-$	seen
Гз	$f_0(1370)\pi^-$	seen
Γ_4	$\rho\pi^-$	not seen
Γ_5	$\eta\eta\pi^-$	seen
Γ6	$a_0(980)\eta$	seen
Γ7	$f_0(1500)\pi^-$	seen
Гв	$\eta \eta'(958) \pi^-$	seen
و۲	K*(1430) K-	seen
Γ ₁₀	K*(892) K	not seen

		π(180	0) BRANCHING	G RA	TIOS		
Γ(%(98 0):	r")/	Γ(f ₀ (1370)π ⁻	-)				Γ_2/Γ_3
VALUE			DOCUMENT ID		<u>TECN</u>	CHG	COMMENT
l.7±1.3			AMELIN	95B	VES	-	$\begin{array}{c} 36 \ \pi^- A \rightarrow \\ \pi^+ \pi^- \pi^- A \end{array}$
(&(1370) /ALUE) = ")	/Γ _{total}	DOCUMENT ID		TECN	снс	Γ ₃ /Γ
100/1			BELLINI	82	SPEC	_	$40 \pi^- A \rightarrow 3\pi A$
Γ (ηηπ⁻) / VALUE	/Г(л	+π-π-) <u>εντς</u>	DOCUMENT ID		TECN	<u>CHG</u>	Γ ₅ /Γ ₁
0.5 ±0.1		1200	AMELIN	96 B	VES	_	37 π ⁻ A → ηηπ ⁻ A
Γ (%(1500))π ⁻)	/Γ(a ₀ (980)η)	1				77. Ω Γ ₇ /Γ ₆
VALUE		<u>EVTS</u>	DOCUMENT ID		<u>TECN</u>	<u>CHG</u>	COMMENT
0.08 ±0.03		1200	⁵ AMELIN	96B	VES	-	$37 \pi^- A \rightarrow \eta \eta \pi^- A$
⁵ Assumin	g tha	t f ₀ (1500) decay	s only to $\eta\eta$ and .	a ₀ (98	0) deca	ys only	
Γ(ηη'(9 58)π ⁻)/Γ(ηηπ ⁻)					Γ_8/Γ_5
VALUE		<u>EVTS</u>	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT
0.29±0.06	OUR	AVERAGE	DELADIDAE	026	VEC		36 - Po
0.29±0.07			BELADIDZE	92C	VES	-	$\pi - \eta' \eta Be$
0.3 ±0.1		426± 57	BITYUKOV	91	VES	-	36 π^- Be \rightarrow $\pi^- \eta' \eta$ Be 36 π^- C \rightarrow $\pi^- \eta \eta$ C
Γ(<i>K</i> °(143	0) K	-)/Γ _{total}	DOCUMENT ID		<u>TECN</u>	<u>CHG</u>	٦٩/٢
VALUE Deen			DOCUMENT ID BERDNIKOV	94	VES	-	$\begin{array}{c} 37 \ \pi^- A \rightarrow \\ K^+ K^- \pi^- A \end{array}$
							$K^+K^-\pi^-A$
Γ(<i>K</i> *(892) <i>K</i> =)/F _{total}					Γ ₁₀ /Γ
VALUE			DOCUMENT ID				COMMENT
	ю пот	use the followin	g data for average			etc.	
not seen			BERDNIKOV	94	VES	_	$\begin{array}{c} 37 \ \pi^- A \rightarrow \\ K^+ K^- \pi^- A \end{array}$
Γ (ρπ)/ Γ	(f ₀ (980)π ⁻)	DOCUMENT ID		TECN	СНС	Γ ₄ /Γ ₂
	lo not		g data for average	s, fits			
<0.14		90	AMELIN	95B	VES	-	$\begin{array}{c} 36 \ \pi^- A \rightarrow \\ \pi^+ \pi^- \pi^- A \end{array}$
Γ(ρπ ⁻)/Γ	total						Γ ₄ /Γ
VALUE			DOCUMENT ID		TECN	CHG	COMMENT
not seen			BELLINI	82	SPEC	-	40 π ⁻ A → 3π A
		π	(1 800) REFERE	ENC	ES		
AMELIN	96B	PAN 59 976 Translated from Y	+Berdnikov, Bity	rukov+			(SERP, TBIL) IGJP
AMELIN BERDNIKOV	95B 94	PL B356 595 PL B337 219 SJNP 55 1535	+Berdnikov, Bity +Bityukov+				(SERP, TBIL) (SERP, TBIL) (SERP, TBIL)
BELADIDZE	92C 91	Translated from Y. PL B268 137	+Borisov+			,,	(SERP, TBIL)
BELLINI	82	PRL 48 1697	+Frabetti, Ivansi HER RELATED			(1	MILA, BGNA, JINR)
	•				ENJ		(5500)
BORISOV	92	SJNP 55 1441	+Gershtein, Zait AF 55 2583.	sev			(SERP)

$f_2(1810)$

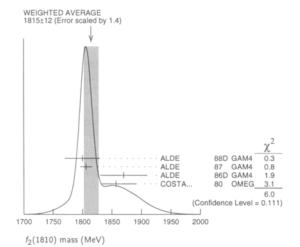
 $I^{G}(J^{PC}) = 0^{+}(2^{+})$

OMITTED FROM SUMMARY TABLE

Needs confirmation.

£(1810) MASS

VALUE (MeV)	EVTS	DOCUMENT ID		CN	COMMENT
1815±12 OUR AVE	RAGE Erro	r includes scale fac			e the ideogram below.
1800 ± 30	40	ALDE			$300 \pi^- p \rightarrow \pi^- p 4\pi^0$
1806 ± 10	1600	ALDE	87 GA	\M 4	$100 \ \pi^- p \rightarrow 4\pi^0 n$
1870±40		1 ALDE	86D GA	AM4	100 $\pi^- p \rightarrow \eta \eta \eta$
$1857 + 35 \\ -24$		² COSTA	80 OR	MEG	10 $\pi^- p \rightarrow K^+ K^- n$
• • • We do not us	e the following	ng data for average	es, fits, Ili	mits,	etc. • • •
$1858 ^{+\ 18}_{-\ 71}$		³ LONGACRE	86 R\	/UE	Compliation
1799±15		⁴ CASON	82 ST	RC	$8 \pi^+ p \rightarrow \Delta^{++} \pi^0 \pi^0$



£(1810) WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
197± 22 OUR AVE	RAGE Erro	Includes scale fac	tor of	1.5. Se	e the ideogram below.
160± 30	40	ALDE			$300 \pi^- p \rightarrow \pi^- p 4 \pi^0$
190± 20 .	1600	ALDE	87	GAM4	$100 \pi^- p \rightarrow 4\pi^0 n$
250± 30		⁵ ALDE	86 D	GAM4	$100 \pi^- p \rightarrow \eta \eta n$
185^{+102}_{-139}		6 COSTA	80	OMEG	$10 \pi^- p \rightarrow K^+ K^- n$
• • • We do not us	e the followin	g data for average	es, fits	, ilmits,	etc. • • •
388 ⁺ 15		7 LONGACRE	86	RVUE	Compilation
280 ⁺ 42 - 35		8 CASON	82	STRC	$8 \pi^+ p \rightarrow \Delta^{++} \pi^0 \pi^0$

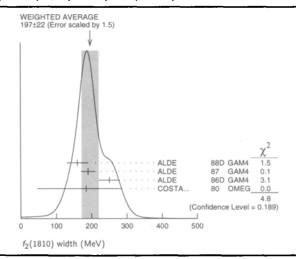
⁵ Seen in only one solution.

¹ Seen in only one solution.
2 Error increased by spread of two solutions. Included in LONGACRE 86 global analysis.

From an amplitude analysis of the reaction $\pi^+\pi^- \to 2\pi^0$. The resonance in the $2\pi^0$ final state is not confilmed by PROKOSHKIN 97.

Seen in only one solution. 6 Error increased by spread of two solutions. Included in LONGACRE 86 global analysis. 7 From a partial-wave analysis of data using a K-matrix formalism with 5 poles. Includes compilation of several other experiments. 8 From an amplitude analysis of the reaction $\pi^+\pi^- \to 2\pi^0$. The resonance in the $2\pi^0$ final state is not confirmed by PROKOSHKIN 97.

 $f_2(1810), \phi_3(1850), \eta_2(1870)$



f2(1810) DECAY MODES

	Mode	Fraction (Γ _I /Γ)
Γ ₁ Γ ₂	π π η η	
Γ ₃ Γ ₄	ηη 4π ⁰ Κ+ Κ-	seen

&(1810) BRANCHING RATIOS

5	(1810) BRANCHIN	IG R	ATIO5		
Γ(ππ)/Γ _{total} VALUE	DOCUMENT ID		TECN	COMMENT	Γ1/Γ
• • We do not use the folk					
not seen	-			38 π − ρ → π	0 , 0 ,
0.21 + 0.02	9 LONGACRE	86	RVUE	Compilation	
0.44±0.03	10 CASON	82	STRC	8π ⁺ ρ → Δ	++ +0 +0
⁹ From a partial-wave analy compilation of several oth ¹⁰ Included in LONGACRE 8	er experiments.	matr	ix formal	ism with 5 pole	s, Include
$\Gamma(\eta\eta)/\Gamma_{\text{total}}$					Γ2/Γ
VALUE	DOCUMENT ID		TECN	COMMENT	
 We do not use the following 	owing data for average	es, fit	s, Ilmits,	etc. • • •	
$0.008^{+0.028}_{-0.003}$	9 LONGACRE	86	RVUE	Compilation	
$\Gamma(\pi\pi)/\Gamma(4\pi^0)$					Γ1/Γ:
VALUE	DOCUMENT ID		TEÇN	COMMENT	
 We do not use the folk 	owing data for average	es, flt	s, ilmits,	etc. • • •	
<0.75	ALDE	87	GAM4	100 $\pi^- p \rightarrow$	4π ⁰ π
$\Gamma(4\pi^0)/\Gamma(\eta\eta)$					Γ3/Γ;
VALUE	DOCUMENT ID		TECN	COMMENT	
 • • We do not use the following 	owing data for average	es, fit	s, limits,	etc. • • •	
0.8±0.3	ALDE	87	GAM4	100 π ⁻ p →	$4\pi^0 n$
Γ(K+K-)/Γ _{total}					Γ4/Ι
VALUE	DOCUMENT ID		TECN	COMMENT	
	owing data for average	es, fit	s, limits,	etc. • • •	
0.003 + 0.019	9 LONGACRE	86	RVUE	Compliation	
seen	COSTA			10 π ⁻ p → K	1

£(1810) REFERENCES +Kondashov, Sadovsky+

		Translated from	DANS 353 323.		
ALDE	88D	SJNP 47 810	+ Bellazzini, Binon+	(SERP, BELG, LA	NL, LAPP, PISA)
		Translated from	YAF 47 1273,		
ALDE	87	PL B198 286	+Binon, Bricman+	(LANL, BR	UX, SERP, LAPP)
ALDE	86D	NP B269 485	+Binon, Bricman+	(BELG, LAPP, SE	
LONGACRE	86	PL B177 223	+Etkin+	(BNL, BRAN, CUN'	, DUKE, NDAM)
CASON	82	PRL 48 1316	+Biswas, Baumbaug)	k, Bishop+	(NDAM, ANL)
COSTA	80	NP B175 402	Costa De Beaurega	rd+ (BARI	BONN, CERN+)
		o	THER RELATED PA	APERS	-

PROKOSHKIN 97 SPD 42 117

(SERP)

+Amsler, Peters+ +Cannata, Baumbaugh, Bishop+ +Foley, Lai+ (BNL, CUNY, TUFTS, VAND)

 $\phi_3(1850)$

 $I^{G}(J^{PC}) = 0^{-}(3^{-})$

φ ₃ (1850) MASS					
VALUE (MeV)	EVTS VERAGE	DOCUMENT ID	TECN	COMMENT	
1855±10		ASTON	88E LASS	11 $K^- p \rightarrow K^- K^+ \Lambda$, $K_S^0 K^{\pm} \pi^{\mp} \Lambda$	
$1870 + 30 \\ -20$	430	ARMSTRONG	82 OMEG	18.5 $K^-p \to K^-K^+\Lambda$	
1850±10	123	ALHARRAN	818 HBC	8.25 K ⁻ p → KKA	
		4-(1850) WID	TU		

♦₃(1850) WIDTH

		•		
VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
87 +28 OUR AVER	AGE Error 1	ncludes scale facto	r of 1.2.	
64±31		ASTON	88E LASS	11 $K^-p \rightarrow K^-K^+\Lambda$, $K_S^0K^{\pm}\pi^{\mp}\Lambda$
160 ^{+ 90} _{- 50}	430	ARMSTRONG	82 OMEG	$18.5~\textrm{K}^-\textrm{p} \rightarrow ~\textrm{K}^-\textrm{K}^+\textrm{\Lambda}$
80 + 40 - 30	123	ALHARRAN	818 HBC	8.25 $K^- \rho \rightarrow K \overline{K} \Lambda$

ϕ_3 (1850) DECAY MODES

	Mode	Fraction (Γ_I/Γ)	
Γ ₁	κ κ	seen	
Γ_2	$K\overline{K}^*(892) + c.c.$	seen	

♦3(1850) BRANCHING RATIOS

$\Gamma(K\overline{K}^{\bullet}(892) + \text{c.c.})/\Gamma(K\overline{K})$			Γ_2/Γ_1
VALUE	DOCUMENT ID	TECN	COMMENT
0.55 + 0.85 - 0.45	ASTON	88E LASS	11 $K^-p \rightarrow K^-K^+\Lambda$, $K_S^0K^{\pm}\pi^{\mp}\Lambda$
 ● ● We do not use the following 	data for average	es, fits, limits,	, etc. • • •
0.8 ±0.4	ALHARRAN	81B HBC	$8.25 K^- D \rightarrow K \overline{K} \pi \Lambda$

♦3(1850) REFERENCES

ASTON	B 2	PL B208 324	+ Awaji, Biewz+	(SLAC, NAGO, CINC, INUS) IGJP			
ARMSTRONG		PL 110B 77	+ Baubillier+	(BARI, BIRM, CERN, MILA, CURIN+) JP			
ALHARRAN		PL 101B 357	+ Amirzadeh+	(BIRM, CERN, GLAS, MICH, CURIN)			
OTHER DELATED DAREDS							

CORDIER ASTON +Bisello, Bizot, Buon, Delcourt, Fayard+ (LALO) (BONN, CERN, EPOL, GLAS, LANC, MCHS+)

 $I^{G}(J^{PC}) = 0^{+}(2^{-})$

1

OMITTED FROM SUMMARY TABLE Needs confirmation.

		η ₂ (1870) ΜΑ	SS			
VALUE (MeV) 1854 ± 20 OUR AVE	EVTS PAGE	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT
1840 ± 25	IVIUL	BARBERIS	97в	OMEG		$450 pp \rightarrow pp = 0$
1875 ± 20 ± 35		ADOMEIT	96	CBAR	0	$\begin{array}{c} pp2(\pi^+\pi^-) \\ 1.94 \ \overline{p}p \rightarrow \ \eta 3\pi^0 \end{array}$
1881 ± 32 ± 40	26	KARCH	92	CBAL		$e^+e^{e^+e^-\eta\pi^0\pi^0}$
		(4000) 1440				

7/2 (1870) WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
202 ± 30 OUR AVE	RAGE					
200 ± 40		BARBERIS	978	OMEG		450 pp →
						pp2(π ⁺ π ⁻)_
200 ± 25 ± 45		ADOMEIT	96	CBAR	0	$\begin{array}{c} p p 2(\pi^+\pi^-) \\ 1.94 \ \overline{p} p \rightarrow \ \eta 3\pi^0 \end{array}$
221 ± 92 ± 44	26	KARCH	92	CBAL		e+e- → 00
						$e^+e^-\eta\pi^0\pi^0$

η₂(1870) DECAY MODES

	Mode			 	
Γ,	ηππ				
Γ2	$a_2(1320)\pi$				
Γ3	$f_2(1270)\eta$				

) BRANCHING RATIOS	$\Gamma(\eta\eta)/\Gamma(\eta\eta')$	000000000000000000000000000000000000000	TEC.	Г3/Г
$\Gamma(a_2(1320)\pi)/\Gamma(f_2(1270)\eta)$	Γ ₂ /Γ ₃	VALUE	<u>DOCUMENT ID</u> ng data for average		
ALUE .1±2.3	POCUMENT ID TECN CHG COMMENT ADOMEIT 96 CBAR 0 1.94 $\overline{p}p \rightarrow \eta 3\pi^0$	<0.05 90	ALDE		$\pi^- p \rightarrow \eta \eta' n$
	ADOME!! 96 CBAR 0 1.94 pp → η 3x**	F(MO MO) /F(/)			
η ₂ (1870) REFERENCES	$\Gamma(K_S^0 K_S^0)/\Gamma(\eta \eta')$	DOCUMENT ID	TECN CO	Γ ₂ /Γι
ARBERIS 97B PL B413 217	D. Barberis+ (WA102 Collab.)				
DOMEIT 96 ZPHY C71 227 ARCH 92 ZPHY C54 33	+Amsler, Armstrong+ (Crystal Barrel Collab.) +Antreasyan, Bartels+ (Crystal Ball Collab.)	<0.066 90	BALOSHIN	86 SPEC 40	$\pi p \rightarrow K_S^0 K_S^0 n$
отн	ER RELATED PAPERS ———	$\Gamma(\eta'\eta')/\Gamma_{ ext{total}}$			Γ ₆ /Ι
ARCH 90 PL B249 353	+Antreasyan, Bartels+ (Crystal Bail Collab.)	VALUE	DOCUMENT ID		
		 We do not use the following possibly seen 		es, 11ts, 11mits, etc 920 VES 37	
X(1910)	$I^{G}(J^{PC}) = 0^{+}(?^{?+})$		((1910) REFER		* p -
OMITTED FROM SUMMAR	RY TABLE	BELADIDZE 928 ZPHY CS4 367	+Bityukov, Bori:		(VES Collab.)
	nt peaks with close masses and widths seen	BELADIDZE 92D ZPHY C57 13 ALDE 91B SJNP 54 455	+Berdnikov+ +Binon +		(VES Collab.) (VES Collab.) NL, LAPP, PISA, KEK)
	s of $\omega\omega$ and $\eta\eta'$ final states. ALDE 91B	Translated from Y. Also 92 Pt B276 375			P, KEK, LANL, LAPP)
argues that they are of o	different nature.	ALDE 90 PL 8241 600 ALDE 89 PL 8216 447	+Binon +	(SERP. BELG, LAI	NL, LAPP, PISA, KEK) , BELG, LANL, LAPP)
	X(1910) MASS	Also 88E SJNP 48 1035 Translated from Y.	Alde, Binon, E 'AF 48 1724.	Bricman+ (BELG	, SERP, LANL, LAPP)
ALUE (MeV)	DOCUMENT ID	ALDE 89B PL B216 451 BALOSHIN 86 SJNP 43 959 Translated from Y.	+Binon, Bricma +Barkov, Bolon! 'AF 43 1487.	n+ (SERP, BELI kin, Vladimirskii, Grig	G, LANL, LAPP, TBIL) oriev+ (ITEP)
810 to 1920 OUR ESTIMATE	,		HER RELATED	PAPERS	
((1910) ωω MODE		LEE 94 PL B323 227			KAIN MYED BILL.
NLUE (MeV)	DOCUMENT ID TECN COMMENT	.cc	+Chung, Kirk+	(BNL, IND,	KYUN, MASD, RICE)
920±10	1 BELADIDZE 928 VES 36 π ⁻ p → ωω n	6 (1050)	,G,	$J^{PC}) = 0^+($	a + + \
	¹ ALDE 90 GAM2 $38 \pi^- \rho \rightarrow \omega \omega n$	$f_2(1950)$	13(J - J = U ''(۷)
$^{1}J^{PC}=2^{++}.$		OMITTED FROM SUMMA	ARY TARIF		
((1910) ηη' MODE	DOCUMENT ID TOOM COMMENT	Needs confirmation.			
**LUE (MeV) • • We do not use the following	DOCUMENT ID TECN COMMENT data for averages, fits, limits, etc. • • •		5(1950) MA	SS	
911±10	ALDE 918 GAM2 38 $\pi^- p \rightarrow \eta \eta' n$		_, ,		
		VALUE (MeV) 1960±30	DOCUMENT ID BARBERIS	7ECN CF 97B OMEG	
	X(1910) WIDTH	1980 230	- DANDENIS	ALR OWER	$450 pp \rightarrow pp2(\pi^+\pi^-)$
ALUE (MeV)	DOCUMENT ID	• • We do not use the following			
0 to 250 OUR ESTIMATE		1918±12	ANTINORI	95 OMEG	$300,450 pp \rightarrow pp2(\pi^{+}\pi^{-})$
MODE س (1910) س		~ 1996	HASAN	94 RVUE	$\overline{\rho}\rho \to \pi\pi$
MLUE (MeV) 0±19 OUR AVERAGE	DOCUMENT ID TECN COMMENT	~ 1990	² OAKDEN	94 RVUE	$0.36-1.55 \overline{p}p \rightarrow \pi^{+}\pi^{-}$
0±20	² BELADIDZE 928 VES 36 π ⁻ p → ωω π	1950±15	³ ASTON	91 LASS 0	11 K [−] p → ΛKKππ
1±50	² ALDE 90 GAM2 $38 \pi^{-} p \rightarrow \omega \omega n$	¹ Possibly two states.			
$^{2}J^{PC}=^{2}++.$		² From solution B of amplitude who find waves only up to J			
((1910) ŋŋ/ MODE		3 Cannot determine spin to be		or nor nor SRUM	cantly resultant.
ALUE (MeV) • We do not use the following	DOCUMENT ID TECN COMMENT data for averages, fits, limits, etc. • • •		£(10E0\ \4/IF	TU.	
0±35	ALDE 91B GAM2 38 $\pi^- p \rightarrow \eta \eta' n$		£(1950) WID		
		VALUE (MeV)	DOCUMENT ID 4 BARBERIS		
X(19	910) DECAY MODES	460±40	DAKDEKIS	97B OMEG	$450 pp \rightarrow pp2(\pi^{+}\pi^{-})$
Mode		• • We do not use the following			. • • •
1 π ⁰ π ⁰		390±60	ANTINORI	95 OMEG	$300,450 pp \rightarrow pp2(\pi^{+}\pi^{-})$
2 KS KS		~ 134	HASAN	94 RVUE	$\overline{\rho}\rho \to \pi\pi$
3 77		~ 100	⁵ OAKDEN	94 RVUE	$0.36-1.55 \overline{p}p \rightarrow \pi^{+}\pi^{-}$
4 ωω 5 ηη'		250 ± 50	6 ASTON	91 LASS 0	11 K ⁻ p → ΛΚΚππ
'6 η' η' Υ /1910)) BRANCHING RATIOS	⁴ Possibly two states. ⁵ From solution B of amplitude who find waves only up to J			
•	•	⁶ Cannot determine spin to be			
(ωω)/Γ _{total}	DOCUMENT ID TECH COMMENT	£	(1950) DECAY	MODES	
	data for averages, fits, limits, etc. • •		,_,_,		
een	ALDE 898 GAM2 38 $\pi^- p \rightarrow \omega \omega n$	Mode		Fraction (Γ_I/Γ)	
		$\Gamma_1 = K^*(892)\overline{K}^*(892)$		seen	
(x ⁰ x ⁰)/Γ(nn')	Γ₁/Γ≡				
ALUE	Γ ₁ /Γ ₅	$\Gamma_{2} \pi^{+}\pi^{-}$ $\Gamma_{3} \pi^{+}\pi^{-}\pi^{+}\pi^{-}$		seen possibly seen	
$(\pi^0\pi^0)/\Gamma(\eta\eta')$ ALUE • • We do not use the following <0.1		$ \Gamma_2 \pi^+ \pi^- \\ \Gamma_3 \pi^+ \pi^- \pi^+ \pi^- \\ \Gamma_4 a_2(1320)\pi $		seen possibly seen	

 $f_2(1950), X(2000), f_2(2010), f_0(2020)$

		£(19	50) BRANCHING RATIOS
	K *	(892))/F _{total}	Γ ₁ /Γ
VALUE			DOCUMENT ID TECN CHG COMMENT ASTON 91 LASS 0 11 K^-p →
Sept.			ASTON 91 LASS 0 11 $K^{-}p \rightarrow \Lambda K \overline{K} \pi \pi$
Γ(a ₂ (1320) π),	/F _{total}	Γ4/Γ
VALUE		····	DOCUMENT ID TECN COMMENT
		use the followin	ng data for averages, fits, limits, etc. • • •
possibly see	1		BARBERIS 978 OMEG 450 $pp \rightarrow pp2(\pi^+\pi^-)$
		f ₂	(1950) REFERENCES
BARBERIS	97B 96	PL B413 217	D. Barberis+ (WA102 Collab.)
KLOET ANTINORI HASAN	95 94	PR D53 6120 PL B353 589	+Myhrer (RUTG, NORD) +Barberis, Bayes+ (ATHU, BARI, BIRM, CERN, JINR) JP
OAKDEN	94	PL B334 215 NPA 574 731	+Bugg (LOQM) +Pennington (DURH)
ASTON	91	NP B21 5 (suppl)	
			HER RELATED PAPERS ———
ALBRECHT ALBRECHT	88N 87Q	PL B212 528 PL B198 255	+ (ARGUS Collab.) +Binder+ (ARGUS Collab.)
ARMSTRONG	87C	ZPHY C34 33	+Bloodworth+ (CERN, BIRM, BARI, ATHU, CURIN+)
			C DC 34
X(20)	00) [$I^G(J^{PC}) = 1^-(?^{?+})$
OMITTEE			ADV TABLE
DMITTEL	LTA	Y 77 favors J ^P	ARY TABLE $= 3^+$. Needs confirmation.
			
			X(2000) MASS
VALUE (MeV)		EVTS	DOCUMENT ID TECN CHG COMMENT
• • • We d	о по	t use the followin	ng data for averages, fits, limits, etc. • • •
1964±35 ~ 2100			¹ ARMSTRONG 93D E760 $pp \rightarrow 3\pi^0 \rightarrow 6\gamma$ ¹ ANTIPOV 77 CIBS - 25 $\pi^- p \rightarrow$
~ 2100			¹ ANTIPOV 77 CIBS $-$ 25 $\pi^- p \rightarrow p\pi^- \rho_3$
2214±15			BALTAY 77 HBC 0 15 $\pi^- p \rightarrow$
2080±40		208	$\Delta^{++}3\pi$ KALELKAR 75 HBC + 15 π^+p $ ightarrow$
			$ ho\pi^{\dot+} ho_3$
¹ Cannot	deter	mine spin to be	3.
			X(2000) WIDTH
VALUE (MeV)		EVTS	DOCUMENT ID TECN CHG COMMENT
	o no		ng data for averages, fits, limits, etc. • • •
225 ± 50			² ARMSTRONG 93D E760 $\bar{p}p \rightarrow 3\pi^0 \rightarrow 6\gamma$
~ 500			² ANTIPOV 77 CIBS – 25 $\pi^- p \rightarrow$
355 ± 21			$p\pi^-\rho_3$ BALTAY 77 HBC 0 15 π^-p $ ightarrow$
340±80		208	$\Delta^{++}3\pi$ KALELKAR 75 HBC + 15 $\pi^{+}p \rightarrow$
3401.00		200	$p\pi^+\rho_3$
² Cannot	deter	mine spin to be	3.
			(2000) DECAY MODES
		^(,2000) DECAT MODES
Mod	e		Fraction (Γ ₁ /Γ)
Γ_1 3π			
$\Gamma_2 \cdot \rho_3(1$	690)π	dominant
		X(20	00) BRANCHING RATIOS
F/a-/1600	n-1		·
Γ(ρ ₃ (1690	')*)		Γ ₂ /Γ ₁ UMENT ID TECN CHG COMMENT
dominant			ELKAR 75 HBC + $15 \pi^+ \rho \rightarrow \rho 3\pi$
			(2000) PEEEDENCES
			((2000) REFERENCES
ARMSTRONG ANTIPOV	93D 77	PL B307 399 NP B119 45	+Bettoni+ (FNAL, FERR, GENO, UCI, NWES+) +Busnello, Damgaard, Kienzle+ (SERP, GEVA)
BALTAY KALELKAR	77 75	PRL 39 591 Thesis Nevis 207	+Cautis. Kaleikar (COLU) JP (COLU)
			HER RELATED PAPERS
UADDIE	٠.		
HARRIS HUSON	81 68	ZPHY C9 275 PL 28B 208	+Dunn, Lubatti, Moriyasu, Podolsky+ (SEAT, UCB) +Lubatti, Six, Veillet+ (ORSAY, MILA, UCLA)
DANYSZ	67B	NC 51A 801	+French, Simak (CERN)

 $f_2(2010)$

 $I^{G}(J^{PC}) = 0^{+}(2^{+})$

	£(2010) i	MASS			
VALUE (MeV)	DOCUMENT	ר סו	rECN	COMMENT	
2011 + 62 76	1 ETKIN		MPS	22 π ⁻ ρ →	φφη
	the following data for ave	rages, fits,	limits,		
1980± 20	² BOLONKI	_	PEC	40 π ⁻ p →	K ⁰ K ⁰ n
2050 + 90	ETKIN		иPS	22 π [−] p →	
50			RVUE		
2120 + 20	LINDENBA				
2160± 50	ETKIN		MPS	22 π ⁻ p →	
	ETKIN 85. The percentage $\begin{pmatrix} +1 & 0 \\ -3 & 0 \end{pmatrix}$, and $\begin{pmatrix} 2+2 \\ -1 \end{pmatrix}$, responses, only 1.4 s.d.		onance	going into φ	<i>p</i> 2
101 H	f ₂ (2010) V	VIDTH			
VALUE (MeV)	DOCUMENT	r ID :	TECN	COMMENT	
202 <mark>+ 67</mark> - 62	³ ETKIN	88 1	MPS	22 π ⁻ p →	φφη
• • We do not use	the following data for ave	rages, fits,	limits,	etc. • • •	
145± 50	⁴ BOLONKI	IN 88 S	PEC	40 $\pi^- p \rightarrow$	K5 K5 n
200 + 160 - 50	ETKIN	85 1	MPS	22 $\pi^- p \rightarrow$	2φ π
300 ^{+ 150} - 50	LINDENB	AUM 84 F	RVUE		
310± 70	ETKIN		MPS	22 π ⁻ ρ →	2φπ
3 includes data of I		J_ ,		·· •	
1 φφ		seen			
	£ (2010) REF	ERENCE	S		
	B309 426 + Bloshenko, B201 568 + Foley, Line			(ITI (BN	P, SERP)
ETKIN 85 PL		ngacre, Linden	baum+	(BN	(CUNY)
ETKIN 82 PRI		ngacre, Linden	baum+	(BN	L, CUNY)
A150 03 BH			:DC _		c, contry
	OTHER RELAT		_ C/A	_	
LANDBERG 96 PR	D53 2839 +Adams, C B221 221 +Benayoun+	han+ +{CERN. CDI	EF, BIRI	BNL, CI) M, BARI, ATHU, NDAM, TUFTS	JNY, RPI) CURIN+)
ARMSTRONG 89B PL	L 56 1639 +Lai+		z, FSU,	NDAM, TUFTS	VAND+)
ARMSTRONG 89B PL GREEN 86 PRI	B242 51 +Ballance,	(FNAL, ARI Carroll, Dona	ld+	(LIVP, GLA	o, ceine,
ARMSTRONG 89B PL GREEN 86 PRI	-	Carroll, Dona	4		o, cem,
ARMSTRONG 898 PL GREEN 86 PRI BOOTH 84 NP	-	Carroll, Dona	4		o, centry
ARMSTRONG 89B PL GREEN 86 PRI	-	Carroll, Dona	4	+(0++)	S, Centry
ARMSTRONG 898 PL GREEN 84 PRI BOOTH 84 NP	/ // SUMMARY TABLE	$G(J^{PC})$	4		
ARMSTRONG 898 PL GREEN 86 PRI BOOTH 84 NP PRI PRI PRI PRI PRI PRI PRI PRI PRI PR	/ // SUMMARY TABLE	$G(J^{PC})$	4		S. CENTY
ARMSTRONG 898 PL GREEN 86 PRI BOOTH 84 NP F ₀ (2020) OMITTED FROM Needs conf	// SUMMARY TABLE irmation.	G(JPC)	= 0	+(0++)	S. CEINIY
ARMSTRONG 89B PL GREEN 86 PRIBOOTH 84 NP $f_0(2020)$ OMITTED FROM Needs conf	// SUMMARY TABLE irmation.	G(JPC) MASS	= 0		
ARMSTRONG 898 PL GREEN 86 PRI BOOTH 84 NP PRI PRI PRI PRI PRI PRI PRI PRI PRI PR	I SUMMARY TABLE irmation. f ₀ (2020)	MASS TID 5 978	= 0	+(0++) <u>COMMENT</u> 450 pp →	
ARMSTRONG 89B PL GREEN 86 PRIBOOTH 84 NP $f_0(2020)$ OMITTED FROM Needs conf	I SUMMARY TABLE irmation. fo(2020) DOCUMENT BARBER: fo(2020) V	(G(JPC)) MASS TID S 978	= 0	+(0++) <u>COMMENT</u> 450 pp →	

10(2020) DECAY MODE:

	Mode	Fraction (Γ _I /Γ)	
Γ ₁	ρππ	seen	

f₀(2020) REFERENCES

BARBERIS 97B PL 8413 217

D. Barberis+

(WA102 Collab.)

$a_4(2040)$

$$I^{G}(J^{PC}) = 1^{-}(4^{+})$$

a4(2040) MASS

VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT
2020±16 OUR AVERAGE					
2010±20	¹ DONSKOV	96	GAM2	0	$38 \pi^- p \rightarrow \eta \pi^0 n$
2040±30	² CLELAND	828	SPEC	±	$38 \pi^{-} p \rightarrow \eta \pi^{0} n$ $50 \pi p \rightarrow K_{5}^{0} K^{\pm} p$
2030±50	³ CORDEN		OMEG		$15 \pi^- p \rightarrow 3\pi n$
• • • We do not use the follo	wing data for aver	ages,	flts, lim	its, etc	. • • •
1903±10	4 BALDI	78	SPEC	_	$10 \pi^- p \rightarrow p K_0^0 K^-$
					pK0K-

 $^{^{1}}$ From a simultaneous fit to the G_{+} and G_{0} wave intensities.

24(2040) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT	
387 ± 70 OUR AVER	AGE					
370± 80	⁵ DONSKOV	96	GAM2	0	$38 \pi^- p \rightarrow \eta \pi^0 n$	ı
380 ± 150	6 CLELAND	82B	SPEC	±	$38 \pi^{-} p \rightarrow \eta \pi^{0} n$ $50 \pi p \rightarrow K_{S}^{0} K^{\pm} p$	
510±200	7 CORDEN		OMEG		$15 \pi^- p \rightarrow 3\pi n$	
• • • We do not use	the following data for ave	rages,	fits, lim	its, etc	C. • • •	
166± 43	8 BALDI	78	SPEC	_	10 π p →	
					$10 \pi^- p \rightarrow pK_0^0 K^-$	
_					· э	

 $^{^{5}\,\}mathrm{From}$ a simultaneous fit to the G_{+} and G_{0} wave intensities.

a₄(2040) DECAY MODES

	Mode	Fraction (Γ _I /Γ)	
۲1	κK	seen	
Γ_2	$ \begin{array}{c} \kappa \kappa \\ \pi^+ \pi^- \pi^0 \\ \eta \pi^0 \end{array} $	seen	
Гз	$\eta \pi^0$	seen	

24(2040) BRANCHING RATIOS

$\Gamma(K\overline{K})/\Gamma_{\text{total}}$		Γ ₁ /Γ
VALUE	DOCUMENT ID TE	CN CHG COMMENT
seen	BALDI 78 SP	FEC \pm 10 $\pi^- p \rightarrow \kappa_5^0 \kappa^- p$
$\Gamma(\pi^+\pi^-\pi^0)/\Gamma_{\text{total}}$	DOCUMENT ID TE	Γ ₂ /Γ
seen	CORDEN 78C ON	$MEG 0 15 \pi^{-} p \rightarrow 3\pi n$
$\Gamma(\eta\pi^0)/\Gamma_{\text{total}}$		Г ₃ /Г
VALUE	DOCUMENT ID	TECN CHG COMMENT
seen	DONSKOV 96	GAM2 0 38 $\pi^- p \rightarrow \eta \pi^0 n$

a₄(2040) REFERENCES

DONSKOV	96	PAN 59 982 Translated from Y	+Inyakin, Kachanov+	(GAMS Collab.) IGJPC
CLELAND BALDI	82B 78	NP B208 228 PL 74B 413	+Delfosse, Dorsaz, Gloor +Bohringer, Dorsaz, Hungert	(DURH, GEVA, LAUS, PITT) publer+ (GEVA) JP
CORDEN		NP B136 77	+Dowell, Garvey+	(BIRM, RHEL, TELA, LOWC) JP
		от	HER RELATED PAPERS	5
DELEGSSE	81	NP R193 340	+Guisan Martin Muhiemanı	n Weill+ (GEVA LAUS)

 $f_4(2050)$

$$I^{G}(J^{PC}) = 0^{+}(4^{+})$$

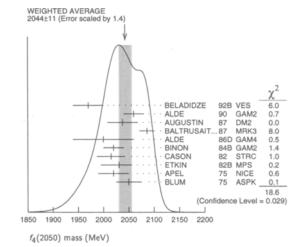
f4(2050) MASS

VALUE (MeV)	EVTS		DOCUMENT ID	1	TECN	COMMENT
2044±11 0	UR AVERAGE	Error	includes scale	factor	of 1.4.	See the ideogram below.
1970±30			BELADIDZE	92B	VES	$36 \pi^- p \rightarrow \omega \omega n$
2060 ± 20			ALDE			38 $\pi^- p \rightarrow \omega \omega n$
2038 ± 30			AUGUSTIN	87	DM2	$J/\psi \rightarrow \gamma \pi^+ \pi^-$
2086 ± 15			BALTRUSAIT	T87	MRK3	$J/\psi \rightarrow \gamma \pi^+ \pi^-$
2000 ± 60			ALDE			$100 \pi^- p \rightarrow n2\eta$
2020 ± 20	40k	1	BINON			$38 \pi^- p \rightarrow n2\pi^0$
2015±28		2	CASON	82	STRC	$8 \pi^+ p \rightarrow \Delta^{++} \pi^0 \pi^0$
$2031 + 25 \\ -36$			ETKIN	82B	MPS	$23 \pi^- p \rightarrow n2K_S^0$
2020 ± 30	700		APEL	75	NICE	$40 \pi^- p \rightarrow n2\pi^0$
2050 ± 25			BLUM	75	ASPK	18.4 $\pi^- p \to n K^+ K^-$
• • • We do	not use the follo	wing d	lata for averag	es, fits	, limits	, etc. • • •

~ 2010	MARTIN	97	RVUE	$\overline{N}N \rightarrow \pi\pi$
~ 2040	³ OAKDEN	94	RVUE	$0.36-1.55 \overline{p}p \rightarrow$
~ 1990	4 OAKDEN			$ \begin{array}{c} \pi^+\pi^-\\ 0.36-1.55\ \overline{p}p\rightarrow \end{array} $
1978± 5	5 ALPER	80	CNTR	$\pi^{+}\pi^{-}$ 62 $\pi^{-}p \rightarrow K^{+}K^{-}n$
2040 ± 10	⁵ ROZANSKA	80	SPRK	18 π ⁻ p → pp̄ n
1935 ± 13	⁵ CORDEN	79	OMEG	$12-15 \pi^- p \rightarrow n2\pi$
1988± 7	EVANGELISTA	79B	OMEG	$10 \pi^- p \rightarrow K^+ K^- n$
1922±14	⁶ ANTIPOV	77	CIBS	$25 \pi^- p \rightarrow p3\pi$

¹ From a partial-wave analysis of the data.

⁶ Width errors enlarged by us to $4\Gamma/\sqrt{N}$; see the note with the $K^*(892)$ mass.



f4(2050) WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
208± 13 OUR AVE	RAGE	Error includes scale fa	ctor	of 1.2.	
300 ± 50		BELADIDZE	92B	VES	36 $\pi^- p \rightarrow \omega \omega n$
170± 60		ALDE			$38 \pi^- p \rightarrow \omega \omega n$
304± 60					$J/\psi ightarrow \gamma \pi^+ \pi^-$
210± 63		BALTRUSAIT.	.87	MRK3	$J/\psi \rightarrow \gamma \pi^+ \pi^-$
400 ± 100		ALDE			$100 \pi^- p \rightarrow n2\eta$
240± 40	40k	7 BINON			$38 \pi^- p \rightarrow \pi 2\pi^0$
190± 14		DENNEY	83	LASS	$10 \pi^{+} n/\pi^{+} p$
186 + 103 - 58		⁸ CASON	82	STRC	$8 \pi^+ \rho \rightarrow \Delta^{++} \pi^0 \pi^0$
305 ^{+ 36} _{- 119}		ETKIN			$23 \pi^- p \rightarrow n2K_S^0$
180 ± 60	700	APEL	75	NICE	$40 \pi^- p \rightarrow n2\pi^0$
$225 + 120 \\ -70$		BLUM	75	ASPK	18.4 $\pi^- \rho \rightarrow nK^+K^-$

 $^{^2}$ From an amplitude analysis. 3 $J^P=4^+$ is favored, though $J^P=2^+$ cannot be excluded. 4 From a fit to the Y^0_8 moment. Limited by phase space.

⁶ From an amplitude analysis.

⁷ $J^P = 4^+$ is favored, though $J^P = 2^+$ cannot be excluded. ⁸ From a fit to the Y_0^0 moment. Limited by phase space.

² From an amplitude analysis of the reaction $\pi^+\pi^- \rightarrow 2\pi^0$.

From an amplitude analysis of the reaction $\pi^+\pi^- \to 2\pi^-$.

From solution A of amplitude analysis of data on $\overline{p}p \to \pi\pi$. See however KLOET 96 who find waves only up to J=3 to be important but not significantly resonant.

From solution B of amplitude analysis of data on $\overline{p}p \to \pi\pi$. See however KLOET 96 who find waves only up to J=3 to be important but not significantly resonant.

Fig. $J^p = 0(4^+)$ from amplitude analysis assuming one-pion exchange.

 $f_4(2050), f_0(2060)$

¹³ Assuming one pion exchange.

 $\Gamma(K\overline{K})/\Gamma(\pi\pi)$

0.04 +0.02

 $\Gamma(\eta\eta)/\Gamma_{\text{total}}$

VALUE (units 10-3)

 $\Gamma(4\pi^0)/\Gamma_{\rm total}$

2.1±0.8

VALUE

<0.012

• • We do not	use the following data for averages, fits, limits, etc. • •	
~ 200	MARTIN 97 RVUE $\overline{N}N \rightarrow$	
~ 60	9 OAKDEN 94 RVUE 0.36-1.	
~ 80	and the second s	55 <i>pp</i> →
243± 16	11 ALPER 80 CNTR 62 π^{-1}	r_ p → K+K-n
140± 15	**	p → ppn
263 ± 57	11 CORDEN 79 OMEG 12-15 1	
100± 28	EVANGELISTA 79B OMEG 10 π	
107± 56	10	p → p3π
⁸ From an ampl ⁹ From solution who find wave ¹⁰ From solution who find wave ¹¹ $I(J^P) = 0(4^+)$	wave analysis of the data. tude analysis of the reaction $\pi^+\pi^- \to 2\pi^0$. A of amplitude analysis of data on $\overline{p}p \to \pi\pi$. See hot only up to $J=3$ to be Important but not significantly. B of amplitude analysis of data on $\overline{p}p \to \pi\pi$. See hot only up to $J=3$ to be Important but not significantly from amplitude analysis assuming one-pion exchange. Narged by us to $4\Gamma/\sqrt{N}$; see the note with the $K^*(892)$	resonant. wever KLOET 96 resonant.
voidell errors e	fa(2050) DECAY MODES) mass.
Mode	Fraction (Γ_i/Γ)	
Γ ₁ ωω	(26 ±6)%	
Γ ₂ ππ΄	(17.0±1.5) %	
-	•	,
Γ ₃ KK	$(6.8^{+3.4}_{-1.8}) \times 10^{-3}$	•
$\Gamma_4 = \eta \eta$	$(2.1\pm0.8)\times10^{-3}$	3
Γ ₅ 4π ⁰	< 1.2 %	
$\Gamma_6 \gamma \gamma$		
	$f_4(2050) \Gamma(1)\Gamma(\gamma\gamma)/\Gamma(\text{total})$	
F(# W) F(r = /-
$\Gamma(K\overline{K}) \times \Gamma(\gamma)$	· ·	Γ ₃ Γ ₆ /Γ
VALUE (keV)	CL% DOCUMENT ID TECN COMME	
	use the following data for averages, fits, limits, etc. • •	
<0.29	95 ALTHOFF 85B TASS $\gamma\gamma \rightarrow$	ΚΚπ
$\Gamma(\pi\pi) \times \Gamma(\gamma\gamma)$)/Farest	Γ ₂ Γ ₆ /Γ
VALUE (keV)	CL% EVTS DOCUMENT ID TECN COMME	
<1.1	95 13 ± OEST 90 JADE e ⁺ e ⁻	
	f4(2050) BRANCHING RATIOS	
$\Gamma(\omega\omega)/\Gamma(\pi\pi)$		Γ_1/Γ_2
VALUE	DOCUMENT ID TECH COMME	-, -
1.5 ±0.3	ALDE 90 GAM2 38 π	
$\Gamma(\pi\pi)/\Gamma_{\text{total}}$		Γ ₂ /Γ
VALUE	DOCUMENT ID TECN COMME	NT
0.170±0.015 OUI		
0.18 ±0.03	13 BINON 83C GAM2 38 π^- , 13 CASON 82 STRC 8 π^+ p	
0.16 ±0.03 0.17 ±0.02	13 CASON 82 STRC 8 $\pi^+ p$ 13 CORDEN 79 OMEG 12–15 :	
	CORDEN /9 OMEG 12-15	τ μ → <i>π</i> ∠π

DOCUMENT ID

DOCUMENT ID

DOCUMENT ID

ETKIN

ALDE

ALDE

TECN COMMENT

TECN COMMENT

TECN COMMENT

828 MPS 23 $\pi^- p \rightarrow n2K_5^0$

860 GAM4 100 $\pi^- p \rightarrow n4\gamma$

87 GAM4 $100 \pi^- p \rightarrow 4\pi^0 n$

f₄(2050) REFERENCES

MARTIN 97	PR C56 1114	B.R. Martin, Oades (LOI	UC. AARH)
KLOET 96			rg, NORD)
		+Pennington	(DURH)
BELADIDZE 92B	ZPHY C54 367		ES Collab.)
ALDE 90	PL B241 600	+Binon+ (SERP, BELG, LANL, LAPP, F	PISA, KEK)
OEST 90		+Olsson+ (JA	DE Collab.)
ALDE 87	PL B198 286	+Olsson+ (JA +Binon, Bricman+ (LANL, BRUX, SE	RP, LAPP)
AUGUSTIN 87	ZPHY C36 369	+Cosme+ (LALO, CLER, FR.	AS, PADO)
BALTRUSAIT 87	PR D35 2077	Baltrusaitis, Coffman, Dubois+ (Mark	III Collab.)
ALDE 86D		+Binon, Bricman+ (BELG, LAPP, SERP, CE	
ALTHOFF 85B	ZPHY C29 189	+Braunschweig, Kirschfink+ (TAS:	SO Collab.)
BINON 84B	LNC 39 41	+Donskov, Duteil, Gouanere+ (SERP, BE +Gouanere, Donskov, Duteil+ (SERI	LG, LAPP)
BINON 83C	SJNP 38 723	+Gouanere, Donskov, Duteil+ (SERI	P. BRUX+)
	Translated from YAF 3	38 1199.	,,
DENNEY 83	PR D28 2726	+Cranley, Firestone, Chapman+ (10)	WA, MICH)
CASON 82	PRL 48 1316	+Biswas, Baumbaugh, Bishop+ (NI	
ETKIN 82B	PR D25 1786	+Foley, Lai+ (BNL, CUNY, TUF	TS. VANDÍ
ALPER 80	Pl. 94B 422	+Becker+ (AMST, CERN, CRAC, MP	IM. OXF+)
ROZANSKA 80		+Blum, Dietl, Grayer, Lorenz+ (MP	IM CERN)
CORDEN 79	NP B157 250	+Dowell, Garvey+ (BIRM, RHEL, TEI	
EVANGELISTA 79B	NP B154 381	+ (BARI, BONN, CERN, DARE, GLA	
		+ (BARI, BUNIN, CERN, DARE, GL)	CO CCIA
ANTIPOV 77		+Busnello, Damgaard, Kienzle+ (SE	RP, GEVA)
APEL 75		+Augenstein+(KARLK, KARLE, PISA, SERP, W	IEN, CERN)JP
BŁUM 75	PL 57B 403	+Chabaud, Dietl, Garelick, Grayer+ (CEI	RN, MPIM) JP

OTHER RELATED PAPERS -

PROKOSHKIN	97	SPD 42 117 Translated from DANS	+Kondashov, Sadovsky+	(SERP)
CASON	83	PR D28 1586	+Cannata, Baumbaugh, Bishop+	(NDAM, ANL)
GOTTESMAN	80	PR D22 1503		RA, BRAN, BNL, CINC)
WAGNER	74	London Conf. 2 27		(MPIM)

 $f_0(2060)$

 Γ_3/Γ_2

 Γ_4/Γ

 Γ_5/Γ

$$I^{G}(J^{PC}) = 0^{+}(0^{+})$$

OMITTED FROM SUMMARY TABLE

Needs confirmation.

f₀(2060) MASS

VALUE	DOCUMENT IL		TECN	COMMENT
• • • We do not use the	ne following data for averag	ges, fit	s, limits,	etc. • • •
~ 2050	¹ OAKDEN	94	RVUE	0.36~1.55 pp →
~ 2060	² OAKDEN	94	RVUE	$0.36-1.55 \overline{p}p \rightarrow$
	amplitude analysis of data			

who find waves only up to J=3 to be important but not significantly resonant.

f₀(2060) WIDTH

VALUE	DOCUMENT IL		TECN	COMMENT
• • • We do not us	e the following data for averag	ges, fit	s, Ilmits,	, etc. • • •
\sim 120	³ OAKDEN	94	RVUE	0.36-1.55 pp →
~ 50	4 OAKDEN	94	RVUE	$\pi^+\pi^-$ 0.36–1.55 $\overline{\rho}\rho \rightarrow$
				$\pi^+\pi^-$
	of amplitude analysis of data only up to $J=3$ to be import			
4	-6			- Con houseway VIOET OF

From solution B of amplitude analysis of data on $\overline{\rho} p \to \pi\pi$ See however KLOET 96 who find waves only up to J=3 to be important but not significantly resonant.

fo(2060) DECAY MODES

	/lode		Fraction (Γ _[/Γ)
Γ ₁ π	+π-		seen	
		fo	(2060) REFERENCES	
KLOET OAKDEN	96 94	PR D53 6120 NPA 574 731	+Myhrer +Pennington	(RUTG, NORD) (DURH)

² From solution B of amplitude analysis of data on $\overline{p}p \to \pi\pi$ See however KLOET 96 who find waves only up to J=3 to be important but not significantly resonant.

 $\pi_2(2100)$

$$I^{G}(J^{PC}) = 1^{-}(2^{-})$$

OMITTED FROM SUMMARY TABLE

Needs confirmation.

$\pi_2(2100)$ MASS

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
2090± 29 OUR AVERAGE			
2090± 30	¹ AMELIN	95B VES	$\begin{array}{c} 36 \ \pi^- A \rightarrow \\ \pi^+ \pi^- \pi^- A \end{array}$
2100±150	² DAUM	81B CNTR	$63,94 \pi^- p \rightarrow 3\pi X$

 $1\,\mathrm{From}\;\mathrm{a}\;\mathrm{fit}\;\mathrm{to}\;J^{PC}=2^{\,-\,+\,}\,\mathit{f}_{2}(1270)\pi,\,(\pi\pi)_{S}\pi$ waves.

² From a two-resonance fit to four 2⁻0⁺ waves.

π_2 (2100) WIDTH

ludes scale AMELIN			
ARACIINI			
VIAITELIA	958	VES	$\begin{array}{c} 36 \ \pi^{-} A \rightarrow \\ \pi^{+} \pi^{-} \pi^{-} A \end{array}$
DAUM	818	CNTR	$63,94 \pi^{-} p \rightarrow 3\pi X$
		DAUM 818	DAUM 818 CNTR 270) π , $(\pi \pi)_{S} \pi$ waves.

⁴ From a two-resonance fit to four 2⁻⁰⁺ waves.

$\pi_2(2100)$ DECAY MODES

	Mode	Fraction (Γ_j/Γ)	_
$\overline{\Gamma_1}$	3π	seen	
Γ_2	$ ho\pi$	seen	
Γ_3	$f_2(1270)\pi$	seen	
Γ_4	$(\pi\pi)_s\pi$	seen	
Γ ₂ Γ ₃ Γ ₄		seen seen	

π₂(2100) BRANCHING RATIOS

$\Gamma(\rho\pi)/\Gamma(3\pi)$					Γ_2/Γ_1
VALUE	DOCUMENT ID	1	ECN	COMMENT	
0.19±0.05	⁵ DAUM	81B C	NTR	63,94 m ⁻ p	
$\Gamma(f_2(1270)\pi)/\Gamma(3\pi)$					Γ_3/Γ_1
VALUE	DOCUMENT ID		ECN	COMMENT	
0.36±0.09	⁵ DAUM	81B C	NTR	63,94 $\pi^- p$	
$\Gamma((\pi\pi)_s\pi)/\Gamma(3\pi)$					Γ_4/Γ_1
VALUE	DOCUMENT ID	1	ECN	COMMENT	
0.45±0.07	⁵ DAUM	81B C	NTR	63,94 $\pi^- p$	
D-wave/S-wave RATIO	FOR π ₂ (2100) →	f ₂ (127	0)π		
VALUE	DOCUMENT ID		ECN	COMMENT	
0.39±0.23	⁵ DAUM	81B (NTR	63,94 $\pi^- p$	
5 From a two-resonance fit	to four 2-0+ waves.				

π₂(2100) REFERENCES

AMELIN	95B	PL B356 595	+Berdníkov, Bityukov+	(SERP, TBIL)
DAUM	81B	NP B182 269	+Hertzberger+ (AMST, CER	N, CRAC, MPIM, OXF+)

 $f_2(2150)$

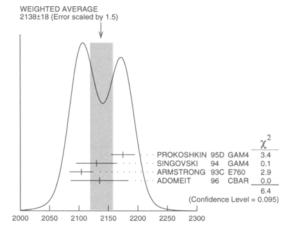
$$I^{G}(J^{PC}) = 0^{+}(2^{+})$$

OMITTED FROM SUMMARY TABLE This entry was previously called T_0 .

f2(2150) MASS

f2(2150) MASS, COMBINED MODES (MeV)

DOCUMENT ID VALUE (MeV) 2138±18 OUR AVERAGE Includes data from the 2 datablocks that follow this one. Error includes scale factor of 1.5. See the ideogram



f2(2150) MASS, COMBINED MODES (MeV)

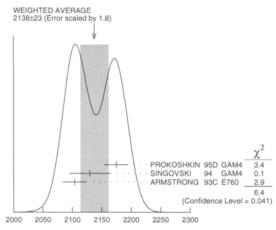
ηη MODE

VALUE (MeV) DOCUMENT ID TECN COMMENT

The data in this block is included in the average printed for a previous datablock.

2138±23 OUR AVERAGE Error includes scale factor of 1.8. See the Ideogram below. 2175 ± 20 2130±35 2104 ± 20

¹ No JPC determination.



 $f_2(2150)$ MASS, $\eta\eta$ MODE (MeV)

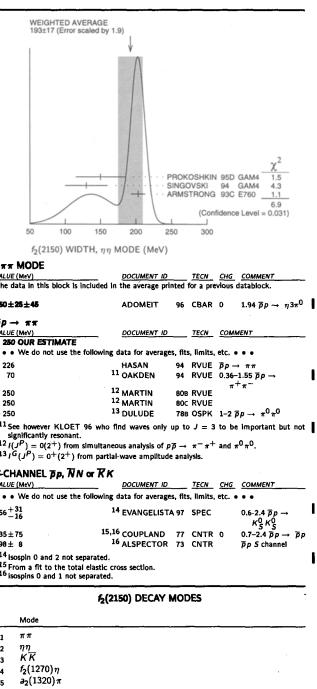
$f_{0}(2150)$

130±30 203 ± 10

10 No JPC determination.

		_		_			WEIC 193±
VALUE (MeV) The data in this block is incl	<u>DOCUMENT IS</u> uded in the average p				COMMENT latablock.		1931
2135±20±45	ADOMEIT	96	CBAR	0	1.94 p̄p → η3	π0	
p p → ππ						_	
VALUE (MeV)	DOCUMENT IL		TECN				
• • We do not use the foll	-	-					
~ 2226 ~ 20 9 0	HASAN ² OAKDEN	94	RVUE RVUE	0.36-	→ ππ 1.55 pp → ⊢π-	1	
~ 2120	3 OAKDEN	94	RVUE	0.36	π 1.55 pp → +π-	1	2
~ 2170	4 MARTIN		RVUE				
~ 2150 ~ 2150	⁴ MARTIN ⁵ DULUDE		RVUE	1_2 7	$i\rho \rightarrow \pi^0\pi^0$		
² OAKDEN 94 makes an a based on Barrelet zeros earlier data as well, and a nearly degenerate resonal MARTIN 97 who make τ 3 From solution B of ampli $t(J^P) = 0(2^+)$ from sim	This is solution A. The essume that the data on nces on the leading Re elated analyses. Itude analysis of data	amplican be egge t	tude anal paramet rajectory $\pi \pi$.	lysis of trized in . See a	HASAN 94 inclu n terms of tower also KLOET 96	des s of	50 f ₂ (2
$5I^{G}(J^{P}) = 0^{+}(2^{+})$ from				4112 11			
S-CHANNEL Pp, NN o							ηππ MODE VALUE (MeV) The data in this
VALUE (MeV)	DOCUMENT IL				COMMENT	_	The data in thi
• • • We do not use the fol	lowing data for average 6 EVANGELIS	•		etc. •	• • 0.6-2.4 pp →	í	250±25±45
~ 2190	7 CUTTS	786	CNTR		$K_S^0 K_S^0$ 0.97-3 $\overline{p}p \rightarrow$		$pp \rightarrow \pi\pi$ VALUE (MeV)
2155±15	7,8 COUPLAND	77	CNTR	0	NN 0.7-2.4 pp →	p̄ρ	250 OUR ES
2193± 2	^{7,9} ALSPECTO	₹ 73	CNTR		pp 5 channel		~ 226
⁹ Referred to as T or T re	·						
C (2422) 11/12/11 CO11/12	f ₂ (2150) W					-	~ 250 11 See however significantly 12 ((P) - 20
		MeV)				_	¹¹ See however significantly $I(J^P) = 0$
VALUE (MeV)	BINED MODES (I	MeV)			llow this one. Er ne ideogram belo		11 See howeve significantly 12 I(JP) = 0(13 IG(JP) = S-CHANNEL
VALUE (MeV) 194 ± 15 OUR AVERAGE II WEIGHTED AVERA	BINED MODES (I DOCUMENT II nocludes data from the Includes scale	MeV)					See howeve significantly $12 I(J^P) = 0(13 I^G(J^P)) = 0$ S-CHANNEL VALUE (MeV)
VALUE (MeV) 194±15 OUR AVERAGE II	BINED MODES (I DOCUMENT II nocludes data from the Includes scale	MeV)					11 See howeve significantly 12 I(JP) = 0(13 IG(JP) = S-CHANNEL
VALUE (MeV) 194±15 OUR AVERAGE II WEIGHTED AVERA	BINED MODES (I DOCUMENT II nocludes data from the Includes scale	MeV)					11 See however significantly 12 $I(J^P) = 0$ (13 $I^G(J^P) = 5$ -CHANNEL VALUE (MeV) • • • We do not $56 + 31$
WEIGHTED AVERA	BINED MODES (I DOCUMENT II nocludes data from the Includes scale	MeV)					11 See however significantly 12 $I(J^P) = 0$ (13 $I^G(J^P) = 5$ - CHANNEL VALUE (MeV) • • • We do not $56 + 31 - 16$ (135 ± 75
VALUE (MeV) 194 ± 15 OUR AVERAGE II WEIGHTED AVERA	BINED MODES (I DOCUMENT II nocludes data from the Includes scale	MeV)					11 See however significantly 12 $I(J^P) = 0$ (13 $I^G(J^P) = 5$ S-CHANNEL VALUE (MeV) • • • Wedo in 56+31 (16 135 ± 75 98 ± 8
VALUE (MeV) 194 ± 15 OUR AVERAGE II WEIGHTED AVERA	BINED MODES (I DOCUMENT II nocludes data from the Includes scale	MeV)					11 See however significantly 12 $I(J^P) = 0$ (13 $I^G(J^P) = 0$) S-CHANNEL VALUE (MeV) • • We do n 56^{+31}_{-16} 135 \pm 75 98 \pm 8 14 isospin 0 ai 15 From a fit
VALUE (MeV) 194±15 OUR AVERAGE II WEIGHTED AVERA	BINED MODES (I DOCUMENT II nocludes data from the Includes scale	MeV)					11 See however significantly 12 $I(J^P) = 0$ (13 $I^G(J^P) = 0$) S-CHANNEL VALUE (MeV) • • We do n 56^{+31}_{-16} 135 \pm 75 98 \pm 8 14 isospin 0 ai 15 From a fit
VALUE (MeV) 194±15 OUR AVERAGE II WEIGHTED AVERA	BINED MODES (I DOCUMENT II nocludes data from the Includes scale	MeV)					11 See however significantly 12 $I(J^P) = 0$ 13 $I^G(J^P) = 0$ 13 $I^G(J^P) = 0$ 5-CHANNEL VALUE (MeV) • • • We do n 56 + 31
VALUE (MeV) 194±15 OUR AVERAGE II WEIGHTED AVERA	BINED MODES (I DOCUMENT II nocludes data from the Includes scale	MeV)					11 See however significantly 12 $I(J^P) = 0$ (13 $I^G(J^P) = 0$) S-CHANNEL VALUE (MeV) • • • We do not $56+31$ 135 ± 75 98 ± 8 14 isospin 0 at 15 From a fit 16 isospins 0 at
VALUE (MeV) 194 ± 15 OUR AVERAGE II WEIGHTED AVERA	BINED MODES (I DOCUMENT II nocludes data from the Includes scale	MeV)					11 See however significantly 12 $I(J^P) = 0$ (13 $I^G(J^P) = 0$) S-CHANNEL VALUE (MeV) • • We do n 56^{+31}_{-16} 135 \pm 75 98 \pm 8 14 isospin 0 ai 15 From a fit
VALUE (MeV) 194 ± 15 OUR AVERAGE II WEIGHTED AVERA	BINED MODES (I DOCUMENT II nocludes data from the includes scale AGE d by 1.6)	MeV)	r of 1.6.	See th			11 See however significantly 12 $I(J^P) = 0$ (13 $I^G(J^P) = 0$) 13 $I^G(J^P) = 0$ S-CHANNEL VALUE (MeV) • • • We do not see that $0 = 0$ (16 $0 = 0$) 15 $0 = 0$ (17 $0 = 0$) 16 $0 = 0$ (18 $0 = 0$) Mode
VALUE (MeV) 194 ± 15 OUR AVERAGE II WEIGHTED AVERA	BINED MODES (I	MeV) 2 date a facto	eit OSHKIN	96 (95D (the ideogram below $\frac{\chi^2}{1.2}$		11 See however significantly 12 $I(J^P) = 0$ (13 $I^G(J^P) = 0$ (13 $I^G(J^P) = 0$ S-CHANNEL VALUE (MeV) • • • We do not $56 + 31$ (16 135 ± 75 98 ± 8 14 Isospin 0 at 15 From a fit 16 Isospins 0 at 16 Isospins 0 at 17 $\pi \pi$ π π π π π π π π
VALUE (MeV) 194±15 OUR AVERAGE II WEIGHTED AVERA	BINED MODES (I	MeV) 2 data 2 data e facto	eit OSHKIN	96 (95D (200		11 See however significantly 12 $I(J^P) = 0$ (13 $I^G(J^P) = 0$) 13 $I^G(J^P) = 0$ S-CHANNEL VALUE (MeV) • • We do note that the second of t
VALUE (MeV) 194 ± 15 OUR AVERAGE II WEIGHTED AVERA	BINED MODES (I	MeV) 2 data 2 data e facto	EIT OSHKIN VSKI TRONG	96 (95D (94 (93C E	2 2BAR 1.2 3AM4 1.6 3AM4 4.6 6760 0.8 8.1		11 See however significantly 12 $I(J^P) = 0$ (13 $I^G(J^P) = 0$ (13 $I^G(J^P) = 0$ S-CHANNEL VALUE (MeV) • • • We do not 156 + 31 (15 + 75 16 16 16 15 + 75 16 16 16 16 16 16 16 16 16 16 16 16 16
VALUE (MeV) 194 ± 15 OUR AVERAGE II WEIGHTED AVERA	BINED MODES (I	MeV) 2 data 2 data e facto	EIT OSHKIN VSKI TRONG	96 (95D (94 (93C E	22 CBAR 1.2 3AM4 1.6 3AM4 4.6 6760 0.8		11 See however significantly 12 $I(J^P) = 0$ (13 $I^G(J^P) = 0$ (13 $I^G(J^P) = 0$ S-CHANNEL VALUE (MeV) • • We do note that the second of t
WEIGHTED AVERAGE WEIGHTED AVERA 194±15 (Error scale	BINED MODES (I DOCUMENT II ncludes data from the includes scale AGE dd by 1.6)	MeV) 2 data 2 data e facto	EIT OSHKIN VSKI TRONG	96 (95D (94 (93C E	22 CBAR 1.2 3AM4 1.6 3AM4 4.6 6760 0.8 8.1		11 See however significantly 12 $I(J^P) = 0$ (13 $I^G(J^P) = 0$ (13 $I^G(J^P) = 0$ S-CHANNEL VALUE (MeV) • • • We do not 156 + 31 (15 + 75 16 16 16 15 + 75 16 16 16 16 16 16 16 16 16 16 16 16 16
WEIGHTED AVERAGE WEIGHTED AVERA 194±15 (Error scale)	BINED MODES (I DOCUMENT II ncludes data from the includes scale AGE dd by 1.6)	MeV) 2 2 dat: e facto ADOM PROK SINGO ARMS	EIT DSHKIN VSKI TRONG (Confi	96 (95D (94 (93C E	22 CBAR 1.2 3AM4 1.6 3AM4 4.6 6760 0.8 8.1		11 See however significantly 12 $I(J^P) = 0$ (13 $I^G(J^P) = 0$) 13 $I^G(J^P) = 0$ S-CHANNEL VALUE (MeV) • • • We do not 156 + 31 (15 From a fit 16 Isospins 0 a lab From a fit 16 Isospins 0 a lab From a fit 16 Isospins 0 a lab From a fit 17 π
WEIGHTED AVERAGE WEIGHTED AVERAGE 194±15 (Error scale) 0 100 f ₂ (2150) WIDTH	BINED MODES (I DOCUMENT II ncludes data from the includes scale AGE d by 1.6)	ADOM PROKE SINGO ARMS I JOSEPH STREET ADOM ADOM ADOM ADOM ADOM ADOM ADOM ADO	er of 1.6. SHKIN SHKIN FRONG (Confi	96 (95D (93C E	22 CBAR 1.2 3AM4 1.6 6AM4 4.6 7760 0.8 1.1 Level = 0.044)		11 See however significantly 12 $I(J^P) = 0$ (13 $I^G(J^P) = 0$) 13 $I^G(J^P) = 0$ S-CHANNEL VALUE (MeV) • • • We do n $56 + 31$ (16 isospin 0 at 15 From a fit 16 isospins 0 at $15 + 10$ $15 + 1$
WEIGHTED AVERAGE WEIGHTED AVERA 194±15 (Error scale) 0 100 f ₂ (2150) WIDTH 77 MODE VALUE (MeV)	BINED MODES (I DOCUMENT II nocludes data from the includes scale AGE d by 1.6) 200 300 , COMBINED MOD DOCUMENT II	ADOM PROKISINGO ARMS	r of 1.6. EIT SSHKIN VSKI TRONG (Confi 500 MeV)	96 (95D (94 ()93C E	22 2 2 2 2 2 3 3 4 4 1.6 3 3 4 4 4.6 2 7 6 0 0.8 8.1 Level = 0.044)		11 See however significantly 12 $I(J^P) = 0$ (13 $I^G(J^P) = 0$) 13 $I^G(J^P) = 0$ S-CHANNEL VALUE (MeV) • • • We do not 156 + 31 (15 From a fit 16 Isospins 0 a lab From a fit 16 Isospins 0 a lab From a fit 16 Isospins 0 a lab From a fit 17 π
WEIGHTED AVERAGE WEIGHTED AVERA 194±15 (Error scale)	BINED MODES (I DOCUMENT II nocludes data from the includes scale AGE d by 1.6) 200 300 I, COMBINED MOD DOCUMENT II uded in the average p	ADOM PROKINGO ARMS L J J J J J J J J J J J J	eiit DSHKIN VSKI (Confirmation of 1.6. (Conf	96 (95D) (97D) (98D) (98	22 CBAR 1.2 SAM4 1.6 SAM4 4.6 C760 0.8 8.1 Level = 0.044)		11 See however significantly 12 $I(J^P) = 0$ (13 $I^G(J^P) = 0$) 13 $I^G(J^P) = 0$ S-CHANNEL VALUE (MeV) • • • We do n 56+31 (15 +75 98 ± 8 14 isospin 0 at 15 From a fit 16 isospins 0 at 15 From a fit 16 isospins 0 at 15 From a fit 17 $\pi \pi$ $\Gamma_2 = \eta \eta$ $\Gamma_3 = K \overline{K}$ $\Gamma_4 = f_2(127) \Gamma_5 = a_2(132) \Gamma(K \overline{K})/\Gamma(\eta)$ VALUE • • • We do n

SINGOVSKI 94 GAM4 450 $pp \rightarrow pp2\eta$ 10 ARMSTRONG 93C E760 $\overline{p}p \rightarrow \pi^0 \eta \eta \rightarrow 6\gamma$



	111000	 	
Γ1	ππ	 	
Γ ₂	ηη ΚΚ		
Γ3 Γ4	$f_2(1270)\eta$		
r_5	$a_2(1320)\pi$		
		 	

f₂(2150) BRANCHING RATIOS

$\Gamma(K\overline{K})/\Gamma(\eta\eta)$			Γ_3/Γ_2
VALUE	CL%	DOCUMENT ID TECH	COMMENT
• • • We do not use	the follow	ing data for averages, fits, limit	s, etc. • • •
<0.1	95	17 PROKOSHKIN 95D GAM	4 300 $\pi^{-} N \rightarrow \pi^{-} N 2\eta$, 450 $pp \rightarrow pp 2\eta$
¹⁷ Using data from A	RMSTRO	NG 89D.	
$\Gamma(\pi\pi)/\Gamma(\eta\eta)$			Γ ₁ /Γ ₂

$\Gamma(\pi\pi)/\Gamma(\eta\eta)$				Γ_1/Γ_2
VALUE	<u>CL%</u>	DOCUMENT ID TECN	COMMENT	
• • • We do not us	e the followin	ng data for averages, fits, Ilmii	is, etc. • • •	
<0.33	95	18 PROKOSHKIN 95D GAM	4 300 π ⁻ N → 450 pp →	
4.0				

¹⁸ Derived from a $\pi^0 \pi^0 / \eta \eta$ limit.

Γ(f ₂ (1270)η)/Γ(a ₂ (1320)π)	Γ ₄ /Γ ₅	$\overline{p}p \rightarrow \pi\pi$ VALUE (MeV)	DOCUMENT ID TECN COMMENT
	PADOMEIT 96 CBAR 1.94 $\bar{p}p \rightarrow \eta 3\pi^0$		ng data for averages, fits, limits, etc. • •
19 Using B($a_2(1320) \rightarrow \eta \pi$) = 0.		~ 296	HASAN 94 RVUE $\overline{p}p \rightarrow \pi\pi$
	-	~ 244	HASAN 94 RVUE $\overline{p}p \rightarrow \pi\pi$
f ₂ (2	150) REFERENCES	~ 40	⁸ OAKDEN 94 RVUE $0.36-1.55 \bar{p}p \rightarrow \pi^+\pi^-$
EVANGELISTA 97 PR D56 3803	C. Evangelista, Palano, Drijard+ (LEAR Collab.)	~ 250	10 MARTIN 80B RVUE
MARTIN 97 PR C56 1114 ADOMEIT 96 ZPHY C71 227	B.R. Martin, Oades (LOUC, AARH) +Amsler, Armstrong+ (Crystal Barrel Collab.)	~ 200	10 MARTIN 80C RVUE
KLOET 96 PR D53 6120	+Myhrer (RUTG, NORD)		o find waves only up to $J=3$ to be important but i
PROKOSHKIN 95D SPD 40 495 Translated from DAN		significantly resonant.	•
HASAN 94 PL B334 215 DAKDEN 94 NPA 574 731	+Bugg (LOQM) +Pennington (DURH)	S-CHANNEL ₩N	
SINGOVSKI 94 NC 107 1911 ARMSTRONG 93C PL 8307 394	(SERP) +Bettoni+ (FNAL, FERR, GENO, UCI, NWES+)	VALUE (MeV)	DOCUMENT ID TECN CHG COMMENT
ARMSTRONG 89D PL B227 186 MARTIN 80B NP B176 355	+ Benayoun (ATHU, BARI, BIRM, CERN, CDEF) + Morgan (LOUC, RHEL) JP		ng data for averages, fits, limits, etc. • • •
MARTIN 80C NP B169 216	+Pennington (DURH) JP	135±75 1 98± 8	1,12 COUPLAND 77 CNTR 0 0.7-2.4 $\overline{p}p \rightarrow$ 12 ALSPECTOR 73 CNTR $\overline{p}p$ S channel
TUTTS 78B PR D17 16 DULUDE 78B PL 79B 335	+Good, Grannis, Green, Lee+ (STON, WISC) +Lanou, Massimo, Peaslee+ (BROW, MIT, BARI) JP	~ 85	13 ABRAMS 70 CNTR 5 channel pN
COUPLAND 77 PL 71B 460 ALSPECTOR 73 PRL 30 511	+Eisenhandler, Gibson, Astbury+ (LOQM, RHEL) +Cohen, Cvijanovich+ (RUTG, UPNJ)	_	,, ,
	, , ,	$\pi^- \rho \rightarrow \omega \pi^0 n$	
—— ОТНЕ	R RELATED PAPERS ———	VALUE (MeV) The data in this block is included	DOCUMENT ID TECN COMMENT In the average printed for a previous datablock.
IELDS 71 PRL 27 1749	+Cooper, Rhines, Allison (ANL, OXF)	The data in this block is melded	in the average printed for a previous autobook.
OH 71 PRL 26 922	+Barish, Caroll, Lobkowicz+ (CIT, BNL, ROCH)	320±70	ALDE 95 GAM2 38 $\pi^- p \rightarrow \omega \pi^0 n$
		 ◆ ◆ We do not use the following 	ng data for averages, fits, limits, etc. • • •
$\rho(2150)$	$I^{G}(J^{PC}) = 1^{+}(1^{-})$	~ 300	ALDE 92C GAM4 100 $\pi^- p \rightarrow \omega \pi^0 n$
r(/		9 Includes ATKINSON 85.	0.0
OMITTED FROM SUMMAR	Y TABLE	$I(J^P) = I(1^-)$ from simulta 11 From a fit to the total elastic	neous analysis of $p\overline{p} \rightarrow \pi^-\pi^+$ and $\pi^0\pi^0$.
This entry was previously		12 Isospins 0 and 1 not separate	. cross section.
		13 Seen as bump in $I = 1$ state	. See also COOPER 68. PEASLEE 75 confirm $\overline{p}p$ resu
	ρ(2150) MASS	of ABRAMS 70, no narrow s	tructure.
$e^+e^- \rightarrow \pi^+\pi^-, K^+K^-, 6\pi$			(MEA) DEFEDENCES
ALUE (MeV)	DOCUMENT ID TECN CHG COMMENT	•	(2150) REFERENCES
	s data from the datablock that follows this one.	KLOET 96 PR D53 6120	+Myhrer (RUTG, NORD)
2153±37	BIAGINI 91 RVUE e ⁺ e ⁻ →	ALDE 95 ZPHY C66 379 HASAN 94 PL B334 215	+Binon, Bricman+ (GAMS Collab.). +Bugg (ŁOQM)
	$\pi^+\pi^-$, $\kappa^+\kappa^-$	OAKDEN 94 NPA 574 731	+Pennington (DURH)
2110±50	2 CLEGG 90 RVUE 0 e ⁺ e ⁻ →	BIAGINI 91 NC 104A 363	+Dubnicka+ (FRAS, PRAG)
	$3(\pi^+\pi^-)$	CLEGG 90 ZPHY C45 677 ATKINSON 85 ZPHY C29 333	+Donnachie (LANC, MCHS) + (BONN, CERN, GLAS, LANC, MCHS, IPNP+)
	$2(\pi^+\pi^-\pi^0)$	MARTIN 80B NP B176 355	+ Morgan (LOUC, RHEL).
δρ → ππ		MARTIN 80C NP 8169 216 CUTTS 78B PR D17 16	+Pennington (DURH) +Good, Grannis, Green, Lee+ (STON, WISC)
VALUE (MeV)	DOCUMENT ID TECN COMMENT	COUPLAND 77 PL 71B 460 PEASLEE 75 PL 57B 189	+Eisenhandler, Gibson, Astbury+ (LOQM, RHEL) +Demarzo, Guerriero+ (CANB, BARI, BROW, MIT)
-	data for averages, fits, limits, etc. • • •	ALSPECTOR 73 PRL 30 511 ABRAMS 70 PR D1 1917	+Cohen, Cvijanovich+ (RUTG, UPNJ)
~ 2191	HASAN 94 RVUE $\overline{p}p \rightarrow \pi\pi$	COOPER 68 PRL 20 1059	+Cool, Giacomelli, Kycia, Leontic, Li+ (BNL) +Hyman, Manner, Musgrave+ (ANL)
∨ 1988 ∨ 2070	HASAN 94 RVUE $\overline{p}p \rightarrow \pi\pi$ OAKDEN 94 RVUE 0.36-1.55 $\overline{p}p \rightarrow$	ОТ	HER RELATED PAPERS ———
	π+π-	O1	HER RELATED PAPERS
	³ MARTIN 80B RVUE ³ MARTIN 80C RVUE	BRICMAN 69 PL 29B 451 ABRAMS 67C PRL 18 1209	+Ferro-Luzzi, Bizard+ (CERN, CAEN, SACL) +Cool, Giacomelli, Kycia, Leontic, Li+ (BNL)
	MARTIN 80C RVUE ind waves only up to J = 3 to be important but not	AGRAMS - 676 - 776 10 1203	+cool, discontini, rejeta, econtic, et+ (one)
significantly resonant.	and waves only up to 3 = 3 to be important but not		0.00
S-CHANNEL NN		$f_0(2200)$	$I^{G}(J^{PC}) = 0^{+}(0^{+})$
S-CHANNEL /V /V VALUE (MeV)	DOCUMENT ID TECN CHG COMMENT	10(7	
	data for averages, fits, limits, etc. • • •	OMITTED FROM SUMM	ARY TABLE
•	4 CUTTS 78B CNTR 0.97-3 pp →	Seen at DCI in the K	$_{5}^{0}$ K_{5}^{0} system. Not seen in \varUpsilon radiative decays
	_ <i>\\</i> \n``	(BARU 89). Needs co	onfirmation.
2155±15 2193+ 2	$^{\circ}$ COUPLAND 77 CNTR 0 0.7–2.4 $\overline{p}p \rightarrow \overline{p}p$ $^{\circ}$ ALSPECTOR 73 CNTR $\overline{p}p$ S channel		f ₀ (2200) MASS
2193± 2 4,	FOR THE PROPERTY OF THE PROPE		10(2200) MM33
2193± 2 2190±10	6 ALSPECTOR 73 CNTR pp S channel	VALUE (MANA	•
2193 ± 2 4.0 2190 ± 10 $r^-p \to \omega \pi^0 n$	⁶ ALSPECTOR 73 CNTR	VALUE (MeV)	DOCUMENT ID TECN CHG COMMENT
$\begin{array}{ccc} 2193 \pm 2 & 4, \\ 2190 \pm 10 & \\ \mathbf{r}^{-} \mathbf{p} \rightarrow \boldsymbol{\omega} \boldsymbol{\pi}^{0} \mathbf{n} \\ \frac{ALUE (MeV)}{} \end{array}$	6 ALSPECTOR 73 CNTR	2197±17	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
2193 \pm 2 2190 \pm 10 $\pi^{-}p \rightarrow \omega \pi^{0}n$ <u>ALUE (MeV)</u> The data in this block is included in	⁶ ALSPECTOR 73 CNTR	2197±17 • • • We do not use the following	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
2193 \pm 2 2190 \pm 10 $\pi^- p \rightarrow \omega \pi^0 n$ <u>VALUE (MeV)</u> The data in this block is included in	ALSPECTOR 73 CNTR	2197±17 • • • We do not use the followi ~ 2122	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
2193 \pm 2 2190 \pm 10 $\tau^- p \rightarrow \omega \pi^0 n$ (ALUE (MeV) The data in this block is included in 1155 \pm 21 OUR AVERAGE 1140 \pm 30	6 ALSPECTOR 73 CNTR p_P S channel 7 ABRAMS 70 CNTR S channel p_N DOCUMENT ID TECN COMMENT The average printed for a previous datablock. ALDE 95 GAM2 38 $\pi^- p \rightarrow \omega \pi^0 n$	2197±17 • • • • We do not use the followi ~ 2122 ~ 2321	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
2193 \pm 2 2190 \pm 10 $\pi^- p \rightarrow \omega \pi^0 n$ ALUE (MeV) The data in this block is included in 1155 \pm 21 OUR AVERAGE 1140 \pm 30 2 Includes ATKINSON 85	6 ALSPECTOR 73 CNTR pp S channel 7 ABRAMS 70 CNTR S channel pn N DOCUMENT ID TECN COMMENT the average printed for a previous datablock. ALDE 95 GAM2 38 $π^-p$ → $ωπ^0$ n ALDE 92C GAM4 100 $π^-p$ → $ωπ^0$ n	2197±17 • • • We do not use the followi ~ 2122	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
2193 \pm 2 2190 \pm 10 $\mathbf{r}^{-}\mathbf{p} \rightarrow \omega \boldsymbol{\pi}^{0} \mathbf{n}$ ALUE (MeV) The data in this block is included in 1155 \pm 21 OUR AVERAGE 1140 \pm 30 1170 \pm 30 2 Includes ATKINSON 85. 3 $I(J^{-}\mathbf{p}) = 1(1^{-}\mathbf{p})$ from simultaneous	6 ALSPECTOR 73 CNTR pp S channel 7 ABRAMS 70 CNTR S channel pn N DOCUMENT ID TECN COMMENT the average printed for a previous datablock. ALDE 95 GAM2 38 $π^-p$ → $ωπ^0$ n ALDE 92C GAM4 100 $π^-p$ → $ωπ^0$ n	2197±17 • • • • We do not use the followi ~ 2122 ~ 2321	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
2193 \pm 2 2190 \pm 10 $\mathbf{r}^{-}\mathbf{p} \rightarrow \boldsymbol{\omega} \boldsymbol{\pi}^{0} \mathbf{n}$ <u>ALUE (MeV)</u> The data in this block is included in 2155 \pm 21 OUR AVERAGE 2140 \pm 30 2170 \pm 30 2 includes ATKINSON 85. 3 $I(J^{-}) = 1(1^{-})$ from simultanec 4 isospins 0 and 1 not separated.	For a previous datablock. ALDE 95 GAM2 38 $\pi^- p \rightarrow \omega \pi^0 n$ ALDE 92 GAM4 100 $\pi^- p \rightarrow \omega \pi^0 n$ ous analysis of $p\overline{p} \rightarrow \pi^- \pi^+$ and $\pi^0 \pi^0$.	2197±17 • • • • We do not use the followi ~ 2122 ~ 2321	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
2193 \pm 2 2190 \pm 10 $\mathbf{r}^{-}\mathbf{p} \rightarrow \omega \pi^{0}\mathbf{n}$ ALUE (MeV) The data in this block is included in this block is included in the thing of this block is included in the thing of this properties of of the this properties of this propert	For a part of the average printed for a previous datablock. ALDE 95 GAM2 $38 \pi^- p \rightarrow \omega \pi^0 n$ ALDE 92c GAM4 $100 \pi^- p \rightarrow \omega \pi^0 n$ ous analysis of $p\overline{p} \rightarrow \pi^- \pi^+$ and $\pi^0 \pi^0$.	2197±17 • • • • We do not use the followi ~ 2122 ~ 2321	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
2193 \pm 2 2190 \pm 10 $T = p \rightarrow \omega \pi^0 n$ ALUE (MeV) The data in this block is included in 155 \pm 21 OUR AVERAGE 140 \pm 30 170 \pm 30 2 Includes ATKINSON 85. 3 $I(J^0) = 1(1^-)$ from simultaned 4 Isospins 0 and 1 not separated. 5 From a fit to the total elastic or 6 Referred to as T or T region by	6 ALSPECTOR 73 CNTR $\overline{p}p$ S channel 7 ABRAMS 70 CNTR S channel $\overline{p}N$ DOCUMENT ID TECN COMMENT The average printed for a previous datablock. ALDE 95 GAM2 $38 \pi^- p \rightarrow \omega \pi^0 n$ ALDE 92C GAM4 $100 \pi^- p \rightarrow \omega \pi^0 n$ ous analysis of $p\overline{p} \rightarrow \pi^- \pi^+$ and $\pi^0 \pi^0$. The average printed for a previous datablock.	2197±17 • • • • We do not use the followi ~ 2122 ~ 2321 ¹ Cannot determine spin to be	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
2193 \pm 2 2190 \pm 10 $\mathbf{r}^{-}\mathbf{p} \rightarrow \omega \boldsymbol{\pi}^{0} \mathbf{n}$ ALUE (MeV) The data in this block is included in this block is included in this \pm 21 OUR AVERAGE 1140 \pm 30 2 Includes ATKINSON 85. 3 $I(J^{-}) = 1(1^{-})$ from simultanet 4 isospins 0 and 1 not separated. 5 From a fit to the total elastic or 6 Referred to as T or T region by	⁶ ALSPECTOR 73 CNTR $\overline{p}p$ S channel 7 ABRAMS 70 CNTR S channel $\overline{p}N$ DOCUMENT ID TECN COMMENT 1 the average printed for a previous datablock. ALDE 95 GAM2 38 $\pi^-p \rightarrow \omega \pi^0 n$ ALDE 92C GAM4 100 $\pi^-p \rightarrow \omega \pi^0 n$ cous analysis of $p\overline{p} \rightarrow \pi^-\pi^+$ and $\pi^0\pi^0$. The average printed for a previous datablock.	2197±17 • • • • We do not use the followi ~ 2122 ~ 2321 ¹ Cannot determine spin to be	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
2193 \pm 2 2190 \pm 10 $\mathbf{r}^{-}\mathbf{p} \rightarrow \mathbf{w} \mathbf{\pi}^{0} \mathbf{n}$ ALUE (MeV) The data in this block is included in RISS \pm 21 OUR AVERAGE RI40 \pm 30 2 includes ATKINSON 85. 3 $I(J^{D}) = 1(1^{-})$ from simultance 4 isospins 0 and 1 not separated. 5 From a fit to the total elastic cr 6 Referred to as T or T region by 7 Seen as bump in $I = 1$ state. S of ABRAMS 70, no narrow structures	6 ALSPECTOR 73 CNTR pp S channel 7 ABRAMS 70 CNTR S channel pn S channel pn S channel pn TECN COMMENT 1 the average printed for a previous datablock. ALDE 95 GAM2 $38 π^- p → ωπ^0 n$ ALDE 92c GAM4 $100 π^- p → ωπ^0 n$ Dous analysis of $pp → π^- π^+$ and $π^0 π^0$. Toss section. ALSPECTOR 73. See also COOPER 68. PEASLEE 75 confirm pp results cture.	2197±17 • • • We do not use the followi ~ 2122 ~ 2321 ¹ Cannot determine spin to be VALUE (MeV) 201±51 • • • We do not use the followi ~ 273	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
2193 \pm 2 2190 \pm 10 $\pi^-p \to \omega \pi^0 \pi$ ALUE (MeV) The data in this block is included in 2155 \pm 21 OUR AVERAGE 2140 \pm 30 2 Includes ATKINSON 85. 3 $f(J^0) = 1(1^-)$ from simultance 4 isospins 0 and 1 not separated. 5 From a fit to the total elastic cr 6 Referred to as T or T region by 7 Seen as bump in $I = 1$ state. S of ABRAMS 70, no narrow structures	⁶ ALSPECTOR 73 CNTR $\overline{p}p$ S channel 7 ABRAMS 70 CNTR S channel $\overline{p}N$ DOCUMENT ID TECN COMMENT 1 the average printed for a previous datablock. ALDE 95 GAM2 38 $\pi^-p \rightarrow \omega \pi^0 n$ ALDE 92C GAM4 100 $\pi^-p \rightarrow \omega \pi^0 n$ cous analysis of $p\overline{p} \rightarrow \pi^-\pi^+$ and $\pi^0\pi^0$. The average printed for a previous datablock.	2197±17 • • • We do not use the followi ~ 2122 ~ 2321 ¹ Cannot determine spin to be VALUE (MeV) 201±51 • • • We do not use the followi ~ 273 ~ 223	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
2193 \pm 2 2190 \pm 10 $r^-p \rightarrow \omega \pi^0 n$ ALUE (MeV) The State of this block is included in this block is included in this block is included in the state of the state of this block is included in the state of th	6 ALSPECTOR 73 CNTR pp S channel 7 ABRAMS 70 CNTR S channel pn S channel pn S channel pn TECN COMMENT 1 the average printed for a previous datablock. ALDE 95 GAM2 $38 π^- p → ωπ^0 n$ ALDE 92c GAM4 $100 π^- p → ωπ^0 n$ Dous analysis of $pp → π^- π^+$ and $π^0 π^0$. Toss section. ALSPECTOR 73. See also COOPER 68. PEASLEE 75 confirm pp results cture.	2197±17 • • • We do not use the followi ~ 2122 ~ 2321 ¹ Cannot determine spin to be VALUE (MeV) 201±51 • • • We do not use the followi ~ 273	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
2193 \pm 2 2190 \pm 10 $T = p \rightarrow \omega \pi^0 R$ ALUE (MeV) The data in this block is included in 155 \pm 21 OUR AVERAGE 140 \pm 30 Includes ATKINSON 85. $3I(J^P) = 1(1^-)$ from simultaned 4 isospins 0 and 1 not separated. 5 From a fit to the total elastic cr 6 Referred to as $T \circ T$ region by 7 Seen as bump in $I = 1$ state. S of ABRAMS 70, no narrow structure $I = 1$ and $I = 1$ state. S of ABRAMS 70, no narrow structure $I = 1$ state. S of ABRAMS 70, no narrow s	6 ALSPECTOR 73 CNTR pp S channel 7 ABRAMS 70 CNTR S channel pn N DOCUMENT ID TECN COMMENT The average printed for a previous datablock. ALDE 95 GAM2 38 $π^-p → ωπ^0 n$ ALDE 92C GAM4 100 $π^-p → ωπ^0 n$ ous analysis of $pp → π^-π^+$ and $π^0π^0$. TOSS section. TALSPECTOR 73. THE ALSPECTOR 73. THE ALSPECTOR 75. THE ALSPECTOR 75. THE ALSPECTOR 75. THE ALSPECTOR 75. THE ALSPECTOR 76. THE ALSPECTOR 76. THE ALSPECTOR 77. THE ALSPECTOR 78. THE ALSPECTOR 79.	2197±17 • • • We do not use the followi ~ 2122 ~ 2321 ¹ Cannot determine spin to be VALUE (MeV) 201±51 • • • We do not use the followi ~ 273 ~ 223 ² Cannot determine spin to be	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
2193 \pm 2 2190 \pm 10 $\mathbf{r} = \mathbf{p} \rightarrow \boldsymbol{\omega} \boldsymbol{\pi}^{0} \mathbf{n}$ ALUE (MeV) ALUE (MeV) ALUE (MeV) 4. 2 4. 3 4.	6 ALSPECTOR 73 CNTR $\bar{p}p$ S channel 7 ABRAMS 70 CNTR S channel $\bar{p}N$ DOCUMENT ID TECN COMMENT 1 the average printed for a previous datablock. ALDE 95 GAM2 38 $\pi^-p \to \omega \pi^0 n$ ALDE 92C GAM4 100 $\pi^-p \to \omega \pi^0 n$ ous analysis of $p\bar{p} \to \pi^-\pi^+$ and $\pi^0\pi^0$. TOSS section. ALSPECTOR 73. TOSS SECTION. ALSPECTOR 73. TOSS SECTION. ALSPECTOR 74. TOSS SECTION. ALSPECTOR 75. TOSS SECTION. ALSPECTOR 75. TOSS SECTION. ALSPECTOR 76. DOCUMENT ID TECN CHG COMMENT 1 TECN CHG	2197±17 • • • We do not use the followi ~ 2122 ~ 2321 ¹ Cannot determine spin to be VALUE (MeV) 201±51 • • • We do not use the followi ~ 273 ~ 223 ² Cannot determine spin to be	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
2193 \pm 2 2190 \pm 10 $\pi^- p \to \omega \pi^0 n$ (ALUE (MeV) The data in this block is included in 2155 \pm 21 OUR AVERAGE 2140 \pm 30 2 Includes ATKINSON 85. 3 $f(J^p) = 1(1^-)$ from simultaned 4 isospins 0 and 1 not separated. 5 From a fit to the total elastic cr 6 Referred to as T or T region by T Seen as bump in T = 1 state. So of ABRAMS 70, no narrow structure T = T	6 ALSPECTOR 73 CNTR pp S channel 7 ABRAMS 70 CNTR S channel pn N DOCUMENT ID TECN COMMENT The average printed for a previous datablock. ALDE 95 GAM2 38 $π^-p → ωπ^0 n$ ALDE 92C GAM4 100 $π^-p → ωπ^0 n$ ous analysis of $pp → π^-π^+$ and $π^0π^0$. TOSS section. TALSPECTOR 73. THE ALSPECTOR 73. THE ALSPECTOR 75. THE ALSPECTOR 75. THE ALSPECTOR 75. THE ALSPECTOR 75. THE ALSPECTOR 76. THE ALSPECTOR 76. THE ALSPECTOR 77. THE ALSPECTOR 78. THE ALSPECTOR 79.	2197±17 • • • We do not use the followi ~ 2122 ~ 2321 ¹ Cannot determine spin to be VALUE (MeV) 201±51 • • • We do not use the followi ~ 273 ~ 223 ² Cannot determine spin to be	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$

 $f_J(2220)$

 $f_J(2220)$

$$I^{G}(J^{PC}) = 0^{+}(2^{++} \text{ or } 4^{++})$$

OMITTED FROM SUMMARY TABLE

THE $f_{J}(2220)$

Written March 1998 by M. Doser (CERN).

This state has been seen in $J/\psi(1S)$ radiative decay into $K\overline{K}$ (K^+K^- and $K_S^0K_S^0$ modes seen (BALTRUSAITIS 86D, BAI 96B)). An upper limit from DM2 for these modes (AUGUSTIN 88) is at the level at which observation is claimed. There are also indications for further decay modes ($\pi^+\pi^-$ and $\overline{p}p$) in the same production process (BAI 96B), although again at the level at which previous upper limits had been obtained (BALTRUSAITIS 86D); also seen in $\eta\eta$ (ALDE 86B), $K_S^0K_S^0$ (ASTON 88D) and in K^+K^- (ALDE 88F), albeit with very low statistics. Its J^{PC} is determined from the angular distributions of these observations.

It is not seen in Υ radiative decays (BARU 89), B inclusive decays (BEHRENDS 84), nor in $\gamma\gamma$ (GODANG 97). It is also not seen in formation in $\overline{p}p \to K^+K^-$ (BARDIN 87, SCULLI 87), in $\overline{p}p \to K_SK_S$ (BARNES 93, EVANGELISTA 97), nor in $\overline{p}p \to \pi^+\pi^-$ (HASAN 96). The upper limit in $\overline{p}p$ formation can be related to the claimed decay into $\overline{p}p$ to give a lower limit for the process $J/\psi(1S) \to \gamma f_J(2220)$ of $\sim 2.5 \times 10^{-3}$. Such a signal should be visible in the inclusive photon spectrum (BLOOM 82). The limit also leads to the conclusion that two-body final states constitute only a small fraction of all decay modes of the $f_J(2220)$. Observation of further decay modes would be very desirable.

				f _J (2220) MAS	SS		
VALUE		. 011	EVTS R AVERAGE	DOCUMENT ID		TECN	COMMENT
2235				BAI	96 8	BES	$e^+e^- \rightarrow J/\psi \rightarrow$
2230	+ 6 - 7	±16	46	BAI	96B	BES	$\gamma \pi^+ \pi^ e^+ e^- \rightarrow J/\psi \rightarrow$
2232	+ 8 - 7	±15	23	BAI	96B	BES	$\gamma K^+ K^ e^+ e^- \rightarrow J/\psi \rightarrow$
2235				BAI	96B	BES	$\begin{array}{c} \gamma K^0_S K^0_S \\ e^+ e^- \to J/\psi \mapsto \gamma p \overline{p} \end{array}$
2209	+17 -15	±10	1	ASTON	88F	LASS	11 $K^-p \rightarrow K^+K^-\Lambda$
2230	± 20			BOLONKIN	88	SPEC	$40 \pi^- p \rightarrow K_5^0 K_5^0 n$
2220	±10		41	¹ ALDE	86B	GA24	38-100 $\pi p \rightarrow n \eta \eta'$
2230	± 6	±14	93	BALTRUSAIT.	. 86 D	MRK3	$e^+e^- \rightarrow \gamma K^+K^-$
2232	± 7	± 7	23	BALTRUSAIT.	.86D	MRK3	$e^+e^- \rightarrow \gamma K_s^0 K_s^0$

	1	ر(2220) WID	TH			
VALUE (MeV) E	VTS	DOCUMENT ID		TECN	COMMENT	
23 + 8 OUR AVERAGE						
19^{+}_{-} $^{13}_{11}\pm12$	74	BAI			$e^+e^- \rightarrow J/\psi \rightarrow$	
20^{+}_{-} $^{20}_{15}\pm17$	46	BAI	96B	BES	$ \begin{array}{c} \gamma \pi^+ \pi^- \\ e^+ e^- \to J/\psi \to \\ \gamma K^+ K^- \end{array} $	
$20^{+}_{-16}^{25}\pm14$	23	BAI	96B	BES	$e^+e^- \rightarrow J/\psi \rightarrow I$ $\gamma K_0^0 K_0^0$	
15 + 12 + 9	32	BAI	968	BES	$e^+e^- \rightarrow J/\psi \rightarrow \gamma \rho \overline{\rho}$	
60 ⁺¹⁰⁷ ₋₅₇		ASTON	88F	LASS	11 $K^-p \rightarrow K^+K^-\Lambda$	
80± 30		BOLONKIN	88	SPEC	40 $\pi^- p \to K_S^0 K_S^0 n$	
$26 + {20 \atop -} \pm 17$	93	BALTRUSAIT.	. 86 D	MRK3	$e^+e^- \rightarrow \gamma K^+K^-$	
$18 + \frac{23}{15} \pm 10$	23	BALTRUSAIT.	. 86 D	MRK3	$e^+e^- \rightarrow \gamma K^0_S K^0_S$	

	fj	(2220) DECAY MODES
Mode		Fraction (Γ_I/Γ)
Γ ₁ ππ		seen
Γ_2 $\pi^+\pi^-$		seen
Γ_3 $K\overline{K}$		seen
Γ ₄ ρ <u>ρ</u>		seen
Γ_5 $\gamma\gamma$		not seen
$\Gamma_6 = \eta \eta'(958)$		seen
		(2220) $\Gamma(1)\Gamma(\gamma\gamma)/\Gamma(\text{total})$
$\Gamma(K\overline{K}) \times \Gamma(\gamma\gamma)$		Г ₃ Г ₅ /Г
VALUE (eV)	<u>CL%</u>	DOCUMENT ID TECN COMMENT
< 5.6	95	² GODANG 97 CLE2 $\gamma \gamma \rightarrow K_S^0 K_S^0$
 ● ● We do not u 	ise the followl	ing data for averages, fits, limits, etc. • • •
< 86	95	² ALBRECHT 90G ARG $\gamma\gamma \rightarrow K^+K^-$
<1000	95	³ ALTHOFF 85B TASS $\gamma\gamma$, $K\overline{K}\pi$
² Assuming J ^P =	= 2+.	
³ True for J ^P =	0 ⁺ and J ^P =	= 2+.
	f _J (:	(2220) Γ(i)Γ(p̄ρ)/Γ(total)
$\Gamma(\rho \overline{\rho}) \times \Gamma(\pi^+)$		Γ ₄ Γ ₂ /Γ
VALUE (keV)	<u>CL%</u>	DOCUMENT ID TECN COMMENT
<3.9	99	⁴ HASAN 96 SPEC $\overline{p}p \rightarrow \pi^{-}\pi^{+}$
⁴ Assuming Γ ==	15 MeV and .	$J^P=2^+$
	f _J (22	220) BRANCHING RATIOS
$\Gamma(\overline{p})/\Gamma_{\text{total}}$		Γ4/Γ
	~. *	••
VALUE (units 10 ⁻⁴)		DOCUMENT ID TECN COMMENT
		ing data for averages, fits, limits, etc. • • •
<3.0	95	⁵ EVANGELISTA 97 SPEC 1.96-2.40 $p_p \rightarrow K_S^0 K_S^0$
<1.1	99.7	⁶ BARNES 93 SPEC 1.3-1.5 $Tpp \rightarrow \kappa_S^0 \kappa_S^0$
<2.6	99.7	⁶ BARDIN 87 CNTR 1.3-1.5 $\overline{p}p \rightarrow K^+K^-$
<3.6	99.7	6 SCULLI 87 CNTR 1.29-1.55pp → K+K-
⁵ Assuming r ~	20 MeV, <i>JP</i>	= 2 ⁺ and B($f_J(2220) \to K\overline{K}$) = 100%.
	30-35 MeV, J	$J^P = 2^+ \text{ and } B(f_J(2220) \to K\overline{K}) = 100\%.$
$\Gamma(\pi\pi)/\Gamma(K\overline{K})$		Γ ₁ /Γ ₃
VALUE		BAI 96B BES $e^+e^- \rightarrow J/\psi \rightarrow$
1.0±0.5		BAI 96B BES $e^+e^- \rightarrow J/\psi \rightarrow \gamma 2\pi, K\overline{K}$
Γ(<u>ρἦ</u>)/Γ(<i>Κ</i> ႗̄)		Γ ₄ /Γ ₃
VALUE		DOCUMENT ID TECH COMMENT
0.17±0.09		BAI 968 BES $e^+e^- \rightarrow J/\psi \rightarrow$
		γρ <u>ъ</u> , κ κ
		f _J (2220) REFERENCES
	PR D56 3803	C. Evangelista, Palano, Drijard+ (LEAR Collab.)
GODANG 97 F	PRL 79 3829 PRL 76 3502	R. Godang, Kinoshita, Lai+ (CLEO Collab.) +Chen, Chen+ (BES Collab.)
HASAN 96 F	PL B388 37 6	+Bugg (BRUN, LOQM)
	PL B309 469 ZPHY C48 183	+Birien, Breunlich (PS185 Collab.) +Ehrlichmann, Harder+ (ARGUS Collab.)
ASTON 88F F	PL 8215 199	+Awaji+ (SLAC, NAGO, CINC, INUS) JP
BOLONKIN 88 1	NP 8309 426 PL B195 292	+Bloshenko, Gorin+ (ITEP, SERP)
SCULLI 87 F	PRL 58 1715	+Christenson, Kreiter, Nemethy, Yamin (NYU, BNL)
ALDE 86B F	PL B177 120 PRL 56 107	+Binon, Bricman+ (SERP, BELG, LÀNL, LAPP) Baltrusaitis (CIT, UCSC, ILL, SLAC, WASH)
	ZPHY C29 189	+Braunschweig, Kirschfink+ (TASSO Collab.)
	от	THER RELATED PAPERS ———
· -		THEN NEED IN LIN
	PL 6380 189	+ lin. Thans. Chao (RHEP. BELL)
BARDIN 87 F YAOUANC 85 2	PL 6380 189 PL 8195 292 PHY C28 309	+ Jin, Zhang, Chao (BHEP, BEIJ) + Burgun+ (SACL, FERR, CERN, PADO, TORI) + Oliver, Pene, Raynal, Ono (ORSAY, TOKY)
BARDIN 87 F YAOUANC 85 Z GODFREY 84 F	PL 6380 189 PL 6195 292	+ Jin, Zhang, Chao (BHEP, BEIJ) +Burgun+ (SACL, FERR, CERN, PADO, TORI)

2225

 $I^{G}(J^{PC}) = 0^{+}(0^{-})^{+}$

OMITTED FROM SUMMARY TABLE

Seen in $J/\psi \to \gamma \phi \phi$. Needs confirmation.

MAS:	ŝ
	MAS

VALUE (MeV)	DOCUMENT IL	TECI	V COMMENT
• • We do not use the f	ollowing data for averag	ges, fits, lim	its, etc. • • •
2230±25±15	BAI	90B MRI	$\begin{array}{c} K3 J/\psi \to \\ \gamma K^+ K^- K^+ K^- \end{array}$
2214±20±13	BAI	90B MRI	$(3 J/\psi \rightarrow \chi K^+ K^- K_0^0 K_1^0)$
~ 2220	BISELLO	868 DM:	$ \begin{array}{ccc} 2 & J/\psi \rightarrow & & & \\ & & \gamma K^+ K^- K^+ K^- \end{array} $

η(2225) WIDTH

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
$150 \pm 300 \pm 60$	BAI	908 MRK3	
• • • We do not use the following	data for averages	s, fits, limits,	γK ⁺ K ⁻ K ⁺ K ⁻ etc. • • •
~ 80	BISELLO	86B DM2	$J/\psi \rightarrow \gamma K^+ K^- K^+ K^-$

7(2225) REFERENCES

BISELLO	86B

90B PRL 65 1309 86B PL 8179 294

+Blaylock+ +Busetto, Castro, Limentani+

(Mark III Collab.) (DM2 Collab.)

 $\rho_3(2250)$

$$I^{G}(J^{PC}) = 1^{+}(3^{-})$$

OMITTED FROM SUMMARY TABLE

Contains results only from formation experiments. For production experiments see the $\overline{N}N(1100-3600)$ entry. See also $\rho(2150)$, $f_2(2150), f_4(2300), \rho_5(2350).$

$\rho_{3}(2250)$ MASS

$\overline{p}p \rightarrow \pi\pi \text{ or } K\overline{K}$

VALUE (MeV)	DOCUMENT IE		TECN	CHG	COMMENT
• • • We do not use t	he following data for averag	ges, fits	, limits,	etc. •	• •
~ 2232	HASAN	94	RVUE		$\overline{p}p \rightarrow \pi\pi$
~ 2007	HASAN	94	RVUE		$\overline{p}p \rightarrow \pi\pi$
~ 2090	¹ OAKDEN	94	RVUE		$0.36-1.55 \ \overline{p}p \rightarrow \pi^{+}\pi^{-}$
~ 2250	² MARTIN	80B	RVUE		π ' π
~ 2300	² MARTIN	80 C	RVUE		
~ 2140	³ CARTER	78B	CNTR	0	0.7-2.4 p p → K-K+
~ 2150	4 CARTER	77	CNTR	0	$0.7-2.4 \overline{p}p \rightarrow \pi \pi$

¹ See however KLOET 96 who find waves only up to J=3 to be important but not significantly resonant.

S-CHANNEL TON

VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT	
• • • We do not use the	following data for average	s, fits	, limits,	etc. •		
~ 2190	⁵ CUTTS		CNTR		0.97-3 pp → NN	
2155 ± 15	^{5,6} COUPLAND	77	CNTR	0	0.7-2.4 pp →	Þρ
2193± 2	5,7 ALSPECTOR	73	CNTR		pp S channel	
2190±10	⁸ ABRAMS	70	CNTR		S channel $\bar{p}N$	
_					•	

⁵ Isospins 0 and 1 not separated.

$\rho_{3}(2250)$ WIDTH

DOCUMENT I		TECN	CHG	COMMENT
he following data for avera	ges, fits	, limits,	etc. •	• •
HASAN	94	RVUE		$\bar{\rho}\rho \rightarrow \pi\pi$
HASAN	94	RVUE		$\overline{\rho}\rho \rightarrow \pi\pi$
⁹ OAKDEN	94	RVUE		0.36-1.55 $\overline{p}p \rightarrow$
10 MARTIN	80B	RVUE		$\pi^+\pi^-$
¹⁰ MARTIN	80C	RVUE		
¹¹ CARTER	78B	CNTR	0	0.7-2.4 p p → K-K+
¹² CARTER	77	CNTR	0	0.7-2.4 p̄ρ →
	he following data for average HASAN HASAN 9 OAKDEN 10 MARTIN 10 MARTIN 11 CARTER	HASAN 94 HASAN 94 9 OAKDEN 94 10 MARTIN 80B 10 MARTIN 80C 11 CARTER 78B	he following data for averages, fits, limits, HASAN 94 RVUE HASAN 94 RVUE 9 OAKDEN 94 RVUE 10 MARTIN 80B RVUE 10 MARTIN 80C RVUE 11 CARTER 78B CNTR	he following data for averages, fits, limits, etc. • HASAN 94 RVUE HASAN 94 RVUE 9 OAKDEN 94 RVUE 10 MARTIN 80B RVUE 10 MARTIN 80C RVUE 11 CARTER 78B CNTR 0

⁹ See however KLOET 96 who find waves only up to J=3 to be important but not significantly resonant. 10 $I(J^P)=1(3^-)$ from simultaneous analysis of $p\bar{p}\to\pi^-\pi^+$ and $\pi^0\pi^0$. 11 I=0,1. $J^P=3^-$ from Barrelet-zero analysis. 12 $I(J^P)=1(3^-)$ from amplitude analysis.

S-CHANNEL NN

VALUE (MeV)	DOCUMENT ID	_	TECN	<u>CHG</u>	COMMENT	
• • • We do not use the	following data for averages,	fits	s, limits,	etc. •		
135±75	13,14 COUPLAND	77	CNTR	0	0.7-2.4 pp →	Бp
98± 8	14 ALSPECTOR				pp S channel	•
~ 85	15 ABRAMS	70	CNTR		S channel ₽N	

¹³ From a fit to the total elastic cross section.
14 Isospins 0 and 1 not separated.

$\rho_3(2250)$ REFERENCES

KLOET	96	PR D53 6120	+Myhrer	(RUTG, NORD)
HASAN	94	PL B334 215	+Bugg	(LOQM)
OAKDEN	94	NPA 574 731	+Pennington	(DURH)
MARTIN	80B	NP B176 355	+ Morgan	(LOUC, RHEL) JF
MARTIN	BOC	NP B169 216	+Pennington	(DURH) JF
CARTER	78B	NP B141 467		(LOQM)
CUTTS	78B	PR D17 16	+Good, Grannis, Green, Lee+	(STON, WISC)
CARTER	77	PL 67B 117	+Coupland, Elsenhandler, Astbury+	(LOQM, RHEL) JF
COUPLAND	77	PL 71B 460	+Eisenhandler, Gibson, Astbury+	(LOQM, RHEL)
PEASLEE	75	PL 57B 189	+Demarzo, Guerriero+ (CANB,	BARI, BROW, MIT)
ALSPECTOR	73	PRL 30 511	+Cohen, Cvijanovich+	(RUTG, UPNJ)
ABRAMS	70	PR D1 1917	+Cool, Giacomelli, Kycia, Leontic, Li+	(BNL)
COOPER	68	PRL 20 1059	+Hyman, Manner, Musgrave+	(ANL)

- OTHER RELATED PAPERS -

MARTIN	79B	PL 86B 93	+Pennington	(DURH)
CARTER	78	NP B132 176	· ·	(LOQM) JP
CARTER	778	PL 67B 122		P. (MOOL)
CARTER	77C	NP B127 202	+Coupland, Atkinson+	(LOQM, DARE, RHEL)
ZEMANY	76	NP B103 537	+MingMa, Mountz, Smith	(MSU)
BERTANZA	74	NC 23A 209	+Bigi, Casali, Lariccia+	(PISA, PADO, TORI)
BETTINI	73	NC 15A 563	+Alston-Garnjost, Bigi+	(PADO, LBL, PISA, TORI)
DONNACHIE	73	LNC 7 285	+Thomas	(MCH5)
NICHOLSON	73	PR D7 2572	+Delorme, Carroll +	(CIT, ROCH, BNL)
FIELDS	71	PRL 27 1749	+Cooper, Rhines, Allison	(ANL, OXF)
YOH	71	PRL 26 922	+Barish, Caroll, Lobkowicz+	(CIT, BNL, ROCH)
ABRAMS	67C	PRL 18 1209	+Cool, Giacomelli, Kycia, Leonti	ic, Li+ (BNL)

 $f_2(2300)$

$$I^{G}(J^{PC}) = 0^{+}(2^{+})$$

See also the mini-review under non- $q\overline{q}$ candidates. (See the index for the page number.)

f2(2300) MASS

VALUE (MeV)	DOCUMENT ID	<u>TECN</u>	COMMENT
2297±28	1 ETKIN 88	MPS	$22 \pi^- p \rightarrow \phi \phi n$
• • • We do not use the f	following data for averages, f	its, limits	, etc. • • •
2231 ± 10	BOOTH 86	OMEG	i 85 π − Be → 2φBe -
2220 ⁺⁹⁰ -20	LINDENBAUM 84	RVUE	
2320 ± 40	ETKIN 82	MPS	$22 \pi^- \rho \rightarrow 2\phi n$

¹ Includes data of ETKIN 85. The percentage of the resonance going into $\phi\phi$ 2 ^{+ +} S_2 , D_2 , and D_0 is 6⁺¹⁵₋₅, 25⁺¹⁸₋₁₄, and 69⁺¹⁶₋₂₇, respectively.

f2(2300) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
149±41	2 ETKIN	88	MPS	$22 \pi^- p \rightarrow \phi \phi n$
• • We do not use the follow	ving data for averages	, fit	s, limits,	etc. • • •
133±50	воотн	86	OMEG	$85 \pi^- \text{Be} \rightarrow 2\phi \text{Be}$
200 ± 50	LINDENBAUM	84	RVUE	
220±70	ETKIN	82	MPS	$22 \pi^- p \rightarrow 2\phi n$
2 Includes data of ETKIN 85				

Significantly resonant. $2(JP) = (13^-)$ from simultaneous analysis of $p\overline{p} \to \pi^-\pi^+$ and $\pi^0\pi^0$. 3J = 0. 1. $J^P = 3^-$ from Barrelet-zero analysis.

 $^{^{4}}I(J^{P})=1(3^{-})$ from amplitude analysis.

From a fit to the total elastic cross section.
Referred to as T or T region by ALSPECTOR 73.

⁸ Seen as bump in I=1 state. See also COOPER 68. PEASLEE 75 confirm $\overline{p}p$ results of ABRAMS 70, no narrow structure.

¹⁵ Seen as bump in I=1 state. See also COOPER 68. PEASLEE 75 confirm $\overline{p}p$ results of ABRAMS 70, no narrow structure.

 $f_2(2300), f_4(2300), f_2(2340)$

f₂(2300) DECAY MODES

	Mode			Fraction (Γ_I/Γ)
Γ ₁	φφ			seen	
			f ₂	(2300) REFERENCES	
ETKIN BOOT ETKIN LINDE ETKIN	H I NBAUM	88 86 85 84 82	PL B201 568 NP B273 677 PL 165B 217 CNPP 13 285 PRL 49 1620	+Foley, Lindenbaum+ +Carroll, Donald, Edwards+ +Foley, Longacre, Lindenbaum+ +Foley, Longacre, Lindenbaum+	(BNL, CUNY) (LIVP, GLAS, CERN) (BNL, CUNY) (CUNY) (BNL, CUNY)
			—— отн	IER RELATED PAPERS —	
LAND ARMS GREEI BOOT	TRONG N	96 89B 86 84	PR D53 2839 PL B221 221 PRL 56 1639 NP B242 51	+Adams, Chan+ +Benayoun+(CERN, CDEF, BIRM, +Lai+ (FNAL, ARIZ, FSU, N +Ballance, Carroll, Donald+	(BNL, CUNY, RP!) , BARI, ATHU, CURIN+) NDAM, TUFTS, VAND+) (LIVP, GLAS, CERN)

$f_4(2300)$

$$I^{G}(J^{PC}) = 0^{+}(4^{+})$$

OMITTED FROM SUMMARY TABLE

This entry was previously called $U_0(2350)$. Contains results only from formation experiments. For production experiments see the $\overline{NN}(1100-3600)$ entry. See also $\rho(2150)$, $f_2(2150)$, $\rho_3(2250)$, $ho_{5}(2350).$

f4(2300) MASS

$\overline{p}p \rightarrow \pi \pi \text{ or } \overline{K}K$

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
• • • We do not use t	he following data for average	es, fits, limits	i, etc. • • •
~ 2314	HASAN	94 RVUE	$\overline{p}p \rightarrow \pi\pi$
~ 2300	¹ MARTIN	80B RVUE	
~ 2300	¹ MARTIN	80c RVUE	·
~ 2340	² CARTER		$0.7-2.4 \overline{p}p \rightarrow K^- K^+$
~ 2330	DULUDE	78B OSPK	$1-2 \overline{p}p \rightarrow \pi^0 \pi^0$
~ 2310	³ CARTER	77 CNTR	$0.7-2.4 \overline{p}p \rightarrow \pi\pi$
$^{1}I(J^{P})=0(4^{+})$ fro	m simultaneous analysis of p	j → π π π -	$+$ and $\pi^0\pi^0$.
	m Barrelet-zero analysis.		
$3I(J^P) = 0(4^+)$ fro	m amplitude analysis.		

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VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
• • • We do not use the	following data for average	s, fits	, limits,	etc. • • •
~ 2380	⁴ cu⊤⊤s			0.97-3 pp → NN
2345±15	^{4,5} COUPLAND	77	CNTR	$0.7-2.4 \overline{p}p \rightarrow \overline{p}p$
2359± 2	4,6 ALSPECTOR	73	CNTR	pp S channel
2375±10	ABRAMS			S channel NN

f4(2300) WIDTH

$\overline{p}p \rightarrow \pi\pi \text{ or } \overline{K}K$

VALUE (MeV)	DOCUMENT ID		<u>TECN</u>	COMMENT	
• • • We do not use ti	he following data for average	es, fits	, limits,	etc. • • •	
~ 278	HASAN	94	RVUE	$\overline{p}p \rightarrow \pi\pi$	
~ 200	⁷ MARTIN	80c	RVUE		
~ 150	8 CARTER	788	CNTR	$0.7-2.4 \overline{p}p \rightarrow$	κ- κ+
~ 210	9 CARTER	77	CNTR	$0.7-2.4 \overline{p}p \rightarrow$	ππ
	m simultaneous analysis of p	ρp→	$\pi^-\pi^+$	and $\pi^0\pi^0$.	

${8 \ I(J^P) = 0(4^+)}$ from Barrelet-zero analysis. ${9 \ I(J^P) = 0(4^+)}$ from amplitude analysis.

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
• • We do not use	the following data for average	s, flt:	s, limits,	etc. • • •
135 ^{+ 150} - 65	. 10,11 COUPLAND	77	CNTR	0.7-2.4 p̄p → p̄p
165 + 18 - 8	¹¹ ALSPECTOR	73	CNTR	pp S channel
~ 190	ABRAMS	70	CNTR	S channel NN

f4(2300) REFERENCES

HASAN MARTIN MARTIN CARTER CUTTS DULUDE CARTER COUPLAND ALSPECTOR ABRAMS	94 80B 80C 78B 78B 78B 77 77 73	PL B334 215 NP B176 355 NP B169 216 NP B141 467 PR D17 16 PL 79B 335 PL 67B 117 PL 71B 460 PRL 30 511 PR D1 1917	+Bugg +Morgan +Pennington +Good, Grannis, Green, Lee+ +Lanou, Massimo, Peaslee+ +Couphand, Eisenhandler, ethoury+ +Eisenhandler, Gibson, Astbury+ +Cohen, Cvijanovich+ +Cohe, Cvijanovich,	(LOQM) (LOUC, RHEL) JP (DURH) JP (LOQM) (STON, WISC) (BROW, MIT, BARI) JP (LOQM, RHEL) JP (RUTG, UPNJ) (BNL)		
OTHER RELATED PAPERS						

FIELDS	71	PRL 27 1749	+Cooper, Rhines, Allison	(ANL, OXF)
YOH		PRL 26 922	+Barish, Caroll, Lobkowicz+	(CIT, BNL, ROCH)
BRICMAN		PL 29B 451	+Ferro-Luzzi, Bizard+	(CERN, CAEN, SACL)
DRICMAN	69	PF 54D 401	+rerro-Luzzi, bizaro+	(CERN, CAEN, SACE)



$$I^{G}(J^{PC}) = 0^{+}(2^{+})$$

See also the mini-review under non- $q\overline{q}$ candidates. (See the index for the page number.)

£2(2340) MASS

VALUE (MeV) 2339±55	DOCUMENT :	88		$\frac{1}{22 \pi^- p \rightarrow \phi \phi n}$
• • • We do not use the follow 2392±10 2360±20	VING data for avera BOOTH LINDENBA	86	OMEG	85 π^- Be $\rightarrow 2\phi$ Be

 1 Includes data of ETKIN 85. The percentage of the resonance going into $\phi\phi$ 2 $^+$ + S_2 , D_2 , and D_0 is 37 \pm 19, 4 $^{+12}_{-4}$, and 59 $^+_{-19}$, respectively.

62(2340) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
319 + 81 - 69	² ETKIN	88	MPS	22 $\pi^- p \rightarrow \phi \phi n$
• • We do not use the following	ng data for averages	, fit	s, limits,	etc. • • •
198± 50	воотн	86	OMEG	$85 \pi^- \text{Be} \rightarrow 2\phi \text{Be}$
150 + 150 - 50	LINDENBAUM	84	RVUE	
² Includes data of ETKIN 85.				

f ₂ (2340) DECAY MODES					
Mode	Fraction (Γ_i/Γ)				
 φφ	seen	_			

£(2340) REFERENCES

ETKIN BOOTH ETKIN LINDENBAUM	88 86 85 84	PL B201 568 NP B273 677 PL 165B 217 CNPP 13 285	+Foley, Lindenbaum+ +Carroll, Donald, Edwards+ +Foley, Longacre, Lindenbaum+	(BNL, CUNY) (LIVP, GLAS, CERN) (BNL, CUNY) (CUNY)	
ATTITO DOL ATTO DA DEDE					

- OTHER RELATED PAPERS -

	_		
89B 86	PR D53 2839 PL B221 221 PRL 56 1639 NP B242 51	+Adams, Chan+ +Benayoun+(CERN, CDEF, BI +Lai+ (FNAL, ARIZ, FSI +Ballance, Carroll, Donald+	(BNL, CUNY, RPI) RM, BARI, ATHU, CURIN+) U, NDAM, TUFTS, VAND+) (LIVP, GLAS, CERN)

 $\rho_5(2350)$, $a_6(2450)$, $f_6(2510)$

$$I^{G}(J^{PC}) = 1^{+}(5^{-})$$

OMITTED FROM SUMMARY TABLE

This entry was previously called $U_1(2400)$. See also the $\overline{N}N(1100-3600)$ and X(1900-3600) entries. See also $\rho(2150)$, $f_2(2150)$, $\rho_3(2250)$, $f_4(2300)$.

ρ_5 (2350) MASS

VALUE (MeV)					
	<u>DOCUMENT ID</u>		TECN	COMN	IENT
2330±35	ALDE	95	GAM2	38 π	$p \rightarrow \omega \pi^0 n$
pp → ππ or KK					
VALUE (MeV)	DOCUMENT ID	,	TECN	сна	COMMENT
• • We do not use the follo					
	HASAN		RVUE		$\overline{D}D \rightarrow \pi\pi$
~ 2303 ~ 2300	1 MARTIN		RVUE		$pp \rightarrow \pi\pi$
~ 2300 ~ 2250	1 MARTIN		RVUE		
~ 2500 ~ 2500	² CARTER		CNTR	0	0.7-2.4 pp →
~ 2500	CANTEN	100	CHIK	·	K-K+
~ 2480	3 CARTER	77	CNTR	0	0.7-2.4 pp →
					$\pi\pi$
S-CHANNEL WN					
VALUE (MeV)	DOCUMENT ID	<u> </u>	<u>TECN</u>	CHG	COMMENT
• • We do not use the folk	owing data for averag	es, fits	, limits,	etc. •	• •
~ 2380	4 CUTTS	78B	CNTR		$0.97-3 \overline{\rho} \rho \rightarrow$
2345±15	4,5 COUPLAND	77	CNTR	•	NN 0.7-2.4 pp → pp
2359± 2	4,6 ALSPECTOR			U	Dρ S channel
2359± 2 2350±10	7 ABRAMS		CNTR		S channel $\overline{N}N$
2360±25	8 OH		HDBC	۸	$\bar{p}(pn), K^*K2\pi$
$\frac{1}{2}I(J^P) = 1(5^-)$ from simi	ultaneous analysis of	ppo→	$\pi^-\pi^+$	and π	σ_{π^0} .
	Donnalat zana anabat				
$2I = 0(1); J^P = 5^-$ from	Darrelet-Zero analysi	3 .			
$^{3}I(J^{P})=1(5^{-})$ from amp	olitude analysis.	٠.			
${}^3I(J^P) = 1(5^-)$ from amp 4 Isospins 0 and 1 not separ	olitude analysis. rated.	.			
${}^{3}I(J^{P}) = 1(5^{-})$ from amp 4 Isospins 0 and 1 not separ 5 From a fit to the total ela	olitude analysis. rated. stic cross section.				
³ I(J ^P) = 1(5 ⁻) from amp ⁴ Isospins 0 and 1 not separ ⁵ From a fit to the total ela ⁶ Referred to as U or U reg	olitude analysis. rated. stic cross section.				
$^3I(J^P)=1(5^-)$ from amp 4 Isospins 0 and 1 not separ 5 From a fit to the total ela 6 Referred to as U or U reg 7 For $I=1$ $\overline{N}N$.	olitude analysis. rated. stic cross section. don by ALSPECTOR	73.			
3 $I(J^P) = 1(5^-)$ from amp 4 Isospins 0 and 1 not separ 5 From a fit to the total ela 6 Referred to as U or U reg 7 For $I = 1 \overline{N}N$. 8 No evidence for this bum	olitude analysis. rated. stic cross section. don by ALSPECTOR p seen in the pp da	73.	СНАРМ	AN 71	B. Narrow state no
$^3I(J^P)=1(5^-)$ from amp 4 Isospins 0 and 1 not separ 5 From a fit to the total ela 6 Referred to as U or U reg 7 For $I=1$ $\overline{N}N$.	olitude analysis. rated. stic cross section. don by ALSPECTOR p seen in the pp da	73.	НАРМ	AN 71	B. Narrow state not
$^3I(J^P)=1(5^-)$ from amp 4 Isospins 0 and 1 not separ 5 From a fit to the total ela 6 Referred to as U or U reg 7 For $I=1$ $\overline{N}N$. 8 No evidence for this bum	olitude analysis. rated. stic cross section. don by ALSPECTOR p seen in the pp da	73. ta of C	СНАРМ	AN 71	B. Narrow state not
$^3I(J^P)=1(5^-)$ from amp 4 Isospins 0 and 1 not separ 5 From a fit to the total ela 6 Referred to as U or U reg 7 For $I=1$ $\overline{N}N$. 8 No evidence for this bum confirmed by OH 73 with	ated. stic cross section. lon by ALSPECTOR p seen in the p da more data.	73. ta of C	CHAPM/	AN 71	B. Narrow state no
3 $I(J^P) = 1(5^-)$ from amp 4 isospins 0 and 1 not separ 5 From a fit to the total ela 6 Referred to as U or U reg 7 For $I = 1$ $\overline{N}N$. 8 No evidence for this burn confirmed by OH 73 with $\pi^- p \rightarrow \omega \pi^0 n$	bitude analysis. ated. stic cross section. from by ALSPECTOR p seen in the $\overline{p}p$ da more data. ρ_5 (2350) Wi	73. ta of (
3 $I(J^P) = 1(5^-)$ from amp 4 isospins 0 and 1 not separ 5 From a fit to the total ela 6 Referred to as U or U reg 7 For $I = 1$ $\overline{N}N$. 8 No evidence for this burn confirmed by OH 73 with $\pi^-p \rightarrow \omega \pi^0 n$ VALUE (MeV)	olitude analysis. ated. stic cross section. Ion by ALSPECTOR p seen in the $\overline{p}p$ da more data. ρ_5 (2350) Wi	73. ta of C	TECN	COMA	<i>MENT</i>
3 $I(J^P) = 1(5^-)$ from amp 4 isospins 0 and 1 not separ 5 From a fit to the total ela 6 Referred to as U or U reg 7 For $I = 1$ $\overline{N}N$. 8 No evidence for this burn confirmed by OH 73 with $\pi^- p \rightarrow \omega \pi^0 n$	bitude analysis. ated. stic cross section. from by ALSPECTOR p seen in the $\overline{p}p$ da more data. ρ_5 (2350) Wi	73. ta of (TECN	COMA	
$^3I(J^P)=1(5^-)$ from amp 4 isospins 0 and 1 not separ 5 From a fit to the total ela 6 Referred to as U or U reg 7 For $I=1$ $\overline{N}N$. 8 No evidence for this bum confirmed by OH 73 with $\pi^-p \longrightarrow \omega\pi^0n$ $VALUE\ (MeV)$	olitude analysis. ated. stic cross section. Ion by ALSPECTOR p seen in the $\overline{p}p$ da more data. ρ_5 (2350) Wi	73. ta of C	TECN	COMA	<i>MENT</i>
$^3I(J^P)=1(5^-)$ from amp 4 isospins 0 and 1 not separ 5 From a fit to the total ela 6 Referred to as U or U reg 7 For $I=1$ $\overline{N}N$. 8 No evidence for this burn confirmed by OH 73 with $\pi^-p \rightarrow \omega \pi^0 n$ $VALUE (MeV)$ $\Phi \to \pi \pi$ or $\overline{K}K$	olitude analysis. ated. stic cross section. Ion by ALSPECTOR p seen in the $\overline{p}p$ da more data. ρ_5 (2350) Wi	73. ta of C DTH	TECN	<u>COMA</u> 38 π	<i>MENT</i>
$^3I(J^P)=1(5^-)$ from amp 4 isospins 0 and 1 not separ 5 From a fit to the total ela 6 Referred to as U or U reg 7 For $I=1$ $\overline{N}N$. 8 No evidence for this bum confirmed by OH 73 with $\pi^-p \longrightarrow \omega\pi^0n$ $VALUE\ (MeV)$	plitude analysis. ated. stic cross section. Ion by ALSPECTOR p seen in the pp da more data. p ₅ (2350) Wi DOCUMENT IL ALDE	73. ta of C DTH	TECN GAM2	<u>COMM</u> 38 π ⁻¹ <u>CHG</u>	4ENT - p → ωπ ⁰ n <u>COMMEN</u> T
3 $I(J^P)=1(5^-)$ from amp 4 isospins 0 and 1 not separ 5 From a fit to the total ela 6 Referred to as U or U reg 7 For $I=1$ $\overline{N}N$. No evidence for this bum confirmed by OH 73 with $\pi^-p \rightarrow \omega \pi^0 n$ VALUE (MeV) $\overline{P}p \rightarrow \pi \pi$ or $\overline{K}K$ VALUE (MeV)	plitude analysis. ated. stic cross section. Ion by ALSPECTOR p seen in the pp da more data. p ₅ (2350) Wi DOCUMENT IL ALDE	73. ta of C DTH	TECN GAM2 TECN 5, limits,	<u>COMM</u> 38 π ⁻¹ <u>CHG</u>	4ENT - p → ωπ ⁰ n - COMMENT

VALUE (MeV)	DOCUMENT ID		TECN	COM	<i>I</i> ENT
400±100	ALDE	95	GAM2	38 π	$p \rightarrow \omega \pi^0 n$
Pp → ππ or KK					
VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT
	owing data for average	s, fits	i, limits,	etc. •	• •
~ 169	HASAN	94	RVUE		$\overline{p}p \rightarrow \pi\pi$
~ 250	9 MARTIN	80B	RVUE		
~ 300		80C	RVUE		
~ 150	10 CARTER	78B	CNTR	0	$0.7-2.4 \overline{p}p \rightarrow$
~ 210	¹¹ CARTER	77	CNTR	0	$\begin{array}{c} K^- K^+ \\ 0.7-2.4 \ \overline{p}p \rightarrow \\ \pi \pi \end{array}$
S-CHANNEL NN					
VALUE (MeV)	DOCUMENT ID		<u>TECN</u>	CHG	COMMENT
 We do not use the following 	owing data for average	s, fits	i, limits,	etc.	• •
135 + 150 - 65	12,13 COUPLAND	77	CNTR	0	$0.72.4~\overline{p}p \rightarrow ~\overline{p}p$
165 ⁺ 18	13 ALSPECTOR	73	CNTR		₽p S channel
< 60	¹⁴ ОН	70B	HDBC	-0	$\overline{p}(pn)$, $K^*K2\pi$
~ 140	ABRAMS		CNTR		S channel PN
${}^{9}I(J^{P}) = 1(5^{-})$ from sim ${}^{10}I = 0(1); J^{P} = 5^{-}$ from	ultaneous analysis of p Barrelet-zero analysis.	p →	$\pi^-\pi^+$	and 1	το πο.
$11 I(J^P) = 1(5^-)$ from am 12 From a fit to the total elast sospins 0 and 1 not sepa	plitude analysis. astic cross section.				

$\rho_{\rm S}(2350)$ REFERENCES

ALDE	95	ZPHY C66 379	+Binon, Bricman+	(GAMS Collab.) JP
HASAN	94	PL B334 215	+Bugg	(LOQM)
MARTIN	80B	NP B176 355	+Morgan	(LOUC, RHEL) JP
MARTIN	80C	NP B169 216	+Pennington	` (DURH) JP
CARTER	78B	NP B141 467	•	(LOQM)
CUTTS	78B	PR D17 16	+Good, Grannis, Green, Lee+	(STON, WISC)
CARTER	77	PL 67B 117	+Coupland, Eisenhandler, Astbury+	(LOQM, RHEL) JP
COUPLAND	77	PL 71B 460	+Eisenhandler, Gibson, Astbury+	(LOQM, RHEL)
ALSPECTOR	73	PRL 30 511	+Cohen, Cvijanovich+	(RUTG, UPNJ)
ОН	73	NP B51 57	+Eastman, MingMa, Parker, Smith+	(MSU)
CHAPMAN	71B	PR D4 1275	+Green, Lys, Murphy, Ring+	(MICH)
ABRAMS	70	PR D1 1917	+Cool, Giacomelli, Kycia, Leontic, Li+	(BNL)
ОН	70B	PRL 24 1257	+Parker, Eastman, Smith, Sprafka, Ma	(MSU)
ABRAMS	67C	PRL 18 1209	+Cool, Giacomelli, Kycia, Leontic, Li+	(BNL)

OTHER RELATED PAPERS -

CASO	LNC 3 707	+Conte, Tomasini+	(GENO, HAMB, MILA, SACL)
BRICMAN	PL 29B 451	+Ferro-Luzzi, Bizard+	(CERN, CAEN, SACL)

 $a_6(2450)$

$$I^{G}(J^{PC}) = 1^{-}(6^{+})$$

OMITTED FROM SUMMARY TABLE Needs confirmation.

a₆(2450) MASS

VALUE (MeV)	DOCUMENT ID	TECN CHG	COMMENT
2450±130	1 CLELAND 8	32B SPEC ±	$50 \pi p \rightarrow K_S^0 K^{\pm} p$

¹ From an amplitude analysis.

a₆(2450) WIDTH

VALUE (MeV)	DOCUMENT ID TEC	N CHG	COMMENT
400±250	² CLELAND 82B SP	EC ±	$50 \pi p \to K_S^0 K^{\pm} p$

² From an amplitude analysis.

a₆(2450) DECAY MODES

	Mode			
Γ ₁	κ κ		,	

a₆(2450) REFERENCES

82B NP B208 228 +Delfosse, Dorsaz, Gloor (DURH, GEVA, LAUS, PITT) CLELAND

 $f_6(2510)$

$$I^{G}(J^{PC}) = 0^{+}(6^{+})$$

OMITTED FROM SUMMARY TABLE

Needs confirmation.

&(2510) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT	
2510±30	BINON	84B	GAM2	$38 \pi^- p \rightarrow n2\pi^0$	
€ (2510) WIDTH					

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
240±60	BINON 84	B GAM2	$23 \pi^- \rho \rightarrow n2\pi^0$

f₆(2510) DECAY MODES

	Mode	Fraction (Γ_{I}/Γ)	_
Γ ₁	ππ	(6.0±1.0) %	_

f₆(2510) BRANCHING RATIOS

$\Gamma(\pi\pi)/\Gamma_{\text{total}}$				Γ_1/Γ
VALUE	DOCUMENT ID	<u>TECN</u>	COMMENT	
0.06 ±0.01	¹ BINON	83C GAM2	38 π ⁻ p →	π4γ
1				

f₆(2510) REFERENCES

BINON	84B	LNC 39 41	+Donskov, Duteil, Gouanere+	(SERP, BELG, LAPP) Ji
BINON	83C	5JNP 38 723	+Gouanere, Donskov, Duteil+	(SERP, BRUX+)
BOLOTOV	74	Translated from Y PL 52B 489	+Isakov, Kakauridze, Khaustov+	(SERP)

X(3250)

X(3250)

 $I^{G}(J^{PC}) = ??(???)$

OMITTED FROM SUMMARY TABLE

Narrow peak observed in several final states with hidden strangeness $(\Lambda \bar{\rho} K^+, \Lambda \bar{\rho} K^+ \pi^\pm, K^0 \rho \bar{\rho} K^\pm)$. Needs confirmation.

X(3250) MASS

3-BODY	DECAYS
VALUE (Me)	n

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT	
• • • We do not use the follow	ng data for averag	es, fits	s, limits	, etc. • • •	
3250±8±20	ALEEV	93	BIS2	$X(3250) \rightarrow$	$\Lambda \overline{p} K^+$
3265 ± 7 ± 20	ALEEV	93	BIS2	$X(3250) \rightarrow$	⊼pK−
4-BODY DECAYS	DOCUMENT ID		TECN	COMMENT	
• • We do not use the following	ng data for averag	es, fits	s, limits	, etc. • • •	
3245±8±20	ALEEV	93	BIS2	$X(3250) \rightarrow$	
3250±9±20	ALEEV	93	B152	$X(3250) \rightarrow$	
3270±8±20	ALEEV	93	BIS2	X(3250) →	KO DEK±

X(3250) WIDTH

ALEEV ALEEV DOCUMENT ID	93 93	BI\$2	$X(3250) \rightarrow \Lambda \overline{\rho} K^{+}$
DOCUMENT ID	93	BIS2	$X(3250) \rightarrow \overline{\Lambda} p K^-$
DOCUMENT ID			` , ,
		TECN	COMMENT
data for average			
uata for average	es, fit	s, limits	, etc. • • •
ALEEV	93	BI\$2	$X(3250) \rightarrow \Lambda \overline{\rho} K^{+} \pi^{-}$
ALEEV	93	BIS2	$X(3250) \rightarrow \overline{\Lambda} p K^{-} \pi^{-}$
ALEEV	93	BIS2	
250) DECAY	MOI	DES	
	ALEEV ALEEV	ALEEV 93 ALEEV 93	ALEEV 93 BIS2

 Γ_1 Γ_2 Γ_3

 $\Lambda \overline{p} K^+$ Λ<u>ρ</u>Κ+ π[±] Κ⁰ρ<u>ρ</u>Κ[±]

X(3250) REFERENCES 93 PAN 56 1358 +Balandin+ Translated from YAF 56 100. (BIS-2 Collab.) ALEEV

OTHER LIGHT UNFLAVORED MESONS (S = C = B = 0)

 $e^+e^-(1100-2200)$

 $I^{G}(J^{PC}) = ??(1 - -)$

OMITTED FROM SUMMARY TABLE

This entry contains unflavored vector mesons coupled to e^+e^- (photon) between the ϕ and $J/\psi(15)$ mass regions. See also $\omega(1420)$, $\rho(1450)$, $\omega(1600)$, $\phi(1680)$, and $\rho(1700)$.

$e^{+}e^{-}(1100-2200)$ MASSES AND WIDTHS

We do not use the following data for averages, fits, limits, etc.

VALUE (MeV) 1100 to 2200 OUR LIMIT	DOCUMENT ID	_		
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1097.0+16.0	BARTALUCCI	79	OSPK	$7 \gamma p \rightarrow e^+ e^- p$
$31.0^{+24.0}_{-20.0}$	BARTALUCCI	79	OSPK	$7 \gamma p \rightarrow e^+e^-p$
VALUE (MeV)	DOCUMENT ID		TECN	CHG COMMENT
1266.0± 5.0	BARTALUCCI	79	DASP	$0 7 \gamma p \rightarrow e^+e^-p$
110.0 ± 35.0	BARTALUCCI	79	DASP	$0 \qquad 7 \ \gamma p \rightarrow e^+e^-p$
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
~ 1830.0	PETERSON	78	SPEC	$\gamma p \rightarrow K^+ K^- p$
~ 120.0	PETERSON	78	SPEC	$\gamma p \rightarrow K^+ K^- p$
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following	ng data for averages,	, fit	s, ilmits,	etc. • • •
1870±10	ANTONELLI	96	SPEC	$e^+e^- \rightarrow hadrons$
10± 5	ANTONELLI	96	SPEC	e ⁺ e → hadrons
VALUE (MeV)	DOCUMENT ID	_	TECN	COMMENT
~ 2130	1 ESPOSITO	78	FRAM	$e^+e^- \rightarrow K^*(892)^+$
~ 30	1 ESPOSITO	78	FRAM	$e^+e^- \to K^*(892)^+$
¹ Not seen by DELCOURT 79.				

		e+e-	(1100-2200) REFERENCES
ANTONELLI	96	PL 8365 427	+ Baldini, Bertani+ (FENICE Collab.) + Basini, Bertolucci+ (DESY, FRAS) + Derado, Bertrand, Bisello, Bizot, Buon+ (LALO) + Felicetti (FRAS, NAPL, PADO, ROMA) + Dixon, Ehrlich, Galik, Larson (CORN, HARV)
BARTALUCCI	79	NC 49A 207	
DELCOURT	79	PL 86B 395	
ESPOSITO	78	LNC 22 305	
PETERSON	78	PR D18 3955	
		—— от	HER RELATED PAPERS
BACCI	76	PL 64B 356	+Bidoli, Penso, Stella, Baldini+
BACCI	75	PL 58B 481	+Bidoli, Penso, Stella+ (ROMA, FRAS)

$\overline{N}N(1100-3600)$

OMITTED FROM SUMMARY TABLE

This entry contains various high mass, unflavored structures coupled to the baryon-antibaryon system, as well as quasi-nuclear bound states below threshold.

™N(1100-3600) MASSES AND WIDTHS

We do not use the following data for averages, fits, limits etc.

VALUE (MeV)	DOCUMENT ID				
1100 to 3600 OUR LIMIT					
VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT
1107±4	DAFTARI	87	DBC	0	0. p n →
111±8±15	DAFTARI	87	DBC	0	$ \begin{array}{c} \rho^- \pi^+ \pi^- \\ 0. \ \overline{\rho}n \to \\ \rho^- \pi^+ \pi^- \end{array} $
VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT
1167 ±7	¹ CHIBA	91	CNTR		$\overline{p}d \rightarrow \gamma X$
1191.0±9.9	¹ CHIBA	87	CNTR	0	$0. \ \overline{p}p \rightarrow \gamma X$
1210 ±5.0	1,2,3,4 RICHTER	83	CNTR	0	Stopped p
VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT
1325 ±5	1 CHIBA	91	CNTR		$\overline{p}d \rightarrow \gamma X$
1329.2±7.6	¹ CHIBA	87	CNTR	0	0. p p → γX

<u> </u>					<u>` </u>	
VALUE (MeV) 1390.9±6.3	- 1	CHIBA		TECN CNTR	<u>снс</u> 0	$0. \ \overline{p}p \rightarrow \ \gamma X$
1395	1,3,4,5			CNTR		Stopped p
VALUE (MeV)	_	DOCUMENT ID BETTINI				COMMENT
~ 1410 ~ 100		BETTINI	-		0	$0. \ \overline{p}N \rightarrow 5\pi$ $0. \ \overline{p}N \rightarrow 5\pi$
100		5211111	••		•	J. p
VALUE (MeV)	_ ,	DOCUMENT ID			<u>CHG</u>	COMMENT
1468± 6 ·	6	BRIDGES	868	DBC	0	0. p N →
88±18	6	BRIDGES	86B	DBC	0	$0. \ \overline{p} \stackrel{2\pi^-\pi^+\pi^0}{\sim}$
						$2\pi^{-}\pi^{+}\pi^{0}$
VALUE (MeV)		DOCUMENT ID		TECN	<u>CHG</u>	COMMENT
1512 ± 7	1	CHIBA	91	CNTR		$\overline{p}d \rightarrow \gamma X$
1523.8± 3.6		CHIBA			0	0. p p → γX
1522 ± 7	•	BRIDGES	808	DBC	0	$0. \ \overline{p}N \rightarrow 2\pi^{-}\pi^{+}$
59 ±12	6	BRIDGES	86B	DBC	0	0. p̃ N →
						$2\pi^-\pi^+$
VALUE (MeV)		DOCUMENT ID		TECN		COMMENT
1577.8± 3.4		CHIBA BRIDGES		CNTR DBC	0	0.
1594 ± 9			000	DBC	_	$2\pi - \pi + \pi^0$
81 ±12	6	BRIDGES	86B	DBC	-	0. <i>p</i> N →
						$2\pi^{-}\pi^{+}\pi^{0}$
VALUE (MeV)	- ,	DOCUMENT ID		-		COMMENT
1633.6 ± 4.1 + 5.6	•	CHIBA		CNTR	0	0. p p → γX
$1637.1^{+5.6}_{-7.3}$		ADIELS	84	CNTR		万He
VALUE (MeV)		DOCUMENT ID		TECN	CHG	COMMENT
1638±3.0	1,2,3,4	RICHTER		CNTR		Stopped p
VALUE (MeV)	_	DOCUMENT ID		TECN	сом	MENT
1644.0 + 5 .6 - 7.3		ADIELS	84	CNTR	₽He	
LALUE (MANA)		DOCUMENT ID		TECN	COM	JENT
VALUE (MeV) 1646	— 1,3,4,5			CNTR		
1070						F
VALUE (MeV)	_	DOCUMENT ID		TECN	сомі	MENT
$1687.1^{+5.0}_{-4.3}$		ADIELS	84	CNTR	₽He	
1684	1,3,4,5	PAVLOPO	78	CNTR	Stop	ped \overline{p}
VALUE (MeV)	- ,	DOCUMENT ID CHIBA	91		CHG	$\overline{p}d \rightarrow \gamma X$
1693±2 1694±2.0	1,2,3,4	RICHTER	83	CNTR	0	Stopped p
VALUE (MeV)		DOCUMENT ID				COMMENT
1713.0±2.6		L CHIBA	87	CNTR	0	0. p ρ → γX
VALUE (MeV)		DOCUMENT ID		TECN	СНС	COMMENT
1731.0±1.5	_ :	CHIBA		CNTR		0. <u>p̄</u> ρ → γX
VALUE (MeV)		DOCUMENT ID				COMMENT
1771±1.0	-,-,-,	7 RICHTER	83	CNTR	U	Stopped \overline{p}
VALUE	_	DOCUMENT ID		TECN	СОМ	MENT
1812.3±1.2		CHIBA		CNTR	•	
3.7 ± 1.3		CHIBA	97	CNTR	Pd-	→ nX
VALUE (MeV)		DOCUMENT ID		TECN	CHG	COMMENT
1856.6±5	_	BRIDGES		SPEC	0	$0. \ \overline{p}d \rightarrow \pi\pi N$
20 ±5		BRIDGES		SPEC	0	$0. \ \overline{p} d \rightarrow \pi \pi N$
		DOCUMENT IT		TECH	~	COMMENT
VALUE (MeV)	- ,	DOCUMENT ID B DALKAROV		TECN RVUE	<u> </u>	COMMENT 0.0 pd →
~ 1870			71	ATUE	-	$p3\pi^-2\pi^+$
~ 10	•	B DALKAROV	97	RVUE	~	0.0 p d →
1072⊥25		BRIDGES	860	SPEC	0	$p3\pi^-2\pi^+$ 0. $\overline{p}d \rightarrow \pi\pi N$
1873 ± 2.5 < 5		BRIDGES		SPEC	0	0. $pd \rightarrow \pi\pi N$ 0. $pd \rightarrow \pi\pi N$
• •					-	
VALUE (MeV)		DOCUMENT ID		TECN	СОМ	MENT
1897±17		9 ABASHIAN	76			p → p3π
110±82 1897± 1		⁹ ABASHIAN KALOGERO	76 75			$p \rightarrow p3\pi$ Innihilation near
					. ti	reshold
25± 6		KALOGERO	75	DBC		nnihilation near rreshold
VALUE (MeV)		DOCUMENT ID		TECN		
~ 1920	1	0 EVANGELIST				
						6 # ⁻ n → 7n

EVANGELISTA 79 OMEG 10,16 $\pi^- p \rightarrow \overline{p}p$

~ 190

$\overline{N}N(1100-3600)$

VALUE (MeV) EV		
1937.3 ⁺ 1.3 - 0.7	11 FRANKLIN 87 SPEC 0.586 P	p 2210 $^{+79}_{-21}$ EVANGELISTA 798 OMEG 10 $\pi^- p \rightarrow K^+ K^- n$
< 3.0	11 FRANKLIN 87 SPEC 0.586 P	
1930 ± 2 12 ± 7	12 ASTON 80D OMEG $\gamma p \rightarrow$ 12 ASTON 80D OMEG $\gamma p \rightarrow$	
	6 DAUM 80E CNTR 0 93 pp -	
6.0	DAUM 80E CNTR 93 pp -	$\rightarrow \overline{p}pX$ 0.59±0.25 32 BARNES 94 SPEC 0-46 $\overline{p}p \rightarrow \overline{\Lambda}\Lambda$
1949 ±10 80 ±20	13 DEFOIX 80 HBC 0 $\overline{p}p \rightarrow$ 13 DEFOIX 80 HBC 0 $\overline{p}p \rightarrow$	
1939 ± 2	14 HAMILTON 80B CNTR 0 5 chann	
22 ± 6	14 HAMILTON 80B CNTR 0 Schann	
1935.5± 1.0	SAKAMOTO 79 HBC 0 0.37-0.1	
2.8± 1.4 1939 ± 3	SAKAMOTO 79 HBC 0 0.37-0.° BRUCKNER 77 SPEC 0 0.4-0.8	$73 pp \sim 440$ 33 EVANGELISTA 79 OMEG `10.16 $\pi^- n \rightarrow \tilde{n} n$
< 4.0	BRUCKNER 77 SPEC 0 0.4-0.8	5 a a
1935.9± 1.0	¹⁵ CHALOUPKA 76 HBC 0 pp tota	I, elastic $\frac{VALUE (MeV)}{2307 \pm 6}$ $\frac{DOCUMENT ID}{ALPER}$ $\frac{TECN}{80}$ CNTR 0 $62 \pi^- p \rightarrow$
8.8 ⁺ 4.3 - 3.2	¹⁶ CHALOUPKA 76 HBC 0 pp tota	il,elastic K^+K^-n
1942 ± 5		$0.750 \overline{p}_{P}$ 245 \pm 20 ALPER 80 CNTR 0 62 $\pi^{-}P \rightarrow$
57.5± 5	¹⁸ D'ANDLAU 75 HBC 0 0.175-0	1.750 p̄p K ⁺ K [−] n
1934.4 ⁺ 2.6 - 1.4	¹⁹ KALOGERO 75 DBC — $\bar{p}N$ ann	ihilation VALUE (MeV) DOCUMENT ID TECN COMMENT
$11 \begin{array}{c} +11 \\ -4 \end{array}$	20 KALOGERO 75 DBC - PN ann	2380 ± 10 34 ROZANSKA 80 SPRK 18 $\pi^ p op p \overline{p}$ n shillation 380 ± 20 34 ROZANSKA 80 SPRK 18 $\pi^ p op p \overline{p}$ n
1932 ± 2	15	ilhilation 380±20 34 ROZANSKA 80 SPRK 18 $\pi^- p \to p \overline{p} n$
	d	VALUE (MeV) DOCUMENT ID TECN COMMENT
9 + 4		nel $\overline{p}p \rightarrow$ 2450±10 35 ROZANSKA 80 SPRK 18 $\pi^-p \rightarrow p\overline{p}n$
1968	²¹ BENVENUTI 71 HBC 0 0.1-0.8	35 DOZANSKA GO CDDV 10 = ==
35	²¹ BENVENUTI 71 HBC 0 0.1-0.8	
ALUE (MeV)	DOCUMENT ID TECN CHG COMMEI	36 000000
049±10		ππ
80±20	00	$\vec{p}p \rightarrow 5\pi$ 210±25 36 CARTER 77 CNTR 0 0.7–2.4 $\vec{p}p \rightarrow \vec{p}p \rightarrow 5\pi$
		VALUE (MeV) DOCUMENT ID TECN CHG COMMENT
ALUE (MeV)	DOCUMENT ID COMMENT	~ 2500 37 CARTER 78B CNTR 0 0.7-2.4 pp →
2011 ± 7	23 FERRER 93 $\pi^- p \rightarrow p p \overline{p} \pi^- \pi^0$	γ- K+
25 ⁺¹⁰ -25	²³ FERRER 93 $\pi^- \rho \rightarrow \rho \rho \overline{\rho} \pi^- \pi^0$	~ 150 37 CARTER 78B CNTR 0 0.7-2.4 $\bar{p}p \rightarrow K^-K^+$
2025	GIBBARD 79 $e^-p \rightarrow e^-pp\overline{p}$	VALUE (MeV) DOCUMENT ID TECN COMMENT
30	GIBBARD 79 $e^-p \rightarrow e^-pp\bar{p}$	2710±20 ROZANSKA 80 SPRK 18 $\pi^- p \rightarrow p \overline{p} n$
2020 ± 3 24 ± 12	BENKHEIRI 77 $\pi^- p \rightarrow p p \bar{p} \pi^-$ BENKHEIRI 77 $\pi^- p \rightarrow p p \bar{p} \pi^-$	170±40 ROZANSKA 80 SPRK 18 $\pi^- p \rightarrow p\bar{p}n$
24712	DEMINIEM II A P PPPA	
ALUE (MeV)	DOCUMENT ID TECN CHG COMME	38
022± 6	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$ ightarrow$ $ ightarrow$ $ ightarrow$ $ ightarrow$ 2850 \pm 5 $ ightarrow$ 58 BRAUN 76 DBC $ ightarrow$ 5.5 $ ightarrow$ 6 $ ightarrow$ 76 DBC $ ightarrow$ 5.5 $ ightarrow$ 6 $ ightarrow$ 78 BRAUN 76 DBC $ ightarrow$ 5.5 $ ightarrow$ 6 $ ightarrow$ 78 BRAUN 76 DBC $ ightarrow$ 78 $ ightarrow$ 79 $ i$
14±13	24 AZOOZ 83 HYBR + 6 $\overline{p}p$ –	$\rightarrow p\bar{n}3\pi$ < 39 SKAUN 76 DBC - 5.5 $pa \rightarrow nn\pi$
ALUE (MeV)	DOCUMENT ID TECN CHG COMME	NT VALUE (MeV) DOCUMENT ID TECN CHG COMMENT
023± 5	BODENKAMP 83 SPEC 0 γp →	Ppp 3370±10 39 ALEXANDER 72 HBC 0 6.94 Pp
27 ± 12	BODENKAMP 83 SPEC 0 $\gamma p \rightarrow$	$\overline{p}pp$ 150±40 39 ALEXANDER 72 HBC 0 6.94 $\overline{p}p$
ALUE (MeV)	DOCUMENT ID TECN CHG COMME	NT VALUE (MeV) DOCUMENT ID TECN CHG COMMENT
026± 5	- ,,	39 ALEXANDER 72 HBC 0 6.94 Pp
20±11	24 AZOOZ 83 HYBR - 4 Pp -	140 L00 37 ALEVANDED 70 LDC 0 6 04 Tm
		Not seen by GRAF 91.
ALUE (MeV)	DOCUMENT ID TECN CHG COMME	3
080±10	25 KREYMER 80 STRC 0 13 π = 0 ppn	
110±20	25 KREYMER 80 STRC 0 13 π - 0	d → 5 Not seen by ADIELS 86.
	ρ <u></u> ρη	
ALUE (MeV)	DOCUMENT ID TECN COMMENT	 Not seen by CHIBA 88, ANGELOPOULOS 86. 8 From a phenomenological analysis of ASTERIX data.
090±20	26 KREYMER 80 STRC 13 π ⁻ d → 1	9 Produced backwards.
170 ± 50	²⁶ KREYMER 80 STRC 13 $\pi^- d \rightarrow r$	$^{10}P^{\pi^{-}P}$ $^{10}I(J^{P}) = 1(1^{-})$ from a mass dependent partial-wave analysis taking solution A.
	DOCUMENT ID TECN COMMENT	11 From reanalysis of data from JASTRZEMBSKI 81. 12 Not seen by BUSENITZ 89.
ALUE (MeV)		Not seen by BUSENITZ 89. 7 P 13 From energy dependence of 5π cross section. $I^G = 1^-$ from observation of $\omega \rho$ decay.
2110	27 EVANGELISTA 79 OMEG 10,16 $\pi^- p$ — 27 EVANGELISTA 79 OMEG 10,16 $\pi^- p$ —	$P = + \text{ and } J > 1$. $a_2(1320)\pi\pi$ also seen.
2110 330	27 EVANGELISTA 79 OMEG 10,16 $\pi^ ^ ^-$ OMEG 10,16 $\pi^ ^ ^-$ OMEG 10,16 $\pi^ ^ ^-$	$ \overline{p}p $ $P = + \text{ and } J > 1$, $a_2(1320)\pi\pi$ also seen. $1^4 J = 0$ favored, $J = 0$ or 1, seen in total $\overline{p}p$ total cross section. Primarily from annihilation
2110 330 ALUE (MeV)	27 EVANGELISTA 79 OMEG 10,16 $\pi^- p$ — 27 EVANGELISTA 79 OMEG 10,16 $\pi^- p$ — DOCUMENT ID TECN COMMENT	$P = +$ and $J > 1$. $a_2(1320)\pi\pi$ also seen. $1^4 J = 0$ favored, $J = 0$ or 1, seen in total $\overline{p}p$ total cross section. Primarily from annihilation reactions. Not seen in $\overline{p}d$ total and annihilation cross sections.
2110 330 <i>LUE</i> (MeV) 10±10	27 EVANGELISTA 79 OMEG $10.16 \pi^- p - 27$ EVANGELISTA 79 OMEG $10.16 \pi^- p - 27$ EVANGELISTA 79 OMEG $10.16 \pi^- p - 27$ OMEG	$P = +$ and $J > 1$. $a_2(1320)\pi\pi$ also seen. 14 $I = 0$ favored, $J = 0$ or 1, seen in total $\overline{p}p$ total cross section. Primarily from annihilation reactions. Not seen in $\overline{p}d$ total and annihilation cross sections. 15 Narrow bump seen in total $\overline{p}p$, $\overline{p}d$ cross sections. Isospin uncertain. Not seen $\overline{p}p$ charge exchange by ALSTON-GARNJOST 75, CHALOUPKA 76. Integrated cross sections.
2110 330 NLUE (MeV) 10±10	27 EVANGELISTA 79 OMEG 10,16 $\pi^- p$ — 27 EVANGELISTA 79 OMEG 10,16 $\pi^- p$ — DOCUMENT ID TECN COMMENT	 P = + and J > 1. a₂(1320)ππ also seen. 14 I = 0 favored, J = 0 or 1, seen in total p̄p total cross section. Primarily from annihilation reactions. Not seen in p̄d total and annihilation cross sections. 15 Narrow bump seen in total p̄p, p̄d cross sections. Isospin uncertain. Not seen p̄p charge exchange by ALSTON-GARNJOST 75, CHALOUPKA 76. Integrated crossection three times larger than BRUCKNER 77.
2110 330 ALUE (MeV) 110±10 190±10	27 EVANGELISTA 79 OMEG $10,16 \pi^- p - 27$ EVANGELISTA 79 OMEG $10,16 \pi^- p - 27$ EVANGELISTA 79 OMEG $10,16 \pi^- p - 27$ EVANGELISTA 80 SPRK $18 \pi^- p - 27$ ROZANSKA 80 SPRK $18 \pi^- p - 27$ DOCUMENT ID TECN CHG COMMENT	$P = +$ and $J > 1$. $a_2(1320)\pi\pi$ also seen. 14 $J = 0$ favored, $J = 0$ or 1, seen in total $\overline{p}p$ total cross section. Primarily from annihilation reactions. Not seen in $\overline{p}d$ total annihilation cross sections. 15 Narrow bump seen in total $\overline{p}p$, $\overline{p}d$ cross sections. Isospin uncertain. Not seen $\overline{p}p$ charge exchange by ALSTON-GARNJOST 75, CHALOUPKA 76. Integrated cross section three times larger than BRUCKNER 77. 16 Narrow bump seen in total $\overline{p}p$, $\overline{p}d$ cross sections. Isospin uncertain. Not seen
2110 330 ALUE (MeV) 110±10 190±10 ALUE (MeV)	27 EVANGELISTA 79 OMEG 10,16 π^-p — 27 EVANGELISTA 79 OMEG 10,16 π^-p — DOCUMENT ID TECN COMMENT 28 ROZANSKA 80 SPRK 18 π^-p — p 28 ROZANSKA 80 SPRK 18 π^-p — p DOCUMENT ID TECN CHG COMMEN 29 DONALD 73 HBC 0 $\overline{p}p$ S ct	P = + and J > 1. a ₂ (1320)ππ also seen. 14 J = 0 favored, J = 0 or 1, seen in total p̄p total cross section. Primarily from annihilation reactions. Not seen in p̄d total and annihilation cross sections. 15 Narrow bump seen in total p̄p, p̄d cross sections. Isospin uncertain. Not seen p̄p charge exchange by ALSTON-GARNJOST 75, CHALOUPKA 76. Integrated crossection three times larger than BRUCKNER 77. 16 Narrow bump seen in total p̄p, p̄d cross sections. Isospin uncertain. Not seen p̄p charge exchange by ALSTON-GARNJOST 75, CHALOUPKA 76. Integrated crossection three times larger than BRUCKNER 77. Not seen by CLOUGH 84.
2110 330 ALUE (MeV) [10±10 190±10 ALUE (MeV)	27 EVANGELISTA 79 OMEG $10,16 \pi^- p - 27$ EVANGELISTA 79 OMEG $10,16 \pi^- p - 27$ EVANGELISTA 79 OMEG $10,16 \pi^- p - 27$ EVANGELISTA 80 SPRK $18 \pi^- p - 27$ ROZANSKA 80 SPRK $18 \pi^- p - 27$ DOCUMENT ID TECN CHG COMMENT	$P = +$ and $J > 1$. $a_2(1320)\pi\pi$ also seen. 14 $J = 0$ favored, $J = 0$ or 1, seen in total $\overline{p}p$ total cross section. Primarily from annihilation reactions. Not seen in $\overline{p}d$ total and annihilation cross sections. 15 Narrow bump seen in total $\overline{p}p$, $\overline{p}d$ cross sections. Isospin uncertain. Not seen $\overline{p}p$ charge exchange by ALSTON-GARNJOST 75, CHALOUPKA 76. Integrated cross section three times larger than BRUCKNER 77. 16 Narrow bump seen in total $\overline{p}p$, $\overline{p}d$ cross sections. Isospin uncertain. Not seen $\overline{p}p$ charge exchange by ALSTON-GARNJOST 75, CHALOUPKA 76. Integrated cross section three times larger than BRUCKNER 77. Not seen by CLOUGH 84. 17 From energy dependence of far backward elastic scattering. Some indication of addition
2110 330 ALUE (MeV) 110±10 190±10 ALUE (MeV) 141	27 EVANGELISTA 79 OMEG 10,16 π^-p — 27 EVANGELISTA 79 OMEG 10,16 π^-p — $\frac{DOCUMENT\ ID}{28}$ ROZANSKA 80 SPRK 18 π^-p — $\frac{DOCUMENT\ ID}{29}$ DONALD 73 HBC 0 $\overline{p}p$ S ct	$P = +$ and $J > 1$. $a_2(1320)\pi\pi$ also seen. $A = 0$ favored, $J = 0$ or 1, seen in total $\overline{p}p$ total cross section. Primarily from annihilation reactions. Not seen in $\overline{p}d$ total and annihilation cross sections. $A = 0$ favored, $A = 0$ for 1, seen in total $A = 0$ for total respectively. $A = 0$ for $A = 0$ for total $A = 0$ for total respectively. So sections. Isospin uncertain. Not seen $A = 0$ for the section three times larger than BRUCKNER 77. $A = 0$ for total $A = 0$ for the section isospin uncertain. Not seen $A = 0$ for the section integrated cross sections. Isospin uncertain. Not seen $A = 0$ for the section three times larger than BRUCKNER 77. Not seen by CLOUGH 84. $A = 0$ for menergy dependence of far backward elastic scattering. Some indication of addition structure.
2110 330 ALUE (MeV) 110±10 190±10 ALUE (MeV) 141 14	27 EVANGELISTA 79 OMEG 10,16 π^-p — 27 EVANGELISTA 79 OMEG 10,16 π^-p — $\frac{DOCUMENT\ ID}{28}$ ROZANSKA 80 SPRK 18 π^-p — $\frac{DOCUMENT\ ID}{29}$ DONALD 73 HBC 0 $\overline{p}p$ S ct $\frac{DOCUMENT\ ID}{29}$ DONALD 73 HBC 0 $\overline{p}p$ S ct $\frac{DOCUMENT\ ID}{29}$ DONALD 73 HBC 0 $\overline{p}p$ S ct	$P = +$ and $J > 1$. $a_2(1320)\pi\pi$ also seen. 14 $J = 0$ favored, $J = 0$ or 1, seen in total $\overline{p}p$ total cross section. Primarily from annihilation reactions. Not seen in $\overline{p}d$ total annihilation cross sections. 15 Narrow bump seen in total $\overline{p}p$, $\overline{p}d$ cross sections. Isospin uncertain. Not seen $\overline{p}p$ charge exchange by ALSTON-GARNJOST 75, CHALOUPKA 76. Integrated cross section three times larger than BRUCKNER 77. 16 Narrow bump seen in total $\overline{p}p$, $\overline{p}d$ cross sections. Isospin uncertain. Not seen $\overline{p}p$ charge exchange by ALSTON-GARNJOST 75, CHALOUPKA 76. Integrated cross section three times larger than BRUCKNER 77. Not seen by CLOUGH 84. 17 From energy dependence of far backward elastic scattering. Some indication of addition structure. 18 From energy dependence of far backward elastic scattering. Some indication of addition structure.
2110 330 ALUE (MeV) 110±10 190±10 ALUE (MeV) 141 14 ALUE (MeV) 180±10	27 EVANGELISTA 79 OMEG 10,16 π^-p — 27 EVANGELISTA 79 OMEG 10,16 π^-p — $\frac{DOCUMENT\ ID}{28}$ ROZANSKA 80 SPRK 18 π^-p — $\frac{DOCUMENT\ ID}{29}$ DONALD 73 HBC 0 $\overline{p}p$ S ct $\frac{DOCUMENT\ ID}{29}$ DONALD 73 HBC 0 $\overline{p}p$ S ct $\frac{DOCUMENT\ ID}{29}$ DONALD 73 HBC 0 $\overline{p}p$ S ct $\frac{DOCUMENT\ ID}{29}$ DONALD 73 HBC 0 $\overline{p}p$ S ct $\frac{DOCUMENT\ ID}{29}$ DONALD 75 HBC 0 $\overline{p}p$ S ct $\frac{DOCUMENT\ ID}{29}$ DONALD 80 SPRK 18 π^-p — $\frac{DOCUMENT\ ID}{29}$ ROZANSKA 80 SPRK 18 π^-p — $\frac{DOCUMENT\ ID}{20}$	$P = + \text{ and } J > 1. \ a_2(1320)\pi\pi \text{ also seen.}$ $14 \ J = 0 \text{ favored, } J = 0 \text{ or } 1, \text{ seen in total } p \text{ total cross section.}$ $15 \ \text{Narrow bump seen in } \overline{p}d \text{ total and annihilation cross sections.}$ $15 \ \text{Narrow bump seen in total } \overline{p}p, \ \overline{p}d \text{ cross sections.}$ $15 \ \text{Narrow bump seen in total } \overline{p}p, \ \overline{p}d \text{ cross sections.}$ $15 \ \text{Narrow bump seen in total } \overline{p}p, \ \overline{p}d \text{ cross sections.}$ $15 \ \text{Narrow bump seen in total } \overline{p}p, \ \overline{p}d \text{ cross sections.}$ $16 \ \text{Narrow bump seen in total } \overline{p}p, \ \overline{p}d \text{ cross sections.}$ $16 \ \text{Narrow bump seen in total } \overline{p}p, \ \overline{p}d \text{ cross sections.}$ $16 \ \text{Narrow bump seen in total } \overline{p}p, \ \overline{p}d \text{ cross sections.}$ $16 \ \text{Narrow bump seen in total } \overline{p}p, \ \overline{p}d \text{ cross sections.}$ $16 \ \text{Narrow bump seen in total } \overline{p}p, \ \overline{p}d \text{ cross sections.}$ $16 \ \text{Narrow bump seen in total } \overline{p}p, \ \overline{p}d \text{ cross sections.}$ $17 \ \text{From energy dependence of far backward elastic scattering.}$ $17 \ \text{From energy dependence of far backward elastic scattering.}$ $18 \ \text{From energy dependence of far backward elastic scattering.}$ $19 \ \text{Not seen by ALBERI 79 with comparable statistics.}$
2110 330 ALUE (MeV) 110±10 190±10 ALUE (MeV) 141 14 ALUE (MeV) 180±10 270±10	27 EVANGELISTA 79 OMEG 10,16 π^-p — 27 EVANGELISTA 79 OMEG 10,16 π^-p — $\frac{DOCUMENT\ ID}{28}$ ROZANSKA 80 SPRK 18 π^-p — $\frac{DOCUMENT\ ID}{29}$ DONALD 73 HBC 0 $\frac{DOCUMENT\ ID}{29}$ DONALD 75 HBC 0 $\frac{DOCUMENT\ ID}{29}$ SCHOOL 18 π^-p — $\frac{DOCUMENT\ ID}{30}$ ROZANSKA 80 SPRK 18 π^-p — $\frac{DOCUMENT\ ID}{30}$	P = + and J > 1. a ₂ (1320)ππ also seen. 14 I = 0 favored, J = 0 or 1, seen in total p̄p total cross section. Primarily from annihilation reactions. Not seen in p̄d total and annihilation cross sections. 15 Narrow bump seen in total p̄p, p̄d cross sections. Isospin uncertain. Not seen p̄p charge exchange by ALSTON-GARNJOST 75, CHALOUPKA 76. Integrated crossction three times larger than BRUCKNER 77. 16 Narrow bump seen in total p̄p, p̄d cross sections. Isospin uncertain. Not seen p̄p charge exchange by ALSTON-GARNJOST 75, CHALOUPKA 76. Integrated crossction three times larger than BRUCKNER 77. Not seen by CLOUGH 84. 17 From energy dependence of far backward elastic scattering. Some indication of addition structure. 18 From energy dependence of far backward elastic scattering. Some indication of addition structure. 19 Not seen by ALBERI 79 with comparable statistics.
2110 2330 ALUE (MeV) 110±10 190±10 ALUE (MeV) 141 14 ALUE (MeV) 180±10 270±10 ALUE (MeV)	27 EVANGELISTA 79 OMEG 10,16 π^-p — 27 EVANGELISTA 79 OMEG 10,16 π^-p — $\frac{DOCUMENT\ ID}{28}$ ROZANSKA 80 SPRK 18 $\pi^-p \to p$ 28 ROZANSKA 80 SPRK 18 $\pi^-p \to p$ $\frac{DOCUMENT\ ID}{29}$ DONALD 73 HBC 0 $\overline{p}p$ S ct $\frac{DOCUMENT\ ID}{29}$ DONALD 73 HBC 0 $\overline{p}p$ S ct $\frac{DOCUMENT\ ID}{30}$ ROZANSKA 80 SPRK 18 $\pi^-p \to p$ $\frac{DOCUMENT\ ID}{30}$ ROZANSKA 80 SPRK 18 $\pi^-p \to p$ $\frac{DOCUMENT\ ID}{30}$ ROZANSKA 80 SPRK 18 $\pi^-p \to p$ $\frac{DOCUMENT\ ID}{30}$ ROZANSKA 80 SPRK 18 $\pi^-p \to p$	$P = + \text{ and } J > 1, \ a_2(1320)\pi\pi \text{ also seen.}$ $14 \ J = 0 \text{ favored, } J = 0 \text{ or 1, seen in total } \frac{1}{p} \text{ total cross section. Primarily from annihilation reactions. Not seen in } \frac{1}{p} \text{ otal annihilation cross sections.}$ $15 \text{ Narrow bump seen in total } \frac{1}{p}, \frac{1}{p} d \text{ cross sections. Isospin uncertain. Not seen } \frac{1}{p} p \text{ charge exchange by ALSTON-GARNJOST 75, CHALOUPKA 76. Integrated cross section three times larger than BRUCKNER 77.}$ $16 \text{ Narrow bump seen in total } \frac{1}{p}, \frac{1}{p} d \text{ cross sections. Isospin uncertain. Not seen } \frac{1}{p} p \text{ charge exchange by ALSTON-GARNJOST 75, CHALOUPKA 76. Integrated cross section three times larger than BRUCKNER 77. Not seen by CLOUGH 84.}$ $17 \text{ From energy dependence of far backward elastic scattering. Some indication of addition structure.}$ $18 \text{ From energy dependence of far backward elastic scattering. Some indication of addition structure.}$ $19 \text{ Not seen by ALBERI 79 with comparable statistics.}$ $20 \text{ Not seen by ALBERI 79 with comparable statistics.}$ $21 \text{ Seen as a bump in the } \frac{1}{p} p \rightarrow K_0^2 K_0^0 \text{ cross section with } J^{PC} = 1$ $22 \text{ Isospin 1 favored.}$
ALUE (MeV) 189±10 270±10 ALUE (MeV) 207±13	27 EVANGELISTA 79 OMEG 10,16 π^-p — 27 EVANGELISTA 79 OMEG 10,16 π^-p — $\frac{DOCUMENT\ ID}{28}$ ROZANSKA 80 SPRK 18 $\pi^-p \rightarrow p$ 28 ROZANSKA 80 SPRK 18 $\pi^-p \rightarrow p$ 29 DONALD 73 HBC 0 $\overline{p}p$ S cl 29 DONALD 73 HBC 0 $\overline{p}p$ S cl 29 DONALD 73 HBC 0 $\overline{p}p$ S cl 29 DONALD 75 HBC 0 $\overline{p}p$ S cl 29 DOCUMENT $\overline{p}p$ S C \overline	$P = + \text{ and } J > 1$, $a_2(1320)\pi\pi$ also seen. 14 $J = 0$ favored, $J = 0$ or 1, seen in total $\overline{p}p$ total cross section. Primarily from annihilation reactions. Not seen in $\overline{p}d$ total and annihilation cross sections. 15 Narrow bump seen in total $\overline{p}p$, $\overline{p}d$ cross sections. Isospin uncertain. Not seen $\overline{p}p$ charge exchange by ALSTON-GARNJOST 75, CHALOUPKA 76. Integrated cross section three times larger than BRUCKNER 77. 16 Narrow bump seen in total $\overline{p}p$, $\overline{p}d$ cross sections. Isospin uncertain. Not seen $\overline{p}p$ charge exchange by ALSTON-GARNJOST 75, CHALOUPKA 76. Integrated crossection three times larger than BRUCKNER 77. Not seen by CLOUGH 84. 17 From energy dependence of far backward elastic scattering. Some indication of addition structure. 18 From energy dependence of far backward elastic scattering. Some indication of addition structure. 19 Not seen by ALBERI 79 with comparable statistics. 20 Not seen by ALBERI 79 with comparable statistics. 21 Seen as a bump in the $\overline{p}p \rightarrow K_0^0 K_0^0$ cross section with $J^{PC} = 1$. 22 Isospin 1 favored. 23 Not seen by AJALTOUNI 82, ARMSTRONG 79, BUZZO 97.
2110 330 ALUE (MeV) .10±10 .90±10 ALUE (MeV) .41 14 ALUE (MeV) .80±10 .70±10 ALUE (MeV)	27 EVANGELISTA 79 OMEG 10,16 π^-p — 27 EVANGELISTA 79 OMEG 10,16 π^-p — $\frac{DOCUMENT\ ID}{28}$ ROZANSKA 80 SPRK 18 $\pi^-p \to p$ 28 ROZANSKA 80 SPRK 18 $\pi^-p \to p$ $\frac{DOCUMENT\ ID}{29}$ DONALD 73 HBC 0 $\overline{p}p$ S ct $\frac{DOCUMENT\ ID}{29}$ DONALD 73 HBC 0 $\overline{p}p$ S ct $\frac{DOCUMENT\ ID}{30}$ ROZANSKA 80 SPRK 18 $\pi^-p \to p$ $\frac{DOCUMENT\ ID}{30}$ ROZANSKA 80 SPRK 18 $\pi^-p \to p$ $\frac{DOCUMENT\ ID}{30}$ ROZANSKA 80 SPRK 18 $\pi^-p \to p$ $\frac{DOCUMENT\ ID}{30}$ ROZANSKA 80 SPRK 18 $\pi^-p \to p$	$P = + \text{ and } J > 1. \ a_2(1320)\pi\pi \text{ also seen.}$ $14 \ J = 0 \text{ favored, } J = 0 \text{ or 1, seen in total } \frac{1}{p} \text{ total cross section. Primarily from annihilation reactions. Not seen in } \frac{1}{p} \text{ dotal annihilation cross sections.}$ $15 \text{ Narrow bump seen in total } \frac{1}{p}, \frac{1}{p} d \text{ cross sections. Isospin uncertain. Not seen } \frac{1}{p} p \text{ charge exchange by ALSTON-GARNJOST 75, CHALOUPKA 76. Integrated cross section three times larger than BRUCKNER 77. 16 \text{ Narrow bump seen in total } \frac{1}{p}, \frac{1}{p} d \text{ cross sections. Isospin uncertain. Not seen } \frac{1}{p} p \text{ charge exchange by ALSTON-GARNJOST 75, CHALOUPKA 76. Integrated cross section three times larger than BRUCKNER 77. Not seen by CLOUGH 84. 17 \text{ From energy dependence of far backward elastic scattering. Some indication of addition structure.} 18 \text{ From energy dependence of far backward elastic scattering. Some indication of addition structure.} 19 \text{ Not seen by ALBERI 79 with comparable statistics.} 20 \text{ Not seen by ALBERI 79 with comparable statistics.} 21 \text{ Seen as a bump in the } \frac{1}{p} p \rightarrow K_0^2 K_0^2 \text{ cross section with } J^{PC} = 1 22 \text{ Isospin 1 favored.}$

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26 Proton spectator. See also p \bar{p} n(n) channel above. 27 I(J^P) = 1(3^-) from a mass dependent partial-wave analysis taking solution A. 28 I(J^P) = 1(3^-) from amplitude analysis assuming one-plon exchange. 29 Seep in final state \omega \pi^+ \pi^-. 30 I(J^P) = 0(2^+) from amplitude analysis assuming one-plon exchange. 31 ALLES-BORELLI 67B see neutral mode only \pi^+ \pi^- \pi^0. 32 Supersedes CARBONELL 93. 33 I(J^P) = 0(4^+) from a mass dependent partial-wave analysis taking solution A. 34 I(J^P) = 0(4^+) from amplitude analysis assuming one-plon exchange. 35 I(J^P) = 1(5^-) from amplitude analysis of \bar{p} p \to \pi \pi. 37 I=0,1 J^P = 5^- from Barrelet-zero analysis. 38 Decays to \bar{N}N and \bar{N}N\pi. Not seen by BARNETT 83. 39 Decays to 4\pi^+ 4\pi^-.
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NN(1100-3600) REFERENCES

BUZZO			
	97	ZPHY C76 475	A. Buzzo, Drijard+ (JETSET Collab.)
CHIBA	97	PR D55 40	+Doi, Fujitani+ (FUKI, INUS, KEK, SANG, OSAK, TMU)
DALKAROV	97	PL B392 229	+Kolybasov, Shapiro+ (LEBD)
BARNES	94	PL B331 203	+Birien+ (PS185 Collab.)
CARBONELL	93	PL B306 407	+Protasov, Dalkarov (ISNG, LEBD)
	93		
FERRER		NP A558 191c	+Grigonian (WA56 Collab.)
CHIBA	91	PR D44 1933	+Fujitani+ (FUKI, KEK, SANG, OSAK, TMU)
GRAF	91	PR D44 1945	+Fero, Gee+(UCI, PENN, NMSU, KARLK, KARLE, ATHU)
BUSENITZ	89	PR D40 1	+Olszewski, Čallahan+ (ILL, FNAL)
CHIBA	88	PL B202 447	+Doi (FUKI, INUS, KEK, SANG, OSAK, TMU)
CHIBA	87	PR D36 3321	+Doi+ (FUKI, INUS, KEK, SANG, OSAK, TMU)
DAFTARI	87	PRL 58 859	Com Kelementer Dem
			+Gray, Kalogeropoulos, Roy (SYRA)
FRANKLIN	87	PL B184 81	
ADIELS	86	PL B182 405	+Backenstoss+ (STOH, BASL, LASL, THES, CERN)
ANGELOPO	86	PL B178 441	Angelopoulos+(ATHU, UCI, KARLK, KARLE, NMSU, PENN)
BRIDGES	86B	PRL 56 215	+Daftari, Kalogeropoulos, Debbe+ (SYRA, CASE)
BRIDGES	86D	PL B180 313	+Brown, Daftari+ (SYRA, BNL, CASE, UMD, COLU)
ADIELS	84	PL 138B 235	(DACE MARIN MARIN CTON CTOR THEE)
			+ (BASL, KARLK, KARLE, STOH, STRB, THES)
CLOUGH	84	Pl. 146B 299	+Beard, Bugg+ (SURR, LOQM, ANIK, TRST, GEVA)
AZOOZ		PL 122B 471	+Butterworth (LOIC, RHEL, SACL, SLAC, TOHOK+)
BARNETT	83	PR D27, 493	+Blockus, Burka, Chien, Christian+ (JHU)
BODENKAMP	83	PL 133B 275	+Fries, Behrend, Fenner+ (KARLK, KARLE, DESY)
RICHTER	83	PL 126B 284	+Adiels (BASL, KARLK, KARLE, STOH, STRB, THES)
	82		
AJALTOUNI		NP B209 301	+Bachman+ (CERN, NEUC+)
BANKS	81	PL 100B 191	+Booth, Campbell, Armstrong+ (LIVP, CERN)
CHUNG	81	PRL 46 395	+Bensinger+ (BNL, BRAN, CINC, FSU, MASD)
JASTRZEM	81	PR D23 2784	Jastrzembski, Mandelkern+ (TEMP, UCI, UNM)
ALPER	80	PL 94B 422	+Becker+ (AMST, CERN, CRAC, MPIM, OXF+)
ASTON	80D	PL 93B 517	(BONN, CERN, EPOL, GLAS, LANC, MCHS, ORSAY+)
			(BONN, CERN, EFOL, GLAS, ERIC, MCHS, ORSATT)
BIONTA	80	PRL 44 909	+Carroll, Edelstein+ (BNL, CMU, FNAL, MASD)
CARROLL	80	PRL 44 1572	+Chiang, Johnson, Cester, Webb+ (BNL, PRIN)
DAUM	80E	PL 90B 475	+Hertzberger+ (AMST, CERN, CRAC, MPIM, OXF+)
DEFOIX	80	NP B162 12	+Dobrzynski, Angelini, Bigi+ (CDEF, PISA)
HAMILTON	80	PRL 44 1179	+Pun, Tripp, Lazarus+ (LBL, BNL, MTHO)
HAMILTON	80B	PRL 44 1182	+Pun, Tripp, Lazarus+ (LBL, BNL, MTHO)
KREYMER	80	PR D22 36	
			+Baggett, Fieguth+ (IND, PURD, SLAC, VAND)
ROZANSKA	80	NP B162 505	+Blum, Dieti, Grayer, Lorenz+ (MPIM, CERN)
ALBERI	79	PL 83B 247	+Alvear, Castelli, Poropat+ (TRST, CERN, IFRJ)
ARMSTRONG	79	PL B85 304	+Baccari, Belletti, Booth+ (DESY, GLAS)
EVANGELISTA	79	NP B153 253	+ (BARI, BONN, CERN, DARE, GLAS, LIVP+)
EVANGELISTA		NP B154 381	+ (BARI, BONN, CERN, DARE, GLAS, LIVP+)
GIBBARD	79	PRL 42 1593	+Ahrens, Berkelman, Cassel, Day, Harding+ (CORN)
SAKAMOTO	79	NP B158 410	+Hashimoto, Sai, Yamamoto+ (INUS)
CARTER	78B	NP B141 467	(LOQM)
PAVLOPO	78	PL 72B 415	Paviopoulos+(KARLK, KARLE, BASL, CERN, STOH, STRB)
BENKHEIRI	77	PL 68B 483	+Boucrot+ (CERN, CDEF, EPOL, LALO)
		PL 68B 483 PL 67B 222	+Boucrot+ (CERN, CDEF, EPOL, LALO) +Granz, Ingham, Kijian+ (MPIH, HEIDP, CERN)
BRUCKNER	77	PL 67B 222	+Granz, Ingham, Kilian+ (MPIH, HEIDP, CERN)
BRUCKNER CARTER	77 77	PL 67B 222 PL 67B 117	+Granz, Ingham, Kilian+ (MPIH, HEIDP, CERN) +Coupland, Eisenhandler, Astbury+ (LOQM, RHEL) JP
BRUCKNER CARTER ABASHIAN	77 77 76	PL 67B 222 PL 67B 117 PR D13 5	+Granz, Ingham, Kilian+ (MPIH, HEIDP, CERN) +Coupland, Eisenhandler, Astbury+ +Watson, Gelfand, Buttram+ (ILL, ANL, CHIC, ISU)
BRUCKNER CARTER ABASHIAN BRAUN	77 77 76 76	PL 67B 222 PL 67B 117 PR D13 5 PL 60B 481	+Granz, Ingham, Kilian+ (MPIH, HEIDP, CERN) +Coupland, Eisenhandler, Astbury+ (LOQM, RHEL) JP +Watson, Gelfand, Buttram+ (ILL, ANL, CHIC, ISU) +Brick, Fridman, Gerber, Juillot, Maurer+ (STRB)
BRUCKNER CARTER ABASHIAN BRAUN CHALOUPKA	77 77 76 76 76	PL 67B 222 PL 67B 117 PR D13 5 PL 60B 481 PL 61B 487	+ Granz, Ingham, Kilian+ + Coupland, Eisenhandler, Astbury+ + Watson, Gefand, Buttram+ + Brick, Fridman, Gerber, Julilov, Maurer+ (CERN, LIVP, MONS, PADO, ROMA, TRST)
BRUCKNER CARTER ABASHIAN BRAUN CHALOUPKA ALSTON	77 77 76 76 76 76	PL 67B 222 PL 67B 117 PR D13 5 PL 60B 481 PL 61B 487 PRL 35 1685	+Granz, Ingham, Kilian+ (MPIH, HEIDP, CERN) +Coupland, Eisenhandler, Astbury+ (LOQM, RHEL) JP +Watson, Gelfand, Buttram+ (ILL, ANL, CHIC, ISU) +Brick, Fridman, Gerber, Juillot, Maurer+ (STRB)
BRUCKNER CARTER ABASHIAN BRAUN CHALOUPKA	77 77 76 76 76	PL 67B 222 PL 67B 117 PR D13 5 PL 60B 481 PL 61B 487	+ Granz, Ingham, Kilian+ + Coupland, Eisenhandler, Astbury+ + Watson, Gefand, Buttram+ + Brick, Fridman, Gerber, Julilov, Maurer+ (CERN, LIVP, MONS, PADO, ROMA, TRST)
BRUCKNER CARTER ABASHIAN BRAUN CHALOUPKA ALSTON D'ANDLAU	77 77 76 76 76 75	PL 67B 222 PL 67B 117 PR D13 5 PL 60B 481 PL 61B 487 PRL 33 1685 PL 58B 223	+ Granz, Ingham, Kilian+ + Coupland, Eisenhandler, Astbury+ + (LOQM, RHEL) /P + Watson, Gelfand, Buttram+ (ILL, ANL, CHIC, ISU) + Brick, Fridman, Gerber, Juliot, Maurer+ + (STRB) + (CERN, LIVP, MONS, PADO, ROMA, TRST) Alston-Garnjost, Kenney, Pollard, Ross, Tripp+(LBL, MTHO) + Cohen-Ganouna, Laloum, Lutz, Petri (CDEF, PISA)
BRUCKNER CARTER ABASHIAN BRAUN CHALOUPKA ALSTON D'ANDLAU KALOGERO	77 77 76 76 76 75 75	PL 67B 222 PL 67B 117 PR D13 5 PL 60B 481 PL 61B 487 PRL 35 1685 PL 58B 223 PRL 34 1047	+-Granz, Ingham, Kilian+ +-Coupland, Eisenhandler, Astbury+ +-Watson, Geffand, Buttram+ +
BRUCKNER CARTER ABASHIAN BRAUN CHALOUPKA ALSTON D'ANDLAU KALOGERO CARROLL	77 77 76 76 76 75 75 75	PL 67B 222 PL 67B 117 PR D13 5 PL 60B 481 PL 61B 487 PRL 33 1685 PL 58B 223 PRL 34 1047 PRL 32 247	+ Granz, Ingham, Kilian+ - Coupland, Eisenhandler, Astbury+ - (LOQM, RHEL) // + Watson, Gelfand, Buttram+ - (ILL, ANL, CHIC, ISU) + Brick, Fridman, Gerber, Juillot, Maurer+ - (STRB) - CERN, LIVP, MONS, PADO, ROMA, TRST) - Alston-Garnjost, Kenney, Pollard, Ross, Tripp+(LBL, MTHO) - Kohen-Ganouna, Laloum, Lutz, Petri - Kalogeropoulos, Tzanakos - Kriang, Kriga, IJ, Mazur, Michael+ - (BNL)
BRUCKNER CARTER ABASHIAN BRAUN CHALOUPKA ALSTON D'ANDLAU KALOGERO CARROLL DONALD	77 76 76 76 75 75 75 74 73	PL 67B 222 PL 67B 117 PR D13 5 PL 60B 481 PL 61B 487 PRL 35 1685 PL 58B 223 PRL 34 1047 PRL 32 247 NP B61 333	+ Granz, Ingham, Kilian+ + Coupland, Eisenhandler, Astbury+ + Watson, Geffand, Butram+ + Brick, Fridman, Gerher, Juillot, Maurer+ - (STRB) + Green, Mons, Pado, Roman, Rst) - Alston-Garnjost, Kenney, Pollard, Ross, Tripp+(LBL, MTHO) - Kohen-Ganouna, Laloum, Lutz, Petri - Kalogeropoulos, Tzanakos - Kalogeropoulos, Tzanakos - Khalogeropoulos, Mazur, Michael+ - Edwards, Gübbins, Briand, Duboc+ - (LIVP, PARIS)
BRUCKNER CARTER ABASHIAN BRAUN CHALOUPKA ALSTON D'ANDLAU KALOGERO CARROLL DONALD ALEXANDER	77 76 76 76 75 75 75 74 73 72	PL 67B 222 PL 67B 117 PR 013 5 PL 60B 481 PL 61B 487 PRL 35 1685 PL 58B 223 PRL 34 1047 PRL 32 247 NP B61 333 NP B45 29	+ Granz, Ingham, Kilian+ - (LOQM, RHEL) P - (LOQM, RHEL) P - (LOQM, RHEL) P - Watson, Gerfand, Buttram+ - (ILI, ANL, CHIC, ISU) - Brick, Fridman, Gerber, Juillot, Maurert - (STRB) - (CERN, LIVP, MONS, PADO, ROMA, TRST) - Alston-Garnjost, Kenney, Pollard, Ross, Tripp+(LBI, MTHO) - Kohen-Ganona, Laloum, Lutz, Petri - (CDEF, PISA) - Kalogeropoulos, Tzanakos - (SYRA) - Khiang, Kycia, Li, Mazur, Michael+ - Edwards, Gibbins, Briand, Duboc+ - (LIVP, PARIS) - HSB-rNir, Benary, Dagan+ - (TELA)
BRUCKNER CARTER ABASHIAN BRAUN CHALOUPKA ALSTON D'ANDLAU KALOGERO CARROLL DONALD ALEXANDER BENVENUTI	77 76 76 76 75 75 75 74 73 72 71	PL 678 222 PL 678 117 PR D13 5 PL 60B 481 PL 61B 487 PRL 35 1685 PL 58B 223 PRL 34 1047 PRL 32 247 NP B61 333 NP B45 29 PRL 27 283	+ Granz, Ingham, Kilian+ + Coupland, Eisenhandler, Astbury+ + COQM, RHEL JP + Watson, Gelfand, Buttram+ + Brick, Fridman, Gerber, Juillot, Maurer+ - CERN, LIVP, MONS, PADO, ROMA, TRST) Alston-Garnjost, Kenney, Pollard, Ross, Tripp+(LBL, MTHO) + Cohen-Ganonua, Laloum, Lutz, Petri - Kalogeropoulos, Tzanakos - Khiang, Kycia, Li, Mazur, Michael+ - Edwards, Gibbins, Briand, Duboc+ - LIVP, PARIS) + Bar-Nir, Benary, Dagan+ - CTILA) - (TELA) + CLINE, RUZ, Reeder, Scherer - (WISC)
BRUCKNER CARTER ABASHIAN BRAUN CHALOUPKA ALSTON D'ANDLAU KALOGERO CARROLL DONALD ALEXANDER	77 76 76 76 75 75 75 74 73 72	PL 67B 222 PL 67B 117 PR D13 5 PL 60B 481 PL 61B 487 PRL 35 1685 PL 58B 223 PRL 34 1047 PRL 32 247 NP B61 333 NP B45 29 PRL 27 283 NC 50A 776	+ Granz, Ingham, Kilian+ - (LOQM, RHEL) P - (LOQM, RHEL) P - (LOQM, RHEL) P - Watson, Gerfand, Buttram+ - (ILI, ANL, CHIC, ISU) - Brick, Fridman, Gerber, Juillot, Maurert - (STRB) - (CERN, LIVP, MONS, PADO, ROMA, TRST) - Alston-Garnjost, Kenney, Pollard, Ross, Tripp+(LBI, MTHO) - Kohen-Ganona, Laloum, Lutz, Petri - (CDEF, PISA) - Kalogeropoulos, Tzanakos - (SYRA) - Khiang, Kycia, Li, Mazur, Michael+ - Edwards, Gibbins, Briand, Duboc+ - (LIVP, PARIS) - HSB-rNir, Benary, Dagan+ - (TELA)
BRUCKNER CARTER ABASHIAN BRAUN CHALOUPKA ALSTON D'ANDLAU KALOGERO CARROLL DONALD ALEXANDER BENVENUTI	77 76 76 76 75 75 75 74 73 72 71	PL 67B 222 PL 67B 117 PR D13 5 PL 60B 481 PL 61B 487 PRL 35 1685 PL 58B 223 PRL 34 1047 PRL 32 247 NP B61 333 NP B45 29 PRL 27 283 NC 50A 776	+ Granz, Ingham, Kilian+ - (LOQM, RHEL) P - (LOQM, RHEL) P - (LOQM, RHEL) P - Watson, Gerfand, Buttram+ - (ILL, ANL, CHIC, ISU) - Brick, Fridman, Gerber, Juillot, Maurer+ - (STRB) - (CERN, LIVP, MONS, PADO, ROMA, TRST) - Alston-Garnjost, Kenney, Pollard, Ross, Tripp+(LBL, MTHO) - Cohen-Ganonia, Laloum, Lutz, Petri - Kohen-Ganonia, Laloum, Lutz, Petri - Kalogeropoulos, Tzanakos - (CDEF, PISA) - Kalogeropoulos, Tzanakos - (SYRA) - Helmag, Kycia, LI, Mazur, Michael+ - Edwards, Gibbins, Briand, Duboc+ - Hedwards, Gibbins, Briand, Duboc+ - Helmag, Kycia, LI, Mazur, Michael+ - Edwards, Gibbins, Briand, Duboc+ - (LIVP, PARIS) - Has-Nir, Benary, Dagan+ - (TELA) - (KIE, Burgli, French, Frisk) - (CERN, BONN) G - (CERN, BONN) G
BRUCKNER CARTER ABASHIAN BRAUN CHALOUPKA ALSTON D'ANDLAU KALOGERO CARROLL DONALD ALEXANDER BENVENUTI ALLES	77 76 76 76 75 75 75 74 73 72 71 678	PL 678 222 PL 678 117 PR D13 5 PL 60B 481 PL 61B 487 PRL 35 1685 PL 58B 223 PRL 34 1047 PRL 32 247 NP B61 333 NP B45 29 PRL 27 283	+ Granz, Ingham, Kilian+ + Coupland, Eisenhandler, Astbury+ + COQM, RHEL JP + Watson, Gelfand, Buttram+ + Brick, Fridman, Gerber, Juillot, Maurer+ - CERN, LIVP, MONS, PADO, ROMA, TRST) Alston-Garnjost, Kenney, Pollard, Ross, Tripp+(LBL, MTHO) + Cohen-Ganonua, Laloum, Lutz, Petri - Kalogeropoulos, Tzanakos - Khiang, Kycia, Li, Mazur, Michael+ - Edwards, Gibbins, Briand, Duboc+ - LIVP, PARIS) + Bar-Nir, Benary, Dagan+ - CTILA) - (TELA) + CLINE, RUZ, Reeder, Scherer - (WISC)
BRUCKNER CARTER ABASHIAN BRAUN CHALOUPKA ALSTON D'ANDLAU KALOGERO CARROLL DONALD ALEXANDER BENVENUTI ALLES	77 76 76 76 75 75 75 74 73 72 71 678	PL 678 222 PL 678 117 PR D13 5 PL 608 481 PL 608 481 PL 618 487 PRL 35 1685 PL 588 223 PRL 37 1047 PRL 32 247 NP B61 333 NP B45 29 PRL 27 283 NC 50A 776 NC 42A 695	+ Granz, Ingham, Kilian+ - Coupland, Eisenhandler, Astbury+ - (LOQM, RHEL) /P + Watson, Geffand, Buttram+ - Birick, Fridman, Gerber, Juillot, Maurer+ - (CERN, LIVP, MONS, PADD, ROMA, TRST) - Alston-Garnjost, Kenney, Pollard, Ross, Tripp+(LBL, MTHO) - Cohen-Ganouna, Laloum, Lutz, Petri - (CDEF, PISA) - Kalogeropoulos, Tzanakos - Kalogeropoulos, Tzanakos - Kolang, Kycia, Li, Mazur, Michael+ - Edwards, Gibbins, Griand, Duboc+ - Heawards, Gibbins, Griand, Duboc+ - Hear-Mir, Benary, Degan+ - (TiLA) - (LIVP, PARIS) - (TELA) - (CERN, BONN) G - (PADD, PISA)
BRUCKNER CARTER ABASHIAN BRAUN CHALOUPKA ALSTON D'ANDLAU KALOGERO CARROLL DONALD ALEXANDER BENVENUTI ALLES	77 76 76 76 75 75 75 74 73 72 71 678	PL 678 222 PL 678 117 PR D13 5 PL 608 481 PL 608 481 PL 618 487 PRL 35 1685 PL 588 223 PRL 37 1047 PRL 32 247 NP B61 333 NP B45 29 PRL 27 283 NC 50A 776 NC 42A 695	+ Granz, Ingham, Kilian+ - (LOQM, RHEL) P - (LOQM, RHEL) P - (LOQM, RHEL) P - Watson, Gerfand, Buttram+ - (ILL, ANL, CHIC, ISU) - Brick, Fridman, Gerber, Juillot, Maurer+ - (STRB) - (CERN, LIVP, MONS, PADO, ROMA, TRST) - Alston-Garnjost, Kenney, Pollard, Ross, Tripp+(LBL, MTHO) - Cohen-Ganonia, Laloum, Lutz, Petri - Kohen-Ganonia, Laloum, Lutz, Petri - Kalogeropoulos, Tzanakos - (CDEF, PISA) - Kalogeropoulos, Tzanakos - (SYRA) - Helmag, Kycia, LI, Mazur, Michael+ - Edwards, Gibbins, Briand, Duboc+ - Hedwards, Gibbins, Briand, Duboc+ - Helmag, Kycia, LI, Mazur, Michael+ - Edwards, Gibbins, Briand, Duboc+ - (LIVP, PARIS) - Has-Nir, Benary, Dagan+ - (TELA) - (KIE, Burgli, French, Frisk) - (CERN, BONN) G - (CERN, BONN) G
BRUCKNER CRATER ABASHIAN BRAUN CHALOUPKA ALSTON D'ANDLAU KALOGERO CARROLL DONALD ALEXANDER BENYENUTI ALLES BETTINI	77 77 76 76 76 75 75 75 74 73 72 71 678 66	PL 678 222 PL 678 117 PR D13 5 PL 608 481 PL 618 487 PRL 35 1685 PRL 35 1685 PRL 32 223 PRL 34 1047 NP 861 333 NP 855 29 PRL 27 283 NC 50A 776 NC 42A 695	+ Granz, Ingham, Kilian+ - Coupland, Eisenhandler, Astbury+ - (LOQM, RHEL) /P + Watson, Gelfand, Buttram+ - (ILL, ANL, CHIC, ISU) + Brick, Fridman, Gerber, Juliot, Maurer+ - (CERN, LIVP, MONS, PADO, ROMA, TRST) - Alston-Garnjost, Kenney, Pollard, Ross, Tripp+(LBL, MTHO) - K-Ochen-Ganouna, Laloum, Lutz, Petri - Kalogeropoulos, Tzanakos - Kriang, Kycia, Li, Mazur, Michael+ - Edwards, Gibbins, Briand, Duboc+ - Haar-Nir, Benary, Dagan+ - Cliner, Rutz, Reeder, Scherer - Alles-Borelli, French, Frisk+ - Cresti, Limentani, Bertanza, Bigi+ - RELATED PAPERS
BRUCKNER CARTER ABASHIAN BRAUN CHALOUPKA ALSTON D'ANDLAU KALOGERO CARROLL DONALD ALEXANDER BENVENUTI ALLES	77 76 76 76 75 75 75 74 73 72 71 678	PL 678 222 PL 678 117 PR D13 5 PL 608 481 PL 608 481 PL 618 487 PRL 35 1685 PL 588 223 PRL 37 1047 PRL 32 247 NP B61 333 NP B45 29 PRL 27 283 NC 50A 776 NC 42A 695	+ Granz, Ingham, Kilian+ - Coupland, Eisenhandler, Astbury+ - (LOQM, RHEL) /P + Watson, Gelfand, Buttram+ - (ILL, ANL, CHIC, ISU) + Brick, Fridman, Gerber, Juliot, Maurer+ - (CERN, LIVP, MONS, PADO, ROMA, TRST) - Alston-Garnjost, Kenney, Pollard, Ross, Tripp+(LBL, MTHO) - K-Ochen-Ganouna, Laloum, Lutz, Petri - Kalogeropoulos, Tzanakos - Kriang, Kycia, Li, Mazur, Michael+ - Edwards, Gibbins, Briand, Duboc+ - Haar-Nir, Benary, Dagan+ - Cliner, Rutz, Reeder, Scherer - Alles-Borelli, French, Frisk+ - Cresti, Limentani, Bertanza, Bigi+ - RELATED PAPERS
BRUCKNER CARTER ABASHIAN BRAUN CHALOUPKA ALSTON D'ANDLAU KALOGERO CARROLL DOMALD ALEXANDER BENVENUTI ALLES BETTINI BUZZO	77 77 76 76 76 75 75 75 74 73 72 71 678 66	PL 67B 222 PL 67B 117 PR D13 5 PL 60B 481 PL 61B 487 PRL 33 1685 PRL 34 1047 PRL 32 247 NP B61 333 NP B45 29 PRL 27 283 NC 50A 776 NC 42A 695	+ Granz, Ingham, Kilian+ - (LOQM, RHEL) /P - (LOQM, RHEL) /P - (HOQM, RHEL) /P - (HOQM, RHEL) /P - (HOQM, RHEL) /P - (HIL, ANL, CHIC, ISU) - (HIC, SI)
BRUCKNER CARTER ABASHIAN BRAUN CHALOUPKA ALSTON D'ANDLAU KALOGERO CARROLL DONALD ALEXANDER BENVENUTI ALLES BETTINI BUZZO TANIMORI	77 77 76 76 76 75 75 74 73 72 71 678 66	PL 678 222 PL 678 117 PR 013 5 PL 608 481 PL 618 487 PRL 35 1665 PRL 35 1665 PRL 32 247 NP 861 333 NC 50A 776 NC 42A 695 PRL 27 283 NC 50A 776 NC 42A 695 PR 041 744	+ Granz, Ingham, Kilian+ - Choupland, Eisenhandler, Astbury+ - (LOQM, RHEL) /P + Watson, Gelfand, Buttram+ - (ILL, ANL, CHIC, ISU) + Brick, Fridman, Gerber, Juillot, Maurer+ - (CERN, LIVP, MONS, PADO, ROMA, TRST) - Alston-Garnjost, Kenney, Pollard, Ross, Tripp+(LBL, MTHO) - Kohen-Ganouna, Laloum, Lutz, Petri - Kalogeropoulos, Tzanakos - Kohiang, Kycia, Li, Mazur, Michael+ - Edwards, Gibbins, Briand, Duboc+ - Hash-Nir, Benary, Dagan+ - Cline, Rutz, Reeder, Scherer - Alles-Borelli, French, Frisk+ - Clresti, Limentani, Bertanza, Bigi+ - RELATED PAPERS - RELATED PAPERS - (JETSET Collab.) - A. Buzzo, Drijard+ - Hshimoto+ - (KEK, INUS, KYOT, TOHOK, HIRO)
BRUCKNER ABASHIAN BRAUN CHALOUPKA ALSTON PANDLAU KALOGERO CARROLL DONALD ALEXANDER BENVENUTI ALLES BETTINI BUZZO TANIMORI LIU	77 77 76 76 76 75 75 74 73 72 71 67B 66	PL 678 222 PL 678 117 PR D13 5 PL 608 481 PL 608 481 PL 188 487 PRL 35 1685 PRL 34 1047 PRI 32 247 NP 861 333 NC 50A 776 NC 42A 695 PRI 27 283 NC 50A 776 NC 42A 695 PRI 27 PRI 58 228	+ Granz, Ingham, Kilian+ - (LOQM, RHEL) P (CDEF, RISA) - (STRB) - (CERN, BONN) G (CERN, BONN) G (PADO, PISA) - (RELATED PAPERS - (JETSET Collab.) - (STON) - (STON) - (STON)
BRUCKNER ABASHIAN BRAUN CHALOUPKA ALSTON D'ANDLAU KALOGERO CARROLL DONALD ALEXANDER BENVENUTI ALLES BETTINI BUZZO TANIMORI LIU ARMSTRONG	77 77 76 76 75 75 75 74 73 72 71 678 66	PL 678 222 PL 678 117 PR 013 5 PL 608 481 PL 618 487 PRL 33 1685 PRL 33 1685 PRL 34 1047 NP 861 333 NP 845 29 PRL 27 283 NC 50A 776 NC 42A 695 OTHEI ZPHY C76 475 PR 041 744 PRL 58 2288 PL 8173 383	+ Granz, Ingham, Kilian+ - Croupland, Eisenhandler, Astbury+ - (LOQM, RHEL) /P + Watson, Geffand, Buttram+ - (ILL, ANL, CHIC, ISU) + Brick, Fridman, Gerber, Juillot, Maurer+ - (CERN, LIVP, MONS, PADO, ROMA, TRST) - Alston-Garnjost, Kenney, Pollard, Ross, Tripp+(LBL, MTHO) - Kohen-Ganouna, Laloum, Lutz, Petri - Kalogeropoulos, Tzanakos - (CDEF, PISA) - Kalogeropoulos, Tzanakos - (SYRA) - Kohiang, Kycia, Li, Mazur, Michael+ - Edwards, Gibbins, Briand, Duboc+ - Hash-Nir, Benary, Dagan+ - Cline, Rutz, Reeder, Scherer - Alles-Borelli, French, Frisk+ - (CERN, BONN) G - CREN, BONN) G - RELATED PAPERS - RELATED PAPERS - A. Buzzo, Drijard+ - Hshimoto+ - (KEK, INUS, KYOT, TOHOK, HIRO) - KÜL, Li - KOLOGE, SENNEY - (BNL), HOUS, PENN, RICE)
BRUCKNER ABASHIAN BRAUN BRAUN CHALOUPKA ALSTON PANDLAU KALOGERO CARROLL DONALD ALEXANDER BENVENUTI ALLES BETTINI BUZZO TANIMORI LIU ARMSTRONG BRIDGES	77 77 76 76 76 75 75 75 74 73 72 71 67B 66	PL 678 222 PL 678 117 PR D13 5 PL 608 481 PL 608 481 PL 188 487 PRL 35 1695 PRL 32 247 NP B61 333 NP B45 29 PRL 27 283 NC 50A 776 NC 42A 695 PR L 27 283 PR L 50 475 PR D41 744 PRL 58 2288 PL 1817 383 PRL 157 383 PRL 157 383	+ Granz, Ingham, Kilian+ - (LOQM, RHEL) P - (CER) RHO) R - (CER) RHO) - (CDEF, PISA) - (SYRA) - (CER) RHA - (SYRA) - (CER) RHIS - (CER)
BRUCKNER ABASHIAN BRAUN CHALOUPKA ALSTON D'ANDLAU KALOGERO CARROLL DONALD ALEXANDER BENVENUTI ALLES BETTINI BUZZO TANIMORI LIU ARMSTRONG BRIDGES BRIDGES BRIDGES	77 76 76 76 75 75 75 74 73 72 71 678 66	PL 678 222 PL 678 117 PR D13 5 PL 608 481 PL 618 487 PRL 33 1685 PRL 32 1685 PRL 32 247 NP 861 333 NP 845 29 PRL 27 283 NC 50A 776 NC 42A 695 PR D41 744 PRL 58 2288 PRL 37 445 PR D41 744 PRL 58 2288 PRL 57 1534	+ Granz, Ingham, Kilian+ - Croupland, Eisenhandler, Astbury+ - (LOQM, RHEL) /P - Watson, Gerfand, Buttram+ - (ILL, ANL, CHIC, ISU) - Brick, Fridman, Gerber, Juillot, Maurer+ - (CERN, LIVP, MONS, PADO, ROMA, TRST) - Alston-Garnjost, Kenney, Pollard, Ross, Tripp+(LBL, MTHO) - Kohen-Ganonua, Laloum, Lutz, Petri - Kalogeropoulos, Tzanakos - (CDEF, PISA) - Koliang, Kycia, Li, Mazur, Michael+ - Edwards, Gibbins, Briand, Duboc+ - Ledwards, Gibbins, Briand, Duboc+ - Han-Nir, Benary, Dagan+ - Cline, Rutz, Reeder, Scherer - Alles Borelli, French, Frisk+ - Cresti, Limentani, Bertanza, Bigi+ - (PADO, PISA) - RELATED PAPERS - A. Buzzo, Drijard+ - KIK, INUS, KYOT, TOHOK, HIRO) - KIL, Li - KEN, INUS, KYOT, TOHOK, HIRO) - KIL, Li - Chu, Clement, Elinon+ - (BNL), BNL, CASE, COLU, UMD, SYRA) - Polartari, Kalogeropoulos+ - (SYRA) JP - Council Condent, Britanda, Color, Collab, Syra) - Polartari, Kalogeropoulos+ - (SYRA) JP - COLOR, STAN, BRICE) - COLOR, STAN, BRICE, STAN, BRICE - Brown+ - (BLSU, BNL, CASE, COLU, UMD, SYRA) - Polartari, Kalogeropoulos+ - (SYRA) JP
BRUCKNER ABASHIAN BRAUN BRAUN CHALOUPKA ALSTON PANDLAU KALOGERO CARROLL DONALD ALEXANDER BENVENUTI ALLES BETTINI BUZZO TANIMORI LIU ARMSTRONG BRIDGES	77 77 76 76 76 75 75 75 74 73 72 71 67B 66	PL 678 222 PL 678 117 PR D13 5 PL 608 481 PL 608 481 PL 188 487 PRL 35 1695 PRL 32 247 NP B61 333 NP B45 29 PRL 27 283 NC 50A 776 NC 42A 695 PR L 27 283 PR L 50 475 PR D41 744 PRL 58 2288 PL 1817 383 PRL 157 383 PRL 157 383	+ Granz, Ingham, Kilian+ - (Coupland, Eisenhandler, Astbury+ - (LOQM, RHEL) // + Watson, Geffand, Buttram+ - (ILL, ANL, CHIC, ISU) - Brick, Fridman, Gerber, Juliot, Maurer+ - (STRB) - (CERN, LIVP, MONS, PADD, ROMA, TRST) - Alston-Garnjost, Kenney, Pollard, Ross, Tripp+(LBL, MTHO) - Cohen-Ganoura, Laloum, Lutz, Petri - Kalogeropoulos, Tzanakos - (CDEF, PISA) - (CERN, BONN) - (CDEF, PISA) - (COEF, PISA) - (FRA) - (CERN, BONN) - (FRA) - (CERN, BONN)
BRUCKNER ABASHIAN BRAUN CHALOUPKA ALSTON D'ANDLAU KALOGERO CARROLL DONALD ALEXANDER BENVENUTI ALLES BETTINI BUZZO TANIMORI LIU ARMSTRONG BRIDGES BRIDGES BRIDGES	77 76 76 76 75 75 75 74 73 72 71 678 66	PL 678 222 PL 678 117 PR 013 5 PL 608 481 PL 618 487 PRL 33 1685 PRL 32 1685 PRL 32 247 NP 861 333 NP 845 29 PRL 27 283 NC 50A 776 NC 42A 695 PR 041 744 PRL 58 2288 PRL 37 445 PR 041 744 PRL 58 2288 PRL 57 1534	+ Granz, Ingham, Kilian+ - (Coupland, Eisenhandler, Astbury+ - (LOQM, RHEL) // + Watson, Geffand, Buttram+ - (ILL, ANL, CHIC, ISU) - Brick, Fridman, Gerber, Juliot, Maurer+ - (STRB) - (CERN, LIVP, MONS, PADD, ROMA, TRST) - Alston-Garnjost, Kenney, Pollard, Ross, Tripp+(LBL, MTHO) - Cohen-Ganoura, Laloum, Lutz, Petri - Kalogeropoulos, Tzanakos - (CDEF, PISA) - (CERN, BONN) - (CDEF, PISA) - (COEF, PISA) - (FRA) - (CERN, BONN) - (FRA) - (CERN, BONN)
BRUCKNER ABASHIAN BRAUN CHALOUPKA ALSTON D'ANDLAU KALOGERO CARROLL DONALD ALEXANDER BENVENUTI ALLES BETTINI BUZZO TANIMORI LIU ARMSTRONG BRIDGES BRIDGES DOVER ANGELOPO	77 76 76 76 75 75 75 74 73 72 71 666 86 86 86 86 86 86 86 86 86 86 86 86	PL 678 222 PL 678 117 PR D13 5 PL 608 481 PL 608 481 PL 508 223 PRL 33 1685 PRL 32 1237 PRL 34 1047 NP 845 29 PRL 27 283 NC 50A 776 NC 42A 695 PR D41 744 PRL 58 2288 PRL 37 1207 PRL 37 1534 PRL 57 1534 PRL 57 1534 PRL 57 1534 PRL 57 1534	+ Granz, Ingham, Kilian+ - Croupland, Eisenhandler, Astbury+ - (LOQM, RHEL) // + Watson, Gerfand, Buttram+ - (ILL, ANL, CHIC, ISU) + Brick, Fridman, Gerber, Juillot, Maurer+ - (CERN, LIVP, MONS, PADO, ROMA, TRST) - Alston-Garnjost, Kenney, Pollard, Ross, Tripp+(LBL, MTHO) - Kohen-Ganona, Laloum, Lutz, Petri - Kalogeropoulos, Tzanakos - Kibiang, Kycia, Li, Mazur, Michael+ - Edwards, Gibbins, Briand, Duboc+ - Hash-Nir, Benary, Dagan+ - Cline, Rutz, Reeder, Scherer - Alles Borelli, French, Frisk+ - Cresti, Limentani, Bertanza, Bigi+ - RELATED PAPERS - A. Buzzo, Drijard+ - Hshimoto+ - KEK, INUS, KYOT, TOHOK, HIRO) - KILL, Li - KEN, Romer, Bertanza, Bigh - KELATED PAPERS - A. Buzzo, Drijard+ - KEK, INUS, KYOT, TOHOK, HIRO) - KILL, Li - KEN, Romer, Bertanza, Bigh - KEN, INUS, KYOT, TOHOK, HIRO) - KILL, Li - KEN, Romer, Bertanza, Bigh - KEN, Romer, Bertanza, Bigh - KELATED PAPERS - A. Buzzo, Drijard+ - KEK, INUS, KYOT, TOHOK, HIRO) - KILL, Li - KEN, Romer, Bertanza, Bigh - KEN, Romer, Bertanza, Ber
BRUCKNER ABASHIAN BRAUN CHALOUPKA ALSTON-A D'ANDLAU KALOGERO D'ANDLAU KALOGERO BETTINI BUZZO TANIMORI LIU ARMSTRONG BRIDGES BRIDGES BRIDGES BOVER	77 76 76 76 75 75 75 74 73 72 71 666 86 86 86 86 86 86 86 86 86 86 86 86	PL 678 222 PL 678 117 PR D13 5 PL 608 481 PL 608 481 PL 618 487 PRL 35 1695 PL 588 223 PPRL 32 247 NP B61 333 NP B61 333 NP B61 329 PRL 27 283 NC 50A 776 NC 42A 695 PRL 52 247 PRL 52 247 PR D41 744 PRL 58 2288 PL B175 383 PRL 157 1534 PRL 57 1534	+ Granz, Ingham, Kilian+ - (Coupland, Eisenhandler, Astbury+ - (LOQM, RHEL) // + Watson, Geffand, Buttram+ - (ILL, ANL, CHIC, ISU) - Brick, Fridman, Gerber, Juliot, Maurer+ - (STRB) - (CERN, LIVP, MONS, PADD, ROMA, TRST) - Alston-Garnjost, Kenney, Pollard, Ross, Tripp+(LBL, MTHO) - Cohen-Ganoura, Laloum, Lutz, Petri - Kalogeropoulos, Tzanakos - (CDEF, PISA) - (CERN, BONN) - (CDEF, PISA) - (COEF, PISA) - (FRA) - (CERN, BONN) - (FRA) - (CERN, BONN)

X(1900-3600)

OMITTED FROM SUMMARY TABLE

THE X(1900-3600) REGION

This high-mass region is covered nearly continuously with evidence for peaks of various widths and decay modes. As no satisfactory grouping into particles is yet possible, we list together in order of increasing mass all the Y=0 bumps above 1900 MeV that are coupled neither to $\overline{N}N$ nor to e^+e^- .

X(1900-3600) MASSES AND WIDTHS

We do not use the following data for averages, fits, limits, etc.

VALUE (MeV)		DOCUMENT ID				
1900 to 3600 OUR	LIMIT					
VALUE (MeV)		DOCUMENT ID		TECN	<u>CHG</u>	COMMENT
1870±40		¹ ALDE	86D	GAM4	0	$100 \pi^- p \rightarrow 2\eta X$
250±30		¹ ALDE	86 D	GAM4	0	$100 \pi^- p \rightarrow 2\eta X$
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
1898 ± 18	100	THOMPSON	74	HBC	+	$13 \pi^+ p \rightarrow 2\rho X$
108^{+41}_{-27}	100	THOMPSON	74	HBC	+	$13 \pi^+ \rho \rightarrow 2\rho X$
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT
1900± 40	100	BOESEBECK	68	нвс	+	$8 \pi^+ \rho \rightarrow \pi^+ \pi^0 X$
216±105	100	BOESEBECK	68	нвс	+	$ 8 \pi^{+} p \xrightarrow{\pi} \\ \pi^{+} \pi^{0} X $
VALUE (MeV)		DOCUMENT ID		TECN	CHG	COMMENT
1929 ± 14		² FOCACCI	66	MMS	_	3-12 π ⁻ p
22± 2		² FOCACCI	66	MMS	-	3-12 π-ρ
VALUE (MeV)		DOCUMENT ID		<u>TECN</u>	CHG	COMMENT
1970±10		CHLIAPNIK	80	нвс	0	$32 K^{+} \rho \rightarrow 2K_{5}^{0} 2\pi X$
40±20		CHLIAPNIK	80	нвс	0	$32 \begin{array}{c} K^+ p \rightarrow \\ 2K_5^0 2\pi X \end{array}$
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
1973±15	30	CASO	70	нвс	-	$11.2 \pi^{-} p \rightarrow \rho 2\pi$
80	30	CASO	70	нвс	-	$11.2 \pi^{-} p \rightarrow \rho 2\pi$
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	соми	MENT
2070	50	TAKAHASHI	72	нвс	8 π	p → N2π
160	50	TAKAHASHI	72	нвс		$p \rightarrow N2\pi$
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
~ 2104		BUGG	95	MRK3		$J/\psi \rightarrow \gamma \pi^{+} \pi^{-} \pi^{+} \pi^{-}$
2103 ± 50	586	3 BISELLO	89B	DM2		$J/\psi \rightarrow 4\pi\gamma$
187 ± 75	586	3 BISELLO	89B	DM2		$J/\psi o 4\pi \gamma$
2100 ± 40		4 ALDE		GAM4	0	$100 \pi^- p \rightarrow 2\eta X$
250 ± 40		⁴ ALDE	86 D	GAM4	0	$100 \pi^- \rho \rightarrow 2\eta X$
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	соми	MENT
2141±12	389	GREEN	86	MPSF	400 p	DA → 4KX
49±28	389	GREEN	86	MPSF	400	oA → 4KX
VALUE (MeV)		DOCUMENT ID		TECN	CHG	COMMENT
2190±10		CLAYTON	67	HBC	±	$2.5 \overline{p}p \rightarrow a_2, \omega$

X(1900-3600)

VALUE (MeV)		DOCUMENT ID		TECN	CHG	COMMENT	VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
2195±15		² FOCACCI	66	MMS	_	3-12 π ⁻ p	2880 ± 20	230	BAUD	69	MMS	_	8~10 π ⁻ p
39±14		² FOCACCI	66	MMS	-	3-12 π p	< 15	230	BAUD	69	MMS	-	8-10 π ⁻ p
VALUE (MeV)		DOCUMENT ID		TECN	CHG	COMMENT	VALUE (MeV)		DOCUMENT ID		TECN	<u>CHG</u>	COMMENT
2207 ± 22		⁵ CASO	70	нвс	_	11.2 $\pi^{-}p$	3025 ± 20		BAUD	70	MMS	_	10.5-13 π ⁻ p
130		⁵ CASO	70	нвс	-	11.2 π ⁻ p	~ 25		BAUD	70	MMS	-	10.5-13 π ⁻ p
VALUE (MeV)		DOCUMENT ID		TECN	СОМ	MENT	VALUE (MeV)		DOCUMENT ID		TECN	CHG	COMMENT
2280± 50		ATKINSON	85	OMEG			3075 ± 20		BAUD	70	MMS	_	10.5-13 π ⁻ p
						$\omega \pi^+ \pi^- \pi^0$	~ 25		BAUD	70	MMS	-	10.5-13 $\pi^- p$
440±110		ATKINSON	85	OMEG		$0 \gamma p \rightarrow \omega \pi^{+} \pi^{-} \pi^{0}$							
					,		VALUE (MeV)		DOCUMENT ID		TECN	_	COMMENT
VALUE (MeV)		DOCUMENT ID		TECN		COMMENT	3145 ± 20		BAUD	70	MMS	-	10.5-15 π ⁻ p
2300 ± 100		ATKINSON		OMEG		$20-70 \ \gamma p \rightarrow \rho f$	< 10		BAUD	70	MMS	-	10.5-15 π ⁻ ρ
~ 250		ATKINSON	84F	OMEG	±0	$20-70 \gamma p \rightarrow \rho f$	VALUE (MeV)		DOCUMENT ID		TECN	CHG	COMMENT
VALUE (MeV)		DOCUMENT ID		TECN	CHC	COMMENT	3475±20		BAUD	70	MMS		14-15.5 π ⁻ D
2330±30		ATKINSON	88	OMEG		25-50 γ p →	~ 30		BAUD	70	MMS	_	14-15.5 π p
2330 ± 30		ATRINSON	00	OWIEG	U	$\rho^{\pm} \rho^{0} \pi^{\mp}$	30		DAOD	, ,	1411413		14 15.5 n p
435±75		ATKINSON	88	OMEG	0	25-50 γp →	VALUE (MeV)		DOCUMENT ID		TECN	<u>CHG</u>	COMMENT
						$ ho^{\pm} ho^0 \pi^{\mp}$	3535 ± 20		BAUD	70	MMS	-	14-15.5 $\pi^- p$
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT	~ 30		BAUD	70	MMS		14-15.5 π ⁻ p
2340±20	126	6 BALTAY	75	HBC	+	$15 \pi^+ p \rightarrow p5\pi$		2 wave in one of					
			75	нвс	+	$15 \pi^+ p \rightarrow p5\pi$		ANTIPOV 72, wh					
180±60	126	6 BALTAY	15	noc									
180±60	126	ABALIAY	15	HBC		15 % p -> p 5 %		3 sees no peak, ha	850 events in A	ineni	co+Bart	h bins.	ARESTOV 80 s
	126	DOCUMENT ID	/5	TECN	СНG	COMMENT	no peak.		•			h bins.	ARESTOV 80 s
VALUE (MeV) 2382±24	126	DOCUMENT ID	66	TECN MMS		<u>СОММЕНТ</u> 3–12 т [—] р	no peak. 4 Seen in $J =$	0 wave in one of	the two ambiguou	ıs sol	utions.	h bins.	ARESTOV 80 s
VALUE (MeV)	126	DOCUMENT ID		TECN	СНG	COMMENT	no peak. 4 Seen in $J = 5$ Seen in $\rho = 6$ Dominant d	0 wave in one of $\pi^+\pi^-$ (ω and η a lecay into $\rho^0\rho^0\pi^+$	the two ambiguou ntiselected in 4π . BALTAY 78 fli	ıs sol syste	utions. m).		
<u>VALUE (MeV)</u> 2382±24 62± 6	126	DOCUMENT ID	66	TECN MMS	<u>снс</u> –	<u>СОММЕНТ</u> 3–12 т [—] р	no peak. 4 Seen In $J = 5$ Seen In $\rho = 5$ 6 Dominant denth which conta	0 wave in one of $\pi^+\pi^-$ (ω and η a lecay into $\rho^0\rho^0\pi^+$ in $\rho^+\rho^0\pi^0$ and 2	the two ambiguountiselected in 4π BALTAY 78 fluor $p^+\pi^-$	ıs sol syste	utions. m).		
VALUE (MeV) 2382±24 62± 6 VALUE (MeV)	126	DOCUMENT ID FOCACCI FOCACCI	66	TECN MMS MMS	<u>снс</u> - -	<u>COMMENT</u> 3-12 π ⁻ p 3-12 π ⁻ p	no peak. 4 Seen In $J = 5$ Seen In $\rho = 5$ 6 Dominant denth which conta	0 wave in one of $\pi^+\pi^-$ (ω and η a lecay into $\rho^0\rho^0\pi^+$	the two ambiguountiselected in 4π BALTAY 78 fluor $p^+\pi^-$	ıs sol syste	utions. m).		
VALUE (MeV) 2382±24 62± 6 VALUE (MeV)	126	POCUMENT ID 2 FOCACCI 2 FOCACCI DOCUMENT ID	66 66	TECN MMS MMS	<u>сн</u> — — — <u>сн</u> с	COMMENT 3-12 π ⁻ p 3-12 π ⁻ p COMMENT	no peak. 4 Seen In $J = 5$ Seen In $\rho = 5$ 6 Dominant denth which conta	0 wave in one of $\pi^+\pi^-$ (ω and η a lecay into $\rho^0\rho^0\pi^+$ in $\rho^+\rho^0\pi^0$ and 2 $\overline{K}\pi\pi$) mass distrib	the two ambiguountiselected in 4π BALTAY 78 fluor $p^+\pi^-$	is sol syste nds c	utions. m). onfirmat		
2382±24 62± 6 VALUE (MeV) 2500±32		DOCUMENT ID FOCACCI FOCACCI DOCUMENT ID ANDERSON	66 66	TECN MMS MMS TECN MMS MMS	<u>сн</u> — — — — — — — — — — — — — — — — — — —	COMMENT 3-12 $\pi^- p$ 3-12 $\pi^- p$ COMMENT 16 $\pi^- p$ backward 16 $\pi^- p$ backward	no peak. 4 Seen In J = 5 Seen In P 6 Dominant d which conta 7 Seen In (K)	o wave in one of $\pi^+\pi^-$ (ω and η a lecay into $\rho^0\rho^0\pi^+$ in $\rho^+\rho^0\pi^0$ and 2 $\overline{K}\pi\pi$) mass distrib	the two ambiguountiselected in 4π . BALTAY 78 fliph τ . Typical control of the second of the sec	is sol syste nds c	utions. m). onfirmat	ion in	2π+π-2π ⁰ eve
VALUE (MeV) 2382±24 62±6 VALUE (MeV) 2500±32 87 VALUE (MeV)	<u>EVTS</u>	DOCUMENT ID POCACCI CONTROL POCUMENT ID ANDERSON ANDERSON DOCUMENT ID	66 66 69	TECN MMS MMS TECN MMS MMS	CHG - CHG - CHG	COMMENT 3-12 $\pi^- p$ 3-12 $\pi^- p$ COMMENT 16 $\pi^- p$ backward 16 $\pi^- p$ backward	no peak. 4 Seen In $J = 5$ Seen in $\rho = 6$ Dominant d which conta	0 wave in one of $\pi^+\pi^-$ (ω and η a lecay into $\rho^0\rho^0\pi^+$ in $\rho^+\rho^0\pi^0$ and 2 $\overline{K}\pi\pi$) mass distrib	the two ambiguous ntiselected in 4π BALTAY 78 fluor 100-3600) REFI	is sol syste nds c	utions. m). onfirmat	ion in	2π + π - 2π ⁰ eve
VALUE (MeV) 2382±24 62±6 VALUE (MeV) 2500±32 87 VALUE (MeV) 2620±20		POCUMENT ID POCACCI FOCACCI DOCUMENT ID ANDERSON ANDERSON DOCUMENT ID BAUD	66 66	TECN MMS MMS TECN MMS MMS TECN MMS	<u>сн</u> — — — — — — — — — — — — — — — — — — —	COMMENT $3-12 \pi^- p$ $3-12 \pi^- p$ COMMENT $16 \pi^- p$ backward $\pi^- p$ backward COMMENT $8-10 \pi^- p$	no peak. 4 Seen In J = 5 Seen in ρ -: 6 Dominant d which conta 7 Seen In (K \bar{I} BUGG 95 BISELLO 891 ATKINSON 88	O wave in one of $\pi^+\pi^-$ (ω and η a lecay into $\rho^0\rho^0\pi^+$ in $\rho^+\rho^0\pi^0$ and 2 $\overline{K}\pi\pi$) mass distrib ### PL B353 378 3 PR D39 701 2PHY C38 535	the two ambiguous ntiselected in 4 π BALTAY 78 fluor 19	is sol syste nds c	utions. m). onfirmat NCES	lon in	2π ⁺ π ⁻ 2π ⁰ eve QM, PNPI, WASH) (DM2 Collab.) IC, MCHS, CURIN)
VALUE (MeV) 2382±24 62±6 VALUE (MeV) 2500±32 87 VALUE (MeV)	<u>EVTS</u>	DOCUMENT ID POCACCI CONTROL POCUMENT ID ANDERSON ANDERSON DOCUMENT ID	66 66 69 69	TECN MMS MMS TECN MMS MMS	CHG - CHG - CHG	COMMENT 3-12 $\pi^- p$ 3-12 $\pi^- p$ COMMENT 16 $\pi^- p$ backward 16 $\pi^- p$ backward	no peak. 4 Seen In J = 5 Seen In P = 6 Dominant d which conta 7 Seen In (K) BUGG 95 BISELLO 95	O wave in one of $\pi^+\pi^-$ (ω and η a lecay into $\rho^0\rho^0\pi^+$ in $\rho^+\rho^0\pi^0$ and 2 $\overline{K}\pi\pi$) mass distrib ### PL B353 378 3 PR D39 701 2PHY C38 535	the two ambiguountiselected in 4π BALTAY 78 floor+π tition. DO-3600) REFI +Scott, Zoil+ Busetto+ +Axon+ (Binon, Bricman	erection in the second	utions. m). onfirmat NCES	lon in (LO AS, LAN	QM, PNPI, WASH) (DM2 Collab.) (C, MCH5, CURIN)
2382±24 62±6 62±6 62±6 62±6 72500±32 87 72620±20 85±30		DOCUMENT ID FOCACCI FOCACCI DOCUMENT ID ANDERSON ANDERSON DOCUMENT ID BAUD BAUD DOCUMENT ID	66 66 69 69	TECN MMS MMS TECN MMS MMS TECN MMS	CHG - CHG - CHG	COMMENT $3-12 \pi^- p$ $3-12 \pi^- p$ COMMENT $16 \pi^- p$ backward $\pi^- p$ backward COMMENT $8-10 \pi^- p$	no peak. 4 Seen In J = 5 Seen in $\rho = 0$ 6 Dominant d which conta 7 Seen In (KT) BUGG 95 BISELLO 891 ATKINSON 88 ALDE 866 GREEN 86 ATKINSON 88	0 wave in one of $\pi^+\pi^-$ (ω and η a lecay into $\rho^0\rho^0\pi^+$ in $\rho^+\rho^0\pi^0$ and 2 $\overline{K}\pi\pi$) mass distrib PL B353 378 3 PR D39 701 ZPHY C38 535 NP B269 485 PR L 56 1639 ZPHY C29 333	the two ambiguountiselected in 4π BALTAY 78 flip+ π thon. DO-3600) REFI +Scott, Zoil+ Busetto+ +Axon+ (BC +Binon, Bricman +Lai+ (FC	ERE	utions. m). onfirmat NCES CERN, GL. (BELG, L (BELG, L (BELG, L (BELG, L	(LO AS, LAN APP, SI NDAM AS, LAN	QM, PNPI, WASH) (DM2 Collab.) (C, MCH5, CURIN) (TUFTS, VAND+) (C, MCH5, WH)
VALUE (MeV) 2382±24 62±6 VALUE (MeV) 2500±32 87 VALUE (MeV) 2620±20 85±30 VALUE (MeV)		DOCUMENT ID FOCACCI FOCACCI DOCUMENT ID ANDERSON ANDERSON DOCUMENT ID BAUD BAUD BOUMENT ID 5 CASO	66 66 69 69	TECN MMS MMS TECN MMS MMS MMS MMS	CHG CHG CHG	COMMENT 3-12 $\pi^{-}p$ 3-12 $\pi^{-}p$ COMMENT 16 $\pi^{-}p$ backward 16 $\pi^{-}p$ backward COMMENT 8-10 $\pi^{-}p$ 8-10 $\pi^{-}p$	no peak. 4 Seen In J = 5 Seen in $\rho = 0$ 6 Dominant d which conta 7 Seen In (KT) BUGG 95 BISELLO 896 ATKINSON 88 ALDE 866 GREEN 86 ATKINSON 88 ATKINSON 88 ATKINSON 88 ATKINSON 84 DENNEY 83	0 wave in one of $\pi^+\pi^-$ (ω and η a lecay into $\rho^0\rho^0\pi^+$ in $\rho^+\rho^0\pi^0$ and 2 $\overline{K}\pi\pi$) mass distrib PL B353 378 3 PR D39 701 ZPHY C38 535 NP B269 485 PRI 56 1639 ZPHY C9 333 NP B239 1 PR D28 2726	the two ambiguountiselected in 4π BALTAY 78 flip p+π tition. DO-3600) REFI +Scott, Zoli+ Busetto+ +Axon+ (FR +Binon, Bricman +Lai+ (FR +CR +CR +CR +CR +CR +CR +CR +CR +CR +C	ERE	utions. m). onfirmat NCES CERN, GL (BELG, L (RIZ, FSU, CERN, GL LERN, GL	(LO AS, LAN APP, SI NDAM AS, LAN	2π ⁺ π ⁻ 2π ⁰ evi 2m, PNPI, WASH) (DM2 collab.) (C, MCH5, CURIN) TUFTS, VAND+) (C, MCH5, IPNP+) (C, MCH5, IPNP+)
VALUE (MeV) 2382±24 62±6 VALUE (MeV) 2500±32 87 VALUE (MeV) 2620±20 85±30 VALUE (MeV)		DOCUMENT ID FOCACCI FOCACCI DOCUMENT ID ANDERSON ANDERSON DOCUMENT ID BAUD BAUD DOCUMENT ID	66 66 69 69 69	TECN MMS MMS TECN MMS MMS TECN MMS MMS	CHG CHG CHG	COMMENT $3-12 \pi^- p$ $3-12 \pi^- p$ COMMENT $16 \pi^- p$ backward $6 \pi^- p$ backward COMMENT $8-10 \pi^- p$ $8-10 \pi^- p$ COMMENT	no peak. 4 Seen In J = 5 Seen in P = 6 Dominant d which conta 7 Seen In (K i BUGG 95 BISELLO 896 ATKINSON 88 ALDE 866 GREEN 86 ATKINSON 85 ATKINSON 85	0 wave in one of $\pi^+\pi^-$ (ω and η a lecay into $\rho^0\rho^0\pi^+$ in $\rho^+\rho^0\pi^0$ and 2 $\overline{K}\pi\pi$) mass distrib 2 PL B353 378 3 PR D39 701 2 PHY C38 535 5 NP B269 485 PRL 56 1639 2 PHY 56 1639 2 PHY 56 1639 3 NP B269 13 5 NP B269 13 5 NP B279 13 5 NP B289 14 5 NP B289 15 5 NP B289 15 5 NP B289 15 5 NP B29 15 6 NP B29 15 6 NP B189 205	the two ambiguountiselected in 4π BALTAY 78 flip+ π Thion. DO-3600) REFI +Scott, Zoli+ Busetto+ +Axon+ (BC +Binon, Bricman +Lai+ (FR +Cranley, Fireste +Bogoljubski-	ERE	utions. m). onfirmat NCES CERN, GL. (BELG, L RIZ, FSU, EERN, GL. EERN, GL. hapman+ ERN, EPC	(LO AS, LAN APP, SI AS, LAN AS, LAN	2π ⁺ π ⁻ 2π ⁰ eve 2π ⁺ π ⁻ 2π ⁰ eve (DM2 collab.) (C, MCH5, CURIN) TUFTS, VAND+) (C, MCH5, IPNP+) (C, MCH5, IPNP+) (IOWA, MCH5, IPNP+) (IOWA, MCH5, IPNP+) S, LANC, MCH5P)
VALUE (MeV) 2382±24 62±6 VALUE (MeV) 2500±32 87 VALUE (MeV) 2620±20 85±30 VALUE (MeV) 2676±27 150		DOCUMENT ID FOCACCI FOCACCI DOCUMENT ID ANDERSON ANDERSON DOCUMENT ID BAUD BAUD BOUMENT ID 5 CASO	66 66 69 69 69	TECN MMS MMS TECN MMS MMS TECN MMS MMS TECN MMS MMS	<u>СНБ</u>	COMMENT 3-12 $\pi^- p$ 3-12 $\pi^- p$ 3-12 $\pi^- p$ COMMENT 16 $\pi^- p$ backward 16 $\pi^- p$ backward COMMENT 8-10 $\pi^- p$ 8-10 $\pi^- p$	no peak. 4 Seen in J = 5 Seen in ρ − 6 Dominant d which conta 7 Seen in (Kī BUGG 95 BISELLO 896 ATKINSON 88 ALDE 866 GREEN 86 ATKINSON 844 DENNEY 83 ASTON 816 ARESTOV 80 CHLAPNIK 80 BALATY 78	0 wave in one of $\pi^+\pi^-$ (ω and η a lecay into $\rho^0\rho^0\pi^+$ in $\rho^+\rho^0\pi^0$ and 2. $\overline{K}\pi\pi$) mass distrib: X(19 PL 8353 378 3 PR D39 701 ZPHY C38 535 NP B269 485 PRI 56 1639 ZPHY C3 933 NP B259 1 PR D28 2726 3 NP B189 205 HEP 80-165 ZPHY C3 285 PR D17 52	the two ambiguountiselected in 4π BALTAY 78 flip + π - trion. OO-3600) REFI + Scott, Zoll+ Busetto+ + Axon+ + Lai+ + (FN + (BC + Cranley, Firestr + Bogoljubskl+ Chiapnikov, G + Cauts, Cohen,	ERE INN, (1+ IAL, ANN, (10) One, CONN, CO	utions. m). onfirmat NCES LERN, GL. (BELG, L. RIZ, FSU. LERN, GL. hapman+ hapman+ a, Kalelka	(LO AS, LAM APP, SI NDAM AS, LAM OL, GLA (SE	QM, PNPI, WASH) (DM2 Collab.) (CMC), CHS, CURIN) (TUFTS, VAND+) (C, MCHS, IPNP+) (GOWA, MCH, MCHS, IPNP+) (GOWA, MCH, MCHS, IPNP+) (GWA, BUR, MCHS) (CAUL, BING) (COLU, BING) (COLU, BING)
VALUE (MeV) 2382±24 62±6 VALUE (MeV) 2500±32 87 VALUE (MeV) 2620±20 85±30 VALUE (MeV) 2676±27 150 VALUE (MeV)		DOCUMENT ID 2 FOCACCI 2 FOCACCI DOCUMENT ID ANDERSON ANDERSON DOCUMENT ID BAUD BAUD BAUD DOCUMENT ID 5 CASO 5 CASO DOCUMENT ID	66 66 69 69 69 70	TECN MMS MMS TECN MMS MMS TECN MMS MMS TECN HBC HBC HBC TECN	CHG CHG CHG CHG CHG CHG	COMMENT $3-12 \pi^{-} p$ $3-12 \pi^{-} p$ $3-12 \pi^{-} p$ COMMENT $16 \pi^{-} p$ backward $6 \pi^{-} p$ backward COMMENT $8-10 \pi^{-} p$ MENT	no peak. 4 Seen In J = 5 Seen in $\rho = 0$ 6 Dominant d which conta 7 Seen In (KT) BUGG 95 BISELLO 89 ATKINSON 88 ALDE 866 GREEN 86 ATKINSON 85 ATKINSON 85 ATKINSON 85 ATKINSON 85 ATKINSON 86 ATKINSON 86 ATKINSON 86 ATKINSON 87 DENNEY 83 ASTON 81 ARESTOV 80 CHLIAPPIK 80 BALTAY 78 BALTAY 78	0 wave in one of $\pi^+\pi^-$ (ω and η a lecay into $\rho^0\rho^0\pi^+$ in $\rho^+\rho^0\pi^0$ and 2 $\overline{K}\pi\pi$) mass distrib PL B353 78 38 39 PR D39 701 ZPHY C38 535 NP B269 485 PR 156 1639 ZPHY C29 333 NP B239 1 PR D28 2726 3 NP B189 205 IHEP 80-165 ZPHY C3 285 PR D17 52 PR D17 52 PR D35 891	the two ambiguous nitiselected in 4π BALTAY 78 find the second of the s	ERE NN, (At+, At-, At-, At-, At-, At-, At-, At-, At-	utions. m). onfirmat NCES CERN, GL. (BELG, L. RIZ, FSU, CERN, GL. HAPMan+ HERN, EPC ov+ a, Kalelka ar, Piselic	(LO AS, LAN APP, SI NDAM AS, LAN AS, LAN (SE	QM, PNPI, WASH) (DM2 Collab.) (C, MCH5, CURIN) (EPP, CERN, LANL) (TUFTS, VAND+) (GWA, MICH5) (SERP) (GWA, MICH5) (SCRP) (COLU, BING) (COLU, BING)
VALUE (MeV) 2382±24 62±6 VALUE (MeV) 2500±32 87 VALUE (MeV) 2620±20 85±30 VALUE (MeV) 2676±27 150 VALUE (MeV)		2 FOCACCI 2 FOCACCI DOCUMENT ID ANDERSON ANDERSON DOCUMENT ID BAUD BAUD BAUD DOCUMENT ID 5 CASO 5 CASO	66 66 69 69 69 70 70	TECN MMS MMS TECN MMS MMS TECN MMS MMS TECN HBC HBC TECN LASS	<u>СНБ</u>	COMMENT 3-12 $\pi^- p$ 3-12 $\pi^- p$ 3-12 $\pi^- p$ COMMENT 16 $\pi^- p$ backward 16 $\pi^- p$ backward COMMENT 8-10 $\pi^- p$ 8-10 $\pi^- p$ COMMENT 11.2 $\pi^- p$ 11.2 $\pi^- p$	no peak. 4 Seen in J = 5 Seen in P = 6 Dominant d which conta 7 Seen in (KT) BUGG 95 BISELLO 89 ATKINSON 88 ALDE 86 GREEN 86 ATKINSON 85 ATTHOMPSON 75 THOMPSON 74 ANTIPOV 72 ANTIPOV 72	0 wave in one of $\pi^+\pi^-$ (ω and η a lecay into $\rho^0\rho^0\pi^+$ in $\rho^+\rho^0\pi^0$ and 2 $\overline{K}\pi\pi$) mass distribution of the control of the contro	the two ambiguous nitiselected in 4π BALTAY 78 find the property of the prope	ERE NNN, (14+1AL, ANN, (20) NNN, Cone, CCorner CCsorner Kalel	utlons. m). onfirmat NCES CERN, GL. (BELG, L. RIZ, FSU, EERN, GL. EERN, GL. hapman+ EERN, EPC ov+ a, Kalelka tar, Piseliciller, Mulei	(LO AS, LAN APP, SI , NDAM AS, LAN AS, LAN OL, GLA (SE I+	2π ⁺ π ⁻ 2π ⁰ eve QM, PNPI, WASH) (DM2 Collab.) (C, MCH5, CURIN) TUFTS, VAND+) (C, MCH5, IPNP+) (IOWA, MICH) SERP) RP, BRUX, MOS) (COLU, BING) (COLU, BING) (COLU, BING) (COLU, BING) (COLU, BING) (COLU, BING) (COLU, BING)
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STRANGE MESONS $(S = \pm 1, C = B = 0)$

 $K^+ = u\overline{s}$, $K^0 = d\overline{s}$, $\overline{K}^0 = \overline{d}s$, $K^- = \overline{u}s$, similarly for K^* 's

 K^{\pm}

$$I(J^P) = \frac{1}{2}(0^-)$$

THE CHARGED KAON MASS

Revised 1994 by T.G. Trippe, (LBNL).

The average of the six charged kaon mass measurements which we use in the Particle Listings is

$$m_{K^{\pm}} = 493.677 \pm 0.013 \text{ MeV (S} = 2.4),$$
 (1)

where the error has been increased by the scale factor S. The large scale factor indicates a serious disagreement between different input data. The average before scaling the error is

$$m_{K^{\pm}} = 493.677 \pm 0.005 \text{ MeV}$$
,
 $\chi^2 = 22.9 \text{ for 5 D.F., Prob.} = 0.04\%$, (2)

where the high χ^2 and correspondingly low χ^2 probability further quantify the disagreement.

The main disagreement is between the two most recent and precise results,

$$m_{K^{\pm}} = 493.696 \pm 0.007 \text{ MeV}$$
 DENISOV 91
 $m_{K^{\pm}} = 493.636 \pm 0.011 \text{ MeV}$ (S = 1.5) GALL 88
 Average = $493.679 \pm 0.006 \text{ MeV}$

$$\chi^2 = 21.2$$
 for 1 D.F., Prob. = 0.0004\%, (3)

both of which are measurements of x-ray energies from kaonic atoms. Comparing the average in Eq. (3) with the overall average in Eq. (2), it is clear that DENISOV 91 and GALL 88 dominate the overall average, and that their disagreement is responsible for most of the high χ^2 .

The GALL 88 measurement was made using four different kaonic atom transitions, K^- Pb (9 \to 8), K^- Pb (11 \to 10), K^- W (9 \to 8), and K^- W (11 \to 10). The m_{K^\pm} values they obtain from each of these transitions is shown in the Particle Listings and in Fig. 1Their K^- Pb (9 \to 8) m_{K^\pm} is below and somewhat inconsistent with their other three transitions. The average of their four measurements is

$$m_{K^{\pm}} = 493.636 \pm 0.007$$
 ,
$$\chi^2 = 7.0 \ \ {\rm for} \ \ 3 \ {\rm D.F., \ Prob.} \ \ = 7.2\% \ . \eqno(4)$$

This is a low but acceptable χ^2 probability so, to be conservative, GALL 88 scaled up the error on their average by S=1.5 to obtain their published error ± 0.011 shown in Eq. (3) above and used in the Particle Listings average.

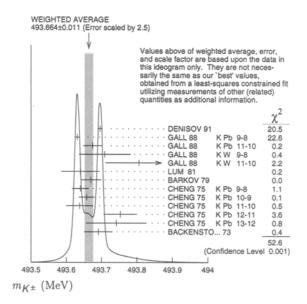


Figure 1: Ideogram of $m_{K^{\pm}}$ mass measurements. GALL 88 and CHENG 75 measurements are shown separately for each transition they measured.

The ideogram in Fig. 1 shows that the DENISOV 91 measurement and the GALL 88 K^- Pb (9 \rightarrow 8) measurement yield two well-separated peaks. One might suspect the GALL 88 K^- Pb (9 \rightarrow 8) measurement since it is responsible both for the internal inconsistency in the GALL 88 measurements and the disagreement with DENISOV 91.

To see if the disagreement could result from a systematic problem with the K^- Pb (9 \rightarrow 8) transition, we have separated the CHENG 75 data, which also used K^- Pb, into its separate transitions. Fig. 1shows that the CHENG 75 and GALL 88 K^- Pb (9 \rightarrow 8) values are consistent, suggesting the possibility of a common effect such as contaminant nuclear γ rays near the K^- Pb (9 \rightarrow 8) transition energy, although the CHENG 75 errors are too large to make a strong conclusion. The average of all 13 measurements has a χ^2 of 52.6 as shown in Fig. 1and the first line of Table 1, yielding an unacceptable χ^2 probability of 0.00005%. The second line of Table 1 excludes both the GALL 88 and CHENG 75 measurements of the K^- Pb (9 \rightarrow 8) transition and yields a χ^2 probability of 43%. The third [fourth] line of Table 1 excludes only the GALL 88 K^- Pb (9 \rightarrow 8) [DENISOV 91] measurement and yields a χ^2 probability of 20% [8.6%]. Table 1 shows that removing both measurements of the K^- Pb (9 \rightarrow 8) transition produces the most consistent set of data, but that excluding only the GALL 88 K^- Pb (9 \rightarrow 8) transition or DENISOV 91 also produces acceptable probabilities.

Yu.M. Ivanov, representing DENISOV 91, has estimated corrections needed for the older experiments because of improved 192 Ir and 198 Au calibration γ -ray energies. He estimates

Table 1: $m_{K^{\pm}}$ averages for some combinations of Fig. 1data.

$m_{K^{\pm}} \text{ (MeV)}$	χ^2	D.F.	Prob. (%	6)	Measurements used
493.664 ± 0.004	52.6	12	0.00005	all	13 measurements
493.690 ± 0.006	10.1	10	43	no	$K^- \text{Pb}(9 \rightarrow 8)$
493.687 ± 0.006	14.6	11	20	no	GALL 88 K^- Pb(9 \rightarrow 8)
493.642 ± 0.006	17.8	11	8.6	no	DENISOV 91

that CHENG 75 and BACKENSTOSS 73 m_{K^\pm} values could be raised by about 15 keV and 22 keV, respectively. With these estimated corrections, Table 1 becomes Table 2. The last line of Table 2 shows that if such corrections are assumed, then GALL 88 K^- Pb (9 \to 8) is inconsistent with the rest of the data even when DENISOV 91 is excluded. Yu.M. Ivanov warns that these are rough estimates. Accordingly, we do not use Table 2 to reject the GALL 88 K^- Pb (9 \to 8) transition, but we note that a future reanalysis of the CHENG 75 data could be useful because it might provide supporting evidence for such a rejection.

Table 2: $m_{K^{\pm}}$ averages for some combinations of Fig. 1data after raising CHENG 75 and BACKENSTOSS 73 values by 0.015 and 0.022 MeV respectively.

$m_{K^{\pm}}$ (MeV)	χ^2	D.F.	Prob. (%	ور و	Measurements used
$\overline{493.666 \pm 0.004}$	53.9	12	0.00003	all	13 measurements
493.693 ± 0.006	9.0	10	53	no	$K^- \text{Pb}(9 \rightarrow 8)$
493.690 ± 0.006	11.5	11	40	no	GALL 88 K^- Pb(9 \rightarrow 8)
493.645 ± 0.006	23.0	11	1.8	no	DENISOV 91

The GALL 88 measurement uses a Ge semiconductor spectrometer which has a resolution of about 1 keV, so they run the risk of some contaminant nuclear γ rays. Studies of γ rays following stopped π^- and Σ^- absorption in nucleii (unpublished) do not show any evidence for contaminants according to GALL 88 spokesperson, B.L. Roberts. The DENISOV 91 measurement uses a crystal diffraction spectrometer with a resolution of 6.3 eV for radiation at 22.1 keV to measure the 4f-3d transition in $K^{--12}C$. The high resolution and the light nucleus reduce the probability for overlap by contaminant γ rays, compared with the measurement of GALL 88. The DENISOV 91 measurement is supported by their high-precision measurement of the 4d-2p transition energy in $\pi^{--12}C$, which is good agreement with the calculated energy.

While we suspect that the GALL 88 K^- Pb (9 \rightarrow 8) measurements could be the problem, we are unable to find clear grounds for rejecting it. Therefore, we retain their measurement in the average and accept the large scale factor until further information can be obtained from new measurements and/or from reanalysis of GALL 88 and CHENG 75 data.

We thank B.L. Roberts (Boston Univ.) and Yu.M. Ivanov (Petersburg Nuclear Physics Inst.) for their extensive help in understanding this problem.

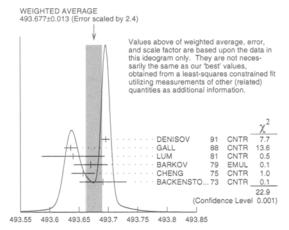
K± MASS

VALUE (MeV)	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT
493.677 ±0.016 OUR FIT Error	includes scale factor	or of	2.8.		
493.677±0.013 OUR AVERAGE	Error Includes sca below.	le fa	ctor of 2	.4. Se	e the ideogram
493.696±0.007	1 DENISOV	91	CNTR	-	Kaonic atoms
493.636±0.011	² GALL	88	CNTR	-	Kaonic atoms
493.640±0.054	LUM	81	CNTR	-	Kaonic atoms
493.670±0.029	BARKOV	79	EMUL	±	e ⁺ e ⁻ → K ⁺ K ⁻
493.657±0.020	² CHENG	75	CNTR	_	Kaonic atoms
493.691±0.040	BACKENSTO.	73	CNTR	-	Kaonic atoms
• • We do not use the following	g data for average:	s, fit	s, ilmits,	etc. •	• •
493.631 ± 0.007	GALL	88	CNTR	_	K~ Pb (9→ 8)
493.675±0.026	GALL	88	CNTR	_	K~ Pb (11→ 10)
493.709±0.073	GALL	88	CNTR	-	K~W (9→ 8)
493.806±0.095	GALL	88	CNTR	_	K~W (11→ 10)
493.640 ± 0.022 ± 0.008	³ CHENG	75	CNTR	_	K~ Pb (9→ 8)
493.658±0.019±0.012	³ CHENG	75	CNTR	_	K-Pb (10→ 9)
493.638±0.035±0.016	³ CHENG	75	CNTR	_	K~Pb (11→ 10)
493.753±0.042±0.021	3 CHENG	75	CNTR	_	K~Pb (12→ 11)
493.742±0.081±0.027	3 CHENG	75	CNTR		K~ Pb (13→ 12)
493.662±0.19	KUNSELMAN	74	CNTR	_	Kaonic atoms
493.78 ±0.17	GREINER	65	EMUL	+	
493.7 ±0.3	BARKAS	63	EMUL	-	
493.9 ±0.2	COHEN	57	RVUE	+	

¹ Error increased from 0.0059 based on the error analysis in IVANOV 92.

² This value is the authors' combination of all of the separate transitions listed for this paper.

 3 The CHENG 75 values for separate transitions were calculated from their Table 7 transition energies. The first error includes a 20% systematic error in the noncircular contaminant shift. The second error is due to a ± 5 eV uncertainty in the theoretical transition energies.



 $m_{K^{\pm}}$ (MeV)

 $\omega^{K+}-\omega^{K-}$

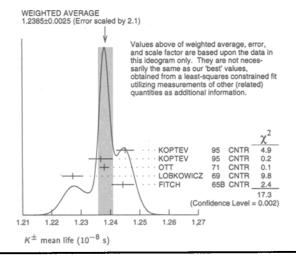
Test of CPT.

K* MEAN LIFE

VALUE (10 ⁻⁸ s)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
1.2386 ± 0.0024 OUR	FIT Error	includes scale facto	or of	2.0.		
1.2385±0.0025 OUR	AVERAGE	Error Includes sca below.	le fac	tor of 2	.1. Se	e the ideogram
1.2451 ± 0.0030	250k	KOPTEV	95	CNTR		K at rest, U tar- get
1.2368±0.0041	150k	KOPTEV	95	CNTR		K at rest, Cu tar- get
1.2380 ± 0.0016	3M	OTT	71	CNTR	+	K at rest
1.2272±0.0036		LOBKOWICZ	69	CNTR	+	K In flight
1 2443 + 0 0038		FITCH	650	CNTR	_	K at rest

1.241	5±0.0024	400k	⁵ KOPTEV	95	CNTR		K at rest
1.221	± 0.011		FORD	67	CNTR	±	
1.231	± 0.011		BOYARSKI	62	CNTR	+	
1.25	+0.22 -0.17		BARKAS	61	EMUL		
1.27	+0.36 -0.23	51	BHOWMIK	61	EMUL		
1.31	±0.08	293	NORDIN	61	HBC	_	
1.24	± 0.07		NORDIN	61	RVUE	. –	
1.38	±0.24	33	FREDEN	60B	EMUL		
1.21	±0.06		BURROWES	59	CNTR		
1.60	±0.3	52	EISENBERG	58	EMUL		
0.95	+0.36 -0.25		ILOFF	56	EMUL		

 5 KOPTEV 95 report this weighted average of their U-target and Cu-target results, where they have weighted by $1/\sigma$ rather than $1/\sigma^2$.



 $(au_{K^+} - au_{K^-}) / au_{average}$

This quantity is a measure of CPT invariance in weak interactions

VALUE (%)	DOCUMENT ID	TECN
0.11 ±0.09 OUR AVERAGE	Error includes scale	factor of 1.2.
0.090 ± 0.078	LOBKOWICZ	69 CNTR
0.47 ±0.30	FORD	67 CNTR

RARE KAON DECAYS

Revised November 1997 by L. Littenberg (BNL) and G. Valencia (Iowa State University)

- A. Introduction: There are several useful reviews on rare kaon decays and related topics [1-10]. The current activity in rare kaon decays can be divided roughly into four categories:
- 1. Searches for explicit violations of the Standard Model
- 2. Measurements of Standard Model parameters
- 3. Searches for CP violation
- 4. Studies of strong interactions at low energy.

The paradigm of Category 1 is the lepton flavor violating decay $K_L \to \mu e$. Category 2 includes processes such as $K^+ \to \pi^+ \nu \overline{\nu}$, which is sensitive to $|V_{td}|$. Much of the interest in Category 3 is focussed on the decays $K_L \to \pi^0 \ell \overline{\ell}$, where $\ell \equiv e, \mu, \nu$. Category 4 includes reactions like $K^+ \to \pi^+ \ell^+ \ell^-$ which constitute a testing ground for the ideas of chiral perturbation theory. Other reactions of this type are $K_L \to \pi^0 \gamma \gamma$, which also scales a CP-conserving background to CP violation in $K_L \to \pi^0 \ell^+ \ell^-$ and $K_L \to \gamma \ell^+ \ell^-$, which could possibly shed light on long distance contributions to $K_L \to \mu^+ \mu^-$.

B. Explicit violations of the Standard Model: Most of the activity here is in searches for lepton flavor violation (LFV). This is motivated by the fact that many extensions of the minimal Standard Model violate lepton flavor and by the potential to access very high energy scales. For example, the tree-level exchange of a LFV vector boson of mass M_X that couples to lefthanded fermions with electroweak strength and without mixing angles yields $B(K_L \to \mu e) = 3.3 \times 10^{-11} (91 \text{ TeV}/M_X)^4$ [5]. This simple dimensional analysis may be used to read from Table 1 that the reaction $K_L \to \mu e$ is already probing scales of nearly 100 TeV. Table 1 summarizes the present experimental situation vis a vis LFV, along with the expected near-future progress. The decays $K_L \to \mu^{\pm} e^{\mp}$ and $K^+ \to \pi^+ e^{\mp} \mu^{\pm}$ (or $K_L \to \pi^0 e^{\mp} \mu^{\pm}$) provide complementary information on potential family number violating interactions since the former is sensitive to axial-vector (or pseudoscalar) couplings and the latter is sensitive to vector (or scalar) couplings.

Table 1: Searches for lepton flavor violation in K decay

Mode	90% CL upper limit	t Exp't	Yr./Ref	(Near-) . future aim
$\overline{K^+ \to \pi^+ e\mu}$	$2.1 \cdot 10^{-10}$	BNL-777	90/11	3 · 10 ⁻¹² (BNL-865)
$K_L\! o\!\mu e$	$3.3 \cdot 10^{-11}$	BNL-791	93/12	$3 \cdot 10^{-12}$ (BNL-871)
$K_L \rightarrow \pi^0 e \mu$	$3.2 \cdot 10^{-9}$	FNAL-799	94/13	$5 \cdot 10^{-11} \text{ (KTeV)}$

Another forbidden decay currently being pursued is $K^+ \to \pi^+ X^0$, where X^0 is a very light, noninteracting particle (e.g. hyperphoton, axion, familon, etc.). Recently the upper limit on this process has been improved to 3×10^{-10} [15]. Data already collected by BNL-787 are expected to yield a further factor in sensitivity to this process.

C. Measurements of Standard Model parameters: Until recently, searches for $K^+ \to \pi^+ \nu \overline{\nu}$ have been motivated by the possibility of observing non-SM physics because the sensitivity attained was far short of the SM prediction for this decay [16] and long-distance contributions were known to be negligible [2]. However, BNL-787 has attained the sensitivity at which the observation of an event can no longer be unambiguously attributed to non-SM physics. The previous 90% CL upper limit [14] is 2.4×10^{-9} , but running with an upgraded beam and detector BNL-787 recently observed one candidate event, corresponding to a branching ratio of $(4.2^{+9.7}_{-3.5}) \times 10^{-10}$ [15]. Further data already collected are expected to increase the sensitivity by more than a factor 2, and there are plans to collect data representing a further large increase in sensitivity. This reaction is now interesting from the point of view of constraining SM parameters. The branching ratio can be written in terms of the very well-measured rate of K_{e3} as [2]:

$$B(K^{+} \to \pi^{+} \nu \overline{\nu}) = \frac{\alpha^{2} B(K^{+} \to \pi^{o} e^{+} \nu)}{V_{us}^{2} 2\pi^{2} \sin^{4} \theta_{W}} \times \sum_{l=e,\mu,\tau} |V_{cs}^{*} V_{cd} X_{NL}^{\ell} + V_{ts}^{*} V_{td} X(m_{t})|^{2}$$
(1)

to eliminate the *a priori* unknown hadronic matrix element. Isospin breaking corrections to the ratio of matrix elements reduce this rate by 10% [17]. In Eq. (1) the Inami-Lim function $X(m_t)$ is of order 1 [18], and X_{NL}^{ℓ} is several hundred times smaller. This form exhibits the strong dependence of this branching ratio on $|V_{td}|$. QCD corrections, which are contained in X_{NL}^{ℓ} , are relatively small and now known [10] to \leq 10%. Evaluating the constants in Eq. (1) with $m_t = 175$ GeV, one can cast this result in terms of the CKM parameters A, ρ and η (see our Section on "The Cabibbo-Kobayashi-Maskawa mixing matrix") [10]

$$B(K^+ \to \pi^+ \nu \overline{\nu}) \approx 1.0 \times 10^{-10} A^4 [\eta^2 + (\rho_o - \rho)^2]$$
 (2)

where $ho_o \equiv 1 + (\frac{2}{3} X_{NL}^e + \frac{1}{3} X_{NL}^{\tau})/(A^2 V_{us}^4 X(m_t)) \approx 1.4$. Thus, $\mathrm{B}(K^+ \to \pi^+ \nu \overline{\nu})$ determines a circle in the ρ , η plane with center $(\rho_o,0)$ and radius $\approx \frac{1}{A^2} \sqrt{\frac{\mathrm{B}(K^+ \to \pi^+ \nu \overline{\nu})}{1.0 \times 10^{-10}}}$. The decay $K_L \to \mu^+ \mu^-$ also has a short distance contribu-

The decay $K_L \to \mu^+\mu^-$ also has a short distance contribution sensitive to the CKM parameter ρ . For $m_t = 175$ GeV it is given by [10]:

$$B_{SD}(K_L \to \mu^+ \mu^-) \approx 1.7 \times 10^{-9} A^4 (\rho_o' - \rho)^2$$
 (3)

where ρ'_{α} depends on the charm quark mass and is around 1.2. This decay, however, is dominated by a long-distance contribution from a two-photon intermediate state. The absorptive (imaginary) part of the long-distance component is calculated in terms of the measured rate for $K_L \to \gamma \gamma$ to be $B_{abs}(K_L \to \gamma \gamma)$ $\mu^+\mu^-$) = $(7.07 \pm 0.18) \times 10^{-9}$; and it almost completely saturates the observed rate B($K_L \rightarrow \mu^+\mu^-$) = $(7.2 \pm 0.5) \times 10^{-9}$ listed in the current edition. The difference between the observed rate and the absorptive component can be attributed to the (coherent) sum of the short-distance amplitude and the real part of the long-distance amplitude. In order to use this mode to constrain ρ it is, therefore, necessary to know the real part of the long-distance contribution. Unlike the absorptive part, the real part of the long-distance contribution cannot be derived from the measured rate for $K_L \to \gamma \gamma$. At present, it is not possible to compute this long-distance component reliably and, therefore, it is not possible to constrain ρ from this mode. It is expected that studies of the reactions $K_L \to \ell^+\ell^-\gamma$, and $K_L \to \ell^+ \ell^- \ell'^+ \ell'^-$ for $\ell, \ell' = e$ or μ will improve our understanding of the long distance effects in $K_L \to \mu^+\mu^-$ (the current data is parameterized in terms of α_K^* , discussed on page 24 of the K_L^0 Particle Properties Listing in our 1997 WWW update).

D. Searches for CP violation: The mode $K_L \to \pi^0 \nu \overline{\nu}$ is dominantly CP-violating and free of hadronic uncertainties [2,19]. The Standard Model predicts a branching ratio $\sim 10^{-11}-10^{-10}$; for $m_t=175$ GeV it is given approximately by [10]:

$$B(K_L \to \pi^0 \nu \overline{\nu}) \approx 4.1 \times 10^{-10} A^4 \eta^2$$
 (4)

The current published upper bound is $B(K_L \to \pi^0 \nu \overline{\nu}) \le 5.8 \times 10^{-5}$ [20] and KTeV (FNAL799II) is expected to place a

bound of order 10^{-8} [21]. The KTeV group has recently quoted a preliminary result of 1.8×10^{-6} [22]. If lepton flavor is conserved, the 90% CL bound on $K^+ \to \pi^+ \nu \bar{\nu}$ provides the model independent bound $B(K_L \to \pi^0 \nu \bar{\nu}) < 1.1 \times 10^{-8}$ [23]. A recent proposal, BNL-926 [24], aims to make a $\sim 15\%$ measurement of $B(K_L \to \pi^0 \nu \bar{\nu})$. There is also a Fermilab EOI [25] with comparable goals.

The decay $K_L \to \pi^0 e^+ e^-$ also has sensitivity to the product $A^4 \eta^2$. It has a direct CP-violating component that depends on the value of the top-quark mass, and that for $m_t = 175$ GeV is given by [10]:

$$B_{\rm dir}(K_L \to \pi^0 e^+ e^-) \approx 6.7 \times 10^{-11} A^4 \eta^2$$
 (5)

However, like $K_L \to \mu^+\mu^-$ this mode suffers from large theoretical uncertainties due to long distance strong interaction effects. It has an indirect CP-violating component given by:

$$B_{\rm ind}(K_L \to \pi^0 e^+ e^-) = |\epsilon|^2 \frac{\tau_{K_L}}{\tau_{K_S}} B(K_S \to \pi^0 e^+ e^-) ,$$
 (6)

that has been estimated to be less than 10^{-12} [26], but that will not be known precisely until a measurement of $K_S \to \pi^0 e^+ e^-$ is available [4,27]. There is also a CP-conserving component dominated by a two-photon intermediate state that cannot be computed reliably at present. This component has an absorptive part that can be, in principle, determined from a detailed analysis of $K_L \to \pi^0 \gamma \gamma$.

An analysis of $K_L \to \pi^0 \gamma \gamma$ within chiral perturbation theory has been carried out in terms of a parameter a_V [28] that determines both the rate and the shape of the distribution $d\Gamma/dm_{\gamma\gamma}$. A fit to the distribution has given $-0.32 < a_V < 0.19$ [29]; a value that suggests that the absorptive part of the CP-conserving contribution to $K_L \to \pi^0 e^+ e^-$ is significantly smaller than the direct CP-violating component [29]. However, there remains some uncertainty in the interpretation of $K_L \to \pi^0 \gamma \gamma$ in terms of a_V . Analyses that go beyond chiral perturbation theory have found larger values of a_V , helping with understanding the rate in that process [30]. This would indicate a sizeable CP-conserving component to $K_L \to \pi^0 e^+ e^-$. The real part of the CP-conserving contribution to $K_L \to \pi^0 e^+ e^-$ is also unknown. The related process, $K_L \to \pi^0 \gamma e^+ e^-$, is an additional background in some region of phase space [31].

Finally, BNL-845 observed a potential background to $K_L \to \pi^0 e^+ e^-$ from the decay $K_L \to \gamma \gamma e^+ e^-$ [32]. This was later confirmed with an order of magnitude larger sample by FNAL-799 [33], which measured additional kinematic quantities. It has been estimated that this background will enter at the level of 10^{-11} [34], comparable to the signal level. Because of this, the observation of $K_L \to \pi^0 e^+ e^-$ will depend on background subtraction with good statistics.

The current upper bound for the process $K_L \to \pi^0 e^+ e^-$ is 4.3×10^{-9} [35]. For the closely related muonic process, the upper bound is $B(K_L \to \pi^0 \mu^+ \mu^-) \le 5.1 \times 10^{-9}$ [36]. KTeV expects to reach a sensitivity of roughly 10^{-11} for both reactions [21].

E. Other long distance dominated modes: The decays $K^+ \to \pi^+ \ell^+ \ell^-$ ($\ell = e$ or μ) are described by chiral perturbation theory in terms of one parameter, ω^+ [37]. This parameter determines both the rate and distribution $d\Gamma/dm_{\ell\ell}$ for these processes. A careful study of these two reactions can provide a measurement of ω^+ and a test of the chiral perturbation theory description. A simultaneous fit to the rate and spectrum of $K^+ \to \pi^+ e^+ e^-$ gives: $\omega^+ = 0.89^{+0.24}_{-0.14}$; $B(K^+ \to \pi^+ e^+ e^-) = (2.99 \pm 0.22) \times 10^{-7}$ [38]. These two results satisfy the prediction of chiral perturbation theory within two standard deviations [4]. Improved statistics for this mode and a measurement of the mode $K^+ \to \pi^+ \mu^+ \mu^-$ are thus desired. BNL-787 has recently measured $B(K^+ \to \pi^+ \mu^+ \mu^-) = (5.0 \pm 1.0) \times 10^{-8}$ [39] which is at about the predicted level, but the result is not yet accurate enough to provide additional constraints.

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K+ DECAY MODES

K⁻ modes are charge conjugates of the modes below

	Mode		cale factor/ fldence level
Γ ₁	$\mu^+ \nu_{\mu}$, (63.51±0.18) %	S=1.3
Γ_2	$e^+\nu_e$	$(1.55\pm0.07)\times10^{-5}$	
Γ3	$\pi^+\pi^0$	(21.16±0.14) %	S=1.1
Γ4	$\pi^{+}\pi^{+}\pi^{-}$	(5.59±0.05) %	S=1.8
Γ5	$\pi^{+}\pi^{0}\pi^{0}$	(1.73±0.04) %	S=1.2
Γ6	$\pi^0 \mu^+ u_{\mu}$	(3.18±0.08) %	S=1.5
	Called $K_{\mu 3}^+$.		
Γ_7	$\pi^0 e^+ \nu_e$	(4.82±0.06) %	S=1.3
	Called K_{e3}^+ .		
Г8	$\pi^{0}\pi^{0}e^{+}\nu_{e}$	$(2.1 \pm 0.4) \times 10^{-5}$	
Γg	$\pi^{+}\pi^{-}e^{+}\nu_{e}$ $\pi^{+}\pi^{-}\mu^{+}\nu_{\mu}$	$(3.91\pm0.17)\times10^{-5}$	
Γ ₁₀	$\pi^+\pi^-\mu^+ u_\mu$	$(1.4 \pm 0.9) \times 10^{-5}$	
Γ11	$\pi^{0}\pi^{0}\pi^{0}e^{+}\nu_{e}$	$< 3.5 \times 10^{-6}$	CL=90%
Γ_{12}	$\pi^+ \gamma \gamma$	[a] $(1.10\pm0.32)\times10^{-6}$	
Γ ₁₃	π^+ 3 γ	$[a] < 1.0 \times 10^{-4}$	CL=90%
Γ ₁₄	$\mu^+ u_{\mu} u \overline{ u}$	< 6.0 × 10 ⁻⁶	CL=90%
Γ ₁₅	$e^+ \nu_e \nu \overline{\nu}$	$< 6 \times 10^{-5}$	CL=90%
Γ ₁₆	$\mu^+ u_\mue^+e^-$	$(1.3 \pm 0.4) \times 10^{-7}$	
Γ ₁₇	$e^+ u_e e^+ e^-$	$(3.0 \begin{array}{c} +3.0 \\ -1.5 \end{array}) \times 10^{-8}$	
Γ ₁₈	$\mu^+ u_\mu \mu^+ \mu^-$	< 4.1 × 10 ⁻⁷	CL=90%
Γ19	$\mu^+ u_\mu\gamma$	[a,b] $(5.50\pm0.28)\times10^{-3}$	
Γ ₂₀	$\pi^+\pi^0\gamma$	[a,b] $(2.75\pm0.15)\times10^{-4}$	
Γ21	$\pi^+\pi^0\gamma$ (DE)	[a,c] (1.8 ± 0.4) $\times 10^{-5}$	
Γ22	$\pi^+\pi^+\pi^-\gamma$	[a,b] (1.04±0.31) × 10 ⁻⁴	
Γ ₂₃	$\pi^+\pi^0\pi^0\gamma$	[a,b] $(7.5 \begin{array}{c} +5.5 \\ -3.0 \end{array}) \times 10^{-6}$	
Γ ₂₄	$\pi^0 \mu^+ u_\mu \gamma$	$[a,b] < 6.1 \times 10^{-5}$	CL=90%
Γ ₂₅	$\pi^0 e^+ \nu_e \gamma$	[a,b] $(2.62\pm0.20)\times10^{-4}$	
Γ ₂₆		$[d] < 5.3 \times 10^{-5}$	CL=90%
Γ ₂₇	$\pi^0\pi^0e^+\nu_e\gamma$	< 5 × 10 ⁻⁶	CL=90%

Lepton Family number	(LF), Lepton	number (L), Δ	$S = \Delta Q (SQ)$
Adating modes of A	C _ 1 week	nautral current	(C1) moder

	Atamonia managed of To -			. (02)	
Γ ₂₈	$\pi^+\pi^+e^-\overline{ u}_e$	5Q	< 1.2	$\times 10^{-8}$	CL=90%
Γ ₂₉	$\pi^+\pi^+\mu^-\overline{\nu}_{\mu}$	SQ	< 3.0	× 10 ⁻⁶	CL=95%
Γ30	$\pi^+e^+e^-$	S1	(2.74±0.2	3) × 10 ⁻⁷	
Γ31	$\pi^+\mu^+\mu^-$	S 1	(5.0 ± 1.0) × 10 ⁻⁸	
Γ32	$\pi^+ u\overline{ u}$	51	$(4.2 \begin{array}{c} +9.7 \\ -3.5 \end{array}$		
Γ33	$\mu^- \nu e^+ e^+$	LF	< 2.0	× 10 ⁻⁸	CL=90%
Γ ₃₄	$\mu^+ \nu_e$	LF	[e] < 4	× 10 ⁻³	CL=90%
Γ ₃₅	$\pi^+\mu^+e^-$	LF	< 2.1	$\times 10^{-10}$	CL=90%
Γ ₃₆	$\pi^+\mu^-e^+$	LF	< 7	× 10 ⁻⁹	CL=90%
Γ37	$\pi^-\mu^+e^+$	L	< 7	× 10 ⁻⁹	CL=90%
Γ ₃₈	$\pi^- e^+ e^+$	L	< 1.0	× 10 ⁻⁸	CL=90%
Γ39	$\pi^-\mu^+\mu^+$	L	[e] < 1.5	\times 10 ⁻⁴	CL=90%
Γ40	$\mu^+ \overline{\nu}_e$	L	[e] < 3.3	× 10 ⁻³	CL=90%
Γ41	$\pi^0 e^+ \overline{\nu}_e$	L	< 3	$\times 10^{-3}$	CL=90%
Γ_{42}	$\pi^+\gamma$				

- [a] See the Particle Listings below for the energy limits used in this measure-
- [b] Most of this radiative mode, the low-momentum γ part, is also included in the parent mode listed without γ 's.
- [c] Direct-emission branching fraction.
- [d] Structure-dependent part.
- [e] Derived from an analysis of neutrino-oscillation experiments.

CONSTRAINED FIT INFORMATION

An overall fit to the mean life, 2 decay rate, and 20 branching ratios uses 60 measurements and one constraint to determine 8 parameters. The overall fit has a $\chi^2=78.1$ for 53 degrees of

The following off-diagonal array elements are the correlation coefficients $\left<\delta
ho_i \delta
ho_j \right>/(\delta
ho_i \cdot \delta
ho_j)$, in percent, from the fit to parameters ho_i , including the branching fractions, $x_i \equiv \Gamma_i/\Gamma_{\rm total}$. The fit constrains the x_i whose labels appear in this array to sum to one.

	Mode	Rate (10 ⁸ s ⁻¹)	Scale factor
$\overline{\Gamma_1}$	$\mu^+ \nu_{\mu}$	0.5128 ±0.0018	1.5
Γ ₃ Γ ₄ Γ ₅ Γ ₆	$\pi^+\pi^0$	0.1708 ±0.0012	1.1
Γ4	$\pi^+\pi^+\pi^-$	0.0452 ±0.0004	1.8
r ₅	$\pi^{+}\pi^{0}\pi^{0}$	0.01399 ± 0.00032	1.2
۲6	$\pi^0 \mu^+ u_{\mu}$	0.0257 ±0.0006	1.5
	Called $K_{\mu3}^+$.		
Γ7	$\pi^0 e^+ \nu_e$	0.0389 ±0.0005	1.3
•	Called K_{e3}^+ .		
Γ8	$\pi^{0}\pi^{0}e^{+}\nu_{e}$	$(1.69 ^{+0.34}_{-0.29}) \times 10^{-5}$	i

K* DECAY RATES

$\Gamma(\mu^+\nu_\mu)$						•
VALUE (10 ⁶ s ⁻¹)		DOCUMENT	<u> 1D</u>	<u>TECN</u>	CHG	
51.28±0.18 OUR	FIT Error Inc	ludes scale fact	or of 1.5	i.		
51.2 ±0.8		FORD	67	CNTR	±	
Γ(π ⁺ π ⁺ π ⁻)	•					Γ4
VALUE (10 ⁶ s ⁻¹)	EVTS	DOCUMENT	ID	TECN	CHG	
4.52 ±0.04 OUR	FIT Error in	cludes scale fac	tor of 1.	.8.		
4.511±0.024		⁶ FORD	70	ASPK		
■ ● ■ We do not a	use the followin	ng data for aver	ages, fit	s, limits,	etc. • • •	
4.529±0.032	3.2M	⁶ FORD	70	ASPK		
4.496 ± 0.030		⁶ FORD	67	CNTR	+	

$(\Gamma(K^+) - \Gamma(K^-)) / \Gamma(K)$

$K^{\pm} \rightarrow \mu^{\pm} \nu_{\mu}$ RATE DIFFER	RENCE/AVERA	GE	
Test of CPT conservation.	-		
VALUE (%)	DOCUMENT ID		TECN
-0.54±0.41	FORD	67	CNT

$\rightarrow \pi^{\pm}\pi^{+}\pi^{-}$ RATE DIFFERENCE/AVERAGE

TEST OF CP C	onservation.				
VALUE (%)	EVTS	DOCUMENT ID		TECN	CHG
0.07±0.12 OUR	AVERAGE				
0.08 ± 0.12		7 FORD	70	ASPK	
-0.50 ± 0.90		FLETCHER	67	OSPK	
• • • We do not i	use the followi	ng data for averag	es, fit	s, limits,	etc. • • •
-0.02 ± 0.16		⁸ SMITH	73	ASPK	±
0.10 ± 0.14	3.2M	7 FORD	70	ASPK	

7 FORD 67 CNTR -0.04±0.21 7 First FORD 70 value is second FORD 70 combined with FORD 67. 8 SMITH 73 value of $K^\pm\to ~\pi^\pm\pi^+\pi^-$ rate difference is derived from $K^\pm\to ~\pi^\pm2\pi^0$ rate difference. rate difference is derived from SMITH 73 value

$K^{\pm} \rightarrow \pi^{\pm} \pi^{0} \pi^{0}$ RATE DIFFERENCE/AVERAGE

Test of CP co	nservation.				
VALUE (%)	EVTS	DOCUMENT I		TECN	CHG-
0.0 ±0.6 OUR	AVERAGE				
0.08 ± 0.58		SMITH	73	ASPK	±
-1.1 ± 1.8	1802	HERZO	69	OSPK	

$K^{\pm} \rightarrow \pi^{\pm} \pi^{0}$ RATE DIFFERENCE/AVERAGE

Test of CPT conservation.				
VALUE (%)	DOCUMENT ID		TECN	
0.8±1.2	HERZO	69	OSPK	

$K^{\pm} \rightarrow \pi^{\pm} \pi^{0} \gamma$ RATE DIFFERENCE/AVERAGE

16	it of CP conservation.					
VALUE (%	EVTS	DOCUMENT ID		TECN_	<u>CHG</u>	COMMENT
0.9± 3.	OUR AVERAGE					
0.8 ± 5.4	2461	SMITH	76	WIRE	±	E _π 55-90 MeV
1.0 ± 4.0	4000	ABRAMS	73B	ASPK	±	E 51-100 MeV
0.0 ± 24.0	24	EDWARDS	72	OSPK		E _π 58-90 MeV

K+ BRANCHING RATIOS

$\Gamma(\mu^+ u_\mu)/\Gamma_{ m total}$						Γ ₁ /Γ
VALUE (units 10-2)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
63.51 ±0.18 OUR FIT	Error Inc	ludes scale factor of	f 1.3			
63.24±0.44	62k	CHIANG	72	OSPK	+	1.84 GeV/c K+
• • • We do not use t	he followir	ng data for average	s, fit:	s, limits,	etc.	• • •
56.9 ±2.6		9 ALEXANDER	57	EMUL	+	
58.5 ±3.0		9 BIRGE	56	EMUL	+	

⁹ Old experiments	not included	in averaging.	
$\Gamma(\mu^+\nu_\mu)/\Gamma(\pi^+\pi$	+π ⁻)		Γ_1/Γ_4
VALUE	<u>EVTS</u>	DOCUMENT ID TECN CHG	
11.36±0.12 OUK F	Error Inci	ludes scale factor of 1.8.	
• • • We do not us	e the followin	g data for averages, fits, limits, etc. • • •	•

427 10 YOUNG 10.38 ± 0.82 65 EMUL + 10 Deleted from overall fit because YOUNG 65 constrains his results to add up to 1. Only YOUNG 65 measured ($\mu\nu$) directly.

$\Gamma(e^+\nu_e)/\Gamma_{\text{total}}$ Γ_2/Γ

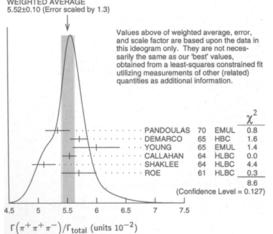
VALUE (DINIS TO -)	CLN EVIS	DOCUMENT ID		TECH	<u>Lnu</u>	
• • • We do not	use the following	data for average	es, fits,	llmits,	etc. •	•
$2.1^{+1.8}_{-1.3}$	4	BOWEN	67B	OSPK	+	
<160.0	95	BORREANI	64	HBC	+	

\100.0	,,	DOM:	••		1	
$\Gamma(e^+\nu_e)/\Gamma($	$(\mu^+ u_\mu)$					Γ_2/Γ_1
VALUE (units 10	·5) <u>EVTS</u>	DOCUMENT ID		TECN	CHG	
2.45±0.11 OL	JR AVERAGE					
2.51 ± 0.15	404	HEINTZE	76	SPEC	+	
0.07.1.0.47		115455		CDEC		

 2.37 ± 0.17 534 HEARD 758 SPEC + 2.42 ± 0.42 112 CLARK 72 OSPK + • • • We do not use the following data for averages, fits, limits, etc. • • • 8 MACEK 69 ASPK +

 $1.9 \begin{array}{l} +0.7 \\ -0.5 \end{array}$ 10 BOTTERILL 67 ASPK +

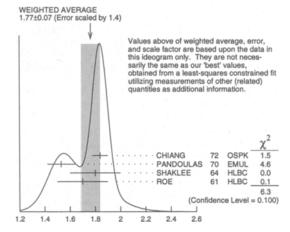
VALUE (units 10 ⁻²)	E) CTE	DOCUMENT 10		TECH	cuc	F3/I
21.16±0.14 OUR FIT	Error in	DOCUMENT ID	f 1.1		CHG	COMMENT
21.18±0.28	16k	CHIANG		OSPK	+	1.84 GeV/c K+
• • We do not use						,
21.0 ±0.6		CALLAHAN	65	HLBC		See $\Gamma(\pi^+\pi^0)$
11.0 10.0		CALLANDA	-			$\Gamma(\pi^{+}\pi^{+}\pi^{-})$
21.6 ±0.6		TRILLING	658	RVUE		1 (<i>n</i>
23.2 ±2.2		11 ALEXANDER		EMUL	+	
27.7 ±2.7		11 BIRGE	56	EMUL		
¹¹ Earlier experiment	ts not avera	iged.				
$\Gamma(\pi^+\pi^0)/\Gamma(\mu^+ u_\mu$		-				r. /r
, , , ,	•	DOCUMENT ID		TECH	cuc	Γ ₃ /Γ
VALUE 0.3331±0.0028 OUR	<u>EVTS</u> FIT Frro	DOCUMENT ID	or of	1 1	CHG	COMMENT
0.3316±0.0032 OUR			U, U,	1.1.		
0.3329±0.0047±0.00		USHER	92	SPEC	+	pp at rest
0.3355 ± 0.0057		12 WEISSENBE	76	SPEC	+	
0.305 ±0.018	1600	ZELLER		ASPK	+	
0.3277 ± 0.0065	4517	¹³ AUERBACH		OSPK	+	
 ● ● We do not use 	the follow	-			, etc.	• • •
0.328 ±0.005	25k	12 WEISSENBE	74	STRC	+	
12 WEISSENBERG 7	76 revises V	VEISSENBERG 74.				
13 AUERBACH 67 c	hanged froi	$n 0.3253 \pm 0.0065$.	See	comme	nt witl	ı ratio Γ $(\pi^0 \mu^+ u_{\mu})$
$\Gamma(\mu^+\nu_{\mu})$.						
•						
$\Gamma(\pi^+\pi^0)/\Gamma(\pi^+\pi^-)$	⁺ π ⁻)					Г ₃ /г
VALUE	<u>EVTS</u>	DOCUMENT ID		TECN	CHG	-
3.78±0.04 OUR FIT						
3.84±0.27 OUR AVE 3.96±0.15	1045	ror includes scale to CALLAHAN	66	OF 1.9. FBC	+	
3.24±0.34	134	YOUNG	65	EMUL		
5.24 2 5.54			•			
$\Gamma(\pi^+\pi^+\pi^-)/\Gamma_{tot}$	ca)					Γ4/
VALUE (units 10 ⁻²)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
5.59±0.05 OUR FIT		ludes scale factor of				
5.52±0.10 OUR AVE						ie ideogram below.
	693	14 PANDOULAS		EMUL HBC	+	
5.71±0.15	44	DEMARCO	65 65			
5.71±0.15 6.0 ±0.4	44 2332	YOUNG	65	EMUL		
5.71±0.15 6.0 ±0.4 5.54±0.12	2332	YOUNG CALLAHAN	65 64	EMUL HLBC	+	
5.71±0.15 6.0 ±0.4 5.54±0.12 5.1 ±0.2		YOUNG	65	EMUL	++	
5.54±0.12 6.0 ±0.4 5.54±0.12 5.1 ±0.2 5.7 ±0.3 • • • We do not use	2332 540	YOUNG CALLAHAN SHAKLEE ROE	65 64 64 61	EMUL HLBC HLBC HLBC	++++++	•••
5.71±0.15 6.0 ±0.4 5.54±0.12 5.1 ±0.2 5.7 ±0.3 • • • We do not use	2332 540 the follow	YOUNG CALLAHAN SHAKLEE ROE ing data for average	65 64 64 61 s, fit	EMUL HLBC HLBC HLBC s, limits	+ + + s, etc.	
5.71±0.15 6.0 ±0.4 5.54±0.12 5.1 ±0.2 5.7 ±0.3 • • • We do not use 5.56±0.20	2332 540	YOUNG CALLAHAN SHAKLEE ROE ing data for average	65 64 64 61	EMUL HLBC HLBC HLBC s, limits	+ + + , etc. +	• • • 1.84 GeV/ <i>c K</i> +
5.71±0.15 6.0 ±0.4 5.54±0.12 5.1 ±0.2 5.7 ±0.3 • • • We do not use 5.56±0.20 5.2 ±0.3	2332 540 the follow	YOUNG CALLAHAN SHAKLEE ROE ing data for average	65 64 64 61 es, fit 72	EMUL HLBC HLBC HLBC s, limits	+ + + s, etc. +	
5.71±0.15 6.0 ±0.4 5.54±0.12 5.1 ±0.2 5.7 ±0.3 • • • We do not use 5.56±0.20 5.2 ±0.3 6.8 ±0.4	2332 540 the follow	YOUNG CALLAHAN SHAKLEE ROE ing data for average 15 CHIANG 16 TAYLOR	65 64 64 61 es, fit 72	EMUL HLBC HLBC HLBC s, limits OSPK EMUL	+ + + i, etc. + +	
5.71±0.15 6.0 ±0.4 5.54±0.12 5.1 ±0.2 5.7 ±0.3 • • • We do not use 5.56±0.20 5.2 ±0.3 6.8 ±0.4 14 laptudes events of	2332 540 the follow 2330	YOUNG CALLAHAN SHAKLEE ROE ing data for average 15 CHIANG 16 TAYLOR 16 ALEXANDER 16 BIRGE	65 64 64 61 es, fit 72 59 57	EMUL HLBC HLBC HLBC S, limits OSPK EMUL EMUL	+ + + i, etc. + + + +	1.84 GeV/ <i>c K</i> +
5.71±0.15 6.0 ±0.4 5.54±0.12 5.1 ±0.2 5.7 ±0.3 • • • We do not use 5.56±0.20 5.2 ±0.3 6.8 ±0.4 5.6 ±0.4 14 Includes events of 15 Value is not in	2332 540 the follow 2330 f TAYLOR	YOUNG CALLAHAN SHAKLEE ROE ing data for average 15 CHIANG 16 TAYLOR 16 ALEXANDER 16 BIRGE 59.	65 64 64 61 es, fit 72 59 57 56	EMUL HLBC HLBC HLBC S, Ilmits OSPK EMUL EMUL	+ + + s, etc. + + + +	1.84 GeV/ c K^+ 1.87 $\Gamma(\pi^+\pi^0)/\Gamma_{\text{tot}}$
5.71±0.15 6.0 ±0.4 5.54±0.12 5.1 ±0.2 5.7 ±0.3 • • • We do not use 5.56±0.20 5.2 ±0.3 6.8 ±0.4 5.6 ±0.4 14 Includes events of 15 Value is not in	2332 540 the follow 2330 f TAYLOR	YOUNG CALLAHAN SHAKLEE ROE ing data for average 15 CHIANG 16 TAYLOR 16 ALEXANDER 16 BIRGE 59.	65 64 64 61 es, fit 72 59 57 56	EMUL HLBC HLBC HLBC S, Ilmits OSPK EMUL EMUL	+ + + s, etc. + + + +	1.84 GeV/ c K^+ 1.87 $\Gamma(\pi^+\pi^0)/\Gamma_{\text{tot}}$
5.71 \pm 0.15 6.0 \pm 0.4 5.54 \pm 0.12 5.1 \pm 0.2 5.7 \pm 0.3 • • • We do not use 5.56 \pm 0.20 5.2 \pm 0.3 6.8 \pm 0.4 5.6 \pm 0.4 14 Includes events of 15 Value is not in $\Gamma(\pi^+\pi^0\pi^0)/\Gamma_{\rm to}$	2332 540 the follow 2330 f TAYLOR independent stal, $\Gamma(\pi^0 \mu$	YOUNG CALLAHAN SHAKLEE ROE ling data for average 15 CHIANG 16 TAYLOR 16 ALEXANDER 16 BIRGE 59. of CHIANG 72 + \(\nu_{\rho}\)/\(\tau_{\rho}\) and	65 64 64 61 es, fit 72 59 57 56	EMUL HLBC HLBC HLBC S, Ilmits OSPK EMUL EMUL	+ + + s, etc. + + + +	1.84 GeV/ c K^+ 1.87 $\Gamma(\pi^+\pi^0)/\Gamma_{\text{tot}}$
5.71±0.15 6.0 ±0.4 5.54±0.12 5.1 ±0.2 5.7 ±0.3 • • • We do not use 5.56±0.20 5.2 ±0.3 6.8 ±0.4 5.6 ±0.4 14 Includes events of 15 Value is not in	2332 540 the follow 2330 f TAYLOR independent stal, $\Gamma(\pi^0 \mu$	YOUNG CALLAHAN SHAKLEE ROE ling data for average 15 CHIANG 16 TAYLOR 16 ALEXANDER 16 BIRGE 59. of CHIANG 72 + \(\nu_{\rho}\)/\(\tau_{\rho}\) and	65 64 64 61 es, fit 72 59 57 56	EMUL HLBC HLBC HLBC S, Ilmits OSPK EMUL EMUL	+ + + s, etc. + + + +	1.84 GeV/ c K^+ 1.87 $\Gamma(\pi^+\pi^0)/\Gamma_{\text{tot}}$
6.0 \pm 0.4 5.54 \pm 0.12 5.1 \pm 0.2 5.7 \pm 0.3 • • • We do not use 5.56 \pm 0.20 5.2 \pm 0.3 6.8 \pm 0.4 5.6 \pm 0.4 14 Includes events of 15 Value is not in $\Gamma(\pi^+\pi^0\pi^0)/\Gamma_{\rm to}$	2332 540 the follow 2330 f TAYLOR independent stal, $\Gamma(\pi^0 \mu$	YOUNG CALLAHAN SHAKLEE ROE ing data for average 15 CHIANG 16 ALEXANDER 16 BIRGE 59. c of CHIANG 72 $+ \nu_{\mu}$ / $\Gamma_{\rm total}$, and aged.	65 64 64 61 es, fit 72 59 57 56	EMUL HLBC HLBC HLBC S, Ilmits OSPK EMUL EMUL	+ + + s, etc. + + + +	1.84 GeV/ c K^+ 1.87 $\Gamma(\pi^+\pi^0)/\Gamma_{\text{tot}}$
5.71 \pm 0.15 6.0 \pm 0.4 5.54 \pm 0.12 5.1 \pm 0.2 5.7 \pm 0.3 • • • We do not use 5.56 \pm 0.20 5.2 \pm 0.3 6.8 \pm 0.4 5.6 \pm 0.4 14 Includes events of 15 Value is not in $\Gamma(\pi^+\pi^0\pi^0)/\Gamma_{\rm to}$ 16 Earlier experimen	2332 540 the follow 2330 f TAYLOR independent that, $\Gamma(\pi^0 \mu$ tts not aver	YOUNG CALLAHAN SHAKLEE ROE ING data for average 15 CHIANG 16 TAYLOR 16 BIRGE 59. TO CHIANG 72 $+\nu_{\mu}$ / Γ total, and aged.	65 64 64 61 es, fit 72 59 57 56	EMUL HLBC HLBC HLBC S, Ilmits OSPK EMUL EMUL	+ + + s, etc. + + + +	1.84 GeV/ c K^+ 1.87 $\Gamma(\pi^+\pi^0)/\Gamma_{\text{tot}}$
5.71 \pm 0.15 6.0 \pm 0.4 5.54 \pm 0.12 5.1 \pm 0.2 5.7 \pm 0.3 • • • We do not use 5.56 \pm 0.20 5.2 \pm 0.3 6.8 \pm 0.4 5.6 \pm 0.4 14 includes events of 15 Value is not in $\Gamma(\pi^+\pi^0\pi^0)/\Gamma_{\rm to}$ 16 Earlier experimen	2332 540 the follow 2330 f TAYLOR independent that, $\Gamma(\pi^0 \mu$ tts not aver	YOUNG CALLAHAN SHAKLEE ROE ING data for average 15 CHIANG 16 TAYLOR 16 BIRGE 59. TO CHIANG 72 $+\nu_{\mu}$ / Γ total, and aged.	65 64 64 61 es, fit 72 59 57 56	EMUL HLBC HLBC HLBC S, Ilmits OSPK EMUL EMUL	+ + + s, etc. + + + +	1.84 GeV/ c K+ $\Gamma(\pi^+\pi^0)/\Gamma_{\text{tot}}$
5.71 \pm 0.15 6.0 \pm 0.4 5.54 \pm 0.12 5.1 \pm 0.2 5.7 \pm 0.3 • • • We do not use 5.56 \pm 0.20 5.2 \pm 0.3 6.8 \pm 0.4 5.6 \pm 0.4 14 includes events of 15 Value is not in $\Gamma(\pi^+\pi^0\pi^0)/\Gamma_{\rm to}$ 16 Earlier experimen	2332 540 the follow 2330 f TAYLOR independent that, $\Gamma(\pi^0 \mu$ tts not aver	YOUNG CALLAHAN SHAKLEE ROE ING data for average 15 CHIANG 16 TAYLOR 16 ALEXANDER 16 BIRGE 59. of CHIANG 72 + \(\nu_{\psi}\)/\(\tau_{\text{total}}\), and aged.	65 64 64 61 72 59 57 56 Γ(μ ⁰	EMUL HLBC HLBC HLBC S, limits OSPK EMUL EMUL $\iota^+\nu_\mu$)/ $e^+\nu_e$)	+ + + + + + + + + + + + + + + + + + +	1.84 GeV/ c K^+ 1.84 GeV/ c K^+ 1. $\Gamma(\pi^+\pi^0)/\Gamma_{\text{tot}}$ 1. Herefore, error,
5.71 \pm 0.15 6.0 \pm 0.4 5.54 \pm 0.12 5.1 \pm 0.2 5.7 \pm 0.3 • • • We do not use 5.56 \pm 0.20 5.2 \pm 0.3 6.8 \pm 0.4 5.6 \pm 0.4 14 includes events of 15 Value is not in $\Gamma(\pi^+\pi^0\pi^0)/\Gamma_{\rm to}$ 16 Earlier experimen	2332 540 the follow 2330 f TAYLOR independent that, $\Gamma(\pi^0 \mu$ tts not aver	YOUNG CALLAHAN SHAKLEE ROE ling data for average 15 CHIANG 16 TAYLOR 16 ALEXANDER 16 BIRGE 59. c of CHIANG 72 + \(\nu_{\mu}\)/\(\tau_{\tau}\) total, and aged.	65 64 64 61 72 59 57 56 Γ(μ	EMUL HLBC HLBC HLBC S, limits OSPK EMUL EMUL $(+ \nu_{\mu})/(e^{+} \nu_{e})$ f weight are bar	+ + + + + + + + + + + + + + + + + + +	1.84 GeV/ c K^+ 1. $\Gamma(\pi^+\pi^0)/\Gamma_{\rm tot}$ 1. erage, error, son the data in
5.71 \pm 0.15 6.0 \pm 0.4 5.54 \pm 0.12 5.1 \pm 0.2 5.7 \pm 0.3 • • • We do not use 5.56 \pm 0.20 5.2 \pm 0.3 6.8 \pm 0.4 5.6 \pm 0.4 14 Includes events of 15 Value is not in $\Gamma(\pi^+\pi^0\pi^0)/\Gamma_{\rm to}$ 16 Earlier experimen	2332 540 the follow 2330 f TAYLOR independent that, $\Gamma(\pi^0 \mu$ tts not aver	YOUNG CALLAHAN SHAKLEE ROE ling data for average 15 CHIANG 16 TAYLOR 16 ALEXANDER 16 BIRGE 59. c of CHIANG 72 + \(\nu_{\mu}\)/\(\tau_{\tau}\) total, and aged.	65 64 64 61 72 59 57 56 Γ(μ	EMUL HLBC HLBC HLBC HLBC S, limits OSPK EMUL EMUL $(+ \nu_{\mu})/(e^+ \nu_e)$ f weight are bandy. The	+ + + + + + + + + + + + + + + + + + +	1.84 GeV/ c K^+ 1.84 GeV/ c K^+ 1.7 $\Gamma(\pi^+\pi^0)/\Gamma_{\text{tot}}$ 1.84 GeV/ c K^+ 1.84 GeV/ c K^+ 1.84 GeV/ c K^+



```
\Gamma(\pi^+\pi^0\pi^0)/\Gamma_{\text{total}}
                                                                                          \Gamma_5/\Gamma
VALUE (units 10<sup>-2</sup>) EVTS DOCUMENT ID TECN CHG COMMENT

1.73±0.04 OUR FIT Error includes scale factor of 1.2.
1.77±0.07 OUR AVERAGE Error includes scale factor of 1.4. See the ideogram below.
                                       CHIANG
                                                        72 OSPK +
1.84 \pm 0.06
                           1307
                                                                            1.84 GeV/c K+
                                    17 PANDOULAS 70 EMUL +
1.53 \pm 0.11
                            198
                                       SHAKLEE
                                                        64 HLBC
1.8 \pm 0.2
1.7 \pm 0.2
                                       ROE
                                                        61 HLBC +
\bullet \,\bullet\, \,\bullet\, We do not use the following data for averages, fits, limits, etc. \,\bullet\, \,\bullet\,
                                    18 TAYLOR
                                                     59 EMUL +
1.5 ±0.2
                                    18 ALEXANDER 57 EMUL +
2.2 \pm 0.4
                                    18 BIRGE
2.1 ±0.5
```

17 Includes events of TAYLOR 59. 18 Earlier experiments not averaged.



 $\Gamma(\pi^+\pi^0\pi^0)/\Gamma(\pi^+\pi^0)$ Γ_5/Γ_3 <u>VALUE</u> <u>EVTS</u> <u>DOCUMENT IV</u> 1E... **0.0619±0.0020 OUR FIT** Error includes scale factor of 1.2. **0.081 ±0.005** 574 ¹⁹ LUCAS 738 HBG TECN CHG COMMENT 73B HBC Dalitz pairs only ¹⁹LUCAS 73B gives N($\pi 2\pi^0$) = 574 ± 5.9%, N(2π) = 3564 ± 3.1%. We quote $0.5N(\pi 2\pi^0)/N(2\pi)$ where 0.5 is because only Dalitz pair π^0 's were used.

 Γ_5/Γ_4 $\Gamma(\pi^+\pi^0\pi^0)/\Gamma(\pi^+\pi^+\pi^-)$ VALUE EVTS DOCUMENT ID T 0.310±0.007 OUR FIT Error includes scale factor of 1.2. TECN CHG COMMENT 0.304±0.009 OUR AVERAGE 0.303 ± 0.009 HBC+HLBC 2027 65 EMUL + 0.393 ± 0.099 YOUNG

 $\Gamma(\pi^0 \mu^+ \nu_\mu)/\Gamma_{\text{total}}$ Γ_6/Γ 3.18±0.08 OUR FIT Error includes scale factor of 1.5.
3.33±0.16 3.33±0.16 2345 CHIANG 72 OSPK + ²⁰ TAYLOR 59 EMUL + 2.8 ± 0.4 20 ALEXANDER 57 EMUL +

 5.9 ± 1.3 ²⁰ BIRGE 2.8 ±1.0 ²⁰ Earlier experiments not averaged.

 $\Gamma(\pi^0\mu^+\nu_\mu)/\Gamma(\mu^+\nu_\mu)$ Γ_6/Γ_1 VALUE EVTS DOCUMENT ID TEC 0.0501±0.0013 OUR FIT Error Includes scale factor of 1.5. TECN CHG 0.0488 ± 0.0026 OUR AVERAGE 0.054 ±0.009 240 ZELLER 69 ASPK + 0.0480±0.0037 21 GARLAND 68 OSPK + 424 22 AUERBACH 67 OSPK + 0.0486 ± 0.0040 307

 21 GARLAND 68 changed from 0.055 \pm 0.004 in agreement with $\mu\text{-spectrum}$ calculation of GAILLARD 70 appendix B. L.G.Pondrom, (private communication 73). ²² AUERBACH 67 changed from 0.0602 \pm 0.0046 by erratum which brings the μ -spectrum calculation into agreement with GAILLARD 70 appendix B.

 $\Gamma(\pi^0\mu^+\nu_\mu)/\Gamma(\pi^+\pi^+\pi^-)$ VALUE EVTS DOCUMENT ID TECN CHG COMMENT

0.569±0.014 OUR FIT Error Includes scale factor of 1.5.

0.517±0.032 OUR AVERAGE Error includes scale factor of 1.8. See the ideogram below. 23 HAIDT 1505 71 HLBC + 0.503 ± 0.019 24 BISI 658 BC HBC+HLBC 0.63 ± 0.07 2845 YOUNG 65 EMUL + 0.90 ±0.16 38 • • • We do not use the following data for averages, fits, limits, etc. • • 1505 23 EICHTEN 0.510 ± 0.017 68 HLBC +

K^{\pm}

 $\Gamma(\pi^+\pi^0)$].

```
23 HAIDT 71 is a reanalysis of EICHTEN 68.
                                                                                                                      \Gamma(\pi^0 e^+ \nu_e) / \Gamma(\pi^+ \pi^0)
                                                                                                                                                                                                                     \Gamma_7/\Gamma_3
 24 Error enlarged for background problems. See GAILLARD 70.
                                                                                                                      0.2280±0.0035 OUR FIT Error includes scale factor of 1.3.
                                                                                                                                                                                       TECN CHG COMMENT
          WEIGHTED AVERAGE
                                                                                                                      0.221 ±0.012
                                                                                                                                                   786
                                                                                                                                                            33 LUCAS
          1.77±0.07 (Error scaled by 1.4)
                                                                                                                       ^{33} LUCAS 73B gives N(K<sub>e3</sub>) = 786 \pm 3.1%, N(2\pi) \approx 3564 \pm 3.1%. We divide.
                                              Values above of weighted average, error,
                                                                                                                      \Gamma(\pi^0 e^+ \nu_e) / \Gamma(\pi^+ \pi^+ \pi^-)
                                                                                                                                                                                                                     \Gamma_7/\Gamma_4
                                              and scale factor are based upon the data in
this ideogram only. They are not neces-
sarily the same as our 'best' values,
                                                                                                                      VALUE EVTS DOCUMENT ID T
0.862±0.011 OUR FIT Error includes scale factor of 1.3.
                                                                                                                                                                                       TECN CHG
                                              obtained from a least-squares constrained fit
                                                                                                                      0.860±0.014 OUR AVERAGE
                                              utilizing measurements of other (related) quantities as additional information.
                                                                                                                     0.867 \pm 0.027
                                                                                                                                                  2768
                                                                                                                                                                BARMIN
                                                                                                                                                                                  87 XEBC
                                                                                                                     0.856 \pm 0.040
                                                                                                                                                  2827
                                                                                                                                                                RRALIN
                                                                                                                                                                                  75 HLBC
                                                                                                                                                            34 HAIDT
                                                                                                                     0.850 \pm 0.019
                                                                                                                                                  4385
                                                                                                                                                                                  71 HLBC
                                                                                                                     0.94 ±0.09
                                                                                                                                                   854
                                                                                                                                                                BELLOTTI
                                                                                                                                                                                  67B HLBC
                                                                                                                                                                BORREANI
                                                                                                                      4385
                                                                                                                                                            34 EICHTEN
                                                                                                                     0.846 \pm 0.021
                                                                                                                                                                                  68 HIBC +
                                                        CHIANG
                                                                         72
70
                                                                                                                                                                                  65 EMUL +
                                                                                                                     0.90 \pm 0.16
                                                                                                                                                    37
                                                                                                                                                                YOUNG
                                                        PANDOULAS
                                                                               EMUL
                                                                                           4.6
                                                        SHAKLEE
                                                                         64
                                                                               HL BC
                                                                                          0.0
                                                                                                                      34 HAIDT 71 is a reanalysis of EICHTEN 68.
                                                                               HLBC
                                                        ROE
                                                                         61
                                                                                          0.1
                                                                                                                      \Gamma(\pi^0 e^+ \nu_e) / \left[ \Gamma(\mu^+ \nu_\mu) + \Gamma(\pi^+ \pi^0) \right]
                                                                                                                                                                                                             \Gamma_7/(\Gamma_1+\Gamma_3)
                                                                  (Confidence Level = 0.100)
                                                                                                                      VALUE (units 10-2)
                                                                                                                                                 EVTS
                                                                                                                                                                DOCUMENT ID
                                                                                                                      5.70±0.08 OUR FIT Error includes scale factor of 1.4.
                                 1.8
                                                          2.4
                                                                                                                      6.01±0.15 OUR AVERAGE
                                                                                                                                                             35 WEISSENBE... 76 SPEC +
            \Gamma(\pi^0 \mu^+ \nu_\mu)/\Gamma(\pi^+ \pi^+ \pi^-)
                                                                                                                      5.92 \pm 0.65
                                                                                                                                                                ESCHSTRUTH 68 OSPK
                                                                                                                      6.16 \pm 0.22
                                                                                                                                                  5110
\Gamma \big(\pi^0\,\mu^+\,\nu_\mu\big)/\Gamma \big(\pi^0\,e^+\,\nu_e\big)
                                                                                                                                                                                 66 OSPK +
                                                                                                                      5.89±0.21
                                                                                                                                                  1679
                                                                                                                                                                CESTER
                                                                                                \Gamma_6/\Gamma_7
VALUE EVTS DOCUMENT ID TECN CHG COMMENT

0.660 ± 0.018 OUR FIT Error includes scale factor of 1.5.
                                                                                                                       ^{35} Value calculated from WEISSENBERG 76 (\pi^0e
u), (\mu
u), and (\pi\pi^0) values to eliminate
                                                                                                                          dependence on our 1974 (\pi 2\pi^0) and (\pi \pi^+ \pi^-) fractions.
0.680 ± 0.013 OUR AVERAGE
                                       <sup>25</sup> LUCAS
0.705 \pm 0.063
                              554
                                                             738 HBC
                                                                                                                     \Gamma(\pi^0\pi^0e^+\nu_e)/\Gamma(\pi^0e^+\nu_e)
                                                                                                                                                                                                                     \Gamma_8/\Gamma_7
                                                                                   Dalitz pairs only
                                       <sup>26</sup> CHIANG
0.698 \pm 0.025
                             3480
                                                             72 OSPK +
                                                                                   1.84 GeV/c K+
                                                                                                                      VALUE (units 10-4) CL% EVTS
                                                                                                                                                                DOCUMENT ID TECN CHG
0.667 \pm 0.017
                             5601
                                          BOTTERILL
                                                            68B ASPK +
                                       27 CALLAHAN 66B HLBC
                                                                                                                          4.3<sup>+0.9</sup> OUR FIT
0.703 \pm 0.056
                             1509
• • • We do not use the following data for averages, fits, limits, etc. • • •
                                       28 HEINTZE
                                                                                                                          4.1+1.0 OUR AVERAGE
0.670 \pm 0.014
                                                            77 SPEC
                                          WEISSENBE ... 76 SPEC +
0.67 \pm 0.12
                                                                                                                          4.2^{+1.0}_{-0.9}
                                       29 BRAUN
                                                                                                                                                                BOLOTOV
                                                                                                                                                                                  86B CALO -
0.608 \pm 0.014
                                                             75 HLBC
                                       30 HAIDT
0.596 \pm 0.025
                                                             71 HLBC
                                                                                                                          3.8^{+5.0}_{-1.2}
                                                                                                                                                                LIUNG
                                                                                                                                                                                  73 HLBC +
                                       30 EICHTEN
                                                             68 HLBC
                                                                                                                     • • • We do not use the following
 ^{25} LUCAS 73B gives N( K_{\mu 3}) = 554 \pm 7.6\%, N( K_{e3}) = 786 \pm 3.1\%. We divide.
                                                                                                                                                              data for averages, fits, limits, etc. . .
                                                                                                                                                                                  71 HLBC +
                                                                                                                      <37.0
                                                                                                                                                                ROMANO
 <sup>26</sup> CHIANG 72 \Gamma(\pi^0 \mu^+ \nu_\mu)/\Gamma(\pi^0 e^+ \nu_e) is statistically independent of CHIANG 72
    \Gamma(\pi^0 \mu^+ \nu_\mu)/\Gamma_{
m total} and \Gamma(\pi^0 e^+ \nu_e)/\Gamma_{
m total}
                                                                                                                     \Gamma(\pi^0\pi^0e^+\nu_e)/\Gamma_{\text{total}}
                                                                                                                                                                                                                       \Gamma_8/\Gamma
 27 From CALLAHA 66B we use only the K_{\mu3}/K_{e3} ratio and do not include in the fit the ratios K_{\mu3}/(\pi\pi^+\pi^0) and K_{e3}/(\pi\pi^+\pi^0), since they show large disagreements with
                                                                                                                     VALUE (units 10<sup>-5</sup>)
2.1 ±0.4 OUR FIT
                                                                                                                                                                DOCUMENT ID
                                                                                                                                                                                     TECN CHG
 the rest of the data. 28 HEINTZE 77 value from fit to \lambda_0. Assumes \mu-e universality.
                                                                                                                      2.54 \pm 0.89
                                                                                                                                                                BARMIN
                                                                                                                                                                                  88B HLBC +
 ^{29} BRAUN 75 value is from form factor fit. Assumes \mu-e universality. ^{30} HAIDT 71 is a reanalysis of EICHTEN 68. Only individual ratios included in fit (see
                                                                                                                      \Gamma(\pi^+\pi^-e^+\nu_e)/\Gamma(\pi^+\pi^+\pi^-)
                                                                                                                                                                                                                     \Gamma_9/\Gamma_4
                                                                                                                      VALUE (units 10-4)
                                                                                                                                                  EVTS
    \Gamma(\pi^0 \mu^+ \nu_\mu)/\Gamma(\pi^+ \pi^+ \pi^-) and \Gamma(\pi^0 e^+ \nu_e)/\Gamma(\pi^+ \pi^+ \pi^-).
                                                                                                                                                                DOCUMENT ID
                                                                                                                                                                                       TECN CHG
                                                                                                                      6.99 ± 0.30 OUR AVERAGE Error includes scale factor of 1.2.
                                                                                                                                                                ROSSELET
 [\Gamma(\pi^+\pi^0) + \Gamma(\pi^0\mu^+\nu_\mu)]/\Gamma_{\text{total}}  (Γ<sub>3</sub>+Γ<sub>6</sub>)/Γ We combine these two modes for experiments measuring them in xenon bubble chambers
                                                                                                                     7.21 \pm 0.32
                                                                                                                                                   500
                                                                                                                                                                BOURQUIN
                                                                                                                      7.36 \pm 0.68
       ber because of difficulties of separating them there.
                                                                                                                                                   106
                                                                                                                     7.0 ±0.9
                                                                                                                                                                SCHWEINB... 71 HLBC
                                                                                                                     5.83 \pm 0.63
                                                                                                                                                   269
                                                                                                                                                                FIY
                                                                                                                                                                                  69 HIBC +

        VALUE (units 10<sup>-2</sup>)
        EVTS
        DOCUMENT ID
        TECN

        24.34±0.15 OUR FIT
        Error includes scale factor of 1.2.

        24.6 ±1.0
        OUR AVERAGE
        Error includes scale factor of 1.4.

                                          DOCUMENT ID
                                                                  TECN CHG
                                                                                                                      • • • We do not use the following data for averages, fits, limits, etc. • • •
                                                                                                                                                     69
                                                                                                                                                                BIRGE
                                                                                                                                                                                  65 FBC
                                          SHAKLEE
                              886
25.4 ±0.9
                                                            64 HLBC
23.4 ±1.1
                                                                                                                     \Gamma(\pi^+\pi^-\mu^+\nu_\mu)/\Gamma_{\rm total}
                                           ROE
                                                             61 HLBC +
                                                                                                                                                                                                                     \Gamma_{10}/\Gamma
                                                                                                                     VALUE (units 10-5)
\Gamma(\pi^0 e^+ \nu_e)/\Gamma_{\text{total}}
                                                                                                 \Gamma_7/\Gamma
                                                                                                                                               EVTS
                                                                                                                                                                DOCUMENT ID
                                                                                                                                                                                       TECN CHG
                                                                                                                      VALUE (units 10<sup>-2</sup>) EVTS DOCUMENT ID

4.82±0.06 OUR FIT Error Includes scale factor of 1.3.

4.85±0.09 OUR AVERAGE
                                                                  TECN CHG COMMENT
                                                                                                                     0.77 + 0.54
                                                                                                                                                                                  65 FBC +
                                                                                                                                                                CLINE
4.86 \pm 0.10
                             3516
                                           CHIANG
                                                             72 OSPK +
                                                                                  1.84 GeV/c K+
                                                                                                                      \Gamma(\pi^+\pi^-\mu^+\nu_\mu)/\Gamma(\pi^+\pi^+\pi^-)
                                                                                                                                                                                                                    \Gamma_{10}/\Gamma_{4}
                                           SHAKLEE
                                                             64 HLBC +
4.7 ±0.3
                              429
                                                                                                                      VALUE (units 10-4)
                                           ROE
                                                             61 HLBC
                                                                                                                                              EVTS
                                                                                                                                                                DOCUMENT ID
                                                                                                                                                                                       TECN CHG
• • • We do not use the following data for averages, fits, limits, etc. • • •
                                                                                                                                                                                  67 DBC +
                                       31 ALEXANDER $7 EMUL +
5.1 ±1.3
                                                                                                                      31 BIRGE
                                                                                                                                                                GREINER
                                                                                                                                                                                  64 EMUL +
 31 Earlier experiments not averaged.
                                                                                                                     \Gamma(\pi^0\pi^0\pi^0e^+\nu_e)/\Gamma_{\rm total}
                                                                                                                                                                                                                     \Gamma_{11}/\Gamma
\Gamma(\pi^0\,e^+\,\nu_e)/\Gamma(\mu^+\,\nu_\mu)
                                                                                                \Gamma_7/\Gamma_1
                                                                                                                      VALUE (units 10-6) CL% EVTS
                                                                                                                                                                DOCUMENT ID
                                                                                                                                                                                      TECN CHG
VALUE EYTS DOCUMENT ID TECN CHG
0.0759±0.0011 OUR FIT Error Includes scale factor of 1.4.
0.0752±0.0024 OUR AVERAGE
                                                                                                                                                                BOLOTOV
                                                                                                                                           90
                                                                                                                      • • • We do not use the following data for averages, fits, limits, etc. • • •
0.069 ±0.006
                              350
                                           ZELLER
                                                             69 ASPK +
                                                                                                                                                                BARMIN
                                                                                                                                                                                  92 XEBC +
0.0775 \pm 0.0033
                                           BOTTERILL 68C ASPK
                               960
0.069 ±0.006
                                           GARLAND
                                                             68 OSPK
                                      32 AUERBACH 67 OSPK +
                              295
 32 AUERBACH 67 changed from 0.0797 \pm 0.0054. See comment with ratio \Gamma(\pi^0 \mu^+ \nu_\mu)/
    \Gamma(\mu^+
u_\mu). The value 0.0785 \pm 0.0025 given in AUERBACH 67 is an average of
    AUERBACH 67 \Gamma(\pi^0 e^+ \nu_e)/\Gamma(\mu^+ \nu_\mu) and CESTER 66 \Gamma(\pi^0 e^+ \nu_e)/[\Gamma(\mu^+ \nu_\mu) +
```

All values given here assume a phase space pion energy spectrum.	$\lceil (\pi^+ \pi^0 \gamma) / \lceil_{\text{total}} \rceil$
VALUE (units 10 ⁻⁷) CL% EVTS DOCUMENT ID TECN CHG COMMENT	VALUE (units 10 ⁻⁴) CL% EVTS DOCUMENT ID TECN CHG COMMENT 2.75±0.15 OUR AVERAGE
11 ± 3 ±1 31 ³⁶ KITCHING 97 B787	2.71±0.45 140 BOLOTOV 87 WIRE - Τπ ⁻ 55-90 Me\
• • We do not use the following data for averages, fits, limits, etc. • • •	2.87 \pm 0.32 2461 SMITH 76 WIRE \pm T π^{\pm} 55–90 MeV
< 10 90 0 ATIYA 90B B787 Tπ 117-127 MeV	2.71 \pm 0.19 2100 ABRAMS 72 ASPK \pm T π^+ 55–90 MeV
< 84 90 0 ASANO 82 CNTR + Tπ 117-127 MeV	• • • We do not use the following data for averages, fits, limits, etc. • •
-420 ±520 0 ABRAMS 77 SPEC + Tπ <92 MeV < 350 90 0 LJUNG 73 HLBC, + 6-102, 114-127	1.5 $^{+1.1}_{-0.6}$ 45 LJUNG 73 HLBC + T π^+ 55–80 Me\
MeV	2.6 $^{+1.5}_{-1.1}$ 45 LJUNG 73 HLBC + T π^+ 55–90 MeV
< 500 90 0 KLEMS 71 OSPK + Tπ <117 MeV -100 ±600 CHEN 68 OSPK + Tπ 60-90 MeV	
36 KITCHING 97 is extrapolated from their model-independent branching fraction (6.0 ±	- 2.1
$1.5 \pm 0.7) \times 10^{-7}$ for 100 MeV/ c <p<sub>π^+ < 180 MeV/c using Chiral Perturbation Theory.</p<sub>	2.4 \pm 0.8 24 EDWARDS 72 OSPK $T\pi^+$ 58-90 MeV <1.0 0 46 MALTSEV 70 HLBC + $T\pi^+$ <55 MeV
•	<1.9 90 0 EMMERSON 69 OSPK T_{π}^{+} 55-80 MeV
$\Gamma(\pi^+ 3\gamma)/\Gamma_{\text{total}}$ Γ_{13}/Γ	2.2 \pm 0.7 18 CLINE 64 FBC + $T\pi^+$ 55-80 MeV
Values given here assume a phase space pion energy spectrum.	45 The LJUNG 73 values are not independent.
VALUE (units 10 ⁻⁴) CL% DOCUMENT ID TECN CHG COMMENT <1.0	⁴⁶ MALTSEV 70 selects low π^+ energy to enhance direct emission contribution.
<1.0 90 ASANO 82 CNTR + T(π) 117-127 MeV	$\Gamma(\pi^+\pi^0\gamma(DE))/\Gamma_{total}$ $\Gamma_{21}/\Gamma_{total}$
• • We do not use the following data for averages, fits, limits, etc. • •	Direct emission part of $\Gamma(\pi^+\pi^0\gamma)/\Gamma_{\text{total}}$.
<3.0 90 KLEMS 71 OSPK + $T(\pi) > 117 \text{ MeV}$	VALUE (units 10 ⁻⁵) DOCUMENT ID TECN CHG COMMENT
=(+++ 	1.8 ±0.4 OUR AVERAGE
$\Gamma(\mu^+ u_\mu u\overline{ u})/\Gamma_{ ext{total}}$	$2.05\pm0.46^{+0.39}_{-0.23}$ BOLOTOV 87 WIRE $-$ T π^- 55-90 MeV
VALUE (units 10 ⁻⁶) CLX EVTS DOCUMENT ID TECN CHG	
<6.0 90 0 ³⁷ PANG 73 CNTR +	2.3 \pm 3.2 SMITH 76 WIRE \pm T π^{\pm} 55-90 MeV 1.56 \pm 0.35 \pm 0.5 ABRAMS 72 ASPK \pm T π^{\pm} 55-90 MeV
³⁷ PANG 73 assumes μ spectrum from ν - ν interaction of BARDIN 70.	
$(e^+\nu_e\nu_{\overline{\nu}})/\Gamma(e^+\nu_e)$ Γ_{15}/Γ_2	$\Gamma(\pi^+\pi^+\pi^-\gamma)/\Gamma_{\text{total}}$
ALUE CLY EVTS DOCUMENT ID TECH CHG	VALUE (units 10 ⁻⁴) EVTS DOCUMENT ID TECN CHG COMMENT
<3.8 90 0 HEINTZE 79 SPEC +	1.04±0.31 OUR AVERAGE
	1.10 \pm 0.48 7 BARMIN 89 XEBC $E(\gamma) > 5$ MeV 1.0 \pm 0.4 STAMER 65 EMUL + $E(\gamma) > 11$ MeV
$\Gamma(\mu^{+}\nu_{\mu}e^{+}e^{-})/\Gamma(\pi^{+}\pi^{-}e^{+}\nu_{e})$ Γ_{16}/Γ_{9}	***
VALUE (units 10 ⁻³) EVTS DOCUMENT ID TECN CHG COMMENT	$\Gamma(\pi^+\pi^0\pi^0\gamma)/\Gamma(\pi^+\pi^0\pi^0)$
3.3±0.9 14 38 DIAMANT 76 SPEC + $m_{e_{-}^{+}e_{-}^{-}}$ >140	VALUE (units 10 ⁻⁴) DOCUMENT ID TECN CHG COMMENT
● ● We do not use the following data for averages, fits, limits, etc. ● ●	4.3 $^{+3.2}_{-1.7}$ BOLOTOV 85 SPEC - $E(\gamma) > 10 \text{ MeV}$
17. ±8. 14 38 DIAMANT 76 SPEC + Extrapolated BR	-1.7 Sold () Sold (
38 DIAMANT-BERGER 76 gives this result times our 1975 π ⁺ π ⁻ eν BR ratio. The second	$\Gamma(\pi^0 \mu^+ \nu_\mu \gamma) / \Gamma_{\text{total}}$ $\Gamma_{24/}$
DIAMANT-BERGER 76 value is the first value extrapolated to 0 to include low mass	VALUE (units 10 ⁻⁵) CL% EVTS DOCUMENT ID TECN CHG COMMENT
e ⁺ e ⁻ pairs. More recent calculations (BIJNENS 93) of this extrapolation disagree with	<6.1 90 0 LJUNG 73 HLBC + $E(\gamma)$ >30 MeV
those of DIAMANT-BERGER 76.	• •
$\Gamma(e^+\nu_ee^+e^-)/\Gamma(\pi^+\pi^-e^+\nu_e)$ Γ_{17}/Γ_9	$\Gamma(\pi^0 e^+ \nu_e \gamma) / \Gamma(\pi^0 e^+ \nu_e)$ $\Gamma_{25} / \Gamma_{25} / \Gamma$
VALUE (units 10 ⁻³) EVTS DOCUMENT ID TECN CHG COMMENT	VALUE (units 10 ⁻²) EVTS DOCUMENT ID TECN CHG COMMENT
1000	0.54 \pm 0.04 OUR AVERAGE Error includes scale factor of 1.1. 0.46 \pm 0.08 82 47 BARMIN 91 XEBC E(γ) > 10
0.76 4 39 DIAMANT 76 SPEC + m _{e+e-} >140 MeV	0.46 \pm 0.08 82 4 BARMIN 91 XEBC E(γ) > 10 MeV, 0.6 <
• • • We do not use the following data for averages, fits, limits, etc. • • •	$\cos heta_{\mathbf{e}} \gamma < 0.9$
5.4 + 5.4 -2.7 4 39 DIAMANT 76 SPEC + Extrapolated BR	0.56 ± 0.04 192 ⁴⁸ BOLOTOV 86B CALO - $E(\gamma) > 10$ MeV
	0.76 \pm 0.28 13 49 ROMANO 71 HLBC $E(\gamma) > 10$ MeV
³⁹ DIAMANT-BERGER 76 gives this result times our 1975 $\pi^+\pi^-e^-\nu$ BR ratio. The second	• • • We do not use the following data for averages, fits, limits, etc. • • •
DIAMANT-BERGER 76 value is the first value extrapolated to 0 to include low mass e^+e^- pairs. More recent calculations (BIJNENS 93) of this extrapolation disagree with	1.51 ± 0.25 82 ⁴⁷ BARMIN 91 XEBC $E(\gamma)>10$ MeV, $\cos\theta_e \gamma<$
those of DIAMANT-BERGER 76.	0.98
	0.48 ± 0.20 16 50 LJUNG 73 HLBC + $E(\gamma) > 30$ MeV
$\Gamma(\mu^+ u_\mu\mu^+\mu^-)/\Gamma_{\text{total}}$ Γ_{18}/Γ	$0.22^{+0.15}_{-0.10}$ 50 LJUNG 73 HLBC + $E(\gamma) > 30$ MeV
VALUE (units 10 ⁻⁷) CL% DOCUMENT ID TECN CHG	0.53 ± 0.22 49 ROMANO 71 HLBC + $E(\gamma) > 30$ MeV
<4.1 90 ATIYA 89 B787 +	1.2 \pm 0.8 BELLOTTI 67 HLBC + $E(\gamma) > 30$ MeV
$\Gamma(\mu^+ u_\mu\gamma)/\Gamma_{ m total}$ $\Gamma_{ m 19}/\Gamma$	⁴⁷ BARMIN 91 quotes branching ratio $\Gamma(K o e\pi^0 u\gamma)/\Gamma_{ m all}$. The measured normalizati
$\Gamma(\mu^+ u_\mu\gamma)/\Gamma_{ ext{total}}$ Γ_{19}/Γ	777 all
•	is $[\Gamma(K \to e \pi^0 \nu) + \Gamma(K \to \pi^+ \pi^+ \pi^-)]$. For comparison with other experiments
ALUE (units 10 ⁻³) EVTS DOCUMENT ID TECN CHG COMMENT	is $[\Gamma(K \to e \pi^0 \nu) + \Gamma(K \to \pi^+ \pi^+ \pi^-)]$. For comparison with other experiments used $\Gamma(K \to e \pi^0 \nu)/\Gamma_{\text{all}} = 0.0482$ to calculate the values quoted here.
VALUE (units 10 ⁻³) EVTS DOCUMENT ID TECN CHG COMMENT 5.50±0.28 OUR AVERAGE	is $[\Gamma(K \to e \pi^0 \nu) + \Gamma(K \to \pi^+ \pi^+ \pi^-)]$. For comparison with other experiments used $\Gamma(K \to e \pi^0 \nu)/\Gamma_{all} = 0.0482$ to calculate the values quoted here. ⁴⁸ $\cos\theta(e\gamma)$ between 0.6 and 0.9.
VALUE (units 10^{-3}) EVTS DOCUMENT ID TECN CHG COMMENT S.50 ± 0.28 OUR AVERAGE $40,41$ DEMIDOV 90 XEBC P(μ) <231.5 MeV/ c	is $[\Gamma(K \to e\pi^0 \nu) + \Gamma(K \to \pi^+\pi^+\pi^-)]$. For comparison with other experiments used $\Gamma(K \to e\pi^0 \nu)/\Gamma_{\rm all} = 0.0482$ to calculate the values quoted here. $^{48}\cos\theta(e\gamma)$ between 0.6 and 0.9. 49 Both ROMANO 71 values are for $\cos\theta(e\gamma)$ between 0.6 and 0.9. Second value is a comparison with second LJUNG 73 value. We use lowest $E(\gamma)$ cut for Summary Tall
VALUE (units 10^{-3}) EVTS DOCUMENT ID TECN CHG COMMENT 5.50 \pm 0.28 OUR AVERAGE 40,41 DEMIDOV 90 XEBC P(μ) <231.5 MeV/c	is $[\Gamma(K \to e\pi^0 \nu) + \Gamma(K \to \pi^+\pi^+\pi^-)]$. For comparison with other experiments used $\Gamma(K \to e\pi^0 \nu)/\Gamma_{\rm all} = 0.0482$ to calculate the values quoted here. $^{48}\cos\theta(e\gamma)$ between 0.6 and 0.9. 49 Both ROMANO 71 values are for $\cos\theta(e\gamma)$ between 0.6 and 0.9. Second value is a comparison with second LJUNG 73 value. We use lowest $E(\gamma)$ cut for Summary Tal value. See ROMANO 71 for E_γ dependence.
ALUE (units 10^{-3}) EVTS DOCUMENT ID TECN CHG COMMENT 5.50 ± 0.28 OUR AVERAGE 40,41 DEMIDOV 90 XEBC P(μ) <231.5 MeV/ c 6.0 ± 0.9 BARMIN 88 HLBC + P(μ) <231.5 MeV/ c	is $[\Gamma(K \to e\pi^0 \nu) + \Gamma(K \to \pi^+\pi^+\pi^-)]$. For comparison with other experiments used $\Gamma(K \to e\pi^0 \nu)/\Gamma_{\rm all} = 0.0482$ to calculate the values quoted here. ⁴⁸ $\cos\theta(e\gamma)$ between 0.6 and 0.9. ⁴⁹ Both ROMANO 71 values are for $\cos\theta(e\gamma)$ between 0.6 and 0.9. Second value is a comparison with second LJUNG 73 value. We use lowest $E(\gamma)$ cut for Summary Tal value. See ROMANO 71 for E_γ dependence. ⁵⁰ First LJUNG 73 value is for $\cos\theta(e\gamma)$ <0.9, second value is for $\cos\theta(e\gamma)$ between 0.
VALUE (units 10^{-3}) EVTS DOCUMENT ID TECN CHG COMMENT 5.50 ± 0.28 OUR AVERAGE $40,41$ DEMIDOV 90 XEBC P(μ) <231.5 MeV/ c 6.0 ± 0.9 BARMIN 88 HLBC + P(μ) <231.5 MeV/ c 5.4 ± 0.3 42 AKIBA 85 SPEC P(μ) <231.5 MeV/ c	is $[\Gamma(K \to e\pi^0 \nu) + \Gamma(K \to \pi^+\pi^+\pi^-)]$. For comparison with other experiments used $\Gamma(K \to e\pi^0 \nu)/\Gamma_{\rm all} = 0.0482$ to calculate the values quoted here. $^{48}\cos\theta(e\gamma)$ between 0.6 and 0.9. 49 Both ROMANO 71 values are for $\cos\theta(e\gamma)$ between 0.6 and 0.9. Second value is comparison with second LJUNG 73 value. We use lowest $E(\gamma)$ cut for Summary Tal value. See ROMANO 71 for E_γ dependence. 50 First LJUNG 73 value is for $\cos\theta(e\gamma)$ <0.9, second value is for $\cos\theta(e\gamma)$ between 0 and 0.9 for comparison with ROMANO 71.
ALUE (units 10^{-3}) EVTS DOCUMENT ID TECN CHG COMMENT S.50 ± 0.28 OUR AVERAGE $40,41$ DEMIDOV 90 XEBC $40,41$ DEMIDOV 90 XEBC $40,41$ DEMIDOV 90 $40,41$ DEMIDOV $40,4$	is $[\Gamma(K \to e\pi^0 \nu) + \Gamma(K \to \pi^+\pi^+\pi^-)]$. For comparison with other experiments used $\Gamma(K \to e\pi^0 \nu)/\Gamma_{\rm all} = 0.0482$ to calculate the values quoted here. ⁴⁸ $\cos\theta(e\gamma)$ between 0.6 and 0.9. ⁴⁹ Both ROMANO 71 values are for $\cos\theta(e\gamma)$ between 0.6 and 0.9. Second value is a comparison with second LJUNG 73 value. We use lowest $E(\gamma)$ cut for Summary Tal value. See ROMANO 71 for E_γ dependence. ⁵⁰ First LJUNG 73 value is for $\cos\theta(e\gamma) < 0.9$, second value is for $\cos\theta(e\gamma)$ between 0 and 0.9 for comparison with ROMANO 71. $\Gamma(\pi^0 e^+\nu_e\gamma(SD))/\Gamma_{total}$
ALUE (units 10^{-3}) EVTS DOCUMENT ID TECN CHG COMMENT S.50 ± 0.28 OUR AVERAGE $40,41$ DEMIDOV 90 XEBC MeV/c	is $[\Gamma(K \to e\pi^0 \nu) + \Gamma(K \to \pi^+\pi^+\pi^-)]$. For comparison with other experiments used $\Gamma(K \to e\pi^0 \nu)/\Gamma_{\rm all} = 0.0482$ to calculate the values quoted here. 48 $\cos\theta(e\gamma)$ between 0.6 and 0.9. 49 Both ROMANO 71 values are for $\cos\theta(e\gamma)$ between 0.6 and 0.9. Second value is a comparison with second LJUNG 73 value. We use lowest $E(\gamma)$ cut for Summary Tal value. See ROMANO 71 for E_γ dependence. 50 First LJUNG 73 value is for $\cos\theta(e\gamma) < 0.9$, second value is for $\cos\theta(e\gamma)$ between 0 and 0.9 for comparison with ROMANO 71. $\Gamma(\pi^0 e^+\nu_e\gamma(SD))/\Gamma_{total}$ Structure-dependent part.
ALUE (units 10^{-3}) EVTS DOCUMENT ID TECN CHG COMMENT S.50 \pm 0.28 OUR AVERAGE 5.6 \pm 1.5 40,41 DEMIDOV 90 XEBC MeV/c 5.6 \pm 0.9 BARMIN 88 HLBC + P(μ) < 231.5 MeV/c 5.4 \pm 0.3 42 AKIBA 85 SPEC P(μ) < 231.5 MeV/c MeV/c 6.0 \pm 0.9 We do not use the following data for averages, fits, limits, etc. • • • • • • • • • • • • • • • • • • •	is $[\Gamma(K \to e\pi^0 \nu) + \Gamma(K \to \pi^+\pi^+\pi^-)]$. For comparison with other experiments used $\Gamma(K \to e\pi^0 \nu)/\Gamma_{\rm all} = 0.0482$ to calculate the values quoted here. 48 $\cos\theta(e\gamma)$ between 0.6 and 0.9. 49 Both ROMANO 71 values are for $\cos\theta(e\gamma)$ between 0.6 and 0.9. Second value is a comparison with second LJUNG 73 value. We use lowest $E(\gamma)$ cut for Summary Tal value. See ROMANO 71 for E_γ dependence. 50 First LJUNG 73 value is for $\cos\theta(e\gamma)$ <0.9, second value is for $\cos\theta(e\gamma)$ between 0 and 0.9 for comparison with ROMANO 71. $\Gamma(\pi^0 e^+\nu_e\gamma(\text{SD}))/\Gamma_{\text{total}}$ Structure-dependent part. $\frac{VALUE(\text{units } 10^{-5})}{\cos\theta(e\gamma)} = \frac{CL\%}{2\pi^0} \frac{DOCUMENTID}{\cos\theta(e\gamma)} \frac{TECN}{2\pi^0} \frac{CHG}{2\pi^0}$
ALUE (units 10^{-3}) EVTS DOCUMENT ID TECN CHG COMMENT 1.50 \pm 0.28 OUR AVERAGE 1.6 \pm 1.5 \pm 0.40,41 DEMIDOV 90 XEBC \pm 0.0 \pm 0.9 BARMIN 88 HLBC + P(μ) <231.5 MeV/c 1.4 \pm 0.3 42 AKIBA 85 SPEC P(μ) <231.5 MeV/c 1.5 \pm 0.8 41,43 DEMIDOV 90 XEBC \pm 0.7) > 20 MeV 1.5 \pm 0.8 41,43 DEMIDOV 90 XEBC \pm 0.7) > 20 MeV 1.6 \pm 0.5 57 44 BARMIN 88 HLBC + E(τ) > 20 MeV 1.8 \pm 3.5 12 WEISSENBE 74 STRC + E(τ) > 9 MeV	is $[\Gamma(K \to e\pi^0 \nu) + \Gamma(K \to \pi^+\pi^+\pi^-)]$. For comparison with other experiments used $\Gamma(K \to e\pi^0 \nu)/\Gamma_{\rm all} = 0.0482$ to calculate the values quoted here. 48 $\cos\theta(e\gamma)$ between 0.6 and 0.9. 49 Both ROMANO 71 values are for $\cos\theta(e\gamma)$ between 0.6 and 0.9. Second value is a comparison with second LJUNG 73 value. We use lowest $E(\gamma)$ cut for Summary Tal value. See ROMANO 71 for E_γ dependence. 50 First LJUNG 73 value is for $\cos\theta(e\gamma)$ <0.9, second value is for $\cos\theta(e\gamma)$ between 0 and 0.9 for comparison with ROMANO 71. $\Gamma(\pi^0 e^+ \nu_e \gamma (\text{SD}))/\Gamma_{\text{total}}$ Structure-dependent part. $\frac{VALUE (\text{units } 10^{-5})}{\text{SOME}} = \frac{CL\%}{\text{SOME}} = \frac{DOCUMENT ID}{\text{BOLOTOV}} = \frac{TECN}{\text{CALO}} = \frac{CHG}{\text{CALO}}$
ALUE (units 10^{-3}) EVTS DOCUMENT ID TECN CHG COMMENT .50 \pm 0.28 OUR AVERAGE .6 \pm 1.5 40,41 DEMIDOV 90 XEBC P(μ) <231.5 MeV/ c .0 \pm 0.9 BARMIN 88 HLBC + P(μ) <231.5 MeV/ c .4 \pm 0.3 42 AKIBA 85 SPEC P(μ) <231.5 MeV/ c • • We do not use the following data for averages, fits, limits, etc. • • • .5 \pm 0.8 41,43 DEMIDOV 90 XEBC E(γ) > 20 MeV .5 \pm 0.8 41,43 DEMIDOV 90 XEBC E(γ) > 20 MeV .8 \pm 3.5 12 WEISSENBE 74 STRC + E(γ) > 9 MeV 40 P(μ) cut given in DEMIDOV 90 paper, 235.1 MeV/ c , is a misprint according to authors	is $[\Gamma(K \to e\pi^0 \nu) + \Gamma(K \to \pi^+\pi^+\pi^-)]$. For comparison with other experiments used $\Gamma(K \to e\pi^0 \nu)/\Gamma_{\rm all} = 0.0482$ to calculate the values quoted here. 48 $\cos\theta(e\gamma)$ between 0.6 and 0.9. 49 Both ROMANO 71 values are for $\cos\theta(e\gamma)$ between 0.6 and 0.9. Second value is a comparison with second LJUNG 73 value. We use lowest $E(\gamma)$ cut for Summary Tal value. See ROMANO 71 for E_γ dependence. 50 First LJUNG 73 value is for $\cos\theta(e\gamma)$ <0.9, second value is for $\cos\theta(e\gamma)$ between 0 and 0.9 for comparison with ROMANO 71. $\Gamma(\pi^0 e^+ \nu_e \gamma (\text{SD}))/\Gamma_{\text{total}}$ Structure-dependent part. $\frac{VALUE (\text{units } 10^{-5})}{\text{SOME}} = \frac{CL\%}{\text{SOME}} = \frac{DOCUMENT ID}{\text{BOLOTOV}} = \frac{TECN}{\text{CALO}} = \frac{CHG}{\text{CALO}}$
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ALUE (units 10^{-3}) EVTS DOCUMENT ID TECN CHG COMMENT 1.50 \pm 0.28 OUR AVERAGE 1.6 \pm 1.5 40,41 DEMIDOV 90 XEBC P(μ) <231.5 MeV/ c 1.0 \pm 0.9 BARMIN 88 HLBC + P(μ) <231.5 MeV/ c 1.4 \pm 0.3 42 AKIBA 85 SPEC P(μ) <231.5 MeV/ c 1.5 \pm 0.8 41,43 DEMIDOV 90 XEBC E(γ) > 20 MeV 1.5 \pm 0.5 57 44 BARMIN 88 HLBC + E(γ) > 20 MeV 1.6 \pm 3.5 12 WEISSENBE 74 STRC + E(γ) > 90 MeV 40 P(μ) cut given in DEMIDOV 90 paper, 235.1 MeV/ c , is a misprint according to authors (private communication). 41 DEMIDOV 90 quotes only inner bremsstrahlung (IB) part. 42 Assumes μ - e universality and uses constraints from $K \rightarrow e\nu\gamma$. 43 Not independent of above DEMIDOV 90 value. Cuts differ.	is $[\Gamma(K \to e\pi^0 \nu) + \Gamma(K \to \pi^+\pi^+\pi^-)]$. For comparison with other experiments used $\Gamma(K \to e\pi^0 \nu)/\Gamma_{all} = 0.0482$ to calculate the values quoted here. 48 $\cos\theta(e\gamma)$ between 0.6 and 0.9. 49 Both ROMANO 71 values are for $\cos\theta(e\gamma)$ between 0.6 and 0.9. Second value is a comparison with second LJUNG 73 value. We use lowest $E(\gamma)$ cut for Summary Tal value. See ROMANO 71 for E_γ dependence. 50 First LJUNG 73 value is for $\cos\theta(e\gamma) < 0.9$, second value is for $\cos\theta(e\gamma)$ between 0 and 0.9 for comparison with ROMANO 71. $\Gamma(\pi^0 e^+\nu_e\gamma(SD))/\Gamma_{total}$ Structure-dependent part. $\frac{VALUE (units 10^{-5})}{\sqrt{5}} \frac{CL\%}{\sqrt{5}} \frac{DOCUMENT ID}{\sqrt{5}} \frac{TECN}{\sqrt{5}} \frac{CHG}{\sqrt{5}}$ $\sqrt{5}.3 \frac{DOCUMENT ID}{\sqrt{5}} \frac{TECN}{\sqrt{5}} \frac{CHG}{\sqrt{5}}$ $\sqrt{5}.3 \frac{DOCUMENT ID}{\sqrt{5}} \frac{TECN}{\sqrt{5}} \frac{CHG}{\sqrt{5}} \frac{COMMENT}{\sqrt{5}}$ $\sqrt{5}.3 \frac{DOCUMENT ID}{\sqrt{5}} \frac{TECN}{\sqrt{5}} \frac{CHG}{\sqrt{5}} \frac{CHG}{\sqrt{5}} \frac{TECN}{\sqrt{5}} \frac{CHG}{\sqrt{5}} \frac{TECN}{\sqrt{5}} \frac{CHG}{\sqrt{5}} \frac{TECN}{\sqrt{5}} \frac{CHG}{\sqrt{5}} \frac{TECN}{\sqrt{5}} \frac{CHG}{\sqrt{5}} \frac{TECN}{\sqrt{5}} \frac{TECN}{\sqrt{5}} \frac$
ALUE (units 10^{-3}) EVTS DOCUMENT ID TECN CHG COMMENT 1.50 \pm 0.28 OUR AVERAGE 1.6 \pm 1.5 40,41 DEMIDOV 90 XEBC P(μ) <231.5 MeV/ c 1.0 \pm 0.9 BARMIN 88 HLBC + P(μ) <231.5 MeV/ c 1.4 \pm 0.3 42 AKIBA 85 SPEC P(μ) <231.5 MeV/ c 1.5 \pm 0.8 41,43 DEMIDOV 90 XEBC E(γ) > 20 MeV 1.5 \pm 0.5 57 44 BARMIN 88 HLBC + E(γ) > 20 MeV 1.6 \pm 3.5 12 WEISSENBE 74 STRC + E(γ) > 90 MeV 40 P(μ) cut given in DEMIDOV 90 paper, 235.1 MeV/ c , is a misprint according to authors (private communication). 41 DEMIDOV 90 quotes only inner bremsstrahlung (IB) part. 42 Assumes μ - e universality and uses constraints from $K \rightarrow e\nu\gamma$. 43 Not independent of above DEMIDOV 90 value. Cuts differ.	is $[\Gamma(K \to e\pi^0 \nu) + \Gamma(K \to \pi^+\pi^+\pi^-)]$. For comparison with other experiments used $\Gamma(K \to e\pi^0 \nu)/\Gamma_{all} = 0.0482$ to calculate the values quoted here. 48 $\cos\theta(e\gamma)$ between 0.6 and 0.9. 49 Both ROMANO 71 values are for $\cos\theta(e\gamma)$ between 0.6 and 0.9. Second value is a comparison with second LJUNG 73 value. We use lowest $E(\gamma)$ cut for Summary Tal value. See ROMANO 71 for E_γ dependence. 50 First LJUNG 73 value is for $\cos\theta(e\gamma) < 0.9$, second value is for $\cos\theta(e\gamma)$ between 0 and 0.9 for comparison with ROMANO 71. $\Gamma(\pi^0 e^+ \nu_e \gamma (SD))/\Gamma_{total}$ Structure-dependent part. $\frac{VALUE (units 10^{-5})}{\sqrt{5.3}} \frac{CL\%}{90} \frac{DOCUMENT ID}{BOLOTOV} \frac{TECN}{86B} \frac{CHG}{CALO} - \frac{COMMENT}{\sqrt{5.3}}$ $\frac{VALUE (units 10^{-6})}{\sqrt{5.3}} \frac{CL\%}{90} \frac{EVTS}{DOCUMENT ID} \frac{TECN}{\sqrt{5.3}} \frac{CHG}{\sqrt{5.3}} \frac{COMMENT}{\sqrt{5.3}}$ $\frac{VALUE (units 10^{-6})}{\sqrt{5.3}} \frac{CL\%}{\sqrt{5.3}} \frac{EVTS}{\sqrt{5.3}} \frac{DOCUMENT ID}{\sqrt{5.3}} \frac{TECN}{\sqrt{5.3}} \frac{COMMENT}{\sqrt{5.3}} = \frac{COMMENT}{$
ALUE (units 10^{-3}) EVTS DOCUMENT ID TECN CHG COMMENT 1.50 \pm 0.28 OUR AVERAGE 1.6 \pm 1.5 40,41 DEMIDOV 90 XEBC P(μ) <231.5 MeV/ c 1.0 \pm 0.9 BARMIN 88 HLBC + P(μ) <231.5 MeV/ c 1.4 \pm 0.3 42 AKIBA 85 SPEC P(μ) <231.5 MeV/ c 1.5 \pm 0.8 41,43 DEMIDOV 90 XEBC E(γ) > 20 MeV 1.5 \pm 0.5 57 44 BARMIN 88 HLBC + E(γ) > 20 MeV 1.6 \pm 3.5 12 WEISSENBE 74 STRC + E(γ) > 90 MeV 40 P(μ) cut given in DEMIDOV 90 paper, 235.1 MeV/ c , is a misprint according to authors (private communication). 41 DEMIDOV 90 quotes only inner bremsstrahlung (IB) part. 42 Assumes μ - e universality and uses constraints from $K \rightarrow e\nu\gamma$. 43 Not independent of above DEMIDOV 90 value. Cuts differ.	is $[\Gamma(K \to e\pi^0 \nu) + \Gamma(K \to \pi^+\pi^+\pi^-)]$. For comparison with other experiments used $\Gamma(K \to e\pi^0 \nu)/\Gamma_{all} = 0.0482$ to calculate the values quoted here. 48 $\cos\theta(e\gamma)$ between 0.6 and 0.9. 49 Both ROMANO 71 values are for $\cos\theta(e\gamma)$ between 0.6 and 0.9. Second value is a comparison with second LJUNG 73 value. We use lowest $E(\gamma)$ cut for Summary Tal value. See ROMANO 71 for E_γ dependence. 50 First LJUNG 73 value is for $\cos\theta(e\gamma) < 0.9$, second value is for $\cos\theta(e\gamma)$ between 0 and 0.9 for comparison with ROMANO 71. $\Gamma(\pi^0 e^+\nu_e\gamma(SD))/\Gamma_{total}$ Structure-dependent part. $\frac{VALUE (units 10^{-5})}{\sqrt{5}} \frac{CL\%}{\sqrt{5}} \frac{DOCUMENT ID}{\sqrt{5}} \frac{TECN}{\sqrt{5}} \frac{CHG}{\sqrt{5}}$ $\sqrt{5}.3 \frac{DOCUMENT ID}{\sqrt{5}} \frac{TECN}{\sqrt{5}} \frac{CHG}{\sqrt{5}}$ $\sqrt{5}.3 \frac{DOCUMENT ID}{\sqrt{5}} \frac{TECN}{\sqrt{5}} \frac{CHG}{\sqrt{5}} \frac{COMMENT}{\sqrt{5}}$ $\sqrt{5}.3 \frac{DOCUMENT ID}{\sqrt{5}} \frac{TECN}{\sqrt{5}} \frac{CHG}{\sqrt{5}} \frac{CHG}{\sqrt{5}} \frac{TECN}{\sqrt{5}} \frac{CHG}{\sqrt{5}} \frac{TECN}{\sqrt{5}} \frac{CHG}{\sqrt{5}} \frac{TECN}{\sqrt{5}} \frac{CHG}{\sqrt{5}} \frac{TECN}{\sqrt{5}} \frac{CHG}{\sqrt{5}} \frac{TECN}{\sqrt{5}} \frac{TECN}{\sqrt{5}} \frac$
VALUE (units 10 ⁻³) EVTS DOCUMENT ID TECN CHG COMMENT 5.80 ± 0.28 OUR AVERAGE 40,41 DEMIDOV 90 XEBC P(μ) <231.5 MeV/c	is $[\Gamma(K \to e\pi^0 \nu) + \Gamma(K \to \pi^+\pi^+\pi^-)]$. For comparison with other experiments used $\Gamma(K \to e\pi^0 \nu)/\Gamma_{all} = 0.0482$ to calculate the values quoted here. 48 $\cos\theta(e\gamma)$ between 0.6 and 0.9. 49 Both ROMANO 71 values are for $\cos\theta(e\gamma)$ between 0.6 and 0.9. Second value is a comparison with second LJUNG 73 value. We use lowest $E(\gamma)$ cut for Summary Tal value. See ROMANO 71 for E_γ dependence. 50 First LJUNG 73 value is for $\cos\theta(e\gamma) < 0.9$, second value is for $\cos\theta(e\gamma)$ between 0 and 0.9 for comparison with ROMANO 71. $\Gamma(\pi^0 e^+ \nu_e \gamma (SD))/\Gamma_{total}$ Structure-dependent part. $\frac{VALUE (units 10^{-5})}{\sqrt{5.3}} \frac{CL\%}{90} \frac{DOCUMENT ID}{BOLOTOV} \frac{TECN}{86B} \frac{CHG}{CALO} - \frac{COMMENT}{\sqrt{5.3}}$ $\frac{VALUE (units 10^{-6})}{\sqrt{5.3}} \frac{CL\%}{90} \frac{EVTS}{DOCUMENT ID} \frac{TECN}{\sqrt{5.3}} \frac{CHG}{\sqrt{5.3}} \frac{COMMENT}{\sqrt{5.3}}$ $\frac{VALUE (units 10^{-6})}{\sqrt{5.3}} \frac{CL\%}{\sqrt{5.3}} \frac{EVTS}{\sqrt{5.3}} \frac{DOCUMENT ID}{\sqrt{5.3}} \frac{TECN}{\sqrt{5.3}} \frac{COMMENT}{\sqrt{5.3}} = \frac{COMMENT}{$

Κ±

```
\Gamma(\pi^+\pi^+e^-\overline{\nu}_e)/\Gamma(\pi^+\pi^-e^+\nu_e)
                                                                                                           \Gamma(\pi^+\mu^+e^-)/\Gamma_{\text{total}}
                                                                                                                                                                                                   Γ<sub>35</sub>/Γ
                                                                                      \Gamma_{28}/\Gamma_{9}
      Test of \Delta S = \Delta Q rule.
                                                                                                                  Test of lepton family number conservation.
                                                                                                           VALUE (units 10<sup>-10</sup>) CL% EVTS
VALUE (units 10-4) CL% EVTS
                                       DOCUMENT ID
                                                                                                                                                  DOCUMENT ID
                                                                                                                                                                     TECN CHG COMMENT
                                  51 BLOCH
                                                      76 SPEC
                                                                                                                                                                  90 SPEC +
                   90
                                                                                                                              90
                                                                                                                                      0
                                                                                                                                                  LEE
• • • We do not use the following data for averages, fits, limits, etc. • • •
                                                                                                           CAMPAGNARI 88 SPEC + In LEE 90
<130. 95 0 BOURQUIN 71 ASPK
                                                                                                            <11
                                                                                                                              90
                                                                                                                                        ٥
                                                                                                                                                  DIAMANT-... 76 SPEC +
                                                                                                                                         0
                                                                                                            <48
<sup>51</sup> BLOCH 76 quotes 3.6 \times 10^{-4} at CL = 95%, we convert.
\Gamma(\pi^+\pi^+\mu^-\overline{\nu}_{\mu})/\Gamma_{\text{total}}
Test of \Delta S = \Delta Q rule.
                                                                                                           \Gamma(\pi^+\mu^-e^+)/\Gamma_{\text{total}}
                                                                                                                                                                                                   \Gamma_{36}/\Gamma
                                                                                        \Gamma_{29}/\Gamma
                                                                                                                  Test of lepton family number conservation.
                                                                                                           VALUE (units 10-6) CL% EVTS
                                       DOCUMENT ID
                                                           TECN CHG
                                                       65 FBC +
<3.0
                                       BIRGE
                                                                                                             \Gamma(\pi^+e^+e^-)/\Gamma_{\text{total}} \qquad \qquad \Gamma_{30}/\Gamma \\ \text{Test for } \Delta S = 1 \text{ weak neutral current. Allowed by combined first-order weak and } 
                                                                                                                                              ^{60} BEIER 72 OSPK \pm
                                                                                                            <28 90
                                                                                                            <sup>60</sup> Measurement actually applies to the sum of the \pi^+\mu^-e^+ and \pi^-\mu^+e^+ modes.
      electromagnetic interactions.
VALUE (units 10<sup>-7</sup>)
                       CL% EVTS
                                            DOCUMENT ID TECN CHG COMMENT
                                                                                                           \Gamma(\pi^-\mu^+e^+)/\Gamma_{\text{total}}
                                                                                                                                                                                                   \Gamma_{37}/\Gamma
     2.74±0.23 OUR AVERAGE
                                                                                                                  Test of total lepton number conservation.
                                        <sup>52</sup> ALLIEGRO
                                                            92 SPEC +
     2.75 \pm 0.23 \pm 0.13
                                500
                                                                                                           VALUE (units 10<sup>-9</sup>) CL% EVTS
                                                                                                                                                  DOCUMENT ID TECN CHG
                                        <sup>53</sup> BLOCH
                                                            75 SPEC +
                                                                                                                                      0 61 DIAMANT-... 76 SPEC +
    2.7 ±0.5
                                 41
                                                                                                                              90
ullet ullet We do not use the following data for averages, fits, limits, etc. ullet ullet

    ● • We do not use the following data for averages, fits, limits, etc.

                        90
                                           CENCE
                                                            74 ASPK +
                                                                                Three track
                                                                                                                                              61 BEIER
                                                                                                                           90
                                                                                                            <28
                                                                                                                                                                  72 OSPK ±
                                                                                evts
Two track
                                                            74 ASPK +
< 2.7
                         90
                                            CENCE
                                                                                                            61 Measurement actually applies to the sum of the \pi^+\mu^-e^+ and \pi^-\mu^+e^+ modes.
<320
                         90
                                            BEIER
                                                            72 OSPK ±
                                                                                                           \Gamma(\pi^+\mu^-e^+)/\Gamma_{\text{total}}
                                                                                                                                                                                                   \Gamma_{36}/\Gamma
                                                            67 DBC
< 44
                         90
                                            BISI
< 8.8
                         90
                                            CLINE
                                                            67B FBC
                                                                                                           VALUE (units 10<sup>--8</sup>)
                                                                                                                                   CL%
                                                                                                                                                 DOCUMENT ID TECN CHG
                                           CAMERINI
                                                           64 FBC
< 24.5
                         90
                                  1
                                                                                                           ^{52} ALLIEGRO 92 assumes a vector interaction with a form factor given by \lambda = 0.105 \pm ·
                                                                                                                                                 BEIER
                                                                                                            <1.4
                                                                                                                                      90
 0.035\pm0.015 and a correlation coefficient of -0.82.\, 53 BLOCH 75 assumes a vector interaction.
                                                                                                           \Gamma(\pi^-e^+e^+)/\Gamma_{\text{total}}
                                                                                                                                                                                                   \Gamma_{38}/\Gamma
                                                                                                                  Test of total lepton number conservation.
\Gamma(\pi^+\mu^+\mu^-)/\Gamma_{\text{total}}
                                                                                        \Gamma_{31}/\Gamma
                                                                                                            VALUE (units 10-5)
                                                                                                                                                  DOCUMENT ID
                                                                                                                                                                    TECN CHG
       Test for \Delta S=1 weak neutral current. Allowed by higher-order electroweak interac-
                                                                                                           tions.
VALUE (units 10<sup>-8</sup>)
                                      DOCUMENT ID
                                                           TECN CHG
                         CL%
                                                                                                                                                  CHANG
                                                                                                                                                                  68 HBC --
                                   54 ADLER
    5.0+0.4+0.9
                                                       97c B787
                                                                                                            \Gamma(\pi^-e^+e^+)/\Gamma(\pi^+\pi^-e^+\nu_e)  Test of total lepton number conservation.
\Gamma_{38}/\Gamma_{9}
                                       ATIYA
                                                       89 B787
< 23
                           90

        VALUE (units 10<sup>-4</sup>)
        CL%
        EVTS
        DOCUMENT ID
        TECN
        CH

        <2.5</td>
        90
        0
        62 DIAMANT-...
        76 SPEC
        +

                                       BISI
                                                        67 DBC
                                                                                                                                                                      TECN CHG
                                       CAMERINI 65 FBC
 <300
                           90
 ^{54} ADLER 97c gives systematic error 0.7 \times 10^{-8} and theoretical uncertainty 0.6 \times 10^{-8}, which we combine in quadrature to obtain our second error.
                                                                                                             62 DIAMANT-BERGER 76 quotes this result times our 1975 BR ratio.
                                                                                                           \Gamma(\pi^-\mu^+\mu^+)/\Gamma_{\text{total}}
Forbidden by total lepton number conservation.
                                                                                                                                                                                                   \Gamma_{39}/\Gamma
\Gamma(\pi^+\nu\overline{\nu})/\Gamma_{\text{total}}
                                                                                        Γ<sub>32</sub>/Γ

        VALUE (units 10<sup>-4</sup>)
        CL%
        DOCUMENT ID
        TECN

        <1.B</td>
        90
        63 LITTENBERG
        92
        HBC

       Test for \Delta S = 1 weak neutral current. Allowed by higher-order electroweak interac-
                                                                                                                                                                      TECN
      tions
VALUE (units 10-9) CL% EVTS
                                       DOCUMENT ID
                                                         TECN CHG COMMENT
                                                                                                             63 LITTENBERG 92 is from retroactive data analysis of CHANG 68 bubble chamber data.
       0.42^{+0.97}_{-0.35}
                                       ADLER
                                                       97 B787
                                                                                                            \Gamma(\mu^+\overline{\nu}_e)/\Gamma_{\text{total}}
• • • We do not use the following data for averages, fits, limits, etc. • • •
                                                                                                                 Forbidden by total lepton number conservation.
                                                                                                           ADLER
                                                        96 B787
                    90
 <
       7.5
                    90
                                       ATIYA
                                                        93 B787
                                                                            7(π) 115-127
MeV
                                    55 ATIYA
                                                       93 B787
                                                                                                             ^{64} COOPER 82 limit on \overline{\nu}_e observation is here interpreted as a limit on lepton number violation in the absence of mixing.
 <
       5.2
                    90
                                                        938 B787
                                                                            T(π) 60-100 MeV
      17
                    90
                                       ATIYA
                                       ATIYA
                                                        90 B787
                    90
                                                                                                           Γ(π<sup>0</sup> e<sup>+</sup>ν̄<sub>e</sub>)/Γ<sub>total</sub>
Forbidden by total lepton number conservation.
                                                        818 CNTR +
                                                                            T(\pi) 116-127
MeV
T(\pi) 60-105 MeV
                                                                                                                                                                                                   \Gamma_{41}/\Gamma
 < 140
                    90
                                       ASANO
                                    <sup>56</sup> CABLE
                                                        73 CNTR +
 <
    940
                    90
                                                                                                                                  <u>cl%</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u>
90 <sup>65</sup> COOPER 82 HLBC Wideband \nu beam
                                                                                                            VALUE
                                    56 CABLE
                                                       73 CNTR +
                                                                            T(π) 60-127 MeV
    560
                    90
                                                                                                            < 0.003
                                                                                                                                90
                                    57 LJUNG
 <57000
                                                        73 HLBC +
                                                                                                             ^{65} COOPER 82 limit on \overline{\nu}_e observation is here interpreted as a limit on lepton number violation in the absence of mixing.
                                    56 KLEMS
                                                        71 OSPK +
 <sup>55</sup> Combining ATIYA 93 and ATIYA 93B results. Superseded by ADLER 96.
                                                                                                                                                                                                   \Gamma_{42}/\Gamma
                                                                                                            \Gamma(\pi^+\gamma)/\Gamma_{\text{total}}
 ^{56} KLEMS 71 and CABLE 73 assume \pi spectrum same as K_{e3} decay. Second CABLE 73 limit combines CABLE 73 and KLEMS 71 data for vector interaction.
                                                                                                                  Violates angular momentum conservation. Not listed in Summary Table.
                                                                                                            VALUE (units 10<sup>-6</sup>) CL% DOCUMENT ID TECN CHG
                                                                                                            • • We do not use the following data for averages, fits, limits, etc. • • •
\Gamma(\mu^-\nu e^+e^+)/\Gamma(\pi^+\pi^-e^+\nu_e)
                                                                                       \Gamma_{33}/\Gamma_{9}
                                                                                                                                                   ASANO
                                                                                                            <1.4
                                                                                                                                      90
                                                                                                                                                                   82 CNTR +
       Test of lepton family number conservation.
                                                                                                                                               66 KLEMS
                                                                                                             <4.0
                                                                                                                                      90
                                                                                                                                                                   71 OSPK +
DOCUMENT ID TECN CHG
                                                                                                             66 Test of model of Selleri, Nuovo Cimento 60A 291 (1969).
 ^{58} DIAMANT-BERGER 76 quotes this result times our 1975 \pi^+\pi^-\,e\nu BR ratio.
\Gamma(\mu^+\nu_e)/\Gamma_{	ext{total}} Forbidden by lepton family number conservation.
                  <u>CL% EVTS</u> <u>DOCUMEN</u>
90 0 <sup>59</sup> LYONS
VALUE
                                      DOCUMENT ID TECN CHG COMMENT
                                                       81 HLBC 0 200 GeV K+ nar-
```

beam

• • We do not use the following data for averages, fits, limits, etc. • • •

 59 COOPER 82 and LYONS 81 limits on $\nu_{\rm e}$ observation are here interpreted as limits on lepton family number violation in the absence of mixing.

<0.012 90

⁵⁹ COOPER 82 HLBC Wideband ν beam

K^+ LONGITUDINAL POLARIZATION OF EMITTED μ^+

VALUE	\1	DOCUMENT 10		1ECN	<u>unu</u>	COMMENT
<-0.990	90	67 AOKI	94	SPEC	+	
• • • We do not use	the follow	ng data for average	s, fit	s, limits,	etc. •	• •
<-0.990	90	IMAZATO	92	SPEC	+	Repl. by AOKI 94
-0.970 ± 0.047		68 YAMANAKA	86	SPEC	+	
-1.0 ± 0.1		68 CUTTS	69	SPRK	+	
-0.96 ± 0.12		68 COOMBES	57	CNTR	+	

 67 AOKI 94 measures $\ell P_{\mu} = -0.9996 \pm 0.0030 \pm 0.0048$. The above limit is obtained by summing the statistical and systematic errors in quadrature, normalizing to the physically significant region $(|\xi P_{\mu}|<1)$ and assuming that $\xi{=}1$, its maximum value.

DALITZ PLOT PARAMETERS FOR $K \rightarrow 3\pi$ DECAYS

Revised 1994 by T.G. Trippe (LBNL).

The Dalitz plot distribution for $K^{\pm} \rightarrow \pi^{\pm}\pi^{\pm}\pi^{\mp}$, $K^{\pm} \rightarrow$ $\pi^0\pi^0\pi^{\pm}$, and $K_L^0\to\pi^+\pi^-\pi^0$ can be parameterized by a series expansion such as that introduced by Weinberg [1]. We use the form

$$\left| M \right|^2 \propto 1 + g \frac{(s_3 - s_0)}{a m_{\pi^+}^2} + h \left[\frac{s_3 - s_0}{m_{\pi^+}^2} \right]^2 + j \frac{(s_2 - s_1)}{m_{\pi^+}^2} + k \left[\frac{s_2 - s_1}{m_{\pi^+}^2} \right]^2 + \cdots , \tag{1}$$

where $m_{\pi^+}^2$ has been introduced to make the coefficients g, h, j, and k dimensionless, and

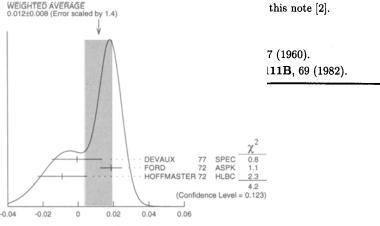
$$s_i = (P_K - P_i)^2 = (m_K - m_i)^2 - 2m_K T_i , i = 1, 2, 3,$$

$$s_0 = \frac{1}{3} \sum_i s_i = \frac{1}{3} (m_K^2 + m_1^2 + m_2^2 + m_3^2)$$

Here the P_i are four-vectors, m_i and T_i are the mass and kinetic energy of the i^{th} pion, and the index 3 is used for the odd pion.

The coefficient g is a measure of the slope in the variable s_3 (or T_3) of the Dalitz plot, while h and k measure the quadratic dependence on s_3 and $(s_2 - s_1)$, respectively. The coefficient jis related to the asymmetry of the plot and must be zero if CPinvariance holds. Note also that if CP is good, g, h, and k must be the same for $K^+ \to \pi^+ \pi^+ \pi^-$ as for $K^- \to \pi^- \pi^- \pi^+$.

Since different experiments use different forms for $|M|^2$, in order to compare the experiments we have converted to g, h, j, and k whatever coefficients have been measured. Where such conversions have been done, the measured coefficient a_y , a_t , a_u , or a_{ν} is given in the comment at the right. For definitions of these coefficients, details of this conversion, and discussion of



ENERGY DEPENDENCE OF K* DALITZ PLOT

|matrix element|² = 1 +
$$gu + hu^2 + kv^2$$

where $u = (s_3 - s_0) / m_{\pi}^2$ and $v = (s_1 - s_2) / m_{\pi}^2$

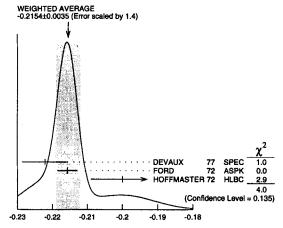
LINEAR COEFFICIENT g_{y+} **FOR** $K^+ \to \pi^+ \pi^+ \pi^-$ Some experiments use Dalltz variables x and y. In the comments we give $a_y =$ coefficient of y term. See note above on "Dalltz Plot Parameters for $K \to 3\pi$ Decays." For discussion of the conversion of a_y to g, see the earlier version of the same note in the Review published in Physics Letters 111B 70 (1982).

VALUE	<u>EVTS</u>	DOCUMENT ID		TECN	CHG	COMMENT
-0.2154±0.0035 OU	RAVERAGE	Error includes s below.	cale	factor o	f 1.4.	See the ideogram
-0.2221 ± 0.0065	225k	DEVAUX	77	SPEC	+	$a_V = .2814 \pm .0082$
-0.2157 ± 0.0028	750k	FORD	72	ASPK	+	$a_V = .2734 \pm .0035$
-0.200 ± 0.009	39819 6	⁹ HOFFMASTEI	R72	HLBC	+	•
• • • We do not use	the following	data for average	s, fit	s, ilmits,	etc.	• • •
-0.196 ± 0.012		[©] GRAUMAN				$a_V = 0.228 \pm 0.030$
-0.218 ± 0.016	9994 7	¹ BUTLER	68	HBC	+	$a_V = 0.277 \pm 0.020$
-0.22 ± 0.024				HBC		$a_{y}=0.28\pm0.03$
6940554457507		ALIBAANI 70 J-4-				•

69 HOFFMASTER 72 Includes GRAUMAN 70 data.
70 Emulsion data added — all events included by HOFFMASTER 72.

71 Experiments with large errors not included in average.

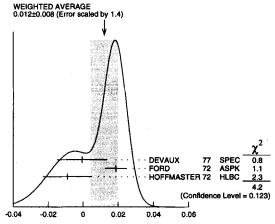
72 Also includes DBC events.



Linear energy dependence for K^+

QUADRATIC COEFFICIENT h FOR K+

VALUE	EVTS	DOCUMENT ID	TECN_	<u>CHG</u>	
0.012 ±0.008	OUR AVERAGE	Error Includes sca below.	le factor o	f 1.4. See the ide	ogram:
-0.0006 ± 0.0143	225k	DEVAUX 7	7 SPEC	+	
0.0187 ± 0.0062	750k	FORD 7	2 ASPK	+	
-0.009 ± 0.014	39819	HOFFMASTER7	2 HLBC	+	

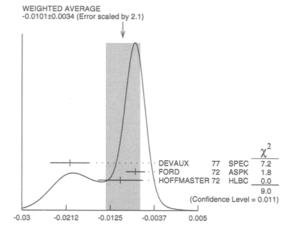


Quadratic coefficient h for $K^+ \rightarrow$

⁶⁸ Assumes $\xi=1$.

QUADRATIC COEFFICIENT k FOR $K^+ \rightarrow \pi^+\pi^+\pi^-$

<u>EVTS</u> AVERAGE DOCUMENT ID Error includes scale factor of 2.1. See the ideogram -0.0205 ± 0.0039 225k **DEVAUX** SPEC + -0.0075 ± 0.0019 FORD ASPK 750k -0.0105 ± 0.0045 39819 HOFFMASTER72 HLBC +



Quadratic coefficient k for $K^+ \rightarrow \pi^+ \pi^+ \pi^-$

LINEAR COEFFICIENT \mathbf{g}_{x} FOR $K^{-} \to \pi^{-}\pi^{-}\pi^{+}$ Some experiments use Dalitz variables x and y. In the comments we give $a_{y} = \frac{1}{2} \left(\frac{1}{2} \left$ coefficient of v term. See note above on "Dalitz Plot Parameters for K -> Decays." For discussion of the conversion of a_v to g, see the earlier version of the same note in the Review published in Physics Letters 111B 70 (1982).

		pas					
							COMMENT
-0.217	±0.007 C	UR AVERAGE	Error includes se	cale	factor o	f 2.5.	
-0.2186	±0.0028	750k	FORD	72	ASPK	-	$a_V = .2770 \pm .0035$
-0.193	± 0.010	50919	MAST	69	HBC	_	$a_V = 0.244 \pm 0.013$
• • • V	Ve do not u	se the following	data for averages	, fit:	s, limits,	etc. •	•••
-0.199	±0.008		⁷³ LUCAS			-	$a_V = 0.252 \pm 0.011$
-0.190	± 0.023	5778 ^{74,7}	⁷⁵ MOSCOSO	68	HBC	-	$a_{y} = 0.242 \pm 0.029$
-0.220	±0.035	1347	⁷⁶ FERRO-LUZZI	61	нвс		$a_y = 0.28 \pm 0.045$
~~			-				•

 $^{^{73}}$ Quadratic dependence is required by κ_I^0 experiments. For comparison we average only those K^{\pm} experiments which quote quadratic fit values.

QUADRATIC COEFFICIENT h FOR $K^- \rightarrow \pi^-\pi^-\pi^+$ VALUE EVTS DOCUMENT ID

0.010 ±0.006	OUR AVERAGE				
0.0125 ± 0.0062	750k	FORD	72	ASPK	_
-0.001 ±0.012	50919	MAST	69	HBC	-

QUADRATIC COEFFICIENT k FOR $K^- \rightarrow \pi$

~0.0084±0.0019 Ol	JR AVERAGE	:			
-0.0083 ± 0.0019	750k	FORD	72	ASPK	_
~0.014 ±0.012	50919	MAST	69	HBC	_

$$(\mathbf{g}_{\tau^+} - \mathbf{g}_{\tau^-}) / (\mathbf{g}_{\tau^+} + \mathbf{g}_{\tau^-})$$
 FOR $K^{\pm} \to \pi^{\pm} \pi^{+} \pi^{-}$
A nonzero value for this quantity indicates CP violation.

71	Turue ioi timo	quantity mateures		
VALUE (%)	EVTŞ	DOCUMENT	D	TECN
-0.70±0.53	3.2M	FORD	70	ASPK

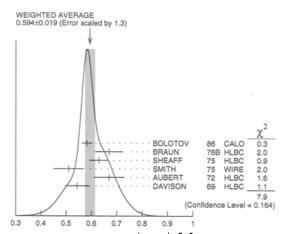
LINEAR COEFFICIENT g FOR $K^{\pm} \rightarrow \pi^{\pm}\pi^{0}\pi^{0}$

Unless otherwise stated, all experiments include terms quadratic in (s_3-s_0) / $m_{\pi^+}^2$. See mini-review above.

COMMENT
COMMENT
the ideogram below.
•
Also emulsion
• • •
Dalitz pairs only
Also HBC

⁷⁷ Experiments with large errors not included in average.

78 Authors give linear fit only.



Linear energy dependence for $K^\pm \to \ \pi^\pm \pi^0 \, \pi^0$

QUADRATIC COEFFICIENT h FOR $K^{\pm} \rightarrow \pi^{\pm}\pi^{0}\pi^{0}$

See mini-revie	w above.					
VALUE	EVTS	DOCUMENT ID		<u>TECN</u>	CHG	COMMENT
0.035±0.015 OUF	RAVERAGE					
0.037 ± 0.024	43k	BOLOTOV	86	CALO	_	
0.152 ± 0.082	3263	BRAUN	76B	HLBC	+	
0.041 ± 0.030	5635	SHEAFF	75	HLBC	+	
0.009 ± 0.040	27k	SMITH	75	WIRE	+	
-0.01 ± 0.08	1365	AUBERT	72	HLBC	+	
0.026 ± 0.050	4048	DAVISON	69	HLBC	+	Also emuision
• • • We do not us	e the following	ig data for average	s, fits	i, limits,	etc. e	• •
0.164 ± 0.121	4639	79 BERTRAND	76	EMUL	+	
0.018 ± 0.124	198	⁷⁹ PANDOULAS	70	EMUL	+	
⁷⁹ Experiments with	h large errors	not included in ave	erage			

$K_{\ell 3}^{\pm}$ AND $K_{\ell 3}^{0}$ FORM FACTORS

Written by T.G. Trippe (LBNL).

Assuming that only the vector current contributes to $K \rightarrow$ $\pi \ell \nu$ decays, we write the matrix element as

$$M \propto f_{+}(t) \left[(P_K + P_{\pi})_{\mu} \bar{\ell} \gamma_{\mu} (1 + \gamma_5) \nu \right]$$

+ $f_{-}(t) \left[m_{\ell} \bar{\ell} (1 + \gamma_5) \nu \right] ,$ (1)

where P_K and P_{π} are the four-momenta of the K and π mesons, m_{ℓ} is the lepton mass, and f_{+} and f_{-} are dimensionless form factors which can depend only on $t = (P_K - P_\pi)^2$, the square of the four-momentum transfer to the leptons. If time-reversal invariance holds, f_+ and f_- are relatively real. $K_{\mu3}$ experiments measure f_+ and f_- , while K_{e3} experiments are sensitive only to f_+ because the small electron mass makes the f_- term

(a) $K_{\mu 3}$ experiments. Analyses of $K_{\mu 3}$ data frequently assume a linear dependence of f_+ and f_- on t, i.e.,

$$f_{\pm}(t) = f_{\pm}(0) \left[1 + \lambda_{\pm}(t/m_{\pi}^2) \right]$$
 (2)

Most $K_{\mu3}$ data are adequately described by Eq. (2) for f_+ and a constant f_{-} (i.e., $\lambda_{-}=0$). There are two equivalent parametrizations commonly used in these analyses:

(1) $\lambda_+, \xi(0)$ parametrization. Analyses of $K_{\mu 3}$ data often introduce the ratio of the two form factors

$$\xi(t) = f_{-}(t)/f_{+}(t)$$
.

⁷⁴ Experiments with large errors not included in average.

 ⁷⁵ Also includes DBC events.
 76 No radiative corrections included.

The $K_{\mu3}$ decay distribution is then described by the two parameters λ_+ and $\xi(0)$ (assuming time reversal invariance and $\lambda_-=0$). These parameters can be determined by three different methods:

Method A. By studying the Dalitz plot or the pion spectrum of $K_{\mu 3}$ decay. The Dalitz plot density is (see, e.g., Chounet et al. [1]):

$$\rho(E_{\pi}, E_{\mu}) \propto f_{+}^{2}(t) \left[A + B\xi(t) + C\xi(t)^{2} \right]$$

where

See key on page 213

$$egin{align} A &= m_K \left(2 E_\mu E_
u - m_K E_\pi'
ight) + m_\mu^2 \left(rac{1}{4} E_\pi' - E_
u
ight) \;, \ \ B &= m_\mu^2 \left(E_
u - rac{1}{2} E_\pi'
ight) \;, \ \ C &= rac{1}{4} m_\mu^2 E_\pi' \;, \ E_\pi' &= E_\pi^{
m max} - E_\pi = \left(m_K^2 + m_\pi^2 - m_
u^2
ight) / 2 m_K - E_\pi \;. \end{split}$$

Here E_{π} , E_{μ} , and E_{ν} are, respectively, the pion, muon, and neutrino energies in the kaon center of mass. The density ρ is fit to the data to determine the values of λ_{+} , $\xi(0)$, and their correlation.

Method B. By measuring the $K_{\mu3}/K_{e3}$ branching ratio and comparing it with the theoretical ratio (see, e.g., Fearing et al. [2]) as given in terms of λ_+ and $\xi(0)$, assuming μ -e universality:

$$\begin{split} \Gamma(K_{\mu 3}^{\pm})/\Gamma(K_{e 3}^{\pm}) &= 0.6457 + 1.4115\lambda_{+} + 0.1264\xi(0) \\ &+ 0.0192\xi(0)^{2} + 0.0080\lambda_{+}\xi(0) \; , \\ \Gamma(K_{\mu 3}^{0})/\Gamma(K_{e 3}^{0}) &= 0.6452 + 1.3162\lambda_{+} + 0.1264\xi(0) \\ &+ 0.0186\xi(0)^{2} + 0.0064\lambda_{+}\xi(0) \; . \end{split}$$

This cannot determine λ_+ and $\xi(0)$ simultaneously but simply fixes a relationship between them.

Method C. By measuring the muon polarization in $K_{\mu 3}$ decay. In the rest frame of the K, the μ is expected to be polarized in the direction ${\bf A}$ with ${\bf P}={\bf A}/\left|{\bf A}\right|$, where ${\bf A}$ is given (Cabibbo and Maksymowicz [3]) by

$$\begin{split} \mathbf{A} &= a_1(\xi) \mathbf{p}_{\mu} \\ &- a_2(\xi) \left[\frac{\mathbf{p}_{\mu}}{m_{\mu}} \left(m_K - E_{\pi} + \frac{\mathbf{p}_{\pi} \cdot \mathbf{p}_{\mu}}{\left| \mathbf{p}_{\mu} \right|^2} (E_{\mu} - m_{\mu}) \right) + \mathbf{p}_{\pi} \right] \\ &+ m_K \mathrm{Im} \xi(t) (\mathbf{p}_{\pi} \times \mathbf{p}_{\mu}) \ . \end{split}$$

If time-reversal invariance holds, ξ is real, and thus there is no polarization perpendicular to the K-decay plane. Polarization experiments measure the weighted average of $\xi(t)$ over the t range of the experiment, where the weighting accounts for the variation with t of the sensitivity to $\xi(t)$.

(2) λ_+, λ_0 parametrization. Most of the more recent $K_{\mu 3}$ analyses have parameterized in terms of the form factors f_+

and f_0 which are associated with vector and scalar exchange, respectively, to the lepton pair. f_0 is related to f_+ and f_- by

$$f_0(t) = f_+(t) + \left[t/(m_K^2 - m_\pi^2)\right] f_-(t)$$
.

Here $f_0(0)$ must equal $f_+(0)$ unless $f_-(t)$ diverges at t=0. The earlier assumption that f_+ is linear in t and f_- is constant leads to f_0 linear in t:

$$f_0(t) = f_0(0) \left[1 + \lambda_0(t/m_\pi^2) \right]$$
.

With the assumption that $f_0(0) = f_+(0)$, the two parametrizations, $(\lambda_+, \xi(0))$ and (λ_+, λ_0) are equivalent as long as correlation information is retained. (λ_+, λ_0) correlations tend to be less strong than $(\lambda_+, \xi(0))$ correlations.

The experimental results for $\xi(0)$ and its correlation with λ_+ are listed in the K^{\pm} and K_L^0 sections of the Particle Listings in section ξ_A , ξ_B , or ξ_C depending on whether method A, B, or C discussed above was used. The corresponding values of λ_+ are also listed.

Because recent experiments tend to use the (λ_+, λ_0) parametrization, we include a subsection for λ_0 results. Wherever possible we have converted $\xi(0)$ results into λ_0 results and vice versa.

See the 1982 version of this note [4] for additional discussion of the $K^0_{\mu3}$ parameters, correlations, and conversion between parametrizations, and also for a comparison of the experimental results.

(b) K_{e3} experiments. Analysis of K_{e3} data is simpler than that of $K_{\mu 3}$ because the second term of the matrix element assuming a pure vector current [Eq. (1) above] can be neglected. Here f_+ is usually assumed to be linear in t, and the linear coefficient λ_+ of Eq. (2) is determined.

If we remove the assumption of a pure vector current, then the matrix element for the decay, in addition to the terms in Eq. (2), would contain

$$+2m_K f_S \overline{\ell}(1+\gamma_5)\nu$$

$$+(2f_T/m_K)(P_K)_{\lambda}(P_{\pi})_{\mu} \overline{\ell} \sigma_{\lambda\mu}(1+\gamma_5)\nu ,$$

where f_S is the scalar form factor, and f_T is the tensor form factor. In the case of the K_{e3} decays where the f_- term can be neglected, experiments have yielded limits on $|f_S/f_+|$ and $|f_T/f_+|$.

References

- L.M. Chounet, J.M. Gaillard, and M.K. Gaillard, Phys. Reports 4C, 199 (1972).
- H.W. Fearing, E. Fischbach, and J. Smith, Phys. Rev. D2, 542 (1970).
- 3. N. Cabibbo and A. Maksymowicz, Phys. Lett. 9, 352 (1964).
- 4. Particle Data Group, Phys. Lett. 111B, 73 (1982).

K FORM FACTORS

in the form factor comments, the following symbols are used.

 f_{+} and f_{-} are form factors for the vector matrix element.

 f_{S} and f_{T} refer to the scalar and tensor term.

 $f_0 = f_+ + f_- t/(m_K^2 - m_\pi^2).$

 λ_+ , λ_- , and λ_0 are the linear expansion coefficients of f_+ , f_- , and f_0 .

 λ_+ refers to the $K_{\mu 3}^\pm$ value except in the K_{e3}^\pm sections.

 $d\xi(0)/d\lambda_{+}$ is the correlation between $\xi(0)$ and λ_{+} in $K_{\mu 3}^{\pm}$.

 $d\lambda_0/d\lambda_+$ is the correlation between λ_0 and λ_+ in $K_{\mu3}^{\pm}$.

t = momentum transfer to the π in units of m_{π}^2 .

DP = Dalitz plot analysis.

 $PI = \pi$ spectrum analysis.

 $MU = \mu$ spectrum analysis.

POL= μ polarization analysis.

BR = $K_{\mu 3}^{\pm}/K_{e3}^{\pm}$ branching ratio analysis.

E = positron or electron spectrum analysis.

RC = radiative corrections.

λ_{+} (LINEAR ENERGY DEPENDENCE OF f_{+} IN K_{e3}^{\pm} DECAY)

For radiative correction of K_{e3}^{\pm} Dalitz plot, see GINSBERG 67 and BECHERRAWY 70.

VALUE	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
0.0286±0.0022 OUR A	VERAGE				
$0.0284 \pm 0.0027 \pm 0.0026$	0 32k	80 AKIMENKO	91 SPEC		PI, no RC
0.029 ±0.004	62k	81 BOLOTOV	88 SPEC		PI, no RC
0.027 ±0.008		82 BRAUN	738 HLBC	+	DP, no RC
0.029 ±0.011	4017	CHIANG	72 OSPK	+	DP, RC neglig- ble
0.027 ±0.010	2707	STEINER	71 HLBC	+	DP, uses RC
0.045 ±0.015	1458	BOTTERILL	70 OSPK		PI, uses RC
0.08 ±0.04	960	BOTTERILL	68c ASPK	+	e^+ , uses RC
$-0.02 \begin{array}{c} +0.08 \\ -0.12 \end{array}$	90	EISLER	68 HLBC	+	PI, uses RC
$0.045 \begin{array}{l} +0.017 \\ -0.018 \end{array}$	854	BELLOTTI	678 FBC	+	OP, uses RC
+0.016 ±0.016	1393	IMLAY	67 OSPK	+	DP, no RC
$+0.028 \begin{array}{l} +0.013 \\ -0.014 \end{array}$	515	KALMUS	67 FBC	+	e ⁺ , PI, no RC
-0.04 ± 0.05	230	BORREANI	64 HBC	+	e^+ , no RC
-0.010 ±0.029	407	JENSEN	64 XEBC	+	PI, no RC
+0.036 ±0.045	217	BROWN	62B XEBC	+	PI, no RC
• • • We do not use the	following	data for averages,	fits, limits, e	tc. •	• •
0.025 ±0.007		83 BRAUN	74 HLBC	+	$K_{\mu3}/K_{e3}$ vs. t

 $^{^{80}}$ AKIMENKO 91 state that radiative corrections would raise λ_+ by 0.0013.

 $\xi_{\rm A}=f_-/f_+$ (determined from $K_{\mu 3}^\pm$ spectra)

The parameter ξ is redundant with λ_0 below and is not put into the Meson Summary

Table.							
VALUE	$d\xi(0)/d\lambda_{+}$	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
-0.33±0.14 (OUR EVAL	UATION	Error includes scale $d\xi(0)/d\lambda_{\perp} = -$				relation is cussed in note on
			K _{£3} form facto 1982).	rs in 1	.982 ed	lition,	PL 111B (April
-0.27 ± 0.25	- 17	3973	WHITMAN	80 :	SPEC	+	DP
-0.8 ± 0.8	20	490	84 ARNOLD	74	HLBC	+	DP
-0.57 ± 0.24	9	6527	⁸⁵ MERLAN	74	ASPK	+	DP
-0.36±0.40	-19	1897	⁸⁶ BRAUN		HLBC	+	DP
-0.62 ± 0.28	12	4025	87 ANKENBRA	72	ASPK	+	PI
$+0.45\pm0.28$	- 15	3480	⁸⁸ CHIANG	72	OSPK	+	DP
-1.1 ± 0.56	- 29	3240	⁸⁹ HAIDT	71	HLBC	+	DP
-0.5 ± 0.8	- 26	2041	90 KIJEWSKI	69	OSPK	+	PI
+0.72±0.93	-17	444	CALLAHAN	66B	FBC	+	PI
• • • We do	not use the	following	data for averages, f	its, IIn	nits, et	C. • •	•
-0.5 ±0.9	none	78	EISLER	68	HLBC	+	PI, λ ₊ =0
$0.0 \begin{array}{c} +1.1 \\ -0.9 \end{array}$		2648	⁹¹ CALLAHAN	66B	FBC	+	μ , $\lambda_{+}=0$
+0.7 ±0.5		87	GIACOMELLI	64	EMUL	+	MU+BR,λ ₊ ≈0
-0.08 ± 0.7			⁹² JENSEN	64	XEBC	+	DP+BR '
+1.8 ±0.6		76	BROWN	628	XEBC	+	DP+BR, $\lambda_{\perp}=0$

⁸⁴ ARNOLD 74 figure 4 was used to obtain ξ_A and $d\xi(0)/d\lambda_+$.

- ⁸⁸ CHIANG 72 figure 10 was used to obtain $d\xi(0)/d\lambda_+$. Fit had $\lambda_-=\lambda_+$ but would not change for $\lambda_{--} = 0$. L.Pondrom, (private communication 74).
- ⁸⁹ HAIDT 71 table 8 (Dalitz plot analysis) gives $d\xi(0)/d\lambda_+=(-1.1+0.5)/(0.050-0.029)=-29$, error raised from 0.50 to agree with $d\xi(0)=0.20$ for fixed λ_+ .
- 90 KIJEWSKI 69 figure 17 was used to obtain $d\xi(0)/d\lambda_+$ and errors.
- 91 CALLAHAN 66 table 1 (π analysis) gives $d\xi(0)/d\lambda_{+} = (0.72-0.05)/(0-0.04) = -17$, error raised from 0.80 to agree with $d\xi(0) = 0.37$ for fixed λ_{+} . t unknown.
- 92 JENSEN 64 gives $\lambda_+^\mu = \lambda_+^e = -0.020 \pm 0.027$. $d\xi(0)/d\lambda_+$ unknown. Includes SHAK-LEE 64 $\xi_B(K_{\mu 3}/K_{e3})$.

$\xi_B = f_-/f_+$ (determined from $K_{\mu 3}^{\pm}/K_{e 3}^{\pm}$)

The $K_{\mu3}^{\pm}/K_{e3}^{\pm}$ branching ratio fixes a relationship between $\xi(0)$ and λ_+ . We quote the author's $\xi(0)$ and associated λ_+ but do not average because the λ_+ values differ. The fit result and scale factor given below are not obtained from these ξ_B values. Instead they are obtained directly from the fitted $K_{\pm J}^{\pm}/K_{\pm 3}^{\pm}$ ratio $\Gamma(\pi^0\mu^+\nu_{\mu l})/\Gamma(\pi^0e^+\nu_e)$, with the exception of HEINTZE 77. The parameter ξ is redundant with λ_0 below and is not put into the Meson Summary Table.

VALUE	<u>EVTS</u>	DOCUMENT ID	TECN	<u>CHG</u>	COMMENT
-0.33±0.14 OUR	EVALUATION	Error includes s			
		$d\xi(0)/d\lambda_{+}=-$	-14. From	a fit dis	scussed in note on
		K _{f3} form facto	ors in 1982 (dition,	PL 111B (April
		1982).			
-0.12 ± 0.12	55k	93 HEINTZE	77 CNTI	₹ +	$\lambda_{+} = 0.029$
• • • We do not	use the following	g data for average	s, fits, limit	s, etc.	• • •
0.0 ±0.15	5825	CHIANG	72 OSPH	(+	$\lambda_{+} = 0.03$, fig.10
-0.81 ± 0.27		94 HAIDT	71 HLBC	: +	$\lambda_{+} = 0.028$, fig.8
-0.35 ± 0.22		95 BOTTERILL	70 OSPH	+ ۱	$\lambda_{+} = 0.045 \pm 0.015$
$+0.91\pm0.82$		ZELLER	69 ASP	(+	$\lambda_{+} = 0.023$
-0.08 ± 0.15		95 BOTTERILL	68B ASPH	+	$\lambda_{+} = 0.023 \pm 0.008$
-0.60 ± 0.20	1398	94 EICHTEN	68 HLBC	+	See note
$+1.0 \pm 0.6$	986	GARLAND	68 OSPI	(+	$\lambda_{+}=0$
$+0.75\pm0.50$	306	AUERBACH	67 OSPI	(+	$\lambda_{+}=0$
$+0.4 \pm 0.4$	636	CALLAHAN	66B FBC	+	$\lambda_{+}=0$
$+0.6 \pm 0.5$		BISI	658 HBC	+	$\lambda_{+}=0$
$+0.8 \pm 0.6$	500	CUTTS	65 OSPH	(+	$\lambda_{+}=0$
$-0.17^{+0.75}_{-0.99}$		SHAKLEE	64 XEB	+	λ ₊ =0
-0.99					,

 $^{^{93}}$ Calculated by us from λ_0 and λ_+ given below.

 $\xi_C = f_-/f_+$ (determined from μ polarization in $K_{\mu 3}^{\pm}$)

The μ polarization is a measure of $\xi(t)$. No assumptions on λ_{+-} necessary, t (weighted by sensitivity to $\xi(t)$) should be specified. In λ_+ , $\xi(0)$ parametrization this is $\xi(0)$ for $\lambda_{+}=0$. $d\xi/d\lambda=\xi t$. For radiative correction to muon polarization in K_{u3}^{\pm} , see GINSBERG 71. The parameter ξ is redundant with λ_0 below and is not put into the Meson Summary Table.

VALUE	EVTS	DOCUMENT ID				COMMENT
-0.33±0.14 OUR 8	VALUATIO					
						ussed in note on
			ors in	1982 ec	lition,	PL 111B (April
		1982).				
-0.25 ± 1.20	1585	96 BRAUN	75	HLBC	+	POL, t=4.2
-0.95 ± 0.3	3133	97 CUTTS	69	OSPK	+	Total pol. $t=4.0$
-1.0 ± 0.3	6000	98 BETTELS	68	HLBC	+	Total pol. t=4.9
• • • We do not us	e the followi	ng data for average	es, fits	, limits,	etc. •	• •
-0.64 ± 0.27	40k	99 MERLAN	74	ASPK	+	POL, $d\xi(0)/d\lambda_{\perp}$
						= +1.7
-1.4 ± 1.8	397	100 CALLAHAN	66B	FBC	+	Total pol.
$-0.7 \begin{array}{l} +0.9 \\ -3.3 \end{array}$	2950	100 CALLAHAN	668	FBC	+	Long. pol.
0.0	2,00					2011 6 1 Poli
$+1.2 \begin{array}{l} +2.4 \\ -1.8 \end{array}$	2100	100 BORREANI	65	HLBC	+	Polarization
-4.0 to +1.7	500	100 CUTTS	65	OSPK	+	Long. pol.
96 BRAUN 75 <i>dξ</i> (0	$1/d\lambda_{\perp} = \epsilon t$	= -0.25×4.2 = -	- 1.0.			
97 CUTTS 69 t = 1	1 0 was calcu	lated from figure 8	de (C	$1/d\lambda$.	= £t =	$= -0.95 \times 4 = -3.8.$
98 BETTELS 68 de	(0) (4)		4.0	<i>,,, ,,,</i> +	_ ,	0.000.1 = 0.01
90	(0)/ax ₊ =	ζt = -1.0x4.9 =	~ 4.9	•		
"MERLAN 74 po	larization re	sult (figure 5) not	possit	ole. See	discus	ssion of polarization
		Form Factors" in	the 19	82 editi	on of t	this <i>Review</i> [Physics
Letters 111B (1)	982)].					

 $100 \frac{1}{t}$ value not given.

 $\begin{array}{ll} \operatorname{Im}(\xi) \operatorname{in} \ K_{\mu 3}^{\pm} \ \operatorname{DECAY} \ (\operatorname{from \ transverse} \ \mu \ \operatorname{pol.}) \\ \operatorname{Test} \ of \ T \ \operatorname{reversal \ invariance}. \\ \underline{VAUE} \qquad \qquad \underbrace{EVTS} \\ -0.017 \pm 0.025 \ \operatorname{OUR} \ \operatorname{AVERAGE} \end{array} \quad \underline{DOCUMENT \ ID}$ TECN CHG COMMENT CAMPBELL -0.016 ± 0.025 20M 81 CNTR + Pol. $-0.3 \begin{array}{c} +0.3 \\ -0.4 \end{array}$ 3133 69 OSPK + Total pol. fig.7 -0.1 ± 0.3 6000 BETTELS 68 HLBC + Total pol. 0.0 2648 CALLAHAN 66B FBC MU ±1.0 $+1.6 \pm 1.3$ 397 CALLAHAN 668 FBC Total pol. $0.5 \begin{array}{c} +1.4 \\ -0.5 \end{array}$ 2950 66B FBC Long. pol. CALLAHAN

• • We do not use the following data for averages, fits, limits, etc. • • •

 $^{^{81}}$ BOLOTOV 88 state radiative corrections of GINSBERG 67 would raise λ_+ by 0.002.

 $^{^{82}}$ BRAUN 73B states that radiative corrections of GINSBERG 67 would lower λ_{+}^{e} by 0.002 but that radiative corrections of BECHERRAWY 70 disagrees and would raise λ_{\perp}^{e} by

⁸³ BRAUN 74 is a combined $K_{\mu3}$ - K_{e3} result. It is not independent of BRAUN 73C ($K_{\mu3}$) and BRAUN 73B (K_{e3}) form factor results.

⁸⁵ MERLAN 74 figure 5 was used to obtain $d\xi(0)/d\lambda_+$.

⁸⁶ BRAUN 73c gives $\xi(t)=-0.34\pm0.20$, $d\xi(t)/d\lambda_+=-14$ for $\lambda_+=0.027$, t=6.6. We calculate above $\xi(0)$ and $d\xi(0)/d\lambda_+$ for their $\lambda_+=0.025\pm0.017$.

 $^{^{87}}$ ANKENBRANDT 72 figure 3 was used to obtain $d\xi(0)/d\lambda_{+}$.

⁹⁴EICHTEN 68 has $\lambda_{+}=0.023\pm0.008$, t=4, independent of λ_{-} . Replaced by HAIDT 71. 95 BOTTERILL 70 is re-evaluation of BOTTERILL 68B with different λ_{\perp} .

-0.010 ± 0.019	32M	101 BLATT	83	CNTR	Polarization
101 Combined result of	MORSE	80 ($K_{\mu3}^0$) and	CAMPBE	LL 81 (<i>F</i>	$(^{+}_{\mu 3}).$

 λ_+ (LINEAR ENERGY DEPENDENCE OF f_+ IN $K^\pm_{\mu3}$ DECAY) See also the corresponding entries and footnotes in sections ξ_A , ξ_C , and λ_0 . For radiative correction of $K_{\mu3}^{\pm}$ Dalitz plot, see GINSBERG 70 and BECHERRAWY 70.

VALUE	EVTS	DOCUMENT ID	3	TECN	CHG	COMMENT
0.032±0.008	OUR EVALUATION					From a fit dis- in 1982 edition,
		PL 111B (April	1982).		
0.029 ± 0.024	3000	ARTEMOV	97 9	SPEC	_	DP
$+0.050\pm0.013$	3973	WHITMAN	80 5	5PEC	+	DP
0.025 ± 0.030	490	ARNOLD	74 1	HLBC	+	DP
0.027 ± 0.019	6527	MERLAN	74 /	ASPK	+	DP
0.025 ± 0.017	1897	BRAUN		HLBC	+	DP
0.024 ± 0.019	4025 102	ANKENBRA	72 /	ASPK	+	PI
-0.006 ± 0.015	3480	CHIANG	72	OSPK	+	DP
0.050 ± 0.018	3240	HAIDT	71	HLBC	+	DP
0.009 ± 0.026	2041	KIJEWSKI	69 (OSPK	+	PI
0.0 ±0.05	444	CALLAHAN	66B	FBC	+	PI ·

 $^{^{102}}$ ANKENBRANDT 72 λ_{+} from figure 3 to match $d\xi(0)/d\lambda_{+}$. Text gives 0.024 \pm 0.022.

λ_0 (LINEAR ENERGY DEPENDENCE OF δ_0 IN $K_{\mu3}^{\pm}$ DECAY)

Wherever possible, we have converted the above values of $\xi(0)$ into values of λ_0 using the associated λ^{μ} and $d\xi/d\lambda$.

VALUE	$d\lambda_0/d\lambda_+$	EVTS	DOCUMENT ID		TECN		COMMENT
0.006±0.007	OUR EVALU	ATION	Error includes scale				
			$d\lambda_0/d\lambda_+ = -6$				
			note on Ke3 fo		ctors in	1982	edition, PL
			111B (April 19	¥82).			
+0.062±0.024	0.0	3000	¹⁰³ ARTEMOV	97 -	SPEC	_	DP
+0.029±0.011	-0.37	3973	WHITMAN	80	SPEC	+	DP
+0.019±0.010	+0.03	55k	¹⁰⁴ HEINTZE	77	SPEC	+	BR
+0.008±0.097	+0.92	1585	¹⁰⁵ BRAUN	75	HLBC	+	POL
-0.040 ± 0.040		490	ARNOLD	74	HLBC	+	DP
-0.019 ± 0.015	+0.27	6527	106 MERLAN	74	ASPK	+	DP
-0.008 ± 0.020		1897	107 BRAUN	73C	HLBC	+	DP
-0.026 ± 0.013	+0.03	4025	108 ANKENBRA	. 72	ASPK	+	PI
+0.030±0.014	-0.21	3480	108 CHIANG	72	OSPK	+	DP
-0.039±0.029		3240	108 HAIDT	71	HLBC	+	DP
-0.056±0.024	+0.69	3133	105 CUTTS	69	OSPK	+	POL .
-0.031 ± 0.045	-1.10	2041	108 KIJEWSKI	69	OSPK	+	PI
-0.063 ± 0.024		6000	105 BETTELS	68	HLBC	+	POL
+0.058±0.036	•	444	108 CALLAHAN	66B	FBC	+	Pi
		lowing d	ata for averages, fits,	. limit	s, etc. e		
			109 BRAUN		HLBC		K . IK .
-0.017 ± 0.011	•		BRAUN	74	HLDC	+	K _{μ3} /K _{e3} νs. t

ARTEMOV 97 does not give $d\lambda_0/d\lambda_+$ so we t

 $|f_S/f_+|$ FOR K_{e3}^{\pm} DECAY Ratio of scalar to f_+ couplings.

VALUE	CL%	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
0.084±0.023 OUR /	WERA	GE Erro	or includes scale fac	tor o	f 1.2.		
0.070±0.016±0.016	•	32k	AKIMENKO	91	SPEC		$\lambda_+, f_S, f_T, \phi$ fit
0.00 ± 0.10		2827	BRAUN	75	HLBC	+	
$0.14 \begin{array}{l} +0.03 \\ -0.04 \end{array}$		2707	STEINER	71	HLBC	+	$\lambda_+, f_S, f_T, \phi$ fit
• • • We do not use t	he foll	owing dat	a for averages, fits	, limi	ts, etc.	• • •	
< 0.13	90	4017	CHIANG	72	OSPK	+	
< 0.23	90		BOTTERILL	680	ASPK		
<0.18	90		BELLOTTI	67B	HLBC		
<0.30	95		KALMUS	67	HLBC	+	

$|f_T/f_+|$ FOR K_{e3}^{\pm} DECAY

Ratlo of tensor t	to f_+ couplings.					
VALUE	CL% EVTS	DOCUMENT ID		TECN	CHG	COMMENT
0.38±0.11 OUR AV	ERAGE Error le	ncludes scale facto	or of	1.1.		
$0.53^{\displaystyle{+0.09}_{\scriptstyle{-0.10}}}\!\pm\!0.10$	32k	AKIMENKO	91	SPEC		$\lambda_+, f_S, f_T, \phi$ fit
0.07 ± 0.37	2827	BRAUN	75	HLBC	+	•
$0.24^{+0.16}_{-0.14}$	2707	STEINER	71	HLBC	+	$\lambda_+, f_S, f_T, \phi$ fit

• • • We d	io not use the foll	lowing data	for averages, fits,	llmi	ts, etc.	• •	•
< 0.75	90	4017	CHIANG	72	OSPK	+	
<0.58	90		BOTTERILL	68 C	ASPK		
< 0.58	90		BELLOTTI	67B	HLBC		
<1.1	95		KALMUS	67	HLBC	+	

1

 f_T/f_+ FOR $K_{\mu 3}^{\pm}$ DECAY
Ratio of tensor to f_+ couplings.

VALUE	EVT5	DOCUMENT ID	<u>TECN</u>
0.02±0.12	1585	BRAUN 75	HLBC

DECAY FORM FACTORS FOR $K^{\pm} \rightarrow \pi^{+}\pi^{-}e^{\pm}\nu_{e}$ Given in ROSSELET 77, BEIER 73, and BASILE 71c.

DECAY FORM FACTOR FOR $K^{\pm} \rightarrow \pi^0 \pi^0 e^{\pm} \nu$ Given in BOLOTOV 868 and BARMIN 888.

K± → ℓ±νγ FORM FACTORS

For definitions of the axial-vector $\mathbf{F}_{\mathbf{A}}$ and vector $\mathbf{F}_{\mathbf{V}}$ form factor, see the "Note on $\pi^\pm\to\ell^\pm\nu\gamma$ and $K^\pm\to\ell^\pm\nu\gamma$ Form Factors" in the π^\pm section. In the kaon literature, often different definitions $a_K=F_A/m_K$ and $v_K = F_V/m_K$ are used.

$F_A + F_V$, SUM OF AXIAL-VECTOR AND VECTOR FORM FACTOR FOR

VALUE 0.148±0.010 OUR AVER	EVTS	DOCUMENT ID		TECN	COMMENT
0.147 ± 0.011	51	110 HEINTZE	79	SPEC	$K \rightarrow e \nu \gamma$
$0.150 ^{+ 0.018}_{- 0.023}$	56	111 HEARD	75	SPEC	$K \rightarrow e \nu \gamma$

110 HEINTZE 79 quotes absolute value of $|F_A+F_V|\sin\theta_C$. We use $\sin\theta_C=V_{US}=0.2205$. 111 HEARD 75 quotes absolute value of $|F_A+F_V|\sin\theta_C$. We use $\sin\theta_C=V_{US}=0.2205$.

$F_A + F_V$, SUM OF AXIAL-VECTOR AND VECTOR FORM FACTOR FOR $K \rightarrow \mu \nu_{\mu} \gamma$

VALUE	CL%	DOCUMENT ID		TECN	COMM	ENT
< 0.23	90	112 AKIBA	85	SPEC	$K \rightarrow$	$\mu\nu\gamma$
• • • We do not us	e the followi	ng data for averag	es, fit	s, limits,	etc. •	• •
-1.2 to 1.1	90	DEMIDOV	90	XEBC	K →	μυγ
112 AKIRA 85 quote	e absolute v	due				, ,

$F_A - F_V$, DIFFERENCE OF AXIAL-VECTOR AND VECTOR FORM FAC-TOP FOR K - AV &

TONTON N -				
VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
<0.49	90	¹¹³ HEINTZE	79 SPEC	$K \rightarrow e \nu \gamma$
113 HEINTZE 79 quo	tes FA - I	$ F_V < \sqrt{11} F_A + 1$	Fv -	

$F_A - F_V$, DIFFERENCE OF AXIAL-VECTOR AND VECTOR FORM FAC-TOR FOR $K \rightarrow \mu \nu_{\mu} \gamma$

VALUE		DOCUMENT ID		TECN	COMMENT	
-2.2 to 0.6	90	DEMIDOV			$K \rightarrow \mu \nu \gamma$	
-2.5 to 0.3	90	AKIBA	85	SPEC	$K \rightarrow \mu \nu \gamma$	

K* REFERENCES

ADLER	97	
ADLER	97C	PRL 79 4756 S. Adler+ (BNL 787 Collab.)
ARTEMOV	97	PAN 60 218 V.M. Artemov+ (JINR)
		Translated from YAF 60 277.
KITCHING	97	PRL 79 4079 P. Kitching+ (BNL 787 Collab.)
ADLER	96	PRL 76 1421 +Atiya, Chiang, Frank, Haggerty, Kycia+ (BNL 787 Collab.)
KOPTEV	95	JETPL 61 877 + Mikirtych'yants, Shcherbakov+ (PNPI)
		Translated from ZETFP 61 865.
AOKI	94	PR D50 69 +Yamazaki, Imazato, Kawashima+ (INUS, KEK, TOKMS)
ATIYA	93	
Also	93C	
ATIYA	93B	PR D48 R1 +Chiang, Frank, Haggerty, Ito+ (BNL 787 Collab.)
BIJNENS	93	NP B396 B1 +Ecker, Gasser (CERN, BERN)
ALLIÉGRO	92	PRL 68 278 +Campagnari+ (BNL, FNAL, PSI, WASH, YALE)
BARMIN	92	SJNP 55 547 +Barylov, Chernukha, Davidenko+ (ITEP)
		Translated from YAF 55 976.
IMAZATO	92	PRL 69 877 +Kawashima, Tanaka+ (KEK, INUS, TOKY, TOKMS)
IVANOV	92	THESIS (PNPI)
LITTENBERG	92	PRL 68 443 +Shrock (BNL, STON)
USHER	92	PR D45 3961 +Fero, Gee, Graf, Mandelkern, Schultz, Schultz (UCI)
AKIMENKO	91	Pl. B259 225 +Beloussov+ (SERP, JINR, TBIL, CMNS, SOFU, KOSI)
BARMIN	91	SJNP 53 606 +Barylov, Davidenko, Demidov+ (ITEP)
		Translated from YAF 53 981.
DENISOV	91	JETPL 54 558 +Zhelamkov, Ivanov, Lapina, Levchenko, Malakhov+ (PNPI)
Also	92	Translated from ZETFP 54 557. THESIS Ivanov (PNPI)
		PRL 64 21 + Chiang, Frank, Haggerty, Ito, Kycla+ (BNL 787 Collab.)
ATIYA	90	PRL 65 1188 +Chiang, Frank, Haggerty, Ito, Kycia+ (BNL 787 Collab.)
ATIYA	90B	SJNP 52 1006 + Dobrokhotov, Lyublev, Nikitenko+ (ITEP)
DEMIDOV	90	Translated from YAF 52 1595.
LEE	90	PRL 64 165 +Alliegro, Campagnari+ (BNL, FNAL, VILL, WASH, YALE)
ATIYA	89	PRL 63 2177 +Chiang, Frank, Haggerty, Ito, Kycia+ (BNL 787 Collab.)
BARMIN	89	SJNP 50 421 +Baryloy, Davidenko, Demidoy, Dolgolenko+ (ITEP)
DARMIN	67	Translated from YAF 50 679.
BARMIN	88	5JNP 47 643 +Barylov, Davidenko, Demidov, Dolgolenko+ (ITEP)
D/111111111		Translated from YAF 47 1011.
BARMIN	88B	SJNP 48 1032 +Barylov, Davidenko, Demidov, Dolgolenko+ (ITEP)
		Translated from YAF 48 1719.
BOLOTOV	88	JETPL 47 7 +Gninenko, Dzhilkibaev, Isakov, Klubakov+ (ASCI)
		Translated from ZETFP 47 8.

 $^{^{104}\,\}mathrm{HEINTZE}$ 77 uses $\lambda_+=0.029\pm0.003,~d\lambda_0/d\lambda_+$ estimated by us.

 $^{^{105}\}lambda_0$ value is for $\lambda_+=$ 0.03 calculated by us from $\xi(0)$ and $d\xi(0)/d\lambda_+$.

 $^{^{106}}$ MERLAN 74 λ_0 and $d\lambda_0/d\lambda_+$ were calculated by us from $\xi_A,\,\lambda_+^\mu,$ and $d\xi(0)/d\lambda_+.$ Their figure 6 gives $\lambda_0 = -0.025 \pm 0.012$ and no $d\lambda_0/d\lambda_+$.

 $^{^{107}}$ This value and error are taken from BRAUN 75 but correspond to the BRAUN 73c λ_{\perp}^{μ} result. $d\lambda_0/d\lambda_+$ is from BRAUN 73C $d\xi(0)/d\lambda_+$ in ξ_A above.

 $^{^{108}\}lambda_0$ calculated by us from $\xi(0)$, λ_+^μ , and $d\xi(0)/d\lambda_+$.

 $^{^{109}}$ BRAUN 74 is a combined $K_{\mu3}$ - K_{e3} result. It is not independent of BRAUN 73C ($K_{\mu3}$) and BRAUN 73B (K_{e3}) form factor results.

K±

	88 68 87	PRL 61 2062 PRL 60 186 SJNP 45 62	+Alliegro, Chaloupka+ (BNL, FNAL, PSI, WASH, YALE) +Austin+ (BOST, MIT, WILL, CIT, CMU, WYOM) +Barylov, Davidenko, Demidov+ (ITEP)	BUTLER 68 UC CHANG 68 PF CHEN 68 PF
	87	Translated from YA SJNP 45 1023	F 45 97. +Gninenko, Dzhilkibaev, Isakov, Klubakov+ (INRM)	EICHTEN 68 PL Eisler 68 PF
BOLOTOV	86	Translated from YA SJNP 44 73	+Gninenko, Dzhilkibaev, Isakov+ (INRM)	ESCHSTRUTH 68 PF GARLAND 68 PF
BOLOTOV	86B	Translated from YA SJNP 44 68	+Gninenko, Dzhilkibaev, Isakov+ (INRM)	MOSCOSO 68 TH AUERBACH 67 PR
YAMANAKA	86	Translated from YA PR D34 85	+Hayano, Taniguchi, Ishikawa+ (KEK, TOKY)	Also 74 Pf Erratum.
Also AKIBA	84 85	PRL 52 329 PR D32 2911	Hayano, Yamanaka, Taniguchi+ (TOKY, KEK) +Ishikawa, twasaki+ (TOKY, TINT, TSUK, KEK)	BELLOTTI 67 He BELLOTTI 67B NO
BOLOTOV	65	JETPL 42 481 Translated from ZE	+Gninenko, Dzhilkibaev, Isakov+ (INRM) TFP 42 390.	Also 668 Pt BISI 67 Pt
BLATT ASANO	83 82	PR D27 1056 PL 113B 195	+Adair, Black, Campbell+ (YALE, BNL) +Kikutani, Kurokawa, Miyachi+(KEK, TOKY, INUS, OSAK)	BOTTERILL 67 PI
COOPER PDG	82 82	PL 112B 97 PL 111B	+Guy, Michette, Tyndel, Venus (RL) Roos, Porter, Aguilar-Benitez+ (HELS, CIT, CERN)	Also 68 PI BOWEN 67B PI
PDG ASANO	82B	PL 111B 70	Roos, Porter, Aguilar-Benitez+ (HELS, CIT, CERN) +Kikutani, Kurokawa, Miyachi+(KEK, TOKY, INUS, OSAK)	CLINE 67B Ho Proc. International
CAMPBELL	81B 81	PL 107B 159 PRL 47 1032	+Black, Blatt, Kasha, Schmidt+ (YALE, BNL)	FLETCHER 67 PI FORD 67 PI
Also LUM	83 81	PR D27 1056 PR D23 2522	Blatt, Adair, Black, Campbell+ (YALE, BNL) +Wiegand, Kessler, Deslattes, Seki+ (LBL, NBS+)	GINSBERG 67 PI IMLAY 67 PI
LYONS MORSE	81 80	ZPHY C10 215 PR D21 1750	+Albajar, Myatt (OXF) +Leipuner, Larsen, Schmidt, Blatt+ (BNL, YALE)	KALMUS 67 PI
WHITMAN BARKOV	80 79	PR D21 652 NP B148 53	+Abrams, Carroll, Kycia, Li+ (ILLC, BNL, ILL) +Vasserman, Zolotorev, Krupin+ (NOVO, KIAE)	ZINCHENKO 67 TI CALLAHAN 66 N
HEINTZE	79	NP B149 365	+Heinzelmann, Igo-Kemenes+ (HEIDP, CERN)	CALLAHAN 66B PI CESTER 66 PI
ABRAMS DEVAUX	77 77	PR D15 22 NP B126 11	+Bloch, Diamant-Berger, Maillard+ (SACL, GEVA)	See footnote 1 in A Also 67 P
HEINTZE ROSSELET	77 77	PL 70B 482 PR D15 574	+Extermann, Fischer, Guisan+ (GEVA, SACL)	BIRGE 65 P
BERTRAND BLOCH	76 76	NP B114 387 PL 60B 393	+Sacton+ (BRUX, KIDR, DUUC, LOUC, WARS) +Bunce, Devaux, Diamant-Berger+ (GEVA, SACL)	BISI 65 N BISI 658 P
BRAUN	76B	LNC 17 521	+Martyn, Erriquez+ (AACH3, BARI, BELG, CERN)	BORREANI 65 P CALLAHAN 65 P
DIAMANT HEINTZE	76 76	PL 62B 485 PL 60B 302	Diamant-Berger, Bloch, Devaux+ (SACL, GEVA) +Heinzelmann, Igo-Kemenes, Mundhenke+ (HEIDP)	CAMERINI 65 N
SMITH WEISSENBE	76 76	NP B109 173 NP B115 55	+Booth, Renshall, Jones+ (GLAS, LIVP, OXF, RHEL) Welssenberg, Egorov, Minervina+ (ITEP, LEBD)	CUTTS 65 P
BLOCH	75	PL 56B 201 NP B89 210	+Brehin, Bunce, Devaux+ +Cornelssen+ (AACH3, BAR1, BRUX, CERN)	DEMARCO 65 P FITCH 65B P
BRAUN CHENG	75 75	NP A254 381	+Asano, Chen, Dugan, Hu, Wu+ (COLU, YALE)	GREINER 65 A STAMER 65 P
HEARD HEARD	75 75B	PL 55B 324 PL 55B 327	+Heintze, Heinzelmann+ (CERN, HEIDH) +Heintze, Heinzelmann+ (CERN, HEIDH)	TRILLING 65B U
SHEAFF SMITH	75 75	PR D12 2570 NP B91 45	(WISC) +Booth, Renshall, Jones+ (GLAS, LIVP, OXF, RHEL)	Updated from 1965 YOUNG 65 T
ARNOLD	74	PR D9 1221	+-Roe. Sinclair (MICH)	Also 67 P BORREANI 64 P
BRAUN CENCE	74 74	PL 51B 393 PR D10 776	+Cornelssen, Martyn+ (AACH3, BARI, BRUX, CERN) +Harris, Jones, Morgado+ (HAWA, LBL, WISC)	CALLAHAN 64 P CAMERINI 64 P
Also KUNSELMAN	73 74	Thesis unpub. PR C9 2469	Clarke (WISC) (WYOM)	CLINE 64 P
MERLAN	74	PR D9 107 PL 48B 474	+Kasha, Wanderer, Adair+ (YALE, BNL, LASL) Weissenberg, Egorov, Minervina+ (ITEP, LEBD)	GIACOMELLI 64 N GREINER 64 P
WEISSENBE ABRAMS	73B	PRL 30 500	+Carroll, Kycia, Li, Menes, Michael+ (BNL)	JENSEN 64 P KALMUS 64 P
BACKENSTO BEIER	. 73 73	PL 43B 431 PRL 30 399	Backenstoss+ (CERN, KARLK, KARLE, HEID, STOH) +Buchholz, Mann, Parker, Roberts (PENN)	SHAKLEE 64 P BARKAS 63 P
BRAUN Also	73B 75	PL 47B 185 NP B89 210	+Cornelssen (AACH3, BARI, BRUX, CERN) Braun, Cornelssen+ (AACH3, BARI, BRUX, CERN)	BOYARSKI 62 P
BRAUN	73C	PL 47B 182 NP B89 210	+Cornelssen (AACH3, BARI, BRUX, CERN) Braun, Cornelssen+ (AACH3, BARI, BRUX, CERN)	BROWN 62B P BARKAS 61 P
Also CABLE	75 73	PR D8 3807	+Hildebrand, Pang, Stiening (EFI, LBL)	BHOWMIK 61 N FERRO-LUZZI 61 N
LJUNG Also	73 72	PR D8 1307 PRL 28 523	+Cline (WISC) Ljung (WISC)	NORDIN 61 F ROE 61 F
Aiso Aiso	72 69	PRL 28 1287 PRL 23 326	Cline, Ljung (WISC) Camerini, Ljung, Sheaff, Cline (WISC)	FREDEN 60B F
LUCAS	73	PR D8 719	+Taft, Willis (YALE)	BURROWES 59 F TAYLOR 59 F
LUCAS PANG	73B 73	PR D8 727 PR D8 1989	+Taft, Willis +Hildebrand, Cable, Stiening (EFI, ARIZ, LBL)	EISENBERG 58 N ALEXANDER 57 N
Also SMITH	72 73	PL 40B 699 NP B60 411	Cable, Hildebrand, Pang, Stiening (EFI, LBL) +Booth, Renshall, Jones+ (GLAS, LIVP, OXF, RHEL)	COHEN 57 F
ABRAMS ANKENBRA	72	PRL 29 1118 PRL 28 1472	+Carroll, Kycia, Li, Menes, Michael+ (BNL) Ankenbrandt, Larsen+ (BNL, LASL, FNAL, YALE)	BIRGE 56 N
AUBERT	72	NC 12A 509	+Heusse, Pascaud, Vialle+ (ORSAY, BRUX, EPOL)	ILOFF 56 F
BEIER CHIANG	72 72	PRL 29 678 PR D6 1254	+Buchholz, Mann, Parker (PENN) +Rosen, Shapiro, Handler, Olsen+ (ROCH, WISC)	-
CLARK EDWARDS	72 72	PRL 29 1274 PR D5 2720	+Cork, Elioff, Kerth, McReynolds, Newton+ (LBL) +Beier, Bertram, Herzo, Koester+ (ILL)	LITTENBERG 93 A
FORD	72	PL 38B 335	+Piroue, Remmel, Smith, Souder (PRIN)	Rare and Radiative
HOFFMASTER BASILE	71C		+Brehin, Diamant-Berger, Kunz+ (SACL, GEVA)	RITCHIE 93 F "Rare K Decays"
BOURQUIN GINSBERG	71 71	PL 36B 615 PR D4 2893	+Boymond, Extermann, Marasco+ (GEVA, SACL) (MIT)	BATTISTON 92 F Status and Perspec
HAIDT Also	71 69	PR D3 10 PL 29B 691	(AACH, BARI, CERN, EPOL, NIJM+) Haidt+ (AACH, BARI, CERN, EPOL, NIJM, OR5AY+)	BRYMAN 89 I "Rare Kaon Decay
KLEMS	71	PR D4 66	+Hildebrand, Stiening (CHIC, LRL)	CHOUNET 72 F FEARING 70 F
Also Also	70 70B		Klems, Hildebrand, Stiening (LRL, CHIC) Klems, Hildebrand, Stiening (LRL, CHIC)	HAIDT 69B F
OTT ROMANO	71 71	PR D3 52 PL 36B 525	+Pritchard (LOQM) +Renton, Aubert, Burban-Lutz (BARI, CERN, ORSAY)	CRONIN 68B \ Rapporteur talk.
SCHWEINB STEINER	71 71	PL 36B 246 PL 36B 521	Schweinberger (AACH, BELG, CERN, NIJM+) (AACH, BARI, CERN, EPOL, ORSAY, NIJM, PADO+)	WILLIS 67 I Rapporteur talk.
BARDIN	70	PL 32B 121	+Bilenky, Pontecorvo (JINR) (ROCH)	CABIBBO 66 I ADAIR 64 I
BECHERRAW BOTTERILL	Y 70 70	PR D1 1452 PL 31B 325	+Brown, Clegg, Corbett, Culligan+ (OXF)	CABIBBO 64 I
FORD GAILLARD	70 70	PRL 25 1370 CERN 70-14	+Piroue, Remmel, Smith, Souder (PRIN) +Chounet (CERN, ORSAY)	Also 64B I Also 65 I
GINSBERG	70 70	PR D1 229 PR D1 1277	(HAIF) +Koller, Taylor, Pandoulas+ (STEV, SETO, LEHI)	BIRGE 63 I BLOCK 62B
GRAUMAN Also	69	PRL 23 737	Grauman, Koller, Taylor+ (STEV, SETO, LEHI)	BRENE 61
MALTSEV	70	SJNP 10 678 Translated from Y	+Pestova, Solodovnikova, Fadeev+ (JINR) AF 10 1195.	
PANDOULAS CUTTS	70 69	PR D2 1205 PR 184 1380	+Taylor, Koller, Grauman+ (STEV, SETO) +Stiening, Wiegand, Deutsch (LRL, MIT)	
Also DAVISON	68 69	PRL 20 955 PR 180 1333	Cutts, Stiening, Wiegand, Deutsch (LRL, MIT) +Bacastow, Barkas, Evans, Fung, Porter+ (UCR)	
ELY EMMERSON	69 69	PR 180 1319 PRL 23 393	+Gidal, Hagopian, Kalmus+ (LOUC, WISC, LRL) +Quirk (OXF)	
HERZO	69	PR 186 1403	+Banner, Beier, Bertram, Edwards+ (ILL)	
KIJEWSKI LOBKOWICZ	69 69	Thesis UCRL 184 PR 185 1676	+Melissinos, Nagashima, Tewksbury+ (ROCH, BNL)	
Also MACEK	66 69	PRL 17 548 PRL 22 32	Lobkowicz, Melissinos, Nagashima+ (ROCH, BNL) +Mann, McFarlane, Roberts+ (PENN, TEMP)	
MAST	69	PR 183 1200	+Gershwin, Alston-Garnjost, Bangerter+ (LRL)	
SELLERI ZELLER	69 69	NC 60A 291 PR 182 1420	+Haddock, Helland, Pahl+ (UCLA, LRL)	
BETTELS	68	NC 56A 1106	(AACH, BARI, BERG, CERN, EPOL, NIJM, ORSAY+)	
Also	71	PR D3 10 3 PRL 21 766	Haidt (AACH, BARI, CERN, EPOL, NIJM+) +Brown, Clegg, Corbett+ (OXF)	

BUTLER	68	UCRL 18420	+Bland, Goldhaber, Goldhaber, Hirata+ (LR	RL)
CHANG	68	PRL 20 510	+Yodh, Ehrlich, Plane+ (UMD, RUT	G)
CHEN	68 68	PRL 20 73 PL 27B 586	+Cutts, Kijewski, Stiening+ (LRL, MI (AACH, BARI, CERN, EPOL, ORSAY, PADO, VAL	E)
EICHTEN EISLER	68	PR 169 1090	+Fung, Marateck, Meyer, Plano (RUT	G)
ESCHSTRUTH	68	PR 165 1487	+Franklin, Hughes+ (PRIN, PEN	N)
GARLAND MOSCOSO	68 68	PR 167 1225 Thesis	+Tsipis, Devons, Rosen+ (COLU, RUTG, WIS (ORSA	NY)
AUERBACH	67	PR 155 1505	+Dobbs, Mann+ (PENN, PRI	IN)
Also Erratum.	74	PR D9 3216	Auerbach	
BELLOTTI	67	Heidelberg Conf.	+Pullia (MIL	
BELLOTTI	67B	NC 52A 1287	+Fiorini, Pullia (Mil. Bellotti, Fiorini, Pullia+ (Mil.	
Also BISI	668 67	PL 20 690 PL 25B 572	Betlotti, Fiorini, Pullia+ +Cester, Chiesa, Vigone (TO	
BOTTERILL	67	PRL 19 982	+Brown, Corbett, Cultigan+ (OX	(F)
Also BOWEN	68 67B	PR 171 1402 PR 154 1314	Botterill, Brown, Clegg, Corbett+ (OX +Mann, McFarlane, Hughes+ (PF	
CLINE	67B	Herceg Novi Tbl. 4		•••,
Proc. Inte	ernatio	nal School on Elementary	Particle Physics. +Beier, Edwards+ (II	LL)
FLETCHER FORD	67	PRL 19 98 PRL 18 1214	+Lemonick, Nauenberg, Piroue (PR)	IN)
GINSBERG	67	PR 162 1570	(MAS	5B)
IMLAY KALMUS	67 67	PR 160 1203	+Eschstruth, Franklin+ (PRI +Kernan (LE	IN) Ri ì
ZINCHENKO	67	PR 159 1187 Thesis Rutgers	(RUT	rg)
CALLAHAN	66	NC 44A 90	(WISC LEI LICE BA	SC)
CALLAHAN CESTER	66B	PR 150 1153 PL 21 343	+Camerini+ (WISC, LRL, UCR, BA +Eschstruth, Oneill+ (PI	PA)
See footn	ote 1 i	in AUERBACH 67.		
Also BIRGE	67 65	PR 155 1505 PR 139B 1600	Auerbach, Dobbs, Mann+ (PENN, PR +Ely, Gidal, Camerini, Cline+ (LRL, WIS	IN) SC)
BISI	65	NC 35 768	+Borreani, Cester, Ferraro+ (TO	RI)
BISI	65B	PR 139B 1068	+Borreani, Marzari-Chiesa, Rinaudo+ (TO	RI)
BORREANI CALLAHAN	65 65	PR 140B 1686 PRL 15 129	+Gidal, Rinaudo, Caforio+ (BARI, TO +Cline (WIS	SC)
CAMERINI	65	NC 37 1795	+Cline, Gidal, Kalmus, Kernan (WISC, LI	RL)
CLINE	65	PL 15 293	+Frv (Wi	SC)
CUTTS DEMARCO	65 65	PR 138B 969 PR 140B 1430	+Elioff, Stiening +Grosso, Rinaudo (TORI, CEF	RN)
FITCH	65B	PR 140B 1088	+Quarles, Wilkins (PRIN, MTI	10)
GREINER STAMER	65 65	ARNS 15 67 PR 138B 440	+Huetter, Koller, Taylor, Grauman (STI	RL) EV)
TRILLING		UCRL 16473		RL)
	from 1	965 Argonne Conference, Thesis UCRL 16362	page 5.	RL)
Also	67	PR 156 1464		RL)
BORREANI	64	PL 12 123	+Rinaudo, Werbrouck (TO)RI)
CALLAHAN CAMERINI	64 64	PR 136B 1463 PRL 13 318	+March, Stark +Cline, Fry, Powell (WISC, L	SC) RL)
CLINE	64	PRL 13 101	+Fry (WI	SC)
GIACOMELLI	64	NC 34 1134	+Monti, Quareni+ (BGNA, MU	JNI) .RL)
GREINER JENSEN	64 64	PRL 13 284 PR 136B 1431	+Shakine, Roe, Sinclair (MI)	
KALMUS	64	PRL 13 99	+Kernan, Pu. Powell, Dowd (LRL, WI	SC)
SHAKLEE BARKAS	64 63	PR 136B 1423	+ Jensen, Roe, Sinclair (Military Herkman (L	CH) .RL)
BOYARSKI	62	PRL 11 26 PR 128 2398	+Loh, Niemela, Ritson (M	MT)
BROWN	62B	PRL 8 450	+Kadyk, Trilling, Roe+ (LRL, MI)	CH) .RL)
BARKAS BHOWMIK	61 61	PR 124 1209 NC 20 857	+Dyer, Mason, Norris, Nickols, Smit +Jain, Mathur (DE	
FERRO-LUZZ	1 61	NC 22 1087	+Miller, Murray, Rosenfeld+ (L	.RL)
NORDIN	61	PR 123 2166 PRL 7 346		RL)
ROE FREDEN	61 60B	PR 118 564	+Glibert, White (L	.RL)
BURROWES	59	PRL 2 117	+Caldwell, Frisch, Hill+ (N	AIT)
TAYLOR EISENBERG	59 58	PR 114 359 NC 8 663	+Harris, Orear, Lee, Baumel (CO +Koch, Lohrmann, Nikolic+ (BE	
ALEXANDER	57	NC 6 478	+ Johnston, Oceallaigh (DU	UC)
COHEN	57 57	Fund. Cons. Phys.	+Crowe, Dumond (NAAS, LRL, C +Cork, Galbraith, Lambertson, Wenzel (L	CIT) .BL)
COOMBES BIRGE	57 56	PR 108 1348 NC 4 834	+Perkins, Peterson, Stork, Whitehead (L	.RL)
ILOFF	56	PR 102 927		RL)
		ОТНЕ	R RELATED PAPERS	
LITTENDEO	. 02	ADNIDS 42 720	+Valencia (BNL, FN	IAL)
LITTENBERG Rare and	a 93 i Radia	ARNPS 43 729 stive Kaon Decays	TYRICIOS (DIAL, FIX	
RITCHIE	93	ntive Kaon Decays RMP 65 1149 rs" PRPL 214 293	+Wojcicki	
"Rare K BATTISTON	Decay 92	'S" PRPL 214 293	+Cocolicchio, Fogli, Paver (PGIA, CERN, TRS	TT)
Status a	nd Per	spectives of K Decay Ph	ysics	•
BRYMAN "Rare K	89 aon De	IJMP A4 79	(π	RIU)
CHOUNET	72	PRPL 4C 199	+Gaillard, Gaillard (ORSAY, CE	
FEARING	70	PR D2 542	+Fischbach, Smith (STON, BO + (AACH, BARI, CERN, EPOL, NIJM, ORSA	
HAIDT CRONIN	69E			RIN)
Rapporte	ur talk	.	·	-
WILLIS Rapporte	67	Heidelberg Conf. 273	(Y/	ALE)
CABIBBO	ur tan 66	Berkeley Conf. 33	(CE	RN)
ADAIR	64	PL 12 67	+Leipuner (YALE, E	BNL) ERN)
CABIBBO Also	64 64E	PL 9 352 3 PL 11 360	Cabibbo, Maksymowicz (CE	RN)
Also	65	PL 14 72	Cabibbo, Maksymowicz (CE	ERN)
BIRGE BLOCK	63 62E	PRL 11 35 3 CERN Conf. 371	+Ely, Gldal, Camerini+ (LRL, WISC, B. +Lendinara, Monari (NWES, BG	AKI) SNA)
BRENE	61	NP 22 553	+Egardt, Qvist (NO	ORD)
			· · · · · · · · · · · · · · · · · · ·	

K^0	

$I(J^P)$	=	$\frac{1}{2}(0$	

KO MASS

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
497.672±0.031 OUI	R FIT				
497.672±0.031 OUI	R AVERAGE				
497.661±0.033	3713	BARKOV	87B	CMD	$e^+e^- \rightarrow K_i^0 K_s^0$
497.742±0.085	780	BARKOV	85B	CMD	$e^+e^- \rightarrow K_L^0 K_S^0$ $e^+e^- \rightarrow K_L^0 K_S^0$
• • • We do not us	e the followin	g data for average			
497.44 ±0.50		FITCH	67	OSPK	
498.9 ±0.5	4500	BALTAY	66	HBC	K^0 from $\overline{p}p$
497.44 ±0.33	2223	KIM	65B	HBC	K^0 from $\overline{p}p$
498.1 ±0.4		CHRISTENS	64	OSPK	

$m_{K^0} - m_{K^{\pm}}$

VALUE (MeV) 3.995±0.034 OUR F • • • We do not use	IT Error Inc		of 1.1.		
3.95 ±0.21	417	HILL	688 DBC	+	$K^+ d \rightarrow K^0 pp$
3.90 ±0.25	9	BURNSTEIN	65 HBC	-	
3.71 ±0.35	7	KIM	65B HBC	~	$K^-p \rightarrow n\overline{K}^0$
5.4 ±1.1		CRAWFORD	59 HBC	+	
3.9 ±0.6		ROSENFELD	59 HBC	-	

m_{K0} - m_{K0} / m_{average}

A test of CPT invariance.

<10⁻¹⁸ OUR EVALUATION

DOCUMENT ID

K⁰ REFERENCES

BARKOV	87B	SJNP 46 630 Translated from YA	+Vasserman, Vorobev, Ivanov+	(NOVO)
BARKOV	85B	JETPL 42 138 Translated from ZE	+Blinov, Vasserman+	(NOVO)
HILL	68B	PR 168 1534	+Robinson, Sakitt, Canter	(BNL, CMU)
FITCH	67	PR 164 1711	+Roth, Russ, Vernon	(PRIN)
BALTAY	66	PR 142 932	+Sandweiss, Stonehill+	(YALE, BNL)
BURNSTEIN	65	PR 138B 895	+Rubin	(UMD)
KIM	65B	PR 140B 1334	+Kirsch, Miller	(COLU)
CHRISTENS	64	PRL 13 138	Christenson, Cronin, Fitch, Turlay	(PRIN)
CRAWFORD	59	PRL 2 112	+Cresti, Good, Stevenson, Ticho	`(LRL)
ROSENFELD	59	PRL 2 110	+Solmitz, Tripp	(LRL)



$$I(J^P) = \frac{1}{2}(0^-)$$

KS MEAN LIFE

For earlier measurements, beginning with BOLDT 58B, see our our 1986 edition, Physics Letters 170B 130 (1986).

OUR FIT is described in the note on "Fits for K_L^0 CP-Violation Parameters" in the K_L^0 Particle Listings.

VALUE (10-10 s)	EVTS	DOCUMENT ID TECN COMMENT
0.8934±0.0008 OU	R FIT	
0.8940±0.0009 OU	R AVERAG	E
0.8971 ± 0.0021		BERTANZA 97 NA31
$0.8941 \pm 0.0014 \pm 0.0014$	0009	SCHWINGEN95 E773 Δm free, $\phi_{+-} = \phi_{SW}$
0.8929 ± 0.0016		GIBBONS 93 E731
0.8920 ± 0.0044	214k	GROSSMAN 87 SPEC ,
0.881 ± 0.009	26k	ARONSON 76 SPEC
0.8924 ± 0.0032		¹ CARITHERS 75 SPEC
0.8937 ± 0.0048	6M	GEWENIGER 748 ASPK
0.8958 ± 0.0045	50k	² SKJEGGEST 72 HBC
• • • We do not u	se the folio	ving data for averages, fits, limits, etc. • • •
0.905 ±0.007		³ ARONSON 82B SPEC
0.867 ±0.024	2173	⁴ FACKLER 73 OSPK
0.856 ±0.008	19994	⁵ DONALD 68B HBC
0.872 ± 0.009	20000	^{5,6} HILL 68 DBC
0.866 ± 0.016		⁵ ALFF 668 OSPK
0.843 ±0.013	5000	⁵ KIRSCH 66 HBC

¹CARITHERS 75 value is for $m_{K_L^0} - m_{K_S^0} \Delta m = 0.5301 \pm 0.0013$. The Δm dependence

of the total decay rate (inverse mean life) is $\Gamma(K_0^0)=[(1.122\pm0.004)+0.16(\Delta m-0.5348)/\Delta m]10^{10}/s$, or, in terms of meanlife $\tau_s=0.8913\pm0.0032-0.238(\Delta m-0.5348)$ where Δm and τ_s are in units of $10^{10}\hbar s^{-1}$ and $10^{-10}s$ respectively.

² HILL 68 has been changed by the authors from the published value (0.865 \pm 0.009) because of a correction in the shift due to η_{+-} . SKJEGGESTAD 72 and HILL 68 give detailed discussions of systematics encountered in this type of experiment.

 3 ARONSON 82 find that K_S^0 mean life may depend on the kaon energy.

⁴ FACKLER 73 does not include systematic errors.

5 Pre-1971 experiments are excluded from the average because of disagreement with later more precise experiments.

⁶ HILL 68 has been changed by the authors from the published value (0.865 \pm 0.009) because of a correction in the shift due to η_{+-} . SKJEGGESTAD 72 and HILL 68 give detailed discussions of systematics encountered in this type of experiment.

KS DECAY MODES

	Mode	Fraction (Γ_I/Γ)	Scale factor/ Confidence level
Γ ₁ Γ ₂ Γ ₃	$\pi^+\pi^-$	(68.61±0.28) %	S=1.2
Γ_2	$\pi^0\pi^0$	(31.39±0.28) %	S=1.2
Гз	$\pi^+\pi^-\gamma$	[a,b] (1.78±0.05) × 10 ⁻¹	3
Γ_4	$\gamma\gamma$	$(2.4 \pm 0.9) \times 10^{-1}$	6
Γ ₅	$\pi^+\pi^-\pi^0$	$(3.4 \begin{array}{c} +1.1 \\ -0.9 \end{array}) \times 10^{-1}$	-7
Γ ₆ Γ ₇ Γ ₈	$3\pi^0$	< 3.7 × 10 ⁻	5 CL=90%
Γ7	$\pi^{\pm} e^{\mp} \nu$ $\pi^{\pm} \mu^{\mp} \nu$	[c] $(6.70\pm0.07)\times10^{-1}$	·4 S=1.1
Гв	$\pi^{\pm}\mu^{\mp} u$	[c] $(4.69\pm0.06)\times10^{-1}$	S=1.1
		$\Delta S = 1$ weak neutral current (S1) modes	
و٦	$\mu^+\mu^-$	\$1 < 3.2 × 10	·7 CL=90%
Γ ₁₀	e^+e^-	51 < 1.4 × 10	·7 CL=90%
Γ11	$\pi^0 e^+ e^-$	S1 < 1.1 × 10	6 CL=90%

- [a] See the Particle Listings below for the energy limits used in this measurement.
- [b] Most of this radiative mode, the low-momentum γ part, is also included in the parent mode listed without γ 's.
- [c] Calculated from K_L^0 semileptonic rates and the K_S^0 lifetime assuming $\Delta S = \Delta O$.

CONSTRAINED FIT INFORMATION

An overall fit to 3 branching ratios uses 17 measurements and one constraint to determine 2 parameters. The overall fit has a $\chi^2=16.5$ for 16 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\langle \delta x_i \delta x_j \rangle / (\delta x_i \cdot \delta x_j)$, in percent, from the fit to the branching fractions, $x_i \equiv \Gamma_i / \Gamma_{\text{total}}$. The fit constrains the x_i whose labels appear in this array to sum to

KO DECAY RATES

$\Gamma(\pi^{\pm}e^{\mp}\nu)$					Γ ₇
VALUE (10 ⁶ s ⁻¹)	DOCUMENT IL	,	TECN	COMMENT	
7.50±0.08 OUR EVALUATION	Error includes so	ale fac	tor of 1	.1. From K 7 n	neasure-
				: ΔQ in K ^O de 0 → π [±] e∓ν	
• • • We do not use the follow	ing data for averag	ges, fit:	s, limits,	etc. • • •	
seen	BURGUN	72	нвс	$K^+p \rightarrow K^0$	$p\pi^+$
9.3 ±2.5	AUBERT	65	HLBC	$\Delta S = \Delta Q$, CP assumed	cons. not
$\Gamma(\pi^{\pm}\mu^{\mp}\nu)$					Гв
VALUE (10 ⁶ s ⁻¹)	DOCUMENT IL				
5.25±0.07 OUR EVALUATION	Error includes so	ale fac	tor of 1	.1. From K ? n	neasure-
	ments, assun	ing th	at ΔS =	= ΔQ in K ^O de O → π [±] μ∓ι	cay so that

KS BRANCHING RATIOS

Γ(π ⁺	-π)/Γ _t	otal				Γ1/Γ
VALUE		<u>EVTS</u>	DOCUMENT ID	TECN	COMMENT	
0.686	1 ± 0.0028	OUR FIT Error	includes scale fac	tor of 1.2.		
0.671	±0.010	OUR AVERAGE				
0.670	± 0.010	3447	7 DOYLE	69 HBC	$\pi^- p \rightarrow \Lambda K^0$	
0.70	±0.08		COLUMBIA	608 HBC	•	
0.68	± 0.04		CRAWFORD	59B HBC		
• • •	We do n	ot use the following	g data for average	es, fits, limits,	etc. • • •	
0.740	±0.024		7 ANDERSON	628 HBC		

⁷ Anderson result not published, events added to Doyle sample.

K_{S}^{0}

$\Gamma(\pi^+\pi^-)/\Gamma(\pi^0\pi^0)$ Γ_1/Γ_2	• • We do not use the following data for averages, fits, limits, etc. • • •
ALUE EVTS DOCUMENT ID TECN COMMENT 2.186±0.028 OUR FTT Error includes scale factor of 1.2.	2.2±1.1 16 ¹⁶ BARR 95B NA31
2.197±0.026 OUR AVERAGE	< 13 90 BALATS 89 SPEC 2.4±1.2 19 BURKHARDT 87 NA31
1.11 ± 0.09 1315 EVERHART 76 WIRE $\pi^- p \rightarrow \Lambda K^0$	2.4±1.2 19 BURKHARDT 87 NA31 < 133 90 BARMIN 86B XEBC
1.169 \pm 0.094 16k COWELL 74 OSPK $\pi^- p \to \Lambda K^0$	< 200 90 VASSERMAN 86 CALO $\phi \rightarrow K_S^0 K_I^0$
.16 ± 0.08 4799 HILL 73 DBC $K^+d \to K^0pp$	< 400 90 0 BARMIN 73B HLBC
.22 ± 0.10 3068 ⁸ ALITTI 72 HBC $K^+ p \to \pi^+ p K^0$	< 710 90 0 ¹⁷ BANNER 72B OSPK
22 ± 0.08 6380 MORSE 728 DBC $K^+ n \to K^0 p$	< 2000 90 0MORSE 728 DBC
10 ± 0.11 701 9 NAGY 72 HLBC $K^+ n \to K^0 p$	< 2200 90 0 17 REPELLIN 71 OSPK
22 ± 0.095 6150 10 BALTAY 71 HBC $Kp \rightarrow K^0$ neutrals	<21000 90 0 ¹⁷ BANNER 69 OSPK
282 ± 0.043 7944 ¹¹ MOFFETT 70 OSPK $K^+ n \rightarrow K^0 p$	15 BARR 95B quotes this as the combined BARR 95B + BURKHARDT 87 result afte
10 ±0.06 3700 MORFIN 69 HLBC $K^+n \rightarrow K^0p$ • • We do not use the following data for averages, fits, limits, etc. • • •	rescaling BURKHARDT 87 to use same branching ratios and lifetimes as BARR 958.
	¹⁶ BARR 958 result is calculated using B($K_L \rightarrow \gamma \gamma$) = (5.86 \pm 0.17) \times 10 ⁻⁴ . ¹⁷ These limits are for maximum interference in K_S^0 - K_L^0 to 2γ 's.
12 ± 0.17 267 9 BOZOKI 69 HLBC 1285 ± 0.055 3016 11 GOBBI 69 OSPK $K^+ n \to K^0 p$	These mins are for maximum interference in KS-KL to 27 s.
·	$\Gamma(\pi^+\pi^-\pi^0)/\Gamma_{\text{total}}$ Γ_5/Γ
⁸ The directly measured quantity is $K_5^0 \rightarrow \pi^+\pi^-/\text{all } K^0 = 0.345 \pm 0.005$.	VALUE (units 10 ⁻⁷) CL% EVTS DOCUMENT ID TECN COMMENT
9 NAGY 72 is a final result which includes BOZOKI 69. 10 The directly measured quantity is $K_S^0 \to \pi^+\pi^-/\text{all }\overline{K}^0 = 0.345 \pm 0.005$.	
1 MODERATE TO be a first south which best the CORD CO	3.4 ^{+1.1} OUR AVERAGE
¹ MOFFETT 70 is a final result which includes GOBBI 69.	2.5 + 1.3 + 0.5 500k 18 ADLER 97B CPLR
$(\pi^0\pi^0)/\Gamma_{\text{total}}$ Γ_2/Γ	-1.0-0.6
LUEEVTS DOCUMENT IDTECN	4.1+2.5+0.5 -1.9-0.6
139±0.0029 OUR FIT Error includes scale factor of 1.2.	
116 ±0.014 OUR AVERAGE Error includes scale factor of 1.3. See the ideogram	-1.6
below. ± 0.014 1066 BROWN 63 HLBC	 ◆ ◆ We do not use the following data for averages, fits, limits, etc. ◆ ◆
88 ±0.021 198 CHRETIEN 63 HLBC	3.9+5.4+0.9 21 THOMSON 94 E621 Sup. by ZOU 96
0 ±0.035 BROWN 61 HLBC	3.9 1.8 0.7 21 HOMSON 94 E621 Sup. by 200 9 <490 90 22 BARMIN 85 HLBC
5 ±0.06 BAGLIN 60 HLBC	<850 90 METCALF 72 ASPK
7 ±0.11 CRAWFORD 598 HBC	¹⁸ ADLER 97B find the <i>CP</i> -conserving parameters $\text{Re}(\lambda) = (28 \pm 7 \pm 3) \times 10^{-3}$, $\text{Im}(\lambda)$
WEIGHTED AVERAGE	= $(-10 \pm 8 \pm 2) \times 10^{-3}$. They estimate $B(K_S^0 \to \pi^+\pi^-\pi^0)$ from $Re(\lambda)$ and the
0.316±0.014 (Error scaled by 1.3)	
1.	K ⁰ _L decay parameters.
Values above of weighted average, error,	19 ADLER 96E is from the measured quantities Re(λ) = 0.036 \pm 0.010 $^{+0.002}_{-0.003}$ and Im(λ
and scale factor are based upon the data in	consistent with zero. Note that the quantity λ is the same as $ ho_{+-0}$ used in other
this ideogram only. They are not neces- sarily the same as our 'best' values,	footnotes. 20 ZOU 96 is from the the measured quantities $ ho_{+-0} =0.039^{+0.009}_{-0.006}\pm0.005$ and ϕ_{p}
obtained from a least-squares constrained fit	$= (-9 \pm 18)^{\circ}$.
utilizing measurements of other (related)	21 THOMSON 94 calculates this branching ratio from their measurements $ \rho_{+-0} $ =
quantities as additional information.	
	$0.035^{+0.019}_{-0.011}\pm 0.004$ and $\phi_{ ho}=(-59\pm 48)^{\circ}$ where $ ho_{+-0} e^{i\phi_{ ho}}={\sf A}({\cal K}^0_5 o\pi^+\pi^-\pi^0_5)$
\sim	$I = 2)/A(K_L^0 \to \pi^+\pi^-\pi^0).$
2	²² BARMIN 85 assumes that <i>CP</i> -allowed and <i>CP</i> -violating amplitudes are equally sup
χ	pressed.
HOWN 63 HLBC 1.8	$\Gamma(3\pi^0)/\Gamma_{\text{total}}$ Γ_6/Γ
- BROWN 61 HLBC 0.2	VALUE (units 10 ⁻⁴) CL% DOCUMENT ID TECN
- BAGLIN 60 HLBC 0.9	<0.37 90 BARMIN 83 HLBC
	• • • We do not use the following data for averages, fits, limits, etc. • • •
(Confidence Level = 0.300)	<4.3 90 BARMIN 73 HLBC
(30	
0.1 0.2 0.3 0.4 0.5 0.6	$\Gamma(\mu^+\mu^-)/\Gamma_{ ext{total}}$
r(_0_0) /r	Test for $\Delta S = 1$ weak neutral current. Allowed by first-order weak interaction combine
$\Gamma(\pi^0\pi^0)/\Gamma_{total}$	with electromagnetic interaction.
± \ /-/ ±\	VALUE (units 10 ⁻⁵) CL% DOCUMENT ID TECN
$\pi^+\pi^-\gamma)/\Gamma(\pi^+\pi^-)$ Γ_3/Γ_1	< 0.032 90 GJESDAL 73 ASPK
UE (units 10 ⁻³) EVTS DOCUMENT ID TECN COMMENT	 • We do not use the following data for averages, fits, limits, etc. • •
D±0.08 OUR AVERAGE	<14 90 BOHM 69 OSPK
6 ± 0.09 1286 RAMBERG 93 E731 p _{γ} >50 MeV/c	< 0.7 90 HYAMS 698 OSPK
8±0.15 12 TAUREG 76 SPEC p_{γ} >50 MeV/c	<22 90 ²³ STUTZKE 69 OSPK
± 0.6 13 BURGUN 73 HBC $p_{\gamma} > 50 \text{ MeV}/c$	< 7 90 BOTT 67 OSPK
± 1.2 10 WEBBER 70 HBC p_{γ} >50 MeV/c	²³ Value calculated by us, using 2.3 instead of 1 event, 90% CL.
ratio given 27 BELLOTTI 66 HBC p _{\gamma} >50 MeV/c	$\Gamma(e^+e^-)/\Gamma_{\text{total}}$ $\Gamma_{10}/\Gamma_{\text{total}}$
■ We do not use the following data for averages, fits, limits, etc. ■ ■ ■ ■ ■ ■ ■	$\Gamma(e^+e^-)/\Gamma_{\text{total}}$ $\Gamma_{10}/\Gamma_{\text{total}}$ Test for $\Delta S = 1$ weak neutral current. Allowed by first-order weak interaction combine
0 \pm 0.22 3723 RAMBERG 93 E731 p $_{\gamma}$ >20 MeV/c	with electromagnetic interaction.
	VALUE (units 10 ⁻⁷) CL% EVTS DOCUMENT ID TECN COMMENT
• • • • • • • • • • • • • • • • • • • •	< 1.4 90 ANGELOPO 97 CPLR
TAUREG 76 find direct emission contribution <0.06, CL = 90%.	• • • We do not use the following data for averages, fits, limits, etc. • • •
BURGUN 73 estimates that direct emission contribution is 0.3 \pm 0.6. BOBISUT 74 not included in average because p_γ cut differs. Estimates direct emission	
contribution to be 0.5 or less, CL = 95%.	< 28 90 0 BLICK 94 CNTR Hyperon facility < 100 90 BARMIN 86 XEBC
•	<1100 90 BITSADZE 86 CALO
$(\gamma \gamma)/\Gamma_{\text{total}}$ $\Gamma_4/\Gamma_{\text{total}}$	<3400 90 BOHM 69 OSPK
UE (units 10 ⁻⁶) CL% EVTS DOCUMENT ID TECN COMMENT	
2.4±0.9 35 15 BARR 958 NA31	$\Gamma(\pi^0 e^+ e^-)/\Gamma_{\text{total}}$ $\Gamma_{11}/\Gamma_{\text{total}}$
	Test for $\Delta S = 1$ weak neutral current. Allowed by first-order weak interaction combined
	with electromagnetic interaction.
	VALUE (units 10 ⁻⁶) CL% EVTS DOCUMENT ID TECN
	< 1.1 90 0 BARR 938 NA31
	 • • We do not use the following data for averages, fits, limits, etc.
	<45 90 GIBBONS 88 E731

<45

90

GIBBONS

88 E731

CP VIOLATION IN $K_S \rightarrow 3\pi$

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The possible final states for the decay $K^0 \to \pi^+\pi^-\pi^0$ have isospin I = 0, 1, 2, and 3. The I = 0 and I = 2 states have CP = +1 and K_S can decay into them without violating CPsymmetry, but they are expected to be strongly suppressed by centrifugal barrier effects. The I=1 and I=3 states, which have no centrifugal barrier, have CP = -1 so that the K_S decay to these requires CP violation.

In order to see CP violation in $K_S \to \pi^+\pi^-\pi^0$, it is necessary to observe the interference between K_S and K_L decay, which determines the amplitude ratio

$$\eta_{+-0} = \frac{A(K_S \to \pi^+ \pi^- \pi^0)}{A(K_L \to \pi^+ \pi^- \pi^0)} \ .$$

If η_{+-0} is obtained from an integration over the whole Dalitz plot, there is no contribution from the I = 0 and I = 2 final states and a nonzero value of η_{+-0} is entirely due to CPviolation.

Only I = 1 and I = 3 states, which are CP = -1, are allowed for $K^0 \to \pi^0 \pi^0 \pi^0$ decays and the decay of K_S into $3\pi^0$ is an unambiguous sign of CP violation. Similarly to η_{+-0} , η_{000} is defined as

$$\eta_{000} = rac{A(K_S o \pi^0 \pi^0 \pi^0)}{A(K_L o \pi^0 \pi^0 \pi^0)} \; .$$

If one assumes that CPT invariance holds and that there are no transitions to I = 3 (or to nonsymmetric I = 1 states), it can be shown that

$$\eta_{+-0} = \eta_{000}$$

$$= \epsilon + i \frac{\operatorname{Im} a_1}{\operatorname{Re} a_1} \ .$$

With the Wu-Yang phase convention, a1 is the weak decay amplitude for K^0 into I=1 final states; ϵ is determined from CP violation in $K_L \to 2\pi$ decays. The real parts of η_{+-0} and η_{000} are equal to $\mathrm{Re}(\epsilon)$. Since currently-known upper limits on $|\eta_{+-0}|$ and $|\eta_{000}|$ are much larger than $|\epsilon|$, they can be interpreted as upper limits on $\text{Im}(\eta_{+-0})$ and $\text{Im}(\eta_{000})$ and so as limits on the CP-violating phase of the decay amplitude a_1 .

CP-VIOLATION PARAMETERS IN KO DECAY

 $\begin{array}{l} \text{Im}(\eta_{+-0})^2 = \Gamma(K_S^0 \to \pi^+\pi^-\pi^0, \textit{CP-violating}) \; / \; \Gamma(K_L^0 \to \pi^+\pi^-\pi^0) \\ \textit{CPT} \; \text{assumed valid} \; \text{(i.e.} \; \operatorname{Re}(\eta_{+-0}) \simeq \; 0). \end{array}$

VALUE	CL SI	<u>EVTS</u>	DOCUMENT ID		TECN	COMMENT
• • • We do	o not use th	e follow	ing data for average	es, fit	s, ilmits,	etc. • • •
<0.23	90	601	24 BARMIN	85	HLBC	
<1.2	90	192	BALDO	75	HLBC	
<0.71	90	148	MALLARY	73	OSPK	$Re(A) = -0.05 \pm 0.17$
< 0.66	90	180	JAMES	72	HBC	
<1.2	90	99	JONES	72	OSPK	
<0.12	90	384	METCALF	72	ASPK	
<1.2	90	99	CHO	71	DBC	
<1.0	90	98	JAMES	71	HBC	Incl. In JAMES 72
<1.2	95	50	²⁵ MEISNER	71	HBC	CL=90% not avail.
<0.8	90	71	WEBBER	70	HBC	
< 0.45	90		BEHR	66	HLBC	
<3.8	90	18	ANDERSON	65	HBC	Incl. in WEBBER 70
~4						

 $^{^{24}}$ BARMIN 85 find Re($\eta_{+-0})=(0.05\pm0.17)$ and Im($\eta_{+-0})=(0.15\pm0.33)$. Includes events of BALDO-CEOLIN 75.

25 These authors find Re(A) = 2.75 \pm 0.65, above value at Re(A) = 0.

 $Im(\eta_{+-0}) = Im(A(K_S^0 \rightarrow \pi^+\pi^-\pi^0, CP\text{-violating}) / A(K_I^0)$ DOCUMENT ID VALUE EYTS
-0.002±0.008 OUR AVERAGE $-0.002\pm0.009^{+0.002}_{-0.001}$ 500k 26 ADLER -0.002±0.018±0.003 137k 27 ADLER 960 CPLR ● ● We do not use the following data for averages, fits, limits, etc. -0.015±0.017±0.025 272k ²⁸ ZOU 94 SPEC 26 ADLER 97B also find Re(η_{+-0}) = $-0.002 \pm 0.007 ^{+0.004}_{-0.001}$ 27 The ADLER 96D fit also yields Re(η_{+-0}) = 0.006 \pm 0.013 \pm 0.001 with a correlation + 0.66 between real and imaginary parts. Their results correspond to $|\eta_{+-0}| <$ 0.037 28 ZOU 94 use theoretical constraint Re(η_{+-0}) = Re(ϵ) = 0.0016. Without this constraint they find Im(η_{+-0}) = 0.019 \pm 0.061 and Re(η_{+-0}) = 0.019 \pm 0.027.

 $Im(\eta_{000})^2 = \Gamma(K_0^0 \to 3\pi^0) / \Gamma(K_1^0 \to 3\pi^0)$ CPT assumed valid (i.e. $Re(\eta_{000}) \simeq 0$). This limit determines branching ratio

VALUE	CL%	EVT5	DOCUMENT IC		TECN_	COMMENT	
<0.1	90	632	²⁹ BARMIN	83	HLBC		
• • • We do	not use th	e follow	ing data for averag	ges, fit	s, ilmits,	etc. • • •	
<0.28	90		30 GJESDAL	74E	SPEC	Indirect meas.	
<1.2	90	22	BARMIN	73	HLBC		
29 DADAJNI	93 find Dat	·	- /n.ng + n.18) a	nd Im/	- /	(_0.05±0.27)	Assuming

BARMIN 83 find Re(η_{000}) = (-0.08 ± 0.18) and im CPT invariance they obtain the limit quoted above.

 30 GJESDAL 74B uses $K2\pi$, $K_{\mu3}$, and K_{e3} decay results, unitarity, and CPT. Calculates $|(\eta_{000})|$ = 0.26 \pm 0.20. We convert to upper limit.

KO REFERENCES

k references						
ADLER 9	7R	PL B407 193	R. Adler+ (CPLEAR Collab.)			
ANGELOPO 9	7	PL B413 232	A. Angelopoulos+ (CPLEAR Collab.)			
BERTANZA 9		ZPHY C73 629	L. Bertanza (PISA, CERN, EDIN, MANZ, ORSAY, SIEG)			
		PL B370 167	+Alhalel, Angelopoulos+ (CPLEAR Collab.)			
		PL B374 313	+Alhalel, Angelopoulos+ (CPLEAR Collab.)			
ZOU 9		PL B369 362	+Beretvas, Caracappa+ (RUTG, MINN, MICH)			
		PL B351 579	+Buchholz+ (CÉRN, EDIN, MANŽ, LALO, PISA, SIEG) Schwingenheuer+ (EFI, CHIC, ELMT, FNAL, ILL, RUTG)			
SCHWINGEN 9: BLICK 9:		PRL 74 4376 PL B334 234	+Kolosov, Kutjin, Shelikov+ (SERP, JINR)			
THOMSON 9		PL B337 411	+Zou, Beretvas, Caracappa, Devlin+ (RUTG, MINN, MICH)			
ZOU 9		PL B329 519	+ Rezetvas, Caracappa, Devlin + (RUTG, MINN, MICH)			
	3B	PL B304 381	+Buchholz+ (CERN, EDIN, MANZ, LALO, PISA, SIEG) +Barker, Briere, Makoff+ (FNAL E731 Collab.)			
	3	PRL 70 1199	+ Barker, Briere, Makoff+ (FNAL E731 Collab.)			
Also 9	7	PR D55 6625	L.K. Gibbons+ (FNAL E731 Collab.)			
RAMBERG 9		PRL 70 2525	+Bock, Coleman, Enagonio, Hsiung+ (FNAL E731 Collab.)			
BALATS 8	19	SJNP 49 828	+Berezin, Bogdanov, Vishnevskii, Vishnyakov+ (ITEP)			
GIBBONS 8		Translated from PRL 61 2661	+Papadimitriou+ (FNAL E731 Collab.)			
BURKHARDT 8	-	PL B199 139	+ (CERN, EDIN, MANZ, LALO, PISA, SIEG)			
GROSSMAN B		PRL 59 18	+ Heller, James, Shupe+ (MINN, MICH, RUTG)			
BARMIN 6	16	SJNP 44 622	+ Barylov, Davidenko, Demidov+ (ITEP)			
		Translated from	YAF 44 965.			
	6B	NC 96A 159	+Barylov, Chistyakova, Chuvilo+ (ITEP, PADO)			
	6	PL 167B 138	+Budagov (CMNS, SOFI, SERP, TBIL, JINR, BAKU+) Aguilar-Benitez, Porter+ (CERN, CIT+)			
	%B	PL 170B 130				
VASSERMAN 8	16	JETPL 43 588 Translated from	+Golubev, Gluskin, Druzhinin+ (NOVO) 7FTFP 43 457.			
BARMIN 8	15	NC 85A 67	+Barylov, Chistyakova, Chuvilo+ (ITEP, PADO)			
	158	SJNP 41 759	Barmin, Barylov, Volkov+ (ITEP)			
		Translated from	YAF 41 1187.			
	33	PL 128B 129	+Barylov, Chistyakova, Chuvilo+ (ITEP, PADO)			
Also 8	34	SJNP 39 269 Translated from	Barmin, Barylov, Golubchikov+ (ITEP, PADO)			
ARONSON 8	32	PRL 48 1078	+Bernstein+ (BNL, CHIC, STAN, WISC)			
	12B	PRL 48 1306	+Bock, Cheng, Fischbach (BNL, CHIC, PURD)			
	12B	PL 116B 73	Fischback Cheng + (PURD, BNL, CHIC)			
	33	PR D28 476	Aronson, Bock, Cheng+ (BNL, CHIC, PURD) Aronson, Bock, Cheng+ (BNL, CHIC, PURD)			
		PR D28 495	Aronson, Bock, Cheng+ (BNL, CHIC, PURD)			
	76	NC 32A 236	+McIntyre, Roehrig+ (WISC, EFI, UCSD, ILLC)			
	76	PR D14 661	+Kraus, Lande, Long, Lowenstein+ (PENN) +Zech, Dydak, Navarria+ (HEIDH, CERN, DORT)			
	76 75	PL 65B 92 NC 25A 688	Baldo-Ceolin, Boblsut, Calimani+ (PADO, WISC)			
	75	PRL 34 1244	+Modis, Nygren, Pun+ (COLU, NYU)			
	74	LNC 11 646	+Huzita, Mattioli, Puglierin (PADO) +Lee-Franzini, Orcutt, Franzini + (STON, COLU)			
	74	PR D10 2083	+Lee-Franzini, Orcutt, Franzini+ (STON, COLU)			
	74B					
		PL 48B 487	+Gjesdal, Presser+ (CERN, HEIDH)			
GJEJDAL /	748	PL 48B 487 PL 52B 119	+Gjesdal, Presser+ (CERN, HEIDH) +Presser, Steffen+ (CERN, HEIDH)			
BARMIN 7	748 73	PL 52B 119 PL 46B 465	+ Gjesdal, Presser+ (CERN, HEIDH) + Presser, Steffen+ (CERN, HEIDH) + Barylov, Davidenko, Demidov+ (ITEP)			
BARMIN 7	748 73 73B	PL 52B 119 PL 46B 465 PL 47B 463	+ Gjeddal, Presser+ (CERN, HEIDH) + Presser, Steffen+ (CERN, HEIDH) + Barylov, Davidenko, Demidov+ (ITEP) + Barylov, Davidenko, Demidov+ (ITEP)			
BARMIN 7 BARMIN 7 BURGUN 7	748 73 73B 73	PL 52B 119 PL 46B 465 PL 47B 463 PL 46B 481	+Gjesdal, Presser+ (CERN, HEIDH) +Presser, Steffen+ (CERN, HEIDH) +Barylov, Davidenko, Demidov+ (ITEP) +Barylov, Davidenko, Demidov+ (ITEP) +Bertranet, Lesquoy, Mulier, Pauli+ (SACL, CERN)			
BARMIN 7 BARMIN 7 BURGUN 7 FACKLER 7	748 73 73B 73 73	PL 52B 119 PL 46B 465 PL 47B 463 PL 46B 481 PRL 31 847	+ Gjedal, Presser+ (CERN, HEIDH) + Presser, Steffen+ (CERN, HEIDH) + Barylov, Davidenko, Demidov+ (ITEP) + Barylov, Davidenko, Demidov+ (ITEP) + Bertranet, Lesquoy, Muller, Pauli+ (SACL, CERN) + Frisch, Martin, Smoot, Sompayrac (MIT)			
BARMIN 7 BARMIN 7 BURGUN 7 FACKLER 7 GJESDAL 7	748 73 73B 73 73 73	PL 52B 119 PL 46B 465 PL 47B 463 PL 46B 481 PRL 31 847 PL 44B 217	+ Gjedal, Preser+ (CERN, HEIDH) + Presser, Steffen+ (CERN, HEIDH) + Barylov, Davidenko, Demidov+ (ITEP) + Bertranet, Lesquoy, Muller, Pauli+ (SACL, CERN) + Frisch, Martin, Smoot, Sompayrac + Presser, Steffen, Steinberger+ (CERN, HEIDH)			
BARMIN 7 BARMIN 7 BURGUN 7 FACKLER 7 GJESDAL 7 HILL 7	748 73 73B 73 73 73 73	PL 52B 119 PL 46B 465 PL 47B 463 PL 46B 481 PRL 31 847 PL 44B 217 PR D8 1290	+ Gjedal, Presser+ (CERN, HEIDH) + Presser, Steffen+ (CERN, HEIDH) + Barylov, Davidenko, Demidov+ (ITEP) + Bertranet, Lesquoy, Muller, Pauli+ + Frisch, Martin, Smoot, Sompayrac + Presser, Steffen, Steinberger+ (CERN, HEIDH) + Sahkt, Samios, Burnis, Engler+ (BNL, CMU)			
BARMIN 7 BARMIN 7 BURGUN 7 FACKLER 7 GJESDAL 7 HILL 7 MALLARY 7	748 73 73B 73 73 73 73 73	PL 52B 119 PL 46B 465 PL 47B 463 PL 46B 481 PRL 31 847 PL 44B 217 PR D8 1290 PR D7 1953	+ Gjedal, Preser+ (CERN, HEIDH) + Presser, Steffen + (CERN, HEIDH) + Barylov, Davidenko, Demidov+ (ITEP) + Bertranet, Lesquoy, Muller, Pauli+ (SACL, CERN) + Frisch, Martin, Smoot, Sompayrac + Presser, Steffen, Steinberger + (CERN, HEIDH) + Bänit, Samios, Burris, Engler+ (CERN, HEIDH) + Bänit, Gallivan, Gomez, Peck, Sciuli+ (CIT)			
BARMIN 7 BARMIN 7 BURGUN 7 FACKLER 7 GJESDAL 7 HILL 7 MALLARY 7 ALITTI 7	748 73 73B 73 73 73 73 73 73	PL 52B 119 PL 46B 465 PL 47B 463 PL 46B 4B1 PRL 31 847 PL 44B 217 PR D8 1290 PR D7 1953 PL 39B 568	+ Gjedal, Preser+ (CERN, HEIDH) + Presser, Steffen+ (CERN, HEIDH) + Barylov, Davidenko, Demidov+ (ITEP) + Bertnent, Lesquoy, Muller, Paull+ (SACL, CERN) + Frisch, Martin, Smoot, Sompayrac + Presser, Steffen, Steinberger+ (CERN, HEIDH) + Sakht, Samios, Burris, Engler+ (CERN, HEIDH) + Bianile, Galilvan, Gomez, Peck, Sciulii+ (CIT)			
BARMIN 7 BARMIN 7 BURGUN 7 FACKLER 7 GJESDAL 7 HILL 7 MALLARY 7 ALITTI 7 BANNER 7	748 73 73B 73 73 73 73 73	PL 52B 119 PL 46B 465 PL 47B 463 PL 46B 481 PRL 31 847 PL 44B 217 PR D8 1290 PR D7 1953 PL 39B 568 PRL 29 237	+ Gjedal, Presser+ (CERN, HEIDH) + Presser, Steffent (CERN, HEIDH) + Barylov, Davidenko, Demidov+ (ITEP) + Bertranet, Lequoy, Muller, Pauli + (SACL, CERN) + Frisch, Martin, Smoot, Sompayrac + Presser, Steffen, Steinberger + (CERN, HEIDH) + Sakitt, Samios, Burris, Engler + (CERN, HEIDH) + Bianie, Gallivan, Gomez, Peck, Sciulii + (ITE) + Lequoy, Muller, Pauli + (SACL, CERN, OSLO) + Lequoy, Muller, Pauli + (SACL, CERN, OSLO)			
BARMIN 7 BARMIN 7 BURGUN 7 FACKLER 7 GJESDAL 7 HILL 7 MALLARY 7 ALITTI 7 BANGER 7 BURGUN 7	748 73 73B 73 73 73 73 73 72 72B	PL 52B 119 PL 46B 465 PL 47B 463 PL 46B 481 PRL 31 847 PL 44B 217 PR D8 1290 PR D7 1953 PL 39B 568 PRL 29 237 NP B50 194 NP B49 1	+ Gjedal, Presser+ (CERN, HEIDH) + Presser, Steffen + (CERN, HEIDH) + Barylov, Davidenko, Demidov + (ITEP) + Bertranet, Lesquoy, Muller, Pauli+ + Frisch, Martin, Smoont, Sompayrac (MIT) + Presser, Steffen, Steinberger + (CERN, HEIDH) + Sahltt, Samios, Burris, Eagler + (CERN, HEIDH) + Binnie, Gallivan, Gomez, Peck, Sculiii + (CIT) + Lesquoy, Muller + Lesquoy, Muller, Pauli+ + Lesquoy, Muller, Pauli+ + Montanet, Paul, Setter+ (CERN, SACL, OSLO)			
BARMIN 7 BARMIN 7 BURGUN 7 FACKLER 7 GJESDAL 7 HILL 7 MALLARY 7 ALITTI 7 BANNER 7 BURGUN 7 JAMES 7	748 73 73B 73 73 73 73 73 72 72 72 72 72	PL 52B 119 PL 46B 465 PL 47B 463 PL 46B 481 PRL 31 847 PL 44B 217 PR D8 1290 PR D7 1953 PL 39B 568 PRL 29 237 NP B50 194 NP B49 1 NC 9A 151	+ Gjedal, Presser+ (CERN, HEIDH) + Presser, Steffen+ (CERN, HEIDH) + Barylov, Davidenko, Demidov+ (ITEP) + Bertranet, Lesquoy, Muller, Pauli+ + Frisch, Martin, Smoot, Sompayrac + Presser, Steffen, Steinberger+ (CERN, HEIDH) + Sahitt, Samios, Burnis, Engler+ (BNL, CMU) + Bianie, Gallivan, Gomez, Peck, Sciuli+ + Lesquoy, Muller, Pauli+ + (Croolin, Hoffman, Knapp, Shochet + Lesquoy, Muller, Pauli+ + Lesquoy, Muller, Sactret+ + Abassian, Garlann, Mantsch, Orr, Smith+ (ILL)			
BARMIN 7 BARMIN 7 BURGUN 7 FACKLER 7 GJESDAL 7 HILL 7 HILL 7 HALLARY 7 ALITTI BANNER 7 BURGUN 1 JAMES 1 JONES 1 JONES 7 METCALF 7	748 73 73B 73 73 73 73 73 72 72 72 72 72	PL 528 119 PL 46B 465 PL 47B 463 PL 468 481 PRL 31 847 PR D8 1290 PR D7 1953 PL 39B 568 PRL 29 237 NP B50 194 NP B49 1 NP B49 1 PL 40B 703	+ Gjedal, Preser+ (CERN, HEIDH) + Presser, Steffen+ (CERN, HEIDH) + Barylov, Davidenko, Demidov+ (ITEP) + Bertranet, Lespuoy, Muller, Paull+ + Frisch, Martin, Smoont, Sompayrac (MIT) + Presser, Steffen, Steinberger+ (CERN, HEIDH) + Sakhtt, Samion, Burris, Engler+ (CERN, HEIDH) + Bianiè, Galivan, Gomez, Peck, Sciulii+ (CIT) + Lesquoy, Muller, Pauli+ + Lesquoy, Muller, Pauli+ (SACL, CERN, OSLO) + Montanet, Paul, Sestre+ (CERN, SACL, OSLO) + Montanet, Paul, Sestre+ (CERN, SACL, OSLO) + Abesikan, Graham, Mantsch, Orr, Smith+ (ILL) + Neubrofer, Niebergäl+ (CERN, SECN, WIEN)			
BARMIN 7 BARMIN 7 BURGUN 7 FACKLER 7 GJESDAL 7 HILL 7 MALLARY 7 ALITTI BANNER 7 BURGUN 7 JAMES 7 JONES METCALF 7 MORSE 7	748 73 73B 73 73 73 73 73 72 72 72 72 72 72	PL 528 119 PL 468 465 PL 478 463 PL 468 481 PRL 31 847 PL 44B 217 PR D8 1290 PR D7 1953 PL 398 568 PRL 29 237 NP B50 194 NP B49 1 NC 9A 151 PL 408 703 PRL 28 388	+ Gjedal, Presser+ (CERN, HEIDH) + Presser, Steffen+ (CERN, HEIDH) + Barylov, Davidenko, Demidov+ (ITEP) + Bertranet, Lesquoy, Muller, Pauli+ (SACL, CERN, + Frisch, Martin, Smoot, Sompayrac (MIT + Presser, Steffen, Steinberger+ (CERN, HEIDH) + Sahitt, Samios, Burris, Engler+ (CERN, HEIDH) + Bianie, Gallivan, Gomez, Peck, Sciulii+ (CIT) + Lesquoy, Muller (SACL, CERN, DSLO) + Lesquoy, Muller, Pauli+ (SACL, CERN, OSLO) + Montanet, Pauli Setre+ (CERN, SACL, OSLO) + Abassilan, Graham, Matsch, Orr, Smith+ (ILL) + Neubofer, Niebergal+ (CERN, IPN, WIEN) + Nasenberg, Blerman, Sager+ (COLO, PRIN, UMD)			
BARMIN 7 BARMIN 7 BURGUN 7 FACKLER 7 GJESDAL 7 HILL 7 MALLARY 1 ALITTI 7 BANNER 7 BURGUN 7 JAMES 1 JONES 7 METCALF 1 MORSE NAGY 7	748 73 73B 73 73 73 73 73 72 72B 72 72 72 72 72	PL 528 119 PL 468 465 PL 478 463 PL 468 461 PRL 31 847 PR D8 1290 PR D7 1953 PL 398 568 PRL 29 237 NP 850 194 NP 849 1 NC 9A 151 PL 408 703 PRL 28 388 PRL 29 37 NP B49 1 NC 9A 151 PL 408 703 PRL 28 388 PRL 29 37 NP B47 44	+ Gjedal, Preser+ (CERN, HEIDH) + Presser, Steffen+ (CERN, HEIDH) + Barylov, Davidenko, Demidov+ (ITEP) + Bertranet, Lesquoy, Muller, Paull+ + Frisch, Martin, Smoont, Sompayrac (MIT) + Presser, Steffen, Steinberger+ (CERN, HEIDH) + Sakhitt, Samios, Burnis, Engler+ (CERN, HEIDH) + Binnie, Gallivan, Gomez, Peck, Sciulii+ + Lesquoy, Muller, Paull+ + Lesquoy, Muller, Paull+ + Lesquoy, Muller, Paull+ + Hondanet, Paul, Seetre+ (CERN, SACL, OSLO) + Montanet, Paul, Seetre+ - (CERN, SACL, OSLO) + Neubrofer, Niebergal+ + Neubrofer, Niebergal+ + Neubrofer, Niebergal+ + Hobstack, Osto, PRIN, MEN) + Telbizz, Vestergombi (CEND, SACL) - KERN, MEN - KEIDH - KEI			
BARMIN 7 BARMIN 7 BURGUN 7 FACKLER 7 GJESDAL 7 GJESDAL 7 HILL 7 MALLARY 7 ALITTI 7 BANNER 7 BURGUN 7 JAMES 7 JONES 7 METCALF 7 MORSE 7 ALSO 66	748 773 773B 773 773 773 773 772 772 772 772 772 772	PL 528 119 PL 45B 465 PL 47B 463 PL 488 481 PL 488 481 PR 131 PR 28 1290 PR D7 1953 PL 398 560 PR 27 1953 PL 398 560 PR 27 1953 PL 398 580 PR 398 1 NC 9A 151 PL 408 703 PRL 28 388 NP 847 94 PL 308 498	+ Gjedal, Preser+ (CERN, HEIDH) + Presser, Steffen + (CERN, HEIDH) + Barylov, Davidenko, Demidov+ (ITEP) + Bertranet, Lesquoy, Muller, Pauli+ (SACL, CERN) + Frisch, Martin, Smoot, Sompayrac + Presser, Steffen, Steinberger+ (CERN, HEIDH) + Sakitt, Samios, Burris, Engler+ (CERN, HEIDH) + Bianie, Gallivan, Gomez, Peck, Sciuli+ (CIT) + Lesquoy, Muller + Lesquoy, Muller + Lesquoy, Muller, Pauli+ (SACL, CERN, OSLO) + Montanet, Paul, Saetre+ (CERN, SACL, OSLO) + Mossikan, Graham, Mantsch, Orr, Smith+ (ILL) + Neubrofer, Niebergal+ (CERN, IPN, MIEN) + Naesnberg, Blerman, Sager+ (COLO, PRIN, UMD) + Telbisz, Vestergombi Bozoki, Feayyes, Gombosi, Nagy+ (BUDA)			
BARMIN 7 BARMIN 7 BURGUN 7 FACKLER 7 GJESDAL 7 HILL MALLARY 7 ALITTIE 7 BANNER 7 JAMES 7 JAMES 7 JONES 7 METCALF 7 MORSE NAGY ALSO SKJEGGEST 7	748 73 73B 73B 73 73 73 73 73 77 72 72 72 72 72 72 72 72 72 72 72 72	PL 528 119 PL 468 465 PL 47B 463 PL 468 481 PRL 518 47 PRL 51 847 PR D6 1290 PR D7 1953 PR 1290 PR D7 1953 PR 129 237 NP 850 194 NP 849 1 NC 9A 151 PL 408 703 PRL 28 388 NP 847 94 PL 308 496 PR 130 498 PR 130 498 PR 130 498 PR 140 503	+ Gjedal, Preser+ (CERN, HEIDH) + Presser, Steffen+ (CERN, HEIDH) + Barylov, Davidenko, Demidov+ (ITEP) + Bertranet, Lesquoy, Muller, Pauli+ + Frisch, Martin, Smoon, Sompayrac (MIT) + Presser, Steffen, Steinberger+ (SACL, CERN) + Sakit, Samios, Burnis, Engler+ + Sakit, Samios, Burnis, Engler+ + Bianile, Gallivan, Gomez, Pech, Sciulii+ + Lesquoy, Muller, Pauli+ + Lesquoy, Muller, Pauli+ + Lesquoy, Muller, Pauli+ + Montanet, Paul, Sachtsch, Orr, Smith+ (ILL) + Montanet, Paul, Sachtsch, Orr, Smith+ (ILL) + Neubrofer, Niebergal, + Nasenberg, Blerman, Sager+ + Hondrofer, Niebergal, + Hondrofer, Niebergal, + Burnis, Sager+ + Roberg, Serves, Gombols, Nagy+ Skjegerstad, James+ (OSLO, CERN, SACL)			
BARMIN 7 BALLARY 7 ALITTI 8 BURGUN 1 JAMES 1 JONES 1 MORSE 1 NACY ALITTI 1 BURGUN 1 SAME S SKIEGGEST 3 BALTAY 8 BALTAY 8 BARMIN 7 BALTAY 9 BARMIN 7 BARMIN 7 BALTAY 9 BARMIN 7 BARMI	748 73 73B 73B 73 73 73 73 73 77 72 72 72 72 72 72 72 72 72 72 72 72	PL 528 119 PL 45B 465 PL 47B 463 PL 488 481 PL 488 481 PL 488 217 PL 488 217 PL 398 568 PRL 29 237 NP 850 194 NP 849 1 NC 9A 151 PL 408 703 PRL 72 388 NP 847 94 PL 308 489 NP 848 343 PRL 27 1678	+ Gjedal, Preser+ (CERN, HEIDH) + Presser, Steffen+ (CERN, HEIDH) + Barylov, Davidenko, Demidov+ (ITEP) + Bertranet, Lesauoy, Muller, Pauli+ (SACL, CERN) + Firsch, Martin, Smoot, Sompayrac + Fresser, Steffen, Steinberger+ (CERN, HEIDH) + Bianie, Gallivan, Comer, Peck, Sciuli+ (CIT) + Lesquoy, Muller + Croolin, Hoffman, Knapp, Shochet + Lesquoy, Muller, Pauli+ (SACL, CERN, OSLO) + Montanet, Paul, Sactte+ (CERN, SACL, OSLO) + Montanet, Paul, Sactte+ (CERN, SACL, OSLO) + Newberg, Blerman, Sager+ (COLO, PRIN, MID) + Telbáz, Vestergombi - Bozoki, Feayves, Gombosi, Nagy+ - Skjeggestad, James+ - (OSLO, CERN, SACL) - Bildfewater, Cooper, Geshwin, Habibi+			
BARMIN 7 BARMIN 7 BURGUN 7 FACKLER 7 GJESDAL 7 HILL BANNER 8 BURGUN 7 JAMES 1 JAMES 1 JAMES 7 METCALF MORSE NAGY ALSO 5 SKJEGGEST 3 BALTAY ALSO 7	748 73 73B 73B 73 73 73 73 73 77 72 72 72 72 72 72 72 72 72 72 72 72	PL 528 119 PL 468 465 PL 47B 463 PL 468 481 PRL 518 47 PRL 51 847 PR D6 1290 PR D7 1953 PR 1290 PR D7 1953 PR 129 237 NP 850 194 NP 849 1 NC 9A 151 PL 408 703 PRL 28 388 NP 847 94 PL 308 496 PR 130 498 PR 130 498 PR 130 498 PR 140 503	+ Gjedal, Presser+ (CERN, HEIDH) + Presser, Steffen + (CERN, HEIDH) + Barylov, Davidenko, Demidov+ (ITEP) + Bertranet, Lesquoy, Malfer, Pauli+ (SACL, CERN) + Frisch, Martin, Smoot, Som payrac + Presser, Steffen, Steinberger+ (CERN, HEIDH) + Sahitt, Samisos, Burris, Engler+ (CERN, HEIDH) + Binnie, Galivan, Gomez, Peck, Sculii+ (CIT) + Lesquoy, Muller + Lesquoy, Muller, Pauli+ (SACL, CERN, OSLO) + Lesquoy, Muller, Pauli+ (SACL, CERN, OSLO) + Montanet, Paul, Sactre+ (CERN, SACL, OSLO) + Montanet, Paul, Sactre+ (CERN, SACL, OSLO) + Nasenberg, Blerman, Sager+ (COLO, PRIN, UMD) + Telbäz, Vestergombi - Bozobi, Fenyves, Gombosi, Nagy+ - Skjeggestad, James+ - Bidgewater, Cooper, Geshwin, Habibi+ (COLU) Cooper - Cooper - Cooper - COUL, CAM, Bid, CASE, CERN, SACL - Cooper - Cooper - COUL, CAM, Bid, CASE, COM, SACL - COOPER, Canter, Engler, Fisk+ (CMU, BNL, CASE)			
BARMIN 7 BALTAY 7 ALITTI 8 BURGUN 1 JAMES 1 JONES MORSE 1 MORSE NAGY Abo SKIEGGEST 2 BALTAY Ako CHO	748 73 73B 73B 73 73 73 77 77 77 77 77 77 77 77 77 77	PL 528 119 PL 45B 445 PL 47B 463 PL 47B 463 PL 47B 461 PRL 31 847 PL 44B 217 PR D8 1290 PR D7 1953 PR 129 237 NP 850 194 NP 849 1 NC 9A 151 PL 40B 703 PRL 73 388 NP B47 94 PL 30B 499 NP B47 34 PR 127 1678 PR D8 155 PR D8 159 PR 128 388 PR 127 1678 PR 138 388 PR 127 1678 PR 138 343 PRL 27 1678 PR 138 155 PR	+ Gjedal, Preser+ (CERN, HEIDH) + Presser, Steffen+ (CERN, HEIDH) + Barylov, Davidenko, Demidov+ (ITEP) + Bertranet, Lesquoy, Muller, Pauli+ (SACL, CERN, HEIDH) + Frisch, Martin, Smoon, Sompayrac (MIT) + Frisch, Martin, Smoon, Sompayrac (MIT) + Sakitt, Samios, Burnis, Engler+ (BNL, CMU) + Sakitt, Samios, Burnis, Engler+ (BNL, CMU) + Bianie, Gallivan, Gomer, Peck, Sciulii+ (CERN, HEIDH) + Lesquoy, Muller, Pauli+ (GERN, SACL, CERN, OSLO) + Croain, Hoffman, Knapp, Shochet + Lesquoy, Muller, Pauli+ (CERN, SACL, OSLO) + Montanet, Paul, Sactre+ (CERN, SACL, OSLO) + Montanet, Paul, Sactre+ (CERN, IPN, WIEN) + Neubrofer, Niebergal, Sactre+ (COLO, PRIN, UMD) - Boxobi, Fesyves, Gombosi, Nagy+ - Bridgevater, Cooper, Gershwin, Habibi+ (COLU) + Bridgevater, Cooper, Gershwin, Habibi+ (COLU) + Draile, Canter, Engler, Fisk+ (CERN, SACL, OSLO)			
BARMIN 7 BURGUN 7 BURGUN 7 FACKLE 7 GJESDAL 7 HILL 7 ALITTI 8 BURGUN 1 JAMES 1 JONES METCALF MORSE 1 NAGY ALITAY A	748 73 73B 73B 73 73 73 77 77 77 77 77 77 77 77 77 77	PL 528 119 PL 45B 445 PL 47B 463 PL 47B 463 PL 47B 461 PRL 31 847 PR 08 1290 PR 07 1953 PL 398 568 PRL 29 237 NP B50 194 NP B49 1 NC 9A 151 PL 40B 703 PRL 29 388 NP B47 94 PR 12 388 NP B47 94 PR 12 388 NP B47 94 PR 13 888 PR 12 71 1678 Theiss Nevis 18* PR 03 1557 PR 03 1557 PR 03 1557 PR 03 559	+ Gjedal, Preser+ (CERN, HEIDH) + Presser, Steffen + (CERN, HEIDH) + Barylov, Davidenko, Demidov+ (ITEP) + Bertranet, Lesquoy, Muller, Pauli+ (SACL, CERN) + Fisch, Martin, Smoont, Sompayrac (MIT) + Presser, Steffen, Steinberger+ (CERN, HEIDH) + Sahitt, Samisos, Burris, Eagler+ (CERN, HEIDH) + Bianie, Galivan, Gomez, Peck, Sculii+ (CIT) + Lesquoy, Muller, Pauli+ (SACL, CERN, OSLO) + Lesquoy, Muller, Pauli+ (SACL, CERN, OSLO) + Montanet, Paul, Sactre+ (CERN, SACL, OSLO) + Montanet, Paul, Sactre+ (CERN, SACL, OSLO) + Naeenberg, Blerman, Sager+ (CERN, SACL) + Neubofer, Niebergal+ (COLO, PRIN, UMD) + Telbizz, Vestergombi - Bozoki, Feayves, Gombosi, Nagy+ - Skjeggertad, James+ (OSLO, CERN, SACL) - Bridgewater, Cooper, Gershwin, Habbibi (COLU) - Cooper (COLU) - Draile, Canter, Engler, Fisk+ (CMU, BNL, CASE) + Montanet, Paul, Pauli+ (CERN, SACL, OSLO) - MASA, BNL, VALE)			
BARMIN 7 BURGUN 7 FACKLER 7 GJESDAL 1 HILL BANNER 1 BURGUN 1 JAMES 1 JAMES 7 ALITTI 7 BURGUN 1 JAMES 7 ALITTI 7 BURGUN 1 JAMES 7 ALITTI 7 BURGUN 1 JAMES MEISNER MEISNER MEISNER MEISNER REPELLIN	748 773 773 773 773 773 772 772 772 772 772	PL 528 119 PL 45B 445 PL 47B 463 PL 47B 463 PL 47B 461 PRL 31 847 PL 44B 217 PR D8 1290 PR D7 1953 PR 129 237 NP 850 194 NP 849 1 NC 9A 151 PL 40B 703 PRL 23 388 NP 847 94 PL 30B 498 NP 848 343 PRL 27 1678 Thesis Newis 181 PR D3 1557 PR D3 1557 PR D3 1557 PR D3 559 PR 359 PR	+ Gjedal, Presser+ (CERN, HEIDH) + Presser, Steffen+ (CERN, HEIDH) + Barylov, Davidenko, Demidov+ (ITEP) + Bertranet, Lesquoy, Muller, Pauli+ + Frisch, Martin, Smoon, Sompayrac (MIT) + Frisch, Martin, Smoon, Sompayrac (MIT) + Salvit, Samion, Burnis, Engler+ (BNL, CMU) + Bianie, Gallivan, Gomer, Peck, Sciuli+ + Lesquoy, Muller, Pauli+ + Lesquore, Muller, Pauli+ + Lesquore, Muller, Pauli+ + Montanet, Paul, Saetre+ (CERN, SACL, OSLO) + Montanet, Paul, Berman, Sager+ + Rosenberg, Blerman, Sager+ + Rosenberg, Blerman, Sager+ + Bindgewater, Cooper, Gershwin, Habibi+ (COLU) - Cooper + Dralle, Canter, Engler, Fisk+ - Montanet, Paul, Pauli+ + (CERN, SACL, OSLO) + Mann, Hertzbach, Kofler- + Wolff, Choliet, Galliard, Jane+ + Wolff, Choliet, Galliard, Jane+ + (ORSAY, CERN)			
BARMIN 7 BURGUN 7 FACKLE 7 GJESDAL 7 HILL 7 MALLARY 7 ALITTI 8 BURGUN 1 JAMES 1 JONES METCALF MORSE NACY 1 METCALF MORSE NACY 1 KENDER METCALF MORSE NACY 1 METCALF MORSE REPELLIN MORSE REPELLIN MOFFETT MORSE NACY 1 METCALF METCALF METCALF NACY 1 METCALF METCALF NACY 1 METCALF NACY	748 738 738 737 737 773 772 772 772 772 772 772 771 771 771 771	PL 528 119 PL 458 465 PL 478 463 PL 478 461 PRL 31 847 PR 08 1290 PR 07 1953 PL 398 568 PRL 29 237 NP 850 194 NP 849 NP 949 151 PL 408 703 PRL 29 388 NP 847 94 PR 130 849 PR 130 849 PR 130 849 PR 130 859 PR 136 859 PR 33 559 PR 348 603 849 PR 349 PR 34 357 PR 35 557 PR 35 555	+ Gjedal, Preser+ (CERN, HEIDH) + Presser, Steffen+ (CERN, HEIDH) + Barylov, Davidenko, Demidov+ (ITEP) + Bertranet, Lespuoy, Muller, Pauli+ (SACL, CERN, HEIDH) + Firsch, Martin, Smoont, Sompayrac (MIT) + Presser, Steffen, Steinberger+ (CERN, HEIDH) + Salkitx, Samios, Burris, Engler+ (CERN, HEIDH) + Bianiè, Galivan, Comez, Peck, Sciulii+ (CIT) + Lesquoy, Muller, Pauli+ (SACL) + Lesquoy, Muller, Pauli+ (CERN, SACL, CERN, OSLO) + Hontanet, Paul, Seatre+ (CERN, SACL, OSLO) + Hontanet, Paul, Seatre+ (CERN, SACL, OSLO) + Holder, Niebergal+ (CERN, SACL, OSLO) + Telbiz, Vestergombi Bozobi, Feayves, Gombosi, Nagy+ + Holder, Vestergombi Bozobi, Feayves, Gombosi, Nagy+ + Bridgewater, Cooper, Gershwin, Habibi+ (COLU) + Draile, Canter, Engler, Fisk+ + Montanet, Paul, Pauli+ (CERN, SACL, OSLO) + Draile, Canter, Engler, Fisk+ + Montanet, Paul, Pauli+ (CERN, SACL, OSLO) + Wasie, Miller, Galilard, Jane+ + Gobbj, Green, Hakel, Rosen (ORSAY, CERN)			
BARMIN 7 BURGUN 7 FACKLER 7 GJESDAL 1 HILL MALLARY 1 ALITIT 7 BURGUN 1 JAMES 1 JONES 1 METCALF MORSE 1 MACY ALIO ALITAY ALITAY 1 METCALF MORSE 1 BALTAY ALIO JONES 1 JAMES MEISNER MEISNER MEISNER MEISNER MEPELLIN MOFFETT WEBBER 1	748 773 773 773 773 773 772 772 772 772 772	PL 528 119 PL 45B 445 PL 47B 463 PL 47B 463 PL 47B 461 PRL 31 847 PL 44B 217 PR D8 1290 PR D7 1953 PR 129 237 NP 850 194 NP 849 1 NC 9A 151 PL 40B 703 PRL 23 388 NP 847 94 PL 30B 498 NP 848 343 PRL 27 1678 Thesis Newis 181 PR D3 1557 PR D3 1557 PR D3 1557 PR D3 559 PR 359 PR	+ Gjedal, Presser+ (CERN, HEIDH) + Presser, Steffen+ (CERN, HEIDH) + Barylov, Davidenko, Demidov+ (ITEP) + Bertranet, Lesquoy, Muller, Pauli+ + Frisch, Martin, Smoon, Sompayrac (MIT) + Frisch, Martin, Smoon, Sompayrac (MIT) + Salitt, Samios, Burnis, Engler+ (BNL, CMU) + Bianie, Gallivan, Gomez, Peck, Sciuli+ + Lesquoy, Muller, Pauli+ + Montanet, Paul, Sectret- + Abasahan, Graham, Mantsch, Orr, Smith+ (CERN, IPN, WIEN) - Burnand, Gomes, Martin, Janibi+ - Gobol, Fenyeet, Gomboul, Nagy+ - Bridgevater, Cooper, Gershwin, Habibi+ - Cooper - Dralle, Gamer, Engler, Fisk+ - Montanet, Paul, Pauli+ - Hoolt, Chollet, Galliard, Jane+ - Hwolf, Chollet, Galliard, Jane+ - Hwolf, Chollet, Galliard, Jane+ - Hoolbi, Green, Hakel, Rosen - Gomes, Cern, Scot, Oslo) - (IRL)			

K_s^0 , K_L^0

BANNER	69	PR 188 2033	+Cronin, Liu, Pilcher	(PRIN)
вонм	69	Thesis	,,	(AACH)
BOZOKI	69	PL 30B 498	+Fenyves, Gombosi, Nagy+	(BUDA)
DOYLE	69	Thesis UCRL 18139	, , , , , , , , , , , , , , , , , , , ,	(LRL)
GOBBI	69	PRL 22 682	+Green, Hakel, Moffett, Rosen+	(RÒCH)
HYAMS	69B	PL 29B 521	+Koch, Potter, VonLindern, Lorenz+	(CERN, MPIM)
MORFIN	69	PRL 23 660	+Sinclair	(MICH)
STUTZKE	69	PR 177 2009	+Abashian, Jones, Mantsch, Orr, Smith	` (ILL)
DONALD	68B	PL 27B 58		ERN, IPNP, CÒEF)
HILL	68	PR 171 1418	+Robinson, Sakitt+	(BNL, CMU)
BOTT	67	PL 24B 194	Bott-Bodenhausen, DeBouard, Cassel+	(CERN)
ALFF	66B	PL 21 595	Alff-Steinberger, Heuer, Kleinknecht+	(CERN)
BEHR	66	PL 22 540	+Brisson, Petiau+ (EPOL, MIL	A, PADO, ÒRSAY)
BELLOTTI	66	NC 45A 737	+Pullia, Baldo-Ceolin+	(MILA, PADO)
KIRSCH	66	PR 147 939	+Schmidt	(COLU)
ANDERSON	65	PRL 14 475	+Crawford, Golden, Stern, Binford+	(LRL, WISC)
AUBERT	65	PL 17 59	+Behr, Canavan, Chounet+	(EPOL, ORSAY)
BROWN	63	PR 130 769	+Kadyk, Trilling, Roe+	(LRL, MICH)
CHRETIEN	63	PR 131 2208		ROW, HARV, MIT)
ANDERSON	62B	CERN Conf. 836	+Crawford+	(LRL)
BROWN	61	NC 19 1155	+Bryant, Burnstein, Glaser, Kadyk+	(MICH)
BAGLIN	60	NC 18 1043	+Bloch, Brisson, Hennessy+	(EPOL)
COLUMBIA	60B	Rochester Conf. 727	Schwartz+	(COLU)
CRAWFORD	59B	PRL 2 266	+Cresti, Douglass, Good, Ticho+	(LRL)
BOLDT	58B	PRL 1 150	+Caldwell, Pal	(MIT)
		OTHE	R RELATED PAPERS	_
LITTENDEDC	0.3	ADNOS 42 700	1 Valencia	(DNI ENAL)

LITTENBERG Rare and	93 Radia	ARNPS 43 729 Live Kaon Decays	+Valencia	(BNL, FNAL)
BATTISTON	92	PRPL 214 293 pectives of K Decay Phy	+Cocolicchio, Fogli, Paver	(PGIA, CERN, TRSTT)
TRILLING Updated 1	65B from 1	UCRL 16473 965 Argonne Conference	page 115.	(LRL)
CRAWFORD	62	CERN Conf. 827		(LRL)
FITCH	61	NC 22 1160	+Piroue, Perkins	(PRIN, LASL)
GOOD	61	PR 124 1223	+Matsen, Muller, Piccioni+	(LRL)
BIRGE	60	Rochester Conf. 601	+Ely+	(LRL, WISC)
MULLER	60	PRL 4 418	+Birge, Fowler, Good, Piccioni+	(LRL, BNL)



 $I(J^P) = \frac{1}{2}(0^-)$

mK0 - mK0

For earlier measurements, beginning with GOOD 61 and FITCH 61, see our 1986 edition, Physics Letters 170B 132 (1986).

OUR FIT is described in the note on "Fits for K^0_L CP-Violation Parameters" in the K_I^0 Particle Listings.

VALUE (1010 h s-1)	DOCUMENT ID		TECN	COMMENT
0.5301±0.0014 OUR FIT				
0.5311±0.0019 OUR AVE	RAGE Error inc	ludes	scale fa	ctor of 1.2.
0.5274±0.0029 ±0.0005	1 ADLER	95	CPLR	
0.5297 ± 0.0030 ± 0.0022	² SCHWINGEN	.95	E773	20~160 GeV K beams
0.5257±0.0049 ±0.0021	² GIBBONS	93C	E731	20-160 GeV K beams
$0.5340 \pm 0.00255 \pm 0.0015$	³ GEWENIGER	74C	SPEC	Gap method
0.5334±0.0040 ±0.0015	³ GJESDAL	74	SPEC	Charge asymmetry in K ₁₃
0.542 ±0.006	CULLEN	70	CNTR	
• • • We do not use the fo	llowing data for a	avera	ges, fits,	limits, etc. • • •
0.5307±0.0013	4 ADLER	96 C	RVUE	
0.5286 ± 0.0028	⁵ GIBBONS	93	E731	20~160 GeV K beams
0.482 ±0.014	⁶ ARONSON	82 8	SPEC	E=30-110 GeV
0.534 ±0.007	⁷ CARNEGIE	71	ASPK	Gap method
0.542 ±0.006	⁷ ARONSON	70	ASPK	Gap method
1	^			

- 1 ADLER 95 uses \overline{K}_{e3}^0 and K_{e3}^0 strangeness tagging at production and decay.

 2 Fits Δm and ϕ_{+-} simultaneously. GIBBONS 93C systematic error is from B. Winstein via private communitication.

 3 These two experiments have a common systematic error due to the uncertainty in the momentum scale, as pointed out in WAHL 89.

 4 ADLER 96C is the result of a fit which includes nearly the same data as entered into the "OUR FIT" value above.

 5 GIBBONS 93 value assume $\phi_{+-} = \phi_{00} = \phi_{\text{SW}} = (43.7 \pm 0.2)^{\circ}$.

 6 ARONSON 82 find that Δm may depend on the kaon energy.

 7 ARONSON 70 and CARNEGIE 71 use K_{0}° mean life = $(0.862 \pm 0.006) \times 10^{-10}$ s. We have not attempted to adjust these values for the subsequent change in the K_{0}° mean have not attempted to adjust these values for the subsequent change in the K^0_S mean If e or in η_{+-} .

KO MEAN LIFE

	E (10 ^{−8} s) ±0.04		DOCUMENT ID	of 1	TECN
		OUR AVERAGE	uucs scale lactor	01 1	
5.15	4±0.044	0.4M	VOSBURGH	72	CNTR
5.15	± 0.14		DEVLIN	67	CNTR
• •	 We do 	not use the following	data for average	es, fits	i, limits, etc. • • •
5.0	±0.5		⁸ LOWYS	67	HLBC
6.1	+1.5 -1.2	1700	ASTBURY	65 C	CNTR
5.3	±0.6		FUJII	64	OSPK
5.1	$^{+2.4}_{-1.3}$	15	DARMON	62	FBC
8.1	+3.2 -2.4	34	BARDON	58	CNTR
8	Sum of pa	ortial decay rates.			

κî	DECAY	MODES
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	Mode	Fraction (Γ_I/Γ)	Scale factor/ Confidence level
$\overline{\Gamma_1}$	$3\pi^{0}$	(21.12 ±0.27) %	S=1.1
Γ_2	$\pi^+\pi^-\pi^0$	(12.56 ±0.20) %	S=1.7
Ţ. ₃	$\pi^{\pm}\mu^{\mp} u$	[a] (27.17 ±0.25)%	S=1.1
	Called $K_{\mu 3}^0$.		
Γ4	$\pi^-\mu^+ u_{\mu}$		
Γ_5	$\pi^+\mu^-\overline{\nu}_{\mu}$		
Γ ₆	$\pi^{\pm} e^{\mp} \nu_e$	[a] (38.78 ±0.27)%	S=1.1
-	Called $K_{e3}^{\bar{0}}$.	,,,,	
Γ_7	$\pi^-e^+ u_e$		
Γ8	$\pi^+e^-\overline{ u}_e$		
۲9	2γ	(5.92 ±0.15)×1	10-4
Γ10	3γ	< 2.4 × 1	10 ⁻⁷ CL=90%
۲ ₁₁	$\pi^0 2\gamma$	[b] $(1.70 \pm 0.28) \times 1$	10-6
	$\pi^0\pi^{\pm}e^{\mp}\nu$	[a] $(5.18 \pm 0.29) \times 1$	_
Γ ₁₃	$(\pi \mu atom) \nu$	(1.06 ±0.11)×	
Γ ₁₄	$\pi^{\pm}e^{\mp} u_{e}\gamma$	$[a,b,c]$ (3.62 $^{+0.26}_{-0.21}$) \times 3	10-3
Γ15	$\pi^+\pi^-\gamma$	$[b,c]$ (4.61 \pm 0.14) \times 1	lo ⁻⁵
Γ16	$\pi^0\pi^0\gamma$	< 5.6 × 1	₁₀ –6

Charge conjugation \times Parity (CP, CPV) or Lepton Family number (LF)

	Aloranus modes or 772 =	T Meg	K INSUI	uai cui	ueur (31) Mode	•
Γ ₁₇	$\pi^+\pi^-$	CPV		(2.067	±0.03	5) × 10 ⁻³	S=1.1
Γ ₁₈	$\pi^0\pi^0$	CPV		(9.36	±0.20	$) \times 10^{-4}$	
Γ ₁₉	$\mu^+\mu^-$	51		(7.2	±0.5) × 10 ⁻⁹	S=1.4
Γ ₂₀	$\mu^+\mu^-\gamma$	SI		(3.25	±0.28	$) \times 10^{-7}$	
Γ ₂₁	e ⁺ e ⁻	S1	<	4.1		$\times 10^{-11}$	CL=90%
Γ ₂₂	$e^+e^-\gamma$	51		(9.1	±0.5) × 10 ⁻⁶	
Γ ₂₃	$e^+e^-\gamma\gamma$	51	[b]	(6.5	±1.2) × 10 ⁻⁷	
Γ ₂₄	$\pi^+\pi^-e^+e^-$	51	[b] <	4.6		× 10 ⁻⁷	CL=90%
Γ ₂₅	$\mu^{+}\mu^{-}e^{+}e^{-}$	51		(2.9	+6.7 -2.4) × 10 ⁻⁹	
Γ ₂₆	e+ e- e+ e-	S1		(4.1	±0.8) × 10 ⁻⁸	S=1.2
Γ_{27}	$\pi^{0} \mu^{+} \mu^{-}$	CP,S1				× 10 ⁻⁹	CL=90%
Γ ₂₈	$\pi^{0}e^{+}e^{-}$	CP,S1	[d] <	4.3		× 10 ⁻⁹	CL=90%
Γ29	$\pi^0 \nu \overline{\nu}$	CP,S1	[e] <	5.8		$\times 10^{-5}$	CL=90%
	$e^{\pm}\mu^{\mp}$	LF	[a] <	3.3		$\times 10^{-11}$	CL=90%
Γ31	$e^{\pm}e^{\pm}\mu^{\mp}\mu^{\mp}$	LF	[a] <	6.1		× 10 ⁻⁹	CL=90%

- [a] The value is for the sum of the charge states of particle/antiparticle states indicated.
- [b] See the Particle Listings below for the energy limits used in this measure-
- [c] Most of this radiative mode, the low-momentum γ part, is also included in the parent mode listed without γ 's.
- [d] Allowed by higher-order electroweak interactions.
- [e] Violates CP in leading order. Test of direct CP violation since the indirect CP-violating and CP-conserving contributions are expected to be suppressed.

CONSTRAINED FIT INFORMATION

An overall fit to the mean life, 4 decay rate, and 12 branching ratios uses 46 measurements and one constraint to determine 8 parameters. The overall fit has a $\chi^2=41.2$ for 39 degrees of

The following off-diagonal array elements are the correlation coefficients $\langle \delta p_i \delta p_j \rangle / (\delta p_i \cdot \delta p_j)$, in percent, from the fit to parameters p_i , including the branching fractions, $x_i \equiv \Gamma_i/\Gamma_{\rm total}$. The fit constrains the x_i whose labels appear in this array to sum to one.

	Mode	Rate (10 ⁸ s ⁻¹)	Scale factor
Γ ₁	$3\pi^0$	0.0408±0.0006	
Γ_2	$\pi^{+}\pi^{-}\pi^{0}$	0.0243 ± 0.0004	1.5
Γ ₃	$\pi^{\pm}\mu^{\mp}\nu$ Called $K^0_{\mu 3}$.	[a] 0.0525 ± 0.0007	1.1
Γ ₆	$\pi^{\pm} e^{\mp} \nu_e$ Called K_{e3}^0 .	[a] 0.0750 ± 0.0008	1.1
Го	2γ	$(1.144 \pm 0.031) \times 10^{-4}$	
Γ ₁₇	$\pi^+\pi^-$	$(4.00 \pm 0.07) \times 10^{-4}$	1.1
Γ ₁₈	$\pi^{0}\pi^{0}$	$(1.81 \pm 0.04) \times 10^{-4}$	

K? DECAY RATES

		-			
Γ(3π ⁰)					r ₁
VALUE (10 ⁶ s ⁻¹)	EVTS	DOCUMENT ID		TECN	COMMENT
4.08±0.06 OUR FIT					
5.22 ^{+1.03} -0.84	54	BEHR	66	HLBC	Assumes CP
$\Gamma(\pi^+\pi^-\pi^0)$					Γ ₂
VALUE (106 s-1)	EVTS	DOCUMENT ID		TECN	COMMENT
2.43±0.04 OUR FIT	Error inclu	des scale factor of	1.5.		
2.38±0.09 OUR AVE	RAGE				
$2.32^{+0.13}_{-0.15}$	192	BALDO	75	HLBC	Assumes CP
2.35 ± 0.2Q	180	⁹ JAMES	72	HBC	Assumes CP
2.71±0.28	99	сно	71	DBC	Assumes CP
2.12±0.33	50	MEISNER	71	HBC	Assumes CP
2.20±0.35	53	WEBBER	70	HBC	Assumes CP
2.62 ^{+0.28} _{-0.27}	136	BEHR	66	HLBC	Assumes CP
• • • We do not use	the following	g data for average	s, fit	s, limits,	etc. • • •
2.5 ±0.3	98	9 JAMES	71	нвс	Assumes CP
3.26±0.77	18	ANDERSON	65	HBC	
1.4 ±0.4	14	FRANZINI	65	HBC	
	rate is well	determined by t	he n	nean life	and the branching ratio
$\Gamma(\pi^+\pi^-\pi^0)$	$\Gamma(\pi^{+}\pi^{-}\pi^{0})$	$) + \Gamma(\pi^{\pm}\mu^{\mp}\nu)$	+ 1	$(\pi^{\pm}e^{\mp}$	$\nu_e)$. For this reason the
of the overall fi		τ'π π ³) measu	reme	nts does	not affect the scale factor
⁹ JAMES 72 is a fli	nal measuren	nent and includes	JAM	ES /1.	

VALUE (10 ⁶ s ⁻¹)	EVT5	DOCUMENT II	D	TECN		
5.25±0.07 OUR FI	T Error Inclu	des scale factor	of 1.1.			
• • • We do not u	se the followin	g data for avera	ges, fit	s, Ilmits,	etc. • • •	
$4.54^{+1.24}_{-1.08}$	19	LOWYS	67	HLBC		
$\Gamma(\pi^{\pm}e^{\mp}\nu_{e})$					г	6
VALUE (10 ⁶ s ⁻¹)	EVTS	DOCUMENT I	D	TECN	COMMENT	_
7.50±0.08 OUR FI	T Error Inclu	des scale factor	of 1.1.			
7.7 ±0.5 OUR A	/ERAGE					
7.81 ± 0.56	620	CHAN	71	HBC		
7 52 + 0.85		AURERT	65	HIRC	A S-A O. CP assumed	

 $\Gamma(\pi^+\pi^-\pi^0) + \Gamma(\pi^\pm\mu^\mp\nu) + \Gamma(\pi^\pm e^\mp\nu_e)$ $(\Gamma_2+\Gamma_3+\Gamma_6)$ $K_L^0 \rightarrow \text{charged}.$

VALUE (10⁶ s⁻¹)

EVTS
DOCUMENT ID
TECN

15.18±0.14 OUR FIT
Error includes scale factor of 1.1.

 $\Gamma(\pi^{\pm}\mu^{\mp}\nu)$

98 AUERBACH 66B OSPK

$\Gamma(\pi^{\pm}\mu^{\mp}\nu) + \Gamma(\pi^{\pm}e^{\mp}\nu_{e})$						
VALUE (10 ⁶ s ⁻¹) 12.75±0.12 OUR FIT		DOCUMENT ID udes scale factor of 1		COMMENT		

			TECN	COMMENT	
T Error in	cludes scale factor	of 1.1			
410	¹⁰ BURGUN	72	HBC	$K^+ p \rightarrow$	$K^0 p \pi^+$
393 ¹	10,11 CHO	70	DBC	$K^+ n \rightarrow$	K ⁰ p
109	¹⁰ FRANZINI	65	нвс		
se the follow	ing data for averag	es, fits	s, limits	, etc. • • •	•
126	10 MANN	72	нвс	κ − ρ →	$n\overline{K}^0$
335	¹¹ HILL	67	DBC	$K^+ n \rightarrow$	K ⁰ p
ΔQ rule. s events of h	HILL 67.				
	VERAGE E 410 252 393 109 se the follow 126 335 Δ Q rule.	WERAGE Error Includes scale 410 10 BURGUN 252 10 WEBBER 393 10,11 CHO 109 10 FRANZINI se the following data for average 126 10 MANN 335 11 HILL	WERAGE Error includes scale factor 410 10 BURGUN 72 252 10 WEBBER 71 393 10,111 CHO 70 109 10 FRANZINI 65 se the following data for averages, fit: 126 10 MANN 72 335 11 HILL 67 Δ Q rule. 70 Manny 72	393 10,11 CHO 70 DBC 109 10 FRANZINI 65 HBC se the following data for averages, fits, limits 126 10 MANN 72 HBC 335 11 HILL 67 DBC $^{\Delta}Q$ rule.	WERAGE Error includes scale factor of 1.2. 410 10 BURGUN 72 HBC $K^+p \rightarrow$ 252 10 WEBBER 71 HBC $K^-p \rightarrow$ 393 10 IOHO 70 DBC $K^+n \rightarrow$ 109 10 FRANZINI 65 HBC se the following data for averages, fits, limits, etc. • • • 126 10 MANN 72 HBC $K^-p \rightarrow$ 335 11 HILL 67 DBC $K^+n \rightarrow$

K? BRANCHING RATIOS

Гз

 0.185 ± 0.038

Γ(3π ⁰)/Γ _{total}				Γ ₁ /Γ
VALUE	EVTS	DOCUMENT ID	TECN	
0.2112±0.0027 OUR I	FIT Erro	includes scale factor of	f 1.1.	
0.2105 ± 0.0028	38k	12 KREUTZ 95	NA31	

 12 KREUTZ 95 measure $3\pi^0$, $\pi^+\pi^-\pi^0$, and $\pi\,e\,\nu_e$ modes. They assume PDG 1992 values for $\pi \mu \nu_{\mu}$, 2π , and 2γ modes.

$$\Gamma(3\pi^0)/\Gamma(\pi^+\pi^-\pi^0)$$

VALUE

1.68 ±0.04 OUR FIT

1.61 ±0.014±0.034

1.61 ±0.014±0.034

1.80 ±0.13

1.90 ±0.16

1.81 ±0.16

1.81 ±0.16

1.81 ±0.17

1.81 ±0.18

1.82 ±0.18

1.83 ±0.19

1.84 × 184

 13 KREUTZ 95 excluded from fit because it is not independent of their $\Gamma(3\pi^0)/\Gamma_{total}$ measurement, which is in the fit.

$$\Gamma(3π^0)/\Gamma(π^\pm e^\mp ν_e)$$

VALUE

0.545±0.009 OUR FIT

0.545±0.004±0.009

2EVTS

DOCUMENT ID

TECN

1 TECN

1

 $^{14}\,\mathrm{KREUTZ}$ 95 measurement excluded from fit because it is not independent of their $\Gamma(3\pi^0)/\Gamma_{total}$ measurement, which is in the fit.

$\Gamma(3\pi^0)/[\Gamma(\pi^+\pi^-\pi$	⁰) + Γ(π	$r^{\pm}\mu^{\mp}\nu)+\Gamma(\pi^{\pm}$	t e∓	$\nu_e)]$	$\Gamma_1/(\Gamma_2+\Gamma_3+\Gamma_6)$
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.269±0.004 OUR FIT		cludes scale factor	of 1	.1.	
0.260 ± 0.011 OUR AVE	RAGE				
0.251 ± 0.014	549	BUDAGOV	68	HLBC	ORSAY measur.
0.277 ± 0.021	444	BUDAGOV	68	HLBC	Ecole polytec.meas
0.31 +0.07 -0.06	29	KULYUKINA	68	cc	

0.24
$$\pm$$
0.08 24 ANIKINA 64 CC
$$\Gamma(\pi^{+}\pi^{-}\pi^{0})/\Gamma_{total}$$
VALUE DOCUMENT ID

VALUE DOCUMENT ID 0.1256 ± 0.0020 OUR FIT Error includes scale factor of 1.7.

$\Gamma(\pi^+\pi^-\pi^0)/\big[\Gamma(\pi^+\pi^-\pi^0)+\Gamma(\pi^\pm\mu^\mp\nu)+\Gamma(\pi^\pm e^\mp\nu_e)\big] \quad \Gamma_2/(\Gamma_2+\Gamma_3+\Gamma_6)$

VALUE	<u>EVTS</u>	DOCUMENT ID	TECN COMMENT
0.1600±0.0025 C	UR FIT Error	includes scale fact	tor of 1.7.
0.1588±0.0024 C	UR AVERAGE	Error includes sca below.	ale factor of 1.4. See the Ideogram
0.163 ±0.003	6499	сно	77 HBC
0.1605 ± 0.0038	1590	ALEXANDER	73B HBC
0.146 ±0.004	3200	BRANDENB	. 73 HBC
0.159 ±0.010	558	EVANS	73 HLBC
0.167 ±0.016	1402	KULYUKINA	68 CC
0.161 ±0.005		HOPKINS	67 HBC
0.162 ±0.015	126	HAWKINS	66 HBC
0.159 ±0.015	326	ASTBURY	65B CC
0.178 ±0.017	566	GUIDONI	65 HBC
	use the following	g data for average	es, fits, limits, etc. • • •
0.15 +0.03 -0.04	66	ASTBURY	65 CC .
0.144 ± 0.004	1729	HOPKINS	65 HBC See HOPKINS 67
0.151 ±0.020	79	ADAIR	64 HBC
$0.157 \begin{array}{l} +0.03 \\ -0.04 \end{array}$	75	LUERS	64 HBC

ASTIER

59

61 CC

 K_I^0

WEIGHTED AVERAGE 0.1588±0.0024 (Error scaled by 1.4)	$\Gamma(2\gamma)/\Gamma_{ ext{total}}$
direction of the state of the s	VALUE (units 10 ⁻⁴) EVTS DOCUMENT ID TECN COMMENT
Values above of weighted average, error,	5.92±0.15 OUR FIT • • • • We do not use the following data for averages, fits, limits, etc. • • •
and scale factor are based upon the data in this ideogram only. They are not neces-	4.54±0.84 18 BANNER 72B OSPK
sarily the same as our 'best' values, obtained from a least-squares constrained fit	4.5 ± 1.0 23 ENSTROM 71 OSPK K_I^0 1.5–9 GeV/c
utilizing measurements of other (related)	5.0 ±1.0 19 REPELLIN 71 OSPK
quantities as additional information.	5.5 \pm 1.1 90 KUNZ 68 OSPK Norm.to 3 π (C+N) 7.4 \pm 1.6 33 20 CRONIN 67 OSPK
<u>χ</u> ²	7.4 ±1.6 33 ²⁰ CRONIN 67 OSPK 6.7 ±2.2 32 TODOROFF 67 OSPK Repl. CRIEGEE 66
+ · · · · · · · · · CHO 77 HBC 2.0	1.3 ±0.6 21 CRIEGEE 66 OSPK
ALEXANDER 73B HBC 0.2	¹⁸ This value uses $(\eta_{00}/\eta_{+-})^2=1.05\pm0.14$. In general, $\Gamma(2\gamma)/\Gamma_{\rm total}=[(4.32\pm0.55) imes$
EVANS 73 HLBC 0.0	10^{-4}] $[(\eta_{00}/\eta_{+-})^2]$.
HOPKINS 67 HBC 0.2	19 Assumes regeneration amplitude in copper at 2 GeV is 22 mb. To evaluate for a given
HAWKINS 66 HBC 0.1	regeneration amplitude and error, multiply by (regeneration amplitude/22mb) ² . 20 CRONIN 67 replaced by KUNZ 68.
→ GUIDONI 65 HBC 1.3	²¹ CRIEGEE 66 replaced by TODOROFF 67.
14.2 (Confidence Level = 0.077)	$\Gamma(2\gamma)/\Gamma(3\pi^0)$ Γ_9/Γ_1
	VALUE (units 10 ⁻³) EVTS DOCUMENT ID TECN COMMENT
0.12 0.14 0.16 0.18 0.2 0.22	2.80 ± 0.06 OUR FIT Error includes scale factor of 1.1.
$\Gamma\left(\pi^{+}\pi^{-}\pi^{0}\right)/\left[\Gamma\left(\pi^{+}\pi^{-}\pi^{0}\right)+\Gamma\left(\pi^{\pm}\mu^{\mp}\nu\right)+\Gamma\left(\pi^{\pm}e^{\mp}\nu_{e}\right)\right]$	
, , , , , , , , , , , , , , , , , , , ,	2.13±0.43 28 BARMIN 71 HLBC
$\Gamma(\pi^{+}\pi^{-}\pi^{0})/\Gamma(\pi^{\pm}e^{\mp}\nu_{e})$	2.24±0.28 115 BANNER 69 OSPK 2.5 ±0.7 16 ARNOLD 688 HLBC Vacuum decay
VALUE EVTS DOCUMENT ID TECN 0.324±0.006 OUR FIT Error includes scale factor of 1.6.	
0.336±0.003±0.007 28k KREUTZ 95 NA31	$\Gamma(2\gamma)/\Gamma(\pi^0\pi^0)$ Γ_9/Γ_{18}
$\Gamma(\pi^{\pm}\mu^{\mp}\nu)/\Gamma(\pi^{\pm}e^{\mp}\nu_{e})$	<u>VALUE </u>
VALUE EYTS DOCUMENT ID TECH COMMENT	0.632±0.004±0.008 110k BURKHARDT 87 NA31
0.701±0.009 OUR FIT	$\Gamma(3\gamma)/\Gamma_{\text{total}}$ Γ_{10}/Γ
0.697±0.010 OUR AVERAGE 0.702±0.011 33k CHO 80 HBC	$\Gamma(3\gamma)/\Gamma_{\text{total}}$ Γ_{10}/Γ VALUE CL% DOCUMENT ID TECN_
0.662±0.037 10k WILLIAMS 74 ASPK	<2.4 × 10 ⁻⁷ 90 ²² BARR 95C NA31
0.741±0.044 6700 BRANDENB 73 HBC 0.662±0.030 1309 EVANS 73 HLBC	²² Assumes a phase-space decay distribution.
0.662±0.030 1309 EVANS 73 HLBC 0.71 ±0.05 770 BUDAGOV 68 HLBC	
● • We do not use the following data for averages, fits, limits, etc. • • •	\[\big(\pi^2\gamma)/\Gamma_{\text{total}} \] \[\big(\pi_1)/\Gamma_{\text{total}} \]
0.68 ±0.08 3548 BASILE 70 OSPK	1.7 ±0.2 ±0.2 63 23 BARR 92 SPEC
0.71 ±0.04 569 ¹⁵ BEILLIERE 69 HLBC 0.648±0.030 1309 EVANS 69 HLBC Repl. by EVANS 73	• • • We do not use the following data for averages, fits, limits, etc. • • •
0.67 ±0.13 16 KULYUKINA 68 CC	$1.86 \pm 0.60 \pm 0.60$ 60 PAPADIMITR91 E731 $m_{\gamma\gamma} > 280$ MeV
0.82 ±0.10 DEBOUARD 67 OSPK	< 5.1 90 PAPADIMITR91 E731 $m_{\gamma\gamma}$ < 264 MeV
0.7 ±0.2 273 HAWKINS 67 HBC 0.81 ±0.08 HOPKINS 67 HBC	2.1 ± 0.6 14 ²⁴ BARR 90C NA31 $m_{\gamma\gamma} > 280$ MeV
0.81 ±0.19 ADAIR 64 HBC	< 2.7 90 PAPADIMITR89 E731 In PAPADI91 <230 90 0 BANNER 69 OSPK
15 BEILLIERE 69 is a scanning experiment using same exposure as BUDAGOV 68.	²³ BARR 92 find that $\Gamma(\pi^0 2\gamma, m_{\gamma\gamma} < 240 \text{ MeV})/\Gamma(\pi^0 2\gamma) < 0.09$ (90% CL).
¹⁶ KULYUKINA 68 $\Gamma(\pi^{\pm}\mu^{\mp}\nu)/\Gamma(\pi^{\pm}e^{\mp}\nu_{e})$ is not measured independently from $\Gamma(\pi^{+}\pi^{-}\pi^{0})/[\Gamma(\pi^{+}\pi^{-}\pi^{0}) + \Gamma(\pi^{\pm}\mu^{\mp}\nu) + \Gamma(\pi^{\pm}e^{\mp}\nu_{e})]$ and $\Gamma(\pi^{\pm}e^{\mp}\nu_{e})/\Gamma(\pi^{+}\pi^{-}\pi^{0})$	²⁴ BARR 90C superseded by BARR 92.
$[\pi' + \pi'']/[i(\pi' \pi' \pi'') + i(\pi' + \nu_e)]$ and $i(\pi' + \nu_e)/[i(\pi' + \pi'') + i(\pi' + \mu'')]$	$\Gamma(\pi^0\pi^{\pm}e^{\mp}\nu)/\Gamma_{\text{total}}$ Γ_{12}/Γ
$\left[\Gamma(\pi^{+}\pi^{-}\pi^{0}) + \Gamma(\pi^{\pm}\mu^{\mp}\nu) + \Gamma(\pi^{\pm}e^{\mp}\nu_{e})\right].$	$\Gamma(\pi^0\pi^\pm e^\mp u)/\Gamma_{ ext{total}}$ VALUE (units 10 $^{-5}$) CL% EVTS DOCUMENT ID TECN
$\Gamma(\pi^{\pm}\mu^{\mp}\nu)/[\Gamma(\pi^{+}\pi^{-}\pi^{0})+\Gamma(\pi^{\pm}\mu^{\mp}\nu)+\Gamma(\pi^{\pm}e^{\mp}\nu_{e})] \qquad \Gamma_{3}/(\Gamma_{2}+\Gamma_{3}+\Gamma_{6})$	5.18±0.29 OUR AVERAGE
VALUE EVTS DOCUMENT ID TECN	5.16±0.20±0.22 729 MAKOFF 93 E731
0.3461±0.0030 OUR FIT Error includes scale factor of 1.1. • • • We do not use the following data for averages, fits, limits, etc. • • •	6.2 ±2.0 16 CARROLL 80C SPEC • • • We do not use the following data for averages, fits, limits, etc. • • •
0.335 ±0.055 330 17 KULYUKINA 68 CC	<220 90 ²⁵ DONALDSON 74 SPEC
0.39 +0.08 172 ¹⁷ ASTBURY 65 CC	²⁵ DONALDSON 74 uses $K_I^0 \rightarrow \pi^+\pi^-\pi^0/(\text{all } K_I^0)$ decays = 0.126.
0.356 ±0.07 251 ¹⁷ LUERS 64 HBC	<u></u>
¹⁷ This mode not measured independently from $\Gamma(\pi^+\pi^-\pi^0)/[\Gamma(\pi^+\pi^-\pi^0)$ +	$\Gamma((\pi \mu \text{atom}) \nu)/\Gamma(\pi^{\pm} \mu^{\mp} \nu)$ Γ_{13}/Γ_{3}
$\Gamma(\pi^{\pm}\mu^{\mp}\nu) + \Gamma(\pi^{\pm}e^{\mp}\nu_{e})$ and $\Gamma(\pi^{\pm}e^{\mp}\nu_{e})/[\Gamma(\pi^{+}\pi^{-}\pi^{0}) + \Gamma(\pi^{\pm}\mu^{\mp}\nu) +$	<u>VALUE (units 10⁻⁷) </u>
$\Gamma(\pi^{\pm}e^{\mp}\nu_{e})$].	• • • We do not use the following data for averages, fits, limits, etc. • • •
	seen 18 COOMBES 76 WIRE
$\Gamma(\pi^{\pm}e^{\mp}\nu_{e})/[\Gamma(\pi^{+}\pi^{-}\pi^{0})+\Gamma(\pi^{\pm}\mu^{\mp}\nu)+\Gamma(\pi^{\pm}e^{\mp}\nu_{e})] \Gamma_{6}/(\Gamma_{2}+\Gamma_{3}+\Gamma_{6})$	26 ARONSON 86 quote theoretical value of (4.31 \pm 0.08) $ imes$ 10 $^{-7}$.
VALUE EVTS DOCUMENT ID TECN 0.4939±0.0030 OUR FIT Error includes scale factor of 1.1.	$\Gamma(\pi^{\pm}e^{\mp}\nu_{e}\gamma)/\Gamma(\pi^{\pm}e^{\mp}\nu_{e})$ Γ_{14}/Γ_{6}
• • • We do not use the following data for averages, fits, limits, etc. • • •	VALUE (units 10 ⁻²) EVTS DOCUMENT ID TECN COMMENT
0.498 ±0.052 500 KULYUKINA 68 CC	LAGE
0.46 +0.08 202 ASTBURY 65 CC	,
0.487 ±0.05 153 LUERS 64 HBC	$ heta_{e\gamma}^* \geq 20^\circ$
0.46 ±0.11 24 NYAGU 61 CC	• • • We do not use the following data for averages, fits, limits, etc. • • •
$ \Gamma(\pi^{\pm}e^{\mp}\nu_{e})/[\Gamma(\pi^{\pm}\mu^{\mp}\nu) + \Gamma(\pi^{\pm}e^{\mp}\nu_{e})] $ $ \Gamma_{6}/(\Gamma_{3}+\Gamma_{6}) $	3.3 ± 2.0 10 PEACH 71 HLBC γ KE >15 MeV
VALUE EVTS DOCUMENT ID TECH	$\Gamma(\pi^+\pi^-\gamma)/\Gamma_{ ext{total}}$ Γ_{15}/Γ
0.5880±0.0033 OUR FIT	For earlier limits see our 1992 edition Physical Review D45 , 1 June, Part II (1992).
• • • We do not use the following data for averages, fits, limits, etc. • • • 0.415 ±0.120 320 ASTIER 61 CC	VALUE (units 10 ⁻⁵) EVTS DOCUMENT ID TECN COMMENT 4.61±0.14 OUR AVERAGE
	4.66 \pm 0.15 3136 27 RAMBERG 93 E731 E_{γ} >20 MeV
$\left[\Gamma(\pi^{\pm}\mu^{\mp}\nu) + \Gamma(\pi^{\pm}e^{\mp}\nu_{e})\right]/\Gamma_{\text{total}} \tag{\Gamma_{3}+\Gamma_{6}}/\Gamma$	4.41 ± 0.32 1062 28 CARROLL 80B SPEC $E_{\gamma}' > 20$ MeV
<u>VALUE</u> <u>DOCUMENT ID</u> 0.6596±0.0030 OUR FIT Error includes scale factor of 1.2.	

ı

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• • • We do not use the following data for averages, fits, limits, etc. • • •
                                                                                                                              • • • We do not use the following data for averages, fits, limits, etc. • • •
                              516 29 CARROLL 80B SPEC E<sub>y</sub> >20 MeV
                                                                                                                              1.21 ±0.30
                                                                                                                                                                       38 REY
                                                                                                                                                                                               76 OSPK \eta_{00}=3.8 ± 0.5
                                                                                                                                                              150
1.52±0.16
                                                                                                                                                                       39 FAISSNER
                                        30 CARROLL
                                                                                                                              0.90 \pm 0.30
                                                                                                                                                              172
                                                                                                                                                                                               70 OSPK \eta_{00}=3.2 ± 0.5
2.89±0.28
                                                               808 SPEC
                                                                                                                                                                       38 CENCE
                                        31 DONALDSON 74C SPEC
                                                                                                                              1.31 \pm 0.31
                                                                                                                                                                                               69 OSPK \eta_{00} = 3.7 \pm 0.5
                                                                                                                                                                        <sup>40</sup> CRONIN
                                                                                                                                                                                               67 OSPK \eta_{00}=4.9 ± 0.5
                                                                                                                              1.89 \pm 0.31
                                                                                                                                                              109
 ^{27} RAMBERG 93 finds that fraction of Direct Emission (DE) decays with E_{\gamma} >20 MeV is
                                                                                                                                                                       40 CRONIN
                                                                                                                              1.36 ±0.18
                                                                                                                                                                                               678 OSPK \eta_{00}=3.92\pm0.3
                                                                                                                               ^{38} CENCE 69 events are included in REY 76. ^{39} FAISSNER 70 contains same 2^{30} events as GAILLARD 69 \Gamma(\pi^0\,\pi^0)/\Gamma_{total}
 <sup>28</sup> Both components. Uses K_I^0 \rightarrow \pi^+\pi^-\pi^0/(\text{all }K_I^0) decays = 0.1239.
 <sup>29</sup>Internal Bremsstrahlung component only.
                                                                                                                               40 CRONIN 67B is further analysis of CRONIN 67, now both withdrawn.
 30 Direct \gamma emission component only.

31 Uses K_L^0 \rightarrow \pi^+\pi^-\pi^0/(\text{all }K_L^0) decays = 0.126.
                                                                                                                              \Gamma(\pi^0\pi^0)/\Gamma(\pi^+\pi^-)
Violates CP conservation.
                                                                                                                                                                                                                                 \Gamma_{18}/\Gamma_{17}
                                                                                                                                                                           DOCUMENT ID
\Gamma(\pi^0\pi^0\gamma)/\Gamma_{\text{total}}
                                                                                                       \Gamma_{16}/\Gamma
                                                                                                                              0.453 ±0.006 OUR FIT
                                                                                                                                                                        41 ETAFIT
VALUE (units 10-6) CL% EVTS
                                                                                                                              0.4535 \pm 0.0063
                                              DOCUMENT ID
                                                                      TECN
                                              BARR
                                                                 94 NA31
                                                                                                                               <sup>41</sup>This ETAFIT value is computed from fitted values of |\eta_{00}|/|\eta_{+-}| and the \Gamma(K^0_S 
ightarrow
• • • We do not use the following data for averages, fits, limits, etc. • •
                                                                                                                                   \pi^+\pi^-)/\Gamma(K_S^0\to\pi^0\pi^0) branching fraction. See the discussion in the note "Fits for
                       90
                                 0
                                             ROBERTS
                                                              94 E799
                                                                                                                                   KO CP-Violation Parameters."
\Gamma(\pi^+\pi^-)/\Gamma_{\text{total}}
Violates CP conservation.
                                                                                                                               \Gamma(\mu^+\mu^-)/[\Gamma(\pi^+\pi^-\pi^0) + \Gamma(\pi^\pm\mu^\mp\nu) + \Gamma(\pi^\pm e^\mp\nu_e)] \qquad \Gamma_{19}/(\Gamma_2+\Gamma_3+\Gamma_e)  Test for \Delta S=1 weak neutral current. Allowed by higher-order electroweak interaction.
                                                                                                       \Gamma_{17}/\Gamma
VALUE (units 10-3)
                                             DOCUMENT ID
                                                                                                                              VALUE (units 10-6)
                                                                                                                                                            CL%
                                                                                                                                                                           DOCUMENT ID
                                                                                                                                                                                                   TECN
2.067±0.035 OUR FIT Error includes scale factor of 1.1.
                                                                                                                              32 ETAFIT
2.107±0.055
                                                                                                                                                                            вотт-...
                                                                                                                                                                                               67 OSPK
                                                                                                                               < 2.0
                                                                                                                                                              90
 ^{32} This ETAFIT value is computed from fitted values of |\eta_{+-}|, the K^0_L and K^0_S lifetimes,
                                                                                                                               < 35.0
                                                                                                                                                              90
                                                                                                                                                                            FITCH
                                                                                                                                                                                               67 OSPK
                                                                                                                                                                            ALFF-
     and the K_5^0 \to \pi^+\pi^- branching fraction. See the discussion in the note "Fits for K_i^0
                                                                                                                               <250.0
                                                                                                                                                              90
                                                                                                                                                                                               668 OSPK
                                                                                                                                                                            ANIKINA
     CP-Violation Parameters."
                                                                                                                               <100.0
                                                                                                                                                                                               65 CC
                                                                                                                              \frac{\Gamma(\mu^+\mu^-)/\Gamma(\pi^+\pi^-)}{\text{Test for }\Delta S=1 \text{ weak neutral current. Allowed by higher-order electroweak interaction.}}
\Gamma(\pi^+\pi^-)/\Gamma(\pi^+\pi^-\pi^0)
                                                                                                     \Gamma_{17}/\Gamma_{2}
Violates CP conservation.

VALUE (units 10<sup>-2</sup>) EVTS
                                                                                                                                    E (units 10<sup>-6</sup>) CL% EVTS DOCUMENT ID TECN COMMENT 3.50±0.21 OUR AVERAGE Error includes scale factor of 1.4.
                                                                                                                               VALUE (units 10<sup>-6</sup>)
VALUE (units 10<sup>-2</sup>) EVTS DOCUMENT ID T
1.645±0.030 OUR FIT Error includes scale factor of 1.1.
                                                                      TECN COMMENT
                                                                                                                                                                             <sup>42</sup> AKAGI
                                                                                                                                                                    179
                                                                                                                                                                                                     95 SPEC
                                             MESSNER 73 ASPK \eta_{+-}=2.23
                                                                                                                                    3.87 \pm 0.30
                               4200
                                                                                                                                                                                                     95 B791
                                                                                                                                                                                 HEINSON
                                                                                                                                    3.38 \pm 0.17
                                                                                                                                                                    707
\begin{array}{c|c} \Gamma(\pi^+\pi^-)/[\Gamma(\pi^\pm\mu^\mp\nu)+\Gamma(\pi^\pm e^\mp\nu_e)] \\ \text{Violates $\it CP$ conservation.} \\ \underline{\it VALUE (units 10^{-3})} & \underline{\it EVTS} & \underline{\it DOCUMENT ID} \\ \hline {\bf 3.13\pm 0.06 \ OUR \ FIT} & Error \ includes \ scale \ factor \ of \ 1.1. \\ \end{array}
                                                                                                                               \Gamma_{17}/(\Gamma_3+\Gamma_6)
                                                                                                                                                                             43 AKAGI
                                                                                                                                    3.9 ±0.3 ±0.1
                                                                                                                                                                    178
                                                                                                                                                                                                     91B SPEC In AKAGI 95
                                                                                                                                                                             44 HEINSON
                                                                                                                                                                                                     91 SPEC
                                                                                                                                    3.45 ± 0.18 ± 0.13
                                                                                                                                                                                                                    In HEINSON 95
                                                                    TECN COMMENT
                                                                                                                                    4.1 ±0.5
                                                                                                                                                                                 INAGAKI
                                                                                                                                                                                                     89 SPEC
3.08±0.10 OUR AVERAGE
                                                                                                                                    2.8 \pm 0.3 \pm 0.2
                                                                                                                                                                     87
                                                                                                                                                                                 MATHIAZHA...89B SPEC In HEINSON 91
                                                                 85 SPEC \eta_{+-}=2.28 \pm 0.06
                              1687
                                             COUPAL
                                                                                                                                    4.0 +1.4
                                                                                                                                                                                 SHOCHET
                                                                                                                                                                                                    79 SPEC
                                                                                                                                                                     15
                                                                 77 SPEC \eta_{+-}=2.25\pm0.05
                                             DEVOE
                              2703
3.04 \pm 0.14
                                                                                                                                    4.2 \begin{array}{l} +5.1 \\ -2.6 \end{array}
                                                                                                                                                                             45 FUKUSHIMA 76 SPEC
• • • We do not use the following data for averages, fits, limits, etc. • •
                                                                                                                                    5.8 \begin{array}{l} +2.3 \\ -1.5 \end{array}
                                          DEBOUARD 67 OSPK \eta_{+-}=2.00 ± 0.09
                                                                                                                                                                             46 CARITHERS 73 SPEC
                                309
2.51 \pm 0.23
                                525
                                          33 FITCH
                                                                 67 OSPK \eta_{+-}=1.94 \pm 0.08
                                                                                                                                                                              47 CLARK
2.35 \pm 0.19
                                                                                                                               < 1.53
                                                                                                                                                           90
                                                                                                                                                                                                     71 SPEC
 ^{33} Old experiments excluded from fit. See subsection on \eta_{+-} in section on "PARAMETERS
                                                                                                                               < 18.
                                                                                                                                                           90
                                                                                                                                                                       0
                                                                                                                                                                                 DARRIULAT
                                                                                                                                                                                                    70 SPEC
                                                                                                                                <140
                                                                                                                                                           90
                                                                                                                                                                       0
                                                                                                                                                                                 FOFTH
                                                                                                                                                                                                     69 SPEC
     FOR K_I^0 \to 2\pi DECAY" below for average \eta_{+-} of these experiments and for note on
                                                                                                                                <sup>42</sup>AKAGI 95 gives this number multiplied by the PDG 1992 average for \Gamma(K_I^0 \rightarrow
 \begin{array}{c} \Gamma(\pi^+\pi^-)/[\Gamma(\pi^+\pi^-\pi^0) + \Gamma(\pi^\pm\mu^\mp\nu) + \Gamma(\pi^\pm\,e^\mp\nu_e)] & \Gamma_{17}/(\Gamma_2 + \Gamma_3 + \Gamma_6) \\ \text{Violates $CP$ conservation.} & \underline{\text{EVTS}} & \underline{\text{DOCUMENT ID}} & \underline{\text{TECN}} & \underline{\text{COMMENT}} \\ \end{array} 
                                                                                                                                    \pi^+\pi^-)/\Gamma(total).
                                                                                                                                <sup>43</sup>AKAGI 91B give this number multiplied by the 1990 PDG average for \Gamma(K_I^0 \rightarrow
                              EVTS
                                                                                                                                44 HEINSON 91 give \Gamma(K_L^0 \to \mu \mu)/\Gamma_{\text{total}}. We divide out the \Gamma(K_L^0 \to \pi^+ \pi^-)/\Gamma_{\text{total}}
 2.63 ±0.04 OUR FIT
                                                                                                                                PDG average which they used. 45 FUKUSHIMA 76 errors are at CL = 90%. 46 CARITHERS 73 errors are at CL = 68%, W.Carithers, (private communication 79). 47 CLARK 71 limit raised from 1.2 \times 10^{-6} by FIELD 74 reanalysis. Not in agreement with subsequent experiments. So not averaged.
• • • We do not use the following data for averages, fits, limits, etc. • • •
                                          34 MESSNER
                                                               73 ASPK \eta_{+-} = 2.23 \pm 0.05
2.60 ±0.07
                               4200
                                          35 BASILE
                                                                 66 OSPK \eta_{+-} = 1.92 \pm 0.13
1.93 ±0.26
                                          <sup>35</sup> BOTT-...
                                                                 66 OSPK \eta_{+-} = 1.95 \pm 0.04
1.993 \pm 0.080
                                                                                                                              \Gamma(\mu^+\mu^-\gamma)/\Gamma_{\text{total}} \Gamma_{20}/\Gamma Test for \Delta S=1 weak neutral current. Allowed by higher-order electroweak interaction.
                                          35 GALBRAITH 65 OSPK \eta_{+-} = 1.99 \pm 0.16
                                  45 35 CHRISTENS... 64 OSPK \eta_{+-} = 1.95 \pm 0.20
                                                                                                                              \frac{\textit{VALUE} \, (\text{units} \, 10^{-7})}{\textbf{3.25} \!\pm\! 0.28 \, \text{OUR AVERAGE}} \, \underline{\textit{CL\%} \, \, \textit{EVTS}}
                                                                                                                                                                                 DOCUMENT ID
                                                                                                                                                                                                       TECN
 <sup>34</sup> From same data as \Gamma(\pi^+\pi^-)/\Gamma(\pi^+\pi^-\pi^0) MESSNER 73, but with different normal-
                                                                                                                                   3.4 \pm 0.6 \pm 0.4
                                                                                                                                                                     45
                                                                                                                                                                                 FANTI
                                                                                                                                                                                                     97 NA48
 35 Old experiments excluded from fit. See subsection on \eta_{+-} in section on "PARAMETERS
                                                                                                                                   3.23 \pm 0.23 \pm 0.19
                                                                                                                                                                    197
                                                                                                                                                                                 SPENCER
                                                                                                                                                                                                     95 E799
     FOR K_I^0 \rightarrow 2\pi DECAY" below for average \eta_{+-}.
                                                                                                                               • • • We do not use the following data for averages, fits, limits, etc. • •
                                                                                                                                                                             <sup>48</sup> CARROLL
                                                                                                                                                                                                     80D SPEC
                                                                                                                                                                      1
\Gamma(\pi^0\pi^0)/\Gamma_{\text{total}}
Violates CP conservation.

VALUE (units 10^{-3})

EVTS
                                                                                                       Γ<sub>18</sub>/Γ
                                                                                                                                                           90
                                                                                                                                                                             <sup>49</sup> DONALDSON 74 SPEC
                                                                                                                                48 Uses K_L^0 \rightarrow \pi^+\pi^-\pi^0/(\text{all } K_L^0) decays = 0.1239.

49 Uses K_L^0 \rightarrow \pi^+\pi^-\pi^0/(\text{all } K_L^0) decays = 0.126.
0.936±0.020 OUR FIT
                                              DOCUMENT ID TECN COMMENT
 \Gamma(e^+e^-)/\Gamma_{total} Test for \Delta S=1 weak neutral current. Allowed by higher-order electroweak interactions
                                         ^{36} GAILLARD 69 OSPK \eta_{00} = 3.6 \pm 0.6
                                 189
2.5 ±0.8
                                                                                                                                                                      DOCUMENT ID TECN COMMENT

50 ARISAKA 938 B791
                                                                                                                               VALUE (units 10-10) CL% EVTS
1.2 \begin{array}{c} +1.5 \\ -1.2 \end{array}
                                          37 CRIEGEE
                                                                 66 OSPK
                                                                                                                                                                                                93B B791
                                                                                                                                     0.41
                                                                                                                                                      90
                                                                                                                                                                 0
 <sup>36</sup> Latest result of this experiment given by FAISSNER 70 \Gamma(\pi^0\pi^0)/\Gamma(3\pi^0).
                                                                                                                               • • • We do not use the following data for averages, fits, limits, etc. • •
 ^{37} CRIEGEE 66 experiment not designed to measure 2\pi^0 decay mode.
                                                                                                                                                                            AKAGI
                                                                                                                                                                                               95 SPEC
                                                                                                                               < 1.6
                                                                                                                                                      90
                                                                                                                                                                 1
                                                                                                                               <
                                                                                                                                                      90
                                                                                                                                                                            AKAGI
                                                                                                                                                                                                91 SPEC Sup. by AKAGI 95
                                                                                                                                     1.6
 \Gamma(\pi^0\pi^0)/\Gamma(3\pi^0)
                                                                                                      \Gamma_{18}/\Gamma_{1}
                                                                                                                                                                            INAGAKI
                                                                                                                                                                                               89 SPEC In AKAGI 91
                                                                                                                                     5.6
Violates CP conservation.

VALUE (units 10<sup>-2</sup>) EVTS
                                                                                                                                      3.2
                                                                                                                                                      90
                                                                                                                                                                            MATHIAZHA...89 SPEC In ARISAKA 93B
                                                                       TECN COMMENT
VALUE (units 10<sup>-2</sup>) EVTS DOCUMENT ID TO 1.1.
                                                                                                                               < 110
                                                                                                                                                      90
                                                                                                                                                                            COUSINS
                                                                                                                                                                                               88 SPEC
                                                                                                                                                                            GREENLEE 88 SPEC Repl. by JASTRZEMB-
SKI 88
                                                                                                                               < 45
                                                                                                                                                      90
 0.39 ±0.06 OUR AVERAGE
                                                                                                                                                                            JASTRZEM... 88 SPEC
                                               BARMIN
                                                                  70 HLBC \eta_{00}=2.02 ± 0.23
                                                                                                                                < 12
                                                                                                                                                      90
 0.37 \pm 0.08
                                                                                                                                                                        51 CLARK
 0.32 ±0.15
                                  30
                                               BUDAGOV
                                                                  70 HLBC \eta_{00} = 1.9 \pm 0.5
                                                                                                                                   15.7
                                                                                                                                                      90
                                                                                                                                                                                               71 ASPK
                                                                                                                                                                            FOETH
                                                                  69 OSPK \eta_{00}=2.2 ± 0.3
                                                                                                                                                                                                69 ASPK
0.46 \pm 0.11
                                  57
                                               BANNER
                                                                                                                                <1500
                                                                                                                                                      90
                                                                 68 OSPK See η<sub>00</sub> below
                                                                                                                                ^{50} ARISAKA 938 includes all events with <6 MeV radiated energy. ^{51} Possible (but unknown) systematic errors. See note on CLARK 71 \Gamma(\mu^+\mu^-)/\Gamma(\pi^+\pi^-)
                                               BARTLETT
 not seen
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I (e 'e'') / [I (π' Test for Δ5	サπ [™] π [™])+Γ(= 1 weak neutral	$\pi^{\pm}\mu^{+}\nu)+\Gamma$	$(\pi^{\pm}e^{\mp}\nu_{e})$ $\Gamma_{21}/(\Gamma_{2}+\Gamma_{3}+\Gamma_{6})$ by higher-order electroweak interaction.
VALUE (units 10-6)		DOCUMENT ID	
			es, fits, limits, etc. • • •
< 23.0	90	вотт	67 OSPK
< 200.0	90	ALFF	66B OSPK
<1000.0		ANIKINA	65 CC
$\Gamma(e^+e^-\gamma)/\Gamma_{\rm tot}$	_		F/F
Test for ΔS:	t al = 1 weak neutral	current, Allowed	Γ22/Γ I by higher-order electroweak interaction.
VALUE (units 10-6)		DOCUMENT ID	
9.1±0.5 OUR			
$9.2 \pm 0.5 \pm 0.5$	1053	BARR	90B NA31
$9.1\pm0.4^{+0.6}_{-0.5}$	919	OHL	908 B845
	use the following	data for average	es, fits, limits, etc. • • •
17.4±8.7		52 CARROLL	80D SPEC
	90 0 !	3 BARMIN	72 HLBC
52 Uses K ⁰ → π	$+\pi - \pi^0 / (all K)$) decays = 0.12	
53 Uses K0 → 3	π^{0} /total = 0.21	[,, 4	
oscs w L - s	" / total = 0.21	••	
$\Gamma(e^+e^-\gamma\gamma)/\Gamma_t$	ntal		Γ ₂₃ /Γ
Test for $\Delta 5$	= 1 weak neutral	current. Allowed	by higher-order electroweak interaction.
VALUE (units 10 ⁻⁷)	EVTS	DOCUMENT ID	TECN COMMENT
6.5±1.2 OUR AVE			
$6.5 \pm 1.2 \pm 0.6$	58	NAKAYA	94 E799 $E_{\gamma} >$ 5 MeV
6.6 ± 3.2		MORSE	92 B845 $E_{\gamma} > 5 \text{ MeV}$
F/_44 \	\/r		
I (π ⊤ π ¯ e ¯ e ¯)	// total	current Aller	Γ_{24}/Γ by higher-order electroweak interaction.
rest for Δ5:	1 weak neutral	DOCUMENT IS	by higher-order electroweak interaction.
VALUE (units 10 ⁻⁷)		_	TECN COMMENT
< 4.6	90		97 SPEC m _{ee} > 4 MeV es, fits, limits, etc. • • •
	-	_	
< 25	90 0	BALATS ⁵⁴ DONALDSON	83 SPEC
< 88.1 <300	3 0	ANIKINA	73 STRC
	+ - 0//		
⁵⁴ Uses $K_L^0 \rightarrow \pi$	'π π°/(all K	\tilde{L}) decays = 0.12	20.
[(u+ u- e+ e-)	/Fa		Γ ₀₀ /Γ
Test for ΔS	= 1 weak neutral	current. Allowed	Γ_{25}/Γ by higher-order electroweak interaction.
VALUE (units 10-9)	CL% EVTS	DOCUMENT ID	
2.9 ^{+6.7}	1	GU	40 E133
• • We do not i	use the following	data for average	es, fits, limits, etc. • • •
<4900	90	BALATS	83 SPEC
Γ(e+e-e+e-)	/C		Γ ₂₆ /Γ
Test for ΔS	/ ' 1002) — 1 weak neutral	current. Allowed	by higher-order electroweak Interaction.
		DOCUMEN	
VALUE (units 10-8)	CL% EVTS	Error includes so	T ID TECN COMMENT : ale factor of 1.2.
VALUE (units 10-8)	CL% EVTS	Error Includes so 55 AKAGI	T ID TECN COMMENT
VALUE (units 10 ⁻⁸) 4.1 ±0.8 Oi 6 ±2 ±1 10.4 ±3.7 ±1	<u>CL% EVTS</u> UR AVERAGE 18 1.1 8	Error Includes so 55 AKAGI 56 BARR	TID TECN COMMENT
VALUE (units 10 ⁻⁸) 4.1 ±0.8 Oi 6 ±2 ±1 10.4 ±3.7 ±1 3.96±0.78±0	CL% EVTS UR AVERAGE 1 18 1.1 8 0.32 27	Error Includes so 55 AKAGI 56 BARR GU	TID TECN COMMENT ale factor of 1.2. 95 SPEC m _{ee} >470 MeV 95 NA31 94 E799
$ \begin{array}{c cccc} \hline $	CL% EVTS UR AVERAGE 18 1.1 8 0.32 27 0.26 6	Error Includes so 55 AKAGI 56 BARR GU VAGINS	TID TECN COMMENT ale factor of 1.2. 95 SPEC m _{ee} >470 MeV 95 NA31 94 E799 93 B845
$ \begin{array}{c cccc} & \underline{VALUE (units \ 10^{-8})} \\ & 4.1 & \pm 0.8 & Oi \\ & 6 & \pm 2 & \pm 1 \\ & 10.4 & \pm 3.7 & \pm 1 \\ & 3.96 \pm 0.78 \pm 0 \\ & 3.07 \pm 1.25 \pm 0 \\ & \bullet & We do not see$	CL% EVTS UR AVERAGE 1 18 1.1 8 0.32 27 0.26 6 use the following	Error Includes so 55 AKAGI 56 BARR GU VAGINS data for average	TID TECN COMMENT
MALUE (units 10 ⁻⁸) 4.1 ±0.8 OI 6 ±2 ±1 10.4 ±3.7 ±1 3.96±0.78±0 3.07±1.25±0 • • • We do not to the control of the con	CL% EVTS UR AVERAGE 1 18 1.1 8 0.32 27 0.26 6 use the following 2 6	Error Includes so 55 AKAGI 56 BARR GU VAGINS data for averago 55 AKAGI	TID TECN COMMENT ale factor of 1.2. 95 SPEC 95 NA31 94 E799 93 B845 es, fits, limits, etc. • • • 95 SPEC mee > 470 MeV
MALUE (units 10 ⁻⁸) 4.1 ±0.8 Oi 6 ±2 ±1 10.4 ±3.7 ±1 3.96±0.78±0 3.07±1.25±0 • • We do not to 7 ±3 ±2 6 ±2 ±1	CL% EVTS UR AVERAGE 1 18 1.1 8 0.32 27 0.26 6 use the following 2 6	Error Includes so 55 AKAGI 56 BARR GU VAGINS data for averago 55 AKAGI AKAGI	TID TECN COMMENT ale factor of 1.2. 95 SPEC 95 NA31 94 E799 93 B845 es, fits, limits, etc. • • • 95 SPEC 96 Wee > 470 MeV 97 CNTR Sup. by AKAGI 95
VALUE (units 10 ⁻⁸) 4.1 ±0.8 00 6 ±2 ±1 10.4 ±3.7 ±1 3.96±0.78±0 3.07±1.25±0 • • • We do not to 7 ±3 ±2 6 ±2 ±1 4 ±3	CL% EVTS UR AVERAGE 18 1.1 8 0.32 27 0.26 6 use the following 2 6 1 18 2	Error Includes so 55 AKAGI 56 BARR GU VAGINS data for averago 55 AKAGI AKAGI BARR	TID TECN COMMENT ale factor of 1.2. 95 SPEC 95 NA31 94 E799 93 B845 es, fits, limits, etc. 95 SPEC 96 CNTR Sup. by AKAGI 95 91 NA31 Sup. by BARR 95
VALUE (units 10 ⁻⁸) 4.1 ±0.8 00 6 ±2 ±1 10.4 ±3.7 ±1 3.96 ±0.78 ±1 3.07±1.25±0 • • We do not t 7 ±3 ±2 6 ±2 ±1 4 ±3 <260	CL% EVTS UR AVERAGE 1 18 1.1 8 1.32 27 1.26 6 use the following 2 6 1 18 2 90	Error Includes so 55 AKAGI 56 BARR GU VAGINS data for averago 55 AKAGI AKAGI BARR BALATS	TID TECN COMMENT ale factor of 1.2. 95 SPEC
VALUE (units 10 ⁻⁸) 4.1 ±0.8 ©0 6 ±2 ±1 10.4 ±3.7 ±1 3.96±0.78±1 3.07±1.25±0 • • • We do not to the state of the s	CL% EVTS UR AVERAGE 18 1.1 8 1.32 27 1.26 6 1 18 2 90 the total branchir	Error Includes so 55 AKAGI 56 BARR GU VAGINS data for average 55 AKAGI AKAGI BARR BALATS ng fraction, accep	TID TECN COMMENT ale factor of 1.2. 95 SPEC 95 NA31 94 E799 93 B845 es, fits, limits, etc. • • • 95 SPEC mee > 470 MeV 93 CNTR Sup. by AKAGI 95 91 NA31 83 SPEC otance-corrected for the mee cuts shown.
### #################################	CL% EVTS UR AVERAGE 1. 18 1.32 27 1.26 6 1.05 16 1.05 18 1.05 18 1.05 19 1.05 10 1.05	Error Includes so \$5 AKAGI \$6 BARR GU VAGINS data for average \$5 AKAGI AKAGI BARR BALATS ng fraction, acceptwo e+e-pair	TID TECN COMMENT ale factor of 1.2. 95 SPEC $m_{ee} > 470 \text{ MeV}$ 95 NA31 94 E799 93 B845 es, fits, limits, etc. 95 SPEC $m_{ee} > 470 \text{ MeV}$ 93 CNTR Sup. by AKAGI 95 91 NA31 Sup. by BARR 95 83 SPEC stance-corrected for the m_{ee} cuts shown. planes favors $CP = -1$ for K_{L}^{0} .
### #################################	CL% EVTS UR AVERAGE 1. 18 1.32 27 1.26 6 1.05 16 1.05 18 1.05 18 1.05 19 1.05 10 1.05	Error Includes so \$5 AKAGI \$6 BARR GU VAGINS data for average \$5 AKAGI AKAGI BARR BALATS ng fraction, acceptwo e+e-pair	TID TECN COMMENT ale factor of 1.2. 95 SPEC $m_{ee} > 470 \text{ MeV}$ 95 NA31 94 E799 93 B845 es, fits, limits, etc. 95 SPEC $m_{ee} > 470 \text{ MeV}$ 93 CNTR Sup. by AKAGI 95 91 NA31 Sup. by BARR 95 83 SPEC stance-corrected for the m_{ee} cuts shown. planes favors $CP = -1$ for K_{L}^{0} .
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	CL% EVTS UR AVERAGE 1 18 1.1 8 1.32 27 1.26 6 1 18 2 90 1 the total branchir angles between	Error Includes SC 55 AKAGI 56 BARR GU VAGINS data for average 55 AKAGI AKAGI BARR BALATS ng fraction, acceptwo e+e-pair Test for \(\Delta S \)	TID TECN COMMENT ale factor of 1.2. 95 SPEC $m_{ee} > 470 \text{ MeV}$ 95 NA31 94 E799 93 B845 es, fits, limits, etc. 95 SPEC $m_{ee} > 470 \text{ MeV}$ 93 CNTR Sup. by AKAGI 95 91 NA31 Sup. by BARR 95 83 SPEC stance-corrected for the m_{ee} cuts shown. planes favors $CP = -1$ for K_{L}^{0} .
### A 1 # A 2 # A	CL% EVTS UR AVERAGE 1.1 8 1.32 27 1.26 6 1.26 16 1.1 8 2 90 1.1 18 2 90 1.1 18 2 90 1.1 18 2 1.1 18 2 1.1 18 2 1.1 18 2 1.1 18 2 1.1 18 2 1.1 18 2 2 1.1 18 2 2 2 2 3 3 4 4 4 4 4 4 4 4 4 4 4 4 4 4	Error Includes so 55 AKAGI 56 BARR GU VAGINS data for average 55 AKAGI AKAGI BARR BALATS ag fraction, acceptwo e+e-pair Test for ΔS craction.	TID TECN COMMENT ale factor of 1.2. 95 SPEC 95 NA31 94 E799 93 B845 es, fits, limits, etc. • • • 95 SPEC mee > 470 MeV 93 CNTR Sup. by AKAGI 95 91 NA31 83 SPEC otance-corrected for the mee cuts shown.
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	CL% EVTS UR AVERAGE 1.1 8 1.32 27 1.26 6 1.26 16 1.1 8 2 90 1.1 18 2 90 1.1 18 2 90 1.1 18 2 1.1 18 2 1.1 18 2 1.1 18 2 1.1 18 2 1.1 18 2 1.1 18 2 2 1.1 18 2 2 2 2 3 3 4 4 4 4 4 4 4 4 4 4 4 4 4 4	Error Includes SC 55 AKAGI 56 BARR GU VAGINS data for average 55 AKAGI AKAGI BARR BALATS ng fraction, acceptwo e+e-pair Test for \(\Delta S \)	TID TECN COMMENT ale factor of 1.2. 95 SPEC $m_{ee} > 470 \text{ MeV}$ 95 NA31 94 E799 93 B845 es, fits, limits, etc. 95 SPEC $m_{ee} > 470 \text{ MeV}$ 93 CNTR Sup. by AKAGI 95 91 NA31 Sup. by BARR 95 83 SPEC stance-corrected for the m_{ee} cuts shown. planes favors $CP = -1$ for K_{L}^{0} .
Value (units 10^{-8}) 4.1 ±0.8 ©0 6 ±2 ±1 10.4 ±3.7 ±1 3.96 ±0.78 ±1 3.07 ±1.25 ±0 • • • We do not to 7 ±3 ±2 6 ±2 ±1 4 ±3 <260 55 Values are for to 56 Distribution of $\Gamma(\pi^0 \mu^+ \mu^-)/\Gamma_1$ Violates CP higher-order Value (units 10^{-9}) < 5.1	CL% EVTS UR AVERAGE 1 18 1.1 8 1.32 27 0.26 6 use the following 2 6 1 18 2 90 the total branchir angles between botal in leading order electroweak inte	Error Includes so 55 AKAGI 56 BARR GU VAGINS data for average AKAGI BARR BALATS ag fraction, acceptwo e ⁺ e ⁻ pair r. Test for ΔS straction. <u>DOCUMENT ID HARRIS</u>	TIO TECN COMMENT ale factor of 1.2. 95 SPEC $m_{ee} > 470 \text{ MeV}$ 95 NA31 94 E799 93 B845 es, fits, limits, etc. • • • • • 95 SPEC $m_{ee} > 470 \text{ MeV}$ 93 CNTR Sup. by AKAGI 95 91 NA31 Sup. by BARR 95 83 SPEC otance-corrected for the m_{ee} cuts shown. planes favors $CP = -1$ for K_0^D . 1 weak neutral current. Allowed by TECN 93 TECN 93 E799
$\frac{VALUE (units 10^{-8})}{4.1 \pm 0.8}$ 00 6 ± 2 ±1 10.4 ±3.7 ±1 3.96 ±0.78 ±1 3.07 ±1.25 ±0 • • • We do not 17 ±3 ±2 6 ±2 ±1 4 ±3 <260 55 Values are for 15 Distribution of $\Gamma(\pi^0 \mu^+ \mu^-)/\Gamma_1$ Violates CP higher-order $\frac{VALUE (units 10^{-9})}{<}$ 5.1	CL% EVTS UR AVERAGE 1 18 1.1 8 1.32 27 0.26 6 1 18 2 90 the total branchir angles between Loctal in leading order electroweak inte	Error Includes SC 55 AKAGI 56 BARR GU VAGINS data for average 55 AKAGI AKAGI BARR BALATS arg fraction, acceptwo e+e-pair T. Test for \(\Delta S \) raction. \[\int DOCUMENT ID HARRIS 6 data for average 6 data for average 7. \]	TID TECN COMMENT ale factor of 1.2. 95 SPEC $m_{ee} > 470 \text{ MeV}$ 95 NA31 94 E799 93 B845 es, fits, limits, etc. • • • • 95 SPEC $m_{ee} > 470 \text{ MeV}$ 93 CNTR Sup. by AKAGI 95 91 NA31 Sup. by BARR 95 83 SPEC otance-corrected for the m_{ee} cuts shown. planes favors $CP = -1$ for K_L^0 . 1 weak neutral current. Allowed by TECN 93 E799 es, fits, limits, etc. • • •
$\frac{VALUE (units 10^{-8})}{4.1 \pm 0.8}$ 00 6 ± 2 ±1 10.4 ±3.7 ±1 3.96 ±0.78 ±1 3.07 ±1.25 ±0 • • • We do not 17 ±3 ±2 6 ±2 ±1 4 ±3 <260 55 Values are for 15 Distribution of $\Gamma(\pi^0 \mu^+ \mu^-)/\Gamma_1$ Violates CP higher-order $\frac{VALUE (units 10^{-9})}{<}$ 5.1	CL% EVTS UR AVERAGE 1.1 8 1.1.1 8 1.32 27 1.26 6 1.18 2 90 1.19 18 2 90 1.19 18 2 90 1.19 18 2 90 1.19 19 1.1	Error Includes SC 55 AKAGI 56 BARR GU VAGINS data for average 55 AKAGI BARR BALATS ag fraction, acceptwo e+e- pair T. Test for ΔS traction. **DOCUMENT ID** HARRIS data for average 57 CARROLL	TECN TECN COMMENT ale factor of 1.2. 95 SPEC $m_{ee} > 470 \text{ MeV}$ 95 NA31 94 E799 93 B845 es, fits, limits, etc. • • • 95 SPEC $m_{ee} > 470 \text{ MeV}$ 93 CNTR Sup. by AKAGI 95 91 NA31 Sup. by BARR 95 83 SPEC otance-corrected for the m_{ee} cuts shown. planes favors $CP = -1$ for K_L^0 . 1 weak neutral current. Allowed by 1 TECN 93 E799 95, fits, limits, etc. • • •
VALUE (units 10 ⁻⁸) 4.1 ±0.8 ° O	CL% EVTS UR AVERAGE 1.1 8 1.32 27 1.26 6 18 2 90 the total branchir angles between total in leading order electroweak inte CL% EVTS 90 0 0 use the following 90 0 190	Error Includes SC 55 AKAGI 56 BARR GU VAGINS data for average 55 AKAGI AKAGI BARR BALATS ng fraction, according to the control of the contro	TECN COMMENT
$\frac{VALUE (units 10^{-8})}{4.1 \pm 0.8}$ 00 6 ± 2 ±1 10.4 ±3.7 ±1 3.96 ±0.78 ±1 3.07 ±1.25 ±0 • • • • We do not 17 ±3 ±2 6 ±2 ±1 4 ±3 <<260 55 Values are for 15 Collection of $\frac{1}{3}$ $\frac{1}{3}$ $\frac{1}{3}$ $\frac{1}{3}$ Violates $\frac{1}{3}$ \frac	CL% EVTS UR AVERAGE 1 18 1.1 8 1.32 27 0.26 6 1.26 6 1.3 2 90 1.4 18 2 90 1.5 18 2 90 1.6 18 2 90 1.6 18 2 90 1.7 18 1.8 18 2 90 1.8 18 2 90 1.8 18 2 90 1.8 18 2 90 1.8 18 2 90 1.8 18 3 2 90 1.8 18 1.8 1	Error Includes so SS AKAGI 56 BARR GU VAGINS data for average 55 AKAGI AKAGI BARR BALATS ag fraction, acceptwo e+e-pair T. Test for ΔS traction. DOCUMENT ID HARRIS data for average 57 CARROLL 58 DONALDSON O decays = 0.12	TIO TECN COMMENT ale factor of 1.2. 95 SPEC $m_{ee} > 470 \text{ MeV}$ 95 NA31 94 E799 93 B845 es, fits, limits, etc. • • • • • • • • • • • • • • • • • • •
$\frac{VALUE (units 10^{-8})}{4.1 \pm 0.8}$ 00 6 ± 2 ±1 10.4 ±3.7 ±1 3.96 ±0.78 ±1 3.07 ±1.25 ±0 • • • • We do not 17 ±3 ±2 6 ±2 ±1 4 ±3 <<260 55 Values are for 15 Collection of $\frac{1}{3}$ $\frac{1}{3}$ $\frac{1}{3}$ $\frac{1}{3}$ Violates $\frac{1}{3}$ \frac	CL% EVTS UR AVERAGE 1 18 1.1 8 1.32 27 0.26 6 1.26 6 1.3 2 90 1.4 18 2 90 1.5 18 2 90 1.6 18 2 90 1.6 18 2 90 1.7 18 1.8 18 2 90 1.8 18 2 90 1.8 18 2 90 1.8 18 2 90 1.8 18 2 90 1.8 18 3 2 90 1.8 18 1.8 1	Error Includes so SS AKAGI 56 BARR GU VAGINS data for average 55 AKAGI AKAGI BARR BALATS ag fraction, acceptwo e+e-pair T. Test for ΔS traction. DOCUMENT ID HARRIS data for average 57 CARROLL 58 DONALDSON O decays = 0.12	TIO TECN COMMENT ale factor of 1.2. 95 SPEC $m_{ee} > 470 \text{ MeV}$ 95 NA31 94 E799 93 B845 es, fits, limits, etc. • • • • • • • • • • • • • • • • • • •
### ALUE (units 10 ⁻⁸) 4.1 ±0.8 Oi 6 ±2 ±1 10.4 ±3.7 ±1 3.96±0.78±0 3.07±1.25±0 • • We do not is 7 ±3 ±2 6 ±2 ±1 4 ±3 <260 55 Values are for t 56 Distribution of F(π ⁰ μ ⁺ μ ⁻)/Γ Vlolates CP higher-order ##################################	CL% EVTS UR AVERAGE 1.1 8 1.32 27 1.26 6 1.26 18 2 90 1.4 total branchir angles between the total branchir angles branchir angles between the total branchir angles branchir ang	Error Includes so SS AKAGI 56 BARR GU VAGINS data for average 55 AKAGI AKAGI BARR BALATS ag fraction, acceptwo e+e-pair T. Test for ΔS traction. DOCUMENT ID HARRIS data for average 57 CARROLL 58 DONALDSON O decays = 0.12	TID TECN COMMENT ale factor of 1.2. 95 SPEC $m_{ee} > 470 \text{ MeV}$ 95 NA31 94 E799 93 B845 es, fits, limits, etc. • • • • • 95 SPEC $m_{ee} > 470 \text{ MeV}$ 93 CNTR Sup. by AKAGI 95 91 NA31 Sup. by BARR 95 83 SPEC obtance-corrected for the m_{ee} cuts shown. planes favors $CP = -1$ for K_L^0 . 1 weak neutral current. Allowed by TECN 93 E799 es, fits, limits, etc. • • • 800 SPEC 174 SPEC 239. 266.
VALUE (units 10 ⁻⁸) 4.1 ±0.8 00 6 ±2 ±1 10.4 ±3.7 ±1 3.96±0.78±0 3.07±1.25±2 • • • We do not if 7 ±3 ±2 6 ±2 ±1 4 ±3 <260 55 Values are for t 56 Distribution of $\Gamma(\pi^0 \mu^+ \mu^-)/\Gamma_0$ Violates CP higher-order VALUE (units 10 ⁻⁹) < 5.1 • • • We do not if < 1200 <56600 57 Uses $K_L^0 \rightarrow \pi$ 58 Uses $K_L^0 \rightarrow \pi$ $\Gamma(\pi^0 e^+ e^-)/\Gamma_0$	CL% EVTS UR AVERAGE 1.1 8 1.32 27 1.26 6 1.26 18 2 90 1.18 2 90 1.19 18 1.19 19 1.19	Error Includes SC 55 AKAGI 56 BARR GU VAGINS data for average 55 AKAGI AKAGI BARR BALATS of fraction, accept two e ⁺ e ⁻ pair T. Test for ΔS traction. DOCUMENT ID HARRIS data for average 57 CARROLL 58 DONALDSON 0 decays = 0.12 0 decay	TECN TECN COMMENT ale factor of 1.2. 95 SPEC $m_{ee} > 470 \text{ MeV}$ 95 NA31 94 E799 93 B845 es, fits, limits, etc. • • • 95 SPEC $m_{ee} > 470 \text{ MeV}$ 93 CNTR Sup. by AKAGI 95 91 NA31 Sup. by BARR 95 83 SPEC otance-corrected for the m_{ee} cuts shown. planes favors $CP = -1$ for K_L^0 . 1 weak neutral current. Allowed by TECN 93 E799 93 E799 93 E799 25, fits, limits, etc. • • • • 800 SPEC 1 74 SPEC 239. 26.
Value (units 10 ⁻⁸) 4.1 ±0.8 00 6 ±2 ±1 10.4 ±3.7 ±1 3.96 ±0.78 ±1 3.07 ±1.25 ±0 • • We do not to 7 ±3 ±2 6 ±2 ±1 4 ±3 <260 55 Values are for to 56 Distribution of $\Gamma(\pi^0 \mu^+ \mu^-)/\Gamma_0$ Violates CP higher-order Value (units 10 ⁻⁹) < 5.1 • • • We do not to < 1200 <56600 57 Uses $K^0 \to \pi$ 58 Uses $K^0 \to \pi$ Violates CP	CL% EVTS UR AVERAGE 1 18 1.1 8 1.32 27 0.26 6 0.use the following 0 6 1 18 2 90 0 18 10 leading order 10 10 leading order 10 10 leading order 11 10 10 10 10 10 10 10 10 10 10 10 10 1	Error Includes SC 55 AKAGI 56 BARR GU VAGINS data for average 55 AKAGI AKAGI BARR BALATS ng fraction, acceptive e + e - pair r. Test for Δ5 reaction. DOCUMENT ID HARRIS data for average 57 CARROLL 58 DONALDSON 0 decays = 0.12 0 decays =	TIO TECN COMMENT ale factor of 1.2. 95 SPEC $m_{ee} > 470 \text{ MeV}$ 95 NA31 94 E799 93 B845 es, fits, limits, etc. • • • • • • • • • • • • • • • • • • •
VALUE (units 10 ⁻⁸)	CL% EVTS UR AVERAGE 1 18 1.1 8 1.32 27 0.26 6 1 18 2 90 the total branchir angles between votal in leading order electroweak inte CL% EVTS 90 0 use the following 90 0 $\frac{1}{2}$ 1	Error Includes SC 55 AKAGI 56 BARR GU VAGINS data for average 55 AKAGI AKAGI BARR BALATS of fraction, acceptive e+e-pair T. Test for \(\Delta S \) raction. \[\frac{DOCUMENT ID}{4} \] HARIS data for average 57 CARROLL 58 DONALDSON 0) decays = 0.12 \] \[\frac{D}{4} \] decays = 0.12 \] \[\frac{D}{4} \] decays = 0.12 \] \[\frac{D}{4} \] Direct and inception of to dominate the control of t	TECN COMMENT
VALUE (units 10 ⁻⁸) 4.1 ±0.8 00 6 ±2 ±1 10.4 ±3.7 ±1 3.96±0.78±0 3.07±1.25±1 6 ±2 ±1 4 ±3 4 ±3 4 ±3 4 ±3 4 ±3 4 ±0 55 Values are for t 56 Distribution of $\Gamma(\pi^0 \mu^+ \mu^-)/\Gamma_0$ Violates CP highter-order VALUE (units 10 ⁻⁹) < 5.1	CL% EVTS UR AVERAGE 1.1 8 1.32 27 1.26 6 1.32 90 1.4 1.5 1.1 1.8 2 90 1.6 1.1 1.8 2 90 1.6 1.1 1.8 2 90 1.6 1.1 1.8 2 90 1.6 1.1 1.8 2 90 1.6 1.1 1.8 2 90 1.6 1.1 1.8 2 90 1.6 1.1 1.8 2 90 1.6 1.8 2 90 1.8 2 90 1.8 2 90 1.8 2 90 1.8 2 90 1.8 2 90 1.8 1.8 2 90 1.8 2 2 90 1.8 2 2 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3	Error Includes SC 55 AKAGI 56 BARR GU VAGINS data for average 55 AKAGI AKAGI BARR BALATS in fraction, acceptive e ⁺ e ⁻ pair T. Test for ΔS straction. DOCUMENT ID HARRIS data for average 57 CARROLL 88 DONALDSON 0 DONAL	TECN COMMENT ale factor of 1.2. 95 SPEC $m_{ee} > 470 \text{ MeV}$ 95 NA31 94 E799 93 B845 es, fits, limits, etc. • • • 95 SPEC $m_{ee} > 470 \text{ MeV}$ 93 CNTR Sup. by AKAGI 95 91 NA31 Sup. by BARR 95 83 SPEC otance-corrected for the m_{ee} cuts shown. planes favors $CP = -1$ for K_L^0 . 1 weak neutral current. Allowed by TECN 93 E799 es, fits, limits, etc. • • • 80D SPEC 1 74 SPEC 239. 26. Girect CP -violating contributions are exite CP -conserving part. Test for $\Delta S = 1$ r electroweak interaction.
VALUE (units 10 ⁻⁸) 4.1 ±0.8 00 6 ±2 ±1 3.96±0.78±0 3.07±1.25±1 6 ±2 ±1 4 ±3 4 ±3 4 ±3 4 ±3 4 ±3 4 ±3 4 ±3 4 ±3	CL% EVTS UR AVERAGE 1.1 8 1.32 27 1.26 6 1.26 6 1.38 2 90 1.4 1.1 1.8 2 90 1.4 1.1 1.8 2 90 1.4 1.1 1.8 1.1 1.8 1.1 1.8 1.1 1.8 1.1 1.8 1.1 1.8 1.1 1.8 1.1 1.8 1.1 1.8 1.1 1.8 1.8	Error Includes SC 55 AKAGI 56 BARR GU VAGINS data for average 55 AKAGI BARR BALATS ag fraction, accept two e+e- pair T. Test for ΔS at a for average 57 CARROLL 58 DONALDSON (1) decays = 0.12 (2) decays = 0.12 (3) decays = 0.12 (4) decays = 0.12 (5) decays = 0.12 (5) decays = 0.12 (5) decays = 0.12 (6) decays = 0.12 (7) decays = 0.12	TECN TECN COMMENT ale factor of 1.2. 95 SPEC $m_{ee} > 470 \text{ MeV}$ 95 NA31 94 E799 93 B845 es, fits, limits, etc. • • • 95 SPEC $m_{ee} > 470 \text{ MeV}$ 93 CNTR Sup. by AKAGI 95 91 NA31 Sup. by BARR 95 83 SPEC otance-corrected for the m_{ee} cuts shown. planes favors $CP = -1$ for K_L^0 . 1 weak neutral current. Allowed by TECN 93 E799 95, fits, limits, etc. • • • 80D SPEC 1 74 SPEC 229. 26. Girect CP -violating contributions are exile CP -conserving part. Test for $\Delta S = 1$ relectroweak interaction. TECN
Value (units 10 ⁻⁸) 4.1 ±0.8 00 6 ±2 ±1 10.4 ±3.7 ±1 3.96 ±0.78 ±1 3.07 ±1.25 ±0 • • • We do not to 7 ±3 ±2 6 ±2 ±1 4 ±3 <260 55 Values are for to 56 Distribution of $\Gamma(\pi^0 \mu^+ \mu^-)/\Gamma_0$ Violates CP higher-order Value (units 10 ⁻⁹) < 5.1 • • • We do not to < 1200 <56600 57 Uses $K^0 \rightarrow \pi$ 58 Uses $K^0 \rightarrow \pi$ 58 Uses $K^0 \rightarrow \pi$ Violates CP pected to be weak neutral VALUE (units 10 ⁻⁸) < 4.3	CL% EVTS UR AVERAGE 1 18 1.1 27 0.26 6 0.25 the following 0 6 1 18 2 90 0 18 0 19 0	Error Includes SC SS AKAGI 56 BARR GU VAGINS data for average 55 AKAGI AKAGI BARR BALATS of fraction, acction. DOCUMENT ID HARRIS data for average 57 CARROLL 58 DONALDSON 0 decays = 0.12 0	TIO TECN COMMENT ale factor of 1.2. 95 SPEC $m_{ee} > 470 \text{ MeV}$ 95 NA31 94 E799 93 B845 es, fits, limits, etc. • • • • 95 SPEC $m_{ee} > 470 \text{ MeV}$ 93 CNTR Sup. by AKAGI 95 91 NA31 Sup. by BARR 95 83 SPEC bitance-corrected for the m_{ee} cuts shown. planes favors $CP = -1$ for K_0^D . 1 weak neutral current. Allowed by TECN 93 E799 es, fits, limits, etc. • • • 80D SPEC 174 SPEC 1239. 26. Girect CP -violating contributions are exits CP -correcting part. Test for $\Delta S = 1$ or electroweak interaction. TECN 93B E799
VALUE (units 10 ⁻⁸)	CL% EVTS UR AVERAGE 1 18 1.1 8 1.32 27 0.26 6 18 2 90 18 18 2 90 19 18 19 19 19 19 19 19 19 19 19 19 19 19 19 1	Error Includes SC 55 AKAGI 56 BARR GU VAGINS data for average 55 AKAGI AKAGI BARR BALATS of fraction, acceptive e+ e- pair 7. Test for \(\Delta S \) raction. \[\int DOCUMENT ID HARRIS of the for average 57 CARROLL 50 DONALDSON DONALD	TIO TECN COMMENT ale factor of 1.2. 95 SPEC $m_{ee} > 470 \text{ MeV}$ 95 NA31 94 E799 93 B845 es, fits, limits, etc. • • • • 95 SPEC $m_{ee} > 470 \text{ MeV}$ 93 CNTR Sup. by AKAGI 95 91 NA31 Sup. by BARR 95 83 SPEC otance-corrected for the m_{ee} cuts shown. planes favors $CP = -1$ for K_L^0 . 1 weak neutral current. Allowed by TECN 93 E799 es, fits, limits, etc. • • • 800 SPEC 174 SPEC 239. 226. Girect CP -violating contributions are except expectation. TECN 93 E799 90 E731
VALUE (units 10 ⁻⁸) 4.1 ±0.8 00 6 ±2 ±1 3.96±0.78±0 3.07±1.25±1 6 ±2 ±1 4 ±3 < •• • We do not 1 7 ±3 ±2 6 ±2 ±1 4 ±3 <260 55 Values are for t 56 Distribution of $\Gamma(\pi^0 \mu^+ \mu^-)/\Gamma_0$ Violates CP higher-order VALUE (units 10 ⁻⁹) < \$.1 $\Gamma(\pi^0 e^+ e^-)/\Gamma_0$ Violates CP pected to be weak neutral VALUE (units 10 ⁻⁹) < 4.3 < 7.5 < 5.5	CL% EVTS UR AVERAGE 1 18 1.1 8 1.32 27 1.26 6 1 18 2 90 1.1 18 2 90 1.1 18 2 90 1.1 18 2 90 1.1 18 2 90 1.1 18 2 90 1.1 18 2 90 1.1 18 1.1 1	Error Includes SC SS AKAGI 56 BARR GU VAGINS data for average 55 AKAGI AKAGI BARR BALATS ag fraction, accept two e+e- pair T. Test for ΔS at action. DOCUMENT ID HARRIS DONALDSON (1) decays = 0.12 (1) decays = 0.13 (1) decays =	TECN TECN COMMENT ale factor of 1.2. 95 SPEC $m_{ee} > 470 \text{ MeV}$ 95 NA31 94 E799 93 B845 es, fits, limits, etc. • • • 95 SPEC $m_{ee} > 470 \text{ MeV}$ 93 CNTR Sup. by AKAGI 95 91 NA31 Sup. by BARR 95 83 SPEC otance-corrected for the m_{ee} cuts shown. planes favors $CP=-1$ for K_L^0 . 1 Tecn 93 E799 es, fits, limits, etc. • • • 80D SPEC 1 74 SPEC 239. 26. 1 relectroweak interaction. 1 Tecn 93 E799 93 E799 94 F731 96 B845
VALUE (units 10 ⁻⁸) 4.1 ±0.8 00 6 ±2 ±1 3.96±0.78±0 3.07±1.25±1 6 ±2 ±1 4 ±3 4 ±3 4 ±3 4 ±3 4 ±3 4 ±3 4 ±3 4 ±3	CL% EVTS UR AVERAGE 1.1 8 1.32 27 1.26 6 1.38 2 90 1.4 1.1 1.8 2 90 1.4 1.1 1.8 2 90 1.4 1.1 1.8 1.1 2 90 1.4 1.1 1.8 1.1 1.8 1.1 1.8 1.1 1.8 1.1 1.8 1.1 1.8 1.1 1.8 1.1 1.8 1.1 1.8 1.1 1.8 1.1 1.8 1.8	Error Includes SC SS AKAGI 56 BARR GU VAGINS data for average 55 AKAGI AKAGI BARR BALATS ag fraction, accept two e+e- pair T. Test for ΔS straction. DOCUMENT ID HARRIS DONALDSON (1) decays = 0.12 (1) decays = 0.13 (1) decays = 0.14 (1) decays = 0.15 (1) decays =	TECN TECN COMMENT ale factor of 1.2. 95 SPEC $m_{ee} > 470 \text{ MeV}$ 95 NA31 94 E799 93 B845 es, fits, limits, etc. • • • 95 SPEC $m_{ee} > 470 \text{ MeV}$ 93 CNTR Sup. by AKAGI 95 91 NA31 Sup. by BARR 95 83 SPEC otance-corrected for the m_{ee} cuts shown. planes favors $CP=-1$ for K_L^0 . 1 TECN 93 E799 es, fits, limits, etc. • • • • • • 80D SPEC 1 74 SPEC 239. 26. Girect CP -violating contributions are exile CP -conserving part. Test for $\Delta S = 1$ or electroweak interaction. TECN 938 E799 90 E731 90 B845 es, fits, limits, etc. • • •
VALUE (units 10 ⁻⁸) 4.1 ±0.8 Oi 6 ± 2 ±1 10.4 ±3.7 ±1 3.96 ±0.78 ±1 5.96 ±0.78 ±1 6 ±2 ±1 4 ±3 <260 55 Values are for to 56 Distribution of (π ⁰ μ ⁺ μ ⁻) / Γ	CL% EVTS UR AVERAGE 1 18 1.1 8 1.32 27 0.26 6 18 2 6 18 2 90 the total branchir angles between the total branchir angles branchir angles branchir angles branchir ang	Error Includes SC 55 AKAGI 56 BARR GU VAGINS data for average 55 AKAGI AKAGI BARR BALATS of fraction, acction. DOCUMENT ID HARRIS data for average 57 CARROLL 58 DONALDSON 0 decays = 0.12 0	TIO TECN COMMENT ale factor of 1.2. 95 SPEC $m_{ee} > 470 \text{ MeV}$ 95 NA31 94 E799 93 B845 es, fits, limits, etc. • • • • 95 SPEC $m_{ee} > 470 \text{ MeV}$ 93 CNTR Sup. by AKAGI 95 91 NA31 Sup. by BARR 95 83 SPEC btance-corrected for the m_{ee} cuts shown. planes favors $CP = -1$ for K_0^D . 1 weak neutral current. Allowed by TECN 93 E799 93, fits, limits, etc. • • • • 800 SPEC VARIANCE S
## ALUE (units 10 ⁻⁸) 4.1 ±0.8 Oi 6 ±2 ±1 3.96±0.78±0 3.07±1.25±0 • • • We do not is 7 ±3 ±2 6 ±2 ±1 4 ±3 <260 55 Values are for t 56 Distribution of $(\pi^0 \mu^+ \mu^-)/\Gamma_1$ $(\pi^0 \mu^+ \mu^-)/\Gamma_2$ $(\pi^0 \mu^+ \mu^-)/\Gamma_3$ $(\pi^0 \mu^+ \mu^-)/\Gamma_4$ $(\pi^0 \mu^+ \mu^-)/\Gamma_3$ $(\pi^0 \mu^+ \mu^-)/\Gamma_4$ $(\pi^0 \mu^+ \mu^-)/\Gamma_5$	CL% EVTS UR AVERAGE 1 18 1.32 27 0.26 6 1 28 2 90 1 18 2 90 1 18 2 90 1 18 2 90 1 18 2 90 1 18 2 90 1 18 2 90 1 18 3 18 4 19 6 18 6 18 6 18 6 18 7 90 8 18 7 90 8 18 7 90 8 18 7 90 8 18 8 18 8 18 8 18 8 18 8 18 8 18 8 1	Error Includes SC SS AKAGI 56 BARR GU VAGINS data for average 55 AKAGI AKAGI BARR BALATS ag fraction, accept two e+e- pair T. Test for ΔS straction. DOCUMENT ID HARRIS DONALDSON (1) decays = 0.12 (1) decays = 0.13 (1) decays = 0.14 (1) decays = 0.15 (1) decays =	TIO TECN COMMENT ale factor of 1.2. 95 SPEC $m_{ee} > 470 \text{ MeV}$ 95 NA31 94 E799 93 B845 es, fits, limits, etc. • • • • 95 SPEC $m_{ee} > 470 \text{ MeV}$ 93 CNTR Sup. by AKAGI 95 91 NA31 Sup. by BARR 95 83 SPEC btance-corrected for the m_{ee} cuts shown. planes favors $CP = -1$ for K_0^D . 1 weak neutral current. Allowed by TECN 93 E799 93, fits, limits, etc. • • • • 800 SPEC VARIANCE S

⁵⁹ Uses $K_I^0 \to \pi^+\pi^-\pi^0/(\text{all } K_I^0)$ decays = 0.1239.

```
\Gamma(\pi^0 \nu \overline{\nu})/\Gamma_{total} \Gamma_{29}/\Gamma Violates CP in leading order. Test of direct CP violation since the indirect CP-violating
       and CP-conserving contributions are expected to be suppressed. Test of \Delta S=1 weak
       neutral current.
                                           DOCUMENT ID
VALUE (units 10<sup>-5</sup>) CL% EVTS
                                                           94 E799
< 5.8
                                           WEAVER
                     90
                                0

    • • • We do not use the following data for averages, fits, limits, etc. • • •
< 22
                 90 0
                                          GRAHAM
                                                           92 CNTR
                                       60 LITTENBERG 89 RVUE
 <760
                     90
 60 LITTENBERG 89 is from retroactive data analysis of CRONIN 67.
\Gamma(e^{\pm}\mu^{\mp})/\Gamma_{
m total} Test of lepton family number conservation.
                                                                                                 Γ<sub>30</sub>/Γ

        VALUE (units 10<sup>-11</sup>)
        CL%
        EVTS
        DOCUMENT III

        <</td>
        3.3
        90
        0
        61 ARISAKA

                                          DOCUMENT ID
                                                                TECN COMMENT
 < 3.3
                     90
                                                             93 B791
• • • We do not use the following data for averages, fits, limits, etc. • •
                                                             95 SPEC
 < 9.4
                      90
                                0
                                           AKAGI
 < 3.9
                                           ARISAKA
                                                              93 B791
 < 9.4
                      90
                                            AKAGI
                                                              91 SPEC Sup. by AKAGI 95
                                           INAGAKI
 < 43
                      90
                                                             89 SPEC In AKAGI 91
                                           MATHIAZHA...89 SPEC
 < 22
                      90
                                           SCHAFFNER 89 SPEC
 < 190
                      90
                                           SCHAFFNER 89 SPEC COUSINS 88 SPEC GREENLEE 88 SPEC Repl. by SCHAFFNER 89
 <1100
                      90
 < 670
                                        62 CLARK
 < 157
                                                             71 ASPK
                      90
 61 This is the combined result of ARISAKA 93 and MATHIAZHAGAN 89.
  62 Possible (but unknown) systematic errors. See note on CLARK 71 \Gamma(\mu^+\mu^-)/\Gamma(\pi^+\pi^-)
 \begin{array}{c} \Gamma (e^{\pm} \, e^{\pm} \, \mu^{\mp} \, \mu^{\mp}) / \Gamma_{\rm total} \\ \text{Test of lepton family number conservation.} \end{array} 
                                                                                                  \Gamma_{31}/\Gamma
<u>VALUE (units 10<sup>-9</sup>) CL% EVTS</u> <u>DOCUMENT ID</u>

<6.1 90 0 63 GU
                                                                 TECN
  ^{63}\,\mathrm{Assuming} uniform phase space distribution.
 \Gamma(e^{\pm}\mu^{\mp})/[\Gamma(\pi^{+}\pi^{-}\pi^{0}) + \Gamma(\pi^{\pm}\mu^{\mp}\nu) + \Gamma(\pi^{\pm}e^{\mp}\nu_{e})] 
Test of lepton family number conservation.
                                                                                 \Gamma_{30}/(\Gamma_2+\Gamma_3+\Gamma_6)
VALUE (units 10<sup>-4</sup>) CL% DOCUMENT ID
• • • We do not use the following data for averages, fits, limits, etc. • • •
 < 0.1
                              90
                                           BOTT-...
 < 0.08
                              90
                                           FITCH
                                                             67 OSPK
                                            CARPENTER 66 OSPK
 < 1.0
                              90
                                            ANIKINA
                                                             65 CC
 <10.0
                   ENERGY DEPENDENCE OF KO DALITZ PLOT
```

For discussion, see note on Dalitz plot parameters in the K^{\pm} section of the Particle Listings above. For definitions of a_{ν} , a_{t} , a_{tr} , and a_{ν} , see the earlier version of the same note in the 1982 edition of this *Review* published in Physics Letters **111B** 70 (1982).

|matrix element|^2 = 1 +
$$gu + hu^2 + Jv + kv^2$$

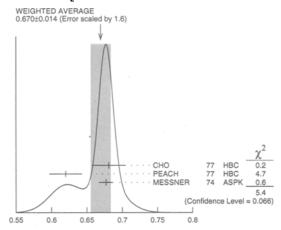
where $u = (s_3 - s_0) / m_\pi^2$ and $v = (s_1 - s_2) / m_\pi^2$

LINEAR COEFFICIENT g FOR $K_L^0 \to \pi^+\pi^-\pi^0$

VALUE	EVTS	DOCUMENT ID			COMMENT -
0.670±0.014 OUR	AVERAGE	Error includes scale	facto	or of 1.6.	See the ideogram below.
0.681 ± 0.024	6499	СНО	77	HBC	
0.620 ± 0.023	4709	PEACH	77	HBC	
0.677 ± 0.010	509k	MESSNER	74	ASPK	$a_V = -0.917 \pm 0.013$
• • • We do not u	ise the follow	ving data for averages	, fits	, limits,	etc. • • •
0.69 ±0.07	192	64 BALDO		HLBC	
0.590 ± 0.022	56k	⁶⁴ BUCHANAN	75	SPEC	$a_{y} = -0.277 \pm 0.010$
0.619 ± 0.027	20k	64,65 BISI	74	ASPK	$a_t = -0.282 \pm 0.011$
0.612 ± 0.032		64 ALEXANDER	73B	HBC	•
0.73 ±0.04	3200	64 BRANDENB	73	HBC	
0.50 ±0.11	180	64 JAMES	72	HBC	
0.608 ± 0.043	1486	64 KRENZ	72	HLBC	$a_t = -0.277 \pm 0.018$
0.688 ± 0.074	384	64 METCALF		ASPK	$a_t = -0.31 \pm 0.03$
0.650 ± 0.012	29k	64 ALBROW	70	ASPK	$a_y = -0.858 \pm 0.015$
0.593 ± 0.022	36k	64,66 BUCHANAN	70	SPEC	$a_{II} = -0.278 \pm 0.010$
0.664 ± 0.056	4400	64 SMITH	70	OSPK	$a_t = -0.306 \pm 0.024$
0.400 ± 0.045	2446	64 BASILE	68B	OSPK	$a_t = -0.188 \pm 0.020$
0.649±0.044	1350	64 HOPKINS	67	HBC	$a_t = -0.294 \pm 0.018$
0.428 ± 0.055	1198	⁶⁴ NEFKENS	67	OSPK	$a_{IJ} = -0.204 \pm 0.025$
0.64 ±0.17	280	64 ANIKINA	66	cc	$a_V = -8.2^{+0.9}_{-1.3}$
0.70 ±0.12	126	64 HAWKINS	66	HBC	$a_V = -8.6 \pm 0.7$
0.32 ±0.13	66	64 ASTBURY	65	CC	$a_V = -5.5 \pm 1.5$
0.51 ±0.09	310	64 ASTBURY	65B	cc	$a_V = -7.3^{+0.6}_{-0.8}$
0.55 ±0.23	79	64 ADAIR	64	нвс	$a_{\nu} = -7.6 \pm 1.7$
0.51 ±0.20	77	64 LUERS	64	HBC	$a_{v} = -7.3 \pm 1.6$
					•

64 Quadratic dependence required by some experiments. (See sections on "QUADRATIC COEFFICIENT h" and "QUADRATIC COEFFICIENT k" below.) Correlations prevent us from averaging results of fits not including g, h, and k terms.

to use more reliable K_L^0 momentum spectrum of second experiment (had same beam).



Linear coeff. g for $K_L^0 \to \pi$ +π-π⁰ matrix element squared

QUADRATIC COEFFICIENT h FOR $K_L^0 \rightarrow \pi^+\pi^-\pi^0$

YALUE	<u> </u>	DOCUMENT ID	COMEN I		
0.079±0.007 OUR	AVERAGE	 -			
0.095 ± 0.032	6499	СНО	77	HBC	
0.048 ± 0.036	4709	PEACH	77	HBC	
0.079 ± 0.007	509k	MESSNER	74	ASPK	
• • • We do not us	the followin	g data for averag	es. fit	s. limits.	

67 ALBROW -0.011 ± 0.018 70 ASPK 67 SMITH 0.043 ± 0.052 4400 70 OSPK

See notes in section "LINEAR COEFFICIENT g FOR $K_L^0 \to \pi^+\pi^-\pi^0$ |MATRIX ELEMENT|2" above.

67 Quadratic coefficients h and k required by some experiments. (See section on "QUADRATIC COEFFICIENT k" below.) Correlations prevent us from averaging results of fits not including g, h, and k terms.

QUADRATIC COEFFICIENT k FOR $K_L^0 \to \pi^+\pi^-\pi^0$

VALUE	EYTS	DOCUMENT ID		TECN
0.0098±0.0018 OU	R AVERAGE			
0.024 ± 0.010	6499	сно	77	HBC
-0.008 ± 0.012	4709	PEACH	77	HBC
0.0097 ± 0.0018	509k	MESSNER	74	ASDK

LINEAR COEFFICIENT J FOR $K_L^0 \rightarrow \pi^+\pi^-\pi^0$ (CP-VIOLATING TERM) Listed in CP-violation section below.

QUADRATIC COEFFICIENT h FOR $K_L^0 \rightarrow \pi^0 \pi^0 \pi^0$

VALUE (units 10 ⁻³)	EVTS	DOCUMENT ID	TECN
-3.3±1.1±0.7	5M	68 SOMALWAR 9	2 E731

 68 SOMALWAR 92 chose m_{π^+} as normalization to make it compatible with the Particle Data Group $K_I^0 \rightarrow \pi^+\pi^-\pi^0$ definitions.

KY FORM FACTORS

For discussion, see note on form factors in the K^{\pm} section of the Particle Listings above.

In the form factor comments, the following symbols are used.

 f_{+} and f_{-} are form factors for the vector matrix element.

 f_S and f_T refer to the scalar and tensor term.

 $f_0 = f_+ + f_- t/(m_K^2 - m_\pi^2).$

 λ_+ , λ_- , and λ_0 are the linear expansion coefficients of f_+ , f_- , and f_0 .

 λ_+ refers to the $K^0_{\mu3}$ value except in the K^0_{e3} sections.

 $d\xi(0)/d\lambda_{+}$ is the correlation between $\xi(0)$ and λ_{+} in $K_{\mu3}^{0}$.

 $d\lambda_0/d\lambda_+$ is the correlation between λ_0 and λ_+ in $K^0_{~\mu3}.$

 $t = momentum transfer to the x in units of <math>m_x^2$.

DP = Dalitz plot analysis.

 $PI = \pi$ spectrum analysis.

 $MU = \mu$ spectrum analysis.

POL= μ polarization analysis.

BR = $K_{\mu 3}^0/K_{e3}^0$ branching ratio analysis.

E = positron or electron spectrum analysis.

RC = radiative corrections.

λ_{+} (LINEAR ENERGY DEPENDENCE OF f_{+} IN K_{43}^{0} DECAY)

For radiative correction of K_{e3}^0 DP, see GINSBERG 67 and BECHERRAWY 70.

VALUE	EVT5	DOCUMENT ID		TECN	COMMENT
0.0300±0.0016 OUI	R AVERAGE	Error Includes s	cale	factor of	f 1.2.
0.0306 ± 0.0034	74k	BIRULEV	81	SPEC	DP
0.025 ±0.005	12k ⁶	9 ENGLER	78B	HBC	DP
0.0348 ± 0.0044	18k	HILL	78	STRC	DP
0.0312 ± 0.0025	500k	GJESDAL	76	SPEC	DP
0.0270 ± 0.0028	25k	BLUMENTHA	L75	SPEC	DP
0.044 ±0.006	24k	BUCHANAN	75	5PEC	DP
0.040 ±0.012	2171	WANG	74	OSPK	DP
0.045 ±0.014	5600	ALBROW	73	ASPK	DP
0.019 ±0.013	1871	BRANDENB	73	HBC	PI transv.
0.022 ± 0.014	1910	NEUHOFER	72	ASPK	PI
0.023 ± 0.005	42k	BISI	71	ASPK	DP
0.05 ± 0.01	16k	CHIEN	71	ASPK	DP, no RC
0.02 ± 0.013	1000	ARONSON	68	OSPK	PI
$+0.023 \pm 0.012$	4800	BASILE	68	OSPK	DP, no RC
-0.01 ± 0.02	762	FIRESTONE	67	HBC	DP, no RC
$+0.01$ ± 0.015	531	KADYK	67	HBC	e,PI, no RC
+0.08 +0.10 -0.08	240	LOWYS	67	FBC	PI
$+0.15 \pm 0.08$	577	FISHER	65	OSPK	DP, no RC
+0.07 ±0.06	153	LUERS	64	нвс	DP, no RC
• • • We do not use	the following	data for average	s, fit:	s, limits,	etc. • • •
0.029 ±0.005	19k	⁹ сно	80	нвс	DP
0.0286 ± 0.0049	26k	BIRULEV	79	SPEC	Repl. by BIRULEV 81
0.032 ±0.0042	48k	BIRULEV	76	SPEC	Repl. by BIRULEV 81

 69 ENGLER 788 uses an unique K_{e3} subset of CHO 80 events and is less subject to systematic effects.

 $\xi_{\rm a}=f_-/f_+$ (determined from $K_{\rm p3}^0$ spectra)

The parameter ξ is redundant with λ_0 below and is not put into the Meson Summary

VALUE	45 (61 (41	FICE	DOCUMENT ID	TECH	COMMENT
	dξ (0)/dλ ₊		DOCUMENT ID	TECN	COMMENT
−0.11±0.09 Oi	JR EVALUAT	ION Er	ror includes scale fa	ctor of 2.3.	Correlation is
			$d\xi(0)/d\lambda_{+}=-$	-14. From a	fit discussed in
			note on Ken fo	orm factors i	n 1982 edition, PL
			111B (April 19	182).	
-0.10 ± 0.09	12	150k	70 BIRULEV	81 SPEC	DP
+0.26±0.16	-13	14k	⁷¹ CHO	80 HBC	DP
+0.13±0.23	- 20	16k	⁷¹ HILL	79 STRC	DP
-0.25 ± 0.22	- 5.9	32k	⁷² BUCHANAN	75 SPEC	DP
-0.11 ± 0.07	-17	1.6M	73 DONALDSON	74B SPEC	DP
-1.00 ± 0.45	-20	1385	⁷⁴ PEACH	73 HLBC	DP
-1.5 ± 0.7	- 28	9086	⁷⁵ ALBROW	72 ASPK	DP
+1.2 ±0.8	- 18	1341	⁷⁶ CARPENTER	66 OSPK	DP
• • • We do no	t use the folk	wing dat	a for averages, fits,	limits, etc.	• • •
+0.50±0.61	unknown	16k	77 DALLY	72 ASPK	DP
-3.9 ±0.4	2	3140	78 BASILE		DP, indep of λ_{\perp}
$-0.68^{+0.12}$	26	16k	77 CHIEN	70 ASPK	DP

⁷⁰ BIRULEV 81 error, $d\xi(0)/d\lambda_+$ calculated by us from λ_0 , λ_+ . $d\lambda_0/d\lambda_+=0$ used.

 $^{^{71}}$ HILL 79 and CHO 80 calculated by us from $\lambda_0,\,\lambda_+,$ and $d\lambda_0/d\lambda_+.$

⁷² BUCHANAN 75 is calculated by us from λ_0 , λ_+ and $d\lambda_0/d\lambda_+$ because their appendix A value -0.20 ± 22 assumes $\xi(t)$ constant, i.e. $\lambda_-=\lambda_+$.

 $^{^{73}}$ DONALDSON 748 gives $\xi=-0.11\pm0.02$ not including systematics. Above error and $d\xi(0)/d\lambda_+$ were calculated by us from λ_0 and λ_+ errors (which include systematics) and $d\lambda_0/d\lambda_+$.

 $^{^{74}}$ PEACH 73 gives $\xi(0)=-0.95\pm0.45$ for $\lambda_{+}=\lambda_{-}=0.025$. The above value is for $\lambda_{-} \approx 0$. K.Peach, private communication (1974).

$\xi_b = f_-/f_+$ (determined from $K_{\mu3}^0/K_{e3}^0$)

The K_{u3}^0/K_{e3}^0 branching ratio fixes a relationship between $\xi(0)$ and λ_+ . We quote the author's $\xi(0)$ and associated λ_+ but do not average because the λ_+ values differ. The fit result and scale factor given below are not obtained from these ξ_b values. Instead they are obtained directly from the authors $\kappa^0_{\mu 3}/\kappa^0_{e 3}$ branching ratio via the fitted $K_{\mu3}^0/K_{e3}^0$ ratio $(\Gamma(\pi^\pm\mu^\mp\nu)/\Gamma(\pi^\pm e^\mp\nu_e))$. The parameter ξ is redundant with λ_0 below and is not put into the Meson Summary Table.

VALUE EVTS

−0.11±0.09 OUR EVALUATION

Error includes scale factor of 2.3. Correlation is $d\xi(0)/d\lambda_+$ =−14. From a fit discussed in note on K₂₃ form factors in 1982 edition, PL **111B** (April 1982).

• • • We do not use the following data for averages, fits, limits, etc. • • •

0.5 ± 0.4	6700		73	HBC	BR, $\lambda_{+}=0.019\pm0.013$
-0.08 ± 0.25	1309	⁷⁹ EVANS	73	HLBC	BR, $\lambda_{+} = 0.02$
-0.5 ± 0.5	3548	BASILE	70	OSPK	BR, $\lambda_{+}=0.02$
$+0.45\pm0.28$	569	BEILLIERE	69	HLBC	BR, $\lambda_{+}=0$
-0.22 ± 0.30	1309	⁷⁹ EVANS	69	HLBC	•
$+0.2 \begin{array}{c} +0.8 \\ -1.2 \end{array}$		KULYUKINA	68	cc	BR, $\lambda_{+}=0$
$+1.1 \pm 1.1$	389	ADAIR	64	HBC	BR, λ ₊ =0
$+0.66^{+0.9}_{-1.3}$	•	LUERS	64	нвс	BR, λ _± =0

⁷⁹ EVANS 73 replaces EVANS 69.

$\xi_c = f_-/f_+$ (determined from μ polarization in $K_{\mu 3}^0$)

The μ polarization is a measure of $\xi(t)$. No assumptions on λ_+ necessary, t (weighted by sensitivity to $\xi(t)$) should be specified. In λ_+ , $\xi(0)$ parametrization this is $\xi(0)$ for $\lambda_{+}=0$. $d\xi/d\lambda=\xi t$. For radiative correction to μ polarization in $K_{\mu,3}^{0}$, see GINSBERG 73. The parameter ξ is redundant with λ_0 below and is not put into the

Meson St	ımmary Table.			
VALUE	<u>EVTS</u>	DOCUMENT ID	TECN	COMMENT
-0.11 ±0.09	OUR EVALUATIO	$d\xi(0)/d\lambda_{+}=$	-14. From a	of 2.3. Correlation is fit discussed in note on lition, PL 111B (April
		1982).		
+0.178±0.105	207k	^{BO} CLARK	77 SPEC	POL, $d\xi(0)/d\lambda_{\perp}=+0.68$
-0.385 ± 0.105	2.2M	^{B1} SANDWEISS	73 CNTR	POL, $d\xi(0)/d\lambda_{+}=-6$
$-1.81 \begin{array}{l} +0.50 \\ -0.26 \end{array}$:	^{B2} LONGO	69 CNTR	POL, t=3.3
● ● • We do n	ot use the following	data for average	s, fits, limits,	etc. • • •
-1.6 ±0.5	638	⁸³ ABRAMS	688 OSPK	Polarization
-1.2 ±0.5	2608	⁸³ AUERBACH	66B OSPK	Polarization
80 CLARK 77	$t \approx +3.80, \ d\xi(0)/c$	$d\lambda_{\perp} = \xi(t)t = 0$.178×3.80 =	+0.68,
81 SANDWEIS	is 73 is for $\lambda_+ = 0$	and $t = 0$.		
82 LONGO 69	t = 3.3 calculated 1	from $dE(0)/d\lambda$	= - 6.0 (tabl	e 1) divided by $\xi = -1.81$.
83 t value not	given.	+		,, •

$Im(\xi)$ in $K_{\mu 3}^{0}$ DECAY (from transverse μ pol.)

Test of T reve	rsal invarian		
VALUE	<u>EVTS</u>	DOCUMENT ID TECN COMMENT	
-0.007±0.026 OUR	AVERAGE		
0.009 ± 0.030	12M	MORSE 80 CNTR Polarization	
0.35 ± 0.30	207k	84 CLARK 77 SPEC POL, t=0	
-0.085 ± 0.064	2.2M	85 SANDWEISS 73 CNTR POL, t=0	
-0.02 ± 0.08		LONGO 69 CNTR POL, $t=3.3$	
-0.2 ±0.6		ABRAMS 68B OSPK Polarization	
• • • We do not us	e the followi	ng data for averages, fits, limits, etc. • • •	
0.012 ± 0.026		SCHMIDT 79 CNTR Rent by MORSE 9	an

⁸⁴CLARK 77 value has additional $\xi(0)$ dependence +0.21Re[$\xi(0)$].

 λ_+ (LINEAR ENERGY DEPENDENCE OF f_+ IN $K^0_{\mu3}$ DECAY) See also the corresponding entries and notes in section " $\xi_{A}=f_-/f_+$ " above and section " λ_0 (LINEAR ENERGY DEPENDENCE OF f_0 IN $\kappa^0_{\mu3}$ DECAY)" below. For radiative correction of $K_{i,a}^0$ Dalitz plot see GINSBERG 70 and BECHERRAWY 70.

			μο				
	VALUE		EVTS	DOCUMENT ID		TECN	COMMENT
	0.034	±0.005	OUR EVALUATION	From a fit dis	CUSSO	d in not	te on Kp3 form factors in
^				1982 edition, P	L 11	1B (Apr	il 1982).
	0.0427	±0.0044	150k	BIRULEV	81	SPEC	DP
	0.028	± 0.010	14k	СНО	80	HBC	DP
	0.028	± 0.011	16k	HILL	79	STRC	DP
	0.046	± 0.030	32k	BUCHANAN	75	SPEC	DP
	0.030	± 0.003	1.6M	DONALDSON	74B	SPEC	DP
	0.085	±0.015	9086	ALBROW	72	ASPK	DP
	• • •	We do no	ot use the following d	ata for average:	s, fits	, limits,	etc. • • •
	0.0337	±0.0033	129k	DZHORD	77	SPEC	Repl. by BIRULEV 81
	0.046	±0.008	82k	ALBRECHT	74	WIRE	Repl. by BIRULEV 81
	0.11	± 0.04	16k	DALLY	72	ASPK	DP
	0.07	± 0.02	16k	CHIEN	70	ASPK	Repl. by DALLY 72

 λ_0 (LINEAR ENERGY DEPENDENCE OF ℓ_0 IN $K^0_{\mu3}$ DECAY)

Wherever possible, we have converted the above values of $\xi(0)$ into values of λ_0 using the associated λ_{+}^{μ} and $d\xi(0)/d\lambda_{+}$.

VALUE		$d\lambda_0/d\lambda_+$		DOCUM	IENT ID		TECN	COMMENT
0.025 ±	0.006	OUR EVALUA	TION					Correlation is
				$d\lambda_0/c$	$l\lambda_{+}=-0.1$	16. F	rom a	fit discussed in
							tors in	1982 edition, Pl
					(April 1982	2).		
0.0341±	0.0067	unknown	150k	⁸⁶ BIRUL	.EV 8	81 9	SPEC	DP
+0.050 ±	0.008	-0.11	14k	CHO	8	BO (HBC	DP
+0.039 ±	0.010	-0.67	16k	HILL	7	79 :	STRC	DP
+0.047 ±	0.009	1.06	207k	87 CLAR	K 7	77 :	SPEC	POL
+0.025 ±	0.019	+0.5	32k	88 BUCH	ANAN 7	75 \$	SPEC	DP
+0.019 ±	0.004	-0.47	1.6M	89 DONA		74B S	SPEC	DP
-0.060 ±	0.038	-0.71	1385	90 PEAC	H 7	73 I	HLBC	DP
-0.018 ±	0.009	+0.49	2.2M	87 SAND	WEISS 7	73 (CNTR	POL
-0.043 ±		-1.39	9086	91 ALBR	ow 7	72	ASPK	DP
-0.140 ±	0.043 0.022	+0.49		87 LONG	0 6	69 (CNTR	POL
+0.08 ±	0.07	-0.54	1371	87 CARP	ENTER 6	66 (OSPK	DP
• • We	do not	use the followi	ng data	for average	s, fits, limi	its, e	tc. • •	•
0.041 ±	0.008		14k	⁹² сно	8	BO 1	нвс	BR, $\lambda_{+}=0.028$
+0.0485±	0.0076		47k	DZHC	RD 7	77 :	SPEC	In BIRULEV 81
+0.024 ±	0.011		82k	ALBR	ECHT 7	74 1	WIRE	In BIRULEV 81
+0.06 ±	0.03		6700	93 BRAN	DENB	73	нвс	BR.
								λ ₊ =0.019 ± 0.013
-0.067 ±	0.227	unknown	16k	94 DALL		72	ASPK	DP
-0.333 ±	0.034	+1.	3140	95 BASIL	.E 7	70 (OSPK	DP
86 RIDHI	FV 81 ø	lues d\ - /d\ .	1	E alvina an	Hnreasona	bb.	narrow i	error ellipse whic

BIRULEV 81 gives $d\lambda_0/d\lambda_+=-1.5$, giving an unredominates all other results. We use $d\lambda_0/d\lambda_+=0$.

⁸⁸ BUCHANAN 75 value is from their appendix A and uses only $K_{\mu3}$ data. $d\lambda_0/d\lambda_+$ was obtained by private communication, C.Buchanan, 1976.

94 DALLY 72 gives $f_0=1.20\pm0.35,\,\lambda_0=-0.080\pm0.272,\,\lambda_0{}'=-0.006\pm0.045,\,{\rm but}$ with a different definition of λ_0 . Our quoted λ_0 is his λ_0/f_0 . We cannot calculate true λ_0 error without his (λ_0,f_0) correlations. See also note on DALLY 72 in section ξ_A .

95 BASILE 70 λ_0 is for $\lambda_+=0$. Calculated by us from ξ_A with $d\xi(0)/d\lambda_+=0$. BASILE 70 is incompatible with all other results. Authors suggest that efficiency estimates might be

| f_S/f₊| FOR K_{e3} DECAY Ratio of scalar to f₊ cou

Natio of	Scului CO	+ conb.	B.s.			
VALUE	CL%	EVTS	DOCUMENT ID		TEÇN	COMMENT
< 0.04	68	25k	BLUMENTHA	L75	SPEC	
• • • We do r	not use th	ne followin	g data for average	s, flt	s, limits,	, etc. • • •
< 0.095	95	18k	HILL	78	STRC	
< 0.07	68	48k	BIRULEV	76	SPEC	See also BIRULEV 81
< 0.19	95	5600	ALBROW	73	ASPK	
< 0.15	68		KULYUKINA	67	cc	

 $|f_T/f_+|$ FOR K_{e3}^0 DECAY Ratio of tensor to f_+ couplings.

VALUE	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
<0.23	68	25k	BLUMENTHA	L75	SPEC	•
• • • We do no	ot use th	ne followi	ng data for average	s, fit	s, limits,	etc. • • •
< 0.40	95	18k	HILL	78	STRC	
< 0.34	68	48k	BIRULEV	76	SPEC	See also BIRULEV 81
<1.0	95	5600	ALBROW	73	ASPK	
<1.0	68		KULYUKINA	67	cc	

⁷⁵ ALBROW 72 fit has λ_{-} free, gets $\lambda_{-} = -0.030 \pm 0.060$ or $\Lambda = +0.15 ^{+0.17}_{-0.11}$

 $^{^{76}}$ CARPENTER 66 $\xi(0)$ is for $\lambda_{+}=0.$ $d\xi(0)/d\lambda_{+}$ is from figure 9.

⁷⁷ CHIEN 70 errors are statistical only. $d\xi(0)/d\lambda_+$ from figure 4. DALLY 72 is a reanalysis of CHIEN 70. The DALLY 72 result is not compatible with assumption $\lambda_{-}=0$ so not Included in our fit. The nonzero λ_- value and the relatively large λ_+ value found by DALLY 72 come mainly from a single low t bin (figures 1,2). The (f_+,ξ) correlation was Ignored. We estimate from figure 2 that fixing $\lambda_{-}=0$ would give $\xi(0)=-1.4\pm0.3$ and would add 10 to χ^2 . $d\xi(0)/d\lambda_+$ is not given.

⁷⁸ BASILE 70 is incompatible with all other results. Authors suggest that efficiency esti-

 $^{^{85}}$ SANDWEISS 73 value corrected from value quoted in their paper due to new value of $Re(\xi)$. See footnote 4 of SCHMIDT 79.

 $^{^{87}\}lambda_0$ value is for $\lambda_+=0.03$ calculated by us from $\xi(0)$ and $d\xi(0)/d\lambda_+$.

⁸⁹ DONALDSON 748 $d\lambda_0/d\lambda_+$ obtained from figure 18.

⁹⁰ PEACH 73 assumes $\lambda_{+}=0.025$. Calculated by us from $\xi(0)$ and $d\xi(0)/d\lambda_{+}$.

⁹¹ ALBROW 72 λ_0 is calculated by us from ξ_A , λ_+ and $d\xi(0)/d\lambda_+$. They give $\lambda_0=-0.043\pm0.039$ for $\lambda_-=0$. We use our larger calculated error.

⁹² CHO 80 BR result not independent of their Dalitz plot result.

 $^{^{93}}$ Fit for λ_0 does not include this value but instead includes the $K_{\mu3}/K_{e3}$ result from this

VALUE	DOCUMENT	TID TECN
0.12±0.12	BIRULEV	81 SPEC
$\alpha_{K^{\bullet}}$ DECAY FORM FA $\alpha_{K^{\bullet}}$ is the constant		$ ightarrow$ $e^+e^-\gamma$ RGSTROM 83 which measures the rela
strength of the vector	or-vector transition K ₁	$I \rightarrow K^* \gamma$ with $K^* \rightarrow \rho$, ω , $\phi \rightarrow \gamma^*$
		$K_I \rightarrow \pi, \eta, \eta' \leftrightarrow \gamma \gamma^*.$
VALUE	DOCUMENT	ID TECN
-0.28 ±0.08 OUR AVE	RAGE	
-0.28 ±0.13	BARR	90B NA31
-0.280 +0.099 -0.090	OHL	90B B845

FITS FOR K_L^0 CP-VIOLATION PARAMETERS

Revised April 1998 by T.G. Trippe (LBNL).

In recent years, K_L^0 CP-violation experiments have improved our knowledge of CP-violation parameters and their consistency with the expectations of CPT invariance and unitarity. For definitions of K_L^0 CP-violation parameters and a brief discussion of the theory, see the article "CP Violation" by L. Wolfenstein in Section 12 of this Review.

This note describes our two fits for the CP-violation parameters in $K_L^0 \to \pi^+\pi^-$ and $\pi^0\pi^0$ decay, one for the phases ϕ_{+-} and ϕ_{00} , and another for the amplitudes $|\eta_{+-}|$ and $|\eta_{00}|$.

Fit to ϕ_{+-} , ϕ_{00} , $\Delta\phi$, Δm , and au_s data: We perform a joint fit to the data on ϕ_{+-} , ϕ_{00} , the phase difference $\Delta \phi = \phi_{00} - \phi_{+-}$, the $K_L^0 - K_S^0$ mass difference Δm , and the K_S^0 mean life τ_S , including the effects of correlations. Measurements of ϕ_{+-} and ϕ_{00} are highly correlated with Δm and τ_s . Some measurements of τ_s are correlated with Δm . The correlations are given in the footnotes of the ϕ_{+-} and ϕ_{00} sections of the K_L^0 Particle Listings and the τ_s section of the K_s^0 Particle listings. In editions of the Review prior to 1996, we adjusted the experimental values of ϕ_{+-} and ϕ_{00} to account for correlations with Δm and τ_s but did not include the effects of these correlations when evaluating Δm and τ_s . When a joint fit including these correlations is done, the ϕ_{+-} measurements have a strong influence on the fitted value of Δm . This is because the CERN NA31 vacuum regeneration experiments (CAROSI 90 [1] and GEWENIGER 74B [2]), the Fermilab E773/E731 regenerator experiments (SCHWIN-GENHEUER 95 [3] and GIBBONS 93 [4]), and the CPLEAR $K^0 - \overline{K}^0$ asymmetry experiment (ADLER 95B [5]) have very different dependences of ϕ_{+-} on Δm , as can be seen from their diagonal bands in Fig. 1. The region where the ϕ_{+-} bands from these experiments cross gives a powerful measurement of Δm which decreases the fitted Δm relative to our pre-1996 average Δm and earlier measurements such as CULLEN 70 [6], GEWENIGER 74C [7], and GJESDAL 74 [8]. This decrease brings the Δm -dependent ϕ_{+-} measurements into good agreement with each other and with ϕ (superweak), where

$$\phi(\text{superweak}) = \tan^{-1}\left(\frac{2\Delta m}{\Delta \Gamma}\right) = \tan^{-1}\left(\frac{2\Delta m \tau_S \tau_L}{\hbar(\tau_L - \tau_S)}\right)$$
. (1)

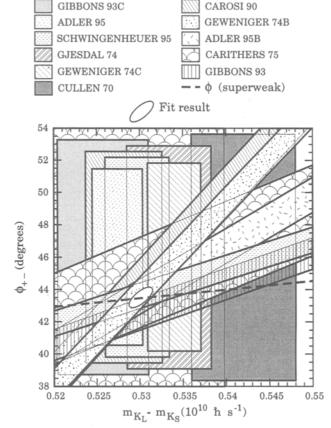


Figure 1: ϕ_{+-} vs Δm . Δm measurements appear as vertical bands spanning $\Delta m \pm 1\sigma$, some of which are cut near the top to aid the eye. The ϕ_{+-} measurements appear as diagonal bands spanning $\phi_{+-} \pm \sigma_{\phi}$. The dashed line shows ϕ (superweak). The ellipse shows the 1σ contour of the fit result. See Table 1 for data references.

The (ϕ_{+-},τ_s) correlations influence the τ_s fit result in a similar manner, as can be seen in Fig. 2. The influence of the ϕ_{+-} experiments is not as great on τ_s as it is on Δm because the indirect measurements of τ_s derived from the diagonal crossing bands in Fig. 2 are not as precise as the direct measurements of τ_s from E773 (SCHWINGENHEUER 95 [3]), E731 (GIBBONS 93 [4]), and NA31 (BERTANZA 97 [9]).

In Fig. 1 [Fig. 2] the slope of the diagonal ϕ_{+-} bands shows the Δm [τ_s] dependence; the unseen τ_s [Δm] dependent term is evaluated using the fitted τ_s [Δm]. The vertical half-width σ_{ϕ} of each band is the ϕ_{+-} error for fixed Δm [τ_s] and includes the systematic error due to the error in the fitted τ_s [Δm].

Table 2 gives the resulting fit values for the parameters and Table 3 gives the correlation matrix. The resulting ϕ_{+-} is in good agreement with $\phi(\text{superweak}) = 43.50 \pm 0.08^{\circ}$ obtained from Eq. (1) using Δm and τ_s from Table 2.

The χ^2 is 15.4 for 18 degrees of freedom, indicating good agreement of the input data. Nevertheless, there has been criticism that Fermilab E773 (SCHWINGENHEUER 95 [3]) and E731 (GIBBONS 93 [4]) measure $\phi_{+-} - \phi_f$ and calculate

Table 1: References and location of input data for Fig. 1 and Fig. 2. Unless otherwise indicated by a footnote, a check (\checkmark) indicates that the data can be found in the ϕ_{+-} or Δm sections of the K_L Particle Listings, or the τ_S section of the K_S Particle Listings, according to the column headers

Loca	tion of	finput	data		
Fig. 1 Fig. 2		g. 2			
$\overline{\phi_{+-}}$	Δm	$\overline{\phi_{+-}}$	$ au_{\scriptscriptstyle S}$	PDG Document ID	Ref.
√	√ *	√	√*	CAROSI 90	[1]
✓		√ †	✓	GEWENIGER 74B	[2]
✓		✓		ADLER 95B	[5]
✓	√‡	√ †	✓	CARITHERS 75	[10]
✓	✓	✓	✓	SCHWINGENHEUER 95	[3]
✓		✓	✓	GIBBONS 93	[4]
	✓			GIBBONS 93C	[11]
	✓			ADLER 95	[12]
	✓			GJESDAL 74	[8]
	✓			GEWENIGER 74C	[7]
	✓			CULLEN 70	[6]
			✓	ARONSON 76	[13]
			✓	GROSSMAN 87	[14]
			✓	SKJEGGESTAD 72	[15]
			✓	BERTANZA 97	[9]

^{*} from $\phi_{00}(\Delta m, \tau_s)$ in ϕ_{00} Particle Listings.

the regeneration phase ϕ_f from the power law momentum dependence of the regeneration amplitude using analyticity and dispersion relations. In the E731 result, a systematic error of ± 0.5 degrees for departures from a pure power-law is included. For the E773 result, they modeled a variety of effects that do distort the amplitude from a pure power law and ascribed a $\pm 0.35^{\circ}$ systematic error from uncertainties in these effects. Even so, the E731 result remains valid within its quoted errors. KLEINKNECHT 94 [16] and KLEINKNECHT 95 [17] argue that these systematic errors should be around 3°, primarily because of the absence of data on the momentum dependence of the regeneration amplitude above 160 GeV/c. BRIERE 95 [18] and BRIERE 95C [19] reply that the current understanding of regeneration is sufficient to allow a precise and reliable correction for the region above 160 GeV/c. The question is one of judgement about the reliability of the assumptions used. In the absence of any contradictory evidence, we choose to accept the judgement of the E731/E773 experimenters in setting their systematic errors.

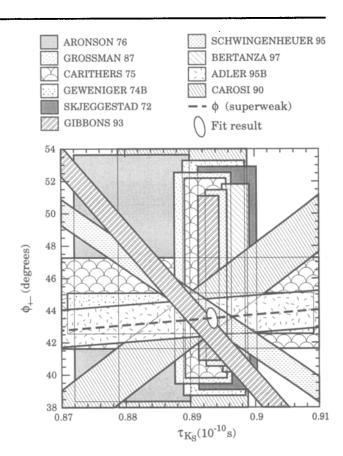


Figure 2: ϕ_{+-} vs τ_s . τ_s measurements appear as vertical bands spanning $\tau_s \pm 1\sigma$, some of which are cut near the top to aid the eye. The ϕ_{+-} measurements appear as diagonal bands spanning $\phi_{+-}\pm\sigma_{\phi}$. The dashed line shows $\phi(\text{superweak})$. The ellipse shows the fit result's 1σ contour. See Table 1 for data references.

Table 2: Results of the fit for ϕ_{+-} , ϕ_{00} , $\phi_{00} - \phi_{+-}$, Δm , and τ_s . The fit has $\chi^2 = 15.4$ for 18 degrees of freedom (22 measurements -5 parameters +1 constraint).

Quantity	Fit Result				
φ+-	$43.5\pm0.6^{\circ}$				
Δm	$(0.5301 \pm 0.0014) \times 10^{10} h \text{ s}^{-1}$				
$ au_{_{S}}$	$(0.8934 \pm 0.0008) \times 10^{-10}$ s				
ϕ_{00}	$43.4 \pm 1.0^{\circ}$				
$\Delta\phi$	$-0.1\pm0.8^{\circ}$				

A similar analysis has been done by the CPLEAR Collaboration [20]. The small differences between their results and ours are due primarily to different treatments of τ_s . Their fit constrains τ_s to the PDG 1994 value, while our fit includes the more recent SCHWINGENHEUER 95 [3] and BERTANZA 97 [9] τ_s measurements.

[†] from $\phi_{+-}(\Delta m)$ in ϕ_{+-} Particle Listings.

[‡] from $\tau_s(\Delta m)$ in τ_s Particle Listings.

Table 3: Correlation matrix for the fitted parameters.

	ϕ_{+-}	Δm	$ au_{\scriptscriptstyle S}$	ϕ_{00}	$\Delta\phi$
$\overline{\phi_{+-}}$	1.00	0.72	-0.35	0.60	-0.02
Δm	0.72	1.00	-0.22	0.48	0.04
$ au_{s}$	-0.35	-0.22	1.00	-0.18	0.04
ϕ_{00}	0.60	0.48	-0.18	1.00	0.79
$\Delta\phi$	-0.02	0.04	0.04	0.79	1.00

Fit for ϵ'/ϵ , $|\eta_{+-}|$, $|\eta_{00}|$, and $\mathrm{B}(K_L \to \pi\pi)$

We list measurements of $|\eta_{+-}|$, $|\eta_{00}|$, $|\eta_{00}/\eta_{+-}|$ and ϵ'/ϵ . Independent information on $|\eta_{+-}|$ and $|\eta_{00}|$ can be obtained from measurements of the K_L^0 and K_S^0 lifetimes $(\tau_L, \, \tau_S)$ and branching ratios (B) to $\pi\pi$, using the relations

$$|\eta_{+-}| = \left[\frac{B(K_L^0 \to \pi^+ \pi^-)}{\tau_L} \frac{\tau_S}{B(K_S^0 \to \pi^+ \pi^-)} \right]^{1/2} ,$$
 (2a)

$$|\eta_{00}| = \left[\frac{\mathrm{B}(K_L^0 \to \pi^0 \pi^0)}{\tau_L} \frac{\tau_S}{\mathrm{B}(K_S^0 \to \pi^0 \pi^0)} \right]^{1/2} .$$
 (2b)

For historical reasons the branching ratio fits and the CPviolation fits are done separately, but we want to include the influence of $|\eta_{+-}|$, $|\eta_{00}|$, $|\eta_{00}/\eta_{+-}|$, and ϵ'/ϵ measurements on ${\rm B}(K_L^0 \to \pi^+\pi^-)$ and ${\rm B}(K_L^0 \to \pi^0\pi^0)$ and vice versa. We approximate a global fit to all of these measurements by first performing two independent fits: 1) BRFIT, a fit to the K_L^0 branching ratios, rates, and mean life, and 2) ETAFIT, a fit to the $|\eta_{+-}|$, $|\eta_{00}|$, $|\eta_{+-}/\eta_{00}|$, and ϵ'/ϵ measurements. The results from fit 1, along with the K_S^0 values from this edition are used to compute values of $|\eta_{+-}|$ and $|\eta_{00}|$ which are included as measurements in the $|\eta_{00}|$ and $|\eta_{+-}|$ sections with a document ID of BRFIT 98. Thus the fit values of $|\eta_{+-}|$ and $|\eta_{00}|$ given in this edition include both the direct measurements and the results from the branching ratio fit.

The process is reversed in order to include the direct $|\eta|$ measurements in the branching ratio fit. The results from fit 2 above (before including BRFIT 98 values) are used along with the K_L^0 and K_S^0 mean lives and the $K_S^0 \to \pi\pi$ branching fractions to compute the K_L^0 branching ratios $\Gamma(K_L^0 \to \pi^+\pi^-)/\Gamma(\text{total}) \text{ and } \Gamma(K_L^0 \to \pi^0\pi^0)/\Gamma(K_L^0 \to \pi^+\pi^-).$ These branching ratio values are included as measurements in the branching ratio section with a document ID of ETAFIT 98. Thus the K_L^0 branching ratio fit values in this edition include the results of direct measurements of $|\eta_{+-}|$, $|\eta_{00}|$, $|\eta_{00}/\eta_{+-}|$, and ϵ'/ϵ . A more detailed discussion of these fits is given in the 1990 edition of this Review [21].

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CP-VIOLATION PARAMETERS IN KL DECAYS

CHARGE ASYMMETRY IN KO DECAYS

Such asymmetry violates CP. It is related to $Re(\epsilon)$.

$\delta =$ weighted average of $\delta(\mu)$ and $\delta(e)$

VALUE (%)	EVTS	DOCUMENT ID	TECN	COMMENT
0.327±0.012 OUR	AVERAGE	Includes data from the	2 datable	cks that follow this one.
0.333 ± 0.050	33M	WILLIAMS 73	ASPK	$K_{\mu 3} + K_{\mu 3}$

 $\begin{array}{ll} \delta(\mu) = [\Gamma(\pi^-\mu^+\nu_\mu) - \Gamma(\pi^+\mu^-\overline{\nu}_\mu)]/\text{SUM} \\ \text{Only the combined value below is put into the Meson Summary Table.} \\ \underline{\text{VALUE (%)}} & \underline{\text{EVTS}} & \underline{\text{DOCUMENT ID}} & \underline{\text{TECN}} \\ \text{The data in this block is included in the average printed for a previous datablock.} \end{array}$

0.304±0.025 OUR AVERAGE

0.313 ± 0.029	15M	GEWENIGER	74	ASPK	
0.278 ± 0.051	7.7M	PICCIONI	72	ASPK	
• • • We do not ι	se the following	ng data for average	s, fit	s, limits, etc. • •	•
0.60 ±0.14	4.1M	MCCARTHY	73	CNTR	
0.57 ±0.17	1M	96 PACIOTTI	69	OSPK	
0.403 ± 0.134	1M	⁹⁶ DORFAN	67	OSPK	

 96 PACIOTTI 69 is a reanalysis of DORFAN 67 and is corrected for $\mu^+\mu^-$ range difference

$\delta(e) = [\Gamma(\pi^- e^+ \nu_e) - \Gamma(\pi^+ e^- \overline{\nu}_e)]/\text{SUM}$

Only the combined value below is put into the Meson Summary Table.

VALUE (%) EVTS DOCUMENT ID TECN
The data in this block is included in the average printed for a previous datablock.

0.333±0.014 OUR AVERAGE

0.341 ± 0.018	34M	GEWENIGER	74	ASPK
0.318 ± 0.038	40M	FITCH		ASPK
0.346±0.033	10M	MARX	70	CNTR
0.246 ± 0.059		97 SAAL		CNTR
				4
• • • We do not us	e the following	ig data for averag	es, iii	5, IIIIILS, ELC. • • •
0.36 ±0.18	600k	ASHFORD	72	ASPK
		97 DENIETT		CNTD

97 SAAL 69 is a reanalysis of BENNETT 67.

- PARAMETERS FOR $K_L^0 \rightarrow 2\pi$ DECAY

$$\eta_{+-} = A(K_L^0 \to \pi^+\pi^-) / A(K_5^0 \to \pi^+\pi^-)
\eta_{00} = A(K_L^0 \to \pi^0\pi^0) / A(K_5^0 \to \pi^0\pi^0)$$

The fitted values of $|\eta_{+-}|$ and $|\eta_{00}|$ given below are the results of a fit to $|\eta_{+-}|$, $|\eta_{00}|$, $|\eta_{00}/\eta_{+-}|$, and $\mathrm{Re}(\epsilon'/\epsilon)$. Independent information on $|\eta_{+-}|$ and $|\eta_{00}|$ can be obtained from the fitted values of the \mathcal{K}_L^0 ightarrow $\pi\pi$ and $K^0_S \to \pi\pi$ branching ratios and the K^0_L and K^0_S lifetimes. This information is included as data in the $|\eta_{+-}|$ and $|\eta_{00}|$ sections with a Document ID "BRFIT." See the note "Fits for K_L^0 CP-Violation Parameters" above for details.

$|\eta_{00}| = |A(K_L^0 \to 2\pi^0) / A(K_S^0 \to 2\pi^0)|$ TECN COMMENT 2.30 ±0.14 OUR AVERAGE 2.25 ±0.22 98 BRFIT 2.33 ±0.18 CHRISTENS... 79 ASPK • • • We do not use the following data for averages, fits, limits, etc. • • • 99 ADLER 2.49 ± 0.40 96B CPLR 100 WOLFF 2.71 ± 0.37 71 OSPK Cu reg., 47's 100 CHOLLET 70 OSPK Cu reg., 4γ's 2.95 ± 0.63 98 This BRFIT value is computed from fitted values of the κ^0_L and κ^0_S lifetimes and

branching fractions to $\pi\pi$. See the discussion in the note "Fits for K_L^0 CP-Violation Parameters."

⁹⁹ ADLER 96B identified initial neutral kaon individually as being a K^0 or a \overline{K}^0 . Error is statistical only.

munication).

COMMENT

$|\eta_{+-}| = |A(K_L^0 \to \pi^+\pi^-) / A(K_S^0 \to \pi^+\pi^-)|$ DOCUMENT ID

THE OL TURNED TO		DOCUMENT ID		COMMENT
2.285 ± 0.019 OUR FIT				
2.284 ± 0.018 OUR AVE	RAGE			
2.271±0.024		101 BRFIT	98	
$2.310 \pm 0.043 \pm 0.031$		102 ADLER	958 CPLR	$K^0 - \overline{K}^0$ asymmetry
$2.32 \pm 0.14 \pm 0.03$	10 ⁵	ADLER	928 SPEC	$K^0 \overline{K}^0$ asymm.
2.27 ±0.12		CHRISTENS	79B ASPK	•
2.30 ±0.035		GEWENIGER	748 ASPK	
• • • We do not use the	ne follow	ing data for average:	i, fits, limits,	etc. • • •
2.28 ±0.06	1687	103 COUPAL	85 SPEC	P(K)=70 GeV/c
2.09 ±0.02		104 ARONSON		F-30-110 GeV

 101 This BRFIT value is computed from fitted values of the κ_L^0 and κ_S^0 lifetimes and branching fractions to $\pi\pi$. See the discussion in the note "Fits for K_I^0 CP-Violation

¹⁰² ADLER 95B report $(2.312 \pm 0.043 \pm 0.030 - 1[\Delta m - 0.5274] + 9.1[\tau_5 - 0.8926]) \times 10^{-3}$. We evaluate for our 1996 best values $\Delta m = (0.5304 \pm 0.0014) \times 10^{-10} \, \text{hs}^{-1}$ and τ_s = (0.8927 \pm 0.0009) \times 10⁻¹⁰ s.

103 COUPAL 85 concludes: no energy dependence of $|\eta_{+-}|$, because their value is consistent with above values which occur at lower energies. Not independent of COUPAL 85 $\Gamma(\pi^+\pi^-)/\Gamma(\pi\ell\nu)$ measurement. Enters $|\eta_{+-}|$ via BRFIT value. In editions prior to 1990, this measurement was erroneously also included in our $|\eta_{+-}|$ average and fit. We thank H. Wahl (WAHL 89) for informing us.

 104 ARONSON 82B find that $|\eta_{+-}|$ may depend on the kaon energy.

700/	'7+-		
VALUE		<u>EVTS</u>	DOCUMENT ID TECN
0.995	6±0.0023 OUR FIT	rror includ	des scale factor of 1.8.
0.993	0±0.0020 OUR AVERA		
0.993	1 ± 0.0020	105	5,106 BARR 93D NA31
0.990	±0.0084±0.0036		¹⁰⁷ WOODS 88 E731
• • •	We do not use the foll	owing data	a for averages, fits, limits, etc. • • •
0.993	9±0.0013±0.0015	1M	105 BARR 93D NA31
0.989	$9 \pm 0.0020 \pm 0.0025$		¹⁰⁵ BURKHARDT 88 NA31
1.014	$\pm 0.016 \pm 0.007$	3152	BERNSTEIN 85B SPEC
0.995	±0.025	1122	BLACK 85 SPEC
1.00	±0.09		108 CHRISTENS 79 ASPK
1.03	±0.07	124	BANNER 72 OSPK
1.00	±0.06	167	HOLDER 72 ASPK

105 This is the square root of the ratio R given by BURKHARDT 88 and BARR 93D. 106 This is the combined results from BARR 93D and BURKHARDT 88, taking into account a common systematic uncertainty of 0.0014.

107 We calculate $|\eta_{00}/\eta_{+-}|=1-3(\epsilon'/\epsilon)$ from WOODS 88 (ϵ'/ϵ) value.

 $^{108}\,\mathrm{Not}$ independent of $|\eta_{+-}|$ and $|\eta_{00}|$ values which are included in fit.

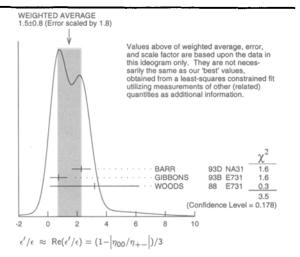
$\epsilon'/\epsilon \approx \text{Re}(\epsilon'/\epsilon) = (1-|\eta_{00}/\eta_{+-}|)/3$

VALUE (units 10-3)	EVTS	DOCUMENT ID	TECN COMMENT	
1.5 ±0.8 OUR FIT Error	Includes	scale factor of 1.8.		_
1.5 ±0.8 OUR AVERAGE			of 1.8. See the ideogram below	١.
2.3 ±0.65	109	^{9,110} BARR	93D NA31	
$0.74 \pm 0.52 \pm 0.29$	>5E5	GIBBONS	938 E731	
$3.2 \pm 2.8 \pm 1.2$		109 WOODS	88 E731	
• • We do not use the follow	ving data	a for averages, fits, li	lmits, etc. • • •	
2.0 ±0.7	1M	111 BARR	93D NA31	
$-0.4 \pm 1.4 \pm 0.6$		PATTERSON	90 E731 in GIBBONS 938	В
3.3 ±1.1		¹¹¹ BURKHARDT	88 NA31	

 109 These values are derived from $|\eta_{00}/\eta_{+-}|$ measurements. They enter the average in this section but enter the fit via the $|\eta_{00}/\eta_{+-}|$ section only.

 $^{110}\,\mathrm{This}$ is the combined results from BARR 93D and BURKHARDT 88, taking into account their common systematic uncertainty.

¹¹¹ These values are derived from $|\eta_{00}/\eta_{+-}|$ measurements.



ı

 ϕ_{+--} , PHASE of η_{+--} The dependence of the phase on Δm and τ_S is given for each experiment in the Comments below, where Δm is the K_L^0 - K_S^0 mass difference in units $10^{10}~h {
m s}^{-1}$ and $\tau_{\rm S}$ is the $K_{\rm S}$ mean life in units $10^{-10}\,{\rm s.}$ For the "used" data, we have evaluated these mass dependences using our 1996 values, $\Delta m=0.5304\pm0.0014$, $\tau_{\rm S}=0.8927\pm0.0009$ to obtain the values quoted below. We also give the regeneration phase ϕ_f in the

OUR FIT is described in the note on "Fits for K_L^0 CP-Violation Parameters" in the €0 Darticle Listings

ALUE (°)	EVTS	DOCUMENT ID		TECN	COMMENT
3.5 ± 0.6 OUR FIT					
3.6 ± 1.2	113	ADLER	95B	CPLR	K^{0} - \overline{K}^{0} asymmetry
3.9 ± 0.8	113,114	SCHWINGEN	.95	E773	CH _{1,1} regenerator
2.9 ± 1.0	114,115	GIBBONS		E731	B ₄ C regenerator
4.3 ± 1.8	116	CAROSI	90	NA31	Vacuum regen.
4.5 ± 2.8	117	CARITHERS		SPEC	C regenerator
4.0 ± 1.3	118	GEWENIGER	74B	ASPK	Vacuum regen.
• • We do not use th					
3.82± 0.63	119,120	ADLER	96C	RVUE	
2.3 ± 4.4 ±1.4	105 121	ADLER			$K^0 - \overline{K}^0$ asymm.
7.7 ± 2.0 ±0.9	114,122	KARLSSON		E731	
5.3 ± 3.9	123	ARONSON		SPEC	
1.7 ± 3.5		CHRISTENS			
6.2 ± 6.1	124	CARNEGIE			Cu regenerator
7 ±12	125	BALATS			Cu regenerator
0 ± 4	126	JENSEN			Vacuum regen.
4 ±10	127	BENNETT			Cu regenerator
4 ±12	128	ВОНМ			Vacuum regen.
5 ± 7	129	FAISSNER			Cu regenerator
1 ±11	130	BENNETT			Cu reg. uses
0 ±21	131	BOTT			C regenerator
5 ±35	131	MISCHKE			Cu regenerator
0 ±45	133	FIRESTONE		HBC	-
5 ±50	131	FITCH	CE	OCDIV	Be regenerator

¹¹³SCHWINGENHEUER 95 reports $\phi_{+-} = 43.53 \pm 0.76 + 173 [\Delta m - 0.5282] - 275 [au_{s} - 0.5282]$

 114 These experiments measure ϕ_{+-} - ϕ_f and calculate the regeneration phase from the power law momentum dependence of the regeneration amplitude using analyticity and dispersion relations. SCHWINGENHEUER 95 [GIBBONS 93] Includes a systematic error of 0.35° [0.5°] for uncertainties in their modeling of the regeneration amplitude. See the discussion of these systematic errors, including criticism that they could be underestimated, in the note on "C violation in K_I^0 decay."

115 GIBBONS 93 measures $\phi_+ - \phi_f$ and calculates the regeneration phase ϕ_f from the power law momentum dependence of the regeneration amplitude using analyticity. An error of 0.6° is included for possible uncertainties in the regeneration phase. They find $\phi_{+-}=42.21\pm0.9+189~[\Delta m-0.5257]-460~[\tau_5-0.8922]^\circ$, as given in SCHWINGEN-HEUER 95, footnote 8. GIBBONS 93 reports ϕ_{+-} (42.2 \pm 1.4)°

116 CAROSI 90 $\phi_{+-} \approx$ 46.9 \pm 1.4 \pm 0.7 +579 [Δm \sim 0.5351] +303 [τ_{s} - 0.8922] $^{\circ}$.

117 CARITHERS 75 $\phi_{+-} = (45.5 \pm 2.8) + 224 [\Delta m - 0.5348]^{\circ}$. $\phi_{f} = -40.9 \pm 2.6^{\circ}$.

¹¹⁸GEWENIGER 748 $\phi_{+-} = (49.4 \pm 1.0) + 565 [\Delta m - 0.540]^{\circ}$.

¹¹⁹ ADLER 96c fit gives $(43.82 \pm 0.41)^{\circ} + 339(\Delta m - 0.5307)^{\circ} - 252(\tau_5 - 0.8922)^{\circ}$.

120 ADLER 96C is the result of a fit which includes nearly the same data as entered into the "OUR FIT" value above.

121 ADLER 92B quote separately two systematic errors: ±0.4 from their experiment and ± 1.0 degrees due to the uncertainty in the value of Δm .

122 KARLSSON 90 systematic error does not include regeneration phase uncertainty.

123 ARONSON 82 find that ϕ_{+-} may depend on the kaon energy.

¹²⁴CARNEGIE 72 ϕ_{+-} is insensitive to Δm . $\phi_f = -56.2 \pm 5.2^{\circ}$.

¹²⁵BALATS 71 $\phi_{+-} = (39.0 \pm 12.0) + 198[\Delta m - 0.544]^{\circ}$. $\phi_{f} = -43.0 \pm 4.0^{\circ}$.

¹²⁶ JENSEN 70 $\phi_{+-} = (42.4 \pm 4.0) + 576 [\Delta m - 0.538]^{\circ}$.

```
^{127} BENNETT 69 uses measurement of (\phi_{+-})–(\phi_f) of ALFF-STEINBERGER 66B. BEN-
   NETT 69 \phi_{+-} = (34.9 \pm 10.0) + 69 [\Delta m - 0.545]^{\circ}. \phi_f = -49.9 \pm 5.4^{\circ}.
```

¹²⁸BOHM 69B $\phi_{+-} = (41.0 \pm 12.0) + 479(\Delta m - 0.526)^{\circ}$.

130 BENNETT 69 is a re-evaluation of BENNETT 68B. 131 Old experiments with large errors not included in average.

ϕ_{00} , PHASE OF η_{00}

See comment in ϕ_{+-} header above for treatment of Δm and τ_{S} dependence.

OUR FIT is described in the note on "Fits for K_L^0 CP-Violation Parameters" in the

·	-					
VALUE (°)	EVTS	DOCUMENT ID		TECN	COMMENT	
43.4± 1.0 OUR FIT						
44.5± 2.5		132 CAROSI	90	NA31		
• • • We do not use th	e followi	ng data for averages	, fits	, limits,	etc. • • •	
50.8± 7.1±1.7		133 ADLER	96B	CPLR		I
47.4± 1.4±0.9		134 KARLSSON	90	E731		-
55.7± 5.8		CHRISTENS	79	ASPK		
38.0 ± 25.0	56	135 WOLFF	71	OSPK	Cu reg., 4γ's	
51.0±30.0		136 CHOLLET	70	OSPK	Cu reg., 4γ's	
first quadrant preferred		GOBBI	69 B	OSPK		
132 CAROSI 90 $\phi_{00} = 4$	17.1 ± 2	$.1 \pm 1.0 + 579 \ [\Delta m]$	(0.5351]	$+252 [\tau_s - 0.8922]^{\circ}$.	
133 ADLER 96B identifi	ed initial	l neutral kaon indivi	idual	lly as be	eing a K^0 or a \overline{K}^0 . The $\pm 0.8^\circ$ due to Δm .	
134 KARLSSON 90 syste	ematic e	rror does not include	reg	eneratio	n phase uncertainty.	•
135 WOLFF 71 uses rege	enerator	phase $\phi_f = -48.2$	± 3.	5°.		
136 CHOLLET 70 uses r	egenerat	or phase $\phi_F = -46$.5 ±	4.4°.		
	-					

PHASE DIFFERENCE $\phi_{00} - \phi_{+-}$

Test of CPT.

OUR FIT is described in the note on "Fits for K_L^0 CP-Violation Parameters" in the K_I^0 Particle Listings.

VALUE (°)	DOCUMENT ID	TECN	COMMENT
- 0.1 ± 0.8 OUR FIT			
- 0.3 ± 0.8 OUR AVERAGE			
-0.30 ± 0.88	137 SCHWINGEN9	5	Combined E731, E773
$0.2 \pm 2.6 \pm 1.2$	138 CAROSI 9	0 NA31	
• • • We do not use the follow	ing data for averages,	flts, limits	s, etc. • • •
$0.62 \pm 0.71 \pm 0.75$	SCHWINGEN9	5 E773	
-1.6 ± 1.2	139 GIBBONS 9	3 E731	
$-0.3 \pm 2.4 \pm 1.2$	KARLSSON 9	0 E731	
12.6 ± 6.2	140 CHRISTENS 7		
7.6 ±18.0	141 BARBIELLINI 7	3 ASPK	

137 This SCHWINGENHEUER 95 values is the combined result of SCHWINGENHEUER 95 and GIBBONS 93, accounting for correlated systematic errors.

138 CAROSI 90 is excluded from the fit because it it is not independent of ϕ_{+-} and ϕ_{00}

values.

139 GIBBONS 93 give detailed dependence of systematic error on lifetime (see the section on the K_S^0 mean life) and mass difference (see the section on $m_{K_S^0} - m_{K_S^0}$.

 140 Not independent of ϕ_{+-} and ϕ_{00} values.

72 ±23 ±17

- CHARGE ASYMMETRY IN $\pi^+\pi^-\pi^0$ DECAYS -

CHARGE ASYMMETRY J FOR $K_L^0 \rightarrow \pi^+\pi^-\pi^0$

Defined at beginning of section "LINEAR COEFFICIENT g FOR $K_I^0 \rightarrow \pi^+\pi^-\pi^0$ above. Such asymmetry violates CP. See also note on Daltitz plot parameters in K^{\pm} section and note on CP violation in K_I^0 decay above.

VALUE	EVTS	DOCUMENT ID		TECN
0.0011±0.0008 OU	R AVERAG	E		
0.001 ± 0.011	6499	СНО	77	
-0.001 ± 0.003	4709	PEACH	77	
0.0013 ± 0.0009	3M	SCRIBANO	70	
0.0 ± 0.017	4400	SMITH	70	OSPK
0.001 ± 0.004	238k	BLANPIED	68	

PARAMETERS for $K_L^0 \rightarrow \pi^+\pi^-\gamma$ DECAY -

RAMBERG 938 E731

		-				
$ \eta_{+-\gamma} = A(K^0_L-$	• π ⁺ π ⁻ γ	, <i>CP</i> violating)/A($K_S^0 \rightarrow$	$\pi^+\pi^-\gamma) $	
VALUE (units 10 ⁻³)	EVTS	DOCUMENT ID		TECN		
2.35 ±0.07 OUR AV	ERAGE					
$2.359 \pm 0.062 \pm 0.040$	9045	MATTHEWS	95	E773		
$2.15 \pm 0.26 \pm 0.20$	3671	RAMBERG	93B	E731		
$\phi_{+-\gamma} = \text{phase of } \eta$	+-7					
VALUE (°)	EVTS	DOCUMENT ID		TECN		
44 ± 4 OUR AVER	AGE					
43 8 ± 3 5 ± 1 9	9045	MATTHEWS	95	F773		

$$|\epsilon'_{+-\gamma}|/\epsilon$$
 for $K_L^0 \rightarrow \pi^+\pi^-\gamma$

VALUE

CLY EVTS

90 3671 142 RAMBERG 93B E731

 142 RAMBERG 93B limit on $|\epsilon_{+}^{'}$ $_{-\gamma}|/\epsilon$ assumes than any difference between η_{+-} and $\eta_{+-\gamma}$ is due to direct CP violation.

$\Delta S = \Delta Q$ IN K^0 DECAYS

The relative amount of $\Delta S \neq \Delta Q$ component present is measured by the parameter x, defined as

$$x = A(\overline{K}^0 \to \pi^- \ell^+ \nu) / A(K^0 \to \pi^- \ell^+ \nu)$$
.

We list $Re\{x\}$ and $Im\{x\}$ for K_{e3} and $K_{\mu3}$ combined.

$x = A(\overline{K}^0 \rightarrow \pi^- \ell^+ \nu)/A(K^0 \rightarrow \pi^- \ell^+ \nu) = A(\Delta S = -\Delta Q)/A(\Delta S = \Delta Q)$

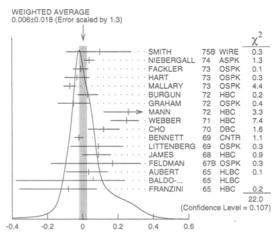
REAL PART OF					
VALUE	EVTS	DOCUMENT ID	_		COMMENT
0.006±0.018 OUI	RAVERAGE	Error includes scale below.	le fac	tor of 1	.3. See the Ideogram
$0.10 \begin{array}{l} +0.18 \\ -0.19 \end{array}$	79	SMITH	75B	WIRE	$\pi^- p \rightarrow \kappa^0 \Lambda$
0.04 ± 0.03	4724	NIEBERGALL	74	ASPK	$K^+ p \rightarrow K^0 p \pi^+$
-0.008 ± 0.044	1757	FACKLER	73	O5PK	Ke3 from K ⁰
-0.03 ± 0.07	1367	HART	73	OSPK	K_{e3} from $K^0\Lambda$
-0.070 ± 0.036	1079	MALLARY	73	OSPK	Ke3 from KOAX
0.03 ± 0.06	410	143 BURGUN	72	HBC	$K^+ p \rightarrow K^0 p \pi^+$
-0.05 ± 0.09	442	144 GRAHAM	72	OSPK	$\pi^- p \rightarrow K^0 \Lambda$
$0.26 \begin{array}{l} +0.10 \\ -0.14 \end{array}$	126	MANN	72	нвс	$K^- p \rightarrow n \overline{K}^0$
0.25 +0.07 -0.09	252	WEBBER	71	нвс	$K^- p \rightarrow n \overline{K}^0$
0.12 ±0.09	215	¹⁴⁵ CHO	70	DBC	$K^+d \rightarrow K^0pp$
-0.020 ± 0.025		146 BENNETT	69	CNTR	Charge asym+ Cu regen.
$0.09 \begin{array}{l} +0.14 \\ -0.16 \end{array}$	686	LITTENBERG	69	OSPK	$K^+ n \rightarrow K^0 p$
0.09 +0.07	121	JAMES	68	нвс	P̄ρ
$0.17 \begin{array}{l} +0.16 \\ -0.35 \end{array}$	116	FELDMAN	67B	OSPK	$\pi^- p \rightarrow \kappa^0 \Lambda$
$0.035^{+0.11}_{-0.13}$	196	AUBERT	65	HLBC	K^+ charge exchange
$0.06 \begin{array}{c} +0.18 \\ -0.44 \end{array}$	152	¹⁴⁷ BALDO	65	HLBC	K ⁺ charge exchange
$-0.08 \begin{array}{l} +0.16 \\ -0.28 \end{array}$	109	148 FRANZINI	65	нвс	Pρ
• • • We do not us	se the followi	ng data for average	s, fits	s, limits,	etc. • • •
$0.04 \begin{array}{l} +0.10 \\ -0.13 \end{array}$	100	¹⁴⁴ GRAHAM	72	OSPK	$K_{\mu3}$ from $K^0 \Lambda$
-0.13 ± 0.11	342	144 MANTSCH	72	O5PK	K _{e3} from K ⁰ Λ
0.04 +0.07	222	143 BURGUN	71	нвс	$K^+ p \rightarrow K^0 p \pi^+$
0.03 ±0.03		146 BENNETT	68	CNTR	
0.17 ± 0.10	335	145 HILL	67	DBC	$K^+ d \rightarrow K^0 pp$

143 BURGUN 72 is a final result which includes BURGUN 71.
144 First GRAHAM 72 value is second GRAHAM 72 value combined with MANTSCH 72.
145 CHO 70 is analysis of unambiguous events in new data and HILL 67.

146 BENNETT 69 is a reanalysis of BENNETT 68.

147 BALDO-CEOLIN 65 gives x and θ converted by us to Re(x) and Im(x).

 148 FRANZINI 65 gives x and θ for Re(x) and Im(x). See SCHMIDT 67.



Re(x) ($\Delta S = -\Delta Q$ amplitude)

 $^{^{129}}$ FAISSNER 69 error enlarged to include error in regenerator phase. FAISSNER 69 ϕ_{+-} = $(49.3 \pm 7.4) + 205[\Delta m - 0.555]^{\circ}$. $\phi_f = -42.7 \pm 5.0^{\circ}$.

 $^{^{141}}$ Independent of regenerator mechanism, Δm , and lifetimes.

IMAGINARY I	PART OF x
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Assumes m,	_0 - m0 po	sitive. See Listings	abov	e.	
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
-0.003±0.026 OU	IR AVERAGE	Error Includes sca	le fac	tor of 1	.2.
$-0.10 \begin{array}{l} +0.16 \\ -0.19 \end{array}$	79	SMITH	75B	WIRE	$\pi^- p \rightarrow \kappa^0 \Lambda$
-0.06 ± 0.05	4724	NIEBERGALL	74	ASPK	$K^+ p \rightarrow K^0 p \pi^+$
-0.017 ± 0.060	1757	FACKLER	73	OSPK	K _{e3} from K ⁰
0.09 ± 0.07	1367	HART	73	OSPK	K_{e3} from $K^0 \Lambda$
$0.107 ^{+0.092}_{-0.074}$	1079	MALLARY	73	OSPK	K _{e3} from K ⁰ AX
$0.07 \begin{array}{l} +0.06 \\ -0.07 \end{array}$	410	¹⁴⁹ BURGUN	72	нвс	$K^+ p \rightarrow K^0 p \pi^+$
0.05 ± 0.13	442	150 GRAHAM	72	OSPK	$\pi^- p \rightarrow \kappa^0 \Lambda$
$0.21 \begin{array}{c} +0.15 \\ -0.12 \end{array}$	126	MANN	72	нвс	$K^- p \rightarrow n \overline{K}^0$
0.0 ± 0.08	252	WEBBER	71	HBC	$K^-p \rightarrow n\overline{K}^0$
-0.08 ± 0.07	215	¹⁵¹ CHO	70	DBC	$K^+ d \rightarrow K^0 pp$
$-0.11 \begin{array}{c} +0.10 \\ -0.11 \end{array}$	686	LITTENBERG	69	OSPK	$K^+ n \rightarrow K^0 p$
$+0.22 \begin{array}{c} +0.37 \\ -0.29 \end{array}$	121	JAMES	68	нвс	$\overline{p}p$
0.0 ±0.25	116	FELDMAN	67B	OSPK	$\pi^- \rho \rightarrow \kappa^0 \Lambda$
$-0.21 \begin{array}{c} +0.11 \\ -0.15 \end{array}$	196	AUBERT	65	HLBC	K^+ charge exchange
$-0.44 \begin{array}{l} +0.32 \\ -0.19 \end{array}$	152	¹⁵² BALDO	65	HLBC	K ⁺ charge exchange
$+0.24 \begin{array}{l} +0.40 \\ -0.30 \end{array}$	109	153 FRANZINI	65	нвс	<u> </u> P
• • • We do not u	use the followi	ng data for average	s, fits	, limits,	etc. • • •
$0.12 \begin{array}{l} +0.17 \\ -0.16 \end{array}$	100	150 GRAHAM	72	OSPK	$K_{\mu3}$ from $K^0\Lambda$
-0.04 ± 0.16	342	150 MANTSCH	72	OSPK	Ke3 from KOA
$0.12 \begin{array}{l} +0.08 \\ -0.09 \end{array}$	222	¹⁴⁹ BURGUN	71	нвс	$K^+ p \rightarrow K^0 p \pi^+$
-0.20 ±0.10	335	151 HILL	67	DBC	$K^+d \rightarrow K^0pp$
440					

 -0.20 ± 0.10

149 BURGUN 72 is a final result which includes BURGUN 71.
150 First GRAHAM 72 value is second GRAHAM 72 value combined with MANTSCH 72.
151 Footnote 10 of HILL 67 should read +0.58, not -0.58 (private communication) CHO 70 is analysis of unambiguous events in new data and HILL 67.
152 BALDO-CEOLIN 65 gives x and θ converted by us to Re(x) and Im(x).

153 FRANZINI 65 gives x and θ for Re(x) and Im(x). See SCHMIDT 67.

CPT-VIOLATION PARAMETERS IN KO DECAY

if $\ensuremath{\textit{CP}}\xspace$ -violating interactions include a $\ensuremath{\textit{T}}\xspace$ conserving part then

$$\begin{split} |\kappa_S\rangle &= [|\kappa_1\rangle + (\epsilon + \Delta)|\kappa_2\rangle]/\sqrt{1 + |\epsilon + \Delta|^2} \\ |\kappa_L\rangle &= [|\kappa_2\rangle + (\epsilon - \Delta)|\kappa_1\rangle]/\sqrt{1 + |\epsilon - \Delta|^2} \\ \text{where} \\ |\kappa_1\rangle &= [|\kappa^0\rangle + |\overline{\kappa}^0\rangle]/\sqrt{2} \\ |\kappa_2\rangle &= [|\kappa^0\rangle - |\overline{\kappa}^0\rangle]/\sqrt{2} \\ \text{and} \\ |\overline{\kappa}^0\rangle &= \mathit{CP}|\kappa^0\rangle. \end{split}$$

The parameter Δ specifies the *CPT*-violating part.

Estimates of Δ are given below. See also THOMSON 95 for a test of $\it CPT$ -symmetry conservation in $\it K^0$ decays using the Bell-Steinberger relation.

REAL PART OF Δ

A nonzero value v	iolates <i>CP</i>	T invariance.		
VALUE	EVTS	DOCUMENT ID	_	COMMENT
0.018±0.020	6481	DEMIDOV 9	5	K _{£3} reanalysis
154 DEMIDOV 95 reana	lvzes data	from HART 73 and	NI	EBERGALL 74.

IMAGINARY PART OF Δ

A nonzero value violates *CPT* invariance.

<u>VALUE</u> <u>EVTS</u> <u>DOCUMENT ID</u> <u>COMMENT</u> **0.021 ± 0.037** 6481 ¹⁵⁵ DEMIDOV 95 K_{£3} reanalysis 155 DEMIDOV 95 reanalyzes data from HART 73 and NIEBERGALL 74.

\mathcal{K}_{L}^{0} REFERENCES

BRFIT ETAFIT	98 98	RPP RPP	
FANTI	97	ZPHY C76 653	V. Fanti+ (NA48 Collab.)
NOMURA	97	PL B408 445	T. Nomura+ (KYOT, KEK, HIRO)
ADLER	96B	ZPHY C70 211	+Alhalel, Angelopoulos+ (CPLEAR Collab.)
ADLER	96C	Pl. B369 367	+Angelopoulos+ (CPLEAR Collab.)
GU	96	PRL 76 4312	+ (RUTG, UCLA, EFI, COLO, ELMT, FNAL, ILL, OSAK)
LEBER	96	PL B369 69	+Beier+ (MANZ, CERN, EDIN, ORSAY, PISA)
ADLER	95	PL B363 237	+Alhalel, Angelopoulos, Apostolakis+ (CPLEAR Collab.)
ADLER	95B	PL B363 243	+Alhalel, Angelopoulos, Apostolakis+ (CPLEAR Collab.)
AKAGI	95	PR D51 2061	+Fukuhisa, Hemmi+ (TOHOK, TOKY, KYOT, KEK)
BARR	95	ZPHY C65 361	+Buchholz+ (CERN, EDIN, MANZ, LALO, PISA, SIEG)
BARR	95C	Pl. B358 399	+Buchholz+ (CERN, EDIN, MANZ, LALO, PISA, SIEG)
DEMIDOV	95	PAN 58 968	+Gusev, Shabalin (ITEP)
From YAF			(1.2.)
HEINSON	95	PR D51 985	+Horvath, Knibbe, Mathiazhagan+ (BNL E791 Collab.)
KREUTZ	95	ZPHY C65 67	+Holder, Rost+ (SIEG, EDIN, MANZ, ORSAY, PISAI)
MATTHEWS	95	PRL 75 2803	+Gu, Haas, Hogan+ (RUTG, EFI, ELMT, FNAL, ILL)
SCHWINGEN	95	PRL 74 4376	Schwingenheuer+ (EFI, CHIC, ELMT, FNAL, ILL, RUTG)
SPENCER	95	PRL 74 3323	+ (UCLA, EFI, COLO, ELMT, FNAL, ILL, OSAK, RUTG)
THOMSON	95	PR D51 1412	+Zou (RUTG)

			_
BARR	94	PL B328 528 +Buchholz+ (CERN, EDIN, MANZ, LALO, PISA, SIEG	(
GU NAKAYA	94 94	PRI. 72 3000 + (RUTG, UCLA, EFI, COLO, ELMT, FNAL, ILL, OSAK, PRI. 73 2169 + (OSAK, UCLA, EFI, COLO, ELMT, FNAL, ILL, USAK, RUTG, PRI. 72 3759 + (UCLA, EFI, COLU, ELMT, FNAL, ILL, OSAK, RUTG, PRI. 72 3759 + (UCLA, EFI, COLU, ELMT, FNAL, ILL, OSAK, RUTG, PRI. 72 3759 + (UCLA, EFI, COLU, ELMT, FNAL, ILL, OSAK, RUTG, PRI. 72 3759 + (UCLA, EFI, COLU, ELMT, FNAL, ILL, OSAK, RUTG, PRI. 72 3759 + (UCLA, EFI, COLU, ELMT, FNAL, ILL, OSAK, RUTG, PRI. 72 3759 + (UCLA, EFI, COLU, ELMT, FNAL, ILL, OSAK, RUTG, PRI. 74 3751 4751 4751 4751 4751 4751 4751 4751 4	(
ROBERTS	94	PR D50 1874 + (UCLA, EFI, COLU, ELMT, FNAL, ILL, OSAK, RUTG	í
WEAVER AKAGI	94 93	PRL 72 3758 + (UCLA, EFI, COLU, ELMT, FNAL, ILL, OSAK, RUTG PR D47 R2644 +Fukuhisa, Hemmi+ (TOHOK, TOKY, KYOT, KEK)
ARISAKA	93	PRL 70 1049 +Auerbach, Axelrod, Belz, Biery+ (BNL E791 Collab.	.)
ARISAKA BARR	93B 93D	PRL 71 3910 +Auerbach, Axelrod, Belz, Biery+ (BNL E791 Collab. PL B317 233 +Buchholz+ (CERN, EDIN, MANZ, LALO, PISA, SIEG	1
GIBBONS	93	PRL 70 1199 +Barker, Briere, Makoff+ (FNAL E731 Collab.	.)
Also GIBBONS	97 93B	PR D55 6625 L.K. Gibbons+ (FNAL E731 Collab. PRL 70 1203 +Barker, Briere, Makoff+ (FNAL E731 Collab.	3
GIBBONS	93C	Thesis RX-1487 (CHIC	:)
Also HARRIS	97 93	PR D55 6625 L.K. Gibbons+ (FNAL E731 Čollab. PRL 71 3914 + (EFI, UCLA, COLO, ELMT, FNAL, ILL, OSAK, RUTG	;
HARRIS	93B	PRL 71 3918 + (EFI, UCLA, COLO, ELMT, FNAL, ILL, OSAK, RUTG	5)
MAKOFF Also	93 95	PRI. 70 1591 +Barker, Briere, Gibbons+ (FNAL E731 Collab. PRI. 75 2069 (erratum)	,
RAMBERG RAMBERG	93 93B	PRL 70 2525 +Bock, Coleman, Enagonio, Hsiung+ (FNAL E731 Collab. PRL 70 2529 +Bock, Coleman, Enagonio, Hsiung+ (FNAL E731 Collab.	(
VAGIN5	93	PRL 71 35 +Adair, Greenlee, Kasha, Mannelli+ (BNL E845 Collab.	.j
ADLER	92B 92	PL B286 180 +Alhalel, Angelopoulos, Apostolakis+ (CPLEAR Collab.	.)
Also BARR	92	SJNP 55 840 Adler, Alhaiel, Angelopoulos+ (CPLEAR Collab. PL B284 440 +Buchholz+ (CERN, EDIN, MANZ, LALO, PISA, SIEG	3
GRAHAM MORSE	92 92	PL B295 169 +Barker, Briere, Gibbons, Makoff+ (FNAL E731 Collab. PR D45 36 +Leipuner, Larsen, Jastrzembski+ (BNL, YALE, VASS	(
PDG	92	PR D45 36 + Leipuner, Larsen, Jastrzembski+ PR D45, 1 June, Part II Hikasa, Barnett, Stone+ PRL 68 2580 + Barker, Birler, Gibbons+ (FNAL E731 Collab	3
SOMALWAR AKAGI	92 91	PRL 68 2580 + Barker, Briere, Gibbons+ (FNAL E731 Collab. PRL 67 2614 + Fukuhisa, Hemmi+ (TOHOK, TOKY, KYOT, KEK	1
AKAGI	91B	PRL 67 2618 +Fukuhisa, Hemmi+ (TOHOK, TOKY, KYOT, KEK	()
BARR HEINSON	91 91	PL B259 389 +Carosi+ (CERN, EDIN, MANZ, LALO, PISA, SIEG PR D44 R1 + (UCI, UCLA, LANL, PENN, STAN, TEMP, TEXA+	3
PAPADIMITR	. 91	PR D44 R573 Papadimitriou, Barker, Briere+ (FNAL E731 Collab.	.)
BARKER Also	90 88	PR D41 3546 +Briere, Gibbons, Makoff+ (FNAL E731 Collab. PRL 61 2661 Gibbons, Papadimitriou+ (FNAL E731 Collab.	
BARR	90B	PL B240 283 +Carosi+ (CERN, EDIN, MANZ, LALO, PISA, SIEG	ő
BARR CAROSI	90C 90	PL B240 283 + Carosi+ (CERN, EDIN, MANZ, LALO, PISA, SIEC PL B242 523 + Carosi+ (CERN, EDIN, MANZ, LALO, PISA, SIEC PL B237 303 + Clarke+ (CERN, EDIN, MANZ, LALO, PISA, SIEC	3
KARLSSON	90	PRL 64 2976 +Gollin, Okamitsu, Tschirhart, Barker+(FNAL E731 Collab	.)
OHL	90 90B	PRL 64 2755 +Adair, Greenlee, Kasha, Mannelli+ (BNL E845 Collab PRL 65 1407 +Adair, Greenlee, Kasha, Mannelli+ (BNL E845 Collab	3
PATTERSON	90	PRL 64 1491 +Barker+ (FNAL E731 Collab	.)
INAGAKI LITTENBERG	89 89	PR D40 1712 +Kobayashi, Sato, Shinkawa+ (KEK, TOKY, KYOT PR D39 3322 (BNL	
MATHIAZHA	. 89	PRL 63 2181 Mathiazhagan+ (UCI, UCLA, LANL, PENN, STAN+	-)
MATHIAZHA PAPADIMITR		PRL 63 2185 Mathiazhagan+ (UCI, UCLA, LANL, PENN, STAN+ PRL 63 28 Papadimitriou, Gibbons, Patterson+ (FNAL E731 Collab	3
SCHAFFNER	89	PR D39 990 +Greenlee, Kasha, Mannelli, Ohl+ (YALE, BNL	.)
WAHL BARR	89 88	CERN-EP/89-86, H. Wahl — Rare Decay Symposium, Vancouver (CERN PL B214 303 + Clarke+ (CERN, EDIN, MANZ, LALO, PISA, SIEC PL B206 169 + Clarke+ (CERN, EDIN, MANZ, LALO, PISA, SIEC PR D38 2914 + Konigsberg+ (UCLA, LASL, PENN, STAN, TEMP, WILL	3
BURKHARDT	88 88	PL B206 169 +Clarke+ (CERN, EDIN, MANZ, LALO, PISA, SIEC	į
COUSINS GREENLEE	88	PRL 60 893 +Kasha, Mannelli, Mannelli+ (YALE, BNL	3
JASTRZEM WOODS	88 88	PRL 60 893 +Kasha, Mannelli, Mannelli+ (YALE, BNL PRL 61 2300 Jastrzembski, Larsen, Leipuner, Morse+ (BNL, YALE NL BING) (CFED) E7NL AMAY JAMO 2015 SEE	(
BURKHARDT	87	PL B199 139 + (CERN, EDIN, MANZ, LALO, PISA, SIEC	·)
ARONSON Also	86 82	PL B199 139 + (CERN, EDIN, MANZ, LALO, PISA, SIEC PR D33 3180 + Bernstein, Bock+ (BNL, CHIC, STAN, WISC PRL 48 1078 Aronson, Bernstein+ (BNL, CHIC, STAN, WISC	?
PDG	86C	PL 170B 132 Aguilar-Benitez, Porter+ (CERN, CIT+	-)
BERNSTEIN BLACK	85B 85	PRL 54 1631 +Bock, Carlsmith, Coupal+ (CHiC, SACI	.)
COUPAL	85	PRL 55 566 +Bernstein, Bock, Carlsmith+ (CHIC, SACI	3
BALATS	83	SJNP 38 556 +Berezin, Bogdanov, Vishnevsky+ (ITEF Translated from YAF 38 927.	')
BERGSTROM	83	PL 131B 229 + Masso, Singer (CERN	ı)
ARONSON ARONSON	82 82B	PRL 48 1078 +Bernstein+ (BNL, CHIC, STAN, WISC PRL 48 1306 +Bock, Cheng, Fischbach (BNL, CHIC, PURC	·)
Also	82B	PI 116B 73 Fischhach Cheng (PURD RNI CHK	٠,
Also Also	83 83B	PR D28 476 Aronson, Bock, Cheng+ (BNL, CHIC, PURE PR D28 495 Aronson, Bock, Chica, Bock,	3
PDG BIRULEV	82B 61	PL 111B 70 Roos, Porter, Aguilar-Benitez+ (HELS, CIT, CERN NP B182 1 +Dzhordzhadze, Genchev, Grigalashvili+ (JINF	4)
Also	80	SJNP 31 622 Birulev, Vestergombi, Genchev+ (JINF	
CARROLL	80B	Translated from YAF 31 1204. PRL 44 529 + Chiang, Kycia, Li, Littenberg, Marx+ (BNL, ROCF	1)
CARROLL	80C 80D	PL 96B 407 +Chiang, Kycia, Li, Littenberg, Marx+ (BNL, ROCH	į
CARROLL CHO	80	PRL 44 525 + Chiang, Kycia, Li, Littenberg, Marx+ (BNL, ROCF- PR D22 2688 + Derrick, Miller, Schlereth, Engler+ (ANL, CML	
MORSE	80	PR D21 1750 +Leipuner, Larsen, Schmidt, Blatt+ (BNL, YALE	Ξ)
BIRULEV	79	Translated from YAF 29 1516.	-
CHRISTENS CHRISTENS	79 79B	PRL 43 1209 Christenson, Goldman, Hummel, Roth+ (NYU PRL 43 1212 Christenson, Goldman, Hummel, Roth+ (NYU	
HILL SCHMIDT	79	NP B153 39 +Sakitt, Snape, Stevens+ (BNL, SLAC, SBEF	₹Ś
SHOCHET	79 79	PRL 43 556 +Blatt, Campbell, Grannan+ (YALE, BNI PR D19 1965 +Linsay, Grosso-Pilcher, Frisch+ (EFI, ANI	3
Also ENGLER	77 78B	PRL 39 59 Shochet, Linsay, Grosso-Pilcher+ (EFI, ANI	L)
HILL	78	PL 73B 483 +Sakitt, Snape, Stevens+ (BNL, SLAC, SBEF	₹)
CHO CLARK	77 77	PR D15 587 +Derrick, Lissauer, Miller, Engler+ (ANL, CML PR D15 553 +Field, Holley, Johnson, Kerth, Sah, Shen (LBI	
Also	75	Thesis LBL-4275 Shen (LBI	L)
DEVOE DZHORD	77 77	PR D16 565 +Cronin, Frisch, Grosso-Pilcher+ (EFI, ANI SJNP 26 478 Dzhordzhadze, Kekelidze, Krivokhizhin+ (JINF	
		Translated from YAF 26 910.	
PEACH BIRULEV	77 76	NP B127 399 +Cameron+ (BGNA, EDIN, GLAS, PISA, RHEI SJNP 24 178 +Vestergombi, Vovenko, Votruba+ (JINF	
COOMBES	76	Translated from YAF 24 340.	
DONALDSON		PR D14 2839 +Hitlin, Kennelly, Kirkby, Liu+ (SLAC	
Also FUKUSHIMA			~,
	74	Thesis SLAC-0184 Donaldson (SLAC	Z)
GJESDAL	74 76 76	Thesis SLAC-0184 Donaldson (SLAC PRL 36 348 + Jensen, Surko, Thaler+ (PRIN, MAEIO NP R109 118 + Kamae Presser, Steffen+ (CERN, HEIO)	~) ()
GJESDAL REY	74 76	Thesis SLAC-0184 Donaldson SLAC-0184 PRL 36 348 - Jensen, Surko, Thaler + (PRIIN, MASS NP B109 118 +Kamae, Presser, Steffen + (CERN, HEIDH PR D13 1161 +Cence, Jones, Parker + (NDAM, HAWA, LRI PRL 22 1210 Cence, Jones, Peterson, Stenger + (HAWA, LRI MAWA, LRI CANANA, LRI	こりりしい
GJESDAL REY Also BALDO	74 76 76 76 69 75	Thesis SLAC-0184 Donaldson SLAC-0184 PRL 36 348 - Jensen, Surko, Thaler + (PRIIN, MASS NP B109 118 +Kamae, Presser, Steffen + (CERN, HEIDH PR D13 1161 +Cence, Jones, Parker + (NDAM, HAWA, LRI PRL 22 1210 Cence, Jones, Peterson, Stenger + (HAWA, LRI MAWA, LRI CANANA, LRI	こりりしい
GJESDAL REY Also	74 76 76 76 69 75	Thesis SLAC-0184 Donaldson FRI State SLAC-0184 Densen, Surko, Thaler + (PRIN, MASS NP B109 118 +Kamae, Presser, Steffen + (CERN, HEID PR D13 1161 +Cence, Jones, Parker + (NDAM, HAWA, LBI PRL 22 1210 Cence, Jones, Peterson, Stenger + (HAWA, LRI PRL 23 468 +Fankk, Nagy + (PADO, WISS NEAR NAGY + (PADO, W	こくりししこう
GJESDAL REY Also BALDO BLUMENTHAI BUCHANAN CARITHERS	74 76 76 76 69 75 75 75	Thesis SLAC-0184 Donaldson	ころうしょこうしょ
GJESÐAL REY Also BALDO BLUMENTHAI BUCHANAN	74 76 76 76 69 75 75 75 75 75 758 74	Thesis SLAC-0184 Donaldson Clark	こうりょうこうしょうこう
GJESDAL REY Also BALDO BLUMENTHAI BUCHANAN CARITHERS SMITH ALBRECHT BISI	74 76 76 76 69 75 75 75 75 75 75 74 74	Thesis UCSD unpub. PL 498 504 Ferrero Tropic SLAC.	こうりょうしょうりょうりょう
GJESDAL REY Also BALDO BLUMENTHAI BUCHANAN CARITHERS SMITH ALBRECHT BISI DONALDSON Also	74 76 76 76 69 75 75 75 75 75 75 74 74 74	Thesis SLAC-0184	こくりいしつうりょうのうじつ
GJESDAL REY Also BALDO BLUMENTHAI BUCHANAN CARITHERS SMITH ALBRECHT BISI DONALDSON Also DONALDSON	74 76 76 76 69 75 75 75 75 75 74 74 74 76 74B	Thesis SLAC-0184	
GJESDAL REY Also BALDO BLUMENTHAI BUCHANAN CARITHERS SMITH ALBRECHT BISI DONALDSON Also DONALDSON DONALDSON	74 76 76 76 69 75 75 75 75 74 74 74 74 74 74B 73B 74C	Thesis SLAC-0184 Donaldson (SLAK PB 109 118 +Kamae, Presser, Steffen + (PRIN, MASS/ PR 109 118 +Kamae, Presser, Steffen + (CERN, HEIDP PR D13 1161 +Cence, Jones, Parker + (CERN, HEIDP PR D13 164 +Frankel, Nagy + (PADO, WISC PR D1 457 +Prickey, Pepper, Rudnick + (PADO, WISC PR D1 457 +Voicey, Pepper, Rudnick + (VCLA, SLAC, JHL PR D1 4839 +Ferrero (JINR, BERL, BUDA, PRAG, SERP, SOF PR D9 2960 +Ferrero Donaldson, Hitlin, Kennelly, Kirkby, Liu+ (SLAC, UCSC PRL 31 337 Donaldson, Fryberger, Hitlin, Liu+ (SLAC, UCSC SLAC, UCSC SL	こうりょうこうりょうかいじゅうこう
GJESDAL REY Also BALDO BLUMENTHAI BUCHANAN CARITHERS SMITH ALBRECHT BISI DONALDSON Also DONALDSON Also	74 76 76 76 69 75 75 75 75 75 74 74 74 74 76 74B 73B	Thesis SLAC-0184 Donaldson (SLAK PB 109 118 +Kamae, Presser, Steffen + (PRIN, MASS/ PR 103 1161 +Cence, Jones, Parker + (CERN, HEIDP PR 123 1161 +Cence, Jones, Parker + (CERN, HEIDP PR 124 1241 +Frankel, Nagy+ +Frankel, Nagy+ +Frankel, Nagy+ +Drickey, Pepper, Rudnick + (UCLA, SLAC, JHL PR 134 1244 +Drickey, Pepper, Rudnick + (UCLA, SLAC, JHL PR 134 1244 +Drickey, Pepper, Rudnick + (UCLA, SLAC, JHL PR 134 1244 +Drickey, Pepper, Rudnick + (UCLA, SLAC, JHL PR 134 1244 +Drickey, Pepper, Rudnick + (UCLA, SLAC, JHL SLAC, JHL PR 134 1233 +Ferrero (JINR, BERL, BUDA, PRAG, SERP, SOF PR 134 2839 Donaldson, Fryberger, Hitlin, Liu+ (SLAC, UCSC SLAC,	
GJESDAL REY Also BALDO BLUMENTHAI BUCHANAN CARITHERS SMITH ALBRECHT BISI DONALDSON Also DONALDSON Also DONALDSON Also FIELD	74 76 76 76 69 75 75 75 75 75 74 74 74 74 74 74 74 74 74 74 74 74 74	Thesis SLAC-0184	
GJESDAL REY Also BALDO BLUMENTHAI BUCHANAN BUCHANAN CARITHERS SMITH ALBRECHT BISI DONALDSON Also DONALDSON Also Also Also	74 76 76 76 69 75 75 75 75 75 74 74 74 74 74 74 74 74 76 74B 73B 74C 74	Thesis SLAC-0184 Donaldson (SLAK PB 109 118 +Kamae, Presser, Steffen + (PRIN, MASS/ PR 103 1161 +Cence, Jones, Parker + (CERN, HEIDP PR 123 1161 +Cence, Jones, Parker + (CERN, HEIDP PR 124 1241 +Frankel, Nagy+ +Frankel, Nagy+ +Frankel, Nagy+ +Drickey, Pepper, Rudnick + (UCLA, SLAC, JHL PR 134 1244 +Drickey, Pepper, Rudnick + (UCLA, SLAC, JHL PR 134 1244 +Drickey, Pepper, Rudnick + (UCLA, SLAC, JHL PR 134 1244 +Drickey, Pepper, Rudnick + (UCLA, SLAC, JHL PR 134 1244 +Drickey, Pepper, Rudnick + (UCLA, SLAC, JHL SLAC, JHL PR 134 1233 +Ferrero (JINR, BERL, BUDA, PRAG, SERP, SOF PR 134 2839 Donaldson, Fryberger, Hitlin, Liu+ (SLAC, UCSC SLAC,	

GEWENIGER Also GEWENIGER GJESDAL MESSNER NIEBERGALL				Commission of the control of the Con
GJESDAL MESSNER	74B	PL 52B 119	+Gjesdal, Presser+ (CERN, HEIDH) Gjesdal, Presser, Steffen+ (CERN, HEIDH)	LITTENBERG 69 PRL 22 654 +Field, Piccioni, Mehlhop+ (UCSD LONGO 69 PR 181 1808 +Young, Helland (MICH, UCLA
MESSNER	74C 74	PL 52B 108 PL 52B 113	+Gjesdal, Presser+ (CERN, HEIDH) +Presser, Kamae, Steffen+ (CERN, HEIDH)	PACIOTTI 69 Thesis UCRL 19446 (LRL SAAL 69 Thesis (COLU
	74	PRL 33 1458	+Franklin, Morse+ (COLO, SLAC, UCSC)	ABRAMS 68B PR 176 1603 +Abashian, Mischke, Nefkens, Smith+ (ILL
WANG	74 74	PL 49B 103 PR D9 540	+Regier, Stier+ (ČERN, ORSAY, VIEN) +Smith, Whatley, Zorn, Hornbostel (UMD, BNL)	ARNOLD 68B PL 28B 56 +Budagov, Cundy, Aubert+ (CERN, ORSAY ARONSON 68 PRL 20 287 +Chen (PRIN
MILLIAMS	74 73	PRL 33 240	+Larsen, Leipuner, Sapp, Sessoms+ (BNL, YALE)	Also 69 PR 175 1708 Aronson, Chen (PRIN BARTLETT 68 PRL 21 558 +Carnegie, Fitch+ (PRIN
ALBROW ALEXANDER	73B	NP B58 22 NP B65 301	+Benary, Borowitz, Lande+ (TELA, HEID)	BASILE 68 PL 26B 542 +Cronin, Thevenet, Turlay+ (SACL
ANIKINA BARBIÉLLINI	73 73	JINR P1 7539 PL 43B 529	+Balashov, Bannik+ (JINR) +Darriulat, Fainberg+ (CERN)	BASILE 68B PL 28B 58 +Cronin, Thevenet, Turlay, Zylberajch+ (SACL 8ENNETT 68 PL 27B 244 +Nygren, Steinberger+ (COLU, CERN
BRANDENB	73	PR D8 1978	Brandenburg, Johnson, Leith, Loos+ (SLAC)	BENNETT 68B PL 27B 248 +Nygren, Steinberger+ (COLU, CERN
CARITHERS Also	73 73B	PRL 31 1025 PRL 30 1336	+Nygren, Gordon+ (COLU, BNL, CERN) Carithers, Modis, Nygren+ (COLU, CERN, NYU)	BLANPIED 68 PRL 21 1650 +Levit, Engels+ (CASE, HARV, MCG BOHM 68B PL 27B 594 +
EVANS	73	PR D7 36	+Muir, Peach, Budagov+ (EDIN, CERN)	BUDAGOV 68 NC 57A 182 +Burmeister, Cundy+ (CERN, ORSAY, IPNF
Also FACKLER	69 73	PRL 23 427 PRL 31 847	Evans, Golden, Muir, Peach+ (EDIN, CERN) +Frisch, Martin, Smoot, Sompayrac (MIT)	Also 68B PL 28B 215 Budagov, Cundy, Myatt+ (CERN, ORSAY, EPOL JAMES 68 NP 88 365 +Briand (IPNP, CERN
FITCH	73	PRL 31 1524	+Hepp, Jensen, Strovink, Webb (PRIN)	Also 68 PRL 21 257 Helland, Longo, Young (UCLA, MICH
Also GINSBERG	72 73	Thesis COO-3072-13 PR D8 3887	Webb (PRIN) +Smith (MIT, STON)	KULYUKINA 68 JETP 26 20 +Mestvirishvili, Nyagu+ (JINF Translated from ZETF 53 29.
HART	73	NP B66 317	+Hutton, Field, Sharo, Blackmore+ (CAVE, RHEL)	KUNZ 68 Thesis PU-68-46 (PRIN BENNETT 67 PRL 19 993 +Nygren, Saal, Steinberger+ (COLU
MALLARY Also	73 70	PR D7 1953 PRL 25 1214	+Binnie, Gallivan, Gomez, Peck, Sciulli+ (CIT) Sciulli, Gallivan, Binnie, Gomez+ (CIT)	BOTT 67 PL 24B 194 Bott-Bodenhausen, DeBouard, Cassel+ (CERN
MCCARTHY	73	PR D7 687	+Brewer, Budnitz, Entis, Graven, Miller+ (LBL) McCarthy, Brewer, Budnitz, Entis, Graven+ (LBL)	BOTT 678 PL 248 438 Bott-Bodenhausen, Debouard, Dekkers+ (CERN Also 66B PL 20 212 Bott-Bodenhausen, Debouard, Cassel+ (CERN
Also Also	72 71	PL 42B 291 Thesis LBL-550	McCarthy (LBL)	Also 66 PL 23 277 Bott-Bodenhausen, DeBouard, Cassel+ (CERN
MESSNER PEACH	73 73	PRL 30 876 PL 43B 441	+ Morse, Nauenberg, Hitlin+ (COLO, SLAC, UCSC) + Evans, Muir, Hopkins, Krenz (EDIN, CERN, AACH)	CRONIN 67 PRL 18 25 +Kunz, Risk, Wheeler (PRIN Also 68 Thesis unpub. Wheeler (PRIN
SANDWEISS	73	PRL 30 1002	+Sunderland, Turner, Willis, Keller (YALE, ANL)	CRONIN 67B Princeton 11/67 +Kunz, Risk, Wheeler (PRIN
WILLIAMS ALBROW	73 72	PRL 31 1521 NP B44 1	+Larsen, Leipuner, Sapp, Sessoms+ (BNL, YALE) +Aston, Barber, Bird, Ellison+ (MCHS, DARE)	DEBOUARD 67 NC 52A 662 +Dekkers, Jordan, Mermod+ (CERN Also 65 PL 15 58 DeBouard, Dekkers, Scharff+ (CERN, ORSAY, MPIN
ASHFORD	72	PL 38B 47	+Brown, Masek, Maung, Miller, Ruderman+ (UCSD)	DEVLIN 67 PRL 18 54 +Solomon, Shepard, Beall+ (PRIN, UMD
BANNER BANNER	72 72B	PRL 28 1597 PRL 29 237	+Cronin, Hoffman, Knapp, Shochet (PRIN) +Cronin, Hoffman, Knapp, Shochet (PRIN)	DORFAN 67 PRL 19 987 +Enstrom, Raymond, Schwartz+ (SLAC, LRI
BARMIN	72	SJNP 15 636	+Davidenko, Demidov, Dolgolenko+ (ITEP)	FELDMAN 67B PR 155 1611 +Frankel, Highland, Sloan (PENN
BARMIN	72B	SJNP 15 638	15 1149. +Barylov, Davidenko, Demidov+ (ITEP)	FIRESTONE 67 PRL 18 176 +Kim, Lach, Sandweiss+ (YALE, BNI FITCH 67 PR 164 1711 +Roth, Russ, Vernon (PRIM
URGUN	72	Translated from YAF NP B50 194	15 1152. +Lesquoy, Muller, Pauli+ (SACL, CERN, OSLO)	GINSBERG 67 PR 162 1570 (MASE
ARNEGIE	72	PR D6 2335	+Cester, Fitch, Strovink, Sulak (PRIN)	HILL 67 PRL 19 668 +Luers, Robinson, Sakitt+ (8NL, CML
DALLY Also	72 70	PL 41B 647 PL 33B 627	+Innocenti, Seppi+ (SLAC, JHU, UCLA) Chien, Cox, Ettlinger+ (JHU, SLAC, UCLA)	HOPKINS 67 PRL 19 185 +Bacon, Eisler (BNI
Also	71	PL 35B 261	Chien, Cox, Ettlinger+ (JHU, SLAC, UCLA)	KULYUKINA 67 Preprint +Mestvirishvili, Nyagu+ (JINF
GRAHAM HOLDER	72 72	NC 9A 166 PL 40B 141	+Abashian, Jones, Mantsch, Orr+ (ILL, NEAS) +Radermacher, Staude+ (AACH, CERN, TORI)	LOWYS 67 PL 24B 75 +Aubert, Chounet, Pascaud+ (EPOL, ORSA) MISCHKE 67 PRL 18 138 +Abashian, Abrams+ (ILI
AMES	72	NP B49 1	+Montanet, Paul, Saetre+ (CERN, SACL, OSLO)	NEFKENS 67 PR 157 1233 +Abashian, Abrams, Carpenter, Fisher+ (ILI
KRENZ MANN	72 72	LNC 4 213 PR D6 137	+Hopkins, Evans, Muir, Peach (AACH, CERN, EDIN) +Kofler, Meisner, Hertzbach+ (MASA, BNL, YALE)	SCHMIDT 67 Thesis Nevis 160 (COLU TODOROFF 67 Thesis (ILI
MANTSCH	72	NC 9A 160	+Abashian, Graham, Jones, Orr+ (ILL, NEAS)	ALFF 66B PL 21 595 Alff-Steinberger, Heuer, Kleinknecht+ (CERN
MCCARTHY METCALF	72 72	PL 42B 291 PL 40B 703	+Brewer, Budnitz, Entis, Graven+ (LBL) +Neuhofer, Niebergall+ (CERN, IPN, WIEN)	ANIKINA 66 SJNP 2 339 +Vardenga, Zhuravleva+ (JINF Translated from YAF 2 471.
NEUHOFER	72	PL 41B 642	+Niebergall, Regler, Stier+ (CERN, ORSAY, VIEN)	AUERBACH 66B PRL 17 980 + Mann, McFarlane, Sciulli (PENN
PICCIONI Also	72 74	PRL 29 1412 PR D9 2939	+Coombes, Donaldson, Dorfan, Fryberger+ (SLAC) Piccioni, Donaldson+ (SLAC, UCSC, COLO)	BASILE 66 Balaton Conf. +Cronin, Thevenet+ (SACI BEHR 66 PL 22 540 +Brisson, Petiau+ (EPOL, MILA, PADO, ORSAY
/OSBURGH	72	PR D6 1834	+Devlin, Esterling, Goz, Bryman+ (RUTG, MASA)	BOTT 66 PL 23 277 Bott-Bodenhausen, DeBouard, Cassel+ (CERN
Also BALATS	71 71	PRL 26 866 SJNP 13 53	Vosburgh, Devlin, Esterling, Goz+ (RUTG, MASA) +Berezin, Vishnevsky, Galanina+ (ITEP)	CRIEGEE 66 PRL 17 150 +Fox, Frauenfelder, Hanson, Moscat+ (ILI
BARMIN	71	Translated from YAF PL 35B 604	13 93. +Barylov, Veselovsky, Davidenko+ (ITEP)	FIRESTONE 66 PRL 16 556 +Kim, Lach, Sandweiss+ (YALE, BNI HAWKINS 66 PL 21 238 (YALI
BISI	71	PL 36B 533	+Darriulat, Ferrero, Rubbia+ (AACH, CERN, TORI)	Also 67 PR 156 1444 Hawkins (YAL)
BURGUN CARNEGIE	71 71	LNC 2 1169 PR D4 1	+Lesquoy, Muller, Pauli+ (SACL, CERN, OSLO) +Cester, Fitch, Strovink, Sulak (PRIN)	ANDERSON 65 PRL 14 475 + Crawford, Golden, Stern, Binford+ (LRL, WISC ANIKINA 65 JINR P 2488 + Vardenga, Zhuravleva, Kotiya+ (JINI
CHAN	71	Thesis LBL-350	(LBL)	ASTBURY 65 PL 16 80 +Finocchiaro, Beusch+ (CERN, ZUR
CHIEN Also	71 72	PL 35B 261 PL 41B 647	+Cox, Ettlinger+ (JHU, SLAC, UCLA) Dally, Innocenti, Seppi+ (SLAC, JHU, UCLA)	Also 65 HPA 39 523 Pepin ASTBURY 65B PL 18 175 + Michelini, Beusch+ (CERN, ZUR
СНО	71	PR D3 1557	+Draile, Canter, Engler, Fisk+ (CMU, BNL, CASE)	ASTBURY 65C PL 18 178 + Michelini, Beusch+ (CERN, ZUR
CLARK Also	71 70	PRL 26 1667 Thesis UCRL 19709	+Elioff, Field, Frisch, Johnson, Kerth+ (LRL) Johnson (LRL)	AUBERT 65 PL 17 59 +Behr, Canavan, Chounet+ (EPOL, ORSA' Also 67 PL 24B 75 Lowys, Aubert, Chounet, Pascaud+ (EPOL, ORSA'
Also Also	71 74	Thesis UCRL 20264 SLAC-PUB-1498 unpu	Frisch (LRL) b. Field (SLAC)	BALDO 65 NC 38 684 Baldo-Ceolin, Calimani, Ciampolillo+ (PADG
ENSTROM	71	PR D4 2629	+Akavia, Coombes, Dorfan+ (SLAC, STAN)	FISHER 65 ANL 7130 83 +Abashian, Abrams, Carpenter+ (IL FITCH 65 PRL 15 73 +Roth, Russ, Vernon (PRI
Also JAMES	70 71	Thesis SLAC-0125 PL 35B 265	Enstrom (STAN) +Montanet, Paul, Pauli+ (CERN, SACL, OSLO)	FRANZINI 65 PR 140B 127 +Kirsch, Plano+ (COLU, RUT)
MEISNER	71	PR D3 59	+Mann, Hertzbach, Kofler+ (MASA, BNL, YALE)	GUIDONI 65 Argonne Conf. 49 +Barnes, Foelsche, Ferbel, Firestone+ (BNL, YAL)
PEACH RÉPELLIN	71 71	PL 35B 351 PL 36B 603	+Evans, Muir, Budagov, Hopkins+ (EDIN, CERN) +Wolff, Chollet, Gaillard, Jane+ (ORSAY, CERN)	HOPKINS 65 Argonne Conf. 67 +Bacon, Eisler (VAND, RUTO ADAIR 64 PL 12 67 +Leipuner (YALE, BN
WEBBER	71	PR D3 64	+Solmitz, Crawford, Alston-Garnjost (LRL)	ALEKSANYAN 64B Dubna Conf. 2 102 +Alikhanyan, Vartazaryan+ (YERI
Also Also	68 69	PRL 21 498 Thesis UCRL 19226	Webber, Solmitz, Crawford, Alston-Garnjost (LRL) Webber (LRL)	Also 64 JETP 19 1019 Aleksanyan+ (LEBD, MPEI, YERI Translated from ZETF 46 1504.
WOLFF	71	PL 36B 517	+Chollet, Repellin, Gaillard+ (ORSAY, CERN)	ANIKINA 64 JETP 19 42 +Zhuravleva+ (GEOR, JINI
ALBROW ARONSON	70 70	PL 33B 516 PRL 25 1057	+Aston, Barber, Bird, Ellison+ (MCHS, DARE) +Ehrlich, Hofer, Jensen+ (EFI, ILLC, SLAC)	Translated from ZETF 46 59. CHRISTENS 64 PRL 13 138 Christenson, Cronin, Fitch, Turlay (PRII
BARMIN	70	PL 33B 377	+Barylov, Borisov, Bysheva+ (ITEP, JINR)	FUJII 64 Dubna Conf. 2 146 + Jovanovich, Turkot+ (BNL, UMD, MI
BASILE BECHERRAW	70 Y 70	PR D2 78 PR D1 1452	+Cronin, Thevent, Turlay, Zylberajch+ (SACL) (ROCH)	DARMON 62 PL 3 57 +Rousset, Six (EPO
BUCHANAN	70	PL 33B 623	+Drickey, Rudnick, Shepard+ (SLAC, JHU, UCLA)	ASTIER 61 Aix Conf. 1 227 + Blaskovic, Rivet, Siaud+ (EPO FITCH 61 NC 22 1160 + Piroue, Perkins (PRIN, LAS
Also BUDAGOV	71 70	Private Comm. PR D2 815	Cox +Cundy, Myatt, Nezrick+ (CERN, ORSAY, EPOL)	GOOD 61 PR 124 1223 +Matsen, Muller, Piccioni+ (LR
Also	68B	PL 28B 215	Budagov, Cundy, Myatt+ (CERN, ORSAY, EPOL)	NYAGU 61 PRL 6 552 +Okonov, Petrov, Rosanova, Rusakov (JINI Also 61B JETP 13 1138 Nyagu, Okonov, Petrov, Rozanova+ (JINI
CHIEN Also	70 71	PL 33B 627 Private Comm.	+Cox, Ettlinger+ (JHU, SLAC, UCLA) Cox	Translated from ZETF 40 1618.
CHO	70	PR D1 3031	+Dralle, Canter, Engler, Fisk+ (CMU, BNL, CASE)	BARDON 58 ANP 5 156 +Lande, Lederman (COLU, BN
Also CHOLLET	67 70	PRL 19 668 PL 31B 658	Hill, Luers, Robinson, Sakitt+ (BNL, CMU) +Gaillard, Jane, Ratcliffe, Repellin+ (CERN)	OTHER RELATED PAPERS
CULLEN	70	PL 32B 523	+Darriulat, Deutsch, Foeth+ (AACH, CERN, TORI)	
OARRIULAT FAISSNER	70 70	PL 33B 249 NC 70A 57	+Ferrero, Grosso, Holder+ (AACH, CERN, TORI) +Reithler, Thome, Gaillard+ (AACH3, CERN, RHEL)	HAYAKAWA 93 PR D48 1150 +Sanda (NAG6 "Searching for T, CP, CPT, ΔS = ΔQ Rule Violations in the Neutral K Meson System: A Guide
GINSBERG	70	PR D1 229	(HAIF)	LITTENBERG 93 ARNPS 43 729 +Valencia (BNL, FNA
JENSEN Also	70 69	Thesis PRL 23 615	(EFI) Jensen, Aronson, Ehrlich, Fryberger+ (EFI, ILL)	Rare and Radiative Kaon Decays RITCHIE 93 RMP 65 1149 +Wojcicki
MARX	70	PL 32B 219	+Nygren, Peoples+ (COLU, HARV, CERN)	"Rare K Decays"
Also SCRIBANO	70B 70	PL 32B 224	Marx +Mannelli, Pierazzini, Marx+ (PISA, COLU, HARV)	WINSTEIN 93 RMP 65 1113 +Wolfenstein "The Search for Direct CP Violation"
	70	PL 32B 133 PR D1 1967	+Wang, Whatley, Zorn, Hornbostel (UMD, BNL)	BATTISTON 92 PRPL 214 293 +Cocolicchio, Fogli, Paver (PGIA, CERN, TRST
SMITH	70 69	Thesis UCRL 19226	+Solmitz, Crawford, Alston-Garnjost (LRL) Webber (LRL)	Status and Perspectives of K Decay Physics DIB 92 PR D46 2265 +Peccei (UCL.
SMITH WEBBER Also	69 68	PR 188 2033 PRL 21 1103	+Cronin, Liu, Pilcher (PRIN) Banner, Cronin, Liu, Pilcher (PRIN)	Tests of CPT conservation in the neutral kaon system. KLEINKNECHT 92 CNPP 20 281 (MAN
SMITH WEBBER Also BANNER	68 68	PRL 21 1107	Cronin, Liu, Pilcher (PRIN)	New Results on CP Violation in Decays of Neutral K Mesons.
SMITH WEBBER Also BANNER Also Also		PL 30B 202	+Boutang, Limon (EPOL) +Nygren, Saal, Steinberger+ (COLU, BNL)	KLEINKNECHT 90 ZPHY C46 S57 (MAN PEACH 90 JPG 16 131 (EDI
SMITH WEBBER Also BANNER Also Also BEILLIERE	69		,, g.co, Jeen, Jiconociger (CULU, DIVL)	
SMITH WEBBER Also BANNER Also Also BEILLIERE BENNETT BOHM	69 69 69B		+Darriulat, Grosso, Kaftanov+ (CERN)	BRYMAN 89 IJMP A4 79 (TRI
SMITH WEBBER Also BANNER Also Also BEILLIERE BENNETT BOHM Also	69 69 69B 68	NP B9 605 PL 27B 321	+Darriulat, Grosso, Kaftanov+ (CERN) Bohm, Darriulat, Grosso, Kaftanov (CERN)	"Rare Kaon Decays"
SMITH WEBBER Also BANNER Also Also BEILLIERE BENNETT BOHM Also CENCE EVANS	69 69 69B	NP B9 605 PL 27B 321 PRL 22 1210 PRL 23 427	+ Darriulat, Grosso, Kaftanov + (CERN) Bohm, Darriulat, Grosso, Kaftanov + Jones, Peterson, Stenger + (HAWA, LRL) + Golden, Muir, Peach + (EDIN, CERN)	
SMITH WEBBER Also BANNER Also Also BEILLIERE BENNETT BOHM Also CEROCE EVANS FAISSNER	69 69B 68 69 69	NP B9 605 PL 27B 321 PRL 22 1210 PRL 23 427 PL 30B 204	+Darriulat, Grosso, Kaftanov+ (CERN) Bahm, Darriulat, Grosso, Kaftanov (CERN) +Jones, Peterson, Stenger+ (HAWA, LRL) +Golden, Muir, Peach+ +Foeth, Staude, Tittel+ (AACH3, CERN, TORI)	"Rare Kaon Decays"
SMITH WEBBER Also BANNER Also BEILLIERE BENNETT BOHM Also CENCE EVANS FAISSNER FOETH GAILLARD	69 69 69B 68 69 69 69	NP B9 605 PL 278 321 PRL 22 1210 PRL 23 427 PL 30B 204 PL 30B 282 NC 59A 453	+Darfulat, Grosso, Kaftanov+ (CERN) Bohm, Darfulat, Grosso, Kaftanov (CERN) +Jones, Peterson, Stenger+ (HAWA, LR!) +Golden, Muir, Peach+ (EDIN, CERN) +Foeth, Staude, Tittel+ (AACH3, CERN, TORI) +Holder, Radermacher+ (AACH, CERN, TORI) +Galbraith, Hussri, Jane+ (CERN, RHEL, AACH)	"Rare Kaon Decays"
SMITH WEBBÉR Also BANNER Also Also BEILLIERE BENNETT BOHM	69 69 69B 68 69 69	NP B9 605 PL 27B 321 PRL 22 1210 PRL 23 427 PL 30B 204 PL 30B 282 NC 59A 453 PRL 18 20	+Darriulat, Grosso, Kaftanov+ (CERN) Bohm, Darriulat, Grosso, Kaftanov (CERN) +Jones, Peterson, Stenger+ (HAWA, LRI) +Golden, Muir, Peach+ (EDIN, CERN) +Foeth, Staude, Tittel+ (AACH3, CERN, TORI) +Holder, Radermacher+ (AACH, CERN, TORI)	"Rare Kaon Decays"

K_L^0 , $K^*(892)$

GINSBERG	73	PR D8 3887	+Smith	(MIT, STON)
GINSBERG	70	PR D1 229	,	(HAIF)
HEUSSE	70	LNC 3 449	+Aubert, Pascaud, Vialle	(ORSAY)
CRONIN	68C	Vienna Conf. 281		(PRIN)
RUBBIA	67	PL 24B 531	+Steinberger	(CERN, COLU)
Also	66C	PL 23 167	Rubbia, Steinberger	(CERN. COLU)
Also	66C	PL 20 207	Alff-Steinberger, Heuer, Kleinknecht+	(CERN)
Also	66B	PL 21 595	Alff-Steinberger, Heuer, Kleinknecht+	(CERN)
AUERBACH	66	PR 149 1052	+Dobbs, Lande, Mann, Sciulli+	(PENN)
Also	65	PRL 14 192	Auerbach, Lande, Mann, Sciulli, Uto+	(PENN)
FIRESTONE	66B	PRL 17 116	+Kim, Lach, Sandweiss+	(YALÈ, BNL)
BEHR	65	Argonne Conf. 59	+Brisson, Bellotti+ (EPC	L, MILA, PADO)
MESTVIRISH.	65	JINR P 2449	Mestvirishvili, Nyagu, Petrov, Rusakov+	(JINR)
TRILLING	65B	UCRL 16473	, , , , , , , , , , , , , , , , , , , ,	`(LRL)
Updated 1	from 1	965 Argonne Conference,	page 115.	
JOVANOV	63	BNL Conf. 42	Jovanovich, Fischer, Burris+	(BNL, UMD)

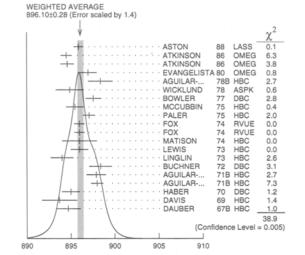
K*(892)

$$I(J^P) = \frac{1}{2}(1^-)$$

K*(8	192) I	M٨	SZ
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		(,		_		
CHARGED ONL						
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT
891.66±0.26 OUR			040	unc		0.00 1/= -
892.6 ±0.5	5840	BAUBILLIER	848	нвс	-	8.25 $K^- \rho \rightarrow \overline{K}^0 \pi^- \rho$
888 ±3		NAPIER	84	SPEC	+	$200 \pi^- p \rightarrow 2K_c^0 X$
891 ±1		NAPIER	84	SPEC	-	$200 \pi^- p \rightarrow 2K_S^0 X$
891.7 ±2.1	3700	BARTH	83	нвс	+ .	70 K ⁺ $\rho \rightarrow K^0 \pi^+ X$
891 ±1	4100	TOAFF	81	HBC	_	$6.5 K^- p \rightarrow \overline{K}{}^0 \pi^- p$
892.8 ±1.6		AJINENKO	80	HBC	+.	32 $K^+ p \rightarrow K^0 \pi^+ X$
890.7 ±0.9	1800	AGUILAR	78B	нвс	±	0.76 pp → κ∓ κ ⁰ _S π±
886.6 ±2.4	1225	BALAND	78	нвс	±	12 $\bar{p}p \rightarrow (K\pi)^{\pm} X$
891.7 ±0.6	6706	COOPER	78	нвс	±	$0.76 \overline{p}p \rightarrow (K\pi)^{\pm} X$
891.9 ±0.7	9000	¹ PALER	75	HBC	_	14.3 $K^- p \to (K\pi)^-$
892.2 ±1.5	4404	AGUILAR	71B	нвс	_	X 3.9,4.6 K ⁻ p →
891 ±2	1000	CRENNELL	69 D	DBC	_	$(K\pi)^{-}p$ 3.9 $K^{-}N \rightarrow K^{0}\pi^{-}X$
890 ±3.0	720	BARLOW	67	нвс	±	K ⁰ π [−] X 1.2 p̄ρ →
						$(\kappa^0\pi)^{\pm}\kappa^{\mp}$
889 ±3.0	600	BARLOW	67	нвс	±	$\begin{array}{c} 1.2 \ \overline{p}p \rightarrow \\ (K^0 \pi)^{\pm} K \pi \end{array}$
891 ±2.3	620	² DEBAERE	67B	HBC	+	$3.5 K^+ p \rightarrow K^0 \pi^+ p$
891.0 ±1.2	1700	3 MOTCICKI	64	нвс	-	1.7 K ⁻ p $\rightarrow \overline{K}^0\pi^-$ p
• • • We do not i	use the folk	owing data for ave	rages	i, fits, lir	nits, e	tc. • • •
890.4 ±0.2 ±0.5	79709± 801	⁴ BIRD	89	LASS	-	11 $K^- p \rightarrow \overline{K}{}^0 \pi^- p$
890.0 ±2.3	800	^{2,3} CLELAND	82	SPEC	+	$30 K^+ p \rightarrow K_S^0 \pi^+ p$
896.0 ±1.1	3200	^{2,3} CLELAND	82	SPEC	+	$50 K^+ p \rightarrow K_5^0 \pi^+ p$
893 ±1	3600	^{2,3} CLELAND	82	SPEC	_	$50 K^+ p \rightarrow K_S^0 \pi^- p$
896.0 ±1.9	380	DELFOSSE	81	SPEC	+	50 $K^{\pm}p \rightarrow K^{\pm}\pi^{0}p$
886.0 ±2.3	187	DELFOSSE	81	SPEC	_	$50 K^{\pm} \rho \rightarrow K^{\pm} \pi^{0} \rho$
894.2 ±2.0	765	² CLARK	73	нвс	-	$\begin{array}{c} 3.13 \ K^- p \rightarrow \\ \overline{K}{}^0 \pi^- p \end{array}$
894.3 ±1.5	1150	^{2,3} CLARK	73	нвс	_	$3.3~K^-p \rightarrow \overline{K}{}^0\pi^-p$
892.0 ±2.6	341	² SCHWEING	68	HBC	_	$5.5 \ K^-p \rightarrow \ \overline{K}{}^0\pi^-p$
NEUTRAL ONI	v					
VALUE (MeV)	EVTS	DOCUMENT ID		TECN_	CHG	COMMENT
896.10±0.28 OUR			cale			See the ideogram below.
895.9 ±0.5 ±0.2		ASTON	88	LASS	0	11 $K^-p \rightarrow K^-\pi^+\pi$
894,52±0.63	25k	1 ATKINSON	86	OMEG		20-70 γp
894.63±0.76	20k	1 ATKINSON	86	OMEG		20-70 γ p
897 ±1	28k	EVANGELISTA	80	OMEG	0	$10 \pi^- \rho \to K^+ \pi^- (\Lambda, \Sigma)$
898.4 ±1.4	1180	AGUILAR	78B	нвс	0	0.76 p̄p → K∓ K ⁰ ₀ π [±]
894.9 ±1.6		WICKLUND	78	ASPK	0	3,4,6 $K^{\pm}N \rightarrow (K\pi)^{0}N$
897.6 ±0.9		BOWLER	77	DBC	0	5.4 K ⁺ d → K ⁺ π ⁻ pp
895.5 ±1.0	3600	MCCUBBIN	75	HBC	0	3.6 K ⁻ p \rightarrow K ⁻ π^+ n
897.1 ±0.7	22k	1 PALER	75	HBC	0	14.3 $K^- p \to (K \pi)^0$
896.0 ±0.6	10k	FOX	74	RVUE	0	$2 \stackrel{\frown}{K^-} p \rightarrow K^- \pi^+ n$
896.0 ±0.6		FOX	74	RVUE	0	$2 K^+ n \rightarrow K^+ \pi^- p$
896 ±2		⁵ MATISON	74	нвс	0	12 K ⁺ p \rightarrow K ⁺ $\pi^-\Delta$
896 ±1	3186	LEWIS	73	нвс	0	$\begin{array}{c} 2.1 - 2.7 \ K^+ p \rightarrow \\ K \pi \pi p \end{array}$
894.0 ±1.3		⁵ LINGLIN	73	нвс	0	$ \begin{array}{c} 2-13 \ K^{+} p \rightarrow \\ K^{+} \pi^{-} \pi^{+} p \end{array} $

	898.4		1.00	² BUCHNER ² AGUILAR	72 DBC	0	$4.6 K^{+} n \rightarrow K^{+} \pi^{-} p$
	897.9	± 1.1	2934	- AGUILAK	LIB HRC	0	3.9.4.6 $K^- p \rightarrow$
	898.0	±0.7	5362	² AGUILAR	718 HBC	0	$K^-\pi^+n$ 3.9,4.6 $K^-p \rightarrow$
				3		_	$K^-\pi^+\pi^-\rho$
	895	±1	4300	³ HABER	70 DBC	0	$3 K^- N \rightarrow K^- \pi^+ X$
ج,	893.7	± 2.0	10k	DAVIS	69 HBC	0	12 $K^+ p \rightarrow$
1							$K^+\pi^-\pi^+p$
	894.7	±1.4	1040	² DAUBER	678 HBC	0	2.0 K ⁻ p →
							$K^{-}\pi^{+}\pi^{-}p$
	• • •	We do n	ot use the follo	owing data for av	erages, fits, li	mits,	etc. • • •
	900.7	±1.1	5900	BARTH	83 HBC	0	70 K ⁺ p \rightarrow K ⁺ π ⁻ X



 $K^*(892)^0$ mass (MeV)

K*(892) MASSES AND MASS DIFFERENCES

Unrealistically small errors have been reported by some experiments. We use simple "realistic" tests for the minimum errors on the determination of a mass and width from a sample of N events:

$$\delta_{\min}(m) = rac{\Gamma}{\sqrt{N}}, \quad \delta_{\min}(\Gamma) = 4rac{\Gamma}{\sqrt{N}} \; .$$

We consistently increase unrealistic errors before averaging. For a detailed discussion, see the 1971 edition of this Note.

$m_{K^{\bullet}(892)^{0}} - m_{K^{\bullet}(892)^{\pm}}$					
VALUE (MeV)	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
6.7±1.2 OUR A	VERAGE				
7.7±1.7	2980	AGUILAR	78B HBC	±0	$0.76 \ \overline{p}p \rightarrow \\ K^{\mp} K_{S}^{0} \pi^{\pm}$
5.7±1.7	7338	AGUILAR	718 HBC	-0	3.9,4.6 K p
6.3±4.1	283	⁶ BARASH	67в НВС		0.0 p p
6 Number of e	vents in pea	k reevaluated by u	5.		

K*(892) RANGE PARAMETER

All from partial wave amplitude analyses.

VALUE (GeV-1)	DOCUMENT ID		TECN	CHG	COMMENT
3.4±0.7	ASTON	88	LASS	0	11 $K^-p \rightarrow K^-\pi^+n$
• • • We do not use th	e following data i	for a	verages,	fits, li	mlts, etc. • • •
$12.1 \pm 3.2 \pm 3.0$	BIRD	89	LASS	-	11 $K^- p \rightarrow \overline{K}^0 \pi^- p$

¹ Inclusive reaction. Complicated background and phase-space effects.

² Mass errors enlarged by us to Γ/\sqrt{N} . See note.

³ Number of events in peak reevaluated by us.

⁴ From a partial wave amplitude analysis.

⁵ From pole extrapolation.

Г4

 Γ_4/Γ

K-	(892)	WID	11

CHARGED ON	LY	CHARGED ONLY				
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
50.8±0.9 OUR FI						
50.8±0.9 OUR A	VERAGE					
49 ±2	5840	BAUBILLIER	84B	нвс	_	$\begin{array}{c} 8.25 \ K^- p \rightarrow \\ \overline{K}^0 \pi^- p \end{array}$
56 ±4		NAPIER	84	SPEC	_	$200 \pi^{-} p \rightarrow 2K_{S}^{0} X$
51 ±2	4100	TOAFF	81	нвс	<u> </u>	$6.5 \ K^- p \rightarrow \overline{K}^0 \pi^- p$
50.5 ± 5.6		AJINENKO	80	нвс	+	32 $K^+p \rightarrow K^0\pi^+X$
45.8±3.6	1800	AGUILAR		HBC	±	0.76 p p →
					_	κ [∓] κ ⁰ ₅ *±
52.0±2.5	6706	7 COOPER	78	нвс	±	$0.76 \overline{p}p \xrightarrow{S} (K\pi)^{\pm} X$
52.1 ± 2.2	9000	8 PALER	75	нвс	_	14.3 $K^- p \to (K\pi)^-$
46.3±6.7	765	7 CLARK	73	нвс	_	X 3.13 K ⁻ p →
		7.0				$\overline{K}^0\pi^-\rho$
48.2 ± 5.7	1150	7,9 CLARK	73	HBC	-	$3.3~K^-p \rightarrow \overline{K}^0\pi^-p$
54.3 ± 3.3	4404	7 AGUILAR	71B	нвс	-	3.9,4.6 K ⁻ p →
46 ±5	1700	7,9 WOJCICKI	64	нвс		$(K\pi)^- p$ 1.7 $K^- p \rightarrow \overline{K}^0 \pi^- p$
		ollowing data for ave			nits e	trass
			_			_
45.2±1 ±2	79709± 801	- BIKD	89	LASS	-	11 $K^-p \rightarrow \overline{K}{}^0\pi^-p$
42.8±7.1	3700	BARTH	83	HBC	+	70 K ⁺ p \rightarrow K ⁰ π ⁺ X
64.0±9.2	800	7,9 CLELAND	82	SPEC	+	30 $K^+ p \to K_5^0 \pi^+ p$
62.0±4.4	3200	^{7,9} CLELAND	82	SPEC	+	50 K+p \rightarrow K $_{S}^{0}\pi^{+}p$
55 ±4	3600	7,9 CLELAND	82	SPEC	<u>,</u>	50 K+p \rightarrow K 0 π^- p
62.6 ± 3.8	380	DELFOSSE	81	SPEC	+	$50 K^{\pm} p \rightarrow K^{\frac{3}{2}} \pi^{0} p$
50.5 ± 3.9	187	DELFOSSE	81	SPEC	_	$50 K^{\pm} p \rightarrow K^{\pm} \pi^{0} p$
NEUTRAL ONLY						
		DOCUMENT ID		TECH	cuc	COMMENT
VALUE (MeV)	EVTS	DOCUMENT ID			<u>CHG</u>	COMMENT
VALUE (MeV) 50.5±0.6 OUR FI	EVTS Error	includes scale facto	r of 1	.1.		COMMENT
VALUE (MeV) 50.5±0.6 OUR FI 50.5±0.6 OUR A	EVTS Error	includes scale facto Error includes scal	r of 1 e fact	.1. or of 1.:	ι,	
VALUE (MeV) 50.5±0.6 OUR FI 50.5±0.6 OUR AV 50.8±0.8±0.9	EVTS IT Error VERAGE	includes scale facto Error includes scal ASTON	r of 1 e fact 88	.1. or of 1.: LASS	ι, 0	11 K ⁻ p → K ⁻ π ⁺ π
VALUE (MeV) 50.5±0.6 OUR FI 50.5±0.6 OUR AV 50.8±0.8±0.9 46.5±4.3	EVTS T Error VERAGE 5900	includes scale facto Error includes scal ASTON BARTH	r of 1 e fact 88 83	.1. or of 1. LASS HBC	ι, ο ο	11 K ⁻ p → K ⁻ π ⁺ π 70 K ⁺ p → K ⁺ π ⁻ X
VALUE (MeV) 50.5±0.6 OUR FI 50.5±0.6 OUR AV 50.8±0.8±0.9 46.5±4.3 54 ±2	EVTS IT Error VERAGE 5900 28k	includes scale facto Error includes scal ASTON BARTH EVANGELISTA	r of 1 e fact 88 83 480	.1. LASS HBC OMEG	l, 0 0	11 $K^-p \rightarrow K^-\pi^+\pi$ 70 $K^+p \rightarrow K^+\pi^-X$ 10 $\pi^-p \rightarrow K^+\pi^-(\Lambda, \Sigma)$
VALUE (MeV) 50.5±0.6 OUR FI 50.5±0.6 OUR AV 50.8±0.8±0.9 46.5±4.3	EVTS T Error VERAGE 5900	includes scale facto Error includes scal ASTON BARTH	r of 1 e fact 88 83 480	.1. or of 1. LASS HBC	ι, ο ο	11 $K^-p \rightarrow K^-\pi^+\pi$ 70 $K^+p \rightarrow K^+\pi^-X$ 10 $\pi^-p \rightarrow K^+\pi^-(\Lambda, \Sigma)$ 0.76 $\overline{p}p \rightarrow$
VALUE (MeV) 50.5±0.6 OUR FI 50.5±0.6 OUR AV 50.8±0.8±0.9 46.5±4.3 54 ±2	EVTS IT Error VERAGE 5900 28k	includes scale facto Error includes scal ASTON BARTH EVANGELISTA	r of 1 e fact 88 83 480	.1. LASS HBC OMEG	l, 0 0	11 $K^-p \rightarrow K^-\pi^+\pi$ 70 $K^+p \rightarrow K^+\pi^-X$ 10 $\pi^-p \rightarrow K^+\pi^-(\Lambda, \Sigma)$ 0.76 $pp \rightarrow K^+K^0_S\pi^\pm$ 3.46 $K^\pm N \rightarrow$
VALUE (MeV) 50.5±0.6 OUR FI 50.5±0.6 OUR SI 50.8±0.8 0.8 ±0.8 50.8±0.8±0.9 46.5±4.3 54 ±2 45.9±4.8 51.2±1.7	EVTS IT Error VERAGE 5900 28k	Includes scale facto Error includes scal ASTON BARTH EVANGELIST/ AGUILAR WICKLUND	78B	.1. LASS HBC OMEG HBC	l. 0 0 0	11 $K^-p \rightarrow K^-\pi^+\pi$ 70 $K^+p \rightarrow K^+\pi^-X$ 10 $\pi^-p \rightarrow K^+\pi^-(\Lambda, \Sigma)$ 0.76 $\bar{p}p \rightarrow K^+K^0_S\pi^\pm$ 3.4,6 $K^\pm N \rightarrow (K\pi)^0 N$
VALUE (MeV) 50.5±0.6 OUR FI 50.5±0.6 OUR AV 50.8±0.8±0.9 46.5±4.3 54 ±2 45.9±4.8 51.2±1.7 48.9±2.5	EVTS IT Error VERAGE 5900 28k	Includes scale facto Error includes scal ASTON BARTH EVANGELISTA AGUILAR	r of 1 e fact 88 83 480 788	.1. cor of 1.: LASS HBC OMEG	0 0 0	11 $K^-p \to K^-\pi^+n$ 70 $K^+p \to K^+\pi^-X$ 10 $\pi^-p \to K^+\pi^-(\Lambda, \Sigma)$ 0.76 $\overline{p}p \to K^{\mp}K_S^0\pi^{\pm}$ 3.4,6 $K^{\pm}N \to (K_{\pi})^0N$ 5.4 $K^+d \to K^+\pi^-pp$
VALUE (MeV) 50.5±0.6 OUR FI 50.5±0.6 OUR FI 50.8±0.8 0.8 ±0.8 50.8±0.8 ±0.9 46.5±4.3 54 ±2 45.9±4.8 51.2±1.7	EVTS IT Error VERAGE 5900 28k	Includes scale facto Error includes scal ASTON BARTH EVANGELIST/ AGUILAR WICKLUND BOWLER MCCUBBIN	78B	.1. LASS HBC OMEG HBC	l. 0 0 0	11 $K^-p \rightarrow K^-\pi^+\pi$ 70 $K^+p \rightarrow K^+\pi^-X$ 10 $\pi^-p \rightarrow$ $K^+\pi^-(\Lambda, \Sigma)$ 0.76 $\overline{p}p \rightarrow$ $K^{\mp}K_S^0\pi^{\pm}$ 3.4,6 $K^{\pm}N \rightarrow$ $(K\pi)^0N$
VALUE (MeV) 50.5±0.6 OUR FI 50.5±0.6 OUR AV 50.8±0.8±0.9 46.5±4.3 54 ±2 45.9±4.8 51.2±1.7 48.9±2.5	EVTS IT Error VERAGE 5900 28k 1180	Includes scale facto Error Includes scal ASTON BARTH EVANGELIST/ AGUILAR WICKLUND BOWLER	7 of 1 e fact 88 83 80 78B 78	.1. LASS HBC OMEG HBC ASPK DBC	0 0 0 0	11 $K^-p \to K^-\pi^+n$ 70 $K^+p \to K^+\pi^-X$ 10 $\pi^-p \to K^+\pi^-(\Lambda, \Sigma)$ 0.76 $\overline{p}p \to K^{\mp}K_S^0\pi^{\pm}$ 3.4,6 $K^{\pm}N \to (K_{\pi})^0N$ 5.4 $K^+d \to K^+\pi^-pp$
VALUE (MeV) 50.5±0.6 OUR FI 50.5±0.6 OUR AV 50.8±0.9 46.5±4.3 54 ±2 45.9±4.8 51.2±1.7 48.9±2.5 48 +3 2	5900 28k 1180	Includes scale facto Error includes scal ASTON BARTH EVANGELIST/ AGUILAR WICKLUND BOWLER MCCUBBIN	7 of 1 e fact 88 83 80 788 78 77	.1. cor of 1.: LASS HBC OMEG HBC ASPK DBC HBC	0 0 0 0	11 $K^-p \to K^-\pi^+\pi$ 70 $K^+p \to K^+\pi^-X$ 10 $\pi^-p \to K^+\pi^-(\Lambda, \Sigma)$ 0.76 $\bar{p}p \to K^+K^0\pi^\pm$ 3.4,6 $K^\pm N \to (K\pi)^0 N$ 5.4 $K^+d \to K^+\pi^-pp$ 3.6 $K^-p \to K^-\pi^+\pi$ 14.3 $K^-p \to (K\pi)^0$
VALUE (MeV) 50.5±0.6 OUR FI 50.5±0.6 OUR AV 50.8±0.9 46.5±4.3 54 ±2 45.9±4.8 51.2±1.7 48.9±2.5 48 +3 -2 50.6±2.5	5900 28k 1180	Includes scale facto Error includes scale ASTON BARTH EVANGELIST/ AGUILAR WICKLUND BOWLER MCCUBBIN 8 PALER	7 of 1 88 83 83 80 78B 77 75	.1. cor of 1.: LASS HBC OMEG HBC ASPK DBC HBC HBC	0 0 0 0 0	11 $K^-p \rightarrow K^-\pi^+ n$ 70 $K^+p \rightarrow K^+\pi^- X$ 10 $\pi^-p \rightarrow K^+\pi^- (\Lambda, \Sigma)$ 0.76 $\bar{p}p \rightarrow K^+K^0\pi^\pm$ 3.4,6 $K^\pm N \rightarrow (K\pi)^0 N$ 5.4 $K^+d \rightarrow K^+\pi^-pp$ 3.6 $K^-p \rightarrow K^-\pi^+ n$ 14.3 $K^-p \rightarrow (K\pi)^0$ 2 $K^-p \rightarrow K^-\pi^+ n$ 2 $K^-p \rightarrow K^-\pi^+ n$ 2 $K^-p \rightarrow K^-\pi^+ n$
VALUE (MeV) 50.5±0.6 OUR FI 50.5±0.6 OUR N 50.8±0.8±0.9 46.5±4.3 54 ±2 45.9±4.8 51.2±1.7 48.9±2.5 48 +3 -2 50.6±2.5 47 ±2	5900 28k 1180	Includes scale facto Error includes scale ASTON BARTH EVANGELIST/ AGUILAR WICKLUND BOWLER MCCUBBIN 8 PALER FOX	7 of 1 88 83 88 78 77 75 75 74	.1. LASS HBC OMEG HBC ASPK DBC HBC HBC RVUE	0 0 0 0	11 $K^-p \to K^-\pi^+ n$ 70 $K^+p \to K^+\pi^- X$ 10 $\pi^-p \to K^+\pi^- (A, \Sigma)$ 0.76 $pp \to K^+K^0 \pi^\pm$ 3.46 $K^\pm N \to (K\pi)^0 N$ 5.4 $K^+d \to K^+\pi^- pp$ 3.6 $K^-p \to K^-\pi^+ n$ 14.3 $K^-p \to (K\pi)^0$ $X \to K^+\pi^- pp$ 2 $K^-p \to K^-\pi^+ n$ 2 $K^-p \to K^-\pi^+ n$
VALUE (MeV) 50.5±0.6 OUR FI 50.5±0.6 OUR AV 50.8±0.8±0.9 46.5±4.3 54 ±2 45.9±4.8 51.2±1.7 48.9±2.5 48 +3/2 50.6±2.5 47 ±2 51 ±2 46.0±3.3 51.4±5.0	EVTS T Error VERAGE 5900 28k 1180 3600 22k 10k	Includes scale facto Error includes scale ASTON BARTH EVANGELISTA AGUILAR WICKLUND BOWLER MCCUBBIN 8 PALER FOX FOX	7 of 1 88 88 83 80 78 87 77 75 74 74	LASS HBC OMEG HBC ASPK DBC HBC HBC RVUE RVUE	0 0 0 0 0 0 0 0 0	11 $K^-p \rightarrow K^-\pi^+ n$ 70 $K^+p \rightarrow K^+\pi^- X$ 10 $\pi^-p \rightarrow K^+\pi^- (\Lambda, \Sigma)$ 0.76 $\bar{p}p \rightarrow K^+K^0\pi^\pm$ 3.4,6 $K^\pm N \rightarrow (K\pi)^0 N$ 5.4 $K^+d \rightarrow K^+\pi^-pp$ 3.6 $K^-p \rightarrow K^-\pi^+ n$ 14.3 $K^-p \rightarrow (K\pi)^0$ 2 $K^-p \rightarrow K^-\pi^+ n$ 2 $K^-p \rightarrow K^-\pi^+ n$ 2 $K^-p \rightarrow K^-\pi^+ n$
### MANUE (MeV) 50.5±0.6 OUR FI 50.5±0.6 OUR AN 50.8±0.9 46.5±4.3 54.±2 45.9±4.8 51.2±1.7 48.9±2.5 48. +3	EVTS TE Fror VERAGE 5900 28k 1180 3600 22k 10k 3186	Includes scale facto Error includes scale ASTON BARTH EVANGELIST/ AGUILAR WICKLUND BOWLER MCCUBBIN 8 PALER FOX FOX 7 LEWIS	7 of 1 e fact 88 83 83 80 78B 77 75 75 74 74 73 72	.1. LASS HBC OMEG HBC ASPK DBC HBC HBC RVUE RVUE HBC	0 0 0 0 0	11 $K^-p \rightarrow K^-\pi^+ n$ 70 $K^+p \rightarrow K^+\pi^- X$ 10 $\pi^-p \rightarrow K^+\pi^- (\Lambda, \Sigma)$ 0.76 $\bar{p}p \rightarrow K^+K^0S^{\pi^{\pm}}$ 3.4.6 $K^{\pm}N \rightarrow (K\pi)^0N$ 5.4 $K^+d \rightarrow K^+\pi^-pp$ 3.6 $K^-p \rightarrow K^-\pi^+ n$ 14.3 $K^-p \rightarrow (K\pi)^0$ 2 $K^-p \rightarrow K^-\pi^+ n$ 2 $K^+n \rightarrow K^+\pi^-p$ 2.1-2.7 $K^+p \rightarrow K^-\pi^+p$ 4.6 $K^+n \rightarrow K^+\pi^-p$ 3.9,4.6 $K^-p \rightarrow K^-\pi^+p$
VALUE (MeV) 50.5±0.6 OUR FI 50.5±0.6 OUR AV 50.8±0.8±0.9 46.5±4.3 54 ±2 45.9±4.8 51.2±1.7 48.9±2.5 48 +3/2 50.6±2.5 47 ±2 51 ±2 46.0±3.3 51.4±5.0	EVTS TE Fror VERAGE 5900 28k 1180 3600 22k 10k 3186 1700	Includes scale facto Error includes scale ASTON BARTH EVANGELIST/ AGUILAR WICKLUND BOWLER MCCUBBIN 8 PALER FOX FOX 7 LEWIS 7 BUCHNER	7 of 1 e fact 88 83 83 80 78 8 77 75 74 74 73 72 71 8	.1. or of 1.: LASS HBC OMEG HBC ASPK DBC HBC HBC RVUE RVUE HBC DBC	0 0 0 0 0 0	11 $K^-p \rightarrow K^-\pi^+n$ 70 $K^+p \rightarrow K^+\pi^-X$ 10 $\pi^-p \rightarrow K^+\pi^-X$ 10 $\pi^-p \rightarrow K^+\pi^-(\Lambda, \Sigma)$ 0.76 $\overline{p}p \rightarrow K^-\pi^+N$ 3.4,6 $K^\pm N \rightarrow (K\pi)^0 N$ 5.4 $K^+d \rightarrow K^+\pi^-p$ 3.6 $K^-p \rightarrow K^-\pi^+n$ 14.3 $K^-p \rightarrow (K\pi)^0$ 2 $K^-p \rightarrow K^-\pi^+n$ 2 $K^+n \rightarrow K^+\pi^-p$ 2.1-2.7 $K^+p \rightarrow K^-\pi^+n$ 4.6 $K^+n \rightarrow K^+\pi^-p$ 3.9,4.6 $K^-p \rightarrow K^-\pi^+n$ 3.9,4.6 $K^-p \rightarrow K^-\pi^+n$ 3.9,4.6 $K^-p \rightarrow K^-\pi^+n$
VALUE (MeV) 50.5±0.6 OUR FI 50.5±0.6 OUR AV 50.8±0.8±0.9 46.5±4.3 54 ±2 45.9±4.8 51.2±1.7 48.9±2.5 48 +3/2 50.6±2.5 47 ±2 51 ±2 46.0±3.3 51.4±5.0 55.8+4.2 55.8+4.2 48.5±2.7	EVTS Error VERAGE 5900 28k 1180 3600 22k 10k 3186 1700 2934 5362	Includes scale facto Error Includes scale ASTON BARTH EVANGELISTA AGUILAR WICKLUND BOWLER MCCUBBIN 8 PALER FOX FOX 7 LEWIS 7 BUCHNER 7 AGUILAR AGUILAR AGUILAR	7 of 1 e fact 88 83 80 78 8 77 75 75 74 73 72 71 8 71 B	LASS HBC ASPK DBC HBC RVUE RVUE HBC DBC HBC HBC HBC HBC HBC HBC HBC	0 0 0 0 0 0 0 0	11 $K^-p \rightarrow K^-\pi^+n$ 70 $K^+p \rightarrow K^+\pi^-X$ 10 $\pi^-p \rightarrow K^+\pi^-(\Lambda, \Sigma)$ 0.76 $\overline{p}p \rightarrow K^+K^0S^-\pi^\pm$ 3.4,6 $K^\pm N \rightarrow (K\pi)^0N$ 5.4 $K^+d \rightarrow K^+\pi^-pp$ 3.6 $K^-p \rightarrow K^-\pi^+n$ 14.3 $K^-p \rightarrow (K\pi)^0$ $X^-p \rightarrow K^-\pi^+n$ 2 $X^-p \rightarrow X^-\pi^+n$ 2 $X^-p \rightarrow X^-\pi^+n$ 2 $X^-p \rightarrow X^-\pi^+n$ 3.9,4.6 $X^-p \rightarrow X^-\pi^+n$ 3.9,4.6 $X^-p \rightarrow X^-\pi^+n$ 3.9,4.6 $X^-p \rightarrow X^-\pi^+n$
VALUE (MeV) 50.5±0.6 OUR FI 50.5±0.6 OUR FI 50.5±0.6 OUR AN 50.8±0.9 46.5±4.3 54 ±2 45.9±4.8 51.2±1.7 48.9±2.5 48 +3/2 50.6±2.5 47 ±2 46.0±3.3 51.4±5.0 55.8+4.2 48.5±2.7 54.0±3.3	EVTS TE Fror VERAGE 5900 28k 1180 3600 22k 10k 3186 1700 2934 5362 4300	Includes scale facto Error includes scale ASTON BARTH EVANGELIST/ AGUILAR WICKLUND BOWLER MCCUBBIN 8 PALER FOX FOX 7 LEWIS 7 BUCHNER 7 AGUILAR AGUILAR 17.9 HABER	7 of 1 e fact 88 83 80 78 8 77 75 75 74 73 72 71 8 70	T. LASS LASS HBC OMEG HBC ASPK DBC HBC RVUE RVUE HBC DBC HBC HBC DBC HBC	0 0 0 0 0 0 0 0	11 $K^-p \rightarrow K^-\pi^+ n$ 70 $K^+p \rightarrow K^+\pi^- X$ 10 $\pi^-p \rightarrow K^+\pi^- (\Lambda, \Sigma)$ 0.76 $\bar{p}p \rightarrow K^+K^0\pi^\pm$ 3.4,6 $K^\pm N \rightarrow (K\pi)^0 N$ 5.4 $K^+d \rightarrow K^+\pi^-pp$ 3.6 $K^-p \rightarrow K^-\pi^+ n$ 14.3 $K^-p \rightarrow (K\pi)^0$ $X^-p \rightarrow K^-\pi^+ n$ 2 $K^-p \rightarrow K^-\pi^+ n$ 2 $K^-p \rightarrow K^-\pi^+ n$ 2 $K^-p \rightarrow K^-\pi^+ n$ 3.9.4.6 $K^-p \rightarrow K^-\pi^+ n$ 3.9.4.6 $K^-p \rightarrow K^-\pi^+ n$ 3.9.4.6 $K^-p \rightarrow K^-\pi^+ n$ 3.9.4.6 $K^-p \rightarrow K^-\pi^+ n$
VALUE (MeV) 50.5±0.6 OUR FI 50.5±0.6 OUR AV 50.8±0.9 46.5±4.3 54 ±2 45.9±4.8 51.2±1.7 48.9±2.5 48 +3 2 50.6±2.5 47 ±2 51 ±2 46.0±3.3 51.4±5.0 55.8+4.2 53.2±2.7 54.0±3.3 53.2±2.1	EVTS TE Fror VERAGE 5900 28k 1180 3600 22k 10k 3186 1700 2934 5362 4300 10k	Includes scale facto Error Includes scale ASTON BARTH EVANGELIST/ AGUILAR WICKLUND BOWLER MCCUBBIN 8 PALER FOX FOX 7 LEWIS 7 BUCHNER 7 AGUILAR AGUILAR AGUILAR 7,9 HABER 7 DAVIS	76 1 1 e fact 88 83 80 78 8 77 75 74 74 73 72 71 8 70 69	T. LASS LASS HBC OMEG HBC ASPK DBC HBC RVUE RVUE HBC DBC HBC HBC HBC HBC HBC HBC HBC	0 0 0 0 0 0 0 0 0	11 $K^-p \rightarrow K^-\pi^+n$ 70 $K^+p \rightarrow K^+\pi^-X$ 10 $\pi^-p \rightarrow K^+\pi^-(\Lambda, \Sigma)$ 0.76 $\overline{p}p \rightarrow K^+K_0^0\pi^\pm$ 3.4,6 $K^\pm N \rightarrow (K\pi)^0N$ 5.4 $K^+d \rightarrow K^+\pi^-pp$ 3.6 $K^-p \rightarrow K^-\pi^+n$ 14.3 $K^-p \rightarrow (K\pi)^0$ 2 $K^-p \rightarrow K^-\pi^+n$ 2 $K^+n \rightarrow K^+\pi^-p$ 2.1-2.7 $K^+p \rightarrow K^-\pi^+p$ 4.6 $K^+n \rightarrow K^+\pi^-p$ 3.9,4.6 $K^-p \rightarrow K^-\pi^+n$ 3.9,4.6 $K^-p \rightarrow K^-\pi^+n$ 3.9,4.6 $K^-p \rightarrow K^-\pi^+n$ 3.9,4.6 $K^-p \rightarrow K^-\pi^+n$ 2 $K^+p \rightarrow K^-\pi^+n$ 3 $K^+n \rightarrow K^+\pi^-p$ 3 $K^-n \rightarrow K^-\pi^+n$
VALUE (MeV) 50.5±0.6 OUR FI 50.5±0.6 OUR FI 50.5±0.6 OUR AN 50.8±0.9 46.5±4.3 54 ±2 45.9±4.8 51.2±1.7 48.9±2.5 48 +3/2 50.6±2.5 47 ±2 46.0±3.3 51.4±5.0 55.8+4.2 48.5±2.7 54.0±3.3	EVTS TE Fror VERAGE 5900 28k 1180 3600 22k 10k 3186 1700 2934 5362 4300	Includes scale facto Error includes scale ASTON BARTH EVANGELIST/ AGUILAR WICKLUND BOWLER MCCUBBIN 8 PALER FOX FOX 7 LEWIS 7 BUCHNER 7 AGUILAR AGUILAR 17.9 HABER	76 1 1 e fact 88 83 80 78 8 77 75 74 74 73 72 71 8 70 69	T. LASS LASS HBC OMEG HBC ASPK DBC HBC RVUE RVUE HBC DBC HBC HBC DBC HBC	0 0 0 0 0 0 0 0	11 $K^-p \rightarrow K^-\pi^+n$ 70 $K^+p \rightarrow K^+\pi^-X$ 10 $\pi^-p \rightarrow K^+\pi^-X$ 10 $\pi^-p \rightarrow K^+\pi^-(\Lambda, \Sigma)$ 0.76 $\overline{p}p \rightarrow K^+K_0^0\pi^\pm$ 3.4,6 $K^\pm N \rightarrow (K\pi)^0N$ 5.4 $K^+d \rightarrow K^+\pi^-p$ 3.6 $K^-p \rightarrow K^-\pi^+n$ 14.3 $K^-p \rightarrow (K\pi)^0$ X^- 2 $K^-p \rightarrow K^-\pi^+n$ 2 $K^+p \rightarrow K^-\pi^+n$ 2 $K^+p \rightarrow K^+\pi^-p$ 4.6 $K^+p \rightarrow K^-\pi^+n$ 3.9,4.6 $K^-p \rightarrow K^-\pi^+n$

⁷Width errors enlarged by us to $4 \times \Gamma/\sqrt{N}$; see note.

K*(892) DECAY MODES

	Mode	Fraction (Γ_I/Γ) Confidence level
Γ,	Κπ	~ 100 %
Γ_2^-	$(K\pi)^{\pm}$	(99.901±0.009) %
Γ ₃ Γ ₄	(Κπ) ⁰ Κ ⁰ γ	(99.770±0.020) %
Γ_4	$K^0\gamma$	$(2.30 \pm 0.20) \times 10^{-3}$
Γ ₅	$K^{\pm}\gamma$	$(9.9 \pm 0.9) \times 10^{-4}$
Γ ₆	$K\pi\pi$	< 7 × 10 ⁻⁴ 95%

CONSTRAINED FIT INFORMATION

An overall fit to the total width and a partial width uses 13 measurements and one constraint to determine 3 parameters. The overall fit has a $\chi^2=7.8$ for 11 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\left\langle \delta p_i \delta p_j \right\rangle / \left\langle \delta p_i \cdot \delta p_j \right\rangle$, in percent, from the fit to parameters p_i , including the branching fractions, $x_i \equiv \Gamma_i / \Gamma_{\text{total}}$. The fit constrains the x_i whose labels appear in this array to sum to one.

Mode	Rate (MeV)
$\Gamma_2 = (K\pi)^{\pm}$ $\Gamma_5 = K^{\pm}\gamma$	50.7 ± 0.9 0.050 ± 0.005

CONSTRAINED FIT INFORMATION

An overall fit to the total width and a partial width uses 18 measurements and one constraint to determine 3 parameters. The overall fit has a $\chi^2=18.4$ for 16 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\left\langle \delta p_i \delta p_j \right\rangle / \left(\delta p_i \cdot \delta p_j \right)$, in percent, from the fit to parameters p_i , including the branching fractions, $x_i \equiv \Gamma_i / \Gamma_{\text{total}}$. The fit constrains the x_i whose labels appear in this array to sum to one.

$$\begin{array}{c|cccc} x_4 & -100 & & \\ \Gamma & 14 & -14 & \\ \hline & x_3 & x_4 & & \end{array}$$

 $\Gamma(K^0\gamma)$

 $\Gamma(K^0\gamma)/\Gamma_{\text{total}}$

VALUE (units 10-3)

< 0.002

	Mode	Rate (MeV)	Scale factor
Γ ₃	$(K\pi)^0$	50.4 ±0.6	1.1
Γ4	$K^0\gamma$	· 0.117±0.010	

K*(892) PARTIAL WIDTHS

VALUE (keV)		OCUMENT ID	TECN	CHG COMME	NT	_
116 ±10 OUR 9 116.5± 9.9		CARLSMITH	86 SPEC	0 KOA-	→ K ⁰ _S π ⁰ A	
$\Gamma(K^{\pm}\gamma)$					ı	5
VALUE (keV) 50± 5 OUR FIT	DOCUME	NT ID	TECN CHG	COMMENT	·	_
50± 5 OUR AVER	RAGE			*		
48 ± 11	BERG	83 9	SPEC -	156 $K^-A \rightarrow$	KπA	
51 ± 5	CHANE	LEE 83 9	SPEC +	200 K+A →	ΚπΑ	

K*(892) BRANCHING RATIOS

TECN CHG COMMENT

WOJCICKI 64 HBC ~ 1.7 K $^-$ p \rightarrow \overline{K}^0 π^- p

DOCUMENT ID

2.30±0.20 OUR F	T ~			_ =		
• • • We do not	use the fo	lowing data for a	verages, fits	, limits,	etc. • • •	
1.5 ±0.7	CA	ARITHERS 75B	CNTR 0	8-1	6 ₹ ⁰ A	
$\Gamma(K^{\pm}\gamma)/\Gamma_{\text{total}}$						Γ ₅ /Γ
VALUE (units 10-3) 0.99±0.09 OUR		DOCUMENT ID	TECN	CHG	COMMENT	
• • • We do not	use the fo	llowing data for a	verages, fit:	, limits,	etc. • • •	
<1.6	95	BEMPORAD	73 CNT	R +	10-16 K+A	
Γ(Κππ)/Γ((Κ	π)±)					Γ_6/Γ_2
VALUE	CL%	DOCUMENT ID	TECN	<u>CHG</u>	COMMENT	
< 0.0007	95	JONGEJANS	70 HDC		4 K ⁻ p → p1	≠0 a

⁸ Inclusive reaction. Complicated background and phase-space effects.

⁹ Number of events in peak reevaluated by us.

¹⁰ From a partial wave amplitude analysis.

 $K^*(892), K_1(1270)$

K*(892) R	EFERENCES
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BIRD 89 SLAC-332	(SLAC)
ASTON 88 NP B296 493	+Awaji, Bienz, Bird+ (SLAC, NAGO, CINC, INUS)
ATKINSON 86 ZPHY C30 521	+ (BONN, CERN, GLAS, LANC, MCHS, CURIN+)
CARLSMITH 86 PRL 56 18	+Bernstein, Peyaud, Turlay (EFI, SACL)
BAUBILLIER 84B ZPHY C26 37	+ (BIRM, CERN, GLAS, MICH, CURIN)
NAPIER 84 PL 149B 514	+Chen+ (TUFTS, ARIZ, FNAL, FLOR, NDAM+)
BARTH 83 NP B223 296	+Drevermann+ (BRUX, CERN, GENO, MONS+)
BERG 83 Thesis UMI 83-21652	(ROCH)
CHANDLEE 83 PRL 51 168	+Berg, Cihangir, Collick+ (ROCH, FNAL, MINN)
CLELAND 82 NP B208 189	+Delfosse, Dorsaz, Gloor (DURH, GEVA, LAUS, PITT)
DELFOSSE 81 NP B183 349	+Guisan, Martin, Muhlemann, Weill+ (GEVA, LAUS)
TOAFF 81 PR D23 1500	+Musgrave, Ammar, Davis, Ecklund+ (ANL, KANS)
AJINENKO 80 ZPHY C5 177	+Barth, Dujardin+ (SERP, BRUX, MONS, SACL)
EVANGELISTA 80 NP B165 383	+ (BARI, BONN, CERN, DARE, GLAS, LIVP+)
AGUILAR 78B NP B141 101	Aguilar-Benitez+ (MADR, TATA, CERN+)
BALAND 78 NP B140 220	+Grard+ (MONS, BELG, CERN, LOIC, LALO)
COOPER 78 NP B136 365	+Gurtu+ (TATA, CERN, CDEF+)
JONGEJANS 78 NP B139 383	+Cerrada+ (ZEEM, CERN, NIJM, OXF)
WICKLUND 78 PR D17 1197	+Ayres, Diebold, Greene, Kramer, Pawlicki (ANL)
BOWLER 77 NP B126 31	+Dainton, Drake, Williams (OXF)
CARITHERS 75B PRL 35 349	+Muhlemann, Underwood+ (ROCH, MCGI)
MCCUBBIN 75 NP B86 13	+Lyons (OXF)
PALER 75 NP B96 1	+Tovey, Shah, Spiro+ (RHEL, SACL, EPOL)
FOX 74 NP B80 403	+Griss (CIT)
MATISON 74 PR D9 1872	+Galtieri, Alston-Garnjost, Flatte, Friedman+ (LBL)
BEMPORAD 73 NP B51 1	+Beusch, Freudenreich+ (CERN, ETH, LOIC)
CLARK 73 NP B54 432	+Lvons, Radolicic (OXF)
LEWIS 73 NP B60 283	+Allen, Jacobs+ (LOWC, LOIC, CDEF)
LINGLIN 73 NP B55 408	(CERN)
BUCHNER 72 NP B45 333	+Dehm, Charriere, Cornet+ (MPIM, CERN, BRUX)
AGUILAR 71B PR D4 2583	Aguilar-Benitez, Eisner, Kinson (BNL)
HABER 70 NP B17 289	+Shapira, Alexander+ (REHO, SACL, BGNA, EPOL)
CRENNELL 69D PRL 22 487	+Karshon, Lai, O'Neall, Scarr (BNL)
DAVIS 69 PRL 23 1071	+Derenzo, Flatte, Garniost, Lynch, Solmitz (LRL)
SCHWEING 68 PR 166 1317	Schweingruber, Derrick, Fields+ (ANL, NWES)
BARASH 67B PR 156 1399	+Kirsch, Miller, Tan (COLU)
BARLOW 67 NC 50A 701	+Lillestol, Montanet+ (CERN, CDEF, IRAD, LIVP)
DAUBER 678 PR 153 1403	+Schlein, Slater, Ticho (UCLA)
DEBAERE 67B NC 51A 401	+Goldschmidt-Clermont, Henri+ (BRUX, CERN)
WOJCICKI 64 PR 135B 484	(LRL)
	(/

- OTHER RELATED PAPERS -

KAMAL	92	PL B284 421	+Xu (ALBE)
NAPIER	84	PL 149B 514	+Chen+ (TUFTS, ARIZ, FNAL, FLOR, NDAM+)
CLELAND	82	NP B208 189	+Delfosse, Dorsaz, Gloor (DURH, GEVA, LAUS, PITT)
ALEXANDER	62	PRL 8 447	+Kalbfleisch, Miller, Smith (LRL)
ALSTON	61	PRL 6 300	+Alvarez, Eberhard, Good+ (LRL)

$K_1(1270)$

 $I(J^P) = \frac{1}{2}(1^+)$

K1(1270) MASS

VALUE (MeV)	DOCUMENT ID
1273±7 OUR AVERAGE	Includes data from the 2 datablocks that follow this one.

PRODUCED BY K-, BACKWARD SCATTERING, HYPERON EXCHANGE WALUE (MeV) EVTS DOCUMENT ID The data in this block is included in the average printed for a previous datablock.

1275±10 700 GAVILLET 78 HBC + 4.2 K⁻ p → $\Xi^-(K\pi\pi)^+$

PRODUCED BY K BEAMS

VALUE (MeV)

DOCUMENT ID

TECN

CHG

COMMENT

The data in this block is included in the average printed for a previous datablock.

1270±10	DAUM	81 C	CNTR	_	63 K p → K 2πp
• • • We do not use t	he following data t	for a	verages,	fits, li	mits, etc. • • •
~ 1276	¹ TORNQVIST	82B	RVUE		
~ 1300	VERGEEST	79	HBC	-	$4.2 K^- p \rightarrow (\overline{K}\pi\pi)^- p$
1289±25	² CARNEGIE	77	ASPK	±	13 $K^{\pm} p \rightarrow (K\pi\pi)^{\pm} p$
~ 1300	BRANDENB	76	ASPK	±	13 $K^{\pm}p \rightarrow (K\pi\pi)^{\pm}p$
~ 1270	OTTER	76	HBC	_	10.14.16 $K^- p \rightarrow$
					$(\overline{K}\pi\pi)^{-}p$
1260	DAVIS	72	HBC	+	12 K ⁺ p
1234 ± 12	FIRESTONE	72B	DBC	+	12 K ⁺ d

¹ From a unitarized quark-model calculation.

PRODUCED BY BEAMS OTHER THAN K MESONS

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
• • • We do no	t use the fol	lowing data for av-	erage	s, fits, li	imits, e	etc. • • •
1294±10	310	RODEBACK	81	HBC		$4 \pi^- p \rightarrow \Lambda K 2\pi$
1300	40	CRENNELL	72	HBC	0	$4.5 \pi^- p \rightarrow \Lambda K 2\pi$
$^{1242}_{-10}^{+9}$		³ ASTIER	69	нвс	0	Pρ
1300	45	CRENNELL	67	HBC	0	$6 \pi^- p \rightarrow \Lambda K 2\pi$
³ This was cal	led the C me	eson.				

K1(1270) WIDTH

VALUE (MEV)	DOCUMENT ID
90±20 OUR ESTIMATE	This is only an educated guess; the error given is larger than
	the error on the average of the published values.
87± 7 OUR AVERAGE	Includes data from the 2 datablocks that follow this one.

VALUE (MeV) EVTS DOCUMENT ID TECN CHG COMMENT • • • We do not use the following data for averages, flts, limits, etc. • • • 66 ± 15 310 RODEBACK 81 HBC $4\pi^-p \rightarrow \Lambda K2\pi$ 60 40 CRENNELL 72 HBC 0 $4.5\pi^-p \rightarrow \Lambda K2\pi$	/ALUE (MeV)							COMME	
PRODUCED BY K BEAMS VALUE (MeV) DOCUMENT ID TECN THE data in this block is included in the average printed for a previous datablock. 150 VERGEEST PHBC ALTER ASPK 130 KFP (K $\pi\pi$) PHBC ALTER ASPK 130 KFP (K $\pi\pi$) PHBC ALTER ASPK 130 KFP (K $\pi\pi$) PHBC DAVIS THE ASPK THE AS	i ne data in this	DIOCK IS INCIL	idea in the	avera	ge prin	tea for	a previ	ous data	DIOCK.
PRODUCED BY K BEAMS VALUE (MeV) DOCUMENT ID TECN CHG COMMENT THE data in this block is included in the average printed for a previous datablock. 90 ± 8 DAUM 81C CNTR - 63 $K^-p \rightarrow K^-2\pi p$ • • • We do not use the following data for averages, fits, limits, etc. • • • 150 VERGEEST 79 HBC - 4.2 $K^-p \rightarrow (K\pi\pi)^-p$ 150 ± 13 $K^\pm p \rightarrow (K\pi\pi)^\pm p$ 200 BRANDENB 76 ASPK ± 13 $K^\pm p \rightarrow (K\pi\pi)^\pm p$ 120 DAVIS 72 HBC + 12 K^+p 4 From a model-dependent fit with Gaussian background to BRANDENBURG 76 data PRODUCED BY BEAMS OTHER THAN K MESONS VALUE (MeV) EVTS DOCUMENT ID TECN CHG COMMENT COMMENT 66±15 310 RODEBACK 81 HBC 4 $\pi^-p \rightarrow \Lambda K 2\pi$ 60 40 CRENNELL 72 HBC 0 Pp	75±15	700	GAVILL	ET	78	нвс	+	4.2 K	$\rho \rightarrow$
The data in this block is included in the average printed for a previous datablock. 90 ± 8 DAUM 81C CNTR - 63 $K^-p \rightarrow K^-2\pi p$ • • • We do not use the following data for averages, fits, limits, etc. • • • 150 VERGEEST 79 HBC - 4.2 $K^-p \rightarrow (K\pi\pi)^-p$ 150 ± 150 ACANEGIE 77 ASPK ± 13 $K^\pm p \rightarrow (K\pi\pi)^\pm p$ 200 BRANDENB 76 ASPK ± 13 $K^\pm p \rightarrow (K\pi\pi)^\pm p$ 120 DAVIS 72 HBC + 12 K^+p 188±21 FIRESTONE 72B DBC + 12 K^+p 4 From a model-dependent fit with Gaussian background to BRANDENBURG 76 data PRODUCED BY BEAMS OTHER THAN K MESONS VALUE (MeV) EVTS DOCUMENT ID TECN CHG COMMENT • • • We do not use the following data for averages, fits, limits, etc. • • • 66±15 310 RODEBACK 81 HBC 4 $\pi^-p \rightarrow \Lambda K 2\pi$ 60 40 CRENNELL 72 HBC 0 4.5 $\pi^-p \rightarrow \Lambda K 2\pi$ 127 $^+$ ASTIER 69 HBC 0 $\overline{p}p$								<u>=</u> -,	Κππ
The data in this block is included in the average printed for a previous datablock. 90± 8 DAUM 81C CNTR $-$ 63 $K^-p \rightarrow K^-2\pi p$ • • • We do not use the following data for averages, fits, limits, etc. • • • 150 VERGEEST 79 HBC $-$ 4.2 $K^-p \rightarrow (K\pi\pi)^-p$ 150±71 4 CARNEGIE 77 ASPK ± 13 $K^\pm p \rightarrow (K\pi\pi)^\pm p$ 200 BRANDENB 76 ASPK ± 13 $K^\pm p \rightarrow (K\pi\pi)^\pm p$ 120 DAVIS 72 HBC + 12 K^+p 188±21 FIRESTONE 72B DBC + 12 K^+p 4 From a model-dependent fit with Gaussian background to BRANDENBURG 76 data PRODUCED BY BEAMS OTHER THAN K MESONS WALUE (MeV) EVTS DOCUMENT ID TECN CHG • • We do not use the following data for averages, fits, limits, etc. • • • 66±15 310 RODEBACK 81 HBC 4 $\pi^-p \rightarrow \Lambda K2\pi$ 60 40 CRENNELL 72 HBC 0 4.5 $\pi^-p \rightarrow \Lambda K2\pi$ 127 $^+$ 7 ASTIER 69 HBC 0 $\overline{p}p$	PRODUCED	BY K BEA	MS						
90± 8 DAUM 81C CNTR $-$ 63 $K^-p \rightarrow K^-2\pi p$ • • • We do not use the following data for averages, fits, limits, etc. • • • ~ 150 VERGEEST 79 HBC $-$ 4.2 $K^-p \rightarrow (K\pi\pi)^-p$ 150±71 4 CARNEGIE 77 ASPK ± 13 $K^\pm p \rightarrow (K\pi\pi)^\pm p$ ~ 200 BRANDENB 76 ASPK ± 13 $K^\pm p \rightarrow (K\pi\pi)^\pm p$ 120 DAVIS 72 HBC + 12 K^+p 188±21 FIRESTONE 728 DBC + 12 K^+p 4 From a model-dependent fit with Gaussian background to BRANDENBURG 76 data PRODUCED BY BEAMS OTHER THAN K MESONS VALUE (MeV) EVTS DOCUMENT ID TECN CHG COMMENT • • • We do not use the following data for averages, fits, limits, etc. • • • 66±15 310 RODEBACK 81 HBC 4 $\pi^-p \rightarrow \Lambda K2\pi$ 60 40 CRENNELL 72 HBC 0 4.5 $\pi^-p \rightarrow \Lambda K2\pi$ 127 $^+$ 77 ASTIER 69 HBC 0 p	VALUE (MeV)	DO	UMENT ID		TECN	CHG	COMM	IENT	
• • • We do not use the following data for averages, fits, limits, etc. • • • • 150 VERGEEST 79 HBC $-$ 4.2 $K^-p \rightarrow (\overline{K}\pi\pi)^-p$ 150 $+$ 4 CARNEGIE 77 ASPK \pm 13 $K^{\pm}p \rightarrow (K\pi\pi)^{\pm}p$ \times 200 BRANDENB 76 ASPK \pm 13 $K^{\pm}p \rightarrow (K\pi\pi)^{\pm}p$ 120 DAVIS 72 HBC $+$ 12 K^+p 188 \pm 21 FIRESTONE 72B DBC $+$ 12 K^+p 4 From a model-dependent fit with Gaussian background to BRANDENBURG 76 data PRODUCED BY BEAMS OTHER THAN K MESONS WALUE (MeV) EVTS DOCUMENT ID TECN CHG COMMENT K^{\pm}	The data in this	block is inclu	ided in the	avera	ge prin	ted for	a previ	ous data	block.
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	90± 8	DA	U M	81 C	CNTR	: -	63 K	~p → F	(⁻ 2π p
150 \pm 71 4 CARNEGIE 77 ASPK \pm 13 $K^{\pm}p \rightarrow (K\pi\pi)^{\pm}p$ 200 BRANDENB 76 ASPK \pm 13 $K^{\pm}p \rightarrow (K\pi\pi)^{\pm}p$ 120 DAVIS 72 HBC $+$ 12 $K^{+}p$ 188 \pm 21 FIRESTONE 728 DBC $+$ 12 $K^{+}p$ 4 From a model-dependent fit with Gaussian background to BRANDENBURG 76 data PRODUCED BY BEAMS OTHER THAN K MESONS VALUE (MeV) EVTS DOCUMENT ID TECN COMMENT COMMENT • • • We do not use the following data for averages, fits, limits, etc. • • • 66 \pm 15 310 RODEBACK 81 HBC 4 $\pi^{-}p \rightarrow \Lambda K2\pi$ 60 40 CRENNELL 72 HBC 0 Pp	• • We do n	ot use the foll	owing data	for a	verages	, fits, li	mits, e	tc. • •	•
150 \pm 71 4 CARNEGIE 77 ASPK \pm 13 $K^{\pm}p \rightarrow (K\pi\pi)^{\pm}p$ 200 BRANDENB 76 ASPK \pm 13 $K^{\pm}p \rightarrow (K\pi\pi)^{\pm}p$ 120 DAVIS 72 HBC $+$ 12 $K^{+}p$ 188 \pm 21 FIRESTONE 728 DBC $+$ 12 $K^{+}p$ 4 From a model-dependent fit with Gaussian background to BRANDENBURG 76 data PRODUCED BY BEAMS OTHER THAN K MESONS VALUE (MeV) EVTS DOCUMENT ID TECN COMMENT COMMENT • • • We do not use the following data for averages, fits, limits, etc. • • • 66 \pm 15 310 RODEBACK 81 HBC 4 $\pi^{-}p \rightarrow \Lambda K2\pi$ 60 40 CRENNELL 72 HBC 0 Pp	~ 150	VE	RGEEST	79	нвс	_	4.2 K	- p → 1	$(\overline{K}\pi\pi)^-p$
120 DAVIS 72 HBC + 12 K^+p 188 \pm 21 FIRESTONE 72B DBC + 12 K^+p 4 From a model-dependent fit with Gaussian background to BRANDENBURG 76 data PRODUCED BY BEAMS OTHER THAN K MESONS VALUE (MeV) EVTS DOCUMENT ID TECN CHG COMMENT • • • We do not use the following data for averages, fits, limits, etc. • • • 66 \pm 15 310 RODEBACK 81 HBC 4 $\pi^-p \rightarrow \Lambda K2\pi$ 60 40 CRENNELL 72 HBC 0 4.5 $\pi^-p \rightarrow \Lambda K2\pi$ 127 $^+$ 7 ASTIER 69 HBC 0 $\overline{p}p$	150±71	4 CA	RNEGIE	77	ASPK	±	13 K	± p → (κππ)± p
120 DAVIS 72 HBC + 12 K^+p 188 ± 21 FIRESTONE 72B DBC + 12 K^+p 4 From a model-dependent fit with Gaussian background to BRANDENBURG 76 data PRODUCED BY BEAMS OTHER THAN K MESONS VALUE (MeV) EVTS DOCUMENT ID TECN CHG COMMENT • • • We do not use the following data for averages, fits, limits, etc. • • • 66 ± 15 310 RODEBACK 81 HBC 4 $\pi^-p \rightarrow \Lambda K2\pi$ 60 40 CRENNELL 72 HBC 0 4.5 $\pi^-p \rightarrow \Lambda K2\pi$ 127 $^+7_{-25}$ ASTIER 69 HBC 0 $\overline{p}p$	~ 200	BR	ANDENB	76	ASPK	±	13 K	±'p → ($(K\pi\pi)^{\pm}p$
4 From a model-dependent fit with Gaussian background to BRANDENBURG 76 data PRODUCED BY BEAMS OTHER THAN K MESONS VALUE (MeV) EVTS DOCUMENT ID TECN CHG COMMENT • • • We do not use the following data for averages, fits, limits, etc. • • • 66 \pm 15 310 RODEBACK 81 HBC 4 $\pi^-p \rightarrow \Lambda K2\pi$ 60 40 CRENNELL 72 HBC 0 4.5 $\pi^-p \rightarrow \Lambda K2\pi$ 127 $^+$ 7 ASTIER 69 HBC 0 $\bar{p}p$	120								• •
PRODUCED BY BEAMS OTHER THAN K MESONS VALUE (MeV) • • • We do not use the following data for averages, flts, limits, etc. • • • We do not use the following data for averages, flts, limits, etc. • • • $\frac{1}{127}$ 40 CRENNELL 72 ROTE 9 HBC 0 \$\overline{p} \to \overline{p} \to \overline{p} \to \overline{h} K 2\pi 127 ASTIER 69 HBC 0 \$\overline{p} \to \overline{p} \to \overline{p} \to \overline{h} K 2\pi 127 127 127 127 127 128 128 129 129 129 129 129 129	188±21	FIR	ESTONE	72B	DBC	+	12 K	+ d	
VALUE (MeV) EVTS DOCUMENT ID TECN CHG COMMENT • • • We do not use the following data for averages, flts, limits, etc. • • • 66±15 310 RODEBACK 81 HBC 4 $\pi^- p \rightarrow \Lambda K 2\pi$ 60 40 CRENNELL 72 HBC 0 4.5 $\pi^- p \rightarrow \Lambda K 2\pi$ 127 $^+_{-25}^7$ ASTIER 69 HBC 0 $\bar{p}p$	⁴ From a mod	del-dependent	fit with Ga	usslar	n backg	ground t	to BRA	NDENB	URG 76 data
• • • We do not use the following data for averages, flts, limits, etc. • • • $ 66\pm15 \qquad 310 \qquad \text{RODEBACK} \qquad 81 \text{HBC} \qquad 4 \pi^-p \rightarrow \Lambda K 2\pi \\ 60 \qquad 40 \qquad \text{CRENNELL} \qquad 72 \text{HBC} \qquad 0 \qquad 4.5 \pi^-p \rightarrow \Lambda K 2\pi \\ 127^{+7}_{-25} \qquad \qquad \text{ASTIER} \qquad 69 \text{HBC} \qquad 0 \overline{p}p $	PRODUCED	BY BEAMS	S OTHER	TH	AN K	MES	ONS		
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	VALUE (MeV)	EVTS	DOCUME	NT IL	}	TECN	CHG	COMME	VT
60 40 CRENNELL 72 HBC 0 4.5 $\pi^- p \rightarrow \Lambda K 2\pi$ 127 $^{+7}_{-25}$ ASTIER 69 HBC 0 $\overline{p}p$	• • We do n	ot use the foll	owing data	for a	verages	s, fits, li	mits, e	tc. • • •	•
127 ⁺ 7 ASTIER 69 HBC 0 pp	66 ± 15	310	RODEB	BACK	81	HBC		4 π ⁻ p	$\rightarrow \Lambda K 2\pi$
	60	40	CRENN	ELL	72	HBC	0	$4.5~\pi^-$	$p \rightarrow \Lambda K 2\pi$
60 45 CRENNELL 67 HBC 0 $6\pi^-p \rightarrow \Lambda K2\pi$	127 ⁺ 7 -25		ASTIER	₹	69	нвс	0	Īρ	
	60	45	CRENN	ELL	67	нвс	0	6 π ⁻ p	$\rightarrow \Lambda K 2\pi$

K1(1270) PARTIAL WIDTHS

(42 ±6)%

(28 ±4)%

(16 ± 5)%

 (11.0 ± 2.0) %

(3.0±2.0) %

 Γ_1/Γ

 Γ_2/Γ

 Γ_1

Γ₂ Γ₃ Γ₄ Γ₅

Κρ

Κω

 $\Gamma(K\rho)/\Gamma_{\text{total}}$

 $\Gamma(K_0^*(1430)\pi)/\Gamma_{\text{total}}$

VALUE

 0.42 ± 0.06

dominant

VALUE

0.28±0.04

 $K_0^*(1430)\pi$ $K^*(892)\pi$

K f₀(1370)

					Г1
DOCUMENT ID		<u>TE</u> CN	CHG	COMMENT	
following data	for a	verages,	fits, li	mits, etc. • • •	
CARNEGIE	77B	ASPK	±	$13 K^{\pm} p \rightarrow (K\pi\pi)^{\pm} p$	
					Γ2
DOCUMENT ID		TECN	<u>CHG</u>	COMMENT	
following data	for a	verages,	fits, li	mits, etc. • • •	
CARNEGIE	778	ASPK	±	$13 K^{\pm} p \rightarrow (K\pi\pi)^{\pm} p$	
					Гэ
DOCUMENT ID		TECN_	CHG	COMMENT	
following data	for a	verages,	fits, li	mits, etc. • • • .	
CARNEGIE	77B	ASPK	±	$13 K^{\pm} p \rightarrow (K\pi\pi)^{\pm} p$	
					Γ4
DOCUMENT ID		TECN	CHG	COMMENT	
e following data	for a	verages,	fits, H	mits, etc. • • •	
CARNEGIE	77B	ASPK	±	$13 K^{\pm} p \rightarrow (K\pi\pi)^{\pm} p$	
					Γ5
DOCUMENT ID		TECN	CHG	COMMENT	_
e following data	for a	verages,	fits, li	imits, etc. • • •	
CARNEGIE	77B	ASPK	±	13 $K^{\pm} p \rightarrow (K \pi \pi)^{\pm} p$	
	e following data MAZZUCATO CARNEGIE DOCUMENT ID: e following data CARNEGIE DOCUMENT ID e following data MAZZUCATO CARNEGIE DOCUMENT ID e following data MAZZUCATO CARNEGIE DOCUMENT ID e following data MAZZUCATO CARNEGIE	e following data for a MAZZUCATO 79 CARNEGIE 778 DOCUMENT ID e following data for a CARNEGIE 778 DOCUMENT ID e following data for a MAZZUCATO 79 CARNEGIE 778 DOCUMENT ID e following data for a MAZZUCATO 79 CARNEGIE 778 DOCUMENT ID e following data for a MAZZUCATO 79 CARNEGIE 778 DOCUMENT ID e following data for a MAZZUCATO 79 CARNEGIE 778	e following data for averages, MAZZUCATO 79 HBC CARNEGIE 778 ASPK DOCUMENT ID: TECN e following data for averages, CARNEGIE 778 ASPK DOCUMENT ID TECN e following data for averages, MAZZUCATO 79 HBC CARNEGIE 778 ASPK DOCUMENT ID TECN e following data for averages, MAZZUCATO 79 HBC CARNEGIE 778 ASPK DOCUMENT ID TECN e following data for averages, MAZZUCATO 79 HBC CARNEGIE 778 ASPK	e following data for averages, fits, II MAZZUCATO 79 HBC + CARNEGIE 778 ASPK ± DOCUMENT ID TECN CHG e following data for averages, fits, II CARNEGIE 778 ASPK ± DOCUMENT ID TECN CHG e following data for averages, fits, II MAZZUCATO 79 HBC + CARNEGIE 778 ASPK ± DOCUMENT ID TECN CHG e following data for averages, fits, II MAZZUCATO 79 HBC + CARNEGIE 778 ASPK ± DOCUMENT ID TECN CHG e following data for averages, fits, II MAZZUCATO 79 HBC + CARNEGIE 778 ASPK ±	POCUMENT ID TECN CHG COMMENT e following data for averages, fits, limits, etc. • • • MAZZUCATO 79 HBC + $4.2~K^-p \rightarrow \Xi^-(K\pi\pi)^+p$ POCUMENT ID TECN CHG COMMENT e following data for averages, fits, limits, etc. • • • CARNEGIE 778 ASPK \pm 13 $K^\pm p \rightarrow (K\pi\pi)^\pm p$ POCUMENT ID TECN CHG COMMENT e following data for averages, fits, limits, etc. • • • CARNEGIE 778 ASPK \pm 13 $K^\pm p \rightarrow (K\pi\pi)^\pm p$ POCUMENT ID TECN CHG COMMENT e following data for averages, fits, limits, etc. • • • MAZZUCATO 79 HBC \pm 4.2 $K^-p \rightarrow \Xi^-(K\pi\pi)^\pm p$ DOCUMENT ID TECN CHG COMMENT e following data for averages, fits, limits, etc. • • • MAZZUCATO 79 HBC \pm 4.2 $K^-p \rightarrow \Xi^-(K\pi\pi)^\pm p$ DOCUMENT ID TECN CHG COMMENT e following data for averages, fits, limits, etc. • • • MAZZUCATO 79 HBC \pm 4.2 $K^-p \rightarrow \Xi^-(K\pi\pi)^\pm p$ CARNEGIE 778 ASPK \pm 13 $K^\pm p \rightarrow (K\pi\pi)^\pm p$

TECN COMMENT

RODEBACK 81 HBC $4\pi^-p \rightarrow \Lambda K 2\pi$

DOCUMENT ID TECN COMMENT

81C CNTR 63 $K^-p \rightarrow K^-2\pi p$

81C CNTR 63 $K^-p \rightarrow K^-2\pi p$

DOCUMENT ID ⁵ DAUM

5 DAUM

ullet ullet We do not use the following data for averages, fits, limits, etc. ullet ullet

² From a model-dependent fit with Gaussian background to BRANDENBURG 76 data.

Γ(<i>K</i> *(892)π)/Γ₁	total	Γ3/Γ
VALUE	DOCUMENT ID TECN COMMENT	
0.16±0.05	⁵ DAUM 81c CNTR 63 $K^-p \rightarrow K^-2\pi p$	
Γ(Κω)/Γ _{total}	DOCUMENT ID TECN COMMENT	Γ4/Γ
0.11 ±0.02	⁵ DAUM 81C CNTR 63 $K^-p \rightarrow K^-2\pi p$	
Γ(Κω)/Γ(Κρ) VALUE	CL% DOCUMENT ID TECN COMMENT	Γ_4/Γ_1
	se the following data for averages, fits, limits, etc. • •	
<0.30	95 RODEBACK 81 HBC 4 π ⁻ ρ → ΛΚ2π	
Γ(<i>K f</i> ₀ (1370))/Γ	total	Γ ₅ /Γ
VALUE	DOCUMENT ID TECN COMMENT	
0.03 ±0.02	5 DAUM 81C CNTR 63 $K^-p \rightarrow K^-2\pi p$	
D-wave/S-wave	RATIO FOR $K_1(1270) \rightarrow K^*(892)\pi$	
VALUE	DOCUMENT ID TECN COMMENT	
1.0±0.7	⁵ DAUM 81C CNTR 63 $K^-p \rightarrow K^-2\pi p$	
_	ow and high t data.	

K₁(1270) REFERENCES

TORNQVIST DAUM RODEBACK MAZZUCATO VERGEEST GAVILLET	82B 81C 81 79 79 78	NP B203 268 NP B187 1 ZPHY C9 9 NP B156 532 NP B158 265 PL 76B 517	HELS +Hertzberger+ (AMST, CERN, CRAC, MPIM, OXF+) +Sjogren+ (CERN, CDEF, MADR, STOH) +Pennington+ (CERN, ZEEM, NIJM, OXF) +Jolaz, Dionisi+ (NIJM, AMST, CERN, OXF) (AMST, CERN, NIJM, OXF) JP
CARNEGIE	77 77B	NP B127 509 PL 68B 287	+Cashmore, Davier, Dunwoodie, Lasinski+ (SLAC) +Cashmore, Dunwoodie, Lasinski+ (SLAC)
BRANDENB	76	PRL 26 703	Brandenburg, Carnegie, Cashmore+ (SLAC) JP
OTTER	76	NP B106 77	 + (AACH3, BERL, CERN, LOIC, VIEN, EPOL+) JP
CRENNELL	72	PR D6 1220	+Gordon, Lai, Scarr (BNL)
DAVIS	72	PR D5 2688	+Alston-Garnjost, Barbaro, Flatte, Friedman, Lynch+ (LBL)
FIRESTONE	72B	PR D5 505	+Goldhaber, Lissauer, Trilling (LBL)
ASTIER	69	NP B10 65	+Marechal, Montanet+ (CDEF, CERN, IPNP, LIVP) IJP
CRENNELL	67	PRL 19 44	+Kalbfleisch, Lai, Scarr, Schumann (BNL) I

OTHER RELATED PAPERS

SUZUKI	93	PR D47 1252			(LBL)	
BAUBILLIER	82B	NP B202 21	+ (E	BIRM, CERN, GLAS	, MSU, CÙRIN)	
FERNANDEZ	82	ZPHY C16 95	+Aguilar-Benitez+	(MADR, CERN,	, CDEF, STOH) J	I
GAVILLET	82	ZPHY C16 119	+Armenteros+	(CERN, CDEF,	PADO, ROMA)	
SHEN	66	PRL 17 726	+Butterworth, Fu, Goldh	aber, Trilling	(LRL)	
Also	66	Private Comm.	Goldhaber		(LRL)	
ALMEIDA	65	PL 16 184	+Atherton, Byer, Dornan	, Forson+	(CAVE)	
ARMENTEROS	64	PL 9 207	+Edwards, D'Andlau+		(CERN, CDEF)	
Also	66	PR 145 1095	Barash, Kirsch, Miller,	Tan	(COLU)	

 $K_1(1400)$

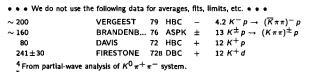
$$I(J^P) = \frac{1}{2}(1^+)$$

K1(1400) MASS

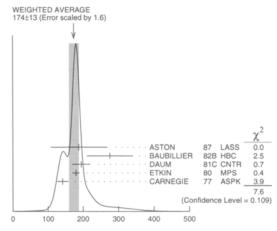
VALUE (MeV)	DOCUMENT ID	TECN	CHG	COMMENT
1402± 7 OUR AV	ERAGE			
$1373 \pm 14 \pm 18$	¹ ASTON	87 LASS	0	$11 K^- p \rightarrow \overline{K}{}^0 \pi^+ \pi^- n$
1392±18	BAUBILLIER	82B HBC	0	8.25 $K^- p \rightarrow K_S^0 \pi^+ \pi^- n$
1410±25	DAUM	81c CNTR	-	$63 K^- p \rightarrow K^- 2\pi p$
1415 ± 15	ETKIN	80 MPS		$6 K^- p \rightarrow \overline{K}^0 \pi^+ \pi^- n$
1404±10	² CARNEGIE	77 ASPK	±	13 $K^{\pm} p \rightarrow (K\pi\pi)^{\pm} p$
• • • We do not use	the following data	for averages, t	its, III	mits, etc. • • •
~ 1350	³ TORNQVIST	828 RVUE		
~ 1400	VERGEEST	79 HBC	-	4.2 $K^- p \rightarrow (\overline{K} \pi \pi)^- p$ 13 $K^{\pm} p \rightarrow (K \pi \pi)^{\pm} p$
~ 1400	BRANDENB	76 ASPK	±	13 $K^{\pm} \rho \rightarrow (K \pi \pi)^{\pm} \rho$
1420	DAVIS	72 HBC	+	12 K ⁺ p
1368 ± 18	FIRESTONE	72B DBC	+	12 K ⁺ d
¹ From partial-wave ² From a model-dep ³ From a unitarized	pendent fit with Ga	ussian backgro	und t	o BRANDENBURG 76 data.

K1 (1400) WIDTH

VALUE (MeV)	DOCUMENT ID	TECN	CHG	COMMENT
174±13 OUR AV	ERAGE Error includ	des scale fact	or of	1.6. See the ideogram below.
188 ± 54 ± 60	⁴ ASTON	87 LASS	0	$11 K^- p \rightarrow \overline{K}{}^0 \pi^+ \pi^- n$
276±65	BAUBILLIER	82B HBC	0	$8.25 K^- p \rightarrow K_5^0 \pi^+ \pi^- n$
195 ± 25	DAUM	81c CNTR	_	$63 K^- p \rightarrow K^- 2\pi p$
180 ± 10	ETKIN	80 MPS	0	$6 K^- p \rightarrow \overline{K}^0 \pi^+ \pi^- n$
142±16	⁵ CARNEGIE	77 ASPK	±	$13 K^{\pm} p \rightarrow (K \pi \pi)^{\pm} p$



⁵ From a model-dependent fit with Gaussian background to BRANDENBURG 76 data.



 $K_1(1400)$ width (MeV)

K1(1400) DECAY MODES

	Mode	Fraction (Γ_i/Γ)	
$\overline{\Gamma_1}$	K*(892)π	(94 ±6)%	
Γ_2	Κρ	(3.0±3.0) %	
Γ³	K f ₀ (1370)	(2.0±2.0) %	
Γ_{4}	Κω	(1.0±1.0) %	
Γ ₄ Γ ₅	$K_0^*(1430)\pi$	not seen	

K1(1400) PARTIAL WIDTHS

Γ(K*(892)π)						Г1
VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT	
117±10	CARNEGIE	77	ASPK	±	13 $K^{\pm} p \rightarrow (K\pi\pi)^{\pm} p$	
$\Gamma(K\rho)$						Γ2
VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT	
2 ±1	CARNEGIE	77	ASPK	±	13 $K^{\pm} p \rightarrow (K\pi\pi)^{\pm} p$	
$\Gamma(K\omega)$						Γ4
VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT	
23±12	CARNEGIE	77	ASPK	±	$13 \ K^{\pm} \rho \rightarrow (K\pi\pi)^{\pm} \rho$	

V (1400) DRANCHING DATIOS

	K ₁ (1400)	BRANCHING	RATIOS	
$\Gamma(K^*(892)\pi)/\Gamma_t$	otal			Γ1/Γ
VALUE		ID TECN		
0.94±0.06	6 DAUM	81c CNTR	63 K $^-p \rightarrow K^-2\pi p$	
$\Gamma(K\rho)/\Gamma_{\text{total}}$				Γ_2/Γ
VALUE	DOCUMENT	ID TECN	COMMENT	
0.03 ±0.03	6 DAUM	81C CNTR	63 K $^-p \rightarrow K^-2\pi p$	
Γ(<i>K f</i> ₀ (1370))/Γ	total			Гз/Г
VALUE		ID TECN	COMMENT	
0.02 ±0.02	6 DAUM	81C CNTR	63 K $^-p \rightarrow K^-2\pi p$	
$\Gamma(K\omega)/\Gamma_{\text{total}}$				Γ4/Γ
VALUE	DOCUMENT	ID TECN	COMMENT	
0.01 ±0.01			63 K ⁻ p → K ⁻ 2πp	
$\Gamma(K_0^*(1430)\pi)/\Gamma$	total			Г _Б /Г
VALUE		ID TECN	COMMENT	
not seen	6 DAUM	81C CNTR	$63~K^-~p \rightarrow ~K^-~2\pi~p$	
D-wave/S-wave	RATIO FOR K	(1400) → K	*(892) <i>π</i>	

VALUE	DOCOMENT ID	7,500	COMMENT		
0.04 ±0.01	⁶ DAUM	81c CNTR	63 $K^-p \rightarrow$	$K^-2\pi p$	

⁶ Average from low and high t data.

 $K_1(1400), K^*(1410), K_0^*(1430)$

K₁(1400) REFERENCES

ACTON		NP B292 693	+Awaji, D'Amore+ (SLAC, NAGO, CINC, INUS)
ASTON	87		
BAUBILLIER	82B	NP B202 21	+ (BIRM, CERN, GLAS, MSU, CURIN)
TORNQVIST	82B	NP B203 268	(HELS)
DAUM	81C	NP B187 1	+Hertzberger+ (AMST, CERN, CRAC, MPIM, OXF+)
ETKIN	80	PR D22 42	+Foley, Lindenbaum, Kramer+ (BNL, CUNY) JP
VERGEEST	79	NP B158 265	+Jongejans, Dionisi+ (NIJM, AMST, CERN, OXF)
CARNEGIE	77	NP B127 509	+Cashmore, Davier, Dunwoodie, Lasinski+ (SLAC)
BRANDENB	76	PRL 26 703	Brandenburg, Carnegie, Cashmore+ (SLAC) JP
DAVIS	72	PR D5 2688	+Alston-Garnjost, Barbaro, Flatte, Friedman, Lynch+ (LBL)
FIRESTONE	72B	PR D5 505	+Goldhaber, Lissauer, Trilling (LBL)

OTHER RELATED PAPERS -

SUZUKI FERNANDEZ	93 82	PR D47 1252 ZPHY C16 95	+Aguilar-Benitez+ (MADR, CERN	(LBL)
SHEN	66	PRL 17 726	+Butterworth, Fu, Goldhaber, Trilling	(LRL) (LRL)
Also	66	Private Comm.	Goldhaber	(LRL)
ALMEIDA	65	PL 16 184	+Atherton, Byer, Dornan, Forson+	(CAVE)
ARMENTEROS	64	PL 9 207	+Edwards, D'Andlau+	(CERN, CDEF)
Also	66	PR 145 1095	Barash, Kirsch, Miller, Tan	(COLU)

$K^*(1410)$

$$I(J^P) = \frac{1}{2}(1^-)$$

K*(1410) MASS

VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT			
1414±15 OUR AVERAGE Error includes scale factor of 1.3.								
1380±21±19	ASTON	88	LASS	0	$11 K^- \rho \rightarrow K^- \pi^+ n$			
1420 ± 7 ± 10	ASTON	87	LASS	0	11 $K^- \rho \rightarrow \overline{K}^0 \pi^+ \pi^- \pi$			
• • • We do not use	the following data	for a	verages,	fits, I	lmits, etc. • • •			
1367±54					11 $K^- \rho \rightarrow \overline{K}^0 \pi^- \rho$			
1474±25	BAUBILLIER	82B	HBC	0	$8.25 K^- p \rightarrow \overline{K}^0 2\pi n$			
1500 ± 30	ETKIN	80	MPS	0	$6 K^- p \rightarrow \overline{K}^0 \pi^+ \pi^- n$			

K*(1410) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT			
232 ± 21 OUR AVERAGE Error includes scale factor of 1.1.								
176± 52±22	ASTON	88	LASS	0	$11 K^- \rho \rightarrow K^- \pi^+ n$			
240 ± 18 ± 12	ASTON	87	LASS	0	11 $K^- p \rightarrow \overline{K}^0 \pi^+ \pi^- n$			
• • • We do not use th	e following data f	for av	/erages,	fits, li	mits, etc. • • •			
114±101					11 $K^- p \rightarrow \overline{K}^0 \pi^- p$			
275± 65	BAUBILLIER	82B	нвс	0	$8.25 K^- p \rightarrow \overline{K}^0 2\pi n$			
500 ± 100	ETKIN	80	MPS	0	$6 K^- p \rightarrow \overline{K}^0 \pi^+ \pi^- n$			

K*(1410) DECAY MODES

	Mode	Fraction (Γ_I/Γ)	Confidence leve	
$\overline{\Gamma_1}$	K*(892)π	> 40 %	95%	
Γ_2	$K\pi$	(6.6±1.3) %		
Γ3	Κρ	< 7 %	95%	

K*(1410) BRANCHING RATIOS

$\Gamma(K\rho)/\Gamma(K^*($	892) x)						Γ_3/Γ_1
VALUE	CL%	DOCUMENT IL		<u>TECN</u>		COMMENT	
<0.17	95	ASTON	84	LASS	0	11 K ⁻ p-	$\rightarrow \overline{K}^0 2\pi n$
$\Gamma(K\pi)/\Gamma(K^*)$	(892)π)						Γ_2/Γ_1
VALUE	CL%	DOCUMENT IL		TECN	<u>CHG</u>	COMMENT	
<0.16	95	ASTON	84	LASS	0	11 K ⁻ p -	$\rightarrow \overline{K}^0 2\pi n$
$\Gamma(K\pi)/\Gamma_{\text{total}}$							Γ_2/Γ
VALUE		OCUMENT ID	TECN	CHG	COM	MENT	
0.066+0.010+0	.008 A	STON 88	LASS	5 0	11 /	(- p → K	$-\pi^{+}n$

K*(1410) REFERENCES

BIRD	89	SLAC-332		(SLAC)
ASTON	88	NP B296 493	+Awaji, Bienz, Bird+ (SLAC, NAGO, CINC,	INUS)
ASTON	87	NP B292 693	+Awaji, D'Amore+ (SLAC, NAGO, CINC,	
ASTON	84	PL 149B 258	+Carnegie, Dunwoodie+ (SLAC, CARL,	OTTA) JP
BAUBILLIER	82B	NP B202 21	+ (BIRM, CERN, GLAS, MSU, C	CURIN)
ETKIN	80	PR D22 42	+Foley, Lindenbaum, Kramer+ (BNL,	CUNY) JP

 $K_0^*(1430)$

$$I(J^P) = \frac{1}{2}(0^+)$$

See our minireview in the 1994 edition and in this edition under the f₀(1370).

K₀*(1430) MASS

VALUE (MeV)	DOCUMENT ID	TECN CHG	COMMENT
1429 ± 4±5	¹ ASTON 88	LASS 0	11 $K^-p \rightarrow K^-\pi^+n$
• • • We do not use	the following data for a	verages, fits, li	mits, etc. • • •
1415 ±25	² ANISOVICH 970	RVUE	$11 K^- \rho \rightarrow K^- \pi^+ n$
~ 1450	³ TORNQVIST 96		$\pi\pi \to \pi\pi$, $K\overline{K}$, $K\pi$
~ 1430	BAUBILLIER 84B	HBC -	8.25 $K^- \rho \rightarrow \overline{K}^0 \pi^- \rho$
~ 1425	4,5 ESTABROOKS 78	ASPK	13 $K^{\pm} p \rightarrow K^{\pm} \pi^{\pm} (n, \Delta)$
~ 1450.0	MARTIN 78	SPEC	$10 K^{\pm} p \rightarrow K_S^0 \pi p$

 1 Uses a model for the background, without this background they get a mass 1340 MeV, where the phase shift passes 90°. 2 T-matrix pole. Reanalysis of ASTON 88 data.

³ T-matrix pole.

⁴ Mass defined by pole position.

⁵ From elastic $K\pi$ partial-wave analysis.

K₀*(1430) WIDTH

VALUE (MeV)	DOCUMENT ID	TEC	N CHG	COMMENT
287±10±21	ASTON	88 LAS	S 0	11 $K^- p \rightarrow K^- \pi^+ \pi$
• • • We do not u	se the following data 1	or averag	ges, fits, l	limits, etc. • • •
330 ± 50	⁶ ANISOVICH	97c RVI	JE	$11 K^- p \rightarrow K^- \pi^+ n$
~ 320	7 TORNQVIST	96 RV	JE	$\pi\pi \rightarrow \pi\pi, K\overline{K}, K\pi$
~ 200	BAUBILLIER			8.25 $K^-p \rightarrow \overline{K}^0\pi^-p$
200 to 300	8 ESTABROOKS	78 ASI	·κ	13 $K^{\pm} p \rightarrow K^{\pm} \pi^{\pm} (n, \Delta)$
⁶ T-matrix pole.	Reanalysis of ASTON	88 data.		
⁷ T-matrix pole.				

⁸ From elastic $K\pi$ partial-wave analysis.

K*(1430) DECAY MODES

	Mode	Fraction (Γ_{f}/Γ)	
Γ ₁	Κπ	(93±10) %	

K₀(1430) BRANCHING RATIOS

Γ(<i>K</i> π)/Γ _{total}					Γ ₁ /Γ
VALUE	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT
0.93±0.04±0.09	ASTON	88	LASS	0	11 $K^-p \rightarrow K^-\pi^+n$

K₀*(1430) REFERENCES

TORNQVIST ASTON	97C 96 88 84B 78 78	PL B413 137 PRL 76 1575 NP B296 493 ZPHY C26 37 NP B133 490 NP B134 392	+ (BIRM, CERN,	(HELS) , NAGO, CINC, INUS) GLAS, MICH, CURIN) CARL, DURH, SLAC) (DURH, GEVA)
TORNQVIST GOLDBERG TRIPPE	82 69 68	PRL 49 624 PL 30B 434 PL 28B 203	+Huffer, Laloum+ +Chien, Malamud, Mellema, Schlein+	(HELS) (SABRE Collab.) (UCLA)

K*(1430)

$$I(J^P) = \frac{1}{2}(2^+)$$

We consider that phase-shift analyses provide more reliable determinations of the mass and width.

K2 (1430) MASS

CHARGED ONLY, WITH FINAL STATE $K\pi$							
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT	
1425.6± 1.5 OUR	AVERAGE	Error includes s	cale f	actor of	1.1.		
1420 ± 4	1587	BAUBILLIER	84B	HBC-	- '	8.25 K ⁻ p →	
1436 ± 5.5		² CLELAND	82	SPEC	+	$\frac{\overline{K}^0\pi^-p}{30\ K^+p\to\ K^0_5\pi^+p}$	
1430 ± 3.2	1500 ¹	^{,2} CLELAND	82	SPEC	+	$50 K^+ p \rightarrow K_S^0 \pi^+ p$	
1430 ± 3.2	1200 1	² CLELAND	82	SPEC	_	$50 K^+ p \rightarrow K_5^{0} \pi^- p$	
1423 ± 5	935	TOAFF	81	нвс	_	$6.5 K^- \rho \rightarrow \overline{K}^0 \pi^- \rho$	
1428.0± 4.6		³ MARTIN	78	SPEC	+	$10 K^{\pm} p \rightarrow K_{5}^{0} \pi p$	
1423.8± 4.6		³ MARTIN	78	SPEC	_	$10 K^{\pm} p \rightarrow K_{5}^{0} \pi p$	
1420.0 ± 3.1	1400	AGUILAR	71B	нвс	_	3.9,4.6 K ⁻ p	
1425 ± 8.0	225 1	² BARNHAM	71c	HBC	+	$K^+ \rho \rightarrow K^0 \pi^+ \rho$	
1416 ±10	220	CRENNELL	69 D	DBC	-	3.9 K - N →	
1414 ±13.0		1 LIND		нвс	+	$\frac{K^{0}\pi^{-}N}{9K^{+}\rho\rightarrow K^{0}\pi^{+}\rho}$	
1427 ±12		1 SCHWEING	68	нвс	-	5.5 $K^-p \rightarrow \overline{K}\pi N$	
1423 ±11.0	39	1 BASSANO	67	HBC	_	4.6-5.0 K ⁻ p →	

 $\overline{\kappa}^0\pi^-p$

⁴ BIRD 89 LASS - 11 $K^- p \to \overline{K}{}^0 \pi^- p$ 1423.4 ± 2 ±3 24809 ±

NEUTRAL	ONLY
VALUE (MeV)	EVTS

HEO HOVE OHE						
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
1432.4± 1.3 OUR	AVERAGE					
1431.2± 1.8± 0.7		⁵ ASTON	88	LASS	0	11 $K^-p \rightarrow K^-\pi^+n$
$1434 \pm 4 \pm 6$		⁵ ASTON	87	LASS	0	11 K ⁻ p →
		_				$\overline{K}^0\pi^+\pi^-\pi^-$
$1433 \pm 6 \pm 10$		⁵ ASTON	84B	LASS	0	$11 K^- p \rightarrow \overline{K}^0 2\pi n$
1471 ±12		⁵ BAUBILLIER	82B	HBC	0	8.25 K p →
						$NK_{S}^{0}\pi\pi$
1428 ± 3		⁵ ASTON	8 1¢	LASS	0	11 $K^-p \rightarrow K^-\pi^+n$
1434 ± 2		⁵ ESTABROOKS	78	ASPK	0	13 $K^{\pm} p \rightarrow p K \pi$
1440 ±10		⁵ BOWLER	77	DBC	0	$5.5 K^+ d \rightarrow K \pi p p$
• • • We do not us	e the follo	wing data for ave	rages	, fits, lir	nits, e	tc. • • •
1420 ± 7	300	HENDRICK	76	DBC		8.25 K ⁺ N →
						$K^{+}\pi N$
1421.6 ± 4.2	800	MCCUBBIN	75	HBC	0	3.6 $K^- p \to K^- \pi^+ n$
1420.1 ± 4.3		⁶ LINGLIN	73	HBC	0	2-13 $K^+p \rightarrow$
						κ+π-X
1419.1 ± 3.7	1800	AGUILAR	71B	HBC	0	3.9,4.6 K p
1416 ± 6	600	CORDS	71	DBC	0	$9 K^+ n \rightarrow K^+ \pi^- p$
1421 1 + 26	2200	DAV/IS	60	HDC	^	12 Kt n . Kt V

¹ Errors enlarged by us to Γ/\sqrt{N} ; see the note with the $K^*(892)$ mass.

K2(1430) WIDTH

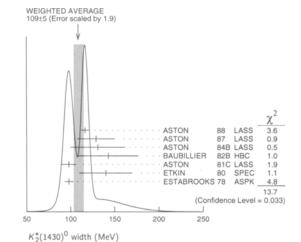
CHARGED	ONLY,	WITH	FINAL	STATE	$K\pi$

	,			•		
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
98.5± 2.7 OU	R FIT Erro	or includes scale fac	tor o	f 1.1.		
98.5± 2.9 OUI	R AVERAGE	Error includes so	cale fa	actor of	1.1.	
109 ±22	400	^{7,8} CLELAND	82	SPEC	+	30 K+p \rightarrow K $_{S}^{0}\pi^{+}p$
124 ±12.8	1500	7,8 CLELAND	82	SPEC	+	50 K+p → K 0π+p
113 ±12.8	1200	7,8 CLELAND	82	SPEC	-	50 K+p → K 5π-p
85 ±16	935	TOAFF	81	HBC	_	$6.5 K^- p \rightarrow \overline{K}^0 \pi^- p$
96.5 ± 3.8		MARTIN	78	SPEC	+	$10 K^{\pm} p \rightarrow K_{S}^{0} \pi p$
97.7± 4.0		MARTIN	78	SPEC	_	$10 K^{\pm} p \rightarrow K_{S}^{0} \pi p$
$94.7^{+15.1}_{-12.5}$	1400	AGUILAR	71B	нвс	-	3.9,4.6 K ⁻ p

^{• • •} We do not use the following data for averages, fits, limits, etc. • • •

98	±	4	±4	24809±	⁹ BIRD	89	LASS	_	11 K [−] p →	$K^0\pi^-$	٠,
				920							

NE	NEUTRAL ONLY							
VALU	E (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT	
109	± 5	OUR AVERAGE		ale f	actor of	1.9. S	ee the ideogram below.	
116.	5 ± 3.6	± 1.7	¹⁰ ASTON	88	LASS	0	11 $K^-p \rightarrow K^-\pi^+n$	
129	±15	±15	¹⁰ ASTON	87	LASS	0	11 $K^-p \rightarrow$	
131	±24	±20	¹⁰ ASTON	84B	LASS	0	$\frac{\overline{K}^0\pi^+\pi^-\underline{n}}{11\ K^-p\to \overline{K}^02\pi n}$	
143	±34		¹⁰ BAUBILLIER	82B	HBC	0	8.25 K ⁻ p →	
							$NK_S^0\pi\pi$	
98	± 8		10 ASTON	81 C	LASS	0	11 $K^-p \rightarrow K^-\pi^+n$	
140	±30		10 ETKIN	80	SPEC	0	6 K ⁻ p →	
98	± 5		10 ESTABROOKS	78	ASPK	0	$ \overline{K}^0 \pi^+ \pi^- n 13 K^{\pm} p \rightarrow p K \pi $	
• •	We d	o not use the foll	owing data for ave	rages	, fits, li	mits, e	tc. • • •	
125	± 29	300	⁷ HENDRICK	76	DBC		8.25 $K^+ N \rightarrow K^+ \pi N$	
116	±18	800	MCCUBBIN	75	нвс	0	$3.6 K^{-}p \rightarrow K^{-}\pi^{+}n$	
61	±14		¹¹ LINGLIN	73	HBC	0	2-13 K ⁺ p →	
							$K^+\pi^-X$	
116.0	5 + 10.3 - 15.5	1800	AGUILAR	718	HBC	0	3.9,4.6 K ⁻ p	
144	±24.0	600	7 CORDS	71	DBC	0	$9 K^+ n \rightarrow K^+ \pi^- p$	
101	±10	2200	DAVIS	69	HBC	0	12 K ⁺ p →	
							v++ n	



- $^{7}_{-}$ Errors enlarged by us to $4\Gamma/\sqrt{N};$ see the note with the $K^{*}(892)$ mass.
- ⁸ Number of events in peak re-evaluated by us.

- 9 From a partial wave amplitude analysis.

 10 From phase shift or partial-wave analysis.

 11 From pole extrapolation, using world K+p data summary tape.

K2(1430) DECAY MODES

	Mode	Fraction (Γ_I/Γ)	Scale factor/ Confidence level
Γ_1	Κπ	(49.9±1.2) %	_
Γ_2	$K^*(892)\pi$	(24.7±1.5) %	
Гз	$K^*(892)\pi\pi$	(13.4±2.2) %	
Γ4	$K\rho$	(8.7±0.8) %	5=1.2
Γ ₅	κ_{ω}	(2.9±0.8) %	
Γ ₆	$K^+\gamma$	$(2.4\pm0.5)\times10^{-3}$	S=1.1
Γ ₇	Κη	$(1.5^{+3.4}_{-1.0}) \times 10^{-3}$	S=1.3
Гв	$K \omega \pi$	$< 7.2 \times 10^{-4}$	CL=95%
Γ9	$K^0\gamma$	< 9 × 10 ⁻⁴	CL=90%

²Number of events in peak re-evaluated by us.

³ Systematic error added by us.
4 From a partial wave amplitude analysis.
5 From phase shift or partial-wave analysis.

⁶ From pole extrapolation, using world K^+p data summary tape.

$K_2^*(1430)$

CONSTRAINED FIT INFORMATION

An overall fit to the total width, a partial width, and 10 branching ratios uses 31 measurements and one constraint to determine 8 parameters. The overall fit has a $\chi^2=20.2$ for 24 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\left\langle \delta p_i \delta p_j \right\rangle / (\delta p_i \cdot \delta p_j)$, in percent, from the fit to parameters p_i , including the branching fractions, $x_i \equiv \Gamma_i / \Gamma_{\text{total}}$. The fit constrains the x_i whose labels appear in this array to sum to one.

<i>x</i> ₂	-9						
<i>x</i> ₃	-40	-73					
X4	-8	36	-52				
<i>x</i> ₅	-11	-3	-26	-7			
<i>x</i> 6	-1	-1	-1	-1	0		
X7	-4	-7	-5	-5	-2	0	
Г		0	0_	0	0	-13	0
	<i>X</i> 1	Χa	Хз	XA	Χs	X	X7

	Mode	Rate (MeV)	Scale factor
Γ ₁	Κπ	49.1 ±1.8	_
Γ_2	$K^*(892)\pi$	24.3 ±1.6	
Γ3	$K^*(892)\pi\pi$	13.2 ±2.2	
Γ_{4}	$K\rho$	8.5 ±0.8	1.2
Γ ₅	$K\omega$	2.9 ±0.8	
۲ ₆	$K^+\gamma$	0.24 ± 0.05	1.1
Γ ₇	$K\eta$	$0.15^{f +0.33}_{f -0.10}$	1.3

K2(1430) PARTIAL WIDTHS

$\Gamma(K^+\gamma)$							Γ ₆
VALUE (keV)	DOC	UMENT ID	TECN	CHG	сом	MENT	
241 ±50 OUR FIT	Error incl	udes scale fac	or of 1.1				
240±45	CIH	ANGIR 82	SPEC	+		$K^+Z \rightarrow ZK^+\pi^0$,	
					Z	$\kappa_S^0 \pi^+$	
Γ(Κ⁰γ)							Г9
VALUE (keV)	CL%	DOCUMENT I	1	ECN	<u>CHG</u>	COMMENT	
<84	90	CARLSMITH	1 87 S	PEC	0	$60-200 \ K_L^0 A \rightarrow K_S^0 \pi^0 A$	

K*(1430) BRANCHING RATIOS

				Γ ₁ /Γ
		TECN	<u>CHG</u>	COMMENT
-				
				11 V V- +-
				11 K $p \rightarrow K \pi \cdot n$ 13 K $\pm p \rightarrow p K \pi$
ESTABROURS	18	ASPK	±	13 $K-p \rightarrow pK\pi$
(π)				Γ_2/Γ_1
		TECN	CHG	COMMENT
			0	11 $K^-p \rightarrow \overline{K}^0 2\pi n$
			0	10,16 $K^- p \to K^- \pi^+ n$
DEHM	74	DBC	0	4.6 K ⁺ N
AGUILAR				3.9,4.6 K ⁻ p
BASSANO	67	нвс	-0	4.6,5.0 K ⁻ p
BADIER	65 C	нвс	-	3 K ⁻ p
				Γ ₅ /Γ ₁
DOCUMENT ID		TECN	CHG	
т				
/ERAGE				
AGUILAR	71B	HBC		3.9,4.6 K ⁻ p
BASSOMPIE	69	нвс	0	5 K+p
				Γ_4/Γ_1
DOCUMENT ID		TECN	CHG	** -
T Error includes s	cale	factor o	f 1.2.	
/ERAGE				
ASTON	84B	LASS	0	$11~K^-p \to ~\overline{K}{}^0 2\pi n$
DEHM	74	DBC	0	4.6 K ⁺ N
	TO DOCUMENT ID DOCUMENT ID TO THE PROPERTY IN THE	TERAGE 12 ASTON 88 12 ESTABROOKS 78 (#) DOCUMENT ID TERAGE ASTON 84B LAUSCHER 75 DEHIM 74 AGUILAR 71B BASSANO 67 BADIER 65c DOCUMENT ID TERAGE AGUILAR 71B BASSOMPIE 69 DOCUMENT ID TERAGE AGUILAR 71B BASSOMPIE 69	TERAGE 112 ASTON 88 LASS 12 ESTABROOKS 78 ASPK (π) DOCUMENT ID TECN TERAGE ASTON 84B LASS LAUSCHER 75 HBC DEHM 74 DBC AGUILAR 71B HBC BASSANO 67 HBC BADIER 65C HBC DOCUMENT ID TECN TERAGE AGUILAR 71B HBC BASSOMPIE 69 HBC DOCUMENT ID TECN TERAGE AGUILAR 71B HBC BASSOMPIE 69 HBC DOCUMENT ID TECN TERAGE AGUILAR 71B HBC BASSOMPIE 69 HBC	TERAGE 12 ASTON 88 LASS 0 12 ESTABROOKS 78 ASPK ± (π) DOCUMENT ID TECN CHG TERAGE ASTON 848 LASS 0 LAUSCHER 75 HBC 0 DEHM 74 DBC 0 AGUILAR 718 HBC BASSANO 67 HBC -0 BADIER 65C HBC - DOCUMENT ID TECN CHG TERAGE AGUILAR 718 HBC BASSOMPIE 69 HBC 0 DOCUMENT ID TECN CHG TERAGE AGUILAR 718 HBC BASSOMPIE 69 HBC 0

AGUILAR-... 718 HBC

67 HBC -0 4.6,5.0 K-p

65c HBC -

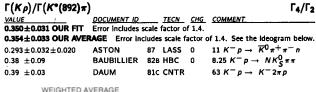
BASSANO

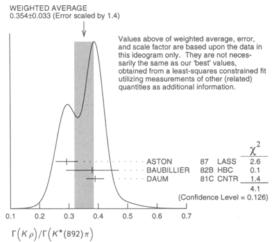
BADIER

0.16 ±0.05

0.14 ±0.10

0.14 ±0.07





Γ(Kω)/Γ(K*(8	92) x)	DOCUMENT	ın	TECN	cuc	COM	MENT	Γ ₅ /Γ
0.118±0.034 OUR 0.10 ±0.04	FIT	FIELD		нвс	-	3.8		
Γ(<i>Kη</i>)/Γ(<i>K</i> *(89	32)π)	DOCUMENT	ID	<u>TECN</u>	<u>CHG</u>	<u>COM</u> !	MENT	Γ ₇ /Γ
0.006 ^{+0.014} _{-0.004} OUR	FIT	Error Includ	des scale	factor	of 1.2.			
0.07 ±0.04		FIELD	67	HBC	-	3.8 <i>F</i>	(p	
Γ(Kη)/Γ(Kπ) VALUE	<u>cl%</u>		MENT ID	1	<u>recn</u>	<u>CHG</u>	COMMENT	Γ ₇ /Γ
0.0030 +0.0068	OUR I	T Error	includes	scale fa	ctor of	1.3.		
0 ±0.0056	se the	13 ASTO		88B L		 imits.	11 K - p - etc. • • •	→ K ⁻ ηρ
<0.04 <0.065 <0.02	95	_	LAR OMPIE.	71B H 69 H	łВС		3.9,4.6 K ⁻ 5.0 K ⁺ p 3.5 K ⁺ p	- р
Γ(K*(892)ππ)/ VALUE 0.134±0.022 OUR 0.12 ±0.04	FIT	<i>DOCUMENT</i> GOLDBER		TECN HBC	<u>сн</u> _	<u>сом</u> 3 К	MENT -p → pK	Γ ₃ /
$\Gamma(K^{+}(892)\pi\pi)/VALUE = 0.27\pm0.05 \text{ OUR FINAL OUR } 0.21\pm0.08$	т Т	r) <u>DOCUMENT</u> JONGEJAI		<i>TECN</i> HBC	CHG.		MENT - p → pK	Γ 3 /Γ
Γ(Κωπ)/Γ _{total}								Га/
VALUE (units 10-3)	CL%	EVTS	DOCUM	ENT ID		TECN_	COMMENT	
<0.72	95	0	JONGE	JANS	78 I	HBC	4 K ⁻ p -	→ pK ⁰ 4π
12 From phase shi 13 ASTON 88B querror in order to 14 Restated by us	ote < o be a	0.0092 at C	In our co	onstrain	ed fit.			ue and 1 sign

15 Assuming $\pi\pi$ system has isospin 1, which is supported by the data.

K2(1430) REFERENCES

BIRD 89	SLAC-332	(SLAC)
ASTON 88	NP B296 493	+Awaji, Bienz, Bird+ (SLAC, NAGO, CINC, INUS)
ASTON 88B	PL 8201 169	+Awaji, Bienz+ (SLAC, NAGO, CINC, INUS)
ASTON 87	NP B292 693	+Awaji, D'Amore+ (SLAC, NAGO, CINC, INUS)
CARLSMITH 87	PR D36 3502	+Bernstein, Bock, Coupal, Peyaud, Turlay+ (EFI, SACL)
ASTON 84B	NP B247 261	+Carnegie, Dunwoodie+ (SLAC, CARL, OTTA)
BAUBILLIER 84B	ZPHY C26 37	+ (BIRM, CERN, GLAS, MICH, CURIN)
BAUBILLIER 82B	NP B202 21	+ (BIRM, CERN, GLAS, MSU, CURIN)
CIHANGIR 82	PL 117B 123	+Berg, Biel, Chandlee+ (FNAL, MINN, ROCH)
CLELAND 82	NP B208 189	+Delfosse, Dorsaz, Gloor (DURH, GEVA, LAUS, PITT)
ASTON 810	PL 106B 235	+Carnegie, Dunwoodie+ (SLAC, CARL, OTTA) JP
DAUM 81C	NP B187 1	+Hertzberger+ (AMST, CERN, CRAC, MPIM, OXF+)
TOAFF 81	PR D23 1500	+Musgrave, Ammar, Davis, Ecklund+ (ANL, KANS)
ETKIN 80	PR D22 42	+Foley, Lindenbaum, Kramer+ (BNL, CUNY) JP
ESTABROOKS 78	NP B133 490	+Carnegie+ (MCGI, CARL, DURH, SLAC)
Also 78B	PR D17 658	Estabrooks, Carnegie+ (MCGI, CARL, DURH+)
JONGEJANS 78	NP B139 383	+Cerrada+ (ZEEM, CERN, NIJM, OXF)
MARTIN 78	NP B134 392	+Shimada, Baldi, Bohringer+ (DURH, GEVA)
BOWLER 77	NP B126 31	+Dainton, Drake, Williams (OXF)
GOLDBERG 76	LNC 17 253	(HAIF)
HENDRICK 76	NP B112 189	+Vignaud, Burlaud+ (MONS, SACL, PARIS, BELG)
LAUSCHER 75	NP B86 189	+Otter, Wieczorek+ (ABCLV Collab.) JP
MCCUBBIN 75	NP B86 13	+Lyons (OXF)
DEHM 74	NP B75 47	+Goebel, Wittek+ (MPIM, BRUX, MONS, CERN)
LINGLIN 73	NP B55 408	(CERN)
AGUILAR 718	PR D4 2583	Aguilar-Benitez, Eisner, Kinson (BNL)
BARNHAM 710		+Colley, Jobes, Griffiths, Hughes+ (BIRM, GLAS)
CORDS 71	PR D4 1974	+Carmony, Erwin, Meiere+ (PURD, UCD, IUPU)
BASSOMPIE 69	NP B13 189	Bassompierre+ (CERN, BRUX) JP
BISHOP 69	NP B9 403	+Goshaw, Erwin, Walker (WISC)
CRENNELL 69D		+Karshon, Lai, O'Neall, Scarr (BNL)
DAVIS 69	PRL 23 1071	+Derenzo, Flatte, Garnjost, Lynch, Solmitz (LRL)
LIND 69	NP B14 1	+Alexander, Firestone, Fu, Goldhaber (LRL) JP
SCHWEING 68	PR 166 1317	Schweingruber, Derrick, Fields+ (ANL, NWES)
Also 67	Thesis	Schweingruber (NWES, NWES)
BASSANO 67	PRL 19 968	+Goldberg, Goz, Barnes, Leitner+ (BNL, SYRA)
FIELD 67		+Hendricks, Piccioni, Yager (UCSD)
BADIER 650	PL 19 612	+Demoulin, Goldberg+ (EPOL, SACL, AMST)

- OTHER RELATED PAPERS ----

ATKINSON BAUBILLIER	86 82B	ZPHY C30 521 NP B202 21	+ (BONN, CERN, GLAS, LANC, M	
			+ (BIRM, CERN, GLAS	
CHUNG	65	PRL 15 325	+Dahl, Hardy, Hess, Jacobs, Kirz	(LRL)
FOCARDI	65	PL 16 351	+Ranzi, Serra+	(BGNA, SACL)
HAQUE	65	PL 14 338	Hague+	
HARDY	65	PRL 14 401	+Chung, Dahl, Hess, Kirz, Miller	(LRL)

K(1460)

 $I(J^P) = \frac{1}{2}(0^-)$

OMITTED FROM SUMMARY TABLE Observed in $K\pi\pi$ partial-wave analysis.

K(1460) MASS

VALUE (MeV)	DOCUMENT ID	TECN	CHG	COMMENT
• • • We do not	use the following data for	averages,	fits, li	mits, etc. • • •
~ 1460	DAUM 8:	ic CNTR	_	63 K ⁻ ρ → K ⁻ 2πρ
				$13 K^{\pm} p \rightarrow K^{+} 2\pi p$

K(1460) WIDTH

VALUE (MeV)	DOCUMENT ID	TECN	CHG	COMMENT
• • • We do not	use the following data f	or averages,	fits, li	mits, etc. • • •
~ 260				$63~K^-p \rightarrow ~K^-2\pi p$
~ 250	² BRANDENB	76B ASPK	±	$13 K^{\pm} p \rightarrow K^{+} 2\pi p$
² Coupled main	y to <i>K f</i> ₀ (1370). Decay	Into K*(89	2)π se	en.

K(1460) DECAY MODES

	Mode	Fraction (Γ_I/Γ)	
Γ1	K*(892)π	seen	
Γ_2	Kρ	seen	
Γ_3	$K_0^*(1430)\pi$	seen	
	-		

K(1460) PARTIAL WIDTHS

Γ(K*(892)	. ,	DOCUME	NT ID 7	TECN .	COMMENT		Г
		use the following				tc. • • •	·····
~ 109		DAUM	81c (NTR	63 K ⁻ p →	$K^{-}2\pi p$	
Γ(Κρ)		Dogung	WT 10		COLUMNIT		Г2
VALUE (MeV)		DOCUME				<u> </u>	
	io noi	use the following	•	•			
~ 34		DAUM	81C (INTR	63 K ⁻ p →	K ⁻ 2π p	
Γ(K ₀ (143	0) a))					Γa
VALUE (MeV)		DOCUME	NT ID 1	TECN	COMMENT		
• • • We d	o not	use the following	g data for ave	erages,	fits, limits, e	tc. • • •	
~ 117		DAUM	81c (INTR	63 K ⁺ p →	K ⁻ 2π p	
		K	(1460) REF	ERE	NCES		
DAUM		NP B187 1			(AMST, CER		
BRANDENB	76B	PRL 36 1239	Brandenb	urg, Car	negie, Cashmore	:+	(SLAC) JP
		отн	IER RELAT	ED P	APERS -		
BARNES	82	PL B116 365 PL 116B 198	+Close				(RHEL) (BIEL)
TANIMOTO	82						

 $K_2(1580)$

 $I(J^P) = \tfrac12(2^-)$

OMITTED FROM SUMMARY TABLE

Seen in partial-wave analysis of the $K^-\pi^+\pi^-$ system. Needs confirmation.

K2(1580) MASS

VALUE (MeV)	DOCUMENT ID	CHG	COMMENT
• • • We do not use th	e following data fo	r average	s, fits, limits, etc. • •
1500	OTTED 7	<u>-</u> ۵۰	10 14 16 KT n

K₂(1580) WIDTH

VALUE (MeV)	DOCUMENT I	D CHG	COMMENT	
• • • We do not us	se the following da	ta for averag	es, fits, limits, etc. • • •	
~ 110	OTTER	79 -	10,14,16 K ⁻ p	

K2(1580) DECAY MODES

	Mode	Fraction (Γ_I/Γ)
Γ1		seen
Γ_2	$K_2^*(1430)\pi$	possibly seen

K2(1580) BRANCHING RATIOS

K-(15)	RO) R	FFFRF	NCES		
OTTER	79	нвс	-	10,14,16 K ⁻ p	
total Document II		TECN	<u>CHG</u>	COMMENT	Γ2/Γ
ntal <u>DOCUMENT II</u> OTTER					Γ1/Γ
	DOCUMENT II OTTER total DOCUMENT II OTTER	DOCUMENT ID OTTER 79 total DOCUMENT ID OTTER 79	DOCUMENT ID TECN	DOCUMENT ID TECN CHG OTTER 79 HBC - total DOCUMENT ID TECN CHG OTTER 79 HBC -	DOCUMENT ID TECN CHG COMMENT OTTER 79 HBC — 10,14,16 K ⁻ p NOTALI DOCUMENT ID TECN CHG COMMENT

OTTER 79 NP B147 1

+Rudolph+

(AACH3, BERL, CERN, LOIC, WIEN) JP

 $K_1(1650)$, $K^*(1680)$, $K_2(1770)$

 $K_1(1650)$

$$I(J^P) = \frac{1}{2}(1^+)$$

OMITTED FROM SUMMARY TABLE

This entry contains various peaks in strange meson systems ($K^+\phi$, $K\pi\pi$) reported in partial-wave analysis in the 1600–1900 mass region.

K1(1650) MASS

VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT
1650±50	FRAME	86	OMEG	+	13 $K^+p \rightarrow \phi K^+p$
• • • We do not use the	following data	for a	verages,	fits, li	mits, etc. • • •
~ 1840	ARMSTRONG	83	OMEG	-	$18.5 K^- p \rightarrow 3Kp$
~ 1800	DAUM	81 C	CNTR	-	$63~K^-~p~\rightarrow~K^-~2\pi~p$

K1(1650) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT
150±50	FRAME	86	OMEG	+	13 $K^+p \rightarrow \phi K^+p$
• • • We do not use the	e following data	for a	verages,	fits, li	mits, etc. • • •
~ 250	DAUM	81 C	CNTR	-	63 $K^-p \rightarrow K^-2\pi p$

K1(1650) DECAY MODES

	Mode			 	
Γ ₁	Κππ		_		
Γ2	$K\phi$	•			

K₁(1650) REFERENCES

FRAME ARMSTRONG	86 83		B276 B221		+Hughes, Lynch, N +	(BARI, BIRM, CERN, MILA	(GLAS)
DAUM	81C	NΡ	B187	1	+Hertzberger+	(AMST, CERN, CRAC, MP	IM, OXF+)
	_	_					

K*(1680)

MALLIE (MAN)

$$I(J^P) = \frac{1}{2}(1^-)$$

K*(1680) MASS

MALDE (MEV)	DOCUMENT ID		TECH	CHO	COMMENT
1717±27 OUR AVER	AGE Error incl	udes	scale fa	ctor of	1.4.
1677±10±32	ASTON	88	LASS	0	$11 K^- p \rightarrow K^- \pi^+ n$
$1735 \pm 10 \pm 20$	ASTON	87	LASS	0	11 $K^-p \rightarrow \overline{K}^0\pi^+\pi^-n$
• • • We do not use th	e following data	for a	verages,	fits, li	mits, etc. • • •
1678±64	BIRD	89	LASS	_	11 $K^- p \rightarrow \overline{K}^0 \pi^- p$
1800 ± 70	ETKIN	80	MPS	0	$6 K^- \rho \rightarrow \overline{K}^0 \pi^+ \pi^- n$
~ 1650	ESTABROOKS	78	ASPK	0	13 $K^{\pm}p \rightarrow K^{\pm}\pi^{\pm}n$

K*(1680) WIDTH

DOCUMENT ID		TECN	CHG	COMMENT
GE Error include	es so	ale facto	or of 4	.2.
ASTON	88	LASS	0	$11 K^- p \rightarrow K^- \pi^+ n$
ASTON	87	LASS	0	11 $K^-p \rightarrow \overline{K}^0\pi^+\pi^-\pi$
e following data	for a	averages,	fits, li	imits, etc. • • •
BIRD	89	LASS	_	11 $K^- \rho \rightarrow \overline{K}^0 \pi^- \rho$
ETKIN	80	MP\$	0	$ \begin{array}{ccc} 6 & K^- p \rightarrow \overline{K}^0 \pi^+ \pi^- n \\ 13 & K^{\pm} p \rightarrow K^{\pm} \pi^{\pm} n \end{array} $
ESTABROOKS	78	ASPK	0	13 $K^{\pm} \rho \rightarrow K^{\pm} \pi^{\pm} n$
	GE Error include ASTON ASTON ne following data BIRD ETKIN	GE Error Includes so ASTON 88 ASTON 87 ne following data for a BIRD 89 ETKIN 80	GE Error includes scale factor ASTON 88 LASS ASTON 87 LASS ne following data for averages, BIRD 89 LASS ETKIN 80 MPS	GE Error includes scale factor of 4. ASTON 88 LASS 0 ASTON 87 LASS 0 ne following data for averages, flts, fl BIRD 89 LASS —

K*(1680) DECAY MODES

	Mode	Fraction (Γ_I/Γ)
Γ ₁	Κπ	(38.7 ± 2.5) %
Γ_2	Κρ	$(31.4^{+4.7}_{-2.1})\%$
Γ3	$K^*(892)\pi$	(29.9 ^{+2.2}) %

CONSTRAINED FIT INFORMATION

An overall fit to 4 branching ratios uses 4 measurements and one constraint to determine 3 parameters. The overall fit has a $\chi^2=2.9$ for 2 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\langle \delta x_i \delta x_j \rangle / (\delta x_i \cdot \delta x_j)$, in percent, from the fit to the branching fractions, $x_i \equiv \Gamma_i / \Gamma_{\text{total}}$. The fit constrains the x_i whose labels appear in this array to sum to one

K*(1680) BRANCHING RATIOS

	(5555) -					
Γ(Kπ)/Γ _{total}	DOCUMENT ID	_	<u>TECN</u>	CHG_	COMMENT	Γ1/Γ
0.387±0.026 OUR FIT 0.388±0.014±0.022	ASTON	88	LASS	0	11 K ⁻ p →	K-π+n
Γ(<i>K</i> π)/Γ(<i>K</i> °(892)π) DOCUMENT ID		<u>TECN</u>	<u>CHG</u>	COMMENT	Γ ₁ /Γ ₃
1.30 ^{+0.23} OUR FIT 2.8 ±1.1	ASTON	84	LASS	0	11 K~p →	K ⁰ 2π π
$\Gamma(K\rho)/\Gamma(K\pi)$ VALUE	DOCUMENT ID		TECN	снс	COMMENT	Γ_2/Γ_1
0.81 ^{+0.14} _{-0.09} OUR FIT	ASTON			_	11 K ⁻ p →	₽02~-
Γ(Κρ)/Γ(Κ*(892)π)			-	,	Γ ₂ /Γ ₃
1.05+0.27 OUR FIT	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT	
$0.97 \pm 0.09 ^{f +0.30}_{f -0.10}$	ASTON	87	LASS	0	11 K ⁻ p →	$\overline{K}^0\pi^+\pi^-n$

K*(1680) REFERENCES

BIRD	89	SLAC-332		(SLAC)
ASTON	88	NP B296 493	+Awaji, Bienz, Bird+	(SLAC, NAGO, CINC, INUS)
ASTON	87	NP B292 693	+Awaji, D'Amore+	(SLAC, NAGO, CINC, INUS)
ASTON	84	PL 149B 258	+Carnegie, Dunwoodie+	(SLAC, CARL, OTTA) JP
ETKIN	BO	PR D22 42	+Foley, Lindenbaum, Kramer-	+ (BNL, CUNY) JP
ESTABROOKS	78	NP B133 490	+Carnegie+	(MCGI, CARL, DURH, SLAC) JP



$$I(J^P) = \frac{1}{2}(2^-)$$

THE $K_2(1770)$ AND THE $K_2(1820)$

A partial-wave analysis of the $K^-\omega$ system based on about 100,000 $K^-p\to K^-\omega p$ events (ASTON 93) gives evidence for two $q\bar{q}$ D-wave states near 1.8 GeV. A previous analysis based on about 200,000 diffractively produced $K^-p\to K^-\pi^+\pi^-p$ events (DAUM 81) gave evidence for two $J^P=2^-$ states in this region, with masses \sim 1780 MeV and \sim 1840 MeV and widths \sim 200 MeV, in good agreement with the results of ASTON 93. In contrast, the masses obtained using a single resonance do not agree well: ASTON 93 obtains 1728 \pm 7 MeV, while DAUM 81 estimates \sim 1820 MeV. We conclude that there are indeed two K_2 resonances here.

We list under the $K_2(1770)$ other measurements that do not resolve the two-resonance structure of the enhancement.

		K ₂ (1770)	MA	SS		
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
1773± 8		¹ ASTON	93	LASS		$11K^-p \rightarrow K^-\omega p$
• • We do not	t use the fol	llowing data for ave	rages	s, fits, lic	nits, e	tc. • • •
1810±20		FRAME	86	OMEG	+	13 $K^+ p \rightarrow \phi K^+ p$
~ 1730		ARMSTRONG	83	OMEG	_	$18.5 K^- p \rightarrow 3Kp$
~ 1780		² DAUM	81c	CNTR	_	$63 K^- p \rightarrow K^- 2\pi p$
1710±15	60	CHUNG	74	нвс	-	7.3 $K^-p \rightarrow K^-\omega p$
1767 ± 6		BLIEDEN	72	MMS	_	11-16 K ⁻ p
1730 ± 20	306	3 FIRESTONE	72B	DBC	+	12 K+ d
1765 ± 40		4 COLLEY	71	нвс	+	$10 K^+ p \rightarrow K 2\pi N$
1740		DENEGRI	71	DBC	_	$12.6 \ K^- d \rightarrow \overline{K} 2\pi d$
1745 ± 20		AGUILAR	70C	HBC	_	4.6 K ⁻ p
		D 4 D T C C 1 1	70-	HBC	-	10.1 K ⁻ p
1780±15		BARTSCH	10C	1100		
1760±15 1 From a partla 2 From a partla 3 Produced in	al wave anal conjunction	LUDLAM lysis of the $K^-\omega$ sy lysis of the $K^-2\pi$ s with excited deuter correspond to sprea	70 stem yster on. d of	HBC n. different	 t fits.	12.6 K ⁻ p
1760±15 1 From a partla 2 From a partla 3 Produced in	al wave anal conjunction	LUDLAM lysis of the $K^-\omega$ sylysis of the $K^-2\pi$ swith excited deuter correspond to sprea $K_2(1770)$	70 stem yster on. d of	HBC n. different	t fits.	12.6 К ⁻ р
1760±15 1 From a partia 2 From a partia 3 Produced in 4 Systematic e	al wave anal conjunction	LUDLAM lysis of the $K^-\omega$ sy lysis of the $K^-2\pi$ s with excited deuter correspond to sprea $K_2(1770)$ V	stem yster on. d of	HBC different TH		12.6 K - p
1760±15 1 From a partiz 2 From a partiz 3 Produced in 4 Systematic e	al wave anal conjunction rrors added 	LUDLAM lysis of the $K^-\omega$ sy lysis of the $K^-2\pi$ so with excited deuter correspond to sprea $K_2(1770)$ V DOCUMENT ID 5 ASTON	70 stem yster on. d of VID	HBC i. m. different TH TECN LASS	fits.	$\frac{COMMENT}{11K^{-}p \rightarrow K^{-}\omega p}$
1760±15 1 From a partiz 2 From a partiz 3 Produced in 4 Systematic en WALUE (MeV) 186±14	al wave anal conjunction rrors added 	LUDLAM lysis of the $K^-\omega$ sy lysis of the $K^-2\pi$ s with excited deuter correspond to sprea $K_2(1770)$ V	70 stem yster on. d of VID	HBC i. m. different TH TECN LASS	fits.	12.6 K^-p COMMENT 11 $K^-p \to K^-\omega p$ etc. • •
1760±15 1 From a partiz 2 From a partiz 3 Produced in 4 Systematic en WALUE (MeV) 186±14	al wave anal conjunction rrors added 	LUDLAM lysis of the $K^-\omega$ sy lysis of the $K^-2\pi$ so with excited deuter correspond to sprea $K_2(1770)$ V DOCUMENT ID 5 ASTON	70 stem yster on. d of VID	HBC i. m. different TH TECN LASS	CHG mits, e	$\frac{COMMENT}{11K^{-}p \rightarrow K^{-}\omega p}$
1760±15 1 From a partic 2 From a partic 3 Produced In 4 Systematic elements 186±14 • • • We do no 140±40	al wave anal conjunction rrors added 	LUDLAM lysis of the K-\overline{\text{w}} sy lysis of the K-\overline{\text{w}} sy with excited deuter correspond to sprea \(\begin{align*} \lambda_2 (1770) \ \text{V} \\ \text{DOCUMENT ID} \\ 5 \text{ASTON} \\ \text{Illowing data for ave}	70 stem yster on. d of VID 93 rages	TH TECN LASS s, fits, ili OMEG	CHG mlts, e	$\frac{COMMENT}{11K^{-}p \rightarrow K^{-}\omega p}$ etc. • • • $13 K^{+}p \rightarrow \phi K^{+}p$ $18.5 K^{-}p \rightarrow 3Kp$
1760±15 1 From a partla 2 From a partla 3 Produced In 4 Systematic e WALUE (MeV) 186±14 • • • We do no 140±40 ~ 220	al wave anal conjunction rrors added 	LUDLAM lysis of the $K^-\omega$ sy lysis of the $K^-2\pi$ s with excited deuter correspond to sprea $ \frac{K_2(1770)}{5} \frac{V}{ASTON} $ llowing data for ave FRAME	70 sstem ystem on. d of VID 93 rages 86 83	TH TECN LASS s, fits, ili OMEG	CHG mlts, e	$ \begin{array}{c} \underline{COMMENT} \\ 11K^{-}p \rightarrow K^{-}\omega p \\ \text{tc.} \bullet \bullet \\ 13 K^{+}p \rightarrow \phi K^{+}p \\ 18.5 K^{-}p \rightarrow 3Kp \\ 63 K^{-}p \rightarrow K^{-}2\pi p \end{array} $
1760±15 1 From a partla 2 From a partla 3 Produced In 4 Systematic e WALUE (MeV) 186±14 • • • We do no 140±40 ~ 220	al wave anal conjunction rrors added 	LUDLAM lysis of the $K^-\omega$ sy lysis of the $K^-2\pi$ s with excited deuter correspond to sprea K2(1770) V DOCUMENT ID 5 ASTON Illowing data for ave FRAME ARMSTRONG	70 stem yyster on. d of VID 93 rages 86 83 81c	TH TECN LASS s, fits, ili OMEG	CHG mlts, e	$\frac{COMMENT}{11K^{-}p \rightarrow K^{-}\omega p}$ etc. • • • $13 K^{+}p \rightarrow \phi K^{+}p$ $18.5 K^{-}p \rightarrow 3Kp$
1760±15 1 From a partla 2 From a partla 3 Produced In 4 Systematic e LALUE (MeV) 186±14 • • We do no 140±40 ~ 220 ~ 210	al wave anal conjunction rrors added	LUDLAM lysis of the $K^-\omega$ sy lysis of the $K^-2\pi$ s with excited deuter correspond to sprea K2(1770) V DOCUMENT ID 5 ASTON Illowing data for ave FRAME ARMSTRONG 6 DAUM CHUNG BLIEDEN	70 stemmyster on. d of VID 93 rages 86 83 81C 74	TH TECN LASS s, fits, ili OMEG OMEG CNTR	CHG mlts, e	$\begin{array}{c} \underline{COMMENT} \\ 11K^-p \rightarrow K^-\omega p \\ \text{tt.} \bullet \bullet \bullet \\ 13K^+p \rightarrow \phi K^+p \\ 18.5K^-p \rightarrow 3Kp \\ 63K^-p \rightarrow K^-2\pi p \\ 7.3K^-p \rightarrow K^-\omega p \\ 11-16K^-p \end{array}$
1760±15 1 From a partla 2 From a partla 3 Produced In 4 Systematic e 186±14 • • • We do no 140±40 ~ 220 ~ 210 110±50 100±26 210±30	al wave anal conjunction rrors added	LUDLAM Lysis of the K = \omega system Lysis of the K = 2\pi system Lysis of the Ly	70 stem yyster on. d of VID 93 rages 86 83 81c 74 72 72B	HBC II. different TH TECN LASS s, fits, ili OMEG CNTR HBC MMS DBC	CHG mits, e	$\frac{COMMENT}{11K^{-}p \rightarrow K^{-}\omega p}$ etc. • • • $13 K^{+}p \rightarrow \phi K^{+}p$ $18.5 K^{-}p \rightarrow 3Kp$ $63 K^{-}p \rightarrow K^{-}2\pi p$ $7.3 K^{-}p \rightarrow K^{-}\omega p$ $11-16 K^{-}p$ $12 K^{+}d$
1760±15 1 From a partla 2 From a partla 3 Produced In 4 Systematic el 186±14 • • • We do no 140±40 ~ 220 ~ 210 110±50 100±26 210±30 90±70	al wave anal conjunction rrors added	LUDLAM All systs of the $K^-\omega$ sy lysts of the $K^-2\pi$ s with excited deuter correspond to sprea **Example 10 **DOCUMENT ID **DOCUMENT	70 stem yyster on. d of VID 93 rages 86 83 81c 74 72 72B 71	HBC II. different TH TECN LASS s, fits, ili OMEG OMEG CNTR HBC MMS DBC HBC	CHG mits, e + + + +	$ \frac{COMMENT}{11K^-p \rightarrow K^-\omega p} $ $ 12.6 K^-p \rightarrow K^-\omega p $ $ 13 K^+p \rightarrow \phi K^+p $ $ 13 K^-p \rightarrow 3Kp $ $ 13 K^-p \rightarrow K^-2\pi p $ $ 13 K^-p \rightarrow K^-\omega p $ $ 11-16 K^-p $ $ 12 K^+d $ $ 10 K^+p \rightarrow K2\pi N $
1760±15 1 From a partic 2 From a partic 3 Produced in 4 Systematic e 186±14 • • • We do not 140±40 • • 220 • 210 110±50 100±26 210±30 90±70 130	al wave anal conjunction rrors added	LUDLAM lysis of the K w sy lysis of the K z n sy with excited deuter correspond to sprea K2(1770) V DOCUMENT ID 5 ASTON Illowing data for ave FRAME ARMSTRONG 6 DAUM CHUNG BLIEDEN 7 FIRESTONE 8 COLLEY DENEGRI	70 stem yyster on. d of VID 93 rages 86 83 81C 72 72B 71 71	TH TECN LASS s, fits, ili OMEG CNTR HBC MMS DBC HBC DBC	CHG mlts, e	$ \frac{COMMENT}{11K^{-}p \to K^{-}\omega p} $ 12.6 K $\to \bullet$ \bullet 13 K $^{+}p \to \phi K^{+}p$ 18.5 K $^{-}p \to 3Kp$ 7.3 K $^{-}p \to K^{-}2\pi p$ 7.1 K $^{-}p \to K^{-}\omega p$ 11-16 K ^{-}p 10 K $^{+}p \to K2\pi N$ 12.6 K $^{-}d \to \overline{K}2\pi d$
1760±15 1 From a partic 2 From a partic 3 Produced in 4 Systematic e WALUE (MeV) 186±14 • • • We do not 140±40 × 220 × 210 110±50 100±26 210±30 90±70 130 100±50	al wave anal conjunction rrors added	LUDLAM lysis of the K = \(\omega \) sy of the K = \(\omega \) to sprea \[\begin{align*} \text{\$DOCUMENT ID} \\ 5 \text{ ASTON} \\ \text{Illowing data for ave} \\ FRAME \\ ARMSTRONG \\ 6 \text{ DAUM} \\ CHUNG \\ BLIEDEN \\ 7 \text{ FIRESTONE} \\ 8 \text{ COLLEY} \\ DENEGRI \\ AGUILAR \end{align*}	70 stem yster on. d of VID 93 rages 86 83 81c 72 72B 71 71 70c	TH TECN LASS s, fits, lir OMEG CNTR HBC MMS DBC HBC HBC HBC	CHG mits, e + + + +	12.6 K^-p $\frac{COMMENT}{11K^-p \to K^-\omega p}$ 12.6 $K^-p \to K^-\omega p$ 13. $K^+p \to \phi K^+p$ 18.5 $K^-p \to 3Kp$ 63 $K^-p \to K^-2\pi p$ 7.3 $K^-p \to K^-\omega p$ 11-16 K^-p 12 K^+d 10 $K^+p \to K2\pi N$ 12.6 $K^-d \to \overline{K}2\pi d$ 4.6 K^-p
1760±15 1 From a partic 2 From a partic 3 Produced in 4 Systematic e WALUE (MeV) 186±14 • • • We do not 140±40 • • 220 • 220 • 210 110±50 100±26 210±30 90±70 130	al wave anal conjunction rrors added	LUDLAM lysis of the K w sy lysis of the K z n sy with excited deuter correspond to sprea K2(1770) V DOCUMENT ID 5 ASTON Illowing data for ave FRAME ARMSTRONG 6 DAUM CHUNG BLIEDEN 7 FIRESTONE 8 COLLEY DENEGRI	70 stem yster on. d of VID 93 rages 86 83 81c 72 72B 71 71 70c	TH TECN LASS s, fits, ili OMEG CNTR HBC MMS DBC HBC DBC	CHG mits, e + + + -	$ \frac{COMMENT}{11K^{-}p \to K^{-}\omega p} $ 12.6 K $\to \bullet$ \bullet 13 K $^{+}p \to \phi K^{+}p$ 18.5 K $^{-}p \to 3Kp$ 7.3 K $^{-}p \to K^{-}2\pi p$ 7.1 K $^{-}p \to K^{-}\omega p$ 11-16 K ^{-}p 10 K $^{+}p \to K2\pi N$ 12.6 K $^{-}d \to \overline{K}2\pi d$

	K₂(1770) DECAY MODES								
	Mode	•	Fraction (Γ_I/Γ)						
Г1	Κππ								
Γ_2^-	$K_2^*(1430)\pi$		dominant						
Гз	$K^{*}(892)\pi$		seen						
Γ4	K f ₂ (1270)		seen						
Γ ₅	Κφ		seen						
Γ6	Κω		seen						

K2(1770) BRANCHING RATIOS

$\Gamma(K_2^*(1430)\pi)$						Γ_2/Γ_1
(K*(1430) - <u>VALUE</u>	→ Λπ) <u>DOCUMENT ID</u>		TECN	<u>CHG</u>	COMMENT	
• • • We do not	use the following data	for a	verages,	fits, li	mits, etc. • • •	
~ 0.03	DAUM	81 C	CNTR		63 K ⁻ p → K ⁻ 2π p	,
~ 1.0	⁹ FIRESTONE	72B	DBC	+	12 K ⁺ d	
<1.0	COLLEY	71	HBC		10 K ⁺ p	
0.2 ± 0.2	AGUILAR	70C	HBC	-	4.6 K ⁻ p	
<1.0	BARTSCH	70C	HBC	_	10.1 K - p	
1.0	BARBARO	69	HBC	+	12.0 K ⁺ p	
⁹ Produced in co	onjunction with excited	deut	eron.			
Γ(Κ*(892)π)/Ι	(K = *)					Γ_3/Γ_1
VALUE	DOCUMENT ID		TECN	соми	MENT	, .
	use the following data	for a	verages,	fits, il	mits, etc. • • •	-
~ 0.23	DAUM	8 1c	CNTR	63 K	$-p \rightarrow K^-2\pi p$	
Γ (Κ ½(1270)) / (½(1270) –	Γ(Κππ) • ππ)					Γ_4/Γ_1
VALUE	DOCUMENT ID		TECN	COMA	MENT	
• • • We do not	use the following data	for a	verages,	fits, II	mits, etc. • • •	
~ 0.74	DAUM	81C	CNTR	63 K	$-p \rightarrow K^{-}2\pi p$	
F/VA\/F :						Γ ₅ /Γ
'(Λ'Ψ)/'total						
Γ(Κφ)/Γ _{total}	DOCUMENT ID		TECN	CHG	COMMENT	

Γ(Κω)/Γ _{total}						Γ_6/Γ
VALUE	DOCUMENT ID		TECN	CHG	COMMENT	
seen	OTTER	81	HBC	±	8.25,10,16 K [±] p	
seen	CHUNG	74	HBC	-	7.3 $K^-p \rightarrow K^-\omega p$	

K₂(1770) REFERENCES

ASTON FRAME ARMSTRONG DAUM OTTER CHUNG	93 86 83 81C 81 74	PL B308 186 NP B276 667 NP B221 1 NP B187 1 NP B181 1 PL 51B 413	+ Bienz, Bird+ + Hughes, Lynch, Minto, McFadzean+ - (GLAS) + (BARI, BIRM, CERN, MILA, CURIN+) + Hertzberger+ (AMST, CERN, CRAC, MPIM, OXF+) (AACH3, BERL, LOIC, VIEN, BIRM, BELG, CERN+) + Elsner, Protopopesus, Samios, Strand (BNL)
BLIEDEN	72	PL 39B 668	+Finocchiaro, Bowen, Earles+ (STON, NEAS)
FIRESTONE	72B	PR D5 505	+Goldhaber, Lissauer, Trilling (LBL)
COLLEY	71	NP B26 71	+Jobes, Kenyon, Pathak, Hughes+ (BIRM, GLAS)
DENEGRI	71	NP B28 13	+Antich, Callahan, Carson, Chien, Cox+ (JHU) JP
AGUILAR	70C	PRL 25 54	Aguilar-Benitez, Barnes, Bassano, Chung+ (BNL)
BARTSCH	70C	PL 33B 186	+Deutschmann+ (AACH, BERL, CERN, LOIC, VIEN)
LUDLAM	70	PR D2 1234	+Sandweiss, Slaughter (YALE)
BARBARO	69	PRL 22 1207	Barbaro-Galtieri, Davis, Flatte+ (LRL)

- OTHER RELATED PAPERS -

BERLINGHIER	67	PRL 18 1087	+Farber, Ferbel, Forman	(ROCH) I
CARMONY	67	PRL 18 615	+Hendricks, Lander	(UCSD)
JOBES	67	PL 26B 49	+Bassompierre, DeBaere+	(BIRM, CERN, BRUX)
BARTSCH	66	PL 22 357	+Deutschmann+	(AACH, BERL, CERN+)

 $K_3^*(1780)$

 $I(J^P) = \frac{1}{2}(3^-)$

K3(1780) MASS

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	I CHG	COMMENT
1776± 7 OUR A					COMMENT
	MEKAGE	Error includes scale			
1781 ± 8 ± 4		1 ASTON	88 LAS	5 0	$11 K^- p \rightarrow K^- \pi^+ n$
$1740 \pm 14 \pm 15$		1 ASTON	87 LAS:	S 0	11 K p →
					$\overline{K}^0\pi^+\pi^-n$
1779±11		² BALDI	76 SPE	c +	$10 K^+ p \rightarrow K^0 \pi^+ p$
1776 ± 26		3 BRANDENB	. 760 ASP	K 0	$13 K^{\pm} p \rightarrow K^{\pm} \pi^{\mp} N$
• • • We do not	use the fol	lowing data for ave	rages, fits,	limits,	etc. • • •
		4 BIRD			v- E0 -
$1720 \pm 10 \pm 15$	6111		89 LAS	_	11 $K^- \rho \rightarrow \overline{K}^0 \pi^- \rho$
1749 ± 10		ASTON	88B LAS	S –	11 $K^-p \rightarrow K^-\eta p$
1780± 9	300	BAUBILLIER	84B HBC	: -	8.25 K ⁻ p →
					$\overline{K}^0\pi^-p$
1790±15		BAUBILLIER	828 HBC	0	8.25 K ⁻ p →
					$K_{S}^{0} 2\pi N$
1784 ± 9	2060	CLELAND	82 SPE	c ±	$50 K^{+} p \rightarrow K_{5}^{0} \pi^{\pm} p$
1786 ± 15		⁵ ASTON	81D LAS	5 0	$11 K^- p \rightarrow K^- \pi^+ \eta$
1762± 9	100	TOAFF			$6.5 K^- p \rightarrow \overline{K}{}^0 \pi^- p$
	190				
1850 ± 50		ETKIN	80 MPS	0	$6 K^- p \rightarrow \overline{K}^0 \pi^+ \pi^-$
1812 ± 28		BEUSCH	78 OM1	ĒG	10 K ⁻ p →
					$\overline{K}^0\pi^+\pi^-n$
1786 ± 8		CHUNG	78 MPS	. 0	$6 K^- p \rightarrow K^- \pi^+ n$

 1 From energy-independent partial-wave analysis. 2 From a fit to Y_{6}^{2} moment. $J^{P}=3^{-}$ found. 2

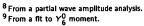
K₃(1780) WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
159±21 OUR			le fa		_	e the ideogram below.
203±30± 8	•	6 ASTON	88	LASS	0	$11 K^- p \rightarrow K^- \pi^+ n$
$171 \pm 42 \pm 20$		6 ASTON	87	LASS	0	11 K ⁻ p →
		7				$ \begin{array}{c} K^0\pi^+\pi^-n\\ 10K^+\rho\to K^0\pi^+\rho \end{array} $
135 ± 22		⁷ BALDI		SPEC		
	use the foll	lowing data for ave	rages	s, fits, lir	nits, e	tc. • • •
187±31±20	6111	8 BIRD	89	LASS	_	11 $K^-p \rightarrow \overline{K}^0\pi^-p$
193 ⁺⁵¹		ASTON	888	LASS	-	11 $K^- \rho \rightarrow K^- \eta \rho$
99±30	300	BAUBILLIER	84B	нвс	_	8.25 K ⁻ p →
						$\mathcal{R}^0\pi^-p$
~ 130		BAUBILLIER	828	HBC	0	8.25 K ⁻ p →
						$K_{\xi}^{0} 2\pi N$
191 ± 24	2060	CLELAND	82	SPEC	±	$50 K^{+}p \rightarrow K_{S}^{0}\pi^{\pm}p$
225 ± 60		9 ASTON	810	LASS	0	11 $K^-p \rightarrow K^-\pi^+n$
~ 80	190	TOAFF	81	HBC	-	$6.5 K^- p \rightarrow \overline{K}^0 \pi^- p$
240 ± 50		ETKIN	80	MPS	0	$6 K^- p \rightarrow \overline{K}^0 \pi^+ \pi^-$
181 ± 44		¹⁰ BEUSCH	78	OMEG		10 K ⁻ p →
						$\overline{K}^0\pi^+\pi^-n$
96 ± 31	,	CHUNG	78	MPS	0	$6 K^- p \rightarrow K^- \pi^+ n$
270±70		11 BRANDENB	760	ASPK	0	13 $K^{\pm} p \rightarrow K^{\pm} \pi^{\mp} N$

 $^{^6}$ From energy-independent partial-wave analysis. 7 From a fit to Y_6^2 moment. $J^P={\bf 3}^-$ found.

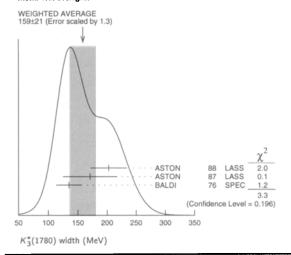
 $^{^3}$ Confirmed by phase shift analysis of ESTABROOKS 78, yields $J^P=3^-.$ 4 From a partial wave amplitude analysis. 5 From a fit to the Y_0^6 moment.

 $K_3^*(1780), K_2(1820)$



 10 Errors enlarged by us to $4\Gamma/\sqrt{N}$; see the note with the $K^*(892)$ mass.

11 ESTABROOKS 78 find that BRANDENBURG 76D data are consistent with 175 MeV width. Not averaged.



K*(1780) DECAY MODES

	Mode	Fraction (Γ_I/Γ)	Confidence level
Γ ₁	Κρ	(31 ± 9)%	
Γ_2	$K^*(892)\pi$	(20 ± 5)%	
Γ3	Κπ	(18.8± 1.0) %	
Γ_4	$K\eta$	(30 ±13)%	
Γ ₅	$K_2^*(1430)\pi$	< 16 %	95%

CONSTRAINED FIT INFORMATION

An overall fit to 3 branching ratios uses 4 measurements and one constraint to determine 4 parameters. The overall fit has a $\chi^2=$ 0.0 for 1 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\langle \delta x_i \delta x_j \rangle / (\delta x_i \cdot \delta x_j)$, in percent, from the fit to the branching fractions, $x_i \equiv$ Γ_i/Γ_{total} . The fit constrains the x_i whose labels appear in this array to sum to one.

K*(1780) BRANCHING RATIOS

	J. /					
$\Gamma(K\rho)/\Gamma(K^*(892)\pi)$						Γ_1/Γ_2
YALUE	DOCUMENT ID		TECN	CHG.	COMMENT	
1.52±0.23 OUR FIT 1.52±0.21±0.10	ASTON	87	LASS	0	11 K ⁻ ρ → K̄ ⁰ π ⁺ π	- n
$\Gamma(K^*(892)\pi)/\Gamma(K\pi)$	١					Γ_2/Γ_3
VALUE 1.09±0.26 OUR FIT	DOCUMENT ID		<u>TECN</u>	<u>CHG</u>		
1.09±0.26	ASTON	84B	LASS	0	$11 \ K^- \rho \rightarrow \ \overline{K}{}^0 2\pi n$	
$\Gamma(K\pi)/\Gamma_{\text{total}}$						Γ_3/Γ
VALUE	DOCUMENT ID		TECN	CHG	COMMENT	
0.188±0.010 OUR FIT						
0.188±0.010 OUR AVER	RAGE					
$0.187 \pm 0.008 \pm 0.008$	ASTON	88	LASS	0	11 $K^-p \rightarrow K^-\pi^+n$	
0.19 ± 0.02	ESTABROOKS	78	ASPK	0	13 $K^{\pm} \rho \rightarrow K \pi N$	
$\Gamma(K\eta)/\Gamma(K\pi)$						Γ4/Γ3
VALUE	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT	
1.6 ±0.7 OUR FIT						
• • • We do not use the	-		_			
0.41±0.050 12	BIRD	89	LASS	-	11 $K^-p \rightarrow \overline{K}^0\pi^-p$	
0.50 ± 0.18	ASTON	888	LASS	-	11 $K^-p \rightarrow K^-\eta p$	
12 This result supersede	s ASTON 88B.					

$\Gamma(K_2^*(1430)\pi)/\Gamma(K^*(892)\pi)$							Γ_5/Γ_2
VALUE	CL%	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT	
<0.78	95	ASTON	87	LASS	0	11 K ⁻ p →	
						$\overline{K}^0\pi^+\pi^-\pi$	

K₃(1780) REFERENCES

		2		
BIRD	89	SLAC-332	(SLAC)	
ASTON	88	NP B296 493	+Awaji, Bienz, Bird+ (SLAC, NAGO, CINC, INUS)	
ASTON	888	PL B201 169	+Awaji, Bienz+ (SLAC, NAGO, CINC, INUS) JP	
ASTON	87	NP B292 693	+Awaji, D'Amore+ (SLAC, NAGO, CINC, INUS)	
ASTON	84B	NP B247 261	+Carnegie, Dunwoodle+ (SLAC, CARL, OTTA)	
BAUBILLIER	84B	ZPHY C26 37	+ (BIRM, CERN, GLAS, MICH, CURIN)	
BAUBILLIER	82B	NP B202 21	 (BIRM, CERN, GLAS, MSU, CURIN) 	
CLELAND	82	NP B208 189	+Delfosse, Dorsaz, Gloor (DURH, GEVA, LAUS, PITT)	
ASTON	81D	PL 99B 502	+Dunwoodie, Durkin, Fieguth+ (SLAC, CARL, OTTA) JP	
TOAFF	81	PR D23 1500	+Musgrave, Ammar, Davis, Ecklund+ (ANL, KANS)	
ETKIN	80	PR D22 42	+Foley, Lindenbaum, Kramer+ (BNL, CUNY) JP	
BEUSCH	78	PL 74B 282	+Birman, Konigs, Otter+ (CERN, AACH3, ETH) JP	
CHUNG	78	PRL 40 355	+Etkin+ (BNL, BRAN, CUNY, MASA, PENN) JP	
ESTABROOKS	78	NP B133 490	+Carnegie+ (MCGI, CARL, DURH, SLAC) JP	
Also	78B	PR D17 658	Estabrooks, Carnegie+ (MCGI, CARL, DURH+)	
BALDI	76	PL 63B 344	+Boehringer, Dorsaz, Hungerbuhler+ (GEVA) JP	
BRANDENB	76D	PL 60B 478	Brandenburg, Carnegle, Cashmore+ (SLAC) JP	

OTHER RELATED PAPERS

WALUCH 73 PR CARMONY 71 PRI	L 30 672 Aguilar-Benitez, (D8 2837 +Flatte, Friedman L 27 1160 +Cords, Clopp, En 36B 513 +Goldhaber, Lissau	(LBL) rin, Meiere+ (PURD, UCD, IUPU)
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$K_2(1820)$

$$I(J^P) = \frac{1}{2}(2^-)$$

Observed by ASTON 93 from a partial wave analysis of the $K^-\omega$ system. See mini-review under $K_2(1770)$.

K2(1820) MASS

CUMENT ID	TECN	COMMENT
		$ \begin{array}{cccccccccccccccccccccccccccccccccccc$
		TON 93 LASS

 $^{^{1}\,\}text{Fron a partial wave analysis of the }\textit{K}^{-}\,\omega$ system.

K2(1820) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
276±35	3 ASTON	93	LASS	$11K^-p \rightarrow K^-\omega p$
~ 230	⁴ DAUM	810	CNTR	$63~K^-p\to~K^-2\pi p$

 $^{^3}$ From a partial wave analysis of the $K^-\omega$ system.

K2(1820) DECAY MODES

	Mode	Fraction (Γ_I/Γ)		
$\overline{\Gamma_1}$	Κππ			
Γ2	$K_2^*(1430)\pi$	seen		
	$K^*(892)\pi$	seen	•	
Γ_4	K f ₂ (1270)	seen		
Γ ₅	Κω	seen		

K2(1820) BRANCHING RATIOS

$\Gamma(K_2^*(1430)\pi)/\Gamma(K\pi\pi)$					Γ_2/Γ_1
VALUE	DOCUMENT ID	- 614-	TECN	COMMENT	
• • We do not use the following	•				
~ 0.77	DAUM	81C	CNTR	63K ⁻ p →	K2πp
$\Gamma(K^*(892)\pi)/\Gamma(K\pi\pi)$	DOCUMENT ID		TECH	COMMENT	Γ_3/Γ_1
VALUE	DOCUMENT ID			COMMENT	
• • We do not use the following	ng data for average				
~ 0.05	DAUM	81 C	CNTR	63K ⁻ p →	Κ 2π <i>p</i>
$\Gamma(Kf_2(1270))/\Gamma(K\pi\pi)$					Γ_4/Γ_1
VALUE	DOCUMENT ID		TECN_	COMMENT	
• • • We do not use the followi	ng data for average	s, fits	i, limits,	etc. • • •	
~ 0.18	DAUM	810	CNTR	63K ⁻ p →	Κ 2π <i>p</i>
K	2(1820) REFER	ENC	ES		

ASTON	93	PL B308 186	+Bienz, Bird+	(SLAC, NAGO, CINC, INUS)
DAUM	81C	NP B187 1	+Hertzberger+	(AMST, CERN, CRAC, MPIM, OXF+)

 $^{^2}$ From a partial wave analysis of the $K^-2\pi$ system.

⁴ From a partial wave analysis of the $K^-2\pi$ system.

K(1830)

 $I(J^P) = \frac{1}{2}(0^-)$

OMITTED FROM SUMMARY TABLE

Seen in partial-wave analysis of $K^-\phi$ system. Needs confirmation.

K(1830) MASS

VALUE (MeV)	DOCUMENT ID TECH	N CHG COMMENT
• • • We do not use the	following data for averag	ges, fits, limitś, etc. • • •
~ 1830	ARMSTRONG 83 OM	EG - 18.5 K ⁻ p → 3Kp

K(1830) WIDTH

VALUE (MeV)	DOCUMENT ID	TECN	CHG	COMMENT
• • • We do not use th	e following data for a	verages,	fits, II	mits, etc. • • •
~ 250	ARMSTRONG 83	OMEG	-	$18.5~K^-~p~\rightarrow~3K~p$

K(1830) DECAY MODES

	Mode	 	
Γ_1	Κφ		

K(1830) REFERENCES

ARMSTRONG 83 NP B221 1

(BARI, BIRM, CERN, MILA, CURIN+) JP

 $K_0^*(1950)$

 $I(J^P) = \frac{1}{2}(0^+)$

OMITTED FROM SUMMARY TABLE

Seen in partial-wave analysis of the $K^-\pi^+$ system. Needs confir-

K*(1950) MASS

VALUE (MeV)	DOCUMENT ID	TECN	CHG	COMMENT
1945±10±20	¹ ASTON	88 LASS	0	$11 K^- p \rightarrow K^- \pi^+ n$
• • • We do not use	the following data	for average	, fits, l	imits, etc. • • •
1820±40	² ANISOVICH	97c RVUE	:	11 $K^-p \rightarrow K^-\pi^+n$
¹ We take the centra ² T-matrix pole. Rea	il value of the two analysis of ASTON	solutions a N 88 data.	nd the I	arger error given.

K₀*(1950) WIDTH

VALUE (MeV)	DOCUMENT ID		ECN	<u>CHG</u>	COMMENT
201± 34±79	³ ASTON	88 L	ASS	0	11 $K^-p \rightarrow K^-\pi^+\pi$
• • • We do not	use the following data	for ave	rages,	fits, li	mits, etc. • • •
250±100	⁴ ANISOVICH	97c R	RVUE		$11 K^- p \rightarrow K^- \pi^+ n$
³ We take the	central value of the two	solutio	ns and	the la	arger error given.
4					

⁴ T-matrix pole. Reanalysis of ASTON 88 data.

K*(1950) DECAY MODES

	Mode	Fraction (Γ_I/Γ)
Γ ₁	Κπ	(52±14) %

K*(1950) BRANCHING RATIOS

$\Gamma(K\pi)/\Gamma_{\text{total}}$						Г1/Г	
VALUE	DOCUMENT ID	1	TECN	CHG	COMMENT		
$0.52 \pm 0.08 \pm 0.12$	5 ASTON	88	LASS	0	11 $K^-p \rightarrow K^-\pi^+n$		
⁵ We take the central value of the two solutions and the larger error given.							

K*(1950) REFERENCES

ANISOVICH	97C	PL B413 137		
ASTON	88	NP B296 493	+Awaji, Bienz, Bird+	(SLAC, NAGO, CINC, INUS

 $I(J^P) = \frac{1}{2}(2^+)$

OMITTED FROM SUMMARY TABLE

Needs confirmation.

K2(1980) MASS

VALUE (MeV)	EVTS	DOCUMENT IL		TECN	CHG	COMMENT
1973± 8±25		ASTON	87	LASS	0	11 K ⁻ p →
• • • We do r	ot use the follo	wing data for a	verages	s, fits, li	mits, e	$K^0\pi^+\pi^-n$
1978±40	241± 47	BIRD	89	LASS	-	$11 \ K^- p \rightarrow \ \overline{K}{}^0 \pi^- p$

K2 (1980) WIDTH

VALUE (MeV)	EVTS	DOCUMENT I	<u> </u>	TECN	CHG	COMMENT
373±33±60		ASTON	87	LASS	0	11 K ⁻ p →
• • • We do	not use the foll	owing data for a	-			$\overline{K}^{0}\pi^{+}\pi^{-}n$ etc. • • • $11 K^{-}p \to \overline{K}^{0}\pi^{-}p$
	47					

K2 (1980) DECAY MODES

 Mode
K*(892)π Κρ

K2(1980) BRANCHING RATIOS

$\Gamma(K\rho)/\Gamma(K^*(892)\pi$	·)				Γ ₂ /Γ ₁	
VALUE	DOCUMENT ID		TECN	CHG	COMMENT	
1.49±0.24±0.09	ASTON	87	LASS	0	11 $K^- p \rightarrow \overline{K}^0 \pi^+ \pi^- n$	

K*(1980) REFERENCES

BIRD	89	SLAC-332	+Awaji, D'Amore+	(SLAC)
ASTON	87	NP B292 693		(SLAC, NAGO, CINC, INUS)
_				

K₄(2045)

 $I(J^P) = \frac{1}{2}(4^+)$

K4(2045) MASS

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
2045± 9 OUR A	WERAGE	Error includes sca	ile fa	ctor of 1	.1.	
2062 ± 14 ± 13		1 ASTON	86	LASS	0	11 $K^- p \rightarrow K^- \pi^+ n$
2039± 10	400	^{2,3} CLELAND	82	SPEC	±	$50 K^+ p \rightarrow K_5^0 \pi^{\pm} p$
2070 + 100 - 40		⁴ ASTON	810	LASS	0	11 $K^-p \rightarrow K^-\pi^+n$
• • • We do not	use the fo	llowing data for ave	erage	s, fits, lle	mits, e	tc. • • •
2079± 7	431	TORRES	86	MPSF		400 pA → 4KX
2088 ± 20	650	BAUBILLIER	82	нвс	-	8.25 K ⁻ p →
						K _S π−p
2115 ± 46	488	CARMONY	77	HBC	0	$9 K^+ d \rightarrow K^+ \pi' s X$
¹ From a fit to a	il momen	ts.				

From a fit to 8 moments.

Number of events evaluated by us.

⁴ From energy-independent partial-wave analysis.

K4(2045) WIDTH

VALUE (MeV)	EVTS ERAGE	DOCUMENT ID		TECN	CHG	COMMENT
221 ± 48 ± 27 189 ± 35	400	⁵ ASTON ^{6,7} CLELAND		LASS SPEC		11 $K^- p \to K^- \pi^+ n$ 50 $K^+ p \to K^0 \pi^{\pm} p$
	use the fo	llowing data for ave				
61 ± 58	431	TORRES	86	MPSF		400 pA → 4KX
170 ^{+ 100} - 50	650	BAUBILLIER	82	нвс		$\begin{array}{c} 8.25 \ K^- p \rightarrow \\ K^0_5 \pi^- p \end{array}$
240 + 500 100		8 ASTON	81C	LASS	0	11 $K^- p \rightarrow K^- \pi^+ n$
300 ± 200		CARMONY	77	нвс	0	$9 K^+ d \rightarrow K^+ \pi' s X$

From a fit to all moments.
 From a fit to 8 moments.
 Number of events evaluated by us.

⁸ From energy-independent partial-wave analysis.

 $K_4^*(2045), K_2(2250), K_3(2320)$

K*(2045)	DECAY	MODES
----------	-------	-------

	Mode	Fraction (Γ _I /Γ)	
Γ ₁	Κπ	(9.9±1.2) %	1
Γ_2	$K^*(892)\pi\pi$	(9 ±5)%	
Гз	$K^*(892) \pi \pi \pi$	(7 ±5)%	
Γ4	ρΚπ	(5.7±3.2) %	
Γ ₅	$\omega K\pi$	(5.0±3.0) %	
Γ6	$\phi K \pi$	(2.8±1.4) %	
Γ_7	φK*(892)	$(1.4\pm0.7)\%$	

K₄(2045) BRANCHING RATIOS

$\Gamma(K\pi)/\Gamma_{\text{total}}$					Γ1/Γ
VALUE	DOCUMENT ID		TECN	CHG	COMMENT
0.099±0.012	ASTON	88	LASS	0	$11 \ K^- p \rightarrow K^- \pi^+ n$
$\Gamma(K^*(892)\pi\pi)/\Gamma($	(Kπ)				Γ_2/Γ_1
VALUE	DOCUMENT ID		TECN	CHG	COMMENT
0.89±0.53	BAUBILLIER	82	нвс	-	$8.25 K^- p \rightarrow p K_S^0 3\pi$
Γ(Κ*(892)πππ)/	Γ(Κπ)				Γ ₃ /Γ ₁
VALUE	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT
0.75±0.49	BAUBILLIER	82	нвс	-	$8.25 \ K^- p \rightarrow p K_S^0 3\pi$
$\Gamma(\rho K\pi)/\Gamma(K\pi)$					Γ ₄ /Γ ₁
VALUE	DOCUMENT ID		<u>TECN</u>		COMMENT
0.58±0.32	BAUBILLIER	82	нвс	-	$8.25 K^- p \rightarrow p K_S^0 3\pi$
$\Gamma(\omega K\pi)/\Gamma(K\pi)$					Γ ₅ /Γ ₁
VALUE	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT
0.50±0.30	BAUBILLIER	82	HBC	-	$8.25 K^- \rho \rightarrow \rho K_5^0 3\pi$
$\Gamma(\phi K\pi)/\Gamma_{\text{total}}$					Γ ₆ /Γ
VALUE	DOCUMENT ID			COM	
0.028±0.014	9 TORRES	86	MPSF	400 £	PA → 4KX
$\Gamma(\phi K^{\circ}(892))/\Gamma_{tot}$					Γ₇/ Γ
VALUE	DOCUMENT ID			COM	
0.014 ± 0.007	9 TORRES	86	MPSF	400 £	OA → 4KX
⁹ Error determination	on is model depende	ent.			

K*(2045) REFERENCES

ASTON	88	NP B296 493	+Awaji, Bienz, Bird+ (SLAC, NAGO, CINC, INUS)
ASTON	86	PL B180 308	+Awaji, D'Amore+ (SLAC, NAGO, CINC, INUS)
TORRES	86	PR 34 707	+Lai+ (VPI, ARIZ, FNAL, FSU, NDAM, TUFTS+)
BAUBILLIER	82	PL 118B 447	+Burns+ (BIRM, CERN, GLAS, MSU, CURIN)
CLELAND	82	NP B208 189	+Delfosse, Dorsaz, Gloor (DURH, GEVA, LAUS, PITT) +Carnegie, Dunwoodie+ (SLAC, CARL, OTTA) JI +Clopp, Lander, Meiere, Yen+ (PURD, UCD, IUPU)
ASTON	81C	PL 106B 235	
CARMONY	77	PR D16 1251	
		оті	HER RELATED PAPERS
ASTON BROMBERG CARMONY	87 80 71	NP B292 693 PR D22 1513 PRL 27 1160	+Awaji, D'Amore+ +Haggerty, Abrams, Dzierba +Cords, Clopp, Erwin, Meiere+ (PURD, UCD, IUPU)

 $K_2(2250)$

 $I(J^P) = \frac{1}{2}(2^-)$

OMITTED FROM SUMMARY TABLE

This entry contains various peaks in strange meson systems reported in the 2150–2260 MeV region, as well as enhancements seen in the antihyperon-nucleon system, either in the mass spectra or in the $J^P = 2^-$ wave.

K2(2250) MASS

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
2247±17 OUR /	AVERAGE					
2200 ± 40						18 $K^-p \rightarrow \Lambda \overline{p} X$
2235 ± 50		1 BAUBILLIER	81	HBC		$8 K^- p \rightarrow \Lambda \overline{p} X$
2260±20		¹ CLELAND	81	SPEC	±	$50 K^+ p \rightarrow \Lambda \overline{p} X$
● ● ● We do no	t use the fol	lowing data for ave	rage	s, fits, lir	nits, e	tc. • • •
2147± 4	37	CHLIAPNIK	79	нвс	+	32 $K^+p \rightarrow \overline{\Lambda}pX$
2240 ± 20	20	LISSAUER	70	HBC		9 K ⁺ p
$^{1}J^{P}=2^{-}$ fro	m moments	analysis.				

K2(2250) WIDTH

VALUE (MeV)	<u>EVTS</u>	DOCUMENT ID		TECN	CHG	COMMENT
180±30 OUR	AVERAGE	Error includes scal	le fac	tor of 1	4.	
150±30		² ARMSTRONG	83C	OMEG	_	18 K p → Λ p X
210±30		² CLELAND	81	SPEC	±	50 K+p → ApX
• • • We do not	use the folio	owing data for ave	rages	i, fits, lir	nits, ei	tc. • • •
~ 200		² BAUBILLIER				
~ 40	37	CHLIAPNIK	79	HBC	+	32 $K^+ p \rightarrow \overline{\Lambda} p X$
80 ± 20	20	LISSAUER	70	HBC		9 K+p
$^{2}J^{P}=2^{-}$ from	m moments	analysis.				

K2(2250) DECAY MODES

	Mode			
Γ ₁ Γ ₂	Kππ pΛ		, 	

K₂(2250) REFERENCES

OTHER RELATED PAPERS

ALEXANDER	68B	PRL 20 755	+Firestone, Goldhaber, Shen	(LRL)
	_			



 $I(J^P) = \frac{1}{2}(3^+)$

OMITTED FROM SUMMARY TABLE Seen in the $J^P=3^+$ wave of the antihyperon-nucleon system. Needs confirmation.

K3(2320) MASS

VALUE (MeV)	DOCUMENT ID	_	TECN	<u>CHG</u>	COMMENT	
2324±24 OUR AVE	RAGE					
2330 ± 40	¹ ARMSTRONG				18 $K^-p \rightarrow$	
2320±30	¹ CLELAND	81	SPEC	±	$50 K^+ p \rightarrow$	ΛĒΧ
$^{1}J^{P}=3^{+}$ from n	noments analysis.				,	

K₃(2320) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	CHG	COMMENT	
150±30	² ARMSTRONG	830	OMEG	_	18 K ⁻ p →	ΛīρΧ
• • • We do not	use the following data	for a	verages,	fits, li	mits, etc. • •	•
~ 250	² CLELAND	81	SPEC	±	50 K+p →	ΛPX
$^2J^P=3^+$ from	n moments analysis.					

K₃(2320) DECAY MODES

	Mode				
$\overline{\Gamma_1}$	pλ				_
			 	 	_

K₃(2320) REFERENCES

ARMSTRONG (NP B227 NP B184	(BARI, , Martin+	MILA, CURIN+) A, LAUS, DURH)
	_			

	$I(J^P) = \frac{1}{2}(5^-)$ OM SUMMARY TABLE	
Needs co	onfirmation.	
######################################	K ₅ (2380) MASS DOCUMENT ID TECN CHG COMMENT	
MLUE (MeV) 382±14±19	¹ ASTON 86 LASS 0 $11 K^- \rho \rightarrow K^- \pi^+ n$	
¹ From a fit to a	all the moments.	
	K ₅ *(2380) WIDTH	
ALUE (MeV)	DOCUMENT ID TECN CHG COMMENT	
78±37±32 ² From a fit to a	² ASTON 86 LASS 0 11 $K^-p \rightarrow K^-\pi^+n$ all the moments.	
	K ₅ (2380) DECAY MODES	
Mode	Fraction (Γ_i/Γ)	
'1 Κπ	(6.1±1.2) %	
	K ₅ (2380) BRANCHING RATIOS	
$\Gamma(K\pi)/\Gamma_{\text{total}}$	•	Γ1/
ALUE 0.061±0.012	DOCUMENT ID TECN CHG COMMENT ASTON 88 LASS 0 11 $K^-p \rightarrow K^-\pi^+n$	
1.061 ± 0.012	ASTON 88 LASS 0 11 $K^-p \rightarrow K^-\pi^+n$	
	K ₅ (2380) REFERENCES	
STON 88 STON 86	NP B296 493 +Awaji, Bienz, Bird+ (SLAC, NAGO, CINC, INI PL B180 308 +Awaji, D'Amore+ (SLAC, NAGO, CINC, INI	US) US)
$K_4(2500)$	$I(J^P) = \frac{1}{2}(4^-)$ TOM SUMMARY TABLE	
Needs c	onfirmation.	
	K4(2500) MASS	
	4()	
	DOCUMENT ID TECN CHG COMMENT	
490±20	DOCUMENT ID TECN CHG COMMENT	
2490±20		
2490 ± 20 1 JP = 4 - froi		
${}^{1}J^{P} = 4^{-} \text{ froi}$ ${}^{VALUE} \text{ (MeV)}$ •• • We do not	$\frac{DOCUMENT\ ID}{1\ CLELAND} \qquad \frac{TECN}{81\ SPEC} \qquad \frac{CHG}{\pm} \qquad \frac{COMMENT}{50\ K^+ p \to \Lambda \overline{p}}$ m moments analysis. $ \frac{K_4(2500)\ WIDTH}{DOCUMENT\ ID} \qquad \frac{TECN}{100\ CHG} \qquad \frac{COMMENT}{100\ COMMENT} $ use the following data for averages, fits, limits, etc. • • •	
$1J^P = 4^- \text{ froi}$ ALUE (MeV) • • • We do not ~ 250	$\frac{DOCUMENT\ ID}{1\ CLELAND} \qquad 81 SPEC \pm \qquad 50\ K^+p \rightarrow \Lambda \overline{p}$ m moments analysis.	
$1J^P = 4^- \text{ froi}$ ALUE (MeV) • • • We do not ~ 250	TECN CHG COMMENT 1 CLELAND 81 SPEC \pm 50 $K^+p \rightarrow \Lambda \overline{p}$ m moments analysis. K4(2500) WIDTH DOCUMENT ID TECN CHG COMMENT 1 use the following data for averages, fits, limits, etc. • • • • 2 CLELAND 81 SPEC \pm 50 $K^+p \rightarrow \Lambda \overline{p}$ m moments analysis.	
$1 J^P = 4^- \text{ froi}$ $VALUE \text{ (MeV)}$ • • • We do not $ 250$ $2 J^P = 4^- \text{ froi}$	$\frac{DOCUMENT\ ID}{1\ CLELAND} \qquad 81 SPEC \pm \qquad 50\ K^+p \rightarrow \Lambda \overline{p}$ m moments analysis.	
$1 J^P = 4^- froi$ $2 J^P = 4^- froi$ $4 J^P = 4^- froi$ $4 J^P = 4^- froi$ $2 J^P = 4^- froi$ $4 Mode$	TECN CHG COMMENT 1 CLELAND 81 SPEC \pm 50 $K^+p \rightarrow \Lambda \overline{p}$ m moments analysis. K4(2500) WIDTH DOCUMENT ID TECN CHG COMMENT 1 use the following data for averages, fits, limits, etc. • • • • 2 CLELAND 81 SPEC \pm 50 $K^+p \rightarrow \Lambda \overline{p}$ m moments analysis.	
$1 J^P = 4^- froi$ $2 J^P = 4^- froi$ $4 WALUE (MeV)$ $4 We do not$ $2 J^P = 4^- froi$ $4 Mode$	TECN CHG COMMENT 1 CLELAND 81 SPEC \pm 50 $K^+p \rightarrow \Lambda \overline{p}$ m moments analysis. K4(2500) WIDTH DOCUMENT ID TECN CHG COMMENT Use the following data for averages, fits, limits, etc. • • • • 2 CLELAND 81 SPEC \pm 50 $K^+p \rightarrow \Lambda \overline{p}$ m moments analysis. K4(2500) DECAY MODES	
$\begin{array}{c} {}^{2}490\pm20 \\ {}^{1}J^{P}=4^{-} \text{ froi} \\ \\ {}^{4}MLUE \text{ (MeV)} \\ {\bullet} \bullet \bullet \text{ We do not} \\ {}^{2}J^{P}=4^{-} \text{ froi} \\ \\ \\ \text{Mode} \end{array}$	TECN CHG COMMENT 1 CLELAND 81 SPEC \pm 50 $K^+p \rightarrow \Lambda \overline{p}$ m moments analysis. K4(2500) WIDTH DOCUMENT ID TECN CHG COMMENT 1 use the following data for averages, fits, limits, etc. • • • • 2 CLELAND 81 SPEC \pm 50 $K^+p \rightarrow \Lambda \overline{p}$ m moments analysis.	RH)

and in np and nA reactions by ALEEV 93. Not seen by BOEHN-LEIN 91. If due to strong decays, this state has exotic quantum numbers (B=0,Q=+1,S=-1 for $\varLambda \overline{p}\pi^+\pi^+$ and $I \geq 3/2$ for $\varLambda \overline{p}\pi^-$).

Needs confirmation.

	K(3100) MA	SS		
VALUE (MeV) ≈ 3100 OUR ESTIMATE	DOCUMENT ID			
3-BODY DECAYS	DOCUMENT ID		TECN	COMMENT
3054±11 OUR AVERAGE	1 ALEEV	0.3	DICO	K(2100) . 45-+
3060 ± 7±20 3056 ± 7±20	1 ALEEV	93 93	BIS2 BIS2	$K(3100) \rightarrow \Lambda \overline{p} \pi^+$ $K(3100) \rightarrow \overline{\Lambda} p \pi^-$
3055± 8±20	1 ALEEV	93	BIS2	$K(3100) \rightarrow \Lambda \bar{p} \pi^-$
3045± 8±20	1 ALEEV	93	BIS2	$K(3100) \rightarrow \overline{\Lambda} p \pi^+$
4-BODY DECAYS	71222	,,	0.02	(0100)
VALUE (MeV) 3059±11 OUR AVERAGE	DOCUMENT ID		<u>TECN</u>	COMMENT
3067± 6±20	1 ALEEV	93	BIS2	$K(3100) \rightarrow \Lambda \overline{p} \pi^+ \pi^+$
3060 ± 8 ± 20	1 ALEEV	93	BIS2	$K(3100) \rightarrow \Lambda \overline{p} \pi^+ \pi^-$
3055 ± 7±20	1 ALEEV	93	BIS2	$K(3100) \rightarrow \overline{\Lambda} p \pi^- \pi^-$
3052± 8±20 • • • We do not use the following	¹ ALEEV	93 es fit		$K(3100) \rightarrow \overline{\Lambda}p\pi^{-}\pi^{+}$
			SPEC	$K(3100) \rightarrow \Lambda \overline{\rho} \pi^+ \pi^+$
3105±30 3115±30	BOURQUIN BOURQUIN	86 86	SPEC	$K(3100) \rightarrow \Lambda \overline{p} \pi^+ \pi^-$ $K(3100) \rightarrow \Lambda \overline{p} \pi^+ \pi^-$
5-BODY DECAYS VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
• • We do not use the following				
3095±30	BOURQUIN		SPEC	$K(3100) \rightarrow \Lambda \overline{p} \pi^+ \pi^+ \pi^-$
¹ Supersedes ALEEV 90.				
	K(3100) WIE	тн		
3-BODY DECAYS VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following	ng data for averag	es, fit	s, limits	, etc. • • •
42±16	² ALEEV	93	BIS2	$K(3100) \rightarrow \Lambda \overline{p} \pi^+$
36±15	² ALEEV	93	BIS2	$K(3100) \rightarrow \overline{\Lambda} p \pi^-$
50±18	² ALEEV	93	BIS2	$K(3100) \rightarrow \Lambda \overline{p} \pi^-$
30±15	² ALEEV	93	BIS2	$K(3100) \rightarrow \overline{\Lambda} p \pi^+$
4-BODY DECAYS VALUE (MeV) CL%	DOCUMENT ID			
• • We do not use the following		es, fit	s, limits	, etc. • • •
22± 8	² ALEEV	93	BIS2	$K(3100) \rightarrow \Lambda \overline{p} \pi^+ \pi^+$
28±12	2 ALEEV	93		$K(3100) \rightarrow \Lambda \overline{p} \pi^+ \pi^-$
32±15	² ALEEV	93		$K(3100) \rightarrow \overline{\Lambda} p \pi^- \pi^-$
30±15	² ALEEV		BIS2	$K(3100) \rightarrow \overline{\Lambda}p\pi^{-}\pi^{+}$
<30 90 <80 90	BOURQUIN BOURQUIN	86 86		$K(3100) \rightarrow \Lambda \overline{p} \pi^+ \pi^+$ $K(3100) \rightarrow \Lambda \overline{p} \pi^+ \pi^-$
5-BODY DECAYS	BOOKQOIN	00	3, 50	N(3100) → Npii ii
• • • We do not use the follow	DOCUMENT ID			
<30 90	BOURQUIN		SPEC	K(3100) →
² Supersedes ALEEV 90.	,			$\Lambda \overline{\rho} \pi^{+} \pi^{+} \pi^{-}$
	(2100) DECAY		DE6	
	(3100) DECAY	MU	<i>-</i>	
Mode = +				
$\Gamma_1 K(3100)^0 \rightarrow \Lambda \overline{p} \pi^+$				
Γ_2 $K(3100)^{} \rightarrow \Lambda \bar{p} \pi$				
Γ_3 $K(3100)^- \rightarrow \Lambda \bar{p} \pi^+$				
Γ_4 $K(3100)^+ \rightarrow \Lambda \bar{p} \pi^+$				
$\Gamma_5 \qquad K(3100)^0 \rightarrow \Lambda \overline{p} \pi^+$				
$\frac{\Gamma_6 K(3100)^0 \rightarrow \Sigma(138)}{\Gamma_6}$	o) ' P			
Γ(Σ(1385)+β)/Γ(Λβπ+)				Γ ₆ /Γ
VALUE CL%	DOCUMENT IE		TECN	COMMENT
<0.04 90	ALEEV	93		$K(3100)^{0} \rightarrow \Sigma(1385)^{+} \overline{p}$
	K(3100) REFER	RENC	ES	
ALEEV 93 PAN 56 1358	+Balandin+			(BIS-2 Collab.)
Translated from NP B21 174 (su	ppl) +Chung+		(FLO	R, BNL, IND, RICE, MASD)
ALEEV 90 ZPHY C47 533 BOURQUIN 86 PL B172 113	+Arefiev, Balar +Brown+	ndin+ (GEV	A, RAL,	(BIS-2 Collab.) HEIDP, LAUS, BRIS, CERN)

Meson Particle Listings D MESONS, D^{\pm}

CHARMED MESONS

 $(C=\pm 1)$

 $D^+ = c\overline{d}$, $D^0 = c\overline{u}$, $\overline{D}{}^0 = \overline{c}u$, $D^- = \overline{c}d$, similarly for D^* 's

NOTE ON D MESONS

Written March 1998 by P.R. Burchat (Stanford University).

The new experimental results on charm meson decays reported in this edition are mostly from CLEO II at the e^+e^- storage ring CESR and from the Fermilab fixed-target experiments E687 and E791. A number of searches have been made for rare decays that are potentially sensitive to new physics, such as $D^0\overline{D}^0$ mixing (AITALA 96C and AITALA 98), CP-violating asymmetries in decay rates (AITALA 97B and AITALA 98C), and decays that would signal flavor-changing neutral currents (ADAMOVICH 97 and ALEXOPOULOS 97) or lepton-family number or lepton number violation (FRABETTI 97B). None of the searches has yielded evidence for new physics.

Significant progress has been made in the area of semileptonic charm decays. Five new results on rates for Cabibbo-suppressed semileptonic decays appear in this edition: $D^+ \to \rho \ell^+ \nu_\ell$ from E687 (FRABETTI 97) and E791 (AITALA 97), $D^0 \to \pi^- \ell^+ \nu_\ell$ from E687 (FRABETTI 96B), and $D^+ \to \pi^0 \ell^+ \nu_\ell$ and $\eta e^+ \nu_e$ from CLEO (BARTELT 97). Our knowledge of the inclusive semileptonic decay rate for the D^0 is greatly improved by new results from ARGUS (ALBRECHT 96C) and CLEO (KUBOTA 96B). The precision of the measurement of the form-factor ratios in the decay $D^+ \to \overline{K}^{*0} \ell^+ \nu_\ell$ has been improved by about a factor of two in a new analysis by E791 (AITALA 98B).

Many new studies of hadronic final states have been made, including measurements of singly and doubly Cabibbo-suppressed D^0 and D^+ decay rates and studies of resonant substructure.

New measurements of the \dot{D}_s^+ decay constant have been made by the L3 collaboration (ACCIARRI 97F) and the E653 collaboration (KODAMA 96). However, the statistical and systematic uncertainties are still on the order of (10–20)% each. Other new measurements on the D_s^+ front include two inclusive branching fractions by BES (BAI 97 and BAI 98), and the first observation of $D_s^+ \to \omega \pi^+$ by CLEO (BALEST 97).



$$I(J^P) = \frac{1}{2}(0^-)$$

D± MASS

The fit includes D^{\pm} , D^0 , D_s^{\pm} , $D^{*\pm}$, D^{*0} , and $D_s^{*\pm}$ mass and mass difference measurements.

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
1869.3± 0.5 OUR FIT			of 1.		
1869.4± 0.5 OUR AVE	RAGE				
1870.0 ± 0.5 ± 1.0	317	BARLAG	90c	ACCM	π Cu 230 GeV
1863 ± 4		DERRICK	84	HRS	e ⁺ e ⁻ 29 GeV
1869.4± 0.6		¹ TRILLING	81	RVUE	e ⁺ e ⁻ 3.77 GeV
• • • We do not use t	he followli	ng data for average:	s, fits	, limits,	etc. • • •
1875 ±10	9	ADAMOVICH	87	EMUL	Photoproduction
1860 ±16	6	ADAMOVICH	84	EMUL	Photoproduction
1868.4± 0.5		¹ SCHINDLER	81	MRK2	e ⁺ e ⁻ 3.77 GeV
1874 ± 5		GOLDHABER	77	MRK1	D^0 , D^+ recoil spectra
1868.3± 0.9		¹ PERUZZI	77	MRK1	e ⁺ e 3.77 GeV
1874 ±11		PICCOLO	77	MRK1	e ⁺ e ⁻ 4.03, 4.41 GeV
1876 + 15	50	PERUZZI	76	MRK1	$K^{\mp}\pi^{\pm}\pi^{\pm}$

 $^{\rm I}$ PERUZZI 77 and SCHINDLER 81 errors do not include the 0.13% uncertainty in the absolute SPEAR energy calibration. TRILLING 81 uses the high precision $J/\psi(15)$ and $\psi(2S)$ measurements of ZHOLENTZ 80 to determine this uncertainty and combines the PERUZZI 77 and SCHINDLER 81 results to obtain the value quoted.

D± MEAN LIFE

Measurements with an error $> 0.1 \times 10^{-12}$ s are omitted from the average, and those with an error $> 0.2 \times 10^{-12}$ s have been omitted from the listings.

VALUE (10-12 s)	EVTS	DOCUMENT ID	TECN	COMMENT
1.057±0.015 OUR AV	ERAGE			
$1.048 \pm 0.015 \pm 0.011$	9k	FRABETTI	94D E687	$D^+ \rightarrow K^- \pi^+ \pi^+$
$1.075 \pm 0.040 \pm 0.018$	2455	FRABETTI	91 E687	γ Be, $D^+ \rightarrow$
				γ , $D^+ \rightarrow K^- \pi^+ \pi^+$
$1.03 \pm 0.08 \pm 0.06$	200	ALVAREZ	90 NA14	γ , $D^+ \rightarrow K^- \pi^+ \pi^+$
$1.05 \begin{array}{l} +0.077 \\ -0.072 \end{array}$	317	² BARLAG	90c ACCM	π ⁻ Cu 230 GeV
1.05 ±0.08 ±0.07	363	ALBRECHT	88I ARG	e+ e- 10 GeV
$1.090 \pm 0.030 \pm 0.025$	2992	RAAB	88 E691	Photoproduction
• • • We do not use	the follow	ing data for average	es, fits, limit	s, etc. • • •
$1.12 \begin{array}{c} +0.14 \\ -0.11 \end{array}$	149	AGUILAR	87D HYBR	π^-p and pp
$1.09 \begin{array}{l} +0.19 \\ -0.15 \end{array}$	59	BARLAG	87B ACCM	K^- and π^- 200 GeV
$1.14 \pm 0.16 \pm 0.07$	247	CSORNA	87 CLEO	e+ e- 10 GeV
1.09 ±0.14	74	³ PALKA	87B SILI	π Be 200 GeV
$0.86 \pm 0.13 \begin{array}{l} +0.07 \\ -0.03 \end{array}$	48	ABE	86 HYBR	γ p 20 GeV

²BARLAG 90c estimates the systematic error to be negligible.

D+ DECAY MODES

Scale factor/

D⁻⁻ modes are charge conjugates of the modes below.

	Mode	Fraction (Γ ₁ /Γ)	Confidence level
		re modes	
Γ_1	e ⁺ anything	(17.2 ±1.9) %	
	K ⁻ anything	(24.2 ±2.8) %	S=1.4
	\overline{K}^0 anything $+K^0$ anything	(59 ±7)%	
Γ_4	K ⁺ anything	(5.8 ±1.4) %	
Γ_5	η anything	[a] < 13 %	CL=90%
Γ ₆	μ^+ anything		
	Leptonic and se	mileptonic modes	
Γ7	$\mu^+ u_\mu$	< 7.2 ×	10 ⁻⁴ CL=90%
Γe	$\overline{K}^0\ell^+\nu$	[b] (6.8 ±0.8)%	
Γ ₉	$\overline{K}^0 e^{\frac{1}{r}} \nu_e$	(6.7 ±0.9)%	
Γ ₁₀	$\overline{\mathcal{K}}{}^0\mu^+ u_\mu$	$(7.0 \ ^{+3.0}_{-2.0})\%$	
Γ_{11}	$K^-\pi^+e^+\nu_e$	$(4.1 \ ^{+0.9}_{-0.7})\%$	
Γ ₁₂	$\overline{K}^*(892)^0 e^+ \nu_e$	(3.2 ±0.33) %	
	\times B($\overline{K}^{*0} \rightarrow K^-\pi^+$)		
Γ ₁₃	$K^-\pi^+e^+\nu_e$ nonresonant	< 7 ×	10 ⁻³ CL=90%
	$K^-\pi^+\mu^+ u_\mu$	(3.2 ±0.4)%	S=1.1
	In the fit as $\frac{2}{3}\Gamma_{26} + \Gamma_{16}$, where	$\frac{2}{3}\Gamma_{26}=\Gamma_{15}.$	

³ PALKA 87B observes this in $D^+ \rightarrow \overline{K}^*(892) e\nu$.

```
\overline{K}^*(892)^0 \mu^+ \nu_{\mu}
Γ<sub>15</sub>
                                                                                  (2.9 \pm 0.4)\%
                                                                                                                                                            \Gamma_{66} \quad \overline{K}{}^0\pi^+\pi^+\pi^-\pi^0
                                                                                                                                                                                                                                              (5.4 + 3.0)\%
                   \times B(\overline{K}^{*0} \rightarrow K^-\pi^+)
                                                                                                                                                                      \overline{K}^{0}\pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}
                                                                                                                                                            Γ<sub>67</sub>
                                                                                                                                                                                                                                              (8 \pm 7) \times 10^{-4}
                \mathcal{K}^-\pi^+\mu^+
u_\mu nonresonant
Γ16
                                                                                  (2.7 \pm 1.1) \times 10^{-3}
                                                                                                                                                                       K^-\pi^+\pi^+\pi^+\pi^-\pi^0
                                                                                                                                                                                                                                              (2.0 \pm 1.8) \times 10^{-3}
                                                                                                                                                            Γ<sub>68</sub>
          \overline{K}{}^0\pi^+\pi^-e^+\nu_e
Γ17
                                                                                                                                                                       \overline{K}{}^{0}\overline{K}{}^{0}K^{+}
                                                                                                                                                                                                                                              (1.8 \pm 0.8)\%
           K^{-}\pi^{+}\pi^{0}e^{+}\nu_{e}
Γ<sub>18</sub>
          (\overline{K}^*(892)\pi)^0 e^+ \nu_e

(\overline{K}\pi\pi)^0 e^+ \nu_e non-\overline{K}^*(892)
Γ19
                                                                                < 1.2
                                                                                                                            CL=90%
                                                                                                                                                                          Fractions of some of the following modes with resonances have already
                                                                                                        \times 10^{-3}
                                                                               < 9
                                                                                                                            CL=:90%
                                                                                                                                                                          appeared above as submodes of particular charged-particle modes.
          K^-\pi^+\pi^0\mu^+\nu_{\mu}
                                                                                                        × 10<sup>-3</sup>
Γ21
                                                                                < 1.4
                                                                                                                            CL=90%
                                                                                                                                                                       \overline{K}{}^0 \rho^+
                                                                                                                                                                                                                                              (6.6 ± 2.5)%
\Gamma_{22} \quad \pi^0 \, \ell^+ \, \nu_\ell
                                                                          [c] ( 3.1 \pm 1.5 ) \times 10<sup>-3</sup>
                                                                                                                                                                       \overline{K}^{0}a_{1}(1260)^{+}
                                                                                                                                                            Γ71
                                                                                                                                                                                                                                             (8.0 \pm 1.7)\%
\Gamma_{23}^{-} \pi^{+}\pi^{-}e^{+}\nu_{e}
                                                                                                                                                                       \overline{K}^0 a_2(1320)^+
                                                                                                                                                            Γ<sub>72</sub>
                                                                                                                                                                                                                                           < 3
                                                                                                                                                                                                                                                                   \times 10^{-3}
                                                                                                                                                                                                                                                                                        CL=90%
                                                                                                                                                                       \overline{K}^*(892)^0\pi^+
                                                                                                                                                                                                                                             ( 1.90±0.19) %
                                                                                                                                                            Γ<sub>73</sub>
                                                                                                                                                                       \overline{K}^*(892)^0 \rho^+ \text{total}
\overline{K}^*(892)^0 \rho^+ S\text{-wave}
              Fractions of some of the following modes with resonances have already
                                                                                                                                                            Γ74
                                                                                                                                                                                                                                      [e] ( 2.1 ±1.3 ) %
              appeared above as submodes of particular charged-particle modes.
                                                                                                                                                            Γ75
                                                                                                                                                                                                                                     [e] ( 1.6 ± 1.6 ) %
           \overline{K}^*(892)^0\ell^+\nu_\ell
                                                                                                                                                                            \overline{K}^*(892)^0 \rho^+ P-wave \overline{K}^*(892)^0 \rho^+ D-wave
                                                                          [b] ( 4.7 ±0.4 )%
                                                                                                                                                            Γ<sub>76</sub>
                                                                                                                                                                                                                                                                   \times 10^{-3}
                                                                                                                                                                                                                                           < 1
                                                                                                                                                                                                                                                                                        CL=90%
               \hat{K}^*(892)^0 e^+ \nu_e
Γ<sub>25</sub>
                                                                                  (4.8 \pm 0.5)\%
                                                                                                                                                                                                                                             (10 \pm 7 ) \times 10<sup>-3</sup>
                                                                                                                                                            Γ77
               \overline{K}^*(892)^0 \mu^+ \nu_{\mu}
\Gamma_{26}
                                                                                                                                 S=1.1
                                                                                                                                                                            \overline{K}^*(892)^0 \rho^+ D-wave longitudi-
                                                                                                                                                                                                                                                                   × 10<sup>-3</sup>
                                                                                  (4.4 \pm 0.6)\%
                                                                                                                                                            Γ78
                                                                                                                                                                                                                                                                                         CL=90%
\Gamma_{27} \rho^0 e^+ \nu_e
                                                                                                                                                                       \frac{\text{nal}}{K_1(1270)^0}\pi^+
                                                                                  (2.2 \pm 0.8) \times 10^{-3}
                                                                                                                                                                                                                                                                    \times 10<sup>-3</sup>
\Gamma_{28} \rho^0 \mu^+ \nu_\mu
                                                                                  (2.7 \pm 0.7) \times 10^{-3}
                                                                                                                                                            Γ79
                                                                                                                                                                                                                                                                                         CL=90%
                                                                                                                                                                                                                                            < 7
                                                                                                                                                                       \frac{\overline{K}_1(1400)^0 \pi^+}{\overline{K}^*(1410)^0 \pi^+}
                                                                                                                                                                                                                                             ( 4.9 ±1.2 )%
\Gamma_{29} \phi e^+ \nu_e
                                                                                                                                                            L<sub>80</sub>
                                                                                < 2.09
                                                                                                        %
                                                                                                                             CL=90%
                                                                                                                                                                                                                                                                   × 10<sup>-3</sup>
         \phi \mu^+ \nu_{\mu}
                                                                                                                                                                                                                                                                                        CI = 90\%
Γ<sub>30</sub>
                                                                                < 3.72
                                                                                                                             CL=90%
                                                                                                                                                            Г81
                                                                                                                                                                                                                                           < 7
                                                                                                                                                                       \overline{K}_{0}^{*}(1430)^{0}\pi^{+}
                                                                                                                                                                                                                                              (3.7 \pm 0.4)\%
          \eta \ell^+ \nu_\ell
                                                                                                        \times 10^{-3}
                                                                                                                                                            F<sub>82</sub>
                                                                                                                            CL=90%
Γ31
                                                                                < 5
                                                                                                                                                                       \overline{K}^*(1680)^0\pi^+
\overline{K}^*(892)^0\pi^+\pi^0total
                                                                                                                                                            \Gamma_{83}
                                                                                                                                                                                                                                              ( 1.43±0.30) %
          \eta'(958) \mu^+ \nu_{\mu}
Γ32
                                                                                < 9
                                                                                                                             CL=90%
                                                                                                                                                            Γ<sub>84</sub>
                                                                                                                                                                                                                                              (6.7 ±1.4)%
                                     Hadronic modes with a \overline{K} or \overline{K}K\overline{K}
                                                                                                                                                                            \vec{K}^*(892)^0\pi^+\pi^03-body
                                                                                                                                                            Γ<sub>85</sub>
                                                                                                                                                                                                                                      [e] (4.2 ±1.4)%
          \overline{K}{}^0\pi^+
Γ<sub>33</sub>
                                                                                   ( 2.89±0.26) %
                                                                                                                                 5=1.1
                                                                                                                                                                        K^*(892)^-\pi^+\pi^+ total
                                                                                                                                                            F86
           K^-\pi^+\pi^+
                                                                                                                                                                            K^*(892)^-\pi^+\pi^+3-body
Γ<sub>34</sub>
                                                                          [d] (9.0 ±0.6)%
                                                                                                                                                            Γ87
                                                                                                                                                                                                                                              (2.0 ±0.9)%
               \overline{K}^*(892)^0\pi^+
                                                                                  ( 1.27±0.13) %
Γ<sub>35</sub>
                                                                                                                                                                       K^-\rho^+\pi^+ total
                                                                                                                                                                                                                                              ( 3.1 ±1.1 )%
                                                                                                                                                            Γ88
                    \times B(\overline{K}^{*0} \rightarrow K^-\pi^+)
                                                                                                                                                                       K^-\rho^+\pi^+3-body

K^0\rho^0\pi^+ total
                                                                                                                                                                                                                                              (1.1 \pm 0.4)\%
                                                                                                                                                            Γρα
                \overline{K}_{0}^{*}(14\dot{3}0)^{0}\pi^{+}
Γ<sub>36</sub>
                                                                                   (2.3 \pm 0.3)\%
                                                                                                                                                            F90
                                                                                                                                                                                                                                              (4.2 \pm 0.9)\%
                                                                                                                                                                                                                                                                                         CL=90%
               \times B(\overline{K}_0^*(1430)^0 \to K^-\pi^+)
\overline{K}^*(1680)^0\pi^+
                                                                                                                                                                           \overline{K}^0 \rho^0 \pi^+ 3-body
                                                                                                                                                                                                                                             (5 ±5 )×10<sup>-3</sup>
                                                                                                                                                            Γ<sub>91</sub>
Γ<sub>37</sub>
                                                                                                                                                                       \overline{K}^0 f_0(980) \pi^+
                                                                                                                                                                                                                                            < 5
                                                                                                                                                                                                                                                                   \times 10^{-3}
                                                                                   (3.7 \pm 0.8) \times 10^{-3}
                                                                                                                                                            \Gamma_{92}
                                                                                                                                                                                                                                                                                         CL=90%
                   \times B(\vec{K}^*(1680)<sup>0</sup> \rightarrow K^-\pi^+)
                                                                                                                                                                        \overline{K}^*(892)^0\pi^+\pi^+\pi^-
                                                                                                                                                                                                                                              ( 8.1~\pm3.4 ) \times\,10^{-3}
                                                                                                                                                            Γ93
                                                                                                                                                                                                                                                                                            S=1.7
                K^-\pi^+\pi^+ nonresonant
                                                                                  (8.5 \pm 0.8)\%
                                                                                                                                                                                                                                              ( 2.9 ^{+1.7}_{-1.5} ) \times 10^{-3}
 Г38
                                                                                                                                                                            \overline{K}^*(892)^0 \rho^0 \pi^+
                                                                                                                                                            Γ94
                                                                                                                                                                                                                                                                                             S=1.8
           \overline{K}^0\pi^+\pi^0
\overline{K}^0\rho^+
Γ39
                                                                          [d] (9.7 ±3.0)%
                                                                                                                                 S=1.1
                                                                                                                                                                            \overline{K}^*(892)^0\pi^+\pi^+\pi^- no- \rho
                                                                                                                                                                                                                                              (4.3 \pm 1.7) \times 10^{-3}
                                                                                                                                                            \Gamma_{95}
Γ<sub>40</sub>
                                                                                   ( 6.6 ± 2.5 ) %
                                                                                                                                                                       K^-\rho^0\pi^+\pi^+
                                                                                                                                                                                                                                              ( 3.1~\pm 0.9~)\times 10^{-3}
                                                                                                                                                            Γος
                \overline{K}^*(892)^0\pi^+
                                                                                   ( 6.3~\pm0.4 ) \times\,10^{-3}
Γ41
                    \times B(\overline{K}^{*0} \rightarrow \overline{K}^0\pi^0)
                                                                                                                                                                                                                     Pionic modes
                \overline{K}{}^0\pi^+\pi^0 nonresonant
                                                                                                                                                            \Gamma_{97} \pi^+\pi^0
                                                                                                                                                                                                                                              (2.5 \pm 0.7) \times 10^{-3}
 Γ42
                                                                                  (1.3 \pm 1.1)\%
           K^-\pi^+\pi^+\pi^0
                                                                                                                                                                    \pi^{+}\pi^{+}\pi^{-}
                                                                                                                                                                                                                                              ( 3.6 \pm 0.4 ) \times 10^{-3}
Γ<sub>43</sub>
                                                                          [d] (6.4 ±1.1)%
                                                                                                                                                            Γ98

\overline{K}^*(892)^{0} \rho^+ \text{ total}

\times B(\overline{K}^{*0} \to K^- \pi^+)

                                                                                                                                                                          \rho^{0}\pi^{+}
                                                                                                                                                                                                                                              ( 1.05\pm0.31) \times 10^{-3}
 Γ44
                                                                                   (1.4 \pm 0.9)\%
                                                                                                                                                            Γ99
                                                                                                                                                                         \pi^+\pi^+\pi^- nonresonant
                                                                                                                                                                                                                                              ( 2.2 \pm 0.4 ) \times\,10^{-3}
                                                                                                                                                            Γ100
                \overline{K}_1(1400)^0 \pi^+
 Γ45
                                                                                   (2.2 \pm 0.6)\%
                                                                                                                                                            \Gamma_{101} \ \pi^+\pi^+\pi^-\pi^0
                                                                                                                                                                                                                                              (1.9 \begin{array}{c} +1.5 \\ -1.2 \end{array})\%
                    \times B(\overline{K}_{1}(1400)^{0} \rightarrow K^{-}\pi^{+}\pi^{0})
                                                                                                                                                                         \eta \pi^+ \times B(\eta \to \pi^+ \pi^- \pi^0)
                                                                                                                                                                                                                                              ( 1.7 \pm 0.6 ) \times\,10^{-3}
                                                                                                                                                            Γ<sub>102</sub>
                K^- \rho^+ \pi^+ total
                                                                                   (3.1 \pm 1.1)\%
 Γ46
                                                                                                                                                                         \omega \pi^+ \times B(\omega \to \pi^+ \pi^- \pi^0)
                                                                                                                                                                                                                                                                   \times 10<sup>-3</sup>
                K^- \rho^+ \pi^+ 3-body

K^* (892)^0 \pi^+ \pi^0 \text{ total}
                                                                                                                                                            Γ<sub>103</sub>
                                                                                                                                                                                                                                            < 6
                                                                                                                                                                                                                                                                                         CL=90%
                                                                                   (1.1 \pm 0.4)\%
 Γ47
                                                                                                                                                            \Gamma_{104} \pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}
                                                                                                                                                                                                                                              (2.1 \pm 0.4) \times 10^{-3}
                                                                                   ( 4.5 ±0.9 )%
Γ48
                    \times B(\overline{K}^{*0} \rightarrow K^-\pi^+)
                                                                                                                                                            \Gamma_{105} \pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{0}
                                                                                                                                                                                                                                              (2.9 \begin{array}{c} +2.9 \\ -2.0 \end{array}) \times 10^{-3}
                    \overline{K}^*(892)^0 \pi^+ \pi^0 3-body
 \times B(\overline{K}^{*0} \to K^- \pi^+)
Γ<sub>49</sub>
                                                                                   (2.8 ±0.9)%
                                                                                                                                                                           Fractions of some of the following modes with resonances have already
                K^*(892)^-\pi^+\pi^+3-body
× B(K^{*-}\to K^-\pi^0)
                                                                                   (7 \pm 3 ) \times 10<sup>-3</sup>
Γ<sub>50</sub>
                                                                                                                                                                          appeared above as submodes of particular charged-particle modes.
                                                                                                                                                            \Gamma_{106} \eta_{.\pi}^{+}
                                                                                                                                                                                                                                              (7.5 \pm 2.5) \times 10^{-3}
                K^-\pi^+\pi^+\pi^0 nonresonant
\Gamma_{51}
                                                                          [e] ( 1.2 ±0.6 )%
                                                                                                                                                            \Gamma_{107} \rho^0 \pi^+
                                                                                                                                                                                                                                              (1.05\pm0.31)\times10^{-3}
\Gamma_{52}
           \overline{K}^0\pi^+\pi^+\pi^-
                                                                                 (7.0 ±0.9)%
                                                                                                                                                                                                                                                                   × 10<sup>-3</sup>
                                                                                                                                                            \Gamma_{108} \omega\pi^+
                                                                                                                                                                                                                                            < 7
                                                                                                                                                                                                                                                                                         CL=90%
                \overline{K}{}^{0} a_{1}(1260)^{+}
                                                                                   (4.0 \pm 0.9)\%
                                                                                                                                                            \Gamma_{109} \eta \rho^+
 Γ<sub>53</sub>
               K_{1}^{\times}(1400)^{0} \pi^{+} \rightarrow \pi^{+}\pi^{+}\pi^{-})
                                                                                                                                                                                                                                           < 1.2
                                                                                                                                                                                                                                                                    %
                                                                                                                                                                                                                                                                                         CL=90%
                                                                                                                                                            \Gamma_{110} \eta'(958)\pi^{+}
                                                                                                                                                                                                                                                                    × 10<sup>-3</sup>
                                                                                                                                                                                                                                                                                         CL=90%
                                                                                                                                                                                                                                           < 9
Γ<sub>54</sub>
                                                                                   (2.2 \pm 0.6)\%
                                                                                                                                                            \Gamma_{111} \eta'(958) \rho^{+}
                                                                                                                                                                                                                                                                                         CL=90%
                                                                                                                                                                                                                                            < 1.5
                                                                                                                                                                                                                                                                    %

\begin{array}{ccc}
 & \times \text{B}(\overline{K}_1(1400)^0 \to \overline{K}^0 \pi^+ \pi^-) \\
 & \times \text{B}(\overline{K}_1(1400)^0 \to \overline{K}^0 \pi^+ \pi^-) \\
 & \times \text{B}(K^{*-} \to \overline{K}^0 \pi^-) \\
 & \times \text{B}(K^{*-} \to \overline{K}^0 \pi^-) \\
 & \times \text{B}(K^{*-} \to \overline{K}^0 \pi^-)
\end{array}

                                                                                                                                                                                                    Hadronic modes with a K\overline{K} pair
 ۲<sub>55</sub>
                                                                                   (1.4 \pm 0.6)\%
                                                                                                                                                            \Gamma_{112} K^+\overline{K}^0
                                                                                                                                                                                                                                              ( 7.4 \pm 1.0 ) \times 10^{-3}
                                                                                                                                                            \Gamma_{113}^{--} K^{+}K^{-}\pi^{+}
                                                                                                                                                                                                                                      [d] ( 8.8 \pm 0.8 ) \times 10^{-3}
 Γ<sub>56</sub>
                                                                                   ( 4.2 \pm 0.9 ) %
                                                                                                                                                                            \phi \pi^+ \times B(\phi \rightarrow K^+ K^-)
                    \overline{K}^0 \rho^0 \pi^+ 3-body
                                                                                                                                                                                                                                              ( 3.0 \pm 0.3 ) \times 10^{-3}
                                                                                   (5 ±5 )×10<sup>-3</sup>
                                                                                                                                                            Γ<sub>114</sub>
Γ<sub>57</sub>
                                                                                                                                                                            \begin{array}{c}
K^{+}\overline{K}^{*}(892)^{0} \\
\times B(\overline{K}^{*0} \to K^{-}\pi^{+})
\end{array}
           \overline{K}^0\pi^+\pi^+\pi^- nonresonant K^-\pi^+\pi^+\pi^+\pi^-
                                                                                                                                                                                                                                              ( 2.8 \pm 0.4 ) \times 10^{-3}
                                                                                   (8 \pm 4 ) \times 10^{-3}
                                                                                                                                                            T115
 Γ<sub>58</sub>
                                                                          [d] ( 7.2 \pm 1.0 ) \times 10^{-3}
 Γ59
                                                                                                                                                                            K^+K^-\pi^+ nonresonant
                \overline{K}*(892)^{0}\pi^{+}\pi^{+}\pi^{-}
                                                                                                                                                                                                                                              (4.5 \pm 0.9) \times 10^{-3}
Γ<sub>60</sub>
                                                                                   (5.4 \pm 2.3) \times 10^{-3}
                                                                                                                                                            Γ<sub>116</sub>
                                                                                                                                                            \Gamma_{117} K^0\overline{K}{}^0\pi^+
                    \times B(\overline{K}^{*0} \rightarrow K^-\pi^+)
                                                                                                                                                                           K^*(892)^+ \overline{K}{}^0
                                                                                                                                                                                                                                              ( 2.1 ±1.0 )%
                    \overline{K}^*(892)^0 \rho^0 \pi^+ \times B(\overline{K}^{*0} \to K^- \pi^+)
                                                                                                                                                            T<sub>118</sub>
                                                                                   (1.9 \begin{array}{c} +1.1 \\ -1.0 \end{array}) \times 10^{-3}
                                                                                                                                                            \times B(K^{*+} \to K^0 \pi^+)

\Gamma_{119} K^+ K^- \pi^+ \pi^0
Γ<sub>61</sub>
                     \overline{K}^*(892)^0 \pi^+ \pi^+ \pi^- \text{ no-} \rho
                                                                                   (2.9 \pm 1.1) \times 10^{-3}
\Gamma_{62}
                                                                                                                                                                            \phi\pi^+\pi^0\times B(\phi\to~K^+K^-)
                                                                                                                                                                                                                                              (1.1 ±0.5)%
                        \times B(\overline{K}^{*0} \rightarrow K^-\pi^+)
                                                                                                                                                            Γ120
                K^- \rho^0 \pi^+ \pi^+
                                                                                   ( 3.1 \pm 0.9 ) \times\,10^{-3}
Γ<sub>63</sub>
                K^-\pi^+\pi^+\pi^+\pi^- nonresonant
                                                                                                     × 10<sup>-3</sup>
 Γ<sub>64</sub>
                                                                                 < 2.3
                                                                                                                             CL=90%
                                                                                   (2.2 \begin{array}{c} +5.0 \\ -0.9 \end{array})\%
         K^-\pi^+\pi^+\pi^0\pi^0
```

$\Gamma_{121} \qquad \phi \rho^+ \times B(\phi \to K^+ K^-)$	< 7 ×	10 ⁻³ CL=90%
$\Gamma_{122} \qquad K^+ K^- \pi^+ \pi^0$ non- ϕ	$(1.5 \begin{array}{c} +0.7 \\ -0.6 \end{array})\%$	•
$\Gamma_{123} K^{+} \overline{K}{}^{0} \pi^{+} \pi^{-}$	< 2 %	
$\Gamma_{124} K^0 K^- \pi^+ \pi^+ \Gamma_{125} K^* (892)^+ \overline{K}^* (892)^0$	(1.0 ±0.6) %	
$\times B^2(K^{*+} \rightarrow K^0\pi^+)$	(1.2 ±0.5)%	
$\Gamma_{126} = K^0 K^- \pi^+ \pi^+ \text{ non-} K^{*+} \overline{K}^{*0}$	< 7.9 ×	10 ⁻³ CL=90%
$\Gamma_{127} K^+ K^- \pi^+ \pi^+ \pi^-$	_	
$\Gamma_{128} \phi \pi^+ \pi^+ \pi^- \times B(\phi \rightarrow K^+ K^-)$	< 1 x	10 ⁻³ CL=90%
$\Gamma_{129} \qquad K^+ K^- \pi^+ \pi^+ \pi^-$ nonresonant	< 3 %	CL=90%

Fractions of the following modes with resonances have already appeared above as submodes of particular charged-particle modes.

Γ ₁₃₀	$\phi \pi^+$	(6.1	± 0.6) $\times 10^{-3}$	
	$\phi \pi^+ \pi^0$	(2.3	±1.0)%	
	ϕho^+	< 1.4	%	CL=90%
	$\phi \pi^+ \pi^+ \pi^-$	< 2	× 10 ⁻³	CL=90%
	K+ K*(89 <u>2)</u> 0	(4.2	± 0.5) $\times 10^{-3}$	
۲ ₁₃₅	$K^*(892)^+\overline{K}^0$	(3.2	±1.5)%	
Γ ₁₃₆	$K^*(892)^+\overline{K}^*(892)^0$	(2.6	±1.1)%	

Doubly Cabibbo suppressed (DC) modes,

$\Delta C = 1$ weak neutral current (C1) modes, or

	Lepton Family number (LF)	or Lep	ton number (<i>l</i>	.) violating n	nodes
Γ ₁₃₇	$K^{+}\pi^{+}\pi^{-}$	DC		.5)×10 ⁻⁴	
Γ ₁₃₈	$K^+ \rho^0$	DC	(2.5 ±1	$.2) \times 10^{-4}$	
Γ ₁₃₉	$K^*(892)^0\pi^+$	DC	(3.6 ± 1)	$.6) \times 10^{-4}$	
Γ ₁₄₀	$K^+\pi^+\pi^-$ nonresonant	DC	(2.4 ±1	.2)×10 ⁻⁴	
Γ ₁₄₁	K+K+K-	DC	< 1.4	× 10 ⁻⁴	CL=90%
Γ ₁₄₂	φK ⁺	DC	< 1.3	× 10 ⁻⁴	CL=90%
Γ ₁₄₃	$\pi^{+}e^{+}e^{-}$	C1	< 6.6	× 10 ⁻⁵	CL=90%
Γ ₁₄₄	$\pi^+\mu^+\mu^-$	C1	< 1.8	× 10 ⁻⁵	CL=90%
	$\rho^+\mu^+\mu^-$	C1	< 5.6	× 10 ⁻⁴	CL=90%
Γ ₁₄₆	K+ e+ e-		[f] < 2.0	× 10 ⁻⁴	CL=90%
Γ ₁₄₇	$K^+\mu^+\mu^-$		[f] < 9.7	× 10 ⁻⁵	CL≔90%
Γ ₁₄₈	$\pi^+e^+\mu^-$	LF	< 1.1	× 10 ⁻⁴	CL=90%
	$\pi^+e^-\mu^+$	LF	< 1.3	× 10 ⁻⁴	CL≃90%
Γ ₁₅₀	$K^+e^+\mu^-$	LF	< 1.3	× 10 ⁻⁴	CL=90%
F ₁₅₁	$K^+e^-\mu^+$	LF	< 1.2	× 10 ⁻⁴	CL=90%
F ₁₅₂	$\pi^-e^+e^+$	L	< 1.1	× 10 ⁻⁴	CL=90%
「 ₁₅₃	$\pi^- \mu^+ \mu^+$	L	< 8.7	× 10 ⁻⁵	CL=90%
Γ ₁₅₄	$\pi^-e^+\mu^+$	L	< 1.1	× 10 ⁻⁴	CL=90%
Γ ₁₅₅	$\rho^-\mu^+\mu^+$	L	< 5.6	× 10 ⁻⁴	CL=90%
「 ₁₅₆	K-e+e+	L	< 1.2	× 10 ⁻⁴	CL=90%
[₁₅₇	$K^-\mu^+\mu^+$	L	< 1.2	× 10 ⁻⁴	CL=90%
	$K^-e^+\mu^+$	L	< 1.3	× 10 ⁻⁴	CL=90%
Γ ₁₅₉	$K^*(892)^-\mu^+\mu^+$	L	< 8.5	× 10 ⁻⁴	CL=90%

 Γ_{160} A dummy mode used by the fit.

- (33 ±5)%
- [a] This is a weighted average of D^{\pm} (44%) and D^{0} (56%) branching fractions. See " D^+ and $D^0 \rightarrow (\eta \text{ anything}) / (\text{total } D^+ \text{ and } D^0)$ " under "D+ Branching Ratios" in these Particle Listings.
- [b] This value averages the e^+ and μ^+ branching fractions, after making a small phase-space adjustment to the μ^+ fraction to be able to use it as an e^+ fraction; hence our ℓ^+ here is really an e^+ .
- [c] An ℓ indicates an e or a μ mode, not a sum over these modes.
- [d] The branching fraction for this mode may differ from the sum of the submodes that contribute to it, due to interference effects. See the relevant papers.
- [e] The two experiments measuring this fraction are in serious disagreement. See the Particle Listings.
- [f] This mode is not a useful test for a $\Delta C=1$ weak neutral current because both quarks must change flavor in this decay.

CONSTRAINED FIT INFORMATION

An overall fit to 32 branching ratios uses 54 measurements and one constraint to determine 20 parameters. The overall fit has a $\chi^2 = 20.8$ for 35 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\langle \delta x_i \delta x_j \rangle / (\delta x_i \cdot \delta x_j)$, in percent, from the fit to the branching fractions, $x_i \equiv$ Γ_i/Γ_{total} . The fit constrains the x_i whose labels appear in this array to sum to

one.										
<i>x</i> ₁₁	5									
<i>x</i> ₁₆	4	2								
x ₂₅	18	29	8							
<i>x</i> ₂₆	14	7	31	25						
×33	38	9	8	31	25					
X34	32	16	14	56	45	55				
<i>x</i> 39	0	0	0	0	0	0	0			
x ₄₃	7	4	3	13	10	12	23	0		
x ₅₂	9	5	4	17	14	16	30	0	18	
<i>×</i> 59	15	8	7	28	22	27	49	0	11	15
X73	21	11	9	37	29	36	65	0	15	20
×80	5	3	2	9	7	8	16	0	31	37
×87	3	1	1	5	. 4	5	9	0	29	13
<i>×</i> 93	5	2	2	9	7	8	15	0	3	5
X94	3	2	1	6	5	6	11	0	2	3
<i>X</i> 98	19	10	9	35	28	33	61	0	14	18
×100	11	5	5	19	15	18	34	0	8	10
x ₁₁₂	22	7	. 6	23	18	53	41	0	9	12
X160	-35	26	-12	-41	-34	-38	55	-58	-46	<u>-45</u>
	X9	<i>x</i> 11	<i>x</i> 16	×25	^x 26	<i>x</i> 33	×34	X39	×43	×52
×73	32									
×80	8	10								
×87	4	6	12							
<i>x</i> 93	29	10	2	1						
×94	8	7	2	1	15					
<i>x</i> 98	30	40	10	5	9	7				
<i>x</i> ₁₀₀	16	22	5	3	5	4	43			
<i>x</i> ₁₁₂	20	26	6	4	6	4	25	14		
× ₁₆₀	-30	38	-46	-32	-16	-10	-35	-19	-27	

*X*93 D+ BRANCHING RATIOS

X94

×98 ×100 X₁₁₂

See the "Note on D Mesons" above. Some now-obsolete measurements have been omitted from these Listings.

Inclusive modes

$\Gamma(e^+ \text{ anything})/\Gamma_{\text{tot}}$	اد			Ì1	/г
VALUE	EVTS	DOCUMENT ID	TECN	COMMENT	•
0.172±0.019 OUR AVE	RAGE	<u> </u>			_
0.20 +0.09		AGUILAR	87E HYBI	R πp, pp 360, 400 GeV	
$0.170 \pm 0.019 \pm 0.007$	158	BALTRUSAIT	Г 85 В MRK	3 e ⁺ e 3.77 GeV	
0.168 ± 0.064	23	SCHINDLER	81 MRK	2 e ⁺ e 3.771 GeV	
• • • We do not use the	ne followin	g data for averag	es, fits, limit	s, etc. • • •	
0.220 + 0.044		BACINO	80 DLC	e ⁺ e ⁻ 3.77 GeV	

D^+ and $D^0 \rightarrow (e^+$ anything) / (total D^+ and D^0)

X59

X73

X80

X87

If measured at the $\psi(3770)$, this quantity is a weighted average of D^+ (44%) and D^0 (56%) branching fractions. Only experiments at $E_{\rm Cm}=3.77$ GeV are included in the average here. We don't put this result in the Meson Summary Table.

VALUE EVTS	DOCUMENT ID TECN COMMENT
0.110±0.011 OUR AVERAGE	Error includes scale factor of 1.1.
0.117±0.011 295	BALTRUSAIT85B MRK3 e+e- 3.77 GeV
0.10 ±0.032	⁴ SCHINDLER 81 MRK2 e ⁺ e ⁻ 3.771 GeV
0.072 ± 0.028	FELLER 78 MRK1 e ⁺ e ⁻ 3.772 GeV

• • • We do not use t	he followin	ng data for average	es, fits, limits,	etc. • • •
$0.096 \pm 0.004 \pm 0.011$	2207	5 ALBRECHT		e^+e^-pprox 10 GeV
$0.134 \pm 0.015 \pm 0.010$		⁶ ABE	93E VNS	e ⁺ e ⁻ 58 GeV
$0.098 \pm 0.009 ^{+0.006}_{-0.005}$	240	7 ALBRECHT	92F ARG	e^+e^-pprox 10 GeV
$0.096 \pm 0.007 \pm 0.015$		⁸ ONG	88 MRK2	e ⁺ e ⁻ 29 GeV
$0.116^{+0.011}_{-0.009}$		8 PAL	86 DLCO	e ⁺ e 29 GeV
$0.091 \pm 0.009 \pm 0.013$		⁸ AIHARA	85 TPC	e ⁺ e ⁻ 29 GeV
$0.092 \pm 0.022 \pm 0.040$		8 ALTHOFF	84J TASS	e ⁺ e 34.6 GeV
0.091 ± 0.013		⁸ KOOP	84 DLCO	See PAL 86
0.08 ±0.015		⁹ BACINO	79 DĽCO	e ⁺ e ⁻ 3.772 GeV

- ⁴ Isolates D^+ and $D^0 \to e^+ X$ and weights for relative production (44%–56%). ⁵ ALBRECHT 96C uses e^- in the hemisphere opposite to $D^{*+} \to D^0 \pi^+$ events.
- ⁶ ABE 93E also measures forward-backward asymmetries and fragmentation functions for c and b quarks.
- C and D quarks.

 7 ALBRECHT 92F uses the excess of right-sign over wrong-sign leptons in a sample of events tagged by fully reconstructed $D^*(2010)^+ \rightarrow D^0 \pi^+$ decays.

 8 Average BR for charm $\rightarrow e^+$ X. Unlike at $E_{\rm cm} = 3.77$ GeV, the admixture of charmed
- mesons is unknown.

 Not independent of BACINO 80 measurements of $\Gamma(e^+$ anything)/ Γ_{total} for the D^+ and D^0 separately.

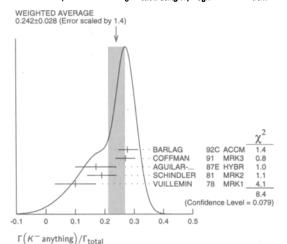
Γ(K-	anything)/F _{total}
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 Γ_2/Γ

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VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
0.242±0.028 OUR A	VERAGE	Error includes scale	factor of 1.4.	See the Ideogram below.
$0.278^{+0.036}_{-0.031}$		10 BARLAG	92c ACCM	π^- Cu 230 GeV
$0.271 \pm 0.023 \pm 0.024$		COFFMAN	91 MRK3	e+ e- 3.77 GeV
0.17 ±0.07		AGUILAR		πp, pp 360, 400 GeV
0.19 ±0.05	26	SCHINDLER	81 MRK2	e ⁺ e 3.771 GeV
0.10 ±0.07	3	VUILLEMIN	78 MRK1	e ⁺ e 3.772 GeV
• • • We do not use	e the follow	ing data for average	s, fits, limits,	etc. • • •
0.16 +0.08		AGUILAR	86B HYBR	See AGUILAR-

 $^{10}\,\mathrm{BARLAG}$ 92c computes the branching fraction using topological normalization.



$[\Gamma(K^0 \text{ anything}) + \Gamma$	(K ^u any	rthing)]/F _{total}			Г ₃ /Г
VALUE	<u>EVTS</u>	DOCUMENT ID		<u>TECN</u>	COMMENT
0.59 ±0.07 OUR AVE	RAGE				
$0.612 \pm 0.065 \pm 0.043$		COFFMAN	91		e ⁺ e ⁻ 3.77 GeV
0.52 ±0.18	15	SCHINDLER	81		e ⁺ e ⁻ 3.771 GeV
0.39 ±0.29	3	VUILLEMIN	78	MRK1	e ⁺ e ⁻ 3.772 GeV
$\Gamma(K^+$ anything) $/\Gamma_{tot}$	tal				Γ4/Γ
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.058±0.014 OUR AVE	RAGE				
$0.055 \pm 0.013 \pm 0.009$		COFFMAN	91	MRK3	e ⁺ e 3.77 GeV
0.08 +0.06 -0.05		AGUILAR	87E	HYBR	πp, pp 360, 400 GeV
0.06 ±0.04	12	SCHINDLER	81	MRK2	e ⁺ e ⁻ 3.771 GeV
0.06 ±0.06	2	VUILLEMIN	78	MRK1	e ⁺ e 3.772 GeV
D^+ and $D^0 o (\eta$ ar	ything)	/ (total D+ an	d <i>D</i>	P)	
		, this quantity is a Only the experime			rage of D^+ (44%) and D^0 = 3.77 GeV is used.
VALUE		DOCUMENT ID		TECN	COMMENT
<0.13		PARTRIDGE	81	CBAL	e ⁺ e ⁻ 3.77 GeV
• • • We do not use th	e followii	ng data for average	s, fits	, limits,	etc. • • •
<0.02		11 BRANDELIK	79	DASP	e ⁺ e ⁻ 4.03 GeV

 $^{^{11}}$ The BRANDELIK 79 result is based on the absence of an η signal at $E_{\rm CM}=4.03$ GeV. PARTRIDGE 81 observes a substantially higher η cross section at 4.03 GeV.

$\Gamma(c/\overline{c} \rightarrow \mu^+ \text{ anything})/\Gamma(c/\overline{c} \rightarrow \text{ anything})$

This is the average branching ratio for charm $\to \mu^+ X$. The mixture of charmed particles is unknown and may actually contain states other than D mesons. We don't put this result in the Meson Summary Table.

VALUE	VT5	DOCUMENT ID	TECN	COMMENT	
0.061+0.010 OUR AVER	AGE				
$0.086 \pm 0.017 ^{+0.008}_{-0.007}$	69	12 ALBRECHT	92F ARG	$e^+e^-pprox~10~{ m GeV}$	
$0.078 \pm 0.009 \pm 0.012$		ONG	88 MRK	2 e ⁺ e ⁻ 29 GeV	
$0.078 \pm 0.015 \pm 0.02$		BARTEL	87 JADE	E e ⁺ e [−] 34.6 GeV	
$0.082 \pm 0.012 ^{+0.02}_{-0.01}$		ALTHOFF	84G TASS	<i>e</i> + <i>e</i> − 34.5 GeV	
$\bullet~\bullet~$ We do not use the	follow	ing data for average	s, fits, limit	s, etc. • • •	
$0.089 \pm 0.018 \pm 0.025$		BARTEL	851 JADE	See BARTEL 87	

 12 ALBRECHT 92F uses the excess of right-sign over wrong-sign leptons in a sample of events tagged by fully reconstructed $D^*(2010)^+\to~D^0~\pi^+$ decays.

Leptonic and semileptonic modes

$\Gamma(\mu^+\nu_\mu)/\Gamma_{\rm total}$

 Γ_7/Γ

See the "Note on Pseudoscalar-Meson Decay Constants" in the π^\pm Listings for the limit inferred on the D^+ decay constant from the limit here on $\Gamma(\mu^+\nu_\mu)/\Gamma_{\rm total}$.

CL% EVTS DOCUMENT ID TECN COMMENT 90 ADLER 888 MRK3 e+e- 3.77 GeV • • • We do not use the following data for averages, fits, limits, etc. • • • 0 13 AUBERT 83 SPEC μ^+ Fe, 250 GeV 90

¹³ AUBERT 83 obtains an upper limit 0.014 assuming the final state contains equal amounts of (D^+,D^-) , (D^+,\overline{D}^0) , (D^-,D^0) , and (D^0,\overline{D}^0) . We quote the limit they get under more general assumptions.

$\Gamma(K^0\ell^+\nu_\ell)/\Gamma_{\text{total}}$

 Γ_8/Γ

We average our $\overline{K}{}^0e^+\nu_e$ and $\overline{K}{}^0\mu^+\nu_\mu$ branching fractions, after multiplying the latter by a phase-space factor of 1.03 to be able to use it with the $\overline{K}{}^0\,e^+\nu_e$ fraction.

mence our e ' nere is rea	ny an e'.				
VALUE	DOCUMENT ID		COMME	NT	
0.068 ± 0.008 OUR AVERAGE					
0.067±0.009	PDG	98	Our F($\overline{K}^0 e^+ \nu_e)/\Gamma_{\text{tot}}$	al
$0.072^{+0.031}_{-0.020}$	PDG	98	1.03 ×	our $\Gamma(\overline{K}^0 \mu^+ \nu_\mu$)/Γ _{total}
$\Gamma(\overline{K}^0 e^+ \nu_e) / \Gamma_{\text{total}}$					٦/و٦
VALUE EVTS	DOCUMENT ID		TECN	COMMENT	
0.067±0.009 OUR FIT					
0.06 +0.022 ±0.007 13	BAI	91	MRK3	$e^+e^-\approx 3.77$	GeV
$\Gamma(\overline{K}^0 e^+ \nu_e) / \Gamma(\overline{K}^0 \pi^+)$					Γ9/Γ33
VALUE EVTS	DOCUMENT ID		TECN	COMMENT	
2.32±0.31 OUR FIT					
2.60±0.35±0.26 186	¹⁴ BEAN	930	CLE2	$e^+e^-\approx \Upsilon(45)$	5)
14 BEAN 93C uses $\overline{K}{}^0\mu^+\nu_\mu$					hase-space
adjustment to the number of	of the μ^+ events to	use t	hem as	e [∓] events.	
$\Gamma(\overline{K}^0e^+\nu_e)/\Gamma(K^-\pi^+\pi^+)$)				Γ9/Γ34
VALUE	DOCUMENT ID		TECN	COMMENT	

$\Gamma(\overline{K}^0 e^+ \nu_e) / \Gamma(K^-$	$\pi^{+}\pi^{+})$					Г9/Гз
VALUE	· · · · ·	DOCUMENT ID		<u>TECN</u>	<u>COMMENT</u>	
0.74±0.10 OUR FIT 0.66±0.09±0.14		ANJOS	91 C	E691	γ Be 80-2	40 GeV
$\Gamma(\overline{K}^0\mu^+ u_\mu)/\Gamma_{ m total}$						Γ ₁₀ /1
VALUE	EVTS	DOCUMENT ID		<u>TECN</u>	COMMENT	
0.07 +0.028 ±0.012	14	BAI	91	MRK3	$e^+e^-\approx$	3.77 GeV
$\Gamma(\overline{K}^0\mu^+\nu_\mu)/\Gamma(\mu^+$	anything)					Γ ₁₀ /Γ ₀
VALUE	<u>EVTS</u>	DOCUMENT ID		COMME	NT	
• • • We do not use t	he following	data for average	s, fits	i, limits,	etc. • • •	
0.76±0.06	• •	¹⁵ AOKI		π — em		
¹⁵ From topological b	ranching rati	ios in emulsion w	ith as	identif	ied muon.	
$\Gamma(K^-\pi^+e^+\nu_e)/\Gamma_1$	otal					Γ ₁₁ /Ι

CL% EVTS DOCUMENT ID TECN COMMENT 0.041+0.009 OUR FIT $0.035^{+0.012}_{-0.007} \pm 0.004$ 14 16 BAI 91 MRK3 $e^+e^- \approx 3.77$ • • • We do not use the following data for averages, fits, limits, etc. • • • 17 AGUILAR-... 87F HYBR πρ, ρρ 360, 400 GeV 90

- 16 BAI 91 finds that a fraction $0.79^{+0.15}_{-0.17}^{+0.09}$ of combined D^+ and D^0 decays to $\overline{K}\pi e^+\nu_e$ (24 events) are $\overline{K}^*(892)e^+\nu_e$.
- 17 AGUILAR-BENITEZ 87F computes the branching fraction using topological normaliza-

 \mathcal{D}^{\pm}

$(\overline{K}^*(892)^0 \ell^+ \nu_\ell) / \Gamma_{\text{total}}$		anchina for	tions sec-	Γ ₂₄ /Γ		Γ(((Κ ππ) ⁰ e ⁺ ν _e ναιυε	non- <i>K</i> *(89)	2))/Γ _{total} DOCUMENT ID		TECN	COMMENT	Γ ₂₀ /
We average our $K^{*0}e^+\nu_e$ and latter by a phase-space factor						<0.009	90	ANJOS			Photoproduc	tion
Hence our <i>t</i> ⁺ here is really an		СОММЕ			1	Γ(K ⁻ π ⁺ π ⁰ μ ⁺ :	ν _μ)/Γ(K ⁻ π	$r^+\mu^+ u_\mu)$		Γ ₂₁ /Γ	₁₄ = Γ ₂₁ /([「16+ <mark>≩</mark> 「26
.047±0.004 OUR AVERAGE						VALUE	CL%	DOCUMENT ID			COMMENT	
.048±0.005	PDG	98 Our Γ($\overline{K}^{*0}e^+\nu_e)/\Gamma_1$	total		<0.042	90	FRABETTI	93E	E687	γ Be $\overline{E}_{\gamma} \approx 3$	200 GeV
0.046±0.006	PDG	98 1.05 ×	our $\Gamma(\overline{K}^{*0}\mu^{+})$	$\lceil u_{\mu} ceil / \lceil_{ ext{total}} ceil$		$\Gamma(\pi^0\ell^+\nu_\ell)/\Gamma(\overline{\ell}$	70 (+ ya)					Γ22/Γ
$-(\overline{K}^{\bullet}(892)^{0}e^{+}\nu_{e})/\Gamma(K^{-}\pi^{+}e^{-})$	e ⁺ ν _α)			Γ_{25}/Γ_{11}		VALUE	EVTS	DOCUMENT ID		TECN	COMMENT	
Unseen decay modes of the \overline{K}		uded.		20, 12		0.046±0.014±0.0	17 100	24 BARTELT	97	CLE2	$e^+e^-pprox \gamma$	(45)
ALUE EVTS	DOCUMENT ID		COMMENT		•	• • • We do not a	se the followi	ng data for averag	es, fits,	limits,	etc. • • •	
1.16 ^{+0.21} OUR FIT						$0.085 \pm 0.027 \pm 0.03$	14 53	²⁵ ALAM	93	CLE2	See BARTE	LT 97
	AD AMONGOU	01 0150	240 CeV	,		24 BARTELT 97						
.0 ±0.3 35	ADAMOVICH	91 OMEG	π 340 GeV			ments and form	n factors at q^2	2 =0: $ V_{cd}/V_{cs} ^{2}$	· f#	$(0)/f_{+}^{K}$	$(0) ^2 = 0.04$	6 ± 0.014
$-(K^{+}(892)^{0}e^{+}\nu_{e})/\Gamma(K^{-}\pi^{+}\pi^{+}\pi^{-})$	r+)			Γ_{25}/Γ_{34}		0.017. 25 ALAM 93 thus	directly meas	ures the product o	f ratios	squared	of CKM ma	trix elemen
Unseen decay modes of the \overline{K}		luded.				and form factor	rs at $q^2=0$: 1	$V_{cd}/V_{cs} ^2 \cdot f_+^{\pi}$	$(0)/f^{K}$	$(0) ^2 =$	0.085 ± 0.0	27 ± 0.01
ALUE EVTS	DOCUMENT ID	<u>TECN</u>	COMMENT					co. cs. r +	· ·· +			
0.53±0.05 OUR FIT 0.54±0.05 OUR AVERAGE					1	$\Gamma(\pi^+\pi^-e^+\nu_e)$	/Γ _{total}					Γ ₂₃ ,
	BEAN	93c CLE2	$e^+e^-\approx r($	(45)		VALUE	CL%	DOCUMENT ID			COMMENT	
0.62±0.15±0.09 35	ADAMOVICH		•	. ,		• • • We do not t	ise the followi					
0.55±0.08±0.10 880		91 ARG	$e^+e^-\approx 10$	0.4 GeV		< 0.057	90	²⁶ AGUILAR	87F	HYBR	πp, pp 360,	400 GeV
$0.49 \pm 0.04 \pm 0.05$	ANJOS		Photoproduct				IITEZ 87F cor	nputes the branch	ing fra	ction usi	ing topologic	al normall:
18 BEAN 93C uses $\overline{K}^{*0} \mu^+ \nu_{\mu}$ as w	vell as $\overline{K}^{*0}e^+ u_e$	events and	makes a small	phase-space		tion.						
adjustment to the number of the						$\Gamma(\rho^0 e^+ \nu_e)/\Gamma_{\rm to}$	tal					Γ ₂₇ ,
•				F /F		VALUE	<u> </u>	DOCUMENT ID		TECN	COMMENT	
$(K^-\pi^+e^+\nu_e \text{ nonresonant})/V$		TECH	COMMENT	Γ ₁₃ /Γ		• • • We do not i						
<u>'ALUE CL%</u> <0.007 90 1¹	DOCUMENT ID ANJOS		Photoproduct	tion		< 0.0037	90	BAI			e ⁺ e ⁻ ≈ 3.	.77 GeV
			· ·									
19 ANJOS 89B assumes a $\Gamma(D^+$ —	→ K ¬π¬π¬)/I	total = 9.1	± 1.3 ± 0.4%) .		$\Gamma(\rho^0 e^+ \nu_e) / \Gamma(I$	₹*(892)° e+	·ν _e)				Γ ₂₇ /Γ
$(K^-\pi^+\mu^+\nu_\mu)/\Gamma_{\text{total}}$		- г	$\Gamma_{14}/\Gamma = (\Gamma_{16})$	+		VALUE	<u>EVTS</u>	DOCUMENT ID		TECN	COMMENT	
ALUE	DOCUMENT ID	-	147 - (- 10	. 3. 20//	1	0.045±0.014±0.0		²⁷ AITALA			π^- nucleus,	
.032±0.004 OUR FIT Error inclu	ides scale factor	of 1.1.				²⁷ AITALA 97 exp	olicitly subtract	ts $D^+ o \eta' e^+ u_e$	and ot	her bacl	kgrounds to g	et this res
(Wt/200) + \/-				- /-		r/.0+\/r/	Ze/20010	F N				- /-
$\Gamma(\overline{K}^*(892)^0 \mu^+ u_\mu)/\Gamma_{ ext{total}}$				Γ ₂₆ /Γ		$\Gamma(\rho^0\mu^+\nu_\mu)/\Gamma(0)$					*****	Γ ₂₈ /Γ
Unseen decay modes of the \overline{K}						VALUE 0.061 ± 0.014 OUR	EVTS	DOCUMENT ID		1ECN	COMMENT	
ALUE <u>EVTS</u> 0.044 ±0.006 OUR FIT Error in	DOCUMENT ID		COMMENT			_		20	07	E701	π^- nucleus,	SOO GeV
								49 ΔΙΤΔΙ Δ				
			π ⁻ emulsion	n 600 GeV		$0.051 \pm 0.015 \pm 0.0$ $0.079 \pm 0.019 \pm 0.0$		²⁸ AITALA ²⁹ FRABETTI				
0.0325±0.0071±0.0075 224	²⁰ KODAMA	92C E653	π ⁻ emulsion			$0.079 \pm 0.019 \pm 0.0$	13 39	²⁹ FRABETTI	97	E687	γ Be, $\overline{E}_{\gamma} \approx$	
$0.0325 \pm 0.0071 \pm 0.0075$ 224 20 KODAMA 92C measures $\Gamma(D^{+})$	20 KODAMA $ ightarrow \overline{K}^{*0} \mu^+ u_{\mu})/$	92c E653 /Γ(D ⁰ → K	$-\mu^+\nu_\mu)=0.$.43 ± 0.09 ±	,	0.079±0.019±0.0 • • • We do not a	13 39 use the followi	²⁹ FRABETTI ing data for averag	97 es, fits	E687 , limits,	γ Be, $\overline{E}_{\gamma} \approx$ etc. • • •	220 GeV
0.0325±0.0071±0.0075 224 20 KODAMA 92C measures $\Gamma(D^+$ 0.09 and then uses $\Gamma(D^0 \to K)$	20 KODAMA $\rightarrow \overline{K}^{*0} \mu^+ \nu_{\mu})/(-\mu^+ \nu_{\mu}) = (7.0)$	92c E653 $\Gamma(D^0 \to K^2)$ $0 \pm 0.7) \times 10^{-1}$	$(-\mu^+\nu_\mu) = 0.00$ $0^{10} \text{s}^{-1} \text{ to get}$	$.43 \pm 0.09 \pm$ t the quoted	,	$0.079 \pm 0.019 \pm 0.0$	13 39 use the followi	²⁹ FRABETTI	97 es, fits	E687 , limits,	γ Be, $\overline{E}_{\gamma} \approx$	220 GeV
20 KODAMA 92C measures $\Gamma(D^+$ 0.09 and then uses $\Gamma(D^0 \to K$ branching fraction. See also the	20 KODAMA $\rightarrow \overline{K}^{*0} \mu^+ \nu_{\mu})/(-\mu^+ \nu_{\mu}) = (7.0)$ footnote to KOI	92c E653 $\Gamma(D^0 \to K^2)$ $0 \pm 0.7) \times 10^{-1}$	$(-\mu^+\nu_\mu) = 0.00$ $0^{10} \text{s}^{-1} \text{ to get}$	$.43 \pm 0.09 \pm$ t the quoted	,	0.079±0.019±0.0 • • • We do not a	13 39 use the followi 14 4	²⁹ FRABETTI ing data for averag ³⁰ KODAMA	97 es, fits 930	E687 , limits, E653	γ Be, $\overline{E}_{\gamma} \approx$ etc. • • • π^- emulsion	220 GeV n 600 GeV
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1.0325±0.0071±0.0075 224 20 KODAMA 92C measures $\Gamma(D^+ \ 0.09)$ and then uses $\Gamma(D^0 \to K)$ branching fraction. See also the $\Gamma(K^*(892)^0 \mu^+ \nu_\mu)/\Gamma(K^- \pi^+ \pi^+ \mu^+ \nu_\mu)/\Gamma(K^- \pi^+ \pi^- \pi^+ \mu^+ \nu^+ \mu^+ \mu^+ \mu^+ \mu^+ \mu^+ \mu^+ \mu^+ \mu^+ \mu^+ \mu$	20 KODAMA $\rightarrow \overline{K}^{*0} \mu^+ \nu_{\mu})/$ $\rightarrow \overline{\mu}^{*0} \mu^+ \nu_{\mu}) = (7.6 \text{ footnote to KOI}$ $\overline{K}^{*+})$ $\overline{K}^{*}(892)^0$ are incl \overline{M}^{*+} $$	92c E653 /F(D ⁰ → K' 0 ± 0.7) × 10 DAMA 92c II Iuded. 7ECN 93E E687 92c E653 ents normalidata block. **P\(\beta\) 93E E687 7ECN 93E E687 93E E687 87F HYBR 10 fraction uses, fits, ilmits, so fits, ilmits, ilmits, so fits, ilmits, so	$-\mu^+\nu_\mu$) = 0. $0^{10} \mathrm{s}^{-1}$ to get in the next data COMMENT γ Be $\overline{E}_{\gamma} \approx 2$ π^- emulsion lizing instead γ $\Gamma_{14} = \Gamma_{15}/(\Gamma$ $COMMENT$ $< 0.12 (90%$ $COMMENT$ $, etc. • • • • • • \pi p, pp 360, sing topological COMMENT , etc. • • • • • • • • • • • • • • • • • • •$	43 \pm 0.09 \pm at the quoted a block. \[\begin{array}{c} \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \		0.079 \pm 0.019 \pm 0.0 • • • We do not to 0.044 $^+$ 0.035 \pm 0.0 28 AITALA 97 exresult. 29 Because the reincludes any D 30 This KODAMA of backgrounds $\Gamma(\phi e^+ \nu_e)/\Gamma_{tot}$ Decay mode $\frac{VALUE}{\sqrt{ALUE}} < 0.0209$ $\Gamma(\phi \mu^+ \nu_\mu)/\Gamma_{tot}$ Decay mode $\frac{VALUE}{\sqrt{ALUE}} < 1.5$ $\Gamma(\eta \ell^+ \nu_\ell)/\Gamma(\pi^4 \nu_\ell)/\Gamma(\pi^6 \nu_\ell)$ $\Gamma(\eta \ell^+ \nu_\ell)/\Gamma(\pi^6 \nu_\ell$	13 39 use the followi 14 4 plicitly subtra construction $e^{+} \rightarrow \eta' \mu^{+} \nu$ $e^{+} \rightarrow \eta' \mu^{$	29 FRABETTI ing data for average 30 KODAMA. Incts $D^+ \rightarrow \eta' \mu^-$ efficiency or photo $^{\prime\prime} \mu \rightarrow \gamma \rho^0 \mu^+ \nu_\mu$ based on a final signals number are some included in the separate 10 BAI included in the separate 10 BAI 10 B	97 98 98 93 93 97 98 99 98 99 99 99 99 99	E687 , limits, E653 d other model of the correct MRK3 e correct MRK3 FECN CLE2 CLE2 TECN TECN	γ Be, $\overline{E}_{\gamma} \approx$ etc. • • • • π^- emulsion background FRABETTI sumerator. ± 1.3 events; dependent. ± 1.3 events; ted for. $\frac{COMMENT}{e^+e^-} \approx 3$ ted for. $\frac{COMMENT}{e^+e^-} \approx 3$ $\frac{COMMENT}{e^+e^-} \approx 7$ corrected for $\frac{COMMENT}{e^-} = \frac{1}{2}$ emulsion $\frac{COMMENT}{e^-} = \frac{1}{2}$	220 GeV n 600 GeV is to get 97 result; the estima:
1.0325±0.0071±0.0075 224 20 KODAMA 92C measures $\Gamma(D^+ \ 0.09)$ and then uses $\Gamma(D^0 \to K)$ branching fraction. See also the $\Gamma(K^*(892)^0 \mu^+ \nu_\mu)/\Gamma(K^- \pi^+ \pi^+ \mu^+ \nu_\mu)/\Gamma(K^- \pi^+ \pi^- \pi^+ \mu^+ \nu^+ \mu^+ \mu^+ \mu^+ \mu^+ \mu^+ \mu^+ \mu^+ \mu^+ \mu^+ \mu$	20 KODAMA $ \rightarrow \overline{K}^{*0} \mu^{+} \nu_{\mu})/(-\mu^{+} \nu_{\mu}) = (7.6) $ footnote to KOI $ \overline{K}^{*+}) $?*(892) ⁰ are incl $ DOCUMENT ID $ FRABETTI 1 KODAMA $ \overline{K}^{*0} \mu^{+} \nu_{\mu} \text{ even} $ in the preceding of $ \overline{K}^{*}(K^{-} \pi^{+} \mu^{+} \pi^{+} \pi^{+} \pi^{+} \pi^{+} \pi^{+} \pi^{+} \pi^{+} \pi^{+} \pi^{+} \pi^{-} \pi^{+} \pi^{+} \pi^{-} \pi^$	92c E653 /F(D ⁰ → K' 0 ± 0.7) × 10 DAMA 92c II Iuded. 7ECN 93E E687 92c E653 ents normalidata block. **P\(\beta\) 93E E687 7ECN 93E E687 93E E687 87F HYBR 10 fraction uses, fits, ilmits, so fits, ilmits, ilmits, so fits, ilmits, so	$-\mu^+\nu_\mu$) = 0. $0^{10} \mathrm{s}^{-1}$ to get in the next data COMMENT γ Be $\overline{E}_{\gamma} \approx 2$ π^- emulsion lizing instead γ $\Gamma_{14} = \Gamma_{15}/(\Gamma$ $COMMENT$ $< 0.12 (90%$ $COMMENT$ $, etc. • • • • • • \pi p, pp 360, sing topological COMMENT , etc. • • • • • • • • • • • • • • • • • • •$	43 \pm 0.09 \pm at the quoted a block. \[\begin{array}{c} \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \		0.079 \pm 0.019 \pm 0.0 • • • We do not to 0.044 $^+$ 0.031 \pm 0.0 28 AITALA 97 exercises the residual includes any Day Decay mode VALUE 10.0209 $\Gamma(\phi e^+ \nu_e)/\Gamma_{total}$ $\Gamma(\eta \ell^+ \nu_\ell)/\Gamma(\pi^0)$ $\Gamma(\eta \ell^+ \nu_\ell)/\Gamma(\pi^0)$ $\Gamma(\eta \ell^+ \nu_\ell)/\Gamma(\pi^0)$ Construction of the properties of	13 39 use the following the f	29 FRABETTI ing data for average 30 KODAMA. icts D+ → η' μ efficiency for photo ict γρ0 μ+ νμ based on a final sign instrumber are sor included in the se <u>POCUMENT ID</u> BAI DOCUMENT ID BAI 20 μ+ νμ 30 not included in <u>POCUMENT ID</u> KODAMA inc modes with	97 98, es, fits. 93c 93c $+\nu_{\mu}$ an ons is keevents and of 4 newhat arch ar 91 97 48 98 97 48 98 98	E687 Ilmits, E653 Id other ww, this in the n 0.1-2.3 model t e correct IECN MRK3 IECN CLE2 ICCN E653 TECN TECN TECN TECN TECN TECN TECN TECN	γ Be, $\overline{E}_{\gamma} \approx$ etc. • • • • π^- emulsion background FRABETTI sumerator. ± 1.3 events; dependent. ± 1.3 events; dependent. ± 1.3 events; ± 1.3 events ± 1.3 events; $\pm $	220 GeV n 600 GeV is to get 97 result: the estimate 725 .77 GeV
20.0325 \pm 0.0071 \pm 0.0075 224 20 KODAMA 92C measures $\Gamma(D^+$ 0.09 and then uses $\Gamma(D^0 \rightarrow K$ branching fraction. See also the $\Gamma(K^*(892)^0 \mu^+ \nu_\mu)/\Gamma(K^- \pi^+; \mu^+ \nu_\mu)/\Gamma(K^- \pi^+; \mu^+ \nu_\mu)/\Gamma(K^- \pi^+; \mu^+ \nu_\mu)/\Gamma(K^- \pi^+; \mu^+ \nu_\mu)$ Unseen decay modes of the $K^- \mu^+ \nu_\mu$ 21 KODAMA 92C uses the same $K^- \mu^+ \nu_\mu$ events, as reported in $\Gamma(K^- \pi^+ \mu^+ \nu_\mu \text{ nonresonant})/\Gamma(K^- \pi^+ \mu^+ \nu_\mu \text{ nonresonant})/\Gamma(K^- \pi^+ \mu^+ \nu_\mu)/\Gamma(K^- $	20 KODAMA $ \rightarrow \overline{K}^{*0} \mu^{+} \nu_{\mu})/(-\mu^{+} \nu_{\mu}) = (7.6) $ footnote to KOI $ \overline{K}^{*+}) $ ** (892) ⁰ are incl $ \underline{DOCUMENT ID} $ FRABETTI 1 KODAMA $ \overline{K}^{*0} \mu^{+} \nu_{\mu} \text{ even} $ in the preceding of $ \overline{K}(K - \pi^{+} \mu^{+} \pi^{+} \pi^{+} \pi^{+} \pi^{-} \pi^{+} \pi^{+} \pi^{-} \pi^{-$	92c E653 /F(D ⁰ → K' 0 ± 0.7) × 10 DAMA 92c li luded. 7ECN 93E E687 92c E653 ents normall data block. Vµ) F16/I 7ECN 93E E687 93E E687 93E E687 F16/I 7ECN 87F HYBR 87F HYBR 87F HYBR	$-\mu^+\nu_\mu)=0.010\mathrm{s}^{-1}$ to get in the next data to get in the next data γ Be $\overline{E}_\gamma\approx 2$ π^- emulsion lizing instead γ COMMENT < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% $< 0.$	43 \pm 0.09 \pm at the quoted a block. \[\begin{align*}		0.079 \pm 0.019 \pm 0.00 • • • We do not to 0.044 $^{+}$ 0.031 \pm 0.00 28 AITALA 97 ex result. 29 Because the reincludes any D 30 This KODAMA of backgrounds $\Gamma(\phi e^{+}\nu_{e})/\Gamma_{tot}$ Decay mode VALUE <0.0209 $\Gamma(\phi \mu^{+}\nu_{\mu})/\Gamma_{tot}$ Decay mode VALUE <1.5 $\Gamma(\eta^{2}+\nu_{\ell})/\Gamma(\pi^{-})$ VALUE <1.5 $\Gamma(\eta^{2}+\nu_{\ell})/\Gamma(\pi^{-})$ Decay mode VALUE <0.0372 $\Gamma(\eta^{2}+\nu_{\ell})/\Gamma(\pi^{-})$ VALUE <0.0372 $\Gamma(\eta^{2}+\nu_{\ell})/\Gamma(\pi^{-})$ VALUE <0.0372 $\Gamma(\eta^{2}+\nu_{\ell})/\Gamma(\pi^{-})$ VALUE <0.0372 $\Gamma(\eta^{2}+\nu_{\ell})/\Gamma(\pi^{-})$ VALUE <0.0372	13 39 use the following the f	29 FRABETTI ing data for average 30 KODAMA. Incomplete 30 KODAMA. Incomplete 30 KODAMA incomplete $^{$	97 98, es, fits. 93c 93c $+\nu_{\mu}$ an ons is keevents and of 4 newhat arch ar 91 97 48 98 97 48 98 98	E687 Ilmits, E653 Id other ww, this in the n 0.1-2.3 model t e correct IECN MRK3 IECN CLE2 ICCN E653 TECN TECN TECN TECN TECN TECN TECN TECN	γ Be, $\overline{E}_{\gamma} \approx$ etc. • • • • π^- emulsion background FRABETTI sumerator. ± 1.3 events; dependent. ± 1.3 events; ted for. $\frac{COMMENT}{e^+e^-} \approx 3$ ted for. $\frac{COMMENT}{e^+e^-} \approx 3$ $\frac{COMMENT}{e^+e^-} \approx 7$ corrected for $\frac{COMMENT}{e^-} = \frac{1}{2}$ emulsion $\frac{COMMENT}{e^-} = \frac{1}{2}$	220 GeV n 600 GeV is to get 97 result: the estimate 725 .77 GeV
20.0325±0.0071±0.0075 224 20 KODAMA 92C measures $\Gamma(D^+ \ 0.09)$ and then uses $\Gamma(D^0 \to K)$ branching fraction. See also the $\Gamma(K^*(892)^0 \mu^+ \nu_\mu)/\Gamma(K^- \pi^+; \mu^+ \nu_\mu)/\Gamma(K^- \pi^+; \mu^+ \nu_\mu)/\Gamma(K^- \pi^+; \mu^+ \nu_\mu)$ 1.53±0.06 OUR FIT 1.53±0.06 OUR AVERAGE 1.56±0.04±0.06 1.56±0.04±0.06 1.64±0.07±0.08 1.221 KODAMA 92C uses the same $K^- \mu^+ \nu_\mu$ events, as reported in $\Gamma(K^- \pi^+ \mu^+ \nu_\mu)$ nonresonant $\Gamma(K^- \pi^+ \pi^- e^+ \nu_e)/\Gamma$ total $\Gamma(K^- \pi^+ \pi^0 e^+ \nu_e)/\Gamma$ total $\Gamma(K^- \pi^0 e^+ $	20 KODAMA $ \rightarrow \overline{K}^{*0} \mu^{+} \nu_{\mu})/(-\mu^{+} \nu_{\mu}) = (7.6) $ footnote to KOI $ \overline{K}^{*+}) $ ** (892) ⁰ are incl $ \underline{DOCUMENT ID} $ FRABETTI 1 KODAMA $ \overline{K}^{*0} \mu^{+} \nu_{\mu} \text{ even} $ in the preceding of $ \overline{K}(K - \pi^{+} \mu^{+} \pi^{+} \pi^{+} \pi^{+} \pi^{-} \pi^{+} \pi^{+} \pi^{-} \pi^{-$	92c E653 /F(D ⁰ → K' 0 ± 0.7) × 10 DAMA 92c li luded. 7ECN 93E E687 92c E653 ents normall data block. Vµ) F16/I 7ECN 93E E687 93E E687 93E E687 F16/I 7ECN 87F HYBR 87F HYBR 87F HYBR	$-\mu^+\nu_\mu)=0.010\mathrm{s}^{-1}$ to get in the next data to get in the next data γ Be $\overline{E}_\gamma\approx 2$ π^- emulsion lizing instead γ COMMENT < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% < 0.12 (90% $< 0.$	43 \pm 0.09 \pm at the quoted a block. \[\begin{align*}		0.079 \pm 0.019 \pm 0.00 • • • We do not to 0.044 $^{+}$ 0.031 \pm 0.00 28 AITALA 97 ex result. 29 Because the reincludes any D 30 This KODAMA of backgrounds $\Gamma(\phi e^{+}\nu_{e})/\Gamma_{tot}$ Decay mode VALUE <0.0209 $\Gamma(\phi \mu^{+}\nu_{\mu})/\Gamma_{tot}$ Decay mode VALUE <1.5 $\Gamma(\eta^{2}+\nu_{\ell})/\Gamma(\pi^{-})$ VALUE <1.5 $\Gamma(\eta^{2}+\nu_{\ell})/\Gamma(\pi^{-})$ Decay mode VALUE <0.0372 $\Gamma(\eta^{2}+\nu_{\ell})/\Gamma(\pi^{-})$ VALUE <0.0372 $\Gamma(\eta^{2}+\nu_{\ell})/\Gamma(\pi^{-})$ VALUE <0.0372 $\Gamma(\eta^{2}+\nu_{\ell})/\Gamma(\pi^{-})$ VALUE <0.0372 $\Gamma(\eta^{2}+\nu_{\ell})/\Gamma(\pi^{-})$ VALUE <0.0372	13 39 use the followi 14 4 plicitly subtra construction e $+ \rightarrow \eta' \mu^+ \nu$ $= 0.00$	29 FRABETTI ing data for average 30 KODAMA. Incomplete 30 KODAMA. Incomplete 30 KODAMA incomplete $^{$	97 yes, fits, 93c $+\nu_{\mu}$ and 93c horse is like one vents and of 4 newhat arch ar 91 97 the sea 93B $= 7$	E687 Ilmits, E653 Ind other In the n In	γ Be, $\overline{E}_{\gamma} \approx$ etc. • • • • π^- emulsion background FRABETTI sumerator. ± 1.3 events; dependent. ± 1.3 events; ted for. $\frac{COMMENT}{e^+e^-} \approx 3$ ted for. $\frac{COMMENT}{e^+e^-} \approx 3$ $\frac{COMMENT}{e^+e^-} \approx 7$ corrected for $\frac{COMMENT}{e^-} = \frac{1}{2}$ emulsion $\frac{COMMENT}{e^-} = \frac{1}{2}$	220 GeV n 600 GeV is to get: 97 result; the estima:
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1.0325±0.0071±0.0075 224 20 KODAMA 92c measures $\Gamma(D^+ \ 0.09)$ and then uses $\Gamma(D^0 \to K)$ branching fraction. See also the $\Gamma(K^*(892)^0 \mu^+ \nu_\mu)/\Gamma(K^- \pi^+; \mu^+ \nu_\mu)/\Gamma(K^- \pi^+; \mu^+ \nu_\mu)/\Gamma(K^- \pi^+; \mu^+ \nu_\mu)/\Gamma(K^- \pi^+; \mu^+ \nu_\mu)$ 1.03±0.05 OUR FIT 1.53±0.05 OUR AVERAGE 1.56±0.04±0.06 1.56±0.04±0.08 1.2021 KODAMA 92c uses the same $K^- \mu^+ \nu_\mu$ events, as reported in $\Gamma(K^- \pi^+ \mu^+ \nu_\mu)$ nonresonant $\Gamma(K^- \pi^+ \pi^- e^+ \nu_e)/\Gamma$ 1.03±0.029 1.040±0.047 1.050±0.047 1.050±0.047 1.050±0.047 22 AGUILAR-BENITEZ 87F compution. 1.064±0.052 23 AGUILAR-BENITEZ 87F compution. 1.044±0.052 24 AGUILAR-BENITEZ 87F compution. 1.044±0.052 25 AGUILAR-BENITEZ 87F compution. 1.044±0.052 26 AGUILAR-BENITEZ 87F compution. 1.044±0.052 27 AGUILAR-BENITEZ 87F compution.	20 KODAMA $\rightarrow K^{*0} \mu^{+} \nu_{\mu})/ (-\mu^{+} \nu_{\mu}) = (7.6)$ footnote to KOI $\pi^{+})$ **(892) ⁰ are incl DOCUMENT ID FRABETTI 1 KODAMA $K^{*0} \mu^{+} \nu_{\mu}$ even the preceding of FRABETTI DOCUMENT ID FRABETTI DOCUMENT ID data for average: 2 AGUILAR utes the branchin DOCUMENT ID data for average: 3 AGUILAR utes the branchin	92c E653 /F(D ⁰ → K' 0 ± 0.7) × 10 DAMA 92c II Iuded. 93E E687 92c E653 ents normalidata block. // // // // // // // // //	$\mu^{+}\nu_{\mu} = 0.010 \text{ s}^{-1}$ to get in the next data to the next data τ^{-1} to get in the next data τ^{-1} and τ^{-1} are a mulsion lizing instead τ^{-1} and τ^{-1} and τ^{-1} are τ^{-1} and τ^{-1} and τ^{-1} are τ^{-1} and τ^{-1} and τ^{-1} are $\tau^$	43 \pm 0.09 \pm at the quoted a block. \[\begin{align*} \Gamma_{26} \sigma_{34} \\ 200 \text{ GeV} \\ 1600 \text{ GeV} \\ with \ D^0 \rightarrow \\ \begin{align*} \Gamma_{17} \sigma_{17} \sigma_{18} \sigma_{18} \sigma_{19} \\ \end{align*} 400 \text{ GeV} \\ \text{al normaliza-} \\ \Gamma_{19} \sigma_{1} \\ \end{align*}		0.079 \pm 0.019 \pm 0.00 • • • We do not to 0.044 $^+$ 0.035 \pm 0.0 28 AITALA 97 expression of backgrounds	13 39 use the following the f	29 FRABETTI ing data for average 30 KODAMA icts $D^+ \rightarrow \eta' \mu$ efficiency for photo $(\mu \rightarrow \gamma \rho^0 \mu^+ \nu_\mu)$ abased on a final signish number are son included in the se <u>POCUMENT ID</u> BAI included in the se <u>POCUMENT ID</u> BAI DOCUMENT ID BAI DOCUMENT ID NOT INCLUDED IN KODAMA inc modes with POCUMENT ID RODAMA TO COMMENT ID ADLER 31 SCHINDLER 32 PERUZZI	97 yes, fits. 93c 93c $+ \nu_{\mu}$ an is ke events anal of 4 newhat arch ar 91 4 arch ar 91 4 ctor of 88c 81 7 tes 88c 88c 88c 88c 88c	E687 , limits, E653 d other my, this in the n n n -2.3 model f E670 MRK3 E correct MRK3 E correct MRK3 FECN CLE2 MRK3 TECN MRK3 MRK1 MRK1 MRK2 MRK1 MRK1 MRK3 MRK1 MRK1 MRK3 MRK1 MRK3 MRK1 MRK1 MRK3 MRK1 MRK1 MRK3 MRK3 MRK1 MRK3 MRK	γ Be, $\overline{E}_{\gamma} \approx$ etc. • • • • π^- emulsion background FRABETTI umerator. ± 1.3 events; dependent. ± 1.3 events; dependent. ± 1.3 events; ± 1.3 events ± 1.3 even	220 GeV 1 GeV GeV 1 GeV 10.66 ± 0.3

									_
$\Gamma(\overline{K}^0\pi^+)/\Gamma(K^-\pi^+\pi^+)$			Γ ₃₃ /Γ	34	$\Gamma(\overline{K}^{\bullet}(892)^{0}\pi^{+})/\Gamma(\overline{K}^{0}\pi^{+})$	π ⁰)			Γ ₇₃ /Γ ₃₉
It is generally assumed for n			hat		Unseen decay modes of t				
	$^{+})=2\Gamma(D^{+}\rightarrow C^{+})$				VALUE 0.20±0.06 OUR FIT	DOCUMENT ID	TECN	COMMENT	
it is the latter Γ that is actua Cabibbo-allowed and doubly	/ Cablbbo-suppress				0.57±0.18±0.18	ADLER	87 MRK3	e^+e^- 3.77	GeV
invalidate this assumption b	y a few percent. DOCUMENT ID	TECN	COMMENT		$\Gamma(\overline{K}^0\pi^+\pi^0 \text{ nonresonant})$	` '			Γ ₄₂ /Γ ₃₉
0.321±0.025 OUR FIT Error inc	cludes scale factor	of 1.1.		_	VALUE	DOCUMENT ID		e ⁺ e ⁻ 3.77	GeV/
	rror includes scale				0.13±0.07±0.08	ADLER	OI MIKKS	e e 3.77	ge v
0.348±0.024±0.022 473 0.274±0.030±0.031 264	33 BISHAI ANJOS	90c E691	$e^+e^-\approx T(4S)$ Photoproduction		$\Gamma(K^-\pi^+\pi^+\pi^0)/\Gamma_{\text{total}}$ VALUE EVTS	DOCUMENT ID	TECN	COMMENT	Γ ₄₃ /Γ
33 See BISHAI 97 for an isospin	analysis of $D^+ \rightarrow$	K π amplitu	des.	ı	0.064±0.011 OUR FIT				
$\Gamma(K^-\pi^+\pi^+)/\Gamma_{\text{total}}$			Г34,	/Γ	0.058±0.012±0.012 142	COFFMAN		e ⁺ e ⁻ 3.77	GeV
VALUE EVTS	DOCUMENT ID		COMMENT	_	• • We do not use the follow	-			
0.090±0.006 OUR FIT 0.091±0.007 OUR AVERAGE					0.034 ^{+ 0.056} - 0.070	³⁹ BARLAG	92C ACCM	π Cu 230 (SeV
0.093±0.006±0.008 1502	34 BALEST	94 CLE2	$e^+e^-pprox T(45)$		$0.022^{+0.047}_{-0.006} \pm 0.004$ 1	³⁹ AGUILAR	87F HYBR	πp, pp 360,	400 GeV
$0.091 \pm 0.013 \pm 0.004$ 1164	ADLER		e ⁺ e ⁻ 3.77 GeV		$0.063^{+0.014}_{-0.013} \pm 0.012$ 175	BALTRUSAIT	Г.,,86E MRK3	See COFFM	AN 92B
0.091±0.019 239	35 SCHINDLER		e+e- 3.771 GeV		39 AGUILAR-BENITEZ 87F a	nd BABLAG 02c co.	moute the braz	nching fraction	by topolog.
0.086 ± 0.020 85 • • • We do not use the followin	³⁶ PERUZZI og data for average		e ⁺ e 3.77 GeV etc. • • •		ical normalization.	IIU BAKLAG 92C COI	npate the brai	icting traction	by topolog-
	37 BARLAG				$\Gamma(K^-\pi^+\pi^+\pi^0)/\Gamma(K^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^$	+-+1			Γ ₄₃ /Γ ₃₄
$0.064^{+0.015}_{-0.014}$			π [—] Cu 230 GeV		VALUE EVTS	DOCUMENT ID	TECN_	COMMENT	1 43/1 34
$0.063^{+0.028}_{-0.014} \pm 0.011$ 8	37 AGUILAR	87F HYBR	πp, pp 360, 400 GeV		0.71±0.12 OUR FIT				
34 BALEST 94 measures the rat	tio of $D^+ \to \kappa^-$	$\pi^+\pi^+$ and	$D^0 \rightarrow \kappa^- \pi^+$ branch	ing	0.76±0.11±0.12 91	ANJOS	92C E691	γ Be 90-260	GeV
fractions to be 2.35 \pm 0.16 \pm	t 0.16 and uses th				• • We do not use the follo				000
K ⁻ π ⁺ fraction (AKERIB 93)					0.69±0.10±0.16	ANJOS		See ANJOS	
35 SCHINDLER 81 (MARK-2) in be 0.38 ± 0.05 nb. We use the	neasures σ(e [™] e [™] e MARK-3 (ADLE	$\rightarrow \psi(3770)$ R 88c) value)) \times branching traction of $\sigma = 4.2 \pm 0.6 \pm 0.3$	to nb.	$0.57^{+0.65}_{-0.17}$ 1	AGUILAR	83B HYBR	π ⁻ p, 360 G	eV
36 PERUZZI 77 (MARK-1) mea	ssures $\sigma(e^+e^- \rightarrow$	 ψ(3770)) > 	branching fraction to	be	$\Gamma(\overline{K}^*(892)^0 \rho^+ \text{total})/\Gamma(F)$	(+-+-0)			Γ ₇₄ /Γ ₄₃
0.36 ± 0.06 nb. We use the N					Unseen decay modes of		cluded.		. 141 . 43
37 AGUILAR-BENITEZ 87F and ical normalization.	BARLAG 92C com	npute the bran	iching traction by topol	og-	VALUE	DOCUMENT ID		COMMENT	
_	43			_	0.33±0.165±0.12	ANJOS	92C E691	γ Be 90-260	GeV
$\Gamma(\overline{K}^{+}(892)^{0}\pi^{+})/\Gamma(K^{-}\pi^{+}\pi^{+}\pi^{-})$,		Γ ₇₃ /Γ	34	⁴⁰ See, however, the next ent	ry, where the two ex	periments disa	gree complete	ely.
Unseen decay modes of the VALUE CL%	DOCUMENT ID		COMMENT		$\Gamma(\overline{K}^*(892)^0 \rho^+ S\text{-wave})/\Gamma$	$(K^-\pi^+\pi^+\pi^0)$			Γ_{75}/Γ_{43}
0.212±0.016 OUR FIT	pocomer in		Comment		Unseen decay modes of t		luded. The tw	o experiments	
0.210±0.015 OUR AVERAGE					completely.				
0.206±0.009±0.014	FRABETTI	94G E687	γ Be, $\overline{E}_{\gamma} \approx 220$ GeV		VALUE	DOCUMENT ID		COMMENT	
0.255 ± 0.014 ± 0.050 0.21 ± 0.06 ± 0.06	ANJOS ALVAREZ	93 E691 918 NA14	γ Be 90-260 GeV Photoproduction		0.26 ±0.25 OUR AVERAGE 0.15 ±0.075±0.045	ANJOS		ι. γBe 90–260	GeV
0.20 ±0.02 ±0.11	ADLER		e ⁺ e ⁻ 3.77 GeV		0.833±0.116±0.165	COFFMAN		e ⁺ e ⁻ 3.77	
• • We do not use the following					= (Fr(000)0 + 5) /5	-			F /F
<0.053 90	SCHINDLER	81 MRK2	e ⁺ e ⁻ 3.771 GeV		Γ(K*(892) ⁰ ρ ⁺ P-wave)/[aludad.		Γ ₇₆ /Γ
			Γ ₈₂ /1		Unseen decay modes of VALUE CL%			COMMENT	
F/12+/1420\0_+\/F/K+	·_+\			34					GeV
$\Gamma(\overline{K}_0^*(1430)^0\pi^+)/\Gamma(K^-\pi^+)$	'# ⁺) . 7*(1430\ ⁰ are le	ncluded	. 02/	••	<0.001 90	ANJOS	92C E691	γ Be 90-260	
Unseen decay modes of the	e \mathcal{R}_0^* (1430) 0 are in	ncluded. TECN		•	<0.001 90 • • • We do not use the folio		92C E691 ges, fits, limits	, etc. • • •	
$\Gamma(\vec{K}_0^*(1430)^0\pi^+)/\Gamma(K^-\pi^+)$ Unseen decay modes of the VALUE 0.41 ±0.04 OUR AVERAGE	* **) e ** (ncluded. <u>TECN</u>	COMMENT	_	•		92C E691 ges, fits, limits		GeV
Unseen decay modes of the <u>VALUE</u> 0.41 ±0.04 OUR AVERAGE 0.458±0.035±0.094	e $\overline{K}_0^*(1430)^0$ are in <u>DOCUMENT ID</u> FRABETTI	94G E687	γ Be, $\overline{E}_{\gamma} pprox 220$ GeV	_	• • • We do not use the folio <0.005 90	wing data for average COFFMAN	92C E691 ges, fits, limits	, etc. • • •	
Unseen decay modes of the VALUE 0.41 ±0.04 OUR AVERAGE	e $K_0^*(1430)^0$ are in <u>DOCUMENT ID</u>	<u>TECN</u>	COMMENT	_	• • • We do not use the folio <0.005 90 \(\text{K*}(892)^0 \rho^+ D\)-wave)/(owing data for average COFFMAN $\Gamma(K^-\pi^+\pi^+\pi^0)$	92C E691 ges, fits, limits 92B MRK3	, etc. • • •	GeV Γ ₇₇ /Γ ₄₃
Unseen decay modes of the <u>VALUE</u> 0.41 ±0.04 OUR AVERAGE 0.458±0.035±0.094 0.400±0.031±0.027	e $\mathcal{R}_0^{\star}(1430)^0$ are in <u>DOCUMENT ID</u> FRABETTI ANJOS	94G E687	γ Be, $\overline{E}_{\gamma} pprox 220$ GeV		• • • We do not use the folio <0.005 90	owing data for average COFFMAN $\Gamma(K^-\pi^+\pi^+\pi^0)$	92C E691 ges, fits, limits 92B MRK3 ncluded.	, etc. • • •	
Unseen decay modes of the VALUE 0.41 \pm 0.04 OUR AVERAGE 0.458 \pm 0.035 \pm 0.094 0.400 \pm 0.031 \pm 0.027 $\Gamma(\overline{K}^{\circ}(1680)^{0}\pi^{+})/\Gamma(K^{-}\pi^{+})$	e $\mathcal{R}_0^*(1430)^0$ are ling <u>DOCUMENT ID</u> FRABETTI ANJOS $\pi^+)$	94G E687 93 E691	$COMMENT$ γ Be, $\overline{E}_{\gamma} \approx$ 220 GeV γ Be 90–260 GeV	 	• • • We do not use the folic <0.005 90 $\Gamma(\overline{K}^*(892)^0 \rho^+ D\text{-wave})/U$ Unseen decay modes of	coving data for average COFFMAN $\Gamma(K^-\pi^+\pi^+\pi^0)$ the $\overline{K}^*(892)^0$ are in	92C E691 ges, fits, limits 92B MRK3 ncluded.	etc. • • • e ⁺ e ⁻ 3.77	Γ ₇₇ /Γ ₄₃
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Unseen decay modes of the VALUE 0.41 \pm 0.04 OUR AVERAGE 0.45 \pm 0.035 \pm 0.094 0.400 \pm 0.031 \pm 0.027 $\Gamma(K^{\bullet}(1680)^{0}\pi^{+})/\Gamma(K^{-}\pi^{+}$ Unseen decay modes of the VALUE 0.160 \pm 0.032 OUR AVERAGE 0.182 \pm 0.023 \pm 0.028 0.113 \pm 0.015 \pm 0.050 $\Gamma(K^{-}\pi^{+}\pi^{+} \text{ nonresonant})/\Gamma(K^{-}\pi^{+}\pi^{+})$	e R ₀ *(1430) ⁰ are in <u>DOCUMENT ID</u> FRABETTI ANJOS • κ* (1680) ⁰ are in <u>DOCUMENT ID</u> Error includes scale FRABETTI ANJOS (Γ(Κ-π+π+)	94G E687 93 E691 ncluded. TECN e factor of 1.1 94G E687 93 E691	COMMENT γ Be, $\overline{E}_{\gamma} \approx 220$ GeV γ Be 90–260 GeV	_	• • • We do not use the folic <0.005 90 \[\begin{align*} (K^*(892)^0 \rho^+ D-wave) / \(\text{Unseen decay modes of } \) \[\text{VALUE} \\	wing data for average COFFMAN $\Gamma(K^-\pi^+\pi^+\pi^0)$ the $\overline{K}^*(892)^0$ are in POCUMENT IS ANJOS ngitudinal) / Γ total the $\overline{K}^*(892)^0$ are in POCUMENT IS COFFMAN $\pi^+\pi^+\pi^0)$	92c E691 ges, fits, limits 92B MRK3 ncluded. 92c E691 ncluded. 92c BMRK3	, etc. • • • • • e+ e- 3.77	Γ ₇₇ /Γ ₄₃ GeV Γ ₇₈ /Γ
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Unseen decay modes of the VALUE 0.41 ±0.04 OUR AVERAGE 0.458 ±0.035 ±0.094 0.400 ±0.031 ±0.027 Γ(Κ*•(1680)*0 π+)/Γ(Κ*- π+ Unseen decay modes of the VALUE 0.160 ±0.032 OUR AVERAGE 0.182 ±0.023 ±0.028 0.113 ±0.015 ±0.050 Γ(Κ*- π+ π+ nonresonant)/ VALUE 0.98 ±0.037 OUR AVERAGE 0.998 ±0.037 ±0.072 0.838 ±0.088 ±0.275 0.79 ±0.07 ±0.15 Γ(Κ*0 π+ π*0)/Γ total VALUE 0.107 ±0.029 OUR AVERAGE 0.102 ±0.025 ±0.016 159 0.19 ±0.12 10 38 SCHINDLER 81 (MARK-2) be 0.78 ± 0.48 nb. We use the Γ(Κ*0 ρ+)/Γ(Κ*0 π+ π*0) VALUE Γ(Κ*0 ρ+)/Γ(Κ*0 π+ π*0)	E R ₀ *(1430) ⁰ are in DOCUMENT ID FRABETTI ANJOS F*+) E K**(1680) ⁰ are in DOCUMENT ID Error includes scale FRABETTI ANJOS IT (K-π+π+) DOCUMENT ID FRABETTI ANJOS ADLER DOCUMENT ID ANJOS ADLER 38 SCHINDLER measures σ(e+e-rive MARK-3 (ADLI) DOCUMENT ID	7ECN 94G E687 93 E691 ncluded. 7ECN 1 Factor of 1.1. 88C MRK3 1 MRK2 1 Factor of 1.1. 88C MRK3 1 MRK2 1 WRK2 1 WRK3 1 MRK2 1 WRK2 2 W (3770 ER 88C) value	$\frac{COMMENT}{\gamma \text{ Be, } \overline{E}_{\gamma} \approx 220 \text{ GeV}}{\gamma \text{ Be 90-260 GeV}}$ $\frac{COMMENT}{\gamma \text{ Be, } \overline{E}_{\gamma} \approx 220 \text{ GeV}}{\gamma \text{ Be 90-260 GeV}}$ $\frac{COMMENT}{\gamma \text{ Be, } \overline{E}_{\gamma} \approx 220 \text{ GeV}}{\gamma \text{ Be 90-260 GeV}}$ $\frac{COMMENT}{\gamma \text{ Be, } \overline{E}_{\gamma} \approx 220 \text{ GeV}}{\gamma \text{ Be 90-260 GeV}}$ $\frac{COMMENT}{\gamma \text{ Be, } \overline{E}_{\gamma} \approx 220 \text{ GeV}}{\gamma \text{ Be 90-260 GeV}}$ $\frac{COMMENT}{\gamma \text{ Be, } \overline{E}_{\gamma} \approx 220 \text{ GeV}}{\gamma \text{ Be 90-260 GeV}}$ $\frac{COMMENT}{\gamma \text{ Be, } \overline{E}_{\gamma} \approx 220 \text{ GeV}}{\gamma \text{ Be 90-260 GeV}}$ $\frac{COMMENT}{\gamma \text{ Be, } \overline{E}_{\gamma} \approx 220 \text{ GeV}}{\gamma \text{ Be 90-260 GeV}}$ $\frac{COMMENT}{\gamma \text{ Be, } \overline{E}_{\gamma} \approx 220 \text{ GeV}}{\gamma \text{ Be, } \overline{E}_{\gamma} \approx 220 \text{ GeV}}{\gamma \text{ Be, } \overline{E}_{\gamma} \approx 220 \text{ GeV}}$ $\frac{COMMENT}{\gamma \text{ Be, } \overline{E}_{\gamma} \approx 220 \text{ GeV}}{\gamma \text{ Be, } \overline{E}_{\gamma} \approx 220 \text{ GeV}$	734 	• • • We do not use the folic <0.005 90 $\Gamma(K^*(892)^0 \rho^+ D\text{-wave})/\Gamma$ Unseen decay modes of VALUE 0.15±0.09±0.045 $\Gamma(K^*(892)^0 \rho^+ D\text{-wave lot}$ Unseen decay modes of VALUE (0.007) $\Gamma(K_1(1400)^0 \pi^+)/\Gamma(K^-)$ Unseen decay modes of VALUE 0.007 90 $\Gamma(K_1(1400)^0 \pi^+)/\Gamma(K^-)$ Unseen decay modes of VALUE 0.1000 OUR FIT 0.907±0.218±0.180 $\Gamma(K^- \rho^+ \pi^+ \text{total})/\Gamma(K^-)$ This includes $K^*(892)^0$ VALUE 0.18±0.08 0.18±0.08 0.18±0.04 0.159±0.065±0.060 $\Gamma(K^*(892)^0 \pi^+ \pi^0 \text{total})/\Gamma(K^*(892)^0 \pi^+ \pi^0 t$	wing data for average COFFMAN $\Gamma(K^-\pi^+\pi^+\pi^0)$ the $K^*(892)^0$ are in POCUMENT IS COFFMAN $\pi^+\pi^+\pi^0$ the $K_1(1400)^0$ are $K_1(1400$	92c E691 ges, fits, limits 928 MRK3 ncluded. 92c E691 ncluded. 92e MRK3 included. 92e E691 92e E691 92c E691 92c E691 92c E691 92c E691	comment γ Be 90–260	GeV F80/F43 GeV F80/F43 GeV F89/F43 GeV F89/F43
Unseen decay modes of the VALUE 0.41 ±0.04 OUR AVERAGE 0.45 ±0.035±0.094 0.400±0.031±0.027 Γ(K*(1680)*0 π+)/Γ(K*π+ Unseen decay modes of the VALUE 0.160±0.032 OUR AVERAGE 0.182±0.023±0.028 0.113±0.015±0.050 Γ(K*π+π+ nonresonant)/ VALUE 0.98 ±0.037 OUR AVERAGE 0.998±0.037±0.072 0.838±0.088±0.275 0.79 ±0.07 ±0.15 Γ(K*0 π+π*0)/Γ total VALUE 0.107±0.029 OUR AVERAGE 0.102±0.025±0.016 159 0.19 ±0.12 10 38 SCHINDLER 81 (MARK-2) be 0.78 ± 0.48 nb. We use the Γ(K*0 ρ+)/Γ(K*0 π+π*0) VALUE Γ(K*0 ρ+)/Γ(K*0 π+π*0)	E R ₀ *(1430) ⁰ are in DOCUMENT ID FRABETTI ANJOS F*+) E K**(1680) ⁰ are in DOCUMENT ID Error includes scale FRABETTI ANJOS IT (K-π+π+) DOCUMENT ID FRABETTI ANJOS ADLER DOCUMENT ID ANJOS ADLER 38 SCHINDLER measures σ(e+e-rive MARK-3 (ADLI) DOCUMENT ID	7ECN 94G E687 93 E691 ncluded. 7ECN 1 Factor of 1.1. 88C MRK3 1 MRK2 1 Factor of 1.1. 88C MRK3 1 MRK2 1 WRK2 1 WRK3 1 MRK2 1 WRK2 2 W (3770 ER 88C) value	$\frac{COMMENT}{\gamma \text{ Be, } \overline{E}_{\gamma} \approx 220 \text{ GeV}}{\gamma \text{ Be 90-260 GeV}}$ $\frac{COMMENT}{\gamma \text{ Be, } \overline{E}_{\gamma} \approx 220 \text{ GeV}}{\gamma \text{ Be 90-260 GeV}}$ $\frac{COMMENT}{\gamma \text{ Be, } \overline{E}_{\gamma} \approx 220 \text{ GeV}}{\gamma \text{ Be 90-260 GeV}}$ $\frac{COMMENT}{\gamma \text{ Be, } \overline{E}_{\gamma} \approx 220 \text{ GeV}}{\gamma \text{ Be 90-260 GeV}}$ $\frac{COMMENT}{\gamma \text{ Be, } \overline{E}_{\gamma} \approx 220 \text{ GeV}}{\gamma \text{ Be 90-260 GeV}}$ $\frac{COMMENT}{\gamma \text{ Be, } \overline{E}_{\gamma} \approx 220 \text{ GeV}}{\gamma \text{ Be 90-260 GeV}}$ $\frac{COMMENT}{\gamma \text{ Be, } \overline{E}_{\gamma} \approx 220 \text{ GeV}}{\gamma \text{ Be 90-260 GeV}}$ $\frac{COMMENT}{\gamma \text{ Be, } \overline{E}_{\gamma} \approx 220 \text{ GeV}}{\gamma \text{ Be 90-260 GeV}}$ $\frac{COMMENT}{\gamma \text{ Be, } \overline{E}_{\gamma} \approx 220 \text{ GeV}}{\gamma \text{ Be, } \overline{E}_{\gamma} \approx 220 \text{ GeV}}{\gamma \text{ Be, } \overline{E}_{\gamma} \approx 220 \text{ GeV}}$ $\frac{COMMENT}{\gamma \text{ Be, } \overline{E}_{\gamma} \approx 220 \text{ GeV}}{\gamma \text{ Be, } \overline{E}_{\gamma} \approx 220 \text{ GeV}$	734 	• • • We do not use the folic <0.005 90 $\Gamma(K^*(892)^0 \rho^+ D\text{-wave})/\Gamma$ Unseen decay modes of VALUE 0.15±0.09±0.045 $\Gamma(K^*(892)^0 \rho^+ D\text{-wave lot}$ Unseen decay modes of VALUE <0.007 90 $\Gamma(K_1(1400)^0 \pi^+)/\Gamma(K^-$ Unseen decay modes of VALUE 0.77 ±0.20 OUR FIT 0.907±0.218±0.180 $\Gamma(K^- \rho^+ \pi^+ \text{total})/\Gamma(K^-$ This includes $K^*(892)^0$ VALUE 0.48±0.13±0.09 $\Gamma(K^- \rho^+ \pi^+ 3\text{-body})/\Gamma(M^-)$ VALUE 0.18 ±0.08 ±0.04 0.159±0.065±0.060 $\Gamma(K^*(892)^0 \pi^+ \pi^0 \text{total})/\Gamma(K^*(892)^0 \text{ traction. Unseen decay}$	wing data for average COFFMAN $\Gamma(K^-\pi^+\pi^+\pi^0)$ the $K^*(892)^0$ are in POCUMENT IS ANJOS Ingitudinal) / Fotal the $K^*(892)^0$ are in POCUMENT IS COFFMAN $\pi^+\pi^+\pi^0)$ ρ^+ , etc. The next encodes of the $K^*(892)^0$ and $K^*\pi^0$	92c E691 ges, fits, limits 928 MRK3 ncluded. 92c E691 ncluded. 92e MRK3 included. 92e E691 92e E691 92c E691 92c E691 92c E691 92c E691 92c E691	comment γ Be 90–260 γ Specifically 3-1 γ Be 90–260 γ Specifically 3-1 γ Be 90–260 γ Specifically 3-1 γ Be 90–260 γ Be 90–90 γ Be 90	GeV F80/F43 GeV F80/F43 GeV F89/F43 GeV F89/F43
Unseen decay modes of the VALUE 0.41 ±0.04 OUR AVERAGE 0.458 ±0.035 ±0.094 0.400 ±0.031 ±0.027 Γ(Κ*0 (1680)*0 π+)/Γ(Κ*π+ Unseen decay modes of the VALUE 0.160 ±0.032 OUR AVERAGE 0.182 ±0.023 ±0.028 0.113 ±0.015 ±0.050 Γ(Κ*π*π* nonresonant)/ VALUE 0.98 ±0.07 OUR AVERAGE 0.998 ±0.037 ±0.072 0.838 ±0.088 ±0.275 0.79 ±0.07 ±0.15 Γ(Κ*0 π*π*0)/Γ total VALUE 0.107 ±0.029 OUR AVERAGE 0.102 ±0.025 ±0.016 0.19 ±0.12 10 38 SCHINDLER 81 (MARK-2) be 0.78 ± 0.48 nb. We use the Γ(Κ*0 ρ*+)/Γ(Κ*0 π*π*0) VALUE Γ(Κ*0 ρ*+)/Γ(Κ*0 π*π*0)	E R ₀ *(1430) ⁰ are in DOCUMENT ID FRABETTI ANJOS F*+) E K**(1680) ⁰ are in DOCUMENT ID Error includes scale FRABETTI ANJOS IT (K-π+π+) DOCUMENT ID FRABETTI ANJOS ADLER DOCUMENT ID ANJOS ADLER 38 SCHINDLER measures σ(e+e-rive MARK-3 (ADLI) DOCUMENT ID	7ECN 94G E687 93 E691 ncluded. 7ECN 1 Factor of 1.1. 88C MRK3 1 MRK2 1 Factor of 1.1. 88C MRK3 1 MRK2 1 WRK2 1 WRK3 1 MRK2 1 WRK2 2 W (3770 ER 88C) value	$\frac{COMMENT}{\gamma \text{ Be, } \overline{E}_{\gamma} \approx 220 \text{ GeV}}{\gamma \text{ Be 90-260 GeV}}$ $\frac{COMMENT}{\gamma \text{ Be, } \overline{E}_{\gamma} \approx 220 \text{ GeV}}{\gamma \text{ Be 90-260 GeV}}$ $\frac{COMMENT}{\gamma \text{ Be, } \overline{E}_{\gamma} \approx 220 \text{ GeV}}{\gamma \text{ Be 90-260 GeV}}$ $\frac{COMMENT}{\gamma \text{ Be, } \overline{E}_{\gamma} \approx 220 \text{ GeV}}{\gamma \text{ Be 90-260 GeV}}$ $\frac{COMMENT}{\gamma \text{ Be, } \overline{E}_{\gamma} \approx 220 \text{ GeV}}{\gamma \text{ Be 90-260 GeV}}$ $\frac{COMMENT}{\gamma \text{ Be, } \overline{E}_{\gamma} \approx 220 \text{ GeV}}{\gamma \text{ Be 90-260 GeV}}$ $\frac{COMMENT}{\gamma \text{ Be, } \overline{E}_{\gamma} \approx 220 \text{ GeV}}{\gamma \text{ Be 90-260 GeV}}$ $\frac{COMMENT}{\gamma \text{ Be, } \overline{E}_{\gamma} \approx 220 \text{ GeV}}{\gamma \text{ Be 90-260 GeV}}$ $\frac{COMMENT}{\gamma \text{ Be, } \overline{E}_{\gamma} \approx 220 \text{ GeV}}{\gamma \text{ Be, } \overline{E}_{\gamma} \approx 220 \text{ GeV}}{\gamma \text{ Be, } \overline{E}_{\gamma} \approx 220 \text{ GeV}}$ $\frac{COMMENT}{\gamma \text{ Be, } \overline{E}_{\gamma} \approx 220 \text{ GeV}}{\gamma \text{ Be, } \overline{E}_{\gamma} \approx 220 \text{ GeV}$	734 	• • • We do not use the folic <0.005 90 $\Gamma(K^*(892)^0 \rho^+ D\text{-wave})/\Gamma$ Unseen decay modes of VALUE 0.15±0.09±0.045 $\Gamma(K^*(892)^0 \rho^+ D\text{-wave lot}$ Unseen decay modes of VALUE (0.007) $\Gamma(K_1(1400)^0 \pi^+)/\Gamma(K^-)$ Unseen decay modes of VALUE 0.007 90 $\Gamma(K_1(1400)^0 \pi^+)/\Gamma(K^-)$ Unseen decay modes of VALUE 0.1000 OUR FIT 0.907±0.218±0.180 $\Gamma(K^- \rho^+ \pi^+ \text{total})/\Gamma(K^-)$ This includes $K^*(892)^0$ VALUE 0.18±0.08 0.18±0.08 0.18±0.04 0.159±0.065±0.060 $\Gamma(K^*(892)^0 \pi^+ \pi^0 \text{total})/\Gamma(K^*(892)^0 \pi^+ \pi^0 t$	wing data for average COFFMAN $\Gamma(K^-\pi^+\pi^+\pi^0)$ the $K^*(892)^0$ are in POCUMENT IS COFFMAN $\pi^+\pi^+\pi^0$ the $K_1(1400)^0$ are $K_1(1400$	92c E691 ges, fits, limits 928 MRK3 ncluded. 92c E691 ncluded. 92c MRK3 included. 928 MRK3 included. 928 MRK3 included. 926 MRK3 included. 927 E691 928 MRK3 included. 920 E691 920 E691 920 MRK3	comment γ Be 90–260	GeV Fas/F43 GeV Fas/F43 GeV Fas/F43 GeV Fas/F43 GeV Fas/F43 GeV Fas/F43

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Unseen decay modes of the $\overline{K}^*(892)^0$ are included.	$\Gamma(\overline{K}^{+}(1410)^{0}\pi^{+})/\Gamma_{\text{total}}$
ALUE CLY DOCUMENT ID TECN COMMENT	Unseen decay modes of the $K^*(1410)^0$ are included. VALUE CLY DOCUMENT ID TECH COMMENT
• We do not use the following data for averages, fits, limits, etc. • •	<0.007 90 COFFMAN 928 MRK3 e ⁺ e ⁻ 3.77 GeV
<0.008 90 ⁴¹ COFFMAN 92B MRK3 e ⁺ e ⁻ 3.77 GeV	5/150(000) + + ++++1 /5 (FO) + -+ \ 5 /5
⁴¹ See, however, the next entry: ANJOS 92C sees a large signal in this channel.	$\Gamma(K^{\bullet}(892)^{-}\pi^{+}\pi^{+}\text{total})/\Gamma(\overline{K^{\bullet}}\pi^{+}\pi^{+}\pi^{-})$ Γ_{86}/Γ_{8}
$\Gamma(K^{+}(892)^{0}\pi^{+}\pi^{0}3\text{-body})/\Gamma(K^{-}\pi^{+}\pi^{+}\pi^{0})$ Γ_{85}/Γ_{43}	Unseen decay modes of the K*(892) are included. VALUE EVTS DOCUMENT ID TECN COMMENT
Unseen decay modes of the $\overline{K}^*(892)^0$ are included.	● ● We do not use the following data for averages, fits, limits, etc. ● ●
ALUE DOCUMENT ID TECH COMMENT	0.41 ± 0.14 14 ALEEV 94 BIS2 nN 20-70 GeV
0.66±0.09±0.17 ANJOS 92¢ E691 γ Be 90–260 GeV	F(V*(000)=_+_+2 bo+\)/F
$\Gamma(K^*(892)^-\pi^+\pi^+3\text{-body})/\Gamma(K^-\pi^+\pi^+\pi^0)$ Γ_{87}/Γ_{43}	$\Gamma(K^{\bullet}(892)^{-}\pi^{+}\pi^{+}3\text{-body})/\Gamma_{\text{total}}$ Unseen decay modes of the $\overline{K}^{\bullet}(892)^{0}$ are included.
Unseen decay modes of the K*(892) are included.	VALUE CL% DOCUMENT ID TECN COMMENT
ALUE DOCUMENT ID TECN COMMENT	0.020±0.009 OUR FIT
3.32±0.14 OUR FIT Error includes scale factor of 1.1. 3.24±0.12±0.09 ANJOS 92c E691 γBe 90-260 GeV	• • We do not use the following data for averages, fits, limits, etc. • • •
	<0.013 90 COFFMAN 928 MRK3 e ⁺ e ⁻ 3.77 GeV
$\Gamma(K^-\pi^+\pi^+\pi^0 \text{ nonresonant})/\Gamma_{\text{total}}$	$\Gamma(K^{+}(892)^{-}\pi^{+}\pi^{+}3\text{-body})/\Gamma(\overline{K}^{0}\pi^{+}\pi^{+}\pi^{-})$ Γ_{87}/Γ_{1}
<u>VALUE CL% DOCUMENT ID TECN COMMENT</u> • • • We do not use the following data for averages, fits, limits, etc. • • •	Unseen decay modes of the $K^*(892)^-$ are included.
<0.002 90 ⁴² ANJOS 92C E691 γBe 90–260 GeV	VALUE <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u> 0.29±0.13 OUR FIT Error includes scale factor of 1.1.
42 Whereas ANJOS 92C finds no signal here, COFFMAN 92B finds a fairly large one; se	0.50±0.09±0.21 Error includes scale factor of 1.1. 0.50±0.09±0.21 ANJOS 92C E691 γBe 90–260 GeV
the next entry.	,
$\Gamma(K^-\pi^+\pi^+\pi^0 \text{ nonresonant})/\Gamma(K^-\pi^+\pi^+\pi^0)$ Γ_{51}/Γ_4	$\Gamma(\overline{K}^{0}\rho^{0}\pi^{+}\text{total})/\Gamma(\overline{K}^{0}\pi^{+}\pi^{+}\pi^{-})$
VALUE DOCUMENT ID TECH COMMENT	This includes \overline{K}^0 $a_1(1260)^+$. The next two entries give the specifically 3-body reation.
0.184±0.070±0.050 COFFMAN 92B MRK3 e ⁺ e [−] 3.77 GeV	VALUE CL% DOCUMENT ID TECN COMMENT
$\Gamma(\overline{K}^0\pi^+\pi^+\pi^-)/\Gamma_{\text{total}}$	0.60 \pm 0.10 \pm 0.17 90 ANJOS 92C E691 γ Be 90–260 GeV
VALUE EVTS DOCUMENT ID TECH COMMENT	$\Gamma(\overline{K}{}^0 ho^0\pi^+$ 3-body)/ $\Gamma_{ ext{total}}$
0.070±0.009 OUR FIT	VALUE CL% DOCUMENT ID TECN COMMENT
D.071±0.016 OUR AVERAGE D.066±0.015±0.005 168 ADLER 88C MRK3 e ⁺ e ⁻ 3.77 GeV	 ● We do not use the following data for averages, fits, limits, etc.
0.12 ±0.05 21 43 SCHINDLER 81 MRK2 e ⁺ e ⁻ 3.771 GeV	<0.004 90 COFFMAN 92B MRK3 e ⁺ e ⁻ 3.77 GeV
	$\Gamma(\overline{K}^0 \rho^0 \pi^+ 3\text{-body})/\Gamma(\overline{K}^0 \pi^+ \pi^+ \pi^-)$
$0.042^{+0.019}_{-0.017}$ 44 BARLAG 92C ACCM π^- Cu 230 GeV	VALUE DOCUMENT ID TECH COMMENT
$0.243^{+0.064}_{-0.041} \pm 0.041$ 11 ⁴⁴ AGUILAR 87F HYBR πp , pp 360, 400 GeV	0.07±0.04±0.06 ANJOS 92c E691 γ Be 90-260 GeV
	F (770 & (200) - + \ /F
⁴³ SCHINDLER 81 (MARK-2) measures $\sigma(e^+e^- \rightarrow \psi(3770)) \times$ branching fraction to be 0.51 \pm 0.08 nb. We use the MARK-3 (ADLER 88C) value of $\sigma=4.2\pm0.6\pm0.3$ nl	
44 AGUILAR-BENITEZ 87F and BARLAG 92c compute the branching fraction by topolog	<0.005 90 ANJOS 92C E691 γ Be 90-260 GeV
ical normalization.	
$\Gamma(\overline{K}^0\pi^+\pi^+\pi^-)/\Gamma(K^-\pi^+\pi^+)$ Γ_{52}/Γ_3	$\Gamma(\overline{K^0}\pi^+\pi^+\pi^- \text{ nonresonant})/\Gamma(\overline{K^0}\pi^+\pi^+\pi^-)$ VALUE POCUMENT ID TECH COMMENT
VALUE EVTS DOCUMENT ID TECN COMMENT	VALUE DOCUMENT ID TECN COMMENT 0.12±0.06 OUR AVERAGE
0.78±0.10 OUR FIT 0.77±0.07±0.11 229 ANJOS 92c E691 γ Be 90−260 GeV	$0.10 \pm 0.04 \pm 0.06$ ANJOS 92C E691 γ Be 90-260 GeV
•	$0.17 \pm 0.056 \pm 0.100$ COFFMAN 928 MRK3 e^+e^- 3.77 GeV
$\Gamma(\overline{K}^0 a_1(1260)^+)/\Gamma(\overline{K}^0 \pi^+ \pi^+ \pi^-)$ Γ_{71}/Γ_5	$\Gamma(K^-\pi^+\pi^+\pi^+\pi^-)/\Gamma_{\text{total}}$
Unseen decay modes of the $a_1(1260)^+$ are included.	Γ(K-π+π+π+π-)/Γ _{total} Γ ₅₉ , <u>VALUE</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u>
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Unseen decay modes of the $a_1(1260)^+$ are included. DOCUMENT ID TECN COMMENT 1.66 \pm 0.28 \pm 0.40 ANJOS 92c E691 γ Be 90-260 GeV 1.078 \pm 0.114 \pm 0.140 COFFMAN 928 MRK3 e^+e^- 3.77 GeV F(\overline{K}^0 $a_2(1320)^+$)/ Γ total Unseen decay modes of the $a_2(1320)^+$ are included. VALUE CLY DOCUMENT ID TECN COMMENT <	$ K = \pi^+ \pi^+ \pi^- / \Gamma \text{total} $ $VALUE $
Unseen decay modes of the $a_1(1260)^+$ are included. DOCUMENT ID TECN COMMENT 1.15 \pm 0.19 OUR AVERAGE Error includes scale factor of 1.1. 1.66 \pm 0.28 \pm 0.40 ANJOS 92c E691 γ Be 90–260 GeV 1.078 \pm 0.114 \pm 0.140 COFFMAN 928 MRK3 e^+e^- 3.77 GeV (KO $a_2(1320)^+$)/ Γ total Unseen decay modes of the $a_2(1320)^+$ are included. VALUE CLY DOCUMENT ID IECN OMMENT COMMENT CO	$ \begin{array}{c} 1 \left(K^{-}\pi^{+}\pi^{+}\pi^{-}\pi^{-}\right)/1 \text{ total} \\ VALUE & 0 \text{ OW do not use the following data for averages, fits, limits, etc.} \bullet \bullet \bullet \\ 0.0037^{+0.0012} & 46 \text{ BARLAG} & 92\text{C ACCM } \pi^{-} \text{ Cu } 230 \text{ GeV} \\ 46 \text{ BARLAG } 92\text{C computes the branching fraction using topological normalization.} \\ \Gamma\left(K^{-}\pi^{+}\pi^{+}\pi^{+}\pi^{-}\right)/\Gamma\left(K^{-}\pi^{+}\pi^{+}\right) & \Gamma_{59}/\Gamma \\ VALUE & EVTS & DOCUMENT ID & TECN & COMMENT \\ 0.080\pm0.009 \text{ OUR FIT} & DOCUMENT ID & TECN & COMMENT \\ 0.090\pm0.009 \text{ OUR AVERAGE} \\ 0.077\pm0.008\pm0.010 & 239 & \text{FRABETTI} & 97\text{C E687} & \gamma \text{Be, } \overline{E}_{\gamma} \approx 200 \text{ GeV} \\ 0.09\pm0.01\pm0.01 & 113 & \text{ANJOS} & 900 \text{ E691} & \text{Photoproduction} \\ \Gamma\left(\overline{K}^{\bullet}(892)^{0}\pi^{+}\pi^{+}\pi^{-}\right)/\Gamma\left(K^{-}\pi^{+}\pi^{+}\pi^{+}\pi^{-}\right) & \Gamma_{93}/\Gamma \\ \text{Unseen decay modes of the } \overline{K}^{*}(892)^{0} \text{ are included.} \\ \frac{VALUE}{1.1\pm0.4 \text{ OUR FIT}} & \text{Error includes scale factor of } 1.8. \\ 1.25\pm0.12\pm0.23 & \text{ANJOS} & 900 \text{ E691} & \text{Photoproduction} \\ \Gamma\left(\overline{K}^{*}(892)^{0}\rho^{0}\pi^{+}\right)/\Gamma\left(K^{-}\pi^{+}\pi^{+}\right) & \Gamma_{94}/\Gamma \\ \text{Unseen decay modes of the } \overline{K}^{*}(892)^{0} \text{ are included.} \\ \frac{VALUE}{1.000000000000000000000000000000000000$
Unseen decay modes of the $a_1(1260)^+$ are included. DOCUMENT ID TECN COMMENT 1.15 \pm 0.19 OUR AVERAGE Error includes scale factor of 1.1. 1.66 \pm 0.28 \pm 0.40 ANJOS 92c E691 γ Be 90–260 GeV 1.078 \pm 0.114 \pm 0.140 COFFMAN 928 MRK3 e^+e^- 3.77 GeV $ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	$ K = \frac{1}{\sqrt{NLUE}} - \frac{1}{\sqrt$
Unseen decay modes of the $a_1(1260)^+$ are included. DOCUMENT ID TECN COMMENT 1.15 \pm 0.19 OUR AVERAGE Error includes scale factor of 1.1. 1.66 \pm 0.28 \pm 0.40 ANJOS 92c E691 γ Be 90–260 GeV 1.078 \pm 0.114 \pm 0.140 COFFMAN 928 MRK3 e^+e^- 3.77 GeV $ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	$ \begin{array}{c} 1 \left(K^{-} \pi^{+} \pi^{+} \pi^{-}\right) / 1 \text{ total} \\ VALUE & 0 \text{ OUMENT ID} \\ \bullet \bullet \text{ We do not use the following data for averages, fits, limits, etc. } \bullet \bullet \bullet \\ 0.0037^{+0.0012} & 46 \text{ BARLAG} & 92\text{C ACCM } \pi^{-} \text{ Cu } 230 \text{ GeV} \\ 46 \text{ BARLAG } & 92\text{C accm } \pi^{-} \text{ Cu } 230 \text{ GeV} \\ 46 \text{ BARLAG } & 92\text{C accm } \pi^{-} \text{ Cu } 230 \text{ GeV} \\ 46 \text{ BARLAG } & 92\text{C accm } \pi^{-} \text{ Cu } 230 \text{ GeV} \\ 46 \text{ BARLAG } & 92\text{C accm } \pi^{-} \text{ Cu } 230 \text{ GeV} \\ 46 \text{ BARLAG } & 92\text{C accm } \pi^{-} \text{ Cu } 230 \text{ GeV} \\ 46 \text{ BARLAG } & 92\text{C accm } \pi^{-} \text{ Cu } 230 \text{ GeV} \\ 46 \text{ BARLAG } & 92\text{C accm } \pi^{-} \text{ Cu } 230 \text{ GeV} \\ 46 \text{ BARLAG } & 92\text{C accm } \pi^{-} \text{ Cu } 230 \text{ GeV} \\ 46 \text{ BARLAG } & 92\text{C accm } \pi^{-} \text{ Cu } 230 \text{ GeV} \\ 46 \text{ BARLAG } & 92\text{C accm } \pi^{-} \text{ Cu } 230 \text{ GeV} \\ 46 \text{ BARLAG } & 92\text{C accm } \pi^{-} \text{ Cu } 230 \text{ GeV} \\ 46 \text{ BARLAG } & 92\text{C accm } \pi^{-} \text{ Cu } 230 \text{ GeV} \\ 46 \text{ BARLAG } & 92\text{C accm } \pi^{-} \text{ Cu } 230 \text{ GeV} \\ 46 \text{ BARLAG } & 92\text{C accm } \pi^{-} \text{ Cu } 230 \text{ GeV} \\ 46 \text{ BARLAG } & 92\text{C accm } \pi^{-} \text{ Cu } 230 \text{ GeV} \\ 46 \text{ BARLAG } & 92\text{C accm } \pi^{-} \text{ Cu } 230 \text{ GeV} \\ 46 \text{ BARLAG } & 92\text{C accm } \pi^{-} \text{ Cu } 230 \text{ GeV} \\ 46 \text{ BARLAG } & 92\text{C accm } \pi^{-} \text{ Cu } 230 \text{ GeV} \\ 46 \text{ BARLAG } & 92\text{C accm } \pi^{-} \text{ Cu } 230 \text{ GeV} \\ 46 \text{ BARLAG } & 92\text{C accm } \pi^{-} \text{ Cu } 230 \text{ GeV} \\ 46 \text{ BARLAG } & 92\text{C accm } \pi^{-} \text{ Cu } 230 \text{ GeV} \\ 46 \text{ BARLAG } & 92\text{C accm } \pi^{-} \text{ Cu } 230 \text{ GeV} \\ 46 \text{ BARLAG } & 92\text{C accm } \pi^{-} \text{ Cu } 230 \text{ GeV} \\ 46 \text{ BARLAG } & 92\text{C accm } \pi^{-} \text{ Cu } Cu$
Unseen decay modes of the $a_1(1260)^+$ are included. DOCUMENT ID TECN COMMENT 1.15 \pm 0.19 OUR AVERAGE Error includes scale factor of 1.1. 1.66 \pm 0.28 \pm 0.40 ANJOS 92c E691 γ Be 90–260 GeV 1.078 \pm 0.114 \pm 0.140 COFFMAN 928 MRK3 e^+e^- 3.77 GeV $ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	$ K = \frac{1}{\sqrt{NLUE}} - \frac{1}{\sqrt$

		$(K^-\pi^+\pi^+)^{-7}$ (892) 0 are included	ed.	Γ ₉₅ /Γ ₃₄	Γ <u>×</u>	(π ⁺ π ⁺ π ⁻ π ⁰)/Γ _{tot}	tal ——	DOCUMENT ID	TECN	COMMENT	Γ ₁₀₁ /Γ
VALUE		DOCUMENT ID	TECN CO.	MMENT	. 0.	019+0.015 -0.012	53	BARLAG	92c ACCM	l π ⁻ Cu 23	0 GeV
0.048±0.015±0.011			'c E687 γB	Be, $\overline{E}_{\gamma} \approx 200 \text{ GeV}$	• :	⁵³ BARLAG 92C compu	ites the bran	ching fraction (using topolog	gical normali	zation.
$\Gamma(K^-\rho^0\pi^+\pi^+)/\Gamma(K^-\rho^0\pi^+\pi^+)$	(- π+π+) DOCUMENT ID	TECN CO	Γ ₆₃ /Γ ₃₄	Г	$(\pi^{+}\pi^{+}\pi^{-}\pi^{0})/\Gamma(R)$	(-π+π+)				Γ ₁₀₁ /Γ ₃₄
0.034±0.009±0.005				$E_{\gamma} \approx 200 \text{ GeV}$	<u> </u>	ALUE	<u>CL%</u>	DOCUMENT ID	TECN		
Г(<i>К</i> -я+я+я+я-п	ionresona	nt)/Γ(<i>K</i> =π+π+	1	Γ ₆₄ /Γ ₃₄		• We do not use the O.4	e following o	ata for average ANJOS	s, rits, ilmits 89E E691	Photoprod	uction
VALUE	<u>CL%</u>	DOCUMENT ID	TECN CO	DMMENT						•	
<0.026	90	FRABETTI 97	'C E687 ΄γΕ	Be, $\overline{E}_{\gamma} \approx 200 \; \text{GeV}$	1 '	$(\eta \pi^+)/\Gamma(K^-\pi^+\pi^-)$ Unseen decay mod	des of the η	are included.			Γ ₁₀₆ /Γ ₃₄
$\Gamma(K^-\pi^+\pi^+\pi^0\pi^0)/\Gamma$	r _{total}			Г ₆₆ /Г	· <u>v</u>	0.083±0.023±0.014	CL% EVTS				<u>IMENT</u> e [—] ≈ 10.5
VALUE	EVTS	DOCUMENT ID	TECN CO			• We do not use the				(seV 10.5
0.022 + 0.047 ± 0.004 • • • We do not use the		⁷ AGUILAR 87				(0.12	90	ANJOS			toproduction
<0.015	_	-		Cu 230 GeV	-	$(\omega \pi^+)/\Gamma(K^-\pi^+\pi^-)$.+1				Γ ₁₀₈ /Γ ₃₄
47 AGUILAR-BENITEZ ical normalization.						Unseen decay mod	des of the ω <u>CL%</u>	are included.	TECN	COMMENT	108/134
$\Gamma(\overline{K}^0\pi^+\pi^+\pi^-\pi^0)/2$	Г			Γ ₆₆ /Γ	. •	<0.08	90	ANJOS	89E E691	Photoproc	luction
VALUE	EVTS	DOCUMENT ID	TECN CO			$(\pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-})$	/Γ _{total}				Γ ₁₀₄ /Γ
0.054 ^{+0.030} _{-0.014} OUR AVEI		٥			<u>y</u>	• We do not use the		DOCUMENT ID	TECN es, fits, limits		
0.099 ^{+0.036} -0.070				Cu 230 GeV	0	.0010 ^{+0.0008} -0.0007	54	BARLAG	92c ACCM	Λ π [—] Cu 23	0 GeV
$0.044^{+0.052}_{-0.013} \pm 0.007$		⁸ AGUILAR 87				⁵⁴ BARLAG 92C compu	utes the brar	ching fraction	using topolog	gical normali	zatlon.
⁴⁸ AGUILAR-BENITEZ ical normalization.	87F and B	ARLAG 92C compute	e the branchi	ing fraction by topolog-	ī	·(π+π+π+π-π-)	/r(K-#+	•			Γ ₁₀₄ /Γ ₃₄
Γ (Κ⁰π+π+π+π- π VALUE	−)/Γ _{total}	DOCUMENT ID	TECN_CO	Γ ₆₇ /Γ	. <u>y</u>	0.023±0.004±0.002	CL% <u>EVTS</u> 58	FRABE		E687 γB	$E, \overline{E}_{\gamma} \approx 200$
0.0008±0.0007	4			Cu 230 GeV	•	• We do not use th	e following	data for averag	es, fits, limits		GeV
⁴⁹ BARLAG 92C compu	ites the bra	nching fraction using	g topological	normalization.	•	<0.019	90	ANJOS	89	E691 Pho	otoproduction
$\Gamma(K^-\pi^+\pi^+\pi^+\pi^-\pi$	r ⁰)/F _{total}			Γ ₆₈ /Γ	- г	$(\eta \rho^+)/\Gamma(K^-\pi^+\pi^-)$					Γ ₁₀₉ /Γ ₃₄
VALUE 0.0020±0.0018		DOCUMENT ID BARLAG 92	TECN CO	<u>OMMENT</u> - Cu 230 GeV	-	Unseen decay mod ALUE	des of the η 	are included. <u>DOCUMENT ID</u>		COMMENT	
50 BARLAG 92c compu					_	<0.13	90	DAOUDI		e ⁺ e ⁻ ≈	
Γ(Κ ° Κ ° κ+)/Γ(κ-			G F G	Г ₆₉ /Г ₃₄		·(π+π+π+π-π-π	CO)/Feodal				Γ ₁₀₅ /Γ
VALUE	<u>EVTS</u>	DOCUMENT ID		OMMENT	_ <u>}</u>	ALUE		DOCUMENT ID	TECN	COMMENT	
0.20±0.09 OUR AVERA 0.14±0.04±0.02	NGE Error 39	includes scale factor ALBRECHT 94		⁺ e ⁻ ≈ 10 GeV	C	.0029 +0.0029 -0.0020	5!	BARLAG	92C ACCM	/ π Cu 23	30 GeV
0.34±0.07	70			+ e ⁻ ≈ 10.5 GeV	· K	55 BARLAG 92C comp	uites the brai	nching fraction	using topolo	gical normal	ization.
					_						- /-
		- Plonic modes -			ı	(η'(958)π ⁺)/Γ(K ⁻	-π+π+)	(OES) are inclu	dad		Γ ₁₁₀ /Γ ₃₄
				Г ₉₇ /Г ₃₄		(η'(958)π ⁺)/Γ(Κ ⁻ Unseen decay mod VALUE	-π+π+)	(958) are inclu DOCUMENT ID	ded.	COMMENT	
Γ(π ⁺ π ⁰)/Γ(Κ ⁻ π ⁺ 1 <u>VALUE</u> 0.028±0.006±0.006	π ⁺) <u>EVTS</u> 34	DOCUMENT ID		OMMENT	<u>, </u>	Unseen decay mod	π ⁺ π ⁺) Indes of the η' <u>CL%</u> 90	DOCUMENT ID	92 CLE2	e+e-≈	10.5 GeV
VALUE 0.028±0.006±0.005	<u>EVTS</u> 34	DOCUMENT ID		<u>OMMENT</u> + e ⁻ ≈ Υ(45)	<u>.</u>	Unseen decay mod	$\frac{-\pi^+\pi^+}{\pi^+\pi^+}$ Indees of the η' $\frac{CL\%}{90}$ 90	DOCUMENT ID DAOUDI ALVAREZ	92 CLE2 91 NA14	e ⁺ e [−] ≈ Photopro	10.5 GeV duction
$VALUE$ 0.028 ± 0.006 ± 0.006 $\Gamma(\pi^{+}\pi^{+}\pi^{-})/\Gamma(K^{-})$ VALUE	34 π+π+) EVTS	DOCUMENT ID		OMMENT	<u>.</u>	Unseen decay mod ALUE <0.1 <0.1	$\frac{-\pi^+\pi^+}{\pi^+\pi^+}$ Indees of the η' $\frac{CL\%}{90}$ 90	DOCUMENT ID DAOUDI ALVAREZ	92 CLE2 91 NA14	$e^+e^-\approx$ Photopros, etc. • •	10.5 GeV duction
VALUE $0.028\pm0.006\pm0.005$ $\Gamma(\pi^{+}\pi^{+}\pi^{-})/\Gamma(K^{-})$ VALUE 0.0406 ± 0.0034 OUR FI	<u>EVTS</u> 34 π+π+) <u>EVTS</u> T	DOCUMENT ID SELEN 93		<u>OMMENT</u> + e ⁻ ≈ Υ(45)	• <u> </u>	Unseen decay modALUE <0.1 <0.1 • • We do not use th <0.13		DOCUMENT ID DAOUDI ALVAREZ data for averag	92 CLE2 91 NA14 es, fits, limit	$e^+e^-\approx$ Photopros, etc. • •	10.5 GeV duction
$0.028\pm0.006\pm0.005$ $\Gamma(\pi^{+}\pi^{+}\pi^{-})/\Gamma(K^{-})$	<u>EVTS</u> 34 π+π+) <u>EVTS</u> T	DOCUMENT ID SELEN 93 DOCUMENT ID FRABETTI 9	3 CLE2 e ⁻¹ <u>TECN</u> C	OMMENT + $e^- \approx r(45)$ F98/F34 COMMENT y Be ≈ 200 GeV	• <u> </u>	Unseen decay mod ALUE <0.1 <0.1 • • We do not use the	$\frac{-\pi^{+}\pi^{+}}{\pi^{+}\pi^{+}}$ $\frac{CL\%}{90}$ 90 he following 90 $-\pi^{+}\pi^{+}$	DOCUMENT ID DAOUDI ALVAREZ data for averag ANJOS	92 CLE2 91 NA14 es, fits, limits 918 E691	$e^+e^-\approx$ Photopros, etc. • •	10.5 GeV duction ≈ 145 GeV
VALUE 0.028±0.006±0.005 Γ(π+π+π-)/Γ(K- VALUE 0.0408±0.0034 OUR FI 0.0403±0.0035 OUR AN 0.043±0.003 ±0.003 0.032±0.011±0.003	<u>EVTS</u> 34 π ⁺ π ⁺) <u>EVTS</u> T VERAGE	DOCUMENT ID SELEN 93 DOCUMENT ID FRABETTI 9 ADAMOVICH 9	3 CLE2 e ⁻¹ <u>TECN C</u> 97D E687 γ 93 WA82 π	OMMENT $+e^{-} \approx T(45)$ $-\frac{798}{500}$ $\frac{798}{500}$ $\frac{798}{500}$ $\frac{798}{500}$ $\frac{798}{500}$ $\frac{798}{500}$ $\frac{798}{500}$ $\frac{798}{500}$		Unseen decay modALUE <0.1 <0.1 •• We do not use th <0.13 $-(\eta'(958)\rho^+)/\Gamma(K^-)$ Unseen decay modALUE	region $\pi + \pi + 1$ redes of the η' 20% 90 the following 90 $\pi + \pi + 1$ and the η' consideration of the η' 20%	DOCUMENT ID DAOUDI ALVAREZ data for averag ANJOS (958) are inclu DOCUMENT ID	92 CLE2 91 NA14 es, fits, limit: 918 E691 ded. TECN	$e^+e^-\approx$ Photopros, etc. • • • • γ Be, \overline{E}_{γ}	10.5 GeV duction ≈ 145 GeV Γ ₁₁₁ /Γ ₃₄
VALUE 0.028±0.006±0.005 Γ(π+π+π-)/Γ(Κ- VALUE 0.0406±0.0034 OUR FI 0.0403±0.0035 OUR AN 0.043±0.003±0.003 0.032±0.011±0.003 0.035±0.007±0.003	236 EVTS 34 π ⁺ π ⁺) EVTS T VERAGE 236	DOCUMENT ID SELEN 93 DOCUMENT ID FRABETTI 9 ADAMOVICH 9	3 CLE2 e ⁻¹ <u>TECN C</u> 97D E687 γ 93 WA82 π 89 E691 F	OMMENT $+e^- \approx T(45)$ F98/ Γ_{34} COMMENT $y \text{ Be } \approx 200 \text{ GeV}$ $\tau^- 340 \text{ GeV}$ Photoproduction		Unseen decay modALUE <0.1 <0.1 <0.13 (0.13) (0.13) (0.13) Unseen decay modALUE Unseen decay modALUE (0.13)	π + π + η des of the η $\frac{CL\%}{90}$ 90 he following 90 π + π + η des of the η $\frac{CL\%}{90}$	DOCUMENT ID DAOUDI ALVAREZ data for averag ANJOS (958) are inclu DOCUMENT ID DAOUDI	92 CLE2 91 NA14 es, fits, limit: 918 E691 ded. 7 ECN 92 CLE2	$e^+e^-\approx$ Photopros, etc. • • • τ τ Be, \overline{E}_{γ} τ τ τ τ τ τ τ	10.5 GeV duction ≈ 145 GeV Γ ₁₁₁ /Γ ₃₄
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VALUE 0.028 ± 0.006 ± 0.005 $\Gamma(\pi^+\pi^+\pi^-)/\Gamma(K^-)$ VALUE 0.0406 ± 0.0034 OUR FT 0.0403 ± 0.003 ± 0.003 0.032 ± 0.011 ± 0.003 0.035 ± 0.007 ± 0.003 0.042 ± 0.016 ± 0.010 $\Gamma(\rho^0\pi^+)/\Gamma(\pi^+\pi^+\pi^-)$ VALUE 51 FRABETTI 97D also resulting decay fract $\Gamma(\rho^0\pi^+)/\Gamma(K^-\pi^+\pi^-)$ VALUE • • • We do not use th <0.015 $\Gamma(\pi^+\pi^+\pi^-)$ nonresco VALUE 0.62 ± 0.11 OUR FIT 0.699 ± 0.105 ± 0.061 52 FRABETTI 97D als 52 FRABETTI 97D als	FVTS 34 $\pi^+\pi^+$) FVTS T VERAGE 236 20 57 τ^-) 9 oincludes clons are no π^+) GLSS the following 90 Smant)/ Γ (oincludes clons are no π^+) Onant) oincludes clons are no π^-)	DOCUMENT ID FRABETTI 9 ADAMOVICH 9 ANJOS 8 BALTRUSAIT8 DOCUMENT ID 12 [1270] π^+ and f_0 t statistically signific DOCUMENT ID 13 data for averages, fi ANJOS 88 $(\pi^+\pi^+\pi^-)$ DOCUMENT ID 15 FRABETTI 97 15 [1270] π^+ and f_0	3 CLE2 e ⁻¹ TECN C 97D E687 γ 93 WA82 π 89 E691 F 85ε MRK3 e TECN C 7D E687 γ (980) π + mo cant. TECN C 17D E687 γ (97D E687 γ (980) π + mo (97D E687 γ (980) π + mo	OMMENT $+e^- \approx r(45)$ F98/F34 COMMENT Y Be $\approx 200 \text{ GeV}$ $r^- 340 \text{ GeV}$ Photoproduction $p^+e^- 3.77 \text{ GeV}$ F99/F98 OMMENT C. • • • Photoproduction F100/F98 OMMENT Be $\approx 200 \text{ GeV}$		Unseen decay modALUE <0.1 • • We do not use th <0.13 - (\(\frac{1}{958} \rho^{+} \) / \((K^{-} \) Unseen decay modALUE <0.17 - (K + \(\bar{K}^{0} \) / \((K^{0} \) \(\pi^{+} \) It is generally assimately assi	$-\pi + \pi + 1$ des of the η' $-\frac{cLk}{90}$ 90 90 $-\pi + \pi + 1$ des of the η' $-\frac{cLk}{90}$ $-\frac{cLk}{90}$ Hadroni -1) unmed for mm $-K^0\pi^+$ hat is actually and doubly of sumption by $-\frac{cLK}{90}$ 129 69 31 6 he following 70 5	DOCUMENT ID DAOUDI ALVAREZ data for averag ANJOS (958) are inclu DOCUMENT ID DAOUDI c modes with c modes with r measured. Bit abiliblo-suppret a few percent. DOCUMENT ID FRABETTI ANJOS BALTRUSAI' SCHINDLER data for averag 6 BISHAI	92 CLE2 91 NA14 es, fits, limit: 918 E691 ded. 72 CLE2 1 a K K pai + → K ⁰ π+ κ ⁰	$e^+e^-\approx Photopros,$ etc. • • • $rac{r}{r}$ $e^+e^-\approx Parameter rac{r}{r} rac{r} rac{r}{r} rac{$	10.5 GeV duction ≈ 145 GeV F111/F34 10.5 GeV F112/F35 ference between the occur, could be compared to the occur, could be compared to the country of t
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VALUE 0.028 ± 0.006 ± 0.005 $\Gamma(\pi^+\pi^+\pi^-)/\Gamma(K^-)$ VALUE 0.0406 ± 0.0034 OUR FT 0.0403 ± 0.003 ± 0.003 0.032 ± 0.011 ± 0.003 0.035 ± 0.007 ± 0.003 0.042 ± 0.016 ± 0.010 $\Gamma(\rho^0\pi^+)/\Gamma(\pi^+\pi^+\pi^-)$ VALUE 0.289 ± 0.055 ± 0.058 51 FRABETTI 97D also resulting decay fract $\Gamma(\rho^0\pi^+)/\Gamma(K^-\pi^+\pi^-)$ VALUE • • • We do not use the contract of the co	EVTS 34 π+π+) EVTS T VERAGE 236 20 57 r) so includes ions are no π+) SLS te following 90 onant)/Γ(DOCUMENT ID SELEN 93 POCUMENT ID FRABETTI 9 ADAMOVICH 9 ANJOS 8 BALTRUSAIT8 DOCUMENT ID 11 FRABETTI 91 $f_2(1270)\pi^+$ and f_0 4 statistically signific DOCUMENT ID 1 data for averages, fi ANJOS 85 $(\pi^+\pi^+\pi^-)$ DOCUMENT ID 52 FRABETTI 91 $f_2(1270)\pi^+$ and f_0 12 statistically signific	3 CLE2 e ⁻¹ TECN C 97D E687 γ 93 WA82 π 89 E691 F 85ε MRK3 e TECN C 7D E687 γ (980)π+ mo cant. TECN C TECN C 100 E687 γ	OMMENT + e ⁻ ≈ $\Upsilon(45)$ F98/F34 COMMENT y Be ≈ 200 GeV τ^- 340 GeV Photoproduction t^+ e ⁻ ≈ 3.77 GeV GMMENT Be ≈ 200 GeV odes in the fit, but the F99/F34 OMMENT C. • • • • Thotoproduction F100/F96 OMMENT Be ≈ 200 GeV odes in the fit, but the		Unseen decay modALUE <0.1 • • We do not use th <0.13 - (\(\frac{1}{958} \rho^{+} \) / \((K^{-} \) Unseen decay modALUE <0.17 - (K + \(\bar{K}^{0} \) / \((K^{0} \) \(\pi^{+} \) It is generally assimately assi	$-\pi + \pi + 1$ des of the η' $-\frac{cLk}{90}$ 90 90 $-\pi + \pi + 1$ des of the η' $-\frac{cLk}{90}$ $-\frac{cLk}{90}$ Hadroni -1) unmed for mm $-K^0\pi^+$ hat is actually and doubly of sumption by $-\frac{cLK}{90}$ 129 69 31 6 he following 70 5	DOCUMENT ID DAOUDI ALVAREZ data for averag ANJOS (958) are inclu DOCUMENT ID DAOUDI c modes with c modes with r measured. Bit abiliblo-suppret a few percent. DOCUMENT ID FRABETTI ANJOS BALTRUSAI' SCHINDLER data for averag 6 BISHAI	92 CLE2 91 NA14 es, fits, limit: 918 E691 ded. 72 CLE2 1 a K K pai + → K ⁰ π+ κ ⁰	$e^+e^-\approx Photopros,$ etc. • • • γ Be, \overline{E}_{γ} That γ Be \overline{E}_{γ}	10.5 GeV duction ≈ 145 GeV F111/F34 10.5 GeV F112/F35 ference between the occur, could be compared to the occur, could be compared to the country of t

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ALUE EVTS		Γ ₁₁₂ /Γ ₃₄	$\Gamma(K^*(892)^+ \overline{K}^*(892)^0) / \Gamma_{\text{total}}$ $\Gamma_{136} / \Gamma_{136} /$
.082±0.010 OUR FIT	DOCUMENT ID TECN	COMMENT	Unseen decay modes of the K*(892)'s are included.
077±0.014±0.007 70	57 BISHAI 97 CLE2	$e^+e^-\approx r(4S)$	VALUE DOCUMENT ID TECN COMMENT 0.026 \pm 0.008 \pm 0.007 ALBRECHT 92B ARG $e^+e^-\simeq 10.4$ GeV
_	In analysis of $D^+ \rightarrow K\overline{K}$ ampli	· · · · <u>-</u>	
•	•	•	$\Gamma(K^0K^-\pi^+\pi^+ \text{non-}K^{*+}\overline{K}^{*0})/\Gamma_{\text{total}}$ $\Gamma_{126}/\Gamma_{126}$
$(K^+K^-\pi^+)/\Gamma(K^-\pi^+\pi^+\pi^+\pi^+\pi^+\pi^+\pi^+\pi^+\pi^+\pi^+\pi^+\pi^+\pi^+\pi$	•	Γ ₁₁₃ /Γ ₃₄	VALUE CL% DOCUMENT ID TECN COMMENT
OTC 0 0040 0 0046	DOCUMENT ID TECN		<0.0079 90 ALBRECHT 928 ARG $e^+e^- \simeq 10.4 \text{ GeV}$
976±0.0042±0.0046	FRABETTI 95B E687	Dalitz plot analysis	$\Gamma(\phi \pi^+ \pi^+ \pi^-)/\Gamma_{\text{total}}$
$\phi\pi^+)/\Gamma(K^-\pi^+\pi^+)$		Γ_{130}/Γ_{34}	Unseen decay modes of the ϕ are included.
Unseen decay modes of t			VALUE CL% EVTS DOCUMENT ID TECN COMMENT
68±0.005 OUR AVERAGE	DOCUMENT ID TECN	COMMENT	<0.002 90 0 ANJOS 88 E691 Photoproduction
58±0.006±0.006	FRABETTI 95B E687	Dalitz plot analysis	$\Gamma(\phi\pi^+\pi^+\pi^-)/\Gamma(K^-\pi^+\pi^+)$ Γ_{133}/Γ_3
62±0.017±0.006 19	ADAMOVICH 93 WA82	2 π ⁻ 340 GeV	Unseen decay modes of the ϕ are included,
77±0.011±0.005 128	DAOUDI 92 CLE2		VALUE CL% DOCUMENT ID TECN COMMENT
98±0.032±0.014 12 71±0.008±0.007 84	ALVAREZ 90c NA14 ANJOS 88 E691	•	 ● We do not use the following data for averages, fits, limits, etc.
84±0.021±0.011 21	BALTRUSAIT85E MRK		<0.031 90 ALVAREZ 90C NA14 Photoproduction
		5 2 2 5 521	$\Gamma(\phi\pi^+\pi^+\pi^-)/\Gamma(\phi\pi^+)$ Γ_{133}/Γ_{13}
K ⁺ K̄*(892) ⁰)/Γ(K π ⁻		Γ ₁₃₄ /Γ ₃₄	$\Gamma(\phi \pi^+ \pi^+ \pi^-)/\Gamma(\phi \pi^+)$ VALUE CL% DOCUMENT ID TECH COMMENT
	the $\overline{K}^*(892)^0$ are included.		• • • We do not use the following data for averages, fits, limits, etc. • • •
UE EVTS	DOCUMENT ID TECN Error includes scale factor of 1.	COMMENT	<0.6 90 FRABETT 92 E687 γBe
14±0.003±0.004	58 FRABETTI 958 E687		· · · · · · · · · · · · · · · · · · ·
58±0.009±0.006 73			$\Gamma(K^+K^-\pi^+\pi^+\pi^-\text{nonresonant})/\Gamma_{\text{total}}$ $\Gamma_{129}/\Gamma_{129}$
18±0.021±0.011 14		(3 e ⁺ e ⁻ 3.77 GeV	VALUE CL% EVTS DOCUMENT ID TECN COMMENT
See FRABETTI 958 for ev	dence also of $\overline{K}_0^*(1430)^0 K^+$ i	in the $D^+ \rightarrow K^+ K^- \pi^+$	<0.03 90 12 ANJOS 88 E691 Photoproduction
Dalitz plot.	V		Rare or forbidden modes
$K^+K^-\pi^+$ nonresonant)/[(K ⁻ π ⁺ π ⁺)	Γ ₁₁₆ /Γ ₃₄	
UE EVTS	DOCUMENT ID TECN	,	$\Gamma(K^{+}\pi^{+}\pi^{-})/\Gamma(K^{-}\pi^{+}\pi^{+})$ Γ_{137}/Γ_{5}
0±0.009 OUR AVERAGE			VALUE EVTS DOCUMENT ID TECN COMMENT 0.0075±0.0016 OUR AVERAGE
49±0.008±0.006 95	ANJOS 88 E691	·	$0.0077 \pm 0.0017 \pm 0.0008$ 59 AITALA 97C E791 π^- nucleus, 500 GeV
59±0.026±0.009 37	BALTRUSAIT85E MRK	3 e ⁺ e ⁻ 3.77 GeV	$0.0072\pm0.0023\pm0.0017$ 21 FRABETTI 95E E687 γ Be, $\overline{E}_{\gamma}=220$ GeV
$K^*(892)^+\overline{K}^0)/\Gamma(\overline{K}^0\pi^+$.)	Γ ₁₃₅ /Γ ₃₃	' '
	the $K^*(892)^+$ are included.	1367 - 33	$\Gamma(K^+\rho^0)/\Gamma(K^+\pi^+\pi^-)$ Γ_{138}/Γ_{13}
UE EVTS	DOCUMENT ID TECN	<u>COMMENT</u>	VALUE DOCUMENT ID TECN COMMENT
±0.3±0.4 67	FRABETTI 95 E687	γ Be $\overline{E}_{\gamma}pprox 200 ext{GeV}$	0.37±0.14±0.07 AITALA 97¢ E791 π ⁻ nucleus, 500 GeV
			$\Gamma(K^+\rho^0)/\Gamma(K^-\pi^+\pi^+)$ Γ_{138}/Γ_{3}
· + 0) /r			
	he & are included	Γ ₁₃₁ /Γ	VALUE CL% DOCUMENT ID TECN COMMENT
Unseen decay modes of t		131/1 COMMENT	, , ,
Unseen decay modes of t	DOCUMENT ID TECN		VALUE CLM DOCUMENT ID TECH COMMENT
Unseen decay modes of t	59 BARLAG 92C ACC	<u>COMMENT</u> Μ π Cu 230 GeV	VALUE CL% DOCUMENT ID TECN COMMENT • • • We do not use the following data for averages, fits, limits, etc. • • • <0.0067
L <u>UE</u> 123±0.010 ⁹ BARLAG 92C computes the	DOCUMENT ID TECN	COMMENT M m Cu 230 GeV gical normalization.	VALUE CLY DOCUMENT ID TECN COMMENT • • • • We do not use the following data for averages, fits, limits, etc. • • • < < 0.0067 90 FRABETTI 95E E687 γ Be, $\overline{E}_{\gamma} = 220$ GeV $\Gamma(K^{\bullet}(892)^{0}\pi^{+})/\Gamma(K^{+}\pi^{+}\pi^{-})$
Unseen decay modes of to the second section of the second	59 BARLAG 92C ACCE branching fraction using topolo	<u>COMMENT</u> Μ π Cu 230 GeV	VALUE CLY DOCUMENT ID TECN COMMENT • • • We do not use the following data for averages, fits, limits, etc. • • • < 0.0067 90 FRABETTI 95E E687 γ Be, $\overline{E}_{\gamma} = 220$ GeV $\Gamma(K^{+}(892)^{0}\pi^{+})/\Gamma(K^{+}\pi^{+}\pi^{-})$ Unseen decay modes of the $K^{+}(892)^{0}$ are included.
Unseen decay modes of t UE 23±0.010 BARLAG 92C computes the	59 BARLAG 92C ACCN branching fraction using topolo	COMMENT M m Cu 230 GeV gical normalization.	VALUE CLY DOCUMENT ID TECN COMMENT • • • We do not use the following data for averages, fits, limits, etc. • • • < 0.0067 90 FRABETTI 95E E687 γ Be, $\overline{E}_{\gamma} = 220$ GeV $\Gamma(K^*(892)^0\pi^+)/\Gamma(K^+\pi^+\pi^-)$ Unseen decay modes of the $K^*(892)^0$ are included. VALUE DOCUMENT ID TECN COMMENT
Unseen decay modes of the Unseen decay mode	59 BARLAG 92C ACCN branching fraction using topolo	COMMENT M \(\pi \) Cu 230 GeV glcal normalization. \[\begin{align*}	VALUE CLY DOCUMENT ID TECN COMMENT • • • We do not use the following data for averages, fits, limits, etc. • • • < 0.0067 90 FRABETTI 95E E687 γ Be, \overline{E}_{γ} = 220 GeV $\Gamma(K^{+}(892)^{0}\pi^{+})/\Gamma(K^{+}\pi^{+}\pi^{-})$ Unseen decay modes of the $K^{*}(892)^{0}$ are included. VALUE DOCUMENT ID TECN COMMENT 0.83 ± 0.21 ± 0.02 AITALA 97C E791 π^{-} nucleus, 500 GeV
Unseen decay modes of the US UE $US = 0.010$ BARLAG 92c computes the $\phi \pi^+ \pi^0$)/ $\Gamma (K^- \pi^+ \pi^+)$ Unseen decay modes of the US UE US US US US US US US US	DOCUMENT ID TECN 59 BARLAG 92C ACCN be branching fraction using topolo the ϕ are included. DOCUMENT ID TECN	COMMENT M π^- Cu 230 GeV gloal normalization. F131/F34 COMMENT 5, etc. • • •	VALUE CLY DOCUMENT ID TECN COMMENT • • • We do not use the following data for averages, fits, limits, etc. • • • < <0.0067 90 FRABETTI 95E E687 γ Be, $\overline{E}_{\gamma} = 220 \text{ GeV}$ $\Gamma(K^{+}(892)^{0}\pi^{+})/\Gamma(K^{+}\pi^{+}\pi^{-}) \qquad \Gamma_{139}/\Gamma_{13}$ Unseen decay modes of the $K^{+}(892)^{0}$ are included. VALUE DOCUMENT ID TECN COMMENT 0.83 \pm 0.21 \pm 0.02 AITALA 97C E791 π^{-} nucleus, 500 GeV
Unseen decay modes of the LUE 223 ± 0.010 PBARLAG 92C computes the $\phi\pi^+\pi^0$ / $\Gamma(K^-\pi^+\pi^+)$ Unseen decay modes of the LUE 250 ± 0.01 • • We do not use the follow 0.58	DOCUMENT ID TECN 59 BARLAG 92C ACCN be branching fraction using topolo the ϕ are included. DOCUMENT ID TECN wing data for averages, fits, limit	COMMENT M π Cu 230 GeV Igical normalization. F131/F34 COMMENT s, etc. • • •	VALUE CLY DOCUMENT ID TECN COMMENT • • • We do not use the following data for averages, fits, limits, etc. • • • < < 0.0067 90 FRABETTI 95E E687 γ Be, $\overline{E}_{\gamma} = 220$ GeV $\Gamma(K^{*}(892)^{0}\pi^{+})/\Gamma(K^{+}\pi^{+}\pi^{-})$ Unseen decay modes of the $K^{*}(892)^{0}$ are included. VALUE DOCUMENT ID TECN COMMENT 0.83 ± 0.21 ± 0.02 AITALA 97C E791 π^{-} nucleus, 500 GeV
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Unseen decay modes of the UE 23±0.010 BARLAG 92c computes the $\phi \pi^+ \pi^0$)/ $\Gamma(K^- \pi^+ \pi^+)$ Unseen decay modes of the UE CLY. • We do not use the follow 0.28 • $\phi \rho^+$)/ $\Gamma(K^- \pi^+ \pi^+)$ Unseen decay modes of the UE CLY. • We do not use the follow 0.28 • $\phi \rho^+$)/ $\Gamma(K^- \pi^+ \pi^+)$ Unseen decay modes of the UE CLY. • $\phi V = CLY$ •	by BARLAG 92C ACCN by BARLAG 92C ACCN by BARLAG 92C ACCN che of are included. DOCUMENT ID TECN Wing data for averages, fits, limit ALVAREZ 90C NA14 ANJOS 89E E691 Che of are included. DOCUMENT ID TECN DAOUDI 92 CLE2 COTAL DOCUMENT ID TECN 60 BARLAG 92C ACCN ce branching fraction using topolo (K-+++++) DOCUMENT ID TECN DOCUMENT ID TECN NOTE: ANJOS 89E E691	COMMENT M π C U 230 GeV Igical normalization. F131/Γ34 COMMENT S, etc. • • • Photoproduction Photoproduction F132/Γ34 COMMENT e+e-≈ 10.5 GeV F122/Γ COMMENT M π C U 230 GeV Igical normalization. F122/Γ34 COMMENT S, etc. • • • Photoproduction	• • • We do not use the following data for averages, fits, limits, etc. • • • • <0.0067 90 FRABETTI 95E E687 γ Be, $\overline{E}_{\gamma} = 220$ GeV $\Gamma(K^*(892)^0\pi^+)/\Gamma(K^+\pi^+\pi^-)$ Γ_{139}/Γ_{13} Unseen decay modes of the $K^*(892)^0$ are included. **MALUE DOCUMENT ID IECN COMMENT π^- nucleus, 500 GeV $\Gamma(K^*(892)^0\pi^+)/\Gamma(K^-\pi^+\pi^+)$ Unseen decay modes of the $K^*(892)^0$ are included. **PALUE DOCUMENT ID IECN COMMENT π^- nucleus, 500 GeV π^- Nucleus π^- nucleus, 500 GeV π^- Nucleus π^- Nucleus, 500 GeV π^- Nucleus π^- Nucleus π^- Nucleus, 500 GeV π^- Nucleus π^- Nucleus π^- Nucleus, 500 GeV π^- Nucleus, 500
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Unseen decay modes of the UE 23±0.010 BARLAG 92c computes the $\phi \pi^+ \pi^0$)/ $\Gamma(K^- \pi^+ \pi^+)$ Unseen decay modes of the UE 25% of We do not use the follow 0.28 $\phi \rho^+$)/ $\Gamma(K^- \pi^+ \pi^+)$ Unseen decay modes of the UE 25% of the	be pocument in the pocument in	COMMENT M π^- Cu 230 GeV gloal normalization. F131/F34 COMMENT 5, etc. • • • Photoproduction Photoproduction F132/F34 COMMENT π^- Cu 230 GeV gloal normalization. F122/F COMMENT S, etc. • • • Photoproduction F123/F COMMENT π^- Cu 230 GeV F122/F34 COMMENT F123/F COMMENT π^- Cu 230 GeV F124/F	value very do not use the following data for averages, fits, limits, etc. • • • • 0.0067 90 FRABETTI 95E E687 γBe, $\overline{E}_{\gamma} = 220$ GeV $\Gamma(K^*(892)^0\pi^+)/\Gamma(K^+\pi^+\pi^-)$ Γ_{139}/Γ_{12} Unseen decay modes of the $K^*(892)^0$ are included. Value
Unseen decay modes of the UE 23±0.010 BARLAG 92c computes the $\phi \pi + \pi^0$)/ $\Gamma(K - \pi + \pi^+)$ Unseen decay modes of the UE CLY. • We do not use the follow 0.58 90 0.28 90 $\phi \rho^+$)/ $\Gamma(K - \pi + \pi^+)$ Unseen decay modes of the UE CLY. 1.16 90 $K + K - \pi + \pi^0 \text{ non-} \phi$)/ Γ_L UE CLY. • We do not use the follow 0.25 0.26 BARLAG 92c computes the $K + K - \pi + \pi^0 \text{ non-} \phi$)/ Γ_L UE CLY. • We do not use the follow 0.25 90 $K + K^0 \pi^+ \pi^-$)/ Γ_L $V = CLY$ 1.02 90 $K + K^0 \pi^+ \pi^-$)/ Γ_L $V = CLY$ 1.02 90 $K + K^0 \pi^+ \pi^-$)/ Γ_L $V = CLY$ 1.02 90 $K + K^0 \pi^+ \pi^-$)/ Γ_L 1.04 $V = CLY$ 1.05 90 $K + K^0 \pi^+ \pi^-$)/ Γ_L 1.05 1.06 1.07 1.08 1.09 1.09 1.09 1.09 1.09 1.09 1.09 1.09	DOCUMENT ID TECN 59 BARLAG 92C ACCh 2 branching fraction using topolo the φ are included. DOCUMENT ID TECN ALVAREZ 90C NA14 ANJOS 89E E691 THE PROPERTIES TECN DAOUDI 92 CLE2 TOTAL DOCUMENT ID TECN 60 BARLAG 92C ACCh 20 branching fraction using topolo (K-π+π+) DOCUMENT ID TECN DOCUMENT ID TECN ANJOS 89E E691 DOCUMENT ID TECN ANJOS 89E E691	COMMENT M π C U 230 GeV Igical normalization. F131/Γ34 COMMENT S, etc. • • • Photoproduction Photoproduction F132/Γ34 COMMENT M π C U 230 GeV Igical normalization. F122/Γ COMMENT S, etc. • • • Photoproduction F122/Γ COMMENT S, etc. • • • Photoproduction F123/Γ COMMENT e + e - ≈ 10.4 GeV F124/Γ COMMENT	value very do not use the following data for averages, fits, limits, etc. • • • • 0.0067 90 FRABETTI 95E E687 γ Be, $\overline{E}_{\gamma} = 220$ GeV
Unseen decay modes of the UE VE VE VE VE VE VE VE VE	DOCUMENT ID 59 BARLAG 20 CACCh 2 branching fraction using topolo the φ are included. DOCUMENT ID ALVAREZ ANJOS 89E 691 TECN DAOUDI 92 CLE2 TECN 60 BARLAG 20 CACCh 20 branching fraction using topolo (κ-π+π+) DOCUMENT ID DOCUMENT ID TECN Note 4 branching fraction using topolo (κ-π+π+) DOCUMENT ID TECN Note 4 branching fraction using topolo (κ-π+π+) DOCUMENT ID TECN ANJOS 89E 691 DOCUMENT ID TECN ALBRECHT 92B ARG	COMMENT M π^- Cu 230 GeV Igical normalization. F131/ Γ 34 COMMENT S, etc. • • • Photoproduction Photoproduction F132/ Γ 34 COMMENT $e^+e^-\approx 10.5 \text{ GeV}$ F122/ Γ M π^- Cu 230 GeV Igical normalization. F122/ Γ 34 COMMENT S, etc. • • • Photoproduction F123/ Γ COMMENT $e^+e^-\simeq 10.4 \text{ GeV}$ F124/ Γ COMMENT $e^+e^-\simeq 10.4 \text{ GeV}$	• • • We do not use the following data for averages, fits, limits, etc. • • • • • (0.0067 90 FRABETTI 95E E687 γ Be, $\overline{E}_{\gamma} = 220 \text{ GeV}$ Γ($K^+(892)^0\pi^+$)/Γ($K^+\pi^+\pi^-$) Unseen decay modes of the $K^*(892)^0$ are included. MALUE DOCUMENT ID Unseen decay modes of the $K^*(892)^0$ are included. F($K^*(892)^0\pi^+$)/Γ($K^-\pi^+\pi^+$) Unseen decay modes of the $K^*(892)^0$ are included. MALUE OLL DOCUMENT ID TECN COMMENT Tancleus, 500 GeV Γ($K^*(892)^0\pi^+$)/Γ($K^-\pi^+\pi^+$) Unseen decay modes of the $K^*(892)^0$ are included. MALUE OLL DOCUMENT ID TECN COMMENT • • • We do not use the following data for averages, fits, limits, etc. • • • • • • • • • • • • • • • • • • •
Unseen decay modes of the UE VE VE VE VE VE VE VE VE	DOCUMENT ID TECN 59 BARLAG 92C ACCN 2 branching fraction using topolo the φ are included. DOCUMENT ID TECN ALVAREZ 90C NA14 ANJOS 89E E691 THE PROPERTY OF TECN DAOUDI 92 CLE2 TOTAL DOCUMENT ID TECN 60 BARLAG 92C ACCN 2 branching fraction using topolo (κ-π+π+) DOCUMENT ID TECN ANJOS 89E E691 ANJOS 89E E691 POCUMENT ID TECN ANJOS 89E E691 DOCUMENT ID TECN ALBRECHT 92B ARG POCUMENT ID TECN ALBRECHT 92B ARG ALBRECHT 92B ARG POCUMENT ID TECN ALBRECHT 92B ARG ALBRECHT 92B ARG POCUMENT ID TECN ALBRECHT 92B ARG	COMMENT M π^- Cu 230 GeV Igical normalization. F131/ Γ 34 COMMENT S, etc. • • • Photoproduction Photoproduction F132/ Γ 34 COMMENT $e^+e^-\approx 10.5 \text{ GeV}$ F122/ Γ M π^- Cu 230 GeV Igical normalization. F122/ Γ 34 COMMENT S, etc. • • • Photoproduction F123/ Γ COMMENT $e^+e^-\simeq 10.4 \text{ GeV}$ F124/ Γ COMMENT $e^+e^-\simeq 10.4 \text{ GeV}$	value very do not use the following data for averages, fits, limits, etc. • • • • • • • • • • • • • • • • • • •

A test for i		= 1 weak	neutral current.	All	owed by	higher-order electroweak	
UE	CLS		DOCUMENT ID				
i.6 x 10 ⁻⁵	90		AITALA ata for averages			π N 500 GeV	
1.1 × 10 ⁻⁴	90	-	_			γ Be, E _γ ≈ 220 GeV	ı
2.5 × 10 ⁻³	90					e+e- 29 GeV	•
2.6 × 10 ⁻³	90	39				e ⁺ e ⁻ 10 GeV	
$\pi^+\mu^+\mu^-)/$	r					, /	
π'μ'μ')/: A test for	i total the Δ <i>C</i>	= 1 weak	neutral current.	. A1	owed by	Γ ₁₄₄ /Γ hlgher-order electroweak γ	
Interactions LUE	i. <u>CL%</u>	FVTS	DOCUMENT ID		TECN	COMMENT	
L8 × 10 ⁻⁵	90	4413	AITALA			π N 500 GeV	
	use the	following d	lata for averages	, fits	, limits,	etc. • • •	
8.9 × 10 ⁻⁵	90		FRABETTI	9 78	E687	γ Be, $\overline{E}_{\gamma} \approx 220$ GeV	
2.2 × 10 ⁻⁴	90	0				π ⁻ emulsion 600 GeV	
5.9 × 10 ³ 2.9 × 10 ³	90 90	36				e ⁺ e ⁻ 29 GeV e ⁺ e ⁻ 10 GeV	
		36	HAAS	00	CLEO	e . e 10 Gev	
$(\rho^{+}\mu^{+}\mu^{-})/(1$	total					Γ ₁₄₅ /Γ	
A test for interaction:		= 1 weak	neutral current	. Al	lowed by	y higher-order electroweak	
LUE	cr.	EVTS	DOCUMENT ID		TECN	COMMENT	
5.6 × 10 ^{—4}	90	0	KODAMA	95	E653	π emulsion 600 GeV	
K+e+e-)/	Faces					Γ ₁₄₆ /Γ	
LUE		CLN	DOCUMENT ID		TECN		
2.0 × 10 ⁻⁴		90	FRABETTI			γ Be, $\overline{E}_{\gamma} \approx 220$ GeV	
• • We do not	use the	following	lata for average	s, fits	, ilmits,	etc. • • •	
4.8 × 10 ⁻³		90	WEIR	90B	MRK2	e ⁺ e ⁻ 29 GeV	
$(K^+\mu^+\mu^-)$	/Fa ·					Γ ₁₄₇ /Γ	
•	CL%	EVTS	DOCUMENT ID		TECN	COMMENT	
9.7 × 10 ⁻⁵	90		FRABETTI			γ Be, $\overline{E}_{\gamma} \approx 220 \text{ GeV}$	
	use the	following	data for average				
3.2 × 10 ⁻⁴	90	0	KODAMA	95	E653	π^- emulsion 600 GeV	
9.2 × 10 ⁻³	90		WEIR	9 08	MRK2	e ⁺ e ⁻ 29 GeV	
$(\pi^+e^+\mu^-)/$	r _{total}					Γ ₁₄₈ /Γ	
A test of le	epton-fai		r conservation.			•	
1.1 × 10 ⁻⁴			DOCUMENT ID				
	tuen the	90 • following :	FRABETTI data for average			γ Be, $\overline{E}_{\gamma} \approx 220 \text{ GeV}$	•
3.3 × 10 ⁻³	t use the	90	WEIR			e+e- 29 GeV	
		30	WEIK	305	WINNE	6 ° 6 25 GeV	
$(\pi^{+}e^{-}\mu^{+})/$	F _{total}					Γ ₁₄₉ /Γ	
A test of k		mily-numbe <u>CL%</u>	er conservation. <u>DOCUMENT ID</u>		TECN	COMMENT	
1.3 × 10 ⁻⁴		90				γ Be, $\overline{E}_{\gamma} \approx 220 \text{ GeV}$	
	t use the	e following	data for average				
3.3×10^{-3}		90	WEIR	90E	MRK2	e+ e- 29 GeV	
(K+e+μ-),	/r. · ·					Γ ₄₇₇ /Γ	
Λ C μ) A test of k	total epton-fa	mlly-numb	er conservation.			Γ ₁₅₀ /Γ	
LUE		CLX	DOCUMENT ID				
1.3 × 10 ⁻⁴		90	FRABETTI			γ Be, $\overline{E}_{\gamma} \approx 220$ GeV	ı
	t use the		data for average				
3.4×10^{-3}		90	WEIR	90E	MRK2	e ⁺ e ⁻ 29 GeV	
$(K^+e^-\mu^+)$						Γ ₁₈₁ /Γ	•
A test of I	epton-fa		er conservation.			••	
1.2 × 10 ⁻⁴		<u>CL%</u>	DOCUMENT ID	97	TECN FED7	γ Be, $\overline{E}_{\gamma} \approx 220 \text{ GeV}$	٠,
	# 115m +h.	90 e following	FRABETTI data for average				
	. uac iin	90	WEIR			e+e-29 GeV	
_		,	FF E-IN	, 01	,		
3.4×10^{-3}						Г ₁₈₂ /Г	•
3.4 × 10 ⁻³ x ⁻ e ⁺ e ⁺)/							
3.4 × 10 ⁻³ (π ⁻ e ⁺ e ⁺)/ A test of I	epton-nı	umber cons			TECN	COMMENT	
3.4 × 10 ⁻³ ($\pi^-e^+e^+$)/ A test of I	epton-nı	CLN	DOCUMENT ID				· I
3.4 × 10 ⁻³ (π ⁻ e ⁺ e ⁺)/ A test of I	epton-nı	90 90	DOCUMENT ID	971	E687	γ Be, $\overline{E}_{\gamma} pprox $ 220 GeV	ı
$(\pi^-e^+e^+)/A$ test of I	epton-nı	90 90	DOCUMENT ID	971 s, fit	s E687 s, limits	γ Be, $\overline{E}_{\gamma} pprox $ 220 GeV	•
$(\pi^-e^+e^+)/A$ test of I test of I test of We do not (4.8×10^{-3})	epton-nu	CL% 90 e following	<u>DOCUMENT ID</u> FRABETTI data for average	971 s, fit	s E687 s, limits	γ Be, $\overline{E}_{\gamma} \approx 220$ GeV i, etc. • • • e^+e^- 29 GeV	
$(\pi^-e^+e^+)/A$ test of I $(\pi^-e^+e^+)/A$ test of I $(1.1 \times 10^{-4})/A$ • • We do not $(4.8 \times 10^{-3})/A$ $(\pi^-\mu^+\mu^+)/A$	epton-nu t use the	<u>CL%</u> 90 e following 90	<u>DOCUMENT ID</u> FRABETTI data for average WEIR	971 s, fit	s E687 s, limits	γ Be, $\overline{E}_{\gamma} \approx 220$ GeV , etc. \bullet \bullet	
$(\pi^-e^+e^+)/A$ test of I $(\pi^-e^+e^+)/A$ test of I $(1.1 \times 10^{-4})/A$ • • We do not $(4.8 \times 10^{-3})/A$ $(\pi^-\mu^+\mu^+)/A$	epton-nu t use the	90 e following 90 umber cons	<u>DOCUMENT ID</u> FRABETTI data for average WEIR	971 ss, fit 901	s E687 s, limits s MRK2	γ Be, $\overline{E}_{\gamma} \approx 220$ GeV i, etc. • • • e^+e^- 29 GeV	
$(\pi^-e^+e^+)/A$ test of I A test of I (1.1×10^{-4}) • • We do not (4.8×10^{-3}) $(\pi^-\mu^+\mu^+)/A$ test of I	epton-nu it use the /Ftotal epton-nu	90 e following 90 umber cons	<u>POCUMENT ID</u> FRABETTI data for average WEIR ervation.	971 s, fit 901	s E687 s, limits s MRK2	γ Be, $\overline{E}_{\gamma} \approx 220$ GeV γ , etc. • • • γ e ⁺ e ⁻ 29 GeV γ 183/F	
$(\pi^-e^+e^+)/A$ test of 1 A test of 1 (1.11×10^{-4}) • • We do not (4.8×10^{-3}) $(\pi^-\mu^+\mu^+)/A$ A test of 1 (1.11×10^{-3})	r use the	90 e following 90 umber cons	DOCUMENT ID FRABETTI data for average WEIR ervation. DOCUMENT ID	971 ss, fft 901	3 E687 s, limits 3 MRK2 . <u>TECN</u> 3 E687	γ Be, $\overline{E}_{\gamma} \approx 220$ GeV γ , etc. • • • γ e ⁺ e ⁻ 29 GeV γ Be, $\overline{E}_{\gamma} \approx 220$ GeV	-

```
\pi^-e^+\mu^+)/\Gamma_{	ext{total}}
A test of lepton-number conservation.
                                                                                    \Gamma_{154}/\Gamma
                                                      TECN COMMENT
                   CLN
                                   DOCUMENT ID
1.1 × 10<sup>-4</sup>
                                    FRABETTI 978 E687 \gamma Be, \overline{E}_{\gamma} \approx 220 GeV
                     90
 • We do not use the following data for averages, fits, limits, etc. • •
1.7 × 10<sup>-3</sup>
                                   WEIR
                                                     908 MRK2 e+e- 29 GeV
                       90
(\rho^-\mu^+\mu^+)/\Gamma_{\text{total}}
A test of lepton-number conservation.
                                                                                    \Gamma_{155}/\Gamma
                                   DOCUMENT ID TECN COMMENT
             CL% EVTS
i.6 × 10<sup>-4</sup>
                                    KODAMA
                                                    95 E653 π<sup>-</sup> emulsion 600 GeV
                90
K^-e^+e^+)/\Gamma_{\text{total}}
A test of lepton-number conservation.
                                                                                    \Gamma_{156}/\Gamma
                                    _____ CL%
l.2 × 10<sup>-4</sup>
                       90
 908 MRK2 e<sup>+</sup>e<sup>-</sup> 29 GeV
9.1 \times 10^{-3}
                        90
                                    WFIR
                                                                                    \Gamma_{157}/\Gamma
K^-\mu^+\mu^+)/\Gamma_{\text{total}}
   A test of lepton-number conservation.
             CL% EVTS
                                    DOCUMENT ID TECN COMMENT
l.2 × 10<sup>-4</sup>
                                    FRABETTI 978 E687 \gamma Be, \overline{E}_{\gamma} \approx 220 GeV
                90
0 KODAMA 95 E653 \pi^- emulsion 600 GeV
3.2 × 10<sup>-4</sup>
              90
4.3 × 10<sup>-3</sup>
                                                     908 MRK2 e+e- 29 GeV
                                    WEIR
                90
(K^-e^+\mu^+)/\Gamma_{\text{total}}
A test of lepton-number conservation.
                                    DOCUMENT ID TECN COMMENT
                    CLN
l.3 × 10<sup>-4</sup>
                                   FRABETTI 978 E687 \gamma Be, \overline{E}_{\gamma} \approx 220 GeV
                     90
• • We do not use the following data for averages, fits, limits, etc. • • •
4.0 × 10<sup>-3</sup>
                        90
                                   WEIR
                                                   908 MRK2 e+e- 29 GeV
(K^{\bullet}(892)^{-}\mu^{+}\mu^{+})/\Gamma_{\text{total}}
A test of lepton-number conservation.
                                                                                    \Gamma_{159}/\Gamma
CL% EVTS
                                    DOCUMENT ID TECH COMMENT
                                    KODAMA
                                                    95 E653 \pi^- emulsion 600 GeV
            D± CP-VIOLATING DECAY-RATE ASYMMETRIES
_{CP}(K^+K^-\pi^\pm) in D^\pm	o K^+K^-\pi^\pm
    This is the difference between D^+ and D^- partial widths for these modes divided by
the sum of the widths.

LUE DOCUMENT ID TECN COMMENT

D.017±0.027 OUR AVERAGE
                   64 AITALA 978 E791 -0.062 <A<sub>CP</sub> < +0.034 (90% CL) 64 FRABETTI 941 E687 -0.14 <A<sub>CP</sub> < +0.081 (90% CL)
0.014±0.029
0.031 \pm 0.068
<sup>4</sup>FRABETTI 941 and AITALA 97B measure N(D^+ \rightarrow K^+K^+\pi^+)/N(D^+ \rightarrow K^+K^+\pi^+)
 K^-\pi^+\pi^+), the ratio of numbers of events observed, and similarly for the D^-.
_{CP}(K^{\pm}K^{*0}) in D^{+} \rightarrow K^{+}\overline{K}^{*0} and D^{-} \rightarrow K^{-}K^{*0}
    This is the difference between D^+ and D^- partial widths for these modes divided by
    the sum of the widths.
0.02 ±0.05 OUR AVERAGE
0.010±0.050 65 AITALA
                                          TECN COMMENT
                   65 AITALA 978 E791 -0.092 <A<sub>CP</sub> < +0.072 (90% CL) 65 FRABETTI 941 E687 -0.33 <A<sub>CP</sub> < +0.094 (90% CL)
<sup>5</sup> FRABETTI 941 and AlTALA 97B measure N(D^+ \rightarrow K^+ \overline{K}^* (892)^0)/N(D^+ \rightarrow K^+ \overline{K}^* (892)^0)
 K^-\pi^+\pi^+), the ratio of numbers of events observed, and similarly for the D^-.
_{CP}(\phi\pi^{\pm}) in D^{\pm} \rightarrow \phi\pi^{\pm}
    This is the difference between D^+ and D^- partial widths for these modes divided by
the sum of the widths.

DOCUMENT ID

0.014±0.033 OUR AVERAGE
                                       TECN COMMENT
                   66 AITALA 97B E791 -0.087 < A<sub>CP</sub> < +0.031 (90% CL) 66 FRABETTI 94I E687 -0.075 < A<sub>CP</sub> < +0.21 (90% CL)
0.028 \pm 0.036
0.066 \pm 0.086
<sup>6</sup> FRABETTI 941 and AITALA 97B measure N(D^+ 	o \phi \pi^+)/N(D^+ 	o K^- \pi^+ \pi^+),
 the ratio of numbers of events observed, and similarly for the D^-.
CP(\pi^+\pi^-\pi^\pm) in D^\pm \to \pi^+\pi^-\pi^\pm
    This is the difference between D^+ and D^- partial widths for these modes divided by
    the sum of the widths.
U UE
                       DOCUMENT ID TECH COMMENT
                   67 AITALA
0.017 \pm 0.042
                                   978 E791 −0.086 <A<sub>CP</sub> < +0.052 (90% CL)
AITALA 97B measure N(D^+ \rightarrow \pi^+\pi^-\pi^+)/N(D^+ \rightarrow K^+\pi^+\pi^+), the ratio of
 numbers of events observed, and similarly for the \bar{D}^-.
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D^{\pm} PRODUCTION CROSS SECTION AT $\psi(3770)$

A compilation of the cross sections for the direct production of D^\pm mesons at or near the $\psi(3770)$ peak in e^+e^- production.

VALUE (nanobarns)	DOCUMENT ID	TECN	COMMENT
• • • We do not use the	following data for average	s, fits, limit	s, etc. • • •
4.2 ±0.6 ±0.3			3 e ⁺ e ⁻ 3.768 GeV
5.5 ±1.0	⁶⁹ PARTRIDGE	84 CBAI	_ e ⁺ e ⁻ 3.771 GeV
$6.00 \pm 0.72 \pm 1.02$	⁷⁰ SCHINDLER	80 MRK	2 e ⁺ e ⁻ 3.771 GeV
9.1 ±2.0	⁷¹ PERUZZI	77 MRK	1 e ⁺ e ⁻ 3.774 GeV
68 This measurement con	nnares events with one de	terted D to	those with two detected D

 68 This measurement compares events with one detected D to those with two detected D mesons, to determine the the absolute cross section. ADLER 88C measure the ratio of cross sections (neutral to charged) to be 1.36 \pm 0.23 \pm 0.14. This measurement does not include the decays of the $\psi(3770)$ not associated with charmed particle production.

69 This measurement comes from a scan of the $\psi(3770)$ resonance and a fit to the cross section. PARTRIDGE 84 measures 6.4 \pm 1.15 nb for the cross section. We take the phase space division of neutral and charged D mesons in $\psi(3770)$ decay to be 1.33, and we assume that the $\psi(3770)$ is an isosinglet to evaluate the cross sections. The noncharm decays (e.g. radiative) of the $\psi(3770)$ are included in this measurement and may amount to a few percent correction.

may amount to a few percent correction.

70 This measurement comes from a scan of the $\psi(3770)$ resonance and a fit to the cross section. SCHINDLER 80 assume the phase space division of neutral and charged D mesons in $\psi(3770)$ decay to be 1.33, and that the $\psi(3770)$ is an isosinglet. The noncharm decays (e.g. radiative) of the $\psi(3770)$ are included in this measurement and may amount to a few percent correction.

71 This measurement comes from a scan of the $\psi(3770)$ resonance and a fit to the cross

to a few percent correction. 71 This measurement comes from a scan of the $\psi(3770)$ resonance and a fit to the cross section. The phase space division of neutral and charged D mesons in $\psi(3770)$ decay is taken to be 1.33, and $\psi(3770)$ is assumed to be an isosinglet. The noncharm decays (e.g. radiative) of the $\psi(3770)$ are included in this measurement and may amount to a few percent correction. We exclude this measurement from the average because of uncertainties in the contamination from τ lepton pairs. Also see RAPIDIS 77.

$D^+ \rightarrow \overline{K}^*(892)^0 \ell^+ \nu_\ell$ FORM FACTORS

VALUE 0.72±0.09 OUR AVE	<u>EVTS</u> RAGE	DOCUMENT ID	TECN	COMMENT
$0.71 \pm 0.08 \pm 0.09$	3000	72 AITALA	98B E791	π^- nucleus, 500 GeV
$0.78 \pm 0.18 \pm 0.10$	874	73 FRABETTI	93E E687	γ Be, 220 GeV
$0.82^{+0.22}_{-0.23}\pm0.11$	305	⁷³ KODAMA	92 E653	π^- N, 600 GeV
0.0 ±0.5 ±0.2	183	⁷² ANJOS	90E E691	γBe, 90-260 GeV
72 AITAL A 000 and	ANJOS 90	E use $D^+ \to \overline{K}^*$	892)0e+ve	decays.
- ALIALA 908 allu				
73 FRABETTI 93E a	nd KODAI	MA 92 use $D^+ \rightarrow$	$K^*(892)^0 \mu$	$^+ u_{\mu}$ decays.
				$^+ u_\mu$ decays.

1.85±0.12 OUR AVE	DACE	DOCUMENT 10	1557	COMMENT	_
1.86 ± 0.12 OUK AVE	JUNGE				
$1.84 \pm 0.11 \pm 0.08$	3000	74 AITALA	988 E791	π ⁻ nucleus, 500 GeV	
$1.74 \pm 0.27 \pm 0.28$	874	⁷⁵ FRABETTI	93E E687	γ Be, 220 GeV	
$2.00^{+0.34}_{-0.32}\pm0.16$	305	⁷⁵ KODAMA	92 E653	π^- N, 600 GeV	
2.0 ±0.6 ±0.3	183	⁷⁴ ANJOS	90E E691	γBe, 90-260 GeV	
74 AITALA 98B and	ANJOS 90	E use $D^+ o \overline{K}^*$	(892) ⁰ e ⁺ v _e o	lecays.	

 75 FRABETTI 93E and KODAMA 92 use $D^+
ightarrow \overline{K}^* (892)^0 \mu^+
u_{\mu}$ decays.

TL/	/Γτ	ln	$D^+ \rightarrow$	K.	(892)" <i>[</i> 7	νį

VALUE	EVTS	DOCUMENT ID		<u>TECN</u>	COMMENT	
1.23±0.13 OUR AVE	RAGE					
$1.20 \pm 0.13 \pm 0.13$	874	⁷⁶ FRABETTI	93E	E687	γ Be, 220 GeV	
$1.18 \pm 0.18 \pm 0.08$	305	⁷⁶ KODAMA	92	E653	π^- N, 600 GeV	
$1.8 \begin{array}{c} +0.6 \\ -0.4 \end{array} \pm 0.3$	183	77 ANJOS	90E	E691	γBe, 90-260 GeV	

 $^{^{76}}$ FRABETTI 93E and KODAMA 92 use $D^+\to \overline{K}^*(892)^0\,\mu^+\nu_\mu$ decays. Γ_L/Γ_{7} is evaluated for a lepton mass of zero. 77 ANJOS 90E uses $D^+\to \overline{K}^*(892)^0\,e^+\nu_e$ decays.

Γ_+/Γ_- in $D^+ \rightarrow \overline{K}^{\circ}(892)^0 \ell^+ \nu_{\ell}$

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT	
0.16±0.04 OUR AVEF	RAGE					
$0.16 \pm 0.05 \pm 0.02$	305	⁷⁸ KODAMA	92	E653	π N, 600 GeV	
$0.15^{+0.07}_{-0.05} \pm 0.03$	183	⁷⁹ ANJOS	90E	E691	γBe, 90–260 GeV	
78 KODAMA 92 uses $D^+ o ~ \widetilde K^*(892)^0 \mu^+ u_\mu$ decays. Γ_+/Γ is evaluated for a lepton						
mass of zero. 79 ANJOS 90E uses E	0+ → K'	*(892) ⁰ e ⁺ ν _a dec	ays.			

D±	REFERENCES
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		_	NEI ENEITOES	
AITALA	98B	PRL 80 1393	+Amato, Anjos, Appel+	(FNAL E791 Collab.)
PDG AITALA	98 97	EPJ C3 1 PL B397 325	C. Caso+ +Amato, Anjos, Appel+	(FNAL E791 Collab.)
AITALA	97B	PL B403 377	+Amato, Anjos, Appel+	(FNAL E791 Collab.) (FNAL E791 Collab.)
AITALA BARTELT	97C 97	PL B404 187 PL B405 373	+Amato, Anjos, Appel+ +Csorna, Jain, Marka+	(CLEO Collab.)
BISHAI	97	PRL 78 3261	+Fast, Gerndt, Hinson+	(CLEO Collab.)
FRABETTI FRABETTI	97 97B	PL B391 235 PL B398 239	+Cheung, Cumalat+ +Cheung, Cumalat+	(FNAL E687 Collab.) (FNAL E687 Collab.)
FRABETTI	97C	PL B401 131	+Cheung, Cumalat+ +Cheung, Cumalat+	(FNAL E687 Collab.)
FRABETTI AITALA	97D 96	PL B407 79 PRL 76 364	+Cheung, Cumalat+ +Amato, Anjos+	(FNAL E687 Collab.) (FNAL E791 Collab.)
ALBRECHT	96C	PL B374 249	+Hamacher, Hofmann+	(ARGUS Collab.)
BIGI	95 95	PL B349 363 PL B346 199	+Yamamoto	(NDAM, HARV) (FNAL E687 Collab.)
FRABETTI FRABETTI	95B	PL B351 591	+Cheung, Cumalat+ +Cheung, Cumalat+	(FNAL E687 Collab.)
FRABETTI	95E	PL B359 403	+Cheung, Cumalat+	(FNAL E687 Collab.)
FRABETTI KODAMA	95F 95	PL B363 259 Pl B345 85	+Cheung, Cumalat+ +Ushida, Mokhtarani+	(FNAL E687 Collab.) (FNAL E653 Collab.)
ALBRECHT	941	ZPHY C64 375	+Hamacher, Hofmann+	(ARGUS Collab.)
ALEEV	94	PAN 57 1370 Translated from YF 5		(Serpukhov BIS-2 Collab.)
BALEST	94	PRL 72 2328	+Cho, Daoudi, Ford+	(CLEO Collab.)
FRABETTI FRABETTI	94D 94G	PL B323 459 PL B331 217	+Cheung, Cumalat+ +Cheung, Cumalat+	(FNAL E687 Collab.) (FNAL E687 Collab.)
FRABETTI	941	PR D50 R2953	+Cheung, Cumalat+ +Amako, Arai, Arima, Asano+	(FNAL E687 Collab.) (VENUS Collab.)
ABE ADAMOVICH	93E 93	PL B313 288 PL B305 177	+Amako, Arai, Arima, Asano+ +Alexandrov, Antinori+	(CERN WA82 Collab.)
AKERIB	93	PRL 71 3070	+Barish, Chadha, Chan+	(CLEO Collab.)
ALAM ANJOS	93 93	PRL 71 1311 PR D48 56	+Kim, Nemati, O'Neill+ +Appel, Bean, Bracker+	(CLEO Collab.) (FNAL E691 Collab.)
BEAN	93C	PL B317 647	+Gronberg, Kutschke, Menary+	(CLEO Collab.)
FRABETTI	93E	PL B307 262	+Grim, Paolone, Yager+	(FNAL E687 Collab.)
KODAMA KODAMA	93B 93C	PL B313 260 PL B316 455	+Ushida, Mokhtarani+ +Ushida, Mokhtarani+	(FNAL E653 Collab.) (FNAL E653 Collab.)
SELEN	93	PRL 71 1973	+Sadoff, Ammar, Ball+	(CLEO Collab.)
ALBRECHT	92B	ZPHY C53 361 PL 8278 202	+Ehrlichmann, Hamacher, Krueger	+ (ARGUS Collab.) (ARGUS Collab.)
ALBRECHT ANJOS	92F 92	PR D45 R2177	+Ehrlichmann, Hamacher+ +Appel, Bean, Bracker+	(FNAL E691 Collab.)
ANJOS	92C	PR D46 1941	+Appel, Bean, Bracker+	(FNAL E691 Collab.)
ANJOS BARLAG	92D 92C	PRL 69 2892 ZPHY C55 383	+Appel, Bean, Bediaga+ +Becker, Bozek, Boehringer+	(FNAL E691 Collab.) (ACCMOR Collab.)
Also	90D	ZPHY C48 29	Barlag, Becker, Boehringer, Bost	man+ (ACCMOR Collab.)
COFFMAN DAOUDI	92B 92	PR D45 2196 PR D45 3965	+DeJongh, Dubois, Eigen+ +Ford, Johnson, Lingel+	(Mark III Collab.) (CLEO Collab.)
FRABETTI	92	PL B281 167	+Bogart, Cheung, Culy+	(FNAL E687 Collab.)
KODAMA	92	PL B274 246	+Bogart, Cheung, Culy+ +Ushida, Mokhtarani+	(FNAL E687 Collab.) (FNAL E653 Collab.)
KODAMA ADAMOVICH	92C 91	PL B286 187 PL B268 142	+Ushida, Mokhtarani+ +Alexandrov, Antinori, Barberis+	(FNAL E653 Collab.) (WA82 Collab.)
ALBRECHT	91	PL B255 634	+Ehrlichmann, Hamacher, Krueger	(ARGUS Collab.)
ALVAREZ	91	PL B255 639 ZPHY C50 11	+Barate, Bloch, Bonamy+ +Barate, Bloch, Bonamy+	(CERN NA14/2 Collab.) (CERN NA14/2 Collab.)
ALVAREZ AMMAR	918 91	PR D44 3383	+Baringer, Coppage, Davis+	(CLEO Collab.)
ANJOS	91B	PR D43 R2063	+Appel, Bean, Bracker+	(FNAL E691 Collab.)
ANJOS BAI	91C 91	PRL 67 1507 PRL 66 1011	+Appel, Bean, Bracker+ +Bolton, Brown, Bunnell+	(FNAL-TPS Collab.) (Mark III Collab.)
COFFMAN	91	PL B263 135	+DeJongh, Dubois, Eigen, Hitlin+	· (Mark III Collab.)
FRABETTI ALVAREZ	91 90	PL 8263 584 ZPHY C47 539	+Bogart, Cheung, Culy+ +Barate, Bloch, Bonamy+	(FNAL E687 Collab.) (CERN NA14/2 Collab.)
ALVAREZ	90C	PL B246 261 PR D41 2705	+Barate, Bloch, Bonamy+ +Appel, Bean+	(CERN NA14/2 Collab.)
ZOLNA ZOLNA	90C 90D	PR D41 2705 PR D42 2414	+Appel, Bean+ +Appel, Bean, Bracker+	(FNAL E691 Collab.) (FNAL E691 Collab.)
ANJOS	90E	PRL 65 2630	+Appel, Bean, Bracker+	(FNAL E691 Collab.)
BARLAG	90C	ZPHY C46 563	+Becker, Boehringer, Bosman+	(ACCMOR Collab.)
WEIR ANJOS	90B 89	PR D41 1384 PRL 62 125	+Klein, Abrams, Adolphsen, Akerl +Appel, Bean, Bracker+	of+ (Mark II Collab.) (FNAL E691 Collab.)
ANJOS	89B	PRL 62 722	+Appel, Bean, Bracker+	(FNAL E691 Collab.)
ANJOS ADLER	89E 88B	Pt 8223 267 PRL 60 1375	+Appel, Bean, Bracker+ +Becker, Blaylock+	(FNAL E691 Collab.) (Mark III Collab.)
ADLER	88C	PRL 60 89	+Becker, Blaylock+	(Mark III Collab.)
ALBRECHT	881	PL B210 267	+ Boeckmann, Glaeser+	(ARGUS Collab.) (FNAL E691 Collab.)
ANJOS AOKI	88 88	PRL 60 897 PL B209 113	+Appel+ +Arnold, Baroni+	(WA75 Collab.)
HAAS	88	PRL 60 1614	+Hempstead, Jensen+	(CLEO Collab.)
ONG RAAB	88 88	PRL 60 2587 PR D37 2391	+Weir, Abrams, Amidei+ +Anjos, Appel, Bracker+	(Mark II Collab.) (FNAL E691 Collab.)
ADAMOVICH	87	EPL 4 887	+Alexandrov, Bolta+	(Photon Emulsion Collab.)
ADLER AGUILAR	87 87D	PL B196 107 PL B193 140	+Becker, Blaylock, Bolton+ Aguilar-Benitez, Allison+	(Mark III Collab.) (LEBC-EHS Collab.)
Also	88B	ZPHY C40 321 ZPHY C36 551	Aguilar-Benitez, Allison, Bailly+	(LEBC-EHS Collab.)
AGUILAR Also	87E 88B	ZPHY C36 551 ZPHY C40 321	Aguilar-Benitez, Allison+ Aguilar-Benitez, Allison, Bailly+	(LEBC-EHS Collab.) (LEBC-EHS Collab.)
AGUILAR	87F	ZPHY C36 559	Aguilar-Benitez, Allison+	(LEBC-EHS Collab.)
Also	88 97B	ZPHY C38 520 errat	um	(ACCMOR Collab.)
BARLAG BARTEL	87B 87	ZPHY C37 17 ZPHY C33 339	+Becker, Boehringer, Bosman+ +Becker, Felst, Haidt+	(JADE Collab.)
CSORNA	87	PL B191 318	+Mestayer, Panvini, Word+	(CLEO Collab.) (ACCMOR Collab.)
PALKA ABE	87B 86	ZPHY C35 151 PR D33 1	+Bailey, Becker+ + (SLAC Hybr	rid Facility Photon Collab.)
AGUILAR	86B	ZPHY C31 491	Aguilar-Benitez, Allison+	(LEBC-EHS Collab.)
BALTRUSAIT PAL	86E 86	PRL 56 2140	Baltrusaitis, Becker, Blaylock, B	rown+ (Mark III Collab.)
AIHARA	85	PR D33 2708 ZPHY C27 39	+Atwood, Barish, Bonneaud+ +Alston-Garnjost, Badtke, Bakken	(DELCO Collab.) + (TPC Collab.)
BALTRUSAIT BALTRUSAIT		PRL 54 1976 PRL 55 150	Baltrusaitis, Becker, Blaylock, B Baltrusaitis, Becker, Blaylock, B	rown+ (Mark III Collab.)
BARTEL	85≟ 85J	PKL 55 150 PL 163B 277	+Becker, Cords, Felst+	(JADE Collab.)
ADAMOVICH	84	PL 140B 119	+Alexandrov, Bolta, Bravo+	(CERN WA58 Collab.) (TASSO Collab.)
ALTHOFF ALTHOFF	84G 84J	ZPHY C22 219 PL 146B 443	+Braunschweig, Kirschfink+ +Branschweig, Kirschfink+	(TASSO Collab.) (TASSO Collab.)
DERRICK	84	PRL 53 1971	+Fernandez, Fries, Hyman+	(HRS Collab.)
KOOP PARTRIDGE	84 84	PRL 52 970 Thesis CALT-68-1150	+Sakuda, Atwood, Baillon+	(DELCO Collab.) (Crystal Ball Collab.)
AGUILAR	83B	PL 123B 98	Aguilar-Benitez, Allison+	(LEBC-EHS Collab.)
AUBERT	83	NP B213 31	+Bassompierre, Becks, Best+	(EMC Collab.)
PARTRIDGE SCHINDLER	81 81	PRL 47 760 PR D24 78	+Peck, Porter, Gu+ +Alam, Boyarski, Breidenbach+	(Crystal Ball Collab.) (Mark II Collab.)
TRILLING	81	PRPL 75 57	_	(LBL, UCB) J
BACINO SCHINDLER	80 80	PRL 45 329 PR D21 2716	+Ferguson+ +Siegrist, Alam, Boyarski+	(DELCO Collab.) (Mark II Collab.)
ZHOLENTZ	80	PL 96B 214	+Kurdadze, Lelchuk, Mishnev+	(NOVO)
Also	81	SJNP 34 814 Translated from YAF	Zholentz, Kurdadze, Lelchuk+	(NOVO)

BACINO	79	PRL 43 1073	+Ferguson, Nodukman+	(DELCO Collab.)
BRANDELIK	79	PL 80B 412	+Braunschweig, Martyn, Sander+	(DASP Collab.)
FELLER	78	PRL 40 274	+Litke, Madaras, Ronan+	(Mark I Collab.)
VUILLEMIN	78	PRL 41 1149	+Feldman, Feller+	(Mark I Collab.)
GOLDHABER	77	PL 69B 503	+Wiss, Abrams, Alam+	(Mark I Collab.)
PERUZZI	77	PRL 39 1301	+Piccolo, Feldman+	(Mark I Collab.)
PICCOLO	77	PL 70B 260	+Peruzzi, Luth, Nguyen, Wiss, Abrams+	(Mark I Collab.)
RAPIDIS	77	PRL 39 526	+Gobbi, Luke, Barbaro-Galtieri+	(Mark I Collab.)
PERUZZI	76	PRL 37 569	+Piccolo, Feldman, Nguyen, Wiss+	(Mark I Collab.)
			TER RELATED PAPERS	
RICHMAN	95	RMP 67 893	+ Burchat	(UCSB, STAN)
ROSNER	95	CNPP 21 369		(CHIC)



 $I(J^P) = \frac{1}{2}(0^-)$

DO MASS

The fit includes D^{\pm} , D^0 , D_s^{\pm} , $D^{*\pm}$, D^{*0} , and $D_s^{*\pm}$ mass and mass difference measurements.

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
1864.6± 0.5 OUR FT	T Error in	cludes scale factor	of 1.1.	
1864.1± 1.0 OUR A	/ERAGE			
1864.6 ± 0.3 ± 1.0	641	BARLAG	90c ACCM	π - Cu 230 GeV
1852 ± 7	16	ADAMOVICH	87 EMUL	Photoproduction
1861 ± 4		DERRICK	84 HRS	e ⁺ e ⁻ 29 GeV
 • • We do not use 	the following	ng data for averages	i, fits, limits,	etc. • • •
1856 ±36	22	ADAMOVICH	848 EMUL	Photoproduction
1847 ± 7	1	FIORINO	81 EMUL	$\gamma N \rightarrow \overline{D}^0 +$
1863.8± 0.5		¹ SCHINDLER	81 MRK2	e ⁺ e ⁻ 3.77 GeV
1864.7± 0.6		¹ TRILLING	81 RVUE	e ⁺ e ⁻ 3.77 GeV
1863.0 ± 2.5	238	ASTON	80E OMEG	$\gamma \rho \rightarrow \overline{D}^0$
1860 ± 2	143	² AVERY	80 SPEC	$\gamma N \rightarrow D^{*+}$
1869 ± 4	35	² AVERY	80 SPEC	$\gamma N \rightarrow D^{*+}$
1854 ± 6	94	² ATIYA	79 SPEC	$\gamma N \rightarrow D^0 \overline{D}{}^0$
1850 ±15	64	BALTAY	78c HBC	$\nu N \rightarrow K^0 \pi \pi$
1863 ± 3		GOLDHABER	77 MRK1	D ⁰ , D ⁺ recoil spectra
1863.3± 0.9		¹ PERUZZI	77 MRK1	e+e- 3.77 GeV
1868 ±11		PICCOLO	77 MRK1	e+e- 4.03, 4.41 GeV
1865 ±15	234	GOLDHABER	76 MRK1	Kπ and K3π

¹ PERUZZI 77 and SCHINDLER 81 errors do not include the 0.13% uncertainty in the absolute SPEAR energy calibration. TRILLING 81 uses the high precision $J/\psi(1.5)$ and $\psi(2.5)$ measurements of ZHOLENTZ 80 to determine this uncertainty and combines the PERUZZI 77 and SCHINDLER 81 results to obtain the value quoted. TRILLING 81 enters the fit in the D^{\pm} mass, and PERUZZI 77 and SCHINDLER 81 enter in the $m_{D^{\pm}} - m_{D^0}$, below.

² Error does not include possible systematic mass scale shift, estimated to be less than 5 MeV.

$m_{D^{\pm}} - m_{D^0}$

The flt includes D^{\pm} , D^{0} , D_{s}^{\pm} , $D^{*\pm}$, D^{*0} , and $D_{s}^{*\pm}$ mass and mass difference measurements.

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
4.76±0.10 OUR FIT	Error Includes scale factor of	1.1.		
4.74±0.28 OUR AVE	RAGE			
4.7 ±0.3	³ SCHINDLER	81	MRK2	e+ e- 3.77 GeV
5.0 ±0.8	³ PERUZZI	77	MRK1	e ⁺ e ⁻ 3.77 GeV
³ See the footnote of	on TRILLING 81 in the \mathcal{D}^{0} and	Di	section	s on the mass.

DO MEAN LIFE

Measurements with an error $> 0.05 \times 10^{-12}$ s are omitted from the average, and those with an error $> 0.1 \times 10^{-12}$ s or that have been superseded by later results have been removed from the Listings.

VALUE (10-12 s)	EVTS	DOCUMENT ID		TECN	COMMENT
0.415±0.004 OUR A	/ERAGE				
$0.413 \pm 0.004 \pm 0.003$	16k	FRABETTI	94D	E687	$K^-\pi^+$, $K^-\pi^+\pi^+\pi^-$
$0.424 \pm 0.011 \pm 0.007$	5118	FRABETTI			$K^{-}\pi^{+}$, $K^{-}\pi^{+}\pi^{+}\pi^{-}$
$0.417 \pm 0.018 \pm 0.015$	890	ALVAREZ	90	NA14	$K^-\pi^+$, $K^-\pi^+\pi^+\pi^-$
$0.388^{+0.023}_{-0.021}$	641	⁴ BARLAG	9 0c	ACCM	π ⁻ Cu 230 GeV
0.48 ±0.04 ±0.03	776	ALBRECHT	881	ARG	e ⁺ e ⁻ 10 GeV
$0.422 \pm 0.008 \pm 0.010$	4212	RAAB	88	E691	Photoproduction
0.42 ± 0.05	90	BARLAG	87R	ACCM	K [™] and + [™] 200 GeV

• • • We do not use	the following	ng data for avera	iges, fits, Ilm	its, etc. • • •
$0.34 \begin{array}{l} +0.06 \\ -0.05 \end{array} \pm 0.03$	58	AMENDOLIA	88 SPEC	Photoproduction
0.46 +0.06 -0.05	145	AGUILAR	870 HYBR	$\pi^- p$ and pp
0.50 ±0.07 ±0.04	317	C5ORNA	87 CLEO	$e^{+}e^{-}$ 10 GeV
$0.61 \pm 0.09 \pm 0.03$	50	ABE	86 HYBR	γp 20 GeV
$0.47 \begin{array}{l} +0.09 \\ -0.08 \end{array} \pm 0.05$	74	GLADNEY	86 MRK2	e ⁺ e ⁻ 29 GeV
0.43 +0.07 +0.01 -0.05 -0.02	58	USHIDA	86B EMUL	u wideband
0.37 +0.10 -0.07	26	BAILEY	85 SILI	π^- Be 200 GeV

⁴BARLAG 90C estimate systematic error to be negligible.

$|m_{D_1^0} - m_{D_2^0}|$

The D_1^0 and D_2^0 are the mass eigenstates of the D^0 meson. To calculate the following limits, we use $\Delta m = [2r/(1-r)]^{1/2} \hbar/4.15 \times 10^{-13}$ s, where r is the experimental $D^0 \cdot \overline{D}{}^0$ mixing ratio.

VALUE (1010 h s-1)	CL%	DOCUMENT ID		TECN	COMMENT		
<24	90	⁵ AITALA	96C	E791	π nucleus, 500 GeV		
• • • We do not use th	e followi	ng data for average	s, fits	, limits,	, etc. • • •		
<32	90	6,7 AITALA	98	E791	π ⁻ nucleus, 500 GeV		
<21	90	^{7,8} ANJOS	88 C	E691	Photoproduction		
⁵ This limit is inferred from the D^0 - \overline{D}^0 mixing ratio $\Gamma(K^+\ell^-\nu_\ell(\text{via }\overline{D}^0))/\Gamma(K^-\ell^+\nu_\ell)$ given near the end of the D^0 Listings. ⁶ AlTALA 98 allows interference between the doubly Cabibbo-suppressed and mixing amplitudes, and also allows CP violation in this term. ⁷ This limit is inferred from the D^0 - \overline{D}^0 mixing ratio $\Gamma(K^+\pi^-\text{ or }K^+\pi^-\pi^+\pi^-)$ (via $\overline{D}^0))/\Gamma(K^-\pi^+\text{ or }K^-\pi^+\pi^+\pi^-)$ near the end of the D^0 Listings. Decay-time information is used to distinguish doubly Cabibbo-suppressed decays from D^0 - \overline{D}^0 mixing. ⁸ ANJOS 88C assumes no interference between doubly Cabibbo-suppressed and mixing amplitudes. When interference is allowed, the limit degrades by about a factor of two.							

$|\Gamma_{D_1^0} - \Gamma_{D_2^0}|/\Gamma_{D^0}$ MEAN LIFE DIFFERENCE/AVERAGE

The D_1^0 and D_2^0 are the mass eigenstates of the D^0 meson. To calculate the following limits, we use $\Delta\Gamma/\Gamma = [8r/(1+r)]^{1/2}$, where r is the experimental $D^0 - \overline{D}{}^0$ mixing ratio.

YALVE.		DOCUMENT	155/1	COMMENT	
<0.20	90	9 AITALA	96C E791	π nucleus, 500 GeV	
• • • We do no	ot use the followi	ng data for avera	iges, fits, limits,	, etc. • • •	
< 0.26		^{),11} AITALA	98 E791	π ⁻ nucleus, 500 GeV	
<0.17	90 1	^{1,12} ANJOS	88C E691	Photoproduction	
	inferred from the he end of the <i>D</i> ⁰		ratio 「(K+ℓ-1	$\overline{\nu}_{\ell}(\text{via }\overline{D}^{0}))/\Gamma(K^{-}\ell^{+}\nu_{\ell})$	
			oubly Cabibboo	suppressed and miving am-	- 1

10 AITALA 98 allows interference between the doubly Cabibbo-suppressed and mixing amplitudes, and also allows CP violation in this term.

11 This limit is inferred from the D^0 . \overline{D}^0 mixing ratio $\Gamma(K^+\pi^-\text{ or }K^+\pi^-\pi^+\pi^-\text{ (via }\overline{D}^0))/\Gamma(K^-\pi^+\text{ or }K^-\pi^+\pi^+\pi^-)$ near the end of the D^0 Listings. Decay-time in the contraction of the D^0 such that D^0 is the contraction of the D^0 such that D^0 is the contraction of the D^0 such that D^0 is the contraction of the D^0 such that D^0 is the contraction of the D^0 such that D^0 is the contraction of D^0 is the contraction of formation is used to distinguish doubly Cabibbo-suppressed decays from $D^0 \cdot \overline{D}{}^0$ mixing. ¹² ANJOS 88C assumes no interference between doubly Cabibbo-suppressed and mixing amplitudes. When interference is allowed, the limit degrades by about a factor of two.

DO DECAY MODES

 $\overline{\mathcal{D}}{}^0$ modes are charge conjugates of the modes below.

Mode	Fraction (Γ_I/Γ)	Scale factor/ Confidence level
	ve modes	
e ⁺ anything	(6.75±0.29) %	
μ^+ anything	(6.6 ±0.8) %	
K ⁻ anything	(53 ±4)%	5=1.3
\overline{K}^0 anything $+K^0$ anything	(42 ±5)%	
K ⁺ anything	$(3.4^{+0.6}_{-0.4})\%$	
η anything	[a] < 13 %	CL=90%
	$\begin{array}{c} \text{Inclust}\\ e^+ \text{ anything}\\ \mu^+ \text{ anything}\\ K^- \text{ anything}\\ \overline{K}^0 \text{ anything} + K^0 \text{ anything}\\ K^+ \text{ anything} \end{array}$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$

 D^0

```
Semileptonic modes
                                                                                                                                                  Γ<sub>55</sub>
                                                                                                                                                            K^-\pi^+\pi^+\pi^-\pi^0
                                                                                                                                                                                                                               (4.1 \pm 0.4)\%
          \overset{K^-\ell^+\nu_\ell}{^{K^-e^+\nu_e}}
                                                                                                                                                                 \widetilde{K}^*(892)^0 \pi^+ \pi^- \pi^0
Γ7
                                                                     [b] ( 3.50±0.17) %
                                                                                                                        S=1.3
                                                                                                                                                  Γ<sub>56</sub>
                                                                                                                                                                                                                               (1.2 \pm 0.6)\%
                                                                                                                                                                    \times B(\overline{K}^{*0} \rightarrow K^-\pi^+)
Γ8
                                                                             (3.66 \pm 0.18)\%
                                                                                                                                                                    \overline{K}^*(892)^0 \eta
\times B(\overline{K}^{*0} \to K^- \pi^+)
Γ٩
              K^-\mu^+\nu_\mu
                                                                             (3.23\pm0.17)\%
                                                                                                                                                  Γ<sub>57</sub>
                                                                                                                                                                                                                               ( 2.9 \pm 0.8 ) \times 10^{-3}
        K^-\pi^0e^+\nu_e
                                                                             (1.6 \begin{array}{c} +1.3 \\ -0.5 \end{array})\%
Γ<sub>10</sub>
                                                                                                                                                                        \times B(\eta \rightarrow \pi^+\pi^-\pi^0)
\Gamma_{11} \quad \overline{K}{}^0\pi^-e^+\nu_e
                                                                             ( 2.8 \ ^{+1.7}_{-0.9} ) %
                                                                                                                                                                 K^-\pi^+\omega \times B(\omega \to \pi^+\pi^-\pi^0)
                                                                                                                                                  Γ<sub>58</sub>
                                                                                                                                                                                                                               (2.7 \pm 0.5)\%
                                                                                                                                                                    \overline{K}^*(892)^0\omega
                                                                                                                                                                                                                               (7 \pm 3) \times 10^{-3}
                                                                                                                                                  Γ59
              \overline{K}^*(892)^-e^+\nu_e \times B(K^{*-} \rightarrow \overline{K}^0\pi^-)
\Gamma_{12}
                                                                             ( 1.35 ± 0.22) %
                                                                                                                                                                        \times B(\overline{K}^{*0} \rightarrow K^-\pi^+)
                                                                                                                                                                        \times B(\omega \rightarrow \pi^{+}\pi^{-}\pi^{0})
          K^*(892)^-\ell^+\nu_\ell
Γ<sub>13</sub>
                                                                                                                                                          \overline{K}^0\pi^+\pi^+\pi^-\pi^-
                                                                                                                                                  Γ<sub>60</sub>
                                                                                                                                                                                                                               (5.8 \pm 1.6) \times 10^{-3}
          \overline{K}^*(892)^0\pi^-e^+\nu_e
Γ<sub>14</sub>
          K^-\pi^+\pi^-\mu^+\nu_\mu
                                                                                                                                                  \Gamma_{61} \quad \overline{K}{}^{0}\pi^{+}\pi^{-}\pi^{0}\pi^{0}(\pi^{0})
                                                                                                  \times 10^{-3}
                                                                                                                                                                                                                               (10.6 \begin{array}{c} +7.3 \\ -3.0 \end{array}) \%
Γ<sub>15</sub>
                                                                                                                    CL=90%
                                                                           < 1.2
                                                                                                 × 10<sup>-3</sup>
              (\overline{K}^*(892)\pi)^-\mu^+\nu_\mu
                                                                                                                                                  Γ<sub>62</sub> \overline{K}^0K^+K^-
\Gamma_{16}
                                                                           < 1.4
                                                                                                                    CL=90%
                                                                                                                                                                                                                               (9.4 \pm 1.0) \times 10^{-3}
\Gamma_{17} \pi^-e^+\nu_e
                                                                             ( 3.7~\pm0.6 ) \times\,10^{-3}
                                                                                                                                                           In the fit as \frac{1}{2}\Gamma_{74}+\Gamma_{64}, where \frac{1}{2}\Gamma_{74}=\Gamma_{63}.
                                                                                                                                                  \Gamma_{63}
                                                                                                                                                                 \overline{K}^0 \phi \times \tilde{B}(\phi \to K^+ K^-)
                                                                                                                                                                                                                              (4.3 \pm 0.5) \times 10^{-3}
                                                                                                                                                                 \overline{K}^0K^+K^- non-\phi
             A fraction of the following resonance mode has already appeared above as
                                                                                                                                                                                                                               ( 5.1 \pm0.8 ) \times 10<sup>-3</sup>
                                                                                                                                                  Γ<sub>64</sub>
             a submode of a charged-particle mode.
                                                                                                                                                          K 6 K 6 K 6
                                                                                                                                                                                                                               ( 8.4 \pm 1.5 ) \times 10^{-4}
                                                                                                                                                  Γ<sub>65</sub>
          K^*(892)^-e^+\nu_e
                                                                             (2.02\pm0.33)\%
                                                                                                                                                          K+K-K-π+
                                                                                                                                                  Γ<sub>66</sub>
                                                                                                                                                                                                                               ( 2.1 \pm 0.5 ) \times 10^{-4}
                                                                                                                                                          K^+K^-\overline{K}^0\pi^0
                                                                                                                                                                                                                               (7.2^{+4.8}_{-3.5}) \times 10^{-3}
                                   Hadronic modes with a \overline{K} or \overline{K}K\overline{K}
          K^-\pi^+
                                                                             (3.85 \pm 0.09)\%
Γ19
          \overline{K}^0\pi^0
Γ<sub>20</sub>
                                                                             (2.12\pm0.21)\%
                                                                                                                        S=1.1
                                                                                                                                                               Fractions of many of the following modes with resonances have already
          \overline{K}^0\pi^+\pi^-
                                                                     [c] (5.4 \pm 0.4)\%
Γ<sub>21</sub>
                                                                                                                        S=1.2
                                                                                                                                                               appeared above as submodes of particular charged-particle modes. (Modes
              \overline{K}^0 \rho^0
Γ<sub>22</sub>
                                                                             (1.21\pm0.17)\%
                                                                                                                                                               for which there are only upper limits and \overline{K}^*(892) \rho submodes only appear
              \overline{K}^0\,f_0(980)
                                                                             (3.0 \pm 0.8) \times 10^{-3}
                                                                                                                                                               below.)
Γ23
                                                                                                                                                            \frac{\overline{K}^{0}\eta}{\overline{K}^{0}\rho^{0}}
\frac{K^{-}\rho^{+}}{\overline{K}^{0}\omega}
                  \times B(f_0 \rightarrow \pi^+\pi^-)
                                                                                                                                                  Γ<sub>68</sub>
                                                                                                                                                                                                                               (7.1 \pm 1.0) \times 10^{-3}
               \overline{K}^0 f_2(1270)
                                                                             ( 2.4 \pm 0.9 ) \times\,10^{-3}
\Gamma_{24}
                                                                                                                                                  Γ<sub>69</sub>
                                                                                                                                                                                                                               (1.21\pm0.17)\%
                  \times B(f_2 \rightarrow \pi^+\pi^-)
                                                                                                                                                  Γ<sub>70</sub>
                                                                                                                                                                                                                               (10.8 \pm 1.0)\%
                                                                                                                                                  Γ71
               \overline{K}^0 f_0(1370)
\Gamma_{25}
                                                                             (4.3 \pm 1.3) \times 10^{-3}
                                                                                                                                                                                                                               (2.1 \pm 0.4)\%
                                                                                                                                                            \frac{\overline{K}^0 \eta'(958)}{\overline{K}^0 f_0(980)}
                  \times B(f_0 \rightarrow \pi^+\pi^-)
                                                                                                                                                                                                                               ( 1.72±0.26) %
                                                                                                                                                  Γ<sub>72</sub>
               K^*(892)^-\pi^+
Γ<sub>26</sub>
                                                                             (3.4 \pm 0.3)\%
                                                                                                                                                  Γ<sub>73</sub>
                                                                                                                                                                                                                               (5.7 \pm 1.6) \times 10^{-3}
                   \times B(K^{*-} \rightarrow \overline{K}^0 \pi^-)
                                                                                                                                                  \Gamma_{74} \overline{K}^0 \phi
                                                                                                                                                                                                                               (8.6 \pm 1.0) \times 10^{-3}
               K_0^*(1430)^-\pi^+
Γ<sub>27</sub>
                                                                                                                                                            K^{-}a_{1}(1260)^{+}
                                                                             ( 6.4~\pm1.6 ) \times\,10^{-3}
                                                                                                                                                  Γ<sub>75</sub>
                                                                                                                                                                                                                               (7.3 \pm 1.1)\%
                  \times B(K_0^*(1430)^- \rightarrow \overline{K}^0\pi^-)
                                                                                                                                                            \overline{K}^0 a_1(1260)^0
                                                                                                                                                  Γ<sub>76</sub>
                                                                                                                                                                                                                             < 1.9
                                                                                                                                                                                                                                                   %
                                                                                                                                                                                                                                                                       CL=90%
                                                                                                                                                            \overline{K}^0 f_2(1270)
               \overline{K}^0\pi^+\pi^- nonresonant
                                                                                                                                                                                                                              (4.2 \pm 1.5) \times 10^{-3}
                                                                                                                                                  F77
Γ<sub>28</sub>
                                                                             (1.47 \pm 0.24)\%
                                                                                                                                                            K^{-}a_{2}(1320)^{+}
                                                                                                                                                                                                                                                  × 10<sup>-3</sup>
          K^-\pi^+\pi^0
                                                                                                                                                  Γ<sub>78</sub>
                                                                                                                                                                                                                             < 2
                                                                                                                                                                                                                                                                       CL=90%
                                                                           (13.9 ±0.9)%
                                                                                                                         S=1.3
Γ29
                                                                                                                                                            \overline{K}^0 f_0(1370)
                                                                                                                                                                                                                               ( 7.0 \pm 2.1 ) \times 10^{-3}
                                                                                                                                                  Γ79
               K^- \rho^+
Γ30
                                                                             (10.8 \pm 1.0)\%
                                                                                                                                                            \frac{K^*(892)^-\pi^+}{K^*(892)^0\pi^0}
               K^*(892)^-\pi^+
                                                                                                                                                  Γ80
                                                                                                                                                                                                                               (5.1 \pm 0.4)\%
                                                                                                                                                                                                                                                                          S=1.2
                                                                             ( 1.7 ±0.2 )%
Г31
                  \times B(K^{*-} \rightarrow K^-\pi^0)
                                                                                                                                                  Γ81
                                                                                                                                                                                                                               (3.2 \pm 0.4)\%
              \overline{K}^*(892)^0\pi^0
                                                                                                                                                  Γ<sub>82</sub>
                                                                                                                                                            \overline{K}^*(892)^0\pi^+\pi^- total
                                                                                                                                                                                                                               (2.3 \pm 0.5)\%
\Gamma_{32}
                                                                             (2.1 \pm 0.3)\%
                  \times B(\overline{K}^{*0} \rightarrow K^-\pi^+)
                                                                                                                                                                \vec{K}^*(892)^0\pi^+\pi^- 3-body
                                                                                                                                                  Γ83
                                                                                                                                                                                                                               ( 1.43±0.32) %
               K^-\pi^+\pi^0 nonresonant
\Gamma_{33}
                                                                                                                                                  Γ84
                                                                                                                                                             K^-\pi^+\rho^0 total
                                                                                                                                                                                                                               (6.3 \pm 0.4)\%
                                                                             (6.9 \pm 2.5) \times 10^{-3}
          K^{0}\pi^{0}\pi^{0}
                                                                                                                                                                 K^-\pi^+\rho^03-body
                                                                                                                                                  ۲<sub>85</sub>
                                                                                                                                                                                                                               (4.8 \pm 2.1) \times 10^{-3}
Γ<sub>34</sub>
              \overline{K}^*(892)^0\pi^0
                                                                                                                                                                 \overline{K}^*(892)^0 \rho^0
                                                                                                                                                                                                                               ( 1.47±0.33) %
Γ<sub>35</sub>
                                                                             (1.1 \pm 0.2)\%
                                                                                                                                                  Γ<sub>86</sub>
                   \times B(\overline{K}^{*0} \to \overline{K}^0\pi^0)
                                                                                                                                                                    \overline{K}^*(892)^0 \rho^0 transverse
                                                                                                                                                  Γ87
                                                                                                                                                                                                                               (1.5 \pm 0.5)\%
                                                                                                                                                                    K^*(892)^0 \rho^0 S-wave K^*(892)^0 \rho^0 S-wave long.
Γ<sub>36</sub>
               \overline{K}^0\pi^0\pi^0 nonresonant
                                                                                                                                                  Γ88
                                                                                                                                                                                                                               (2.8 \pm 0.6)\%
                                                                             (7.9 \pm 2.1) \times 10^{-3}
                                                                                                                                                                                                                                                   \times 10<sup>-3</sup>
          K^-\pi^+\pi^+\pi^-
                                                                                                                                                                                                                             < 3
                                                                                                                                                                                                                                                                       CL=90%
                                                                                                                                                  ۲<sub>89</sub>
Γ37
                                                                     [c] (7.6 \pm 0.4)\%
                                                                                                                        S=1.1
                                                                                                                                                                    \overline{K}^*(892)^0 \rho^0 P-wave \overline{K}^*(892)^0 \rho^0 D-wave
              K^-\pi^+\rho^0 total
                                                                                                                                                                                                                                                   \times 10^{-3}
                                                                                                                                                  Γ<sub>90</sub>
Γ<sub>38</sub>
                                                                             (6.3 \pm 0.4)\%
                                                                                                                                                                                                                             < 3
                                                                                                                                                                                                                                                                       CL=90%
                   K^-\pi^+\rho^03-body
Γ39
                                                                             ( 4.8 \pm 2.1 ) \times 10^{-3}
                                                                                                                                                  Γ<sub>91</sub>
                                                                                                                                                                                                                               (1.9 \pm 0.6)\%
                  \overline{K}^*(892)^0 \rho^0
\times B(\overline{K}^{*0} \to K^- \pi^+)
                                                                             ( 9.8 \pm 2.2 ) \times 10<sup>-3</sup>
                                                                                                                                                            K^*(892)^+ \rho^+
                                                                                                                                                  Γ<sub>92</sub>
                                                                                                                                                                                                                               (6.1 \pm 2.4)\%
Γ<sub>40</sub>
                                                                                                                                                                K^*(892)^- \rho^+ longitudinal K^*(892)^- \rho^+ transverse K^*(892)^- \rho^+ P-wave
                                                                                                                                                                                                                               (2.9 \pm 1.2)\%
                   K^-a_1(1260)^+
                                                                                                                                                  Γ94
                                                                                                                                                                                                                               (3.2 \pm 1.8)\%
Γ41
                                                                             (3.6 \pm 0.6)\%
                       \times B(a_1(1260)^+ \rightarrow \pi^+\pi^+\pi^-)
                                                                                                                                                  Γ<sub>95</sub>
                                                                                                                                                                                                                             < 1.5
                                                                                                                                                                                                                                                                       CL=90%
              \overline{K}^*(892)^0\pi^+\pi^- total
                                                                                                                                                  Γ<sub>96</sub>
                                                                                                                                                            K^-\pi^+f_0(980)
                                                                                                                                                                                                                                                    %
                                                                             (1.5 \pm 0.4)\%
                                                                                                                                                                                                                            < 1.1
                                                                                                                                                                                                                                                                       CL=90%
Γ<sub>42</sub>
                                                                                                                                                                \overline{K}^*(892)^0 f_0(980)
                    K B(\overline{K}^{*0} \rightarrow K^-\pi^+)
                                                                                                                                                                                                                                                   × 10<sup>-3</sup>
                                                                                                                                                  Γ<sub>97</sub>
                                                                                                                                                                                                                            < 7
                                                                                                                                                                                                                                                                       CL=90%
                   \overline{K}^*(892)^0 \pi^+ \pi^- 3-body
\Gamma_{43}
                                                                                                                                                  Г<sub>98</sub>
                                                                                                                                                            K_1(1270)^-\pi^+
                                                                                                                                                                                                                       [d] ( 1.06±0.29) %
                                                                             (9.5 \pm 2.1) \times 10^{-3}
                                                                                                                                                  \Gamma_{99} \frac{K_1(1400)^- \pi^+}{K_1(1400)^0 \pi^0}
                       \times B(\overline{K}^{*0} \rightarrow K^-\pi^+)
                                                                                                                                                                                                                            < 1.2
                                                                                                                                                                                                                                                    %
                                                                                                                                                                                                                                                                       CL=90%
               K_1(1270)^-\pi^+
Γ44
                                                                           (3.6 \pm 1.0) \times 10^{-3}
                                                                                                                                                                                                                            < 3.7
                                                                                                                                                                                                                                                    %
                                                                                                                                                                                                                                                                       CL=90%
                                                                                                                                                  \Gamma_{101} K^*(1410)^-\pi^+
                   \times B(K_1(1270)^- \to K^-\pi^+\pi^-)
                                                                                                                                                                                                                                                                       CL=90%
                                                                                                                                                                                                                             < 1.2
                                                                                                                                                  \Gamma_{102} \quad K_0^*(1430)^- \pi^+
\Gamma_{45}
               K^-\pi^+\pi^+\pi^- nonresonant
                                                                                                                                                                                                                             (1.04\pm0.26)\%
                                                                             (1.76 \pm 0.25)\%
         \overline{K}^0\pi^+\pi^-\pi^0
                                                                                                                                                                                                                                                   × 10<sup>-3</sup>
Γ<sub>46</sub>
                                                                                                                                                  \Gamma_{103} \quad \underline{K_2^*}(1430)^-\pi^+
                                                                            (10.0 \pm 1.2)\%
                                                                                                                                                                                                                            < 8
                                                                                                                                                                                                                                                                       CL=90%
                                                                                                                                                  \Gamma_{104} \ \overline{K}_{2}^{4}(1430)^{0}\pi^{0}
              \overline{\underline{K}}{}^{0}\eta \times B(\eta \rightarrow \pi^{+}\pi^{-}\pi^{0})
Γ<sub>47</sub>
                                                                             ( 1.6 \pm 0.3 ) \times\,10^{-3}
                                                                                                                                                                                                                                                   \times 10^{-3}
                                                                                                                                                                                                                            < 4
                                                                                                                                                                                                                                                                       CL=90%
Γ<sub>48</sub>
               \overline{K}^0\omega \times B(\omega \to \pi^+\pi^-\pi^0)
                                                                                                                                                  \Gamma_{105} \ \overline{K}^{*}(892)^{0} \pi^{+} \pi^{-} \pi^{0}
                                                                             (1.9 \pm 0.4)\%
                                                                                                                                                                                                                              ( 1.8 ±0.9 )%
              K^*(892)^-\rho^+
 \times B(K^{*-} \rightarrow \overline{K}^0\pi^-)
Γ49
                                                                             (4.1 \pm 1.6)\%
                                                                                                                                                               \vec{K}^*(892)^0\eta
                                                                                                                                                                                                                               ( 1.9 ±0.5 )%
                                                                                                                                                  Γ<sub>106</sub>
                                                                                                                                                  \Gamma_{107} K^- \pi^+ \omega
                                                                                                                                                                                                                               (3.0 \pm 0.6)\%
              \overline{K}^*(892)^0 \rho^0
Γ50
                                                                             (4.9 \pm 1.1) \times 10^{-3}
                                                                                                                                                               \overline{K}^*(892)^0 \omega
                                                                                                                                                  Γ<sub>108</sub>
                                                                                                                                                                                                                              (1.1 ±0.5)%
                  \times B(\overline{K}^*) \rightarrow \overline{K}^0\pi^0
             \Gamma_{109} \quad K^- \pi^+ \eta'(958)
                                                                                                                                                                                                                              (7.0 \pm 1.8) \times 10^{-3}
                                                                                                                                                                                                                                                   × 10<sup>-3</sup>
Γ<sub>51</sub>
                                                                                                                                                                \overline{K}^*(892)^0 \eta'(958)
                                                                                                                                                  F<sub>110</sub>
                                                                                                                                                                                                                             < 1.1
                                                                                                                                                                                                                                                                       CL=90%
Γ<sub>52</sub>
Γ<sub>53</sub>
          K^-\pi^+\pi^0\pi^0
Γ<sub>54</sub>
                                                                             (15 ±5 )%
```

Γ₁₄₇

Γ₁₄₈

Γ₁₅₁

 $\Gamma_{146} \phi \pi^+ \pi^-$

 $\phi \rho^0$

 $\phi \pi^+ \pi^-$ 3-body

 $\overline{K}^*(892)^0 K^+ \pi^-$

 $K^*(892)^0 \overline{K}^*(892)^0$

 $\Gamma_{149} = K^*(892)^0 K^- \pi^+ + \text{c.c.}$ $\Gamma_{150} = \frac{K^*(892)^0 K^- \pi^+}{K^*(892)^0 K^- \pi^+}$

CL=90% CL=90%

CL=90% CL=90% CL=90% CL=90% C1 = 90%CL=90% CL=90% CL=90%

S=1.1

	Pionic	modes			Doubly Cabibb	o supp	ressed (DC) mo	odes,
Γ ₁₁₁	$\pi^{+}\pi^{-}$	$(1.53\pm0.09)\times10^{-3}$			$\Delta C = 2$ forbidd	en via r	nbdng (<i>C2M</i>) r	nodes,
[112	$\pi^{0}\pi^{0}$	$(8.5 \pm 2.2) \times 10^{-4}$			$\Delta C = 1$ weak no	eutral co	rrent (C1) mo	des, or
[112	$\pi^+\pi^-\pi^0$	(1.6 ±1.1)%	S=2.7		Lepton Family n	umber	(LF) violating	modes
T114	$\pi^{+}\pi^{+}\pi^{-}\pi^{-}$	$(7.4 \pm 0.6) \times 10^{-3}$		T153	$K^+\ell^-\overline{\nu}_{\ell}(\text{via }\overline{D}^0)$	C2M	< 1.7	× 10 ⁻⁴
T115	$\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{0}$	(1.9 ±0.4)%		T ₁₅₄	$K^+\pi^-$ or	C2M	< 1.0	× 10 ⁻³
T116	$\pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{-}$	$(4.0 \pm 3.0) \times 10^{-4}$		134	$K^+\pi^-\pi^+\pi^-$ (via \overline{D}^0)			
110				Γ155	$K^+\pi^-$	DC	(2.8 ±0	.9) × 10 ⁻⁴
_	Hadronic modes	-		T ₁₅₆	$K^+\pi^-$ (via $\overline{D}{}^0$)		< 1.9	× 10 ⁻⁴
Γ ₁₁₇	K+K-	$(4.27\pm0.16)\times10^{-3}$		Γ ₁₅₇	$K^{+}\pi^{-}\pi^{+}\pi^{-}$	DC		.7)×10 ⁻⁴
Γ ₁₁₈	$K^0\overline{K}^0$	$(6.5 \pm 1.8) \times 10^{-4}$	S=1.2	Γ159	$K^+\pi^-\pi^+\pi^-$ (via $\overline{D}{}^0$)		<`4	× 10 ⁻⁴
	$K^0K^-\pi^+$	$(6.4 \pm 1.0) \times 10^{-3}$	S=1.1		μ^- anything (via \overline{D}^0)		< 4	× 10 ⁻⁴
Γ ₁₂₀	$\overline{K}^*(892)^0 K^0$	$< 1.1 \times 10^{-3}$	CL=90%	Γ160	e+ e-	C1	< 1.3	× 10 ⁻⁵
	\times B($\overline{K}^{*0} \rightarrow K^-\pi^+$)			F161	$\mu^+\mu^-$	C1	< 4.1	× 10 ⁻⁶
Γ_{121}	K*(892)+K-	$(2.3 \pm 0.5) \times 10^{-3}$		Γ161	$\pi^0 e^+ e^-$	C1	< 4.5	× 10 ⁻⁵
	$\times B(K^{*+} \rightarrow K^0\pi^+)$	•		Γ162	$\pi^{0}\mu^{+}\mu^{-}$	C1	< 1.8	× 10 ⁻⁴
Γ ₁₂₂	$K^0K^-\pi^+$ nonresonant	$(2.3 \pm 2.3) \times 10^{-3}$		F164	$\eta e^+ e^-$	C1	< 1.1	× 10 ⁻⁴
Γ ₁₂₃	$\overline{K}^0K^+\pi^-$	$(5.0 \pm 1.0) \times 10^{-3}$		Г164	$\eta \mu^+ \mu^-$	CI	< 5.3	× 10 ⁻⁴
Γ_{124}	$K^*(892)^0 \overline{K}^0$	$< 5 \times 10^{-4}$	CL=90%	L102	$\rho^0 e^+ e^-$	C1	< 1.0	× 10 ⁻⁴
	\times B($K^{*0} \rightarrow K^{+}\pi^{-}$)			Γ166	$\rho^{0}\mu^{+}\mu^{-}$	C1	< 2.3	× 10 ⁻⁴
Γ ₁₂₅	K*(892) ⁻ K ⁺	$(1.2 \pm 0.7) \times 10^{-3}$		Γ167	ω e ⁺ e ⁻	C1	< 1.8	× 10 ⁻⁴
	\times B($K^{*-} \rightarrow \overline{K}{}^{0}\pi^{-}$)			L160	$\omega \mu^+ \mu^-$	C1	< 8.3	× 10 ⁻⁴
Γ ₁₂₆	$\overline{K}^0 K^+ \pi^-$ nonresonant	$(3.9 \begin{array}{c} +2.3 \\ -1.9 \end{array}) \times 10^{-3}$		F ₁₇₀	φe+e-	C1	< 5.2	× 10 ⁻⁵
	$K^+K^-\pi^0$	$(1.3 \pm 0.4) \times 10^{-3}$		Γ171	$\phi \mu^+ \mu^-$	CI	< 4.1	× 10 ⁻⁴
T127	$K_S^0 K_S^0 \pi^0$	< 5.9 × 10 ⁻⁴		Γ ₁₇₂	$\overline{K}^0 e^+ e^-$		[g] < 1.1	× 10 ⁻⁴
1 128	$K^+K^-\pi^+\pi^-$			F172	$\overline{K}{}^0\mu^+\mu^-$		[g] < 2.6	× 10 ⁻⁴
	$\phi \pi^+ \pi^- \times B(\phi \to K^+ K^-)$	[e] $(2.52\pm0.24)\times10^{-3}$		Γ174	$\overline{K}^*(892)^0 e^+ e^-$		[g] < 1.4	× 10 ⁻⁴
ر 130	$\phi \pi^+ \pi^- \times B(\phi \to K^+ K^-)$ $\phi \rho^0 \times B(\phi \to K^+ K^-)$	$(5.3 \pm 1.4) \times 10^{-4}$		Γ ₁₇₅	$\overline{K}^*(892)^0 \mu^+ \mu^-$		[g] < 1.18	× 10 ⁻³
Γ ₁₃₁	$K^+K^-\rho^0$ 3-body	$(3.0 \pm 1.6) \times 10^{-4}$		Γ176	$\pi^{+}\pi^{-}\pi^{0}\mu^{+}\mu^{-}$	C1	< 8.1	× 10 ⁻⁴
Γ ₁₃₂	$K^*(892)^0 K^- \pi^+ + \text{c.c.}$	$(9.1 \pm 2.3) \times 10^{-4}$ [f] < 5 $\times 10^{-4}$		Γ177	$\mu^{\pm}e^{\mp}$	LF	[h] < 1.9	× 10 ⁻⁵
Γ ₁₃₃	$\times B(K^{*0} \rightarrow K^{+}\pi^{-})$	$[f] < 5 \times 10^{-4}$		Γ170	$\pi^0 e^{\pm} \mu^{\mp}$	LF	[h] < 8.6	× 10 ⁻⁵
-	$K^*(892)^0 \overline{K}^*(892)^0$	4.6 1.0 1.1.0-4		Γ ₁₇₀	$\eta e^{\pm} \mu^{\mp}$	LF	[h] < 1.0	× 10 ⁻⁴
Γ ₁₃₄	$\times B^{2}(K^{*0} \rightarrow K^{+}\pi^{-})$	$(6 \pm 2) \times 10^{-4}$		F190	$\rho^0 e^{\pm} \mu^{\mp}$	LF	[h] < 4.9	× 10 ⁻⁵
_	$K^+K^-\pi^+\pi^-$ non- ϕ			Γ101	$\omega e^{\pm} \mu^{\mp}$	LF	[h] < 1.2	× 10 ⁻⁴
「135 「	$K^+K^-\pi^+\pi^-$ nonresonant	< 8 × 10 ⁻⁴	CI non/	F182	$\phi e^{\pm} \mu^{\mp}$	LF	[h] < 3.4	× 10 ⁻⁵
F ₁₃₆	$K^0\overline{K^0}\pi^+\pi^-$		CL=90%	Γ183	$\overline{K}^0 e^{\pm} \mu^{\mp}$	LF	[h] < 1.0	× 10 ⁻⁴
137	$K^+K^-\pi^+\pi^-\pi^0$	$(6.9 \pm 2.7) \times 10^{-3}$ $(3.1 \pm 2.0) \times 10^{-3}$		Γ184	\vec{K}^* (892) ⁰ $e^{\pm} \mu^{\mp}$	LF	[h] < 1.0	× 10 ⁻⁴
138	Fractions of most of the following r	,	udv		A dummy mode used by t	ha fit	.,	
	appeared above as submodes of parti		,	1 185	A dullilly mode used by t	ne nt.	(16.9 ±3	.5) 76
F139	$\overline{K}^*(892)^0 K^0$	$< 1.6 \times 10^{-3}$	CL=90%	[2]	This is a weighted average	of D±	(44%) and D ⁰	(56%) branch
Γ140	K*(892)+K-	$(3.5 \pm 0.8) \times 10^{-3}$		رسا	tions. See " D^+ and $D^0 \rightarrow$			
Γ ₁₄₁	K*(892)0 K0	< 8 × 10 ⁻⁴	CL=90%		"D+ Branching Ratios" in			
Γ142	K*(892)-K+	$(1.8 \pm 1.0) \times 10^{-3}$		f 4.1	• •		_	
Γ ₁₄₃	$\phi \pi^{\dot{0}}$	< 1.4 × 10 ⁻³	CL=90%	[D]	This value averages the e			
Γ ₁₄₄		< 2.8 × 10 ⁻³	CL=90%		small phase-space adjustm			
Γ ₁₄₅		< 2.1 × 10 ⁻³	CL=90%		an e ⁺ fraction; hence our		•	
	1 _+	(1.00 0.00) :: 10=3		[c]	The branching fraction fo	r this n	node may diffe	r from the sun

CL=90%

[f] < 8

(1.08 ± 0.29) $\times 10^{-3}$

(6 ±3)×10⁻⁴

 $(7 \pm 5) \times 10^{-4}$

(1.4 ± 0.5) $\times\,10^{-3}$

× 10⁻⁴

- hing frac-⁰)" under
- making a o use it as
- [c] The branching fraction for this mode may differ from the sum of the submodes that contribute to it, due to interference effects. See the relevant papers.
- [d] The two experiments measuring this fraction are in serious disagreement. See the Particle Listings.
- [e] The experiments on the division of this charge mode amongst its submodes disagree, and the submode branching fractions here add up to considerably more than the charged-mode fraction.
- [f] However, these upper limits are in serious disagreement with values obtained in another experiment.
- [g] This mode is not a useful test for a $\Delta C=1$ weak neutral current because both quarks must change flavor in this decay.
- [h] The value is for the sum of the charge states of particle/antiparticle states indicated.

CONSTRAINED FIT INFORMATION

An overall fit to 51 branching ratios uses 122 measurements and one constraint to determine 28 parameters. The overall fit has a $\chi^2 = 64.8$ for 95 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\langle \delta x_i \delta x_j \rangle / (\delta x_i \cdot \delta x_j)$, in percent, from the fit to the branching fractions, $x_i \equiv \Gamma_i / \Gamma_{\text{total}}$. The fit constrains the x_i whose labels appear in this array to sum to

Xg 6 y 32 19 X17 11 24 5 X18 1 8 3 2 X19 13 46 42 11 6 X20 1 5 3 1 24 8 X21 1 6 4 2 36 10 66 X29 3 11 10 3 7 23 16 18 X37 3 12 11 3 2 26 3 3 6 X46 1 3 2 1 17 1 2 4 32 X46 1 3 2 1 16 5 30 46 8 2 X55 2 8 7 2 1 16 4 3 3 6 1 1 2 X68 1 3 2 <t< th=""><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th></t<>											
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$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$		13	0	11	12	9	15	21	5	0	1
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$		20	1	18	18	14	23	33	7	0	2
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		×98	×106	×117	×118	×119	×123	X ₁₄₀			

D⁰ BRANCHING RATIOS

See the "Note on D Mesons" in the D^{\pm} Listings.

		— Inc	om svizut	des -		-		
Γ(e+anything)/Γ	i total							Γ1/Ι
VALUE		EVTS	DOCUM	ENT ID		TECN	COMMENT	, .
0.0675±0.0029 OUI								
0.069 ±0.003 ±0.0 0.0664±0.0018±0.0		1670 4 6 09	ALBRE 13 KUBO		96C	ARG CLE2	e ⁺ e ⁻ ≈	
0.075 ±0.0010 ±0.0		137					$e^+e^-\approx$ $e^+e^-3.7$	
• • • We do not us								
0.15 ±0.05			AGUIL				πp, pp 36 GeV	60, 400
0.055 ±0.037		12	SCHIN	DLER	81	MRK2	e+e- 3.7	71 GeV
13 KUBOTA 968 u subsequently dec			+ (and cha	arge co	onJugate	е) ечеп	its in which	the D
$\Gamma(\mu^+$ anything)/i	Ttotal							Γ ₂ /
VALUE 0.066±0.008 OUR	<u>EVTS</u> FTT	D	OCUMENT ID		TECN	COM	HENT	
0.060±0.007±0.01	2 310	Al	LBRECHT	96 C	ARG	e ⁺ e	¯ ≈ 10 Ge	·V
Γ(K anything)/		_						Γ ₃ /
VALUE D.53 ±0.04 OUR	<u>EVTS</u> AVERAGE		ocument io ncludes scal		<u>TECN</u> or of 1.3			m below
0.546 + 0.039 - 0.038		14 B	ARLAG	92 C	ACCM	π- (u 230 GeV	
0.609 ± 0.032 ± 0.05	2	C	OFFMAN	91			− 3.77 GeV	
0.42 ±0.08			GUILAR				pp 360, 400	
0.55 ±0.11 0.35 ±0.10	121 19		CHINDLER UILLEMIN	81 78			[—] 3.771 Ge [—] 3.772 Ge	
0.53±0.04 (Error	ERAGE scaled by	1.3)		·			rmalization	•
		1.3)	··· BARLA ·· COFFI ·· AGUIL ·· SCHIN	NG MAN AR IDLER	92C 91 87E 81	ACCM MRK3 HYBR MRK2	$\frac{\chi^2}{0.2}$	
0.53±0.04 (Error	scaled by		· · · · · · · · · · · · · · · · · · ·	AG MAN AR DLER EMIN (Co	92C 91 87E 81 78	ACCM MRK3 HYBR MRK2 MRK1	$\frac{\chi^2}{0.2}$	
0.53±0.04 (Error	scaled by	0.6	· · · COFFI · · · · AGUIL · · · · SCHIN	NG MAN AR IDLER EMIN	92C 91 87E 81 78	ACCM MRK3 HYBR MRK2 MRK1	2 0.2 1.7 1.9 0.0 3.2 7.0	
0.53±0.04 (Error	scaled by		· · · · · · · · · · · · · · · · · · ·	AG MAN AR DLER EMIN (Co	92C 91 87E 81 78	ACCM MRK3 HYBR MRK2 MRK1	2 0.2 1.7 1.9 0.0 3.2 7.0	
0.53±0.04 (Error 0.2 \(\tau \) \((K^-\) anything \) \(\text{YALUE} \)	0.4 g)/\(\Gamma_{\text{total}}\) +\(\Gamma_{\text{EVTS}}\)	0.6	COFFI AGUIL SCHIN VUILLI	AG MAN AR DLER (Co	92C 91 87E 81 78	ACCM MRK3 HYBR MRK2 MRK1	$ \frac{\chi^{2}}{\begin{array}{c} 0.2\\ 1.7\\ 0.0\\ 0.0\\ 3.2\\ 7.0\\ = 0.135 \end{array}} $	Γ4/
0.53±0.04 (Error 0.2 Γ(K ⁻ anything)	0.4 g)/\(\Gamma_{\text{total}}\) +\(\Gamma_{\text{VTS}}\) \(\text{AVERAGE}\)	0.6	OFFI AGUIL SCHIN O.8	AG MAN AR DLER (Co	92C 91 87E 81 78 Infidence	ACCMM MRK3 HYBR MRK2 MRK1 0 Level	$ \frac{\chi^{2}}{\begin{array}{c} 0.2\\ 1.7\\ 0.0\\ 0.0\\ 3.2\\ 7.0\\ = 0.135 \end{array}} $	Γ4/

 Γ_{5}/Γ

DOCUMENT ID TECN COMMENT

92C ACCM π^- Cu 230 GeV

91 MRK3 e⁺e⁻ 3.77 GeV

AGUILAR-... 87ε HYBR πp, pp 360, 400 GeV

SCHINDLER 81 MRK2 e+e- 3.771 GeV

15 BARLAG

 $^{\rm 15}\,{\rm BARLAG}$ 92C computes the branching fraction using topological normalization.

25

COFFMAN

 $\Gamma(K^+ \, anything)/\Gamma_{total}$

 $0.034 ^{+0.007}_{-0.005}$

 $0.03 \begin{array}{l} +0.05 \\ -0.02 \end{array}$

0.08 ±0.03

 $0.028 \pm 0.009 \pm 0.004$

0.034+0.006 OUR AVERAGE

		Semileptonic n	1000			Γ(K*(892)
$(K^-\ell^+\nu_\ell)/\Gamma_{\text{total}}$					Γ ₇ /Γ	This at modes
We average our K						VALUE
latter by a phase-s			ble to use it w	vith the K = e	ν_e fraction.	• • • We do
Hence our e ⁺ here	is really	y an e ⁺ . <u>DOCUMENT ID</u>	СОММ	FNT		0.24±0.07±
350±0.0017 OUR AV	/ERAGE					25 ALEXAN
366±0.0018		PDG	'98 Our F	$(K^-e^+\nu_e)/\Gamma$	total	for more
333±0.0018		PDG	98 1.03 ×	cour Γ(K = μ=	$^{\dagger} \nu_{\mu})/\Gamma_{\mathrm{total}}$	Γ(<i>R</i> *(892)
$(K^-e^+\nu_e)/\Gamma_{\text{total}}$. ,		Гв/Г	Unseei
	EVT\$	DOCUMENT ID	TECN	COMMENT	18/1	VALUE
366±0.0018 OUR FT				LO MILLOY		• • • We do
34 ±0.005 ±0.004	55	ADLER	89 MRK3	e ⁺ e ⁻ 3.77	GeV	< 0.64
$(K^-e^+\nu_e)/\Gamma(K^-e^+)$	-+)	,			Γε/Γ19	²⁶ The limit
LUE	EVTS	DOCUMENT ID	TECN	COMMENT	. 8/ . 19	Γ(Κ -π+π
65 ±0.04 OUR FIT		-				VALUE
95 ±0.04 OUR AVE		16 55	00- 51-		r(4.5)	<0.037
978±0.027±0.044 90 ±0.06 ±0.06	2510 584	16 BEAN 17 CRAWFORD	930 CLE2	e+e−≈ 7 e+e−≈ 1		·
91 ±0.07 ±0.11	250	18 ANJOS	89F E691	Photoprodu		Γ((液*(892
⁶ BEAN 93C uses K ⁻	μ ⁺ ν., ε	is well as $K^- e^+ \nu$	events and	makes a smal	I phase-space	VALUE
adjustment to the nu						<0.043
$2.00 \pm 0.12 \pm 0.18$	GeV/c ²	is obtained from t	he <i>q</i> 2 depend	ence of the de	cay rate.	27 KODAM
⁷ CRAWFORD 918 us	es K – e	$^+ u_e$ and $K^-\mu^+ u$	ν_{μ} candidates	to measure a	pole mass of	charge st
2.1+0.4+0.3 GeV/	c ² from	the q^2 dependence	e of the decay	y rate.		$\Gamma(\pi^-e^+\nu_e^-)$
8 ANJOS 89F measure	es a pole	mass of 2.1 + 0.4	± 0.2 GeV/c	c^2 from the q^2	dependence	VALUE
of the decay rate.		-0.2	,			0.0037±0.00
$(K^-\mu^+ u_\mu)/\Gamma(K^-$	- +1				Γ9/Γ19	0.009+0.00
LUE	EYTS	DOCUMENT ID	TECN	COMMENT	- ' 7/ ' 19	²⁸ This resu
4 ±0.04 OUR FIT						i nis resi
14 ±0.04 OUR AVE		19				r/
352±0.034±0.028	1897	¹⁹ FRABETTI ²⁰ FRABETTI		$\gamma \operatorname{Be} \overline{E}_{\gamma} = 2$	20 GeV	Γ(π ⁻ e ⁺ ν _ι
32 ±0.13 ±0.13	338		931 E687	γ Be $\overline{E}_{\gamma} = 2$ $e^+e^- \approx 1$		<u>VALUE</u> 0.102±0.01
79 ±0.08 ±0.09	231	²¹ CRAWFORD	918 CLEO		.U.5 GeV	0.101±0.01
0						0.101 ± 0.01
⁹ FRABETTI 95G extr	acts the	ratio of form facto	ors f_(0)/f_($(0) = -1.3 + \frac{3}{3}$	$\frac{.6}{.4} \pm 0.6$, and	0.101±0.020
measures a pole mas	acts the s of 1.87	ratio of form factor +0.11+0.07 -0.08-0.06 GeV	ors $f_{-}(0)/f_{+}($	$(0) = -1.3 + \frac{3}{3}$	$\frac{.6}{.4} \pm 0.6$, and	0.101 ± 0.026
measures a pole mas	s of 1.87	+0.11+0.07 -0.08-0.06 GeV	$/c^2$ from the	$0) = -1.3 + \frac{3}{3}$ $q^2 \text{ dependence}$	$^{1.6}_{1.4}\pm 0.6$, and e of the decay	0.101 ± 0.026 0.103 ± 0.036
measures a pole mas rate. OFRABETTI 93I meas of the decay rate.	s of 1.87 sures a p	+0.11+0.07 -0.08-0.06 GeV cole mass of 2.1+0	$/c^2$ from the $0.7 + 0.7$ GeV/ $0.3 - 0.3$	$(0) = -1.3 \frac{+3}{-3}$ $q^2 \text{ dependence}$ $(c^2 \text{ from the } q^2)$	$^{6}_{4}\pm0.6$, and e of the decay	0.101 ± 0.020 0.103 ± 0.03 ²⁹ FRABET
measures a pole mas rate. OFRABETTI 931 meas of the decay rate. CRAWFORD 918 m	s of 1.87 sures a p neasures	$+0.11+0.07 \\ -0.08-0.06$ GeV sole mass of 2.1^{+0}_{-0} a pole mass of 2.	$/c^2$ from the $0.7 + 0.7$ GeV/ $0.3 - 0.3$	$(0) = -1.3 \frac{+3}{-3}$ $q^2 \text{ dependence}$ $(c^2 \text{ from the } q^2)$	$^{6}_{4}\pm0.6$, and e of the decay	0.101 ± 0.020 0.103 ± 0.03 ²⁹ FRABET
measures a pole mas rate. OFRABETTI 93I meas of the decay rate. I CRAWFORD 91B m dependence of the d	s of 1.87 sures a p neasures ecay rate	0.011+0.07 GeV 0.08-0.06 GeV sole mass of $0.100000000000000000000000000000000000$	$/c^2$ from the $0.7 + 0.7$ GeV/ $0.3 - 0.3$	$(0) = -1.3 \frac{+3}{-3}$ $q^2 \text{ dependence}$ $(c^2 \text{ from the } q^2)$	$^{6}_{4}\pm0.6$, and e of the decay	
measures a pole mas rate. FRABETTI 93I meas of the decay rate. CRAWFORD 91B m dependence of the d $(K^-\mu^+\nu_\mu)/\Gamma(\mu^+s)$	s of 1.87 sures a p neasures ecay rate	+0.11+0.07 GeV -0.08-0.06 GeV note mass of 2.1+0 a pole mass of 2. e.	$/c^2$ from the $.7+0.7_{.3}-0.3_{-0.3}$ GeV/	$0) = -1.3 + \frac{3}{3}$ $q^2 \text{ dependence}$ $(c^2 \text{ from the } q^2)$ $0.18 \text{ GeV}/c^2$	$^{6}_{4}\pm0.6$, and e of the decay	0.101 ± 0.026 0.103 ± 0.03 29 FRABET
measures a pole mas rate. OFRABETTI 93I meas of the decay rate. I CRAWFORD 91B m dependence of the d $(K^-\mu^+\nu_\mu)/\Gamma(\mu^+)$	s of 1.87 sures a p neasures ecay rate	0.011+0.07 GeV 0.08-0.06 GeV sole mass of $0.100000000000000000000000000000000000$	$/c^2$ from the $.7+0.7_{.3}-0.3_{-0.3}$ GeV/	$(0) = -1.3 \frac{+3}{-3}$ $q^2 \text{ dependence}$ $(c^2 \text{ from the } q^2)$	$\frac{6}{4} \pm 0.6$, and e of the decay $\frac{2}{4}$ dependence from the $\frac{q^2}{4}$	0.101 ± 0.024 0.103 ± 0.03 ²⁹ FRABET make the
measures a pole mas rate. FRABETTI 93I meas of the decay rate. CRAWFORD 91B m dependence of the dep	s of 1.87 sures a p neasures ecay rate anythin EVTS	+0.11+0.07 GeV -0.08-0.06 GeV note mass of 2.1+0 a pole mass of 2. e.	$/c^{2}$ from the .7+0.7 GeV/.3-0.3 GeV/.00 \pm 0.12 \pm	$0) = -1.3 + \frac{3}{3}$ $q^2 \text{ dependence}$ $c^2 \text{ from the } q^2$ $0.18 \text{ GeV}/c^2$ $COMMENT$	$^{1.6}_{-4}\pm0.6$, and e of the decay 2 dependence from the 2 2	0.101 ± 0.020 0.103 ± 0.031 ²⁹ FRABET make the ³⁰ BUTLEF 0.020 ±
measures a pole mas rate. OFRABETTI 93I meas of the decay rate. I CRAWFORD 91B m dependence of the d $(K^-\mu^+\nu_\mu)/\Gamma(\mu^+)$	s of 1.87 sures a p leasures ecay rate anythin EVTS 232	+0.11+0.07 GeV -0.08-0.06 GeV note mass of 2.1+0 a pole mass of 2. e. g)	$/c^{2}$ from the .7+0.7 GeV/.3-0.3 GeV/.00 ± 0.12 ±	0) = -1.3^{+3}_{-3} q^2 dependence c^2 from the q 0.18 GeV/ c^2 $\frac{COMMENT}{\pi^-}$ emulsio	$^{1.6}_{-4}\pm0.6$, and e of the decay 2 dependence from the 2 2	0.101 ± 0.024 0.103 ± 0.03 ²⁹ FRABET make the
measures a pole mas rate. OFRABETTI 93I meas of the decay rate. CRAWFORD 91B m dependence of the d $(K^-\mu^+\nu_\mu)/\Gamma(\mu^+;\frac{UUE}{9}\pm0.06$ OUR FIT 472 $\pm0.061\pm0.040$	s of 1.87 sures a p leasures ecay rate anythin EVTS 232	+0.11+0.07 GeV -0.08-0.06 GeV note mass of 2.1+0 a pole mass of 2. e. g)	$/c^{2}$ from the .7+0.7 GeV/ $.3-0.3$ GeV/ $.00 \pm 0.12 \pm \frac{TECN}{2}$ 94 E653 ges, fits, limits	0) = -1.3^{+3}_{-3} q^2 dependence c^2 from the q 0.18 GeV/ c^2 $\frac{COMMENT}{\pi^-}$ emulsio	$^{1.6}_{4}\pm0.6$, and e of the decay 2 dependence from the q^{2} Γ_{9}/Γ_{2} on 600 GeV	0.101±0.024 0.103±0.034 29 FRABET make the 30 BUTLEF 0.020± \(\begin{array}{c} \epsilon \cdot \pi & \text{*} \\ \epsilon \cdot \epsilon \cdot \epsilon \epsilon \\ \epsilon \cdot \epsilon \epsilon \epsilon \epsilon \\ \epsilon \cdot \epsilon \epsilon \epsilon \epsilon \\ \epsilon \cdot \epsilon \eps
measures a pole mas rate. 0 FRABETTI 93I meas of the decay rate. 1 CRAWFORD 91B m dependence of the d $(K^-\mu^+\nu_\mu)/\Gamma(\mu^+;\mu^+)$ 49 ± 0.06 OUR FIT 472 $\pm 0.061\pm 0.040$ • We do not use th 32 ± 0.05	s of 1.87 sures a p leasures ecay rate anythin EVIS 232 le followid	+0.11+0.07 GeV -0.08-0.06 GeV note mass of 2.1+0 a pole mass of 2. b. pocument ip KODAMA Ing data for average	$/c^{2}$ from the .7+0.7 GeV/ $.3-0.3$ GeV/ $.00 \pm 0.12 \pm \frac{TECN}{2}$ 94 E653 ges, fits, limits	0) = $-1.3 + \frac{3}{3}$ q^2 dependence c^2 from the q 0.18 GeV/ c^2 $\frac{COMMENT}{\pi}$ emulsions, etc. • • •	$^{1.6}\pm0.6$, and e of the decay 2 dependence from the q^{2} Γ_{9}/Γ_{2} on 600 GeV	0.101 ± 0.024 0.103 ± 0.034 29 FRABET make the 30 BUTLEF 0.020 ± \(\varPsi \lambda - \pi^+ + \rangle \) \(\varPsi \lambda \la
measures a pole mas rate. OFRABETTI 931 meas of the decay rate. CRAWFORD 91B m dependence of the d $(K^-\mu^+\nu_\mu)/\Gamma(\mu^+;\mu^+)$ 49 ±0.06 OUR FIT 472±0.051±0.040 • We do not use th 32 ±0.05 ±0.05 $(K^-\pi^0e^+\nu_e)/\Gamma_{\rm tot}$	s of 1.87 sures a p leasures ecay rate anythinEVTS232 le followid124	+0.11+0.07 GeV -0.08-0.06 GeV pole mass of 2.1+0 a pole mass of 2. e. <u>POCUMENT ID</u> KODAMA Ing data for averag	$/c^{2}$ from the .7+0.7 GeV/ $.3-0.3$ GeV/ $.00\pm0.12\pm\frac{7ECN}{94}$ E653 ges, fits, limits 91 EMUL	0) = $-1.3 + \frac{3}{3}$ q^2 dependence c^2 from the q 0.18 GeV/ c^2 COMMENT π^- emulsions, etc. • • •	$^{1.6}_{4}\pm0.6$, and e of the decay 2 dependence from the q^{2} Γ_{9}/Γ_{2} on 600 GeV	0.101±0.024 0.103±0.034 29 FRABET make the 30 BUTLEF 0.020± \(\begin{array}{c} \epsilon \cdot \pi & \text{*} \\ \epsilon \cdot \epsilon \cdot \epsilon \epsilon \\ \epsilon \cdot \epsilon \epsilon \epsilon \epsilon \\ \epsilon \cdot \epsilon \epsilon \epsilon \epsilon \\ \epsilon \cdot \epsilon \eps
measures a pole mas rate. O FRABETTI 93I meas of the decay rate. CRAWFORD 91B m dependence of the d $(K^-\mu^+\nu_\mu)/\Gamma(\mu^+;\mu)$ 49 ±0.06 OUR FIT 472±0.061±0.040 • We do not use th 32 ±0.05 ± 0.05 $\pm $	s of 1.87 sures a p leasures ecay rate anythin EVIS 232 le followid	+0.11+0.07 GeV -0.08-0.06 GeV note mass of 2.1+0 a pole mass of 2. b. EQUIMENT ID KODAMA Ing data for averag KODAMA	$/c^{2}$ from the .7+0.7 GeV/ $.3-0.3$ GeV/ $.00\pm0.12\pm0.12$ 4 E653 ges, fits, limits 91 EMUL	0) = $-1.3 + \frac{3}{3}$ q^2 dependence c^2 from the q 0.18 GeV/ c^2 COMMENT π^- emulsions, etc. • • • pA 800 GeV	$^{1.6}\pm0.6$, and e of the decay 2 dependence from the q^{2} Γ_{9}/Γ_{2} on 600 GeV	0.101±0.024 0.103±0.034 29 FRABET make the 30 BUTLEF 0.020± \(\varGamma(K^-\pi^+)\) \(\varYALVE\) 0.0385±0.00 0.0388±0.00
measures a pole mas rate. OFRABETTI 93I meas of the decay rate. CRAWFORD 91B m dependence of the d $(K^-\mu^+\nu_\mu)/\Gamma(\mu^+;\mu^+\nu^-)$ 49 ±0.06 OUR FIT 472±0.051±0.040 • We do not use th 32 ±0.05 ±0.05 $(K^-\pi^0e^+\nu_e)/\Gamma_{tot}$ LULUE 116 + 0.013 ± 0.002	s of 1.87 sures a p neasures ecay rate anythin EVIS 232 ne followin 124 tal EVIS 4	+0.11+0.07 GeV -0.08-0.06 GeV pole mass of 2.1+0 a pole mass of 2. e. KODAMA Ing data for averag KODAMA	/c ² from the .7+0.7 GeV/ .3-0.3 GeV/ .00 ± 0.12 ±	0) = $-1.3 + \frac{3}{3}$ q^2 dependence c^2 from the q 0.18 GeV/ c^2 $\frac{COMMENT}{\pi} = \text{emulsions}, \text{ etc.} \bullet \bullet \bullet$ $pA 800 \text{ GeV}$ $\frac{COMMENT}{3} = e^+e^- \approx 3$	$^{1.6}\pm0.6$, and e of the decay 2 dependence from the q^{2} 1 $^{$	0.101±0.024 0.103±0.034 29 FRABET make the 30 BUTLEF 0.020± \(\begin{array}{c} \(K^-\pi^+\) \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \
measures a pole mas rate. OFRABETTI 93I meas of the decay rate. CRAWFORD 91B m dependence of the d $(K^-\mu^+\nu_\mu)/\Gamma(\mu^+;\mu^+\nu^-)$ 49 ±0.06 OUR FIT 472±0.051±0.040 • We do not use th 32 ±0.05 ±0.05 $(K^-\pi^0e^+\nu_e)/\Gamma_{tot}$ LULUE 116 + 0.013 ± 0.002	s of 1.87 sures a p neasures ecay rate anythin EVIS 232 ne followin 124 tal EVIS 4	+0.11+0.07 GeV -0.08-0.06 GeV pole mass of 2.1+0 a pole mass of 2. e. KODAMA Ing data for averag KODAMA	/c ² from the .7+0.7 GeV/ .3-0.3 GeV/ .00 ± 0.12 ±	0) = $-1.3 + \frac{3}{3}$ q^2 dependence c^2 from the q 0.18 GeV/ c^2 $\frac{COMMENT}{\pi} = \text{emulsions}, \text{ etc.} \bullet \bullet \bullet$ $pA 800 \text{ GeV}$ $\frac{COMMENT}{3} = e^+e^- \approx 3$	$^{1.6}\pm0.6$, and e of the decay 2 dependence from the q^{2} 1 $^{$	0.101±0.021 0.103±0.031 29 FRABET make the 30 BUTLEF 0.020± \(\begin{array}{ccccc} \begin{array}{cccccccccccccccccccccccccccccccccccc
measures a pole mas rate. OFRABETTI 93I meas of the decay rate. CRAWFORD 91B m dependence of the d $(K^-\mu^+\nu_\mu)/\Gamma(\mu^+;\mu^+)$ 49 ±0.06 OUR FIT 472±0.081±0.040 • We do not use the decay to the decay	s of 1.87 sures a p leasures ecay rate anythin _EVIS 232 le followi 124 tal _EVIS 4 a fraction	+0.11+0.07 GeV -0.08-0.06 GeV olde mass of 2.1+0 a pole mass of 2. E DOCUMENT ID KODAMA Ing data for averag KODAMA 22 BAI 00 0.79+0.15+0.0 0.079-0.17-0.0	$/c^{2}$ from the .7+0.7 GeV/ .3-0.3 GeV/ .00 ± 0.12 ±	0) = $-1.3 + \frac{3}{3}$ q^2 dependence c^2 from the q^2 0.18 GeV/ c^2 $\frac{COMMENT}{\pi^- \text{ emulsions, etc.}} = pA 800 \text{ GeV}$ $\frac{COMMENT}{3} = e^+e^- \approx 3$ $\text{and } D^+ \text{ and } M = 0$	1.6 \pm 0.6, and e of the decay 2 dependence from the q^2 Γ_9/Γ_2 on 600 GeV Γ_10/Γ_1 1.77 GeV	0.101±0.021 0.103±0.031 29 FRABET make the 30 BUTLEF 0.020± Γ(K-π+) <u>VALUE</u> 0.0386±0.00 0.0390±0.00 0.045±0.00 0.0395±0.00 0.0395±0.00
measures a pole mas rate. OFRABETTI 93I meas of the decay rate. CRAWFORD 91B m dependence of the d $(K^-\mu^+\nu_\mu)/\Gamma(\mu^+;\mu^+\nu^-)$ 49 ±0.06 OUR FIT 472±0.051±0.040 • We do not use th 32 ±0.05 ±0.05 $(K^-\pi^0e^+\nu_e)/\Gamma_{tot}$ LULUE 116 + 0.013 ± 0.002	s of 1.87 sures a p leasures ecay rati anythin EVIS 232 le followi 124 al EVIS 4 a fraction s) are K	## +0.11 + 0.07 GeV -0.08 - 0.06 GeV note mass of 2.1 + 0 a pole mass of 2. ## ADDAMA Ing data for average KODAMA ## ADDAMA ## AD	/c ² from the .7+0.7 GeV/ .3-0.3 GeV/ .00 ± 0.12 ±	0) = $-1.3 + \frac{3}{3}$ q^2 dependence c^2 from the q 0.18 GeV/ c^2 COMMENT — π^- emulsions, etc. • • • • — pA 800 GeV COMMENT — 3 ded D^+ and D^+ and D^+ and D^+ and D^+ even	0.6 ± 0.6 , and 0.6 ± 0.6 , and 0.6 ± 0.6 and 0.6 ± 0.6 and 0.6 ± 0.6 from the $0.6 $	0.101±0.021 0.103±0.031 29 FRABET make the 30 BUTLEF 0.020± \(\begin{array}{ccccc} \begin{array}{cccccccccccccccccccccccccccccccccccc
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(-\ell^+\nu_\ell)/\Gamma(\overline{K}{}^0\pi^+\pi^-)
                                                                                     \Gamma_{13}/\Gamma_{21}
an average of the K^*(892)^-e^+
u_e and K^*(892)^-\mu^+
u_\mu ratios. Unseen decay
s of the K^*(892)^- are included.
                             DOCUMENT ID TECN COMMENT
              EVTS
o not use the following data for averages, fits, limits, etc. • • •
                137 25 ALEXANDER 908 CLEO e+e- 10.5-11 GeV
NDER 90B cannot exclude extra \pi^0's in the final state. See nearby data blocks
)^{0}\pi^{-}e^{+}\nu_{e})/\Gamma(K^{\circ}(892)^{-}e^{+}\nu_{e})
                                                                                     \Gamma_{14}/\Gamma_{18}
in decay modes of the \overline{K}^*(892)^0 are included.
            CLS DOCUMENT ID TECH COMMENT
o not use the following data for averages, fits, limits, etc. • • •
                90 26 CRAWFORD 918 CLEO e^+e^-\approx 10.5 GeV
It on (\overline{K}^*(892)\pi)^-~\mu^+
u_\mu below is much stronger.
\pi^- \mu^+ 
u_\mu) / \Gamma (K^- \mu^+ 
u_\mu)
                                                                                       \Gamma_{15}/\Gamma_{9}
                              DOCUMENT ID TECH COMMENT
              CL%
                               KODAMA
                                                  938 E653 π<sup>-</sup> emulsion 600 GeV
(2)\pi)^-\mu^+\nu_\mu/\Gamma(K^-\mu^+\nu_\mu)
                                                                                       \Gamma_{16}/\Gamma_{9}
                             DOCUMENT ID TECN COMMENT

        CL%
        DOCUMENT ID
        TECN
        COMMENT

        90
        27 KODAMA
        93B E653
        π<sup>-</sup> emulsion 600 GeV

AA 93B searched in K^-\pi^+\pi^-\mu^+
u_\mu , but the limit includes other (\overline{K}^*(892)\pi)^-
'e)/F<sub>totel</sub>
                                                                                         \Gamma_{17}/\Gamma
                             DOCUMENT ID TECH COMMENT
2006 OUR FIT
023 ± 0.0004 7 28 ADLER
                                                 89 MRK3 e+e- 3.77 GeV
with of ADLER 89 gives \left| \frac{V_{cd}}{V_{cs}} \cdot \frac{f_{+}^{\pi}(0)}{f_{-}^{\kappa}(0)} \right|^2 = 0.057_{-0.015}^{+0.038} \pm 0.005.
(e)/\Gamma(K^-e^+\nu_e)
                                                                                       \Gamma_{17}/\Gamma_{8}
17 OUR FIT
                               DOCUMENT ID TECN COMMENT
8 OUR AVERAGE
                           ^{29} FRABETTI 968 E687 \gamma Be, \overline{E}_{\gamma} \approx 200~{
m GeV}
0±0.003
                          30 BUTLER
                                                  95 CLE2 < 0.156 (90% CL)
TTI 968 uses both e and \mu events, and makes a small correction to the \mu events to
nem effectively e events. This result gives \left| \frac{V_{cd}}{V_{cs}}, \frac{f_{r}^{\pi}(0)}{f_{r}^{\pi}(0)} \right|^2 = 0.050 \pm 0.011 \pm 0.002.
R 95 has 87 \pm 33 \pi^- e^+ \nu_e events. The result gives |\frac{V_{Cd}}{V_{Cs}} \cdot \frac{f_+^{\pi}(0)}{f_+^{\kappa}(0)}|^2 = 0.052 \pm
0.007.
           — Hadronic modes with a \mathcal R or \mathcal R \kappa \mathcal R —
)/F<sub>total</sub>
                                       DOCUMENT ID TECN COMMENT
                      EVTS
2009 OUR FIT
1009 OUR AVERAGE
                                   31 ARTUSO
                                                          98 CLE2 e^+e^-\approx \Upsilon(4S)
97C ALEP From Z decays
015+0.0016
                                   31 BARATE
0.009 \pm 0.0012
                        5392
                                   32 ALBRECHT
                                                          94 ARG e^+e^- \approx T(45)
94F ARG e^+e^- \approx T(45)
006 ± 0.004
                                  31 ALBRECHT
0012±0.0028
                        1173
                               31,33 AKERIB
                                                           93 CLE2 e+e- ≈ T(45)
0008±0.0017
                        4208
                                   31 DECAMP
0034±0.0044
                                                           91. ALEP From Z decays
                                   31 ABACHI
008 ± 0.005
                                                           88 HRS e+e- 29 GeV
                                   ADLER 88C MRK3 e<sup>+</sup> e<sup>-</sup> 3.77 GeV 34 SCHINDLER 81 MRK2 e<sup>+</sup> e<sup>-</sup> 3.771 GeV
0.004 ±0.004
                         930
006
                         263
                                  35 PERUZZI
                                                          77 MRK1 e+e- 3.77 GeV
II 88, DECAMP 911, AKERIB 93, ALBRECHT 94F, BARATE 97c, and AR-
98 use D^*(2010)^+ \rightarrow D^0 \pi^+ decays. The \pi^+ is both slow and of low p_T with
to the event thrust axis or nearest let (\approx D^{*+} direction). The excess number
\pi^+'s over background gives the number of D^*(2010)^+ \to D^0 \pi^+ events, and those with D^0 \to K^- \pi^+ gives the D^0 \to K^- \pi^+ branching fraction. ECHT 94 uses D^0 mesons from \overline B{}^0 \to D^{*+} \ell^- \overline{\nu}_\ell decays. This is a different set ts than used by ALBRECHT 94F.
(ERIB 93 value includes radiative corrections; without them the value is 0.0391 \pm
DLER 81 (MARK-2) measures \sigma(e^+e^-
                                                    \rightarrow \psi(3770)) \times branching fraction to
\pm 0.02 nb. We use the MARK-3 (ADLER 88C) value of \sigma = 5.8 \pm 0.5 \pm 0.6 nb.
ZI 77 (MARK-1) measures \sigma(e^+e^-\to \psi(3770)) \times branching fraction to be 0.05 nb. We use the MARK-3 (ADLER 88C) value of \sigma=5.8\pm0.5\pm0.6 nb.
/Γ(K-π+)
                                                                                      \Gamma_{20}/\Gamma_{19}
OUR FIT Error includes scale factor of 1.1.
```

ANJOS

92B E691 γ Be 80-240 GeV

 D^0

$\Gamma(\overline{K}^0\pi^0)/\Gamma(\overline{K}^0\pi^0)$	+π ⁻)				Γ_{20}/Γ_{21}	
0.390±0.031 OUR F		DOÇUMENT ID	TECN	COMMENT		
		PP064 P10		4		
$0.44 \pm 0.02 \pm 0.05$	1942	PROCARIO	93B CLE2	e ⁺ e ⁻ 10.30		
$0.34 \pm 0.04 \pm 0.02$		³⁶ ALBRECHT	92P ARG	e ⁺ e ⁻ ≈ 1		
$0.36 \pm 0.04 \pm 0.08$	104	KINOSHITA	91 CLEO	$e^+e^-\sim 10$	0.7 GeV ·	
³⁶ This value is calc	ulated from n	umbers in Table :	of ALBREC	HT 92P.	,	,
$\Gamma(\overline{K}^0\pi^+\pi^-)/\Gamma_{\text{tot}}$					Γ ₂₁ /Γ	
VALUE 0.054 ±0.004 OUR	ETT Error II	<u>DOCUME</u> noludes scale fact		TECN COMM	IENT	
0.065 ±0.005 OUR		iciades scale laci	OF 01 1.2.			
0.0503 ± 0.0039 ± 0.00		4 37 ALBRE	CHT DAE	ARG e+e-	~ ~ ~/45)	
					- ≈ Υ(45)	
0.064 ±0.005 ±0.03		ADLER		MRK3 e+e-		
0.052 ±0.016		2 38 SCHINE		MRK2 e+e-		
0.079 ±0.023		8 ³⁹ PERUZ		MRK1 e ⁺ e ⁻		
37 See the footnote	on the ALBI	RECHT 94F mea	surement of	$\Gamma(K^-\pi^+)/\Gamma$	total for the	
method used.						
38 SCHINDLER 81	(MARK-2) M	easures σ(e ' e	→ ψ(3//0)) × branchin	ig traction to	
be 0.30 ± 0.08 nb						
³⁹ PERUZZI 77 (M. 0.46 ± 0.12 nb. V						
0.40 ± 0.12 lib. V	Ac nac tile Mi	ANN-3 (ADLER	oc, value of	b = 5.6 ± 0.	.5 ± 0.6 IIU.	
$\Gamma(\overline{K}^0\pi^+\pi^-)/\Gamma(K^0\pi^+\pi^-)$	(− +)				Γ_{21}/Γ_{19}	
VALUE	EVTS	DOCUMENT ID	TECN	COMMENT	. 21/ . 19	
1.41±0.10 OUR FIT		es scale factor of		COMMENT		
1.65±0.17 OUR AVE						
1.61 ± 0.10 ± 0.15	856	FRABETTI	94J E687	γ Be $\overline{E}_{\gamma} = 22$	0 GeV	
1.7 ±0.8	35	AVERY	80 SPEC	$\gamma N \rightarrow D^{\bullet}$		
2.8 ±1.0	116	PICCOLO	77 MRK1	e ⁺ e ⁻ 4.03	, 4.41 GEV	
$\Gamma(\overline{K^0}\rho^0)/\Gamma(\overline{K^0}\pi^{-1})$	+ ₋ -1				Γ_{22}/Γ_{21}	
YALUE	- /	DOCUMENT IN	TECN	COMMENT	22/21	
0.223±0.027 OUR A	VERAGE F	DOCUMENT ID ror Includes scale		COMMENT		
0.350±0.028±0.067		FRABETTI	94G E687	_	220 GeV	
				γ Be, $E_{\gamma} \approx$		
0.227±0.032±0.009		ALBRECHT	93D ARG	e ⁺ e ⁻ ≈ 10		
0.215±0.051±0.037		ANJOS	93 E691	γ Be 90-260		
$0.20 \pm 0.06 \pm 0.03$		FRABETTI	92B E687	$\gamma \operatorname{Be} E_{\gamma} = 2$		
$0.12 \pm 0.01 \pm 0.07$		ADLER	87 MRK3	e ⁺ e ⁻ 3.77	GeV	
E (120 & (appl)) /E (120 ±\					
୮ <i>(K</i> º ቈ(980))/୮(/		. (000)			Γ_{73}/Γ_{21}	
	nodes of the	5(980) are include				
VALUE	TDACE.	DOCUMENT ID	TECN_	COMMENT		
0.105±0.029 OUR A	VERAGE		*** =***	. 7		
$0.131 \pm 0.031 \pm 0.034$		FRABETTI	94G E687	γ Be, $\overline{E}_{\gamma} \approx$		
$0.088 \pm 0.035 \pm 0.012$		ALBRECHT	93D ARG	$e^+e^-\approx 10$	GeV	
F (1070)\ /F	<i>(</i> 270 _+ _−\				r /r	
Γ(K ⁰ f ₂ (1270))/Γ	(N-# #)	f /1270\ ass last			Γ_{77}/Γ_{21}	
	nodes of the f	2(1270) are Incli		COMMENT		
VALUE 0.076±0.028 OUR A	VERAGE	DOCUMENT ID		COMMENT		
0.065 ± 0.025 ± 0.030	LIVIOL	FRABETTI	94G E687	γ Be, $\overline{E}_{\gamma} \approx$	220 GeV/	
$0.088 \pm 0.037 \pm 0.014$		ALBRECHT	93D ARG	$e^+e^-\approx 10$	GeV	
Γ(K ⁰ f ₀ (1370))/Γ	//////////////////////////////////////				Γ_{79}/Γ_{21}	
Unseen decay r	nodes of the	$_0^{\prime}(1370)$ are inclu	ıded		179/121	
VALUE	ve tille i	DOCUMENT ID	TECN	COMMENT		
0.13 ±0.04 OUR A	VERAGE					
0.123±0.035±0.049		FRABETTI	94G E687	γ Be, $\overline{E}_{\gamma} pprox$	220 GeV	
0.131±0.045±0.021		ALBRECHT		e+e-≈ 10		
			, or And	~ 10		
$\Gamma(K^*(892)^-\pi^+)/$	Γ(Κ 0π+π-	-)			Γ_{20}/Γ_{21}	
		/ K*(892) are in	cluded.			
				COMMENT		
<u>VALUE</u> 0.93 ±0.04 OUR F	T Error Incl	udes scale factor	of 1.1.			
0.96 ±0.04 OUR A						
$0.938 \pm 0.054 \pm 0.038$		FRABETTI	94G E687	γBe, \overline{E}_{γ} ≈	220 GeV	
1.08 ±0.063±0.045		ALBRECHT		e ⁺ e ⁻ ≈ 10		
0.720±0.145±0.185		ANJOS	93 E691			
0.96 ±0.12 ±0.075		FRABETTI	928 E687			
0.84 ±0.06 ±0.08		ADLER		e^+e^- 3.77		
1.05 +0.23 +0.07 -0.26 -0.09	25	SCHINDLER	81 MRK2	e ⁺ e ⁻ 3.77	1 GeV	
_4	. — .					
$\Gamma(K_0^*(1430)^-\pi^+)$					Γ_{102}/Γ_{21}	
		ਨ੍ਹਿੰ(1430) [—] are i	ncluded.			
VALUE		DOCUMENT ID		COMMENT		
0.19 ±0.05 OUR A	VERAGE					
0.176±0.044±0.047		FRABETTI	94G E687	γBe, E ≈	220 GeV	
0.208±0.055±0.034		ALBRECHT	93D APC	+ 4 = ~ 10	GeV	
J.200 I U.U33 I U.U34		ACDUECH!	טאא טנק	e e ≈ 10	OE V	
$\Gamma(K_2^*(1430)^-\pi^+)$	/r(K0+++	-)			Γ_{103}/Γ_{21}	
			ncluded		· 103/ · 21	
		K**(1430) are i		*****		
VALUE	CL%	DUCUMENT ID	<u>TECN</u>	COMMENT		
-0 4P				_		
<0.15	90	ALBRECHT	93D ARG	e ⁺ e [−] ≈ 10	GeV	

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\Gamma(\overline{K}^0\pi^+\pi^- \text{ nonresonant})/\Gamma(\overline{K}^0\pi^+\pi^-)
                                                                                                 \Gamma_{28}/\Gamma_{21}
VALUE
                                             DOCUMENT ID
                                                                   TECN COMMENT
0.27 ±0.04 OUR AVERAGE
0.263 \pm 0.024 \pm 0.041
                                             ANJOS
                                                               93 E691 γBe 90-260 GeV
                                                               928 E687 \gamma Be \overline{E}_{\gamma}= 221 GeV
0.26 \pm 0.08 \pm 0.05
                                             FRABETTI
0.33 ±0.05 ±0.10
                                             ADLER
                                                               87 MRK3 e+e-3.77 GeV
\Gamma(K^-\pi^+\pi^0)/\Gamma_{\text{total}}
                                                                                                    \Gamma_{29}/\Gamma
VALUE EVTS DOCUMENT ID T
0.139±0.009 OUR FTT Error includes scale factor of 1.3.
                                                                    TECN COMMENT
0.131±0.016 OUR AVERAGE
0.133±0.012±0.013 931
                                             ADLER
                                                               88C MRK3 e+e- 3.77 GeV
                                       40 SCHINDLER 81 MRK2 e+e- 3.771 GeV
0.117±0.043
                               37
 ^{40} SCHINDLER 81 (MARK-2) measures \sigma(e^+e^- 	o \psi(3770)) 	imes branching fraction to be 0.68 \pm 0.23 nb. We use the MARK-3 (ADLER 88C) value of \sigma= 5.8 \pm 0.5 \pm 0.6 nb.
\Gamma(K^-\pi^+\pi^0)/\Gamma(K^-\pi^+)
VALUE EVTS DOCUMENT ID TECH COMMENT
3.62±0.23 OUR FIT Error includes scale factor of 1.4.
3.47±0.30 OUR AVERAGE Error includes scale factor of 1.5. See the ideogram below.
3.81 \pm 0.07 \pm 0.26
                                            BARISH
                                                               96 CLE2 e+e-≈ T(45)
                               10k
                                         41 ALBRECHT
                                                               92P ARG e+e-≈ 10 GeV
3 04 + 0 16 + 0 34
                               931
                                             ALVAREZ
                                                               918 NA14 Photoproduction
4.0 \pm 0.9 \pm 1.0
                                69
                                             KINOSHITA 91 CLEO e^+e^- \sim 10.7 \text{ GeV}
2.8 \pm 0.14 \pm 0.52
                              1050
                                             SUMMERS 84 E691 Photoproduction
                                41
4.2 ±1.4
 <sup>41</sup>This value is calculated from numbers in Table 1 of ALBRECHT 92P.
        WEIGHTED AVERAGE
        3.47±0.30 (Error scaled by 1.5)
                                              Values above of weighted average, error,
                                              and scale factor are based upon the data in
this ideogram only. They are not neces-
sarily the same as our 'best' values,
                                              obtained from a least-squares constrained fit
utilizing measurements of other (related)
quantities as additional information.
                                                       BARISH
                                                                               CLE2
                                                        ALBRECHT
ALVAREZ
                                                                          92P ARG
91B NA14
                                                                                            0.2
                                                        KINOSHITA
                                                                          91 CLEO
                                                                                            1.5
                                                        SUMMERS
                                                                          84 E691
                                                                                            0.3
                                                                   (Confidence Level = 0.300)
                                                                    10
         \Gamma(K^-\pi^+\pi^0)/\Gamma(K^-\pi^+)
\Gamma(K^-\rho^+)/\Gamma(K^-\pi^+\pi^0)
                                                                                                 \Gamma_{30}/\Gamma_{29}
VALUE EVTS
0.78 ±0.05 OUR AVERAGE
                                             DOCUMENT ID TECN COMMENT
                                                               94G E687 \gamma Be, \overline{E}_{\gamma} \approx 220 GeV
0.765 \pm 0.041 \pm 0.054
                                             FRABETTI
0.647 \pm 0.039 \pm 0.150
                                             ANJOS
                                                               93 E691 γBe 90-260 GeV .
87 MRK3 e<sup>+</sup>e<sup>-</sup> 3.77 GeV
0.81 ±0.03 ±0.06
                                             ADLER
• • We do not use the following data for averages, fits, limits, etc. • • •
0.31 \begin{array}{l} +0.20 \\ -0.14 \end{array}
                                             SUMMERS 84 E691 Photoproduction
0.85 \begin{array}{c} +0.11 \\ -0.15 \end{array} \begin{array}{c} +0.09 \\ -0.10 \end{array}
                                             SCHINDLER 81 MRK2 e+e- 3.771 GeV
 \Gamma(K^{+}(892)^{-}\pi^{+})/\Gamma(K^{-}\pi^{+}\pi^{0})
                                                                                                 \Gamma_{80}/\Gamma_{29}
        Unseen decay modes of the K^*(892)^- are included.
VALUE DOCUMENT ID TO 0.363 ± 0.035 OUR FIT Error includes scale factor of 1.3.
                                                                   TECN COMMENT
 0.28 ±0.04 OUR AVERAGE
0.444 \pm 0.084 \pm 0.147
                                             FRABETTI
                                                               94G E687 γBe, \overline{E}_{\gamma} ≈ 220 GeV
                                                               93 E691 γBe 90-260 GeV
87 MRK3 e<sup>+</sup>e<sup>-</sup> 3.77 GeV
0.252 \pm 0.033 \pm 0.035
                                             ANJOS
0.36 ±0.06 ±0.09
                                             ADLER
 \Gamma(\overline{K}^{+}(892)^{0}\pi^{0})/\Gamma(K^{-}\pi^{+}\pi^{0})
                                                                                                 \Gamma_{01}/\Gamma_{29}
       Unseen decay modes of the K^*(892)^0 are included.
VALUE
0.227±0.027 OUR FIT
                                             DOCUMENT ID TECN COMMENT
0.221 ± 0.029 OUR AVERAGE
0.248 ± 0.047 ± 0.023
                                             FRABETTI
                                                               94G E687 \gamma Be, \overline{\mathcal{E}}_{\gamma} \approx 220 GeV
                                                               93 E691 γBe 90-260 GeV
87 MRK3 e<sup>+</sup>e<sup>-</sup> 3.77 GeV
0.213 \pm 0.027 \pm 0.035
                                             ANJOS
```

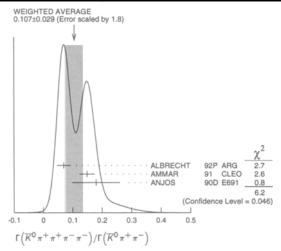
ADLER

 $0.20 \pm 0.03 \pm 0.05$

Γ ₃₈ /Γ ₃₇		·+π ⁻)	$/\Gamma(K^-\pi^+\pi^-)$	I(K'π'ρ=τουαλ)/	F33/I			-π ⁺ π ^υ)	rt)/[(K	[⊢] π ⁰ nonresonant
entry gives the specifically		, $\overline{K}^*(892)^0 ho^0$, et	-a ₁ (1260)+,	This Includes K	ENT			OCUMENT ID	<u>TS</u> .	EVT
amplitude analyses of the					E - 000 5.14	-				D18 OUR AVERAG
ure. <u>COMMENT</u>	TECN	alues of the reson DOCUMENT ID		VALUE	Ē _γ ≈ 220 GeV Ю–260 GeV		94G I 93 I	RABETTI		033±0.040 004±0.018
		*****	VERAGE	0.835±0.035 OUR A	3.77 GeV			ADLER		02 ±0.04
γ8e 90-260 GeV e ⁺ e ⁻ 3.77 GeV		ANJOS COFFMAN		0.80 ±0.03 ±0.05 0.855±0.032±0.030						do not use the foll
			the following		production	691 P	84 I	UMMERS	21	22 2
Photoproduction	918 NA14	ALVAREZ		0.98 ±0.12 ±0.10	Γ ₈₁ /		لماسات	Occor	•	$(2)^0 \pi^0$ /Γ($\overline{K}^0 \pi^0$
Γ ₃₉ /Γ ₃₁		•		$\Gamma(K^-\pi^+\rho^0$ 3-body	ENT	<u>ÉECN</u> C		092) are in OCCUMENT ID		een decay modes o
ies of the $K^-\pi^+\pi^+\pi^-$		nd E691 full amp						scale factor o		OUR FIT Error
COMMENT		DOCUMENT ID	<u>EVTS</u>	VALUE	π^0 Dalltz plot	CLE2 K	93B	PROCARIO	22	±0.20 12
γBe 90-260 GeV	92c E691	SOLNA	VERAGE	0.063 ± 0.028 OUR AN 0.05 ± 0.03 ± 0.02	Γ ₁₀₄ /			וס	(892) ⁰ #	30) ⁰ π ⁰)/Γ(Κ *(
e ⁺ e ⁻ 3.77 GeV		COFFMAN		$0.084 \pm 0.022 \pm 0.04$) ⁰ are in-	K *(892			een decay modes o
			- · · · · · · · · · · · · · · · · ·	• • We do not use		TECN C		OCUMENT ID		cu
Photoproduction		6 ALVAREZ		0.77 ±0.06 ±0.06	π^0 Dalitz plot			ROCARIO		90
e ⁺ e ⁻ 4.03, 4.41 GeV		PICCOLO	180	0.85 +0.11 -0.22	r //			-0)	\ /r/ 127 0	π ^{0'} nonresonant)
nnot determine what frac	AREZ 918 cai	onresonant. ALV			Г <u>36</u> /	TECN C)	DOCUMENT ID	,	m nonresonant)
			$a_1(1260)^+$.	tion of this is K-	π^0 Dalitz plot			ROCARIO	_	
Γ ₈₆ /Γ ₃₇		π −)	(K-++++	$\Gamma(\overline{K}^*(892)^0 \rho^0)/\Gamma$						\ <i>I</i> F
rely on the MARKIII and		$\overline{K}^*(892)^0$ are in	modes of the \overline{I}	Unseen decay n	COMMENT	***	IENT ID	nocus	EVTS	$^{\perp}\pi^{+}\pi^{-})/\Gamma_{\text{total}}$
for values of the resonan	$+\pi^-$ channel	of the $K^-\pi^+\pi^+$	tude analyses o		~ Autun⊁M I	.1.				.004 OUR FIT
COMMENT	TECN	DOCUMENT ID	EVTS	substructure. VALUE	the ideogram			or includes s		.006 OUR AVERA
γ Be 90-260 GeV		ANJOS		0.195±0.03±0.03	$e^+e^-\approx r(4.5)$	94 AR	ECHT	below. 42 ALBRE		.015 ±0.009
etc. • • •	s, fits, limits,	data for average	the following	• • • We do not use	$e^+e^-\approx T(45)$		ECHT	43 ALBRE	1430	.0027±0.0057
Photoproduction		ALVAREZ		$0.34 \pm 0.09 \pm 0.09$	e+e- 3.77 Ge			ADLE	992	800.0± 800.
$\pi \text{Be} \rightarrow D^0$		BAILEY	5	0.75 ±0.3	e ⁺ e ⁻ 3.771 G			44 SCHIN	185	.025
e ⁺ e ⁻ 4.03, 4.41 GeV	77 MRK1	PICCOLO	20	$0.15 \begin{array}{l} +0.16 \\ -0.15 \end{array}$	e ⁺ e ⁻ 3.77 Ge	77 MF				.019
				-0.15				45 PERUZ	44	
r /r		K+_+\			his is a different	⊽ _ℓ decay		$rom \ \overline{B}^0 \rightarrow$	mesons	ECHT 94 uses D ⁰
Γ ₀₇ /Γ ₃₇				Γ(K*(892) ⁰ ρ ⁰ tran			D*+ ℓ-	rom \overline{B}^0 → . T 94 F.	mesons t	ECHT 94 uses D ^O nts than used by A ne footnote on the
COMMENT	luded.	$K^-\pi^+\pi^+\pi^-$) $K^+(892)^0$ are included to the pocument in		Γ(K*(892) ⁰ ρ ⁰ tran	π ⁺)/Γ _{total} for	ent of ((D*+ l- easurem	rom $\widetilde{B}^0 \rightarrow 0$ T 94F. CHT 94F me	mesons : ALBRECH e ALBRE	ECHT 94 uses D ^O nts than used by A ne footnote on the
COMMENT	luded. <u>TECN</u>	(*(892) ⁰ are incl DOCUMENT ID	nodes of the K	Γ(K*(892) ⁰ ρ ⁰ tran Unseen decay π VALUE 0.20 ±0.07 OUR FI	π^+)/ Γ_{total} for anching fraction 5.8 \pm 0.5 \pm 0.6	ent of F((3770)) value of	D*+ℓ- easurem - → ↓ ER 88c)	rom $\overline{B}^0 \rightarrow 0$ T 94F. CHT 94F me ures $\sigma(e^+e^-)$ ARK-3 (ADL)	mesons in ALBRECH e ALBRECH (-2) measures the M.	ECHT 94 uses D^0 nts than used by A ne footnote on the od used. NDLER 81 (MARK 8 \pm 0.11 nb. We use
	luded. <u>TECN</u>	₹*(892) ⁰ are incl	nodes of the K	Γ (K*(892)⁰ ρ⁰ tran Unseen decay m <u>VALUE</u>	$(\pi^+)/\Gamma_{\text{total}}$ for anching fraction $5.8 \pm 0.5 \pm 0.6$ thing fraction to	ent of F((3770)) value of (70)) × t	$D^{*+}\ell^{-}$ easurem $- \rightarrow \psi$ ER 88C) $\rightarrow \psi(37)$	rom $\overline{B}^0 \rightarrow 0$ T 94F. CHT 94F me ures $\sigma(e^+e^-$ ARK-3 (ADLI s $\sigma(e^+e^-$	mesons in ALBRECH e ALBRECH (-2) measure the M.) measure	ECHT 94 uses D^0 nts than used by A ne footnote on the od used. NDLER 81 (MARK 8 \pm 0.11 nb. We used.
COMMENT	luded. <u>TECN</u>	K*(892) ⁰ are incl <u>POCUMENT ID</u> COFFMAN	nodes of the K	Γ(K*(892) ⁰ ρ ⁰ tran Unseen decay π VALUE 0.20 ±0.07 OUR FI	$(\pi^+)/\Gamma_{\text{total}}$ for anching fraction $5.8 \pm 0.5 \pm 0.6$ thing fraction to	ent of F((3770)) value of (70)) × t	$D^{*+}\ell^{-}$ easurem $- \rightarrow \psi$ ER 88C) $\rightarrow \psi(37)$	rom $\overline{B}^0 \rightarrow 0$ T 94F. CHT 94F me ures $\sigma(e^+e^-$ ARK-3 (ADLI s $\sigma(e^+e^-$	mesons: ALBRECH e ALBRE <-2) measure ise the M.) measure the MAR	ECHT 94 uses D^0 nts than used by A ne footnote on the od used. NDLER 81 (MARK 8 ± 0.11 nb. We us ZZI 77 (MARK-1) to 0.10 nb. We use the output of the out
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COMMENT e ⁺ e ⁻ 3.77 GeV Fee/Γ3; COMMENT γ Be 90–260 GeV Fee/Γ3; COMMENT e ⁺ e ⁻ 3.77 GeV etc. • • • γ Be 90–260 GeV Fee/Γ3; COMMENT γ Be 90–260 GeV Fee/Γ3; COMMENT γ Be 90–260 GeV Fee/Γ4 COMMENT γ Be 90–260 GeV Fee/Γ4 COMMENT γ Be 90–260 GeV	Inded.	(892) ⁰ are incl pocument in COFFMAN (***********************************	Nave) / (K-nodes of the K-nodes of t	Γ (Κ* (892)° ρ° train Unseen decay in VALUE 0.20 ±0.07 OUR FI 0.213±0.024±0.075 Γ (Κ* (892)° ρ° S-W Unseen decay in VALUE 0.375±0.045±0.06 Γ (Κ* (892)° ρ° S-W Unseen decay in VALUE <0.003 Γ (Κ* (892)° ρ° P-W Unseen decay in VALUE <0.009 Γ (Κ* (892)° ρ° P-W Unseen decay in VALUE <0.009 Γ (Κ* (892)° ρ° D-W Unseen decay in VALUE <0.011 Γ (Κ* (892)° β° (980) VALUE <0.007 Γ (Κ* (892)° β° (980) VALUE <0.007 Γ (Κ* 21(1260)*)	π^+)/ Γ_{total} for anching fraction 5.8 ± 0.5 ± 0.6 thing fraction to 8 ± 0.5 ± 0.6 r. thing fraction to 8 ± 0.5 ± 0.6 r. the data in ot necesures, constrained fit (related) ion. $\frac{\chi^2}{1000}$ RRG 0.1 RRG 2.8 RRG 1.2 RRG 2.0 RRC2 2.8 RRG 1.0 5.6 6.6 evel = 0.160)	ent of Γ((3770)) × (1) (70) × (D*+ t- easurem - w telegraphic states and telegraphic states and telegraphic states are states and telegraphic states are states and telegraphic states are states are as additionally states are states are as additionally states are as additionally states are as a stat	T 94F. T 94F. CHT 94F me ures $\sigma(e^+e^-)$ KRK-3 (ADLER Values ab and scale this ideog sarily the obtained i utilizing m quantities OCCUMENT IC ANJOS ALVAREZ BOOKTOLET BAILEY ALBRECHT	mesons in ALBRECHE ALBRECHE ALBRECHE ALBRECHE ALBRECHE MARKEN AGE Scaled by	ECHT 94 uses D^0 nts than used by A he footnote on the do used. VDLER 81 (MARK 8 \pm 0.11 nb. We us 2Z1 77 (MARK-1) \pm 0.10 nb. We use 1 WEIGHTED AVERA 0.075 \pm 0.006 (Error s out of the control of
COMMENT e ⁺ e ⁻ 3.77 GeV Fee/F37 COMMENT γ Be 90–260 GeV F90/F COMMENT e ⁺ e ⁻ 3.77 GeV etc. • • • γ Be 90–260 GeV F91/F37 COMMENT γ Be 90–260 GeV F96/F COMMENT γ Be 90–260 GeV F97/F COMMENT γ Be 90–260 GeV F97/F COMMENT γ Be 90–260 GeV	luded. 928 MRK3 luded. 92c E691 luded. 92e MRK3 luded. 92e MRK3 luded. 92e MRK3 luded. 92e E691 luded. 92c E691 luded. 92c E691 luded. 92c E691 luded. 92c E691 cluded. 92c E691	(892) ⁰ are incl pocument ID COFFMAN (***********************************	rave) / Γ (K-nodes of the K rave) / Γ (K-nodes of the K rave) / Γ total modes of the K rave) / Γ total modes of the K rave) / Γ (K-nodes of the K rave) / Γ (K-nodes of the K rave) / Γ (K-nodes of the K rave) / Γ (K-π+π nodes of the K	Γ(K*(892)° ρ° train Unseen decay in VALUE 0.20 ±0.07 OUR FI 0.213±0.024±0.075 Γ(K*(892)° ρ° S-W Unseen decay in VALUE 0.375±0.045±0.06 Γ(K*(892)° ρ° S-W Unseen decay in VALUE <0.003 Γ(K*(892)° ρ° β-W Unseen decay in VALUE <0.009 Γ(K*(892)° ρ° β-W Unseen decay in VALUE <0.009 Γ(K*(892)° ρ° β-W Unseen decay in VALUE <0.011 Γ(K*(892)° \$(980) VALUE <0.001 Γ(K*(892)° \$(980) VALUE <0.007 Γ(K*(892)° \$(980) VALUE <0.007 Γ(K*(892)° \$(980) VALUE <0.007 Γ(K*(892)° \$(980) VALUE <0.007	m+)/Γ _{total} for anching fraction 5.8 ± 0.5 ± 0.6 thing fraction to 8 ± 0.5 ± 0.6 rd 8 things from the data in	reighted a reighted a re based a. They a sour besaust-squaments of ctional info	D*+ t- easurem - w to the term of the te	T 94F. T 94F me T 94F me ures $\sigma(e^+e^-$ K-3 (ADLER K-3 (ADLER 1.3) Values ab and scale this ideog sarily the obtained in utilizing in quantities O.15 O.15 O.15 O.20CUMENT IE O.15 O.20CUMENT IE O.20CUMENT I	omesons in ALBRECHE A	ECHT 94 uses D^0 nts than used by A he footnote on the doused. NDLER 81 (MARK 8± 0.11 nb. We us 2Z1 77 (MARK-1) to 0.10 nb. We use 1 mark 10 mark
COMMENT e+e- 3.77 GeV COMMENT γ Be 90-260 GeV COMMENT e+e- 3.77 GeV COMMENT e+e- 3.77 GeV etc. • • • γ Be 90-260 GeV COMMENT γ Be 90-260 GeV	luded. 928 MRK3 luded. 92c E691 luded. 7ECN 928 MRK3 luded. 7ECN 928 MRK3 luded. 7ECN 920 E691 luded. 920 E691 luded. 920 E691 luded. 920 E691 luded. 920 E691 cluded. 920 E691	(892) ⁰ are incl pocument in COFFMAN (***********************************	rave) / Γ (K-nodes of the K rave) / Γ (K-nodes of the K rave) / Γ total modes of the K rave) / Γ total modes of the K rave) / Γ (K-nodes of the K rave) / Γ (K-nodes of the K rave) / Γ (K-nodes of the K rave) / Γ (K-π+π nodes of the K	Γ (Κ* (892)° ρ° train Unseen decay in VALUE 0.20 ±0.07 OUR FI 0.213±0.024±0.075 Γ (Κ* (892)° ρ° S-W Unseen decay in VALUE 0.375±0.045±0.06 Γ (Κ* (892)° ρ° S-W Unseen decay in VALUE <0.003 Γ (Κ* (892)° ρ° P-W Unseen decay in VALUE <0.003 Γ (Κ* (892)° ρ° P-W Unseen decay in VALUE <0.003 Γ (Κ* (892)° ρ° D-W Unseen decay in VALUE 0.285±0.045±0.06 Γ (Κ - π + f₀ (980)), VALUE <0.011 Γ (Κ* (892)° f₀ (980)), VALUE <0.007 Γ (Κ - a₁(1260) +) Unseen decay in VALUE <0.007	π^+)/ Γ_{total} for anching fraction 5.8 ± 0.5 ± 0.6 thing fraction to 8 ± 0.5 ± 0.6 r. thing fraction to 8 ± 0.5 ± 0.6 r. the data in ot necesures, constrained fit (related) ion. $\frac{\chi^2}{1000}$ RRG 0.1 RRG 2.8 RRG 1.2 RRG 2.0 RRC2 2.8 RRG 1.0 5.6 6.6 evel = 0.160)	reighted a reighted a re based a. They a sour besaust-squaments of ctional info	D*+ t- easurem - w to the term of the te	T 94F. T 94F. CHT 94F me ures $\sigma(e^+e^-)$ KRK-3 (ADLER Values ab and scale this ideog sarily the obtained i utilizing m quantities OCCUMENT IC ANJOS ALVAREZ BOOKTOLET BAILEY ALBRECHT	mesons is ALBRECHE ALBRECHE ALBRECHE ALBRECHE ALBRECHE M.) measure the MAR AGE scaled by	ECHT 94 uses D^0 nts than used by A he footnote on the found of used. NDLER 81 (MARK 8 ± 0.11 nb. We us 2ZI 77 (MARK-1) to 0.10 nb. We use 1 MEIGHTED AVERA 0.075±0.006 (Error s 5 0 OUR FIT 5 0 OUR AVERAGE ± 0.2 174 5 ± 0.2 33 6 ± 0.09 48 ± 0.23

Oliscell decay fillodes	of the $a_2(1320)^+$ are in	ncluded.	Γ ₇₈ /Γ		nodes of the ω are			1/5
VALUE C				VALUE 0.38±0.07 OUR FIT	EVT\$ DO	CUMENT ID TECN	COMMENT	
<0.002 99 ■ ■ • We do not use the fo		92C E691 γ Be 90-260	0 GeV	0.33 ± 0.09 OUR AVE				
				0.29±0.08±0.05		BRECHT 92P ARG		
<0.006 9	0 COFFMAN	928 MRK3 e ⁺ e ⁻ 3.77	7 GeV	0.54±0.14±0.16			0 e ⁺ e ⁻ ~ 10.7 GeV	/
$(K_1(1270)^-\pi^+)/\Gamma(K_1(1270)^-\pi^+)$	~ _		Γ_{99}/Γ_{37}	·		rs in Table 1 of ALBRE	CH 1 92P.	
	•	included. The MARK3 and	d E691 experi-	Γ(Κ° ω)/Γ(Κ °π+:			Γ ₇₁	1/54
ments disagree consid	ierably here,	•		Unseen decay m	nodes of the ω are i		COLUENT	
0.14 ±0.04 OUR FIT	LN DOCUMENT ID	TECN COMMENT		0.21 ±0.04 OUR FT	T 20	CUMENT ID TECN	COMMENT	
0.194±0.056±0.088	COFFMAN	928 MRK3 e ⁺ e ⁻ 3.77	7 GeV	$0.220 \pm 0.048 \pm 0.0116$	co	FFMAN 928 MRK	(3 e ⁺ e ⁻ 3.77 GeV	
We do not use the for				r (70 - 1/050\\ /F (7	7 0 _+ _−\		-	/-
< 0.013 9		92¢ E691 γ Be 90-266	0 GeV	Γ (Κ° η (958))/Γ(<i>Γ</i>			l 72	2/Г:
		,		Unseen decay m VALUE	nodes of the $\eta^I (958 - 500)$		COMMENT	
$(K_1(1400)^-\pi^+)/\Gamma_{\text{total}}$			Г99/Г	0.32±0.04 OUR AVE	RAGE		327077277	
ALUE C	LK DOCUMENT ID			$0.31 \pm 0.02 \pm 0.04$			$2 \eta' \rightarrow \eta \pi^+ \pi^-, \rho^0$	
<0.012 9	D COFFMAN	92B MRK3 e ⁺ e ⁻ 3.77	7 GeV	0.37±0.13±0.06		BRECHT 92P ARG		
$(K^{\circ}(1410)^{-}\pi^{+})/\Gamma_{\text{tot}}$	-d		Γ ₁₀₁ /Γ	⁵⁰ This value is calcu	ilated from number	rs in Table 1 of ALBRE	CHT 92P.	
	L <u>% DOCUMENT ID</u>	TECN COMMENT	- 101/ -	Γ(K*(892)-ρ+)/Γ	$-(R^0\pi^+\pi^-\pi^0)$		Гез	2/14
<0.012 9		928 MRK3 e ⁺ e ⁻ 3.77	7 GeV		odes of the K*(89	2) are included.	-	., .
(Parass)) !	· · · · · · · · · · · · · · · · · · ·		•	VALUE			COMMENT	
$(K^{\bullet}(892)^{0}\pi^{+}\pi^{-}\text{total})$			Γ ₈₂ /Γ ₃₇	$0.606 \pm 0.188 \pm 0.126$	co	FFMAN 92B MRK	(3 e ⁺ e ⁻ 3.77 GeV	
This includes ₹*(892) ρ ⁰ , etc. The next ent	try gives the specifically 3-	body fraction.	$\Gamma(K^*(892)^- \rho^+ \text{lon}$	eftudinal) /r 🕟	0_+0)	Г	3/F4
Unseen decay modes ALUE	of the $K^{\bullet}(892)^{0}$ are inc <u>DOCUMENT ID</u>				nodes of the K*(89		' 90	3/ 14
30±0.06±0.09	ANJOS	92C E691 γBe 90-266	0 GeV	VALUE _			COMMENT	
				0.290±0.111			(3 e ⁺ e ⁻ 3.77 GeV	
$(\overline{K}^{\circ}(892)^{0}\pi^{+}\pi^{-}3\text{-bo}$			Γ ₈₃ /Γ ₃₇	F(#8/900)- +	················· /= (126)	_+0\	-	. /=
	of the $\overline{K}^*(892)^0$ are inc			Γ(K*(892) – ρ+tra			1 94	4/F
19 ±0.04 OUR FIT	DOCUMENT ID	TECN COMMENT		Unseen decay m	nodes of the K*(89		COMMENT	
.18 ±0.04 OUR AVERA	GE			0.317±0.180			(3 e ⁺ e ⁻ 3.77 GeV	
.165±0.03 ±0.045		92C E691 γ Be 90-260 G	ieV				_	_
0.210±0.027±0.06	COFFMAN 9	92в MRK3 e ⁺ e 3.77 Ge	eV	Γ(K*(892) ⁻ ρ ⁺ P-1			ſ	Γ ₉₅ /
(N+-+	\/F(#+_+	·_ - \	r /r		nodes of the K*(89			
(K [−] π ⁺ π ⁺ π [−] nonreso	DOCUMENT ID		Γ ₄₅ /Γ ₃₇	<u>VALUE</u> <0.015		CUMENT ID TECN FFMAN 928 MRK	<u>: </u>	_
.233 ± 0.032 OUR AVERA		TECN COMMENT						
.23 ±0.02 ±0.03	ANJOS	92C E691 γ Be 90-266	0 GeV			ive limits and isospin r	elations.	
.242±0.025±0.06	COFFMAN	928 MRK3 e ⁺ e ⁻ 3.77	7 GeV	$\Gamma(\overline{K}^{\bullet}(892)^{0}\rho^{0}$ tran	isverse)/ $\Gamma(\overline{K}{}^0\pi^0$	+π ⁻ π ⁰)	Г87	7/5
$(K^0\pi^+\pi^-\pi^0)/\Gamma_{\text{total}}$			F.,, /F		nodes of the \overline{K}^* (89			
	TS DOCUMENT ID	TECN COMMENT	Γ ₄₆ /Γ	VALUE 0.15 ±0.06 OUR FT		CUMENT ID TECN	COMMENT	
.100±0.012 OUR FIT	19 POCUMENT 10	TECH COMMENT		0.126±0.111		FFMAN 928 MRK	(3 e ⁺ e ⁻ 3.77 GeV	
	40 COFFMAN	928 MRK3 e ⁺ e ⁻ 3.77	7 GeV	E/730 - (1010)\ (1	_		_	_
 We do not use the formula 	sllowing data for average	es, fits, limits, etc. • • •		$\Gamma(\overline{K}^0 =_1 (1260)^0) / \Gamma$			ſ	Γ ₇₆ /
				4.4				
0.134 + 0.032	47 BARLAG	92C ACCM π Cu 230) GeV	Unseen decay m			COLUMENT	
	47 BARLAG			VALUE		CUMENT ID TECN		
⁴⁷ BARLAG 92C computes	47 BARLAG s the branching fraction			<u>value</u> <0.019	90 CO	FFMAN 928 MRK	COMMENT (3 e ⁺ e ⁻ 3.77 GeV	
47 BARLAG 92C computer	47 BARLAG s the branching fraction			VALUE <0.019 Γ(K ₁ (1270) π ⁺)/	<u>cιν</u> <u>ρο</u> 90 co /Γ(Κ ⁰ π+π-π ⁰)	<u>CUMENT ID TECN</u> FFMAN 92B MRK	(3 e ⁺ e ⁻ 3.77 GeV	e/Γ
⁴⁷ BARLAG 92c computes (Κ ⁰ π+π-π ⁰)/Γ(Κ ⁰)	47 BARLAG s the branching fraction $\pi^+\pi^-$)	using topological normaliz	ration.	<u><0.019</u> Γ(K₁(1270) π ⁺)/ Unseen decay m	CLX $DO90 CO/\Gamma(\overline{K^0}\pi^+\pi^-\pi^0)nodes of the K_1(12)$	CUMENT ID TECN FFMAN 92B MRK	(3 e ⁺ e [−] 3.77 GeV Г 98	e/Γ.
47 BARLAG 92C computes $^{(R^0π^+π^-π^0)/\Gamma}(R^0π^0π^+π^-π^0)$	47 BARLAG s the branching fraction $\pi^+\pi^-$) DOCUMENT ID	using topological normaliz	ration.	VALUE <0.019 $\Gamma(K_1(1270)^-\pi^+)/U$ Unseen decay m	CLX $DO90 CO/\Gamma(\overline{K^0}\pi^+\pi^-\pi^0)nodes of the K_1(12)$	CUMENT ID TECN FFMAN 92B MRK	(3 e ⁺ e ⁻ 3.77 GeV	e/Γ
$(K^0\pi^+\pi^-\pi^0)/\Gamma(K^0\pi^+\pi^-\pi^0)/\Gamma(K^0\pi^+\pi^-\pi^0)$ ALUE 84±0.20 OUR FIT 86±0.23 OUR AVERAGE	47 BARLAG s the branching fraction $\pi^+\pi^-$) DOCUMENT ID	using topological normaliz	Γ46/Γ <u>21</u>	<u><0.019</u> Γ(K₁(1270) π ⁺)/ Unseen decay m	$\frac{CIX}{90} = \frac{DO}{50}$ $\frac{CIX}{90} = \frac{DO}{50}$ $\frac{CIX}{90} = \frac{DO}{50}$ $\frac{CIX}{90} = \frac{DO}{50}$ $\frac{DO}{50} = \frac{DO}{50}$	<u>CUMENT ID</u> <u>TECN</u> FFMAN 92B MRK) (70) are included. CUMENT ID TECN	(3 e ⁺ e [−] 3.77 GeV Г 98	€/ Γ.
47 BARLAG 92c computes $^{-1}$ (60 π + π - π 0) /Γ (60 .84 ± 0.20 OUR FIT85 ± 0.23 OUR AVERAGE .80 ± 0.20 ± 0.21	47 BARLAG s the branching fraction $\pi^+\pi^-$) 75 DOCUMENT ID	using topological normaliz	Γ46/Γ21	VALUE <0.019 \(\begin{align*} \begin{align*} \cdot \left(\begin{align*} \left(\reft(\left(\reft(\left(\left(\left(\left(\left(\left(\left(\left(\text{\reft(\left(\reft(\left(\reft(\reft(\left(\reft(\ref	$ \frac{\text{CLX}}{90} = \frac{\text{DO}}{90} $ Todes of the $K_1(12)$ Todes $ \frac{\text{DO}}{\text{T}} $	<u>CUMENT ID</u> <u>TECN</u> FFMAN 92B MRK) (70) are included. CUMENT ID TECN	(3 e ⁺ e ⁻ 3.77 GeV F ₉₀ COMMENT	<u>·</u>
47 BARLAG 92c computes $(K^0π^+π^-π^0)/\Gamma(K^0.4LVE - E).$ 84±0.20 OUR FIT. 85±0.23 OUR AVERAGE. 80±0.20±0.21 12. 85±0.8 ±0.8 .85±0.80±0.26±0.30 13	47 BARLAG s the branching fraction π+π-) (TS DOCUMENT ID E 190 48 ALBRECHT 46 ANJOS 158 KINOSHITA	using topological normaliz TECN COMMENT 92P ARG $e^+e^-\approx 1$ 92C E691 γ Be 90–266 91 CLEO $e^+e^-\sim 1$	10 GeV 0 GeV	$\langle 0.019 \rangle$ $\Gamma(K_1(1270)^-\pi^+)/U$ Unseen decay m $VALUE$ 0.106 ± 0.028 OUR FT 0.10 ± 0.03 $\Gamma(K_1(1400)^0\pi^0)/U$	90 CO $/\Gamma(\overline{K^0}\pi^+\pi^-\pi^0)$ Tookal	COMENT ID	(3 e ⁺ e ⁻ 3.77 GeV	
47 BARLAG 92C computes $(K^0\pi^+\pi^-\pi^0)/\Gamma(K^0\pi^+\pi^-\pi^0)/\Gamma(K^0\pi^0\pi^+\pi^-\pi^0)/\Gamma(K^0\pi^0\pi^+\pi^-\pi^0)$ 44.UE E. 84±0.20 OUR FIT 88±0.23 OUR AVERAGE 88±0.20±0.21 18. ±0.8 ±0.8 85±0.26±0.30 1	47 BARLAG s the branching fraction π+π-) (TS DOCUMENT ID E 190 48 ALBRECHT 46 ANJOS 158 KINOSHITA	using topological normaliz TECN COMMENT 92P ARG $e^+e^-\approx 1$ 92C E691 γ Be 90–266 91 CLEO $e^+e^-\sim 1$	10 GeV 0 GeV	$\langle 0.019 \rangle$ $\Gamma(K_1(1270)^-\pi^+)/\Gamma(K_1(1270)^-\pi^+)/\Gamma(K_1(1270)^-\pi^-)/\Gamma(K_1(1400)^0\pi^0)/\Gamma(K_1(1400)^0\pi^-)/\Gamma(K_1(140)^0\pi^-)/\Gamma(K_1(140$	$CLX = \frac{CLX}{90}$ CO $F(R^0\pi^+\pi^-\pi^0)$ CO T CO Ftotal $CLX = \frac{CLX}{200}$	COMENT ID	(3 e ⁺ e ⁻ 3.77 GeV COMMENT	
47 BARLAG 92c computes $(K^0\pi^+\pi^-\pi^0)/\Gamma(K^0\pi^+\pi^-\pi^0)/\Gamma(K^0\pi^+\pi^-\pi^0)/\Gamma(K^0\pi^+\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi$	47 BARLAG s the branching fraction π+π-) (TS DOCUMENT ID E 190 48 ALBRECHT 46 ANJOS 158 KINOSHITA	using topological normaliz TECN COMMENT 92P ARG $e^+e^-\approx 1$ 92C E691 γ Be 90–266 91 CLEO $e^+e^-\sim 1$	10 GeV 0 GeV 10.7 GeV	$\langle 0.019 \rangle$ $\Gamma(K_1(1270)^-\pi^+)/\Gamma(K_1(1270)^-\pi^+)/\Gamma(K_1(1270)^-\pi^-)/\Gamma(K_1(1400)^0\pi^0)/\Gamma(K_1(1400)^0\pi^-)/\Gamma(K_1(140)^0\pi^-)/\Gamma(K_1(140)$	$\begin{array}{ccc} \underline{CLS} & \underline{DOS} \\ 90 & \underline{CO} \\ \hline \\ 7 & (\overline{K^0}\pi^+\pi^-\pi^0) \\ \underline{CO} \\ \hline \\ T & \underline{CO} \\ \hline \\ \underline{CLS} & \underline{DOS} \\ \\ 90 & \underline{CO} \\ \end{array}$	COMENT ID TECN FFMAN 92B MRK) 70) are included. COMENT ID TECN FFMAN 92B MRK CUMENT ID TECN FFMAN 92B MRK	(3 e ⁺ e ⁻ 3.77 GeV	100/
47 BARLAG 92C computes $(K^0\pi^+\pi^-\pi^0)/\Gamma(K^0\pi^0\pi^+\pi^-\pi^0)/\Gamma(K^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^$	47 BARLAG s the branching fraction π+π-) (TS DOCUMENT ID E 190 48 ALBRECHT 46 ANJOS 158 KINOSHITA	using topological normaliz TECN COMMENT 92P ARG $e^+e^-\approx 1$ 92C E691 γ Be 90–266 91 CLEO $e^+e^-\sim 1$	10 GeV 0 GeV	$\langle 0.019 \rangle$ $\Gamma(K_1(1270)^-\pi^+)/\Gamma(K_1(1270)^-\pi^+)/\Gamma(K_1(1270)^-\pi^-)/\Gamma(K_1(1400)^0\pi^0)/\Gamma(K_1(1400)^0\pi^-)/\Gamma(K_1(140)^0\pi^-)/\Gamma(K_1(140$	$\begin{array}{ccc} \underline{CLS} & \underline{DOS} \\ 90 & \underline{CO} \\ \hline \\ 7 & (\overline{K^0}\pi^+\pi^-\pi^0) \\ \underline{CO} \\ \hline \\ T & \underline{CO} \\ \hline \\ \underline{CLS} & \underline{DOS} \\ \\ 90 & \underline{CO} \\ \end{array}$	COMENT ID TECN FFMAN 92B MRK) 70) are included. COMENT ID TECN FFMAN 92B MRK CUMENT ID TECN FFMAN 92B MRK	(3 e^+e^- 3.77 GeV Γ_{96} (3 e^+e^- 3.77 GeV Γ_{1} (4 $COMMENT$ (5 e^+e^- 3.77 GeV	
47 BARLAG 92c computes $-(R^0\pi^+\pi^-\pi^0)/\Gamma(R^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^$	47 BARLAG s the branching fraction $\pi^+\pi^-$) 775 DOCUMENT ID 190 48 ALBRECHT 46 ANJOS 58 KINOSHITA from numbers in Table of the η are included.	using topological normaliz TECN COMMENT 92P ARG $e^+e^-\approx 192C$ E691 γ Be 90–26 91 CLEO $e^+e^-\sim 1$ 1 of ALBRECHT 92P.	10 GeV 0 GeV 10.7 GeV	$\langle 0.019 \rangle$ $\Gamma(K_1(1270)^-\pi^+)/\Gamma(K_1(1270)^-\pi^+)/\Gamma(K_1(1270)^-\pi^-)/\Gamma(K_1(1400)^0\pi^0)/\Gamma(K_1(140)^0\pi^0)/\Gamma(K_1(14$	90 CO $\Gamma(\overline{K^0}_{\pi^+\pi^-\pi^0})$ rodes of the $K_1(12)$ $\Gamma(\overline{K^0}_{\pi^+\pi^-\pi^0})$ $\Gamma(\overline{K^0}_{\pi^+\pi^-\pi^0})$ $\Gamma(\overline{K^0}_{\pi^+\pi^-\pi^0})$ $\Gamma(\overline{K^0}_{\pi^+\pi^-\pi^0})$ rodes of the $\Gamma(\overline{K^0}_{\pi^+\pi^0})$	CUMENT ID TECN FFMAN 92B MRK 170) are included. CUMENT ID TECN FFMAN 92B MRK CUMENT ID TECN FFMAN 92B MRK CUMENT ID TECN FFMAN 92B MRK CUMENT ID TECN 1200 are included.	(3 e^+e^- 3.77 GeV Γ_{96} (3 e^+e^- 3.77 GeV (3 e^+e^- 3.77 GeV Γ_{17} (3 e^+e^- 3.77 GeV	100/
47 BARLAG 92c computes $^{-}(\mathbf{K}^0\pi^+\pi^-\pi^0)/\Gamma(\mathbf{K}^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^$	47 BARLAG s the branching fraction $\pi^+\pi^-$) 775 DOCUMENT ID 190 48 ALBRECHT 46 ANJOS 58 KINOSHITA from numbers in Table of the η are included.	using topological normaliz TECN COMMENT 92P ARG $e^+e^-\approx 192C$ E691 γ Be 90–26 91 CLEO $e^+e^-\sim 1$ 1 of ALBRECHT 92P.	10 GeV 0 GeV 10.7 GeV	$\langle 0.019 \rangle$ $\Gamma(K_1(1270)^-\pi^+)/\Gamma(K_1(1270)^-\pi^+)/\Gamma(K_1(1270)^-\pi^-)/\Gamma(K_1(1400)^0\pi^0)/\Gamma(K_1(1400)^0\pi^0)/\Gamma(K^*(892)^0\pi^+\pi^-)$ Unseen decay m	90 CO $/\Gamma(\overline{K^0}_{\pi} + \pi - \pi^0)$ Thodes of the $K_1(12)$ T CO Γ_{total} $\frac{CLX}{90}$ CO $(3-\text{bods})/\Gamma(\overline{K^0}_{\pi})$	COMENT ID TECN	(3 e^+e^- 3.77 GeV Γ_{96} (3 e^+e^- 3.77 GeV Γ_{1} (4 $COMMENT$ (5 e^+e^- 3.77 GeV	100/
47 BARLAG 92c computes $-(\mathbf{K}^0\pi^+\pi^-\pi^0)/\Gamma(\mathbf{K}^0\pi^+\pi^-\pi^0)/\Gamma(\mathbf{K}^0\pi^+\pi^-\pi^0)/\Gamma(\mathbf{K}^0\pi^+\pi^-\pi^0)/\Gamma(\mathbf{K}^0\pi^+\pi^-\pi^0)/\Gamma(\mathbf{K}^0\pi^+\pi^-\pi^0)/\Gamma(\mathbf{K}^0\pi^+\pi^+\pi^0)$.86 ± 0.20 ± 0.21 11.88 ± 0.8 ± 0.8 ± 0.8 ± 0.8 ± 0.8 ± 0.8 ± 0.8 ± 0.8 ± 0.8 ± 0.8 ± 0.8 ± 0.20 ± 0.21 ± 0.	47 BARLAG s the branching fraction $\pi^+\pi^-$) 775 DOCUMENT ID 190 48 ALBRECHT 46 ANJOS 158 KINOSHITA from numbers in Table of the η are included. 15 DOCUMENT ID 16 DOCUMENT ID 17 DOCUMENT ID 18 DOCUMENT ID 18 DOCUMENT ID 18 DOCUMENT ID 18 DOCUMENT ID	using topological normaliz TECN COMMENT 92P ARG $e^+e^-\approx 192C$ E691 γ Be 90–26 91 CLEO $e^+e^-\sim 1$ 1 of ALBRECHT 92P.	10 GeV 0 GeV 0.0.7 GeV	$\langle 0.019 \rangle$ $\Gamma(K_1(1270)^-\pi^+)/U$ Unseen decay m VALUE 0.106±0.028 OUR FT 0.10 ±0.03 $\Gamma(K_1(1400)^0\pi^0)/U$ VALUE <0.057 $\Gamma(K^e(892)^0\pi^+\pi^-$ Unseen decay m VALUE 0.14 ±0.04 OUR FT	90 CO $\Gamma(R^0\pi^+\pi^-\pi^0)$ rodes of the $K_1(12)$ Γ CO Γ_{total} Γ_{col} 90 CO 3-body) $\Gamma(R^0\pi^0)$ Γ_{col}	FFMAN 92B MRK 170	(3 e ⁺ e ⁻ 3.77 GeV COMMENT 3 e ⁺ e ⁻ 3.77 GeV COMMENT COMMEN	100/
47 BARLAG 92C computes $(\mathbf{K}^0\pi^+\pi^-\pi^0)/\Gamma(\mathbf{K}^0,\mathbf{K}^0)$ ($\mathbf{K}^0\pi^+\pi^-\pi^0)/\Gamma(\mathbf{K}^0,\mathbf{K}^0)$ ($\mathbf{K}^0\pi^+\pi^-\pi^0)/\Gamma(\mathbf{K}^0,\mathbf{K}^0)$ (86 ±0.29 OUR FIT 1.86 ±0.29 OUR AVERAGE 1.86 ±0.8 ±0.8 ±0.8 ±0.8 ±0.8 ±0.8 ±0.8 ±0.8	47 BARLAG s the branching fraction $\pi^+\pi^-$) 775 DOCUMENT ID 190 48 ALBRECHT 46 ANJOS 158 KINOSHITA from numbers in Table of the η are included. 15 DOCUMENT ID 16 DOCUMENT ID 17 DOCUMENT ID 18 DOCUMENT ID 18 DOCUMENT ID 18 DOCUMENT ID 18 DOCUMENT ID	using topological normaliz TECN COMMENT 92P ARG $e^+e^-\approx 192$ 92C E691 γ Be 90–261 91 CLEO $e^+e^-\sim 1$ 1 of ALBRECHT 92P. TECN COMMENT es, fits, limits, etc. • • •	10 GeV 0 GeV 0.0.7 GeV	$\langle 0.019 \rangle$ $\Gamma(K_1(1270)^-\pi^+)/\Gamma(K_1(1270)^-\pi^+)/\Gamma(K_1(1270)^-\pi^-)/\Gamma(K_1(1400)^0\pi^0)/\Gamma(K_1(1400)^0\pi^0)/\Gamma(K_1(1400)^0\pi^0)/\Gamma(K^*(892)^0\pi^+\pi^-)$ Unseen decay m $\langle 0.037 \rangle$ $\Gamma(K^*(892)^0\pi^+\pi^-)$ Unseen decay m $\langle 0.14 \pm 0.04 \rangle$ $\langle 0.191 \pm 0.106 \rangle$	90 CO $/\Gamma(K^0\pi^+\pi^-\pi^0)$ rodes of the $K_1(12)$ T CO Γ_{total} GL_{X}^{**} 90 CO 3-body) $/\Gamma(K^0\pi^0)$ T Error Includes:	COMENT ID	(3 e^+e^- 3.77 GeV Γ_{96} (3 e^+e^- 3.77 GeV (3 e^+e^- 3.77 GeV Γ_{17} (3 e^+e^- 3.77 GeV	100/
47 BARLAG 92C computes $\frac{(K^0 \pi^+ \pi^- \pi^0)}{(K^0 \pi^+ \pi^- \pi^0)} / \Gamma(K^0 \pi^+ \pi^- \pi^0) / \Gamma(K^0 \pi^0)$ $\frac{ALUE}{.96 \pm 0.20} \text{ OUR FIT}$.86 ±0.20 ±0.21 11.86 ±0.20 ±0.21 12.86 ±0.30 13.85 ±0.26 ±0.30 148 This value is calculated $\frac{(K^0 \eta)}{\Gamma(K^- \pi^+)} / \Gamma(K^- \pi^+)$ Unseen decay modes $\frac{ALUE}{(K^0 \eta)} / \Gamma(K^0 \pi^0)$ $\frac{(K^0 \eta)}{\Gamma(K^0 \pi^0)} / \Gamma(K^0 \pi^0)$	47 BARLAG s the branching fraction $\pi^+\pi^-$) 75 DOCUMENT ID 190 48 ALBRECHT 46 ANJOS 158 KINOSHITA from numbers in Table of the η are included. 1.5 DOCUMENT ID Ollowing data for average 0 ALBRECHT	using topological normaliz TECN COMMENT 92P ARG $e^+e^-\approx 192$ 92C E691 γ Be 90–261 91 CLEO $e^+e^-\sim 1$ 1 of ALBRECHT 92P. TECN COMMENT es, fits, limits, etc. • • •	10 GeV 0 GeV 0.0.7 GeV	$\langle 0.019 \rangle$ $\Gamma(K_1(1270)^-\pi^+)/\Gamma(K_1(1270)^-\pi^+)/\Gamma(K_1(1270)^-\pi^+)/\Gamma(K_1(1400)^0\pi^0)/\Gamma(K_1(1400)^0\pi^0)/\Gamma(K^*(892)^0\pi^+\pi^-)$ Unseen decay m $\frac{VALUE}{VALUE}$ 0.14 ± 0.04 OUR FT 0.191 ± 0.105 $\Gamma(K^0\pi^+\pi^-\pi^0$ non	90 CO $/\Gamma(\overline{K^0}_{\pi^+\pi^-\pi^0})$ rodes of the $K_1(12)$ T CO $/\Gamma_{\text{total}}$ $SLX = DO$ 90 CO $/\Gamma_{\text{total}}$ $SLX = DO$ 90 CO $/\Gamma_{\text{total}}$ $SLX = DO$ $/\Gamma_{\text{total}}$ $SLX = $	CUMENT ID TECN FFMAN 92B MRK) (70) are included. CUMENT ID TECN FFMAN 92B MRK CUMENT ID TECN FFMAN 92B MRK x+x-x0) (20)0 are included. CUMENT ID TECN Scale factor of 1.1. FFMAN 92B MRK 0x+x-x0) x+x-x0	(3 e ⁺ e ⁻ 3.77 GeV COMMENT 3 e ⁺ e ⁻ 3.77 GeV COMMENT COMMEN	100/ 3/F
47 BARLAG 92C computes $(\mathbf{K}^0\pi^+\pi^-\pi^0)/\Gamma(\mathbf{K}^0, \mathbf{K}^0, \mathbf$	47 BARLAG s the branching fraction $\pi^+\pi^-$) 775 DOCUMENT ID 190 48 ALBRECHT 46 ANJOS 158 KINOSHITA from numbers in Table of the η are included. 15 DOCUMENT ID 16 DOCUMENT ID 17 DOCUMENT ID 18 DOCUMENT ID 18 DOCUMENT ID 18 DOCUMENT ID 18 DOCUMENT ID	using topological normaliz TECN COMMENT 92P ARG $e^+e^- \approx 1$ 92C E691 γ Be 90–26 91 CLEO $e^+e^- \sim 1$ 1 of ALBRECHT 92P. TECN COMMENT es, fits, limits, etc. • • • 89D ARG e^+e^- 10 (10 GeV 0 GeV 0.0.7 GeV	$\langle 0.019 \rangle$ $\Gamma(K_1(1270)^-\pi^+)/\Gamma(K_1(1270)^-\pi^+)/\Gamma(K_1(1270)^-\pi^+)/\Gamma(K_1(1400)^0\pi^0)/\Gamma(K_1(1400)^0\pi^0)/\Gamma(K^*(892)^0\pi^+\pi^-)$ Unseen decay m VALUE 0.14 ±0.04 OUR FT 0.191±0.105 $\Gamma(K^0\pi^+\pi^-\pi^0$ non	90 CO $/\Gamma(K^0\pi^+\pi^-\pi^0)$ rodes of the $K_1(12)$ $/\Gamma(K^0\pi^+\pi^-\pi^0)$ rodes of the $K_2(12)$ $/\Gamma(K^0\pi^+\pi^-\pi^0)$ $/\Gamma(K^0\pi^+\pi^-\pi^-\pi^0)$ $/\Gamma(K^0\pi^+\pi^-\pi^-\pi^0)$	COMENT ID	(3 e ⁺ e ⁻ 3.77 GeV COMMENT COMMEN	100/
47 BARLAG 92C computes $(K^0\pi^+\pi^-\pi^0)/\Gamma(K^0, ALUE)$.84 ± 0.20 OUR FIT .85 ± 0.25 OUR AVERAGE .80 $\pm 0.20 \pm 0.21$.8 ± 0.8 .85 ± 0.8 .86 ± 0.8 .87 ± 0.8 .88 ± 0.8 .89 ± 0.8 .80 \pm	47 BARLAG s the branching fraction $\pi^+\pi^-$) CTS DOCUMENT ID 190 48 ALBRECHT 46 ANJOS 158 KINOSHITA from numbers in Table of the η are included. LY DOCUMENT ID of the η are included. O ALBRECHT of the η are included. O ALBRECHT of the η are included. O ALBRECHT	using topological normaliz TECN COMMENT 92P ARG $e^+e^- \approx 1$ 92C E691 γ Be 90–266 91 CLEO $e^+e^- \sim 1$ 1 of ALBRECHT 92P. TECN COMMENT 89D ARG e^+e^- 10 G	10 GeV 0 GeV 0.0.7 GeV	$\langle 0.019 \rangle$ $\Gamma(K_1(1270)^-\pi^+)/\Gamma(K_1(1270)^-\pi^+)/\Gamma(K_1(1270)^-\pi^+)/\Gamma(K_1(1400)^0\pi^0)/\Gamma(K_1(1400)^0\pi^0)/\Gamma(K^*(892)^0\pi^+\pi^-)$ Unseen decay m $\frac{VALUE}{VALUE}$ 0.14 ± 0.04 OUR FT 0.191 ± 0.105 $\Gamma(K^0\pi^+\pi^-\pi^0$ non	90 CO $/\Gamma(K^0\pi^+\pi^-\pi^0)$ rodes of the $K_1(12)$ $/\Gamma(K^0\pi^+\pi^-\pi^0)$ rodes of the $K_2(12)$ $/\Gamma(K^0\pi^+\pi^-\pi^0)$ $/\Gamma(K^0\pi^+\pi^-\pi^-\pi^0)$ $/\Gamma(K^0\pi^+\pi^-\pi^-\pi^0)$	COMENT ID	(3 e ⁺ e ⁻ 3.77 GeV COMMENT 3 e ⁺ e ⁻ 3.77 GeV COMMENT COMMEN	100/ 3/F
17 BARLAG 92C computes $(R^0\pi^+\pi^-\pi^0)/\Gamma(R^0)$ 14 UE 15 $\pm \pm 0.20$ OUR FIT 16 ± 0.23 OUR AVERAGE 18 ± 0.8 18 ± 0.8 19 ± 0.8 19 ± 0.8 10 ± 0.8 10 ± 0.8 10 ± 0.8 11 ± 0.8 12 ± 0.8 13 ± 0.8 15 ± 0.8 16 This value is calculated $(R^0\pi)/\Gamma(K^-\pi^+)$ Unseen decay modes 16 ± 0.6 17 Unseen decay modes 18 ± 0.8 19 ± 0.8 10 ± 0.8 10 ± 0.8 10 ± 0.8 11 ± 0.8 11 ± 0.8 12 ± 0.8 13 ± 0.8 15 ± 0.8 16 ± 0.8 17 ± 0.8 18 ± 0.8 18 ± 0.8 19 ± 0.8 10 ± 0.8 11 ± 0.8 12 ± 0.8 13 ± 0.8 14 ± 0.8 15 ± 0.8 16 ± 0.8 16 ± 0.8 17 ± 0.8 18 ± 0.8 18 ± 0.8 19 ± 0.8 19 ± 0.8 19 ± 0.8 10 ± 0.8 11 ± 0.8 12 ± 0.8 13 ± 0.8 14 ± 0.8 15 ± 0.8 16 ± 0.8 16 ± 0.8 17 ± 0.8 18 ± 0.8 18 ± 0.8 18 ± 0.8 19 ± 0.8 19 ± 0.8 10 $\pm $	47 BARLAG s the branching fraction $\pi^+\pi^-$) 775 DOCUMENT ID 190 48 ALBRECHT 46 ANJOS 158 KINOSHITA from numbers in Table of the η are included. 15 DOCUMENT ID 15 DOCUMENT ID 16 DOCUMENT ID 17 DOLOWING data for average 18 ALBRECHT 19 Of the η are included.	using topological normaliz TECN COMMENT 92P ARG $e^+e^- \approx 1$ 92C E691 γ Be 90–26 91 CLEO $e^+e^- \sim 1$ 1 of ALBRECHT 92P. TECN COMMENT es, fits, limits, etc. • • • 89D ARG e^+e^- 10 (10 GeV 0 GeV 0.0.7 GeV	$\langle 0.019 \rangle$ $\Gamma(K_1(1270)^-\pi^+)/\Gamma(K_1(1270)^-\pi^+)/\Gamma(K_1(1270)^-\pi^+)/\Gamma(K_1(1400)^0\pi^0$	90 CO $/\Gamma(K^0\pi^+\pi^-\pi^0)$ rodes of the $K_1(12)$ T CO Γ_{total} $GLX = DO$ 90 CO 3-body)/ $\Gamma(K^0\pi^0)$ T Error includes: CO $T_{total} = T_{T}$ $T_{T} = T_{T}$	COMENT ID	(3 e ⁺ e ⁻ 3.77 GeV COMMENT COMMEN	3/F
47 BARLAG 92C computes $(K^0\pi^+\pi^-\pi^0)/\Gamma(K^0\pi^+\pi^-\pi^0)/\Gamma(K^0\pi^0)$ 44.UE EV. 84±0.20 OUR FIT 86±0.23 OUR AVERAGE 80±0.20±0.21 18 ±0.8 ±0.8 ±0.8 85±0.26±0.30 1 18 This value is calculated $(K^0\pi)/\Gamma(K^-\pi^+)$ Unseen decay modes 44.UE CO.64 90 Unseen decay modes 60.64 $(K^0\pi)/\Gamma(K^0\pi^0)$ Unseen decay modes 93±0.04 OUR FIT 53±0.04 OUR FIT 53±0.04 OUR FIT 53±0.04±0.03	47 BARLAG s the branching fraction $\pi^+\pi^-$) CTS DOCUMENT ID 190 48 ALBRECHT 46 ANJOS 158 KINOSHITA from numbers in Table of the η are included. LY DOCUMENT ID of the η are included. O ALBRECHT of the η are included. O ALBRECHT of the η are included. O ALBRECHT	using topological normaliz TECN COMMENT 92P ARG $e^+e^- \approx 1$ 92C E691 γ Be 90–266 91 CLEO $e^+e^- \sim 1$ 1 of ALBRECHT 92P. TECN COMMENT 89D ARG e^+e^- 10 G	10 GeV 0 GeV 10.0.7 GeV GeV	$\langle 0.019 \rangle$ $\Gamma(K_1(1270)^-\pi^+)/\Gamma(K_1(1270)^-\pi^+)/\Gamma(K_1(1270)^-\pi^+)/\Gamma(K_1(1400)^0\pi^0)/\Gamma(K_1(1400)^0\pi^0)/\Gamma(K^*(892)^0\pi^+\pi^-)$ Unseen decay m $\frac{VALUE}{VALUE}$ 0.14 ± 0.04 OUR FT 0.191 ± 0.105 $\Gamma(K^0\pi^+\pi^-\pi^0$ non $\frac{VALUE}{VALUE}$ 0.210 $\pm 0.147\pm 0.150$ $\Gamma(K^-\pi^+\pi^0\pi^0)/\Gamma(K^-\pi^+\pi^0\pi^0)/\Gamma(K^-\pi^+\pi^0\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0\pi^0\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi$	90 CO $\Gamma(R^0\pi^+\pi^-\pi^0)$ rodes of the $K_1(12$ Γ CO Γ_{total} $SLX = DO$ 90 CO 3-body)/ $\Gamma(R^0\pi^0)$ T Error Includes CO Γ_{total}	COMENT ID TECN	(3 e ⁺ e ⁻ 3.77 GeV COMMENT 3 e ⁺ e ⁻ 3.77 GeV COMMENT 4 COMMENT 5 COMMENT 6 COMMENT 6 COMMENT 7 COMMENT 6 COMMENT 7 COMMENT 8 COMMENT 9 COMMENT 1 COMMENT 1 COMMENT 2 COMMENT 3 COMMENT 4 COMMENT 5 COMMENT 6 COMMENT 6 COMMENT 7 COMMENT 7 COMMENT 8 COMMENT 9 COMMENT 1 CO	3/F
47 BARLAG 92C computes $(K^0 \pi^+ \pi^- \pi^0)/\Gamma(K^0, K^0, K^0, K^0, K^0, K^0, K^0, K^0, $	47 BARLAG s the branching fraction $\pi^+\pi^-$) CTS DOCUMENT ID 190 48 ALBRECHT 46 ANJOS 158 KINOSHITA from numbers in Table of the η are included. LY DOCUMENT ID of the η are included. O ALBRECHT of the η are included. O ALBRECHT of the η are included. O ALBRECHT	using topological normaliz TECN COMMENT 92P ARG $e^+e^- \approx 1$ 92C E691 γ Be 90–266 91 CLEO $e^+e^- \sim 1$ 1 of ALBRECHT 92P. TECN COMMENT 89D ARG e^+e^- 10 G	10 GeV 0 GeV 0.0.7 GeV	$\langle 0.019 \rangle$ $\Gamma(K_1(1270)^-\pi^+)/\Gamma(K_1(1270)^-\pi^+)/\Gamma(K_1(1270)^-\pi^+)/\Gamma(K_1(1400)^0\pi^0$	90 CO $\Gamma(R^0\pi^+\pi^-\pi^0)$ rodes of the $K_1(12$ Γ CO Γ_{total} $SLX = DO$ 90 CO 3-body)/ $\Gamma(R^0\pi^0)$ T Error Includes CO Γ_{total}	COMENT ID	(3 e ⁺ e ⁻ 3.77 GeV COMMENT COMMEN	3/F
47 BARLAG 92C computes $(K^0\pi^+\pi^-\pi^0)/\Gamma(K^0, K^0, K^0, K^0, K^0, K^0, K^0, K^0, $	47 BARLAG s the branching fraction $\pi^+\pi^-$) CTS DOCUMENT ID 190 48 ALBRECHT 46 ANJOS 158 KINOSHITA from numbers in Table of the η are included. LY DOCUMENT ID DIOWING data for average 0 ALBRECHT of the η are included. CTS DOCUMENT ID DOCUMENT ID 125 PROCARIO	using topological normaliz TECN COMMENT 92P ARG $e^+e^- \approx 1$ 92C E691 γ Be 90–266 91 CLEO $e^+e^- \sim 1$ 1 of ALBRECHT 92P. TECN COMMENT 89D ARG e^+e^- 10 G	10 GeV 0 GeV 10.0.7 GeV GeV	$\langle 0.019 \rangle$ $\Gamma(K_1(1270)^-\pi^+)/\Gamma(K_1(1270)^-\pi^+)/\Gamma(K_1(1270)^-\pi^+)/\Gamma(K_1(1400)^0\pi^0)/\Gamma(K_1(1400)^0\pi^0)/\Gamma(K_1(1400)^0\pi^0)/\Gamma(K^*(892)^0\pi^+\pi^-)$ $VALUE$ $0.14 \pm 0.04 OUR \ FT$ 0.191 ± 0.106 $\Gamma(K^0\pi^+\pi^-\pi^0 \ non \ VALUE$ $0.210 \pm 0.147 \pm 0.150$ $\Gamma(K^-\pi^+\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0)/\Gamma(K^0\pi^0)/\Gamma(K^-\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0)/\Gamma(K^0\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0)/\Gamma(K^0\pi^0\pi^0)/\Gamma(K^0\pi^0\pi^0)/\Gamma(K^0\pi^0\pi^0)/\Gamma(K^0\pi^0\pi^0)/\Gamma(K^0\pi^0\pi^0)/\Gamma(K^0\pi^0\pi^0)/\Gamma(K^0\pi^0)/\Gamma(K^0\pi^0\pi^0)/\Gamma(K^0\pi^0)/\Gamma(K^0\pi^0\pi^0)/\Gamma(K^0\pi^0\pi^0)/\Gamma(K^0\pi^0)/\Gamma$	90 CO $\Gamma(R^0\pi^+\pi^-\pi^0)$ rodes of the $K_1(12$ Γ CO Γ_{total}	(CUMENT 10 TECN (CUME	(3 e ⁺ e ⁻ 3.77 GeV COMMENT COMMEN	100/ 33/F
47 BARLAG 92C computes $(K^0\pi^+\pi^-\pi^0)/\Gamma(K^0, ALUE) = (K^0\pi^+\pi^-\pi^0)/\Gamma(K^0, ALUE) = (K^0\pi^+\pi^-\pi^0)/\Gamma(K^0\pi^+\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi$	47 BARLAG s the branching fraction $\pi^+\pi^-$) (75 DOCUMENT ID 190 48 ALBRECHT 46 ANJOS 158 KINOSHITA from numbers in Table of the η are included. 15 DOCUMENT ID 15 DOCUMENT ID 15 PROCARIO of the η are included. (75 DOCUMENT ID 15 DOCUMENT ID 16 PARTICIPATION 17 PROCARIO of the η are included.	using topological normaliz TECN COMMENT 92P ARG $e^+e^-\approx 1$ 92C E691 γ Be 90–26 91 CLEO $e^+e^-\sim 1$ 1 of ALBRECHT 92P. TECN COMMENT 93B CLE2 $\eta \rightarrow \gamma \gamma$ TECN COMMENT	10 GeV 10 GeV 10 GeV 10 GeV 10.7 GeV Γ68/Γ19 Γ68/Γ20	$VALUE$ <0.019 $\Gamma(K_1(1270)^-\pi^+)/U$ Unseen decay m $VALUE$ 0.106 ± 0.028 OUR FT 0.10 ± 0.03 $\Gamma(K_1(1400)^0\pi^0)/U$ $VALUE$ <0.037 $\Gamma(K^e(892)^0\pi^+\pi^-U$ Unseen decay m $VALUE$ 0.14 ± 0.04 OUR FT 0.191 ± 0.105 $\Gamma(K^0\pi^+\pi^-\pi^0$ non $VALUE$ 0.210 ± 0.147 ± 0.150 $\Gamma(K^-\pi^+\pi^0\pi^0)/\Gamma_0$ $VALUE$ 0.149 ± 0.037 ± 0.030	90 CO $\Gamma(R^0\pi^+\pi^-\pi^0)$ rodes of the $K_1(12$ Γ CO Γ_{total}	(CUMENT ID TECN FFMAN 92B MRK	(3 e ⁺ e ⁻ 3.77 GeV COMMENT COMMEN	100/ 33/F
47 BARLAG 92C computes $(K^0\pi^+\pi^-\pi^0)/\Gamma(K^0, ALUE) = (K^0\pi^+\pi^-\pi^0)/\Gamma(K^0, ALUE) = (K^0\pi^+\pi^-\pi^0)/\Gamma(K^0\pi^+\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi$	47 BARLAG s the branching fraction π+π-) 775	using topological normaliz $TECN = COMMENT$ 92P ARG $e^+e^- \approx 1$ 92c E691 γ Be 90-26 91 CLEO $e^+e^- \sim 1$ 1 of ALBRECHT 92P. $TECN = COMMENT$ es, fits, limits, etc. • • • 89D ARG e^+e^- 10 ($TECN = COMMENT$ 938 CLE2 $\eta \rightarrow \gamma \gamma$	10 GeV 10 GeV 10 GeV 10 GeV 10.7 GeV Γ68/Γ19 Γ68/Γ20	$VALUE$ <0.019 $\Gamma(K_1(1270)^-\pi^+)/U$ Unseen decay m $VALUE$ 0.106 ± 0.028 OUR FT 0.10 ± 0.03 $\Gamma(K_1(1400)^0\pi^0)/U$ $VALUE$ <0.037 $\Gamma(K^*(892)^0\pi^+\pi^-$ Unseen decay m $VALUE$ 0.14 ± 0.04 OUR FT 0.191 ± 0.105 $\Gamma(K^0\pi^+\pi^-\pi^0$ non $VALUE$ 0.210 ± 0.147 ± 0.150 $\Gamma(K^-\pi^+\pi^0\pi^0)/\Gamma$ $VALUE$ 0.149 ± 0.037 ± 0.030 • • We do not use 0.177 ± 0.029	90 CO $\Gamma(R^0\pi^+\pi^-\pi^0)$ rodes of the $K_1(12)$ Γ CO Γ_{total} Γ_{cols} 90 CO 3-body)/ $\Gamma(R^0\pi^0)$ T Error includes contresonant)/ $\Gamma(R^0\pi^0)$ Γ_{col} Γ_{c	COMENT ID	(3 e ⁺ e ⁻ 3.77 GeV COMMENT (3 e ⁺ e ⁻ 3.77 GeV (3 e ⁺ e ⁻ 3.77 GeV (4 COMMENT (3 e ⁺ e ⁻ 3.77 GeV (4 COMMENT (3 e ⁺ e ⁻ 3.77 GeV (4 COMMENT (4 COMMENT (5 COMMENT (6 COMMENT (7 COMMENT (7 COMMENT (8 CO	
1.84±0.20 OUR FIT 1.86±0.23 OUR AVERAGE 1.80±0.20±0.21 1.8.±0.8 ±0.8 1.85±0.26±0.30 1 48 This value is calculated $\Gamma(K^0\eta)/\Gamma(K^-\pi^+)$ Unseen decay modes V_{ALVE} 0 • • We do not use the fit V_{ALVE} $V_$	47 BARLAG s the branching fraction $\pi^+\pi^-$) (75 DOCUMENT ID 190 48 ALBRECHT 46 ANJOS 158 KINOSHITA from numbers in Table of the η are included. 15 DOCUMENT ID 15 DOCUMENT ID 15 PROCARIO of the η are included. (75 DOCUMENT ID 15 DOCUMENT ID 16 PARTICIPATION 17 PROCARIO of the η are included.	using topological normaliz TECN COMMENT 92P ARG $e^+e^-\approx 1$ 92C E691 γ Be 90–26 91 CLEO $e^+e^-\sim 1$ 1 of ALBRECHT 92P. TECN COMMENT 93B CLE2 $\eta \rightarrow \gamma \gamma$ TECN COMMENT	10 GeV 10 GeV 10 GeV 10 GeV 10.7 GeV Γ68/Γ19 Γ68/Γ20 Γ68/Γ21 Γ68/Γ21	VALUE <0.019 $\Gamma(K_1(1270)^-\pi^+)/U$ Unseen decay m VALUE 0.106 ± 0.028 OUR FT 0.10 ± 0.03 $\Gamma(K_1(1400)^0\pi^0)/U$ VALUE <0.037 $\Gamma(K^*(892)^0\pi^+\pi^-U$ Unseen decay m VALUE 0.14 ± 0.04 OUR FT 0.191 ± 0.105 $\Gamma(K^0\pi^+\pi^-\pi^0$ non VALUE 0.210 ± 0.147 ± 0.150 $\Gamma(K^-\pi^+\pi^0\pi^0)/\Gamma$ VALUE 0.149 ± 0.037 ± 0.030 • • • We do not use 0.177 ± 0.029 0.209 ± 0.074 ± 0.012	90 CO $\Gamma(R^0\pi^+\pi^-\pi^0)$ rodes of the $K_1(12$ Γ CO Γ_{total} $\Gamma_$	(CUMENT ID TECN (CUMENT ID TE	(3 e ⁺ e ⁻ 3.77 GeV COMMENT COMMEN	100/ 133/F
47 BARLAG 92c computes ($(R^0\pi^+\pi^-\pi^0)/\Gamma(R^0, R^0)$ ($(R^0\pi^+\pi^-\pi^0)/\Gamma(R^0, R^0)$ ($(R^0\pi^+\pi^-\pi^0)/\Gamma(R^0, R^0)$ ($(R^0\pi^-\pi^-\pi^0)/\Gamma(R^0\pi^-\pi^0)$ ($(R^0\pi^-\pi^-\pi^0)/\Gamma(R^0\pi^-\pi^-\pi^0)$ ($(R^0\pi^-\pi^-\pi^0)/\Gamma(R^0\pi^-\pi^-\pi^0)$ ($(R^0\pi^-\pi^-\pi^0)/\Gamma(R^0\pi^-\pi^-\pi^0)$ ($(R^0\pi^-\pi^-\pi^0)/\Gamma(R^0\pi^-\pi^-\pi^0)$ ($(R^0\pi^-\pi^-\pi^0)/\Gamma(R^0\pi^-\pi^-\pi^0)$ ($(R^0\pi^-\pi^-\pi^0)/\Gamma(R^0\pi^-\pi^-\pi^0)$ ($(R^0\pi^-\pi^-\pi^0)/\Gamma(R^0\pi^-\pi^-\pi^-\pi^0)$ ($(R^0\pi^-\pi^-\pi^-\pi^0)/\Gamma(R^0\pi^-\pi^-\pi^-\pi^0)$ ($(R^0\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi$	47 BARLAG s the branching fraction $\pi^+\pi^-$) (75 DOCUMENT ID 190 48 ALBRECHT 46 ANJOS 158 KINOSHITA from numbers in Table of the η are included. 15 DOCUMENT ID 15 DOCUMENT ID 15 PROCARIO of the η are included. (75 DOCUMENT ID 15 DOCUMENT ID 16 PARTICIPATION 17 PROCARIO of the η are included.	using topological normaliz TECN COMMENT 92P ARG $e^+e^-\approx 1$ 92C E691 γ Be 90–26 91 CLEO $e^+e^-\sim 1$ 1 of ALBRECHT 92P. TECN COMMENT 93B CLE2 $\eta \rightarrow \gamma \gamma$ TECN COMMENT	10 GeV 10 GeV 10 GeV 10 GeV 10.7 GeV Γ68/Γ19 Γ68/Γ20	$VALUE$ <0.019 $\Gamma(K_1(1270)^-\pi^+)/U$ Unseen decay m $VALUE$ 0.106 ± 0.028 OUR FT 0.10 ± 0.03 $\Gamma(K_1(1400)^0\pi^0)/U$ $VALUE$ <0.037 $\Gamma(K^*(892)^0\pi^+\pi^-$ Unseen decay m $VALUE$ 0.14 ± 0.04 OUR FT 0.191 ± 0.106 $\Gamma(K^0\pi^+\pi^-\pi^0$ non $VALUE$ $0.210\pm0.147\pm0.150$ $\Gamma(K^-\pi^+\pi^0\pi^0)/\Gamma$ $VALUE$ $0.149\pm0.037\pm0.030$ • • We do not use 0.177 ± 0.029 $0.209\pm0.074\pm0.012$ 52 ADLER 88C uses as	$\frac{\text{CL}}{90}$ CO $\frac{\text{F}}{(R^0 * + * - * * * * * * * * * * * * * * * *$	COMENT ID TECN	(3 e ⁺ e ⁻ 3.77 GeV COMMENT (3 e ⁺ e ⁻ 3.77 GeV (3 e ⁺ e ⁻ 3.77 GeV (4 COMMENT (3 e ⁺ e ⁻ 3.77 GeV (4 COMMENT (3 e ⁺ e ⁻ 3.77 GeV (4 COMMENT (4 COMMENT (5 COMMENT (6 COMMENT (7 COMMENT (7 COMMENT (8 CO	100/ 133/F
47 BARLAG 92C computes $(K^0 \pi^+ \pi^- \pi^0)/\Gamma(K^0, K^0, K^0, K^0, K^0, K^0, K^0, K^0, $	47 BARLAG s the branching fraction π+π-) (TS DOCUMENT ID 190 48 ALBRECHT 46 ANJOS 158 KINOSHITA from numbers in Table of the η are included. 15 DOCUMENT ID 15 DOCUMENT ID 15 PROCARIO 16 The η are included. 17 DOCUMENT ID 18 PROCARIO 18 PROCARIO 18 PROCARIO	using topological normaliz TECN COMMENT 92P ARG $e^+e^-\approx 1$ 92C E691 γ Be 90–26 91 CLEO $e^+e^-\sim 1$ 1 of ALBRECHT 92P. TECN COMMENT 93B CLE2 $\eta \rightarrow \gamma \gamma$ TECN COMMENT	10 GeV 10 GeV 10 GeV 10 GeV 10.7 GeV Γ68/Γ19 Γ68/Γ20 Γ68/Γ21 Γ68/Γ21	$VALUE$ <0.019 $\Gamma(K_1(1270)^-\pi^+)/\Gamma(K_1(1270)^-\pi^+)/\Gamma(K_1(1270)^-\pi^+)/\Gamma(K_1(1400)^0\pi^0)/\Gamma(K_1(1400)^0\pi^0)/\Gamma(K_1(1400)^0\pi^0)/\Gamma(K^*(892)^0\pi^+\pi^-)$ Unseen decay m $VALUE$ 0.14 ±0.04 OUR FT 0.191 ±0.105 $\Gamma(K^0\pi^+\pi^-\pi^0 \text{ non } VALUE$ 0.210 ±0.147 ±0.150 $\Gamma(K^-\pi^+\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0)/\Gamma(K^-\pi^0\pi^0)/\Gamma(K^-\pi^$	SLM POOL POOL POOL POOL POOL POOL POOL PO	COMENT ID TECN	(3 e ⁺ e ⁻ 3.77 GeV COMMENT COMMEN	100/ 33/Г.

Γ(K -π+π+π-π ⁰) VALUE)/Γ(<i>K</i> = π <u>EVTS</u>	+) DOCUMENT ID	TECN	Γ ₅₅ /Γ ₁₉
1.05±0.10 OUR FIT		54		1
0.98±0.11±0.11	225	54 ALBRECHT	92P ARG	$e^+e^-\approx 10 \text{ GeV}$
54 This value is calcul	ated from i	numbers in Table	1 of ALBREC	HT 92P.
$\Gamma(K^-\pi^+\pi^+\pi^-\pi^0)$	/Γ(K ⁻ π	$^{+}\pi^{+}\pi^{-}$)		Γ ₅₅ /Γ ₃₇
VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
0.54±0.05 OUR FIT				
0.56±0.07 OUR AVER	AGE			
$0.55 \pm 0.07 ^{+0.12}_{-0.09}$	167	KINOSHITA	91 CLEO	$e^+e^-\sim$ 10.7 GeV
0.57±0.06±0.05	180	ANJOS	90D E691	Photoproduction
Γ(K *(892) ⁰ π ⁺ π ⁻	-0\ /r/ <i>K</i> -	+-+0)		Γ ₁₀₅ /Γ ₅₅
		$\overline{K}^*(892)^0$ are inc		, 109/ . 20
VALUE	Jues of the	DOCUMENT ID		COMMENT
0.45±0.15±0.15		ANJOS /	90D E691	Photoproduction
- (V *(000)0) /-(4	/+\			r /r
Γ(Κ *(892) ⁰ η)/Γ(<i>k</i>	•	T/# (000)		Γ ₁₀₆ /Γ ₁₉
Unseen decay mo VALUE		K*(892) ⁰ and η DOCUMENT ID		
0.49±0.12 OUR FIT	EVIS	DOCOMENT ID	TECH	COMMENT
0.58±0.19 ^{+0.24} -0.28	46	KINOSHITA	91 CLEO	$e^+e^-\sim$ 10.7 GeV
Γ(Κ *(892) ⁰ η)/Γ(<i>κ</i>	(- _# + _# 0)	\		Γ ₁₀₆ /Γ ₂₉
		$\overline{K}*(892)^0$ and η	are included	- 100/ - 21
VALUE	EVTS	DOCUMENT ID		COMMENT
0.134±0.034 OUR FIT 0.13 ±0.02 ±0.03	214	PROCARIO		$\overline{K}^{*0}n \rightarrow K^-\pi^+/\gamma\gamma$
	-13			
$\Gamma(K^-\pi^+\omega)/\Gamma(K^-$				Γ ₁₀₇ /Γ ₁₉
Unseen decay me VALUE	<u>EVTS</u>	DOCUMENT ID	TECN	COMMENT
0.78±0.12±0.10	99	55 ALBRECHT	92P ARG	e ⁺ e ⁻ ≈ 10 GeV
55 This value is calcul	ated from	numbers in Table	1 of ALBREC	HT 92P.
Γ(依 *(892) ⁰ ω)/Γ(<i>I</i>				Γ ₁₀₈ /Γ ₁₉
Unseen decay mo VALUE		K*(892) ⁰ and ω DOCUMENT ID		
0.28±0.11±0.04	<u>EVTS</u> 17	56 ALBRECHT	92P ARG	e ⁺ e ⁻ ≈ 10 GeV
⁵⁶ This value is calcul	ated from	numbers in Table	1 Of ALBREC	.н г 92Р.
$\Gamma(\overline{K}^*(892)^0\omega)/\Gamma(I$	√-π+π+	$\pi^{-}\pi^{0}$		Γ ₁₀₈ /Γ ₅₅
		$\overline{K}^*(892)^0$ and ω	are included.	
		DOCUMENT ID		
 • • We do not use t 	he followin	g data for averag	es, fits, limits	, etc. • • •
<0.44	90	SOLNA ⁵⁷	900 E691	Photoproduction
⁵⁷ Recovered from th mallzation consiste		i limit, Γ(<i>K</i> *(892	$)^{0}\omega)/\Gamma_{ m total}$	in order to make our nor
$\Gamma(K^-\pi^+\eta'(958))/$	$\Gamma(K^-\pi^+$	$(\pi^{+}\pi^{-})$		Γ ₁₀₉ /Γ ₃₇
Unseen decay m	odes of the	$\eta'(958)$ are inclu		
VALUE	EVTS	DOCUMENT ID		
0.093±0.014±0.019	286	PROCARIO	93B CLE2	$\eta' \rightarrow \eta \pi^+ \pi^-, \rho^0 \gamma$
Γ(K *(892) ⁰ η/(958))/r(<i>K</i> =	π ⁺ η' (958))		Γ ₁₁₀ /Γ ₁₀₉
-		\overline{K}^* (892) ⁰ are in		
VALUE	CL%	DOCUMENT ID		•
<0.15	90	PROCARIO	93B CLE2	
Γ(Κ 0π+π+π-π-				Γ ₆₀ /Γ ₂₁
	<u>EVTS</u>	<u>DOCUMENT ID</u> Error includes scal		8. See the ideogram below
VALUE	EDAGE 4			o, occ the incortain below
VALUE 0.107±0.029 OUR AV				
VALUE 0.107±0.029 OUR AV 0.07 ±0.02 ±0.01	11	58 ALBRECHT	92P ARG	$e^+e^-\approx 10 \text{ GeV}$
VALUE 0.107±0.029 OUR AV				e ⁺ e ⁻ ≈ 10 GeV



$\Gamma(\overline{K}^0\pi^+\pi^-\pi^0\pi^0(\pi$	⁰))/Γ _{to}	tal		Γ ₆₁ /Γ
VALUE	EVTS	DOCUMENT ID	<u>TECN</u>	COMMENT
$0.106^{+0.073}_{-0.029} \pm 0.006$	4	⁵⁹ AGUILAR	87F HYBR	πp, pp 360, 400 GeV

 59 AGUILAR-BENITEZ 87F computes the branching fraction using topological normalization, and does not distinguish the presence of a third π^0 .

Γ(₹ ⁰ <i>K</i> + <i>K</i> −)/Γ(₹	¹⁰ π ⁺ π ⁻)		Γ ₆₂ /Ι	$\Gamma_{21} = (\Gamma_{64} + \frac{1}{2}\Gamma_{74})/\Gamma_{21}$
VALUE	EVTS	DOCUMENT ID	TECN_	COMMENT
0.172±0.014 OUR FIT 0.178±0.019 OUR AV				
0.20 ±0.05 ±0.04	47	FRABETTI	92B E687	γ Be \widetilde{E}_{γ} = 221 GeV
0.170±0.022 0.24 ±0.08	136	AMMAR BEBEK	86 CLEO	$e^+e^-\approx 10.5 \text{ GeV}$ $e^+e^- \text{ near } \Upsilon(4S)$
0.185 ± 0.055	52	ALBRECHT	85B ARG	e ⁺ e ⁻ 10 GeV

EVTS	DOCUMENT ID	TECN	COMMENT
	and the second		
ERAGE			
13	FRABETTI	92B E687	γ Be \overline{E}_{γ} = 221 GeV
63	AMMAR		e ⁺ e [−] ≈ 10.5 GeV
56	ALBRECHT	87E ARG	e ⁺ e ⁻ 10 GeV
29	BEBEK	86 CLEO	e^+e^- near $\Upsilon(4S)$
	13 63 56	ERAGE 13 FRABETTI 63 AMMAR 56 ALBRECHT	ERAGE 13 FRABETTI 928 E687 63 AMMAR 91 CLEO 56 ALBRECHT 87E ARG

Γ(K ⁰ K ⁺ K ⁻ non-φ)/Γ(Κ⁰π	⁺ π⁻)		Γ ₆₄ /	Γ21
VALUE	EVTS	DOCUMENT ID	TECN	COMMENT	
0.093±0.014 OUR FIT	•				
0.088±0.019 OUR AV	ERAGE				
$0.11 \pm 0.04 \pm 0.03$	20	FRABETTI	928 E687	γ Be \overline{E}_{γ} = 221 GeV	
0.084 ± 0.020		ALBRECHT	87E ARG	e ⁺ e ⁻ 10 GeV	

π-)			Γ ₆₅ /Γ ₂₁
EVTS	DOCUMENT ID	TECN	COMMENT
AGE			
61	ASNER	96B CLE2	$e^+e^-\approx \Upsilon(45)$
10	FRABETTI	94J E687	γ Be \overline{E}_{γ} =220 GeV
22	AMMAR	91 CLEO	e ⁺ e ⁻ ≈ 10.5 GeV
5	ALBRECHT	90c ARG	e ⁺ e ⁻ ≈ 10 GeV
	61 10	AGE 61 ASNER 10 FRABETTI 22 AMMAR	EVTS DOCUMENT ID TECN AGE 61 ASNER 96B CLE2 10 FRABETTI 94J E687 22 AMMAR 91 CLEO

$0.017 \pm 0.007 \pm 0.005$	5	ALBRECHT	90c ARG	$e^+e^-\approx 10 \text{ GeV}$
$\Gamma(K^+K^-K^-\pi^+)/\Gamma(K^-$	· _ + _ +	-)		Γ ₆₆ /Γ ₃₇
VALUE	EVTS	DOCUMENT ID	<u>TECN</u>	COMMENT
0.0028±0.0007±0.0001	20	FRABETTI	95C E687	γ Be, $\overline{E}_{\gamma} \approx 200$

			GeV	
$\Gamma(K^+K^-\overline{K}^0\pi^0)/\Gamma_{\text{total}}$				Γ ₆₇ /Γ
VALUE	DOCUMENT ID	TECN	COMMENT	
0.0072 ^{+0.0048} -0.0035	⁶⁰ BARLAG	92c ACCM	π ⁻ Cu 230 GeV	

 $^{^{60}\,\}mathrm{BARLAG}$ 92C computes the branching fraction using topological normalization.

 D^0

Pionic modes ———	$\Gamma(K^0\overline{K}^0)/\Gamma(\overline{K}^0\pi^+\pi^-)$ Γ_{118}/Γ_2
$\Gamma(\pi^+\pi^-)/\Gamma(K^-\pi^+)$ Γ_{111}/Γ_{19}	VALUE EVTS DOCUMENT ID TECN COMMENT 0.0120±0.0033 OUR FIT Error includes scale factor of 1.3.
ALUE EVTS DOCUMENT ID TECN COMMENT	0.0117±0.0033 OUR AVERAGE Error includes scale factor of 1.3. See the ideogram
0.0097±0.0021 OUR AVERAGE 0.040 ±0.002 ±0.003 2043 AITALA 98C E791 π ⁻ nucleus. 500	below.
GeV	0.0101±0.0022±0.0016 26 A5NER 96B CLE2 e ⁺ e ⁻ ≈ Υ (45) 0.039 ±0.013 ±0.013 20 FRABETTI 94J E687 γ Be \overline{E}_{γ} =220 GeV
$0.043 \pm 0.007 \pm 0.003$ 177 FRABETTI 94C E687 γ Be $\overline{E}_{\gamma} = 220$	10011
GeV .0348 \pm 0.0030 \pm 0.0023 227 SELEN 93 CLE2 $e^+e^-pprox \varUpsilon(4S)$	$0.021 + 0.011 \pm 0.002$ 5 ALEXANDER 90 CLEO e^+e^- 10.5-11 GeV
1.048 $\pm 0.013 \pm 0.008$ 51 ADAMOVICH 92 OMEG π^- 340 GeV	WEIGHTED AVERAGE
0.055 ±0.008 ±0.005 120 ANJOS 91D E691 Photoproduction	0.0117±0.0033 (Error scaled by 1.3)
.040 $\pm 0.007 \pm 0.006$ 57 ALBRECHT 90C ARG $e^+e^- \approx 10 \text{ GeV}$	
$.050 \pm 0.007 \pm 0.005$ 110 ALEXANDER 90 CLEO e^+e^- 10.5-11	Values above of weighted average, error,
GeV .033 ±0.010 ±0.006 39 BALTRUSAIT85€ MRK3 e ⁺ e ⁻ 3.77 GeV	and scale factor are based upon the data in this ideogram only. They are not neces-
.033 ± 0.015 ABRAMS 790 MRK2 e^+e^- 3.77 GeV	sarily the same as our 'best' values,
$\Gamma(\pi^0\pi^0)/\Gamma(K^-\pi^+)$ Γ_{112}/Γ_{19}	obtained from a least-squares constrained fit utilizing measurements of other (related)
· /· /	quantities as additional information.
ALUE EVTS DOCUMENT ID TECN COMMENT .022 \pm 0.004 \pm 0.004 40 SELEN 93 CLE2 $e^+e^-\approx T(45)$	
. ,	
$(\pi^{+}\pi^{-}\pi^{0})/\Gamma_{\text{total}}$ Γ_{113}/Γ	
ALUE EVTS DOCUMENT ID TECN COMMENT	
.016 ±0.011 OUR AVERAGE Error includes scale factor of 2.7.	v ²
.0390 ⁺ 0.0100 61 BARLAG 92c ACCM π ⁻ Cu 230 GeV	4 ASNER 96B CLE2 0.3
-0.0095 .011 ±0.004 ±0.002 10 62 BALTRUSAIT85E MRK3 e ⁺ e ⁻ 3.77 GeV	
61 BARLAG 92C computes the branching fraction using topological normalization. Possible	- LEO 1.3
contamination by extra π^{U} 's may partly explain the unexpectedly large value.	3.8 (Confidence Level = 0.148)
62 All the BALTRUSAITIS 85E events are consistent with $ ho^0\pi^0$.	(Confidence Level = 0.146)
A I I Smith I I S	0 0.02 0.04 0.06 0.08 0.1
$(\pi^{+}\pi^{+}\pi^{-}\pi^{-})/\Gamma(K^{-}\pi^{+}\pi^{+}\pi^{-})$ Γ_{114}/Γ_{37}	=(x0\\ \tau \) \((=\(\tau \) \) + =\\
ALUEEVTS DOCUMENT ID TECN COMMENT	$\Gamma\left(K^0\overline{K}^0\right)/\Gamma\left(\overline{K}^0\pi^+\pi^-\right)$
$095\pm0.007\pm0.002$ 814 FRABETTI 95C E687 γ Be, $\overline{E}_{\gamma}\approx 200$ GeV	$\Gamma(K^0\overline{K}^0)/\Gamma(K^+K^-)$ Γ_{118}/Γ_1
115 \pm 0.023 \pm 0.016 64 ADAMOVICH 92 OMEG π^- 340 GeV	. , , ,
108±0.024±0.008 79 FRABETTI 92 E687 γBe	VALUE <u>EVTS</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u> 0.15±0.04 OUR FIT Error includes scale factor of 1.2.
.102 \pm 0.013 345 63 AMMAR 91 CLEO $e^+e^-\approx$ 10.5 GeV	0.24±0.16 4 66 CUMALAT 88 SPEC nN 0-800 GeV
096±0.018±0.007 66 ANJOS 91 E691 γ Be 80-240 GeV	⁶⁶ Includes a correction communicated to us by the authors of CUMALAT 88.
63 AMMAR 91 finds 1.25 \pm 0.25 \pm 0.25 $ ho^0$'s per $\pi^+\pi^+\pi^-\pi^-$ decay, but can't untangle	
the resonant substructure ($\rho^0 \rho^0$, $a_1^{\pm} \pi^{\mp}$, $\rho^0 \pi^+ \pi^-$).	$\Gamma(K^0K^-\pi^+)/\Gamma(K^-\pi^+)$ $\Gamma_{119}/\Gamma_{119}$
	VALUE DOCUMENT ID TECN COMMENT
$\Gamma(\pi^+\pi^+\pi^-\pi^-\pi^0)/\Gamma_{\text{total}}$ Γ_{115}/Γ	0.167±0.026 OUR FIT Error includes scale factor of 1.1.
ALUE DOCUMENT ID TECN COMMENT	0.16 ±0.06 67 ANJOS 91 E691 γBe 80–240 GeV
ALUE DOCUMENT ID TECN COMMENT	/3
ALUE <u>DOCUMENT ID TECN COMMENT</u> 1.0192+0.0041 64 BARLAG 92C ACCM π^- Cu 230 GeV	0.16 \pm 0.06 67 ANJOS 91 E691 γ Be 80–240 GeV 67 The factor 100 at the top of column 2 of Table I of ANJOS 91 should be omitted.
ALUE DOCUMENT ID TECN COMMENT $0.0192 + 0.0041$ 0.0038 $0.0192 + 0.0038$ $0.0192 + $	0.16 \pm 0.06 67 ANJOS 91 E691 γ Be 80–240 GeV 67 The factor 100 at the top of column 2 of Table I of ANJOS 91 should be omitted. $\Gamma(K^0K^-\pi^+)/\Gamma(\overline{K^0}\pi^+\pi^-)$ $\frac{\Gamma_{119}/\Gamma_{119}}{NALUE}$ $\frac{EVTS}{DOCUMENT ID}$ $\frac{TECN}{TECN}$ COMMENT
ALUE DOCUMENT ID TECN COMMENT 1.0192 $+$ 0.0041 64 BARLAG 92c ACCM π^- Cu 230 GeV 64 BARLAG 92c computes the branching fraction using topological normalization.	0.16 \pm 0.06 67 ANJOS 91 E691 γ Be 80–240 GeV 67 The factor 100 at the top of column 2 of Table I of ANJOS 91 should be omitted. $\Gamma(K^0K^-\pi^+)/\Gamma(\overline{K^0}\pi^+\pi^-) \qquad \qquad \Gamma_{119}/\Gamma_{119}$ $\frac{VALUE}{0.118\pm0.018} \text{ OUR FIT} \qquad \text{Error includes scale factor of 1.1.}$
ALUE DOCUMENT ID TECN COMMENT 1.0192+0.0041 64 BARLAG 92C ACCM π^- Cu 230 GeV 64 BARLAG 92C computes the branching fraction using topological normalization. ($\pi^+\pi^+\pi^+\pi^-\pi^-\pi^-$)/ Γ_{total} COMMENT ID TECN COMMENT	0.16 \pm 0.06 67 ANJOS 91 E691 γ Be 80–240 GeV 67 The factor 100 at the top of column 2 of Table I of ANJOS 91 should be omitted. $\Gamma(K^0K^-\pi^+)/\Gamma(\overline{K^0}\pi^+\pi^-) \qquad \qquad \Gamma_{119}/\Gamma_{119}/\Gamma_{119}$ 0.118 \pm 0.018 OUR FIT Error includes scale factor of 1.1. 0.119 \pm 0.021 OUR AVERAGE Error includes scale factor of 1.3.
ALUE DOCUMENT ID TECN COMMENT $0.0192 + 0.0041$ 0.0038 $0.0192 + 0.0041$ 0.0038 $0.004 + 0.0041$ $0.$	0.16 \pm 0.06 67 ANJOS 91 E691 γ Be 80–240 GeV 67 The factor 100 at the top of column 2 of Table I of ANJOS 91 should be omitted. $\Gamma(K^0K^-\pi^+)/\Gamma(\overline{K^0\pi^+\pi^-}) \qquad \qquad \Gamma_{119}/\Gamma_{118\pm0.018\ 0.018\pm0.018\ 0.018\pm0.018\ 0.018\ 0.019} \qquad \qquad \Gamma_{119\pm0.001\ 0.018\pm0.019} \qquad \qquad \Gamma_{119\pm0.001\ $
ALUE DOCUMENT ID TECN COMMENT 1.0192+0.0041 64 BARLAG 92C ACCM π^- Cu 230 GeV 64 BARLAG 92C computes the branching fraction using topological normalization. ($\pi^+\pi^+\pi^+\pi^-\pi^-$)/ Γ_{total} 1.0192+0.0003 65 BARLAG 92C ACCM π^- Cu 230 GeV 65 BARLAG 92C ACCM π^- Cu 230 GeV	0.16 \pm 0.06 67 ANJOS 91 E691 γ Be 80–240 GeV 67 The factor 100 at the top of column 2 of Table I of ANJOS 91 should be omitted. $\Gamma(K^0K^-\pi^+)/\Gamma(\overline{K^0}\pi^+\pi^-) \qquad \qquad \Gamma_{119}/\Gamma_{119}/\Gamma_{119}$ 0.118 \pm 0.018 OUR FIT Error includes scale factor of 1.1. 0.119 \pm 0.021 OUR AVERAGE Error includes scale factor of 1.3. 0.108 \pm 0.019 61 AMMAR 91 CLEO $e^+e^-\approx 10.5$ GeV 0.16 \pm 0.03 \pm 0.02 39 ALBRECHT 90C ARG $e^+e^-\approx 10$ GeV
ALUE DOCUMENT ID TECN COMMENT L0192+0.0041 64 BARLAG 92c ACCM π^- Cu 230 GeV 64 BARLAG 92c computes the branching fraction using topological normalization.	0.16 \pm 0.06 67 ANJOS 91 E691 γ Be 80–240 GeV 67 The factor 100 at the top of column 2 of Table I of ANJOS 91 should be omitted. $\Gamma(K^0K^-\pi^+)/\Gamma(\overline{K^0}\pi^+\pi^-) \qquad \qquad \Gamma_{119}/\Gamma_{119$
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ALUE DOCUMENT ID TECN COMMENT 1.0192+0.0041 64 BARLAG 92c ACCM π^- Cu 230 GeV 64 BARLAG 92c computes the branching fraction using topological normalization. The state of the sta	0.16 \pm 0.06 67 ANJOS 91 E691 γ Be 80–240 GeV 67 The factor 100 at the top of column 2 of Table I of ANJOS 91 should be omitted. $\Gamma(K^0K^-\pi^+)/\Gamma(\overline{K^0}\pi^+\pi^-) \qquad \qquad \Gamma_{119}/\Gamma_{119}/\Gamma_{119}\Gamma_{119}/\Gamma$
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$\frac{ALUE}{0.0038}$ 64 BARLAG 92C ACCM π ⁻ Cu 230 GeV 64 BARLAG 92C computes the branching fraction using topological normalization. $\frac{\Gamma}{(\pi^+\pi^+\pi^+\pi^-\pi^-\pi^-)/\Gamma_{total}}$ $\frac{\Gamma_{116}/\Gamma_{total}}{\Gamma_{100004\pm0.0003}}$ 65 BARLAG 92C ACCM π ⁻ Cu 230 GeV 65 BARLAG 92C ACCM π ⁻ Cu 230 GeV 65 BARLAG 92C computes the branching fraction using topological normalization. Hadronic modes with a KK pair $\frac{\Gamma_{117}/\Gamma_{19}}{\Gamma_{1109\pm0.0033}}$ $\frac{\Gamma_{117}/\Gamma_{19}}{\Gamma_{117}/\Gamma_{19}}$ $\frac{\Gamma_{117}/\Gamma_{19}}{\Gamma_{117}/\Gamma_{19}}$ $\frac{\Gamma_{117}/\Gamma_{19}}{\Gamma_{1109\pm0.0033}}$ $\frac{\Gamma_{117}/\Gamma_{19}}{\Gamma_{1109}}$ $\frac{\Gamma_{117}/\Gamma_{19}}{\Gamma_{1109}}$ $\frac{\Gamma_{117}/\Gamma_{19}}{\Gamma_{1109}}$ $\frac{\Gamma_{117}/\Gamma_{19}}{\Gamma_{1109}}$ $\frac{\Gamma_{117}/\Gamma_{19}}{\Gamma_{1109}}$ $\frac{\Gamma_{117}/\Gamma_{19}}{\Gamma_{1109}}$ $\frac{\Gamma_{117}/\Gamma_{19}}{\Gamma_{1109}}$ $\frac{\Gamma_{117}/\Gamma_{19}}{\Gamma_{1109}}$ $\frac{\Gamma_{117}/\Gamma_{19}}{\Gamma_{1109}}$ $\frac{\Gamma_{117}/\Gamma$	0.16 \pm 0.06 67 ANJOS 91 E691 γ Be 80–240 GeV 67 The factor 100 at the top of column 2 of Table I of ANJOS 91 should be omitted. $\Gamma(K^0K^-\pi^+)/\Gamma(K^0\pi^+\pi^-) \qquad \qquad \Gamma_{119}/\Gamma_{20}$ $\frac{F_{ALUE}}{NALUE} \qquad \frac{EVTS}{NALUE} \qquad \frac{DOCUMENT\ ID}{NALUE} \qquad \frac{TECN}{NALUE} \qquad \frac{COMMENT}{NALUE} \qquad \frac{TECN}{NALUE} \qquad \frac{COMMENT}{NALUE} \qquad COMME$
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$\frac{ALUE}{0.003}$ $\frac{DOCUMENT\ ID}{0.0004}$ $\frac{TECN}{\pi}$ $\frac{COMMENT}{\pi}$ $$	0.16 \pm 0.06 67 ANJOS 91 E691 γ Be 80-240 GeV 67 The factor 100 at the top of column 2 of Table I of ANJOS 91 should be omitted. $\Gamma(K^0K^-\pi^+)/\Gamma(\overline{K^0}\pi^+\pi^-)$ $\Gamma_{119}/\Gamma_{119}/\Gamma_{119}$ Γ_{119}/Γ_{119
$\frac{AUE}{0.0038}$ 64 BARLAG 92C ACCM π ⁻ Cu 230 GeV 64 BARLAG 92C computes the branching fraction using topological normalization. (π ⁺ π ⁺ π ⁺ π ⁻ π ⁻ π ⁻)/Γ _{total} Γ ₁₁₆ /Γ 4ΔUE Γ _{0.0003} 65 BARLAG 92C ACCM π ⁻ Cu 230 GeV 7.5 BARLAG 92C computes the branching fraction using topological normalization. Hadronic modes with a K \overline{K} pair Γ117/Γ19 4ΔUE Γ17/Γ(K ⁻ π ⁺) Γ(K ⁺ κ ⁻)/Γ(K ⁻ π ⁺) Γ17/Γ19 4ΔUE Γ19/Γ(K ⁻ π ⁺) Γ17/Γ19 4ΔUE Γ19/Γ(K ⁻ π ⁺) Γ17/Γ19 4ΔUE Γ19/Γ(K ⁻ π ⁺) Γ109 ±0.0033 OUR AVERAGE Γ109 ±0.003 ±0.003 3317 AITALA 98C E791 π ⁻ nucleus, 500 GeV 7.109 ±0.007 ±0.009 581 FRABETTI 94C E687 γBe \overline{E}_{7} = 220 GeV 7.109 ±0.007 ±0.009 581 FRABETTI 94C E687 γBe \overline{E}_{7} = 220 GeV 7.109 ±0.007 ±0.009 193 ADAMOVICH 92 OMEG π ⁻ 340 GeV 138 ±0.027 ±0.010 155 FRABETTI 92 E687 γBe 16 ±0.05 34 ALVAREZ 91B NA14 Photoproduction 10 ±0.05 34 ALVAREZ 91B NA14 Photoproduction 10 ±0.02 ±0.01 131 ALBRECHT 90 ARG e ⁺ e ⁻ ≈ 10 GeV 117 ±0.010 ±0.007 249 ALEXANDER 90 CLEO e ⁺ e ⁻ 10.5-11 GeV	0.16 \pm 0.06 67 ANJOS 91 E691 γ Be 80-240 GeV 67 The factor 100 at the top of column 2 of Table I of ANJOS 91 should be omitted. $\Gamma(K^0K^-\pi^+)/\Gamma(K^0\pi^+\pi^-) \qquad \qquad \Gamma_{119}/\Gamma_{120}/\Gamma_{120}$ 0.118 \pm 0.018 OUR FIT Error includes scale factor of 1.3. 0.108 \pm 0.019 61 AMMAR 91 CLEO $e^+e^-\approx 10.5$ GeV 0.16 \pm 0.03 \pm 0.02 39 ALBRECHT 90c ARG $e^+e^-\approx 10$ GeV $\Gamma(K^*(892)^0K^0)/\Gamma(K^-\pi^+) \qquad \qquad \Gamma_{139}/\Gamma_{120}/\Gamma_{1$
$\frac{ALUE}{0.003} + 0.0041$ $\frac{ALUE}{0.0038}$ $\frac{ACUE}{0.0038}$	0.16 \pm 0.06 67 ANJOS 91 E691 γ Be 80-240 GeV 67 The factor 100 at the top of column 2 of Table I of ANJOS 91 should be omitted. $\Gamma(K^0K^-\pi^+)/\Gamma(\overline{K^0}\pi^+\pi^-) \qquad \Gamma_{119}/\Gamma_$
$\frac{1}{4}$ $$	0.16 ±0.06 67 ANJOS 91 E691 γBe 80-240 GeV 67 The factor 100 at the top of column 2 of Table I of ANJOS 91 should be omitted. Γ($K^0K^-\pi^+$)/Γ($K^0\pi^+\pi^-$) VALUE 0.118±0.018 OUR FIT Error includes scale factor of 1.3. 0.108±0.019 61 AMMAR 91 CLEO $e^+e^-\approx 10.5$ GeV 0.16 ±0.03 ±0.02 39 ALBRECHT 90C ARG $e^+e^-\approx 10.5$ GeV Γ(K^0 (892) $^0K^0$)/Γ($K^-\pi^+$) Unseen decay modes of the K^0 (892) 0 are included. VALUE • • • We do not use the following data for averages, fits, limits, etc. • • • 0.00 $^+$ 0.03 68 ANJOS 91 E691 γBe 80-240 GeV Γ(K^0 (892) $^0K^0$)/Γ($K^0\pi^+\pi^-$) Unseen decay modes of the K^0 (892) 0 are included. Γ(K^0 (892) $^0K^0$)/Γ($K^0\pi^+\pi^-$) Unseen decay modes of the K^0 (892) 0 are included. Γ(K^0 (892) $^0K^0$)/Γ($K^0\pi^+\pi^-$) Unseen decay modes of the K^0 (892) 0 are included. VALUE CLY DOCUMENT ID TECN COMMENT COMMENT COMMENT C.0.029 90 AMMAR 91 CLEO $e^+e^-\approx 10.5$ GeV • • • We do not use the following data for averages, fits, limits, etc. • • • C.0.03 90 ALBRECHT 90C ARG $e^+e^-\approx 10.5$ GeV K^0 (892) K^0)/Γ($K^-\pi^+$) Unseen decay modes of the K^0 (892) K^0 are included. VALUE CLY DOCUMENT ID TECN COMMENT COMMENT Unseen decay modes of the K^0 (892) K^0 are included. VALUE Unseen decay modes of the K^0 (892) K^0 0 are included. VALUE DOCUMENT ID TECN COMMENT Unseen decay modes of the K^0 (892) K^0 0 are included. VALUE DOCUMENT ID TECN COMMENT Unseen decay modes of the K^0 (892) K^0 0 are included. VALUE DOCUMENT ID TECN COMMENT OMMENT DOSUMENT ID TECN COMMENT
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$\frac{AUVE}{0.0092} + \frac{0.0041}{0.0038} = \frac{64 \text{ BARLAG}}{64 \text{ BARLAG}} = \frac{92\text{C ACCM}}{\pi} = \frac{\text{COMMENT}}{\text{C U 230 GeV}}$ $\frac{64 \text{ BARLAG}}{64 \text{ BARLAG}} = \frac{92\text{C ACCM}}{\pi} = \frac{\pi}{\text{C U 230 GeV}}$ $\frac{(\pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{-})}{\text{F total}} = \frac{\text{DOCUMENT ID}}{\pi} = \frac{\text{TECN}}{\pi} = \frac{\text{COMMENT}}{\pi}$ $\frac{(\pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{-})}{\pi} = \frac{\text{DOCUMENT ID}}{\pi} = \frac{\text{TECN}}{\pi} = \frac{\text{COMMENT}}{\pi}$ $\frac{(\pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{-})}{\pi} = \frac{\pi}{\pi} = \frac{\pi}{\pi}$ $\frac{(\pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{-})}{\pi} = \frac{\pi}{\pi} = \frac{\pi}{\pi}$ $\frac{(\pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{-})}{\pi} = \frac{\pi}{\pi} = \frac{\pi}{\pi}$ $\frac{(\pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{-})}{\pi} = \frac{\pi}{\pi} = \frac{\pi}{\pi} = \frac{\pi}{\pi}$ $\frac{(\pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{-})}{\pi} = \frac{\pi}{\pi} = \frac{\pi}{\pi} = \frac{\pi}{\pi}$ $\frac{(\pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{-})}{\pi} = \frac{\pi}{\pi} = \frac{\pi}{\pi} = \frac{\pi}{\pi} = \frac{\pi}{\pi}$ $\frac{(\pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{-})}{\pi} = \frac{\pi}{\pi} = \frac{\pi}{\pi}$	0.16 \pm 0.06 67 ANJOS 91 E691 γ Be 80-240 GeV 67 The factor 100 at the top of column 2 of Table I of ANJOS 91 should be omitted. $\Gamma(K^0K^-\pi^+)/\Gamma(\overline{K^0}\pi^+\pi^-) \qquad \Gamma_{119}/\Gamma_{NLUE} \qquad \Gamma_{NLUE} \qquad \Gamma_{N$
1019 ± 0.003 $+$ 0.003 $+$ 0.003 $+$ 0.003 $+$ 0.003 $+$ 0.003 $+$ 0.003 $+$ 0.003 $+$ 0.003 $+$ 0.003 $+$ 0.003 $+$ 0.003 $+$ 0.003 $+$ 0.003 $+$ 0.003 $+$ 0.003 $+$ 0.004 $+$ 0.003 $+$ 0.004 $+$ 0.003 $+$ 0.004 $+$ 0.003 $+$ 0.004 $+$ 0.003 $+$ 0.004 $+$ 0.003 $+$ 0.004 $+$ 0.003 $+$ 0.004 $+$ 0.003 $+$ 0.004 $+$ 0.007 $+$ 0.007 $+$ 0.009	0.16 \pm 0.06 67 ANJOS 91 E691 γ Be 80-240 GeV 67 The factor 100 at the top of column 2 of Table I of ANJOS 91 should be omitted. $\Gamma(K^0K^-\pi^+)/\Gamma(K^0\pi^+\pi^-) \qquad \Gamma_{119}/\Gamma_{11$
$\frac{AUF}{0.003} = \frac{DOCUMENT\ ID}{64\ BARLAG} = \frac{FCN}{92C\ ACCM} \pi^- Cu\ 230\ GeV$ $\frac{(\pi^+\pi^+\pi^+\pi^-\pi^-\pi^-)/\Gamma_{total}}{F_{116}/\Gamma_{total}} = \frac{F_{116}/\Gamma_{total}}{F_{116}/\Gamma_{total}} = \frac{F_{116}/\Gamma_{tot$	0.16 \pm 0.06 67 ANJOS 91 E691 γ Be 80-240 GeV 67 The factor 100 at the top of column 2 of Table I of ANJOS 91 should be omitted. $\Gamma(K^0K^-\pi^+)/\Gamma(K^0\pi^+\pi^-) \qquad \Gamma_{119}/\Gamma_{11$
$\frac{ALUE}{0.0038} = \frac{DOCUMENT\ ID}{64\ BARLAG} = \frac{JECN}{92C\ ACCM} \pi^- Cu\ 230\ GeV$ $\frac{(\pi^+\pi^+\pi^+\pi^-\pi^-\pi^-)}{\Gamma_{1004a}} = \frac{DOCUMENT\ ID}{\Gamma_{110}/\Gamma_{110}/\Gamma_{110}} = \frac{\Gamma_{110}/\Gamma_{110}}{\Gamma_{110}/\Gamma_{110}/\Gamma_{110}} = \frac{\Gamma_{110}/\Gamma_{110}/\Gamma_{110}}{\Gamma_{110}/\Gamma_{1$	0.16 \pm 0.06 67 ANJOS 91 E691 γ Be 80-240 GeV 67 The factor 100 at the top of column 2 of Table I of ANJOS 91 should be omitted. $\Gamma(K^0K^-\pi^+)/\Gamma(K^0\pi^+\pi^-) \qquad \Gamma_{119}/\Gamma_{11$
$\frac{ALUE}{0.0038} = \frac{DOCUMENT ID}{64 \text{ BARLAG}} = \frac{TECN}{20 \text{ ACCM } \pi^- \text{ Cu } 230 \text{ GeV}}$ $\frac{1}{64 \text{ BARLAG}} = \frac{1}{20 \text{ COMMENT}}$ $\frac{1}{64 \text{ COMMENT}} = \frac{1}{20 \text{ COMMENT}$	0.16 \pm 0.06 67 ANJOS 91 E691 γ Be 80-240 GeV 67 The factor 100 at the top of column 2 of Table I of ANJOS 91 should be omitted. $\Gamma(K^0K^-\pi^+)/\Gamma(K^0\pi^+\pi^-) \qquad \Gamma_{119}/\Gamma_{11$
20192 + 0.0041 20192 + 0.0041 304 BARLAG 305 ABRLAG 306 BARLAG 307 ACCM π^- Cu 230 GeV 307 ACCM π^- Cu 230 GeV 308 BARLAG 307 ACCM π^- Cu 230 GeV 308 BARLAG 308 ARLAG 308 ARRAG 309 ARRAG	0.16 \pm 0.06 67 ANJOS 91 E691 γ Be 80-240 GeV 67 The factor 100 at the top of column 2 of Table I of ANJOS 91 should be omitted. $\Gamma(K^0K^-\pi^+)/\Gamma(K^0\pi^+\pi^-)$ Γ_{119}/Γ_{11
2019 ± 0.0041 2019 ± 0.0038 64 BARLAG 64 BARLAG 65 BARLAG 65 BARLAG 65 BARLAG 65 BARLAG 66 BARLAG 66 BARLAG 66 BARLAG 67 BARLAG 67 BARLAG 68 BARLAG 69 BARLAG 69 BARLAG 60 B	0.16 \pm 0.06 67 ANJOS 91 E691 γ Be 80-240 GeV 67 The factor 100 at the top of column 2 of Table I of ANJOS 91 should be omitted. $\Gamma(K^0K^-\pi^+)/\Gamma(K^0\pi^+\pi^-) \qquad \Gamma_{119}/\Gamma_{NLUE} \qquad \Gamma_{NLUE} \qquad \Gamma_{NLUE$
20 COMMENT 1D 1ECN COMMENT 1.0192 + 0.0041 1.0192 + 0.0038 64 BARLAG 92c ACCM π ⁻ Cu 230 GeV 64 BARLAG 92c computes the branching fraction using topological normalization. 1. (π + π + π + π - π - π)/Γtotal 1. (π + π + π + π - π - π)/Γtotal 1. (π + π + π + π - π - π)/Γtotal 1. (π + π + π + π - π - π)/Γtotal 1. (π + π + π + π - π - π)/Γtotal 1. (π + π + π + π - π - π)/Γtotal 1. (π + π + π + π - π - π)/Γtotal 1. (π + π + π + π - π - π)/Γtotal 1. (π + π + π + π - π - π)/Γtotal 1. (π + π + π + π - π - π)/Γtotal 1. (π + π + π + π - π - π)/Γtotal 1. (π + π + π + π - π - π)/Γtotal 1. (π + π + π + π - π - π)/Γtotal 1. (π + π + π + π - π - π)/Γtotal 1. (π + π + π + π - π - π)/Γtotal 1. (π + π + π + π - π - π)/Γtotal 1. (π + π - π - π - π - π - π - π - π - π -	0.16 \pm 0.06 67 ANJOS 91 E691 γ Be 80-240 GeV 67 The factor 100 at the top of column 2 of Table I of ANJOS 91 should be omitted. $\Gamma(K^0K^-\pi^+)/\Gamma(K^0\pi^+\pi^-)$ $\Gamma_{119}/\Gamma_{NALUE}$ $EVTS$ DOCUMENT ID TECN COMMENT 0.118 \pm 0.018 OUR FIT Error includes scale factor of 1.3. 0.108 \pm 0.019 61 AMMAR 91 CLEO $e^+e^-\approx 10.5$ GeV 0.16 \pm 0.03 \pm 0.02 39 ALBRECHT 90C ARG $e^+e^-\approx 10$ GeV $\Gamma(K^*(892)^0K^0)/\Gamma(K^-\pi^+)$ Unseen decay modes of the $K^*(892)^0$ are included. $\frac{DOCUMENT\ ID}{VALUE}$ $\frac{TECN}{N}$ COMMENT $TECN$

(K ⁰ K π ⁺ nonresc	nant)/F						Γ_{122}/Γ_{19}
ALUE		70 ANJOS	ENT ID			COMMEN	
1 .06±0.06 ⁷⁰ The factor 100 at th	a ton of a				E691		-240 GeV
		Joiumn 2 Oi	Ianiei	UI A	N3O3 9.	L Snould	be omitted.
'(Κ º Κ+π-)/Γ(Κ-	-π ⁺)						Γ ₁₂₃ /Γ ₁₉
ALUE .129±0.025 OUR FIT		DOCUM	<u>ENT ID</u>		TECN	COMMEN	<u> </u>
.10 ±0.05		71 ANJOS	; ´ ·	´91	E691	γBe 80-	-240 GeV
⁷¹ The factor 100 at th	ne top of o	column 2 of	Table I	of A	NJOS 9	i should	be omitted.
·(Κ ⁰ Κ+π ⁻)/Γ(Κ ⁰)_+\				100		Γ ₁₂₃ /Γ ₂₁
ALUE	EVTS	DOCUM	ENT ID		TECN	COMME	,
.091±0.018 OUR FIT							
.098±0.020	55	AMMA	·R	91	CLEO	e+e-	≈ 10.5 GeV
(K*(892)0K0)/r($K^-\pi^+$						Γ ₁₄₁ /Γ ₁₉
Unseen decay mo	•						
ALUE	 .					COMME	
• We do not use the	he followin		_	s, fits	, limits,	etc. • •	•
.00+0.04 -0.00		72 ANJOS	5	91	E691	γ Be 80-	-240 GeV
⁷² The factor 100 at ti	he top of	column 2 of	f Table I	of A	NJOS 9	1 should	be omitted.
(K*(892) ⁰ κ̄ ⁰)/Γ(Γ ₁₄₁ /Γ ₂₁
Unseen decay mo			are incl	uded			' 141/ ' 21
ALUE	<u>CL%</u>					COMME	<u>/T</u>
<0.015	90	AMMA	·R	91	CLEO	e+e-	≈ 10.5 GeV
(K*(892)-K+)/F	(K+	١					Γ ₁₄₂ /Γ ₁₉
Unseen decay mo			are inc	:luded	t.		142/119
ALUE						COMME	IT
• • We do not use ti	he followir	g data for	average	s, fits	, limits,	etc. • •	•
0.00 ^{+0.03}		73 ANJOS	5	91	E691	γ Be 80-	-240 GeV
-0.00							
	he top of	column 2 of	f Table !	of A	NJOS a	1 should	be omitted
⁷³ The factor 100 at ti			f Table I	of A	NJOS 9	1 should	
⁷³ The factor 100 at th (K*(892) – K +)/Γ	$(K^0\pi^+)$	r ⁻)				1 should	
⁷³ The factor 100 at th -(K*(892) – K +)/Γ Unseen decay mo	$(K^0\pi^+)$ odes of the	r [—]) : K*(892) [—]	are inc	ludec	i.		Γ ₁₄₂ /Γ ₂₁
⁷³ The factor 100 at the fa	$(K^0\pi^+)$	r ⁻)	are inc	dudec	i. <u>TECN</u>	COMME	Γ ₁₄₂ /Γ ₂₁
73 The factor 100 at the factor 100 at the factor 100 at the factor fac	des of the $\frac{EVTS}{12}$	r ") : K*(892) ⁻ <u>DOCUM</u> AMMA	are inc IENT ID	dudec	i. <u>TECN</u>	COMME	Γ ₁₄₂ /Γ ₂₁ <i>γτ</i> ≈ 10.5 GeV
73 The factor 100 at the factor 100 at the factor 100 at the factor fac	des of the $\frac{EVTS}{12}$	r) : K*(892) ⁻ <u>DOCUM</u> AMMA ((Κ π ⁺)	are inc IENT ID AR	cluded 91	i. <u>TECN</u> CLEO	<u>COMMEI</u> e ⁺ e ⁻	Γ ₁₄₂ /Γ ₂₁
73 The factor 100 at the $(K^*(892)^-K^+)/\Gamma$ Unseen decay module034 \pm 0.019 $(K^0K^+\pi^-$ nonrese ALUE	des of the $\frac{EVTS}{12}$	κ*(892)* <u>DOCUM</u> AMMA (K*-π*) <u>DOCUM</u>	are ind IENT ID AR IENT ID	oludeo 91	i. <u>TECN</u> CLEO <u>TECN</u>	COMME!	Γ ₁₄₂ /Γ ₂₁ ≈ 10.5 GeV Γ ₁₂₆ /Γ ₁₉
73 The factor 100 at the factor 100 at the factor 100 at the factor for the fact	$(K^0\pi^+)$ des of the $\frac{EVTS}{12}$ conant)/ Γ	κ ⁻) • K*(892) ⁻ <u>DOCUM</u> AMMA • (K ⁻ π ⁺) <u>DOCUM</u> 74 ANJOS	are inc IENT ID AR IENT ID	91 91	i. TECN CLEO TECN E691	<u>COMME</u> e ⁺ e ⁻ <u>COMME</u> γ Be 80	Γ ₁₄₂ /Γ ₂₁ VT ≈ 10.5 GeV Γ ₁₂₆ /Γ ₁₉ VT -240 GeV
73 The factor 100 at the fact	des of the EVTS 12 pnant)/[κ ⁻) • K*(892) ⁻ <u>DOCUM</u> AMMA • (K ⁻ π ⁺) <u>DOCUM</u> 74 ANJOS	are inc IENT ID AR IENT ID	91 91	i. TECN CLEO TECN E691	<u>COMME</u> e ⁺ e ⁻ <u>COMME</u> γ Be 80	Γ ₁₄₂ /Γ ₂₁ VT ≈ 10.5 GeV Γ ₁₂₆ /Γ ₁₉ VT -240 GeV
73 The factor 100 at the fact	des of the EVTS 12 pnant)/[κ ⁻) • K*(892) ⁻ <u>DOCUM</u> AMMA • (K ⁻ π ⁺) <u>DOCUM</u> 74 ANJOS	are inc IENT ID AR IENT ID	91 91	i. TECN CLEO TECN E691	<u>COMME</u> e ⁺ e ⁻ <u>COMME</u> γ Be 80	Γ ₁₄₂ /Γ ₂₁ 77 ≈ 10.5 GeV Γ ₁₂₆ /Γ ₁₉ 77 -240 GeV be omitted.
73 The factor 100 at the fact	des of the EVTS 12 conant $/\Gamma$	** (892) -	are inc IENT ID AR IENT ID 6 6 6 Table I	91 91 of A	I. TECN CLEO TECN E691 NJOS 9	COMMEI c+e- COMMEI γ Be 80- 1 should	Γ ₁₄₂ /Γ ₂₁ 77 ≈ 10.5 GeV Γ ₁₂₆ /Γ ₁₉ 77 -240 GeV be omitted. Γ ₁₂₇ /Γ ₂₉
73 The factor 100 at the fact	des of the $\frac{EVTS}{12}$ conant)/ Γ	π ⁻) • K*(892) ⁻ <u>DOCUM</u> AMMA • (K ⁻ π ⁺) <u>DOCUM</u> 74 ANJOS	are inc IENT ID AR IENT ID 6 6 6 Table I	91 91 of A	1. <u>TECN</u> CLEO <u>TECN</u> E691 NJOS 9	COMMEI c+e- COMMEI γ Be 80- 1 should	Γ ₁₄₂ /Γ ₂₁ 77 ≈ 10.5 GeV Γ ₁₂₆ /Γ ₁₉ 77 -240 GeV be omitted. Γ ₁₂₇ /Γ ₂₉
73 The factor 100 at ti - ($K^*(892)^-K^+$)/Γ Unseen decay mo ALUE 0.034±0.019 - ($K^0K^+\pi^-$ nonresc ALUE 0.10+0.06 74 The factor 100 at ti - ($K^+K^-\pi^0$)/Γ (K^- ALUE 0.0095±0.0026	$(K^0\pi^+)^{1/2}$ des of the $\frac{EVTS}{12}$ ponant)/ Γ the top of $\frac{EVTS}{\pi^+\pi^0}$ $\frac{EVTS}{151}$	** (892) -	are inc IENT ID AR IENT ID 6 6 6 Table I	91 91 of A	I. TECN CLEO TECN E691 NJOS 9	COMMEI c+e- COMMEI γ Be 80- 1 should	F ₁₄₂ /F ₂₁ ≥ 10.5 GeV F ₁₂₆ /F ₁₉ ≥ 7 240 GeV be omitted. F ₁₂₇ /F ₂₉ ≥ 7 × 7 × 7 × 7 × 7 × 7 × 7
73 The factor 100 at the fact	$(K^0\pi^+)^{1/2}$ des of the $\frac{EVTS}{12}$ ponant)/ Γ the top of $\frac{EVTS}{\pi^+\pi^0}$ $\frac{EVTS}{151}$	*** ** K* (892)** ** ** ** ** ** ** ** ** ** ** ** **	are inc IENT ID AR IENT ID 6 6 6 Table I	91 91 of A	I. TECN CLEO TECN E691 NJOS 9 TECN CLE2	COMMEI γ Be 80 1 should COMMEI e+e-	Γ_{142}/Γ_{21} $\approx 10.5 \text{ GeV}$ Γ_{126}/Γ_{19} VT $\sim T(25)$ T_{128}/Γ VT
73 The factor 100 at the fact	$(K^0\pi^+)^{1/2}$ des of the $\frac{EVTS}{12}$ ponant)/ Γ the top of $\frac{EVTS}{\pi^+\pi^0}$ $\frac{EVTS}{151}$	*** ** K* (892)** ** ** ** ** ** ** ** ** ** ** ** **	are inc IENT ID RR IENT ID F Table I	91 91 of A	I. TECN CLEO TECN E691 NJOS 9 TECN CLE2	COMMEI γ Be 80 1 should COMMEI e+e-	Γ_{142}/Γ_{21} $\approx 10.5 \text{ GeV}$ Γ_{126}/Γ_{19} $= -240 \text{ GeV}$ be omitted. Γ_{127}/Γ_{29} $= \tau(45)$
73 The factor 100 at ti $-(K^{*}(892)^{-}K^{+})/\Gamma$ Unseen decay mo $ALUE$ 0.034 ± 0.019 $-(K^{0}K^{+}\pi^{-}\text{ nonresc})$ $ALUE$ 1.10 ± 0.06 $-(K^{0}K^{+}\pi^{-}\pi^{0})/\Gamma(K^{-}ALUE)$ 0.0095 ± 0.0026 $-(K_{S}^{0}K_{S}^{0}\pi^{0})/\Gamma_{\text{total}}$ $ALUE$ <0.00059	$(K^0\pi^+)^{1/2}$ des of the $\frac{EVTS}{12}$ ponant)/ Γ the top of $\frac{EVTS}{\pi^+\pi^0}$ $\frac{EVTS}{151}$	*** ** K* (892)** ** ** ** ** ** ** ** ** ** ** ** **	are inc IENT ID RR IENT ID F Table I	91 91 of A	I. TECN CLEO TECN E691 NJOS 9 TECN CLE2	COMMEI γ Be 80 1 should COMMEI e+e-	Γ_{142}/Γ_{21} VT ≈ 10.5 GeV Γ_{126}/Γ_{19} VT VT ≈ $T(45)$ Γ_{128}/Γ_{19}
73 The factor 100 at ti $-(K^{+}(892)^{-}K^{+})/\Gamma$ Unseen decay mo $ALUE$ 1.034 \pm 0.019 $-(K^{0}K^{+}\pi^{-}\text{ nonresc})$ $-(ALUE$ 1.10 \pm 0.06 $-(K^{0}K^{+}\pi^{-}\pi^{0})/\Gamma(K^{-}K^{-}K^{0})$ 1.0095 \pm 0.0026 $-(K^{0}S^{-}S^{-}\pi^{0})/\Gamma_{\text{total}}$ $-(K^{0}S^{-}S^{-}\pi^{0})/\Gamma_{\text{total}}$ 1.10 \pm 0.0059 $-(K^{0}S^{-}S^{-}\pi^{0})/\Gamma_{\text{total}}$	$(K^0\pi^+)^{1/2}$ des of the $\frac{EVTS}{12}$ ponant)/ Γ the top of $\frac{EVTS}{\pi^+\pi^0}$ $\frac{EVTS}{151}$	*** *** *** *** ** ** ** ** **	are inc IENT ID F Table I IENT ID R	91 91 of A	I. TECN CLEO TECN E691 NJOS 9 TECN CLE2 TECN CLE2	COMMEI γ Be 80 1 should COMMEI e+e-	Γ_{142}/Γ_{21} VT ≈ 10.5 GeV Γ_{126}/Γ_{19} VT T_{127}/Γ_{29} VT ≈ $T(4S)$ T_{128}/Γ VT ≈ $T(4S)$
73 The factor 100 at ti $\Gamma(K^{+}(892)^{-}K^{+})/\Gamma$ Unseen decay mo $ALUE$ 0.034 ± 0.019 $\Gamma(K^{0}K^{+}\pi^{-}\text{ nonresc}$ $ALUE$ $0.10^{+}0.06$ $7^{4}\text{ The factor 100 at ti}$ $\Gamma(K^{+}K^{-}\pi^{0})/\Gamma(K^{-}K^{-}K^{-}K^{0})$ $\Gamma(K^{0}S^{0}\pi^{0})/\Gamma_{\text{total}}$ $ALUE$ <0.00059 $\Gamma(\phi\pi^{0})/\Gamma_{\text{total}}$ $ALUE$	$(K^0\pi^+)^{-1}$ ded so of the deds of the series 12 conant)/ Γ the top of Γ	*** *** *** *** ** ** ** ** **	are inc IENT ID AR S F Table I R RENT ID R	91 91 of A 968	I. TECN CLEO TECN E691 NJOS 9 TECN CLE2 TECN CLE2	COMMEI c + c -	Γ_{142}/Γ_{21} VT ≈ 10.5 GeV Γ_{126}/Γ_{19} VT T_{127}/Γ_{29} VT ≈ $T(4S)$ T_{128}/Γ VT ≈ $T(4S)$
73 The factor 100 at ti 7 (K^{*} (892) $^{-}$ K^{+})/Γ Unseen decay mo ALUE 0.034 \pm 0.019 7 (K^{0} K^{+} π^{-} nonresc ALUE 0.10 $^{+0.06}$ 74 The factor 100 at ti 74 The factor 100 at ti 74 The factor 100 at ti 74 (K^{+} K^{-} π^{0})/Γ (K^{-} ALUE 0.0095 \pm 0.0026 74 (K^{0} K^{0} K^{0})/Γ total ALUE 0.00059 74 (K^{0} K^{0})/Γ total ALUE 0.0014	$(K^0\pi^+)^{-1}$ does of the deso of the $\frac{EVTS}{12}$ $\frac{EVTS}{12}$ $\frac{EVTS}{12}$ the top of $\frac{EVTS}{151}$ $\frac{EVTS}{151}$	K*(892)* DOCUM AMMA T(K**-π*+) DOCUM T4 ANJOS Column 2 ol DOCUM ASNEF	are inc IENT ID AR S F Table I R RENT ID R	91 91 of A 968	TECN CLEO TECN E691 NJOS 9 TECN CLE2 TECN CLE2	COMMEI c + c -	Γ_{142}/Γ_{21} VT ≈ 10.5 GeV Γ_{126}/Γ_{19} VT T_{-240} GeV be omitted. Γ_{127}/Γ_{29} VT T_{128}/Γ VT T_{128}/Γ VT T_{143}/Γ VT VT VT VT VT VT VT V
73 The factor 100 at ti $-(K^{*}(892)^{-}K^{+})/\Gamma$ Unseen decay mo ALUE 0.034 ± 0.019 $-(K^{0}K^{+}\pi^{-}\text{ nonresc})$ ALUE 1.10 + 0.06 $-(K^{0}K^{+}\pi^{-}\text{ nonresc})$ 74 The factor 100 at ti $-(K^{0}K^{-}K^{-}\pi^{0})/\Gamma(K^{-}K^{-}K^{-}K^{-}K^{-}K^{-}K^{-}K^{-}$	$(K^0\pi^+)^{-1}$ ded so of the deds of the constant $(K^0\pi^+)^{-1}$ the top of $(K^0\pi^+)^{-1}$	*** *** *** *** ** ** ** ** **	are incident	91 91 968 968	I. IECN CLE2 TECN CLE2 TECN CLE2 TECN CLE2	COMMEI γ Be 80 1 should COMMEI e+e- COMMEI e-e- COM	$Γ_{142}/Γ_{21}$ VT ≈ 10.5 GeV $Γ_{126}/Γ_{19}$ VT VT ≈ $T(4S)$
73 The factor 100 at ti $-(K^{*}(892)^{-}K^{+})/\Gamma$ Unseen decay mo $ALUE$ 0.034 ± 0.019 $-(K^{0}K^{+}\pi^{-}\text{ nonresc}$ $ALUE$ $0.10^{+}0.06$ 7^{4} The factor 100 at ti $-(K^{+}K^{-}\pi^{0})/\Gamma(K^{-}ALUE)$ 0.0095 ± 0.0026 $-(K^{0}S^{0}S^{0})/\Gamma_{\text{total}}$ $ALUE$ <0.00059 $-(\phi\pi^{0})/\Gamma_{\text{total}}$ $ALUE$ <0.00014	$(K^0\pi^+)^{-1}$ does of the deso of the $\frac{EVTS}{12}$ $\frac{EVTS}{12}$ $\frac{EVTS}{12}$ the top of $\frac{EVTS}{151}$ $\frac{EVTS}{151}$	*** *** *** *** ** ** ** ** **	are incident identification in the second identification in the second identification in the second identification identificat	91 91 of A 968	I. IECN CLE2 TECN CLE2 TECN CLE2 TECN CLE2	COMMEI c+e- COMMEI c-e- COMMEI COMME	$Γ_{142}/Γ_{21}$ VT ≈ 10.5 GeV $Γ_{126}/Γ_{19}$ VT VT ≈ $T(4S)$
73 The factor 100 at ti $-(K^{\bullet}(892)^{-}K^{+})/\Gamma$ Unseen decay mo $ALUE$ 0.034 ± 0.019 $-(K^{0}K^{+}\pi^{-}\text{ nonreso})$ $ALUE$ $0.10+0.06$ $7^{4}\text{ The factor 100 at ti}$ $-(K^{+}K^{-}\pi^{0})/\Gamma(K^{-}K^{-}K^{0})$ $-(K^{0}S^{0}K^{0}\pi^{0})/\Gamma_{\text{total}}$ $ALUE$ 0.0005 ± 0.0026 $-(K^{0}S^{0}K^{0}\pi^{0})/\Gamma_{\text{total}}$ $-(ALUE)$ 0.0005 $-(\Phi\pi^{0})/\Gamma_{\text{total}}$ $-(\Phi\pi^{0})/\Gamma_{\text{total}}$ $-(ALUE)$ $-(A$	$(K^0\pi^+)$	K*(892)* DOCUM AMMA F(K*-π+) DOCUM 74 ANJOS Column 2 ol DOCUM ASNEF DOCUM ASNEF DOCUM ALBRE	are incident identification in the second identification in the second identification in the second identification identificat	91 91 of A 968	I. IECN CLE2 TECN CLE2 TECN CLE2 TECN CLE2 TECN CLE2	COMMEI c+e- COMMEI c-e- COMMEI COMME	T ₁₄₂ T ₂₁
73 The factor 100 at ti $-(K^{+}(892)^{-}K^{+})/\Gamma$ Unseen decay mo $ALUE$ 1.034 \pm 0.019 $-(K^{0}K^{+}\pi^{-}\text{ nonresc})$ $ALUE$ 1.10 \pm 0.06 -0.08 74 The factor 100 at ti $-(K^{+}K^{-}\pi^{0})/\Gamma(K^{-}K^{-}K^{0})/\Gamma(K^{-}K^{-}K^{0})/\Gamma(K^{-}K^{-}K^{0})/\Gamma(K^{-}K^{-}K^{0})/\Gamma(K^{-}K^{-}K^{0})/\Gamma(K^{-}K^{-}K^{0})/\Gamma(K^{-}K^{-}K^{0})/\Gamma(K^{-}K^{-}K^{0})/\Gamma(K^{-}K^{-}K^{0})/\Gamma(K^{-}K^{-}K^{0})/\Gamma(K^{-}K^{-}K^{0})/\Gamma(K^{-}K^{-}K^{0})/\Gamma(K^{-}K^{-}K^{0})/\Gamma(K^{-}K^{-}K^{0})/\Gamma(K^{-}K^{-}K^{0})/\Gamma(K^{-}K^{-}K^{-}K^{0})/\Gamma(K^{-}K^{-}K^{-}K^{-}K^{-}K^{-}K^{-}K^{-}$	$\frac{(K^0\pi^+)^2}{(K^0\pi^+)^2}$ deds of the deds of the LeVTS 12 ponant)/ Γ the top of $\frac{\pi^+\pi^0}{(K^0\pi^+)^2}$ 151 151 151 200 200 200 200 200 200 200 200 200 20	*** *** ** ** ** ** ** ** ** ** ** **	are incident	91 91 of A 968 968	I. IECN CLE2 TECN CLE2 TECN CLE2 TECN CLE2 TECN CLE2 TECN ARG	COMMEI γ Be 80 1 should COMMEI ε+ ε- COMMEI ε+ Ε- COMMEI ε+ Ε- COMMEI ε+ Ε- COMMEI Ε- COM COM COM COM COM COM COM CO	T ₁₄₂ T ₂₁
73 The factor 100 at ti $-(K^{+}(892)^{-}K^{+})/\Gamma$ Unseen decay mo $ALUE$ 0.034 ± 0.019 $-(K^{0}K^{+}\pi^{-}\text{ nonresc}$ $ALUE$ $0.10^{+}0.06$ 7^{4} The factor 100 at ti $-(K^{+}K^{-}\pi^{0})/\Gamma(K^{-}ALUE$ 0.0095 ± 0.0026 $-(K^{0}S^{0}S^{0})/\Gamma\text{total}$ $ALUE$ <0.00059 $-(\phi\pi^{0})/\Gamma\text{total}$ $ALUE$ <0.0014 $-(\phi\eta)/\Gamma\text{total}$ $ALUE$ <0.0028 $-(\phi\omega)/\Gamma\text{total}$ $ALUE$ <0.0028	(K ⁰ π+1) ded of the ded of the control of the con	*** ** ** ** ** ** ** ** ** *	Table I	91 91 of A 96B 941	i. IECN CLEO IECN E691 NJOS 9 TECN CLE2 TECN CLE2 TECN ARG IECN ARG	COMMEI checker COMME	Γ_{142}/Γ_{21} VT ≈ 10.5 GeV Γ_{126}/Γ_{19} VT T_{120}/Γ_{29} VT ≈ $T(4S)$ T_{143}/Γ_{29} VT ≈ 10 GeV VT ≈ 10 GeV VT ≈ 10 GeV VT VT ≈ 10 GeV
73 The factor 100 at the control of	(K ⁰ π+1 (K	*** ** ** ** ** ** ** ** ** *	are incident	91 91 of A 96B 941	I. IECN CLE2 TECN CLE2 TECN CLE2 TECN CLE2 TECN CLE2 TECN ARG	COMMEI checker COMME	T ₁₄₂ T ₂₁
73 The factor 100 at ti $-(K^{+}(892)^{-}K^{+})/\Gamma$ Unseen decay mo ALUE 1.034 \pm 0.019 $-(K^{0}K^{+}\pi^{-}\text{ nonresc})$ ALUE 1.10 \pm 0.06 $-(K^{0}K^{+}\pi^{-}\pi^{0})/\Gamma(K^{-}K^{0}K^{0})/\Gamma(K^{0}K^{$	(K ⁰ π+1 (K	*** *** *** *** ** ** ** ** **	Table I Tab	91 91 96 96 96 941	I. IECN CLE2 TECN CLE2 TECN CLE2 TECN CLE2 TECN ARG TECN ARG	COMMEI c+e- COMMEI γ Be 80 1 should COMMEI c+e- COMMEI c- COMMEI	T ₁₄₂ T ₂₁
73 The factor 100 at ti $\Gamma(K^*(892)^-K^+)/\Gamma$ Unseen decay mo ALUE 1.034±0.019 $\Gamma(K^0K^+\pi^-\text{nonreso})$ ALUE 1.10+0.06 74 The factor 100 at ti $\Gamma(K^+K^-\pi^0)/\Gamma(K^-)$ ALUE 1.0095±0.0026 $\Gamma(K^0S^0)/\Gamma_{\text{total}}$ ALUE 1.00069 $\Gamma(\Phi\pi^0)/\Gamma_{\text{total}}$ ALUE 1.00028 $\Gamma(\Phi\pi^0)/\Gamma_{\text{total}}$ ALUE 1.00028 $\Gamma(\Phi\pi^0)/\Gamma_{\text{total}}$ 1.00028 $\Gamma(\Phi\pi^0)/\Gamma_{\text{total}}$ 1.00021 $\Gamma(K^+K^-\pi^+\pi^-)/\Gamma_{\text{ALUE}}$ 1.00021 $\Gamma(K^+K^-\pi^+\pi^-)/\Gamma_{\text{ALUE}}$ 1.00021 $\Gamma(K^+K^-\pi^+\pi^-)/\Gamma_{\text{ALUE}}$ 1.00021 $\Gamma(K^+K^-\pi^+\pi^-)/\Gamma_{\text{ALUE}}$ 1.00021 $\Gamma(K^+K^-\pi^+\pi^-)/\Gamma_{\text{ALUE}}$	(K ⁰ π+1) (ded so f the leaves of the leaves	*** ** ** ** ** ** ** ** ** *	Table I Tab	91 91 96 96 96 941	I. IECN CLE2 TECN CLE2 TECN CLE2 TECN CLE2 TECN ARG TECN ARG	COMMEI c+e- COMMEI γ Be 80 1 should COMMEI c+e- COMMEI c- COMMEI	T ₁₄₂ T ₂₁
73 The factor 100 at ti $-(K^{+}(892)^{-}K^{+})/\Gamma$ Unseen decay mo ALUE 1.034 \pm 0.019 $-(K^{0}K^{+}\pi^{-}\text{ nonresc})$ ALUE 1.10 \pm 0.06 74 The factor 100 at ti $-(K^{+}K^{-}\pi^{0})/\Gamma(K^{-}K^{-}K^{0})$ ALUE 1.0095 \pm 0.0026 $-(K^{0}K^{0}\pi^{0})/\Gamma_{\text{total}}$ ALUE 1.00059 $-(\phi\pi^{0})/\Gamma_{\text{total}}$ ALUE 1.00028 $-(\phi\pi^{0})/\Gamma_{\text{total}}$ ALUE 1.00021 $-(K^{+}K^{-}\pi^{+}\pi^{-})/\Gamma_{\text{ALUE}}$ 1.00334 \pm 0.0029 OUR ALUE	(K ⁰ π+1 (K	*** ** ** ** ** ** ** ** ** *	Tare Inc. Table I T	91 91 96 A 96 B 94 I	I I I I I I I I I I I I I I I I I I I	COMMEI c+e- COMMEI γ Be 80 1 should COMMEI c+e- COMMEI c- COMMEI	T ₁₄₂ T ₂₁
73 The factor 100 at ti $-(K^{+}(892)^{-}K^{+})/\Gamma$ Unseen decay mo ALUE 0.034 \pm 0.019 $-(K^{0}K^{+}\pi^{-}\text{ nonresc})$ ALUE 1.10 \pm 0.06 74 The factor 100 at ti $-(K^{+}K^{-}\pi^{0})/\Gamma(K^{-}K^{-}K^{-}K^{-}K^{-}K^{-}K^{-}K^{-}$	(K ⁰ π+1 des of the EVTS 12 Donant)/Γ the top of π+π ⁰) EVTS 151	*** *** *** *** *** ** ** ** *	Tare Inc. Table I T	91 91 968 968 941 941	i. TECN CLEO TECN E691 NJOS 9 TECN CLE2 TECN CLE2 TECN ARG TECN ARG ID 980	COMMEI c+e- COMMEI c- COMMEI	T ₁₄₂ T ₂₁
73 The factor 100 at ti $-(K^{*}(892)^{-}K^{+})/\Gamma$ Unseen decay mo $ALUE$ 0.034 ± 0.019 $-(K^{0}K^{+}\pi^{-}\text{ nonresc}$ $ALUE$ $0.10^{+}0.06$ 7^{4} The factor 100 at ti $-(K^{+}K^{-}\pi^{0})/\Gamma(K^{-}ALUE)$ 0.0095 ± 0.0026 $-(K^{0}S^{0}S^{0})/\Gamma_{\text{total}}$ $ALUE$ <0.00059 $-(\phi\pi^{0})/\Gamma_{\text{total}}$ $ALUE$ <0.00014	(K ⁰ π+1 des of the EVTS 12 Donant)/Γ the top of π+π ⁰) EVTS 151	*** ** ** ** ** ** ** ** ** *	Tare Inc. Table I T	91 91 968 968 941 941	i. TECN CLEO TECN E691 NJOS 9 TECN CLE2 TECN CLE2 TECN ARG TECN ARG ID 980	COMMEI c+e- COMMEI c- COMMEI	T ₁₄₂ T ₂₁
73 The factor 100 at ti $-(K^{+}(892)^{-}K^{+})/\Gamma$ Unseen decay mo $ALUE$ 0.034 \pm 0.019 $-(K^{0}K^{+}\pi^{-}\text{ nonresc})$ $ALUE$ 1.10 \pm 0.06 7^{4} The factor 100 at ti $-(K^{+}K^{-}\pi^{0})/\Gamma(K^{-}K^{-}K^{-})$ $-(K^{0}K^{0}\pi^{0})/\Gamma_{\text{total}}$ $ALUE$ $<0.0005\pm0.0026$ $-(K^{0}K^{0}\pi^{0})/\Gamma_{\text{total}}$ $ALUE$ <0.0005 $-(\phi\pi^{0})/\Gamma_{\text{total}}$ $-($	(K ⁰ π+1 (K	*** *** *** *** *** ** ** ** *	Table I S F Table I R R R F Table I R R R R R R R R R R R R R	91 91 968 968 941 941 941 EETTI	i. IECN CLEO TECN CLE2 TECN CLE2 TECN ARG IECN ARG IECN ARG 10 980 950 7 941	COMMEI checker COMMEI	T ₁₄₂ T ₂₁
73 The factor 100 at ti $-(K^{*}(892)^{-}K^{+})/\Gamma$ Unseen decay mo ALUE 0.034 \pm 0.019 $-(K^{0}K^{+}\pi^{-}\text{ nonresc})$ ALUE 0.10 \pm 0.06 74 The factor 100 at ti $-(K^{+}K^{-}\pi^{0})/\Gamma(K^{-}K^{-}K^{0})$ ALUE 0.0095 \pm 0.0026 $-(K_{0}^{0}K_{0}^{0}\pi^{0})/\Gamma_{\text{total}}$ ALUE 0.00059 $-(\phi\pi^{0})/\Gamma_{\text{total}}$ ALUE 0.0028 $-(\phi\pi^{0})/\Gamma_{\text{total}}$ ALUE 0.0021 $-(K^{+}K^{-}\pi^{+}\pi^{-})/\Gamma_{\text{ALUE}}$ 0.0313 \pm 0.0037 \pm 0.003 0.035 \pm 0.004 \pm 0.002	(K ⁰ π+1 (K	*** *** *** *** ** ** ** ** **	Table I FRANT ID TO SECULT AITAL AITAL FRAB	91 91 968 968 941 941 941 EETTI	i. IECN CLEO TECN CLE2 TECN CLE2 TECN ARG IECN ARG IECN ARG 10 980 950 7 941	COMMEI c+e- COMMEI c- COMMEI CO	$Γ_{142}/Γ_{21}$ VT ≈ 10.5 GeV $Γ_{126}/Γ_{19}$ VT $= 240$ GeV be omitted. $Γ_{127}/Γ_{29}$ VT ≈ $T(45)$ $Γ_{128}/Γ$ VT ≈ 10 GeV $Γ_{144}/Γ$ VT ≈ 10 GeV $Γ_{145}/Γ$ VT ≈ 10 GeV $Γ_{145}/Γ$ VT $= 10$ GeV $Γ_{145}/Γ$ $= 10$ GeV $Γ_{145}/Γ$ $= 10$ GeV $Γ_{145}/Γ$ $= 10$ GeV
73 The factor 100 at ti $-(K^{+}(892)^{-}K^{+})/\Gamma$ Unseen decay mo $ALUE$ 0.034 ± 0.019 $-(K^{0}K^{+}\pi^{-}\text{ nonresc}$ $ALUE$ $0.10+0.06$ $74 \text{ The factor } 100 \text{ at ti}$ $-(K^{+}K^{-}\pi^{0})/\Gamma(K^{-}ALUE)$ 0.0095 ± 0.0026 $-(K^{0}S^{-}S^{-}\pi^{0})/\Gamma\text{ total}$ $ALUE$ <0.00059 $-(\phi\pi^{0})/\Gamma\text{ total}$ $ALUE$ <0.0014 $-(\phi\eta)/\Gamma\text{ total}$ $ALUE$ <0.0028 $-(\phi\omega)/\Gamma\text{ total}$	(K ⁰ π+1 (K	*** *** *** *** *** ** ** ** *	Table I S F Table I R R R F Table I R R R R R R R R R R R R R	91 91 968 968 941 941 941 ECHTAR	i. IECN CLEO TECN CLE2 TECN CLE2 TECN ARG IECN ARG IECN ARG 10 980 950 7 941	COMMEI checker COMMEI	T ₁₄₂ T ₂₁

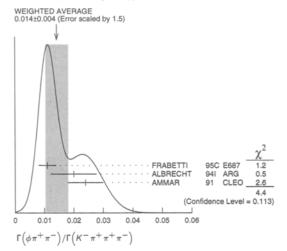
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\Gamma(\phi \pi^+ \pi^-)/\Gamma(K^- \pi^+ \pi^+ \pi^-)
Unseen decay modes of the \phi are included.

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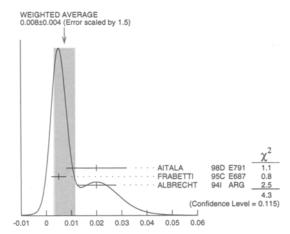
The find as or
                                                                                               \Gamma_{146} / \Gamma_{37}
                                                                    TECN COMMENT
0.014 ±0.004 OUR AVERAGE Error Includes scale factor of 1.5. See the ideogram below.
0.011 \pm 0.003
                                            FRABETTI
                                                              95C E687 \gamma Be, \overline{E}_{\gamma} \approx 200 GeV
                                            ALBRECHT
0.020 ±0.006 ±0.005 28
                                                              941 ARG e+e-≈ 10 GeV
                                      75 AMMAR
                                                               91 CLEO e^+e^-\approx 10.5 \text{ GeV}
0.024 \pm 0.006
                                34
• • • We do not use the following data for averages, fits, limits, etc. • • •
                                            SOLNA
                                                               91 E691 γBe 80-240 GeV
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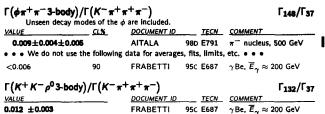
 75 AMMAR 91 measures $\phi\rho^0$, but notes that $\phi\rho^0$ dominates $\phi\pi^+\pi^-.$ We put the measurement here to keep from having more $\phi\rho^0$ than $\phi\pi^+\pi^-.$



 $\Gamma(\phi \rho^0)/\Gamma(K^-\pi^+\pi^+\pi^-)$ Unseen decay modes of the ϕ are included. Γ_{147}/Γ_{37} VALUE EVTS DOCUMENT ID TECN COMMENT

0.008±0.004 OUR AVERAGE Error includes scale factor of 1.5. See the ideogram below. 0.02 ±0.009±0.008 AITALA 980 E791 π^- nucleus, 500 GeV 0.005 ± 0.003 FRABETTI 95c E687 γ Be, $\overline{E}_{\gamma} \approx$ 200 GeV $0.020 \pm 0.006 \pm 0.005$ ALBRECHT 941 ARG e+e-≈ 10 GeV 28





$\Gamma(K^{\bullet}(892)^{0}K^{-}\pi^{+} + c.c.)/\Gamma(K^{-}\pi^{+}\pi^{+}\pi^{-})$ Γ_{149}/Γ_{37}	$\Gamma(K^+\pi^-)/\Gamma(K^-\pi^+)$ Γ_{155}/Γ_{5}
Unseen decay modes of the K*(892) ^U are included. VALUE CL% DOCUMENT ID TECN COMMENT	The $D^0 o K^+\pi^-$ mode is doubly Cabibbo suppressed. VALUE CLY EVTS DOCUMENT ID TECN COMMENT
<0.01 90 ⁷⁶ AlTALA 98D E791 π ⁻ nucleus, 500 GeV	0.0072±0.0025 OUR AVERAGE
• • • We do not use the following data for averages, fits, limits, etc. • • • <0.017 90 76 FRABETTI 95C E687 $_{\gamma}$ Be, $\overline{E}_{\gamma} \approx$ 200 GeV	0.0068+0.0034±0.0007 84 AITALA 98 E791 x− nucleus, 500 GeV
0.010 + 0.016 ANIOS 01 F601 ~ Re 80-240 GeV :	$0.0077 \pm 0.0025 \pm 0.0025$ 19 ⁸⁵ CINABRO 94 CLE2 $e^+e^- \approx T(4S)$
	• • • We do not use the following data for averages, fits, limits, etc. • • •
76 These upper limits are in conflict with values in the next two data blocks.	<0.011 90 85 AMMAR 91 CLEO $e^+e^-\approx 10$.
$\Gamma(K^{\bullet}(892)^{0}K^{-}\pi^{+})/\Gamma(K^{-}\pi^{+}\pi^{+}\pi^{-})$ The $K^{\bullet0}K^{-}\pi^{+}$ and $\overline{K}^{\bullet0}K^{+}\pi^{-}$ modes are distinguished by the charge of the pion	<0.015 90 1 ± 6 86 ANJOS 88C E691 Photoproduc-
In $D^*(2010)^{\pm} \rightarrow D^0 \pi^{\pm}$ decays. Unseen decay modes of the $K^*(892)^0$ are included.	<0.014 90 87 ALBRECHT 87 ABACHI 860 HRS e ⁺ e ⁻ 10 Ge ⁻ <0.04 90 87 ABACHI 860 HRS e ⁺ e ⁻ 29 Ge ⁻
<u>VALUE</u> <u>EVTS</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u> • • • We do not use the following data for averages, fits, limits, etc. • • •	<0.07 90 0 88 BAILEY 86 ACCM # Be fixed
0.043 \pm 0.014 \pm 0.009 55 ⁷⁷ ALBRECHT 941 ARG $e^+e^-\approx$ 10 GeV	target <0.11 90 2 ⁸⁷ ALBRECHT 85F ARG e ⁺ e ⁻ 10 Ge
77 This ALBRECHT 94: value is in conflict with upper limits given above.	<0.081 90 87,89 YAMAMOTO 85 DLCO e+e- 29 Ge
$\Gamma(\overline{K}^{a}(892)^{0}K^{+}\pi^{-})/\Gamma(K^{-}\pi^{+}\pi^{+}\pi^{-})$ Γ_{151}/Γ_{37}	<0.23 90 ^{87,89} ALTHOFF 84B TASS e ⁺ e ⁻ 34.4 GeV
The $K^{*0}K^{-}\pi^{+}$ and $\overline{K}^{*0}K^{+}\pi^{-}$ modes are distinguished by the charge of the pion	<0.11 90 87,89 AVERY 80 SPEC $\gamma N \rightarrow D^{*+}$ <0.16 90 87,89 FELDMAN 778 MRK1 e^+e^- 4 GeV
in $D^*(2010)^{\pm} \rightarrow D^0 \pi^{\pm}$ decays. Unseen decay modes of the $\overline{K}^*(892)^0$ are included. VALUE EVTS POCUMENT ID TECN COMMENT	<0.16 90 87,89 FELDMAN 778 MRK1 e ⁺ e ⁻ 4 GeV <0.18 90 87,89 GOLDHABER 77 MRK1 e ⁺ e ⁻ 4 GeV
• • We do not use the following data for averages, fits, limits, etc. • • •	⁸⁴ AITALA 98 uses the charge of the pion in $D^{*\pm} \rightarrow (D^0 \text{ or } \overline{D}{}^0) \pi^{\pm}$ to tell whether a L
$0.023 \pm 0.013 \pm 0.009$ 30 ⁷⁸ ALBRECHT 941 ARG $e^+e^- \approx 10$ GeV	or a \overline{D}^0 was born. This result assumes no $D^0 - \overline{D}^0$ mixing; it becomes $0.0090 + 0.0120$
78 This ALBRECHT 941 value is in conflict with upper limits given above.	0.0044 when mixing is allowed and decay-time information is used to distinguish dout Cabibbo-suppressed decays from mixing.
$\Gamma(K^{\circ}(892)^{0}\overline{K}^{\circ}(892)^{0})/\Gamma(K^{-}\pi^{+}\pi^{+}\pi^{-})$ Γ_{182}/Γ_{37}	85 These experiments cannot distinguish between doubly Cabibbo-suppressed decay a
Unseen decay modes of the $K^*(892)^0$ and $\overline{K}^*(892)^0$ are included.	D^0 \overline{D}^0 mixing. 86 ANJOS 88c uses decay-time information to distinguish doubly Cabibbo-suppressed (DC
VALUE CL% EVTS DOCUMENT ID TECH COMMENT 0.018±0.007 OUR AVERAGE Error includes scale factor of 1.2.	decays from D^0 - \overline{D}^0 mixing. However, the result assumes no interference between t
0.016 ± 0.006 FRABETTI 95C E687 γ Be, $\overline{E}_{\gamma} \approx 200$ GeV	DCS and mixing amplitudes. When interference is allowed, the limit degrades to 0.04 ⁸⁷ in these measurements, the charge of the pion in $D^{\bullet\pm} \rightarrow (D^0 \text{ or } \overline{D}^0)\pi^{\pm}$ is used
0.036 + 0.020 11 ANJOS 91 E691 γ Be 80-240 GeV	tell whether a D^0 or a $\overline{D}{}^0$ was born. None of the measurements can distinguish between
• • • We do not use the following data for averages, fits, limits, etc. • • •	double Cabibbo suppression and mixing for the decay. 88 BAILEY 86 searches for events with an oppositely charged e.K. pair. The limit is actual.
<0.02 90 AITALA 98D E791 π nucleus, 500 GeV	for $\Gamma(D^0 \to K^+\pi^- \text{ or } K^+\pi^-\pi^+\pi^-)/\Gamma(D^0 \to K^-\pi^+ \text{ or } K^-\pi^+\pi^+\pi^-)$.
<0.033 90 ⁷⁹ AMMAR 91 CLEO e ⁺ e ⁻ ≈ 10.5 GeV	⁸⁹ The results are given as $\Gamma(K^+\pi^-)/[\Gamma(K^-\pi^+)+\Gamma(K^+\pi^-)]$ but do not change sign leantly for our denominator.
79 A corrected value (G. Moneti, private communication).	•
$\Gamma(K^+K^-\pi^+\pi^-\text{non-}\phi)/\Gamma_{\text{total}}$ Γ_{135}/Γ	$\Gamma(K^{+}\pi^{-}(\text{via }\overline{D^{0}}))/\Gamma(K^{-}\pi^{+})$ This is a $\Omega^{0}\overline{D^{0}}$ mixture that if so the limits on I^{-} and I^{-} .
VALUE DOCUMENT ID TECN COMMENT	This is a D^0 - \overline{D}^0 mixing limit. For the limits on $ m_{D_1^0} - m_{D_2^0} $ and $ \Gamma_{D_1^0} - \Gamma_{D_2^0} /\Gamma_{D_2^0}$
• • • We do not use the following data for averages, fits, limits, etc. • • • 0.0017±0.0005 80 BARLAG 92C ACCM π ⁻ Cu 230 GeV	that come from the best mixing limit, see near the beginning of these D ⁰ Listings. <u>YALUE CLY EVTS DOCUMENT ID TECN COMMENT</u>
80 BARLAG 92C computes the branching fraction using topological normalization.	<u>YALUE CL% EVTS DOCUMENT ID TECN COMMENT</u> <0.008 90 1 ± 4 90 ANJOS 88C E691 Photoproduction
	90 ANJOS 88C uses decay-time information to distinguish doubly Cabibbo-suppressed (DC
$\Gamma(K^+K^-\pi^+\pi^-\text{nonresonant})/\Gamma(K^-\pi^+\pi^+\pi^-)$ VALUE CLY DOCUMENT ID TECH COMMENT COMMENT	decays from D^0 - \overline{D}^0 mixing. However, the result assumes no interference between t DCS and mixing amplitudes. When interference is allowed, the limit degrades to 0.01
<0.011 90 FRABETTI 95C E687 γ Be, $\overline{E}_{\gamma} \approx 200$ GeV	Combined with results on $K^{\pm}\pi^{\mp}\pi^{+}\pi^{-}$, the limit is, assuming no interference, 0.003
	$\Gamma(K^{+}\pi^{-}\pi^{+}\pi^{-})/\Gamma(K^{-}\pi^{+}\pi^{+}\pi^{-})$ Γ_{157}/Γ_{1}
0.001 +0.011 ANJOS 91 E691 γ Be 80-240 GeV	Doubly Cabibbo suppressed.
$\Gamma(K^0\overline{K}^0\pi^+\pi^-)/\Gamma(\overline{K}^0\pi^+\pi^-)$ Γ_{137}/Γ_{21}	VALUE CL% EYTS DOCUMENT ID TECN COMMENT 0.0025 ±0.0034 91 AITALA 98 E791 π - nucleus,
VALUE EVTS DOCUMENT ID TECH COMMENT	500 GeV
0.126 \pm 0.038 \pm 0.030 25 ALBRECHT 941 ARG $e^+e^-\approx$ 10 GeV	• • • We do not use the following data for averages, fits, limits, etc. • • • <0.018 90 92 AMMAR 91 CLEO $e^+e^-\approx 10$
$\Gamma(K^+K^-\pi^+\pi^-\pi^0)/\Gamma_{\text{total}}$ Γ_{139}/Γ	GeV *
VALUE DOCUMENT ID TECH COMMENT	<0.018 90 5 ± 93 ANJOS 88C E691 Photoproduc- 12 tion
0.0031±0.0020 81 BARLAG 92C ACCM π Cu 230 GeV	⁹¹ AITALA 98 uses the charge of the pion in $D^{*\pm} \rightarrow (D^0 \text{ or } \overline{D}^0) \pi^{\pm}$ to tell whether a $U^{*\pm} \rightarrow U^{*\pm}$
81 BARLAG 92C computes the branching fraction using topological normalization.	or a \overline{D}^0 was born. This result assumes no D^0 . \overline{D}^0 mixing; it becomes $-0.020^+0.013^+$ 0.0106 0.0035 when mixing is allowed and decay time information is used to distinguish doul
Rare or forbidden modes	Cabibbo-suppressed decays from mixing.
$\Gamma(K^{+}\ell^{-}\nabla_{\ell}(\text{via }\overline{D}^{0}))/\Gamma(K^{-}\ell^{+}\nu_{\ell})$ Γ_{153}/Γ_{7}	⁹² AMMAR 91 cannot distinguish between doubly Cabibbo-suppressed decay and D ⁰ -I mixing.
This is a $D^0 - \overline{D}{}^0$ mixing limit without the complications of possible doubly-Cabibbo-	93 ANJOS 88C uses decay-time information to distinguish doubly Cabibbo-suppressed (DC
suppressed decays that occur when using hadronic modes. For the limits on $ m_{D_1^0} $ –	decays from $D^0 - \overline{D}^0$ mixing. However, the result assumes no interference between t DCS and mixing amplitudes. When interference is allowed, the limit degrades to 0.03
$m_{D_2^0}$ and $ \Gamma_{D_1^0} - \Gamma_{D_2^0} /\Gamma_{D^0}$ that come from the best mixing limit, see near the	-/
beginning of these D^0 Listings.	This is a D^0 - $\overline{D^0}$ mixing limit. For the limits on $ m_{D_1^0} - m_{D_2^0} $ and $ \Gamma_{D_1^0} - \Gamma_{D_2^0} /\Gamma_L^0$
VALUE CL% DOCUMENT ID TECN COMMENT <0.006	· · · · · · · · · · · · · · · · · · ·
<0.005 90 82 AITALA 96C E791 π^- nucleus, 500 GeV 82 AITALA 96C uses $D^{*+} \rightarrow D^0 \pi^+$ (and charge conjugate) decays to identify the charm	that come from the best mixing limit, see near the beginning of these D ⁰ Listings. VALUE CLY EVTS DOCUMENT ID TECH COMMENT
at production and $D^0 \to K^- \ell^+ \nu_\ell$ (and charge conjugate) decays to identify the charm	<0.005 90 0 ± 4 94 ANJOS 88c E691 Photoproduction
at decay.	94 ANJOS 88C uses decay-time information to distinguish doubly Cabibbo-suppressed (DC
$ \Gamma \left(K^{+}\pi^{-} \text{ or } K^{+}\pi^{-}\pi^{+}\pi^{-} \left(\text{ via } \overline{D^{0}} \right) \right) / \Gamma \left(K^{-}\pi^{+} \text{ or } K^{-}\pi^{+}\pi^{+}\pi^{-} \right) $ $ \Gamma_{154} / \Gamma_{0} $ This is a $D^{0} \cdot \overline{D^{0}}$ mixing limit. For the limits on $ m_{D_{1}^{0}} - m_{D_{2}^{0}} $ and $ \Gamma_{D_{1}^{0}} - \Gamma_{D_{2}^{0}} / \Gamma_{D^{0}} $	decays from D^0 - \overline{D}^0 mixing. However, the result assumes no interference between t DCS and mixing amplitudes. When interference is allowed, the limit degrades to 0.00 Combined with results on $K^{\pm}\pi^{\mp}$, the limit is, assuming no interference, 0.0037.
that come from the best mixing limit, see near the beginning of these D^0 Listings,	$\Gamma(\mu^- \text{ anything (via } \overline{D}^0))/\Gamma(\mu^+ \text{ anything})$ $\Gamma_{159}/\Gamma_{159}$
VALUE CLS DOCUMENT ID TECH COMMENT	This is a $D^{0}-\overline{D}{}^{0}$ mixing limit. See the somewhat better limits above.
<0.0085 90 83 AITALA 98 E791 π ⁻ nucleus, 500 GeV	VALUE CLY DOCUMENT ID TECN COMMENT
83 AITALA 98 uses decay-time information to distinguish doubly Cabibbo-suppressed decays from D ⁰ -D mixing. The fit allows interference between the two amplitudes, and also	<0.0056 90 LOUIS 86 SPEC π ⁻ W 225 GeV • • • We do not use the following data for averages, fits, limits, etc. • • •
non p -p mixing. The m allows interference between the two amplitudes, and also	
allows CP violation in this term. The central value obtained is $0.0039 + 0.0036 \pm 0.0016$.	<0.012 90 BENVENUTI 85 CNTR μC, 200 GeV
allows CP violation in this term. The central value obtained is $0.0039 \stackrel{+}{-}0.0036 \pm 0.0016$. When interference is disallowed, the result becomes $0.0021 \pm 0.0009 \pm 0.0002$.	

```
\Gamma(e^+e^-)/\Gamma_{\text{total}}
                                                                                                                                                              T160/F
            A test for the \Delta C = 1 weak neutral current. Allowed by first-order weak interaction
            combined with electromagnetic interaction.
                                                                                                          TECN COMMENT
                                CL% EVTS
                                                                       DOCUMENT ID
 <1.3 × 10<sup>-5</sup>
                                                                       FREYBERGER 96 CLE2 e^+e^- \approx T(45)
                                    90
                                                  0
• • • We do not use the following data for averages, fits, limits, etc. • • •
 < 1.3 \times 10^{-4}
                                    90
                                                                       ADLER
                                                                                                  88 MRK3 e+e- 3.77 GeV
 < 1.7 \times 10^{-4}
                                                                        ALBRECHT 88G ARG e+e-10 GeV
 < 2.2 \times 10^{-4}
                                                      8
                                                                       HAAS
                                                                                           88 CLEO e+e- 10 GeV
\Gamma(\mu^+\mu^-)/\Gamma_{\text{total}} A test for the \Delta C=1 weak neutral current. Allowed by first-order weak interaction
            combined with electromagnetic interaction.
                                                                    DOCUMENT ID
                                __ CL% _EVTS
                                                                                                           TECN COMMENT
 <4.1 × 10<sup>-6</sup>
                                                                        ADAMOVICH 97 BEAT # Cu, W 350 GeV
 • • • We do not use the following data for averages, fits, limits, etc. • • •
 < 4.2 \times 10^{-6}
                                    90
                                                                       ALEXOPOU... 96 E771 p SI, 800 GeV
 < 3.4 \times 10^{-5}
                                                                       FREYBERGER 96 CLE2 e^+e^- \approx T(4S)
                                    90
                                                      1
 < 7.6 \times 10^{-6}
                                    90
                                                      O
                                                                        ADAMOVICH 95 BEAT See ADAMOVICH 97
 < 4.4 \times 10^{-5}
                                                                        KODAMA
                                    90
                                                      ۵
                                                                                                     95 E653 π<sup>--</sup> emulsion 600 GeV
                                                                 95 MISHRA
 < 3.1 \times 10^{-5}
                                    90
                                                                                                     94 F789
                                                                                                                            -41 + 48 events
 < 7.0 \times 10^{-5}
                                                                       ALBRECHT 88G ARG
                                                                                                                              e+e- 10 GeV
                                    90
 < 1.1 \times 10^{-5}
                                                                                                     86 SPEC ±™W 225 GeV
                                    90
                                                                       LOUIS
  < 3.4 \times 10^{-4}
                                    90
                                                                       AUBERT
                                                                                                     85 EMC Deep inelast. μ<sup>-</sup> N
  95 Here MISHRA 94 uses "the statistical approach advocated by the PDG." For an alternate
       approach, giving a limit of 9 \times 10^{-6} at 90% confidence level, see the paper.
 \Gamma(\pi^0 e^+ e^-)/\Gamma_{\text{total}}
                                                                                                                                                              T162/F
            A test for the \Delta C = 1 weak neutral current. Allowed by higher-order electroweak
            interactions.
                                CL% EVTS
                                                                       DOCUMENT ID TECN COMMENT
 <4.5 × 10<sup>-5</sup> 90
                                                                       FREYBERGER 96 CLE2 e^+e^- \approx T(45)
                                                  0
\Gamma(\pi^0\mu^+\mu^-)/\Gamma_{\text{total}}
           A test for the \Delta C=1 weak neutral current. Allowed by higher-order electroweak inter-
            actions.
                                                                       DOCUMENT ID TECN COMMENT
                                   CLN EVTS
 <1.8 × 10<sup>-4</sup> 90 2
                                                                       KODAMA 95 E653 π<sup>-</sup> emulsion 600 GeV
 < 5.4 \times 10^{-4} 90
                                                                      FREYBERGER 96 CLE2 e^+e^- \approx T(45)
                                                  3
 \Gamma(\eta e^+ e^-)/\Gamma_{\text{total}}
            A test for the \Delta C = 1 weak neutral current. Allowed by higher-order electroweak
            Interactions.
                                                                       DOCUMENT ID TECN COMMENT
 <u>VALUE</u> <u>CL% EVTS</u>

<1.1 × 10<sup>-4</sup> 90 0
 VALUE
                                                                       FREYBERGER 96 CLE2 e^+e^-\approx T(45)
 \Gamma(\eta \mu^+ \mu^-)/\Gamma_{\text{total}}
            A test for the \Delta C = 1 weak neutral current. Allowed by higher-order electroweak
  interactions.

VALUE

CL% EVTS

CS.3 × 10<sup>-4</sup>

90

0
                                                                       DOCUMENT ID TECN COMMENT
VALUE
                                                                       FREYBERGER 96 CLE2 e^+e^- \approx \Upsilon(45)
\Gamma(\rho^0 e^+ e^-)/\Gamma_{\text{total}}
                                                                                                                                                              Ties/F
            A test for the \Delta C = 1 weak neutral current. Allowed by higher-order electroweak
 <u>VALUE</u> <u>CLW EVTS</u>

<1.0 × 10<sup>-4</sup> 90 2
                                                                       DOCUMENT ID TECH COMMENT
                                                  2 96 FREYBERGER 96 CLE2 e^+e^- \approx \Upsilon(45)
 • • • We do not use the following data for averages, fits, limits, etc. • • •
  <4.5 × 10<sup>-4</sup> 90 2 HAAS
  ^{96}\,\mathrm{This} FREYBERGER 96 limit is obtained using a phase-space model. The limit changes
       to < 1.8 \times 10^{-4} using a photon pole amplitude model.
\Gamma(\rho^0\,\mu^+\,\mu^-)/\Gamma_{\rm total} \qquad \qquad \Gamma_{167}/\Gamma_{\rm total} \qquad
            Interactions.
 <u>VALUE</u> <u>CL% EVTS</u>

<2.3 × 10<sup>-4</sup> 90 0
 VAI LIE
                                                                       DOCUMENT ID TECH COMMENT
                                                                       KODAMA 95 E653 π<sup>-</sup> emulsion 600 GeV
 • • • We do not use the following data for averages, fits, limits, etc. • • •
 <4.9 \times 10^{-4} 90 1 97 FREYBERGER 96 CLE2 e^+e^- \approx \tau(45) <8.1 \times 10^{-4} 90 5 HAAS 88 CLEO e^+e^- 10 GeV
                                                                                                     88 CLEO e+e- 10 GeV
  97 This FREYBERGER 96 limit is obtained using a phase-space model. The limit changes
        to < 4.5 \times 10^{-4} using a photon pole amplitude model.
Interactions. 

VALUE CL% EVTS DOCUMENT ID TECN COMMENT (4.8 x 10^{-4} 90 1 ^{98} FREYBERGER 96 CLE2 _{e}^{+}e^{-}\approx \Upsilon(45)
  98 This FREYBERGER 96 limit is obtained using a phase-space model. The limit changes
       to < 2.7 \times 10^{-4} using a photon pole amplitude model.
```

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\Gamma(\omega \mu^+ \mu^-)/\Gamma_{\text{total}}
                                                                                T169/T
      A test for the \Delta C = 1 weak neutral current. Allowed by higher-order electroweak
     Interactions.
                                   DOCUMENT ID TECN COMMENT
                CLN EVTS
VALUE
<8.3 x 10<sup>-4</sup> 90 0 <sup>99</sup> FREYBERGER 96 CLE2 e<sup>+</sup>e<sup>-</sup> ≈ T(45)
 <sup>99</sup> This FREYBERGER 96 limit is obtained using a phase-space model. The limit changes
   to < 6.5 \times 10^{-4} using a photon pole amplitude model.
\Gamma(\phi e^+e^-)/\Gamma_{	ext{total}}
A test for the \Delta C=1 weak neutral current. Allowed by higher-order electron
VALUE
^{100} This FREYBERGER 96 limit is obtained using a phase-space model. The limit changes
   to < 7.6 \times 10^{-5} using a photon pole amplitude model.
\Gamma(\phi \mu^+ \mu^-)/\Gamma_{\text{total}}
     A test for the \Delta C = 1 weak neutral current. Allowed by higher-order electroweak
      interactions.
VALUE CLY EVTS DOCUMENT ID TECN COMMENT

<4.1 \times 10^{-4} 90 0 ^{101} FREYBERGER 96 CLE2 e^+e^- \approx T(45)
^{101} This FREYBERGER 96 limit is obtained using a phase-space model. The limit changes
   to < 2.4 \times 10^{-4} using a photon pole amplitude model.
\Gamma(\overline{K}^0 e^+ e^-)/\Gamma_{\text{total}}
                                                                                \Gamma_{172}/\Gamma
     Allowed by first-order weak interaction combined with electromagnetic interaction.
<u>VALUE</u> <u>CL% EVTS</u>
<1.1 × 10<sup>-4</sup> 90 0
                                   DOCUMENT ID TECN COMMENT
                                   FREYBERGER 96 CLE2 e+e- = T(45)
<1.7 \times 10^{-3} 90
                                   ADLER
                                                   89C MRK3 e+e- 3.77 GeV
\Gamma(\overline{K}^0\mu^+\mu^-)/\Gamma_{\text{total}}
     Allowed by first-order weak interaction combined with electromagnetic interaction.
               CLN EVTS
                                   DOCUMENT ID TECH COMMENT
<2.6 × 10<sup>-4</sup>
                                   KODAMA 95 E653 x emulsion 600 GeV
                          2
                 90
FREYBERGER 96 CLE2 e^+e^-\approx T(45)
\Gamma(\overline{K}^{\bullet}(892)^{0}e^{+}e^{-})/\Gamma_{\text{total}}
     Allowed by first-order weak interaction combined with electromagnetic interaction.

E CLY EYTS DOCUMENT ID TECN COMMENT
<1.4 × 10<sup>-4</sup> 90
                        1 102 FREYBERGER 96 CLE2 e+e-≈ T(45)
^{102}This FREYBERGER 96 limit is obtained using a phase-space model. The limit changes
   to < 2.0 \times 10^{-4} using a photon pole amplitude model.
\Gamma(\overline{K}^{\bullet}(892)^{0}\mu^{+}\mu^{-})/\Gamma_{\text{total}}
                                                                                \Gamma_{175}/\Gamma
      Allowed by first-order weak interaction combined with electromagnetic interaction.
VALUE CLY EVTS DOCUMENT ID TECH COMMENT

<1.18 \times 10^{-3} 90 1 ^{103} FREYBERGER 96 CLE2 e^+e^- \approx \tau(45)
<sup>103</sup>This FREYBERGER 96 limit is obtained using a phase-space model. The #mit changes
   to < 1.0 \times 10^{-3} using a photon pole amplitude model.
actions.
VALUE CL% EVTS
<8.1 × 10<sup>-4</sup> 90 1
                                    DOCUMENT ID TECN COMMENT
                                                   95 E653 π emulsion 600 GeV
                                    KODAMA
\Gamma(\mu^{\pm}e^{\mp})/\Gamma_{\text{total}}
                                                                                \Gamma_{177}/\Gamma
     A test of lepton family number conservation.
VALUE CLY EYTS DOCUMENT ID TECN COMMENT < 1.9 \times 10^{-5} 90 2 104 FREYBERGER 96 CLE2 e^+e^- \approx T(45)
VALUE
< 1.0 \times 10^{-4} 90
                                   ALBRECHT 88G ARG e+e- 10 GeV
                          4
< 2.7 \times 10^{-4} 90
                                                   88 CLEO e+e- 10 GeV
                           9
                                    HAAS
< 1.2 \times 10^{-4}
                                                   87C MRK3 e+e- 3.77 GeV
                 90
                                    BECKER
< 9 \times 10^{-4} \quad 90
                                    PALKA
                                                   87 SIL1 200 GeV π p
<21 × 10<sup>-4</sup> 90
                         o 105 RILES
                                                   87 MRK2 e+e- 29 GeV
104 This is the corrected result given in the erratum to FREYBERGER 96.
                                                                                          ۱
<sup>105</sup> RILES 87 assumes B(D \rightarrow K\pi) = 3.0% and has production model dependency.
\Gamma(\pi^0e^\pm\mu^\mp)/\Gamma_{\rm total} Γ<sub>178</sub>/Γ Α test of lepton family number conservation. The value is for the sum of the two
      charge states.
VALUE CL% EV7S
<8.6 × 10<sup>-5</sup> 90 2
                                    DOCUMENT ID TECH COMMENT
VALUE
                                    FREYBERGER 96 CLE2 e^+e^- \approx \Upsilon(4S)
\Gamma(\eta e^{\pm} \mu^{\mp})/\Gamma_{\text{total}}
                                                                                 T179/F
      A test of lepton family number conservation. The value is for the sum of the two
      charge states.
<u>VALUE</u> <u>CL% EVTS</u>
<1.0 × 10<sup>-4</sup> 90 0
                                    DOCUMENT ID
                                                      TECN COMMENT
VALUE
                                    FREYBERGER 96 CLE2 e^+e^- \approx T(4S)
```

	el on family r	number conservatio	n. Th	e value	Γ_{180}/Γ is for the sum of the two
charge states.	K EVTS	DOCUMENT ID		TECN	COMMENT
<4.9 × 10 ⁻⁵ 90	D 0				$e^+e^-\approx T(45)$
					` '
					model. The limit changes
to < 5.0 × 10 °	using a pr	oton pole amplitud	e mot	ж.	
	i on family r	number conservatio	n. Th	e value	Γ_{181}/Γ is for the sum of the two
charge states.	W EVER	DOCUMENT ID		TECH	COMMENT
<1.2 × 10 ⁻⁴ 90	LSKEVTS				$e^+e^-\approx T(45)$
	-				e model. The same limit is
		ie amplitude model		ise-space	e model. The same innic is
Γ(φe [±] μ [∓])/Γ _{total} A test of lepto charge states.	i on family (number conservatio	n. Th	e value	Γ_{182}/Γ is for the sum of the two
-	LX EVTS	DOCUMENT ID		TECN	COMMENT
<3.4 x 10 ⁻⁵ 90	0 0	108 FREYBERGE	R 96	CLE2	$e^+e^-\approx T(45)$
		it is obtained using noton pole amplitud			model. The limit changes
	-	,			
$\Gamma(\overline{K}^0 e^{\pm} \mu^{\mp})/\Gamma_{tot}$ A test of leptocharge states.	tal on family :	number conservation	n. Ti	ne value	Is for the sum of the two
•	LX EVTS	DOCUMENT IS)	TECN	COMMENT
<1.0 × 10 ⁻⁴ 9		FREYBERGI	R 96	CLE2	$e^+e^-\approx T(45)$
	F)/Γ _{total} on family :	number conservatio	on. Ti	ne value	Γ_{184}/Γ is for the sum of the two
charge states.	ar come	DOCUMENT I		TECH	COMMENT
<1.0 × 10 ⁻⁴ 9	LX EVTS 0 0	DOCUMENT II			$e^+e^-\approx T(45)$
	-				
		it is obtained using He amplitude mode		se-spac	e model. The same limit is
Optamed dang a	prioton po	ne umpireudo mode	•		
		ATING DECAY-F → <i>K⁺K⁻</i>	EATE	ASYN	
$A_{CP}(K^+K^-)$ in					
This is the diff the sum of the D^* : $D^{*+} \rightarrow$	ference being widths. The $D^0\pi^+$ and	tween D^0 and \overline{D}^0 The D^0 and \overline{D}^0 are of $D^0\pi^-$	distin	guished	for these modes divided by by the charge of the parent
This is the diff the sum of the D^* : $D^{*+} \rightarrow YALUE$	ference being widths. The $D^0\pi^+$ and $EVTS$	tween D^0 and \overline{D}^0 The D^0 and \overline{D}^0 are and $D^{*-} \rightarrow D^0 \pi^{-}$ DOCUMENT ID	distin	guished	by the charge of the paren
This is the diff the sum of the D^* : $D^{*+} \rightarrow$	Terence bet e widths. T D ⁰ π ⁺ an <u>EVTS</u> R AVERAG	tween D^0 and \overline{D}^0 The D^0 and \overline{D}^0 are id $D^*- o D^0\pi^-$ $\underline{DOCUMENTID}$	distin	guished	by the charge of the parent comment $COMMENT$ $-0.093 < A_{CP} < +0.073$
This is the diff the sum of the D*: D*+ → VALUE 0.025±0.035 OUF	Terence bet e widths. T D ⁰ π ⁺ an <u>EVTS</u> R AVERAG	tween D^0 and \overline{D}^0 The D^0 and \overline{D}^0 are id $D^*- o D^0\pi^-$ $\underline{DOCUMENTID}$	distin 980	guished <u>TECN</u>	by the charge of the parent <u>COMMENT</u> −0.093 <a<sub>CP < +0.073 (90% CL)</a<sub>
This is the difference that the sum of the D^+ : $D^{++} \rightarrow VALUE$ 0.025 \pm 0.015 OUF -0.010 \pm 0.049 \pm 0.0	Terence bet e widths. T D ⁰ π ⁺ an <u>EVTS</u> R AVERAG	tween D^0 and \overline{D}^0 he D^0 and \overline{D}^0 are d $D^+ \rightarrow D^0 \pi^ D^0 \pi$	98C	guished TECN E791	COMMENT -0.093 < A _{CP} < +0.073 (90% CL) -0.022 < A _{CP} < +0.18 (90% CL)
This is the diff the sum of the D*: D*+ → YALUE 0.026 ± 0.035 OUF - 0.010 ± 0.049 ± 0.0 + 0.080 ± 0.061 + 0.024 ± 0.084	ference be e widths. T D ⁰ π ⁺ an <u>EVIS</u> R AVERAG D12 609	Neen D ⁰ and D ⁰ he D ⁰ and D ⁰ are d D ⁰ - D ⁰ are D0 x - D0 x - D0CUMENT ID E 110 AITALA BARTELT 110 FRABETTI	980 95 941	guished TECN E791 CLE2 E687	COMMENT -0.093 < A _{CP} < +0.073 (90% CL) -0.022 < A _{CP} < +0.18 (90% CL) -0.11 < A _{CP} < +0.16 (90% CL)
This is the diff the sum of the D*: D*+ → YALUE 0.025±0.035 OUF − 0.010±0.049±0.0 + 0.080±0.061 + 0.024±0.084 110 AITALA 98C and	Terence be e widths. T D ⁰ π + an EVTS R AVERAG D12 609	Neen D ⁰ and D ⁰ he D ⁰ and D ⁰ are d D ⁰ - D ⁰ are D0 x - D0 x - D0CUMENT ID E 110 AITALA BARTELT 110 FRABETTI	980 95 941	guished TECN E791 CLE2 E687 K+K	by the charge of the parent comment $-0.093 < A_{CP} < +0.073 < (90\% CL) -0.022 < A_{CP} < +0.18 < (90\% CL) -0.11 < A_{CP} < +0.16 < (90\% CL) -0.17 < A_{CP} < +0.16 < (90\% CL) -1 / N(D^0 \rightarrow K^-\pi^+), the$
This is the diff the sum of the D*: D*+ → VALUE 0.025±0.035 OUF − 0.010±0.049±0.0 + 0.080±0.061 + 0.024±0.084 110 AITALA 98c and ratio of numbers	ference being with the service of th	Neen D ⁰ and D ⁰ he D ⁰ and D ⁰ are d D ⁰ - D ⁰ x -	980 95 941	guished TECN E791 CLE2 E687 K+K	by the charge of the parent comment $-0.093 < A_{CP} < +0.073 < (90\% CL) -0.022 < A_{CP} < +0.18 < (90\% CL) -0.11 < A_{CP} < +0.16 < (90\% CL) -0.17 < A_{CP} < +0.16 < (90\% CL) -1 / N(D^0 \rightarrow K^-\pi^+), the$
This is the diff the sum of the D*: D^* :	ference be e widths. T D o x + an EVTS R AVERAGE 12 609 d FRABET s of events 00, 700 — ference be	Neen D^0 and \overline{D}^0 he D^0 and \overline{D}^0 are $D^0 = D^0 \pi^-$ $DOCUMENT ID$ E 110 AITALA BARTELT 110 FRABETTI TI 94! measure $N(1)$ observed, and similars $\pi^+\pi^-$	980 95 941 00 → arly fo	guished TECN E791 CLE2 E687 K+K or the D	by the charge of the parent $COMMENT$ -0.093 < A_{CP} < +0.073 (90% CL) -0.022 < A_{CP} < +0.18 (90% CL) -0.11 < A_{CP} < +0.16 (90% CL) -)/ $N(D^0 \rightarrow K^-\pi^+)$, the office these modes divided by
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This is the diff the sum of the D*: D^* :	ference bete widths. To the widths.	tween D^0 and D^0 he D^0 and D^0 are D^0 and D^0 are D^0	980 95 941 00 → arly for	guished TECN E791 CLE2 E687 K+K or the D	by the charge of the parent COMMENT $ -0.093 < A_{CP} < +0.073 \\ (90\% \text{ CL}) \\ -0.022 < A_{CP} < +0.18 \\ (90\% \text{ CL}) \\ -0.11 < A_{CP} < +0.16 \\ (90\% \text{ CL}) \\ -)/N(D^0 \rightarrow K^-\pi^+), the Description of these modes divided by the charge of the parent COMMENT CO$
This is the diff the sum of the D*: D^* :	ference bete widths. In $D^0\pi^+$ and $EVIS$ AVERAGE 12 609 d FRABET is of events D^0 , D^0 — ference be e widths. In $D^0\pi^+$ are $EVIS$.	Neen D^0 and \overline{D}^0 he D^0 and \overline{D}^0 are $D^0 = D^0 \pi^-$ $DOCUMENT ID$ E 110 AITALA BARTELT 110 FRABETTI TI 94! measure $N(1)$ observed, and similars $\pi^+\pi^-$	980 95 941 00 → arly fo	guished TECN E791 CLE2 E687 K+K or the D	by the charge of the parent $COMMENT$ $-0.093 < A_{CP} < +0.073 < 90\% CL)$ $-0.022 < A_{CP} < +0.18 < 90\% CL)$ $-0.11 < A_{CP} < +0.16 < 90\% CL)$ $-)/N(D^{0} \rightarrow K^{-}\pi^{+}), \text{ the parent } 0$ for these modes divided by the charge of the parent $COMMENT$ $-0.186 < A_{CP} <$
This is the diff the sum of the D*: D*+ → VALUE 0.025±0.035 QUF -0.010±0.049±0.0 +0.080±0.061 +0.024±0.084 110 AITALA 98c and ratio of numbers ACP(π+π-) in L This is the diff the sum of the D*: D*+ → VALUE -0.049±0.078±0.0	Ference be: widths. The property of the prope	tween D^0 and D^0 the D^0 and D^0 are $d D^0 - D^0 \pi^-$ $D^0 \pi^-$	98C 95 94I On arily for partial distin	guished TECN E791 CLE2 E687 K+K or the D widths guished TECN C E791	by the charge of the parent comment $COMMENT$ -0.093 $<$ A $_{CP}$ $<$ +0.073 $<$ (90% CL) -0.022 $<$ A $_{CP}$ $<$ +0.18 $<$ (90% CL) -0.11 $<$ A $_{CP}$ $<$ +0.16 $<$ (90% CL) -)/N($D^0 \rightarrow K^-\pi^+$), the for these modes divided by the charge of the parent $<$ $<$ $<$ $<$ $<$ $<$ $<$ $<$ $<$ $<$
This is the diff the sum of the D*: D*+ → VALUE 0.025±0.035 OUF -0.010±0.049±0.0 +0.080±0.061 +0.024±0.084 110 AITALA 98c and ratio of numbers ACP(π+π-) in L This is the diff the sum of the D*: D*+ → VALUE -0.049±0.078±0.0 111 AITALA 98c me events observed, ACP(KS ≠) in D*	Ference be: v widths. T $p^0\pi^+$ and $p^0\pi^+$ and $p^0\pi^+$ and $p^0\pi^+$ by: $v^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^0\pi^$	Neen D^0 and D^0 he D^0 and D^0 and D^0 are D^0 are D^0 are D^0 are D^0 are D^0 are D^0 and D^0 are D^0 are D^0 and D^0 are D^0 are D^0 are D^0 and D^0 are D^0 are D^0 and D^0 are D^0 are D^0 are D^0 are D^0 and D^0 are D^0 are D^0 are D^0 and D^0 are D^0 and D^0 are	98C 95 94I partial distin	guished TECN E791 CLE2 E687 K+K or the D widths guished TECN C E791 K- x	by the charge of the parent COMMENT $-0.093 < A_{CP} < +0.073 (90% CL)$ $-0.022 < A_{CP} < +0.18 (90% CL)$ $-0.11 < A_{CP} < +0.16 (90% CL)$ $-)/N(D^0 \rightarrow K^-\pi^+), the Description of the parent conditions of the parent condition$
This is the diff the sum of the D*: D^* :	Ference be: widths. T $p0\pi^+$ and EVTS R MERAG D12 609 d FRABET s of events $p00\pi^+$ are widths. T $p00\pi^+$ are EVTS 343 casures $N(l)$ and similar $p00\pi^+$ are ference be:	tween D^0 and D^0 he D^0 and D^0 are D^0 and D^0 are D^0 and D^0 are D^0 and D^0 are D^0 are D^0 are D^0 are D^0 are D^0 are D^0 and D^0 are D^0 are D^0 are D^0 are D^0 and D^0 are D^0 and D^0 are D^0 are D^0 and D^0 are D^0 and D^0 are D^0 and D^0	98c 95 94i partial distin	guished TECN E791 CLE2 E687 K+K A the Widths guished TECN C E791 K-A Widths	by the charge of the parent COMMENT $-0.093 < A_{CP} < +0.073 (90% CL)$ $-0.022 < A_{CP} < +0.18 (90% CL)$ $-0.11 < A_{CP} < +0.16 (90% CL)$ $-)/N(D^0 \rightarrow K^-\pi^+), \text{ the Description of the parent constants}$ for these modes divided by the charge of the parent constants are comment constants.
This is the diff the sum of the D*: D^* :	Ference be: widths. T $D^0\pi^+$ and EVTS R MERAG of FRABET of of events of events of events of events of events of and similar and similar of the control of the control of the c	tween D^0 and D^0 the D^0 and D^0 are D^0 are D^0 and D^0 and D^0 are D^0 and	980 95 941 90 → arity for distin	guished $TECN$. E791 CLE2 E687 $K+K'$ \times the \overline{D} wildths guished $TECN$ C E791 \times	by the charge of the parent COMMENT $-0.093 < A_{CP} < +0.073 (90% CL)$ $-0.022 < A_{CP} < +0.18 (90% CL)$ $-0.11 < A_{CP} < +0.16 (90% CL)$ $-)/N(D^0 \rightarrow K^-\pi^+), the Description of the parent $
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This is the diff the sum of the D*: D^* : D^* \rightarrow $VALUE$ 0.028 \pm 0.035 \pm 0.049 \pm 0.04 \pm 0.080 \pm 0.061 \pm 0.084 \pm 0.084 110 AITALA 98c and ratio of numbers $ACP(\pi^+\pi^-)$ in L This is the diff the sum of the D^* : $D^*+\to VALUE$ 111 AITALA 98c me events observed, $ACP(K_S^0\phi)$ in D^0 This is the diff the sum of the D^* : $D^*+\to VALUE$ - 0.028 \pm 0.094 $ACP(K_S^0\phi)$ in D^0	Ference be: widths. T $D^0\pi^+$ and EVTS RAMERAG D12 609 d FRABET s of events of events D^0 , D^0 — ference be: widths. T $D^0\pi^+$ ard EVTS 343 easures $M(I)$ and similar D^0 , D^0 — ference be: widths. T $D^0\pi^+$ ard	Neen D^0 and D^0 he D^0 and D^0 are D^0 and D^0 are D^0 are D^0 and	98C 95 94I OO → arity for a significant of the sig	guished TECN_ E791 CLE2 E687 K+K' w the D wildths guished TECN C E791 Wildths guished MMENT 1.182 </td <td>by the charge of the parent COMMENT $-0.093 < A_{CP} < +0.073 (90% CL)$ $-0.022 < A_{CP} < +0.18 (90% CL)$ $-0.11 < A_{CP} < +0.16 (90% CL)$ $-)/N(D^0 \rightarrow K^-\pi^+), the Description of the parent$</td>	by the charge of the parent COMMENT $-0.093 < A_{CP} < +0.073 (90% CL)$ $-0.022 < A_{CP} < +0.18 (90% CL)$ $-0.11 < A_{CP} < +0.16 (90% CL)$ $-)/N(D^0 \rightarrow K^-\pi^+), the Description of the parent $
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This is the diff the sum of the $D^*: D^*+ \rightarrow VALUE$ 0.028±0.038 OUF -0.010±0.049±0.0 +0.080±0.061 +0.024±0.084 110 AITALA 98c and ratio of numbers $ACP(\pi^+\pi^-)$ in L This is the diff the sum of the $D^*: D^*+ \rightarrow VALUE$ -0.028±0.078 $ACP(K_S^0\phi)$ in D^0 This is the diff the sum of the $D^*: D^*+ \rightarrow VALUE$ -0.028±0.094 $ACP(K_S^0\phi)$ in L This is the diff the sum of the $D^*: D^*+ \rightarrow VALUE$ -0.028±0.094	Terence be a widths. The polymer of	tween D^0 and D^0 and D^0 and D^0 and D^0 are D^0 and D^0 and D^0 are D^0 and	98c 95 94i 00 → arily for distinguishment of the partial disti	guished TECN. E791 CLE2 E687 $K+K$ x the \overline{D} widths guished TECN. $K-x$ widths guished	by the charge of the parent COMMENT $-0.093 < A_{CP} < +0.073 < (90\% \text{ CL}) < -0.022 < A_{CP} < +0.18 $

95 CLE2 -0.067 < A_{CP} < +0.031 (90%CL)

D⁰ PRODUCTION CROSS SECTION AT \$\psi(3770)

A compilation of the cross sections for the direct production of D^0 mesons at or near the $\psi(3770)$ peak in $e^+\,e^-$ production.

VALUE (nanobarns)	DOCUMENT ID		TECN	COMMENT
• • • We do not use the	following data for average	s, fits	, ilmits,	etc. • • •
5.8 ±0.5 ±0.6	112 ADLER	88 C	MRK3	e ⁺ e ⁻ 3.768 GeV
7.3 ±1.3	113 PARTRIDGE	84	CBAL	e ⁺ e 3.771 GeV
$8.00 \pm 0.95 \pm 1.21$	114 SCHINDLER	80	MRK2	e ⁺ e ⁻ 3.771 GeV
115 +25	115 PERUZZI	77	MRK1	e+e- 3.774 GeV

- 112 This measurement compares events with one detected D to those with two detected D
- This measurement compares events with one detected D to those with two detected D mesons, to determine the the absolute cross section. ADLER 88C find the ratio of cross sections (neutral to charged) to be 1.36 ± 0.23 ± 0.14.
 This measurement comes from a scan of the ψ(3770) resonance and a fit to the cross section. PARTRIDGE 84 measures 6.4 ± 1.15 nb for the cross section. We take the phase space division of neutral and charged D mesons in ψ(3770) decay to be 1.33, and we assume that the ψ(3770) is an isosinglet to evaluate the cross sections. The noncharm decays (e.g. radiative) of the ψ(3770) are included in this measurement and may amount to a few percent correction.
 This measurement comes from a scan of the ψ(3770) resonance and a fit to the cross
- may amount to a few percent correction.
 114 This measurement comes from a scan of the $\psi(3770)$ resonance and a fit to the cross section.
 SCHINDLER 80 assume the phase space division of neutral and charged D mesons in $\psi(3770)$ decay to be 1.33, and that the $\psi(3770)$ is an isosinglet. The noncharm decays (e.g. radiative) of the $\psi(3770)$ are included in this measurement and may amount to a few percent correction.
- to a few percent correction. 115 This measurement comes from a scan of the $\psi(3770)$ resonance and a fit to the cross section. The phase space division of neutral and charged D mesons in $\psi(3770)$ decay is taken to be 1.33, and $\psi(3770)$ is assumed to be an isosinglet. The noncharm decays (e.g. radiative) of the $\psi(3770)$ are included in this measurement and may amount to a few percent correction. We exclude this measurement from the average because of uncertainties in the contamination from τ lepton pairs. Also see RAPIDIS 77.

DO REFERENCES

			KEI EKEITOES		
AITALA	98	PR D57 13	+Amato, Anjos, Appel+	(FNAL E791 C	Collab.)
AITALA	98C	PL B421 405	+Amato, Anjos, Appel+	(FNAL E791 C	Collab.)
AITALA	98D	PL B423 185	+Amato, Anjos, Appel+	(FNAL E791 C	(.deBo.
ARTUSO	98	PRL 80 3193	M. Artuso+	(CLEO	Collab.)
PDG	98	EPJ C3 1	C. Caso+	CEDAL DEATRICE C	^allah \
ADAMOVICH BARATE	97 97C	PL B408 469 PL B403 367	+Alexandrov, Angelini+ +Buskulic, Decamp, Ghez+	CERN BEATRICE (ALEPH (
AITALA	96C	PRL 77 2384	+Amato, Anjos, Appel+	(FNAL E791 C	
ALBRECHT	96C	PL B374 249	+Hamacher, Hofmann+	(ARGUS (
ALEXOPOU	96	PRL 77 2380	Alexopoulos, Antoniazzi+	(FNÅL E771 (
ASNER	96B	PR D54 4211	+Athanas, Bliss, Brower+	(CLEO	
BARISH	96	PL B373 334	+Chadha, Chan, Eigen+	(CLEO	ollab.)
FRABETTI	96B	PL B382 312	+Cheung, Cumalat+ +Gibaut, Kinoshita+	(FNAL E687 C	
FREYBERGER Also	96B	PRL 76 3065 PRL 77 2147 (errata)	+ Gibaut, Kinosnita+	(CLEO C	conab.,
KUBOTA	96B	PR D54 2994	+Lattery, Neison, Patton+	(CLEO (Collab.)
ADAMOVICH		PL B353 563	+Adinolfi, Alexandrov+	(CERN BEATRICE (Collab.)
BARTELT	95	PR D52 4860	+Csorna, Egyed, Jain+	CLEO (
BUTLER	95	PR D52 2656	+Fu, Nemati, Ross, Skubic+	(CLEO	Collab.)
FRABETTI	95C	PL B354 486	+ Cheung, Cumalat+	(FNAL E687 (Collab.)
FRABETTI	95G 95	PL B364 127 PL B345 85	+Cheung, Cumalat+ +Ushida, Mokhtarani+	(FNAL E653 (Collab.
KODAMA ALBRECHT	94	PL B324 249	+Ehrlichmann, Hamacher+	(ARGUS	Collab.)
ALBRECHT	94F	PL B340 125	+Hamacher, Hofmann+	(ARGUS	Cottab.)
ALBRECHT	941	ZPHY C64 375	+Hamacher, Hofmann+	(ARGUS (Collab.)
CINABRO	94	PRL 72 1406	+Henderson, Liu, Saulnier+	(CLEO	Collab.)
FRABETTI	94C	PL B321 295	+ Cheung, Cumalat+	(FNAL E687 (Collab.)
FRABETTI	94D	PL B323 459	+Cheung, Cumalat+	(FNAL E687 (Collab.)
FRABETTI	94G 94I	PL B331 217 PR D50 R2953	+Cheung, Cumalat+ +Cheung, Cumalat+	(FNAL E687 ((FNAL E687 (Collab \
FRABETTI FRABETTI	94.1	PL B340 254	+Cheung, Cumalat+	(FNAL E687	
KODAMA	94	PL B336 605	+Ushida, Mokhtarani+	(FNAL E653 (
MISHRA	94	PR D50 R9	+Brown, Cooper+	(FNAL E789 (Collab.)
AKERIB	93	PRL 71 3070	+Barish, Chadha, Chan+	(CLEO	
ALBRECHT		PL B308 435	+Ehrlichmann, Hamacher+	(ARGUS (
ANJOS BEAN	93 93C	PR D48 56 PL B317 647	+Appel, Bean, Bracker+ +Gronberg, Kutschke, Menary+	(FNAL E691 (CLEO (
FRABETTI	93C	PL 8315 203	+ Bogart, Cheung, Culy+	(FNAL E687	Collab.)
KODAMA	93B	PL B313 260	+Ushida, Mokhtarani+	(FNAL E653	
PROCARIO	93B	PR D48 4007	+Yang, Akerib, Barish+	(CLEO	Collab.)
SELEN	93	PRL 71 1973	+Sadoff, Ammar, Ball+	(CLEO	
ADAMOVICH	92	PL B280 163	+Alexandrov, Antinori+	(CERN WA82	Collab.
ALBRECHT	92P	ZPHY C56 7 PR D46 R1	+Cronstroem, Ehrlichmann+	(ARGUS (Collab.)
2OLNA 2OLNA	92B 92C	PR D46 1941	+Appel, Bean, Bracker+ +Appel, Bean, Bracker+	(FNAL E691	
BARLAG	92C	ZPHY C55 383	+Becker, Bozek, Boehringer+	(ACCMOR	
Also	90D	ZPHY C48 29	Barlag, Becker, Boehringer, Bo	sman+ (ACCMOR (Collab.)
COFFMAN	92B	PR D45 2196	+DeJongh, Dubois, Eigen+	(Mark III (Collab.)
Also	90	PRL 64 2615	Adler, Blaylock, Bolton+	(Mark III (
FRABETTI	92	PL B281 167	+Bogart, Cheung, Culy+	(FNAL E687	
FRABETTI	92B 91B	PL B286 195 ZPHY C50 11	+Bogart, Cheung, Culy+ +Barate, Bloch, Bonamy+	(FNAL E687 ((CERN NA14/2 (
AMMAR	91	PR D44 3383	+Baringer, Coppage, Davis+	(CLEO	Collab.
ANJOS	91	PR D43 R635	+Appel, Bean, Bracker+	(FNAL-TPS	Collab.)
ANJOS		PR D44 R3371	+Appel, Bean, Bracker+	(FNAL-TPS	
BAI	91	PRL 66 1011	+Bolton, Brown, Bunnell+	(Mark III	
COFFMAN	91	PL 8263 135	+DeJongh, Dubois, Eigen, Hitlin	+ (Mark III)	
CRAWFORD	91B 91J	PR D44 3394	+Fulton, Gan, Jensen+	(CLEO	
DECAMP FRABETTI	91	PL B266 218 PL B263 584	+Deschizeaux, Goy, Lees+ +Bogart, Cheung, Culy+	(FNAL E687	
KINOSHITA	91	PR D43 2836	+Pipkin, Procario, Wilson+	CLEO	Collab.)
KODAMA	91	PRL 66 1819	+Ushida, Mokhtarani, Paolone+	(FNAL E653	Collab.)
ALBRECHT	90C	ZPHY C46 9	+Glaeser, Harder, Krueger+	` (ARGUS	Collab.)
ALEXANDER	90	PRL 65 1184	+Artuso, Bebek, Berkelman+	(CLEO	
ALEXANDER	908	PRL 65 1531	+Artuso, Bebek, Berkelman+	(CLEO (CERN NA14/2	Collab.
ALVAREZ ANJOS	90 90D	ZPHY C47 539 PR D42 2414	+ Barate, Bloch, Bonamy+ + Appel, Bean, Bracker+	(FNAL E691	
BARLAG	90C	ZPHY C46 563	+Becker, Boehringer, Bosman+	(ACCMOR	
ADLER	89	PRL 62 1821	+Becker, Blaylock, Bolton+	(Mark III	Collab.)
ADLER	89C	PR D40 906	+Bai, Becker, Blaylock, Bolton+		
ALBRECHT	89D	ZPHY C43 181	+ Boeckmann, Glaeser, Harder+	(ARGUS	
ZOLNA	89F	PRL 62 1587	+Appel, Bean, Bracker, Browder	+ (FNAL E691	COMAD.)

ABACHI	88	PL B205 411	+Akerlof, Baringer+	(HRS Collab.)
ADLER	88	PR D37 2023	+Becker, Blaylock+	(Mark III Collab.)
ADLER	88C	PRL 60 89	+Becker, Blaylock+	(Mark III Collab.)
ALBRECHT	88G	PL B209 380	+Boeckmann, Glaeser+	(ARGUS Collab.)
LBRECHT	881	PL B210 267	+Boeckmann, Glaeser+	(ARGUS Collab.)
MENDOLIA	88	EPL 5 407	+Bagliesi, Batignani+	` (NA1 Collab.)
ANJOS	BBC	PRL 60 1239	+Appel+	(FNAL E691 Collab.)
BORTOLETTO	88	PR D37 1719	+Goldberg, Horwitz, Mestayer, Moneti-	+ (CLEO Collab.)
Also	89D	PR D39 1471 erratum		
CUMALAT	88	PL B210 253	+Shipbaugh, Binkley+	(E-400 Collab.)
HAAS	88	PRL 60 1614	+Hempstead, Jensen+	(CLEO Collab.)
RAAB	88	PR D37 2391		(FNAL E691 Collab.)
ADAMOVICH	87	EPL 4 887		ton Emulsion Collab.)
ADLER	87	PL B196 107	+Becker, Blaylock, Bolton+	(Mark III Collab.)
AGUILAR	87D	PL B193 140	Aguilar-Benitez, Allison+ Aguilar-Benitez, Allison, Bailly+	(LEBC-EHS Collab.)
Also	88B	ZPHY C40 321	Aguilar-Benitez, Allison, Bailly+	(LEBC-EHS Collab.)
AGUILAR	87E	ZPHY C36 551	Aguilar-Benitez, Allison+	(LEBC-EHS Collab.) (LEBC-EHS Collab.)
Also	88B	ZPHY C40 321	Aguilar-Benitez, Allison, Bailly+	
AGUILAR	87F	ZPHY C36 559	Aguilar-Benitez, Allison+	(LEBC-EHS Collab.)
Also	88	ZPHY C38 520 erratur		/4Deue = 11 1 1
ALBRECHT	87E	ZPHY C33 359	+Binder, Boeckmann, Glaser+	(ARGUS Collab.)
ALBRECHT	87K	PL B199 447	+Andam, Binder, Boeckmann+	(ARGUS Collab.)
BARLAG	878	ZPHY C37 17	+Becker, Boehringer, Bosman+	(ACCMOR Collab.)
BECKER	87C	PL B193 147	+Blaylock, Bolton, Brown+	(Mark III Collab.)
Also	87D	PL B198 590 erratum	Becker, Blaylock, Bolton+	(Mark III Collab.)
CSORNA	87	PL B191 318	+Mestayer, Panvini, Word+	(CLEO Collab.)
PALKA	87	PL B189 238	+Bailey, Becker, Belau+	(ACCMOR Collab.)
RILES	87	PR D35 2914	+Dorfan, Abrams, Amidei+	(Mark II Collab.)
ABACHI ABE	86D 86	PL B182 101 PR D33 1	+Akerlof, Baringer, Ballam+	(HRS Collab.) cility Photon Collab.)
BAILEY	86	ZPHY C30 51	+ (SEAC Hybrid Fa +Belau, Boehringer, Bosman+	(ACCMOR Collab.)
	86	PRL 56 1893		(CLEO Collab.)
BEBEK GLADNEY	86	PR D34 2601	+Berkelman, Blucher, Cassel+	(Mark II Collab.)
LOUIS	86	PRL 56 1027	+ Jaros, Ong, Barklow+ + Adolphsen, Alexander+	(PRIN, CHIC, ISU)
USHIDA	86B	PRL 56 1771	+Kondo+ (AICH, FNAL, KC	DBE, SEOU, MCGI+)
ALBRECHT	85B	PL 158B 525	+Binder, Harder, Philipp+	(ARGUS Collab.)
ALBRECHT	85F	PL 150B 235	+Binder, Harder, Philipp+	(ARGUS Collab.)
AUBERT	85	PL 155B 461	+Bassompierre, Becks, Benchouk+	(EMC Collab.)
BAILEY	85	ZPHY C28 357	+Belau, Boehringer, Bosman+	(ABCCMR Collab.)
BALTRUSAIT		PRL 54 1976	Baltrusaitis, Becker, Blaylock, Brown	
BALTRUSAIT		PRL 55 150	Baltrusaitis, Becker, Blaylock, Brown-	
BENVENUTI	85	PL 158B 531	+Bollini, Bruni, Camporesi+	(BCDMS Collab.)
YAMAMOTO	85	PRL 54 522	+Yamamoto, Atwood, Baillon+	(DELCO Collab.)
ADAMOVICH	84B	PL 140B 123	+Alexandrov, Bravo+ (CERN WASE Collab.)
ALTHOFF	84B	PL 138B 317	+Braunschweig, Kirschfink+	(TASSO Collab.)
DERRICK	84	PRL 53 1971	+Fernandez, Fries, Hyman+	(HRS Collab.)
PARTRIDGE	84	Thesis CALT-68-1150	Tremonder Tries, Tryman ;	(Crystal Ball Collab.)
SUMMERS	84	PRL 52 410	+ (UCSB, CARL, COLO, FNAL, T	
BAILEY	83B	PL 132B 237	+Bardsley, Becker, Blanar+	(ACCMOR Collab.)
BODEK	82	PL 113B 82		CHIC, FNAL, STAN)
FIORINO	81	LNC 30 166	+ (Photon-Emulsion and O	mega-Photon Collab.)
SCHINDLER	81	PR D24 78	+Alam, Boyarski, Breidenbach+	(Mark II Collab.)
TRILLING	81	PRPL 75 57		(LBL, UCB) J
ASTON	80E	PL 94B 113	+ (BONN, CERN, EPOL, GL	
AVERY	80	PRL 44 1309	+Wiss, Butler, Gladding+	(ILL, FNAL, COLU)
SCHINDLER	80	PR D21 2716	+Siegrist, Alam, Boyarski+	(Mark II Collab.)
ZHOLENTZ	80	PL 96B 214	+Kurdadze, Lelchuk, Mishnev+	(NOVO)
Also	81	SJNP 34 814	Zholentz, Kurdadze, Lelchuk+	(NOVO)
		Translated from YAF 3	4 1471.	
ABRAMS	79D	PRL 43 481	+Alam, Blocker, Boyarski+	(Mark II Collab.)
ATIYA	79	PRL 43 414	+Holmes, Knapp, Lee+	(COLU, ILL, FNAL)
BALTAY	78C	PRL 41 73	+Caroumbalis, French, Hibbs, Hylton+	
VUILLEMIN	78	PRL 41 1149	+Feldman, Feller+	(Mark I Collab.)
FELDMAN	77B	PRL 38 1313	+Peruzzi, Piccolo, Abrams, Alam+	(Mark I Collab.)
GOLDHABER	77	PL 69B 503	+Wiss, Abrams, Alam+	(Mark I Collab.) (Mark I Collab.)
PERUZZI	77	PRL 39 1301	+Piccolo, Feldman+	
PICCOLO	77	PL 70B 260	+Peruzzi, Luth, Nguyen, Wiss, Abrams	
RAPIDIS	77 76	PRL 39 526	+Gobbi, Luke, Barbaro-Galtieri+	(Mark I Collab.) (Mark I Collab.)
GOLDHABER	10	PRL 37 255	+Pierre, Abrams, Alam+	(Mark I Collab.)
		OTHE	R RELATED PAPERS	
RICHMAN ROSNER	95 95	RMP 67 893 CNPP 21 369	+Burchat	(UCSB, STAN) (CHIC)

$D^*(2007)^0$

 $I(J^P) = \frac{1}{2}(1^-)$ I, J, P need confirmation.

J consistent with 1, value 0 ruled out (NGUYEN 77).

D*(2007)0 MASS

The fit includes D^\pm , D^0 , D_s^\pm , $D^{*\pm}$, D^{*0} , and $D_s^{*\pm}$ mass and mass difference measurements.

VALUE (MeV)	DOCUMENT ID TECN COMMENT	
2006.7±0.5 OUR FIT E	rror includes scale factor of 1.1.	
• • • We do not use the	following data for averages, fits, limits, etc. • • •	
2006 ±1.5	¹ GOLDHABER 77 MRK1 e ⁺ e ⁻	
¹ From simultaneous fit	to $D^*(2010)^+$, $D^*(2007)^0$, D^+ , and D^0 .	

$m_{D^*(2007)^0} - m_{D^0}$

The fit includes D^{\pm} , D^0 , D_s^{\pm} , $D^{*\pm}$, D^{*0} , and $D_s^{*\pm}$ mass and mass

VALUE (MeV)	EVTS	DOCUMENT ID TECN COMMENT
142.12±0.07 OUR FI	T	
142.12±0.07 OUR AV	'ERAGE	· ·
142.2 ±0.3 ±0.2	145	ALBRECHT 95F ARG $e^+e^- \rightarrow hadrons$
$142.12 \pm 0.05 \pm 0.05$	1176	BORTOLETTO928 CLE2 $e^+e^- \rightarrow hadrons$
• • • We do not use	the followin	ng data for averages, fits, limits, etc. • • •
142.2 ±2.0		SADROZINSKI 80 CBAL $D^{*0} \rightarrow D^0 \pi^0$
142.7 ±1.7		² GOLDHABER 77 MRK1 e ⁺ e ⁻
² From simultaneous	s fit to D*((2010)+, D*(2007) ⁰ , D+, and D ⁰ .

D*(2007)0 WIDTH

VALUE (MeV)	CL%		DOCUMENT ID		TECN	COMMENT
<2.1	90	3	ABACHI	88B	HRS	$D^{*0} \rightarrow D^+\pi^-$
³ Assuming $m_{D*0} = 2$	2007.2 ± 2	2.1	MeV/c^2 .			

D*(2007)0 DECAY MODES

 $\overline{\it D}^*(2007)^0\,$ modes are charge conjugates of modes below.

	Mode	Fraction (Γ_i/Γ)
Γ ₁	$D^{0} \pi^{0}$	(61.9±2.9) %
Γ ₂	$D^{0} \gamma$	(38.1±2.9) %

CONSTRAINED FIT INFORMATION

An overall fit to a branching ratio uses 3 measurements and one constraint to determine 2 parameters. The overall fit has a $\chi^2=$ 0.5 for 2 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\langle \delta x_i \delta x_j \rangle / (\delta x_i \cdot \delta x_j)$, in percent, from the fit to the branching fractions, $x_i \equiv$ $\Gamma_i/\Gamma_{\text{total}}$. The fit constrains the x_i whose labels appear in this array to sum to

D*(2007) BRANCHING RATIOS

$\Gamma(D^0\pi^0)/\Gamma_{\text{total}}$					Γ_1/Γ
VALUE	EVTS	DOCUMENT ID	TECN	COMMENT	
0.619±0.029 OUR FIT	•				
 • • We do not use t 	he followi	ng data for average:	s, fits, limits	, etc. • • •	
0.596 ± 0.035 ± 0.028	858	ALBRECHT	95F ARG	e+e- →	hadrons
$0.636 \pm 0.023 \pm 0.033$	1097	⁴ BUTLER	92 CLE2	$e^+e^- \rightarrow$	hadrons
$\Gamma(D^0\gamma)/\Gamma_{\text{total}}$					Γ_2/Γ
VALUE	EVTS	DOCUMENT ID	TECN	COMMENT	
0.381±0.029 OUR FIT	•				
0.381±0.029 OUR AV	ERAGE				
$0.404 \pm 0.035 \pm 0.028$	456	ALBRECHT	95F ARG	$e^+e^- \rightarrow$	hadrons
$0.364 \pm 0.023 \pm 0.033$	621	⁴ BUTLER	92 CLE2	$e^+e^- \rightarrow$	hadrons
0.37 ±0.08 ±0.08		ADLER	88D MRK3	e+e-	
• • • We do not use t	he followi	ng data for average	s, fits, limits	, etc. • • •	
0.47 ±0.23		LOW	87 HRS	29 GeV e	+ e-
0.53 ±0.13		BARTEL	85G JADE	e^+e^- , ha	drons
0.47 ±0.12		COLES	82 MRK2	e ⁺ e ⁻	
0.45 ±0.15		GOLDHABER	77 MRK1	e ⁺ e ⁻	
4 The BUTLED 02 F		ration are not inden	andont that	, have been	constrained by

The BUTLER 92 branching ratios are not Independent, they have been constrained by the authors to sum to 100%.

D*(2007)0 REFERENCES

	- ,-	,				
ALBRECHT 95F	ZPHY C66 63	+Ehrlichmann+	(ARGUS Collab.)			
BORTOLETTO 92B	PRL 69 2046	+Brown, Dominick+	(CLEO Collab.)			
BUTLER 92	PRL 69 2041	+Fv, Kalbfleish+	(CLEO Collab.)			
ABACHI 88B	PL B212 533	+Akerlof+ (ANL, II	ND, MICH, PURD, LBL)			
ADLER 88D	PL B208 152	+Becker+	(Mark III Collab.)			
LOW 87	PL B183 232	+Abachi, Akerlof, Baringer+	(HRS Collab.)			
BARTEL 85G	PL 161B 197	+Dietrich, Ambrus+	(JADE Collab.)			
COLES 82	PR D26 2190	+Abrams, Blocker, Blondel+	(LBL, SLAC)			
SADROZINSKI 80	Madison Conf. 681	+ (PRIN, CI	T, HARV, SLAC, STAN)			
GOLDHABER 77	PL 69B 503	+Wiss, Abrams, Alam+	(Mark I Collab.)			
NGUYEN 77	PRL 39 262	+Wiss, Abrams, Alam, Boyarski+	(LBL, SLAC) J			
OTHER RELATED PAPERS						
KAMAL 92 TRILLING 81	PL B284 421 PRPL 75 57	+Xu ,	(ALBE) (LBL, UCB)			
GOLDHABER 76	PRL 37 255	+Pierre, Abrams, Alam+	(Mark I Collab.)			

 $D^*(2010)^{\pm}$

 $D^*(2010)^{\pm}$

$$I(J^P) = \frac{1}{2}(1^-)$$

I, J, P need confirmation.

D*(2010)* MASS

The fit includes D^{\pm} , D^0 , D_s^{\pm} , $D^{*\pm}$, D^{*0} , and $D_s^{*\pm}$ mass and mass difference measurements.

VALUE (MeV)				CHG	COMMENT
	Error includes scale factor of ne following data for averages,			etc. •	• •
2008 ±3	¹ GOLDHABER				
2008.6 ± 1.0	² PERUZZI	77	MRK1	±	e+ e-

From simultaneous fit to $D^*(2010)^+$, $D^*(2007)^0$, D^+ , and D^0 ; not independent of FELDMAN 778 mass difference below.

PERUZZI 77 mass not independent of FELDMAN 778 mass difference below and PERUZZI 77 D^0 mass value.

$m_{D^{*}(2010)^{+}} - m_{D^{+}}$

The fit includes D^{\pm} , D^0 , D_s^{\pm} , $D^{*\pm}$, D^{*0} , and $D_s^{*\pm}$ mass and mass difference measurements.

VALUE (MeV)	EVTS	DOCUMENT ID TECN	COMMENT
140.64±0.10 OUR FIT	Error i	ncludes scale factor of 1.1.	
140.64±0.08±0.06	620	BORTOLETTO92B CLE2	e ⁺ e [−] → hadrons

$m_{D^{*}(2010)^{+}} - m_{D^{0}}$

The fit includes D^\pm , D^0 , D^\pm_s , $D^{o\pm}$, D^{o0} , and $D^{o\pm}_s$ mass and mass difference measurements.

VALUE (MeV)		EVTS	DOCUMENT ID		TECN	COMMENT	
145.397	±0.030	OUR FIT	•					
145.397	±0.030	OUR AVI	ERAGE					
145.5	±0.15		103	3 ADLOFF	97B	H1	$D^{*\pm} \rightarrow D^0 \pi^{\pm}$	
145.44	±0.08		152	3 BREITWEG	97	ZEUS	$D^{*\pm} \rightarrow D^0 \pi^{\pm}$,	
145.42	±0.11		199	3 BREITWEG	97	ZEUS	$D \stackrel{+}{\rightarrow} \stackrel{-}{\rightarrow} D_0 \stackrel{+}{\rightarrow} \stackrel{+}{\rightarrow}$	
145.4	±0.2		48	3 DERRICK	95	ZEUS	$D^{*\pm} \rightarrow D^0\pi^{\pm}$	
145.39	±0.06	±0.03		BARLAG	92B	ACCM	π - 230 GeV	
145.5	±0.2		115	³ ALEXANDER	918	OPAL	$D^{*\pm} \rightarrow D^0 \pi^{\pm}$	
145.30	±0.06			3 DECAMP	91J	ALEP	$D^{*\pm} \rightarrow D^0 \pi^{\pm}$	
145.40	±0.05	±0.10		ABACHI	888	HRS	$D^{*\pm} \rightarrow D^0 \pi^{\pm}$	
145.46	±0.07	±0.03		ALBRECHT	85F	ARG	$D^{*\pm} \rightarrow D^0 \pi^+$	
145.5	±0.3		28	BAILEY	83	SPEC	$D^{*\pm} \rightarrow D^0 \pi^{\pm}$	
145.5	±0.3		60	FITCH	81	SPEC	π A	
145.3	±0.5		30	FELDMAN	77B	MRK1	$D^{*+} \rightarrow D^0 \pi^+$	
• • • We	do not	use the fo	liowing d	ata for averages, fit	ts, ilr	nits, etc	. • • •	
145.44	±0.09		122	3 BREITWEG	97B	ZEUS	$D^{*\pm} \rightarrow D^0 \pi^{\pm}$,	
145.8	±1.5		16	AHLEN	83	HRS	$D^{*+} \rightarrow D^0 \pi^+$	
145.1	±1.8		12	BAILEY	83	SPEC	$D^{*\pm} \rightarrow D^0 \pi^{\pm}$	
145.1	±0.5		14	BAILEY	83	SPEC	$D^{*\pm} \rightarrow D^0 \pi^{\pm}$	
145.5	±0.5		14	YELTON	82	MRK2	29 e ⁺ e ⁻ →	
~ 145.5				AVERY	80	SPEC	γA	
145.2	±0.6		2	BLIETSCHAU	79	BEBC	νp	
3 System	natic er	ror not eva	aluated.					

$m_{D^{*}(2010)^{+}} - m_{D^{*}(2007)^{0}}$

VALUE (MeV)	DOCUMENT IL	TECN	COMMENT	
• • • We do not use the follow	ing data for averag	ges, fits, limits	, etc. • • •	
2.6 ± 1.8	⁴ PERUZZI	77 MRK	e+e-	
⁴ Not Independent of FELDM	AN 77B mass diffe	rence above,	PERUZZI 77 <i>D</i>	mass, and

GOLDHABER 77 D*(2007)0 mass.

D*(2010)* WIDTH

VALUE (MeV)	CL%.	EVTS	DOCUMENT ID		TECN	COMMENT
<0.131	90	110	BARLAG	92B	ACCM	π ⁻ 230 GeV
• • • We do	not use the	follow	ing data for averages,	, fits	limits,	etc. • • •
<1.1	90		ABACHI	888	HRS	$D^{*\pm} \rightarrow D^0 \pi^{\pm}$
<2.2						$e^+e^- \rightarrow K^-\pi^+\pi^-$
<2.0	90	30	FELDMAN	77B	MRK1	$D^{*+} \rightarrow D^0 \pi^+$

D*(2010) DECAY MODES

 $D^*(2010)^-$ modes are charge conjugates of the modes below.

	Mode	Fraction (Γ_I/Γ)
$\overline{\Gamma_1}$	$D^{0}\pi^{+}$ $D^{+}\pi^{0}$	(68.3±1.4) %
Γ_2	$D^+\pi^0$	(30.6±2.5) %
Γ3	$D^+\gamma$	$(1.1^{+2.1}_{-0.7})\%$

CONSTRAINED FIT INFORMATION

An overall fit to 2 branching ratios uses 3 measurements and one constraint to determine 3 parameters. The overall fit has a $\chi^2=$ 0.0 for 1 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\langle \delta x_i \delta x_j \rangle / (\delta x_i \cdot \delta x_j)$, in percent, from the fit to the branching fractions, $x_i \equiv$ $\Gamma_i/\Gamma_{\text{total}}$. The fit constrains the x_i whose labels appear in this array to sum to one.

D*(2010)+ BRANCHING RATIOS

Γ(D ⁰ π ⁺)/Γ _{total} VALUE 0.683 ± 0.014 OUR FIT		<u>DOÇUI</u>	MENT ID		TECN	COMMENT	Γ ₁ /Γ
0.683±0.014 OUR AVE 0.688±0.024±0.013 0.681±0.010±0.013		5 BUTL	ER	92	CLE2	e ⁺ e ⁻ -	hadronshadrons
• • We do not use th	e followin	g data for	average	s, fits	i, limits,	etc. • •	•
0.57 ±0.04 ±0.04 0.44 ±0.10 0.6 ±0.15		COLE	R S HABER	82		e+ e-	
$\Gamma(D^+\pi^0)/\Gamma_{\text{total}}$ $VALUE$ 0.305 ± 0.025 OUR FIT	EYTS	DOCUI	MENT ID		<u>TECN</u>	COMMEN'	Γ ₂ /Γ
• • We do not use th	e followin	g data for	average:	s, fits	, limits,	etc. • •	•
0.312±0.011±0.008 0.308±0.004±0.008 0.26 ±0.02 ±0.02 0.34 ±0.07	1404 410			92 88D		e+e	→ hadrons→ hadrons
$\Gamma(D^+\gamma)/\Gamma_{\text{total}}$ $VALUE$ 0.011 $^{+0.021}_{-0.007}$ OUR FI	<u>clx</u>	EVTS	<u>DOCU</u>	MEN1	· ID	<u>TECN</u>	Γ ₃ /Γ
0.011±0.014±0.016	•	12	5 BUTI	ER	92	CLE2	e ⁺ e [−] → hadrons
• • • We do not use th	e followin	g data fo	r average	s, flt:	s, limits,	etc. • •	
<0.052	90		ALBF	RECH	IT 95	F ARG	e+e- →
0.17 ±0.05 ±0.05 0.22 ±0.12			ADLE 7 COLE			D MRK3 MRK2	
⁵ The BUTLER 92 br the authors to sum 1 ⁶ Assuming that isosp ⁷ Not independent of	to 100%. In is conse	erved in t	he decay.				

D*(2010) + REFERENCES

ADLOFF	97B	ZPHY C72 593	+Aid, Anderson+ (H1 Collab.)
BREITWEG	97	PL B401 192	+Derrick, Krakauer+ (ZEUS Collab.)
BREITWEG	97B	PL B407 402	J. Breitweg+ (ZEUS Collab.)
ALBRECHT	95F	ZPHY C66 63	+Ehrlichmann+ (ARGUS Collab.)
DERRICK	95	PL B349 225	+Krakauer+ (ZEUS Collab.)
BARLAG	92B	PL B278 480	+Becker, Bozek+ (ACCMOR Collab.)
BORTOLETTO		PRL 69 2046	+Brown, Dominick+ (CLEO Collab.)
BUTLER	92	PRL 69 2041	+Fu, Kalbfleish+ (CLEO Collab.)
ALEXANDER	91B	PL B262 341	+Allison, Allport, Anderson, Arcelli+ (OPAL Collab.)
DECAMP	91 J	PL B266 218	+ Deschizeaux, Gov. Lees+ (ALEPH Collab.)
ABACHI	88B	PL B212 533	+Akerlof+ (ANL, IND, MICH, PURD, LBL)
ADLER	88D	PL B208 152	+Becker+ (Mark III Collab.)
ALBRECHT	85F	PL 150B 235	+Binder, Harder, Philipp+ (ARGUS Collab.)
AHLEN	83	PRL 51 1147	+Akerlof+ (ANL, IND, LBL, MICH, PURD, SLAC)
BAILEY	83	PL 132B 230	+ Bardsley+ (AMST, BRIS, CERN, CRAC, MPIM+)
COLES	82	PR D26 2190	+Abrams, Blocker, Blondel+ (LBL, SLAC)
YELTON	82	PRL 49 430	+Feldman, Goldhaber+ (SLAC, LBL, UCB, HARV)
FITCH	81	PRL 46 761	+ Devaux, Cavaglia, May+ (PRIN, SACL, TORI, BNL)
AVERY	80	PRL 44 1309	+Wiss, Butler, Gladding+ (ILL, FNAL, COLU)
BLIETSCHAU	79	PL 86B 108	+ (AACH3, BONN, CERN, MPIM, OXF)
FELDMAN	77B	PRL 38 1313	+Peruzzi, Piccolo, Abrams, Alam+ (Mark I Collab.)
GOLDHABER	77	PL 69B 503	+Wiss, Abrams, Alam+ (Mark I Collab.)
PERITZI	77	PRI 39 1301	+Piccolo, Feldman+ (Mark I Collab.)

	OTHER	REL	ATED	PAP	ERS	
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KAMAL ALTHOFF BEBEK TRILLING PERUZZI		PL B284 421 PL 126B 493 PRL 49 610 PRPL 75 57 PRL 37 569	+Xu +Fischer, Burkhardt+ + (HARV, OSU, ROCH, RUTG, +Piccolo, Feldman, Næven, Wiss+	(ALBE (TASSO Collab. SYRA, VAND+ (LBL, UCB (Mark I Collab.
PERUZZI	76	PRL 37 569	+Piccolo, Feldman, Nguyen, Wiss+	(Mark I Collab.

$D_1(2420)^0$

$$I(J^P) = \frac{1}{2}(1^+)$$

I, J, P need confirmation.

Seen in $D^*(2010)^+\pi^-$. $J^P=1^+$ according to ALBRECHT 89H.

D1(2420)0 MASS

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
2422.2±1.8 OUR A	VERAGE Er	ror includes scale t	factor of 1.2.	
$2421 \begin{array}{c} +1 \\ -2 \end{array} \pm 2$	286	AVERY	94C CLE2	$e^+e^- \rightarrow D^{*+}\pi^-X$
2422 ±2 ±2	51	FRABETTI		$\gamma \text{Be} \rightarrow D^{\bullet+} \pi^- X$
2428 ±3 ±2	279	AVERY	90 CLEO	$e^+e^- \rightarrow D^{*+}\pi^-X$
2414 ±2 ±5	171	ALBRECHT	89H ARG	$e^+e^- \rightarrow D^{*+}\pi^-X$
2428 ±8 ±5	171	ANJOS	89C TPS	$\gamma N \rightarrow D^{*+}\pi^{-}X$

D1(2420)0 WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT		
18.9 + 4.6 OUR AVERA	GE					
$20 + \frac{6}{5} \pm 3$	286	AVERY	94C CLE2	$e^+e^- \rightarrow D^{*+}\pi^-X$		
15 ± 8 ± 4	51	FRABETTI	94B E687	$\gamma \text{Be} \rightarrow D^{*+} \pi^- X$		
$23 \begin{array}{cccccccccccccccccccccccccccccccccccc$	279	AVERY	90 CLEO	$e^+e^- \rightarrow D^{e+}\pi^-X$		
$13 \pm 6 \begin{array}{c} +10 \\ -5 \end{array}$	171	ALBRECHT	89H ARG	$e^+e^- \rightarrow D^{*+}\pi^-X$		
• • • We do not use the following data for averages, fits, limits, etc. • •						
58 ±14 ±10	171	ANJOS	89c TPS	$\gamma N \rightarrow D^{*+}\pi^{-}X$		

$D_1(2420)^0$ DECAY MODES

 $\overline{\mathcal{D}}_1(2420)^0$ modes are charge conjugates of modes below.

	Mode	Fraction (Γ_I/Γ)
Γ ₁	$D^*(2010)^+\pi^-$	seen
Γ ₂	$D^+\pi^-$	not seen

D1(2420)0 BRANCHING RATIOS

$\Gamma(D^{\bullet}(2010)^{+}$	π ⁻)/Γ _{total}				Γ ₁ /Γ
VALUE		DOCUMENT ID		TECN	
seen		AVERY	90	CLEO	$e^+e^- \rightarrow D^{*+}\pi^-X$
900R		ALBRECHT			$e^+e^- \rightarrow D^*\pi^-X$
2000		ANJOS	89 C	TP5	$\gamma N \rightarrow D^{*+}\pi^- X$
$\Gamma(D^+\pi^-)/\Gamma($	$(D^*(2010)^+\pi^-)$				Γ ₂ /Γ ₁
VALUE		DOCUMENT ID		TECN	COMMENT
<0.24	90	AVERY	90	CLEO	$e^+e^- \rightarrow D^+\pi^-X$
					···

D ₁ (2420) ⁰ REFERENCES						
94B 90 89H	PRL 72 324 PR D41 774 PL B232 398	+Freyberger, Rodríguez+ +Cheung, Cumalat+ +Besson +Glaser, Harder+ +Appel+	(CLEO Collab.) (FNAL E687 Collab.) (CLEO Collab.) (ARGUS Collab.) JF (FNAL E691 Collab.)			
	94B 90 89H	94C PL B331 236 94B PRL 72 324 90 PR D41 774	94C PL B331 236 +Freyberger, Rodriguez+ 94B PRI. 72 324 +Cheung. Cumalat+ 90 PR D41 774 +Besson 94H PL B212 398 +Glaser, Harder+			



 $I(J^P) = \frac{1}{2}(?^?)$ I needs confirmation.

OMITTED FROM SUMMARY TABLE Seen in $D^{\bullet}(2007)^{0}\pi^{+}$. $J^{P}=0^{+}$ ruled out.

$D_1(2420)^{\pm}$ MASS

2427±5 OUR AVERAGE Error includes scale factor of 2.0. 2425±2±2 146 BERGFELD 94B CLE2 $e^+e^- \rightarrow D^{40}\pi$	
	•
2443±7±5 190 ANJOS 89C TPS $\gamma N \rightarrow D^0 \pi^+ X^0$. X ₀

$m_{D_1^{\bullet}(2420)^{\pm}} - m_{D_1^{\bullet}(2420)^{0}}$

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
4 ⁺² ₋₃ ±3	BERGFELD	94B CLE2	e ⁺ e [−] → hadrons

$D_1(2420)^{\pm}$ WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
26± 8 OUR AVERAGE				
26 + 8 ± 4	146	BERGFELD	948 CLE2	$e^+e^- \rightarrow D^{*0}\pi^+X$
41±19±8	190	ANJOS	89C TPS	$\gamma N \rightarrow D^0 \pi^+ X^0$

D1(2420) DECAY MODES

 $D_1^*(2420)^-$ modes are charge conjugates of modes below.

	Mode	Fraction (Γ_I/Γ)
$\overline{\Gamma_1}$	$D^*(2007)^0 \pi^+$ $D^0 \pi^+$	seen
Γ_2	$D^0\pi^+$	not seen

D1(2420) BRANCHING RATIOS

Γ(D*(2007) ⁰	$\pi^+)/\Gamma_{\text{total}}$	DOCUMENT ID		TECN	COMMENT	•
DOOR .		SOLIA			$\gamma N \rightarrow D^0 \pi^+ X^0$	_
$\Gamma(D^0\pi^+)/\Gamma($	$D^*(2007)^0\pi^+)$				Γ ₂ /Γ	ı
, , ,	CLS	DOCUMENT ID		TECN	COMMENT	_
• • • We do no	ot use the followin	g data for average	es, fits	, limits	, etc. • • •	
<0.18	90	BERGFELD	94B	CLE2	e ⁺ e [−] → hadrons	

D1(2420) + REFERENCES

BERGFELD	94B PL B340 194	+Eisenstein, Gollin+	(CLEO Collab.)
ANJOS	89C PRL 62 1717	+Appel+	(FNAL £691 Collab.)
COLMA	89C PKL 62 1/1/	+Apper+	(LIANT EGGY COMP)

 $D_1(2420)^{\pm}$, $D_2^*(2460)^0$, $D_2^*(2460)^+$

 $D_2^*(2460)^0$

 $I(J^P) = \frac{1}{2}(2^+)$

 $J^P = 2^+$ assignment strongly favored (ALBRECHT 89B).

D*(2460)0 MASS

VALUE (N	AeV)		EVTS	DOCUMENT ID		TECN	COMMENT
2458.9	F 2.0	OUR	AVERAGE E	rror includes scale	factor	of 1.2.	
2465 ±	-3	±3	486	AVERY	94C	CLE2	$e^+e^- \rightarrow D^+\pi^-X$
2453 Ⅎ	Ŀ3	±2	128	FRABETTI	94B	E687	$\gamma Be \rightarrow D^+ \pi^- X$
2461 ±	Ŀ3	±1	440	AVERY	90	CLEO	$e^+e^- \rightarrow D^{*+}\pi^-X$
2455 ±	<u> 3</u>	±5	337	ALBRECHT	89B	ARG	$e^+e^- \rightarrow D^+\pi^-X$
2459 ±	-3	±2	153	ANJOS	89C	TPS	$\gamma N \rightarrow D^{+}\pi^{-}X$
• • • V	Ve o	do not	use the followi	ing data for average	s, fits	, limits,	etc. • • •
2466 ±	t 7		1	ASRATYAN	95	BEBC	$\begin{array}{ccc} 53,40 \ \nu(\overline{\nu}) \rightarrow & p + X, \\ d + X & \end{array}$

$D_2^*(2460)^0$ WIDTH

VALUE (MeV) 23± 5 OUR AVERA	EVTS	DOCUMENT ID	TECN	COMMENT
28 + 8 ± 6	486	AVERY	94c CLE2	$e^+e^- \rightarrow D^+\pi^-X$
25±10± 5	128	FRABETTI	94B E687	$\gamma Be \rightarrow D^{+}\pi^{-}X$
20^{+9+9}_{-12-10}	440	AVERY	90 CLEO	$e^+e^- \rightarrow D^{*+}\pi^-X$
$15^{+13}_{-10}^{+5}_{-10}$	337	ALBRECHT	89B ARG	$e^+e^- \rightarrow D^+\pi^-X$
20±10± 5	153	ANJOS	89C TPS	$\gamma N \rightarrow D^{+}\pi^{-}X$

D*(2460)0 DECAY MODES

 $\overline{\mathcal{D}}_2^*(2460)^0$ modes are charge conjugates of modes below.

	Mode	Fraction (Γ_I/Γ)
Γ ₁	$D^{+}\pi^{-}$	seen
Γ ₂	$D^{*}(2010)^{+}\pi^{-}$	seen

D₂(2460)⁰ BRANCHING RATIOS

	4.	•			
$\Gamma(D^+\pi^-)/\Gamma_{\rm tota}$	I			Γ ₁ /	r
VALUE	EVTS	DOCUMENT ID	TECN	COMMENT	_
seen	337	ALBRECHT	898 ARG	$e^+e^- \rightarrow D^+\pi^-X$	
SOCIA		ANJO\$	89C TPS	$\gamma N \rightarrow D^{+}\pi^{-}X$	
Γ(D*(2010)+π-)/F _{total}			Γ2/	r
VALUE		DOCUMENT ID	TECN	COMMENT	
seen		AVERY	90 CLEO	$e^+e^- \rightarrow D^{*+}\pi^-X$	
SCCR		ALBRECHT	89H ARG	$e^+e^- \rightarrow D^*\pi^-X$	
$\Gamma(D^+\pi^-)/\Gamma(D^4$	² (2010) ⁺ π ⁻)			Γ1/Γ	2
VALUE	•	DOCUMENT ID	TECN_	COMMENT	_
2.3±0.6 OUR AVE	RAGE				
2.2±0.7±0.6		AVERY	94C CLE2	$e^+e^- \rightarrow D^{*+}\pi^-X$	
2.3±0.8		AVERY	90 CLEO	e+e-	
$3.0 \pm 1.1 \pm 1.5$		ALBRECHT	89H ARG	$e^+e^- \rightarrow D^*\pi^-X$	

$D_2^*(2460)^0$ REFERENCES

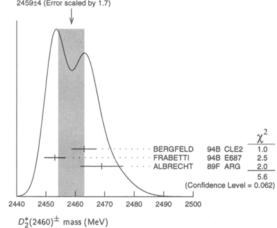
ASRATYAN AVERY FRABETTI AVERY ALBRECHT ALBRECHT ANIOS	94B 90 89B 89H	ZPHY C68 43 PL B331 236 PRL 72 324 PR D41 774 PL B221 422 PL B232 398 PBI 62 1717	+Freyberger, Rodriguez+ +Cheung, Cumalat+ +Besson +Boeckmann+ +Glaser, Harder+	N, SERP, ITEP, MPIM, RAL) (CLEO Collab.) (FNAL E687 Collab.) (CLEO Collab.) (ARGUS Collab.) JF (ANGUS Collab.) JF (FNAL E681 Collab.)
ROLMA	89C	PRL 62 1717	+Appel+	(FNAL E691 Collab.)

 $D_2^*(2460)^{\pm}$

 $I(J^P) = \frac{1}{2}(2^+)$

$D_2^*(2460)^{\pm}$ MASS

VALUE (MeV) EVTS DOCUMENT ID TEC	CN COMMENT
2459±4 OUR AVERAGE Error includes scale factor of 1.7.	See the ideogram below.
2463±3±3 310 BERGFELD 948 CL	.E2 $e^+e^- \rightarrow D^0\pi^+X$
2453±3±2 185 FRABETTI 948 E66	
2469±4±6 ALBRECHT 89F AR	$e^+e^- \rightarrow D^0\pi^+X$
WEIGHTED AVERAGE 2459±4 (Error scaled by 1.7)	



$m_{D_2^0(2460)^{\pm}} - m_{D_2^0(2460)^0}$

0.9±3.3 OUR AVERAGE Error includes scale factor of 1.1.
- 2 ±4 ±4 BERGFELD 94B CLE2 e^+e^- → hadrons
0 ± 4 FRABETTI 94B E687 γ Be $\rightarrow D\pi X$
14 ± 5 ± 8 ALBRECHT 89F ARG $e^+e^- \rightarrow D^0\pi^+X$

D*(2460) + WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
25 + 9 OUR AVE	RAGE			
27 + 11 ± 5	310	BERGFELD	94B CLE2	$e^+e^- \rightarrow D^0\pi^+X$
23± 9±5	185	FRABETTI	94B E687	$\gamma \text{Be} \rightarrow D^0 \pi^+ X$

$D_2^*(2460)^{\pm}$ DECAY MODES

 $D_2^*(2460)^-$ modes are charge conjugates of modes below.

	Mode	Fraction (Γ_I/Γ)
Γ ₁ Γ ₂	$D^0 \pi^+ D^{*0} \pi^+$	seen seen

D₂(2460) BRANCHING RATIOS

Γ(D ⁰ π ⁺)/Γ _{total}	DOCUMENT ID	TECN	COMMENT	Γ1/Γ
scen		89F ARG	e+ e- →	$D^0\pi^+X$
$\Gamma(D^0\pi^+)/\Gamma(D^{*0}\pi^+)$				Γ_1/Γ_2
VALUE	DOCUMENT ID	TECN	COMMENT	
1.9±1.1±0.3	BERGFELD	948 CLE2	$e^+e^- \rightarrow$	hadrons

D2(2460) + REFERENCES

	•, ,	
BERGFELD 94B PL B34 FRABETTI 94B PRL 77 ALBRECHT 89F PL B23	324 +Cheung, Cumalat+	(CLEO Collab.) (FNAL E687 Collab.) (ARGUS Collab.)

 $D_s^+ = c\overline{s}, D_s^- = \overline{c}s$, similarly for D_s^* 's



$$I(J^P) = 0(0^-)$$

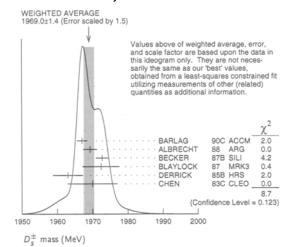
The angular distributions of the decays of the ϕ and $\overline{K}^*(892)^0$ in the $\phi\pi^+$ and $K^+\overline{K}^*(892)^0$ modes strongly indicate that the spin is zero. The parity given is that expected of a c3 ground state.

D_s^{\pm} MASS

The fit includes D^{\pm} , D^0 , D_s^{\pm} , $D^{\pm\pm}$, D^{*0} , and $D_s^{*\pm}$ mass and mass difference measurements. Measurements of the D_s^{\pm} mass with an error greater than 10 MeV are omitted from the fit and average. A number of early measurements have been omitted altogether.

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
1968.5± 0.6 OUR FTT	Error Includes	scale factor of 1	.1.	
1969.0± 1.4 OUR AVER	AGE Error i	ncludes scale fact	tor of 1.5. Se	e the ideogram below
1967.0± 1.0± 1.0	54	BARLAG	90c ACCM	π – Cu 230 GeV
1969.3± 1.4± 1.4		ALBRECHT	88 ARG	e ⁺ e 9.4-10.6 GeV
1972.7 ± 1.5 ± 1.0	21	BECKER	87B SILI	200 GeV π,K,p
1972.4± 3.7± 3.7	27	BLAYLOCK	87 MRK3	c+c- 4.14 GeV
1963 \pm 3 \pm 3	30	DERRICK	85B HRS	e ⁺ e ⁻ 29 GeV
1970 ± 5 ± 5	104	CHEN	83C CLEO	$e^{+}e^{-}$ 10.5 GeV
• • • We do not use the	following dat	a for averages, fli	ts, limits, etc.	• • •
1968.3± 0.7± 0.7	290	¹ ANJOS	88 E691	Photoproduction
1980 ±15	6	USHIDA	86 EMUL	u wideband
1973.6± 2.6± 3.0	163	ALBRECHT	85D ARG	e ⁺ e ⁻ 10 GeV
1948 ±28 ±10	65	AIHARA	84D TPC	e ⁺ e 29 GeV
1975 ± 9 ±10	49	ALTHOFF	84 TA5S	e+e- 14-25 GeV
1975 ± 4	3	BAILEY	84 ACCM	hadron ⁺ Be →

 1 ANJOS 88 enters the fit via $m_{D_{c}^{\pm}}-m_{D^{\pm}}$ (see below).



$m_{D_{\bullet}^{\pm}} - m_{D^{\pm}}$

The fit includes D^\pm , D^0 , D_s^\pm , $D^{*\pm}$, D^{*0} , and $D_s^{*\pm}$ mass and mass difference measurements.

VALUE (MeV)	EVTS	DOCUMENT I	D	TECN	COMMENT
99.2±0.5 OUR FIT	Error Includ	es scale factor o	of 1.1.		
99.2±0.5 OUR AVE	RAGE				
$99.5 \pm 0.6 \pm 0.3$		BROWN	94	CLE2	$e^+e^-\approx T(4S)$
98.5 ± 1.5	555	CHEN	89	CLEO	e+ e- 10.5 GeV
99.0±0.8	290	ANJOS	88	E691	Photoproduction

DE MEAN LIFE

Measurements with an error greater than $0.2\times 10^{-12}\,\mathrm{s}$ are omitted from the average.

VALUE (10-12 s)	EVTS	DOCUMENT ID		TECN	COMMENT
0.467±0.017 OUR AV	ERAGE				
$0.475 \pm 0.020 \pm 0.007$	900	FRABETTI	93F	E687	γ Be, $D_s^+ \rightarrow \phi \pi^+$
$0.33 \begin{array}{l} +0.12 \\ -0.00 \end{array} \pm 0.03$	15	ALVAREZ	90	NA14	$\gamma, D_s^+ \rightarrow \phi \pi^+$
$0.469^{+0.102}_{-0.086}$	54	² BARLAG	90 C	ACCM	π – Cu 230 GeV
$0.50 \pm 0.06 \pm 0.03$	104	FRABETTI	90	E687	γ Be, $\phi \pi^+$
$0.56 \begin{array}{l} +0.13 \\ -0.12 \end{array} \pm 0.08$	144	ALBRECHT	881	ARG	e ⁺ e ⁻ 10 GeV
$0.47 \pm 0.04 \pm 0.02$	228	RAAB	88	E691	Photoproduction
0.33 +0.10 -0.06	21	³ BECKER	87B	SILI	200 GeV π,K,p
0.26 +0.16 -0.09	6	USHIDA	86	EMUL	u wideband
• • • We do not use t	he following	g data for averages	, fits	, limits,	etc. • • •
$0.31 \begin{array}{l} +0.24 \\ -0.20 \end{array} \pm 0.05$	18	AVERILL	89	HRS	e ⁺ e ⁻ 29 GeV
$0.48 \begin{array}{l} +0.06 \\ -0.05 \end{array} \pm 0.02$	99	ANJOS	878	E691	See RAAB 88
$0.57 \begin{array}{l} +0.36 \\ -0.26 \end{array} \pm 0.09$	9	BRAUNSCH	87	TASS	e ⁺ e ⁻ 35-44 GeV
$0.47 \pm 0.22 \pm 0.05$	141	CSORNA	87	CLEO	e ⁺ e 10 GeV
$0.35 \begin{array}{l} +0.24 \\ -0.18 \end{array} \pm 0.09$	17	JUNG	86	HRS	See AVERILL 89
0.32 +0.30 -0.13	3	BAILEY	84	ACCM	hadron ⁺ Be $\rightarrow \phi \pi^+ X$
$0.19 \begin{array}{l} +0.13 \\ -0.07 \end{array}$	4	USHIDA	83	EMUL	See USHIDA 86

² BARLAG 90C estimates the systematic error to be negligible. ³ BECKER 87B estimates the systematic error to be negligible.

D+ DECAY MODES

Branching fractions for modes with a resonance in the final state include all the decay modes of the resonance. D_s^- modes are charge conjugates of the modes below.

	Mode		Fractio	ы (Г _/ /	Γ)		factor/ nce level
	Inclusiv	е то	des				
Γ_1	K anything		(13	+14 -12) %		
Γ2	\overline{K}^0 anything $+K^0$ anything		(39	± 28			
Γ_3	K ⁺ anything		(20	+ 18 - 14) %		
Γ4	non- $K\overline{K}$ anything		(64	±17			
Г ₅	e ⁺ anything		(8	+ 6 - 5) %		
Γ ₆	ϕ anything		(18	+15 -10) %		
	Leptonic and se	milep	tonic r	nodes			
۲7	$\mu^+ u_{\mu}$		(4.	+ 2	2)×1	0-3	S=1.4
	$\tau^+ \nu_{\tau}$		(7	± 4) %		
	$\phi \ell^+ \nu_\ell$		(2.		•		
	$\eta \ell^+ \nu_{\ell} + \eta'(958) \ell^+ \nu_{\ell}$	[a]	(3.		•		
۲ ₁₁	Table 1		•	5 ± 0.	,	,	
Γ ₁₂	$\eta'(958)\ell^+\nu_\ell$		(8.	8 ± 3.	4)×1	0-3	
	Hadronic modes with a K^{7}	K pai	ir (ind	uding	from a	ϕ)	
r ₁₃	K+ K ⁰		(3.	5 ± 1.	1)%		
Γ ₁₄	$K^+K^-\pi^+$	[b]	(4.	\$ ± 1.	2)%		5=1.1
Γ ₁₅	$\phi \pi^+ \ K^+ \overline{K}^* (892)^0$	[c]	(3.	5 ± 0.	9)%		
		[c]		3 ± 0.	•		
	$f_0(980)\pi^+$		[[1.0			_	S=1.3
	$K^{+}\overline{K}_{0}^{*}(1430)^{0}$	[c]) × 1		
۲ ₁₉	$f_J(1710)\pi^+ \to K^+K^-\pi^+$	[d]			9)×1		
Γ ₂₀	$K^+K^-\pi^+$ nonresonant		(9	± 4) × 10	0-3	
	$K^0\overline{K}{}^0\pi^+$						
Γ ₂₂	$K^*(892)^+\overline{K}^0$	[c]	(4.:	3 ± 1.	4)%		
Γ ₂₃	$K^{+}K^{-}\pi^{+}\pi^{0}$			_			
Γ ₂₄	$\phi \pi^+ \pi^0$	[c]	(9	± 5) %		

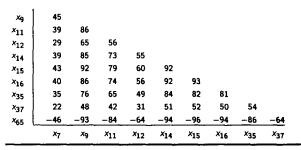
_	, +				
Γ ₂₅	$\phi \rho^+$		[c] (6.7 ± 2.	•	
Γ ₂₆	$\phi\pi^+\pi^0$ 3-body		[c] < 2.6	%	CL=90%
Γ ₂₇	$K^+K^-\pi^+\pi^0$ non- ϕ		< 9	%	CL=90%
Γ ₂₈	$K^{+}\overline{K^{0}}\pi^{+}\pi^{-}$		< 2.8	%	CL=90%
۲ ₂₉	$K^{0}K^{-}\pi^{+}\pi^{+}$		$(4.3 \pm 1.$	5)%	
Γ ₃₀	$K^*(892)^+\overline{K}^*(892)^0$		[c] (5.8 ± 2.	5)%	
Γ ₃₁	$K^{0}K^{-}\pi^{+}\pi^{+}$ non- $K^{*+}T$	₹•0	< 2.9	%	CL=90%
Γ ₃₂	$K^{+}K^{-}\pi^{+}\pi^{+}\pi^{-}$		(8.3 ± 3.	$3) \times 10^{-3}$	
Γ33	$\phi \pi^+ \pi^+ \pi^-$		[c] (1.18± 0.	-	
	$K^{+}K^{-}\pi^{+}\pi^{+}\pi^{-}$ non- ϕ				
Γ ₃₄	$\kappa \cdot \kappa = \pi \cdot \pi \cdot \pi \text{non-} \varphi$		(3.0 + 3.	0) × 10 ° °	
	Hadronic	: mode	s without K's		
Γ ₃₅	$\pi^{+}\pi^{+}\pi^{-}$		(1.0 ± 0.	4)%	S=1.2
Γ36	$\rho^0\pi^+$		< 8	× 10 ⁻⁴	CL=90%
Г37	$f_0(980)\pi^+$		[c] (1.8 ± 0.		5=1.7
Г38	$f_2(1270)\pi^+$		[c] (2.3 ± 1.		
Γ39	$f_0(1500)\pi^+ \rightarrow \pi^+\pi^-\pi$	+	[e] (2.8 ± 1.		
Γ ₄₀	$\pi^+\pi^+\pi^-$ nonresonant	•	< 2.8	× 10 ⁻³	CL=90%
Γ ₄₁	$\pi^+\pi^+\pi^-\pi^0$		< 12	%	CL=90%
	$\eta \pi^+$		[c] (2.0 ± 0.		CL=30/6
[42					
Γ ₄₃	$\omega \pi^+ \\ \pi^+ \pi^+ \pi^+ \pi^- \pi^-$		[c] (3.1 ± 1. (6.9 ± 3.		
[₄₄	$\pi^+\pi^+\pi^-\pi^0\pi^0$		(b.9 ± 3.	0) × 10 °	
Γ ₄₅					
Γ ₄₆	$\eta \rho^+$		[c] $(10.3 \pm 3.$	•	
Γ ₄₇	$\eta \pi^+ \pi^0$ 3-body		[c] < 3.0	%	CL=90%
Γ ₄₈	$\pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{0}$		$(4.9 \pm 3.$		
Γ49	$\eta'(958)\pi^+$		[c] $(4.9 \pm 1.$	8)%	
⁻ 50	$\pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{0}\pi^{0}$		_		
Γ ₅₁	$\eta'(958) \rho^{+}$		$[c] (12 \pm 4$) %	
Γ ₅₂	$\eta'(958) \pi^+ \pi^0 3$ -body		[c] < 3.1	%	CL=90%
	Modes w	ith on	e or three K's		
Γ ₅₃	$K^0\pi^+$		< 8	× 10 ⁻³	CL=90%
Γ ₅₄	$K^{+}\pi^{+}\pi^{-}$		(1.0 ± 0.	4) %	
Γ ₅₅	$K^+ \rho^0$		< 2.9	× 10 ⁻³	CL=90%
Γ ₅₆	$K^*(892)^0\pi^+$		[c] (6.5 ± 2.		
Γ ₅₇	K+K+K-		< 6	× 10 ⁻⁴	CL=90%
Γ ₅₈	φK ⁺		[c] < 5	× 10 ⁻⁴	CL=90%
- 50	•		- •		
	$\Delta C = 1$ weak ne				
_		per (L) violating modes		
Γ ₅₉	$\pi^+\mu^+\mu^-$		[f] < 4.3	× 10 ⁻⁴	CL=90%
r ₆₀	$K^{+}\mu^{+}\mu^{-}$	Cı	< 5.9	× 10 ⁻⁴	CL=90%
۲ ₆₁	$K^*(892)^+\mu^+\mu^-$	Cı	< 1.4	× 10 ⁻³	CL=90%
Γ ₆₂	$\pi^-\dot{\mu}^+\dot{\mu}^+$	L	< 4.3	× 10 ⁻⁴	CL=90%
_63	$K^{-}\mu^{+}\mu^{+}$	L	< 5.9	× 10 ⁻⁴	CL=90%
Γ ₆₄	$K^*(892)^-\mu^+\mu^+$	L	< 1.4	× 10 ⁻³	CL=90%
Γ ₆₅	A dummy mode used by th	e fit.	(80 ± 5) %	
[a]	For now, we average togeth branching fractions. This is				d X $\mu^+ u_\mu$

- [b] The branching fraction for this mode may differ from the sum of the submodes that contribute to it, due to interference effects. See the relevant papers.
- [c] This branching fraction includes all the decay modes of the final-state
- [d] This value includes only K^+K^- decays of the $f_J(1710)$, because branching fractions of this resonance are not known.
- [e] This value includes only $\pi^+\pi^-$ decays of the $f_0(1500)$, because branching fractions of this resonance are not known.
- [f] This mode is not a useful test for a $\Delta C=1$ weak neutral current because both quarks must change flavor in this decay.

CONSTRAINED FIT INFORMATION

An overall fit to 15 branching ratios uses 24 measurements and one constraint to determine 10 parameters. The overall fit has a $\chi^2 = 17.8$ for 15 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\langle \delta x_i \delta x_j \rangle / (\delta x_i \cdot \delta x_j)$, in percent, from the fit to the branching fractions, $x_i \equiv$ $\Gamma_i/\Gamma_{\text{total}}$. The fit constrains the x_i whose labels appear in this array to sum to



D# BRANCHING RATIOS

A few older, now obsolete results have been omitted. They may be found in earlier editions.

		- inclusive m	odes ·		-	
$\Gamma(K^-$ anything)/ Γ_{to}	tal	DOCUMENT I	D	TECN.	COMMENT	Γ1/Γ
0.13 ^{+0.14} ±0.02		COFFMAN	91		e ⁺ e ⁻ 4.14	GeV
$[\Gamma(\overline{K}^0)]$ anything $+\Gamma$	(K ⁰ any	thing)]/ Γ_{total}				Γ_2/Γ
VALUE		DOCUMENT I	0	TECN_	COMMENT	
0.39 + 0.28 ± 0.04		COFFMAN	91	MRK3	e+e~ 4.14	GeV
$\Gamma(K^+ \text{ anything})/\Gamma_{to}$	tai					Г3/Г
VALUE		DOCUMENT I	D	<u>TECN</u>	COMMENT	
0.20 ^{+ 0.18} ± 0.04		COFFMAN	91	MRK3	e ⁺ e ⁻ 4.14	GeV
(non- <i>KT</i> /anything)/r _{total}					Γ ₄ /Γ
VALUE D.64±0.17±0.03		DOCUMENT I			e+e- 4.14	
⁴ COFFMAN 91 uses		measurements of	of the k	aon cont	ent to determi	
⁴ COFFMAN 91 uses KK fraction. This and/or non-spectate	number l or decays.	measurements of	of the k	aon cont	ent to determi	
⁴ COFFMAN 91 uses KK fraction. This and/or non-spectate (e ⁺ anything)/Γ _{tot}	number l or decays.	measurements of mplies that a la	of the k	aon cont	ent to determi	volve η, η [/] ,
4 COFFMAN 91 uses KK fraction. This and/or non-spectato (e+ anything)/Fust ALUE 0.077+0.057+0.024 0.077-0.043-0.021	number I or decays.	measurements of mplies that a la process of the mplies that a la process of the mplies	of the k rge frac ID 97	aon cont ction of <u>TECN</u> BES	ent to determine D_s^+ decays in $D_s^ D_s^ D$	rotve η, η', Γ ₅ /Γ
4 COFFMAN 91 uses KK fraction. This and/or non-spectato (e+ anything)/Fust ALUE 0.077+0.057+0.024 0.077-0.043-0.021	number I or decays.	measurements of mpiles that a la pocument BAI and a data for avera	of the k rge frac ID 97 ges, fits	aon cont ction of <u>TECN</u> BES s, limits,	ent to determine D_s^+ decays in D_s^- decays in $COMMENT$ $e^+e^- \rightarrow CCC$	volve η , η' . $\frac{\Gamma_5/\Gamma}{D_s^+D_s^-}$
4 COFFMAN 91 uses KR fraction. This and/or non-spectate (e+ anything)/Ftot/ALUE 0.077+0.057+0.024 0.043-0.021 0.040 We do not use th <0.20	number I or decays. CLX ne followin 90	measurements of mpiles that a la pocument BAI and a for avera BAI BAI	of the k rge frac ID 97 ges, fits	TECN BES BIMITS,	ent to determine D_s^+ decays in D_s^+ decays in $COMMENT$ $e^+e^- \rightarrow COMMENT$ etc. • • • • • • • • • • • • • • • • • • •	volve η , η' , $\frac{\Gamma_{5}/\Gamma}{D_{s}^{+}D_{s}^{-}}$ GeV
4 COFFMAN 91 uses KK fraction. This and/or non-spectate (e+ anything)/Fuot (ALUE 0.077+0.057+0.024 0.077 + 0.043 + 0.021	number I or decays. CLX ne followin 90	measurements of mpiles that a la pocument BAI and a for avera BAI BAI	of the k rge frac ID 97 ges, fits	TECN BES BIMITS,	ent to determine D_s^+ decays in D_s^+ decays in $COMMENT$ $e^+e^- \rightarrow COMMENT$ etc. • • • • • • • • • • • • • • • • • • •	volve η , η' , $\frac{\Gamma_{5}/\Gamma}{D_{s}^{+}D_{s}^{-}}$ GeV
4 COFFMAN 91 uses KK fraction. This and/or non-spectato (e+ anything)/Foot ALUE 0.077+0.057+0.024 0.077+0.043-0.021 0 • We do not use th <0.20 5 Expressed as a value (• anything)/Foots	number I by decays. Cl.% ne followin 90 c, the BAI	measurements of mpiles that a la <u>DOCUMENT</u> BAI ag data for avera 5 BAI 90 result is Γ(e ⁻¹	of the k rge frac 10 97 ges, fit: 90 + anyth	TECN BES S, limits, MRK:	ent to determine D_s^+ decays in D_s^+ decays in $e^+e^- \rightarrow$ etc. • • • 3 e^+e^- 4.14 = 0.05 ± 6	volve η , η' , $\frac{\Gamma_{5}/\Gamma}{D_{s}^{+}D_{s}^{-}}$ GeV
4 COFFMAN 91 uses KK fraction. This and/or non-spectate (e+ anything)/Ftot VALUE 0.077+0.057+0.024 0.043-0.021 0.040-0.021 5 Expressed as a value (4 anything)/Ftotal VALUE	number I or decays. CLN ne followin 90 c, the BAI	DOCUMENT BAI g data for avera 5 BAI 90 result is $\Gamma(e^-)$	of the k rge frac 10 97 ges, fit: 90 + anyth	TECN TECN TECN TECN TECN	ent to determine to determine the decays in the decay in	Volve η, η',
4 COFFMAN 91 uses KK fraction. This and/or non-spectate (e+ anything)/Ftot ALUE 0.077+0.057+0.024 0.043-0.021 0.040 5 Expressed as a value (4 anything)/Ftotal ALUE	number I by decays. Cl.% ne followin 90 c, the BAI	measurements of mpiles that a la <u>DOCUMENT</u> BAI ag data for avera 5 BAI 90 result is Γ(e ⁻¹	of the k rge frac 10 97 ges, fit: 90 + anyth	TECN BES S, limits, MRK:	ent to determine D_s^+ decays in D_s^+ decays in $e^+e^- \rightarrow$ etc. • • • 3 e^+e^- 4.14 = 0.05 ± 6	Volve η, η',
4 COFFMAN 91 uses KK fraction. This and/or non-spectate (e+ anything)/Fust VALUE 0.077+0.057+0.024 0.077-0.043-0.021 0.080 5 Expressed as a value (0.20 5 Expressed as a value (0.40 1 (\$\phi\$ anything)/Fust VALUE 0.178+0.151+0.006 0.178+0.151+0.006	number I or decays. GLS GLS ne followin 90 c, the BAI EYTS 3	DOCUMENT BAI g data for avera 5 BAI 90 result is $\Gamma(e^-)$	of the k rge frac 1D 97 ges, fit: 90 + anyth	TECN BES MRK: lng)/\(\Gamma_{tc}\)	ent to determine D_s^+ decays in D_s^+ decays in $COMMENT$ $e^+e^- \rightarrow COMMENT$ $e^+e^- \rightarrow D$	Volve η, η',
4 COFFMAN 91 uses KK fraction. This and/or non-spectate Γ (e ⁺ anything)/ Γ total Γ (e ⁺ Γ	number I or decays. Left GLS clss clss	DOCUMENT IN BAI SOUTH STATE OF THE BAI DOCUMENT IN BAI DOCUMENT IN BAI BAI BAI BAI BAI BAI BAI BAI	of the k rge frac 97 ges, fits 90 + anyth	IECN BES s, ilmits, MRK: lng)/\(\Gamma_{\text{tecn}}\) BES	ent to determine the decays in the decay in the de	volve η , η' , $ \frac{\Gamma_{5}/\Gamma}{D_{s}^{+}D_{s}^{-}} $ GeV $ 0.05 \pm 0.02. $ $ \frac{\Gamma_{6}/\Gamma}{T_{7}/\Gamma} $
4 COFFMAN 91 uses KK fraction. This and/or non-spectate (e+ anything)/Fust VALUE 0.077+0.057+0.024 0.077-0.043-0.021 0.080 5 Expressed as a value (0.20 5 Expressed as a value (0.40 1 (\$\phi\$ anything)/Fust VALUE 0.178+0.151+0.006 0.178+0.151+0.006	number I or decays. Left GLS clss clss	measurements of mpiles that a la **DOCUMENT** BAI g data for avera 5 BAI 90 result is \(\text{F}(e^2 \) **DOCUMENT** BAI and semile; alar-Meson Deca	of the k rge frac 97 ges, fit: 90 + anyth 98 ptonic	TECN BES Imply TECN BES TECN BES TECN BES TECN BES	ent to determine to determine the decays in the decay in the d	volve η , η' . Γ_{5}/Γ $D_{s}^{+}D_{s}^{-}$ GeV 0.05 ± 0.02 . Γ_{6}/Γ $+ D_{s}^{-}$ Γ_{7}/Γ

⁷ AOKI 93 WA75 x⁻⁻ emulsion 350 GeV 8 AUBERT 83 SPEC μ+ Fe, 250 GeV ⁶BAI 95 uses one actual $D_s^+ \rightarrow \mu^+ \nu_\mu$ event together with two $D_s^+ \rightarrow \tau^+ \nu_\tau$ events and assumes μ -au universality. This value of $\Gamma(\mu^+
u_\mu)/\Gamma_{ ext{total}}$ gives a pseudoscalar decay

95 BES $e^+e^- \to D_s^+ D_s^-$

 $\substack{0.015 \, \substack{+\, 0.013 \\ -\, 0.006} \,\, -\, 0.002}$

constant of $(430^{+150}_{-130} \pm 40)$ MeV. 7 AOKI 93 assumes the ratio of production cross sections of the ${\it D}_{\rm S}^+$ and ${\it D}^0$ is 0.27. The value of $\Gamma(\mu^+\nu_\mu)/\Gamma_{\rm total}$ gives a pseudoscalar decay constant $f_{D_g}=(232\pm45\pm52)$

8 AUBERT 83 assume that the D_s^{\pm} production rate is 20% of total charm production rate.

$(\mu^+ \nu_\mu)/\Gamma(\phi \pi^+)$ Γ_7/Γ_{15} See the "Note on Pseudoscalar-Meson Decay Constants" in the Listings for the π^\pm .	$\Gamma(\phi\pi^+)/\Gamma_{total}$ We now have model-independent measurements of this branching fraction, and so no longer use the earlier, model-dependent results. See the "Note on D Mesons"
0.11 ±0.05 OUR FIT Error Includes scale factor of 1.6.	the D ⁺ Listings for a discussion. YALUE CL% EYTS DOCUMENT ID TECN COMMENT
$0.245 \pm 0.052 \pm 0.074$ 39 9 ACOSTA 94 CLE2 $e^+e^- \approx T(4S)$	0.036 ±0.009 OUR FIT
⁹ ACOSTA 94 obtains $f_{D_s} = (344 \pm 37 \pm 52 \pm 42)$ MeV from this measurement, using	0.036 ±0.009 OUR AVERAGE
$\Gamma(D_s^+ \to \phi \pi^+)/\Gamma(\text{total}) = 0.037 \pm 0.009.$	0.0359±0.0077±0.0048 21 ARTUSO 96 CLE2 e ⁺ e ⁻ at T(45)
$\Gamma(\mu^+ u_\mu)/\Gamma(\phi\ell^+ u_\ell)$ Γ_7/Γ_9	$0.039 \ ^{+0.051}_{-0.019} \ ^{+0.018}_{-0.011}$ 22 BAI 95C BES e^+e^- 4.03 GeV
	 • • We do not use the following data for averages, flts, limits, etc. • •
See the "Note on Pseudoscalar-Meson Decay Constants" In the Listings for the π^{\pm} . ALUE	0.051 \pm 0.004 \pm 0.008 23 BUTLER 94 CLE2 $e^+e^-\approx T(45)$
1.20 ± 0.10 OUR FIT Error includes scale factor of 1.6.	<0.048 90 MUHEIM 94
0.16±0.06±0.03 23 ¹⁰ KODAMA 96 E653 π ⁻ emulsion, 600 GeV	0.046 ±0.015
10 KODAMA 96 obtains $f_{D_s} = (194 \pm 35 \pm 20 \pm 14)$ MeV from this measurement, using	0.031 ± 0.009 ± 0.006 23 FRABETTI 93G E687 γ Be $\overline{E}_{\gamma} = 220$ Ge
$\Gamma(D_s^+ \to \phi \ell^+ \nu)/\Gamma_{\text{total}} = 0.0188 \pm 0.0029$. The third error is from the uncertainty on	0.024 ± 0.010 23 ALBRECHT 91 ARG $e^+e^- \approx 10.4$ G
$\phi \ell^+ \nu_{\ell}$ branching fraction.	<0.041 90 0 22 ADLER 908 MRK3 · e ⁺ e ⁻ 4.14 GeV
40 of armaning manners	0.031 $\pm 0.006 ^{+0.011}_{-0.009}$ 23 ALEXANDER 908 CLEO $ e^+ e^- 10.5$ -11 G
$\Gamma(au^+ u_ au)/\Gamma_{ ext{total}}$	0.048 ±0.017 ±0.019 25 ALVAREZ 90C NA14 Photoproduction
See the "Note on Pseudoscalar-Meson Decay Constants" in the Listings for the π^{\pm} .	>0.034 90 23 ANJOS 908 E691 γ Be, $\overline{E}_{\gamma} \approx 145$
VALUE EYTS DOCUMENT ID TECH COMMENT	GeV '
$0.074 \pm 0.028 \pm 0.024$ 16 ¹¹ ACCIARRI 97F L3 $D_5^{*+} \rightarrow \gamma D_5^{+}$	0.02 ± 0.01 405 26 CHEN 89 CLEO e ⁺ e ⁻ 10 GeV
11 The second ACCIARRI 97F error here combines in quadrature systematic (0.016) and	0.033 ±0.016 ±0.010 9 26 BRAUNSCH 87 TASS e ⁺ e ⁻ 35-44 GeV
normalization (0.018) errors. The branching fraction gives $f_{D_3} = (309 \pm 58 \pm 33 \pm 38)$	0.033 \pm 0.011 30 ²⁶ DERRICK 85B HRS e^+e^- 29 GeV
MeV.	²¹ ARTUSO 96 uses partially reconstructed $\overline B{}^0 \to D^{*+}D_S^{*-}$ decays to get a mod
$\Gamma(\phi\ell^+ u_\ell)/\Gamma(\phi\pi^+)$	Independent value for $\Gamma(D_s^- \to \phi \pi^-)/\Gamma(D^0 \to K^- \pi^+)$ of 0.92 \pm 0.20 \pm 0.11.
For now, we average together measurements of the $\Gamma(\phi e^+ \nu_e)/\Gamma(\phi \pi^+)$ and	²² BAI 95c uses $e^+e^- \rightarrow D_s^+D_5^-$ events in which one or both of the D_s^\pm are observed
	obtain the first model-independent measurement of the $D_s^+ o \phi \pi^+$ branching fraction
$\Gamma(\phi \mu^+ \nu_\mu)/\Gamma(\phi \pi^+)$ ratios. See the end of the D_s^+ Listings for measurements of	
$D_s^+ o \phi \ell^+ \nu_\ell$ form-factor ratios.	without assumptions about $\sigma(D_s^{\pm})$. However, with only two "doubly-tagged" events, is statistical error is too large for the result to be competitive with indirect measurements.
VALUE EYTS DOCUMENT ID TECN COMMENT D.56±0.05 OUR FIT	ADJED DOD used the same method to set a limit
0.54±0.05 OUR AVERAGE	23 BUTLER 94, FRABETTI 93G, ALBRECHT 91, ALEXANDER 90B, and ANJOS 9
$0.54 \pm 0.05 \pm 0.04$ 367 ¹² BUTLER 94 CLE2 $e^+e^- \approx T(45)$	measure the ratio $\Gamma(D_s^+ \to \phi \ell^+ \nu_\ell)/\Gamma(D_s^+ \to \phi \pi^+)$, where $\ell = e$ and/or μ , a
$0.58 \pm 0.17 \pm 0.07$ 97 13 FRABETTI 93G E687 γ Be $\overline{E}_{\gamma} = 220$ GeV	then use a theoretical calculation of the ratio of widths $\Gamma(D_s^+ o \phi \ell^+ \nu_\ell)/\Gamma(D^+)$
$0.57 \pm 0.15 \pm 0.15$ 104 14 ALBRECHT 91 ARG $e^+e^-\approx 10.4 \text{ GeV}$	$\overline{K}^{*0}\ell^{+}\nu$). Not everyone uses the same value for this ratio.
$0.49 \pm 0.10 ^{+0.10}_{-0.14}$ 54 15 ALEXANDER 90B CLEO e^+e^- 10.5-11 GeV	²⁴ The two MUHEIM 94 values here are model-dependent calculations based on distin
_	data sets. The first uses measurements of the $D_2^*(2460)^0$ and $D_{s1}(2536)^+$, the second
12 BUTLER 94 uses both $\phi e^+ \nu_e$ and $\phi \mu^+ \nu_\mu$ events, and makes a phase-space adjustment	
= 1. Till a see a	uses B-decay factorization and $\Gamma(D_S^+ o \mu^+ u_\mu)/\Gamma(D_S^+ o \phi\ell^+ u_\ell)$. A third calculati
to the latter to use them as $\phi e^+ \nu_e$ events.	uses B-decay factorization and $\Gamma(D_s^+ \to \mu^+ \nu_\mu)/\Gamma(D_s^+ \to \phi \ell^+ \nu_\ell)$. A third calculat using the semileptonic width of $D_s^+ \to \phi \ell^+ \nu_\ell$ is not independent of other results list
	using the semileptonic width of $D_s^+ o \phi \ell^+ u_\ell$ is not independent of other results list
to the latter to use them as $\phi e^+ \nu_e$ events. ¹³ FRABETTI 93G measures the $\Gamma(\phi \mu^+ \nu_\mu)/\Gamma(\phi \pi^+)$ ratio. ¹⁴ ALBRECHT 91 measures the $\Gamma(\phi e^+ \nu_e)/\Gamma(\phi \pi^+)$ ratio.	using the semileptonic width of $D_s^+ \to \phi \ell^+ \nu_\ell$ is not independent of other results list here. Note also the upper limit, based on the sum of established D_s^+ branching ratio
to the latter to use them as $\phi e^+ \nu_e$ events. 13 FRABETTI 93G measures the $\Gamma(\phi \mu^+ \nu_\mu)/\Gamma(\phi \pi^+)$ ratio. 14 ALBRECHT 91 measures the $\Gamma(\phi e^+ \nu_e)/\Gamma(\phi \pi^+)$ ratio. 15 ALEXAN-	using the semileptonic width of $D_s^+ \to \phi \ell^+ \nu_\ell$ is not independent of other results list here. Note also the upper limit, based on the sum of established D_s^+ branching ratio 25 ALVAREZ 90c relies on the Lund model to estimate the ratio of D_s^+ to D^+ cross section
to the latter to use them as $\phi e^+ \nu_e$ events. 13 FRABETTI 93G measures the $\Gamma(\phi \mu^+ \nu_\mu)/\Gamma(\phi \pi^+)$ ratio. 14 ALBRECHT 91 measures the $\Gamma(\phi e^+ \nu_e)/\Gamma(\phi \pi^+)$ ratio. 15 ALEXAN. DER 90B measures an average of the $\Gamma(\phi e^+ \nu_e)/\Gamma(\phi \pi^+)$ and $\Gamma(\phi \mu^+ \nu_\mu)/\Gamma(\phi \pi^+)$	using the semileptonic width of $D_s^+ \to \phi \ell^+ \nu_\ell$ is not independent of other results list here. Note also the upper limit, based on the sum of established D_s^+ branching ratio 25 ALVAREZ 90c relies on the Lund model to estimate the ratio of D_s^+ to D^+ cross section 26 Values based on crude estimates of the D_s^\pm production level. DERRICK 858 errors
to the latter to use them as $\phi e^+ \nu_e$ events. 13 FRABETTI 93G measures the $\Gamma(\phi \mu^+ \nu_\mu)/\Gamma(\phi \pi^+)$ ratio. 14 ALBRECHT 91 measures the $\Gamma(\phi e^+ \nu_e)/\Gamma(\phi \pi^+)$ ratio. 15 ALEXAN. DER 90B measures an average of the $\Gamma(\phi e^+ \nu_e)/\Gamma(\phi \pi^+)$ and $\Gamma(\phi \mu^+ \nu_\mu)/\Gamma(\phi \pi^+)$ ratios.	using the semileptonic width of $D_s^+ \to \phi \ell^+ \nu_\ell$ is not independent of other results list here. Note also the upper limit, based on the sum of established D_s^+ branching ratio 25 ALVAREZ 90c relies on the Lund model to estimate the ratio of D_s^+ to D^+ cross section 26 Values based on crude estimates of the D_s^\pm production level. DERRICK 85B errors statistical only.
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$\Gamma(K^+K^-\pi^+$ nonress	onant)/F		Γ_{20}/Γ_{15}	$\Gamma(\pi^+\pi^+\pi^-)/\Gamma(\phi\pi^+)$ Γ_{35}/Γ_{15}
VALUE 0.25±0.07±0.05	<u>EVT\$</u> 48	ANJOS 88 E691	<u>COMMENT</u> Photoproduction	<u>VALUE</u> <u>EVTS</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u> 0.28±0.06 OUR FIT Error includes scale factor of 1.3.
Γ(Κ* (892)+ Κ ⁰)/Γ((φπ ⁺)		Γ_{22}/Γ_{15}	0.39±0.08 OUR AVERAGE 0.33±0.10±0.04 29 ADAMOVICH 93 WA82 π ⁻ 340 GeV
Unseen decay mo	des of the r	esonances are included. DOCUMENT ID TECN	COMMENT	0.44±0.10±0.04 ANJOS 89 E691 Photoproduction
1.20±0.21±0.13			e ⁺ e ⁻ 10 GeV	$\Gamma(\rho^0\pi^+)/\Gamma(\pi^+\pi^+\pi^-)$
Γ(Κ*(892) + \(\bar{K}^0\))/Γ(K*(892) ⁺ are included.	Γ ₂₂ /Γ ₁₃	VALUE CLS DOCUMENT ID TECN COMMENT <0.073 90 FRABETTI 97D E687 γ Be ≈ 200 GeV
VALUE	<u>CL%</u>	DOCUMENT ID TECN	COMMENT	$\Gamma(\rho^0\pi^+)/\Gamma(\phi\pi^+)$ Γ_{36}/Γ_{15}
	_	data for averages, fits, limits	_	<u>VALUE</u> <u>CL'S</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u> • • • • We do not use the following data for averages, fits, limits, etc. • • •
<0.9	90	FRABETTI 95 E687	γ Be $\overline{E}_{\gamma} \approx 200$ GeV	<0.08 90 ANJOS 89 E691 Photoproduction
Γ(φπ ⁺ π ⁰)/Γ(φπ ⁺)		DOCUMENT ID TECH	Γ ₂₄ /Γ ₁₅	<0.22 90 ALBRECHT 87G ARG e ⁺ e 10 GeV
2.4±1.0±0.5	<u>EVT5</u> 11	ANJOS 89E E691	<u>COMMENT</u> Photoproduction	$\Gamma(f_0(980)\pi^+)/\Gamma(\pi^+\pi^+\pi^-)$ Γ_{37}/Γ_{35}
	e following	data for averages, fits, limits		Unseen decay modes of the f ₀ (980) are included. YALUE DOCUMENT ID TECN COMMENT
<2.6 90		ALVAREZ 90c NA14	Photoproduction	1.7 \pm 0.6 OUR FIT Error includes scale factor of 2.4. 2.06 \pm 0.27 \pm 0.00 FRABETTI 97D E687 γ Be \approx 200 GeV
$\Gamma(\phi \rho^+)/\Gamma(\phi \pi^+)$			Γ ₂₅ /Γ ₁₅	•
1.86±0.26+0.29 1.86±0.26+0.29	EVTS		$\frac{COMMENT}{e^+e^-} \simeq 10.5 \text{ GeV}$	$\Gamma(f_0(980)\pi^+)/\Gamma(\phi\pi^+)$
1.46 ± 0.26 _ 0.40	253	AVERY 92 CLE2	e ' e ≃ 10.5 GeV	<u>VALUE</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u> 0.49±0.20 OUR FIT Error includes scale factor of 2.6.
$\Gamma(\phi\pi^+\pi^0$ 3-body)/ Γ	$(\phi \pi^+)$		Γ ₂₆ /Γ ₁₅	0.28±0.10±0.03 ANJOS 89 E691 Photoproduction
<u>VALUE</u>	<u>CL%</u> 90		<u>COMMENT</u> e ⁺ e ⁻ ≈ 10.5 GeV	$\Gamma(f_2(1270)\pi^+)/\Gamma(\pi^+\pi^+\pi^-)$ Γ_{36}/Γ_{35}
-				Unseen decay modes of the $f_2(1270)$ are included.
Γ(K+K-π+π ⁰ non-	-φ)/Γ(φπ _ <u><ι</u> .χ.	DOCUMENT ID TECH	Γ ₂₇ /Γ ₁₅	VALUEDOCUMENT IDTECN.COMMENT $0.22 \pm 0.10 \pm 0.03$ FRABETTI97D E687 γ Be \approx 200 GeV
<2.4		27 ANJOS 89E E691	Photoproduction	$\Gamma(f_0(1500)\pi^+ \to \pi^+\pi^-\pi^+)/\Gamma(\pi^+\pi^+\pi^-)$ Γ_{99}/Γ_{35}
²⁷ Total minus φ comp	onent.			This includes only $\pi^+\pi^-$ decays of the $f_0(1500)$, because branching fractions of this
$\Gamma(K^+\overline{K}^0\pi^+\pi^-)/\Gamma($	$(\phi\pi^+)$		Γ ₂₈ /Γ ₁₅	resonance are not known. VALUE DOCUMENT ID TECN COMMENT
<u>VALUE</u> <0.77	<u>CL%</u> 90	DOCUMENT ID TECN ALBRECHT 928 ARG	<u>COMMENT</u> e ⁺ e ⁻ ≈ 10.4 GeV	0.274±0.114±0.019 28 FRABETTI 970 E687 γ Be ≈ 200 GeV
-		ALBRECHT 328 ANG		²⁸ FRABETTI 97D calls this mode $S(1475) \pi^+$, but finds the mass and width of this $S(1475)$ to be in excellent agreement with those of the $f_0(1500)$.
Γ(Κ ⁰ Κ ⁻ π ⁺ π ⁺)/Γ(VALUE	(φπ [™])	DOCUMENT ID TECN	Γ ₂₉ /Γ ₁₅	· · · · · · · · · · · · · · · · · · ·
1.2 ±0.2 ±0.2		ALBRECHT 928 ARG	e ⁺ e ⁻ ≈ 10.4 GeV	$\Gamma(\pi^+\pi^+\pi^-\text{nonresonant})/\Gamma(\pi^+\pi^+\pi^-)$ VALUE CLY DOCUMENT ID TECH COMMENT.
Γ(<i>K</i> °(892)+ <i>K</i> °(892) ⁰)/Γ(φπ	r+)	Γ ₃₀ /Γ ₁₅	<0.269 90 ²⁹ FRABETTI 97D E687 γ Be \approx 200 GeV
		esonances are included.	COMMENT	²⁹ We rather arbitrarily use this FRABETTI 97D limit instead of the much large ANJOS 89 value given in the next entry. See, however, FRABETTI 97D on the difficulty of disten-
1.6±0.4±0.4		ALBRECHT 928 ARG	e ⁺ e ⁻ ≈ 10.4 GeV	gangling the $f_0(1500)\pi^+$ and nonresonant modes.
Γ(<i>K</i> ⁰ <i>K</i> ⁻ π ⁺ π ⁺ non-	-K++ K +0)/Γ(φπ ⁺)	Γ ₃₁ /Γ ₁₅	$\Gamma(\pi^+\pi^+\pi^-\text{nonresonant})/\Gamma(\phi\pi^+)$ Γ_{40}/Γ_{15}
YALUE	CLN	DOCUMENT ID TECN	COMMENT	VALUE DOCUMENT ID TECN COMMENT • • • We do not use the following data for averages, fits, limits, etc. • • •
<0.80	90	ALBRECHT 928 ARG	e ⁺ e ⁻ ≃ 10.4 GeV	0.29±0.09±0.03 ANJOS 89 E691 Photoproduction
$\Gamma(K^+K^-\pi^+\pi^+\pi^-)$			Γ ₃₂ /Γ ₁₄	$\Gamma(\pi^{+}\pi^{+}\pi^{-}\pi^{0})/\Gamma(\phi\pi^{+})$ Γ_{41}/Γ_{15}
VALUE 0.188±0.036±0.040	<u>EVTS</u> 75	POCUMENT ID TECN FRABETTI 97C E687	γ Be, $E_{\gamma} \approx 200 \text{ GeV}$	YALUE CL'S DOCUMENT ID TECH COMMENT
-(+ + -\/-(+	_+\			<3.3 90 ANJOS 89E E691 Photoproduction
$\Gamma(\phi \pi^+ \pi^+ \pi^-)/\Gamma(\phi \pi^+ \pi^+ \pi^-)$	EVTS	DOCUMENT ID TECN	Γ33/Γ15 <u>COMMENT</u>	$\Gamma(\eta \pi^+)/\Gamma(\phi \pi^+)$ Γ_{42}/Γ_{15}
0.33±0.06 OUR AVE	RAGE		<u>_</u>	Unseen decay modes of the resonances are included. YALUE CLY EVTS DOCUMENT ID TECN COMMENT
0.28±0.06±0.01 0.58±0.21±0.10	40 21	FRABETTI 97C E687 FRABETTI 92 E687	γ Be, $\overline{E}_{\gamma} \approx 200$ GeV γ Be	$0.84\pm0.09\pm0.06$ 165 ALEXANDER 92 CLE2 $\eta \rightarrow \gamma\gamma$,
0.42±0.13±0.07	19	ANJOS 88 E691	Photoproduction e+e- 10 GeV	$\pi^+\pi^-\pi^0$ • • • We do not use the following data for averages, fits, limits, etc. • • •
1.11±0.37±0.28 • • • We do not use th	62 ie following	ALBRECHT 85D ARG data for averages, fits, limits.		<1.5 90 ANJOS 89E E691 Photoproduction
<0.24 90		ALVAREZ 90c NA14	Photoproduction	$\Gamma(\omega \pi^+)/\Gamma(\phi \pi^+)$
Γ(K + K- π+ π+ π- ι	non- ∳)/Γ		COMMENT	Unseen decay modes of the resonances are Included. VALUE CLY DOCUMENT ID TECN COMMENT.
0.003 +0.003			π ⁻ 230 GeV	• • • We do not use the following data for averages, fits, limits, etc. • • • < <0.5 90 ANJOS 89€ E691 Photoproduction
 Γ(<i>K</i> + <i>K</i> -π+π+π-	non-4\/F	(4 + +)	Γ ₃₄ /Γ ₁₈	$\Gamma(\omega \pi^+)/\Gamma(\eta \pi^+)$ Γ_{43}/Γ_{42}
•	EYTS		COMMENT	VALUE DOCUMENT ID TECN COMMENT
	_	data for averages, fits, limits,		0.16±0.04±0.03 BALEST 97 CLE2 e ⁺ e ⁻ ≈ T(45)
<0.32 90	10 — Hadro	ANJOS 88 E691 SIC modes without K's	Photoproduction	$\Gamma(\pi^+\pi^+\pi^+\pi^-\pi^-)/\Gamma(K^+K^-\pi^+)$ VALUE EVTS DOCUMENT ID TECH COMMENT
Γ(π+π+π-)/Γ(Κ+			Γ ₃₅ /Γ ₁₄	0.189 \pm 0.042 \pm 0.031 37 FRABETTI 97C E687 γ Be, $\overline{E}_{\gamma} \approx 200$ GeV
VALUE	EVTS	DOCUMENT ID TECN		$\Gamma(\pi^+\pi^+\pi^+\pi^-\pi^-)/\Gamma(\phi\pi^+)$
0.23 ±0.04 OUR FIT 0.265±0.041±0.031	Error Incl	udes scale factor of 1.2. FRABETTI 97D E687	γ Be ≈ 200 GeV	<u>VALUE</u> <u>CLY</u> <u>POCUMENT ID</u> <u>TECN</u> <u>COMMENT</u> • • • • We do not use the following data for averages, fits, limits, etc. • • •
	•			<0.29 90 ANJOS 89 E691 Photoproduction
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$\Gamma(\eta \rho^+)/\Gamma(\phi \pi^+)$ Unseen decay m	odes of the	resonances are i	included			Γ_{46}/Γ_{15}	Γ(K+K+K-			10	TECT	COMMENT
VALUE	EVTS	DOCUMENT ID			COMMENT		<u>∨ALUE</u> <0.016	90	<i>DOCUMENT</i> FRABETTI		IECN_ E687	$\gamma \text{ Be, } \overline{E}_{\gamma} \approx 220 \text{ C}$
.86±0.38 ^{+0.36}	217	AVERY	92 (CLE2	$\eta \rightarrow \gamma \gamma, \pi^+$	- _π _π 0	Γ(φΚ+)/Γ(۸ + ۱				, Г <mark>а</mark>
$(\eta \pi^+ \pi^0 3\text{-body})$	/Γ(φπ ⁺)					Γ ₄₇ /Γ ₁₅	VALUE	CL9	DOCUMENT	ID	TECN	COMMENT
Unseen decay in	odes of the					. 417 . 10	< 0.013	90	FRABETTI		E687	γ Be, $\overline{E}_{\gamma} \approx 220$ C
(0.82	<u>CL%</u> 90	DAOUDI			$e^+e^-\approx 10$	E GeV			owing data for avera	-		
			,,,		~ 10	_	<0.071	90	SOLNA	92D	E691	γ Be, $\overline{E}_{\gamma} = 145$ G
(π ⁺ π ⁺ π ⁺ π ⁻ π ⁻	π ^υ)/Γ _{total}	DOCUMENT IL	n 7	TECN	COMMENT	Γ ₄₈ /Γ			Rare or forbidd	en mod	des	
.049 ^{+0.033} -0.030		BARLAG			π 230 GeV			le is not a use		weak ne	eutral c	urrent because both
$(\eta'(958)\pi^+)/\Gamma(\phi)$						Γ_{49}/Γ_{15}	VALUE	nge flavor in t		D	TECN	COMMENT
Unseen decay m ALUE	odes of the CL% EVTS			TEC	CN COMMEN	T	<4.3 × 10 ⁴	90 (KODAMA	95	E653	π^- emulsion 600
1.4 ±0.4 OUR AV	/ERAGE E	ror includes sca	le factor	of 2.1.	See the ideo	gram below.	$\Gamma(K^+\mu^+\mu^-)$)/F _{total}				
$1.20 \pm 0.15 \pm 0.11$	281	ALEXA	NDER 9	92 CLI	E2 $\eta' \rightarrow \eta_1$ $\rho^0 \gamma$	$\pi^+\pi^-$,	A test for		eak neutral current.	Allowed	l by higi	her-order electroweal
$2.5 \pm 1.0 \begin{array}{l} +1.5 \\ -0.4 \end{array}$	22	ALVARE	Z 9	91 NA	.14 Photopro	duction	actions. <u>VALUE</u>	CL% EVT	DOCUMENT I	D	TECN	COMMENT
2.5 ±0.5 ±0.3	215			OD AR		± 10.4 GeV	<5.9 × 10 ⁻⁴	90 (KODAMA	95	E653	π^- emulsion 600
• • We do not use <1.3	the following 90	data for average ANJOS	_		91 γ Be, \overline{E}_{γ}	≈ 145		$(\mu^+\mu^-)/\Gamma_{ m tot}$ the $\Delta C=1$ w	tal eak neutral current.	Allowed	l by higi	her-order electroweal
					GeV		actions. <u>VALUE</u>	CL% EVT	DOCUMENT I	0	TECN	COMMENT
WEIGHTED 1.4±0.4 (Erro	AVERAGE or scaled by 2	2.1)					<1.4 × 10 ⁻³	90 (KODAMA	95	E653	π^- emulsion 600
. 1	,						$\Gamma(\pi^-\mu^+\mu^+)$	/F _{total}				
Α	100								r conservation.	חי	TECN	COMMENT
A							<4.3 × 10 ⁻⁴	90 (E653	π ⁻ emulsion 600
							$\Gamma(K^-\mu^+\mu^+)$					
							A test of <u>VALUE</u>	lepton-numbe <i>CL%EVT</i> :	r conservation. S DOCUMENT I	D	TECN	COMMENT
							<5.9 × 10 ⁻⁴	90 (E653	π emulsion 600
							F/##(000)-	$\mu^+\mu^+)/\Gamma_{\rm tot}$	I			
	100											
1000	10					. 2	A test of	lepton-numbe	r conservation.			
			AI EVANI	DEB	02 CLE2	χ^2	A test of <u>VALUE</u>	lepton-numbe CL% <u>EVT</u> :	r conservation. DOCUMENT I		TECN E	COMMENT
+			ALEXANI ALVARE	Z	92 CLE2 91 NA14	χ ² 0.7 1.1	A test of	lepton-numbe	r conservation. DOCUMENT I			COMMENT π emulsion 600
+			ALEXANI ALVAREZ ALBREC	Z			A test of <u>VALUE</u>	lepton-numbe CL% EVTS 90 C	r conservation. DOCUMENT I	95	E653	π ⁻ emulsion 600
+	+		ALVARE	Z HT	91 NA14	1.1 3.9 5.7	A test of <u>VALUE</u> <1.4 × 10 ⁻³	Lepton-numbe CL% EVTS 90 C	r conservation. $ \begin{array}{ccc} & & & & & & & & & \\ DOCUMENT & & & & & & \\ DOCUMENT & & & & & & \\ DOCUMENT & & & & \\ DOCUMENT & $	95	E653	π ⁻ emulsion 600
0 1	2	3 4	ALVARE	Z HT	91 NA14 90D ARG _	1.1 3.9 5.7	A test of <u>VALUE</u>	Lepton-numbe CL% EVTS 90 C	r conservation. $ \begin{array}{ccc} & & & & & & & \\ & & & & & & \\ & & & & &$	95 RM FAC	E653	π ⁻ emulsion 600
		3 4	ALVARE	Z HT	91 NA14 90D ARG _	1.1 3.9 5.7	A test of $ \frac{A \times 10^{-3}}{< 1.4 \times 10^{-3}} $ $ F_2 \equiv A_2(0) / A_{VALUE} $ 1.6±0.4 OUR A	lepton-numbe CL% EVTS 90 D+ In (0) in D+ EVTS EVTS WERAGE	r conservation. DOCUMENT I KODAMA $\ell \rightarrow \phi \ell^+ \nu_\ell$ FOR $\phi \ell^+ \nu_\ell$ FOR $\phi \ell^+ \nu_\ell$	95 RM FAC	E653	π ⁻ emulsion 600
Γ(η'(958)	τ^+)/ $\Gamma(\phi \pi^+$	3 4	ALVARE	Z HT	91 NA14 90D ARG _	1.1 3.9 5.7 0.058)	A test of VALUE $<1.4 \times 10^{-3}$ $F_2 \equiv A_2(0)/A$ VALUE 1.6 ± 0.4 OUR $1.4 \pm 0.5 \pm 0.3$	90 (D+ 1(0) in D+ EVT:	r conservation. DOCUMENT I KODAMA $\rightarrow \phi \ell^+ \nu_{\ell}$ FOR $\rightarrow \phi \ell^+ \nu_{\ell}$ DOCUMENT I 30 AVERY	95 RM FAC	E653	π^- emulsion 600 S $\frac{COMMENT}{e^+e^-$ 10 GeV
$\Gamma(\eta'(958)\tau)$	$(\pi^+)/\Gamma(\phi\pi^+)$	3 4	ALVAREALBREC	Z HT	91 NA14 90D ARG _	1.1 3.9 5.7	A test of $VALUE$ $<1.4 \times 10^{-3}$ $F_2 \equiv A_2(0)/A$ $VALUE$ 1.6 ± 0.4 OUR $A_1 = 0.4$ $A_2 = 0.4$ $A_3 = 0.4$ $A_4 = 0.4$	lepton-numbe CL% EVT: 90 C D_s Nation Position P	r conservation. DOCUMENT: KODAMA $\rightarrow \phi \ell^+ \nu_\ell$ FOR $\rightarrow \phi \ell^+ \nu_\ell$ DOCUMENT: 30 AVERY 31 FRABETTI	95 RM FAC 1D 948 946	TECN CLE2 E687	π^- emulsion 600 S $\frac{COMMENT}{e^+e^- \ 10 \ {\rm GeV}} \gamma {\rm Be}, \overline{E}_{\gamma} = 220 \ {\rm Ge}$
$\Gamma(\eta'(958)\rho^+)/\Gamma(\phi$ Unseen decay m	$(\pi^+)/\Gamma(\phi\pi^+)$	3 4	ALVAREALBREC	Z CHT (Confid	91 NA14 90D ARG _	1.1 3.9 5.7 0.058)	A test of VALUE $<1.4 \times 10^{-3}$ $F_2 \equiv A_2(0)/A$ VALUE 1.6 ± 0.4 OUR $1.4 \pm 0.5 \pm 0.3$ $1.1 \pm 0.8 \pm 0.1$ $2.1 + 0.6 \pm 0.2$	Lepton-numbe CL% EVT: 90 C D;	r conservation. DOCUMENT I KODAMA $ \rightarrow \phi \ell^+ \nu_{\ell} \text{ FOR} $ $ \rightarrow \phi \ell^+ \nu_{\ell} \text{ FOR} $ DOCUMENT I 30 AVERY 31 FRABETTI 31 KODAMA	95 RM FAC 1D 948 946	E653 CTORS TECN CLE2	π^- emulsion 600 S $\frac{COMMENT}{e^+e^-$ 10 GeV
$\Gamma(\eta'(958)\rho^+)/\Gamma(\phi)$ Unseen decay m 4LUE 44±0.62+0.44	$(\pi^+)/\Gamma(\phi\pi^+)$ (π^+) $(\pi^+$	resonances are in DOCUMENT ID	ALVAREALBREC	Z CHT (Confid	91 NA14 90D ARG dence Level =	1.1 3.9 5.7 0.058)	A test of VALUE $<1.4 \times 10^{-3}$ $F_2 \equiv A_2(0)/A$ $VALUE$ 1.6 ± 0.4 OUR $A = 0.1$ $1.4 \pm 0.5 \pm 0.3$ $1.1 \pm 0.8 \pm 0.1$ 2.1 ± 0.6 30 AVERY 948	lepton-numbe $\begin{array}{ccc} \underline{CL\%} & \underline{EVT} \\ 90 & C \\ \hline D_{g}^{+} & \underline{EVT} \\ \hline A_{1}(0) \text{ in } D_{g}^{+} & \underline{EVT} \\ \hline WERAGE & 308 \\ 90 \\ \underline{19} \\ $	r conservation. DOCUMENT: KODAMA $\rightarrow \phi \ell^+ \nu_\ell$ FOR $\rightarrow \phi \ell^+ \nu_\ell$ DOCUMENT: 30 AVERY 31 FRABETTI	95 RM FAC	TECN CLE2 E687 E653	π^- emulsion 600 S $\frac{COMMENT}{e^+e^- \ 10 \ \text{GeV}}$ γ Be, $E_{\gamma}=220 \ \text{Ge}$ 600 GeV $\pi^- N$
$\Gamma(\eta'(958)\rho^+)/\Gamma(\phi)$ Unseen decay m ALUE .44±0.62+0.44	$(\pi^+)/\Gamma(\phi\pi^+)$ odes of the r $EVTS$ 68 (π^+)	3 4 pocument in AVERY ** ** ** ** ** ** ** ** **	ALVAREZALBRECO	Z CHT (Confid	91 NA14 90D ARG dence Level = '	1.1 3.9 5.7 0.058)	A test of VALUE $<1.4 \times 10^{-3}$ $F_2 \equiv A_2(0)/A$ VALUE 1.6 ± 0.4 OUR $A_1 = 0.5 \pm 0.3$ $1.1 \pm 0.8 \pm 0.1$ $2.1 \pm 0.6 \pm 0.2$ 30 AVERY 948 31 FRABETTI $F_V \equiv V(0)/A_1$	lepton-numbe $\frac{CL_{N}^{+}}{CL_{N}^{+}} = \frac{EVT}{90}$ $\frac{D_{s}^{+}}{N} = \frac{EVT}{N}$ $\frac{SVERAGE}{S}$ $\frac{306}{90}$ $\frac{19}{94F} = \frac{19}{94F} = \frac{19}{100}$	r conservation. DOCUMENT! KODAMA $\rightarrow \phi \ell^+ \nu_\ell$ FOR $\rightarrow \phi \ell^+ \nu_\ell$ DOCUMENT! 30 AVERY 31 FRABETTI 31 KODAMA $\phi e^+ \nu_e$ decays. AMA 93 use $D_s^+ \rightarrow \phi \ell^+ \nu_\ell$	95 RM FAC 948 94F 93 φ μ+ 1	E653 TECN CLE2 E687 E653 ν _μ deca	π^- emulsion 600 S $\frac{COMMENT}{e^+e^- \ 10 \ \text{GeV}}$ $\gamma \text{Be}, \ \overline{E}_{\gamma} = 220 \ \text{Ge}$ 600 GeV $\pi^- N$
$\Gamma(\eta'(958)\rho^+)/\Gamma(\phi'(958)\rho^+)/\Gamma(\phi'(958)\rho^+)/\Gamma(\phi'(958)\sigma^+)$.44±0.62+0.44 $\Gamma(\eta'(958)\sigma^+\sigma^0$ 3-b Unseen decay m	$(\pi^+)/\Gamma(\phi\pi^+)$ odes of the results $(\pi^+) = \frac{EVTS}{68}$ 68 cody)/ $\Gamma(\phi)$ odes of the results	aresonances are in DOCUMENT ID AVERY The Sonances are in DOCUMENT ID	ALVAREZALBRECO	(Confice 6	91 NA14 90D ARG dence Level = $^{\prime}$ $\frac{COMMENT}{\eta' \rightarrow \eta \pi^{+} \pi}$ $\frac{COMMENT}{\eta' \rightarrow \eta \pi^{+} \pi}$	Γ ₅₁ /Γ ₁₅	A test of YALVE $<1.4 \times 10^{-3}$ $r_2 \equiv A_2(0)/A$ YALVE 1.6 ± 0.4 OUR $1.4 \pm 0.5 \pm 0.3$ $1.1 \pm 0.8 \pm 0.1$ $2.1 + 0.6 \pm 0.2$ 30 AVERY 94B 31 FRABETTI $r_y \equiv V(0)/A$ YALVE	lepton-numbe $CL\% = VTS$ 90 D_s^+ $A_1(0) \text{ in } D_s^+$ $VERAGE$ 308 99 19 1 uses $D_s^+ \rightarrow 0$ 94F and KOD $(0) \text{ in } D_s^+$ VTS	r conservation. DOCUMENT! KODAMA $\rightarrow \phi \ell^+ \nu_\ell$ FOR $\rightarrow \phi \ell^+ \nu_\ell$ DOCUMENT! 30 AVERY 31 FRABETTI 31 KODAMA $\phi e^+ \nu_e$ decays. AMA 93 use $D_s^+ \rightarrow \phi \ell^+ \nu_\ell$	95 RM FAC 948 94F 93 φ μ+ 1	E653 TECN CLE2 E687 E653 ν _μ deca	π^- emulsion 600 S $\frac{COMMENT}{e^+e^- \ 10 \ \text{GeV}}$ γ Be, $E_{\gamma}=220 \ \text{Ge}$ 600 GeV $\pi^- N$
$\Gamma(\eta'(958)\rho^+)/\Gamma(\phi'(958)\rho^+)/\Gamma(\phi'(958)\rho^+)/\Gamma(\phi'(958)\sigma^+)$.44±0.62+0.44 .44±0.62+0.44 .5($\eta'(958)\pi^+\pi^0$ 3-b .5 .5($\eta'(958)\pi^+\pi^0$ 3-b .7 .7 .7 .7 .7 .7 .7 .7 .7 .7 .7 .7 .7	$(\pi^+)/\Gamma(\phi \pi^+)$ odes of the results $(\pi^+) = \frac{EVTS}{68}$ $(\pi^+) = \frac{EVTS}{68}$ $(\pi^+)/\Gamma(\phi)$ odes of the results $(\pi^+)/\Gamma(\phi)$ odes of the results $(\pi^+)/\Gamma(\phi)$	resonances are in DOCUMENT ID AVERY A+) resonances are in DOCUMENT ID DAOUDI	alvarez ALBREC 5 ncluded. 92 C	(Confidence of the confidence	91 NA14 90D ARG dence Level = $^{\prime}$ $COMMENT$ $\eta' \rightarrow \eta \pi^+ \pi$	Γ ₅₁ /Γ ₁₅	A test of VALUE $<1.4 \times 10^{-3}$ $F_2 \equiv A_2(0)/A_1$ $VALUE$ $1.6 \pm 0.4 \text{ OUR}$ $1.4 \pm 0.5 \pm 0.3$ $1.1 \pm 0.8 \pm 0.1$ $2.1 \stackrel{+}{-}0.5 \pm 0.2$ 30 AVERY 94B 31 FRABETTI $F_V \equiv V(0)/A_1$ $VALUE$ $1.5 \pm 0.5 \text{ OUR}$ $0.9 \pm 0.6 \pm 0.3$	lepton-numbe CL_{S}^{+} EVT: 90 D_{S}^{+} N1(0) in D_{S}^{+} EVT: WERAGE 15 10 uses $D_{S}^{+} \rightarrow 94$ F and KOD 10 in D_{S}^{+} EVT: WERAGE 308	r conservation. DOCUMENT! KODAMA $\rightarrow \phi \ell^+ \nu_\ell$ FOR $\rightarrow \phi \ell^+ \nu_\ell$ DOCUMENT! 30 AVERY 31 FRABETT! 31 KODAMA $\phi e^+ \nu_e$ decays. AMA 93 use $D_s^+ - \phi \ell^+ \nu_\ell$ DOCUMENT! 32 AVERY	95 RM FAC 948 947 93 φ μ+1	TECN CLE2 E687 E653 ν _μ deca	π^- emulsion 600 S $\frac{COMMENT}{e^+e^- \ 10 \ \text{GeV}}$ $\gamma \text{Be}, \overline{E}_{\gamma} = 220 \ \text{Ge}$ 600 GeV $\pi^- N$ ays. $\frac{COMMENT}{e^+e^- \ 10 \ \text{GeV}}$
$\Gamma(\eta'(958) \pi')/\Gamma(\phi'(958) \pi')/\Gamma(\phi'(958) \pi')/\Gamma(\phi'(958) \pi')/\Gamma(\phi'(958) \pi')$ Unseen decay m	$(\pi^+)/\Gamma(\phi \pi^+)$ odes of the results $(\pi^+) = \frac{EVTS}{68}$ $(\pi^+) = \frac{EVTS}{68}$ $(\pi^+)/\Gamma(\phi)$ odes of the results $(\pi^+)/\Gamma(\phi)$ odes of the results $(\pi^+)/\Gamma(\phi)$	aresonances are in DOCUMENT ID AVERY The Sonances are in DOCUMENT ID	alvarez ALBREC 5 ncluded. 92 C	(Confidence of the confidence	91 NA14 90D ARG dence Level = $^{\prime}$ $\frac{COMMENT}{\eta' \rightarrow \eta \pi^{+} \pi}$ $\frac{COMMENT}{\eta' \rightarrow \eta \pi^{+} \pi}$	Γ ₅₁ /Γ ₁₅	A test of VALUE $<1.4 \times 10^{-3}$ $F_2 \equiv A_2(0)/A$ VALUE 1.6 ± 0.4 OUR $A_2 = 0.5 \pm 0.2$ 1.6 ± 0.1	lepton-numbe $CL\% = VT$ $90 \qquad (C)$ D_s^+ $A_1(0) \text{ in } D_s^+$ $VERAGE$ 00 00 19 00 10 00 10 00 00 00 00	r conservation. DOCUMENT! KODAMA $\rightarrow \phi \ell^+ \nu_\ell$ FOR $\phi \ell^+ \nu_\ell$ FOR 30 AVERY 31 FRABETTI 31 KODAMA $\phi e^+ \nu_e$ decays. AMA 93 use $D_s^+ - \phi \ell^+ \nu_\ell$ DOCUMENT! 32 AVERY 33 FRABETTI	95 RM FAC 948 947 948 946	E653 TECN CLE2 E687 E653 ν _μ deca TECN CLE2 E687	π^- emulsion 600 S $\frac{COMMENT}{e^+e^- \ 10 \ \text{GeV}}$ γ Ge, $E_{\gamma}=220 \ \text{Ge}$ 600 GeV $\pi^- N$ ays.
$\Gamma(\eta'(958) + \eta')/\Gamma(\phi'(958) + \eta')/\Gamma(\phi'(958) + \eta')/\Gamma(\phi'(958) + \eta') - 10$ Unseen decay m Unseen decay m UUE	π ⁺)/Γ(φπ ⁺) odes of the r EVTS 68 cody)/Γ(φ odes of the r CL% 90 Mode	resonances are in DOCUMENT ID AVERY A+) resonances are in DOCUMENT ID DAOUDI	alvarez ALBREC 5 ncluded. 92 C	(Confidence of the confidence	91 NA14 90D ARG dence Level = $^{\prime}$ $\frac{COMMENT}{\eta' \rightarrow \eta \pi^{+} \pi}$ $\frac{COMMENT}{\eta' \rightarrow \eta \pi^{+} \pi}$	Γ ₅₁ /Γ ₁₅	A test of VALUE $<1.4 \times 10^{-3}$ $F_2 \equiv A_2(0)/A_1$ $VALUE$ $1.6 \pm 0.4 \text{ OUR}$ $1.4 \pm 0.5 \pm 0.3$ $1.1 \pm 0.8 \pm 0.1$ $2.1 \stackrel{+}{-}0.5 \pm 0.2$ 30 AVERY 94B 31 FRABETTI $F_V \equiv V(0)/A_1$ $VALUE$ $1.5 \pm 0.5 \text{ OUR}$ $0.9 \pm 0.6 \pm 0.3$	lepton-numbe CL_{S}^{+} EVT: 90 D_{S}^{+} N1(0) in D_{S}^{+} EVT: WERAGE 15 10 uses $D_{S}^{+} \rightarrow 94$ F and KOD 10 in D_{S}^{+} EVT: WERAGE 308	r conservation. DOCUMENT: KODAMA $\rightarrow \phi \ell^+ \nu_\ell$ FOR $\phi \ell^+ \nu_\ell$ FOR 30 AVERY 31 FRABETTI 31 KODAMA $\phi e^+ \nu_e$ decays. AMA 93 use $D_s^+ - \phi \ell^+ \nu_\ell$ DOCUMENT: DOCUMENT: 32 AVERY 33 FRABETTI	95 RM FAC 948 947 948 946	TECN CLE2 E687 E653 ν _μ deca	π^- emulsion 600 S $\frac{COMMENT}{e^+e^- \ 10 \ \text{GeV}}$ $\gamma \text{Be}, \overline{E}_{\gamma} = 220 \ \text{Ge}$ 600 GeV $\pi^- N$ ays. $\frac{COMMENT}{e^+e^- \ 10 \ \text{GeV}}$
$\Gamma(\eta'(958), \rho^+)/\Gamma(\phi)$ Unseen decay m ΔUE $44\pm 0.62 + 0.44$ $(\eta'(958), \pi^+, \pi^0.3 + 0.46)$ Unseen decay m ΔUE (0.85) $(K^0\pi^+)/\Gamma(\phi\pi^+)$	π ⁺)/Γ (φπ ⁺) rodes of the reference	avesonances are in DOCUMENT ID AVERY a++) resonances are in DOCUMENT ID DAOUDI ss with one or	shoulded.	ZHT (Conflict 6 6 CLE2 CLE2 K's —	91 NA14 90D ARG COMMENT $\eta' \rightarrow \eta \pi^+ \pi$ COMMENT $e^+e^- \approx 10$.	Γ ₅₁ /Γ ₁₅ - Γ ₅₂ /Γ ₁₅ - Γ ₅₃ /Γ ₁₅	A test of VALUE $<1.4 \times 10^{-3}$ $F_2 \equiv A_2(0)/A_1$ $VALUE$ 1.6 ± 0.4 OUR $1.4 \pm 0.5 \pm 0.3$ $1.1 \pm 0.8 \pm 0.1$ $2.1 \pm 0.5 \pm 0.2$ 30 AVERY 94B 31 FRABETTI $F_V \equiv V(0)/A_1$ $VALUE$ 1.5 ± 0.5 OUR $0.9 \pm 0.6 \pm 0.3$ $1.8 \pm 0.9 \pm 0.2$ $2.3 \pm 0.9 \pm 0.4$ 32 AVERY 94B	lepton-numbe $CL_{S} = VTS$ 90 D_{S}^{+} $N_{1}(0) \text{ in } D_{S}^{+}$ $VERAGE$ 00 00 00 00 00 00 00 0	r conservation. DOCUMENT! KODAMA $\rightarrow \phi \ell^+ \nu_\ell$ FOR $\phi \ell^+ \nu_\ell$ FOR 30 AVERY 31 FRABETTI 31 KODAMA $\phi e^+ \nu_e$ decays. AMA 93 use $D_s^+ - \phi \ell^+ \nu_\ell$ DOCUMENT! 32 AVERY 33 FRABETTI 33 KODAMA $\phi e^+ \nu_e$ decays.	95 RM FAC 948 94F 93 φ μ+ 1 948 94F 93	E653 TECN CLE2 E687 E653 TECN CLE2 E687 E653	$\pi^- \text{ emulsion } 600$ $\frac{COMMENT}{e^+e^- \ 10 \ \text{GeV}}$ $\gamma \text{ Be, } E_{\gamma} = 220 \ \text{ Ge}$ $600 \ \text{GeV} \ \pi^- N$ ays. $\frac{COMMENT}{e^+e^- \ 10 \ \text{GeV}}$ $\gamma \text{ Be, } E_{\gamma} = 220 \ \text{ Ge}$ $600 \ \text{GeV} \ \pi^- N$
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$\Gamma(\eta'(958) \rho^+)/\Gamma(\phi)$ (1958) $\rho^+)/\Gamma(\phi)$ (1958) $\rho^+ \rho^0$ (1958) $\rho^0 \rho^0$	(π+)/Γ(φπ+) (απ+)	resonances are in DOCUMENT ID AVERY A** BOCUMENT ID DOCUMENT ID DOCUMENT ID AVERY DOCUMENT ID AVERY DOCUMENT ID AVERY ADLER	alvare all alvare alvar	ZHT (Conflict 6 CLE2 CLE2 K's —	OMMENT e^+e^- 4.14 G	Γ ₅₁ /Γ ₁₅ - Γ ₅₂ /Γ ₁₅ - Γ ₅₃ /Γ ₁₅	A test of YALUE <1.4 × 10 ⁻³ F ₂ = A ₂ (0)/A YALUE 1.6±0.4 OUR 1.4±0.5±0.3 1.1±0.8±0.1 2.1±0.5±0.2 30 AVERY 94B 31 FRABETTI F _V = V(0)/A YALUE 1.5±0.5 OUR 0.9±0.6±0.3 1.8±0.9±0.2 2.3±0.9±0.4 32 AVERY 94B 33 FRABETTI	lepton-numbe $\frac{CL_{N}^{+}}{CL_{N}^{+}} = \frac{CL_{N}^{+}}{CL_{N}^{+}} = \frac{CL_{N}^{+}}{C$	r conservation. DOCUMENT: KODAMA $\rightarrow \phi \ell^+ \nu_\ell$ FOR $\rightarrow \phi \ell^+ \nu_\ell$ SOUMENT: 30 AVERY 31 FRABETTI 31 KODAMA $\phi e^+ \nu_e$ decays. AMA 93 use D_s^+ DOCUMENT: 32 AVERY 33 FRABETTI 33 KODAMA $\phi e^+ \nu_e$ decays. AMA 93 use D_s^+ AMA 93 use D_s^+	95 RM FAC 948 94F 93 φ μ+ 1 948 94F 93	E653 TECN CLE2 E687 E653 TECN CLE2 E687 E653	$\pi^- \text{ emulsion } 600$ $\frac{COMMENT}{e^+e^- \ 10 \ \text{GeV}}$ $\gamma \text{ Be, } E_{\gamma} = 220 \ \text{ Ge}$ $600 \ \text{GeV} \ \pi^- N$ ays. $\frac{COMMENT}{e^+e^- \ 10 \ \text{GeV}}$ $\gamma \text{ Be, } E_{\gamma} = 220 \ \text{ Ge}$ $600 \ \text{GeV} \ \pi^- N$
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$\Gamma(\eta'(958) r)$ $(\eta'(958) \rho^+)/\Gamma(\phi)$ Unseen decay m 44±0.62±0.46 $(\eta'(958) \pi^+ \pi^0 3$ -b Unseen decay m 4.0.62 $(K^0 \pi^+)/\Gamma(\phi \pi^+)$ $(K^0 \pi^+)/\Gamma(K^+ K^-)$ $(K^0 \pi^+)/\Gamma(K^+ K^-)$ $(K^0 \pi^+)/\Gamma(\phi \pi^+)$	(φπ ⁺) (φπ	resonances are in DOCUMENT ID AVERY AVERY as an	alvare Albreco	ZHT (Confice 6 6 6 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7	OMMENT $e^+e^- \approx 10$. COMMENT $e^+e^- \approx 10$. COMMENT $e^+e^- \approx 10$. COMMENT $e^+e^- \approx 10$. $e^+e^- \approx 10$. $e^+e^- \approx 10$.	1.1 3.9 5.7 0.058) F ₅₁ /\(\Gamma_{15}\) F ₅₂ /\(\Gamma_{15}\) F ₅₂ /\(\Gamma_{15}\) F ₅₃ /\(\Gamma_{15}\) GeV F ₅₃ /\(\Gamma_{15}\) GeV F ₅₄ /\(\Gamma_{15}\) F ₅₄ /\(\Gamma_{15}\	A test of VALUE $<1.4 \times 10^{-3}$ $f_2 \equiv A_2(0)//VALUE$ 1.6 ± 0.4 OUR $//VALUE$ 1.6 ± 0.4 OUR $//VALUE$ $1.6 \pm 0.5 \pm 0.3$ $1.1 \pm 0.8 \pm 0.1$ $2.1 \pm 0.6 \pm 0.2$ 30 AVERY 94B 31 FRABETTI $f_y \equiv V(0)/A_1$ $VALUE$ 1.5 ± 0.5 OUR $//VALUE$ 1.5 ± 0.5 OUS $//VALUE$ $1.5 \pm $	lepton-numbe $CLX = VT$ 90 $CLX = VT$ 90 $CLX = VT$ 90 $CLX = VT$ $VERAGE$ 308 90 19 $40 \text{ In } D_s^+ \rightarrow VT$ $VERAGE$ 308 90 19 $40 \text{ In } D_s^+ \rightarrow VT$ $VERAGE$ 308 90 19 $40 \text{ In } A$ $40 \text$	r conservation. Document is NODAMA $\rightarrow \phi \ell^+ \nu_\ell$ FOR $\phi \ell^+ \nu_\ell$ FOR $\phi \ell^+ \nu_\ell$ So AVERY 31 FRABETTI 31 KODAMA $\phi e^+ \nu_e$ decays. AMA 93 use $D_s^+ - \Phi^+ \nu_e$ Document is 32 AVERY 33 FRABETTI 33 KODAMA $\phi e^+ \nu_e$ decays. AMA 93 use $D_s^+ - \Phi^+ \nu_e$ decays. AMA 93 use $D_s^+ - \Phi^+ \nu_e$ decays. $\phi \ell^+ \nu_e$ decays. $\phi \ell^+ \nu_e$ decays. $\phi \ell^+ \nu_e$ decays.	95 SM FAC 948 947 93 948 947 93 948 947 93 948 947 93	E653 TECN CLE2 E687 E653 νμ deca TECN CLE2 E687 E653 ΤΕCN CLE2 E687 E653	π^- emulsion 600 π^- emulsion 600 π^- emulsion 600 π^- et π^- 10 GeV π^- Be, π^- 220 Ge 600 GeV π^- N ays. COMMENT π^+ π^- 10 GeV π^- R ays. COMMENT π^+ π^- 10 GeV π^- R ays. $\pi^ \pi^ \pi^-$
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$\Gamma(\eta'(958) \eta')/\Gamma(\phi)$ Unseen decay m ALUE 10.53 $(K^0 \pi^+)/\Gamma(\phi \pi^+)$ ALUE 10.53 $(K^0 \pi^+)/\Gamma(K^+ K^-)$ $(K^0 \pi^+)/\Gamma(K^-)$ $(K^0 \pi^+)/\Gamma(K^+ K^-)$ $(K^0 \pi^+)/\Gamma(K^-)$	(φπ ⁺) (φπ	resonances are in DOCUMENT ID AVERY ** ** DOCUMENT ID DAOUDI ss with one or DOCUMENT ID ADLER DOCUMENT	alvare Albreco	ZHT (Confice 6 6 CLE2 K's— MRK3 TECN Illimits, (1687 TECN 1687	OMMENT etc. • • • γ Be $E_{\gamma} \approx 20$	1.1 3.9 5.7 0.058) F ₅₁ /\(\Gamma_{15}\) F ₅₂ /\(\Gamma_{15}\) F ₅₂ /\(\Gamma_{15}\) F ₅₃ /\(\Gamma_{15}\) F ₅₃ /\(\Gamma_{15}\) F ₅₃ /\(\Gamma_{15}\) F ₅₄ /\(\Gamma_{15}\) F ₅₅ /\(A test of VALUE $<1.4 \times 10^{-3}$ $f_2 \equiv A_2(0)//VALUE$ 1.6 ± 0.4 OUR $//VALUE$ 1.6 ± 0.4 OUR $//VALUE$ $1.6 \pm 0.5 \pm 0.3$ $1.1 \pm 0.8 \pm 0.1$ $2.1 \pm 0.6 \pm 0.2$ 30 AVERY 94B 31 FRABETTI $f_y \equiv V(0)/A_1$ $VALUE$ 1.5 ± 0.5 OUR $//VALUE$ 1.5 ± 0.5 OUS $//VALUE$ $1.5 \pm $	lepton-numbe $CLX = VT$ 90 $CLX = VT$ 90 $CLX = VT$ 90 $CLX = VT$ $VERAGE$ 308 90 19 $40 \text{ In } D_s^+ \rightarrow VT$ $VERAGE$ 308 90 19 $40 \text{ In } D_s^+ \rightarrow VT$ $VERAGE$ 308 90 19 $40 \text{ In } A$ $40 \text$	r conservation. Document is NODAMA $\rightarrow \phi \ell^+ \nu_\ell$ FOR $\phi \ell^+ \nu_\ell$ FOR $\phi \ell^+ \nu_\ell$ So AVERY 31 FRABETTI 31 KODAMA $\phi e^+ \nu_e$ decays. AMA 93 use $D_s^+ - \Phi^+ \nu_e$ Document is 32 AVERY 33 FRABETTI 33 KODAMA $\phi e^+ \nu_e$ decays. AMA 93 use $D_s^+ - \Phi^+ \nu_e$ decays. AMA 93 use $D_s^+ - \Phi^+ \nu_e$ decays. $\phi \ell^+ \nu_e$ decays. $\phi \ell^+ \nu_e$ decays. $\phi \ell^+ \nu_e$ decays.	95 SM FAC 948 947 93 948 947 93 948 947 93 948 947 93	E653 TECN CLE2 E687 E653 νμ deca TECN CLE2 E687 E653 ΤΕCN CLE2 E687 E653	π^- emulsion 600 π^- emulsion 600 π^- emulsion 600 $\pi^ \pi^ \pi$
$\Gamma(\eta'(958)\rho^+)/\Gamma(\phi_{MLUE})$ Unseen decay m ALUE $(\eta'(958)\pi^+\pi^0 3-b$ Unseen decay m ALUE $(\eta'(958)\pi^+\pi^0 3-b$ Unseen decay m ALUE $(\eta'(958)\pi^+\pi^0 3-b$ $(\eta'(958)\pi^0 3-b)$ $(\eta'(958)\pi^0 3-$	(φπ ⁺) Γ (φπ ⁺) rodes of the results FVTS 68 rode) Γ (φ rodes of the results FVTS	resonances are in DOCUMENT ID AVERY AVERY AVERY AVERY ADOCUMENT ID DOCUMENT ID ADOUDING ID ADOLD ID ADOLD ID ADOLD ID ADOCUMENT ID ADDLE ID ADD	alvare Albreco	ZHT (Confice 6 6 CLE2 K's— MRK3 TECN Illimits, (1687 TECN 1687	OMMENT $\gamma' \rightarrow \gamma \pi^+ \pi$ COMMENT $e^+e^- \approx 10$. COMMENT $e^+e^- \approx 10$. COMMENT $e^+e^- \approx 20$ COMMENT $e^+e^- \approx 20$ COMMENT $e^+e^- \approx 20$	1.1 3.9 5.7 0.058) F ₅₁ /\(\Gamma_{15}\) F ₅₂ /\(\Gamma_{15}\) F ₅₂ /\(\Gamma_{15}\) F ₅₃ /\(\Gamma_{15}\) F ₅₃ /\(\Gamma_{15}\) F ₅₃ /\(\Gamma_{15}\) F ₅₄ /\(\Gamma_{15}\) F ₅₅ /\(A test of VALUE $<1.4 \times 10^{-3}$ $f_2 \equiv A_2(0)//VALUE$ 1.6 ± 0.4 OUR $//VALUE$ 1.6 ± 0.4 OUR $//VALUE$ $1.6 \pm 0.5 \pm 0.3$ $1.1 \pm 0.8 \pm 0.1$ $2.1 \pm 0.6 \pm 0.2$ 30 AVERY 94B 31 FRABETTI $f_y \equiv V(0)/A_1$ $VALUE$ 1.5 ± 0.5 OUR $//VALUE$ 1.5 ± 0.5 OUS $//VALUE$ $1.5 \pm $	lepton-numbe $CLX = VT$ 90 $CLX = VT$ 90 $CLX = VT$ 90 $CLX = VT$ $VERAGE$ 308 90 19 $40 \text{ In } D_s^+ \rightarrow P$ $94F \text{ and KOD}$ $94F \text{ and KOD}$ $P = VT$	r conservation. Document is NODAMA $\rightarrow \phi \ell^+ \nu_\ell$ FOR $\phi \ell^+ \nu_\ell$ FOR $\phi \ell^+ \nu_\ell$ So AVERY 31 FRABETTI 31 KODAMA $\phi e^+ \nu_e$ decays. AMA 93 use $D_s^+ - \Phi^+ \nu_e$ Document is 32 AVERY 33 FRABETTI 33 KODAMA $\phi e^+ \nu_e$ decays. AMA 93 use $D_s^+ - \Phi^+ \nu_e$ decays. AMA 93 use $D_s^+ - \Phi^+ \nu_e$ decays. $\phi \ell^+ \nu_e$ decays. $\phi \ell^+ \nu_e$ decays. $\phi \ell^+ \nu_e$ decays.	95 SM FAC 948 947 93 948 947 93 948 947 93 948 947 93	E653 TECN CLE2 E687 E653 νμ deca TECN CLE2 E687 E653 ΤΕCN CLE2 E687 E653	π^- emulsion 600 π^- emulsion 600 π^- emulsion 600 $\pi^ \pi^ \pi$

D REFERENCES

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BAI	98	PR D57 28	+Bardon, Blum+	(BEPC BES	Collab.)
ACCIARRI	97F	PL B396 327	M. Acciarrí+	(L3	Collab.)
BALECT	97	PR D56 3779 PRL 79 1436	+Bardon, Bian, Blum+	(BEPC BES (CLEO	Collab.)
BALEST FRABETTI	97 97C	PL B401 131	+Behrens, Cho, Ford+ +Cheung, Cumalat+	(FNAL E687	Collab.)
FRABETTI	97D	PL B407 79	+Cheung, Cumalat+	(FNAL E687	Collab.)
ARTUSO	96	PL B378 364	+Efimov, Gao, Goldberg+	(CLEO	
KODAMA	96 95	PL B382 299	+Torikai, Ushida+	(FNAL E653	Collab.)
BAI BAI	95C	PRL 74 4599 PR D52 3781	+Bardon, Blum, Breakstone+ +Bardon, Blum, Breakstone+	(BES	Collab.) Collab.)
BRANDENB	95	PR D52 3781 PRL 75 3804	Brandenburg, Cinabro, Liu+	(CLEO	Collab.)
FRABETTI	95	PL B346 199	+Cheung, Cumalat+	(FNAL E687	Collab.)
FRABETTI FRABETTI	95B 95E	PL B351 591 PL B359 403	+Cheung, Cumalat+ +Cheung, Cumalat+	(FNAL E687 (FNAL E687	
FRABETTI	95F	PL B363 259	+Cheung, Cumalat+	(FNAL E687	
KODAMA	95	PL B345 85	+Ushida, Mokhtarani+	(FNAL E653	Collab.)
ACOSTA	94	PR D49 5690	+Athanas, Masek, Paar+	(CLEO (CLEO	Collab.)
AVERY BROWN	94B 94	PL B337 405 PR D50 1884	+Freyberger, Rodriguez+ +Fast, McIlwain, Miao+	(CLEO	Collab.)
BUTLER	94	PL B324 255	+Fu, Kalbfleisch, Ross+	(CLEO	
FRABETTI	94F	PL B328 187	+Cheung, Cumalat+	(FNAL E687	
MUHEIM	94 93	PR D49 3767 PL B305 177	+Stone	(CERN WAB2	(SYRA)
ADAMOVICH AOKI	93	PTP 89 131	+Alexandrov, Antinori+ +Baroni, Bisi, Breslin+	(CERN WA75	Collab.)
FRABETTI	93F	PTP 89 131 PRL 71 827	+Cheung, Cumalat, Dallapiccola+	(FNAL E687	Collab.)
FRABETTI	93G	PL B313 253	+Cheung, Cumalat+	(FNAL E687	
KODAMA KODAMA	93 93B	PL B309 483 PL B313 260	+Ushida, Mokhtarani+ +Ushida, Mokhtarani+	(FNAL E653 (FNAL E653	Collab.)
ALBRECHT	928	ZPHY C53 361	+Ehrlichmann, Hamacher, Krueger+		
ALEXANDER	92	PRL 68 1275	+Bebek, Berkelman, Besson+	(CLEO	Collab.)
ANJOS	92D	PRL 69 2892	+Appel, Bean, Bediaga+	(FNAL E691	Collab.)
AVERY BARLAG	92 92C	PRL 68 1279 ZPHY C55 383	+Freyberger, Rodriguez, Yelton+	(CLEO (ACCMOR	Collab.)
Also	90D	ZPHY C48 29	+Becker, Bozek, Boehringer+ Barlag, Becker, Boehringer, Bosma	n+ (ACCMOR	Collab.)
DAOUDI	92	PR D45 3965	Barlag, Becker, Boehringer, Bosma +Ford, Johnson, Lingel+	(CLEO	Collab.)
FRABETTI	92	PL B281 167	+Bogart, Cheung, Culy+	(FNAL E687	Collab.)
ALBRECHT ALVAREZ	91 91	PL B255 634 PL B255 639	+Ehrlichmann, Hamacher, Krueger+	(ARGUS (CERN NA14/2	Collab.)
ANJOS	91B	PR D43 R2063	+Barate, Bloch, Bonamy+ +Appel, Bean, Bracker+	(FNAL E691	Collab.)
COFFMAN	91	PL B263 135	+Delongh, Dubois, Eigen, Hitlin+	(Mark III	Collab.)
ADLER	90B	PRL 64 169	+Bai, Blaylock, Bolton+	(Mark III	Collab.)
ALBRECHT ALEXANDER	90D 90B	PL B245 315 PRL 65 1531	+Ehrlichmann, Glaeser, Harder+ +Artuso, Bebek, Berkelman+	(ARGUS (CLEO	Collab.)
ALVAREZ	90	ZPHY C47 539	+Barate, Bloch, Bonamy+	(CERN NA14/2	Collab.)
ALVAREZ	90C	PL B246 261	+Barate, Bloch, Bonamy+	(CERN NA14/2	Collab.)
ANJOS	90B	PRL 64 2885	+Appel, Bean, Bracker+	(FNAL E691	
ANJOS BAI	90C 90	PR D41 2705 PRL 65 686	+Appel, Bean+ +Blaylock, Bolton, Brient+	(FNAL E691 (Mark III	
BARLAG	90C	ZPHY C46 563	+Becker, Boehringer, Bosman+	(ACCMOR	Collab.)
FRABETTI	90	PL B251 639	+Bogart, Cheung, Coteus+	(FNAL E687	Collab.)
ADLER	89B	PRL 63 1211	+Bai, Becker, Blaylock, Bolton+	(Mark III	Collab.)
Also ANJOS	89D 89	PRL 63 2858 erratum PRL 62 125	+Appel, Bean, Bracker+	(FNAL E691	Collab 1
ANJOS	89E	PL B223 267	+Appel, Bean, Bracker+	(FNAL E691	
AVERILL	89	PR D39 123	+Blockus, Brabson+	(HRS	Collab.)
CHEN	89	Pl. B226 192	+Mcliwain, Miller, Ng. Shibata+	(CLEO	Collab.)
ALBRECHT ALBRECHT	88 881	Pl. B207 349 Pl. B210 267	+Binder, Boeckmann+ +Boeckmann, Glaeser+	(ARGUS (ARGUS	Collab.)
ANJOS	88	PRL 60 897	+Appel+	(FNAL E691	Collab.)
RAAB	88	PR D37 2391	+Anjos, Appel, Bracker+	(FNAL E691	
ALBRECHT	87F	PL B179 398	+Binder, Boeckmann, Glaeser+	(ARGUS	
ALBRECHT ANJOS	87G 87B	PL B195 102 PRL 58 1818	+Andam, Binder, Boeckmann+ +Appel, Bracker, Browder+	(ARGUS (FNAL E691	Collab.)
BECKER	87B	PL B184 277	+Boehringer, Bosman+ (N	A11 and NA32	Collab.)
BLAYLOCK	87	PRL 58 2171	+Bolton, Brown, Bunnell+	(Mark III	Collab.)
BRAUNSCH CSORNA	87 87	ZPHY C35 317 PL B191 318	Braunschweig, Gerhards+ +Mestayer, Panvini, Word+	(CLEO	Collab.)
JUNG	86	PRL 56 1775	+Abachi+	(HRS	Collab.)
USHIDA	86	PRL 56 1767	+Kondo, Tasaka, Park+	(FNAL E531	Collab.)
ALBRECHT	85D	PL 153B 343	+Drescher, Binder, Drews+	(ARGUS	Collab.)
DERRICK AIHARA	85B 84D	PRL 54 2568 PRL 53 2465	+Fernandez, Fries, Hyman+ +Alston-Garnjost, Badtke, Bakken+	(HRS (TPC (TASSO	Collab.)
ALTHOFF	84	PL 136B 130	+Braunschweig, Kirschfink+	(TASSO	Collab.)
BAILEY	84	PL 139B 320	+Belau, Bohringer, Bosman+	(ACCMOR	Collab.)
AUBERT CHEN	83 83C	NP B213 31 PRL 51 634	+Bassompierre, Becks, Best+ +Alam, Giles, Kagan+	(CLEO	Collab.)
USHIDA	83 83	PRL 51 834 PRL 51 2362	+Kondo, Fujioka, Fukushima+	(FNAL E653	Collab.
				,	

OTHER RELATED PAPERS -

RICHMAN 95 RMP 67 893

(UCSB, STAN)



 $I(J^P) = 0(??)$

is natural, width and decay modes consistent with 1^- .

Ds MASS

The fit includes D^\pm , D^0 , D_s^\pm , $D^{*\pm}$, D^{*0} , and $D_s^{*\pm}$ mass and mass

VALUE (MeV)	DOCUMENT ID TECN COMMENT	
2112.4±0.7 OUR FIT	Error includes scale factor of 1.1.	
2106.6±2.1±2.7	. 1 BLAYLOCK 87 MRK3 $e^+e^- \rightarrow D_S^{\pm} \gamma X$	

¹ Assuming D_s^{\pm} mass = 1968.7 \pm 0.9 MeV.

$m_{D_s^{\bullet\pm}}-m_{D_s^{\pm}}$

The fit includes D^\pm , D^0 , D_s^\pm , $D^{*\pm}$, D^{*0} , and $D_s^{*\pm}$ mass and mass difference measurements.

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
143.8 ± 0.4 OUR	FIT			
143.9 ± 0.4 OUR	AVERAGE			
143.76± 0.39±0.40	1	GRONBERG	95 CLE2	e+ e
144.22± 0.47±0.37	•	BROWN		
142.5 ± 0.8 ±1.5		² ALBRECHT	88 ARG	$e^+e^- \rightarrow D_s^{\pm} \gamma X$
139.5 ± 8.3 ± 9.7	60	AIHARA	84D TPC	$e^+e^- \rightarrow hadrons$
 We do not use 	e the followin	g data for average	s, fits, limits	i, etc. • • •
143.0 ±18.0	8	ASRATYAN	85 HLBC	FNAL 15-ft, ν-2H
110 ±46		BRANDELIK	79 DASP	$e^+e^- \rightarrow D_s^{\pm} \gamma X$
² Result includes d	ata of ALBRI	ECHT 84B.		•

D*± WIDTH

VALUE (MeV)	CL%	DOCUMENT ID		TECN	COMMENT
< 1.9	90	GRONBERG	95	CLE2	e+e-
< 4.5	90	ALBRECHT	88	ARG	$E_{cm}^{ee} = 10.2 \text{ GeV}$
• • • We do not use the	following o	lata for averages	, fits	i, limits,	etc. • • •
< 4.9	90	BROWN	94	CLE2	e+ e-
<22	90	BLAYLOCK	87	MRK3	$e^+e^- \rightarrow D_5^{\pm} \gamma X$

D*+ DECAY MODES

 $D_{\rm S}^{*-}$ modes are charge conjugates of the modes below.

	Mode	Fraction (Γ_I/Γ)	
$\overline{\Gamma_1}$	$D_5^+ \gamma$	(94.2±2.5) %	
Γ_2	$\begin{array}{c}D_s^+\gamma\\D_s^+\pi^0\end{array}$	(5.8±2.5) %	

CONSTRAINED FIT INFORMATION

An overall fit to a branching ratio uses 1 measurements and one constraint to determine 2 parameters. The overall fit has a $\chi^2=$ 0.0 for 0 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\langle \delta x_i \delta x_j \rangle / (\delta x_i \cdot \delta x_j)$, in percent, from the fit to the branching fractions, $x_i \equiv \Gamma_i / \Gamma_{\text{total}}$. The fit constrains the x_i whose labels appear in this array to sum to

D*+ BRANCHING RATIOS

Γ_1/Γ
<u> </u>
γX
Γ_2/Γ_1
_

D* REFERENCES

GRONBERG BROWN ASRATYAN ALBRECHT BLAYLOCK ASRATYAN AHARA ALBRECHT	95 94 91 88 87 85 84D 84B	PRL 75 3232 PR D50 1884 PL 8257 525 PL 8207 349 PRL 58 2171 PL 156B 441 PRL 53 2465 PL 146B 111	+Korte, Kutschke+ +Fast, McIlwain, Miao+ +Marage+(TEP, BELG, SACL, SERP, +Binder, Boeckmann+ +Botton, Brown, Bunnell+ +Fedotov, Ammosov, Burtovoy+ +Alston-Garijost, Badtke, Bakken+ +Drescher, Heller+	(CLEO Collab.) (CLEO Collab.) (CRAC, BARI, CERN) (ARGUS Collab.) (Mark III Collab.) (ITEP, SERP) (TPC Collab.) (ARGUS Collab.)
BRANDELIK	79	PL 80B 412	+Braunschweig, Martyn, Sander+	(DASP Collab.)
			HER RELATED PAPERS	
KAMAI	92	PI B284 421	∔Xu	(ALBE)

KAMAL	78C	PL B284 421	+Xu	(ALBE)
BRANDELIK		PL 76B 361	+Cords+	(DASP Collab.)
BRANDELIK		PL 70B 132	+Braunschweig, Martyn, Sander+	(DASP Collab.)

$D_{s1}(2536)^{\pm}$

 $I(J^P) = 0(1^+)$ J, P need confirmation.

Seen in $D^*(2010)^+ K^0$. Not seen in $D^+ K^0$ or $D^0 K^+$. $J^P = 1^+$ assignment strongly favored.

	Dest	(2536)	j±	M/	SS
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VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
2535.35± 0.34±0.5 C	UR EVALL	JATION		
2635.35± 0.34 OUR A	WERAGE			
2534.2 ± 1.2	9	ASRATYAN	94 BEBC	$V \stackrel{N}{\longrightarrow} K^0 \times, D^{*0} K^{\pm} \times$
2535 ± 0.6 ±1	75	FRABETTI	94B E687	$\gamma \text{Be} \rightarrow D^{\bullet+} K^0 X,$ $D^{\bullet0} K^+ X$ $e^+ e^- \rightarrow D^{\bullet0} K^+ X$
$2535.3 \pm 0.2 \pm 0.5$	134	ALEXANDER	93 CLE2	
2534.8 ± 0.6 ±0.6	44	ALEXANDER	93 CLE2	$e^+e^- \rightarrow D^{*+}K^0X$
$2535.2 \pm 0.5 \pm 1.5$	28	ALBRECHT	92R ARG	10.4 $e^+e^- \rightarrow D^{*0}K^+X$ $e^+e^- \rightarrow D^{*+}K^0X$
$2536.6 \pm 0.7 \pm 0.4$		AVERY	90 CLEO	$e^+e^- \rightarrow D^{*+}K^0X$
$2535.9 \pm 0.6 \pm 2.0$		ALBRECHT	89E ARG	$D_{s1}^* \rightarrow D^*(2010)K^0$
• • • We do not use t	he following	data for average	s, fits, limits,	etc. • • •
2535 ±28		1 ASRATYAN	88 HLBC	$\nu N \rightarrow D_S \gamma \gamma X$
¹ Not seen in D* K.				-

$m_{D_{s1}(2536)^{\pm}} - m_{D_{s}^{0}(2111)}$

	•	-	
VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
424±28	ASRATYAN 88	HLBC	$D_5^{*\pm}\gamma$

$D_{s1}(2536)^{\pm}$ WIDTH

VALUE (MeV)	CL% EVTS	DOCUMENT ID	TECN	COMMENT
<2.3	90	ALEXANDER	93 CLEO	$e^+e^- \rightarrow D^{*0}K^+X$
• • • We do not	use the follo	wing data for averages	i, fits, limits,	etc. • • •
<3.2	90 75	FRABETTI	94B E687	$\gamma \text{Be} \rightarrow D^{*+} K^0 X,$ $D^{*0} K^+ X$
<3.9	90	ALBRECHT	92R ARG	10.4 e ⁺ e ⁻ →
<5.44	90	AVERY	90 CLEO	$D^{*0}K^+X$ $e^+e^- \rightarrow D^{*+}K^0X$
<4.6	90	ALBRECHT	89E ARG	$D_{51}^* \to D^*(2010)K^0$

$D_{s1}(2536)^+$ DECAY MODES

 $D_{\rm S1}(2536)^-$ modes are charge conjugates of the modes below.

	Mode	Fraction (Γ_I/Γ)
Γ ₁	D*(2010)+K ⁰	seen
Γ ₂	D*(2007) ⁰ K+ D+ K ⁰	seen
Γ ₂ Γ ₃		not seen
Γ_{4}	D ⁰ K ⁺	not seen
Γ ₄ Γ ₅	$D_s^{*+}\gamma$	possibly seen

D_{s1}(2536)+ BRANCHING RATIOS

$\Gamma(D^+K^0)/\Gamma(D^*(2))$	010)+ K ⁰)				Γ ₃ /Γ ₁
YALUE		DOCUMENT ID		TECN	COMMENT
<0.40	90	ALEXANDER	93	CLEO	$e^+e^- \rightarrow D^{*+}K^0X$
<0.43	90	ALBRECHT	89E	ARG	$D_{s1}^* \to D^*(2010)K^0$
$\Gamma(D_s^{*+}\gamma)/\Gamma_{\text{total}}$					Γ ₅ /Γ
YALUE		DOCUMENT ID		TEÇN	COMMENT
possibily seen		ASRATYAN	88	HLBC	$\nu N \rightarrow D_S \gamma \gamma X$
$\Gamma(D^0K^+)/\Gamma(D^*(2k))$	007) ⁰ K ⁺)				Γ_4/Γ_2
VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<0.12	90	ALEXANDER	93	CLEO	$e^+e^- \rightarrow D^{*0}K^+X$

VALUE	CLX	DOCUMENT ID		TECN .	COMMENT
<0.42	90	ALEXANDER	93	CLEO	$e^+e^- \rightarrow D^{*0}K^+X$
Γ(D*(2007) ⁰ K+)	/Γ(<i>D</i> *(201	0)+ K ⁰)			Γ ₂ /Γ ₁
VALUE		DOCUMENT ID		TECN	COMMENT
1.22±0.23 OUR AV	ERAGE				
1.1 ±0.3		ALEXANDER	93	CLEO	$e^+e^- \rightarrow D^{*0}K^+X, D^{*+}K^0X$
1.4 ±0.3 ±0.2		² ALBRECHT	92R	ARG	10.4 e ⁺ e ⁻ → D*0 K+X, D*+ K ⁰ X
² Evaluated by us	from published	d inclusive cross-se	ection	15.	

$D_{s1}(2536)^{\pm}$ REFERENCES

ASRATYAN	94	ZPHY C 61 563	+Aderholz+ (BIRM, BEL	G, CERN, SERP, ITEP, RAL
FRABETTI	94 B	PRL 72 324	+Cheung, Cumalat+	(FNAL E687 Collab.
ALEXANDER	93	PL B303 377	+Bebek+	(CLEO Collab.
ALBRECHT	92R	PL B297 425	+Ehrlichmann+	(ARGUS Collab.
AVERY	90	PR D41 774	+ Besson	(CLEO Collab.
ALBRECHT	89E	PL B230 162	+Glaser, Harder+	(ARGUS Collab.
ASRATYAN	88	ZPHY C40 483	+Fedotov+	(ITEP, SERP



16 +5 ±3

$$I(J^P) = 0(??)$$

 J^P is natural, width and decay modes consistent with 2^+ .

$D_{sJ}(2573)^{\pm}$ MASS

VALUE (MeV)	<u>EVTS</u>	DOCUMENT ID		TECN	CHG	COMMENT
2573.5±1.7 OUR /	WERAGE					
2574.5±3.3±1.6		ALBRECHT	96	ARG		$e^+e^- \rightarrow D^0K^+X$
$2573.2_{-1.6}^{+1.7} \pm 0.9$	217	KUBOTA	94	CLE2	+	$e^+e^-\sim~10.5~{\rm GeV}$
,		D _{sJ} (2573) [±]	WID	TH		
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
15 +8 OUR AV	ERAGE					
10.4 ± 8.3 ± 3.0		ALBRECHT	96	ARG		$e^+e^- \rightarrow D^0K^+X$

$D_{sJ}(2573)^+$ DECAY MODES

94 CLE2 +

 $e^+e^-\sim 10.5 \text{ GeV}$

 $D_{sJ}(2573)^{-}$ modes are charge conjugates of the modes below.

KUBOTA

	Mode	Fraction (Γ_I/Γ)
$\overline{\Gamma_1}$	D ⁰ K ⁺	seen
Γ_2	D*(2007) ⁰ K+	not seen

D_{sJ}(2573)+ BRANCHING RATIOS

$\Gamma(D^0K^+)/\Gamma_{\text{total}}$						Γ ₁ /
VALUE	<u>EVTS</u>	DOCUMENT ID		<u>TECN</u>		COMMENT
9000	217	KUBOTA	94	CLE2	±	$e^+e^-\sim~10.5~{\rm GeV}$
Γ(D*(2007) ⁰ K+)/r(<i>D</i> 0/	K+)				Γ ₂ /Γ
VALUE	CLX	DOCUMENT ID		TECN	CHG	COMMENT
<0.33	90	KUBOTA	94	CLE2	+	$e^+e^-\sim~10.5~{\rm GeV}$
D. 1(2573)± REFERENCES						

ALBRECHT	96	ZPHY C69 405	+Hamacker, Hofmann+	(ARGUS Collab.)
KUBOTA	94	PRL 72 1972	+Lattery, Nelson, Patton+	(CLEO Collab.)

B Meson Production and Decay, b-flavored hadrons

BOTTOM MESONS

 $(B=\pm 1)$

 $B^+ = u\overline{b}$, $B^0 = d\overline{b}$, $\overline{B}{}^0 = \overline{d}b$, $B^- = \overline{u}b$, similarly for $B^{\bullet *}$'s

B-particle organization

Many measurements of B decays involve admixtures of B hadrons. Previously we arbitrarily included such admixtures in the B^{\pm} section, but because of their importance we have created two new sections: " B^{\pm}/B^0 Admixture" for T(4S) results and " $B^{\pm}/B^0/B_s^0/b$ -baryon Admixture" for results at higher energies. Most inclusive decay branching fractions are found in the Admixture sections. $B^0.\overline{B}^0$ mixing data and B- \overline{B} mixing data for a B^0/B_s^0 admixture are found in the B_s^0 section. CP-violation data are found in the B^0 section. D-baryons are found near the end of the Baryon section.

The organization of the B sections is now as follows, where bullets indicate particle sections and brackets indicate reviews.

```
[Production and Decay of b-flavored Hadrons]
        [Semileptonic Decays of B Mesons]
        • B<sup>±</sup>
            mass, mean life
            branching fractions

    B<sup>0</sup>

            mass, mean life
            branching fractions
            polarization in B^0 decay
            B^0 - \bar{B}^0 mixing
            [B^0 \overline{B}^0 Mixing and CP Violation in B Decay]
            CP violation
        • B<sup>±</sup> B<sup>0</sup> Admixture
            branching fractions
        • B^{\pm}/B^{0}/B_{s}^{0}/b-baryon Admixture
            mean life
            production fractions
            branching fractions
            mass

 B<sub>J</sub>(5732)

            mass, width
        • B0
           mass, mean life
            branching fractions
            polarizaton in B_s^0 decay
            B_s^0 - \overline{B}_s^0 mixing
            B-\overline{B} mixing (admixture of B^0, B_s^0)
        • B*
            mass
        \bullet B_{sJ}^*(5850)
            mass, width
        • Bc
            mass, mean life
            branching fractions
At end of Baryon Listings:
        • 1h
            mass, mean life
            branching fractions
        • <u>=</u>0, <u>=</u> −
            mean life
        • b-baryon Admixture
            mean life
            branching fractions
```

PRODUCTION AND DECAY OF b-FLAVORED HADRONS

Written March 1998 by K. Honscheid (Ohio State University, Columbus).

In 1997 we celebrated the 20th anniversary of the discovery of the b quark. What started out as a bump in the dimuon invariant mass spectrum has turned into the exciting field of heavy flavor physics. Weak decays of heavy quarks provide access to fundamental parameters of the Standard Model, in particular the weak mixing angles of the Cabibbo-Kobayashi-Maskawa matrix. There is great hope that experiments with B mesons may lead to the first precise determination of the fourth CKM parameter, the complex phase. While the underlying decay of the heavy quark is governed by the weak interaction, it is the strong force that is responsible for the formation of the hadrons that are observed by experimenters. Although this complicates the extraction of the Standard Model parameters from the experimental data it also means that decays of B mesons provide an important laboratory to test our understanding of the strong interaction

New results that were added to this edition fall into two categories. Arguably the most exciting development since the last edition of this review is the progress in b-quark decays beyond the tree level. Gluonic penguin decays such as $B \to K^-\pi^+$ have been measured for the first time providing us with new opportunities to search for physics beyond the Standard Model and/or to probe the phase structure of the CKM matrix.

At tree level, i.e. for $b \to c$ transitions, the CLEO collaboration used a sample of more than 6 million B decays to update branching fractions for many exclusive hadronic decay channels. New results on semileptonic decays have been reported by CLEO and the LEP collaborations. Lifetime measurements improved steadily and now have reached a precision of a few percent.

Heavy flavor physics is a very dynamic field and in this brief review it is impossible to do justice to all recent theoretical and experimental developments. I will highlight a few new results but otherwise refer the interested reader to several excellent reviews [1-4].

Production and spectroscopy: Elementary particles are characterized by their masses, lifetimes and internal quantum numbers. The bound states with a b quark and a \overline{u} or \overline{d} antiquark are referred to as the B_d $(\overline{B^0})$ and the B_u (B^-) mesons, respectively. The first excitation is called the B^* meson. B^{**} is the generic name for the four orbitally excited (L=1) B-meson states that correspond to the P-wave mesons in the charm system, D^{**} . Mesons containing an s or a c quark are denoted B_s and B_c , respectively.

Experimental studies of b decay are performed at the $\Upsilon(4S)$ resonance near production threshold as well as at higher energies in proton-antiproton collisions and Z decays. Most new results from CLEO are based on a sample of $\approx 3.1 \times 10^6$ $B\overline{B}$ events. At the Tevatron, CDF and DØ have collected 100

pb⁻¹ of data. Operating at the Z resonance each of the four LEP collaborations recorded slightly under a million $b\bar{b}$ events while the SLD experiment collected about 0.2 million hadronic Z decays.

For quantitative studies of B decays the initial composition of the data sample must be known. The $\Upsilon(4S)$ resonance decays only to $B^0\overline{B}^0$ and B^+B^- pairs, while at high-energy collider experiments heavier states such as B_s or B_c mesons and b-flavored baryons are produced as well. The current experimental limit for non- $B\overline{B}$ decays of the $\Upsilon(4S)$ is less than 4% at the 95% confidence level [5]. CLEO has measured the ratio of charged to neutral $\Upsilon(4S)$ decays using semileptonic B decays and found [6]

$$\frac{f_{+}}{f_{0}} = \frac{\mathcal{B}(\Upsilon(4S) \to B^{+}B^{-})}{\mathcal{B}(\Upsilon(4S) \to B^{0}\overline{B}^{0})} = 1.13 \pm 0.14 \pm 0.13 \pm 0.06 \quad (1)$$

where the last error is due to the uncertainties in the ratio of B^0 and B^+ lifetimes. Assuming isospin symmetry an independent value can be obtained from $\mathcal{B}(B^- \to J/\psi K^{(*)-})$ and $\mathcal{B}(\overline{B}^0 \to J/\psi \overline{K}^{(*)0})$ [7]:

$$\frac{f_{+}}{f_{0}} = 1.11 \pm 0.17 \ . \tag{2}$$

This is consistent with equal production of B^+B^- and $B^0\overline{B}^0$ pairs and unless explicitly stated otherwise we will assume $f_+/f_0=1$. This assumption is further supported by the near equality of the B^+ and B^0 masses.

At high-energy collider experiments b quarks hadronize as $\bar{B}^0, B^-, \bar{B}^0_s$, and B_c^- mesons or as baryons containing b quarks. The b-hadron sample composition is not very precisely known although over the last few years significant improvements have been achieved, in particular thanks to B^0 oscillation measurements. The fractions $f_{B^0}, f_{B^+}, f_{B_s}$, and f_{A_b} of B^0, B^+, B_s^0 , and b baryons in an unbiased sample of weakly decaying b hadrons produced at the b resonance are shown in Table 1. They have been estimated by the LEP b oscillations working group [8] using the assumptions b and b and b are the b summarized below.

An estimate of f_{B_s} is obtained from the measurements of the product branching fraction $f_{B_s} \times \mathcal{B}(B_s \to D_s^- \ell^+ \nu_{\ell} X)$. Under the assumption of equal semileptonic partial widths for b-flavored hadrons, results from the $\Upsilon(4S)$ experiments and the b-hadron lifetimes (Table 2) are combined to obtain an estimate for $\mathcal{B}(B_s \to D_s^- \ell \nu_\ell X)$. Together these are used to extract $f_{B_s} =$ $(12.0^{+4.5}_{-3.4})$ %. A similar procedure is followed to obtain $f_{A_b} =$ $(10.1^{+3.9}_{-3.1})\%$ from measurements of $f_{\Lambda_b} \times \mathcal{B}(\Lambda_b \to \Lambda_c^+ \ell^- \overline{\nu}_\ell X)$. A statistically independent estimate $f_{B_s} = (10.1^{+2.0}_{-1.9})\%$ is then derived from measurements of B^0 oscillations. This is done using measurements of the mixing parameters $\chi_d = (1/2)$. $x_d^2/(1+x_d^2)$, in which $x_d=\Delta m_d \tau_{B^0}$, and $\overline{\chi}=f_{B_s}' \chi_s + f_{B^0}' \chi_d$. Here f'_{B_s} and f'_{B^0} are the fractions of B^0_s and B^0 mesons among semileptonic b decays. The dependence on the lifetimes is taken into account and $\chi_s = 1/2$ is assumed. This estimation is performed simultaneously with the Δm_d averaging described

in the mixing section below. An average of the two estimates of f_{B_s} , taking the correlated systematic effects into account, yields $f_{B_s} = (10.5^{+1.8}_{-1.7})\%$ and hence the fractions of Table 1.

Table 1: Fractions of weakly decaying b-hadron species in $Z \to b\bar{b}$ decay.

\overline{b} hadron	Fraction [%]
$\overline{B^-}$	$39.7^{+1.8}_{-2.2}$
$ ilde{B}^0$	$39.7^{+1.8}_{-2.2}$
$ar{B}^0_s$	$10.5_{-1.7}^{+1.8}$
b baryons	$10.1^{+3.9}_{-3.1}$

To date, the existence of four b-flavored mesons $(B^-, \overline{B}^0, B^*, B_s)$ as well as the Λ_b baryon has been established. Using exclusive hadronic decays such as $B_s^0 \to J/\psi \phi$ and $\Lambda_b \to J/\psi \Lambda$ the masses of these states are now known with a precision of a few MeV. The current world averages of the B_s and the Λ_b mass are 5369.6 ± 2.4 MeV/ c^2 and 5624 ± 9 MeV/ c^2 , respectively.

The B_c is the last weakly decaying bottom meson to be observed. Potential models predict its mass in the range 6.2–6.3 GeV/ c^2 . At the 1998 La Thuile conference CDF presented an analysis providing clear evidence for semileptonic $B_c \rightarrow J/\psi \ell X$ decays with $20.4^{+6.2}_{-5.5}$ observed events [13]. CDF reconstructs a B_c mass of $6.4 \pm 0.39 \pm~0.13$ MeV/ c^2 and a B_c lifetime of $0.46^{+0.18}_{-0.16} \pm 0.03$ ps.

First indications of Σ_b and Ξ_b production have been presented by the LEP collaborations [14]. DELPHI has measured the $\Sigma_b^* - \Sigma_b$ hyperfine splitting to 56 ± 16 MeV [15].

Excited B-mesons states have been observed by CLEO, CUSB, and LEP. Evidence for B^{**} production has been presented by ALEPH, OPAL, and DELPHI [3]. Inclusively reconstructing a bottom hadron candidate combined with a charged pion from the primary vertex they see the B^{**} as broad resonance in the $M(B\pi)$ M(B) mass distribution. The LEP experiments have also provided preliminary evidence for excited B_s^{**} states and DELPHI [16] has reported a possible observation of the B', the first radial excitation in the B meson system.

Lifetimes: In the naive spectator model the heavy quark can decay only via the external spectator mechanism and thus the lifetimes of all mesons and baryons containing b quarks would be equal. Nonspectator effects such as the interference between contributing amplitudes modify this simple picture and give rise to a lifetime hierarchy for b-flavored hadrons similar to the one in the charm sector. However, since the lifetime differences are expected to scale as $1/m_Q^2$, where m_Q is the mass of the heavy quark, the variation in the b system should be significantly smaller, of order 10% or less [17]. For the b system we expect

$$\tau(B^-) \geq \tau(\overline{B}^0) \approx \tau(B_s) > \tau(\Lambda_b^0) . \tag{3}$$

Measurements of lifetimes for the various b-flavored hadrons thus provide a means to determine the importance of non-spectator mechanisms in the b sector. Precise lifetimes are

b-flavored hadrons

important for the determination of V_{cb} . They also enter in $B\overline{B}$ mixing measurements.

Over the past years the field has matured and advanced algorithms based on impact parameter or decay length measurements exploit the potential of silicon vertex detectors. However, in order to reach the precision necessary to test theoretical predictions, the results from different experiments need to be averaged. This is a challenging task that requires detailed knowledge of common systematic uncertainties and correlations between the results from different experiments. The average lifetimes for b-flavored hadrons given in this edition have been determined by the LEP B Lifetimes Working Group [19]. The papers used in this calculation are listed in the appropriate sections. A detailed description of the procedures and the treatment of correlated and uncorrelated errors can be found in [20]. The new world average b-hadron lifetimes are summarized in Table 2. Lifetime measurements have reached a precision that the average b-hadron lifetime result becomes sensitive to the composition of the data sample. The result listed in Table 2 takes into account correlations between different experiments and analysis techniques but does not correct for differences due to different admixtures of b-flavored hadrons. In order to estimate the size of this effect the available results have been divided into three sets. LEP measurements based on the identification of a lepton from the *b* decay yield $\tau_{b \text{ hadron}} = 1.537 \pm 0.020 \text{ ps}^{-1}$ [21–23]. The average b-hadron lifetime based on inclusive secondary vertex techniques is $\tau_{b \text{ hadron}} = 1.576 \pm 0.016 \text{ ps}^{-1}$ [24–29]. Finally, CDF [30] used ψ mesons to tag the b vertex resulting in $\tau_{b \text{ hadron}} = 1.533 \pm 0.015^{+0.035}_{-0.031} \text{ ps}^{-1}.$

Table 2: Summary of inclusive and exclusive b-hadron lifetime measurement.

	·
Particle	Lifetime [ps]
$\overline{B^0}$	1.56 ± 0.04
B^+	1.65 ± 0.04
B_s	1.54 ± 0.07
\boldsymbol{b} baryon	1.22 ± 0.05
b hadron	1.564 ± 0.014

For comparison with theory lifetime ratios are preferred. Experimentally we find [19]

$$\frac{\tau_{B^+}}{\tau_{B^0}} = 1.04 \pm 0.04 \; , \; \; \frac{\tau_{B_s}}{\tau_{B^0}} = 0.99 \pm 0.05 \; , \; \; \frac{\tau_{\Lambda_b}}{\tau_{B^0}} = 0.79 \pm 0.06 \; \; (4)$$

while theory makes the following predictions [1]

$$\frac{\tau_{B^+}}{\tau_{B^0}} = 1 + 0.05 \left(\frac{f_B}{200 \text{ MeV}}\right)^2 , \quad \frac{\tau_{B_{\bullet}}}{\tau_{B^0}} = 1 \pm 0.01 , \quad \frac{\tau_{A_b}}{\tau_{B^0}} = 0.9 .$$
 (5)

In conclusion, the pattern of measured B-mesons lifetimes follows the theoretical expectations and non-spectator effects are observed to be small. However, the Λ_b -baryon lifetime is unexpectedly short. As has been noted by several authors, the observed value of the Λ_b lifetime is quite difficult to accommodate

theoretically [31–33]. This apparent breakdown of the heavy-quark expansion for inclusive, non-leptonic B decays could be caused by violations of local quark-hadron duality. Neubert, however, argues that this conclusion is premature because a reliable field-theoretical calculation is still lacking. Exploring a reasonable parameter space for the unknown hadronic matrix elements he demonstrated that within the experimental errors theory can accommodate the measured lifetime ratios [1].

 $B\overline{B}$ mixing: In production processes involving the strong or the electromagnetic interaction neutral B and \overline{B} mesons can be produced. These flavor eigenstates are not eigenstates of the weak interaction which is responsible for the decay of neutral mesons containing b quarks. This feature and the small difference between the masses and/or lifetimes of the weak interaction eigenstates give rise to the phenomenon of $B-\overline{B}$ mixing. The formalism which describes B-meson mixing closely follows that used to describe $K^0-\overline{K}^0$ mixing, although the time scale characteristic of $B^0-\overline{B}^0$ oscillations is much shorter [34].

The ALEPH, DELPHI, L3, OPAL, SLD, and CDF experiments have performed explicit measurements of $\operatorname{Prob}(B^0 \to \overline{B}^0)$ as a function of proper time to extract the oscillation parameter $\Delta m_d = x_d \Gamma_d$ [3]. The flavor of the final state b quark is tagged using the charge of a lepton, a fully or partially reconstructed charmed meson, or a charged kaon, from $b \to \ell^-$, $b \to c$ or $b \rightarrow c \rightarrow s$ decays respectively. For fully inclusive analyses, final state tagging techniques include jet charge and charge dipole methods. The initial state flavor is either tagged directly (same-side tag) or indirectly by tagging the flavor of the other b hadron produced in the event (opposite-side tag). Same-side tagging can be performed with a charged hadron produced in association with the B meson (possibly through a B^{**} state), and opposite-side tagging can be performed with a lepton or a kaon from the decay of the other b hadron. Jet charge techniques have also been used on both sides. If the B meson is produced with polarized beams, its polar angle with respect to the incoming beam axis can also be used to construct an initial

The LEP B oscillations working group has combined all published measurements of Δm_d to obtain an average of $0.470 \pm 0.019 \ \mathrm{ps^{-1}}$ [8]. The averaging procedure takes into account all correlated uncertainties as well as the latest knowledge on the b-hadron production fractions (Table 1), lifetimes (Table 2) and time-integrated parameters. Including the data from the time-integrated measurements performed by ARGUS and CLEO at the $\Upsilon(4S)$ resonance yields a combined result of $\Delta m_d = 0.464 \pm 0.018 \ \mathrm{ps^{-1}}$. Averaging time-dependent results from LEP and CDF and time-integrated measurements from CLEO and ARGUS the time-integrated mixing parameter χ_d is determined to 0.172 ± 0.010 . As stated earlier, Δm_d and the b-hadron fractions are determined simultaneously, providing a self-consistent set of results.

The measurement of the oscillation parameter $\Delta m_s = x_s \Gamma_s$ for the B_s^0 meson combined with the results from the $B^0-\overline{B}^0$

Meson Particle Listings b-flavored hadrons

oscillations allows the determination of the ratio of the CKM matrix elements $|V_{td}|^2/|V_{ts}|^2$ with significantly reduced theoretical uncertainties. For large values, as expected for the B_s^0 meson, time-integrated measurements of B_s^0 mixing become insensitive to Δm_s and one must make time-dependent measurements in order to extract this parameter. The observation of the rapid oscillation rate of the B_s^0 meson is an experimental challenge that is still to be met. The ALEPH, DELPHI, and OPAL experiments have provided lower limits on Δm_s [3]. The most sensitive analyses use inclusive leptons or fully reconstructed D_s^- mesons. All published data have been combined by the LEP B oscillations working group to yield the limit $\Delta m_s > 9.1 \, \mathrm{ps}^{-1}$ at 95% C.L. [8].

For the B_s meson, the quantity $\Delta\Gamma$ may be large enough to be observable [18]. Parton model calculations [9] and calculations with exclusive final states [10] suggest that the width difference may be 10–20%. This lifetime difference could be determined experimentally by using decays to final states with different CP. For example, a measurement of a difference in the lifetimes between $\overline{B}_s^0 \to J/\psi K_s$ and $\overline{B}_s^0 \to D_s^- \ell^+ \nu_\ell$ would yield $\Delta\Gamma/\Gamma^2$. It has also been suggested that such measurements could be used to constrain $|V_{ts}/V_{td}|^2$ if parton model calculations are reliable [11].

Semileptonic B decays: Measurements of semileptonic B decays are important to determine the weak couplings $|V_{cb}|$ and $|V_{ub}|$. In addition, these decays can be used to probe the dynamics of heavy quark decay. The leptonic current can be calculated exactly while corrections due to the strong interaction are restricted to the $b \to c$ and $b \to u$ vertices, respectively.

Experimentally, semileptonic decays have the advantage of large branching ratios and the characteristic signature of the energetic charged lepton. The neutrino, however, escapes undetected so a full reconstruction of the decaying B meson is impossible. Various techniques which take advantage of production at threshold or the hermiticity of the detector have been developed by the ARGUS, CLEO, and LEP experiments to overcome this difficulty.

Three different approaches have been used to measure the inclusive semileptonic rate $B \to X \ell \nu_{\ell}$. These are measurements of the inclusive single lepton momentum spectrum, measurements of dilepton events using charge and angular correlations, and measurements of the separate B^- and \overline{B}^0 branching ratios by using events which contain a lepton and a reconstructed B meson. The dilepton method has the least model-dependency and the current averages based on this method are listed in Table 3 [2]. Differences in \mathcal{B}_{sl} measured at the $\Upsilon(4S)$ and the Z are expected due to the different admixture of b-flavored hadrons. Given the short Λ_b lifetime, however, the LEP value should be lower than the $\Upsilon(4S)$ result. While the experimental errors are still too large to draw any conclusions a potential systematic effect in the LEP results has been pointed out by Dunietz [12]. He noted that the LEP analyses have not yet been corrected for the recently observed production of \overline{D} mesons in \overline{B} decay.

A few new results on exclusive semileptonic B decays have been reported. The current world averages are listed in Table 3. It is interesting to compare the inclusive semileptonic branching fraction to the sum of branching fractions for exclusive modes. At the 2–3 σ level the exclusive modes saturate the inclusive rate leaving little room for extra contributions.

Table 3: Inclusive and exclusive semileptonic branching fractions of B mesons. $\mathcal{B}(\overline{B} \to X_u \ell^- \overline{\nu}_\ell) = 0.15 \pm 0.1\%$ has been included in the sum of the exclusive branching fractions.

Mode		Branching fraction [%]
$\overline{\overline{B}} \to X \ell^- \overline{\nu}_{\ell}(\Upsilon(4S))$		10.18 ± 0.39
$b \to X \ell^- \overline{\nu}_{\ell}(Z)$		10.95 ± 0.32
$\overline{\overline{B}} \to D\ell^-\overline{\nu}_{\ell}$		1.95 ± 0.27
$\overline{B} o D^* \ell^- \overline{ u}_\ell$		5.05 ± 0.25
$\overline{B} \to D^{(*)} \pi \ell^- \overline{\nu}_{\ell}$		2.3 ± 0.44
with $\overline{B} \to D_1^0(2420) \ell^- \overline{\nu}_{\ell}$	0.65 ± 0.11	
$\overline{B} \to D_2^{\stackrel{\bullet}{*}\stackrel{\circ}{0}}(2460)\ell^{-}\overline{\nu}_{\ell}$	$<0.8~90\%~\mathrm{CL}$	
$\Sigma \mathcal{B}_{ ext{exclusive}}$		9.45 ± 0.58

Dynamics of semileptonic B decay: Since leptons are not sensitive to the strong interaction, the amplitude for a semileptonic B decay can be factorized into two parts, a leptonic and a hadronic current. The leptonic factor can be calculated exactly while the hadronic part is parameterized by form factors. A simple example is the transition $B \to D\ell\nu_{\ell}$. The differential decay rate in this case is given by

$$\frac{d\Gamma}{dq^2} = \frac{G_F^2}{24\pi^3} |V_{cb}^2| P_D^3 f_+^2(q^2) \tag{6}$$

where q^2 is the mass of the virtual W $(\ell \nu_{\ell})$ and $f_{+}(q^2)$ is the single vector form factor which gives the probability that the final state quarks will form a D meson. Since the leptons are very light the corresponding $f_{-}(q^2)$ form factor can be neglected. For $B \to D^* \ell \nu_\ell$ decays there are three form factors which correspond to the three possible partial waves of the $B \rightarrow$ $D^*\widehat{W}$ system (here \widehat{W} is the virtual W boson which becomes the lepton-antineutrino pair). Currently, form factors cannot be predicted by theory and need to be determined experimentally. Over the last years, however, it has been appreciated that there is a symmetry of QCD that is useful in understanding systems containing one heavy quark. This symmetry arises when the quark becomes sufficiently heavy to make its mass irrelevant to the nonperturbative dynamics of the light quarks. This allows the heavy quark degrees of freedom to be treated in isolation from the the light quark degrees of freedom. This is analogous to the canonical treatment of hydrogenic atoms, in which the spin and other properties of the nucleus can be neglected. The behavior and electronic structure of the atom are determined by the light electronic degrees of freedom. Heavy quark effective theory (HQET) was created by Isgur and Wise [35] who define

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a single universal form factor, $\xi(v\cdot v')$, known as the Isgur-Wise function. In this function v and v' are the four velocities of the initial and final state heavy mesons. The Isgur-Wise function cannot be calculated from first principles but unlike the hadronic form factors mentioned above it is universal. In the heavy quark limit it is the same for all heavy meson to heavy meson transitions and the four form factors parameterizing $B \to D^*\ell\nu_\ell$ and $B \to D\ell\nu_\ell$ decays can be related to this single function ξ .

In this framework the differential semileptonic decay rates as function of $w=v_B\cdot v_{D^{(\bullet)}}=(m_B^2+m_{D^{(\bullet)}}^2-q^2)/2m_Bm_{D^{(\bullet)}}$ are given by [1]

$$\begin{split} \frac{d\Gamma(\overline{B} \to D^* \ell \overline{\nu}_{\ell})}{dw} &= \frac{G_F^2 M_B^5}{48\pi^3} r_*^3 (1 - r_*)^2 \sqrt{w^2 - 1} (w + 1)^2 \\ & \times \left[1 + \frac{4w}{w + 1} \frac{1 - 2w r_* + r_*^2}{(1 - r_*)^2} \right] |V_{cb}|^2 \mathcal{F}^2(w) \\ \frac{d\Gamma(\overline{B} \to D \ell \overline{\nu}_{\ell})}{dw} &= \frac{G_F^2 M_B^5}{48\pi^3} r^3 (1 + r)^2 (w^2 - 1)^{3/2} |V_{cb}|^2 \mathcal{G}^2(w) \quad (7) \end{split}$$

where $r_{(\star)} = M_{D^{(\star)}}/M_B$ and q^2 is the invariant momentum transfer. For $m_Q \to \infty$, the two form factors $\mathcal{F}(w)$ and $\mathcal{G}(w)$ coincide with the Isgur-Wise function $\xi(w)$.

Both CLEO [36] and ALEPH [37] have measured the differential decay rate distributions and extracted the ratio $\mathcal{G}(w)/\mathcal{F}(w)$ which is expected to be close to unity. As can be seen from the ALEPH result shown in Fig. 1, the data are compatible with a universal form factor $\xi(w)$

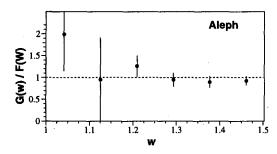


Figure 1: Ratio of the two form factors $\mathcal{G}(w)$ and $\mathcal{F}(w)$ in semileptonic B decay [37].

CLEO has also performed a direct measurement of the three form factors that are used to parameterize $B \to D^*\ell\nu_\ell$ decays [38]. These are usually expressed in terms of form factor ratios R_1 and R_2 [39]. At zero recoil, i.e. w=1, CLEO finds $R_1=1.24\pm0.26\pm0.12$ and $R_2=0.72\pm0.18\pm0.07$. While the errors are still large, this is in good agreement with a theoretical prediction of $R_1=1.3\pm0.1$ and $R_2=0.8\pm0.2$ [1].

Extraction of $|V_{cb}|$: The universal form factor $\xi(w)$ describes the overlap of wavefunctions of the light degrees of freedom in the initial and final heavy meson. At zero recoil, *i.e.* when the two mesons move with the same velocity, the overlap is

perfect and the form factor is absolutely normalized, $\xi(1)=1$. In principle, all that experimentalists have to do to extract a model-independent value for $|V_{cb}|$ is to measure $d\Gamma(B \to D^{(*)}\ell\nu_{\ell})/dw$ for $w\to 1$. However, in the real world the b and c quarks are not infinitely heavy so corrections to the limiting case have to be calculated. After much theoretical effort, the current results are [1]:

$$\mathcal{F}(1) = 0.924 \pm 0.027$$
,
 $\mathcal{G}(1) = 1.00 \pm 0.07$. (8)

Furthermore, the shape of the form factor has to be parameterized because at zero recoil the differential decay rate actually vanishes. Experimentally, the decay rate is measured as function of w and then extrapolated to zero recoil using an expansion of form

$$\mathcal{F}(w) = \mathcal{F}(1) \left(1 - \widehat{\rho}^2(w - 1) \right) . \tag{9}$$

The slope $\hat{\rho}^2$ of the form factor and $|V_{cb}|$ are correlated. The current world averages for $|V_{cb}|$ and $\hat{\rho}$ as extracted from exclusive semileptonic B decays have been compiled by Drell [2]. This value of $|V_{cb}|$ is in good agreement with independent determinations of $|V_{cb}|$ from inclusive B decays.

Table 4: Current world averages.

Mode	$ V_{cb} $	$\widehat{ ho}^2$
$\overline{\overline{B}} \to D^* \ell^- \overline{\nu}_{\ell}$	0.0387 ± 0.0031	0.71 ± 0.11
$\overline{B} \to D\ell^- \overline{\nu}_\ell$	0.0394 ± 0.0050	0.66 ± 0.19

Hadronic B decays: In hadronic decays of B mesons the underlying weak transition of the b quark is overshadowed by strong interaction effects caused by the surrounding cloud of light quarks and gluons. While this complicates the extraction of CKM matrix elements from experimental results it also turns the B meson into an ideal laboratory to study our understanding of perturbative and non-perturbative QCD, of hadronization, and of Final State Interaction (FSI) effects.

The precision of the experimental data has steadily improved over the past years. In 1997 CLEO updated most branching fractions for exclusive $B \to (n\pi)^- D^{(*)}$ and $B \to J/\psi K^{(*)}$ transitions. New, tighter limits on color suppressed decays such as $\overline{B} \to D^0 \pi^0$ have been presented [41] and a new measurement of the polarization in $B \to J/\psi K^*$ resolved an outstanding discrepancy between theory and experiment [40]. Progress has been made in experimental techniques. Last summer CLEO presented several analyses based on partial reconstruction [48,49]. In this method, D^* mesons are not fully reconstructed but rather tagged by the presence of the characteristic slow pion from the $D^* \to D^0\pi$ decay. This results in substantially increased event yields, e.g., $281 \pm 56 \ D^{**}(2420)$ candidates have been reconstructed. The preliminary results are

$$\mathcal{B}(\overline{B}^0 \to D^{*+}\pi^-) = (2.81 \pm 0.11 \pm 0.21 \pm 0.05) \times 10^{-3}$$

$$\mathcal{B}(B^- \to D^{*0}\pi^-) = (4.81 \pm 0.42 \pm 0.40 \pm 0.21) \times 10^{-3}$$

$$\mathcal{B}(B^- \to D_1(2420)\pi^-) = (1.17 \pm 0.24 \pm 0.16 \pm 0.03) \times 10^{-3}$$

$$\mathcal{B}(B^- \to D_2(2460)\pi^-) = (2.1 \pm 0.8 \pm 0.3 \pm 0.05) \times 10^{-3}. (10)$$

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The second systematic error reflects the uncertainty in the D^* branching fractions.

Gronau and Wyler [50] first suggested that decays of the type $B \to DK$ can be used to extract the angle γ of the CKM unitarity triangle, $\gamma \approx \arg(V_{ub})$. The first example of such a Cabibbo suppressed mode has recently been observed by CLEO [51]:

$$\frac{\mathcal{B}(B^- \to D^0 K^-)}{\mathcal{B}(B^- \to D^0 \pi^-)} = 0.055 \pm 0.014 \pm 0.005 \ . \tag{11}$$

Measurements of exclusive hadronic B decays have reached sufficient precision to challenge our understanding of the dynamics of these decays. It has been suggested that in analogy to semileptonic decays, two-body hadronic decays of B mesons can be expressed as the product of two independent hadronic currents, one describing the formation of a charm meson and the other the hadronization of the remaining $\overline{u}d$ (or $\overline{c}s$) system from the virtual W^- . Qualitatively, for a B decay with a large energy release, the $\overline{u}d$ pair, which is produced as a color singlet, travels fast enough to leave the interaction region without influencing the second hadron formed from the c quark and the spectator antiquark. The assumption that the amplitude can be expressed as the product of two hadronic currents is called "factorization" in this paper. By comparing exclusive hadronic B decays to the corresponding semileptonic modes the factorization hypothesis has been experimentally confirmed for decays with large energy release [40]. Note that it is possible that factorization will be a poorer approximation for decays with smaller energy release or larger q^2 . For internal spectator decays the validity of the factorization hypothesis is also questionable and requires experimental verification. The naive color transparency argument used in the previous sections is not applicable to decays such as $B \to J/\psi K$, and there is no corresponding semileptonic decay to compare to. For internal spectator decays one can only compare experimental observables to quantities predicted by models based on factorization. Two such quantities are the production ratio

$$\mathcal{R} = \frac{\mathcal{B}(B \to J/\psi K^*)}{\mathcal{B}(B \to J/\psi K)} \tag{12}$$

and the amount of longitudinal polarization Γ_L/Γ in $B \rightarrow$ $J/\psi K^*$ decays. Previous experimental results, $\mathcal{R}=1.68\pm0.33$ and $\Gamma_L/\Gamma = 0.78 \pm 0.04$, were inconsistent with all model predictions. The theory had difficulties in simultaneously accommodating a large longitudinal polarization and a large vector-to-pseudoscalar production ratio. Non-factorizable contributions that reduce the transverse amplitude were proposed to remedy the situation. New experimental results, however, make this apparent breakdown of the factorization hypothesis less likely. The CLEO collaboration published new data on $B \to \text{charmonium transitions}$ [7]. Their values,

$$\mathcal{R} = 1.45 \pm 0.20 \pm 0.17$$
, $\Gamma_L/\Gamma = 0.52 \pm 0.07 \pm 0.04$, (13)

are now consistent with factorization-based models.

In the decays of charm mesons, the effect of color suppression is obscured by the effects of FSI or reduced by nonfactorizable effects. Because of the larger mass of the b quark, a more consistent pattern of color-suppression is expected in the B system, and current experimental results seem to support that color-suppression is operative in hadronic decays of B mesons. Besides $B \to \text{charmonium transitions no other color-suppressed}$ decay has been observed experimentally [41]. The current upper limit on $\mathcal{B}(\overline{B}^0 \to D^0 \pi^0)$ is 0.012% at 90% C.L.

By comparing hadronic B^- and \overline{B}^0 decays, the relative contributions from external and internal spectator decays have been disentangled. For all decay modes studied the B^- branching ratio was found to be larger than the corresponding \overline{B}^0 branching ratio indicating constructive interference between the external and internal spectator amplitudes. In the BSW model [42] the two amplitudes are proportional to effective coefficients, a_1 and a2, respectively. A least squares fit using the latest branching ratio measurements and a model by Neubert et al. [43] gives

$$a_2/a_1 = 0.22 \pm 0.04 \pm 0.06$$
, (14)

where we have ignored uncertainties in the theoretical predictions. The second error is due to the uncertainty in the B-meson production fractions (f_+, f_0) and lifetimes (τ_+, τ_0) that enter into the determination of a_1/a_2 in the combination $(f_+\tau_+/f_0\tau_0)$. As this ratio increases, the value of a_2/a_1 decreases. Varying $(f_+\tau_+/f_0\tau_0)$ in the allowed experimental range $(\pm 20\%)$ excludes a negative value of a_2/a_1 . Other uncertainties in the magnitude of the decay constants f_D and f_{D^*} as well as in the hadronic form factors can change the magnitude of a_2/a_1 but not its sign.

The magnitude of a_2 determined from this fit to the ratio of B^- and \overline{B}^0 branching fractions is consistent with the value of $|a_2|$ determined from the fit to the $B \to J/\psi$ decay modes which only via the color suppressed amplitude. The coefficient a_1 also shows little or no process dependency.

The observation that the coefficients a_1 and a_2 have the same relative sign in B^- decay came as a surprise, since destructive interference was observed in hadronic charm decay. The sign of a_2 disagrees with the theoretical extrapolation from the fit to charm meson decays using the BSW model. It also disagrees with the expectation from the $1/N_c$ rule [44]. The result may be consistent with the expectation of perturbative QCD [45]. B. Stech proposed that the observed interference pattern in charged B and D decay can be understood in terms of the running strong coupling constant α_s [46]. A solution based on PQCD factorization theorems has been suggested by B. Tseng and H.N. Li [47].

Although constructive interference has been observed in all the B^- modes studied so far, these comprise only a small fraction of the total hadronic rate. It is conceivable that higher multiplicity B^- decays demonstrate a very different behaviour.

It is intriguing that $|a_1|$ determined from $B \to D^{(*)}\pi$, $D^{(*)}\rho$ modes agrees well with the value of a_1 extracted from $B \to DD_s$ decays. The observation of color-suppressed decays such as

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 $\overline{B}^0 \to D^0 \pi^0$ would give another measure of $|a_2|$ complementary to that obtained from $B \to$ charmonium decays.

In summary, experimental results on exclusive B decay match very nicely with theoretical expectations. Unlike charm the b quark appears to be heavy enough so that corrections due to the strong interaction are small. Factorization and color-suppression are at work. An intriguing pattern of constructive interference in charged B decays has been observed.

Inclusive hadronic decays: Over the last years inclusive B decays have become an area of intensive studies, experimentally as well as theoretically. Since the hadronization process to specific final state mesons is not involved in inclusive calculations the theoretical results and predictions are generally believed to be more reliable.

CLEO and the LEP collaborations presented new measurements of inclusive $b \rightarrow c$ transitions that can be used to extract n_c , the number of charm quarks produced per b decay. Naively we expect $n_c = 115\%$ with the additional 15% coming from the decay of the W boson to $\bar{c}s$. This expectation can be verified experimentally by adding all inclusive $b \rightarrow c$ branching fractions. Using CLEO and LEP results we can perform the calculation shown in Table 5. Modes with 2 charm quarks in the final state are counted twice. For the unobserved $B \to \eta_c X$ decay we take the experimental upper limit. B_s mesons and bbaryons produced at the Z but not at the $\Upsilon(4S)$ cause the increase in D_s and Λ_c production rates seen by LEP. To first order, however, this should not affect the charm yield and it should be compensated by reduced branching fractions for D mesons. This is not reflected in the current data but the errors are still large. In addition, there are significant uncertainties in the D_s and Λ_c absolute branching fractions.

Table 5: Charm yield per B decay.

Channel	Branching fraction [%] $\Upsilon(4S)$ [40] LEP [2]
$B \to D^0 X$	63.6 ± 3.0 57.6 ± 2.6
$+ B \rightarrow D^+X$	$23.5 \pm 2.7 22.4 \pm 1.9$
$+ B \rightarrow D_s^+ X$	12.1 ± 1.7 19.1 ± 5.0
$+ B \rightarrow \Lambda_c^+ X$	2.9 ± 2.0 11.4 ± 2.0
$+ B \rightarrow \Xi_c^{+,0} X$	2.0 ± 1.0 6.3 ± 2.1
$+ 2 \times B \rightarrow J/\psi_{\text{direct}} X$	0.8 ± 0.08
$+ 2 \times B \rightarrow \psi(2S)_{\text{direct}} X$	0.35 ± 0.05
$+ 2 \times B \rightarrow \chi_{c1} X$	0.37 ± 0.07
$+ 2 \times B \rightarrow \chi_{c2} X$	0.25 ± 0.1
$+ 2 \times B \rightarrow \eta_c X$	< 0.9 (90%C.L.)
$+ 2 \times b \rightarrow (c\overline{c})X$	3.4 ± 1.2
n_c	110 ± 5 120 ± 7

Inclusive $b \to c\overline{c}s$ transitions: It was previously assumed that the conventional $b \to c\overline{u}d \to DX$ and $b \to c\overline{c}s \to D\overline{D}_sX$ mechanisms account for all D meson production in B decay. Buchalla et al. [57] suggested that a significant fraction of D mesons could also arise from $b \to c\overline{c}s$ transitions with light quark pair production at the upper vertex, i.e. $b \to c\overline{c}s$

 $c\overline{c}s \to D\overline{D}X_s$. The two mechanisms can be distinguished by the different final states they produce. In the first case the final state includes only D mesons whereas in the second case two D mesons can be produced, one of which has to be a \overline{D} .

Table 6: CLEO results on $B \to DDK$ decays (preliminary).

Mode	Branching fraction [%]
$\overline{\mathcal{B}(\overline{B}^0 \to D^{*+} \overline{D}^0 K^-)}$	$0.45^{+0.25}_{-0.19} \pm 0.08\%$
$\mathcal{B}(B^- \to D^{*0}\overline{D}^0K^-)$	$0.54^{+0.33}_{-0.24} \pm 0.12\%$
$\mathcal{B}(\overline{B}^0 \to D^{*+} \overline{D}^{*0} K^-)$	$1.30^{+0.61}_{-0.47} \pm 0.27\%$
$\mathcal{B}(B^- \to D^{*0}\overline{D}^{*0}K^-)$	$1.45^{+0.78}_{-0.58} \pm 0.36\%$

Two routes to search for this addition to $\Gamma(b \to c\bar{c}s)$ have been pursued experimentally. In an exclusive search for $B \to D\overline{D}K$ decays CLEO required the final state to include a D and a \overline{D} meson. Statistically significant signals are observed for several $D^{(*)}\overline{D}^{(*)}$ combinations. The preliminary CLEO results are listed in Table 6 [52]. While the observation of these decays proves the existence of \overline{D} -meson production at the upper vertex, a more inclusive measurement is needed to estimate the overall magnitude of this effect. A recent CLEO analysis exploits the fact that the flavor of the final state D-meson tags the decay mechanism. A high momentum lepton $(p_{\ell} > 1.4 \text{ GeV/}c)$ from the second B meson is used to classify the flavor of the decaying B meson. $b \to c\overline{u}d$ transitions lead to $D\ell^+$ combinations while the observation of $\overline{D}\ell^+$ identifies the new $b \to c\overline{c}s$ mechanism. Angular correlations are used to remove combinations with both particles coming from the same B meson. CLEO finds [53]

$$\frac{\Gamma(\overline{B} \to \overline{D}X)}{\Gamma(\overline{B} \to DX)} = 0.100 \pm 0.026 \pm 0.016 , \qquad (15)$$

which implies

$$\mathcal{B}(\overline{B} \to \overline{D}X) = 0.079 \pm 0.022 \ . \tag{16}$$

 $b \to D\overline{D}X$ decays have also been observed at LEP. ALEPH [54] finds

$$\mathcal{B}(B \to D^0 \overline{D}^0 X + D^0 D^{\mp} X) = 0.078^{+0.02}_{-0.018} {}^{+0.017}_{-0.004} {}^{+0.05}_{,,}$$
(17)

where the last error reflects the uncertainty in D meson branching fractions. DELPHI reports the observation of $D^{*+}D^{*-}$ production [55]

$$\mathcal{B}(\overline{B} \to D^{*+}D^{*-}X) = 0.01 \pm 0.002 \pm 0.003$$
. (18)

These results are still preliminary. We can now calculate $n_{cc} = \mathcal{B}(b \to c\bar{c}s)$. Using the data listed in Table 5 and the new result, $\mathcal{B}(\overline{B} \to \overline{D}X) = 0.079 \pm 0.022$, we find

$$n_{cc} = 23.9 \pm 3.0\%$$
 (19)

The contribution from $B \to \Xi_c^0 X$ was reduced by 1/3 to take into account the fraction that is not produced by the $b \to c\bar{c}s$ subprocess but by $b \to c\bar{u}d + s\bar{s}$ quark pair production.

This result is consistent with theoretical predictions, $\mathcal{B}(b \to c \bar{c}s) = 22 \pm 6\%$ [31,56]. n_{cc} is related to n_c , the number of charm quarks produced per b decay. We expect $n_c = 1 + n_{cc} - n_{B \to \text{no charm}}$ which is consistent with the LEP result reported above. If the smaller value of n_c observed by CLEO is confirmed it could indicate a problem with $\Gamma(b \to c \bar{u} d)$ or a very large $\mathcal{B}(b \to sg)$.

Charm counting and the semileptonic branching fraction: The charm yield per B-meson decay is related to an intriguing puzzle in B physics: the experimental value for the semileptonic branching ratio of B mesons, $\mathcal{B}(B \to X \ell \nu_{\ell}) = 10.18 \pm 0.39\%$ ($\Upsilon(4S)$), is significantly below the theoretical lower bound $\mathcal{B} > 12.5\%$ from QCD calculations within the parton model [58]. Since the semileptonic and hadronic widths are connected via

$$1/\tau = \Gamma = \Gamma_{\text{semileptonic}} + \Gamma_{\text{hadronic}} \tag{20}$$

an enhanced hadronic rate is necessary to accommodate the low semileptonic branching fraction. The hadronic width can be expressed as

$$\Gamma_{\text{hadronic}} = \Gamma(b \to c\overline{c}s) + \Gamma(b \to c\overline{u}d) + \Gamma(b \to sg + \text{no charm})$$
 (21)

Several explanations of this $n_c/\mathcal{B}_{\rm sl}$ discrepancy have been proposed:

- 1. Enhancement of $b \to c\overline{c}s$ due to large QCD corrections or a breakdown of local duality;
- 2. Enhancement of $b \rightarrow c\overline{u}d$ due to non-perturbative effects;
- 3. Enhancement of $b \to sg$ and/or $b \to dg$ due to new physics;
- 4. Systematic problem in the experimental results;

or the problem could be caused by some combination of the above. Arguably the most intriguing solution to this puzzle would be an enhanced $b \to sg$ rate but as we will see in the next section, new results from CLEO and LEP show no indication for new physics and place tight limits on this process.

 $\mathcal{B}(b \to c\overline{u}d)$ has been calculated to next-to-leading order. Bagan *et al.* [59] find:

$$r_{ud} = \frac{\mathcal{B}(b \to c\overline{u}d)}{\mathcal{B}(b \to c\ell\nu_{\ell})} = 4.0 \pm 0.4 \to \mathcal{B}(b \to c\overline{u}d)_{\text{theory}} = 41 \pm 4\%$$
 (22)

Experimentally, we can extract this quantity in the way shown in Table 7.

Table 7: Experimental extraction of $\mathcal{B}(b \to c\overline{u}d)$.

$\mathcal{B}(b \to c\overline{u}d)_{\text{exp.}} = \mathcal{B}(B \to (D + \overline{D})X)$	$87.1 \pm 4.0\%$
$+ \mathcal{B}(B o D_s X)_{\mathrm{lower vertex}}$	$1.8 \pm 0.9\%$
$+ \mathcal{B}(B \to \text{baryons}X)$	$4.6\pm2.1\%$
$-2 \times \mathcal{B}(B \to \overline{D}X)_{\text{upper vertex}}$	$2\times(7.9\pm2.2\%)$
$-\mathcal{B}(B o D_sX)$	$12.1\pm1.7\%$
$-$ 2.25 $ imes$ $\mathcal{B}(b o c\ell u_\ell)$	$22.9\pm0.9\%$
	$43 \pm 6\%$

Here upper vertex refers to the W decay while lower vertex refers to the $b \to c$ transition. For the total semileptonic branching fraction we assumed $\mathcal{B}(b \to c\tau\nu_{\tau}) = 0.25 \times \mathcal{B}(b \to ce\nu_e)$. There is good agreement between theory and experiment but the errors are still too large to completely rule out an enhanced $b \to c\overline{u}d$ rate.

The theoretically preferred solution calls for an enhancement of the $b\to c\bar cs$ channel [31,59]. Increasing the $b\to c\bar cs$ component, however, would increase the average number of c quarks produced per b-quark decay as well as n_{cc} , the number of b decays with 2 charm quarks in the final state. Figure 2 taken from Ref. 1 shows the theoretical range together with experimental values from LEP and CLEO/ARGUS.

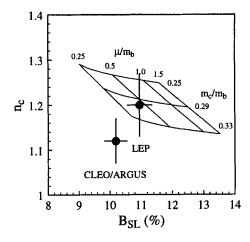


Figure 2: Charm yield (n_c) versus semileptonic branching fraction.

While the experimental value of n_{cc} is consistent with this scenario, the value of n_c measured at the $\Upsilon(4S)$ appears to be too low at the few σ -level. Systematic problems with D meson branching fractions have been pointed out as a potential solution [12] but new results from ALEPH [60] and CLEO [61] on $\mathcal{B}(D^0 \to K^-\pi^+)$ make this less likely.

After years of experimental and theoretical efforts the missing charm/ \mathcal{B}_{sl} problem has begun to fade away. There is still a discrepancy between the charm yield measured by CLEO and the theoretical prediction. More data are needed to either resolve this issue or to demonstrate that the problem persists.

Rare B decays: All B-meson decays that do not occur through the usual $b \to c$ transition are known as rare B decays. These include semileptonic and hadronic $b \to u$ decays that—although at tree level—are suppressed by the small CKM matrix element V_{ub} as well as higher order processes such as electromagnetic and gluonic penguin decays. Branching fractions are typically around 10^{-5} for exclusive channels and sophisticated background suppression techniques are essential for these analyses.

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Arguably the most exciting new experimental results since the last edition of this review are in the field of rare B decays. For many charmless B-decay modes the addition of new data and the refinement of analysis techniques allowed CLEO to observe signals where previously there have been upper limits. For other channels new tighter upper limits have been published [62].

Semileptonic $b \to u$ transitions: The simplest diagram for a rare B decay is obtained by replacing the $b \to c$ spectator diagram a CKM suppressed $b \to u$ transition. These decays probe the small CKM matrix element V_{ub} , the magnitude of which sets bounds on the combination $\rho^2 + \eta^2$ in the Wolfenstein parameterization of the CKM matrix. Measurements of the magnitude of V_{ub} have been obtained from both inclusive and exclusive semileptonic B decays [63,65]. Inclusive analyses at the $\Upsilon(4S)$ focus on leptons in the endpoint region of the single lepton spectrum which are kinematically incompatible with coming from a $b \to c$ transition. Models are used to extrapolate to the full spectrum from which $|V_{ub}| = (3.7 \pm 0.6) \times 10^{-3}$ is extracted [64]. The error is dominated by uncertainties in the models.

Exclusive semileptonic $b \to u$ transitions have been observed by the CLEO Collaboration [63]. Using their large data sample and employing the excellent hermiticity of the CLEO II detector they were able to measure $\mathcal{B}(B^0 \to \pi^- \ell^+ \nu_\ell) = (1.8 \pm 0.4 \pm 0.3 \pm 0.2) \times 10^{-4}$ and $\mathcal{B}(B^0 \to \rho^- \ell^+ \nu_\ell) = (2.5 \pm 0.4^{+0.5}_{-0.7} \pm 0.5) \times 10^{-4}$ which can be used to extract $|V_{ub}| = (3.3 \pm 0.2^{+0.3}_{-0.4} \pm 0.7) \times 10^{-3}$. The last error in these results reflects the model-dependence.

While the consistency of the two methods is encouraging, the errors, in particular the theoretical uncertainties, are still large.

Hadronic $b \to u$ transitions: Exclusive hadronic $b \to u$ transitions still await experimental discovery. Using 3.3×10^6 $B\overline{B}$ decays CLEO searched for exclusive charmless final states such as $\pi^+\pi^-$ and $\rho^+\pi^-$. No significant excess has been observed and some of the new upper limits are listed in Table 8 [66]. The mode $B^0 \to \pi^+\pi^-$ is of particular interest for CP-violation studies in the B-meson system. The branching fraction is smaller than initial expectations and extracting $\sin(2\alpha)$, i.e. one of the angles in the unitarity triangle, will become increasingly more difficult. Assuming factorization we can use CLEO's measurement of $B^0 \to \pi^-\ell^+\nu_\ell$ and the ISGW II form factors [67] to predict $\mathcal{B}(B^0 \to \pi^+\pi^-) = (1.2 \pm 0.4) \times 10^{-5}$ and $\mathcal{B}(B^+ \to \pi^+\pi^0) = (0.6 \pm 0.2) \times 10^{-5}$.

Electromagnetic penguin decays: The observation of the decay $B \to K^*(892)\gamma$, reported in 1993 by the CLEO II experiment, provided first evidence for the one-loop penguin diagram [69]. Using a larger data sample the analysis was re-done in 1996 yielding [69]

$$\mathcal{B}(B \to K^* \gamma) = (4.2 \pm 0.8 \pm 0.6) \times 10^{-5}$$
 (23)

The observed branching fractions were used to constrain a large class of Standard Model extensions [72]. However, due to the

Table 8: Summary of new CLEO results on $B \to \pi\pi, K\pi$ and KK branching fractions. The branching fractions and the 90% C.L. upper limits are given in units of 10^{-5} . Using the notation of Gronau *et al.* [68] the last column indicates the dominant amplitudes for each decay (T, C, P, E denote tree, color suppressed, penguin, and exchange amplitudes and the unprimed (primed) amplitudes refer to $\bar{b} \to \bar{u}u\bar{d}$ ($\bar{b} \to \bar{u}u\bar{s}$) transitions, respectively.)

$\begin{array}{c} \hline \text{Mode} \\ (B \rightarrow) \end{array}$	В	Amplitude	Theoretical expectation
$\pi^+\pi^-$	< 1.5	-(T+P)	0.8-2.6
$\pi^{+}\pi^{0}$	< 2.0	$-(T+C)/\sqrt{(2)}$	0.4 - 2.0
$\pi^0\pi^0$	< 0.93	$-(C-P)/\sqrt{(2)}$	0.006-0.1
$K^+\pi^-$	$1.5^{+0.5}_{-0.4} \pm 0.1 \pm 0.1$	-(T'+P')	0.7-2.4
$K^+\pi^0$	< 1.6	$-(T'+C'+P')/\sqrt{(2)}$	0.3-1.3
$K^0\pi^-$	$2.3^{+1.1}_{-1.0} \pm 0.3 \pm 0.2$	P'	0.8 - 1.5
$K^0\pi^0$	< 4.1	$-(C'-P')/\sqrt{(2)}$	0.3-0.8
$\overline{K^+K^-}$	< 0.43	E	
K^+K^0	< 2.1	P	0.07-0.13
K^0K^0	< 1.7	P	0.07 - 0.12
$\overline{(K^+ \text{ or } \pi^+)}$	$)\pi^0 \ 1.6^{+0.6}_{-0.5} \pm 0.3 \pm 0.2$	_	

uncertainties in the hadronization, only the inclusive $b \to s\gamma$ rate can be reliably compared with theoretical calculations. This rate can be measured from the endpoint of the inclusive photon spectrum in B decay. CLEO [70] found

$$\mathcal{B}(b \to s\gamma) = (2.32 \pm 0.57 \pm 0.35) \times 10^{-4} \text{ (CLEO)}$$
. (24)

ALEPH used a lifetime tagged sample of $Z \to b\bar{b}$ events to search for high-energy photons in the hemisphere opposite to the tag. This allows them to measure the photon spectrum from B decays which ultimately leads to [71]

$$\mathcal{B}(b \to s\gamma) = (3.11 \pm 0.80 \pm 0.72) \times 10^{-4} \,(\text{ALEPH}) \,.$$
 (25)

Our theoretical understanding of inclusive $b \to s\gamma$ transitions has been significantly enhanced by two new calculations that now include all terms to next-to-leading order [73]. The expected Standard Model rate, while slightly larger now, is still consistent with both the CLEO and ALEPH results. The substantially reduced uncertainties result in tighter constraints on new physics such as double Higgs models [2].

Gluonic penguin decays: A larger total rate is expected for gluonic penguins, the counterpart of $b \to s\gamma$ with the photon replaced by a gluon.

Experimentally, it is a major challenge to measure the inclusive $b\to sg$ rate. The virtual gluon hadronizes as a $q\overline{q}$ pair without leaving a characteristic signature in the detector. CLEO extended $D-\ell$ correlation measurements described in the section on hadronic B decays to obtain the flavor specific decay rate $\Gamma(\overline{B}\to DX)_{\text{lower vertex}}/\Gamma_{\text{total}}$. This quantity should be 1 minus corrections for charmonium production, $b\to u$ transitions, $B\to \text{baryons}$, and D_s production at the lower vertex. Most importantly, the $b\to sg$ rate must also be subtracted. To remove uncertainties due to $\mathcal{B}(D^0\to K^-\pi^+)$

CLEO normalizes to $\Gamma(\overline{B}\to DX\ell\nu_\ell)/\Gamma(\overline{B}\to X\ell\nu_\ell)$. Their preliminary result is

$$\frac{\Gamma(\overline{B} \to DX)_{\text{lower vertex}}/\Gamma_{\text{total}}}{\Gamma(\overline{B} \to DX\ell\nu_{\ell})/\Gamma(\overline{B} \to X\ell\nu_{\ell})} = 0.901 \pm 0.034 \pm 0.014 \quad (26)$$

whereas $0.903 \pm 0.018 - \mathcal{B}(b \to sg)$ was expected. This corresponds to an upper limit of $\mathcal{B}(b \to sg) < 6.8\%$ [53]. DELPHI [55] studied the the p_T spectrum of charged kaons in B decays and found a model-dependent limit $\mathcal{B}(b \to sg) < 5\%$ (95% C.L.). These results agree well with the Standard Model prediction of $\mathcal{B}(\overline{B} \to \text{no charm}) = (1.6 \pm 0.8)\%$ [74] and there is little experimental support for new physics and an enhanced $b \to sg$ rate [75]. However, experimental uncertainties are still large and it is too early to draw final conclusions. Last summer, the SLD collaboration reported an excess in the kaon spectrum at high p_T [76].

Exclusive decays such as $B^0 \to K^+\pi^-$ are strongly suppressed to first order and are expected to proceed via loop processes. CLEO studied these decay modes and last summer reported the first observation of $B^0 \to K^+\pi^-$ and $B^+ \to K^0\pi^+$ decays. The results are listed in Table 8. $\mathcal{B}(B^+ \to K^0\pi^+)$ is of particular interest since it directly measures the strength of the gluonic penguin amplitude (Table 8). The smaller rate measured for $B^0 \to K^+\pi^-$ could indicate that the two amplitudes contributing to this channel interfere destructively. This observation has been extended by Fleischer and Mannel [77] to place some constraints on γ , the phase of V_{ub} .

CLEO extended their search of charmless B decay to modes including light meson resonances such as ρ , K^* , ω , η , and η' [78]. Statistically significant signals have been seen in several channels; the results are summarized in Table 9.

Table 9: Summary of new CLEO results on rare B decays involving light meson resonances.

Mode	Branching fraction (×10 ⁻⁵)
$B \to \omega K^+$ $B \to \eta' K^+$ $B \to \eta' K^0$ $B \to \eta' X_s$	$\begin{array}{c} 1.5^{+0.7}_{-0.6} \pm 0.3 \\ 7.1^{+2.5}_{-2.1} \pm 0.9 \\ 5.3^{+2.8}_{-2.2} \pm 1.2 \\ 62 \pm 16 \pm 13 \\ (2.0 < p_{\eta'} < 2.7 \text{GeV/c}) \end{array}$

A surprisingly large signal has been observed for $B \to \eta' K$ (see Fig. 3) while no evidence for ηK or $\eta' K^*$ final states has been found [79].

The interpretation of these results is subject of an ongoing discussion. It has been suggested that interference between different penguin amplitudes causes $\mathcal{B}(B \to \eta' K)$ to be larger than $\mathcal{B}(B \to \eta K)$ [80,81]. Other proposals try to explain the large $\eta' K$ rate by the anomalous coupling of the η' to glue [82,83], a $c\bar{c}$ component in the η' [84] or by an enhanced $b \to sg$ rate due to some new physics [85]. Additional experimental input to this puzzle comes from a CLEO measurement of inclusive η' production. At high momenta the η' spectrum is dominated by

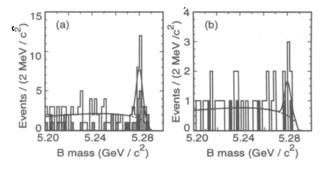


Figure 3: Beam-constrained mass for (a) $B^+ \to \eta' h^+$ with $h^+ = K^+$ or π^+ and (b) $B^0 \to \eta' K^0$. A likelihood analysis shows that the $B^+ \to \eta' h^+$ channel is dominated by $\eta' K^+$. (CLEO)

 $B \to \eta' X_s$ decays and a study of the system recoiling against the η' shows that large masses $m(X_s)$ are preferred [86].

In summary, gluonic penguin decays have been established. Many decay modes have been observed for the first time and the emerging pattern is full of surprises. The observed penguin effects are large and while old favorites such as $B^0 \to \pi^+\pi^-$ might be less useful for CP-violation studies there is hope that new opportunities will open up.

Outlook: With the next Fermilab collider run still years away and LEP running at higher energies it is not likely that the B-meson lifetimes presented in this edition will change substantially over the next two years. Nor should we expect many new results on b-hadron spectroscopy. In the short term, CLEO is still taking data and so is SLD. The SLD collaboration expects to collect half a million hadronic Z events. Combining this with the excellent resolution of the SLD vertex detector could push the sensitivity on B_s mixing up to $\Delta m_s = 15 \text{ ps}^{-1}$. We have just began to observe rare B decays and already now we see many intriguing patterns: Why is $B \to \eta' K$ so large? Where are the $B^0 \to \pi^+\pi^-$ events? The size of the CLEO data sample will soon reach the 10 fb⁻¹ mark and many results, answers and new questions should be expected.

In the long term, which is actually only a year away, the next generation of B experiments will come on line: BaBar, BELLE, CLEO III, as well as HERA-B. So there is hope that in two years when the next edition of this *Review* will be written we have reached another milestone in our understanding of B mesons and b baryons.

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$$I(J^P) = \frac{1}{2}(0^-)$$

Quantum numbers not measured. Values shown are quark-model

See also the B^{\pm}/B^0 ADMIXTURE and $B^{\pm}/B^0/B_s^0/b$ -baryon AD-MIXTURE sections.

The fit uses m_{B^+} , $(m_{B^0}-m_{B^+})$, $m_{B_0^0}$, and $(m_{B_0^0}-(m_{B^+}+m_{B^0})/2)$ to determine m_{B^+} , m_{B^0} , $m_{B_0^0}$, and the mass differences.

VALUE (MeV) 5278.9±1.8 OUR FIT	<u>EVTS</u>	DOCUMENT ID	TEC	N COMMENT
5278.9±1.5 OUR AV	ERAGE			
5279.1±1.7 ±1.4	147	1 ABE	968 CD	F pp at 1.8 TeV
5278.8±0.54±2.0	362	² ALAM	94 CLE	$2 e^+e^- \rightarrow \Upsilon(45)$
5278.3±0.4 ±2.0		² BORTOLETT	O92 CLE	$0 e^+e^- \rightarrow r(45)$
5280.5±1.0 ±2.0		^{2,3} ALBRECHT	90J AR	$3 e^+e^- \rightarrow r(45)$
5278.6±0.8 ±2.0		² BEBEK	87 CLE	$e^+e^- \rightarrow r(45)$
• • • We do not use	he follow	ing data for average	s, fits, lim	lts, etc. • • •
5275.8±1.3 ±3.0	32	ALBRECHT	87C AR	$e^+e^- \rightarrow \Upsilon(4S)$
5278.2±1.8 ±3.0	12	4 ALBRECHT	870 AR	, , , ,

¹ Excluded from fit because it is not independent of ABE 968 B_c^0 mass and B_c^0 -B mass

difference. ² These experiments all report a common systematic error 2.0 MeV. We have artificially

increased the systematic error to allow the experiments to be treated as independent measurements in our average. See "Treatment of Errors" section of the introductory Text. These experiments actually measure the difference between half of $E_{\rm CM}$ and the 3 B mass. 3 ALBRECHT 90J assumes 10580 for 7 (4S) mass. Supersedes ALBRECHT 87c and

ALBRECHT 87D

⁴ Found using fully reconstructed decays with $J/\psi(1S)$. ALBRECHT 87D assume $m_{\Upsilon(4S)}$ = 10577 MeV.

B* MEAN LIFE

See $B^{\pm}/B^0/B_s^0/b$ -baryon ADMIXTURE section for data on B-hadron mean life averaged over species of bottom particles.

"OUR EVALUATION" is an average of the data listed below performed by the LEP B Lifetimes Working Group as described in our review "Production and Decay of b-flavored Hadrons" in the B^\pm Section of the Listings. The averaging procedure takes into account correlations between the measurements and asymmetric lifetime errors.

VALUE (10 ⁻¹² s)	EVT5	DOCUMENT ID	TEC	N COMMENT
1.65±0.04 OUR EV	LUATION			
$1.68 \pm 0.07 \pm 0.02$		5 ABE	988 CDI	F <i>p</i> p̄ at 1.8 TeV
$1.66 \pm 0.06 \pm 0.05$		6 ABE	97J SLC) e ⁺ e ⁻ → Z
$1.56 \pm 0.13 \pm 0.06$		⁷ ABE	96c CDI	
$1.58 \pm 0.09 \pm 0.04$		⁷ BUSKULIC	96J ALE	$P e^+e^- \rightarrow Z$
$1.58 ^{+ 0.21 + 0.04}_{- 0.18 - 0.03}$	94	⁵ BUSKULIC	96J ALE	$P e^+e^- \to Z$
$1.61 \pm 0.16 \pm 0.12$		7,8 ABREU	95Q DLF	PH e ⁺ e ⁻ → Z
$1.72 \pm 0.08 \pm 0.06$		9 ADAM	95 DLF	$^{ m PH}$ $e^+e^- ightarrow Z$
$1.52 \pm 0.14 \pm 0.09$		⁷ AKERS	95T OP/	$\lambda L e^+e^- \rightarrow Z$
• • • We do not use	the follow	ing data for averag	ges, fits, lin	nits, etc. • • •
$1.58 \pm 0.09 \pm 0.03$		¹⁰ BUSKULIC	96J ALE	$P e^+e^- \rightarrow Z$
1.70±0.09		11 ADAM	95 DLF	PH $e^+e^- \rightarrow Z$
$1.61 \pm 0.16 \pm 0.05$	148	⁵ ABE	94D CDI	Repl. by ABE 988
$1.30^{+0.33}_{-0.29}\pm0.16$	92	⁷ ABREU	93D DLF	PH Sup. by ABREU 95Q
$1.56 \pm 0.19 \pm 0.13$	134	9 ABREU	93G DLF	PH Sup. by ADAM 95
$1.51^{+0.30}_{-0.28}^{+0.12}_{-0.14}$	59	7 ACTON	93C OP/	AL Sup. by AKERS 95T
$1.47^{+0.22}_{-0.19}^{+0.15}_{-0.14}$	77	⁷ BUSKULIC	93D ALE	P Sup. by BUSKULIC 961

- ⁵ Measured mean life using fully reconstructed decays.

- 6 Data analyzed using charge of secondary vertex. 7 Data analyzed using $D/D^*\ell X$ event vertices. 8 ABREU 95Q assumes $B(B^0 \to D^{**-}\ell^+\nu_\ell) = 3.2 \pm 1.7\%$.
- ⁹ Data analyzed using vertex-charge technique to tag B charge. ¹⁰ Combined result of $D/D^*\ell X$ analysis and fully reconstructed B analysis.
- 11 Combined ABREU 950 and ADAM 95 result.

R^{\pm}

	B+ DEC	AY MODES			Г ₅₂	$D_s^-\pi^+K^+$	<	8	× 10 ⁻⁴	CL=90%
	B ⁻ modes are charge conjugates o	the modes below. Modes wi	hich do n	ot	Γ ₅₃	$D_s^{*-}\pi^+K^+$	<	1.2	× 10 ⁻³	CL=90%
	identify the charge state of the B	are listed in the B^\pm/B^0 AD	MIXTUR	RE	Γ ₅₄	$D_s^- \pi^+ K^*(892)^+$	<	6	$\times 10^{-3}$	CL=90%
	section.				Γ ₅₅	$D_s^{*-}\pi^+K^*(892)^+$	<	8	$\times 10^{-3}$	CL=90%
		- 0-0				· ·				
	The branching fractions listed below production at the $\Upsilon(4S)$. We have	v assume 50% B ^o B ^o and 50)% B+ B	rte	r	$J/\psi(1S)K^+$ Charmoniu		es 9.9 ± 1.0	1 × 10-4	
	up to date by rescaling their assu				Г ₅₆ Г ₅₇	$J/\psi(15)K^{+}\pi^{+}\pi^{-}$		1.4 ±0.6		
	and their assumed D , D_s , D^* , an					$J/\psi(15)K^*(892)^+$		1.47±0.2		
	whenever this would affect our ave				' 58 Γ	$J/\psi(1S)\pi^{+}$		5.0 ±1.5		
	Indentation is used to indicate a	subchannel of a previous re-	action A	ΔII		$J/\psi(15)^{n}$ $J/\psi(15)\rho^{+}$		7.7	× 10 ⁻⁴	CL=90%
	resonant subchannels have been of					$J/\psi(15) \rho^+$ $J/\psi(15) a_1(1260)^+$		1.2	× 10 ⁻³	CL=90%
	tions to the final state so the sum					$\psi(2S)K^{+}$		6.9 ±3.1		S=1.3
	can exceed that of the final state.						-	3.0	× 10 ⁻³	CL=90%
			S	cale factor/	Γ ₆₃	$\psi(2S)K^{+}\pi^{+}\pi^{-}$		1.9 ±1.2		CL=3070
	Mode	Fraction (Γ_f/Γ)	Conf	idence level	_	$\chi_{c1}(1P)K^+$	(1.9 ±1.2) × 10-3	
					Γ ₆₅ Γ ₆₆	$\chi_{c1}(1P)K^*(892)^+$		2.1	× 10 ⁻³	CL=90%
_		nd leptonic modes			' 66	x _{c1} (11) / (032)	_	2.1	^ 10	CL=3070
Γ ₁	$\ell^+ \nu_\ell$ anything	[a] (10.3 ±0.9) %				K or K*				4
<u></u>	$\overline{D}^0\ell^+\nu_\ell$	[a] (1.86 ± 0.33) %			Γ ₆₇	$K^0\pi^+$	(2.3 ±1.1		
<u>[</u> 3	$\overline{D}^*(2007)^0 \ell^+ \nu_\ell \ \pi^0 e^+ \nu_e$	[a] (5.3 ±0.8)%	3	CI 008/	Γ ₆₈	$K^+\pi^0$		1.6	× 10 ⁻⁵	CL=90%
Γ4	$\pi^{\circ}e^{\circ}\nu_{e}$		10 ³ 10 ⁴	CL=90%	Γ ₆₉	$\eta' K^+$	(6.5 ± 1.7		
ſ ₅	$\omega \ell^+_+ \nu_\ell$	[a] < 2.1 imes 1	10	CL=90%	Γ ₇₀	η' K*(892) ⁺	<	1.3	× 10 ⁻⁴	CL=90%
Γ ₆	$\omega \mu^+ \nu_{\mu}$		4	G1 008/	Γ ₇₁	ηK^+		1.4	× 10 ⁻⁵	CL=90%
<u> </u>	$\rho^0_{\perp}\ell^+\nu_{\ell}$	• •	10-4	CL=90%	Γ ₇₂	η Κ* (892) ⁺		3.0	× 10 ⁻⁵	CL=90%
Ĺ8	$e^+_{\perp}\nu_e$		10 ⁵	CL=90%	Γ ₇₃	$K^*(892)^0\pi^+$	<	4.1	× 10 ⁻⁵	CL=90%
Г9	$\mu^+ u_\mu$		10 ⁻⁵	CL=90%	Γ ₇₄	$K^*(892)^+\pi^0$		9.9	× 10 ⁻⁵	CL=90%
Γ ₁₀	$ au^+ u_ au$		10-4	CL=90%	Γ ₇₅	$K^+\pi^-\pi^+$ nonresonant		2.8	× 10 ⁻⁵	CL=90%
Γ ₁₁	$e^+_{\ \ } u_e\gamma$		10-4	CL=90%	Γ ₇₆	$K^-\pi^+\pi^+$ nonresonant		5.6	× 10 ⁻⁵	CL=90%
Γ ₁₂	$\mu^+ u_\mu \gamma$	< 5.2 × 1	10 ⁻⁵	CL=90%	Г ₇₇	$K_1(1400)^0\pi^+$		2.6	× 10 ⁻³	CL=90%
	D D* 4	or D _s modes			Γ ₇₈	$K_2^*(1430)^0\pi^+$	<	6.8	× 10 ⁻⁴	CL=90%
-	$\overline{D}{}^0\pi^+$	(5.3 ±0.5)×1	-0-3		Γ ₇₉	$\kappa^+ \rho^0$	<	1.9	× 10 ⁻⁵	CL=90%
Γ ₁₃	$\frac{D^-\pi^+}{D^0\rho^+}$,	10 -		Г ₈₀	$\kappa^0 \rho^+$	<	4.8	× 10 ⁻⁵	CL=90%
Γ ₁₄	$\frac{D^2 \rho}{D^0 \pi^+ \pi^+ \pi^-}$	$(1.34\pm0.18)\%$ $(1.1\pm0.4)\%$			Γ ₈₁	$K^*(892)^+\pi^+\pi^-$		1.1	× 10 ⁻³	CL=90%
Γ ₁₅	$\overline{D}^0\pi^+\pi^+\pi^-$ nonresonant	$(5 \pm 4) \times 1$	10-3		Γ ₈₂	$K^*(892)^+ \rho^0$		9.0	× 10 ⁻⁴	CL=90%
Γ ₁₆	$\overline{D}^0\pi^+\rho^0$	(4.2 ±3.0)×1	10-3		Г ₈₃	$K_1(1400)^+ \rho^0$	<	7.8	× 10 ⁻⁴	CL=90%
Γ ₁₇ Γ ₁₈	$\frac{D}{D^0} a_1(1260)^+$	(4.2 ±3.0) × 1	10-3		Γ ₈₄	$K_2^*(1430)^+\rho^0$	<	1.5	× 10 ⁻³	CL=90%
	$D^*(2010)^-\pi^+\pi^+$	$(2.1 \pm 0.6) \times 1$			Γ ₈₅	$K^+\overline{K}^0$	<	2.1	× 10 ⁻⁵	CL=90%
Γ ₁₉ Γ ₂₀	$D^{-}\pi^{+}\pi^{+}$		10 ⁻³	CL=90%	Г ₈₆	$K^+K^-\pi^+$ nonresonant	<	7.5	× 10 ⁻⁵	CL=90%
Γ ₂₁	$\frac{D}{D}^*(2007)^0\pi^+$	(4.6 ±0.4)×1		CL=3076	Γ ₈₇	K ⁺ K ⁻ K ⁺	<	2.0	× 10 ⁻⁴	CL=90%
Γ ₂₂	$D^*(2010)^+\pi^0$		10-4	CL=90%	Γ ₈₈	$K^+\phi$	<	1.2	× 10 ⁻⁵	CL=90%
Γ ₂₃	$\frac{D}{D}$ *(2007) ⁰ ρ ⁺	(1.55±0.31) %	10	CL=3070	Г ₈₉	$K^+K^-K^+$ nonresonant	<	3.8	× 10 ⁻⁵	CL=90%
Γ ₂₄	$\frac{D}{D}^*(2007)^0 \pi^+ \pi^+ \pi^-$	$(9.4 \pm 2.6) \times 1$	10-3		Γ ₉₀	K*(892)+ K+ K-	<	1.6	× 10 ⁻³	CL=90%
Γ ₂₅	$\overline{D}^*(2007)^0 a_1(1260)^+$	(1.9 ±0.5)%	••		Γ ₉₁	$K^*(892)^+\phi$	<	7.0	× 10 ⁻⁵	CL=90%
Γ ₂₆	$D^*(2010)^-\pi^+\pi^+\pi^0$	(1.5 ±0.7) %			Γ ₉₂	$K_1(1400)^+\phi$	<	1.1	× 10 ⁻³	CL=90%
Γ ₂₇	$D^*(2010)^-\pi^+\pi^+\pi^+\pi^-$	< 1 %		CL=90%	Γ ₉₃	$K_2^*(1430)^+\phi$	<	3.4	× 10 ⁻³	CL=90%
Γ ₂₈	$\overline{D}_{1}^{*}(2420)^{0}\pi^{+}$	(1.5 ±0.6)×1	10~3	S=1.3	Γ ₉₄	$K^+ f_0(980)$		8	× 10 ⁻⁵	CL=90%
Γ ₂₉	$\overline{D}_{1}^{*}(2420)^{0}\rho^{+}$		10-3	CL=90%	Γ ₉₅	K*(892) ⁺ γ	(5.7 ± 3.3		
Γ ₃₀	$\overline{D}_{2}^{*}(2460)^{0}\pi^{+}$		10-3	CL=90%	Γ ₉₆	$K_1(1270)^+\gamma$		7.3	× 10 ⁻³	CL=90%
	$\overline{D}_{2}^{*}(2460)^{0} \rho^{+}$		10 ⁻³		Γ ₉₇	$K_1(1400)^+ \gamma$		2.2	× 10 ⁻³	CL=90%
F ₃₁	$\overline{D}^{0}D^{+}$		10 -	CL=90%	Γ ₉₈	$K_2^*(1430)^+\gamma$		1.4	× 10 ⁻³	CL=90%
Γ ₃₂		(1.3 ±0.4)%	2		وو٦	$K^*(1680)^+ \gamma$	<	1.9	× 10 ⁻³	CL=90%
Γ ₃₃	D ⁰ D _s *+	(9 ±4)×1	10 3		Γ ₁₀₀	$K_3^*(1780)^+\gamma$		5.5	× 10 ⁻³	CL=90%
Γ ₃₄	$\overline{D}^*(2007)^0 D_s^+$	(1.2 \pm 0.5)%			Γ ₁₀₁	$K_4^*(2045)^+\gamma$	<	9.9	× 10 ⁻³	CL=90%
Γ ₃₅	$\overline{D}^*(2007)^0 D_s^{*+}$	(2.7 ±1.0) %				Light unflavored	macon	modes		
Γ ₃₆	$D_s^+\pi^0$	< 2.0 × 1	10-4	CL=90%	F				× 10 ⁻⁵	CL=90%
Γ ₃₇	$D_{s}^{3+}\pi^{0}$	< 3.3 × 1	10-4	CL=90%	' 102 F	$\pi^{+}\pi^{0}$ $\pi^{+}\pi^{+}\pi^{-}$		2.0	× 10 -4	CL=90%
Γ ₃₈	$D_s^+\eta$		10-4	CL=90%				1.3 4.3	× 10 · · · × 10 · ·	CL=90%
Γ ₃₉	$D_s^{s} \eta$		10-4	CL=90%	i 104				× 10 -4 × 10-4	CL=90%
_	$D_s^+ \rho^0$		10 ⁻⁴	CL=90%	Г ₁₀₅	1 - 2 2 2 2		1.4 2.4	× 10 ⁻⁴	CL=90%
Γ ₄₀	0*+ °0		10-4	CL=90%	Γ ₁₀₆			4.1	× 10 ⁻⁵	CL=90%
Γ ₄₁	$D_s^{*+}\rho^0$				Γ ₁₀₇	$\pi^+\pi^0\pi^0$		8.9	× 10 ⁻⁴	CL=90%
Γ ₄₂	$D_{s}^{+}\omega$		10-4	CL=90%				7.7	× 10 × 10 ⁻⁵	CL=90%
Γ ₄₃	$D_s^{*+}\omega$		10-4	CL=90%	「109 「110	$\pi^{+}\pi^{-}\pi^{+}\pi^{0}$		4.0	× 10 ⁻³	CL=90%
Γ_{44}	$D_s^+ a_1 (1260)^0$	< 2.2 × 1	10-3	CL=90%				1.0	× 10 ⁻³	CL=90%
Γ ₄₅	$D_s^{*+} a_1 (1260)^0$	< 1.6 × 1	10-3	CL=90%	「111 「	(1.7	× 10 ⁻³	CL=90% CL=90%
Γ ₄₆	$D_s^+\phi$		10-4	CL=90%	「112 「			9.0	× 10 -4	CL=90%
Γ ₄₇	$D_s^{*+}\phi$		10-4	CL=90%	「113 「	31(1200) π μπ+		4.0	× 10 ⁻⁴	CL=90%
Γ ₄₈	$D_s^+ \overline{K}^0$		₁₀ -3	CL=90%	' 114 Γ	$\omega\pi^+$ $\eta\pi^+$		1.5	× 10 ⁻⁵	CL=90%
	$D_s \stackrel{K}{K}$		10 10 ⁻³	CL=90%	' 115 Г	$\eta'\pi^+$		3.1	× 10 ⁻⁵	CL=90%
Γ ₄₉	D = K*(200)0				' 116	<i>q</i> "	`	3.1	^ ••	CL-70/0
Γ ₅₀	$D_s^+ \overline{K}^* (892)^0$		10-4	CL=90%						
۲ ₅₁	$D_s^{*+}\overline{K}^*(892)^0$	< 4 × 1	10 ⁻⁴	CL=90%						

$\Gamma_{117} \eta' \rho^+$	<	4.7	× 10 ⁻⁵	CL=90%	Assuming a value of V_{CD} , they measure V , A_1 , and A_2 , the three form factors for the
$\Gamma_{118} \eta \rho^+$		3.2	\times 10 ⁻⁵	CL=90%	$D^*\ell u_\ell$ decay, where results are slightly dependent on model assumptions.
$\Gamma_{119} \pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}$		8.6	× 10 ⁻⁴	CL=90%	¹⁸ Assumes equal production of $B^0\overline{B}^0$ and B^+B^- at the $\Upsilon(4S)$. Uncorrected for D and
$\Gamma_{120} \qquad \rho^0 a_1(1260)^+$		6.2	× 10 ⁻⁴	CL=90%	D^* branching ratio assumptions. ¹⁹ ANTREASYAN 90B is average over B and \overline{D}^* (2010) charge states.
$\Gamma_{121} \rho^0 a_2(1320)^+$		7.2	× 10 ⁻⁴	CL=90%	
$\Gamma_{122} \pi^+ \pi^+ \pi^+ \pi^- \pi^- \pi^0$ $\Gamma_{123} a_1 (1260)^+ a_1 (1260)^+$		6.3 1.3	× 10 ⁻³	CL=90%	$\Gamma(\pi^0 e^+ \nu_e) / \Gamma_{\text{total}}$ Γ_4 / Γ
$\Gamma_{123} a_1(1260)^+ a_1(1260)$	•		70	CL=90%	VALUE CL% DOCUMENT ID TECN COMMENT <0.0022 90 ANTREASYAN 908 CBAL $e^+e^- \rightarrow \Upsilon(4S)$
r _= +	Baryon modes		4		
$\Gamma_{124} p \overline{p} \pi^+$		1.6	× 10 ⁻⁴	CL=90%	$\Gamma(\omega \ell^+ \nu_\ell)/\Gamma_{\text{total}}$ Γ_5/Γ
Γ_{125} $p \overline{p} \pi^+$ nonresonant Γ_{126} $p \overline{p} \pi^+ \pi^+ \pi^-$		5.3 5.2	× 10 ⁻⁵ × 10 ⁻⁴	CL=90% CL=90%	$\ell = e$ or μ , not sum over e and μ modes. VALUE
$\Gamma_{127} p \overline{p} K^+$ nonresonant		8.9	× 10 ⁻⁵	CL=90%	$<2.1 \times 10^{-4}$ 90 20 BEAN 93B CLE2 e ⁺ e ⁻ → $\Upsilon(45)$
$\Gamma_{128} p \overline{\Lambda}$		6	× 10 ⁻⁵	CL=90%	20 BEAN 938 limit set using ISGW Model. Using isospin and the quark model to combine
$\Gamma_{129} p \overline{\Lambda} \pi^+ \pi^-$		2.0	× 10 ⁻⁴	CL=90%	$\Gamma(\rho^0\ell^+ u_\ell)$ and $\Gamma(\rho^-\ell^+ u_\ell)$ with this result, they obtain a limit $<(1.6-2.7)\times 10^{-4}$ at
$\Gamma_{130} \overline{\Delta}{}^{0} p$	<	3.8	\times 10 ⁻⁴	CL=90%	90% CL for $B^+ \to \omega \ell^+ \nu_\ell$. The range corresponds to the ISGW, WSB, and KS models.
$\Gamma_{131} \Delta^{++} \overline{p}$		1.5	× 10 ⁻⁴	CL=90%	An upper limit on $ V_{ub}/V_{cb} < 0.8$ –0.13 at 90% CL is derived as well.
$\Gamma_{132} \Lambda_c^- p \pi^+$	((6.2 ±2.7	7)×10 ⁻⁴		$\Gamma(\omega \mu^+ \nu_\mu) / \Gamma_{\text{total}}$ Γ_6 / Γ
$\Gamma_{133} \Lambda_c^- p \pi^+ \pi^0$	<	3.12	× 10 ⁻³	CL=90%	VALUE DOCUMENT ID TECN
$\Gamma_{134} \Lambda_c^- p \pi^+ \pi^+ \pi^-$	<	1.46	\times 10 ⁻³	CL=90%	
$\Gamma_{135} \Lambda_c^- \rho \pi^+ \pi^+ \pi^- \pi^0$	<	1.34	%	CL=90%	seen 21 ALBRECHT 91C ARG
Lepton Family number (LF) or Lepton num	nber (/) v	iolating mo	des. or	²¹ In ALBRECHT 91C, one event is fully reconstructed providing evidence for the $b \rightarrow u$
	veak neutral current			,	transition.
$\Gamma_{136} \pi^{+} e^{+} e^{-}$		3.9	× 10 ⁻³	CL=90%	$\Gamma(\rho^0 \ell^+ \nu_\ell)/\Gamma_{\text{total}}$ Γ_7/Γ
$\Gamma_{137} \pi^{+} \mu^{+} \mu^{-}$		9.1	× 10 ⁻³	CL=90%	$\ell = e$ or μ , not sum over e and μ modes. VALUE
$\Gamma_{138} K^+ e^+ e^-$	B1 <	6	× 10 ⁻⁵	CL=90%	<2.1 × 10 ⁻⁴ 90 22 BEAN 93B CLE2 e^+e^- → $T(45)$
$\Gamma_{139} K^{+} \mu^{+} \mu^{-}$		1.0	× 10 ⁻⁵	CL=90%	²² BEAN 93B limit set using ISGW Model. Using isospin and the quark model to combine
$\Gamma_{140} K^*(892)^+ e^+ e^-$		6.9	× 10 ⁻⁴	CL=90%	$\Gamma(\omega^0\ell^+\nu_\ell)$ and $\Gamma(\rho^-\ell^+\nu_\ell)$ with this result, they obtain a limit $<(1.6$ – $2.7) imes 10^{-4}$
$\Gamma_{141} K^*(892)^+ \mu^+ \mu^- \\ \Gamma_{142} \dot{\pi}^+ e^+ \mu^-$		1.2	× 10 ⁻³	CL=90%	at 90% CL for $B^+ \to \rho^0 \ell^+ \nu_\ell$. The range corresponds to the ISGW, WSB, and KS
$\Gamma_{142} \pi^+ e^- \mu^+$		6.4 6.4	× 10 ⁻³ × 10 ⁻³	CL=90% CL=90%	models. An upper limit on $\left V_{ub}/V_{cb} ight <$ 0.8–0.13 at 90% CL is derived as well.
$\Gamma_{144} K^+ e^+ \mu^-$		6.4	× 10 ⁻³	CL=90%	$\Gamma(e^+ u_e)/\Gamma_{ ext{total}}$
$\Gamma_{145} K^{+} e^{-} \mu^{+}$		6.4	× 10 ⁻³	CL=90%	VALUE CL% DOCUMENT ID TECN COMMENT
$\Gamma_{146} \pi^- e^+ e^+$		3.9	× 10 ⁻³	CL=90%	<1.5 × 10 ⁻⁵ 90 ARTUSO 95 CLE2 e^+e^- → $\Upsilon(4S)$
$\Gamma_{147} \pi^- \mu^+ \mu^+$	L <	9.1	× 10 ⁻³	CL=90%	$\Gamma(\mu^+ u_\mu)/\Gamma_{ ext{total}}$
$\Gamma_{148} \pi^- e^+ \mu^+$		6.4	× 10 ⁻³	CL=90%	VALUECL% DOCUMENT ID TECN COMMENT
$\Gamma_{149} K^- e^+ e^+$		3.9	× 10 ⁻³	CL=90%	$<2.1 \times 10^{-5}$ 90 ARTUSO 95 CLE2 e ⁺ e ⁻ → Υ (45)
$\Gamma_{150} K^- \mu^+ \mu^+ \\ \Gamma_{151} K^- e^+ \mu^+$		9.1	× 10 ⁻³ × 10 ⁻³	CL=90%	, ,
151 N e µ	. <i>LF</i> <	6.4	X 10 -	CL=90%	$\Gamma(\tau^+ u_{ au})/\Gamma_{ au au}$ Γ_{10}/Γ VALUE CL% DOCUMENT ID TECH COMMENT
[a] An ℓ indicates an e or	a μ mode, not a s	um over t	these modes	i .	VALUE CL% DOCUMENT ID TECN COMMENT <5.7 × 10 ⁻⁴ 90 23 ACCIARRI 97F L3 $^{+}$ $^{-}$ $^{-}$ $^{-}$ $^{-}$ $^{-}$ $^{-}$
					• • • We do not use the following data for averages, fits, limits, etc. • • •
B	BRANCHING RA	TIOS			$<1.04 \times 10^{-2}$ 90 ²⁴ ALBRECHT 95D ARG $e^+e^- \rightarrow T(45)$
$\Gamma(\ell^+ \nu_\ell \text{ anything}) / \Gamma_{\text{total}}$				Γ_1/Γ	$<2.2 \times 10^{-3}$ 90 ARTUSO 95 CLE2 $e^+e^- \rightarrow r(4S)$ $<1.8 \times 10^{-3}$ 90 25 BUSKULIC 95 ALEP $e^+e^- \rightarrow Z$
VALUE	DOCUMENT ID	TECN	COMMENT	. 1/-	23 ACCIARRI 97F uses missing-energy technique and $f(b \rightarrow B^{-}) = (38.2 \pm 2.5)\%$.
$0.1025 \pm 0.0057 \pm 0.0065$	12 ARTUSO 97	7 CLE2	$e^+e^- \rightarrow \Upsilon$	(45)	24 ALBRECHT 95D use full reconstruction of one B decay as tag.
• • We do not use the following	ng data for averages, f	its, limits, o	etc. • • •		²⁵ BUSKULIC 95 uses same missing-energy technique as in $\bar{b} \to \tau^+ \nu_{\tau} X$, but analysis is
0.101 ±0.018 ±0.015			Sup. by ART		restricted to endpoint region of missing-energy distribution.
12 ARTUSO 97 uses partial re- branching ratio from BARISH	construction of $B \rightarrow 1.968 (0.1049 \pm 0.001)$	$D^*\ell\nu_\ell$ a 7 + 0.0043	nd inclusive s	emileptonic	$\Gamma(e^+ u_e\gamma)/\Gamma_{\text{total}}$ Γ_{11}/Γ
-	1 305 (0.2043 ± 0.001	1 1 0.0043	,,,		VALUE CLY DOCUMENT ID TECH COMMENT
$ \Gamma(\overline{D}^0 \ell^+ \nu_{\ell}) / \Gamma_{\text{total}} $ $\ell = e \text{ or } \mu, \text{ not sum over } \ell$				Γ_2/Γ	$<2.0 \times 10^{-4}$ 90 ²⁶ BROWDER 97 CLE2 e ⁺ e ⁻ → $\Upsilon(4S)$ ²⁶ BROWDER 97 uses the hermiticity of the CLEO II detector to reconstruct the neutrino
$t = e \text{ or } \mu$, not sum over e	e and μ modes. <u>DOCUMENT ID</u>	TECN	COMMENT		energy and momentum.
0.0186±0.0033 OUR AVERAGE					F(+
0.0194 ± 0.0015 ± 0.0034			$e^+e^- \rightarrow r$		$\Gamma(\mu^+ u_\mu\gamma)/\Gamma_{\text{total}}$ VALUE CLY DOCUMENT ID TECH COMMENT
0.016 ±0.006 ±0.003			e+e- → r		$\frac{1}{\sqrt{5.2} \times 10^{-5}}$ 90 27 BROWDER 97 CLE2 e ⁺ e ⁻ → $T(45)$
13 ATHANAS 97 uses missing e 14 FULTON 91 assumes equal p	nergy and missing mor	mentum to	reconstruct no	eutrino.	27 BROWDER 97 uses the hermiticity of the CLEO II detector to reconstruct the neutrino
	ioduction of B B an	id D · D	at the 7 (43)		energy and momentum.
$\Gamma(\overline{D}^*(2007)^0\ell^+\nu_\ell)/\Gamma_{\text{total}}$				Γ₃/Γ	$\Gamma(\overline{\mathcal{D}}{}^{0}\pi^{+})/\Gamma_{\text{total}}$ Γ_{13}/Γ
$\ell = e \text{ or } \mu$, not sum over ϵ VALUE	•	TECN	COMMENT		VALUE EVTS DOCUMENT ID TECH COMMENT
0.053 ±0.008 OUR AVERAGE					0.0053±0.0005 OUR AVERAGE
$0.0513 \pm 0.0054 \pm 0.0064$ 303			2 e ⁺ e ⁻ →		$0.0055 \pm 0.0004 \pm 0.0005$ 304 ²⁸ ALAM 94 CLE2 e ⁺ e ⁻ $\rightarrow \Upsilon(4S)$
0.066 ±0.016 ±0.015 • • • We do not use the following	16 ALBRECHT ng data for averages, fl		e+e-→	1 (45)	$0.0050 \pm 0.0007 \pm 0.0006$ 54 29 BORTOLETTO92 CLEO $e^+e^- \rightarrow T(4S)$ $0.0054 \pm 0.0018 \pm 0.0012$ 14 30 BEBEK 87 CLEO $e^+e^- \rightarrow T(4S)$
seen 398			2 e ⁺ e ⁻ →	2/45)	-0.0013 -0.0009
0.041 ±0.008 +0.008 -0.009	18 FULTON		2 e e - → O e + e - →		• • • We do not use the following data for averages, fits, limits, etc. • • •
					$0.0020\pm0.0008\pm0.0006$ 12 ²⁹ ALBRECHT 90J ARG $e^+e^- \rightarrow T(45)$ $0.0019\pm0.0010\pm0.0006$ 7 ³¹ ALBRECHT 88K ARG $e^+e^- \rightarrow T(45)$
0.070 ±0.018 ±0.014	19 ANTREASYAN			` '	28 ALAM 94 assume equal production of B^+ and B^0 at the $\Upsilon(4S)$ and use the CLEO II
¹⁵ BARISH 95 use B($D^0 \rightarrow K$ = (63.6 ± 2.3 ± 3.3)%.	$-\pi^{+}$) = (3.91 ± 0.08	B ± 0.17)%	and B(D*U	$\rightarrow D^{\circ}\pi^{\circ}$	absolute B($D^0 o K^-\pi^+$) and the PDG 1992 B($D^0 o K^-\pi^+\pi^0$)/B($D^0 o K^-\pi^+$)
16 ALBRECHT 92C reports 0.056	B ± 0.014 ± 0.013. We r	rescale usini	g the method	described in	and B($D^0 \to K^-\pi^+\pi^+\pi^-$)/B($D^0 \to K^-\pi^+$).
STONE 94 but with the upda	ted PDG 94 B($D^0 \rightarrow 1$				²⁹ Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and uses the Mark III branching
of $B^0 \overline{B^0}$ and $B^+ B^-$ at the					fractions for the D . 30 BEBEK 87 value has been updated in BERKELMAN 91 to use same assumptions as
17 Combining $\overline{D}^{*0}\ell^+\nu_{\ell}$ and \overline{D}	ε ε ν _ε SANGHERA	93 test <i>V</i> r−. r+∨	−A structure	and fit the	noted for BORTOLETTO 92. 31 ALBRECHT 88k assumes $B^0\overline{B}^0.8+B^-$ ratio is 45:55. Superseded by ALBRECHT 90).
decay angular distributions to	ODIAIN AFB = 3/4*([-1')/	ı = 0.14 ± 0	.vo ± 0.03.	ALBRECH I Box assumes 8" 8" B B ratio is 45:55. Superseded by ALBRECHT 90J.

 B^{\pm}

$\Gamma(\overline{D}^0 \rho^+)/\Gamma_{\text{total}}$	F14/F EVTS DOCUMENT ID TECN COMMENT
0.0134±0.0018 OUR AVERA	NGE
0.0135±0.0012±0.0015	212 32 ALAM 94 CLE2 $e^+e^- \rightarrow T(4S)$
0.013 ±0.004 ±0.004	19 33 ALBRECHT 90.1 ARG $e^+e^- \rightarrow \Upsilon(4S)$ lowing data for averages, fits, limits, etc. • • •
0.021 ±0.008 ±0.009	10 34 ALBRECHT 88K ARG $e^+e^- \rightarrow T(45)$
	production of B^+ and B^0 at the $\Upsilon(4S)$ and use the CLEO II
	and the PDG 1992 B($D^0 \rightarrow K^-\pi^+\pi^0$)/B($D^0 \rightarrow K^-\pi^+$)
and B($D^0 \rightarrow K^-\pi^+\pi^+$	π^-)/B($D^0 \rightarrow K^-\pi^+$).
33 Assumes equal production fractions for the D.	of B^+ and B^0 at the $arphi(4S)$ and uses the Mark III branching
34 ALBRECHT 88K assumes	$B^0 \overline{B}{}^0: B^+ B^-$ ratio is 45:55.
$\Gamma(\overline{D}{}^0\pi^+\pi^+\pi^-)/\Gamma_{\text{total}}$	Г _{1Б} /Г
VALUE	DOCUMENT ID TECN COMMENT
0.0115±0.0029±0.0021	35 BORTOLETTO92 CLEO $e^+e^- \rightarrow r$ (45)
35 BORTOLETTO 92 assum Mark III branching fraction	nes equal production of \mathcal{B}^+ and \mathcal{B}^0 at the $\dot{\mathcal{T}}(45)$ and uses ns for the D .
$\Gamma(\overline{D}{}^0\pi^+\pi^+\pi^-$ nonresona	ant)/F _{total} F ₁₆ /F
VALUE	DOCUMENT ID TECN COMMENT
0.0051±0.0034±0.0023	³⁶ BORTOLETTO92 CLEO $e^+e^- \rightarrow \Upsilon(4S)$
Mark III branching fraction	mes equal production of \mathcal{B}^+ and \mathcal{B}^0 at the $\mathcal{T}(4S)$ and uses ns for the D .
$\Gamma(\overline{D}{}^0\pi^+ ho^0)/\Gamma_{ m total}$	Γ ₁₇ /Γ
VALUE	$\frac{DOCUMENT \ ID}{37} \frac{TECN}{BORTOLETTO92} CLEO e^{+}e^{-} \rightarrow T(4S)$
0.0042±0.0023±0.0020	
Mark III branching fraction	
Γ(D ⁰ a ₁ (1260) ⁺)/Γ _{total}	F ₁₈ /F
0.0045±0.0019±0.0031	38 BORTOLETTO92 CLEO $e^+e^- \rightarrow \Upsilon(45)$
	nes equal production of B^+ and B^0 at the $T(4S)$ and uses
Mark III branching fraction	
144 LEWISH TO TO THE P. L. P. L.	
0.0021±0.0006 OUR AVER	LY EVTS DOCUMENT ID TECN COMMENT
ALUE CL	L <u>X EVTS DOCUMENT ID TECN COMMENT</u> RAGE 14 39 ALAM 94' CLE2 e ⁺ e ⁻ →
0.0021±0.0006 OUR AVER	LY, EYTS DOCUMENT ID TECN COMMENT 14 39 ALAM 94' CLE2 $e^+e^- \rightarrow T(45)$ 11 40 ALBRECHT 90J ARG $e^+e^- \rightarrow T(45)$
0.0021±0.0006 OUR AVER 0.0019±0.0007±0.0003 0.0026±0.0014±0.0007	TAGE 14 39 ALAM 94' CLE2 $e^+e^- \rightarrow r(45)$ 11 40 ALBRECHT 90J ARG $e^+e^- \rightarrow r(45)$
0.0021±0.0006 OUR AVER 0.0019±0.0007±0.0003 0.0026±0.0014±0.0007 0.0024+0.0017+0.0010 -0.0016-0.0006	TAGE 14 39 ALAM 94' CLE2 $e^+e^- \rightarrow T(4S)$ 11 40 ALBRECHT 90, ARG $e^+e^- \rightarrow T(4S)$ 3 41 BEBEK 87 CLEO $e^+e^- \rightarrow T(4S)$
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0.0021±0.0006 OUR AVER 0.0019±0.0007±0.0003 0.0026±0.0014±0.0007 0.0024+0.0017+0.0010 0.0024+0.0016-0.0006 0 • We do not use the folio <0.004 0.005±0.002±0.003 39 ALAM 94 assume equal p $B(D^*(2010)^+ \rightarrow D^0\pi^+)$ $K^-\pi^+\pi^0)/B(D^0 \rightarrow K^-$ 40 Assumes equal production fractions for the D . 41 BEBEK 87 value has beel noted for BORTOLETTO 92 assum Mark III branching fraction into D^* 0.0003 where D^* * represented the second of t	TABLE EVTS 14 39 ALAM 94' CLE2 $e^+e^- \rightarrow \Upsilon(4S)$ 11 40 ALBRECHT 90 JARG $e^+e^- \rightarrow \Upsilon(4S)$ 11 40 ALBRECHT 90 JARG $e^+e^- \rightarrow \Upsilon(4S)$ 7(45) 3 41 BEBEK 87 CLE0 $e^+e^- \rightarrow \Upsilon(4S)$ 50 Swing data for averages, fits, limits, etc. 90 42 BORTOLETTO92 CLEO $e^+e^- \rightarrow \Upsilon(4S)$ 7 43 ALBRECHT 87C ARG $e^+e^- \rightarrow \Upsilon(4S)$ 7 43 ALBRECHT 87C ARG $e^+e^- \rightarrow \Upsilon(4S)$ 87 Albrecht 87C ARG $e^+e^- \rightarrow \Upsilon(4S)$ 88 Albrecht 87C ARG $e^+e^- \rightarrow \Upsilon(4S)$ 89 And absolute B($D^0 \rightarrow K^-\pi^+$) and the PDG 1992 B($D^0 \rightarrow K^-\pi^+$). 91 And absolute B($D^0 \rightarrow K^-\pi^+\pi^+\pi^-$)/B($D^0 \rightarrow K^-\pi^+$). 92 Albrecht 92 Albrecht 93 Albrecht 94 Albrecht 95 Albrecht 96 Albrecht 97C Albrecht 98 Albrecht 99 Albrecht 99 Albrecht 90 Albrech
0.0021 \pm 0.0005 OUR AVER 0.0021 \pm 0.0005 OUR AVER 0.0019 \pm 0.0007 \pm 0.0003 0.0024 \pm 0.0017 \pm 0.0007 0.0024 \pm 0.0017 \pm 0.0006 0 • We do not use the folio 0.004 0.005 \pm 0.002 \pm 0.003 39 ALAM 94 assume equal p B(D^* (2010) $^+$ \rightarrow D^0 π^+) $^+$ $^+$ $^+$ $^+$ $^+$ $^+$ $^+$ $^+$	THE PARTS DOCUMENT (D) TECN COMMENT 14 39 ALAM 94' CLE2 $e^+e^- \rightarrow \Upsilon(4S)$ 11 40 ALBRECHT 90J ARG $e^+e^- \rightarrow \Upsilon(4S)$ 3 41 BEBEK 87 CLEO $e^+e^- \rightarrow \Upsilon(4S)$ 3 41 BEBEK 87 CLEO $e^+e^- \rightarrow \Upsilon(4S)$ 3 42 BORTOLETTO92 CLEO $e^+e^- \rightarrow \Upsilon(4S)$ 7 43 ALBRECHT 87C ARG $e^+e^- \rightarrow \Upsilon(4S)$ 43 ALBRECHT 87C ARG $e^+e^- \rightarrow \Upsilon(4S)$ 6 And absolute $B(D^0 \rightarrow K^-\pi^+)$ and the PDG 1992 $B(D^0 \rightarrow K^-\pi^+)$ and $B(D^0 \rightarrow K^-\pi^+)$ and the PDG 1992 $B(D^0 \rightarrow K^-\pi^+)$. 6 B And B at the $T(4S)$ and uses the Mark III branching an updated in BERKELMAN 91 to use same assumptions as 92. 7 And BERECHT 87C ARG $e^+e^- \rightarrow \Upsilon(4S)$ and uses the Mark III branching an updated in BERKELMAN 91 to use same assumptions as 92. 8 And B and B at the $T(4S)$ and uses the Mark III branching are sequal production of B^+ and B^0 at the $T(4S)$ and uses as for the D and D*(2010). The authors also find the product $A^+\pi$ followed by $A^+\pi^+\pi^-$ D*(2010) $A^+\pi^-$ to $A^+\pi^-$ obtained by $A^+\pi^-$ D*(2010) $A^+\pi^-$ to $A^+\pi^-$ obtained by $A^+\pi^-$ D*(2010) $A^+\pi^-$ Alam $A^+\pi^-$ D*(2010) and assume 55% and B($A^+\pi^-$ D*(2010) And Assume 55% And B($A^+\pi^-$ D*(2010) Adam 4 Sume 55% And B($A^+\pi^-$ D*(2010) Adam 50 CLEO E*(2010)
0.0021 \pm 0.0005 OUR AVER 0.0021 \pm 0.0005 OUR AVER 0.0019 \pm 0.0007 \pm 0.0003 0.0024 \pm 0.0017 \pm 0.0007 0.0024 \pm 0.0017 \pm 0.0010 0.0024 \pm 0.0017 \pm 0.0010 0.005 \pm 0.002 \pm 0.003 39 ALAM 94 assume equal p B(D*(2010)+ \rightarrow D0 π +) K- π + π 0)/B(D0 \rightarrow K- 40 Assumes equal production fractions for the D. 41 BEBEK 87 value has been noted for BORTOLETTO 42 BORTOLETTO 92 assum Mark III branching fraction branching fraction into D* 0.0003 where D** represent 43 ALBRECHT 87C use PD B(T(45) \rightarrow B* B*) = BRECHT 90J.	TABLE EVTS 14 39 ALAM 94' CLE2 $e^+e^- \rightarrow \Upsilon(4S)$ 11 40 ALBRECHT 90 JARG $e^+e^- \rightarrow \Upsilon(4S)$ 11 40 ALBRECHT 90 JARG $e^+e^- \rightarrow \Upsilon(4S)$ 7(45) 3 41 BEBEK 87 CLE0 $e^+e^- \rightarrow \Upsilon(4S)$ 50 Swing data for averages, fits, limits, etc. 90 42 BORTOLETTO92 CLEO $e^+e^- \rightarrow \Upsilon(4S)$ 7 43 ALBRECHT 87C ARG $e^+e^- \rightarrow \Upsilon(4S)$ 7 43 ALBRECHT 87C ARG $e^+e^- \rightarrow \Upsilon(4S)$ 87 Albrecht 87C ARG $e^+e^- \rightarrow \Upsilon(4S)$ 88 Albrecht 87C ARG $e^+e^- \rightarrow \Upsilon(4S)$ 89 And absolute B($D^0 \rightarrow K^-\pi^+$) and the PDG 1992 B($D^0 \rightarrow K^-\pi^+$). 91 And absolute B($D^0 \rightarrow K^-\pi^+\pi^+\pi^-$)/B($D^0 \rightarrow K^-\pi^+$). 92 Albrecht 92 Albrecht 93 Albrecht 94 Albrecht 95 Albrecht 96 Albrecht 97C Albrecht 98 Albrecht 99 Albrecht 99 Albrecht 90 Albrech
VALUE 0.0021±0.0005 OUR AVER 0.0019±0.0007±0.0003 0.0026±0.0014±0.0007 0.0024+0.0017+0.0010 0.0024+0.0017+0.0010 0.005±0.002±0.003 39 ALAM 94 assume equal plant $E(t) = E(t) = E(t)$ 40 Assumes equal production fractions for the $E(t) = E(t)$ 41 BEBEK 87 value has been noted for BORTOLETTO 42 BORTOLETTO 92 assum Mark III branching fraction into $E(t) = E(t)$ 43 ALBRECHT 87 cuse PD 44 BEECHT 90. 0.0003 where $E(t) = E(t)$ 45 ALBRECHT 87 cuse PD 46 E(t) $E(t) = E(t)$ 60.0014 • • We do not use the folio $E(t)$ 60.0007	THE STS DOCUMENT (D) TECN COMMENT 14 39 ALAM 94' CLE2 $e^+e^- \rightarrow \Upsilon(4S)$ 11 40 ALBRECHT 90J ARG $e^+e^- \rightarrow \Upsilon(4S)$ 11 40 ALBRECHT 90J ARG $e^+e^- \rightarrow \Upsilon(4S)$ 3 41 BEBEK 87 CLEO $e^+e^- \rightarrow \Upsilon(4S)$ 3 41 BEBEK 87 CLEO $e^+e^- \rightarrow \Upsilon(4S)$ 3 42 BORTOLETTO92 CLEO $e^+e^- \rightarrow \Upsilon(4S)$ 43 ALBRECHT 87C ARG $e^+e^- \rightarrow \Upsilon(4S)$ 43 ALBRECHT 87C ARG $e^+e^- \rightarrow \Upsilon(4S)$ 43 ALBRECHT 87C ARG $e^+e^- \rightarrow \Upsilon(4S)$ 44 ALAM 91 to use same assumptions as 192. 10 and absolute $B(D^0 \rightarrow K^-\pi^+ + \pi^+\pi^-)/B(D^0 \rightarrow K^-\pi^+)$. 11 40 ALBRECHT 87C ARG $e^+e^- \rightarrow \Upsilon(4S)$ 12 and uses the Mark III branching in updated in BERKELMAN 91 to use same assumptions as 192. 13 and absolute $e^+e^- \rightarrow \Upsilon(4S)$ and uses the Mark III branching in updated in BERKELMAN 91 to use same assumptions as 192. 14 and $e^+e^- \rightarrow \Upsilon(4S)$ and uses the Mark III branching in updated by $e^+e^- \rightarrow \Upsilon(4S)$ and uses the Mark III branching in updated by $e^+e^- \rightarrow \Upsilon(4S)$ and uses the Mark III branching in the product $e^+e^- \rightarrow \Upsilon(4S)$ and $e^+e^$

followed by $D_0^*(2340) \rightarrow D\pi$ is < 0.005 at 90%CL and into $D_2^*(2460)$ followed by

⁴⁶ BEBEK 87 assume the $\Upsilon(4S)$ decays 43% to $B^0\overline{B}^0$. B($D^-\to K^+\pi^-\pi^-$) = (9.1 \pm

 $D_2^*(2460) \rightarrow D\pi$ is < 0.004 at 90%CL.

 $1.3 \pm 0.4)\%$ is assumed.

```
\Gamma(\overline{D}^{+}(2007)^{0}\pi^{+})/\Gamma_{\text{total}}
                                                                                                                   \Gamma_{21}/\Gamma
                                                         DOCUMENT ID TECN COMMENT
 0.0046 ±0.0004 OUR AVERAGE
                                                    ^{47} BRANDENB... 98 CLE2 e^+e^- \rightarrow \Upsilon(4S)
 0.00434 \pm 0.00047 \pm 0.00018
                                                    <sup>48</sup> ALAM
                                                    <sup>48</sup> ALAM 94 CLE2 e^+e^- \rightarrow T(45)

<sup>49</sup> BORTOLETTO92 CLEO e^+e^- \rightarrow T(45)
 0.0052 ±0.0007 ±0.0007
 0.0072 \pm 0.0018 \pm 0.0016
                                                    <sup>49</sup> ALBRECHT 901 ARG e^+e^- \rightarrow \Upsilon(45)
0.0040 \pm 0.0014 \pm 0.0012
 \bullet \bullet \bullet We do not use the following data for averages, fits, limits, etc. \bullet \bullet
0.0027 \pm 0.0044
                                                    <sup>50</sup> BEBEK
                                                                             87 CLEO e^+e^- \rightarrow \Upsilon(45)
  <sup>47</sup> BRANDENBURG 98 assume equal production of B^+ and B^0 at \Upsilon(4S) and use the D^*
       reconstruction technique. The first error is their experiment's error and the second error
      is the systematic error from the PDG 96 value of B(D^* \rightarrow D\pi).
  A8 ALAM 94 assume equal production of B^+ and B^0 at the \Upsilon(4S) and use the CLEO II B(D^*(2007)^0 \rightarrow D^0\pi^0) and absolute B(D^0 \rightarrow K^-\pi^+) and the PDG 1992 B(D^0 \rightarrow K^-\pi^+\pi^0)/B(D^0 \rightarrow K^-\pi^+) and B(D^0 \rightarrow K^-\pi^+\pi^+)/B(D^0 \rightarrow K^-\pi^+).

49 Assumes equal production of B^+ and B^0 at the \Upsilon(4S) and uses Mark III branching
      fractions for the D and D^*(2010).
  <sup>50</sup> This is a derived branching ratio, using the inclusive pion spectrum and other two-body B decays. BEBEK 87 assume the \Upsilon(4S) decays 43% to B^0\overline{B}^0.
\Gamma(D^*(2010)^+\pi^0)/\Gamma_{\rm total}
                                                                                                                  \Gamma_{22}/\Gamma
                                                   DOCUMENT ID TECN COMMENT
                                 CLN
                                               <sup>51</sup> BRANDENB... 98 CLE2 e^+e^- \rightarrow \Upsilon(4S)
  < 0.00017
                                   90
  ^{51} BRANDENBURG 98 assume equal production of \mathcal{B}^+ and \mathcal{B}^0 at \mathcal{T}(4S) and use the
      D^{ullet} partial reconstruction technique. The first error is their experiment's error and the
      second error is the systematic error from the PDG 96 value of B(D^* \rightarrow D\pi).
\Gamma(\overline{D}^*(2007)^0 \rho^+)/\Gamma_{\text{total}}
                                                                                                                  \Gamma_{23}/\Gamma
                                                        DOCUMENT ID TECN COMMENT
0.0155+0.0031 OUR AVERAGE
                                                   52 ALAM
                                                                             94 CLE2 e^+e^- \rightarrow \Upsilon(45)
0.0168 \pm 0.0021 \pm 0.0028
                                          86
                                                  <sup>53</sup> ALBRECHT 90J ARG e^+e^- \rightarrow \Upsilon(45)
0.010 \pm 0.006 \pm 0.004
  ^{52} ALAM 94 assume equal production of B^+ and B^0 at the T(45) and use the CLEO II
     B(D^{\bullet}(2007)^0 \rightarrow D^0\pi^0) and absolute B(D^0 \rightarrow K^-\pi^+) and the PDG 1992 B(D^0 \rightarrow K^-\pi^+\pi^0)/B(D^0 \rightarrow K^-\pi^+) and B(D^0 \rightarrow K^-\pi^+\pi^0)/B(D^0 \rightarrow K^-\pi^+). The
 nonresonant \pi^+\pi^0 contribution under the \rho^+ is negligible. 53 Assumes equal production of B^+ and B^0 at the T(4S) and uses Mark III branching
      fractions for the D and D^*(2010).
\Gamma(\widetilde{D}^*(2007)^0\pi^+\pi^+\pi^-)/\Gamma_{\text{total}}
                                   EVTS DOCUME
48 54,55 ALAM
                                                        DOCUMENT ID
                                                                                TECN COMMENT
0.0094±0.0020±0.0017
                                                                             94 CLE2 e^+e^- \rightarrow \Upsilon(4S)
  ^{54} ALAM 94 assume equal production of B^+ and B^0 at the \Upsilon(45) and use the CLEO !!
     B(D^*(2007)^0 \rightarrow D^0\pi^0) and absolute B(D^0 \rightarrow K^-\pi^+) and the PDG 1992 B(D^0 \rightarrow K^-\pi^+)
         -\pi^{+}\pi^{0})/B(D^{0} \to K^{-}\pi^{+}) and B(D^{0} \to K^{-}\pi^{+}\pi^{+}\pi^{-})/B(D^{0} \to K^{-}\pi^{+}).
  ^{55} The three pion mass is required to be between 1.0 and 1.6 GeV consistent with an a_1
     meson. (If this channel is dominated by a_1^+, the branching ratio for \overline{D}^{*0}a_1^+ is twice
     that for \overline{D}^{*0}\pi^{+}\pi^{+}\pi^{-}.)
\Gamma(\overline{D}^{\circ}(2007)^{0}\,a_{1}(1260)^{+})/\Gamma_{total}
                                                                                                                  \Gamma_{25}/\Gamma
                                                  DOCUMENT ID
VALUE
                                                                          TECN COMMENT
                                         56,57 ALAM
                                                                       94 CLE2 e^+e^- \rightarrow \Upsilon(4S)
0.0188 \pm 0.0040 \pm 0.0034
 <sup>56</sup>ALAM 94 value is twice their \Gamma(\overline{D}^*(2007)^0\pi^+\pi^+\pi^-)/\Gamma_{\text{total}} value based on their observation that the three pions are dominantly in the a_1(1260) mass range 1.0 to 1.6 GeV.
 <sup>57</sup> ALAM 94 assume equal production of B^+ and B^0 at the \Upsilon(4S) and use the CLEO II
     B(D*(2007)<sup>0</sup> \rightarrow D<sup>0</sup>\pi<sup>0</sup>) and absolute B(D<sup>0</sup> \rightarrow K<sup>-</sup>\pi<sup>+</sup>) and the PDG 1992 B(D<sup>0</sup> \rightarrow K<sup>-</sup>\pi<sup>+</sup>\pi<sup>0</sup>)/B(D<sup>0</sup> \rightarrow K<sup>-</sup>\pi<sup>+</sup>) and B(D<sup>0</sup> \rightarrow K<sup>-</sup>\pi<sup>+</sup>\pi<sup>+</sup>).
\Gamma \big(D^+(2010)^-\pi^+\pi^+\pi^0\big)/\Gamma_{\rm total}
                                                                                                                  Γ<sub>26</sub>/Γ
                                   0.0150±0.0070±0.0003
24 59 ALBRECHT 87C ARG e^+e^- \rightarrow T(4S)
0.043 ±0.013 ±0.026
 <sup>58</sup> ALBRECHT 90J reports 0.018 \pm 0.007 \pm 0.005 for B(D*(2010)+ \rightarrow D<sup>0</sup> \pi+) = 0.57 \pm
     0.06. We rescale to our best value B(D^*(2010)^+ \rightarrow D^0\pi^+) = (68.3 \pm 1.4) \times 10^{-2}. Our first error is their experiment's error and our second error is the systematic error
     from using our best value. Assumes equal production of B^+ and B^0 at the T(4S) and
      uses Mark III branching fractions for the D.
 ^{59} ALBRECHT 87C use PDG 86 branching ratios for D and D*(2010) and assume
     B(T(4S) \to B^+B^-) = 55\% and B(T(4S) \to B^0\overline{B}{}^0) = 45\%. Superseded by ALBRECHT 90J.
\Gamma(D^{\bullet}(2010)^{-}\pi^{+}\pi^{+}\pi^{+}\pi^{-})/\Gamma_{\text{total}}
                                                                                                                  \Gamma_{27}/\Gamma
                                                  DOCUMENT ID TECN COMMENT
VALUE
                                 CL%
                                              60 ALBRECHT 90J ARG e^+e^- \rightarrow \Upsilon(45)
                                  90
 ^{60} Assumes equal production of B^+ and B^0 at the T(4S) and uses Mark III branching
     fractions for the D and D^*(2010).
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VALUE	total EV	TS DOCUME	NT ID T	ECN COMM	Γ ₂₈ /Γ
.0015±0.0006 OUR A		Error Includes			
$0.0011 \pm 0.0005 \pm 0.0002$ $0.0025 \pm 0.0007 \pm 0.0006$	5	8 ⁶¹ ALAM ⁶² ALBREO		RG e+e-	$\begin{array}{ccc} \rightarrow & \Upsilon(45) \\ \rightarrow & \Upsilon(45) \end{array}$
⁶¹ ALAM 94 assume e	qual pro	duction of B^+ as	nd B ^O at the	$\mathcal{T}(45)$ and	use the CLEO II
$B(D^*(2010)^+ \to D)$ $K^-\pi^+\pi^0)/B(D^0-D)$	→ K ⁻ π	$^{+}$) and assuming $^{\parallel}$	B(D ₁ (2420) ⁰	$\rightarrow D^*(2010)$	$()^+\pi^-)=67\%.$
62 ALBRECHT 94D as CLEO II B(D*(2010 67%.	sume eq	ual production of	fB^+ and B^0	at the 7'(4	5) and use the
$(\overline{D}_{1}^{o}(2420)^{0} ho^{+})/\Gamma_{t}$	total 	DOCUMENT_I	D TECN	COMMENT	Γ ₂₉ /Γ
<0.0014	90	63 ALAM	94 CLE2		
63 ALAM 94 assume ea B(D^* (2010) $^+ \rightarrow L$					
$(\overline{D}_2^*(2460)^0\pi^+)/\Gamma_1$	total				Γ ₃₀ /Γ
ALUE	<u>CL%</u>		D <u>TECN</u>		
<0.0013 • • We do not use th	90 e followi	64 ALAM Ing data for avera	94 CLE2		
<0.0028	90	65 ALAM	94 CLE2		
<0.0023	90	66 ALBRECHT	94D ARG	$e^+e^- \rightarrow$	T(45)
⁶⁴ ALAM 94 assume ed B($D^+ \rightarrow K^- \pi^+ \pi$	+) and	$B(D_2^*(2460)^0 \rightarrow$	$D^+\pi^-)=3$	30%.	
⁶⁵ ALAM 94 assume ec	qual prod	duction of B+ an	d B ^O at the	$\Upsilon(45)$ and ι	ise the Mark III
$B(D^+ \to K^- \pi^+ \pi$	†), the	CLEO II B(D*(2	010) ⁺ → <i>D</i> ($^\prime\pi^+)$ and B	$(D_2^*(2460)^0 \to$
$D^*(2010)^+\pi^-)=2$	20%.		. n.+		
GEO II B(D*(2010)	sume eq $)^+ \rightarrow t$	D $^0\pi^+$) and B(D_2^0	$(2460)^0 \rightarrow $	at the 7(4 D*(2010)+1	r^-) = 30%.
$(\overline{D_2^*}(2460)^0 ho^+)/\Gamma_{ m t}$	otal 	<u>DOCUMENT II</u>) TECN	COMMENT	Γ ₃₁ /Γ
<0.0047	90	67 ALAM	94 CLE2		
< 0.005	90	68 ALAM	94 CLE2		
ALAM 94 assume ed	ual prod	duction of B+ an	d B^0 at the	γ(45) and ι	ise the Mark III
$B(D^+ \rightarrow K^-\pi^+\pi$	+) and qual proc +), the	$B(D_2^*(2460)^0 \rightarrow \text{duction of } B^+ \text{ an}$	d B^0 at the $D^+\pi^-)=3$ d B^0 at the	ア(45) and に 80%. ア(45) and に	ise the Mark III
B($D^+ \rightarrow K^- \pi^+ \pi^-$ 68 ALAM 94 assume ec B($D^+ \rightarrow K^- \pi^+ \pi^-$ $D^*(2010)^+ \pi^-) = 2$ $(D^0 D_g^+)/\Gamma_{total}$	+) and qual proce +), the 20%.	B(D_2^* (2460) ⁰ → duction of B^+ an CLEO II B(D^* (2)	d B^0 at the $D^+\pi^-)=3$ d B^0 at the D10) $^+\to D^0$	T(45) and $00%$. T(45) and 0	ise the Mark III
⁶⁸ ALAM 94 assume ec $B(D^+ \rightarrow K^- \pi^+ \pi^- \pi^+ \pi^- \pi^+ \pi^- \pi^+ \pi^- \pi^+ \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^-$	+) and qual proc +), the 20%.	B(D_2^* (2460) ⁰ → duction of B^+ and CLEO II B(D^* (2)	d B^0 at the $D^+\pi^-)=3$ d B^0 at the D10) $^+\to D^0$	ア(45) and に 80%. ア(45) and に	ise the Mark III $(D_2^*(2460)^0 \rightarrow$
B($D^+ \to K^- \pi^+ \pi^- \pi^+ \pi^- \pi^+ \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^-$	+) and qual proceed, the 20%.	B(D_2^* (2460) ⁰ → duction of B^+ and CLEO II B(D^* (2)	d B^0 at the $D^+\pi^-)=3$ d B^0 at the D10) $^+\to D^0$	T(45) and $00%$. T(45) and 0	ise the Mark III (<i>D</i> [*] ₂ (2460) ⁰ → Г 32/ Г
B($D^+ o K^- \pi^+ \pi^- \pi^+ \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^-$	+) and qual proceed, the 20%.	B(D_2^* (2460) ⁰ → duction of B^+ and CLEO II B(D^* (24)	d B^0 at the $D^+\pi^-)=3$ d B^0 at the $D^{(0)}+\rightarrow D^0$	T (45) and t (45) and t (45) and t (45) and t	use the Mark III $(D_2^*(2460)^0 \rightarrow \Gamma_{32}/\Gamma$
B($D^+ \rightarrow K^- \pi^+ \pi^- \pi^+ \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^-$	+) and qual proceed, the 20%.	B(D*2(2460) ⁰ → duction of B+ an CLEO II B(D*(2) DOCUMENT ID 69 GIBAUT	d B^0 at the $D^+\pi^-)=3$ d B^0 at the D10)+ \rightarrow D^0 7ECN 96 CLE2 92G ARG	$T(45)$ and t 10%. $T(45)$ and t π^+) and t π^+ and t π^+ t	ise the Mark III $(D_2^*(2460)^0 \rightarrow \Gamma_{32}/\Gamma$ $T(4S)$ $T(4S)$
B($D^+ \rightarrow K^- \pi^+ \pi^- \pi^+ \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^-$	+) and qual proc +), the 20%. <u>EVTS</u> /ERAGE	B(D*(2460) ⁰ → fuction of B+ an CLEO II B(D*(2) DOCUMENT ID 69 GIBAUT 70 ALBRECHT 71 BORTOLETT	d B^0 at the $D^+\pi^-)=3$ d B^0 at the $D^0\to D^0$	$T(45)$ and t 10%. $T(45)$ and t π^+) and t π^+ and t π^+ t	use the Mark III $(D_2^*(2460)^0 \rightarrow \Gamma_{32}/\Gamma$ Γ_{45} Γ_{45} Γ_{45}
B($D^+ \rightarrow K^- \pi^+ \pi^-$ 68 ALAM 94 assume ec B($D^+ \rightarrow K^- \pi^+ \pi^-$ $D^*(2010)^+ \pi^-) = 2$ ($D^0 D_a^+$)/ Γ_{total} ALUE .012 ± 0.004 OUR AV .0122 ± 0.0032 $^+$ 0.0029 .016 ± 0.007 ± 0.004 59 GIBAUT 96 reports 0 to our best value B experiment's error an	+) and qual proc. +), the 20%. EVTS /ERAGE 5.0.0126 ± (D ₅ ⁺ → d our sed	B($D_2^*(2460)^0 \rightarrow$ duction of B^+ and CLEO II B($D^*(2i)^0$ 0 0 0 0 0 0 0 0 0	d B^0 at the $D^+\pi^-)=3$ d B^0 at the D^0 0) D^0 1 D^0 2 D^0 3 at the D^0 4 D^0 5 D^0 6 D^0 7 D^0 7 D^0 7 D^0 7 D^0 7 D^0 8 D^0 9 CLEO for D^0 9 CLEO for D^0 9 $D^$	T(45) and t 10%. $T(45)$ and t θ	use the Mark III $(D_2^*(2460)^0 \rightarrow \Gamma_{32}/\Gamma$ $\Gamma(45)$ $\Gamma(45)$ $\Gamma(45)$ 335. We rescale it error is their our best value.
B($D^+ \rightarrow K^- \pi^+ \pi^-$ 68 ALAM 94 assume ec B($D^+ \rightarrow K^- \pi^+ \pi^ D^*(2010)^+ \pi^-) = 2$ ($D^0 D_a^+$)/ Γ_{total} ALUE .012 ±0.004 OUR AV .0122 ±0.0032 ±0.0029 .018 ±0.009 ±0.004 .016 ±0.007 ±0.004 .059 GIBAUT 96 reports 0 to our best value B experiment's error an TO ALBRECHT 92G rep	+) and qual proc. +), the 20%. EVTS /ERAGE 5 0.0126 ± (D + → d our seconts 0.0	B($D_2^*(2460)^0 \rightarrow$ duction of B^+ and CLEO II B($D^*(2i)^0$ DOCUMENT ID 69 GIBAUT 70 ALBRECHT 71 BORTOLETT 0.0022 \pm 0.0025 $\phi \pi^+$) = (3.6 cond error is the second error is th	d B^0 at the $D^+\pi^-)=3$ d B^0 at the D10) $^+\to D^0$ 7ECN 96 CLE2 926 ARG 6090 CLEO for B($D^+_s\to 0$) × 10 ⁻¹ ystematic erro 1004 for B($D^+_s\to 0$)	T(45) and t 10%. $T(45)$ and t θ π^+) and θ	use the Mark III $(D_2^*(2460)^0 \rightarrow \Gamma_{32}/\Gamma$ $\Gamma(45)$ $\Gamma(45)$ $\Gamma(45)$ 335. We rescale it error is their our best value. = 0.027. We
B($D^+ \rightarrow K^- \pi^+ \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^-$	+) and qual proc. $+$), the 20%. EVTS /ERAGE 5 0.0126 \pm do our seconts 0.0 alue B(D our second our se	B($D_2^*(2460)^0 \rightarrow$ fuction of B^+ and CLEO II B($D^*(2i)^0$ DOCUMENT ID 69 GIBAUT 70 ALBRECHT 71 BORTOLETT 0.0022 \pm 0.0025 $\phi \pi^+$) = (3.6 cond error is the s 24 \pm 0.012 \pm 0.0 $\phi \pi^+$) = (5.0 cond error is the sching ratios, e.g.,	d B^0 at the $D^+\pi^-)=3$ d B^0 at the D10) $^+\to D^0$ 96 CLE2 92G ARG FO90 CLEO for B($D_s^+\to t^0$) ystematic erropod for B($D_s^0\to t^0$)	T(45) and t 10%. $T(45)$ and t π^+) and t	ise the Mark III $(D_2^*(2460)^0 \rightarrow F_{32}/\Gamma$ $T(45)$ $T(45)$ $T(45)$ $T(45)$ 335. We rescale at error is their our best value. $= 0.027. \text{ We rester our beta to ur best value.}$ $= 1.5 \times 10^{-10} \text{ m}$
B($D^+ \rightarrow K^- \pi^+ \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^-$	+) and qual proc. +), the 20%. EVTS /ERAGE 5.0.0126 \pm 0.0126 \pm 0.0136 do our seconts 0.0 allow B(D) did our seconts 0.0 allow B(D) bran eports 0.0 al	B($D_2^*(2460)^0 \rightarrow$ fuction of B^+ and CLEO II B($D^*(2i)^0$ further in the properties of the prope	d B^0 at the $D^+\pi^-)=3$ d B^0 at the D10)+ \rightarrow D^0 TECN 96 CLE2 92G ARG 7990 CLE0 for $B(D_s^+\to \pm 0.9)\times 10^-$ ystematic erro 004 for $B(D_s^+\to 0.9)\times 10^-$ ystematic erro $B(D^0\to K^-)$ $B(D^0\to K^-)$ $C(D_s^+\to \phi\pi^+)$	T(45) and t 100%. $T(45)$ and t π^+) and t	ise the Mark III. $(D_2^*(2460)^0 \rightarrow \Gamma_{32}/\Gamma$ $T(45)$ $T(45)$ $T(45)$ 335. We rescale it error is their our best value. = 0.027. We rester our best value. 1 ± 0.25%. The rescale to our best value.
B($D^+ \rightarrow K^- \pi^+ \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^-$	+) and qual proc +), the 20%. EVIS /ERAGE 5 0.0126 \pm d our seconts 0.0 alue B(D d our seconts 0.0 \pm methods of D 0 bran exports 0.0 \pm	B($D_2^*(2460)^0 \rightarrow$ function of B^+ and CLEO II B($D^*(2i)^0$ function of B^+ and CLEO II B($D^*(2i)^0$ function of B^+ and CLEO II B($D^*(2i)^0$ function of B^+ fun	d B^0 at the $D^+\pi^-)=3$ d B^0 at the $D^0+\pi^-=3$ d D^0	T(45) and t 10%. $T(45)$ and t π^+) and t	tise the Mark III $(D_2^*(2460)^0 \rightarrow \Gamma_{32}/\Gamma$ $\Gamma(45)$ $\Gamma(45)$ $\Gamma(45)$ $\Gamma(45)$ 335. We rescale it error is their our best value. = 0.027. We set error is their our best value. 1 ± 0.25%. e rescale to our dir experiment's
B($D^+ \to K^- \pi^+ \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^-$	+) and qual proc +), the 20%. EVIS /ERAGE 5 0.0126 \pm d our seconts 0.0 alue B(D d our seconts 0.0 \pm methods of D 0 bran exports 0.0 \pm	B($D_2^*(2460)^0 \rightarrow$ function of B^+ and CLEO II B($D^*(2i)^0$ function of B^+ and CLEO II B($D^*(2i)^0$ function of B^+ and CLEO II B($D^*(2i)^0$ function of B^+ fun	d B^0 at the $D^+\pi^-)=3$ d B^0 at the $D^0+\pi^-=3$ d D^0	T(45) and t 10%. $T(45)$ and t π^+) and t	tise the Mark III $(D_2^*(2460)^0 \rightarrow \Gamma_{32}/\Gamma$ $\Gamma(45)$ $\Gamma(45)$ $\Gamma(45)$ $\Gamma(45)$ 335. We rescale it error is their our best value. = 0.027. We set error is their our best value. 1 ± 0.25%. e rescale to our dir experiment's
B($D^+ \rightarrow K^-\pi^+\pi^-\pi^+\pi^-\pi^+\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi$	+) and qual proc- +), the 20%. EVTS /ERAGE 5 0.0126 \pm 0.0126 \pm 0.0126 do ur see ports 0.0 Alue B(D 0 do ur see ports 0.0 \pm 0.00 do ur see ports 0.0 error is	B($D_2^*(2460)^0 \rightarrow$ fuction of B^+ and CLEO II B($D^*(2i)^0$ further in the properties of the prope	d B^0 at the $D^+\pi^-)=3$ d B^0 at the $D^0+\pi^-=3$ d D^0	T(45) and t 10%. $T(45)$ and t π^+) and t	ise the Mark III. $(D_2^*(2460)^0 \rightarrow F_{32}/\Gamma$ $T(45)$ $T(45)$ $T(45)$ 335. We rescale it error is their our best value. $= 0.027$. We state error is their our best value. 1 $\pm 0.25\%$. The rescale is the error is their our best value. 1 $\pm 0.25\%$. The error is their our best value.
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B($D^+ \rightarrow K^- \pi^+ \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^-$	+) and qual proc- +), the 20%. EVTS /ERAGE 5 0.0126 \pm 0.0126 \pm 0.0126 do ur see ports 0.0 Alue B(D 0 do ur see ports 0.0 \pm 0.00 do ur see ports 0.0 error is	B($D_2^*(2460)^0 \rightarrow$ function of B^+ and CLEO II B($D^*(2i)^0$ function of B^+ and CLEO II B($D^*(2i)^0$ function of B^+ and CLEO II B($D^*(2i)^0$ function of B^+ fun	d B^0 at the $D^+\pi^-$) = 3 d B^0 at the D10) $^+\to D^0$ 96 CLE2 92G ARG GO90 CLE0 for B($D^+_s\to D^0$) $^+\to D^0$ 3.6 ± 0.9) $^+\to D^0$ 13ystematic error B($D^+_s\to D^0$) $^+\to D^0$ 14ystematic error B($D^+_s\to D^0$) $^+\to D^0$ 15ystematic error B($D^+_s\to D^0$) $^+\to D^0$ 16ystematic error B($D^+_s\to D^0$) $^+\to D^0$ 17ystematic error B($D^+_s\to D^0$) $^+\to D^0$	$T(45)$ and t 10%. $T(45)$ and t 10%. $T(45)$ and t θ π^+) and t θ	ise the Mark III $(D_2^*(2460)^0 \rightarrow \Gamma_{32}/\Gamma$ $T(45)$ $T(45)$ $T(45)$ 335. We rescale at error is their our best value. $= 0.027. \text{ We esteror is their our best value.}$ $= 1.0.25\%.$ e rescale to our dir experiment's lue. Γ_{33}/Γ $T(45)$
B($D^+ \rightarrow K^- \pi^+ \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^-$	+) and qual proc++), the 20%. EVTS //ERAGE 5 0.0126 \pm 0.00136	B($D_2^*(2460)^0 \rightarrow$ fuction of B^+ and CLEO II B($D^*(2i)^0$ fuction of B^+ and CLEO II B($D^*(2i)^0$ function of B^+ and B^+ function of B^+ fun	d B^0 at the $D^+\pi^-$) = 3 d B^0 at the D10) $^+\to D^0$ 96 CLE2 92G ARG GO90 CLE0 for B($D^+_s\to D^0$) $^+\to D^0$ 3.6 ± 0.9) $^+\to D^0$ 1.5 yetematic erro 1.6 ± 0.9 $^+\to D^0$ 1.6 ± 0.9 $^+\to D^0$ 1.7 yetematic erro 1.8 ± 0.9 $^+\to D^0$ 1.8 yetematic erro 1.9 yetemat	$T(45)$ and t 10%. $T(45)$ and t 10%. $T(45)$ and t θ π^+) and t θ	ise the Mark III $(D_2^*(2460)^0 \rightarrow \Gamma_{32}/\Gamma$ $T(45)$ $T(45)$ $T(45)$ 335. We rescale at error is their our best value. $= 0.027. \text{ We est error is their our best value.}$ $= 1 \pm 0.25\%.$ e rescale to our dir experiment's lue. Γ_{33}/Γ $T(45)$ $T(45)$
B($D^+ \rightarrow K^- \pi^+ \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^-$	+) and qual proc. +), the 20%. EVTS // ERAGE 5 0.0126 \pm ($D_s^+ \rightarrow$ do our seconts 0.0 alue B(D_s^0 do our seconts 0.0 eports 0. $\phi \pi^+$): error is	B($D_2^*(2460)^0 \rightarrow$ fuction of B^+ and CLEO II B($D^*(2i)^0$ fuction of B^+ and CLEO II B($D^*(2i)^0$ function of B^+ and CLEO II B($D^*(2i)^0$ function of B^+ funct	d B^0 at the $D^+\pi^-$) = 3 d B^0 at the D10) $^+\to D^0$ $^-\to D$	$T(45)$ and t 10%. $T(45)$ and t 10%. $T(45)$ and t θ π^+) and t θ	ise the Mark III $(D_2^*(2460)^0 \rightarrow \Gamma_{32}/\Gamma$ $T(45)$ $T(45)$ $T(45)$ 335. We rescale at error is their our best value. $= 0.027. \text{ We}$ $= 0.027. \text{ We}$ $= 1 \pm 0.25\%.$ e rescale to our dir experiment's lue. Γ_{33}/Γ $T(45)$ $T(45)$ 335. We rescale
B($D^+ \rightarrow K^- \pi^+ \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^- \pi^-$	+) and qual proc. +), the 20%. EVTS /ERAGE 5 0.0126 \pm 0.0127	B($D_2^*(2460)^0 \rightarrow$ fuction of B^+ and CLEO II B($D^*(2i)^0$ further in the properties of the prope	d B^0 at the $D^+\pi^-$) = 3 d B^0 at the D10) $+\to D^0$	$T(45)$ and t 10%. $T(45)$ and t 10%. $T(45)$ and t π^+) and t	ise the Mark III. $(D_2^*(2460)^0 \rightarrow \Gamma_{32}/\Gamma$ $T(45)$ $T(45)$ $T(45)$ 335. We rescale at error is their our best value. $= 0.027$. We rescale to our direct value. $1 \pm 0.25\%$. The rescale to our direct value. Γ_{33}/Γ $T(45)$ $T(45)$ 335. We rescale te error is their our best value. Γ_{33}/Γ $T(45)$ $T(45)$ 335. We rescale te error is their our best value. Γ_{33}/Γ

	DOCUMENT ID TECH COMMENT
0.012±0.005 OUR AVERA	
0.014±0.005±0.003 0.010±0.007±0.002	⁷⁴ GIBAUT 96 CLE2 $e^+e^- \rightarrow \Upsilon(4S)$ ⁷⁵ ALBRECHT 92G ARG $e^+e^- \rightarrow \Upsilon(4S)$
	$140 \pm 0.0043 \pm 0.0035$ for B($D_s^+ \rightarrow \phi \pi^+$) = 0.035. We re
experiment's error and o	$_{2}^{+}$ \rightarrow $\phi\pi^{+}$) = (3.6 \pm 0.9) \times 10 ⁻² . Our first error is our second error is the systematic error from using our best v ts 0.013 \pm 0.009 \pm 0.002 for B(D_{s}^{+} \rightarrow $\phi\pi^{+}$) = 0.027.
rescale to our best value experiment's error and o Assumes PDG 1990 D ⁰	e B($D_s^+ \to \phi \pi^+$) = (3.6 \pm 0.9) \times 10 ⁻² . Our first error is our second error is the systematic error from using our best v. D_s^0 and D^* (2007) D_s^0 branching ratios, e.g., B($D^0 \to K^- \pi^+$ *(2007) $D_s^0 \to D^0 \pi^0$) = 55 \pm 6%.
$\Gamma(\widehat{D}^{\circ}(2007)^{0}D_{g}^{\circ+})/\Gamma_{to}$	tal Fg
VALUE	DOCUMENT ID TECN COMMENT
0.027±0.010 OUR AVERA	
0.030 ± 0.011 ± 0.007 0.023 ± 0.013 ± 0.006	⁷⁶ GIBAUT 96 CLE2 $e^+e^- \rightarrow \Upsilon(4S)$ ⁷⁷ ALBRECHT 92G ARG $e^+e^- \rightarrow \Upsilon(4S)$
	$310 \pm 0.0088 \pm 0.0065$ for B($D_s^+ \rightarrow \phi \pi^+$) = 0.035. We rest
experiment's error and of 77 ALBRECHT 92G report	$_{2}^{+}$ \rightarrow $\phi\pi^{+}$) = (3.6 \pm 0.9) \times 10 ⁻² . Our first error is our second error is the systematic error from using our best vision 0.031 \pm 0.016 \pm 0.005 for B(D_{S}^{+} \rightarrow $\phi\pi^{+}$) = 0.027.
experiment's error and of Assumes PDG 1990 D ^C	e B($D_s^+ \to \phi \pi^+$) = (3.6 \pm 0.9) × 10 ⁻² . Our first error is our second error is the systematic error from using our best value of the properties of t
	, ·
$\Gamma(D_s^+\pi^0)/\Gamma_{\text{total}}$	Гэ
	38 DOCUMENT ID TECN COMMENT
<0.00020 9	
	rts $< 2.0 imes 10^{-4}$ for B($D_s^+ o \phi \pi^+$) = 0.037. We rescal
our best value $B(D_s^+$ -	$\phi \pi^{+} = 0.036.$
$\left[\Gamma(D_s^+\pi^0)+\Gamma(D_s^{*+}\pi^0\right]$	
	% DOCUMENT ID TECN COMMENT
<0.0007 90	
'ALBRECHT 93E reports	$6 < 0.9 \times 10^{-3}$ for B($D_s^+ o \phi \pi^+$) = 0.027. We rescale to
	4.
best value $B(D_s^+ \rightarrow \phi)$	π^{-}) = 0.036.
•	
$\Gamma(D_s^{*+}\pi^0)/\Gamma_{\text{total}}$	Гз
$\Gamma(D_s^{*+}\pi^0)/\Gamma_{\text{total}}$	S DOCUMENT ID TECN COMMENT
Γ(D _s ⁺⁺ π ⁰)/Γ _{total} <u>VALUE</u> GI <0.00033 90	$\begin{array}{cccccccccccccccccccccccccccccccccccc$
Γ(D _g ⁺⁺ π ⁰)/Γ _{total} VALUE CO.00033 SO ALEXANDER 93B report	1.3 DOCUMENT ID TECN COMMENT 80 ALEXANDER 938 CLE2 $e^+e^- \rightarrow T(45)$ 1.5 $< 3.2 \times 10^{-4}$ for $B(D_5^+ \rightarrow \phi \pi^+) = 0.037$. We rescal
Γ(D _s ⁺⁺ π ⁰)/Γ _{total} <u>VALUE</u> GI <0.00033 90	1.3 DOCUMENT ID TECN COMMENT 80 ALEXANDER 938 CLE2 $e^+e^- \rightarrow T(45)$ 1.5 $< 3.2 \times 10^{-4}$ for $B(D_5^+ \rightarrow \phi \pi^+) = 0.037$. We rescal
$\Gamma(D_g^{o+}\pi^0)/\Gamma_{\text{total}}$ VALUE GI <a.00033< a=""> 90 80 ALEXANDER 938 report our best value $B(D_g^+$ —</a.00033<>	Tech Comment in Tech Comment 10 80 ALEXANDER 938 CLE2 $e^+e^- \rightarrow T(45)$ at $< 3.2 \times 10^{-4}$ for $B(D_s^+ \rightarrow \phi \pi^+) = 0.037$. We rescale $\phi \pi^+ = 0.036$.
$\Gamma(D_s^{o+}\pi^0)/\Gamma_{\text{total}}$ VALUE GI 80 ALEXANDER 93B report our best value $B(D_s^+ \rightarrow \Gamma(D_s^+\eta)/\Gamma_{\text{total}})$	Table 1.25. DOCUMENT ID TECN COMMENT 1.26. BO ALEXANDER 93B CLE2 $e^+e^- \rightarrow T(45)$ 1.27. $e^+e^- \rightarrow T(45)$ 1.28. $e^+e^- \rightarrow T(45)$ 1.29. $e^+e^- \rightarrow T(45)$ 1.29. $e^+e^- \rightarrow T(45)$ 1.29. $e^+e^- \rightarrow T(45)$ 1.29. $e^+e^- \rightarrow T(45)$ 1.20. $e^-e^- \rightarrow T$
$\Gamma(D_s^{o+}\pi^0)/\Gamma_{\text{total}}$ VALUE GI 80 ALEXANDER 93B report our best value $B(D_s^+ \rightarrow \Gamma(D_s^+\eta)/\Gamma_{\text{total}})$	Table 1.35. DOCUMENT ID TECN COMMENT 1.36. DOCUMENT ID TECN COMMENT 1.37. 80 ALEXANDER 938 CLE2 $e^+e^- \rightarrow T(45)$ 1.38. 40 ALEXANDER 938 CLE2 $e^+e^- \rightarrow T(45)$ 1.39. 40 ALEXANDER 938 CLE2 $e^-e^- \rightarrow T(45)$ 1.39.
$\Gamma(D_s^{o+}\pi^0)/\Gamma_{\text{total}}$ VALUE 60 C1.00033 90 80 ALEXANDER 938 repoir our best value $B(D_s^+ - \Gamma(D_s^+\eta)/\Gamma_{\text{total}})$ VALUE C1.0005 90	Table 20 Section 1.5 Section
$\Gamma(D_s^{o+} \pi^0)/\Gamma_{\text{total}}$ VALUE 63 80 ALEXANDER 938 repoin our best value $B(D_s^+ - \Gamma(D_s^+ \eta)/\Gamma_{\text{total}})$ VALUE 61 81 ALEXANDER 938 repoin 938 repoin 940	Table 1.5. So that the second
$\Gamma(D_s^{o+}\pi^0)/\Gamma_{\text{total}}$ VALUE GI 40.00033 90 80 ALEXANDER 93B repoi our best value B(D_s^+ — $\Gamma(D_s^+\eta)/\Gamma_{\text{total}}$ VALUE CI <0.0006 91 ALEXANDER 93B repoi our best value B(D_s^+ — GI VALUE GI	Table 1.5. So that the second
$\Gamma(D_s^{o+}\pi^0)/\Gamma_{\text{total}}$ <u>VALUE</u> GI 80 ALEXANDER 93B repoi our best value B(D_s^+ — $\Gamma(D_s^+\eta)/\Gamma_{\text{total}}$ <u>VALUE</u> GI <0.0005 93 81 ALEXANDER 93B repoi our best value B(D_s^+ —	The second state of the s
$\Gamma(D_s^{o+}\pi^0)/\Gamma_{\text{total}}$ VALUE GI 80 ALEXANDER 93B report our best value $B(D_s^+ \rightarrow C_s^+)/\Gamma_{\text{total}}$ VALUE CI <0.0005 81 ALEXANDER 93B report our best value $B(D_s^+ \rightarrow C_s^+)/\Gamma_{\text{total}}$ $\Gamma(D_s^+\pi)/\Gamma_{\text{total}}$ VALUE CI $\Gamma(D_s^+\pi)/\Gamma_{\text{total}}$ VALUE CI $\Gamma(D_s^+\pi)/\Gamma_{\text{total}}$	Table 1.35 and 1.36
$\Gamma(D_s^{o+} \pi^0)/\Gamma_{\text{total}}$ VALUE < 0.00033 $= 90$ $= 80$ ALEXANDER 938 report our best value $B(D_s^+ - 1)$ $= 100005$ $= 10$	Table 2.5 Solution 1.0 Solutio
$\Gamma(D_s^{+} + \pi^0)/\Gamma_{\text{total}}$ $VALUE$ < 0.00033 90 0.0033 90 0.0033 90 0.0033 90 0.0033 90 0.0033 0.0	The second state of the second secon
$\Gamma(D_s^{o+} \pi^0)/\Gamma_{\text{total}}$ VALUE < 0.00033 $= 90$ $= 80$ ALEXANDER 938 report our best value $B(D_s^+ - 1)$ $= 100005$ $= 10$	The second state of the second secon
$\Gamma(D_s^{o+}\pi^0)/\Gamma_{\text{total}}$ VALUE 40.00033 80 ALEXANDER 93B report our best value $B(D_s^+ \rightarrow C_s^+)/\Gamma_{\text{total}}$ VALUE 40.0005 81 ALEXANDER 93B report our best value $B(D_s^+ \rightarrow C_s^+)/\Gamma_{\text{total}}$ VALUE 40.0008 90 82 ALEXANDER 93B report our best value $B(D_s^+ \rightarrow C_s^+)/\Gamma_{\text{total}}$ VALUE 40.0008 90 82 ALEXANDER 93B report our best value $B(D_s^+ \rightarrow C_s^+)/\Gamma_{\text{total}}$	Table 1.35 Solution 1.05 Solu
$\Gamma(D_s^{o+} \pi^0)/\Gamma_{\text{total}}$ VALUE Q.00033 80 ALEXANDER 93B report our best value $B(D_s^+ \rightarrow C_s^+ \pi^0)/\Gamma_{\text{total}}$ VALUE Q.0006 91 ALEXANDER 93B report our best value $B(D_s^+ \rightarrow C_s^+ \pi^0)/\Gamma_{\text{total}}$ VALUE Q.0008 82 ALEXANDER 93B report our best value $B(D_s^+ \rightarrow C_s^+ \pi^0)/\Gamma_{\text{total}}$ VALUE $C(D_s^+ \pi^0)/\Gamma_{\text{total}}$ $C(D_s^+ \pi^0)/\Gamma_{\text{total}}$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$
$\Gamma(D_s^{o+} \pi^0)/\Gamma_{\text{total}}$ VALUE (20.00033) (30) (30) ALEXANDER 93B report our best value $B(D_s^+ \rightarrow 0.0005)$ (30)	The second state of the s
$\Gamma(D_s^{+} + \pi^0)/\Gamma_{\text{total}}$ VALUE Signal Si	The second state of the s
$\Gamma(D_s^{+} + \pi^0)/\Gamma_{\text{total}}$ VALUE Signature 40.00033 80 ALEXANDER 938 report our best value $B(D_s^+ \rightarrow C_s^+)/\Gamma_{\text{total}}$ VALUE CI CO.0005 81 ALEXANDER 938 report our best value $B(D_s^+ \rightarrow C_s^+)/\Gamma_{\text{total}}$ VALUE CI CO.0008 82 ALEXANDER 938 report our best value $B(D_s^+ \rightarrow C_s^+)/\Gamma_{\text{total}}$ VALUE CI CO.0008 82 ALEXANDER 938 report our best value $B(D_s^+ \rightarrow C_s^+)/\Gamma_{\text{total}}$ VALUE CI CO.0004 83 ALEXANDER 938 report 90 83 ALEXANDER 938 report	The second state of the s
$\Gamma(D_s^{+} + \pi^0)/\Gamma_{\text{total}}$ VALUE Signal Si	The second state of the s
$\Gamma(D_s^{+} + \pi^0)/\Gamma_{\text{total}}$ VALUE $<$ $<$ $<$ $<$ $<$ $<$ $<$ $<$ $<$ $<$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$
$\Gamma(D_s^{+} + \pi^0)/\Gamma_{\text{total}}$ 20.00033 90 80 ALEXANDER 93B report our best value $B(D_s^+ \rightarrow C_s^+)/\Gamma_{\text{total}}$ 20.0006 90 81 ALEXANDER 93B report our best value $B(D_s^+ \rightarrow C_s^+)/\Gamma_{\text{total}}$ 20.0008 90 82 ALEXANDER 93B report our best value $B(D_s^+ \rightarrow C_s^+)/\Gamma_{\text{total}}$ 21.0008 90 82 ALEXANDER 93B report our best value $B(D_s^+ \rightarrow C_s^+)/\Gamma_{\text{total}}$ 22.0004 90 83 ALEXANDER 93B report our best value $B(D_s^+ \rightarrow C_s^+)/\Gamma_{\text{total}}$ 24.0004 90 83 ALEXANDER 93B report our best value $B(D_s^+ \rightarrow C_s^+)/\Gamma_{\text{total}}$ 26.0004 90 87 ALEXANDER 93B report our best value $B(D_s^+ \rightarrow C_s^+)/\Gamma_{\text{total}}$	The second state of the s
$\Gamma(D_s^{+} + \pi^0)/\Gamma_{\text{total}}$ VALUE Signature 80 ALEXANDER 938 report our best value $B(D_s^+ \rightarrow D_s^+)/\Gamma_{\text{total}}$ VALUE CO.0005 81 ALEXANDER 938 report our best value $B(D_s^+ \rightarrow D_s^+)/\Gamma_{\text{total}}$ VALUE CO.0008 82 ALEXANDER 938 report our best value $B(D_s^+ \rightarrow D_s^+)/\Gamma_{\text{total}}$ VALUE CO.0004 90 83 ALEXANDER 938 report our best value $B(D_s^+ \rightarrow D_s^+)/\Gamma_{\text{total}}$ VALUE CI. CO.0004 93 ALEXANDER 938 report our best value $B(D_s^+ \rightarrow D_s^+)/\Gamma_{\text{total}}$ VALUE CI. CO.0004 CO.0004	The second state of the s
$\Gamma(D_s^{\bullet+}\pi^0)/\Gamma_{\text{total}}$ VALUE Signature 40.00033 90 80 ALEXANDER 938 report our best value $B(D_s^+ \rightarrow C_s^+)/\Gamma_{\text{total}}$ VALUE C1.0006 91 81 ALEXANDER 938 report our best value $B(D_s^+ \rightarrow C_s^+)/\Gamma_{\text{total}}$ VALUE C2.0008 82 ALEXANDER 938 report our best value $B(D_s^+ \rightarrow C_s^+)/\Gamma_{\text{total}}$ VALUE C3.0008 83 ALEXANDER 938 report our best value $B(D_s^+ \rightarrow C_s^+)/\Gamma_{\text{total}}$ VALUE C4.0004 90 83 ALEXANDER 938 report our best value $B(D_s^+ \rightarrow C_s^+)/\Gamma_{\text{total}}$ VALUE C4.0004 91 83 ALEXANDER 938 report our best value $B(D_s^+ \rightarrow C_s^+)/\Gamma_{\text{total}}$ VALUE C4.0004 92 84 ALEXANDER 938 report our best value $B(D_s^+ \rightarrow C_s^+)/\Gamma_{\text{total}}$ VALUE C4.0005 90 C4.0005	$\begin{array}{cccccccccccccccccccccccccccccccccccc$
$\Gamma(D_s^{\bullet+}\pi^0)/\Gamma_{\text{total}}$ VALUE Signature 40.00033 90 80 ALEXANDER 938 report our best value $B(D_s^+ \rightarrow C_s^+)/\Gamma_{\text{total}}$ VALUE C1.0006 91 81 ALEXANDER 938 report our best value $B(D_s^+ \rightarrow C_s^+)/\Gamma_{\text{total}}$ VALUE C2.0008 82 ALEXANDER 938 report our best value $B(D_s^+ \rightarrow C_s^+)/\Gamma_{\text{total}}$ VALUE C3.0008 83 ALEXANDER 938 report our best value $B(D_s^+ \rightarrow C_s^+)/\Gamma_{\text{total}}$ VALUE C4.0004 90 83 ALEXANDER 938 report our best value $B(D_s^+ \rightarrow C_s^+)/\Gamma_{\text{total}}$ VALUE C4.0004 91 83 ALEXANDER 938 report our best value $B(D_s^+ \rightarrow C_s^+)/\Gamma_{\text{total}}$ VALUE C4.0004 92 84 ALEXANDER 938 report our best value $B(D_s^+ \rightarrow C_s^+)/\Gamma_{\text{total}}$ VALUE C4.0005 90 C4.0005	$\begin{array}{cccccccccccccccccccccccccccccccccccc$
$\Gamma(D_s^{+} + \pi^0)/\Gamma_{\text{total}}$ VALUE Signature 80 ALEXANDER 93B report our best value $B(D_s^+ \rightarrow C_s^+ \pi^0)/\Gamma_{\text{total}}$ VALUE C1. C2. C3. C4. C4. C9. C9. C9. C9. C9. C9	The second state of the s
$\Gamma(D_s^{\bullet+}\pi^0)/\Gamma_{total}$ VALUE 20.00033 80 ALEXANDER 938 report our best value $B(D_s^+ \rightarrow C_s^+)/\Gamma_{total}$ VALUE 20.0006 81 ALEXANDER 938 report our best value $B(D_s^+ \rightarrow C_s^+)/\Gamma_{total}$ VALUE 20.0008 82 ALEXANDER 938 report our best value $B(D_s^+ \rightarrow C_s^+)/\Gamma_{total}$ VALUE 21.0004 22.0004 23. ALEXANDER 938 report our best value $B(D_s^+ \rightarrow C_s^+)/\Gamma_{total}$ VALUE 24.0004 25. $C_s^+ \rho^0/\Gamma_{total}$ VALUE 26.0004 27. $C_s^+ \rho^0/\Gamma_{total}$ VALUE 28. $C_s^+ \rho^0/\Gamma_{total}$ VALUE 29. $C_s^+ \rho^0/\Gamma_{total}$ VALUE 20.0004 20.0004 20.0004 21. $C_s^+ \rho^0/\Gamma_{total}$ VALUE 22. $C_s^+ \rho^0/\Gamma_{total}$ VALUE 24. $C_s^+ \rho^0/\Gamma_{total}$ VALUE 25. $C_s^+ \rho^0/\Gamma_{total}$ VALUE 26. $C_s^+ \rho^0/\Gamma_{total}$ VALUE 27. $C_s^+ \rho^0/\Gamma_{total}$ VALUE 28. $C_s^+ \rho^0/\Gamma_{total}$ VALUE 29. $C_s^+ \rho^0/\Gamma_{total}$ VALUE 29. $C_s^+ \rho^0/\Gamma_{total}$ VALUE 20. $C_s^+ \rho^0/\Gamma_{total}$ VALUE 21. $C_s^+ \rho^0/\Gamma_{total}$ 22. $C_s^+ \rho^0/\Gamma_{total}$ VALUE 24. $C_s^+ \rho^0/\Gamma_{total}$ 25. $C_s^+ \rho^0/\Gamma_{total}$ 26. $C_s^+ \rho^0/\Gamma_{total}$ 27. $C_s^+ \rho^0/\Gamma_{total}$ 28. $C_s^+ \rho^0/\Gamma_{total}$ 29. $C_s^+ \rho^0/\Gamma_{total}$ 29. $C_s^+ \rho^0/\Gamma_{total}$ 20. $C_s^+ \rho^0/\Gamma_{total}$ 20. $C_s^+ \rho^0/\Gamma_{total}$ 20. $C_s^+ \rho^0/\Gamma_{total}$ 21. $C_s^+ \rho^0/\Gamma_{total}$ 22. $C_s^+ \rho^0/\Gamma_{total}$ 23. $C_s^+ \rho^0/\Gamma_{total}$ 24. $C_s^+ \rho^0/\Gamma_{total}$ 25. $C_s^+ \rho^0/\Gamma_{total}$ 26. $C_s^+ \rho^0/\Gamma_{total}$ 27. $C_s^+ \rho^0/\Gamma_{total}$ 28. $C_s^+ \rho^0/\Gamma_{total}$ 29. $C_s^+ \rho^0/\Gamma_{total}$	The second state of the s
$\Gamma(D_s^{+} + \pi^0)/\Gamma_{\text{total}}$ $VALUE$ GI 80 ALEXANDER 93B report our best value $B(D_s^{+} \rightarrow C_s^{-})$ $\Gamma(D_s^{+} \eta)/\Gamma_{\text{total}}$ $VALUE$ GI $VALU$	The second state of the s

⁸⁵ ALEXANDER 938 reports < 4.8 \times 10⁻⁴ for B($D_s^+ \rightarrow \phi \pi^+$) = 0.037. We rescale to

our best value B($D_s^+ \rightarrow \phi \pi^+$) = 0.036.

 R^{\pm}

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\left[\Gamma(D_s^{*+}\rho^0) + \Gamma(D_s^{*+}\vec{K}^*(892)^0)\right]/\Gamma_{\text{total}}
                                                                                                                        \Gamma(D_s^{\bullet+}\overline{K}^0)/\Gamma_{\text{total}}
                                                                                        (\Gamma_{41} + \Gamma_{51})/\Gamma
                                                                                                                                                                                                                          \Gamma_{49}/\Gamma
                                      DOCUMENT ID TECN COMMENT

86 ALBRECHT 93E ARG e+e- → \(\cap (45)\)
                                                                                                                                                               POCUMENT ID TECN COMMENT

99 ALEXANDER 93B CLE2 e^+e^- \rightarrow \Upsilon(45)
                                                                                                                        VALUE
                                                                                                                                                    CLX.
                           CLX
                                                                                                                         <0.0011
                                                                                                                                                      90
  <sup>86</sup> ALBRECHT 93E reports < 2.0 \times 10^{-3} for B(D_s^+ \rightarrow \phi \pi^+) = 0.027. We rescale to our
                                                                                                                         90 100 ALBRECHT 93E ARG e^+e^- \rightarrow T(45)
     best value B(D_e^+ \rightarrow \phi \pi^+) = 0.036.
                                                                                                                         <sup>99</sup>ALEXANDER 93B reports < 10.9 \times 10^{-4} for B(D_s^+ \rightarrow \phi \pi^+) = 0.037. We rescale to
 \Gamma(D_s^+\omega)/\Gamma_{\text{total}}
                                                                                                  \Gamma_{42}/\Gamma
                                                                                                                            our best value B(D_c^+ \rightarrow \phi \pi^+) = 0.036.
                                      POCUMENT ID TECN COMMENT

87 ALEXANDER 93B CLE2 e^+e^- \rightarrow T(4S)
                              CL%
                                                                                                                        <sup>100</sup>ALBRECHT 93E reports < 3.1 \times 10^{-3} for B(D_c^+ \rightarrow \phi \pi^+) = 0.027. We rescale to our
                              90
                                                                                                                            best value B(D_s^+ \rightarrow \phi \pi^+) = 0.036.
 • • • We do not use the following data for averages, fits, limits, etc. • • •
                              90 88 ALBRECHT 93E ARG e^+e^- \rightarrow \Upsilon(45)
                                                                                                                        \Gamma(D_s^+\overline{K}^*(892)^0)/\Gamma_{\text{total}}
                                                                                                                                                                                                                          \Gamma_{50}/\Gamma
  <sup>87</sup> ALEXANDER 93B reports < 4.8 \times 10^{-4} for B(D_c^+ \rightarrow \phi \pi^+) = 0.037. We rescale to
                                                                                                                                                                   DOCUMENT ID TECN COMMENT
                                                                                                                                                      CL%
                                                                                                                                                     90 101 ALEXANDER 93B CLE2 e^+e^- \rightarrow T(45)
     our best value B(D_s^+ \rightarrow \phi \pi^+) = 0.036.
  <sup>88</sup> ALBRECHT 93E reports < 3.4 \times 10^{-3} for B(D_s^+ 	o \phi \pi^+) = 0.027. We rescale to our
                                                                                                                        <sup>101</sup>ALEXANDER 93B reports < 4.4 \times 10<sup>-4</sup> for B(D_s^+ \rightarrow \phi \pi^+) = 0.037. We rescale to
                                                                                                                            our best value B(D_s^+ \rightarrow \phi \pi^+) = 0.036.
    best value B(D_s^+ \rightarrow \phi \pi^+) = 0.036.
 \Gamma(D_s^{*+}\omega)/\Gamma_{\text{total}}
                                                                                                                        \Gamma(D_s^{*+}\overline{K}^*(892)^0)/\Gamma_{\text{total}}
                                                                                                  \Gamma_{43}/\Gamma
                                                                                                                                                                                                                          \Gamma_{51}/\Gamma
                          CL% DOCUMENT ID TECN COMMENT

90 89 ALEXANDER 938 CLE2 e^+e^- \rightarrow \Upsilon(4S)
                                                                                                                                                   CL%
                                                                                                                                                                   DOCUMENT ID TECN COMMENT
                                                                                                                                                     90 102 ALEXANDER 938 CLE2 e^+e^- \rightarrow T(45)
 < 0.0007
                                                                                                                         < 0.0004
 ^{102} ALEXANDER 93B reports < 4.3 \times 10^{-4} for B(D_{c}^{+} \rightarrow \phi \pi^{+}) = 0.037. We rescale to
                                       ^{90} ALBRECHT 93E ARG e^+e^- \rightarrow \Upsilon(4S)
                              90
                                                                                                                             our best value B(D_s^+ \rightarrow \phi \pi^+) = 0.036.
  <sup>89</sup> ALEXANDER 93B reports < 6.8 \times 10^{-4} for B(D_s^+ \rightarrow \phi \pi^+) = 0.037. We rescale to
                                                                                                                        \Gamma(D_s^-\pi^+K^+)/\Gamma_{\text{total}}
                                                                                                                                                                                                                         \Gamma_{52}/\Gamma
     our best value B(D_s^+ \rightarrow \phi \pi^+) = 0.036.
                                                                                                                                                   90 103 ALBRECHT 93E ARG e^+e^- \rightarrow \Upsilon(4S)
                                                                                                                        VALUE
  ^{90} ALBRECHT 93E reports < 1.9 \times 10^{-3} for B(D_c^+ \to \phi \pi^+) = 0.027. We rescale to our
     best value B(D_s^+ \rightarrow \phi \pi^+) = 0.036.
                                                                                                                        ^{103} ALBRECHT 93E reports < 1.1 \times 10^{-3} for B(D_s^+ 	o \phi \pi^+) = 0.027. We rescale to our
\Gamma(D_s^+ a_1(1260)^0) / \Gamma_{\text{total}}
                                                                                                 \Gamma_{44}/\Gamma
                                                                                                                            best value B(D_s^+ \rightarrow \phi \pi^+) = 0.036.
                                           DOCUMENT ID TECN COMMENT
                       CL%
                                       91 ALBRECHT 93E ARG e+e- - T(45)
                                                                                                                        \Gamma(D_s^{*-}\pi^+K^+)/\Gamma_{\text{total}}
                                                                                                                                                                                                                          \Gamma_{53}/\Gamma
                                                                                                                                              <sup>91</sup> ALBRECHT 93E reports < 3.0 \times 10^{-3} for B(D_s^+ \rightarrow \phi \pi^+) = 0.027. We rescale to our
     best value B(D_s^+ \rightarrow \phi \pi^+) = 0.036.
                                                                                                                        <sup>104</sup> ALBRECHT 93E reports < 1.6 \times 10^{-3} for B(D_c^+ \rightarrow \phi \pi^+) = 0.027. We rescale to our
\Gamma(D_s^{++}a_1(1260)^0)/\Gamma_{\text{total}}
                                                                                                                            best value B(D_s^+ \rightarrow \phi \pi^+) = 0.036.
                                           DOCUMENT ID TECN COMMENT
VALUE
                            CL%
                                       92 ALBRECHT 93E ARG e^+e^- \rightarrow r(4S)
                                                                                                                        \Gamma(D_s^-\pi^+K^*(892)^+)/\Gamma_{\text{total}}
                                                                                                                                                                                                                         \Gamma_{54}/\Gamma
 < 0.0016
                              90
                                                                                                                                                                   DOCUMENT ID TECN COMMENT
                                                                                                                                                    92 ALBRECHT 93E reports < 2.2 \times 10^{-3} for B(D_c^+ \rightarrow \phi \pi^+) = 0.027. We rescale to our
     best value B(D_s^+ \rightarrow \phi \pi^+) = 0.036.
                                                                                                                        ^{105} ALBRECHT 93E reports < 8.6 \times 10^{-3} for B(D_s^+ 	o \phi \pi^+) = 0.027. We rescale to our
\Gamma(D_s^+\phi)/\Gamma_{\text{total}}
                                                                                                                            best value B(D_c^+ \rightarrow \phi \pi^+) = 0.036.
                                                                                                 Γ46/Γ
                                       \frac{DOCUMENT\ ID}{93} \ \frac{TECN}{COMMENT} \frac{COMMENT}{P^2} + \frac{TECN}{P^2} \frac{COMMENT}{P^2}
                             _____CL%_
                                                                                                                       \Gamma(D_s^{*-}\pi^+K^*(892)^+)/\Gamma_{\text{total}}
                                                                                                                                                                                                                         \Gamma_{55}/\Gamma
 < 0.00032
                              90
                                                                                                                                                 <sup>94</sup> ALBRECHT 93E ARG e^+e^- \rightarrow \Upsilon(4S)
                             90
                                                                                                                        <sup>106</sup> ALBRECHT 93E reports < 1.1 \times 10^{-2} for B(D_c^+ \rightarrow \phi \pi^+) = 0.027. We rescale to our
  <sup>93</sup> ALEXANDER 93B reports < 3.1 \times 10^{-4} for B(D_s^+ \rightarrow \phi \pi^+) = 0.037. We rescale to
                                                                                                                            best value B(D_s^+ \rightarrow \phi \pi^+) = 0.036.
    our best value B(D_s^+ \rightarrow \phi \pi^+) = 0.036.
 <sup>94</sup> ALBRECHT 93E reports < 1.7 \times 10^{-3} for B(D_s^+ \rightarrow \phi \pi^+) = 0.027. We rescale to our
                                                                                                                       \Gamma(J/\psi(15)K^+)/\Gamma_{\text{total}}
                                                                                                                                                                                                                         \Gamma_{56}/\Gamma
    best value B(D_c^+ \rightarrow \phi \pi^+) = 0.036.
                                                                                                                        VALUE (units 10-4) EVTS
                                                                                                                                                             DOCUMENT ID
                                                                                                                                                                                 TECN COMMENT
                                                                                                                         9.9 ± 1.0 OUR AVERAGE
\Gamma(D_s^{*+}\phi)/\Gamma_{\text{total}}
                                                                                                 \Gamma_{47}/\Gamma
                                                                                                                                                        107 JESSOP
                                                                                                                       10.2 \pm 0.8 \pm 0.7
                                                                                                                                                                                97 CLE2 e^+e^- \to \Upsilon(45)
VALUE
                              CL%
                                           DOCUMENT ID
                                                                 TECN COMMENT
                                                                                                                                                        108 BORTOLETTO92 CLEO e^+e^- \rightarrow \tau(45)
                                                                                                                         9.16 ± 3.01 ± 0.30
                                       95 ALEXANDER 938 CLE2 e^+e^- \rightarrow \Upsilon(45)
 < 0.0004
                                                                                                                                                       109 ALBRECHT 90J ARG e^+e^- \rightarrow T(4S)
                                                                                                                         8.0 \pm 3.5 \pm 0.3

    • • We do not use the following data for averages, fits, limits, etc.

                                                                                                                        • • • We do not use the following data for averages, fits, limits, etc. • • •
                          90 96 ALBRECHT 93E ARG e^+e^- \rightarrow r(4S)
                                                                                                                                                  59 110 ALAM
                                                                                                                       11.0 \pm 1.5 \pm 0.9
                                                                                                                                                                                94 CLE2 Repl. by JESSOP 97
                                                                                                                                                                               92G ALEP e^+e^- \rightarrow Z
87D ARG e^+e^- \rightarrow \Upsilon(4S)
 ^{95} ALEXANDER 93B reports < 4.2 	imes 10 ^{-4} for B(D_s^+ 	o \phi \pi^+) = 0.037. We rescale to
                                                                                                                       22 ±10 ±2
                                                                                                                                                             BUSKULIC
                                                                                                                                                       111 ALBRECHT
                                                                                                                        7 ± 4
    our best value B(D_s^+ \rightarrow \phi \pi^+) = 0.036.
                                                                                                                                                       112 BEBEK
                                                                                                                                                                                87 CLEO e+e- → T(45)
                                                                                                                       10\phantom{0}\pm\phantom{0}7\phantom{0}\pm2\phantom{0}
 ^{96} ALBRECHT 93E reports < 2.1 \times 10^{-3} for B(D_s^+ 	o \phi \pi^+) = 0.027. We rescale to our
                                                                                                                                                   3 113 ALAM
                                                                                                                                                                                86 CLEO e^+e^- \rightarrow \Upsilon(45)
                                                                                                                         9 ± 5
    best value B(D_5^+ \rightarrow \phi \pi^+) = 0.036.
                                                                                                                       ^{107} Assumes equal production of B^+ and B^0 at the \Upsilon(45).
                                                                                                                       108 BORTOLETTO 92 reports 8\pm2\pm2 for B(J/\psi(15)\rightarrow e^+e^-) = 0.069 \pm 0.009. We rescale to our best value B(J/\psi(15)\rightarrow e^+e^-) = (6.02 \pm 0.19) \times 10<sup>-2</sup>. Our first error is their experiment's error and our second error is the systematic error from using
\Gamma(D_s^+ \overline{K}^0)/\Gamma_{\text{total}}
                                                                                                 Γ<sub>48</sub>/Γ
                             <u>CL%</u>
                                                                                                                            our best value. Assumes equal production of B^+ and B^0 at the \Upsilon(4S).
                                                                                                                        109 ALBRECHT 90J reports 7 \pm 3 \pm 1 for B(J/\psi(15) \rightarrow e^+e^-) = 0.069 \pm 0.009. We
ullet ullet We do not use the following data for averages, fits, limits, etc. ullet ullet
                                                                                                                            rescale to our best value B(J/\psi(15) \rightarrow e^+e^-) = (6.02 \pm 0.19) \times 10^{-2}. Our first error is their experiment's error and our second error is the systematic error from using
                             90 98 ALBRECHT 93E ARG e^+e^- \rightarrow \Upsilon(4S)
 ^{97} ALEXANDER 93B reports < 10.3 \times 10^{-4} for B(D_c^+ \rightarrow \phi \pi^+) = 0.037. We rescale to
                                                                                                                            our best value. Assumes equal production of B^+ and B^0 at the \Upsilon(4S).
                                                                                                                       <sup>110</sup> Assumes equal production of B^+ and B^0 at the \Upsilon(45).
    our best value B(D_s^+ \rightarrow \phi \pi^+) = 0.036.
                                                                                                                       111 ALBRECHT 87D assume B^+B^-/B^0\overline{B}^0 ratio is 55/45. Superseded by ALBRECHT 90.
 <sup>98</sup> ALBRECHT 93E reports < 2.5 \times 10^{-3} for B(D_s^+ \rightarrow \phi \pi^+) = 0.027. We rescale to our
                                                                                                                       ^{112} BEBEK 87 value has been updated in BERKELMAN 91 to use same assumptions as noted for BORTOLETTO 92.  
    best value B(D_c^+ \rightarrow \phi \pi^+) = 0.036.
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\Gamma(\psi(2S) K^*(892)^+)/\Gamma_{\text{total}}
                                                                                                                                                                                                                                           \Gamma_{63}/\Gamma
\Gamma(J/\psi(15)K^+\pi^+\pi^-)/\Gamma_{\text{total}}
                                                                                                         \Gamma_{57}/\Gamma
  0.0014 ±0.0006 OUR AVERAGE
                                                          DOCUMENT ID TECN COMMENT
                                                                                                                                 VALUE
                                                                                                                                                                CL%
                                                                                                                                                                                DOCUMENT ID
                                                                                                                                                                                                       TECN COMMENT
                                                                                                                                                                          126 ALAM
                                                                                                                                                                                                   94 CLE2 e^+e^- \rightarrow \Upsilon(4S)
                                                                                                                                  < 0.0030
                                                                                                                                                                  90
                                                     114 BORTOLETTO92 CLEO e+e-
  0.00137 \pm 0.00081 \pm 0.00004
                                                                                                                                  ^{126} BORTOLETTO92 CLEO e^+e^- \rightarrow \Upsilon(45)
                                                                                                                                  < 0.0035
                                                                                                                                                                 90
                                                   115 ALBRECHT
  0.00137 \pm 0.00090 \pm 0.00004
                                                                            87D ARG
                                                                                                                                                                          <sup>126</sup> ALBRECHT 90J ARG e^+e^- \rightarrow T(45)
                                                                                                                                  <n nn49
                                                                                                                                                                 90
• • • We do not use the following data for averages, fits, limits, etc. • • •
                                                                                                                                 <sup>126</sup> Assumes equal production of B^+ and B^0 at the T(45).
                                                     116 ALBRECHT 903 ARG e+e
                                                                                                                                 \Gamma(\psi(2S)K^+\pi^+\pi^-)/\Gamma_{\text{total}}
                                                                                                                                                                                                                                           \Gamma_{64}/\Gamma
                                                                                                                                                                   EVTS
                                                                                                                                                                                    DOCUMENT ID
114 BORTOLETTO 92 reports 0.0012 \pm 0.0006 \pm 0.0004 for B(J/\psi(1S) \rightarrow e^{+}e^{-}) =
                                                                                                                                 VALUE
                                                                                                                                                                                                            TECN COMMENT
                                                                                                                                                                         3 127 ALBRECHT 90J ARG e^+e^- \rightarrow T(4S)
                                                                                                                                 0.0019 \pm 0.0011 \pm 0.0004
     0.069 \pm 0.009. We rescale to our best value B(J/\psi(15) \rightarrow e^{+}e^{-}) = (6.02 \pm 0.19) \times
     10<sup>-2</sup>. Our first error is their experiment's error and our second error is the systematic
                                                                                                                                 <sup>127</sup> Assumes equal production of B^+ and B^0 at the T(45).
     error from using our best value. Assumes equal production of B^+ and B^0 at the \Upsilon(45).
                                                                                                                                 \Gamma(\chi_{c1}(1P)K^+)/\Gamma_{total}
<sup>115</sup>ALBRECHT 87D reports 0.0012 \pm 0.0008 for B(J/\psi(1S) \rightarrow e^+e^-) = 0.069 \pm 0.009.
                                                                                                                                                                                                                                           \Gamma_{65}/\Gamma
    We rescale to our best value B(J/\psi(15)\to e^+e^-)=(6.02\pm0.19)\times10^{-2}. Our first error is their experiment's error and our second error is the systematic error from using
                                                                                                                                 <u>VALUE</u> <u>EVTS</u>
0.0010 ±0.0004 OUR AVERAGE
                                                                                                                                                                                    DOCUMENT ID
                                                                                                                                                                                                             TECN COMMENT
                                                                                                                                                                               128 ALAM
                                                                                                                                                                                                        94 CLE2 e^+e^- \rightarrow T(45)
     our best value. They actually report 0.0011 \pm 0.0007 assuming B^+B^-/B^0\overline{B}{}^0 ratio is
                                                                                                                                 0.00097 \pm 0.00040 \pm 0.00009
                                                                                                                                                                              129 ALBRECHT 92E ARG e^+e^- \rightarrow \Upsilon(45)
     55/45. We rescale to 50/50. Analysis explicitly removes B^+ \to \psi(2S) K^+.
^{116}ALBRECHT 90J reports < 0.0016 for B(J/\psi(15) 
ightarrow e^+e^-) = 0.069. We rescale to
                                                                                                                                 <sup>128</sup> Assumes equal production of B^+ and B^0 at the T(45).
                                                                                                                                 <sup>129</sup>ALBRECHT 92E assumes no \chi_{c2}(1P) production and B(\Upsilon(4S) \rightarrow B^+B^-) = 50%.
     our best value B(J/\psi(1S) \rightarrow e^+e^-) = 0.0602. Assumes equal production of B^+ and
     B^0 at the \Upsilon(45).
                                                                                                                                 \Gamma(X_{c1}(1P)K^*(892)^+)/\Gamma_{total}
                                                                                                                                                                                                                                           F66/F
\Gamma(J/\psi(1S)K^*(892)^+)/\Gamma_{\text{total}}
                                                                                                                                 VALUE
                                                                                                                                                                 CL%
                                                                                                                                                                               DOCUMENT ID
                                                                                                                                                                                                        TECN COMMENT
                                                                                                                                                                         130 ALAM
       For polarization information see the Listings at the end of the "BO Branching Ratios"
                                                                                                                                  < 0.0021
                                                                                                                                                                 90
                                                                                                                                                                                                   94 CLE2 e^+e^- \rightarrow \Upsilon(4S)
                                                                                                                                 <sup>130</sup>Assumes equal production of B^+ and B^0 at the T(4S).
                                                   DOCUMENT ID
                                                                          TECN COMMENT
0.00147+0.00027 OUR AVERAGE
                                                                                                                                 \Gamma(K^0\pi^+)/\Gamma_{\text{total}}
                                                                                                                                                                                                                                           \Gamma_{67}/\Gamma
                                              117 JESSOP
                                                                       97 CLE2 e^+e^- \rightarrow \Upsilon(4S)
0.00141 \pm 0.00023 \pm 0.00024
                                              118 ABE
0.00158 \pm 0.00047 \pm 0.00027
                                                                       96H CDF
                                                                                     pp at 1.8 TeV
                                                                                                                                 VALUE (units 10-5)
                                                                                                                                                                 CL%
                                                                                                                                                                               DOCUMENT ID
                                                                                                                                                                                                         TECN COMMENT
                                              <sup>119</sup> BORTOLETTO92 CLEO e^+e^- \rightarrow T(45)
0.00149 \pm 0.00107 \pm 0.00005
                                                                                                                                     2.3+1.1 ±0.36
                                                                                                                                                                               GODANG
                                                                                                                                                                                                    98 CLE2 e^+e^- \to T(45)
0.0018 ±0.0013 ±0.0001
                                        2 120 ALBRECHT 901 ARG e^+e^- \rightarrow \Upsilon(4S)
                                                                                                                                  • • • We do not use the following data for averages, fits, limits, etc. • • •
0.00178±0.00051±0.00023 13 <sup>121</sup> ALAM
                                                                                                                                  < 4.8
                                                                                                                                                                 90
                                                                                                                                                                               ASNER
                                                                                                                                                                                                    96 CLE2 Repl. by GODANG 98
                                                                       94 CLE2 Sup. by JESSOP 97
                                                                                                                                  <19
                                                                                                                                                                 90
                                                                                                                                                                                ALBRECHT
                                                                                                                                                                                                   91B ARG e^+e^- \rightarrow \Upsilon(45)
89B CLEO e^+e^- \rightarrow \Upsilon(45)
<sup>117</sup>Assumes equal production of B^+ and B^0 at the T(45).
                                                                                                                                                                           131 AVERY
                                                                                                                                  <10
                                                                                                                                                                 90
<sup>118</sup> ABE 96H assumes that B(B<sup>+</sup> \rightarrow J/\psi K^+) = (1.02 ± 0.14) × 10<sup>-3</sup>.
                                                                                                                                                                                                   87 CLEO e^+e^- \rightarrow T(45)
                                                                                                                                  < 68
                                                                                                                                                                 90
                                                                                                                                                                               AVERY
<sup>119</sup>BORTOLETTO 92 reports 0.0013 \pm 0.0009 \pm 0.0003 for B(J/\psi(1S) \rightarrow e^{+}e^{-}) =
                                                                                                                                 <sup>131</sup> AVERY 89B reports < 9 \times 10^{-5} assuming the \Upsilon(4S) decays 43% to B^0 \overline{B}{}^0. We rescale
    0.069 \pm 0.009. We rescale to our best value B(J/\psi(15) \rightarrow e^+e^-) = (6.02 ± 0.19) ×
     10<sup>-2</sup>. Our first error is their experiment's error and our second error is the systematic
     error from using our best value. Assumes equal production of B^+ and B^0 at the T(45).
                                                                                                                                 \Gamma(K^+\pi^0)/\Gamma_{\text{total}}
                                                                                                                                                                                                                                           Γ<sub>68</sub>/Γ
<sup>120</sup> ALBRECHT 903 reports 0.0016 \pm 0.0011 \pm 0.0003 for B(J/\psi(1S) \rightarrow e^+e^-) = 0.069 \pm 0.0011 \pm 0.0003
                                                                                                                                 VALUE
                                                                                                                                                                               DOCUMENT ID
                                                                                                                                                                 CL%
                                                                                                                                                                                                       TECN COMMENT
     0.009. We rescale to our best value B(J/\psi(15) \rightarrow e^+e^-) = (6.02 ± 0.19) × 10<sup>-2</sup>. Our first error is their experiment's error and our second error is the systematic error
                                                                                                                                  <1.6 × 10<sup>-5</sup>
                                                                                                                                                                                                   98 CLE2 e^+e^- \rightarrow \Upsilon(4S)
                                                                                                                                                                                GODANG
                                                                                                                                                                 90
                                                                                                                                  from using our best value. Assumes equal production of B^+ and B^0 at the \Upsilon(4S).
                                                                                                                                  < 1.4 \times 10^{-5}
<sup>121</sup> Assumes equal production of B^+ and B^0 at the T(45).
                                                                                                                                                                                ASNER
                                                                                                                                                                                                   96 CLE2 Repl. by GODANG 98
                                                                                                                                 \left[\Gamma(K^+\pi^0) + \Gamma(\pi^+\pi^0)\right]/\Gamma_{\text{total}}
\Gamma(J/\psi(15)K^{*}(892)^{+})/\Gamma(J/\psi(15)K^{+})
                                                                                                      \Gamma_{58}/\Gamma_{56}
                                                                                                                                                                                                                               (\Gamma_{68} + \Gamma_{102})/\Gamma
                                              DOCUMENT ID
                                                                     TECN COMMENT
                                                                                                                                                                                DOCUMENT ID
                                                                                                                                                                                                        TECN COMMENT
1.52±0.24 OUR AVERAGE
                                                                                                                                 (1.6^{+0.6}_{-0.5}\pm0.36)\times10^{-5}
                                                                                                                                                                                                   98 CLE2 e^+e^- \rightarrow T(45)
                                                                                                                                                                                GODANG
                                          122 JESSOP
                                                                   97 CLE2 e^+e^- \rightarrow \Upsilon(45)
1.45 \pm 0.20 \pm 0.17
                                                                   960 CDF pp
1.92 \pm 0.60 \pm 0.17
                                              ABE
                                                                                                                                 \Gamma(\eta' K^+)/\Gamma_{\text{total}}
                                                                                                                                                                                                                                           Γ<sub>69</sub>/Γ
^{122} JESSOP 97 assumes equal production of B^+ and B^0 at the \Upsilon(4S). The measurement
                                                                                                                                                                                DOCUMENT ID
                                                                                                                                                                                                         TECN COMMENT
     is actually measured as an average over kaon charged and neutral states.
                                                                                                                                 (6.5^{+1.5}_{-1.4}\pm0.9)\times10^{-5}
                                                                                                                                                                                BEHRENS
                                                                                                                                                                                                   98 CLE2 e^+e^- \to T(45)
\Gamma(J/\psi(1S)\pi^+)/\Gamma(J/\psi(1S)K^+)
                                                                                                      \Gamma_{59}/\Gamma_{56}
                                                   DOCUMENT ID
                                                                        TECN COMMENT
VALUE EVTS 0.051±0.014 OUR AVERAGE
                                                                                                                                 \Gamma(\eta' K^*(892)^+)/\Gamma_{total}
                                                                                                                                                                                                                                           \Gamma_{70}/\Gamma
                                                                                                                                 VALUE
                                                                                                                                                                CL%
                                                                                                                                                                                DOCUMENT ID
                                                                                                                                                                                                         TECN COMMENT
0.05 \begin{array}{l} +0.019 \\ -0.017 \\ \pm 0.001 \end{array}
                                                   ARF
                                                                       <1.3 × 10<sup>-4</sup>
                                                                                                                                                                                BEHRENS
                                                                                                                                                                                                   98 CLE2 e^+e^- \rightarrow \Upsilon(45)
                                                                                                                                                                 90
                                                                       96 CLE2 e^+e^- \rightarrow T(45)
0.052 \pm 0.024
                                                   BISHAL
\Gamma(\eta K^+)/\Gamma_{\text{total}}
                                                                                                                                                                                                                                           \Gamma_{71}/\Gamma
                                        5 123 ALEXANDER 95 CLE2 Sup. by BISHAI 96
                                                                                                                                                                 CL%
                                                                                                                                                                                DOCUMENT ID
                                                                                                                                                                                                       TECN COMMENT
                                                                                                                                  <1.4 × 10<sup>-5</sup>
<sup>123</sup> Assumes equal production of B^+B^- and B^0\overline{B}{}^0 on \Upsilon(45).
                                                                                                                                                                                BEHRENS
                                                                                                                                                                                                   98 CLE2 e^+e^- \rightarrow \Upsilon(4S)
                                                                                                                                 \Gamma(\eta K^*(892)^+)/\Gamma_{\text{total}}
                                                                                                                                                                                                                                           \Gamma_{72}/\Gamma
\Gamma(J/\psi(1S)\rho^+)/\Gamma_{\text{total}}
                                                                                                         DOCUMENT ID
                                                                      TECN COMMENT
                                                                                                                                 VALUE
                                                                                                                                                                                DOCUMENT ID
                                                                                                                                                                                                        TECN COMMENT
                                                                                                                                  <3.0 × 10<sup>-5</sup>
                                               BISHAI
                                                                   96 CLE2 e^+e^- \to T(45)
                                                                                                                                                                                BEHRENS
                                                                                                                                                                                                   98 CLE2 e^+e^- \rightarrow \Upsilon(45)
                                                                                                                                 \Gamma(K^*(892)^0\pi^+)/\Gamma_{\text{total}}
\Gamma(J/\psi(15) a_1(1260)^+)/\Gamma_{\text{total}}
                                                                                                         \Gamma_{61}/\Gamma
                                                                                                                                                                                                                                           \Gamma_{73}/\Gamma
                                               DOCUMENT ID
                                                                   TECN COMMENT
                                                                                                                                                                                DOCUMENT ID
                                                                                                                                                                                                       TECN COMMENT
                                                                                                                                  <4.1 × 10<sup>-5</sup>
 <1.2 × 10<sup>-3</sup>
                                90
                                               BISHAI
                                                                  96 CLE2 e^+e^- \rightarrow T(45)
                                                                                                                                                                 90
                                                                                                                                                                               ASNER
                                                                                                                                                                                                   96 CLE2 e^+e^- \rightarrow \Upsilon(45)
                                                                                                                                  • • • We do not use
                                                                                                                                                             the follo
                                                                                                                                                                        wing data for averages, fits, limits, etc. • • •
\Gamma(\psi(2S)K^+)/\Gamma_{\text{total}}
                                                                                                         \Gamma_{62}/\Gamma
                                                                                                                                  <3.9 × 10<sup>-4</sup>
                                                                                                                                                                          132 ADAM
                                                                                                                                                                                                   960 DLPH e^+e^- \rightarrow Z
                                                                                                                                                                                                                                                      ı
                                                                                                                                                                 90
                                                                                                                                  <4.8 × 10<sup>-4</sup>
                                                                                                                                                                          133 ABREU
VALUE (units 10-4)
                                                          DOCUMENT ID
                                                                                                                                                                                                   95N DLPH Sup. by ADAM 96D
                                   CL% EVTS
                                                                                   TECN COMMENT
                                                                                                                                                                 90
    6.9 ± 3.1 OUR AVERAGE Error includes scale factor of 1.3.
                                                                                                                                  < 1.7 \times 10^{-4}
                                                                                                                                                                               ALBRECHT
                                                                                                                                                                                                   918 ARG e+e- → T(45)
                                                                                                                                                                 90
                                                                                                                                                                          134 AVERY
                                                    124 ALAM
                                                                                                                                  < 1.5 \times 10^{-4}
                                                                                                                                                                                                   898 CLEO e+e- → T(45)
    6.1 ± 2.3 ± 0.9
                                                                             94 CLE2
                                                                                                                                                                 90
                                                                                                  T(45)
                                                                                                                                  < 2.6 \times 10^{-4}
                                                                                                                                                                               AVERY
                                                                                                                                                                                                   87 CLEO e^+e^- \rightarrow T(45)
                                                                                                                                                                 90
                                               5 124 ALBRECHT
                                                                             90J ARG
  18 ± 8 ±4
                                                                                                                                 132 ADAM 96D assumes f_{B^0} = f_{B^-} = 0.39 and f_{B_s} = 0.12.
                                                                                                  T(45)
                                                                                                                                 133 Assumes a B^0, B^- production fraction of 0.39 and a B_s production fraction of 0.12.
• • • We do not use the following data for averages, fits, limits, etc. • • •
                                                    or averages, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0
                                                                                                                                 ^{134} AVERY 898 reports <1.3\times10^{-4} assuming the T(45) decays 43% to B^0\overline{B}^0. We rescale to 50%.
                                               3 125 ALBRECHT 87D ARG
                                                                                                  ₹(45)
                                                                                                                                 \Gamma(K^*(892)^+\pi^0)/\Gamma_{\text{total}}
                                                                                                                                                                                                                                           \Gamma_{74}/\Gamma
<sup>124</sup>Assumes equal production of B^+ and B^0 at the \Upsilon(45).
                                                                                                                                                                                                         TECN_COMMENT
                                                                                                                                 VALUE
                                                                                                                                                                 CL%
                                                                                                                                                                               DOCUMENT ID
                                                                                                                                  <9.9 × 10<sup>-5</sup>
^{125} ALBRECHT 87D assume B^+B^-/B^0\overline{B}{}^0 ratio is 55/45. Superseded by ALBRECHT 901.
                                                                                                                                                                                                   96 CLE2 e^+e^- \rightarrow \Upsilon(4S)
                                                                                                                                                                 90
                                                                                                                                                                               ASNER
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 B^{\pm}

(K+π-π+nonre	<u>CL%_</u>	total DOCUMENT ID	TECN	COMMENT	Γ ₇₅ /Γ		Γ(K ⁺ φ)/Γ _{total}	CL%	DOCUMENT ID	TECN	COMMENT	Γ _{BI}
<2.8 × 10 ⁻⁵	90	BERGFELD		e ⁺ e ⁻ →	Υ(45)	Ī	<1.2 × 10 ⁻⁵	90	ASNER		e+e~ →	
• • We do not use	the follow	ing data for averag			` '	-		ise the follow	ing data for average			
<3.3 × 10 ⁻⁴	90	135 ADAM	960 DLPH	e ⁺ e ⁻ →	z	1	$< 2.8 \times 10^{-4}$	90	143 ADAM	960 DLPH	e+e- →	. z
4.0×10^{-4}	90	136 ABREU		Sup. by Al		•	$<4.4 \times 10^{-4}$	90	144 ABREU		Sup. by A	
3.3 × 10 ⁻⁴	90	ALBRECHT	91E ARG	e+ e→			$<1.8 \times 10^{-4}$	90	ALBRECHT	91B ARG	e+e- →	
1.9 × 10 ⁻⁴	90	137 AVERY		$e^+e^- \rightarrow$			<9 × 10 ⁻⁵	90	145 AVERY	89B CLEO	e+e- →	
35 ADAM 96D assur	mes f =	f - 0.39 and f	- 0.12				<2.1 × 10 ⁻⁴	90	AVERY		e+e- →	
36	B0 -	B 0.03 did 12	3, _ 0.12.			. 1	143 ADAM 960 ass	umes f_a -	$f_{B^-} = 0.39 \text{ and } f_B$	= 0.12		` '
 36 Assumes a 8⁰, B 37 AVERY 89B reporescale to 50%. (K-π+π+ nonrescale) 	orts < 1.7	× 10 ^{—4} assuming	and a B_{S} prothe $\Upsilon(4S)$ de	ecays 43% to	о в ⁰ в ⁰ . We		144 Assumes a B ⁰ .	B product	tion fraction of 0.39 0^{-5} assuming the γ	and a Be pro	oduction fra 43% to B ^O	ection of 0.1 \overline{B}^0 . We res
•	•				Γ ₇₆ /Γ		Γ(K+K-K+no		/r			г.
ALUE	<u>CL%</u>	DOCUMENT ID										Ге
<5.6 × 10 ⁻⁵ (<i>K</i> ₁ (1400) ⁰ π ⁺)/	90 /r	BERGFELD	968 CLE2	e ⁺ e ⁻ →	`		<3.8 × 10 ⁻⁵	90	<u>DOCUMENT ID</u> BERGFELD		$e^+e^- \rightarrow$	
		DOCUMENT ID	TECH	COLUMENT	Γ ₇₇ /Γ		Γ(K*(892)+K+	K-1/F.				وآ
ALUE	<u>CL%</u>	DOCUMENT ID				-				TCCH	5014151I	
<2.6 × 10 ⁻³ (K ₂ (1430) ⁰ *+)	90 /F	ALBRECHT	91B ARG	e ⁺ e [−] →	т(45) Г ₇₈ /Г		<1.6 × 10 ⁻³	90	<u>DOCUMENT ID</u> ALBRECHT	91E ARG	e ⁺ e ⁻ →	
ALUE		DOCUMENT ID	TECN	COMMENT	78/1		Γ(K*(892)+φ)/	/Fa				رو ۲
<6.8 × 10 ⁻⁴	<u>CL%</u>				20(45)	-			DOCUMENT ID	TEAL	COLUMN	
′o'Q X 10	90	ALBRECHT	918 ARG	e+ e ⁻ →	1 (45)		VALUE	<u>CL%</u>		TECN		
$(K^+ \rho^0)/\Gamma_{\text{total}}$					Γ ₇₉ /Γ		<7.0 × 10 ⁻⁵	90	ASNER		e+e	
	ره دم	DOC:		COMME	1 79/1			ise the follow	ring data for average			
ALUE	<u>CL%</u>	DOCUMENT ID			****	-	$<1.3 \times 10^{-3}$	90	ALBRECHT	918 ARG	$e^+e^- \rightarrow$	T(45)
(1.9 × 10 ⁻⁵	90	ASNER	96 CLE2		T(45)		P/10 12 10 12 1 1	-				_
We do not use	the followi						$\Gamma(K_1(1400)^+\phi)$	/ Total				Γg
1.2 × 10 ⁻⁴	90	138 ADAM		e ⁺ e ⁻ →		J	VALUE	<u> </u>	DOCUMENT ID	TECN		
1.9 × 10 ⁻⁴	90	139 ABREU		Sup. by Al			<1.1 × 10 ³	90	ALBRECHT	918 ARG	e+e- →	T(45)
1.8 × 10 ⁴	90	ALBRECHT	918 ARG	e+e− →			#/4###					
8 × 10 ⁻⁵	90	140 AVERY		$e^+e^- \rightarrow$			$\Gamma(K_2^*(1430)^+\phi)$	/F _{total}				Γį
2.6 × 10 ⁴	90	AVERY		$e^+e^- \rightarrow$	T(45)		VALUE	<u>CL%</u>	DOCUMENT ID	TECN	COMMENT	
⁸ ADAM 96D assun	nes fon = :	$f_{\alpha-}=0.39$ and f_{α}	= 0.12.			1	<3.4 × 10 ⁻³	90	ALBRECHT	91B ARG	e ⁺ e ⁻ →	T(45)
390 -	o~ nendusel	B- Location of 0.20	's and a B no	duation food	#l== of 0.12	ı						
^{IO} AVERY 898 repor	rts < 7 × 10	-5 assuming the 7	7(45) decays	43% to B ^O B	30. We rescale	:	Γ(K+ f ₀ (980))/I		DOCUMENT ID	TECN	COMMENT	
⁴⁰ AVERY 89B repor to 50%. (<i>K</i> ⁰ ρ ⁺)/Γ _{total}	rts < 7 × 10	-5 assuming the 7	T(45) decays	43% to B ^O B	- Γ ₈₀ /Γ		<u>VALUE</u> <8 × 10 ^{−5}	<u>CL%</u> 90	$\frac{DOCUMENT\ ID}{146\ AVERY}$ 0 ⁻⁵ assuming the γ	89B CLEO	$\frac{COMMENT}{e^+e^-} \rightarrow 43\% \text{ to } B^0$	T(45)
$(K^0 \rho^+)/\Gamma_{\text{total}}$ (4.8×10^{-5})	rts < 7 × 10 <u>CL%</u> 90	^{—5} assuming the 7	T(45) decays	43% to <i>B^OB</i>	³⁰ . We rescale		VALUE <8 × 10 ⁻⁵ 146 AVERY 898 rep	90 oorts < 7 × 10	146 AVERY	89B CLEO	e ⁺ e ⁻ →	T(45)
⁴⁰ AVERY 898 repor to 50%. (K ⁰ ρ ⁺)/Γ _{total} ALUE (4.8 × 10 ⁻⁵	rts < 7 × 10 <u>CL%</u> 90	⁻⁵ assuming the 7	T(45) decays	43% to <i>B^OB</i>	7(45)		<u>VALUE</u> <8 × 10^{−5} 146 AVERY 89B rep to 50%.	90 ports < 7 × 10	146 AVERY 0-5 assuming the 7	89B CLEO (45) decays	e ⁺ e ⁻ →	ア(4 <i>5</i>) 彦 ⁰ . We res 「g
¹⁰ AVERY 898 repor to 50%. (K ⁰ ρ ⁺)/Γ _{total} Δ <i>UE</i> (4.8 × 10 ⁻⁵ (K*(892) ⁺ π ⁺ π ⁻	rts < 7 × 10 <u>CL%</u> 90	⁻⁵ assuming the 7	T(45) decays	43% to <i>B^OB</i>	³⁰ . We rescale		×10-5 146 AVERY 898 rep to 50%. Γ(Κ*(892)+γ)/	90 ports < 7 × 10	146 AVERY 0-5 assuming the 7	89B CLEO (45) decays	e ⁺ e ⁻ → 43% to <i>B</i> ⁰	Υ(45) B ⁰ . We res Γ <u>α</u>
10 AVERY 898 reports 50%. (K ⁰ ρ ⁺)/Γtotal ALUE 4.8 × 10 ⁻⁵ (K*(892) ⁺ π ⁺ π ⁻ ALUE	rts < 7 × 10	-5 assuming the 7 <u>DOCUMENT ID</u> ASNER <u>DOCUMENT ID</u>	### TECN TECN	43% to B ^O B <u>COMMENT</u> e+e- → <u>COMMENT</u>	Γ ₈₀ /Γ (45) Γ ₈₁ /Γ		VALUE <8 × 10 ⁻⁵ 146 AVERY 898 rep to 50%. Γ(Κ* (892) + γ)/ VALUE (5.7±3.1±1.1) >	21% 90 ports < 7 × 10 (Total × 10 ⁻⁵	146 AVERY D=5 assuming the T EVTS DOCUM 5 147 AMM/	89B CLEO (45) decays MENT ID AR 93	e ⁺ e ⁻ → 43% to B ⁰ <u>TECN</u> CC	$\Upsilon(45)$ \overline{B}^0 . We resolve Γ_9 $COMMENT$ $+ e^- \rightarrow \Upsilon(45)$
$(K^0 \rho^+)/\Gamma_{\text{total}}$ $(K^0 \rho^+)/\Gamma_{\text{total}}$ MUE $(K^*(892)^+\pi^+\pi^-)$ MUE (1.1×10^{-3})	-)/Ftotal	^{—5} assuming the 7 <u>DOCUMENT ID</u> ASNER	T(45) decays	43% to B ^O B <u>COMMENT</u> e+e- →	Γ ₈₀ /Γ (45) Γ ₈₁ /Γ	· ·	 ×ALUE <8 × 10⁻⁵ 146 AVERY 89B rep to 50%. Γ (Κ° (892)⁺ γ)/	21% 90 ports < 7 × 10 (Total × 10 ⁻⁵	146 AVERY 0-5 assuming the 7	89B CLEO (45) decays AENT ID AR 93 s, fits, limits,	e ⁺ e ⁻ → 43% to B ⁰ TECN CC CLE2 e ⁻ , etc. • • •	$T(45)$ \overline{B}^0 . We resolve T_{g}
10 AVERY 898 report to 50%. $(K^0 \rho^+)/\Gamma_{\text{total}}$ AVER 4.8 × 10^{-5} $(K^*(892)^+\pi^+\pi^-)$ ALUE 1.1 × 10^{-3} $(K^*(892)^+\rho^0)/\Gamma$	-)/Ftotal	-5 assuming the 7 <u>DOCUMENT ID</u> ASNER <u>DOCUMENT ID</u>	### TECN TECN	43% to B ^O B <u>COMMENT</u> e+e- → <u>COMMENT</u>	7(45) 7(45)	· ·	VALUE <8 × 10 ⁻⁵ 146 AVERY 898 rep to 50%. Γ(Κ*(892)+γ)/ VALUE (5.7±3.1±1.1) > • • • We do not u < 5.5	$\frac{CL\%}{90}$ ports < 7 × 10 $\frac{CL\%}{\text{Lotal}} \times 10^{-5}$ is the follow × 10 ⁻⁴ 90	146 AVERY 2-5 assuming the 7 EVTS DOCUM 5 147 AMM/ Ing data for average 148 ALBRI	89B CLEO (45) decays MENT ID AR 93 s, fits, limits,	e ⁺ e ⁻ → 43% to B ⁰ TECN CC CLE2 e ⁻ , etc. • • • GARG e ⁻	$T(45)$ \overline{B}^0 . We respond to T_0
$(K^0 \rho^+)/\Gamma_{\text{total}}$ UE (4.8×10^{-5}) $(K^0 (892)^+ \pi^+ \pi^-)$ UE (4.1×10^{-3}) $(K^0 (892)^+ \rho^0)/\Gamma_{UUE}$			### TECN 96 CLE2 ### 1ECN 91E ARG	43% to $B^0\bar{B}$ COMMENT $e^+e^- \rightarrow$ COMMENT $e^+e^- \rightarrow$	70. We rescale \[\text{F80/\Gamma} \tau \] \[\tau(45) \] \[\tau(45) \] \[\tau(45) \] \[\tau(45) \]	· ·	VALUE <8 × 10 ⁻⁵ 146 AVERY 898 rep to 50%. Γ (Κ*(892)+γ)/ VALUE (5.7±3.1±1.1) > • • • We do not u < 5.5 > < 5.5	20% 90 ports < 7 × 10 (Tootal × 10 ⁻⁵ use the follow × 10 ⁻⁴ 90 × 10 ⁻⁴ 90	146 AVERY 0-5 assuming the 7 EVTS DOCUM 5 147 AMM/ ling data for average	89B CLEO (45) decays MENT ID AR 93 s, fits, limits,	e ⁺ e ⁻ → 43% to B ⁰ TECN CC CLE2 e ⁻ , etc. • • •	$T(45)$ \overline{B}^0 . We resonant T
10 AVERY 898 report to 50%. ($K^0 \rho^+$)/ Γ_{total} AUVE: 4.8 × 10^{-5} (K^* (892) $^+$ π^+ π^- AUVE: 1.1 × 10^{-3} (K^* (892) $^+$ ρ^0)/ Γ_{title} (9.0 × 10^{-4} (K_1 (1400) $^+$ ρ^0)/ Γ_{title}	CL% 90 -)/\Gamma_cL% 90 -total	DOCUMENT ID ASNER DOCUMENT ID ALBRECHT DOCUMENT ID ALBRECHT	7(45) decays	43% to $B^0 \overline{B}$ COMMENT $e^+ e^- \rightarrow$ COMMENT $e^+ e^- \rightarrow$ COMMENT $e^+ e^- \rightarrow$	70. We rescale \[\text{F80/\Gamma} \tau \] \[\tau(45) \] \[\tau(45) \] \[\tau(45) \] \[\tau(45) \]		VALUE	$\frac{CL\%}{90}$ ports < 7 × 10 $\frac{CL\%}{10^{-5}}$ is the follow × 10 ⁻⁴ 90 × 10 ⁻⁴ 90 × 10 ⁻³ 90	146 AVERY D=5 assuming the 7 EVTS DOCUM 5 147 AMM/ ling data for average 148 ALBRI 149 AVERY AVERY	89B CLEO (45) decays MENT ID AR 93 s, fits, limits, ECHT 89c Y 89E Y 87	e ⁺ e ⁻ → 43% to B ⁰ TECN CC CLE2 e ⁻ , etc. • • • GARG e ⁻	$T(4S)$ \overline{B}^0 . We respond to $T(4S)$ $T(4S)$ $T(4S)$ $T(4S)$
10 AVERY 89B report to 50%. $(K^0 \rho^+)/\Gamma_{\text{total}}$ AUE: $^{24.8} \times 10^{-5}$ $(K^*(892)^+ \pi^+ \pi^-)$ AUE: $^{21.1} \times 10^{-3}$ $(K^*(892)^+ \rho^0)/\Gamma_{\text{total}}$ AUE: $^{29.0} \times 10^{-4}$ $(K_1(1400)^+ \rho^0)/\Gamma_{\text{total}}$			### TECN 1ECN 96 CLE2 1ECN 91E ARG 1ECN 1E	$\frac{COMMENT}{e^+e^-}$ → $\frac{COMMENT}{e^+e^-}$ → $\frac{COMMENT}{e^+e^-}$ → $\frac{COMMENT}{e^+e^-}$	7(45) (45) (45) (45) (45) (45)		VALUE	90 ports $< 7 \times 10^{-10}$ fortal $\times 10^{-5}$ is the follow $\times 10^{-4}$ 90 $\times 10^{-4}$ 90 $\times 10^{-3}$ 90 served $4.1 \pm$	2.3 events above ba	89B CLEO (45) decays MENT ID AR 93 s, fits, limits, ECHT 89c Y 89E Y 87	e+e- → 43% to B ⁰ TECN CC CLE2 e- etc. • • • 3 ARG e- 3 CLEO e-	$T(45)$ \overline{B}^0 . We re Γ_{q} $DMMENT$ $+ e^- \rightarrow T(45)$ $+ e^- \rightarrow T(45)$ $+ e^- \rightarrow T(45)$ $+ e^- \rightarrow T(45)$
0 AVERY 898 report to 50%. $(K^{0}\rho^{+})/\Gamma_{\text{total}}$ LUE 4 4.8 × 10^{-5} $(K^{*}(892)^{+}\pi^{+}\pi^{-}$ LUE 1 1.1 × 10^{-3} $(K^{*}(892)^{+}\rho^{0})/\Gamma_{\text{LUE}}$ 9.0 × 10^{-4} $(K_{1}(1400)^{+}\rho^{0})/\Gamma_{\text{LUE}}$ 7.8 × 10^{-4}	CL% 90 -)/\Gamma_cL% 90 -total	DOCUMENT ID ASNER DOCUMENT ID ALBRECHT DOCUMENT ID ALBRECHT	7(45) decays	43% to $B^0 \overline{B}$ COMMENT $e^+ e^- \rightarrow$ COMMENT $e^+ e^- \rightarrow$ COMMENT $e^+ e^- \rightarrow$	7(45) 7(45) 7(45) 7(45) 7(45) 7(45) 7(45)		 ×ALUE <8 × 10⁻⁵ 146 AVERY 89B rep to 50%. Γ (K*(892)⁺ γ)/	90 ports $< 7 \times 10^{-1}$ fotal $\times 10^{-5}$ is the follow $\times 10^{-4}$ 90 $\times 10^{-4}$ 90 $\times 10^{-3}$ 90 served $4.1 \pm (4.5)$ decays 4	146 AVERY 2-5 assuming the 7 EVTS DOCUM 5 147 AMM/ Ing data for average 148 ALBRI 149 AVERY AVERY 2.3 events above ba 55% to 80 \$\overline{B}\$\overline{D}\$\over	89B CLEO (45) decays MENT ID AR 93 s, fits, limits, ECHT 89c Y 89E Y 87	e+e- → 43% to B ⁰ TECN CC CLE2 e- etc. • • • 3 ARG e- 3 CLEO e-	$T(45)$ \overline{B}^0 . We re T_6 $DMMENT$ $+ e^- \rightarrow T(45)$ $+ e^- \rightarrow T(45)$ $+ e^- \rightarrow T(45)$ $+ e^- \rightarrow T(45)$
0 AVERY 898 report to 50%. $(K^{0}\rho^{+})/\Gamma_{\text{total}}$ LUE 4 4.8 × 10^{-5} $(K^{*}(892)^{+}\pi^{+}\pi^{-}$ LUE 1 1.1 × 10^{-3} $(K^{*}(892)^{+}\rho^{0})/\Gamma_{\text{LUE}}$ 9.0 × 10^{-4} $(K_{1}(1400)^{+}\rho^{0})/\Gamma_{\text{LUE}}$ 7.8 × 10^{-4}	CL% 90 -)/\Gamma_cL% 90 -total	DOCUMENT ID ASNER DOCUMENT ID ALBRECHT DOCUMENT ID ALBRECHT DOCUMENT ID ALBRECHT	7(45) decays	43% to $B^0 \overline{B}$ COMMENT $e^+ e^- \rightarrow$ COMMENT $e^+ e^- \rightarrow$ COMMENT $e^+ e^- \rightarrow$ COMMENT $e^+ e^- \rightarrow$	τ(45) τ(45) τ(45) τ(45) τ(45) τ(45) τ(45) τ(45) τ(45)		VALUE	90 orts < 7 × 10 (Total × 10 ⁻⁵ se the follow × 10 ⁻⁴ 90 × 10 ⁻³ 90 served 4.1 \pm (45) decays 4 (45) decays 4	146 AVERY 2-5 assuming the 7 EVTS DOCUM 5 147 AMM/ Ing data for average 148 ALBRI 149 AVERY AVERY 2.3 events above ba 55% to 80 \$\overline{B}\$\overline{D}\$\over	89B CLEO (45) decays MENT ID AR 93 s. fits, limits, ECHT 89c Y 89E Y 87	e+e- → 43% to B ⁰ TECN CC CLE2 e- etc. • • • 3 ARG e- 3 CLEO e-	$T(45)$ \overline{B}^0 . We re Γ_5 $COMMENT$ $+ e^- \rightarrow T(45)$ $+ e^- \rightarrow T(45)$ $+ e^- \rightarrow T(45)$
0 AVERY 898 report to 50%. ($K^{0} \rho^{+}$)/ Γ_{total} LUE 4.8 × 10^{-5} (K^{*} (892) $^{+} \pi^{+} \pi^{-}$ LUE 9.0 × 10^{-4} (K_{1} (1400) $^{+} \rho^{0}$)/ Γ_{1} LUE 7.8 × 10^{-4} (K_{2} (1430) $^{+} \rho^{0}$)/ Γ_{2} LUE (K_{2} (1430) $^{+} \rho^{0}$)/ Γ_{3} LUE (K_{2} (1430) $^{+} \rho^{0}$)/ Γ_{4} LUE	CLS. 90 -)/\Gamma_cLS. 90 -total	DOCUMENT ID ALBRECHT	7(45) decays	43% to $B^0 \overline{B}$ COMMENT $e^+e^- \rightarrow$ COMMENT $e^+e^- \rightarrow$ COMMENT $e^+e^- \rightarrow$ COMMENT $e^+e^- \rightarrow$	780/Г 7(45) 7(45) 7(45) 7(45) 7(45) 7(45) 7(45) 7(45) 7(45)		VALUE	$\frac{CL\%}{90}$ sorts < 7 × 10 $\frac{7}{1000}$ $\frac{CL\%}{1000}$ set the follow × 10 ⁻⁴ 90 × 10 ⁻³ 90 served 4.1 ± (45) decays 4 (45) decays 4 (45) decays 4 (45) decays 4 (47) decays 4	146 AVERY D=5 assuming the 7 EVTS DOCUM 5 147 AMM/ Ing data for average 148 ALBRI 149 AVERY AVERY 2.3 events above ba 45% to $B^0 \overline{B}^0$.	89B CLEO (4 <i>S</i>) decays MENT ID AR 93 s, fits, limits, ECHT 89c Y 89E Y 87 ackground.	e ⁺ e [−] → 43% to B ⁰ . <u>TECN</u> <u>CC</u> CLE2 e ⁻ . etc. • • • GARG e ⁻ 3 CLEO e ⁻ CLEO e ⁻	$T(45)$ \overline{B}^0 . We re Fig. $T(45)$ $T(45)$ $T(45)$ $T(45)$ $T(45)$
10 AVERY 898 report to 50%. $(K^0 \rho^+)/\Gamma_{\text{total}}$ AVER 2 $(K^* (892)^+ \pi^+ \pi^-)$ $(K^* (892)^+ \mu^0)/\Gamma_{\text{total}}$ $(K^* (892)^+ \rho^0)/\Gamma_{\text{total}}$ $(K^* (892)^+ \rho^0)/\Gamma_{\text{total}}$ $(K_1 (1400)^+ \rho^0)/\Gamma_{\text{total}}$ $(K_1 (1400)^+ \rho^0)/\Gamma_{\text{total}}$ $(K_2 (1430)^+ \rho^0)/\Gamma_{\text{total}}$ $(K_2 (1430)^+ \rho^0)/\Gamma_{\text{total}}$ $(K_2 (1430)^+ \rho^0)/\Gamma_{\text{total}}$	CL% 90 -)/\Gamma_cL% 90 -total	DOCUMENT ID ASNER DOCUMENT ID ALBRECHT DOCUMENT ID ALBRECHT DOCUMENT ID ALBRECHT	7(45) decays	43% to $B^0 \overline{B}$ COMMENT $e^+ e^- \rightarrow$ COMMENT $e^+ e^- \rightarrow$ COMMENT $e^+ e^- \rightarrow$ COMMENT $e^+ e^- \rightarrow$	7(45) 7(45) 7(45) 7(45) 7(45) 7(45) 7(45) 7(45) 7(45)		VALUE	CL% 90 ports < 7 × 10 (Ttotal x 10-5 see the follow x 10-4 90 x 10-4 90 x 10-3 90 served 4.1 ± (4.5) decays 4 (4.5) decays 4 (4.5) decays 4	146 AVERY 2-5 assuming the 7 EVTS DOCUM 5 147 AMM/ ling data for average 148 ALBRI 149 AVER' AVER' 2.3 events above ba 45% to $B^0 \overline{B}^0$. 2.3 events above ba 45% to $B^0 \overline{B}^0$.	89B CLEO (4S) decays MENT ID AR 93 s, fits, limits, ECHT 89c Y 89e Y 87 ackground.	e ⁺ e ⁻ → 43% to B ⁰ . TECN CC CLE2 e ⁻ . etc. • • • . ARG e ⁻ . CLEO e ⁻ . CLEO e ⁻ . CLEO e ⁻	$T(45)$ B^0 . We re Γ_g $DMMENT$ $+e^- \rightarrow T(45)$ $+e^- \rightarrow T(45)$ $+e^- \rightarrow T(45)$ $+e^- \rightarrow T(45)$
10 AVERY 898 report to 50%. ($K^0 \rho^+$)/ Γ_{total} LUE	CLS. 90 -)/\Gamma_cLS. 90 -total	DOCUMENT ID ALBRECHT	7(45) decays	43% to $B^0 \overline{B}$ COMMENT $e^+e^- \rightarrow$ COMMENT $e^+e^- \rightarrow$ COMMENT $e^+e^- \rightarrow$ COMMENT $e^+e^- \rightarrow$	780/Г 7(45) 7(45) 7(45) 7(45) 7(45) 7(45) 7(45) 7(45) 7(45)		VALUE	CL% 90 ports < 7 × 10 (Ttotal x 10-5 see the follow x 10-4 90 x 10-4 90 x 10-3 90 served 4.1 ± (4.5) decays 4 (4.5) decays 4 (4.5) decays 4	146 AVERY 2-5 assuming the 7 EVTS DOCUM 5 147 AMM/ ling data for average 148 ALBRI 149 AVER' AVER' 2.3 events above ba 45% to $B^0 \overline{B}^0$. 2.3 events above ba 45% to $B^0 \overline{B}^0$.	89B CLEO (4S) decays MENT ID AR 93 s, fits, limits, ECHT 89c Y 89e Y 87 ackground.	e ⁺ e ⁻ → 43% to B ⁰ . TECN CC CLE2 e ⁻ . etc. • • • . ARG e ⁻ . CLEO e ⁻ . CLEO e ⁻ . CLEO e ⁻	$T(45)$ B^0 . We re Γ_6 $DMMENT$ $+e^- \rightarrow T(45)$
10 AVERY 898 report to 50%. ($K^0 \rho^+$)/ Γ_{total} AUVE 4.8 × 10^{-5} ($K^*(892)^+ \pi^+ \pi^-$ AUVE 1.1.1 × 10^{-3} ($K^*(892)^+ \rho^0$)/ Γ_{total} AUVE 1.5 × 10^{-4} ($K_1(1400)^+ \rho^0$)/ Γ_{total} AUVE 1.5 × 10^{-3} ($K^*(892)^+ \rho^0$)/ Γ_{total} AUVE 2.1 × 10^{-5}	CL% 90 Total CL% 90	DOCUMENT ID ALBRECHT	7(45) decays	43% to $B^0 \overline{B}$ COMMENT $e^+ e^- \rightarrow$ COMMENT $e^+ e^- \rightarrow$ COMMENT $e^+ e^- \rightarrow$ COMMENT $e^+ e^- \rightarrow$	780/Г 7(45) 781/Г 7(45) 782/Г 7(45) 783/Г 7(45) 784/Г 7(45) 785/Г		VALUE	CL% 90 90 90 90 90 90 90 9	146 AVERY 2-5 assuming the 7 EVTS DOCUM 5 147 AMM/ ling data for average 148 ALBRI 149 AVER' AVER' 2.3 events above ba 45% to $B^0 \overline{B}^0$. 2.3 events above ba 45% to $B^0 \overline{B}^0$.	89B CLEO (4S) decays MENT ID AR 93 s, fits, limits, ECHT 89c Y 89e Y 87 ackground.	e ⁺ e ⁻ → 43% to B ⁰ . TECN CC CLE2 e ⁻ . etc. • • • . ARG e ⁻ . CLEO e ⁻ . CLEO e ⁻ . CLEO e ⁻	$T(45)$ B^0 . We re Fig. $DMMENT$ $+e^- \rightarrow T(45)$
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0 AVERY 898 report to 50%. ($K^{0}\rho^{+}$)/ Γ_{total} LUE 4.8 × 10^{-5} (K^{*} (892) $^{+}\pi^{+}\pi^{-}$ LUE 1.1 × 10^{-3} (K^{*} (892) $^{+}\rho^{0}$)/ Γ_{LUE} 9.0 × 10^{-4} (K_{1} (1400) $^{+}\rho^{0}$)/ L_{LUE} 1.5 × 10^{-3} (K^{*} (1430) $^{+}\rho^{0}$)/ Γ_{total} LUE 1.5 × 10^{-3} (K^{*} K^{*} (K^{*} K^{*})/ Γ_{total} LUE 2.1 × 10^{-5} (K^{*} K^{*} K^{*} K^{*} K^{*} K^{*} K^{*} K^{*} K^{*}	CLS. 90 Cotal	DOCUMENT ID ALBRECHT DOCUMENT ID ALBRECHT	7(45) decays 7 TECN 96 CLE2 1ECN 91E ARG 1ECN 91B ARG 1ECN 91B ARG 7ECN 91B ARG 7ECN 91B ARG	COMMENT c+c-→	780/Γ 7(45) F81/Γ 7(45) F82/Γ 7(45) F83/Γ 7(45) F84/Γ 7(45) F85/Γ		VALUE	CL% 90 90 90 90 90 90 90 9	146 AVERY 0-5 assuming the 7 EVTS DOCUMENT ID 151 ALBRECHT 10-5 assuming the 7 EVTS DOCUMENT ID 151 ALBRECHT 151 ALBRECHT	89B CLEO (45) decays MENT ID AR 93 s, fits, limits, ECHT 89c Y 87 ackground. TECN 89G ARG 89G ARG	$e^+e^- \rightarrow$ 43% to B^0 TECN CC CLE2 e ⁻ etc. • • • GARG e ⁻ CLEO e ⁻ CLEO e ⁻ COMMENT $e^+e^- \rightarrow$ $e^+e^- \rightarrow$ $e^+e^- \rightarrow$	T(45) B ⁰ . We re Fg CMMENT + e ⁻ → T(45) + e ⁻ → T(45) + e ⁻ → T(45) T(45) T(45) T(45) T(45)
10 AVERY 898 report to 50%. $(K^0 \rho^+)/\Gamma_{\text{total}}$ LUE 4.8 × 10^{-5} $(K^*(892)^+\pi^+\pi^-)$ LUE 1.1 × 10^{-3} $(K^*(892)^+\rho^0)/\Gamma_{\text{total}}$ LUE 9.0 × 10^{-4} $(K_1(1400)^+\rho^0)/\Gamma_{\text{total}}$ LUE 7.8 × 10^{-4} $(K_2^*(1430)^+\rho^0)/\Gamma_{\text{total}}$ LUE 1.5 × 10^{-3} $(K^+K^0)/\Gamma_{\text{total}}$ LUE 2.1 × 10^{-5} $(K^+K^-\pi^+ \text{nonrec})$ LUE 7.5 × 10^{-5}	CLX 90	DOCUMENT ID ALBRECHT DOCUMENT ID GODANG	7(45) decays 7 TECN 96 CLE2 1ECN 91E ARG 1ECN 91B ARG 1ECN 91B ARG 7ECN 91B ARG 7ECN 91B ARG	COMMENT e+e-→ COMMENT e+e-→ COMMENT e+e-→ COMMENT e+e-→ COMMENT e+e-→ COMMENT e+e-→	780/Г 7(45) 7(45) 7(45) 7(45) 7(45) 7(45) 7(45) 7(45) 7(45) 7(45) 7(45)		VALUE	CL% 90 90 90 90 90 90 90 9	146 AVERY 0-5 assuming the 7 EVTS DOCUMENT ID 151 ALBRECHT 10-5 assuming the 7 EVTS DOCUMENT ID 151 ALBRECHT 151 ALBRECHT	89B CLEO (45) decays MENT ID AR 93 s, fits, limits, ECHT 89c Y 87 ackground. TECN 89G ARG 89G ARG	$e^+e^- \rightarrow$ 43% to B^0 TECN CC CLE2 e ⁻ etc. • • • GARG e ⁻ CLEO e ⁻ CLEO e ⁻ COMMENT $e^+e^- \rightarrow$ $e^+e^- \rightarrow$ $e^+e^- \rightarrow$	T(45) B . We re Fg CMMENT +e - → T(45) +e - → T(45) +e - → T(45) Fg T(45) T(45) T(45) T(45)
10 AVERY 898 report to 50%. $(K^0 \rho^+)/\Gamma_{\text{total}}$ 11 LUE 10 $(K^*(892)^+\pi^+\pi^-)$ 11 LUE 11 $(K^*(892)^+\rho^0)/\Gamma_{\text{total}}$ 11 $(K^*(892)^+\rho^0)/\Gamma_{\text{total}}$ 11	CLX 90	DOCUMENT ID ALBRECHT DOCUMENT ID BERGFELD	7(45) decays 7	COMMENT e+e-→	780/Γ 7(45) F81/Γ 7(45) F82/Γ 7(45) F83/Γ 7(45) F84/Γ 7(45) F85/Γ		VALUE	CL% 90 90 90 90 90 90 90 9	146 AVERY 0-5 assuming the 7 EVTS DOCUMENT ID 151 ALBRECHT 10-5 assuming the 7 EVTS DOCUMENT ID 151 ALBRECHT 151 ALBRECHT	89B CLEO (45) decays MENT ID AR 93 s, fits, limits, ECHT 89c Y 87 ackground. TECN 89G ARG 89G ARG	$e^+e^- \rightarrow$ 43% to B^0 TECN CC CLE2 e etc. • • • GARG e GCLEO e CLEO e CLEO e COMMENT $e^+e^- \rightarrow$ $e^+e^- \rightarrow$ $e^+e^- \rightarrow$	T(45) B . We re Fg CMMENT + e - → T(45) - T(45) - T(45) T(45) T(45) T(45) T(45) T(45) T(45)
0 AVERY 898 report to 50%. ($K^{0}\rho^{+}$)/ Γ_{total} LUE 4.8 × 10^{-5} (K^{*} (892)+ $\pi^{+}\pi^{-}$ LUE 1.1 × 10^{-3} (K^{*} (892)+ ρ^{0})/ Γ_{LUE} 9.0 × 10^{-4} (K_{1} (1400)+ ρ^{0})/ Γ_{LUE} 1.5 × 10^{-4} (K_{2} (1430)+ ρ^{0})/ Γ_{total} LUE 2.1 × 10^{-5} ($K^{*}K^{-}\pi^{+}$ nonrective 7.5 × 10^{-5} ($K^{+}K^{-}\pi^{+}$)/ Γ_{total} LUE 7.5 × 10^{-5} ($K^{+}K^{-}\pi^{+}$)/ Γ_{total} LUE 7.5 × 10^{-5}	CLS. 90 Tootal CLS. 90 Tootal CLS. 90 Tootal CLS. 90 Tootal CLS. 90 CLS. 90 Cotal CLS.	DOCUMENT ID ALBRECHT DOCUMENT ID BOCUMENT ID	### TECN 1	COMMENT c+e-→	780/Г 7(45) 781/Г 7(45) 782/Г 7(45) 784/Г 7(45) 784/Г 7(45) 784/Г 7(45) 784/Г		VALUE	CL% 90 90 90 90 90 90 90 9	146 AVERY 0-5 assuming the 7 EVTS DOCUM 5 147 AMM/ Ing data for average 148 ALBRI 149 AVERY AVERY 2.3 events above ba 45% to B^0B^0 . 43% to B^0B^0 . 150 ALBRECHT 0.0066 assuming the 151 ALBRECHT 0.0020 assuming the	89B CLEO (4S) decays AENT ID AR 93 s, fits, limits, ECHT 89c Y 87 ackground. 89G ARG the \(\tau(4S)\) decays	$e^+e^- \rightarrow$ 43% to B^0 TECN CC CLE2 e ⁻ etc. • • • GARG e ⁻ GCLEO e ⁻ CLEO e ⁻ COMMENT $e^+e^- \rightarrow$ CCAYS 45% t	$T(45)$ \overline{B}^0 . We re F_9 $COMMENT$ $+ e^- \rightarrow T(45)$ $+ e$
$(K^0 \rho^+)/\Gamma_{\text{total}}$ $(K^0 \rho^+)/\Gamma_{\text{total}}$ (LUE) $(A.8 \times 10^{-5})$ $(K^*(892)^+ \pi^+ \pi^-)$ $(K^*(892)^+ \rho^0)/\Gamma_{\text{total}}$ $(K^*(892)^+ \rho^0)/\Gamma_{\text{total}}$ $(K^*(892)^+ \rho^0)/\Gamma_{\text{total}}$ $(K_1(1400)^+ \rho^0)/\Gamma_{\text{total}}$ $(K_2(1430)^+ \rho^0)/\Gamma_{\text{total}}$ $(K_2^*(1430)^+ \rho^0)/\Gamma_{\text{total}}$	CLS: 90 Cotal CLS: 90	DOCUMENT ID ALBRECHT DOCUMENT ID BERGFELD DOCUMENT ID BERGFELD	### TECN 1	COMMENT e+e-→	780/Г 7(45) 781/Г 7(45) 782/Г 7(45) 784/Г 7(45) 784/Г 7(45) 784/Г 7(45) 784/Г		VALUE	CL% 90 90 90 90 90 90 90 9	2.3 events above ba 45% to 80 B0. DOCUMENT ID 151 ALBRECHT DOCUMENT ID 151 ALBRECHT DOCUMENT ID 151 ALBRECHT 0.0020 assuming th	89B CLEO (45) decays MENT ID AR 93 s, fits, limits, ECHT 89c Y 89 ickground. FECN 89G ARG the T(45) decays	e ⁺ e ⁻ → 43% to B ⁰ . TECN CC CLE2 e ⁻ . etc. • • • . ARG e ⁻ . CLEO e ⁻ . COMMENT e ⁺ e ⁻ → e ⁻ . cays 45% t	T(45) B ⁰ . We re F(45) T(45) + e ⁻ → T(45) + e ⁻ → T(45) T(45) T(45) T(45) T(45) T(45)
0 AVERY 898 report to 50%. $(K^{0}\rho^{+})/\Gamma_{\text{total}}$ LUE 4.8 × 10^{-5} $(K^{*}(892)^{+}\pi^{+}\pi^{-})$ LUE 1.1 × 10^{-3} $(K^{*}(892)^{+}\rho^{0})/\Gamma_{\text{LUE}}$ 9.0 × 10^{-4} $(K_{1}(1400)^{+}\rho^{0})/\Gamma_{\text{LUE}}$ 7.5 × 10^{-4} $(K_{2}^{*}(1430)^{+}\rho^{0})/\Gamma_{\text{total}}$ LUE 2.1 × 10^{-5} $(K^{*}K^{-})/\Gamma_{\text{total}}$ (LUE) 7.5 × 10^{-5} $(K^{*}K^{-})/\Gamma_{\text{total}}$ (LUE) 7.5 × 10^{-5} (LUE) 7.6 × 10^{-4} (LUE) 7.7 × 10^{-5} (LUE) 7.8 × 10^{-5} (LUE) 7.9 × 10^{-4} (LUE) 7	CL% 90	DOCUMENT ID ALBRECHT DOCUMENT ID BERGFELD DOCUMENT ID DOCUMENT ID ALBRECHT DOCUMENT ID ALBRECHT ADAM AND ADAM ADAM	### TECN 1	COMMENT e+e-→	780/Г 7(45) 781/Г 7(45) 782/Г 7(45) 783/Г 7(45) 785/Г 7(45) 785/Г 7(45) 785/Г		VALUE	CL% 90 90 90 90 90 90 90 9	2.3 events above ba 45% to B ⁰ B ⁰ . 2.3 events above ba 45% to B ⁰ B ⁰ . 2.4 events above ba 45% to B ⁰ B ⁰ . 2.5 events above ba 45% to B ⁰ B ⁰ . 2.6 events above ba 45% to B ⁰ B ⁰ . 2.7 events above ba 45% to B ⁰ B ⁰ . 2.8 events above ba 45% to B ⁰ B ⁰ . 2.9 events above ba 45% to B ⁰ B ⁰ . 2.1 events above ba 45% to B ⁰ B ⁰ . 2.2 events above ba 45% to B ⁰ B ⁰ . 2.3 events above ba 45% to B ⁰ B ⁰ . 2.4 events above ba 45% to B ⁰ B ⁰ . 2.5 events above ba 45% to B ⁰ B ⁰ . 2.6 events above ba 45% to B ⁰ B ⁰ . 2.7 events above ba 45% to B ⁰ B ⁰ . 2.8 events above ba 45% to B ⁰ B ⁰ . 2.9 events above ba 45% to B ⁰ B ⁰ . 2.1 events above ba 45% to B ⁰ B ⁰ . 2.2 events above ba 45% to B ⁰ B ⁰ . 2.3 events above ba 45% to B ⁰ B ⁰ . 2.4 events above ba 45% to B ⁰ B ⁰ . 2.5 events above ba 45% to B ⁰ B ⁰ . 2.6 events above ba 45% to B ⁰ B ⁰ . 2.7 events above ba 45% to B ⁰ B ⁰ . 2.8 events above ba 45% to B ⁰ B ⁰ . 2.9 events above ba 45% to B ⁰ B ⁰ .	89B CLEO (45) decays MENT ID AR 93 s, fits, limits, ECHT 89c Y 89e Y 87 ackground. 89G ARG the T(45) de TECN 89G ARG	$e^+e^- \rightarrow$ 43% to B^0 . TECN CC CLE2 e . etc. • • • . ARG e . CLEO e . COMMENT . e+e- \rightarrow . cays 45% t . COMMENT . e+e- \rightarrow . cays 45% t	T(45) B ⁰ . We re F(45) T(45) T(45) T(45) T(45) T(45) T(45) T(45) T(45) T(45)
$(K^0 \rho^+)/\Gamma_{\text{total}}$ $(K^0 \rho^+)/\Gamma_{\text{total}}$ (LUE) (4.8×10^{-5}) $(K^*(892)^+\pi^+\pi^-)$ $(K^*(892)^+\rho^0)/\Gamma_{\text{total}}$ $(K^*(892)^+\rho^0)/\Gamma_{\text{total}}$ $(K^*(892)^+\rho^0)/\Gamma_{\text{total}}$ $(K_1(1400)^+\rho^0)/\Gamma_{\text{total}}$ $(K_1(1400)^+\rho^0)/\Gamma_{\text{total}}$ $(K_2^*(1430)^+\rho^0)/\Gamma_{\text{total}}$ $(K_2^*(K^+K^-\pi^+)/\Gamma_{\text{total}})$ $(K^+K^-\pi^+)/\Gamma_{\text{total}}$	CL% 90	DOCUMENT ID ALBRECHT DOCUMENT ID BERGFELD DOCUMENT ID BERGFELD	### TECN 1	43% to B ^O B COMMENT e+e-→ COMMENT e-e-→ COMME	780/Г 7(45) 781/Г 7(45) 783/Г 7(45) 784/Г 7(45) 785/Г 7(45) 785/Г 7(45) 785/Г 7(45) 786/Г		VALUE	CL% 90 90 90 90 90 90 90 9	2.3 events above ba 45% to B ⁰ B ⁰ . 2.3 events above ba 45% to B ⁰ B ⁰ . 2.4 events above ba 45% to B ⁰ B ⁰ . 2.5 events above ba 45% to B ⁰ B ⁰ . 2.6 events above ba 45% to B ⁰ B ⁰ . 2.7 events above ba 45% to B ⁰ B ⁰ . 2.8 events above ba 45% to B ⁰ B ⁰ . 2.9 events above ba 45% to B ⁰ B ⁰ . 2.1 events above ba 45% to B ⁰ B ⁰ . 2.2 events above ba 45% to B ⁰ B ⁰ . 2.3 events above ba 45% to B ⁰ B ⁰ . 2.4 events above ba 45% to B ⁰ B ⁰ . 2.5 events above ba 45% to B ⁰ B ⁰ . 2.6 events above ba 45% to B ⁰ B ⁰ . 2.7 events above ba 45% to B ⁰ B ⁰ . 2.8 events above ba 45% to B ⁰ B ⁰ . 2.9 events above ba 45% to B ⁰ B ⁰ . 2.1 events above ba 45% to B ⁰ B ⁰ . 2.2 events above ba 45% to B ⁰ B ⁰ . 2.3 events above ba 45% to B ⁰ B ⁰ . 2.4 events above ba 45% to B ⁰ B ⁰ . 2.5 events above ba 45% to B ⁰ B ⁰ . 2.6 events above ba 45% to B ⁰ B ⁰ . 2.7 events above ba 45% to B ⁰ B ⁰ . 2.8 events above ba 45% to B ⁰ B ⁰ . 2.9 events above ba 45% to B ⁰ B ⁰ .	89B CLEO (45) decays MENT ID AR 93 s, fits, limits, ECHT 89c Y 89e Y 87 ackground. 89G ARG the T(45) de TECN 89G ARG	$e^+e^- \rightarrow$ 43% to B^0 . TECN CC CLE2 e . etc. • • • . ARG e . CLEO e . COMMENT . e+e- \rightarrow . cays 45% t . COMMENT . e+e- \rightarrow . cays 45% t	T(45) B ⁰ . We re F ₀ DMMENT +e ⁻ → T(45) +e ⁻ → T(45) +e ⁻ → T(45) T(45) T(45) T(45) T(45) T(45) T(45) T(45)
$(K^0 \rho^+)/\Gamma_{\text{total}}$ $(K^0 \rho^+)/\Gamma_{\text{total}}$ $(K^0 \rho^+)/\Gamma_{\text{total}}$ $(K^0 (892)^+ \pi^+ \pi^-)$ $(K^0 (892)^+ \pi^+ \pi^-)$ $(K^0 (892)^+ \rho^0)/\Gamma_{\text{total}}$ $(K^0 (892)^+ \rho^0)/\Gamma_{\text{total}}$ $(K^1 (1400)^+ \rho^0)/\Gamma_{\text{total}}$ $(K^1 (1400)^+ \rho^0)/\Gamma_{\text{total}}$ $(K^2 (1430)^+ \rho^0)/\Gamma_{\text{total}}$ $(K^2 (1430)^+ \rho^0)/\Gamma_{\text{total}}$ $(K^1 K^0)/\Gamma_{\text{total}}$	CL% 90	DOCUMENT ID ALBRECHT DOCUMENT ID BERGFELD DOCUMENT ID DOCUMENT ID ALBRECHT DOCUMENT ID ALBRECHT ADAM AND ADAM ADAM	### 150 ### 16	COMMENT e+e-→	780/Г 7(45) 781/Г 7(45) 783/Г 7(45) 784/Г 7(45) 785/Г 7(45) 785/Г 7(45) 785/Г 7(45) 786/Г		VALUE	CL% 90 90 90 90 90 90 90 9	2.3 events above ba 45% to B ⁰ B ⁰ . 2.3 events above ba 45% to B ⁰ B ⁰ . 2.4 events above ba 45% to B ⁰ B ⁰ . 2.5 events above ba 45% to B ⁰ B ⁰ . 2.6 events above ba 45% to B ⁰ B ⁰ . 2.7 events above ba 45% to B ⁰ B ⁰ . 2.8 events above ba 45% to B ⁰ B ⁰ . 2.9 events above ba 45% to B ⁰ B ⁰ . 2.1 events above ba 45% to B ⁰ B ⁰ . 2.2 events above ba 45% to B ⁰ B ⁰ . 2.3 events above ba 45% to B ⁰ B ⁰ . 2.4 events above ba 45% to B ⁰ B ⁰ . 2.5 events above ba 45% to B ⁰ B ⁰ . 2.6 events above ba 45% to B ⁰ B ⁰ . 2.7 events above ba 45% to B ⁰ B ⁰ . 2.8 events above ba 45% to B ⁰ B ⁰ . 2.9 events above ba 45% to B ⁰ B ⁰ . 2.1 events above ba 45% to B ⁰ B ⁰ . 2.2 events above ba 45% to B ⁰ B ⁰ . 2.3 events above ba 45% to B ⁰ B ⁰ . 2.4 events above ba 45% to B ⁰ B ⁰ . 2.5 events above ba 45% to B ⁰ B ⁰ . 2.6 events above ba 45% to B ⁰ B ⁰ . 2.7 events above ba 45% to B ⁰ B ⁰ . 2.8 events above ba 45% to B ⁰ B ⁰ . 2.9 events above ba 45% to B ⁰ B ⁰ .	89B CLEO (45) decays MENT ID AR 93 s, fits, limits, ECHT 89c Y 89e Y 87 ackground. 89G ARG the T(45) de TECN 89G ARG	$e^+e^- \rightarrow$ 43% to B^0 . TECN CC CLE2 e . etc. • • • . ARG e . CLEO e . COMMENT . e+e- \rightarrow . cays 45% t . COMMENT . e+e- \rightarrow . cays 45% t	T(45) B ⁰ . We re F ₉ DMMENT +e ⁻ → T(45) +e ⁻ → T(45) +e ⁻ → T(45) T(45) T(45) T(45) T(45) T(45) T(45)
10 AVERY 89B report to 50%. $(K^0 \rho^+)/\Gamma_{\text{total}}$ ALUE 24.8 × 10 ⁻⁸ $(K^*(892)^+\pi^+\pi^-$ ALUE 21.1 × 10 ⁻³ $(K^*(892)^+\rho^0)/\Gamma_{\text{total}}$ ALUE 29.0 × 10 ⁻⁴ $(K_1(1400)^+\rho^0)/\Gamma_{\text{total}}$ ALUE 21.5 × 10 ⁻³ $(K^+K^0)/\Gamma_{\text{total}}$ ALUE 21.1 × 10 ⁻⁵ $(K^+K^-\pi^+\text{nonre})$ ALUE 22.1 × 10 ⁻⁴ ALUE 23.5 × 10 ⁻⁴ ALUE 24.0 × 10 ⁻⁴ 35.5 × 10 ⁻⁴	CLX 90 90 CLX 90 90 CLX 90 CLX 90 CLX 90 90 CLX 90 90 CLX 90 CLX 90 CLX 90 CLX 90 CLX 90 CLX 90 90 CLX 90 CLX	DOCUMENT ID ALBRECHT DOCUMENT ID BERGFELD 141 ADAM 182 data for average 142 ABREU ALBRECHT	7(45) decays	43% to B ^O B COMMENT e+e-→ COMMENT e-e-→ COMME	780/Г 7(45) 781/Г 7(45) 783/Г 7(45) 784/Г 7(45) 785/Г 7(45) 785/Г 7(45) 785/Г 7(45) 786/Г		VALUE	CL% 90 90 90 90 90 90 90 9	2.3 events above ba 45% to B ⁰ B ⁰ . 2.3 events above ba 45% to B ⁰ B ⁰ . 2.4 events above ba 45% to B ⁰ B ⁰ . 2.5 events above ba 45% to B ⁰ B ⁰ . 2.6 events above ba 45% to B ⁰ B ⁰ . 2.7 events above ba 45% to B ⁰ B ⁰ . 2.8 events above ba 45% to B ⁰ B ⁰ . 2.9 events above ba 45% to B ⁰ B ⁰ . 2.1 events above ba 45% to B ⁰ B ⁰ . 2.2 events above ba 45% to B ⁰ B ⁰ . 2.3 events above ba 45% to B ⁰ B ⁰ . 2.4 events above ba 45% to B ⁰ B ⁰ . 2.5 events above ba 45% to B ⁰ B ⁰ . 2.6 events above ba 45% to B ⁰ B ⁰ . 2.7 events above ba 45% to B ⁰ B ⁰ . 2.8 events above ba 45% to B ⁰ B ⁰ . 2.9 events above ba 45% to B ⁰ B ⁰ . 2.1 events above ba 45% to B ⁰ B ⁰ . 2.2 events above ba 45% to B ⁰ B ⁰ . 2.3 events above ba 45% to B ⁰ B ⁰ . 2.4 events above ba 45% to B ⁰ B ⁰ . 2.5 events above ba 45% to B ⁰ B ⁰ . 2.6 events above ba 45% to B ⁰ B ⁰ . 2.7 events above ba 45% to B ⁰ B ⁰ . 2.8 events above ba 45% to B ⁰ B ⁰ . 2.9 events above ba 45% to B ⁰ B ⁰ .	89B CLEO (45) decays MENT ID AR 93 s, fits, limits, ECHT 89c Y 89e Y 87 ackground. 89G ARG the T(45) de TECN 89G ARG	$e^+e^- \rightarrow$ 43% to B^0 . TECN CC CLE2 e . etc. • • • . ARG e . CLEO e . COMMENT . e+e- \rightarrow . cays 45% t . COMMENT . e+e- \rightarrow . cays 45% t	T(45) B ⁰ . We re Fg DMMENT +e ⁻ → T(45) +e ⁻ → T(45) +e ⁻ → T(45) to B ⁰ B ⁰ . Fg T(45) to B ⁰ B ⁰ .
10 AVERY 89B report to 50%. $(K^0 \rho^+)/\Gamma_{\text{total}}$ ALUE 1.1. × 10 ⁻³ $(K^*(892)^+ \pi^+ \pi^-)$ ALUE 1.2. × 10 ⁻⁴ $(K_1(1400)^+ \rho^0)/\Gamma_{\text{total}}$ ALUE 1.3. × 10 ⁻⁴ $(K_2^*(1430)^+ \rho^0)/\Gamma_{\text{total}}$ ALUE 1.5. × 10 ⁻⁵ $(K^+K^-)/\Gamma_{\text{total}}$ ALUE 1.5. × 10 ⁻⁵ $(K^+K^-)/\Gamma_{\text{total}}$ ALUE 1.5. × 10 ⁻⁵ $(K^+K^-)/\Gamma_{\text{total}}$ ALUE 2.0. × 10 ⁻⁴ • • We do not use 3.1 × 10 ⁻⁴ 3.5 × 10 ⁻⁴ 1. ADAM 96D assumm 1. ADAM 96D assumm 1. ADAM 96D assumm 1. ADAM 96D assumm	CLX 90	DOCUMENT ID ALBRECHT DOCUMENT ID BERGFELD 141 ADAM 18 data for average 142 ABRECHT B - 0.39 and f _B	### 150 ### 15	43% to B ⁰ B COMMENT e+e-→	780/Г 7(45) 781/Г 7(45) 782/Г 7(45) 783/Г 7(45) 784/Г 7(45) 784/Г 7(45) 785/Г 7(45) 786/Г 7(45)		VALUE	CL% 90 90 90 90 90 90 90 9	2.3 events above ba 45% to 80 B0. 2.3 events above ba 45% to 80 B0. 2.4 events above ba 45% to 80 B0. 2.5 events above ba 45% to 80 B0. 2.6 events above ba 45% to 80 B0. 2.7 events above ba 45% to 80 B0. 2.8 events above ba 45% to 80 B0. 2.9 events above ba 45% to 80 B0. 2.1 events above ba 45% to 80 B0. 2.2 events above ba 45% to 80 B0. 2.3 events above ba 45% to 80 B0. 2.4 events above ba 45% to 80 B0. 2.5 events above ba 45% to 80 B0. 2.6 events above ba 45% to 80 B0. 2.7 events above ba 45% to 80 B0. 2.8 events above ba 45% to 80 B0. 2.9 events above ba 45% to 80 B0. 2.1 events above ba 45% to 80 B0. 2.2 events above ba 45% to 80 B0. 2.3 events above ba 45% to 80 B0. 2.4 events above ba 45% to 80 B0. 2.5 events above ba 45% to 80 B0. 2.6 events above ba 45% to 80 B0. 2.7 events above ba 45% to 80 B0. 2.8 events above ba 45% to 80 B0. 2.9 events above ba 45% to 80 B0. 2.0 events above ba 45% to 80 B0. 2.1 events above ba 45% to 80 B0. 2.2 events above ba 45% to 80 B0. 2.3 events above ba 45% to 80 B0. 2.3 events above ba 45% to 80 B0. 2.4 events above ba 45% to 80 B0. 2.5 events above ba 45% to 80 B0. 2.6 events above ba 45% to 80 B0. 2.7 events above ba 45% to 80 B0. 2.8 events above	### SPB CLEO ### C(4S) decays ### PROPERTY #	$e^+e^- \rightarrow$ 43% to B^0 . TECN CC CLE2 e ⁻ . etc. • • • . ARG e ⁻ . CLEO e ⁻ . CLEO e ⁻ . CLEO e ⁻ . CLEO e ⁻ . COMMENT e ⁺ e ⁻ \rightarrow . cays 45% t . COMMENT e ⁺ e ⁻ \rightarrow . cays 45% t	T(45) B ⁰ . We res Fg DMMENT +e ⁻ → T(45) T(45) T(45) T(45) T(45)
$(K^0 \rho^+)/\Gamma_{\text{total}}$ LUE $(K^0 \rho^+)/\Gamma_{\text{total}}$ LUE $(K^*(892)^+ \pi^+ \pi^-)$ $(K^*(892)^+ \pi^+ \pi^-)$ $(K^*(892)^+ \rho^0)/\Gamma_{\text{LUE}}$ $(K^*(892)^+ \rho^0)/\Gamma_{\text{LUE}}$ $(K_1(1400)^+ \rho^0)/\Gamma_{\text{LUE}}$ $(K_1(1400)^+ \rho^0)/\Gamma_{\text{LUE}}$ $(K_2(1430)^+ \rho^0)/\Gamma_{\text{LUE}}$ $(K_2^*(1430)^+ \rho^0)/\Gamma_{\text{LUE}}$ $(K^* K^- \pi^+ \text{nonre})$ $(K^+ K^- \pi^+ \text{nonre})$	CLX 90	DOCUMENT ID ALBRECHT DOCUMENT ID BERGFELD 141 ADAM 18 data for average 142 ABRECHT B - 0.39 and f _B	### 150 ### 15	43% to B ⁰ B COMMENT e+e-→	780/Г 7(45) 781/Г 7(45) 782/Г 7(45) 783/Г 7(45) 784/Г 7(45) 784/Г 7(45) 785/Г 7(45) 786/Г 7(45)		VALUE	CL% 90 90 90 90 90 90 90 9	2.3 events above ba 45% to B ⁰ B ⁰ . 2.3 events above ba 45% to B ⁰ B ⁰ . 2.4 events above ba 45% to B ⁰ B ⁰ . 2.5 events above ba 45% to B ⁰ B ⁰ . 2.6 events above ba 45% to B ⁰ B ⁰ . 2.7 events above ba 45% to B ⁰ B ⁰ . 2.8 events above ba 45% to B ⁰ B ⁰ . 2.9 events above ba 45% to B ⁰ B ⁰ . 2.1 events above ba 45% to B ⁰ B ⁰ . 2.2 events above ba 45% to B ⁰ B ⁰ . 2.3 events above ba 45% to B ⁰ B ⁰ . 2.4 events above ba 45% to B ⁰ B ⁰ . 2.5 events above ba 45% to B ⁰ B ⁰ . 2.6 events above ba 45% to B ⁰ B ⁰ . 2.7 events above ba 45% to B ⁰ B ⁰ . 2.8 events above ba 45% to B ⁰ B ⁰ . 2.9 events above ba 45% to B ⁰ B ⁰ . 2.1 events above ba 45% to B ⁰ B ⁰ . 2.2 events above ba 45% to B ⁰ B ⁰ . 2.3 events above ba 45% to B ⁰ B ⁰ . 2.4 events above ba 45% to B ⁰ B ⁰ . 2.5 events above ba 45% to B ⁰ B ⁰ . 2.6 events above ba 45% to B ⁰ B ⁰ . 2.7 events above ba 45% to B ⁰ B ⁰ . 2.8 events above ba 45% to B ⁰ B ⁰ . 2.9 events above ba 45% to B ⁰ B ⁰ .	### SPB CLEO ### C(4S) decays ### PROPERTY #	$e^+e^- \rightarrow$ 43% to B^0 . TECN CC CLE2 e . etc. • • • . ARG e . CLEO e . COMMENT . e+e- \rightarrow . cays 45% t . COMMENT . e+e- \rightarrow . cays 45% t	T(45) B ⁰ . We re F ₀ P(45) T(45) + e ⁻ → T(45) + e ⁻ → T(45) + e ⁻ → T(45)

Γ₁₀₉/Γ

al UK	DOCUMENT IN	TECN	COMMENT	Γ ₁₀₀ /Γ	$\Gamma(\rho^+\pi^0)/\Gamma_{\text{total}}$	CL N
	154 ALBRECHT	89G ARG		r(45)	<7.7 × 10 ⁻⁸	90
1				Γ101 /Γ		
	DOCUMENT ID	İECN	COMMENT	1017.		
90	155 ALBRECHT	89G ARG	e+e- → 1	r(45)	•	total cl%_
orts <	0.0090 assuming t	he $\Upsilon(4S)$ de	cays 45% to	$B^0\widehat{B}^0$. We	<4.0 × 10 ⁻³	90
				Γ /Γ		imit assum
CL%	DOCUMENT ID	TECN	COMMENT	102/		
90	GODANG	98 CLE2	e+e- → 1	r(4S)		<u>CL%</u>
	_					
	157 BEBEK				• • • • • • • • • • • • • • • • • • • •	total CL%
t assum	es equal production	of B ⁰ B ⁰ an	nd $\mathcal{B}^+\mathcal{B}^-$ at	T(45).	<1.7 × 10 ⁻³	90
ie T(45) decays 43% to B	0 78 0.			173 ALBRECHT 90B	lmit assum
				Γ ₁₀₃ /Γ		
<u>CL %</u>						CL%_
				ı	<9.0 × 10 ⁻⁴	90
	-			AM 96D	174 ALBRECHT 908 I	imit assum
90	160 ALBRECHT	90B ARG	e+e- → 1	r(45)		
			e+e~ → 1	r(45)	VALUE	CLN.
$I_{B_0} = I$	$f_{B^-}=0.39$ and f_{B}	s == 0.12.		1	<4.0 × 10 ⁻⁴	90
roductio	on fraction of 0.39	and a B_s pro	duction fraction	on of 0.12.	175 ALBRECHT 908	imit assum
eports <	< 1.7 × 10 ⁻⁴ assur	ming the 7(4	5) decays 43	7 (43). % to 8 ⁰ 8 ⁰ .	$\Gamma(\eta \pi^+)/\Gamma_{\eta \sigma \sigma}$	
•		• (, ,		VALUE	CL%
				Γ_{104}/Γ		90
<u>EVTS</u>	DOCUMENT ID					
d-H-mb	ASNER			r(45)		90
						ımıt assum
	163 ABREU				• •	
	164 ALBRECHT	90B ARG	e+e- → 7	(45)		<u>CLN</u> _ 90
						,,
0	GILES					
$f_{R^0} = f$	$f_{B^-} = 0.39 \text{ and } f_{B_0}$	= 0.12.				<u>CL%</u>
roductio	on fraction of 0.39	and a B _s pro	duction fraction	on of 0.12.	-	30
				T(45).	• •	
	·	. we rescale	10 50%.			<u>CLN</u>
$(\rho^0\pi^+$				3+Г ₁₀₄)/Г		
						•
			$e^+e^- \rightarrow Z$	•	<8.6 × 10 ⁻⁴	<u>CL%.</u> 90
_	$f_{B^-} = 0.39 \text{ and } f_{B_0}$	s = 0.12.		1	177 ALBRECHT 90B I	
1 _{B0} = 1						
¹ B ⁰ = 1				Гаст /Г		-
		TECN	COMMENT	Γ ₁₀₅ /Γ	Γ(ρ ⁰ a ₁ (1260) ⁺)/Γ	
CL%.	DOCUMENT ID				(ρ ^ω a ₁ (1260) ⁺)/! <u>VALUE</u> <6.2 × 10 ⁻⁴	total <u>CL%</u> 90
<u>CL%</u> . 90	DOCUMENT ID	O89 CLEO	e+e- → 7	(45)	<u>VALUE</u> <6.2 × 10 ⁻⁴ • • • We do not use	90 CL%
<u>CL%</u> . 90	DOCUMENT ID	O89 CLEO	e+e- → 7	(45)	VALUE <6.2 × 10 ⁻⁴ • • • We do not use <6.0 × 10⁻⁴ 	90 the followi
<u>CL%</u> . 90	DOCUMENT ID 167 BORTOLETTO 1.2 × 10 ⁻⁴ assur	O89 CLEO	$e^+e^- \rightarrow 7$ S) decays 43	(45)	VALUE <6.2 × 10 ⁻⁴ • • • We do not use <6.0 × 10 ⁻⁴ <3.2 × 10 ⁻³	90 the followi 90 90
CL%. 90 eports <	DOCUMENT ID 167 BORTOLETT 1.2 × 10 ⁻⁴ assur	O89 CLEO ming the T(4	e ⁺ e [−] → 7 S) decays 43° COMMENT	Γ(45) % to Β ⁰ Β̄ ⁰ .	VALUE <6.2 × 10 ⁻⁴ • • • We do not use <6.0 × 10 ⁻⁴ <3.2 × 10 ⁻³ 178 BORTOLETTO 8 We smooth to Follow	90 the followi 90 90 90
CL%. 90 eports < CL%. 90	DOCUMENT ID 167 BORTOLETTO 1.2 × 10 ⁻⁴ assur DOCUMENT ID 168 BORTOLETTO	089 CLEO ming the T(4	$e^+e^- \rightarrow 7$ (S) decays 43.5 COMMENT $e^+e^- \rightarrow 7$	Γ(45) % to B ⁰ B̄ ⁰ . Γ ₁₀₆ /Γ	 ✓6.2 x 10⁻⁴ • • We do not use <6.0 x 10⁻⁴ <3.2 x 10⁻³ 178 BORTOLETTO 8 	90 the followi 90 90 90
CL%. 90 eports < CL%. 90	DOCUMENT ID 167 BORTOLETT 1.2 × 10 ⁻⁴ assur	089 CLEO ming the T(4	$e^+e^- \rightarrow 7$ (S) decays 43.5 COMMENT $e^+e^- \rightarrow 7$	Γ(45) % to B ⁰ B̄ ⁰ . Γ ₁₀₆ /Γ	 ✓6.2 x 10⁻⁴ • • • We do not use ✓6.0 x 10⁻⁴ ✓3.2 x 10⁻³ 178 BORTOLETTO 8 We rescale to 50% 179 ALBRECHT 908 I 	90 the followi 90 90 9 reports
<u>CL%</u> 90 eports < I <u>CL%</u> 90 eports <	DOCUMENT ID 167 BORTOLETTO 1.2 × 10 ⁻⁴ assur DOCUMENT ID 168 BORTOLETTO 2.1 × 10 ⁻⁴ assur	089 CLEO ming the T(4	$e^+e^- \rightarrow 7$ (S) decays 43.5 COMMENT $e^+e^- \rightarrow 7$	Γ(45) % to B ⁰ B ⁰ . Γ106/Γ Γ(45) % to B ⁰ B ⁰ .	***C\$\text{\sigma} \text{\sigma} \sin	90 the followi 90 90 9 reports
CL%. 90 eports < CL%. 90 eports < ant)/	DOCUMENT ID 167 BORTOLETT 1.2 × 10 ⁻⁴ assur DOCUMENT ID 168 BORTOLETT 2.1 × 10 ⁻⁴ assur	OB9 CLEO ming the T(4	$e^+e^- \rightarrow 7$ S) decays 43! COMMENT $e^+e^- \rightarrow 7$ S) decays 43!	Γ(45) % to B ⁰ B̄ ⁰ . Γ ₁₀₆ /Γ	**XAUE <6.2 × 10 ⁻⁴ • • • • We do not use <6.0 × 10 ⁻⁴ <3.2 × 10 ⁻³ 178 BORTOLETTO 8 We rescale to 50% 179 ALBRECHT 908 I F(p ⁰ 2/2(1320)+)/I **XAUE <7.2 × 10 ⁻⁴	90 the followi 90 90 9reports init assum total
<u>CL%</u> 90 eports < I <u>CL%</u> 90 eports <	DOCUMENT ID 167 BORTOLETTO 1.2 × 10 ⁻⁴ assur DOCUMENT ID 168 BORTOLETTO 2.1 × 10 ⁻⁴ assur	OB9 CLEO ming the T(4	$e^+e^- \rightarrow 7$ (S) decays 43.5 COMMENT $e^+e^- \rightarrow 7$	(45) % to 8 ⁰ 8 ⁰ . F106/F (45) % to 8 ⁰ 8 ⁰ .	**XLUE <6.2 × 10 ⁻⁴ • • • We do not use <6.0 × 10 ⁻⁴ <3.2 × 10 ⁻³ 178 BORTOLETTO 8 We rescale to 50% 179 ALBRECHT 908 I F(p ⁰ 2 ₂ (1320) ⁺)/I **XLUE <7.2 × 10 ⁻⁴ • • • We do not use	90 the following 90 90 9 reports - imit assum total
CL%. 90 eports < CL%. 90 eports < cus. 90 eports < ant)/F	DOCUMENT ID 167 BORTOLETTO 1.2 × 10 ⁻⁴ assur DOCUMENT ID 168 BORTOLETTO 2.1 × 10 ⁻⁴ assur total	OB9 CLEO ming the T(4	e+e- → 1 S) decays 43 COMMENT e+e- → 1 S) decays 43 COMMENT	(45) % to B ⁰ B̄ ⁰ . (45) (45) % to B ⁰ B̄ ⁰ . (45)	**XLUE	90 90 9 reports - imit assum total CLS 90 the following total 90 90 90 90 90 90 90 90 90 90 90 90 90
CLN. 90 eports < CLN. 90 eports < continuous continuo	DOCUMENT ID 167 BORTOLETTI 1.2 × 10 ⁻⁴ assur DOCUMENT ID 168 BORTOLETTI 2.1 × 10 ⁻⁴ assur Total DOCUMENT ID BERGFELD	O89 CLEO ming the T(4	$e^+e^- \rightarrow \gamma$ S) decays 43? SOMMENT $e^+e^- \rightarrow \gamma$ S) decays 43? COMMENT $e^+e^- \rightarrow \gamma$	(45) % to 8 ⁰ 8 ⁰ . F106/F (45) % to 8 ⁰ 8 ⁰ .	***CF*********************************	90 90 90 9reports - imit assum total CLN 90 90 9 reports - imit assum
CLN. 90 eports < 1 CLN. 90 eports < ant)/F CLN. 90	DOCUMENT ID 167 BORTOLETTO 1.2 × 10 ⁻⁴ assur DOCUMENT ID 168 BORTOLETTO 2.1 × 10 ⁻⁴ assur total	O89 CLEO ming the T(4	e+e- → 1 S) decays 43 COMMENT e+e- → 1 S) decays 43 COMMENT	(45) % to B ⁰ B ⁰ . F106/F (45) % to B ⁰ B ⁰ . F107/F	 ✓6.2 x 10⁻⁴ • • We do not use ✓6.0 x 10⁻⁴ ✓3.2 x 10⁻³ 178 BORTOLETTO 8 We rescale to 50% 179 ALBRECHT 908 I Γ(ρ⁰ a₂(1320)⁺)/Γ ✓1.2 x 10⁻⁴ • • We do not use ✓2.6 x 10⁻³ 180 BORTOLETTO 8 	90 90 90 9reports - imit assum total CLN 90 90 9 reports - imit assum
	orts < 0. CLY. 90 orts < CLY. 90 ort	154 ALBRECHT 157 C 0.005 assuming the 1 158 DOCUMENT ID 159 ALBRECHT 159 GODANG 150 GODANG 150 GODANG 151 OF BEBEK 156 ALBRECHT 157 BEBEK 157 BEBEK 158 ADAM 159 ADAM 159 ADAM 150 ALBRECHT 159 ABREU 150 ALBRECHT 151 BEBEK 151 ADAM 152 ADAM 153 ADAM 154 ALBRECHT 155 ALBRECHT 157 BEBEK 158 ADAM 159 ABREU 150 ALBRECHT 151 ADAM 151 ADAM 152 ADAM 153 ABREU 154 ALBRECHT 155 BORTOLETTI 156 BORTOLETTI 157 BORTOLETTI 157 BORTOLETTI 157 BORTOLETTI 158 BORTOLETTI 158 BORTOLETTI 159 BORTOLETTI 159 BORTOLETTI 150 BORTOLETTI 150 BORTOLETTI 150 BORTOLETTI 150 BORTOLETTI 151 BORTOLETTI 155 BORTOLETTI	90 154 ALBRECHT 89G ARG orts < 0.005 assuming the $T(4S)$ decays orts < 0.005 assuming the $T(4S)$ decays 155 ALBRECHT 89G ARG orts < 0.0090 assuming the $T(4S)$ decays 90 155 ALBRECHT 89G ARG orts < 0.0090 assuming the $T(4S)$ decays 90 GODANG 98 CLE2 following data for averages, fits, limits, 90 ASNER 96 CLE2 156 ALBRECHT 90B ARG 90 157 BEBEK 87 CLE0 158 ADAM 96D DLPH 90 160 ALBRECHT 90B ARG 161 BORTOLETTO89 CLE0 161 BORTOLETTO89 CLE0 161 BORTOLETTO89 CLE0 161 BORTOLETTO89 CLE0 161 ASSUMING the $T(4S)$ decays 43% to $T(4S)$ decays 90 and $T(4S)$ assuming the $T(4S)$ decays 43% to $T(4$	90 154 ALBRECHT 89G ARG $e^+e^- \rightarrow 7$ orts < 0.005 assuming the $\Upsilon(4S)$ decays 45% to $B^0\overline{B}^0$ orts < 0.005 assuming the $\Upsilon(4S)$ decays 45% to $B^0\overline{B}^0$ orts < 0.0090 assuming the $\Upsilon(4S)$ decays 45% to $B^0\overline{B}^0$ orts < 0.0090 assuming the $\Upsilon(4S)$ decays 45% to orts < 0.0090 assuming the $\Upsilon(4S)$ decays 45% to orts < 0.0090 assuming the $\Upsilon(4S)$ decays 45% to $B^0\overline{B}^0$ orts < 0.0090 assuming the $T(4S)$ decays 45% to $B^0\overline{B}^0$ orts < 0.0090 assuming the $T(4S)$ decays 45% to $B^0\overline{B}^0$ orts < 0.0090 assuming the $T(4S)$ decays 45% to $B^0\overline{B}^0$ orts < 0.0090 assuming the $T(4S)$ decays 43% to $B^0\overline{B}^0$ and B^+B^- at the $T(4S)$ decays 43% to $B^0\overline{B}^0$ orts of $B^0\overline{B}^0$ and B^+B^- at the $T(4S)$ decays 43% to $B^0\overline{B}^0$. CLX: DOCUMENT ID TECN COMMENT or 158 ADAM 96D DLPH $e^+e^- \rightarrow Z$ of 161 BORTOLETTO89 CLEO $e^+e^- \rightarrow T$ orts of $B^0\overline{B}^0$ and B^+B^- at the summary of $B^0\overline{B}^0$ and B^+B^- at $B^0\overline{B}^0$ and $B^0\overline{B}^0$	154 ALBRECHT 89G ARG $e^+e^- \rightarrow T(45)$ orts < 0.005 assuming the $T(45)$ decays 45% to $B^0\overline{B}^0$. We rescale of the second sec	90 154 ALBRECHT 89G ARG $e^+e^- \rightarrow T(45)$ orts < 0.005 assuming the $T(45)$ decays 45% to B^0B^0 . We rescale 170 155 ALBRECHT 89G ARG $e^+e^- \rightarrow T(45)$ orts < 0.0090 assuming the $T(45)$ decays 45% to B^0B^0 . We 175 ALBRECHT 89G ARG $e^+e^- \rightarrow T(45)$ orts < 0.0090 assuming the $T(45)$ decays 45% to B^0B^0 . We 175 ALBRECHT 99G BRG $e^+e^- \rightarrow T(45)$ following data for averages, fits, limits, etc. ••• 190 ASNER 96 CLE2 Repl. by GODANG 98 176 ALBRECHT 90B ARG $e^+e^- \rightarrow T(45)$ to 356 ALBRECHT 90B ARG $e^+e^- \rightarrow T(45)$ at assumes equal production of B^0B^0 and B^+B^- at $T(45)$. The $T(45)$ decays 43% to B^0B^0 . 170 158 ADAM 96D DLPH $e^+e^- \rightarrow Z$ 171 ALBRECHT 90B ARG $e^+e^- \rightarrow T(45)$ 172 ALBRECHT 90B ARG $e^+e^- \rightarrow T(45)$ 173 ALBRECHT 90B ARG $e^+e^- \rightarrow T(45)$ 174 ALBRECHT 90B ARG $e^+e^- \rightarrow T(45)$ 175 ALBRECHT 90B ARG $e^+e^- \rightarrow T(45)$ 176 ALBRECHT 90B ARG

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DOCUMENT ID TECH COMMENT
                                        ASNER 96 CLE2 e^+e^- \rightarrow \Upsilon(4S)
                                      data for averages, fits, limits, etc. • • •
                                      <sup>0</sup> ALBRECHT 90B ARG e^+e^- \rightarrow \Upsilon(45)
                                      equal production of B^0\overline{B}^0 and B^+B^- at \Upsilon(4S).
                                                                                        \Gamma_{110}/\Gamma
                                       DOCUMENT ID TECN COMMENT
                                      <sup>1</sup> ALBRECHT 908 ARG e^+e^- \rightarrow T(4S)
                                      equal production of B^0 \overline{B}{}^0 and B^+ B^- at \Upsilon(4S).
                                                                                        Γ<sub>111</sub>/Γ
                                     DOCUMENT ID TECN COMMENT

12 ALBRECHT 90B ARG e+e- → T(45)
                                      equal production of B^0\overline{B}^0 and B^+B^- at T(45).
                                                                                       \Gamma_{112}/\Gamma
                                        DOCUMENT ID TECH COMMENT
                                      <sup>3</sup> ALBRECHT 908 ARG e^+e^- \rightarrow T(45)
                                      equal production of B^0 \overline{B}{}^0 and B^+ B^- at T(45).
                                                                                       \Gamma_{113}/\Gamma
                                       DOCUMENT ID TECH COMMENT
                                      <sup>'4</sup> ALBRECHT 90B ARG e^+e^- \rightarrow \Upsilon(4S)
                                      equal production of B^0\overline{B}^0 and B^+B^- at T(4S).
                                       DOCUMENT ID TECH COMMENT
                                      <sup>'5</sup> ALBRECHT 908 ARG e^+e^- \rightarrow T(45)
                                      equal production of B^0 \overline{B}{}^0 and B^+ B^- at T(45).
                                                                                        \Gamma_{115}/\Gamma
                                       DOCUMENT ID TECH COMMENT
                                       BEHRENS 98 CLE2 e^+e^- \rightarrow T(45)
                                      data for averages, fits, limits, etc. • • •
                                      <sup>6</sup> ALBRECHT 908 ARG e^+e^- \rightarrow \Upsilon(4S)
                                      equal production of B^0\overline{B}{}^0 and B^+B^- at \Upsilon(4S).
                                                                                        \Gamma_{116}/\Gamma
                                       DOCUMENT ID TECN COMMENT
                                       BEHRENS 98 CLE2 e^+e^- \rightarrow \Upsilon(4S)
                                                                                        F117/F
                                       DOCUMENT ID TECH COMMENT
                                       BEHRENS 98 CLE2 e^+e^- \rightarrow T(45)
                                                                                        \Gamma_{118}/\Gamma
                                       DOCUMENT ID TECN COMMENT
                                       BEHRENS 98 CLE2 e^+e^- \rightarrow T(45)
                                                                                        \Gamma_{119}/\Gamma
                                       DOCUMENT ID TECH COMMENT
                                      <sup>7</sup> ALBRECHT 908 ARG e^+e^- \rightarrow \tau(4S)
                                      equal production of B^0 \overline{B}{}^0 and B^+ B^- at \Upsilon(4S).
                                                                                        \Gamma_{120}/\Gamma
                                       DOCUMENT ID TECH COMMENT
                                      '8 BORTOLETTO89 CLEO e^+e^- \rightarrow \Upsilon(45)
                                      data for averages, fits, limits, etc. • • •
                                      9 ALBRECHT 908 ARG e^+e^- \rightarrow \Upsilon(45)
                                      <sup>8</sup> BEBEK 87 CLEO e^+e^- \rightarrow \tau(45)
                                      6.4 	imes 10^{-4} assuming the T(4S) decays 43% to B^0 \overline{B}{}^0.
                                      equal production of B^0 \overline B{}^0 and B^+ B^- at T(4S).
                                                                                       \Gamma_{121}/\Gamma
                                       DOCUMENT ID
                                                            TECH COMMENT
                                      BORTOLETTO89 CLEO e^+e^- \rightarrow T(4S)
                                      data for averages, fits, limits, etc. \bullet \bullet
                                                        87 CLEO e^+e^- \rightarrow T(45)
                                      .3 \times 10^{-4} assuming the \Upsilon(45) decays 43% to B^0 \overline{B}^0.
                                      assuming the \Upsilon(4S) decays 43% to B^0\overline{B}{}^0. We rescale
                                                                                        \Gamma_{122}/\Gamma
                                       DOCUMENT ID
                                                         TECN COMMENT
                          90 182 ALBRECHT 908 ARG e+e- → T(45)
<sup>182</sup> ALBRECHT 908 limit assumes equal production of B^0 \overline{B}{}^0 and B^+ B^- at \Upsilon(45).
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 B^{\pm}

	.260) ⁰)/F _{tot}				Γ ₁₂₃ /Γ
<1.3 × 10 ⁻²	<u>CL%</u> 90 1	DOCUMENT ID 83 ALBRECHT	90B ARG		
83 ALBRECHT 908					
「(ppπ+)/Γ _{total}	<u> </u>	DOCUMENT	ID <u>TEC</u> I	N COMMEN	Γ ₁₂₄ /Γ
	10-4 90	184 BEBEK			
• • We do not us	e the following				, ,
	10-4 90	185 ABREU			ADAM 96D
(5.7±1.5±2.1) ×		186 ALBRECHT		i e ⁺ e ⁻ -	
.84 BEBEK 89 repor to 50%.	ts < 1.4 × 10 ⁻	assuming the 1	r(45) decays	43% to B	B ^o . We rescale
to 50%. 85 Assumes a B ⁰ , I	3 production	fraction of 0.39	and a B _S pro	oduction frac	tion of 0.12.
.86 ALBRECHT 88F B ⁰ B ⁰ . We resca	reports (5.2 ±	± 1.4 ± 1.9) × 10	^{—4} assuming	the $\Upsilon(4S)$	decays 45% to
$(p\bar{p}\pi^+$ nonreson					Γ ₁₂₅ /Γ
<5.3 × 10 ⁻⁵	<u>CL%</u> 90	DOCUMENT ID BERGFELD	968 CLE2		T(45)
		BERGFELD	70B CLEZ	e · c	1 (43)
$(\rho \overline{\rho} \pi^+ \pi^+ \pi^-)/$					Г ₁₂₆ /Г
ALUE	<u>CL%</u>	DOCUMENT ID 87 ALBRECHT			m(4C)
<5.2 × 10⁻⁴ ⁸⁷ ALBRECHT 88F					
rescale to 50%.	reports < 4.7	x 10 · assumin	g the 1 (43)	decays 45%	to B B. We
(<i>p̄p̄K</i> + nonr es o	nant) /[Γ ₁₂₇ /Γ
ALUE	CL%	DOCUMENT ID	TECN	COMMENT	1 127/1
<8.9 × 10 ⁵	90	BERGFELD			T(45)
(p∕A)/Γ _{total}					F /F
ALUE	<u>CL%</u>	DOCUMENT ID	TECN	COMMENT	Γ ₁₂₈ /Γ
(6 × 10 ⁻⁵		88 AVERY			T(45)
• We do not use	e the following	data for average	s, fits, limits	, etc. • • •	
9.3 × 10 ⁻⁵		⁸⁹ ALBRECHT			
38 AL (PRO) 4 AA-		Б. —			=n
ANERA RAB LEDO	rts $< 5 \times 10^{-1}$	assuming the 7	~(4 <i>5</i>) decays	43% to B ^O	30. We rescale
to 50%. 89 AL RRECHT 88F	reports < 8.5	\sim assuming the T	(45) decays	43% to <i>B^OT</i>	3°. We rescale
to 50%. B9 ALBRECHT 88F rescale to 50%.	rts < 5 × 10 ⁻¹ reports < 8.5	$^{\circ}$ assuming the $^{\circ}$ $^{\circ}$ $^{\circ}$ assuming	(45) decays	43% to B ^O l decays 45%	to $B^0 \overline{B}{}^0$. We
to 50%. B9 ALBRECHT 88F rescale to 50%.	reports < 8.5	$^{\circ}$ assuming the 7 $ imes$ 10 $^{-5}$ assuming	$^{\circ}(4S)$ decays	43% to <i>B^O l</i> decays 45%	to <i>B⁰ B⁰.</i> We
to 50%. 89 ALBRECHT 88F rescale to 50%. $(p \overline{\Lambda} \pi^+ \pi^-) / \Gamma_{to}$	reports < 8.5	× 10 ⁻⁵ assumin _i	g the <i>T</i> (45)	decays 45%	to <i>Β⁰ B̄⁰.</i> We
10 50%. 39 ALBRECHT 88F rescale to 50%. (pΛπ ⁺ π ⁻)/Γ _{to} ALUE (2.0 × 10 ⁻⁴	reports < 8.5	× 10 ⁻⁵ assuming DOCUMENT ID OALBRECHT	g the <i>T</i> (45) TECN 88F ARG	decays 45% <u>COMMENT</u> e+e- →	to <i>B</i> ⁰ B ⁰ . We Γ ₁₂₉ /Γ
to 50%. 9 ALBRECHT 88F rescale to 50%. $(p \overline{\Lambda} \pi^+ \pi^-) / \Gamma_{to}$ 10 ALUE 22.0 × 10 ⁻⁴ 90 ALBRECHT 88F	reports < 8.5	× 10 ⁻⁵ assuming DOCUMENT ID OALBRECHT	g the <i>T</i> (45) TECN 88F ARG	decays 45% <u>COMMENT</u> e+e- →	to <i>B</i> ⁰ B ⁰ . We Γ ₁₂₉ /Γ
to 50%. 9 ALBRECHT 88F rescale to 50%. $(p \overline{A} \pi^{+} \pi^{-}) / \Gamma_{to}$ ALUE 2.0 × 10 ⁻⁴ 90 ALBRECHT 88F rescale to 50%.	reports < 8.5	× 10 ⁻⁵ assuming DOCUMENT ID OALBRECHT	g the <i>T</i> (45) TECN 88F ARG	decays 45% <u>COMMENT</u> e+e- →	to <i>B</i> ⁰ B ⁰ . We Γ ₁₂₉ /Γ
to 50%. 99 ALBRECHT 88F rescale to 50%. $(p \overline{\Lambda} \pi^+ \pi^-) / \Gamma_{to}$ 44. UE 22.0 × 10 ⁻⁴ 90 ALBRECHT 88F rescale to 50%. $(\overline{\Delta}^0 p) / \Gamma_{total}$	reports < 8.5	$ imes$ 10^{-5} assuming $\frac{DOCUMENT~1D}{4}$ ALBRECHT $ imes$ 10^{-4} assuming	g the T(4S) TECN 88F ARG g the T(4S)	COMMENT e+e-→ decays 45%	to <i>B</i> ⁰ B ⁰ . We Γ ₁₂₉ /Γ
to 50%. 99 ALBRECHT 88F rescale to 50%. $(\rho \overline{A} \pi^+ \pi^-)/\Gamma_{tot}$ 100 ALBRECHT 88F rescale to 50%. $(\overline{\Delta}^0 \rho)/\Gamma_{total}$ LUE	reports < 8.5 CL% 90 19 reports < 1.8	× 10 ⁻⁵ assuming DOCUMENT ID 90 ALBRECHT × 10 ⁻⁴ assuming	## TECN	COMMENT e+e-→ decays 45%	to $B^0\overline{B}^0$. We Γ_{129}/Γ $\Upsilon(45)$ to $B^0\overline{B}^0$. We Γ_{130}/Γ
to 50%. 9 ALBRECHT 88F rescale to 50%. ($p \overline{A} \pi^+ \pi^-$)/ Γ_{tot} 1.UE 2.0 × 10 ⁻⁴ OALBRECHT 88F rescale to 50%. ($\overline{A}^0 p$)/ Γ_{total} 1.UE 3.8 × 10 ⁻⁴	reports < 8.5 tal	× 10 ⁻⁵ assuming DOCUMENT ID ALBRECHT × 10 ⁻⁴ assuming DOCUMENT ID BORTOLETTO	g the T(45) TECN 88F ARG g the T(45) TECN 089 CLEO	decays 45% $ \begin{array}{c} COMMENT \\ e^+e^- \rightarrow \\ decays 45\% \end{array} $ $ \begin{array}{c} COMMENT \\ e^+e^- \rightarrow \\ \end{array} $	to $B^0\overline{B}^0$. We Γ_{129}/Γ $\Upsilon(45)$ to $B^0\overline{B}^0$. We Γ_{130}/Γ $\Upsilon(45)$
to 50%. 9 ALBRECHT 88F rescale to 50%. ($p \overline{A} \pi^+ \pi^-$)/ Γ_{tot} 1.UE 2.0 × 10 ⁻⁴ OALBRECHT 88F rescale to 50%. ($\overline{A}^0 p$)/ Γ_{total} 1.UE 3.8 × 10 ⁻⁴	reports < 8.5 tal	× 10 ⁻⁵ assuming DOCUMENT ID ALBRECHT × 10 ⁻⁴ assuming DOCUMENT ID BORTOLETTO	g the T(45) TECN 88F ARG g the T(45) TECN 089 CLEO	decays 45% $ \begin{array}{c} COMMENT \\ e^+e^- \rightarrow \\ decays 45\% \end{array} $ $ \begin{array}{c} COMMENT \\ e^+e^- \rightarrow \\ \end{array} $	to $B^0\overline{B}^0$. We Γ_{129}/Γ $\Upsilon(45)$ to $B^0\overline{B}^0$. We Γ_{130}/Γ $\Upsilon(45)$
10 50%. 19 ALBRECHT 8BF rescale to 50%. (p/Λπ+π-)/Γto ALUE 22.0 × 10-4 190 ALBRECHT 8BF rescale to 50%. (Δ0 p)/Γtotal ALUE 23.8 × 10-4 191 BORTOLETTO We rescale to 50	reports < 8.5 tal	× 10 ⁻⁵ assuming DOCUMENT ID ALBRECHT × 10 ⁻⁴ assuming DOCUMENT ID BORTOLETTO	g the T(45) TECN 88F ARG g the T(45) TECN 089 CLEO	decays 45% $ \begin{array}{c} COMMENT \\ e^+e^- \rightarrow \\ decays 45\% \end{array} $ $ \begin{array}{c} COMMENT \\ e^+e^- \rightarrow \\ \end{array} $	to $B^0 \overline{B}^0$. We Γ_{129}/Γ $\Upsilon(45)$ to $B^0 \overline{B}^0$. We Γ_{130}/Γ $\Upsilon(45)$ 3% to $B^0 \overline{B}^0$.
to 50%. 99 ALBRECHT 8BF rescale to 50%. $(p / \pi \pi^+ \pi^-) / \Gamma_{tot}$ ALUE C2.0 × 10 ⁻⁴ 90 ALBRECHT 8BF rescale to 50%. $(\Delta^0 p) / \Gamma_{total}$ ALUE C3.8 × 10 ⁻⁴ 91 BORTOLETTO We rescale to 50' $(\Delta^{++} p) / \Gamma_{total}$	reports < 8.5 tal	× 10 ⁻⁵ assuming DOCUMENT ID ALBRECHT × 10 ⁻⁴ assuming DOCUMENT ID BORTOLETTO	TECN BBF ARG g the T(45) TECN O89 CLEO	decays 45% $ \begin{array}{c} COMMENT \\ e^+e^- \rightarrow \\ decays 45\% \end{array} $ $ \begin{array}{c} COMMENT \\ e^+e^- \rightarrow \\ \end{array} $	to $B^0\overline{B}^0$. We Γ_{129}/Γ $\Upsilon(45)$ to $B^0\overline{B}^0$. We Γ_{130}/Γ $\Upsilon(45)$
80 50%. 89 ALBRECHT 88F rescale to 50%. (ρ/λπ+π-)/Γ tor ALUE 20 × 10-4 90 ALBRECHT 88F rescale to 50%. (Δ0 p)/Γ total ALUE 23.8 × 10-4 91 BORTOLETTO We rescale to 50 (Δ++p)/Γ total ALUE	reports < 8.5 tal CL% 90 19 reports < 1.8 CL% 90 10 89 reports < 3 %.	× 10 ⁻⁵ assuming DOCUMENT ID ALBRECHT × 10 ⁻⁴ assuming DOCUMENT ID BORTOLETTO 3.3 × 10 ⁻⁴ assur	### TECN COMMENT $e^+e^- \rightarrow$ decays 45% COMMENT $e^+e^- \rightarrow$ 15) decays 4	to $B^0 \overline{B}^0$. We Γ_{129}/Γ $\Upsilon(45)$ to $B^0 \overline{B}^0$. We Γ_{130}/Γ $\Upsilon(45)$ 3% to $B^0 \overline{B}^0$.	
80 50%. 80 ALBRECHT 88F rescale to 50%. (ρ/Λπ+π-)/Γτο ALUE (2.0 × 10-4 90 ALBRECHT 88F rescale to 50%. (Δ0 p)/Γτοταί ALUE (3.8 × 10-4 91 BORTOLETTO We rescale to 50 (Δ++p)/Γτοταί ALUE (3.15 × 10-4 92 BORTOLETTO	reports < 8.5 CL% 90 19	× 10 ⁻⁵ assuming DOCUMENT ID ALBRECHT × 10 ⁻⁴ assuming DOCUMENT ID BORTOLETTO 3.3 × 10 ⁻⁴ assur	### TECN 1ECN decays 45% $\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow \\ \\ \underline{COMMENT} \\ e^+e^- \rightarrow \\ 15) \ \\ \underline{COMMENT} \\ e^+e^- \rightarrow \\ \\ \underline{COMMENT} \\ e^+e^- \rightarrow \\ \end{array}$	to $B^0 \overline{B}^0$. We Γ_{129}/Γ $T(45)$ to $B^0 \overline{B}^0$. We Γ_{130}/Γ $T(45)$ 3% to $B^0 \overline{B}^0$. Γ_{131}/Γ $T(45)$	
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80 50%. 80 50%. 80 ALBRECHT 88F rescale to 50%. $(p/\pi \pi^+\pi^-)/\Gamma_{tot}$ (2.0×10^{-4}) 90 ALBRECHT 88F rescale to 50%. $(\Delta^0 p)/\Gamma_{total}$ $(\Delta^0 p)/\Gamma_{total}$ (ΔUE) 23.8 × 10 ⁻⁴ 191 BORTOLETTO We rescale to 50' $(\Delta^++p)/\Gamma_{total}$ $(\Delta^++p)/\Gamma_{total}$ $(\Delta^-+p)/\Gamma_{total}$ $(\Delta^-+p)/\Gamma_{total}$ $(\Delta^-p\pi^+)/\Gamma_{total}$ $(\Delta^-p\pi^+)/\Gamma_{total}$ $(\Delta^-p\pi^+)/\Gamma_{total}$ $(\Delta^-p\pi^+)/\Gamma_{total}$ $(\Delta^-p\pi^+)/\Gamma_{total}$ $(\Delta^-p\pi^+)/\Gamma_{total}$ $(\Delta^-p\pi^+)/\Gamma_{total}$ $(\Delta^-p\pi^+)/\Gamma_{total}$ $(\Delta^-p\pi^+\pi^-)/\Gamma_{total}$ $(\Delta^-p\pi^+\pi^-)/\Gamma_{total}$ $(\Delta^-p\pi^+\pi^+\pi^-)/\Gamma_{total}$ $(\Delta^-p\pi^+\pi^+\pi^-)/\Gamma_{total}$ $(\Delta^-p\pi^+\pi^+\pi^-)/\Gamma_{total}$ $(\Delta^-p\pi^+\pi^+\pi^-)/\Gamma_{total}$ $(\Delta^-p\pi^+\pi^+\pi^-)/\Gamma_{total}$ $(\Delta^-p\pi^+\pi^+\pi^-)/\Gamma_{total}$	reports < 8.5 tal	DOCUMENT ID POSITION ASSUMING DOCUMENT ID ALBRECHT × 10 ⁻⁴ assuming DOCUMENT ID BORTOLETTO 3.3 × 10 ⁻⁴ assur DOCUMENT ID TO DOCUMENT ID TO DOCUMENT ID C branching fract DOCUMENT ID C branching ratio	### TECN decays 45% $\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow \\ \\ \underline{COMMENT} \\ e^+e^- \rightarrow \\ 15) \text{ decays 4} \\ \\ \underline{COMMENT} \\ e^+e^- \rightarrow \\ \\ COMM$	to $B^0 \overline{B}^0$. We Γ_{129}/Γ $T(45)$ to $B^0 \overline{B}^0$. We Γ_{130}/Γ $T(45)$ 3% to $F^0 \overline{B}^0$. Γ_{131}/Γ $T(45)$ 3% to $F^0 \overline{B}^0$. Γ_{132}/Γ $T(45)$ Γ_{133}/Γ $T(45)$	
10 50%. 10 50%. 10 50%. 10 50%. 10 ALBRECHT 88F rescale to 50%. ($p \overline{\Lambda} \pi^+ \pi^-$)/ Γ_{tot} LUE 2.0 × 10 ⁻⁴ 10 ALBRECHT 88F rescale to 50%. ($\overline{\Delta}^0 p$)/ Γ_{total} LUE 3.8 × 10 ⁻⁴ 1 BORTOLETTO We rescale to 50' ($\Delta^{++} \overline{p}$)/ Γ_{total} LUE 1.1.5 × 10 ⁻⁴ 2 BORTOLETTO We rescale to 50' ($\Lambda^- p \pi^+$)/ Γ_{total} LUE 1.1.6 × 10 ⁻⁴ 2 + 2.3 ± 1.6 3 FU 97 uses PDG ($\Lambda^- p \pi^+ \pi^0$)/ Γ_0 LUE 1.4.6 × 10 ⁻³ 5 FU 97 uses PDG	reports < 8.5 tal	DOCUMENT ID ALBRECHT ALBRECHT 10 ⁻⁴ assuming DOCUMENT ID BORTOLETT 3.3 × 10 ⁻⁴ assur DOCUMENT ID BORTOLETT 1.3 × 10 ⁻⁴ assur DOCUMENT ID To branching frace DOCUMENT ID To branching ratio DOCUMENT ID To branching ratio DOCUMENT ID To branching ratio	### TECN decays 45% $\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow \\ \\ \underline{COMMENT} \\ e^+e^- \rightarrow \\ 15) \text{ decays 4} \\ \\ \underline{COMMENT} \\ e^+e^- \rightarrow \\ \\ COMM$	T129/Γ T(45) to B ⁰ B̄ ⁰ . We Γ129/Γ T(45) to B ⁰ B̄ ⁰ . We Γ130/Γ T(45) 3% to B ⁰ B̄ ⁰ . We Γ131/Γ T(45) Γ132/Γ T(45) Γ134/Γ T(45) Γ134/Γ	

```
(\pi^+ e^+ e^-)/\Gamma_{\text{total}}
                                                                                                                                                                                                  \Gamma_{136}/\Gamma
             Test for \Delta B = 1 weak neutral current. Allowed by higher-order electroweak interac-
             tions.

        CL%
        DOCUMENT ID
        TECN
        COMMENT

        90
        197 WEIR
        908 MRK2
        e+e-29 GeV

    LUE
    0.0039
    <sup>97</sup>WEIR 90B assumes B^+ production cross section from LUND.
   (\pi^+\mu^+\mu^-)/\Gamma_{	ext{total}} Test for \Delta B=1 weak neutral current. Allowed by higher-order electroweak interac-
   tions.

<u>ALUE CL% DOCUMENT ID TECN COMMENT.</u>

C0.0091 90 198 WEIR 908 MRK2 e<sup>+</sup>e<sup>-</sup> 29 GeV
    <sup>18</sup>WEIR 90B assumes B^+ production cross section from LUND.
   (K^+e^+e^-)/\Gamma_{	ext{total}} Test for \Delta B=1 weak neutral current. Allowed by higher-order electroweak interac-
             tions.
                                                      LUE
    6 × 10<sup>-5</sup>
    • • We do not use the following data for averages, fits, limits, etc. • • •
    (9.9 × 10<sup>-5</sup>
                                                        90 200 ALBRECHT 91E ARG e^+e^- \rightarrow T(45)
90 201 WEIR 90B MRK2 e^+e^- 29 GeV
90 202 AVERY 87 CLEO e^+e^- \rightarrow T(45)
    6.8\times10^{-3}
                                                                                                            908 MRK2 e<sup>+</sup> e 25 00.
87 CLEO e<sup>+</sup> e<sup>-</sup> → T(45)
    (2.5 \times 10^{-4})
    <sup>19</sup> AVERY 89B reports < 5 \times 10^{-5} assuming the \Upsilon(4S) decays 43% to B^0 \overline{B}{}^0. We rescale
    to 50%. ^{00} ALBRECHT 91E reports < 9.0 	imes 10^{-5} assuming the \varUpsilon(4.5) decays 45% to B^0\overline{B}{}^0. We
    rescale to 50%. 

11 WEIR 90B assumes B^+ production cross section from LUND. 

12 AVERY 87 reports < 2.1 \times 10^{-4} assuming the T(45) decays 40% to B^0 \overline{B}{}^0. We rescale
       to 50%.
    CL%
                                                                                     DOCUMENT ID TECN COMMENT
    1.0 × 10<sup>-5</sup>
                                                          90 203 ABE
   $\text{$<1.0} \times 10^{-5}$ 90 $203 \text{ ABE}$ 96L CDF $p\vec{p}$ at 1.8 TeV $\ldot$ $\ldot$ We do not use the following data for averages, fits, limits, etc. $\ldot$ $\ldot$
   (2.4 × 10<sup>-4</sup>
                                                                          <sup>204</sup> ALBRECHT 91E ARG e^+e^- \rightarrow \Upsilon(4S)
                                                         90
90
                                                                          205 WEIR
    6.4 \times 10^{-3}
                                                                                                                           908 MRK2 e+e- 29 GeV
                                                                          206 AVERY
    1.7 \times 10^{-4}
                                                                                                                         89B CLEO e^+e^- \rightarrow \Upsilon(45)
87 CLEO e^+e^- \rightarrow \Upsilon(45)
                                                         90
90
   (3.8 × 10<sup>-4</sup>
                                                                          207 AVERY
   ^{03} ABE 96L measured relative to B^0 \to J/\psi(1S)K^+ using PDG 94 branching ratios, ^{04} ALBRECHT 91E reports < 2.2 \times 10^{-4} assuming the \varUpsilon(4S) decays 45% to B^0\overline{B}{}^0. We
    TALDREUTH 321 TO THE PROPERTY OF THE PROPERTY
   rescale to 50%. The same of t
    (K^{*}(892)^{+}e^{+}e^{-})/\Gamma_{\text{total}}
             Test for \Delta B = 1 weak neutral current. Allowed by higher-order electroweak interac-
   ALUE CL% DOCUMENT ID TECN COMMENT

(6.9 × 10<sup>-4</sup>
90 208 ALBRECHT 91E ARG e^+e^- \rightarrow \Upsilon(4S)
    ^{18} ALBRECHT 91E reports < 6.3 \times 10^{-4} assuming the \Upsilon(4S) decays 45% to B^0 \overline{B}{}^0. We
       rescale to 50%.
    (K^{e}(892)^{+}\mu^{+}\mu^{-})/\Gamma_{total} Test for \Delta B=1 weak neutral current. Allowed by higher-order electroweak interac-
                                           1.2 × 10<sup>-3</sup>
    <sup>19</sup> ALBRECHT 91E reports < 1.1 \times 10^{-3} assuming the \Upsilon(4S) decays 45% to B^0 \overline{B}{}^0. We
       rescale to 50%
   (\pi^+e^+\mu^-)/\Gamma_{\text{total}}
Test of lepton family number conservation.
    0.0064 90 210 WEIR
                                                                                    DOCUMENT ID
                                                                                                                           TECN COMMENT
                                                                                                                90B MRK2 e+e- 29 GeV
   ^{10}WEIR 90B assumes B^+ production cross section from LUND.
    (\pi^+e^-\mu^+)/\Gamma_{
m total}
                                                                                                                                                                                                Γ<sub>143</sub>/Γ
           Test of lepton family number conservation.
                                                                                   DOCUMENT ID TECH COMMENT
   1.0064 CL% DOCUME

20.0064 90 211 WEIR
                                                                                                                         908 MRK2 e+e- 29 GeV
    ^{1}WEIR 90B assumes B^{+} production cross section from LUND.
    (K^+e^+\mu^-)/\Gamma_{\text{total}}
                                                                                                                                                                                                \Gamma_{144}/\Gamma
           Test of lepton family number conservation.

        LUE
        CL%
        DOCUME

        0.0064
        90
        212 WEIR

                                                                                 DOCUMENT ID
                                                                                                                                TECN COMMENT
                                                                                                                         90B MRK2 e+e- 29 GeV
   0.0064
   ^{2}WEIR 90B assumes B^{+} production cross section from LUND.
    (K^+e^-\mu^+)/\Gamma_{\text{total}}
                                                                                                                                                                                                \Gamma_{145}/\Gamma
           Test of lepton family number conservation.
    LUE
                                 CL% DOCUMENT ID
90 213 WEIR
                                                                                                                                 TECN COMMENT
<0.0064
                                                                                                                         908 MRK2 e+e- 29 GeV
```

 $^{213}\mathrm{WEIR}$ 90B assumes B^+ production cross section from LUND.

						Γ ₁₄₆ /Ι
Test of total leptovalue			2	TECN	COMMENT	
<0.0039	90	²¹⁴ WEIR	90B	MRK2	e+e- 29 GeV	
214 WEIR 90B assumes	B ⁺ pro					
$\Gamma(\pi^-\mu^+\mu^+)/\Gamma_{\text{total}}$ Test of total lepton		ner consensation				Γ ₁₄₇ /
VALUE			2.	TECN	COMMENT	
<0.0091	90					
215 WEIR 90B assumes	B ⁺ pro					
$(\pi^-e^+\mu^+)/\Gamma_{\text{total}}$ Test of total lepton	on numl	per conservation.				Γ ₁₄₈ /
VALUE	CL%	DOCUMENT I	0	TECN	COMMENT	
<0.0064	90	²¹⁶ WEIR	90B	MRK2	e+e- 29 GeV	
216 WEIR 90B assumes	B+ pro	duction cross secti	ion from	LUND		
		per conservation.				Γ ₁₄₉ /
Test of total lept	on numt		<u> </u>	TECN	COMMENT	2.0,
Test of total leptor	on numt	DOCUMENT IL	90B	<u>TECN</u> MRK2	COMMENT e+e- 29 GeV	,
Test of total leptor/ALUE	on numb <u>CL%</u> 90	DOCUMENT II 217 WEIR	90B	MRK2	e ⁺ e ⁻ 29 GeV	2.0,
Test of total lepting $(ALUE)$ (0.0039 217 WEIR 908 assumes $\Gamma(K^-\mu^+\mu^+)/\Gamma_{total}$ Test of total lepting assumes	on numb <u>CL%</u> 90 B ⁺ pro I	DOCUMENT IL 217 WEIR Iduction cross sections	90B ion fron	MRK2 LUND	e ⁺ e ⁻ 29 GeV	Г ₁₅₀ /
Test of total lepting $(ALUE)$ (0.0039 (17 WEIR 908 assumes $(K^-\mu^+\mu^+)/\Gamma_{total}$ Test of total lepting assumes	on numb <u>CL%</u> 90 B ⁺ pro I on numb <u>CL%</u>	DOCUMENT IL 217 WEIR duction cross sections per conservation. DOCUMENT IL	90B ion fron	MRK2 LUND	e ⁺ e ⁻ 29 GeV	Г ₁₅₀ /
Test of total lepting $KLUE$ Co.0039 117 WEIR 90B assumes $(K^-\mu^+\mu^+)/\Gamma_{\text{total}}$ Test of total lepting $KLUE$	on numb <u>CL%</u> 90 B ⁺ pro I on numb <u>CL%</u>	DOCUMENT IL 217 WEIR Iduction cross sections	90B ion fron	MRK2 LUND	e ⁺ e ⁻ 29 GeV	Г ₁₅₀ /
Test of total leptivalue (0.0039) 17 WEIR 90B assumes $(K^-\mu^+\mu^+)/\Gamma_{\text{total}}$ Test of total leptivalue (0.0091)	on numb 	217 WEIR duction cross sections cross sections cross section cross section. DOCUMENT II 218 WEIR	908 ion from 2 908	MRK2 LUND <u>TECN</u> MRK2	e+e- 29 GeV	Г ₁₅₀ /
Test of total leptimal μ Test of total leptim	on numb	DOCUMENT IL 217 WEIR duction cross section DOCUMENT IL 218 WEIR duction cross section	908 ion from 2 908	MRK2 LUND <u>TECN</u> MRK2	e+e- 29 GeV	Γ ₁₅₀ /
Test of total lept ALUE <0.0039 $^{1.17}$ WEIR 90B assumes $-(K^-\mu^+\mu^+)/\Gamma_{total}$ Test of total lept ALUE <0.0091 $^{1.18}$ WEIR 90B assumes $-(K^-e^+\mu^+)/\Gamma_{total}$ Test of total lept	on numb	DOCUMENT IL 217 WEIR duction cross section cross section DOCUMENT IL 218 WEIR duction cross section Decrease	90B ion from 5 90B ion from	MRK2 LUND TECN MRK2 LUND	e ⁺ e ⁻ 29 GeV	Γ ₁₅₀ /
<0.0039 <1217 WEIR 908 assumes $\Gamma(K^-\mu^+\mu^+)/\Gamma_{\text{total}}$ Test of total leptivalue <0.0091 <1218 WEIR 908 assumes $\Gamma(K^-e^+\mu^+)/\Gamma_{\text{total}}$	on numb	DOCUMENT IL 217 WEIR duction cross section cross section DOCUMENT IL 218 WEIR duction cross section Decrease	90B ion fron 90B ion fron	MRK2 LUND TECN MRK2 LUND	e+e-29 GeV	Γ ₁₅₀ /

B[±] REFERENCES

ABE	98B	PR D57 5382	F. Abe+		Collab.)
BEHRENS	98	PRL 80 3710	B.H. Behrens+		Collab.)
BRANDENB	98	PRL 80 2762	G. Brandenbrug+	(CLEO	Collab.)
GODANG	98	PRL 80 3456	R. Godang+	(CLEO	Coliab.)
ABE	97J	PRL 79 590	+Abe, Akagi, Allen+	`(SLD	Collab.)
ACCIARRI	97F	PL 8396 327	M. Acciarri+		Collab.)
ARTUSO	97	PL B399 321	M. Artuso+		Collab.)
ATHANAS	97	PRL 79 2208	M. Athanas+		Collab.)
BROWDER	97	PR D56 11	T. Browder+		Collab.)
FU	97	PRL 79 3125	X. Fu+		Collab.)
JESSOP	97	PRL 79 4533	C.P. Jessop+		Collab.)
ABE	96B	PR D53 3496	+Albrow, Amendolia, Amidei+		Collab.)
ABE	96C	PRL 76 4462	+Akimoto, Akopian, Albrow+		Collab.)
ABE	96H	PRL 76 2015	+Albrow, Amendolia, Amidei+		Collab.)
ABE	96L	PRL 76 4675	+Akimoto, Akopian, Albrow+		Collab.)
ABE	96Q	PR D54 6596	+Akimoto, Akopian, Albrow+	(CDF	Collab.)
ABE	96R	PRL 77 5176	+Akimoto, Akopian, Albrow+	(CDF	Collab.)
ADAM	96D	ZPHY C72 207	W. Adam+	(DELPHI	Collab.)
ASNER	96	PR D53 1039	+Athanas, Bliss, Brower+		Collab.)
BARISH	968	PRL 76 1570	+Chadha, Chan, Eigen+		Collab.)
BERGFELD	96B	PRL 77 4503	+Eisenstein, Ernst, Gladding+		Collab.)
BISHAI	96	PL B369 186	+Fast, Gerndt, Hinson+		Collab.)
	96J		+De Bonis, Decamp, Ghez+		
BUSKULIC		ZPHY C71 31		(ALEPH	
GIBAUT	96	PR D53 4734	+Kinoshita, Pomianowski, Barish+	(CLEO	Collab.)
PDG	96	PR D54 1			
ABREU	95N	PL B357 255	+Adam, Adye, Agasi+	(DELPHI	
ABREU	95Q	ZPHY C68 13	+Adam, Adye, Agasi+	(DELPHI	
ADAM	95	ZPHY C68 363	+Adye, Agasi, Ajinenko+	(DELPHI	Collab.)
AKERS	95T	ZPHY C67 379	+Alexander, Allison, Ametewee+	(OPAL	Collab.)
ALBRECHT	95D	PL B353 554	+Hamacher, Hofmann, Kirchoff+	(ARGUS	Collab.)
ALEXANDER	95	PL B341 435	+Bebek, Berkelman, Bloom+	(CLEO	Collab.)
Also	95C		Alexander, Bebek, Berkelman, Bloom+		Collab.)
ARTUSO	95	PRL 75 785	+Gao. Goldberg, He+		Collab.)
BARISH	95	PR D51 1014	+Chadha, Chan, Cowen+		Collab.
BUSKULIC	95	PL B343 444	+Casper, De Bonis, Decamp, Ghez, Goy+		
ABE	94D		+Albrow, Amidei, Anway-Wiese, Apollinari		
		PRL 72 3456			Collab.)
ALAM	94	PR D50 43	+Kim, Nemati, O'Neill, Severini+		Collab.)
ALBRECHT	94D		+Hamacher, Hofmann, Kirchhoff, Mankel-		
ATHANAS	94	PRL 73 3503	+Brower, Masek, Paar, Gronberg+		Collab.)
Also	95) Athanas, Brower, Masek, Paar+		Collab.)
PDG	94	PR D50 1173	Montanet+ (CERN, LI	BL, BOST	. IFIC+)
STONE	94	HEPSY 93-11			
ABREU	93D	ZPHY C57 181	+Adam, Adye, Agasi, Alekseev+	(DELPHI	Collab.)
ABREU	93G	PL B312 253	+Adam, Adye, Agasi, Ajinenko+	(DELPHI	Collab.)
ACTON	93C	PL B307 247	+Alexander, Allison, Allport, Anderson+	(OPAL	Collab.)
ALBRECHT	93E	ZPHY C60 11	+Ehrlichmann, Hamacher, Hofmann+	(ARGUS	
ALEXANDER	93B	PL B319 365	+Bebek, Berkelman, Bloom, Browder+		Collab.)
AMMAR	93	PRL 71 674	+Ball, Baringer, Coppage, Copty+		Collab.)
BEAN	93B	PRL 70 2681	+Gronberg, Kutschke, Menary, Morrison+		Collab.)
BUSKULIC	93D	PL B307 194	+Decamp, Goy, Lees, Minard+	(ALEPH	
	93D		Tuecamp, Goy, Lees, William T	ALEPIN	Collab.)
Also		PL B325 537 (errata)	Chambelli Chambelli Artura Caldha	- 1/0150	Collab 1
SANGHERA	93	PR D47 791	+Skwarnicki, Stroynowski, Artuso, Goldber		
ALBRECHT	92C	PL B275 195	+Ehrlichmann, Hamacher, Krueger, Nau+		
ALBRECHT	92E	PL B277 209	+Ehrlichmann, Hamacher, Krueger, Nau+		
ALBRECHT	92G	ZPHY C54 1	+Ehrlichmann, Hamacher, Krueger, Nau+		
BORTOLETTO		PR D45 21	+Brown, Dominick, McIlwain+		Collab.)
BUSKULIC	92G	PL B295 396	+Decamp, Goy, Lees, Minard+	(ALEPH	Collab.)
ALBRECHT	91B	PL B254 288	+Glaeser, Harder, Krueger, Nippe+	(ARGUS	
			• • • • • • • • • • • • • • • • • • • •		,

ALBRECHT 91C	PL B255 297	+Ehrlichmann, Glaeser, Harder, Krueger+	(ARGUS Collab.)
ALBRECHT 91E	PL B262 148	+Glaeser, Harder, Krueger, Nippe+	(ARGUS Cotlab.)
BERKELMAN 91	ARNPS 41 1	+Stone	(CORN, SYRA)
"Decays of B M	lesons"		•
FULTON 91	PR D43 651	+Jensen, Johnson, Kagan, Kass+	(CLEO Collab.)
ALBRECHT 90B	PL B241 278	+Glaeser, Harder, Krueger, Nilsson+	(ARGUS Collab.)
ALBRECHT 90J	ZPHY C48 543	+Ehrlichmann, Harder, Krueger+	(ARGUS Collab.)
ANTREASYAN 90B	ZPHY C48 553	+Bartels, Bieler, Bienlein, Bizzeti+ (Cr	vstal Ball Collab.)
BORTOLETTO 90	PRL 64 2117	+Goldberg, Horwitz, Jain, Mestayer+	(CLEO Collab.)
Also 92	PR D45 21	Bortoletto, Brown, Dominick, McIlwain+	(CLEO Collab.)
WEIR 90B	PR D41 1384	+Klein, Abrams, Adolphsen, Akerlof+	(Mark II Collab.)
ALBRECHT 89G	PL B229 304	+Glaeser, Harder, Krueger+	(ARGUS Collab.)
AVERY 89B	PL B223 470	+Besson, Garren, Yelton+	(CLEO Collab.)
BEBEK 89	PRL 62 8	+Berkelman, Blucher+	(CLEO Collab.)
BORTOLETTO 89	PRL 62 2436	+Goldberg, Horwitz, Mestayer+	(CLEO Collab.)
ALBRECHT 88F	PL B209 119	+Boeckmann, Glaeser+	(ARGUS Collab.)
ALBRECHT 88K	PL B215 424	+Boeckmann, Glaeser+	(ARGUS Collab.)
ALBRECHT 87C	PL B185 218	+Binder, Boeckmann, Glaser+	(ARGUS Collab.)
ALBRECHT 87D	PL B199 451	+Andam, Binder, Boeckmann+	(ARGUS Collab.)
AVERY 87	Pl. B183 429	+Besson, Bowcock, Giles+	(CLEO Collab.)
BEBEK 87	PR D36 1289	+Berkelman, Blucher, Cassel+	(CLEO Collab.)
ALAM 86	PR D34 3279	+Katayama, Kim, Sun+	(CLEO Collab.)
PDG 86	PL 170B	Aguilar-Benitez, Porter+	(CERN, CIT+)
GILES 84	PR D30 2279	+Hassard, Hempstead, Kinoshita+	(CLEO Collab.)

 B^0

$$I(J^P) = \frac{1}{2}(0^-)$$

Quantum numbers not measured. Values shown are quark-model predictions.

See also the B^{\pm}/B^0 ADMIXTURE and $B^{\pm}/B^0/B_s^0/b$ -baryon AD-MIXTURE sections.

See the Notes "Experimental Highlights of B Meson Production and Decay" and "Semileptonic Decays of B Mesons" at the beginning of the B^{\pm} Particle Listings and the Note on " B^0 - \overline{B}^0 Mixing and CPViolation in B Decay" near the end of the B⁰ Particle Listings.

BO MASS

The fit uses m_{B^+} , $(m_{B^0}-m_{B^+})$, $m_{B^0_c}$, and $(m_{B^0_c}-(m_{B^+}+m_{B^0})/2)$ to determine m_{B^+} , m_{B^0} , m_{B^0} , and the mass differences. m_{B^0} data are excluded from the fit because they are not independent.

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT	
5279.2±1.8 OUR FI	Т				
5279.8±1.6 OUR A	/ERAGE				
$5281.3 \pm 2.2 \pm 1.4$	51	¹ ABE	96B CDF	pp at 1.8 TeV	
$5279.2 \pm 0.54 \pm 2.0$	340	² ALAM	94 CLE2	$e^+e^- \rightarrow \Upsilon(45)$	
5278.0±0.4 ±2.0		² BORTOLETTO	092 CLEC	$e^+e^- \rightarrow \Upsilon(45)$	
5279.6±0.7 ±2.0	40	^{2,3} ALBRECHT	90J ARG	$e^+e^- \rightarrow T(45)$	
$5280.6 \pm 0.8 \pm 2.0$		² BEBEK	87 CLEC	$e^+e^- \rightarrow \Upsilon(4S)$	
• • • We do not use	the followi	ing data for average:	s, fits, limit	s, etc. • • •	
5278.2 ± 1.0 ± 3.0	40	ALBRECHT	87c ARG	$e^+e^- \rightarrow \Upsilon(45)$	
$5279.5 \pm 1.6 \pm 3.0$	7	4 ALBRECHT	87D ARG	$e^+e^- \rightarrow \Upsilon(45)$	

¹ Excluded from fit because it is not independent of ABE 968 B_s^0 mass and B_s^0 -B mass

B mass.

3 ALBRECHT 90J assumes 10580 for T(45) mass. Supersedes ALBRECHT 87C and

ALBRECHT 87D. Found using fully reconstructed decays with J/ψ . ALBRECHT 87D assume $m_{\Upsilon(4S)} =$ 10577 MeV.

$m_{B^0} - m_{B^+}$

The mass difference measurements are not Independent of the B^\pm and B^0 mass measurement by the same experimenters. The fit uses m_{B^+} , $(m_{B^0}-m_{B^+})$, m_{B^0} and $(m_{B^0_3}-(m_{B^+}+m_{B^0})/2)$ to determine m_{B^+} , m_{B^0} , m_{B^0} , and the mass differences.

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT	
0.35±0.29 OUR FIT Error	includes scale factor of	1.1.		
0.34±0.32 OUR AVERAGE				
$0.41 \pm 0.25 \pm 0.19$	ALAM 9	4 CLE2	$e^+e^- \rightarrow$	T(45)
$-0.4 \pm 0.6 \pm 0.5$	BORTOLETTOS	2 CLEO	$e^+e^- \rightarrow$	T(45)
$-0.9 \pm 1.2 \pm 0.5$	ALBRECHT 9	OJ ARG	$e^+e^- \rightarrow$	T(45)
$2.0 \pm 1.1 \pm 0.3$	⁵ BEBEK 8	7 CLEO	$e^+e^- \rightarrow$	T(45)

⁵ BEBEK 87 actually measure the difference between half of $E_{\rm CRR}$ and the B^\pm or B^0 mass, so the m_{B^0} – m_{B^\pm} is more accurate. Assume $m_{T(4S)}=10580$ MeV.

$m_{B_H^0} - m_{B_L^0}$

See the B^0 - \overline{B}^0 MIXING PARAMETERS section near the end of these B^0

difference.

These experiments all report a common systematic error 2.0 MeV. We have artificially increased the systematic error to allow the experiments to be treated as independent measurements in our average. See "Treatment of Errors" section of the introductory Text. These experiments actually measure the difference between half of E_{Cm} and the

BO MEAN LIFE

See $B^{\pm}/B^{0}/B_{s}^{0}/b$ -baryon ADMIXTURE section for data on B-hadron mean life averaged over species of bottom particles.

"OUR EVALUATION" is an average of the data listed below performed by the LEP B Lifetimes Working Group as described in our review "Production and Decay of befavored Hadrons" in the B± Section of the Listings. The averaging procedure takes into account correlations between the measurements and asymmetric lifetime errors.

	elations i	between the measur	ements and a	symmetric meture errors.
VALUE (10 ⁻¹² s)	EVTS	DOCUMENT ID	TECN	COMMENT
1.56 ±0.04 OUR EV	ALUATIO			
$1.58 \pm 0.09 \pm 0.02$		⁶ ABE	98B CDF	pp at 1.8 TeV
1.64 ±0.08 ±0.08		⁷ ABE	97J SLD	e ⁺ e [−] → Z
$1.532 \pm 0.041 \pm 0.040$		⁸ ABREU	97F DLPH	e ⁺ e ⁻ → Z
1.54 ±0.08 ±0.06		9 ABE	96c CDF	pp at 1.8 TeV
$1.61 \pm 0.07 \pm 0.04$		⁹ BUSKULIC	96J ALEP	$e^+e^- \rightarrow Z$
$1.25 \begin{array}{c} +0.15 \\ -0.13 \end{array} \pm 0.05$	121	⁶ BUSKULIC	96J ALEP	$e^+e^- \rightarrow Z$
$1.49 \begin{array}{l} +0.17 \\ -0.15 \end{array} \begin{array}{l} +0.08 \\ -0.06 \end{array}$		¹⁰ BUSKULIC	96J ALEP	$e^+e^- \rightarrow Z$
$1.61 \begin{array}{c} +0.14 \\ -0.13 \end{array} \pm 0.08$		9,11 ABREU	95Q DLPH	$e^+e^- \rightarrow Z$
$1.63 \pm 0.14 \pm 0.13$		12 ADAM	95 DLPH	$e^+e^- \rightarrow Z$
$1.53 \pm 0.12 \pm 0.08$		9,13 AKERS	95T OPAL	e ⁺ e → Z
• • • We do not use t	he fallowi	ing data for average	s, fits, limits,	etc. • • •
1.55 ±0.06 ±0.03		14 BUSKULIC	961 ALEP	$e^+e^- \rightarrow Z$
1.62 ±0.12		15 ADAM		$e^+e^- \rightarrow Z$
1.57 ±0.18 ±0.08	121	6 ABE	94D CDF	Repl. by ABE 988
$1.17 \begin{array}{l} +0.29 \\ -0.23 \end{array} \pm 0.16$	96	⁹ ABREU	930 DLPH	Sup. by ABREU 95Q
$1.55 \pm 0.25 \pm 0.18$	76	¹² ABREU	93G DLPH	Sup. by ADAM 95
$1.51 \begin{array}{c} +0.24 \\ -0.23 \end{array} \begin{array}{c} +0.12 \\ -0.14 \end{array}$	78	9 ACTON	93C OPAL	Sup. by AKERS 95T
$1.52 \begin{array}{c} +0.20 & +0.07 \\ -0.18 & -0.13 \end{array}$	77	9 BUSKULIC	93D ALEP	Sup. by BUSKULIC 961
$1.20 \begin{array}{c} +0.52 \\ -0.36 \end{array} \begin{array}{c} +0.16 \\ -0.14 \end{array}$	15	¹⁶ WAGNER	90 MRK2	Eee = 29 GeV
$0.82 \begin{array}{l} +0.57 \\ -0.37 \end{array} \pm 0.27$		17 AVERILL	89 HRS	Ecm= 29 GeV

- ⁶ Measured mean life using fully reconstructed decays.
- ⁷ Data analyzed using charge of secondary vertex. ⁸ Data analyzed using inclusive D/D* £X.
- ⁹ Data analyzed using D/D* LX event vertices.
- 10 Measured mean life using partially reconstructed $D^{*-}\pi^+ X$ vertices. 11 ABREU 95Q assumes B($B^0 \rightarrow D^{**-}\ell^+\nu_\ell$) = 3.2 \pm 1.7%.

- 12 Data analyzed using vertex-charge technique to tag B charge. 13 AKERS 95T assumes $B(B^0 \rightarrow D_5^{(*)}D^{0(*)}) \approx 5.0 \pm 0.9\%$ to find B^+/B^0 yield.
- ¹⁴ Combined result of $D/D^*\ell x$ analysis, fully reconstructed B analysis, and partially reconstruced $D^{*-}\pi^+ X$ analysis. ¹⁵ Combined ABREU 95g and ADAM 95 result. ¹⁶ WAGNER 90 tagged B^0 mesons by their decays into $D^{*-}e^+\nu$ and $D^{*-}\mu^+\nu$ where
- where the D^* is tagged by its decay into $\pi^-\overline{D}^0$. 17 AVERILL 89 is an estimate of the B^0 mean lifetime assuming that $B^0\to D^{*+}+X$

MEAN LIFE RATIO au_{B^+}/ au_{B^0}

τ_{B^+}/τ_{B^0} (average of direct and inferred)

1.02±0.04 OUR AVERAGE Includes data from the 2 datablocks that follow this one.

 $au_{\rm B+}/ au_{\rm B0}$ (direct measurements) "OUR EVALUATION" is an average of the data listed below performed by the LEP B Lifetimes Working Group as described in our review "Production and Decay of b-flavored Hadrons" in the B^\pm Section of the Listings. The averaging procedure takes Into account correlations between the measurements and asymmetric lifetime errors.

<u>VALUE</u> <u>EVTS</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u>

The data in this block is included in the average printed for a previous datablock.

1.04±0.04 OUR E	VALUATION			
$1.06 \pm 0.07 \pm 0.02$	18	B ABE	988 CDF	p p at 1.8 TeV
$1.01 \pm 0.07 \pm 0.06$		ABE	971 SLD	$e^+e^- \rightarrow Z$
$1.01 \pm 0.11 \pm 0.02$		ABE	96c CDF	pp at 1.8 TeV
$0.98 \pm 0.08 \pm 0.03$	20	BUSKULIC	96J ALEP	$e^+e^- \rightarrow Z$
$1.27^{+0.23}_{-0.19}^{+0.03}_{-0.02}$	18	B BUSKULIC	96J ALEP	$e^+e^- \rightarrow Z$
$1.00^{+0.17}_{-0.15} \pm 0.10$	20,21	1 ABREU	95Q DLPH	$e^+e^- \rightarrow Z$
$1.06^{+0.13}_{-0.10}\pm0.10$	23	2 ADAM	95 DLPH	$e^+e^- \rightarrow Z$
$0.99 \pm 0.14 ^{+0.05}_{-0.04}$	20,23	3 AKERS	95T OPAL	$e^+e^- \rightarrow Z$
• • • We do not u	ise the following	data for average	es, fits, limits,	etc. • • •
$1.03 \pm 0.08 \pm 0.02$	24	BUSKULIC	96J ALEP	$e^+e^- \rightarrow Z$
$1.02 \pm 0.16 \pm 0.05$	269 ¹⁸	BABE	94D CDF	Repl. by ABE 98B
$1.11^{+0.51}_{-0.39}\pm0.11$	188 20	ABREU	930 DLPH	Sup. by ABREU 95Q
$1.01^{+0.29}_{-0.22}\pm0.12$	253 23	2 ABREU	93G DLPH	Sup. by ADAM 95
$1.0 \ ^{+0.33}_{-0.25}{\pm} 0.08$	130	ACTON	93C OPAL	Sup. by AKERS 95T
$0.96^{+0.19}_{-0.15}^{+0.18}_{-0.12}$	154 ²⁰	BUSKULIC	93D ALEP	Sup. by BUSKULIC 961

- 18 Measured using fully reconstructed decays.
- 19 Data analyzed using charge of secondary vertex.
 20 Data analyzed using D/D*tX vertices.
- ²¹ ABREU 95Q assumes B($B^0 \rightarrow D^{**-}\ell^+\nu_{\ell}$) = 3.2 ± 1.7%.
- ²² Data analyzed using vertex-charge technique to tag B charge. ²³ AKERS 95T assumes B($B^0 \rightarrow D_S^{(*)}D^0(*)$) = 5.0 ± 0.9% to find B^+/B^0 yield.
- ²⁴ Combined result of $D/D^*\ell X$ analysis and fully reconstructed B analysis.

 au_{B^+}/ au_{B^0} (Inferred from branching fractions)

These measurements are inferred from the branching fractions for semileptonic decay or other spectator-dominated decays by assuming that the rates for such decays are equal for B^0 and B^+ . We do not use measurements which assume equal production of B^0 and B^+ because of the large uncertainty in the production ratio.

VALUE The data in this bloc	ck is included in	DOCUMENT ID the average printed	for a previou	s datablock.
0.95 ^{+0.117} ±0.091		25 ARTUSO	97 CLE2	$e^+e^- \rightarrow \gamma(45)$
 • • We do not us 	e the following		ts, limits, etc.	• • •
1.15±0.17 ±0.06		²⁶ JESSOP	97 CLE2	$e^+e^- \rightarrow \Upsilon(45)$
0.93±0.18 ±0.12		²⁷ ATHANAS		Sup. by AR- TUSO 97
0.91±0.27 ±0.21		28 ALBRECHT		$e^+e^- \rightarrow \Upsilon(45)$
1.0 ±0.4	29	^{28,29} ALBRECHT	92G ARG	$e^+e^- \rightarrow T(45)$
0.89±0.19 ±0.13		28 FULTON	91 CLEO	$e^+e^- \rightarrow T(45)$
1.00±0.23 ±0.14		28 ALBRECHT	89L ARG	$e^+e^- \rightarrow \Upsilon(45)$
0.49 to 2.3	90	30 BEAN	87B CLEO	$e^+e^- \rightarrow \Upsilon(45)$
B ⁺ production f 26 Assumes equal p	raction. roduction of <i>B</i> es events tagge	$^+$ and B^0 at the $\Upsilon($	45).	dependent of B^{0} and r
28 A	uccays.	ا م د د ا		
28 Assumes equal p	roduction of B	and B^{\top} .	5* 0*5	D* O*
20	uata analyzeo	using $B \to D_S \overline{D}$, E of $B^0 \overline{B}{}^0$ events at t	$S_{S}U$, $U_{S}U$,	os D' events.

BO DECAY MODES

 $\overline{B}{}^0$ modes are charge conjugates of the modes below. Reactions indicate the weak decay vertex and do not include mixing. Modes which do not identify the charge state of the B are listed in the B^\pm/B^0 ADMIXTURE

The branching fractions listed below assume 50% $B^0 \overline{B}{}^0$ and 50% $B^+ B^$ production at the $\Upsilon(45)$. We have attempted to bring older measurements up to date by rescaling their assumed $\Upsilon(45)$ production ratio to 50:50 and their assumed $D,\ D_s,\ D^*$, and ψ branching ratios to current values whenever this would affect our averages and best limits significantly.

Indentation is used to indicate a subchannel of a previous reaction. All resonant subchannels have been corrected for resonance branching fractions to the final state so the sum of the subchannel branching fractions can exceed that of the final state.

	Mode	$\begin{array}{c} \text{Scale factor}/\\ \text{Fraction } (\Gamma_{j}/\Gamma) & \text{Confidence level} \end{array}$
Γ ₁ Γ ₂ Γ ₃ Γ ₄	$\ell^+ u_\ell$ anything $D^-\ell^+ u_\ell$ $D^*(2010)^-\ell^+ u_\ell$ $\rho^-\ell^+ u_\ell$ $\pi^-\ell^+ u_\ell$	[a] (10.5 ± 0.8) % [a] (2.00± 0.25) % [a] (4.60± 0.27) % [a] (2.5 + 0.8) × 10-4 (1.8 ± 0.6) × 10-4
' 5	π ε·ν _ℓ	,
Γ ₆	$\pi^-\mu^+\nu_\mu$	
Γ7	K ⁺ anything	(78 ±80)%
	D, D*, or i	O _s modes
Γ ₁₀ Γ ₁₁ Γ ₁₂ Γ ₁₃ Γ ₁₄	$\begin{array}{l} D^-\pi^+ \\ D^-\rho^+ \\ \overline{D^0}\pi^+\pi^- \\ D^*(2010)^-\pi^+ \\ D^-\pi^+\pi^+\pi^- \\ (D^-\pi^+\pi^+\pi^-) \text{ nonresonant } \\ D^-\pi^+\rho^0 \\ D^-a_1(1260)^+ \\ D^*(2010)^-\pi^+\pi^0 \\ D^*(2010)^-\rho^+ \\ D^*(2010)^-\pi^+\pi^- \\ (D^*(2010)^-\pi^+\pi^+\pi^-) \text{ nonresonant } \end{array}$	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$
Γ ₂₃	$D^{+}(2010)^{-}\pi^{+}\rho^{0}$ $D^{+}(2010)^{-}a_{1}(1260)^{+}$ $D^{+}(2010)^{-}\pi^{+}\pi^{+}\pi^{-}\pi^{0}$ $D_{2}^{+}(2460)^{-}\pi^{+}$ $D_{2}^{+}(2460)^{-}\rho^{+}$	$\begin{array}{l} (5.7 \pm 3.1) \times 10^{-3} \\ (1.30 \pm 0.27) \% \\ (3.4 \pm 1.8) \% \\ < 2.2 \times 10^{-3} \text{CL=90\%} \\ < 4.9 \times 10^{-3} \text{CL=90\%} \end{array}$

					B^0
 Γ ₂₅	D-D+	$(8.0 \pm 3.0) \times 10^{-3}$		$\Gamma_{91} K^*(892)^0 K^+ K^-$ < 6.1	× 10 ⁻⁴ CL=90%
Γ ₂₆	$D^*(2010)^-D_s^+$	$(9.6 \pm 3.4) \times 10^{-3}$		$\Gamma_{92} K^*(892)^0 \phi $ < 4.3	× 10 ⁻⁵ CL=90%
Γ ₂₇	$D^-D_s^{*+}$	$(1.0 \pm 0.5)\%$		$\Gamma_{93} K_1(1400)^0 \rho^0$ < 3.0	× 10 ⁻³ CL=90%
_	$D^*(2010)^-D_s^{*+}$	$(2.0 \pm 0.7)\%$		$\Gamma_{94} K_1(1400)^0 \phi$ < 5.0	× 10 ⁻³ CL=90%
Г ₂₈	$D_s^+\pi^-$	$< 2.8 \times 10^{-4}$	CL=90%	$\Gamma_{95} K_2^*(1430)^0 \rho^0 $ < 1.1	× 10 ⁻³ CL=90%
Γ ₂₉		< 5 × 10 ⁻⁴	CL=90% CL=90%	$\Gamma_{96} K_2^* (1430)^0 \phi $ < 1.4	$\times 10^{-3}$ CL=90%
Г ₃₀	$D_s^{*+}\pi^-$			$\Gamma_{97} K^{*}(892)^{0}\gamma$ (4.0 ±	1.9) × 10 ⁻⁵
Г ₃₁	$D_{s}^{+}\rho^{-}$	< 7 × 10 ⁻⁴	CL=90%	$\Gamma_{98} K_1(1270)^0_{\Omega} \gamma $ < 7.0	× 10 ⁻³ CL=90%
Γ ₃₂	$D_{5}^{*+}\rho^{-}$	< 8 × 10 ⁻⁴	CL=90%	$\Gamma_{99} K_1(1400)^0 \gamma$ < 4.3	× 10 ⁻³ CL=90%
Г33	$D_5^+ a_1(1260)^-$	$< 2.6 \times 10^{-3}$	CL=90%	$\Gamma_{100} K_2^*(1430)^0 \gamma$ < 4.0	× 10 ⁻⁴ CL=90%
34	$D_s^{*+} a_1(1260)^-$	$< 2.2 \times 10^{-3}$	CL=90%	$\Gamma_{101} \ K^*(1680)^0 \gamma < 2.0$	$\times 10^{-3}$ CL=90%
Γ ₃₅	$D_s^- K^+$	$< 2.4 \times 10^{-4}$	CL=90%	$\Gamma_{102} \ K_3^*(1780)^0 \gamma < 1.0$	% CL=90%
۲ ₃₆	$D_s^{*-}K^+$	$< 1.7 \times 10^{-4}$	CL=90%	$\Gamma_{103} \ K_4^*(2045)^0 \gamma < 4.3$	× 10 ⁻³ CL=90%
Γ ₃₇	$D_s^- K^*(892)^+$	< 9.9 × 10 ⁻⁴	CL=90%	$\Gamma_{104} \phi \phi$ < 3.9	× 10 ⁻⁵ CL=90%
Γ ₃₈	D _s *- K*(892)+	$< 1.1 \times 10^{-3}$	CL=90%	Light unflavored meson mode	\$
Г39	$D_s^- \pi^+ K^0$	< 5 × 10 ⁻³	CL=90%	$\Gamma_{105} \pi^{+} \pi^{-}$ < 1.5	× 10 ⁻⁵ CL=90%
Γ_{40}	$D_s^{*-}\pi^+K^0$	$< 3.1 \times 10^{-3}$	CL=90%	$\Gamma_{106}^{103} \pi^0 \pi^0$ < 9.3	× 10 ⁻⁶ CL=90%
Γ ₄₁	$D_s^- \pi^+ K^* (892)^0$	$< 4 \times 10^{-3}$	CL=90%	$\Gamma_{107} \eta \pi^0$ < 8	× 10 ⁻⁶ CL=90%
Γ_{42}	$D_s^{*-}\pi^+K^*(892)^0$	$< 2.0 \times 10^{-3}$	CL=90%	$\Gamma_{108} \eta \eta$ < 1.8	× 10 ⁻⁵ CL=90%
Γ ₄₃	$\overline{D}{}^{0}\pi^{0}$	< 1.2 × 10 ⁻⁴	CL=90%	$\Gamma_{109} \eta' \pi^0 \qquad < 1.1$	× 10 ⁻⁵ CL=90%
Γ44	$\overline{D}{}^0 ho^0$	$< 3.9 \times 10^{-4}$	CL=90%	$\Gamma_{110} \eta' \eta' \qquad < 4.7$	× 10 ⁻⁵ CL=90%
Γ ₄₅	$\overline{D}{}^0\eta$	$< 1.3 \times 10^{-4}$	CL=90%	$\Gamma_{111} \eta' \eta \qquad < 2.7$	× 10 ⁻⁵ CL=90%
Γ ₄₆	$\overline{D}{}^0\eta'$	< 9.4 × 10 ⁻⁴	CL=90%	$\Gamma_{112} \eta' \rho^0 \qquad < 2.3$	× 10 ⁻⁵ CL=90%
Γ ₄₇	$\overline{D}^0\omega$	$< 5.1 \times 10^{-4}$	CL=90%	$\Gamma_{113} \eta \rho^0 $ < 1.3	× 10 ⁻⁵ CL=90%
Г48	$\overline{D}^*(2007)^0\pi^0$	< 4.4 × 10 ⁻⁴	CL=90%	$\Gamma_{114} \pi^{+} \pi^{-} \pi^{0}$ < 7.2 $\Gamma_{115} \rho^{0} \pi^{0}$ < 2.4	× 10 ⁻⁴ CL=90% × 10 ⁻⁵ CL=90%
Г 49	$\overline{D}^*(2007)^0 \rho^0$	< 5.6 × 10 ⁻⁴	CL=90%	$\Gamma_{115} \rho^0 \pi^0 < 2.4 \\ \Gamma_{116} \rho^{\mp} \pi^{\pm} \qquad [c] < 8.8$	× 10 5 CL=90% × 10 ⁻⁵ CL=90%
50	$D^*(2007)^0 \eta$	$< 2.6 \times 10^{-4} < 1.4 \times 10^{-3}$	CL=90%	$\Gamma_{117} \pi^{+}\pi^{-}\pi^{+}\pi^{-}$ (2.3)	× 10 ⁻⁴ CL=90%
51	$D^*(2007)^0 \eta'$		CL=90% CL=90%	$\Gamma_{118} \rho^{0} \rho^{0}$ < 2.8	× 10 ⁻⁴ CL=90%
52	$D^*(2007)^0 \omega$ $D^*(2010)^+ D^*(2010)^-$	$< 7.4 \times 10^{-4} < 2.2 \times 10^{-3}$	CL=90% CL=90%	$\Gamma_{119} = a_1(1260)^{\mp} \pi^{\pm}$ [c] < 4.9	× 10 ⁻⁴ CL=90%
53. 154	D*(2010)+D-	< 1.8 × 10 ⁻³	CL=90%	$\Gamma_{120} = a_2(1320)^{\mp} \pi^{\pm}$ [c] < 3.0	× 10 ⁻⁴ CL=90%
Γ ₅₅	D+D*(2010)-	< 1.2 × 10 ⁻³	CL=90%	$\Gamma_{121}^{120} \pi^{+} \pi^{-} \pi^{0} \pi^{0}$ < 3.1	× 10 ⁻³ CL=90%
' 55	` ,			$\Gamma_{122} \rho^{+} \rho^{-} $ < 2.2	× 10 ⁻³ CL=90%
_	1/1/16)1/0	Charmonium modes		$\Gamma_{123} a_1(1260)^0 \pi^0 < 1.1$	× 10 ⁻³ CL=90%
Γ ₅₆	$J/\psi(15)K^0$	$(8.9 \pm 1.2) \times 10^{-4}$		$\Gamma_{124} \omega \pi^0 \qquad < 4.6$	× 10 ⁻⁴ CL=90%
Γ ₅₇	$J/\psi(1S)K^+\pi^-$ $J/\psi(1S)K^*(892)^0$	$(1.1 \pm 0.6) \times 10^{-3}$ $(1.35 \pm 0.18) \times 10^{-3}$		$\Gamma_{125} \pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{0}$ < 9.0	× 10 ⁻³ CL=90%
Γ ₅₈ Γ ₅₉	$J/\psi(15) \pi^0$	< 5.8 × 10 ⁻⁵	CL=90%	$\Gamma_{126} = a_1(1260)^+ \rho^- < 3.4$	× 10 ⁻³ CL=90%
Γ ₆₀	$J/\psi(1S)\eta$	< 1.2 × 10 ⁻³	CL=90%	$\Gamma_{127} a_1(1260)^0 \rho^0 $ < 2.4	× 10 ⁻³ CL=90%
Γ ₆₁	$J/\psi(15)\rho^{0}$	< 2.5 × 10 ⁻⁴	CL=90%	$\Gamma_{128} \pi^{+} \pi^{+} \pi^{+} \pi^{-} \pi^{-} \pi^{-}$ < 3.0 $\Gamma_{129} a_{1}(1260)^{+} a_{1}(1260)^{-}$ < 2.8	× 10 ⁻³ CL=90% × 10 ⁻³ CL=90%
Γ ₆₂	$J/\psi(1S)\omega$	$< 2.7 \times 10^{-4}$	CL=90%	$\Gamma_{129} a_1(1260)^+ a_1(1260)^- < 2.8$ $\Gamma_{130} \pi^+ \pi^+ \pi^+ \pi^- \pi^- \pi^- \pi^0 < 1.1$	% CL=90%
Γ ₆₃	$\psi(2\hat{S})K^0$	< 8 × 10 ⁻⁴	CL=90%		70 02-7070
Γ ₆₄	$\psi(25) K^{+} \pi^{-}$	< 1 × 10 ⁻³	CL=90%	Baryon modes	
Γ ₆₅	$\psi(2S) K^*(892)^0$	$(1.4 \pm 0.9) \times 10^{-3}$		$\Gamma_{131} \rho \overline{p}$ < 1.8	× 10 ⁻⁵ CL=90%
Γ ₆₆	$\chi_{c1}(1P)K^0$	$< 2.7 \times 10^{-3}$	CL=90%	$\Gamma_{132} p \overline{p} \pi^+ \pi^- \qquad < 2.5$	× 10 ⁻⁴ CL=90%
Γ ₆₇	$\chi_{c1}(1P)K^*(892)^0$	$< 2.1 \times 10^{-3}$	CL=90%	$\Gamma_{133} p \overline{\Lambda} \pi^- < 1.8$	× 10 ⁻⁴ CL=90% × 10 ⁻³ CL=90%
		K or K* modes		$\Gamma_{134} \Delta^0 \overline{\Delta}^0$ < 1.5 $\Gamma_{135} \Delta^{++} \Delta^{}$ < 1.1	× 10 ⁻³ CL=90% × 10 ⁻⁴ CL=90%
г	$K^+\pi^-$	$(1.5 + 0.5 - 0.4) \times 10^{-5}$		$\Gamma_{135} \frac{\Delta^{++}\Delta^{}}{\sum_{c}^{}\Delta^{++}} $ < 1.1 < 1.0	× 10 ⁻³ CL=90%
		(1.5 - 0.4) \ 10		136 Z _C Zi	0.6) × 10 ⁻³
Γ ₆₉	$K^0\pi^0$	< 4.1 × 10 ⁻⁵	CL=90%		× 10 ⁻⁴ CL=90%
Γ ₇₀	$\eta' K^0$	$(4.7 + 2.8 \times 10^{-5}) \times 10^{-5}$			× 10 ⁻⁴ CL=90%
Γ ₇₁	η' K*(892 <u>)</u> 0	< 3.9 × 10 ⁻⁵	CL=90%	$\Gamma_{139} \Lambda_c^- \rho \pi^0$ < 5.9	× 10 × CL=90% × 10 ⁻³ CL=90%
Γ ₇₂	$\eta K^*(892)^0$	< 3.0 × 10 ⁻⁵	CL=90%	$\Gamma_{140} \Lambda_{c}^{-} \rho \pi^{+} \pi^{-} \pi^{0}$ < 5.07 $\Gamma_{141} \Lambda_{c}^{-} \rho \pi^{+} \pi^{-} \pi^{+} \pi^{-}$ < 2.74	× 10 ° CL=90% × 10 ⁻³ CL=90%
Γ ₇₃	ηK^0	< 3.3 × 10 ⁻⁵	CL=90%	$\Gamma_{141} \Lambda_c^+ p \pi^+ \pi^- \pi^+ \pi^- $ < 2.74	X 10 - CL=90%
Γ ₇₄	K+K-	< 4.3 × 10 ⁻⁶	CL=90%	Lepton Family number (LF) violating	modes, or
Γ ₇₅	K ⁰ K̄ ⁰	< 1.7 × 10 ⁻⁵	CL=90%	$\Delta B = 1$ weak neutral current (B1)	modes
76	$K^+ ho^- K^0 \pi^+ \pi^-$	< 3.5 × 10 ⁻⁵	CL=90%	$\Gamma_{142} \gamma \gamma$ B1 < 3.9	× 10 ⁻⁵ CL=90%
Γ77 Γ	$K^0 \rho^0$	< 3.9 × 10 ⁻⁵	CL=90%	$\Gamma_{143} e^{+}e^{-}$ B1 < 5.9	× 10 ⁻⁶ CL≔90%
Γ ₇₈ Γ ₇₉	$K^0 f_0(980)$	$< 3.9 \times 10^{-5}$ $< 3.6 \times 10^{-4}$	CL=90%	$\Gamma_{1AA} \ \mu^{+} \mu^{-}$ B1 < 6.8	× 10 ⁻⁷ CL=90%
Γ ₈₀	$K^*(892)^+\pi^-$	< 7.2 × 10 ⁻⁵	CL=90%	$\Gamma_{145} K^0 e^+ e^-$ B1 < 3.0	× 10 ⁻⁴ CL=90%
Γ ₈₁	$K^*(892)^0 \pi^0$	< 2.8 × 10 ⁻⁵	CL=90%	$\Gamma_{146} K^0 \mu^+ \mu^- \qquad B1 < 3.6$	× 10 ⁻⁴ CL=90%
Γ ₈₂	$K_2^*(1430)^+\pi^-$	< 2.6 × 10 ⁻³	CL=90%	$\Gamma_{147} K^*(892)^0 e^+ e^-$ B1 < 2.9	× 10 ⁻⁴ CL=90%
Γ ₈₃	K° K+ K-	< 1.3 × 10 ⁻³	CL=90%	$\Gamma_{148} K^*(892)^0 \mu^+ \mu^- \qquad B1 < 2.3$	× 10 ⁻⁵ CL=90% × 10 ⁻³ CL=90%
Γ ₈₄	$K^0\phi$	< 8.8 × 10 ⁻⁵	CL=90%	$\Gamma_{149}^{149} K^*(892)^0 \nu \overline{\nu}$ $B1 < 1.0$ $\Gamma_{150} e^{\pm} \mu^{\mp}$ $LF [c] < 5.9$	× 10 ⁻³ CL=90% × 10 ⁻⁶ CL=90%
Γ ₈₅	$K^-\pi^+\pi^+\pi^-$	$[b] < 2.3 \times 10^{-4}$	CL=90%	$\Gamma_{151} e^{\pm} \tau^{\mp}$ LF [c] < 5.3	× 10 ⁻⁴ CL=90%
Γ ₈₆	$K^*(892)^0\pi^+\pi^-$	$< 1.4 \times 10^{-3}$	CL=90%	$\Gamma_{152} \mu^{\pm} \tau^{\mp}$ $\Gamma_{16} LF [c] < 8.3$	× 10 ⁻⁴ CL=90%
Γ ₈₇	$K^*(892)^0 \rho^0$	< 4.6 × 10 ⁻⁴	CL=90%	102 1	
Γ ₈₈	$K^*(892)^0 f_0(980)$	< 1.7 × 10 ⁻⁴	CL=90%	[a] An ℓ indicates an e or a μ mode, not a sum ov	er these modes.
L 89	$K_1(1400)^+\pi^-$	$< 1.1 \times 10^{-3}$	CL=90%	[b] B^0 and B^0_s contributions not separated. Limit i	s on weighted average of
Γ ₉₀	$K^-a_1(1260)^+$	$[b] < 2.3 \times 10^{-4}$	CL=90%	the two decay rates.	

[[]b] B^0 and B^0_s contributions not separated. Limit is on weighted average of the two decay rates.

[[]c] The value is for the sum of the charge states of particle/antiparticle states indicated.

BO BRANCHING RATIOS

For branching ratios in which the charge of the decaying B is not determined, see the B^{\pm} section.

$\Gamma(\ell^+\nu_\ell \text{ anything})/\Gamma_{\text{total}}$				Γ_1/Γ
VALUE	DOCUMENT ID	TE	CN COMMENT	
0.105 ±0.008 OUR AVERA	GE			_
$0.1078 \pm 0.0060 \pm 0.0069$	31 ARTUSO	97 CL	E2 e ⁺ e →	T(45)
0.093 ±0.011 ±0.015	ALBRECHT	94 AF	G e ⁺ e ⁻ →	T(45)
0.099 ±0.030 ±0.009	HENDERSON	1 92 CL	EO $e^+e^- \rightarrow$	T(45)
• • We do not use the following the fol	wing data for averag	es, fits, lir	nits, etc. • • •	,
0.109 ±0.007 ±0.011	ATHANAS	94 CL	E2 Sup. by A	RTUSO 97
31 ARTUSO 97 uses partial	reconstruction of B	-→ D* t	v_{ℓ} and inclusion	ve semileptonic

 $\Gamma(D^-\ell^+\nu_\ell)/\Gamma_{\text{total}}$ Γ_2/Γ ℓ denotes e or μ , not the sum

e denotes E of 12, not the s	DIII.			
VALUE	DOCUMENT ID		TECN_	COMMENT
0.0200 ± 0.0025 OUR AVERAGE				
$0.0187 \pm 0.0015 \pm 0.0032$	32 ATHANAS	97	CLE2	$e^+e^- \rightarrow \Upsilon(4S)$
$0.0235 \pm 0.0020 \pm 0.0044$	33 BUSKULIC	97	ALEP	$e^+e^- \rightarrow Z$
0.018 ±0.006 ±0.003	34 FULTON	91	CLEO	$e^+e^- \rightarrow \Upsilon(4S)$
0.020 ±0.007 ±0.006	35 ALBRECHT	8 9 J	ARG	$e^+e^- \rightarrow \Upsilon(4S)$

- 32 ATHANAS 97 uses missing energy and missing momentum to reconstruct neutrino.
- ³³ BUSKULIC 97 assumes fraction (B^+) = fraction (B^0) = (37.8 ± 2.2)% and PDG 96 values for B lifetime and branching ratio of D^* and D decays.
- 34 FULTON 91 assumes assuming equal production of B^0 and B^+ at the $\varUpsilon(45)$ and uses Mark III D and D^* branching ratios.
- 35 ALBRECHT 89) reports $0.018\pm0.006\pm0.005$. We rescale using the method described in STONE 94 but with the updated PDG 94 B($D^0 \rightarrow K^-\pi^+$).

$\Gamma(D^{\bullet}(2010)^{-}\ell^{+}\nu_{\ell})/\Gamma_{t}$	otal	Г ₃ /Г
VALUE	EVTS	DOCUMENT ID TECN COMMENT
0.0460±0.0027 OUR AVER	AGE	
$0.0508 \pm 0.0021 \pm 0.0066$		36 ACKERSTAFF 97G OPAL $e^+e^- \rightarrow Z$
$0.0553 \pm 0.0026 \pm 0.0052$		³⁷ BUSKULIC 97 ALEP $e^+e^- \rightarrow Z$
$0.0552 \pm 0.0017 \pm 0.0068$		³⁸ ABREU 96P DLPH $e^+e^- \rightarrow Z$
$0.0449 \pm 0.0032 \pm 0.0039$	376	³⁹ BARISH 95 CLE2 $e^+e^- \rightarrow \Upsilon(45)$
$0.045 \pm 0.003 \pm 0.004$		⁴⁰ ALBRECHT 94 ARG $e^+e^- \rightarrow \Upsilon(4S)$
0.047 ±0.005 ±0.005	235	⁴¹ ALBRECHT 93 ARG $e^+e^- \rightarrow \Upsilon(45)$
0.040 ±0.004 ±0.006		⁴² BORTOLETTO898 CLEO $e^+e^- \rightarrow \Upsilon(45)$
• • • We do not use the fo	ollowing	data for averages, fits, limits, etc. • • •
$0.0518 \pm 0.0030 \pm 0.0062$	410	⁴³ BUSKULIC 95N ALEP Sup. by BUSKULIC 97
seen	398	⁴⁴ SANGHERA 93 CLE2 $e^+e^- \rightarrow T(45)$
0.070 ±0.018 ±0.014		⁴⁵ ANTREASYAN 90B CBAL $e^+e^- \rightarrow \Upsilon(45)$
		⁴⁶ ALBRECHT 89C ARG $e^+e^- \rightarrow r(45)$
0.060 ±0.010 ±0.014		⁴⁷ ALBRECHT 891 ARG $e^+e^- \rightarrow r(4S)$
$0.070 \pm 0.012 \pm 0.019$	47	⁴⁸ ALBRECHT 87J ARG $e^+e^- \rightarrow T(45)$
36		11 (D+) 1 11 (D0) (070 100) 1000 00

- ³⁶ ACKERSTAFF 97G assumes fraction (B^+) = fraction (B^0) = $(37.8 \pm 2.2)\%$ and PDG 96 values for B lifetime and branching ratio of D^* and D decays.
- 37 BUSKULIC 97 assumes fraction (B^+) = fraction (B^0) = (37.8 \pm 2.2)% and PDG 96 values for B lifetime and D^* and D branching fractions.
- 38 ABREU 96P result is the average of two methods using exclusive and partial D^{st} recon-
- ³⁹ BARISH 95 use B($D^0 \rightarrow K^- \pi^+$) = (3.91 ± 0.08 ± 0.17)% and B($D^{*+} \rightarrow D^0 \pi^+$) $= (68.1 \pm 1.0 \pm 1.3)\%.$
- ⁴⁰ ALBRECHT 94 assumes B($D^{*+} \rightarrow D^0 \pi^+$) = 68.1 ± 1.0 ± 1.3%. Uses partial reconstruction of D^{*+} and is independent of D^{0} branching ratios.
- 41 ALBRECHT 93 reports $0.052 \pm 0.005 \pm 0.006$. We rescale using the method described in STONE 94 but with the updated PDG 94 B($D^0 \rightarrow K^-\pi^+$). We have taken their average e and μ value. They also obtain $\alpha = 2*\Gamma^0/(\Gamma^- + \Gamma^+) 1 = 1.1 \pm 0.4 \pm 0.2$. $A_{AF}=3/4*(\Gamma^--\Gamma^+)/\Gamma=0.2\pm0.08\pm0.06$ and a value of $|V_{cb}|=0.036$ -0.045 depending on model assumptions.
- 42 We have taken average of the the BORTOLETTO 89B values for electrons and muons, 0.046 \pm 0.005 \pm 0.007. We rescale using the method described in STONE 94 but with the updated PDG 94 B($D^0 \to K^-\pi^+$). The measurement suggests a D^* polarization parameter value $lpha=0.65\pm0.66\pm0.25$.
- ⁴³ BUSKULIC 95N assumes fraction (B^+) = fraction (B^0) = 38.2 \pm 1.3 \pm 2.2% and au_{B^0} = 1.58 \pm 0.06 ps. $\Gamma(D^{*-}\ell^{+}\nu_{\ell})/\text{total} = [5.18 - 0.13(\text{fraction}(B^{0}) - 38.2) - 1.5(\tau_{B^{0}} - 1.5)$
- 44 Combining $\overline{D}^{*0}\ell^+\nu_\ell$ and $\overline{D}^{*-}\ell^+\nu_\ell$ SANGHERA 93 test V-A structure and fit the decay angular distributions to obtain $A_{FB}=3/4*(\Gamma^--\Gamma^+)/\Gamma=0.14\pm0.06\pm0.03$. Assuming a value of V_{CD} , they measure V, A_1 , and A_2 , the three form factors for the $D^*\ell\nu_\ell$ decay, where results are slightly dependent on model assumptions.
- 45 ANTREASYAN 90B is average over B and \overline{D}^* (2010) charge states.
- ⁴⁶ The measurement of ALBRECHT 89C suggests a D^* polarization γ_L/γ_T of 0.85 \pm 0.45.
- or $\alpha = 0.7 \pm 0.9$. 47 ALBRECHT 89,1 is ALBRECHT 87,1 value rescaled using B($D^*(2010)^- \rightarrow D^0 \pi^-$) = 0.57 \pm 0.04 \pm 0.04. Superseded by ALBRECHT 93.
- ⁴⁸ ALBRECHT 87J assume μ -e universality, the B($\Upsilon(4S) \rightarrow B^0 \overline{B}{}^0$) = 0.45, the B($D^0 \rightarrow$ $K^-\pi^+)=(0.042\pm0.004\pm0.004)$, and the B($D^*(2010)^-\to D^0\pi^-)=0.49\pm0.08$. Superseded by ALBRECHT 89J.

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\Gamma(\rho^-\ell^+\nu_\ell)/\Gamma_{\text{total}}
                                                                                                              \Gamma_4/\Gamma
        \ell = e or \mu, not sum over e and \mu modes.
VALUE (units 10<sup>-4</sup>)
                              CL%
                                                DOCUMENT ID
                                                                       TECN COMMENT
   2.5±0.4+0.7
                                            <sup>49</sup> ALEXANDER 96T CLE2 e + e^- \rightarrow T(4S)
• • • We do not use the following data for averages, fits, limits, etc. • • •
                                           <sup>50</sup> BEAN
                                 90
                                                                     938 CLE2 e^+e^- \rightarrow T(45)
 ^{49} ALEXANDER 96T gives systematic errors ^{+0.5}_{-0.7}\pm 0.5 where the second error reflects the estimated model dependence. We combine these in quadrature. Assumes isospin
     symmetry: \Gamma(B^0 \to \rho^- \ell^+ \nu_\ell) = 2 \times \Gamma(B^+ \to \rho^0 \ell^+ \nu_\ell) \sim 2 \times \Gamma(B^+ \to \omega \ell^+ \nu_\ell).
 <sup>50</sup> BEAN 93B limit set using ISGW Model. Using isospin and the quark model to combine
    \Gamma(\rho^0\ell^+\nu_\ell) and \Gamma(\omega\ell^+\nu_\ell) with this result, they obtain a limit <(1.6-2.7)\times 10^{-4} at
     90% CL for B^+ \to (\omega \, {\rm or} \, \, \rho^0) \ell^+ \nu_\ell. The range corresponds to the ISGW, WSB, and
     K5 models. An upper limit on |V_{ub}/V_{cb}| < 0.08–0.13 at 90% CL is derived as well.
\Gamma(\pi^-\ell^+\nu_\ell)/\Gamma_{\rm total}
                                                                                                              \Gamma_5/\Gamma
VALUE (units 10-4)
                                                DOCUMENT ID
                                                                        TECN COMMENT
                                            ^{51} ALEXANDER 96T CLE2 e+e^-
ightarrow \varUpsilon(45)
1.8\pm0.4\pm0.4
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 51 ALEXANDER 96T gives systematic errors $\pm 0.3\,\pm\,0.2$ where the second error reflects the estimated model dependence. We combine these in quadrature. Assumes isospin symmetry: $\Gamma(B^0 \to \pi^- \ell^+ \nu_\ell) = 2 \times \Gamma(B^+ \to \pi^0 \ell^+ \nu_\ell)$. Γ_6/Γ $\Gamma(\pi^-\mu^+\nu_\mu)/\Gamma_{\text{total}}$

DOCUMENT ID TECN • • • We do not use the following data for averages, fits, limits, etc. • • • 52 ALBRECHT 91c ARG 52 In ALBRECHT 91C, one event is fully reconstructed providing evidence for the $b \rightarrow u$

 $\Gamma(K^+ \text{ anything})/\Gamma_{\text{total}}$ Γ_7/Γ VALUE DOCUMENT ID TECN COMMENT 0.78±0.8 53 ALBRECHT 96D ARG $e^+e^- \rightarrow \tau(4S)$

⁵³ Average multiplicity. Γ_8/Γ $\Gamma(D^-\pi^+)/\Gamma_{\text{total}}$ VALUE **EVTS** DOCUMENT ID TECN COMMENT 0.0030 ±0.0004 OUR AVERAGE $0.0029 \pm 0.0004 \pm 0.0002$ 94 CLE2 $e^+e^- \rightarrow \Upsilon(4S)$ ⁵⁵ BORTOLETTO92 CLEO $e^+e^- \rightarrow r(4S)$ $0.0027 \pm 0.0006 \pm 0.0005$

 $0.0051 {}^{+0.0028}_{-0.0025} {}^{+0.0013}_{-0.0012}$ 57 BEBEK 87 CLEO $e^+e^- \rightarrow T(4S)$ \bullet \bullet \bullet We do not use the following data for averages, fits, limits, etc. \bullet \bullet

 $0.0048 \pm 0.0011 \pm 0.0011$

7 ⁵⁶ ALBRECHT 88K ARG $e^+e^- \rightarrow \Upsilon(4S)$ $0.0031 \pm 0.0013 \pm 0.0010$

- ⁵⁴ ALAM 94 reports $[B(B^0 \rightarrow D^-\pi^+) \times B(D^+ \rightarrow K^-\pi^+\pi^+)] = 0.000265 \pm 0.000265$ 0.000032 ± 0.000023 . We divide by our best value B(D⁺ $\rightarrow K^-\pi^+\pi^+$) = $(9.0 \pm 0.6) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value. Assumes equal production of B^+ and B^0 at the T(45).
- 55 BORTOLETTO 92 assumes equal production of B^+ and B^0 at the \varUpsilon (45) and uses Mark III branching fractions for the D.
- 56 ALBRECHT 88K assumes $B^0\overline{B}^0$: B^+B^- production ratio is 45:55. Superseded by AL-
- BRECHT 90J which assumes 50:50.

 57 BEBEK 87 value has been updated in BERKELMAN 91 to use same assumptions as noted for BORTOLETTO 92.

$\Gamma(D^-\rho^+)/\Gamma_{\text{total}}$					٦/و٦
VALUE	EVTS	DOCUMENT I	D TECN	COMMENT	
0.0079±0.0014 OUR AV	ERAGE				
0.0078±0.0013±0.0005	79	⁵⁸ ALAM	94 CLE2	$e^+e^- \rightarrow$	T(4S)
0.009 ±0.005 ±0.003	9	⁵⁹ ALBRECHT	901 ARG	e ⁺ e →	r(45)
• • • We do not use the	following	data for averages,	fits, limits, et	C. • • •	
0.022 ±0.012 ±0.009	6	⁵⁹ ALBRECHT	88K ARG	$e^+e^- \rightarrow$	T(45)
58 ALAM 94 reports [8	$3(B^0 \rightarrow$	$D^-\rho^+) \times B(D$	+ → K-π	$+\pi^{+})1 = 0$.000704 ±
0.000096 ± 0.000076					
$(9.0 \pm 0.6) \times 10^{-2}$.					
is the systematic error B^0 at the $T(4S)$.					
_ D at the 1 (43).	_				

⁵⁹ ALBRECHT 88K assumes $B^0 \overline{B}{}^0: B^+ B^-$ production ratio is 45:55. Superseded by AL-BRECHT 901 which assumes 50:50.

$\Gamma(\overline{D}{}^0\pi^0$	⁺ π ⁻)/Γ	total						Γ_{10}/Γ
VALUE		CL% EV	<u>TS</u>	DOCUMENT ID		TECN	COMMENT	
< 0.0016		90		O ALAM	94	CLE2	$e^+e^- \rightarrow$	Y(45)
• • • W	e do not	use the fo	llowing	data for average	s, flt	s, limits,	etc. • • •	` '
< 0.007		90	(51 BORTOLETT	O92	CLEO	$e^+e^- \rightarrow$	Y(45)
< 0.034		90	•	⁵² BEBEK	87	CLEO	$e^+e^- \rightarrow$	r(45)
0.07	± 0.05		5 (⁵³ BEHRENDS	83	CLEO	$e^+e^- \rightarrow$	T(45)
60 Assul	mes equal	producti	on of B	$+$ and B^0 at the	r(4	S).		

 61 BORTOLETTO 92 assumes equal production of B^+ and B^0 at the arphi(4S) and uses Mark III branching fractions for the D. The product branching fraction into $D_0^*(2340)\pi$

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followed by D_0^*(2340) \rightarrow D^0 \pi is < 0.0001 at 90% CL and into D_2^*(2460) followed by
D_2^*(2460) \rightarrow D^0 \pi is < 0.0004 at 90% CL.
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⁶² BEBEK 87 assume the *T*(45) decays 43% to $B^0\overline{B}^0$. We rescale to 50%. B($D^0\to K^-\pi^+$) = (4.2 ± 0.4 ± 0.4)% and B($D^0\to K^-\pi^+\pi^+\pi^-$) = (9.1 ± 0.8 ± 0.8)%

63 were used. Sumptions: $B(D^0 \rightarrow K^-\pi^+) = (0.042 \pm 0.006)$ and $B(\Upsilon(45) \rightarrow B^0\overline{B}^0) = 50\%$. The product branching ratio is $B(B^0 \rightarrow K^-\pi^+) = (0.042 \pm 0.006)$ $\overline{D}{}^0\pi^+\pi^-)B(\overline{D}{}^0\to K^+\pi^-)=(0.39\pm0.26)\times10^{-2}.$

ı

Γ(Δ)*(2010) ⁻	$\pi^+)/\Gamma_{\text{total}}$						Γ11/Γ
VALL	JE		EVTS	DOCUMENT ID		TECN	COMMENT	
0.00	276±0.000	21 OUR AVE	RAGE					
0.00	281 ± 0.000	24±0.00005		64 BRANDENB	98	CLE2	$e^+e^- \rightarrow$	T(45)
0.00	26 ±0.000	3 ±0.0004	82				$e^+e^- \rightarrow$	
0.00	33 ±0.001	0 ±0.0001		66 BORTOLETTO)92	CLEO	$e^+e^- \rightarrow$	T(45)
0.00	234 ± 0.000	87±0.00005	12	67 ALBRECHT	90 J	ARG	$e^+e^- \rightarrow$	T(45)
0.00	$234 + 0.001 \\ -0.001$	48 09 ± 0.00005	5	68 BEBEK	87	CLEO	$e^+e^- \to$	T(45)
• •	 We do n 	ot use the fol	lowing d	lata for averages, fi	ts, lir	nits, etc	. • • •	
0.01	0 ±0.004	± 0.001	8	⁶⁹ AKERS	94 J	OPAL	$e^+e^- \rightarrow$	Z
0.00	27 ±0.001	4 ±0.0010	5	70 ALBRECHT	87C	ARG	$e^+e^- \rightarrow$	T(45)
0.00	35 ±0.002	± 0.002		71 ALBRECHT	86F	ARG	$e^+e^- \rightarrow$	T(45)
0.01	7 ±0.005	± 0.005	41	72 GILES	84	CLEO	$e^+e^- \rightarrow$	T(4S)
						_		

 64 BRANDENBURG 98 assume equal production of B^+ and B^0 at $\Upsilon(4S)$ and use the D^* reconstruction technique. The first error is their experiment's error and the second error is the systematic error from the PDG 96 value of B($D^* \rightarrow D\pi$). ⁶⁵ ALAM 94 assume equal production of B^+ and B^0 at the $\Upsilon(45)$ and use the CLEO II

B($D^*(2010)^+ \rightarrow D^0\pi^+$) and absolute B($D^0 \rightarrow K^-\pi^+$) and the PDG 1992 B($D^0 \rightarrow K^-\pi^+$) and the PDG 1992 B($D^0 \rightarrow K^-\pi^+$) and B($D^0 \rightarrow K^-\pi^+$) and B($D^0 \rightarrow K^-\pi^+$). B($D^0 \rightarrow K^$ 10-2. Our first error is their experiment's error and our second error is the systematic error from using our best value. Assumes equal production of B^+ and B^0 at the T(45) and uses Mark III branching fractions for the D.

67 ALBRECHT 901 reports 0.0028 \pm 0.0009 \pm 0.0006 for B(D*(2010)+ \rightarrow D⁰ π +) = 0.57 ± 0.06 . We rescale to our best value B($D^*(2010)^+ \rightarrow D^0\pi^+$) = (68.3 ± 1.4) × 10⁻². Our first error is their experiment's error and our second error is the systematic error from using our best value. Assumes equal production of B^+ and B^0 at the T(45) and uses Mark III branching fractions for the D.

68 BEBEK 87 reports $0.0028^{+} \stackrel{0.0015}{-} + 0.0012$ for $B(D^{+}(2010)^{+} \rightarrow D^{0}\pi^{+}) = 0.57 \pm 0.0012$

0.06. We rescale to our best value $B(D^*(2010)^+ \rightarrow D^0\pi^+) = (68.3 \pm 1.4) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value. Updated in BERKELMAN 91 to use same assumptions as 9 noted for BORTOLETTO 92 and ALBRECHT 90. 69 Assumes $B(Z \rightarrow bb) = 0.217$ and 38% B_d production fraction.

$\Gamma(D^-\pi^+\pi^+\pi^-)/\Gamma_{\text{total}}$				Γ ₁₂ /Γ
VALUE	DOCUMENT ID	TECN	COMMENT	
$0.0080 \pm 0.0021 \pm 0.0014$	73 BORTOLETTO92	CLEO	$e^+e^- \rightarrow$	Y(45)

 73 BORTOLETTO 92 assumes equal production of B^+ and B^0 at the $\Upsilon(45)$ and uses Mark III branching fractions for the D.

$\Gamma((D^-\pi^+\pi^+\pi^-) \text{ nonresonant})/\Gamma_{\text{total}}$ Γ_{13}/Γ DOCUMENT ID VALUE TECN COMMENT ⁷⁴ BORTOLETTO92 CLEO $e^+e^- \rightarrow \Upsilon(45)$ $0.0039 \pm 0.0014 \pm 0.0013$

 74 BORTOLETTO 92 assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and uses Mark III branching fractions for the D.

$\Gamma(D^-\pi^+ ho^0)/\Gamma_{ m total}$				ſ	14/
VALUE	DOCUMENT ID	TECN	COMMENT		
0.0011±0.0009±0.0004	75 BORTOLETTO92	CLEO	e+e	T(45)	
75		٠ ـ			

 5 BORTOLETTO 92 assumes equal production of B^+ and B^0 at the arphi(45) and uses Mark III branching fractions for the D.

$\Gamma(D^-a_1(1260)^+)/\Gamma_{\text{total}}$				ı	Γ ₁₅ /Γ
VALUE	DOCUMENT ID	<u>TECN</u>	COMMENT		
0.0060±0.0022±0.0024	⁷⁶ BORTOLETTO92	CLEO	$e^+e^- \rightarrow$	Y(45)	

 76 BORTOLETTO 92 assumes equal production of B^+ and B^0 at the $\it T(4S)$ and uses Mark III branching fractions for the $\it D$.

$\Gamma(D^*(2010)^-\pi^+\pi^0)/\Gamma$	total				Γ ₁₆ /Γ
VALUE	EVTS	DOCUMENT ID	TECN	COMMENT	
$0.0150 \pm 0.0051 \pm 0.0003$	51	77 ALBRECHT 9	OJ ARG	$e^+e^- \rightarrow$	T(45)
• • • We do not use the fe	ollowing	data for averages, fits,	limits, etc	. • • •	
0.015 ±0.008 ±0.008	8	78 ALBRECHT 8	7c ARG	$e^+e^- \rightarrow$	T(45)

⁷⁷ ALBRECHT 90J reports $0.018 \pm 0.004 \pm 0.005$ for B(D*(2010)⁺ $\rightarrow D^0 \pi^+$) = 0.57 \pm 0.06. We rescale to our best value B($D^*(2010)^+ \rightarrow D^0\pi^+$) = (68.3 ± 1.4) × 10⁻². Our first error is their experiment's error and our second error is the systematic error from using our best value. Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and uses Mark III branching fractions for the D.

78 ALBRECHT 87C use PDG 86 branching ratios for D and $D^*(2010)$ and assume

B($\Upsilon(4S) \to B^+B^-$) = 55% and B($\Upsilon(4S) \to B^0\widetilde{B}^0$) = 45%. Superseded by ALBRECHT 90J.

 $\Gamma(D^{\bullet}(2010)^{-}\rho^{+})/\Gamma_{\text{total}}$ Γ_{17}/Γ DOCUMENT ID TECN COMMENT 0.0067±0.0033 OUR AVERAGE ⁷⁹ BORTOLETTO92 CLEO $e^+e^- \rightarrow \Upsilon(45)$ $0.0159 \pm 0.0112 \pm 0.0003$ 80 ALBRECHT 90J ARG $e^+e^- \rightarrow T(4S)$ $0.0058 \pm 0.0035 \pm 0.0001$ • • We do not use the following data for averages, fits, limits, etc. • • 76 81,82 ALAM $0.0074 \pm 0.0010 \pm 0.0014$ 94 CLE2 Sup. by JESSOP 97 83 CHEN $0.081 \pm 0.029 \begin{tabular}{c} +0.059 \\ -0.024 \end{tabular}$ 85 CLEO $e^+e^- \rightarrow \Upsilon(4S)$

⁷⁹BORTOLETTO 92 reports 0.019 \pm 0.008 \pm 0.011 for B(D*(2010)⁺ \rightarrow D⁰ π ⁺) = 0.57 ± 0.06 . We rescale to our best value B($D^*(2010)^+\to D^0\pi^+$) = (68.3 \pm 1.4) \times 10^{-2} . Our first error is their experiment's error and our second error is the systematic error from using our best value. Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and uses Mark III branching fractions for the D.

⁸⁰ ALBRECHT 90J reports $0.007 \pm 0.003 \pm 0.003$ for B(D*(2010)+ \rightarrow D⁰ π +) = 0.57 \pm 0.06. We rescale to our best value B($D^*(2010)^+ \rightarrow D^0\pi^+$) = (68.3 \pm 1.4) \times 10⁻². Our first error is their experiment's error and our second error is the systematic error from using our best value. Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and uses Mark III branching fractions for the D.

81 ALAM 94 assume equal production of B^+ and B^0 at the $\Upsilon(4S)$ and use the CLEO II $B(D^*(2010)^+ \to D^0 \pi^+)$ and absolute $B(D^0 \to K^- \pi^+)$ and the PDG 1992 $B(D^0 \to K^- \pi^+)$ and the PDG 1992 $B(D^0 \to K^- \pi^+ \pi^0)/B(D^0 \to K^- \pi^+)$ and $B(D^0 \to K^- \pi^+ \pi^+ \pi^-)/B(D^0 \to K^- \pi^+)$.

⁸² This decay is nearly completely longitudinally polarized, $\Gamma_L/\Gamma=(93\pm5\pm5)\%$, as expected from the factorization hypothesis (ROSNER 90). The nonresonant $\pi^+\pi^0$

contribution under the ho^+ is less than 9% at 90% CL. ⁸³ Uses B($D^* \to D^0 \pi^+$) = 0.6 ± 0.15 and B($\Upsilon(45) \to B^0 \overline{B}{}^0$) = 0.4. Does not depend on D branching ratios.

 $\Gamma(D^*(2010)^-\pi^+\pi^+\pi^-)/\Gamma_{\text{total}}$ Γ_{18}/Γ TETO Includes scale factor of 1.3. See the ideogram below. 0.0076±0.0017 OUR AVERAGE E 49 84,85 ALAM $0.0063 \pm 0.0010 \pm 0.0011$ 94 CLE2 7(45) 86 BORTOLETTO92 CLEO $0.0133 \pm 0.0036 \pm 0.0003$ 87 ALBRECHT 90J ARG $0.0100 \pm 0.0040 \pm 0.0002$ e → → T(45) • • We do not use the following data for averages, fits, limits, etc. • $e^+e^- \rightarrow \Upsilon(4S)$ 88 ALBRECHT 87C ARG $0.033 \pm 0.009 \pm 0.016$ 27 89 REREK < 0.042 87 CLEO $e^+e^- \rightarrow \Upsilon(4S)$

 84 ALAM 94 assume equal production of B^+ and B^0 at the $\Upsilon(4S)$ and use the CLEO II $B(D^*(2010)^+ \to D^0\pi^+)$ and absolute $B(D^0 \to K^-\pi^+)$ and the PDG 1992 $B(D^0 \to K^-\pi^+\pi^0)/B(D^0 \to K^-\pi^+)$ and $B(D^0 \to K^-\pi^+\pi^0)/B(D^0 \to K^-\pi^+)$.

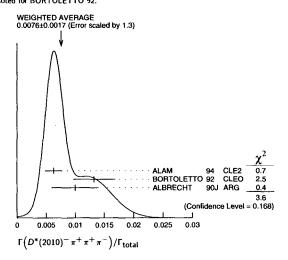
85 The three pion mass is required to be between 1.0 and 1.6 GeV consistent with an a_1 meson. (If this channel is dominated by a_1^+ , the branching ratio for $\overline{D}^{*-}a_1^+$ is twice that for $\overline{D}^{*-}\pi^{+}\pi^{+}\pi^{-}$.)

⁸⁶ BORTOLETTO 92 reports 0.0159 \pm 0.0028 \pm 0.0037 for B($D^*(2010)^+ \rightarrow D^0 \pi^+$) = 0.57 ± 0.06 . We rescale to our best value B($D^*(2010)^+ \rightarrow D^0 \pi^+$) = (68.3 ± 1.4) × 10-2. Our first error is their experiment's error and our second error is the systematic error from using our best value. Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and uses Mark III branching fractions for the D.

87 ALBRECHT 90J reports $0.012 \pm 0.003 \pm 0.004$ for B(D*(2010)⁺ \rightarrow D⁰ π ⁺) = 0.57 \pm 0.06. We rescale to our best value $B(D^*(2010)^+ \to D^0\pi^+) = (68.3 \pm 1.4) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value. Assumes equal production of B^+ and B^0 at the T(45) and uses Mark III branching fractions for the D.

 88 ALBRECHT 87C use PDG 86 branching ratios for D and D^* (2010) and assume B($\Upsilon(4S) \rightarrow B^+B^-$) = 55% and B($\Upsilon(4S) \rightarrow B^0\overline{B}^0$) = 45%. Superseded by AL-BRECHT 90J.

89 BEBEK 87 value has been updated in BERKELMAN 91 to use same assumptions as noted for BORTOLETTO 92.



 B^0

((D°(2010) π ⁺ π ⁺ π ⁻) nonresonant)/Γ _{total} Γ ₁₉ /Γ ΔΕΕΕΕΕΕΕΕΕΕΕΕΕΕΕΕΕΕΕΕΕΕΕΕΕΕΕΕΕΕΕΕΕΕΕ	$\Gamma(D^{+}(2010)^{-}D_{s}^{+})/\Gamma_{total}$ VALUE EVTS DOCUMENT ID. TECH. COMMENT
1.0000 \pm 0.0019 \pm 0.0016 90 BORTOLETTO92 CLEO $e^+e^- \rightarrow \Upsilon(4S)$	0.0096±0.0034 OUR AVERAGE
90 BORTOLETTO 92 assumes equal production of B^+ and B^0 at the $T(45)$ and uses Mark III branching fractions for the D and D^* (2010).	0.0090 ± 0.0027 ± 0.0022 102 GIBAUT 96 CLE2 e^+e^- → $T(45)$ 0.010 ± 0.008 ± 0.003 103 ALBRECHT 92G ARG e^+e^- → $T(45)$
$\Gamma(D^*(2010)^{-}\pi^{+}\rho^{0})/\Gamma_{\text{total}}$ Γ_{20}/Γ	0.013 \pm 0.008 \pm 0.003
ALUE DOCUMENT ID TECN COMMENT 91 BORTOLETTO92 CLEO $e^+e^- \rightarrow T(45)$	102 GIBAUT 96 reports 0.0093 \pm 0.0023 \pm 0.0016 for B($D_s^+ \rightarrow \phi \pi^+$) = 0.035. We resca
91 BORTOLETTO 92 reports $0.0068 \pm 0.0032 \pm 0.0021$ for $B(D^*(2010)^+ \rightarrow D^0\pi^+) = 0.57 \pm 0.06$. We rescale to our best value $B(D^*(2010)^+ \rightarrow D^0\pi^+) = (68.3 \pm 1.4) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value. Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and uses Mark III branching fractions for the D .	to our best value B($D_s^+ \to \phi \pi^+$) = (3.6 \pm 0.9) \times 10 ⁻² . Our first error is the experiment's error and our second error is the systematic error from using our best value 103 ALBRECHT 92G reports 0.014 \pm 0.010 \pm 0.003 for B($D_s^+ \to \phi \pi^+$) = 0.027. W rescale to our best value B($D_s^+ \to \phi \pi^+$) = (3.6 \pm 0.9) \times 10 ⁻² . Our first error is the experiment's error and our second error is the systematic error from using our best value
(D*(2010) ⁻ a ₁ (1260) ⁺)/Γ _{total} Γ ₂₁ /Γ ALUE DOCUMENT ID TECH COMMENT	Assumes PDG 1990 D^+ and $D^*(2010)^+$ branching ratios, e.g., $B(D^0 \to K^-\pi^+)$ 3.71 \pm 0.25%, $B(D^+ \to K^-\pi^+\pi^+) = 7.1 \pm 1.0$ %, and $B(D^*(2010)^+ \to D^0\pi^+$
.0130±0.0027 OUR AVERAGE	= 55 \pm 4%. 104 BORTOLETTO 92 reports 0.016 \pm 0.009 \pm 0.006 for B($D_S^+ \to \phi \pi^+$) = 0.030 \pm 0.01
.0126±0.0020±0.0022 92,93 ALAM 94 CLE2 $e^+e^- \rightarrow \tau$ (45) 94 BORTOLETTO92 CLEO $e^+e^- \rightarrow \tau$ (45)	We rescale to our best value B($D_s^+ \rightarrow \phi \pi^+$) = (3.6 ± 0.9) × 10 ⁻² . Our first error
92 ALAM 94 value is twice their $\Gamma(D^*(2010)^-\pi^+\pi^+\pi^-\pi^-)/\Gamma_{total}$ value based on their observation that the three pions are dominantly in the $a_1(1260)$ mass range 1.0 to 1.6	is their experiment's error and our second error is the systematic error from using or best value. Assumes equal production of B^+ and B^0 at the $\Upsilon(45)$ and uses Mark branching fractions for the D and $D^*(2010)$.
GeV. 93 ALAM 94 assume equal production of B^+ and B^0 at the $\Upsilon(45)$ and use the CLEO II	105 BORTOLETTO 90 assume B($D_s ightarrow \phi \pi^+$) = 2%. Superseded by BORTOLETTO 9
$B(D^*(2010)^+ \rightarrow D^0\pi^+)$ and absolute $B(D^0 \rightarrow K^-\pi^+)$ and the PDG 1992 $B(D^0 \rightarrow K^-\pi^+)$	$\Gamma(D^-D_s^{*+})/\Gamma_{\text{total}}$ $\Gamma_{27}/\Gamma_{\text{total}}$
$K = \pi^{+} \pi^{0})/B(D^{0} \rightarrow K = \pi^{+})$ and $B(D^{0} \rightarrow K = \pi^{+} \pi^{+} \pi^{-})/B(D^{0} \rightarrow K = \pi^{+})$. 94 BORTOLETTO 92 reports $0.018 \pm 0.006 \pm 0.006$ for $B(D^{*}(2010)^{+} \rightarrow D^{0}\pi^{+}) = 0.006$	VALUE DOCUMENT ID TECN COMMENT
0.57 \pm 0.06. We rescale to our best value B(D^* (2010) $^+$ \rightarrow $D^0\pi^+$) = (68.3 \pm 1.4) \times	0.010±0.005 OUR AVERAGE 0.010±0.004±0.002 106 GIBAUT 96 CLE2 e^+e^- → $\Upsilon(45)$
10 ⁻² . Our first error is their experiment's error and our second error is the systematic	$0.010\pm0.004\pm0.002$ 106 GIBAUT 96 CLE2 $e^+e^- \rightarrow \Upsilon(45)$ $0.020\pm0.014\pm0.005$ 107 ALBRECHT 926 ARG $e^+e^- \rightarrow \Upsilon(45)$
error from using our best value. Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and uses Mark III branching fractions for the D .	$106 \text{ GIBAUT } 96 \text{ reports } 0.0100 \pm 0.0035 \pm 0.0022 \text{ for B}(D_s^+ \rightarrow \phi \pi^+) = 0.035. \text{ We resca}$
/marana)- + + - 0)	to our best value B($D_s^+ \rightarrow \phi \pi^+$) = (3.6 ± 0.9) × 10 ⁻² . Our first error is the
(Δ*(2010)**π**π*π*π*0)/Γ _{total} ALUE EVTS DOCUMENT ID TECN COMMENT 95 95	experiment's error and $\frac{\delta}{\delta}$ ur second error is the systematic error from using our best value 107 ALBRECHT 92G reports 0.027 \pm 0.017 \pm 0.009 for B($D_s^+ o \phi \pi^+$) = 0.027. We have $\frac{\delta}{\delta}$
.034±0.018±0.001 28 95 ALBRECHT 90J ARG $e^+e^- → \tau(45)$	rescale to our best value B($D_s^+ \rightarrow \phi \pi^+$) = (3.6 ± 0.9) × 10 ⁻² . Our first error is the
95 ALBRECHT 90J reports $0.041 \pm 0.015 \pm 0.016$ for B($D^*(2010)^+ \rightarrow D^0 \pi^+$) = 0.57 ± 0.06 . We rescale to our best value B($D^*(2010)^+ \rightarrow D^0 \pi^+$) = $(68.3 \pm 1.4) \times 10^{-2}$.	experiment's error and our second error is the systematic error from using our best value
Our first error is their experiment's error and our second error is the systematic error	Assumes PDG 1990 D^+ branching ratios, e.g., B($D^+ \rightarrow K^- \pi^+ \pi^+$) = 7.7 \pm 1.0%
from using our best value. Assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and	$\left[\Gamma(D^{*}(2010)^{-}D_{s}^{+}) + \Gamma(D^{*}(2010)^{-}D_{s}^{*+}) \right] / \Gamma_{\text{total}} $ (\Gamma_{26} + \Gamma_{28})/
uses Mark III branching fractions for the D.	VALUE (units 10 ⁻²) EVTS DOCUMENT ID TECN COMMENT
$(\overline{D}_2^*(2460)^-\pi^+)/\Gamma_{\text{total}}$ Γ_{23}/Γ	4.15 ± 1.11 $^{+0.99}_{-1.02}$ 22 ¹⁰⁸ BORTOLETTO90 CLEO $e^+e^- \rightarrow T(45)$
ALUE <u>CL% DOCUMENT ID TECN COMMENT</u> $C0.0022 90 96 ALAM 94 CLE2 e^+e^- \rightarrow \Upsilon(4S)$	108 BORTOLETTO 90 reports 7.5 \pm 2.0 for B($D_s^+ \rightarrow \phi \pi^+$) = 0.02. We rescale to or
<0.0022 90 ⁹⁶ ALAM 94 CLE2 $e^+e^- \rightarrow \Upsilon(4S)$ 96 ALAM 94 assumes equal production of B^+ and B^0 at the $\Upsilon(4S)$ and use the CLEO II absolute $B(D^0 \rightarrow K^-\pi^+)$ and $B(D_2^*(2460)^+ \rightarrow D^0\pi^+) = 30\%$.	best value B($D_s^+ \to \phi \pi^+$) = (3.6 ± 0.9) × 10 ⁻² . Our first error is their experiment error and our second error is the systematic error from using our best value.
$(\overline{D}_2^*(2460)^- \rho^+)/\Gamma_{\text{total}}$ Γ_{24}/Γ	$\Gamma(D^*(2010)^-D_s^{++})/\Gamma_{\text{total}}$ Γ_{28}/Γ_{28}
ALUE CL% DOCUMENT ID TECN COMMENT	VALUE DOCUMENT ID TECN COMMENT 0.020±0.007 OUR AVERAGE
<0.0049 90 97 ALAM 94 CLE2 $e^+e^- \rightarrow T(45)$	$0.020 \pm 0.006 \pm 0.005$ 109 GIBAUT 96 CLE2 $e^+e^- \rightarrow \Upsilon(45)$
97 ALAM 94 assumesequal production of B^+ and B^0 at the $\Upsilon(4S)$ and use the CLEO II absolute B($D^0 \to K^-\pi^+$) and B($D^0_2(2460)^+ \to D^0\pi^+$) = 30%.	0.019 \pm 0.011 \pm 0.005
$(D^-D_s^+)/\Gamma_{\text{total}}$ Γ_{25}/Γ	to our best value B($D_s^+ o \phi \pi^+$) = (3.6 \pm 0.9) \times 10 ⁻² . Our first error is the experiment's error and our second error is the systematic error from using our best value
ALUE EVTS DOCUMENT ID TECN COMMENT .0080 ± 0.0030 OUR AVERAGE	110 ALBRECHT 92G reports 0.026 \pm 0.014 \pm 0.006 for B($D_s^+ \rightarrow \phi \pi^+$) = 0.027. W
$0.0084 \pm 0.0030 + 0.0020$ 98 GIBAUT 96 CLE2 $e^+e^- \rightarrow \Upsilon(45)$	rescale to our best value B($D_s^+ \rightarrow \phi \pi^+$) = (3.6 \pm 0.9) \times 10 ⁻² . Our first error is the experiment's error and our second error is the systematic error from using our best value
$0.013 \pm 0.011 \pm 0.003$ 99 ALBRECHT 92G ARG $e^+e^- \rightarrow T(45)$	Assumes PDG 1990 D^+ and $D^*(2010)^+$ branching ratios, e.g., $B(D^0 \rightarrow K^-\pi^+)$
007 ± 0.004 ± 0.002 100 BORTOLETTO92 CLEO $e^+e^- \rightarrow T(4S)$ • • We do not use the following data for averages, fits, limits, etc. • • •	3.71 \pm 0.25%, B(D ⁺ \rightarrow K ⁻ π ⁺ π ⁺) = 7.1 \pm 1.0%, and B(D*(2010) ⁺ \rightarrow D ⁰ π ⁺ = 55 \pm 4%.
.012 ± 0.007 3 101 BORTOLETTO90 CLEO $e^+e^- \rightarrow \Upsilon(45)$	$\Gamma(D_s^+\pi^-)/\Gamma_{\text{total}}$ $\Gamma_{29}/\Gamma_{\text{total}}$
⁹⁸ GIBAUT 96 reports $0.0087 \pm 0.0024 \pm 0.0020$ for B($D_s^+ \to \phi \pi^+$) = 0.035. We rescale	VALUE CL% DOCUMENT ID TECH COMMENT
to our best value B($D_s^+ \rightarrow \phi \pi^+$) = $(3.6 \pm 0.9) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.	<0.00028 90 111 ALEXANDER 93B CLE2 $e^+e^- \rightarrow \Upsilon(4S)$ • • • We do not use the following data for averages, fits, limits, etc. • •
ALBRECHT 92G reports 0.017 \pm 0.013 \pm 0.006 for B($D_s^+ \rightarrow \phi \pi^+$) = 0.027. We	<0.0013 90 112 BORTOLETTO90 CLEO $e^+e^- \rightarrow \tau(45)$
rescale to our best value B($D_s^+ \to \phi \pi^+$) = $(3.6 \pm 0.9) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.	111 ALEXANDER 93B reports $< 2.7 \times 10^{-4}$ for B($D_s^+ \rightarrow \phi \pi^+$) = 0.037. We rescale to
Assumes PDG 1990 D^+ branching ratios, e.g., $B(D^+ \to K^- \pi^+ \pi^+) = 7.7 \pm 1.0\%$. PM BORTOLETTO 92 reports 0.0080 \pm 0.0045 \pm 0.0030 for $B(D_s^+ \to \phi \pi^+) = 0.030 \pm 1.0\%$	our best value B($D_S^+ \to \phi \pi^+$) = 0.036. 112 BORTOLETTO 90 assume B($D_S^- \to \phi \pi^+$) = 2%.
0.011. We rescale to our best value B($D^+ \rightarrow \phi \pi^+$) = (3.6 ± 0.9) × 10 ⁻² . Our first	$\Gamma(D_s^{*+}\pi^-)/\Gamma_{\text{total}}$ $\Gamma_{30}/\Gamma_{\text{total}}$
0.011. We rescale to our best value B($D_s^+ \to \phi \pi^+$) = $(3.6 \pm 0.9) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using	VALUE CL% DOCUMENT ID TECN COMMENT
our best value. Assumes equal production of B^+ and B^0 at the $\Upsilon(45)$ and uses Mark III	
branching fractions for the D . Diagrams of the Boundary of the Diagrams of $D_s \to \phi \pi^+) = 2\%$. Superseded by BORTOLETTO 92.	¹¹³ ALEXANDER 93B reports $< 4.4 \times 10^{-4}$ for B($D_s^+ \rightarrow \phi \pi^+$) = 0.037. We rescale to our best value B($D_s^+ \rightarrow \phi \pi^+$) = 0.036.
	· • · · ·
	$\left[\Gamma(D_s^+\pi^-) + \Gamma(D_s^-K^+)\right]/\Gamma_{\text{total}} \tag{\Gamma_{29}+\Gamma_{38}}$

best value B($D_s^+ \rightarrow \phi \pi^+$) = 0.036.

$\left[\Gamma(D_s^{*+}\pi^-)+\Gamma(D_s^{*+}\pi^-)\right]$	<u> </u>	DOCUMENT ID	$\frac{(\Gamma_{30} + \Gamma_{30})}{TECN} = \frac{COMMENT}{93E \text{ ARG}} = e^+ e^- \rightarrow T(45)$	ا/(ز
¹¹⁵ ALBRECHT 93E re	ports < 1	$.2 \times 10^{-3} \text{ for B}(D_s^+)$	$\rightarrow \phi \pi^+$) = 0.027. We rescale to	o our
best value B(D_s^+ -	$\rightarrow \phi \pi^+$)	= 0.036.		
r/D±\/r			r	/⊏
$\Gamma(D_s^+ ho^-)/\Gamma_{ ext{total}}$	<u>CL%</u> 90	DOCUMENT ID	TECN COMMENT	11/F
<0.0007	90	116 ALEXANDER	938 CLE2 e ⁺ e ⁻ → T(45)	
• • • We do not use t	he followi	ng data for averages	i, fits, limits, etc. • • •	
< 0.0016	90	117 ALBRECHT	93E ARG $e^+e^- \rightarrow \Upsilon(45)$	
116 ALEXANDER 93B	reports <	6.6 × 10 ⁻⁴ for B($D_s^+ \to \phi \pi^+) = 0.037$. We resca	le to
our best value B(D			•	
117 ALBRECHT 93E re	ports < 2	$.2 \times 10^{-3}$ for B(D=	$\rightarrow \phi \pi^+) = 0.027$. We rescale to	o our
best value B(D+ -			•	
			_	
$\Gamma(D_s^{*+}\rho^-)/\Gamma_{\text{total}}$				12/5
VALUE	<u>CL%</u> _	118 ALEXANDED	$\begin{array}{ccc} \underline{TECN} & \underline{COMMENT} \\ 93B & \text{CLE2} & e^+e^- \rightarrow & \mathcal{T}(45) \end{array}$	
<0.0008 • • • We do not use t	90 he followi		i, fits, limits, etc. $\bullet \bullet \bullet$	
<0.0019	90		93E ARG $e^+e^- \rightarrow \Upsilon(45)$	
			$D_s^+ \rightarrow \phi \pi^+) = 0.037$. We resca	ile to
our best value B(D			's - ψn j = 0.031. We lesca	
			$\rightarrow \phi \pi^+) = 0.027$. We rescale to	0 0
best value B(D_s^+ -			$\rightarrow \varphi \pi \cdot j = 0.021$, we rescale to	J Gul
nest value B(D' -	<i>→ φπ')</i>	_ U.U30.		
$\Gamma(D_s^+ a_1(1260)^-)/6$	Ttotal		Γs	33/F
	CL%	DOCUMENT ID	TECN COMMENT	
<0.0026	90		93E ARG $e^+e^- \rightarrow T(45)$	
120 ALBRECHT 93E re	ports < 3	$.5 \times 10^{-3}$ for B(D_e^+	$\rightarrow \phi \pi^+) = 0.027$. We rescale to	o our
best value $B(D_s^+$ -				
•			-	,-
$\Gamma(D_s^{*+}a_1(1260)^-)$		DOCUMENT OF	Г	4/ [
VALUE <0.0022	<u>CL%</u>	121 ALRECUT	$\begin{array}{ccc} \underline{\text{TECN}} & \underline{\text{COMMENT}} \\ 93E & \text{ARG} & e^+e^- \rightarrow & \Upsilon(45) \end{array}$	
			$\rightarrow \phi \pi^+) = 0.027$. We rescale to	0 000
best value B(D_S^+ -			→ ψn · j = 0.021. We rescale to	J Gui
DEST VALUE D(D'S	→ ψπ')	_ 0.030.		
$\Gamma(D_s^-K^+)/\Gamma_{\text{total}}$			Γ	35/F
VALUE	CL%		TECN COMMENT	
<0.00024	90		93B CLE2 $e^+e^- \rightarrow \Upsilon(4S)$	
		-	i, fits, limits, etc. • • •	
<0.0013	90		090 CLEO $e^+e^- \rightarrow \Upsilon(45)$	
			$D_s^+ o \phi \pi^+) = 0.037$. We resca	le to
our best value B(D	$s \to \phi_1$	r ⁺) = 0.036.		
123 BORTOLETTO 90	assume l	$3(D_S \to \phi \pi^+) = 2$	%.	
$\Gamma(D_s^{*-}K^+)/\Gamma_{\text{total}}$			· F3	56/r
VALUE	CL%	DOCUMENT ID	TECN COMMENT	,
<0.00017	90	124 ALEXANDER	93B CLE2 $e^+e^- \rightarrow \Upsilon(4S)$	
124 ALEXANDER 93B	reports <	1.7 × 10 ⁻⁴ for B($D_s^+ \rightarrow \phi \pi^+) = 0.037$. We resca	ile to
our best value B(D	$\theta_s^+ \rightarrow \phi_1$	r ⁺) = 0.036.		
	-		_	,-
$\Gamma(D_s^-K^*(892)^+)/\Gamma$		nacimient :-		37/F
<u>VALUE</u> <0.0010	<u>CL%</u> 90	125 ALEYANDER	938 CLE2 e ⁺ e ⁻ → T(4S)	
		ing data for averages	s, fits, limits, etc. $\bullet \bullet \bullet$	
< 0.0034	90	-	93E ARG e ⁺ e ⁻ → T(45)	
			$D_s^+ \rightarrow \phi \pi^+) = 0.037$. We resca	ile to
our best value B(D			5 - y y = 0.031. WE IESC	
126 AI ROECUT ass	$_{S} \rightarrow \varphi^{7}$. , = 0.000. .6 × 10=3 for R/D+	$\rightarrow \phi \pi^+) =$ 0.027. We rescale t	0 0111
			· ψ · j = υ.υει. vve rescale t	J 001
best value B(D_s^+ -	→ φπ '`)	= 0.036.		
$\Gamma(D_s^{*-}K^*(892)^+)/$	Γ _{total}		Γ	38/F
VALUE	CL%_	DOCUMENT ID	TECN COMMENT	,
		127 ALEXANDED	93B CLE2 $e^+e^- \rightarrow \Upsilon(4S)$	
<0.0011	90	ALEXANDER	350 CLLE C C - 7 (45)	
		ng data for averages	s, fits, limits, etc. • • •	
• • • We do not use t <0.004	the followi	ng data for averages 128 ALBRECHT	93E ARG $e^+e^- \rightarrow \Upsilon(45)$	
 • • We do not use t <0.004 127 ALEXANDER 93B 	the following 90 reports <	ing data for averages ¹²⁸ ALBRECHT 11.0 × 10 ⁻⁴ for B(s, fits, limits, etc. • • •	ile to
• • • We do not use t <0.004	the following 90 reports <	ing data for averages ¹²⁸ ALBRECHT 11.0 × 10 ⁻⁴ for B(93E ARG $e^+e^- \rightarrow \Upsilon(45)$	ile to

¹²⁸ ALBRECHT 93E reports $< 5.8 \times 10^{-3}$ for B($D_s^+ \rightarrow \phi \pi^+$) = 0.027. We rescale to our

best value B($D_s^+ \rightarrow \phi \pi^+$) = 0.036.

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\Gamma(D_s^-\pi^+K^0)/\Gamma_{\text{total}}
                                                                                                 Γ<sub>39</sub>/Γ
                            CLX
                                          DOCUMENT ID
                                                              TECN COMMENT
VALUE
                                     129 ALBRECHT 93E ARG e^+e^- \rightarrow \Upsilon(45)
 < 0.005
                             90
<sup>129</sup>ALBRECHT 93E reports < 7.3 \times 10^{-3} for B(D_s^+ \rightarrow \phi \pi^+) = 0.027. We rescale to our
     best value B(D_c^+ \rightarrow \phi \pi^+) = 0.036.
\Gamma(D_s^{*-}\pi^+K^0)/\Gamma_{\text{total}}
                                                                                                 \Gamma_{40}/\Gamma
VALUE
                            CLX
                                           DOCUMENT ID
                                                              TECN COMMENT
                                     130 ALBRECHT 93E ARG e^+e^- \rightarrow \Upsilon(45)
 <0.0031
^{130} ALBRECHT 93E reports < 4.2 \times 10^{-3} for B(D_s^+ 	o \phi \pi^+) = 0.027. We rescale to our
    best value B(D_s^+ \rightarrow \phi \pi^+) = 0.036.
\Gamma(D_s^-\pi^+K^*(892)^0)/\Gamma_{\text{total}}
                                                                                                 \Gamma_{41}/\Gamma
                                           DOCUMENT ID TECN COMMENT
VALUE
                             90 131 ALBRECHT 93E ARG e^+e^- \rightarrow \tau(45)
 < 0.004
<sup>131</sup>ALBRECHT 93E reports < 5.0 \times 10^{-3} for B(D_c^+ \rightarrow \phi \pi^+) = 0.027. We rescale to our
    best value B(D_s^+ \rightarrow \phi \pi^+) = 0.036.
\Gamma(D_z^{*-}\pi^+K^*(892)^0)/\Gamma_{\text{total}}
                                                                                                 \Gamma_{42}/\Gamma
                            < 0.0020
^{132}ALBRECHT 93E reports < 2.7 \times 10^{-3} for B(D_s^+ \to \phi \pi^+) = 0.027. We rescale to our
    best value B(D_s^+ \rightarrow \phi \pi^+) = 0.036.
\Gamma(\overline{D}{}^0\pi^0)/\Gamma_{\text{total}}
                                                                                                 \Gamma_{43}/\Gamma
                                           DOCUMENT ID TECN COMMENT
VALUE
                            CL%
                                    133 NEMATI
 <0.00012
                                                             98 CLE2 e^+e^- \rightarrow T(4S)
                              90
 • • • We do not use the following data for averages, fits, limits, etc. • •
                                     134 ALAM
                             90
                                                             94 CLE2 Repl. by NEMATI 98
^{133}NEMATI 98 assumes equal production of B^+ and B^0 at the \varUpsilon(4S) and use the PDG 96
     values for D^0, D^{*0}, \eta, \eta', and \omega branching fractions.
^{134}ALAM 94 assume equal production of B^+ and B^0 at the T(45) and use the CLEO II
    absolute B(D^0 \to K^-\pi^+) and the PDG 1992 B(D^0 \to K^-\pi^+\pi^0)/B(D^0 \to K^-\pi^+) and B(D^0 \to K^-\pi^+\pi^-)/B(D^0 \to K^-\pi^+).
\Gamma(\overline{D}{}^0 \rho^0)/\Gamma_{\mathrm{total}}
                                                                                                 \Gamma_{44}/\Gamma
VALUE
                    CL% EVTS
                                           DOCUMENT ID TECN COMMENT
                                     135 NEMATI
 < 0.00039
                                                         98 CLE2 e^+e^- \rightarrow \Upsilon(4S)
                      90

    ● ● We do not use the following data for averages, fits, limits, etc. ● ●
                                      136 ALAM
                                                             94 CLE2 Repl. by NEMATI 98
 < 0.00055
                                 137 BORTOLETTO92 CLEO e^+e^- \rightarrow T(45)
4 138 ALBRECHT 88K ARG e^+e^- \rightarrow T(45)
 < 0.0006
^{135} NEMATI 98 assumes equal production of B^+ and B^0 at the \varUpsilon(45) and use the PDG 96
values for D^0, D^{*0}, \eta, \eta', and \omega branching fractions.

136 ALAM 94 assume equal production of B^+ and B^0 at the T(4S) and use the CLEO II
    absolute B(D^0 \to K^-\pi^+) and the PDG 1992 B(D^0 \to K^-\pi^+\pi^0)/B(D^0 \to K^-\pi^+) and B(D^0 \to K^-\pi^+\pi^-)/B(D^0 \to K^-\pi^+).
137 BORTOLETTO 92 assumes equal production of B^+ and B^0 at the \Upsilon(45) and uses Mark III branching fractions for the D.
<sup>138</sup>ALBRECHT 88K reports < 0.003 assuming B^0\overline{B}^0: B^+B^- production ratio is 45:55.
     We rescale to 50%.
\Gamma(\overline{D}{}^0\eta)/\Gamma_{\text{total}}
                                                                                                 \Gamma_{45}/\Gamma
VALUE
                              CL%
                                           DOCUMENT ID
                                                                TECN COMMENT
                                    139 NEMATI
 < 0.00013
                                                             98 CLE2 e^+e^- \rightarrow \Upsilon(45)
                              90
 • • • We do not use the following data for averages, fits, limits, etc. • •
                             90 140 ALAM
                                                             94 CLE2 Repl. by NEMAT! 98
 ^{139}NEMATI 98 assumes equal production of B^+ and B^0 at the \varUpsilon(4S) and use the PDG 96
values for D^0, p^{*0}, \eta, \eta', and \omega branching fractions. <sup>140</sup>ALAM 94 assume equal production of B^+ and B^0 at the T(4S) and use the CLEO II
     absolute B(D^0 	o K^-\pi^+) and the PDG 1992 B(D^0 	o K^-\pi^+\pi^0)/B(D^0 	o K^-\pi^+)
     and B(D^0 \to K^-\pi^+\pi^+\pi^-)/B(D^0 \to K^-\pi^+).
\Gamma(\overline{\mathcal{D}}{}^{0}\eta')/\Gamma_{\text{total}}
                                                                                                 \Gamma_{46}/\Gamma
                            <u>CL%</u> <u>DOCUMENT</u>
90 <sup>141</sup> NEMATI
VALUE
                                           DOCUMENT ID TECN COMMENT
                                                             98 CLE2 e^+e^- \rightarrow \Upsilon(45)
 90 <sup>142</sup> ALAM
  <0.00086
                                                             94 CLE2 Repl. by NEMATI 98
 ^{141} NEMATI 98 assumes equal production of B^+ and B^0 at the \varUpsilon(4S) and use the PDG 96
values for D^0, D^{*0}, \eta, \eta', and \omega branching fractions. 
 <sup>142</sup> ALAM 94 assume equal production of B^+ and B^0 at the \Upsilon(4S) and use the CLEO II
     absolute B(D^0 \rightarrow K^-\pi^+) and the PDG 1992 B(D^0 \rightarrow K^-\pi^+\pi^0)/B(D^0 \rightarrow K^-\pi^+)
     and B(D^0 \to K^-\pi^+\pi^+\pi^-)/B(D^0 \to K^-\pi^+).
```

 B^0

$(\overline{D}^0\omega)/\Gamma_{\text{total}}$	·			Γ ₄₇ /Γ	$\Gamma(J/\psi(1S)K^0)/\Gamma_{\text{total}}$				Γ ₅₆ ,
ALUE <0.00051	<u>CL% DOCUMENT :</u> 90 ¹⁴³ NEMATI		$e^+e^- \rightarrow T$	(45)	VALUE (units 10 4) CLS 8.9 ±1.2 OUR AVER		OCUMENT ID	TECN C	OMMENT
	the following data for avera			•	$8.5 \begin{array}{c} +1.4 \\ -1.2 \end{array} \pm 0.6$	156 JE	SSOP 9	7 CLF2 #	+e ⁻ → T(45)
0.00063	90 ¹⁴⁴ ALAM	94 CLE2	Repl. by NEM	MATI 98	11.5 ±2.3 ±1.7	157 AE			p at 1.8 TeV
³ NEMATI 98 assum	nes equal production of B				6.87 ± 4.03 ± 0.22			DHCDF P	$+e^- \rightarrow T(45)$
	0 , η , η' , and ω branching for		. ()		9.2 ±7.1 ±0.3	2 ¹⁵⁹ A1	BRECHT 9		$+e^- \rightarrow r(45)$
	equal production of B^+ as				• • • We do not use the f				
absolute B($D^0 \rightarrow$	$K^-\pi^+$) and the PDG 1992	$B(D^0 \rightarrow K^-)$	$\pi^{+}\pi^{0})/B(D^{0}$	· κ-π+)	7.5 ±2.4 ±0.8	10 ¹⁵⁸ Al			up. by JESSOP
	$\pi^{+}\pi^{+}\pi^{-})/B(D^{0} \rightarrow K^{-}$	-π ⁺).			<50 90				$+e^- \rightarrow r(45)$
(D *(2007) ⁰ π ⁰)/Γ				Г ₄₈ /Г	156 Assumes equal product 157 ABE 96H assumes that				3
LUE	CL% DOCUMENT		COMMENT	446	158 BORTOLETTO 92 rep				
	90 ¹⁴⁵ NEMATI the following data for avera	ges, fits, limits		,	rescale to our best val error is their experimer	lue B $(J/\psi(1S) \rightarrow$	$e^+e^-)=(6$	6.02 ± 0.19)	\times 10 ⁻² . Our fi
0.00097	90 146 ALAM		Rept. by NEM		our best value. Assume				
	nes equal production of B^+		$\mathcal{T}(4S)$ and use t	the PDG 96	159 ALBRECHT 901 report				
values for D^0 , D^{*0}	0 , η , η' , and ω branching for	ractions.			rescale to our best val				
	equal production of B^+ as $D^0\pi^0$) and absolute $B(D^0)$				error is their experimer our best value. Assume				
K- +++01/2/00	$D^0\pi^0$) and absolute $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$	— Λ π'jal , K=π"++-	~)/B/∩0 _ 4	72 O(D: → (~π+1).				/ (_
)/U(D - F		$\Gamma(J/\psi(1S)K^{+}\pi^{-})/\Gamma_{t}$				Γ ₅₇ ,
(̄̄̄̄̄̄̄̄̄̄̄̄ (2007) ⁰ ρ ⁰)/Γ		ID ====:	6011115 	Γ ₄₉ /Γ	VALUE 0.00115±0.00055±0.00	CL% EVTS	DOCUMENT IE BORTOLET		COMMENT
D.00056	<u>CL% DOCUMENT :</u> 90 ¹⁴⁷ NEMATI		$e^+e^- \rightarrow \Upsilon$	(45)					T(45)
	the following data for avera			· · · · ·	• • We do not use the f				
0.00117	90 ¹⁴⁸ ALAM		Repl. by NEM	MATI 98	< 0.0013	90 16	ALBRECHT	87D ARG	
	nes equal production of B+	_			<0.0063	90 2	GILES	84 CLFC	7(45) > e+e- →
	0 , η , η' , and ω branching for		, ,						T(45)
⁸ ALAM 94 assume $B(D^*(2007)^0 \rightarrow 0$	equal production of B^+ as $D^0\pi^0$) and absolute $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$	nd B^0 at the T $ o$ $K^{-1}\pi^+$) and	nd the PDG 199	92 B(<i>D</i> ⁰ →	160 BORTOLETTO 92 rej 0.069 \pm 0.009. We res 10^{-2} . Our first error l	cale to our best vi is their experimen	alue B $(J/\psi(1S))$ t's error and ou) → e ⁺ e ⁻) ir second erri	$= (6.02 \pm 0.19)$ or is the systema
$(\overline{D}^*(2007)^0\eta)/\Gamma_b$	total			Γ ₅₀ /Γ	error from using our be 161 ALBRECHT 87D assur	me B+B-/B ⁰ B			
LUE		D TECN			lected as nonresonant.			-	
0.00026	90 149 NEMATI		$e^+e^- \rightarrow \gamma$	(45)	$\Gamma(J/\psi(15)K^{*}(892)^{0})$	/Fanana			Г ₅₈ ,
 vve do not use f 	the following data for avera						CUMENT ID	TECN CO	
					VALUE	EVIS DO			
	90 ¹⁵⁰ ALAM	_	Repl. by NEW		0.00135±0.00018 OUR AN	VERAGE			
⁴⁹ NEMATI 98 assum	nes equal production of B+	and B^0 at the			0.00135±0.00018 OUR AN 0.00132±0.00017±0.0001	VERAGE	SSOP 97	CLE2 e	+e ⁻ → T(45)
¹⁹ NEMATI 98 assum values for D ⁰ , D* ⁰	nes equal production of B^+ 0, η , η' , and ω branching fi	and B ^O at the ractions.	$\varUpsilon(45)$ and use t	the PDG 96	0.00135±0.00018 OUR AN 0.00132±0.00017±0.0001 0.00136±0.00027±0.0002	VERAGE 17 162 JES 22 163 AB	SSOP 97 E 96	CLE2 e ⁻¹ H CDF p]	+e ⁻ → T(45) 5 at 1.8 TeV
9 NEMATI 98 assum values for D^0 , D^{*0} ALAM 94 assume	nes equal production of B^+ 0, η , η' , and ω branching fi equal production of B^+ at	and B^0 at the ractions. and B^0 at the 7	T(45) and use the $T(45)$ and use the	the PDG 96 the CLEO II	0.00135±0.00018 OUR AV 0.00132±0.00017±0.0001 0.00136±0.00027±0.0002 0.00126±0.00065±0.0000	VERAGE 17 162 JES 22 163 AB 04 164 BO	SSOP 97 E 96 RTOLETTO92	CLE2 e ⁻¹ H CDF p) CLEO e ⁻¹	+e- → T(45) 5 at 1.8 TeV +e- → T(45)
¹⁹ NEMATI 98 assum values for D^0 , D^{*0} OALAM 94 assume $B(D^*(2007)^0 \rightarrow$	nes equal production of B^+ 0 , η , η' , and ω branching for equal production of B^+ at $D^0\pi^0$) and absolute $B(D^0$	and B^0 at the ractions. and B^0 at the $T \mapsto K^- \pi^+$) as	$\Upsilon(45)$ and use to $\Upsilon(45)$ and use to $\Upsilon(45)$ and $\Upsilon(45)$	the PDG 96 the CLEO II $92 B(D^0 \rightarrow$	0.00135±0.00018 OUR AN 0.00132±0.00017±0.0001 0.00136±0.00027±0.0002	VERAGE 17 162 JES 163 AB 164 BO 165 AL	SSOP 97 E 96 RTOLETTO92 BRECHT 90	CLE2 e ^d H CDF p) CLEO e ^d J ARG e ^d	+e ⁻ → T(45) 5 at 1.8 TeV
9 NEMATI 98 assum values for D^0 , D^* 0 ALAM 94 assume $B(D^*(2007)^0 \rightarrow K^-\pi^+\pi^0)/B(D^0$	nes equal production of B^+ 0 , η , η' , and ω branching fine equal production of B^+ and $D^0\pi^0$) and absolute $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$	and B^0 at the ractions. and B^0 at the $T \mapsto K^- \pi^+$) as	$\Upsilon(45)$ and use to $\Upsilon(45)$ and use to $\Upsilon(45)$ and $\Upsilon(45)$	the PDG 96 the CLEO II 92 B($D^0 \rightarrow K^-\pi^+$).	0.00135±0.00018 OUR AV 0.00132 ±0.00017±0.0001 0.00136 ±0.00027±0.0002 0.00126±0.00065±0.0000 0.00126±0.00059±0.0000	VERAGE 17 162 JES 163 AB 164 164 BO 164 6 165 AL 1 5 166 BE	SSOP 97 E 96 RTOLETTO92 BRECHT 90 BEK 87	CLE2 ef H CDF p) CLEO ef J ARG ef	$e^+e^- \rightarrow T(45)$ B at 1.8 TeV $e^- \rightarrow T(45)$ $e^- \rightarrow T(45)$ $e^- \rightarrow T(45)$
9 NEMATI 98 assum values for D^0 , $D^{*(0)}$ 0 ALAM 94 assume $B(D^*(2007)^0 \rightarrow K^-\pi^+\pi^0)/B(D^0)$ $(\overline{D}^*(2007)^0 \eta')/\Gamma_{\eta'}$	hes equal production of B^+ 0 , η , η' , and ω branching fi equal production of B^+ at $D^0\pi^0$) and absolute B(D^0 $0 \to K^-\pi^+$) and B($D^0 \to K^0$	and B^0 at the ractions. Ind B^0 at the T^0 at T	$\Upsilon(45)$ and use to $\Upsilon(45)$ and use to $\Upsilon(45)$ and use to $\Upsilon(45)$ and $\Upsilon(45)$	the PDG 96 the CLEO II $92 B(D^0 \rightarrow$	0.00135±0.00018 OUR A\ 0.00132±0.00017±0.0001 0.00136±0.00027±0.0002 0.00126±0.00065±0.0000 0.00126±0.00059±0.0000 0.0040±0.0018±0.0001	VERAGE 17 162 JES 163 AB 164 164 BO 164 6 165 AL 1 5 166 BE 161 5 167 AL 18 29 167 AL	SSOP 97 E 96 RTOLETTO92 BRECHT 90 BEK 87 averages, fits, I	CLE2 e ⁻¹ H CDF p) CLEO e ⁻¹ J ARG e ⁻¹ CLEO e ⁻¹ Imits, etc.	$e^+e^- \rightarrow T(45)$ B at 1.8 TeV $e^- \rightarrow T(45)$ $e^- \rightarrow T(45)$ $e^- \rightarrow T(45)$
⁹ NEMATI 98 assum values for D^0 , D^{*0} ⁰ ALAM 94 assume B(D^* (2007) ⁰ → $K^-\pi^+\pi^0$)/B(D^0 (\overline{D}^* (2007) ⁰ η')/Γ ₀	nes equal production of B^+ 0 , η , η' , and ω branching fi equal production of B^+ at $D^0\pi^0$) and absolute $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$	and B^0 at the ractions. Ind B^0 at the 7 \rightarrow $K^-\pi^+$ at $K^-\pi^+\pi^+\pi^+\pi^-$	T(45) and use the following of the PDG 199 and the PDG 199 and the PDG 190	the PDG 96 the CLEO II $92 B(D^0 \rightarrow K^-\pi^+)$.	0.00135±0.00018 OUR AN 0.00132±0.00017±0.0001 0.00136±0.00027±0.0002 0.00126±0.00065±0.0000 0.00126±0.00059±0.0000 0.0040±0.0018±0.0001 • • • We do not use the 1	VERAGE 17 162 JES 162 163 AB 164 164 BO 164 6 165 AL 1 5 166 BE following data for 1.8 29 167 AL 168 AL	SSOP 97 E 96 RTOLETTO92 BRECHT 90 BEK 87 averages, fits, I AM 94 BRECHT 94	CLE2 eff H CDF pp CLEO eff CLEO eff CLEO eff Imits, etc. • CLE2 Su G ARG eff	$+e^- \rightarrow T(45)$ 5 at 1.8 TeV $+e^- \rightarrow T(45)$ $+e^- \rightarrow T(45)$ $+e^- \rightarrow T(45)$ sp. by JESSOP 9 $+e^- \rightarrow T(45)$
9 NEMATI 98 assum values for D^0 , D^{*0} ALAM 94 assume $B(D^*(2007)^0 \rightarrow K^-\pi^+\pi^0)/B(D^0)$ $(\overline{D^*(2007)^0}\pi')/\Gamma_{000000000000000000000000000000000000$	nes equal production of B^+ 0 , η , η' , and ω branching fi equal production of B^+ at $D^0\pi^0$) and absolute $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$	and B^0 at the ractions. Ind B^0 at the 7 \rightarrow $K^-\pi^+$) and $K^-\pi^+\pi^+\pi^+\pi^-$ 3 98 CLE2	$\Upsilon(45)$ and use to $\Upsilon(45)$ and use to $\Upsilon(45)$ and use to $\Upsilon(45)$ and use to $\Upsilon(45)$ and	the PDG 96 the CLEO II $92 B(D^0 \rightarrow K^-\pi^+)$.	0.00135±0.00018 OUR AN 0.00132±0.00017±0.0001 0.00136±0.00027±0.0002 0.00126±0.00065±0.0000 0.00126±0.00059±0.0000 0.0040±0.0018±0.0001 • • • We do not use the 1	VERAGE 17 162 JES 162 163 AB 164 164 BO 165 166 BE 160 IOWING data for 18 29 167 AL 168 AL 169 AL	SSOP 97 E 96 RTOLETTO92 BRECHT 90 BEK 87 averages, flts, I AM 94 BRECHT 94 BAJAR 91	CLE2 e ⁻¹ H CDF p) CLEO e ⁻¹ J ARG e ⁻¹ CLEO e ⁻¹ Imits, etc. • CLE2 Su G ARG e ⁻¹	f = - T(45) $f = 1.8 TeV$ $f = - T(45)$
9 NEMATI 98 assume values for D^0 , D^{*0} 0 ALAM 94 assume $B(D^*(2007)^0 \rightarrow K^-\pi^+\pi^0)/B(D^0$ $D^*(2007)^0 \gamma')/\Gamma_0$ 1.UF 0.0014	nes equal production of B^+ 0, η , η' , and ω branching fixequal production of B^+ at $D^0\pi^0$) and absolute $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$ are following data for averaging the following data for averaging $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$ are also as $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$ are also as $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$ are also as $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$ are also as $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$ are also as $B(D^0\to K^-\pi^+)$ and	and B^0 at the ractions. Ind B^0 at the T^0 and T^0 at the T^0 and T^0 at the T^0 and T^0 are T^0 and T^0 and T^0 are T^0 and T^0 are T^0 and T^0 are T^0 are T^0 are T^0 are T^0 and T^0 are T^0 are T^0 are T^0 and T^0 are T^0 are T^0 are T^0 and T^0 are T^0 are T^0 are T^0 are T^0 and T^0 are T^0 are T^0 and T^0 are T^0 are T^0 are T^0 are T^0 and T^0 are T^0 and T^0 are T^0 and T^0 are T^0 and T^0 are T^0 are T^0 and T^0 are T^0 are T^0 are T^0 are T^0 are T^0 are T^0	$\Upsilon(45)$ and use to $\Upsilon(45)$ and use to $\Upsilon(45)$ and use to $\Upsilon(45)$ and use to $\Upsilon(45)$ and	the PDG 96 the CLEO II $\frac{192 \text{ B}(D^0 \rightarrow \text{K}^-\pi^+)}{\Gamma_{51}/\Gamma}$	0.00135±0.00018 OUR AN 0.00132±0.00017±0.0001 0.00136±0.00027±0.0002 0.00126±0.00065±0.0000 0.00126±0.00059±0.0000 0.0040±0.0018±0.0001 • • • We do not use the f 0.00169±0.00031±0.0001 0.0040±0.0030	VERAGE 17 162 JE: 17 163 AB 164 164 BO 165 AL 1 5 166 BE 161 FOIL BOWN BOWN BOWN 18 29 167 AL 169 AL 169 AL 5 170 AL	SSOP 97 E 96 PRTOLETTO92 BRECHT 90 BEK 87 averages, fits, i AM 94 BRECHT 94 BAJAR 91 BRECHT 87	CLE2 e ⁻¹ CLEO e ⁻¹ ARG e ⁻¹ CLEO e ⁻¹ Imits, etc. • CLE2 Su G ARG e ⁻¹ E UA1 E ⁰ D ARG e ⁻¹	$+e^- \rightarrow T(45)$ $\neq a + 1.8 \text{ TeV}$ $+e^- \rightarrow T(45)$
9 NEMATI 98 assume values for D^0 , D^{*0} of ALAM 94 assume $B(D^*(2007)^0 \rightarrow \pi^*\pi^*\pi^0)/B(D^0)$ ($\overline{D^*}(2007)^0\pi^*\pi^*\pi^0$)/Fig. 10.0014	nes equal production of B^+ 0, η , η' , and ω branching fixequal production of B^+ at $D^0\pi^0$) and absolute $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$ by $BRANDENE the following data for average B(D^0\to K^-\pi^+)$	and B^0 at the ractions. and B^0 at the 7 \rightarrow $K^-\pi^+$ at $K^-\pi^+\pi^+\pi^+\pi^+$ K^0 K^0	$\Upsilon(45)$ and use to $\Upsilon(45)$ and use to $\Upsilon(45)$ and use to $\Upsilon(45)$ and use to $\Upsilon(45)$ and	the PDG 96 the CLEO II $22 B(D^0 \rightarrow K^-\pi^+).$ Γ_{51}/Γ (45)	0.00135±0.00018 OUR AN 0.00132±0.00017±0.0001 0.00136±0.00027±0.0002 0.00126±0.00065±0.0000 0.00126±0.00059±0.0000 0.0040±0.0018±0.0001 • • • We do not use the f 0.00169±0.00031±0.0001 0.0040±0.0030 0.0040±0.0030	VERAGE 17 162 JESS 163 AB 164 164 BO 165 AL 1 5 166 BE 160 IOWIng data for 18 29 167 AL 169 AL 169 AL 5 171 AL	SSOP 97 E 96 RTOLETTO92 BRECHT 90 BEK 87 averages, flts, I AM 94 BRECHT 94 BRECHT 94 BRECHT 94	CLE2 e ⁻¹ CLEO e ⁻¹ ARG e ⁻¹ CLEO e ⁻¹ Imits, etc. • CLE2 Su G ARG e ⁻¹ E UA1 E ⁰ CLEO Re	f = - T(45) $f = 1.8 TeV$ $f = - T(45)$
9 NEMATI 98 assume values for D^0 , D^{*0} ALAM 94 assume $B(D^*(2007)^0 \rightarrow K^-\pi^+\pi^0)/B(D^0$ ($\overline{D^*}(2007)^0 \eta')/\Gamma_1$ • • We do not use to 0.0019	nes equal production of B^+ 0, η , η' , and ω branching fixequal production of B^+ at $D^0\pi^0$) and absolute $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$ are following data for average $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$ are following data for average $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$ are following data for average $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$ are following data for average $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$ are following data for average $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$ are following data for average $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$ are following data for average $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$ are following data for average $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$ are following data for average $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$ are following data for average $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$ are following data for average $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$ are following data for average $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$ are following data for average $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$ are following data for average $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$ are following data for average $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$ are following data for average $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$ are following data for average $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$ are following data for average $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$ are following data for average $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$ are following data for average $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$ are following data for avera	and B^0 at the ractions. and B^0 at the 7 \rightarrow $K^-\pi^+$ at \rightarrow $K^-\pi^+\pi^+\pi^-$ at \rightarrow $K^-\pi^+\pi^+\pi^-$ B. CLE2 ges, fits, limits 98 CLE2 94 CLE2	T(45) and use to the the PDG 199 $T(45)$ and $T(45)$ and use to the the PDG 199 $T(45)$ $T($	the PDG 96 the CLEO II $22 \ B(D^0 \to K^- \pi^+)$. Γ_{51}/Γ (45) (45) MATI 98	0.00135±0.00018 OUR AN 0.00132±0.00017±0.0001 0.00136±0.00027±0.0002 0.00126±0.00065±0.0000 0.00126±0.00059±0.0000 0.0040±0.0018±0.0001 • • • We do not use the f 0.00169±0.00031±0.0001 0.0040±0.0030 0.0041±0.0018	VERAGE 17	SSOP 97 E 96 RTOLETTO92 BRECHT 90 BEK 87 averages, fits, i AM 94 BRECHT 94 BAJAR 91 BRECHT 87 AM 86	CLE2 e ⁻¹ H CDF p ⁻¹ CLEO e ⁻¹ J ARG e ⁻¹ CLEO e ⁻¹ Imits, etc. • CLE2 Su G ARG e ⁻¹ E UA1 E D ARG e ⁻¹	$+e^- \rightarrow T(45)$ $\overline{5}$ at 1.8 TeV $+e^- \rightarrow T(45)$
9 NEMATI 98 assume values for D^0 , D^{*0} . ALAM 94 assume $B(D^*(2007)^0 \rightarrow K^-\pi^+\pi^0)/B(D^0)$. ($D^*(2007)^0 \eta')/\Gamma_1$. 4 UF. • • We do not use 1 0.0019 0.0027	nes equal production of B^+ 0, η , η' , and ω branching fixequal production of B^+ at $D^0\pi^0$) and absolute $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$ are equal production of B^+ and $B(D^0\to K^-\pi^+)$ are equal production of B^+	and B^0 at the ractions. and B^0 at the 7 \rightarrow $K^-\pi^+$) at $K^-\pi^+\pi^+\pi^-$ 3 98 CLE2 ges, fits, limits 98 CLE2 94 CLE2 and B^0 at the	T(45) and use to the the PDG 199 $T(45)$ and $T(45)$ and use to the the PDG 199 $T(45)$ $T($	the PDG 96 the CLEO II $22 B(D^0 \rightarrow K^-\pi^+)$. Γ_{51}/Γ (45) (45) MATI 98	0.00135±0.00018 OUR AN 0.00132±0.00017±0.0001 0.00136±0.00027±0.0002 0.00126±0.00065±0.0000 0.00126±0.00059±0.0000 0.0040±0.0018±0.0001 • • • We do not use the f 0.00169±0.00031±0.0001 0.0040±0.0018 0.0041±0.0018	VERAGE 17 162 JE: 163 AB 164 BO 165 ALI 1 5 166 BE 160 Illowing data for 18 29 167 ALI 168 ALI 169 ALI 5 171 ALI thon of B+ and B 18 B(B+ → J/ψ h	SSOP 97 E 97 E 97 E RTOLETTO92 BRECHT 90 BEK 87 averages, fits, I AM 94 BRECHT 94 BAJAR 91 BRECHT 87 AM 86	CLE2 e ⁻¹ H CDF p ⁻¹ CLEO e ⁻¹ J ARG e ⁻¹ CLEO e ⁻¹ Imits, etc. • CLE2 Su G ARG e ⁻¹ E UA1 E D ARG e ⁻¹ CLEO Re I. 0.14) × 10 ⁻¹	$f = - \rightarrow T(45)$ 5 at 1.8 TeV $f = - \rightarrow T(45)$
19 NEMATI 98 assume values for D^0 , D^{*0} ALAM 94 assume $B(D^*(2007)^0 \rightarrow K^-\pi^+\pi^0)/B(D^0)$ ($\overline{D}^*(2007)^0 \eta'$)/ Γ_{11} • • We do not use 10.0019 10 11 NEMATI 98 assume values for D^0 , D^{*0} 12 ALAM 94 assume	nes equal production of B^+ 0, η , η' , and ω branching fixequal production of B^+ at $D^0\pi^0$) and absolute $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$ a	and B^0 at the ractions. of B^0 at the 7 \rightarrow $K^-\pi^+$ at \rightarrow $K^-\pi^+\pi^+\pi^-$ 3 98 CLE2 gges, fits, limits 98 CLE2 and B^0 at the ractions.	T(45) and use to the third the PDG 199 $T(45)$ and $T(45)$ and the PDG 199 $T(45)$ and $T(45)$ and use to the third third the third thi	the PDG 96 the CLEO II $22 B(D^0 \rightarrow K^-\pi^+)$. F51/F (45) (45) AATI 98 the PDG 96 the CLEO II	0.00135±0.00018 OUR AN 0.00132±0.00017±0.0001 0.00136±0.00027±0.0001 0.00126±0.00065±0.0000 0.00126±0.00018±0.0001 • • • We do not use the 1 0.00169±0.00031±0.0001 0.0040±0.0030 0.0033±0.0018 0.0041±0.0018 162 Assumes equal product 163 ABE 96H assumes that 164 BORTOLETTO 92 tel	VERAGE 162 JESS 163 AB 164 BO 165 AL 1 5 166 BE 160 IOWIng data for 18 29 167 AL 169 AL 170 AL 5 171 AL 5 171 AL 5 the second of	SSOP 97 E 96 RTOLETTO92 BRECHT 90 BEK 87 averages, flts, I AM 94 BRECHT 94 BAJAR 91 BRECHT 87 AM 86 0 at the \tau(4.5) (+^+) = (1.02 ± 0.0005 ± 0.0003	CLE2 e^+ H CDF e^+ CLEO e^+ J ARG e^+ CLEO e^+ Imits, etc. \bullet CLE2 Su G ARG e^+ E UA1 E^+_{C} D ARG e^+ CLEO Re 1.0.14) × 10 ⁻ for B(J/ψ ($+e^- \rightarrow T(45)$ 5 at 1.8 TeV $+e^- \rightarrow T(45)$
9 NEMATI 98 assume values for D^0 , D^{*0} of ALAM 94 assume $B(D^*(2007)^0 \rightarrow + \pi^0)/B(D^0)$ $(\overline{D}^*(2007)^0 + f')/\Gamma_1$ UUF • • We do not use 10.0019 0.0027 1 NEMATI 98 assume values for D^0 , D^{*0} 2 ALAM 94 assume $B(D^*(2007)^0 \rightarrow + \pi^0)/B(D^*(2007)^0 \rightarrow + \pi^0)/B(D$	nes equal production of B^+ 0, η , η' , and ω branching fixequal production of B^+ at $D^0\pi^0$) and absolute $B(D^0\pi^0)$. Total Section 152 ALAM resequal production of B^+ 0, η , η' , and ω branching fixequal production of B^+ 0, η , η' , and ω branching fixequal production of B^+ 10 and $D^0\pi^0$) and absolute $B(D^0\pi^0)$	and B^0 at the ractions. and B^0 at the 7 \rightarrow $K^-\pi^+$ at \rightarrow $K^-\pi^+\pi^+\pi^-$ 3 98 CLE2 ges, fits, limits 98 CLE2 94 CLE2 and B^0 at the ractions. and B^0 at the 7 \rightarrow $K^-\pi^+$) at the 7 \rightarrow $K^-\pi^+$) at	T(45) and use to the thick that the PDG 199 $T(45)$ and $T(45)$ and $T(45)$ and $T(45)$ and $T(45)$ and use to the PDG 199 $T(45)$	the PDG 96 the CLEO II $22 B(D^0 \rightarrow K^-\pi^+)$. F51/F (45) (45) MATI 98 the PDG 96 the CLEO II $22 B(D^0 \rightarrow K^-\pi^+)$	0.00135±0.00018 OUR AN 0.00132±0.00017±0.0001 0.00136±0.00027±0.0002 0.00126±0.00065±0.0000 0.00126±0.00059±0.0000 0.0040±0.0018±0.0001 • • • We do not use the f 0.00169±0.00031±0.0001 0.0040±0.0030 0.0033±0.0018 0.0041±0.0018 162 Assumes equal product 163 ABE 96H assumes that 164 BORTOLETTO 92 rej 0.069±0.009, We res	VERAGE 17 162 JEEE 163 AB 164 164 BO 165 ALI 169 ALI 169 ALI 170 ALI 5 171 ALI thon of B^+ and B ports 0.0011 \pm 0. cale to our best vicales	5SOP 97 E 96 (RTOLETTO92 BRECHT 90 BEK 87 averages, flts, I BRECHT 94 BAJAR 91 BRECHT 87 AM 86 0 at the $^{\tau}(4.5)$ $^{(+)} = (1.02 \pm 0.0003 \pm 0.0003 \pm 0.0003$ alue B($J/\psi(1.5)$	CLE2 e ⁻¹ H CDF p ⁻¹ CLEO e ⁻¹ J ARG e ⁻¹ CLEO e ⁻¹ Imits, etc. • CLE2 Su G ARG e ⁻¹ E UA1 E ¹ D ARG e ⁻¹ CLEO Re 0.14) × 10 ⁻¹ for B(J/\psi()) \rightarrow e ⁻¹ e ⁻¹	$+e^- \rightarrow T(45)$ 5 at 1.8 TeV $+e^- \rightarrow T(45)$ $+e^- $
9 NEMATI 98 assume values for D^0 , D^{*0} of ALAM 94 assume $B(D^*(2007)^0 \rightarrow + \pi^0)/B(D^0)$ $(\overline{D}^*(2007)^0 + f')/\Gamma_1$ UUF • • We do not use 10.0019 0.0027 1 NEMATI 98 assume values for D^0 , D^{*0} 2 ALAM 94 assume $B(D^*(2007)^0 \rightarrow + \pi^0)/B(D^*(2007)^0 \rightarrow + \pi^0)/B(D$	nes equal production of B^+ 0, η , η' , and ω branching fixequal production of B^+ at $D^0\pi^0$) and absolute $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$ a	and B^0 at the ractions. and B^0 at the 7 \rightarrow $K^-\pi^+$ at \rightarrow $K^-\pi^+\pi^+\pi^-$ 3 98 CLE2 ges, fits, limits 98 CLE2 and B^0 at the ractions. and B^0 at the 7 \rightarrow $K^-\pi^+$) at the 7 \rightarrow $K^-\pi^+$) at	T(45) and use to the thick that the PDG 199 $T(45)$ and $T(45)$ and $T(45)$ and $T(45)$ and $T(45)$ and use to the PDG 199 $T(45)$	the PDG 96 the CLEO II $22 B(D^0 \rightarrow K^-\pi^+)$. F51/F (45) (45) MATI 98 the PDG 96 the CLEO II $22 B(D^0 \rightarrow K^-\pi^+)$	0.00135±0.00018 OUR AN 0.00132±0.00017±0.0001 0.00136±0.00027±0.0001 0.00126±0.00065±0.0000 0.00126±0.00018±0.0001 • • • We do not use the 1 0.00169±0.00031±0.0001 0.0040±0.0030 0.0033±0.0018 0.0041±0.0018 162 Assumes equal product 163 ABE 96H assumes that 164 BORTOLETTO 92 tel	VERAGE 17 162 JESS 163 AB 164 164 BO 165 AL 169 AL 167 AL 169 AL 169 AL 170 AL 171 AL 181 BB	SSOP 97 E 96 IRTOLETTO92 BRECHT 90 BEK 87 averages, flts, I AM 94 BRECHT 94 BRECHT 87 AM 86 0 at the $\Upsilon(45)$ $(+) = (1.02 \pm 0.0003$ alue $B(J/\psi(15)$ t's error and ou	CLE2 e^+ H CDF e^- CLE0 e^+ CLE0 e^+ CLE0 e^+ CLE2 Su CLE2 Su CLE2 Su CLE2 Su CLE2 Su CLE0 Re E UA1 e^+ CLE0 Re I. 0.14) × 10 ⁻ for B($J/\psi()$ If second error	$t^+e^- o T(45)$ 5 at 1.8 TeV $t^+e^- o T(45)$
9 NEMATI 98 assume values for D^0 , D^{*0} 0.0000 0.000	nes equal production of B^+ 0, η , η' , and ω branching fixed production of B^+ and B^0 0 and absolute $B(D^0 \to K^-\pi^+)$ and $B(D^0 \to K^-\pi^+)$	and B^0 at the ractions. and B^0 at the 7 \rightarrow $K^-\pi^+$ at \rightarrow $K^-\pi^+\pi^+\pi^-$ 3 98 CLE2 ges, fits, limits 98 CLE2 and B^0 at the ractions. and B^0 at the 7 \rightarrow $K^-\pi^+$) at the 7 \rightarrow $K^-\pi^+$) at	T(45) and use to the thick that the PDG 199 $T(45)$ and $T(45)$ and $T(45)$ and $T(45)$ and $T(45)$ and use to the PDG 199 $T(45)$	the PDG 96 the CLEO II $22 B(D^0 \rightarrow K^-\pi^+)$. F51/F (45) AATI 98 the PDG 96 the CLEO II $22 B(D^0 \rightarrow K^-\pi^+)$.	0.00135±0.00016 OUR AN 0.00132±0.00017±0.0001 0.00136±0.00027±0.0001 0.00126±0.00065±0.0000 0.00126±0.00018±0.0001 • • • We do not use the 1 0.00169±0.00031±0.0001 0.0040±0.0033 0.0033±0.0018 0.0041±0.0018 162 Assumes equal product 163 ABE 96H assumes that 164 BORTOLETTO 92 tep 0.069±0.009, We res 10−2. Our first error 1 error from using our be 165 ALBRECHT 901 report	VERAGE 162 JEEE 163 AB 164 BO 165 AL 169 AL 169 AL 170 AL 171	SSOP 97 E 96 RTOLETTO92 BRECHT 90 BEK 87 averages, fits, 1 AM 94 BRECHT 94 BAJAR 91 BRECHT 87 AM 86 0 at the $\Upsilon(45)$ $(+^+) = (1.02 \pm 0.0003$ alue $B(J/\psi(15)$ $(+^+) = 0.0003$	CLE2 e^+ H CDF p^- CLEO e^+ J ARG e^+ CLEO e^+ Imits, etc. \bullet GLE2 Su G ARG e^+ E UA1 E^+_{C} D ARG e^+ CLEO Re 1.0.14) × 10 ⁻ for B($J/\psi($) \rightarrow e^+ e^-) if second error on of B^+ and B^+	$+e^- \rightarrow T(45)$ 5 at 1.8 TeV $+e^- \rightarrow T(45)$ $+e^+ $
9 NEMATI 98 assume values for D^0 , D^{*0} in ALAM 94 assume $B(D^*(2007)^0 \rightarrow + \pi^0)/B(D^0)$ ($\overline{D^*(2007)^0} \eta'$)/Γ ₀ UF 10.0014 • We do not use 10.0019 (10.0027 in NEMATI 98 assume $B(D^*(2007)^0 \rightarrow + \pi^0)/B(D^0)$ ($\overline{D^*(2007)^0} \rightarrow + \pi^0)/B(D^0)$ ($\overline{D^*(2007)^0} \omega$)/Γ ₈ ($\overline{D^*(2007)^0} \omega$)/Γ ₈	nes equal production of B^+ 0, η , η' , and ω branching fixequal production of B^+ and B^0 and absolute $B(D^0 \to K^-\pi^+)$ and $B(D^0 \to K^-\pi^+)$	and B^0 at the ractions. of B^0 at the 7 $ K^-\pi^+$ at $ K^-\pi^+\pi^+\pi^-$ 3 98 CLE2 ggs, fits, limits 98 CLE2 94 CLE2 and B^0 at the ractions. In the $ -$	T(45) and use the third the PDG 199 $T(45)$ and use the	the PDG 96 the CLEO II $22 B(D^0 \rightarrow K^-\pi^+)$. F51/F (45) (45) MATI 98 the PDG 96 the CLEO II $22 B(D^0 \rightarrow K^-\pi^+)$	0.00135±0.00018 OUR AN 0.00132±0.00017±0.0001 0.00136±0.00027±0.0001 0.00126±0.00055±0.0000 0.00126±0.00059±0.0000 0.0040±0.00018±0.0001 ■ ● ■ We do not use the f 0.00169±0.00031±0.0001 0.0040±0.0030 0.0033±0.0018 0.0041±0.0018 162 Assumes equal product 163 ABE 96H assumes that 164 BORTOLETTO 92 rej 0.069±0.009. We res 10 ⁻² . Our first error is error from using our be error from using our be 165 ALBRECHT 901 report 0.009. We rescale to 0	VERAGE 17 162 JEEE 17 163 AB 164 BO 165 AL 169 AL 169 AL 170 AL 171 AL 181 BB \rightarrow J/ ψ μ 181 be our best visits their experiments tvalue. Assumests value B(J	SSOP 97 E 96 (RTOLETTO92 BRECHT 90 BEK 87 averages, flts, i BAJAR 91 BRECHT 94 BAJAR 91 BRECHT 87 AM 86 0 at the $T(45)$ $(-1) = (1.02 \pm 0.0003 \pm 0.0003$ alue $B(J/\psi(15)$ t's error and ou equal production ± 0.0002 for $B(1/\psi(15)) = e^{+1}$	CLE2 e^+ H CDF e^- CLEO e^+ CLEO e^+ CLEO e^+ Imits, etc. \bullet CLE2 Su G ARG e^+ E UA1 E^+_{C} D ARG e^+ CLEO Re 0.14) × 10 ⁻ for B($J/\psi($ $) \rightarrow e^+e^-$) if second error on of B^+ and on of B^+ and one of B^+ $(J/\psi(15) \rightarrow e^+$ $(E^-) = (6.0)$	$+e^- \rightarrow T(45)$ 5 at 1.8 TeV $+e^- \rightarrow T(45)$ $+e^+ \rightarrow$
PNEMATI 98 assume values for D^0 , D^{*0} (DALAM 94 assume B(D^* (2007) $D^0 \rightarrow K^-\pi^+\pi^0$)/B(D^0 (D^* (2007) D^0 D^*)/Γ ₁ MUF. 10.0014 • We do not use 10.0019 10.0027 11 NEMATI 98 assume values for D^0 , D^{*0} (D^* (2007) $D^0 \rightarrow K^-\pi^+\pi^0$)/B(D^0 (D^* (2007) $D^0 \rightarrow K^-\pi^+\pi^0$)/B(D^0 (D^* (2007) $D^0 \rightarrow K^-\pi^+\pi^0$)/B(D^0	nes equal production of B^+ 0, η , η' , and ω branching fixequal production of B^+ at $D^0\pi^0$) and absolute $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$	and B^0 at the ractions. and B^0 at the 7 \rightarrow $K^-\pi^+$ at \rightarrow $K^-\pi^+\pi^+\pi^-$ at \rightarrow $K^-\pi^+\pi^+\pi^-$ 3 98 CLE2 gges, fits, limits 98 CLE2 and B^0 at the ractions, and B^0 at the 7 \rightarrow $K^-\pi^+$ at \rightarrow $K^-\pi^+\pi^+\pi^-$	T(45) and use to the the PDG 199 $T(45)$ and use to the the PDG 199 $T(45)$ and $T(45)$ and $T(45)$ and use to the PDG 199 $T(45)$ and use to the PDG 19	the PDG 96 the CLEO II $22 B(D^0 \rightarrow K^-\pi^+)$. F51/F (45) (45) MATI 98 the PDG 96 the CLEO II $22 B(D^0 \rightarrow K^-\pi^+)$. F52/F	0.00135±0.00018 OUR AN 0.00132±0.00017±0.0001 0.00136±0.00027±0.0001 0.00126±0.00065±0.0000 0.00126±0.00059±0.0000 0.0040±0.0018±0.0001 • • • We do not use the f 0.00169±0.00031±0.0001 0.0040±0.0030 0.0033±0.0018 0.0041±0.0018 162 Assumes equal product 163 ABE 96h assumes that 164 BORTOLETTO 92 rep 0.069±0.009, We res 10⁻². Our first error ls error from using our be 165 ALBRECHT 90 report 0.009. We rescale to o Our first error is their	VERAGE 162 JESS 163 AB 164 BO 165 AL 169 AL 169 AL 169 AL 170 AL 171 AL 181 BO 181 BO 182 BO 183 BO 184 BO 185 BO 185 BO 186 BO 187 AL 187 AL 187 AL 188 BO 188	SSOP 97 E 96 RTOLETTO92 BRECHT 90 BEK 87 averages, fits, I AM 94 BRECHT 94 BAIAR 91 BRECHT 87 AM 86 0 at the $\Upsilon(45)$ $(+) = (1.02 \pm 0.0003)$ alue $B(J/\psi(15)$ t's error and out equal productl ± 0.0002 for B	CLE2 e ⁻¹ H CDF p ⁻¹ CLEO e ⁻¹ CLEO e ⁻¹ J ARG e ⁻¹ CLEO e ⁻¹ Imits, etc. • CLE2 Su G ARG e ⁻¹ E UA1 E ¹ D ARG e ⁻¹ CLEO Re 1. 0.14) × 10 ⁻¹ for B(J/ψ (.) 0.14) × 10 ⁻¹ if second error of B^+ and $(J/\psi(.15) \rightarrow 0^+$ Te ⁻¹ = (6.00) Indiagraphy (1.50) Indiagraphy ($e^+e^- \rightarrow T(45)$ of at 1.8 TeV $e^+e^- \rightarrow T(45)$ $e^-e^- $
19 NEMATI 98 assume values for D^0 , D^{*0} , D^{*0	nes equal production of B^+ 0, η , η' , and ω branching fixequal production of B^+ at $D^0\pi^0$) and absolute $B(D^0\pi^0)$. Total Start Document 1 90 BRANDENE the following data for avera 90 151 NEMATI 90 152 ALAM nes equal production of B^+ 0, η , η' , and ω branching fixequal production of B^+ 0 0, η , η' , and ω branching for equal production of B^+ 0 0, η , η' , and ω branching for $D^0\pi^0$) and absolute $B(D^0\pi^0)$	and B^0 at the ractions. and B^0 at the 7 \rightarrow $K^-\pi^+$ at \rightarrow $K^-\pi^+\pi^+\pi^-$ at \rightarrow CLE2 and B^0 at the 7 \rightarrow CLE2 and B^0 at the ractions. and B^0 at the 7 \rightarrow	T(45) and use to the the PDG 199 $T(45)$ and use to the the PDG 199 $T(45)$ and $T(45)$ and $T(45)$ and use to the PDG 199 $T(45)$ and $T($	the PDG 96 the CLEO II $22 B(D^0 \rightarrow K^-\pi^+)$. F51/F (45) (45) MATI 98 the PDG 96 the CLEO II $22 B(D^0 \rightarrow K^-\pi^+)$. F52/F	0.00135±0.00018 OUR AN 0.00132±0.00017±0.0001 0.00136±0.00027±0.0001 0.00136±0.00059±0.0000 0.00126±0.00018±0.0001 • • • We do not use the f 0.00169±0.00031±0.0001 0.0040±0.0031±0.0001 0.0041±0.0018 162 Assumes equal product 163 ABE 96H assumes that 164 BORTOLETTO 92 rep 0.069±0.009. We rescale to 0 error from using our be 165 ALBRECHT 901 report 0.009. We rescale to 0 Our first error is their	VERAGE 162 JEEE 163 AB 164 BO 165 AL 1 5 166 BE 169 AL 169 AL 170 AL 171 AL 15 171 AL 15 to of B^+ and B^+ 15 to our best value 15 0.0011 \pm 0.0005 15 bur best value B(L 28 experiment's error 10e. Assumes equation.	SSOP 97 E 96 RTOLETTO92 BRECHT 90 BEK 87 averages, fits, 1 AM 94 BRECHT 94 BAJAR 91 BRECHT 87 AM (45) $(+^+) = (1.02 \pm 0.0005 \pm 0.0003$ alue $B(J/\psi(15) \rightarrow e^+$ $(+^+) = (1.03 \pm 0.0002$ for B($(+^+)/\psi(15) \rightarrow e^+$ or and our seco	CLE2 e^+ H CDF p] CLEO e^+ J ARG e^+ CLEO e^+ Imits, etc. e^- J CLEO e^+ J ARG e^+ J CLEO Re J J J J J J J J J J	$f e^- \rightarrow T(45)$ 5 at 1.8 TeV $f e^- \rightarrow T(45)$
19 NEMATI 98 assume values for D^0 , D^{*0} , D^{*	nes equal production of B^+ 0, η , η' , and ω branching fixequal production of B^+ at $D^0\pi^0$) and absolute $B(D^0\to K^-\pi^+)$ and $B(D^0\to K^-\pi^+)$	and B^0 at the ractions. and B^0 at the 7 \rightarrow $K^-\pi^+$ at \rightarrow $K^-\pi^+\pi^+\pi^-$ at \rightarrow CLE2 and B^0 at the 7 \rightarrow CLE2 and B^0 at the ractions. and B^0 at the 7 \rightarrow	T(45) and use to the the PDG 199 $T(45)$ and use to the the PDG 199 $T(45)$ and $T(45)$ and $T(45)$ and use to the PDG 199 $T(45)$ and $T($	the PDG 96 the CLEO II $92 B(D^0 \rightarrow K^-\pi^+)$. Γ_{51}/Γ (45) (45) AATI 98 the PDG 96 the CLEO II $92 B(D^0 \rightarrow K^-\pi^+)$. Γ_{52}/Γ (45)	0.00135±0.00018 OUR AN 0.00132±0.00017±0.0001 0.00136±0.00027±0.0001 0.00126±0.00065±0.0000 0.00126±0.00059±0.0000 0.0040±0.0018±0.0001 • • • We do not use the f 0.00169±0.00031±0.0001 0.0040±0.0030 0.0033±0.0018 0.0041±0.0018 162 Assumes equal product 163 ABE 96h assumes that 164 BORTOLETTO 92 rep 0.069±0.009, We res 10⁻². Our first error ls error from using our be 165 ALBRECHT 90 report 0.009. We rescale to o Our first error is their	VERAGE 162 JESS 163 AB 164 BO 165 AL 169 AL 169 AL 170 AL 171	SSOP 97 E 96 RTOLETTO92 BRECHT 90 BEK 87 averages, fits, 1 AM 94 BRECHT 94 BAJAR 91 BRECHT 87 AM 86 0 at the $\Upsilon(45)$ $(+^+) = (1.02 \pm 0.0003$ alue $B(J/\psi(15)$ $(+^+) = (0.0003 \pm 0.0003$ alue $B(J/\psi(15) \rightarrow e^+)$ $(+^+) = (1.0003 + 0.0003$	CLE2 e^+ H CDF p ? CLEO e^+ J ARG e^+ CLEO e^+ Imits, etc. \bullet CLE2 Su G ARG e^+ E UA1 E^+_0 D ARG e^+ CLEO Re 1. 0.14) × 10 ⁻ for B($J/\psi($ 1) \rightarrow e^+ e^-) if second error on of B^+ and D^+_0 B^+ and D^+ B^+ and D^+ 1.5) \rightarrow e^+ e^+	$f e^- \rightarrow T(45)$ 5 at 1.8 TeV $f e^- \rightarrow T(45)$ $f e^+ e^- \rightarrow T(45)$ $f e^- \rightarrow T(45)$
values for D^0 , D^{*0}	nes equal production of B^+ 0, η , η' , and ω branching fixequal production of B^+ 1 and $B(D^0\pi^0)$ and absolute $B(D^0\pi^0)$ and absolute $B(D^0\pi^0)$. Total CLY DOCUMENT: 90 BRANDENE the following data for avera 90 151 NEMATI 90 152 ALAM nes equal production of B^+ 10, η , η' , and ω branching fixed equal production of B^+ 10 and $B(D^0\pi^0)$ and absolute $B(D^0\pi^0)$ and absolu	and B^0 at the ractions. and B^0 at the 7 \rightarrow $K^-\pi^+$ at \rightarrow $K^-\pi^+\pi^+\pi^-$ at \rightarrow CLE2 and B^0 at the 7 \rightarrow CLE2 and B^0 at the 7 \rightarrow $K^-\pi^+$ at the 7 \rightarrow $K^-\pi^+$ at \rightarrow CLE2 ges, fits, limits 94 CLE2	T(45) and use to the third property of third property of the third property of the third property of the th	the PDG 96 the CLEO II $92 B(D^0 \rightarrow K^-\pi^+)$. Γ_{51}/Γ (45) (45) AATI 98 the CLEO II $92 B(D^0 \rightarrow K^-\pi^+)$. Γ_{52}/Γ (45)	0.00135±0.00018 OUR AN 0.00132 ±0.00017±0.0001 0.00136 ±0.00027±0.0001 0.00136 ±0.00059±0.0000 0.00126 ±0.00059±0.0000 0.0040 ±0.0018 ±0.0001 ■ ● ■ We do not use the f 0.00169 ±0.00031±0.0001 0.0040 ±0.0018 0.0041 ±0.0018 162 Assumes equal product 163 ABE 96H assumes that 164 BORTOLETTO 92 rej 0.069 ±0.009. We res 10−2. Our first error I error from using our be 165 ALBRECHT 901 report 0.009. We rescale to o Our first error is their from using our best va 166 BEBEK BT reports 0.00 We rescale to our best error Is their	VERAGE 162 JESS 163 AB 164 164 BO 165 AL 169 AL 169 AL 171 AL	SSOP 97 E 96 RTOLETTO92 BRECHT 90 BEK 87 averages, fits, I AM 94 BRECHT 94 BAJAR 91 BRECHT 94 BAJAR 91 AM 86 0 at the $\Upsilon(45)$ $(+^+) = (1.02 \pm 0.003 \pm 0.003)$ alue $B(J/\psi(15)$ $(+^+) = (1.02 \pm 0.002)$ for Bi $J/\psi(15) \rightarrow e^+$ $v^+ = 0.002$ for Bi $J/\psi(15) \rightarrow e^+$ $v^- = 0.003$ for Bi $J/\psi(15) \rightarrow e^+$ $J/$	CLE2 e ⁺¹ H CDF p] CLEO e ⁺¹ Imits, etc. e CLE2 Su G ARG e ⁺¹ E UA1 E CLEO Re 0.14) × 10 ⁻¹ for B(J/ψ (.) \rightarrow e ⁺ e ⁻¹ $(J/\psi$ (15) \rightarrow inderiron is t f B ⁺ and B ⁰ (6.02 ± 0.19) (6.02 ± 0.19) the systema	e^{-} → $T(45)$ 5 at 1.8 TeV e^{-} → $T(45)$ e^{-} e^{-} → e^{-}
19 NEMATI 98 assume values for D^0 , D^{*0} 0.0019 $(D^*(2007)^0 \tau')/\Gamma_0$ 10.0019 $(D^*(2007)^0 \tau')/\Gamma_0$ 10.0019 $(D^*(2007)^0 \tau')/\Gamma_0$ 10.0027 $(D^*(2007)^0 \tau')/\Gamma_0$ 10.0021 $(D^*($	nes equal production of B^+ 0, η , η' , and ω branching fixequal production of B^+ 1 and $B(D^0 \rightarrow K^-\pi^+)$ and absolute $B(D^0 \rightarrow K^-\pi^+)$ and $B(D^$	and B^0 at the ractions. of B^0 at the 7 \rightarrow $K^-\pi^+$ at \rightarrow $K^-\pi^+\pi^+\pi^-$ 3 98 CLE2 gges, fits, limits 94 CLE2 and B^0 at the ractions. of $K^-\pi^+\pi^+$ at $K^-\pi^-\pi^+$ at $K^-\pi^-\pi^+\pi^+$ at $K^-\pi^-\pi^+\pi^+$ at $K^-\pi^-\pi^+\pi^+$ at CLE2 and K^0 at the ractions.	T(45) and use to the third the PDG 199 $T(45)$ and use to the third the PDG 199 $T(45)$ and use to the third the PDG 199 $T(45)$ and use to the PDG 199 $T(45)$	the PDG 96 the CLEO II $22 \ B(D^0 \to K^-\pi^+)$. F51/F (45) (45) AATI 98 the CLEO II $22 \ B(D^0 \to K^-\pi^+)$. F52/F (45) AATI 98 the PDG 96 the PDG 96	0.00135±0.00018 OUR AN 0.00132±0.00017±0.0001 0.00136±0.00027±0.0001 0.00136±0.00059±0.0000 0.00126±0.00059±0.0000 0.0040±0.0018±0.0001 • • • We do not use the 1 0.00169±0.00031±0.0001 0.0040±0.0030 0.0033±0.0018 0.0041±0.0018 162 Assumes equal product 163 ABE 96H assumes that 164 BORTOLETTO 92 rej 0.069±0.009. We res 10−2 Our first error 1 error from using our be 165 ALBRECHT 901 report 0.009. We rescale to 0 Our first error is their from using our best value to be the rescale to 0 We rescale to our best error is their experimer our best value. Update	VERAGE 162 JEEE 163 AB 164 BO 165 AL 169 AL 169 AL 170 AL 171	SSOP 97 E 96 RTOLETTO92 BRECHT 90 BEK 87 averages, fits, I AM 94 BRECHT 94 BAJAR 91 BRECHT 87 AM 86 0 at the $\Upsilon(45)$ $(+^+) = (1.02 \pm 0.0005 \pm 0.0003$ alue $B(J/\psi(15)$ $(+^+) = (1.02 \pm 0.0002$ for $B(1/\psi(15) \rightarrow e^+)$ or and our second al production of 003 for $B(J/\psi(15) \rightarrow e^+) = (1.00 \pm 0.0002)$ $(-^+) = (-^$	CLE2 e^+ H CDF p ? CLEO e^+ CLEO e^+ Imits, etc. \bullet CLE2 Su G ARG e^+ E UA1 E^+_{C} D ARG e^+ CLEO Re 1.0.14) × 10 ⁻ for B($J/\psi($) \rightarrow e^+e^-) is second error on of B^+ and B^- $(J/\psi(15) \rightarrow$ $e^-) = (6.0$ $(5.0) \rightarrow$ e^+ e^- $(6.02 \pm 0.19$ the systema the same assu	$f e^- \rightarrow T(45)$ 5 at 1.8 TeV $f e^- \rightarrow T(45)$ $f e^+ e^- \rightarrow T(45)$ $f e^- \rightarrow T($
9 NEMATI 98 assume values for D^0 , D^{*0} 0.0010° 0.0014° 0.0019° 0.0014° 0.0019° 0.0027° 0.0019° 0.0027° 0.0019° 0.0019°	nes equal production of B^+ 0, η , η' , and ω branching fixequal production of B^+ 1 and $B(D^0\pi^0)$ and absolute $B(D^0\pi^0)$ and absolute $B(D^0\pi^0)$. Total CLY: 90 BRANDENE 151 NEMATI 90 152 ALAM nes equal production of B^+ 0, η , η' , and ω branching fixequal production of B^+ 0 and absolute $B(D^0\pi^0)$ and absolute $B(D^0\pi$	and B^0 at the ractions. of B^0 at the 7 $ K^-\pi^+$ at $ K^-\pi^+\pi^+\pi^-$ at $ -$	T(45) and use to the third the PDG 199 $T(45)$ and use to $T(45)$	the PDG 96 the CLEO II $22 B(D^0 \rightarrow K^-\pi^+)$. F51/F (45) (45) AATI 98 the CLEO II $22 B(D^0 \rightarrow K^-\pi^+)$. F52/F (45) AATI 98 the PDG 96 the CLEO II the PDG 96	0.00135±0.00018 OUR AN 0.00132 ±0.00017±0.0001 0.00136 ±0.00027±0.0001 0.00136 ±0.00059±0.0000 0.00126 ±0.00059±0.0000 0.0040 ±0.0018 ±0.0001 ■ ● ■ We do not use the f 0.00169 ±0.00031±0.0001 0.0040 ±0.0018 0.0041 ±0.0018 162 Assumes equal product 163 ABE 96H assumes that 164 BORTOLETTO 92 rej 0.069 ±0.009. We res 10−2. Our first error I error from using our be 165 ALBRECHT 901 report 0.009. We rescale to o Our first error is their from using our best va 166 BEBEK BT reports 0.00 We rescale to our best error Is their	VERAGE 162 JESS 163 AB 164 BO 165 AL 169 AL 169 AL 170 AL 171 AL 171 AL 180 BB \rightarrow J/ ψ μ 181 below on the service service. 182 Source service. 183 Source service. 184 Source service. 185 Source service. 186 Source service. 187 AL 187 AL 187 AL 188 BB \rightarrow J/ ψ μ 188 below on the service. 189 Source service. 180 So	SSOP 97 E 96 RTOLETTO92 BRECHT 90 BEK 87 averages, fits, i BAJAR 91 BRECHT 94 BAJAR 91 BRECHT 87 AM 86 0 at the $T(45)$ (**) = (1.02 ± 0.0003 ± 0.0003 alue B($J/\psi(15)$) t's error and ou secon all production of the property of the propert	CLE2 e^+ H CDF p ? CLEO e^+ CLEO e^+ CLE2 Su G ARG e^+ E UA1 E_0^+ D ARG e^+ CLEO Re 1. 0.14) \times 10 ⁻ 1 for B($J/\psi($ 1) \rightarrow e^+e^-) if second error on of B^+ and B^+ (1) $J/\psi(15) \rightarrow 0$ 1 for $J/\psi(15) \rightarrow 0$ 2 for $J/\psi(15) \rightarrow 0$ 3 for $J/\psi(15) \rightarrow 0$ 1 for $J/\psi(15) \rightarrow 0$ 2 for $J/\psi(15) \rightarrow 0$ 3 for $J/\psi(15) \rightarrow 0$ 3 for $J/\psi(15) \rightarrow 0$ 4 for $J/\psi(15) \rightarrow 0$ 3 for $J/\psi(15) \rightarrow 0$ 4 for $J/\psi(15) \rightarrow 0$ 1 for $J/\psi(15) \rightarrow 0$ 2 for $J/\psi(15) \rightarrow 0$ 3 for $J/\psi(15) \rightarrow 0$ 4 for $J/\psi(15) \rightarrow 0$ 3 for $J/\psi(15) \rightarrow 0$ 4 for $J/\psi(15) \rightarrow 0$ 3 for $J/\psi(15) \rightarrow 0$ 4 for $J/\psi(15) \rightarrow 0$ 5 for $J/\psi(15) \rightarrow 0$ 6 for $J/\psi(15) \rightarrow 0$ 1 for $J/\psi(15) \rightarrow 0$ 1 for $J/\psi(15) \rightarrow 0$ 2 for $J/\psi(15) \rightarrow 0$ 3 for $J/\psi(15) \rightarrow 0$ 4 for $J/\psi(15) \rightarrow 0$ 5 for $J/\psi(15) \rightarrow 0$ 6 for $J/\psi(15) \rightarrow 0$ 1 for $J/\psi(15) \rightarrow 0$ 1 for $J/\psi(15) \rightarrow 0$ 1 for $J/\psi(15) \rightarrow 0$ 2 for $J/\psi(15) \rightarrow 0$ 3 for $J/\psi(15) \rightarrow 0$ 1 for $J/\psi(15) \rightarrow 0$ 1 for $J/\psi(15) \rightarrow 0$ 2 for $J/\psi(15) \rightarrow 0$ 3 for $J/\psi(15) \rightarrow 0$ 4 for $J/\psi(15) \rightarrow 0$ 5 for $J/\psi(15) \rightarrow 0$ 1 for $J/\psi(15) \rightarrow 0$ 2 for $J/\psi(15) \rightarrow 0$ 3 for $J/\psi(15) \rightarrow 0$ 4 for $J/\psi(15) \rightarrow 0$ 5 for $J/\psi(15) \rightarrow 0$ 6 for $J/\psi(15) \rightarrow 0$ 1 for $J/\psi(15) \rightarrow 0$ 2 for $J/\psi(15) \rightarrow 0$ 2 for $J/\psi(15) \rightarrow 0$ 2 for $J/\psi(15) \rightarrow 0$	$e^+e^- \rightarrow T(45)$ f at 1.8 TeV $e^+e^- \rightarrow T(45)$ e^+e^-
9 NEMATI 98 assume values for D^0 , D^{*0} 0. ALAM 94 assume B(D^* (2007) 0 0 0 0 0 0 0 ALAM 94 assume B(D^* (2007) 0 0 0 0 0 0 0 0	nes equal production of B^+ on 0 , η , η' , and ω branching fixequal production of B^+ and $D^0\pi^0$) and absolute $B(D^0\pi^0)$ and absolute $B(D^0\pi^0)$. Total Signature of B^+ and $B(D^0\pi^0)$ branching fixed and $B(D^0\pi^0)$ branching fixed $B(D^0\pi^0)$ and absolute $B(D^0\pi^0)$	and B^0 at the ractions. and B^0 at the 7 \rightarrow $K^-\pi^+$ at \rightarrow $K^-\pi^+\pi^+\pi^-$ at \rightarrow CLE2 ges, fits, limits 98 CLE2 and B^0 at the 7 \rightarrow $K^-\pi^+$ at \rightarrow CLE2 ges, fits, limits 94 CLE2 and B^0 at the 7 \rightarrow $K^-\pi^+$ at \rightarrow CLE2 ges, fits, limits 94 CLE2 and B^0 at the 7 \rightarrow $K^-\pi^+$ at $X^-\pi^+$ at $X^-\pi^$	T(45) and use to the the PDG 199 $T(45)$ and use to the the PDG 199 $T(45)$ and $T(45)$ and $T(45)$ and use to the PDG 199	the PDG 96 the CLEO II $22 B(D^0 \rightarrow K^-\pi^+)$. Γ_{51}/Γ (45) (45) AATI 98 the CLEO II $22 B(D^0 \rightarrow K^-\pi^+)$. Γ_{52}/Γ (45) (45) (45) (45) (45) (45) (45) (45) (45) (45) (45) (45) (45)	0.00135±0.00018 OUR AN 0.00132 ±0.00017±0.0001 0.00136 ±0.00027±0.0001 0.00136 ±0.00059±0.0000 0.00126 ±0.00059±0.0000 0.00126 ±0.00018 ±0.0001 • • • We do not use the f 0.00169 ±0.00031±0.0001 0.0040 ±0.0018 0.0041 ±0.0018 162 Assumes equal product 163 ABE 96H assumes that 164 BORTOLETTO 92 rep 0.069 ±0.009. We res 10−2. Our first error lerror from using our be 165 ALBRECHT 901 report 0.009. We rescale to o Our first error is their from using our best val 166 BEBEK 87 reports 0.00 We rescale to our best error is their experimer our best value. Update 167 The neutral and charg Γ L/F =0.080 ±0.08 ± (KRAMER 92). This p	VERAGE 162 JESS 163 AB 164 BO 165 AL 169 AL 169 AL 170 AL 171 AL 150 IT AL 150 IT AL 169 AL 170 AL 171 AL 150 IT AL	SSOP 97 E 96 RTOLETTO92 BRECHT 90 BEK 87 averages, fits, 1 AM 94 BRECHT 94 BAJAR 91 BRECHT 87 AM 94 C 10.02 \pm 0.0003 alue $B(J/\psi(15)$ \pm 1's error and ou seco al production of 003 for $B(J/\psi(15) \rightarrow e^+$ $\rightarrow e^+e^ \rightarrow e^+e^ \rightarrow e^ \rightarrow e$	CLE2 e^+ H CDF p P CLEO e^+ P	$f e^- o T(45)$ 5 at 1.8 TeV $f e^- o T(45)$ 6 applies by JESSOP 9 $f e^- o T(45)$ 6 applies by JESSOP 9 $f e^- o T(45)$ 6 applies by JESSOP 9 $f e^- o T(45)$ 6 applies by JESSOP 9 $f e^- o T(45)$ 6 at 1.5 $f e^- o T(45)$ 6 at 1.5 $f e^- o T(45)$ 6 at 1.5 $f e^- o T(45)$ 7 at 1.6 applies by JESSOP 9 $f e^- o T(45)$ 7 at 1.6 applies by JESSOP 9 $f e^- o T(45)$ 6 at 1.6 at 1.6 applies by JESSOP 9 $f e^- o T(45)$ 6 at 1.6 at 1.
9 NEMATI 98 assume values for D^0 , D^{*0} (D^0 (2007) D^0 D^0 (D^0 (2007) D^0 D^0 D^0 (D^0 (2007) D^0 D^0 D^0 (D^0 (2007) D^0 D	nes equal production of B^+ 0, η , η' , and ω branching fixequal production of B^+ 1 and $B(D^0\pi^0)$ and absolute $B(D^0\pi^0)$ and absolute $B(D^0\pi^0)$. Total CLY: 90 BRANDENE 151 NEMATI 90 152 ALAM nes equal production of B^+ 0, η , η' , and ω branching fixequal production of B^+ 0 and absolute $B(D^0\pi^0)$ and absolute $B(D^0\pi$	and B^0 at the ractions. and B^0 at the 7 \rightarrow $K^-\pi^+$ at \rightarrow $K^-\pi^+\pi^+\pi^-$ at \rightarrow CLE2 ges, fits, limits 98 CLE2 and B^0 at the 7 \rightarrow $K^-\pi^+$ at \rightarrow CLE2 ges, fits, limits 94 CLE2 and B^0 at the 7 \rightarrow $K^-\pi^+$ at \rightarrow CLE2 ges, fits, limits 94 CLE2 and B^0 at the 7 \rightarrow $K^-\pi^+$ at $X^-\pi^+$ at $X^-\pi^$	T(45) and use to the the PDG 199 $T(45)$ and use to the the PDG 199 $T(45)$ and $T(45)$ and $T(45)$ and use to the PDG 199	the PDG 96 the CLEO II $22 B(D^0 \rightarrow K^-\pi^+)$. Γ_{51}/Γ (45) (45) AATI 98 the CLEO II $22 B(D^0 \rightarrow K^-\pi^+)$. Γ_{52}/Γ (45) (45) (45) (45) (45) (45) (45) (45) (45) (45) (45) (45) (45)	0.00135±0.00018 OUR AN 0.00132±0.00017±0.0001 0.00136±0.00027±0.0001 0.00136±0.00055±0.0000 0.00126±0.00055±0.0000 0.00126±0.00018±0.0001 • • • We do not use the 1 0.00169±0.00031±0.0001 0.0040±0.0030 0.0033±0.0018 0.0041±0.0018 162 Assumes equal product 163 ABE 96H assumes that 164 BORTOLETTO 92 rej 0.069±0.009. We res 10−2. Our first error is error from using our be 165 ALBRECHT 90J report 0.009. We rescale to 0 Our first error is their from using our best value. Update error is their experimer our best value. Update 167 The neutral and charg	VERAGE 162 JESS 163 AB 164 BO 165 AL 169 AL 169 AL 170 AL 171	SSOP 97 E 96 RTOLETTO92 BRECHT 90 BEK 87 averages, fits, 1 AM 94 BRECHT 94 BAJAR 91 BRECHT 87 AM 86 0 at the $T(45)$ $(+^+) = (1.02 \pm 0.0003 \pm 0.0003$ alue $B(J/\psi(15) \div e^+) = (1.02 \pm 0.0002 \text{ for B} I)/\psi(15) \rightarrow e^+$ or and our second al production of 003 for $B(J/\psi(15) \rightarrow e^+) = 0.0002$ second error is 1 TO 92 to use there are predome e compared with the B equal production of 91 and	CLE2 e^+ H CDF p ? CLEO e^+ J ARG e^+ CLEO e^+ Imits, etc. \bullet CLE2 Su G ARG e^+ E UA1 E^+_{0} D ARG e^+ CLEO Re 1.0.14) × 10 ⁻ for B($J/\psi($) $\rightarrow e^+e^-$) is second error on of B^+ and B^+_{0} 1.5) $\rightarrow e^+e^-$ (6.02 \pm 0.19 the systema he same assuminantly longing the sa	$f e^- \rightarrow T(45)$ $f at 1.8 \text{ TeV}$ $f at 1.8 \text{ TeV}$ $f e^- \rightarrow T(45)$ $f e^- $
19 NEMATI 98 assume values for D^0 , D^{*0} of ALAM 94 assume $B(D^*(2007)^0 \rightarrow K^-\pi^+\pi^0)/B(D^0)$ 10 NEMATI 98 assume $B(D^*(2007)^0 \rightarrow K^-\pi^0)/B(D^0)$ 11 NEMATI 98 assume $B(D^*(2007)^0 \rightarrow K^-\pi^+\pi^0)/B(D^0)$ 12 ALAM 94 assume $B(D^*(2007)^0 \rightarrow K^-\pi^+\pi^0)/B(D^0)$ 13 NEMATI 98 assume values for D^0 , D^{*0} 14 ALAM 94 assume $B(D^*(2007)^0 \rightarrow K^-\pi^0)/B(D^0)$	nes equal production of B^+ 0, η , η' , and ω branching fixequal production of B^+ 1 and $B(D^0 \rightarrow K^-\pi^+)$ and absolute $B(D^0 \rightarrow K^-\pi^+)$ and $B(D^0 \rightarrow K^-\pi^+)$	and B^0 at the ractions. and B^0 at the 7 \rightarrow $K^-\pi^+$ at \rightarrow $K^-\pi^+\pi^+\pi^-$ at \rightarrow CLE2 ges, fits, limits 98 CLE2 and B^0 at the 7 \rightarrow $K^-\pi^+$ at \rightarrow CLE2 ges, fits, limits 94 CLE2 and B^0 at the 7 \rightarrow $K^-\pi^+$ at \rightarrow CLE2 ges, fits, limits 94 CLE2 and B^0 at the 7 \rightarrow $K^-\pi^+$ at $X^-\pi^+$ at $X^-\pi^$	T(45) and use to the the PDG 199 $T(45)$ and use to the the PDG 199 $T(45)$ and $T(45)$ and $T(45)$ and use to the PDG 199	the PDG 96 the CLEO II $22 B(D^0 \rightarrow K^-\pi^+)$. F51/F (45) (45) AATI 98 the CLEO II $22 B(D^0 \rightarrow K^-\pi^+)$. F52/F (45) AATI 98 the CLEO II $22 B(D^0 \rightarrow K^-\pi^+)$. (45)	0.00135±0.00018 OUR AN 0.00132±0.00017±0.0001 0.00136±0.00027±0.0001 0.00126±0.00055±0.0000 0.00126±0.00055±0.0000 0.00126±0.00018±0.0001 • • • We do not use the f 0.00169±0.00031±0.0001 0.0040±0.0030 0.0033±0.0018 0.0041±0.0018 162 Assumes equal product 163 ABE 96H assumes that 164 BORTOLETTO 92 rej 0.069±0.009. We res 10⁻², Our first error is error from using our best error from using our best error is their from using our best value. Update 166 BEBEK 87 reports 0.00 We rescale to our best error is their experiment our best value. Update 167 The neutral and charge	VERAGE 162 JESS 163 AB 164 BO 165 AL 169 AL 169 AL 169 AL 170 AL 171	SSOP 97 E 96 RTOLETTO92 BRECHT 90 BEK 87 averages, fits, I BAJAR 91 BRECHT 94 BAJAR 91 BRECHT 87 AM 86 0 at the $T(45)$ (t^+) = (1.02 \pm 0.0005 \pm 0.0003 alue B($J/\psi(15)$) t^+ 's error and ou sequal production of all production of 1003 for B($J/\psi(15)$) t^- erecond error is TO 92 to use to the rare predome e compared with the B tes that the B qual production in in the vector-	CLE2 e^+ H CDF p ? CLEO e^+ CLEO e^+ CLE2 Su GARG e^+ E UA1 E^+_{c} D ARG e^+ CLEO Re 1. 0.14) × 10 ⁻ 1 for $B(J/\psi($ 1) $\rightarrow e^+e^-$) is second error on of B^+ and B^- (1) $(J/\psi(15) \rightarrow e^+e^-)$ (6.02 \pm 0.19 the systema he same assuminantly long in a prediction A^+ A^+ A^+ decreased in a finite of A^+ and A^+ A	$e^+e^- \rightarrow T(45)$ 5 at 1.8 TeV $e^- \rightarrow T(45)$
19 NEMATI 98 assume values for D^0 , D^{*0} of ALAM 94 assume $B(D^*(2007)^0 \rightarrow K^-\pi^+\pi^0)/B(D^0)$ 10 NEMATI 98 assume $B(D^*(2007)^0 \rightarrow K^-\pi^0)/B(D^0)$ 11 NEMATI 98 assume $B(D^*(2007)^0 \rightarrow K^-\pi^+\pi^0)/B(D^0)$ 12 ALAM 94 assume $B(D^*(2007)^0 \rightarrow K^-\pi^+\pi^0)/B(D^0)$ 13 NEMATI 98 assume values for D^0 , D^{*0} 14 ALAM 94 assume $B(D^*(2007)^0 \rightarrow K^-\pi^+\pi^0)/B(D^0)$ 15 NEMATI 98 assume $B(D^*(2007)^0 \rightarrow K^-\pi^+\pi^0)/B(D^0)$ 16 ALAM 94 assume $B(D^*(2007)^0 \rightarrow K^-\pi^+\pi^0)/B(D^0)$ 17 ($D^*(2007)^0 \rightarrow K^-\pi^+\pi^0)/B(D^0)$ 18 ($D^*(2007)^0 \rightarrow K^-\pi^+\pi^0)/B(D^0)$	nes equal production of B^+ 0, η , η' , and ω branching fixequal production of B^+ 1 and $B(D^0 \rightarrow K^-\pi^+)$ and absolute $B(D^0 \rightarrow K^-\pi^+)$ and $B(D^0 \rightarrow K^-\pi^+)$	and B^0 at the ractions. of B^0 at the T at the T at the T at T a	T(45) and use to the the PDG 199 $T(45)$ and use to the the PDG 199 $T(45)$ and $T(45)$ and $T(45)$ and use to the PDG 199	the PDG 96 the CLEO II $22 B(D^0 \rightarrow K^-\pi^+)$. Γ_{51}/Γ (45) (45) AATI 98 the CLEO II $22 B(D^0 \rightarrow K^-\pi^+)$. Γ_{52}/Γ (45) (45) (45) (45) (45) (45) (45) (45) (45) (45) (45) (45) (45)	0.00135±0.00018 OUR AM 0.00132±0.00017±0.0001 0.00136±0.00027±0.0002 0.00126±0.00055±0.0000 0.00126±0.00055±0.0000 0.00126±0.00018±0.0001 • • • We do not use the 1 0.00169±0.00031±0.0001 0.0040±0.0018 0.0041±0.0018 162 Assumes equal product 163 ABE 96H assumes that 164 BORTOLETTO 92 rep 0.069±0.009. We ress 10−2. Our first error is error from using our be 165 ALBRECHT 901 report 0.009. We rescale to our 0.001 first error is their from using our best value. Update 167 The neutral and charge Γ _L /Γ = 0.080±0.08± (KRAMER 92). This p the CP = 1 CP elger 168 ALBRECHT 96 meass longitudinal, Γ _T /Γ = 0	VERAGE 162 JESS 163 AB 164 164 BO 165 AL 169 AL 169 AL 171 AL	SSOP 97 E 96 RTOLETTO92 BRECHT 90 BEK 87 averages, fits, I BAJAR 91 BRECHT 94 BAJAR 91 BRECHT 87 AM 86 0 at the $T(45)$ (t^+) = (1.02 \pm 0.0005 \pm 0.0003 alue B($J/\psi(15)$) t^+ 's error and ou sequal production of all production of 1003 for B($J/\psi(15)$) t^- erecond error is TO 92 to use to the rare predome e compared with the B tes that the B qual production in in the vector-	CLE2 e^+ H CDF p ? CLEO e^+ CLEO e^+ CLE2 Su GARG e^+ E UA1 E^+_{c} D ARG e^+ CLEO Re 1. 0.14) × 10 ⁻ 1 for $B(J/\psi($ 1) $\rightarrow e^+e^-$) is second error on of B^+ and B^- (1) $(J/\psi(15) \rightarrow e^+e^-)$ (6.02 \pm 0.19 the systema he same assuminantly long in a prediction A^+ A^+ A^+ decreased in a finite of A^+ and A^+ A	$e^+e^- \rightarrow T(45)$ 5 at 1.8 TeV $e^- \rightarrow T(45)$
9 NEMATI 98 assume values for D^0 , D^{*0} 0 ALAM 94 assume $B(D^*(2007)^0 \rightarrow K^-\pi^+\pi^0)/B(D^0)$ • • We do not use 10.0019 • • We do not use 10.0027 10 NEMATI 98 assume $B(D^*(2007)^0 \rightarrow K^-\pi^+\pi^0)/B(D^0)$ • • We do not use 10.0027 • • We do not use 10.0021 3 NEMATI 98 assume $B(D^*(2007)^0 \rightarrow K^-\pi^+\pi^0)/B(D^0)$ • • We do not use 10.0021	nes equal production of B^+ 0, η , η' , and ω branching fixequal production of B^+ 1 and $B(D^0\pi^0)$ and absolute $B(D^0\pi^0)$ and absolute $B(D^0\pi^0)$. Total CLY: 90 BRANDENE of the following data for average of the production of B^+ 1 and $B(D^0\pi^0)$ and absolute $B(D^0\pi^0)$ and absolute $B(D^0\pi^0)$ and absolute $B(D^0\pi^0)$ and absolute $B(D^0\pi^0)$ and absolute $B(D^0\pi^0)$.	and B^0 at the ractions. and B^0 at the $7 \rightarrow K^-\pi^+$ at $6 \rightarrow K^-\pi^+$ at	T(45) and use to the PDG 199 $T(45)$ and use	the PDG 96 the CLEO II $22 B(D^0 \rightarrow K^-\pi^+)$. Γ_{51}/Γ (45) (45)	0.00135±0.00018 OUR AN 0.00132±0.00017±0.0001 0.00136±0.00027±0.0001 0.00136±0.00059±0.0000 0.00126±0.00059±0.0000 0.00126±0.00018±0.0001 • • • We do not use the f 0.00169±0.00031±0.0001 0.0040±0.0018 0.0041±0.0018 162 Assumes equal product 163 ABE 96H assumes that 164 BORTOLETTO 92 rep 0.069±0.009. We rescale to o Our first error is represented from using our best value. Our best value from the serior is their from using our best value. Update 167 The neutral and charg	VERAGE 162 JESS 163 AB 164 BO 165 AL 169 AL 169 AL 170 AL 171 AL 160 BF and B 161 BF and B 162 BF and B 163 BF and B 164 BO 165 AL 169 AL 169 AL 170 AL 170 AL 170 AL 170 AL 180 AB 190	SSOP 97 E 96 RTOLETTO92 BRECHT 90 BEK 87 averages, fits, I AM 94 BRECHT 94 BAJAR 91 BRECHT 87 AM 94 BRECHT 87 $(++++++++++++++++++++++++++++++++++++$	CLE2 e^+ H CDF p CLEO e^+ CLEO e^+ J ARG e^+ CLEO e^+ Imits, etc. e^- CLEO Re CLEO Re 0.14) × 10 ⁻ If or B($J/\psi(t)$ For or of B^+ In or of B^+ H and B^0 15) $\rightarrow e^+e^-$ (6.02 \pm 0.18) $\rightarrow e^+e^-$ (6.02 \pm 0.19) $\rightarrow e^+e^-$	$e^+e^- \rightarrow T(45)$ 5 at 1.8 TeV $e^- \rightarrow T(45)$
19 NEMATI 98 assume values for D^0 , D^{*0} 0 ALAM 94 assume $B(D^*(2007)^0 - H)/\Gamma_0$ 10 P. NEMATI 98 assume $B(D^*(2007)^0 - H)/\Gamma_0$ 11 NEMATI 98 assume $B(D^*(2007)^0 - H)/\Gamma_0$ 12 ALAM 94 assume $B(D^*(2007)^0 - H)/\Gamma_0$ 13 NEMATI 98 assume $B(D^*(2007)^0 - H)/\Gamma_0$ 14 U.E. 15 NEMATI 98 assume $B(D^*(2007)^0 - H)/\Gamma_0$ 16 U.E. 17 NEMATI 98 assume $B(D^*(2007)^0 - H)/\Gamma_0$ 17 NEMATI 98 assume $B(D^*(2007)^0 - H)/\Gamma_0$ 18 NEMATI 98 assume $B(D^*(2007)^0 - H)/\Gamma_0$ 19 NEMATI 98 assume $B(D^*(2007)^0 - H)/\Gamma_0$ 10 U.E. 10 NEMATI 98 assume $B(D^*(2007)^0 - H)/\Gamma_0$ 11 NEMATI 98 assume $B(D^*(2007)^0 - H)/\Gamma_0$ 12 NEMATI 98 assume $B(D^*(2007)^0 - H)/\Gamma_0$ 13 NEMATI 98 assume $B(D^*(2007)^0 - H)/\Gamma_0$ 14 ALAM 94 assume $B(D^*(2007)^0 - H)/\Gamma_0$ 15 ASNER 97 at CLE	nes equal production of B^+ 0, η , η' , and ω branching fixequal production of B^+ 1 and $B(D^0 \rightarrow K^-\pi^+)$ and absolute $B(D^0 \rightarrow K^-\pi^+)$ and $B(D^0 \rightarrow K^-\pi^+)$	and B^0 at the ractions. and B^0 at the 7 $K^-\pi^+\pi^+\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi$	T(45) and use to the third the PDG 199 $T(45)$ and use to t	the PDG 96 the CLEO II $22 B(D^0 \rightarrow K^-\pi^+)$. F51/F (45) (45) (45) AATI 98 the PDG 96 the CLEO II $22 B(D^0 \rightarrow K^-\pi^+)$. F52/F (45) AATI 98 the PDG 96 the CLEO II $22 B(D^0 \rightarrow K^-\pi^+)$. F53/F (45)	0.00135±0.00018 OUR AN 0.00132±0.00017±0.0001 0.00136±0.00027±0.0001 0.00136±0.00055±0.0000 0.00126±0.00055±0.0000 0.00126±0.00018±0.0001 0.0040±0.0018±0.0001 0.0040±0.0031±0.0001 0.0040±0.0031 0.0041±0.0018 162 Assumes equal product 163 ABE 96H assumes that 164 BORTOLETTO 92 rej 0.069±0.009. We res 10−2. Our first error is error from using our bes 165 ALBRECHT 901 report 0.009. We rescale to o Our first error is their from using our best val 166 BEBEK 87 reports 0.00 We rescale to our best error is their experimer our best value. Update 167 The neutral and charge Γ_L/T=0.080±0.08± (KRAMER 92). This p the CP = −1 CP elger 168 ALBRECHT 94 meass longitudinal, Γ_T/T=0 the K*0 decays throug 169 ALBAJAR 91E assume 170 ALBRECHT 870 assume	VERAGE 162 JESS 163 AB 164 BO 165 AL 169 AL 169 AL 169 AL 170 AL 169 AL 171 AL 160 OS 161 BC 171 AL 161 BC 171 AL 171	SSOP 97 E 96 RTOLETTO92 BRECHT 90 BEK 87 averages, fits, 1 AM 94 BRECHT 94 BAJAR 91 BRECHT 87 AM 86 0 at the $T(4S)$ c 10.002 alue $B(J/\psi(1S)$ t's error and our second a production of 30 of $B(J/\psi(1S) \rightarrow e^+$ or and our second error is second error is second error is second error is econd error is the rare predome e compared with the B squal production in in the vector- making the neu fraction of 36% ratio is 55/45.	CLE2 e^+ H CDF p ? CLEO e^+ CLEO e^+ Imits, etc. e^- CLEO Summits, etc. e^- Imits, etc. e^- CLEO Ref. 0.14) × 10 ⁻ 1 for B(J/ψ (1) $\rightarrow e^+e^-$) If second error on of B^+ and J/ψ (15) $\rightarrow e^+e^-$ (6.02 \pm 0.19) the systema he same as the sa	$e^+e^- \rightarrow T(45)$ 5 at 1.8 TeV $e^- \rightarrow T(45)$
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9 NEMATI 98 assume values for D^0 , D^{*0} (D^* (2007) $D^0 \rightarrow K^-\pi^+\pi^0$)/B(D^0 (D^* (2007) $D^0 \rightarrow K^-\pi^+\pi^0$)/B(D^0 (D^* (2007) $D^0 \rightarrow K^0$)/F(D^0 (2007) D^0)/ D^0 (D^0 (2007) D^0 (D^0 (D^0 (2010) D^0 (D^0	nes equal production of B^+ 0, η , η' , and ω branching fixequal production of B^+ 1 and $B(D^0 \rightarrow K^-\pi^+)$ and absolute $B(D^0 \rightarrow K^-\pi^+)$ and $B(D^$	and B^0 at the ractions. of B^0 at the 7 \rightarrow $K^-\pi^+$ at \rightarrow $K^-\pi^+\pi^+\pi^+$ at \rightarrow $K^-\pi^+\pi^+\pi^+$ at \rightarrow $K^-\pi^+\pi^+\pi^+$ at \rightarrow $K^-\pi^+\pi^+$ at \rightarrow $K^-\pi^+$ at the ractions. of B^0 at the 7 \rightarrow $K^-\pi^+$ at \rightarrow $K^-\pi$	T(45) and use to the third the PDG 199 $T(45)$ and use to t	the PDG 96 the CLEO II $22 B(D^0 \rightarrow K^-\pi^+)$. F51/F (45) (45) (45) AATI 98 the PDG 96 the CLEO II $22 B(D^0 \rightarrow K^-\pi^+)$. F52/F (45) AATI 98 the PDG 96 the CLEO II $22 B(D^0 \rightarrow K^-\pi^+)$. F53/F (45)	0.00135±0.00018 OUR AN 0.00132±0.00017±0.0001 0.00136±0.00027±0.0001 0.00136±0.00055±0.0000 0.00126±0.00055±0.0000 0.00126±0.00018±0.0001 0.0040±0.0018±0.0001 0.0040±0.0031±0.0001 0.0040±0.0031 0.0041±0.0018 162 Assumes equal product 163 ABE 96H assumes that 164 BORTOLETTO 92 rej 0.069±0.009. We res 10−2. Our first error is error from using our bes 165 ALBRECHT 901 report 0.009. We rescale to o Our first error is their from using our best val 166 BEBEK 87 reports 0.00 We rescale to our best error is their experimer our best value. Update 167 The neutral and charge Γ_L/T=0.080±0.08± (KRAMER 92). This p the CP = −1 CP elger 168 ALBRECHT 94 meass longitudinal, Γ _T /T=0 the K*0 decays throug 169 ALBAJAR 91E assume 170 ALBRECHT 870 assume 170 ALBRECHT 870 assume 170 ALBRECHT 870 assume	VERAGE 162 JESS 163 AB 164 BO 165 AL 169 AL 169 AL 170 AL 170 AL 171 AL 172 AL 173 AL 174 AL 175 AL 177	SSOP 97 E 96 RTOLETTO92 BRECHT 90 BEK 87 averages, fits, 1 AM 94 BRECHT 94 BAJAR 91 BRECHT 87 AM 65 0 at the $\Upsilon(45)$ $(+^+) = (1.02 \pm 0.0005 \pm 0.0003$ alue $B(J/\psi(15)$ $(+^+) = (1.02 \pm 0.0003 \pm 0.0003$ alue $B(J/\psi(15)$ $(+^+) = (1.02 \pm 0.0003$ alue $B(J/\psi(15) \rightarrow e^+$ or and our second approduction of 3 for $B(J/\psi(15) \rightarrow e^+$ or and our second approduction of 1003 for $B(J/\psi(15) \rightarrow e^+$ or and our second production of 1003 for $B(J/\psi(15) \rightarrow e^+$ or and our second production of 1003 for $B(J/\psi(15) \rightarrow e^+$ or and our second production of 1003 for $B(J/\psi(15) \rightarrow e^+$ or and our second production of 1003 for $B(J/\psi(15) \rightarrow e^+$ or and our second production of 1003 for $B(J/\psi(15) \rightarrow e^+$ or and our second production of 1003 for $B(J/\psi(15) \rightarrow e^+$ or and our second production of 1003 for $B(J/\psi(15) \rightarrow e^+$ or and our second production of 1003 for $B(J/\psi(15) \rightarrow e^+$ or and our second production of 1003 for $B(J/\psi(15) \rightarrow e^+$ or and our second production of 1003 for $B(J/\psi(15) \rightarrow e^+$ or and our second production of 1003 for $B(J/\psi(15) \rightarrow e^+$ or and our second production of 1003 for $B(J/\psi(15) \rightarrow e^+$ or and our second production of 1003 for $B(J/\psi(15) \rightarrow e^+$ or and our second production of 1003 for $B(J/\psi(15) \rightarrow e^+$ or and our second production of 1003 for $B(J/\psi(15) \rightarrow e^+$ or and our second production of 1003 for $B(J/\psi(15) \rightarrow e^+$ or and our second production of 1003 for $B(J/\psi(15) \rightarrow e^+$ or and our second production of 1003 for $B(J/\psi(15) \rightarrow e^+$ or and our second production of 1003 for $B(J/\psi(15) \rightarrow e^+$ or and our second production of 1003 for $B(J/\psi(15) \rightarrow e^+$ or and our second production of 1003 for $B(J/\psi(15) \rightarrow e^+$ or and our second production of 1003 for $B(J/\psi(15) \rightarrow e^+$ or and our second production of 1003 for $B(J/\psi(15) \rightarrow e^+$ or and our second production of 1003 for $B(J/\psi(15) \rightarrow e^+$ or and our second production of 1003 for $B(J/\psi(15) \rightarrow e^+$ or and our second production of 1003 for $B(J/\psi(15) \rightarrow e^+$ or and our second production of 1003 for $B(J/\psi(15) \rightarrow e^+$ or and our second production of 1003 for $B(J/\psi(15) \rightarrow e^+$ or and	CLE2 e^+ H CDF p ? CLEO e^+ CLEO e^+ Imits, etc. e^- Imits, etc. e^- CLEO e^+ Imits, etc. e^- CLEO e^+ Imits, etc. e^- CLEO Re 1. 0.14) × 10 ⁻ 1. or B(J/ψ (1. or B(J/ψ (1. or B+ and B(1. or B+ and	$e^+e^- \rightarrow T(45)$ 5 at 1.8 TeV $e^- \rightarrow T(45)$
9 NEMATI 98 assume values for D^0 , D^{*0} 0 ALAM 94 assume B(D^* (2007) 0 → $K^-\pi^+\pi^0$)/B(D^0 (\overline{D}^* (2007) $^0\pi^\prime$)/Γ ₁ 10.0014 • • We do not use 10.0019 0.0027 1 NEMATI 98 assume B(D^* (2007) 0 → $K^-\pi^+\pi^0$)/B(D^0 (\overline{D}^* (2007) 0 → $K^-\pi^+\pi^0$)/B(D^0 (\overline{D}^* (2007) 0 → $K^-\pi^+\pi^0$)/B(D^0 (\overline{D}^* (2007) 0 → $K^-\pi^+\pi^0$)/B(D^0 4 ALAM 94 assume B(D^* (2007) 0 → $K^-\pi^+\pi^0$)/B(D^0 (D^* (2010) $^+$ 0 → $K^-\pi^+\pi^0$)/B(D^0 (D^* (2010) $^+$ 0 → 10.1019 10.10	nes equal production of B^+ 0, η , η' , and ω branching fixequal production of B^+ 1 and $B(D^0 \rightarrow K^-\pi^+)$ and absolute $B(D^0 \rightarrow K^-\pi^+)$ and $B(D^$	and B^0 at the ractions. and B^0 at the 7 $K^-\pi^+$ at $K^-\pi^+\pi^+\pi^+\pi^-$ B. IECN 3 98 CLE2 ges, fits, limits 98 CLE2 94 CLE2 and B^0 at the 7 $K^-\pi^+$ at the ractions. and B^0 at the 7 $K^-\pi^+$ at $K^-\pi^+\pi^+\pi^-\pi^+\pi^-$ B. IECN 97 CLE2 n expected bace K^+T^2 . $K^-\pi^+\pi^+\pi^-$	T(45) and use to the third the PDG 199 $T(45)$ and use to the third the PDG 199 $T(45)$ and use to the third the PDG 199 $T(45)$ and use to the PDG 199	the PDG 96 the CLEO II $22 \ B(D^0 \rightarrow K^-\pi^+)$. (45)	0.00135±0.00018 OUR AN 0.00132±0.00017±0.0001 0.00136±0.00027±0.0001 0.00136±0.00055±0.0000 0.00126±0.00055±0.0000 0.00126±0.00059±0.0000 0.0040±0.0018±0.0001 • • • We do not use the following the	VERAGE 162 JESS 163 AB 164 BO 165 AL 169 AL 169 AL 169 AL 170 AL 169 AL 171 AL 160 OS AB 160 OS AB 170 AL 171 AL 160 OS AB 171 AL 161 AB 171 AL 161 AB 171 AL 162 AB 171 AL 163 AB 171 AL 164 AL 167 AL 168 AL 169 AL 171 AL 160 OS AB 171 AL	SSOP 97 E 96 RTOLETTO92 BRECHT 90 BEK 87 averages, fits, 1 BAJAR 91 BRECHT 94 BAJAR 91 BRECHT 87 AM 86 0 at the $T(4S)$ c 10.0005 \pm 0.0003 alue $B(J/\psi(1S)$ t's error and out see equal production \pm 0.0002 for B $I/\psi(1S) \rightarrow e^+$ or and our second error is second error is second error is second error is the rare predome to making the new fraction of 36% ratio is 55/45. 0/40. The ob- racted in this pi) ENT ID 1	CLE2 e^+ H CDF p ? CLEO e^+ CLEO e^+ Imits, etc. e^- Imits, etc. e^- Imits, etc. e^- Imits, etc. e^- CLEO e^+ Imits, etc. e^- Imits, etc. e^- Imits, etc. e^- CLEO Re 1.0.14) × 10 ⁻ 1.0.15 or B(J/ψ (1.5) → e^+e^-) 1.0.14) × 10 ⁻ 1.0.15 or B(J/ψ (1.5) → e^+e^- 1.0.16 or B + and B + same as a he same a he same as a he same as a he same a	$f = - \rightarrow T(45)$ $f = 18$ TeV $f = - \rightarrow T(45)$
9 NEMATI 98 assume values for D^0 , $D^{*(0)}$ D^0	nes equal production of B^+ 0, η , η' , and ω branching fixequal production of B^+ 1 and $B(D^0 \rightarrow K^-\pi^+)$ and absolute $B(D^0 \rightarrow K^-\pi^+)$ and $B(D^$	and B^0 at the ractions. and B^0 at the 7 $K^-\pi^+$ at $K^-\pi^+\pi^+\pi^+\pi^-$ B. IECN 3 98 CLE2 ges, fits, limits 98 CLE2 94 CLE2 and B^0 at the 7 $K^-\pi^+$ at the ractions. and B^0 at the 7 $K^-\pi^+$ at $K^-\pi^+\pi^+\pi^-\pi^+\pi^-$ B. IECN 97 CLE2 n expected bace K^+T^2 . $K^-\pi^+\pi^+\pi^-$	T(45) and use to the third the PDG 199- $T(45)$ and use to the PDG 199- $T(45)$ and use to the third the PDG 199- $T(45)$ and use to the PDG 199- $T(45)$ and	the PDG 96 the CLEO II $22 \ B(D^0 \rightarrow K^-\pi^+)$. (45)	0.00135±0.00016 OUR AN 0.00132±0.00017±0.0001 0.00136±0.00027±0.0001 0.00136±0.00055±0.0000 0.00126±0.00055±0.0000 0.00126±0.00018±0.0001 • • • We do not use the 1 0.00169±0.00031±0.0001 0.0040±0.0030 0.0033±0.0018 0.0041±0.0018 162 Assumes equal product 163 ABE 96H assumes that 164 BORTOLETTO 92 rej 0.069±0.009. We res 10−2. Our first error 1 error from using our be 165 ALBRECHT 90 report 0.009. We rescale to 0 Our first error is their from using our best value. Update 167 The neutral and charg our best value. Update 167 The neutral and charg f L/F =0.080±0.08± (KRAMER 92). This p the CP = −1 CP eiger 168 ALBRECHT 94G meass iongtitudinal, Γ _T /F = 0 the K*0 decays throug 169 ALBAJAR 91E assumes 170 ALBRECHT 87D assume 170 ALBRECHT 87D assume 171 ALAM 86 assumes B J/ψ K*(892)* (HAAS) Γ (J/ψ(15) K*(892)* (HAAS)	VERAGE 162 JESS 163 AB 164 BO 165 AL 169 AL 169 AL 170 AL 170 AL 171 AL 172 AL 173 AL 174 AL 175 AL 177	SSOP 97 E 96 RTOLETTO92 BRECHT 90 BEK 87 averages, fits, 1 AM 94 BRECHT 94 BAJAR 91 BRECHT 87 AM 65 O at the $\Upsilon(45)$ $(+^+) = (1.02 \pm 0.0003 \pm 0.0003$ alue $B(J/\psi(15)$ $(+^+) = (1.02 \pm 0.0003 \pm 0.0003$ alue $B(J/\psi(15)$ $(+^+) = (1.02 \pm 0.0003 \pm 0.0003$ alue $B(J/\psi(15)$ $(+^+) = (1.02 \pm 0.0003 \pm 0.0003$ alue $B(J/\psi(15)$ $(+^+) = (1.02 \pm 0.0003 \pm 0.0003$ alue $B(J/\psi(15)$ $(+^+) = (1.02 \pm 0.0003 \pm 0.0003$ sequal production of 3 for $B(J/\psi(15)$ $(+^+) = (-^+) = 0.0003$ second error is $B(J/\psi(15) = 0.0003$ $(+^+) = (-^+) = 0.0003$ second error is $B(J/\psi(15) = 0.0003$ $(+^+) = (-^+) = 0.0003$ second error is $B(J/\psi(15) = 0.0003$ $(+^+) = (-^+) = 0.0003$ second error is $B(J/\psi(15) = 0.0003$ $(+^+) = (-^+) = 0.0003$ second error is $B(J/\psi(15) = 0.0003$ $(+^+) = (-^+) = 0.0003$ second error is $B(J/\psi(15) = 0.0003$ $(+^+) = (-^+) = 0.0003$ second error is $B(J/\psi(15) = 0.0003$ $(+^+) = (-^+) = 0.0003$ second error is $B(J/\psi(15) = 0.0003$ $(+^+) = (-^+) = 0.0003$ $(+^+) = (-^+) = 0.0003$ $(+^+) = (-^+) = 0.0003$ $(+^+) = (-^+) = 0.0003$ $(+^+) = (-^+) = 0.0003$ $(+^+) = (-^+) = 0.0003$ $(+^+) = (-^+) = 0.0003$ $(+^+) = (-^+) = 0.0003$ $(+^+) = (-^+) = 0.0003$ $(+^+) = (-^+) = 0.0003$ $(+^+) = (-^+) = 0.0003$ $(+^+) = (-^+) = 0.0003$ $(+^+) = (-^+) = 0.0003$ $(+^+) = (-^+) = 0.0003$ $(+^+) = (-^+) = 0.003$ $(+^+) = ($	CLE2 e^+ H CDF p ? CLEO e^+ CLEO e^+ Imits, etc. e^- Imits, etc. e^- Imits, etc. e^- Imits, etc. e^- CLEO e^+ Imits, etc. e^- Imits, etc. e^- Imits, etc. e^- CLEO Re 1.0.14) × 10 ⁻ 1.0.15 or B(J/ψ (1.5) → e^+e^-) 1.0.14) × 10 ⁻ 1.0.15 or B(J/ψ (1.5) → e^+e^- 1.0.16 or B + and B + same as a he same a he same as a he same as a he same a	$f = - \rightarrow T(45)$ $f = 18$ TeV $f = - \rightarrow T(45)$

VALUE CLAY	ıl				Γ ₅₉ /Γ	Γ(Κ 0 π0)	/F _{total}				Γ ₆₉
	<u>EVTS</u>	DOCUMENT ID		<u>COMMENT</u>		VALUE	<u> </u>	DOCUMENT GODANG		<u>COMMENT</u>	77(4.5)
< 5.8 × 10^{—5} 90 •• We do not use the	e followin	BISHAI or data for average		e ⁺ e ⁻ →	T(45)	<4.1 × 10		GODANG owing data for avera		e+e- → s. etc. • • •	7 (45)
<3.2 × 10 ⁻⁴ 90		¹⁷² ACCIARRI	97c L3			<4.0 × 10		ASNER	-	Rep. by G	ODANG 98
<6.9 × 10 ⁻³ 90		173 ALEXANDER		Sup. by BIS	SHAL 96	-		ASITER	70 CLL1	nep. by G	ODAING 30
172 ACCIARRI 970 assun						Γ(η' K ⁰),	Γ _{total}				Γ ₇₀
173 Assumes equal produ	uction of	B^+B^- and $B^0\overline{B}^0$	on T(45).	-, (-		YALUE		DOCUMENT	ID TECN	COMMENT	
			(/-		- /-	(4.7 ^{+2.7}	:0.9) × 10 ^{—5}	BEHRENS	98 CLE2	$e^+e^- \rightarrow$	T(45)
$\Gamma(J/\psi(1S)\eta)/\Gamma_{\text{total}}$					Γ ₆₀ /Γ						
VALUE	<u> </u>	DOCUMENT ID	TEÇN			Γ(η' K*(8	92) ⁰)/F _{total}				F71
<1.2 × 10 ⁻³		¹⁷⁴ ACCIARRI	97C L3			VALUE	CLS				
¹⁷⁴ ACCIARRI 97C assun	mes B^{\vee} p	roduction fraction	$(39.5 \pm 4.0\%)$	(a) and $B_{m{s}}$ (1	$2.0 \pm 3.0\%$).	<3.9 × 10	- s 90	BEHRENS	98 CLE2	e ⁺ e ⁻ →	T(45)
$\Gamma(J/\psi(1S)\rho^0)/\Gamma_{ m total}$					Γ ₆₁ /Γ	Γ(π Κ *(8	92) ⁰)/F _{total}				Γ ₇₂
VALUE	CL%	DOCUMENT ID	TECN	COMMENT		VALUE		DOCUMENT	ID TECN	COMMENT	. 12
<2.5 × 10 ⁻⁴	90	BISHAI	96 CLE2	e+e- →	T(45)	<3.0 × 10		BEHRENS		e+e- →	T(45)
-(-(-(- /-	_(_				` _
$\Gamma(J/\psi(15)\omega)/\Gamma_{\text{total}}$				COLUMENT	Γ ₆₂ /Γ	Γ(η <i>Κ</i> °)/					Γ ₇₃
<2.7 × 10 ⁻⁴	90	DOCUMENT ID		$\frac{COMMENT}{e^+e^-} \rightarrow$	T(45)	YALUE	<u>CL9</u>				
•	90	BISHAI	96 CLE2	e c →	1 (43)	<3.3 × 10	-5 90	BEHRENS	98 CLE2	e ⁺ e ⁻ →	T(45)
$\Gamma(\psi(2S)K^0)/\Gamma_{\text{total}}$					Γ ₆₃ /Γ	[Γ(K+π	Γ) + $\Gamma(\pi^+\pi^-)$	/Ferren		(r	68+F ₁₀₅)
VALUE	CL%	DOCUMENT ID	TECN_	COMMENT		VALUE		VTS DOCUME!	IT ID TEC	-	
<0.000		¹⁷⁵ ALAM		e^+e^-	T(45)	(1.9±0.6) × 10 ⁻⁵ OUF				
• • • We do not use the						(2.8+1.5	2.0) × 10 ⁻⁵	186 ADAM	960 DI	PH e+e	<i>→ Z</i>
<0.0015		175 BORTOLETT									
<0.0028		175 ALBRECHT		e ⁺ e ⁻ →	T(45)		0.47	7.2 ASNER		E2 e ⁺ e ⁻ -	→ T(45)
¹⁷⁵ Assumes equal produ	uction of	B^+ and B^0 at the	Υ(45).			• • • We	do not use the foll	owing data for aver-	ages, fits, limit:	s, etc. • • •	
$\Gamma(\psi(2S)K^+\pi^-)/\Gamma_{to}$	ntal .				Γ ₆₄ /Γ	(2.4+0.8	:0.2) × 10 ⁻⁵	187 BATTLE	93 CL	E2 e ⁺ e ⁻ -	→ T(45)
VALUE	CL%.	DOÇUMENT ID	TECN	COMMENT		-		= f _B - = 0.39 and	l / 0.12	Contributions	from BO
<0.001	90	176 ALBRECHT	90J ARG	e+e- →	T(45)	B_ dec	avs cannot be sepa	rated. Limits are g	ing = 0.12. Iven for the we	ighted averag	re of the de
176 Assumes equal produ	uction of	B^+ and B^0 at the	≥ Υ(4S).			rates fo	r the two neutral .	9 mesons			,
-(.(- =) .(+()() .	-		, ,			101 BATTI	.E 93 assumes equ	al production of B^0	B ^U and B ⁺ B	− at γ(45).	
Γ(ψ(2 <i>S</i>) K*(892) ⁰)/						Γ(K+K-)/[****				Γ ₇₄
VALUE 0.0014±0.0000±0.00	CF\$F	DOCUMENT I		COMMENT		VALUE	CLS	DOCUMENT	ID TECN	COMMENT	
• • We do not use the					, , (43)	<4.3 × 10	-6 90	GODANG	98 CLE2	e ⁺ e ⁻ →	T(45)
<0.0019	90	177 ALAM		2 e+e	. T(45)	• • • We	do not use the foll	owing data for aver-	ages, fits, limit	s, etc. • • •	
<0.0023	90	177 ALBRECHT				<4.6 × 10		188 ADAM		l e ⁺ e ⁻ →	
177 Assumes equal produ	uction of	B^+ and B^0 at the	e Υ(45).		` '	<0.4 × 10		ASNER ¹⁸⁹ BUSKULIC		Repl. by G	
						<1.8 × 10 <1.2 × 10		190 ABREU		e+e−⊸ ISup.byAl	
					Γ ₆₆ /Γ	<0.7 × 10		191 BATTLE		e+e- →	
$\Gamma(\chi_{c1}(1P)K^0)/\Gamma_{\mathrm{total}}$	<u>CL%</u>	<u>DOCUMENT ID</u> 178 ALAM		COMMENT e ⁺ e ⁻ →	~(4C)			$= f_{-} = 0.39 \text{ and}$	$f_{\rm P} = 0.12$.	Contributions	s from B^0 :
VALUE	00		_		` '	B _s der	ays cannot be sepa	$= f_{B^{-}} = 0.39$ and rated. Limits are g	lven for the we	ighted averag	e of the de
<0.0027				at the 7 (43	,).	rates fo	er the two neutral.	8 mesons. PDG 96 production			
<0.0027			, , , , , , , ,					uction fraction of 0			
VALUE	assumes e		, b und b		Γ ₆₇ /Γ						
VALUE <0.0027 178 BORTOLETTO 92 a Γ(X _{C1} (1 <i>P</i>) K*(892)01 VALUE	assumes e	equal production of	TECN	COMMENT		Contrib	utions from B ^O a	nd B_{\perp}^{0} decays cann	ot be separate	d. Limits are	e given for
$\frac{\sqrt{(1)UE}}{\sqrt{0.0027}}$ 178 BORTOLETTO 92 a $\Gamma(X_{c1}(1P)K^{6}(892)^{0})$ $\sqrt{(1)UE}$ $\sqrt{0.0021}$	assumes e)/F _{total} _ <u>CL%</u> 90	equal production of production	<u>TECN</u> 94 CLE2	e ⁺ e ⁻ →	Υ(45)	Contrib weight	ed average of the o	nd B_s^0 decays cannected ecay rates for the t	wo neutral <i>B</i> n	nesons.	e given for
VALUE <0.0027 178 BORTOLETTO 92 a T (X _{C1} (1P) K* (892)0°) VALUE <0.0021	assumes e)/F _{total} _ <u>CL%</u> 90	equal production of production	<u>TECN</u> 94 CLE2	e ⁺ e ⁻ →	Υ(45)	Contrib weight	ed average of the o	nd B_s^0 decays canniecay rates for the ${ m t}$	wo neutral <i>B</i> n	nesons.	e given for
√0.0027 √178 BORTOLETTO 92 a Γ(X _{c1} (1P) K* (892) ⁰ √0.0021 179 BORTOLETTO 92 a √179 BORTOLETTO 92	assumes e)/F _{total} _ <u>CL%</u> 90	equal production of production	<u>TECN</u> 94 CLE2	e ⁺ e ⁻ →	T(45)	Contrib welghte 191 BATTI	ed average of the o E 93 assumes equ	ecay rates for the t	wo neutral <i>B</i> n	nesons.	
κ_{ALUE} <0.0027 κ_{C1} (178 BORTOLETTO 92 a κ_{C1} (19 K° (892)0 κ_{ALUE} <0.0021 κ_{C1} $\kappa_{$	assumes e)/Γ _{total} _ <u>CL%</u> _ 90 assumes e	equal production of <u>DOCUMENT ID</u> 179 ALAM equal production of	94 CLE2 f B ⁺ and B ⁰	$e^+e^- \rightarrow$ at the $\Upsilon(45)$	Υ(45)	Contrib weight	ed average of the o E 93 assumes equ	ecay rates for the t al production of B ⁰	wo neutral <i>B</i> n B ⁰ and B ⁺ B	nesons.	F ₇₅
ALUE (A.0027) $(78800000000000000000000000000000000000$	assumes e)/F _{total} _ <u>CL%</u> 90	DOCUMENT ID DOCUMENT ID DOCUMENT ID	94 CLE2 f B ⁺ and B ⁰	$e^+e^- \rightarrow$ at the $\Upsilon(45)$	Υ(45) 5). Γ ₆₈ /Γ	Contrib weighte 191 BATTI Г(К⁰ 🏸	ed average of the of th	ecay rates for the t al production of B ⁰	wo neutral B n B ⁰ and B+B ID TECN	nesons. — at <i>T</i> (45).	Γ ₇₅
$\frac{(ALUE)}{(ALUE)}$ <0.0027 $\frac{(AC)}{(AC)}$ (892)0 $\frac{(AC)}{(AC)}$ (892)0 $\frac{(AC)}{(AC)}$ (892)0 $\frac{(AC)}{(AC)}$ (892)0 $\frac{(AC)}{(AC)}$ (892)0 $\frac{(AC)}{(AC)}$ (190)0 $\frac{(AC)}{(AC)}$ (190)0 $\frac{(AC)}{(AC)}$ (190)0 $\frac{(AC)}{(AC)}$ (190)0 $\frac{(AC)}{(AC)}$ (190)0 $\frac{(AC)}{(AC)}$ (190)0 $\frac{(AC)}{(AC)}$ (190)0 $\frac{(AC)}{(AC)}$ (190)0 $\frac{(AC)}{(AC)}$ (190)0	assumes e // / / total // ct% // 90 // asssumes e // ct%	DOCUMENT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID	94 CLE2 f B ⁺ and B ⁰ TECN 98 CLE2	$e^+e^- \rightarrow$ at the $\Upsilon(45)$ $\frac{COMMENT}{e^+e^- \rightarrow}$	Υ(45) 5). Γ ₆₈ /Γ	Contrib weight 191 BATTI F (K ^O R ^O) <u>YALUE</u> <1.7 x 10	ed average of the content of the con	ecay rates for the t al production of B ⁰ DOCUMENT	wo neutral B n B ⁰ and B+B ID TECN	at T(45).	Γ ₇₅
$\frac{(ALUE)}{(ALUE)}$ <0.0027 $\frac{(AC)}{(AC)}$ (892)0 $\frac{(AC)}{(AC)}$ (892)0 $\frac{(AC)}{(AC)}$ (892)0 $\frac{(AC)}{(AC)}$ (892)0 $\frac{(AC)}{(AC)}$ (892)0 $\frac{(AC)}{(AC)}$ (190)0 $\frac{(AC)}{(AC)}$ (190)0 $\frac{(AC)}{(AC)}$ (190)0 $\frac{(AC)}{(AC)}$ (190)0 $\frac{(AC)}{(AC)}$ (190)0 $\frac{(AC)}{(AC)}$ (190)0 $\frac{(AC)}{(AC)}$ (190)0 $\frac{(AC)}{(AC)}$ (190)0 $\frac{(AC)}{(AC)}$ (190)0	assumes e // / / total // ct% // 90 // asssumes e // ct%	DOCUMENT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID	94 CLE2 f B ⁺ and B ⁰ TECN 98 CLE2	$e^+e^- \rightarrow$ at the $\Upsilon(45)$ $\frac{COMMENT}{e^+e^- \rightarrow}$	Υ(45) 5). Γ ₆₈ /Γ	Contrib weight 191 BATTI F (K ⁰ K ⁰) YALUE <1.7 × 10 F (K ⁺ p ⁻	ed average of the of E 93 assumes equition (CLS) / \(\begin{align*} \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \	ecay rates for the t al production of B ^O . <u>DOCUMENT</u> GODANG	wo neutral B n B ^O and B+ B ID TECN 98 CLE2	nesons. at $T(45)$. COMMENT $e^+e^- \rightarrow$	Γ ₇₅
<0.0027 <178 BORTOLETTO 92 a $=$ $(X_{c1}(1P)K^{\circ}(892)^{0})$ = $<$ 0.0021 = $<$ 0.0021 = $=$ $=$ $=$ $=$ $=$ $=$ $=$ $=$ $=$	assumes e)//total	DOCUMENT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID	94 CLE2 f B+ and B ⁰ TECN 98 CLE2 es, fits, limits,	$e^+e^- \rightarrow$ at the $\Upsilon(45)$ $\frac{COMMENT}{e^+e^- \rightarrow}$	Υ(45) 5). Γ68/Γ	Contrib weight 191 BATTI \(\begin{align*} \begi	20 20 20 20 20 20 20 20	ecay rates for the tal production of B ⁰ DOCUMENT GODANG DOCUMENT	wo neutral B n B ^O and B+ B ID TECN 98 CLE2 ID TECN	resons. at $T(45)$. COMMENT $e^+e^- \rightarrow$ COMMENT	Γ ₇₅ Γ(45)
<0.0027 <7.78 BORTOLETTO 92 a = ($<$ c ₁ (1 P) K * (892) ⁰ <0.0021 = ($<$ Fibre 10.0021 = ($<$ F	assumes e)//total	DOCUMENT ID 179 ALAM Equal production of DOCUMENT ID GODANG Ig data for average	7ECN 94 CLE2 1 B+ and B ⁰ 7ECN 98 CLE2 25, fits, limits,	$e^+e^- \rightarrow$ at the $\Upsilon(45)$ $\frac{COMMENT}{e^+e^- \rightarrow}$ etc. • • •	τ(45) 5). Γ68/Γ τ(45)	Contrib weight 191 BATTI F (K ⁰ K ⁰) VALUE <1.7 × 10 F (K ⁺ p ⁻ VALUE <3.5 × 10	d average of the ci.E 93 assumes equi // Γtotal	ecay rates for the t al production of B ^O . <u>DOCUMENT</u> GODANG	wo neutral B n BO and B+ B ID TECN 98 CLE2	nesons. at $T(45)$. COMMENT $e^+e^- \rightarrow$	Γ ₇₅ Γ(45)
<0.0027 <178 BORTOLETTO 92 a $=$ $(K_{c1}(1P)K^{\circ}(892)^{0})$ = $<$ 0.0021 = $<$ 0.0021 = $=$ $=$ $=$ $=$ $=$ $=$ $=$ $=$ $=$	assumes e)// total - CL% 90 assumes e - CL% 90 90 90	DOCUMENT ID DOCUMENT ID ALAM Equal production of DOCUMENT ID GODANG AG data for average 180 ADAM ASNER 181 BUSKULIC	94 CLE2 f B+ and B ⁰ TECN 98 CLE2 es, fits, limits, 960 DLPH 96 CLE2 96V ALEP	$e^+e^- \rightarrow$ at the $\Upsilon(43)$ $\frac{COMMENT}{e^+e^- \rightarrow}$ etc. • • • $e^+e^- \rightarrow$ Sup. by AE $e^+e^- \rightarrow$	7(45) 5). F68/F T(45) Z	Contrib weight 191 BATTI F (K ⁰ K ⁰) VALUE <1.7 × 10 F (K ⁺ p ⁻ VALUE <3.5 × 10	d average of the ci.E 93 assumes equi // Γtotal	ecay rates for the tal production of B ⁰ DOCUMENT GODANG DOCUMENT	wo neutral B n BO and B+ B ID TECN 98 CLE2	resons. at $T(45)$. COMMENT $e^+e^- \rightarrow$ COMMENT	T(45) T(45)
<0.0027 178 BORTOLETTO 92 a $\Gamma(\chi_{c1}(1P) K^{\bullet}(892)^{0})$ VALUE <0.0021 179 BORTOLETTO 92 a $\Gamma(K^{+}\pi^{-})/\Gamma_{total}$ VALUE (units 10^{-5}) $1.5^{+}0.5_{-0.4}^{+}\pm0.14$ \bullet • • We do not use the $2.4^{+}1.7_{-1.1}^{+}\pm0.2$ < 1.7 < 3.0 < 9	assumes e (1) / \(\tau_{\text{total}}\) (2) / \(\text{Fotal} \) (2) / \(\text{Fotal} \) (3) / \(\text{Fotal} \) (4) / \(\text{Fotal} \) (5) / \(\text{Fotal} \) (6) / \(\text{Fotal} \) (6) / \(\text{Fotal} \) (7) / \(\text{Fotal} \) (8) / \(\text{Fotal} \) (9) / \(\text{Fotal} \) (1) / \(\text{Fotal} \) (1) / \(\text{Fotal} \) (1) / \(\text{Fotal} \) (2) / \(\text{Fotal} \) (3) / \(\text{Fotal} \) (4) / \(\text{Fotal} \) (5) / \(\text{Fotal} \) (6) / \(\text{Fotal} \) (7) / \(\text{Fotal} \) (8) / \(\text{Fotal} \) (8) / \(\text{Fotal} \) (9) / \(\text{Fotal} \) (1) / \(\text{Fotal} \) (1) / \(\text{Fotal} \) (1)	Equal production of DOCUMENT ID ALAM Equal production of DOCUMENT ID GODANG ag data for average 180 ADAM ASNER 181 BUSKULIC 182 ABREU	7ECN 94 CLE2 1 B+ and B ⁰ TECN 98 CLE2 25, fits, limits, 96D DLPH 96 CLE2 96V ALEP 95N DLPH	$e^+e^- \rightarrow$ at the $\Upsilon(45)$ $\frac{COMMENT}{e^+e^- \rightarrow}$ etc. • • • $e^+e^- \rightarrow$ Sup. by AE $e^+e^- \rightarrow$ Sup. by AE	7(45) 5). F68/F 7(45) Z DAM 96D Z DAM 96D	Contrib weight 191 BATTI F (K ⁰ K ⁰) VALUE <1.7 × 10 F (K ⁺ p ⁻ VALUE <3.5 × 10	20 20 20 20 20 20 20 20	ecay rates for the t all production of B ^Q <u>DOCUMENT</u> GODANG <u>DOCUMENT</u> ASNER	wo neutral <i>B</i> n B ⁰ and B ⁺ B 10 TECN 98 CLE2 10 TECN 96 CLE2	resons. at $T(45)$. COMMENT $e^+e^- \rightarrow$ COMMENT	Γ ₇₅ Γ(45)
<0.0027 <178 BORTOLETTO 92 a $\Gamma(\chi_{c1}(1P) K^{\bullet}(892)^{0})$ $<$ 0.0021 <179 BORTOLETTO 92 a $\Gamma(K^{+}\pi^{-})/\Gamma$ total $<$ 1.04 \pm 0.14 $<$ 0 • • We do not use the 2.4 \pm 1.7 \pm 0.2 <1.30 <9 $<$ 8.1	assumes e (i) / Ftotal CLX 90 assumes e CLX ie followin 90 90 90 90	Equal production of DOCUMENT ID SQUAL PRODUCTION OF THE SQUAL PRODUCTION OF TH	94 CLE2 f B+ and B ⁰ TECN 98 CLE2 es, fits, limits, 960 DLPH 96 CLE2 96v ALEP 95N DLPH 94L OPAL	$e^+e^- \rightarrow$ at the $\Upsilon(45)$ $\frac{COMMENT}{e^+e^- \rightarrow}$ etc. • • • $e^+e^- \rightarrow$ Sup. by AE $e^+e^- \rightarrow$ Sup. by AE $e^+e^- \rightarrow$	T(45) 5). F68/F T(45) Z DAM 96D Z DAM 96D Z	Contrib weight 191 BATTI F (K ⁰ R ⁰) VALUE <1.7 × 10 F (K ⁺ p ⁻ VALUE <3.5 × 10 F (K ⁰ π ⁺ VALUE	d average of the c E 93 assumes equ // Γtotal -5 90 // Γtotal -5 90 π ⁻ // Γtotal 61.2	ecay rates for the t all production of B ^Q <u>DOCUMENT</u> GODANG <u>DOCUMENT</u> ASNER	wo neutral <i>B</i> n	esons. — at T(4S). — COMMENT— — e ⁺ e ⁻ → — COMMENT— — c ⁺ e ⁻ →	T(45) T(45)
**ALUE (NOTE OF THE PROOF OF T	assumes e 2) / Ftotal CLX 90 assumes e CLX e followin 90 90 90 90	DOCUMENT ID TO ALAM Equal production of DOCUMENT ID GODANG Ig data for average 180 ADAM ASNER 181 BUSKULIC 182 ABREU 183 AKERS 184 BATTLE	94 CLE2 f B→ and B ^O TECN 98 CLE2 es, fits, limits, 96D DLPH 96 CLE2 96V ALEP 95N DLPH 94L OPAL 93 CLE2	$e^+e^- \rightarrow$ at the $\Upsilon(45)$ $COMMENT$ $e^+e^- \rightarrow$ etc. • • • $e^+e^- \rightarrow$ Sup. by AE $e^+e^- \rightarrow$ Sup. by AE $e^+e^- \rightarrow$ $e^+e^- \rightarrow$	T(45) 5). F68/F T(45) Z DAM 96D Z DAM 96D Z T(45)	Contribution weight 191 BATTI F (K ⁰ K ⁰) VALUE <1.7 × 10 F (K ⁺ p ⁻ VALUE <3.5 × 10 F (K ⁰ π ⁺ VALUE •••• We	ed average of the ci.E 93 assumes equi	ecay rates for the tall production of B ^Q DOCUMENT GODANG DOCUMENT ASNER DOCUMENT DOCUMENT	wo neutral <i>B</i> n <i>B</i> ⁰ and <i>B</i> + <i>B</i> 10	esons. — at T(4S). — COMMENT— — e ⁺ e ⁻ → — COMMENT— — c ⁺ e ⁻ →	T(45) T(45) T(45)
**ALUE	assumes e (1) / \(\bar{\tau} \) / / \(\bar{\tau} \) / \(\bar{\tau}	DOCUMENT ID 179 ALAM equal production of DOCUMENT ID GODANG Ig data for average 180 ADAM ASNER 181 BUSKULIC 182 ABREU 183 AKERS 184 BATTLE ALBRECHT	94 CLE2 f B+ and B ⁰ 7ECN 98 CLE2 es, fits, limits, 96D DLPH 96 CLE2 96V ALEP 95N DLPH 94L OPAL 93 CLE2 91B ARG	$e^+e^- \rightarrow$ at the $\Upsilon(45)$ $COMMENT$ $e^+e^- \rightarrow$ etc. • • • $e^+e^- \rightarrow$ Sup. by AE $e^+e^- \rightarrow$ Sup. by AE $e^+e^- \rightarrow$ $e^+e^- \rightarrow$ $e^+e^- \rightarrow$ $e^+e^- \rightarrow$	T(45) 5). T(45) Z DAM 96D Z DAM 96D Z T(45) T(45)	Contribution weight 191 BATTI F(K ⁰ K ⁰) YALUE <1.7 × 10 F(K ⁺ p ⁻ WALUE <3.5 × 10 F(K ⁰ π ⁺ VALUE ••• We <4.4 × 10	da average of the of E 93 assumes equivalent	ecay rates for the tall production of B ^Q DOCUMENT GODANG DOCUMENT ASNER DOCUMENT Owing data for aver	wo neutral <i>B</i> n <i>B</i> ⁰ and <i>B</i> + <i>B</i> 10	esons. — at T(45). — <u>COMMENT</u> — e ⁺ e ⁻ → — <u>COMMENT</u> — e ⁺ e ⁻ → — <u>COMMENT</u> s, etc. • • •	T(45) T(45) T(45) T(45) T(45)
**ALUE	assumes e (1) / \(\bar{\tau} \) / / \(\bar{\tau} \) / \(\bar{\tau}	DOCUMENT ID TO ALAM Equal production of DOCUMENT ID GODANG Ig data for average 180 ADAM ASNER 181 BUSKULIC 182 ABREU 183 AKERS 184 BATTLE	94 CLE2 f B+ and B ⁰ TECN 98 CLE2 es, fits, limits, 960 DLPH 96 CLE2 96V ALEP 95N DLPH 94L OPAL 93 CLE2 91B ARG 89B CLEO	$e^+e^- \rightarrow$ at the $\Upsilon(45)$ $COMMENT$ $e^+e^- \rightarrow$ etc. • • • $e^+e^- \rightarrow$ Sup. by AE $e^+e^- \rightarrow$ Sup. by AE $e^+e^- \rightarrow$ $e^+e^- \rightarrow$	T(45) 5). F68/F T(45) Z DAM 96D Z DAM 96D Z T(45) T(45) T(45)	Contrib weight 191 BATTI Γ (Κ ⁰ Κ ⁰) YALUE < 1.7 × 10 Γ (Κ ⁺ ρ ⁻ VALUE < 3.5 × 10 Γ (Κ ⁰ π ⁺ VALUE • • • We < 4.4 × 10 Γ (Κ ⁰ ρ ⁰)	Section Section	ecay rates for the tall production of B ⁰ L <u>DOCUMENT</u> GODANG DOCUMENT ASNER DOCUMENT Owing data for aver ALBRECH	wo neutral B n B and B+B ID TECN 98 CLE2 ID TECN 96 CLE2 ID TECN ages, fits, limit F 91E ARG		T(45) T(45) T(45)
CALUE <0.0027 178 BORTOLETTO 92 a $\Gamma(\chi_{c1}(1P) K^{\bullet}(892)^{0})$ CALUE <0.0021 179 BORTOLETTO 92 a $\Gamma(K^{+}\pi^{-})/\Gamma$ total CALUE 1.5 + 0.5 + 0.14 • • • We do not use the 2.4 + 1.7 ± 0.2 < 1.7 < 3.0 < 9 < 8.1 < 2.6 < 18 < 9 < 32	assumes of (1) / Ftotal (1) / F	Equal production of DOCUMENT ID 179 ALAM Equal production of DOCUMENT ID GODANG AG data for average 180 ADAM ASNER 181 BUSKULIC 182 ABREU 183 AKERS 184 BATTLE ALBRECHT 185 AVERY AVERY	94 CLE2 f B+ and B ⁰ TECN 98 CLE2 es, fits, limits, 960 DLPH 96 CLE2 96∨ ALEP 95N DLPH 94L OPAL 93 CLE2 91B ARG 898 CLEO 87 CLEO	$e^+e^- \rightarrow$ at the $T(4S)$ $COMMENT$ $e^+e^- \rightarrow$ etc. • • • $e^+e^- \rightarrow$ Sup. by AE $e^+e^- \rightarrow$	T(45) 5). F68/F T(45) Z DAM 96D Z DAM 96D Z T(45) T(45) T(45) T(45)	Contribution weight 191 BATTI F (K ⁰ R ⁰) VALUE <1.7 × 10 F (K ⁺ p ⁻ VALUE <3.5 × 10 F (K ⁰ π ⁺ VALUE ••• We <4.4 × 10 F (K ⁰ p ⁰) VALUE	dayerage of the color	ecay rates for the to all production of B ^Q DOCUMENT GODANG DOCUMENT ASNER DOCUMENT Owing data for aver ALBRECH	wo neutral <i>B</i> n	esons. — at T(45). — <u>COMMENT</u> — e ⁺ e ⁻ → — <u>COMMENT</u> — s, etc. • • • — e ⁺ e ⁻ →	7(45) 7(45) 7(45) 7(45) 7(45)
**ALUE	assumes of P)/ Γ total P 0/ Γ 10 P 10	DOCUMENT ID TO ALAM Equal production of DOCUMENT ID GODANG Ig data for average 180 ADAM ASNER 181 BUSKULIC 182 ABREU 183 AKERS 184 BATTLE ALBRECHT 185 AVERY AVERY To Be 39 and for the control of the c	94 CLE2 f B+ and B ⁰ TECN 98 CLE2 es, fits, limits, 960 DLPH 96 CLE2 96v ALEP 95N DLPH 94L OPAL 93 CLE2 91B ARG 89B CLE0 87 CLE0 87 CLEO	$e^+e^- \rightarrow$ at the $T(43)$ $COMMENT$ $e^+e^- \rightarrow$ etc. • • • $e^+e^- \rightarrow$ Sup. by AE $e^+e^- \rightarrow$	T(45) 5). F68/F T(45) Z DAM 96D Z DAM 96D Z T(45) T(45) T(45) from B ⁰ and	Contribution weight 191 BATTI F (K ⁰ R ⁰) VALUE <1.7 × 10 F (K ⁺ p ⁻ VALUE <3.5 × 10 F (K ⁰ π ⁺ VALUE ••• We <4.4 × 10 F (K ⁰ p ⁰) VALUE <3.9 ×	dayerage of the color	ecay rates for the total production of B ^Q DOCUMENT GODANG DOCUMENT ASNER DOCUMENT OWING data for aver ALBRECH* DOCUMENT ASNER	wo neutral <i>B</i> n \$\begin{array}{l} \begin{array}{l} \begin{array} \begin{array}{l} \begin{array}{l} \begin{array}{l}		7(45) 7(45) 7(45) 7(45) 7(45)
ALUE **CALUE**	assumes of $\frac{CL\%}{90}$	DOCUMENT ID TO ALAM Equal production of DOCUMENT ID GODANG To ASNER 181 BUSKULIC 182 ABREU 183 AKERS 184 BATTLE ALBRECHT 185 AVERY AVERY AVERY To BY ALIMITS are givened in the seconds	94 CLE2 f B+ and B ⁰ 98 CLE2 es, fits, limits, 960 DLPH 96 CLE2 96v ALEP 95N DLPH 94L OPAL 93 CLE2 918 ARG 898 CLE0 87 CLEO 87 CLEO	$e^+e^- \rightarrow$ at the $T(43)$ $\frac{COMMENT}{e^+e^-}$ etc. • • • $e^+e^- \rightarrow$ Sup. by AE $e^+e^- \rightarrow$ $e^+e^- \rightarrow$ $e^+e^- \rightarrow$ $e^+e^- \rightarrow$ $e^+e^- \rightarrow$ $e^+e^- \rightarrow$ contributions, thed average.	T(45) 5). F68/F T(45) Z DAM 96D Z DAM 96D Z T(45) T(45) T(45) T(45) from B ⁰ and e of the decay	Contribution weight 191 BATTI F (K ⁰ K ⁰) VALUE <1.7 × 10 F (K ⁺ p ⁻ VALUE <3.5 × 10 F (K ⁰ π ⁺ VALUE ••• We <4.4 × 10 F (K ⁰ p ⁰) VALUE <3.9 × ••• We	A syrange of the color	DOCUMENT ASNER OCUMENT ASNER DOCUMENT ASNER DOCUMENT ASNER DOCUMENT ASNER	wo neutral <i>B</i> n ### B and B + B ### B CLE2 ### P6 CLE2 ### TECN 96 CLE2		T(45) T(45) T(45) T(45) T(45) T(45)
ALUE **CALUE**	assumes of $\frac{CL\%}{90}$ and $\frac{CL\%}{90}$ assumes of $\frac{CL\%}{90}$ and $\frac{CL\%}{90}$ and $\frac{CL\%}{90}$ and $\frac{CL\%}{90}$ assumes of $\frac{CL\%}{90}$ and $\frac{CL\%}{90$	Equal production of DOCUMENT ID 179 ALAM Equal production of DOCUMENT ID GODANG IS data for average 180 ADAM ASNER 181 BUSKULIC 182 ABREU 183 AKERS 184 BATTLE ALBRECHT 185 AVERY Tellow ALBRECHT 185 AVERY Tellow ALBRECHT 186 ALBRECHT 187 AVERY Tellow ALBRECHT 188 AVERY Tellow ALBRECHT 188 AVERY Tellow ALBRECHT 188 AVERY Tellow ALBRECHT 188 AVERY Tellow ALBRECHT 189 AVERY Tellow ALBRECHT 189 AVERY Tellow ALBRECHT 189 AUGUST 189 ALAM	94 CLE2 f B+ and B ⁰ TECN 98 CLE2 es, fits, limits, 96D DLPH 96 CLE2 96V ALEP 95N DLPH 94L OPAL 93 CLE2 91B ARG 89B CLEO 87 CLEO n for the weig	$e^+e^- \rightarrow$ at the $T(43)$ $COMMENT$ $e^+e^- \rightarrow$ etc. • • • $e^+e^- \rightarrow$ Sup. by AE $e^+e^- \rightarrow$ $e^+e^- \rightarrow$ $e^+e^- \rightarrow$ $e^+e^- \rightarrow$ $e^+e^- \rightarrow$ contributions thed average $e^+e^- \rightarrow e^+e^- \rightarrow$ $e^+e^- \rightarrow e^+e^- \rightarrow$	T(45) 5). F68/F T(45) Z DAM 96D Z DAM 96D Z T(45) T(45) T(45) from B ⁰ and e of the decay of baryons.	Contribution weight 191 BATTI F (K° K°) YALUE <1.7 × 10 F (K+ p- YALUE <3.5 × 10 F (K° π+ VALUE ••• We <4.4 × 10 F (K° p°) YALUE <3.9 × ••• We <3.2 ×	A serage of the color	ecay rates for the tall production of B ^Q L DOCUMENT GODANG DOCUMENT ASNER DOCUMENT ASNER ALBRECH ASNER Owing data for aver ALBRECH ALBRECH ALBRECH	## wo neutral B in ## B and B + B ## B CLE2 ## 96 CLE2 ## 10	esons. — at T(45). — COMMENT — e+e — → — COMMENT — s, etc. • • • — +e — → — COMMENT — e+e — →	T(45) T(45) T(45) T(45) T(45) T(45) T(45)
ALUE **C.1.0027* **L78** **BORTOLETTO 92 a **[(X_{c1}(1P) K^*(892)^0]* **PALUE** **C.0021* **L79** **BORTOLETTO 92 a **[(K+ π -)/\(\tau\)/\(\tau\) **L0.5** **L0.4*\(\tau\).14 **•* We do not use the 2.4+1.7\(\tau\).2 < 1.7 < 3.0 < 9 < 8.1 < 2.6 < 18 < 9 < 3.2 \$180** **ADAM 96D assumes **B_s** **B_s** **B_s** **BOSKULLO 96v assumes **BUSKULLO 96v assumes **B	assumes of $\frac{CL\%}{90}$ and $\frac{CL\%}{90}$ assumes of $\frac{CL\%}{90}$ and $\frac{CL\%}{90}$ and $\frac{CL\%}{90}$ assumes of $\frac{CL\%}{90}$ and $\frac{CL\%}{90}$ and $\frac{CL\%}{90}$ and $\frac{CL\%}{90}$	Equal production of DOCUMENT ID 179 ALAM Equal production of DOCUMENT ID GODANG IS data for average 180 ADAM ASNER 181 BUSKULIC 182 ABREU 183 AKERS 184 BATTLE ALBRECHT 185 AVERY VERY (Fa. = 0.39 and fa. Indicate the second of the second o	94 CLE2 f B^+ and B^0 98 CLE2 es, fits, limits, 96D DLPH 96 CLE2 96V ALEP 95N DLPH 94L OPAL 93 CLE2 91B ARG 89B CLEO 87 CLEO n for the weig actions for B^0	$e^+e^- \rightarrow$ at the $T(43)$ $\frac{COMMENT}{e^+e^-} \rightarrow$ etc. • • • $e^+e^- \rightarrow$ Sup. by AE $e^+e^- \rightarrow$ $e^+e^- \rightarrow$ $e^+e^- \rightarrow$ $e^+e^- \rightarrow$ $e^+e^- \rightarrow$ contributions thed average $e^+e^- \rightarrow$ roduction fra $e^+e^- \rightarrow$ roduction fra	T(45) 5). F68/F T(45) Z DAM 96D Z DAM 96D Z T(45) T(45) T(45) from B ⁰ and e of the decay of baryons. ection of 0.12.	Contribution weight 191 BATTI F (K° K°) YALUE <1.7 × 10 F (K+ p- YALUE <3.5 × 10 F (K0 π+ VALUE <4.4 × 10 F (K0 p°) YALUE <3.9 × <5.0 ×	Section Section Section	CONTROL OF THE ENTRY OF THE ENT	wo neutral <i>B</i> n \$\overline{B}^0\$ and \$B^+\$ B \$\overline{B}^0\$ CLE2 \$\overline{B}^0\$ CLE2 \$\overline{B}^0\$ TECN \$\overline{A}^0\$ ages, fits, limit: \$\overline{B}^0\$ TECN \$\overline{B}^0\$ CLE2 \$\overline{B}^0\$ SPB CLEC \$\overline{B}^0\$ ARG \$\overline{B}^0\$ SPB CLEC \$\overline{B}^0\$ SPB CLEC	COMMENT c+c- COMMENT c+c- COMMENT c+c- COMMENT c+c- c+c- comment c+c- c+	T(45) T(45) T(45) T(45) T(45) T(45) T(45) T(45)
ALUE **C.10027* **I78** **BORTOLETTO 92 a	assumes of $\frac{CLN}{90}$ assumes of $\frac{CLN}{90}$ assumes of $\frac{CLN}{90}$ assumes of $\frac{CLN}{90}$ as following $\frac{90}{90}$	Equal production of DOCUMENT ID 179 ALAM Equal production of DOCUMENT ID GODANG Ig data for average 180 ADAM ASNER 181 BUSKULIC 182 ABREU 183 AKERS 184 BATTLE ALBRECHT 185 AVERY AVERY AVERY AVERY GE = 0.39 and for It limits are give esons. 5 96 production fraction of 0.35 90 decays cannot	$\frac{TECN}{94}$ CLE2 f B^+ and B^0 $\frac{TECN}{98}$ CLE2 es, fits, limits, 96D DLPH 96 CLE2 96V ALEP 95N DLPH 94 LOPAL 93 CLE2 918 ARG 898 CLEO 87 CLEO 87 CLEO 87 CLEO 87 and a 85 pub be separated	$e^+e^- \rightarrow$ at the $T(4S)$ $COMMENT$ $e^+e^- \rightarrow$ etc. • • • $e^+e^- \rightarrow$ Sup. by AE $e^+e^- \rightarrow$ $e^+e^- \rightarrow$ $e^+e^- \rightarrow$ $e^+e^- \rightarrow$ $e^+e^- \rightarrow$ contributions the average $e^+e^- \rightarrow$ $e^- $	T(45) 5). F68/F T(45) Z DAM 96D Z DAM 96D Z T(45) T(45) T(45) from B ⁰ and e of the decay of baryons. ection of 0.12.	Contribution weight 191 BATTI F (K ⁰ K ⁰) YALUE <1.7 × 10 F (K ⁺ p ⁻ WALUE <3.5 × 10 F (K ⁰ π ⁺ VALUE ••• We <4.4 × 10 F (K ⁰ p ⁰) YALUE <3.9 × ••• We <5.0 × <0.064	CL2	ecay rates for the tall production of B ^Q DOCUMENT GODANG DOCUMENT ASNER DOCUMENT ASNER DOCUMENT ASNER DOCUMENT ASNER DOCUMENT ASNER Owing data for aver ALBRECH' 192 AVERY 193 AVERY	wo neutral B n B ⁰ and B ⁺ B ID TECN 98 CLE2 ID TECN 96 CLE2 ID TECN 96 CLE2 ages, fits, limit: 1 918 ARG 918 ARG 87 CLEC 87 CLEC		T(45) T(45) T(45) T(45) T(45) T(45) T(45) T(45) T(45)
ALUE **CALUE** **LOS ALUE** **CALUE** **LOS ALUE** **CALUE** **LOS ALUE** **CALUE** **CALUE** **LOS ALUE** **CALUE**	assumes e $CL\%$	DOCUMENT ID 179 ALAM equal production of DOCUMENT ID GODANG g data for average 180 ADAM ASNER 181 BUSKULIC 182 ABREU 183 AKERS 184 BATTLE ALBRECHT 185 AVERY AVERY FB = 0.39 and fp cd. Limits are give esons. 6 96 production fra on fraction of 0.38 g decays cannot y rates for the two	94 CLE2 f B+ and B ⁰ TECN 98 CLE2 es, fits, limits, 96D DLPH 96 CLE2 96V ALEP 95N DLPH 94L OPAL 93 CLE2 91B ARG 89B CLEO 87 CLEO (85 = 0.12. C) n for the weig actions for B ⁰ 9 and a B ₅ pi be separated	$e^+e^- \rightarrow$ at the $T(4S)$ $COMMENT$ $e^+e^- \rightarrow$ etc. • • • $e^+e^- \rightarrow$ Sup. by AE $e^+e^- \rightarrow$ $e^+e^- \rightarrow$ $e^+e^- \rightarrow$ $e^+e^- \rightarrow$ $e^+e^- \rightarrow$ $e^+e^- \rightarrow$ contributions thed average (AB^+, B_S, E^-) roduction fra Limits are	T(45) 5). F68/F T(45) Z DAM 96D Z DAM 96D Z T(45) T(45) T(45) from B ⁰ and e of the decay of baryons. ection of 0.12.	Contribution weight 191 BATTI F(K°K°) YALUE <1.7 × 10 F(K+ p- YALUE <3.5 × 10 F(K° π+ WALUE <4.4 × 10 F(K° p°) YALUE <3.9 × <5.0 × <0.064 192 ALES rescale	Separate of the calculation	ecay rates for the total production of B ⁰ DOCUMENT GODANG DOCUMENT ASNER DOCUMENT Owing data for aver ALBRECH ASNER Owing data for aver ALBRECH 192 AVERY 193 AVERY 18 × 10 ⁻⁴ assuming	wo neutral B n B ⁰ and B ⁺ B ID TECN 98 CLE2 ID TECN 96 CLE2 ID TECN 1D	COMMENT c+e- → COMMENT c+e- → COMMENT c+e- → COMMENT c, etc. • • • c+e- → c+	T(45)
ALUE **C.10027* **I78** **BORTOLETTO 92 a	assumes e $CL\%$	DOCUMENT ID DOCUMENT ID TO ALAM Equal production of DOCUMENT ID GODANG TO ASNER THE BUSKULIC THE ALBREU THE ALBRECHT THE A	94 CLE2 f B+ and B ⁰ 7ECN 98 CLE2 es, fits, limits, 96D DLPH 96 CLE2 96V ALEP 95N DLPH 94L OPAL 93 CLE2 91B ARG 89B CLEO 87 CLEO (8 ₂ = 0.12. C n for the weig actions for B ⁰ 9 and a B ₅ pi be separated faction 39.5%	$e^+e^- \rightarrow$ at the $T(4S)$ $e^+e^- \rightarrow$ etc. • • • $e^+e^- \rightarrow$ Sup. by AE $e^+e^- \rightarrow$ $e^+e^- \rightarrow$ $e^+e^- \rightarrow$ $e^+e^- \rightarrow$ $e^+e^- \rightarrow$ $e^+e^- \rightarrow$ contributions (hted average) $e^+e^- \rightarrow$ $e^- \rightarrow$ e	T(45) 5). F68/F T(45) Z DAM 96D Z DAM 96D Z T(45) T(45) T(45) from B ⁰ and e of the decay of baryons. ection of 0.12.	Contribution weight 191 BATTI F(K°K°) YALUE <1.7 × 10 F(K+ p- YALUE <3.5 × 10 F(K° π+ WALUE <4.4 × 10 F(K° p°) YALUE <3.9 × <5.0 × <0.064 192 ALES rescale	Separate of the calculation	ecay rates for the tall production of B ^Q DOCUMENT GODANG DOCUMENT ASNER DOCUMENT ASNER DOCUMENT ASNER DOCUMENT ASNER DOCUMENT ASNER Owing data for aver ALBRECH' 192 AVERY 193 AVERY	wo neutral B n B ⁰ and B ⁺ B ID TECN 98 CLE2 ID TECN 96 CLE2 ID TECN 1D	COMMENT c+e- → COMMENT c+e- → COMMENT c+e- → COMMENT c, etc. • • • c+e- → c+	T(45)

(K ⁰ f ₀ (980))/Γ _{total} Γ ₇₉ /Γ	Γ(<i>K</i> ~ a ₁ (1260)+)	/r _{total}				Г
LUE CL% DOCUMENT ID TECN COMMENT	VALUE	CT.R	DOCUMENT ID		COMMENT	
3.6 × 10 ⁻⁴ 90 ¹⁹⁴ AVERY 89B CLEO $e^+e^- \rightarrow \Upsilon(45)$	<2.3 x 10 ⁻⁴ • • • We do not use		204 ADAM		e ⁺ e ⁻ →	Z
⁴ AVERY 89B reports $< 4.2 \times 10^{-4}$ assuming the $T(45)$ decays 43% to $B^0 \overline{B}{}^0$. We						
rescale to 50%.	<3.9 × 10 ⁻⁴				Sup. by AD	
$(K^*(892)^+\pi^-)/\Gamma_{\text{total}}$ Γ_{80}/Γ	204 ADAM 96D assur	$\operatorname{mes} f_{B^0} = f$	$B^- = 0.39$ and f_B	= 0.12. C	ontributions	from B
LUE CLY DOCUMENT ID TECN COMMENT	rates for the two	neutral R m	d. Limits are given			
7.2 × 10 ⁻⁵ 90 ASNER 96 CLE2 $e^+e^- → \Upsilon(4S)$	205 Assumes a B ⁰ , I	B production	on fraction of 0.39	and a B _c pi	roduction fra	ction of
3.8 × 10⁻⁴ 90 ¹⁹⁵ AVERY 89B CLEO $e^+e^- \rightarrow \Upsilon(45)$	Contributions fro	om B^0 and B	G decays cannot b	e separated	. Limits are	given fo
■ We do not use the following data for averages, fits, limits, etc. ■ ■ ■			rates for the two r			•
6.2×10^{-4} 90 ALBRECHT 91B ARG $e^+e^- \rightarrow \Upsilon(4S)$	Γ(K*(892) ⁰ K+ K	(=) /F				г.
6.6×10^{-4} 90 196 AVERY 87 CLEO $e^+e^- \rightarrow T(4S)$		•				Γę
AVERY 898 reports $< 4.4 \times 10^{-4}$ assuming the $\Upsilon(45)$ decays 43% to $B^0 \overline{B}{}^0$. We	VALUE	cr.zr	DOCUMENT ID	TECN		*****
rescale to 50%	<6.1 × 10 ⁻⁴	90	ALBRECHT	91E ARG	e ⁺ e ⁻ →	7(45)
AVERY 87 reports $< 7 \times 10^{-4}$ assuming the $\Upsilon(4S)$ decays 40% to $B^0\overline{B}^0$. We rescale to 50%.	$\Gamma(K^{*}(892)^{0}\phi)/\Gamma_{t}$	hotai				Γg
	VALUE	CI X	DOCUMENT ID	TECN	COMMENT	
$K^*(892)^0\pi^0)/\Gamma_{total}$ Γ_{81}/Γ	<4.3 × 10 ⁵	90	ASNER		$e^+e^- \rightarrow$	T(45)
UE CL% DOCUMENT ID TECN COMMENT	• • We do not use					. ()
$.8 \times 10^{-5}$ 90 ASNER 96 CLE2 $e^+e^- \rightarrow \Upsilon(4S)$	$< 3.2 \times 10^{-4}$	90	ALBRECHT	91B ARG	e ⁺ e ⁻ →	T(45)
` '	<3.8 × 10 ⁻⁴		206 AVERY		e+e- →	
$\binom{*}{2}(1430)^{+}\pi^{-})/\Gamma_{\text{total}}$ Γ_{82}/Γ	<3.8 × 10 ⁻⁴				e+ e- →	
UE CLY DOCUMENT ID TECN COMMENT	206 AVERY 89B repo					
.6 × 10 ⁻³ 90 ALBRECHT 918 ARG e^+e^- → $T(45)$	rescale to 50%					
Λν+ν-\/r	207 AVERY 87 report	ts < 4.7 × 10°	$^{-4}$ assuming the $ au$	45) decays	40% to B ⁰ B	U. We n
(° K+ K-)/\(\Gamma_{\text{total}}\)	to 50%.					
UE CL% DOCUMENT ID TECN COMMENT	$\Gamma(K_1(1400)^0 \rho^0)/$	Tental				Г
.3 × 10 ⁻³ 90 ALBRECHT 91E ARG e^+e^- → $T(45)$	VALUE	CLN	DOCUMENT ID	TECN_	COMMENT	
K ⁰ φ)/Γ _{total} Γ ₈₄ /Γ	<3.0 × 10 ⁻³	90	ALBRECHT	91B ARG	e+e- →	T(45)
UE CL% DOCUMENT ID TECN COMMENT						,
.8 × 10^{-5} 90 ASNER 96 CLE2 $e^+e^- \rightarrow \Upsilon(4S)$	$\Gamma(K_1(1400)^0\phi)/\Gamma$	total				Г
• We do not use the following data for averages, fits, limits, etc. • • •	VALUE	CL%	DOCUMENT ID	TECN	COMMENT	
2×10^{-4} 90 ALBRECHT 918 ARG $e^+e^- \rightarrow \Upsilon(4S)$	<5.0 × 10 ⁻³	90	ALBRECHT	91B ARG	$e^+e^- \rightarrow$	T(45)
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	F/W#/44000 0\	/r				_
0×10^{-3} 90 198 AVERY 87 CLEO $e^+e^- \rightarrow T(45)$	$\Gamma(K_2^*(1430)^0 \rho^0)/$					F
AVERY 89B reports $< 4.9 \times 10^{-4}$ assuming the $T(4.5)$ decays 43% to $B^{0}\overline{B}^{0}$. We	VALUE	<u>cr</u> %.	DOCUMENT ID	<u>TECN</u>	COMMENT	
rescale to 50%	<1.1 × 10 ⁻³	90	ALBRECHT	91B ARG	e ⁺ e ⁻ →	T(45)
AVERY 87 reports $<$ 1.3 \times 10 ⁻³ assuming the $\Upsilon(45)$ decays 40% to $B^0\overline{B}^0$. We rescale to 50%.	Γ(K ₂ (1430) ⁰ φ)/Γ		DOCUMENT ID	TECN	COMMENT	Γş
$(K^-\pi^+\pi^+\pi^-)/\Gamma_{\text{total}}$ Γ_{85}/Γ	VALUE <1.4 × 10 ⁻³	90 90	DOCUMENT ID ALBRECHT	<u>TECN</u> 91B ARG	$e^+e^- \rightarrow$	T(45)
LUE CL% DOCUMENT ID TECN COMMENT						` '
						Γş
	$\Gamma(K^*(892)^0\gamma)/\Gamma_t$	COCEI				
2.3 × 10 ⁻⁴ 90 199 ADAM 960 DLPH $e^+e^- \rightarrow Z$	Γ(K*(892) ⁰ γ)/Γ _t <u>VALUE</u> (units 10 ⁻⁵)	CL%				MMENT
2.3 \times 10 ⁻⁴ 90 199 ADAM 96D DLPH e ⁺ e ⁻ \rightarrow Z \rightarrow • We do not use the following data for averages, fits, limits, etc. • • •			8 208 AMMA		CLE2 e+	MMENT e →
2.3 \times 10 ⁻⁴ 90 199 ADAM 96D DLPH e ⁺ e ⁻ \rightarrow Z \bullet • We do not use the following data for averages, fits, limits, etc. \bullet • • 2.1 \times 10 ⁻⁴ 90 200 ABREU 95N DLPH Sup. by ADAM 96D	VALUE (units 10 ⁻⁵) 4.0±1.7±0.8	<u>C1%</u>	8 ²⁰⁸ AMMA	R 93	CLE2 e+	MMENT
2.3 × 10 ⁻⁴ 90 199 ADAM 96D DLPH $e^+e^- \rightarrow Z$ • • We do not use the following data for averages, fits, limits, etc. • • • 2.1 × 10 ⁻⁴ 90 200 ABREU 95N DLPH Sup. by ADAM 96D • ADAM 96D assumes $f_{B0} = f_{B^-} = 0.39$ and $f_{B_5} = 0.12$. Contributions from B^0 and B_5 decays cannot be separated. Limits are given for the weighted average of the decay	VALUE (units 10 ⁻⁵) 4.0±1.7±0.8 • • • We do not use	CL%	8 208 AMMA g data for averages	R 93 , fits, limits,	CLE2 e ⁺	MMENT e → T(45)
2.3 × 10 ⁻⁴ 90 199 ADAM 96D DLPH $e^+e^- \rightarrow Z$ • • We do not use the following data for averages, fits, limits, etc. • • • 2.1 × 10 ⁻⁴ 90 200 ABREU 95N DLPH Sup. by ADAM 96D • ADAM 96D assumes $f_{B0} = f_{B^-} = 0.39$ and $f_{B_5} = 0.12$. Contributions from B^0 and B_5 decays cannot be separated. Limits are given for the weighted average of the decay	VALUE (units 10 ⁻⁵) 4.0±1.7±0.8 • • • • We do not use < 21	ct% e the followin	8 208 AMMA g data for averages 209 ADAM	R 93 , fits, limits, 960	CLE2 e ⁺ etc. • • DLPH e ⁺	$ \begin{array}{c} $
2.3 \times 10 ⁻⁴ 90 199 ADAM 96D DLPH $e^+e^- \rightarrow Z$ • We do not use the following data for averages, fits, limits, etc. • • • 2.1 \times 10 ⁻⁴ 90 200 ABREU 95N DLPH Sup. by ADAM 96D ADAM 96D assumes $f_{B^0} = f_{B^-} = 0.39$ and $f_{B_s} = 0.12$. Contributions from B^0 and B_s decays cannot be separated. Limits are given for the weighted average of the decay rates for the two neutral B mesons. Assumes a B^0 , B^- production fraction of 0.39 and a B_s production fraction of 0.12.	VALUE (units 10 ⁻⁵) 4.0±1.7±0.8 • • • We do not use	CL%	8 208 AMMA g data for averages 209 ADAM ALBRE	R 93 , fits, limits, 960 CHT 890	CLE2 e+ etc. • • • DLPH e+ ARG e+	MMENT e → T(45)
2.3 \times 10 ⁻⁴ 90 199 ADAM 96D DLPH $e^+e^- \rightarrow Z$ • We do not use the following data for averages, fits, limits, etc. • • • 2.1 \times 10 ⁻⁴ 90 200 ABREU 95N DLPH Sup. by ADAM 96D ADAM 96D assumes $f_{B^0} = f_{B^-} = 0.39$ and $f_{B_5} = 0.12$. Contributions from B^0 and B_5 decays cannot be separated. Limits are given for the weighted average of the decay rates for the two neutral B mesons. Assumes a B^0 , B^- production fraction of 0.39 and a B_5 production fraction of 0.12. Contributions from B^0 and B_5^0 decays cannot be separated. Limits are given for the	VALUE (units 10 ⁻⁵) 4.0±1.7±0.8 • • • • We do not use < 21	ct% e the followin	8 208 AMMA g data for averages 209 ADAM	R 93 , fits, limits, 960 CHT 890	CLE2 e+ etc. • • DLPH e+ ARG e+	$ \begin{array}{c} $
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199 ADAM 96D DLPH $e^+e^- \rightarrow Z$ • We do not use the following data for averages, fits, limits, etc. • • • 1 × 10 ⁻⁴ 90 200 ABREU 95N DLPH Sup. by ADAM 96D ADAM 96D assumes $f_{B^0} = f_{B^-} = 0.39$ and $f_{B_s} = 0.12$. Contributions from B^0 and B_s decays cannot be separated. Limits are given for the weighted average of the decay rates for the two neutral B mesons. Assumes a B^0 , B^- production fraction of 0.39 and a B_s production fraction of 0.12. Contributions from B^0 and B_s^0 decays cannot be separated. Limits are given for the weighted average of the decay rates for the two neutral B mesons.	VALUE (units 10 ⁻⁵) 4.0±1.7±0.8 • • • We do not use < 21 < 42	CL% e the followin 90 90	8 208 AMMA g data for averages 209 ADAM ALBRE	R 93 , fits, limits, 960 CHT 890 898	CLE2 e+ etc. • • DLPH e+ ARG e+ CLEO e+	$ \begin{array}{c} $
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• We do not use the following data for averages, fits, limits, etc. • • • • • • • • • • • • • • • • • • •	VALUE (units 10 ⁻⁵) 4.0±1.7±0.8 • • • We do not use < 21 < 42 < 24 <210 208 AMMAR 93 obse 209 ADAM 96D assur	e the following 90 90 90 erved 6.6 ± 2 mes $f_{B^0} = f_{B^0}$	8 208 AMMA g data for averages 209 ADAM ALBRE 210 AVERY AVERY .8 events above bat $B_{3-} = 0.39$ and f_{B_3}	R 93 , fits, limits, 96c CHT 896 898 87 ckground. = 0.12.	etc. • • • DLPH e+ ARG e+ CLEO e+	$ \begin{array}{ccc} & & & \\ & & & &$
• We do not use the following data for averages, fits, limits, etc. • • • • $1 \times 10^{-4} \qquad 90 \qquad 200 \text{ ABREU} \qquad 95 \text{N DLPH} \text{Sup. by ADAM 96D}$ ADAM 96D assumes $f_{B0} = f_{B-} = 0.39$ and $f_{B_S} = 0.12$. Contributions from B^0 and B_S decays cannot be separated. Limits are given for the weighted average of the decay rates for the two neutral B mesons. Assumes a B^0 , B^- production fraction of 0.39 and a B_S production fraction of 0.12. Contributions from B^0 and B_S^0 decays cannot be separated. Limits are given for the weighted average of the decay rates for the two neutral B mesons. $K^*(892)^0 \pi^+ \pi^-)/\Gamma_{\text{total}} \qquad \Gamma_{\text{BOCUMENT ID}} \qquad \Gamma_{\text$	VALUE (units 10 ⁻⁵) 4.0±1.7±0.8 • • • We do not use < 21 < 42 < 24 <210 208 AMMAR 93 obse	e the following 90 90 90 erved 6.6 ± 2 mes $f_{B^0} = f_{B^0}$	8 208 AMMA g data for averages 209 ADAM ALBRE 210 AVERY AVERY .8 events above bat $B_{3-} = 0.39$ and f_{B_3}	R 93 , fits, limits, 96c CHT 896 898 87 ckground. = 0.12.	etc. • • • DLPH e+ ARG e+ CLEO e+	$ \begin{array}{ccc} & & & & \\ & & & & \\ & & & & \\ & & & &$
• We do not use the following data for averages, fits, limits, etc. • • • • • • • • • • • • • • • • • • •	VALUE (units 10 ⁻⁵) 4.0±1.7±0.8 • • • We do not use < 21 < 42 < 24 <210 208 AMMAR 93 obse 209 ADAM 96D assur 210 AVERY 898 reporescale to 50%.	e the followin 90 90 90 90 erved 6.6 ± 2 mes $f_{B^0} = f_{10}$ orts $< 2.8 \times 10^{-10}$	8 208 AMMA g data for averages 209 ADAM ALBRE 210 AVERY AVERY .8 events above bat $B_{3-} = 0.39$ and f_{B_3}	R 93 , fits, limits, 96c CHT 896 898 87 ckground. = 0.12.	etc. • • • DLPH e+ ARG e+ CLEO e+	$ \begin{array}{ccc} & & & & & \\ & & & & & \\ & & & & \\ & & & &$
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2.3 × 10 ⁻⁴ 90 199 ADAM 96D DLPH $e^+e^- \rightarrow Z$ • We do not use the following data for averages, fits, limits, etc. • • • 2.1 × 10 ⁻⁴ 90 200 ABREU 95N DLPH Sup. by ADAM 96D PADAM 96D 95N DLPH Sup. by ADAM 96D PADAM 96D 95N DLPH Sup. by ADAM 96D 95N D	**AUE (units 10 ⁻⁵) 4.0±1.7±0.8 • • • We do not use < 21 < 42 < 24 < 210 208 AMMAR 93 obse 209 ADAM 96D assur 210 AVERY 898 repor rescale to 50%. Γ(Κ ₁ (1270) ⁰ γ)/Γ YALUE <0.0070 211 ALBRECHT 896 rescale to 50%. Γ(Κ ₁ (1400) ⁰ γ)/Γ VALUE <0.0043 212 ALBRECHT 896 rescale to 50%. Γ(Κ ₂ (1430) ⁰ γ)/Γ YALUE <4.0 × 10 ⁻⁴ 213 ALBRECHT 896 rescale to 50%.	e the followin 90 90 90 90 erved 6.6 ± 2 mes $f_{B0} = f_0$ forts $< 2.8 \times 1$ total CL% 90 reports < 0.0 total CL% 90 reports < 0.0 reports < 0.0	8 208 AMMA g data for averages 209 ADAM ALBRE 210 AVERY AVERY AVERY 8 events above bac 3 - = 0.39 and fB ₅ 10 ⁻⁴ assuming th 211 ALBRECHT 212 ALBRECHT 212 ALBRECHT 213 ALBRECHT 213 ALBRECHT 213 ALBRECHT	R 93 R 93 R 195 R 196 R 196 R 196 R 197 R	CLE2 e+ etc. • • • etc. • • • DLPH e+ i ARG e+ i CLEO e+ CLEO e+ ccays 43% to COMMENT e+e- ccays 45% to COMMENT e+e- ccays 45% to COMMENT e+e- ccays 45% to	$ \begin{array}{ccc} & & & & & & & \\ & & & & & & \\ & & & &$
2.3 × 10 ⁻⁴ 90 199 ADAM 96D DLPH $e^+e^- \rightarrow Z$ • We do not use the following data for averages, fits, limits, etc. • • • 2.1 × 10 ⁻⁴ 90 200 ABREU 95N DLPH Sup. by ADAM 96D 9ADAM 96D 9ADAM 96D 9ADAM 9ADAM 96D	**AUE (units 10 ⁻⁵) 4.0±1.7±0.8 • • • We do not use < 21 < 42 < 24 < 210 208 AMMAR 93 obse 209 ADAM 96D assur 210 AVERY 898 repor rescale to 50%. Γ(Κ ₁ (1270) ⁰ γ)/Γ YALUE < 0.0070 211 ALBRECHT 896 rescale to 50%. Γ(Κ ₁ (1400) ⁰ γ)/Γ VALUE < 0.0043 212 ALBRECHT 896 rescale to 50%. Γ(Κ ₂ (1430) ⁰ γ)/Γ YALUE < 4.0 × 10 ⁻⁴ 213 ALBRECHT 896	e the followin 90 90 90 90 erved 6.6 ± 2 mes $f_{B0} = f_0$ forts $< 2.8 \times 1$ total CL% 90 reports < 0.1 total CL% 90 reports < 0.1	8 208 AMMA g data for averages 209 ADAM ALBRE 210 AVERY AVERY AVERY 8 events above bac 3 - = 0.39 and fB ₅ 10 ⁻⁴ assuming th 211 ALBRECHT 212 ALBRECHT 212 ALBRECHT 213 ALBRECHT 213 ALBRECHT 213 ALBRECHT	R 93 R 93 R 195 R 196 R 196 R 196 R 197 R	CLE2 e+ etc. • • • etc. • • • DLPH e+ i ARG e+ i CLEO e+ CLEO e+ ccays 43% to COMMENT e+e- ccays 45% to COMMENT e+e- ccays 45% to COMMENT e+e- ccays 45% to	$ \begin{array}{ccc} & & & & & & & \\ & & & & & & \\ & & & &$
2.3 × 10 ⁻⁴ 90 199 ADAM 96D DLPH $e^+e^- \rightarrow Z$ • We do not use the following data for averages, fits, limits, etc. • • • 2.1 × 10 ⁻⁴ 90 200 ABREU 95N DLPH Sup. by ADAM 96D PADAM 96D assumes $f_{B0} = f_{B-} = 0.39$ and $f_{B_5} = 0.12$. Contributions from B^0 and B_5 decays cannot be separated. Limits are given for the weighted average of the decay rates for the two neutral B mesons. Assumes a B^0 , B^- production fraction of 0.39 and a B_5 production fraction of 0.12. Contributions from B^0 and B_5^0 decays cannot be separated. Limits are given for the weighted average of the decay rates for the two neutral B mesons. $K^*(892)^0\pi^+\pi^-)/\Gamma_{total}$ $UE $	**AUE (units 10 ⁻⁵) 4.0±1.7±0.8 • • • We do not use < 21 < 42 < 24 < 210 208 AMMAR 93 obse 209 ADAM 96D assur 210 AVERY 898 repor rescale to 50%. Γ(Κ ₁ (1270) ⁰ γ)/Γ YALUE <0.0070 211 ALBRECHT 896 rescale to 50%. Γ(Κ ₁ (1400) ⁰ γ)/Γ VALUE <0.0043 212 ALBRECHT 896 rescale to 50%. Γ(Κ ₂ (1430) ⁰ γ)/Γ YALUE <4.0 × 10 ⁻⁴ 213 ALBRECHT 896 rescale to 50%.	e the followin 90 90 90 90 erved 6.6 ± 2 mes f _{B0} = f ₁ orts < 2.8 × total CL% 90 is reports < 0 total CL% 90 is reports < 4.	a 208 AMMA g data for averages 209 ADAM ALBRE 210 AVERY AVERY AVERY .8 events above bad 3— = 0.39 and f _{B₃} 10—4 assuming th DOCUMENT ID 212 ALBRECHT 1.0.0078 assuming th 213 ALBRECHT 214 ALBRECHT 215 ALBRECHT 216 ALBRECHT 217 ALBRECHT 218 ALBRECHT 219 ALBRECHT 210—4 assuming th	R 93 R 93 R, fits, limits, 966 RHT 896 87 Reground. = 0.12 RHT 896 ARG RHT 1ECN RHG ARG RHT 1ECN RHT 1ECN RHG ARG RHT 1ECN RHG ARG RHT 1ECN RHG ARG RHT 1ECN RHT 1ECN RHG ARG RHT 1ECN RHT 1ECN RHG ARG RHT 1ECN RHT 1ECN RHG ARG RHT 1ECN RHG ARG RHT 1ECN R	CLE2 e+ etc. • • • o DLPH e+ i ARG e+ i CLEO e+ CLEO e+ CLEO e+ ccays 43% to COMMENT e+e- ccays 45% to COMMENT e+e- ccays 45% to COMMENT e+e- decays 45% to	MMENT e → → e → → e → → (45) e → ← e → → (45) e → ← (45) e → → (45) e
2.3 × 10 ⁻⁴ 90 199 ADAM 96D DLPH $e^+e^- \rightarrow Z$ • We do not use the following data for averages, fits, limits, etc. • • • 2.1 × 10 ⁻⁴ 90 200 ABREU 95N DLPH Sup. by ADAM 96D PADAM 96D 95N DLPH Sup. by ADAM 96D PADAM 96D 95N DLPH Sup. by ADAM 96D 95N D	**A0±1.7±0.8 • • • • We do not use < 21 < 42 < 24 < 210 208 AMMAR 93 obse 209 ADAM 96D assur 210 AVERY 89B repor rescale to 50%. Γ(Κ ₁ (1270) ⁰ γ)/Γ **YALUE* < 0.0070 211 ALBRECHT 89G rescale to 50%. Γ(Κ ₂ (1430) ⁰ γ)/Γ **YALUE* < 1.0043 212 ALBRECHT 89G rescale to 50%. Γ(Κ ₂ (1430) ⁰ γ)/Γ **YALUE* < 4.0 × 10-4 213 ALBRECHT 89G rescale to 50%. Γ(Κ°(1680) ⁰ γ)/Γ **YALUE* < 4.0 × 10-4 213 ALBRECHT 89G rescale to 50%. Γ(Κ°(1680) ⁰ γ)/Γ	e the followin 90 90 90 90 erved 6.6 ± 2 mes f _{B0} = f ₁ orts < 2.8 × total CL% 90 is reports < 0 total CL% 90 is reports < 4.	8 208 AMMA g data for averages 209 ADAM ALBRE 210 AVERY AVERY 8 events above bac 3 - = 0.39 and fB ₅ 10 ⁻⁴ assuming th 211 ALBRECHT 200078 assuming th 212 ALBRECHT 213 ALBRECHT 214 ALBRECHT 215 ALBRECHT 216 ALBRECHT 217 ALBRECHT 218 ALBRECHT 219 ALBRECHT 210 ALBRECHT 210 ALBRECHT 211 ALBRECHT 212 ALBRECHT 213 ALBRECHT 213 ALBRECHT 214 ALBRECHT 215 ALBRECHT 216 ASSUMING	R 93 R 93 R, fits, limits, 966 RHT 896 87 Reground. = 0.12 RHT 896 ARG RHT 1ECN RHG ARG RHT 1ECN RHT 1ECN RHG ARG RHT 1ECN RHG ARG RHT 1ECN RHG ARG RHT 1ECN RHT 1ECN RHG ARG RHT 1ECN RHT 1ECN RHG ARG RHT 1ECN RHT 1ECN RHG ARG RHT 1ECN RHG ARG RHT 1ECN R	CLE2 e+ etc. • • • o DLPH e+ i ARG e+ i CLEO e+ CLEO e+ CLEO e+ ccays 43% to COMMENT e+e- ccays 45% to COMMENT e+e- ccays 45% to COMMENT e+e- decays 45% to	MMENT e → → e → → e → → (45) e → ← e → → (45) e → ← (45) e → → (45) e

$\Gamma(K_3^*(1780)^0\gamma)/\Gamma_1$	total			Γ ₁₀₂ /ί	$\Gamma(\pi^+\pi^-\pi^0)/\Gamma_{to}$	tal				Γ ₁₁₄ /
VALUE	CL%	DOCUMENT ID	TECN C	OMMENT	VALUE	CL%			COMMENT	
<0.010	90			$^+e^- \rightarrow r$ (45)	<7.2 × 10 ⁴	90	227 ALBRECHT		$e^+e^- \rightarrow r$. ,
215 ALBRECHT 89G r	eports < 0.	011 assuming the $ au($	4.5) decays 45	% to $B^0\overline{B}{}^0$. We rescale	227 ALBRECHT 90	3 limit assı	umes equal production	on of $B^0\overline B{}^0$ and	d <i>B</i> + <i>B</i> - at '	T(45).
to 50%.					$\Gamma(ho^0\pi^0)/\Gamma_{ m total}$					Γ ₁₁₅ /
$(K_4^*(2045)^0\gamma)/\Gamma_1$	total			Γ ₁₀₃ /Γ	VALUE	CL%	DOCUMENT IE	TECN	COMMENT	. 119/
ALUE	CL%	DOCUMENT ID		OMMENT	<2.4 × 10 ⁻⁵	90	ASNER		$e^+e^- \rightarrow \tau$	(45)
<0.0043	90			$^+e^- \rightarrow \Upsilon(45)$		e the follo	wing data for averag	ges, fits, limits,	etc. • • •	•
	reports <	0.0048 assuming the	e $T(45)$ decay	ys 45% to <i>B^OB</i> O. W	$<4.0 \times 10^{-4}$	90	228 ALBRECHT	90B ARG	$e^+e^- \rightarrow \tau$	^(4 <i>S</i>)
rescale to 50%.					228 ALBRECHT 908	3 limit assı	umes equal production	on of $B^0\overline B{}^0$ and	d <i>B</i> + <i>B</i> - at '	T(45).
$\Gamma(\phi\phi)/\Gamma_{\text{total}}$				Γ ₁₀₄ /Γ	$\Gamma(ho^{\mp}\pi^{\pm})/\Gamma_{ ext{total}}$					Ė
ALUE	CL%_	DOCUMENT ID		OMMENT	VALUE VALUE	a	% DOCUMENT	ID TECN	COMMENT	Γ ₁₁₆ /
<3.9 × 10 ^{—5}	90	ASNER	96 CLE2 e	$^+e^- \rightarrow T(45)$	<8.8 × 10 ⁻⁵				: e+e- →	T(45)
$(\pi^+\pi^-)/\Gamma_{\text{total}}$				Γ ₁₀₅ /Γ		e the follo	wing data for averag			` '
	<u>EVTS</u>	DOCUMENT, ID	TECN C	OMMENT	<5.2 × 10 ⁻⁴	90		T 90B ARG	e+e- →	T(45)
<1.5 × 10 ⁻⁵ 90				$^+e^- \rightarrow \Upsilon(45)$	$< 5.2 \times 10^{-3}$	90) e ⁺ e ⁻ →	
• • We do not use	the followi		fits, limits, et	C. • • •	229 ALBRECHT 908	3 limit assı	umes equal production	on of $B^0\overline{B}{}^0$ and	d B+B- at	T(45).
<4.5 × 10 ⁻⁵ 90			960 DLPH e		230 BEBEK 87 report to 50%.	rts < 6.1 ×	10 ⁻³ assuming the	T(45) decays 4	13% to <i>B^OB</i> O.	. We resca
$< 2.0 \times 10^{-5}$ 90		010		epl. by GODANG 98	10 50%.					
$<4.1 \times 10^{-5}$ 90 $<5.5 \times 10^{-5}$ 90				⁺ e → <i>Z</i> up. by ADAM 96D	¹ Γ(π ⁺ π ⁻ π ⁺ π ⁻)	/Γ _{total}				Γ117/
$<4.7 \times 10^{-5}$ 90		000		$+e^- \rightarrow Z$	VALUE	CL%			COMMENT	
<2.9 × 10 ⁻⁵ 90		221 BATTLE	93 CLE2 e	$+e^- \rightarrow \Upsilon(4S)$	<2.3 × 10 ⁻⁴	90	²³¹ ADAM		$e^+e^- \rightarrow Z$!
<1.3 × 10 ⁻⁴ 90				$+e^- \rightarrow \Upsilon(4S)$			wing data for averag			
<7.7 × 10 ⁻⁵ 90		222 BORTOLETTO 222 BEBEK			<2.8 × 10 ⁻⁴	90	232 ABREU 233 ALBBECUT		Sup. by ADA	
<2.6 × 10 ⁻⁴ 90 <5 × 10 ⁻⁴ 90	4			$^+e^- \rightarrow \Upsilon(4S)$ $^+e^- \rightarrow \Upsilon(4S)$	<6.7 × 10 ⁻⁴	90	233 ALBRECHT		e+e- → γ	(43)
				0 7 7 (43)	231 ADAM 96D assu	mes 1 _{B0} =	$= t_{B^-} = 0.39$ and t	$B_{s} = 0.12.$		
¹⁷ ADAM 96D assum ¹⁸ BUSKULIC 96V as	'B0 -	$B^- = 0.39$ and $^{\prime}B_{s}$	~ 0.12.	D+ D	232 Assumes a B ⁰ ,	B produ	ction fraction of 0.3	and a B _s proc	duction fractio	on of 0.12
19 Accument 2 DO D	ssumes PD	o 96 production trac	tions for B°, i	ction fraction of 0.12.	233 ALBRECHT 901	3 limit assu	umes equal production	on of BUBU and	d BTBT at	T(45).
20 Assumes R(7 -	$b\overline{b}) = 0.2$	17 and B_d^0 (B_s^0) frac	nu a <i>0₅ produ</i> Hinn 39 5% (1	2%)	$\Gamma(ho^0 ho^0)/\Gamma_{ m total}$					Г118
21 Assumes equal pro	duction of	RORO and R+R-	at Y(45)		VALUE	CL%	DOCUMENT IL	TECN_	COMMENT	
22 Paper assumes the	γ(45) de	cavs 43% to BOBO.	We rescale to	50%.	<2.8 × 10 ⁻⁴	90	234 ALBRECHT		$e^+e^- \rightarrow \gamma$	^(45)
	(,					se the follo	wing data for averag			
$(\pi^0\pi^0)/\Gamma_{\text{total}}$				Γ ₁₀₆ /Ι		90	235 BORTOLET			
<9.3 × 10 ⁻⁶	<u>CL%</u>	DOCUMENT ID	TECN C	$+e^- \rightarrow \Upsilon(4S)$	<4.3 × 10 ⁻⁴	90	235 BEBEK		e ⁺ e ⁻ → 7	
• • We do not use	90 the followi				234 ALBRECHT 901					T(45).
<0.91 × 10 ⁻⁵	90			epl. by GODANG 98	233 Paper assumes 1	he 7(45)	decays 43% to B ^O I	. We rescale	to 50%.	
<6.0 × 10 ⁻⁵	90			$+e^- \rightarrow Z$	$\Gamma(a_1(1260)^{\mp}\pi^{\pm})$	i/Γ _{total}				Γ119
²³ ACCIARRI 95H as:	sumes f			.0%.	VALUE	CL%			COMMENT	
	Во		os .		<4.9 × 10 ⁻⁴	90	²³⁶ BORTOLET			^(45)
$(\eta \pi^0)/\Gamma_{\text{total}}$				Γ ₁₀₇ /Ι			wing data for averag			
ALUE	<u>CL%</u>	DOCUMENT ID		OMMENT	<6.3 × 10 ⁻⁴	90	237 ALBRECHT			
<8 × 10 ⁻⁶	90			$^+e^- \rightarrow \Upsilon(45)$	<1.0 × 10 ⁻³	90	²³⁶ BEBEK		$e^+e^- \rightarrow \gamma$	(45)
We do not use					236 Paper assumes t					m(+ a)
<2.5 × 10 ⁻⁴	90	²²⁴ ACCIARRI ²²⁵ ALBRECHT	95H L3 e	⁺ e → Z ⁺ e → Υ(45)	237 ALBRECHT 90		umes equal production	on or Bo Bo and	OB'B at	7 (45).
<1.8 × 10 ⁻³	90				$\Gamma(a_2(1320)^{\mp}\pi^{\pm})$	/Γ _{total}				Γ ₁₂₀
²⁴ ACCIARRI 95H as:	sumes 7 _B 0	= 39.5 ± 4.0 and 7 _E	$3_s = 12.0 \pm 3$.0%.	VALUE	C1%			COMMENT	
²⁵ ALBRECHT 908 I	imit assum	es equal production of	of Bo Bo and	$B^{+}B^{-}$ at $T(45)$.	<3.0 × 10 ⁻⁴	90	²³⁸ BORTOLET			^(45)
$(\eta\eta)/\Gamma_{\text{total}}$				Γ ₁₀₈ /Ι			wing data for averag			
ALUE	CL%	DOCUMENT ID	TECN C		<1.4 × 10 ⁻³	90	238 BEBEK		$e^+e^- \rightarrow \gamma$	`(45)
(1.8 × 10 ⁵	90			$^+e^- \rightarrow ~ \Upsilon(4S)$	²³⁸ Paper assumes t	he T(45)	decays 43% to BOT	J ^U . We rescale	to 50%.	
		ng data for averages,			$\Gamma(\pi^{+}\pi^{-}\pi^{0}\pi^{0})/$	Г				Γ ₁₂₁
(4.1 × 10 ⁴	90			$^+e^- \rightarrow Z$	VALUE	CL%	DOCUMENT IE	TECN	COMMENT	- 141
²⁶ ACCIARRI 95H as	sumes f _B 0	= 39.5 \pm 4.0 and f_{E}	$B_s = 12.0 \pm 3$.0%.	<3.1 × 10 ⁻³	90	239 ALBRECHT		e ⁺ e → γ	r(45)
	_				239 AL PRECUT AN					
$(\eta'\pi^0)/\Gamma_{\text{total}}$		B06:##5::= :=	TF.C	Γ ₁₀₉ /Ι			p			
1.1 × 10 ⁻⁵	<u> </u>	DOCUMENT ID BEHRENS	7ECN C	$^+e^- \rightarrow \Upsilon(4S)$	$\Gamma(\rho^+\rho^-)/\Gamma_{\text{total}}$					Γ ₁₂₂
	90	DEHKENS	O CLEZ 6	· · · · · (43)	VALUE	<u>cr%</u>			COMMENT	
(η' η') /Γ _{total}				Γ ₁₁₀ /Ι	<2.2 × 10 ⁻³	90	240 ALBRECHT			
LUE	<u>CL%</u> _	DOCUMENT ID	TECN C	OMMENT	ALBRECHT 90		umes equal production	on of BYBY and	o <i>B™B</i> at '	T (45).
4.7 × 10 ⁻⁵	90	BEHRENS	98 CLE2 <i>e</i>	$+e^- \rightarrow \Upsilon(45)$	$\Gamma(a_1(1260)^0\pi^0)$	/r _{total}				Γ ₁₂₃
$(\eta'\eta)/\Gamma_{\text{total}}$				Fac: //		CL%			COMMENT	
(ザワ)/i total NLUE	CI W	DOCUMENT ID	TECN C	Γ ₁₁₁ /Ι	<1.1 × 10 ⁻³	90	241 ALBRECHT	908 ARG	$e^+e^- \rightarrow \gamma$	
2.7 × 10 ⁻⁵	<u>CL%</u> 90			$+e^- \rightarrow \Upsilon(4S)$	241 ALBRECHT 90	3 limit asso	umes equal production		d <i>B</i> + <i>B</i> - at	T(45).
	-	DEHKENS	70 CLE2 6		-(0) /=					
$(\eta' \rho^0)/\Gamma_{\text{total}}$				Γ ₁₁₂ /!	$\Gamma(\omega\pi^0)/\Gamma_{\text{total}}$			_		r ₁₂₆
ALUE	CL%	DOCUMENT ID	TECN C	OMMENT	VALUE	<u>cr</u> #			COMMENT	
<2.3 × 10 ⁻⁵	90	BEHRENS	98 CLE2 <i>e</i>	$^+e^- \rightarrow T(45)$	<4.6 × 10 ⁻⁴	90	242 ALBRECHT		e ⁺ e ⁻ → 7	٠,
					242 ALBRECHT 90	a limit assi	umes equal production	n of B ^U B ^U and	d B+B- at '	T(45).
(0\ / *				- "						
$(\eta ho^0)/\Gamma_{ m total}$	CL%_	DOCUMENT ID	TECN C	Γ ₁₁₃ /Ι	•					

 B^0

$\Gamma(\pi^+\pi^+\pi^-\pi^-\pi^0)/\Gamma_{\text{total}}$ Γ_{125}/Γ	$\Gamma(\overline{\Sigma}_c^{}\Delta^{++})/\Gamma_{\text{total}}$	36/F
ALUE CLY DOCUMENT ID TECN COMMENT	VALUE CL% DOCUMENT ID TECN COMMENT	
<9.0 × 10 ⁻³ 90 243 ALBRECHT 90B ARG $e^+e^- \rightarrow T(45)$	<0.0010 90 260 PROCARIO 94 CLE2 $e^+e^- \rightarrow T(45)$	
⁴³ ALBRECHT 90B limit assumes equal production of $B^0\overline{B}{}^0$ and B^+B^- at $\Upsilon(45)$.	²⁶⁰ PROCARIO 94 reports < 0.0012 for B($\Lambda_c^+ \rightarrow pK^-\pi^+$) = 0.043. We rescale	to our
$(a_1(1260)^+\rho^-)/\Gamma_{\text{total}}$ Γ_{126}/Γ	best value B($\Lambda_c^+ \to p K^- \pi^+$) = 0.050.	
ALUE - CL% DOCUMENT ID TECN COMMENT	$\Gamma(\Lambda_c^- p \pi^+ \pi^-) / \Gamma_{\text{total}}$	/F
<3.4 × 10⁻³ 90 ²⁴⁴ ALBRECHT 90B ARG $e^+e^- \rightarrow \Upsilon(45)$		37/F
⁴⁴ ALBRECHT 90B limit assumes equal production of $B^0\overline{B}^0$ and B^+B^- at $\Upsilon(45)$.	VALUE (units 10 ⁻³) DOCUMENT ID TECN COMMENT	
$\Gamma(a_1(1260)^0 \rho^0)/\Gamma_{\text{total}}$ Γ_{127}/Γ	1.33 $^{+0.46}_{-0.42}$ ±0.37 261 FU 97 CLE2 $e^+e^- \rightarrow \Upsilon(45)$	
ALUECL% DOCUMENT ID TECN COMMENT	261 FU 97 uses PDG 96 values of Λ_{c} branching fraction.	
(2.4×10^{-3}) 90 245 ALBRECHT 908 ARG $e^+e^- \rightarrow \Upsilon(45)$	F(A= a)/F	/F
⁴⁵ ALBRECHT 908 limit assumes equal production of $B^0\overline{B}^0$ and B^+B^- at $T(45)$.	$\Gamma(A_c^-p)/\Gamma_{\text{total}}$ Γ_1	38/F
/ +_+_+ =\r	$\frac{1}{\sqrt{2.1} \times 10^{-4}}$ 90 $\frac{262}{500}$ FU 97 CLE2 $e^+e^- \rightarrow T(45)$	
(\pi + \pi + \pi + \pi - \pi - \pi)/\tag{\Gamma} \[\begin{array}{cccccccccccccccccccccccccccccccccccc	262 FU 97 uses PDG 96 values of Λ_C branching ratio.	
$\frac{246}{\text{ALBRECHT}} = \frac{1}{90} \frac{1}{246} \frac{1}{\text{ALBRECHT}} = \frac{1}{90} \frac{1}{100} \frac{1}$		
⁴⁶ ALBRECHT 90B limit assumes equal production of $B^0 \overline{B}{}^0$ and $B^+ B^-$ at $\Upsilon(45)$.	,	.39/F
• •	VALUE CL% DOCUMENT ID TECN COMMENT $<$ 5.9 x 10 ⁻⁴ 90 263 FU 97 CLE2 $e^+e^- \rightarrow \Upsilon(45)$	
$(a_1(1260)^+ a_1(1260)^-)/\Gamma_{\text{total}}$ Γ_{129}/Γ		
ALUE CL% DOCUMENT ID TECN COMMENT C2.8 × 10 ⁻³ 90 247 BORTOLETTO89 CLEO $e^+e^- \rightarrow \Upsilon(45)$	$^{263}\mathrm{FU}$ 97 uses PDG 96 values of Λ_C branching ratio.	
<.28 × 10⁻³ 90 ²⁴⁷ BORTOLETTO89 CLEO $e^+e^- \rightarrow \Upsilon(45)$ • • We do not use the following data for averages, fits, limits, etc. • • •	$\Gamma(\Lambda_c^- \rho \pi^+ \pi^- \pi^0) / \Gamma_{\text{total}}$	40/F
$<6.0 \times 10^{-3}$ 90 248 ALBRECHT 908 ARG $e^+e^- \rightarrow \Upsilon(45)$	VALUE CL% DOCUMENT ID TECN COMMENT	
FROM TO SET TO SO THE STATE OF	<5.07 × 10⁻³ 90 ²⁶⁴ FU 97 CLE2 e^+e^- → Υ (45)	
We rescale to 50%	264 FU 97 uses PDG 96 values of Λ_c branching ratio.	
48 ALBRECHT 908 limit assumes equal production of $B^0\overline{B}{}^0$ and B^+B^- at $\Upsilon(4S)$.		/F
$\Gamma(\pi^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}\pi^{-}\pi^{0})/\Gamma_{\text{total}}$ Γ_{130}/Γ	$\Gamma(A_c^-p\pi^+\pi^-\pi^+\pi^-)/\Gamma_{\text{total}}$ VALUECL% DOCUMENT ID TECH COMMENT	41/F
ALUE CLY DOCUMENT ID TECN COMMENT	$\frac{7.74 \times 10^{-3}}{90}$ 90 $\frac{265}{\text{FU}}$ 97 CLE2 $e^+e^- \rightarrow T(45)$	
$<1.1 \times 10^{-2}$ 90 249 ALBRECHT 908 ARG $e^+e^- \rightarrow \Upsilon(45)$	265 FU 97 uses PDG 96 values of Λ_{C} branching ratio.	
⁴⁹ ALBRECHT 90B limit assumes equal production of $B^0\overline{B}{}^0$ and B^+B^- at $\Upsilon(4S)$.		
(<i>pp</i>)/Γ _{total} Γ ₁₃₁ /Γ		42/F
ALUE CL% DOCUMENT ID TECN COMMENT	Test for $\Delta B = 1$ weak neutral current. Allowed by higher-order electroweak in tions.	terac-
<1.8 × 10⁻⁵ 90 250 BUSKULIC 96v ALEP $e^+e^- \rightarrow Z$	VALUE CL% DOCUMENT ID TECN COMMENT	
 We do not use the following data for averages, fits, limits, etc. 	<3.9 × 10⁻⁵ 90 ²⁶⁶ ACCIARRI 951 L3 e ⁺ e ⁻ → Z	
<3.5 × 10 ⁻⁴ 90 ²⁵¹ / ₂₅₂ ABREU 95N DLPH Sup. by ADAM 96D	200 ACCIARRI 951 assumes $f_{-2} = 39.5 \pm 4.0$ and $f_{-2} = 12.0 \pm 3.0\%$	
	²⁶⁶ ACCIARRI 951 assumes $f_{B^0} = 39.5 \pm 4.0$ and $f_{B_g} = 12.0 \pm 3.0\%$.	
$<1.2 \times 10^{-4}$ 90 253 ALBRECHT 88F ARG $e^+e^- \rightarrow r(45)$	$\Gamma(e^+e^-)/\Gamma_{\text{total}}$	43/F
(1.2×10^{-4}) 90 253 ALBRECHT 88F ARG $e^+e^- \rightarrow \Upsilon(45)$ (1.7×10^{-4}) 90 252 BEBEK 87 CLEO $e^+e^- \rightarrow \Upsilon(45)$	$\Gamma(e^+e^-)/\Gamma_{ ext{total}}$ Test for $\Delta B=1$ weak neutral current. Allowed by higher-order electroweak in	
$<1.2 \times 10^{-4}$ 90 253 ALBRECHT 88F ARG $e^+e^- \rightarrow \Upsilon(4S)$ $<1.7 \times 10^{-4}$ 90 252 BEBEK 87 CLEO $e^+e^- \rightarrow \Upsilon(4S)$ 50 BUSKULIC 96V assumes PDG 96 production fractions for B^0 , B^+ , B_s , b baryons.	$\Gamma(e^+e^-)/\Gamma_{total}$ Test for $\Delta B=1$ weak neutral current. Allowed by higher-order electroweak in tions. VALUE CLY DOCUMENT ID TECN COMMENT	
$<1.2 \times 10^{-4}$ 90 253 ALBRECHT 88F ARG $e^+e^- \rightarrow \Upsilon(45)$ $<1.7 \times 10^{-4}$ 90 252 BEBEK 87 CLEO $e^+e^- \rightarrow \Upsilon(45)$ 50 BUSKULIC 96V assumes PDG 96 production fractions for B^0 , B^+ , B_s , b baryons. 51 Assumes a B^0 , B^- production fraction of 0.39 and a B_s production fraction of 0.12.	$\Gamma(e^+e^-)/\Gamma_{\text{total}}$ Test for $\Delta B = 1$ weak neutral current. Allowed by higher-order electroweak in tions. VALUE CLY DOCUMENT ID TECN COMMENT <8.9 × 10^{-6} 90 AMMAR 94 CLE2 $e^+e^- \rightarrow T(4S)$	
$<1.2 \times 10^{-4}$ 90 253 ALBRECHT 88F ARG $e^+e^- \rightarrow T(4S)$ $<1.7 \times 10^{-4}$ 90 252 BEBEK $e^+e^- \rightarrow T(4S)$ 87 CLEO $e^+e^- \rightarrow T(4S)$ $<1.5 \times 10^{-4}$ 90 87 BUSKULIC 96v assumes PDG 96 96 97 97 98 98 97 98 98 98 98 98 99 90<	$\Gamma(e^+e^-)/\Gamma_{\text{total}}$ Test for $\Delta B=1$ weak neutral current. Allowed by higher-order electroweak in tions. VALUE CL% DOCUMENT ID TECN COMMENT C5.9 × 10^-6 90 AMMAR 94 CLE2 $e^+e^- \to T(4S)$ • • • We do not use the following data for averages, fits, limits, etc. • •	
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C1.2 × 10 ⁻⁴ 90 253 ALBRECHT 88F ARG $e^+e^- \rightarrow T(4S)$ C1.7 × 10 ⁻⁴ 90 252 BEBEK 87 CLEO $e^+e^- \rightarrow T(4S)$ C1.7 × 10 ⁻⁴ 90 252 BEBEK 87 CLEO $e^+e^- \rightarrow T(4S)$ Sign BUSKULIC 96v assumes PDG 96 production fractions for B^0 , B^+ , B_s , b baryons. 51 Assumes a B^0 , B^- production fraction of 0.39 and a B_s production fraction of 0.12. 52 Paper assumes the $T(4S)$ decays 43% to $B^0\overline{B^0}$. We rescale to 50%. 53 ALBRECHT 88F reports < 1.3 × 10 ⁻⁴ assuming the $T(4S)$ decays 45% to $B^0\overline{B^0}$. We rescale to 50%. ($\overline{PP}\pi^+\pi^-$)/ Γ total LE DOCUMENT ID </td <td>Test for $\Delta B=1$ weak neutral current. Allowed by higher-order electroweak in tions. VALUE CLY DOCUMENT ID TECN COMMENT C\$,9 × 10^-6 90 AMMAR 94 CLE2 $e^+e^- \rightarrow T(4S)$ • • • We do not use the following data for averages, fits, limits, etc. • • • <1.4 × 10^-5 90 267 ACCIARRI 978 L3 $e^+e^- \rightarrow T(4S)$ <2.6 × 10^-5 90 268 AVERY 898 CLE0 $e^+e^- \rightarrow T(4S)$ <3 × 10^-5 90 269 ALBRECHT 870 ARG $e^+e^- \rightarrow T(4S)$ <3 × 10^-4 90 GILES 84 CLE0 Repl. by AVERY 8: 267 ACCIARRI 978 BA CLEO Repl. by AVERY 8: 267 ACCIARRI 978 BA CLEO Repl. by AVERY 8: 267 ACCIARRI 978 BA CLEO Repl. by AVERY 8: 267 ACCIARRI 978 BA CLEO Repl. by AVERY 8: 268 AVERY 898 reports < 3 × 10^-5 assuming the $T(4S)$ decays 43% to B^0 \overline{B}^0. We rescale to 50%. 270 AVERY 87 reports < 8 × 10^-5 assuming the $T(4S)$ decays 40% to B^0 \overline{B}^0. We rescale to 50%.</td> <td>escale). We</td>	Test for $\Delta B=1$ weak neutral current. Allowed by higher-order electroweak in tions. VALUE CLY DOCUMENT ID TECN COMMENT C\$,9 × 10^-6 90 AMMAR 94 CLE2 $e^+e^- \rightarrow T(4S)$ • • • We do not use the following data for averages, fits, limits, etc. • • • <1.4 × 10^-5 90 267 ACCIARRI 978 L3 $e^+e^- \rightarrow T(4S)$ <2.6 × 10^-5 90 268 AVERY 898 CLE0 $e^+e^- \rightarrow T(4S)$ <3 × 10^-5 90 269 ALBRECHT 870 ARG $e^+e^- \rightarrow T(4S)$ <3 × 10^-4 90 GILES 84 CLE0 Repl. by AVERY 8: 267 ACCIARRI 978 BA CLEO Repl. by AVERY 8: 267 ACCIARRI 978 BA CLEO Repl. by AVERY 8: 267 ACCIARRI 978 BA CLEO Repl. by AVERY 8: 267 ACCIARRI 978 BA CLEO Repl. by AVERY 8: 268 AVERY 898 reports < 3 × 10^-5 assuming the $T(4S)$ decays 43% to B^0 \overline{B}^0 . We rescale to 50%. 270 AVERY 87 reports < 8 × 10^-5 assuming the $T(4S)$ decays 40% to B^0 \overline{B}^0 . We rescale to 50%.	escale). We
\$\(\text{2.1.2} \times 10^{-4} \\ 90 \text{253} \text{ ALBRECHT} \text{8BF} \text{ ARG} \text{e}^+e^- \rightarrow \text{7(45)} \\ \text{c1.7} \times 10^{-4} 90 \text{252} \text{BEBEK} 87 \text{CLEO} \text{e}^+e^- \rightarrow \text{7(45)} \\ \text{550} \text{BUSKULIC} 90 \text{ssumes pDG} \text{production fractions for } 0.39 \text{production fraction of } 0.12. \\ \text{552} \qua	Γ(e+e-)/Γ _{total} Test for $\Delta B=1$ weak neutral current. Allowed by higher-order electroweak in tions. VALUE CL% DOCUMENT ID TECN COMMENT <	escale . We escale
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\$\(\cdot 2 \times 10^{-4}\) 90 \(^{253}\) ALBRECHT \(^{8}BF\) ARG \(^{+}e^{-} \rightarrow T(45)\) (21.7 \times 10^{-4}\) 90 \(^{252}\) BEBEK \(^{8}T\) CLEO \(^{+}e^{-} \rightarrow T(45)\) (21.7 \times 10^{-4}\) 90 \(^{252}\) BEBEK \(^{8}T\) CLEO \(^{+}e^{-} \rightarrow T(45)\) (250 BUSKULIC 96v assumes PDG 96 production fractions for B^{0} , B^{+} , B_{S} , b baryons. • 151 Assumes a B^{0} , B^{-} production fraction of 0.39 and a B_{S} production fraction of 0.12. (252 Paper assumes the $T(4S)$ decays 43% to $B^{0}\overline{B}^{0}$. We rescale to 50%. (16) Fig. 10 ALUE (units 10^{-4}) (1.3 \times 10^{-4}) (Γ(e+e-)/Γ _{total} Test for $\Delta B = 1$ weak neutral current. Allowed by higher-order electroweak in tions. VALUE CLY DOCUMENT ID TECN COMMENT <	escale . We escale
\$\(\cdot 2 \times 10^{-4}\) 90 \(253\) ALBRECHT \(88F\) ARG \(e^+e^- \to T(45)\) \(21.7 \times 10^{-4}\) 90 \(252\) BEBEK \(87\) CLEO \(e^+e^- \to T(45)\) \(252\) BEBEK \(87\) CLEO \(e^+e^- \to T(45)\) \(252\) BEBEK \(87\) CLEO \(e^+e^- \to T(45)\) \(253\) ALBRECHT \(88F\) production fractions for B^0 , B^+ , B_S , b baryons. \(.\frac{51}{2}\) Assumes a B^0 , B^- production fraction of 0.39 and a B_S production fraction of 0.12. \(.\frac{52}{2}\) Paper assumes the $T(45)$ decays 43% to $B^0\overline{B}^0$. We rescale to 50%. 13 ALBRECHT \(88F\) reports \(< 1.3 \times 10^{-4}\) assuming the $T(45)$ decays 45% to $B^0\overline{B}^0$. We rescale to 50%. 14 \(.\frac{54}{2}\) BEBEK \(89\) CLEO \(e^+e^- \to T(45)\) \(.\frac{54}{2}\) BEBEK \(89\) reports \(< 2.9 \times 10^{-4}\) assuming the $T(45)$ decays 43% to $B^0\overline{B}^0$. We rescale to 50%. 15 \(48\) ALBRECHT \(88F\) RAG \(e^+e^- \to T(45)\) \(.\frac{54}{2}\) BEBEK \(89\) reports \(< 2.9 \times 10^{-4}\) assuming the $T(45)$ decays 43% to $B^0\overline{B}^0$. We rescale to 50%. 15 \(6\) ALBRECHT \(88F\) Rapports \(.20\) \(\frac{2}{2}\) 2.0 \(\pm 2.0\) 2.2 assuming the $T(45)$ decays 45% to $B^0\overline{B}^0$. We rescale to 50%. 16 \(\frac{7}{2}\) Total 17 \(.\frac{7}{2}\) Total 18 \(.\frac{133}{2}\) Tech \(.\frac{7}{2}\) ALBRECHT \(.88F\) ARG \(e^+e^- \to T(45)\)	Test for $\Delta B=1$ weak neutral current. Allowed by higher-order electroweak in tions. **YALUE** **CL\(\) **DOCUMENT ID** **TECN** **COMMENT**	escale . We escale
\$\frac{1.2 \times 10^{-4}}{90}\$ \frac{253}{90}\$ ALBRECHT 88F \text{ ARG } \qu	Γ(e+e-)/Γ _{total} Test for $\Delta B = 1$ weak neutral current. Allowed by higher-order electroweak in tions. VALUE CLY DOCUMENT ID TECN COMMENT COMENT COMMENT	escale . We escale
\$\(\cdot 2.\times 10^{-4}\) 90 \(253\) ALBRECHT \(88F\) ARG \(e^+e^- \rightarrow T(4S)\) \(21.7 \times 10^{-4}\) 90 \(252\) BEBEK \(87\) CLEO \(e^+e^- \rightarrow T(4S)\) \(252\) BEBEK \(87\) CLEO \(e^+e^- \rightarrow T(4S)\) \(255\) BUSKULIC 96v assumes PDG 96 production fractions for \$B^0\), \$\(B^+\), \$\(B_5\), \$\(b\) baryons. \(.\times 151\) Assumes a \$B^0\), \$B^-\$ production fraction of 0.39 and a \$B_5\) production fraction of 0.12. \(252\) Paper assumes the \$T(4S)\) decays 43% to \$B^0\)\(\overline{B}^0\). We rescale to 50%. \(276\)\(\frac{7}{2}\)\(\frac{7}{4}\)\(\frac{7}{1}\)\(\text{total}\) (\$\(\frac{7}{2}\)\(\frac{7}{4}\)\(\frac{7}{1}\)\(\frac{7}{1}\)\(\text{total}\) (\$\(\frac{7}{2}\)\(\frac{7}{4}\)\(Γ(e+e-)/Γ _{total} Test for $\Delta B = 1$ weak neutral current. Allowed by higher-order electroweak in tions. VALUE CL% DOCUMENT ID TECN COMMENT C5.9 × 10 ⁻⁶ 90 AMMAR 94 CLE2 e+e-→ T(4S) • • • We do not use the following data for averages, fits, limits, etc. • • • <1.4 × 10 ⁻⁵ 90 267 ACCIARRI 978 B.3 e+e-→ Z <2.6 × 10 ⁻⁵ 90 268 AVERY 898 CLE0 e+e-→ T(4S) <3 × 10 ⁻⁵ 90 269 ALBRECHT 870 AVERY 87 CLE0 e+e-→ T(4S) <3 × 10 ⁻⁴ 90 GILES 84 CLE0 Repl. by AVERY 8: 267 ACCIARRI 978 B.3 e+e-→ T(4S) AVERY 87 CLEO Repl. by AVERY 88 CLEO Repl. by AVERY 88 CLEO Repl. by AVERY 89 CROWNET Test for ΔB = 1 Weak neutral current. Allowed by higher-order electroweak in tions. VALUE CL% DOCUMENT ID TECN COMMENT F1 Test for ΔB = 1 Weak neutral current. Allowed by higher-order electroweak in tions. VALUE CL% DOCUMENT ID TECN COMMENT CAB TO P	escale . We escale
\$\frac{\cdot 2.2 \times 10^{-4}}{90}\$ \frac{253}{90}\$ ALBRECHT 88F \text{ ARG } \qu	Γ(e+e-)/Γ _{total} Test for ΔB = 1 weak neutral current. Allowed by higher-order electroweak in tions. VALUE CL% DOCUMENT ID TECN COMMENT C5.9 × 10 ⁻⁶ 90 AMMAR 94 CLE2 e+e-→ T(4S) • • We do not use the following data for averages, fits, limits, etc. • • • <1.4 × 10 ⁻⁵ 90 267 ACCIARRI 97B L3 e+e-→ Z <2.6 × 10 ⁻⁵ 90 268 AVERY 89B CLEO e+e-→ T(4S) <7.6 × 10 ⁻⁵ 90 269 ALBRECHT 87D ARG e+e-→ T(4S) <3 × 10 ⁻⁴ 90 GILES 84 CLEO Repl. by AVERY 83 267 ACCIARRI 97B L3 e+e-→ T(4S) AND ARG AND AND AND AND AND AND AND AN	escale . We escale
\$\frac{2.2 \times 10^{-4}}{2.1.7 \times 10^{-4}} = \frac{90}{90} \frac{253}{252} \text{ BEBEK} \text{87} \text{CLO} \end{align*} \text{7} \text{1.7} \times 10^{-4} \text{90} \text{252} \text{BEBEK} \text{87} \text{CLO} \end{align*} \end{align*} \text{1.60} \text{87} \text{LEO} \end{align*} \text{1.8} \text{1.8} \text{1.9} \text{1.9} \text{1.9} \text{1.8} \text{1.9} \text{1.9} \text{1.8} \text{1.9} \text{1.9} \text{1.9} \text{1.9} \text{1.9} \text{1.9} \text{1.9} \text{1.9} \text{1.9} \text{1.9} \text{1.9} \text{1.9} \text{1.9} \text{1.9} \text{1.9} \text{1.9} \text{1.9} \text{1.9} \text{1.9}	Γ(e+e-)/Γ _{total} Test for ΔB = 1 weak neutral current. Allowed by higher-order electroweak in tions. VALUE CL% DOCUMENT ID TECN COMMENT <	escale . We escale
\$\frac{c1.2 \times 10^{-4}}{c1.7 \times 10^{-4}} = 90 \frac{253}{252} \text{BEBEK} \text{87} \text{CLO} \end{align*} \text{7} \text{1.6} \text{90} \text{25} \text{BEBEK} \qu	Γ(e+e-)/Γ _{total} Test for ΔB = 1 weak neutral current. Allowed by higher-order electroweak in tions. YALUE CLY DOCUMENT ID TECN COMMENT <	escale . We escale
\$\frac{c} 1.2 \times 10^{-4}\$ 90 \$\frac{253}{252}\$ \text{ BEBEK}\$ 87 \text{ CLO } e^+e^- \to T(45)\$ \\ colored{c} 1.7 \times 10^{-4}\$ 90 \$\frac{252}{252}\$ \text{ BEBEK}\$ 87 \text{ CLO } e^+e^- \to T(45)\$ \\ colored{c} 1.7 \times 10^{-4}\$ 90 \$\frac{252}{252}\$ \text{ BEBEK}\$ 87 \text{ CLO } e^+e^- \to T(45)\$ \\ colored{c} 1.8 \times 10^{-6}\$ 90 \text{ Porduction fraction of 0.39}\$ and a \$B_s\$ production fraction of 0.12. \\ colored{c} 2.9 \text{ Paper assumes the } T(45)\$ decays 43% to \$B^0 \overline{B}^0\$. We rescale to 50%. \\ colored{c} 2.9 \text{ Paper assumes the } T(45)\$ decays 43% to \$B^0 \overline{B}^0\$. We rescale to 50%. \\ colored{c} \frac{7}{132} \sum \text{ Fig. 1} \\ colored{c} \frac{132}{152} \sum \text{ Fig. 1} \\ colored	Γ(e+e-)/Γ _{total} Test for ΔB = 1 weak neutral current. Allowed by higher-order electroweak in tions. VALUE CL% DOCUMENT ID TECN COMMENT C5.9 × 10 ⁻⁶ 90 AMMAR 94 CLE2 e+e- → T(4S) • • • We do not use the following data for averages, fits, limits, etc. • • • <1.4 × 10 ⁻⁵ 90 267 ACCIARRI 978 L3 e+e- → Z <2.6 × 10 ⁻⁵ 90 268 AVERY 898 CLE0 e+e- → T(4S) <3 × 10 ⁻⁵ 90 269 ALBRECHT 870 AVERY 87 CLE0 e+e- → T(4S) c3 × 10 ⁻⁴ 90 GILES 84 CLE0 Repl. by AVERY 87 CLEO Repl. by AVERY Repl. by AVERY Repl. by AVERY Repl. by AVERY Repl. by ABE 98 CLEO Repl. by ABE 98 Repl. CLEO	escale . We escale
\$\frac{c1.2 \times 10^{-4}}{c1.7 \times 10^{-4}} = 90 \frac{253}{252} \text{BEBEK} \text{87} \text{CLO} \text{257} \text{BEBEK} \text{87} \text{CLO} \text{17} \text{17} \text{17} \text{17} \text{18} q	Γ(e+e-)/Γ _{total} Test for ΔB = 1 weak neutral current. Allowed by higher-order electroweak in tions. VALUE CL% DOCUMENT ID TECN COMMENT C5.9 × 10 ⁻⁶ 90 AMMAR 94 CLE2 $e^+e^- \rightarrow T(4S)$ • • We do not use the following data for averages, fits, limits, etc. • • • (2.6 × 10 ⁻⁵ 90 267 ACCIARRI 97B L3 $e^+e^- \rightarrow T(4S)$ < 2.6 × 10 ⁻⁵ 90 268 AVERY 89B CLEO $e^+e^- \rightarrow T(4S)$ < 2.6 × 10 ⁻⁵ 90 269 ALBRECHT 87D ARG $e^+e^- \rightarrow T(4S)$ < 3 × 10 ⁻⁴ 90 GILES 84 CLEO Repl. by AVERY 83 267 ACCIARRI 97B assume PDG 96 production fractions for B+, B0, B5, and Λb. 268 AVERY 898 reports < 3 × 10 ⁻⁵ assuming the $T(4S)$ decays 43% to $B^0\overline{B}^0$. We rescale to 50%. 269 ALBRECHT 87D Reports < 8 × 10 ⁻⁵ assuming the $T(4S)$ decays 45% to $B^0\overline{B}^0$. We rescale to 50%. 77D AVERY 87 reports < 8 × 10 ⁻⁵ assuming the $T(4S)$ decays 40% to $B^0\overline{B}^0$. We rescale to 50%. F($\mu^+\mu^-$)/Γtotal Test for $\Delta B = 1$ weak neutral current. Allowed by higher-order electroweak in tions. VALUE CL% DOCUMENT ID TECN COMMENT C1.8 TECN	escale . We escale
\$\frac{\cdot 2.2 \times 10^{-4}}{90}\$ \frac{253}{252}\$ \text{ ALBRECHT} \text{ 88F} \text{ ARG} \end{align*} \text{ To 4} \text{ 252}\$ \text{ BEBEK}	Γ(e+e-)/Γ _{total} Test for ΔB = 1 weak neutral current. Allowed by higher-order electroweak in tions. VALUE CL% DOCUMENT ID TECN COMMENT	escale). We escale 44/\(\Gamma\)
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Γ(e+e-)/Γ _{total} Test for ΔB = 1 weak neutral current. Allowed by higher-order electroweak in tions. VALUE CL% DOCUMENT ID TECN COMMENT <	escale We escale 44/\(\Gamma\)
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Test for $\Delta B=1$ weak neutral current. Allowed by higher-order electroweak in tions. **YALUE** **CL\(\begin{array}{c} \) DOCUMENT ID** **S.9 \times 10^{-6} **90 **AMMAR** **AMMAR** **94 **CLE2** **e^+e^- \to T(4S) **e^** **e^** **We do not use the following data for averages, fits, limits, etc. • • • **C.1.4 \times 10^{-5} **90 **267 **ACCIARRI** **98 **CLEO** **e^+e^- \to T(4S) **C.1.6 \times 10^{-5} **90 **268 **AVERY** **990 **C1.6 \times 10^{-5} **90 **269 **ALBRECHT** **37 **ACCIARRI** **97 **GILES** **40 **CLEO** **Ce^+e^- \to T(4S) **CLEO** **CLEO** **CLEO** **CLEO** **CLEO** **Repl. by AVERY 8: **CLEO** **CLEO** **Repl. by AVERY 8: **COMMENT** **CALUE** **CLS** **COMMENT** **CALUE** **CLS** **COMMENT** **COMMENT** **CALUE** **CLS** **COMMENT** **CALUE** **CLS** **COMMENT** **CALUE** **CLS** **COMMENT** **CALUE** **CLS** **COMMENT** **CALUE** **	escale). We escale 44/\Gamma terac-
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Test for $\Delta B=1$ weak neutral current. Allowed by higher-order electroweak in tions. VALUE CLY DOCUMENT ID TECN COMMENT C5.9 × 10^-6 90 AMMAR 94 CLE2 $e^+e^- \rightarrow T(4S)$ • • • We do not use the following data for averages, fits, limits, etc. • • • (2.6 × 10^-5) 90 267 ACCIARRI 978 L3 $e^+e^- \rightarrow T(4S)$ (2.6 × 10^-5 90 268 AVERY 898 CLE0 $e^+e^- \rightarrow T(4S)$ (2.6 × 10^-5 90 269 ALBRECHT 870 AVERY 87 CLE0 $e^+e^- \rightarrow T(4S)$ (3 × 10^-4 90 GILES 84 CLE0 Repl. by AVERY 8: (3 × 10^-5) assuming the $T(4S)$ decays 43% to $B^0\overline{B}^0$. We replaced to 50%. 269 ALBRECHT 870 reports < 8.5 × 10^-5 assuming the $T(4S)$ decays 45% to $B^0\overline{B}^0$. We rescale to 50%. 270 AVERY 87 reports < 8 × 10^-5 assuming the $T(4S)$ decays 40% to $B^0\overline{B}^0$. We rescale to 50%. F($\mu^+\mu^-$)/Fotal Test for $\Delta B=1$ weak neutral current. Allowed by higher-order electroweak in thons. VALUE CLY OCCUMENT ID TECN COMMENT CLS COMMENT CLS CLY DOCUMENT ID TECN COMMENT CLS COMMENT CLS CLS DOCUMENT ID TECN COMMENT CLS CLS CLS DOCUMENT ID TECN COMMENT CLS CLS DOCUMENT ID TECN COMMENT CLS CLS CLS DOCUMENT ID TECN COMMENT CLS CLS CLS CLS CLS CLS CLS CL	escale). We escale 44/\Gamma_terac-
\$\frac{\cdot 2.1.2 \times 10^{-4}}{90}\$ \$\frac{253}{252}\$ \text{BEBEK}\$ 87 \text{CLO}\$ \$\epsilon + e^- \to T(45)\$ \$\epsilon T(45)\$ \text{BEBEK}\$ 87 \text{CLO}\$ \$\epsilon + e^- \to T(45)\$ \$\epsilon T(45)\$ \text{BEBEK}\$ 87 \text{CLO}\$ \$\epsilon + e^- \to T(45)\$ \$\epsilon T(45)\$ \text{BEBEK}\$ 87 \text{CLO}\$ \$\epsilon + e^- \to T(45)\$ \$\epsilon T(45)\$ \text{BESKULIC}\$ 96v assumes PDG 96 production fractions for \$B^0\$, \$B^+\$, \$B_5\$, \$b\$ baryons. \$\to 55\$ Assumes a \$B^0\$, \$B^-\$ production fraction of 0.39 and a \$B_5\$ production fraction of 0.12. \$\frac{52}{252}\$ Paper assumes the \$T(45)\$ decays 43% to \$B^0\$ \$\overline{B}^0\$. We rescale to 50%. \$\frac{(15)}{252}\$ \text{Paper assumes the } \$T(45)\$ decays 45% to \$B^0\$ \$\overline{B}^0\$. We rescale to 50%. \$\frac{(15)}{252}\$ \text{Paper assuming the } \$T(45)\$ decays 45% to \$B^0\$ \$\overline{B}^0\$. We rescale to 50%. \$\frac{50}{255}\$ ABREU 95N DLPH Sup. by ADAM 96D 255 ALBRECHT 887 ARG \$\epsilon + e^- \to T(45)\$ \text{256}\$ ALBRECHT 887 ARG \$\epsilon + e^- \to T(45)\$ \text{256}\$ ALBRECHT 887 ARG \$\epsilon + e^- \to T(45)\$ \text{256}\$ ALBRECHT 887 RRG \$\epsilon + e^- \to T(45)\$ \text{256}\$ ALBRECHT 887 reports 6.0 \$\pm 2.0 \$\pm 2.5 \text{2.2}\$ assuming the \$T(45)\$ decays 45% to \$B^0\$ \$\overline{B}^0\$. We rescale to 50%. \$\frac{(15)}{257}\$ ALBRECHT 887 reports 6.0 \$\pm 2.0 \$\pm 2.5 \text{2.18}\$ ALUE \$\frac{(15)}{257}\$ ALBRECHT 887 reports \$< 2.0 \times 10^{-4}\$ assuming the \$T(45)\$ decays 45% to \$B^0\$ \$\overline{B}^0\$. We rescale to 50%. \$\frac{(15)}{257}\$ ALBRECHT 887 reports \$< 2.0 \times 10^{-4}\$ assuming the \$T(45)\$ decays 45% to \$B^0\$ \$\overline{B}^0\$. We rescale to 50%. \$\frac{(15)}{257}\$ ALBRECHT 887 reports \$< 2.0 \times 10^{-4}\$ assuming the \$T(45)\$ decays 45% to \$B^0\$ \$\overline{B}^0\$. We rescale to 50%. \$\frac{(15)}{257}\$ ALBRECHT 887 reports \$< 0.0018\$ assuming \$T(45)\$ decays 45% to \$B^0\$ \$\overline{B}^0\$. We rescale to 50%. \$\frac{(15)}{258}\$ BORTOLETTO89 CLEO \$\epsilon + e^- \to T(45)\$ \$\frac{(15)}{257}\$ BOLUETTO89 CLEO \$\epsilon + e^- \to T(45)\$ \$\end{B}^0\$.	Γ(e+e-)/Γ _{total} Test for $\Delta B = 1$ weak neutral current. Allowed by higher-order electroweak in tions. VALUE CLY DOCUMENT ID S.9 × 10 ⁻⁶ 90 AMMAR 94 CLE2 $e^+e^- \rightarrow T(4S)$ • • We do not use the following data for averages, fits, limits, etc. • • • • • • • Vec do not use the following data for averages, fits, limits, etc. • • • • • • • Vec do not use the following data for averages, fits, limits, etc. • • • • • • • Vec do not use the following data for averages, fits, limits, etc. • • • • • • • • Vec do not use the following data for averages, fits, limits, etc. • • • • • • • Vec do not use the following data for averages, fits, limits, etc. • • • • • • • Vec do not use the following data for averages, fits, limits, etc. • • • • • • • Vec do not use the following data for averages, fits, limits, etc. • • • • • Vec do not use the following data for averages, fits, limits, etc. • • • • Vec do not use the following data for averages, fits, limits, etc. • • • • • Vec do not use the following data for averages, fits, limits, etc. • • • • • Vec do not use the following data for averages, fits, limits, etc. • • • • • Vec do not use the following data for averages, fits, limits, etc. • • • • • Vec do not use the following data for averages, fits, limits, etc. • • • • • Vec do not use the following data for averages, fits, limits, etc. • • • • • Vec do not use the following data for averages, fits, limits, etc. • • • • • Vec do not use the following data for averages, fits, limits, etc. • • • • • Vec do not use the following data for averages, fits, limits, etc. • • • • • Vec do not use the following data for averages, fits, limits, etc. • • • • • Vec do not use the following data for averages, fits, limits, etc. • • • • • Vec do not use the following data for averages, fits, limits, etc. • • • • • • Vec do not use the following data for averages, fits, limits, etc. • • • • • • Vec do not use the following data for averages, fits, limits, etc. • • • • • • Vec do not use the following data for averages, fits, l	escale 3. We escale 44/Γ terac-
\$\(\cdot 2.\times 1.0^{-4}\) 90 \(253\) ALBRECHT \(88F\) ARG \(e^+e^- \rightarrow T(45)\) \(21.T \times 1.0^{-4}\) 90 \(252\) BEBEK \(87\) CLEO \(e^+e^- \rightarrow T(45)\) \(21.T \times 1.0^{-4}\) 90 \(252\) BEBEK \(87\) CLEO \(e^+e^- \rightarrow T(45)\) \(21.T \times 1.0^{-4}\) Assumes a B^0 , B^- production fraction of 0.39 and a B_s production fraction of 0.12. \(252\) Paper assumes the $T(45)$ decays 43% to $B^0 \overline{B}^0$. We rescale to 50%. \(25\) ALBRECHT 88F reports $< 1.3 \times 10^{-4}\) assuming the T(45) decays 45% to B^0 \overline{B}^0. We rescale to 50%. \(26\) \(254\) BEBEK \(89\) CLEO \(e^+e^- \rightarrow T(45)\) \(402\) \(254\) BEBEK \(89\) CLEO \(e^+e^- \rightarrow T(45)\) \(402\) \(254\) BEBEK \(89\) CLEO \(e^+e^- \rightarrow T(45)\) \(402\) \(254\) BEBEK \(89\) reports < 2.9 \times 10^{-4}\ assuming the T(45) decays 43% to B^0 \overline{B}^0. We rescale to 50%. \(263\) ALBRECHT 88F RARG \(e^+e^- \rightarrow T(45)\) \(402\) BEBEK \(89\) reports < 2.9 \times 10^{-4}\ assuming the T(45) decays 45% to B^0 \overline{B}^0. We rescale to 50%. \(107\) We rescale to 50%. \(107\) Protal \(107\) \(257\) ALBRECHT 88F reports < 2.0 \times 10^{-4}\) assuming the T(45) decays 45% to B^0 \overline{B}^0. We rescale to 50%. \(107\) \(1$	Test for $\Delta B=1$ weak neutral current. Allowed by higher-order electroweak in tions. YALUE CLY DOCUMENT ID TECN COMMENT C5.9 × 10^-6 90 AMMAR 94 CLE2 $e^+e^- \rightarrow T(4S)$ • • We do not use the following data for averages, fits, limits, etc. • • • <1.4 × 10^-5 90 267 ACCIARRI 978 B A C1.4 × 10^-5 90 268 AVERY 898 CLE0 $e^+e^- \rightarrow T(4S)$ C1.5 × 10^-5 90 269 ALBRECHT 870 AVERY 87 CLE0 $e^+e^- \rightarrow T(4S)$ C1.6 × 10^-5 90 269 ALBRECHT 870 AVERY 87 CLE0 $e^+e^- \rightarrow T(4S)$ C1.6 × 10^-5 90 270 AVERY 87 CLE0 Repl. by AVERY 87 Repl. by AVERY 87 CLE0 Repl. by AVERY 87 Repl. by AVERY 88 Repl. by AVERY 89 Repl. by AVERY 89 Repl. by AVERY 87 CLE0 Repl. by AVERY 87 Repl. by AVERY 87 CLE0 Repl. by AVERY 87 Repl. by AVERY 88 Repl. by AVERY 88 Repl. by AVERY 89 Repl. by AVERY 87 Repl. by AVERY 89	escale 3. We escale 44/Γ terac-
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Γ(e+e-)/Γ _{total} Test for $\Delta B = 1$ weak neutral current. Allowed by higher-order electroweak in tions. VALUE CLY DOCUMENT ID S.9 × 10 ⁻⁶ 90 AMMAR 94 CLE2 $e^+e^- \rightarrow T(4S)$ • • We do not use the following data for averages, fits, limits, etc. • • • • • • • Vec do not use the following data for averages, fits, limits, etc. • • • • • • • Vec do not use the following data for averages, fits, limits, etc. • • • • • • • Vec do not use the following data for averages, fits, limits, etc. • • • • • • • • Vec do not use the following data for averages, fits, limits, etc. • • • • • • • Vec do not use the following data for averages, fits, limits, etc. • • • • • • • Vec do not use the following data for averages, fits, limits, etc. • • • • • • • Vec do not use the following data for averages, fits, limits, etc. • • • • • Vec do not use the following data for averages, fits, limits, etc. • • • • Vec do not use the following data for averages, fits, limits, etc. • • • • • Vec do not use the following data for averages, fits, limits, etc. • • • • • Vec do not use the following data for averages, fits, limits, etc. • • • • • Vec do not use the following data for averages, fits, limits, etc. • • • • • Vec do not use the following data for averages, fits, limits, etc. • • • • • Vec do not use the following data for averages, fits, limits, etc. • • • • • Vec do not use the following data for averages, fits, limits, etc. • • • • • Vec do not use the following data for averages, fits, limits, etc. • • • • • Vec do not use the following data for averages, fits, limits, etc. • • • • • Vec do not use the following data for averages, fits, limits, etc. • • • • • Vec do not use the following data for averages, fits, limits, etc. • • • • • Vec do not use the following data for averages, fits, limits, etc. • • • • • • Vec do not use the following data for averages, fits, limits, etc. • • • • • • Vec do not use the following data for averages, fits, limits, etc. • • • • • • Vec do not use the following data for averages, fits, l	7 rescale). We escale 44/\(\Gamma\) terac-

<8.3 × 10

90

AMMAR

94 CLE2 $e^+e^- \rightarrow \Upsilon(45)$

```
276 AVERY 89B reports < 5 \times 10^{-3} assuming the \Upsilon(4S) decays 43% to B^0 \, \overline{B}{}^0. We rescale
 277 ALBRECHT 87D reports < 5 \times 10^{-5} assuming the \Upsilon(45) decays 45% to B^0 \overline{B}{}^0. We
 278 AVERY 87 reports < 9 \times 10^{-5} assuming the \Upsilon(4S) decays 40% to B^0 \overline{B}{}^0. We rescale
\Gamma(K^0e^+e^-)/\Gamma_{\text{total}}
Test for \Delta B = 1
                                                      weak neutral current. Allowed by higher-order electroweak interac-
              tions.
                                                         CLN
                                                                                   DOCUMENT ID
                                                                                                                             TECN COMMENT
 VALUE
  <3.0 × 10
                                                                                  ALBRECHT
                                                                                                                    91E ARG e^+e^- \rightarrow \Upsilon(45)
                                                         90
 • • We do not use the following data for averages, fits, limits, etc. • • •
 <5.2 \times 10<sup>-4</sup>
                                                                      279 AVERY
                                                         90
                                                                                                                    87 CLEO e^+e^- \rightarrow \Upsilon(4S)
 <sup>279</sup> AVERY 87 reports < 6.5 \times 10^{-4} assuming the \Upsilon(45) decays 40% to B^0 \overline{B}{}^0. We rescale
        to 50%.
 \Gamma(K^0\mu^+\mu^-)/\Gamma_{\text{total}}
                                                                                                                                                                                     Γ146/Γ
              Test for \Delta B = 1 weak neutral current. Allowed by higher-order electroweak interac-
              tions.
                                                         CL%
                                                                                  DOCUMENT ID
                                                                                                                               TECN COMMENT
                                                                        280 AVERY
 <3.6 \times 10^{-4}
                                                         90
                                                                                                                     87 CLEO e^+e^- \rightarrow T(45)
 • • We do not use the following data for averages, fits, limits, etc. • •
 <5.2 \times 10<sup>-4</sup>
                                                         90
                                                                                  ALBRECHT 91F ARG e^+e^- \rightarrow \Upsilon(4S)
 <sup>280</sup> AVERY 87 reports < 4.5 \times 10^{-4} assuming the T(4S) decays 40% to B^0 \overline{B}{}^0. We rescale
        to 50%.
 \Gamma(K^{*}(892)^{0}e^{+}e^{-})/\Gamma_{\text{total}}
                                                                                                                                                                                     \Gamma_{147}/\Gamma
              Test for \Delta B = 1 weak neutral current.
                                                     CL%
                                                                                 DOCUMENT ID
                                                                                                                              TECN COMMENT
  <2.9 × 10<sup>-4</sup>
                                                                                                                                            e^+e^- \rightarrow \Upsilon(4S)
                                                                                  ALBRECHT
                                                                                                                    91E ARG
 \Gamma(K^*(892)^0 \mu^+ \mu^-)/\Gamma_{\text{total}}
                                                                                                                                                                                     \Gamma_{148}/\Gamma
              Test for \Delta B = 1
                                                    weak neutral current
                                                                                  DOCUMENT ID
                                                       <u>CL%</u>
                                                                                                                              TECN COMMENT
                                                                        <sup>281</sup> ALBAJAR
 < 2.3 \times 10^{-5}
                                                                                                                    91c UA1 E_{\text{cm}}^{p\overline{p}} = 630 GeV
                                                         90
 • • • We do not use the following data for averages, fits, limits, etc. • • •
 <2.5 × 10<sup>-5</sup>
                                                                         282 ABE
                                                                                                                    96L CDF
                                                         90
                                                                                                                                               pp at 1.8 TeV
 <3.4 × 10<sup>-4</sup>
                                                                                 ALBRECHT
                                                                                                                                                e^+e^- \rightarrow \Upsilon(45)
                                                         90
                                                                                                                    91E ARG
 <sup>281</sup> ALBAJAR 91C assumes 36% of \overline{b} quarks give B^0 mesons.
<sup>282</sup>ABE 96L measured relative to B^0 \to J/\psi(1S) K^*(892)^0 using PDG 94 branching ratios.
\Gamma(K^*(892)^0 \nu \overline{\nu})/\Gamma_{\text{total}}
Test for \Delta B = 1 weak neutral current
                                                                                                                                                                                     T149/F
VALUE
                                                                                                                              TECN_ COMMENT
                                                        CL%
                                                                                 DOCUMENT ID
 <1.0 × 10<sup>-3</sup>
                                                                       283 ADAM
                                                        90
                                                                                                                     96D DLPH e+e- → Z
 <sup>283</sup>ADAM 96D assumes f_{B^0} = f_{B^-} = 0.39 and f_{B_g} = 0.12.
\Gamma(e^{\pm}\mu^{\mp})/\Gamma_{\text{total}}
                                                                                                                                                                                     \Gamma_{150} / \Gamma_{1
              Test of lepton family number conservation.
                                                                                  DOCUMENT ID
                                                                                                                              TECN COMMENT
                                                       CL%
 <5.9 \times 10^{-6}
                                                         90
                                                                                  AMMAR
                                                                                                                    94 CLE2 e^+e^- \rightarrow \Upsilon(4S)
 • • • We do not use
                                                 the following data for averages, fits, limits, etc. . .
                                                                        <sup>284</sup> ACCIARRI
 <1.6 × 10<sup>-5</sup>
                                                                                                                    97B L3
                                                                        <sup>285</sup> AVERY
  <3.4 × 10<sup>--5</sup>
                                                         90
                                                                                                                     89B CLEO
  <4.5 × 10<sup>-5</sup>
                                                                        286 ALBRECHT
                                                                                                                    87D ARG
 < 7.7 \times 10^{-5}
                                                                         <sup>287</sup> AVERY
                                                         90
                                                                                                                     87
                                                                                                                             CLEO
  <3 × 10<sup>-4</sup>
                                                         90
                                                                                  GILES
                                                                                                                    84 CLEO Repl. by AVERY 87
<sup>284</sup>ACCIARRI 97B assume PDG 96 production fractions for B^+, B^0, B_s, and \Lambda_b.
<sup>285</sup> Paper assumes the \Upsilon(4S) decays 43% to B^0\,\overline{B}{}^0. We rescale to 50%.
<sup>286</sup>ALBRECHT 87D reports < 5 \times 10^{-5} assuming the \Upsilon(4S) decays 45% to B^0 \, \overline{B}{}^0. We
rescale to 50%.  

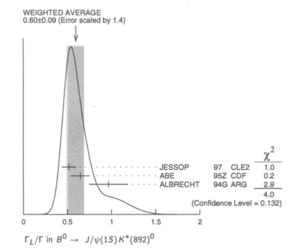
287 AVERY 87 reports < 9 \times 10<sup>-5</sup> assuming the T(4S) decays 40% to B^0 \, \overline{B}{}^0. We rescale
\Gamma(e^{\pm} 	au^{\mp})/\Gamma_{	ext{total}}
Test of lepton family number conservation.
                                                                                                                                                                                     Γ<sub>151</sub>/Γ
VALUE
                                                                                  DOCUMENT ID
                                                                                                                               TECN__COMMENT
                                                        CL%
  <5.3 × 10<sup>-4</sup>
                                                                                   AMMAR
                                                                                                                    94
                                                                                                                             CLE2 e^+e^- \rightarrow \Upsilon(45)
 \Gamma(\mu^{\pm}\tau^{\mp})/\Gamma_{\text{total}}
                                                                                                                                                                                     \Gamma_{152}/\Gamma
             Test of lepton family number conservation.
 VALUE
                                                        CL%
                                                                                  DOCUMENT IS
                                                                                                                               TECN_ COMMENT
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POLARIZATION IN BO DECAY

 $\Gamma_L/\Gamma \text{ in } B^0 \to J/\psi(15) K^*(892)^0$

 $\Gamma_L/\Gamma=1[0]$ would indicate that $B^0\to J/\psi(1S)K^*(892)^0$ followed by $K^*(892)^0\to K_S^0\pi^0$ is a pure CP eigenstate with CP=-1[+1].

	288 JESSOP	97 CLE	$2 e^+e^- \rightarrow T(45)$
65	ABE	95z CDF	F pp at 1.8 TeV
13	289 ALBRECHT	94G ARC	$s e^+e^- \rightarrow T(45)$
he follow	ing data for average	es, fits, lim	its, etc. • • •
42	²⁸⁹ ALAM	94 CLE	2 Sup. by JESSOP 97
		0 and B+	decays. The P-wave fraction
	13 the follow 42 average (65 ABE 13 ²⁸⁹ ALBRECHT the following data for average 42 ²⁸⁹ ALAM	65 ABE 95Z CDI 13 289 ALBRECHT 94G ARG the following data for averages, fits, lim 42 289 ALAM 94 CLE average over a mixture of 80 and $^{8+}$



$$\Gamma_L/\Gamma$$
 In $B^0 o D^{\bullet-} \rho^+$

VALUE EVTS DOCUMENT ID TECN COMMENT

0.93±0.05±0.05

76 ALAM 94 CLE2 $e^+e^- o T(45)$

$B^0-\overline{B}^0$ MIXING

Revised December 1997 by H. Quinn (SLAC)

There are two neutral B meson systems which are like the neutral kaon system, in that two CP-conjugate states exist: the states $B^0 = \overline{b}d$, and $\overline{B}^0 = \overline{d}b$, which we will call the B_d system; and the states $B_s^0 = \overline{b}s$, and $\overline{B}_s^0 = \overline{s}b$, which we call the B_s system. For early work on CP violation in the B systems, chiefly the B_d system, see Ref. 1. In both these systems the mass eigenstates are not CP eigenstates, but are mixtures of the two CP-conjugate quark states. The fact that the mixing, due to box diagrams, shown in Fig. 1, produces non-CP eigenstates means that there is a CP-violating phase that enters in the amplitude for these diagrams. The two mass eigenstates can be written, for example for the B_d system,

$$|B_L\rangle = p|B^0\rangle + q|\overline{B}^0\rangle ,$$

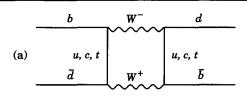
 $|B_H\rangle = p|B^0\rangle - q|\overline{B}^0\rangle .$ (1)

Here H and L stand for Heavy and Light, respectively.

The complex coefficients p and q obey the normalization condition

$$|q|^2 + |p|^2 = 1. (2)$$

 B^0



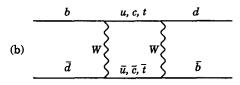


Figure 1: Mixing Diagrams.

We define the mass difference ΔM and width difference $\Delta \Gamma$ between the neutral B mesons:

$$\Delta M \equiv M_H - M_L ,$$

$$\Delta \Gamma \equiv \Gamma_H - \Gamma_L ,$$
(3)

so that ΔM is positive by definition. Finding the eigenvalues of the mass-mixing matrix, one gets

$$(\Delta M)^2 - \frac{1}{4}(\Delta \Gamma)^2 = 4(|M_{12}|^2 - \frac{1}{4}|\Gamma_{12}|^2) \tag{4}$$

and

$$\Delta M \Delta \Gamma = 4 \operatorname{Re} \left(M_{12} \Gamma_{12}^* \right) \,, \tag{5}$$

where the off-diagonal term of the mixing matrix is written as $M_{12} + i\Gamma_{12}$. Note that both M_{12} and Γ_{12} may be complex quantities; the separation is defined by the fact that Γ_{12} is given by the absorbtive part of the diagrams (cut contributions). The ratio q/p is given by

$$\frac{q}{p} = -\frac{\Delta M - \frac{i}{2}\Delta\Gamma}{2(M_{12} - \frac{i}{2}\Gamma_{12})} = -\frac{2(M_{12}^* - \frac{i}{2}\Gamma_{12}^*)}{\Delta M - \frac{i}{2}\Delta\Gamma}.$$
 (6)

Whereas in the kaon case the lifetimes of the two eigenstates are significantly different and the difference in masses between them is small, in the B_d system it is the mass differences that dominate the physics, and the two states have nearly equal predicted widths (and thus lifetimes). We define, for q = d, s

$$x_q = \frac{\Delta M_q}{\Gamma_q}$$
, $y_q = \frac{\Delta \Gamma_q}{\Gamma_q}$. (7)

The value of x_d is about 0.7, not very different from the similar quantity for the K^0 which is 0.48. The difference between the widths of the two B_d eigenstates is produced by the contributions from channels to which both B^0 and \overline{B}^0 can decay. These have branching ratios of $\mathcal{O}(10^{-3})$ [2]. Furthermore there are contributions of both signs to the difference, so there is no reason that the net effect should be much larger than the individual terms. Conservatively, one expects $y_d \leq 10^{-2}$ and thus also $|q/p|_d$ equal to 1 to a very good approximation. Experimentally no effect of a difference in lifetimes has been observed.

For B_s there is currently only a lower bound on the value of x_s . Theoretical expectation is that it may be as large as 20 or more, which makes it quite difficult to measure. A significant difference in widths is possible, due to the fact that a number of the simplest two-body channels contribute only to a single CP (like the two-pion state which dominates K-decays and is the source of the large width difference in that system). The difference in widths could be as much as 20% of the total width in the B_s system [3]. Note that this still gives a small ratio, of order a few percent, for $\Delta\Gamma/\Delta M$.

The proper time evolution of an initially (t=0) pure B^0 or $\overline{B}{}^0$ is given by

$$|B_{\text{phys}}^{0}(t)\rangle = g_{+}(t)|B^{0}\rangle + (q/p)g_{-}(t)|\overline{B}^{0}\rangle ,$$

$$|\overline{B}_{\text{phys}}^{0}(t)\rangle = (p/q)g_{-}(t)|B^{0}\rangle + g_{+}(t)|\overline{B}^{0}\rangle .$$
(8)

where

$$g_{\pm} = \frac{1}{2} \exp(-\Gamma t/2) \exp(-iMt)$$

$$\times \left\{ e^{-(\Delta \Gamma/2 - \Delta M)t} \pm e^{+(\Delta \Gamma/2 - \Delta M)t} \right\} . \tag{9}$$

The rate at which an initial B_q^0 (\overline{B}_q^0) decays as a \overline{B}_q^0 (B_q^0) is thus

$$R_q(t) = q/p \text{ (or } p/q)\Gamma |g_-(t)|^2$$
 (10)

The quantity χ_q measures the total probability that a created B^0 decays as a \overline{B}^0 ; it is given by

$$\chi_q = \int_0^\infty R_q(t) dt = \frac{1}{2} |q/p|^2 \frac{x_q^2 - y_q^2/4}{(1 + x_q^2)(1 - y_q^2/4)} , \qquad (11)$$

Time-dependent mixing measurements are now being done for the B_d system; earlier experiments measured only the time-integrated mixing, which is parameterized by a parameter χ_d . In this case to a good approximation we can set |q/p|=1 and $|y_d| \ll x_d < 1$ so that the simpler form $\chi_d = \frac{1}{2} \frac{x_d^2}{1+x_d^2}$ applies, and a measurement of χ_d implies a value of x_d .

In the B^0 – \overline{B}^0 mixing section of the B^0 Particle Listings, we list the χ_d measurements, most of which come from $\Upsilon(4S)$ data, and the Δm_{B^0} measurements, which come from Z data. We average these sections separately, but then include the results from both sections in "OUR EVALUATION" of χ_s and $\Delta M_{B^0_s}$. We convert both of these sets of measurements and list them in the χ_d section. The χ_d values obtained from Δm_{B^0} measurements have a common systematic error due to the error on τ_{B^0} . The averaging takes this common systematic error into account.

Because of the large value of x_s the quantity χ_s will be close to its upper limit of 0.5. This means that one cannot determine x_s accurately by measuring χ_s . It will require excellent time resolution to resolve the time-dependent mixing of the B_s^0 system, and thereby determine $\Delta M_{R_s^0}$.

In the $B_s^0 - \overline{B}_s^0$ mixing section of the B_s^0 Particle Listings, we give measurements of χ_B , the mixing parameter for a high-energy admixture of b-hadrons

$$\chi_B = f_d \frac{\mathcal{B}_d}{\langle \mathcal{B} \rangle} \chi_d + f_s \frac{\mathcal{B}_s}{\langle \mathcal{B} \rangle} \chi_s . \tag{12}$$

Here f_d and f_s are the fractions of b hadrons that are produced as B^0 and B^0_s mesons respectively, and \mathcal{B}_d , \mathcal{B}_s , and $\langle \mathcal{B} \rangle$ are branching fractions for B_d , B_s , and the b-hadron admixture respectively decaying to the observed mode. If we assume that $\chi_s = 0.5$ and $\mathcal{B}_d/\langle \mathcal{B} \rangle = \mathcal{B}_s/\langle \mathcal{B} \rangle = 1$, Eq. (12) can be used to determine f_s as discussed in the note on "Production and Decay of b-Flavored Hadrons."

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- 1. A.B. Carter and A.I. Sanda, Phys. Rev. Lett. 45, 952 (1980); Phys. Rev. D23, 1567 (1981); I.I. Bigi and A.I. Sanda Nucl. Phys. B193, 85 (1981) and Nucl. Phys. B281, 41 (1987).
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- 3. R. Aleksan, A. Le Yaouanc, L. Oliver, O. Pene and J.C. Raynall, Phys. Lett. **B316**, 567 (1993); M. Beneke, G. Buchalla, I. Dunietz, Phys. Rev. D54, 4419 (1996).

B⁰-B⁰ MIXING PARAMETERS

or a discussion of $B^0 ext{-}\overline{B}{}^0$ mixing see the note on " $B^0 ext{-}\overline{B}{}^0$ Mixing" in the For a discussion of B^--B^- B Particle Listings above.

 x_d is a measure of the time-integrated $B^0 \overline{B}{}^0$ mixing probability that a produced $B^0(\overline{B}^0)$ decays as a $\overline{B}^0(B^0)$. Mixing violates $\Delta B \neq 2$ rule.

$$x_d = \frac{x_d^2}{2(1+x_d^2)}$$

$$x_d = \frac{\Delta m_{B^0}}{\Gamma_{B^0}} = (m_{B^0_H} - m_{B^0_L}) \, \tau_{B^0} \; .$$

where H,L stand for heavy and light states of two B^0 CP eigenstates and $au_{B^0} = \frac{1}{0.5(\Gamma_{B_H^0 + \Gamma_{B_L^0}}^0)}$.

This B^0 - \overline{B}^0 mixing parameter is the the probability (integrated over time) that a produced B^0 (or \overline{B}^0) decays as a \overline{B}^0 (or B^0), e.g. for inclusive lepton decays

$$X_d = \Gamma(B^0 \to \ell^+ X \text{ (via } \overline{B}^0))/\Gamma(B^0 \to \ell^{\pm} X)$$

$$= \Gamma(\overline{B}^0 \to \ell^{\pm} X \text{ (via } B^0))/\Gamma(\overline{B}^0 \to \ell^{\pm} X)$$

 $= r(\overline{B}^0 \to \ell^{\pm} X \text{ (via } B^0))/r(\overline{B}^0 \to \ell^{\pm} X)$ Where experiments have measured the parameter r = X/(1-X), we have converted to X. Mixing violates the $\Delta B \neq 2$ rule.

Note that the measurement of χ at energies higher than the $\Upsilon(4S)$ have not separated x_d from x_s where the subscripts indicate $B^0(\overline{b}d)$ or $B^0_s(\overline{b}s)$. They are listed in the $B_s^0 - \overline{B}_s^0$ MIXING section.

The experiments at $\Upsilon(45)$ make an assumption about the $B^0\overline{B}{}^0$ fraction and about the ratio of the B^{\pm} and B^{0} semileptonic branching ratios (usually that it equals one).

OUR EVALUATION, provided by the LEP B Oscillation Working Group, includes X_d calculated from Δm_{B^0} and au_{B^0} .

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
0.172±0.010 OUR EV	ALUATIO	N		
0.156±0.024 OUR AV	ERAGE			
$0.16 \pm 0.04 \pm 0.04$		290 ALBRECHT	94 ARG	$e^+e^- \rightarrow T(45)$
$0.149 \pm 0.023 \pm 0.022$		²⁹¹ BARTELT	93 CLE2	$e^+e^- \rightarrow \gamma(4S)$
0.171 ± 0.048		292 ALBRECHT	92L ARG	$e^+e^- \rightarrow \Upsilon(4S)$
• • • We do not use the	following	data for averages,	fits, limits, e	tc. • • •
0.20 ±0.13 ±0.12		293 ALBRECHT	96D ARG	$e^+e^- \rightarrow \Upsilon(45)$
0.19 ±0.07 ±0.09		294 ALBRECHT	96D ARG	$e^+e^- \rightarrow r(4s)$
0.24 ±0.12		²⁹⁵ ELSEN	90 JADE	e+e~ 35-44 GeV
$0.158 + 0.052 \\ -0.059$		ARTUSO	89 CLEO	$e^+e^- \rightarrow \Upsilon(4S)$
0.17 ±0.05		296 ALBRECHT	871 ARG	$e^+e^- \rightarrow \Upsilon(45)$
< 0.19	90	²⁹⁷ BEAN		$e^+e^- \rightarrow \Upsilon(45)$
<0.27	90	298 AVERY		$e^+e^- \rightarrow \Upsilon(45)$
90				

 $^{^{290}}$ ALBRECHT 94 reports $r=0.194\pm0.062\pm0.054$. We convert to χ for comparison. Uses tagged events (lepton + pion from D^*).

- 292 ALBRECHT 92L is a combined measurement employing several lepton-based techniques. it uses all previous ARGUS data in addition to new data and therefore supersedes ALBRECHT 87L A value of $r=20.6\pm7.0\%$ is directly measured. The value can be used to measure $x=\Delta M/f=0.72\pm0.15$ for the B_0 meson. Assumes $f_+ = f_0 = 1.0\pm0.05$ and uses $\tau_{B^{\pm}}/\tau_{B^0} = (0.95 \pm 0.14) (f_{+-}/f_0)$.
- 293 Uses $D^{*+}K^{\pm}$ correlations. 294 Uses $(D^{*+}\ell^{-})K^{\pm}$ correlations.
- 295 These experiments see a combination of $B_{\it s}$ and $B_{\it d}$ mesons.
- ²⁹⁶ ALBRECHT 87i is inclusive measurement with like-sign dileptons, with tagged B decays plus leptons, and one fully reconstructed event. Measures r=0.21 \pm 0.08. We convert to X for comparison. Superseded by ALBRECHT 92L.
- 297 BEAN 878 measured r < 0.24; we converted to x.
- 298 Same-sign dilepton events. Limit assumes semileptonic BR for B^+ and B^0 equal. If B^0/B^\pm ratio <0.58, no limit exists. The limit was corrected in BEAN 87B from r < 0.30 to r < 0.37. We converted this limit to χ .

$\Delta m_{B^0} = m_{B^0_H} - m_{B^0_L}$

 $\Delta m_{B_0^0}$ is a measure of 2π times the $B^0 - \overline{B}{}^0$ oscillation frequency in time-dependent mixing experiments.

The second "OUR EVALUATION" (0.470 \pm 0.019) is an average of the data listed below performed by the LEP B Oscillation Working Group as described in our review "Production and Decays of B-flavored Hadrons" in the B^\pm Section of these Listings. The averaging procedure takes into account correlations between the measurements.

The first "OUR EVALUATION" (0.464 \pm 0.018), also provided by the LEP B Oscillation Working Group, includes Δm_d calculated from x_d measured at T(45).

VALUE (10 ¹² h s ⁻¹) EVTS		DOCUMENT ID		TECN	COMMENT
0.464 ± 0.018 OUR EVALUAT					
0.470±0.019 OUR EVALUAT					
$0.471 + 0.078 + 0.033 \\ -0.068 - 0.034$		ABE	98 C	CDF	p₱ at 1.8 TeV
$0.458 \pm 0.046 \pm 0.032$	300	ACCIARRI	98D	L3	$e^+e^- \rightarrow Z$
$0.437 \pm 0.043 \pm 0.044$	301	ACCIARRI	98D	L3	e ⁺ e [−] → Z
$0.472 \pm 0.049 \pm 0.053$	302	ACCIARRI	98D	L3	$e^+e^- \rightarrow Z$
$0.523 \pm 0.072 \pm 0.043$		ABREU	97N	DLPH	$e^+e^- \rightarrow Z$
$0.493 \pm 0.042 \pm 0.027$		ABREU		DLPH	$e^+e^- \rightarrow Z$
$0.499 \pm 0.053 \pm 0.015$	304	ABREU	97N	DLPH	$e^+e^- \rightarrow Z$
$0.480 \pm 0.040 \pm 0.051$	300	ABREU	97N	DLPH	$e^+e^- \rightarrow Z$
$0.444 \pm 0.029 {+0.020 \atop -0.017}$	301	ACKERSTAFF	97 U	OPAL	$e^+e^- \rightarrow Z$
$0.430 \pm 0.043 {+0.028 \atop -0.030}$		ACKERSTAFF	97∨	OPAL	$e^+e^- \rightarrow Z$
$0.482 \pm 0.044 \pm 0.024$	305	BUSKULIC		ALEP	
$0.404 \pm 0.045 \pm 0.027$	301	BUSKULIC	97 D	ALEP	$e^+e^- \rightarrow Z$
$0.452 \pm 0.039 \pm 0.044$		BUSKULIC	97D	ÁLEP	$e^+e^- \rightarrow Z$
$0.539 \pm 0.060 \pm 0.024$	306	ALEXANDER	96v	OPAL	$e^+e^- \rightarrow Z$
$0.567 \pm 0.089 ^{+0.029}_{-0.023}$	307	ALEXANDER	96v	OPAL	$e^+e^- \rightarrow Z$
• • We do not use the folk	_	_	, fits	, Ilmits,	
$0.444 \pm 0.028 \pm 0.028$	308	ACCIARRI	98D		$e^+e^- \rightarrow Z$
0.497 ± 0.035	309	ABREU	97N	DLPH	e ⁺ e ⁻ → Z
$0.467 \pm 0.022 ^{+0.017}_{-0.015}$		ACKERSTAFF	97∨	OPAL	$e^+e^- \rightarrow Z$
0.446 ± 0.032	311	BUSKULIC	97D	ALEP	$e^+e^- \rightarrow Z$
$0.531^{+0.050}_{-0.046}\pm0.078$	312	ABREU	96Q	DLPH	Sup. by ABREU 97N
$0.496 ^{+0.055}_{-0.051} \pm 0.043$	300	ACCIARRI	96E	L3	Repl. by ACCIARRI 980
$0.548 \pm 0.050 ^{+0.023}_{-0.019}$		ALEXANDER	9 6 v	OPAL	$e^+e^- \rightarrow Z$
0.496 ± 0.046	314	AKERS	95)	OPAL	Repl. by ACKER- STAFF 97V
$0.462 + 0.040 + 0.052 \\ -0.053 - 0.035$	300	AKERS	95J	OPAL	Repl. by ACKER- STAFF 97V
0.50 ±0.12 ±0.06	303	ABREU	94M	DLPH	Sup. by ABREU 97N
$0.508 \pm 0.075 \pm 0.025$	306	AKERS	94c	OPAL	Repl. by ALEXAN-
0.57 ±0.11 ±0.02 153		AKERS		OPAL	DER 96V Repl. by ALEXAN-
+0.07 +0.11	, 300				DER 96V
0.50 +0.07 +0.11 -0.06 -0.10		BUSKULIC		ALEP	Sup. by BUSKULIC 97D
0.52 +0.10 +0.04 -0.03		BUSKULIC	93K	ALEP	Sup. by BUSKULIC 970
299 Uses π - B in the same side	ì.				
300 Uses <i>l-l</i> . 301 Uses <i>l-Q</i> _{hem} .					
302 Uses <i>l-l</i> with impact para	meter				
303 Uses D*±-Qhem					
304 Hore = ± 4.0					
304 Uses π _s ± ℓ-Q _{hem} .					
305 Uses D*±-t/Qhem.					
306 Uses D*± ℓ-Qhem.					
307 Uses <i>D</i> *±-ℓ. 308 ACCIARRI 98D combines	results	from <i>l-L</i> , <i>l-Q</i> _{he}	m, a	nd l-l w	rith Impact parameters.
309 ABREU 97N combines res	ults fro	m D*±-Q _{hem} .	l-Q	ıem, π±	L-Q _{hern} , and L-L.
310 ACKERSTAFF 97v combi	ines resi	ults from <i>l-l. l-</i>	Qn.	n. D*-l	and D*±-Qham.
311 BUSKULIC 97D combines	resulte	from D*±-1/C	-11EF	. 1-0-	and <i>l-l</i> .
312 ABREU 96Q analysis perfe	ormed :	ising lepton. kar	nem on. >	nd let-cl	harge tags.
313 ALEXANDER 96v combin	ies resu	its from D*±-1	and	D*± 1-	Oham.
314 AKERS 951 combines resu	ilte from	nt charge mean		+ D*	± In Oh and In!

314 AKERS 953 combines results fromt charge measurement, $D^{*\pm}\ell$ - Q_{hem} and ℓ - ℓ .

²⁹¹ BARTELT 93 analysis performed using tagged events (lepton+plon from D*). Using dilepton events they obtain 0.157 ± 0.016 +0.038.

 $x_d = \Delta m_{B^0}/\Gamma_{B^0}$ The second "OUR EVALUATION" (0.734 \pm 0.035) is an average of the data listed in Δm_{B^0} section performed by the LEP B Oscillation Working Group as described the contraction and Decays of B-flavored Hadrons" in the B^\pm Section of these Listings. The averaging procedure takes into account correlations between the

The first "OUR EVALUATION" (0.723 \pm 0.032), also provided by the LEP B Oscillation Working Group, includes x_d measured at $\Upsilon(4S)$.

0.723±0.032 OUR EVALUATION 0.734±0.035 OUR EVALUATION

VIOLATION IN B DECAY **STANDARD** MODEL PREDICTIONS

Revised February 1998 by H. Quinn (SLAC).

The study of CP violation in B decays [1] offers an opportunity to test whether the Standard Model mechanism for CP violation, due to the phase structure of the CKM matrix, is the only source of such effects [2]. The known CP-violation effects in K decays can be accommodated by this mechanism, but do not provide a critical test of it.

The Unitarity conditions (see our Section on "The Cabibbo-Kobayashi-Maskawa mixing matrix")

$$V_{uq}V_{ub}^* + V_{cq}V_{cb}^* + V_{tq}V_{tb}^* = 0 , (1)$$

with q = s or q = d where V_{ij} is an element of the CKM matrix can be represented as triangles in the complex plane. The three interior angles of the q = d triangle are labeled

$$\alpha \equiv \arg\left(-\frac{V_{td}V_{tb}^*}{V_{ud}V_{ub}^*}\right) , \quad \beta \equiv \arg\left(-\frac{V_{cd}V_{cb}^*}{V_{td}V_{tb}^*}\right) ,$$

$$\gamma \equiv \arg\left(-\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*}\right) . \tag{2}$$

In terms of the Wolfenstein parameters [3] we can also write

$$\tan \alpha = \frac{\eta}{\eta^2 - \rho(1 - \rho)}$$
, $\tan \beta = \frac{\eta}{1 - \rho}$,
 $\tan \gamma = \frac{\eta}{\rho}$. (3)

Notice that the sign as well the magnitude of these angles is meaningful and can be measured.

A major aim of CP-violation studies of B decays is to make enough independent measurements of the sides and angles that the Unitarity triangle is overdetermined and thereby to check the validity of the Standard Model predictions that relate various measurements to aspects of this triangle. Constraints can be made on the basis of present data on the B-meson masses and lifetimes, on the ratio of charmless decays to decays with charm (V_{ub}/V_{cb}) , and on ϵ [4] in K decays. These constraints have been discussed in many places in the literature; for a recent summary see Ref. 5. The range of allowed values depends on matrix element estimates, these are difficult to calculate hadronic physics effects. Improved methods to calculate such quantities, and understand the uncertainties in them, are needed to further sharpen tests of the Standard Model. Because of the uncertainties in these quantities, any given "Standard Model allowed range," for example for (ρ, η) , cannot be interpreted as a statistically-based error range.

The phases in decay amplitudes which arise because of the phase in the CKM matrix, are called weak phases; the phases which arise from final state rescattering effects are referred to as strong phases. When one compares the amplitude for decay to a CP eigenstate to that for the related CP-conjugate process, the weak phase ϕ_i of each contribution changes sign, while the strong phase δ_i is unchanged:

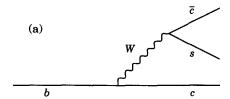
$$\mathcal{A} = \Sigma_i \mathcal{A}_i e^{i(\delta_i + \phi_i)} , \overline{\mathcal{A}} = \Sigma_i \mathcal{A}_i e^{i(\delta_i - \phi_i)} .$$
 (4)

Direct CP violation is a difference in the direct decay rate between $B \to f$ and $\overline{B} \to \overline{f}$ without any contribution from mixing effects. This requires $|A| \neq |\overline{A}|$, which occurs only if there is more than one term in the sum Eq. (4), and then only if the two terms have both different weak phases and different strong phases. A nonzero result for $Re(\epsilon'/\epsilon)$ in K decay is a direct CP-violation effect. Direct CP violation can occur both in charged channels and in neutral channels in B decays [4].

In the Standard Model direct CP violation occurs because there are two major classes of diagrams that contribute to weak decays, tree diagrams, and penguin diagrams, examples of which are shown in Fig. 1. Tree diagrams are those in which the W does not reconnect to the quark line from which it was emitted. Penguin diagrams are loop diagrams in which the W is re absorbed on the same quark line, producing a net change of flavor, and a gluon (for a strong penguin) or a photon or Z (for an electroweak penguin) is emitted from the loop. There may be several different tree diagrams for a given process, namely Wemission and decay, W decay, W exchange between the initial valence quarks, and/or valence quark-antiquark annihilation to produce the W. However all such contributions which enter a given transition do so with the same CKM (weak) phase. Direct CP violation occurs because of interference between tree diagrams and those penguin diagrams which have different weak phases than the trees. In channels where there are no tree contributions, direct CP violation can arise because of interference between different penguin contributions.

To calculate the size of expected CP-violation effects one begins from the relevant quark decay diagrams. We divide the amplitudes into two factors: a CKM factor given by the CKMmatrix elements that enter at each W vertex, and a Feynman amplitude from evaluating the remainder of the diagram. The Feynman amplitude of the penguin diagram is suppressed relative to tree diagrams by a factor of order $\alpha_s(m_b)/4\pi$. Firm predictions based on this argument for the strength of the CP-violating effects in particular exclusive charged B-decay channels are not possible because the relationship between the free-quark decay diagrams and the exclusive meson-decay amplitudes depends on operator matrix elements and thus estimates are model dependent. Furthermore one cannot reliably predict the strong phases that contribute to the asymmetry.

There is one interesting exception to this last statement that gives a possible way to find large direct CP-violation effects with known strong phase differences. This is any situation where two or more resonance channels contribute to the same final state



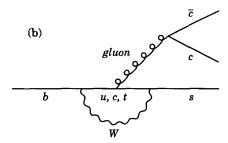


Figure 1: Quark level processes for $b \to c\bar{c}s$: (a) Tree diagram; (b) Penguin diagram. In the case of electroweak penguin contributions, the gluon is replaced by a Z or a γ .

set of particles in overlapping kinematic regions. The dominant contributions to the strong phases are then the resonant decay phases, which are known from measurements that determine the resonance mass and width. These give a known strong phase contribution which varies with the kinematics of the final particles and overlays the fixed strong phase of the resonanceproduction process. If two such resonant channels interfere, then there is a large and kinematically-varying known contribution to the strong phase difference between the contributions of the two channels. Examples include the interference of the different ρ - π charge combinations in the three pion final states [6] or interference between different $K^*\pi$ combinations in $K\pi\pi$ states. Detailed exploration of possible applications of these ideas can be found in Ref. 7.

A second type of CP violation, referred to as indirect CPviolation, or CP violation in the mixing, would arise from any difference in the widths $\Delta\Gamma$ of the two mass eigenstates, or more precisely from complex mixing effects $Arg(\Gamma_{12}M_{12}^*) \neq 0$, that would give $|q/p| \neq 1$ and also give a nonvanishing lifetime difference for the two B mass eigenstates [8]. Indirect CPviolation in the K system is responsible for Re $\epsilon \neq 0$, which give CP-violating asymmetries in leptonic decay rates. Such effects are expected to be tiny in the B_d system, where both |q/p|-1 and the difference of lifetimes $\Delta\Gamma/\Gamma$ are expected to be of order 10^{-2} [8]. For B_s a difference in the widths is possible, due to the fact that a number of the simplest two-body channels contribute only to a single CP. The difference in widths could be as much as 20% of the total width in the B_s system [9]. However the quantity |q/p|-1 is expected to be even smaller in the B_s system than in the B_d system. An indirect CPviolating asymmetry would be seen as an charge asymmetry in the same-sign dilepton events produced via mixing from an incoherent state that initially contains a $B^0\overline{B}{}^0$ pair. This asymmetry vanishes with $\Delta\Gamma$; it is expected to be no larger than 1% in B_d decays [10].

There are additional CP-violating effects in neutral B decays which arise from interference between the two paths to a given final state f

$$B \to f \text{ or } B \to \overline{B} \to f$$
 (5)

This effect, an interference between decay with and without mixing, is seen also in K decays where it contributes to the parameter Im ϵ . This interference can produce rate differences between B decay to a CP-eigenstate and the CP-conjugate \overline{B} decay. Such asymmetries can be directly related to the CKM phases, provided there is no direct CP violation in addition to this effect. In channels where there is also direct CP violation, the relationship between the measured asymmetry and the CKM parameters is more complicated.

A simple way to distinguish the three types of CP violation is to note that direct CP violation occurs when $|\overline{A}/A| \neq 1$ while indirect CP violation requires $|q/p| \neq 1$ (see the review on B^0 \overline{B}^0 Mixing). CP violation due to the interference between direct decay and decay after mixing can occur when both quantities have unit absolute value; it requires only that their product have a nonzero weak phase [11].

Neutral B decays to CP eigenstates: The decays of neutral B mesons into CP eigenstates are of particular interest because many of these decays allow clean theoretical interpretation in terms of the parameters of the Standard Model [12]. We denote such a state by f_{CP} , for example $f_{CP} = J/\psi(1S)K_S$ or $f_{CP} = \pi \pi$, and define the amplitudes

$$\mathcal{A}_{f_{CP}} \equiv \langle f_{CP} | B^0 \rangle, \quad \overline{\mathcal{A}}_{f_{CP}} \equiv \langle f_{CP} | \overline{B}^0 \rangle .$$
 (6)

For convenience let us introduce the quantity $\lambda_{f_{CP}}$

$$\lambda_{f_{CP}} \equiv \frac{q}{p} \frac{\overline{\mathcal{A}_{f_{CP}}}}{\mathcal{A}_{f_{CP}}} \ . \tag{7}$$

In the limit of no CP violation, $\lambda_{f_{CP}} = \pm 1$, where the sign is given by the CP eigenvalue of the particular state f_{CP} .

When the small difference in width of the two B_d states is ignored we can write

$$(q/p)_{B_d} = \frac{(V_{tb}^* V_{td})}{(V_{tb} V_{td}^*)} = e^{-2i\phi_M} ,$$
 (8)

where $2\phi_M$ denotes the CKM phase of the $B-\overline{B}$ mixing diagram (see the review on $B^0 - \overline{B}{}^0$ Mixing). The time-dependent decay width for an initial $B^0(\overline{B}^0)$ state to decay to a state f is then given by

$$\begin{split} &\Gamma(B^0_{\rm phys}(t) \to f_{CP}) = \\ &|\mathcal{A}_{f_{CP}}|^2 e^{-\Gamma t} \bigg[\frac{1 + |\lambda_{f_{CP}}|^2}{2} + \frac{1 - |\lambda_{f_{CP}}|^2}{2} \\ &\quad \times \cos(\Delta M t) - \operatorname{Im} \, \lambda_{f_{CP}} \sin(\Delta M t) \bigg], \end{split}$$

$$B^0$$

$$\Gamma(\overline{B}_{\text{phys}}^{0}(t) \to f_{CP}) =$$

$$|\mathcal{A}_{f_{CP}}|^{2} e^{-\Gamma t} \left[\frac{1 + |\lambda_{f_{CP}}|^{2}}{2} - \frac{1 - |\lambda_{f_{CP}}|^{2}}{2} \right] \times \cos(\Delta M t) + \operatorname{Im} \lambda_{f_{CP}} \sin(\Delta M t) . \tag{9}$$

The time-dependent CP asymmetry is thus

$$\begin{split} a_{f_{CP}}(t) &\equiv \frac{\Gamma(B_{\text{phys}}^{0}(t) \to f_{CP}) - \Gamma(\overline{B}_{\text{phys}}^{0}(t) \to f_{CP})}{\Gamma(B_{\text{phys}}^{0}(t) \to f_{CP}) + \Gamma(\overline{B}_{\text{phys}}^{0}(t) \to f_{CP})} \\ &= \frac{(1 - |\lambda_{f_{CP}}|^{2})\cos(\Delta M t) - 2\text{Im} \; (\lambda_{f_{CP}})\sin(\Delta M t)}{1 + |\lambda_{f_{CP}}|^{2}} \; . \; (10) \end{split}$$

Further, when there is no direct CP violation in a channel, that is when all amplitudes that contribute have the same CKM decay-phase, ϕ_D , then $|\mathcal{A}_{f_{CP}}/\overline{\mathcal{A}_{f_{CP}}}|=1$. In that case $\lambda_{f_{CP}}$ depends on CKM-matrix parameters only, without hadronic uncertainties, and can be written $\lambda_{f_{CP}}=\pm e^{-2i(\phi_D+\phi_M)}$. Then Eq. (10) simplifies to

$$a_{f_{CP}}(t) = \mp \text{Im} (\lambda_{f_{CP}}) \sin(\Delta M t)$$
$$= \pm \sin(2(\phi_M + \phi_D)) \sin(\Delta M t) . \tag{11}$$

where the overall sign is given by the CP eigenvalue, ± 1 , of the final state f_{CP} . The mixing phase ϕ_M and the decay phase ϕ_D are each convention dependent, that is their value can be changed by redefining the phases of some of the quark fields. However Im $\lambda_{f_{CP}}$ depends on convention-independent combinations of CKM parameters only. From Eq. (11) one can directly relate the measured CP-violating asymmetry to the phase of particular combination of CKM-matrix elements in the Standard Model.

Extracting CKM parameters from measured asymmetries: In order make this relationship one looks at the CKM elements that appear in the relevant decay amplitudes and in the mixing diagrams. If the final state of the decay includes a K_S , an additional contribution from the K-mixing phase must be included in relating the measured asymmetry to the CKM parameters.

Table 1: $B \rightarrow q\overline{q}s$ decay modes

Whenever a penguin amplitude can contribute there are three separate diagrams, corresponding to the three flavors of up-type quarks in the loop. Each of these has a different CKM coefficient. We use the Unitarity condition Eq. (1) to express one coefficient as minus the sum of the other two. This regroups the three terms as a sum of two terms each of which involves a difference of two penguin diagrams (and thus is an ultra-violet finite quantity). As we will see below, the most convenient regrouping is different for $b \to q\bar{q}s$ decays and for $b \to q\bar{q}d$ decays.

When there is a tree diagram one of the two penguin terms will have the same CKM coefficient (and hence the same weak phase) as the tree diagram. Terms with the same weak phase can always be treated as a single contribution, from the perspective of looking for CP violations, although one must be sure to include all the relevant operators when estimating the expected size of such a term. In what follows we use the term "tree-dominated contribution" to describe a tree contribution plus any penguin contribution with the same weak phase. We label the second penguin term, which has a different CKM coefficient from the tree diagram as a "pure penguin contribution." Where no tree diagrams contribute there are two pure penguin terms. With this convention there are at most two terms with different weak decay phases that contribute for any decay in the Standard Model. It is instructive to note that any beyond-Standard-Model contribution, whatever its weak phase, can always be written as a sum of two terms with the weak phases of the two Standard Model terms, thus it is the pattern of relative strengths, and isospin structure, of the two terms that is peculiar to the Standard Model. (Care should be taken when comparing the terms defined by this grouping with statements in the literature about the sizes of terms made using definitions that do not include this regrouping.)

Table 1 gives the CKM factors for the various $b \to q \overline{q}'s$ quark decay channels. Here we choose to group penguin terms
by eliminating the coefficient $V_{ts}V_{tb}^*$. Note that the two penguin
terms in this arrangement are each the difference between a top
quark contribution and a lighter (c or u) quark contribution, so
they differ only by the mass dependent factors in this second

Quark process	Leading term	Secondary term	$\begin{array}{c} {\rm Sample} \\ B_d \ {\rm modes} \end{array}$	B_d angle	Sample B_s modes	B_s angle
$b \rightarrow c\overline{c}s$	$V_{cb}V_{cs}^* = A\lambda^2$ tree + penguin $(c-t)$	$V_{ub}V_{us}^* = A\lambda^4(\rho - i\eta)$ penguin only $(u - t)$	$J/\psi \ K_S$	β	$\psi\eta \ D_s\overline{D}_s$	0
$b o s \overline{s} s$	$V_{cb}V_{cs}^* = A\lambda^2$ penguin only $(c-t)$	$V_{ub}V_{us}^* = A\lambda^4(\rho - i\eta)$ penguin only $(u - t)$	ϕK_S	β	$\phi\eta^{t}$	0
$b \to u\overline{u}s$ $b \to d\overline{d}s$	$V_{cb}V_{cs}^* = A\lambda^2$ penguin only $(c-t)$	$V_{ub}V_{us}^* = A\lambda^4(\rho - i\eta)$ tree + penguin $(u - t)$	$\pi^0 K_S$ $ ho K_S$	competing terms	$\phi\pi^0 \ K_S \overline{K}_S$	competing terms

contribution and by their overall sign and the CKM factors. One is suppressed by the CKM factor $\lambda^2(\rho - i\eta)$ compared to the other.

The columns labeled "Sample B_d Modes" and "Sample B_s Modes" list some of the simplest CP-study modes for each case. (These are either CP eigenstates, or modes from which CP-eigenstate contributions can be isolated, for example by angular analysis.) The columns labeled "Angle" show the angle of the unitarity triangle measured by $\phi_M + \phi_D$ where ϕ_M is the weak phase due to mixing, and ϕ_D that of the dominant decay amplitude (only the sum of these quantities is convention independent). Any Cabibbo-suppressed pure-penguin terms gives a negligible correction to this result. For the decay $b \to s\overline{s}s$ there is no tree contribution so the angle given is that due to the dominant penguin term, ignoring the Cabibbo-suppressed penguin term.

The quark decays to $u\overline{u}s$ and $d\overline{d}s$ contribute to the same set of final state hadrons and so must be combined. Here the tree diagram contributes to the Cabibbo-suppressed amplitude, so that the net result is that the two terms are expected to give comparable contributions with different CKM phases. For these decays, as with other direct CP-violating processes, there is no simple relationship between the measured asymmetry and a CKM phase, and thus no entry in the "Angle" columns in Table 1.

In addition to the neutral CP-eigenstate methods to determine the angles of the unitarity triangle listed in the tables, there are a number of other methods that involve decays that self-tag B-flavor, such as $DK^*(892)$ in either neutral [13] or charged [14] B decays. Further methods to measure γ in charged $B \to DK$ or $B \to D\pi$ have been suggested [15], which use interferences between a suppressed B decay followed by an allowed D decay and an allowed B decay followed by a suppressed D decay. However the relationship between the decay asymmetry and the angle is not as simple as Eq. (11) in this case. These methods require accurate measurements of several branching ratios, including a number that are quite small.

Table 2: $B \rightarrow q\overline{q}d$ decay modes

In Table 2 we list decays $b \to q\overline{q}'d$ decays. Here we choose to eliminate whichever of the two terms $V_{ud}V_{ub}^*$ or $V_{cd}V_{cb}^*$ is not present in the tree diagrams, so that the two penguin terms are one with the same weak phase as the tree and a second with CKM coefficient $V_{td}V_{tb}^*$ which has the opposite weak phase as the dominant mixing term in the Standard Model and hence a known value, zero, for $\phi_M + \phi_D$.

Here the competition between the tree-dominated and purepenguin amplitudes is stronger because there is no Cabibbo suppression of the latter. The pure-penguin contributions are expected to be somewhat smaller because of the $\alpha(m_b)/\pi$ suppression factor. Table 2 lists the angle $\phi_M + \phi_D$, using ϕ_D for the tree-dominated terms as the angle measured. However the measured angle may be significantly shifted from this value if the pure-penguin terms turn out to be large. In certain cases one still may be able to extract a measurement of an angle, for example of $\sin(2\alpha)$ from the $\pi^+\pi^-$ asymmetry by measuring the rates in several isospin-related channels and using a multiparameter fit to separate a tree-only contribution [16]. The impact of electroweak penguins, which will not be removed by this analysis [17] is quite small in this channel [18]. This isospin analysis requires measuring the decay rate for channel $\pi^0\pi^0$, which will be a challenge. For the $\rho\pi$ decays the restrictions due to isospin can again be used to make a multiparameter fit to the ρ -regions of the Dalitz plot for $\pi^+\pi^-\pi^0$ distribution [6]. The interference between different p-charge channels is significant and may provide sufficient information to allow the separation of tree-dominated and pure-penguin effects and thus extraction of the parameter α . Isospin analyses at the very least can be used to test whether the penguin contributions are indeed small enough to be neglected in the determination of α .

In the case $b \to s\overline{s}d$ there are no tree graph contributions. The phase of the dominant penguin contribution is such that, combined with mixing effects, it gives a zero asymmetry for B_d decays and an asymmetry proportional to β for B_s decays. However, Gérard and Hou [19] have pointed out that interference with the sub-dominant penguin terms, proportional to

Quark process	Leading term	Secondary term	$\begin{array}{c} {\rm Sample} \\ B_d \ {\rm modes} \end{array}$	B_d angle	Sample B_s modes	B_s angle
$b \to c\bar{c}d$	$V_{cb}V_{cd}^* = -A\lambda^3$ tree + penguin $(c-u)$	$V_{tb}V_{td}^* = A\lambda^3(1- ho+i\eta)$ penguin only $(t-u)$	D+D-	*β	ψK_S	*\$\beta_{\text{s}}\$
$b o s \overline{s} d$	$V_{tb}V_{td}^* = A\lambda^3(1- ho+i\eta)$ penguin only $(t-u)$	$V_{cb}V_{cd}^* = A\lambda^3$ penguin only $(c-u)$	$\phi\pi \ K_S \overline{K}_S$	competing terms	ϕK_S	competing terms
$b \to u \overline{u} d$ $b \to d \overline{d} d$	$V_{ub}V_{ud}^* = A\lambda^3(\rho - i\eta)$ tree + penguin $(u - c)$	$V_{tb}V_{td}^* = A\lambda^3(1-\rho+i\eta)$ penguin only $(t-c)$	$\pi\pi;\pi ho \ \pi a_1$	*α	$\pi^0 K_S \ ho^0 K_S$	competing terms
$b \rightarrow c\overline{u}d$	$V_{cb}V_{ud}^* = A\lambda^2$	0	$D^0\pi^0, D^0\rho^0$ $\downarrow \longrightarrow \downarrow C$	β P eigenstate	$\stackrel{D^0K_S}{\bigsqcup}_{CP \text{ eigenstate}}$	0

^{*}Leading terms only.

B^0

 $V_{ub}V_{ud}^*$ can give significant direct CP-violation asymmetries for such channels. Fleischer [20] has estimated that this asymmetry is possibly as large as 50%. While the sub-dominant term in this case would vanish if the masses of the up quark and the charm quark were equal, these estimates, which are based on the actual quark mass values and extreme values of operator matrix elements estimated using models, cannot be excluded. Thus, contrary to some comments in the literature, observation of CP-violating asymmetries in channels such as $B_d \to \phi \pi^0$ or $K^0\overline{K}^0$ would not necessarily require beyond-Standard-Model effects to explain them.

The entry for $b \to c\overline{u}d$ where the D^0 decays to a CP eigenstate ignores the small effect of doubly-Cabibbo-suppressed D-decays [21]. In contrast, the last entry indicates that one can select modes reached only by doubly-Cabibbo-suppressed decays from $D^0\pi$ and observe their interference with unsuppressed decays to the same channel from $\overline{D}^0\pi$ states, and thereby obtain a measurement of gamma [22].

There are some decay channels which are common to the B^0 and $\overline{B}{}^0$ but which are not CP eigenstates. For example the channel $J/\psi(1S)K^*(892)$ where the $K^*(892) \to K_S\pi^0$, the final state is not a CP eigenstate because both even and odd relative angular momenta between the $J/\psi(1S)$ and the $K^*(892)$ are allowed. One can use angular analysis to separate the different CP final states and measure the asymmetry in each [23]. The method applies in many quasi-two-body decays, such as other vector-vector channels, or those with higher-spin particles in final states. The branching ratio to these channels may be significantly larger than the CP-eigenstate (vector-scalar or scalar-scalar) channels with the same quark content. Such angular analyses may therefore be important in achieving accurate values for the parameters α and β .

Additional ways to extract CKM parameters by relationships between rates for channels such as $\pi\pi$, πK that can be extracted using SU(3) invariance have received considerable attention in the literature [24]. While these relationships will be interesting to investigate, the uncertainties introduced by SU(3) corrections may be significant. The review by Buras [5] gives a good summary of these ideas.

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CP VIOLATION PARAMETERS

Re(cgo)

 \overline{CP} impurity in B_0^0 system. It is obtained from $a_{\ell\ell}$, the charge asymmetry in like-sign dilepton events at the T(4S).

$$\mathrm{Re}(\epsilon_{B^0}) \simeq \tfrac{1}{4} \mathsf{a}_{\ell\ell} = \tfrac{1}{4} \; \tfrac{N(\ell^+\ell^+) - N(\ell^-\ell^-)}{N(\ell^+\ell^+) + N(\ell^-\ell^-)} \; .$$

315 ACKERSTAFF 970 assumes CPT and is based on measuring the charge asymmetry in a sample of B^0 decays defined by lepton and $Q_{\rm hem}$ tags. If CPT is not invoked, Re(ϵ_B) = -0.006 ± 0.006 is found. The indirect CPT violation parameter is determined to ${\rm Im}(\delta B) = -0.020 \pm 0.016 \pm 0.006$.

316 BARTELT 93 finds $s_{\ell\ell}=0.031\pm0.096\pm0.032$ which corresponds to $|s_{\ell\ell}|<0.18$, which yields the above ${\rm Re}(\epsilon_{\rm B0})$.

$B^0 \rightarrow D^{\bullet-}\ell^+\nu_{\ell}$ FORM FACTORS

See the review "Semileptonic decays of ${\it B}$ mesons" for the definition of these parameters.

R_1 (form factor ratio $\sim V$	• •					
VALUE	DOCUMENT ID		TECN	<u>COMMENT</u>		
1.18±0.30±0.12	DUBOSCQ	96 (CLE2	e ⁺ e ⁻ →	T(45)	ı
R_2 (form factor ratio $\sim A$	$_{2}/A_{1})$					
VALUE	DOCUMENT ID		TECN	COMMENT		_
0.71±0.22±0.07	DUBOSCQ	96	CLE2	e^+e^-	T(45)	ı
$ ho_{A_1}^2$ (form factor slope)						
VALUE	DOCUMENT ID		TECN	COMMENT		_
0.91±0.15±0.06	DUBOSCQ	96	CLE2	$e^+ e^- \rightarrow$	T(45)	

B⁰ REFERENCES

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ABBOTT ABE	98B	PL B423 419	B. Abbott+	(D0	Collab.)
ABE	98	PR D57 R3811	F. Abe+	(CDF	Collab.)
ABE ABE	98C	PR 057 5382 PRL 80 2057	F. Abe+	(CDF	Collab.) Collab.)
ACCIARRI	98D	PL B423 419 PR D57 R3811 PR D57 5382 PRL 80 2057 EPJ C (to be publ.)	M. Acciarri+	(L3	Collab.)
CERN-EP/	98-28 98	PRI 86 3710	R H Rehrens L	(CLEO	Collab)
BRANDENB	98	PRL 80 3710 PRL 80 2762 PRL 80 3456 PR D57 5363 PRL 79 590 ZPHY C74 19 ZPHY C75 579 erratum	G. Brandenbrug+	(CLEO	Collab.) Collab.) Collab.) Collab.) Collab.)
GODANG NEMATI	98 98	PRL 80 3456	R. Godang+	(CLEO	Collab.)
ABE	97J	PRL 79 590	+Abe, Akagi, Allen+	(SLD	Collab.)
ABREU	97F 97K	ZPHY C74 19	+Adam, Adye, Agasi+	(DELPHI	Collab.)
Also ABREU	97N	ZPHY C75 579 erratum ZPHY C76 579	P. Abreu+	(DELPHI	Collab.)
ACCIARRI	97B	PL B391 474	M. Acciarri+	` (L3	Collab.)
ACKERSTAFF	97G	PL B391 481 PL B395 128	M. Acciarri+ K. Ackerstaff+	(OPAL	Collab.)
ACKERSTAFF	97U	ZPHY C76 401	K. Ackerstaff +	(OPAL	Collab.)
ACKERSTAFF	97V 97	PL B399 321	M. Artuso+	(CLEO	Collab.)
ASNER	97	PRL 79 799	D. Asner+	(CLEO	Collab.)
ATHANAS	97 97	PRL 79 2208 PL R395 373	M. Athanas +	(CLEO	Collab.)
BUSKULIC	97D	ZPHY C75 397	D. Buskulic+	(ALEPH	Collab.)
FU	97	PRL 79 3125	X. Fu+	(CLEO	Collab.)
ABE	96B	PR D53 3496	+Albrow, Amendolia, Amidei+	(CDF	Collab.)
ABE	96C	PRL 76 4462	+Akimoto, Akopian, Albrow+	(CDF	Collab.)
ABE	96H 96L	PRL 76 2015 PRL 76 4675	+Albrow, Amendoka, Amidei+ +Akimpto, Akopian, Albrow+	(CDF	Collab.)
ABE	96Q	PR D54 6596	+Akimoto, Akopian, Albrow+	(CDF	Collab.)
ABREU	96P 96O	ZPHY C71 539 ZPHY C72 17	+Adam, Adye, Agasi+	(DELPHI	Collab.)
ACCIARRI	96E	PL B383 487	+Adriani, Aguilar-Benitez, Ahlen -	(L3	Collab.)
ADAM	96D	ZPHY C72 207	W. Adam +	(DELPHI	Collab.)
ALEXANDER	96T	PRL 77 5000	+Bebek, Berger, Berkelman+	(CLEO	Collab.)
ALEXANDER	96V	ZPHY C72 377	G. Alexander+	(OPAL	Collab.)
BARISH	96B	PR USS 1039 PRL 76 1570	+Atranas, Birss, Brower+ +Chadha, Chan, Eigen+	(CLEO	CoHab.)
BISHAI	96	PL B369 186	+Fast, Gerndt, Hinson+	(CLEO	Collab.)
BUSKULIC	96V	PL B384 471	+De Bonis, Decamp, Gnez+ +De Bonis, Decamp, Ghez+	(ALEPH	Collab.)
DUBOSCQ	96	PRL 76 3898	+Fulton, Fujino, Gan+	(CL EO	Collab.)
PDG	96 96	PR D53 4734 PR D54 1	+ Kinoshita, Pomianowski, Barish +	(CLEO	Collab.)
ABE	95Z	PRL 75 3068	+Albrow, Amendolia, Amidei+	(CDF	Collab.)
ABREU	95N	PL B357 255	+Adam, Adye, Agasi+	(DELPHI	Collab.)
ACCIARRI	95H	PL B363 127	+Adam, Adriani, Aguilar-Benitez+	(L3	Collab.)
ACCIARRI	95I	PL B363 137	+Adam, Adriani, Aguilar-Benitez+	(L3	Collab.)
AKERS	95J	ZPHY C66 555	+Alexander, Allison, Ametewee+	(OPAL	Collab.)
AKERS	95T	ZPHY C67 379	+ Alexander, Allison, Ametewee +	(OPAL	Collab.)
Also	95C	PL B347 469 (erratum)	Alexander, Bebek, Berkelman, Bloom +	(CLEO	Collab.)
BARISH	95	PR D51 1014	+Chadha, Chan, Cowen+	(CLEO	Collab.)
ABE	94D	PRL 72 3456	+Casper, De Bonis, Decamp+ +Albrow, Amidel, Anway-Wiese, Apollinari	(CDF	Collab.)
ABREU	94M	PL B338 409	+Adam, Adye, Agasi, Ajinenko+	(DELPHI	Collab.)
AKERS	94C 94H	PL 8327 411 PL 8336 585	+ Alexander, Allison, Anderson, Arcelli + + Alexander, Allison, Anderson, Arcelli +	(OPAL	Collab.)
AKERS	94J	PL B337 196	+Alexander, Allison, Anderson, Arcelli +	(OPAL	Collab.)
AKERS ALAM	94L 94	PL 6337 393 PR 050 43	+Alexander, Allison, Anderson, Arcelli+ +Kim, Nemati, O'Neill, Severini+	(CLEO	Collab.)
ALBRECHT	94	PL B324 249	+Ehrlichmann, Hamacher+	(ARGUS	Collab.)
ALBRECHT AMMAR	94G	PL 8340 217 PR D49 5701	+ Hamacher, Hofmann, Kirchhoff, Mankel + Ball Baringer, Rean Besson Connage+	(CLEO	Collab.)
ATHANAS	94	PRL 73 3503	+Brower, Masek, Paar, Gronberg+	(CLEO	Collab.)
Also RUSKUUC	95 94R	PRL 74 3090 (erratum)	Athanas, Brower, Masek, Paar+	(CLEO	Collab.)
PDG	94	PR D50 1173	Montanet+ (CERN, LE	BL, BOST,	IFIC+)
PROCARIO	94	PRL 73 1306	+Balest, Cho, Daoudi, Ford+	(CLEO	Collab.)
ABREU	93D	ZPHY C57 181	+Adam, Adye, Agasi, Alekseev+	(DELPHI	Collab.)
AGTON	93G	PL 8312 253	+ Adam, Adye, Agasi, Ajinenko+	(DELPHI	Collab.)
ALBRECHT	93	ZPHY CS7 533	+ Ehrlichmann, Hamacher, Hofmann+	(ARGUS	Collab.)
ALBRECHT	93E	ZPHY C60 11	+Ehrlichmann, Hamacher, Hofmann+	(ARGUS	Collab.
AMMAR	93 93	PRL 71 674	+ Ball, Baringer, Coppage, Copty+	(CLEO	Collab.)
BARTELT	93	PRL 71 1680	+Csorna, Egyed, Jain, Sheldon+	CLEO	Collab.
BEAN	93B	PRL 71 3922 PRL 70 2681	+Ernst, Arona, Kwon, Roberts + +Gronberg, Kutschke. Menary. Morrison+	(CLEO	Collab.)
BUSKULIC	93D	PL B307 194	+ Decamp, Goy, Lees, Minard+	(ALEPH	Collab.)
Also BUSKULIC	94H 93K	PL B325 537 (errata) PL B313 498	+De Bonis, Decamp, Ghez, Gov+	(ALEPH	Collab 1
SANGHERA	93	PR D47 791	+Skwarnicki, Stroynowski, Artuso, Goldber	+(CLEO	Collab.)
ALBRECHT ALBRECHT	92C 92G	PL B275 195 7PHY CS4 1	+Ehrlichmann, Hamacher, Krueger, Nau+ +Ehrlichmann, Hamacher, Krueger, Nau+	(ARGUS	Collab.)
ALBRECHT	92L	ZPHY C55 357	B. Nematü- +Abe, Akaği, Allent- +Adam, Adye, Agasi+ P. Abreu+ M. Acciarri+ M. Acciarri+ M. Acciarri+ K. Ackerstaff- Aklinoh, Akopian, Albrow+ +Aklimoto, Akopian, Albrow+ +Aklimoto, Akopian, Albrow+ +Aklimoto, Akopian, Albrow+ +Aklimoto, Akopian, Albrow+ +Adam, Adye, Agasi+ +Adam, Adye, Agasi+ +Adam, Adye, Agasi- +Bebek, Berger, Berkelman+ C. Alexander- H. Albrow, Amendokia, Amidel+ +Fast, Gerndt, Hinson+ +De Bonis, Decamp, Ghez+ +Fulton, Fujino, Gan+ +Fulton, Fujino, Gan+ +Albrow, Amendokia, Amidel+ +Adam, Adye, Agasi- +Adam, Adye, Agasi- +Adam, Adye, Agasi- +Adam, Adye, Agasi, Ajinenko+ +Adaman, Adye, Agasi, Ajinenkoh +Alexander, Alison, Ametewee+ +Alexander, Alison, Ametewee+ +Alexander, Alison, Anderson, Arcelil+ +Alexander, Alison, Anderso	(ARGUS	Collab.)

BORTOLETTO	92	PR D45 21	+Brown, Dominick, McIlwain+	(CLEO Collab.)
HENDERSON	92	PR D45 2212	+Kinoshita, Pipkin, Procario+	(CLEO Collab.)
KRAMER	92	PL B279 181	+Palmer	(HAMB, OSU)
ALBAJAR	91C	PL B262 163	+ Albrow, Allkofer, Ankoviak, Apsimon+	(UA1 Collab.)
ALBAJAR	91E	PL B273 540	+Albrow, Alikofer, Ankoviak+	(UA1 Collab.)
ALBRECHT	91B	PL 8254 288.	+Glaeser, Harder, Krueger, Nippe+	(ARGUS Collab.)
ALBRECHT	91C	PL B255 297	+Ehrlichmann, Glaeser, Harder, Krueger+	(ARGUS Collab.)
ALBRECHT	91E	PL B262 148	+Glaeser, Harder, Krueger, Nippe+	(ARGUS Collab.)
BERKELMAN	91	ARNPS 41 1	+Stone	(CORN, SYRA)
"Decays of	ВМ	esons"		, , ,
FULTON	91	PR D43 651	+ Jensen, Johnson, Kagan, Kass+	(CLEO Collab.)
ALBRECHT	90B	PL B241 278	+Glaeser, Harder, Krueger, Nilsson+	(ARGUS Collab.)
ALBRECHT	100	ZPHY C48 543	+Ehrlichmann, Harder, Krueger+	(ARGUS Collab.)
ANTREASYAN	90B	ZPHY C48 553	+Bartels, Bieler, Bienlein, Bizzeti+ (Cr	vital Ball Collab.)
BORTOLETTO	90	PRL 64 2117	+Goldberg, Horwitz, Jain, Mestayer+	(CLEO Collab.)
ELSEN	90	ZPHY C46 349	+Allison, Ambrus, Barlow, Bartel+	(JADE Collab.)
ROSNER	90	PR D42 3732		·
WAGNER	90	PRL 64 1095	+Hinshaw, Ong, Snyder+	(Mark II Collab.)
AL BRECHT	89C	PL B219 121	+Boeckmannn, Glaeser, Harder+	(ARGUS Collab.)
ALBRECHT	89G	PL B229 304	+Glaeser, Harder, Krueger+	(ARGUS Collab.)
ALBRECHT	89.)	PL B229 175	+Glaser, Harder+	(ARGUS Collab.)
ALBRECHT	89L	PL B232 554	+Glaeser, Harder, Krueger, Nippe, Oest+	(ARGUS Collab.)
ARTUSO	89	PRL 62 2233	+Bebek, Berkelman, Blucher+	(CLEO Collab.)
AVERILL	89	PR D39 123	+ Blockus, Brabson+	(HRS Collab.)
AVERY	89B	PL B223 470	+ Besson, Garren, Yelton+	(CLEO Collab.)
BEBEK	89	PRL 62 8	+ Berkelman, Blucher+	(CLEO Collab.)
BORTOLETTO	89	PRL 62 2436	+Goldberg, Horwitz, Mestayer+	(CLEO Collab.)
BORTOLETTO	89B	PRL 63 1667	+Goldberg, Horwitz, Mestaver+	CLEO Collab.
ALBRECHT	B8F	PL B209 119	+Boeckmann, Glaeser+	(ARGUS Collab.)
ALBRECHT	B8K	PL B215 424	+Boeckmann, Glaeser+	(ARGUS Collab.)
ALBRECHT	B7C	PL B185 218	+ Binder, Boeckmann, Glaser+	(ARGUS Collab.)
ALBRECHT	87D	PL B199 451	+Andam, Binder, Boeckmann+	(ARGUS Collab.)
	-871	PL B192 245	+Andam, Binder, Boeckmann+	(ARGUS Collab.)
ALBRECHT	87J	PL B197 452	+Andam, Binder, Boeckmann+	(ARGUS Collab.)
AVERY	87	PL B183 429	+Besson, Bowcock, Giles+	(CLEO Collab.)
BEAN	87B		+Bobbink, Brock, Engler+	(CLEO Collab.)
BEBEK	87	PR D36 1289	+ Berkelman, Blucher, Cassel+	(CLEO Collab.)
ALAM	86	PR D34 3279	+Katayama, Kim, Sun+	(CLEO Collab.)
ALBRECHT	86F	PL B182 95	+Binder, Boeckmann, Glaser+	(ARGUS Collab.)
PDG	86	PL 1708	Aguilar-Benitez, Porter +	(CERN. CIT+)
CHEN	85	PR D31 2386	+Goldberg, Horwitz, Jawahery+	(CLEO Collab.)
HAAS	85	PRL 55 1248	+Hempstead, Jensen, Kagan+	(CLEO Collab.)
AVERY	84	PRL 53 1309	+Bebek, Berkelman, Cassel+	(CLEO Collab.)
GILES	84	PR D30 2279	+Hassard, Hempstead, Kinoshita+	(CLEO Collab.)
BEHRENDS	B3	PRL 50 881	+ Chadwick. Chauveau. Ganci+	(CLEO Collab.)
				,

B^{\pm}/B^{0} ADMIXTURE

B DECAY MODES

The branching fraction measurements are for an admixture of B mesons at the $\Upsilon(4S)$. The values quoted assume that $B(\Upsilon(4S) \to B\overline{B}) = 100\%$.

For inclusive branching fractions, e.g., $B \to D^\pm$ anything, the treatment of multiple D's in the final state must be defined. One possibilty would be to count the number of events with one-or-more D's and divide by the total number of B's. Another possibility would be to count the total number of D's and divide by the total number of B's, which is the definition of average multiplicity. The two definitions are identical when only one of the specified particles is allowed in the final state. Even though the "one-or-more" definition seems sensible, for practical reasons inclusive branching fractions are almost always measured using the multiplicity definition. For heavy final state particles, authors call their results inclusive branching fractions while for light particles some authors call their results multiplicities. In the B sections, we list all results as inclusive branching fractions can exceed 100% and that inclusive partial widths can exceed total widths, just as inclusive cross sections can exceed total cross sections.

 $\overline{\cal B}$ modes are charge conjugates of the modes below. Reactions indicate the weak decay vertex and do not include mixing.

	Mode		Fra	ction	(۲ _/ /۲)			cale factor/ Idence level
	Semilep	tonic and lepte	onk	c mo	des			
Γ_1	$B \rightarrow e^+ \nu_e$ anything	[a]	(10.43	±0.2	9) %		5=1.2
Γ2	$B \rightarrow \overline{p}e^+\nu_e$ anythin	g	<	1.6		× 10)-3	CL=90%
r_3	$B \rightarrow \mu^+ \nu_\mu$ anything	[a]	(10.3	±0.5) %		
Γ_4	$B \rightarrow \ell^+ \nu_\ell$ anything	[a,b]	(10.4	± 0.2	1) %		
Γ ₅	$B \rightarrow D^- \ell^+ \nu_{\ell}$ anyth	ing [b]	ĺ	2.7	±0.8) %		
Γ ₆	$B \rightarrow \overline{D}^0 \ell^+ \nu_{\ell}$ anythi	ng [b]	(7.0	±1.4) %		
Γ ₇	$B \rightarrow D^{*-} \ell^+ \nu_{\ell}$ anyt	hing						
Га	$B \rightarrow D^{*0} \ell^+ \nu_{\ell}$ anyth	ing						
Г	$B \rightarrow \overline{D}^{\bullet \bullet} \ell^+ \nu_{\ell}$	[b,c]	(2.7	±0.7) %		
Γ10	$B \rightarrow \overline{D}_1(2420)\ell^+$	νį any-	(7.4	±1.6) × 10	₎ –3	
	thing							
Γ11	$B \rightarrow D\pi \ell^+ \nu_{\ell}$ any	thing +	(2.3	±0.4) %		
	$D^*\pi\ell^+ u_\ell$ anyth							
Γ ₁₂	$B \rightarrow \overline{D}_2^*(2460)\ell^+$	ν _ℓ any-	<	6.5		× 10	₎ 3	CL=95%
	thing							

B^{\pm}/B^{0} ADMIXTURE

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B \rightarrow D^{*-}\pi^+\ell^+\nu_\ellany-
  \Gamma_{13}
                                                                       (1.00\pm0.34)\%
                                                                                                                                                                                                           (4.5 + 1.3) \times 10^{-4}
                                                                                                                                      \Gamma_{68} \quad B \rightarrow \Xi_c^+ \text{ anything }
                       thing
                                                                                                                                                     \times B(\Xi_c^+ \rightarrow \Xi^- \pi^+ \pi^+)
               B \rightarrow D_s^- \ell^+ \nu_\ell anything
  Γ<sub>14</sub>
                                                                                           \times 10^{-3}
                                                                                                           CL=90%
                                                                                                                                      Γ<sub>69</sub>
                                                                                                                                               B \rightarrow p/\overline{p} anything
                                                                                                                                                                                                    [d] (8.0 \pm 0.4)\%
                  B \rightarrow D_s^- \ell^+ \nu_\ell K^+ anything [b] < 6
                                                                                           × 10<sup>-3</sup>
  Γ15
                                                                                                           CL=90%
                                                                                                                                              B \rightarrow p/\overline{p} (direct) anything
                                                                                                                                                                                                    [d] ( 5.5 \pm 0.5 )%
                  B \rightarrow D_s^- \ell^+ \nu_\ell K^0 anything [b] < 9
 Γ<sub>16</sub>
                                                                                           × 10<sup>-3</sup>
                                                                                                           CL=90%
                                                                                                                                              B \rightarrow \Lambda/\overline{\Lambda} anything
                                                                                                                                      Γ71
                                                                                                                                                                                                    [d] (4.0 \pm 0.5)\%
               B \rightarrow \ell^+ \nu_\ell noncharmed
  Γ<sub>17</sub>
                                                                [6]
                                                                                                                                      \Gamma_{72} B \rightarrow \Lambda anything
 Γ<sub>18</sub>
               B \rightarrow K^+ \ell^+ \nu_{\ell} anything
                                                                [b] (6.0 \pm 0.5)\%
                                                                                                                                      \Gamma_{73} B \rightarrow \overline{\Lambda} anything
              B \rightarrow K^- \ell^+ \nu_\ell anything B \rightarrow K^0 / \overline{K}^0 \ell^+ \nu_\ell anything
                                                                [b] ( 10 \pm 4 ) \times 10<sup>-3</sup>
 Γ19
                                                                                                                                             B \rightarrow \Xi^-/\overline{\Xi}^+ anything
                                                                                                                                      Γ<sub>74</sub>
                                                                                                                                                                                                    [d] (2.7 \pm 0.6) \times 10^{-3}
                                                                [b] (4.4 \pm 0.5)\%
                                                                                                                                      \Gamma_{75} B \rightarrow baryons anything
                                                                                                                                                                                                           (6.8 \pm 0.6)\%
                                                                                                                                             B \rightarrow p\overline{p} anything
                                                                                                                                      Γ<sub>76</sub>
                                                                                                                                                                                                           ( 2.47±0.23) %
                                             D, D^*, or D_s modes
                                                                                                                                      \Gamma_{77} B \rightarrow \Lambda \overline{p} / \overline{\Lambda} p anything
 \Gamma_{21} B \rightarrow D^{\pm} anything
                                                                                                                                                                                                    [d] ( 2.5 ±0.4)%
                                                                     `(24.1 ±1.9)%
                                                                                                                                              B \rightarrow \Lambda \overline{\Lambda} anything
                                                                                                                                                                                                          < 5
                                                                                                                                                                                                                               \times 10^{-3}
           B \rightarrow D^0/\overline{D}^0 anything
                                                                                                                                                                                                                                               CL=90%
 Γ22
                                                                       (63.1 \pm 2.9)\%
                                                                                                               S=1.1
           B \rightarrow D^*(2010)^{\pm} anything
                                                                                                                                                             Lepton Family number (LF) violating modes or
 Γ<sub>23</sub>
                                                                       (22.7 \pm 1.6)\%
 \Gamma_{24} \quad B \rightarrow D^*(2007)^0 anything \Gamma_{25} \quad B \rightarrow D_s^{\pm} anything
                                                                       (26.0 \pm 2.7)\%
                                                                                                                                                                \Delta B = 1 weak neutral current (B1) modes
                                                                                                                                      \Gamma_{79} B \rightarrow e^+e^-s
                                                                                                                                                                                                                               × 10<sup>-5</sup>
                                                                [d] ( 10.0 \pm 2.5 )%
                                                                                                                                                                                          B1
                                                                                                                                                                                                         < 5.7
                                                                                                                                                                                                                                               CL=90%
 \Gamma_{26} \quad b \rightarrow c \overline{c} s
                                                                                                                                                                                                                               × 10<sup>-5</sup>
                                                                                                                                      \Gamma_{80} B \rightarrow \mu^{+}\mu^{-}s
                                                                       (22 ±4 )%
                                                                                                                                                                                          В1
                                                                                                                                                                                                         <
                                                                                                                                                                                                               5.8
                                                                                                                                                                                                                                               CL=90%
         B \rightarrow D_s D_s D_s D_s D_s D^*, or
                                                                [d] ( 4.9 ±1.3)%
                                                                                                                                             B \rightarrow e^{\pm} \mu^{\mp} s
                                                                                                                                                                                                                               × 10<sup>-5</sup>
                                                                                                                                                                                          LF
                                                                                                                                                                                                         < 2.2
                                                                                                                                                                                                                                               CL=90%
                D_s^*D^*
                                                                                                                                          [a] These values are model dependent. See 'Note on Semileptonic Decays'
 \Gamma_{28} \quad B \rightarrow D^*(2010)\gamma
                                                                                           \times 10^{-3}
                                                                                                          CL=90%
                                                                     < 1.1
         B \to D \begin{cases} 2010J^{\gamma} \\ B \to D_s^+ \pi^-, D_s^{*+} \pi^-, D_s^+ \rho^-, [d] < 5 \\ D_s^{*+} \rho^-, D_s^+ \pi^0, D_s^{*+} \pi^0, \\ D_s^+ \eta, D_s^{*+} \eta, D_s^+ \rho^0, \end{cases}
                                                                                                                                               in the B^+ Particle Listings.
                                                                                           × 10<sup>-4</sup>
                                                                                                          CL=90%
                                                                                                                                          [b] An \ell indicates an e or a \mu mode, not a sum over these modes.
                                                                                                                                          [c] D^{**} stands for the sum of the D(1^{1}P_{1}), D(1^{3}P_{0}), D(1^{3}P_{1}), D(1^{3}P_{2}),
                                                                                                                                               D(2^{1}S_{0}), and D(2^{1}S_{1}) resonances.
                D_{s}^{*+}\rho^{0}, D_{s}^{+}\omega, D_{s}^{*+}\omega
                                                                                                                                          [d] The value is for the sum of the charge states of particle/antiparticle states
          B \rightarrow D_{s1}(2536)^+ anything
                                                                                                          CL=90%
                                                                                                                                               indicated.
                                             Charmonium modes
                                                                                                                                          [e] Inclusive branching fractions have a multiplicity definition and can be
 Γ31
          B \rightarrow J/\psi(1S) anything
                                                                       (1.13\pm0.06)\%
                                                                                                                                               greater than 100%.
              B \rightarrow J/\psi(1S) (direct) any-
 \Gamma_{32}
                                                                       (8.0 \pm 0.8) \times 10^{-3}
                   thing
                                                                                                                                                              B±/B0 ADMIXTURE BRANCHING RATIOS
 Γ33
          B \rightarrow \psi(2S) anything
                                                                       (3.5 \pm 0.5) \times 10^{-3}
          B \rightarrow \chi_{c1}(1P) anything
                                                                      (4.2 \pm 0.7) \times 10^{-3}
                                                                                                                                     \Gamma(\ell^+ \nu_\ell \text{ anything})/\Gamma_{\text{total}}
These branching fracti
 Γ<sub>34</sub>
                                                                                                                                                                ng fraction values are model dependent. See the note on "Semileptonic
                                                                       ( 3.7 \pm 0.7 ) \times 10^{-3}
              B \rightarrow \chi_{c1}(1P) (direct) any-
 Γ<sub>35</sub>
                   thing
                                                                                                                                              Decays of B Mesons at the beginning of the B^+ Particle Listings.
          B \rightarrow \chi_{c2}(1P) anything
                                                                                           \times 10^{-3}
                                                                                                                                     VALUE DOCUMENT ID TECN COMMENT

0.1045±0.0021 OUR AVERAGE Includes data from the 2 datablocks that follow this
                                                                                                                                                                                      DOCUMENT ID
                                                                                                          CL=90%
                                                                                           \times 10<sup>-3</sup>
 Γ<sub>37</sub>
          B \rightarrow \eta_c(1S) anything
                                                                          9
                                                                                                          CL=90%
                                                                     <
                                                                                                                                                                                   <sup>1</sup> HENDERSON 92 CLEO e^+e^- \rightarrow \tau(45)
                                                                                                                                     0.108 \pm 0.002 \pm 0.0056
                                                K or K* modes
          B \rightarrow K^{\pm} anything
                                                                                                                                        ^{1} HENDERSON 92 measurement employs e and \mu. The systematic error contains 0.004 in
 Γ38
                                                               [d] ( 78.9 \pm 2.5 )%
             B \rightarrow K^+ anything
                                                                                                                                          quadrature from model dependence. The authors average a variation of the Isgur, Scora, Grinstein, and Wise model with that of the Altarelli-Cabibbo-Corbò-Malani-Martinelli
 Γ39
                                                                       (66 ±5)%
 \Gamma_{40} B \rightarrow K^- anything \Gamma_{41} B \rightarrow K^0/\overline{K}^0 anything
                                                                       (13 \pm 4)\%
                                                                                                                                          model for semileptonic decays to correct the acceptance.
                                                               [d] (64 ±4 )%
                                                                                                                                     B \rightarrow K^*(892)^{\pm} anything
                                                                       (18 \pm 6)\%
          B \to K^*(892)^0 / \overline{K}^*(892)^0 any-
                                                               [d] ( 14.6 \pm 2.6 )%
                                                                                                                                              Decays of B Mesons at the beginning of the B^+ Particle Listings.
          thing B \to K^*(892)\gamma
                                                                                                                                     <u>VALUE</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u>
The data in this block is included in the average printed for a previous datablock.
 Γ44
         B \rightarrow K_1(1400)\gamma
                                                                                           \times 10<sup>-4</sup>
 Γ<sub>45</sub>
                                                                    < 4.1
                                                                                                          CI =90%
                                                                                                                                     0.1041 ± 0.0029 OUR AVERAGE Error includes scale factor of 1.2.
                                                                                           × 10<sup>-4</sup>
         B \rightarrow K_2^*(1430)\gamma
                                                                     < 8.3
                                                                                                          CL=90%
                                                                                                                                     0.1049 \pm 0.0017 \pm 0.0043
                                                                                                                                                                                   <sup>2</sup> BARISH
                                                                                                                                                                                                         96B CLE2 e^+e^- \rightarrow \Upsilon(4S)
 Γ<sub>47</sub>
        B \rightarrow K_2(1770)\gamma
                                                                                           \times 10^{-3}
                                                                    < 1.2
                                                                                                          CL=90%
                                                                                                                                                                                   ^3 ALBRECHT 93H ARG e^+e^- \rightarrow \tau(45)

^4 YANAGISAWA 91 CSB2 e^+e^- \rightarrow \tau(45)
                                                                                                                                     0.097 \pm 0.005 \pm 0.004
 \Gamma_{48} \quad B \rightarrow K_3^*(1780)\gamma
                                                                                           \times 10<sup>-3</sup>
                                                                    <
                                                                         3.0
                                                                                                          CL=90%
                                                                                                                                     0.100 \pm 0.004 \pm 0.003
                                                                                          \times 10<sup>-3</sup>
 \Gamma_{49} \quad B \rightarrow K_4^*(2045)\gamma
                                                                    < 1.0
                                                                                                          CL=90%
                                                                                                                                                                                   <sup>5</sup> ALBRECHT 90H ARG e^+e^- \rightarrow r(45)
                                                                                                                                     0.103 \pm 0.006 \pm 0.002
        B \rightarrow \overline{b} \rightarrow \overline{s}\gamma
Γ<sub>50</sub>
                                                                     (2.3 \pm 0.7) \times 10^{-4}
                                                                                                                                                                                   6 WACHS
                                                                                                                                     0.117 ±0.004 ±0.010
                                                                                                                                                                                                          89 CBAL Direct e at T(45)
         B \rightarrow \overline{b} \rightarrow \overline{s} gluon
                                                                    < 6.8
                                                                                           %
                                                                                                          CL=90%
                                                                                                                                     0.120 ±0.007 ±0.005
                                                                                                                                                                                    CHEN
                                                                                                                                                                                                         84 CLEO Direct e at T(45)
                                                                                                                                     Light unflavored meson modes
                                                                                                                                                                                  ^7 KLOPFEN... 83B CUSB Direct e at \Upsilon(45)
                                                                                                                                     0.132 \pm 0.008 \pm 0.014
         B \rightarrow \pi^{\pm} anything
Γ<sub>52</sub>
                                                            [d,e] (359 \pm 7 )%
                                                                                                                                        ^2 BARISH 968 analysis performed using tagged semileptonic decays of the \it B . This technique is almost model independent for the lepton branching ratio.
        B \rightarrow \eta anything
 Γ<sub>53</sub>
                                                                       (17.6 \pm 1.6)\%
                                                                                                                                        3ALBRECHT 93H analysis performed using tagged semileptonic decays of the B. This technique is almost model independent for the lepton branching ratio.
 \Gamma_{54} B \rightarrow \rho^0 anything
                                                                     (21 ±5)%
Γ<sub>55</sub>
        B \rightarrow \omega anything
                                                                    < 81
                                                                                          %
                                                                                                                                        ^4 YANAGISAWA 91 also measures an average semileptonic branching ratio at the \Upsilon(5S) of 9.6–10.5% depending on assumptions about the relative production of different B
                                                                                                          CI = 90\%
         B \rightarrow \phi anything
Γ<sub>56</sub>
                                                                      (3.5 \pm 0.7)\%
                                                                                                              S=1.8
                                                                                                                                        ALBRECHT 90H uses the model of ALTARELLI 82 to correct over all lepton momenta.
                                                Barvon modes
                                                                                                                                        0.099 \pm 0.006 is obtained using ISGUR 898.

6 Using data above p(e)=2.4 GeV, WACHS 89 determine \sigma(B\to e\nu \text{up})/\sigma(B\to e\nu \text{charm})<0.065 at 90% CL.
 \Gamma_{57} B \rightarrow \Lambda_c^{\pm} anything
                                                                     ( 6.4 \pm 1.1 )%
        B \rightarrow \Lambda_c^{+} anything
Γ<sub>58</sub>
\Gamma_{59} B \rightarrow \Lambda_c^- anything
                                                                                                                                        <sup>7</sup>Ratio \sigma(b \rightarrow e \nu up)/\sigma(b \rightarrow e \nu charm) < 0.055 at CL = 90%.
 \Gamma_{60} B \rightarrow \Lambda_c^- e^+ anything
                                                                                          \times 10<sup>-3</sup>
                                                                    < 3.2
                                                                                                          CL=90%
                                                                                                                                     \Gamma_{61} \quad B \rightarrow \Lambda_c^- panything
                                                                     (3.6 \pm 0.7)\%
\Gamma_{62} \quad B \rightarrow \Lambda_c^- p e^+ \nu_e
\Gamma_{63} \quad B \rightarrow \overline{\Sigma}_c^- \text{ anyth}
                                                                                          \times 10<sup>-3</sup>
                                                                    < 1.5
                                                                                                          CL=90%
\Gamma_{63} B \rightarrow \overline{\Sigma}_{c}^{-} anything \Gamma_{64} B \rightarrow \overline{\Sigma}_{c}^{-} anything \Gamma_{65} B \rightarrow \overline{\Sigma}_{c}^{0} anything
                                                                     (4.2 \pm 2.4) \times 10^{-3}
                                                                                                                                     <u>VALUE</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u>
The data in this block is included in the average printed for a previous datablock.
                                                                    < 9.6
                                                                                          \times 10^{-3}
                                                                                                          CL=90%
                                                                     ( 4.6 \pm 2.4 ) \times 10<sup>-3</sup>
                                                                                                                                     0.103 ± 0.005 OUR AVERAGE
\Gamma_{66} \quad B \rightarrow \overline{\Sigma}_{6}^{0} N(N = p \text{ or } n)
                                                                                         × 10<sup>-3</sup>
                                                                                                                                                                                   <sup>8</sup> ALBRECHT 90H ARG e^+e^- \rightarrow \Upsilon(4S)
                                                                                                                                     0.100 \pm 0.006 \pm 0.002
                                                                    < 1.5
                                                                                                          CL=90%
        B \rightarrow \Xi_c^{\circ} anything
                                                                                                                                                                                                         84 CLEO Direct \u03c4 at T(45)
                                                                                                                                     0.108 \pm 0.006 \pm 0.01
                                                                                                                                                                                    CHEN
                                                                     ( 1.4 \pm 0.5 ) \times 10^{-4}
                                                                                                                                     0.112 \pm 0.009 \pm 0.01
                                                                                                                                                                                    LEVMAN
                                                                                                                                                                                                         84 CUSB Direct \mu at \Upsilon(45)
                \times B(\Xi_c^0 \to \Xi^-\pi^+)
                                                                                                                                        ^{8} ALBRECHT 90H uses the model of ALTARELLI 82 to correct over all lepton momenta. 0.097 \pm 0.006 is obtained using ISGUR 89B.
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²⁰ BUSKULIC 95B reports $f_B \times {\rm B}(B \to \overline{D}^*(2010)^- \pi^+ \ell^+ \nu_\ell$ anything) = (3.7 \pm 1.0 \pm 0.7)10⁻³. Above value assumes $f_B = 0.37 \pm 0.03$.

Meson Particle Listings B^{\pm}/B^{0} ADMIXTURE

VALUE CL%	DOCUMENT ID TECN	COMMENT.	VALUE	anything)/F _{tota}	<u>DOCUMENT ID</u>) TECN	COMMENT	Γ ₁₄ /Γ
<0.0016 90		$e^+e^- \rightarrow \Upsilon(45)$	<0.009	90	21 ALBRECHT		e ⁺ e ⁻ →	T(45)
$\Gamma(D^+\ell^+ u_\ell$ anything)/ $\Gamma(\ell^+$	wamthing)	Γ ₅ /Γ ₄	21 ALBRECH	IT 93E reports < 0	0.012 for B($D_s^+ \rightarrow$		27. We resc	ale to our bes
$\ell = e \text{ or } \mu.$	»¿=nyciiiiB)	15/14		$\rho_s^+ \rightarrow \phi \pi^+) = 0$				
VALUE		COMMENT		-				
0.26±0.07±0.04		$e^+e^- \rightarrow \Upsilon(45)$	• •	K+anything)/[Γ ₁₅ /
FULTON 91 uses B($D^+ \rightarrow B$	$(K^-\pi^+\pi^+) = (9.1 \pm 1.3 \pm 0.4)\%$	as measured by MARK III.	<u>VALUE</u> <0.006		DOCUMENT ID 22 ALBRECHT		<u>COMMENT</u>	T(45)
$\Gamma(\overline{D}^0\ell^+ u_\ell$ anything) $/\Gamma(\ell^+)$	v _e anything)	Γ_6/Γ_4	•	90			e+e- →	
$\ell = e \text{ or } \mu$.	·	-, -			0.008 for B($D_s^+ \rightarrow$	$\phi \pi^{+}) = 0.0$	127. We resc	ale to our bes
VALUE 0.67±0.09±0.10		$ \frac{COMMENT}{e^+e^- \rightarrow T(45)} $	value B(E	$\phi_s^+ \rightarrow \phi \pi^+) = 0.$.036.			
		, ,	Γ(D=£+ν.	K ⁰ anything)/□	Audul			Γ ₁₆ /Ι
·	$K^-\pi^+$) = $(4.2 \pm 0.4 \pm 0.4)\%$	as measured by MARK III.	VALUE	<u>CI X</u>	DOCUMENT ID	TECN	COMMENT	- 10/
$\Gamma(D^{\bullet-}\ell^+ u_\ell$ anything $)/\Gamma_{ m tot}$		Γ ₇ /Γ	<0.009	90	23 ALBRECHT		e+e- →	T(45)
VALUE (units 10 ⁻²)	DOCUMENT ID TECN	COMMENT	²³ ALBRECI	IT 93E reports < 0	0.012 for B($D_s^+ \rightarrow$	$\phi \pi^{+}) = 0.0$	27. We resc	ale to our bes
• • We do not use the follow	ing data for averages, fits, limits,	, etc. • • •		$\rho_s^+ \rightarrow \phi \pi^+) = 0.$. ,		
0.6±0.3±0.1	11 BARISH 95 CLE2	$e^+e^- \rightarrow \Upsilon(45)$						
	$(-\pi^+) = (3.91 \pm 0.08 \pm 0.17)$ %	% and B($D^{*+} \to D^0 \pi^+$)		charmed)/ $\Gamma(\ell^+$				Γ ₁₇ /Γ.
$= (68.1 \pm 1.0 \pm 1.3)\%.$				es e or μ, not the tum intervals.	sum. These exper	Iments measu	re this ratio	in very limite
$\Gamma(D^{*0}\ell^+\nu_\ell \text{ anything})/\Gamma_{\text{total}}$	1	Γ∎/Γ	VALUE	CL% EVTS	DOCUMENT ID	TECN	COMMENT	
VALUE (units 10 ⁻²)		COMMENT			24 ALBRECHT	94c ARG	e ⁺ e ⁻ →	, ,
	ing data for averages, fits, limits,			107	25 BARTELT		e ⁺ e ⁻ →	
0.6±0.6±0.1		$e^+e^- \rightarrow \Upsilon(4S)$		77 76	²⁶ ALBRECHT ²⁷ FULTON			
	$(-\pi^+) = (3.91 \pm 0.08 \pm 0.17)$		e e e We do		ring data for averag		e ⁺ e ⁻ →	1 (43)
	$0 \rightarrow D^0 \pi^0 = (63.6 \pm 2.3 \pm 3)$		5 - 5 170 00	41	28 ALBRECHT	90 ARG	e+e- →	T(45)
, , , ,	, ,	•	< 0.04	90	29 BEHRENDS		e+ e- →	` '
$\Gamma(\overline{D}^{oo}\ell^+\nu_\ell)/\Gamma_{\text{total}}$		Γ ₉ /Γ	< 0.04	90	CHEN		Direct e at	
	of the $D(1^{1}P_{1})$, $D(1^{3}P_{0})$, $D(1^{3}P_{0})$		< 0.055	90		83B CUSB		r(45)
	$\ell = e$ or μ , not sum over e an		24 ALBRECI	4Τ 94c find Γ(b —	+ $c)/\Gamma(b \rightarrow all)$:	= 0.99 ± 0.02	± 0.04.	
VALUE CL% 0.027±0.005±0.005	EVTS DOCUMENT ID 63 13 ALBRECHT 93	TECN COMMENT ARG e+e- →	25 BARTEL	F 93B (CLEO II) n	neasures an excess	of 107 ± 15	± 11 lepton:	s in the lepto
0.021 10.000 10.000	03 AEBREETT 33	7(45)			GeV/c which is attr		-	
 We do not use the follow 	ing data for averages, fits, limits,				$ranching$ $ratio$ ΔB_{t} $model$ (KOERNER			
<0.028 95	14 BARISH 95	CLE2 e ⁺ e ⁻ →			RTUSO 93). The			
model, the result becomes (GISW model to correct for unsee 0.023 \pm 0.006 \pm 0.004. Assume	$es B(D^{*+} \rightarrow D^{0}\pi^{+}) =$	0.056 ± 0 26 ALBRECI providing	0.006 and 0.076 ± HT 91C result supe evidence for the b	0.008, respectively ersedes ALBRECH [*] → u transition.	T 90. Two ev Using the mo	del of ALTAF	RELLI 82, the
model, the result becomes 68.1%, $B(D^0 \rightarrow K^-\pi^+)$ taken their average e and μ 14 BARISH 95 use $B(D^0 \rightarrow K^-\pi^+)$	$0.023 \pm 0.006 \pm 0.004$. Assumo = 3.65%, B($D^0 \rightarrow K^- \pi^+ \pi^-$	in modes. Using the BHKT es $B(D^{a+} \rightarrow D^{0}\pi^{+}) = -\pi^{+}) = 7.5\%$. We have %, assume all nonresonant	0.056 \pm 0 26 ALBRECI providing obtain $ V $ 27 FULTON p=2.4-2 ratio, (1.4	0.006 and 0.076 \pm HT 91c result superevidence for the <i>b</i> $ub/V_Cb = 0.11 \pm$ 90 observe 76 \pm 2 1.6 GeV signaling to 3 \pm 0.4 \pm 0.3) \times	0.008, respectively ersedes ALBRECH [*] : $\rightarrow \mu$ transition. 0.012 from 77 lept excess e and μ (he presence of the μ).	T 90. Two events on s in the 2.3- lepton) events $b \rightarrow u$ transition a model-	del of ALTAF -2.6 GeV mo s in the mom lon. The ave dependent m	RELLI 82, the mentum range entum intervi rage branchin leasurement c
model, the result becomes $(68.1\%, B(D^0 \rightarrow K^-\pi^+))$ taken their average e and μ 14 BARISH 95 use $B(D^0 \rightarrow K^-\pi^+)$ channels are zero, and use $G(D^0 \rightarrow K^-\pi^+)$	0.023 \pm 0.006 \pm 0.004. Assum: = 3.65%, B($D^0 \rightarrow K^-\pi^+\pi^-$ value. ($^-\pi^+$) = (3.91 \pm 0.08 \pm 0.17)': IISW model for relative abundance.	n modes. Using the BHKT es $B(D^{*+} \rightarrow D^0 \pi^+) = -\pi^+) = 7.5\%$. We have %, assume all nonresonant ces of D^{**} states.	0.056 \pm 0.26 ALBRECI providing obtain $ V $ 27 FULTON p = 2.4-2 ratio, (1.1 approximi	0.006 and 0.076 \pm HT 91c result super evidence for the b $u_b/V_{Cb} =0.11\pm$ 90 observe 76 \pm 2 0.6 GeV signaling the second of 0.30 \times 0.30 \times	0.008, respectively ersedes ALBRECH [*] $\rightarrow \mu$ transition. 0.0012 from 77 lept 20 excess e and μ (the presence of the μ) 10 ⁻⁴ , corresponds 0.1 using B($b \rightarrow 0$	T 90. Two events on sin the 2.3-depton) events $b \rightarrow u$ transites to a model- $c \ell \nu = 10.2$	del of ALTAF -2.6 GeV mo s in the mom ion. The ave dependent m $2 \pm 0.2 \pm 0.7$	RELLI 82, the mentum range lentum intervarage branchin leasurement of 7%.
model, the result becomes 68.1%, $B(D^0 \to K^-\pi^+)$ 68.1%, $B(D^0 \to K^-\pi^+)$ 14 BARISH 95 use $B(D^0 \to K^-\pi^+)$ channels are zero, and use $G(D^0 \to K^+\nu_e)$	0.023 \pm 0.006 \pm 0.004. Assuming 3.65%, B($D^0 \rightarrow K^-\pi^+\pi^-$ value. ($^-\pi^+$) = (3.91 \pm 0.08 \pm 0.17) (15W model for relative abundance)	n modes. Using the BHKT es $B(D^{*+} \rightarrow D^0 \pi^+) = -\pi^+) = 7.5\%$. We have %, assume all nonresonant ces of D^{**} states.	0.056 ± 0 26 ALBRECI providing obtain V 27 FULTON p = 2.4-2 ratio, (1.1 approxim. 28 ALBRECI interval p	0.006 and 0.076 \pm HT 91c results up be vidence for the <i>b</i> ub/ V_{Cb} = 0.11 \pm 90 observe 76 \pm 2.6 GeV signaling that 3 \pm 0.4 \pm 0.3) \times ately $ V_{ub}/V_{cb} $ = HT 90 observes 41 = 2.3–2.6 GeV signaling that \times 1 = 2.3–2.6 GeV signaling that \times 1 = 2.3–2.6 GeV signaling that \times 2 = 2.3–2.6 GeV signaling that \times 3 = 2.3–2.6 GeV signaling that \times	0.008, respectively ersedes ALBRECH $\rightarrow \rightarrow \nu$ transition. 0.012 from 77 lept to excess e and μ (he presence of the t = 0.1 using B($b \rightarrow t$ = 0.1 using B($b \rightarrow t$ = 1 ± 10 excess e a gnaling the presence	T 90. Two evenus the most one in the 2.3-lepton) events $b \rightarrow u$ transition to a modelectry $(c\ell \nu) = 10.2$ and μ (lepton) ce of the $b \rightarrow 0$	del of ALTAF -2.6 GeV mo s in the mom ion. The ave dependent m $2 \pm 0.2 \pm 0.$ events in t u transitio	RELLI 82, the mentum range pranchin intervarage branchin intervarage branchin interval for the momentum. The eventum.
model, the result becomes 68.1% , $B(D^0 \rightarrow K^-\pi^+)$ taken their average e and μ 14 BARISH 95 use $B(D^0 \rightarrow K$ channels are zero, and use $G(D_1(2420)\ell^+\nu_\ell$ anything)	0.023 \pm 0.006 \pm 0.004. Assuming a 3.65%, B($D^0 \rightarrow K^-\pi^+\pi^-\pi^+\pi^-\pi^+\pi^-\pi^+\pi^-\pi^+\pi^-\pi^+\pi^-\pi^+\pi^-\pi^+\pi^-\pi^+\pi^-\pi^+\pi^-\pi^-\pi^+\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi$	in modes. Using the BHKT es $B(D^{*+} \rightarrow D^0 \pi^+) = \pi^+) = 7.5\%$. We have %, assume all nonresonant ces of D^{**} states. \[\text{\Gamma}_{10} / \text{\Gamma}_{COMMENT}. \]	0.056 ± C 26 ALBRECI providing obtain V 27 FULTON p = 2.4-7 ratio, (1.1) approxim 28 ALBRECI interval p correspon	0.006 and 0.076 \pm 1T 91c result super evidence for the b $u_b/V_{Cb} =0.11\pm$ 90 observe 76 \pm 2.6 GeV signaling to 3 \pm 0.4 \pm 0.3) \times ately $ V_{ub}/V_{Cb} =1$ T 90 observes 41 \pm 2.3 \pm 0.4 \pm 0.3 \times 4 d \pm 0.3 \times 4 d \pm 0.3 \times 6 d \pm 0 observes 41 \pm 0 observes 42 \pm 0.3 \pm 0 observes 41 \pm 0 observes 42 \pm 0 observes 41 \pm 0	0.008, respectively exceeds ALBRECH's $\rightarrow u$ transition. 0.012 from 77 lept 10 excess e and μ (the presence of the i 10-4, corresponds $= 0.1$ using $B(b \rightarrow 1 \pm 1)$ 0 excess e a grading the presented the measurement measurement measurement.	T 90. Two eventual the monons in the 2.3-depton) events by u transit is to a modelect v (lepton) ce of the b to d (v) and d (v) to d) to d (v) to d) to d	del of ALTAF -2.6 GeV mo s in the mom ion. The ave dependent m $2 \pm 0.2 \pm 0.1$ events in t u transitio u u u u u u u u u u	RELLI 82, the mentum range pranchin intervarage branchin leasurement of 7%. The momentum of the event in The event.
model, the result becomes 68.1% , $B(D^0 \rightarrow K^-\pi^+)$ taken their average e and μ 14 BARISH 95 use $B(D^0 \rightarrow K^-\pi^+)$ channels are zero, and use G $\Gamma(\overline{D}_1(2420)\ell^+\nu_\ell)$ anything) WALUE 0.0074 \pm 0.0076	0.023 \pm 0.006 \pm 0.004. Assuming a 3.65%, B($D^0 \rightarrow K^-\pi^+\pi^-\pi^+\pi^-\pi^-\pi^+\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi$	in modes. Using the BHKT es $B(D^{*+} \rightarrow D^0\pi^+) = \pi^+) = 7.5\%$. We have %, assume all nonresonant tes of D^{**} states. $\Gamma_{10}/\Gamma_{COMMENT}$ $e^+e^- \rightarrow Z$	0.056 ± C 26 ALBRECI providing obtain V 27 FULTON p = 2.4-7 ratho, (1.1) approxim. 28 ALBRECI interval p correspon 29 The quot	0.006 and 0.076 \pm 1T 91c result supprevidence for the b $_{ub}/V_{Cb} =0.11\pm$ 90 observe 76 \pm 2.6 GeV signaling the 3 \pm 0.4 \pm 0.3) \times ately $ V_{ub}/V_{Cb} =1$ T 90 observes 41 \pm 2.3 \pm 2.4 \pm 0.3 \times ately $ V_{ub}/V_{Cb} =1$ \pm 0.4 \pm 0.3 \times 1 \pm 0.4 \pm 0.3 \times 1 \pm 0.4 \pm 0.4 \pm 0.3 \times 1 \pm 0.4 \pm 0.4 \pm 0.3 \times 1 \pm 0.4 \pm 0.5 \pm	0.008, respectively ersedes ALBRECH $\rightarrow \rightarrow \nu$ transition. 0.012 from 77 lept to excess e and μ (he presence of the t = 0.1 using B($b \rightarrow t$ = 0.1 using B($b \rightarrow t$ = 1 ± 10 excess e a gnaling the presence	T 90. Two every Using the mo- ons in the 2.3-depton) events $b \rightarrow \nu$ transit $b \rightarrow \nu$ transit $c \leftarrow c\ell\nu$ = 10.2 and μ (lepton) ce of the $b \rightarrow \nu$ to $c \leftarrow c\ell\nu$ = 0.0.4 for the	del of ALTAF -2.6 GeV mo s in the mom ion. The ave dependent m $2 \pm 0.2 \pm 0.1$ events in t u transition u is a constant u transition u transition u transition	RELLI 82, the mentum range ientum intervarage branchin leasurement of 7%. The momentum in The event is 0.01. Inding on which mentum in the event is 0.01.
model, the result becomes $(68.1\%, \mathbb{B}/\mathbb{D}^0 \to K^-\pi^+)$ taken their average e and μ than 14 BARISH 95 use $\mathbb{B}(\mathbb{D}^0 \to K$ channels are zero, and use $\mathbb{G}(\mathbb{D}_1(2420)\ell^+\nu_\ell)$ anything) WALUE 0.0074 \pm 0.0016	0.023 \pm 0.006 \pm 0.004. Assuming 3.65%, B($D^0 \rightarrow K^-\pi^+\pi^-\pi^+\pi^-\pi^-\pi^+\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi$	in modes. Using the BHKT es $B(D^{*+} \rightarrow D^0\pi^+) = \pi^+) = 7.5\%$. We have %, assume all nonresonant tes of D^{**} states. $\Gamma_{10}/\Gamma_{COMMENT}$ $e^+e^- \rightarrow Z$	0.056 ± C 26 ALBRECI providing obtain V 27 FULTON p = 2.4-7 ratio, (1.1) approxim 28 ALBRECI interval p correspon 29 The quot model or calculate	0.006 and 0.076 \pm 1T 91c result super evidence for the b $u_b/V_{Cb} = 0.11 \pm$ 90 observe 76 \pm 2.6 GeV signaling to 3 \pm 0.4 \pm 0.3) \times ately $ V_{ub}/V_{Cb} =$ 1T 90 observes 41 \pm 0.3 \pm 0.4 \pm 0.3 \pm 0.4 \pm 0.3 \pm 0.7	0.008, respectively exceeds ALBRECH's $\rightarrow u$ transition. 0.012 from 77 lept 10 excess e and μ (be presence of the 10^{-4} , corresponds $= 0.1$ using B($b \rightarrow 1 \pm 10$ excess e a gnaling the presendent measurement measurement is chosen. We sele is to a limit on $ V $	T 90. Two ev Using the mo- ons in the 2.3- lepton) events $b \rightarrow u$ transits s to a model- $c \ell \nu$) = 10.3 in d μ (lepton) ce of the b — it of $ V_{ub}/V_{c}$ o 0.04 for the event the most of $ V_{ub}/V_{cb} < V_{cb} < V_{cb} $	del of ALTAF -2.6 GeV mo lon. The ave dependent m $2 \pm 0.2 \pm 0.$ events in t μ transition μ = 0.10 ± ratio, deper 0.20. While	RELLI 82, the mentum range is the time intervier rage branchin leasurement of 7%. The event is 0.01. The event is 0.01 on whice limit they have the endpoir
model, the result becomes $(68.1\%, B(D^0 \rightarrow K^-\pi^+))$ taken their average e and μ 14 BARISH 95 use $B(D^0 \rightarrow K^-\pi^+)$ channels are zero, and use G $\Gamma(\overline{D_1(2420)}\ell^+\nu_\ell$ anything) WALUE • • • We do not use the follow seen 15 BUSKULIC 97B assumes $B(E^0 \rightarrow E^0)$	0.023 \pm 0.006 \pm 0.004. Assuming 3.65%, B($D^0 \rightarrow K^-\pi^+\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi^-\pi$	n modes. Using the BHKT es $B(D^{*+} \rightarrow D^0\pi^+) = -\pi^+) = 7.5\%$. We have %, assume all nonresonant tes of D^{**} states. \[\begin{align*} \(\text{COMMENT} \\ e^+e^- \rightarrow \ Z \\ etc. \ \end{align*} \ \] Repl. by BUSKULIC 978	0.056 ± C 26 ALBRECI providing obtain V 27 FULTON p = 2.4-7 ratho, (1.1) approxim. 28 ALBRECI interval p correspon 29 The quot model or calculatec	0.006 and 0.076 \pm 17 91c result supprevidence for the b $_{ub}/V_{Cb} = 0.11 \pm$ 90 observe 76 \pm 2.6 GeV signaling the 3 \pm 0.4 \pm 0.3) \times ately $ V_{ub}/V_{Cb} = 17$ 90 observes 41 \pm 2.3 \pm 2.6 GeV sid to a model-depeed possible limits $_{ub}$ momentum range $_{ub}$ 1. This correspondemployed is more	0.008, respectively exceeds ALBRECH's $\rightarrow u$ transition. 0.012 from 77 lept 00 excess e and μ (the presence of the i 10 ⁻⁴ , corresponds $= 0.1$ using $B(b \rightarrow 1 \pm 10)$ excess e a gnaling the presented in the presented of the i 1s chosen. We select the i 1s chosen. We select i 2s i 2s i 3s i	T 90. Two ev Using the mo- ons in the 2.3- lepton) events $b \rightarrow u$ transit is to a model- c(u) = 10.2 and μ (lepton) ce of the $b \rightarrow$ of $ V_{ub} /V_{cb} $ o 0.04 for the sect the most of $ V_{ub} /V_{cb} $ orevious result:	del of ALTAF -2.6 GeV mo lon. The ave dependent m $2 \pm 0.2 \pm 0.$ events in t μ transition μ = 0.10 ± ratio, deper 0.20. While	RELLI 82, the mentum range is the time intervier rage branchin leasurement of 7%. The event is 0.01. The event is 0.01 on whice limit they have the endpoir
model, the result becomes $(68.1\%, \mathbb{B}(D^0 \to K^-\pi^+))$ taken their average e and μ taken their average e and μ channels are zero, and use G $\Gamma(\overline{D_1(2420)}\ell^+\nu_\ell \text{anything})$ VALUE 0.0074 \pm 0.0016 • • We do not use the follow seen (16.00) \pm 0.0078 \pm 0.0018 \pm 0.00	0.023 \pm 0.006 \pm 0.004. Assuming a 3.65%, B($D^0 \rightarrow K^-\pi^+\pi^+\pi^+\pi^+\pi^+\pi^+\pi^+\pi^+\pi^+\pi^+\pi^+\pi^+\pi^+\pi$	In modes. Using the BHKT es $B(D^{*+} \rightarrow D^0\pi^+) = \pi^+) = 7.5\%$. We have %, assume all nonresonant tes of D^{**} states. $ \Gamma_{10}/\Gamma $ $ \frac{COMMENT}{e^+e^- \rightarrow Z} $ etc. • • • Repl. by BUSKULIC 978 (2420) $\rightarrow D^*\pi^\pm$) = 2/3,	0.056 ± C 26 ALBRECI providing obtain V 27 FULTON p = 2.4-72 ratio, (1.1) approxim 28 ALBRECI interval p correspon 29 The quot model or calculatec technique do not pr	0.006 and 0.076 \pm 1T 91c result super evidence for the b $u_b/V_{Cb} =0.11\pm$ 90 observe 76 \pm 2.6 GeV signaling to 3 \pm 0.4 \pm 0.3) \times ately $ V_{ub}/V_{Cb} =1$ T 90 observes 41 \pm 2.3 \pm 2.6 GeV sid d to a model-depe ed possible limits t_c momentum range t_c 1. This correspond employed is more ovide a numerical t_c	0.008, respectively exceeds ALBRECH's $\rightarrow u$ transition. 0.012 from 77 lept 10 excess e and μ (u) excess e and μ (u) excess e and u) expressed in u (u) expressed in u) excess u) and u) excess u) and u) excess u) excess u 0 except the u 1 excess u 2 except the u 3 except the u 3 except the u 4 except the u 5 except the u 6 except the u 6 except the u 7 except the u 8 except the u 9 except	T 90. Two ev Using the mo- ons in the 2.3- lepton) events $b \rightarrow u$ transit is to a model- c(u) = 10.2 and μ (lepton) ce of the $b \rightarrow$ of $ V_{ub} /V_{cb} $ o 0.04 for the sect the most of $ V_{ub} /V_{cb} $ orevious result:	del of ALTAF -2.6 GeV mo lon. The ave dependent m $2 \pm 0.2 \pm 0.$ events in t μ transition μ = 0.10 ± ratio, deper 0.20. While	RELLI 82, the mentum range mentum intervarage branchin leasurement of 7%. The momentum in The event in 0.01. Iding on which limit they have the endpoir 4, these result
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model, the result becomes $(68.1\%, B D^0 \rightarrow K^-\pi^+)$ taken their average e and μ taken their average e and μ channels are zero, and use G $(D_1(2420)\ell^+\nu_\ell anything)$ with ℓ	0.023 \pm 0.06 \pm 0.004. Assume $=$ 3.65%, B($D^0 \rightarrow K^-\pi^+\pi^+\pi^+\pi^+\pi^+\pi^+\pi^+\pi^+\pi^+\pi^+\pi^+\pi^+\pi^+\pi$	In modes. Using the BHKT es $B(D^{*+} \rightarrow D^0\pi^+) = \pi^+) = 7.5\%$. We have $\%$, assume all nonresonant res of D^{**} states. Fig./ COMMENT $e^+e^- \rightarrow Z$ etc. • • • Repl. by BUSKULIC 97B (2420) $\rightarrow D^*\pi^\pm) = 2/3$, thing) $\times B(\overline{D}_1(2420)^0 \rightarrow D^*\pi^\pm) = 2/3$, thing) $\times B(\overline{D}_1(2420)^0 \rightarrow D^*\pi^\pm) = 2/3$, the production fraction for Γ_{11}/Γ COMMENT $e^+e^- \rightarrow Z$ uses isospin invariance by $+\pi^-$ are from D^{**} states. of B_S^0 and A_D^0 . Fig./ COMMENT $e^+e^- \rightarrow Z$ etc. • • •	0.056 ± 0 26 ALBRECI providing obtain V 27 FULTON p = 2.4-2 ratio, (1.1 approxim: 28 ALBRECI interval p correspon 29 The quoto model or calculated technique do not pr VALUE 0.58 ±0.05 0.594 ±0.07 30 ALAM 87 (K-2+v L denot VALUE 0.092±0.035 0.086±0.011 0.10 ±0.05 31 ALAM 87	0.006 and 0.076 \pm 17 91c result superviolence for the b $ub/V_cb =0.11 \pm$ 90 observe 76 \pm 2 0.05 steely 0 0 0 0 0 0 0 0 0 0	0.008, respectively exceeded a LBRECHT → U transition. 0.012 from 77 lept the presence of the interpretation of the interpretati	T 90. Two every consist the 2.3-lepton) events $b \rightarrow u$ transit s to a model- $c\ell\nu$) = 10.2 and μ (lepton) co of the b - t of $ V_{u}b /C_{c}$ o 0.04 for the set the most c t corevious result: e limit. TECN 94C ARG 87B CLEO correlations.	del of ALTAF-2-2.6 GeV mo s in the mom lon. The ave dependent m $2 \pm 0.0 \pm 0.0$ events in the mom lon. The since $b = 0.10 \pm 0.0$ events in the mom lon. The since $b = 0.10 \pm 0.0$ events in the moment of the since $b = 0.10 \pm 0.0$ events in the since $b = 0.10 \pm 0.0$ events in CHEN 8. COMMENT $e^+e^- \rightarrow e^+e^- \rightarrow 0.0$	RELLI 82, the mentum range mentum range mentum intervarage branchin leasurement of 7%. The event of 0.01. Iding on whice limit they have the endpoint of 18/1/1/1/1/1/1/1/1/1/1/1/1/1/1/1/1/1/1/
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model, the result becomes $(68.1\%, B D^0 \rightarrow K^-\pi^+)$ taken their average e and μ taken their average e and μ channels are zero, and use G $(D_1(2420)\ell^+\nu_\ell anything)$ walve e	0.023 \pm 0.006 \pm 0.004. Assum: $= 3.65\%$, B($D^0 \rightarrow K^-\pi^+\pi^+\pi^+\pi^+\pi^+\pi^+\pi^+\pi^+\pi^+\pi^+\pi^+\pi^+\pi^+\pi$	In modes. Using the BHKT es $B(D^{*+} \rightarrow D^0\pi^+) = -\pi^+) = 7.5\%$. We have %, assume all nonresonant tes of D^{**} states. Fig./ COMMENT $e^+e^- \rightarrow Z$ etc. • • • Repl. by BUSKULIC 978 $(2420) \rightarrow D^*\pi^\pm) = 2/3$, thing) $\times B(\overline{D}_1(2420)^0 \rightarrow 0$ the production fraction for Fil/F COMMENT $e^+e^- \rightarrow Z$ uses isospin invariance by $^+\pi^-$ are from D^{**} states. of B_S^0 and A_D^0 . Fig./ COMMENT $e^+e^- \rightarrow Z$ etc. • • • $e^+e^- \rightarrow Z$ etc. • • $e^+e^- \rightarrow Z$ etc. • • • $e^+e^- \rightarrow Z$ etc. • • $e^+e^- \rightarrow Z$ etc. • • • $e^+e^- \rightarrow Z$ etc. • $e^+e^- \rightarrow Z$	0.056 ± 0 26 ALBRECI providing obtain V 27 FULTON p = 2.4-2 ratio, (1.1 approxim: 28 ALBRECI interval p correspon 29 The quot model or calculated technique do not pr (K+ ℓ+ ν _ℓ ℓ denot VALUE 0.58 ± 0.05 0.594 ± 0.07 0.54 ± 0.07 0.54 ± 0.07 0.54 ± 0.07 0.54 ± 0.07 0.54 ± 0.07 0.55 ± 0.05 0.594 ± 0.07 0.594 ± 0.07 0.594 ± 0.07 0.594 ± 0.07 0.594 ± 0.07 0.594 ± 0.07 0.594 ± 0.07 0.594 ± 0.07 0.594 ± 0.07 0.086 ± 0.01 0.10 ± 0.05 0.11 ± 0.05 0.12 ± 0.05 0.12 ± 0.05 0.12 ± 0.05 0.13 ± 0.06 0.452 ± 0.03 0.39 ± 0.06 0.32 ALBRECI	0.006 and 0.076 \pm 17 91c result super evidence for the b $ub/V_{Cb} = 0.11 \pm$ 90 observe $76 \pm 2.00 \pm$ 90 \pm 0.4 \pm 0.3) \times atter $ V_{ub}/V_{Cb} = 11$ 17 90 observes 41 \pm 2.3 \pm 2.6 GeV signaling the explosible limits \pm 17 90 observes 41 \pm 2.3 \pm 2.6 GeV side to a model-dependent of the explosible limits \pm 18 correspond employed is more ovide a numerical \pm anything) $/\Gamma(\xi^+)$ es \pm 0.05 \pm 0.06 \pm 0.06 \pm 0.07 measurement relative anything) $/\Gamma(\xi^+)$ es \pm 0.02 \pm 0.02 \pm 0.02 \pm 0.04 \pm 0.05 \pm 0.04 \pm 0.05 \pm 0.04 \pm 0.05 \pm 0.04 \pm 0.05 \pm 0.05 \pm 0.06 \pm 0.06 \pm 0.07 \pm 0.07 \pm 0.07 \pm 0.07 \pm 0.09 \pm	0.008, respectively exceeded a LBRECHT in a Uransition. 0.012 from 77 lept in a Uransition. 0.012 from 77 lept in a Uransition. 0.012 from 77 lept in a Uransition. 10 excess e and µ in a Uransition in	T 90. Two ev Using the moon one in the 2.3- lepton) events b → u transit so a model- c clu) = 10.2 nd \(\mu \) (lepton) co of the b — to it of lepton of the b — to it of lepton one of the b — to it of lepton one of the b — to it of lepton one of the b — to it of lepton one of the b — to it of lepton one of the b — to one of lepton one of lepto	del of ALTAF-2-2.6 GeV mo s in the mom lon. The ave dependent m $2 \pm 0.2 \pm 0.$ levents in t u transitio $b = 0.10 \pm 0.$ ratio, dependents in t or transitio $b = 0.10 \pm 0.$ ratio, dependents in t or transitio $b = 0.10 \pm 0.$ ratio, dependence on servative is ratio, dependence on the conservative in t or transitio $b = 0.10 \pm 0.$ ratio, dependence on the conservative in the cons	RELLI 82, the mentum range mentum range mentum range pranchin leasurement of 7%. The event of 0.01. In the event of 0.01. In the endpoint of 18/15/ T(45) T(45) T(45) T(45) T(45) T(45) T(45)
model, the result becomes $(68.1\%, B D^0 \rightarrow K^-\pi^+)$ taken their average e and μ taken their average e and μ channels are zero, and use G $(D_1(2420)\ell^+\nu_\ell anything)$ where ℓ	0.023 \pm 0.006 \pm 0.004. Assum: $= 3.65\%, B(D^0 \rightarrow K^-\pi^+\pi^-\pi^-)$ value. $(-\pi^+) = (3.91 \pm 0.08 \pm 0.17)^{\circ}$ its W model for relative abundance of the production of the pro	In modes. Using the BHKT es $B(D^{*+} \rightarrow D^0\pi^+) = -\pi^+) = 7.5\%$. We have $\%$, assume all nonresonant tes of D^{**} states. Fig. 10/ Γ COMMENT $e^+e^- \rightarrow Z$ etc. • • • Repl. by BUSKULIC 978 (2420) $\rightarrow D^*\pi^{\pm}) = 2/3$, thing) $\times B(\overline{D}_1(2420)^0 \rightarrow D^*\pi^{\pm}) = 2/3$, thing) $\times B(\overline{D}_1(2420)^0 \rightarrow D^*\pi^{\pm}) = 2/3$, thing) $\times B(\overline{D}_1(2420)^0 \rightarrow D^*\pi^{\pm}) = 2/3$, uses isospin invariance by $^+\pi^-$ are from D^{**} states. of B_0^0 and A_0^0 . Fig. 12/ Γ COMMENT $e^+e^- \rightarrow Z$ etc. • • • $e^+e^- \rightarrow Z$ etc. • • • $e^+e^- \rightarrow Z$ etc. • • • $e^+e^- \rightarrow Z$ etching) $\times B(\overline{D}_2^*(2460)^0 \rightarrow D^*\pi^{\pm}) = 2$ thing) $\times B(\overline{D}_2^*(2460)^0 \rightarrow D^*\pi^{\pm}) = 2$	0.056 ± 0 26 ALBRECI providing obtain V 27 FULTON p = 2.4-2 ratio, (1.1 approxim: 28 ALBRECI interval p correspon 29 The quot model or calculated technique do not pr (K+ ℓ+ ν _ℓ ℓ denot VALUE 0.58 ± 0.05 0.594 ± 0.07 0.54 ± 0.07 0.54 ± 0.07 0.54 ± 0.07 0.54 ± 0.07 0.54 ± 0.07 0.55 ± 0.05 0.594 ± 0.07 0.594 ± 0.07 0.594 ± 0.07 0.594 ± 0.07 0.594 ± 0.07 0.594 ± 0.07 0.594 ± 0.07 0.594 ± 0.07 0.594 ± 0.07 0.086 ± 0.01 0.10 ± 0.05 0.11 ± 0.05 0.12 ± 0.05 0.12 ± 0.05 0.12 ± 0.05 0.13 ± 0.06 0.452 ± 0.03 0.39 ± 0.06 0.32 ALBRECI	0.006 and 0.076 \pm 17 91c result super evidence for the b $ub/V_{Cb} = 0.11 \pm$ 90 observe $76 \pm 2.00 \pm$ 90 \pm 0.4 \pm 0.3) \times atter $ V_{ub}/V_{Cb} = 11$ 17 90 observes 41 \pm 2.3 \pm 2.6 GeV signaling the explosible limits \pm 17 90 observes 41 \pm 2.3 \pm 2.6 GeV side to a model-dependent of the explosible limits \pm 18 correspond employed is more ovide a numerical \pm anything) $/\Gamma(\xi^+)$ es \pm 0.05 \pm 0.06 \pm 0.06 \pm 0.07 measurement relative anything) $/\Gamma(\xi^+)$ es \pm 0.02 \pm 0.02 \pm 0.02 \pm 0.04 \pm 0.05 \pm 0.04 \pm 0.05 \pm 0.04 \pm 0.05 \pm 0.04 \pm 0.05 \pm 0.05 \pm 0.06 \pm 0.06 \pm 0.07 \pm 0.07 \pm 0.07 \pm 0.07 \pm 0.09 \pm	0.008, respectively exceeded a LBRECHT → U transition. 0.012 from 77 lept in the presence of the left in the lef	T 90. Two ev Using the moon one in the 2.3- lepton) events b → u transit so a model- c clu) = 10.2 nd \(\mu \) (lepton) co of the b — to it of lepton of the b — to it of lepton one of the b — to it of lepton one of the b — to it of lepton one of the b — to it of lepton one of the b — to it of lepton one of the b — to one of lepton one of lepto	del of ALTAF-2-2.6 GeV mo s in the mom lon. The ave dependent m $2 \pm 0.2 \pm 0.$ levents in t u transitio $b = 0.10 \pm 0.$ ratio, dependents in t or transitio $b = 0.10 \pm 0.$ ratio, dependents in t or transitio $b = 0.10 \pm 0.$ ratio, dependence on servative is ratio, dependence on the conservative in t or transitio $b = 0.10 \pm 0.$ ratio, dependence on the conservative in the cons	RELLI 82, the mentum range mentum range lentum intervalues and range branchin leasurement of 7%. The event of 0.01. In the event of 0.01, and the event of 0.01, and the event of 0.01, and the end political form of 18/15/15/15/15/15/15/15/15/15/15/15/15/15/
model, the result becomes $(68.1\%, B(D^0 \rightarrow K^-\pi^+))$ taken their average e and μ taken their average e and μ channels are zero, and use G $(D_1(2420)\ell^+\nu_\ell anything)$ and $(D_1(2420)\ell^+\nu_\ell anything)$ $(D_1(24$	0.023 \pm 0.06 \pm 0.004. Assum: = 3.65%, B($D^0 \rightarrow K^-\pi^+\pi^+\pi^+\pi^+\pi^+\pi^+\pi^+\pi^+\pi^+\pi^+\pi^+\pi^+\pi^+\pi$	In modes. Using the BHKT es $B(D^{*+} \rightarrow D^0\pi^+) = -\pi^+) = 7.5\%$. We have %, assume all nonresonant tes of D^{**} states. Fig./ COMMENT $e^+e^- \rightarrow Z$ etc. • • • Repl. by BUSKULIC 978 $(2420) \rightarrow D^*\pi^\pm) = 2/3$, thing) $\times B(\overline{D}_1(2420)^0 \rightarrow 0$ the production fraction for Fil/F COMMENT $e^+e^- \rightarrow Z$ uses isospin invariance by $^+\pi^-$ are from D^{**} states. of B_S^0 and A_D^0 . Fig./ COMMENT $e^+e^- \rightarrow Z$ etc. • • • $e^+e^- \rightarrow Z$ etc. • • $e^+e^- \rightarrow Z$ etc. • • • $e^+e^- \rightarrow Z$ etc. • • $e^+e^- \rightarrow Z$ etc. • • • $e^+e^- \rightarrow Z$ etc. • $e^+e^- \rightarrow Z$	0.056 ± 0 26 ALBRECI providing obtain V 27 FULTON p = 2.4-2 ratio, (1.1 approxim: 28 ALBRECI interval p correspon 29 The quot model or calculated technique do not pr (K+ ℓ+ ν _ℓ ℓ denot VALUE 0.58 ± 0.05 0.594 ± 0.07 0.54 ± 0.07 0.54 ± 0.07 0.54 ± 0.07 0.54 ± 0.07 0.54 ± 0.07 0.55 ± 0.05 0.594 ± 0.07 0.594 ± 0.07 0.594 ± 0.07 0.594 ± 0.07 0.594 ± 0.07 0.594 ± 0.07 0.594 ± 0.07 0.594 ± 0.07 0.594 ± 0.07 0.086 ± 0.01 0.10 ± 0.05 0.11 ± 0.05 0.12 ± 0.05 0.12 ± 0.05 0.12 ± 0.05 0.13 ± 0.06 0.452 ± 0.03 0.39 ± 0.06 0.32 ALBRECI	0.006 and 0.076 \pm 17 91c result super evidence for the b $ub/V_{Cb} = 0.11 \pm$ 90 observe $76 \pm 2.00 \pm$ 90 \pm 0.4 \pm 0.3) \times atter $ V_{ub}/V_{Cb} = 11$ 17 90 observes 41 \pm 2.3 \pm 2.6 GeV signaling the explosible limits \pm 17 90 observes 41 \pm 2.3 \pm 2.6 GeV side to a model-dependent of the explosible limits \pm 18 correspond employed is more ovide a numerical \pm anything) $/\Gamma(\xi^+)$ es \pm 0.05 \pm 0.06 \pm 0.06 \pm 0.07 measurement relative anything) $/\Gamma(\xi^+)$ es \pm 0.02 \pm 0.02 \pm 0.02 \pm 0.04 \pm 0.05 \pm 0.04 \pm 0.05 \pm 0.04 \pm 0.05 \pm 0.04 \pm 0.05 \pm 0.05 \pm 0.06 \pm 0.06 \pm 0.07 \pm 0.07 \pm 0.07 \pm 0.07 \pm 0.09 \pm	0.008, respectively exceeded a LBRECHT in a Uransition. 0.012 from 77 lept in a Uransition. 0.012 from 77 lept in a Uransition. 0.012 from 77 lept in a Uransition. 10 excess e and µ in a Uransition in	T 90. Two ev Using the moon one in the 2.3- lepton) events b → u transit so a model- c clu) = 10.2 nd \(\mu \) (lepton) co of the b — to it of lepton of the b — to it of lepton one of the b — to it of lepton one of the b — to it of lepton one of the b — to it of lepton one of the b — to it of lepton one of the b — to one of lepton one of lepto	del of ALTAF-2-2.6 GeV mo s in the mom lon. The ave dependent m $2 \pm 0.2 \pm 0.$ levents in t u transitio $b = 0.10 \pm 0.$ ratio, dependents in t or transitio $b = 0.10 \pm 0.$ ratio, dependents in t or transitio $b = 0.10 \pm 0.$ ratio, dependence on servative is ratio, dependence on the conservative in t or transitio $b = 0.10 \pm 0.$ ratio, dependence on the conservative in the cons	RELLI 82, the mentum range mentum intervage branchineasurement 7%. The even is 0.01. Inding on while limit they have the endpol 4, these resulting T(45) T(45) T(45) T(45) T(45) T(45)

Meson Particle Listings B^{\pm}/B^{0} ADMIXTURE

/ALUE L.10±0.06	$\frac{DOCUMENT ID}{34 \text{ GIBBONS}} \frac{TECN}{978 \text{ CLE2}} \frac{COMMENT}{e^+e^-} \rightarrow \Upsilon(45)$
	ie following data for averages, fits, limits, etc. • • •
0.98±0.16±0.12	35 ALAM 878 CLEO $e^+e^- \rightarrow \Upsilon(4S)$
34 GIBBONS 978 from	charm counting using B($D_s^+ \rightarrow \phi \pi$) = 0.036 \pm 0.009 and B($A_c^+ \rightarrow$
$pK^-\pi^+) = 0.044 \pm$	
	between K^+ and K^+ widths. ALAM 878 measurement relies on ions. It does not consider the possibility of $B\widetilde{B}$ mixing. We have n the average.
$\Gamma(D^{\pm}$ anything $)/\Gamma_{ m tot}$	Γ ₂₁ /Γ
VALUE 0.241±0.019 OUR AVE	EVTS DOCUMENT ID TECN COMMENT PAGE
$0.240 \pm 0.013 ^{+0.015}_{-0.016}$	³⁶ GIBBONS 97B CLE2 $e^+e^- \rightarrow \Upsilon(45)$
0.25 ±0.04 ±0.02	37 BORTOLETTO92 CLEO $e^+e^- \rightarrow r(45)$
0.23 ±0.05 +0.01 -0.02	³⁸ ALBRECHT 91H ARG $e^+e^- \rightarrow T(45)$
	ne following data for averages, fits, limits, etc. • •
0.21 ±0.05 ±0.01	20k 39 BORTOLETTO87 CLEO Sup. by BORTO-
	LETTO 92
0.0008 + 0.00082 V	rts $[B(B o D^{\pm} \text{ anything}) imes B(D^{+} o K^{-}\pi^{+}\pi^{+})] = 0.0216 \pm We$ divide by our best value $B(D^{+} o K^{-}\pi^{+}\pi^{+}) = (9.0 \pm 0.6) imes We$
10 ⁻² . Our first erro	or is their experiment's error and our second error is the systematic
error from using our	best value. Peperts $[B(B \to D^{\pm} \text{ anything}) \times B(D^{+} \to K^{-} \pi^{+} \pi^{+})] = 0.0226 \pm 0.0000$
0.0030 ± 0.0018. W	/e divide by our best value B(D ⁺ $\rightarrow K^-\pi^+\pi^+$) = (9.0 \pm 0.6) \times
10 ⁻² . Our first erro	or is their experiment's error and our second error is the systematic
error from using our 38 ALBRECHT 91H rep	best value. Ports $[B(B \to D^{\pm} \text{ anything}) \times B(D^{+} \to K^{-}\pi^{+}\pi^{+})] = 0.0209 \pm 0.0209$
0.0027 ± 0.0040. W	/e divide by our best value B($D^+ \rightarrow K^- \pi^+ \pi^+$) = (9.0 ± 0.6) ×
10 ⁻² . Our first erro	or is their experiment's error and our second error is the systematic
error from using our 39 BORTOLETTO 87 re	reports $[B(B \to D^{\pm} \text{ anything}) \times B(D^{+} \to K^{-} \pi^{+} \pi^{+})] = 0.019 \pm$
0.004 ± 0.002. We di	livide by our best value B($D^+ \rightarrow K^- \pi^+ \pi^+$) = $(9.0 \pm 0.6) \times 10^{-2}$.
Our first error is their using our best value.	r experiment's error and our second error is the systematic error from
<u> </u>	
「(<i>D</i> ⁰ / D⁰ anything) /	/Ftotal F22/F EVTS DOCUMENT ID TECH COMMENT
0.631±0.029 OUR AVE	RAGE Error includes scale factor of 1.1.
0.651±0.025±0.015	⁴⁰ GIBBONS 97B CLE2 $e^+e^- \rightarrow T(45)$ ⁴¹ BORTOLETTO92 CLEO $e^+e^- \rightarrow T(45)$
0.60 ±0.05 ±0.01 0.50 ±0.08 ±0.01	⁴¹ BORTOLETTO92 CLEO $e^+e^- \rightarrow T(45)$ ⁴² ALBRECHT 91H ARG $e^+e^- \rightarrow T(45)$
	e following data for averages, fits, limits, etc. • •
0.55 ±0.07 ±0.01	21k 43 BORTOLETTO87 CLEO $e^+e^- \rightarrow T(45)$
0.62 ±0.19 ±0.01	44 GREEN 83 CLEO Repl. by BORTO- LETTO 87
⁴⁰ GIBBONS 97B repor	rts $[B(B \to D^0/\overline{D}^0 \text{ anything}) \times B(D^0 \to K^-\pi^+)] = 0.0251 \pm 0.0251$
	/e divide by our best value B($D^0 \to K^-\pi^+$) = (3.85 \pm 0.09)×10 ⁻² . r experiment's error and our second error is the systematic error from
using our best value.	
41 BORTOLETTO 92 re	reports $[B(B \to D^0/\overline{D}^0]$ anything) $\times B(D^0 \to K^-\pi^+) = 0.0233 \pm 0.023$
O.0012 ± 0.0014. We Our first error is their	e divide by our best value B($D^0 \rightarrow K^-\pi^+$) = (3.85 ± 0.09) × 10 ⁻² , r experiment's error and our second error is the systematic error from
using our best value.	
ALBRECHT 91H rep	ports $[B(B o D^0/\overline{D}^0]$ anything) $ imes B(D^0 o K^-\pi^+)] = 0.0194 \pm 0.0194$ e divide by our best value $B(D^0 o K^-\pi^+) = (3.85 \pm 0.09) imes 10^{-2}$.
U 0005 + 0 0025. We	r experiment's error and our second error is the systematic error from
Our first error is their	
Our first error is their using our best value.	•
Our first error is their using our best value. 43 BORTOLETTO 87 rd 0.0015 ± 0.0021. We	. reports $[B(B o D^0/\bar{D}^0]$ anything) $ imes B(D^0 o K^-\pi^+)] = 0.0210 \pm 0.0210 \pm 0.0210$ e divide by our best value $B(D^0 o K^-\pi^+) = (3.85 \pm 0.09) \times 10^{-2}$.
Our first error is their using our best value. 43 BORTOLETTO 87 rd 0.0015 ± 0.0021. We Our first error is their	. reports $[B(B \to D^0/\overline{D}^0 \text{ anything}) \times B(D^0 \to K^-\pi^+)] = 0.0210 \pm e$ divide by our best value $B(D^0 \to K^-\pi^+) = (3.85 \pm 0.09) \times 10^{-2}$. $T^0 \to T^0 \to T^0$ resperiment's error and our second error is the systematic error from
Our first error is their using our best value. 43 BORTOLETTO 87 rd 0.0015±0.0021. We Our first error is their using our best value. 44 GREEN 83 reports [8]	. reports $[B(B o D^0/\overline{D}^0 ext{ anything}) imes B(D^0 o K^-\pi^+)] = 0.0210 \pm 6$ divide by our best value $B(D^0 o K^-\pi^+) = (3.85 \pm 0.09) imes 10^{-2}$. The experiment's error and our second error is the systematic error from $B(B o D^0/\overline{D}^0 ext{ anything}) imes B(D^0 o K^-\pi^+)] = 0.024 \pm 0.006 \pm 0.006$
Our first error is their using our best value. 43 BORTOLETTO 87 rd 0.0015 ± 0.0021. We Our first error is their using our best value. 44 GREEN 83 reports [B 0.004. We divide by	e divide by our best value $B(D^0 \to K^-\pi^+) = 0.0210\pm 0.0210\pm 0.0210\pm 0.0210\pm 0.0210\pm 0.0210\pm 0.0210\pm 0.0210\pm 0.0010\pm
Our first error is their using our best value. 43 BORTOLETTO 87 rd 0.0015 ± 0.0021. We Our first error is their using our best value. 44 GREEN 83 reports [B 0.004. We divide by	reports $[B(B \to D^0/\overline{D}^0 \text{anything}) \times B(D^0 \to K^-\pi^+)] = 0.0210 \pm 0 \text{divide by our best value} B(D^0 \to K^-\pi^+) = (3.85 \pm 0.09) \times 10^{-2},$ or experiment's error and our second error is the systematic error from an $B(B \to D^0/\overline{D}^0 \text{anything}) \times B(D^0 \to K^-\pi^+)] = 0.024 \pm 0.006 \pm 0 \text{our best value} B(D^0 \to K^-\pi^+) = (3.85 \pm 0.09) \times 10^{-2}.$ Our speriment's error and our second error is the systematic error from
Our first error is theli using our best value. 43 BORTOLETTO 87 rd 0.0015 ± 0.0021. We Our first error is their using our best value. 44 GREEN 83 reports [E 0.004. We divide by first error is their exusing our best value.	e peorts $[B(B \to D^0/\overline{D}^0 \text{anything}) \times B(D^0 \to K^-\pi^+)] = 0.0210 \pm 0$
Our first error is their using our best value. 43 BORTOLETTO 87 r 0.0015 ± 0.0021. We Our first error is their using our best value. 44 GREEN 83 reports [E 0.004. We divide by first error is their excusing our best value. T (D*(2010) ± anythin	e divide by our best value $B(D^0 \to K^-\pi^+) = 0.0210\pm 0.0010\pm
Our first error is their using our best value. 43 BORTOLETTO 87 rr 0.0015±0.0021. We Our first error is their using our best value. 44 GREEN 83 reports [E 0.004. We divide by first error is their exturing our best value. (D*(2010)** anythir XALUE**	reports $[B(B \to D^0/\overline{D^0} \text{ anything}) \times B(D^0 \to K^-\pi^+)] = 0.0210 \pm 0.0$
Our first error is their using our best value. 43 BORTOLETTO 87 r 0.0015±0.0021. We Our first error is their using our best value. 44 GREEN 83 reports [E 0.004. We divide by first error is their excusing our best value. F(D*(2010)±anythin (ALUE 0.227±0.016 OUR AVE) 0.247±0.019±0.01	reports $[B(B \to D^0/\bar{D}^0 \text{ anything}) \times B(D^0 \to K^-\pi^+)] = 0.0210 \pm 0.0$
Our first error is their using our best value. 43 BORTOLETTO 87 r 0.0015±0.0021. We Our first error is their using our best value. 44 GREEN 83 reports [E 0.004. We divide by first error is their excusing our best value. F (D*(2010)± anythin VALUE 0.227±0.016 OUR AVEI 0.227±0.019±0.01	e divide by our best value $B(D^0 \to K^-\pi^+) = 0.0210\pm$ e divide by our best value $B(D^0 \to K^-\pi^+) = (3.85\pm0.09)\times10^{-2}$. It experiment's error and our second error is the systematic error from $B(B\to D^0/\overline{D}^0)$ anything) $\times B(D^0\to K^-\pi^+) = 0.024\pm0.006\pm$ or our best value $B(D^0\to K^-\pi^+) = (3.85\pm0.09)\times10^{-2}$. Our operiment's error and our second error is the systematic error from $B(B^0\to K^-\pi^+) = (3.85\pm0.09)\times10^{-2}$. Our operiment's error and our second error is the systematic error from $B(B^0\to K^-\pi^+) = (3.85\pm0.09)\times10^{-2}$. Fig. $B(B^0\to K^-\pi^+) = (3.85\pm0.09)\times10^{-2}$. Our operiment's error and our second error is the systematic error from $B(B^0\to K^-\pi^+) = (3.85\pm0.09)\times10^{-2}$. Our operiment's error and our second error is the systematic error from $B(B^0\to K^-\pi^+) = (3.85\pm0.09)\times10^{-2}$.
Our first error is their using our best value. 43 BORTOLETTO 87 r 0.0015±0.0021. We Our first error is their using our best value. 44 GREEN 83 reports [E 0.004. We divide by first error is their ex using our best value. F (D*(2010) = anythin VALUE 0.227±0.016 OUR AVEI 0.227±0.019±0.01 0.225±0.019±0.007 0.230±0.028±0.009	e divide by our best value $B(D^0 \to K^-\pi^+) = 0.0210\pm$ e divide by our best value $B(D^0 \to K^-\pi^+) = (3.85\pm0.09)\times10^{-2}$. It experiment's error and our second error is the systematic error from the course of th
Our first error is their using our best value. 43 BORTOLETTO 87 rr 0.0015±0.0021. We Our first error is their using our best value. 44 GREEN 83 reports [E 0.004. We divide by first error is their ex using our best value. F (D*(2010)** anythin VALUE 0.227±0.016 OUR AVEI 0.227±0.019±0.01 0.225±0.019±0.007 0.230±0.028±0.009 0 • • We do not use the	e divide by our best value $B(D^0 \to K^-\pi^+) = 0.0210\pm$ e divide by our best value $B(D^0 \to K^-\pi^+) = (3.85\pm0.09)\times10^{-2}$. It experiment's error and our second error is the systematic error from $B(B\to D^0/\overline{D}^0)$ anything) $\times B(D^0\to K^-\pi^+) = 0.024\pm0.006\pm$ or our best value $B(D^0\to K^-\pi^+) = (3.85\pm0.09)\times10^{-2}$. Our operiment's error and our second error is the systematic error from $B(B^0\to K^-\pi^+) = (3.85\pm0.09)\times10^{-2}$. Our operiment's error and our second error is the systematic error from $B(B^0\to K^-\pi^+) = (3.85\pm0.09)\times10^{-2}$. Fig. $B(B^0\to K^-\pi^+) = (3.85\pm0.09)\times10^{-2}$. Our operiment's error and our second error is the systematic error from $B(B^0\to K^-\pi^+) = (3.85\pm0.09)\times10^{-2}$. Our operiment's error and our second error is the systematic error from $B(B^0\to K^-\pi^+) = (3.85\pm0.09)\times10^{-2}$.
Our first error is their using our best value. 43 BORTOLETTO 87 r 0.0015±0.0021. We Our first error is their using our best value. 44 GREEN 83 reports [E 0.004. We divide by first error is their ex using our best value. F (D*(2010) = anythin VALUE 0.227±0.016 OUR AVEI 0.227±0.019±0.01 0.225±0.019±0.007 0.230±0.028±0.009 0 • We do not use the 0.28 ±0.05 ±0.01	reports $[B(B \to D^0/\bar{D}^0 \text{ anything}) \times B(D^0 \to K^-\pi^+)] = 0.0210 \pm 0.0$
Our first error is their using our best value. 43 BORTOLETTO 87 r 0.0015±0.0021. We Our first error is their using our best value. 44 GREEN 83 reports [E 0.004. We divide by first error is their excusing our best value. F(D*(2010)± anythin value. 0.227±0.016 OUR AVEI 0.227±0.019±0.007 0.230±0.028±0.009 • • We do not use the 0.28 ±0.05 ±0.01 0.22 ±0.04 +0.07 -0.04	reports $[B(B \to D^0/\overline{D}^0 \text{anything}) \times B(D^0 \to K^-\pi^+)] = 0.0210 \pm 0.$
Our first error is their using our best value. 43 BORTOLETTO 87 r 0.0015±0.0021. We Our first error is their using our best value. 44 GREEN 83 reports [E 0.004. We divide by first error is their ex using our best value. (**D**(2010)**± anythin** **D**(2010)**± anythin** **D**(2010)**± 0.010 0.227±0.016 OUR AWEI 0.227±0.019±0.01 0.205±0.019±0.007 0.230±0.028±0.009 0.008±0.009 0.008±0.009 0.008±0.009 0.008±0.009 0.008±0.009 0.008±0.009 0.008±0.009 0.008±0.009	reports $[B(B \to D^0/\bar{D}^0 \text{ anything}) \times B(D^0 \to K^-\pi^+)] = 0.0210 \pm 0.0$

⁴⁶ ALBRECHT 96D reports B($B \rightarrow D^*(2010)^+$ anything) 0.196 \pm 0.019 using CLEO measured B($D^*(2010)^+ \rightarrow D^0 \pi^+$) = 0.681 ± 0.01 ± 0.013, B($D^0 \rightarrow K^- \pi^+$) = 0.0401 ± 0.0014, B($D^0 \rightarrow K^- \pi^+ \pi^+ \pi^-$) = 0.081 ± 0.005., We rescale to our PDG 96 values of D and D^* branching ratios. Our first error is their experiment's error and our second error is the systematic error from using our best value. ⁴⁷ BORTOLETTO 92 reports B($B \rightarrow D^*(2010)^+$ anything) = 0.25 \pm 0.03 \pm 0.04 using MARK II B($D^*(2010)^+ \rightarrow D^0 \pi^+$) = 0.57 \pm 0.06 and B($D^0 \rightarrow K^- \pi^+$) = 0.042 \pm 0.008. We rescale to our PDG 96 values of D and D^* branching ratios. Our first error is their experiment's error and our second error is the systematic error from using our best ⁴⁸ ALBRECHT 91H reports 0.348 \pm 0.060 \pm 0.035 for B(D^* (2010) $^+ \rightarrow D^0 \pi^+$) = 0.55 \pm 0.04. We rescale to our best value $B(D^*(2010)^+ \rightarrow D^0 \pi^+) = (68.3 \pm 1.4) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value. Uses the PDG 90 B($D^0 \rightarrow K^-\pi^+$) =0.0371 \pm 0.0025. ⁴⁹BORTOLETTO 87 uses old MARK III (BALTRUSAITIS 86E) branching ratios $B(D^0 \rightarrow$ $(K^-\pi^+) = 0.056 \pm 0.004 \pm 0.003$ and also assumes $B(D^*(2010)^+ \to D^0\pi^+) = 0.60^+0.08$. The product branching ratio for $B(B \to D^*(2010)^+)$ $B(D^*(2010)^+ \to D^0\pi^+)$ $D^0\pi^+$) is 0.13 \pm 0.02 \pm 0.012. Superseded by BORTOLETTO 92. ⁵⁰ V – A momentum spectrum used to extrapolate below p=1 GeV. We correct the value assuming B($D^0 \to K^-\pi^+$) = 0.042 ± 0.006 and B($D^{e+} \to D^0\pi^+$) = 0.6 $^+$ 0.15. The product branching fraction is B(B $\rightarrow D^{*+}X$)·B($D^{*+} \rightarrow \pi^{+}D^{0}$)·B($D^{0} \rightarrow K^{-}\pi^{+}$) - (68 \pm 15 \pm 9) \times 10⁻⁴. $\Gamma(D^*(2007)^0$ anything)/ Γ_{total} Γ_{24}/Γ DOCUMENT ID TECN COMMENT 51 GIBBONS 0.260±0.023±0.015 97B CLE2 e+e- → T(45) ⁵¹ GIBBONS 97B reports B($B \rightarrow D^*(2007)^0$ anything) 0.247 \pm 0.012 \pm 0.018 \pm 0.018 using CLEO measured D and D^* branching fractions. We rescale to our PDG 96 values of D and D^{\bullet} branching ratios. Our first error is their experiment's error and our second error is the systematic error from using our best value. $\Gamma(D_s^{\pm} \text{ anything})/\Gamma_{\text{total}}$ Γ_{25}/Γ DOCUMENT ID TECN COMMENT 0.100±0.025 OUR AVERAGE 0.117±0.009+0.028 -0.029 52 GIBAUT 96 CLE2 $e^+e^- \to T(45)$ $0.081 \pm 0.014 ^{+0.019}_{-0.020}$ 53 ALBRECHT 92G ARG e+e- → T(45) $0.085 \pm 0.013 ^{+0.020}_{-0.021}$ ⁵⁴ BORTOLETTO90 CLEO $e^+e^- \rightarrow T(45)$ $0.105 \pm 0.028 ^{+\, 0.025}_{-\, 0.026}$ 55 HAAS 86 CLEO $e^+e^- \rightarrow \Upsilon(4S)$ • • • We do not use the following data for averages, fits, limits, etc. • • • ⁵⁶ ALBRECHT 87H ARG $e^+e^- \rightarrow \Upsilon(45)$ $0.116 \pm 0.030 \pm 0.028$ ⁵² GIBAUT 96 reports 0.1211 \pm 0.0039 \pm 0.0088 for B($D_c^+ \to \phi \pi^+$) = 0.035. We rescale to our best value $B(D_s^+ \to \phi \pi^+) = (3.6 \pm 0.9) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value. ⁵³ ALBRECHT 92G reports [B(B \rightarrow D_s^{\pm} anything) \times B(D_s^{+} \rightarrow $\phi\pi^{+}$)] = 0.00292 \pm 0.0039 ± 0.0031 . We divide by our best value $B(D_+^+\to\phi\pi^+)=(3.6\pm0.9)\times10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value. ⁵⁴BORTOLETTO 90 reports [B($B \rightarrow D_s^{\pm}$ anything) \times B($D_s^{+} \rightarrow \phi \pi^{+}$)] = 0.00306 \pm 0.00047. We divide by our best value B($D_s^+ \rightarrow \phi \pi^+$) = (3.6 ± 0.9) × 10⁻². Our first error is their experiment's error and our second error is the systematic error from using ur best value. 55 HAAS 86 reports [B($B \rightarrow D_s^{\pm}$ anything) \times B($D_s^{+} \rightarrow \phi \pi^{+}$)] = 0.0038 \pm 0.0010. We divide by our best value B($D_s^{+} \rightarrow \phi \pi^{+}$) = (3.6 \pm 0.9) \times 10⁻². Our first error is their experiment's error and our second error is the systematic error from using our best value. $64 \pm 22\%$ decays are 2-body. ⁵⁶ ALBRECHT 87H reports $[B(B \rightarrow D_s^{\pm} \text{ anything}) \times B(D_s^{+} \rightarrow \phi \pi^{+})] = 0.0042 \pm 0.0042$ 0.0009 ± 0.0006 . We divide by our best value B($D_5^+ \rightarrow \phi \pi^+$) = $(3.6 \pm 0.9) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value. 46 \pm 16% of $B\to D_S$ X decays are 2-body. Superseded by ALBRECHT 92G. Γ_{26}/Γ $\Gamma(c\overline{c}s)/\Gamma_{total}$ DOCUMENT ID TECH COMMENT VALUE

$\Gamma(D_sD, D_s^*D, D_sD^*)$ Sum over modes.	or <i>E</i>	$(D_s^{\pm}D^{+})/\Gamma(D_s^{\pm})$ any	thin	g)		Γ_{27}/Γ_{2}
VALUE		DOCUMENT ID		TECN	COMMENT	
0.48 ±0.04 OUR AVE	RAGE	·				
0.457 ± 0.019 ± 0.037		GIBAUT	96	CLE2	e+e- →	T(45)
0.58 ±0.07 ±0.09		ALBRECHT	92G	ARG	e ⁺ e ⁻ →	T(45)
0.56 ±0.10		BORTOLETT	O90	CLEO	$e^+e^- \rightarrow$	T(45)
$\Gamma(D^*(2010)\gamma)/\Gamma_{\mathrm{total}}$	1					Γ ₂₆ /
VALUE	CLX	DOCUMENT ID		TECN	COMMENT	
<1.1 × 10 ⁻³	90	⁵⁸ LESIAK	92	CBAL	e+ e~ →	T(45)

$D_{-}(2536) \top D$ is the narrow P wave D_{-}' meson with $J'_{-} \equiv 1$.	Γ(X _{C2} (1P) anything) / Γ _{total} VALUE CLY, EVTS POCUMENT ID TECH COMMENT
$D_{S1}(2536)^+$ is the narrow P-wave D_S^+ meson with $J^P = 1^+$. ALUE CLY DOCUMENT ID TECH COMMENT	<0.0038 90 35 ⁷² BALEST 958 CLE2 $e^+e^- \rightarrow T(45)$
<0.0095 90 59 BISHAI 98 CLE2 e+e→ T(4S)	⁷² BALEST 95B assume B($\chi_{C2}(1P) \rightarrow J/\psi(1S)\gamma$) = (13.5 ± 1.1) × 10 ⁻² , the PDG 199
⁵⁹ Assuming factorization, the decay constant $f_{D_{+}^{+}}$ is at least a factor of 2.5 times smaller	value. $J/\psi(15)$ mesons are reconstructed in the e^+e^- and $\mu^+\mu^-$ modes, and PD
than $f_{D_3^+}$.	1994 branching fractions are used. If interpreted as signal, the 35 \pm 13 events correspond to B(B $\rightarrow x_{c2}(1P)X)$ =(0.25 \pm 0.10 \pm 0.03) \times 10 ⁻² .
$\Gamma(D_s^+\pi^-, D_s^{0+}\pi^-, D_s^+\rho^-, D_s^{0+}\rho^-, D_s^+\pi^0, D_s^{0+}\pi^0, D_s^+\eta, D_s^{0+}\eta, D_s^+\rho^0,$	$\Gamma(\eta_c(1S))$ anything $\Gamma(T_{total})$
	VALUE CL'S DOCUMENT ID TECN COMMENT
$D_s^{++} \rho^0$, $D_s^{++} \omega$, $D_s^{++} \omega$)/ Γ_{total} Γ_{29} / Γ_{total}	<0.009 90 73 BALEST 958 CLE2 $e^+e^- \rightarrow \Upsilon(45)$
VALUE CLY DOCUMENT ID TECN COMMENT	73 BALEST 95B assume PDG 1994 values for sub-mode branching ratios. $J/\psi(1S)$ meson
<0.0006 90 ⁶⁰ ALEXANDER 93B CLE2 $e^+e^- \rightarrow T(4S)$ ⁶⁰ ALEXANDER 93B reports < 4.8×10^{-4} for B($D_s^+ \rightarrow \phi \pi^+$) = 0.037. We rescale	are reconstructed in $J/\psi(15) \rightarrow e^+e^-$ and $J/\psi(15) \rightarrow \mu^+\mu^-$. Search region 2960 $< m_{\eta_c(15)} < 3010 \; {\rm MeV/}c^2$.
to our best value B($D_s^+ \rightarrow \phi \pi^+$) = 0.036. This branching ratio limit provides a model-dependent upper limit $ V_{UB} / V_{CB} $ < 0.16 at CL=90%.	Γ(K [±] anything)/Γ _{total} Γ ₃₆ /Γ
	VALUE DOCUMENT ID TECN COMMENT 0.789±0.025 OUR AVERAGE
	$0.82 \pm 0.01 \pm 0.05$ ALBRECHT 94c ARG $e^+e^- \rightarrow T(45)$
VALUE (units 10 ⁻²) EVTS DOCUMENT ID TECN COMMENT 1.13±0.06 OUR AVERAGE	$0.775 \pm 0.015 \pm 0.025$ 74 ALBRECHT 931 ARG $e^+e^- \rightarrow T(45)$
$1.11\pm0.05\pm0.04$ 1489 61 BALEST 95B CLE2 $e^+e^- \rightarrow \Upsilon(4S)$	0.85 $\pm 0.07 \pm 0.09$ ALAM 878 CLEO $e^{+}e^{-} \rightarrow \Upsilon(45)$
1.28±0.44±0.04 27 62 MASCHMANN 90 CBAL $e^+e^- \rightarrow T(4S)$	 ● We do not use the following data for averages, fits, limits, etc.
1.23 \pm 0.27 \pm 0.04 120 63 ALBRECHT 87D ARG $e^+e^- \rightarrow \Upsilon(4S)$	seen 75 BRODY 82 CLEO $e^+e^- \rightarrow T(45)$
$1.34 \pm 0.24 \pm 0.04$ 52 64 ALAM 86 CLEO $e^+e^- \rightarrow T(4S)$	seen 76 GIANNINI 82 CUSB $e^+e^- \rightarrow T(45)$
• • We do not use the following data for averages, fits, limits, etc. • •	⁷⁴ ALBRECHT 931 value is not independent of the sum of $B \rightarrow K^+$ anything and $B \rightarrow K^+$
1.4 $^{+0.6}_{-0.5}$ 7 65 ALBRECHT 85H ARG $e^+e^- \rightarrow \Upsilon(45)$	K [™] anything ALBRECHT 94c values.
1.1 ±0.21±0.23 46 66 HAAS 85 CLEO Repl. by ALAM 86	75 Assuming $T(4S) \rightarrow B\overline{B}$, a total of 3.38 \pm 0.34 \pm 0.68 kaons per $T(4S)$ decay is found (the second error is systematic). In the context of the standard B-decay model, this
61 BALEST 958 reports $1.12 \pm 0.04 \pm 0.06$ for B $(J/\psi(15) \rightarrow e^+e^-) = 0.0599 \pm 0.0025$.	leads to a value for $(b\text{-quark} \rightarrow c\text{-quark})/(b\text{-quark} \rightarrow all)$ of $1.09 \pm 0.33 \pm 0.13$.
We rescale to our best value B $(J/\psi(1S) \rightarrow e^+e^-) = (6.02 \pm 0.19) \times 10^{-2}$. Our	76 GIANNINI 82 at CESR-CUSB observed 1.58 \pm 0.35 K^0 per hadronic event much highe
first error is their experiment's error and our second error is the systematic error from using our best value. They measure $J/\psi(15) \rightarrow e^+e^-$ and $\mu^+\mu^-$ and use PDG 1994	than 0.82 \pm 0.10 below threshold. Consistent with predominant $b ightharpoonup c X$ decay.
values for the branching fractions. The rescaling is the same for either mode so we use	$\Gamma(K^+ \text{ anything})/\Gamma_{\text{total}}$ Γ_{39}/Γ_{39}
e^+e^- . 62 MASCHMANN 90 reports 1.12 ± 0.33 ± 0.25 for B($J/\psi(15) \rightarrow e^+e^-$) = 0.069 ± 0.009.	VALUE DOCUMENT ID TECH COMMENT
⁹² MASCHMANN 90 reports 1.12 ± 0.33 ± 0.25 for B(J/ψ(15) → e^+e^-) = 0.069 ± 0.009. We rescale to our best value B(J/ψ(15) → e^+e^-) = (6.02 ± 0.19) × 10 ⁻² . Our first	0.66 ±0.05 77 ALBRECHT 94c ARG $e^+e^- \rightarrow \Upsilon(4S)$
error is their experiment's error and our second error is the systematic error from using	 • • We do not use the following data for averages, fits, limits, etc. • •
our best value. 63 ALBRECHT 87D reports $1.07 \pm 0.16 \pm 0.22$ for B($J/\psi(15) \rightarrow e^+e^-$) = 0.069 ± 0.009 .	$0.620 \pm 0.013 \pm 0.038$ 78 ALBRECHT 94C ARG $e^+e^- \rightarrow T(45)$
⁹³ ALBRECHT 87D reports $1.07 \pm 0.16 \pm 0.22$ for B($J/\psi(15) \rightarrow e^+e^-$) = 0.069 ± 0.009 . We rescale to our best value B($J/\psi(1S) \rightarrow e^+e^-$) = $(6.02 \pm 0.19) \times 10^{-2}$. Our first	0.66 $\pm 0.05 \pm 0.07$ 78 ALAM 878 CLEO $e^+e^- \rightarrow \Upsilon(45)$
error is their experiment's error and our second error is the systematic error from using	77 Measurement relies on lepton-kaon correlations. It is for the weak decay vertex and doe
our best value. ALBRECHT 87D find the branching ratio for J/ψ not from $\psi(2S)$ to be	not include mixing of the neutral B meson. Mixing effects were corrected for by assuming
0.0081 ± 0.0023 . 64 ALAM 86 reports $1.09 \pm 0.16 \pm 0.21$ for B($J/\psi(15) \rightarrow \mu^+\mu^-$) = 0.074 ± 0.012 . We	a mixing parameter r of (18.1 \pm 4.3)%. 78 Measurement relies on lepton-kaon correlations. It includes production through mixin
rescale to our best value B($J/\psi(15) \rightarrow \mu^+\mu^-$) = (6.01 \pm 0.19) \times 10 ⁻² . Our first	of the neutral B meson.
error is their experiment's error and our second error is the systematic error from using	$\Gamma(K^-\text{anything})/\Gamma_{\text{total}}$ $\Gamma_{40}/\Gamma_{\text{total}}$
our best value. 65 Statistical and systematic errors were added in quadrature. ALBRECHT 85H also report	VALUE DOCUMENT ID TECH COMMENT
a CL = 90% limit of 0.007 for $B \rightarrow J/\psi(15) + X$ where $m_X < 1$ GeV.	0.13 \pm 0.04 79 ALBRECHT 94C ARG $e^+e^- \rightarrow T(45)$
66 Dimuon and dielectron events used.	
$\Gamma(J/\psi(1S))$ (direct) anything) Γ_{total} Γ_{32}/Γ	$0.165 \pm 0.011 \pm 0.036$ 80 ALBRECHT 94c ARG $e^+e^- \rightarrow T(45)$

VALUE DOCUMENT ID TECN COMMENT	0.19 $\pm 0.05 \pm 0.02$ 80 ALAM 878 CLEO $e^+e^- \rightarrow \Upsilon(45)$
0.0080 \pm 0.0008 67 BALEST 958 CLE2 $e^+e^- \rightarrow \Upsilon(45)$	$0.19 \pm 0.05 \pm 0.02$ ⁸⁰ ALAM 87B CLEO $e^+e^- \rightarrow \Upsilon(4S)$ 79 Measurement relies on lepton-kaon correlations. It is for the weak decay vertex and doe
0.0080 \pm 0.0008 67 BALEST 958 CLE2 $e^+e^- \rightarrow \Upsilon(4S)$ 67 BALEST 958 assume PDG 1994 values for sub mode branching ratios. $J/\psi(1S)$ mesons	0.19 ±0.05 ±0.02 ⁸⁰ ALAM 87B CLEO e ⁺ e ⁻ → T(4S) 79 Measurement relies on lepton-kaon correlations. It is for the weak decay vertex and doe not include mixing of the neutral B meson. Mixing effects were corrected for by assumin
0.0000 \pm 0.00000 \pm 0.00000 \pm 0.00000 \pm 0.000000 \pm 0.00000 \pm 0.00000 0000000000000000000000000000	0.19 ±0.05 ±0.02 ⁸⁰ ALAM 87B CLEO $e^+e^- \rightarrow r(45)$ 79 Measurement relies on lepton-kaon correlations. It is for the weak decay vertex and doe not include mixing of the neutral <i>B</i> meson. Mixing effects were corrected for by assumin a mixing parameter <i>r</i> of (18.1 ± 4.3)%. 80 Measurement relies on lepton-kaon correlations. It includes production through mixing
67 BALEST 958 CLE2 $e^+e^- \rightarrow \Upsilon(4S)$ 67 BALEST 958 assume PDG 1994 values for sub mode branching ratios. $J/\psi(1S)$ mesons are reconstructed in $J/\psi(1S) \rightarrow e^+e^-$ and $J/\psi(1S) \rightarrow \mu^+\mu^-$. The $B \rightarrow J/\psi(1S) X$ branching ratio contains $J/\psi(1S)$ mesons directly from B decays and also from feeddown through $\psi(2S) \rightarrow J/\psi(1S)$, $\chi_{-1}(1P) \rightarrow J/\psi(1S)$, or $\chi_{-2}(1P) \rightarrow J/\psi(1S)$. Using	0.19 ±0.05 ±0.02 80 ALAM 87B CLEO e ⁺ e ⁻ → r(45) 79 Measurement relies on lepton-kaon correlations. It is for the weak decay vertex and doe not include mixing of the neutral B meson. Mixing effects were corrected for by assumin a mixing parameter r of (18.1 ± 4.3)%. 80 Measurement relies on lepton-kaon correlations. It includes production through mixin of the neutral B meson.
0.0000 \pm 0.00000 \pm 0.00000 \pm 0.00000 \pm 0.000000 \pm 0.00000 \pm 0.00000 0000000000000000000000000000	0.19 ±0.05 ±0.02 ⁸⁰ ALAM 87B CLEO $e^+e^- \rightarrow r(45)$ 79 Measurement relies on lepton-kaon correlations. It is for the weak decay vertex and doe not include mixing of the neutral <i>B</i> meson. Mixing effects were corrected for by assumin a mixing parameter <i>r</i> of (18.1 ± 4.3)%. 80 Measurement relies on lepton-kaon correlations. It includes production through mixing
67 BALEST 958 CLE2 $e^+e^- \rightarrow \Upsilon(4S)$ 67 BALEST 958 assume PDG 1994 values for sub mode branching ratios. $J/\psi(1S)$ mesons are reconstructed in $J/\psi(1S) \rightarrow e^+e^-$ and $J/\psi(1S) \rightarrow \mu^+\mu^-$. The $B \rightarrow J/\psi(1S)$ branching ratio contains $J/\psi(1S)$ mesons directly from B decays and also from feeddown through $\psi(2S) \rightarrow J/\psi(1S)$, $\chi_{-1}(1P) \rightarrow J/\psi(1S)$, or $\chi_{-2}(1P) \rightarrow J/\psi(1S)$. Using the measured inclusive rates, BALEST 958 corrects for the feeddown and finds the $B \rightarrow J/\psi(1S)$ (direct) X branching ratio.	0.19 \pm 0.05 \pm 0.02 80 ALAM 878 CLEO $e^+e^- \rightarrow r(45)$ 79 Measurement relies on lepton-kaon correlations. It is for the weak decay vertex and doe not include mixing of the neutral B meson. Mixing effects were corrected for by assumin a mixing parameter r of $(18.1 \pm 4.3)\%$. 80 Measurement relies on lepton-kaon correlations. It includes production through mixin of the neutral B meson. $\Gamma(K^0/K^0 \text{ anything})/\Gamma_{\text{total}}$ 741/1
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67 BALEST 95B CLE2 $e^+e^- \rightarrow T(4S)$ 67 BALEST 95B CLE2 $e^+e^- \rightarrow T(4S)$ 67 BALEST 95B assume PDG 1994 values for sub mode branching ratios. $J/\psi(1S)$ mesons are reconstructed in $J/\psi(1S) \rightarrow e^+e^-$ and $J/\psi(1S) \rightarrow \mu^+\mu^-$. The $B \rightarrow J/\psi(1S)$ branching ratio contains $J/\psi(1S)$ mesons directly from B decays and also from feeddown through $\psi(2S) \rightarrow J/\psi(1S)$, $\chi_{11}(P) \rightarrow J/\psi(1S)$, or $\chi_{C2}(P) \rightarrow J/\psi(1S)$. Using the measured inclusive rates, BALEST 95B corrects for the feeddown and finds the $B \rightarrow J/\psi(1S)$ (direct) X branching ratio. $\Gamma(\psi(2S) \text{ anything})/\Gamma_{\text{total}}$ $\chi_{AUE} \qquad EVTS \qquad DOCUMENT ID \qquad TECN \qquad COMMENT$ 0.0003± ±0.0004 ±0.0003 240 68 BALEST 95B CLE2 $e^+e^- \rightarrow T(4S)$ 0.004± 0.0017±0.0011 8 ALBRECHT 87D ARG $e^+e^- \rightarrow T(4S)$ 68 BALEST 95B assume PDG 1994 values for sub mode branching ratios. They find $B(B \rightarrow \psi(2S)X)$, $\psi(2S) \rightarrow J/\psi(1S) \pi^+\pi^-) = 0.37 \pm 0.05 \pm 0.05$ weighted average is quoted for $B(B \rightarrow \psi(2S)X)$. $\Gamma(\chi_{c1}(1P) \text{ anything})/\Gamma_{\text{total}}$ VALUE $EVTS$ $DOCUMENT ID \qquad TECN \qquad COMMENT$	0.19 ±0.05 ±0.02 80 ALAM 87B CLEO $e^+e^- \rightarrow r(45)$ 79 Measurement relies on lepton-kaon correlations. It is for the weak decay vertex and doe not include mixing of the neutral B meson. Mixing effects were corrected for by assumin a mixing parameter r of (18.1 ± 4.3)%. 80 Measurement relies on lepton-kaon correlations. It includes production through mixin of the neutral B meson. $\Gamma(K^0/\overline{K^0} \text{ anything})/\Gamma_{\text{total}}$ VALUE 0.64 ±0.04 OUR AVERAGE 0.642 ±0.010 ±0.042 81 ALBRECHT 94C ARG $e^+e^- \rightarrow T(45)$ 0.63 ±0.06 ±0.06 ALAM 87B CLEO $e^+e^- \rightarrow T(45)$ 81 ALBRECHT 94C assume a $K^0/\overline{K^0}$ multiplicity twice that of K_5^0 . $\Gamma(K^*(892)^{\pm} \text{ anything})/\Gamma_{\text{total}}$ MALUE 0.182 ±0.064 ±0.024 ALBRECHT 94J ARG $e^+e^- \rightarrow T(45)$ 0.182 ±0.064 ±0.024 ALBRECHT 94J ARG $e^+e^- \rightarrow T(45)$
67 BALEST 958 CLE2 $e^+e^- \rightarrow T(4S)$ 67 BALEST 958 CLE2 $e^+e^- \rightarrow T(4S)$ 67 BALEST 958 assume PDG 1994 values for sub mode branching ratios. $J/\psi(15)$ mesons are reconstructed in $J/\psi(15) \rightarrow e^+e^-$ and $J/\psi(15) \rightarrow \mu^+\mu^-$. The $B \rightarrow J/\psi(15)$ branching ratio contains $J/\psi(15)$ mesons directly from B decays and also from feeddown through $\psi(25) \rightarrow J/\psi(15)$, $\chi_{c1}(1P) \rightarrow J/\psi(15)$, or $\chi_{c2}(1P) \rightarrow J/\psi(15)$. Using the measured inclusive rates, BALEST 958 corrects for the feeddown and finds the $B \rightarrow J/\psi(1S)$ (direct) X branching ratio. F($\psi(25)$ anything)/ Γ_{total} FYTS 0.0034 \pm 0.0005 OUR AVERAGE 0.0034 \pm 0.0004 \pm 0.0003 240 68 BALEST 958 CLE2 $e^+e^- \rightarrow T(4S)$ 0.0046 \pm 0.0017 \pm 0.0011 8 ALBRECHT 870 ARG $e^+e^- \rightarrow T(4S)$ 68 BALEST 958 assume PDG 1994 values for sub mode branching ratios. They find $B(B \rightarrow \psi(25)X, \psi(25) \rightarrow J/\psi(15) \pi^+\pi^-) = 0.37 \pm 0.05 \pm 0.05$ weighted average is quoted for $B(B \rightarrow \psi(25)X, \psi(25) \rightarrow J/\psi(15) \pi^+\pi^-) = 0.37 \pm 0.05 \pm 0.05$. Weighted average is quoted for $B(B \rightarrow \psi(25)X)$. F($\chi_{c1}(1P)$ anything)/ Γ_{total} FYTS DOCUMENT ID TECN COMMENT 134/ Γ 134/ Γ 134/ Γ 134/ Γ 134/ Γ 134/ Γ	0.19 ±0.05 ±0.02 80 ALAM 87B CLEO $e^+e^- \rightarrow r(4S)$ 79 Measurement relies on lepton-kaon correlations. It is for the weak decay vertex and doe not include mixing of the neutral B meson. Mixing effects were corrected for by assumin a mixing parameter r of $(18.1 \pm 4.3)\%$. 80 Measurement relies on lepton-kaon correlations. It includes production through mixin of the neutral B meson. $\Gamma(K^0/K^0 \text{ anything})/\Gamma_{\text{total}}$ 741/1 741/1 742/1 743/1 744/1 744/1 745/1 746/1
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67 BALEST 958 CLE2 $e^+e^- \rightarrow T(4S)$ 67 BALEST 958 CLE2 $e^+e^- \rightarrow T(4S)$ 67 BALEST 958 assume PDG 1994 values for sub mode branching ratios. $J/\psi(1S)$ mesons are reconstructed in $J/\psi(1S) \rightarrow e^+e^-$ and $J/\psi(1S) \rightarrow \mu^+\mu^-$. The $B \rightarrow J/\psi(1S)$ branching ratio contains $J/\psi(1S)$ mesons directly from B decays and also from feeddown through $\psi(2S) \rightarrow J/\psi(1S)$, $\chi_{c1}(1P) \rightarrow J/\psi(1S)$, or $\chi_{c2}(1P) \rightarrow J/\psi(1S)$. Using the measured inclusive rates, BALEST 958 corrects for the feeddown and finds the $B \rightarrow J/\psi(1S)$ (direct) X branching ratio. $\Gamma(\psi(2S) \text{ anything})/\Gamma_{\text{total}}$ $VALUE$ $EVTS$ $DOCUMENT ID$ $TECN$ $0.0034 \pm 0.0004 \pm 0.0003$ 240 68 $BALEST 958 CLE2 e^+e^- \rightarrow T(4S) 0.0046 \pm 0.0017 \pm 0.0011 8 ALBRECHT 870 ARG e^+e^- \rightarrow T(4S) 68 BALEST 958 assume PDG 1994 values for sub mode branching ratios. They find B(B \rightarrow \psi(2S)X, \psi(2S) \rightarrow J/\psi(1S) \pi^+\pi^-) = 0.37 \pm 0.05 \pm 0.05. Weighted average is quoted for B(B \rightarrow \psi(2S)X). \Gamma(X_{c1}(1P) \text{ anything})/\Gamma_{\text{total}} VALUE EVTS 0.00042 \pm 0.0007 \text{ CUR AVERAGE} 0.0040 \pm 0.0007 CUR A$	0.19 ±0.05 ±0.02 80 ALAM 87B CLEO e ⁺ e ⁻ → T(45) 79 Measurement relies on lepton-kaon correlations. It is for the weak decay vertex and doe not include mixing of the neutral B meson. Mixing effects were corrected for by assumin a mixing parameter r of (18.1 ± 4.3)%. 80 Measurement relies on lepton-kaon correlations. It includes production through mixin of the neutral B meson. Γ(K ⁰ /K ⁰ anything)/Γ _{total} MALUE DOCUMENT ID TECN COMMENT 1 (45) 81 ALBRECHT 94C ARG e ⁺ e ⁻ → T(45) 81 ALBRECHT 94C assume a K ⁰ /K ⁰ multiplicity twice that of K ⁰ _S . Γ(K*(892)± anything)/Γ _{total} MALUE DOCUMENT ID TECN COMMENT 1 (42) MALUE DOCUMENT ID TECN COMMENT 1 (45) F(K*(892) ⁰ /K*(892) ⁰ anything)/Γ _{total} MALUE DOCUMENT ID TECN COMMENT T42/ MALUE DOCUMENT ID TECN COMMENT F43/ MALUE DOCUMENT ID TECN COMMENT TECN COMMENT F44/ MALUE DOCUMENT ID TECN COMMENT TECN COMMENT F44/ MALUE DOCUMENT ID TECN COMMENT T45/ F44/ MALUE DOCUMENT ID TECN COMMENT T45/ T44/ MALUE DOCUMENT ID TECN COMMENT T45/ T46/ T47/ T45/ T46/ T46/ T47/ T4
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67 BALEST 95B CLE2 $e^+e^- \rightarrow T(4S)$ 67 BALEST 95B assume PDG 1994 values for sub mode branching ratios. $J/\psi(15)$ mesons are reconstructed in $J/\psi(15) \rightarrow e^+e^-$ and $J/\psi(15) \rightarrow \mu^+\mu^-$. The $B \rightarrow J/\psi(15)$ branching ratio contains $J/\psi(15)$ mesons decays and also from feeddown through $\psi(25) \rightarrow J/\psi(15)$, $\chi_{c1}(1P) \rightarrow J/\psi(15)$, or $\chi_{c2}(1P) \rightarrow J/\psi(15)$. Using the measured inclusive rates. BALEST 95B corrects for the feeddown and finds the $B \rightarrow J/\psi(15)$ (direct) X branching ratio. $\Gamma(\psi(25) \text{ anything})/\Gamma_{\text{total}}$ VALUE EVTS 0.0034±0.0005 OUR AVERAGE 0.0034±0.0005 OUR AVERAGE 0.0034±0.0001 8 ALBRECHT 87D ARG $e^+e^- \rightarrow T(4S)$ 0.0046±0.0017±0.0011 8 ALBRECHT 87D ARG $e^+e^- \rightarrow T(4S)$ 68 BALEST 95B assume PDG 1994 values for sub mode branching ratios. They find $B(B \rightarrow \psi(25)X, \psi(2S) \rightarrow J/\psi(15) \pi^+\pi^-) = 0.37 \pm 0.05 \pm 0.05$. Weighted average is quoted for $B(B \rightarrow \psi(25)X)$. $\Gamma(\chi_{c1}(1P) \text{ anything})/\Gamma_{\text{total}}$ VALUE 0.0040±0.0007 OUR AVERAGE 0.0040±0.0006±0.0004 112 69 BALEST 95B CLE2 $e^+e^- \rightarrow T(4S)$ 0.0105±0.0035±0.0025 70 ALBRECHT 92E ARG $e^+e^- \rightarrow T(4S)$ 0.0105±0.0035±0.0025 70 ALBRECHT 92E ARG $e^+e^- \rightarrow T(4S)$ 0.0106±0.007+0.0006+0.0006 112 69 BALEST 95B assume B($\chi_{c1}(1P) \rightarrow J/\psi(15) \gamma$) = (27.3 ± 1.6) × 10 ⁻² , the PDG 1994 value. Fit to ψ -photon invariant mass distribution allows for a $\chi_{c1}(1P)$ and a $\chi_{c2}(1P)$ component. 70 ALBRECHT 92E assumes no $\chi_{c2}(1P)$ production.	0.19 ±0.05 ±0.02 80 ALAM 87B CLEO $e^+e^- \rightarrow r(45)$ 79 Measurement relies on lepton-kaon correlations. It is for the weak decay vertex and doe not include mixing of the neutral B meson. Mixing effects were corrected for by assumin a mixing parameter r of (18.1 ± 4.3)%. 80 Measurement relies on lepton-kaon correlations. It includes production through mixin of the neutral B meson. $\Gamma(K^0/K^0 \text{ anything})/\Gamma_{\text{total}} \qquad \Gamma_{\text{41}}/\Gamma_{\text{MAUE}} \qquad \Gamma_{\text{42}}/\Gamma_{\text{42}}/\Gamma_{\text{42}} \qquad \Gamma_{\text{43}}/\Gamma_{\text{44}}/\Gamma_{\text{43}}/\Gamma_{\text{44}}/\Gamma_{$
67 BALEST 95B CLE2 $e^+e^- \rightarrow T(4S)$ 67 BALEST 95B CLE2 $e^+e^- \rightarrow T(4S)$ 67 BALEST 95B assume PDG 1994 values for sub mode branching ratios. $J/\psi(15)$ mesons are reconstructed in $J/\psi(15) \rightarrow e^+e^-$ and $J/\psi(15) \rightarrow \mu^+\mu^-$. The $B \rightarrow J/\psi(15)$ branching ratio contains $J/\psi(15)$ mesons directly from B decays and also from feeddown through $\psi(2S) \rightarrow J/\psi(1S)$, $X_{c1}(1P) \rightarrow J/\psi(1S)$, or $X_{c2}(1P) \rightarrow J/\psi(1S)$. Using the measured inclusive rates, BALEST 95B corrects for the feeddown and finds the $B \rightarrow J/\psi(1S)$ (direct) X branching ratio. $\Gamma(\psi(2S) \text{ anything})/\Gamma_{\text{total}}$ $VALUE \qquad EVTS \qquad DOCUMENT ID \qquad TECN \qquad COMMENT$ 0.0038±0.0005 OUR AVERAGE 0.0034±0.0004±0.0003 240 68 BALEST 95B CLE2 $e^+e^- \rightarrow T(4S)$ 0.0034±0.0004±0.0001 8 ALBRECHT 87D ARG $e^+e^- \rightarrow T(4S)$ 68 BALEST 95B assume PDG 1994 values for sub mode branching ratios. They find B($B \rightarrow \psi(2S)X$), $\psi(2S) \rightarrow J/\psi(1S) \pi^+\pi^-) = 0.37 \pm 0.05 \pm 0.05$. Weighted average is quoted for B($B \rightarrow \psi(2S)X$). $\Gamma(X_{c1}(1P) \text{ anything})/\Gamma_{\text{total}}$ VALUE $VALUE$	0.19 ±0.05 ±0.02 80 ALAM 87B CLEO e ⁺ e ⁻ → T(45) 79 Measurement relies on lepton-kaon correlations. It is for the weak decay vertex and doe not include mixing of the neutral B meson. Mixing effects were corrected for by assumin a mixing parameter r of (18.1 ± 4.3)%. 80 Measurement relies on lepton-kaon correlations. It includes production through mixin of the neutral B meson. Γ(K ⁰ /K ⁰ anything)/Γ _{total} MALUE 0.64 ±0.04 OUR AVERAGE 0.642±0.010±0.042 81 ALBRECHT 94C ARG e ⁺ e ⁻ → T(45) 81 ALBRECHT 94C assume a K ⁰ /K ⁰ multiplicity twice that of K ⁰ /S. Γ(K*(892)± anything)/Γ _{total} MALUE 0.182±0.084±0.024 ALBRECHT 94J ARG e ⁺ e ⁻ → T(45) Γ(K*(892) ⁰ /K*(892) ⁰ anything)/Γ _{total} Γ(K*(892) ⁰ /K*(892) ⁰ anything)/Γ _{total} Γ(K*(892) ⁰ /F _{total} Γ(K*(892) ⁰ /F _{total} Γ(K*(892) ⁰ /F _{total} Λ(F) Γ(F)
67 BALEST 958 CLE2 $e^+e^- \rightarrow T(4S)$ 67 BALEST 958 CLE2 $e^+e^- \rightarrow T(4S)$ 67 BALEST 958 assume PDG 1994 values for sub mode branching ratios. $J/\psi(15)$ mesons are reconstructed in $J/\psi(15) \rightarrow e^+e^-$ and $J/\psi(15) \rightarrow \mu^+\mu^-$. The $B \rightarrow J/\psi(15)$ branching ratio contains $J/\psi(15)$ mesons directly from B decays and also from feeddown through $\psi(25) \rightarrow J/\psi(15)$, $\chi_{c1}(1P) \rightarrow J/\psi(1S)$, or $\chi_{c2}(1P) \rightarrow J/\psi(1S)$. Using the measured inclusive rates, BALEST 958 corrects for the feeddown and finds the $B \rightarrow J/\psi(1S)$ (direct) X branching ratio. $\Gamma(\psi(2S) \text{ anything})/\Gamma_{\text{total}}$ $VALUE \qquad EVTS \qquad DOCUMENT ID \qquad TECN \qquad COMMENT$ 0.0035±0.0005 OUR AVERAGE 0.0034±0.0004±0.0003 240 68 BALEST 958 CLE2 $e^+e^- \rightarrow T(4S)$ 0.0046±0.0017±0.0011 8 ALBRECHT 870 ARG $e^+e^- \rightarrow T(4S)$ 68 BALEST 958 assume PDG 1994 values for sub mode branching ratios. They find $B(B \rightarrow \psi(2S)X)$, $\psi(2S) \rightarrow J/\psi(1S) \pi^+\pi^-) = 0.37 \pm 0.05 \pm 0.05$ weighted average is quoted for $B(B \rightarrow \psi(2S)X)$. $\Gamma(\chi_{c1}(1P) \text{ anything})/\Gamma_{\text{total}}$ $VALUE \qquad EVTS \qquad DOCUMENT ID \qquad TECN \qquad COMMENT$ 0.0042±0.0007 OUR AVERAGE 0.0040±0.0006±0.0004 112 69 BALEST 958 CLE2 $e^+e^- \rightarrow T(4S)$ 0.0105±0.0035±0.0025 70 ALBRECHT 92E ARG $e^+e^- \rightarrow T(4S)$ 0.0105±0.0035±0.0005 70 ALBRECHT 92E ARG $e^+e^- \rightarrow T(4S)$ 0.0105±0.0001 10 ALBRECHT 92E ARG $e^+e^- \rightarrow T(4S)$	0.19 ±0.05 ±0.02 80 ALAM 87B CLEO $e^+e^- \rightarrow r(45)$ 79 Measurement relies on lepton-kaon correlations. It is for the weak decay vertex and doe not include mixing of the neutral B meson. Mixing effects were corrected for by assumin a mixing parameter r of (18.1 ± 4.3)%. 80 Measurement relies on lepton-kaon correlations. It includes production through mixin of the neutral B meson. $\Gamma(K^0/K^0 \text{ anything})/\Gamma_{\text{total}}$ $\frac{r_{41}}{r_{41}} = \frac{r_{41}}{r_{41}} = \frac{r_{41}}{r$
67 BALEST 95B CLE2 $e^+e^- \rightarrow T(4S)$ 67 BALEST 95B assume PDG 1994 values for sub mode branching ratios. $J/\psi(15)$ mesons are reconstructed in $J/\psi(15) \rightarrow e^+e^-$ and $J/\psi(15) \rightarrow \mu^+\mu^-$. The $B \rightarrow J/\psi(15)$ branching ratio contains $J/\psi(15)$ mesons decays and also from feeddown through $\psi(2S) \rightarrow J/\psi(1S)$, $\chi_{c1}(1P) \rightarrow J/\psi(1S)$, or $\chi_{c2}(1P) \rightarrow J/\psi(1S)$. Using the measured inclusive rates, BALEST 95B corrects for the feeddown and finds the $B \rightarrow J/\psi(1S)$ (direct) X branching ratio. $\Gamma(\psi(2S) \text{ anything})/\Gamma_{\text{total}}$ $VALUE \qquad EVTS \qquad DOCUMENT ID \qquad TECN \qquad COMMENT$ $0.0038 \pm 0.0005 \text{ OUR AVERAGE}$ $0.0034 \pm 0.0004 \pm 0.0003 \qquad 240 \qquad 68 \text{ BALEST} \qquad 95B \text{ CLE2 } e^+e^- \rightarrow T(4S)$ $0.0034 \pm 0.0004 \pm 0.0001 \qquad 8 \qquad \text{ALBRECHT} \qquad 870 \text{ ARG} \qquad e^+e^- \rightarrow T(4S)$ $68 \text{ BALEST 95B assume PDG 1994 values for sub mode branching ratios. They find B(B \rightarrow \psi(2S)X), \psi(2S) \rightarrow J/\psi(1S) \pi^+\pi^-) = 0.37 \pm 0.05 \pm 0.05. Weighted average is quoted for B(B \rightarrow \psi(2S)X). \Gamma(\chi_{c1}(1P) \text{ anything})/\Gamma_{\text{total}} VALUE \qquad DOCUMENT ID \qquad TECN \qquad COMMENT 0.00042 \pm 0.0006 \pm 0.0004 \qquad 112 \qquad 69 \text{ BALEST} \qquad 95B \text{ CLE2 } e^+e^- \rightarrow T(4S) 0.00042 \pm 0.0006 \pm 0.0004 \qquad 112 \qquad 69 \text{ BALEST} \qquad 95B \text{ CLE2 } e^+e^- \rightarrow T(4S) 0.00042 \pm 0.0006 \pm 0.0004 \qquad 112 \qquad 69 \text{ BALEST} \qquad 95B \text{ CLE2 } e^+e^- \rightarrow T(4S) 0.0105 \pm 0.0035 \pm 0.0025 \qquad 70 \text{ ALBRECHT} \qquad 92E \text{ ARG} \qquad e^+e^- \rightarrow T(4S) 0.0105 \pm 0.0035 \pm 0.0025 \qquad 70 \text{ ALBRECHT} \qquad 92E \text{ ARG} \qquad e^+e^- \rightarrow T(4S) 0.0105 \pm 0.0035 \pm 0.0025 \qquad 70 \text{ ALBRECHT} \qquad 92E \text{ ARG} \qquad e^+e^- \rightarrow T(4S) 0.0105 \pm 0.0035 \pm 0.0005 \qquad 170 \text{ ALBRECHT} \qquad 92E \text{ ARG} \qquad e^+e^- \rightarrow T(4S) 0.0105 \pm 0.0035 \pm 0.0005 \qquad 170 \text{ ALBRECHT} \qquad 190 \text{ AUDE} 0.0007 \text{ Poton invariant mass distribution allows for a } \chi_{c1}(1P) \text{ and a } \chi_{c2}(1P) 0.0007 \text{ ALBRECHT in other invariant mass distribution.} \Gamma(\chi_{c1}(1P) \text{ (direct) anything})/\Gamma_{\text{total}} \qquad 190 \text{ (Direct)} 0.0007 \text{ Poton invariant mass distribution.} 71 \text{ BALEST 95B assume PDG 1994 values.} 71 \text{ BALEST 95B assume reconstructed in the } e^+e^- \text{ and } \mu^+\mu^- \text{ modes.} $	10.19 \pm 0.05 \pm 0.02 10.19 \pm 0.05 \pm 0.06 10.19 \pm 0.06 10.19 \pm 0.07 \pm 0.06 10.19 \pm 0.07 \pm 0.
0.0080±0.0008 67 BALEST 958 CLE2 $e^+e^- \rightarrow T(4S)$ 67 BALEST 958 CLE2 $e^+e^- \rightarrow T(4S)$ 68 BALEST 958 SALEST 958 SALES	0.19 ±0.05 ±0.02 80 ALAM 87B CLEO $e^+e^- \rightarrow T(45)$ 79 Measurement relies on lepton-kaon correlations. It is for the weak decay vertex and do not include mixing of the neutral B meson. Mixing effects were corrected for by assumin a mixing parameter r of (18.1 ± 4.3)%. 80 Measurement relies on lepton-kaon correlations. It includes production through mixing of the neutral B meson. $\Gamma(K^0/K^0 \text{ anything})/\Gamma_{\text{total}}$ 741/ 742/ 742/ 743/ 743/ 743/ 744/ 745

B^{\pm}/B^{0} ADMIXTURE

$\Gamma(K_1(1400)\gamma)/\Gamma_{\text{total}}$	<u> </u>	DOCUMENT ID	TECN	COMMENT	Γ ₄₅ /Γ	Γ(Λ _c anything)/Γ(Λ _c anything) VALUE DOCUMENT ID TECH. COMMENT
<4.1 × 10 ⁻⁴ • • • We do not use the	90	ALBRECHT	88H ARG	e+ e~ →	Y(45)	0.19±0.13±0.04 92 AMMAR 97 CLE2 $e^+e^- \rightarrow \Upsilon(45)$ 92 AMMAR 97 uses a high-momentum lepton tag $(P_f > 1.4 \text{ GeV}/c^2)$.
<1.6 × 10 ⁻³	90	83 LESIAK		e+e	T(45)	• •
83 LESIAK 92 set a Ilm for the range of mas						$\Gamma(\Lambda_c^-e^+\text{anything})/\Gamma(\Lambda_c^\pm\text{anything})$ VALUE CLY DOCUMENT ID TECH COMMENT
hadronization. $\Gamma(K_2^*(1430)\gamma)/\Gamma_{\text{total}}$					Γ ₄₆ /Γ	<0.06 90 93 BONVICINI 98 CLE2 $e^+e^- \rightarrow \Upsilon(45)$ 93 BONVICINI 98 uses the electron with momentum above 0.6 GeV/c.
VALUE	<u> </u>	DOCUMENT ID	7ECN 88H ARG	<u>COMMENT</u> e+e- →		$\Gamma(\Lambda_c^- p_{anything})/\Gamma(\Lambda_c^{\pm} anything)$
	70	ALDRECHI	BON ANG	e • e →		$\begin{array}{cccccccccccccccccccccccccccccccccccc$
Γ(<i>K</i> ₂ (1770)γ)/Γ _{total}	- <i>CT 2</i>	DOCUMENT ID		COMMENT	Г ₄₇ /Г 	0.57±0.06±0.06 BONVICINI 98 CLE2 $e^+e^- \rightarrow \tau(45)$ $\Gamma(\Lambda_c^- p e^+ \nu_e)/\Gamma(\Lambda_c^- p \text{anything})$ Γ_{62}/Γ_{62}
<1.2 × 10 ⁻³	90	84 LESIAK		. e+e- ⊶		VALUE CLY DOCUMENT ID TECH COMMENT
84 LESIAK 92 set a lim for the range of mas hadronization.						<0.04 90 9^4 BONVICINI 98 CLE2 $e^+e^- \rightarrow T(45)$ 9^4 BONVICINI 98 uses the electron with momentum above 0.6 GeV/c.
Γ(K *(1780)γ)/Γ _{total}	l				Γ ₄₈ /Γ	r(\(\mathbb{E}_{c}^{}\) anything)/r _{botal} value
<3.0 × 10 ⁻³	90 - <u>CLX</u>	DOCUMENT ID ALBRECHT		c+e- →	T(45)	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
				'		95 PROCARIO 94 reports $[B(B \to \overline{\Sigma}_c^- \text{ anything}) \times B(\Lambda_c^+ \to \rho K^- \pi^+)] = 0.0002$
$\Gamma(K_4^*(2045)\gamma)/\Gamma_{\text{total}}$	Ι _ <u>cι x</u> _	DOCUMENT ID	TECH	COMMENT	Γ ₄₉ /Γ	0.00008 \pm 0.00007. We divide by our best value B($\Lambda_c^+ \to \rho K^- \pi^+$) = (5.0 \pm 1.
<1.0 × 10 ⁻³	90	85 LESIAK	92 CBAL	e+e- →	` '	10^{-2} . Our first error is their experiment's error and our second error is the system error from using our best value.
85 LESIAK 92 set a lim for the range of mas hadronization.						(E_anything)/Fotal VALUE SLY DOCUMENT ID TECH COMMENT
$\Gamma(\overline{b} o \overline{s}\gamma)/\Gamma_{ ext{total}}$					Γ ₅₀ /Γ	<0.010 90 96 PROCARIO 94 CLE2 $e^+e^- \rightarrow r(45)$
VALUE.		DOCUMENT ID	TECN	COMMENT		⁹⁶ PROCARIO 94 reports $[B(B \to \overline{\Sigma}_c^- \text{ anything}) \times B(\Lambda_c^+ \to pK^-\pi^+)] = < 0.00$
(2.32±0.57±0.35) × 10		ALAM	95 CLE2	e+e- →	T(45)	We divide by our best value B($\Lambda_c^+ \rightarrow pK^-\pi^+$) = 0.050.
$\lceil (b \rightarrow 3 \text{gluon}) / \Gamma_{\text{total}} \rceil$					Γ ₅₁ /Γ	$\Gamma(\Sigma_c^0)$ anything Γ_{total} Γ_6
<u> </u>	EVTS	B6 COAN		$e^+e^- \rightarrow$	7/45)	VALUE EVTS DOCUMENT ID TECH COMMENT
• • We do not use the	e followin				, (43)	0.0046±0.0021±0.0012 76 97 PROCARIO 94 CLE2 e^+e^- → $T(4S)$
<0.08	2	87 ALBRECHT	050 485			⁹⁷ PROCARIO 94 reports [B(B $\rightarrow \overline{\Gamma}_c^0$ anything) \times B($\Lambda_c^+ \rightarrow pK^-\pi^+$)] = 0.0002
86 COAN 98 uses D-1 c	orrelation		75U ARG	e+ e- →	T(4S)	0.00008 \pm 0.00007. We divide by our best value B($\Lambda_c^+ \to \rho K^- \pi^+$) = (5.0 \pm 1.
86 COAN 98 uses D-l c 87 ALBRECHT 95D use for charmless B deca If interpreted as b — quoted above. Result	e full reco ny can be • sgluon	i. Instruction of one Interpreted as elf they find a branc	B decay as ther $b \rightarrow s_1$ thing ratio of	tag. Two ca gluon or b →	ndidate events u transition.	10 ⁻² . Our first error is their experiment's error and our second error is the system error from using our best value. \[\tilde{\mathbb{C}}_{\mathbb{C}} \mathbb{N} (\mathbb{N} = \mathbb{p} \text{ or } n) \) / \(\Gamma_{\mathbb{O}} / \Gamma_{\mathbb{O}} \)
87 ALBRECHT 95D use for charmless B deca If Interpreted as b → quoted above. Result	e full reco sy can be sgluon t Is highly	i. Instruction of one Interpreted as elf they find a branc	B decay as ther $b \rightarrow s_1$ thing ratio of	tag. Two ca gluon or b →	ndidate events u transition.	10 ⁻² . Our first error is their experiment's error and our second error is the system error from using our best value.
ar ALBRECHT 95D use for charmless B deca if interpreted as b → quoted above. Result \[\((\pi^\pm \) \text{anything} \) \(\psi \) \(\	e full reco sy can be sgluon t Is highly	n. Instruction of one Interpreted as eli they find a brand In model dependen In DOCUMENT ID	B decay as ther b → sp thing ratio of t. TECN	tag. Two ca gluon or b → ' ~ 0.026 or t	ndidate events u transition. the upper limit	10 ⁻² . Our first error is their experiment's error and our second error is the system error from using our best value. $\Gamma(\Sigma_{C}^{c}N(N=p \text{ or } n))/\Gamma_{\text{total}}$ VALUE 20.0015 90 98 PROCARIO 94 CLE2 $e^{+}e^{-} \rightarrow T(45)$
87 ALBRECHT 95D use for charmless B deca If Interpreted as b — quoted above. Result [(π ± anything) / Γ toob VALUE 88 ALBRECHT 93 excli	e full reco	n. Instruction of one Interpreted as elf they find a branc In model dependen DOCUMENT ID 88 ALBRECHT	B decay as ther b → sphing ratio of t. TECN 931 ARG	tag. Two capuon or $b \rightarrow 0.026$ or 1 $comment$ $e^+e^- \rightarrow$	ndidate events u transition. the upper limit F ₅₂ /Γ T(45)	10 ⁻² . Our first error is their experiment's error and our second error is the system error from using our best value. $\Gamma(\frac{\mathbf{T}_{C}^{0}N(N=\rho \text{ or } n))/\Gamma_{\text{total}}}{\text{VALUE}} \qquad \qquad \Gamma_{\mathbf{S}^{0}} \qquad \qquad \Gamma_{\mathbf{S}^$
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87 ALBRECHT 950 use for charmless B deca for charmless B deca for charmless B deca for charmless A beau quoted above. Result [(π± anything) / Γ total (π anyth	e full recca ay can be • s gluon t is highly al udes π± udes π± (FRAGE	nstruction of one interpreted as elit they find a branc model dependen model depe	B decay as ther b → s y hing ratio of t. 931 ARG decays. If is 1 TECN 96 CLE2 TECN 94J ARG TECN 94J ARG 1 TEC	tag. Two ca gluon or $b \rightarrow -$ ~ 0.026 or $t \rightarrow -$ ~ 0.026 or	T(4S)	10 ⁻² . Our first error is their experiment's error and our second error is the system error from using our best value. $\Gamma(\Sigma_{C}^{0}N(N=\rho \text{ or }n))/\Gamma_{\text{total}}$ $\frac{VALUE}{CLN} = \frac{CLN}{90} = \frac{DOCUMENT\ ID}{98\ PROCARIO} = \frac{TECN}{94\ CLE2} = \frac{e^{+}e^{-} \rightarrow T(45)}{e^{+}e^{-} \rightarrow T(45)}$ 98 PROCARIO 94 reports < 0.0017 for $B(\Lambda_{c}^{+} \rightarrow pK^{-}\pi^{+}) = 0.043$. We rescale to best value $B(\Lambda_{c}^{+} \rightarrow pK^{-}\pi^{+}) = 0.050$. $\Gamma(\Xi_{C}^{0} \text{ anything } \times B(\Xi_{C}^{0} \rightarrow \Xi^{-}\pi^{+}))/\Gamma_{\text{total}}$ $\frac{VALUE\ (units\ 10^{-3})}{99\ BARISH} = \frac{DOCUMENT\ ID}{99\ BARISH} = \frac{TECN}{97\ CLE2} = \frac{COMMENT}{e^{+}e^{-} \rightarrow T(45)}$ 99 BARISH 97 find 79 ± 27 Ξ_{C}^{0} events. $\Gamma(\Xi_{C}^{+} \text{ anything } \times B(\Xi_{C}^{+} \rightarrow \Xi^{-}\pi^{+}\pi^{+}))/\Gamma_{\text{total}}$ $\frac{VALUE\ (units\ 10^{-3})}{VALUE\ (units\ 10^{-3})} = \frac{DOCUMENT\ ID}{DOCUMENT\ ID} = \frac{TECN}{ID} = \frac{COMMENT}{ID}$ 0.453 ± 0.096 ± 0.065 100 BARISH 97 find 125 ± 28 Ξ_{C}^{+} events. $\Gamma(p/\overline{p} \text{ anything})/\Gamma_{\text{total}}$ $\frac{IC}{ID} = \frac{IC}{ID} = I$
87 ALBRECHT 950 use for charmless B deca for charmless B deca for charmless B deca for charmless A b — quoted above. Result Γ(π [±] anything)/Γ _{total} 88 ALBRECHT 93 exclusion (0.025 ± 0.080.) Γ(η anything)/Γ _{total} VALUE 0.176 ± 0.011 ± 0.012 Γ(ρ ⁰ anything)/Γ _{total} VALUE 0.208 ± 0.042 ± 0.032 Γ(ω anything)/Γ _{total} VALUE 0.035 ± 0.007 OUR AV 0.0390 ± 0.0030 ± 0.0035 0.023 ± 0.006 ± 0.005 Γ(Λ [±] anything)/Γ _{total} VALUE 0.064 ± 0.008 ± 0.008 0.14 ± 0.09 <0.112	e full reccay y can be y sgluon t is highly al CLΣ 90 /ERAGE	n. Instruction of one interpreted as eli they find a branc model dependen model depende	B decay as ther b → s shing ratio of t. 931 ARG decays. If in the shift of the sh	tag. Two ca gluon or $b \rightarrow -$ ~ 0.026 or $t \rightarrow -$ $\sim 0.00MENT$ $e^+e^- \rightarrow -$ $\sim 0.00MENT$ $e^+e^- \rightarrow -$ $\sim 0.00MENT$ $e^+e^- \rightarrow -$ $\sim 0.00MENT$ $e^+e^- \rightarrow -$ $\sim 0.00MENT$ $\sim 0.00MENT$	T(45)	10 ⁻² . Our first error is their experiment's error and our second error is the system error from using our best value. $\Gamma(\Sigma_c^0 N(N=p \text{ or } n))/\Gamma_{\text{total}} \qquad $
8/ALBRECHT 950 use for charmless B deca for charmless B deca for charmless B deca for charmless A b — quoted above. Result Γ(π± anything)/Γtotal 88 ALBRECHT 93 exclu 0.025 ± 0.080. Γ(η anything)/Γtotal VALUE 0.176±0.011±0.012 Γ(ρ0 anything)/Γtotal VALUE 0.208±0.042±0.032 Γ(ω anything)/Γtotal VALUE 0.035 ±0.007 OUR AV 0.0390±0.0030±0.0035 0.003 ±0.006 ±0.005 Γ(Λ± anything)/Γtotal VALUE 0.064±0.008±0.008 • • • We do not use the 0.14 ±0.09 <0.112 89 CRAWFORD 92 results 1/4 quick of the control of the	e full recca sy can be s gluon t is highly and udes π^{\pm} udes π^{\pm} 90 /ERAGE	DOCUMENT ID ALBRECHT DOCUMENT ID ETTO Includes SC ALBRECHT BORTOLETT DOCUMENT ID 89 CRAWFORD g data for average 90 ALBRECHT 91 ALAM d from lepton bai	B decay as ther b → s shing ratio of t. 931 ARG decays. If in the shift of the sh	tag. Two ca gluon or $b \rightarrow -$ ~ 0.026 or $t \rightarrow -$ $\sim 0.00MENT$ $e^+e^- \rightarrow -$ $\sim 0.00MENT$ $e^+e^- \rightarrow -$ $\sim 0.00MENT$ $e^+e^- \rightarrow -$ $\sim 0.00MENT$ $e^+e^- \rightarrow -$ $\sim 0.00MENT$ $\sim 0.00MENT$	T(45)	10 ⁻² . Our first error is their experiment's error and our second error is the system error from using our best value. $\Gamma(\Sigma_c^0 N(N=\rho \text{ or } n))/\Gamma_{\text{total}}$ $\frac{VALVE}{CLN} = \frac{CLN}{90} = \frac{DOCUMENT\ ID}{98\ PROCARIO} = \frac{TECN}{94\ CLE2} = \frac{e^+e^- \rightarrow T(45)}{e^+e^- \rightarrow T(45)}$ $98\ PROCARIO 94\ reports < 0.0017\ for B(\Lambda_c^+ \rightarrow pK^-\pi^+) = 0.043. \text{ We rescale to best value B}(\Lambda_c^+ \rightarrow pK^-\pi^+) = 0.050.$ $\Gamma(\Xi_c^0 \text{ anything } \times B(\Xi_c^0 \rightarrow \Xi^-\pi^+))/\Gamma_{\text{total}}$ $\frac{VALUE\ (units\ 10^{-3})}{VALUE\ (units\ 10^{-3})} = \frac{DOCUMENT\ ID}{99\ BARISH} = \frac{TECN}{97\ CLE2} = \frac{COMMENT}{e^+e^- \rightarrow T(45)}$ $99\ BARISH 97\ find 79 \pm 27\ \Xi_c^0 \text{ events.}$ $\Gamma(\Xi_c^+ \text{ anything } \times B(\Xi_c^+ \rightarrow \Xi^-\pi^+\pi^+))/\Gamma_{\text{total}}$ $\frac{VALUE\ (units\ 10^{-3})}{VALUE\ (units\ 10^{-3})} = \frac{DOCUMENT\ ID}{DOCUMENT\ ID} = \frac{TECN}{TECN} = \frac{COMMENT}{TECN}$ $0.453\pm0.096 + \frac{0.065}{0.065} = \frac{100}{0.065} BARISH = 97\ CLE2\ e^+e^- \rightarrow T(45)$ $100\ BARISH 97\ find\ 125 \pm 28\ \Xi_c^+ \text{ events.}$ $\Gamma(p/\overline{p} \text{ anything})/\Gamma_{\text{total}}$ $\ln \text{ locludes } p\ \text{ and } \overline{p}\ \text{ from } \Lambda \text{ and } \overline{\Lambda} \text{ decay.}$ $\frac{VALUE\ (units\ 10^{-3})}{0.080\pm0.005\pm0.005} = \frac{EVT}{0.090} = TECN\ (COMMENT\
87 ALBRECHT 950 use for charmless B deca for charmless B deca for charmless B deca for charmless A beautiful function of the following of the	e full recca yet and a service full recca he so gluon to so gluon to so full full full full full full full ful	nstruction of one interpreted as elithey find a branc model dependen model depend	B decay as ther b s s there b s s there b s s there b s s there b s there	tag. Two cas gluon or b ~ 0.026 or s ~ 0.026 or s — COMMENT e+e- → comment che- → che	T(4S)	10 ⁻² . Our first error is their experiment's error and our second error is the system error from using our best value. $\Gamma(\Sigma_c^0 N(N=p \text{ or } n))/\Gamma_{\text{total}} \qquad $
87 ALBRECHT 950 use for charmless B deca for charmless B deca for charmless B deca for charmless A beautiful filter preted as b quoted above. Result [(π ± anything) / Γ total (π + anything) / Γ	e full recca ay can be • s gluon t is highly al udes π± LES 90 VERAGE	nstruction of one interpreted as elithey find a branch model dependen model depen	B decay as ther b s shing ratio of t. 931 ARG decays. If ii 1ECN 96 CLE2 1ECN 941 ARG 1ECN 941 ARG 1ECN 941 ARG 086 CLE0 7ECN 92 CLEO es, fits, limits 88E ARG 87 CLEO ryon correlati	tag. Two ca gluon or $b \rightarrow \infty$ 0.026 or $t \rightarrow \infty$ 0.027 or $t \rightarrow \infty$ 0.028 or $t \rightarrow \infty$ 0.028 or $t \rightarrow \infty$ 0.030 or	T(45)	10 ⁻² . Our first error is their experiment's error and our second error is the system error from using our best value. $\Gamma(\Sigma_c^0 N(N=\rho \text{ or } n))/\Gamma_{\text{total}}$ $\frac{VALVE}{CLN} = \frac{CLN}{90} \frac{DOCUMENT\ ID}{98\ PROCARIO} \frac{TECN}{94\ CLE2} e^+e^- \rightarrow T(45)$ $98\ PROCARIO 94\ CLE2 e^+e^- \rightarrow T(45)$ $98\ PROCARIO 94\ CLE2 e^+e^- \rightarrow T(45)$ $98\ PROCARIO 94\ CLE2 e^+e^- \rightarrow T(45)$ $98\ PROCARIO 94\ PK^-\pi^+) = 0.050.$ $\Gamma(\Xi_c^0 \text{ anything } \times B(\Xi_c^0 \rightarrow \Xi^-\pi^+))/\Gamma_{\text{total}}$ $VALUE\ (units\ 10^{-3}) \qquad DOCUMENT\ ID \qquad TECN \qquad COMMENT$ $99\ BARISH 97\ find 79 \pm 27\ \Xi_c^0 \text{ events.}$ $\Gamma(\Xi_c^+ \text{ anything } \times B(\Xi_c^+ \rightarrow \Xi^-\pi^+\pi^+))/\Gamma_{\text{total}}$ $VALUE\ (units\ 10^{-3}) \qquad DOCUMENT\ ID \qquad TECN \qquad COMMENT$ $0.453\pm0.096^+0.065$ $100\ BARISH 97\ find 125 \pm 28\ \Xi_c^+ \text{ events.}$ $\Gamma(p/\overline{p} \text{ anything})/\Gamma_{\text{total}}$ $100\ BARISH 97\ find 125 \pm 28\ \Xi_c^+ \text{ events.}$ $\Gamma(p/\overline{p} \text{ anything})/\Gamma_{\text{total}}$ $100\ BARISH 97\ find 125 \pm 28\ \Xi_c^+ \text{ events.}$ $\Gamma(p/\overline{p} \text{ anything})/\Gamma_{\text{total}}$ $0.080\pm0.005\pm0.003$ $0.090\pm0.005\pm0.003$ 0.09
87 ALBRECHT 950 use for charmless B deca for charmless B deca for charmless B deca for charmless A beautiful filter preted as b — quoted above. Result [(π ± anything) / Γ total (π + anything) /	e full recca ay can be • s gluon t is highly al udes π± LEX 90 VERAGE e followin 90 uit deriver ± decay asured B(i K ⁻ π ⁺)	nstruction of one interpreted as elithey find a branch model dependen model depen	B decay as ther b sylhing ratio of t. 931 ARG decays. If ii 1ECN 96 CLE2 1ECN 941 ARG 1ECN 941 ARG 1ECN 941 ARG 2CLEO 941 ARG O86 CLEO 700 CORPORT CORPORT CORPORT CORPORT TECN 92 CLEO TOPORT CORPORT CORPORT CORPORT TO THE	tag. Two cases gluon or $b \rightarrow \infty$ 0.026 or $t \rightarrow \infty$ 0.027 or $t \rightarrow \infty$ 0.028 or $t \rightarrow \infty$ 0.030 decide of $t \rightarrow$	T(45)	10 ⁻² . Our first error is their experiment's error and our second error is the system error from using our best value. $\Gamma(\Gamma_c^0 N(N=p \text{ or } n))/\Gamma_{\text{total}} \qquad $

Meson Particle Listings B^{\pm}/B^{0} ADMIXTURE

$\Gamma(\Lambda/\overline{\Lambda}$ anything)/ Γ_{total}		₁ /Γ
0.040±0.005 OUR AVERAGE	DOCUMENT ID TECN COMMENT	
0.038±0.004±0.006 2998 0.042±0.005±0.006 943	CRAWFORD 92 CLEO $e^+e^- \rightarrow \Upsilon(45)$ ALBRECHT 89K ARG $e^+e^- \rightarrow \Upsilon(45)$	
• • • We do not use the following of	data for averages, fits, limits, etc. • • •	_
	04 ACKERSTAFF 97N OPAL $e^+e^- \rightarrow Z$ 05 ALAM 83B CLEO $e^+e^- \rightarrow \Upsilon(4S)$	ı
	$\Rightarrow B) = 0.868 \pm 0.041, i.e., an admixture of B0,$	B±. ▮
and B_S .	ult as $> 0.022 \pm 0.007 \pm 0.004$. Values are	-
$(B(\Lambda X)+B(\overline{\Lambda}X))/2$. Data are of yields below cut, $B(B \rightarrow \Lambda X) \simeq$	consistent with equal yields of p and \overline{p} . Using assu	imed
Γ(Λanything)/Γ(Λanything) VALUE	DOCUMENT ID TECN COMMENT	Γ ₇₃
	6 AMMAR 97 CLE2 $e^+e^- \rightarrow \Upsilon(45)$	ļ
106 AMMAR 97 uses a high-moment	turn lepton tag $(P_{\ell} > 1.4 \text{ GeV}/c^2)$.	ı
$\Gamma(\Xi^-/\Xi^+ \text{ anything})/\Gamma_{\text{total}}$	•	4/F
0.0027±0.0006 OUR AVERAGE	DOCUMENT ID TECN COMMENT	_
0.0027±0.0005±0.0004 147 0.0028±0.0014 54	CRAWFORD 92 CLEO $e^+e^- \rightarrow \Upsilon(45)$ ALBRECHT 89K ARG $e^+e^- \rightarrow \Upsilon(45)$	•
	•	٠.
Γ(baryons anything)/Γ _{total}	DOCUMENT ID TECH COMMENT	ъ/Г
0.068±0.005±0.003	⁷ ALBRECHT 920 ARG $e^+e^- \rightarrow \Upsilon(45)$	
_	data for averages, fits, limits, etc. $\bullet \bullet \bullet$ BALBRECHT 89K ARG $e^+e^- \rightarrow \Upsilon(4S)$	
	imultaneous analysis of p and Λ yields, $p\overline{p}$ and $\Lambda\overline{p}$ c	orre-
lations, and various lepton-baryon	n and lepton-baryon-antibaryon correlations. Supers	iedes
108 ALBRECHT 89K obtain this resu	uit by adding their their measurements (5.5 \pm 1.6)% for inclusive Λ production. They then ass	% for
	iction and add it in also. Since each B decay has	
Γ(ppanything)/Γ _{total} Includes p and p̄ from Λ and λ	_ ,	₆ /Γ
<u>VALUE</u> <u>EVTS</u> 0.0247±0.0023 OUR AVERAGE	DOCUMENT ID TECN COMMENT	
0.024 ±0.001 ±0.004	CRAWFORD 92 CLEO $e^+e^- \rightarrow T(45)$	
$0.025 \pm 0.002 \pm 0.002$ 918	ALBRECHT 89K ARG $e^+e^- \rightarrow T(45)$	
$\Gamma(p\overline{p}$ anything)/ $\Gamma(p/\overline{p}$ anything		/F ₆₉
Includes p and \overline{p} from Λ and $\overline{\rho}$	DOCUMENT ID TECN COMMENT	
_	data for averages, fits, limits, etc. • •	
	⁹ CRAWFORD 92 CLEO $e^+e^- \rightarrow T(45)$ lependent of their $\Gamma(p\bar{p}$ anything)/ Γ_{total} value.	
		_ /r
$\Gamma(\Lambda \overline{p}/\overline{\Lambda} p \text{ anything})/\Gamma_{\text{total}}$ Includes p and \overline{p} from Λ and $\overline{\lambda}$	_	7/F
0.025±0.004 OUR AVERAGE	DOCUMENT ID TECN COMMENT	
$0.029 \pm 0.005 \pm 0.005$	CRAWFORD 92 CLEO $e^+e^- \rightarrow T(45)$	
0.023±0.004±0.003 165	ALBRECHT 89K ARG $e^+e^- \rightarrow \Upsilon(4S)$	
$\Gamma(\Lambda \overline{p}/\overline{\Lambda} p \text{ anything})/\Gamma(\Lambda/\overline{\Lambda} \text{ and } \overline{p} \text{ from } \Lambda \text{ and } \overline{p}$		/F ₇₁
VALUE	DOCUMENT ID TECN COMMENT	
	data for averages, fits, limits, etc. $\bullet \bullet \bullet$ CRAWFORD 92 CLEO $e^+e^- \rightarrow T(45)$	
110 CRAWFORD 92 value	e is not independent of	their
$[\Gamma(\Lambda \overline{\rho})]$ anything)+ $\Gamma(\overline{\Lambda} \rho)$ anything))]/F _{total} value.	
$\Gamma(\Lambda \overline{\Lambda} \text{ anything})/\Gamma_{\text{total}}$		₁₈ /Γ
<u>VALUE</u> <u>CL% EVTS</u> <0.005 90	CRAWFORD 92 CLEO $e^+e^- \rightarrow T(45)$	_
	data for averages, fits, limits, etc. • •	
<0.0088 90 12	ALBRECHT 89K ARG $e^+e^- \rightarrow \Upsilon(4S)$	
$\Gamma(\Lambda \overline{\Lambda} \text{ anything})/\Gamma(\Lambda / \overline{\Lambda} \text{ anything})$		/Г ₇₁
	DOCUMENT ID TECN COMMENT data for averages, fits, limits, etc. ● ●	
-	CRAWFORD 92 CLEO $e^+e^- \rightarrow \Upsilon(45)$	
111 CRAWFORD 92 value is not ind	lependent of their $\Gamma(\Lambda\overline{\Lambda})$ anything)/ Γ_{total} value.	
$\Gamma(e^+e^-s)/\Gamma_{\text{total}}$		·9/Γ
Test for $\Delta B = 1$ weak neutral VALUE CL%		
< 5.7 × 10⁻⁵ 90	GLENN 98 CLEO $e^+e^- \rightarrow \Upsilon(45)$	
• • • We do not use the following of <0.05 90	data for averages, fits, limits, etc. • • • BEBEK 81 CLEO $e^+e^- \rightarrow \Upsilon(45)$	
_U.UJ 70	51 CLEO € € → 1(43)	

$\Gamma(\mu^+\mu^-s)/\Gamma_{\text{total}}$					Γ ₈₀ /Γ
Test for $\Delta B = VALUE$	CL%_	DOCUMENT ID		TECN	COMMENT
<5.8 × 10 ⁻⁵	90	GLENN	98	CLEO	$e^+e^- \rightarrow \Upsilon(4S)$
• • • We do not use	the following	ig data for average	es, fit	s, limits,	etc. • • •
<0.017	90	CHADWICK	81	CLEO	$e^+e^- \rightarrow \Upsilon(45)$
$ \Gamma(e^+e^-s) + \Gamma(p) $ Test for $\Delta B =$					(Г ₇₉ +Г ₈₀)/Г
	CL%	DOCUMENT ID		TECN	COMMENT
<4.2 × 10 ⁻⁵	90				$e^+e^- \rightarrow \gamma(45)$
• • We do not use	the following	ng data for average	es, fit	s, limits,	etc. • • •
<0.0024		¹¹² BEAN			Repl. by GLENN 98
< 0.0062	90	¹¹³ AVERY	84	CLEO	Repl. by BEAN 87
12 BEAN 87 reports	$[(\mu^{+}\mu^{-})+$	$(e^+e^-)]/2$ and v	ve co	nverted i	lt.
13 Determine ratio					
Γ(e [±] μ [∓] s)/Γ _{total}	family num	ber conservation.			Г ₈₁ /г
•	CL%	DOCUMENT ID		TECN	COMMENT
<2.2 × 10 ⁻⁵	90	GLENN		CLEO	$e^+e^- \rightarrow \gamma(45)$

B±/B⁰ ADMIXTURE REFERENCES

	,	
BISHAI 98		M. Bishai+ (CLEO Collab.)
BONVICINI 98 CLNS 97/151		.) G. Bonvicini+ (CLEO Collab.)
COAN 98		T.E. Coan+ (CLEO Collab.)
GLENN 98		5. Glenn+ (CLEO Collab.)
ACKERSTAFF 97 AMMAR 97		K. Ackerstaff+ (OPAL Collab.) R. Ammar+ (CLEO Collab.)
BARISH 97		B. Barish+ (CLEO Collab.)
BUSKULIC 97	B ZPHY C73 601	D. Buskulic+ (ALEPH Collab.)
GIBBONS 97		L. Gibbons+ (CLEO Collab.)
ALBRECHT 96 BARISH 96		+Hamacher, Hofmann, Kirchhoff+ (ARGUS Collab.) +Chadha, Chan, Eigen+ (CLEO Collab.)
GIBAUT 96		+Kinoshita, Pomianowski, Barish+ (CLEO Collab.)
KUBOTA 96		+Lattery, Momayezi, Nelson+ (CLEO Collab.)
PDG 96 ALAM 95		+Kim, Ling, Mahmood+ (CLEO Collab.)
ALBRECHT 95		+Hamacher, Hofmann, Kirchoff+ (ARGUS Collab.)
BALEST 95	B PR D52 2661	+Cho, Ford, Johnson+ (CLEO Collab.)
BARISH 95		+Chadha, Chan, Cowen+ (CLEO Collab.)
BUSKULIC 95 ALBRECHT 94	SB PL B345 103 SC ZPHY C62 371	+Casper, De Bonis, Decamp+ (ALEPH Collab.) +Ehrlichmann, Harnacher, Hofmann+ (ARGUS Collab.)
ALBRECHT 94		+Ehrlichmann, Hamacher, Hofmann+ (ARGUS Collab.)
PROCARIO 94		+Balest, Cho, Daoudi, Ford+ (CLEO Collab.)
ALBRECHT 93 ALBRECHT 93		+Ehrlichmann, Hamacher, Hofmann+ (ARGUS Collab.) +Ehrlichmann, Hamacher, Hofmann+ (ARGUS Collab.)
ALBRECHT 93		+Ehrlichmann, Hamacher, Hofmann+ (ARGUS Collab.)
ALBRECHT 93	I ZPHY C58 191	+Cronstroem, Ehrlichmann, Hamacher+ (ARGUS Collab.)
ALEXANDER 93		+Bebek, Berkelman, Bloom, Browder+ (CLEO Collab.)
ARTUSO 93 BARTELT 93		(SYRA) +Csorna, Egyed, Jain, Akerib+ (CLEO Collab.)
ALBRECHT 92	E PL B277 209	+Ehrlichmann, Hamacher, Krueger, Nau+ (ARGUS Collab.)
ALBRECHT 92	G ZPHY C54 1	+Ehrlichmann, Hamacher, Krueger, Nau+ (ARGUS Collab.)
ALBRECHT 92 BORTOLETTO 92		+Cronstroem, Ehrlichmann+ (ARGUS Collab.) +Brown, Dominick, McIlwain+ (CLEO Collab.)
CRAWFORD 92		+Fulton, Jensen, Johnson+ (CLEO Collab.)
HENDERSON 92	PR D45 2212	+Kinoshita, Pipkin, Procario+ (CLEO Collab.)
LESIAK 92 ALBRECHT 91		+Antreasyan, Bartels, Besset, Bieler+ (Crystal Ball Collab.)
	IC PL B255 297 IH ZPHY C52 353	+Ehrlichmann, Glaeser, Harder, Krueger+ (ARGUS Collab.) +Ehrlichmann, Hamacher, Harder+ (ARGUS Collab.)
FULTON 91	PR D43 651	+ Jensen, Johnson, Kagan, Kass+ (CLEO Collab.)
YANAGISAWA 91		+Heintz, Lee-Franzini, Lovelock, Narain+ (CUSB II Collab.)
ALBRECHT 90 ALBRECHT 90		+ Glaeser, Harder, Krueger+ (ARGUS Collab.) + Ehrlichmann, Glaeser, Harder, Krueger+ (Argus Collab.)
BORTOLETTO 90	PRL 64 2117	+Goldberg, Horwitz, Jain, Mestayer+ (CLEO Collab.)
Also 92		Bortoletto, Brown, Dominick, McIlwain+ (CLEO Collab.)
FULTON 90 MASCHMANN 90		+Hempstead, Jensen, Johnson+ (CLEO Collab.) +Antreasyan, Bartels, Besset+ (Crystal Ball Collab.)
PDG 90		Hernandez, Stone, Porter+ (IFIC, BOST, CIT+)
ALBRECHT 89	K ZPHY C42 519	+Boeckmann, Glaeser, Harder+ (ARGUS Collab.)
ISGUR 89 WACHS 89		+Scora, Grinstein, Wise (TNTO, CIT) +Antreasyan, Bartels, Bieler+ (Crystal Ball Collab.)
ALBRECHT 88	BE PL B210 263	+Antreasyan, Bartels, Bieler+ (Crystal Ball Collab.) +Boeckmann, Glaeser+ (ARGUS Collab.)
ALBRECHT 88	H PL B210 258	+Boeckmann, Glaeser+ (ARGUS Collab.)
KOERNER BE		+Schuler (MANZ, DESY)
ALAM 87 ALAM 87		+Kitukama, Kim, Li+ (CLEO Collab.) +Katayama, Kim, Sun+ (CLEO Collab.)
ALBRECHT 87	D PL B199 451	+Andam, Binder, Boeckmann+ (ARGUS Collab.)
ALBRECHT 87		+Binder, Boeckmann, Glaser+ (ARGUS Collab.)
BEAN 87 BEHRENDS 87		+Bobbink, Brock, Engler+ (CLEO Collab.) +Morrow, Guida, Guida+ (CLEO Collab.)
BORTOLETTO 87		+Chen, Garren, Goldberg+ (CLEO Collab.)
ALAM 86	PR D34 3279	+Katayama, Kim, Sun+ (CLEO Collab.)
BALTRUSAIT 86 BORTOLETTO 86		Baltrusaitis, Becker, Blaylock, Brown+ (Mark III Coliab.) +Chen, Garren, Goldberg+ (CLEO Collab.)
HAAS 86		+Lenen, Garren, Goldberg+ (CLEO Collab.) +Hempstead, Jensen, Kagan+ (CLEO Collab.)
ALBRECHT 85	H PL 162B 395	+Binder, Harder+ (ARGUS Collab.)
CSORNA 85		+Garren, Mestayer, Panvini+ (CLEO Collab.)
HAAS 85 AVERY 84		+Hempstead, Jensen, Kagan+ (CLEO Collab.) +Bebek, Berkelman, Cassel+ (CLEO Collab.)
CHEN 84		+Goldberg, Horwitz, Jawahery+ (CLEO Collab.)
LEVMAN 84		+Sreedhar, Han, Imlay+ (CUSB Collab.)
ALAM 83 GREEN 83		+Csorna, Garren, Mestayer+ (CLEO Collab.) +Hicks, Sannes, Skubic+ (CLEO Collab.)
KLOPFEN 83		Klopfenstein, Horstkotte+ (CUSB Collab.)
ALTARELLI 82	NP B208 365	+Cabibbo, Corbo, Maini, Martinelli (ROMA, INFN, FRAS)
BRODY 82 GIANNINI 82		+Chen, Goldberg, Horwitz+ (CLEO Collab.) +Finocchiaro, Franzini+ (CUSB Collab.)
BEBEK 81		+Finocchiaro, Franzini+ (CUSB Collab.) +Haggerty, izen, Longuermare+ (CLEO Collab.)
CHADWICK 81	PRL 46 88	+Ganci, Kagar, Kass+ (CLEO Collab.)
ABRAMS 80	PRL 44 10	+Alam, Blocker, Boyarski+ (SLAC, LBL)

$B^{\pm}/B^{0}/B_{s}^{0}/b$ -baryon ADMIXTURE

$B^{\pm}/B^{0}/B_{s}^{0}/b$ -baryon ADMIXTURE

B±/B0/B0/b-baryon ADMIXTURE MEAN LIFE

Each measurement of the B mean life is an average over an admixture of various bottom mesons and baryons which decay weakly. Different techniques emphasize different admixtures of produced particles, which could result in a different B mean life.

"OUR EVALUATION" is an average of the data listed below performed by the LEP B Lifetime Working Group as described in our review "Production and Decay of b-flavored Hadrons" in the B^\pm Section of these Listings. The averaging procedure takes into account correlations between the measurements and asymmetric lifetime errors, but ignores the small differences due to different techniques.

VALUE (10 ⁻¹² s) EVTS	DOCUMENT ID TECN	COMMENT
1.564±0.014 OUR EVALUA	TION	
$1.533 \pm 0.015 {+0.035 \atop -0.031}$	¹ ABE 988 CDF	p p at 1.8 TeV
$1.549 \pm 0.009 \pm 0.015$	² ACCIARRI 98 L3	$e^+e^- \rightarrow Z$
$1.611 \pm 0.010 \pm 0.027$	3 ACKERSTAFF 97F OPAL	$e^+e^- \rightarrow Z$
$1.582 \pm 0.011 \pm 0.027$	³ ABREU 96E DLPH	e ⁺ e ⁻ → Z
1.533±0.013±0.022 19.8k	⁴ BUSKULIC 96F ALEP	$e^+e^- \rightarrow Z$
$1.564 \pm 0.030 \pm 0.036$	⁵ ABE,K 95B SLD	$e^+e^- \rightarrow Z$
$1.542 \pm 0.021 \pm 0.045$	6 ABREU 94L DLPH	$e^+e^- \rightarrow Z$
$1.523 \pm 0.034 \pm 0.038$ 5372	ACTON 93L OPAL	e ⁺ e [−] → Z
$1.535 \pm 0.035 \pm 0.028$ 7357	⁷ ADRIANI 93K L3	$e^+e^- \rightarrow Z$
$1.511 \pm 0.022 \pm 0.078$	⁸ BUSKULIC 930 ALEP	e ⁺ e ⁻ → Z
• • We do not use the foll	owing data for averages, fits, lim	its, etc. • • •
$1.575 \pm 0.010 \pm 0.026$	9 ABREU 96E DLPH	$e^+e^- \rightarrow Z$
$1.50 \begin{array}{l} +0.24 \\ -0.21 \end{array} \pm 0.03$	10 ABREU 94P DLPH	$e^+e^- \rightarrow Z$
1.46 ±0.06 ±0.06 5344	11 ABE 93J CDF	Repl. by ABE 988
$1.23 \begin{array}{c} +0.14 \\ -0.13 \end{array} \pm 0.15 \qquad 188$	12 ABREU 93D DLPH	Sup. by ABREU 94L
$1.49 \pm 0.11 \pm 0.12$ 253	13 ABREU 93G DLPH	Sup. by ABREU 94L
$1.51 \begin{array}{c} +0.16 \\ -0.14 \end{array} \pm 0.11 130$	14 ACTON 93C OPAL	$e^+e^- \rightarrow Z$
1.28 ±0.10	15 ABREU 92 DLPH	Sup. by ABREU 94L
1.37 ±0.07 ±0.06 1354	¹⁶ ACTON 92 OPAL	Sup. by ACTON 93L
1.49 ±0.03 ±0.06	17 BUSKULIC 92F ALEP	Sup. by BUSKULIC 96F
$1.35 \begin{array}{c} +0.19 \\ -0.17 \end{array} \pm 0.05$	18 BUSKULIC 92G ALEP	$e^+e^- \rightarrow Z$
1.32 ±0.08 ±0.09 1386	¹⁹ ADEVA 91H L3	Sup. by ADRIANI 93K
$1.32 \begin{array}{c} +0.31 \\ -0.25 \end{array} \pm 0.15 \qquad 37$	²⁰ ALEXANDER 91G OPAL	$e^+e^- \rightarrow Z$
1.29 ±0.06 ±0.10 2973	²¹ DECAMP 91c ALEP	Sup. by BUSKULIC 92F
1.36 +0.25 -0.23	²² HAGEMANN 90 JADE	Ecm = 35 GeV
1.13 ±0.15	²³ LYONS 90 RVUE	
1.35 ±0.10 ±0.24	BRAUNSCH 89B TASS	Ecm = 35 GeV
0.98 ±0.12 ±0.13	ONG 89 MRK2	Ecm = 29 GeV
$1.17 \begin{array}{c} +0.27 \\ -0.22 \end{array} \begin{array}{c} +0.17 \\ -0.16 \end{array}$	KLEM 88 DLCO	Ecm= 29 GeV
1.29 ±0.20 ±0.21	²⁴ ASH 87 MAC	Ecm = 29 GeV
1.02 +0.42 301	²⁵ BROM 87 HRS	Eee = 29 GeV
1		

- ¹ Measured using inclusive $J/\psi(1S) \rightarrow \mu^{+}\mu^{-}$ vertex.
- 2 ACCIARRI 98 uses inclusively reconstructed secondary vertex and lepton impact parameter.
- eter.

 3 ACKERSTAFF 97F uses inclusively reconstructed secondary vertices.
- ⁴ BUSKULIC 96F analyzed using 3D impact parameter.
- ⁵ ABE,K 95B uses an inclusive topological technique.
- ⁶ ABREU 94L uses charged particle impact parameters. Their result from inclusively reconstructed secondary vertices is superseded by ABREU 96E.
- ⁷ ACTON 93L and ADRIANI 93K analyzed using lepton (e and μ) impact parameter at Z.
- ⁸ BUSKULIC 930 analyzed using dipole method.
- 9 Combines ABREU 96E secondary vertex result with ABREU 94L impact parameter result.
- 10 From proper time distribution of $b o J/\psi(15)$ anything.
- 11 ABE 93J analyzed using $J/\psi(1S)
 ightarrow ~\mu \mu$ vertices.
- ¹² ABREU 93D data analyzed using $D/D^*\ell$ anything event vertices.
- 13 ABREU 93G data analyzed using charged and neutral vertices.
- 14 ACTON 93C analysed using $D/D^*\ell$ anything event vertices.
- 15 ABREU 92 is combined result of muon and hadron impact parameter analyses. Hadron tracks gave $(12.7 \pm 0.4 \pm 1.2) \times 10^{-13}$ s for an admixture of B species weighted by production fraction and mean charge multiplicity, while muon tracks gave $(13.0 \pm 1.0 \pm 0.8) \times 10^{-13}$ s for an admixture weighted by production fraction and semileptonic branching fraction.
- 16 ACTON 92 is combined result of muon and electron impact parameter analyses.
- ¹⁷ BUSKULIC 92F uses the lepton impact parameter distribution for data from the 1991
- run. ¹⁸ BUSKULIC 92G use $J/\psi(15)$ tags to measure the average b lifetime. This is comparable to other methods only if the $J/\psi(15)$ branching fractions of the different b-flavored hadrons are in the same ratio.
- hadrons are in the same ratio. 19 Using $Z\to \,{\rm e^+X}$ or $\mu^+{\rm X}$, ADEVA 91H determined the average lifetime for an admixture of B hadrons from the impact parameter distribution of the lepton.
- ²⁰ Using $Z \to J/\psi(1S)$ X, $J/\psi(1S) \to \ell^+\ell^-$, ALEXANDER 91G determined the average lifetime for an admixture of B hadrons from the decay point of the $J/\psi(1S)$.

- 21 Using $Z\to e X$ or $\mu X,$ DECAMP 91C determines the average lifetime for an admixture of B hadrons from the signed impact parameter distribution of the lepton.
- 22 HAGEMANN 90 uses electrons and muons in an impact parameter analysis.
- 23 LYONS 90 combine the results of the B lifetime measuresments of ONG 89, BRAUN-SCHWEIG 89B, KLEM 88, and ASH 87, and JADE data by private communication. They use statistical techniques which include variation of the error with the mean life, and possible correlations between the systematic errors. This result is not independent of the measured results used in our average.
- 24 We have combined an overall scale error of 15% in quadrature with the systematic error of ± 0.7 to obtain ± 2.1 systematic error.
- ²⁵ Statistical and systematic errors were combined by BROM 87.

CHARGED b-HADRON ADMIXTURE MEAN LIFE

VALUE (10 ⁻¹² s)	DOCUMENT I		TECN	COMMENT
1.72±0.08±0.06	²⁶ ADAM	95	DLPH	$e^+e^- \rightarrow Z$
²⁶ ADAM 95 data analyzed us	ing vertex-charge t	echniqu	e to tag	b-hadron charge.

NEUTRAL b-HADRON ADMIXTURE MEAN LIFE

VALUE (10 ⁻¹² s)	DOCUMENT ID	TECN	COMMENT	
1.58±0.11±0.09	27 ADAM	95 DLP	$e^+e^- \rightarrow Z$	
²⁷ ADAM 95 data analyzed usia	ng vertex-charge to	chnique to t	ag <i>b</i> -hadron charge.	

MEAN LIFE RATIO $ au_{ ext{charged }b- ext{hadron}}/ au_{ ext{neutral }b- ext{hadron}}$							
VALUE	DOCUMENT ID		TECN	COMMENT			
$1.09^{+0.11}_{-0.10}\pm0.08$	²⁸ ADAM	95	DLPH	$e^+e^- \rightarrow Z$			
28 A DAM OF data and board				- b b - d b			

 $^{^{28}}$ ADAM 95 data analyzed using vertex-charge technique to tag b-hadron charge.

b PRODUCTION FRACTIONS AND DECAY MODES

The branching fraction measurements are for an admixture of B mesons and baryons at energies above the $\Upsilon(4S)$. Only the highest energy results (LEP, Tevatron, $Sp\bar{p}S$) are used in the branching fraction averages. The production fractions give our best current estimate of the admixture at

For inclusive branching fractions, e.g., $B \to D^\pm$ anything, the treatment of multiple D's in the final state must be defined. One possibility would be to count the number of events with one-or-more D's and divide by the total number of B's. Another possibility would be to count the total number of D's and divide by the total number of B's, which is the definition of average multiplicity. The two definitions are identical when only one of the specified particles is allowed in the final state. Even though the "one-or-more" definition seems sensible, for practical reasons inclusive branching fractions are almost always measured using the multiplicity definition. For heavy final state particles, authors call their results inclusive branching fractions while for light particles some authors call their results multiplicities. In the B sections, we list all results as inclusive branching fractions, adopting a multiplicity definition. This means that inclusive branching fractions can exceed 100% and that inclusive partial widths can exceed total widths, just as inclusive cross sections can exceed total cross sections.

The modes below are listed for a \overline{b} initial state. b modes are their charge conjugates. Reactions indicate the weak decay vertex and do not include mixing.

Mode Fraction (Γ_I/Γ) Confidence level

PRODUCTION FRACTIONS

The production fractions for weakly decaying b-hadrons at the Z have been calculated from the best values of mean lives, mixing parameters, and branching fractions in this edition by the LEP B Oscillation Working Group as described in the note "Production and Decay of b-Flavored Hadrons" in the B^\pm Particle Listings. Values assume

$$\begin{array}{ll} B(\overline{b} \rightarrow B^+) = B(\overline{b} \rightarrow B^0) \\ B(\overline{b} \rightarrow B^+) + B(\overline{b} \rightarrow B^0) + B(\overline{b} \rightarrow B^0_s) + B(b \rightarrow \Lambda_b) = 100 \ \%. \end{array}$$

The notation for production fractions varies in the literature $(f_{B^0}, f(b \to \overline{B}^0))$, $Br(b \to \overline{B}^0))$. We use our own branching fraction notation here, $B(\overline{b} \to B^0)$.

Γ_1	B ⁺	(39.7 + 1.8)%
Γ_2	B^0	(39.7 + 1.8) %
r ₃	B_s^0	(10.5 + 1.8)%
Γ_4	Λ_b	(10.1 + 3.9)%
Γ ₅	B_c	

DECAY MODES Semileptonic and leptonic modes ν anything $(23.1 \pm 1.5)\%$ $\ell^+ \nu_\ell$ anything Γ7 [a,b] $(10.99 \pm 0.23)\%$ $e^+ \nu_e$ anything $(10.9 \pm 0.5)\%$ Г8 [a] $\mu^+ \, \nu_\mu$ anything Го (10.8 ± 0.5) % [a] $D^-\ell^+ u_\ell$ anything (2.02± 0.29) % Γ₁₀ $\overline{D}{}^0 \ell^+ u_\ell$ anything Γ11 [b] 6.5 ± 0.6)% $D^{*-}\ell^+\nu_\ell$ anything Γ_{12} (2.76 ± 0.29) % [6] $\overline{D}_I^0 \ell^+ \nu_\ell$ anything Γ_{13} [b,c] seen $D_I^-\ell^+\nu_\ell$ anything Γ14 [b,c] seen $\overline{D}_{2}^{*}(2460)^{0}\ell^{+}\nu_{\ell}$ anything Γ₁₅ seen $D_2^*(2460)^- \ell^+ \nu_\ell$ anything Γ₁₆ seen $au^+ u_ au$ anything 2.6 ± 0.4) % Γ17 Γ_{18} $\overline{c} \rightarrow \ell^- \overline{\nu}_\ell$ anything [b] (7.8 ± 0.6)% Charmed meson and baryon modes $\overline{\mathcal{D}}{}^0$ anything Γ₁₉ $(60.1 \pm 3.2)\%$ D- anything $(23.7 \pm 2.3)\%$ Γ20 \overline{D}_s anything Γ_{21} $(18 \pm 5)\%$ Λ_c anything Γ22 $(9.7 \pm 2.9)\%$ \overline{c}/c anything [d] $(117 \pm 4)\%$ Charmonium modes Γ24 $J/\psi(1S)$ anything 1.16 ± 0.10) % $4.8 \pm 2.4 \times 10^{-3}$ Γ₂₅ $\psi(25)$ anything $\chi_{c1}(1P)$ anything 1.8 ± 0.5)% Γ₂₆ K or K* modes $\overline{s}\gamma$ K^{\pm} anything 5.4 × 10⁻⁴ 90% Γ₂₇ (88 ±19)% Γ_{28} Γ29 K anything $(29.0 \pm 2.9)\%$ Pion modes π^0 anything (278 [d] ±60)% Baryon modes (14 p/\overline{p} anything ±6)% Other modes [d] (497 ± 7)% charged anything Γ_{32} $(1.7 + 1.0) \times 10^{-5}$ hadron+ hadron-Γ33 $(7 \pm 21) \times 10^{-3}$ Γ34 charmless Baryon modes $\Lambda/\overline{\Lambda}$ anything $(5.9 \pm 0.6)\%$ Γ₃₅ $\Delta B = 1$ weak neutral current (B1) modes Γ_{36} e^+e^- anything \times 10⁻⁴ $\mu^+\mu^-$ anything 90% В1 < 3.2 Γ₃₇ $\nu \overline{\nu}$ anything [a] These values are model dependent. See 'Note on Semileptonic Decays' in the B⁺ Particle Listings. [b] An ℓ indicates an e or a μ mode, not a sum over these modes. [c] D_l represents an unresolved mixture of pseudoscalar and tensor D^{**} (Pwave) states. [d] Inclusive branching fractions have a multiplicity definition and can be greater than 100%. B±/B0/B0/b-baryon ADMIXTURE BRANCHING RATIOS

Γ(ν anything)/Γ _{total}	DOCUMENT ID		TECN	COMMENT	Γ ₆ /Γ
0.2308±0.0077±0.0124	29,30 ACCIARRI			$e^+e^- \rightarrow Z$	
29 ACCIARRI 96C assumes	s relative <i>b</i> semileptonic d n.	iecay	rates e	:μ:τ of 1:1:0.25	. Based on

Vally Lines / I total

These branching fraction values are model dependent. See the note on "Semileptonic Decays of D and B Mesons, Part II" at the beginning of the B+ Particle Listings.

VALUE	DOCUMENT ID	TECN	COMMENT	
0.1099±0.0023 OUR AVERAGE	Includes data fro	om the 2 data	blocks that follow	this
0.1106±0.0039±0.0022 0.114 ±0.003 ±0.004	one. 31 ABREU 32 BUSKULIC	94G ALEP	$\begin{array}{ccc} e^+ e^- &\rightarrow & Z \\ e^+ e^- &\rightarrow & Z \end{array}$	
0.105 ±0.006 ±0.005	33 AKERS	938 OPAL	$e^+e^- \rightarrow Z$	ı

 31 ABREU 95D give systematic errors ± 0.0019 (model) and 0.0012 ($R_{
m C}$). We combine

32 BUSKULIC 94G uses e and μ events. This value is from a global fit to the lepton p and p_T (relative to jet) spectra which also determines the b and c production fractions, the fragmentation functions, and the forward-backward asymmetries. This beautiful properties to the production of the properties o depends primarily on the ratio of dileptons to single leptons at high p_T , but the lower p_T portion of the lepton spectrum is included in the global fit to reduce the model dependence. The model dependence is ± 0.0026 and is included in the systematic error.

33 AKERS 93B analysis performed using single and dilepton events.

$\Gamma(e^+\nu_e$ anything)/ Γ_{total}

 Γ_8/Γ

These branching fraction values are model dependent. See the note on "Semileptonic Decays of D and B Mesons, Part II" at the beginning of the B^+ Particle Listings.

TL - 4-	A- I- ALT		<u> </u>	DOCOMENT ID			
ne da	ta in thi	S DIOCK IS 1	nciudeo	I in the average printe	eu for	a previ	ous datablock.
0.109	±0.005	OUR AVE	ERAGE				
0.1089	±0.0020	±0.0051		34,35 ACCIARRI	96C	L3	$e^+e^- \rightarrow Z$
0.107	±0.015	± 0.007	260	36 ABREU	93 C	DLPH	$e^+e^- \rightarrow Z$
0.109	+0.014	±0.0055	2719	37 AKERS	93B	OPAL	$e^+e^- \rightarrow Z$
0.138	±0.032	±0.008		38 ADEVA	91C	L3	$e^+e^- \rightarrow Z$
• • • '	We do n	ot use the	followi	ng data for averages,	fits, I	imits, e	tc. • • •
0.086	±0.027	±0.008		39 ABE	93E	VNS	<i>E</i> ee = 58 GeV
0.111	±0.028	± 0.026		BEHREND	90D	CELL	Ecm= 43 GeV
0.150	±0.011	± 0.022		BEHREND	90D	CELL	$E_{\rm CM}^{\rm ee} = 35 {\rm GeV}$
0.112	±0.009	± 0.011		ONG	88	MRK2	Eee = 29 GeV
0.149	+0.022 -0.019			PAL	86	DLCO	Ecm= 29 GeV
0.110	±0.018	± 0.010		AIHARA	85	TPC	$E_{cm}^{ee} = 29 \text{ GeV}$
0.111	±0.034	± 0.040		ALTHOFF	84J	TASS	Eee = 34.6 GeV
0.146	±0.028			KOOP			Repl. by PAL 86
111	+0.021	± 0.017		NELSON	83	MRK2	Ecm = 29 GeV

 35 Assumes Standard Model value for R_B .

 36 ABREU 93C event count includes ee events. Combining ee, $\mu\mu$, and $e\mu$ events, they obtain 0.100 ± 0.007 ± 0.007.

37 AKERS 93B analysis performed using single and dilepton events.

38 ADEVA 91c measure the average $B(b\to eX)$ branching ratio using single and double tagged b enhanced Z events. Combining e and μ results, they obtain $0.113\pm0.010\pm0.006$. Constraining the initial number of b quarks by the Standard Model prediction $(378\pm3$ MeV) for the decay of the Z into $b\bar{b}$, the electron result gives $0.112\pm0.004\pm0.008$. They obtain $0.119\pm0.003\pm0.006$ when e and μ results are combined. Used to measure the $b\bar{b}$ width itself, this electron result gives $370\pm12\pm24$ MeV and combined with the muon result these $388\pm7.4\pm23$ MeV. with the muon result gives 385 \pm 7 \pm 22 MeV.

39 ABE 932 experiment also measures forward-backward asymmetries and fragmentation functions for b and c.

 $\Gamma(\mu^+\nu_\mu {
m anything})/\Gamma_{{
m total}}$ These branching fraction values are model dependent. See the note on "Semileptonic "Se Decays of D and B Mesons, Part II" at the beginning of the B^+ Particle Listings.

VALUE EVIS	DOCOMENTIO		
The data in this block is included	in the average print	ed for a previ	ous datablock.
0.108 ±0.005 OUR AVERAGE			
$0.1082 \pm 0.0015 \pm 0.0059$ 4	^{0,41} ACCIARRI		e ⁺ e ⁻ → Z
0.110 ±0.012 ±0.007 656	⁴² ABREU	93c DLPH	$e^+e^- \rightarrow Z$
$0.101 \begin{array}{l} +0.010 \\ -0.009 \end{array} \pm 0.0055 4248$	43 AKERS	93B OPAL	e ⁺ e [−] → Z
0.113 ±0.012 ±0.006	44 ADEVA	91C L3	$e^+e^- \rightarrow Z$
 We do not use the following 	g data for averages,	fits, limits, e	tc. • • •
0.122 ±0.006 ±0.007	⁴¹ UENO	96 AMY	e^+e^- at 57.9 GeV
0.104 ±0.023 ±0.016	BEHREND	90D CELL	Ecm = 43 GeV
0.148 ±0.010 ±0.016	BEHREND	90D CELL	Eee = 35 GeV
$0.118 \pm 0.012 \pm 0.010$	ONG	88 MRK2	Ecm = 29 GeV
0.117 ±0.016 ±0.015	BARTEL	87 JADE	<i>Ecm</i> = 34.6 GeV
0.114 ±0.018 ±0.025	BARTEL	85J JADE	Repl. by BARTEL 87
0.117 ±0.028 ±0.010	ALTHOFF	84G TASS	Eee = 34.5 GeV
0.105 ±0.015 ±0.013	ADEVA	83B MRKJ	Eee = 33-38.5 GeV
0.155 ^{+0.054} -0.029	FERNANDEZ	83D MAC	Eee = 29 GeV

40 ACCIARRI 96c result obtained by a fit to the single lepton spectrum.

⁴¹ Assumes Standard Model value for R_B.

 42 ABREU 93c event count includes $\mu\mu$ events. Combining ee, $\mu\mu$, and e μ events, they obtain 0.100 \pm 0.007 \pm 0.007.

44 ADEVA 91C measure the average B(b → eX) branching ratio using single and double tagged b enhanced Z events. Combining e and μ results, they obtain 0.113 ± 0.010 ± 0.006. Constraining the initial number of b quarks by the Standard Model prediction Colors Constanting the minimal number D quants D the muon result gives $0.123\pm0.003\pm0.006$. They obtain $0.119\pm0.003\pm0.006$ when e and μ results are combined. Used to measure the $b\bar{D}$ width itself, this muon result gives $394\pm9\pm22$ MeV and combined with the electron result gives 385 \pm 7 \pm 22 MeV.

$B^{\pm}/B^{0}/B_{s}^{0}/b$ -baryon ADMIXTURE

Γ(D ⁻ ℓ ⁺ ν _ℓ anything)/Γ _{total} VALUE DOCUMENT ID TECN COMMENT TECN COMMENT	Γ(D ⁰ anything)/Γ _{total} Γ ₁₉ /Γ VALUE DOCUMENT ID TECH COMMENT
VALUE DOCUMENT ID TECN COMMENT 0.0202 \pm 0.0026 \pm 0.0013 45 AKERS 95Q OPAL $e^+e^- \rightarrow Z$	0.601±0.029±0.014 59 BUSKULIC 96Y ALEP e ⁺ e ⁻ → Z
45 AKERS 95Q reports $[B(\overline{b} \rightarrow D^- \ell^+ \nu_\ell \text{anything}) \times B(D^+ \rightarrow K^- \pi^+ \pi^+)] = (1.82 \pm 1.82 \pm 1$	⁵⁹ BUSKULIC 96Y reports 0.605 \pm 0.024 \pm 0.016 for B($D^0 \rightarrow K^- \pi^+$) = 0.0383. We
0.20 ± 0.12) × 10^{-3} . We divide by our best value B($D^+ \rightarrow K^-\pi^+\pi^+$) = (9.0±0.6) ×	rescale to our best value B($D^0 \rightarrow K^-\pi^+$) = (3.85 ± 0.09) × 10 ⁻² . Our first error is
10 ⁻² . Our first error is their experiment's error and our second error is the systematic error from using our best value.	their experiment's error and our second error is the systematic error from using our best value.
$\Gamma(\tilde{D}^0\ell^+\nu_\ell \text{anything})/\Gamma_{\text{total}}$ Γ_{11}/Γ	$\Gamma(D^-$ anything)/ Γ_{total} Γ_{20}/Γ
VALUE DOCUMENT ID TECN COMMENT	$\begin{array}{cccccccccccccccccccccccccccccccccccc$
0.065±0.006±0.001 46 AKERS 95Q OPAL e^+e^- → Z	
⁴⁶ AKERS 95Q reports $[B(\overline{b} \to \overline{D}^0 \ell^+ \nu_\ell \text{ anything}) \times B(D^0 \to K^- \pi^+)] = (2.52 \pm 0.14 \pm 0.17) \times 10^{-3}$. We divide by our best value $B(D^0 \to K^- \pi^+) = (3.85 \pm 0.09) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.	⁶⁰ BUSKULIC 96Y reports $0.234\pm0.013\pm0.010$ for B($D^+ \rightarrow K^-\pi^+\pi^+$) = 0.091. We rescale to our best value B($D^+ \rightarrow K^-\pi^+\pi^+$) = (9.0 \pm 0.6) \times 10 ⁻² . Our first error is their experiment's error and our second error is the systematic error from using our best value.
$\Gamma(D^{*-}\ell^{+}\nu_{\ell} \text{anything})/\Gamma_{\text{total}}$ Γ_{12}/Γ	Γ(D̄sanything)/Γtotal Γ21/Γ
VALUE DOCUMENT ID TECN COMMENT	<u>VALUE</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u> 0.18±0.02±0.04 61 BUSKULIC 96Y ALEP $e^+e^- \rightarrow Z$
0.0276±0.0027±0.0011 47 AKERS 95Q OPAL $e^+e^- → Z$	61 BUSKULIC 96Y reports 0.183 \pm 0.019 \pm 0.009 for B($D_s^+ \rightarrow \phi \pi^+$) = 0.036. We
⁴⁷ AKERS 950 reports $[B(\overline{b} \rightarrow D^* \ell^+ \nu_{\ell} X) \times B(D^{*+} \rightarrow D^0 \pi^+) \times B(D^0 \rightarrow K^- \pi^+)]$	rescale to our best value B($D_s^+ \to \phi \pi^+$) = (3.6 ± 0.9) × 10 ⁻² . Our first error is their
= ((7.53 \pm 0.47 \pm 0.56) \times 10 ⁻⁴) and uses B($D^{*+} \rightarrow D^0 \pi^+$) = 0.681 \pm 0.013 and B($D^0 \rightarrow K^- \pi^+$) = 0.0401 \pm 0.0014 to obtain the above result. The first error is the	experiment's error and our second error is the systematic error from using our best value.
experiments error and the second error is the systematic error from the D^{*+} and D^{0}	
branching ratios.	$\Gamma(b \rightarrow \Lambda_c \text{ anything})/\Gamma_{\text{total}}$ VALUE $\Gamma_{\text{22}}/\Gamma$ $\Gamma_{\text{22}}/\Gamma$
$\Gamma(\overline{D}_i^0 \ell^+ \nu_\ell \text{ anything}) / \Gamma_{\text{total}}$ Γ_{13} / Γ	<u>VALUE</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u> 0.097±0.013±0.025 62 BUSKULIC 96Y ALEP $e^+e^- \rightarrow Z$
D_i represents an unresolved mixture of pseudoscalar and tensor D^{**} (<i>P</i> -wave) states.	62 BUSKULIC 96Y reports $0.110 \pm 0.014 \pm 0.006$ for $B(\Lambda_c^+ \to pK^-\pi^+) = 0.044$. We
VALUE DOCUMENT ID TECH COMMENT	rescale to our best value $B(\Lambda_c^+ \to pK^-\pi^+) = (5.0 \pm 1.3) \times 10^{-2}$. Our first error is
48 AKERS 95Q OPAL e ⁺ e ⁻ → Z	rescale to our best value $B(\Lambda_c^i \to p K^- \pi^+) = (5.0 \pm 1.3) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best
⁴⁸ AKERS 95Q quotes the product branching ratio B($\overline{b} \to \overline{D}_1^0 \ell^+ \nu_{\ell} X$) B($\overline{D}_1^0 \to D^{*+} \pi^-$)	value.
$= ((6.1 \pm 1.3 \pm 1.3) \times 10^{-3}).$	$\Gamma(\overline{c}/canything)/\Gamma_{total}$ Γ_{23}/Γ
,,	VALUE DOCUMENT ID TECN COMMENT
$\Gamma(D_j^-\ell^+\nu_\ell \text{anything})/\Gamma_{\text{total}}$ Γ_{14}/Γ	1.17 ±0.04 OUR AVERAGE 1.147±0.041 63 ABREU 980 DLPH e ⁺ e ⁻ → Z
D _j represents an unresolved mixture of pseudoscalar and tensor D** (P-wave) states. VALUE DOCUMENT ID TECN COMMENT	1.230 \pm 0.036 \pm 0.065 64 BUSKULIC 96Y ALEP $e^+e^- \rightarrow Z$
value DOCUMENT ID TECN COMMENT 49 AKERS 95Q OPAL e^+e^- → Z	63 ABREU 98D results are extracted from a fit to the b-tagging probability distribution
⁴⁹ AKERS 95Q quotes the product branching ratio B($\bar{b} \rightarrow D_f^- \ell^+ \nu_\ell$ anything) B($D_f^- \rightarrow D^0 \pi^-$) = ((7.0 \pm 1.9 $^+$ 1.2) \times 10 $^-$ 3).	based on the impact parameter. ⁶⁴ BUSKULIC 96Y assumes PDG 96 production fractions for B^0 , B^+ , B_s , b baryons, and PDG 96 branching ratios for charm decays. This is sum of their inclusive \overline{D}^0 , D^- , \overline{D}_s , and A_c branching ratios, corrected to include inclusive Ξ_c and charmonium.
$\Gamma(\overline{D}_2^{\bullet}(2460)^0 \ell^+ \nu_{\ell} \text{ anything}) / \Gamma_{\text{total}}$ Γ_{15} / Γ	
VALUE DOCUMENT ID TECN COMMENT	$\Gamma(J/\psi(1S)) = \Gamma(total) $ $\Gamma(J/\psi(1S)) = \Gamma(total) $ $\Gamma(J/\psi(1S)) = \Gamma(total) $
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seen 50 AKERS 95Q OPAL $e^+e^- \rightarrow Z$	VALUE (units 10 ⁻²) CL% EVTS DOCUMENT ID TECN COMMENT
\$\frac{50}{\text{ AKERS}}\$ \$95Q \text{ OPAL } \$e^+e^- \to Z\$ \$\frac{50}{\text{ AKERS}}\$ \$95Q \text{ quotes the product branching ratio } \$B(\overline{b}\) \to \$\overline{D}_2^*(2460)^0 \ell^+\nu_{\ell}\text{ anything}}\$ \$B(D_2^*(2460)^0 \to D^+\pi^-) = (1.6 \pm 0.7 \pm 0.3) \times 10^{-3}.\$	1.16 \pm 0.10 OUR AVERAGE 1.12 \pm 0.12 \pm 0.10 65 ABREU 94P DLPH $e^+e^- \rightarrow Z$ 1.16 \pm 0.16 \pm 0.14 121 66 ADRIANI 93J L3 $e^+e^- \rightarrow Z$
⁵⁰ AKERS 95Q quotes the product branching ratio B($\bar{b} \rightarrow \bar{D}_2^*(2460)^0 \ell^+ \nu_\ell$ anything) B($D_2^*(2460)^0 \rightarrow D^+ \pi^-$) = (1.6 ± 0.7 ± 0.3) × 10 ⁻³ .	1.16 \pm 0.10 OUR AVERAGE 1.12 \pm 0.12 \pm 0.10 65 ABREU 94P DLPH $e^+e^- \rightarrow Z$ 1.16 \pm 0.16 \pm 0.14 121 66 ADRIANI 93J L3 $e^+e^- \rightarrow Z$ 1.21 \pm 0.13 \pm 0.08 BUSKULIC 92G ALEP $e^+e^- \rightarrow Z$
To a kers 95Q quotes the product branching ratio $B(\overline{b} \to \overline{D}_2^*(2460)^0 \ell^+ \nu_\ell$ anything) $B(D_2^*(2460)^0 \to D^+\pi^-) = (1.6 \pm 0.7 \pm 0.3) \times 10^{-3}$. $F(D_2^*(2460)^- \ell^+ \nu_\ell \text{anything}) / \Gamma_{\text{total}} \qquad \qquad \Gamma_{16} / \Gamma_{\text{VALUE}} \qquad \qquad DOCUMENT ID \qquad TECN \qquad COMMENT$	1.16 \pm 0.10 OUR AVERAGE 1.12 \pm 0.12 \pm 0.10 65 ABREU 94P DLPH $e^+e^- \rightarrow Z$ 1.16 \pm 0.16 \pm 0.14 121 66 ADRIANI 93J L3 $e^+e^- \rightarrow Z$ 1.21 \pm 0.13 \pm 0.08 BUSKULIC 92G ALEP $e^+e^- \rightarrow Z$ • • • We do not use the following data for averages, fits, limits, etc. • •
$\begin{array}{c} ^{50}\text{AKERS 95Q quotes the product branching ratio B}(\overline{b} \rightarrow \overline{D}_2^*(2460)^0 \ell^+ \nu_\ell \text{anything}) \\ \text{B}(\mathcal{D}_2^*(2460)^0 \rightarrow \mathcal{D}^+ \pi^-) = (1.6 \pm 0.7 \pm 0.3) \times 10^{-3}. \\ \hline \Gamma(\mathcal{D}_2^*(2460)^- \ell^+ \nu_\ell \text{anything}) / \Gamma_{\text{total}} & \Gamma_{16} / \Gamma_{\text{VALUE}} \\ \hline \nu_{\text{ALUE}} & \underline{DOCUMENT ID} & \underline{TECN} \\ \hline 51 \text{ AKERS} & 95Q \text{ OPAL} & e^+ e^- \rightarrow Z \\ \end{array}$	1.16 \pm 0.10 OUR AVERAGE 1.12 \pm 0.12 \pm 0.10 65 ABREU 94P DLPH $e^+e^- \rightarrow Z$ 1.16 \pm 0.16 \pm 0.14 121 66 ADRIANI 93J L3 $e^+e^- \rightarrow Z$ 1.21 \pm 0.13 \pm 0.08 BUSKULIC 92G ALEP $e^+e^- \rightarrow Z$
To a kers 95Q quotes the product branching ratio $B(\overline{D} \to \overline{D}_2^*(2460)^0 \ell^+ \nu_\ell$ anything) $B(D_2^*(2460)^0 \to D^+ \pi^-) = (1.6 \pm 0.7 \pm 0.3) \times 10^{-3}.$ $F(D_2^*(2460)^- \ell^+ \nu_\ell \text{anything}) / \Gamma_{\text{total}} \qquad \qquad \Gamma_{16} / \Gamma_{\text{VALUE}} $ POCUMENT ID TECN COMMENT	1.16±0.10 OUR AVERAGE 1.12±0.12±0.10 65 ABREU 94P DLPH 1.16±0.16±0.14 121 66 ADRIANI 93J L3 e+e- → Z 94.9 90 MATTEUZZI 83 MRK2 $E_{CM}^{+}=0$ 65 ABREU 94P DLPH $E_{CM}^{+}=0$ $E_{CM}^{+}=0$ $E_{CM}^{+}=0$ $E_{CM}^{+}=0$ 92 ALEP $E_{CM}^{+}=0$ $E_{CM}^{+}=0$ 72 $E_{CM}^{+}=0$ 84.9 90 MATTEUZZI 83 MRK2 $E_{CM}^{+}=0$ 96 ABREU 94P is an inclusive measurement from $E_{CM}^{+}=0$ $E_{CM}^{+}=0$ 97 $E_{CM}^{+}=0$ 85 ABREU 94P is an inclusive measurement from $E_{CM}^{+}=0$ 97 $E_{CM}^{+}=0$ 98 $E_{CM}^{+}=0$ 99 $E_{CM}^{+}=0$ 90 90 $E_{CM}^{+}=0$ 90 $E_{CM}^{+}=0$ 90 90 $E_{CM}^{+}=0$ 90 90 90 90 90 90 90 90 90 90 90 90 90
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$\begin{array}{c} 50 \text{ AKERS } 95Q \text{ quotes the product branching ratio } B(\overline{b} \rightarrow \overline{D}_2^*(2460)^0 \ell^+ \nu_\ell \text{ anything}) \\ B(D_2^*(2460)^0 \rightarrow D^+ \pi^-) = (1.6 \pm 0.7 \pm 0.3) \times 10^{-3}. \\ \hline \Gamma(D_2^*(2460)^- \ell^+ \nu_\ell \text{ anything}) / \Gamma_{\text{total}} & \Gamma_{16} / \Gamma_{\text{VALUE}} \\ \hline Seen & 51 \text{ AKERS } 95Q \text{ OPAL } e^+ e^- \rightarrow Z \\ \hline 51 \text{ AKERS } 95Q \text{ quotes the product branching ratio } B(\overline{b} \rightarrow D_2^*(2460) \ell^+ \nu_\ell \text{ anything}) \\ B(D_2^*(2460)^+ \rightarrow D^0 \pi^-) = 4.2 \pm 1.3 ^{+0.7}_{-1.2}. \\ \hline \Gamma(\tau^+ \nu_\tau \text{ anything}) / \Gamma_{\text{total}} & \Gamma_{17} / \Gamma_{\text{total}} \\ \hline MALUE \text{ DOCUMENT } ID \text{ TECN } \text{ COMMENT} \\ 2.6 \pm 0.4 \text{ OUR AVERAGE} \\ 1.7 \pm 0.5 \pm 1.1 & 52.53 \text{ ACCIARRI} & 96\text{c L3} & e^+ e^- \rightarrow Z \\ 2.4 \pm 0.7 \pm 0.8 & 1032 & 55 \text{ ACCIARRI} & 96\text{c L3} & e^+ e^- \rightarrow Z \\ 2.4 \pm 0.7 \pm 0.8 & 1032 & 55 \text{ ACCIARRI} & 94\text{c L3} & e^+ e^- \rightarrow Z \\ 2.4 \pm 0.7 \pm 0.8 & 1032 & 55 \text{ ACCIARRI} & 94\text{c L3} & e^+ e^- \rightarrow Z \\ 4.08 \pm 0.76 \pm 0.62 & \text{BUSKULIC} & 93\text{B ALEP } \text{ Repl. by BUSKULIC} \\ 52 \text{ ACCIARRI} & 96\text{c result obtained from missing energy spectrum.} \\ 53 \text{ Assumes Standard Model value for } R_B. \\ 54 \text{ BUSKULIC} & 93\text{ be ALEP } \text{ Repl. by BUSKULIC} \\ 55 \text{ This is a direct result using tagged } b\overline{b} \text{ events at the } Z, \text{ but species are not separated.} \\ \hline \Gamma(\overline{b} \rightarrow \overline{C} \rightarrow \ell^- \overline{\nu}_\ell \text{ anything}) / \Gamma_{\text{total}} & \Gamma_{18} / \Gamma_{\text{total}} \\ \hline \nu_{ALUE} & DOCUMENT & D & TECN & COMMENT \\ \hline 0.0778 \pm 0.0000 \text{ OUR AVERAGE} \\ 0.0770 \pm 0.0097 \pm 0.0046 & 56 \text{ ABREU} & 95\text{ DLPH } e^+ e^- \rightarrow Z \\ \hline \end{array}$	1.16±0.10 OUR AVERAGE 1.12±0.12±0.10 1.16±0.16±0.14 1.16±0.16±0.14 1.12±0.13±0.08 BUSKULIC 92c ALEP $e^+e^- \rightarrow Z$ 1.21±0.13±0.08 1.3±0.2±0.2 67 ADRIANI 92 L3 $e^+e^- \rightarrow Z$ 4.9 90 MATTEUZZI 83 MRK2 $E^{ee}_{cm} = 29$ GeV 65 ABREU 94P is an inclusive measurement from b decays at the Z . Uses $J/\psi(15) \rightarrow e^+e^-$ and $J/\psi(15) \rightarrow e^+e^-$ channels. Assumes $\Gamma(Z \rightarrow b\bar{b})/\Gamma_{hadron} = 0.22$. 66 ADRIANI 93 L3 $e^+e^- \rightarrow Z$ 74 ADRIANI 92 L3 $e^+e^- \rightarrow Z$ 85 ABREU 94P is an inclusive measurement from b decays at the Z . Uses $J/\psi(15) \rightarrow e^+e^-$ and $J/\psi(15) \rightarrow e^+e^-$ channels. 66 ADRIANI 93 L3 $e^+e^- \rightarrow Z$ 67 ADRIANI 92 L3 $e^+e^- \rightarrow Z$ 68 ADRIANI 93 L3 $e^+e^- \rightarrow Z$ 68 ADRIANI 93 L3 $e^+e^- \rightarrow Z$ 69 ADRIANI 91 EVTS DOCUMENT ID TECN COMMENT 10 L3 Sept. (25) $\rightarrow J/\psi(15) \rightarrow E^+e^- \rightarrow Z$ 68 ABREU 94P DLPH $e^+e^- \rightarrow Z$ 69 ABREU 94P DLPH $e^+e^- \rightarrow Z$ 0.014±0.006±0.002 69 ABREU 94P DLPH $e^+e^- \rightarrow Z$ 0.014±0.006±0.002 69 ABREU 94P DLPH $e^+e^- \rightarrow Z$ 0.014±0.006±0.002 19 70 ADRIANI 93 L3 $e^+e^- \rightarrow Z$ 0.024±0.009±0.002 19 70 ADRIANI 93 L3 $e^+e^- \rightarrow Z$ Uses $\chi_{c1}(1P) \rightarrow Z$
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	1.16±0.10 OUR AVERAGE 1.12±0.12±0.10 1.16±0.16±0.14 1.11 66 ADRIANI 1.12±0.13±0.08 BUSKULIC 92G ALEP $e^+e^- \rightarrow Z$ 1.21±0.13±0.08 • • We do not use the following data for averages, fits, limits, etc. • • • 1.3 ±0.2 ±0.2 67 ADRIANI 92 L3 $e^+e^- \rightarrow Z$ 4.9 90 MATTEUZZI 83 MRK2 $E^{ee}_{cm} = 29$ GeV 65 ABREU 94P is an inclusive measurement from b decays at the Z . Uses $J/\psi(15) \rightarrow e^+e^-$ and $\mu^+\mu^-$ channels. Assumes $\Gamma(Z \rightarrow b\bar{D})/\Gamma_{hadron} = 0.22$. 66 ADRIANI 93 L3 $e^+e^- \rightarrow Z$ 4.9 90 MATTEUZZI 83 MRK2 $E^{ee}_{cm} = 29$ GeV 65 ABREU 94P is an inclusive measurement from b decays at the Z . Uses $J/\psi(15) \rightarrow e^+e^-$ and $\mu^+\mu^-$ channels. Assumes $\Gamma(Z \rightarrow b\bar{D})/\Gamma_{hadron} = 0.22$. 66 ADRIANI 93 L3 $e^+e^- \rightarrow Z$ 67 ADRIANI 92 L3 $e^+e^- \rightarrow Z$ 68 ADREU 94P is an inclusive measurement from b decays at the Z . Uses $J/\psi(15) \rightarrow \mu^+\mu^-$ and $J/\psi(15) \rightarrow e^+e^-$ channels. 67 ADRIANI 92 L3 $e^+e^- \rightarrow Z$ 4.9 68 ADRIANI 92 L3 $e^+e^- \rightarrow Z$ Uses $J/\psi(15) \rightarrow \mu^+\mu^-$ channels. Fig. (C) MENT 10 (25) anything)/ Γ_{total} 11 DECN 12 DOCUMENT ID 13 DOCUMENT ID 14 DOCUMENT ID 15 DOCUMENT ID 16 DOCUMENT ID 17 DOCUMENT ID 18 DOCUMENT ID 19 DOCUMENT ID 19 DOCUMENT ID 10 DOCUMENT ID 10 DOCUMENT ID 11 DOCUMENT ID 12 DOCUMENT ID 13 DOCUMENT ID 14 DOCUMENT ID 15 DOCUMENT ID 16 DOCUMENT ID 17 DOCUMENT ID 18 DOCUMENT ID 19 DOCUMENT ID 19 DOCUMENT ID 10 DOCUMENT ID 10 DOCUMENT ID 10 DOCUMENT ID 10 DOCUMENT ID 11 DOCUMENT ID 12 DOCUMENT ID 13 DOCUMENT ID 14 DOCUMENT ID 15 DOCUMENT ID 15 DOCUMENT ID 16 DOCUMENT ID 17 DOCUMENT ID 18 DOCUMENT ID 19 DOCUMENT ID 19 DOCUMENT ID 19 DOCUMENT ID 19 DOCUMENT ID 10 DOCUMENT ID 11 DOCUMENT ID 12 DOCUMENT ID 13 DOCUMENT ID 14 DOCUMENT ID 15 DOCUMENT ID 15 DOCUMENT ID 16 DOCUMENT ID 17 DOCUMENT ID 18 DOCUMENT ID 19 DOCUMENT ID 10 DOCU
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(\$γ)/Γ _{total}	C1.44	DOCUMENT IO	TCCN	COMMENT	Γ ₂₇ /Γ
ALUE	<u>CL%</u> _ 90	DOCUMENT ID 72 ADAM	960 DLPH		
< 5.4 × 10 ● ● We do not use t					
< 0.0012	90	73 ADRIANI	93L L3	$e^+e^- \rightarrow Z$	
			,	e · e → 2	
72 ADAM 960 assume					
⁷³ ADRIANI 93L resul	It IS TOT D	→ sγ is periorme	a inclusively.		
$(K^{\pm} \text{ anything})/\Gamma_{b}$	otal				Γ ₂₈ /Γ
ALUE		DOCUMENT ID	TECN	COMMENT	
.88±0.05±0.18		ABREU	95c DLPI	$1 e^+e^- \rightarrow Z$	
(160 ALI) /C					r /r
$(K_S^0 \text{ anything})/\Gamma_{tx}$	otal	DOCUMENT ID	TE C.		Γ ₂₉ /Γ
ALUE .290±0.011±0.027		<u>DOCUMENT ID</u> ABREU		$\begin{array}{c} COMMENT \\ I e^+e^- \rightarrow Z \end{array}$	
		ABREO	99C DEPT	1 e e → 2	
$(\pi^0$ anything)/ Γ_{to}	tal				Γ ₃₀ /Γ
ALUE		DOCUMENT ID	TECN	COMMENT	
.78±0.15±0.60		⁷⁴ ADAM	96 DLPI	$i e^+e^- \rightarrow Z$	
⁷⁴ ADAM 96 measure	ement obta	alned from a fit to	the rapidity	distribtuion of π	0's In $Z ightarrow$
bb events.					
$(p/\overline{p}$ anything $)/\Gamma$					Γ ₃₁ /Γ
ALUE	totai	DOCUMENT ID	TECN	COMMENT	. 21/
.141±0.018±0.056		ABREU		$e^+e^- \rightarrow Z$	
(charged anything)/F _{total}				Γ ₃₂ /Γ
ALUE		DOCUMENT ID		COMMENT	
.97±0.03±0.06		75 ABREU		1 e ⁺ e ⁻ → Z	
We do not use to	the followi	-			
84±0.04±0.38		ABREU		Repl. by ABR	EU 98H
⁷⁵ ABREU 98H measi	urement e	cludes the contrib	ution from F	(O and /I decay.	
(hadron+ hadron-	-) /Fa				Γ ₃₃ /Γ
(madron madron	// . (COCIE)		TECN	COMMENT	. 33/ .
4/ 1/E (in. 10-5)					
		DOCUMENT ID			
ALUE (units 10 ⁻⁵) . 7^{+1.0}±0.2 ⁷⁶ BUSKULIC 96V as	sumes PD	6,77 BUSKULIC	96V ALEF	$e^+e^- \rightarrow Z$ B^0, B^+, B_s, b	
.7+1.0±0.2 76 BUSKULIC 96∨ as 77 Average branching hadrons, weighted	sumes PD fraction by their p	6,77 BUSKULIC G 96 production from weakly decaying	96V ALEF	$e^+e^- \rightarrow Z$ B^0 , B^+ , B_S , b b Into two long-live	ved charged
.7+1.0 -0.7±0.2 76 BUSKULIC 96V as 77 Average branching hadrons, weighted (charmless)/\(\Gamma\)	sumes PD fraction by their p	6,77 BUSKULIC G 96 production frof weakly decaying roduction cross sec	96V ALER actions for I B hadrons tion and life	$e^+e^- \rightarrow Z$ 8^0 , 8^+ , 8_s , b to linto two long-lintimes.	
.7+1.0±0.2 76 BUSKULIC 96∨ as 77 Average branching hadrons, weighted	sumes PD fraction by their p	6,77 BUSKULIC G 96 production from weakly decaying	96V ALER actions for I B hadrons tion and life	$e^+e^- \rightarrow Z$ 8^0 , 8^+ , 8_S , b in the two long-like times.	ved charged
.7+1.0+0.2 76 BUSKULIC 96V as 77 Average branching hadrons, weighted (charmless)/Ftotal ALUE	sumes PD fraction by their p	6,77 BUSKULIC G 96 production frof weakly decaying roduction cross second to the control of the	96V ALEF actions for It B hadrons tion and life TECN 98D DLPI to the b-tag	$e^+e^- \rightarrow Z$ g^0 , g^+ , g_s , g_s by into two long-like times. COMMENT $e^+e^- \rightarrow Z$ Ging probability	Γ ₃₄ /Γ
.7+1.0 ± 0.2 77-0.7 ± 0.2 77 Average branching hadrons, weighted (charmless)/\(\tau_{\text{tota}}\) 6.007±0.021 78 ABREU 98D result based on the impachas been subtracted	sumes PD fraction by their p	6,77 BUSKULIC G 96 production frof weakly decaying roduction cross second to the control of the	96V ALEF actions for It B hadrons tion and life TECN 98D DLPI to the b-tag	$e^+e^- \rightarrow Z$ g^0 , g^+ , g_s , g_s by into two long-like times. COMMENT $e^+e^- \rightarrow Z$ Ging probability	Γ ₃₄ /Γ distribution 026 ± 0.004
7-1.0 ± 0.2 7-0.7 ± 0.2 7-0.7 ± 0.2 7-7 Average branching hadrons, weighted (charmless)/\(\Gamma_{\text{tota}}\) 6-1.007 ± 0.021 7-8 ABREU 98D result based on the impachas been subtracte (\(\Lambda/\lambda\) anything\)/\(\Gamma_{\text{tota}}\)	sumes PD fraction by their p	6,77 BUSKULIC G 96 production frof weakly decaying roduction cross sec DOCUMENT ID 78 ABREU racted from a fit ter. The expected hi	96V ALEF ractions for II (B hadrons tion and life TECN 98D DLPI to the b-tag	$e^+e^- \rightarrow Z$ 8^0 , B^+ , B_S , b b into two long-livitimes. COMMENT $1 e^+e^- \rightarrow Z$ ging probability contribution of 0	Γ ₃₄ /Γ distribution 026 ± 0.004
.7+1.0±0.2 77 6 BUSKULIC 96V as 77 Average branching hadrons, weighted (charmless)/\(\Gamma\) total 44UE .007±0.021 78 ABREU 98D result based on the Impachas been subtracte (\((\Lambda/\)\) Amything\(()/\) \(\Gamma\)	sumes PD fraction by their p	6,77 BUSKULIC G 96 production fro f weakly decaying roduction cross sec DOCUMENT ID 78 ABREU racted from a fit t er. The expected hi	96V ALEF ractions for II (B hadrons tion and life TECN 98D DLPI to the b-tag	$e^+e^- \rightarrow Z$ g^0 , g^+ , g_s , g_s by into two long-like times. COMMENT $e^+e^- \rightarrow Z$ Ging probability	Γ ₃₄ /Γ distribution 026 ± 0.004
77+1.0±0.2 76 BUSKULIC 96V as 77 Average branching hadrons, weighted (charmless)/\(\Gamma\) total 44UE .007±0.021 78 ABREU 98D result based on the impachas been subtracte (\(\Lambda/\Lambda/\Lambda\) anything)/\(\Gamma\)	fraction of the polynomial of	6,77 BUSKULIC G 96 production fro f weakly decaying roduction cross sec DOCUMENT ID 78 ABREU racted from a fit t er. The expected hi	96V ALEF actions for It, B hadrons tition and life IECN 98D DLPI to the b-tag didden charm IECN F 97N OPA	$e^+e^- \rightarrow Z$ g^0 , g^+ , g_s , b b into two long-livitimes. COMMENT $e^+e^- \rightarrow Z$ ging probability contribution of 0 COMMENT $e^+e^- \rightarrow Z$	Γ ₃₄ /Γ distribution 026 ± 0.004
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7+1.0 ± 0.2 76 BUSKULIC 96V as 77 Average branching hadrons, weighted (charmless)/\(\Gamma\) total ALUE 007±0.021 78 ABREU 98D result based on the impachas been subtracted (\(\Lambda/\sigma\) Anything\)/\(\Gamma\)/\(\Gamma\) 0587±0.0046±0.004 (\(\Gamma\) + 0.007 (\(\Gamma\) + 0.007 (\(\Gamma\) + 0.007 (\(\Gamma\) + 0.007	ts are extit parameted. total AVERAGE 48 9	6,77 BUSKULIC G 96 production for weakly decaying roduction cross second and the second secon	96V ALEF actions for It B hadrons tion and life IECN 98D DLPI o the b-tag idden charm IECN F 97N OPA	$e^+e^- \rightarrow Z$ g^0 , g^+ , g_s , b b into two long-livitimes. COMMENT $e^+e^- \rightarrow Z$ ging probability contribution of 0 COMMENT $e^+e^- \rightarrow Z$	Γ34/Γ distribution 026±0.004
7+1.0 ± 0.2 76 BUSKULIC 96V as 77 Average branching hadrons, weighted (charmless) / Γ total 44UE	ts are extit parameted. total AVERAGE 48 9	6,77 BUSKULIC G 96 production for weakly decaying roduction cross second and the second secon	96V ALEF actions for It B hadrons tition and life TECN 98D DLPI to the b-tag didden charm TECN F 97N OPAL	$e^+e^- \rightarrow Z$ g^0 , g^+ , g_s , b b into two long-livitimes. COMMENT $e^+e^- \rightarrow Z$ ging probability contribution of 0 COMMENT $e^+e^- \rightarrow Z$	Γ34/Γ distribution 026±0.004
7+1.0 ± 0.2 7-0.7 ± 0.2 76 BUSKULIC 96V as 77 Average branching hadrons, weighted (charmless)/\(\Gamma\) total 44.0E .007 ± 0.021 78 ABREU 98D result based on the impachas been subtracte (\(A/\overline{A}\) anything)/\(\Gamma\) 6.059 ± 0.004 6 ± 0.00 6.059 ± 0.007 ± 0.00 (\(\psi\) \(\psi\) anything) Test for \(\Delta\) B = 34.0E 6.3.2 × 10-4	ts are extit parameted. total AVERAGE 48 9 / Total 1 week nei	6,77 BUSKULIC G 96 production for weakly decaying roduction cross seconduction and seconduction and seconduction and seconduction cross seconduction and seconduct	96V ALER actions for I B hadrons tion and life TECN 98D DLPI o the b-tag idden charm F 97N OPA 95C DLPI 98B DO	$e^+e^- \rightarrow Z$ s^0 , s^+ , s_s , b is into two long-livitimes. COMMENT $e^+e^- \rightarrow Z$ s^0 , s^+ , s_s , b is into two long-livitimes. COMMENT $e^+e^- \rightarrow Z$ s^0 ,	Γ34/Γ distribution 026±0.004
7+1.0 ± 0.2 7-0.7 ± 0.2 76 BUSKULIC 96V as 77 Average branching hadrons, weighted (charmless)/\(\Gamma\) total 44.0E .007 ± 0.021 78 ABREU 98D result based on the impachas been subtracte (\(A/\overline{A}\) anything)/\(\Gamma\) 6.059 ± 0.004 6 ± 0.00 6.059 ± 0.007 ± 0.00 (\(\psi\) \(\psi\) anything) Test for \(\Delta\) B = 34.0E 6.3.2 × 10-4	ts are extit parameted. total AVERAGE 48 9 / Total 1 week nei	6,77 BUSKULIC G 96 production for weakly decaying roduction cross seconduction and seconduction and seconduction and seconduction cross seconduction and seconduct	96V ALER actions for I B hadrons tion and life TECN 98D DLPI o the b-tag dden charm F 97N OPA 95C DLPI 98B DO	$e^+e^- \rightarrow Z$ s^0 , s^+ , s_s , b is into two long-livitimes. COMMENT $e^+e^- \rightarrow Z$ s^0 , s^+ , s_s , b is into two long-livitimes. COMMENT $e^+e^- \rightarrow Z$ s^0 ,	Γ34/Γ distribution 026±0.004
7+1.0 ± 0.2 7-0.7 ± 0.2 76 BUSKULIC 96V as 77 Average branching hadrons, weighted (charmless) / Γ total 44.0E .007 ± 0.021 78 ABREU 98D result based on the impact has been subtracted has been subtracted with the control of	ts are extit parameted. total AVERAGE 48 9 / Total 1 week nei	6,77 BUSKULIC G 96 production for weakly decaying roduction cross seconduction and seconduction and seconduction and seconduction cross seconduction and seconduct	96V ALER actions for I B hadrons tion and life TECN 98D DLPI o the b-tag dden charm F 97N OPA 95C DLPI 98B DO	$e^+e^- \rightarrow Z$ s^0 , s^+ , s_s , b is into two long-livitimes. $\frac{COMMENT}{1} + e^+e^- \rightarrow Z$ ging probability contribution of 0 $\frac{COMMENT}{1} = e^+e^- \rightarrow Z$ $e^+e^- \rightarrow Z$ $e^+e^- \rightarrow Z$ $\frac{COMMENT}{p\bar{p}} 1.8 \text{ TeV}$ s, etc. • • •	
7+1.0 ± 0.2 7-0.7 ± 0.2 76 BUSKULIC 96V as 77 Average branching hadrons, weighted (charmless) / Γ total 44.02	ts are extra total AVERAGE 48 9 / Total 1 weak net CLY 90 the follow	6,77 BUSKULIC G 96 production for weakly decaying roduction cross seconduction and seconduction and seconduction and seconduction and seconduction cross seconduction and seconduct	96V ALEF actions for It B hadrons tion and life TECN 98D DLPI to the b-tag dden charm IECN F 97N OPA 95C DLPI 98B DO es, fits, limit 91C UA1	$e^+e^- \rightarrow Z$ s^0 , s^+ , s_s , b is into two long-livitimes. $\frac{COMMENT}{1} + e^+e^- \rightarrow Z$ $\frac{COMMENT}{2} + \frac{COMMENT}{2} + COM$	red charged T34/
7+1.0 ± 0.2 7-0.7 ± 0.2 76 BUSKULIC 96V as 77 Average branching hadrons, weighted with the second secon	ts are extit paramet dd. total AVERAGE 48 9 / Total 1 weak net	6,77 BUSKULIC G 96 production for weakly decaying roduction cross seconduction and the seconduction are seconduction as a seconduction are seconduction as a seconduction are secon	96V ALEF actions for It B hadrons tition and life TECN 98D DLPI o the b-tag idden charm IECN F 97N OPA 95C DLPI 98B DO es, fits, limit 91C UA1 84G TASS	$e^+e^- \rightarrow Z$ 50 , B^+ , B_5 , b b into two long-like itimes. COMMENT $e^+e^- \rightarrow Z$ ging probability contribution of 0 COMMENT $e^+e^- \rightarrow Z$ $e^+e^- \rightarrow Z$ $e^+e^- \rightarrow Z$ $e^+e^- \rightarrow Z$ $e^-e^- \rightarrow Z$	red charged T34 F
7+1.0 ± 0.2 7-0.7 ± 0.2 76 BUSKULIC 96V as 77 Average branching hadrons, weighted (charmless)/Γ total ALUE .007±0.021 78 ABREU 98D result based on the impachas been subtracted (Δ//λanything)/Γ .0587±0.0046±0.00 .059 ±0.007 ±0.00 (μ+μ-anything) Test for ΔB = 1 ALUE .050.2 × 10-5 .0002 .0007	ts are extit parameted. total AVERAGE 48 9 / Total 1 weak net	6,77 BUSKULIC G 96 production fro f weakly decaying roduction cross second cross se	96V ALEF actions for It B hadrons tion and life TECN 98D DLPI O the b-tag idden charm TECN F 97N OPA 95C DLPI 98B DO es, fits, limit 91C UA1 84G TASS 83 MRK	$e^+e^- \rightarrow Z$ s^0 , s^+ , s_s , b is into two long-livitimes. $\frac{COMMENT}{1} + e^+e^- \rightarrow Z$ $\frac{COMMENT}{2} + \frac{COMMENT}{2} + COM$	F34/F distribution 026±0.004 F35/F F37/F eV GeV
7+1.0 ± 0.2 7-0.7 ± 0.2 7-0.	ts are extitured at the same substitute of th	6,77 BUSKULIC G 96 production frof weakly decaying roduction cross second control of	96V ALEF actions for It B hadrons tion and life IECN 98D DLPI O the b-tag idden charm IECN F 97N OPA 95C DLPI 98B DO es, fits, limit 91C UA1 84G TASS 83 MRK 83B JADI	$e^+e^- \rightarrow Z$ s^0 , s^+ , s_s , b b into two long-like times. COMMENT $e^+e^- \rightarrow Z$ ging probability contribution of 0 COMMENT $e^+e^- \rightarrow Z$ $e^-e^- \rightarrow Z$	F34/F distribution 026±0.004 F35/F F37/F eV GeV GeV GeV
7+1.0 ± 0.2 7-0.7 ± 0.2 76 BUSKULIC 96V as 77 Average branching hadrons, weighted (charmless) / Γ total MUE 907 ± 0.021 78 ABREU 98D result based on the impachas been subtracte (Λ/Λanything) / Γ 44.05 9059 ± 0.006 OUR 10587 ± 0.0046 ± 0.00 1059 ± 0.007 ± 0.00 (μ+ μ- anything) Test for ΔB = 3 44.05 3.2 × 10-4 • We do not use (5.0 × 10-5 (0.02 10.007 79 Both ABBOTT 95 was overestimated	ts are extra total AVERAGE 48 9 / Total 1 weak net 90 90 95 95 95 98 and GL by a large	6,77 BUSKULIC G 96 PRODUCTION for weakly decaying roduction cross second control of the	96V ALEF actions for It, B hadrons tion and life IECN 98D DLPI to the b-tag idden charm F 97N OPAI 95C DLPI 7ECN 98B DO es, fits, limit 91C UA1 84G TAS: 83 MRK 83B JADI t the efficient	$e^+e^- \rightarrow Z$ s^0 , s^+ , s_s , b b into two long-livitimes. $\frac{COMMENT}{e^+e^- \rightarrow Z}$ ging probability contribution of 0 $\frac{COMMENT}{e^+e^- \rightarrow Z}$ $e^+e^- \rightarrow Z$ $e^+e^- \rightarrow Z$ $\frac{COMMENT}{p\bar{p}} = 530 \text{ G}$ $s^- \in E^{\text{CM}}_{\text{CM}} = 30-38$	red charged T34 T
7+1.0 ± 0.2 76 BUSKULIC 96V as 77 Average branching hadrons, weighted (charmless)/Γtotal 44.02 .007±0.021 78 ABREU 98D result based on the impachas been subtracted has been subtracted to the impachas been subtracted has been subtracted to the impachas been subtracted has been subtracted to the impachas been subtracted has been subtracted to the impachas been subtracted to	total AVERAGE 49 / Ttotal 1 weak net 20 90 95 95 95 98 Band GL by a large + \(\(\(\(\mu^+ \) \) \)	6,77 BUSKULIC G 96 production for weakly decaying roduction cross seconduction and seconduction cross seconduction and seconduction and seconduction and seconduction cross seconduction and seconduction and seconduction cross seconduction and secondu	96V ALEF actions for It, B hadrons tion and life IECN 98D DLPI to the b-tag idden charm F 97N OPAI 95C DLPI 7ECN 98B DO es, fits, limit 91C UA1 84G TAS: 83 MRK 83B JADI t the efficient	$e^+e^- \rightarrow Z$ s^0 , s^+ , s_s , b b into two long-livitimes. $\frac{COMMENT}{e^+e^- \rightarrow Z}$ ging probability contribution of 0 $\frac{COMMENT}{e^+e^- \rightarrow Z}$ $e^+e^- \rightarrow Z$ $e^+e^- \rightarrow Z$ $\frac{COMMENT}{p\bar{p}} = 530 \text{ G}$ $s^- \in E^m_{cm} = 34.5 \text{ G}$ $s^- \in E^m_{cm} = 34.5 \text{ G}$ $s^- \in E^m_{cm} = 33-37$	red charged T34 T
77+1.0 ± 0.2 77-0.7 ± 0.2 77-6 BUSKULIC 96V as 77 Average branching hadrons, weighted (charmless) / Γ total 44.0E .007±0.021 78 ABREU 98D result based on the impachas been subtracte (A/ Λ anything) / Γ 44.0E .0587±0.0046±0.00 .059±0.007 ±0.007 (μ + μ -anything) Test for $\Delta B = \frac{1}{2}$ 40.02 40.0307 40.007 79 Both ABBOTT 98 was overestimated Γ (e+e-anything) Test for $\Delta B = \frac{1}{2}$	ts are extit paramet d. total AVERAGE 48 9 / Total 1 weak net	6,77 BUSKULIC G 96 production for weakly decaying roduction cross seconduction and seconduction cross seconduction and seconduction and seconduction and seconduction cross seconduction and seconduction and seconduction cross seconduction and secondu	96V ALER 98D DLPI 0 the b-tag idden charm F 97N OPA 95C DLPI 98B DO 98B DO 99C UA1 84G TAS: 83 MRK 83B JADI t the efficient	$e^+e^- \rightarrow Z$ s^0 , s^+ , s_s , b into two long-livings. $\frac{COMMENT}{e^+e^- \rightarrow Z}$ s^0 , s^+ , s_s , b into two long-livings. $\frac{COMMENT}{e^+e^- \rightarrow Z}$ s^0 ,	red charged T34 T
7+1.0 ± 0.2 7-0.7 ± 0.2 76 BUSKULIC 96V as 77 Average branching hadrons, weighted (charmless)/\(\Gamma\) total ALUE .007 ± 0.021 78 ABREU 98D result based on the impachas been subtracted with the subtracted of the impachas been subtracted. (A/\(\Tanything\))/\(\Gamma\) (587 ± 0.0046 ± 0.00-0.059 ± 0.007 ± 0.007 (\(\mu^+\mu^-\text{anything}\)) Test for $\Delta B = \frac{1}{2}$ ALUE 2.3.2 × 10-4 • We do not use considered was overestimated. (5.0 × 10-5 considered was overestimated. (e+e-\text{anything}\) Test for $\Delta B = \frac{1}{2}$	ts are extit parametric. total AVERAGE 48 9 / Total 1 weak nei 90 95 95 98 and GL by a large 1 weak nei	6,77 BUSKULIC G 96 production fro weakly decaying roduction cross second control of weakly decaying roduction cross second control of weakly decaying roduction cross second control of weakly decaying roduction and respected his control of the expected hi	96V ALEF actions for I B hadrons tion and life TECN 98D DLPI O the b-tag idden charm IECN 98D DLPI 7 F 97N OPA 98C DLPI 98D DL 98D DLPI 1 ECN 98D DLPI 1 ECN 98D DLPI 1 ECN 98D DLPI 1 ECN 98D DLPI 1 ECN 98D DLPI 1 ECN	$e^+e^- \rightarrow Z$ s^0 , s^+ , s_s , b b into two long-like times. COMMENT $e^+e^- \rightarrow Z$ ging probability contribution of 0 COMMENT $e^+e^- \rightarrow Z$ $e^-e^- \rightarrow Z$ e	red charged T34 T
7-1.0 ± 0.2 7-0.7 ± 0.2 76 BUSKULIC 96V as 77 Average branching hadrons, weighted (charmless)/Γ total ALUE	ts are extit parametric distribution of the following series of the following	6,77 BUSKULIC G 96 production fro weakly decaying roduction cross second control of weakly decaying roduction cross second control of weakly decaying roduction cross second control of weakly decaying roduction and respected his control of the con	96V ALEF actions for It B hadrons tition and life TECN 98D DLPI o the b-tag idden charm IECN 98D DLPI TECN 100 T	$e^+e^- \rightarrow Z$ 50 , B^+ , B_5 , b b into two long-like times. COMMENT $e^+e^- \rightarrow Z$ ging probability contribution of 0 COMMENT $e^+e^- \rightarrow Z$ $e^-e^- \rightarrow Z$	F34/F distribution 026±0.004 F35/F F37/F eV GeV GeV GeV BAJAR 916
7+1.0 ± 0.2 7-0.7 ± 0.2 7-0.7 ± 0.2 7-0.7 ± 0.2 7-0.7 ± 0.2 7-0.7 ± 0.20 7-0.7 ± 0.20 8-0.00	ts are extit parametric. total AVERAGE 48 9 / Total 1 weak nei 90 95 95 98 and GL by a large 1 weak nei	6,77 BUSKULIC G 96 production fro weakly decaying roduction cross second control of weakly decaying roduction cross second control of weakly decaying roduction cross second control of weakly decaying roduction and respected his control of the con	96V ALEF actions for It B hadrons tition and life TECN 98D DLPI o the b-tag idden charm IECN 98D DLPI TECN 100 T	$e^+e^- \rightarrow Z$ s^0 , s^+ , s_s , b b into two long-like times. COMMENT $e^+e^- \rightarrow Z$ ging probability contribution of 0 COMMENT $e^+e^- \rightarrow Z$ $e^-e^- \rightarrow Z$ e	F34/F distribution 026±0.004 F35/F F37/F eV GeV GeV GeV BAJAR 916
77+1.0 ± 0.2 77-0.7 ± 0.2 77-6 BUSKULIC 96V as 77 Average branching hadrons, weighted (charmless) / Γ total 44.0E .007±0.021 78 ABREU 98D result based on the impact has been subtracted. Alone 1.0589 ± 0.0046 ± 0.000.059 ± 0.007 ± 0.007 (μ + μ -anything) / Γ Test for $\Delta B = \frac{1}{2}$ ALOE <0.007 79 Both ABBOTT 98 was overestimated. Γ (e^+e^- anything) Test for $\Delta B = \frac{1}{2}$ Test for $\Delta B = \frac{1}{2}$ ALOE • • We do not use Γ (e^+e^- anything) Test for $\Delta B = \frac{1}{2}$ Test for $\Delta B = \frac{1}{2}$ ALOE • • We do not use Γ (e^+e^- anything) Test for $\Delta B = \frac{1}{2}$ ALOE • • We do not use Γ (e^+e^- anything) Test for $\Delta B = \frac{1}{2}$ ALOE • • We do not use Γ (e^+ 0.008	ts are extraction of by their p I ts are extracted. total AVERAGE 48 9 / Ftotal 1 weak net 2L% 90 the follow 90 95 95 95 88 and GL by a large 1 weak net 2L% 1 weak net 2L% 1 weak net 90 90	6,77 BUSKULIC G 96 production fro weakly decaying roduction cross second control of weakly decaying roduction cross second control of weakly decaying roduction cross second control of weakly decaying roduction and respected his control of the expected hi	96V ALEF actions for It B hadrons tition and life TECN 98D DLPI o the b-tag idden charm IECN 98D DLPI TECN 100 T	$e^+e^- \rightarrow Z$ 50 , B^+ , B_5 , b b into two long-like times. COMMENT $e^+e^- \rightarrow Z$ ging probability contribution of 0 COMMENT $e^+e^- \rightarrow Z$ $e^-e^- \rightarrow Z$	red charged T34/ distribution 026±0.004 T35/ T37/ eV GeV GeV GeV BAJAR 910 W
7-1.0 ± 0.2 77-0.7 ± 0.2 76 BUSKULIC 96V as 77 Average branching hadrons, weighted (charmless) / Γ total 44.0E .007 ± 0.021 78 ABREU 98D result based on the impachas been subtracted has been subtracted. (A/Aanything) / Γ 44.0E .0587 ± 0.0046 ± 0.00 .059 ± 0.007 ± 0.007 (μ+μ-anything) Test for ΔB = 34.0E 4.0007 4.0007 79 Both ABBOTT 98 was overestimated of (e+e-anything) Test for ΔB = 34.0E 4.0007 Test for ΔB = 34.0E 4.0007 79 Both ABBOTT 98 was overestimated of (e+e-anything) Test for ΔB = 34.0E 4.0008	ts are extraction of by their p I ts are extracted. total AVERAGE 48 9 / Ftotal 1 weak net 2L% 90 the follow 90 95 95 95 88 and GL by a large 1 weak net 2L% 1 weak net 2L% 1 weak net 90 90	6,77 BUSKULIC G 96 production fro weakly decaying roduction cross second control of weakly decaying roduction cross second control of weakly decaying roduction cross second control of weakly decaying roduction and respected his control of the expected hi	96V ALER 98b DLPI o the b-tag dden charm F 97n OPA 95c DLPI 98B DO es, fits, limit 91c UA1 846 TAS: 83 MRK 83B JADi t the efficien es, fits, limit 83 MRK	$e^+e^- \rightarrow Z$ s^0 , s^+ , s_s , b is into two long-like times. $\frac{COMMENT}{1} + e^+e^- \rightarrow Z$ $\frac{COMMENT}{2} + \frac{e^+e^-}{2} + \frac{e^-e^-}{2} + \frac{e^-e^-}{2}$ $\frac{COMMENT}{2} + \frac{e^-e^-}{2} + \frac{e^-e^-}{2} + \frac{e^-e^-}{2}$ $\frac{COMMENT}{2} + \frac{e^-e^-}{2} + \frac{e^-e^-}{2} + \frac{e^-e^-}{2}$ $\frac{COMMENT}{2} + \frac{e^-e^-}{2} + \frac{e^-e^-}{2$	red charged T34/ distribution 026±0.004 T35/ T37/ eV GeV GeV GeV BAJAR 910 W
7-1.0 ± 0.2 77-0.7 ± 0.2 76 BUSKULIC 96V as 77 Average branching hadrons, weighted (charmless) / Γ total ALUE .007 ± 0.021 78 ABREU 98D result based on the impact has been subtracted has been subtra	ts are extit paramet dd. total AVERAGE 48 9 / Total 1 weak nei - CL% 58 and GL 59 a large 1 weak nei - CL% 1 weak n	6,77 BUSKULIC G 96 production frof weakly decaying roduction cross secondary and the secondary s	96V ALER 96V ALER 16 hadrons 17 hadron 18 hadrons 18 hadrons 18 hadrons 18 hadrons 18 hadrons 18 hadron 18 h	$e^+e^- \rightarrow Z$ s^0 , s^+ , s_s , b into two long-livings. COMMENT $e^+e^- \rightarrow Z$ ging probability contribution of 0 COMMENT $e^+e^- \rightarrow Z$ $e^- \rightarrow Z$	F34/F distribution 026±0.004 F35/F F37/F eV GeV GeV GeV BAJAR 910
77-1.0 ± 0.2 77-0.7 ± 0.2 77-0.7 ± 0.2 77-0.7 ± 0.2 77-0.7 ± 0.2 77-0.7 ± 0.2 78-0.2 ± 0.001 78-0.2 ± 0.002 78-0.2 ± 0.004 78-0.0 ± 0.004 78	ts are extit paramet dd. total AVERAGE 48 9 / Total 1 weak nei - CL% 58 and GL 59 a large 1 weak nei - CL% 1 weak n	6,77 BUSKULIC G 96 production frof weakly decaying roduction cross secondary and the secondary s	96V ALEF 96V ALEF actions for I B hadrons tion and life TECN 98D DLPI o the b-tag diden charm IECN 98E DD 98E DD 98E DD 98E DD 18E DD 98E DD 18E	$e^+e^- \rightarrow Z$ s^0 , s^+ , s_s , b into two long-livings. COMMENT $e^+e^- \rightarrow Z$ ging probability contribution of 0 COMMENT $e^+e^- \rightarrow Z$ $e^- \rightarrow Z$	red charged T34/ distribution 026±0.004 T35/ T37/ eV GeV GeV GeV BAJAR 910 W
7+1.0 ± 0.2 7-0.7 ± 0.2 7-0.7 ± 0.2 7-0.7 ± 0.2 7-0.7 ± 0.2 7-0.7 ± 0.2 7-0.7 ± 0.2 7-0.7 ± 0.2 8-0.0 ± 0.0 8-0.0 ± 0.0 8-0.0 ± 0.0 9-0.0 ± 0.0 9-0.0 ± 0.0 9-0.0 ± 0.0 9-0.0 ± 0.0 9-0.0 ± 0.0 9-0.0 ± 0.0 9-0.0 ± 0.0 9-0.0 ± 0.0 9-0.0 9-0.0 ± 0.0 1-0.0	ts are extituted by their p is are extituted. total AVERAGE 49 / Ttotal 1 weak nei	6,77 BUSKULIC G 96 production frof weakly decaying roduction cross second control of weakly decaying a BAREU DOCUMENT ID ABBOTT Ing data for averag roduction control of the control of t	96V ALEF 96V ALEF actions for I B hadrons tion and life TECN 98D DLPI o the b-tag idden charm IECN 98E DD 98E DD 98E DD 98E DD 18E DD 98E DD 18E	$e^+e^- \rightarrow Z$ 50 , 8^+ , 8_5 , b b into two long-like times. COMMENT $e^+e^- \rightarrow Z$ ging probability contribution of 0 COMMENT $e^+e^- \rightarrow Z$	red charged Ta4 F

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ABBOTT	98B	PL B423 419	B. Abbott+	(D0 Collab.)
ABE	98B	PR D57 5382	F. Abe+	(CDF Collab.)
ABREU	98D	PL B426 193	P. Abreu+	(DELPHI Collab.)
ABREU	98H	PL B425 399	P. Abreu+	(DELPHI Collab.)
ACCIARRI	98	PL B416 220	M. Acciarri+	(L3 Collab.)
GLENN	98	PRL 80 2289	S. Glenn+	(CLÈO Collab.)
ACKERSTAFF	97F	7PHY C73 397	+Alexander, Allison, Ametewee+	(OPAL Collab.)
ACKERSTAFF		ZPHY C73 397 ZPHY C74 423	K. Ackerstaff+	(OPAL Collab.)
	96E	PL B377 195		(DELPHI Collab.)
ABREU			+Adam, Adye, Agasi+	
ACCIARRI	96C	ZPHY C71 379	+Adam, Adriani, Aguilar-Benitez+	(L3 Collab.)
ADAM	96	ZPHY C69 561	+Adye, Agasi, Ajinenko+	(DELPHI Collab.)
ADAM	96D	ZPHY C72 207	W. Adam+	(DELPHI Collab.)
BUSKULIC	96F	PL B369 151	+Casper, De Bonis, Decamp+	(ALEPH Collab.)
BUSKULIC		PL B384 471	+De Bonis, Decamp, Ghez+	(ALEPH Collab.)
BUSKULIC	96Y	PL B388 648	+De Bonis, Decamp, Ghez+	(ALEPH Collab.)
GROSSMAN	96	NP B465 369	+Ligeti, Nardi	(REHO, CIT)
Also	968	NP B480 753 (erra	tum)	
PDG	96	PR D54 1	,	
UENO	96	PL B381 365	+Kanda, Olsen, Kirk+	(AMY Collab.)
ABE,K	95B	PRL 75 3624	Abe, Abt, Ahn, Akagi+	(SLD Collab.)
				(DELPHI Collab.)
ABREU	95C	PL B347 447	+Adam, Adye, Agasi+	(DELFIII Collab.)
ABREU	95D	ZPHY C66 323	+Adam, Adye, Agasi+	(DELPHI Collab.)
ADAM	95	ZPHY C68 363	+Adye, Agasi, Ajinenko+	(DELPHI Collab.)
AKERS		ZPHY C67 57	+Alexander, Allison, Ametewee+	(OPAL Collab.)
BUSKULIC	95	PL B343 444	+Casper, De Bonis, Decamp, Ghez, Goy	+ (ALEPH Collab.)
ABREU	94L	ZPHY C63 3	+Adam, Adye, Agasi, Aleksan+	(DELPHI Collab.)
ABREU	94P	PL B341 109	+Adam, Adye, Agasi, Ajinenko+	(DELPHI Collab.)
ACCIARRI	94C	PL B332 201	+Adam, Adriani, Aguilar-Benitez, Ahlen+	- ` (L3 Collab.)
BUSKULIC	94G	ZPHY C62 179	+Casper, De Bonis, Decamp, Ghez+	(ALEPH Collab.)
ABE	93E	PL B313 288	+Amako, Arai, Arima, Asano+	A/ENHIS Collab)
ABE	93J	PRL 71 3421	+Albrow, Amidei, Anway-Wiese+	(CDF Collab.)
ABREU	93C	PL B301 145	Adam Adva Agasi Aleksan I	(DELPHI Collab.)
		PL D301 143	+Adam, Adye, Agasi, Aleksan+	
ABREU	93D	ZPHY C57 181	+Adam, Adye, Agasi, Alekseev+	(DELPHI Collab.)
ABREU	93G	PL B312 253 PL B307 247	+Adam, Adye, Agasi, Ajinenko+	(DELPHI Collab.)
ACTON	93C	PL B307 247	+Alexander, Allison, Allport, Anderson+	(OPAL Collab.)
ACTON	93L	ZPHY C60 217	+Akers, Alexander, Allison, Anderson+	(OPAL Collab.)
ADRIANI	93 J	PL B317 467	+Aguilar-Benitez, Ahlen, Alcaraz+	(L3 Collab.)
ADRIANI	93K	PL B317 474	+Aguilar-Benitez, Ahlen, Alcarez+	(L3 Collab.)
ADRIANI	93L	PL B317 637	+Aguilar-Benitez, Ahlen, Alcaraz+	(L3 Collab.)
AKERS	93B	ZPHY C60 199	+Alexander, Allison, Anderson, Arcelli+	(OPAL Collab.)
BUSKULIC	93B	PL B298 479	+Decamp, Goy, Lees, Minard+	(ALEPH Collab.)
BUSKULIC		PL B314 459	+De Bonis, Decamp, Ghez, Goy+	(ALEPH Collab.)
	92	ZPHY C53 567	+Adam, Adami, Adye+	(DELPHI Collab.)
ABREU				(OPAL Collab.)
ACTON	92	PL 8274 513	+Alexander, Allison, Allport, Anderson+	
ADRIANI	92	PL 8288 412	+Aguilar-Benitez, Ahlen, Akbari+	(L3 Collab.)
BUSKULIC	92F	PL B295 174	+Decamp, Goy, Lees, Minard+	(ALEPH Collab.)
BUSKULIC	92G	PL B295 396	+Decamp, Goy, Lees, Minard+	(ALEPH Collab.)
ADEVA	91C	PL B261 177	+Adriani, Aguitar-Benitez, Akbari+	(L3 Collab.)
ADEVA	91H	PL B270 111	+Adrani, Aguilar-Benitez, Akbari, Alcara:	r+ (L3 Collab.)
ALBAJAR	91C	PL B262 163	+Albrow, Allkofer, Ankoviak, Apsimon+	(UA1 Collab.)
ALEXANDER	91G	PL B266 485	+Allison, Allport+	(OPAL Collab.)
DECAMP	91C	PL B257 492	+Deschizeaux, Goy, Lees, Minard+	(ALEPH Collab.)
BEHREND	900	ZPHY C47 333	+Criegee, Field, Franke, Jung+	(CELLO Collab.)
HAGEMANN		ZPHY C48 401	+Ramcke, Allison, Ambrus, Barlow+	(JADE Collab.)
LYONS	90	PR D41 982	+Martin, Saxon	(OXF, BRIS, RAL)
BRAUNSCH			Braunschweig, Gerhards, Kirschfink+	(TASSO Collab.)
			Laren Abrama Amidei Daden I	(Mark II Collab.)
ONG	89	PRL 62 1236	+ Jaros, Abrams, Amidei, Baden+	(DELCO Collab.)
KLEM	88	PR D37 41	+Atwood, Barish+	
ONG	88	PRL 60 2587	+Weir, Abrams, Amidei+	(Mark II Collab.)
ASH	B7	PRL 58 640	+Band, Bloom, Bosman+	(MAC Collab.)
BARTEL	87	ZPHY C33 339	+Becker, Felst, Haidt+	(JADE Collab.)
BROM	87	PL B195 301	+Abachi, Akerlof, Baringer+	(HRS Collab.)
PAL	86	PR D33 2708	+Atwood, Barish, Bonneaud+	(DÈLCO Collab.)
AIHARA	85	ZPHY C27 39	+Alston-Garnjost, Badtke, Bakken+	` (TPC Collab.)
BARTEL	85J	PL 163B 277	+Becker, Cords, Felst+	(JADE Collab.)
ALTHOFF	84G	ZPHY C22 219	+Braunschweig, Kirschfink+	(TASSO Collab.)
ALTHOFF	84J	PL 146B 443	+Branschweig, Kirschfink+	(TASSO Collab.)
KOOP	84	PRL 52 970	+Sakuda, Atwood, Baillon+	(DELCO Collab.)
				(Mark-J Collab.)
ADEVA	83	PRL 50 799	+Barber, Becker, Berdugo+	(Mark-J Collab.)
ADEVA		PRL 51 443	+Barber, Becker, Berdugo+	
BARTEL		PL 132B 241	+Becker, Bowdery, Cords+	(JADE Collab.)
FERNANDEZ		PRL 50 2054	+Ford, Read, Smith+	(MAC Collab.)
MATTEUZZI	83	PL 129B 141	+Abrams, Amidei, Blocker+	(Mark II Collab.)
NELSON	83	PRL 50 1542	+Blondei, Trilling, Abrams+	(Mark il Collab.)

*B**

$$I(J^P) = \frac{1}{2}(1^-)$$

I, J, P need confirmation. Quantum numbers shown are quark-model predictions.

B* MASS

From mass difference below and the average of our B masses $(m_{B^\pm} + m_{B^0})/2.$

VALUE (MeV)
5324.9±1.8 OUR FIT

DOCUMENT ID

$m_{B^{\bullet}}-m_{B}$						
VALUE (MeV) EVTS			DOCUMENT ID 1		TECN	COMMENT
45.78士	0.35 OUR FIT					
45.78±0.35 OUR AVERAGE						
46.2 ±	0.3 ±0.8		¹ ACKERSTAFF	97M	OPAL	$e^+e^- \rightarrow Z$
45.3 ±	0.35 ± 0.87	4227	¹ BUSKULIC	96D	ALEP	Ecm = 88-94 GeV
45.5 ±	0.3 ±0.8		¹ ABREU	95R	DLPH	Ecm = 88-94 GeV
46.3 ±	1.9	1378	¹ ACCIARRI	95B	L3	Ecm = 88-94 GeV
46.4 ±	0.3 ±0.8					$e^+e^- \rightarrow \gamma X$
45.6 ±	0.8					$e^+e^- \rightarrow \gamma X, \gamma \ell X$
45.4 ±	1.0		3 LEE-FRANZINI	90	CSB2	$e^+e^- \rightarrow \Upsilon(55)$
● ● We do not use the following data for averages, fits, limits, etc. ● ●						
52 ±	2 ±4	1400	⁴ HAN	85	CUSB	$e^+e^- \rightarrow \gamma e X$
^{1}u , d , s flavor averaged.						

B^* , $B_J^*(5732)$

 2 These papers report E_{γ} in the B^* center of mass. The $m_{B^*}-m_B$ is 0.2 MeV higher. $E_{\rm cm} = 10.61-10.7$ GeV. Admixture of $B^{\rm O}$ and B^{+} mesons, but not $B_{\rm S}$.

 3 LEE-FRANZINI 90 value is for an admixture of B^0 and B^+ . They measure 46.7 \pm 0.4 \pm 0.2 MeV for an admixture of B^0 , B^+ , and B_s , and use the shape of the photon line to separate the above value. ⁴ HAN 85 is for $E_{\rm cm}=10.6$ –11.2 GeV, giving an admixture of B^0 , B^+ , and B_s .

$|(m_{B^{*+}}-m_{B^+})-(m_{B^{*0}}-m_{B^0})|$

VALUE (MeV)	CL%	DOCUMENT ID	TECN	COMMENT
<6	95	ABREU	95R DLPH	Ecm = 88-94 GeV

B* DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ1	$B\gamma$	dominant

B* REFERENCES

ACKERSTAFF	97M	ZPHY C74 413	
BUSKULIC	96D	ZPHY C69 393	
ABREU	95R	ZPHY C68 353	
ACCIARRI	95B	PL B345 589	
AKERIB	91	PRL 67 1692	
WU	91	PL B273 177	
LEE-FRANZINI	90	PRL 65 2947	
HAN	85	PRL 55 36	

K. Ackerstaff+ (OPAL Collab.)
+ Casper, De Bonis, Decamp+ (ALEPH Collab.)
+ Adam, Adrian, Aguilar-Benitez+
+ Adam, Adrian, Aguilar-Benitez+
+ Franzini, Kanekai, Tuts+
+ Heintz, Lovelock, Narain, Schamberger+ (CUSB II Collab.)
+ Klopfenstein, Mageras+ (COLU, LSU, MPIM, STON)

 $B_{J}^{*}(5732)$

$$I(J^P) = ?(?^?)$$

I, J, P need confirmation.

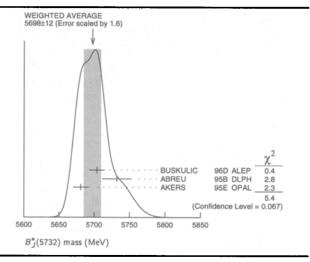
OMITTED FROM SUMMARY TABLE

Signal can be interpreted as stemming from several narrow and broad resonances. Needs confirmation.

B*,(5732) MASS

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
5698 ± 12 OUR AVE	RAGE Error	includes scale fa	ctor of 1.6. Se	e the ideogram below.
5704± 4±10	1944	¹ BUSKULIC	96D ALEP	Ecm = 88-94 GeV
5732± 5±20	2157	ABREU	95B DLPH	Eee = 88-94 GeV
5681 ± 11	1738	AKERS	95E OPAL	Ecm = 88-94 GeV

¹ Using $m_{B\pi} - m_B = 424 \pm 4 \pm 10$ MeV.



B*(5732) WIDTH

VALUE (MeV)	<u>EVTS</u>	DOCUMENT ID	TECN	COMMENT
145±28	2157	ABREU	95B DLPH	<i>E</i> cm = 88−94 GeV
116 ± 24	1738	AKERS	95E OPAL	Ecm = 88-94 GeV

$B_J^*(5732)$ DECAY MODES

Mode			Fraction (Γ_I/Γ)		
Γ ₁	B*π +	Вπ	dominant		
		B*j	(5732) REFERENCES		
BUSK ABRE AKER	U 95B		+Casper, De Bonis, Decamp+ + +Alexander, Allison+	(ALEPH Collab.) (DELPHI Collab.) (OPAL Collab.)	

BOTTOM, STRANGE MESONS $(B = \pm 1, S = \mp 1)$

 $B_s^0 = s\overline{b}, \overline{B}_s^0 = \overline{s}b,$ similarly for B_s^* 's

 $I(J^P) = 0(0^-)$

1, J, P need confirmation. Quantum numbers shown are quarkmodel predictions.

Bo MASS

The fit uses m_{B^+} , $(m_{B^0}-m_{B^+})$, $m_{B_s^0}$, and $(m_{B_s^0}-(m_{B^+}+m_{B^0})/2)$ to determine m_{B^+} , m_{B^0} , $m_{B^0_2}$, and the mass differences.

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
5369.3± 2.0 OUR FIT				
5369.6± 2.4 OUR AVER/	AGE			
5369.9± 2.3±1.3	32	¹ ABE		ρ̄p̄ at 1.8 TeV
5374 ±16 ±2	3	ABREU	94D DLPH	$e^+e^- \rightarrow Z$
5359 ±19 ±7	1	¹ AKERS		$e^+e^- \rightarrow Z$
5368.6± 5.6±1.5	2	BUSKULIC	93G ALEP	$e^+e^- \rightarrow Z$
• • • We do not use the	following	data for averages,	fits, limits, et	C. ● ● ●
5370 ±40	6	² AKERS	94J OPAL	$e^+e^- \rightarrow Z$
5383.3 ± 4.5 ± 5.0	14	ABE	93F CDF	Repl by ABE 96B
1 From the decay $B_{s} \rightarrow$				
2 From the decay $B_s \rightarrow$	$D_s^-\pi^+$.			

 m_B is the average of our B masses $(m_{B^\pm}+m_{B^0})/2$. The fits uses m_{B^+} , $(m_{B^0}-m_{B^+})$, $m_{B^0_s}$, and $m_{B^0_s}-m_B$ to determine m_{B^+} , m_{B^0} , $m_{B^0_s}$ and the mass differences.

VALUE (MeV)	CL%	DOCUMENT ID		TECN	COMMENT
90.2±2.2 OUR FIT					
89.7±2.7±1.2		ABE	96B	CDF	pp at 1.8 TeV
• • • We do not use the	following o	lata for averages	, fits	, limits,	etc. • • •
80 to 130	68	LEE-FRANZINI	90	CSB2	$e^+e^- \rightarrow \Upsilon(5S)$

$m_{B^0_{sH}}-m_{B^0_{sL}}$

See the $B_s^0 \cdot \overline{B}_s^0$ MIXING section near the end of these B_s^0 Listings.

BO MEAN LIFE

"OUR EVALUATION" is an average of the data listed below performed by the LEP "OUR EVALUATION" is an average of the data fished below Production and Decay of b-flavored Hadrons" in the B^{\pm} Section of the Listings. The averaging procedure takes

VALUE (10 ⁻¹² s)	<u>EVTS</u>	DOCUMENT ID	TECN	COMMENT
1.54±0.07 OUR EVA	LUATION			
$1.34^{+0.23}_{-0.19} \pm 0.05$		3 ABE	98B CDF	ρ̄p̄ at 1.8 TeV
$1.72^{+0.20+0.18}_{-0.19-0.17}$		⁴ ACKERSTAFF	98F OPAL	$e^+e^- \rightarrow Z$
$1.50^{+0.16}_{-0.15} \pm 0.04$		⁵ ACKERSTAFF	98G OPAL	$e^+e^- \rightarrow Z$
1.47±0.14±0.08		⁶ BARATE	98c ALEP	$e^+e^- \rightarrow Z$
1.56+0.29+0.08 -0.26-0.07		⁵ ABREU	96F DLPH	$e^+e^- \rightarrow Z$
$1.65^{+0.34}_{-0.31}\pm0.12$		⁶ ABREU	96F DLPH	$e^+e^- \rightarrow Z$
$1.76 \pm 0.20 ^{+0.15}_{-0.10}$		⁷ ABREU	96F DLPH	$e^+e^- \rightarrow Z$
$1.60\pm0.26^{+0.13}_{-0.15}$		8 ABREU	96F DLPH	$e^+e^- \rightarrow Z$
$1.54^{+0.14}_{-0.13}\pm0.04$		⁵ BUSKULIC	96M ALEP	$e^+e^- \rightarrow Z$
$1.42^{+0.27}_{-0.23} \pm 0.11$	76	⁵ ABE	95R CDF	p₱ at 1.8 TeV
 • • We do not use 	the followin	g data for averages	s, fits, limits	, etc. • • •
1.51±0.11		9 BARATE	98C ALEP	$e^+e^- \rightarrow Z$

$1.34^{+0.23}_{-0.19}\pm0.05$		¹⁰ ABE	96N CDF	Repl. by ABE 98B
1.67 ± 0.14		¹¹ ABREU	96F DLPH	e ⁺ e ⁻ → Z
$1.61^{+0.30}_{-0.29}^{+0.18}_{-0.16}$	90	⁶ BUSKULIC	96E ALEP	Repl. by BARATE 98C
$1.74^{+1.08}_{-0.69}\pm0.07$	8	¹² ABE	95R CDF	Sup. by ABE 96N
$1.54^{+0.25}_{-0.21}\pm0.06$	79	⁵ AKERS	95G OPAL	Repl. by ACKER- STAFF 98G
$1.59^{+0.17}_{-0.15}\pm0.03$	134	⁵ BUSKULIC	950 ALEP	
0.96 ± 0.37	41	¹³ ABREU	94E DLPH	Sup. by ABREU 96F
$1.92^{+0.45}_{-0.35}\pm0.04$	31	⁵ BUSKULIC	94c ALEP	Sup. by BUSKULIC 950
$1.13^{+0.35}_{-0.26} \pm 0.09$	22	⁵ ACTON	93H OPAL	Sup. by AKERS 95G

 3 Measured using fully reconstructed $B_S \to J/\psi(1S)\phi$ decay.

 4 ACKERSTAFF 98F use fully reconstructed $D_s^+ o \phi \pi^-$ and $D_s^- o K^{*0} K^-$ in the inclusive B_s^0 decay.

⁵ Measured using $D_s^- \ell^+$ vertices.

 6 Measured using D_{s}^{-} hadron vertices.

⁷ Measured using $\phi \ell$ vertices.

⁸ Measured using inclusive D_S vertices.

 9 Combined results from $D_{s}^{-}\ell^{+}$ and D_{s} hadron.

 $^{10}\,\mathrm{ABE}$ 96N uses 58 \pm 12 exclusive $B_{\mathrm{S}} \to ~J/\psi(1S)\phi$ events.

 11 Combined result for the four ABREU 96F methods. 12 Exclusive reconstruction of $B_{\rm S} \to ~\psi \, \phi.$

 13 ABREU 94E uses the flight-distance distribution of $D_{_{S}}$ vertices, ϕ -lepton vertices, and $D_S \mu$ vertices.

BO DECAY MODES

These branching fractions all scale with B($\overline{b} \rightarrow B_s^0$), the LEP B_s^0 production fraction. The first four were evaluated using $B(\overline{b} \rightarrow B_s^0) =$ $(10.5^{+1.8}_{-1.7})\%$ and the rest assume B($\bar{b} \to B_s^0$) = 12%.

The branching fraction B($B_s^0 o D_s^- \ell^+
u_\ell$ anything) is not a pure measurement since the measured product branching fraction $B(\overline{b} \to B_s^0) \times$ ${\sf B}(B_0^0\to D_0^-\ell^+\nu_\ell$ anything) was used to determine ${\sf B}(\overline{b}\to B_0^0)$, as described in the note on "Production and Decay of b-Flavored Hadrons."

	Mode	Fraction (Γ_I/Γ)	Confidence level				
$\overline{\Gamma_1}$	D_ anything	(92 ±33) °					
Γ_2	$D_s^- \ell^+ \nu_\ell$ anything	[a] (8.1 ± 2.5) ?	%				
Г3	$D_s^-\pi^+$	< 13	%				
Γ4	$J/\psi(15)\phi$	(9.3 ± 3.3)	× 10 ⁻⁴				
Γ ₅	$J/\psi(1S)\pi^0$	< 1.2	× 10 ⁻³ 90%				
۲6	$J/\psi(1S)\eta$	< 3.8	× 10 ⁻³ 90%				
Γ_7	$\psi(2S)\phi$	seen					
Г8	$\pi^+\pi^-$	< 1.7	× 10 ⁻⁴ 90%				
Г9	$\pi^0\pi^0$	< 2.1	× 10 ⁻⁴ 90%				
Γ_{10}	$\eta\pi^0$	< 1.0	× 10 ⁻³ 90%				
Γ_{11}	$\eta\eta$	< 1.5	× 10 ⁻³ 90%				
Γ ₁₂	$\pi^+ K^-$	< 2.1	× 10 ⁻⁴ 90%				
Γ ₁₃	K+ K-	< 5.9	× 10 ⁻⁵ 90%				
Γ ₁₄	₽₽	< 5.9	× 10 ⁻⁵ 90%				
Γ ₁₅	$\gamma\gamma$	< 1.48	× 10 ⁻⁴ 90%				
Γ ₁₆	$\phi\gamma$	< 7	× 10 ⁻⁴ 90%				
	Lenton Family number (LE) violating modes or						

$\Delta B = 1$ weak neutral current (B1) modes

				,		
	$\mu^+\mu^-$	B1	<	2.0	× 10 ⁻⁶	90%
	e^+e^-	B1	<	5.4	× 10 ⁵	90%
Γ19	$e^{\pm}\mu^{\mp}$	LF	[b] <	4.1	× 10 ⁻⁵	90%
Γ_{20}	$\phi u \overline{ u}$	B1	<	5.4	× 10 ⁻³	90%

- [a] Not a pure measurement. See note at head of B_s^0 Decay Modes.
- [b] The value is for the sum of the charge states of particle/antiparticle states indicated.

	<i>B</i> _s B	RANCHING	RATIOS		
$(D_s^-$ anything)/ Γ_{to}	tal			. г	1/Г
VALUE 0.92±0.33 OUR AVER/	<u>EVTS</u>	DOCUMENT ID	<u>TECN</u>	COMMENT	
0.81±0.24±0.24 1.56±0.58±0.47	90 1	⁴ BUSKULIC ⁵ ACTON		e ⁺ e ⁻ → Z e ⁺ e ⁻ → Z	
14 BUSKULIC 96E sepa	arate c∂ and	$b\overline{b}$ sources of b	D_s^+ mesons usin	ng a lifetime tag, sub	tract
= 0.088 \pm 0.020 \pm 0 values for the relative values B($\overline{b} \rightarrow B_s^0$)	0.020 assum e partial wid = 0.105 +0.	ing B($D_S \rightarrow \phi$; ths to other D_S 018 and B(D_S	π) = (3.5 ± 0.4 channels. We channels. ϕ π) = 0.03	$B(B_s^0 \rightarrow D_s^+)$ anyth $A(S) \times 10^{-2}$ and PDG evaluate using our cu $A(S) \times 10^{-2}$ and PDG $A(S) \times 10^{-2}$ and PDG $A(S) \times 10^{-2}$ anything $A(S) \times 10^{-2}$ and PDG $A(S) \times 10^{-$	1994 rrent error
¹⁵ ACTON 92n assum	e that exces	s of 147 ± 48	DS events over	that expected from	в0,
B^+ , and cc is all $B(\overline{b} \rightarrow B_S^0)B(B_S^0)$ We evaluate using C	from B_S^0 dec $\rightarrow D_S^-$ anytour current volume first error	tay. The production $B(D_s^- + i)$ values $B(\overline{b} \rightarrow i)$ or is their experi	ct branching fr $\phi \pi^{+}) = (5$ $B_{s}^{0}) = 0.105 + \frac{1}{2}$	action is measured to $.9 \pm 1.9 \pm 1.1) \times 10$ 0.018 and B($D_S \rightarrow$ r second error is that	to be 0^{-3} . $\phi\pi$)
$\Gamma(D_s^-\ell^+ u_\ell$ anything	λ/г			г	· ₂ /Γ
The values and a assumes our $B(\overline{b})$	verages in to $\rightarrow B_s^0$).	They cannot be fractions were a	thought of as also used to de	what values result if measurements since terminine $B(\overline{b} \rightarrow B)$	one the
VALUE 0.081±0.025 OUR AVE	<u>EVTS</u> ERAGE	DOCUMENT ID	TECN	COMMENT	
0.076±0.012±0.022		6 BUSKULIC	950 ALEP	e+e- → Z	
0.107±0.043±0.032		⁷ ABREU ⁸ ACTON	92M DLPH 92N OPAL	e+e- → Z e+e- → Z	
0.103 ± 0.036 ± 0.031 ■ ■ We do not use t					
0.13 ±0.04 ±0.04	-	9 BUSKULIC		$e^+e^- \rightarrow Z$	
16 BUSKULIC 950 use					<i>ī</i> . →
this can be used to current values $B(\overline{b})$ first error is their e $B(D_S \to \phi \pi)$. 17 ABREU 92M measu $\overline{b}) \times B(\overline{b} \to B_S) \times We$ evaluate using 0.036 ± 0.009 . 0.08×0.009 .	extract $B(\overline{b})$ = 0 B_S^0 = 0 experiment's ured muons of $B(B_S \rightarrow L)$ our current of $B(D_S \rightarrow L)$ Our first error and $B(D_S \rightarrow L)$ 9).	\rightarrow $B_{S}) = (11.00000000000000000000000000000000000$	$0 \pm 1.2^{+2.5}_{-2.6}$) and $B(D_S \rightarrow \phi)$ deform is that ed product bra ang) $\times B(D_S \rightarrow \phi)$ $B(D_S \rightarrow \phi)$	$\phi \pi$) = (18 ± 8) × 1 0.018 and B($D_S \rightarrow$ r second error is that \overline{b}) = 2B($Z \rightarrow b$	Our Dor 0^{-5} . $\phi\pi$) t due \overline{b}) =
$\times B(D_s^- \to \phi \pi^-)$	$= (3.9 \pm 1.0)$	1 ± 0.8) × 10 ⁻	$B(\overline{b} \rightarrow B_S^0)B(\overline{b})$	$B_s^0 o D_s^- \ell^+ u_\ell$ anyt e using our current v	hing) alues
$ B(D_s^- \to \phi \pi^-) $ $ B(\overline{b} \to B_s^0) = 0.1 $	$= (3.9 \pm 1.05 + 0.018)$	$1 \pm 0.8) \times 10^{-1}$ and B($D_S \rightarrow G$	$B(\overline{b} \rightarrow B_S^0)B(B)$ $B(\overline{b} \rightarrow B_S^0)B(B)$ $B(\overline{b} \rightarrow B)$ $B(\overline{b} \rightarrow B)$	$B_s^0 \rightarrow D_s^- \ell^+ \nu_\ell$ anyt e using our current v : 0.009. Our first er	hing) alues ror is
\times B($D_s^- \rightarrow \phi \pi^-$) B($\overline{b} \rightarrow B_s^0$) = 0.1 their experiment's a 19 BUSKULIC 92E is 2.7 ± 0.7% for the measured to be B(We evaluate using = 0.036 ± 0.009.	$= (3.9 \pm 1.05 + 0.018)$ $= (0.05 + 0.017)$ and our seconneasured us $\phi \pi^+ \text{ branch}$ $= \frac{1}{b} \rightarrow B_s^0 \text{ B}$ our current of the course o	and $B(D_S \rightarrow G)$ and error is that thing $D_S \rightarrow G$ hing fraction. T $(B_S^0 \rightarrow D_S^- \ell^+)$ values $B(\overline{b} \rightarrow G)$ or is their exper	$B(\overline{b} \rightarrow B_{S}^{0})$ B($\overline{b} \rightarrow B_{S}^{0})$ B(\overline{b} . We evaluat $\phi\pi$) = 0.036 \pm due to B($\overline{b} \rightarrow +$ and K^{*} (892) the average pro $+\nu_{\ell}$ anything) : B_{S}^{0}) = 0.105 \pm iment's and out	${}^{O}_{S} \rightarrow D_{S}^{-} \ell^{+} \nu_{\ell}$ any to eusing our current v (0.009). Our first error B_{S}^{O}) and $B(D_{S} \rightarrow v_{\ell})^{O} \ell^{+}$ events. The duct branching fracti=0.020 \pm 0.0055+0.0.018 and $B(D_{S} \rightarrow v_{\ell})^{O}$ and $B(D_{S} \rightarrow v_{\ell})^{O}$ r second error is that	hing) raiues ror is $\phi\pi$). y use ion is
\times B($D_s^- \to \phi \pi^-$) B($\overline{b} \to B_s^0$) = 0.1 their experiment's a 19 BUSKULIC 92E is 2.7 ± 0.7% for the measured to be B(We evaluate using = 0.036 ± 0.009. 0 to B($\overline{b} \to B_s^0$) and	$= (3.9 \pm 1.05 + 0.018) \times 10.05 + 0.017 \times 10.018 \times 10.01$	$1\pm0.8)\times10^{-}$ and $B(D_S\to q$ and error is that sing $D_S\to \phi\pi$ ning fraction. The $(B_S^0\to D_S^0)$ corresponds to the experiments $(B_S^0\to D_S^0)$. Superseden	$3(\overline{b} o B_S^0)$ B(E) 4 . We evaluate $\phi \pi$) = 0.036 \pm due to B($\overline{b} o \pm$ and K^* (89) he average profugations of Φ_L anything): Φ_S^0) = 0.105 \pm liment's and out d by BUSKULI	${}^{0}_{s} \rightarrow D_{s}^{-}\ell^{+}\nu_{\ell}$ any to e using our current v: 0.009. Our first er B_{s}^{0}) and $B(D_{s} \rightarrow E)^{0}$ K^{+} events. They duct branching fraction $\pm 0.020 \pm 0.0055^{+0}_{-0}$ 0.018 and $B(D_{s} \rightarrow E)^{0}$ r second error is tha C 950.	hing) raiues ror is $\phi\pi$). y use ion is
\times B($D_s^- \rightarrow \phi \pi^-$) B($\overline{b} \rightarrow B_s^0$) = 0.1 their experiment's a 19 BUSKULIC 92E is 2.7 ± 0.7% for the measured to be B(We evaluate using = 0.036 ± 0.009. to B($\overline{b} \rightarrow B_s^0$) and $\Gamma(D_s^- \pi^+)/\Gamma_{\text{total}}$ VALUE <0.13	$= (3.9 \pm 1.05 + 0.018)$ $= 0.017 \cdot 0.017$ and our secone as ured us $\phi \pi^+$ branch $\overline{b} \rightarrow B_S^0$) Bour current to Our first error if B($D_S \rightarrow C_S$) B = $C_S \rightarrow C_S$	$1\pm0.8)\times10^{-}$ and $B(D_S\to \phi$ and error is that ining $D_S\to \phi$ and fraction. The ining fraction of $(B_S^0\to D_S^{-}C^+)$ values $B(\overline{b}\to D_S^-)$ or is their exper $\phi\pi$). Superseden $DOCUMENT\ ID$	$3(\overline{b} \rightarrow B_{S}^{0})B(E^{-4})$. We evaluat $\phi\pi$) = 0.036 ± due to $B(\overline{b} \rightarrow + and K^{*}(89; he average pro h^{-1} \nu_{\ell} anything) = h^{0} B_{S}^{0}) = 0.105 ± liment's and oud d by BUSKULI$	${}^{O}_{S} \rightarrow D_{S}^{-} \ell^{+} \nu_{\ell}$ any to e using our current v : 0.009. Our first er B_{S}^{O}) and $B(D_{S} \rightarrow v_{\ell})^{O} \ell^{+}$ events. The duct branching fracti=0.020 \pm 0.0055+0.0.018 and $B(D_{S} \rightarrow v_{\ell})^{O}$ and $B(D_{S} \rightarrow v_{\ell})^{O}$ compared error is that C 950.	hing) values ror is $\phi\pi$). y use ion is .005 .006 $\phi\pi$) t due
$ \begin{array}{c} \times B(D_S^- \to \phi\pi^-) \\ B(\overline{b} \to B_g^0) = 0.1 \\ \text{their experiment's a} \\ 19 BUSKULIC 92E is \\ 2.7 \pm 0.7\% for the \\ measured to be B(\\ We evaluate using \\ = 0.036 \pm 0.009. to \\ B(\overline{b} \to B_S^0) and \\ T(D_g^-\pi^+)/\Gamma_{total} \\ VALUE \\ < 0.13 \\ \bullet \bullet We do not use to \\ \end{array} $	$= (3.9 \pm 1.05^{+}0.018^{+})$ and our second measured us $\phi \pi^{+}$ branch $\overline{b} \rightarrow B_{S}^{0})$ Bour current our first error d B($D_{S} \rightarrow C_{S}^{0}$) be following	$1\pm0.8)\times10^{-}$ and $B(D_S\to \phi$ and error is that ining $D_S\to \phi$ and ining fraction. The initial initi	$3(\overline{b} \rightarrow B_{S}^{0})B(E^{-4})$. We evaluate $\phi\pi$) = 0.036 ± due to $B(\overline{b} \rightarrow + and K^{*}(89;$ the average properties B_{S}^{0}) = 0.105 ± B_{S}^{0} 0 = 0.10	${}^{O}_{S} \rightarrow D_{S}^{-} \ell^{+} \nu_{\ell}$ any to e using our current v: 0.009. Our first er B_{S}^{O}) and $B(D_{S} \rightarrow e^{+})^{O}$ K^{+} events. The duct branching fracti=0.020 \pm 0.0055 $^{+}$ 0.018 and $B(D_{S} \rightarrow e^{-})^{O}$ and $B(D_{S} \rightarrow e^{-})^{O}$ C 950.	hing) values ror is $\phi\pi$). y use ion is .005 .006 $\phi\pi$) t due
\times B($D_s^- \to \phi \pi^-$) B($\overline{b} \to B_s^0$) = 0.1 their experiment's a 19 BUSKULIC 92E is 2.7 ± 0.7% for the measured to be B(We evaluate using = 0.036 ± 0.009. 0 to B($\overline{b} \to B_s^0$) and $\Gamma(D_s^- \pi^+)/\Gamma_{\text{total}}$ VALUE • • We do not use to seen	$= (3.9 \pm 1.105 \pm 0.018)$ and our secone measured us $\phi \pi^+$ branch $\overline{b} \rightarrow B_s^S$) Bour current our current of B($D_s \rightarrow C_s$) Before the following 1 $= \frac{EVTS}{6} = \frac{6}{2}$ the following 1 $= \frac{6}{2} = \frac$	$1\pm0.8)\times10^{-}$ and $B(D_S\to q$ and error is that sing $D_S\to \phi\pi$ ming fraction. The fraction of the fraction o	$3(\overline{b} \rightarrow B_S^0)B(E^{-4})$. We evaluate $\phi \pi = 0.036 \pm 0.036 $	${}^{O}_{S} \rightarrow D_{S}^{-} \ell^{+} \nu_{\ell}$ any to e using our current v: 0.009. Our first er B_{S}^{O}) and $B(D_{S} \rightarrow E^{O})$ K^{+} events. The duct branching fraction = 0.020 \pm 0.0055 \pm^{+} 0.018 and $B(D_{S} \rightarrow E^{O})$ er second error is that C 950.	hing) values ror is $\phi\pi$). You use ion is .005 $\phi\pi$) t due
$\begin{array}{lll} \times B(D_S^- \to \phi\pi^-) \\ B(\overline{b} \to B_S^0) = 0.1 \\ their \ experiment's \ a \\ 19 \ BUSKULIC \ 92E \ is \\ 2.7 \pm 0.7\% \ for \ their \\ measured \ to \ be \ B \\ We \ evaluate \ using \\ e \ e \ evaluate \ using \\ to \ B(\overline{b} \to B_S^0) \ and \\ f(D_S^- \pi^+) / \Gamma_{\mathbf{total}} \\ value \\ vol.13 \\ \bullet \ \bullet \ \bullet \ We \ do \ not \ use \ ts \\ seen \\ 20 \ AKERS \ 94J \ sees \\ f(\overline{b} \to B_S^0) \ B(B_S^0) \\ B(\overline{b} \to B_S^0) = 0.1 \\ \end{array}$	$= (3.9 \pm 1.05 \pm 0.018 + 0.018 + 0.017 + 0.018 + 0.017 + 0.018 + 0.017 + 0.018 + 0.01$	$1\pm0.8)\times10^{-}$ and $B(D_S\to q$ and error is that sing $D_S\to \phi\pi$ ming fraction. The fraction of the fraction o	$3(\overline{b} \rightarrow B_S^0)B(E^{-4})$. We evaluate $\phi \pi = 0.036 \pm 0.036 $	${}^{O}_{S} \rightarrow {}^{O}_{S} + {}^{+}\nu_{\ell}$ anyte e using our current v: 0.009. Our first er B_{S}^{O}) and $B(D_{S} \rightarrow {}^{+}v)^{O}K^{+}$ events. The duct branching fractien =0.020 \pm 0.0055 \pm 0.018 and $B(D_{S} \rightarrow {}^{+}v)^{O}K^{+}$ events is that C 950.	hing) values ror is $\phi\pi$). You use ion is .005 $\phi\pi$) t due
\times B($D_s^- \to \phi \pi^-$) B($\overline{b} \to B_s^0$) = 0.1 their experiment's a 19 BUSKULIC 92E is 2.7 ± 0.7% for the measured to be B(We evaluate using = = 0.036 ± 0.009. One to B($\overline{b} \to B_s^0$) and $\Gamma(D_s^- \pi^+)/\Gamma_{\text{total}}$ \times VALUE • • • We do not use to seen 20 AKERS 94J sees \leq $f(\overline{b} \to B_s^0)$ -B(B_s^0)	$= (3.9 \pm 1.05 \pm 0.018 + 0.01$	$1\pm0.8)\times10^{-}$ and $B(D_S\to q$ and error is that sing $D_S\to \phi\pi$ ming fraction. The fraction of the fraction o	$3(\overline{b} \rightarrow B_S^0)B(E^4)$. We evaluate $\phi\pi$) = 0.036 ± due to $B(\overline{b} \rightarrow + and K^*(89; he average properties B_S^0) = 0.105 ± \mu0.105 ± \mu1. TECN 94J OPAL tes, fits, limits, 93G ALEP is limit on the \mu1. = 90%. We consider the example of the $	${}^{O}_{S} \rightarrow {}^{O}_{S} + {}^{+}\nu_{\ell}$ anyte e using our current v: 0.009. Our first er B_{S}^{O}) and $B(D_{S} \rightarrow {}^{+}v)^{O}K^{+}$ events. The duct branching fractien =0.020 \pm 0.0055 \pm 0.018 and $B(D_{S} \rightarrow {}^{+}v)^{O}K^{+}$ events is that C 950.	hing) values for is $\phi\pi$). Ye use ion is .005 .006 $\phi\pi$) t due

```
1 <sup>22</sup> AKERS
                                                        94J OPAL e^+e^- \rightarrow Z
<6
                                    23 ABE
                                                        seen
                             1 24 ACTON
  seen
<sup>21</sup> ABE 96Q assumes f_u = f_d and f_s/f_u = 0.40 \pm 0.06. Uses B \rightarrow J/\psi(15) K and B \rightarrow
    J/\psi(1S)/\star^* branching fractions from PDG 94. They quote two systematic errors, \pm 0.10 and \pm 0.14 where the latter is the uncertainty in f_{\rm S}. We combine in quadrature.
and \pm 0.14 where the latter is the uncartainty in r_s. We combine in quantitative f(\overline{b} \to B_s^0) \cdot B(B_s^0 \to J/\psi(15)\phi) < 7 \times 10^{-4} at CL = 90%. We divide by our current value B(\overline{b} \to B_s^0) = 0.112.
<sup>23</sup> ABE 93F measured using J/\psi(1S) \rightarrow \mu^+\mu^- and \phi \rightarrow K^+K^-.
<sup>24</sup> In ACTON 92N a limit on the product branching fraction is measured to be f(\overline{b} \to B_s^0) \cdot B(B_s^0 \to J/\psi(1S)\phi) \le 0.22 \times 10^{-2}.
                                                                                           \Gamma_{\overline{b}}/\Gamma
\Gamma(J/\psi(1S)\pi^0)/\Gamma_{\text{total}}
                         <u>CL% DOCUMENT ID TECN</u>
90 <sup>25</sup> ACCIARRI 97C L3
<1.2 × 10<sup>-3</sup>
^{25} ACCIARRI 97c assumes B^0 production fraction (39.5 \pm 4.0%) and B_s (12.0 \pm 3.0%).
\Gamma(J/\psi(1S)\eta)/\Gamma_{\rm total}
                                                                                           \Gamma_6/\Gamma
                          CL%
                                       DOCUMENT ID
                                                             TECN
<3.8 × 10<sup>-3</sup>
                                   26 ACCIARRI 97C L3
                           90
^{26} ACCIARRI 97C assumes B^0 production fraction (39.5 \pm 4.0%) and B_{\rm 5} (12.0 \pm 3.0%).
                                                                                           \Gamma_7/\Gamma
\Gamma(\psi(2S)\phi)/\Gamma_{\text{total}}
                          EVTS
                                        DOCUMENT ID
                                                            TECN COMMENT
                                       BUSKULIC 93G ALEP e+e- → Z
\Gamma(\pi^+\pi^-)/\Gamma_{\text{total}}
                                                                                            \Gamma_8/\Gamma
                           CL%
                                        DOCUMENT ID
                                                           TECN COMMENT
                                   27 BUSKULIC 96V ALEP e+e- → Z
                           90
<sup>27</sup> BUSKULIC 96V assumes PDG 96 production fractions for B^0, B^+, B_S, b baryons.
\Gamma(\pi^0\pi^0)/\Gamma_{\text{total}}
                                                                                            ٦/و٦
                          CL%
                                       DOCUMENT ID
                                                            TECN COMMENT
<2.1 × 10<sup>-4</sup>
                                   <sup>28</sup> ACCIARRI 95H L3 e^+e^- \rightarrow Z
                           90
^{28} ACCIARRI 95H assumes f_{B^0}=39.5\pm4.0 and f_{B_g}=12.0\pm3.0\%.
\Gamma(\eta\pi^0)/\Gamma_{\text{total}}
                                                                                           \Gamma_{10}/\Gamma
                                        DOCUMENT ID
                                                            TECN COMMENT
<1.0 × 10<sup>-3</sup>
                                  29 ACCIARRI 95H L3 e+e- → Z
 ^{29} ACCIARRI 95H assumes f_{B^0}=39.5\pm4.0 and f_{B_g}=12.0\pm3.0\%.
                                                                                          \Gamma_{11}/\Gamma
\Gamma(\eta\eta)/\Gamma_{\text{total}}
                                        DOCUMENT ID
                                                            TECN COMMENT
                           CLN
<1.5 × 10<sup>-3</sup>
                           90 30 ACCIARRI 95H L3 e^+e^- \rightarrow Z
 ^{30}\,\mathrm{ACCIARRI} 95H assumes f_{B^0}=39.5\pm4.0 and f_{B_g}=12.0\pm3.0\%.
\Gamma(\pi^+K^-)/\Gamma_{\text{total}}
                                                                                          \Gamma_{12}/\Gamma
                                       DOCUMENT ID TECN COMMENT
VALUE
                          CL%
<2.1 × 10<sup>-4</sup>
                                   31 BUSKULIC 96V ALEP e+e- → Z
                           90
32 AKERS
                                                        94L OPAL e+e- → Z
                           90
 31 BUSKULIC 96V assumes PDG 96 production fractions for B^0, B^+, B_S, b baryons.
 <sup>32</sup> Assumes B(Z \to b\bar{b}) = 0.217 and B_d^0 (B_s^0) fraction 39.5% (12%).
\Gamma(K^+K^-)/\Gamma_{\text{total}}
                                                                                          Γ<sub>13</sub>/Γ
VALUE
                          <5.9 × 10<sup>-5</sup>
<1.4 × 10<sup>-4</sup>
                                  34 AKERS
                                                       94L OPAL e+e- → Z
                        90
 ^{33} BUSKULIC 96v assumes PDG 96 production fractions for B^0, B^+, B_s, b baryons.
 34 Assumes B(Z \to b\overline{b}) = 0.217 and B_d^0 (B_s^0) fraction 39.5% (12%).
                                                                                           \Gamma_{14}/\Gamma
Γ(pp)/Γ<sub>total</sub>
                                        DOCUMENT ID
                                                            TECN COMMENT
                            CL%
 <5.9 × 10<sup>-5</sup>
                                    35 BUSKULIC
                                                         96V ALEP e+e- → Z
                           90
 35 BUSKULIC 96V assumes PDG 96 production fractions for B^0, B^+, B_{\rm g}, b baryons.
                                                                                           \Gamma_{15}/\Gamma
\Gamma(\gamma\gamma)/\Gamma_{\text{total}}
                                        DOCUMENT ID
                                                         TECN COMMENT
 <14.8 × 10<sup>-5</sup>
                                    36 ACCIARRI
                           90
                                                       951 L3 e<sup>+</sup>e<sup>-</sup> → Z
 <sup>36</sup> ACCIARRI 951 assumes f_{B^0}=39.5\pm4.0 and f_{B_S}=12.0\pm3.0\%.
                                                                                           \Gamma_{16}/\Gamma
\Gamma(\phi\gamma)/\Gamma_{\text{total}}
                                        DOCUMENT ID
                                                            TECN COMMENT
                           CL%
VALUE
 <7 × 10<sup>-4</sup>
                                   37 ADAM
                                                         96D DLPH e^+e^- \rightarrow Z
                           90
 ^{37}\,\mathrm{ADAM} 96D assumes f_{B^0}=f_{B^-}=0.39 and f_{B_8}=0.12.
```

$(\mu^+\mu^-)/\Gamma_{\text{total}}$					Γ ₁₇ /Γ
Test for ΔB =	= 1 weak ne 	DOCUMENT ID	TECN	COMMENT	
(2.0 × 10 ⁻⁶	90	38 ABE		pp at 1.8 TeV	
	e the follow	ing data for averag			
<3.8 × 10 ⁻⁵	90	39 ACCIARRI	978 L3	e+e- → Z	
<8.4 × 10 ⁻⁶	90	⁴⁰ ABE		Repl. by ABE	98
malize to their r ³⁹ ACCIARRI 978	neasured σ(assume PDC	of $\sigma(B^0) = \sigma(B^0)$ $\sigma(B^0, p_T(B)) > 6$, $ y < 6$ 96 production fra production ratio 3	< 1.0) = 2.39 actions for B^+	\pm 0.32 \pm 0.44 μ , B^0 , B_S , and Λ	ib. b·
	6 GeV/c,	$ y < 1) = 2.39 \pm 1$	0.54 μb.		
(e ⁺ e ⁻)/Γ _{total} Test for Δ <i>B</i> :		utral current.		CO. 11. 151. T	Γ ₁₈ /Ι
ALUE	CL%		978 L3	$e^+e^- \rightarrow Z$	
<5.4 × 10 ⁻⁵	90				
⁴¹ ACCIARRI 97B	assume PD0	G 96 production fra	ictions for B+	, B^0 , $B_{f s}$, and Λ	p.
(e [±] µ [∓])/Γ _{total}	family num	ber conservation.			Γ ₁₉ /Ι
test of lepton	raining mum				
test of lepton	<u>CL%</u>	DOCUMENT ID	TECN		
test of lepton ALUE <4.1 × 10 ⁻⁵			978 L3	$\frac{COMMENT}{e^+e^- \rightarrow Z}$	
test of lepton ALUE <4.1 × 10 ⁻⁵	90	DOCUMENT ID	97B L3	$e^+e^- \rightarrow Z$	b∙
test of lepton ALUE <4.1 × 10 ⁻⁵ ⁴² ACCIARRI 97B (φνν)/Γtotal Test for ΔB:	90 assume PDG = 1 weak ne	DOCUMENT ID 42 ACCIARRI 5 96 production fra	97B L3 actions for B ⁺	$e^+e^- \rightarrow Z$, B^0 , B_S , and A	_b . Г 20/ I
test of lepton ALUE C4.1 × 10 ⁻⁵ 42 ACCIARRI 978 ($\phi \nu \overline{\nu}$)/ Γ_{total} Test for ΔB : ALUE	90 assume PDG = 1 weak ne	DOCUMENT ID 42 ACCIARRI 3 96 production fra cutral current. DOCUMENT ID	97B L3 actions for B+	$e^+e^- \rightarrow Z$, B^0 , B_s , and A COMMENT	
test of lepton ALUE $<4.1 \times 10^{-5}$ 42 ACCIARRI 97B Test for ΔB : ALUE $<5.4 \times 10^{-3}$	20% 90 assume PDO = 1 weak ne 20% 90	DOCUMENT ID 42 ACCIARRI 5 96 production fra	978 L3 actions for <i>B</i> + 7 TECN 96D DLPH	$e^+e^- \rightarrow Z$, B^0 , B_S , and A	

POLARIZATION IN BO DECAY

Γ_L/Γ in $B_s^0 \to J$	$I/\psi(1S)\phi$			
VALUE	<u>EVTS</u>	DOCUMENT ID	<u>TECN</u>	COMMENT
$0.56\pm0.21^{+0.02}_{-0.04}$	19	ABE	95z CDF	ρ p at 1.8 TeV

BO-BO MIXING

For a discussion of $B^0_S - \overline B^0_S$ mixing see the note on " $B^0 - \overline B^0$ Mixing" in the \mathcal{B}^{0} Particle Listings above.

 x_s is a measure of the time-integrated $\mathcal{B}_s^0 - \overline{\mathcal{B}}_s^0$ mixing probability that produced $B^0_s(\overline{B}^0_s)$ decays as a $\overline{B}^0_s(B^0_s)$. Mixing violates $\Delta B \neq 2$ rule.

$$X_S = \frac{x_S^2}{2(1+x_s^2)}$$

$$x_{s} = \frac{\Delta m_{B_{s}^{0}}}{\Gamma_{B_{s}^{0}}} = (m_{B_{sH}^{0}} - m_{B_{sL}^{0}}) \tau_{B_{s}^{0}},$$

where \emph{H} , \emph{L} stand for heavy and light states of two $\emph{B}^0_\emph{s}$ \emph{CP} eigenstates and $\tau_{B_s^0} = \frac{1}{0.5(\Gamma_{B_{sH}^0} + \Gamma_{B_{sL}^0})}$

x_B at high energy

This is a B-B mixing measurement for an admixture of B^0 and B^0_s at high energy. $X_B = r'_d X_d + r'_s X_s$ where r'_d and r'_s are the branching ratio times production fractions of B^0_d and B^0_s mesons relative to all b-flavored hadrons which decay weakly. Mixing violates $\Delta B \neq 0$

VALUE		cı	% EVTS		DOCUMENT ID		TECN	COMMENT	
0.118 ±	-0.006	OUR AVER	AGE						
0.131 ±	0.020	±0.016			ABE		CDF	p 7 1.8 TeV	
0.1107±	0.0062	±0.0055		45	ALEXANDER	96	OPAL	$e^+e^- \rightarrow Z$	
0.121 ±	0.016	±0.006		46	ABREU	94J	DLPH	$e^+e^- \rightarrow Z$	
0.123 ±	0.012	±0.008			ACCIARRI	94D	L3	$e^+e^- \rightarrow Z$	
0.114 ±	0.014	±0.008			BUSKULIC	94G	ALEP	$e^+e^- \rightarrow Z$	
0.129 ±	0.022				BUSKULIC	92B	ALEP	$e^+e^- \rightarrow Z$	
0.176 ±	0.031	±0.032	1112		ABE	91G	CDF	p 7 1.8 TeV	
0.148 ±	0.029	±0.017		50	ALBAJAR	91D	UA1	p₱ 630 GeV	

• • • W	/e do not	use the fo	ollowing data	for averages, fits,	ilmits, etc. • •	•
	±0.037			⁵¹ UENO	96 AMY	e ⁺ e at 57.9 GeV
0.144	±0.014	+0.017 -0.011		⁵² ABREU	94F DLPH	Sup. by ABREU 941
0.131	±0.014			⁵³ ABREU	94J DLPH	$e^+e^- \rightarrow Z$
0.157	± 0.020	±0.032		⁵⁴ ALBAJAR	94 UA1	$\sqrt{s} = 630 \text{ GeV}$
0.121	+0.044 -0.040	±0.017	1665	⁵⁵ ABREU	93c DLPH	Sup. by ABREU 941
0.143	-0.021	±0.007		⁵⁶ AKERS	93B OPAL	Sup. by ALEXAN- DER 96
0.145	+0.041	±0.018		57 ACTON	92c OPAL	$e^+e^- \rightarrow Z$
	±0.017	±0.006		⁵⁸ ADEVA	92C L3	Sup. by AC- CIARRI 940
0.132	±0.22	$+0.015 \\ -0.012$	823	59 DECAMP	91 ALEP	$e^+e^- \rightarrow Z$
0.178	+0.049 -0.040	±0.020		60 ADEVA	90P L3	$e^+e^- \rightarrow Z$
0.17	+0.15 -0.08			61,62 WEIR	90 MRK2	e ⁺ e ⁻ 29 GeV
0.21	+0.29 -0.15			61 BAND	88 MAC	Ecm= 29 GeV
>0.02			90	61 BAND	88 MAC	Ecm = 29 GeV
0.121	±0.047			61,63 ALBAJAR	87C UA1	Repl. by AL- BAJAR 91D
<0.12			90	61,64 SCHAAD	85 MRK2	Ecm = 29 GeV

 44 Uses di-muon events. 45 ALEXANDER 96 uses a maximum likelihood fit to simultaneously extract χ as well as the forward-backward asymmetries in $e^+e^- \rightarrow Z \rightarrow b\overline{b}$ and $c\overline{c}$.

 46 This ABREU 94J result is from 5182 $\ell\ell$ and 279 $\Lambda\ell$ events. The systematic error includes 0.004 for model dependence.

 $^{47}\, \rm BUSKULIC$ 94G data analyzed using e.e, e.u, and $\mu\mu$ events.

48 BUSKULIC 92B uses a jet charge technique combined with electrons and muons.

 $^{49}\,\mathrm{ABE}$ 91G measurement of χ is done with $e\,\mu$ and $e\,e$ events.

50 ALBAJAR 91D measurement of X is done with dimuons.
51 UENO 96 extracted X from the energy dependence of the forward-backward asymmetry. ⁵² AREU 94F uses the average electric charge sum of the Jets recoiling against a *b*-quark jet tagged by a high p_T muon. The result is for $\overline{X} = f_d X_d + 0.9 f_s X_s$.

53 This ABREU 941 result combines ££, \$\Lambda\$£, and jet-charge £ (ABREU 94F) analyses. It is for $\overline{X} = f_d X_d + 0.96 f_s X_s$.

54 ALBAJAR 94 uses dimuon events. Not independent of ALBAJAR 91D.

 $^{55} \text{ABREU}$ 93C data analyzed using e.e., e.u., and $\mu\mu$ events.

56 AKERS 93B analysis performed using dilepton events.

57 ACTON 92C uses electrons and muons. Superseded by AKERS 93B.

58 ADEVA 92c uses electrons and muons.
59 DECAMP 91 done with opposite and like-sign dileptons. Superseded by BUSKULIC 928. 60 ADEVA 90P measurement uses e.e, $\mu\mu$, and e. μ events from 118k events at the Z. Superseded by ADEVA 92C.

 61 These experiments are not in the average because the combination of $B_{\rm S}$ and $B_{\rm d}$ mesons which they see could differ from those at higher energy.

62 The WEIR 90 measurement supersedes the limit obtained in SCHAAD 85. The 90% CL

are 0.06 and 0.38. 63 ALBAJAR 87c measured $x=(\overline{B}^0\to B^0\to \mu^+ X)$ divided by the average production weighted semileptonic branching fraction for B hadrons at 546 and 630 GeV.

 64 Limit is average probability for hadron containing ${\it B}$ quark to produce a positive lepton.

 $\Delta m_{B_s^0} = m_{B_{sH}^0} - m_{B_{sL}^0}$ $\Delta m_{B_s^0}$ is a measure of 2π times the $B_s^0 - \overline{B}_s^0$ oscillation frequency in time-dependent mixing experiments.

"OUR EVALUATION" is an average of the data listed below performed by the LEP B Oscillation Working Group as described in our review "Production and Decays of B-flavored Hadrons" in the B^\pm Section of these Listings. The averaging procedure takes into account correlations between the measurements.

VALUE (10 ¹² h s ⁻¹)		DOCUMENT ID	<u>TECN</u>	COMMENT
>9.1 (CL = 95%) O	UR EVAL	JATION		
>7.9	95	⁶⁵ BARATE	98C ALEP	$e^+e^- \rightarrow Z$
>3.1	95	66 ACKERSTAFF	97U OPAL	e ⁺ e [−] → Z
>6.5	95	67 ADAM	97 DLPH	$e^+e^- \rightarrow Z$
• • • We do not use	the follow	ing data for averages	, fits, ilmits,	etc. • • •
>2.2	95	68 ACKERSTAFF	97V OPAL	e ⁺ e [−] → Z
>6.6	95	⁶⁹ BUSKULIC	96M ALEP	Repl. by BARATE 980
>2.2	95	⁶⁸ AKERS		Sup. by ACKER- STAFF 97V
>5.7	95	⁷⁰ BUSKULIC	95J ALEP	e ⁺ e ⁻ → Z
>1.8	95	⁶⁸ BUSKULIC	948 ALEP	$e^+e^- \rightarrow Z$
65 BARATE 98C con \$\ell/Q_{\text{hem}} \and D_s \ell 66 Uses \ell-Q_{\text{hem}}. 67 ADAM 97 combin	-K in the	same side.		ζ in the same side, $D_{\mathcal{S}}$

68 Uses ℓ - ℓ .
69 BUSKULIC 96M uses D_g lepton correlations and lepton, kaon, and jet charge tags.

 70 BUSKULIC 95J uses £-Qhem. They find $\Delta m_S>5.6$ [> 6.1] for $f_S\!=\!10\%$ [12%]. We interpolate to our central value $f_S\!=\!10.5\%$.

 B_s^0 , B_s^* , B_{sJ}^* (5850)

 $\mathbf{x_s} = \mathbf{\Delta m_{B_s^0}/\Gamma_{B_s^0}}$ This is derived from "OUR EVALUATION" of $\mathbf{\Delta m_{B_s^0}}$ measurements and $\tau_{B_s^0}$

1.54 ps, our central value.

>14.0 (CL = 95%) OUR EVALUATION

This $B_s^0 \cdot \overline{B}_s^0$ integrated mixing parameter is derived from x_s above.

<u>VALUE</u> <u>CL%</u> <u>DOCUMENT ID</u> >0.4975 (CL = 95%) OUR EVALUATION

B_s REFERENCES

			=	(CDC C.H.L.)
ABE	98	PR D57 R3811	F. Abe+	(CDF Collab.)
ABE	98B	PR D57 5382	F. Abe+	(CDF Collab.)
ACKERSTAFF	98F	EPJ C2 407	K. Ackerstaff+	(OPAL Collab.)
ACKERSTAFF	98G	PL B426 161	K. Ackerstaff+	(OPAL Collab.)
BARATE	9BC	EPJ C (to be publ.)	R. Barate+	(ALEPH Collab.)
CERN-PPE	/97-1	57		
ABE	971	PR D55 2546	F. Abe+	(CDF Collab.)
ACCIARRI	97B	PL B391 474	M. Acciarri+	(L3 Collab.)
ACCIARRI	97C	PL B391 481	M. Acciarri+	(L3 Collab.)
ACKERSTAFF	97U	ZPHY C76 401	K. Ackerstaff+	(OPAL Collab.)
ACKERSTAFF	97V	ZPHY C76 417	K. Ackerstaff+	(OPAL Collab.)
ADAM	97	PL B414 382	W. Adam+	(DELPHI Collab.)
ABE	96B	PR D53 3496	+Albrow, Amendolia, Amidei+	(CDF Collab.)
ABE	96L		+Akimoto, Akopian, Albrow+	(CDF Collab.)
		PRL 76 4675		(CDF Collab.)
ABE	96N	PRL 77 1945	+Akimoto, Akopian, Albrow+	(CDF Collab.)
ABE	96Q	PR D54 6596	+Akimoto, Akopian, Albrow+	
ABREU	96F	ZPHY C71 11	+Adam, Adye, Agasi+	(DELPHI Collab.)
ADAM	96D	ZPHY C72 207	W. Adam+	(DELPHI Collab.)
ALEXANDER	96	ZPHY C70 357	+Allison, Altekamp+	(OPAL Collab.)
BUSKULIC	96E	ZPHY C69 585	+Casper, De Bonis, Decamp+	(ALEPH Collab.)
BUSKULIC	96M	PL B377 205	+De Bonis, Decamp, Ghez+	(ALEPH Collab.)
BUSKULIC	96V	PL B384 471	+De Bonis, Decamp, Ghez+	(ALEPH Collab.)
PDG	96	PR D54 1		
UENO	96	PL B381 365	+Kanda, Olsen, Kirk+	(AMY Collab.)
ABE	95R	PRL 74 4988	+Albrow, Amendolia, Amidei+	(CDF Collab.)
ABE	95Z	PRL 75 3068	+Albrow, Amendolia, Amidei+	(CDF Collab.)
ACCIARRI	95H	PL B363 127	+Adam, Adriani, Aguilar-Benitez+	(L3 Collab.)
ACCIARRI	951	PL B363 137	+Adam, Adriani, Aguilar-Benitez+	(L3 Collab.)
AKERS	95G	PL B350 273	+Alexander, Allison, Ametewee+	(OPAL Collab.)
AKERS	95J	ZPHY C66 555		(OPAL Collab.)
	95J		+Alexander, Allison, Ametewee+	(ALEPH Collab.)
BUSKULIC		PL B356 409	+Casper, De Bonis, Decamp+	(ALEPH Collab.)
BUSKULIC	950	PL B361 221	+Casper, De Bonis, Decamp+	
ABREU	94D	PL 8324 500	+Adam, Adye, Agasi, Aleksan+	(DELPHI Collab.)
ABREU	94E	ZPHY C61 407	+Adam, Adye, Agasi, Aleksan+	(DELPHI Collab.)
Also	92M	PL B289 199	Abreu, Adam, Adye, Agasi, Alekseev+	(DELPHI Collab.)
ABREU	94F	PL B322 459	+Adam, Adye, Agasi, Ajinenko+	(DELPHI Collab.)
ABREU	94J	PL B332 488	+Adam, Adye, Agasi, Ajinenko+	(DELPHI Collab.)
ACCIARRI	94D	PL B335 542	+Adam, Adriani, Aguilar-Benitez, Ahlen+	(L3 Collab.)
AKERS	94.1	PL B337 196	+Alexander, Allison, Anderson, Arcelli+	(OPAL Collab.)
AKERS	94L	PL B337 393	+Alexander, Allison, Anderson, Arcelli+	(OPAL Collab.)
ALBAJAR	94	ZPHY C61 41	+Ankoviak, Bartha, Bezaguet, Boehrer+	(UA1 Collab.)
BUSKULIC	94B	PL B322 441	+De Bonis, Decamp, Ghez, Goy, Lees+	(ALEPH Collab.)
BUSKULIC	94C	PL B322 275	+De Bonis, Decamp, Ghez, Goy, Lees+	(ALEPH Collab.)
BUSKULIC	94G	ZPHY C62 179	+Casper, De Bonis, Decamp, Ghez+	(ALEPH Collab.)
PDG	94	PR D50 1173		BL, BOST, IFIC+)
ABE	93F	PRL 71 1685	+Albrow, Amidei, Anway-Wiese+	(CDF Collab.)
ABREU	93C	PL B301 145	+Adam, Adye, Agasi, Aleksan+	(DELPHI Collab.)
ACTON	93H	PL B312 501	+Akers, Alexander, Allison, Anderson+	(OPAL Collab.)
AKERS	93B	ZPHY C60 199	+Alexander, Allison, Anderson, Arcelli+	(OPAL Collab.)
BUSKULIC	93G	PL B311 425	+De Bonis, Decamp, Ghez, Goy, Lees+	(ALEPH Collab.)
ABREU	92M	PL B289 199	+Adam, Adye, Agasi, Alekseev+	(DELPHI Collab.)
ACTON	92C	PL B276 379	+Alexander, Allison, Allport, Anderson+	(OPAL Collab.)
ACTON	92N	PL B295 357	+Alexander, Allison, Allport, Anderson+	(OPAL Collab.)
ADEVA	92C	PL B288 395	+Adriani, Aguilar-Benitez, Ahlen+	(L3 Collab.)
BUSKULIC	92B	PL B284 177	+Decamp, Goy, Lees, Minard+	(ALEPH Collab.)
BUSKULIC	92€	PL B294 145	+Decamp, Goy, Lees, Minard+	(ALEPH Collab.)
ABE	91G	PRL 67 3351	+Amidei, Apollinari, Atac, Auchincloss+	(CDF Collab.)
ALBAJAR	91D	PL B262 171	+Albrow, Allkofer, Ankoviak, Apsimon+	(UA1 Collab.)
DECAMP	91	PL B258 236	+Deschizeaux, Goy, Lees, Minard+	(ALEPH Collab.)
ADEVA	90P	PL B252 703	+Adriani, Aguilar-Benitez, Akbari, Alcaraz	
LEE-FRANZIN	90	PRL 65 2947	+Heintz, Lovelock, Narain, Schamberger+	- (CUSB II Collab.)
WEIR	90	PL B240 289	+Abrams, Adolphsen, Alexander, Alvarez-	
BAND	88	PL B200 221	+Camporesi, Chadwick+	` (MAC Collab.)
ALBAJAR	87C	PL B186 247	+Albrow, Allkofer, Arnison+	(UA1 Collab.)
SCHAAD	85	PL 160B 188	+Nelson, Abrams, Amidei+	(Mark II Collab.)



47.0±2.6

 $I(J^P) = 0(1^-)$

OMITTED FROM SUMMARY TABLE

I, J, P need confirmation. Quantum numbers shown are quarkmodel predictions.

B. MASS

From mass difference below and the ${\cal B}^0_{\it s}$ mass.

5416.3±3.3 OUR FIT

DOCUMENT ID

 $m_{B_s^*} - m_{B_s}$

VALUE (MeV)
47.0±2.6 OUR FIT

DOCUMENT ID TECN COMMENT ¹LEE-FRANZINI 90 CSB2 $e^+e^- \rightarrow \Upsilon(55)$

 $^1\text{LEE-FRANZINI}$ 90 measure 46.7 \pm 0.4 \pm 0.2 MeV for an admixture of $B^0,~B^+,~\text{and}~B_{\text{S}}.$ They use the shape of the photon line to separate the above value for $B_{\text{S}}.$

 $|(m_{B_{\bullet}^{\bullet}}-m_{B_{\bullet}})-(m_{B^{\bullet}}-m_{B})|$

<u>CL%</u> VALUE (MeV) <6 95

DOCUMENT ID TECN COMMENT 95R DLPH ECM = 88-94 GeV ABREU

B_s^* DECAY MODES

Fraction (Γ_I/Γ) Mode Γ_1 $B_s \gamma$ dominant

B* REFERENCES

ABREU 95R ZPHY C68 353 LEE-FRANZINI 90 PRL 65 2947

+Adam, Adye, Agasi+ +Heintz, Lovelock, Narain, Schamberger+ (CUSB II Collab.)

 $B_{sJ}^{*}(5850)$

 $I(J^P) = ?(??)$ I, J, P need confirmation.

OMITTED FROM SUMMARY TABLE

Signal can be interpreted as coming from $\overline{b}s$ states. Needs confirmation.

B*, (5850) MASS

VALUE (MeV) **EVTS** 5853±15 141

TECN COMMENT DOCUMENT ID AKERS 95E OPAL Ecm = 88-94 GeV

 B_{aJ}^* (5850) WIDTH

VALUE (MeV) EVTS 47+22 141

DOCUMENT ID TECN COMMENT 95E OPAL Ecm = 88-94 GeV **AKERS**

B*, (5850) REFERENCES

AKERS 95E ZPHY C66 19 +Alexander, Allison+

(OPAL Collab.)

BOTTOM, CHARMED MESONS

 $(B=C=\pm 1)$

 $B_c^+ = c\overline{b}, B_c^- = \overline{c}b,$ similarly for B_c^* 's



$$I(J^P) = 0(0^-)$$

OMITTED FROM SUMMARY TABLE

I, J, P need confirmation. Quantum numbers shown are quarkmodel predictions.

B_c^+ DECAY MODES

 $\boldsymbol{B}_{\boldsymbol{C}}^{-}$ modes are charge conjugates of the modes below.

Mode		

- $J/\psi(1S)\ell^+\nu_\ell$ anything $J/\psi(1S)\pi^+$
- Γ₂ Γ₃
- $J/\psi(1S)\pi^{+}\pi^{+}\pi^{-}$

B⁺ BRANCHING RATIOS

VALUE	<u>CL%</u>	DOCUMENT I	<u> </u>	TECN	COMMENT	
<1.2 × 10 ⁻⁴	90	¹ BARATE	97H /	ALEP	e+e- →	Z
• • • We do not u	se the followl	ng data for avera	ges, fits,	limits,	etc. • • •	
<1.9 × 10 ⁻⁴	90	² ABREU	97E I	DLPH	e+ e- →	Z
¹ BARATE 97H re	ports B(Z →	$B_c X)/B(Z \rightarrow$	q q)⋅B(<i>B</i> ,	. → J	/ψ(15)lν,) < 5.2 × 10 ⁻⁵
		PDG 96 values o				
candidate event	is found, co	ompared to all the 25 GeV and $ au_{B_c}$	e known	backg	round sour	
² ABREU 97E val	ue listed is fo	r an assumed $ au_{B_c}$	= 0.4 p	s and i	mproves to	1.6×10^{-4} for
$\tau_{R_{-}} = 1.4 \text{ ps.}$						

I (J/ψ(15)# [™])/	I total × B($D \rightarrow B_C$			12/1 X B
VALUE	<u>CL%</u>	DOCUMENT ID	TECN	COMMENT	
<8.2 × 10 ⁻⁵	90	3 BARATE	97H ALEP	$e^+e^- \rightarrow Z$	Z
• • • We do not u	se the follow	ng data for averag	ges, fits, limits,	, etc. • • •	
$< 3.4 \times 10^{-4}$	90	4 ABREU	97E DLPH	e+e- → 2	Z
$< 2.0 \times 10^{-5}$	95	⁵ ABE	96R CDF	p p	
at 90%CL. We	rescale to our	$B_C X)/B(Z \rightarrow PDG 96 values of an assumed \tau_{B_C}$	$f B(Z \rightarrow b\overline{b})$).	
		$B_c X)/B(b \rightarrow B^-)$ 5%CL for $\tau_{B_c} = 0$			
0.17 ps< $ au_{B_c}$ <	1.6 ps. We re	escale to our PDG	96 values of B($(b \to B^+) = 0$	0.378±0.022
and B($B^+ \rightarrow $	$J/\psi(15)K^{+}$	$= 0.00101 \pm 0.0$	0014.		

$\Gamma(J/\psi(1S)\pi^+\pi^+$	r ⁻)/Γ _{tota}	$_{bl} \times B(\overline{b} \rightarrow B_c)$			$\Gamma_3/\Gamma \times B$
VALUE	CL%	DOCUMENT ID	TECN	COMMENT	
<5.7 × 10 ⁻⁴	90	6 ABREU	97E DLPH	e+ e- →	Z
6 ARRELL 97F value	listed is in	dependent of 0.4 ps	CTD < 1.4	DS.	

B_c^{\pm} REFERENCES

ABREU BARATE ABE PDG	97H	PL B398 207 PL B402 213 PRL 77 5176 PR D54 1	P. Abreu+ R. Barate+ +Akimoto, Akopian, Albrow+	(DELPHI Collab.) (ALEPH Collab.) (CDF Collab.)
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Charmonium, $\eta_c(1S)$

cc MESONS

 $\eta_c(1S)$

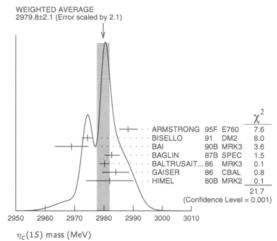
$$I^{G}(J^{PC}) = 0^{+}(0^{-})$$

$\eta_c(1S)$ MASS

VALUE (MeV) EVTS	DOCUMENT ID TECN COMMENT
2979.8± 2.1 OUR AVERAGE	Error includes scale factor of 2.1. See the ideogram below
2988.3 ⁺ 3.3 - 3.1	ARMSTRONG 95F E760 $\overline{p}p \rightarrow \gamma \gamma$
2974.4± 1.9	¹ BISELLO 91 DM2 $J/\psi \rightarrow \eta_C \gamma$
2969 ± 4 ± 4 80	BAI 908 MRK3 $J/\psi \rightarrow$
	7K+K-K+K-
2982.6 ⁺ 2.7 12	BAGLIN 87B SPEC $\overline{p}p \rightarrow \gamma \gamma$
2980.2± 1.6	¹ BALTRUSAIT86 MRK3 $J/\psi \rightarrow \eta_C \gamma$
2984 ± 2.3± 4.0	GAISER 86 CBAL $J/\psi \rightarrow \gamma X, \psi(25) \rightarrow \gamma X$
2982 ± 8 18	$^{\gamma}$ X ² HIMEL 80B MRK2 e ⁺ e ⁻
• • • We do not use the follow	ring data for averages, fits, limits, etc. • • •
2956 ±12 ±12	BAI 90B MRK3 $J/\psi \rightarrow$
	$\gamma K^+ K^- K^0_S K^0_I$
2976 ± 8	3 BALTRUSAIT84 MRK3 $J/\psi ightarrow 2\phi \gamma$
2980 ± 9	² PARTRIDGE 80B CBAL e ⁺ e ⁻
Average of several decay me	odes.

Mass adjusted by us to correspond to $J/\psi(15)$ mass = 3097 MeV.

 $3 \eta_C \rightarrow \dot{\phi} \phi$.

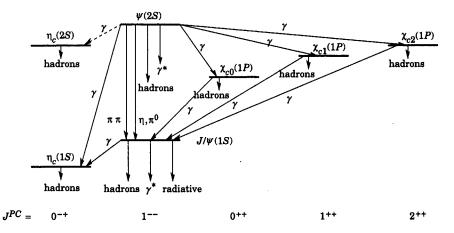


			$\eta_c(15)$ WIDT	Ή		
VALUE (MeV)	CL%	<u>EVTS</u>	DOCUMENT 1D	_	TECN	COMMENT
13.2 + 3.8 OU	IR AVER	AGE				
$23.9^{+12.6}_{-7.1}$			ARMSTRONG	95F	E760	$\overline{p}p \rightarrow \gamma \gamma$
7.0^{+}_{-} 7.5		12	BAGLIN	87в	SPEC	$\overline{p}p \rightarrow \gamma\gamma$
10.1 + 33.0		23	⁴ BALTRUSAIT.	.86	MRK3	$J/\psi \rightarrow \gamma \rho \overline{\rho}$
11.5± 4.5			GAISER	86	CBAL	$J/\psi \rightarrow \gamma X, \psi(2S) \rightarrow \gamma X$
• • • We do not	use the	following				1
<40	90	18	HIMEL	80B	MRK2	e ⁺ e ⁻
<20	90		PARTRIDGE	80B	CBAL	e+e-
⁴ Positive and	negative	errors cor	respond to 90% o	onfic	ience lev	/el.

$\eta_c(1S)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)	Confidence level
	Decays involving	hadronic resonances	
Γ_1	$\eta'(958)\pi\pi$	(4.1 ±1.7) %)
Γ_2	$\rho \rho$	(2.6 ±0.9) %	1
Гз	$K^*(892)^0 K^- \pi^+ + \text{c.c.}$	(2.0 ±0.7) %	1
Γ4	K*(892) K*(892)	(8.5 ±3.1) ×	₁₀ -3
Γ ₅	$\phi\phi$	(7.1 ±2.8) ×	10-3
Γ ₆	$a_0(980)\pi$	< 2 %	90%
Γ7	$a_2(1320)\pi$	< 2 %	90%
Γ8	$K^*(892)\overline{K} + \text{c.c.}$	< 1.28 %	90%
Г9	$f_2(1270)\eta$	< 1.1 %	90%
Γ ₁₀	$\omega \omega$	< 3.1 ×	10 ⁻³ 90%
	Decays into	stable hadrons	
Γ11	$K\overline{K}\pi$	(5.5 ±1.7) %	•
Γ ₁₂	$\eta\pi\pi$	(4.9 ±1.8) %	•
Γ_{13}	$\pi^+\pi^-K^+K^-$	$(2.0 \begin{array}{c} +0.7 \\ -0.6 \end{array})\%$	•
Γ14	2(K+K-)	(2.1 ±1.2) %	•
Γ15	$2(\pi^{+}\pi^{-})$	(1.2 ±0.4) %	,
Γ16		(1.2 ±0.4) ×	10-3
Γ ₁₇	$K\overline{K}\eta$	< 3.1 %	90%
Γ ₁₈	$\pi^+\pi^-\rho\overline{\rho}$	< 1.2 %	90%
Γ ₁₉	$\Lambda \overline{\Lambda}$	< 2 ×	10 ⁻³ 90%
	Radia	tive decays	
Γ ₂₀	$\gamma\gamma$	(3.0 ±1.2) ×	10-4

THE CHARMONIUM SYSTEM



The current state of knowledge of the charmonium system and transitions, as interpreted by the charmonium model. Uncertain states and transitions are indicated by dashed lines. The notation γ^* refers to decay processes involving intermediate virtual photons, including decays to e^+e^- and $\mu^+\mu^-$.

	$\eta_c(15)$ PARTIAL WIDTHS	$\Gamma(f_2(1270)\eta)/\Gamma_{\text{total}}$ Γ_9/Γ
(77)		Γ_{20} $\frac{VALUE}{<0.011}$ $\frac{CL\%}{90}$ $\frac{DOCUMENT ID}{7}$ $\frac{TECN}{MRK3}$ $\frac{COMMENT}{J/ψ \rightarrow η_C γ}$
* * * *	EVTS DOCUMENT ID TECN COMMENT	SACTIONALISE WITH 3/6 4
.5+ 1.6 OUR AV	/ERAGE	$\Gamma(\omega\omega)/\Gamma_{ ext{total}}$ $\Gamma_{10}/\Gamma_{ ext{total}}$
.7+ 2.4 ± 2.3	ARMSTRONG 95F E760 pp → γγ	$VALUE$ CL% DOCUMENT ID TECN COMMENT <0.0031 90 7 BALTRUSAIT86 MRK3 $J/ψ → η_C γ$
3± 4.2	ALBRECHT 94H ARG YY	● ● We do not use the following data for averages, fits, limits, etc. ● ●
0± 2.3±2.4	17 ADRIANI 93N L3 $e^+e^- \rightarrow e^+e^-\eta_C$	< 0.0063 7 BISELLO 91 DM2 $J/\psi \rightarrow \gamma \omega \omega$
$9^{+}_{-1.8}^{2.1}_{\pm 1.9}$	CHEN 90B CLEO $e^+e^- \rightarrow e^+e^-\eta_C$	$\Gamma(K\overline{K}\pi)/\Gamma_{\text{total}}$ $\Gamma_{11}/\Gamma_{\text{total}}$
.4 + 5.0 - 3.4	AIHARA 88D TPC $e^+e^- \rightarrow e^+e^- X$	VALUE CL% EVTS DOCUMENT ID TECN COMMENT
± 15	⁵ BERGER 86 PLUT $\gamma\gamma \rightarrow K\overline{K}\pi$	0.055 ±0.017 OUR EVALUATION (Treating systematic errors as correlated.)
⁵ Re-evaluated by	AIHARA 88D.	0.055 ±0.008 OUR AYERAGE 0.0690±0.0142±0.0132 33 7 BISELLO 91 DM2 J/ψ →
	$\eta_c(1S) \Gamma(i)\Gamma(\gamma\gamma)/\Gamma(total)$	$\gamma K^+K^-\pi^0$ 0.0543 \pm 0.0094 \pm 0.0094 68 7 BISELLO 91 DM2 $J/\psi ightarrow$
'VV-1 v F/a		$\gamma K^{\pm} \pi^{\mp} K^{0}$
$(K\overline{K}\pi) \times \Gamma(\gamma)$	(YY)/F _{total} F ₁₁ F CL% EVTS DOCUMENT ID TECN COMMENT	0.046 \pm 0.011 93 PALTROSATT26 WKR3 $J/\psi \rightarrow \eta_C \gamma$
0.94±0.18 OUR	AVERAGE	0.161 $^{+0.092}_{-0.073}$ 10 HIMEL 808 MRK2 $\psi(25) ightarrow \eta_{c} \gamma$
0.84±0.21	⁶ ALBRECHT 94H ARG $\gamma\gamma \rightarrow K^{\pm}K_{S}^{0}$	
$1.06 \pm 0.41 \pm 0.27$ $1.5 \begin{array}{c} +0.60 \\ -0.45 \pm 0.3 \end{array}$	_	<0.107 90 7 PARTRIDGE 80B CBAL $J/\psi \rightarrow \eta_{\rm C} \gamma$
	7 b BERGER 86 PLUT $\gamma\gamma \to K\overline{K}\pi$ se the following data for averages, fits, limits, etc. • • •	$\Gamma(\eta\pi\pi)/\Gamma_{\text{total}}$ $\Gamma_{12}/\Gamma_{\text{total}}$
• • vve do not us 0.63	95 GEHREND 89 CELL $\gamma\gamma \rightarrow K_5^0 K^{\pm}$	VALUE EVTS DOCUMENT ID TECN COMMENT
4.4	95 ALTHOFF 85B TASS $\gamma \gamma \rightarrow KK\pi$	π^+ 0.049 \pm 0.018 OUR EVALUATION 0.047 \pm 0.015 OUR AVERAGE
6 K± K ⁰ Sπ [∓] corr	rected to $K\overline{K}\pi$ by factor 3.	0.054 \pm 0.020 75 $\frac{7}{2}$ BALTRUSAIT86 MRK3 $J/\psi ightarrow \eta_{C} \gamma$
		0.037 \pm 0.013 \pm 0.020 18 ⁷ PARTRIDGE 808 CBAL $J/\psi \rightarrow \eta \pi^+ \pi^- \gamma$
	$\eta_c(15)$ BRANCHING RATIOS	$\Gamma(\pi^+\pi^-K^+K^-)/\Gamma_{\text{total}}$ Γ_{13}/Γ_{13}
	HADRONIC DECAYS	VALUE EVTS DOCUMENT ID TECN COMMENT
η'(958)ππ)/Γ ₁	total	Γ ₁ /Γ 0.020 ^{+0.007} OUR AVERAGE
LUE	EVTS DOCUMENT ID TECN COMMENT	0.021 \pm 0.007 110 ⁷ BALTRUSAIT86 MRK3 $J/\psi \rightarrow \eta_C \gamma$
041±0.017	14 7 BALTRUSAIT86 MRK3 $J/\psi ightarrow \eta_{c} \gamma$	$0.014^{+0.022}_{-0.009}$ 10 HIMEL 80B MRK2 $\psi(25) ightarrow \eta_{C} \gamma$
$(\rho \rho)/\Gamma_{\text{total}}$		Γ_2/Γ $\Gamma(2(\pi^+\pi^-))/\Gamma_{ ext{total}}$ $\Gamma_{15}/\Gamma_{ ext{total}}$
LUE (units 10 ⁻³)	CL% EVTS DOCUMENT ID TECN COMMENT	VALUE EVTS DOCUMENT ID TECN COMMENT
26 ± 9 OUR	R EVALUATION (Treating systematicerrors as correlated.)	
		0.012 ±0.004 OUR EVALUATION
25 ± 8 OUR 26.0± 2.4±8.8	R AVERAGE 113 7 BISELLO 91 DM2 $J/\psi ightarrow \gamma ho^0 ho^0$	0.0120±0.0031 OUR AVERAGE
25 ± 8 OUR 26.0± 2.4±8.8 23.6±10.6±8.2	R AVERAGE 3 113 7 BISELLO 91 DM2 $J/\psi \rightarrow \gamma \rho^0 \rho^0$ 2 32 7 BISELLO 91 DM2 $J/\psi \rightarrow \gamma \rho^+ \rho$	0.0120 \pm 0.0031 OUR AVERAGE 0.0105 \pm 0.0017 \pm 0.0034 137 ⁷ BISELLO 91 DM2 $J/\psi \rightarrow \gamma 2\pi^+ 2\pi^-$
25 ± 8 OUR 26.0 ± 2.4 ± 8.8 23.6 ± 10.6 ± 8.2 • • We do not us	R AVERAGE 3 113 7 BISELLO 91 DM2 $J/\psi \rightarrow \gamma \rho^0 \rho^0$ 2 32 7 BISELLO 91 DM2 $J/\psi \rightarrow \gamma \rho^+ \rho^0$ see the following data for averages, fits, limits, etc. • • •	0.0120 \pm 0.0031 OUR AVERAGE 0.0105 \pm 0.0017 \pm 0.0034 137 ⁷ BISELLO 91 DM2 $J/\psi \rightarrow \gamma 2\pi^{+}2\pi^{-}$ 0.013 \pm 0.006 25 ⁷ BALTRUSAIT86 MRK3 $J/\psi \rightarrow \eta_{C}\gamma$
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25 ± 8 OUR 26.0± 2.4±8.8 23.6±10.6±8.2 • We do not us 140 (K*(892)** K*- 22 ±0.007 (K*(892)** K*- 28±27 ±50 (K*(892)** K*+ 28±27 ±50 (K*(892)** K*+ 28±27 ±50 (K*(892)** K*+ 28±27 ±50 LUE (units 10-4) ±28±0 OUR EVALU ±28 OUR EVALU ±22 OUR AVER ±18±24 ±21±24 • • We do not us ± 7±10	R AVERAGE 3 113 7 BISELLO 91 DM2 $J/\psi \rightarrow \gamma \rho^0 \rho^0$ 2 32 7 BISELLO 91 DM2 $J/\psi \rightarrow \gamma \rho^0 \rho^0$ 32 7 BISELLO 91 DM2 $J/\psi \rightarrow \gamma \rho^0 \rho^0$ 32 8 BISELLO 91 DM2 $J/\psi \rightarrow \gamma \rho^0 \rho^0$ 33 7 BALTRUSAIT86 MRK3 $J/\psi \rightarrow \eta_C \gamma$ 34 + c.c.)/\(\text{Ftotal}\) \[\begin{array}{c} \text{EVTS} & \text{DOCUMENT ID} & \text{TECN} & \text{COMMENT} \\ \text{92}\)/\(\text{Ftotal}\) \[\begin{array}{c} \text{EVTS} & \text{DOCUMENT ID} & \text{TECN} & \text{COMMENT} \\ \text{92}\) 4 BISELLO 91 DM2 $e^+e^- \rightarrow \gamma K^+K^-\pi^+\pi^-$ 9 BALTRUSAIT86 MRK3 $J/\psi \rightarrow \eta_C \gamma$ 5.C.C.)/\(\text{Ftotal}\) \[\begin{array}{c} \text{CLS} & \text{DOCUMENT ID} & \text{TECN} & \text{COMMENT} \\ \text{90} & \text{BISELLO} & 91 DM2 \\ \text{90} & \text{BISELLO} & 91 DM2 \\ \text{90} & \text{BISELLO} & 91 DM2 \\ \text{90} & \text{7} \text{BISELLO} & \text{91} DM2 \\ \text{90} & \text{7} \text{BAI} & \text{90B MRK3} \\ \text{7} \text{BISELLO} & \text{91} DM2 \\ \text{7} \text{90} \\ \text{7} \text{BISELLO} & \text{91} DM2 \\ \text{7} \text{7} \\ \text{90} \\ \text{7} \text{BISELLO} & \text{91} DM2 \\ \text{7} \text{7} \\ \text{90B MRK3} \\ \text{7} \text{90} \\ \text{7} \text{81 BISELLO} & \text{91} DM2 \\ \text{7} \text{7} \\ \text{7} \text{7} \\ \text{7} \text{81 BISELLO} & \text{91} DM2 \\ \text{7} \text{7} \\ \text{7} \text{7} \\ \text{7} \text{81 BISELLO} & \text{91} DM2 \\ \text{7} \text{7} \\ \text{7} \text{7} \\ \text{7} \text{7} \\ \text{7} \text{7} \\ \text{7} \text{81 BISELLO} & \text{91} DM2 \\ \text{7} \text{7} \\	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
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25 ± 8 OUR 26.0± 2.4±8.8 23.6±10.6±8.2 • We do not us 140 (K*(892)** K*- 22 ± 0.007 (K*(892)** K*- 22 ± 0.007 (K*(892)** K*- 23 ± 0.007 (K*(892)** K*- 24 ± 28 ± 27 25 ± 50 (K*(892)** K*+ 25 ± 28 ± 27 25 ± 50 (K*(892)** K*+ 26 ± 28 ± 27 25 ± 50 (K*(892)** K*+ 27 ± 50 (K*(892)** K*+ 28 ± 27 25 ± 50 (K*(892)** K*+ 28 ± 28 ± 27 25 ± 50 (K*(892)** K*+ 28 ± 28 ± 27 25 ± 50 (K*(892)** K*+ 28 ± 28 ± 27 25 ± 28 ± 28 26 ± 28 ± 28 27 ± 21 ± 24 28 • We do not us 12 ± 21 ± 24 28 • We do not us 12 ± 7 ± 10 (4a)(980)** // Tatal	R AVERAGE 3 113 7 BISELLO 91 DM2 $J/\psi \rightarrow \gamma \rho^0 \rho^0$ 3 2 32 7 BISELLO 91 DM2 $J/\psi \rightarrow \gamma \rho^0 \rho^0$ is the following data for averages, fits, limits, etc. • • • 90 7 BALTRUSAIT86 MRK3 $J/\psi \rightarrow \eta_C \gamma$ $\pi^+ + \text{c.c.})/\Gamma_{\text{total}}$ EVTS DOCUMENT ID TECN COMMENT 63 7 BALTRUSAIT86 MRK3 $J/\psi \rightarrow \eta_C \gamma$ 692))/ Γ_{total} EVTS DOCUMENT ID TECN COMMENT 4 7 BISELLO 91 DM2 $e^+e^- \rightarrow \gamma K^+ K^- \pi^+ \pi^-$ 9 7 BALTRUSAIT86 MRK3 $J/\psi \rightarrow \eta_C \gamma$ C.C.)/ Γ_{total} CLY. DOCUMENT ID TECN COMMENT 90 BISELLO 91 DM2 $J/\psi \rightarrow \gamma K^0 K^\pm \pi^-$ 90 BISELLO 91 DM2 $J/\psi \rightarrow \gamma K^0 K^\pm \pi^-$ 90 BISELLO 91 DM2 $J/\psi \rightarrow \gamma K^0 K^\pm \pi^-$ EVTS DOCUMENT ID TECN COMMENT LUATION (Treating systematic errors as correlated.) AGE 80 7 BAI 90B MRK3 $J/\psi \rightarrow \gamma K^+ K^- K^- K^- K^- K^- K^- K^- K^- K^- K^-$	0.0120±0.0031 OUR AVERAGE 0.0105±0.0017±0.0034 137 7 BISELLO 91 DM2 $J/\psi \rightarrow \gamma 2\pi^{+}2\pi^{-}$ 0.013±0.006 0.020±0.015 10 HIMEL 808 MRK2 $\psi(2S) \rightarrow \eta_{C}\gamma$ 14/1 VALUE 0.021±0.010±0.006 Fa/f 12±4 OUR AVERAGE 10±3±4 11±6 23 7 BALTRUSAIT86 MRK3 $J/\psi \rightarrow \eta_{C}\gamma$ 10±4 MRK2 11±6 12±3 FBALTRUSAIT86 MRK3 $J/\psi \rightarrow \eta_{C}\gamma$ 10±1 MRK2 11±6 12±4 OUR AVERAGE 10±3±4 18 7 BISELLO 91 DM2 $J/\psi \rightarrow \gamma p \bar{p}$ 11±6 23 7 BALTRUSAIT86 MRK3 $J/\psi \rightarrow \eta_{C}\gamma$ 10 HIMEL 808 MRK2 $\psi(2S) \rightarrow \eta_{C}\gamma$ 10 HIMEL 808 MRK2 $\psi(2S) \rightarrow \eta_{C}\gamma$ 10 HIMEL 808 MRK2 $\psi(2S) \rightarrow \eta_{C}\gamma$ 11/1 Fa/f
25 ± 8 OUR 26.0± 2.4±8.8 23.6±10.6±8.2 • • We do not us 140 (K*(892)** (K*(8	R AVERAGE 3 113 7 BISELLO 91 DM2 $J/\psi \rightarrow \gamma \rho^0 \rho^0$ 2 32 7 BISELLO 91 DM2 $J/\psi \rightarrow \gamma \rho^0 \rho^0$ Isse the following data for averages, fits, limits, etc. • • • 90 7 BALTRUSAIT86 MRK3 $J/\psi \rightarrow \eta_C \gamma$ $\pi^+ + \text{c.c.})/\Gamma_{\text{total}}$ EVTS DOCUMENT ID TECN COMMENT 63 7 BALTRUSAIT86 MRK3 $J/\psi \rightarrow \eta_C \gamma$ (92))/ Γ_{total} EVTS DOCUMENT ID TECN COMMENT 49 7 BALTRUSAIT86 MRK3 $J/\psi \rightarrow \eta_C \gamma$ C.C.)/ Γ_{total} CLS. DOCUMENT ID TECN COMMENT 90 BISELLO 91 DM2 $e^+e^- \rightarrow \gamma K^+K^- \pi^+ \pi^-$ 90 BISELLO 91 DM2 $J/\psi \rightarrow \gamma K^0_S K^{\pm}$ 90 7 BISELLO 91 DM2 $J/\psi \rightarrow \gamma K^0_S K^{\pm}$ 14 7 BALTRUSAIT86 MRK3 $J/\psi \rightarrow \eta_C \gamma$ C.C.)/ Γ_{total} CLS. DOCUMENT ID TECN COMMENT 19 90 BISELLO 91 DM2 $J/\psi \rightarrow \gamma K^0_S K^{\pm}$ 10 PM3 $J/\psi \rightarrow \gamma K^0_S K^{\pm}$ 10 PM4 PM5 $J/\psi \rightarrow \gamma K^0_S K^{\pm}$ 11 PM5	0.0120±0.0031 OUR AVERAGE 0.0105±0.0017±0.0034 137 7 BISELLO 91 DM2 $J/\psi \rightarrow \gamma 2\pi^{+}2\pi^{-}$ 0.013 ±0.006 0.020 +0.015 10 HIMEL 808 MRK2 $\psi(2S) \rightarrow \eta_{C}\gamma$ 10 HIMEL 808 MRK2 $\psi(2S) \rightarrow \eta_{C}\gamma$ 14/1 VALUE 0.021±0.010±0.006 ALBRECHT 94H ARG 7 $\gamma \rightarrow K^{+}K^{-}K^{+}K^{-}K^{-}K^{+}K^{-}K^{-}K^{-}K^{-}K^{-}K^{-}K^{-}K^{-$
25 ± 8 OUR 26.0± 2.4±8.8 23.6±10.6±8.2 • We do not us 140 (K*(892)** K*- 22 ±0.007 (K*(892)** K*- 23 ±0.007 (K*(892)** K*- 24 ±0.007 (K*(892)** K*- 25 ±0.007 (K*(892)**	R AVERAGE 3 113 7 BISELLO 91 DM2 $J/\psi \rightarrow \gamma \rho^0 \rho^0$ 3 2 32 7 BISELLO 91 DM2 $J/\psi \rightarrow \gamma \rho^0 \rho^0$ is the following data for averages, fits, limits, etc. • • • 90 7 BALTRUSAIT86 MRK3 $J/\psi \rightarrow \eta_C \gamma$ $\pi^+ + \text{c.c.})/\Gamma_{\text{total}}$ EVTS DOCUMENT ID TECN COMMENT 63 7 BALTRUSAIT86 MRK3 $J/\psi \rightarrow \eta_C \gamma$ 692))/ Γ_{total} EVTS DOCUMENT ID TECN COMMENT 49 7 BALTRUSAIT86 MRK3 $J/\psi \rightarrow \eta_C \gamma$ C.C.)/ Γ_{total} CLX. DOCUMENT ID TECN COMMENT 90 BISELLO 91 DM2 $e^+e^- \rightarrow \gamma K^+ K^- \pi^+ \pi^-$ 90 BISELLO 91 DM2 $J/\psi \rightarrow \gamma K^0 K^{\pm} \pi^+ \pi^-$ 90 BISELLO 91 DM2 $J/\psi \rightarrow \gamma K^0 K^{\pm} \pi^-$ 10 BISELLO 91 DM2 $J/\psi \rightarrow \gamma K^0 K^{\pm} \pi^-$ 10 BISELLO 91 DM2 $J/\psi \rightarrow \gamma K^+ K^- \pi^-$ EVTS DOCUMENT ID TECN COMMENT 10 DATE OF TECN COMMENT 10 DATE OF TECN COMMENT 11 PALL POST OF TECN COMMENT 12 PALL POST OF TECN COMMENT 13 PALL POST OF TECN COMMENT 14 PALL POST OF TECN COMMENT 15 PALL POST OF TECN COMMENT 16 PALL POST OF TECN COMMENT 17 BALL POST OF TECN COMMENT 18 PALL POST OF TECN COMMENT 19 PA	0.0120±0.0031 OUR AVERAGE 0.0105±0.0017±0.0034 137 7 BISELLO 91 DM2 $J/\psi \rightarrow \gamma 2\pi^{+}2\pi^{-}$ 0.013 ±0.006 0.020 +0.015 10 HIMEL 808 MRK2 $\psi(2S) \rightarrow \eta_{C}\gamma$ 10 HIMEL 808 MRK2 $\psi(2S) \rightarrow \eta_{C}\gamma$ 14/1 VALUE 0.021±0.010±0.006 ALBRECHT 94H ARG 77 → K ⁺ K ⁻ K ⁺ K ⁻ 12± 4 OUR AVERAGE 10± 3±4 18 16 23 7 BALTRUSAIT86 MRK3 $J/\psi \rightarrow \eta_{C}\gamma$ 12± 4 OUR AVERAGE 10± 3±4 18 7 BISELLO 91 DM2 $J/\psi \rightarrow \gamma_{P}p$ 11± 6 23 7 BALTRUSAIT86 MRK3 $J/\psi \rightarrow \eta_{C}\gamma$ 10 HIMEL 808 MRK2 $\psi(2S) \rightarrow \eta_{C}\gamma$ 11 Fig. Comment 12 DOCUMENT ID 13 DOCUMENT ID 14 DOCUMENT ID 15 DOCUMENT ID 16 DOCUMENT ID 17 DOCUMENT ID 18 DOCUMENT
25 ± 8 OUR 26.0± 2.4±8.8 23.6±10.6±8.2 • • We do not us 140 (K*(892)** (K*(8)** (K*(8)** (K*(8)** (K*(8)** (K*(8)** (K*(8)** (K*(8)** (K*(8)*	R AVERAGE 3 113 7 BISELLO 91 DM2 $J/\psi \rightarrow \gamma \rho^0 \rho^0$ 3 2 32 7 BISELLO 91 DM2 $J/\psi \rightarrow \gamma \rho^0 \rho^0$ is the following data for averages, fits, limits, etc. • • • 90 7 BALTRUSAIT86 MRK3 $J/\psi \rightarrow \eta_C \gamma$ $\pi^+ + \text{c.c.})/\Gamma_{\text{total}}$ EVTS DOCUMENT ID TECN COMMENT 63 7 BALTRUSAIT86 MRK3 $J/\psi \rightarrow \eta_C \gamma$ 692))/ Γ_{total} EVTS DOCUMENT ID TECN COMMENT 49 7 BALTRUSAIT86 MRK3 $J/\psi \rightarrow \eta_C \gamma$ C.C.)/ Γ_{total} CLX. DOCUMENT ID TECN COMMENT 90 BISELLO 91 DM2 $e^+e^- \rightarrow \gamma K^+ K^- \pi^+ \pi^-$ 90 BISELLO 91 DM2 $J/\psi \rightarrow \gamma K^0 K^{\pm} \pi^+ \pi^-$ 90 BISELLO 91 DM2 $J/\psi \rightarrow \gamma K^0 K^{\pm} \pi^-$ 10 BISELLO 91 DM2 $J/\psi \rightarrow \gamma K^0 K^{\pm} \pi^-$ 10 BISELLO 91 DM2 $J/\psi \rightarrow \gamma K^+ K^- \pi^-$ EVTS DOCUMENT ID TECN COMMENT 10 DATE OF TECN COMMENT 10 DATE OF TECN COMMENT 11 PALL POST OF TECN COMMENT 12 PALL POST OF TECN COMMENT 13 PALL POST OF TECN COMMENT 14 PALL POST OF TECN COMMENT 15 PALL POST OF TECN COMMENT 16 PALL POST OF TECN COMMENT 17 BALL POST OF TECN COMMENT 18 PALL POST OF TECN COMMENT 19 PA	0.0120±0.0031 OUR AVERAGE 0.0105±0.0017±0.0034 137 7 BISELLO 91 DM2 $J/\psi \rightarrow \gamma 2\pi^{+}2\pi^{-}$ 0.013 ±0.006 0.020 +0.015 10 HIMEL 808 MRK2 $\psi(2S) \rightarrow \eta_{C}\gamma$ 7 BALTRUSAIT86 MRK3 $J/\psi \rightarrow \eta_{C}\gamma$ 10 HIMEL 808 MRK2 $\psi(2S) \rightarrow \eta_{C}\gamma$ 7 F14/ 7 F12/ 7 F14/ 7 F14/ 7 F15/ 7 F14/ 7 F15/ 7

 $\eta_c(1S)$, $J/\psi(1S)$

RADIATIVE DECAYS	Decays involving hadronic resonances
Γ _(γγ) /Γ _{total} Γ ₂₀ /Γ	$\Gamma_5 \rho \pi$ (1.27±0.09)%
·	$\Gamma_6 \qquad \rho^0 \pi^0 \qquad (4.2 \pm 0.5) \times 10^{-3}$
ALUE (units 10 ⁻⁴) CL% DOCUMENT ID TECN COMMENT 3.0 ±1.2 OUR AVERAGE	$\Gamma_7 = a_2(1320) \rho$ (1.09±0.22)%
$2.80^{+0.67}_{-0.58}\pm 1.0$ ARMSTRONG 95F E760 $\overline{p}p \rightarrow \gamma\gamma$	$\Gamma_8 \omega \pi^+ \pi^+ \pi^- \pi^- $ (8.5 ± 3.4) × 10 ⁻³ $\Gamma_9 \omega \pi^+ \pi^- $ (7.2 ± 1.0) × 10 ⁻³
	· · · · · · · · · · · · · · · · · · ·
6 $^{+4}_{-3}$ ± 4 BAGLIN 87B SPEC $\overline{p}p \rightarrow \gamma\gamma$	$\Gamma_{10} \qquad \omega f_2(1270)$ (4.3 ±0.6)×10 ⁻³ $\Gamma_{11} \qquad K^*(892)^0 \overline{K}_2^*(1430)^0 + \text{c.c.}$ (6.7 ±2.6)×10 ⁻³
• We do not use the following data for averages, fits, limits, etc. • •	$\Gamma_{12} \omega K^*(892) \overline{K} + \text{c.c.}$ (6.7 ±2.6)×10 ⁻³
< 9 90 $\frac{7}{11}$ BISELLO 91 DM2 $J/\psi \rightarrow \gamma \gamma \gamma$	$\Gamma_{13} K^+ \overline{K}^* (892)^- + \text{c.c.}$ (5.5 ±0.4) × 10 ⁻³
<18 90 ¹¹ BLOOM 83 CBAL $J/\psi \rightarrow \eta_C \gamma$	$\Gamma_{14} K^0 \overline{K}^* (892)^0 + \text{c.c.}$ (4.2 ±0.4) × 10 ⁻³
11 Using B $(J/\psi(15) \rightarrow \gamma \eta_{\mathcal{C}}(15)) = 0.0127 \pm 0.0036$.	$\Gamma_{15} \omega \pi^0 \pi^0$ (3.4 ±0.8) × 10 ⁻³
$_{1}\Gamma_{f}/\Gamma_{\text{total}}^{2}$ in $p\overline{p} \rightarrow \eta_{c}(1S) \rightarrow \gamma\gamma$ $\Gamma_{16}\Gamma_{20}/\Gamma^{2}$	$\Gamma_{16} b_1(1235)^{\pm} \pi^{\mp}$ [a] (3.0 ±0.5) × 10 ⁻³
ALUE (units 10 ⁻⁶) EVTS DOCUMENT ID TECN COMMENT	$\Gamma_{17} = \omega \hat{K}^{\pm} K_{5}^{0} \pi^{\mp}$ [a] (3.0 ±0.7) × 10 ⁻³
	$\Gamma_{18} b_1(1235)^0 \pi^0$ (2.3 ±0.6) × 10 ⁻³
36 +0.08 OUR AVERAGE Error includes scale factor of 1.1.	$\Gamma_{19} = \phi K^*(892) \overline{K} + \text{c.c.}$ (2.04±0.28) × 10 ⁻³
336 $^{+0.080}_{-0.070}$ ARMSTRONG 95F E760 $\overline{p}p \rightarrow \gamma\gamma$	$\Gamma_{20} \omega K \overline{K}$ (1.9 ±0.4) × 10 ⁻³
	$\Gamma_{21} \qquad \omega f_J(1710) \rightarrow \omega K \overline{K} \qquad (4.8 \pm 1.1) \times 10^{-4}$
$68 \begin{array}{c} +0.42 \\ -0.31 \end{array}$ 12 BAGLIN 87B SPEC $\overline{p}p \rightarrow \gamma\gamma$	$\Gamma_{22} \phi 2(\pi^+ \pi^-) $ (1.60±0.32) × 10 ⁻³
	$\Gamma_{23} \Delta (1232)^{++} \overline{p} \pi^{-}$ (1.6 ±0.5) × 10 ⁻³
$\eta_c(1S)$ REFERENCES	$\Gamma_{24} = \omega \eta$ (1.58±0.16) × 10 ⁻³
RMSTRONG 95F PR D52 4839 +Bettoni+ (FNAL, FERR, GENO, UCI, NWES+)	$\Gamma_{25} \phi K \overline{K}$ (1.48±0.22) × 10 ⁻³ $\Gamma_{26} \phi f_J(1710) \rightarrow \phi K \overline{K}$ (3.6 ±0.6) × 10 ⁻⁴
LBRECHT 94H PL B338 390 +Hamacher, Hofmann+ (ARGUS Collab.) DRIANI 93N PL B318 575 +Aguilar-Benitez, Ahlen+ (L3 Collab.)	
SELLO 91 NP B350 1 +Busetto+ (DM2 Collab.)	$ \Gamma_{27} p\overline{p}\omega \qquad (1.30\pm0.25)\times 10^{-3} \qquad \text{S=1} \\ \Gamma_{28} \Delta(1232)^{++} \overline{\Delta}(1232)^{} \qquad (1.10\pm0.29)\times 10^{-3} $
HEN 90B PL B243 169 +Mcflwain+ (CLEO Collab.)	$\Gamma_{28} = \Sigma(1385)^{+} \Sigma(1385)^{+} \text{ (or c.c.)}$ [a] $(1.03 \pm 0.13) \times 10^{-3}$
AGLIN 89 PL B231 557 +Baird, Bassompierre (R704 Collab.) EHREND 89 ZPHY C42 367 +Criegee+ (CELLO Collab.)	$\Gamma_{29} = 2(1363) \times 2(1363) \times (61 \text{ c.c.})$ [a] $(1.03 \pm 0.13) \times 10^{-4}$ S=1
RAUNSCH 89 ZPHY C41 533 Braunschweig, Bock+ (TASSO Collab.)	$\Gamma_{30} \rho \rho_{1} (930)$ (9 ±4)×10 ⁻⁴ S=2
AGLIN 87B PL B187 191 +Baird, Bassompierre, Borreani+ (R704 Collab.)	$\Gamma_{32} \phi \pi^+ \pi^-$ (8.0 ±1.2)×10 ⁻⁴
ALTRUSAIT 86 PR D33 629 Baltrusaitis, Coffman, Hauser+ (Mark III Collab.) ERGER 86 PL 167B 120 +Genzel, Lackas, Pielorz+ (PLUTO Collab.)	$\Gamma_{33} \phi K^{\pm} K_5^0 \pi^{\mp}$ [a] (7.2 ±0.9)×10 ⁻⁴
AISER 86 PR D34 711 +Bloom, Bulos, Godfrey+ (Crystal Ball Collab.) LTHOFF 85B ZPHY C29 189 +Braunschweig, Kirschfink+ (TASSO Collab.)	$\Gamma_{34} \omega f_1(1420)$ (6.8 ±2.4)×10 ⁻⁴
ALTRUSAIT 84 PRL 52 2126 Baltrusaitis+ (CIT, UCSC, ILL, SLAC, WASH) JP	$\Gamma_{35} \phi \eta$ (6.5 ±0.7) × 10 ⁻⁴
IIMEL 80B PRL 45 1146 +Trilling, Abrams, Alam+ (SLAC, LBL, UCB)	$\Gamma_{36} = (1530)^{-} = \pm (5.9 \pm 1.5) \times 10^{-4}$
ARTRIDGE 80B PRL 45 1150 +Peck+ (CIT, HARV, PRIN, STAN, SLAC)	$\Gamma_{37} pK^{-}\overline{\Sigma}(1385)^{0}$ (5.1 ±3.2) × 10 ⁻⁴
OTHER RELATED PAPERS	$\Gamma_{38} \omega \pi^0$ (4.2 ±0.6)×10 ⁻⁴ S=1
ARMSTRONG 89 PL B221 216 +Benayoun+(CERN, CDEF, BIRM, BARI, ATHU, CURIN+)	$\Gamma_{39} \phi \eta'(958) \qquad (3.3 \pm 0.4) \times 10^{-4}$
	$\Gamma_{40} \phi f_0(980)$ (3.2 ±0.9) × 10 ⁻⁴ S=1
c nc	$\Gamma_{41} = (1530)^0 = 0$ (3.2 ±1.4) × 10 ⁻⁴
$J/\psi(1S)$ $I^{G}(J^{PC}) = 0^{-(1-1)}$	$\Gamma_{42} \Sigma(1385)^- \overline{\Sigma}^+ \text{ (or c.c.)}$ [a] $(3.1 \pm 0.5) \times 10^{-4}$
	$\Gamma_{43} \phi f_1(1285)$ (2.6 ±0.5) × 10 ⁻⁴ S=: $\Gamma_{44} \rho \eta$ (1.93±0.23) × 10 ⁻⁴
	$\Gamma_{44} \rho \eta \qquad (1.93 \pm 0.23) \times 10^{-4}$ $\Gamma_{45} \omega \eta'(958) \qquad (1.67 \pm 0.25) \times 10^{-4}$
$J/\psi(1S)$ MASS	$\Gamma_{46} = \omega f_0(980)$ (1.6 ± 0.5) × 10 ⁻⁴
ALUE (MeV) EVTS DOCUMENT ID TECN COMMENT	$\Gamma_{47} = \rho \eta' (958)$ (1.05±0.18) × 10 ⁻⁴
096.88±0.04 OUR AVERAGE	$\Gamma_{48} p \overline{p} \phi$ (4.5 ±1.5) × 10 ⁻⁵
$096.87 \pm 0.03 \pm 0.03$ ARMSTRONG 938 E760 $\bar{p}p \rightarrow e^+e^-$	$\Gamma_{49} = a_2(1320)^{\pm} \pi^{\mp}$ [a] < 4.3 × 10 ⁻³ CL=96
1096.95 ± 0.1 ± 0.3 193 BAGLIN 87 SPEC $\overline{p}p \rightarrow e^+e^-X$	$\Gamma_{50} K \overline{K}_2^*(1430) + \text{c.c.}$ < 4.0 × 10 ⁻³ CL=90
1096.93±0.09 502 ZHOLENTZ 80 REDE e ⁺ e • • • We do not use the following data for averages, fits, limits, etc. • • •	$\Gamma_{51} K_2^* (1430)^0 \overline{K_2^*} (1430)^0 $ < 2.9 × 10 ⁻³ CL=90
•	$\Gamma_{52} K^*(892)^0 \overline{K}^*(892)^0 $ < 5 × 10 ⁻⁴ CL=90
097.5 \pm 0.3 GRIBUSHIN 96 FMPS 515 π^- Be $\rightarrow 2\mu X$ 098.4 \pm 2.0 38k LEMOIGNE 82 GOLI 190 π^- Be $\rightarrow 2\mu$	$\Gamma_{53} \phi f_2(1270)$ < 3.7 × 10 ⁻⁴ CL=90
1 BRANDELIK 79C DASP e+e-	$\Gamma_{54} p \overline{p} \rho$ < 3.1 × 10 ⁻⁴ CL=96
1 From a simultaneous fit to $e^+e^-,\mu^+\mu^-$ and hadronic channels assuming $\Gamma(e^+e^-)$	$\Gamma_{55} \phi \eta (1440) \rightarrow \phi \eta \pi \pi \qquad < 2.5 \qquad \times 10^{-4} \text{CL} = 90$
$= \Gamma(\mu^+\mu^-).$	$\Gamma_{56} \omega f_2^i (1525)$ < 2.2 × 10 ⁻⁴ CL=9
,	$\Gamma_{57} \Sigma (\overline{1385})^{0} \overline{\Lambda}$ < 2 × 10 ⁻⁴ CL=90
$J/\psi(1S)$ WIDTH	$\Gamma_{58} \Delta (1232)^{+} \overline{p}$ < 1 × 10 ⁻⁴ CL=90
	$\Gamma_{59} \Sigma^{0} \overline{\Lambda} \qquad < 9 \times 10^{-5} \text{CL} = 90$ $\Gamma_{60} \phi \pi^{0} \qquad < 6.8 \times 10^{-6} \text{CL} = 90$
ALUE (keV) DOCUMENT ID TECN COMMENT 77 ± 5 OUR AVERAGE	$\Gamma_{60} \phi \pi^{0}$ < 6.8 × 10 ⁻⁶ CL=90
67 ± 8 OUR AVERAGE 44.4 \pm 8.9 BAI 95B BES e^+e^-	Decays into stable hadrons
9 $\pm 12 \pm 6$ ARMSTRONG 93B E760 $\overline{p}p \rightarrow e^+e^-$	$\Gamma_{61} = 2(\pi^+\pi^-)\pi^0$ (3.37±0.26)%
15.5 + 6.1 2 HSUEH 92 RVUE See 7 mini-review	$\Gamma_{62} = 3(\pi^{+}\pi^{-})\pi^{0}$ (2.9 ±0.6)%
	$\Gamma_{63} = \pi^{+}\pi^{-}\pi^{0}$ (1.50±0.20)%
² Using data from COFFMAN 92, BALDINI-CELIO 75, BOYARSKI 75, ESPOSITO 75B, BRANDELIK 79C.	$\Gamma_{64} \pi^{+} \pi^{-} \pi^{0} K^{+} K^{-} \qquad (1.20 \pm 0.30) \%$
	$ \Gamma_{65} = 4(\pi^{+}\pi^{-})\pi^{0} \qquad (9.0 \pm 3.0) \times 10^{-3} $ $ \Gamma_{65} = 4\pi^{-} \times 4\pi^{-} \qquad (7.0 \pm 3.0) \times 10^{-3} $
$J/\psi(1S)$ DECAY MODES	$\Gamma_{66} \pi^{+}\pi^{-}K^{+}K^{-}$ (7.2 ±2.3)×10 ⁻³ $\Gamma_{67} K\overline{K}\pi$ (6.1 ±1.0)×10 ⁻³
Scale factor/	$\Gamma_{67} KK\pi$ (6.1 ±1.0)×10 ⁻³ $\Gamma_{68} p\overline{p}\pi^{+}\pi^{-}$ (6.0 ±0.5)×10 ⁻³ S=
Mode Fraction (Γ_I/Γ) Confidence level	$\Gamma_{68} PP\pi^+\pi^-$ (6.0 ±0.5)×10 - S= $\Gamma_{69} 2(\pi^+\pi^-)$ (4.0 ±1.0)×10-3
1 hadrons (87.7 ±0.5) %	$\Gamma_{70} = 2(\pi + \pi)$ (4.0 ±1.0) × 10 ⁻³ (4.0 ±2.0) × 10 ⁻³
$\begin{array}{ccc} & \text{limited} \\ 2 & \text{virtual } \gamma \rightarrow \text{ hadrons} \\ & & & & & & & & \\ & & & & & & & \\ & & & & & & & \\ & & & & & & & \\ & & & & & & & \\ & & & & & & & \\ & & & & & & & \\ & & & & & & & \\ & & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & \\ & & & & & \\ & & & & & \\ & & & & & \\ & & & & & \\ & & & & \\ & & & & \\ & & & & \\ & & & & \\ & & & & \\ & & & & \\ & & & & \\ & & & & \\ & & & & \\ & & & \\ & & & \\ & & & & \\ & & \\ & & & \\ & & \\ & & & \\ & \\ &$	$\Gamma_{71} = n \overline{n} \pi^{+} \pi^{-}$ (4.5 ± 2.5) × 10 - 3 (4.5 ± 2.6) × 10 - 3
e^+e^- (6.02±0.19)%	170 Z Z (1.27 ± 0.17) X 10 -
$\Gamma_3 e^+e^-$ (6.02±0.19)%	
$\Gamma_3 = e^+ e^-$ (6.02 ± 0.19) %	$ \begin{array}{ccccccccccccccccccccccccccccccccc$

Meson Particle Listings $J/\psi(1S)$

								3/	$\psi(13)$
 Г ₇₆	$p\overline{p}\eta$	(2.09±0	.18) × 10 ⁻³		Γ(e ⁺ e ⁻)				Гз
Γ77	$\rho \overline{n} \pi^-$	(2.00±0	$.10) \times 10^{-3}$		VALUE (keV)	DOCUMENT ID	TECN	COMMENT	•
Γ ₇₈	n n	(1.9 ±0	$.5) \times 10^{-3}$		5.26±0.37 OUR EVALUATION				
Γ79	ΞΞ	(1.8 ±0	.4) × 10 ⁻³	S=1.8	• • We do not use the following	g data for average	es, fits, limits	, etc. • • •	
Γ ₈₀	$\Lambda \overline{\Lambda}$	(1.35±0	$.14) \times 10^{-3}$	S=1.2	5.14±0.39	BAI	958 BES	e+e-	
Γ ₈₁	$ ho \overline{ ho} \pi^0$	(1.09±0	$.09) \times 10^{-3}$		5.36 ^{+ 0.29} - 0.28	⁴ HSUEH	92 RVUE	See 7 mini-i	review
Γ82	$\Lambda \overline{\Sigma}^- \pi^+$ (or c.c.)	[a] (1.06±0	$.12) \times 10^{-3}$		4.72±0.35	ALEXANDER			
Γ ₈₃	ρK−⊼	(8.9 ±1	$.6) \times 10^{-4}$		4.4 ±0.6	4 BRANDELIK			CVICIV
Γ ₈₄	$2(K^{+}K^{-})$	(7.0 ±3	$.0) \times 10^{-4}$		4.6 ±0.8	5 BALDINI	75 FRAG		
۲ ₈₅	$pK^{-}\overline{\Sigma}^{0}$	(2.9 ±0	$.8) \times 10^{-4}$		4.8 ±0.6	BOYARSKI	75 MRK1	e+e-	
Γ86	K+K-	(2.37±0	$.31) \times 10^{-4}$		4.6 ±1.0	ESPOSITO	75B FRAM	e ⁺ e ⁻	
Γ ₈₇	$\Lambda \overline{\Lambda} \pi^0$	(2.2 ±0	$.7) \times 10^{-4}$		⁴ From a simultaneous fit to e ⁺	$e^-, \mu^+\mu^-$, and	i hadronic ch	annels assumir	ıg Γ(e ⁺ e ⁻)
Γ88	$\pi^+\pi^-$	(1.47±0	$.23) \times 10^{-4}$		$=\Gamma(\mu^+\mu^-).$				• • •
۲89	$K_S^0 K_L^0$	(1.08±0	$.14) \times 10^{-4}$		⁵ Assuming equal partial widths	for e^+e^- and μ	$^{+}\mu^{-}$.		
Γ ₉₀	$\Lambda \overline{\Sigma} + c.c.$	< 1.5	× 10 ⁻⁴	CL=90%	r(+)				_
Γ91	$K_S^0 K_S^0$	< 5.2	× 10 ⁻⁶	CL=90%	$\Gamma(\mu^+\mu^-)$				Г4
	_				VALUE (keV)	DOCUMENT ID		COMMENT	
_		adiative decays			• • We do not use the following	g data for average			
Γ92	$\gamma \eta_c(1S)$	(1.3 ±0			5.13±0.52	BAI	95B BES	e+ e-	
Γ93	$\gamma \pi^+ \pi^- 2\pi^0$		1.1×10^{-3}		4.8 ±0.6	BOYARSKI	75 MRK1		
Г94	$\gamma \eta \pi \pi$.0)×10 ⁻³		5 ±1	ESPOSITO	75B FRAM	e e e	
Γ95	$\gamma \eta(1440) \rightarrow \gamma K \overline{K} \pi$	[c] (9.1 \pm 1			$\Gamma(\gamma\gamma)$				Г116
Γ ₉₆	$\gamma \eta(1440) \rightarrow \gamma \gamma \rho^0$.4)×10 ⁻⁵		VALUE (eV) CL%	DOCUMENT ID	TECN	COMMENT	. 110
Γ97	$\gamma \eta(1440) \rightarrow \gamma \eta \pi^+ \pi^-$.7) × 10 ⁻⁴		< 5.4 90	BRANDELIK			
Γ98	$\gamma \rho \rho$		$.8) \times 10^{-3}$		70	DIANDLEIK	170 0701		
Г99	$\gamma \eta'(958)$.30) × 10 ⁻³		1/-669	.S) Γ(i)Γ(e ⁺ e ⁻	-\ /C/+a+a \		
	$\gamma 2\pi^+ 2\pi^-$		$.5) \times 10^{-3}$	S=1.9	3/ψ(1	.3) i (i)i (e · e)/I (wai)		
	$\gamma f_4(2050)$	•	.7)×10 ⁻³		This combination of a p	artial width with	the partial v	vidth into e+	e ⁻
Γ ₁₀₂	$\gamma \omega \omega$	•	.33) × 10 ⁻³		and with the total width		he integrated	cross section i	nto
	$\gamma \eta (1440) \rightarrow \gamma \rho^0 \rho^0$	•	.4)×10 ⁻³	S=1.3	channel _l in the e ⁺ e ⁻ ar	minilation.			
Γ ₁₀₄	$\gamma f_2(1270)$	(1.38±0	$.14) \times 10^{-3}$		F(badasas) v. F(a+ a=)/F				/-
Γ ₁₀₅	$\gamma f_J(1710) \rightarrow \gamma K \overline{K}$	(8.5 +1	$\binom{2}{9} \times 10^{-4}$	S=1.2	$\Gamma(\text{hadrons}) \times \Gamma(e^+e^-)/\Gamma_{\text{to}}$				$\Gamma_1\Gamma_3/\Gamma$
Γ ₁₀₆	, , .		.9) .8) × 10 ⁻⁴		VALUE (keV)	DOCUMENT ID		COMMENT	
	$\gamma f_1(1420) \rightarrow \gamma K \overline{K} \pi$	•	.5) × 10 ⁻⁴		• • We do not use the following				
	$\gamma f_1(1285)$.0) × 10 ⁻⁴		4 ±0.8	6 BALDINI	75 FRAG		
		•	•		3.9 ± 0.8	⁶ ESPOSITO	75B FRAM	e ⁺ e ⁻	
109	$\gamma f_2'(1525)$	(4.7 ±0	7 5) × 10 ⁻⁴		$\Gamma(e^+e^-) \times \Gamma(e^+e^-)/\Gamma_{\text{tota}}$				$\Gamma_3\Gamma_3/\Gamma$
Γ ₁₁₀	$\gamma \phi \phi$	(4.0 ±1	.2) × 10 ⁻⁴	S=2.1	VALUE (keV)	DOCUMENT ID	TECN	COMMENT	. 3. 3/
Γ_{111}	γ ρ <u></u>	(3.8 ±1	.0)×10 ⁻⁴		• • We do not use the following				
Γ ₁₁₂	$\gamma \eta$ (2225)	(2.9 ±0	.6)×10 ⁻⁴		0.35±0.02	BRANDELIK			
Γ ₁₁₃	$\gamma \eta (1760) \rightarrow \gamma \rho^0 \rho^0$	•	.9)×10 ⁻⁴		0.32±0.07	6 BALDINI	75 FRAG		
Γ ₁₁₄		•	.3)×10 ⁻⁵		0.34±0.09	6 ESPOSITO	75B FRAM		
	$\gamma p \overline{p} \pi^+ \pi^-$	< 7.9	× 10 ⁻⁴	CL=90%	0.36 ± 0.10	⁶ FORD	75 SPEC		
Γ ₁₁₆		< 5	× 10 ⁻⁴	CL=90%	F(± -) . F(± -) F				
	$\gamma \Lambda \overline{\Lambda}$	< 1.3	× 10 ⁻⁴	CL=90%	$\Gamma(\mu^+\mu^-) \times \Gamma(e^+e^-)/\Gamma_{\text{tota}}$				$\Gamma_4\Gamma_3/\Gamma$
Γ ₁₁₈		< 5.5	× 10 ⁻⁵	CL=90%	VALUE (keV)	DOCUMENT ID		COMMENT	
	$\gamma f_0(2200)$				 ◆ ◆ We do not use the following 	g data for average			
Γ ₁₂₀	$\gamma f_J(2220)$	> 2.50	× 10 ⁻³	CL=99.9%	0.51 ± 0.09	DASP	75 DASP		
Γ ₁₂₁	$\gamma f_0(1500)$.8)×10 ⁻⁴		0.38 ± 0.05	⁶ ESPOSITO	75B FRAM	c+ e+	
Г ₁₂₂	$\gamma e^+ e^-$	(8.8 ±1	$4) \times 10^{-3}$		$\Gamma(p\overline{p}) \times \Gamma(e^+e^-)/\Gamma_{\text{total}}$				F F /F
						DOCUMENT IS	Trou	COMMENT	$\Gamma_{75}\Gamma_3/\Gamma$
[a]	The value is for the sum of indicated.	the charge states of par	ticle/antipa	rticle states	VALUE (eV) 9.7±1.7	7 ARMSTRONG	93B E760		
[6]	Includes $p\overline{p}\pi^+\pi^-\gamma$ and e	xcludes não não nã	in'		Data redundant with branchin	g ratios or partial	widths above	·.	
			•		⁷ Using $\Gamma_{\text{total}} = 85.5 + 6.1 \text{ MeV}$	<i>/</i> .			
[c]	See the "Note on the $\eta(14)$	-+0) in the η(1440) P	arcicle LISTIF	ıkə.				***	
	J/ψ(1S	PARTIAL WIDTHS			$J/\psi(1$	S) BRANCHIN	IG RATIOS		
Γ(had	irons)			Г	For the first four branching	g ratios, see also	the partial wi	dths. and (par	tial

Γ(hadrons)					Г1
VALUE (keV)	DOCUMENT ID		TECN	COMMENT	
• • We do not use the follow	ing data for average	s, fits	, limits,	etc. • • •	
74.1± 8.1	BAI	95B	BES	e ⁺ e ⁻	
59 ±24	BALDINI	75	FRAG	e+ e-	
59 ±14	BOYARSKI	75	MRK1	e+e-	
50 ±25	ESPOSITO	758	FRAM	e ⁺ e ⁻	
$\Gamma(\text{virtual}\gamma \rightarrow \text{hadrons})$					Γ ₂
VALUE (keV)	DOCUMENT ID		TECN	COMMENT	
12 ±2	3 BOYARSKI	75	MRK1	e+e-	
³ Included in Γ(hadrons).					

For the first four branching ratios, see also the partial widths, and (partial widths) $\times \Gamma(e^+e^-)/\Gamma_{\rm total}$ above.

			Γ ₁ /Γ
DOCUMENT ID		TECN	COMMENT
BAI	95B	BES	e ⁺ e ⁻
BOYARSKI	75	MRK1	e+ e-
			Γ ₂ /Γ
DOCUMENT ID		TECN	COMMENT
⁸ BOYARSKI	75	MRK1	e+e-
			Г ₃ /Г
DOCUMENT ID		TECN	COMMENT
BAI	95B	BES	e+e-
COFFMAN	92	MRK3	$\psi(2S) \rightarrow J/\psi \pi^+ \pi^-$
BOYARSKI	75	MRK1	e+e-
	BAI BOYARSKI POCUMENT ID 8 BOYARSKI POCUMENT ID BAI COFFMAN	BAI 958 BOYARSKI 75 POCUMENT ID BOYARSKI 75 POCUMENT ID BAI 958 COFFMAN 92	BAI 958 BES BOYARSKI 75 MRK1 DOCUMENT ID TECN BOYARSKI 75 MRK1 DOCUMENT ID TECN BAI 958 BES COFFMAN 92 MRK3

 $J/\psi(1S)$

$\Gamma(\mu^+\mu^-)/\Gamma_{ m total}$		Γ ₄ /Γ	Γ(<i>K</i> + K *(892)-+ c	.c.)/F _{total}					Γ ₁₃ /Ι
ALUE 0.0601±0.0019 OUR AVERAGE	DOCUMENT ID TECN	COMMENT	VALUE (units 10 ⁻³) 5.0 ±0.4 OUR AVER	EVTS AGE	DOCUMENT ID	<u></u>	ECN	COMMENT	
.0608±0.0033	BAI 958 BES	e+ e-	4.57±0.17±0.70	2285	JOUSSET	90 D	M2	$J/\psi ightarrow hadrons$	s
.0590±0.0015±0.0019 .069 ±0.009	COFFMAN 92 MRK3 BOYARSKI 75 MRK1	$\psi(2S) \rightarrow J/\psi \pi^+ \pi^-$ $e^+ e^-$	5.26±0.13±0.53		COFFMAN	88 N		$J/\psi \rightarrow K^{\pm}K_{S}^{0}$ $K^{+}K^{-}\pi^{0}$	
$\Gamma(e^+e^-)/\Gamma(\mu^+\mu^-)$		Γ ₃ /Γ ₄	• • We do not use to	-				etc. • • •	^
(e·e)/I (μ·μ·)	DOCUMENT ID TECN_	COMMENT	2.6 ±0.6	24 48	FRANKLIN VANNUCCI			J/ψ → K ⁺ K ⁻ J/ψ → K [±] K ⁰	
We do not use the following			3.2 ±0.6 4.1 ±1.2	48 39	BRAUNSCH				5 π
.00±0.07	BAI 958 BES	e ⁺ e			510,1011341			-, +	
.00±0.05	BOYARSKI 75 MRK1		$\Gamma(K^0\overline{K}^*(892)^0 + c.$						Γ ₁₄ /
.91±0.15	ESPOSITO 758 FRAM (FORD 75 SPEC (VALUE (units 10 ⁻³) 4.2 ±0.4 OUR AVER	EVTS AGE	DOCUMENT ID		ECN	COMMENT	
.93±0.10		e · e	3.96±0.15±0.60	1192	JOUSSET	90 D	M2	$J/\psi ightarrow hadrons$	s
—— н	ADRONIC DECAYS		$4.33 \pm 0.12 \pm 0.45$		COFFMAN			$J/\psi \rightarrow K^{\pm}K_{S}^{0}$) π [∓]
$(\rho\pi)/\Gamma_{\text{total}}$		Γ ₅ /Γ	• • • We do not use t						
ALUE EVTS	DOCUMENT ID TECH	COMMENT	2.7 ±0.6	45	VANNUCCI	77 N	MRK1	$J/\psi \to K^{\pm}K_{S}^{0}$	5π+
.0127±0.0009 OUR AVERAGE .0121±0.0020	BAI 960 BES	$e^+e^- \rightarrow \rho\pi$	$\Gamma(K^0\overline{K}^*(892)^0 + c.$	c.)/r(<i>K</i> +7	₹*(892) ⁻ + c.	.c.)		1	Γ_{14}/Γ_{1}
.0121±0.0020 .0142±0.0001±0.0019		e e → μπ (3 e+e-	VALUE		DOCUMENT ID			COMMENT	
.013 ±0.003 150	FRANKLIN 83 MRK	(2 e ⁺ e ⁻	0.82±0.05±0.09		COFFMAN	88 N	MRK3	J/ψ → ∀∀*(000) +	
.016 ±0.004 183	ALEXANDER 78 PLU							K K*(892)+	c.c.
.0133±0.0021 .010 ±0.002 543	BRANDELIK 788 DAS BARTEL 76 CNT		$\Gamma(\omega \pi^0 \pi^0)/\Gamma_{\text{total}}$						Γ ₁₅ /
.010 ±0.002 543	JEAN-MARIE 76 MRM		VALUE (units 10 ⁻³)	EVTS	DOCUMENT ID			COMMENT	
			3.4±0.3±0.7	509	AUGUSTIN	89 E	DM2	$J/\psi \rightarrow \pi^+\pi^-$	3π0
$(ho^0\pi^0)/\Gamma(ho\pi)$	DOCUMENT ID TECN	Γ ₆ /Γ ₅	$\Gamma(b_1(1235)^{\pm}\pi^{\mp})/\Gamma$	total					Γ ₁₆ /
.328±0.005±0.027	COFFMAN 88 MRK3		VALUE (units 10 ⁻⁴)	EVTS	DOCUMENT ID	7	TECN	COMMENT	
• We do not use the following			30±5 OUR AVERAGE						^
.35 ±0.08	ALEXANDER 78 PLUT		31±6	4600	AUGUSTIN BURMESTER	89 E		$J/\psi \rightarrow 2(\pi^+\pi^-)$	r [—])π ⁰
.32 ±0.08		e+e-	29±7	87	BUKMES I ER	. 110 F	- LU I	e. e	
39 ±0.11	BARTEL 76 CNTR JEAN-MARIE 76 MRK1		Γ(ω K [±] K ⁰ _S π [∓])/Γ _{ti}	otal					Γ ₁₇ /
37 ±0.09	PEWIA-MANUE TO MIKKT		VALUE (units 10 ⁻⁴)	EVTS	DOCUMENT ID			COMMENT	
$(a_2(1320)\rho)/\Gamma_{\text{total}}$		Γ ₇ /Γ	29.5±1.4±7.0	879±	BECKER	87 N	MRK3	e ⁺ e → hadr	rons
ALUE (units 10 ⁻³) EVTS	DOCUMENT ID TECN	COMMENT	m/s /sac=10 01 (=	41					
0.9±2.2 OUR AVERAGE 1.7±0.7±2.5 7584	AUGUSTIN 89 DM2	$J/\psi \rightarrow \rho^0 \rho^{\pm} \pi^{\mp}$	$\Gamma(b_1(1235)^0\pi^0)/\Gamma_1$						Γ ₁₈ /
1.7±0.7±2.5 7584 8.4±4.5 36		$e^+e^- \rightarrow 2(\pi^+\pi^-)\pi^0$	VALUE (units 10 ⁻⁴)	EVTS	DOCUMENT ID		TECN	e+e-	
		· · ·	23±3±5	229	AUGUSTIN	89 E	DM2	e' e "	
$(\omega \pi^+ \pi^+ \pi^- \pi^-)/\Gamma_{\text{total}}$		Г8/Г	Γ(φ <i>K</i> *(892) K +c.	c.)/F _{total}					Γ ₁₉ /
ALUE (units 10 ⁻⁴) EVTS		$\frac{COMMENT}{e^+e^- \rightarrow 3(\pi^+\pi^-)\pi^0}$	VALUE (units 10 ⁻⁴)	EVTS	DOCUMENT ID	2	TECN	COMMENT	
5±34 140	VANNUCCI 77 MRK1	$e^+e^- \rightarrow 3(\pi^+\pi^-)\pi^0$	20.4±2.8 OUR AVER/ 20.7±2.4±3.0	AGE	FALVARD	88 [DM2	$J/\psi ightarrow hadron$	15
$(\omega \pi^+ \pi^-)/\Gamma_{\text{total}}$		Г9/Г	20.7±2.4±3.0 20 ±3 ±3	155±	BECKER			e ⁺ e ⁻ → hadr	
/ALUE (units 10 ⁻³) EVTS	DOCUMENT ID TECN	COMMENT	÷	20					
7.2±1.0 OUR AVERAGE	ALICHETIN DO DMO	$J/\psi \rightarrow 2(\pi^+\pi^-)\pi^0$	$\Gamma(\omega K\overline{K})/\Gamma_{\text{total}}$						Γ ₂₀ /
7.0±1.6 18058 7.8±1.6 215		$J/\psi \rightarrow 2(\pi^+\pi^+)\pi^0$ e^+e^-	VALUE (units 10-4)	EVTS	DOCUMENT ID	:	TECN	COMMENT	
5.8±1.9 348		$e^+e^- \to 2(\pi^+\pi^-)\pi^0$	19 ± 4 OUR AVER 19.8± 2.1±3.9		¹⁰ FALVARD	88 [DM2	$J/\psi ightarrow hadron$	ns
		r_ /r	19.8± 2.1±3.9 16 ±10	22	FELDMAN		MRK1	*. *	
$\Gamma(\omega \pi^+ \pi^-)/\Gamma(2(\pi^+ \pi^-)\pi^0)$	DOCUMENT ID TECN	Γ ₉ /Γ ₆₁	¹⁰ Addition of ωK^+I						
• • We do not use the following			Γ(ωf _J (1710) → ωf						Γ ₂₁ /
0.3	9 JEAN-MARIE 76 MRK1			・ハ// total	DOCUMENT ID		TECN	COMMENT	' 21/
⁹ Final state $(\pi^+\pi^-)\pi^0$ under	•		<u>VALUE (units 10⁻⁴)</u> 4.8±1.1±0.3	11,1	12 FALVARD			$J/\psi \rightarrow \text{hadron}$	15
•			11 Includes unknown					-, -	
$\Gamma(K^{\bullet}(892)^{0}\overline{K}_{2}^{\bullet}(1430)^{0} + \text{c.c.}$	•	Γ ₁₁ /Γ	12 Addition of f _j (171					ranching ratios.	
VALUE (units 10 ⁻⁴) EVTS		COMMENT	F/49/-+\\/F						Г 4
7 ±26 40	VANNUCCI 77 MRK1	$\pi^+\pi^-K^+K^-$	$\Gamma(\phi 2(\pi^+\pi^-))/\Gamma_{to}$	tai	000		TEC+	COMMENT	Γ ₂₂ /
$\Gamma(\omega K^*(892)\overline{K} + \text{c.c.})/\Gamma_{\text{total}}$		Γ ₁₂ /Γ	VALUE (units 10-4) 16.0±1.0±3.0		FALVARD	88	TECN DM2	$J/\psi \rightarrow \text{hadror}$	ns .
VALUE (units 10 ⁻⁴) EVTS	DOCUMENT ID TECN	COMMENT		\ <i>-</i> -		'		, ,	_
53±14±14 530±		e ⁺ e ⁻ → hadrons	Γ(Δ(1232) ⁺⁺ 万π ⁻	-					Γ ₂₃ /
140			VALUE (units 10 ⁻³)	EVTS	DOCUMENT ID		TECN		
「(ω f ₂ (1270)) / Γ _{total}		Γ ₁₀ /Γ	1.58±0.23±0.40	332	EATON	84	MKK2	e ⁺ e ⁻	
VALUE (units 10 ⁻³) EVTS	DOCUMENT ID TECN	COMMENT	$\Gamma(\omega\eta)/\Gamma_{ m total}$						Γ ₂₄ /
1.3±0.6 OUR AVERAGE		4 _	VALUE (units 10 ⁻³)	EVT5	DOCUMENT ID		TECN	COMMENT	
1.3±0.2±0.6 5860		e+e-	1.58±0.16 OUR AVE		IOUSSET	00	DMC	1/alı → badros	ne
4.0±1.6 70 • • • We do not use the following	BURMESTER 77D PLUT and data for averages, fits, limits.		$1.43\pm0.10\pm0.21$ $1.71\pm0.08\pm0.20$	378	JOUSSET COFFMAN			$J/\psi \rightarrow \text{hadror}$ $e^+e^- \rightarrow 3\pi r$	
1.9±0.8 81		$e^+e^- \to 2(\pi^+\pi^-)\pi^0$							-
			Γ(φ <i>ΚΤ</i> Κ)/Γ _{total}						Γ ₂₅ ,
			VALUE (units 10-4) 14.8 ± 2.2 OUR AVER	<u>EVTS</u> AGE	DOCUMENT ID	<u> </u>	TECN	COMMENT	
			14.6±0.8±2.1		¹³ FALVARD	88	DM2	$J/\psi ightarrow hadron$	ns
			18 \pm 8 13 Addition of ϕK^+	14	FELDMAN		MRK1	e ⁺ e ⁻	

$Meson\,Particle\,Listings$

 $J/\psi(1S)$

$\Gamma(\phi f_J(1710) \rightarrow \phi$	KK)/Γ _{total}				Γ ₂₆ /Γ	Γ(φη/(958))/Γ _{total}						Γ ₃₉ /
ALUE (units 10 ⁻⁴)		DOCUMENT ID	TECN	COMMENT		VALUE (units 10 ⁻³)		EVTS I	OCUMEN	IT ID	TECN COMME	NT_
1.6±0.2±0.6		15 FALVARD	88 DM2	$J/\psi ightarrow $ hadron	S	0.33 ±0.04 OUR 0.41 ±0.03 ±0.08		167 .	OUSSE	T 90	DM2 J/ψ →	
¹⁴ Including Interference ¹⁵ Includes unknown			→ K K .			0.308±0.034±0.03			COFFMA		hadi MRK3 e ⁺ e ⁻	
(pβω)/Γ _{total}					Γ ₂₇ /Γ	• • We do not use	the followin	g data for av	erages, fl	ts, limits,		Λ η
(PPW)/1 total ALUE (units 10^{-3})	F1 CTC		TECH	COMMENT	127/1	<1.3	90	-	/ANNUC		MRK1 e+e-	
.30±0.25 OUR AVE	EVTS ERAGE Error	DOCUMENT ID Includes scale fa	TECN actor of 1.3.	COMMENT								_
1.10±0.17±0.18	486	EATON	84 MRK2			Γ(φ f ₀ (980))/Γ _{total}						Γ ₄₀
1.6 ±0.3	77	PERUZZI	78 MRK1	e+ e-		VALUE (units 10 ⁻⁴) 3.2±0.9 OUR AVER	EVTS	DOCUMEN			COMMENT	
Γ(Δ(1232) ⁺⁺ Δ(1232)\/[Γ ₂₈ /Γ	4.6±0.4±0.8	Was Elloi	18 FALVARD			$J/\psi ightarrow hadrons$	5
ALUE (units 10 ⁻³)	EVTS	DOCUMENT ID	TECN	COMMENT	. 201 .	2.6±0.6	50	18 GIDAL		MRK2	$J/\psi \rightarrow$	
1.10±0.09±0.28	233	EATON	84 MRK2			18 Assuming B(f ₀ (98)O)	_ 0.70			K+K-K+	κ-
Γ(Σ(1385) ⁻ <u>Σ</u> (13	385)+(orc.o	:))/[Γ ₂₉ /Γ	•		_ 0.10.				_
ALUE (units 10 ⁻³)	EVTS	DOCUMENT	r ID TE	CNCOMMENT	. 23/	Γ(Ξ(1530) ⁰ Ξ̄ ⁰)/ſ						Г41
L.03±0.13 OUR AVE						VALUE (units 10 ⁻³)	EVTS	DOCUMEN		TECN	COMMENT e+e-	
$1.00 \pm 0.04 \pm 0.21$	631±	HENRARI	D 87 DN	$A2 e^+e^- \rightarrow .$	Σ*-	$0.32 \pm 0.12 \pm 0.07$	24 ± 9	HENRAR	D 87	DM2	e+e-	
1.19±0.04±0.25	25 754±	HENRAR	D 87 DN	12 e ⁺ e ⁻ →	Σ*+	Γ(Σ(1385)-Σ+(α	wcc 1) /E					Γ ₄₂
0.86±0.18±0.22	27 56	EATON	84 MI	RK2 e+e- →	Σ*-	VALUE (units 10 ⁻³)	EVTS	DOCUMEN	T ID	TECN	COMMENT	- 42
1.03±0.24±0.25	68	EATON		RK2 e+e- →		0.31±0.05 OUR AVE		DOCUMEN				
Γ(<i>ρЂη</i> ′(958))/Γ _{ts}	-4-1				Γ ₃₀ /Γ	$0.30 \pm 0.03 \pm 0.07$	74 ±	HENRAR	D 87	7 DM2	$e^+e^- \rightarrow \Sigma^{*-}$	-
「(タタガ(956))/「仮 <i>VALUE</i> (units 10 ⁻³)	otal EVTS	DOCUMENT ID	TECN	COMMENT	· 30/ '	$0.34 \pm 0.04 \pm 0.07$	8 77 ±	HENRAR	D 87	7 DM2	$e^+e^- \rightarrow \Sigma^{*+}$	-
0.9 ±0.4 OUR AVI			actor of 1.7.			0.29±0.11±0.10	9 26	EATON	84	↓ MRK2	e ⁺ e ⁻ → Σ*-	-
$0.68 \pm 0.23 \pm 0.17$	19	EATON	84 MRK2	e+e-		$0.31 \pm 0.11 \pm 0.11$	28	EATON			$e^+e^- \rightarrow \Sigma^{*+}$	
1.8 ±0.6	19	PERUZZI	78 MRK1	e+ e-		F/A6(1295)\/F.						Γ ₄₃
$\Gamma(\phi f_2'(1525))/\Gamma_{\rm tr}$	otal				Γ ₃₁ /Γ	Γ(φf ₁ (1285))/Γ _{tol}	EVTS	DOCUMEN	T 10	TECN	COMMENT	1 43
ALUE (units 10 ⁻⁴)	EVTS	DOCUMENT ID	TECN	COMMENT		2.6±0.5 OUR AVER					COMMENT	
8 ±4 OUR AVE						3.2±0.6±0.4		JOUSSE'	г 90	DM2	$J/\psi \rightarrow \phi 2(\pi^+$	
12.3±0.6±2.0 4.8±1.8		17 FALVARD 16 GIDAL	88 DM2 81 MRK2	$J/\psi \rightarrow \text{hadror}$	15	2.1±0.5±0.4	25	19 JOUSSE			$J/\psi \rightarrow \phi \eta \pi^+$	π_
4.0 ± 1.0	40	GIDAL	OI WINNE	K+K-K+	κ-	• • We do not use		-	-			
16 Re-evaluated usin	ng B(f' ₂ (1525	$\rightarrow K\overline{K}) \equiv 0.7$	13.			$0.6 \pm 0.2 \pm 0.1$	16 ±	BECKER	87	7 MRK3	$J/\psi \rightarrow \phi K \overline{K} \eta$	
17 Including interfer	rence with f_j (1710).				19 We attrribute to	the f ₁ (1285)	the signal of	oserved i	n the π^+	$\pi^-\eta$ invariant m	ass dis
	_				F /F	bution at 1297 M		•				
Γ(φπ ⁺ π ⁻)/Γ _{tota}		000000000000000000000000000000000000000		CO1445NT	Γ ₃₂ /Γ	$\Gamma(ho\eta)/\Gamma_{ m total}$						Γ44
VALUE (units 10 ⁻³) 0.80±0.12 OUR AV	EVTS ERAGE	DOCUMENT ID	TECN	COMMENT		VALUE (units 10 ⁻³)	EVTS	DOCUMEN	T ID	TECN	COMMENT	
0.78±0.03±0.12		FALVARD	88 DM2	$J/\psi ightarrow $ hadron	ns	0.193±0.023 OUR A		,				
2.1 ±0.9	23	FELDMAN	77 MRK1	e ⁺ e ⁻		0.194±0.017±0.029 0.193±0.013±0.029	299	JOUSSE*		DM2	$J/\psi ightarrow { m hadron}$ $e^+e^- ightarrow \pi^+$	
Γ(φK±K ⁰ _S π [∓])/!	Tental				Γ ₃₃ /Γ			COLLINIA		, MIKKS		
VALUE (units 10 ⁻⁴)	EVTS	DOCUMENT ID	TECN	COMMENT	,	Γ(ωη'(958))/Γ _{tota}	ol					Γąę
7.2±0.9 OUR AVER						VALUE (units 10 ⁻³)	EVTS	DOCUMEN	IT ID	TECN	COMMENT	
7.4±0.9±1.1 7 ±0.6±1.0	163±	FALVARD BECKER	88 DM2	$J/\psi \rightarrow \text{hadror}$ $e^+e^- \rightarrow \text{had}$		0.167±0.025 OUR A		LOUISSE				_
/ ±0.6±1.0	15	BECKER	or winns) c·e → nau	TOTA	$0.18 \begin{array}{l} +0.10 \\ -0.08 \end{array} \pm 0.03$	6	JOUSSE.			$J/\psi ightarrow $ hadron $e^+e^- ightarrow 3\pi n$	
Γ(ω f ₁ (1420))/Γ _{ts}	nden)				Г34/Г	0.166±0.017±0.019		COFFMA	NN 8	3 MKK3	$e'e \rightarrow 3\pi\eta$	
VALUE (units 10 ⁻⁴)	EVTS	DOCUMENT ID	TECN	COMMENT	· 34/ ·	Γ(ω f ₀ (980))/Γ _{tota}	ol					Γ44
6.8 ^{+1.9} ±1.7	111+31	BECKER		$e^+e^- \rightarrow had$	ZODE	VALUE (units 10 ⁻⁴)		DOCUMEN		TECN	COMMENT	
-1.6 = 1.7	111 – 26	BECKER	or with	o e e → nau	ions	1.41±0.27±0.47		²⁰ AUGUST	IN 89	9 DM2	$J/\psi \rightarrow 2(\pi^{+}\tau)$	-)π ⁽
$\Gamma(\phi\eta)/\Gamma_{\text{total}}$					Γ ₃₅ /Γ	²⁰ Assuming B(f ₀ (9	$80) \rightarrow \pi\pi$	= 0.78.				
VALUE (units 10 ⁻³)	EVTS	DOCUMENT ID	TECN	COMMENT		Γ(ρη'(958))/Γ _{tota}						Γ47
0.65 ±0.07 OUR	AVERAGE					VALUE (units 10 ⁻³)	EVTS	DOCUMEN	IT ID	TECN	COMMENT	- 41
0.64 ±0.04 ±0.11 0.661±0.045±0.078	346	JOUSSET COFFMAN	90 DM2	$J/\psi \rightarrow hadron$ 3 $e^+e^- \rightarrow K^+$		0.105±0.018 OUR A		_ JCOME!			-	
		COLLINAM	OU WIRE	, e·e → n·	"	0.083 ± 0.030 ± 0.012	19	JOUSSE		0 DM2	$J/\psi \rightarrow \text{hadror}$	
	/r _{total}				Γ ₃₆ /Γ	$0.114 \pm 0.014 \pm 0.016$		COFFMA	AN 8	s MRK3	$J/\psi \rightarrow \pi^+\pi^-$	η
「(<i>Ξ</i> (1530) <i>Ξ</i> +)		DOCUMENT ID		COMMENT		$\Gamma(p\overline{p}\phi)/\Gamma_{ m total}$						Γ4
VALUE (units 10 ⁻³)	EVTS	HENDARD	87 DM2	e+ e-		VALUE (units 10 ⁻⁴)		DOCUMEN	IT ID	TECN	COMMENT	
VALUE (units 10 ⁻³)	75 ±	HENRARD				0.45±0.13±0.07		FALVAR) R	8 DM2	$J/\psi ightarrow hadron$	
VALUE (units 10 ⁻³) 0.59±0.09±0.12	75 ± 11	HENKARD							, ,		3/ P . 1144101	
$VALUE (units 10^{-3})$ $0.59 \pm 0.09 \pm 0.12$ $\Gamma(p K^- \Sigma (1385)^0$	75 ± 11 0)/Γ _{total}				Γ ₃₇ /Γ		/[, ,		3/ P / Haulo	
VALUE (units 10^{-3}) 0.59 \pm 0.09 \pm 0.12 $\Gamma(pK^{-}\overline{\Sigma}(1385)^{0})$ VALUE (units 10^{-3})	75 ± 11 0)/Γ _{total} Εντς	DOCUMENT ID	<u>TECN</u>		Γ ₃₇ /Γ	$\Gamma(a_2(1320)^{\pm}\pi^{\mp})$		Dogwood				
VALUE (units 10 ⁻³) 0.59±0.09±0.12 \(\(\Gamma(\text{I}) \overline{K} - \overline{\text{I}} (1385)^0\) VALUE (units 10 ⁻³)	75 ± 11 0)/Γ _{total}				Γ ₃₇ /Γ	$\Gamma(a_2(1320)^{\pm}\pi^{\mp})$ VALUE (units 10^{-4})	CL%	DOCUME!	מו זו	<u>TECN</u>	COMMENT	
VALUE (units 10 ⁻³) 0.59±0.09±0.12 \[\begin{align*} alig	75 ± 11 0)/Γ _{total} Εντς	DOCUMENT ID	<u>TECN</u>			$\Gamma(a_2(1320)^{\pm}\pi^{\mp})$ VALUE (units 10^{-4}) <43	<u>CL%</u> 90	BRAUNS	מו זו		COMMENT	Γ4
VALUE (units 10^{-3}) 0.59 \pm 0.09 \pm 0.12 $\Gamma(\rho K - \overline{L}(1385)^0$ VALUE (units 10^{-3}) 0.51 \pm 0.26 \pm 0.18 $\Gamma(\omega \pi^0) / \Gamma_{\text{total}}$	75 ± 11 0)/Γ _{total} Εντς	DOCUMENT ID	9 <u>TECN</u> 84 MRK2	2 e+e-	Γ ₃₇ /Γ ———	$\Gamma(a_2(1320)^{\pm}\pi^{\mp})$ VALUE (units 10^{-4})	<u>CL%</u> 90	BRAUNS	מו זו	<u>TECN</u>	COMMENT	Γ44
VALUE (units 10^{-3}) $0.59 \pm 0.09 \pm 0.12$ $\Gamma(\rho K^- \overline{L}(1385)^0$ $VALUE (units 10^{-3}) 0.51 \pm 0.26 \pm 0.18 \Gamma(\omega \pi^0) / \Gamma_{total} VALUE (units 10^{-3}) 0.42 \pm 0.06 OUR A$	75 ± 11 0)/\(\Gamma\) EVTS 89 EVTS AVERAGE	<u>DOCUMENT ID</u> EATON <u>DOCUMENT ID</u> irror Includes scal	84 MRK2 0 <u>TECN</u> 10 TECN 10 In factor of 1.	2 e ⁺ e ⁻ <u>СОММЕНТ</u> 4.	Г38/Г	$\Gamma(a_2(1320)^{\pm}\pi^{\mp})$ VALUE (units 10^{-4}) <43	<u>CL%</u> 90 c.c.)/Γ _{total}	BRAUNS	<i>IT ID</i> SCH 7	TECN TECN TECN	COMMENT COMMENT	Γ ₄₄
VALUE (units 10^{-3}) $0.59\pm0.09\pm0.12$ $\Gamma(\rhoK^-\overline{L}(1385)^0$ $VALUE$ (units 10^{-3}) $0.51\pm0.26\pm0.18$ $\Gamma(\omega\pi^0)/\Gamma_{total}$ $VALUE$ (units 10^{-3}) 0.42 ± 0.06 0.018 $0.360\pm0.028\pm0.056$	75 ± 11 7) / \(\Gamma\) total \(\frac{EVTS}{89}\) 89 89 8VERAGE 4 222	<u>DOCUMENT ID</u> EATON <u>DOCUMENT ID</u> rror includes scal	9 <u>TECN</u> 84 MRK2 9 <u>TECN</u> 10 TECN 10 PO DM2	$\begin{array}{c} e^+e^-\\ \hline & COMMENT\\ 4.\\ \hline & J/\psi \rightarrow \text{ hadro} \end{array}$	Г ₃₈ /Г	$\Gamma(a_2(1320)^{\pm}\pi^{\mp})$, VALUE (units 10^{-4}) <48 $\Gamma(K\overline{K}_2^*(1430) + c$ VALUE (units 10^{-4}) <40	<u>CL%</u> 90 .c.)/Γ _{total} <u>CL%</u> 90	BRAUNS DOCUMEN VANNUO	17 10 SCH 7 17 10 CCI 7	TECN 6 DASP TECN 7 MRK1	$ \begin{array}{c} COMMENT \\ e^+e^- \\ \hline COMMENT \\ e^+e^- \rightarrow K^0 \end{array} $	Γ ₄₄
$\Gamma\left(\Xi(1530)^{-}\Xi^{+}\right)$ $VALUE (units 10^{-3}) 0.59\pm0.09\pm0.12 \Gamma\left(pK^{-}\Xi(1385)^{0}\right) VALUE (units 10^{-3}) 0.51\pm0.26\pm0.18 \Gamma\left(\omega\pi^{0}\right)/\Gamma_{total} VALUE (units 10^{-3}) 0.42\pm0.06 \text{OUR } N 0.360\pm0.028\pm0.05 0.482\pm0.019\pm0.06$	75 ± 11 7) / \(\Gamma\) total \(\frac{EVTS}{89}\) 89 89 8VERAGE 4 222	<u>DOCUMENT ID</u> EATON <u>DOCUMENT ID</u> irror Includes scal	9 <u>TECN</u> 84 MRK2 9 <u>TECN</u> 10 TECN 10 PO DM2	2 e ⁺ e ⁻ <u>СОММЕНТ</u> 4.	Г ₃₈ /Г	$\Gamma(a_2(1320)^{\pm}\pi^{\mp})$, VALUE (units 10 ⁻⁴) <43 $\Gamma(KK_2^*(1430) + c$ VALUE (units 10 ⁻⁴)	<u>CL%</u> 90 .c.)/Γ _{total} <u>CL%</u> 90	BRAUNS DOCUMENT VANNUE ng data for a	SCH 7	TECN 6 DASP TECN 7 MRK1 flts, limits	$ \begin{array}{c} \underline{COMMENT} \\ e^+e^- \\ \underline{COMMENT} \\ e^+e^- \rightarrow K^0 \\ s, etc. \bullet \bullet \bullet \end{array} $	Γ ₄₉
VALUE (units 10^{-3}) 0.59 \pm 0.09 \pm 0.12 $\Gamma(pK^-\overline{L}(1385)^0$ VALUE (units 10^{-3}) 0.51 \pm 0.26 \pm 0.18 $\Gamma(\omega\pi^0)/\Gamma_{total}$ VALUE (units 10^{-3}) 0.42 \pm 0.05 OUR I 0.360 \pm 0.028 \pm 0.054	75 ± 11 7) / \(\Gamma\) total \(\frac{EVTS}{89}\) 89 89 8VERAGE 4 222	<u>DOCUMENT ID</u> EATON <u>DOCUMENT ID</u> rror includes scal	9 <u>TECN</u> 84 MRK2 9 <u>TECN</u> 10 TECN 10 PO DM2	$\begin{array}{c} e^+e^-\\ \hline & COMMENT\\ 4.\\ \hline & J/\psi \rightarrow \text{ hadro} \end{array}$	Г ₃₈ /Г	$\Gamma(a_2(1320)^{\pm}\pi^{\mp})$, VALUE (units 10^{-4}) <48 $\Gamma(K\overline{K}_2^*(1430) + c$ VALUE (units 10^{-4}) <40	<u>CL%</u> 90 .c.)/Γ _{total} <u>CL%</u> 90	BRAUNS DOCUMENT VANNUE ng data for a	SCH 7	TECN 6 DASP TECN 7 MRK1 flts, limits	$ \begin{array}{c} COMMENT \\ e^+e^- \\ \hline COMMENT \\ e^+e^- \rightarrow K^0 \end{array} $	Γ ₄₉ Γ ₅₀

$J/\psi(1S)$

NALUE (units 10^-4) CLN VANNUCCI 77 MRK1 $e^+e^ e^+e^				_			
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	$\Gamma(K_2^*(1430)^0\overline{K}_2^*(143)^0$	0) ⁰)/Γ _{tot}	ai				Γ_{51}/Γ
	VALUE (units 10 ⁻⁴)	CL%	DOCUMENT ID		TECN	COMMENT	
$ \begin{aligned} &\Gamma(K^*(892)^0)/\Gamma_{total} \\ &VALUE (units 10^{-4}) & CL_K^* \\ &< & 90 \end{aligned} $	<29	90	VANNUCCI	77	MRK1		_
VALUE (units 10^-4) CL% OCCUMENT ID TECN COMMENT (IP Fig. (1270))/ Γ total (III) (ULS) (units 10^-4) QL (III) (ULS) (units 10^-4) QL (III) (ULS) (units 10^-4) QL (III) QCCUMENT ID TECN COMMENT (III) QCCUMENT ID TECN COMMENT (III) QCCUMENT ID TECN COMMENT (IIII) QCCUMENT ID TECN COMMENT (IIII) QCCUMENT ID TECN COMMENT (IIIII) QCCUMENT ID TECN COMMENT (IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII						π'π Κ'Κ	
VANNUCCI 77 MRK1 $e^+e^- + \pi^- K^+ K^ \Gamma(\phi f_2(1270))/\Gamma_{total}$ VALUE (units 10^{-4}) CLS VANNUCCI 77 MRK1 $e^+e^- + \pi^- K^+ K^ CA.7$ 90 VANNUCCI 77 MRK1 $e^+e^- + \pi^- K^+ K^ CA.7$ 90 VANNUCCI 77 MRK1 $e^+e^- + \pi^- K^+ K^ CA.7$ 90 FALVARD 88 DM2 $J/\psi \rightarrow \text{hadrons}$ $CA.5$ 90 FALVARD 88 DM2 $J/\psi \rightarrow \text{hadrons}$ $CA.5$ 90 FALVARD 88 DM2 $J/\psi \rightarrow \text{hadrons}$ $CA.5$ $CA.5$ 90 FALVARD 88 DM2 $J/\psi \rightarrow \text{hadrons}$ $CA.5$ $CA.5$ 90 PALVARD 88 DM2 $J/\psi \rightarrow \text{hadrons}$ $CA.5$ $CA.5$ 90 PALVARD 88 DM2 $J/\psi \rightarrow \text{hadrons}$ $CA.5$ $CA.5$ 90 PALVARD 88 DM2 $J/\psi \rightarrow \text{hadrons}$ $CA.5$ $CA.5$ 90 PALVARD 88 DM2 $J/\psi \rightarrow \text{hadrons}$ $CA.5$ 90 PALVALUE (units 10^{-3}) 90 PALVALUE (units $10^$	Γ(<i>K</i> *(892) ^ν <i>K</i> *(892)	u)/F _{total}					Γ_{52}/Γ
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	VALUE (units 10 ⁻⁴)	<u>CL%</u>					
Γ(φ $\frac{\rho}{2}$ (1270))/Γtotal VALUE (with: 10 ⁻⁴) CLK VANNUCCI 77 WARK1 $e^+e^ e^+e^ e^-$ ** • • • We do not use the following data for averages, fits, limits, etc. • • • • • • • • • • • • • • • • • • •	<5	90	VANNUCCI	77	MRK1	e+e- → + ×+ ×	_
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	-(N · N · N · N	
VANNUCCI 77 MRK1 $e^+e^ e^	•						Γ ₅₃ /Γ
** • We do not use the following data for averages, fits, limits, etc. • • • < 4.5 90 FALVARD 88 DM2 $J/\psi \rightarrow$ hadrons $\Gamma(\rho P \rho)/\Gamma_{\text{total}}$ **MALVE** (units 10^{-4})** 0.1							
** • * We do not use the following data for averages, fits, limits, etc. • • • • • < < 4.5 ** 90 ** FALVARD ** 88 ** DM2 ** J/ ψ → hadrons ** Falvard ** FALVARD ** SET ON	<3.7	90	VANNUCCI	77	MRK1	e ⁺ e ⁻ → π ⁺ π ⁻ κ ⁺ κ	
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	• • We do not use the	e following	data for average	s, flts	s, limits,	etc. • • •	
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	<4.5	90	FALVARD	88	DM2	$J/\psi ightarrow hadrons$	
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	[(n\overline{\sigma})/[Γ ₅₄ /Γ
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	• •	C1.0/	DOCUMENT ID		TECN	COMMENT	154/1
The state of the				84			
CALUE (units 10^{-4}) $\frac{\text{CL} \times}{90}$ $\frac{\text{21}}{\text{FALVARD}}$ $\frac{\text{RECN}}{80}$ $\frac{\text{COMMENT}}{\text{J}/\psi} \rightarrow \text{hadrons}}$ Cals 1 Includes unknown branching fraction $\eta(1440) \rightarrow \eta \pi \pi$. Fig. 1 Includes unknown branching fraction $\eta(1440) \rightarrow \eta \pi \pi$. Fig. 2 Includes unknown branching fraction $\eta(1440) \rightarrow \eta \pi \pi$. Fig. 2 Includes unknown branching fraction $\eta(1440) \rightarrow \eta \pi \pi$. Fig. 3 Includes unknown branching fraction $\eta(1440) \rightarrow \eta \pi \pi$. Fig. 3 Includes unknown branching fraction $\eta(1440) \rightarrow \eta \pi \pi$. Fig. 3 Includes unknown branching fraction $\eta(1440) \rightarrow \eta \pi \pi$. Fig. 4 Includes $\eta(1810^{-1})$			CATON	•	14111114	C C Induit	-
22.5 90 21 FALVARD 88 DM2 $J/\psi \rightarrow$ hadrons 21 Includes unknown branching fraction $\eta(1440) \rightarrow \eta \pi \pi$. [(ωf'_2(1525))/Γtotal	$\Gamma(\phi\eta(1440) o\phi\eta\pi^{-}$	$\pi)/\Gamma_{\text{total}}$					Γ ₅₅ /Γ
21 Includes unknown branching fraction $\eta(1440) \rightarrow \eta \pi \pi$. $\Gamma(\omega f_2'(1525))/\Gamma_{total} \qquad \Gamma_{\omega} f_{\omega} f$	VALUE (units 10 ⁻⁴)				TECN	COMMENT	
	-					$J/\psi ightarrow hadrons$	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	²¹ Includes unknown br	anching fra	ction $\eta(1440) \rightarrow$	ηπ	π.		
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Γ(ω f' ₀ (1525))/Γ ₁₄₄₁						Γ ₅₆ /Γ
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	• •		DOCUMENT ID		TECN	COMMENT	. 507
$\begin{array}{cccccccccccccccccccccccccccccccccccc$							
$\begin{array}{cccccccccccccccccccccccccccccccccccc$						$\pi^{+}\pi^{-}\pi^{0}K^{+}$	-κ-
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$							
The entire is a company of the entire is a comp						$J/\psi ightarrow hadrons$	
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	** Re-evaluated assum!	ng B(f' ₂ (15	(25) → KK) =	0.71	3.		
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	Γ(Σ(1385) ⁰ Ā)/Γ ₁ ,	4					Γ ₅₇ /Γ
$(0.2) = 90 \qquad \text{HENRARD} \qquad 87 \text{DM2} e^+e^-$ $\Gamma(\Delta(1232)^+\vec{p})/\Gamma_{\text{total}} \qquad $			DOCUMENT ID		TECN	COMMENT	- 017
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$				87			
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	- (- ()						
$(0.1 90 HENRARD 87 DM2 e^+e^-$ $\Gamma(\Sigma^0\Lambda)/\Gamma_{total} VALUE (units 10^{-4}) CL\% DOCUMENT ID TECN COMMENT$ $(0.9 90 HENRARD 87 DM2 e^+e^-$ $\Gamma(\phi\pi^0)/\Gamma_{total} VALUE (units 10^{-4}) CL\% DOCUMENT ID TECN COMMENT$ $(0.06 90 COFFMAN 88 MRK3 e^+e^- \to K^+K^-\pi$ $\Gamma(2(\pi^+\pi^-)\pi^0)/\Gamma_{total} VALUE EVTS DOCUMENT ID TECN COMMENT$ $(0.0397\pm0.0026 OUR AVERAGE D.0325\pm0.0049 46055 AUGUSTIN 89 DM2 J/\psi \to 2(\pi^+\pi^-)\pi$ $(0.0317\pm0.0042 147 FRANKLIN 83 MRK2 e^+e^- \to hadrons$ $(0.0317\pm0.0042 1500 BURMESTER 770 PLUT e^+e^-$ $(0.0364\pm0.0052 1500 BURMESTER 770 PLUT e^+e^-$ $(13(\pi^+\pi^-)\pi^0)/\Gamma_{total} VALUE EVTS DOCUMENT ID TECN COMMENT$ $(0.029\pm0.006 OUR AVERAGE DOCUMENT ID TECN COMMENT TECN COMMENT$		el					Γ ₅₈ /Γ
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$							
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	<0.1	90	HENRARD	87	DM2	e+ e-	
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	Γ(Σ ⁰ λ̄)/Γ _{****}						Γ ₅₉ /Γ
(0.9) 90 HENRARD 87 DM2 $e^+e^ (0.9)$ (0.9)		CL%	DOCUMENT ID		TECN	COMMENT	
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$		-		87			
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	-/. M /-						_ /-
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	•						Γ ₆₀ /Γ
$\begin{array}{cccccccccccccccccccccccccccccccccccc$							
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	<0.068	90	COFFMAN	88	MRK3	e+e- → K+1	(-πυ
$VALUE$ EVTS 0.0337±0.0026 OUR AVERAGE 0.0337±0.0049 46055 AUGUSTIN 89 DM2 $J/\psi \rightarrow 2(\pi^+\pi^-)\pi$ 0.0364±0.0052 1500 BURMESTER 770 PLUT e^+e^- 0.0364±0.0052 1500 BURMESTER 770 PLUT e^+e^- 0.0364±0.0052 1500 0.04 ±0.01 675 JEAN-MARIE 76 MRK1 e^+e^- 0.028±0.006 OUR AVERAGE 0.029±0.007 181 FRANKLIN 83 MRK2 $e^+e^- \rightarrow \text{hadrons}$ 0.029±0.007 181 JEAN-MARIE 76 MRK1 e^+e^- 0.029±0.007 181 JEAN-MARIE 76 MRK1 e^+e^- 0.015 ±0.002 168 FRANKLIN 83 MRK2 $e^+e^- \rightarrow \text{hadrons}$ 0.029±0.007 181 JEAN-MARIE 76 MRK1 e^+e^- 0.015 ±0.002 168 FRANKLIN 83 MRK2 $e^+e^- \rightarrow \text{hadrons}$ 0.016 ±0.002 168 FRANKLIN 83 MRK2 $e^+e^- \rightarrow \text{hadrons}$ 0.017 $(\pi^+\pi^-\pi^0)/\Gamma_{\text{total}}$ VALUE EVTS 0.018 ±0.002 168 FRANKLIN 83 MRK2 $e^+e^- \rightarrow \text{hadrons}$ 0.019 ±0.003 309 VANNUCCI 77 MRK1 e^+e^- 76 VALUE (units 10-4) EVTS DOCUMENT ID TECN COMMENT TECN TECN TECN TECN TECN TECN TECN T	$\Gamma(2(\pi^{+}\pi^{-})\pi^{0})/\Gamma_{ma}$	al le					Γ_{61}/Γ
0.0325±0.0049 46055 AUGUSTIN 89 DM2 $J/\psi \rightarrow 2(\pi^{+}\pi^{-})\pi$ 0.0315±0.0042 147 FRANKLIN 83 MRK2 $e^{+}e^{-} \rightarrow \text{hadrons}$ 0.0364±0.0052 1500 BURMESTER 77D PLUT $e^{+}e^{-}$ 0.04 ±0.01 675 JEAN-MARIE 76 MRK1 $e^{+}e^{-}$ 1. (3($\pi^{+}\pi^{-})\pi^{0}$)/ Γ_{total} 0.029±0.006 OUR AVERAGE 0.029±0.007 181 FRANKLIN 83 MRK2 $e^{+}e^{-} \rightarrow \text{hadrons}$ 0.029±0.007 181 JEAN-MARIE 76 MRK1 $e^{+}e^{-}$ 1. ($\pi^{+}\pi^{-}\pi^{0}$)/ Γ_{total} 0.015 ±0.002 168 FRANKLIN 83 MRK2 $e^{+}e^{-}$ 1. ($\pi^{+}\pi^{-}\pi^{0}$)/ Γ_{total} 0.012 ±0.003 309 VANNUCCI 77 MRK1 $e^{+}e^{-}$ 1. ($\pi^{+}\pi^{-}\pi^{0}$)/ Γ_{total} 0.012 ±0.003 309 VANNUCCI 77 MRK1 $e^{+}e^{-}$ 1. ($\pi^{+}\pi^{-}\pi^{0}$)/ Γ_{total} 0.012 ±0.003 309 JEAN-MARIE 76 MRK1 $e^{+}e^{-}$ 1. ($\pi^{+}\pi^{-}\pi^{0}$)/ π^{-} 0.012 ±0.003 309 VANNUCCI 77 MRK1 $e^{+}e^{-}$ 1. ($\pi^{+}\pi^{-}\pi^{0}$)/ π^{-} 0.012 ±0.003 309 JEAN-MARIE 76 MRK1 $e^{+}e^{-}$ 1. ($\pi^{+}\pi^{-}\pi^{0}$)/ π^{-} 0.012 ±0.003 309 VANNUCCI 77 MRK1 $e^{+}e^{-}$ 1. ($\pi^{+}\pi^{-}\pi^{0}$)/ π^{-} 0. ($\pi^{-}\pi^{-}\pi^{0}$)/ π^{-} 1. ($\pi^{-}\pi^{$	VALUE	<u>EVTS</u>	DOCUMENT ID		TECN	COMMENT	
0.0317±0.0042 147 FRANKLIN 83 MRK2 e^+e^- → hadrons BURMESTER 77D PLUT e^+e^- 1500 BURMESTER 77D PLUT e^+e^- 17D							n
$\begin{array}{cccccccccccccccccccccccccccccccccccc$						$J/\psi \rightarrow 2(\pi^+\pi^-)$	_)π ⁰
$\begin{array}{cccccccccccccccccccccccccccccccccccc$							J113
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$							
VALUE							F. /F
0.029 ± 0.006 OUR AVERAGE 0.028 ± 0.009 11			DOCUMENT IN		TECN	COMMENT	Γ ₆₂ /Γ
0.028 ± 0.009 11 FRANKLIN 83 MRK2 e^+e^- → hadrons 0.029 ± 0.007 181 JEAN-MARIE 76 MRK1 e^+e^- → hadrons 0.029 ± 0.002 168 FRANKLIN 83 MRK2 e^+e^- ← e^- 0.015 ± 0.002 168 FRANKLIN 83 MRK2 $e^+e^ e^			DOCUMENT ID		ICCN	SOMMEN!	
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	0.028±0.009						ons
VALUE EVTS DOCUMENT ID TECN COMMENT 168 FRANKLIN 83 MRK2 e^+e^- 168 FRANKLIN 83 MRK2 e^+e^- 169 FRANKLIN 83 MRK2 e^+e^- 160 FRANKLIN 83 MRK2 e^+e^- 170 FRANKLIN 83 MRK2 $e^$	0.029±0.007	181	JEAN-MARIE	76	MRK1	e+ e~	
VALUE EVTS DOCUMENT ID TECN COMMENT 168 FRANKLIN 83 MRK2 e^+e^- 168 FRANKLIN 83 MRK2 e^+e^- 169 FRANKLIN 83 MRK2 e^+e^- 160 FRANKLIN 83 MRK2 e^+e^- 170 FRANKLIN 83 MRK2 $e^$	r(g+ g- g0) /r						Γ ₆₃ /Γ
168 FRANKLIN 83 MRK2 e ⁺ e ⁻ Γ(π ⁺ π ⁻ π ⁰ K ⁺ K ⁻)/Γtotal WALUE EVTS DOCUMENT ID TECN COMMENT 10.012 ±0.003 309 VANNUCCI 77 MRK1 e ⁺ e ⁻ Γ(4(π ⁺ π ⁻)π ⁰)/Γtotal VALUE (units 10 ⁻⁴) EVTS DOCUMENT ID TECN COMMENT 13 JEAN-MARIE 76 MRK1 e ⁺ e ⁻ Γ(π ⁺ π ⁻ K ⁺ K ⁻)/Γtotal VALUE (units 10 ⁻⁴) EVTS DOCUMENT ID TECN COMMENT Γ(π ⁺ π ⁻ K ⁺ K ⁻)/Γtotal VALUE (units 10 ⁻⁴) EVTS DOCUMENT ID TECN COMMENT	, , , , , , , , , , , , , , , , , , , ,	EVTS	DOCUMENT ID		TECN	COMMENT	. 62/
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$							
ALUE Equals 10-4 EVTS DOCUMENT ID TECN COMMENT VANNUCCI 77 MRK1 e^+e^- (4($\pi^+\pi^-$) π^0)/ Γ_{total} VALUE (units 10-4) EVTS DOCUMENT ID TECN COMMENT 13 JEAN-MARIE 76 MRK1 e^+e^- ($\pi^+\pi^-K^+K^-$)/ Γ_{total} VALUE (units 10-4) EVTS DOCUMENT ID TECN COMMENT				-			
2.012 \pm 0.003 309 VANNUCCI 77 MRK1 $e^+e^ \Gamma(4(\pi^+\pi^-)\pi^0)/\Gamma_{\text{total}}$ $\Gamma(4(\pi^+\pi^-)\pi^0)/\Gamma_{\text{total}}$ $\Gamma(4(\pi^+\pi^-)\pi^0)/\Gamma_{\text{total}}$ $\Gamma(\pi^+\pi^-K^+K^-)/\Gamma_{\text{total}}$							Γ ₆₄ /Γ
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$						4	
ALUE (units 10 ⁻⁴) EVTS DOCUMENT ID TECN COMMENT			VANNUCCI	77	MKK1	e'e-	
ALUE (units 10 ⁻⁴) EVTS DOCUMENT ID TECN COMMENT	$\Gamma(4(\pi^+\pi^-)\pi^0)/\Gamma_{\rm tot}$	ai					Γ ₆₈ /Γ
90±30 13 JEAN-MARIE 76 MRK1 e ⁺ e ⁻ Γ(π ⁺ π ⁻ K ⁺ K ⁻)/Γ _{total} Γ ₆ VALUE (units 10 ⁻⁴) <u>EVTS</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u>	•		DOCUMENT ID		TECN	COMMENT	
Γ(π+π-K+K-)/Γtotal Γ ₆ VALUE (units 10 ⁻⁴) <u>EVTS</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u>							
VALUE (units 10 ⁻⁴) EVTS DOCUMENT ID TECN COMMENT							-
	•						Γ ₆₆ /Γ
72 ± 23 205 VANNUCCI 77 MRK1 e ⁺ e ⁻	-						
	72±23	205	VANNUCCI	77	MRK1	e+e-	

$\Gamma(K\overline{K}\pi)/\Gamma_{total}$						Г ₆₇ /Г
VALUE (units 10 ⁻⁴) 61 ±10 OUR AVE	EVTS	DOCUMENT ID		TECN	COMMENT	
55.2±12.0	25	FRANKLIN	83	MDK2	a+a	$K^+K^-\pi^0$
78.0±21.0	25 126	VANNUCCI	77	MRK1	e+e- →	KOK±##
$\Gamma(p\overline{p}\pi^+\pi^-)/\Gamma_{\mathrm{tot}}$	al					Г ₆₈ /Г
VALUE (units 10 ⁻³)	EVTS	DOCUMENT ID		TECN	COMMENT	
6.0 ±0.5 OUR AVE	RAGE Erro	or includes scale f	actor			gram below.
6.46±0.17±0.43	1435	EATON	84		e+ e-	
3.8 ±1.6	48	BESCH	81		e+ e-	
5.5 ±0.6	533	PERUZZI	78	MRK1	e e	
WEIGHTED A 6.0±0.5 (Error		.3)				
_		· · · · · B	ATON ESCH ERUZ	ZI	84 MRK2 81 BONA 78 MRK1 dence Level	1.0 1.9 0.7 3.6 = 0.167)
0 2	1 4	· · · · · B	ESCH	ZI	81 BONA 78 MRK1	1.0 1.9 0.7 3.6
$0 \qquad 2$ $\Gamma(\rho \overline{\rho} \pi^+ \pi^-$,	6 8	ESCH	ZI (Confid	81 BONA 78 MRK1	1.0 1.9 0.7
$\Gamma(ho\overline{ ho}\pi^+\pi^-)/\Gamma(2(\pi^+\pi^-))/\Gamma_{ ext{tot}}$	-)/Γ _{total} (6 8 units 10 ⁻³)	ESCH	(Confid	81 BONA 78 MRK1 dence Level	1.0 1.9 0.7
$\Gamma(ho \overline{ ho} \pi^+ \pi^-) / \Gamma_{ ext{tot}}$)/r _{total} (6 8 units 10 ⁻³)	ESCH	(Confidence of the confidence	81 BONA 78 MRK1 dence Level	1.0 1.9 0.7 3.6 = 0.167)
$\Gamma(ho \overline{ ho} \pi^+ \pi^-) / \Gamma_{ ext{tot}}$	-)/Γ _{total} (6 8 units 10 ⁻³)	ESCH	(Confidence of the confidence	81 BONA 78 MRK1 dence Level	1.0 1.9 0.7 3.6 = 0.167)
Γ(ρρπ ⁺ π ⁻))/Γ _{tob}	-)/Γ _{total} (ι 	6 8 units 10 ⁻³)	ESCH	(Confidence of the confidence	81 BONA 78 MRK1 dence Level	1.0 1.9 0.7 3.6 = 0.167)
$\Gamma(\rho \bar{\rho} \pi^{+} \pi^{-}))/\Gamma_{\text{total}}$ $\Gamma(2(\pi^{+} \pi^{-}))/\Gamma_{\text{total}}$ 0.004 ± 0.001 $\Gamma(3(\pi^{+} \pi^{-}))/\Gamma_{\text{total}}$	-)/Γ _{total} (ι 	6 8 units 10 ⁻³)	ESCHERUZ	(Confidence of the confidence	81 BONA 78 MRK1 dence Level	7.0 1.9 1.9 0.7 3.6 = 0.167)
$\Gamma(\rho \bar{\rho} \pi^{+} \pi^{-}))/\Gamma_{\text{tot}}$ $VALUE$ 0.004 ± 0.001 $\Gamma(3(\pi^{+} \pi^{-}))/\Gamma_{\text{tot}}$ $VALUE (units 10^{-4})$)/F _{total} (1	6 8 units 10 ⁻³)	ESCHERUZ	(Confic 10 10	81 BONA 78 MRK1 dence Level	7.0 1.9 1.9 0.7 3.6 = 0.167)
$\Gamma(2(\pi^{+}\pi^{-}))/\Gamma_{\text{tot}}$ $VALUE$ 0.004 ± 0.001 $\Gamma(3(\pi^{+}\pi^{-}))/\Gamma_{\text{tot}}$ $VALUE (units 10^{-4})$ 40 ± 20 $\Gamma(\pi \overline{n}\pi^{+}\pi^{-})/\Gamma_{\text{tot}}$	-)/Γ _{total} (1	6 8 DOCUMENT ID JEAN-MARIE DOCUMENT ID JEAN-MARIE	ESCHERUZ	(Confic 10 10 IECN MRK1	81 BONA 78 MRK1 dence Level COMMENT e+e- COMMENT e+e-	7.0 1.9 1.9 0.7 3.6 = 0.167)
$\Gamma(p\bar{p}\pi^{+}\pi^{-}))/\Gamma_{\text{tot}}$ $VALUE$ 0.004 ±0.001 $\Gamma(3(\pi^{+}\pi^{-}))/\Gamma_{\text{tot}}$ $VALUE$ (units 10^{-4}) 40 ± 20 $\Gamma(n\bar{n}\pi^{+}\pi^{-})/\Gamma_{\text{tot}}$ $VALUE$ (units 10^{-3})	EVTS 32 EVTS EVTS 32 EVTS EVTS	6 8 DOCUMENT ID JEAN-MARIE DOCUMENT ID JEAN-MARIE	ESCHERUZ	(Confidence of the confidence	81 BONA 78 MRK1 dence Level COMMENT e+e- COMMENT e+e-	7 1.0 1.9 0.7 3.6 = 0.167)
$\Gamma(2(\pi^{+}\pi^{-}))/\Gamma_{\text{tot}}$ $VALUE$ 0.004 ± 0.001 $\Gamma(3(\pi^{+}\pi^{-}))/\Gamma_{\text{tot}}$ $VALUE (units 10^{-4})$ 40 ± 20 $\Gamma(\pi \overline{n}\pi^{+}\pi^{-})/\Gamma_{\text{tot}}$	-)/Γ _{total} (1	6 8 DOCUMENT ID JEAN-MARIE DOCUMENT ID JEAN-MARIE	ESCHERUZ	(Confidence of the confidence	81 BONA 78 MRK1 dence Level COMMENT e+e- COMMENT e+e-	7 1.0 1.9 0.7 3.6 = 0.167)
$\Gamma(p\bar{p}\pi^{+}\pi^{-}))/\Gamma_{\text{tot}}$ $VALUE$ 0.004 ±0.001 $\Gamma(3(\pi^{+}\pi^{-}))/\Gamma_{\text{tot}}$ $VALUE$ (units 10^{-4}) 40 ± 20 $\Gamma(n\bar{n}\pi^{+}\pi^{-})/\Gamma_{\text{tot}}$ $VALUE$ (units 10^{-3})	EVTS 32 EVTS EVTS 32 EVTS EVTS	6 8 DOCUMENT ID JEAN-MARIE DOCUMENT ID JEAN-MARIE	ESCHERUZ	(Confidence of the confidence	81 BONA 78 MRK1 dence Level COMMENT e+e- COMMENT e+e-	7 1.0 1.9 0.7 3.6 = 0.167)

$\Gamma(3(\pi^+\pi^-))/\Gamma_{\text{total}}$					Γ ₇₀ /Γ
VALUE (units 10 ⁻⁴)	EVTS	DOCUMENT ID	TECN	COMMENT	
40±20	32	JEAN-MARIE	76 MRK	1 e ⁺ e ⁻	
$\Gamma(n\overline{n}\pi^+\pi^-)/\Gamma_{\text{total}}$					Γ ₇₁ /Γ
VALUE (units 10 ⁻³)	EVTS	DOCUMENT ID	TECN	COMMENT	
3.8±3.6	5	BESCH	81 BON	A e+e-	
$\Gamma(\Sigma^0\overline{\Sigma}^0)/\Gamma_{total}$					Γ ₇₂ /Γ
VALUE (units 10 ⁻³) 1.27±0.17 OUR AVER	AGE EVTS	DOCUMENT	ם ד	ECN COMMENT	
1.06±0.04±0.23	884±	PALLIN	87 D	M2 e ⁺ e ⁻ -	$\Sigma_0 \Sigma_0$
1.58±0.16±0.25	90	EATON		IRK2 e ⁺ e ⁻	
1.3 ±0.4	52	PERUZZI	78 N	IRK1 e ⁺ e ⁻ -	, Σ <u>0</u> Σ0
• • • We do not use t	he following	data for average	s, fits, ilmit	s, etc. • • •	
2.4 ±2.6	3	BESCH	81 B	ONA e+e	· Σ+ <u>Σ</u> -
$\Gamma(2(\pi^{+}\pi^{-})K^{+}K^{-}$)/F _{total}				Γ ₇₃ /Γ
VALUE (units 10-4)	EVTS	DOCUMENT ID	TECN	COMMENT	
31±13	30	VANNUCCI	77 MRK	1 e ⁺ e ⁻	
$\Gamma(p\overline{p}\pi^+\pi^-\pi^0)/\Gamma_{ti}$	Xai				Γ ₇₄ /Γ
Including $p\overline{p}\pi^+$	$\pi^-\gamma$ and ex	cluding ω , η , η'			
VALUE (units 10 ⁻³)	EVTS	DOCUMENT ID	TECN	COMMENT	
2.3 ±0.9 OUR AVER	AGE Erro	includes scale fa	ctor of 1.9.		
$3.36 \pm 0.65 \pm 0.28$	364	EATON		2 e+e-	
1.6 ±0.6	39	PERUZZI	78 MRK	1 e ⁺ e ⁻	
Γ(ρβ)/Γ _{total}					Γ ₇₅ /Γ
VALUE (units 10 ⁻³)	EVTS	DOCUMENT ID	TECN	COMMENT	
2.14±0.10 OUR AVER	AGE				
2.0 ±0.3	48	ANTONELLI	93 SPEC		
$1.91 \pm 0.04 \pm 0.30$		PALLIN	87 DM2		
$2.16 \pm 0.07 \pm 0.15$	1420	EATON	84 MRK	-	
2.5 ±0.4	133	BRANDELIK	79C DAS		
2.0 ±0.5		BESCH	78 BON		
2.2 ±0.2	331	²³ PERUZZI	78 MRK	1 e+e-	
²³ Assuming angular o	listribution ($(1+\cos^2\theta)$.			

Meson Particle Listings $J/\psi(1S)$

「(p̄pη)/Γ _{total}						$\Gamma(2(K^+K^-))/\Gamma_{\text{tota}}$						Γ ₈₄ /Ι
ALUE (units 10 ⁻³)	EVTS	DOCUMENT ID	TECN	COMMENT		VALUE (units 10 ⁻⁴)		DOCUMENT ID			COMMENT	
.09±0.18 OUR AVE		E4T01:				7 ±3		VANNUCCI	77	MRK1	e ⁺ e ⁻	
.03±0.13±0.15	826	EATON	84 MRK2			E/- W- 150\ /E						- /
.5 ±1.2		BRANDELIK	79C DASP			$\Gamma(\rho K^{-} \overline{\Sigma}^{0}) / \Gamma_{\text{total}}$						Γ₈₅/ Ι
.3 ±0.4	197	PERUZZI	78 MRK1	L e⊤e		VALUE (units 10 ⁻³)	EVTS	DOCUMENT ID			COMMENT	
(pħπ ⁻)/Γ _{total}					Γ ₇₇ /Γ	$0.29 \pm 0.06 \pm 0.05$	90	EATON	84	MRK2	e+e-	
,,												
ALUE (units 10 ⁻³)	EVTS	DOCUMENT ID	TECN	COMMENT		$\Gamma(K^+K^-)/\Gamma_{\text{total}}$						Γ ₈₆ /
.00±0.10 OUR AVE		FATON	04 MBV	+	_	VALUE (units 10-4)	EVTS	DOCUMENT ID		TECN	COMMENT	
.02±0.07±0.16	1288	EATON		2 e ⁺ e ⁻ → pπ		2.37±0.31 OUR AVER	AGE					
.93±0.07±0.16	1191	EATON		$e^+e^- \rightarrow \overline{p}\pi$		$2.39 \pm 0.24 \pm 0.22$	107	BALTRUSAIT	.85 D	MRK3	e+e-	
.7 ±0.7	32	BESCH		$A e^+e^- \rightarrow p\pi$ $A e^+e^- \rightarrow \overline{p}\pi$		2.2 ±0.9	6	BRANDELIK	79 C	DASP	e+ e-	
.6 ±1.2	5	BESCH				-1- = 0						
.16±0.29	194	PERUZZI		1 e ⁺ e ⁻ → ρπ 1 e ⁺ e ⁻ → ρπ		Γ(Λ/Λπ ⁰)/Γ _{total}						Γ ₈₇ /
.04±0.27	204	PERUZZI	78 MRK1	$1 e \cdot e \rightarrow p\pi$	r'	VALUE (units 10 ⁻³)	EVTS	DOCUMENT ID		TECN	COMMENT	
·(ΞΞ)/Γ _{total}					Γ ₇₉ /Γ	0.22±0.05±0.05	19 ±	HENRARD	87	DM2	e+ e-	
					. /9/ .		4					
ALUE (units 10 ⁻³)	EVTS	DOCUMENT		COMMENT		F(-+) /F						F
.8 ±0.4 OUR AVE				See the Ideogra		$\Gamma(\pi^+\pi^-)/\Gamma_{\text{total}}$						Γ ₈₈ /
$.40 \pm 0.12 \pm 0.24$	132±	HENRARD	87 DI	M2 e ⁺ e ⁻ →	<i>===</i>	VALUE (units 10 ⁻⁴)	EVTS	DOCUMENT ID		TECN	COMMENT	<u> </u>
.28±0.16±0.40	11 194	EATON	84 M	RK2 e+e- →	=- =+	1.47±0.23 OUR AVER	AGE					
.2 ±0.8	71	PERUZZI		RK1 e+e-		$1.58 \pm 0.20 \pm 0.15$	84	BALTRUSAIT				
						1.0 ±0.5	5	BRANDELIK			e+ e-	
WEIGHTED AVER						1.6 ±1.6	1	VANNUCCI	77	MRK1	e+ e	
1.8±0.4 (Error scal	led by 1.8)					-400\-						_
						$\Gamma(K_S^0 K_L^0)/\Gamma_{\text{total}}$						Гв9/
						VALUE (units 10 ⁻⁴)	EVTS	DOCUMENT ID		TECN	COMMENT	
						1.08±0.14 OUR AVER	AGE		_			
						$1.18 \pm 0.12 \pm 0.18$		JOUSSET		DM2	$J/\psi ightarrow h$	adrons
	8					$1.01 \pm 0.16 \pm 0.09$	74	BALTRUSAIT	85 D	MRK3	e+e-	
						-4.5						_
						$\Gamma(\Lambda \overline{\Sigma} + \text{c.c.})/\Gamma_{\text{total}}$	ı					Γ _{90/}
						VALUE (units 10 ⁻³)	CL%	DOCUMENT ID		TECN	COMMENT	
	9					<0.15	90	PERUZZI	78	MRK1	e+e- →	· AX
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						F(K'e K'e)/Frotal						i 91 /
				2		$\Gamma(K_S^0 K_S^0)/\Gamma_{\text{total}}$	C! N	DOCUMENT ID		TECN	COMMENT	
				χ^2		VALUE (units 10 ⁻⁴)	<u> </u>	DOCUMENT ID		TECN		
-	<u></u>	· · · · · HENRA		χ^2 DM2 1.8		VALUE (units 10 ⁻⁴) <0.052	<u>CL%</u> 90	DOCUMENT ID	85c			
+-		· · · · · EATON	84	MRK2 1.4		VALUE (units 10 ⁻⁴)			85c			-
			84	MRK2 1.4 MRK1 3.2		VALUE (units 10 ⁻⁴) <0.052	90	24 BALTRUSAIT		MRK3		F ₉₁ /
	1	· · · · · EATON	84 ZI 78	MRK2 1.4 MRK1 3.2 6.5		VALUE (units 10 ⁻⁴) <0.052	90			MRK3		
		· · · · · EATON	84 ZI 78	MRK2 1.4 MRK1 3.2)	VALUE (units 10 ⁻⁴) <0.052 24 Forbidden by <i>CP</i> .	90	24 BALTRUSAIT		MRK3		
0 1 2	2 3	· · · · · EATON	84 ZI 78	MRK2 1.4 MRK1 3.2 6.5		VALUE (units 10^{-4}) <0.052 24 Forbidden by CP. $-\Gamma(\gamma\eta_c(15))/\Gamma_{\text{total}}$	90	²⁴ BALTRUSAIT		MRK3	e+e-	Г _{92,}
		PERUZ	ZI 78	MRK2 1.4 MRK1 3.2 6.5	-	VALUE (units 10^{-4}) <0.052 24 Forbidden by CP. $\Gamma(\gamma\eta_c(15))/\Gamma_{total}$ VALUE	90	²⁴ BALTRUSAIT RADIATIVE DE	CAY!	MRK3	e+e-	Г _{92,}
0 1 2 Γ(ΞΞ)/Γ _{total} (PERUZ	ZI 78	MRK2 1.4 MRK1 3.2 6.5		VALUE (units 10^{-4}) <0.052 24 Forbidden by CP. $\Gamma(\gamma \eta_c(15))/\Gamma_{\text{total}}$ VALUE 0.0127 \pm 0.0036	90 	24 BALTRUSAIT RADIATIVE DE DOCUMENT ID GAISER	ECAY:	MRK3 TECN CBAL	e^+e^- $\frac{COMMENT}{J/\psi \rightarrow \gamma}$	Г 92 /
$\Gamma(\Xi\overline{\Xi})/\Gamma_{total}$		PERUZ	ZI 78	MRK2 1.4 MRK1 3.2 6.5		VALUE (units 10^{-4}) <0.062 24 Forbidden by CP.	90 EVTS	24 BALTRUSAIT RADIATIVE DE DOCUMENT ID GAISER ng data for average	86 es, fits	MRK3 TECN CBAL , limits,	$\frac{COMMENT}{J/\psi \rightarrow \gamma}$, etc. • •	Г 92 ,
$\Gamma(\Xi\overline{\Xi})/\Gamma_{total}$		PERUZ	ZI 78	MRK2 1.4 MRK1 3.2 6.5	-) Г 78 /Г	VALUE (units 10^{-4}) <0.052 24 Forbidden by CP. $\Gamma(\gamma \eta_c(15))/\Gamma_{\text{total}}$ VALUE 0.0127 \pm 0.0036	90 	24 BALTRUSAIT RADIATIVE DE DOCUMENT ID GAISER	86 es, fits	MRK3 TECN CBAL , limits,	$\frac{COMMENT}{J/\psi \rightarrow \gamma}$, etc. • •	Г 92/ УХ
$\Gamma(\Xi\Xi)/\Gamma_{\text{total}}$	(units 10 ⁻³)	PERUZ	ZI 78 (Confidence) 6	MRK2 1.4 MRK1 3.2 6.5 ce Level = 0.039)		VALUE (units 10^{-4}) <0.062 24 Forbidden by CP.	90 EVTS the followin	24 BALTRUSAIT RADIATIVE DE DOCUMENT ID GAISER ng data for average	86 es, fits	MRK3 TECN CBAL , limits,	$\frac{COMMENT}{J/\psi \rightarrow \gamma}$, etc. • •	Γ92 / γΧ •
$\Gamma(\Xi\Xi)/\Gamma_{\text{total}}$ $\Gamma(n\pi)/\Gamma_{\text{total}}$ $\Gamma(\text{ALUE (units }10^{-2}))$	(units 10 ⁻³)	PERUZ	ZI 78	MRK2 1.4 MRK1 3.2 6.5 ce Level = 0.039)		VALUE (units 10^{-4}) <0.052 24 Forbidden by CP . $\Gamma(\gamma\eta_{c}(1S))/\Gamma_{total}$ VALUE 0.0127 ± 0.0036 • • • We do not use to seen $\Gamma(\gamma\pi^{+}\pi^{-}2\pi^{0})/\Gamma_{total}$	90 EVTS the followin	PACTIVE DE DOCUMENT ID GAISER GATE GATE GATE GATE GATE GATE GATE GATE	86 es, fits	TECN CBAL , limits, MRK3	$\frac{COMMENT}{J/\psi \rightarrow \gamma}$, etc. • • • • $J/\psi \rightarrow 2$	Γ _{92/} γ× • • • • • • • • • • • • • • • • • •
$\Gamma(\Xi\Xi)/\Gamma_{\text{total}}$ $\Gamma(n\pi)/\Gamma_{\text{total}}$ $P(\mu)$	(units 10 ⁻³)	4 5	(Confidence 6	MRK2 1.4 MRK1 3.2 6.5 ce Level = 0.039)		VALUE (units 10^{-4}) <0.062 24 Forbidden by CP.	90 EVTS the followin	24 BALTRUSAIT RADIATIVE DE DOCUMENT ID GAISER ng data for average BALTRUSAIT	86 es, fits	TECN CBAL , limits, MRK3	$c+e$ $\frac{COMMENT}{J/\psi \rightarrow \gamma}$ $etc. \bullet \bullet \bullet$ $J/\psi \rightarrow 2$ $COMMENT$	Γ92/ γΧ 2 <i>φ</i> γ Γ93 /
Γ(ΞΞ)/Γ _{total} (ΠΠ)/Γ _{total} ALUE (units 10 ⁻²) 19 ±0.05 OUR AN 190±0.055	(units 10 ⁻³)	DOCUMENT ID	(Confidence 6 TECN 93 SPEC	MRK2 1.4 MRK1 3.2 Cce Level = 0.039		VALUE (units 10^{-4}) <0.052 24 Forbidden by CP . $\Gamma(\gamma\eta_{c}(1S))/\Gamma_{total}$ VALUE 0.0127 ± 0.0036 • • • We do not use to seen $\Gamma(\gamma\pi^{+}\pi^{-}2\pi^{0})/\Gamma_{total}$	90 EVTS the followin	PACTIVE DE DOCUMENT ID GAISER GATE GATE GATE GATE GATE GATE GATE GATE	86 es, fits	TECN CBAL , limits, MRK3	$c+e$ $\frac{COMMENT}{J/\psi \rightarrow \gamma}$ $etc. \bullet \bullet \bullet$ $J/\psi \rightarrow 2$ $COMMENT$	Γ92 / γΧ 2 <i>φ</i> γ Γ93 /
Γ(ΞΞ)/Γ _{total} ((ΠΠ)/Γ _{total} (ALUE (units 10 ⁻²) .19 ±0.05 OUR AN .190±0.055 .18 ±0.09	(units 10 ⁻³)	4 5	(Confidence 6	MRK2 1.4 MRK1 3.2 Cce Level = 0.039		VALUE (units 10^{-4}) <0.062 24 Forbidden by CP. $\Gamma(\gamma \eta_c(15))/\Gamma_{\text{total}}$ VALUE 0.0127 \pm 0.0036 • • • We do not use to seen $\Gamma(\gamma \pi^+ \pi^- 2\pi^0)/\Gamma_{\text{total}}$ VALUE (units 10^{-3})	90 EVTS the followin 16	24 BALTRUSAIT RADIATIVE DE DOCUMENT ID GAISER ng data for average BALTRUSAIT	86 es, fits	TECN CBAL , limits, MRK3	$c+e$ $\frac{COMMENT}{J/\psi \rightarrow \gamma}$ $etc. \bullet \bullet \bullet$ $J/\psi \rightarrow 2$ $COMMENT$	Γ _{92,} γΧ • 2φγ Γ _{93,}
Γ(ΞΞ)/Γ _{total} ((ΠΠ)/Γ _{total} (ALUE (units 10 ⁻²) .19 ±0.05 OUR AN .190±0.055 .18 ±0.09	(units 10 ⁻³)	DOCUMENT ID	(Confidence 6 TECN 93 SPEC	MRK2 1.4 MRK1 3.2 Cce Level = 0.039	Γ ₇₈ /Γ	$VALUE$ (units 10 ⁻⁴) <0.052 24 Forbidden by CP . Γ ($\gamma\eta_c(15)$)/Γ total VALUE 0.0127±0.0036 • • • We do not use to seen Γ ($\gamma\pi^+\pi^-2\pi^0$)/Γ total VALUE (units 10 ⁻³) 8.3±0.2±3.1 25 4 π mass less than	90 EVTS the followin 16	24 BALTRUSAIT RADIATIVE DE DOCUMENT ID GAISER ng data for average BALTRUSAIT	86 es, fits	TECN CBAL , limits, MRK3	$c+e$ $\frac{COMMENT}{J/\psi \rightarrow \gamma}$ $etc. \bullet \bullet \bullet$ $J/\psi \rightarrow 2$ $COMMENT$	Γ _{92,} γΧ • • • • • • • • • • • • • • • • • •
Γ(ΞΞ)/Γ _{total} (nπ)/Γ _{total} (Δ(DE (units 10 ⁻²)) 19 ±0.05 OUR AN 1.190±0.055 1.8 ±0.09 (ΛΛ)/Γ _{total}	(units 10 ⁻³) EVTS VERAGE 40	DOCUMENT ID ANTONELLI BESCH	ZI 84 78 (Confidence 6 TECN 93 SPEC 78 BONJ	MRK2 1.4 MRK1 3.2 6.5 ce Level = 0.039) COMMENT c+c- A e+c-		$VALUE$ (units 10 ⁻⁴) <0.052 24 Forbidden by CP . Γ ($\gamma\eta_c(15)$)/Γ total VALUE 0.0127±0.0036 • • • We do not use to seen Γ ($\gamma\pi^+\pi^-2\pi^0$)/Γ total VALUE (units 10 ⁻³) 8.3±0.2±3.1 25 4 π mass less than	90 EVTS the followin 16	24 BALTRUSAIT RADIATIVE DE DOCUMENT ID GAISER ng data for average BALTRUSAIT	86 es, fits	TECN CBAL , limits, MRK3	$c+e$ $\frac{COMMENT}{J/\psi \rightarrow \gamma}$ $etc. \bullet \bullet \bullet$ $J/\psi \rightarrow 2$ $COMMENT$	Γ _{92,} γΧ • • • • • • • • • • • • • • • • • •
$\Gamma(\Xi\Xi)/\Gamma_{\text{total}}$ $(n\pi)/\Gamma_{\text{total}}$ $4LUE \text{ (units } 10^{-2})$ $19 \pm 0.05 \text{ OUR AN}$ 190 ± 0.055 18 ± 0.09 $(\Lambda\Lambda)/\Gamma_{\text{total}}$ $4LUE \text{ (units } 10^{-3})$	(units 10 ⁻³) EVTS VERAGE 40	DOCUMENT ID ANTONELLI BESCH	ZI 84 78 (Confidence 6 6 TECN 93 SPEC 78 BON.)	MRK2 1.4 MRK1 3.2 Sce Level = 0.039 COMMENT COMMENT	Γ ₇₈ /Γ	$VALUE (units 10^{-4})$ <0.052 2^4 Forbidden by CP . $\Gamma(\gamma \eta_c(15))/\Gamma_{total}$ $VALUE$ 0.0127 ± 0.0036 • • • We do not use the seen $\Gamma(\gamma \pi^+ \pi^- 2\pi^0)/\Gamma_{total}$ $VALUE (units 10^{-3})$ 8.3 ± 0.2 ± 3.1 2^5 4 π mass less than $\Gamma(\gamma \eta \pi \pi)/\Gamma_{total}$	90 EVTS the followin 16	24 BALTRUSAIT RADIATIVE DE DOCUMENT ID GAISER ng data for average BALTRUSAIT DOCUMENT ID 25 BALTRUSAIT	86 es, fits 84	TECN CBAL , limits, MRK3	$\begin{array}{c} c + c - \\ \hline \\ COMMENT \\ J/\psi \rightarrow \gamma \\ etc. \bullet \bullet \\ J/\psi \rightarrow 2 \\ \hline \\ COMMENT \\ J/\psi \rightarrow 4 \\ \hline \end{array}$	Γ ₉₂ , γΧ ε 2φγ Γ ₉₃ ,
Γ(ΞΞ)/Γ _{total} (nπ)/Γ _{total} Δ(UE (units 10 ⁻²) 19 ±0.05 OUR AN 190±0.055 18 ±0.09 (ΛΛ)/Γ _{total} Δ(UE (units 10 ⁻³) 38±0.14 OUR AVE	(units 10 ⁻³) EVTS VERAGE 40 EVTS ERAGE Error	DOCUMENT ID ANTONELLI BESCH DOCUMENT ID Includes scale fa	ZI 84 78 (Confidence 6	MRK2 1.4 MRK1 3.2 Sce Level = 0.039 COMMENT COMMENT COMMENT	Γ ₇₈ /Γ	VALUE (units 10^{-4}) <0.062 24 Forbidden by CP. $\Gamma(\gamma \eta_c(15))/\Gamma_{total}$ VALUE 0.0127 \pm 0.0036 • • • We do not use 1 seen $\Gamma(\gamma \pi^+ \pi^- 2\pi^0)/\Gamma_{total}$ VALUE (units 10^{-3}) 8.3 \pm 0.2 \pm 3.1 25 \pm 4 π mass less than $\Gamma(\gamma \eta \pi \pi)/\Gamma_{total}$ VALUE (units 10^{-3})	90	24 BALTRUSAIT RADIATIVE DE DOCUMENT ID GAISER ng data for average BALTRUSAIT	86 es, fits 84	TECN CBAL , limits, MRK3	$\begin{array}{c} c + c - \\ \hline \\ COMMENT \\ J/\psi \rightarrow \gamma \\ etc. \bullet \bullet \\ J/\psi \rightarrow 2 \\ \hline \\ COMMENT \\ J/\psi \rightarrow 4 \\ \hline \end{array}$	Γ ₉₂ , γΧ ε 2φγ Γ ₉₃ ,
Γ(ΞΞ)/Γ _{total} (nπ)/Γ _{total} (μυΕ (units 10 ⁻²) 19 ±0.05 OUR AN 190±0.055 18 ±0.09 (ΛΛ)/Γ _{total} ΔυΕ (units 10 ⁻³) 38±0.14 OUR AVE 38±0.05±0.20	(units 10 ⁻³) EVTS VERAGE 40 EVTS ERAGE Error 1847	DOCUMENT ID ANTONELLI BESCH DOCUMENT ID includes scale fa PALLIN	ZI 84 78 (Confident 6 Feb. 7 TECN 93 SPEC 78 BON/ Ctor of 1.2. 87 DM2	MRK2 1.4 MRK1 3.2 Sce Level = 0.039 COMMENT COMMENT COMMENT C+ c+ c- COMMENT C+ c+ c-	Γ ₇₈ /Γ	VALUE (units 10 ⁻⁴) <0.052 24 Forbidden by <i>CP</i> . Γ (γη _C (15)) / Γ total VALUE 0.0127±0.0036 • • • We do not use to seen Γ (γπ ⁺ π ⁻ 2π ⁰) / Γ total VALUE (units 10 ⁻³) 8.3±0.2±3.1 25 4π mass less than Γ (γηππ) / Γ total VALUE (units 10 ⁻³) 6.1 ±1.0 OUR AVERU	90	24 BALTRUSAIT RADIATIVE DE DOCUMENT ID GAISER ng data for average BALTRUSAIT DOCUMENT ID DOCUMENT ID	86 es, fits	TECN MRK3	$\begin{array}{c} c + c - \\ \hline \\ COMMENT \\ J/\psi \rightarrow \gamma \\ ctc. \bullet \bullet \circ \\ J/\psi \rightarrow 2 \\ \hline \\ COMMENT \\ \hline \\ COMMENT \\ \hline \end{array}$	Γ ₉₂ , γΧ •2 <i>φ</i> γ Γ ₉₃
Γ(ΞΞ)/Γ _{total} ((ΛΠ)/Γ _{total} (19 ±0.05 OUR A) 19 ±0.05 OUR A) 190±0.055 18 ±0.09 ((ΛΠ)/Γ _{total} (ΛΠ)/Γ _{total} 33±0.14 OUR AVE 38±0.05±0.20 58±0.08±0.19	EVTS VERAGE 40 EVTS ERAGE ETTO 1847 365	DOCUMENT ID ANTONELLI BESCH DOCUMENT ID Includes scale fa PALLIN EATON	ZI 84 78 (Confidence 6 TECN 93 SPEC 78 BON TECN Cotor of 1.2. 87 DM2 84 MRK	MRK2 1.4 MRK1 3.2 6.5 ce Level = 0.039) COMMENT c+c- c+c- c+c- c+c- c+c- c+c- c+c- c+c	Γ ₇₈ /Γ	VALUE (units 10 ⁻⁴) <0.052 24 Forbidden by <i>CP</i> . Γ (γη _C (1S))/Γ total VALUE 0.0127±0.0036 • • • We do not use the seen Γ (γπ ⁺ π ⁻ 2π ⁰)/Γ _{th} VALUE (units 10 ⁻³) 8.3±0.2±3.1 25 4π mass less than Γ (γηππ)/Γ total VALUE (units 10 ⁻³) 6.1 ±1.0 OUR AVERU 5.85±0.3±1.05	90	24 BALTRUSAIT RADIATIVE DE DOCUMENT ID GAISER ng data for average BALTRUSAIT DOCUMENT ID 25 BALTRUSAIT DOCUMENT ID 26 EDWARDS	86 es, fits84	TECN CBAL , limits, MRK3 TECN MRK3 TECN CBAL	$\begin{array}{c} c + c - \\ \hline \\ COMMENT \\ J/\psi \rightarrow \gamma \\ etc. \bullet \bullet \circ \\ J/\psi \rightarrow 2 \\ \hline \\ COMMENT \\ J/\psi \rightarrow \tau \\ \\ \hline \\ J/\psi \rightarrow \tau \\ \end{array}$	Γ92, γχ 2φγ Γ93, 4πγ Γ94
Γ(ΞΞ)/Γ _{total} (nπ)/Γ _{total} 4LUE (units 10 ⁻²) 19 ±0.05 OUR AN 190±0.055 18 ±0.09 (ΛΛ)/Γ _{total} 4LUE (units 10 ⁻³) 38±0.14 OUR AVE 38±0.14 OUR AVE 36±0.05±0.20 56±0.08±0.19 6 ±1.6	EVTS VERAGE 40 EVTS EVTS ERAGE Error 1847 365 5	DOCUMENT ID Includes scale fa PALIN EATON BESCH	21 84 78 (Confidence 6 7 7 7 7 7 7 7 8 7 8 7 9 7 8 7 9 7 9 7 9	MRK2 1.4 MRK1 3.2 6.5 ce Level = 0.039) COMMENT c+c- A c+c- 2 c+c- A c+c- A c+c-	Γ ₇₈ /Γ	$VALUE$ (units 10^{-4}) <0.052 2^4 Forbidden by CP . Γ ($\gamma\eta_c(1S)$)/Γ total VALUE (units 10^{-3}) 8.3±0.2±3.1 25 4π mass less than Γ ($\gamma\eta\pi\pi$)/Γ total VALUE (units 10^{-3}) 8.1±0.0 OUR AVER/ 5.85±0.3±1.05 7.8 ±1.2±2.4	90 EVTS the following 16 otal 2.0 GeV.	24 BALTRUSAIT RADIATIVE DE DOCUMENT ID GAISER BALTRUSAIT DOCUMENT ID 25 BALTRUSAIT DOCUMENT ID 26 EDWARDS 26 EDWARDS 26 EDWARDS	86 es, fits84	TECN CBAL , limits, MRK3 TECN MRK3 TECN CBAL	$\begin{array}{c} c + c - \\ \hline \\ COMMENT \\ J/\psi \rightarrow \gamma \\ ctc. \bullet \bullet \circ \\ J/\psi \rightarrow 2 \\ \hline \\ COMMENT \\ \hline \\ COMMENT \\ \hline \end{array}$	Γ92, γχ 2φγ Γ93, 4πγ Γ94,
Γ(ΞΞ)/Γ _{total} (nπ)/Γ _{total} 4LUE (units 10 ⁻²) 19 ±0.05 OUR AN 190±0.055 18 ±0.09 (ΛΛ)/Γ _{total} 4LUE (units 10 ⁻³) 38±0.14 OUR AVE 38±0.14 OUR AVE 36±0.05±0.20 56±0.08±0.19 6 ±1.6	EVTS VERAGE 40 EVTS ERAGE ETTO 1847 365	DOCUMENT ID ANTONELLI BESCH DOCUMENT ID Includes scale fa PALLIN EATON	ZI 84 78 (Confidence 6 TECN 93 SPEC 78 BON TECN Cotor of 1.2. 87 DM2 84 MRK	MRK2 1.4 MRK1 3.2 6.5 ce Level = 0.039) COMMENT c+c- A c+c- 2 c+c- A c+c- A c+c-	Γ ₇₈ /Γ	VALUE (units 10 ⁻⁴) <0.052 24 Forbidden by <i>CP</i> . Γ (γη _C (1S))/Γ total VALUE 0.0127±0.0036 • • • We do not use the seen Γ (γπ ⁺ π ⁻ 2π ⁰)/Γ _{th} VALUE (units 10 ⁻³) 8.3±0.2±3.1 25 4π mass less than Γ (γηππ)/Γ total VALUE (units 10 ⁻³) 6.1 ±1.0 OUR AVERU 5.85±0.3±1.05	90 EVTS the following 16 otal 2.0 GeV.	24 BALTRUSAIT RADIATIVE DE DOCUMENT ID GAISER BALTRUSAIT DOCUMENT ID 25 BALTRUSAIT DOCUMENT ID 26 EDWARDS 26 EDWARDS 26 EDWARDS	86 es, fits84	TECN CBAL , limits, MRK3 TECN MRK3 TECN CBAL	$\begin{array}{c} c + c - \\ \hline \\ COMMENT \\ J/\psi \rightarrow \gamma \\ etc. \bullet \bullet \circ \\ J/\psi \rightarrow 2 \\ \hline \\ COMMENT \\ J/\psi \rightarrow \tau \\ \\ \hline \\ J/\psi \rightarrow \tau \\ \end{array}$	Γ92, γχ 2φγ Γ93, 4πγ Γ94,
Γ(ΞΞ)/Γ _{total} (nπ)/Γ _{total} 4ΔUE (units 10 ⁻²) 19 ±0.05 OUR AN 190±0.055 18 ±0.09 (ΛΛ)/Γ _{total} 4ΔUE (units 10 ⁻³) 38±0.14 OUR AN 38±0.14 OUR AN 38±0.25±0.20 55±0.08±0.19 6. ±1.6 1. ±0.2	EVTS VERAGE 40 EVTS EVTS ERAGE Error 1847 365 5	DOCUMENT ID Includes scale fa PALIN EATON BESCH	21 84 78 (Confidence 6 7 7 7 7 7 7 7 8 7 8 7 9 7 8 7 9 7 9 7 9	MRK2 1.4 MRK1 3.2 6.5 ce Level = 0.039) COMMENT c+c- A c+c- 2 c+c- A c+c- A c+c-	Γ ₇₈ /Γ Γ ₈₀ /Γ	VALUE (units 10 ⁻⁴) <0.052 24 Forbidden by <i>CP</i> . Γ (γη _C (1S)) / Γ total VALUE 0.0127±0.0036 • • • We do not use to seen Γ (γπ ⁺ π ⁻ 2π ⁰) / Γ _{tot} VALUE (units 10 ⁻³) 8.3±0.2±3.1 25 4π mass less than Γ (γηππ) / Γ total VALUE (units 10 ⁻³) 6.1 ±1.0 OUR AVER 5.85±0.3±1.25 7.8 ±1.2±2.4 26 Broad enhancement	90 EVTS the followin 16 otal 2.0 GeV.	24 BALTRUSAIT RADIATIVE DE DOCUMENT ID GAISER IN BALTRUSAIT DOCUMENT ID 25 BALTRUSAIT DOCUMENT ID 26 EDWARDS 26 EDWARDS MeV.	86 es, fits84	TECN CBAL , limits, MRK3 TECN MRK3 TECN CBAL	$\begin{array}{c} c + c - \\ \hline \\ COMMENT \\ J/\psi \rightarrow \gamma \\ etc. \bullet \bullet \circ \\ J/\psi \rightarrow 2 \\ \hline \\ COMMENT \\ J/\psi \rightarrow \tau \\ \\ \hline \\ J/\psi \rightarrow \tau \\ \end{array}$	Γ ₉₂ , γχ • • • • • • • • • • • • • • • • • •
Γ(ΞΞ)/Γ _{total} (Λħ)/Γ _{total} <u>MUE (units 10⁻²)</u> 19 ±0.05 OUR AN 190±0.055 18 ±0.05 (ΛΛ)/Γ _{total} <u>MUE (units 10⁻³)</u> 38±0.05±0.20 58±0.08±0.19 6 ±1.6 1 ±0.2 (ρρπ ⁰)/Γ _{total}	EVTS VERAGE 40 EVTS ERAGE Error 1847 365 5 196	DOCUMENT ID ANTONELLI BESCH DOCUMENT ID Includes scale fa PALLIN EATON BESCH PERUZZI	21 84 78 (Confidence 6 6 7 7 7 7 7 8 8 9 9 3 8 9 7 8 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9	MRK2 1.4 MRK1 3.2 6.5 ce Level = 0.039)	Γ ₇₈ /Γ	VALUE (units 10 ⁻⁴) <0.052 24 Forbidden by <i>CP</i> . Γ (γη _C (15)) / Γ total VALUE 0.0127±0.0036 • • • We do not use to seen Γ (γπ ⁺ π ⁻ 2π ⁰) / Γ _{tot} VALUE (units 10 ⁻³) 8.3±0.2±3.1 25 4π mass less than Γ (γηππ) / Γ total VALUE (units 10 ⁻³) 6.1 ±1.0 OUR AVERU 5.85±0.3±1.05 7.8 ±1.2±2.4 26 Broad enhancemer Γ (γη(1440) → γ Κ	90 EVTS the followin 16 otal 2.0 GeV.	24 BALTRUSAIT RADIATIVE DE DOCUMENT ID GAISER IN BALTRUSAIT DOCUMENT ID 25 BALTRUSAIT DOCUMENT ID 26 EDWARDS 26 EDWARDS MeV.	86 es, fits84	MRK3 5 TECN CBAL , limits, MRK3 TECN MRK3 TECN CBAL CBAL	$\begin{array}{c} c + c - \\ \hline \\ COMMENT \\ J/\psi \rightarrow \gamma \\ etc. \bullet \bullet \circ \\ J/\psi \rightarrow 2 \\ \hline \\ COMMENT \\ J/\psi \rightarrow \tau \\ J/\psi \rightarrow \tau \\ \end{array}$	Γ ₉₂ , γχ • 2φγ Γ ₉₃ , · 4πγ Γ ₉₄ • Γ ₉₆
Γ(ΞΞ)/Γ _{total} (nħ)/Γ _{total} LUE (units 10 ⁻²) 19 ±0.05 OUR AN 190±0.055 18 ±0.09 (ΛĀ)/Γ _{total} LUE (units 10 ⁻³) 35±0.14 OUR ANE 35±0.14 OUR ANE 35±0.19 6 ±1.6 1 ±0.2 (ρ₱π ⁰)/Γ _{total} LUE (units 10 ⁻³)	EVTS VERAGE 40 EVTS EVTS ERAGE Error 1847 365 5 196	DOCUMENT ID Includes scale fa PALIN EATON BESCH	21 84 78 (Confidence 6 6 7 7 7 7 7 8 8 9 9 3 8 9 7 8 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9	MRK2 1.4 MRK1 3.2 6.5 ce Level = 0.039) COMMENT c+c- A c+c- 2 c+c- A c+c- A c+c-	Γ ₇₈ /Γ Γ ₈₀ /Γ	VALUE (units 10^{-4}) <0.052 2^4 Forbidden by CP . $\Gamma(\gamma\eta_c(1S))/\Gamma_{total}$ VALUE 0.0127±0.0036 • • • We do not use to seen $\Gamma(\gamma\pi^+\pi^-2\pi^0)/\Gamma_{total}$ VALUE (units 10^{-3}) 8.3±0.2±3.1 2^5 4 π mass less than $\Gamma(\gamma\eta\pi\pi)/\Gamma_{total}$ VALUE (units 10^{-3}) 6.1 ±1.0 OUR AVERUE 5.85±0.3±1.05 7.8 ±1.2±2.4 26 Broad enhancement $\Gamma(\gamma\eta(1440) \to \gamma K$ VALUE (units 10^{-3})	90	24 BALTRUSAIT RADIATIVE DE DOCUMENT ID GAISER IN BALTRUSAIT DOCUMENT ID 25 BALTRUSAIT DOCUMENT ID 26 EDWARDS 26 EDWARDS MeV.	86 es, fits84	TECN CBAL , limits, MRK3 TECN MRK3 TECN CBAL	$\begin{array}{c} c + c - \\ \hline \\ COMMENT \\ J/\psi \rightarrow \gamma \\ etc. \bullet \bullet \circ \\ J/\psi \rightarrow 2 \\ \hline \\ COMMENT \\ J/\psi \rightarrow \tau \\ \\ \hline \\ J/\psi \rightarrow \tau \\ \end{array}$	Γ ₉₂ γΧ • 2φγ Γ ₉₃ • 4πγ Γ ₉₄ • Γ ₉₆
Γ(ΞΞ)/Γ _{total} (nπ)/Γ _{total} ALUE (units 10 ⁻²) 19 ±0.05 OUR AN 190±0.055 18 ±0.09 (ΛΛ)/Γ _{total} ALUE (units 10 ⁻³) 38±0.14 OUR AVE 38±0.05±0.20 58±0.08±0.19 6 ±1.6 1 ±0.2 (ρΡπ ⁰)/Γ _{total} ALUE (units 10 ⁻³) 19±0.09 OUR AVE	EVTS WERAGE 40 EVTS ERAGE Error 1847 365 5 196 EVTS ERAGE	DOCUMENT ID DOCUMENT ID ANTONELLI BESCH DOCUMENT ID Includes scale fa PALLIN EATON BESCH PERUZZI	21 84 78 (Confidence 6 6 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7	MRK2 1.4 MRK1 3.2 Sce Level = 0.039 COMMENT	Γ ₇₈ /Γ Γ ₈₀ /Γ	$VALUE$ (units 10 ⁻⁴) <0.052 2 ⁴ Forbidden by <i>CP</i> . Γ($\gamma\eta_c(1S)$)/Γtotal VALUE 0.0127 ± 0.0036 • • • We do not use to seen Γ($\gamma\pi^+\pi^-2\pi^0$)/Γtotal VALUE (units 10 ⁻³) 8.3 ± 0.2 ± 3.1 2 ⁵ 4π mass less than Γ($\gamma\eta\pi\pi$)/Γtotal VALUE (units 10 ⁻³) 6.1 ± 1.0 OUR AVERUE 5.85 ± 0.3 ± 1.05 7.8 ± 1.2 ± 2.4 2 ⁶ Broad enhancemer Γ($\gamma\eta(1440) \rightarrow \gamma K$ VALUE (units 10 ⁻³) 0.91 ± 0.18 OUR AVERUE 0.91	90 EVTS the followin 16 otal 2.0 GeV. AGE TRAGE	24 BALTRUSAIT RADIATIVE DE DOCUMENT ID GAISER IN DOCUMENT ID 25 BALTRUSAIT DOCUMENT ID 26 EDWARDS 26 EDWARDS MeV. Otal DOCUMENT ID	86 es, fits	MRK3 TECN CBAL , Imits, MRK3 TECN CBAL CBAL CBAL	$\begin{array}{c} e^+e^-\\ \hline \\ COMMENT\\ J/\psi \to \gamma\\ etc. \bullet \bullet \bullet\\ J/\psi \to 2\\ \hline \\ COMMENT\\ J/\psi \to \tau\\ \hline \\ J/\psi \to \tau\\ \hline \\ COMMENT\\ COMME$	Γ ₉₂ γχ ε 2φγ Γ ₉₃ π _{4πγ} Γ ₉₄ Γ ₉₄ Γ ₉₅
$\Gamma(\Xi\Xi)/\Gamma_{\text{total}}$ $(n\pi)/\Gamma_{\text{total}}$ $\frac{ALUE \{\text{units }10^{-2}\}}{19 \pm 0.05}$ 190 ± 0.055 18 ± 0.09 $(\Lambda\Lambda)/\Gamma_{\text{total}}$ $\frac{ALUE \{\text{units }10^{-3}\}}{38 \pm 0.14}$ $\frac{38 \pm 0.14}{200}$ $\frac{38 \pm 0.14}{200}$ $\frac{38 \pm 0.05 \pm 0.20}{200}$ $\frac{6 \pm 1.6}{1 \pm 0.2}$ $\frac{4LUE \{\text{units }10^{-3}\}}{09 \pm 0.09}$ $\frac{4LUE \{\text{units }10^{-3}\}}{09 \pm 0.09}$ $\frac{4LUE \{\text{units }10^{-3}\}}{13 \pm 0.09 \pm 0.09}$	EVTS VERAGE 40 EVTS EVTS ERAGE Error 1847 365 5 196	DOCUMENT ID ANTONELLI BESCH DOCUMENT ID Includes scale fa PALLIN EATON BESCH PERUZZI DOCUMENT ID EATON	21 84 78 (Confidence 6 TECN 93 SPEC 78 BON. TECN 87 DM2 84 MRK 81 BON. 78 MRK TECN 84 MRK	MRK2 1.4 MRK1 3.2 Sce Level = 0.039 COMMENT c+c- c+c- 2 c+c- 1 c+c- 1 c+c- 2 c+c- 3 c+c- 3 c+c- 3 c+c- 4 c+c- 4 c+c- 5 c-c- 6 c-c- 6 c-c- 7 c-c- 8 c-c- 8 c-c- 9	Γ ₇₈ /Γ Γ ₈₀ /Γ	VALUE (units 10 ⁻⁴) <0.052 24 Forbidden by <i>CP</i> . Γ (γη _C (15)) / Γ total VALUE 0.0127±0.0036 • • • We do not use to seen Γ (γπ ⁺ π ⁻ 2π ⁰) / Γ total VALUE (units 10 ⁻³) 8.3±0.2±3.1 25 4π mass less than Γ (γηππ) / Γ total VALUE (units 10 ⁻³) 6.1 ±1.0 OUR AVERU 5.85±0.3±1.05 7.8 ±1.2±2.4 26 Broad enhancemer Γ (γη(1440) → γ K VALUE (units 10 ⁻³) 0.91±0.18 OUR AVERU 0.83±0.13±0.13±0.18	90	24 BALTRUSAIT RADIATIVE DE DOCUMENT ID GAISER IN GAISE	86 es, fits84868838	MRK3 TECN CBAL , Ilmits, MRK3 TECN CBAL CBAL CBAL CBAL CBAL CBAL DM2	$\begin{array}{c} e^+e^-\\ \hline \\ COMMENT\\ J/\psi \to \gamma\\ etc. \bullet \bullet \bullet\\ J/\psi \to 2\\ \hline \\ COMMENT\\ J/\psi \to \tau\\ \hline \\ J/\psi \to \tau\\ \hline \\ COMMENT\\ J/\psi \to \tau\\ \hline \end{array}$	Γ ₉₂ γΧ • 2φγ Γ ₉₃ • 4πγ Γ ₉₄ · γκΚπ
Γ(ΞΞ)/Γ _{total} (n/ħ)/Γ _{total} 11/L/E (units 10 ⁻²) 19 ±0.05 OUR AV 190±0.055 18 ±0.09 (ΛΛ)/Γ _{total} 11/L/E (units 10 ⁻³) 38±0.14 OUR AVE 38±0.08±0.19 6 ±1.6 1 ±0.2 (ρ/₱/π ⁰)/Γ _{total} 11/L/E (units 10 ⁻³) 10/L/E (units 10 ⁻³) 10/±0.09±0.09 10/±0.09 10/±0.09 10/±0.09 10/±0.09 10/±0.09 10/±0.09 10/±0.09	EVTS VERAGE 40 EVTS ERAGE Error 1847 365 5 196 EVTS ERAGE 685	DOCUMENT ID DOCUMENT ID ANTONELLI BESCH DOCUMENT ID EATON BESCH PERUZZI DOCUMENT ID EATON BRANDELIK	21 84 78 (Confidence 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6	MRK2 1.4 MRK1 3.2 6.5 ce Level = 0.039)	Γ ₇₈ /Γ Γ ₈₀ /Γ	VALUE (units 10 ⁻⁴) <0.052 24 Forbidden by <i>CP</i> . Γ (γη _C (15)) / Γ total VALUE 0.0127±0.0036 • • • We do not use to seen Γ (γπ ⁺ π ⁻ 2π ⁰) / Γ total VALUE (units 10 ⁻³) 8.3±0.2±3.1 25 4π mass less than Γ (γηππ) / Γ total VALUE (units 10 ⁻³) 6.1 ±1.0 OUR AVERU 5.85±0.3±1.05 7.8 ±1.2±2.4 26 Broad enhancemer Γ (γη(1440) → γ K VALUE (units 10 ⁻³) 0.91±0.18 OUR AVERU 0.83±0.13±0.13±0.18	90	24 BALTRUSAIT RADIATIVE DE DOCUMENT ID GAISER IN DOCUMENT ID 25 BALTRUSAIT DOCUMENT ID 26 EDWARDS 26 EDWARDS MeV. Otal DOCUMENT ID	86 es, fits84868838	MRK3 TECN CBAL , Ilmits, MRK3 TECN CBAL CBAL CBAL CBAL CBAL CBAL DM2	$\begin{array}{c} e^+e^-\\ \hline \\ COMMENT\\ J/\psi \to \gamma\\ etc. \bullet \bullet \bullet\\ J/\psi \to 2\\ \hline \\ COMMENT\\ J/\psi \to \tau\\ \hline \\ J/\psi \to \tau\\ \hline \\ COMMENT\\ J/\psi \to \tau\\ \hline \end{array}$	Γ ₉₂ , γχ ε 2φγ Γ ₉₃ , ηπ ⁺ π ⁻ ηπ ^{2π⁰}
Γ(ΞΞ)/Γ _{total} (nπ)/Γ _{total} LUE (units 10 ⁻²) 19 ±0.05 OUR AV 190±0.055 18 ±0.09 (ΛΛ)/Γ _{total} LUE (units 10 ⁻³) 38±0.14 OUR AVE 38±0.08±0.19 6 ±1.6 1 ±0.2 (ρ̄̄̄̄̄̄̄̄̄̄̄̄̄̄̄̄̄̄̄̄̄̄̄̄̄̄̄̄̄̄̄̄̄̄̄	EVTS WERAGE 40 EVTS ERAGE Error 1847 365 5 196 EVTS ERAGE	DOCUMENT ID ANTONELLI BESCH DOCUMENT ID Includes scale fa PALLIN EATON BESCH PERUZZI DOCUMENT ID EATON	21 84 78 (Confidence 6 TECN 93 SPEC 78 BON. TECN 87 DM2 84 MRK 81 BON. 78 MRK TECN 84 MRK	MRK2 1.4 MRK1 3.2 6.5 ce Level = 0.039)	Γ ₇₈ /Γ Γ ₈₀ /Γ	$VALUE$ (units 10^{-4}) <0.062 24 Forbidden by CP . Γ ($\gamma \eta_c(15)$) / Γ total $VALUE$ 0.0127±0.0036 • • • We do not use to seen Γ ($\gamma \pi^+ \pi^- 2\pi^0$) / Γ total $VALUE$ (units 10^{-3}) 8.3±0.2±3.1 25 4π mass less than Γ ($\gamma \eta \pi \pi$) / Γ total $VALUE$ (units 10^{-3}) 6.1 ±1.0 OUR AVERUE 5.85±0.3±0.15 7.8 ±1.2±2.4 26 Broad enhancemer Γ ($\gamma \eta$ (1440) → γ K $VALUE$ (units 10^{-3}) 0.91±0.18 OUR AVERUE 0.83±0.13±0.18 1.03+0.21±0.26	90	24 BALTRUSAIT RADIATIVE DE DOCUMENT ID GAISER IN data for average BALTRUSAIT 25 BALTRUSAIT DOCUMENT ID 26 EDWARDS 26 EDWARDS MeV. DOCUMENT ID T,28 AUGUSTIN 7,28 AUGUSTIN 7,29 BAI	86 es, fits84 838 838	MRK3 TECN CBAL , Imits, MRK3 TECN CBAL CBAL CBAL TECN CBAL DM2 MRK3	$\begin{array}{c} e^+e^-\\ \hline\\ \hline\\ COMMENT\\ J/\psi \rightarrow \gamma\\ etc. \bullet \bullet \bullet\\ J/\psi \rightarrow 2\\ \hline\\ COMMENT\\ J/\psi \rightarrow \tau\\ \hline\\ J/\psi \rightarrow \tau\\ \hline\\ COMMENT\\ J/\psi \rightarrow \tau\\ \hline\\ J/\psi \rightarrow \tau$	Γ92 γΧ 2φγ Γ93 4πγ Γ94 γκκπ γκοκ±π=
Γ(ΞΞ)/Γ _{total} (nħ)/Γ _{total} MUE (units 10 ⁻²) 19 ±0.05 OUR AN 190±0.055 18 ±0.09 (ΛĀ)/Γ _{total} MUE (units 10 ⁻³) 38±0.14 OUR AVE 38±0.05±0.20 58±0.08±0.19 6 ±1.6 1 ±0.2 (ρ₱π ⁰)/Γ _{total} MUE (units 10 ⁻³) 09±0.09 OUR AVE 13±0.09±0.09 4 ±0.4 00±0.15	EVTS VERAGE 40 EVTS VERAGE FOR 1847 365 5 196 EVTS ERAGE 685 109	DOCUMENT ID DOCUMENT ID ANTONELLI BESCH DOCUMENT ID EATON BESCH PERUZZI DOCUMENT ID EATON BRANDELIK	21 84 78 (Confidence 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6	MRK2 1.4 MRK1 3.2 6.5 ce Level = 0.039)	Γ ₇₈ /Γ Γ ₈₀ /Γ	$VALUE$ (units 10^{-4}) <0.062 24 Forbidden by CP . Γ ($\gamma \eta_c(15)$) / Γ total $VALUE$ 0.0127±0.0036 • • • We do not use to seen Γ ($\gamma \pi^+ \pi^- 2\pi^0$) / Γ total $VALUE$ (units 10^{-3}) 8.3±0.2±3.1 25 4π mass less than Γ ($\gamma \eta \pi \pi$) / Γ total $VALUE$ (units 10^{-3}) 6.1 ±1.0 OUR AVERUE 5.85±0.3±1.05 7.8 ±1.2±2.4 26 Broad enhancemer Γ ($\gamma \eta$ (1440) → γ K $VALUE$ (units 10^{-3}) 0.91±0.18 OUR AVERUE 0.83±0.13±0.18 1.03+0.19-0.19 • • • We do not use	90 EVTS the followin 16 otal 2.0 GeV. AGE TRAGE 2 2 2 2 the followin	24 BALTRUSAIT RADIATIVE DE DOCUMENT ID GAISER IN GAISE	86 es, fits84 838 838 92 90c es, fits	MRK3 TECN CBAL , Imits, MRK3 TECN CBAL CBAL TECN DM2 MRK3 , limits,	$\begin{array}{c} e^+e^-\\ \hline\\ \hline\\ COMMENT\\ J/\psi \rightarrow \gamma\\ \hline\\ COMMENT\\ J/\psi \rightarrow 4\\ \hline\\ \hline\\ COMMENT\\ J/\psi \rightarrow \tau\\ \hline\\ J/\psi \rightarrow \tau\\ \hline\\ J/\psi \rightarrow \tau\\ \hline\\ COMMENT\\ COM$	Γ ₉₂ γχ 2φγ Γ ₉₃ 4πγ Γ ₉₄ γκκπ γκοκ±π∓
Γ(ΞΞ)/Γ _{total} (n/ħ)/Γ _{total} LUE (units 10 ⁻²) 19 ±0.05 OUR AV 190±0.055 18 ±0.09 (ΛΛ)/Γ _{total} LUE (units 10 ⁻³) 38±0.14 OUR AVE 38±0.08±0.19 6 ±1.6 1 ±0.2 (ρ/₱/π ⁰)/Γ _{total} LUE (units 10 ⁻³) 09±0.09 OUR AVE 13±0.09±0.09 4 ±0.4 00±0.15	EVTS VERAGE 40 EVTS VERAGE FOR 1847 365 5 196 EVTS ERAGE 685 109	DOCUMENT ID DOCUMENT ID ANTONELLI BESCH DOCUMENT ID EATON BESCH PERUZZI DOCUMENT ID EATON BRANDELIK	21 84 78 (Confidence 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6	MRK2 1.4 MRK1 3.2 6.5 ce Level = 0.039)	Γ ₇₈ /Γ Γ ₈₀ /Γ	VALUE (units 10 ⁻⁴) <0.052 24 Forbidden by <i>CP</i> . Γ (γη _C (15)) / Γ total VALUE 0.0127±0.0036 • • • We do not use to seen Γ (γπ ⁺ π ⁻ 2π ⁰) / Γ total VALUE (units 10 ⁻³) 8.3±0.2±3.1 25 4π mass less than Γ (γηππ) / Γ total VALUE (units 10 ⁻³) 6.1 ±1.0 OUR AVERU 5.85±0.3±1.05 7.8 ±1.2±2.4 26 Broad enhancemer Γ (γη(1440) → γ K VALUE (units 10 ⁻³) 0.91±0.18 OUR AVERU 0.83±0.13±0.18 1.03+0.21±0.26 -0.18 -0.19 • • We do not use to We do not use to We do not use to 1.78±0.21±0.33	90 EVTS the followin 16 otal 2.0 GeV. AGE TRAGE 2 2 2 2 the followin	24 BALTRUSAIT RADIATIVE DE DOCUMENT ID GAISER IN BALTRUSAIT DOCUMENT ID 25 BALTRUSAIT DOCUMENT ID 26 EDWARDS 26 EDWARDS MeV. Otal DOCUMENT ID 7,28 AUGUSTIN 7,29 BAI IN data for averag 7,30 AUGUSTIN	86 86 85, fits 868 838 838 92 90c es, fits	MRK3 5	$\begin{array}{c} c + c - \\ \hline \\ \hline \\ COMMENT \\ \hline \\ J/\psi \rightarrow \gamma \\ \hline \\ COMMENT \\ \hline \\ J/\psi \rightarrow \tau \\ \hline \\ COMMENT \\ COMMENT \\ \hline \\ COMMENT	Γ ₉₂ Γ ₉₃ Γ ₉₄ Γ ₉₄ Γ ₉₅ Γ ₉₅ Γ ₉₆ Γ ₉
$\Gamma(\Xi\Xi)/\Gamma_{\text{total}}$ $(n\pi)/\Gamma_{\text{total}}$ $\frac{ALUE (units 10^{-2})}{19 \pm 0.05}$ OUR AN 190 ± 0.055 18 ± 0.09 $(\Lambda\Lambda)/\Gamma_{\text{total}}$ $\frac{ALUE (units 10^{-3})}{38 \pm 0.14}$ OUR AVE 38 ± 0.14 OUR AVE 38 $\pm 0.05 \pm 0.20$ $58 \pm 0.08 \pm 0.19$ 6 ± 1.6 1 ± 0.2 $(\rho \overline{p} \pi^0)/\Gamma_{\text{total}}$ $\frac{ALUE (units 10^{-3})}{09 \pm 0.09}$ OUR AVE 13 $\pm 0.09 \pm 0.09$ 4 ± 0.4 00 ± 0.15 $(\Lambda \overline{\Sigma}^- \pi^+)$ (or c.c.	EVTS VERAGE 40 EVTS VERAGE FOR 1847 365 5 196 EVTS ERAGE 685 109	DOCUMENT ID DOCUMENT ID ANTONELLI BESCH DOCUMENT ID EATON BESCH PERUZZI DOCUMENT ID EATON BRANDELIK	21 84 78 (Confidence 6 6 78 80 N.) TECN 93 SPEC 78 BON. TECN 87 DM2 84 MRK 81 BON. 78 MRK 81 MRK 79 DASF 78 MRK	MRK2 1.4 MRK1 3.2 6.5 ce Level = 0.039)	Γ ₇₈ /Γ Γ ₈₀ /Γ	VALUE (units 10 ⁻⁴) <0.052 24 Forbidden by <i>CP</i> . Γ (γη _C (1S)) / Γ total VALUE 0.0127±0.0036 • • • We do not use to seen Γ (γπ ⁺ π ⁻ 2π ⁰) / Γ _{total} VALUE (units 10 ⁻³) 8.3±0.2±3.1 25 4π mass less than Γ (γηππ) / Γ total VALUE (units 10 ⁻³) 6.1 ±1.0 OUR AVER 5.85±0.3±1.05 7.8 ±1.2±2.4 26 Broad enhancemer Γ (γη(1440) → γ K VALUE (units 10 ⁻³) 0.91±0.18 OUR AVER 0.83±0.13±0.18 1.03+0.21±0.26 1.78±0.21±0.33 3.8 ±0.3 ±0.6	90 EVTS the followin 16 otal 2.0 GeV. AGE at 1700 (*Kπ)/Γta RAGE 2: 2: the followin	24 BALTRUSAIT RADIATIVE DE DOCUMENT ID GAISER IN GAISER BALTRUSAIT DOCUMENT ID 25 BALTRUSAIT DOCUMENT ID 26 EDWARDS 26 EDWARDS MeV. DOCUMENT ID 7,28 AUGUSTIN 7,29 BAI IN G data for averag 7,30 AUGUSTIN 27 AUGUSTIN	86 es, fits84 838 838 92 90c es, fits 92 90	MRK3 5 ———————————————————————————————————	$\begin{array}{c} c + c - \\ \hline \\ \hline \\ COMMENT \\ \hline \\ J/\psi \rightarrow \gamma \\ \hline \\ COMMENT \\ \hline \\ J/\psi \rightarrow \tau \\ \hline \\ COMMENT \\ COMMENT \\ \hline \\ COMMENT \\ \hline \\ COMMENT \\ COMMENT \\ \hline \\ COMMENT \\$	Γ92 7 Γ93 1 Γ94 Γ94 Γ95 Γ96 Γ
Γ(ΞΞ)/Γ _{total} (nπ)/Γ _{total} 44.0E (units 10 ⁻²) 19 ±0.05 OUR AN 190±0.055 18 ±0.09 (ΛΛ)/Γ _{total} 44.0E (units 10 ⁻³) 38±0.05±0.20 58±0.08±0.19 6. ±1.6 1. ±0.2 (ρΡπ ⁰)/Γ _{total} 44.0E (units 10 ⁻³) 13±0.09±0.09 4. ±0.4 .00±0.15 (ΛΣ-π+(or c.c. ALUE (units 10 ⁻³)	EVTS VERAGE 40 EVTS STAGE 1847 365 5 196 EVTS ERAGE 685 109 .))// total	DOCUMENT ID ANTONELLI BESCH DOCUMENT ID Includes scale fa PALLIN EATON BESCH PERUZZI DOCUMENT ID EATON BRANDELIK PERUZZI	21 84 78 (Confidence 6 6 78 80 N.) TECN 93 SPEC 78 BON. TECN 87 DM2 84 MRK 81 BON. 78 MRK 81 MRK 79 DASF 78 MRK	MRK2 1.4 MRK1 3.2 6.5 ce Level = 0.039	Γ ₇₈ /Γ Γ ₈₀ /Γ	VALUE (units 10 ⁻⁴) <0.052 24 Forbidden by <i>CP</i> . Γ (γη _C (1S)) / Γ total VALUE 0.0127±0.0036 • • • We do not use to seen Γ (γπ ⁺ π ⁻ 2π ⁰) / Γ _{total} VALUE (units 10 ⁻³) 8.3±0.2±3.1 25 4π mass less than Γ (γηππ) / Γ total VALUE (units 10 ⁻³) 6.1 ±1.0 OUR AVER 5.85±0.3±1.05 7.8 ±1.2±2.4 26 Broad enhancemer Γ (γη(1440) → γ K VALUE (units 10 ⁻³) 0.91±0.18 OUR AVER 0.83±0.13±0.18 1.03+0.21±0.26 1.78±0.21±0.33 3.8 ±0.3 ±0.6	90 EVTS the followin 16 otal 2.0 GeV. AGE at 1700 (*Kπ)/Γta RAGE 2: 2: the followin	24 BALTRUSAIT RADIATIVE DE DOCUMENT ID GAISER IN BALTRUSAIT DOCUMENT ID 25 BALTRUSAIT DOCUMENT ID 26 EDWARDS 26 EDWARDS MeV. Otal DOCUMENT ID 7,28 AUGUSTIN 7,29 BAI IN data for averag 7,30 AUGUSTIN	86 es, fits84 838 838 92 90c es, fits 92 90	MRK3 5 ———————————————————————————————————	$\begin{array}{c} c + c - \\ \hline \\ \hline \\ COMMENT \\ \hline \\ J/\psi \rightarrow \gamma \\ \hline \\ COMMENT \\ \hline \\ J/\psi \rightarrow \tau \\ \hline \\ COMMENT \\ COMMENT \\ \hline \\ COMMENT \\ \hline \\ COMMENT \\ COMMENT \\ \hline \\ COMMENT \\$	Γ92 17 Γ93 14 Γ94 17 Γ94 17 Γ95 18 Γ95 19 19 Γ95 19 19 Γ95 19 19 19 19 19 19 19 19
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Γ(ΞΞ)/Γ _{total} (nπ)/Γ _{total} 4LUE (units 10 ⁻²) 19 ±0.05 OUR AN 190±0.055 18 ±0.09 (ΛΛ)/Γ _{total} 4LUE (units 10 ⁻³) 38±0.05±0.20 58±0.08±0.19 6 ±1.6 1 ±0.2 (ρρπ ⁰)/Γ _{total} 4LUE (units 10 ⁻³) 09±0.09 OUR AVE 13±0.09 OUR AVE 13±0.09±0.09 4 ±0.4 00±0.15 (ΛΣπ + (or c.c. 4LUE (units 10 ⁻³) 06±0.12 OUR AVE 90±0.06±0.16 11±0.06±0.20 53±0.17±0.38	EVTS VERAGE 40 EVTS VERAGE 40 EVTS 1847 365 5 196 EVTS ERAGE 685 109 2)// total EVTS ERAGE 225± 15 342± 18 135	DOCUMENT ID ANTONELLI BESCH DOCUMENT ID Includes scale fa PALLIN EATON BESCH PERUZZI DOCUMENT ID EATON BRANDELIK PERUZZI DOCUMENT ID EATON BRANDELIK PERUZZI EATON BRANDELIK PERUZZI DOCUMENT ID EATON BRANDELIK PERUZZI EATON	21 84 84 78 (Confidence 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6	MRK2 1.4 MRK1 3.2 6.5 ce Level = 0.039)	Γ ₇₈ /Γ Γ ₈₀ /Γ Γ ₈₁ /Γ Γ ₈₂ /Γ ΛΣ+π-	$VALUE (units 10^{-4})$ <0.062 24 Forbidden by CP . Γ (γη _c (15)) / Γ total VALUE 0.0127±0.0036 • • • We do not use to seen Γ (γπ + π - 2π ⁰) / Γ total VALUE (units 10 ⁻³) 8.3±0.2±3.1 25 4π mass less than Γ (γηππ) / Γ total VALUE (units 10 ⁻³) 6.1 ±1.0 OUR AVER 5.85±0.3±0.5 7.8 ±1.2±2.4 26 Broad enhancemer Γ (γη(1440) → γ K VALUE (units 10 ⁻³) 0.91±0.18 OUR AVER 0.83±0.13±0.18 1.03+0.21+0.26 0.83±0.13±0.18 1.03+0.21+0.26 0.66-0.16-0.15 4.0 ±0.7 ±1.0 4.3 ±1.7 27 [Includes unknown 28 From fit to the K ⁴	90	24 BALTRUSAIT RADIATIVE DE DOCUMENT ID GAISER IN GAISER IN GAISER BALTRUSAIT DOCUMENT ID 25 BALTRUSAIT DOCUMENT ID 26 EDWARDS 26 EDWARDS MeV. DOCUMENT ID 7,28 AUGUSTIN 7,29 BAI IN GAIGNATIN 27 AUGUSTIN 27 AUGUSTIN 27 AUGUSTIN 27,31 BAI 27 EDWARDS 7,32 SCHARRE fraction 17(1440) -	86 es, fits 92 90c es, fits 92 90c 82E 80	MRK3 S —— CBAL , limits, MRK3 TECN MRK3 TECN DM2 MRK3 DM2 DM2 MRK3 CBAL DM2 MRK3 CBAL MRK3	$\begin{array}{c} c + c - \\ \hline \\ \hline \\ COMMENT \\ \hline \\ J/\psi \rightarrow \gamma \\ \hline \\ COMMENT \\ \hline \\ J/\psi \rightarrow \gamma \\ \hline \\ COMMENT \\ \hline \\ J/\psi \rightarrow \gamma \\ \hline \\ COMMENT \\ \hline \\ J/\psi \rightarrow \gamma \\ \hline \\ \hline $	Γ92 7 Γ93 1 Γ94 Γ94 Γ95 Γ96 Γ
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Γ(ΞΞ)/Γ _{total} (nπ)/Γ _{total} ALUE (units 10 ⁻²) 19 ±0.05 OUR AN 190±0.055 18 ±0.09 (ΛΛ)/Γ _{total} ALUE (units 10 ⁻³) 38±0.14 OUR AVE 38±0.15 ±0.20 (ρ[π])/Γ _{total} 1 ±0.2 (ρ[π])/Γ _{total} 1 ±0.2 (ρ[π])/Γ _{total} (Λ[[[units 10 ⁻³]) 09±0.09 OUR AVE 13±0.09±0.09 (Λ[[[units 10 ⁻³]) 09±0.09 (Λ[[[units 10 ⁻³]) 09±0.15 (Λ[[[units 10 ⁻³]) 09±0.16 1.1±0.06±0.16 1.1±0.06±0.20 1.53±0.17±0.38 38±0.21±0.35	EVTS VERAGE 40 EVTS VERAGE 40 EVTS 1847 365 5 196 EVTS ERAGE 685 109 2)// total EVTS ERAGE 225± 15 342± 18 135	DOCUMENT ID ANTONELLI BESCH DOCUMENT ID Includes scale fa PALLIN EATON BESCH PERUZZI DOCUMENT ID EATON BRANDELIK PERUZZI DOCUMENT ID EATON BRANDELIK PERUZZI EATON BRANDELIK PERUZZI DOCUMENT ID EATON BRANDELIK PERUZZI EATON	21 84 84 78 (Confidence 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6	MRK2 1.4 MRK1 3.2 6.5 ce Level = 0.039)	Γ ₇₈ /Γ Γ ₈₀ /Γ Γ ₈₁ /Γ Γ ₈₂ /Γ ΛΣ+π- ΛΣ+π- ΛΣ+π- ΛΣ+π-	$VALUE (units 10^{-4})$ <0.062 24 Forbidden by CP . Γ (γη _c (15)) / Γ total VALUE 0.0127±0.0036 • • • We do not use to seen Γ (γπ + π - 2π ⁰) / Γ total VALUE (units 10 ⁻³) 8.3±0.2±3.1 25 4π mass less than Γ (γηππ) / Γ total VALUE (units 10 ⁻³) 6.1 ±1.0 OUR AVER 5.85±0.3±0.5 7.8 ±1.2±2.4 26 Broad enhancemer Γ (γη(1440) → γ K VALUE (units 10 ⁻³) 0.91±0.18 OUR AVER 0.83±0.13±0.18 1.03+0.21+0.26 0.83±0.13±0.18 1.03+0.21+0.26 0.66-0.16-0.15 4.0 ±0.7 ±1.0 4.3 ±1.7 27 [Includes unknown 28 From fit to the K ⁴	90 EVTS the followin 16 otal	24 BALTRUSAIT RADIATIVE DE DOCUMENT ID GAISER ING data for average BALTRUSAIT 25 BALTRUSAIT DOCUMENT ID 26 EDWARDS 26 EDWARDS MeV. Otal DOCUMENT ID 7,28 AUGUSTIN 7,29 BAI ING data for average 7,30 AUGUSTIN 27 AUGUSTIN 27 AUGUSTIN 27,31 BAI 27 EDWARDS 7,32 SCHARRE Fraction 17(1440) + partial wave.	86 es, fits 92 90c es, fits 92 90c 82E 80	MRK3 S —— CBAL , limits, MRK3 TECN MRK3 TECN DM2 MRK3 DM2 DM2 MRK3 CBAL DM2 MRK3 CBAL MRK3	$\begin{array}{c} c + c - \\ \hline \\ \hline \\ COMMENT \\ \hline \\ J/\psi \rightarrow \gamma \\ \hline \\ COMMENT \\ \hline \\ J/\psi \rightarrow \gamma \\ \hline \\ COMMENT \\ \hline \\ J/\psi \rightarrow \gamma \\ \hline \\ COMMENT \\ \hline \\ J/\psi \rightarrow \gamma \\ \hline \\ \hline $	Γ92, γΧ 1 1 1 1 1 1 1 1 1
Γ(ΞΞ)/Γ _{total} (nπ)/Γ _{total} 44.0E (units 10 ⁻²) 19 ±0.05 OUR AN 190±0.055 18 ±0.09 (ΛΛ)/Γ _{total} 44.0E (units 10 ⁻³) 38±0.14 OUR AVE 38±0.09±0.09 6 ±1.6 1 ±0.2 (ρ̄ρπ ⁰)/Γ _{total} 44.0E (units 10 ⁻³) 13±0.09±0.09 4 ±0.4 00±0.15 (ΛΣ̄-π+(or c.c. 44.0E (units 10 ⁻³) .06±0.12 OUR AVE 90±0.06±0.16	EVTS VERAGE 40 EVTS VERAGE 40 EVTS 1847 365 5 196 EVTS ERAGE 685 109 2)// total EVTS ERAGE 225± 15 342± 18 135	DOCUMENT ID ANTONELLI BESCH DOCUMENT ID Includes scale fa PALLIN EATON BESCH PERUZZI DOCUMENT ID EATON BRANDELIK PERUZZI DOCUMENT ID EATON BRANDELIK PERUZZI EATON BRANDELIK PERUZZI DOCUMENT ID EATON BRANDELIK PERUZZI EATON	21 84 84 78 (Confidence 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6	MRK2 1.4 MRK1 3.2 6.5 Ce Level = 0.039)	Γ ₇₈ /Γ Γ ₈₀ /Γ Γ ₈₁ /Γ Γ ₈₂ /Γ ΛΣ+π-	$VALUE$ (units 10 ⁻⁴) <0.052 24 Forbidden by CP . Γ ($\gamma \eta_c(15)$) / Γ total VALUE 0.0127±0.0036 • • • We do not use to seen Γ ($\gamma \pi^+ \pi^- 2\pi^0$) / Γ total VALUE (units 10 ⁻³) 8.3±0.2±3.1 25 4π mass less than Γ ($\gamma \eta \pi \pi$) / Γ total VALUE (units 10 ⁻³) 6.1 ±1.0 OUR AVERU 5.85±0.3±1.05 7.8 ±1.2±2.4 26 Broad enhancemer Γ ($\gamma \eta$ (1440) → γ K VALUE (units 10 ⁻³) 0.91±0.18 OUR AVERU 0.83±0.13±0.18 1.03+0.21+0.26 1.03+0.21+0.26 1.03+0.21+0.26 1.78±0.21±0.33 3.8 ±0.3 ±0.6 0.66+0.17+0.24 0.16-0.15 4.0 ±0.7 ±1.0 4.3 ±1.7 27 Includes unknown 28 From fit to the K* 29 From K*(890) K f From K*(890) K f 27 From K*(890) K f	90	24 BALTRUSAIT RADIATIVE DE DOCUMENT ID GAISER ING data for average BALTRUSAIT 25 BALTRUSAIT DOCUMENT ID 26 EDWARDS 26 EDWARDS MeV. Otal DOCUMENT ID 7,28 AUGUSTIN 7,29 BAI ING data for average 7,30 AUGUSTIN 27 AUGUSTIN 27 AUGUSTIN 27,31 BAI 27 EDWARDS 7,32 SCHARRE Fraction 17(1440) + partial wave.	86 es, fits 92 90c es, fits 92 90c 82E 80	MRK3 S —— CBAL , limits, MRK3 TECN MRK3 TECN DM2 MRK3 DM2 DM2 MRK3 CBAL DM2 MRK3 CBAL MRK3	$\begin{array}{c} c + c - \\ \hline \\ \hline \\ COMMENT \\ \hline \\ J/\psi \rightarrow \gamma \\ \hline \\ COMMENT \\ \hline \\ J/\psi \rightarrow \gamma \\ \hline \\ COMMENT \\ \hline \\ J/\psi \rightarrow \gamma \\ \hline \\ COMMENT \\ \hline \\ J/\psi \rightarrow \gamma \\ \hline \\ \hline $	Γ92 7 Γ93 1 Γ94 Γ94 Γ95 Γ96 Γ

$J/\psi(15)$

$\Gamma(\gamma\eta(1440) \rightarrow \gamma\gamma\rho^0)/\Gamma_{tot}$			Г ₉₆ /Г	Γ(γωω)/Γ _{total}			Γ ₁
VALUE (units 10 ⁻⁵)	DOCUMENT ID	TECN COMM		VALUE (units 10 ⁻³) 1.59±0.33 OUR AVERA	EVTS DOCUMEN	NT ID TECN	COMMENT
5.4±1.2±0.7		MRK3 J/ψ	$\rightarrow \gamma \gamma \pi^+ \pi^-$	1.41±0.2 ±0.42	ASE 120± BISELLO) 87 SPEC	e ⁺ e ⁻ , hadrons
33 Includes unknown branching	fraction $\eta(1440) \rightarrow \gamma$	$\gamma \rho^{0}$.			17	· · · · · · · · · · · · · · · · · · ·	•
$\gamma (\gamma \eta (1440) \rightarrow \gamma \eta \pi^+ \pi^-)$	/F _{total}		Γ ₉₇ /Γ	$1.76 \pm 0.09 \pm 0.45$		SAIT85C MRK	$3 e^+e^- \rightarrow hadr$
ALUE (units 10 ⁻⁴) EVTS	DOCUMENT ID	TECN COMM	IENT	$\Gamma(\gamma\eta(1440) \rightarrow \gamma\rho^0\rho$	⁰)/Γ _{total}		Г1
.38±0.33±0.64	34 BOLTON 9	28 MRK3 J/ψ -	$\rightarrow \gamma \eta \pi^+ \pi^-$	VALUE (units 10 ⁻³)	DOCUMENT I	D TECN (COMMENT
• • We do not use the follow	ing data for averages,	fits, Ilmits, etc. •	• •	1.7 ±0.4 OUR AVERA	GE Error includes scale	factor of 1.3.	
.0 ±0.6 ±1.1 261	35 AUGUSTIN 9	0 DM2 J/ψ -	$\rightarrow \gamma \eta \pi^+ \pi^-$	2.1 ±0.4	BUGG ^{43,44} BISELLO		$J/\psi \rightarrow \gamma \pi^+ \pi^- \pi^-$
³⁴ VIa a ₀ (980)π.			1	1.36 ± 0.38 ⁴³ Estimated by us from		89B DM2	$J/\psi o 4\pi \gamma$
35 Includes unknown branching	fraction to $\eta \pi^+ \pi^-$.			44 Includes unknown bra	inching fraction to $\rho^0 \rho^0$.		
$(\gamma \rho \rho)/\Gamma_{\text{total}}$			Г98/Г				_
ALUE (units 10 ⁻³) CL%	DOCUMENT ID	TECNCOMM	•	$\Gamma(\gamma f_2(1270))/\Gamma_{\text{total}}$			Г1
4.5 ±0.8 OUR AVERAGE	26			VALUE (units 10 ⁻³) 1.38±0.14 OUR AVERA	EVTS DOCUMENT IS	TECN C	CHG COMMENT
4.7 ±0.3 ±0.9 3.75±1.05±1.20	36 BALTRUSAIT8 37 BURKE 8	16B MRK3 J/ψ - 12 MRK2 J/ψ -		1.33±0.05±0.20	45 AUGUSTIN	87 DM2	$J/\psi \rightarrow \gamma \pi^{+}$
• We do not use the follow				$1.36 \pm 0.09 \pm 0.23$	⁴⁵ BALTRUSAI	T87 MRK3	$J/\psi \rightarrow \gamma \pi^+$
<0.09 90			→ 4πγ	$1.48 \pm 0.25 \pm 0.30$	178 EDWARDS	82B CBAL	e ⁺ e ⁻ → 2:
64 mass less than 2.0 GeV		-,+	1	2.0 ±0.7 1.2 ±0.6	35 ALEXANDE 30 ⁴⁶ BRANDELIF	R 78 PLUT () e ⁺ e ⁻
3 4 π mass less than 2.0 GeV.	$2\rho^0$ corrected to 2ρ by	factor of 3.		1.2 ±0.6	30 TO BRANDELIN	78B DASP	$e^+e^- \rightarrow \pi^+\pi^-\gamma$
$^{38}4\pi$ mass in the range 2.0–2!	GeV.			45 Estimated using B(f-	$\chi_2(1270) \rightarrow \pi\pi)=0.843$	± 0.012. The e	rrors do not conta
(γη/(958))/Γ _{total}			Γ ₉₉ /Γ	uncertainty in the fol	(1270) decay.		
	DOCUMENT ID	TECN COMM	•	46 Restated by us to tal	ke account of spread of E	1, M2, E3 transit	ions.
ALUE (units 10 ⁻³) EVTS 31±0.30 OUR AVERAGE	DOCUMEN! ID	TECN COMM	ENI	$\Gamma(\gamma f_J(1710) \rightarrow \gamma K \overline{I})$	Z) / [r ₁
50±0.14±0.53	BOLTON 9	28 MRK3 J/ψ -	$\rightarrow \gamma \pi^+ \pi^- \eta, \eta \rightarrow$	VALUE (units 10 ⁻⁴)	`)/'total CL% DOCUMENT II	D TECN (' 1' COMMENT
30±0.31±0.71		ריל	$\rightarrow \gamma \pi^+ \pi^- \eta, \eta \rightarrow$		AGE Error includes scal		OMMENI
4±0.16±0.85 622		π ⁻¹ 10 DM2 <i>J/ψ</i> -	-π-π ⁰	-0.5	47,48 BAI		
9±0.09±0.66 2420		10 DM2 J/ψ-	→ γηπ ⁺ π ⁻ → γγπ ⁺ π ⁻	$5.0\pm0.8^{+1.8}_{-0.4}$			$J/\psi \rightarrow \gamma K^+ K^-$
1 ±0.3 ±0.6			- , , ,	$9.2 \pm 1.4 \pm 1.4$	48 AUGUSTIN		$J/\psi \rightarrow \gamma K^+ K^-$
		ha	dronsγ	10.4±1.2±1.6	48 AUGUSTIN		$J/\psi \rightarrow \gamma K_S^0 K_S^0$
We do not use the follow				9.6 ± 1.2 ± 1.8			$J/\psi \rightarrow \gamma K^+ K^-$
9 ±1.1 6		9C DASP e+e-			e following data for avera	-	
4 ±0.7 57	BARTEL 7	6 CNTR e ⁺ e ⁻	- → 2 γρ	$1.6 \pm 0.2 ^{+0.6}_{-0.2}$	^{48,49} BAI	96C BES	$J/\psi \rightarrow \gamma K^+ K^-$
$(\gamma 2\pi^+ 2\pi^-)/\Gamma_{\text{total}}$			Γ ₁₀₀ /Γ	< 0.8	90 50 BISELLO		$J/\psi ightarrow 4\pi\gamma$
ALUE (units 10 ⁻³)	DOCUMENT ID	TECN COMM		$1.6 \pm 0.4 \pm 0.3$	51 BALTRUSAI	T87 MRK3 .	
	rror includes scale fact			3.8±1.6	52 EDWARDS	82D CBAL	$e^+ e^- o \eta \eta \gamma$
32±0.14±0.73	³⁹ BISELLO 8		$\rightarrow 4\pi\gamma$	$^{47}_{40} \text{ Assuming } J^P = 2^+$	for f _J (1710).		
08±0.13±0.35	40 BISELLO 8	19B DM2 J/か・	→ 4π <i>γ</i>	48 Includes unknown bra	nching fraction to K+K	or K & K & . We	have multiplied K
05±0.08±0.45	40 BALTRUSAIT8			measurement by 2, a	nd $K^0_{\mathcal{S}}K^0_{\mathcal{S}}$ by 4 to obtain	KK result.	
.85±0.45±1.20	41 BURKE 8	2 MRK2 e ⁺ e ⁻		⁴⁹ Assuming $J^P = 0^+$			
$39 \ 4\pi$ mass less than 3.0 GeV. $40 \ 4\pi$ mass less than 2.0 GeV.					enching fraction to $\rho^0 \rho^0$.		
$^{-4}\pi$ mass less than 2.5 GeV.				52 Includes unknown bra 52 Includes unknown bra	enching fraction to $\pi^+\pi^-$ enching fraction to $\eta\eta$.		
WEIGHTED AVERAGE 2.8±0.5 (Error scaled by	1.9)			$\Gamma(\gamma\eta)/\Gamma_{ m total}$			Г
J .				VALUE (units 10 ⁻³)	EVTS DOCUMENT II	D TECN (' 1 COMMENT
A				0.86±0.08 OUR AVERA		- IECN C	
				0.88±0.08±0.11	BLOOM	83 CBAL 6	e+ e-
				0.82 ± 0.10	BRANDELIH		e+e
				1.3 ±0.4	21 BARTEL	77 CNTR	r+ e-
5				$\Gamma(\gamma f_1(1420) \rightarrow \gamma K \overline{K})$	₹π)/Γ _{total}		Г1
				VALUE (units 10 ⁻³)	DOCUMENT I	D TECN C	COMMENT
				0.83±0.15 OUR AVERA 0.76±0.15±0.21	GE 53,54 AUGUSTIN	92 DM2 .	$J/\psi \rightarrow \gamma K \overline{K} \pi$
			2				
			χ	$0.87\pm0.14^{+0.14}{-0.11}$	⁵³ BAI		$J/\psi \to \gamma K_S^0 K^{\pm} \pi$
	— ····· BISEL			53 Included unknown bra	anching fraction $f_1(1420)$	$\rightarrow KR\pi$.	
1	·\···· BALTE	RUSAIT 86B MF	RK3 0.3	²⁴ From fit to the K*(8	92) K 1 ^{+ +} partial wave	ı .	
	+\ BURK	E 82 MF	RK2	$\Gamma(\gamma f_1(1285))/\Gamma_{\text{total}}$			Гз
		(Confidence Le	10.8 evel = 0.013)	VALUE (units 10 ⁻³)	DOCUMENT II	n <i>TEC</i> U .	L' I COMMENT
				0.65 ±0.10 OUR AVER		· IECN C	.UMMEN I
0 2 4	6 8	10		0.625 ± 0.063 ± 0.103	55 BOLTON	92 MRK3 .	$J/\psi \rightarrow \gamma f_1(1285)$
	(units 10-3)			0.70 ±0.08 ±0.16	56 BOLTON		$J/\psi \rightarrow \gamma \eta \pi^+ \pi^-$
F(2/2-+2)/F	(milita 10 -)				ne sequential decay chanr		
$\Gamma(\gamma 2\pi^+ 2\pi^-)/\Gamma_{total}$), $f_1(1285) \rightarrow \pi\pi\pi\pi) =$		0.27) × 10-4.
				-1-14 1.1/	,,,,(amou) · · · · · · · · · · · · · · · · · · ·	· (2,77 ± 0,37 ±	0.27) ~ 10 ,
(γ f ₄ (2050))/Γ _{total}			Γ ₁₀₁ /Γ	$B(J/\psi \to \gamma f_1(1285$), $f_1(1285) \rightarrow \delta \pi, \delta \rightarrow$	$\eta\pi)\approx(3.90\pm0$	0.42 ± 0.87) × 10
$\Gamma(\gamma 2\pi^{+}2\pi^{-})/\Gamma_{\text{total}}$ $\Gamma(\gamma f_4(2050))/\Gamma_{\text{total}}$ ALUE (units 10^{-3}) $1.7\pm0.5\pm0.8$	DOCUMENT ID	TECN COMM	ENT	$B(J/\psi \rightarrow \gamma f_1(1285) B(J/\psi \rightarrow \gamma f_1(1285) $		$\eta \pi$) \approx (3.90 \pm 0 $K\overline{K}$) $=$ (0.66 \pm	$0.42 \pm 0.87) \times 10^{-1}$ $0.26 \pm 0.29) \times 10^{-1}$

I

$\Gamma(\gamma f_2'(1525))/\Gamma_{tx}$	otal				Γ ₁₀₉ /Γ		$\Gamma(\gamma p \overline{p} \pi^+ \pi^-)/\Gamma_b$	otal				Γ ₁₁₅ /Γ
VALUE (units 10-3)	<u>ax</u> <u>E</u>	VTS DOCUM	ENT ID	TECN	COMMENT		VALUE (units 10 ⁻³)	<u>C1%</u>	DOCUMENT ID	TECN CO		
0.47 +0.07 OUR A	WERAGE					_	<0.79	90	EATON 84	MRK2 e ⁺	e-	
$0.36\pm0.04^{+0.14}_{-0.04}$		57 BAI	96	C BES	$J/\psi \rightarrow$	i.	$\Gamma(\gamma\gamma)/\Gamma_{\text{total}}$					Γ ₁₁₆ /Γ
0.56±0.14±0.09		⁵⁷ AUGU	STIN 88	DM2	γK ⁺ K ⁻ J/ψ →	ŀ	VALUE (units 10 ⁻³)	90	DOCUMENT ID BARTEL 77	CNTR e+	MMENT	
0.45±0.04±0.09		⁵⁷ AUGU	STIN 88	DM2	γK+K- J/ψ →	1	$\Gamma(\gamma\Lambda\overline{\Lambda})/\Gamma_{\text{total}}$				•	r/r
					7KO KO		VALUE (units 10 ⁻³)	CL%	DOCUMENT ID	TECN CO	MMENT	Γ ₁₁₇ /Γ
0.68±0.16±0.14			RUSAIT87		J/ψ → γK+K-	•	<0.13	90	HENRARD 87		· e	
• • • We do not use	e the following of	_	, fits, limits, DELIK 79		. • + ·		$\Gamma(3\gamma)/\Gamma_{\text{total}}$					Γ ₁₁₈ /Γ
<0.34					x+x-7		VALUE (units 10 ⁻³)	<u>cl%</u>	DOCUMENT ID		MMENT	
<0.23	90		ANDER 78	PLUT	e ⁺ e ⁻ → K ⁺ K ⁻ γ		<0.055	90	PARTRIDGE 80	CBAL e	-e	
57 Using B(f'_2 (1525 58 Assuming isotrop	$(i) \rightarrow K\overline{K}) = 0$.888.	f (1525) an	d leasure		1	Γ(γ & (2200)) / Γ _{to}	tal				Γ ₁₁₉ /Γ
•	ac production a	no decay of the i	2(1525) 411	iu isospini			VALUE (units 10 ⁻⁴)	the following	DOCUMENT ID g data for averages, fit		MMENT	
$\Gamma(\gamma\phi\phi)/\Gamma_{\text{total}}$ VALUE (units 10 ⁻⁴)	EVTS	DOCUMENT ID	TECN	COMME	Γ ₁₁₀ /Γ		1.5				ψ → γK	OKO
4.0±1.2 OUR AVER	AGE Error Inc	ludes scale facto	r of 2.1. Se	e the idea	ogram below.		65 Includes unknown	n branching fi	raction to K ⁰ ₅ K ⁰ ₅ .			
7.5±0.6±1.2 3.4±0.8±0.6	168 33 ± 5	BAI BISELLO	908 MRK3 90 DM2	$J/\psi \rightarrow J/\psi \rightarrow$	74K		$\Gamma(\gamma f_J(2220))/\Gamma_{to}$	ė				Γ ₁₂₀ /Γ
	7			γK	+ K- K0 KL		VALUE (units 10 ⁻⁵)	CLN .				MMENT
3.1±0.7±0.4	2,	BISELLO	868 DM2	J/ψ → γ K⁻	+ K- K+ K-		>250	99.9	⁶⁶ HASAN g data for averages, fit	96 S		→ π ⁺ π ⁻
$^{59}\phi\phi$ mass less tha	in 2.9 GeV, η_{C}	excluded.		•			>300	e the followin	67 BAI	3, ainits, etc 968 B		e
WEIGHTED AVE 4.0±1.2 (Error so	ERAGE						< 2.3	95	68 AUGUSTI			7Pp, KK # →
4.021.2 (2.101.00	alou by 2.17						< 1.6	95	68 AUGUST		•	γK+K- ψ →
							$12.4^{+6.4}_{-5.2}\pm2.8$		23 68 BALTRUS	5AIT860 N	IRK3 J/	
							$8.4^{+3.4}_{-2.8}\pm1.6$		93 ⁶⁸ BALTRUS	A 088TIA		7KgKg U→
							-2.8					
							66 Using BAI 968.	•				γK+K-
							66 Using BAI 968. 67 Using BARNES 9	93.		۲0 ۲0		
							66 Using BAI 968. 67 Using BARNES 9 68 Includes unknown	n branching f	raction to K^+K^- or i	κ§ κ§.		7K+K-
					χ²		66 Using BAI 968. 67 Using BARNES 9 68 Includes unknown Γ (γ ξ ₀ (1500))/Γ ₃₀	n branching f		J J		
		····· BAI ···· BISELLO	O 90	MRK3 DM2	χ ² 6.9 0.3		66 Using BAI 968. 67 Using BARNES 9 68 Includes unknown	n branching fi Itali	DOCUMENT ID	TECN CO	OMMENT _	7K+K-
+	<u></u>		O 90	DM2 DM2	0.3 1.2 8.4		66 Using BAI 968. 67 Using BARNES 9 68 Includes unknown Γ (γ 50 (1500)) / Γ 50 VALUE (units 10 ⁻⁴) 5.7±0.8 69 Including unknown	tal 69	DOCUMENT ID ,70 BUGG 95 ratio for f ₀ (1500) →	<u>ΤΕCN</u> <u>CC</u> MRK3 J/ π ⁺ π ⁻ π ⁺ π	О <u>ммент</u> ′∳ → үк	γκ+κ- Γ ₁₂₁ /Γ
0 5	10	BISELLO	O 90 O 86B (Confidence	DM2 DM2	0.3 1.2 8.4		66 Using BAI 968. 67 Using BARNES 9 68 Includes unknown $\Gamma(\gamma f_0(1500))/\Gamma_{bo}$ VALUE (units 10 ⁻⁴) 5.7±0.8 69 Including unknown 70 Assuming that f ₀	tal 69 on branching for branching (1500) decay	<u>DOCUMENT ID</u> ,70 BUGG 95	<u>ΤΕCN</u> <u>CC</u> MRK3 J/ π ⁺ π ⁻ π ⁺ π	О <u>ммент</u> ′∳ → үк	γK+K Г <u>121</u> /Г + _π - _π + _π -
	10 10 10 (units 10 ⁻⁴	BISELLO BISELLO 15	0 90 0 86B	DM2 DM2	0.3 1.2 8.4		66 Using BAI 968. 67 Using BARNES 9 68 Includes unknown Γ (γ 50 (1500)) / Γ 50 VALUE (units 10 ⁻⁴) 5.7±0.8 69 Including unknown	tal 69 on branching for branching (1500) decay	DOCUMENT ID ,70 BUGG 95 ratio for f ₀ (1500) →	TECN CC MRK3 J/ $\pi^+\pi^-\pi^+\pi$ diplons.	О <u>ммент</u> ′∳ → үк	γκ+κ- Γ ₁₂₁ /Γ
$\Gamma(\gamma\phi\phi)/\Gamma_{tota}$		BISELLO BISELLO 15	O 90 O 86B (Confidence	DM2 DM2	0.3 1.2 8.4		66 Using BAI 968. 67 Using BARNES 9 68 Includes unknown $\Gamma(\gamma f_0(1500))/\Gamma_{bo}$ VALUE (units 10^{-4}) 5.7 \pm 0.8 69 Including unknown 70 Assuming that f_0 $\Gamma(\gamma e^+e^-)/\Gamma_{botal}$ VALUE (units 10^{-3}) 8.8 \pm 1.3 \pm 0.4	fin branching finds	DOCUMENT ID 70 BUGG 95 ratio for $f_0(1500) \rightarrow f_0(1500)$ is only to two S-wave of	TECN CC MRK3 J/ π+π-π+π diplons.	D <u>MME</u> NT 'ψ → γπ .— .	γK+K- Γ121/Γ +π-π+π- Γ122/Γ
$\Gamma\left(\gamma\phi\phi\right)/\Gamma_{ ext{total}}$ $\Gamma\left(\gamma ho\overline{ ho}\right)/\Gamma_{ ext{total}}$	$_{\rm al}$ (units 10^{-4}	BISELLO L 15	0 90 0 86B (Confidence) 20	DM2 DM2 _ ce Level =	0.3 1.2 8.4 0.015)		66 Using BAI 968. 67 Using BARNES 9 68 Includes unknown $\Gamma(\gamma f_0(1500))/\Gamma_{to}$ VALUE (units 10^{-4}) 5.7 \pm 0.8 69 Including unknow 70 Assuming that f_0 $\Gamma(\gamma e^+ e^-)/\Gamma_{total}$ VALUE (units 10^{-3})	fin branching finds	DOCUMENT ID 70 BUGG 95 ratio for f ₀ (1500) → rs only to two S-wave of	TECN CC MRK3 J/ π+π-π+π diplons.	OMMENT ψ → γπ — .	γK+K- Γ121/Γ +π-π+π- Γ122/Γ
$\Gamma(\gamma\phi\phi)/\Gamma_{\text{total}}$ $\Gamma(\gamma\rho\overline{\rho})/\Gamma_{\text{total}}$ VALUE (units 10^{-3})	$_{\rm bl}$ (units 10^{-4}	BISELLO I 15) VTS DOCUM	COnfidence 20	DM2 _ DM2 _ ce Level =	0.3 1.2 8.4 0.015)		66 Using BAI 968. 67 Using BARNES 9 68 Includes unknown $\Gamma(\gamma f_0(1500))/\Gamma_{bo}$ VALUE (units 10^{-4}) 5.7 \pm 0.8 69 Including unknown 70 Assuming that f_0 $\Gamma(\gamma e^+e^-)/\Gamma_{botal}$ VALUE (units 10^{-3}) 8.8 \pm 1.3 \pm 0.4	69 on branching for branching (1500) decay	DOCUMENT ID 70 BUGG 95 ratio for f ₀ (1500) → rs only to two S-wave of DOCUMENT ID 71 ARMSTRONG 96	$\frac{TECN}{MRK3} \frac{CC}{J/\pi} + \frac{CC}{\pi} + \frac{CC}{\pi}$ diplons. $\frac{TECN}{E760} \frac{CC}{P/\pi}$	OMMENT ψ → γπ — .	γK+K- Γ121/Γ +π-π+π- Γ122/Γ
$\Gamma(\gamma\phi\phi)/\Gamma_{\text{total}}$ $\Gamma(\gamma\rho\overline{\rho})/\Gamma_{\text{total}}$	cis E	15 VTS DOCUM 49 EATO	(Confidence 20	DM2 _	0.3 1.2 8.4 0.015)		66 Using BAI 968. 67 Using BARNES 9 68 Includes unknown $\Gamma(\gamma f_0(1500))/\Gamma_{20}$ $VALUE (units 10^{-4})$ 5.7 \pm 0.8 69 Including unknown 70 Assuming that f_0 $\Gamma(\gamma e^+e^-)/\Gamma_{2020}$ $VALUE (units 10^{-3})$ 8.9 \pm 1.3 \pm 0.4 71 For $E_{\gamma} > 100$ M	69 (1500) decay	DOCUMENT ID 70 BUGG 95 ratio for f ₀ (1500) → rs only to two S-wave of DOCUMENT ID 71 ARMSTRONG 96	TECN CC E760 P	OMMENT √ψ → γπ 	γK+K- Γ121/Γ + π- π+ π- Γ122/Γ = γ
Γ(γφφ)/Γ _{total} Γ(γ ρ β)/Γ _{total} <u>VALUE (units 10⁻³)</u> 0.38±0.07±0.07	cis E	15 VTS DOCUM 49 EATO	(Confidence 20 MENT ID N 845, fifts, limits	DM2 _	0.3 1.2 8.4 0.015)		66 Using BAI 968. 67 Using BARNES 9 68 Includes unknown $\Gamma(\gamma f_0(1500))/\Gamma_{20}$ $VALUE (units 10^{-4})$ 5.7 ± 0.8 69 Including unknown $^{70} \text{ Assuming that } f_0$ $\Gamma(\gamma e^+ e^-)/\Gamma_{\text{total}}$ $VALUE (units 10^{-3})$ 8.8 ± 1.3 ± 0.4 71 For $E_{\gamma} > 100 \text{ N}$ ARMSTRONG % PR BAI 968 PR	fixed 69 In branching fixed 69 In branching (1500) decay MeV. D54 7067 1. 76 3502	DOCUMENT ID 70 BUGG 95 ratio for f ₀ (1500) → s only to two S-wave of DOCUMENT ID 71 ARMSTRONG 96 +Bettonl+(FNAL, FEF+Chen, Chen+	TECN CC E760 P	DMMENT $\uparrow \psi \rightarrow \gamma \pi$ $\downarrow \uparrow \uparrow \pi$ DMMENT $\downarrow \downarrow \downarrow$	γK+K- Γ121/Γ
$\Gamma(\gamma\phi\phi)/\Gamma_{\text{total}}$ $\Gamma(\gamma\rho\overline{\rho})/\Gamma_{\text{total}}$ $VALUE \text{ (units } 10^{-3})$ $0.38\pm0.07\pm0.07$ • • • We do not use <0.11 $\Gamma(\gamma\eta(2225))/\Gamma_{\text{total}}$	cis E the following	15 VTS DOCUM 49 EATO data for averages	(Confidence 20 MENT ID N 845, fifts, limits	DM2 _	0.3 1.2 8.4 0.015)	-	66 Using BAI 968. 67 Using BARNES 9 68 Includes unknown $\Gamma(\gamma f_0(1500))/\Gamma_{to}$ VALUE (units 10^{-4}) 5.7 \pm 0.8 69 Including unknown 70 Assuming that f_0 $\Gamma(\gamma e^+e^-)/\Gamma_{total}$ VALUE (units 10^{-3}) 8.8 \pm 1.3 \pm 0.4 71 For $E_{\gamma} > 100$ N ARMSTRONG % PR BAI 960 PR	69 In branching fi branching (1500) decay MeV. D54 7067 1 76 7592 1 77 3929 D54 1221 D53 4723	DOCUMENT ID 70 BUGG 95 ratio for f ₀ (1500) → rs only to two S-wave of DOCUMENT ID 71 ARMSTRONG 96 **Petton!+(FNAL, FEF+Chen, Chen+ J.Z. Bal, Bardon+ +Abramov, Antipov+	$\frac{TECN}{MRK3} \frac{CC}{J/\pi} + \pi^{-\pi} + \pi^{-\pi}$ $\frac{TECN}{E760} \frac{CC}{P_0}$ CES	0 0 0 0 0 0 0 0 0 0	γ K+ K- Γ121/Γ + π - π + π - Γ122/Γ ε- γ ENN, TORI) ES Collab.) ES Collab.) ES Collab.) TOR Collab.)
$\Gamma(\gamma\phi\phi)/\Gamma_{\text{total}}$ $\Gamma(\gamma\rho\overline{\rho})/\Gamma_{\text{total}}$ $VALUE \text{ (units }10^{-3}\text{)}$ $0.98\pm0.07\pm0.07$ \bullet \bullet \bullet We do not us: <0.11 $\Gamma(\gamma\eta(2225))/\Gamma_{\text{total}}$ $VALUE \text{ (units }10^{-3}\text{)}$	units 10 ⁻⁴	15 VTS DOCUM 49 EATO data for averages	(Confidence 20 MENT ID N 845, fifts, limits	DM2	0.3 1.2 8.4 0.0015)	-	66 Using BAI 968. 67 Using BARNES 9 68 Includes unknown $\Gamma(\gamma f_0(1500))/\Gamma_{total}$ $VALUE (units 10^{-4})$ 5.7 \pm 0.8 69 Including unknown 70 Assuming that f_0 $\Gamma(\gamma e^+e^-)/\Gamma_{total}$ $VALUE (units 10^{-3})$ 8.8 \pm 1.3 \pm 0.4 71 For $E_{\gamma} > 100$ N ARMSTRONG % PR BAI %6 PR	69 In branching for branching (1500) decay MeV. D54 7067 t. 76 3599 p. 73999 p. 754 1221 p. 753 4723 B388 376 B355 374	DOCUMENT ID 70 BUGG 95 ratio for f ₀ (1500) → rs only to two S-wave of DOCUMENT ID 71 ARMSTRONG 96 **Petton!+(FNAL, FEF+Chen, Chen+ J.Z. Bal, Bardon+ +Abramov, Antipov+ +Bugg +Chen, Chen+	$\frac{TECN}{MRK3} \frac{CC}{J/\pi} + \pi^{-\pi} + \pi^{-\pi}$ $\frac{TECN}{E760} \frac{CC}{P_0}$ CES RR. GENO, UC. (E67:	DMMENT $(\psi \rightarrow \gamma \pi)$ $$ DMMENT $p \rightarrow e^{+} (\theta)$ (B) (B) (B) (C) (C) (C) (C) (C) (C) (C) (C) (C) (C	Γ121/Γ + π - π + π - Γ122/Γ + π - π + π - Γ122/Γ ENN, TORI) MES Collab.] MES Collab.] MES Collab.] TOR Collab.] TOR Collab.] TOR Collab.]
$\Gamma(\gamma\phi\phi)/\Gamma_{\text{total}}$ $\Gamma(\gamma\rho\overline{\rho})/\Gamma_{\text{total}}$ $VALUE \text{ (units } 10^{-3})$ 0.98 ± 0.07 ± 0.07 • • • We do not us <0.11 $\Gamma(\gamma\eta(2225))/\Gamma_{\text{total}}$ $VALUE \text{ (units } 10^{-3})$ 0.29 ± 0.05 OUR AM	CL% E e the following 90	15 VTS DOCUM 49 EATO data for averages	O 90 86B (Confidence 20 AENY ID NN 84 5, fits, limits	DM2	Γ ₁₁₁ /Γ <u>COMMENT</u> ! e+e- Γ ₁₁₂ /Γ NT	-	66 Using BAI 968. 67 Using BARNES 9 68 Includes unknown F (76(1500))/Fte VALUE (units 10 ⁻⁴) 5.7±0.9 69 Including unknow 70 Assuming that fo F (7e+e-)/Ftetail VALUE (units 10 ⁻³) 8.9±1.3±0.4 71 For E ₇ > 100 M ARMSTRONG 96 PR BAI 96B PR BAI 96C PR BAI 96C PR BAI 96C PR BAI 96 PR BAI 97 PR BAI 98 PL BAI	69 (1500) decay (1	DOCUMENT ID 70 BUGG 95 ratio for f ₀ (1500) → rs only to two S-wave of POCUMENT ID 71 ARMSTRONG 96 74 (15) REFERENC +Bettonl+(FNAL, FEF+Chen, Chen+ 1.2. Bal, Bardon+ +Abramov, Antipov+ +Buddis+ Foots, ZoR+ +Baddis+		$\psi \rightarrow \gamma \pi$ $\phi \rightarrow e^+ \phi$ 1. NEAS, PI 2. Collab., E 3. (BR) (COM, PR) (EQ) (COM, PR)	γ K+ K- Γ121/Γ
$\Gamma(\gamma\phi\phi)/\Gamma_{\text{total}}$ $\Gamma(\gamma\rho\overline{\rho})/\Gamma_{\text{total}}$ $VALUE \text{ (units } 10^{-3}\text{)}$ 0.38±0.07±0.07 • • • We do not use <0.11 $\Gamma(\gamma\eta(2225))/\Gamma_{\text{total}}$ $VALUE \text{ (units } 10^{-3}\text{)}$ 0.29±0.06 OUR AM 0.33±0.08±0.05	C% E e the following 90 tal	15 VTS DOCUMENT ID	90 86B (Confidence 20 MENT ID N 84, fits, limits ZZI 78 90B MRK3	TECN MRK2 MRK2 MRK2 MRK1 COMME	1.3 1.2 8.4 0.015 0.015	-	66 Using BAI 968. 67 Using BARNES 9 68 Includes unknown F (76(1500))/Fte VALUE (units 10 ⁻⁴) 5.7±0.9 69 Including unknow 70 Assuming that fo F (7e+e-)/Ftotal VALUE (units 10 ⁻³) 8.9±1.3±0.4 71 For E ₇ > 100 M ARMSTRONG 96 PR BAI 96C PR BAI	69 (1500) decay (1	DOCUMENT ID 70 BUGG 95 ratio for f ₀ (1500) → s only to two S-wave of DOCUMENT ID 71 ARMSTRONG 96 / \$\psi\$ (15) REFERENC +Bettonl+(FNAL, FEF+Chen, Chen+ J.Z. Bal+ J.Z. Bal+ J.Z. Bal, Bardon+ +Akramov, Antipov+ +Bugg +Chen, Chen+ +Scott, Zoil+ +Bettonl, Bharadwaj+ +Britonl, Bharadwaj+ +Britonl, Bharadwaj+ +Britonl, Bharadwaj+ +Britonl, Bharadwaj+ +Britonl, Bharadwaj+		DMMENT ψ → γπ DMMENT P → e ⁺ (E E C Collab., E (LOQM, PR (FNAL E (FNAL E	γK+K- Γ121/Γ
Γ(γφφ)/Γ _{total} Γ(γρβ)/Γ _{total} VALUE (units 10 ⁻³) 0.39±0.07±0.07 • • • We do not us <0.11 Γ(γη(2225))/Γ _{total} VALUE (units 10 ⁻³) 0.29±0.06 OUR AM 0.33±0.08±0.05 0.27±0.06±0.06	CL% E e the following 90 tal	15 VTS DOCUMA 49 EATO data for averages PERU DOCUMENT ID D BAI BISELLO 15	90 86B (Confidence 20 MENT ID N 84, fits, limits ZZI 78 908 MRK3	TECN 4 MRK2 5 MRK1 COMME 1 J/ψ → 7 K*	Γ111/Γ <u>COMMENT</u> : e+e- Γ112/Γ NT + K- K+K- + K- K ⁰ ₂ K ⁰ ₁	-	66 Using BAI 968. 67 Using BARNES 9 68 Includes unknown $\Gamma(\gamma f_0(1500))/\Gamma_{50}$ $VALUE (units 10^{-4})$ 5.7 \pm 0.3 69 Including unknown 70 Assuming that f_0 $VALUE (units 10^{-3})$ 8.8 \pm 1.3 \pm 0.4 71 For $E_{\gamma} > 100$ N ARMSTRONG 96 PR BAI 97 PR BAI 98 PR B	MeV. D54 7067 1 76 3502 1 77 3959 D54 1723 B388 376 B383	DOCUMENT ID 70 BUGG 95 ratio for f ₀ (1500) s only to two S-wave of DOCUMENT ID 71 ARMSTRONG 96 **Hettonl+(FNAL, FEF+Chen, Chen+ J.Z. Bai+ J.Z. Bai+ J.Z. Bai- Haramov, Antipov+ +Bugg +Chen, Chen+ +Scott, Zoil+ +Baddial+ +Brown, Breunich +Cosme +Brown, Bunneil+ +Brown, Bunneil+ +Brown, Bunneil+ +Brown, Bunneil+ +Brown, Bunneil+	$\frac{TECN}{MRK3} \frac{CC}{J/\pi} + \pi^- \pi^+ \pi$ $\frac{TECN}{E760} \frac{CC}{P_0}$ CES RR. GENO. UC.	DMMENT DMMENT DMMENT DMMENT DMMENT DMMENT DMMENT DMMENT (8) (8) (CLOQM, PR (FENI (FENI (FINI Mark Mark Mark Mark Mark	Γ121/Γ + π - π + π - Γ122/Γ + π - π + π - Γ122/Γ + π - π + π - Γ122/Γ - π - π + π -
$\Gamma(\gamma\phi\phi)/\Gamma_{\text{total}}$ $\Gamma(\gamma\rho\overline{\rho})/\Gamma_{\text{total}}$ $VALUE (units 10^{-3}) 0.98±0.07±0.07 • • • We do not use <0.11 \Gamma(\gamma\eta(2225))/\Gamma_{\text{total}} VALUE (units 10^{-3}) 0.29±0.06 OUR AVI 0.33±0.08±0.05 0.27±0.06±0.06$	C.% E e the following 90 tal ERAGE 6 61,6	15 VTS DOCUMENT ID DOCUMENT ID DO BAI BISELLO	90 86B (Confidence 20 MENT ID N 84, fits, limits ZZI 78 90B MRK3	TECN 4 MRK2 5 MRK1 COMME 1 J/ψ → 7 K*	Γ111/Γ <u>COMMENT</u> : e+e- Γ112/Γ NT + K- K+K- + K- K ⁰ ₂ K ⁰ ₁	-	66 Using BAI 968. 67 Using BARNES 9 68 Includes unknown Γ (γ 6 (1500)) / Γ 60 VALUE (units 10 ⁻⁴) 5.7 ± 0.8 69 Including unknown 70 Assuming that fo Γ (γ e e -) / Γ total VALUE (units 10 ⁻³) 8.8 ± 1.3 ± 0.4 71 For E _γ > 100 N ARMSTRONG 96 PR BAI 97 PR BAI 98 PR	MeV. D54 7067 1, 76 3502 1, 77 3959 1, 504 1723 1, 63 376 1, 63 282 1, 64 282 1, 64 282 1, 64 282 1, 64 282 1, 64 282 1, 64 282 1, 64 282 1, 64 282 1, 65 2	DOCUMENT ID 70 BUGG 95 ratio for f ₀ (1500) → s only to two S-wave of DOCUMENT ID 71 ARMSTRONG 96 **Hettonl+(FNAL, FEF+Chen, Chen+ J.Z. Bai+ J.Z. Bai+ J.Z. Bai- Baddial+ Bettonl, Bharadwej+ Bettonl, Bharadwej+ Brown, Bneunich + Brown, Bneunich + Brown, Bunneil+ + Brown, Bunneil+ + Brown, Bunneil+ + Delongh, Dubois, H + Palastinl + Palastinl + Delongh, Dubois, H + Palastinl + Delongh, Dubois, H + Palastinl	$\frac{TECN}{MRK3} \frac{CC}{J/\pi} + \pi^- \pi^+ \pi$ $\frac{TECN}{E760} \frac{CC}{P_0}$ CES RR. GENO. UC.	DMMENT \(\psi \rightarrow \gamma \pi \) \(\text{NEAS}, \text{P} \) \(\text{PS} \) \(\text{Collab.}, \text{E} \) \(\t	Γ121/Γ + π - π + π - Γ122/Γ + π - π + π - Γ122/Γ - γ ENN, TORI) HES Collab. HES Collab. TOG Collab. TOG Collab. TOG Collab. HES Collab. HI Collab.
Γ(γφφ)/Γ _{total} Γ(γρβ)/Γ _{total} VALUE (units 10 ⁻³) 0.39±0.07±0.07 • • • We do not use <0.11 Γ(γη(2225))/Γ _{tot} VALUE (units 10 ⁻³) 0.29±0.06 OUR AM 0.33±0.08±0.05 0.27±0.06±0.06 0.24±0.15 60 includes unknow 61 Estimated by use	e the following 90 tol	15 VTS DOCUM 49 EATO data for averages PERU DOCUMENT ID BAI BISELLO CITION TO \$\phi\$.	90 86B (Confidence 20 MENT ID N 84, fits, limits ZZI 78 908 MRK3	TECN 4 MRK2 5 MRK1 COMME 1 J/ψ → 7 K*	Γ111/Γ <u>COMMENT</u> : e+e- Γ112/Γ NT + K- K+K- + K- K ⁰ ₂ K ⁰ ₁	-	66 Using BAI 968. 67 Using BARNES 9 68 Includes unknown \(\begin{align*} \begin{align*} \lambda \cdot \lambda \lambd	MeV. D54 7067 t. 76 3509 D54 1231 D53 374 B353	DOCUMENT ID 70 BUGG 95 ratio for f ₀ (1500) **s only to two S-wave of **DOCUMENT ID 71 ARMSTRONG 96 **Hettonl+(FNAL, FEF+Chen, Chen+ 1.2. Bai+ 1.2. Bai+ 1.2. Bai, Bardon+ +Abramov, Antipov+ +Bugg +Chen, Chen+ +Scott, Zoil+ +Baddial+ +Bettonl, Bharadwej+ +Birdon, Brownich +Cosme +Brown, Bunnell+ +Delongh, Dubols, H +Palastinl +Cosme+ +Brown, Bunnell+ +Brown, Brown Brown, Brown Br	$\frac{TECN}{MRK3} \frac{CC}{J/\pi} + \pi^- \pi^+ \pi$ $\frac{TECN}{E760} \frac{CC}{P_0}$ CES RR. GENO. UC.	DMMENT (\$\psi \rightarrow \gamma \pi	T121/Γ + π - π + π - Γ122/Γ + π - π + π - Γ122/Γ - γ ENN, TORI) HES Collab. HES Collab. HES Collab. HIS Collab. HIS Collab. HI Collab.
Γ(γφφ)/Γ _{total} Γ(γρβ)/Γ _{total} VALUE (units 10 ⁻³) 0.98±0.07±0.07 • • • We do not us <0.11 Γ(γη(2225))/Γ _{total} VALUE (units 10 ⁻³) 0.29±0.05 OUR AM 0.33±0.08±0.05 0.27±0.06±0.06 0.24±0.15 60 Includes unknow 61 Estimated by us 62 Includes unknow	e the following 90 tal EPAGE 6 61,6 n branching fra from various fit n branching fra	15 VTS DOCUM 49 EATO data for averages PERU DOCUMENT ID BAI BISELLO CITION TO \$\phi\$.	90 86B (Confidence 20 MENT ID N 84, fits, limits ZZI 78 908 MRK3	TECN 4 MRK2 5 MRK1 COMME 1 J/ψ → 7 K*	1.2 8.4 8.4 9.0015) F111/Γ COMMENT 1.2 e+e- F112/Γ NT + K-K+K- + K-K- + K-K- - K-		66 Using BAI 968. 67 Using BARNES 9 68 Includes unknown Γ (γ 6(1500)) / Γ 60 VALUE (units 10 ⁻⁴) 5.7 ± 0.8 69 including unknow 70 Assuming that 6 Γ (γ 6 + 6 -) / Γ 100 M R.S ± 1.3 ± 0.4 71 For E _γ > 100 M ARMSTRONG 96 PR BAI 97 PR BAI 97 PR BAI 98 PR BAI 99 PR BAI 90 PR	AeV. D54 7067 i. 76 3509 D53 4723 D53 374 B353	DOCUMENT ID 70 BUGG 95 ratio for f ₀ (1500) **s only to two S-wave of **DOCUMENT ID 71 ARMSTRONG 96 **HESTONG 96 **HESTON	$\frac{TECN}{MRK3} \frac{CC}{J/m^{+}\pi^{-}\pi^{+}\pi^{-}\pi^{+}\pi^{-}\pi^{+}\pi^{-}\pi^{+}\pi^{-}\pi^{+}\pi^{-}\pi^{-}\pi^{-}\pi^{-}\pi^{-}\pi^{-}\pi^{-}\pi^{-$	DMMENT V → Y X I. NEAS, P. (B) (B) (COllab., E (COllab., E (COMMENT) (PS.) (LOQM, PP (FNAL E (Mark	T121/Γ + π - π + π - Γ122/Γ + π - π + π - Γ122/Γ - γ ENN, TORI) HES Collab. HES Collab. HES Collab. HES Collab. HES Collab. HI Collab.
Γ(γφφ)/Γ _{total} Γ(γρβ)/Γ _{total} VALUE (units 10 ⁻³) 0.98±0.07±0.07 • • • We do not us <0.11 Γ(γη(2225))/Γ _{total} VALUE (units 10 ⁻³) 0.29±0.05 OUR AM 0.33±0.08±0.05 0.27±0.06±0.06 0.24±0.15 60 Includes unknow 61 Estimated by us 62 Includes unknow	e the following 90 tal EPAGE 6 6 1,6 n branching fra from various fit n branching fra	15 VTS DOCUMENT ID DOCUMENT ID BISELLO CIT. DOCUMENT ID BAI BISELLO CIT. CIT. DOCUMENT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID DOCUMENT ID	90 86B (Confidence 20 MENT ID N 84, fits, limits ZZI 78 908 MRK3	DM2	1.2 8.4 8.4 9.0015) F111/Γ COMMENT 1.2 e+e- F112/Γ NT + K-K+K- + K-KS - KS - KS - KS - T113/Γ		66 Using BAI 968. 67 Using BARNES 9 68 Includes unknown F (7 6 (1500)) / F 60 VALUE (units 10-4) 5.7 ± 0.8 69 including unknown 70 Assuming that f 6 F (7 e e) / F 60 VALUE (units 10-3) 8.8 ± 1.3 ± 0.4 71 For E 7 > 100 N ARMSTRONG 96 PR BAI 96D PR GRIBUSHIN 96 PR BAI 96D PR GRIBUSHIN 97 PR BAI 95B PL ARMSTRONG 93B PR BAI 95B PR BOLTON 72 PR COFFMAN 72 PR AUGUSTIN 90 PR AUGUSTIN 90 PR BAI 90C PR	AeV. D54 7067 1 76 7057 1 76 7057 2	DOCUMENT ID 70 BUGG 95 ratio for fo(1500) ratio for for for for for for for for for fo	$\frac{TECN}{MRK3} \frac{CC}{J/m^{+}\pi^{-}\pi^{+}\pi^{-}\pi^{+}\pi^{-}\pi^{+}\pi^{-}\pi^{+}\pi^{-}\pi^{+}\pi^{-}\pi^{-}\pi^{-}\pi^{-}\pi^{-}\pi^{-}\pi^{-}\pi^{-$	DAMENT V → 7 x DAMENT D → e+ ((BR) (BR) (FNAL E- (FENAL E- (Mark (M	T121/Γ + π - π + π - Γ122/Γ + π - π + π - Γ122/Γ - γ ENN, TORI) HES Collab-, HES Collab-, HES Collab-, HES Collab-, HES Collab-, HES Collab-, HI Co
Γ($\gamma \phi \phi$)/Γtotal Γ($\gamma P P$)/Γtotal (ALUE (units 10 ⁻³) 0.38±0.07±0.07 • • • We do not use <0.11 Γ($\gamma \eta$ (2225))/Γtotal (ALUE (units 10 ⁻³) 0.29±0.06 OUR AM 0.33±0.08±0.05 0.27±0.06±0.06 0.24+0.15 0.10 cludes unknow 61 Estimated by us 62 Includes unknow Γ($\gamma \eta$ (1760) → γ (ALUE (units 10 ⁻³) 0.13±0.09	e the following 90 tol EPAGE 6 61,6 n branching fra from various fit n branching fra 60,00 (63,6	DOCUMENT ID DOCUMENT ID BISELLO LIST DOCUMENT ID BAI BISELLO CITION TO \$\phi\$, CITION TO \$\rho^0\$, CITION TO \$\rho^0\$, CITION TO \$\rho^0\$, BISELLO CITION TO \$\rho^0\$, CITION TO \$\rho^0\$, BISELLO BISELLO BISELLO BISELLO BISELLO BISELLO	90 86B (Confidence 20 MENT ID N 845, fits, limits ZZI 78 90B MRK3 90B MRK3 89B DM2	DM2	0.3 1.2 8.4 8.4 9.0.015) F111/F COMMENT 1: e+e- F112/F NT + K-K+K- + K-K-K- + K-K-K		66 Using BAI 968. 67 Using BARNES 9 68 Includes unknown Γ (γ 6 (1500)) / Γ 20 VALUE (units 10 ⁻⁴) 5.7 ± 0.8 69 Including unknown 70 Assuming that fo Γ (γ e + e -) / Γ 2018 VALUE (units 10 ⁻³) 8.8 ± 1.3 ± 0.4 71 For E _γ > 100 M ARMSTRONG 96 PR BAI 96C PR BAI 97 PR BAI 98 PR BAI 90 PR BOLTON 92 PR HSUEH 92 PR AUGUSTIN 90 PR BISELLO 90 PR AUGUSTIN 90 PR	69 // branching file // branching // bran	DOCUMENT ID 70 BUGG 95 ratio for f ₀ (1500) → rs only to two S-wave of DOCUMENT ID 71 ARMSTRONG 96 **Bettonl+(FNAL, FEF+Chen, Chen+ J.Z. Bai+ J.Z. Bai+ J.Z. Bai+ Bustionl+(FNAL, FEF+Chen, Chen+ Abramov, Antipov+ +Bugg +Chen, Chen+ +Scott, Zoil+ +Buddial+ +Bettonl, Bharadwaj+ +Bustion, Brewnich, Busadial+ +Betwen, Bunneil+ +Brown, Bunneil+ +Brown, Bunneil+ +Brown, Bunneil+ +Busyloch+ +Busyloch+ +Busyloch+ +Busyloch+ +Busyloch+ +Busyloch+ +Busyloch+ +Busyloch+ +Coame Busetto- +Coame Busett	TECN CC MRK3 J MRK3 J MRK3 J MRK3 J MRK3 MRK4 DMMENT \psi	Γ121/Γ + π - π + π - Γ122/Γ + π - π + π - Γ122/Γ + π - π + π - Γ122/Γ - γ ENN, TORI) NES Collab. N	
Γ(γφφ)/Γtotal Γ(γρβ)/Γtotal VALUE (units 10 ⁻³) 0.38±0.07±0.07 • • • We do not use <0.11 Γ(γη(2225))/Γτο VALUE (units 10 ⁻³) 0.29±0.06 OUR AM 0.33±0.08±0.05 0.27±0.06±0.06 0.24+0.15 60 Includes unknow 61 Estimated by us 62 Includes unknow Γ(γη(1760) → γ VALUE (units 10 ⁻³) 6.38±0.09 63 Estimated by us	e the following 90 tal ERAGE 6 61,6 n branching fra from various fit in branching fra 63,6 from various fit from various fit in branching fra	DOCUMENT ID A BISELLO	90 86B (Confidence 20) MENT ID N 84s, fits, limits ZZI 78 TECN 908 MRK3 898 DM2	DM2	0.3 1.2 8.4 8.4 9.0.015) F111/F COMMENT 1: e+e- F112/F NT + K-K+K- + K-K-K- + K-K-K		66 Using BAI 968. 67 Using BARNES 9 68 includes unknown F (76(1500))/F 20 VALUE (units 10 ⁻⁴) 5.7±0.8 69 including unknown 70 Assuming that fo F (7¢+e-)/F 20tal VALUE (units 10 ⁻³) 8.8±1.3±0.4 71 For E ₇ > 100 M ARMSTRONG BAI 96C PR BAI 96	MeV. D54 7067 L 76 5502 L 77 3959 D54 1221 D53 4723 B303 317 D47 772 B309 449 D46 1951 B278 495 L 65 282 D45 282 D45 282 D45 282 D47 128 D47	DOCUMENT ID 70 BUGG 95 ratio for f ₀ (1500) → rs only to two S-wave of DOCUMENT ID 71 ARMSTRONG 96 **Betton!+(FNAL, FEF+Chen, Chen+ J.Z. Bai+ J.Z. Bai+ J.Z. Bai+ Baddiel+ +Betton!, Bharadwel+ +Betton!, Branel+ +Betwen, Buneel+ +Brown, Buneel+ +Brown, Buneel+ +Brown, Buneel+ +Brown, Buneel+ +Brown, Buneel+ +Busylock+ +Busylo	- TECN	DMMENT \psi	Γ121/Γ + π - π + π - Γ122/Γ + π - π + π - Γ122/Γ + π - π + π - Γ122/Γ - γ ENN, TORI) NES Collab. N
Γ(γφφ)/Γtotal Γ(γρβ)/Γtotal VALUE (units 10 ⁻³) 0.38±0.07±0.07 • • • We do not use <0.11 Γ(γη(2225))/Γτοται VALUE (units 10 ⁻³) 0.29±0.06 OUR AM 0.33±0.08±0.05 0.27±0.06±0.06 0.24±0.15 60 Includes unknow 61 Estimated by us 61 Estimated by us 62 Includes unknow Γ(γη(1760) → γ VALUE (units 10 ⁻³) 0.13±0.09 63 Estimated by us 64 Includes unknow 64 Includes unknow Γ(γη(1760) → γ	e the following 90 tal ERAGE 6 61,6 n branching fra from various fit in branching fra 63,6 from various fit from various fit in branching fra	DOCUMENT ID A BISELLO	90 86B (Confidence 20) MENT ID N 84s, fits, limits ZZI 78 TECN 908 MRK3 898 DM2	DM2	Γ111/Γ COMMENT e+e- F112/Γ NT + K- K+ K- + K- K K K Λ Λ Λ Λ Λ Λ Λ Λ Λ Λ Λ Λ Λ Λ Λ		66 Using BAI 968. 67 Using BARNES 9 68 Includes unknown F (76(1500))/F 20 VALUE (units 10 ⁻⁴) 5.7±0.8 69 Including unknown 70 Assuming that for the following that following the following the following the following that follow	MeV. D54 7067 L 76 502 L 77 3959 D54 1221 D53 4723 B303 376 B353	DOCUMENT ID 70 BUGG 95 ratio for f ₀ (1500) → rs only to two S-wave of POCUMENT ID 71 ARMSTRONG 96 **Hetton!+(FNAL, FEF+Chen, Chen+ J.Z. Bai+ J.Z. Bai+ J.Z. Bai+ Baddial+ +Batton!, Bharadwaj+ +Briten, Breunich, Bharadwaj+ +Brown, Bunnel+ +Brown, Bunnel+ +Brown, Bunnel+ +Brown, Bunnel+ +Brown, Bunnel+ +Brown, Bunnel+ +Busylock+ +Busyl	TECN CC MRK3 J/ m+ m- m+ m diplons. TECN CC E760 P E760 P (E67:	DMMENT \psi	Γ121/Γ + π - π + π - Γ122/Γ + π - π + π - Γ122/Γ + π - π + π - Γ122/Γ - γ ENN, TORI) NES Collab. N
Γ(γφφ)/Γtotal Γ(γρβ)/Γtotal Λ(10E (units 10 ⁻³) 0.38±0.07±0.07 • • • We do not use <0.11 Γ(γη(2225))/Γτοται Λ(10E (units 10 ⁻³) 0.29±0.06 OUR AM 0.33±0.08±0.05 0.27±0.06±0.06 0.24±0.15 60 includes unknow 61 Estimated by use 62 includes unknow Γ(γη(1760) → γ ΛΑLUE (units 10 ⁻³) 0.13±0.09 63 Estimated by use 64 includes unknow Γ(γη ⁰)/Γtotal ΜΑLUE (units 10 ⁻³)	e the following 90 tal ERAGE 6 61,6 n branching fra from various fit n branching fra EVTS	DOCUMENT ID A BISELLO	90 86B (Confidence 20) MENT ID N 84s, fits, limits ZZI 78 TECN 908 MRK3 898 DM2	DM2	Γ111/Γ COMMENT e+e- F12/Γ K-K+K- + K-K ⁰ Aπγ Γ114/Γ		66 Using BAI 968. 67 Using BARNES 9 68 Includes unknown F (76(1500))/F 20 VALUE (units 10 ⁻⁴) 5.7±0.8 69 Including unknown 70 Assuming that fo F (7¢+¢-)/F total VALUE (units 10 ⁻³) 8.8±1.3±0.4 71 For E ₇ > 100 M ARMSTRONG 98 PR BAI 96C PR BAI 96C PR GRIBUSHIN 96 PR BAI 96C PR GRIBUSHIN 96 PR BAI 96C PR BOLTON 128 PR COFFMAN 97 PR BAUGUSTIN 90 PR BAI 90B PR AUGUSTIN 90 PR BAITANDA 90 PR	MeV. D54 7067 L 76 5502 L 77 3959 D54 17067 L 76 5502 L 77 3959 D54 1221 D53 4723 B388 376 B383 376 B383 378 B301 317 D47 772 B309 449 D46 1951 L 65 1309 L	DOCUMENT ID 70 BUGG 95 ratio for f ₀ (1500) → rs only to two S-wave of POCUMENT ID 71 ARMSTRONG 74 HBettonl+(FNAL, FEF+Chen, Chen+ J.Z. Bai+ J.Z. Bai+ J.Z. Bai+ Baddial+ +Battonl, Bharadwaj+ +Brown, Bunneil+ +Brown Bunneil+ +Coarne +Busetton- +Castera+ +Busylock +Busetton- +Castera+ +Coarne Busetton- +Coarne	TECN CC MRK3 J/	DMMENT \psi	Γ121/Γ + π - π + π - Γ122/Γ + π - π + π - Γ122/Γ + π - π + π - Γ122/Γ - π + π + π + π - Γ122/Γ - π + π + π + π + π + π + Γ122/Γ - π + π + π + π + π + Γ122/Γ - π + π + π + π + Γ122/Γ - π + π + π + π + Γ1
Γ($\gamma \phi \phi$)/Γtotal Γ($\gamma P P$)/Γtotal VALUE (units 10 ⁻³) 0.38±0.07±0.07 • • • We do not use <0.11 Γ($\gamma \eta$ (2225))/Γtotal VALUE (units 10 ⁻³) 0.29±0.06 OUR AM 0.33±0.08±0.05 0.27±0.06±0.06 0.24+0.15 60 Includes unknow 61 Estimated by us 62 Includes unknow Γ($\gamma \eta$ (1760) → γ VALUE (units 10 ⁻³) 0.13±0.09 63 Estimated by us 64 Includes unknow Γ($\gamma \pi$ 0)/Γtotal	e the following 90 tal ERAGE 6 61,6 n branching fra from various fit n branching fra 63,6 from various fit n branching fra	DOCUMENT ID DOCUMENT ID BISELLO CITION 10 PO PO. DOCUMENT ID DOCUMENT ID DOCUMENT ID A BISELLO CITION 10 PO PO. LECTION 10 PO PO. CITION 10 PO PO.	90 86B (Confidence 20) MENT ID N 84, fits, limits ZZI 78 TECN 908 MRK3 908 MRK3 898 DM2	TECN MRK2 MRK2 MRK2 MRK1 COMME J/ COMME COMME	Γ111/Γ COMMENT e+e- F12/Γ K-K+K- + K-K ⁰ Aπγ Γ114/Γ		66 Using BAI 968. 67 Using BARNES 9 68 Includes unknown F (76(1500))/F 20 VALUE (units 10 ⁻⁴) 5.7±0.8 69 Including unknown 70 Assuming that fo F (7¢+¢-)/F total VALUE (units 10 ⁻³) 8.8±1.3±0.4 71 For E ₇ > 100 N ARMSTRONG 98 PR BAI 96C PR B	AeV. D54 7067 1. 76 3502 1. 77 3509 1. 76 3502 1. 77 3509 1. 76 3502 1. 77 3509 1. 76 3502 1. 77 3509 1. 78 3503 1. 78 3503 1. 77 3509 1. 78 3503 1. 77 3509 1. 78 3503 1. 77 3509 1. 78 3503 1. 78 3	DOCUMENT ID 70 BUGG 95 ratio for fo(1500) **s only to two S-wave of **DOCUMENT ID 71 ARMSTRONG 96 **HESTONG	TECN CC MRK3 J MRK3 J MRK3 J MRK3 J MRK3 J MRK3 J MRK3 MRK4 MRK4	DMMENT ψ → γ ×	T121/Γ

 $J/\psi(1S)$, $\chi_{c0}(1P)$

SELLO 86B PL B179 294 + Busetto, Castro, Limentani+ (DM2 Collab.)	X _{c0} (1P) PARTIAL WIDTHS '
ALTRUSAIT 85C PRL 55 1723 Baltrusaitis+ (CIT, UCSC, ILL, SLAC, WASH)	$\Gamma(\gamma\gamma)$
ALTRUSAIT 85D PR D32 566 Baltrusaitis, Coffman+ (CIT, UCSC, ILL, SLAC, WASH) ALTRUSAIT 84 PRL 52 2126 Baltrusaitis+ (CIT, UCSC, ILL, SLAC, WASH)	VALUE (keV) CL% DOCUMENT ID TECN COMMENT
TON 84 PR D29 804 +Goldhaber, Abrams, Alam, Boyarski+ (LBL, SLAC) OOM 83 ARNS 33 143 +Peck (SLAC, CIT)	< 6.2 95 CHEN 908 CLEO $e^+e^- \rightarrow e^+e^- \chi_{CO}$
WARDS 83B PRL 51 859 +Partridge, Peck+ (CIT, HARV, PRIN, STAN, SLAC)	4.9±2.8 LEE 85 CBAL $\psi' \rightarrow$ photons
ANKLIN 83 PRL 51 963 +Franklin, Feldman, Abrams, Alam+ (LBL, SLAC) RKE 82 PRL 49 632 +Trilling, Abrams, Alam, Blocker+ (LBL, SLAC)	 ● ● We do not use the following data for averages, fits, limits, etc.
VARD\$ 82B PR D2S 3065 +Partridge, Peck+ (CIT, HARV, PRIN, STAN, SLAC)	<17 95 AIHARA 880 TPC $e^+e^- \rightarrow e^+e^- X$
Also 83 ARNS 33 143 Bloom, Peck (SLAC, CIT)	
VARDS 82E PRIL 49 259 + Partridge, Peck ; (CIT, HARV, PRIN, STAN, SLAC) HOIGNE 82 PL 113B 509 + Barate, Astbury ; (SACL, LOFC, SHMP, IND)	$\chi_{c0}(1P)$ branching ratios
CH 81 ZPHY CB 1 +Eisermann, Lohr, Kowalski+ (BONN, DESY, MANZ)	•
NL 81 PL 107B 153 +Goldhaber, Guy, Millikan, Abrams+ (SLAC, LBL) TRIDGE 80 PRL 44 712 +Peck+ (CIT, HARV, PRIN, SLAC, STAN)	HADRONIC DECAYS
ARRE 80 PL 97B 329 +Trilling, Abrams, Alam, Blocker+ (SLAC, LBL)	$\Gamma(2(\pi^{+}\pi^{-}))/\Gamma_{\text{total}}$ $\Gamma_{1}/\Gamma_{\text{total}}$
NENTZ 80 PL 96B 214 +Kurdadze, Lelchuk, Mishnev+ (NOVO) Also 81 SJNP 34 814 Zholentz, Kurdadze, Lelchuk+ (NOVO)	VALUE DOCUMENT ID TECH COMMENT
Translated from YAF 34 1471. WDELIK 79C ZPHY C1 233 + Cords+ (DASP Collab.)	0.037 ± 0.007 3 TANENBAUM 78 MRK1 $\psi(25) \rightarrow \gamma \chi_{CO}$
EXANDER 78 PL 728 493 +Criegee+ (DESY, HAMB, SIEG, WUPP)	(λιτισμοία το μικίτ φ(23) - γ. c0
CH 78 PL 78B 347 + Eisermann, Kowalski, Eyss+ (BONN, DESY, MANZ) NDELIK 78B PL 74B 292 + Cords+ (DASP Collab.)	$\Gamma(\pi^+\pi^-K^+K^-)/\Gamma_{\text{total}}$ $\Gamma_2/\Gamma_{\text{total}}$
UZZI 78 PR D17 2901 +Piccolo, Alam, Boyarski, Goldhaber+ (SLAC, LBL) TEL 77 PL 66B 489 +Duinker, Olsson, Heintze+ (DESY, HEIDP)	VALUE DOCUMENT ID TECH COMMENT
MESTER 77D PL 72B 13S +Criegee+ (DESY, HAMB, SIEG, WUPP)	0.030 \pm 0.007 3 TANENBAUM 78 MRK1 $\psi(25) \rightarrow \gamma \chi_{C0}$
DMAN 77 PRPL 33C 285 + Perl (LBL, SLAC) NUCCI 77 PR D15 1814 + Abrams, Alam, Boyarski+ (SLAC, LBL)	=/ 0 ± _\/=
tTEL 76 PL 64B 483 + Duinker, Oksson, Steffen, Heintze+ (DESY, HEIDP)	$\Gamma(\rho^0\pi^+\pi^-)/\Gamma_{\text{total}}$ $\Gamma_3/\Gamma_{\text{total}}$
.UNSCH 76 PL 63B 487 Braunschweig+ (DASP Collab.) N-MARIE 76 PRL 36 291 + Abrams, Boyarski, Breidenbach+ (SLAC, LBL) IG	VALUE DOCUMENT ID TECH COMMENT
DINI 75 PL 58B 471 Baldini-Celio, Bozzo, Capon+ (FRAS, ROMA)	0.016±0.005 3 TANENBAUM 78 MRK1 $\psi(25) \rightarrow \gamma \chi_{c0}$
ARSKI 75 PRL 34 1357 + Breidenbach, Bulos, Feldman + (SLAC, LBL) JPC P 75 PL 56B 491 Braunschweig, Konigs + (DASP Collab.)	$\Gamma(3(\pi^+\pi^-))/\Gamma_{\text{total}}$ $\Gamma_4/\Gamma_{\text{total}}$
OSITO 75B LNC 14 73 +Bartoll, Bisello+ (FRAS, NAPL, PADO, ROMA) D 75 PRL 34 604 +Beron, Hilger, Hofstadter+ (SLAC, PENN)	VALUE DOCUMENT ID TECH COMMENT
FIRE 34 OUT + DETUR, FINEE, FOULSMOTEL+ (SLAC, PENN)	0.018 \pm 0.005 3 TANENBAUM 78 MRK1 $\psi(25) \rightarrow \gamma \chi_{CO}$
OTHER RELATED PAPERS	
97 PR D55 6952 Wei-Shu Hou	$\Gamma(K^+\overline{K}^{\bullet}(892)^0\pi^- + \text{c.c.})/\Gamma_{\text{total}}$ Γ_5/Γ
ATE 83 PL 121B 449 + Bareyre, Bonamy+ (SACL, LOIC, SHMP, IND)	VALUE DOCUMENT ID TECH COMMENT
AMS 74 PRL 33 1453 + Briggs, Augustin, Boyarski+ (LBL, SLAC) 74 LNC 11 705 + Zorn, Bartoli+ (FRAS, UMD, NAPL, PADO, ROMA)	0.012±0.004 3 TANENBAUM 78 MRK1 $\psi(25) \rightarrow \gamma \chi_{C0}$
ERT 74 PRL 33 1404 +Becker, Biggs, Burger, Chen, Everhart (MIT, BNL)	r(_+ _\/r
iUSTIN 74 PRL 33 1406 +Boyarski, Abrams, Briggs+ (SLAC, LBL) CI 74 PRL 33 1408 +Bartoli, Barbarino, Barbiellini+ (FRAS)	$\Gamma(\pi^+\pi^-)/\Gamma_{\text{total}}$ Γ_6/i
Also 74B PRL 33 1649 Bacci DINI 74 LNC 11 711 Baldini-Celio, Bacci+ (FRAS, ROMA)	VALUE (units 10 ⁻⁴) DOCUMENT ID TECN COMMENT
BIELLINI 74 LNC 11 718 +Bemporad+ (FRAS. NAPL. PISA. ROMA)	75±21 OUR AVERAGE
UNSCH 74 PL 538 393 Braunschweig+ (DASP Collab.) ISTENS 70 PRL 25 1523 Christenson, Hicks, Lederman+ (COLU, BNL, CERN)	70±30 3 BRANDELIK 798 DASP $\psi(2S) \rightarrow \gamma \chi_{CO}$ 80±30 3 TANENBAUM 78 MRK1 $\psi(2S) \rightarrow \gamma \chi_{CO}$
STENS TO FRE 20 1920 CHINELINAN, TROO, EQUINANT (COEO, DRE, CERT)	80±30 TANENBAUM 78 MRK1 $\psi(2S) \rightarrow \gamma \chi_{CO}$
	$\Gamma(K^+K^-)/\Gamma_{\text{total}}$ $\Gamma_7/\Gamma_{\text{total}}$
$\chi_{c0}(1P) = 0^{+(0++)}$	VALUE (units 10 ⁻⁴) DOCUMENT ID TECN COMMENT
100(11)	71±24 OUR AVERAGE
	60 ± 30 BRANDELIK 798 DASP $\psi(2S) \rightarrow \gamma \chi_{CO}$
$\chi_{c0}(1P)$ MASS	90 ± 40 3 TANENBAUM 78 MRK1 $\psi(25) \rightarrow \gamma X_{CO}$
720(11) 111123	r/_+ _= \ /r
JE (MeV) DOCUMENT ID TECN COMMENT	$\Gamma(\pi^+\pi^-p\overline{p})/\Gamma_{\text{total}}$
7.3± 2.8 OUR AVERAGE	0.005 \pm 0.002 000 000 000 000 000 000 000 000 0
7.8 \pm 0.4 \pm 4	- INIVERDACION 16 MINUT A(52) - 47/00
_ =	$\Gamma(\pi^0\pi^0)/\Gamma_{\text{total}}$
6 \pm 3 \pm 4 2 TANENBAUM 78 MRK1 e^+e^- 5 \pm 9 2 BIDDICK 77 CNTR $e^+e^- \rightarrow \gamma X$	VALUE (units 10 ⁻³) DOCUMENT ID TECN COMMENT
	• • We do not use the following data for averages, fits, limits, etc. • • •
Using mass of $\psi(2S)=3686.0$ MeV. Mass value shifted by us by amount appropriate for $\psi(2S)$ mass $=3686$ MeV and	$3.1\pm0.4\pm0.5$ 4 LEE 85 CBAL $\psi' \rightarrow$ photons
mass value shifted by us by amount appropriate for $\psi(25)$ mass = 3000 MeV and $J/\psi(15)$ mass = 3097 MeV.	
	$\Gamma(\eta\eta)/\Gamma_{ ext{total}}$ $\Gamma_{10}/\Gamma_{ ext{total}}$
X _{c0} (1P) WIDTH	VALUE (units 10 ⁻³) DOCUMENT ID TECN COMMENT
	● ● We do not use the following data for averages, fits, limits, etc. ● ●
JE (MeV) DOCUMENT ID TECN COMMENT	$2.5\pm0.8\pm0.8$ 4 LEE 85 CBAL $\psi' \rightarrow$ photons
±3.3±4.2 GAISER 86 CBAL $\psi(2S) \to \gamma X, \gamma \pi^0 \pi^0$	
	$\Gamma(p\overline{p})/\Gamma_{\text{total}}$ $\Gamma_{11}/\Gamma_{\text{total}}$
$x_{c0}(1P)$ DECAY MODES	VALUE (units 10-4) CL% DOCUMENT ID TECN COMMENT
	<9.0 90 3 BRANDELIK 798 DASP $\psi(25) \rightarrow \gamma \chi_{CO}$
Mode Fraction (Γ_I/Γ) Confidence level	³ Calculated using B($\psi(2S) \rightarrow \gamma \chi_{CO}(1P)$) = 0.094; the errors do not contain the uncer
11-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1-1	tainty in the $\psi(2S)$ decay.
Hadronic decays	⁴ Calculated using B($\psi(25) \rightarrow \gamma X_{c0}(1P)$) = 0.093 ± 0.008.
$2(\pi^+\pi^-)$ (3.7±0.7)%	
$\pi^{+}\pi^{-}K^{+}K^{-}$ (3.0±0.7)%	RADIATIVE DECAYS
$\rho^0 \pi^+ \pi^-$ (1.6±0.5) %	$\Gamma(\gamma J/\psi(1S))/\Gamma_{\text{total}}$ Γ_{12}/Γ_{12}
$3(\pi^+\pi^-)$ (1.5±0.5) %	VALUE (units 10 ⁻⁴) DOCUMENT ID TECN COMMENT
$K^{+}\overline{K}^{*}(892)^{0}\pi^{-}$ + c.c. (1.2±0.4)%	66± 18 OUR AVERAGE
$\pi^{+}\pi^{-}$ (7.5±2.1) × 10 ⁻³	60 ± 18 GAISER 86 CBAL $\psi(25) \rightarrow \gamma \chi_{CO}$
K^+K^- (7.1±2.4) × 10 ⁻³	320±210 S BRANDELIK 798 DASP $\psi(2S) \rightarrow \gamma X_{CO}$
$\pi^{+}\pi^{-}p\bar{p}$ (5.0±2.0) × 10 ⁻³	150 ± 100 5 BARTEL 78B CNTR $\psi(2S) \rightarrow \gamma \chi_{c0}$
$\pi^0\pi^0$	210±210 5 TANENBAUM 78 MRK1 $\psi(25) \to \gamma \chi_{c0}^{c0}$
	$\Gamma(\gamma\gamma)/\Gamma_{\text{total}}$ $\Gamma_{13}/\Gamma_{\text{total}}$
	\ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \
· · · · · · · · · · · · · · · · · · ·	• • • • • • • • • • • • • • • • • • • •
$p\overline{p}$ $< 9.0 \times 10^{-4}$ 90%	VALUE (units 10 4) DOCUMENT ID TECH COMMENT
$p\overline{p}$ < 9.0 × 10 ⁻⁴ 90% Radiative decays	• • • We do not use the following data for averages, fits, limits, etc. • •
$p\overline{p}$ < 9.0 $ imes$ 10 ⁻⁴ 90% Radiative decays $ imes \gamma J/\psi(15)$ (6.6 \pm 1.8) $ imes$ 10 ⁻³	VALUE (units 10^{-4}) ■ • We do not use the following data for averages, fits, limits, etc. • • • $4.0 \pm 2.0 \pm 1.1$ DOCUMENT ID TECH COMMENT A LEE 85 CBAL $\psi' \rightarrow$ photons
$p\overline{p}$ < 9.0 × 10 ⁻⁴ 90% Radiative decays	• ■ • We do not use the following data for averages, fits, limits, etc. • •

			X _{c0} (1P) REFERENCES
IEN HARA	90B 88D	PL B243 169 PRL 60 2355	+Mcllwain+ (CLEO Collab.) +Alston-Garnjost+ (TPC Collab.)
ISER	86 85	PR D34 711 SLAC 282	+Bloom, Bulos, Godfrey+ (Crystal Ball Collab.) (SLAC)
NDELIK RTEL	79B 76B	NP B160 426 PL 79B 492	+Cords + (DASP Collab.) +Dittmann, Duinker, Olsson, O'Neill+ (DESY, HEIDP)
NENBAUM Also	76 82	PR D17 1731 Private Comm	+Alam, Boyarski+ (SLAC, LBL)
DICK	77	PRL 38 1324	+Burnett+ (UCSD, UMD, PAVI, PRIN, SLAC, STAN)
		c	OTHER RELATED PAPERS
EGLIA DMAN Also	82 758 75C	PR D25 2259 PRL 35 821 PRL 35 1189	+Partridge+ (SLAC, CIT, HARV, PRIN, STAN) +Jean-Marie, Sadoulet, Vannucci+ (LBL, SLAC) Feldman
Erratum. IENBAUM	75	PRL 35 1323	+Whitaker, Abrams+ (LBL, SLAC)
$\chi_{c1}(1$.P))	$I^{G}(J^{PC}) = 0^{+}(1^{+})$
			X _{c1} (1P) MASS
LUE (MeV)		EVTS	
		OUR AVERA	
10.53± (11.3 ± (······································
12.3 ± (1 GAISER 86 CBAL $\psi(25) \rightarrow \gamma X$
07.4 ± :		91	² LEMOIGNE 82 GOLI 190 π^- Be $\rightarrow \gamma 2\mu$
10.4 ± (OREGLIA 82 CBAL $e^+e^- \rightarrow J/\psi 2\gamma$
10.1 ± : 09 ±1:		254 21	-,,,-,
D9 ±1.		21	BRANDELIK 798 DASP $e^+e^- \rightarrow J/\psi 2\gamma$ BARTEL 78B CNTR $e^+e^- \rightarrow J/\psi 2\gamma$
05.0 ±	_	-4	3,4 TANENBAUM 78 MRK1 e+e-
13 ±		367	³ BIDDICK 77 CNTR $\psi(25) \rightarrow \gamma X$
			owing data for averages, fits, limits, etc. • • •
00 ±1		40 of $\psi(25) = 36$	
³ Mass v	lue s	shifted by us	I to 3097 MeV. by amount appropriate for $\psi(2S)$ mass $=$ 3686 MeV and
$\frac{3}{J/\psi}$ Mass vi	lue s) mas	shifted by us ss = 3097 Me	by amount appropriate for $\psi(2S)$ mass = 3686 MeV and eV. or adiative and hadronic decay channels.
³ Mass ν: <i>J/ψ</i> (1 <i>S</i> ⁴ From a	ilue s) mas simul	shifted by us ss = 3097 Me Itaneous fit to	by amount appropriate for $\psi(2S)$ mass = 3686 MeV and eV. or adilative and hadronic decay channels. $\chi_{c1}(1P)$ WIDTH
³ Mass vs J/ψ(15 ⁴ From a	alue s) mas simul	shifted by us ss = 3097 Me taneous fit to CL%	by amount appropriate for $\psi(2S)$ mass = 3686 MeV and eV. or adiative and hadronic decay channels.
3 Mass v: J/ψ(1.5 4 From a LUE (MeV) 0.88±0.1	alue s) mas simul	shifted by us ss = 3097 Me taneous fit to CL%	by amount appropriate for $\psi(2S)$ mass = 3686 MeV and eV. or adilative and hadronic decay channels. $ x_{c1}(1P) \text{ WIDTH} $
3 Mass v: J/ψ(1.5 4 From a LUE (MeV) 0.88±0.1 • • We α 1.3	alue s) mas simul	shifted by us ss = 3097 Me taneous fit to CL%	by amount appropriate for $\psi(2S)$ mass = 3686 MeV and eV. or radiative and hadronic decay channels. $X_{c1}(1P)$ WIDTH $\frac{6}{5}$ EVTS DOCUMENT ID TECN COMMENT 513 ARMSTRONG 92 E760 $\overline{p}p \rightarrow e^+e^-\gamma$ owing data for averages, fits, limits, etc. • • BAGLIN 868 SPEC $\overline{p}p \rightarrow e^+e^-\chi$
3 Mass v: J/ψ(1.5 4 From a LUE (MeV) 0.88±0.1 • • We of	alue s) mas simul	chifted by us ss = 3097 Me itaneous fit to clamber of the clamber	by amount appropriate for $\psi(2S)$ mass = 3686 MeV and eV. a radiative and hadronic decay channels. $X_{c1}(1P) \text{ WIDTH}$ $\frac{6}{5} \frac{EVTS}{5} \frac{DOCUMENT \ ID}{5} \frac{TECN}{5} \frac{COMMENT}{pp \rightarrow e^+e^-\gamma}$ wing data for averages, fits, limits, etc. • • • BAGLIN 868 SPEC $\overline{p}p \rightarrow e^+e^-X$ GAISER 86 CBAL $\psi(2S) \rightarrow \gamma X$
3 Mass v: J/ψ(1.5 4 From a LUE (MeV) 0.88±0.1 • • We α 1.3	alue s) mas simul	chifted by us ss = 3097 Me itaneous fit to clamber of the clamber	by amount appropriate for $\psi(2S)$ mass = 3686 MeV and eV. or radiative and hadronic decay channels. $X_{c1}(1P)$ WIDTH $\frac{6}{5}$ EVTS DOCUMENT ID TECN COMMENT 513 ARMSTRONG 92 E760 $\overline{p}p \rightarrow e^+e^-\gamma$ owing data for averages, fits, limits, etc. • • BAGLIN 868 SPEC $\overline{p}p \rightarrow e^+e^-\chi$
3 Mass v: J/ψ(1.5 4 From a MLUE (MeV) 0.33±0.1 • • We c 1.3	alue s) mas slmul	chifted by us ss = 3097 Me itaneous fit to clamber of the clamber	by amount appropriate for $\psi(25)$ mass = 3686 MeV and ev. a radiative and hadronic decay channels.
3 Mass v: J/ψ(1S ⁴ From a 4 From a 6 LUE (MeV) 0.88±0.1 • • We of 1.3 3.8	alue s) mas simul 1±0 not	shifted by us ss = 3097 Me traneous fit to CL%	by amount appropriate for $\psi(2S)$ mass = 3686 MeV and ev. a radiative and hadronic decay channels.
3 Mass v:	lue s) mas simul 1±0 lo not	shifted by us ss = 3097 Me traneous fit to CL% CL% OB t use the folkown population of the control of the cont	by amount appropriate for $\psi(25)$ mass = 3686 MeV and ev. a radiative and hadronic decay channels.
3 Mass v:	1±0.	shifted by us ss = 3097 Me traneous fit to CL% CL% OB truse the folk 95 90	by amount appropriate for $\psi(25)$ mass = 3686 MeV and eV. To radiative and hadronic decay channels. $X_{c1}(1P) \text{ WIDTH}$ $\frac{6}{5} \frac{EVTS}{513} \qquad \frac{DOCUMENT \ ID}{ARMSTRONG} \frac{72}{92} \frac{E760}{PP} \rightarrow e^+e^-\gamma$ Diving data for averages, fits, limits, etc. • • • BAGLIN 868 SPEC $\overline{p}p \rightarrow e^+e^-\chi$ GAISER 86 CBAL $\psi(25) \rightarrow \gamma \chi$ $X_{c1}(1P) \text{ DECAY MODES}$ Fraction (Γ_I/Γ) Hadronic decays $(2.2 \pm 0.8) \%$ $(1.6 \pm 0.5) \%$
3 Mass v: $^{\prime\prime}J/\psi(1.5^4$ From a $^{\prime\prime}$ C. WeV) 0.88 \pm 0.1 $^{\prime\prime}$ 0.88 \pm 0.1 $^{\prime\prime}$ Mod $^{\prime\prime}$ 3.8 $^{\prime\prime}$ Mod $^{\prime\prime}$ 2(π $^{\prime\prime}$ $^{\prime$	1±0. 1±0. 1±π- 1=π-	shifted by us ss = 3097 Me transcous fit to CLM CLM OB trush the folk 95 90	by amount appropriate for $\psi(25)$ mass = 3686 MeV and eV. $x_{c1}(1P)$ WIDTH $y_{c1}(1P)$ WIDTH $y_{c1}(1P)$ MODTH $y_{c1}(1P)$ MODTH $y_{c1}(1P)$ MODTH $y_{c1}(1P)$ MODTH $y_{c2}(1P)$ MODTH $y_{c2}(1P)$ MODTH $y_{c3}(1P)$ MODTH $y_{c4}(1P)$ MODTH $y_{c4}(1P)$ MODTH $y_{c5}(1P)$ MODTH $y_{c6}(1P)$ MODTH y_{c6
3 Mass v:	1±0. sistemate 1	shifted by us ss = 3097 Me transcous fit to class to use the folk 95 90	by amount appropriate for $\psi(25)$ mass = 3686 MeV and eV. $x_{c1}(1P)$ WIDTH $y_{c1}(1P)$ WIDTH $y_{c1}(1P)$ MIDTH $y_{c2}(1P)$ MODTH $y_{c3}(1P)$ MODTH $y_{c4}(1P)$ MODTH y_{c4
3 Mass v:	1±0. sistematical statement 1±0. s	shifted by us ss = 3097 Me Itaneous fit to CL% CL% OB It use the folk 95 90 90 90 $\pi^- +$	by amount appropriate for $\psi(25)$ mass = 3686 MeV and eV. $x_{c1}(1P)$ WIDTH $y_{c1}(1P)$ WIDTH $y_{c1}(1P)$ MIDTH $y_{c2}(1P)$ MODTH $y_{c3}(1P)$ MODTH $y_{c4}(1P)$ MODTH y_{c4
Mass vi. $J/\psi(1.5)$ From a UUE (MeV) $\psi(1.5)$ We consider $\psi(1.5)$ $\psi(1.$	1±0. 1±0. 1±0. 1±0. 1±0.	shifted by us as a 3097 Me Itaneous fit to 20%. CL% OS t use the folk 95 90 (1) (2) (2) (3) (4) (5) (6) (7) (7) (8) (8) (9) (9) (9)	by amount appropriate for $\psi(25)$ mass = 3686 MeV and eV. $x_{c1}(1P)$ WIDTH $y_{c1}(1P)$ WIDTH $y_{c1}(1P)$ WIDTH $y_{c2}(1P)$ MODTH $y_{c3}(1P)$ MODTH $y_{c4}(1P)$ MODTH $y_{c4}(1P)$ MODTH $y_{c5}(1P)$ MODTH $y_{c5}(1P)$ MODTH $y_{c5}(1P)$ MODTH $y_{c5}(1P)$ MODTH $y_{c5}(1P)$ MODTH $y_{c6}(1P)$ MODTH y_{c6
3 Mass v: $J/\psi(1.5^4$ From a J	1±0. 1±0. 1±0. 1±0. 1±0.	shifted by us ss = 3097 Me Itaneous fit to CL% CL% OB It use the folk 95 90 90 90 $\pi^- +$	by amount appropriate for $\psi(25)$ mass = 3686 MeV and ev. a radiative and hadronic decay channels.
3 Mass v:	1±0. 1±0.	shifted by us ss = 3097 Me Itaneous fit to CLY. CLY. OB It use the folk 95 90 $\pi^- + \bar{p}$ K^+K^-	by amount appropriate for $\psi(25)$ mass = 3686 MeV and eV. $x_{c1}(1P)$ WIDTH $y_{c1}(1P)$ WIDTH $y_{c2}(1P)$ WIDTH $y_{c2}(1P)$ MODTH $y_{c3}(1P)$ MODTH $y_{c4}(1P)$ MODTH $y_{c4}(1P)$ MODTH $y_{c5}(1P)$ MODTH $y_{c5}(1P)$ MODTH $y_{c5}(1P)$ MODTH $y_{c5}(1P)$ MODTH $y_{c5}(1P)$ MODTH $y_{c6}(1P)$ MODTH $y_{c7}(1P)$ MODTH y_{c7
3 Mass v : $J/\psi(1S$ 4 From a $J/\psi(1S$ 4 From a $J/\psi(1S$ 3.8 Mod 3.8 $J/\psi(1S)$ 3.8 $J/\psi(1S)$ 4 From a $J/\psi(1S)$ 4 From a $J/\psi(1S)$ 4 From a $J/\psi(1S)$ 6 $J/\psi(1S)$ 7 $J/\psi(1S)$ 7 $J/\psi(1S)$ 7 $J/\psi(1S)$ 8 $J/\psi(1S)$ 8 $J/\psi(1S)$ 8 $J/\psi(1S)$ 8 $J/\psi(1S)$ 9 $J/\psi(1S)$	1±0. 1±0.	shifted by us ss = 3097 Me Itaneous fit to CLY. CLY. OB It use the folk 95 90 $\pi^- + \bar{p}$ K^+K^-	by amount appropriate for $\psi(25)$ mass = 3686 MeV and eV. $x_{c1}(1P)$ WIDTH $y_{c1}(1P)$ WIDTH $y_{c1}(1P)$ WIDTH $y_{c2}(1P)$ MODTH $y_{c3}(1P)$ MODTH $y_{c4}(1P)$ MODTH $y_{c4}(1P)$ MODTH $y_{c5}(1P)$ MODTH $y_{c5}(1P)$ MODTH $y_{c5}(1P)$ MODTH $y_{c5}(1P)$ MODTH $y_{c5}(1P)$ MODTH $y_{c6}(1P)$ MODTH $y_{c6}(1P)$ MODTH $y_{c7}(1P)$ MODTH y_{c7
3 Mass v: $J/\psi(1S$ 4 From a $J/\psi(1S$ 4 From a $J/\psi(1S)$ 6 $J/\psi(1S)$ 6 $J/\psi(1S)$ 7 $J/\psi(1S)$ 8 $J/\psi(1S)$ 9 $J/\psi(1S)$ 8 $J/\psi(1S)$ 8 $J/\psi(1S)$ 8 $J/\psi(1S)$ 8 $J/\psi(1S)$ 8 $J/\psi(1S)$ 8 $J/\psi(1S)$ 9 $J/\psi(1S)$ 8 $J/\psi(1S)$ 9 $J/\psi(1S)$ 8 $J/\psi(1S)$ 9 $J/$	1±0. 1±0.	shifted by us as = 3097 Me Itaneous fit to CLM CLM OB It use the folk 95 90 $\pi^- + \pi^ \pi^- + K^- + K^- + K^-$ S)	by amount appropriate for $\psi(25)$ mass = 3686 MeV and eV. $x_{c1}(1P)$ WIDTH $y_{c1}(1P)$ WIDTH $y_{c2}(1P)$ WIDTH $y_{c2}(1P)$ MODTH $y_{c3}(1P)$ MODTH $y_{c4}(1P)$ MODTH $y_{c4}(1P)$ MODTH $y_{c5}(1P)$ MODTH $y_{c5}(1P)$ MODTH $y_{c5}(1P)$ MODTH $y_{c5}(1P)$ MODTH $y_{c5}(1P)$ MODTH $y_{c6}(1P)$ MODTH $y_{c7}(1P)$ MODTH y_{c7
3 Mass v : $J/\psi(1S$ 4 From a V : $J/\psi(1S)$ 4 From a V :	1±0. 1±0.	shifted by us as = 3097 Me Itaneous fit to CLM CLM OB It use the folk 95 90 $\pi^- + \pi^ \pi^- + K^- + K^- + K^-$ S)	by amount appropriate for $\psi(25)$ mass = 3686 MeV and eV. $x_{c1}(1P)$ WIDTH $\frac{EVTS}{513}$ ARMSTRONG 92 E760 $\overline{p}p \rightarrow e^+e^-\gamma$ Diving data for averages, fits, limits, etc. • • BAGLIN 868 SPEC $\overline{p}p \rightarrow e^+e^-\chi$ GAISER 86 CBAL $\psi(25) \rightarrow \gamma\chi$ $x_{c1}(1P)$ DECAY MODES Fraction (Γ_f/Γ) Hadronic decays $(2.2\pm0.8)\%$ $(9\pm4)\times10^{-3}$ $(3.9\pm3.5)\times10^{-3}$ $(3.9\pm3.5)\times10^{-3}$ $(1.4\pm0.9)\times10^{-3}$ $(8.6\pm1.2)\times10^{-5}$ <2.1 $\times10^{-3}$ Radiative decays $(27.3\pm1.6)\%$
3 Mass v: $J/\psi(1S)$ 4 From a	1 ± 0. 1 ± 0. 1 + 7 - 4 1 + 7 - 4 1 + 7 - 4	shifted by us as = 3097 Me transcous fit to transcous fit transcous fit	by amount appropriate for $\psi(25)$ mass = 3686 MeV and eV. $x_{c1}(1P)$ WIDTH $y_{c1}(1P)$ WIDTH $y_{c1}(1P)$ MIDTH $y_{c2}(1P)$ MODTH $y_{c3}(1P)$ MODTH $y_{c4}(1P)$ MODTH y_{c4
3 Mass vi $J/\psi(1S^4$ From a 4 From a 6 • We of 1.3 3.8 Mod $3(\pi \pi + \rho^0 \pi K + $	1 ± 0. 1 ± 0. 1 + 7 - 4 1 + 7 - 4 1 + 7 - 4	shifted by us as = 3097 Me transcous fit to transcous fit transcous fit	by amount appropriate for $\psi(25)$ mass = 3686 MeV and eV. $x_{c1}(1P)$ WIDTH $y_{c1}(1P)$ WIDTH $y_{c2}(1P)$ MIDTH $y_{c2}(1P)$ MODTH $y_{c3}(1P)$ MODTH $y_{c4}(1P)$ MODTH $y_{c4}(1P)$ MODTH $y_{c5}(1P)$ MODTH $y_{c5}(1P)$ MODTH $y_{c5}(1P)$ MODTH $y_{c5}(1P)$ MODTH $y_{c5}(1P)$ MODTH Hadronic decays $y_{c5}(1P)$ MODTH $y_{c5}(1$
3 Mass v: $J/\psi(1S)$ 4 From a	1 ± 0. 1 ± 0. 1 + 7 - 4 1 + 7 - 4 1 + 7 - 4	shifted by us ss = 3097 Me Itaneous fit to CLM CLM OB It use the folkows fit was the folkows fit with the shift fit with the shift folkows fit with the shift fi	by amount appropriate for $\psi(25)$ mass = 3686 MeV and eV. $x_{c1}(1P)$ WIDTH $y_{c1}(1P)$ WIDTH $y_{c2}(1P)$ MIDTH $y_{c2}(1P)$ MODTH $y_{c3}(1P)$ MODTH $y_{c4}(1P)$ MODTH $y_{c4}(1P)$ MODTH $y_{c5}(1P)$ MODTH $y_{c5}(1P)$ MODTH $y_{c5}(1P)$ MODTH $y_{c5}(1P)$ MODTH Hadronic decays $y_{c5}(1P)$ MODTH $y_{c5}(1P)$ MODTH $y_{c6}(1P)$ MODTH $y_{c6}(1$

Xc1(1P) BRANCHING RATIOS - HADRONIC DECAYS - $\Gamma(3(\pi^+\pi^-))/\Gamma_{\text{total}}$ Γ_1/Γ VALUE DOCUMENT ID TECN COMMENT ⁶ TANENBAUM 78 MRK1 $\psi(25) \rightarrow \gamma \chi_{c1}$ 0.022 ± 0.008 $\Gamma(2(\pi^+\pi^-))/\Gamma_{\text{total}}$ Γ_2/Γ DOCUMENT ID TECN COMMENT ⁶ TANENBAUM 78 MRK1 $\psi(25) \rightarrow \gamma \chi_{c1}$ 0.016±0.005 $\Gamma(\pi^+\pi^-K^+K^-)/\Gamma_{\text{total}}$ Γ_3/Γ VALUE (units 10⁻⁴) DOCUMENT ID TECN COMMENT 6 TANENBAUM 78 MRK1 $\psi(2S) \rightarrow ~\gamma^{\chi}_{c1}$ $\Gamma(\rho^0\pi^+\pi^-)/\Gamma_{\rm total}$ Γ_4/Γ VALUE (units 10⁻⁴) DOCUMENT ID TECN COMMENT 6 TANENBAUM 78 MRK1 $\psi(25) \rightarrow \gamma x_{c1}$ 39±35 $\Gamma(K^+\overline{K}^*(892)^0\pi^- + \text{c.c.})/\Gamma_{\text{total}}$ Γ_B/Γ VALUE (units 10-4) DOCUMENT ID TECN COMMENT ⁶ TANENBAUM 78 MRK1 $\psi(2S) \rightarrow \gamma \chi_{c1}$ 32±21 $\Gamma(\pi^+\pi^-p\overline{p})/\Gamma_{\text{total}}$ Γ_6/Γ VALUE (units 10-4) DOCUMENT ID TECN COMMENT ⁶ TANENBAUM 78 MRK1 $\psi(2S) \rightarrow \gamma \chi_{c1}$ 14±9 $\Gamma(p\overline{p})/\Gamma_{\text{total}}$ Γ_7/Γ VALUE (units 10⁻⁴) CL% EVTS DOCUMENT ID TECN COMMENT 513 ⁷ ARMSTRONG 92 E760 $pp \rightarrow e^+e^-\gamma$ BAGLIN 86B SPEC $\overline{p}p \rightarrow e^+e^-X$ > 0.54 95 ⁶ BRANDELIK 79B DASP $\psi(2S) \rightarrow \gamma X_{c1}$ <12.0 $[\Gamma(\pi^+\pi^-) + \Gamma(K^+K^-)]/\Gamma_{\text{total}}$ Γ_B/Γ VALUE (units 10⁻⁴) CL% DOCUMENT ID TECN COMMENT ⁶ FELDMAN 77 MRK1 $\psi(2S) \rightarrow \gamma X_{c1}$ • • • We do not use the following data for averages, fits, limits, etc. • • • ⁶ BRANDELIK 79B DASP $\psi(25) \rightarrow \gamma \chi_{c1}$ <38 90 6 Estimated using B($\psi(2S)\to \gamma\chi_{c1}(1P))=$ 0.087. The errors do not contain the uncertainty in the $\psi(2S)$ decay. ⁷ Restated by us using B($\chi_{c1}(1P) \rightarrow J/\psi(1S)\gamma$)B($J/\psi(1S) \rightarrow e^+e^-$) = 0.0171 ± - RADIATIVE DECAYS - $\Gamma(\gamma J/\psi(1S))/\Gamma_{\text{total}}$ Γ_9/Γ DOCUMENT ID TECN COMMENT VALUE EVTS 0.273±0.016 OUR AVERAGE 0.284 ± 0.021 GAISER 86 CBAL $\psi(25) \rightarrow \gamma X$ 0.274 ± 0.046 8 OREGLIA 82 CBAL $\psi(25) \rightarrow \gamma \chi_{c1}$ 8 HIMEL 80 MRK2 $\psi(2S) \rightarrow \gamma \chi_{c1}$ 0.28 ±0.07 ⁸ BRANDELIK 798 DASP $\psi(2S) \rightarrow \gamma \chi_{c1}$ 0.19 ±0.05 8 BARTEL 788 CNTR $\psi(25) \rightarrow \gamma^{\chi}_{c1}$ 0.29 ±0.05 ⁸ TANENBAUM 78 MRK1 $\psi(2S) \rightarrow \gamma \chi_{c1}$ 0.28 ±0.09 8 BIDDICK 0.57 ±0.17 77 CNTR $\psi(25) \rightarrow \gamma X$ $\Gamma(\gamma\gamma)/\Gamma_{\text{total}}$ Γ_{10}/Γ VALUE CLY DOCUMENT ID TECN COMMENT • • We do not use the following data for averages, fits, limits, etc. • • • 8 YAMADA 90 77 DASP $e^+e^- \rightarrow 3\gamma$ ⁸ Estimated using $B(\psi(2S)\to \gamma\chi_{C1}(1P))=0.087$. The errors do not contain the uncertainty in the $\psi(2S)$ decay. $x_{c1}(1P)$ REFERENCES ARMSTRONG 92 Also 928 BAGLIN 68 GAISER 86 LEMOIGNE 52 OREGILA 82 Also 82 HIMEL 80 Also 82 BRANDELIK 78 BARTEL 78 TANENBAUM 78 PELDMAN 77 YAMADA 77 TANENBAUM 75 +Bettoni+ Armstrong, Bettoni+(FMAL, FERR, GENO, UCI, NWES+) Armstrong, Bettoni+(FMAL, FERR, GENO, UCI, NWES+) (LAPP, CERN, GENO, LYON, OSLO, ROMA+) +Bloom, Bulos, Godfrey+ (Crystal Ball Collab, +Barate, Astbury+ (SACL, LOIC, SHMP, INS, PAN) +Partidge+ (SLAC, CIT, HARV, PRIN, STAN) Orderla NP 8373 35 PRL 68 1468 PL B172 455 PR D34 711 PL 113B 509 PR D25 2259 +Barate, Astbury + (SACL +Partridge+ (SLAC, CIT, Oregila +Abrams, Jiam, Blocker+ Trilling +Cords+ +Dittmann, Duinker, Olsson, O'Neill+ +Alam, Boyanski+ Trilling (LBL, SLAC) (LBL, UCB) (DASP Collab.) (DESY, HEIDP) Private Comm PRL 44 920 PRL 44 920 Private Comm. NP B160 426 PL 79B 492 PR D17 1731 Private Comm. PRL 38 1324 PRPL 33C 285 Hamburg Conf. 69 PRL 35 1323 | (DESY, HEIDP) | (SLAC, LBL) | (SLAC, LBL) | (SLAC, LBL) | (BL, UCB) | (UCSD, UMD, PAVI, PRIN, SLAC, STAN) | (LBL, SLAC) | (DASP Collab.) | (LBL, SLAC) | (+Whitaker, Abrams+ OTHER RELATED PAPERS -BARATE 83 BRAUNSCH... 75B SIMPSON 75 (SACL, LOIC, SHMP, IND) (DASP Collab.) H+ (STAN, PENN) PL 121B 449 PL 57B 407 PRL 35 699 + Bareyre, Bonamy+ (5 Braunschweig, Konigs+ + Beron, Ford, Hilger, Hofstadter+

 $h_c(1P), \chi_{c2}(1P)$

$h_c(1P)$

$I^{G}(J^{PC}) = ??(???)$	ΙG	J^{PC}	1 =	??	(???	?
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OMITTED FROM SUMMARY TABLE Needs confirmation.

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
3526.1	4±0.24 OUR AV	ERAGE				
3526.2	0±0.15±0.20	59	ARMSTRONG	92D	E760	$\overline{\rho}\rho \rightarrow J/\psi \pi^0$
3525.4	±0.8 ±0.4	5	BAGLIN	86	SPEC	$\overline{p}p \rightarrow J/\psi X$
• • •	We do not use th	e following	data for averages	, fits	, limits,	etc. • • •
3527	±8	42	ANTONIAZZI	94	E705	300 π^{\pm} , $p \downarrow 1 \rightarrow J/\psi \pi^0 X$
						$J/\psi\pi^{0}X$

$h_c(1P)$ WIDTH

VALUE (MeV)	CLN	EVT\$	DOCUMENT ID	TECN	COMMENT
<1.1	90	59	ARMSTRONG 920	E760	$\overline{p} \rho \rightarrow J/\psi \pi^0$

$h_c(1P)$ DECAY MODES

Mode		Fraction (F _I /F)
	$J/\psi(1S)\pi^0$	seen
Γ_2	$J/\psi(1S)\pi\pi$	not seen
Гз	ρ p	

$\Gamma(J/\psi(1S)\pi\pi)$	/Γ(J/ ψ (1S)π	(م			Γ_2/Γ_1
VALUE	CLN	DOCUMENT ID	TECN	COMMENT	
< 0.18	90	ARMSTRONG 9	2D E760	$\overline{D}D \rightarrow J/\psi \pi^0$	

h_c(1P) REFERENCES

ANTONIAZZI		PR D50 4258	+Arenton+	(E705 Collab.)
ARMSTRONG			+ Bettoni+	(FNAL, FERR, GENO, UCI, PENN, TORI)
BAGLIN	86	PL B171 135	+Baird+	(LAPP, CERN, TORI, STRB, OSLO, ROMA+)



$$I^{G}(J^{PC}) = 0^{+}(2^{+})$$

$\chi_{c2}(1P)$ MASS

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
3556.17± 0.13 OUR A	/ERAGE				
3556.15 ± 0.07 ± 0.12	585	ARMSTRONG	92	E760	$\vec{p}p \rightarrow e^+e^-\gamma$
$3556.9 \pm 0.4 \pm 0.5$	50	BAGLIN	86B	SPEC	$\overline{p}p \rightarrow e^+e^-X$
$3557.8 \pm 0.2 \pm 4$		¹ GAISER	86	CBAL	$\psi(2S) \rightarrow \gamma X$
3553.4 ± 2.2	66	² LEMOIGNE	82	GOLI	190 π^- Be → $\gamma 2\mu$
3555.9 ± 0.7		³ OREGLIA	82	CBAL	$e^+e^- \rightarrow J/\psi 2\gamma$
3557 ± 1.5	69	⁴ HIMEL	80	MRK2	$e^+e^- \rightarrow J/\psi 2\gamma$
3551 ±11	15	BRANDELIK	79B	DASP	$e^+e^- \rightarrow J/\psi 2\gamma$
3553 ± 4		4 BARTEL	78B	CNTR	$e^+e^- \rightarrow J/\psi 2\gamma$
3553 ± 4 ±4		4,5 TANENBAUM	78	MRK1	e+ e-
3563 ± 7	360	⁴ BIDDICK	77	CNTR	$e^+e^- \rightarrow \gamma X$
• • • We do not use the	e followi	ng data for averages	i, fits	, limits,	etc. • • •
3543 ±10	4	WHITAKER	76	MRK1	$e^+e^- \rightarrow J/\psi 2\gamma$
¹ Using mass of $\psi(2S)$	= 3686	i.0 MeV.			

$\chi_{c2}(1P)$ WIDTH

VALUE (MeV) 2.00±0.18 OUR AVE	<u>EVTS</u> RAGE	DOCUMENT ID		<u>TECN</u>	COMMENT
$1.98 \pm 0.17 \pm 0.07$	585	ARMSTRONG	92	E760	$\overline{p}p \rightarrow e^+e^-\gamma$
2.6 +1.4	50	BAGLIN	86B	SPEC	$\overline{\rho} \rho \rightarrow e^+ e^- X$
2.8 +2.1 -2.0		⁶ GAISER	86	CBAL	$\psi(25) \rightarrow \gamma X$

 $^{^{\}mbox{\scriptsize 6}}$ Errors correspond to 90% confidence level; authors give only width range.

Xc2(1P) DECAY MODES

48±28

	Mode	Fraction (Γ_I/Γ)	Confidence level
	t ·	ladronic decays	
Γ_1	$2(\pi^{+}\pi^{-})$	(2.2±0.5) %	
Γ_2	$\pi^{+}\pi^{-}K^{+}K^{-}$	(1.9±0.5) %	
Гз	$3(\pi^+\pi^-)$ $\rho^0\pi^+\pi^-$	(1.2±0.8) %	
Γ_4	$\rho^0 \pi^+ \pi^-$	$(7 \pm 4) \times 10^{-3}$	
Γ ₅	$K^{+}\overline{K}^{*}(892)^{0}\pi^{-}+\text{c.c.}$	$(4.8\pm2.8)\times10^{-3}$	
Γ ₆	$\pi^+\pi^-\rho\overline{\rho}$	$(3.3\pm1.3)\times10^{-3}$	
Γ,	$\pi^{+}\pi^{-}$	$(1.9\pm1.0)\times10^{-3}$	
	K+K-	$(1.5\pm1.1)\times10^{-3}$	
و۲	ρ β	$(10.0\pm1.0)\times10^{-5}$	
Γ ₁₀	$p \overline{p} \atop \pi^0 \pi^0$, ,	
Γ11	ηη		
Γ ₁₂	$J/\psi(1S)\pi^{+}\pi^{-}\pi^{0}$	< 1.5 %	90%
	R	ladiative decays	
Γ_{13}	$\gamma J/\psi(1S)$	(13.5±1.1) %	
	77	$(1.6\pm0.5)\times10^{-4}$	

$\chi_{c2}(1P)$ PARTIAL WIDTHS

Γ(<i>p</i> p)			Г
VALUE (eV)	EVTS	DOCUMENT ID TECN COM	MENT
206±22 OUR AVE	RAGE		
197±18±16	585	7 ARMSTRONG 92 E760 ₽p -	→ c ⁺ e ⁻ γ
$252^{+55}_{-48}\pm21$		7 BAGLIN 868 SPEC Pp -	→ e ⁺ e ⁻ X
7			

⁷Restated by us using B($\chi_{c2}(1P) \rightarrow J/\psi(1S)\gamma$)B($J/\psi(1S) \rightarrow e^+e^-$) = 0.0085 ± 0.0007.

$\Gamma(\gamma\gamma)$						Γ ₁₄
VALUE (keV)		CL%	DOCUMENT ID		TECN	COMMENT
0.37 ±0.	17 OUR AV	ERAGE	Error Includes sca			
1.08 ±0.	30 ±0.26		DOMINICK	94	CLE2	$e^+e^- \rightarrow e^+e^- \chi_{c2}$ $\overline{p}p \rightarrow \gamma\gamma$
0.321 ± 0.0	078±0.054		8 ARMSTRONG	93	E760	$\overline{p}p \rightarrow \gamma \gamma$
3.4 ±1.	7 ±0.9		BAUER	93	TPC	$e^+e^- \rightarrow e^+e^-\chi_{c2}$
$2.9 \begin{array}{c} +1.5 \\ -1.5 \end{array}$	3 ±1.7		BAGLIN	87B	SPEC	$\overline{p}p \rightarrow \gamma \gamma$
• • • We d	o not use the	e following	g data for average:	s, fits	, limits,	etc. • • •
<4.2		95	UEHARA	91	VNS	$e^+e^- \rightarrow e^+e^-\chi_{c2}$
<1.0		95	CHEN	90B	CLEO	$e^+e^- \rightarrow e^+e^-\chi_{c2}^{c2}$
<4.2		95	AIHARA	88D	TPC	e+e- → e+e-X
⁸ Using B	$(x_{c2}(1P) \rightarrow$	p7) = ((1.00 ± 0.23) × 10)~4 a	nd Γ _{tol}	$tal = 2.00 \pm 0.18 \text{ MeV}.$

X_{C2}(1P) BRANCHING RATIOS

- HADRONIC DECAYS -

Γ(2(π ⁺ π ⁻))/Γ _{total}	DOCUMENT ID	TECN	COMMENT	Γ ₁ /Γ
0.022±0.006	9 TANENBAUM 78	MRK1	$\psi(25) \rightarrow \gamma \chi_{c2}$	
$\Gamma(\pi^+\pi^-K^+K^-)/\Gamma_{\text{total}}$	DOCUMENT ID	<u>TECN</u>	COMMENT	Γ ₂ /Γ
0.019±0.005	9 TANENBAUM 78	MRK1	$\psi(25)\to~\gamma\chi_{c2}$	
$\Gamma(3(\pi^+\pi^-))/\Gamma_{\text{total}}$ VALUE	DOCUMENT ID	<u>TECN</u>	COMMENT	Γ3/Γ
0.012±0.008	9 TANENBAUM 78	MRK1	$\psi(25)\to~\gamma^\chi_{c2}$	
$\Gamma(\rho^0\pi^+\pi^-)/\Gamma_{\text{total}}$ VALUE (units 10^{-4})	DOCUMENT ID	TECN	COMMENT	Γ ₄ /Γ
68±40	9 TANENBAUM 78	MRK1	$\psi(2S) \to \gamma \chi_{c2}$	
Γ(K+K*(892)0π-+c.c.)	/F _{total}			Γ ₆ /Γ
VALUE (units 10-4)		TECN	COMMENT	

9 TANENBAUM 78 MRK1 $\psi(25) \rightarrow \gamma \chi_{c2}$

 $^{^2}$ $J/\psi(15)$ mass constrained to 3097 MeV.

³ Assuming $\psi(2S)$ mass = 3686 MeV and $J/\psi(1S)$ mass = 3097 MeV. Mass value shifted by us by amount appropriate for $\psi(2S)$ mass = 3686 MeV and $J/\psi(1S)$ mass = 3097 MeV.

⁵ From a simultaneous fit to radiative and hadronic decay channels.

	Г	·6/Γ	Xc2	(1P) REFERENCES
VALUE (units 10 ⁻⁴)	DOCUMENT ID TECN COMMENT	DOMINICK 94	PR D50 4265	+Sanghera+ (CLEO Collab.)
\$3±13	⁹ TANENBAUM 78 MRK1 $\psi(25) \rightarrow \gamma^{\chi}_{C2}$	ARMSTRONG 93 BAUER 93	PRL 70 2988 PL B302 345	+Bettoni, Bharadwaj+ (FNAL E760 Collab.) +Betcinski+ (TPC Collab.)
$\Gamma(\pi^+\pi^-)/\Gamma_{\text{total}}$	Γ	7/F ARMSTRONG 92 Also 92B	NP B373 35	+Bettoni+ (FNAL, FERR, GENO, ÚCI, NWES+) Armstrong, Bettoni+(FNAL, FERR, GENO, UCI, NWES+)
VALUE (units 10 ⁻³) EVTS	DOCUMENT ID TECN COMMENT	UEHARA 91	PL B266 188	+Abe+ (VENUS Collab.)
1.9±1.0 4	9 BRANDELIK 79C DASP $\psi(2S) \rightarrow \gamma^{\chi}_{C2}$	—— CHEN 908 Aihara 88D	PRL 60 2355	+ Mcliwain + (CLEO Collab.) + Alston-Garnjost + (TPC Collab.)
-		BAGLIN 878		+Baird, Bassomplerre, Borreanl+ (R704 Collab.) (LAPP, CERN, GENO, LYON, OSLO, ROMA+)
$[\Gamma(\pi^+\pi^-)+\Gamma(K^+K^-)],$	/Γ _{total} (Γ ₇ +Γ ₁	B)/F GAISER 86	PR D34 711	+Bloom, Bulos, Godfrey+ (Crystal Ball Collab.)
VALUE (units 10 ⁻⁴)	DOCUMENT ID TECN COMMENT	LEE 85 LEMOIGNE 82	SLAC 282 PL 113B 509	(SLAC) +Barate, Astbury+ (SACL, LOIC, SHMP, IND)
#±10	⁹ TANENBAUM 78 MRK1 $\psi(2S) \rightarrow \gamma X_{C2}$	OREGLIA 82 Also 82B	PR D25 2259 Private Comm.	+Partridge + (SLAC, CIT, HARV, PRIN, STAN Oreglia (EFI
-/ v+ v-\ /-	,	BARATE 81	PR D24 2994 PRL 44 920	+Astbury+ (SACL, LOIC, SHMP, CERN, IND)
Γ(K+K-)/Γ _{total}		Also 82	Private Comm.	Trilling (LBL, UCB)
VALUE (units 10 ⁻³) EVTS	DOCUMENT ID TECN COMMENT	BRANDELIK 79B BRANDELIK 79C		+Cords+ (DASP Collab.) +Cords+ (DASP Collab.)
1.5±1.1 2	⁹ BRANDELIK 79C DASP $\psi(25) \rightarrow \gamma \chi_{c2}$	BARTEL 78B TANENBAUM 78		+Dittmann, Duinker, Olsson, O'Neill+ (DESY, HEIDP) +Alam, Boyarski+ (SLAC, LBL)
Γ(pp)/Γ _{total}	Г	_/F Also 82	Private Comm.	Trilling (LBL, UCB)
• • •	EVTS DOCUMENT ID TECN COMMENT	BIDDICK 77 WHITAKER 76	PRL 38 1324 PRL 37 1596	+Burnett+ (UCSD, UMD, PAVI, PRIN, SLAC, STAN +Tanenbaum, Abrams, Alam+ (SLAC, LBL)
1.00±0.10 OUR AVERAGE			07:15	D DELL'ED DADEDE
1.00 ± 0.11	585 10 ARMSTRONG 92 E760 pp → e+e	-γ	OTHE	R RELATED PAPERS ———
$0.97^{+0.44}_{-0.28}\pm0.08$	BAGLIN 86B SPEC pp → e+e	X BARATE 83	PL 121B 449	+Bareyre, Bonarny+ (SACL, LOIC, SHMP, IND)
	wing data for averages, fits, limits, etc. • •	FELDMAN 75B Also 75C		+ Jean-Marie, Sadoulet, Vannucci+ (LBL, SLAC) Feldman
< 9.5 90	9 BRANDELIK 798 DASP $\psi(25) \rightarrow \gamma$	Erratum. X 7 TANENBAUM 75	PRL 35 1323	+Whitaker, Abrams+ (LBL, SLAC)
		·		· · · · · · · · · · · · · · · · · · ·
$\Gamma_i \Gamma_f / \Gamma_{\text{total}}^2 \ln p \mathcal{P} \to X_{c2}(1)$	$(P) \rightarrow \gamma \gamma$	5/F ²	3	C. PC. 2.21.
VALUE (units 10 ⁻⁷) EVTS	DOCUMENT ID TECN COMMENT	$ \eta_c(2S)$		$I^{G}(J^{PC}) = ?^{?}(?^{?+})$
 • • We do not use the follow 	wing data for averages, fits, limits, etc. • • •	,,,	8	
$0.160 \pm 0.039 \pm 0.016$	ARMSTRONG 93 E760 $\vec{p}p \rightarrow \gamma \gamma$		ROM SUMMAR	Y TABLE
0.99 +0.46 6	11 BAGLIN 87B SPEC pp → γγ	Needs	confirmation.	
Γ(π ⁰ π ⁰)/Γ _{total}	r		-	η _c (25) MASS
· · · · · · · · · · · · · · · · · · ·		₁₀ /Γ		
VALUE (units 10 ⁻³)	DOCUMENT ID TECH COMMENT	VALUE (MeV)		DOCUMENT ID TECN COMMENT
	wing data for averages, fits, limits, etc. • • •	3594±5		1 EDWARDS 82c CBAL e+e- → γX
1.1±0.2±0.2	12 LEE 85 CBAL $\psi' \rightarrow$ photons	¹ Assuming m	ass of $\psi(25)=368$	6 MeV.
$\Gamma(\eta\eta)/\Gamma_{\text{total}}$	Γ;	п/Г		- (26) MIDTU
VALUE (units 10 ⁻⁴)	DOCUMENT ID TECN COMMENT			η _c (2 <i>S</i>) WIDTH
• • • We do not use the follow	wing data for averages, fits, limits, etc. • • •	VALUE (MeV)	CL%	DOCUMENT ID TECNCOMMENT
7.9±4.1±2.4	12 LEE 85 CBAL $\psi' \rightarrow$ photons	• • • We do no		data for averages, fits, limits, etc. • • •
	_	<8.0	95	EDWARDS 82c CBAL e+e- → γX
$\Gamma(J/\psi(15)\pi^{+}\pi^{-}\pi^{0})/\Gamma_{to}$				
VALUE CL%			$\eta_c(2$	2S) DECAY MODES
<0.015 90	BARATE 81 SPEC 190 GeV π^- Be \rightarrow $2\pi 2\mu$,,,	•
		NA-4-		Fraction (Γ_I/Γ)
	•	ncer- Mode		
⁹ Estimated using B(ψ (25) - tainty in the ψ (25) decay.	$\rightarrow \gamma \chi_{c2}(1P)$) = 0.078; the errors do not contain the u	rcer- F- hadrons	· ************************************	seen
9 Estimated using B($\psi(2S)$ - tainty in the $\psi(2S)$ decay. 10 Restated by us using B(χ_c	•	rcer- F- hadrons	i	
⁹ Estimated using B($\psi(2S)$) tainty in the $\psi(2S)$ decay. 10 Restated by us using B(χ_0)	$\rightarrow \gamma X_{c2}(1P)) = 0.078$; the errors do not contain the u $c_{c2}(1P) \rightarrow J/\psi(1S)\gamma)B(J/\psi(1S) \rightarrow e^+e^-) = 0.00$	Γ ₁ hadrons		
9 Estimated using B($\psi(2S)$ tainty in the $\psi(2S)$ decay. 10 Restated by us using B($\chi_{c0.0007}$. 11 Assuming Isotropic $\chi_{c2}(1F)$	$ ightarrow \gamma X_{c2}(1P))=0.078$; the errors do not contain the u $_{c2}(1P) ightarrow J/\psi(1S)\gamma) B(J/\psi(1S) ightarrow e^+e^-)=0.00$ $P) ightarrow \gamma \gamma$ distribution.	Γ ₁ hadrons		
9 Estimated using B($\psi(2S)$ tainty in the $\psi(2S)$ decay. 10 Restated by us using B(χ_c 0.0007. 11 Assuming isotropic $\chi_{c2}(1F)$ LEE 85 result is calculated	$ ightarrow \gamma \chi_{c2}(1P)) = 0.078$; the errors do not contain the u $c_2(1P) \rightarrow J/\psi(1S)\gamma) B(J/\psi(1S) \rightarrow e^+e^-) = 0.00$ $P) \rightarrow \gamma \gamma$ distribution. using $B(\psi(2S) \rightarrow \gamma \chi_{c2}(1P)) = 0.078 \pm 0.008$.	Rest Γ_1 hadrons Γ_2 $\gamma\gamma$	η _C (25)	seen BRANCHING RATIOS
9 Estimated using B($\psi(2S)$ tainty in the $\psi(2S)$ decay. 10 Restated by us using B(χ_c 0.0007. 11 Assuming isotropic $\chi_{c2}(1F)$ LEE 85 result is calculated	$ ightarrow \gamma X_{c2}(1P))=0.078$; the errors do not contain the u $_{c2}(1P) ightarrow J/\psi(1S)\gamma) B(J/\psi(1S) ightarrow e^+e^-)=0.00$ $P) ightarrow \gamma \gamma$ distribution.	ncer- 85 ± Γ_1 hadrons Γ_2 $\gamma\gamma$ $\Gamma(\text{hadrons})/\Gamma$	η _C (25)	Seen BRANCHING RATIOS
9 Estimated using B($\psi(2S)$ tainty in the $\psi(2S)$ decay. 10 Restated by us using B(χ_c 0.0007. 11 Assuming isotropic $\chi_{c2}(1F)$ LEE 85 result is calculated	$ ightarrow \gamma \chi_{c2}(1P))=0.078$; the errors do not contain the u $c_{c2}(1P) ightarrow J/\psi(1S)\gamma) B(J/\psi(1S) ightarrow e^+e^-)=0.00$ $e^-P) ightarrow \gamma \gamma$ distribution. using $B(\psi(2S) ightarrow \gamma \chi_{c2}(1P))=0.078 \pm 0.008$.	ncer- 85 ± Γ_1 hadrons Γ_2 $\gamma\gamma$ $\Gamma(\text{hadrons})/\Gamma$ YALUE	η _C (25)	BRANCHING RATIOS DOCUMENT ID TECN COMMENT
⁹ Estimated using $B(\psi(2S))$ tainty in the $\psi(2S)$ decay. 10 Restated by us using $B(X_0)$ 0.0007. 11 Assuming isotropic $X_{C2}(1F)$ 12 LEE 85 result is calculated $\Gamma(\gamma J/\psi(1S))/\Gamma_{total}$ VALUE EVTS	$ ightarrow \gamma \chi_{c2}(1P)) = 0.078$; the errors do not contain the u $c_{c2}(1P) ightarrow J/\psi(1S)\gamma)B(J/\psi(1S) ightarrow e^+e^-) = 0.00$ $e^+e^-) = 0.00$ $\gamma \gamma$ distribution. using $B(\psi(2S) ightarrow \gamma \chi_{c2}(1P)) = 0.078 \pm 0.008$ RADIATIVE DECAYS	Γ ₁ hadrons Γ ₂ γγ	η _C (25)	BRANCHING RATIOS DOCUMENT ID TECN COMMENT EDWARDS 82C CBAL $e^+e^- \rightarrow \gamma X$
⁹ Estimated using $B(\psi(2S))$ tainty in the $\psi(2S)$ decay. 10 Restated by us using $B(X_c)$ 0.0007. 11 Assuming isotropic $X_{C2}(1F)$ 12 LEE 85 result is calculated $\Gamma(\gamma J/\psi(1S))/\Gamma_{total}$ VALUE EVTS 0.138±0.011 OUR AVERAGE	$ ightarrow \gamma \chi_{c2}(1P)) = 0.078$; the errors do not contain the u $c_{c2}(1P) ightarrow J/\psi(1S)\gamma)B(J/\psi(1S) ightarrow e^+e^-) = 0.00$ $P) ightarrow \gamma \gamma$ distribution. using $B(\psi(2S) ightarrow \gamma \chi_{c2}(1P)) = 0.078 \pm 0.008$ RADIATIVE DECAYS	ncer- 85 ± Γ_1 hadrons Γ_2 $\gamma\gamma$ $\Gamma(\text{hadrons})/\Gamma$ YALUE	η _C (25)	BRANCHING RATIOS DOCUMENT ID TECN COMMENT
9 Estimated using B($\psi(2S)$ tainty in the $\psi(2S)$ decay. 10 Restated by us using B(χ 0.0007. 11 Assuming isotropic $\chi_{c2}(1f$ 12 LEE 85 result is calculated $\Gamma(\gamma J/\psi(1S))/\Gamma_{total}$ VALUE EVIS 0.138 ± 0.011 OUR AVERAGE 0.124 ± 0.015	$ ightarrow \gamma \chi_{c2}(1P)) = 0.078$; the errors do not contain the u $c_{c2}(1P) ightarrow J/\psi(1S)\gamma)B(J/\psi(1S) ightarrow e^+e^-) = 0.00$ $ ho ightarrow \gamma \gamma$ distribution. using $B(\psi(2S) ightarrow \gamma \chi_{c2}(1P)) = 0.078 \pm 0.008$. - RADIATIVE DECAYS	Γ ₁ hadrons Γ ₂ γγ	η _C (25)	BRANCHING RATIOS DOCUMENT ID TECN COMMENT EDWARDS 82C CBAL $e^+e^- \rightarrow \gamma X$
⁹ Estimated using B($\psi(2S)$ tainty in the $\psi(2S)$ decay. ¹⁰ Restated by us using B(χ 0.0007. ¹¹ Assuming isotropic $\chi_{C2}(1F)$ ¹² LEE 85 result is calculated $\Gamma(\gamma J/\psi(1S))/\Gamma_{total}$ <u>YALUE</u> EYTS 0.138±0.011 OUR AVERAGE 0.124±0.015 0.162±0.028 479	$ ightarrow \gamma \chi_{c2}(1P)) = 0.078$; the errors do not contain the u $c_{c2}(1P) ightarrow J/\psi(1S)\gamma)B(J/\psi(1S) ightarrow e^+e^-) = 0.00$ $e^+e^-) = 0.00$ $e^+e^-) ightarrow \gamma \gamma$ distribution. using $B(\psi(2S) ightarrow \gamma \chi_{c2}(1P)) = 0.078 \pm 0.008$ RADIATIVE DECAYS	ncer- 85 ± Γ_1 hadrons Γ_2 $\gamma\gamma$ $\Gamma(\text{hadrons})/\Gamma$ $\frac{\text{YALUE}}{\text{seen}}$ $\Gamma(\gamma\gamma)/\Gamma_{\text{total}}$ $\frac{\text{YALUE}}{\text{YALUE}}$	η _C (25)	Seen BRANCHING RATIOS DOCUMENT ID IECN COMMENT EDWARDS 82C CBAL $e^+e^- \rightarrow \gamma X$
⁹ Estimated using B($\psi(2S)$ tainty in the $\psi(2S)$ decay. 10 Restated by us using B(χ 0.0007. 11 Assuming isotropic $\chi_{C2}(1F)$ 12 LEE 85 result is calculated $\Gamma(\gamma J/\psi(1S))/\Gamma_{total}$ <u>VALUE</u> <u>EVTS</u> 0.138±0.011 OUR AVERAGE 0.124±0.015 0.162±0.028 479 0.14±0.04	$ ightarrow \gamma \chi_{c2}(1P)) = 0.078$; the errors do not contain the u $c_{c2}(1P) ightarrow J/\psi(1S)\gamma)B(J/\psi(1S) ightarrow e^+e^-) = 0.00$ $e^+e^-) = 0.00$ $rac{\gamma}{\gamma}$ distribution. using $B(\psi(2S) ightarrow \gamma \chi_{c2}(1P)) = 0.078 \pm 0.008$ RADIATIVE DECAYS	ncer- 85 ± Γ_1 hadrons Γ_2 $\gamma\gamma$ $\Gamma(\text{hadrons})/\Gamma$ $\frac{\text{YALUE}}{\text{seen}}$ $\Gamma(\gamma\gamma)/\Gamma_{\text{total}}$ $\frac{\text{YALUE}}{\text{YALUE}}$	η _C (25)	SEEN BRANCHING RATIOS DOCUMENT ID TECN COMMENT EDWARDS 82C CBAL e+e-→ γX DOCUMENT ID TECN COMMENT
⁹ Estimated using B($\psi(25)$ tainty in the $\psi(25)$ decay. 10 Restated by us using B(χ , 0.0007. 11 Assuming isotropic $\chi_{c2}(1f$ 12 LEE 85 result is calculated $\Gamma(\gamma J/\psi(1S))/\Gamma_{total}$ YALUE 0.138 ± 0.011 OUR AVERAGE 0.124 ± 0.015 0.162 ± 0.028 0.14 ± 0.04 0.18 ± 0.05	$ ightarrow \gamma \chi_{c2}(1P)) = 0.078$; the errors do not contain the u $c_{c2}(1P) ightarrow J/\psi(1S)\gamma)B(J/\psi(1S) ightarrow e^+e^-) = 0.00$ $e^+e^-) = 0.00$ $e^+e^-) = 0.008$. P) $ ightarrow \gamma \gamma$ distribution. using $B(\psi(2S) ightarrow \gamma \chi_{c2}(1P)) = 0.078 \pm 0.008$. PADIATIVE DECAYS Fig. 13 OCCUMENT ID TECN COMMENT GAISER 86 CBAL $\psi(2S) ightarrow \gamma \chi_{c2}$ 13 HIMEL 80 MRK2 $\psi(2S) ightarrow \gamma \chi_{c2}$ 13 BRANDELIK 798 DASP $\psi(2S) ightarrow \gamma \chi_{c2}$ 13 BRANTEL 788 CNTR $\psi(2S) ightarrow \gamma \chi_{c2}$	ncer- 85 ± Γ_1 hadrons Γ_2 $\gamma\gamma$ $\Gamma(\text{hadrons})/\Gamma$ $\frac{\sqrt{ALUE}}{\text{seen}}$ $\Gamma(\gamma\gamma)/\Gamma_{\text{total}}$ $\frac{\sqrt{ALUE}}{\sqrt{ALUE}}$ • • • We do no	η _C (25)	BRANCHING RATIOS DOCUMENT ID IECN COMMENT EDWARDS 82C CBAL e ⁺ e ⁻ → γX DOCUMENT ID IECN COMMENT data for averages, fits, limits, etc. • • •
9 Estimated using B($\psi(2S)$ tainty in the $\psi(2S)$ decay. 10 Restated by us using B(χ 0.0007. 11 Assuming isotropic $\chi_{C2}(1F)$ 12 LEE 85 result is calculated Γ($\gamma J/\psi(1S)$)/Γτοτιαί VALUE EYTS 0.138 ±0.011 OUR AVERAGE 0.124 ±0.015 0.162 ±0.028 479 0.14 ±0.04 0.18 ±0.05 0.13 ±0.03 0.13 ±0.08	$ ightarrow \gamma \chi_{c2}(1P)) = 0.078$; the errors do not contain the u $c_{c2}(1P) ightarrow J/\psi(1S)\gamma) B(J/\psi(1S) ightarrow e^+e^-) = 0.00$ $e^+e^-) = 0.00$ $e^+e^-) = 0.008$. Using $g(\psi(2S) ightarrow \gamma \chi_{c2}(1P)) = 0.078 \pm 0.008$. PADIATIVE DECAYS FECH SOLUTION TECH SOLUTION TO SUMMENT OF SUMENT OF SUMMENT OF SUMENT OF SUMENT OF SUMENT OF SUMMENT OF SUMENT OF SUMMENT OF SUMMENT OF	ncer- 85 ± Γ_1 hadrons Γ_2 $\gamma\gamma$ $\Gamma(\text{hadrons})/\Gamma$ $\frac{\sqrt{ALUE}}{\text{seen}}$ $\Gamma(\gamma\gamma)/\Gamma_{\text{total}}$ $\frac{\sqrt{ALUE}}{\sqrt{ALUE}}$ • • • We do no	n _C (25)	BRANCHING RATIOS DOCUMENT ID IECN COMMENT EDWARDS 82C CBAL e ⁺ e ⁻ → γX DOCUMENT ID IECN COMMENT data for averages, fits, limits, etc. • • •
9 Estimated using B($\psi(2S)$ tainty in the $\psi(2S)$ decay. 10 Restated by us using B(χ 0.0007. 11 Assuming isotropic $\chi_{C2}(1F$ 12 LEE 85 result is calculated $\Gamma(\gamma J/\psi(1S))/\Gamma_{total}$ YALUE EYTS 0.138±0.011 OUR AVERAGE 0.124±0.015 0.162±0.028 479 0.14 ±0.04 0.18 ±0.05 0.13 ±0.03 0.13 ±0.03 0.13 ±0.08 ••• We do not use the folio	$ ightarrow \gamma \chi_{c2}(1P)) = 0.078$; the errors do not contain the u $c_{c2}(1P) ightarrow J/\psi(1S)\gamma) B(J/\psi(1S) ightarrow e^+e^-) = 0.00$ $e^+e^-) = 0.00$ $e^+e^-) = 0.008$. Using $g(\psi(2S) ightarrow \gamma \chi_{c2}(1P)) = 0.078 \pm 0.008$. PADIATIVE DECAYS FEAN TOOMS. TECHNOLOGY TE	ncer- 85 ± $ \Gamma_{1} \text{ hadrons} $ $ \Gamma_{2} \gamma \gamma $ $ \Gamma(\text{hadrons})/\Gamma $ $ \frac{YALVE}{\text{seen}} $ $ \Gamma(\gamma \gamma)/\Gamma_{\text{total}} $ $ \frac{VALUE}{VALUE} $ • • We do not <0.01	η _C (25) total SL3 It use the following 90	BRANCHING RATIOS DOCUMENT ID IECN COMMENT EDWARDS 82C CBAL e ⁺ e ⁻ → γX DOCUMENT ID IECN COMMENT data for averages, fits, limits, etc. • • • LEE 85 CBAL ψ' → photons (2S) REFERENCES
⁹ Estimated using B($\psi(2S)$ tainty in the $\psi(2S)$ decay. 10 Restated by us using B(χ 0.0007. 11 Assuming isotropic $\chi_{C2}(1F)$ 12 LEE 85 result is calculated $\Gamma(\gamma J/\psi(1S))/\Gamma_{total}$ VALUE EVTS 0.138±0.011 OUR AVERAGE 0.124±0.015 0.162±0.028 479 0.14±0.04 0.18±0.05 0.13±0.03 0.13±0.08 • • We do not use the follood.28±0.13	$ ightarrow \gamma \chi_{c2}(1P)) = 0.078$; the errors do not contain the u $c_{c2}(1P) ightarrow J/\psi(1S)\gamma) B(J/\psi(1S) ightarrow e^+e^-) = 0.00$ $c_{c2}(1P) ightarrow J/\psi(1S)\gamma) B(J/\psi(1S) ightarrow e^+e^-) = 0.00$ $c_{c2}(1P) ightarrow \gamma \gamma$ distribution. Using $B(\psi(2S) ightarrow \gamma \chi_{c2}(1P)) = 0.078 \pm 0.008$. $c_{c2}(1P) ightarrow 0.008$.	ncer- 85 ± $ \Gamma_{1} \text{ hadrons} $ $ \Gamma_{2} \gamma \gamma $ $ \Gamma(\text{hadrons})/\Gamma $ $ \frac{13}{\Gamma} $ seen $ \Gamma(\gamma \gamma)/\Gamma_{\text{total}} $ $ \frac{13}{VALUE} $ • • • We do not $ <0.01 $ LEE $ \Gamma(\gamma \gamma) = \Gamma(\gamma) = \Gamma$	nc(25) total CLN t use the following 90 7c(BRANCHING RATIOS DOCUMENT ID IECN COMMENT EDWARDS 82C CBAL e ⁺ e ⁻ → γX DOCUMENT ID IECN COMMENT data for averages, fits, limits, etc. • • • LEE 85 CBAL ψ' → photons
9 Estimated using B($\psi(25)$ tainty in the $\psi(25)$ decay. 10 Restated by us using B(χ , 0.0007. 11 Assuming isotropic $\chi_{c2}(1f$ 12 LEE 85 result is calculated $\Gamma(\gamma J/\psi(1S))/\Gamma_{total}$ $\frac{VALUE}{2}$ 0.138 ±0.011 OUR AVERAGE 0.124±0.015 0.16±0.028 479 0.14±0.04 0.18±0.05 0.13±0.03 0.13±0.08 0 • • We do not use the folio 0.28±0.13 13 Estimated using B($\psi(25)$	$ ightarrow \gamma \chi_{c2}(1P)) = 0.078$; the errors do not contain the u $c_{c2}(1P) ightarrow J/\psi(1S)\gamma) B(J/\psi(1S) ightarrow e^+e^-) = 0.00$ $e^+e^-) = 0.00$ $e^+e^-) = 0.008$. Using $g(\psi(2S) ightarrow \gamma \chi_{c2}(1P)) = 0.078 \pm 0.008$. PADIATIVE DECAYS FEAN TOOMS. TECHNOLOGY TE	ncer- 85 ± $ \Gamma_{1} \text{ hadrons} $ $ \Gamma_{2} \gamma \gamma $ $ \Gamma(\text{hadrons})/\Gamma $ $ \frac{13}{\Gamma} $ seen $ \Gamma(\gamma \gamma)/\Gamma_{\text{total}} $ $ \frac{13}{VALUE} $ • • • We do not $ <0.01 $ LEE $ \Gamma(\gamma \gamma) = \Gamma(\gamma) = \Gamma$	Total CLN St use the following 90 7ct SLAC 282 PRL 48 70	BRANCHING RATIOS DOCUMENT ID IECN COMMENT EDWARDS 82C CBAL e ⁺ e ⁻ → γX DOCUMENT ID IECN COMMENT data for averages, fits, limits, etc. • • • LEE 85 CBAL ψ' → photons (2S) REFERENCES (SLAC
9 Estimated using B($\psi(2S)$ tainty in the $\psi(2S)$ decay. 10 Restated by us using B(χ 0.0007. 11 Assuming isotropic $\chi_{C2}(1F)$ 12 LEE 85 result is calculated F($\gamma J/\psi(1S)$)/Ftotal VALUE EYTS 0.138±0.011 OUR AVERAGE 0.124±0.015 0.162±0.028 479 0.14 ±0.04 0.18 ±0.05 0.13 ±0.03 0.13 ±0.03 0.13 ±0.03 0.13 ±0.03 0.13 ±0.03 0.13 ±0.03 0.13 ±0.03 0.13 ±0.03 0.13 ±0.03 0.13 ±0.03 0.13 ±0.03 0.13 ±0.03 0.13 ±0.03 0.13 ±0.03 0.13 ±0.03 0.13 ±0.03 0.14 ±0.04 0.15 ±0.05 0.17 ±0.05 0.18 ±0.05 0.19 ±0.05 0.28 ±0.13	$ ightarrow \gamma \chi_{c2}(1P)) = 0.078$; the errors do not contain the ucc2(1P) $ ightarrow J/\psi(1S)\gamma)B(J/\psi(1S) ightarrow e^+e^-) = 0.00$ $ ightarrow \gamma \gamma$ distribution. using $B(\psi(2S) ightarrow \gamma \chi_{c2}(1P)) = 0.078 \pm 0.008$. - RADIATIVE DECAYS	ncer- 85 ± Γ_1 hadrons Γ_2 $\gamma \gamma$ F (hadrons)/ Γ YALUE • • • We do not considered to the second	7c(25) total SLM SLM 90 7cl SLAC 282 PRL 48 70 OTHE	BRANCHING RATIOS DOCUMENT ID IECN COMMENT EDWARDS 82C CBAL e ⁺ e ⁻ → γX DOCUMENT ID IECN COMMENT data for averages, fits, limits, etc. • • • LEE 85 CBAL ψ' → photons (2S) REFERENCES +Partidge, Peck+ (CIT, HARV, PRIN, STAN, SLACER RELATED PAPERS
9 Estimated using B($\psi(2S)$ tainty in the $\psi(2S)$ decay. 10 Restated by us using B(χ , 0.0007. 11 Assuming isotropic $\chi_{C2}(1F)$ 12 LEE 85 result is calculated F(γ J/ ψ (1S))/ Γ total WALUE	$\rightarrow \gamma \chi_{c2}(1P)) = 0.078; \text{ the errors do not contain the u}$ $c_{c2}(1P) \rightarrow J/\psi(1S)\gamma)B(J/\psi(1S) \rightarrow e^+e^-) = 0.00$ $P) \rightarrow \gamma \gamma \text{ distribution.}$ $\text{using } B(\psi(2S) \rightarrow \gamma \chi_{c2}(1P)) = 0.078 \pm 0.008.$ $- \text{RADIATIVE DECAYS}$ $\frac{DOCUMENT\ ID}{13\ \text{OREGLIA}} = 86\ \text{CBAL}\ \psi(2S) \rightarrow \gamma \chi_{c2}$ $13\ \text{OREGLIA} = 82\ \text{CBAL}\ \psi(2S) \rightarrow \gamma \chi_{c2}$ $13\ \text{HIMEL} = 80\ \text{MRK2}\ \psi(2S) \rightarrow \gamma \chi_{c2}$ $13\ \text{BRANDELIK} 798\ \text{DASP}\ \psi(2S) \rightarrow \gamma \chi_{c2}$ $13\ \text{BARTEL} 798\ \text{CNTR}\ \psi(2S) \rightarrow \gamma \chi_{c2}$ $13\ \text{TANENBAUM} 78\ \text{MRK1}\ \psi(2S) \rightarrow \gamma \chi_{c2}$ wing data for averages, fits, limits, etc. • • • $13\ \text{BIDDICK} 77\ \text{CNTR}\ \psi(2S) \rightarrow \gamma \chi_{c2}$ $13\ \text{BIDDICK} 77\ \text{CNTR}\ \psi(2S) \rightarrow \gamma \chi_{c2}$	ncer- 85 ± Γ_1 hadrons Γ_2 $\gamma \gamma$ F (hadrons)/ Γ YALVE BEEN F ($\gamma \gamma$)/ Γ_{total} YALVE • • • We do not consider the second sec	Total SLAC 282 PRL 48 70 PR D25 2259 SLAC Summer Inst.	BRANCHING RATIOS DOCUMENT ID IECN COMMENT EDWARDS 82C CBAL e ⁺ e ⁻ → γX DOCUMENT ID IECN COMMENT data for averages, fits, limits, etc. • • • LEE 85 CBAL ψ' → photons (2S) REFERENCES +Partridge, Peck+ (CIT, HARV, PRIN, STAN, SLACER RELATED PAPERS +Partridge+ (SLAC, CIT, HARV, PRIN, STAN, SLACER RELATED PAPERS +Partridge+ (SLAC, CIT, HARV, PRIN, STAN, SLACER RELATED PAPERS
9 Estimated using B($\psi(25)$ tainty in the $\psi(25)$ decay. 10 Restated by us using B(χ , 0.007. 11 Assuming isotropic $\chi_{c2}(1f$ 12 LEE 85 result is calculated $\Gamma(\gamma J/\psi(1S))/\Gamma_{total}$ VALUE EVIS 0.138 ± 0.011 OUR AVERAGE 0.124 ± 0.015 0.16 ± 0.020 0.14 ± 0.04 0.18 ± 0.05 0.13 ± 0.03 0.13 ± 0.03 0.13 ± 0.08 0 • • We do not use the folio 0.28 ± 0.13 13 Estimated using B($\psi(2S)$	$ ightarrow \gamma \chi_{c2}(1P)) = 0.078$; the errors do not contain the ucc2(1P) $ ightarrow J/\psi(1S)\gamma)B(J/\psi(1S) ightarrow e^+e^-) = 0.00$ $ ightarrow \gamma \gamma$ distribution. using $B(\psi(2S) ightarrow \gamma \chi_{c2}(1P)) = 0.078 \pm 0.008$. - RADIATIVE DECAYS	Γ hadrons Γ hadrons Γ γ γ γ γ γ γ γ γ γ	η _C (25) total SLM SLM 90 7c SLAC 282 PRL 48 70 OTHE PR D25 2259 SLAC Summer Inst.	BRANCHING RATIOS DOCUMENT ID IECN COMMENT EDWARDS 82C CBAL e+e-→ γX DOCUMENT ID IECN COMMENT data for averages, fits, limits, etc. • • • LEE 85 CBAL ψ'→ photons (2S) REFERENCES +Partridge, Peck+ (CIT, HARV, PRIN, STAN, SLACER RELATED PAPERS +Partridge+ (SLAC, CIT, HARV, PRIN, STAN, STAN)

 $\psi(2S)$

ψ ((25)		IG()	PC) = 0	-(1)	
ψ(25) MASS							
VALUE	(MeV)	EVTS	DOCUMENT ID		TECN	COMMENT	
3686.0	0±0.09 OUR AV	/ERAGE					•
3686.0	2±0.09±0.27		ARMSTRONG	93B	E760	$\overline{p}p \rightarrow e^+e^-$	
3686.0	0 ± 0.10	413	ZHOLENTZ	80	OLYA	e ⁺ e ⁻	
	We do not use t	he following	data for average	i, fits	i, limits,	etc. • • •	
3684	±2		GRIBUSHIN	96	FMPS	515 π^- Be $\rightarrow 2\mu X$	-
3683	±5	77	ANTONIAZZI	94	E705	300 π^{\pm} , pLi \rightarrow $J/\psi \pi^{+} \pi^{-} X$	

$m_{\psi(25)} - m_{J/\psi(15)}$

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
509.07±0.13 OUR AVERAGE				
589.7 ±1.2				190 π^- Be $\rightarrow 2\mu$
589.07±0.13	¹ ZHOLENTZ	80	OLYA	e ⁺ e ⁻
588.7 ±0.8	LUTH	75	MRK1	

¹ Redundant with data in mass above.

ψ(25) WIDTH

VALUE (keV)	DOCUMENT ID	TECN	COMMENT
277±31 OUR AVERAGE	Error includes scale factor of :	1.1.	
306 ± 36 ± 16	ARMSTRONG 93B	E760	$\overline{p}p \rightarrow e^+e^-$
243 ± 43	² PDG 92	RVUE	

 $^{^2}$ Uses F(ee) from ALEXANDER 89 and B(ee) = (88 \pm 13) \times 10 $^{-4}$ from FELDMAN 77.

♦(25) DECAY MODES

	Mode	Fraction (Γ_I/Γ)	Scale factor/ Confidence level
$\overline{\Gamma_1}$	hadrons	(98.10±0.30) %	
Γ_2^-	virtual $\gamma \rightarrow hadrons$	(2.9 ±0.4) %	
Гз	e+ e-	(8.5 ±0.7) × 10	₎ –3
Γ4	$\mu^+\mu^-$	$(7.7 \pm 1.7) \times 10$	₎ –3
	Decays into $J/\psi(1S)$	and anything	
Γ_5	$J/\psi(1S)$ anything	(54.2 ±3.0)%	
	$J/\psi(1S)$ neutrals	(22.8 ±1.7)%	
۲,	$J/\psi(1S)\pi^+\pi^-$	(30.2 ±1.9)%	
Γ8	$J/\psi(1S)\pi^0\pi^0$	(17.9 ±1.8)%	
Γq	$J/\psi(1S)\eta$	(2.7 ±0.4) %	S=1.7
Γ10	$J/\psi(15)\pi^0$	(9.7 ±2.1) × 10) -4
Γ11	$J/\psi(1S)\mu^+\mu^-$	(10.0 ±3.3) × 10	₎ –3
	Hadronic de	cays	
Γ ₁₂	$3(\pi^{+}\pi^{-})\pi^{0}$	(3.5 ±1.6) × 10	₎ –3
Γ ₁₃	$2(\pi^{+}\pi^{-})\pi^{0}$	(3.0 ±0.8) × 10)-3
Γ ₁₄	$\pi^+\pi^-K^+K^-$	(1.6 ±0.4) × 10	₎ –3
Γ15	$\pi^+\pi^-p\overline{p}$	(8.0 ±2.0) × 10	
Γ ₁₆	$K^{+}\overline{K}^{*}(892)^{0}\pi^{-}+\text{c.c.}$	(6.7 ±2.5) × 10	
Γ ₁₇	$2(\pi^{+}\pi^{-})$	(4.5 ±1.0) × 10	
Γ ₁₈	$\rho^{0}\pi^{+}\pi^{-}$	(4.2 ±1.5)×10	
Γ19	Pρ	(1.9 ±0.5) × 10	₎ –4
Γ ₂₀	$3(\pi^{+}\pi^{-})$	(1.5 ±1.0) × 10	₎ -4
Γ21	$\vec{p} \rho \pi^0$	(1.4 ±0.5) × 10	₎ –4
Γ22	K+K-	(1.0 ±0.7)×10	
F ₂₃	$\pi^+\pi^-\pi^0$	(9 ±5)×10	
Γ24	$ ho\pi$	< 8.3 × 10) ⁻⁵ CL=90%
Γ ₂₅	$\pi_{-}^{+}\pi^{-}$	(8 ±5)×10	₎ –5
Γ_{26}	$\Lambda \overline{\Lambda}$	< 4 × 10	
Γ_{27}	<u>=-</u> =+	< 2 × 10	
Γ ₂₈	$K^+K^-\pi^0$	< 2.96 × 10	0 ⁻⁵ CL=90%
Γ ₂₉	$K^{+}\overline{K}^{*}(892)^{-}$ + c.c.	< 5.4 × 10) ⁻⁵ CL=90%

		Radiative decays			
Γ ₃₀	$\gamma \chi_{c0}(1P)$	(9.3	±0.9) %	
	$\gamma \chi_{c1}(1P)$	(8.7	±0.8) %	
Γ ₃₂	$\gamma \chi_{c2}(1P)$	(7.8	± 0.8) %	
Γ33	$\gamma \eta_c(15)$	(2.8	± 0.6	$) \times 10^{-3}$	
Γ ₃₄	$\gamma \eta_{c}(2S)$				
Γ35	$\gamma \pi^0$				
	$\gamma \eta'(958)$	< 1.1	l	× 10 ⁻³	CL=90%
Γ37	$\gamma\eta$				
Γ ₃₈	$\gamma\gamma$	< 1.6	5	× 10 ⁻⁴	CL=90%
Γ39	$\gamma \eta (1440) \rightarrow \gamma K \overline{K} \pi$	< 1.2	2	× 10 ⁻⁴	CL=90%

Mode needed for fitting purposes

Γ ₄₀	1 other fit modes	(22.4 ±3.3) %
. 40	21 021101 112 1110200	(, , ,

CONSTRAINED FIT INFORMATION

An overall fit to 9 branching ratios uses 17 measurements and one constraint to determine 8 parameters. The overall fit has a $\chi^2=8.9$ for 10 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\langle \delta x_i \delta x_j \rangle / (\delta x_i \cdot \delta x_j)$, in percent, from the fit to the branching fractions, $x_i \equiv \Gamma_i / \Gamma_{\text{total}}$. The fit constrains the x_i whose labels appear in this array to sum to one

<i>x</i> 8	25						
<i>X</i> 9	2	-8					
<i>×</i> 11	19	5	0				
×30	0	0	0	0			
×31	2	-5	-1	0	0		
×32	1	-2	0	0	0	0	
×40	-75	-66	-10	-24	-26	-22	-23
	Х7	x ₈	Χq	<i>X</i> 11	<i>x</i> ₃₀	X31	X32

♦(25) PARTIAL WIDTHS

Γ(hadrons)					Γ ₁
VALUE (keV)		DOCUMENT ID		TECN	COMMENT
• • • We do not	use the followin	ig data for average	s, flts	s, limits,	etc. • • •
224±56		LUTH	75	MRK1	e+ e-
Γ(e ⁺ e ⁻)					r ₃
VALUE (keV)		DOCUMENT ID		TECN	COMMENT
2.14±0.21		ALEXANDER	89	RVUE	See 7 mIni-review
• • • We do not	use the following	ng data for average	s, fit:	s, limits,	etc. • • •
2.0 ±0.3		BRANDELIK	790	DASP	e+ e-
2.1 ±0.3		³ LUTH	75	MRK1	e ⁺ e ⁻
³ From a simult $= \Gamma(\mu^+ \mu^-).$	aneous fit to e	$^{+}e^{-},\mu^{+}\mu^{-},{ m and}$	had	ronic ch	annels assuming Γ(e ⁺ e ⁻)
$\Gamma(\gamma\gamma)$. Γ ₃₆
VALUE (eV)	<u> </u>	DOCUMENT ID		TECN	COMMENT
<43	90	BRANDELIK	790	DASP	e ⁺ e ⁻
	∳ (2	S)	/ Г (1	otal)	

This combination of a partial width with the partial width into e^+e^- and with the total width is obtained from the integrated cross section into channel, in the e^+e^- annihilation. We list only data that have not been used to determine the partial width $\Gamma(1)$ or the branching ratio $\Gamma(1)/\text{total}$.

$\Gamma(\text{hadrons}) \times \Gamma(e^+e^-)/\Gamma_{\text{tot}}$	al				$\Gamma_1\Gamma_3/\Gamma$
VALUE (keV)	DOCUMENT ID		TECN	COMMENT	
• • • We do not use the following	data for averag	es, fits	s, limits,	etc. • • •	
2.2±0.4	ABRAMS	75	MRK1	e ⁺ e ⁻	

 ψ (25)

ψ(2:	S) BRANCHING RATIOS		$\Gamma(J/\psi(1S)\eta)/\Gamma_{\text{total}}$	EVTS	DOCUMENT ID	TECN	Γ ₉ /
(hadrons)/F _{total}		Γ1/Γ	0.027 ±0.004 OUR FIT 0.027 ±0.004 OUR AVE		s scale factor of 1	.7.	
LUE	DOCUMENT ID TECN COM				below.		
981 ±0.003	⁴ LUTH 75 MRK1 e ⁺ e	_	0.025 ±0.006 0.0218±0.0014±0.0035	166 386	HIMEL OREGLIA	80 MRK2 80 CBAL	e+e- +e-→
$(virtual_{oldsymbol{\gamma}} ightarrow hadrons)/\Gamma_{total}$	ni .	Γ ₂ /Γ	•				$J/\psi 2\gamma$
LUE	DOCUMENT ID TECN COMI		0.036 ±0.005 • • • We do not use the f	164	BARTEL	78B CNTR	
029±0.004	⁵ LUTH 75 MRK1 e ⁺ e	_	0.032 ±0.010 ±0.002	_	14 ARMSTRONG		
(e ⁺ e [−])/Γ _{total}		Γ ₃ /Γ	0.035 ±0.009		14 BRANDELIK		
ALUE (units 10 ⁻⁴)	DOCUMENT ID TECN COM	MENT	0.040 0.000		14	4 74 14014	$J/\psi 2\gamma$
± 7 OUR AVERAGE	6.5		0.043 ±0.008	44	¹⁴ TANENBAUM	1 76 MRK1	e · e
± 5±7 ±13	⁶ ARMSTRONG 97 E760 pp - ⁷ FELDMAN 77 RVUE e ⁺ e		WEIGHTED AVERAGE				
	I LEDWAR II ROL E E		0.027±0.004 (Error scal	led by 1.6)			
$(\mu^+\mu^-)/\Gamma_{\text{total}}$		Γ ₄ /Γ	1	Value	e above of weight	tod augrage au	
LUE (units 10 ⁻⁴)		MENT	\wedge	and s	es above of weight cale factor are ba	sed upon the d	data in
±17	⁸ HILGER 75 SPEC e ⁺ e	, 		this id	deogram only. The the same as our	ey are not nece 'best' values.	es-
$(\mu^+\mu^-)/\Gamma(e^+e^-)$		Γ_4/Γ_3		obtair	ned from a least-s	quares constra	
LUE .	DOCUMENT ID TECN COMI				ng measurements tities as additional		ed)
• We do not use the following	ng data for averages, fits, limits, etc.	• • •		1			
9±0.16	BOYARSKI 75C MRK1 e+e	-		1			
Includes cascade decay into J	l/ψ(1 S).			1			
Included in $\Gamma(\text{hadrons})/\Gamma_{\text{tota}}$	·		- A A A A A A	1			
Using B $(J/\psi \rightarrow e^+e^-) =$	0.0599+-0.0025 and B($\psi(25) \rightarrow J$	$I/\psi(15)$ anything $)=$					γ^2
0.04. From an overall fit assuming	equal partial widths for e^+e^- and	u ⁺ u [−] . For a mea-	- 1		· HIMEL	80 MRK2	0.1
surement of the ratio see the	e entry $\Gamma(\mu^+\mu^-)/\Gamma(e^+e^-)$ below.		- - - - - - - - - -		OREGLIA BARTEL	80 CBAL	1.6
HILGER 75, BURMESTER 7	7.				BARTEL	78B CNTR_	5.2
Restated by us using $B(\psi(25))$	$) \rightarrow J/\psi(1S)$ anything) = 0.55.			AL AL	(Conf	fidence Level =	
DECAYS II	NTO $J/\psi(1S)$ AND ANYTHING		0 0.01 0.02	0.03 0.04	0.05 0.06		
$J/\psi(1S)$ anything) $/\Gamma_{ m total}$	$\Gamma_5/\Gamma = (\Gamma_7 + \Gamma_8 + \Gamma_9 + 0.273)$	Γ _{α+} ↓Ω 135Γ _{α=} \/Γ			0.05 0.06		
UE	DOCUMENT ID TECH COM		$\Gamma(J/\psi(1S)\eta)/\Gamma_{\text{total}}$				
42±0.030 OUR FIT			$\Gamma(J/\psi(1S)\pi^0)/\Gamma_{\text{total}}$				-
			1 (J/10113) 18" / debal				Γ ₁₀ /
8 ±0.07 OUR AVERAGE			•				·
1 ±0.12	BRANDELIK 79C DASP e+e		VALUE (units 10-4)	EVTS	DOCUMENT ID	TECN	COMMENT
51 ±0.12	BRANDELIK 79C DASP e+e ABRAMS 75B MRK1 e+e		VALUE (units 10 ⁻⁴) 9.7±2.1 OUR AVERAGE				
51 ±0.12 57 ±0.08			VALUE (units 10-4)		DOCUMENT ID HIMEL OREGLIA	80 MRK2 80 CBAL	e+e-
$_{51}$ $_{\pm 0.12}$ $_{57}$ $_{\pm 0.08}$ $(J/\psi(1S)$ neutrals $)/\Gamma_{ m total}$		$\mu^- \rightarrow \mu^+ \mu^- X$	VALUE (units 10 ⁻⁴) 9.7±2.1 OUR AVERAGE 15 ±6 9 ±2 ±1	7 23	HIMEL OREGLIA	80 MRK2 80 CBAL	e^+e^- $\psi(25) \rightarrow$ $J/\psi 2\gamma$
51 \pm 0.12 57 \pm 0.08 $(J/\psi(15)$ neutrals)/ Γ_{total} Γ_{6}	ABRAMS 758 MRK1 e ⁺ e	$\mu^- \rightarrow \mu^+ \mu^- X$	VALUE (units 10 ⁻⁴) 9.7±2.1 OUR AVERAGE 15 ±6 9 ±2 ±1 9 The ABRAMS 758 me	7 23 asurement of F	HIMEL OREGLIA	80 MRK2 80 CBAL	$e^+e^ \psi(25) \rightarrow$ $J/\psi 2\gamma$ '6 result for Γ_6/I
88 \pm 0.07 OUR AVERAGE 51 \pm 0.12 57 \pm 0.08 $(J/\psi(1S)$ neutrals)/ Γ_{total} $\Gamma_{6/}$ 228 \pm 0.017 OUR FIT	ABRAMS 758 MRK1 e^+e^-	$\mu^- \rightarrow \mu^+ \mu^- X$	VALUE (units 10 ⁻⁴) 9.7±2.1 OUR AVERAGE 15 ±6 9 ±2 ±1	7 23 asurement of F	HIMEL OREGLIA 6/F ₅ and the TA UM 76 result is u	80 MRK2 80 CBAL	$e^+e^ \psi(25) \rightarrow$ $J/\psi 2\gamma$ '6 result for Γ_6/I
51 \pm 0.12 57 \pm 0.08 $(J/\psi(1.5)$ neutrals)/ Γ_{total} $\Gamma_{6/2}$ $\Gamma_{6/2}$ 228 \pm 0.017 OUR FIT	ABRAMS 758 MRK1 e ⁺ e /Γ = (0.9761Γ ₈ +0.715Γ ₉ +0.273) <u>DOCUMENT ID</u>	- → μ+μ-× Γ ₃₁ +0.135Γ ₃₂)/Γ	9.7 \pm 2.1 OUR AVERAGE 15 \pm 6 9 \pm 2 \pm 1 9.7he ABRAMS 758 me are not independent. To more accurate correctle 10 Using B($J/\psi \rightarrow e^+e^-$	7 23 casurement of f The TANENBA cons for angular (2) = 0.0599+	HIMEL OREGLIA 6/F ₅ and the TA UM 76 result is u distributions0.0025.	80 MRK2 80 CBAL ANENBAUM 7 Ised in the fit	$e^+e^ \psi(25) \rightarrow$ $J/\psi 2\gamma$ '6 result for Γ_6/I
51 ± 0.12 57 ± 0.08 $(J/\psi(1S) \text{ neutrals})/\Gamma_{\text{total}}$ Γ_{6} $\frac{UUF}{228 \pm 0.017 \text{ OUR FIT}}$ $(J/\psi(1S) \text{ neutrals})/\Gamma(J/\psi$ $715\Gamma_9 + 0.273\Gamma_{31} + 0.135\Gamma_{3}$	ABRAMS 758 MRK1 e^+e^- $ /\Gamma = (0.9761\Gamma_8 + 0.715\Gamma_9 + 0.273) $ DOCUMENT ID $ (1.5) \text{ anything} \qquad \Gamma_6/$ $ 2)/(\Gamma_7 + \Gamma_8 + \Gamma_9 + 0.273\Gamma_{31} + 0.13) $	$\Gamma_{31} + 0.135\Gamma_{32}$ / $\Gamma_{5} = (0.9761\Gamma_{8} +$	VALUE (units 10^{-4}) 9.7 \pm 2.1 OUR AVERAGE 15 \pm 6 9 \pm 2 \pm 1 9 The ABRAMS 758 me are not independent. 7 more accurate correctle 10 Using B($J/\psi \rightarrow e^+e^-$ 11 Not independent of the	7 23 casurement of f The TANENBA cons for angular) = 0.0599+ control TANENBAU	HIMEL OREGLIA 6/F ₅ and the TA UM 76 result is u distributions0.0025. In 76 result for F ₆	80 MRK2 80 CBAL ANENBAUM 7 Ised in the fit	$e^+e^ \psi(25) \rightarrow$ $J/\psi 2\gamma$ '6 result for Γ_6/I
51 ± 0.12 57 ± 0.08 (J/ ψ (15) neutrals)/ Γ_{total} Γ_{6} 228 ± 0.017 OUR FIT (J/ ψ (15) neutrals)/ Γ (J/ ψ 715 Γ_{9} +0.273 Γ_{31} +0.135 Γ_{3}	ABRAMS 758 MRK1 e^+e^- $/\Gamma = (0.9761\Gamma_8 + 0.715\Gamma_9 + 0.273)$ $\frac{DOCUMENT 10}{(15) \text{ anything}}$ $\Gamma_6/$	$\Gamma_{31} + 0.135\Gamma_{32}$ / $\Gamma_{5} = (0.9761\Gamma_{8} + 5\Gamma_{32})$	9.7 \pm 2.1 OUR AVERAGE 15 \pm 6 9 \pm 2 \pm 1 9The ABRAMS 758 me are not independent. The more accurate correctle 10 Using B($J/\psi \rightarrow e^+e^-$ 11 Not independent of the 12 ignoring the $J/\psi(1S)\eta$	7 23 Easurement of f The TANENBA ons for angular	HIMEL OREGLIA 6/Fs and the TA UM 76 result is u distributions. 0.0025. M 76 result for F6 γγ decays.	80 MRK2 80 CBAL ANENBAUM 7 Ised in the fit	$e^+e^ \psi(25) \rightarrow$ $J/\psi 2\gamma$ '6 result for Γ_6/I
1 ± 0.12 7 ± 0.08 $J/\psi(1S)$ neutrals)/ Γ_{total} Γ_{6} 228 ± 0.017 OUR FIT $J/\psi(1S)$ neutrals)/ $\Gamma(J/\psi$ 715 Γ_{9} +0.273 Γ_{31} +0.135 Γ_{3}	ABRAMS 758 MRK1 $e^+e^ /\Gamma = (0.9761\Gamma_8 + 0.715\Gamma_9 + 0.273\Gamma_{0.00000000000000000000000000000000000$	Γ_{31} +0.135 Γ_{32})/Γ Γ_{5} = (0.9761 Γ_{8} + 15 Γ_{32}) MENT	9.7±2.1 OUR AVERAGE 15 ±6 9 ±2 ±1 9 The ABRAMS 758 me are not Independent. The more accurate corrects and Using $B(J/\psi \rightarrow e^+e^-11)$ Not independent of the 12 Ignoring the $J/\psi(1.5)\eta$ 13 Using $B(J/\psi(1.5) \rightarrow J)$ 13 Using $B(J/\psi(1.5) \rightarrow J)$	7 23 casurement of f The TANENBA ons for angular f = TANENBAUP f = TANENBAUP f and f = f = f = 0.01 f = 0.01	HIMEL OREGLIA $_6/\Gamma_5$ and the TA UM 76 result is u distributions0.0025. $_4$ 76 result for $_6$ $_{77}$ decays.	80 MRK2 80 CBAL ANENBAUM 7 Ised in the fit	$e^+e^ \psi(25) \rightarrow$ $J/\psi 2\gamma$ '6 result for Γ_6/V
1 \pm 0.12 17 \pm 0.08 $J/\psi(1S)$ neutrals)/ Γ_{total} Γ_{6} 10E 128 \pm 0.017 OUR FIT $J/\psi(1S)$ neutrals)/ $\Gamma(J/\psi$ 715 Γ_{9} +0.273 Γ_{31} +0.135 Γ_{3} 121 \pm 0.021 OUR FIT • • We do not use the following	ABRAMS 75B MRK1 e ⁺ e / $\Gamma = (0.9761\Gamma_8 + 0.715\Gamma_9 + 0.2731)$ DOCUMENT ID (15) anything) Γ_6/Γ_9 (15) anything) Γ_6/Γ_9	$\Gamma_{31} + 0.135\Gamma_{32}$ / $\Gamma_{31} + 0.135\Gamma_{32}$ / $\Gamma_{5} = (0.9761\Gamma_{8} + 5\Gamma_{32})$	9.7 \pm 2.1 OUR AVERAGE 15 \pm 6 9 \pm 2 \pm 1 9The ABRAMS 758 me are not independent. The more accurate correctle 10 Using B($J/\psi \rightarrow e^+e^-$ 11 Not independent of the 12 ignoring the $J/\psi(1S)\eta$	assurement of f The TANENBA ons for angular (-) = 0.0599 + (-) = 0.0599 + (-) = 0.0599 + (-) = 0.0199 + (-	HIMEL OREGLIA 6/ Γ_5 and the TA UM 76 result is u distributions0.0025. M 76 result for Γ_6 $\gamma\gamma$ decays. 197 \pm 0.0025. rage.	80 MRK2 80 CBAL ANENBAUM 7 sed in the fit	$e^+e^ \psi(25) \rightarrow$ $J/\psi 2\gamma$ '6 result for Γ_6/I
51 \pm 0.12 67 \pm 0.08 $J/\psi(1S)$ neutrals)/ Γ_{total} Γ_{6} 1228 \pm 0.017 OUR FIT $J/\psi(1S)$ neutrals)/ $\Gamma(J/\psi$ 715 Γ_{9} +0.273 Γ_{31} +0.135 Γ_{3} 121 \pm 0.021 OUR FIT • • We do not use the following	ABRAMS 758 MRK1 $e^+e^ /\Gamma = (0.9761\Gamma_8 + 0.715\Gamma_9 + 0.273\Gamma_{0.00000000000000000000000000000000000$	$\Gamma_{31} + 0.135\Gamma_{32}$ / $\Gamma_{31} + 0.135\Gamma_{32}$ / $\Gamma_{5} = (0.9761\Gamma_{8} + 5\Gamma_{32})$	9.7±2.1 OUR AVERAGE 15 ±6 9 ±2 ±1 9 The ABRAMS 758 me are not Independent. The more accurate corrects and Using $B(J/\psi \rightarrow e^+e^-11)$ Not independent of the 12 Ignoring the $J/\psi(1.5)\eta$ 13 Using $B(J/\psi(1.5) \rightarrow J)$ 13 Using $B(J/\psi(1.5) \rightarrow J)$	assurement of f The TANENBA ons for angular (-) = 0.0599 + (-) = 0.0599 + (-) = 0.0599 + (-) = 0.0199 + (-	HIMEL OREGLIA $_6/\Gamma_5$ and the TA UM 76 result is u distributions0.0025. $_4$ 76 result for $_6$ $_{77}$ decays.	80 MRK2 80 CBAL ANENBAUM 7 sed in the fit	$e^+e^ \psi(25) \rightarrow$ $J/\psi 2\gamma$ '6 result for Γ_6/I
1 ± 0.12 7 ± 0.08 $J/\psi(1S)$ neutrals)/ Γ_{total} Γ_{6} 228 ± 0.017 OUR FIT $J/\psi(1S)$ neutrals)/ $\Gamma(J/\psi$ 715 $\Gamma_{9}+0.273\Gamma_{31}+0.135\Gamma_{3}$ 21 ± 0.021 OUR FIT • We do not use the followin 4 ± 0.03 $J/\psi(1S)$ neutrals)/ $\Gamma(J/\psi$	ABRAMS 758 MRK1 $e^+e^ I = (0.9761\Gamma_8 + 0.715\Gamma_9 + 0.273\Gamma_{0.00000000000000000000000000000000000$	$- \rightarrow \mu^{+}\mu^{-}$ X Γ_{31} +0.135 Γ_{32})/Γ Γ_{5} = (0.9761 Γ_{8} + 5 Γ_{32}) MENT $- \rightarrow J/\psi$ X	9.7±2.1 OUR AVERAGE 15 ±6 9 ±2 ±1 9 The ABRAMS 758 me are not independent. T more accurate correctle 10 Using $B(J/\psi \rightarrow e^+e^-)$ 11 Not independent of the 12 Ignoring the $J/\psi(1.5)$ m 13 Using $B(J/\psi(1.5) \rightarrow f^-)$ 14 Low statistics data rem	assurement of f The TANENBA ons for angular (-) = 0.0599 + (-) = 0.0599 + (-) = 0.0599 + (-) = 0.0199 + (-	HIMEL OREGLIA 6/ Γ_5 and the TA UM 76 result is u distributions0.0025. M 76 result for Γ_6 $\gamma\gamma$ decays. 197 \pm 0.0025. rage.	80 MRK2 80 CBAL ANENBAUM 7 used in the fit	e^+e^- $\psi(25) \rightarrow$ $J/\psi 2\gamma$ '6 result for Γ_6/Γ_6 because it includ
1 ± 0.12 7 ± 0.08 $J/\psi(1S)$ neutrals)/ Γ_{total} Γ_{6} 28 ± 0.017 OUR FIT $J/\psi(1S)$ neutrals)/ $\Gamma(J/\psi$ 715 Γ_{9} +0.273 Γ_{31} +0.135 Γ_{3} 22 ± 0.021 OUR FIT • We do not use the followin 4 ± 0.03 $J/\psi(1S)$ neutrals)/ $\Gamma(J/\psi$ Γ_{6}/Γ_{7}	ABRAMS 758 MRK1 $e^+e^ I = (0.9761\Gamma_8 + 0.715\Gamma_9 + 0.273\Gamma_{0.000MENT 10})$ (15) anything) $I = (0.9761\Gamma_8 + 0.273\Gamma_{31} + 0.13\Gamma_{0.000MENT 10})$ and data for averages, fits, limits, etc. of 9 ABRAMS 758 MRK1 e^+e^- (15) $\pi^+\pi^-$) $I = (0.9761\Gamma_8 + 0.715\Gamma_9 + 0.273\Gamma_9 + 0.273\Gamma$	$\Gamma_{31} + 0.135\Gamma_{32}$ / $\Gamma_{5} = (0.9761\Gamma_{8} + 5\Gamma_{32})$ $\Gamma_{5} = \int_{-\infty}^{\infty} J/\psi \times \frac{1}{31} + 0.135\Gamma_{32}$ / Γ_{7}	9.7±2.1 OUR AVERAGE 15 ±6 9 ±2 ±1 9 The ABRAMS 758 me are not independent. The more accurate correction of the correc	7 23 23 23 24 25 26 27 27 28 28 29 29 29 29 29 29 29 29 29 29 29 29 29	HIMEL OREGLIA $_6/\Gamma_5$ and the TA UM 76 result is u distributions. -0.0025. M 76 result for Γ_6 $\gamma\gamma$ decays. 597 \pm 0.0025. rage. DNIC DECAYS	80 MRK2 80 CBAL ANENBAUM 7 Ised in the fit	$e^+e^ \psi(25) \rightarrow J/\psi 2\gamma$ '6 result for Γ_6/Γ_6 because it includ
1 ± 0.12 7 ± 0.08 $J/\psi(1S)$ neutrals)/ Γ_{total} Γ_{6} 28 ± 0.017 OUR FIT $J/\psi(1S)$ neutrals)/ $\Gamma(J/\psi$ 715 Γ_{9} +0.273 Γ_{31} +0.135 Γ_{3} UE 12 ± 0.021 OUR FIT • • We do not use the following Γ_{4} Γ_{6} Γ_{6} UE UE	ABRAMS 758 MRK1 $e^+e^ I = (0.9761\Gamma_8 + 0.715\Gamma_9 + 0.273\Gamma_{0.00000000000000000000000000000000000$	$\Gamma_{31} + 0.135\Gamma_{32}$ / $\Gamma_{5} = (0.9761\Gamma_{8} + 5\Gamma_{32})$ $\Gamma_{5} = \int_{-\infty}^{\infty} J/\psi \times \frac{1}{31} + 0.135\Gamma_{32}$ / Γ_{7}	9.7±2.1 OUR AVERAGE 15 ±6 9 ±2 ±1 9 The ABRAMS 758 me are not independent. The more accurate correction of the correc	assurement of fine TANENBA nons for angle -1 = 0.0599+ -1 = TANENBAUP, and $J/\psi(1.5)$ · -1 -1 -1 -1 -1 -1 -1 -1	HIMEL OREGLIA $^{6}/\Gamma_{5}$ and the TA UM 76 result is u distributions0.0025. M 76 result for Γ_{6} $\gamma\gamma$ decays. $^{597} \pm 0.0025$. rage. ONIC DECAYS	80 MRK2 80 CBAL ANENBAUM 7 used in the fit	e ⁺ e ⁻ $\psi(25) \rightarrow J/\psi 2\gamma$ 76 result for Γ_6/Γ_6 because it includ
1 ± 0.12 17 ± 0.08 1/ ψ (15) neutrals)/ Γ_{total} 18 19 10 10 10 10 10 10 10 10 10 10 10 10 10	ABRAMS 758 MRK1 e^+e^- (1.5) anything) (1.5) anything) $\frac{DOCUMENT\ ID}{DOCUMENT\ ID}$ TECN COMING data for averages, fits, limits, etc. $e^ e^-$ ABRAMS 758 MRK1 e^+e^- (1.5) $\pi^+\pi^-$) $\pi^ \pi^ $	F_{31} +0.135 F_{32})/Γ F_{5} = (0.9761 F_{8} + F_{5} + F_{5} = F_{5} +	9.7±2.1 OUR AVERAGE 15 ±6 9 ±2 ±1 9 The ABRAMS 758 me are not independent. To more accurate correctle 10 Using $B(J/\psi \rightarrow e^+e^-)$ 11 Not independent of the 12 ignoring the $J/\psi(1S)$ 13 Using $B(J/\psi(1S) \rightarrow J^-)$ 14 Low statistics data rem $\Gamma(3(\pi^+\pi^-)\pi^0)/\Gamma_{\text{total}}$ VALUE (units 10^{-4}) 5±16	7 23 Passurement of I fine TANENBAN ons for angular or μ = 0.0599+ μ = TANENBAUI of and $J/\psi(1S)$ = 0.004 from ave HADRO of FRANCE of FRANCE OF TANENBAUI of μ = 0.004 from ave μ = 0.004 fr	HIMEL OREGLIA $^{6}/\Gamma_{5}$ and the TA UM 76 result is u distributions0.0025. M 76 result for Γ_{6} $\gamma\gamma$ decays. $^{597} \pm 0.0025$. rage. ONIC DECAYS	80 MRK2 80 CBAL ANENBAUM 7 sed in the fit	$e^+e^ \psi(25) \rightarrow J/\psi 2\gamma$ '6 result for Γ_6/I because it includ
1 ± 0.12 7 ± 0.08 $J/\psi(1S)$ neutrals)/ Γ_{total} Γ_{6} UE 228 ± 0.017 OUR FIT $J/\psi(1S)$ neutrals)/ $\Gamma(J/\psi$ 715 $\Gamma_{9}+0.273\Gamma_{31}+0.135\Gamma_{3}$ UE 21 ± 0.021 OUR FIT • We do not use the following 4 ± 0.03 $J/\psi(1S)$ neutrals)/ $\Gamma(J/\psi$ Γ_{6}/Γ_{7} UE UE 6 ± 0.07 OUR FIT 3 ± 0.09	ABRAMS 758 MRK1 $e^+e^ I = (0.9761\Gamma_8 + 0.715\Gamma_9 + 0.273\Gamma_{0.000MENT 10})$ (15) anything) $I = (0.9761\Gamma_8 + 0.273\Gamma_{31} + 0.13\Gamma_{0.000MENT 10})$ and data for averages, fits, limits, etc. of 9 ABRAMS 758 MRK1 e^+e^- (15) $\pi^+\pi^-$) $I = (0.9761\Gamma_8 + 0.715\Gamma_9 + 0.273\Gamma_9 + 0.273\Gamma$	Γ_{31} +0.135Γ ₃₂)/Γ Γ_{5} = (0.9761Γ ₈ + 15Γ ₃₂) MENT • • • • Γ_{31} +0.135Γ ₃₂)/Γ ₇ MENT	9.7±2.1 OUR AVERAGE 15 ±6 9 ±2 ±1 9 The ABRAMS 75B me are not independent. To more accurate correction of the correcti	7 23 Passurement of I fine TANENBAN ons for angular or μ = 0.0599+ μ = TANENBAUI of and $J/\psi(1S)$ = 0.004 from ave HADRO of FRANCE of FRANCE OF TANENBAUI of μ = 0.004 from ave μ = 0.004 fr	HIMEL OREGLIA $^{6}/\Gamma_{5}$ and the TA UM 76 result is u distributions0.0025. M 76 result for Γ_{6} $\gamma\gamma$ decays. $^{597} \pm 0.0025$. rage. ONIC DECAYS	80 MRK2 80 CBAL ANENBAUM 7 sed in the fit	$e^+e^ \psi(25) \rightarrow J/\psi 2\gamma$ '6 result for Γ_6/I because it includ
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1 ± 0.12 7 ± 0.08 $J/\psi(1S)$ neutrals)/ Γ_{total} Γ_{6} 228 ± 0.017 OUR FIT $J/\psi(1S)$ neutrals)/ $\Gamma(J/\psi$ 715 $\Gamma_{9}+0.273\Gamma_{31}+0.135\Gamma_{3}$ 22 ± 0.021 OUR FIT • • We do not use the following 4 ± 0.03 $J/\psi(1S)$ neutrals)/ $\Gamma(J/\psi$ Γ_{6}/Γ_{7} 12.02 6 ± 0.07 OUR FIT 3 ± 0.09 $J/\psi(1S)\pi^{+}\pi^{-}$)/ Γ_{total} 12.02 12.02 13.02 13.03 14.04 15.05 15.05 16.05 17.05 17.05 18.05 18.05 19.05	ABRAMS 758 MRK1 e^+e^- (15) anything) (15) anything) (15) anything) (17) $f_8 + f_9 + 0.273 f_{31} + 0.13$ DOCUMENT ID 10 data for averages, fits, limits, etc. of a BRAMS 758 MRK1 e^+e^- (15) $\pi^+\pi^-$) 7 = (0.9761 $f_8 + 0.715 f_9 + 0.273 f_{31} + 0.273 f_{31} + 0.273 f_{32} + 0.273 f_{33} + 0.273 f_{34} + $	F_{31} +0.135Γ ₃₂)/Γ F_{5} = (0.9761Γ ₈ +5Γ ₃₂) F_{5} = F_{5} = F_{5}	9.7±2.1 OUR AVERAGE 15 ±6 9 ±2 ±1 9 The ABRAMS 758 me are not independent. The more accurate correctle of the properties of the properti	23 casurement of Fifthe TANENBA on Signal $J/\psi(1S)$ $\mu^+\mu^-)=0.0599+$ $\mu^+\mu^-)=0.0599+$ cand $J/\psi(1S)$ $\mu^+\mu^-)=0.05$ coved from ave HADRO VTS DOC	HIMEL OREGLIA 6/F ₅ and the TA UM 76 result is u distributions. -0.0025. M 76 result for F ₆ YY decays. 597 ± 0.0025. rage. DNIC DECAYS NKLIN 83 I	80 MRK2 80 CBAL ANENBAUM 7 Ised in the fit TECN COMMI MRK2 e+e- TECN COMMI MRK2 e+e- TECN COMMI	e ⁺ e ⁻ $\psi(25) \rightarrow J/\psi 2\gamma$ '6 result for Γ_6/I because it includ Γ_{12}/ENT \rightarrow hadrons Γ_{13}/ENT
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11 \pm 0.12 17 \pm 0.08 $J/\psi(1S)$ neutrals)/ Γ_{total} $I_{\text{C28}\pm 0.017}$ OUR FIT $J/\psi(1S)$ neutrals)/ $\Gamma(J/\psi$ 1715 $\Gamma_9+0.273\Gamma_{31}+0.135\Gamma_{3}$ 121 \pm 0.021 OUR FIT 19 • We do not use the following the following that the following the follow	ABRAMS 758 MRK1 e+e // = (0.9761 + 0.715 + 0.273 DOCUMENT ID (15) anything) 2) / (- 7 + - 8 + - 9 + 0.273 - 31 + 0.13 DOCUMENT ID 10 data for averages, fits, limits, etc. of a BRAMS 758 MRK1 e+e (15) \(\pi + \pi^- \) 7 = (0.9761 - 8 + 0.715 - 9 + 0.273 - 273 - 200 9 TANENBAUM 76 MRK1 e+e DOCUMENT ID 10 ARMSTRONG 97 E760 PP - ABRAMS 10 ARMSTRONG 97 E760 PP - 200 - 200 - 200 10 ARMSTRONG 97 E760 PP - 200 - 200 - 200 - 200 10 ARMSTRONG 97 E760 PP - 200 - 200 - 200 10 ARMSTRONG 97 E760 PP - 200 - 200 - 200 - 200 10 ARMSTRONG 97 E760 PP - 200 - 200 - 200 - 200 10 ARMSTRONG 97 E760 PP - 200 - 200 - 200 - 200 11 TANENBAUM 76 MRK1 e+e - 200 - 200 - 200 - 200 - 200 12 HILGER 75 SPEC e+e	F_{31} +0.135Γ ₃₂)/Γ F_{5} = (0.9761Γ ₈ + F_{5} + 5Γ ₃₂) F_{5} = F_{5} + F_{5}	VALUE (units 10^{-4}) 9.7±2.1 OUR AVERAGE 15 ±6 9 ±2 ±1 9 The ABRAMS 758 me are not independent. The independent of the	23 Passurement of I from TANENBA Market Passurement of I from Sor angular -1 = 0.0599+ -1 = TANENBAU -1 = 0.0599+ -1 = TANENBAU -1 = 0.0599+ -1 = TANENBAU -1 = 0.0599+ -1 = 0.059+ -1 = 0.0599+ -1 = 0.0599+ -1 = 0.0599+ -1 = 0.0599+ -1	HIMEL OREGLIA 76/F ₅ and the TA UM 76 result is u distributions0.0025. M 76 result for F ₆ 77 decays. S97 ± 0.0025. rage. DNIC DECAYS UMENT ID NENBAUM 78 IN UMENT ID	80 MRK2 80 CBAL ANENBAUM 7 Ised in the fit TECN COMMINMRK2 e+e- TECN COMMINMRK1 e+e- TECN COMMINMRK1 e+e- TECN COMMINMRK1 e+e- TECN COMMINMRK1 e+e-	e+e- $\psi(25) \rightarrow J/\psi 2\gamma$ 1/6 result for Γ_6/I because it includ F12/ ENT F14/ ENT F16/ ENT F16/ ENT
1 ± 0.12 7 ± 0.08 $J/\psi(1S)$ neutrals)/ Γ_{total} Γ_{6} 28 ± 0.017 OUR FIT $J/\psi(1S)$ neutrals)/ $\Gamma(J/\psi$ 715 Γ_{9} +0.273 Γ_{31} +0.135 Γ_{3} 22 ± 0.021 OUR FIT • We do not use the followin 4 ± 0.03 $J/\psi(1S)$ neutrals)/ $\Gamma(J/\psi$ Γ_{6}/Γ_{7} 102 ± 0.07 OUR FIT 3 ± 0.09 $J/\psi(1S)\pi^{+}\pi^{-}$ / Γ_{total} 102 ± 0.021 OUR FIT 104 ± 0.023 OUR AVERAGE 105 ± 0.021 OUR FIT 106 ± 0.023 OUR AVERAGE 107 ± 0.023 OUR AVERAGE 108 ± 0.021 OUR FIT 109 ± 0.031 OUR FIT	ABRAMS 758 MRK1 e+e /Γ = (0.9761Γ ₈ +0.715Γ ₉ +0.2731 DOCUMENT ID (15) anything) 2)/(Γ ₇ +Γ ₈ +Γ ₉ +0.273Γ ₃₁ +0.13 DOCUMENT ID 10 data for averages, fits, limits, etc. of a BRAMS 758 MRK1 e+e (15)π+π-) 7 = (0.9761Γ ₈ +0.715Γ ₉ +0.273Γ ₃ DOCUMENT ID 10 ARMSTRONG 97 E760 pp-ABRAMS 11 TANENBAUM 76 MRK1 e+e 12 HILGER 75 SPEC e+e 15)μ+μ-)	F_{31} +0.135Γ ₃₂)/Γ F_{5} = (0.9761Γ ₈ + F_{5} + (0.9761Γ ₈ + F_{7} + (0.9761Γ	VALUE (units 10 ⁻⁴) 9.7±2.1 OUR AVERAGE 15 ±6 9 ±2 ±1 9 The ABRAMS 75B me are not independent. To more accurate correctle 10 Using $B(J/\psi \rightarrow e^+e^-)$ 11 Not independent of the 12 ignoring the $J/\psi(1.S)$ γ 13 Using $B(J/\psi(1.S) \rightarrow J$ 14 Low statistics data rem $\Gamma(3(\pi^+\pi^-)\pi^0)/\Gamma_{\text{total}}$ VALUE (units 10 ⁻⁴) 35±16 $\Gamma(2(\pi^+\pi^-)\pi^0)/\Gamma_{\text{total}}$ VALUE (units 10 ⁻⁴) 50±8 $\Gamma(\pi^+\pi^-K^+K^-)/\Gamma_{\text{total}}$ VALUE (units 10 ⁻⁴) 16±4 $\Gamma(\pi^+\pi^-p\overline{p})/\Gamma_{\text{total}}$ VALUE (units 10 ⁻⁴) 8 ±2 $\Gamma(K^+\overline{K}^*(892)^0\pi^- + C^-)$ VALUE (units 10 ⁻⁴) 6.7±2.5 $\Gamma(2(\pi^+\pi^-))/\Gamma_{\text{total}}$	23 Passurement of I from TANENBA Market Passurement of I from Sor angular -1 = 0.0599+ -1 = TANENBAU -1 = 0.0599+ -1 = TANENBAU -1 = 0.0599+ -1 = TANENBAU -1 = 0.0599+ -1 = 0.059+ -1 = 0.0599+ -1 = 0.0599+ -1 = 0.0599+ -1 = 0.0599+ -1	HIMEL OREGLIA 6/F ₅ and the TA UM 76 result is u distribution0.0025. M 76 result for F ₆ 77 decays. 597 ± 0.0025. rage. DNIC DECAYS WIMENT ID WINKLIN 83 IN WINKLI	80 MRK2 80 CBAL ANENBAUM 7 Ised in the fit TECN COMMINMRK2 e+e- TECN COMMINMRK1 e+e- TECN COMMINMRK1 e+e- TECN COMMINMRK1 e+e- TECN COMMINMRK1 e+e-	e+e- $\psi(25) \rightarrow J/\psi 2\gamma$ '6 result for Γ_6/I because it includ F12/ ENT F14/ ENT F16/ ENT F17/ ENT
11 \pm 0.12 17 \pm 0.08 (J/ ψ (1S) neutrals)/ Γ total Γ_6 / (228 \pm 0.017 OUR FIT (J/ ψ (1S) neutrals)/ Γ (J/ ψ 1715 Γ_9 + 0.273 Γ_{31} + 0.135 Γ_3 1212 \pm 0.021 OUR FIT 14 \pm 0.03 (J/ ψ (1S) neutrals)/ Γ (J/ ψ 16 \pm 0.07 OUR FIT 173 \pm 0.09 (J/ ψ (1S) π + π -)/ Γ total (222 \pm 0.019 OUR FIT 1966 \pm 0.021 \pm 0.020 197 \pm 0.018 OUR FIT 1984 \pm 0.021 \pm 0.020 197 \pm 0.018 OUR FIT 1984 \pm 0.019 \pm 0.013 157 (J/ ψ (1S) π 0 π 0)/ Γ total 199 \pm 0.05 OUR FIT 199 \pm 0.05 OUR FIT 1016 \pm 0.019 \pm 0.013 157 (J/ ψ (1S) π 0 π 0)/ Γ (J/ ψ (1) 1026 1036 1047 1057	ABRAMS 758 MRK1 e+e // = (0.9761 + 0.715 + 0.273 DOCUMENT ID (15) anything) 2) / (- 7 + - 8 + - 9 + 0.273 - 31 + 0.13 DOCUMENT ID 10 data for averages, fits, limits, etc. of a BRAMS 758 MRK1 e+e (15) \(\pi + \pi^- \) 7 = (0.9761 - 8 + 0.715 - 9 + 0.273 - 273 - 200 9 TANENBAUM 76 MRK1 e+e DOCUMENT ID 10 ARMSTRONG 97 E760 PP - ABRAMS 10 ARMSTRONG 97 E760 PP - 200 - 200 - 200 10 ARMSTRONG 97 E760 PP - 200 - 200 - 200 - 200 10 ARMSTRONG 97 E760 PP - 200 - 200 - 200 10 ARMSTRONG 97 E760 PP - 200 - 200 - 200 - 200 10 ARMSTRONG 97 E760 PP - 200 - 200 - 200 - 200 10 ARMSTRONG 97 E760 PP - 200 - 200 - 200 - 200 11 TANENBAUM 76 MRK1 e+e - 200 - 200 - 200 - 200 - 200 12 HILGER 75 SPEC e+e	F_{31} +0.135Γ ₃₂)/Γ F_{5} = (0.9761Γ ₈ + F_{5} + (0.9761Γ ₈ + F_{7} + (0.9761Γ	VALUE (units 10^{-4}) 9.7±2.1 OUR AVERAGE 15 ±6 9 ±2 ±1 9 The ABRAMS 758 me are not independent. The independent of the	23 Passurement of I from TANENBA Market Passurement of I from Sor angular -1 = 0.0599+ -1 = TANENBAU -1 = 0.0599+ -1 = TANENBAU -1 = 0.0599+ -1 = TANENBAU -1 = 0.0599+ -1 = 0.059+ -1 = 0.0599+ -1 = 0.0599+ -1 = 0.0599+ -1 = 0.0599+ -1	HIMEL OREGLIA 76/F ₅ and the TA UM 76 result is u distributions0.0025. M 76 result for F ₆ 77 decays. S97 ± 0.0025. rage. DNIC DECAYS UMENT ID NENBAUM 78 IN UMENT ID	80 MRK2 80 CBAL ANENBAUM 7 Ised in the fit TECN COMMINMRK2 e+e- TECN COMMINMRK1 e+e- TECN COMMINMRK1 e+e- TECN COMMINMRK1 e+e- TECN COMMINMRK1 e+e-	e+e- $\psi(25) \rightarrow J/\psi 2\gamma$ 1/6 result for Γ_6/I because it includ F12/ ENT F14/ ENT F16/ ENT F16/ ENT
51 \pm 0.12 57 \pm 0.08 $(J/\psi(1S) \text{ neutrals})/\Gamma_{\text{total}}$ $\Gamma_{6}/\Gamma_{\text{total}}$ $(J/\psi(1S) \text{ neutrals})/\Gamma(J/\psi$ $(J/\psi(1S) \pi^{+}\pi^{-})/\Gamma_{\text{total}}$ UUE	ABRAMS 758 MRK1 e+e /Γ = (0.9761Γ ₈ +0.715Γ ₉ +0.2731 DOCUMENT ID (15) anything) 2)/(Γ ₇ +Γ ₈ +Γ ₉ +0.273Γ ₃₁ +0.13 DOCUMENT ID 10 data for averages, fits, limits, etc. of a BRAMS 758 MRK1 e+e (15)π+π-) 7 = (0.9761Γ ₈ +0.715Γ ₉ +0.273Γ ₃ DOCUMENT ID 10 ARMSTRONG 97 E760 pp-ABRAMS 11 TANENBAUM 76 MRK1 e+e 12 HILGER 75 SPEC e+e 15)μ+μ-)	$F \rightarrow \mu^+ \mu^- X$ $F_{31} + 0.135F_{32})/\Gamma$ $F_{5} = (0.9761F_{8} + 5F_{32})$ $F_{5} = (0.9761F_{8} + 5F_{32})/\Gamma$ $F_{7} = (0.9761F_{8} + 5F_{32})/\Gamma$	VALUE (units 10 ⁻⁴) 9.7±2.1 OUR AVERAGE 15 ±6 9 ±2 ±1 9 The ABRAMS 75B me are not Independent. To more accurate correctle 10 Using $B(J/\psi \to e^+e^-)$ 11 Not independent of the 12 ignoring the $J/\psi(1S) \to J/\psi(1S)$ 13 Using $B(J/\psi(1S) \to J/\psi(1S))$ 14 Low statistics data rem $\Gamma(3(\pi^+\pi^-)\pi^0)/\Gamma \text{total}$ VALUE (units 10 ⁻⁴) E 30±8 $\Gamma(\pi^+\pi^-K^+K^-)/\Gamma \text{total}$ VALUE (units 10 ⁻⁴) 16±4 $\Gamma(\pi^+\pi^-p\bar{p})/\Gamma \text{total}$ VALUE (units 10 ⁻⁴) 8 ±2 $\Gamma(K^+K^*(892)^0\pi^-+e^-)/\Gamma \text{total}$ VALUE (units 10 ⁻⁴) 6.7±2.5 $\Gamma(2(\pi^+\pi^-))/\Gamma \text{total}$ VALUE (units 10 ⁻⁴) 6.7±2.5 $\Gamma(2(\pi^+\pi^-))/\Gamma \text{total}$ VALUE (units 10 ⁻⁴)	23 casurement of Fi the TANENBA c	HIMEL OREGLIA 76/F ₅ and the TA UM 76 result is u distribution0.0025. M 76 result for F ₆ 77 decays0.0025. INCLIDECAYS INCLID	80 MRK2 80 CBAL ANENBAUM 7 Ised in the fit TECN COMMINMRK2 e+e- TECN COMMINMRK1 e+e- TECN COMMINMRK1 e+e- TECN COMMINMRK1 e+e- TECN COMMINMRK1 e+e-	e+e- $\psi(2S) \rightarrow J/\psi 2\gamma$ $J/\psi 2\gamma$ '6 result for Γ_6/I because it includ F12/ ENT F14/ ENT F16/ ENT F17/ ENT F18/

 $\psi(2S)$

(pp)/rtotal				Γ ₁₉ /Γ	$\Gamma(\gamma\eta_c(1S))/\Gamma_{\text{total}}$	DOCUMENT ID TECH COMMENT
/ALUE (units 10 ⁻⁴) EVTS	DOCUMENT ID	TECN	COMMENT		VALUE (units 10 ⁻²) 0.28±0.06	DOCUMENT ID TECN COMMENT GAISER 86 CBAL $e^+e^- \rightarrow \gamma X$
.4±0.8 4	BRANDELIK	79c DASP	e+e-			,
2.3±0.7	FELDMAN	77 MRK1	e+e-		$\Gamma(\gamma\eta_c(2S))/\Gamma_{ m total}$	Γ34/
$(3(\pi^+\pi^-))/\Gamma_{\text{total}}$				Γ ₂₀ /Γ	VALUE (units 10 ⁻²) CL%	DOCUMENT ID TECN COMMENT
	DOCUMENT ID	TECH	COMMENT	1 20/1	 • • We do not use the following 	owing data for averages, fits, limits, etc. • • •
ALUE (units 10 ⁻⁴) .5±1.0	15 TANENBAUM				0.2 to 1.3 95	EDWARDS 82c CBAL e ⁺ e ⁻ → γX
	IAMENDAOM	10 1011111			$\Gamma(\gamma\pi^0)/\Gamma_{ m total}$	Г _{35/}
$\Gamma(\overline{\rho}\rho\pi^0)/\Gamma_{\text{total}}$				Γ ₂₁ /Γ	VALUE (units 10 ⁻⁴) CL%	
ALUE (units 10 ⁻⁴) EVTS	DOCUMENT ID	TECN	COMMENT			wing data for averages, fits, limits, etc. • • •
.4±0.5	FRANKLIN	83 MRK2	e ⁺ e ⁻		< 54 95	21 LIBERMAN 75 SPEC e+e-
(K+K-)/r _{total}				Γ ₂₂ /Γ	<100 90	WIIK 75 DASP e+e-
4L <u>UE (u</u> nits 10 ⁻⁴) CL%	DOCUMENT ID	TECN	COMMENT	. 22/	r/ //aral\ /#	·
1.0±0.7	BRANDELIK				Γ(γη'(958))/Γ _{total}	F ₃₆ ,
• We do not use the folk					VALUE (units 10 ⁻²) CL%	
(0.5 90	FELDMAN	77 MRK1	e^+e^-		<0.11 90	²² BARTEL 76 CNTR e ⁺ e ⁻ owing data for averages, fits, limits, etc. • •
						23 BRAUNSCH 77 DASP e+e-
$(\pi^+\pi^-)/\Gamma_{\text{total}}$				Γ ₂₅ /Γ	<0.6 90	- BRAUNSCH II DASP E E
ALUE (units 10 ⁻⁴) CL%		TECN			$\Gamma(\gamma\eta)/\Gamma_{\text{total}}$	Г ₃₇ ,
0.8±0.5	BRANDELIK				VALUE (units 10 ⁻²) CL9	DOCUMENT ID TECN COMMENT
We do not use the follows:	_				• • We do not use the following the fol	owing data for averages, fits, limits, etc. • • •
(0.5 90	FELDMAN	77 MRK1	e		<0.02 90	YAMADA 77 DASP $e^+e^- \rightarrow 3\gamma$
$(\pi^+\pi^-\pi^0)/\Gamma_{\text{total}}$				Γ ₂₃ /Γ	r/ (1110) VV	r
ALUE (units 10 ⁻⁴) EVT:	DOCUMENT ID	TECN	COMMENT		$\Gamma(\gamma\eta(1440)\to\gamma K\overline{K}\pi)/$	
85±0.46	FRANKLIN		$e^+e^- \rightarrow ha$	drons	VALUE (units 10 ⁻³) CLS	
(A TO 1 ==				E /E	<0.12 90	
(Aオ)/ľ _{total}				Γ ₂₆ /Γ	17 Angular distribution (1+c	
LUE (units 10 ⁻⁴) CL%			COMMENT		¹⁸ Angular distribution (1–0 ¹⁹ Valid for isotropic distribu	
4 90	FELDMAN	77 MRK1	e+e-		20 Angular distribution (1–0	
(≘~≌+)/Γ _{total}				Γ ₂₇ /Γ	21 Restated by us using Β(ψ	
4LUE (units 10 ⁻⁴) CLS	DOCUMENT ID	TECN	COMMENT	. 217		the branching ratio for $\Gamma(J/\psi(1S)\eta)/\Gamma_{\text{total}}$.
2 90	FELDMAN	77 MRK1			²³ Restated by us using tota	
.2 90	LEDWAI	77 77111114			²⁹ Includes unknown branchi	ng fraction $\eta(1440) \rightarrow K\overline{K}\pi$.
$(ho\pi)/\Gamma_{ m total}$				Γ ₂₄ /Γ		♦(25) REFERENCES
ALUE (units 10 ⁻⁴) CL% EVT.	DOCUMENT ID		COMMENT			V(25) REFERENCES
	FD A MIZE IN	83 MRK2	a+ a-			+Bettoni, Bharadwaj+ (E760 Collab.)
					ARMSTRONG 97 PR D55 1153	
• We do not use the foll	owing data for average	es, fits, limits	, etc. • • •		GRIBUSHIN 96 PR D53 4723 ANTONIAZZI 94 PR D50 4258	+Abramov, Antipov+ (E672 Collab., E706 Collab.) +Arenton+ (E705 Collab.)
• • We do not use the following the followin	owing data for average BARTEL	es, fits, ilmits 76 CNTR	e+e-		GRIBUSHIN 96 PR D53 4723 ANTONIAZZI 94 PR D50 4258 ARMSTRONG 938 PR D47 772 PDG 92 PR D45, 1 J	+Abramov, Antipov+ (E672 Collab., E706 Collab.) +Arenton+ (E705 Collab.) +Bettoni, Bharadwaj+ (FNAL E760 Collab.) une, Part II Hikasa, Barnett, Stone+ (KEK, LBL, BOST+)
• • We do not use the following the followin	owing data for average	es, fits, limits	e+e-		GRIBUSHIN 96 PR D53 4723 ANTONIAZZI 94 PR D50 4258 ARMSTRONG 938 PR D47 772 PDG 92 PR D45, 1 J ALEXANDER 89 NP B320 45	+ Abramov, Antipov+ (E672 Collab., E706 Collab.) + Arenton+ (E705 Collab.) + Bettoni, Bharadwaj+ (FNAL E760 Collab.) + Bonvicini, Dreil, Frey, Luth (LBL, MICH, SLAC)
• • We do not use the following to 90 (10 90)	owing data for average BARTEL	es, fits, ilmits 76 CNTR	e+e-	Γ ₂₈ /Γ	GRIBUSHIN 96 PR D53 4725 ANTONIAZZI 94 PR D50 4258 ARMSTRONG 93B PR D47 772 PDG 92 PR D47 772 ALEXANDER 89 NF B320 45 GAISER 86 PR D34 711 FRANKLIN 83 PRL 51 963	+ Abramov, Antipov+ (E672 Collab.). E706 Collab.) + Arenton+ (E705 Collab.) + Bettoni, Bharadwaj+ (FNAL E760 Collab.) une, Part II Hibasa, Barnett, Stone+ (KEK, LBL, BOST+) + Bloom, Bulos, Godfrey+ (LBL, MIGH, SLAC) + Firanklin, Feldman, Abrams, Alam+ (LBL, SLAC)
• • We do not use the following the followi	owing data for average BARTEL ¹⁶ ABRAMS	es, fits, limits 76 CNTR 75 MRK1	e+e-	Γ ₂₈ /Γ	GRIBUSHIN 96 PR D53 4723 ANTONIAZI 94 PR D50 4256 ARMSTRONG 93B PR D47 772 PDG 22 PR D45, 1 J ALEXANDER 96 PR D34 711 FRANKLIN 83 PR D34 711 FRANKLIN 83 EDWARDS 82C PRL 48 70 LEMOIGNE 82 PL 1138 509	+ Abramov, Antipov+ (E672 Collab., E706 Collab.) + Aerenton+ (E705 Collab.) + Bettoni, Bharadwaj+ (FNAL E760 Collab.) une, Part II Hikasa, Barnett, Stone+ (KEK, LBI, BOST+) + Benoriini, Drelin, Frey, Luth (LBI, MICH, SLAC) + Bloom, Bulos, Godfrey+ (Crystal Ball Collab.) + Franklin, Feldman, Abrams, Alam+ (LBI, SLAC) + Partridge, Peck+ (CIT, HARV, PRIN, STAN, SLAC) + Barate, Astbury+ (SACL, LOIC, SHMP, IND)
• • We do not use the foli 10 90 10 90 (K+K-\pi^0)/\(\Gamma^0\)/\(\Gamma^1\) LUE (units 10^{-5}) CL\(\frac{\pi}{2}\) EVT.	owing data for average BARTEL 16 ABRAMS DOCUMENT ID	es, fits, limits 76 CNTR 75 MRK1 TECN	, etc. • • • e ⁺ e ⁻ e ⁺ e ⁻		GRIBUSHIN 96 PR D53 4723 ARMSTRONG 93B PR D47 772 PDG 92 PR D45, 1 J ALEXANDER 89 PR D34 711 FRANKLIN 83 PRL 51 93 EDWARDS 82C PRL 48 70 LEMOIGNE 82 PL 1138 509 HIMEL 80 PR L4 4920	+ Abramov, Antipov+ (E672 Collab., E706 Collab.) + Arenton+ (E705 Collab.) + Arenton+ (E705 Collab.) + Bettoni, Bharadwaj+ (FNAL E766 Collab.) + Bonvicini, Drail, Frey, Luth (LBL, MICH, SLAC.) + Bloom, Bulos, Godfrey+ (Crystal Ball Collab.) + Franklin, Feldman, Abrams, Alam+ (LBL, SLAC.) + Partridge, Peck+ (CIT, HARV, PRIN, STAN, SLAC.) + Barate, Astbury+ (SACL, LOIC, SHMP, IND) + Abrams Alam, Rijocker+
• • We do not use the following the followi	owing data for average BARTEL 16 ABRAMS DOCUMENT ID FRANKLIN	es, fits, limits 76 CNTR 75 MRK1 TECN	etc. • • • e+e− e+e− COMMENT	adrons	GRIBUSHIN 96 PR D53 4723 ANTONIAZZI 94 PR D50 4258 ARMSTRONG 93B PR D47 772 PLEXANDER 89 PR D54 712 FRANKLIN 83 PRL 51 963 EDWARDS 82C PRL 48 70 LEMOIGNE 82 HIMEL 80 OREGLIA 80 PRL 45 959 SCHARRE 80 PL 978 329	+ Abramov, Antipov+ (E672 Collab., E706 Collab.) + Arenton+ (E705 Collab.) + Arenton+ (E705 Collab.) + Bettoni, Bharadwaj+ (FNAL E760 Collab.) + Bonvicini, Dreli, Frey, Luth (LBL, MICH, SLAC) + Bloom, Bulos, Godfrey+ (Crystal Ball Collab.) + Franklin, Feldman, Abrams, Alam+ (LBL, SLAC) + Partridge, Peck+ (CIT, HARV, PRIN, STAN, SLAC) + Barate, Astbury+ (SACL, LOIC, SHMP, IND) + Abrams, Alam, Blocker+ (CIB, SLAC) + Partridge+ (SLAC, CIT, HARV, PRIN, STAN) + Tillibra, Abrams, Alam, Blocker+ (SLAC, LGL)
• • We do not use the following the followi	owing data for average BARTEL 16 ABRAMS DOCUMENT ID FRANKLIN	76 CNTR 75 MRK1 75 MRK2 83 MRK2	$e^{+}e^{-}$ $e^{+}e^{-}$ $e^{+}e^{-}$ $\frac{COMMENT}{e^{+}e^{-} \rightarrow ha}$		GRIBUSHIN 96 PR D53 4723 ANTONIAZI 94 PR D50 4258 ARMSTRONG 93B PR D47 772 PDG 92 PR D45, 1 J ALEXANDER 89 PR D34 711 FRANIKLIN 83 PRL 51 963 EDWARDS 82C PRL 48 70 LEMOIGNE 82 PRL 1318 509 HIMEL 80 PRL 44 920 OREGLIA 80 PRL 45 959 SCHARRE 80 PRL 97B 329 ZHOLENTZ 80 PL 97B 329 ZHOLENTZ 80 PL 98B 214 Also 81 SINP 348 817	+ Abramov, Antipov+ (E672 Collab.). E706 Collab.) + Arenton+ + (E705 Collab.) + Arenton+ + (E705 Collab.) + Bettoni, Bharadwaj+ (FNAL E760 Collab.) + Hatkas, Barnett, Stone+ (KEK, LBL, BOST+) + Bloom, Bulos, Godfrey+ (LBL, MICH, SLAC) + Franklin, Feldman, Abrams, Alam+ (LBL, SLAC) + Partridge, Peck+ (CLT, HARV, PRIN, STAN, SLAC) + Barate, Astbury+ (SACL, LOIC, SHMP, IND) + Abrams, Alam, Blocker+ (SLAC, LBL, SLAC) + Partridge+ (SLAC, CLT, HARV, PRIN, STAN) + Tilling, Abrams, Alam, Blocker+ (SLAC, LBL, LBL) + Kurdadze, Leichuk, Mishnev+ (NOVO) Zholentz, Kurdadze, Leichuk+ (NOVO)
• • We do not use the following the followi	BARTEL 16 ABRAMS DOCUMENT ID FORMAL DOCUMENT ID DOCUMENT ID DOCUMENT ID	76 CNTR 75 MRK1 75 MRK1 TECN 83 MRK2	etc. • • • • $e^+e^ e^+e^ e^+e^ e^+e^ hat be denoted by the equation of the equation e^+e^- \to hat be denoted by the equation of the equation e^+e^- \to hat be denoted by the equation e^+e^- \to hat be denoted by the equation of the equation e^+e^- \to hat be denoted by the equation e^+e^- \to hat be denoted by the equation of the equation e^+e^- \to hat be denoted by the equation of the equation e^+e^- \to hat be denoted by the equation of the equation e^+e^- \to hat be denoted by the equation of the equation e^+e^- \to hat be denoted by the equation of the equation of the equation e^+e^- \to hat be denoted by the equation of	adrons	GRIBUSHIN 96 PR D53 4723 ARTONIAZI 94 PR D50 4252 ARMSTRONG 93B PR D47 772 PDG 92 PR D45 712 PR D45 715 PR D45 715 FRANKLIN 83 PR D34 711 FRANKLIN 83 PR D34 711 FRANKLIN 84 PR D34 711 EMOIGNE 82 PRL 48 70 LEMOIGNE 80 PRL 44 920 OREGLIA 80 PRL 44 920 OREGLIA 80 PRL 45 959 ZHOLENTZ 80 PL 97B 327 ZHOLENTZ 80 SINP 34 8145 Also 81 SINP 34 8145 Translated fr BRANDELIK 798 N PB 166 427	+ Abramov, Antipov+ (E672 Collab.). E706 Collab.) + Arenton+ + Bettoni, Bharadwaj+ (E705 Collab.) + Bettoni, Bharadwaj+ (FNAL E760 Collab.) + Benovicini, Dreli, Frey, Luth + Bioom, Bulos, Godfrey+ (LBL, MIGH, SLAC) + Franklin, Feldman, Abrams, Alam+ (LBL, SLAC) + Partridge, Peck+ (CIT, HARV, PRIN, STAN, SLAC) + Barate, Astbury+ (SACL, LOIC, SHAP), IND) + Abrams, Alam, Blocker+ (SLAC, LIT, HARV, PRIN, STAN) + Trilling, Abrams, Alam, Blocker+ (SLAC, LIS, LAC) + Trilling, Abrams, Alam, Blocker+ (SLAC, LIS, LAC) + Kurdadze, Leichuk, Mishnev+ (NOVO) Dom YAF 34 1471.
• • We do not use the following the followi	bwing data for average BARTEL 16 ABRAMS DOCUMENT ID FRANKLIN Total FRANKLIN	76 CNTR 75 MRK1 75 MRK1 TECN 83 MRK2	$e^{+}e^{-}$ $e^{+}e^{-}$ $e^{+}e^{-}$ $\frac{COMMENT}{e^{+}e^{-} \rightarrow ha}$	adrons	GRIBUSHIN 96 PR D53 4723 ARMSTRONG 93B PR D47 772 PDG 22 PR D45, 1 J ALEXANDER 86 PR D34 711 PFANIKLIN 83 PR D47 712 PEMBARDS 86 PR D34 711 PFANIKLIN 83 PR D34 711 PFANIKLIN 80 PR D34 711 EMOIGNE 82 PR 48 70 LEMOIGNE 80 PR 44 920 OREGLIA 80 PR 44 920 OREGLIA 80 PR 44 920 CHEGLIA 80 PR 45 99 SCHARRE 80 PL 97B 329 ZHOLENTZ 80 PL 96 214 AISO 81 BRANDELIK 79B N B166 426 BRANDELIK 79C ZPHY C1 23 BARTEL 78B PL 798 427 PL 97B 227 PL	+ Abramov, Antipov+ (E672 Collab.). E706 Collab.) + Arenton+ + Bettoni, Bharadwaj+ (E705 Collab.) une, Part II Hibasa, Barnett, Stone+ (EK, LBt, B057+) + Bloomi, Bulos, Godfrey+ (LBt, MIGH, SLAC) + Franklin, Feldman, Abrams, Alam+ (LBt, SLAC) + Partridge, Peck+ (CIT, HARV, PRIN, STAN, SLAC) + Barate, Astbury+ (SACL, LOIC, SHMP, IND) + Abrams, Alam, Blocker+ (SACL, LOIC, SHMP, IND) + Trilling, Abrams, Alam, Biocker+ (SLAC, CIT, HARV, PRIN, STAN) + Trilling, Abrams, Alam, Biocker+ (SLAC, LBL) + Kurdadze, Leichuk, Mishnev+ (NOVO) DOM YAF 34 1471. 53 + Cords+ (DASP Collab.) 54 + Cords+ (DASP Collab.) 55 + Cords+ (DASP Collab.) 56 + Cords+ (DASP Collab.)
• • We do not use the following the followin	bwing data for average BARTEL 16 ABRAMS DOCUMENT ID FRANKLIN Total FRANKLIN	76 CNTR 75 MRK1 75 MRK1 TECN 83 MRK2	etc. • • • • $e^+e^ e^+e^ e^+e^ e^+e^ hat be denoted by the equation of the equation e^+e^- \to hat be denoted by the equation of the equation e^+e^- \to hat be denoted by the equation e^+e^- \to hat be denoted by the equation of the equation e^+e^- \to hat be denoted by the equation e^+e^- \to hat be denoted by the equation of the equation e^+e^- \to hat be denoted by the equation of the equation e^+e^- \to hat be denoted by the equation of the equation e^+e^- \to hat be denoted by the equation of the equation e^+e^- \to hat be denoted by the equation of the equation of the equation e^+e^- \to hat be denoted by the equation of	adrons	GRIBUSHIN 96 PR D53 4723 ARMSTRONG 93B PR D47 772 PDG 97 PR D45, 12 ALEXANDER 89 NP B320 45 GAISER 86 PR D34 711 FRANKLIN 83 PRL 51 963 EDWARDS 82C PRL 48 70 ELEMOIGNE 82 HIMEL 80 PRL 45 920 COREGLIA 80 PRL 44 920 OREGLIA 80 PRL 44 920 COREGLIA 80 PRL 45 939 SCHARRE 80 PL 978 329 ZHOLENTZ 80 PL 978 342 ZHOLENTZ 80 PL 97	+ Abramov, Antipov+ (E672 Collab.). E706 Collab.) + Arenton+ + Bettoni, Bharadwaj+ (FNAL E780 Collab.) + Bettoni, Bharadwaj+ (FNAL E780 Collab.) une, Part II Hikasa, Barnett, Stone+ (KEK, I&I, BOST++ Bonvicini, Dreli, Frey, Luth (LBL, MICH, SLAC) + Bisoom, Bulos, Godfrey+ (CHT, HARV, PRIN, STAN, SLAC) + Partridge, Peck+ (CIT, HARV, PRIN, STAN, SLAC) + Abrams, Alam, Blocker+ (SACL, LOIC, SHMP, IND) + Abrams, Alam, Blocker+ (SLAC, CIT, HARV, PRIN, STAN) + Trilling, Abrams, Alam, Blocker+ (NOVO) Tolentz, Kurdadze, Leichuk+ (NOVO) MYAF 34 1471. Tords+ (DASP Collab.) DASP Gollab.) DASP Gollab.) DATMAN, Bovarish (SLAC, LBIC) + Alam, Bovarish (DSSon, O'Nell+) DASP Gollab.) (DASP Collab.)
• • We do not use the following the followin	bwing data for average BARTEL 16 ABRAMS DOCUMENT ID FRANKLIN Total FRANKLIN	76 CNTR 75 MRK1 75 MRK1 TECN 83 MRK2	etc. • • • • $e^+e^ e^+e^ e^+e^ e^+e^ hat be denoted by the equation of the equation e^+e^- \to hat be denoted by the equation of the equation e^+e^- \to hat be denoted by the equation e^+e^- \to hat be denoted by the equation of the equation e^+e^- \to hat be denoted by the equation e^+e^- \to hat be denoted by the equation of the equation e^+e^- \to hat be denoted by the equation of the equation e^+e^- \to hat be denoted by the equation of the equation e^+e^- \to hat be denoted by the equation of the equation e^+e^- \to hat be denoted by the equation of the equation of the equation e^+e^- \to hat be denoted by the equation of	adrons	GRIBUSHIN 96 PR D53 4723 ARMSTRONG 93B PR D47 772 PDG 97 PR D45, 12 PR D45, 12 PR D47 772 ALEXANDER 89 PR D47 772 ALEXANDER 89 PR D47 772 PR D47 772 PDG 97 PR D45, 12 PR D47 772 PR D47 77	+ Abramov, Antipov+ (E672 Collab., E706 Collab.) + Aernton+ Bettoni, Bharadwaj+ (FNAL E780 Collab.) + Bettoni, Bharadwaj+ (FNAL E780 Collab.) + Bettoni, Drell, Frey, Luth (LBL, MICH, SLAC) + Bloom, Bulos, Godfrey+ (Crystal Ball Collab.) + Franklin, Feldman, Abrams, Alam+ (Crystal Ball Collab.) + Franklin, Feldman, Abrams, Alam+ (LBL, SLAC) + Partridge, Peck- (CTT, HARV, PRIN, STAN, SLAC) + Abrams, Alam, Blocker+ (SACL, LOIC, SHMP, IND) + Abrams, Alam, Blocker+ (SLAC, LIC, SHMP, IND) + Trillilling, Abrams, Alam, Blocker+ (RIN) - Com YAF 34 1471 Cords+ (DASP Collab.) - DASP Collab.) - DASP Collab DASP Collab DASP Collab Barnschweig+ (DASP Collab.) - Barnschweig+ (DASP Collab.) - Barnschweig+ (DASP Collab.) - Branschweig+ (DASP Collab.)
• • We do not use the foll (10 90 90 (1(K+K-\pi^0))/\(\Gamma_{\text{total}}\) (2.96 90 (K+\(\Gamma_{\text{total}}\) (2.96 90 (K+\(\Gamma_{\text{total}}\) (4.0\(\Gamma_{\text{total}}\) (4.0\(\Gamma_{\text{total}}\) (5.6\(\Gamma_{\text{total}}\) (5.6\(\Gamma_{\text{total}}\) (5.6\(\Gamma_{\text{total}}\) (5.6\(\Gamma_{\text{total}}\) (5.6\(\Gamma_{\text{total}}\) (5.6\(\Gamma_{\text{total}}\) (6.6\(\Gamma_{\text{total}}\) (6.6\(\Gamma_{\text{total}	bwing data for average BARTEL 16 ABRAMS DOCUMENT ID FRANKLIN Total FRANKLIN	76 CNTR 75 MRK1 75 MRK1 83 MRK2 7ECN 83 MRK2	etc. • • • • $e^+e^ e^+e^ e^+e^ e^+e^ hat be denoted by the equation of the equation e^+e^- \to hat be denoted by the equation of the equation e^+e^- \to hat be denoted by the equation e^+e^- \to hat be denoted by the equation of the equation e^+e^- \to hat be denoted by the equation e^+e^- \to hat be denoted by the equation of the equation e^+e^- \to hat be denoted by the equation of the equation e^+e^- \to hat be denoted by the equation of the equation e^+e^- \to hat be denoted by the equation of the equation e^+e^- \to hat be denoted by the equation of the equation of the equation e^+e^- \to hat be denoted by the equation of	adrons	GRIBUSHIN 96 PR D53 4723 ARMSTRONG 93B PR D47 772 PDG 97 PR D45, 12 PR D45, 12 PR D47 772 ALEXANDER 99 NP B320 45 GAISER 96 PR D34 711 FRANKLIN 83 PRL 51 963 EDWARDS 82C PRL 48 70 LEMOIGNE 80 PRL 44 970 OREGLIA 80 PRL 44 920 OREGLIA 80 PRL 45 939 SCHARRE 80 PL 978 329 ZHOLENTZ 80 PRL 45 930 SCHARRE 18 SINP 34 814 TANENBAUM 79B NP B160 428 BRANDELIK 79B NP B160 428 BRANDELIK 77 PRL 38 1324 BRANDELIK 77 PRL 68 395 FELDMAN 77 PRPL 37 PRL 68 395	+ Abramov, Antipov+
• • We do not use the following the followi	BARTEL 16 ABRAMS DOCUMENT ID FRANKLIN Total FRANKLIN FRANKLIN Total FRANKLIN	76 CNTR 75 MRK1 75 MRK1 83 MRK2 7ECN 83 MRK2	etc. • • • • $e^+e^ e^+e^ e^+e^ e^+e^ hat be denoted by the equation of the equation e^+e^- \to hat be denoted by the equation of the equation e^+e^- \to hat be denoted by the equation e^+e^- \to hat be denoted by the equation of the equation e^+e^- \to hat be denoted by the equation e^+e^- \to hat be denoted by the equation of the equation e^+e^- \to hat be denoted by the equation of the equation e^+e^- \to hat be denoted by the equation of the equation e^+e^- \to hat be denoted by the equation of the equation e^+e^- \to hat be denoted by the equation of the equation of the equation e^+e^- \to hat be denoted by the equation of	F ₂₉ /F	GRIBUSHIN 96 PR D53 4723 ARMSTRONG 93B PR D47 772 PDG 92 PR D45, 12 PR D45, 24 PR D45 4726 ALEXANDER 99 PR D47 171 FRANKLIN 83 PRL 51 963 EDWARDS 82C PRL 48 70 LEMOIGNE 80 PRL 44 920 OREGLIA 80 PRL 45 970 SCHARRE 80 PR D34 711 AISO 81 PRL 48 970 FR 44 920 OREGLIA 80 PRL 48 970 SCHARRE 80 PR 198 339 SCHARRE 80 PR 198 349 ZHOLENTZ 80 PR 198 349 ZHOLENTZ 80 PR 198 349 ZHOLENTZ 978 814 BRANDELIK 79B NP BIG6 428 BRANDELIK 79B PR 107 1731 BRANDELIK 79PR 138 1324 PR 138 1324 PR 138 1324 PR 138 1324 PR 139 139 492 TANENBAUM 77 PR 16 88 395 FELDMAN 77 PRPL 33C 2 YAMADA 77 Hamburg Cor	+ Abramov, Antipov+
• • We do not use the following the followi	BARTEL 16 ABRAMS DOCUMENT ID FRANKLIN Total FRANKLIN TOTAL	76 CNTR 75 MRK1 75 MRK1 83 MRK2 TECN 83 MRK2	etc. • • • • $e^+e^ e^+e^ e^+e^- \rightarrow h$:	adrons	GRIBUSHIN 96 PR D53 4723 ARMSTRONO 938 PR D47 772 PDG 97 PR D45, 12 PR D45 173 ALEXANDER 86 PR D34 711 FRANKLIN 85 PR D34 711 FRANKLIN 80 PRL 51 943 EDWARDS 82C HIMEL 80 PRL 48 70 COREGLIA 80 PRL 48 70 SCHARRE 80 PRL 48 70 SCHARRE 80 PRL 49 920 SCHARRE 80 PRL 49 920 SCHARRE 80 PRL 49 920 SCHARRE 80 PL 978 329 ZHOLENTZ 80 PRL 48 930 SCHARRE 180 PR 196 324 Also 81 SINP 34 814 TANBENBAUM 77 PR D17 1731 BIODICK 77 PRL 38 1324 BRANDELIK 77 PRL 38 1324 BRANDELIK 77 PRL 38 1324 BRANDELIK 77 PRL 38 1324 BRANDESCH. 77 PRL 38 1324 BRANDESCH. 77 PRL 38 1324 BRANDESCH. 77 PRL 68 385 FELDMAN 77 PRPL 33C 2 FAMENBAUM 77 HAMBUR COL BRANDA 77 HAMBUR COL BRANDA 77 HAMBUR COL BRANDA 77 PRPL 38 124 FRANDA 77 PRL 68 483 TANBENBAUM 76 PRL 68 483 TANBENBAUM 77 PRPL 38 72 BRANDA 77 PRPL 38 124 FRANDA 77 PRPL 48 483 TANBENBAUM 77 PRPL 38 424 FRANDA 77 PRPL 48 483 TANBENBAUM 77 PRPL 48 483 TANBENBAUM 77 PRL 38 482 FRANDA 77 PRPL 38 492 FR D47 772 FRANDA 772	+ Abramov, Antipov+ (E672 Collab.). E706 Collab.) + Arenton+ + Bettoni, Bharadwaj+ (FNAL E780 Collab.) + Bettoni, Bharadwaj+ (FNAL E780 Collab.) + Benoricini, Drell, Frey, Luth (LBL, BOST+) + Bloom, Bulos, Godfrey+ (LBL, MICH, SLAC) + Franklin, Feldman, Abrams, Alam+ (Crystal Ball Collab.) + Partridge, Peck+ (CIT, HARV, PRIN, STAN, SLAC) + Barate, Astbury+ (SACL, LOIC, SAMP, IND) + Abrams, Alam, Blocker+ (SACL, LOIC, SAMP, IND) + Abrams, Alam, Blocker+ (SACL, CIT, HARV, PRIN, STAN, FRIN, STAN) + Trillilling, Abrams, Alam, Blocker+ (NOVO) MYAF 34 1473 + Cords+ (DASP Collab.) - Dittmann, Duinker, Olsson, O'Nelli+ (DESY, HEIDP) + Alam, Boyarski+ (UCSD, UMD, PAVI, PRIN, SLAC, STAN) Braunschweig+ (DESY, HAMB, SIEG, WUPP) # Duinker, Olsson, Steffen, Heintze+ (DESY, HEIDP) + Alams, Boyarski, Bulos+ (SLAC, LBL) + Eurigee+ (DESY, HAMB, SIEG, WUPP) + Alams, Boyarski, Bulos+ (SLAC, LBL) DASP Collab.) - Duinker, Olsson, Steffen, Heintze+ (DESY, HEIDP) + Alams, Boyarski, Bulos+ (SLAC, LBL) - (SLAC, LBL)
• • We do not use the following the followi	BARTEL 16 ABRAMS DOCUMENT ID FRANKLIN Total FRANKLIN FRANKLIN Total FRANKLIN	76 CNTR 75 MRK1 75 MRK1 83 MRK2 TECN 83 MRK2	etc. • • • • $e^+e^ e^+e^ e^+e^ e^+e^ hat be denoted by the equation of the equation e^+e^- \to hat be denoted by the equation of the equation e^+e^- \to hat be denoted by the equation e^+e^- \to hat be denoted by the equation of the equation e^+e^- \to hat be denoted by the equation e^+e^- \to hat be denoted by the equation of the equation e^+e^- \to hat be denoted by the equation of the equation e^+e^- \to hat be denoted by the equation of the equation e^+e^- \to hat be denoted by the equation of the equation e^+e^- \to hat be denoted by the equation of the equation of the equation e^+e^- \to hat be denoted by the equation of	F ₂₉ /F	GRIBUSHIN 96 PR D53 4723 ARMSTRONO 938 PR D47 772 PDG 97 PR D45, 127 ALEXANDER 86 PR D320 45 GAISER 86 PR D34 711 FRANKLIN 85 PR. 13 96 33 EDWARDS 82C HIMEL 80 PRL 48 70 CREGLIA 80 PRL 48 70 CREGLIA 80 PRL 48 70 SCHARRE 80 PR. 49 99 SCHARRE 79B PR. 19B 329 THOLENTZ 80 PR. 49 99 SCHARRE 79B PR. 19B 329 THOLENTZ 80 PR. 49 91 BRANDELIK 79B PR. 19B 492 TANENBAUM 77 BARTEL 78B PL 79B 492 TANENBAUM 77 BURMESTER 77 BARTEL 76 BURMESTER 77 BURMES	+ Abramov, Antipov+
• • We do not use the following the followi	BARTEL 16 ABRAMS DOCUMENT ID FRANKLIN Total FRANKLIN TOTAL	76 CNTR 75 MRK1 75 MRK1 83 MRK2 TECN 83 MRK2	etc. • • • • $e^+e^ e^+e^ e^+e^- \rightarrow h$:	F ₂₉ /F	GRIBUSHIN 96 PR D53 4723 ARMSTRONG 93B PR D47 772 PDG 97 PR D45, 12 PR D45, 12 PR D47 772 ALEXANDER 86 PR D34 711 FRANKLIN 80 PR D34 711 EMOIGNE 80 PR L 48 70 EEMOGRE 80 PR L 48 70 CREGLIA 80 PR L 48 70 CREGLIA 80 PR L 49 920 COREGLIA 80 PR L 44 920 COREGLIA 80 PR L 49 920 COREGLIA 80 PR L 49 920 COREGLIA 80 PR L 49 80 SCHARRE 80 PL 97B 329 CHOLENTZ 80 PR L 49 80 SCHARRE 79B PR 139 329 CHOLENTZ 80 PR L 49 80 ABO 81 SIAPPE 19B 829 TANENBAUM 79 PR D17 1731 BIODICK 77 PR 138 1324 BRANDELIK 76 PR D17 1731 BIODICK 77 PR 138 1324 BRANDESTER 77 PR 68 395 FELDMAN 77 BRUMBESTER 77 PR 68 395 FELDMAN 78 BRUMBESTER 78 PR 68 31 PR	+ Abramov, Antipov+
• • We do not use the following the followi	BARTEL 16 ABRAMS DOCUMENT ID FRANKLIN Total FRANKLIN DOCUMENT ID FRANKLIN TOTAL FRANKLIN DOCUMENT ID FRANKLIN TOTAL FRANKLIN DOCUMENT ID FRANKLIN TOTAL	es, fits, Ilmits 76 CNTR 75 MRK1 TECN 83 MRK2 TECN 83 MRK2	etc. • • • • $e^+e^ e^+e^ e^+e^- \rightarrow h$:	F ₂₉ /Γ	GRIBUSHIN 96 PR D53 4723 ARMSTRONG 93B PR D47 772 PDG 92 PR D45, 12 PR D45, 24 PR D50 4258 GAISER 86 PR D34 711 FRANKLIN 83 PRL 51 963 EDWARDS 82C PRL 48 70 LEMOIGNE 82 PL 1138 509 HIMEL 80 PRL 44 920 HIMEL 80 PRL 44 920 HIMEL 80 PRL 45 959 SCHARRE 80 PRL 46 920 AISO 81 TAINBARD 17 PR 18 124 BRANDELIK 96C PR 18 13 124 BRANDELIK 97C PR 18 18 124 BRANDELIK 97C PR 1	+ Abramov, Antipov+
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• • We do not use the following the followi	BARTEL 16 ABRAMS DOCUMENT ID FRANKLIN Total FRANKLIN COLUMENT ID FRANKLIN DOCUMENT ID FRANKLIN DOCUMENT ID FRANKLIN DOCUMENT ID FRANKLIN	es, fits, Ilmits 76 CNTR 75 MRK1 TECN 83 MRK2 TECN 83 MRK2 TECN 84 TECN 85 CBAL	etc. • • • • $e^+e^ e^+e^ hi$	T ₂₉ /Γ adrons F ₃₀ /Γ	GRIBUSHIN 96 PR D53 4723 ARMSTRONG 93B PR D47 772 PDG 92 PR D45, 12) ALEXANDER 89 PR D47 772 FRANKLIN 83 PRL 51 963 EDWARDS 82C PRL 48 70 LEMOIGNE 82 PL 1138 509 HIMEL 80 PRL 45 959 SCHARRE 80 PRL 48 959 SCHARRE 80 PRL 47 920 ABBOANDELIK 79C ZPHY C1 23 BRANDELIK 79C ZPHY C1 23 BRANDER 79C ZPHY	+ Abramov, Antipov+ (E672 Collab., E706 Collab.) + Arenton+ + Bettoni, Bharadwaj+ (FNAL E780 Collab.) + Bettoni, Bharadwaj+ (FNAL E780 Collab.) + Bettoni, Drell, Frey, Luth (LBL, MICH, SLAC) + Boowlcini, Drell, Frey, Luth (LBL, MICH, SLAC) + Franklin, Feldman, Abrams, Alam+ (LBL, SLAC) + Franklin, Feldman, Abrams, Alam+ (LBL, SLAC) + Barate, Astbury+ (SACL, LOIC, SHMP, IND) (LBL, SLAC) + Partridge, Peck- (SLAC, CIT, HARV, PRIN, STAN), SLAC) + Partridge, Peck- (SLAC, CIT, HARV, PRIN, STAN), SLAC) + Partridge, Alam, Blocker+ (SLAC, LBL, SLAC) + Partridge, Peck- (SLAC, CIT, HARV, PRIN, STAN), SLAC) - Trillinge, Abrams, Alam, Blocker+ (SLAC, LBL, SLAC) - Trillinge, Abrams, Alam, Blocker+ (NOVO) - YAF 34 1471 - Trillinge, Abrams, Alam, Blocker+ (NOVO) - Trillinge, Abrams, Alam, Blocker+ (NOVO) - Trillinge, Abrams, Alam, Blocker+ (NOVO) - Trillinge, Abrams, Duinker, Olsson, O'Nell+ (DSSY, Gollab.) - Distrimann, Duinker, Olsson, O'Nell+ (DSSY, HEIDP) - Halam, Boyarski, CUCSD, UMD, PAVI, PRIN, SLAC, STAN) - Braunschweig+ (DESY, HAMB, SIEG, WUPP) - Luinker, Olsson, Steffen, Heintze+ (SLAC, LBL) - Burinker, Olsson, Steffen, Heintze+ (SLAC
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• • We do not use the following the followi	DOCUMENT ID TO GAISER 16 ABRAMS DOCUMENT ID FRANKLIN DOCUMENT ID FRANKLIN DOCUMENT ID TO GAISER TO BIDDICK TO WHITAKER DOCUMENT ID TO GAISER TO BIDDICK TO WHITAKER DOCUMENT ID TO GAISER TO BIDDICK TO WHITAKER	### 15 ### 15	etc. • • • • • • • • • • • • • • • • • • •	F ₂₉ /Γ adrons F ₃₀ /Γ × F ₃₁ /Γ	GRIBUSHIN 96 PR D53 4723 ARMSTRONG 93B PR D47 772 PDG 92 PR D45, 12) ALEXANDER 89 PR D47 772 FRANKLIN 83 PRL 51 963 EDWARDS 82C PRL 48 70 LEMOIGNE 82 PL 1138 509 HIMEL 80 PRL 44 959 SCHARRE 80 PRL 45 959 SCHARRE 80 PRL 47 807 JAMOADA 75 PR 198 214 BRANDELIK 79C ZPHY CL 23 BRANDELIK 79C ZPHY	+ Abramov, Antipov+
• • We do not use the following the followi	DOCUMENT ID TOTAL TOT	### 15 ### 15	etc. • • • • • • • • • • • • • • • • • • •	F ₂₉ /Γ adrons F ₃₀ /Γ × F ₃₁ /Γ	GRIBUSHIN 96 PR D53 4723 ARMSTRONG 93B PR D47 772 PDG 92 PR D45, 12) ALEXANDER 89 PR D47 772 FRANKLIN 83 PRL 51 963 EDWARDS 82C PRL 48 70 LEMOIGNE 82 PL 1138 509 HIMEL 80 PRL 44 959 SCHARRE 80 PRL 45 959 SCHARRE 80 PRL 47 807 JAMOADA 75 PR 198 214 BRANDELIK 79C ZPHY CL 23 BRANDELIK 79C ZPHY	+ Abramov, Antipov+
• • We do not use the following the followi	DOCUMENT ID TOTAL TOT	## 15 ##	etc. • • • • • • • • • • • • • • • • • • •	F ₂₉ / F ₂₉ / F ₂₉ / F ₃₀ / F ₃₀ / F ₃₁ / F ₃₁ / F ₃₂ / F ₂₂	GRIBUSHIN 96 PR D53 4723 ARMSTRONG 93B PR D47 772 PDG 92 PR D45, 12) ALEXANDER 89 PR D47 772 FRANKLIN 83 PRL 51 963 EDWARDS 82C PRL 48 70 LEMOIGNE 82 PL 1138 509 HIMEL 80 PRL 44 959 SCHARRE 80 PRL 45 959 SCHARRE 80 PRL 47 807 JAMOADA 75 PR 198 214 BRANDELIK 79C ZPHY CL 23 BRANDELIK 79C ZPHY	+ Abramov, Antipov+

 Γ_1/Γ

	1 110
ı	a/1(3770)
ı	$\psi(3110)$

$$I^{G}(J^{PC}) = ?^{?}(1--)$$

ψ(3770) MASS

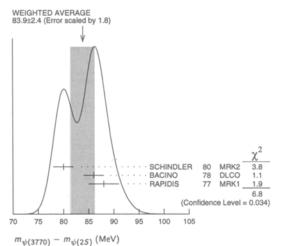
VALUE (MeV) 3769.9±2.5 OUR EVALUATION		TECN COMMENT cale factor of 1.8. From $m_{\psi(25)}$ and
• • We do not use the follow	mass difference ing data for average	
3764 ±5	1 SCHINDLER	80 MRK2 e+e-
3770 ±6	¹ BACINO	78 DLCO e+e-
3772 ±6	1 RAPIDIS	77 MRK1 e ⁺ e ⁻

 $^{^{\}mbox{\scriptsize 1}}\mbox{\it Errors}$ include systematic common to all experiments.

$m_{\psi(3770)} - m_{\psi(25)}$

VALUE (MeV)	DOCUMENT ID TECN COMMENT
83.9±2.4 OUR AVERAGE	Error includes scale factor of 1.8. See the ideogram below.
80 ±2	SCHINDLER 80 MRK2 e ⁺ e ⁻
86 ±2	² BACINO 78 DLCO e ⁺ e ⁻
00 T3	PADIDIS 77 MPK1 ata-

 $^{^2}$ SPEAR $\psi(2S)$ mass subtracted (see SCHINDLER 80).



ψ (3770) WIDTH

VAL	UE (MeV)		DOCUMENT ID		TECN	COMMENT
23.	5±2.7 OUR FIT	Error includes	scale factor of	1.1.		
25.	8±2.9 OUR AVE	RAGE				
24	±5		SCHINDLER	80	MRK2	e ⁺ e ⁻
24	±5		BACINO	78	DLCO	e ⁺ e ⁻
28	±5		RAPIDIS	77	MRK1	e+e-

$\psi(3770)$ DECAY MODES

	Mode	Fraction (Γ_I/Γ)	Scale factor
Γ ₁	DD	dominant	
Γ_2	e+ e-	$(1.12\pm0.17)\times10^{-5}$	1.2

ψ (3770) PARTIAL WIDTHS

· Γ(e+e-)					Г;
VALUE (keV)	DOCUMENT ID		TECN	COMMENT	
0.26 ±0.04 OUR FIT Error	includes scale factor	of 1.	.2.		
0.24 ±0.05 OUR AVERAGE	Error includes scale	fact	or of 1.2		
0.276±0.050	SCHINDLER	80	MRK2	e ⁺ e ⁻	
0.18 ±0.06	BACINO	78	DLCO	e^+e^-	
• • • We do not use the follow	ving data for average	s, flt	s, limits,	etc. • • •	
0.37 ±0.09	3 RAPIDIS	77	MRK1	e+e-	
³ See also $\Gamma(e^+e^-)/\Gamma_{\text{total}}$	below.				

ψ(3770) BRANCHING RATIOS

	ψ(3770) REFER	ENC	ES		
1.3 ±0.2	RAPIDIS	77	MRK1	e+e-	
1.12±0.17 OUR FIT	Error includes scale factor of				
VALUE (units 10 ⁻⁵)	DOCUMENT ID		TECN	COMMENT	
$\Gamma(e^+e^-)/\Gamma_{\text{total}}$					Γ_2/Γ
dominant	PERUZZI	77	MRK1	e ⁺ e [−] → DD	
Γ(DD)/Γ _{total}	DOCUMENT ID			COMMENT	Γ ₁ /Γ

SCHINDLER 80	PR D21 2716	+Siegrist, Alam, Boyarski+	(Mark II Collab.)
BACINO 78	PRL 40 671	+Baumgarten, Birkwood+	(SLAC, UCLA, UCI)
PERUZZI 77	PRL 39 1301	+Piccolo, Feldman+	(Mark I Collab.)
RAPIDIS 77	PRL 39 526	+Gobbi, Luke, Barbaro-Galtieri+	(Mark I Collab.)

$\psi(4040)$

 $\Gamma(e^+e^-)/\Gamma_{\text{total}}$

$$I^{G}(J^{PC}) = ?^{?}(1^{-})$$

$\psi(4040)$ MASS

VALUE (MeV)	DOCUMENT ID TEC	N COMMENT
4040±10	BRANDELIK 78c DAS	SP e ⁺ e ⁻

ψ(4040) WIDTH

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
82±10	BRANDELIK 78C	DASP	e+e-

ψ(4040) DECAY MODES

	Mode	Fraction (Γ_I/Γ)
Γ1	e ⁺ e ⁻	$(1.4\pm0.4)\times10^{-5}$
Γ_2	$D^0\overline{D}{}^0$	seen
Γ3	$D^*(2007)^0 \overline{D}{}^0 + \text{c.c.}$	seen
Γ ₄ Γ ₅ Γ ₆	$D^*(2007)^0 \overline{D}^*(2007)^0 \ J/\psi(15)$ hadrons $\mu^+ \mu^-$	seen

ψ (4040) PARTIAL WIDTHS

Γ(e ⁺ e ⁻)				Γ1
VALUE (keV)	DOCUMENT ID	<u>TECN</u>	COMMENT	
0.75±0.15	BRANDELIK	78C DASP	e ⁺ e ⁻	
	·			

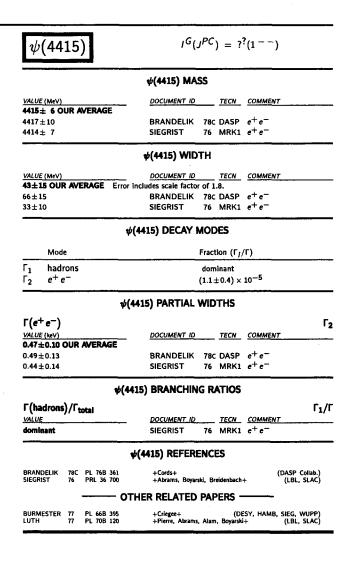
∲(4040) BRANCHING RATIOS

VALUE (units 10 ⁻⁵)	DOCUMENT ID		TECN	COMMENT	
• • • We do not use the	following data for averages	, fits	i, limits,	etc. • • •	
~ 1.0	FELDMAN	77	MRK1	e+ e-	
$\Gamma(D^0\overline{D}^0)/\Gamma(D^*(2007$	') ⁰ \overline{D} ⁰ + c.c.)				Γ_2/Γ_3
VALUE	DOCUMENT ID				
0.05 ±0.03	¹ GOLDHABER	77	MRK1	e+e-	
Γ(D*(2007) ⁰ D*(2007	') ⁰)/Γ(<i>D</i> *(2007) ⁰ <i>D</i> ⁰ +	c.c	.)		Γ4/Γ3
VALUE	DOCUMENT ID				
32.0±12.0	¹ GOLDHABER	77	MRK1	e ⁺ e ⁻	
¹ Phase-space factor (p	3) explicitly removed.				

ψ(4040) REFERENCES						
BRANDELIK Also FELDMAN GOLDHABER	78C 79C 77 77	PL 76B 361 ZPHY C1 233 PRPL 33C 285 PL 69B 503	+Cords+ Brandelik, Cords+ +Peri +Wiss, Abrams, Alam+	(DASP Collab.) (DASP Collab.) (LBL, SLAC) (Mark 1 Collab.)		
		отн	IER RELATED PAPERS	_		
HEIKKILA ONO	84 84	PR D29 110 ZPHY C26 307	+Tornqvist, Ono	(HELS, AACHT) (ORSAY)		
SIEGRIST	82	PR D26 969	+Schwitters, Alam, Chinowsky+	(SLÀC, LBL)		
AUGUSTIN	75	PRL 34 764	+Boyarski, Abrams, Briggs+	(SLAC, LBL)		
BACCI	75	PL 58B 481	+Bidoli, Penso, Stella+	(ROMA, FRAS)		
BOYARSKI	75B	PRL 34 762	+Breidenbach, Abrams, Briggs+	(SLAC, LBL)		
ESPOSITO	75	PL 58B 478	+Felicetti, Peruzzi+ (FRAS, N/	APL, PADO, ROMA)		

 ψ (4160), ψ (4415)

ψ (4160)	$I^{G}(J^{PC}) = ?^{?}(1^{})$
	ψ(4160) MASS
VALUE (MeV)	DOCUMENT ID TECN COMMENT
4159±20	BRANDELIK 78C DASP e ⁺ e ⁻
	ψ(4160) WIDTH
VALUE (MeV)	DOCUMENT ID TECN COMMENT
78±20	BRANDELIK 78C DASP e+e-
	ψ (4160) DECAY MODES
Mode	Fraction (Γ_I/Γ)
Γ ₁ e ⁺ e ⁻	$(10\pm4)\times10^{-6}$
	ψ(4160) PARTIAL WIDTHS
Γ(e ⁺ e ⁻)	Γ ₁
VALUE (keV)	DOCUMENT ID TECN COMMENT
0.77±0.23	BRANDELIK 78C DASP e+e-
	ψ(4160) REFERENCES
BRANDELIK 78C PL 76B 361	+Cords+ (DASP Collab.)
	OTHER RELATED PAPERS
ONO 84 ZPHY C26 3 BURMESTER 77 PL 66B 395	(ORSAY) +Criegee+ (DESY, HAMB, SIEG, WUPP)



Meson Particle Listings Bottomonium

bb MESONS

WIDTH DETERMINATIONS OF THE Υ STATES

As is the case for the $J/\psi(1S)$ and $\psi(2S)$, the full widths of the $b\bar{b}$ states $\Upsilon(1S)$, $\Upsilon(2S)$, and $\Upsilon(3S)$ are not directly measurable, since they are much narrower than the energy resolution of the e^+e^- storage rings where these states are produced. The common indirect method to determine Γ starts from

$$\Gamma = \Gamma_{\ell\ell}/B_{\ell\ell} \,\,, \tag{1}$$

where $\Gamma_{\ell\ell}$ is one leptonic partial width and $B_{\ell\ell}$ is the corresponding branching fraction ($\ell=e, \mu, \text{ or } \tau$). One then assumes e- μ - τ universality and uses

$$\Gamma_{\ell\ell} = \Gamma_{ee}$$

$$B_{\ell\ell}$$
 = average of B_{ee} , $B_{\mu\mu}$, and $B_{\tau\tau}$. (2)

The electronic partial width Γ_{ee} is also not directly measurable at e^+e^- storage rings, only in the combination $\Gamma_{ee}\Gamma_{\rm had}/\Gamma$, where $\Gamma_{\rm had}$ is the hadronic partial width and

$$\Gamma_{\text{had}} + 3\Gamma_{ee} = \Gamma . \tag{3}$$

This combination is obtained experimentally from the energyintegrated hadronic cross section

$$\int \sigma(e^+e^- \to \Upsilon \to \text{hadrons})dE$$

resonance

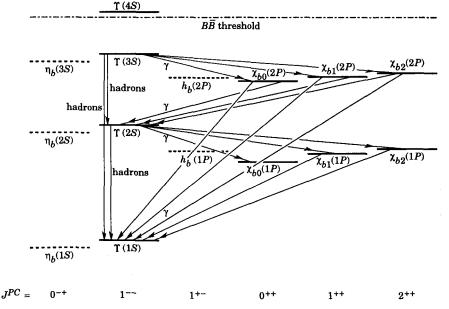
$$=\frac{6\pi^2}{M^2}\frac{\Gamma_{ee}\Gamma_{had}}{\Gamma}C_r = \frac{6\pi^2}{M^2}\frac{\Gamma_{ee}^{(0)}\Gamma_{had}}{\Gamma}C_r^{(0)}, \qquad (4)$$

where M is the Υ mass, and C_r and $C_r^{(0)}$ are radiative correction factors. C_r is used for obtaining Γ_{ee} as defined in Eq. (1), and contains corrections from all orders of QED for describing $(b\bar{b}) \to e^+e^-$. The lowest order QED value $\Gamma_{ee}^{(0)}$, relevant for comparison with potential-model calculations, is defined by the lowest order QED graph (Born term) alone, and is about 7% lower than Γ_{ee} .

THE BOTTOMONIUM SYSTEM

Υ (11020)

T (10860)



The level scheme of the $b\bar{b}$ states showing experimentally established states with solid lines. Singlet states are called η_b and h_b , triplet states Υ and χ_{bJ} . In parentheses it is sufficient to give the radial quantum number and the orbital angular momentum to specify the states with all their quantum numbers. E.g., $h_b(2P)$ means 2^1P_1 with n=2, L=1, S=0, J=1, PC=+-. If found, D-wave states would be called $\eta_b(nD)$ and $\Upsilon_J(nD)$, with J=1,2,3 and $n=1,2,3,4,\cdots$. For the χ_b states, the spins of only the $\chi_{b2}(1P)$ and $\chi_{b1}(1P)$ have been experimentally established. The spins of the other χ_b are given as the preferred values, based on the quarkonium models. The figure also shows the observed hadronic and radiative transitions.

Bottomonium, $\Upsilon(1S)$

The Listings give experimental results on B_{ee} , $B_{\mu\mu}$, $B_{\tau\tau}$, and $\Gamma_{ee}\Gamma_{had}/\Gamma$. The entries of the last quantity have been re-evaluated consistently using the correction procedure of KURAEV 85. The partial width Γ_{ee} is obtained from the average values for $\Gamma_{ee}\Gamma_{had}/\Gamma$ and $B_{\ell\ell}$ using

$$\Gamma_{ee} = \frac{\Gamma_{ee}\Gamma_{had}}{\Gamma(1 - 3B_{\ell\ell})} \ . \tag{5}$$

The total width Γ is then obtained from Eq. (1). We do not list Γ_{ee} and Γ values of individual experiments. The Γ_{ee} values in the Meson Summary Table are also those defined in Eq. (1).

 $\overline{\Upsilon(1S)}$

$$I^{G}(J^{PC}) = 0^{-}(1^{-})$$

7(15) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
9460.37±0.21 OUR AVERAGE	Error includes scale below.	fact	or of 2.	7. See the Ideogram
9460.60±0.09±0.05	¹ BARU	92B	REDE	$e^+e^- \rightarrow hadrons$
9460.6 ±0.4	² ARTAMONOV	84	REDE	$e^+e^- \rightarrow hadrons$
9459.97±0.11±0.07	MACKAY	84	REDE	e ⁺ e ⁻ → hadrons
• • We do not use the following	ing data for average:	i, fits	, limits,	etc. • • •
9460.59±0.12	BARU	86	REDE	$e^+e^- \rightarrow hadrons$

¹ Superseding BARU 86. ² Value includes data of ARTAMONOV 82.

WEIGHTED AVERAGE 9460.37±0.21 (Error scaled by 2.7) ARTAMONOV 84 MACKAY 84 9459.5 9460 9460.5 9461 9461.5 9462 $\Upsilon(1S)$ mass (MeV)

T(15) WIDTH

VALUE (keV)	DOCUMENT ID
52.5±1.8 OUR EVALUATION	See the Note on Width Determinations of the Υ states

T(1S) DECAY MODES

Scale factor/

	Mode	Fraction (I	[_/ /r)	Confidence level
Γ_1	τ ⁺ τ ⁻	(2.67 + (0.14 0.16) %	
Γ_2	e+ e-	(2.52±0	0.17) %	
Гз	$\mu^+\mu^-$	(2.48±0	0.07) %	S≔1.1
	Had	ronic decays		
Γ4.	$J/\psi(1S)$ anything	(1.1 ±0	0.4) × 10 ⁻	3
Γ ₅	$ ho\pi$	< 2	× 10	4 CL=90%
Γ6	$\pi^+\pi^-$	< 5	× 10 ⁻	4 CL=90%
Γ7	"к+"к-	< 5	× 10	4 CL=90%
Γ ₈	$p\overline{p}$ $D^*(2010)^{\pm}$ anything	< 5	× 10	4 CL=90%

	Radiative dec	ays		
Γ10	$\gamma 2h^+2h^-$	(7.0 ±1.5) × 10 ⁻⁴	
Γ11	$\gamma 3h^{+}3h^{-}$)×10 ⁻⁴	
Γ_{12}	γ 4 h ⁺ 4 h ⁻	(7.4 ±3.5	5)×10 ⁻⁴	
Γ ₁₃	$\gamma \pi^+ \pi^- K^+ K^-$	(2.9 ±0.9)×10 ⁻⁴	
	$\gamma 2\pi^+ 2\pi^-$)×10 ⁻⁴	
Γ ₁₅	$\gamma 3\pi^+3\pi^-$		≥)×10 ⁻⁴	
	$\gamma 2\pi^+ 2\pi^- K^+ K^-$		2)×10 ⁻⁴	
	$\gamma \pi^+ \pi^- \rho \overline{\rho}$		5)×10 ⁻⁴	
Γ ₁₈	$\gamma 2\pi^{+}2\pi^{-}p\overline{p}$) × 10 ⁻⁵	
	γ2K+2K-) × 10 ⁻⁵	
	$\gamma \eta'$ (958)	< 1.3	× 10 ⁻³	CL≃90%
	$\gamma \eta$	< 3.5	× 10 ⁻⁴	CL=90%
	$\gamma f_2'(1525)$	< 1.4	× 10 ⁻⁴	CL=90%
	$\gamma f_2(1270)$	< 1.3	× 10 ⁻⁴	CL=90%
	$\gamma \eta(1440)$	< 8.2	× 10 ⁻⁵	CL=90%
	$\gamma f_J(1710) \rightarrow \gamma K \overline{K}$	< 2.6	× 10 ⁻⁴	CL=90%
	$\gamma f_0(2200) \rightarrow \gamma K^+ K^-$	< 2	× 10 ⁻⁴	CL=90%
	$\gamma f_J(2220) \rightarrow \gamma K^+ K^-$	< 1.5	× 10 ⁻⁵	CL=90%
	$\gamma \eta(2225) \rightarrow \gamma \phi \phi$	< 3	× 10 ⁻³	CL=90%
Γ ₂₉	γX	< 3	× 10 ⁻⁵	CL=90%
F20	$X = \text{pseudoscalar with } m < 7.2 \text{ GeV}$) $\gamma X \overline{X}$	< 1	× 10 ⁻³	CL=90%
30	$X\overline{X}$ = vectors with m < 3.1 GeV)	·		

$\Upsilon(1S) \Gamma(i)\Gamma(e^+e^-)/\Gamma(\text{total})$

$\Gamma(e^+e^-) \times \Gamma(\mu^+\mu^-)/\Gamma_{\rm total}$					$\Gamma_2\Gamma_3/\Gamma$
VALUE (eV)	DOCUMENT ID		TECN	COMMENT	
31.2±1.6±1.7	KOBEL	92	CBAL	e+ e ⁻ →	μ+μ-
$\Gamma(\text{hadrons}) \times \Gamma(e^+e^-)/\Gamma_{\text{total}}$	i				$\Gamma_0\Gamma_2/\Gamma$
VALUE (keV)	DOCUMENT ID		TECN	COMMENT	
1.216±0.027 OUR AVERAGE					
1.187±0.023±0.031	³ BARU	92B	MD1	$e^+e^- \rightarrow$	hadrons
1.23 ±0.02 ±0.05	³ JAKUBOWSKI	88	CBAL	$e^+e^- \rightarrow$	hadrons
1.37 ±0.06 ±0.09	⁴ GILES	84B	CLEO	e+e- →	hadrons
1.23 ±0.08 ±0.04	4 ALBRECHT	82	DASP	e+e	hadrons
1.13 ±0.07 ±0.11	⁴ NICZYPORUK	82	LENA	e+ e- →	hadrons
1.09 ±0.25	⁴ BOCK	80	CNTR	e+e- →	hadrons
1.35 ±0.14	⁵ BERGER	79	PLUT	e+e- →	hadrons
3 Padlathus convertions surfueted	fallandar KIIDAD	3/6			

T(15) PARTIAL WIDTHS

Γ(e+e-)				Γ ₂
VALUE (keV)	DOCUMENT ID	TECN	COMMENT	
1.32±0.04±0.03	6 ALBRECHT	95E ARG	e ⁺ e [−] → hadrons	
⁶ Applying the formula of Ku	raev and Fadin.			

7(15) BRANCHING RATIOS

$\Gamma(\tau^+\tau^-)/\Gamma_{\text{total}}$						Γ_1/Γ
VALUE	<u>EVTS</u>	DOCUMENT ID	TECN	r co	MMENT	
0.0267+0.0014 OUR AVE	RAGE					
$0.0261 \pm 0.0012 ^{+0.0009}_{-0.0013}$	25k	CINABRO	94B CLE	2 e ⁺	e- → ++	τ-
0.027 ±0.004 ±0.002	7	ALBRECHT	85c ARG		(25) →	
0.034 ±0.004 ±0.004		GILES	83 CLE	0 e+	$e^+\pi^-\tau^+$	<u>τ</u> _
⁷ Using B($\Upsilon(15) \rightarrow ee$	$)=B(\Upsilon(1S)$	$\rightarrow \mu\mu) = 0.025$	56; not u	sed for	width eval	uations.
$\Gamma(\mu^+\mu^-)/\Gamma_{\text{total}}$						Γ_3/Γ
VALUE	<u>EYTS</u>	DOCUMENT I		ECN	COMMENT	
0.0248±0.0007 OUR AVE	RAGE Error	includes scale fac	ctor of 1.	1.		
$0.0212 \pm 0.0020 \pm 0.0010$		8 BARU	92 N	MD1	e+e- "+"-	
0.0231±0.0012±0.0010		8 KOBEL	92 (BAL	e+e	
0.0252±0.0007±0.0007		CHEN	89B (LEO	e+e- →	
$0.0261 \pm 0.0009 \pm 0.0011$		KAARSBER	G 89 (CSB2	e+e- →	
$0.0230 \pm 0.0025 \pm 0.0013$	86	ALBRECHT	87 /	ARG	$r(25) \rightarrow$	
0.029 ±0.003 ±0.002	864	BESSON	84 (CLEO	$\tau^+\pi^ \tau(25) \rightarrow$	μ+ μ-
					$\pi^+\pi^-$	$\mu^{+} \mu^{-}$

⁴ Radiative corrections reevaluated by BUCHMUELLER 88 following KURAEV 85. ⁵ Radiative corrections reevaluated by ALEXANDER 89 using B($\mu\mu$) = 0.026.

	$\Upsilon(1S)$

0.027 $\pm 0.003 \pm 0.003$ ANDREWS 83 CLEO $e^+e^$	$\Gamma(\gamma 2\pi^+ 2\pi^- p\overline{p})/\Gamma_{\text{total}}$
$\mu^+\mu^-$ 0.032 \pm 0.013 \pm 0.003 ALBRECHT 82 DASP $e^+e^-\to$	VALUE (units 10 ⁻⁴) EVTS DOCUMENT ID TECN COMMENT
0.038 ± 0.005 ± 0.002 ALBRECH 02 DASP $e^+e^ \mu^+\mu^-$ 0.038 ± 0.015 ± 0.002 NICZYPORUK 82 LENA e^+e^-	$0.4\pm0.4\pm0.4$ 7 ± 6 FULTON 90B CLEO $e^+e^- \rightarrow$ hadrons
$\mu^+\mu^-$	$\Gamma(\gamma 2h^+2h^-)/\Gamma_{\text{total}}$
0.014 $^{+0.034}$ BOCK 80 CNTR $e^{+}e^{-} \rightarrow \mu^{+}\mu^{-}$	VALUE (units 10 ⁻⁴) EVTS DOCUMENT ID TECN COMMENT 7.0±1.1±1.0 80 ± FULTON 908 CLEO e^+e^- → hadrons
0.022 \pm 0.020 BERGER 79 PLUT $e^+e^{\mu}\rightarrow \mu^+_{\mu}$	12
8 Taking into account interference between the resonance and continuum.	$\Gamma(\gamma 3 h^+ 3 h^-)/\Gamma_{total}$ VALUE (units 10 ⁻⁴) EVTS DOCUMENT ID TECH . COMMENT
Γ(e ⁺ e ⁻)/Γ _{total} Γ ₂ /Γ VALUE EVTS DOCUMENT ID TECN COMMENT D.0282 ± 0.0017 OUR AVERAGE	5.4±1.5±1.3 39 ± FULTON 90B CLEO $e^+e^- \rightarrow$ hadrons 11
$0.0242 \pm 0.0014 \pm 0.0014$ 307 ALBRECHT 87 ARG $T(25) \rightarrow$	$\Gamma(\gamma 4h^+4h^-)/\Gamma_{\text{total}}$
0.028 $\pm 0.003 \pm 0.002$ 826 BESSON 84 CLEO $T(25) \rightarrow$	VALUE (units 10 ⁻⁴) EVTS DOCUMENT ID TECN COMMENT
0.051 ± 0.030 BERGER 80C PLUT $e^+e^- \rightarrow e^-$	7.4 \pm 2.5 \pm 2.5 36 \pm FULTON 90B CLEO $e^+e^- \rightarrow$ hadrons 12
ere	$\Gamma(\rho\pi)/\Gamma_{\text{total}}$
$\Gamma(J/\psi(1S) \text{ anything})/\Gamma_{\text{total}}$ Γ_4/Γ	VALUE (units 10 ⁻⁴) CL% DOCUMENT ID TECN COMMENT
VALUE (units 10^{-3}) CL% DOCUMENT ID TECN COMMENT < 0.68 90 ALBRECHT 92J ARG $e^+e^- \rightarrow e^+e^- X$,	< 2 90 FULTON 90B $\Upsilon(15) \rightarrow \rho^0 \pi^0$
< 0.68 90 ALBRECHT 92J ARG $e^+e^- \rightarrow e^+e^- X$, $e^+e^- \rightarrow \mu^+\mu^- X$	• • • We do not use the following data for averages, fits, limits, etc. • • • <10 90 BLINOV 90 MD1 $T(15) \rightarrow \rho^0 \pi^0$
1.1 \pm 0.4 \pm 0.2 9 FULTON 89 CLEO $e^+e^- \rightarrow \mu^+\mu^- X$ • • • We do not use the following data for averages, flts, limits, etc. • • •	<10 90 BLINOV 90 MD1 $T(15) \rightarrow \rho^0 \pi^0$ <21 90 NICZYPORUK 83 LENA $T(15) \rightarrow \rho^0 \pi^0$
< 1.7 90 MASCHMANN 90 CBAL $e^+e^- \rightarrow$ hadrons	$\Gamma(D^*(2010)^{\pm} \text{ anything})/\Gamma_{\text{total}}$ $\Gamma_9/\Gamma_{\text{total}}$
<20 90 NICZYPORUK 83 LENA	VALUE (units 10 ⁻³) CL% DOCUMENT ID TECN COMMENT
⁹ Using B($(J/\psi) \rightarrow \mu^{+}\mu^{-}$) = (6.9 ± 0.9)%.	<19 90 13 ALBRECHT 921 ARG $e^+e^- \rightarrow D^0\pi^{\pm}X$
$\Gamma(\pi^+\pi^-)/\Gamma_{\text{total}}$ Γ_6/Γ	13 For $x_p > 0.2$.
VALUE (units 10^{-4}) CL% DOCUMENT ID TECN COMMENT <5 90 BARU 92 MD1 $\Upsilon(15) \rightarrow \pi^{+}\pi^{-}$	$\Gamma(\gamma\eta(1440))/\Gamma_{\text{total}}$ $\Gamma_{24}/$
	VALUE (units 10 ⁻⁵) CL% DOCUMENT ID TECN COMMENT
$\Gamma(K^+K^-)/\Gamma_{\text{total}}$	<8.2 90 ¹⁴ FULTON 90B CLEO $T(15) \rightarrow \gamma K^{+} \pi^{\mp} K^{+}$
VALUE (units 10^{-4}) CL% DOCUMENT ID TECN COMMENT <5 90 BARU 92 MD1 $T(15) \rightarrow K^+K^-$	¹⁴ Includes unknown branching ratio of $\eta(1440) \rightarrow K^{\pm} \pi^{\mp} K_{S}^{0}$.
	$\Gamma(\gamma \eta'(958))/\Gamma_{\text{total}}$
$\Gamma(p\overline{p})/\Gamma_{\text{total}}$ Γ_8/Γ	VALUE (units 10 ⁻³) CL% DOCUMENT ID TECN COMMENT
VALUE (units 10 ⁻⁴) CL% DOCUMENT ID TECN COMMENT	<1.3 90 SCHMITT 88 CBAL $\Upsilon(15) \rightarrow \gamma X$
<5 90 10 BARU 96 MD1 $T(15) \rightarrow p\overline{p}$	$\Gamma(\gamma\eta)/\Gamma_{\text{total}}$ Γ_{21}/Γ_{22}
10 Supersedes BARU 92 in this node.	Γ(γη)/Γ _{total} VALUE (units 10 ⁻⁴) CL% DOCUMENT ID TECN COMMENT
	VALUE (units 10^{-4}) CL% DOCUMENT ID TECN COMMENT <3.5 90 SCHMITT 88 CBAL $T(15) \rightarrow \gamma X$
10 Supersedes BARU 92 In this node. $\Gamma(\gamma X)/\Gamma_{\text{total}}$ $(X = \text{pseudoscalar with } m < 7.2 \text{ GeV})$ $VALUE (units 10^{-5}) CLY DOCUMENT ID TECN COMMENT$	VALUE (units 10 ⁻⁴) CL% DOCUMENT ID TECN COMMENT
10 Supersedes BARU 92 In this node.	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
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10 Supersedes BARU 92 In this node.	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
10 Supersedes BARU 92 In this node.	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
10 Supersedes BARU 92 In this node.	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
10 Supersedes BARU 92 In this node. $\Gamma(\gamma X)/\Gamma_{\text{total}} \qquad \qquad \Gamma_{29}/\Gamma$ $(X = \text{pseudoscalar with } m < 7.2 \text{ GeV})$ $VALUE (units 10^{-5}) \qquad CLS \qquad DOCUMENT D \qquad TECN \qquad COMMENT <3 \qquad 90 \qquad 11 \text{ BALEST} \qquad 95 \text{CLEO} \qquad e^+e^- \rightarrow \gamma + X 11 \text{ For a noninteracting pseudoscalar } X \text{ with mass} < 7.2 \text{ GeV}. \Gamma(\gamma XX)/\Gamma_{\text{total}} \qquad \qquad \Gamma_{30}/\Gamma (XX = \text{vectors with } m < 3.1 \text{ GeV}) VALUE (units 10^{-3}) \qquad CLS \qquad DOCUMENT D \qquad TECN \qquad COMMENT \\ <1 \qquad 90 \qquad 12 \text{ BALEST} \qquad 95 \qquad CLEO \qquad e^+e^- \rightarrow \gamma + XX 12 \text{ For a noninteracting vector } X \text{ with mass} < 3.1 \text{ GeV}.$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
10 Supersedes BARU 92 In this node.	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
10 Supersedes BARU 92 In this node.	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
10 Supersedes BARU 92 In this node.	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
10 Supersedes BARU 92 In this node.	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
10 Supersedes BARU 92 In this node. $\Gamma(\gamma X)/\Gamma_{\text{total}} \qquad \qquad \qquad \Gamma_{29}/\Gamma$ $(X = \text{pseudoscalar with } m < 7.2 \text{ GeV})$ $\frac{VALUE (\text{units } 10^{-5})}{\sqrt{3}} \qquad \frac{CL\%}{\sqrt{90}} \qquad \frac{DOCUMENT ID}{\sqrt{11}} \qquad \frac{TECN}{\sqrt{90}} \qquad \frac{COMMENT}{\sqrt{90}}$ $11 \text{ BALEST} \qquad 95 \qquad \text{CLEO} \qquad e^+e^- \rightarrow \gamma + X$ $11^{1} \text{ For a noninteracting pseudoscalar } X \text{ with mass} < 7.2 \text{ GeV}.$ $\Gamma(\gamma XX)/\Gamma_{\text{total}} \qquad \qquad \qquad \Gamma_{30}/\Gamma$ $(X\overline{X} = \text{vectors with } m < 3.1 \text{ GeV})$ $\frac{VALUE (\text{units } 10^{-3})}{\sqrt{12}} \qquad \frac{CL\%}{\sqrt{90}} \qquad \frac{DOCUMENT ID}{\sqrt{90}} \qquad \frac{TECN}{\sqrt{90}} \qquad \frac{COMMENT}{\sqrt{90}}$ $12 \text{ BALEST} \qquad 95 \qquad \text{CLEO} \qquad e^+e^- \rightarrow \gamma + X\overline{X}$ $12^{12} \text{ For a noninteracting vector } X \text{ with mass} < 3.1 \text{ GeV}.$ $\Gamma(\gamma 2\pi^{+}2\pi^{-})/\Gamma_{\text{total}} \qquad \qquad \Gamma_{14}/\Gamma$ $\frac{VALUE (\text{units } 10^{-4})}{\sqrt{90}} \qquad \frac{EVTS}{\sqrt{90}} \qquad \frac{DOCUMENT ID}{\sqrt{90}} \qquad \frac{TECN}{\sqrt{90}} \qquad \frac{COMMENT}{e^+e^- \rightarrow \text{ hadrons}}$ Γ_{13}/Γ $\frac{VALUE (\text{units } 10^{-4})}{\sqrt{90}} \qquad \frac{EVTS}{\sqrt{90}} \qquad \frac{DOCUMENT ID}{\sqrt{90}} \qquad \frac{TECN}{\sqrt{90}} \qquad \frac{COMMENT}{\sqrt{90}}$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
10 Supersedes BARU 92 In this node. $\Gamma(\gamma X)/\Gamma_{\text{total}} \qquad \qquad \qquad \Gamma_{29}/\Gamma$ $(X = \text{pseudoscalar with } m < 7.2 \text{ GeV})$ $\frac{VALUE (\text{units } 10^{-5})}{\sqrt{3}} \qquad \frac{CL\%}{90} \qquad \frac{DOCUMENT ID}{10} \qquad \frac{TECN}{90} \qquad \frac{COMMENT}{\sqrt{3}}$ $\frac{11}{10} \text{ For a noninteracting pseudoscalar } X \text{ with mass} < 7.2 \text{ GeV}.$ $\Gamma(\gamma XX)/\Gamma_{\text{total}} \qquad \qquad \qquad \Gamma_{30}/\Gamma$ $(XX = \text{vectors with } m < 3.1 \text{ GeV})$ $\frac{VALUE (\text{units } 10^{-3})}{\sqrt{10}} \qquad \frac{CL\%}{90} \qquad \frac{DOCUMENT ID}{\sqrt{10}} \qquad \frac{TECN}{\sqrt{10}} \qquad \frac{COMMENT}{\sqrt{10}}$ $12 \text{ BALEST} \qquad 95 \qquad \text{CLEO} \qquad e^+e^- \rightarrow \gamma + X\overline{X}$ $1^{12} \text{ For a noninteracting vector } X \text{ with mass} < 3.1 \text{ GeV}.$ $\Gamma(\gamma 2\pi^+2\pi^-)/\Gamma_{\text{total}} \qquad \qquad \Gamma_{14}/\Gamma$ $\frac{VALUE (\text{units } 10^{-4})}{\sqrt{10}} \qquad \frac{EVTS}{7} \qquad \frac{DOCUMENT ID}{\sqrt{10}} \qquad \frac{TECN}{\sqrt{10}} \qquad \frac{COMMENT}{\sqrt{10}}$ $2.5 \pm 0.7 \pm 0.5 \qquad 26 \pm \frac{1}{7} \qquad \text{FULTON} \qquad 908 \text{ CLEO} \qquad e^+e^- \rightarrow \text{ hadrons}$ $\Gamma(\gamma \pi^+\pi^-K^+K^-)/\Gamma_{\text{total}} \qquad \qquad \Gamma_{13}/\Gamma$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
10 Supersedes BARU 92 In this node. $\Gamma(\gamma X)/\Gamma_{total} \qquad \qquad \Gamma_{29}/\Gamma$ $(X = pseudoscalar with m < 7.2 \text{ GeV}) \frac{VALUE (units 10^{-5})}{\sqrt{3}} \qquad \frac{CL\%}{\sqrt{90}} \qquad \frac{DOCUMENT ID}{\sqrt{11}} \qquad \frac{TECN}{\sqrt{90}} \qquad \frac{COMMENT}{\sqrt{90}} \frac{11}{\sqrt{11}} For a noninteracting pseudoscalar X with mass < 7.2 \text{ GeV}. \Gamma(\gamma XX)/\Gamma_{total} \qquad \qquad \Gamma_{30}/\Gamma (XX = vectors with m < 3.1 \text{ GeV}) \frac{VALUE (units 10^{-3})}{\sqrt{12}} \qquad \frac{CL\%}{\sqrt{90}} \qquad \frac{DOCUMENT ID}{\sqrt{90}} \qquad \frac{TECN}{\sqrt{90}} \qquad \frac{COMMENT}{\sqrt{90}} \frac{12}{\sqrt{90}} \qquad \frac{DOCUMENT ID}{\sqrt{90}} \qquad \frac{TECN}{\sqrt{90}} \qquad \frac{COMMENT}{\sqrt{90}} \frac{12}{\sqrt{90}} For a noninteracting vector X with mass < 3.1 \text{ GeV}. \Gamma(\gamma 2\pi + 2\pi^{-})/\Gamma_{total} \qquad \qquad \Gamma_{14}/\Gamma \frac{VALUE (units 10^{-4})}{\sqrt{90}} \qquad \frac{EVTS}{\sqrt{90}} \qquad \frac{DOCUMENT ID}{\sqrt{90}} \qquad \frac{TECN}{\sqrt{90}} \qquad \frac{COMMENT}{\sqrt{90}} \frac{VALUE (units 10^{-4})}{\sqrt{90}} \qquad \frac{EVTS}{\sqrt{90}} \qquad \frac{DOCUMENT ID}{\sqrt{90}} \qquad \frac{TECN}{\sqrt{90}} \qquad \frac{COMMENT}{\sqrt{90}} \frac{\Gamma_{13}/\Gamma}{\sqrt{90}} \qquad \frac{VALUE (units 10^{-4})}{\sqrt{90}} \qquad \frac{EVTS}{\sqrt{90}} \qquad \frac{DOCUMENT ID}{\sqrt{90}} \qquad \frac{TECN}{\sqrt{90}} \qquad \frac{COMMENT}{\sqrt{90}} \frac{\Gamma_{13}/\Gamma}{\sqrt{90}} \qquad \frac{VALUE (units 10^{-4})}{\sqrt{90}} \qquad \frac{EVTS}{\sqrt{90}} \qquad \frac{DOCUMENT ID}{\sqrt{90}} \qquad \frac{TECN}{\sqrt{90}} \qquad \frac{COMMENT}{\sqrt{90}} \frac{\Gamma_{13}/\Gamma}{\sqrt{90}} \qquad \frac{VALUE (units 10^{-4})}{\sqrt{90}} \qquad \frac{EVTS}{\sqrt{90}} \qquad \frac{DOCUMENT ID}{\sqrt{90}} \qquad \frac{TECN}{\sqrt{90}} \qquad \frac{COMMENT}{\sqrt{90}} \frac{\Gamma_{13}/\Gamma}{\sqrt{90}} \qquad \frac{VALUE (units 10^{-4})}{\sqrt{90}} \qquad \frac{EVTS}{\sqrt{90}} \qquad \frac{DOCUMENT ID}{\sqrt{90}} \qquad \frac{TECN}{\sqrt{90}} \qquad \frac{COMMENT}{\sqrt{90}} \frac{\Gamma_{13}/\Gamma}{\sqrt{90}} \qquad \frac{COMMENT}{\sqrt{90}} \qquad COMMENT$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
10 Supersedes BARU 92 In this node.	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
10 Supersedes BARU 92 In this node. $\Gamma(\gamma X)/\Gamma_{total} \qquad \qquad \Gamma_{29}/\Gamma$ $(X = pseudoscalar with m < 7.2 \text{ GeV}) \frac{VALUE (units 10^{-5})}{\sqrt{3}} \qquad \frac{CL\%}{\sqrt{90}} \qquad \frac{DOCUMENT ID}{\sqrt{11}} \qquad \frac{TECN}{\sqrt{90}} \qquad \frac{COMMENT}{\sqrt{90}} \frac{11}{\sqrt{11}} For a noninteracting pseudoscalar X with mass < 7.2 \text{ GeV}. \Gamma(\gamma XX)/\Gamma_{total} \qquad \qquad \Gamma_{30}/\Gamma (XX = vectors with m < 3.1 \text{ GeV}) \frac{VALUE (units 10^{-3})}{\sqrt{12}} \qquad \frac{CL\%}{\sqrt{90}} \qquad \frac{DOCUMENT ID}{\sqrt{90}} \qquad \frac{TECN}{\sqrt{90}} \qquad \frac{COMMENT}{\sqrt{90}} \frac{12}{\sqrt{90}} \qquad \frac{DOCUMENT ID}{\sqrt{90}} \qquad \frac{TECN}{\sqrt{90}} \qquad \frac{COMMENT}{\sqrt{90}} \frac{12}{\sqrt{90}} For a noninteracting vector X with mass < 3.1 \text{ GeV}. \Gamma(\gamma 2\pi + 2\pi^{-})/\Gamma_{total} \qquad \qquad \Gamma_{14}/\Gamma \frac{VALUE (units 10^{-4})}{\sqrt{90}} \qquad \frac{EVTS}{\sqrt{90}} \qquad \frac{DOCUMENT ID}{\sqrt{90}} \qquad \frac{TECN}{\sqrt{90}} \qquad \frac{COMMENT}{\sqrt{90}} \frac{VALUE (units 10^{-4})}{\sqrt{90}} \qquad \frac{EVTS}{\sqrt{90}} \qquad \frac{DOCUMENT ID}{\sqrt{90}} \qquad \frac{TECN}{\sqrt{90}} \qquad \frac{COMMENT}{\sqrt{90}} \frac{\Gamma_{13}/\Gamma}{\sqrt{90}} \qquad \frac{VALUE (units 10^{-4})}{\sqrt{90}} \qquad \frac{EVTS}{\sqrt{90}} \qquad \frac{DOCUMENT ID}{\sqrt{90}} \qquad \frac{TECN}{\sqrt{90}} \qquad \frac{COMMENT}{\sqrt{90}} \frac{\Gamma_{13}/\Gamma}{\sqrt{90}} \qquad \frac{VALUE (units 10^{-4})}{\sqrt{90}} \qquad \frac{EVTS}{\sqrt{90}} \qquad \frac{DOCUMENT ID}{\sqrt{90}} \qquad \frac{TECN}{\sqrt{90}} \qquad \frac{COMMENT}{\sqrt{90}} \frac{\Gamma_{13}/\Gamma}{\sqrt{90}} \qquad \frac{VALUE (units 10^{-4})}{\sqrt{90}} \qquad \frac{EVTS}{\sqrt{90}} \qquad \frac{DOCUMENT ID}{\sqrt{90}} \qquad \frac{TECN}{\sqrt{90}} \qquad \frac{COMMENT}{\sqrt{90}} \frac{\Gamma_{13}/\Gamma}{\sqrt{90}} \qquad \frac{VALUE (units 10^{-4})}{\sqrt{90}} \qquad \frac{EVTS}{\sqrt{90}} \qquad \frac{DOCUMENT ID}{\sqrt{90}} \qquad \frac{TECN}{\sqrt{90}} \qquad \frac{COMMENT}{\sqrt{90}} \frac{\Gamma_{13}/\Gamma}{\sqrt{90}} \qquad \frac{COMMENT}{\sqrt{90}} \qquad COMMENT$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
10 Supersedes BARU 92 In this node. $\Gamma(\gamma X)/\Gamma_{total} \qquad \qquad \Gamma_{29}/\Gamma$ $(X = pseudoscalar with m < 7.2 \text{ GeV})$ $VALUE (units 10^{-5}) $	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
10 Supersedes BARU 92 In this node. $\Gamma(\gamma X)/\Gamma_{total} \qquad \qquad \Gamma_{29}/\Gamma$ $(X = pseudoscalar with m < 7.2 \text{ GeV})$ $VALUE (units 10^{-5}) CL% DOCUMENT ID TECN e^+e^- \rightarrow \gamma + X 11 For a noninteracting pseudoscalar X with mass < 7.2 GeV. \Gamma(\gamma XX)/\Gamma_{total} \qquad \qquad \Gamma_{30}/\Gamma (XX = \text{vectors with } m < 3.1 \text{ GeV}) VALUE (units 10^{-3}) CL% DOCUMENT ID TECN e^+e^- \rightarrow \gamma + XX 12 For a noninteracting vector X with mass < 3.1 GeV. \Gamma(\gamma 2\pi^+ 2\pi^-)/\Gamma_{total} \qquad \qquad \Gamma_{14}/\Gamma VALUE (units 10^{-4}) EVTS DOCUMENT ID TECN e^+e^- \rightarrow \gamma + XX \Gamma(\gamma \pi^+ \pi^- K^+ K^-)/\Gamma_{total} \qquad \qquad \Gamma_{13}/\Gamma VALUE (units 10^{-4}) EVTS DOCUMENT ID TECN e^+e^- \rightarrow \gamma + \lambda X \Gamma(\gamma \pi^+ \pi^- K^+ K^-)/\Gamma_{total} \qquad \qquad \Gamma_{13}/\Gamma VALUE (units 10^{-4}) EVTS DOCUMENT ID TECN e^+e^- \rightarrow \gamma + \lambda X \Gamma(\gamma \pi^+ \pi^- K^+ K^-)/\Gamma_{total} \qquad \qquad \Gamma_{13}/\Gamma VALUE (units 10^{-4}) EVTS DOCUMENT ID TECN e^+e^- \rightarrow \gamma + \lambda X \Gamma(\gamma \pi^+ \pi^- K^+ K^-)/\Gamma_{total} \qquad \qquad \Gamma_{13}/\Gamma VALUE (units 10^{-4}) EVTS DOCUMENT ID TECN e^+e^- \rightarrow \gamma + \lambda X \Gamma(\gamma \pi^+ \pi^- F^-)/\Gamma_{total} \qquad \qquad \Gamma_{13}/\Gamma VALUE (units 10^{-4}) EVTS DOCUMENT ID TECN \gamma + \gamma $	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
10 Supersedes BARU 92 In this node. $\Gamma(\gamma X)/\Gamma_{total} \qquad \qquad \Gamma_{29}/\Gamma$ $(X = pseudoscalar with m < 7.2 \text{ GeV})$ $VALUE (units 10^{-5}) $	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
10 Supersedes BARU 92 In this node.	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
10 Supersedes BARU 92 In this node. $\Gamma(\gamma X)/\Gamma_{total} \qquad \qquad \Gamma_{29}/\Gamma \\ (X = pseudoscalar with m < 7.2 \text{ GeV}) \qquad \qquad \Gamma_{total} \qquad \Gamma_{total} \qquad \Gamma_{total} \qquad \Gamma_{total} \qquad \Gamma_{total} \qquad \qquad \Gamma_{total} \qquad \Gamma_{total} \qquad \Gamma_{total} \qquad \Gamma_{total} \qquad$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
10 Supersedes BARU 92 In this node. $\Gamma(\gamma X)/\Gamma_{\text{total}} \qquad $	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
10 Supersedes BARU 92 In this node. $\Gamma(\gamma X)/\Gamma_{total} \qquad \qquad \Gamma_{29}/\Gamma \\ (X = pseudoscalar with m < 7.2 \text{ GeV}) \\ \hline VALUE (units 10^{-5}) $	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$
10 Supersedes BARU 92 In this node. $\Gamma(\gamma X)/\Gamma_{total} \qquad \qquad \Gamma_{29}/\Gamma$ $(X = pseudoscalar with m < 7.2 \text{ GeV})$ $VALUE (units 10^{-5}) CLS DOCUMENT ID TECN e^+e^- \rightarrow \gamma + X 11 For a noninteracting pseudoscalar X with mass < 7.2 \text{ GeV}. \Gamma(\gamma XX)/\Gamma_{total} \qquad \qquad \Gamma_{30}/\Gamma (XX = vectors with m < 3.1 \text{ GeV}) VALUE (units 10^{-3}) CLS DOCUMENT ID TECN e^+e^- \rightarrow \gamma + X\overline{X} 12 For a noninteracting vector X with mass < 3.1 \text{ GeV}. \Gamma(\gamma 2\pi^+ 2\pi^-)/\Gamma_{total} \qquad \qquad \Gamma_{14}/\Gamma VALUE (units 10^{-4}) EVTS DOCUMENT ID e^+e^- \rightarrow \gamma + X\overline{X} 12.5 \pm 0.7 \pm 0.5 26 \pm 0.7 \pm 0.5 FULTON 90B CLEO e^+e^- \rightarrow 0.7 \pm 0.5 Rulled (units 10^{-4}) EVTS DOCUMENT ID TECN e^+e^- \rightarrow 0.7 \pm 0.5 Rulled (units 10^{-4}) EVTS DOCUMENT ID TECN e^+e^- \rightarrow 0.7 \pm 0.5 Rulled (units 10^{-4}) EVTS DOCUMENT ID TECN e^+e^- \rightarrow 0.7 \pm 0.5 Rulled (units 10^{-4}) EVTS DOCUMENT ID TECN e^+e^- \rightarrow 0.7 \pm 0.5 Rulled (units 10^{-4}) EVTS DOCUMENT ID TECN e^+e^- \rightarrow 0.7 \pm 0.5 Rulled (units 10^{-4}) EVTS DOCUMENT ID TECN e^+e^- \rightarrow 0.7 \pm 0.5 Rulled (units 10^{-4}) EVTS DOCUMENT ID TECN e^+e^- \rightarrow 0.7 \pm 0.5 Rulled (units 10^{-4}) EVTS DOCUMENT ID TECN e^+e^- \rightarrow 0.7 \pm 0.5 Rulled (units 10^{-4}) EVTS DOCUMENT ID TECN e^+e^- \rightarrow 0.7 \pm 0.5 Rulled (units 10^{-4}) EVTS DOCUMENT ID TECN e^+e^- \rightarrow 0.7 \pm 0.5 Rulled (units 10^{-4}) EVTS DOCUMENT ID TECN e^+e^- \rightarrow 0.7 \pm 0.5 Rulled (units 10^{-4}) EVTS DOCUMENT ID TECN e^+e^- \rightarrow 0.7 \pm 0.5 Rulled (units 10^{-4}) EVTS DOCUMENT ID TECN e^+e^- \rightarrow 0.7 \pm 0.5 Rulled (units 10^{-4}) EVTS DOCUMENT ID TECN e^+e^- \rightarrow 0.7 \pm 0.5 Rulled (units 10^{-4}) EVTS DOCUMENT ID TECN e^+e^- \rightarrow 0.7 \pm 0.5 Rulled (units 10^{-4}) EVTS DOCUMENT ID TECN e^+e^- \rightarrow 0.7 \pm 0.5 Rulled (units 10^{-4}) EVTS DOCUMENT ID TECN e^+e^- \rightarrow 0.7 \pm 0.5 Rulled (units 10^{-4}) EVTS DOCUMENT ID TECN e^+e^- \rightarrow 0.7 \pm 0.5 Rulled (units 10^{-4}) EVTS DOCUMENT ID TECN e^+e^- \rightarrow 0.7 \pm 0.5 Rulled (units 10^{-4}) EVTS DOCUMENT ID TECN e^-e^- \rightarrow 0.7 \pm 0.5 Rulled (units 10^{-4}) EVTS DOCUMENT ID TECN 10^{-4} Rulle$	$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$

 $\Upsilon(1S), \chi_{10}(1P), \chi_{11}(1P)$

	i) →	$\gamma \phi \phi)/\Gamma_{ m total}$					Γ ₂₈ /Γ
VALUE		<u>CL%</u>	DOCUMENT ID		<u>TECN</u>	COMMENT	
<0.003		90	²¹ BARU	89	MD1	T(15) → γK+K-I	κ+ κ-
²¹ Assumin	g tha	it the $\eta(2225)$ d	ecays only into ϕ	þ .		,	
Γ(γ f ₀ (220	0) –	• γK+K-)/	r _{total}				Γ ₂₆ /Γ
VALUE		CL%	DOCUMENT ID		TECN		
<0.0002		90	²² BARU	89	MD1	T(15) → γ	K+ K-
²² Assumin	g tha	t the f ₀ (2200)	decays only into F	+ K-	•		
			7(15) REFERI	ENCE	S		
BARU	96	PRPL 267 71	+Blinov, Blinov	, Bonda	r+		(NOVO)
ALBRECHT	95E	ZPHY C65 619	+Hamacher+				Collab.)
BALEST	95	PR D51 2053	+Cho, Ford, Jo				Collab.)
CINABRO ALBRECHT	94B 92J	PL B340 129 ZPHY C55 25	+Liu, Saulnier, +Ehrlichmann,				Collab.) Collab.)
BARU	923	ZPHY C54 229	+Beilin, Blinov		iei +	(ARGU	(NOVO)
BARU	92B	ZPHY C56 547	+Blinov, Blinov		NF.4		(NOVO)
KOBEL	92	ZPHY C53 193	+Antreasyan, E			(Crystal Bai	
BLINOV	90	PL B245 311	+Bondar+		DC33CL 1	(0.33.01.00	(NOVO)
FULTON	90B	PR D41 1401	+Hempstead+			(CLF)	Collab.)
MASCHMANN		ZPHY C46 555	+Antreasyan, E	arteis. I	Resset +	(Crystal Bal	
ALBRECHT	89	ZPHY C42 349	+Boeckmann, (5 Coltab.)
ALEXANDER	89	NP B320 45	+Bonvicini, Dre			(LBL, MIC	
BARU	89	ZPHY C42 505	+Beilin, Blinov			\	(NOVO)
CHEN	89B	PR D39 3528	+McIlwain, Mil			(CLEC	Collab.)
FULTON	89	PL B224 445	+Haas, Hemps	ead+			Collab.)
KAARSBERG	89	PRL 62 2077	+Heintz+			(CUSI	3 Collab.)
BUCHMUEL	88	HE e+e~ Physic	s 412 Buchmueller,	Cooper		(HANN, DE	SY, MIT)
			orld Scientific, Singapo			•	
JAKUBOWSKI		ZPHY C40 49	+Antreasyan, E			(Crystal Ba	R Collab.) IGJF
SCHMITT	88	ZPHY C40 199	+Antreasyan+			(Crystal Ba	
ALBRECHT	87	ZPHY C35 283	+Binder, Boeck			(ARGU	5 Collab.)
BARU	86	ZPHY C30 551	+Blinov, Bonda		n+		(NOVO)
ALBRECHT	85C	PL 154B 452	+Drescher, Hel	er+		(ARGU:	S Collab.)
KURAEV	85	SJNP 41 466	+Fadin				(NOVO)
ARTAMONOV	84	Translated from Y PL 137B 272		Dand			(NOVO)
BESSON	84	PR D30 1433	+Baru, Blinov, +Green, Hicks,			e. (C) E(Collab.)
GILES	84B	PR D29 1285	+Hassard, Hem				Collab.)
MACKAY	84	PR D29 2483	+Hasard, Giles,				3 Collab.)
ANDREWS	83	PRL 50 807	+Avery, Berkeli				Collab.)
GILES	83	PRL 50 877				H, RUTG, SYRA,	
NICZYPORUK	83	ZPHY C17 197	+ Jakubowski, 2				A Collab.
ALBRECHT	82	PL 116B 383	+Hofmann+			ORT, HEIDH, LUN	
ARTAMONOV		PL 118B 225	+Baru, Blinov,				(NOVO)
NICZYPORUK		ZPHY C15 299	+Folger, Bienle			(LEN	A Collab.)
BERGER	80C	PL 93B 497	+Lackas, Raup			(PLUTO	O Collab.)
BOCK	80	ZPHY C6 125	+Blanar, Blum	+	(HE	IDP, MPIM, DESY	
BERGER	79	ZPHY C1 343	+Alexander+			/DLUT/	Collab.)

_	ATLED	DEI	ATED	DADEDC	

	отн	HER RELATED PAPERS
86 84 84 82 78 78 78 78	DESY 86/136 PL 134B 137 PL 137B 272 PL 118B 225 PL 76B 243 PL 76B 246 PR D18 945 PR U8 945 PR U8 945	Koenigmann Koenigmann Horescher, Heller+ Haru, Bilnov, Bondar+ Haru, Bilnov, Bondar, Bukin, Groshev+ Kovov Hakexander, Dawm+ Hofmann, Schubert+ Hofmann, Schubert+ Hoguther, Hicks, Oliver+ Hoguther, Hicks, Oliver+ Horescher, Hom+ Horescher, Home, Homenan+ Koron, Final, Colu, Final, Stony Koron, Final,
77 77 77	PL 72B 273 PRL 39 252 PRL 39 1240	+Hom, Lederman, Appel, Ito+ (COLU, FNAL, STON) +Appel, Brown, Herb, Hom+ (COLU, FNAL, STON)
	84 84 82 78 78 78 78 78 78 77	86 DESY 86/136 84 PL 1348 137 84 PL 1378 272 78 PL 788 360 78 PL 788 360 78 PR 188 360 78 PR 189 45 78 PR 40 435 78 PR 41 684 77 PR 139 252



$$I^G(J^{PC}) = 0^+(0^{++})$$

J needs confirmation.

Observed in radiative decay of the $\Upsilon(2S)$, therefore C = +. Branching ratio requires E1 transition, M1 is strongly disfavored, therefore

	Х _{b0} (1 <i>P</i>) МА	SS			
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT	
9659.8±1.3 OUR AVERAGE	_			PD (+ P)	
9860.0±0.5±1.4	1 ALBRECHT			T(25) →	
9858.3±1.6±2.7	¹ NERNST			T(25) →	
9864.1±7 ±1	1 HAAS	84	CLEO	Y (25) →	$conv.\gamma X$
 We do not use the following 	owing data for average	s, fits	, limits,	etc. • • •	
9872.8±0.7±5.0	¹ KLOPFEN	83	CUSB	T(25) →	γX
1 From γ energy below, ass	suming $\Upsilon(2S)$ mass =	1002	3.4 Me\	<i>1</i> .	

γ ENERGY IN Υ(25) DECAY

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
162.3±1.3 OUR AVERAGE			
$162.1 \pm 0.5 \pm 1.4$	ALBRECHT	85E ARG	$\Upsilon(25) \rightarrow \text{conv.} \gamma X$
163.8±1.6±2.7	NERNST	85 CBAL	$\Upsilon(25) \rightarrow \gamma X$
158.0±7 ±1	HAAS	84 CLEO	$\Upsilon(25) \rightarrow \text{conv.} \gamma X$
• • We do not use the following	ng data for average	es, fits, limits	, etc. • • •
149.4±0.7±5.0	KLOPFEN	83 CUSB	$\Upsilon(2S) \rightarrow \gamma X$

X_{b0}(1P) DECAY MODES

	Mode	Fraction (Γ_I/Γ)	Confidence level
Γ ₁	γ T(15)	<6 %	90%

X_{b0}(1P) BRANCHING RATIOS

Γ(<i>γ Υ</i> (1 <i>S</i>))/Γ	total				Γ1/Γ
VALUE	CL%	DOCUMENT	ID TECN	COMMENT	
<0.06	90	WALK	86 CBAL	T(25) →	$\gamma\gamma\ell^+\ell^-$
• • • We do not	use the following	g data for aver	ages, fits, limits	, etc. • • •	
<0.11	90	PAUSS	83 CUSB	7 (25) →	771+l-

X_{b0}(1P) REFERENCES

WALK ALBRECHT NERNST HAAS KLOPFEN	85E	PR D34 2611 PL 160B 331 PRL 54 2195 PRL 52 799 PRL 51 160	+Zschorsch+ +Drescher, Heller+ +Antreasyan, Aschman+ +Jensen, Kagan, Kass, Behrends+ Klopfenstein, Horstkotte+	(CUSB Collab.)
PAUSS	83	PL 130B 439		LU, CORN, LSU, STON)



$$I^G(J^{PC}) = 0^+(1^{++})$$

J needs confirmation.

Observed in radiative decay of the $\Upsilon(2S)$, therefore C=+. Branching ratio requires E1 transition, M1 is strongly disfavored, therefore P = +. J = 1 from SKWARNICKI 87.

Xb1(1P) MASS

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
9891.9±0.7 OUR AVERAGE			
9890.8±0.9±1.3	¹ WALK	86 CBAL	$\Upsilon(2S) \rightarrow \gamma \gamma \ell^+ \ell^-$
9890.8±0.3±1.1	1 ALBRECHT	85E ARG	$\Upsilon(25) \rightarrow \text{conv.} \gamma X$
9892.0±0.8±2.4	¹ NERNST	85 CBAL	$\Upsilon(25) \rightarrow \gamma X$
9893.6±0.8±1.0	¹ HAAS	84 CLEO	$\Upsilon(2S) \rightarrow \text{conv.} \gamma X$
9894.4±0.4±3.0	1 KLOPFEN	83 CUSB	$T(2S) \rightarrow \gamma X$
9892 ±3	1 PAUSS	83 CUSB	$T(2S) \rightarrow \gamma \gamma \ell^+ \ell^-$
4			• •

¹ From γ energy below, assuming $\Upsilon(2S)$ mass = 10023.4 MeV.

γ ENERGY IN $\Upsilon(2S)$ DECAY

VALUE (MeV) 130.6±0.7 OUR AVERAGE	DOCUMENT ID	TEC	NCOMMENT
131.7±0.9±1.3	WALK	86 CB/	AL $T(25) \rightarrow \gamma \gamma \ell^+ \ell^-$
$131.7 \pm 0.3 \pm 1.1$	ALBRECHT	85E ARG	
130.6 ± 0.8 ± 2.4	NERNST	85 CB/	AL $T(2S) \rightarrow \gamma X$
129 ±0.8±1	HAAS	84 CLE	$(O \ T(2S) \rightarrow conv.\gamma X$
$128.1 \pm 0.4 \pm 3.0$	KLOPFEN	83 CUS	$SB \Upsilon(2S) \rightarrow \gamma X$
130.6 ± 3.0	PAUSS	83 CUS	$SB T(2S) \rightarrow \gamma \gamma \ell^+ \ell^-$

$x_{b1}(1P)$ DECAY MODES

	Mode	Fraction (Γ_I/Γ)	
Γ1	γ T(15)	(35±8) %	

$x_{b1}(1P)$ BRANCHING RATIOS

$\Gamma(\gamma T(1S)$)/Γ _{total}					Γ1/Γ
VALUE		DOCUMENT ID		TECN_	COMMENT	
0.35±0.08 C	OUR AVERAGE					
$0.32 \pm 0.06 \pm$	0.07	WALK	86	CBAL	Y(25) →	771+1-
0.47 ± 0.18		KLOPFEN	83	CUSB	7(25) →	$\gamma\gamma\ell^+\ell^-$

X_{b1}(1P) REFERENCES

SKWARNICKI	87	PRL 58 972	+Antreasyan, Besset+	(Crystal Ball Collab.) J
WALK	86	PR D34 2611	+Zschorsch+	(Crystal Ball Collab.)
ALBRECHT	85E	PL 160B 331	+Drescher, Heller+	(ARGUS Collab.)
NERNST	85	PRL 54 2195	+Antreasyan, Aschman+	(Crystal Ball Collab.)
HAAS	84	PRL 52 799	+Jensen, Kagan, Kass, Behrends+	(CLEO Collab.)
KLOPFEN	83	PRL 51 160	Klopfenstein, Horstkotte+	(CUSB Collab.)
PAUSS	83	PL 130B 439		CORN, LSU, STON)

	-	
~	/1	D)
X_{b2}	(T	P
	•	,

$I^G(J^{PC})$	$) = 0^{+}(2^{+})$
J needs	confirmation.

Observed in radiative decay of the $\Upsilon(25)$, therefore C=+. Branching ratio requires E1 transition, M1 is strongly disfavored, therefore P=+. J=2 from SKWARNICKI 87.

$\chi_{to}(1P)$	MASS
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VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
9913.2±0.6 OUR AVERAGE				
9915.8±1.1±1.3	¹ WALK	86	CBAL	$\Upsilon(2S) \rightarrow \gamma \gamma \ell^+ \ell^-$
9912.2±0.3±0.9	1 ALBRECHT	85E	ARG	$\Upsilon(2S) \rightarrow \text{conv.} \gamma X$
9912.4±0.8±2.2	¹ NERNST	85	CBAL	$T(2S) \rightarrow \gamma X$
9913.3±0.7±1.0	1 HAAS	84	CLEO	$\Upsilon(2S) \rightarrow \text{conv.} \gamma X$
9914.6±0.3±2.0	1 KLOPFEN	83	CUSB	$\Upsilon(25) \rightarrow \gamma X$
9914 ±4	¹ PAUSS	83	CUSB	$\Upsilon(25) \rightarrow \gamma \gamma \ell^+ \ell^-$
_				

¹ From γ energy below, assuming $\Upsilon(2S)$ mass = 10023.4 MeV.

γ ENERGY IN T(2S) DECAY

VALUE (MeV) 109.6±0.6 OUR AVERAGE	DOCUMENT ID	TECN	COMMENT
$107.0 \pm 1.1 \pm 1.3$	WALK	86 CBAL	$T(25) \rightarrow \gamma \gamma \ell^+ \ell^-$
110.6±0.3±0.9	ALBRECHT	85E ARG	
110.4±0.8±2.2	NERNST	85 CBAL	$r(2S) \rightarrow \gamma X$
109.5 ± 0.7 ± 1.0	HAAS	84 CLEO	$T(25) \rightarrow \text{conv.}\gamma X$
108.2±0.3±2.0	KLOPFEN	83 CUSB	T(25) → 7X
108.8±4.0	PAUSS	83 CUSB	$\Upsilon(25) \rightarrow \gamma \gamma \ell^+ \ell^-$

Xb2(1P) DECAY MODES

	Mode	Fraction (Γ _{//} Γ)
Γ ₁	γ T(15)	(22±4) %

X_{b2}(1P) BRANCHING RATIOS

$\Gamma(\gamma \Upsilon(1S))/\Gamma_{\text{total}}$					Γ ₁ /
VALUE	DOCUMENT ID		TECN	COMMENT	
0.22±0.04 OUR AVERAGE					
$0.27 \pm 0.06 \pm 0.06$	WALK	86	CBAL	T(25) →	778+l-
0.20 ± 0.05	KLOPFEN	83	CUSB	T(25) →	$\gamma\gamma\ell^+\ell^-$

$\chi_{b2}(1P)$ REFERENCES

SKWARNICKI	87	PRL 58 972	+Antreasyan, Besset+	(Crystal Ball	Collab.) J
WALK	86	PR D34 2611	+Zschorsch+	(Crystal Ball	Collab.)
ALBRECHT	85E	PL 160B 331	+Drescher, Heller+	(ARGUS	Collab.)
NERNST	85	PRL 54 2195	+Antreasyan, Aschman+	(Crystal Ball	Collab.)
HAAS	84	PRL 52 799	+Jensen, Kagan, Kass, Behrends+	` (CLEO	Collab.)
KLOPFEN	83	PRL 51 160	Klopfenstein, Horstkotte+	(CUSB	Collab.
PAUSS	83	PL 130B 439	+Dietl, Eigen+ (MPIM, COLU,	, CORN, LSU,	STON)



$$I^{G}(J^{PC}) = 0^{-}(1^{-})$$

7(25) MASS

VALUE (GeV)	DOCUMENT ID		TECN	COMMENT
10.02330±0.00031 OUR AVERAGE				
10.0236 ±0.0005	I BARU	86B	REDE	$e^+e^- \rightarrow hadrons$
10.0231 ±0.0004	BARBER	84	REDE	$e^+e^- \rightarrow hadrons$
¹ Reanalysis of ARTAMONOV 84				

7(25) WIDTH

VALUE (keV)	DOCUMENT ID
44+7 OUR FVAI HATION See to	e Note on Width Determinations of the 7 states

T(2S) DECAY MODES

	Mode	Fraction (Γ_I/Γ)	Confidence le	vel
Γ ₁	$\Upsilon(1S)\pi^+\pi^-$	(18.5 ±0.8) %	<u> </u>	_
Γ_2^-	$\Upsilon(1S)\pi^0\pi^0$	(8.8 ±1.1) %	•	
Γ3	$ au^+ au^-$	(1.7 ±1.6) %	,	
Γ_4	$\mu^+\mu^-$	(1.31 ± 0.21) %	,	
Γ_5	e ⁺ e ⁻	(1.18±0.20) %	•	
Γ ₆	$\Upsilon(1S)\pi^0$	< 8 ×	10 ⁻³ 90	0%
Γ7	$\Upsilon(1S)\eta$	< 2 x	10 ⁻³ 90	0%
Γ8	$J/\psi(1S)$ anything	< 6 x	10-3 90	0%

		Radiativ	ve decays		
Γg	$\gamma \chi_{b1}(1P)$		(6.7 ±0.9)%	
Γ ₁₀	$\gamma X_{b2}(1P)$		(6.6 ±0.9)%	
Γ_{11}	$\gamma \chi_{b0}(1P)$		(4.3 ± 1.0))%	
Γ ₁₂	$\gamma f_J(1710)$		< 5.9	× 10 ⁻⁴	90%
Γ ₁₃	$\gamma f_2'(1525)$		< 5.3	× 10 ⁻⁴	90%
Γ14	$\gamma f_2(1270)$		< 2.41	× 10 ⁻⁴	90%
Γ ₁₅	$\gamma f_J(2220)$				

$T(2S) \Gamma(I)\Gamma(e^+e^-)/\Gamma(total)$

VALUE (eV)	DOCUMENT ID		TECN	COMMENT	
6.5±1.5±1.0	KOBEL	92	CBAL	e+e- →	$\mu^+\mu^-$
$\Gamma(\text{hadrons}) \times \Gamma(e^+e^-)/\Gamma_{\text{tot}}$	al				$\Gamma_0\Gamma_5/\Gamma$
VALUE (keV)	DOCUMENT ID		TECN	COMMENT	
0.553±0.023 OUR AVERAGE					
0.552±0.031±0.017	² BARU	96	MD1	e+e- →	hadrons
0.54 ±0.04 ±0.02	² JAKUBOWSKI	88	CBAL	e+e- →	hadrons
0.58 ±0.03 ±0.04	³ GILES	84B	CLEO	$e^+e^- \rightarrow$	hadrons
0.60 ±0.12 ±0.07	3 ALBRECHT	82	DASP	e+e- →	hadrons
+0.09	3 NICZYPORUK	81 C	LENA	e+e- →	hadrons
0.54 ±0.07 +0.09 -0.05					hadrons

r(2S) PARTIAL WIDTHS

Γ(e ⁺ e ⁻)				Γş
VALUE (keV)	DOCUMENT ID	TECN	COMMENT	
0.52 ±0.03 ±0.01	4 ALBRECHT 956	ARG	e ⁺ e [−] → hadron	S
4 Applying the formula of	Kuraev and Fadin.			

au(2S) BRANCHING RATIOS

$\Gamma(J/\psi(1S))$ anything)/F _{total}			Г ₈ /Г
VALUE	CL%	DOCUMENT ID	TECN	COMMENT
<0.006	90	MASCHMANN 90	CBAL	$e^+e^- \rightarrow hadrons$
$\Gamma(T(1S)\pi^+\pi^-)/\Gamma$	total			Г1/Г
VALUE	EVTS	DOCUMENT ID	TEC	N COMMENT
0.185±0.008 OUR AV	ERAGE			
$0.181 \pm 0.005 \pm 0.010$	11.6k	ALBRECHT	87 ARG	· · · · · · · · · · · · · · · · · · ·
0.169±0.040		GELPHMAN	85 CB/	π ⁺ π ⁻ MM AL e ⁺ e ⁻ → e ⁺ e ⁻ -+
0.191±0.012±0.006		BESSON	84 CLE	O π ⁺ π ⁻ ΜΜ
0.189 ± 0.026		FONSECA	84 CUS	SB e ⁺ e ⁻ →
0.21 ±0.07	7	NICZYPORUK	818 LEN	$\begin{array}{c} IA e^+ \stackrel{\ell^- \ell^-}{-} \stackrel{\pi^+ \pi^-}{-} \\ \ell^+ \ell^- \stackrel{\pi^+ \pi^-}{-} \end{array}$

$\Gamma(\Upsilon(1S)\pi^0\pi^0)/\Gamma_{tr}$	otal					Γ_2/Γ
VALUE	<u>EVTS</u>	DOCUMENT ID		TECN	COMMENT	
0.088 ± 0.011 OUR AV	ERAGE					
$0.095 \pm 0.019 \pm 0.019$	25	ALBRECHT				$\pi^{0}\pi^{0}\ell^{+}\ell^{-}$
0.080 ± 0.015		GELPHMAN				$\ell^{+}\ell^{-}\pi^{0}\pi^{0}$
0.103±0.023		FONSECA	84	CUSB	e+ e ⁻ →	$\ell^+\ell^-\pi^0\pi^0$
$\Gamma(\tau^+\tau^-)/\Gamma_{\text{total}}$						Г ₃ /Г
VALUE		DOCUMENT ID		TECN	COMMENT	
$0.017 \pm 0.015 \pm 0.006$		HAAS	848	CLEO	$e^+e^- \rightarrow$	$\tau^+\tau^-$

$\Gamma(\mu^+\mu^-)/\Gamma_{\text{total}}$						Γ_4/Γ
VALUE	CL%	DOCUMENT ID		TECN_	COMMENT	
0.0131±0.0021 OUR AVE	ERAGE					
$0.0122 \pm 0.0028 \pm 0.0019$		⁵ KOBEL	92	CBAL	e+e- →	$\mu^+\mu^-$
$0.0138 \pm 0.0025 \pm 0.0015$		KAARSBERG	89	CSB2	$e^+e^- \rightarrow$	$\mu^+\mu^-$
0.009 ±0.006 ±0.006		6 ALBRECHT	85	ARG	$e^+e^- \rightarrow$	$\mu^+\mu^-$
0.018 ±0.008 ±0.005		HAAS	84B	CLEO	$e^+e^- \rightarrow$	$\mu^+\mu^-$
• • • We do not use the fo	llowing da	ta for averages, fits,	limit	ts, etc.	• • •	
<0.038	90	NICZYPORUK	81 C	LENA	$e^+e^- \rightarrow$	$\mu^+\mu^-$
5 Taking into account inte	rference b	etween the resonance	e an	d contin	uum.	

⁶ Re-evaluated using B($\Upsilon(15) \rightarrow \mu^{+}\mu^{-}$) = 0.026.

$\Gamma(\Upsilon(15)\pi^0)/\Gamma_{\text{total}}$					Γ_6/Γ
VALUE	CL%	DOCUMENT ID	TECN	COMMENT	
<0.008	90	IURZ 87	CBAL	e+e- →	1+1-22

 $\Upsilon(2S), \, \chi_{b0}(2P)$

Γ(? (1 5)η)/Γ _{total} <u>VALUE</u> <0.002			Γ ₇ /Γ	OTHER RELATED PAPERS
<0.002	CL% DOCUMEN	-	COMMENT	ALEXANDER 89 NP B320 45 +Bonvicini, Drell, Frey, Luth (LBL, MICH, SLAC) WALK 86 PR D34 2611 +Zschorsch+ (Crystal Ball Collab.)
• • • We do not use the	90 FONSEC		, etc. • • •	ALBRECHT 84 PL 134B 137 +Drescher, Heller+ (ARGUS Collab.)
< 0.005	90 ALBRECI		e+e- →	ARTAMONOV 84 PL 137B 272 +Baru, Blinov, Bondar+ (NOVO) ANDREWS 83 PRL 50 807 +Avery, Berkelman, Cassel+ (CLEO Collab.)
			$\pi^{+}\pi^{-}\ell^{+}\ell^{-}MM$	GREEN 82 PRL 49 617 +Sannes, Skubic, Snyder+ (CLEO Collab.) BIENLEIN 78 PL 78B 360 +Glawe, Bock, Blanar+ (DESY, HAMB, HEIDP, MPIM)
<0.007	90 LURZ	87 CBAL	$3\pi^0$)	DARDEN 78 PL 76B 246 +Hofmann, Schubert+ (DESY, DORT, HEIDH, LUND) KAPLAN 78 PRL 40 435 +Appel, Herb, Hom+ (STON, FNAL, COLU)
<0.010	90 BESSON	84 CLEO	•	YOH 78 PRL 41 684 +Herb, Hom, Lederman+ (COLU, FNAL, STON) COBB 77 PL 72B 273 +Iwata, Fabjan+ (BNL, CERN, SYRA, YALE)
$\Gamma(\gamma X_{b1}(1P))/\Gamma_{total}$			Г9/Г	HERB 77 PRL 39 252 +Hom, Lederman, Appel, Ito+ (COLU, FNAL, STON) INNES 77 PRL 39 1240 +Appel, Brown, Herb, Hom+ (COLU, FNAL, STON)
VALUE	DOCUMEN	IT ID TECN		
0.067±0.009 OUR AVER		UT OFF ADC	e ⁺ e ⁻ → γconv. X	$\gamma_{co}(2P)$ $I^{G}(J^{PC}) = 0^{+}(0^{+})$
0.091±0.018±0.022 0.065±0.007±0.012	ALBREC NERNST		$e^+e^- \rightarrow \gamma CORV. X$ $e^+e^- \rightarrow \gamma X$	$\chi_{b0}(2P) \qquad \qquad I^{G}(J^{PC}) = 0^{+}(0^{+})$ J needs confirmation.
0.080±0.017±0.016	HAAS		e ⁺ e [−] → γconv. X	
0.059±0.014	KLOPFE	N 83 CUSB	$e^+e^- \rightarrow \gamma X$	Observed in radiative decay of the $T(35)$, therefore $C = +$. Branching ratio requires E1 transition, M1 is strongly disfavored, therefore
$\Gamma(\gamma \chi_{b2}(1P))/\Gamma_{total}$			Γ ₁₀ /Γ	P = +.
VALUE	DOCUMEN	NT ID TECN		(60)
0.066±0.009 OUR AVE				X _{b0} (2P) MASS
0.098±0.021±0.024 0.058±0.007±0.010	ALBREC NERNST		$e^+e^- \rightarrow \gamma \text{conv. X}$ $e^+e^- \rightarrow \gamma \text{X}$	VALUE (GeV) DOCUMENT ID TECN COMMENT
0.102±0.018±0.021	HAAS		e ⁺ e ⁻ → γconv. X	10.2321±0.0006 OUR AVERAGE
0.061±0.014	KLOPFE	N 83 CUSB	$e^+e^- \rightarrow \gamma X$	10.2312±0.0008±0.0012
F(v (1.0\\ /F			Γ ₁₁ /Γ	10.2323 \pm 0.0007
$\Gamma(\gamma \chi_{b0}(1P))/\Gamma_{total}$	DOCUMEN	NT ID TECN		¹ From the average photon energy for inclusive and exclusive events and assuming $\Upsilon(3.$ mass = 10355.3 \pm 0.5 MeV. Supersedes HEINTZ 91 and NARAIN 91.
0.043±0.010 OUR AVE	RAGE			² From γ energy below assuming $\Upsilon(3S)$ mass = 10355.3 \pm 0.5 MeV. The error on t
0.064±0.014±0.016	ALBREC		$e^+e^- \rightarrow \gamma \text{conv. X}$	$\Upsilon(35)$ mass is not included in the individual measurements. It is included in the financiaries
0.036±0.008±0.009 0.044±0.023±0.009	NERNST HAAS		e ⁺ e ⁻ → γX e ⁺ e ⁻ → γconv. X	
• • We do not use the				γ energy in \varUpsilon (35) decay
0.035±0.014	KLOPFE		: e ⁺ e ⁻ → γX	VALUE (MeV) EVTS DOCUMENT ID TECN COMMENT
E/ (1710\) /E			F/F	VALUE (MeV) EVTS DOCUMENT ID TECN COMMENT 122.8±0.5 OUR AVERAGE Error Includes scale factor of 1.1.
$\Gamma(\gamma f_J(1710))/\Gamma_{\text{total}}$			Γ ₁₂ /Γ	123.0 ± 0.8 4959 3 HEINTZ 92 CSB2 $e^+e^- \rightarrow \gamma X$
VALUE (units 10 ⁻⁵)	OCUME!		$\frac{COMMENT}{\Upsilon(2S) \rightarrow \gamma K^+ K^-}$	124.6 ± 1.4 17 ⁴ HEINTZ 92 CSB2 $e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$
<59 ■ ■ We do not use the				122.3±0.3±0.6 9903 MORRISON 91 CLE2 $e^+e^- → \gamma X$
< 5.9	90 8 ALBREC		$\Upsilon(2S) \rightarrow \gamma \pi^+ \pi^-$	³ A systematic uncertainty on the energy scale of 0.9% not included. Supersed NARAIN 91.
⁷ Re-evaluated assuming 8 Includes unknown bra				⁴ A systematic uncertainty on the energy scale of 0.9% not included. Supersed HEINTZ 91.
$\Gamma(\gamma f_2'(1525))/\Gamma_{\text{total}}$			Γ ₁₃ /Γ	X _{b0} (2P) DECAY MODES
VALUE (units 10 ⁻⁵)	CL% DOCUME		COMMENT	Mode Fraction (Γ_I/Γ)
<53	90 ⁹ ALBREC		$\Upsilon(25) \rightarrow \gamma K^+ K^-$	$\Gamma_1 \qquad \gamma \Upsilon(25) \qquad (4.6 \pm 2.1) \%$
⁹ Re-evaluated assumi	$ng B(f_2'(1525) \to K$	\overline{K}) = 0.71.		$\Gamma_2 \qquad \gamma \Upsilon(1S)$ (9 ±6) × 10 ⁻³
$\Gamma(\gamma f_2(1270))/\Gamma_{\text{total}}$			Γ ₁₄ /Γ	
VALUE (units 10 ⁻⁵)	CL% DOCUME	NT ID TECN		$x_{b0}(2P)$ Branching Ratios
<24.1	90 10 ALBREC	CHT 89 ARG	$\Upsilon(2S) \rightarrow \gamma \pi^+ \pi^-$	$\Gamma(\gamma T(2S))/\Gamma_{\text{total}}$ $\Gamma_{1/2}$
¹⁰ Using B($f_2(1270) \rightarrow$	$\pi\pi)=0.84.$			VALUE CL% DOCUMENT ID TECN COMMENT
			Γ ₁₅ /Γ	<0.089 90 5 CRAWFORD 928 CLE2 $e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$
Γ(~£.(2220\\ /Γ				
Γ(γf _J (2220))/Γ _{total}		NT IO TECN	==•	0.046±0.020±0.007 6 HEINTZ 92 CSB2 $e^+e^- \to t^+t^-\gamma\gamma$
VALUE (units 10 ⁻⁵)	CL% DOCUME		COMMENT	⁵ Using B($\Upsilon(2S) \rightarrow \mu^+ \mu^-$) = (1.37 ± 0.26)%, B($\Upsilon(3S) \rightarrow \gamma \gamma \Upsilon(2S)$)×2 B($\Upsilon(2S)$
VALUE (units 10 ⁻⁵) • • • We do not use th	CL% DOCUME	verages, fits, limit	COMMENT s, etc. • • •	5 Using B($T(25) \rightarrow ~\mu^+\mu^-) = (1.37 \pm 0.26)\%$, B($T(3S) \rightarrow ~\gamma\gamma~T(2S))\times 2$ B($T(2S)$ $~\mu^+\mu^-) < 1.19 \times 10^{-4}$, and B($T(3S) \rightarrow ~\chi_{D0}(2P)\gamma) = 0.049$.
<i>VALUE</i> (units 10 ⁻⁵) ■ ■ We do not use th <6.8	CL% DOCUMENT of following data for an 90 11 ALBREC	verages, fits, limit CHT 89 ARG	$\begin{array}{c} COMMENT \\ \text{s, etc.} \bullet \bullet \bullet \\ \mathcal{T}(2S) \to \gamma K^+ K^- \end{array}$	⁵ Using B($\Upsilon(2S) \rightarrow \mu^+ \mu^-$) = (1.37 ± 0.26)%, B($\Upsilon(3S) \rightarrow \gamma \gamma \Upsilon(2S)$)×2 B($\Upsilon(2S)$
VALUE (units 10 ⁻⁵) • • • We do not use th	CL% DOCUMENT of following data for an 90 11 ALBREC	verages, fits, limit CHT 89 ARG	$\begin{array}{c} COMMENT \\ \text{s, etc.} \bullet \bullet \bullet \\ \mathcal{T}(2S) \to \gamma K^+ K^- \end{array}$	⁵ Using B($T(25) \rightarrow \mu^+\mu^-$) = (1.37 ± 0.26)%, B($T(35) \rightarrow \gamma \gamma T(25)$)×2 B($T(25) \mu^+\mu^-$) < 1.19 × 10 ⁻⁴ , and B($T(35) \rightarrow \chi_{b0}(2P)\gamma$) = 0.049. ⁶ Using B($T(25) \rightarrow \mu^+\mu^-$) = (1.44 ± 0.10)%, B($T(35) \rightarrow \gamma \chi_{b0}(2P)$) = (6.0 0.4 ± 0.6)% and assuming eμ universality. Supersedes HEINTZ 91.
<i>VALUE</i> (units 10 ⁻⁵) ■ ■ We do not use th <6.8	The following data for a $90 ext{ }	verages, fits, limit CHT 89 ARG	$\begin{array}{c} COMMENT \\ \text{s, etc.} \bullet \bullet \bullet \\ \mathcal{T}(2S) \to \gamma K^+ K^- \end{array}$	⁵ Using B($T(25) \rightarrow \mu^+\mu^-$) = (1.37 ± 0.26)%, B($T(35) \rightarrow \gamma\gamma T(25)$)×2 B($T(25) \mu^+\mu^-$) < 1.19 × 10 ⁻⁴ , and B($T(35) \rightarrow \chi_{b0}(2P)\gamma$) = 0.049. ⁶ Using B($T(25) \rightarrow \mu^+\mu^-$) = (1.44 ± 0.10)%, B($T(35) \rightarrow \gamma\chi_{b0}(2P)$) = (6.0 0.4 ± 0.6)% and assuming $e\mu$ universality. Supersedes HEINTZ 91. Γ($\gamma T(15)$)/Γ _{total}
WALUE (units 10 ⁻⁵) • • • We do not use th <6.8 11 Includes unknown br	e following data for a 90 11 ALBREC ranching ratio of $f_J(25)$ REF	verages, fits, limit CHT 89 ARG $(220) \rightarrow K^+K^-$.	COMMENT s, etc. • • • $T(25) \rightarrow \gamma K^+ K^-$	5 Using B($\Upsilon(2S) \rightarrow \mu^+\mu^-$) = (1.37 ± 0.26)%, B($\Upsilon(3S) \rightarrow \gamma\gamma \Upsilon(2S)$)×2 B($\Upsilon(2S) \mu^+\mu^-$) < 1.19 × 10 ⁻⁴ , and B($\Upsilon(3S) \rightarrow \chi_{D0}(2P)\gamma$) = 0.049. 6 Using B($\Upsilon(2S) \rightarrow \mu^+\mu^-$) = (1.44 ± 0.10)%, B($\Upsilon(3S) \rightarrow \gamma\chi_{D0}(2P)$) = (6.0 0.4 ± 0.6)% and assuming $e\mu$ universality. Supersedes HEINTZ 91. F($\gamma\Upsilon(1S)$)/Γ _{total} VALUE C1% 90 7 CRAWFORD 928 CLE2 $e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$
WALUE (units 10 ⁻⁵) • • • We do not use th <6.8 11 (includes unknown br BARU 96 PRPL: ALBRECHT 95E ZPHY	te following data for a 90 11 ALBREC ranching ratio of $f_J(22)$ $T(25)$ REF 267 71 $+$ Blinov, C65 619 $+$ Hamach	verages, fits, limit CHT 89 ARG 220) → K ⁺ K ⁻ . FERENCES Blinov, Bondar+ her+	comment s, etc. • • • $T(25) \rightarrow \gamma K^+ K^-$ (ARGUS Collab.)	⁵ Using B($T(25) \rightarrow \mu^+\mu^-$) = (1.37 ± 0.26)%, B($T(35) \rightarrow \gamma\gamma T(25)$)×2 B($T(25) \mu^+\mu^-$) < 1.19 × 10 ⁻⁴ , and B($T(35) \rightarrow \chi_{b0}(2P)\gamma$) = 0.049. ⁶ Using B($T(25) \rightarrow \mu^+\mu^-$) = (1.44 ± 0.10)%, B($T(35) \rightarrow \gamma\chi_{b0}(2P)$) = (6.0 0.4 ± 0.6)% and assuming eμ universality. Supersedes HEINTZ 91. Γ(γ T(15))/Γ total <u>VALUE</u> <u>CLS.</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u>
### ALURE (units 10 ⁻⁵) • • • • We do not use the control of the	26.5 19 + Antreas C64 555 + Antreas C65 619 + An	verages, fits, limit CHT 89 ARG 220) $\rightarrow K^+K^-$. FERENCES Blinov, Bondar+ her+ yan, Bartels, Besset+ yan, Bartels, Besset+	COMMENT 5, etc. • • • $T(2S) \rightarrow \gamma K^+ K^-$ (ARGUS Collab.) (Crystal Ball Collab.) (Crystal Ball Collab.)	$\begin{array}{c} ^{5} \text{Using B}(\mathcal{T}(25) \to \mu^{+} \mu^{-}) = (1.37 \pm 0.26)\%, \text{B}(\mathcal{T}(3S) \to \gamma \gamma \mathcal{T}(2S)) \times 2 \text{B}(\mathcal{T}(2S) \\ \mu^{+} \mu^{-}) < 1.19 \times 10^{-4}, \text{and B}(\mathcal{T}(3S) \to \chi_{b0}(2P) \gamma) = 0.049. \\ ^{6} \text{Using B}(\mathcal{T}(2S) \to \mu^{+} \mu^{-}) = (1.44 \pm 0.10)\%, \text{B}(\mathcal{T}(3S) \to \gamma \chi_{b0}(2P)) = (6.0 \pm 0.6)\%, \text{and assuming } e_{\mu} \text{universality.} \text{Supersedes HEINTZ 91.} \\ \hline \Gamma(\gamma \mathcal{T}(1S))/\Gamma_{\text{total}} & \Gamma_{\text{C}} & \Gamma_{\text{C}} & \Gamma_{\text{C}} \\ \hline \chi_{\text{AUVE}} & \chi_{\text{C}} & \chi_{\text{C}} & \chi_{\text{C}} \\ \hline <0.025 & 90 & 7 \text{CRAWFORD} & 928 \text{CLE2} & e^{+} e^{-} \to \ell^{+} \ell^{-} \gamma \gamma \\ \hline <0.025 & 90 & 8 \text{HEINTZ} & 92 \text{CSB2} & e^{+} e^{-} \to \ell^{+} \ell^{-} \gamma \gamma \\ \hline <0.038 \text{Using B}(\mathcal{T}(1S) \to \mu^{+} \mu^{-}) = (2.57 \pm 0.07)\%, \text{B}(\mathcal{T}(3S) \to \gamma \gamma \mathcal{T}(1S)) \times 2 \text{B}(\mathcal{T}(1S)) \end{array}$
### ALDRECHT 95 PRPL 2 BARU 96 PRPL 2 ALBRECHT 95 PRPL 2 ALBRECHT 92 PRPY MASCHMANN 90 PPHY ALBRECHT 99 PPHY ALBRECHT 99 PRPY PRPY PRPY PRPY PRPY PRPY PRPY P	267 71 +Blinov, C65 619 +Antreas C46 555 +Antreas C42 349 +Bockman C42 349 +Bockman C42 349 +Bockman C46 555 +Bockman C46 549 +Bockman C47 549	verages, fits, limit CHT 89 ARG 220) → K+K FERENCES Blinov, Bondar+ heyan, Bartels, Besset+ yan, Bartels, Besset+ nann, Glasser, Harder-	COMMENT 5, etc. • • • $T(2S) \rightarrow \gamma K^+ K^-$ (ARGUS Collab.) (Crystal Ball Collab.) (Crystal Ball Collab.)	$\begin{array}{c} ^{5} \text{Using B}(T(25) \to \mu^{+}\mu^{-}) = (1.37 \pm 0.26)\%, \ B(T(3S) \to \gamma\gammaT(2S)) \times 2 \ B(T(2S) \\ \mu^{+}\mu^{-}) < 1.19 \times 10^{-4}, \ \text{and B}(T(3S) \to \chi_{b0}(2P)\gamma) = 0.049. \\ ^{6} \text{Using B}(T(2S) \to \mu^{+}\mu^{-}) = (1.44 \pm 0.10)\%, \ B(T(3S) \to \gamma\chi_{b0}(2P)) = (6.0 \\ 0.4 \pm 0.6)\% \ \text{and assuming } e\mu \ \text{universality. Supersedes HEINTZ 91.} \\ \hline \hline $T(\gammaT(1S))/\Gamma_{total}$ & ClS & $DOCUMENT\ ID$ & $TECN$ & $COMMENT$ \\ \hline $\sqrt{0.025}$ & 90 & $7\ \text{CRAWFORD}$ & 928 \ \text{CLE2}$ & $e^{+}e^{-} \to \ell^{+}\ell^{-}\gamma\gamma$ \\ \hline $0.009\pm 0.006\pm 0.001$ & $8\ \text{HEINTZ}$ & 92 \ \text{CSB2}$ & $e^{+}e^{-} \to \ell^{+}\ell^{-}\gamma\gamma$ \\ \hline $T_{0}(1S) \to \mu^{+}\mu^{-}) = (2.57 \pm 0.07)\%, \ B(T(3S) \to \gamma\gammaT(1S)) \times 2 \ B(T(1S) \to \mu^{+}\mu^{-}) < 0.63 \times 10^{-4}, \ \text{and B}(T(3S) \to \chi_{b0}(2P)\gamma) = 0.049. \\ \hline \end{array}$
### ALBRECHT ## 25 PRH CALBRECHT ## 25 PRH	267 71 +Binov, C65 619 +Antreas C64 349 +Bockward 20 2077 +Bockwar	verages, fits, limit CHT 89 ARG 220) K+K- FERENCES Blinov, Bondar+ her+ hyan, Bartels, Besset+ yan, Bartels, Besset+ hann, Glaser, Harder+ helter, Cooper	COMMENT 5, etc. • • • T(2S) → γK+K- (ARGUS Collab.) (Crystal Ball Collab.) (Crystal Ball Collab.) (ARGUS Collab.)	$\begin{array}{c} ^{5} \text{Using B}(T(25) \to \mu^{+}\mu^{-}) = (1.37 \pm 0.26)\%, \ B(T(3S) \to \gamma\gammaT(2S)) \times 2 \ B(T(2S) \\ \mu^{+}\mu^{-}) < 1.19 \times 10^{-4}, \ \text{and B}(T(3S) \to \chi_{b0}(2P)\gamma) = 0.049. \\ ^{6} \text{Using B}(T(2S) \to \mu^{+}\mu^{-}) = (1.44 \pm 0.10)\%, \ B(T(3S) \to \gamma\chi_{b0}(2P)) = (6.0 \\ 0.4 \pm 0.6)\% \ \text{and assuming } e\mu \ \text{universality. Supersedes HEINTZ 91.} \\ \hline \hline $T(\gammaT(1S))/\Gamma_{total}$ & ClS & $DOCUMENT\ ID$ & $TECN$ & $COMMENT$ \\ \hline $\sqrt{0.025}$ & 90 & $7\ \text{CRAWFORD}$ & 928 \ \text{CLE2}$ & $e^{+}e^{-} \to \ell^{+}\ell^{-}\gamma\gamma$ \\ \hline $0.009\pm 0.006\pm 0.001$ & $8\ \text{HEINTZ}$ & 92 \ \text{CSB2}$ & $e^{+}e^{-} \to \ell^{+}\ell^{-}\gamma\gamma$ \\ \hline $T_{0}(1S) \to \mu^{+}\mu^{-}) = (2.57 \pm 0.07)\%, \ B(T(3S) \to \gamma\gammaT(1S)) \times 2 \ B(T(1S) \to \mu^{+}\mu^{-}) < 0.63 \times 10^{-4}, \ \text{and B}(T(3S) \to \chi_{b0}(2P)\gamma) = 0.049. \\ \hline \end{array}$
VALUE (units 10 ⁻⁵) • • • We do not use th	267 71 +Binov. C65 619 +Hamach C62 3193 +Antreas C42 349 +Bockim C40 49 +Antreas C40 49 +Antreas C40 49 +Antreas	verages, fits, limit CHT 89 ARG 220) K+K- FERENCES Blinov, Bondar+ her+ her+ hyan, Bartels, Besset+ yan, Bartels, Besset+ heller, Cooper Singapore yan, Bartels+	COMMENT S, etc. ● ● ● T(2S) → γK+K- (ARGUS Collab.) (Crystal Ball Collab.) (Crystal Ball Collab.) (Crystal Ball Collab.) (CUSB Collab.) (CUSB Collab.) ((ANN, DESY, MIT) (Crystal Ball Collab.) IGJPC	$\begin{array}{c} ^{5} \text{Using B}(\mathcal{T}(25) \to \mu^{+} \mu^{-}) = (1.37 \pm 0.26)\%, \text{B}(\mathcal{T}(3S) \to \gamma \gamma \mathcal{T}(2S)) \times 2 \text{B}(\mathcal{T}(2S) \\ \mu^{+} \mu^{-}) < 1.19 \times 10^{-4}, \text{and B}(\mathcal{T}(3S) \to \chi_{b0}(2P) \gamma) = 0.049. \\ ^{6} \text{Using B}(\mathcal{T}(2S) \to \mu^{+} \mu^{-}) = (1.44 \pm 0.10)\%, \text{B}(\mathcal{T}(3S) \to \gamma \chi_{b0}(2P)) = (6.0 \pm 0.6)\%, \text{and assuming } e_{\mu} \text{universality.} \text{Supersedes HEINTZ 91.} \\ \hline \Gamma(\gamma \mathcal{T}(1S))/\Gamma_{\text{total}} & \Gamma_{\text{C}} & \Gamma_{\text{C}} & \Gamma_{\text{C}} \\ \hline \chi_{\text{AUVE}} & \chi_{\text{C}} & \chi_{\text{C}} & \chi_{\text{C}} \\ \hline <0.025 & 90 & 7 \text{CRAWFORD} & 928 \text{CLE2} & e^{+} e^{-} \to \ell^{+} \ell^{-} \gamma \gamma \\ \hline <0.025 & 90 & 8 \text{HEINTZ} & 92 \text{CSB2} & e^{+} e^{-} \to \ell^{+} \ell^{-} \gamma \gamma \\ \hline <0.038 \text{Using B}(\mathcal{T}(1S) \to \mu^{+} \mu^{-}) = (2.57 \pm 0.07)\%, \text{B}(\mathcal{T}(3S) \to \gamma \gamma \mathcal{T}(1S)) \times 2 \text{B}(\mathcal{T}(1S)) \end{array}$
WALUE (units 10 ⁻⁵) • • • We do not use th <6.8 11 Includes unknown br BARU 96 PRPL: ALBRECHT 95E ZPHY MASCHMANN 2PHY MASCHMANN 2PHY KAARSBERG 99 PRL 62 BUCHMUEL 88 HE Editors: A. Ali and P. S AKUBOWSKI 88 ZPHY ALBRECHT 87 ZPHY	265 19 + Blinov, C65 619 + Antreas C64 39 + Antreas C64 52 2077 Blinov, C65 619 + C6	verages, fits, limit CHT 89 ARG 220) — K+K- FERENCES Blinov, Bondar+ her+ her+ hyan, Bartels, Besset+ yan, Bartels, Besset+ heller, Cooper Singapore Singapore Boeckmann, Glaeser- yan, Bartels+ Boeckmann, Glaeser- yan, Bartels+	COMMENT S, etc. ● ● ● T(2S) → γK+K- (NOVO) (ARGUS Collab.) (Crystal Ball Collab.) (Crystal Ball Collab.) (CUSB Collab.) (CUSB Collab.) (HANN, DESY, MIT) (Crystal Ball Collab.) IGJPC (ARGUS Collab.) (Crystal Ball Collab.) (Crystal Ball Collab.)	$\begin{array}{c} ^{5} \text{Using B}(T(25) \to \mu^{+}\mu^{-}) = (1.37 \pm 0.26)\%, \ B(T(3S) \to \gamma\gammaT(2S)) \times 2 \ B(T(2S) \\ \mu^{+}\mu^{-}) < 1.19 \times 10^{-4}, \ \text{and B}(T(3S) \to \chi_{b0}(2P)\gamma) = 0.049. \\ ^{6} \text{Using B}(T(2S) \to \mu^{+}\mu^{-}) = (1.44 \pm 0.10)\%, \ B(T(3S) \to \gamma\chi_{b0}(2P)) = (6.0 \\ 0.4 \pm 0.6)\% \ \text{and assuming } e\mu \ \text{universality. Supersedes HEINTZ 91.} \\ \hline \hline $T(\gammaT(1S))/\Gamma_{total}$ & ClS & $DOCUMENT\ ID$ & $TECN$ & $COMMENT$ \\ \hline $\sqrt{0.025}$ & 90 & $7\ \text{CRAWFORD}$ & 928 \ \text{CLE2}$ & $e^{+}e^{-} \to \ell^{+}\ell^{-}\gamma\gamma$ \\ \hline $0.009\pm 0.006\pm 0.001$ & $8\ \text{HEINTZ}$ & 92 \ \text{CSB2}$ & $e^{+}e^{-} \to \ell^{+}\ell^{-}\gamma\gamma$ \\ \hline $T_{0}(1S) \to \mu^{+}\mu^{-}) = (2.57 \pm 0.07)\%, \ B(T(3S) \to \gamma\gammaT(1S)) \times 2 \ B(T(1S) \to \mu^{+}\mu^{-}) < 0.63 \times 10^{-4}, \ \text{and B}(T(3S) \to \chi_{b0}(2P)\gamma) = 0.049. \\ \hline \end{array}$
BARU 96 PRPL: ALBRECHT 95E ZPHY MASCHMANN 90 PRPL: ALBRECHT 95E ZPHY MASCHMANN 90 ZPHY MASCHMANN 90 PRL 62 BUCHMUEL 88 E Editors: A. Ali and P. S. ALKUBOWSKI 88 ZPHY ALBRECHT 87 ZPHY LURZ 87 ZPHY BARU 86B ZPHY ALBRECHT 85 ZPHY	265 Biolowing data for a go 11 ALBREC (anching ratio of f / (25) REI (25) R	verages, fits, limit CHT 89 ARG 220) K+K- FERENCES Blinov, Bondar+ her+ her+ hyan, Bartels, Besset+ yan, Bartels, Besset+ heller, Cooper Singapore yan, Bartels+ Boeckmann, Glaeser+ yan, Bartels+ Boekmann, Glaeser+ Hondar, Bukin+ Boekmann, Glaeser+ Hondar, Bukin+ Boekmann, Glaeser+	COMMENT S, etc. ● ● ● T(2S) → γK+K- (NOVO) (ARGUS Collab.) (Crystal Ball Collab.) (Crystal Ball Collab.) (CUSB Collab.) (CUSB Collab.) (CHNN, DESY, MIT) (Crystal Ball Collab.) (Clystal Ball Collab.) (Crystal Ball Collab.) (Crystal Ball Collab.) (Crystal Ball Collab.) (CROVO) (ARGUS Collab.)	5 Using B($T(25) \rightarrow \mu^+\mu^-$) = (1.37 ± 0.26)%, B($T(3S) \rightarrow \gamma \gamma T(2S)$)×2 B($T(2S) \mu^+\mu^-$) < 1.19 × 10 ⁻⁴ , and B($T(3S) \rightarrow \chi_{b0}(2P)\gamma$) = 0.049. 6 Using B($T(2S) \rightarrow \mu^+\mu^-$) = (1.44 ± 0.10)%, B($T(3S) \rightarrow \gamma \chi_{b0}(2P)$) = (6.0 0.4 ± 0.6)% and assuming $e\mu$ universality. Supersedes HEINTZ 91. F($\gamma T(1S)$)/F _{total} VALUE CLS DOCUMENT ID TECN COMMENT COMMENT 7 CRAWFORD 928 CLE2 $e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$ 0.009±0.006±0.001 8 HEINTZ 92 CSB2 $e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$ 7 Using B($T(1S) \rightarrow \mu^+\mu^-$) = (2.57 ± 0.07)%, B($T(3S) \rightarrow \gamma \gamma T(1S)$)×2 B($T(1S) \mu^+\mu^-$) < 0.63 × 10 ⁻⁴ , and B($T(3S) \rightarrow \chi_{b0}(2P)\gamma$) = 0.049. 8 Using B($T(1S) \rightarrow \mu^+\mu^-$) = (2.57 ± 0.07)%, B($T(3S) \rightarrow \gamma \chi_{b0}(2P)$) = (6.0 0.4 ± 0.6)% and assuming $e\mu$ universality. Supersedes HEINTZ 91.
### ALBRECHT ### ### ALBRECHT #### ALBRECHT ### ALBRECHT #### ALBRECHT #### ALBRECHT #### ALBRECHT #### ALBR	26.5 Poscure (14 Poscure (15 P	verages, fits, limit CHT 89 ARG 220) → K+K FERENCES Blinov, Bondar+ her+ hyan, Bartels, Besset+ hyan, Bartels, Besset+ hann, Glaeser, Harder- teller, Cooper Singapore yan, Bartels+ Boeckman, Glaeser- yan, Besset+ Bondar, Bukin+ ell, Heller+ er, Heller+ er, Heller+	COMMENT 5, etc. ● ● ● T(2S) → γK+K- (ARGUS Collab.) (Crystal Ball Collab.) (Crystal Ball Collab.) (CUSB Collab.) (CUSB Collab.) (CHANN, DESY, MIT) (ARGUS Collab.) (Crystal Ball Collab.) (GPC (ARGUS Collab.) (Crystal Ball Collab.) (Crystal Ball Collab.) (CRYSTAL COLLAB.) (NOVO) (ARGUS Collab.) (ARGUS Collab.) (ARGUS Collab.)	5 Using B($T(25) \rightarrow \mu^+\mu^-$) = (1.37 ± 0.26)%, B($T(3S) \rightarrow \gamma\gamma T(2S)$)×2 B($T(2S) \mu^+\mu^-$) < 1.19 × 10 ⁻⁴ , and B($T(3S) \rightarrow \chi_{b0}(2P)\gamma$) = 0.049. 6 Using B($T(2S) \rightarrow \mu^+\mu^-$) = (1.44 ± 0.10)%, B($T(3S) \rightarrow \gamma\chi_{b0}(2P)$) = (6.0 0.4 ± 0.6)% and assuming $e\mu$ universality. Supersedes HEINTZ 91. F($\gamma T(1S)$)/F total VALUE CLX COMMENT 7 CRAWFORD 928 CLE2 $e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$ 7 Using B($T(1S) \rightarrow \mu^+\mu^-$) = (2.57 ± 0.07)%, B($T(3S) \rightarrow \gamma\gamma T(1S)$)×2 B($T(1S) \mu^+\mu^-$) < 0.63 × 10 ⁻⁴ , and B($T(3S) \rightarrow \chi_{b0}(2P)\gamma$) = 0.049. 8 Using B($T(1S) \rightarrow \mu^+\mu^-$) = (2.57 ± 0.07)%, B($T(3S) \rightarrow \gamma\chi_{b0}(2P)$) = (6.0 0.4 ± 0.6)% and assuming $e\mu$ universality. Supersedes HEINTZ 91. X _{b0} (2P) REFERENCES CRAWFORD 92B PL B294 139 +Fulton (CLEO Collab.) (CUSE II Collab.) (CUSE II Collab.)
## ALBRECHT SE PH	26.5 Poscure (14 Poscure (15 P	verages, fits, limit CHT 89 ARG 220) K+K- FERENCES Blinov, Bondar+ her+ her+ hyan, Bartels, Besset+ yan, Bartels, Besset+ heller, Cooper Singapore yan, Bartels+ Boeckmann, Glaeser+ yan, Bartels+ Boekmann, Glaeser+ Hondar, Bukin+ Boekmann, Glaeser+ Hondar, Bukin+ Boekmann, Glaeser+	COMMENT S, etc. ● ● ● T(2S) → γK+K- (NOVO) (ARGUS Collab.) (Crystal Ball Collab.) (Crystal Ball Collab.) (CUSB Collab.) (CUSB Collab.) (CHNN, DESY, MIT) (Crystal Ball Collab.) (Clystal Ball Collab.) (Crystal Ball Collab.) (Crystal Ball Collab.) (Crystal Ball Collab.) (CROVO) (ARGUS Collab.)	$\begin{array}{c} 5 \text{ Using B}(T(25) \to \mu^+\mu^-) = (1.37 \pm 0.26)\%, \ B(T(3S) \to \gamma\gamma T(2S)) \times 2 \ B(T(2S) \\ \mu^+\mu^-) < 1.19 \times 10^{-4}, \ \text{and B}(T(3S) \to \chi_{b0}(2P)\gamma) = 0.049. \\ 6 \text{ Using B}(T(2S) \to \mu^+\mu^-) = (1.44 \pm 0.10)\%, \ B(T(3S) \to \gamma\chi_{b0}(2P)) = (6.0 \pm 0.6)\%, \ \text{and assuming } e\mu \ \text{universality.} \ \text{Supersedes HEINTZ 91.} \\ \hline \Gamma(\gamma T(1S))/\Gamma_{\text{total}} & & & & & & & & & & & & & & & & & & $
### ALBRECHT SP PRP CALBRECHT SP PRP	26.5 Pocume. 26.7 11 ALBREC 26.7 71 +Blinov, C65 619 +Hamach C65 619 +Antreas C46 555 +Antreas C46 555 +Antreas C46 24349 +Bockmi C60 619, World Scientific, C50 49 +Antreas C20 72 +Heintz-t C20 72 +Blinov, C20 62 +Blinov	verages, fits, limit CHT 89 ARG 220) → K+K FERENCES Blinov, Bondar+ her+ hyan, Bartels, Besset+ hyan, Bartels, Besset+ hann, Glaeser, Harder- heller, Cooper Singapore yan, Bartels+ Boockmann, Glaeser- hyan, Besset+ Bondar, Bukin+ ell, Heller+ er, Heller+ er, Heller+ hartreasyan+	COMMENT 5, etc. ● ● ● T(2S) → γK+K- (ARGUS Collab.) (Crystal Ball Collab.) (Crystal Ball Collab.) (CUSB Collab.) (CUSB Collab.) (CHYSTAL BALL Collab.) (CHYSTAL BALL COLLAB.) (CRYSTAL BALL COLLAB.)	5 Using B($T(25) \rightarrow \mu^+\mu^-$) = (1.37 ± 0.26)%, B($T(3S) \rightarrow \gamma\gamma T(2S)$)×2 B($T(2S) \mu^+\mu^-$) < 1.19 × 10 ⁻⁴ , and B($T(3S) \rightarrow \chi_{b0}(2P)\gamma$) = 0.049. 6 Using B($T(2S) \rightarrow \mu^+\mu^-$) = (1.44 ± 0.10)%, B($T(3S) \rightarrow \gamma\chi_{b0}(2P)$) = (6.0 0.4 ± 0.6)% and assuming $e\mu$ universality. Supersedes HEINTZ 91. F($\gamma T(1S)$)/F total VALUE CLX COMMENT 7 CRAWFORD 928 CLE2 $e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$ 7 Using B($T(1S) \rightarrow \mu^+\mu^-$) = (2.57 ± 0.07)%, B($T(3S) \rightarrow \gamma\gamma T(1S)$)×2 B($T(1S) \mu^+\mu^-$) < 0.63 × 10 ⁻⁴ , and B($T(3S) \rightarrow \chi_{b0}(2P)\gamma$) = 0.049. 8 Using B($T(1S) \rightarrow \mu^+\mu^-$) = (2.57 ± 0.07)%, B($T(3S) \rightarrow \gamma\chi_{b0}(2P)$) = (6.0 0.4 ± 0.6)% and assuming $e\mu$ universality. Supersedes HEINTZ 91. X _{b0} (2P) REFERENCES CRAWFORD 92B PL B294 139 +Fulton (CLEO Collab.) (CUSE II Collab.) (CUSE II Collab.)
### ALBRECHT ### ### ALBRECHT #	26.5 DOCUME: 10 Property of the following data for at a good and a for a good and a good a good and a good a good and a good a good and a good and a good and a good and a good a good and a good and a good and a good a g	verages, fits, limit CHT 89 ARG 220) → K+K FERENCES Blinov, Bondar+ her+ hyan, Bartels, Besset+ hyan, Bartels, Besset+ hann, Glaeser, Harder- heller, Cooper Singapore yan, Bartels+ Boockman, Glaeser- hyan, Bessett- heller+ kerten bessett- heller+ heller+ kerten bessett- heller+ heller+ heller+ kerten bessett- heller+ heller+ heller+ heller+ kerten bessett- heller+ heller+ heller+ heller+ kerten bessett- heller+ heller- hel	COMMENT 5, etc. ● ● ● T(2S) → γK+K- (ARGUS Collab.) (Crystal Ball Collab.) (Crystal Ball Collab.) (Cuse Collab.) (Cuse Collab.) (Cuse Collab.) (Crystal Ball Collab.) (NOVO) (Crystal Ball Collab.) (Collab., Crystal Ball Collab.)	$\begin{array}{c} 5 \text{ Using B}(T(25) \to \mu^+\mu^-) = (1.37 \pm 0.26)\%, \ B(T(3S) \to \gamma\gamma T(2S)) \times 2 \ B(T(2S) \\ \mu^+\mu^-) < 1.19 \times 10^{-4}, \ \text{and B}(T(3S) \to \chi_{b0}(2P)\gamma) = 0.049. \\ 6 \text{ Using B}(T(2S) \to \mu^+\mu^-) = (1.44 \pm 0.10)\%, \ B(T(3S) \to \gamma\chi_{b0}(2P)) = (6.0 \times 10^{-2}), \ B(100) = (1.00) =$
### ALBRECHT ### SEPHY ALBRECHT ### ALBRECHT	26.5 DOCUME: 10 Following data for at 90 11 ALBREC (anching ratio of f J (22 anching ratio of f J (23 anching ratio of f J (24 anching ratio of f J (25 anching ratio of f	verages, fits, limit CHT 89 ARG 220) → K+K FERENCES Blinov, Bondar+ her+ hyan, Bartels, Besset+ hyan, Bartels, Besset+ hyan, Bartels, Besset- heller, Cooper Singapore yan, Bartels, Boockman, Glaeser- hyan, Bessett- bendar, Bukin- lell, Heller+ er, Heller+ er, Heller+ (DESY, ARGUS Hicks, Namjoshi, San (DESY, ARGUS Hicks, Namjoshi, San S, Son, Diet, Eigen+	COMMENT 5, etc. ● ● ● T(2S) → γK+K- (ARGUS Collab.) (Crystal Ball Collab.) (Crystal Ball Collab.) (Crystal Ball Collab.) (CUSB Collab.) (CUSB Collab.) (Crystal Ball Collab.) (COVO) (Crystal Ball Collab.) (COUSB Collab.)	$\begin{array}{c} ^{5} \text{Using B}(T(25) \to \mu^{+}\mu^{-}) = (1.37 \pm 0.26)\%, \ B(T(3S) \to \gamma\gammaT(2S)) \times 2 \ B(T(2S) \\ \mu^{+}\mu^{-}) < 1.19 \times 10^{-4}, \ \text{and B}(T(3S) \to \chi_{b0}(2P)\gamma) = 0.049. \\ ^{6} \text{Using B}(T(2S) \to \mu^{+}\mu^{-}) = (1.44 \pm 0.10)\%, \ B(T(3S) \to \gamma\chi_{b0}(2P)) = (6.0 \pm 0.6)\%, \ \text{and assuming } e\mu \ \text{universality.} \ \text{Supersedes HEINTZ } 91. \\ \hline \Gamma(\gammaT(1S))/\Gamma_{\text{total}} & & & & & & & & & & & & & & & & & & $
### ALBRECHT ### SZPHY BARU ### ALBRECHT ### SZPHY BARU ### BESSON ## PR DS SINP & FRISTONSEC ### PR L 138 BESSON ## PR DS GILES ### PR L 55 GILES #### PR L 55 GILES ##### PR L 55 GILES ####################################	26.5 DOCUME: 10 Following data for at 90 11 ALBREC (anching ratio of f f (22 anching ratio of f f) (23 anching ratio of f) (25 Feb. 12 anching ratio of f) (25 Feb. 12 anching ratio of f) (25 Feb. 12 anching world Scientific, S C42 349 + Block, more of f) (26 Feb. 12 anching world Scientific, S C40 49 + Antreas C32 623 + Hantreas C32 622 + Blinov, C28 45 + Dresche B3 31 + Dresche B3 31 + Dresche B3 31 + Dresche B3 31 + Dresche C4 from VAF 11 733. + Fadin ted from VAF 11 733. + Fadin ted from VAF 11 733. + Fadin 42 195 44 219 + Hansard 42 31 + Hansard 42 31 + Hansard 42 799 + Hensen, E 78 279 + Hansard 42 799 + Hensen, E 78 279 + Hansard 42 799 + Hensen, E 78 279 + Hansard 42 799 + Hensen, E 78 279 + Hansard 42 799 + Hensen, E 78 279 + Hansard 42 799 + Hensen, E 78 279 + Hansard 42 799 + Hensen, E 78 279 + Hansard 42 799 + Hensen, E 78 279 + Hansard 42 799 + Han	verages, fits, limit CHT 89 ARG 220) — K+K FERENCES Blinov, Bondar+ her+ hyan, Bartels, Besset+ yan, Bartels, Besset+ hore, Bartels, Besseth boekmann, Glaeser- yan, Bartels+ Boekmann, Glaeser- yan, Bartels+ Boekmann, Glaeser- yan, Besseth Bondar, Bukin- ell, Heller+ kyan, Bartels- Bondar, Bukin- ell, Heller+ kyan, Aschman+ Silnov, Bondar- (DESY, ARGUS Hicks, Namjoshi, San (DESY, ARGUS Hicks, Namjoshi, San , Son, Dietl, Eigen+ d, Hempstead, Kinoshi Kagan, Kass, Behrer	COMMENT 5, etc. • • • • T(2S) -> \gamma K+K- (ARGUS Collab.) (Crystal Ball Collab.) (Crystal Ball Collab.) (Cuystal Ball Collab.) (Cuystal Ball Collab.) (Cuystal Ball Collab.) (Cuystal Ball Collab.) (Crystal Ball Collab.) (Crystal Ball Collab.) (Crystal Ball Collab.) (ARGUS Collab.) (ARGUS Collab.) (ARGUS Collab.) (ARGUS Collab.) (Crystal Ball Collab.) (Crystal Ball Collab.) (Crystal Ball Collab.) (Crystal Ball Collab.) (CUYSTAL Collab.) (CUYSTAL COLLAB.) (CUSTAL COLLAB.) (CUSTAL COLLAB.)	$\begin{array}{c} ^{5} \text{Using B}(T(25) \to \mu^{+}\mu^{-}) = (1.37 \pm 0.26)\%, \ B(T(3S) \to \gamma\gamma T(2S)) \times 2 \ B(T(2S) \\ \mu^{+}\mu^{-}) < 1.19 \times 10^{-4}, \ \text{and B}(T(3S) \to \chi_{b0}(2P)\gamma) = 0.049. \\ ^{6} \text{Using B}(T(2S) \to \mu^{+}\mu^{-}) = (1.44 \pm 0.10)\%, \ B(T(3S) \to \gamma\chi_{b0}(2P)) = (6.0 \pm 0.6)\%, \ \text{and assuming } e\mu \ \text{universality.} \ \text{Supersedes HEINTZ 91.} \\ \hline F(\gamma T(1S))/F_{\text{total}} & & & & & & & & & & & & & & & & & & $
BARU 96 PRPL: ALBRECHT 95E ZPHY KOBEL 92 ZPHY MASCHMANN 90 ZPHY MASCHMANN 90 ZPHY KARSBERG 89 PRL 63 BUCHMUEL 88 HE e* Editors: A. Ali and P. S. JAKUBOWSKI 88 ZPHY BARU 86 ZPHY BARU 87 ZPHY BARU 88 ZPHY BARU 87 ZPHY BARU 87 ZPHY BARU 88 ZPHY BARU 87 ZPHY BARU 88 ZPHY BARU 87 ZPHY BARU 88 ZPHY BARU 89 ZPHY BARU 85	## DOCUME ## DOCUME ## DOCUME ## DOCUME ## DOCUME ## DOCUME ## T(25) REF ## T(25) REF ## Hamach ## Hamach ## Hamach ## Hamach ## Hoeckim ## Heint: ## H	verages, fits, limit CHT 89 ARG 220) → K+K- FERENCES Blinov, Bondar+ her+ hyan, Bartels, Besset+ hyan, Bartels, Besseth hyan, Bartels, Besseth hyan, Bartels, Besseth hyan, Bartels, Beckmann, Glaeser, hyan, Bartels+ Bondar, Bukin+ lil, Heller+ er, Heller+ httreasyan+ horar, Bartelsh Binov, Rodus Hicks, Namjoshi, San s, Son, Diet, Eigen+ d, Hempstead, Kinoshi Kagan, Kass, Behrer	COMMENT 5, etc. ● ● ● T(2S) → γK+K- (ARGUS Collab.) (Crystal Ball Collab.) (Crystal Ball Collab.) (Crystal Ball Collab.) (CUSB Collab.) (CUSB Collab.) (Crystal Ball Collab.) (ARGUS Collab.) (ARGUS Collab.) (ARGUS Collab.) (ARGUS Collab.) (Crystal Ball Collab.) (Crystal Ball Collab.) (Crystal Ball Collab.) (CUSB Collab.) (CUSB Collab.) (CUSB Collab.) (tcleO Collab.) (ds+ (CLEO Collab.) (ds+ (CLEO Collab.) (CUSB Collab.)	5 Using B($T(25) \rightarrow \mu^+\mu^-$) = (1.37 ± 0.26)%, B($T(35) \rightarrow \gamma\gamma T(25)$)×2 B($T(25) \mu^+\mu^-$) < 1.19 × 10 ⁻⁴ , and B($T(35) \rightarrow \chi_{b0}(2P)\gamma$) = 0.049. 6 Using B($T(25) \rightarrow \mu^+\mu^-$) = (1.44 ± 0.10)%, B($T(35) \rightarrow \gamma\chi_{b0}(2P)$) = (6.0 0.4 ± 0.6)% and assuming $e\mu$ universality. Supersedes HEINTZ 91. F($\gamma T(15)$)/F total VALUE CLX COMMENT COMMENT 7 CRAWFORD 928 CLE2 $e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$ 7 Using B($T(15) \rightarrow \mu^+\mu^-$) = (2.57 ± 0.07)%, B($T(35) \rightarrow \gamma\gamma T(15)$)×2 B($T(15) \mu^+\mu^-$) < 0.63 × 10 ⁻⁴ , and B($T(35) \rightarrow \chi_{b0}(2P)\gamma$) = 0.049. 8 Using B($T(15) \rightarrow \mu^+\mu^-$) = (2.57 ± 0.07)%, B($T(35) \rightarrow \gamma\chi_{b0}(2P)$) = (6.0 0.4 ± 0.6)% and assuming $e\mu$ universality. Supersedes HEINTZ 91. $X_{b0}(2P)$ REFERENCES CRAWFORD 928 PL B294 139 +Fulton HEINTZ 91 PR 66 1563 +Fulton (CLEO Collab.) MORRISON 91 PRI 67 1696 +Schmidt+ (CUSB Ollab.) OTHER RELATED PAPERS EIGEN 82 PRL 49 1616 +Bohringer, Herb+ (CUSB Collab.)
### ALBRECHT ### SZPHY BARU ### BESSON ## PR L 58 BESSON ## PR L 5	267 71 +Blinov, C65 619 +Hamseh C53 193 +Antreas C46 555 +Antreas C46 383 +Blockn C53 183 +Antreas C640 49 +Antreas C540 49 +Antreas C55 283 +Blinder, C56 383 +Antreas C32 622 +Blinder, C68 455 +Antreas C32 622 +Blinder, C48 45 +Cresche C48	verages, fits, limit CHT 89 ARG 220) → K+K- FERENCES Blinov, Bondar+ her+ hyan, Bartels, Besset+ hyan, Bartels, Besseth hyan, Bartels, Besseth hyan, Bartels, Besseth hyan, Bartels, Beckmann, Glaeser, hyan, Bartels+ Bondar, Bukin+ lil, Heller+ er, Heller+ httreasyan+ horar, Bartelsh Binov, Rodus Hicks, Namjoshi, San s, Son, Diet, Eigen+ d, Hempstead, Kinoshi Kagan, Kass, Behrer	COMMENT S, etc. ● ● ● T(2S) → γK+K- (NOVO) (ARGUS Collab.) (Crystal Ball Collab.) (Crystal Ball Collab.) (CUSB Collab.) (CUSB Collab.) (CUSB Collab.) (Cystal Ball Collab.) (Glystal Ball Collab.) (Crystal Ball Collab.) (ARGUS Collab.) (Crystal Ball Collab.) (Crystal Ball Collab.) (Crystal Ball Collab.) (COLIBb. Crystal Ball Collab.) (CUSB Collab.) (CUSB Collab.) (CUSB Collab.) (CUSB Collab.) (CUSB Collab.) (CUEO Collab.) (CLEO Collab.)	5 Using B($T(25) \rightarrow \mu^+\mu^-$) = (1.37 ± 0.26)%, B($T(35) \rightarrow \gamma\gamma T(25)$)×2 B($T(25) \mu^+\mu^-$) < 1.19 × 10 ⁻⁴ , and B($T(35) \rightarrow \chi_{b0}(2P)\gamma$) = 0.049. 6 Using B($T(25) \rightarrow \mu^+\mu^-$) = (1.44 ± 0.10)%, B($T(35) \rightarrow \gamma\chi_{b0}(2P)$) = (6.0 0.4 ± 0.6)% and assuming $e\mu$ universality. Supersedes HEINTZ 91. F($\gamma T(15)$)/F total VALUE CLX COMMENT COMMENT 7 CRAWFORD 928 CLE2 $e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$ 7 Using B($T(15) \rightarrow \mu^+\mu^-$) = (2.57 ± 0.07)%, B($T(35) \rightarrow \gamma\gamma T(15)$)×2 B($T(15) \mu^+\mu^-$) < 0.63 × 10 ⁻⁴ , and B($T(35) \rightarrow \chi_{b0}(2P)\gamma$) = 0.049. 8 Using B($T(15) \rightarrow \mu^+\mu^-$) = (2.57 ± 0.07)%, B($T(35) \rightarrow \gamma\chi_{b0}(2P)$) = (6.0 0.4 ± 0.6)% and assuming $e\mu$ universality. Supersedes HEINTZ 91. $X_{b0}(2P)$ REFERENCES CRAWFORD 928 PL B294 139 +Fulton HEINTZ 91 PR 66 1563 +Fulton (CLEO Collab.) MORRISON 91 PRI 67 1696 +Schmidt+ (CUSB Ollab.) OTHER RELATED PAPERS EIGEN 82 PRL 49 1616 +Bohringer, Herb+ (CUSB Collab.)

 Γ_2/Γ

Meson Particle Listings $\chi_{b1}(2P), \chi_{b2}(2P)$

 $\chi_{b1}(2P)$

 $I^{G}(J^{PC}) = 0^{+}(1^{+})$ J needs confirmation.

Observed in radiative decay of the $\Upsilon(35)$, therefore C=+. Branching ratio requires E1 transition, M1 is strongly disfavored, therefore

$\chi_{b1}(2P)$ MASS

VALUE (GeV)	DOCUMENT ID		TECN	COMMENT
10.2552±0.0005 OUR AVERAGE				
$10.2547 \pm 0.0004 \pm 0.0010$	1 HEINTZ	92	CSB2	$e^+e^- \rightarrow \gamma X, \ell^+\ell^- \gamma \gamma$
10.2553±0.0005	² MORRISON	91	CLE2	$e^+e^- \rightarrow \gamma X$

- 1 From the average photon energy for inclusive and exclusive events and assuming $\varUpsilon(3S)$ mass = 10355.3 \pm 0.5 MeV. Supersedes HEINTZ 91 and NARAIN 91.
- 2 From γ energy below assuming T(3S) mass = 10355.3 \pm 0.5 MeV. The error on the $\Upsilon(35)$ mass is not included in the individual measurements. It is included in the final

$m\chi_{b1}(2P) - m\chi_{b0}(2P)$

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT	
23.5±0.7±0.7	3 HEINTZ 92	CSB2	e+e- →	$\gamma X, \ell^+ \ell^- \gamma \gamma$

³ From the average photon energy for inclusive and exclusive events. Supersedes NARAIN 91.

γ ENERGY IN T(35) DECAY

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
99.90±0.26 OUR AV	ERAGE			
99 ±1	169	CRAWFORD		$e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$
100.1 ±0.4	11147	4 HEINTZ		e ⁺ e [−] → γX
100.2 ±0.5	223	⁵ HEINTZ		$e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$
99.5 ±0.1 ±0.5	25759	MORRISON	91 CLE2	$e^+e^- \rightarrow \gamma X$

- ⁴A systematic uncertainty on the energy scale of 0.9% not included. Supersedes
- systematic uncertainty on the energy scale of 0.9% not included. HEINTZ 91.

$x_{b1}(2P)$ DECAY MODES

	Mode	Fraction (Γ _/ /Γ)	Scale factor
$\overline{\Gamma_1}$	γ T(25)	(21 ±4)%	1.5
Γ_2	$\gamma \Upsilon(1S)$	(8.5±1.3) %	1.3

X_{b1}(2P) BRANCHING RATIOS

$\Gamma(\gamma \Upsilon(2S))/\Gamma_{\text{total}}$				Γ_1/Γ
VALUE	DOCUMENT ID	<u>TECN</u>	COMMENT	
0.21 ±0.04 OUR AVERAGE	Error includes scale fac	tor of 1.5	•	

⁶ CRAWFORD 928 CLE2 $e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$ $0.356 \pm 0.042 \pm 0.092$ 7 HEINTZ 92 CSB2 $e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$ $0.199 \pm 0.020 \pm 0.022$

⁶ Using B($\Upsilon(2S) \to \mu^+ \mu^-$) = (1.37 ± 0.26)%, B($\Upsilon(3S) \to \gamma \gamma \Upsilon(2S)$)×2 B($\Upsilon(2S)$ Fusing B($\Upsilon(25) \to \mu^+ \mu^-$) = (1.37 ± 0.26)%, B($\Upsilon(35) \to \gamma \gamma^+ \Gamma(25)$)×2 B($\Upsilon(25) \to \mu^+ \mu^-$) = (10.23±1.20±1.26)×10⁻⁴, and B($\Upsilon(35) \to \gamma \chi_{b1}(2P)$) = 0.105+0.003 ± 0.013. 7 Using B($\Upsilon(25) \rightarrow \mu^+\mu^-$) = (1.44 ± 0.10)%, B($\Upsilon(35) \rightarrow \gamma \chi_{b1}(2P)$) = (11.5 ± 0.5 ± 0.5)% and assuming $e\mu$ universality. Supersedes HEINTZ 91.

$\Gamma(\gamma \Upsilon(1S))/\Gamma_{\text{total}}$				Γ_2/Γ
VALUE	DOCUMENT ID	TECN	COMMENT	
0.085±0.013 OUR AVERAGE	Error includes scale fa	ctor of 1.3	.	

⁸ CRAWFORD 92B CLE2 $e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$ $0.120 \pm 0.021 \pm 0.021$ 9 HEINTZ 92 CSB2 $e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$ $0.080 \pm 0.009 \pm 0.007$

⁸ Using B($\Upsilon(1S) \to \mu^+ \mu^-$) = (2.57 ± 0.07)%, B($\Upsilon(3S) \to \gamma \gamma \Upsilon(1S)$)×2 B($\Upsilon(1S) \to \gamma \gamma \Upsilon(1S)$)×3 B($\Upsilon(1S) \to \gamma \gamma \Upsilon(1S)$)×4 B($\Upsilon(1S) \to \gamma \gamma \Upsilon(1S)$)×5 B($\Upsilon(1S) \to \gamma \gamma \Upsilon(1S)$)×5 B($\Upsilon(1S) \to \gamma \gamma \Upsilon(1S)$)×5 B($\Upsilon(1S) \to \gamma \gamma \Upsilon(1S)$)×6 B($\Upsilon(1S) \to \gamma \gamma \Upsilon(1S)$)×7 B($\Upsilon(1S) \to \gamma \gamma \Upsilon(1S)$ $\mu^{+}\,\mu^{-}) = (6.47 \pm 1.12 \pm 0.82) \times 10^{-4}$ and B($\Upsilon(35) \rightarrow \gamma X_{b1}(2P)) = 0.105 {+0.003 \atop -0.002} \pm 0.003 \pm 0.003$

0.013. 9 Using B($\Upsilon(1S) \rightarrow \mu^+\mu^-$)=(2.57 \pm 0.07)%, B($\Upsilon(3S) \rightarrow \gamma \chi_{b1}(2P)$) = (11.5 \pm 0.5 \pm 0.5)% and assuming $e\mu$ universality. Supersedes HEINTZ 91.

Xb1(2P) REFERENCES

CRAWFORD HEINTZ HEINTZ MORRISON NARAIN	92B 92 91 91	PL B294 139 PR D46 1928 PRL 66 1563 PRL 67 1696 PRL 66 3113	+Fulton +Lee, Franzini+ +Kaarsberg+ +Schmidt+ +Lovelock+	(CLEO Collab.) (CUSB II Collab.) (CUSB Collab.) (CLEO Collab.) (CUSB Collab.)

OTHER RELATED PAPERS

EIGEN	82	PRL 49 1616	+Bohringer, Herb+	(CUSB Collab.)
HAN	82	PRL 49 1612	+Horstkotte, Imlay+	(CUSB Collab.)

 $\chi_{b2}(2P)$

 $I^{G}(J^{PC}) = 0^{+}(2^{+})$ J needs confirmation.

Observed in radiative decay of the $\Upsilon(3S)$, therefore C=+. Branching ratio requires E1 transition, M1 is strongly disfavored, therefore

$X_{b2}(2P)$ MASS

VALUE (GeV)	DOCUMENT ID		TECN	COMMENT
10.2685±0.0004 OUR AVERAGE	_			
$10.2681 \pm 0.0004 \pm 0.0010$	1 HEINTZ			$e^+e^- \rightarrow \gamma X, \ell^+\ell^- \gamma \gamma$
10.2685±0.0004	² MORRISON	91	CLE2	$e^+e^- \rightarrow \gamma X$

- 1 From the average photon energy for inclusive and exclusive events and assuming $\varUpsilon(3s)$ mass = 10355.3 \pm 0.5 MeV. Supersedes HEINTZ 91 and NARAIN 91.
- ² From γ energy below, assuming $\Upsilon(3S)$ mass = 10355.3 \pm 0.5 MeV. The error on the $\Upsilon(3S)$ mass is not included in the individual measurements. It is included in the final average.

$m\chi_{b2}(2P) - m\chi_{b1}(2P)$

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
13.5±0.4±0.5	3 HEINTZ 92	CSB2	$e^+e^- \rightarrow \gamma X, \ell^+\ell^- \gamma \gamma$

³ From the average photon energy for inclusive and exclusive events. Supersedes NARAIN 91.

γ ENERGY IN $\Upsilon(3S)$ DECAY

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
86.64±0.23 QUR AVI	RAGE			
86 ±1	101	CRAWFORD		$e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$
86.7 ±0.4	10319	4 HEINTZ		$e^+e^- \rightarrow \gamma X$
86.9 ±0.4	157	⁵ HEINTZ		$e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$
86.4 ±0.1 ±0.4	30741	MORRISON	91 CLE2	$e^+e^- \rightarrow \gamma X$

- ⁴A systematic uncertainty on the energy scale of 0.9% not included. Supersedes NAŘAIN 91.
- systematic uncertainty on the energy scale of 0.9% not included. Supersedes HEINTZ 91.

X_{b2}(2P) DECAY MODES

	Mode	Fraction (Γ_I/Γ)
Γ_1	γ Υ(2S)	(16.2±2.4) %
Γ2	$\gamma \Upsilon(1S)$	(7.1±1.0) %

X_{b2}(2P) BRANCHING RATIOS

$\Gamma(\gamma \Upsilon(2S))/\Gamma_{\text{total}}$		· Γ ₁ /Γ
VALUE	DOCUMENT ID TECN	COMMENT
0.162 ± 0.024 OUR AVERAGE		
$0.135 \pm 0.025 \pm 0.035$		$e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$
$0.173 \pm 0.021 \pm 0.019$	⁷ HEINTZ 92 CSB2	$e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$
6		m(= a)) = a(m(= a)

⁶ Using B(γ(25) → $\mu^+\mu^-$) = (1.37 ± 0.26)%, B(γ(35) → $\gamma\gamma$ γ(25))×2 B(γ(25) → $\mu^+\mu^-$) = (4.98 ± 0.94 ± 0.62)×10⁻⁴, and B(γ(35) → γ γ_{b2}(2P)) = 0.135 ± 0.003 ±

70.017. γ Using B(γ (25) $\rightarrow \mu^+\mu^-$) = (1.44 \pm 0.10)%, B(γ (35) $\rightarrow \gamma \chi_{b2}(2P)$) = (11.1 \pm 0.5 \pm 0.4)% and assuming e μ universality. Supersedes HEINTZ 91.

$\Gamma(\gamma \Upsilon(1S))/\Gamma_{\text{total}}$ DOCUMENT ID TECN COMMENT

0.071 ± 0.010 OUR AVERAGE ⁸ CRAWFORD 92B CLE2 $e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$ $0.072 \pm 0.014 \pm 0.013$ ⁹ HEINTZ 92 CSB2 $e^+e^- \rightarrow \ell^+\ell^-\gamma\gamma$ $0.070 \pm 0.010 \pm 0.006$

⁸ Using B($\Upsilon(15) \rightarrow \mu^+ \mu^-$) = (2.57 ± 0.07)%, B($\Upsilon(35) \rightarrow \gamma \gamma \Upsilon(25)$)×2 B($\Upsilon(15) \rightarrow \gamma \gamma \Upsilon(25)$)×3 B($\Upsilon(15) \rightarrow \gamma \gamma \Upsilon(25)$)×4 B($\Upsilon(15) \rightarrow \gamma \gamma \Upsilon(25)$)×5 B($\Upsilon(15) \rightarrow \gamma \gamma \Upsilon(25)$)×5 B($\Upsilon(15) \rightarrow \gamma \gamma \Upsilon(25)$)×5 B($\Upsilon(15) \rightarrow \gamma \gamma \Upsilon(25)$)×6 B($\Upsilon(15) \rightarrow \gamma \gamma \Upsilon(25)$)×6 B($\Upsilon(15) \rightarrow \gamma \gamma \Upsilon(25)$)×7 B($\Upsilon(15) \rightarrow \gamma \gamma \Upsilon(25)$ $\mu^+\mu^-)=(5.03\pm0.94\pm0.63)\times10^{-4}$, and B($\Upsilon(35)\to\gamma\chi_{b2}(2P))=0.135\pm0.003\pm0.017$.

0.017. 9 Using B(τ (15) $\rightarrow \ \mu^+\mu^-$) = (2.57 \pm 0.07)%, B(τ (35) $\rightarrow \ \gamma^\chi_{b2}(2P)$) = (11.1 \pm 0.5 \pm 0.4)% and assuming $e\mu$ universality. Supersedes HEINTZ 91.

Xb2(2P) REFERENCES

CRAWFORD	92B	PL B294 139	+Fulton	(CLEO Collab.) (CUSB II Collab.) (CUSB Collab.) (CLEO Collab.) (CUSB Collab.)
HEINTZ	92	PR D46 1928	+Lee, Franzini+	
HEINTZ	91	PRL 66 1563	+Kaarsberg+	
MORRISON	91	PRL 67 1696	+Schmidt+	
NARAIN	91	PRL 66 3113	+Lovelock+	
		оті	HER RELATED PAPERS	
EIGEN	82	PRL 49 1616	+Bohringer, Herb+	(CUSB Collab.)
HAN	82	PRL 49 1612	+Horstkotte, Imlay+	(CUSB Collab.)

 $\Upsilon(3S)$

20/061
11351
1 (33)

$I^G(J^{PC})$	= 0-((1)
---------------	-------	------------------

7(35) MASS

VALUE (GeV)	DOCUMENT ID	TECN	COMMENT
10.3553±0.0005	¹ BARU	86B REDE	e ⁺ e [−] → hadrons
1 Respenses of ARTAMONO	N/ 84		

7(35) WIDTH

T(3S) DECAY MODES

	Mode	Fraction (Γ_I/Γ)	Scale factor/ Confidence level
$\overline{\Gamma_1}$	$\Upsilon(2S)$ anything	(10.6 ±0.8) %	
Γ_2	$\Upsilon(2S)\pi^+\pi^-$	(2.8 ±0.6) %	5=2.2
Гз	$\Upsilon(2S)\pi^0\pi^0$	(2.00±0.32) %	
Γ_4	$\Upsilon(2S)_{\gamma\gamma}$	(5.0 ±0.7)%	
Γ ₅	$\Upsilon(1S)\pi^+\pi^-$	(4.48±0.21) %	
Γ ₆	$\Upsilon(1S)\pi^0\pi^0$	(2.06 ± 0.28) %	
Γ7	$\Upsilon(1S)_{\eta}$	< 2.2 × 10 ⁻¹	-3 CL=90%
Гв	$\mu^{+}\mu^{-}$	(1.81±0.17) %	
Γġ	e+ e-	seen	
		Radiative decays	
Γ ₁₀	$\gamma \chi_{b2}(2P)$	(11.4 ±0.8)%	S=1.3
	$\gamma \chi_{b1}(2P)$	(11.3 ±0.6)%	
	$\gamma \chi_{b0}(2P)$	(5.4 ±0.6)%	S=1.1

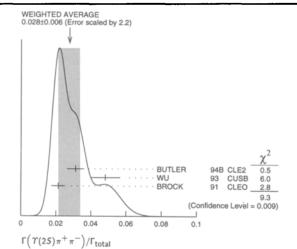
$\Upsilon(3S) \Gamma(1)\Gamma(e^+e^-)/\Gamma(\text{total})$

$\Gamma(\text{hadrons}) \times \Gamma(e^+e^-)$	-)/F _{total}				Γ ₀ Γ ₉ /Γ
VALUE (keV)	DOCUMENT ID		TECN	COMMENT	
0.45±0.03±0.03	² GILES	84B	CLEO	$e^+e^- \rightarrow$	hadrons
² Radiative corrections re	eevaluated by BUCHMUI	ELLER	88 foll	owing KUR/	AEV 85.

T(35) BRANCHING RATIOS

$\Gamma(\Upsilon(2S))$ anyt	hing)/F _{total}				Γ ₁ /Ι
VALUE	EVTS	DOCUMENT ID	TECN	COMMENT	
0.106 ±0.008					
0.1023 ± 0.0105		^{3,4,5} BUTLER	94B CLE2	$e^+e^- \rightarrow \ell$	+_ℓ-X
0.111 ± 0.012	4891	^{4,5,6} BROCK	91 CLEO	$e^+e^- \rightarrow \pi$	+π-X,
				_+ +	- /

$\Gamma(T(2S)\pi^+\pi^-)/\Gamma_{\text{total}}$				Γ2/Γ
VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
0.028 ±0.006 OUR AVERA	NGE Erro	r includes scale fac below.		=
0.0312 ± 0.0049	980	3,7 BUTLER	94B CLE2	$ \begin{array}{c} e^+e^- \rightarrow \\ \pi^+\pi^-\ell^+\ell^-\\ T(35) \rightarrow \end{array} $
$0.0482 \pm 0.0065 \pm 0.0053$	138	6 WU	93 CUSB	T(35) → T
0.0213±0.0038	974	⁶ BROCK	91 CLEO	$e^{+}e^{-} \rightarrow \\ \pi^{+}\pi^{-}\ell^{+}\ell^{-}$ $e^{+}e^{-} \rightarrow \\ \pi^{+}\pi^{-}X, \\ \pi^{+}\pi^{-}\ell^{+}\ell^{-}$
• • • We do not use the following	lowing dat	a for averages, fits,	limits, etc. •	
0.031 ±0.020	5	MAGERAS	82 CUSB	γ(3S) → -+



/ total				
$\Gamma(\Upsilon(2S)\pi^0\pi^0)/\Gamma_{\text{total}}$				Г3/Г
YALUEEVTS	DOCUMEN	IT ID TECN	COMMENT	
0.0200±0.0032 OUR AVERAG	E			-
0.0216 ± 0.0039	7,8 BUTLER	94B CLE2		$\ell^{+}\ell^{-}\pi^{0}\pi^{0}$
0.017 ±0.005 ±0.002 10	⁹ HEINTZ	92 CSB2	$e^+e^- \rightarrow$	$\ell^{+}\ell^{-}\pi^{0}\pi^{0}$
7(m(a, n)) (7				- /-
$\Gamma(\Upsilon(2S)\gamma\gamma)/\Gamma_{\text{total}}$				Γ ₄ /Γ
VALUE	DOCUMEN			.1
0.0502±0.0069	7 BUTLER	94B CLE2	e ⁺ e ⁻ →	ℓ+ℓ-2γ
$\Gamma(T(1S)\pi^{+}\pi^{-})/\Gamma_{\text{total}}$				Γ ₅ /Γ
VALUE	EVTS D	OCUMENT ID	TECN COL	MMENT
0.0448±0.0021 OUR AVERAG			<u> </u>	ennace:
0.0452 ± 0.0035	11830 ⁴ B	UTLER 948	CLE2 e+	e_ →
				π ⁺ π ⁻ Χ,
0.0446 ± 0.0034 ± 0.0050	451 ⁴ W	/U 93		π ⁺ π ⁻ ℓ ⁺ ℓ ⁻ 35) →
0.0446±0.0034±0.0030	451 4	10 93		$\pi^+\pi^-\ell^+\ell^-$
0.0446±0.0030	11221 ⁴ B	ROCK 91	CLEO e+	π π ε ε e →
				$\pi^+\pi^-X$
		gs. H		$\pi^{+}\pi^{-}\ell^{+}\ell^{-}$
• • We do not use the follow				
0.049 ±0.010	22 G	REEN 82		35) →
0.039 ±0.013	26 M	IAGERAS 82		$\pi^{+}\pi^{-}\ell^{+}\ell^{-}$
0.039 ±0.013	26 17	IAGERAS 02		$35) \rightarrow \pi^{+}\pi^{-}\ell^{+}\ell^{-}$
				* * E . E
$\Gamma(\Upsilon(1S)\pi^0\pi^0)/\Gamma_{\text{total}}$				Γ ₆ /Γ
VALUE EVTS	DOCUMEN	IT ID TECN	COMMENT	
0.0206±0.0028 OUR AVERAG	-			
0.0199±0.0034 56	4 BUTLER			$\ell^{+}\ell^{-}\pi^{0}\pi^{0}$
0.022 ±0.004 ±0.003 33	¹⁰ HEINTZ	92 CSB2	e ⁺ e ⁻ →	$\ell^{+}\ell^{-}\pi^{0}\pi^{0}$
$\Gamma(\Upsilon(1S)\eta)/\Gamma_{\text{total}}$				Γ ₇ /Γ
VALUE CL%	DOCUME	IT ID TECN	COMMENT	. '7'
<0.0022 90	BROCK	91 CLEO		
<0.0022 90	BRUCK	91 CLEO	σ π +π-	$\pi^{0}\ell^{+}\ell^{-}$
-4.1.3.4				
$\Gamma(\mu^+\mu^-)/\Gamma_{\text{total}}$				Γ ₈ /Γ
VALUE		OCUMENT ID	TECN CO	MMENT
0.0181±0.0017 OUR AVERAG			+	
$0.0202 \pm 0.0019 \pm 0.0033$	C	HEN 89	CLEO e+	$\mu^+\mu^-$
$0.0173 \pm 0.0015 \pm 0.0011$	k	AARSBERG 89	CSB2 e+	e →
				$\mu^+\mu^-$
$0.033 \pm 0.013 \pm 0.007$	1096 A	NDREWS 83	CLEO e+	e_ →
				$\mu^+\mu^-$
$\Gamma(\gamma \chi_{b2}(2P))/\Gamma_{total}$				Γ ₁₀ /Γ
VALUE	EVTS D	OCUMENT ID	TECN CO	MMENT
0.114±0.008 OUR AVERAGE		scale factor of 1.		
0.111±0.005±0.004		EINTZ 92		e ⁻ → γ
$0.135 \pm 0.003 \pm 0.017$		IORRISON 91	CLE2 e+	e → γX
$\Gamma(\gamma \chi_{b1}(2P))/\Gamma_{\text{total}}$				Γ ₁₁ /Γ
VALUE	<u>EVTS</u> D	OCUMENT ID	TECN CO	MMENT
0.113±0.006 OUR AVERAGE				_
0.115 ± 0.005 ± 0.005	11147 II H	FINT7 92	CSB2 e+	e -> ~

11147 11 HEINTZ

25759

92 CSB2 $e^+e^- \rightarrow \gamma$

MORRISON 91 CLE2 $e^+e^- \rightarrow \gamma X$

 $0.115 \pm 0.005 \pm 0.005$

 $0.105^{+0.003}_{-0.002} \pm 0.013$

ΒB

non-*B* \overline{B}

e+ e-

 J/ψ (3097) anything D^{*+} anything + c.c.

 ϕ anything T(1S) anything

Γ₁ Γ₂ Γ₃ Γ₄ Γ₅ Γ₆ Γ₇

$\Gamma(\gamma X_{b0}(2P))/\Gamma_{total}$	Г ₁₂ /Г
VALUE 0.054±0.006 OUR AVERAGE	EVTS DOCUMENT ID TECN COMMENT Error includes scale factor of 1.1.
0.060±0.004±0.006	4959 ¹¹ HEINTZ 92 CSB2 $e^+e^- \rightarrow \gamma$
$0.049^{+0.003}_{-0.004} \pm 0.006$	9903 MORRISON 91 CLE2 $e^+e^- \rightarrow \gamma X$
(1/2)B($\Upsilon(2S) \to \Upsilon(1S)$: 4 Using B($\Upsilon(1S) \to \mu^+\mu^-$ 5 Using B($\Upsilon(2S) \to \Upsilon(1S)$ 6 Using B($\Upsilon(2S) \to \mu^+\mu^-$ $\mu^+\mu^-$) = (0.188 ± 0.035 = (0.436 ± 0.056)%. With 7 From the exclusive mode. 8 B($\Upsilon(2S) \to \mu^+\mu^-$) = () = (2.48 \pm 0.06)%. With the assumption of $e\mu$ universality.
HEINTZ 91.) = $(2.57 \pm 0.07)\%$ and assuming $e\mu$ universality. Supersedes
	T(3S) REFERENCES
UTLER 94B PR D49 40	
VU 93 PL B301 307 HEINTZ 92 PR D46 1928	+Franzini, Kanekal+ (CUSB Collab.)
ROCK 91 PR D43 1448	+Ferguson+ (CLEO Collab.)
EINTZ 91 PRL 66 1563 ORRISON 91 PRL 67 1696	+Kaarsberg+ (CUSB Collab.) +Schmidt+ (CLEO Collab.)
ARAIN 91 PRL 66 3113 HEN 89B PR D39 3528	+Lovelock+ (CUSB Collab.) +Mcliwain, Miller+ (CLEO Collab.)
AARSBERG 89 PRL 62 2077	+Heintz+ (CUSB Collab.)
Editors: A. Ali and P. Soeding,	rsics 412 Buchmueller, Cooper (HANN, DESY, MIT) World Scientific, Singapore (NOVO)
ARU 868 ZPHY C32 623 URAEV 85 SJNP 41 466	+Fadin (NOVO)
RTAMONOV 84 PL 137B 272	YAF 41 733. +Baru, Blinov, Bondar+ (NOVO)
ILES 84B PR D29 1285 NDREWS 83 PRL 50 807	+Hassard, Hempstead, Kinoshita+ (CLEO Collab.) +Avery, Berkelman, Cassel+ (CLEO Collab.)
REEN 82 PRL 49 617 AGERAS 82 PL 118B 453	+Sannes, Skubic, Snyder+ (CLEO Collab.) +Herb, Imlay+ (COLU, CORN, LSU, MPIM, STON)
—— c	THER RELATED PAPERS ——
LEXANDER 89 NP B320 45	+Bonvicini, Drell, Frey, Luth (LBL, MICH, SLAC)
ARTAMONOV 84 PL 137B 272 GILES 84B PR D29 1285	+Baru, Blinov, Bondar+ (NOVO) +Hassard, Hempstead, Kinoshita+ (CLEO Collab.)
AN 82 PRL 49 1612 ETERSON 82 PL 114B 277	+Horstkotte, Imlay+ (CUSB Collab.)
APLAN 78 PRL 40 435 OH 78 PRL 41 684	+Appel, Herb, Hom+ (STON, FNAL, COLU)
OBB 77 PL 72B 273	+lwata, Fabjan+ (BNL, CERN, SYRA, YALE)
ERB 77 PRL 39 252 INES 77 PRL 39 1240	+Hom, Lederman, Appel, Ito+ (COLU, FNAL, STON) +Appel, Brown, Herb, Hom+ (COLU, FNAL, STON)
Υ (4 S) or Υ (10580)	$I^{G}(J^{PC}) = ?^{?}(1^{})$
	T(45) MASS
/ALUE (GeV)	DOCUMENT ID TECN COMMENT
0.5800±0.0035	¹ BEBEK 87 CLEO e ⁺ e ⁻ → hadrons
	wing data for averages, fits, limits, etc. • • • $\frac{1}{2}$ LOVELOCK 85 CUSB $e^+e^- \rightarrow \text{hadrons}$
0.5774±0.0010 1 Reanalysis of BESSON 85 2 No systematic error given.	
	T(4S) WIDTH
/ALUE (MeV)	DOCUMENT ID TECN COMMENT
10.0±2.8±2.7	3 ALBRECHT 95E ARG e ⁺ e ⁻ → hadrons
	wing data for averages, fits, limits, etc. • • •
20 ±2 ±4	BESSON 85 CLEO $e^+e^- \rightarrow \text{hadrons}$
25 ±2.5	LOVELOCK 85 CUSB $e^+e^- \rightarrow \text{hadrons}$
³ Using LEYAOUANC 77 pa	
	T(4S) DECAY MODES
Mode	Fraction (Γ_I/Γ) Confidence leve

< 4

< 7.4

< 2.3

< 4

 $(2.8\pm0.7)\times10^{-5}$

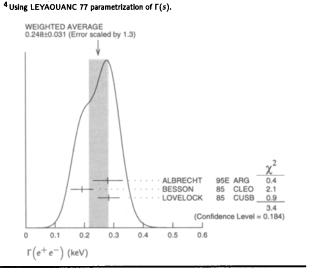
 $(2.2\pm0.7)\times10^{-3}$

× 10⁻³

 $\times 10^{-3}$

T(45) PARTIAL WIDTHS

Γ(e ⁺ e ⁻)			Гз
VALUE (keV)	DOCUMENT ID	TECN	COMMENT
0.248 ± 0.031 OUR AVERAGE	Error includes scale fact	or of 1.3	See the ideogram below.
0.28 ±0.05 ±0.01	⁴ ALBRECHT 95	ARG	e ⁺ e [−] → hadrons
$0.192 \pm 0.007 \pm 0.038$	BESSON 85	CLEO	$e^+e^- \rightarrow \text{hadrons}$
0.283±0.037	LOVELOCK 85	CUSB	$e^+e^- \rightarrow hadrons$



au(45) BRANCHING RATIOS

Γ(e ⁺ e ⁻)/		al .					Г3/Г
VALUE (units 1			DOCUMENT ID 5 ALBRECHT		TECN ARG	COMMENT e+e- →	hadaaa
2.77±0.50±					ARG	e.e →	nadrons
⁵ Using LE	YAO	UANC 77 p	arametrization of $\Gamma(s)$	•			
Γ (J/ψ(30 9	17) a	nything)/i	total DOCUMENT ID		TECN	COMMENT	Γ ₄ /Γ
0.0022±0.0	706+	0.0004	ALEXANDER	900		e+e-	
U.UULL 4. U.U.		.0.000	ALLAMIDEN	,,,,			
$[\Gamma(D^{*+})]$ an	ythi	ng) + Γ(c.	c.)]/F _{total}				Γ ₅ /Γ
VALUE		CL9			TECN	COMMENT	
<0.074		90	⁶ ALEXANDER	90 C	CLEO	e+e-	
6 For x >	0.47	3.					
Γ(φanythi	ng)/						Γ ₆ /Γ
VALUE		CLS			TECN	COMMENT	
< 0.0023		90	⁷ ALEXANDER	9 00	CLEO	e+e-	
7 For $x >$	0.52						
Γ(<i>T</i> (15)a	nvth	ing)/[•				Γ ₇ /Γ
VALUE		CL?			TECN	COMMENT	
<0.004		90	ALEXANDER	900	CLEO	e+ e-	
Γ(non- <i>B</i> B)/r						Γ2/Γ
VALUE		CL9			TECN	COMMENT	
<0.04		95	BARISH	96B	CLEO	e ⁺ e ⁻	
			T(45) REFERE	NCE	S		
BARISH ALBRECHT ALEXANDER BEBEK BESSON LOVELOCK LEYAOUANC	96B 95E 90C 87 85 85 77	PRL 76 1570 ZPHY C65 6 PRL 64 2226 PR D36 1289 PRL 54 381 PRL 54 377 PL B71 397	+Artuso+	icher, hi, Sar opfenst	Cassel+	(A) (0 (0	CLEO Collab.) RGUS Collab.) CLEO Collab.) CLEO Collab.) CLEO Collab.) CUSB Collab.) (ORSAY)

+Artuso+ +Berkelman, Blucher, Cassel+ +Green, Namjoshi, Sannes+ +Horstkotte, Klopfenstein+ +Oliver, Pene, Raynal

95%

95%

90%

90%

90%

OTHER RELATED PAPERS					
HENDERSON	92	PR D45 2212	+Kinoshita, Pipkin, Procario+	(CLEO Collab.)	
ANDREWS	80B	PRL 45 219	+Berkelman, Cabenda, Cassel+	(CLEO Collab.)	
FINOCCHI	80	PRL 45 222	Finocchiaro, Giannini, Lee-Franzini+	(CUSB Collab.)	

Meson Particle Listings $\Upsilon(10860)$, $\Upsilon(11020)$

 γ (10860)

 $I^{G}(J^{PC}) = ??(1--)$

27/1	DOCU)	MASS

VALUE (GeV)	DOCUMENT ID		TECN	COMMENT
10.865±0.008 OUR AVERAGE	Error includes scale	e fac	tor of 1.	1.
$10.868 \pm 0.006 \pm 0.005$	BESSON	85	CLEO	$e^+e^- \rightarrow hadrons$
10.845 ± 0.020	LOVELOCK	85	CUSB	$e^+e^- \rightarrow hadrons$

γ(10860) WIDTH

VALUE (MeV) 110±13 OUR AVERAGE	DOCUMENT ID	TE	CN	COMMENT
112±17±23	BESSON 8	35 CL	EO.	$e^+e^- \rightarrow hadrons$
110±15	LOVELOCK 8	35 CU	ISB	e ⁺ e ⁻ → hadrons

7(10860) DECAY MODES

	Mode	Fraction (Γ_I/Γ)
Г	e+ e-	$(2.8\pm0.7)\times10^{-6}$

au(10860) PARTIAL WIDTHS

Γ(e ⁺ e ⁻)			r ₁	
VALUE (keV)		TECN	COMMENT	
0.31 ±0.07 OUR AVERAGE	Error includes scale facto	or of 1.3		
0.22 ±0.05 ±0.07	BESSON 85	CLEO	e ⁺ e [−] → hadrons	
0.365±0.070	LOVELOCK 85	CUSB	$e^+e^- \rightarrow hadrons$	

7(10860) REFERENCES

BESSON LOVELOCK	85 85	PRL 54 381 PRL 54 377	+Green, Namjoshi, Sannes+	(CLEO Collab.)
LOVELUCK	85	PRL 54 377	+Horstkotte, Klopfenstein+	(CUSB Collab.)

 Υ (11020)

 $I^{G}(J^{PC}) = ?^{?}(1^{--})$

T	11020	MASS
---	-------	------

DOCUMENT ID		TECN	COMMENT
BESSON	85	CLEO	e ⁺ e ⁻ → hadrons
LOVELOCK	85	CUSB	$e^+e^- \rightarrow \text{hadrons}$
	BESSON	BESSON 85	BESSON 85 CLEO

au(11020) WIDTH

VALUE (MeV) 79±16 OUR AVERAGE	DOCUMENT ID	TECN	COMMENT
61±13±22	BESSON 85	CLEO	e ⁺ e ⁻ → hadrons
90±20	LOVELOCK 85	CUSB	e ⁺ e [−] → hadrons

au(11020) DECAY MODES

Mode		Fraction (Γ_I/Γ)
Γ ₁	e+ e-	$(1.6\pm0.5)\times10^{-6}$

au(11020) PARTIAL WIDTHS

Γ(e ⁺ e ⁻)					Γ ₁
VALUE (keV)	DOCUMENT ID		TECN	COMMENT	
0.130±0.030 OUR AVERAGE					
0.095±0.03 ±0.035	BESSON	85	CLEO	e ⁺ e [−] → hadrons	
0.156 ± 0.040	LOVELOCK	85	CUSB	e ⁺ e ⁻ → hadrons	

au(11020) REFERENCES

BESSON	85	PRL 54 381	+Green, Namjoshi, Sannes+
LOVELOCK	85	PRL 54 377	+Horstkotte, Klopfenstein+

NON-qq CANDIDATES

We include here mini-reviews and reference lists on gluonium and other non- $q\overline{q}$ candidates. See also $N\overline{N}(1100\text{--}3600)$ for possible bound states.

$NON-q\overline{q}$ MESONS

Written March 1998 by R. Landua (CERN).

The constituent quark model describes the observed meson spectrum as bound $q\overline{q}$ states grouped into SU(3) flavour nonets. The existence of gluon self-coupling in QCD suggests that additional bound states of gluons (glueballs gg,ggg) or hybrids $(q\overline{q}g)$ might exist. Another possible kind of non- $q\overline{q}$ mesons is multiquark states $(qq\overline{q}q, \text{ or } q\overline{q}-q\overline{q})$.

A glueball has no place in a $q\bar{q}$ nonet, it is a flavour-singlet, produced mainly in gluon-rich channels (radiative $J/\psi(1S)$ decays, antiproton-proton annihilation), and has a small gammagamma coupling. However, mixing with $q\bar{q}$ mesons of the same quantum numbers will modify the expected glueball signatures, such as flavour-blind decay modes. If the mixing is large, only the finding of more states than predicted by the quark model remains a clear signal for a non- $q\bar{q}$ state. Theoretical calculations based on lattice gauge theory and QCD sum rules agree that the lightest glueball should be a scalar resonance ($J^{PC}=0^{++}$) with a mass of 1600 \pm 150 MeV (BALI 93, SEXTON 95), followed by a tensor (2^{++}) and a pseudoscalar (0^{-+}) glueball in the 2000–2500 MeV mass region (SZCZEPANIAK 96).

Hybrid mesons are $q\overline{q}$ states combined with a gluonic excitation, allowing exotic (non- $q\overline{q}$) quantum numbers such as $J^{PC}=1^{-+}$). Hybrids span flavour nonets. In flux tube models, they are predicted to have characteristic decay modes into a pair of $S^-(l=0)$ and $P^-(l=1)$ wave mesons (ISGUR 85, CLOSE 95). The lightest hybrid nonets are expected in the 1500-2000 MeV mass range in the flux tube model and the ground state around 2000 MeV in lattice gauge theories (LACOCK 97). Charm hybrids $(c\overline{c}g)$ are expected in the 4000-4400 MeV mass range and are attractive experimentally since they may appear as supernumerary states in the predictable charmonium spectrum.

Multiquark states might exist as a colour-singlet configuration of four or more quarks. A four-quark state can be either baglike $(qq\overline{qq})$ or like a meson-meson bound state $(q\overline{q}-q\overline{q})$. Several well-established non- $q\overline{q}$ candidates have masses close to meson-meson thresholds. Examples include the $f_0(980)$ (close to the $K\overline{K}$ threshold), the $f_1(1420)$ $(K\overline{K}^*)$, the $f_2(1565)$ and $f_0(1500)(\omega\omega$ and $\rho\rho$), the $f_J(1710)$ $(K^*\overline{K}^*)$, and the $\psi(4040)$ $(D^*\overline{D}^*)$.

The following discussion is restricted to well-established resonances which are difficult to interpret as conventional $q\overline{q}$ states. We do not see it as our task to discuss theoretical interpretations of the candidates, but merely to summarize the observations of possible relevance. See also the corresponding Note in the 1996 issue of *Review of Particle Physics*.

Resonances with exotic quantum numbers

The first direct evidence for a non- $q\overline{q}$ state is the exotic $J^{PC}=1^{-+}$ isovector resonance $\hat{\rho}(1405)$. It has been clearly observed in $\overline{p}d$ annihilation at rest (ABELE 98B), corroborating earlier evidence from πp scattering experiments (ALDE 88B, THOMPSON 97). The $\hat{\rho}(1405)$ is observed as a resonant $(\eta\pi^-)$ P-wave with a width of 200–300 MeV. There is weaker evidence for a $J^{PC}=1^{-+}$ state around 1900 MeV (LEE 94).

The mass of the $\hat{\rho}(1405)$ is lower than expected by the flux tube model and lattice gauge theories for a hybrid meson, and its decay into two S-wave mesons does not correspond to the expected hybrid decay pattern. A 1⁻⁺ hybrid around 1400 MeV is, however, predicted by the bag model (BARNES 83). Whatever the correct interpretation will be (hybrid or four-quark state), it is expected to be part of a multiplet in the same mass region, and its identification will be an important goal for future experiments.

A resonance-like structure has been observed in $\gamma\gamma$ collisions near the $\rho\rho$ threshold, decaying into $\rho^0\rho^0$ and $\rho^+\rho^-$, and with a dominating 2^{++} partial wave. The small relative branching ratio $\rho^+\rho^-/\rho^0\rho^0$ (1:4) (ALBRECHT 91F) requires both I=0 and I=2 for the $\rho\rho$ system, which might be due to the presence of a $qq\overline{qq}$ resonance with I=2 (ACHASOV 90).

Scalar glueball

Four isoscalar resonances with $J^{PC}=0^{++}$ are considered as well-established: the σ or $f_0(400-1200)$, a very broad structure with a width of 600–1000 MeV, the $f_0(980)$, the $f_0(1370)$, and the $f_0(1500)$. Another isoscalar, the $f_J(1710)$, may have spin J=0 or 2.

In the quark model, one expects two scalar nonets (1 ${}^{3}P_{0}$) and 2 ${}^{3}P_{0}$) below 2000 MeV. However, the spectrum of scalar $q\bar{q}$ resonances may be strongly distorted by the opening of inelastic thresholds (TORNQVIST 96). For a detailed discussion, see the Note on scalar mesons under the $f_{0}(1370)$.

Several models interpret the $f_0(1500)$ as a supernumerary scalar state due to a glueball mixed with $q\bar{q}$ states in the same mass region (see for example AMSLER 96). This is based on the observation that both the $f_0(1370)$ and the $f_0(1500)$ have similar decay properties (mainly to light quarks), while the quark model expects the heavier resonance to couple strongly to strange quarks. The $f_0(1500)$ has been observed in 4π (ABELE 96), 2π (AMSLER 95B, BERTIN 98), $\eta\eta$ (AMSLER 95C), $\eta\eta'(958)$ (AMSLER 94E), and—weakly—in $K\overline{K}$ decays (ABELE 96B). The $f_0(1500)$ is observed in gluon-rich reactions, such as central production (ALDE 88, BARBERIS 97B), and in radiative $J/\psi(1S)$ decay, while it is not seen in gamma-gamma fusion (ACCIARRI 95J).

The key issue is the identification of the 3P_0 $(s\overline{s})$ -like state in the 1600–2000 MeV mass region. This might be the $f_J(1710)$, if spin 0 is confirmed. In radiative $J/\psi(1S)$ decays, both spin 0 and spin 2 components are found in the $f_J(1710)$ mass region, while the resonance observed in central production has spin 2.

Meson Particle Listings

Non- $q\overline{q}$ Candidates

An $f_0(1710)$ has also been suggested for the ground state scalar glueball (SEXTON 95). See the Note on $f_J(1710)$.

Tensor glueball

The twol 3P_2 $q\bar{q}$ states are very likely the $f_2(1270)$ and $f_2'(1525)$. In the 1800–2400 MeV mass range, one expects three more tensor nonets: the 2 3P_2 and 3 3P_2 radial excitations, and the 1 3F_4 nonet, i.e. six isoscalar 2^{++} resonances. They are all expected to have widths above 100 MeV. There is indeed evidence for several broad resonances in the 1800–2400 MeV region, but the experimental information is too sparse to make a meaningful assignment to $q\bar{q}$ nonets. There is at present no compelling reason to assume that any of these states is a non- $q\bar{q}$ state.

Two states below 2000 MeV, the $f_2(1565)$ and the $f_J(1710)$, are hard to accommodate in the quark model, because their masses are too close to the 1 3P_2 ground state to be members of the 2 3P_2 nonet. The $f_2(1565)$ has only been observed in $p\bar{p}$ annihilation, decaying to $\pi\pi$ (MAY 90, BERTIN 98). The proximity of the $\rho\rho$ and $\omega\omega$ thresholds suggest a possible interpretation as a meson-meson bound state. The $f_J(1710)$ has a well-established 2^{++} component. It is prominently observed in radiative $J/\psi(1S)$ decays, and in central production. It is observed to decay into $K\bar{K}$ (BAI 96C, LONGACRE 86), and its proximity to the $K^*\bar{K}^*$ threshold suggests again a meson-meson bound state.

The narrow $f_2(2220)$ still needs confirmation. There are also still doubts whether it has spin 2 or spin 4. The experimental evidence from $J/\psi(1S)$ radiative decays, πp and Kp scattering is inconclusive. It has not been observed in $p\overline{p}$ annihilation (BARNES 93). If it exists, it couples mainly to strange quark final states, and if spin 2 is confirmed, its prominence in radiative $J/\psi(1S)$ decays and its small width would make it a good glueball candidate.

Pseudoscalar mesons

Four pseudoscalar I = 0 resonances are well established below 1500 MeV: η , $\eta'(958)$, $\eta(1295)$, and $\eta(1440)$. It would be natural to identify the latter two with the $u\overline{u} + d\overline{d}$ and $s\overline{s}$ first radial excitations and $s\bar{s}$ of the 1S_0 ground states. Since the $\pi(1300)$ and the $\eta(1295)$ have nearly the same masses, the $\eta(1295)$ can be assigned to the $(u\overline{u} + d\overline{d})$ 2 ${}^{1}S_{0}$ state. The crucial issue is the identification of the $(s\overline{s})$ 2 ${}^{1}S_{0}$ state. An assignment to the $\eta(1440)$ is not evident. The $\eta(1440)$ is prominently produced in radiative $J/\psi(1S)$ decays and hence expected to have some glueball admixture, and it is mainly produced in $s\bar{s}$ depleted reactions, such as πp scattering, $p\bar{p}$ annihilation, or radiative $J/\psi(1S)$ decays. There is—albeit weak—evidence that the $\eta(1440)$ is made of two resonances with only about 50-100 MeV difference in mass, and with similar widths, the lower mass state decaying to $a_0(980)\pi$ and $\eta\pi\pi$, the higher mass state to $K^*\overline{K}$. It is therefore conceivable that the higher mass state is the $s\bar{s}$ member of the 2 1S_0 nonet (see the Note on $\eta(1440)$).

The $\pi(1800)$ is surprisingly narrow (if interpreted as the second radial excitation of the π). It decays frequently via a pair of S- and P-wave mesons (AMELIN 95B, 96B), which is a signature expected for a hybrid meson.

Axial-vector mesons

The $f_1(1285)$ and $f_1(1420)$ are the two well-established axial-vector resonances. The $f_1(1510)$ still needs confirmation (see the Note on the $f_1(1510)$ under the $\eta(1440)$). The $f_1(1285)$ has the expected properties of the isoscalar $u\bar{u} + d\bar{d}$ member of a ground state 3P_1 nonet. The $f_1(1420)$ has a dominant $K\bar{K}^*$ coupling, as expected for the corresponding $s\bar{s}$ member. In πp scattering, $p\bar{p}$ annihilation at rest from P waves (BERTIN 97) and radiative $J/\psi(1S)$ decays, the $f_1(1420)$ is produced together with the $\eta(1440)$, which gave rise to the former E/ι puzzle. In central production, only the $f_1(1420)$ state is produced (BARBERIS 97C).

Presently, there is no strong evidence for an exotic axial-vector state. However, if the $f_1(1510)$ state is corroborated, the proximity of the $f_1(1420)$ mass to the KK^* threshold suggests a $K\overline{K}^*$ meson-bound state or a threshold enhancement.

Non- $q\overline{q}$ Candidates

OMITTED FROM SUMMARY TABLE

NON-qq CANDIDATES REFERENCES

ABELE	98B	PL B423 175	A. Abele, Adomeit, Amsler+	(Crystal Barrel Collab.)
BERTIN	98	PR D57 55	A. Bertin, Bruschi, Capponi+	(OBELIX Collab.)
ACHASOV	97C	PR D56 4084	N.N. Achasov+	
ACHASOV	97D	PR D56 203	N.N. Achasov+	·
ANISOVICH	97B	ZPHY A357 123	A.V. Anisovich+	(PNPI)
ANISOVICH	97C	PL B413 137		(may m.)
ANISOVICH	97E	PAN 60 1892	A.V. Anisovich+	(PNPI)
BARBERIS	97	Translated from YAF		(MAIA 100 Callah)
	97B	PL B397 339	D. Barberis+	(WA102 Collab.)
BARBERIS		PL B413 217	D. Barberis+	(WA102 Collab.)
BARBERIS BERTIN	97C 97	PL B413 225	D. Barberis+	(WA102 Collab.)
	97	PL B400 226	+Bruschi, Capponi+	(OBELIX Collab.)
BOGLIONE		PRL 79 1998	M. Boglione+	
BUGG	97	PL B396 295	D.V. Bugg+	(DAL DIDLA)
CLOSE	97	PL B397 333	F. Close+	(RAL, BIRM)
CLOSE	97B	PR D55 5749	F. Close+	(RAL, RUTG, BEIJT)
GERASYUTA	97	ZPHY C74 325	5.M. Gerasyuta+	
HOU	97	PR D55 6952	Wei-Shu Hou	
KISSLINGER	97	PL B410 1	L.S. Kisslinger+	
LACOCK	97	PL B401 308	P. Lacock+	(EDIN, LIVP)
PAGE	97	PL B402 183	P.R. Page	
PAGE	97B	NPB 495 268	P.R. Page	
PAGE	97C	PL B415 205	P.R. Page	(CEBAF)
THOMPSON	97	PRL 79 1630	+Adams+	(E852 Collab.)
YAN	97	JP G23 L33	Y. Yan+	
ABELE	96	PL B380 453	+Adomeit, Amsler+	(Crystal Barrel Collab.)
AMELIN	96B	PAN 59 976	+Berdnikov, Bityukov+	(SERP, TBIL)
		Translated from YAF		
AMSLER	96	PR D53 295	+Close	(ZURI, RAL)
BAI	96C	PRL 77 3959	J.Z. Bai+	(BES Collab.)
BAJC	96	ZPHY A356 187	B. Bajc+	
CLOSE	96	PL B366 323	+Page	(RAL)
SZCZEPANIAK		PRL 76 2011	A. Szczepaniak+	(NCARO)
TORNQVIST	96	PRL 76 1575	+Roos	(HELS)
AMELIN	95B	PL B356 595	+Berdnikov, Bityukov+	(SERP, TBIL)
AMSLER	95B	PL B342 433	+Armstrong, Brose+	(Crystal Barrel Collab.)
AMSLER	95C	PL B353 571	+Armstrong, Hackman+	(Crystal Barrel Collab.)
AMSLER	95D	PL B355 425	+Armstrong, Spanier+	(Crystal Barrel Collab.)
AMSLER	95E	PL B353 385	+Close	(ZURI, RAL)
AMSLER	95F	PL B358 389	+Armstrong, Urner+	(Crystal Barrel Collab.)
BERTIN	95	PL B361 187	+Bruschi+	(OBELIX Collab.)
BUGG	95	PL B353 378	+\$cott, Zoli+	(LOQM, PNPI, WASH)
CLOSE	95	NP B443 233	+Page	(RAL)
PROKOSHKIN	95B	PAN 58 606	+Sadovski	(SERP)
		Translated from YAF		(
PROKOSHKIN	95C	PAN 58 853	+\$adovski	(SERP)
CENTON		Translated from YAF		(IDAA)
SEXTON	95	PRL 75 4563	+Vaccarino, Weingarten+	(IBM)
ALBRECHT	94Z	PL B332 451	+Ehrlichmann+	(ARGUS Collab.)
AMSLER	94D	PL B333 277	+Anisovich, Spanier+	(Crystal Barrel Collab.)
ANISOVICH	94	PL B323 233	+Armstrong+	(Crystal Barrel Collab.)
BERDNIKOV	94	PL B337 219	+Bityukov+	(SERP, TBIL)

LEE	94	PL 8323 227	+Chung, Kirk+ (BNL, IND, KYUN, MASD, RICE)
TORNQVIST	94	ZPHY C61 525	Tornquist (HELS)
ALEEV	93	PAN 56 1358	+Balandin+ (BIS-2 Coliab.)
		Translated from YAF 5	56 100.
AOYAGI	93	PL B314 246	+Fukui, Hasegawa+ (BKEI Collab.)
BALI	93	PL B309 378	+Schilling, Hulsebo, Irving, Michael+ (LIVP)
BARNES	93	PL B309 469	+Birien, Breunlich (PS185 Collab.)
DONNACHIE	93 93	ZP C60 187 PL B309 426	+Kalashnikova, Clegg (BNL) +Karl (CERN)
ERICSON MANOHAR	93	NP B399 17	
AMSLER	93 92	PL B291 347	
BARNES	92	PR D46 131	+Augustin, Baker+ (Crystal Barrel Collab.) +Swanson (ORNL)
DOOLEY	92	PL B275 478	+Swanson, Barnes (ORNL)
ALBRECHT	91F	ZPHY C50 1	+Appuan, Paulini, Funk+ (ARGUS Collab.)
DOVER	91	PR C43 379	+Gutsche, Faessier (BNL)
FUKUI	91	PL B257 241	+Horikawa+ (SUGI, NAGO, KEK, KYOT, MIYA)
TORNOVIST	91	PRL 67 556	(HELS)
ACHASOV	90	TF 20 (178)	+Shestakov (NOVM)
BREAKSTONE		ZPHY C48 569	+ (ISU, BGNA, CERN, DORT, HEIDH, WARS)
BURNETT	90	ARNPS 46 332	+Sharpe (RAL)
LONGACRE	90	PR D42 874	(BNL)
MAY	90	ZPHY C46 203	+Duch, Heel+ (ASTERIX Collab.)
WEINSTEIN	90	PR D41 2236	+lsgur (TNTO)
ALDE	89	PL B216 447	+Binon, Bricman, Donskov+ (SERP, BELG, LANL, LAPP)
ARMSTRONG	89B	PL B221 221	+Benayoun+(CERN, CDEF, BIRM, BARI, ATHU, CURIN+)
ARMSTRONG	89D	PL B227 186	+Benayoun (ATHU, BARI, BIRM, CERN, CDEF)
MAY	89	PL B225 450	+Duch, Heel+ (ASTERIX Collab.)
ACHASOV	88	PL B207 199	+Kozhevnikov (NOVM)
AIHARA	88	PR D37 28	+Alston, Avery, Barbaro-Galtieri+ (TPC-2\gamma Collab.)
ALDE	88	PL B201 160	+Bellazzini, Binon+ (SERP, BELG, LANL, LAPP, PISA)
ALDE	88B	PL B205 397	+Binon, Boutemeur+ (SERP, BELG, LANL, LAPP)
ASTON	88D	NP B301 525	+Awaji, Bienz+ (SLAC, NAGO, CINC, INUS)
BERGER	88B	ZPHY C38 521	+Klovning, Burger+ (PLUTO Collab.)
BIRMAN	88	PRL 61 1557	+Chung, Peaslee+ (BNL, FSU, IND, MASD)
CLEGG	88	ZPHY C40 313	+Donnachie (MCHS, LANC)
ETKIN	88	PL B201 568	+Foley, Lindenbaum+ (BNL, CUNY)
IDDIR	88	PL B205 564	+Le Yaouanc, Ono+ (ORSAY, TOKY)
ACHASOV	87	ZPHY C36 161	+Karnakov, Shestakov (NOVM)
ASTON	87	NP B292 693	+Awaji, D'Amore+ (SLAC, NAGO, CINC, INUS)
BITYUKOV	87	PL B188 383	+Dzhelyadin, Dorofeev, Golovkin+ (SERP)
CLOSE	87	RPP 51 833	(RHEL)
ANDO	86	PRL 57 1296	+Imai+ (KEK, KYOT, NIRS, SAGA, INUS, TSUK+)
BOURQUIN	86	PL B172 113	+Brown+ (GEVA, RAL, HEIDP, LAUS, BRIS, CERN)
LONGACRE	86	PL B177 223	+Etkin+ (BNL, BRAN, CUNY, DUKE, NDAM)
CHUNG	85	PRL 55 779	+Fernow, Boehnlein+ (BNL, FLOR, IND, MASD)
ISGUR	85	PRL 54 869	+Kokorski, Patou (TNTO)
LEYAQUANC	85	ZPHY C28 309	+Olivek, Pene, Raynal, Ono (ORSAY)
BEHREND	84E	ZPHY C21 205	+Achenberg, Deboer+ (CELLO Collab.)
BARNES	83	NP B224 241	T. Barnes+ (RAL, LOUV)
BINON	83	NC 78A 313	+Donskov, Duteil+ (BELG, LAPP, SERP, CERN)
WEINSTEIN	83B	PR D27 588	+lsgur (TNTO)
AIHARA	82	PR D37 28	+Aiston, Avery, Barbaro-Galtieri+ (TPC Collab.)
ALTHOFF	82	ZPHY C16 13	+Boerner, Burkhardt+ (TASSO Collab.)
BARNES	82	PL B116 365	+Close (RHEL)
BURKE	81	PL B103 153	+Abrams, Alam, BLocher+ (Mark II Collab.)
BRANDELIK	80B	PL B97 448	+Boerner, Burkhard+ (TASSO Collab.)
GUTBROD	79	ZP C1 391	+Kramer, Rumpf (DESY)
JAFFE	77	PR D15 267,281	(MIT)
VOLOSHIN	76	JETPL 23 333	+Okun (ITEP)
		Translated from ZETF	
BAILLON	67	NC 50A 393	+Edwards, D'Andlau, Astier+ (CERN, CDEF, IRAD)

$N ext{ BARYONS } (S=0,I=1/2)$	
p	613
$\stackrel{\cdot}{n}$	619
N resonances	628
Δ BARYONS ($S=0,I=3/2$)	653
Δ resonances	000
$\Lambda \text{ BARYONS } (S = -1, I = 0)$	670
Λ	672
Λ resonances	675
Σ BARYONS ($S = -1, I = 1$)	
Σ^+	690
Σ^0	692
Σ^-	693
Σ resonances	695
2 resonances	030
Ξ BARYONS ($S=-2, I=1/2$)	
$arepsilon^0$	714
<i>8</i>	715
	718
□ resonances	110
Ω BARYONS ($S = -3$, $I = 0$)	
$arOmega^-$	725
Ω resonances	
as reconditions	
CHARMED BARYONS $(C = +1)$	
A_c^+	727
$A_c(2593)^+$	732
$A_c(2625)^+$	732
= (a + = 1)	733
	734
$\Sigma_c(2520)$	
$oldsymbol{arphi}_{\mathbf{c}}^{+}$	734
$\mathbf{E}_{\mathbf{c}}^{\mathbf{v}}$	735
$\Xi_{c}(2645)$	736
$arOmega_c^0$	737
BOTTOM (BEAUTY) BARYON ($B = -1$)	
	738
A_b^0	
$oldsymbol{arXi}_b^0,oldsymbol{arXi}_b^-$	739
b -baryon admixture $(\Lambda_b, \Xi_b, \Sigma_b, \Omega_b)$	739
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N and Δ Resonances (rev.)	623
Baryon Magnetic Moments	672
Λ and Σ Resonances	675
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The $\Sigma(1670)$ Region	700
E Resonances	718
Charmed Baryons	727
The Λ_c^+ Branching Fractions (new)	728

N BARYONS (S=0, I=1/2)

 $p, N^+ = uud; \quad n, N^0 = udd$

p

 $I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$ Status: ***

p MASS

The mass is known much more precisely in u (atomic mass units) than in MeV; see the footnote. The conversion from u to MeV, 1 $u=931.49432\pm0.00028$ MeV, involves the relatively poorly known electronic charge.

DOCUMENT ID		TECN_	COMMENT
1 COHEN	87	RVUE	1986 CODATA value
lowing data for averages	, fit	s, Ilmits,	etc. • • •
COHEN	73	RVUE	1973 CODATA value
	1 COHEN lowing data for averages	1 COHEN 87 lowing data for averages, fits	¹ COHEN 87 RVUE lowing data for averages, fits, limits,

7 MASS

See, however, the next entry in the Listings, which establishes the $\overline{\it p}$ mass much more precisely.

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
• • • We do not use the follow	ving data for averages, i	fits, limi	ts, etc. • • •
938.30 ±0.13	ROBERTS 7	8 CNT	R
938.229±0.049	ROBERSON 7	7 CNT	R
938.179±0.058	HU 7	5 CNT	R Exotic atoms
938.3 ±0.5	BAMBERGER 7	0 CNT	'R

\overline{p}/p CHARGE-TO-MASS RATIO, $|\frac{q_{\overline{p}}}{m_{\overline{p}}}|/(\frac{q_{\overline{p}}}{m_{\overline{p}}})$

A test of CPT invariance. Listed here are measurements involving the inertial masses. For a discussion of what may be inferred about the ratio of \overline{p} and p gravitational masses, see ERICSON 90; they obtain an upper bound of 10^{-6} - 10^{-7} for violation of the equivalence principle for \overline{p} 's.

DOCUMENT ID TECN COMMENT

$1.0000000015 \pm 0.0000000011$	² GABRIELSE	95 TRAP Penning	trap
• • We do not use the following	ig data for averages	, fits, limits, etc. • •	•
1.000000023 ±0.000000042	³ GABRIELSE	90 TRAP Penning	trap
² Equation (2) of GABRIELS (G. Gabrielse, private commun ³ GABRIELSE 90 also measur = 1836.152680 ± 0.000088.	SE 95 should read nication). es $m=/m = 18$	$M(\overline{p})/M(p) \approx 0.9$	99 999 99 <u>8</u> 5 (11)
= 1836.152680 \pm 0.000088. (COHEN 87) value for m_D/r	Both are complete m_ of 1836.15270	ly consistent with the 1 ± 0.000037. We u	1986 CODATA
values of the masses (they com			

$(\left|\frac{q_p}{m_p}\right| - \frac{q_p}{m_p})/\left|\frac{q}{m}\right|_{\text{average}}$

A test of CPT Invariance. Taken from the \overline{p}/p charge-to-mass ratio, above.

VALUE <u>DOCUMENT ID</u>
(1.5±1.1) × 10⁻⁹ OUR EVALUATION

masses.

$|q_p + q_{\overline{p}}|/e$

A test of *CPT* invariance. Note that the \overline{p}/p charge-to-mass ratio, given above, is much better determined. See also a similar test involving the electron.

VALUE	DOCUMENT	- ID	TECN		
<2 × 10 ⁻⁵	⁴ HUGHES	92	RVUE		
⁴ HUGHES 92 u tios.	ises recent measurements of f	Rydberg-e	energy and	cyclotron-frequency	ra-

$|q_p + q_e|/\epsilon$

See DYLLA 73 for a summary of experiments on the neutrality of matter. See also "n CHARGE" in the neutron Listings.

VALUE	DOCUMENT ID		COMMENT	
<1.0 × 10 ⁻²¹	5 DYLLA	73	Neutrality of SF6	
• • • We do not use the	following data for average	es, fit	s, limits, etc. • • •	
<0.8 × 10 ⁻²¹	MARINELLI	84	Magnetic levitation	
$\frac{5}{4}$ Assumes that $a_{-} = a_{-}$	+a			

p MAGNETIC MOMENT

See the "Note on Baryon Magnetic Moments" in the Λ Listings.

VALUE (µN)	DOCUMENT ID)	TECN	COMMENT
2.792847386±0.000000063	COHEN	87	RVUE	1986 CODATA value
• • • We do not use the following	data for averag	ges, fits	, limits,	etc. • • •
2.7928456 ±0.0000011	COHEN	73	RVUE	1973 CODATA value

T MAGNETIC MOMENT

A few early results have been omitted.

VALUE (µN)	DOCUMENT ID		TECN	COMMENT
-2.800 ±0.006 OUR AVERAGE				
-2.8005 ± 0.0090	KREISSL	88	CNTR	\overline{p} ²⁰⁸ Pb 11 \rightarrow 10 X-ray
-2.817 ±0.048	ROBERTS	78	CNTR	
-2.791 ± 0.021	HU	75	CNTR	Exotic atoms

$(\mu_p + \mu_{\overline{p}}) / |\mu|_{average}$

A test of *CPT* invariance. Calculated from the p and \overline{p} magnetic moments, above.

VALUE DOCUMENT ID

(-2.6±2.9) × 10⁻³ OUR EVALUATION

p ELECTRIC DIPOLE MOMENT

A nonzero value is forbidden by both T invariance and P invariance.

/ALUE (10 ⁻²³ ecm)	EVTS DOCUMENT ID		TECN	COMMENT
- 3.7± 6.3	СНО	89	NMR	TI F molecules
• • We do not use	the following data for average	es, fit:	s, limits,	etc. • • •
< 400	DZUBA	85	THEO	Uses 129Xe moment
130 ± 200	⁶ WILKENING	84		
900 ±1400	⁷ WILKENING	84		
700 ± 900	1G HARRISON	69	MBR	Molecular beam
6				

 $^{^6}$ This WILKENING 84 value includes a finite-size effect and a magnetic effect.

p ELECTRIC POLARIZABILITY ₹p

VALUE (10-4 fm ³)	DOCUMENT ID		TECN	COMMENT
12.1 ±0.8 ±0.5	8 MACGIBBON	95	RVUE	global average
• • • We do not use the fol	lowing data for averages	, fit	s, limits,	etc. • • •
12.5 ±0.6 ±0.9	MACGIBBON	95	CNTR	γp Compton scattering
$9.8 \pm 0.4 \pm 1.1$	HALLIN	93	CNTR	γp Compton scattering
$10.62 + 1.25 + 1.07 \\ -1.19 - 1.03$	ZIEGER	92	CNTR	γp Compton scattering
10.9 ±2.2 ±1.3	⁹ FEDERSPIEL	91	CNTR	γp Compton scattering

⁸ MACGIBBON 95 combine the results of ZIEGER 92, FEDERSPIEL 91, and their own experiment to get a "global average" in which model errors and systematic errors are treated in a consistent way. See MACGIBBON 95 for a discussion.

P MAGNETIC POLARIZABILITY B.

The electric and magnetic polarizabilities are subject to a dispersion sumrule constraint $\overline{\alpha}+\overline{\beta}=(14.2\pm0.5)\times10^{-4}~{\rm fm}^3$. Errors here are anticorrelated with those on $\overline{\alpha}_p$ due to this constraint.

VALUE (10 ⁻⁴ fm ³)	DOCUMENT ID		TECN	COMMENT
2.1 ±0.8 ±0.5	10 MACGIBBON	95	RVUE	global average
• • • We do not use the f	following data for averages	, fits	s, limits,	etc. • • •
1.7 ±0.6 ±0.9	MACGIBBON	95	CNTR	γp Compton scattering
4.4 ±0.4 ±1.1	HALLIN	93	CNTR	γp Compton scattering
$3.58^{+1.19}_{-1.25}^{+1.03}_{-1.07}$	ZIEGER	92	CNTR	γp Compton scattering
3.3 ±2.2 ±1.3	FEDERSPIEL	91	CNTR	γp Compton scattering

¹⁰ MACGIBBON 95 combine the results of ZIEGER 92, FEDERSPIEL 91, and their own experiment to get a "global average" in which model errors and systematic errors are treated in a consistent way. See MACGIBBON 95 for a discussion.

⁷ This WILKENING 84 value is more cautious than the other and excludes the finite-size effect, which relies on uncertain nuclear integrals.

FEDERSPIEL 91 obtains for the (static) electric polarizability α_p , defined in terms of the induced electric dipole moment by $\mathbf{D}=4\pi\epsilon_0\alpha_p\mathbf{E}$, the value $(7.0\pm2.2\pm1.3)\times10^{-4}\,\mathrm{fm}^3$.

MEAN LII م	۲E
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A test of baryon conservation. See the "p Partial Mean Lives" section below for limits that depend on decay modes. p = proton, n = bound neutron.

.IMIT years)	PARTICLE	DOCUMENT I	<u>TECN</u>
>1.6 × 10 ²⁵	p, n	11,12 EVANS	77
	use the follow	ng data for averages,	fits, limits, etc. • • •
>3 × 10 ²³	P	12 DIX	70 CNTR
>3 × 10 ²³	р, п	12,13 FLEROV	58
11 Mean lifetime 12 Converted to 13 Mean lifetime	mean life by div	iding half-life by In(2	2) = 0.693.

MEAN LIFE

The best limit by far, that of GOLDEN 79, relies, however, on a number of astrophysical assumptions. The other limits come from direct observations of stored antiprotons. See also " \bar{p} Partial Mean Lives" after "p Partial Mean Lives," below.

LIMIT (years)	CL%	EVTS	DOCUMENT ID		TECN	COMMENT	_
• • • We do not a	se the fo	llowing o	lata for averages,	fits, I	imits, et	C. • • •	
>0.28			GABRIELSE	90	TRAP	Penning trap	
>0.08	90	1	BELL	79	CNTR	Storage ring	
>1 × 10 ⁷			GOLDEN	79	SPEC	\overline{p}/p , cosmic rays	
$>3.7 \times 10^{-3}$			BREGMAN	78	CNTR	Storage ring	

P DECAY MODES

Below, for N decays, p and n distinguish proton and neutron partial lifetimes. See also the "Note on Nucleon Decay" in our 1994 edition (Phys. Rev. DSO, 1673) for a short review.

The "partial mean life" limits tabulated here are the limits on τ/B_I , where τ is the total mean life and B_I is the branching fraction for the mode in question.

Partial mean life

	Mode	(10 ³⁰ years)	Confidence level
		Antilepton + meson	
$ au_1$	$N \rightarrow e^+ \pi$	> 130 (n), > 550 (p)	90%
τ_2	$N \rightarrow \mu^+ \pi$	> 100 (n), > 270 (p)	90%
$ au_3$	$N \rightarrow \nu \pi$	> 100 (n), > 25 (p)	90%
τ_4	$p \rightarrow e^+ \eta$	> 140	90%
$ au_5$	$p \rightarrow \mu^+ \eta$	> 69	90%
	$n \rightarrow \nu \eta$	> 54	90%
$ au_7$	$N \rightarrow e^+ \rho$	> 58 (n), > 75 (p)	90%
$ au_8$	$N \rightarrow \mu^+ \rho$	> 23 (n), > 110 (p)	90%
79	$N \rightarrow \nu \rho$	> 19 (n), > 27 (p)	90%
$ au_{10}$	$p \rightarrow e^+ \omega$	> 45	90%
$ au_{11}$	$p \rightarrow \mu^+ \omega$	> 57	90%
$ au_{12}$	$\Pi \rightarrow \nu \omega$	> 43	90%
τ_{13}	$N \rightarrow e^+ K$	> 1.3 (n), > 150 (p)	90%
τ_{14}	$p \rightarrow e^+ K_S^0$	> 76	90%
$ au_{15}$	$p \rightarrow e^+ K_L^{\delta}$	> 44	90%
τ ₁₆	$N \rightarrow \mu^+ K$	> 1.1 (n), > 120 (p)	90%
$ au_{17}$	$p \rightarrow \mu^+ K_S^0$	> 64	90%
τ_{18}	$p \rightarrow \mu^+ K_L^{\bullet}$	> 44	90%
<i>T</i> 19	$N \rightarrow \nu K$	> 86 (n), > 100 (p)	90%
τ_{20}	$p \to e^+ K^*(892)^0$	> 52	90%
$ au_{21}$	$N \rightarrow \nu K^*(892)$	> 22 (n), > 20 (p)	90%
		Antilepton + mesons	
$ au_{22}$	$p \rightarrow e^{+}\pi^{+}\pi^{-}$	> 21	90%
τ_{23}	$p \rightarrow e^+ \pi^0 \pi^0$	> 38	90%
T24	$n \rightarrow e^{+}\pi^{-}\pi^{0}$	> 32	90%
τ_{25}	$p \rightarrow \mu^+ \pi^+ \pi^-$	> 17	90%
⁷ 26	$ ho \rightarrow \mu^+ \pi^0 \pi^0$	> 33	90%
τ_{27}	$n \rightarrow \mu^+ \pi^- \pi^0$	> 33	90%
$ au_{28}$	$n \rightarrow e^+ K^0 \pi^-$	> 18	90%
		Lepton + meson	
$ au_{29}$	$n \rightarrow e^- \pi^+$	> 65	90%
τ_{30}	$n \rightarrow \mu^- \pi^+$	> 49	90%
τ_{31}	$n \rightarrow e^- \rho^+$	> 62	90%
$ au_{32}$	$n \rightarrow \mu^- \rho^+$	> 7	90%
$ au_{33}$	$n \rightarrow e^- K^+$	> 32	90%
$ au_{34}$	$n \rightarrow \mu^- K^+$	> 57	90%

	Lepto	n + mesons	
$ au_{35}$	$p \rightarrow e^- \pi^+ \pi^+$	> 30	90%
τ ₃₆	$n \rightarrow e^- \pi^+ \pi^0$	> 29	90%
T37	$p \rightarrow \mu^- \pi^+ \pi^+$	> 17	90%
τ ₃₈	$n \rightarrow \mu^- \pi^+ \pi^0$	> 34	90%
T39	$p \rightarrow e^-\pi^+K^+$	> 20	90%
$ au_{40}$	$p \rightarrow \mu^- \pi^+ K^+$	> 5	90%
	Antilepto	on + photon(s)	
T41	$p \rightarrow e^+ \gamma$	> 460	90%
	$p \rightarrow \mu^+ \gamma$	> 380	90%
	$n \rightarrow \nu \gamma$	> 24	90%
	$p \rightarrow e^{+} \gamma \gamma$	> 100	90%
	Three (o	r more) leptons	
T45	$p \rightarrow e^+e^+e^-$	> 510	90%
746	$p \rightarrow e^+ \mu^+ \mu^-$	> 81	90%
T47	$p \rightarrow e^+ \nu \nu$	> 11	90%
T48	$n \rightarrow e^+e^-\nu$	> 74	90%
$ au_{49}$	$n \rightarrow \mu^+ e^- \nu$	> 47	90%
τ_{50}	$n \rightarrow \mu^+ \mu^- \nu$	> 42	90%
τ_{51}	$p \rightarrow \mu^+ e^+ e^-$	> 91	90%
τ_{52}	$p \rightarrow \mu^+ \mu^+ \mu^-$	> 190	90%
₹53	$p \rightarrow \mu^+ \nu \nu$	> 21	90%
τ_{54}	$p \rightarrow e^- \mu^+ \mu^+$	> 6	90%
$ au_{55}$	$n \rightarrow 3\nu$	> 0.0005	90%
$ au_{56}$	$n \rightarrow 5\nu$		
		isive modes	
$ au_{57}$	$N \rightarrow e^+$ anything	> 0.6 (n, p)	90%
$ au_{58}$	$N \rightarrow \mu^+$ anything	> 12 (n, p)	90%
759	$N \rightarrow \nu$ anything		
τ_{60}	$N \rightarrow e^+ \pi^0$ anything	> 0.6 (n, p)	90%
$ au_{61}$	$N \rightarrow 2$ bodies, ν -free		
	$\Delta B = 2$	dinucleon modes	

The following are lifetime limits per iron nucleus.

7 ₆₂	$pp \rightarrow \pi^+\pi^+$	> 0.7	90%
₹63	$pn \rightarrow \pi^+\pi^0$	> 2	90%
τ ₆₄	$nn \rightarrow \pi^+\pi^-$	> 0.7	90%
τ_{65}	$nn \rightarrow \pi^0 \pi^0$	> 3.4	90%
₹66	$pp \rightarrow e^+e^+$	> 5.8	90%
T67	$pp \rightarrow e^+\mu^+$	> 3.6	90%
₹68	$pp \rightarrow \mu^+ \mu^+$	> 1.7	90%
₹69	$pn \rightarrow e^+ \overline{\nu}$	> 2.8	90%
⁷ 70	$pn \rightarrow \mu^+ \overline{\nu}$	> 1.6	90%
⁷ 71	$nn \rightarrow \nu_e \overline{\nu}_e$	> 0.000012	90%
τ ₇₂	$nn \rightarrow \nu_{\mu} \overline{\nu}_{\mu}$	> 0.00006	90%

P DECAY MODES

	Mode	Partial mean life (years)	Confidence level
<i>T</i> 73	$\overline{p} \rightarrow e^- \gamma$	> 1848	95%
T74	$\overline{\rho} \rightarrow e^- \pi^0$	> 554	95%
775	$\overline{p} \rightarrow e^- \eta$	> 171	95%
<i>∓</i> 76	$\overline{p} \rightarrow e^- K_S^0$	> 29	95%
$ au_{77}$	$\overline{p} \rightarrow e^- K_L^0$	> 9	95%

p PARTIAL MEAN LIVES

The "partial mean life" limits tabulated here are the limits on au/B_{I} , where au is the total mean life for the proton and B, is the branching fraction for the mode in question.

Decaying particle: p = proton, n = bound neutron. The same event may appear under more than one partial decay mode. Background estimates may be accurate to a factor of two.

$\tau(N \rightarrow e^{-}$	[⊢] π)						7)	L
LIMIT (10 ³⁰ years)	PARTICLE	CL%	EVTS	BKGD EST		DOCUMENT ID	 TECN	
>550 >130	P n	90 90	-	0.7 <0.2	14	BECKER-SZ HIRATA	 IMB3 KAMI	

• We	do not use th	e follow	ing dat	a for averages,	fits, limits, etc. • • •			$\tau(p \rightarrow \mu^{-}$							
70	P	90	0	0.5	BERGER	91	FREJ	LIMIT (10 ³⁰ years)							
70	п	90	0	≤ 0.1	BERGER	91	FREJ			CL%		BKGD EST	DOCUMENT ID		_ 2
60	P	90	0	< 0.04	HIRATA	890	: KAMI	>69	P	90		<0.08	HIRATA	890	C F
10	p	90	0	0.6	SEIDEL	88	IMB	• • • We o	to not use th	e follow	ng dat	a for averages, f	its, limits, etc. • • •	•	
00	n	90	0	1.6	SEIDEL	88	IMB	>26	P	90	1	0.8	BERGER	91	F
1.3	n	90	0		BARTELT	87	SOUD	> 1.3	P	90	0	0.7	PHILLIPS	89	
1.3	P	90	0		BARTELT	87	SOUD	>34	P	90	1	1.5	SEIDEL	88	
50	P	90	0	0.3	HAINES	86	IMB	>46	P	90	7		HAINES	86	
31	n	90	8	9	HAINES	86	IMB	>26	P	90	1		ARISAKA	85	
4	p	90	0	<0.4	ARISAKA	85	KAMI	>17	p (free)	90	6		BLEWITT	85	
26	n	90	0	<0.7	ARISAKA	85	KAMI	>46	D ()	90	7		BLEWITT	85	
32	p (free)	90	0	0.2	BLEWITT	85	IMB	7.5	•	,,	•	•	OCC WITT	0.5	
50	p	90		0.2	BLEWITT	85	IMB	$\tau(n \rightarrow \nu)$	•)						
25	'n	90	4	4	PARK	85	IMB		",						
15	 р, п	90	ò	•	BATTISTONI	84	NUSX	(10 ³⁰ years)	PARTICLE	CL%	EVT5	BKGD EST	DOCUMENT ID		
0.5	p	90		0.3	15 BARTELT	83	SOUD	>54	n	90		0.9		904	
0.5	'n	90	1	0.3	15 BARTELT	83	SOUD						HIRATA	890	-
5.8	p	90	2	0.5	16 KRISHNA		KOLR	• • • We d	io not use th	e ronow	ng cat	a for averages, i	īts, limits, etc. • • •	•	
5.8	•	90	2		16 KRISHNA	82	KOLR	>29	n	90	0	0.9	BERGER	89	
0.1	n	90	-	*	17 GURR			>16	n	90	3	2.1	SEIDEL	88	
	п					01	CNTR	>25	п	90	7	6	HAINES	86	
This B	ECKER-SZEI	1DY 90	result li	ncludes data fr	om SEIDEL 88.			>30	n	90	0	0.4	KAJITA	86	
imit b	ased on zero	PVPNtc						>18	n	90	4	3	PARK	85	-
we hav	e calculated	90% CL	limit fi	om 1 confined	event.			> 0.6	n	90	2		22 CHERRY	81	
rve nav	e converted	nan-me	10 90%	CL mean life.				22 We have	e converted ?	nocelhi		s to 90% CL IIr			
l μ	+-1						_	- vvc nav	e converted 2	r pussibi	e eveni	2 10 30% CE HI	mit.		
,	. ",						72	$\tau(N \rightarrow e^{-})$	+ p)						
vears)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	LIMIT	r,						
)(C		90	0	<0.2			KAMI	(10 ³⁰ years)	PARTICLE	CL%	EVT5	BKGD EST	DOCUMENT ID		
	#				HIRATA			>75		90		2.7	HIRATA	890	
70 - 14/a	p	90 fall	0	0.5	SEIDEL	88	IMB	>76 >58	P N	90		1.9		890	
• vve	uo not use ti	e tollow	ing data	a tor averages,	fits, limits, etc. • • •								HIRATA		•
1	p	90	0	0.2	BERGER	91	FREJ		io not use th				its, limits, etc. • • •		
5	n	90	1	1.0	BERGER	91	FREJ	>29	p	90	0	2.2	BERGER	91	
0	p	90	0	< 0.07	HIRATA	890	KAMI	>41	п	90	0	1.4	BERGER	91	
3	'n	90	0	0.5	SEIDEL	88	IMB	>38	п	90	2	4.1	SEIDEL	88	
6	P	90		1	HAINES	86	IMB	> 1.2	p	90	0		BARTELT	87	
:3	n	90	8	7	HAINES	86	IMB	> 1.5	'n	90	0		BARTELT	87	
6	 p	90	ō	<0.7		85	KAMI	>17	P	90	7	7	HAINES	86	
0	-	90	ő	<0.4	ARISAKA			>14	'n	90	9	4	HAINES	86	
9	л р (free)	90		0.2	ARISAKA	85 85	KAMI	>12	p	90	ó	<1.2	ARISAKA	85	
90		90			BLEWITT		IMB	> 6	P D	90	2	<1.2	ARISAKA	85	
	P		1	0.4	BLEWITT	85	IMB	> 6.7		90	6	6			
88	n	90	1	4	PARK	85	IMB		p (free)	90			BLEWITT	85	
0	p, n	90	0		BATTISTONI	84	NUSX	>17	P		7		BLEWITT	85	
1.3	р, п	90	0		ALEKSEEV	81	BAKS	>12	<i>n</i>	90	4	2	PARK	85	
								> 0.6	п	90		0.3	23 BARTELT	83	
$l \rightarrow \nu$	π)						73	> 0.5	P	90		0.3	23 BARTELT	83	
years)								> 9.8	₽	90	1		24 KRISHNA	82	
	PARTICLE	CL%	<u>EVTS</u>	BKGD EST	DOCUMENT ID		TECN	> 0.8	p	90	2		²⁵ CHERRY	81	
5	P	90	32	32.8	HIRATA	890	KAMI	23 Limit b	ased on zero	events.					
Ю .	П	90	1	3	HIRATA	890	KAMI	24 We hav	e calculated (90% CI	limit fr	om 0 confined	events.		
We	do not use th	e follow	ing data	a for averages,	fits, limits, etc. • • •			²⁵ We hav	e converted 2	2 possibi	e event	s to 90% CL lin	nit.		
.3	n	90	1	1.2	BERGER	89	FREJ								
.0	 P	90	11		BERGER	89	FREJ	$\tau(N \rightarrow \mu)$	' ρ)						
6	n	90	73		HAINES	86	IMB	LIMIT							
2	p P	90	16		KAJITA	86	KAMI	(10 ³⁰ years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		_
0	n	90	0		KAJITA		KAMI	>110	P	90		1.7	HIRATA	890	
7	'n	90	28		PARK		IMB	> 23	n	90	1	1.8	HIRATA	890	C
7	n	90	0		BATTISTONI		NUSX	• • • We	do not use th	e follow	ng dat	a for averages, 1	its, limits, etc. • • •	•	
2	p P	90	≤ 3		BATTISTONI		NUSX	> 12	P	90	0	0.5	BERGER	91	
5.8	•	90			18 KRISHNA	82	KOLR	> 22	'n	90		1.1	BERGER	91	
0.3	P	90	2		19 CHERRY		HOME	> 4.3	 D	90		0.7	PHILLIPS	89	
0.3	P	90	2		20 GURR			> 30	P	90		0.5	SEIDEL	88	
	P			_		0/	CNTR	> 11	n	90		1.1	SEIDEL	88	
ve hav	e calculated	90% CL	limit fr	om 1 confined	event.			> 16	 p	90		4.5	HAINES	86	
ve hav	e converted	z possibl	e event	s to 90% CL II	mit.			> 7	n n	90	6		HAINES	86	
ve hav	e converted	naif-iife	ta 90%	CL mean life.				> 12	p p	90		<0.7	ARISAKA	85	
	+_\							> 5	p n	90		<1.2	ARISAKA	85	
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years)		CL%		BKGD EST	DOCUMENT ID		TECN	> 16	P	90	4		BLEWITT	85	
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4	p	90	n	0.1	BERGER	Q1	FREJ								
0	-	90		0.6	SEIDEL		IMB								
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	P	90		<0.8	ARISAKA	85	KAMI								
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8.4 p 2 n 0.9 p 0.6 n 6 We have composite $p \rightarrow e^+ \omega$) 117 120 p 1.5 p 2.6 p 2.7 p 2.8 p 2.8 p 2.8 p 2.8 p 4.4 p 3.9 We have calculated with p 3.9 p 4.4 p 4.4 p 4.4 p 4.4 p 4.5 p 6.5 p	Special services of the servic	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	6 5 7 3 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	BLEWITT PARK 26 CHERRY 26 CHERRY 26 CHERRY Ilmit. DOCUMENT ID HIRATA as, fits, Ilmits, etc. • • • • BERGER SEIDEL BARTELT HAINES ARISAKA BLEWITT BLEWITT 27 BARTELT	85 85 81 81 890 91 88 87 86 85	IMB IMB IMB HOME HOME T10 TECN KAMI FREJ IMB SOUD IMB	> 40 > 19 > 6.7 > 40 > 6 > 0.6 > 0.4 > 5.8 > 2.0 > 0.2 31 BARTE 32 Limit b 33 We hav	p p p (free) p p n p n p p n ELT 87 ilmit:	90 90 90 90 90 90 90 90 90 90	7 1 11 7 1 0 0 2	<1.1 13 8	HAINES ARISAKA BLEWITT BLEWITT BATTISTONI 32 BARTELT 32 BARTELT 33 KRISHNA CHERRY	86 85 85 84 83 83 82	IMB KAM IMB IMB NUS SOU SOU KOL HOM
2 n n 0.9 p n 0.6 n n $p \rightarrow e^+\omega$) We have comp $p \rightarrow e^+\omega$) 10 years) PAR1 15 p $p \rightarrow e^+\omega$ 17 p $p \rightarrow e^+\omega$ 17 p $p \rightarrow e^+\omega$ 18 p $p \rightarrow e^+\omega$ 19 p $p \rightarrow e^+\omega$ 19 years) PAR1 10 p $p \rightarrow e^+\omega$ 11 p $p \rightarrow e^+\omega$ 12 p $p \rightarrow e^+\omega$ 13 We have calcomp $p \rightarrow e^+\omega$ 14 p $p \rightarrow e^+\omega$ 15 p $p \rightarrow e^+\omega$ 16 P $p \rightarrow e^+\omega$ 17 p $p \rightarrow e^+\omega$ 17 p $p \rightarrow e^+\omega$ 18 p $p \rightarrow e^+\omega$ 19 p $p \rightarrow e^+\omega$ 10 p $p \rightarrow e^+\omega$ 11 p $p \rightarrow e^+\omega$ 12 p $p \rightarrow e^+\omega$	sonverted 2 pr RTICLE	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	7 3 2 2 2 events to 90% CL EVTS BKGD EST 2 1.45 4 data for average 0 1.1 1 1.0 0 6 5.3 1 <1.4 6 7.5 6 5.7 1 0.3 1	PARK 26 CHERRY 26 CHERRY 26 CHERRY . limit. DOCUMENT ID HIRATA 25, flts, Ilmits, etc. • • • BERGER SCIDEL BARTELT HAINES ARISAKA BLEWITT BLEWITT 27 BARTELT	85 81 81 890 91 88 87 86 85	T10 TECN KAMI FREJ IMB SOUD IMB	> 19 > 6.7 > 40 > 6 > 0.6 > 0.4 > 5.8 > 2.0 > 0.2 31 BARTE 32 Limit b 33 We hav	p p (free) p p p n p n ELT 87 ilmit: sased on zero	90 90 90 90 90 90 90 90 90	1 11 7 1 0 0 2	<1.1 13 8	ARISAKA BLEWITT BLEWITT BATTISTONI 32 BARTELT 33 KRISHNA CHERRY	85 85 85 84 83 83 82 81	KAM IMB NUS SOU SOU KOL HOM
0.9 p 0.6 n We have conv $p \rightarrow e^+\omega$) 15 p • We do not 17 p 26 p 1.5 p 1.5 p 27 p 28 p 29 p 29 p 37 p 37 p 38 p 4.4 p 39 p 4.4 p 4.4 p 4.4 p 4.4 p 4.4 p 4.5 p 6.5 p	9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9	O O O O O O O O O O O O O O O O O O O	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	26 CHERRY 26 CHERRY 26 CHERRY I limit. DOCUMENT ID HIRATA es, fits, limits, etc. • • • BERGER SEIDEL BARTELT HAINES ARISAKA BLEWITT BLEWITT 27 BARTELT	81 81 890 91 88 87 86 85	T10 TECN KAMI FREJ IMB SOUD IMB	> 6.7 > 40 > 6 > 0.6 > 0.4 > 5.8 > 2.0 > 0.2 31 BARTE 32 Limit b 33 We hav	p (free) p p n p n p n sett 87 fimit:	90 90 90 90 90 90 90 90 applies t	11 7 1 0 0 2	13 8	BLEWITT BLEWITT BATTISTONI 32 BARTELT 32 BARTELT 33 KRISHNA CHERRY	85 85 84 83 83 82 81	IMB NUS SOU SOU KOL HOM
0.6 n We have comp $p \rightarrow e^+ \omega$) $p \rightarrow e^+ \omega$ $p \rightarrow e$	sonverted 2 printing and a printing	O possible of the control of the con	2 events to 90% CL EVTS BKGD EST 2 1.45 c data for average 0 1.1 1 1.0 0 6 5.3 1 < 1.4 6 7.5 6 5.7 1 0.3 1	26 CHERRY I limit. DOCUMENT ID HIRATA es, fits, limits, etc. • • • BERGER SCIDEL BARTELT HAINES ARISAKA BLEWITT BLEWITT 27 BARTELT	890 91 88 87 86 85	T10 TECN KAMI FREJ IMB SOUD IMB	> 40 > 6 > 0.6 > 0.4 > 5.8 > 2.0 > 0.2 31 BARTE 32 Limit b 33 We hav	p p n p n p n p n sett 87 ilmit:	90 90 90 90 90 90 90 applies t	7 1 0 0 2 0	8	BLEWITT BATTISTONI 32 BARTELT 32 BARTELT 33 KRISHNA CHERRY	85 84 83 83 82 81	IMB NUS SOU SOU KOL HOM
when have converged by the series of the se	RTICLE G	ossible of the control of the contro	EVERY BKGD EST 2 1.45 g data for average 0 1.1 1 1.0 0 6 5.3 1 <1.4 6 7.5 6 5.7 1 0.3 1	DOCUMENT ID HIRATA s, fits, limits, etc. • • • BERGER SEIDEL BARTELT HAINES ARISAKA BLEWITT BLEWITT 27 BARTELT	890 91 88 87 86 85	T10 TECN KAMI FREJ IMB SOUD IMB	> 6 > 0.6 > 0.4 > 5.8 > 2.0 > 0.2 31 BARTE 32 Limit b 33 We hav	p p n p p n p n self 87 ilmit :	90 90 90 90 90 90 applies t	1 0 0 2 0		BATTISTONI 32 BARTELT 32 BARTELT 33 KRISHNA CHERRY	84 83 83 82 81	NUS SOU SOU KOL HOM
$p \rightarrow e^+ \omega$) $p \rightarrow e^+ \omega$) $p \rightarrow e^+ \omega$	RRTICLE 6	12% <u>E</u> 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	EVTS BKGD EST 1.45; data for average 0 1.1 1 1.0 0 6 5.3 1 <1.4 6 7.5 6 5.7 1 0.3 1	DOCUMENT ID HIRATA s, fits, limits, etc. • • • BERGER SEIDEL BARTELT HAINES ARISAKA BLEWITT BLEWITT 27 BARTELT	91 88 87 86 85	TECN KAMI FREJ IMB SOUD IMB	> 0.6 > 0.4 > 5.8 > 2.0 > 0.2 31 BARTE 32 Limit b 33 We hav	p n p n n self="1" style="text-align: center;" by	90 90 90 90 90 applies t	0 0 2 0	μ ⁺ Κ ⁰ _S .	32 BARTELT 32 BARTELT 33 KRISHNA CHERRY	83 83 82 81	SOU SOU KOL HOM
p p p p p p p p	RTICLE Control of the second o	O Dillowing O O O O O O O O O O O O O O O O O O O	2 1.45; data for average 0 1.1 1.0 0 6 5.3 1 <1.4 6 7.5 6 5.7 1 0.3 1	HIRATA s, fits, limits, etc. • • • BERGER SEIDEL BARTELT HAINES ARISAKA BLEWITT BLEWITT 27 BARTELT	91 88 87 86 85	TECN KAMI FREJ IMB SOUD IMB	> 0.4 > 5.8 > 2.0 > 0.2 31 BARTE 32 Limit b 33 We hav	n p p n ELT 87 limit :	90 90 90 90 applies t	0 2 0	$\mu^{+} K_{S}^{0}$.	32 BARTELT 33 KRISHNA CHERRY	83 82 81	KOL HOM
p p p p p p p p	RTICLE Control of the second o	O Dillowing O O O O O O O O O O O O O O O O O O O	2 1.45; data for average 0 1.1 1.0 0 6 5.3 1 <1.4 6 7.5 6 5.7 1 0.3 1	HIRATA s, fits, limits, etc. • • • BERGER SEIDEL BARTELT HAINES ARISAKA BLEWITT BLEWITT 27 BARTELT	91 88 87 86 85	TECN KAMI FREJ IMB SOUD IMB	> 5.8 > 2.0 > 0.2 31 BARTE 32 Limit b 33 We hav	p p n ELT 87 ilmit :	90 90 90 applies t	2 0	$\mu^+ \kappa_S^0$.	33 KRISHNA CHERRY	82 81	KOL HON
p • We do not 17 p 26 p 1.5 p 1.5 p 1.5 p 1.5 p 1.5 p 1.5 p 1.7 p 1.5 p 1.6 p 1.2 p 1.7 p 1.2	of use the fi	O Dillowing O O O O O O O O O O O O O O O O O O O	2 1.45; data for average 0 1.1 1.0 0 6 5.3 1 <1.4 6 7.5 6 5.7 1 0.3 1	HIRATA s, fits, limits, etc. • • • BERGER SEIDEL BARTELT HAINES ARISAKA BLEWITT BLEWITT 27 BARTELT	91 88 87 86 85	FREJ IMB SOUD IMB	> 2.0 > 0.2 31 BARTE 32 Limit b 33 We hav 34 We hav	p n ELT 87 limit : lased on zero re calculated	90 90 applies t	0	μ ⁺ Κ ⁰ ₅ .	CHERRY	81	HON
p • We do not 17 p 26 p 1.5 p 1.5 p 1.5 p 1.5 p 1.5 p 1.5 p 1.7 p 1.5 p 1.6 p 1.2 p 1.7 p 1.2	of use the fi	O Dillowing O O O O O O O O O O O O O O O O O O O	2 1.45; data for average 0 1.1 1.0 0 6 5.3 1 <1.4 6 7.5 6 5.7 1 0.3 1	HIRATA s, fits, limits, etc. • • • BERGER SEIDEL BARTELT HAINES ARISAKA BLEWITT BLEWITT 27 BARTELT	91 88 87 86 85	FREJ IMB SOUD IMB	31 BARTE 32 Limit b 33 We hav 34 We hav	n ELT 87 limit : ased on zero re calculated	applies t	o <i>p</i> →	$\mu^+ K_S^0$.	³⁴ GURR	67	CNT
• • We do not 17 p 766 p 777 p 1757 p 1	ot use the fi	0 0 0 0 0 0 0 0 0 0 0 0	(data for average 0 1.1 1 1.0 0 6 5.3 1 <1.4 6 7.5 6 5.7 1 0.3 1	es, fits, limits, etc. • • • • • • BERGER SEIDEL BARTELT HAINES ARISAKA BLEWITT BLEWITT 27 BARTELT	91 88 87 86 85	FREJ IMB SOUD IMB	32 Limit b 33 We hav 34 We hav	ased on zero	events.	o <i>p</i> →	$\mu^+ K_S^0$.			
17 p 26 p 1.5 p 1.5 p 37 p 25 p 26 p 27 p 28 p 29 p 29 p 40 p 40 p 40 p 41 p 42 p 43 p 6.5 p	(free) 9	0 0 0 0 0 0 0 0 0	0 1.1 1 1.0 0 6 5.3 1 <1.4 6 7.5 6 5.7 1 0.3	BERGER SEIDEL BARTELT HAINES ARISAKA BLEWITT BLEWITT 27 BARTELT	91 88 87 86 85	IMB SOUD IMB	32 Limit b 33 We hav 34 We hav	ased on zero	events.	'				
1.5 p 1.5 p 3.7 p 2.5 p 2.2 p (fi 3.7 p 3.6 p 9.8 p 2.8 p 4.1 Limit based of p 3.8 We have calc 3.9 We have comp $p \rightarrow \mu^+ \omega$ 5. • We do not 1.1 p 4.4 p 1.0 p 1.2 p 1.1 p 1.1 p 1.2 p 1.2 p 1.3 p 1.4 p 1.5 p 1.5 p 1.6 p 1.7 p 1.7 p 1.8 p 1.9 p 1.9 p 1.9 p 1.0	(free) 9	0 0 0 0 0 0 0 0 0	1 1.0 0 6 5.3 1 <1.4 6 7.5 6 5.7 1 0.3	SEIDEL BARTELT HAINES ARISAKA BLEWITT BLEWITT 27 BARTELT	88 87 86 85	IMB SOUD IMB	34 We hav	e calculated	90% CL					
1.5 p 27 p 28 p 29 p 21 p 30 p 31 p 32 p 43 p 44 p 44 p 46 p 46 p 47 p 48 p 49 p 49 p 40 p 40 p 40 p 40 p 40 p 41 p 42 p 42 p 43 p 44 p 46 p 47 p 48 p 49 p 49 p 40 p 40 p 40 p 40 p 40 p 41 p 42 p 42 p 43 p 46 p 47 p 48 p 49 p	(free) 9	0 0 0 0 0 0 0 0	0 6 5.3 1 <1.4 6 7.5 6 5.7 1 0.3	BARTELT HAINES ARISAKA BLEWITT BLEWITT ²⁷ BARTELT	87 86 85	SOUD IMB	34 We hav	e converted		limit fo	om 1 confined	l event.		
37 p 25 p 26 p 27 p 28 p 28 p 39 p 40 p 41 p 42 p 43 p 46 p 47 p 48 p 49 p 49 p 40 p	(free) 9 9 9 9 9 1 on zero eve	0 0 0 0 0 0	1 <1.4 6 7.5 6 5.7 1 0.3	HAINES ARISAKA BLEWITT BLEWITT ²⁷ BARTELT	86 85	IMB	~(n→ .:		half-life	to 90%	CL mean life.			
12 p (fr 137 p 0.6 p 9.8 p 2.8 p 2.8 p Climit based of p 30 We have calcomposition $p \rightarrow \mu^+ \omega$) 100 p 101 p 102 p 103 p 104 p 105 p 107 p 108 p 109 p 1	(free) 9 9 9 9 1 on zero eve	0 0 0 0 0 nts.	6 7.5 6 5.7 1 0.3	BLEWITT BLEWITT ²⁷ BARTELT		KAMI		+ 201						
87 p 0.6 p 9.8 p 2.8 p (Limit based of We have calc) We have converged by We for the West of West	on zero eve	0 0 0 0 nts.	6 5.7 1 0.3 1	BLEWITT ²⁷ BARTELT	85		$ \frac{1}{4} \mu \rightarrow \mu $	· ^5)						
0.6 p 9.8 p 2.8 p Limit based of We have calc. We have conv $p \rightarrow \mu^+ \omega$) 157 p • • We do not 11 p 4.4 p 10 p 23 p 6.5 p (fi 23 p	on zero eve	0 0 0 nts.	1 0.3 1	27 BARTELT		IMB	LIMIT (10 ³⁰ years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TEC
9.8 p 2.8 p Limit based of We have calc. We have comp $p \rightarrow \mu^{+}\omega)$ 10 p 10 p 10 p 10 p 11 p 14 p 16 p 16 p 17 p 18 p 19 p 19 p 19 p 19 p 10 p 10 p 10 p 11 p 13 p 16 p 16 p 17 p 18 p 19 p	on zero eve doubated 90%	O O nts.	1		85	IMB	>64	D	90		1.2	BERGER	91	FRE
2.8 p [Limit based of We have calc] We have comp $p \rightarrow \mu^+ \omega$) The We do not the point of the	i on zero eve Sculated 90%	o nts.		28 KRISHNA	83	SOUD	<i>></i>	•		·		DENGER	71	
Limit based of We have calc. We have converge to the work of the	on zero eve	nts.		29 CHERRY		KOLR HOME	$\tau(p \rightarrow \mu)$	+ K?)						
PWe have calc. We have compared to the property of the proper	doulated 90%	nts.	_	CHERRY	01	HOME								
PWe have confidence of the property of the pr	nculated 907	/ CI 12.	- le fra 0				(10 ³⁰ years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TEC
$P \rightarrow \mu^{+}\omega$) From PART PART PART PART PART PART PART PART		o CL III	events to 90% CI	limit			>44	P	90	0	≤ 0.1	BERGER	91	FRE
77 P 78 • We do not 11 P 14.4 P 10 P 23 P 6.5 P (fit) $n \rightarrow \nu \omega$							-/N	. 1/1						
57 p • We do not 11 p 4.4 p 10 p 23 p 6.5 p (fi 23 p)					711	$\tau(N \rightarrow \nu$							
57 p • We do not 11 p 4.4 p 10 p 23 p 6.5 p (fi 23 p							LIMIT (10 ³⁰ years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
• • We do not 11			VTS BKGD EST			TECN	>100 >100		90	9	7.3			KAN
11 p 4.4 p 10 p 23 p 6.5 p (fi 23 p		0	2 1.9	HIRATA		KAMI	> 9e >100	P N	90	0	2.4	HIRATA HIRATA		KAN
4.4 p 10 p 23 p 6.5 p (fi 23 p	ot use the f	priwolk	data for average	es, fits, limits, etc. • • •	•							fits, limits, etc. • • •	070	KAN
10 p 23 p 6.5 p(fi 23 p		0	0 1.0	BERGER	91	FREJ				-	_			FDE
23 ρ 6.5 ρ (fi 23 ρ		0	0 0.7	PHILLIPS	89	HPW	> 15 > 15	n	90 90		1.8 1.8	BERGER BERGER	89 89	FRE
$\begin{array}{cc} 6.5 & p \text{ (fill)} \\ 23 & p \\ n \rightarrow \nu\omega \end{array}$		0	2 1.3	SEIDEL	88	IMB	> 0.28	P P	90		0.7	PHILLIPS	89	HPV
23 ρ` n → νω)		0	2 1	HAINES	86	IMB	> 0.20	P	90	ő	0.7	BARTELT	87	sou
n → νω)		0	9 8.7 8 7	BLEWITT	85 85	IMB IMB	> 0.75	n	90	ő		35 BARTELT	87	SOU
	•	U	0 /	BLEWITT	03	IIVID	> 10	P	90	6	5	HAINES	86	ІМВ
						712	> 15	'n	90	3	5	HAINES	86	IMB
30 DADI						- 12	> 28	P	90	3	3	KAJITA	86	KAN
years) FAR	RTICLE C	1% 1	VTS BKGD EST	DOCUMENT ID		TECN	> 32	n	90	Ö	1.4	KAJITA	86	KAN
13 n		0	3 2.7	HIRATA	890	KAMI	> 1.8	p (free)	90	6	11	BLEWITT	85	IME
				es, fits, limits, etc. • • •		==	> 9.6	P	90	6	5	BLEWITT	85	IME
17 n		0	1 0.7	BERGER		FREJ	> 10	n	90	2	2	PARK	85	IME
6 n		0	2 1.3	SEIDEL	88	IMB	> 5	n	90	0		BATTISTONI		NU
12 n		0	6 6	HAINES	86	IMB	> 2	P	90	0		BATTISTONI ³⁶ BARTELT		NU:
.8 n		0	2 2	KAJITA	86	KAMI	> 0.3 > 0.1	n	90 90	0		36 BARTELT		SO
.6 n		0	1 2	PARK	85	IMB	> 0.1 > 5.8	p n	90	1		37 KRISHNA		KO
2.0 n		0	2	30 CHERRY		HOME	> 0.3	P n	90	2		38 CHERRY		но
We have con	onverted 2 p	ossible	events to 90% Cl								0	CITETINI I	~.	
								ELT 87 limit						
$N \rightarrow e^+ K)$	7)					<i>T</i> 13	36 Limit b	ased on zero	events.	11,000	rom 1 confined	l avant		
IIT 30 years) PART	OT-0:-					****	38 We have	ve converted	20% CL 2 possih	. amit t Je even	rom 1 contined ts to 90% CL 1	i event. limit.		
			VTS BKGD EST			TECN								
150 p		0	0 <0.27	HIRATA		: KAMI	τ(p→ e	⁺ K*(892) ⁰	')					
1.3 n		iO Marria	O	ALEKSEEV		BAK5	LIMIT (10 ³⁰ years)		-					
				es, fits, limits, etc. • • •					CL%		BKGD EST	DOCUMENT ID		TEC
60 p		0	0	BERGER		FREJ	>52	P	90		1.55	HIRATA	89 C	: KA
70 p		0	0 1.8	SEIDEL	88	IMB	• • • We	do not use th	he follow	ing dat	a for averages,	, fits, limits, etc. • • •		
77 p		0	5 4.5	HAINES	86	IMB	>10	P	90	0	0.8	BERGER	91	FRE
38 p		0	0 <0.8	ARISAKA		KAMI	>10	P	90		<1	ARISAKA		KA
		0	7 8.5	BLEWITT		IMB		-						
77 p		0	5 4	BLEWITT		IMB		·K*(892))						
1.3 p		0	0	ALEKSEEV	81	BAKS	LIMIT (10 ³⁰ years)			_				
$p \rightarrow e^+ K_S^0$						714			<u>CL%</u>		BKGD EST	DOCUMENT ID		TEC
	9					<i>T</i> 14	>22	n	90	0	2.1	BERGER		FRI
IT 30 years) PART	9			DOCUMENT ID		TECN	>20	P	90	5	2.1	HIRATA		: KAI

17		followi 90	-		i, limits, etc. • • •		F0E1	τ(n→ e ⁻							
21	P	90		2.4 2.4	BERGER HIRATA		FREJ KAMI	(10 ³⁰ years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN
10	n P	90		6	HAINES		IMB	>32	n	90	3	2.96	BERGER	91B	FRE.
5	n	90	8		HAINES		IMB	• • • We d	o not use the	followin	g data	for averages, fl	ts, limits, etc. • • •		
8	p p	90	3		KAJITA	86	KAMI	> 0.23	n	90	'n	0.7	PHILLIPS	89	нρν
6	•	90		1.6	KAJITA		KAMI	J 0.23	"	70	۰	0.7	rinceir 3	.,	
5.8	n n (fran)	90	10				IMB	$\tau(n \rightarrow \mu^{-}$	K+)						
	p (free)				BLEWITT				K-)						
9.6	P	90		6	BLEWITT		IMB	LIMIT (10 ³⁰ years)	PARTICLE	CL%	FVTS	BKGD EST	DOCUMENT ID		TEC
7	n	90		4	PARK		IMB							_	
2.1	P	90	1		39 BATTISTONI	82	NOSX	>57	n	90		2.18	BERGER	91 8	FKE
We hav	ve converted 1	possibi	e event	to 90% CL limit.				• • • We d	o not use the	tollowin	ig data	i for averages, fi	ts, limits, etc. • • •		
								> 4.7	п	90	0	0.7	PHILLIPS	89	HPV
) -→ e	+ + + + -)						T22								
T	•							$\tau(p \rightarrow e^-$	· ** * * * * * * * * * * * * * * * * *						
years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		<u>TECN</u>								
1	P	90	0	2.2	BERGER	91	FREJ	LIMIT (10 ³⁰ years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECI
								>30	P	90	1	2.50	BERGER	918	FRE
7 → e	$^{+}\pi^{0}\pi^{0}$)						T23	-	•	followi	ng data	for averages, fi	ts, limits, etc. • • •		
											-	-			
Ó years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	> 2.0	P	90	0	0.7	PHILLIPS	89	HP
8		90		0.5	BERGER	91	FREJ	, _	0\						
•	μ.	,	•	0.3	DENGER	71	, KLS	$\tau(n \rightarrow e^-$	·π ⁺ π ⁰)						
	$^{+}\pi^{-}\pi^{0}$						To	•	•						
							T24	(10 ³⁰ years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TEC
7 0 years)	D4.0T	-,-,	-	DKCD CC	DOCUMENT		TECH	>29	7	90	1	0.78	BERGER	91B	FRE
	PARTICLE	CL%		BKGD EST	DOCUMENT ID		TECN				-				
2	n	90	1	0.8	BERGER	91	FREJ	$\tau(p \rightarrow \mu^-$	· _ + _ +)						
									~ ~)						
$\rightarrow \mu$	s ⁺ π ⁺ π ⁻)						⁷ 25	<i>LIMIT</i> (10 ³⁰ years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TEC
	•													918	
years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	>17	P	90		1.72	BERGER	218	rKt
7	P	90	1	2.6	BERGER	91	FREJ	• • • We d	io not use the	tollowi	ig data	a tor averages, fi	its, limits, etc. • • •		
	-				s, limits, etc. • • •	-		> 7.8	p	90	٥	0.7	PHILLIPS	89	HP
			-	=			LIDIA	_							
3.3	P	90	0	0.7	PHILLIPS	89	HPW	$\tau(n \rightarrow \mu^-$	-π+π ⁰)						
_	.+_0 0\						_	LIMIT	,						
$\gamma \rightarrow \mu$	ι ⁺ π ⁰ π ⁰)						⁷ 26	(10 ³⁰ years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TEC
7			e	0460 565			TECH	>34	n	90	0	0.78	BERGER	91B	FRE
years)	PARTICLE	CL%		BKGD EST	DOCUMENT ID		TECN			- -	_				
3	P	90	1	0.9	BERGER	91	FREJ	$\tau(p \rightarrow e^-$	-+ 4+1						
	-														
7 → µ	$(+\pi^-\pi^0)$						T27	LIMIT (10 ³⁰ years)	DARTICIE	CIN	EVTE	RKGD EST	DOCUMENT ID		TEC
										CL%		BKGD EST		_	
IT ⁽⁰ years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	>20	P	90	3	2.50	BERGER	91B	FRI
<u> </u>	B	90		1.1	BERGER	01	FREJ		1 1 5						
	,,	7 0	•	4.4	DENGEN	71	11163	$\tau(p \rightarrow \mu^-$	~**K+)						
	$^{+}K^{0}\pi^{-})$						-	LIMIT	•						
							T28	(10 ³⁰ years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TEC
IT O years)	BARTICLE	C194	EVITE	DECD EST	DOCUMENT ID		TECN	>5	P	90	2	0.78	BERGER	918	FRI
		CL%	_	BKGD EST					•						
.8	n	90	1	0.2	BERGER	91	FREJ	$\tau(p \rightarrow e^+$	· ~}						
								LIMIT	"						
7> €	; [–] π ⁺)						729	LIMIT (10 ³⁰ years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TEC
IT	•											0.6	SEIDEL	88	IM
o years)	PARTICLE	CL%	EVT5	BKGD EST	DOCUMENT ID		<u>TECN</u>	>460	P	90				00	13411
5	n	90	0	1.6	SEIDEL	88	IMB	• • • We d	do not use the	tollowi	ng dat	a tor averages, t	îts, limits, etc. • • •		
_					s, limits, etc. • • •			>133	P	90	0	0.3	BERGER	91	FRI
			-				:	>360	P	90		0.3	HAINES	86	IME
55	n	90	-	1.09	BERGER		FREJ	> 87	p (free)	90		0.2	BLEWITT		IME
	n	90		7	HAINES		IMB	>360		90		0.2	BLEWITT	85	
6		90	2	4	PARK	85	IMB		P	an o	,	~·•	40 GURR	67	
	n							> 0.1	μ	30			JUNK	01	CIV
	n							⁴⁰ We hav	e converted h	alf-life t	o 90%	CL mean life.			
5							<i>T</i> 30								
5	n u-π+)						730								
5 1 → μ π	u ⁻ π ⁺)	CL%_	_EVTS	BKGD EST	DOCUMENT ID		730 <u>TECN</u>	$\tau(p \to \mu^{\dagger}$							
5 7 → μ ^T _{0 years)}	u ⁻ π ⁺) PARTICLE					дд	TECN	$\tau(p \to \mu^{-1})$	⁺ γ)						
5 1 → μ ⁷ years) 9	r π+) PARTICLE n	90		0.5	SEIDEL			$ au(p o \mu^4)$	⁺ γ)	<u>CL%</u>	<u>EVTS</u>	BKGD EST	DOCUMENT ID		TE
$ \begin{array}{ccc} 7 & \rightarrow & \mu \\ 7 & & & \\ 7 & & & \\ 9 & & & \\ \bullet & & & \\ 9 & & & \\ \end{array} $	r π+) PARTICLE n	90 e follow	O ing dat	0.5 a for averages, fit	SEIDEL s, limits, etc. • • •	•	TECN IMB	$\tau(p \to \mu^{-1})$	⁺ γ)	<u>CL%</u> 90		<u>BKGD EST</u>	<u>DOCUMENT ID</u> SEIDEL	88	
$ \begin{array}{ccc} 7 & \rightarrow & \mu \\ 7 & & & \\ 7 & & & \\ 9 & & & \\ \bullet & & & \\ 9 & & & \\ \end{array} $	r π+) PARTICLE n	90	o ing dat 0	0.5 a for averages, fit: 1.40	SEIDEL s, limits, etc. • • • BERGER	91E	TECN IMB FREJ	$\tau(p \to \mu^{-1})$ LIMIT (10 ³⁰ years) >380	⁺ γ) PARTICLE P	90	0	0.5	SEIDEL		
$ \begin{array}{ccc} 7 & \longrightarrow & \mu \\ 7 & & & \\ 9 & & \\ \bullet & & \\ 9 & & \\ 9 & & \\ 3 & & \\ \end{array} $	μ π+) PARTICLE n e do not use th	90 e follow	o ing dat 0	0.5 a for averages, fit	SEIDEL s, limits, etc. • • • BERGER PHILLIPS	91E 89	IMB FREJ HPW	$ \begin{array}{c} \tau(p \to \mu^{-1}) \\ LIMIT \\ (10^{30} \text{ years}) \\ >380 \\ \bullet \bullet \bullet \text{ We constituted} \end{array} $	PARTICLE P do not use the	90 e followi	O ng dat	0.5 a for averages, f	SEIDEL its, limits, etc. • •		IM
$ \begin{array}{ccc} 7 & \rightarrow & \mu \\ 7 & & \\ 7 & & \\ 9 & & \\ 9 & & \\ 0 & & \\ 9 & & \\ 0 & & \\ 3 & \\ 2.7 & & \\ \end{array} $	PARTICLE n e do not use th	90 e follow 90	o ving dat O O	0.5 a for averages, fit: 1.40	SEIDEL s, limits, etc. • • • BERGER	91E 89	TECN IMB FREJ	$\tau(p \rightarrow \mu^{-1})$ LIMIT (10 ³⁰ years) >380 • • • We (>155	PARTICLE P do not use the	90 e followi 90	0 ng dat 0	0.5 a for averages, f 0.1	SEIDEL its, limits, etc. • • • BERGER	91	FR
$ \begin{array}{ccc} 7 & \rightarrow & \mu \\ \hline 0 & \text{years} \\ 9 & \text{We} \\ 3 & 2.7 & 5 \end{array} $	PARTICLE n e do not use th n	90 e follow 90 90	o ving dat 0 0 7	0.5 a for averages, fit: 1.40 0.7	SEIDEL s, limits, etc. • • • BERGER PHILLIPS	916 89 86	IMB FREJ HPW	$\tau(p \rightarrow \mu^{-1})$ LIMIT (10 ³⁰ years) >380 • • • We of (155) > 97	PARTICLE P do not use the p p	90 e followi 90 90	ong dat 0 3	0.5 a for averages, f 0.1 2	SEIDEL Its, limits, etc. • • • BERGER HAINES	91 86	FR
5	PARTICLE n de do not use the n n n	90 e follow 90 90 90	o ving dat 0 0 7	0.5 a for averages, fit: 1.40 0.7 6	SEIDEL s, limits, etc. • • • BERGER PHILLIPS HAINES	916 89 86	IMB FREJ HPW IMB	$\tau(p \to \mu^{-1})$ LIMIT (10 ³⁰ years) >380 • • • We of >155 > 97 > 61	PARTICLE P do not use the	90 followi 90 90 90	ong dat 0 3	0.5 a for averages, f 0.1 2 0.2	SEIDEL its, limits, etc. • • • BERGER HAINES BLEWITT	91 86 85	FR IMI
5	PARTICLE n de do not use the n n n	90 e follow 90 90 90	o ving dat 0 0 7	0.5 a for averages, fit: 1.40 0.7 6	SEIDEL s, limits, etc. • • • BERGER PHILLIPS HAINES	916 89 86	TECN IMB FREJ HPW IMB IMB	$\tau(p \rightarrow \mu^{-1})$ LIMIT (10 ³⁰ years) >380 • • • We of (155) > 97	PARTICLE P do not use the p p	90 followi 90 90 90 90	ong dat 0 3	0.5 a for averages, f 0.1 2	SEIDEL its, limits, etc. • • • BERGER HAINES BLEWITT BLEWITT	91 86 85 85	FRI IMI IMI
5 $n \rightarrow \mu$ $\binom{77}{0 \text{ years}}$ • We 3 2.7 5 $\binom{7}{0}$	PARTICLE n d on out use the n n n n n n n n n n	90 e follow 90 90 90	o ving dat 0 0 7	0.5 a for averages, fit: 1.40 0.7 6	SEIDEL s, limits, etc. • • • BERGER PHILLIPS HAINES	916 89 86	IMB FREJ HPW IMB	$\tau(p \to \mu^{-1})$ LIMIT (10 ³⁰ years) >380 • • • We of >155 > 97 > 61	PARTICLE p do not use the p p p p p (free)	90 followi 90 90 90	ong dat 0 3	0.5 a for averages, f 0.1 2 0.2	SEIDEL its, limits, etc. • • • BERGER HAINES BLEWITT	91 86 85 85	FRI IMI IMI
5 $n \rightarrow \mu$ $\binom{77}{0 \text{ years}}$ • We 3 2.7 5 $\binom{7}{0}$	PARTICLE n d on out use the n n n n n n n n n n	90 e follow 90 90 90 90	ving dat 0 0 7 2	0.5 a for averages, fit: 1.40 0.7 6 3	SEIDEL s, limits, etc. • • • BERGER PHILLIPS HAINES	916 89 86	TECN IMB FREJ HPW IMB IMB	T(p → μ ⁻¹ LIMIT (10 ³⁰ years) >380 • • • • We o >155 > 97 > 61 >280 > 0.3	PARTICLE P do not use the p p p p p p p p p p free) p p	90 e followi 90 90 90 90 90	0 ng dat 0 3 0	0.5 a for averages, f 0.1 2 0.2 0.6	SEIDEL its, limits, etc. • • • BERGER HAINES BLEWITT BLEWITT	91 86 85 85	FRI IMI IMI
5 $n \rightarrow \mu$ To years) We 3 2.7 5 7 $n \rightarrow e$ To years)	PARTICLE n n n n n n n n n n n n n	90 e follow 90 90 90 90	0 on dat 0 0 7 2 EVTS	0.5 a for averages, fit: 1.40 0.7 6 3	SEIDEL s, limits, etc. • • • BERGER PHILLIPS HAINES PARK	916 89 86 85	TECN IMB FREJ HPW IMB IMB T31	T(p → μ ⁻¹ LIMIT (10 ³⁰ years) >380 • • • • We o >155 > 97 > 61 >280 > 0.3	PARTICLE P do not use the p p p p p p p p p p free) p p	90 e followi 90 90 90 90 90	0 ng dat 0 3 0	0.5 a for averages, f 0.1 2 0.2	SEIDEL its, limits, etc. • • • BERGER HAINES BLEWITT BLEWITT	91 86 85 85	FRI IMI IMI
5 $n \rightarrow \mu$ $r \rightarrow 0$	PARTICLE n e do not use the n n n n n n n n n n n n n n n n n n n	90 e follow 90 90 90 90	0 0 0 0 0 7 2 EVTS	0.5 a for averages, fit: 1.40 0.7 6 3 BKGD EST 4.1	SEIDEL s, limits, etc. • • • BERGER PHILLIPS HAINES PARK DOCUMENT ID SEIDEL	916 89 86 85	TECN IMB FREJ HPW IMB IMB	$\tau(p \rightarrow \mu^{-1})$ LIMIT (10 ³⁰ years) >380 • • • We of 155 > 97 > 61 > 280 > 0.3 41 We hav	PARTICLE P do not use the p p p (free) p p c converted h	90 e followi 90 90 90 90 90	0 ng dat 0 3 0	0.5 a for averages, f 0.1 2 0.2 0.6	SEIDEL its, limits, etc. • • • BERGER HAINES BLEWITT BLEWITT	91 86 85 85	FR IMI IMI
5 $n \rightarrow \mu$ $r \rightarrow 0$	PARTICLE n e do not use the n n n n n n n n n n n n n n n n n n n	90 e follow 90 90 90 90	0 0 0 0 0 7 2 EVTS	0.5 a for averages, fit: 1.40 0.7 6 3 BKGD EST 4.1	SEIDEL s, limits, etc. • • • BERGER PHILLIPS HAINES PARK DOCUMENT ID SEIDEL s, limits, etc. • • •	918 89 86 85	FREJ HPW IMB IMB IMB IMB	$τ(p → μ^{-1})$ LIMIT (10 ³⁰ years) >380 • • • • We considered to the second secon	PARTICLE P p p p p p p p p p p free) p p p ce converted h	90 e followi 90 90 90 90 90	0 ng dat 0 3 0	0.5 a for averages, f 0.1 2 0.2 0.6	SEIDEL its, limits, etc. • • • BERGER HAINES BLEWITT BLEWITT	91 86 85 85	FRI IMI IMI
$ \begin{array}{ccc} n & \rightarrow & \mu \\ & & \\ 0 & \text{years} \\ 0 & \text{we} \\ 3 & 2.7 \\ 5 & \\ 7 & \\ 7 & \\ 0 & \text{years} \\ 0 & \text{years} \\ 2 & & \text{we} \end{array} $	PARTICLE n e do not use the n n n n n n n n n n n n n n n n n n n	90 e follow 90 90 90 90	0 0 0 0 7 2 EVTS	0.5 a for averages, fit: 1.40 0.7 6 3 BKGD EST 4.1 a for averages, fit:	SEIDEL s, limits, etc. • • • BERGER PHILLIPS HAINES PARK DOCUMENT ID SEIDEL	918 89 86 85	TECN IMB FREJ HPW IMB IMB T31	$τ(p → μ^{-1})$ LIMIT (10 ³⁰ years) >380 • • • • We considered to the second secon	PARTICLE P p p p p p p p p p p free) p p p ce converted h	90 e followi 90 90 90 90 90 90	0 ng dat 0 3 0 0 0	0.5 a for averages, f 0.1 2 0.2 0.6 CL mean Hfe.	SEIDEL its, limits, etc. • • • BERGER HAINES BLEWITT BLEWITT 41 GURR	91 86 85 85	FRIMI IMI IMI CN
$\begin{array}{ccc} \mathbf{n} & \rightarrow & \mu \\ \mathbf{n} & \rightarrow & \mu \\ \mathbf{n} & \mathbf{n} \\ 0 & \mathbf{years}) \end{array}$ $\begin{array}{c} 0 & \mathbf{vears} \\ 0 & \mathbf{vears} \end{array}$ $\begin{array}{c} \mathbf{n} & \rightarrow & \mathbf{e} \\ \mathbf{n} & \mathbf{n} \\ \mathbf{n} & \mathbf{vears} \end{array}$	PARTICLE n n n n n n n n n n n n n n n n n n	90 e follow 90 90 90 90 90	0 0 0 7 2 2 EVTS 2 ving dat	0.5 a for averages, fit: 1.40 0.7 6 3 BKGD EST 4.1 a for averages, fit: 6	SEIDEL s, limits, etc. • • • BERGER PHILLIPS HAINES PARK DOCUMENT ID SEIDEL s, limits, etc. • • •	916 89 86 85 88	FREJ HPW IMB IMB T31 TECN IMB	$τ(p \rightarrow μ^{-1})$ LIMIT (10 ³⁰ years) >380 • • • We construct the second se	PARTICLE p p p p p p p p ffree) p p p ec converted h	90 e followi 90 90 90 90 90 90	0 ng dat 0 3 0 0 0 0	0.5 a for averages, f 0.1 2 0.2 0.6 CL mean life. BKGD EST	SEIDEL its, limits, etc. • • • BERGER HAINES BLEWITT BLEWITT 41 GURR	91 86 85 85 67	FR IMI
5 $n \rightarrow \mu$ To years) 9 • We 3 2.7 5 7 $n \rightarrow e$ $n \rightarrow e$ 10 years) 2 • We	PARTICLE n n n n n n n n particle particle particle particle n n n n n n n n n n n n n	90 e follow 90 90 90 90 90	0 0 0 7 2 2 EVTS 2 ving dat	0.5 a for averages, fit: 1.40 0.7 6 3 BKGD EST 4.1 a for averages, fit:	SEIDEL s, limits, etc. • • • BERGER PHILLIPS HAINES PARK DOCUMENT ID SEIDEL s, limits, etc. • • •	916 89 86 85 88	FREJ HPW IMB IMB IMB IMB	$\tau(p \rightarrow \mu^{-1})$ LIMIT (10 ³⁰ years) >380 • • • We of the control of the cont	PARTICLE p p p p p p p p p f(free) p p p ec converted h y) PARTICLE n	90 e followi 90 90 90 90 90 90 90 90 90 90 90 90 90 9	0 ng dat 0 3 0 0 0 0 0 0 0 0 0 90%	0.5 a for averages, f 0.1 2 0.2 0.6 CL mean life. BKGD EST 6.96	SEIDEL its, limits, etc. • • • BERGER HAINES BLEWITT BLEWITT 41 GURR DOCUMENT ID BERGER	91 86 85 85 67	FR IMI
$\begin{array}{ccc} & & & & & & & & & & & & & & & & & & &$	PARTICLE n e do not use the n n n n n n n n n n n n n	90 e follow 90 90 90 90 90	0 0 0 7 2 2 EVTS 2 ving dat	0.5 a for averages, fit: 1.40 0.7 6 3 BKGD EST 4.1 a for averages, fit: 6	SEIDEL s, limits, etc. • • • BERGER PHILLIPS HAINES PARK DOCUMENT ID SEIDEL s, limits, etc. • • •	916 89 86 85 88	FREJ HPW IMB IMB T31 TECN IMB	$\tau(p \rightarrow \mu^{-1})$ LIMIT (10 ³⁰ years) >380 • • • We of the control of the cont	PARTICLE p p p p p p p p p f(free) p p p ec converted h y) PARTICLE n	90 e followi 90 90 90 90 90 90 90 90 90 90 90 90 90 9	0 ng dat 0 3 0 0 0 0 0 0 0 0 0 90%	0.5 a for averages, f 0.1 2 0.2 0.6 CL mean life. BKGD EST 6.96	SEIDEL its, limits, etc. • • • BERGER HAINES BLEWITT BLEWITT 41 GURR	91 86 85 85 67	FR IMI
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$\mu = \pi^+$) PARTICLE n e do not use the n n n n PARTICLE n n n n n n n n n n n n n	90 e follow 90 90 90 90 90	0 0 0 7 2 2 EVTS 2 ving dat	0.5 a for averages, fit: 1.40 0.7 6 3 BKGD EST 4.1 a for averages, fit: 6	SEIDEL s, limits, etc. • • • BERGER PHILLIPS HAINES PARK DOCUMENT ID SEIDEL s, limits, etc. • • •	916 89 86 85 88	FREJ HPW IMB IMB T31 TECN IMB	$\tau(p \rightarrow \mu^{-})$ LIMIT (10 ³⁰ years) >380 • • • We of >155 > 97 > 61 > 280 > 0.3 41 We hav $\tau(n \rightarrow \nu^{-})$ LIMIT (10 ³⁰ years) >24 • • • We of	PARTICLE p p p p p p p p free) p p p ce converted h y PARTICLE n do not use the	90 e followie 90 90 90 90 90 90 90 90 e followie	0 ng dat 0 3 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0.5 a for averages, f 0.1 2 0.2 0.6 CL mean life. BKGD EST 6.86 a for averages, f	SEIDEL its, limits, etc. • • • BERGER HAINES BLEWITT BLEWITT 41 GURR DOCUMENT ID BERGER its, limits, etc. • • •	91 86 85 85 67	FR IMI IMI CN
5 $7 \rightarrow \mu$	$\mu = \pi^+$) PARTICLE n e do not use the n n n n PARTICLE n n n n n n n n n n n n n	90 e follow 90 90 90 90 90 e follow 90 90 90	0 on one of the control of the contr	0.5 a for averages, fit: 1.40 0.7 6 3 BKGD EST 4.1 a for averages, fit: 6 3	SEIDEL s, limits, etc. • • • BERGER PHILLIPS HAINES PARK DOCUMENT ID SEIDEL s, limits, etc. • • • HAINES PARK	916 89 86 85 88	FREJ HPW IMB IMB Fan IMB IMB IMB	$τ(p \rightarrow μ^{-1})$ LIMIT (10 ³⁰ years) >380 • • • We considered to which the second se	PARTICLE p p p p (free) p p p econverted h p p PARTICLE n do not use the	90 e following 90 90 90 90 90 90 90 90 90 90 90 90 90	0 ng dat 0 3 0 0 0 0 90% EVTS 10 ng dat	0.5 a for averages, f 0.1 2 0.2 0.6 CL mean life. BKGD EST 6.86 a for averages, f 60	SEIDEL its, limits, etc. • • • BERGER HAINES BLEWITT BLEWITT 41 GURR DOCUMENT ID BERGER its, limits, etc. • • •	91 86 85 85 67	FRIMI IMI CN
10 years) 19 10 wears) 19 10 wears) 10 years) 10 years) 11 wears) 12 12 14 wears) 15 wears) 16 wears) 17 wears) 18 wears) 19 wears) 19 wears) 19 wears)	$(\mu - \pi^+)$ PARTICLE n n n n n PARTICLE n n n n PARTICLE n n p PARTICLE n n n p PARTICLE n n n n p PARTICLE	90 e follow 90 90 90 e follow 90 90 90 e follow 90 90 90 90 90 90 90 90 90 90 90 90 90	0 ving dat 0 0 7 2 2 2 ving dat 13 5	0.5 a for averages, fit: 1.40 0.7 6 3 BKGD EST 4.1 a for averages, fit: 6 3	SEIDEL s, limits, etc. • • • BERGER PHILLIPS HAINES PARK DOCUMENT ID SEIDEL s, limits, etc. • • • HAINES PARK	91E 89 86 85 88 88	TECN IMB FREJ HPW IMB IMB T31 TECN IMB IMB IMB T32 TECN	$\tau(p \rightarrow \mu^{-})$ LIMIT (10 ³⁰ years) >380 • • • We of >155 > 97 > 61 > 280 > 0.3 41 We hav $\tau(n \rightarrow \nu^{-})$ LIMIT (10 ³⁰ years) >24 • • • We of	PARTICLE p p p p p p p p free) p p p ce converted h y PARTICLE n do not use the	90 e followie 90 90 90 90 90 90 90 90 e followie	0 ng dat 0 3 0 0 0 0 90% EVTS 10 ng dat	0.5 a for averages, f 0.1 2 0.2 0.6 CL mean life. BKGD EST 6.86 a for averages, f	SEIDEL its, limits, etc. • • • BERGER HAINES BLEWITT BLEWITT 41 GURR DOCUMENT ID BERGER its, limits, etc. • • •	91 86 85 85 67	FRI IME
$n \rightarrow \mu$ $(T \cap V) = 0$ $(T \cap V) = $	$\mu = \pi^+$ PARTICLE n n n n n n n n n n n n n	90 e follow 90 90 90 90 90 90 90 90 90 90 90 90 90	0 ving dat 0 0 7 2 2 ving dat 13 5	0.5 a for averages, fit: 1.40 0.7 6 3 BKGD EST 4.1 a for averages, fit: 6 3 BKGD EST 1.1	SEIDEL s, limits, etc. • • • BERGER PHILLIPS HAINES PARK DOCUMENT ID SEIDEL s, limits, etc. • • • HAINES PARK	91E 89 86 85 88 88	FREJ HPW IMB IMB Fan IMB IMB IMB	$\tau(p \rightarrow \mu^{-})$ LIMIT (10 ³⁰ years) >380 • • • We of >155 > 97 > 61 > 280 > 0.3 41 We hav $\tau(n \rightarrow \nu^{-})$ LIMIT (10 ³⁰ years) > 24 • • • We of > 9 > 11	PARTICLE p p p p p f(free) p p p ec converted h y PARTICLE n do not use the n n	90 e following 90 90 90 90 90 90 90 90 90 90 90 90 90	0 ng dat 0 3 0 0 0 0 90% EVTS 10 ng dat	0.5 a for averages, f 0.1 2 0.2 0.6 CL mean life. BKGD EST 6.86 a for averages, f 60	SEIDEL its, limits, etc. • • • BERGER HAINES BLEWITT BLEWITT 41 GURR DOCUMENT ID BERGER its, limits, etc. • • •	91 86 85 85 67	FRI IME
5 7 $\rightarrow \mu$ (7) (7) (9) • We 3 2.7 5 7 7 • We 2 2 17 17 17 17 17 17 17 17	$\mu = \pi^+$ PARTICLE n n n n n n n n n n n n n	90 e follow 90 90 90 90 90 90 90 90 90 90 90 90 90	0 ving dat 0 0 7 2 2 ving dat 13 5	0.5 a for averages, fit: 1.40 0.7 6 3 BKGD EST 4.1 a for averages, fit: 6 3 BKGD EST 1.1	SEIDEL s, limits, etc. • • • BERGER PHILLIPS HAINES PARK DOCUMENT ID SEIDEL s, limits, etc. • • • HAINES PARK	91E 89 86 85 88 88	TECN IMB FREJ HPW IMB IMB T31 TECN IMB IMB IMB T32 TECN	$τ(p \rightarrow μ^{-1})$ LIMIT (10 ³⁰ years) >380 • • • We considered to which the second se	PARTICLE p p p p p f(free) p p p ec converted h y PARTICLE n do not use the n n	90 e following 90 90 90 90 90 90 90 90 90 90 90 90 90	0 ng dat 0 3 0 0 0 0 90% EVTS 10 ng dat	0.5 a for averages, f 0.1 2 0.2 0.6 CL mean life. BKGD EST 6.86 a for averages, f 60	SEIDEL its, limits, etc. • • • BERGER HAINES BLEWITT BLEWITT 41 GURR DOCUMENT ID BERGER its, limits, etc. • • •	91 86 85 85 67	TEC IMI
5 $ 7 \rightarrow \mu $ To years) We $ 7 \rightarrow \mu $	$\mu = \pi^+$ PARTICLE n e do not use the n n n n PARTICLE n e do not use the n n PARTICLE n e do not use the n n particle n n particle n n particle n n n particle n n particle n n n n n n n n n n n n n	90 e follow 90 90 90 90 90 90 90 90 90 90 90 90 90	0 ving dat 0 0 7 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	0.5 a for averages, fit: 1.40 0.7 6 3 BKGD EST 4.1 a for averages, fit: 6 3 BKGD EST 1.1 a for averages, fit:	SEIDEL s, limits, etc. • • • BERGER PHILLIPS HAINES PARK DOCUMENT ID SEIDEL s, limits, etc. • • • HAINES PARK DOCUMENT ID SEIDEL s, limits, etc. • • •	91E 89 86 85 88 86 85	TECN IMB FREJ HPW IMB IMB T31 TECN IMB IMB T32 TECN IMB	$τ(p \rightarrow μ^{-1})$ LIMIT (10 ³⁰ years) >380 • • • We construct the weak of the second through t	PARTICLE P p p p p p p p free p p p p re converted h r p p PARTICLE n n n n + 77)	90 e followie 90 90 90 90 90 e followie 90 90 90 90 90 90 90 90 90 90 90 90	0 ang dat 0 3 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0.5 a for averages, f 0.1 2 0.2 0.6 CL mean life. BKGD EST 6.96 a for averages, f 60 19	SEIDEL its, limits, etc. • • • BERGER HAINES BLEWITT BLEWITT 41 GURR DOCUMENT ID BERGER its, limits, etc. • • •	91 86 85 85 67	FRI IMI
$n \rightarrow \mu$ $(T \cap V) = 0$ $(T \cap V) = $	$\mu = \pi^+$ PARTICLE n n n n n n n n n n n n n	90 e follow 90 90 90 90 90 90 90 90 90 90 90 90 90	0 0 0 7 2 2 EVTS 2 2 EVTS 1 13 5 5 EVTS 1 10 10 10 10 10 10 10 10 10 10 10 10 1	0.5 a for averages, fit: 1.40 0.7 6 3 BKGD EST 4.1 a for averages, fit: 6 3 BKGD EST 1.1	SEIDEL s, limits, etc. • • • BERGER PHILLIPS HAINES PARK DOCUMENT ID SEIDEL s, limits, etc. • • • HAINES PARK	91E 89 86 85 88 86 85	TECN IMB FREJ HPW IMB IMB T31 TECN IMB IMB IMB T32 TECN	$τ(p \rightarrow μ^{-1})$ LIMIT (10 ³⁰ years) >380 • • • We construct the vertical state of	PARTICLE p p p p p f(free) p p p ec converted h y PARTICLE n do not use the n n	90 e following 90 90 90 90 90 90 90 90 90 90 90 90 90	0 ang dat 0 3 0 0 0 0 90% 10 10 10 10 10 10 10 10 10 10 10 10 10	0.5 a for averages, f 0.1 2 0.2 0.6 CL mean life. BKGD EST 6.86 a for averages, f 60	SEIDEL its, limits, etc. • • • BERGER HAINES BLEWITT BLEWITT 41 GURR DOCUMENT ID BERGER its, limits, etc. • • •	91 86 85 85 67 918 86 85	FRI IME

p

$\tau(p \rightarrow e^{-})$	+e+e-)						<i>7</i> 45	$\tau(n \rightarrow 5\nu)$)					756
LIMIT (10 ³⁰ years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	LIMIT (10 ³⁰ years)	PARTICLE	CI% EV	TS BKGD EST	DOCUMEN1	ר וח	TECN
>510	P	90	0	0.3	HAINES	86					data for averages, fits			TECH.
• • • We	do not use the	follow	ng dat	a for averages, fit	s, limits, etc. • • •				п	90		46 GLICENST		KAMI
>147	P	90		0.1	BERGER		FREJ	46 GLICENS	STEIN 97 us	es Kamiok	a data and the idea ti			
> 89 >510	p (free) p	90 90		0.5 0.7	BLEWITT BLEWITT	85 85	IMB IMB	tron's m	agnetic mom	ent should	produce radiation.			
	•	,,	·	0.1	DECTTO	0.5		$\tau(N \rightarrow e^+$	anything)					757
$\tau(\rho \to e^{-})$	+μ+μ-)						T46	LIMIT	,					
LIMIT (10 ³⁰ years)	PARTICLE	CL%	EVTS	BKGD EST	DOCUMENT ID		TECN	(10 ³⁰ years) >0.6		CL% EV	TS BKGD EST	47 LEARNED		TECN RVUE
>81	P	90	0		BERGER		FREJ		p, n tron may be		coonder.	LEARNEL	, 19	RVUE
• • • We	do not use the	followi	ng dat	a for averages, fit	s, Ilmits, etc. • • •					primary or	secondary.			
> 5.0	p	90	0	0.7	PHILLIPS	89	HPW	$\tau(N \rightarrow \mu^{\dagger}$						758
$\tau(p \rightarrow e^-$	١,,,,١							LIMIT (10 ³⁰ years)	PARTICLE	CL% EV	TS BKGD EST	DOCUMENT	· ID	TECN
LIMIT							T47		p, n	90		,49 CHERRY		HOME
	PARTICLE			BKGD EST	DOCUMENT ID		TECN	• • • We do	o not use the	following	data for averages, fits		• •	
>11	P	90	11	6.08	BERGER	91B	FREJ		p, n	90		49 COWSIK		CNTR
$\tau(n \rightarrow e^{-}$	[⊢] e ν)						<i>⊤</i> 48		p, n	90		49 LEARNED	79	RVUE
LIMIT (10 ³⁰ years)				nuen cer				49 The muc	converted 2 on may be pri	possible ev	vents to 90% CL limit	•		
>74	PARTICLE	<u>CL%</u> 90	<u>EV15</u>	< 0.1	DOCUMENT ID		TECN FREJ	•		illiary or se	condary.			
			_	-	s, limits, etc. • • •		FREJ	τ(N → νa						759
>45	n	90	5	5	HAINES	86	IMB	LIMIT	$ ing = \pi, \rho, F $	(, etc.				
>26	п	90	4	3	PARK	85	IMB	(10 ³⁰ years)			/TS BKGD EST	DOCUMENT		TECN
$\tau(n \rightarrow \mu)$	+ a-,,)						T49				data for averages, fits			
LIMIT	• •,						.49	>0.0002	р, п	90	0	LEARNED	79	RVUE
	PARTICLE	CL%		BKGD EST	DOCUMENT ID	_	TECN	$\tau(N \rightarrow e^+$	π ⁰ anythin	g)				760
>47	n	90	0	< 0.1	BERGER	91B	FREJ	LIMIT (10 ³⁰ years)	DADTIC: C	-, -,	TE DUCE SET	200000000		
$\tau(n \rightarrow \mu)$	+ μ ν)						750		P. R	CL% EV	/TS BKGD EST	DOCUMENT LEARNED		TECN RVUE
LIMIT (10 ³⁰ years)	DADTICE F	C18/	F1 (TE	BKGD EST					•		. •	CUARTEL	, ,,	KVOL
>42	PARTICLE n	<u>CL%</u>	<u>EV13</u>	1.4	DOCUMENT ID BERGER		<u>TECN</u> FREJ	$\tau(N \rightarrow 2b)$						761
-					s, limits, etc. • • •		11123	(10 ³⁰ years)	PARTICLE	CL% EV	TS BKGD EST	DOCUMENT	T ID	TECN
> 5.1	п	90	0	0.7	PHILLIPS	89	HPW				data for averages, fits			
>16	n	90	14		HAINES		IMB	>1.3	p, n	90	0	ALEKSEE	V 81	BAKS
>19	n	90	4	7	PARK	85 .	IMB	$\tau(pp \rightarrow \pi$	+_+\					_
$\tau(p \to \mu)$	+ e+ e-)						•							762
							751	IIMIT						
LIMIT	DARTICIE	CIN	EVTE	BYCD SET	DOCUMENT ID			LIMIT (10 ³⁰ years)	CL% EVTS	BKGD EST	DOCUMENT ID	TECN	COMMEN	<u> </u>
	PARTICLE	<u>CL%</u>		BKGD EST	DOCUMENT ID	91	TECN	LIMIT (10 ³⁰ years) >0.7	CL% EVTS 90 4	BKGD EST 2.34	DOCUMENT ID BERGER	918 FREJ	COMMENT τ per Iron	
>91	P	<u>CL%</u> 90	EVTS Q	BKGD EST ≤ 0.1	DOCUMENT ID	91		>0.7	90 4	8KGD EST 2.34	DOCUMENT ID BERGER			n nucleus
>91 τ(p → μ'	+ μ+ μ-)					91	TECN	>0.7 τ(pπ → π'	90 4 +π ⁰)	2.34	BERGER	918 FREJ	τ per Iro	n nucleus
>91 τ(p → μ'	+ μ+ μ-)		0				TECN FREJ	>0.7 τ (pn → π ['] LIMIT (10 ³⁰ years)	90 4 +π ⁰) <u>cι% εντς</u>	BKGD EST	BERGER DOCUMENT ID	918 FREJ	τ per Iro	n nucleus 763
>91 $\tau(p \rightarrow \mu)$ $LIMIT (10^{30} \text{ years})$ >190	P + μ+ μ-) PARTICLE P	90 CL% 90	EVTS	≤ 0.1 BKGD EST 0.1	BERGER DOCUMENT ID HAINES		TECN FREJ 752	>0.7 τ (pπ → π LIMIT (10 ³⁰ years) >2.0	90 4 + π^0) <u>CL% EVTS</u> 90 0	BKGD EST	BERGER	918 FREJ	τ per Iro	n nucleus 763
>91 $\tau(p \rightarrow \mu)$ LIMIT (10 ³⁰ years) >190 • • • We	P + μ+ μ-) PARTICLE P	90 CL% 90 follow	EVTS 1	SKGD EST 0.1 a for averages, fit	DOCUMENT ID HAINES s, limits, etc. • • •	86	TECN FREJ T52 TECN IMB	>0.7 $\tau(pn \to \pi)$ $t_{(1030 \text{ years})}^{LIMIT}$ >2.0 $\tau(nn \to \pi)$	90 4 + π^0) <u>CL% EVTS</u> 90 0	BKGD EST	BERGER DOCUMENT ID	918 FREJ	τ per Iro	n nucleus 763
>91 $\tau(p \to \mu)$ LIMIT (10 ³⁰ years) >190 • • • We >119	P PARTICLE P do not use the	90 <u>CL%</u> 90 e following	EVTS 1 ing dat	SKGD EST 0.1 a for averages, fit 0.2	DOCUMENT ID HAINES s, limits, etc. • • • BERGER	86	TECN FREJ 752 TECN IMB	>0.7 $\tau(pn \to \pi)$ $\frac{10^{30} \text{ years}}{2.0}$ >2.0 $\tau(nn \to \pi)$ LIMIT	90 4 +π ⁰) <u>CU%</u> <u>EVTS</u> 90 0 +π ⁻)	2.34 <u>BKGD EST</u> 0.31	BERGER <u>Document id</u> Berger	918 FREJ <i>TECN</i> 918 FREJ	τ per Iron COMMENT τ per Iron	763 T nucleus
>91 $\tau(p \rightarrow \mu)$ LIMIT (10 ³⁰ years) >190 • • • We	β + μ+μ-) PARTICLE P do not use the	90 CL% 90 follow	EVTS 1 ing dat 0 0	SKGD EST 0.1 a for averages, fit	DOCUMENT ID HAINES s, limits, etc. • • • BERGER PHILLIPS	86 91 89	TECN FREJ T52 TECN IMB	>0.7 $\tau(pn \to \pi)$ $\lim_{(10^{30} \text{ years})} >2.0$ $\tau(nn \to \pi)$ $\lim_{(10^{30} \text{ years})} = 10^{30} \text{ years}$	90 4 +π ⁰) <u>CU%</u> <u>EVTS</u> 90 0 +π ⁻)	### 2.34 ### BKGD EST 0.31 ### BKGD EST	BERGER <u>Document id</u> Berger	918 FREJ <i>TECN</i> 918 FREJ	τ per Iro	763 r nucleus 764
>91 $\tau(p \to \mu)$ Limit (10 ³⁰ years) >190 ••• We >119 > 10.5 > 44 >190	β + μ+ μ-) PARTICLE p do not use the p p	90 90 90 90 90 90 90	EVTS 1 ing dat 0 0 1	SKGD EST 0.1 a for averages, fit 0.2 0.7	DOCUMENT ID HAINES S, Ilmits, etc. • • • BERGER PHILLIPS BLEWITT BLEWITT	86 91 89 85 85	TECN FREJ TECN IMB FREJ HPW IMB IMB	>0.7 $\tau(pn \rightarrow \pi)$ LIMIT (10^{30} years) >2.0 $\tau(nn \rightarrow \pi)$ LIMIT (10^{30} years) >0.7	90 4 +π ⁰) <u>CU%</u> <u>EVTS</u> 90 0 +π ⁻) <u>CU%</u> <u>EVTS</u> 90 4	### 2.34 ### BKGD EST 0.31 ### BKGD EST	BERGER DOCUMENT ID BERGER DOCUMENT ID	918 FREJ 918 FREJ	COMMENT	763 7 n nucleus 764 7 n nucleus
>91 τ(p → μ LiMiT (10 ³⁰ years) >190 • • • We >119 > 10.5 > 44 >190 > 2.1	P PARTICLE P do not use the P P p p p (free) P P	90 90 90 90 90 90 90	EVTS 1 ing date 0 0 1 1 1 1	SECTION BKGD EST 0.1 a for averages, fit 0.2 0.7 0.7 0.9	DOCUMENT ID HAINES s, limits, etc. • • • BERGER PHILLIPS BLEWITT BLEWITT 42 BATTISTONI	86 91 89 85 85	TECN FREJ TECN IMB FREJ HPW IMB	>0.7 $\tau(pn \rightarrow \pi)$ $\frac{(10^{30} \text{ years})}{>2.0}$ $\tau(nn \rightarrow \pi)$ $\frac{(10^{30} \text{ years})}{>0.7}$ $\tau(nn \rightarrow \pi)$	90 4 +π ⁰) <u>CU%</u> <u>EVTS</u> 90 0 +π ⁻) <u>CU%</u> <u>EVTS</u> 90 4	### 2.34 ### BKGD EST 0.31 ### BKGD EST	BERGER DOCUMENT ID BERGER DOCUMENT ID	918 FREJ 918 FREJ	COMMENT	763 r nucleus 764
>91 τ(p → μ LiMiT (10 ³⁰ years) >190 • • • We >119 > 10.5 > 44 >190 > 2.1	P PARTICLE P do not use the P P p p p (free) P P	90 90 90 90 90 90 90	EVTS 1 ing date 0 0 1 1 1 1	EKGD EST 0.1 a for averages, fit 0.2 0.7 0.7	DOCUMENT ID HAINES s, limits, etc. • • • BERGER PHILLIPS BLEWITT BLEWITT 42 BATTISTONI	86 91 89 85 85	TECN FREJ TECN IMB FREJ HPW IMB IMB	>0.7 $\tau(pn \rightarrow \pi)$ (10^{20} years) >2.0 $\tau(nn \rightarrow \pi)$ (10^{30} years) >0.7 $\tau(nn \rightarrow \pi)$	90 4 +π ⁰) <u>CU%</u> <u>EVTS</u> 90 0 +π ⁻) <u>CU%</u> <u>EVTS</u> 90 4 0 π ⁰)	### 2.34 ### BKGD EST 0.31 ### BKGD EST	BERGER DOCUMENT ID BERGER DOCUMENT ID BERGER	918 FREJ TECN 918 FREJ TECN 918 FREJ	COMMENT	763 To nucleus 764 To nucleus 765
>91 τ(p → μ LiMiT (10 ³⁰ years) >190 • • • We >119 > 10.5 > 44 >190 > 2.1	P PARTICLE P do not use the P P P (free) P P P P P P P P P P P P P P P P P P	90 90 90 90 90 90 90	EVTS 1 ing date 0 0 1 1 1 1	SECTION BKGD EST 0.1 a for averages, fit 0.2 0.7 0.7 0.9	DOCUMENT ID HAINES s, limits, etc. • • • BERGER PHILLIPS BLEWITT BLEWITT 42 BATTISTONI	86 91 89 85 85	TECN FREJ TECN IMB FREJ HPW IMB IMB	>0.7 $\tau(pn \rightarrow \pi)$ LIMIT (10 ³⁰ years) >2.0 $\tau(nn \rightarrow \pi)$ LIMIT (10 ³⁰ years) >0.7 $\tau(nn \rightarrow \pi)$ LIMIT (10 ³⁰ years)	90 4 +π ⁰) <u>C(%</u> EVTS 90 0 +π ⁻) <u>C(%</u> EVTS 90 4 0π ⁰) <u>C(%</u> EVTS 4	BKGD EST 0.31 BKGD EST 2.18	BERGER DOCUMENT ID BERGER DOCUMENT ID BERGER	918 FREJ TECN 918 FREJ TECN 918 FREJ	COMMENT COMMENT COMMENT COMMENT COMMENT	763 7 n nucleus 764 7 n nucleus 765
>91 $\tau(p \to \mu)$ LiMIT (10^{30} years) >190 • • • We >119 > 10.5 > 44 >190 > 2.1 42 We hav $\tau(p \to \mu)$	P PARTICLE P do not use the P P P (free) P P P re converted 1	90 90 90 90 90 90 90 90 90	EVTS 1 1 ing dat 0 0 1 1 1 1 ie eveni	BKGD EST 0.1 a for averages, fit 0.2 0.7 0.7 0.9 t to 90% CL Umit	BERGER DOCUMENT ID HAINES Imits, etc. • • • BERGER PHILLIPS BLEWITT BLEWITT 42 BATTISTONI	86 91 89 85 85 82	TECN FREJ TECN IMB FREJ HPW IMB IMB NUSX	>0.7 $\tau(pn \to \pi^{LIMIT} (10^{30} \text{ years})$ >2.0 $\tau(nn \to \pi^{LIMIT} (10^{30} \text{ years})$ >0.7 $\tau(nn \to \pi^{LIMIT} (10^{30} \text{ years})$ >3.4	90 4 +\pi^0) \(\frac{ct\%}{90} \frac{\infty\text{TS}}{90} \text{0} +\pi^-) \(\frac{ct\%}{90} \frac{\infty\text{TS}}{4} \text{0}\pi^0) \(\frac{ct\%}{90} \frac{\infty\text{TS}}{90} \text{0}	### BKGD EST 2.18 ### BKGD EST 2.18	BERGER DOCUMENT ID BERGER DOCUMENT ID BERGER	918 FREJ 918 FREJ 918 FREJ 918 FREJ	COMMENT COMMENT COMMENT COMMENT COMMENT	763 7 n nucleus 764 7 n nucleus 765 7 n nucleus
>91 $\tau(p \to \mu)$ LiMIT (10^{30} year) >190 • • • We >119 > 10.5 > 44 >190 > 2.1 42 We have	P PARTICLE P do not use the P P P (free) P P P re converted 1	90 90 90 90 90 90 90	EVTS 1 ing dat 0 1 1 1 e even	SKGD EST 0.1 BKGD EST 0.2 0.7 0.7 0.9 t to 90% CL limit	DOCUMENT ID HAINES s, limits, etc. • • • BERGER PHILLIPS BLEWITT BLEWITT 42 BATTISTONI	86 91 89 85 85 82	TECN FREJ TECN IMB FREJ HPW IMB IMB NUSX	>0.7 $\tau(pn \rightarrow \pi)$ LIMIT (10^{30} years) >2.0 $\tau(nn \rightarrow \pi)$ LIMIT (10^{30} years) >0.7 $\tau(nn \rightarrow \pi)$ LIMIT (10^{30} years) >3.4 $\tau(pp \rightarrow e)$	90 4 +\pi^0) \(\frac{ct\%}{90} \frac{\infty\text{TS}}{90} \text{0} +\pi^-) \(\frac{ct\%}{90} \frac{\infty\text{TS}}{4} \(\frac{0}{\pi^0}\) \(\frac{\infty}{90} \text{0} \(\frac{\infty\text{TS}}{90} \text{0} \end{argument}	BKGD EST 2.18 BKGD EST 2.18 BKGD EST 0.78	BERGER DOCUMENT ID BERGER DOCUMENT ID BERGER DOCUMENT ID BERGER	918 FREJ 918 FREJ 918 FREJ 918 FREJ 918 FREJ	T per Iron COMMENT T per Iron COMMENT T per Iron COMMENT T per Iron	763 7 n nucleus 764 7 n nucleus 765 7 n nucleus 765 7 n nucleus
>91 $\tau(p \to \mu)$ Limit (10 ³⁰ years) >190 • • • We >119 > 10.5 > 44 >190 > 2.1 42 We hav $\tau(p \to \mu)$ Limit (10 ³⁰ years) >21	P PARTICLE P do not use the P P p (free) P p re converted 1 P PARTICLE P	90 90 90 90 90 90 90 90 90	EVTS 1 ing dat 0 1 1 1 e even	BKGD EST 0.1 a for averages, fit 0.2 0.7 0.7 0.9 t to 90% CL Umit	DOCUMENT ID HAINES Ilmits, etc. • • • BERGER PHILLIPS BLEWITT BLEWITT 42 BATTISTONI	86 91 89 85 85 82	TECN FREJ HPW IMB IMB NUSX TESS TECN TESS TECN	>0.7 $\tau(pn \rightarrow \pi)$ LIMIT (10 ³⁰ years) >2.0 $\tau(nn \rightarrow \pi)$ LIMIT (10 ³⁰ years) >0.7 $\tau(nn \rightarrow \pi)$ LIMIT (10 ³⁰ years) >3.4 $\tau(pp \rightarrow e)$ LIMIT (10 ³⁰ years)	90 4 +π ⁰) <u>C(%</u> <u>EVTS</u> 90 0 +π ⁻) <u>C(%</u> <u>EVTS</u> 90 4 0 π ⁰) <u>C(%</u> <u>EVTS</u> 90 0 +e ⁺) <u>C(%</u> <u>EVTS</u> <u>EVTS</u> 90 0	### BKGD EST 0.78 BKGD EST 0.78 BKGD EST 0.78	BERGER DOCUMENT ID BERGER DOCUMENT ID BERGER DOCUMENT ID BERGER	918 FREJ 918 FREJ 7ECN 918 FREJ 7ECN 918 FREJ	COMMENT COMMENT T per Iron COMMENT T per Iron COMMENT T per Iron COMMENT	763 7 n nucleus 764 7 n nucleus 765 7 n nucleus
>91 $\tau(p \to \mu)$ t_{limiT}	P PARTICLE P do not use the P P p (free) P p re converted 1 P PARTICLE P	90 90 90 90 90 90 90 90 90	EVTS 1 ing dat 0 1 1 1 e even	SKGD EST 0.1 BKGD EST 0.2 0.7 0.7 0.9 t to 90% CL limit	DOCUMENT ID HAINES Ilmits, etc. • • • BERGER PHILLIPS BLEWITT BLEWITT 42 BATTISTONI	86 91 89 85 85 82	TECN FREJ HPW IMB IMB NUSX TESS TECN TESS TECN	>0.7 $\tau(pn \to \pi)$ LIMIT (10 ³⁰ years) >2.0 $\tau(nn \to \pi)$ LIMIT (10 ³⁰ years) >0.7 $\tau(nn \to \pi)$ LIMIT (10 ³⁰ years) >3.4 $\tau(pp \to e^{\epsilon})$ LIMIT (10 ³⁰ years) >3.6	90 4 +π ⁰) <u>CL%</u> <u>EVTS</u> 90 0 +π ⁻) <u>CL%</u> <u>EVTS</u> 90 4 0 π ⁰) <u>CL%</u> <u>EVTS</u> 90 0 + e+) <u>CL%</u> <u>EVTS</u> 90 0	BKGD EST 2.18 BKGD EST 2.18 BKGD EST 0.78	BERGER DOCUMENT ID BERGER DOCUMENT ID BERGER DOCUMENT ID BERGER	918 FREJ 918 FREJ 918 FREJ 918 FREJ 918 FREJ	T per Iron COMMENT T per Iron COMMENT T per Iron COMMENT T per Iron	763 7 n nucleus 764 7 n nucleus 765 7 n nucleus
>91 $\tau(p \to \mu)$ t_{10MT} $t_{10^{30} \text{ years}}$ >190 • • • We >119 > 10.5 > 44 >190 > 2.1 42 We hav $\tau(p \to \mu)$ $t_{10^{30} \text{ years}}$ >21 $\tau(p \to e)$	P PARTICLE P do not use the P P p (free) P p re converted 1 P PARTICLE P	90 90 90 90 90 90 90 90 90 90 90 90	EVTS 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	SKGD EST 0.1 BKGD EST 0.2 0.7 0.7 0.9 t to 90% CL limit	DOCUMENT ID HAINES Ilmits, etc. • • • BERGER PHILLIPS BLEWITT BLEWITT 42 BATTISTONI	91 89 85 85 82	TECN FREJ TECN IMB FREJ HPW IMB IMB NUSX TECN FREJ	>0.7 $\tau(\rho n \to \pi)$ LIMIT (10 ³⁰ years) >2.0 $\tau(nn \to \pi)$ LIMIT (10 ³⁰ years) >0.7 $\tau(nn \to \pi)$ LIMIT (10 ³⁰ years) >3.4 $\tau(\rho p \to e^{-1})$ >8.6 $\tau(\rho p \to e^{-1})$	90 4 +π ⁰) <u>CL%</u> <u>EVTS</u> 90 0 +π ⁻) <u>CL%</u> <u>EVTS</u> 90 4 0 π ⁰) <u>CL%</u> <u>EVTS</u> 90 0 + e+) <u>CL%</u> <u>EVTS</u> 90 0 + e+)	### BKGD EST 0.78 BKGD EST 0.78 BKGD EST 0.78	BERGER DOCUMENT ID BERGER DOCUMENT ID BERGER DOCUMENT ID BERGER	918 FREJ 918 FREJ 7ECN 918 FREJ 7ECN 918 FREJ	COMMENT COMMENT T per Iron COMMENT T per Iron COMMENT T per Iron COMMENT	763 7 n nucleus 764 7 n nucleus 765 7 n nucleus
>91 $\tau(p \to \mu)$ t_{limiT}	p p p p p p p p p p	90 90 90 90 90 90 90 90 90 90 90 90	EVTS 7	BKGD EST 0.1 0.1 a for averages, flt 0.2 0.7 0.7 0.9 t to 90% CL limit BKGD EST 11.23	DOCUMENT ID HAINES Imits, etc. • • • BERGER PHILLIPS BLEWITT BLEWITT 42 BATTISTONI DOCUMENT ID BERGER	86 91 89 85 85 85 82	TECN FREJ TECN IMB FREJ HPW IMB IMB NUSX TECN FREJ FREJ	>0.7 $\tau(\rho n \to \pi)$ LIMIT (10 ³⁰ years) >2.0 $\tau(nn \to \pi)$ LIMIT (10 ³⁰ years) >0.7 $\tau(nn \to \pi)$ LIMIT (10 ³⁰ years) >3.4 $\tau(\rho p \to e^{-1})$ >8.6 $\tau(\rho p \to e^{-1})$	90 4 +π ⁰) <u>CL%</u> <u>EVTS</u> 90 0 +π ⁻) <u>CL%</u> <u>EVTS</u> 90 4 0 π ⁰) <u>CL%</u> <u>EVTS</u> 90 0 + e+) <u>CL%</u> <u>EVTS</u> 90 0 + e+)	### BKGD EST 2.18 #### BKGD EST 0.78 ###################################	BERGER DOCUMENT ID BERGER DOCUMENT ID BERGER DOCUMENT ID BERGER DOCUMENT ID BERGER	918 FREJ 918 FREJ 918 FREJ 918 FREJ 918 FREJ 918 FREJ	COMMENT T per Iron COMMENT T per Iron COMMENT T per Iron COMMENT T per Iron COMMENT	763 7 n nucleus 764 7 n nucleus 765 7 n nucleus 766 7 n nucleus
>91 τ (p → μ LiMiT (10 ³⁰ years) >190 • • • We >119 > 10.5 > 44 >190 > 2.1 42 We hav τ (p → μ LiMiT (10 ³⁰ years) >21 τ (p → e LiMiT (10 ³⁰ years) >6.0	P PARTICLE P do not use the P P P (free) P P R Converted 1 + + + - - - - - - - - - -	90 CL% 90 90 90 90 90 possibil	EVTS 7	BKGD EST 0.1 a for averages, fit 0.2 0.7 0.7 0.9 t to 90% CL limit BKGD EST 11.23	DOCUMENT ID HAINES S, limits, etc. • • • BERGER PHILLIPS BLEWITT BLEWITT 42 BATTISTONI DOCUMENT ID BERGER	86 91 89 85 85 85 82	TECN FREJ HPW IMB IMB NUSX TESS TECN FREJ TECN FREJ TECN FREJ TECN HPW	>0.7 $\tau(pn \to \pi)$ LIMIT (10 ³⁰ years) >2.0 $\tau(nn \to \pi)$ LIMIT (10 ³⁰ years) >0.7 $\tau(nn \to \pi)$ LIMIT (10 ³⁰ years) >3.4 $\tau(pp \to e)$ LIMIT (10 ³⁰ years) >8.8 $\tau(pp \to e)$ LIMIT (10 ³⁰ years)	90 4 +π0) CL% EVTS 90 0 +π-) CL% EVTS 90 4 0π0) CL% EVTS 90 0 +e+) CL% EVTS 90 0	### BKGD EST 0.78 BKGD EST 0.78 BKGD EST 0.78	BERGER DOCUMENT ID BERGER DOCUMENT ID BERGER DOCUMENT ID BERGER DOCUMENT ID BERGER	918 FREJ 918 FREJ 918 FREJ 918 FREJ 918 FREJ 918 FREJ	COMMENT COMMENT T per Iron COMMENT T per Iron COMMENT T per Iron COMMENT	763 7 n nucleus 764 7 n nucleus 765 7 n nucleus 765 7 n nucleus 767
>91 $\tau(p \to \mu)$ t_{limiT}	P PARTICLE P do not use the P P p (free) P p re converted 1 + \(\nu\nu\) PARTICLE P PARTICLE P PARTICLE P	90 CL% 90 90 90 90 90 possibil	EVTS 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	S 0.1 BKGD EST 0.1 a for averages, fit 0.2 0.7 0.7 0.9 t to 90% CL Umit BKGD EST 11.23 BKGD EST 0.7	BERGER DOCUMENT ID HAINES IMITS, etc. • • • • BERGER PHILLIPS BLEWITT BLEWITT 42 BATTISTONI DOCUMENT ID BERGER DOCUMENT ID PHILLIPS	86 91 89 85 85 85 82	TECN FREJ IMB FREJ HPW IMB IMB NUSX TECN FREJ TECN FREJ TECN FREJ	>0.7 $\tau(pn \to \pi)$ LIMIT (10^{30} years) >2.0 $\tau(nn \to \pi)$ LIMIT (10^{30} years) >0.7 $\tau(nn \to \pi)$ LIMIT (10^{30} years) >3.4 $\tau(pp \to e)$ LIMIT (10^{30} years) >5.6	90 4 + \pi^0) \[\frac{\clim{1}}{\clim{1}} & \clim{1	### BKGD EST 0.78 #### DEST 0.78 ###################################	BERGER DOCUMENT ID BERGER DOCUMENT ID BERGER DOCUMENT ID BERGER DOCUMENT ID BERGER	918 FREJ 918 FREJ 918 FREJ 918 FREJ 918 FREJ 918 FREJ 7ECN 918 FREJ	COMMENT T per Iron	763 7 n nucleus 764 7 n nucleus 765 7 n nucleus 765 7 n nucleus 767
>91 $\tau(p \to \mu)$ $timit$ $tio 30$ years) >190 • • • We >119 > 10.5 > 44 >190 > 2.1 42 We hav $\tau(p \to \mu)$ $timit$ $tio 30$ years) >21 $\tau(p \to e)$ $timit$ $tio 30$ years) >6 $timit$ $tio 30$ years) $timit$ $tio 30$ years) $timit$ $tio 30$ years) $timit$ $tio 30$ years)	PARTICLE PARTICLE P p (free) P p (free) P p re converted 1 + \(\nu \nu \) PARTICLE P	20 CL% CL% CL% CL% CL% CL%	EVTS 1 1 1 1 1 1 1 1 1	SO.1 BKGD EST 0.1 a for averages, fit 0.2 0.7 0.7 0.9 t to 90% CL Umit BKGD EST 11.23 BKGD EST 0.7	DOCUMENT ID HAINES S, Ilmits, etc. • • • BERGER PHILLIPS BLEWITT 42 BATTISTONI DOCUMENT ID BERGER DOCUMENT ID PHILLIPS DOCUMENT ID	91 89 85 85 82 91B	TECN FREJ HPW IMB IMB NUSX TECN FREJ TECN FREJ TECN FREJ TECN TECN TECN TECN TECN TECN TECN TECN	>0.7 $\tau(pn \to \pi)$ LIMIT (10 ³⁰ years) >2.0 $\tau(nn \to \pi)$ LIMIT (10 ³⁰ years) >0.7 $\tau(nn \to \pi)$ LIMIT (10 ³⁰ years) >3.4 $\tau(pp \to e)$ LIMIT (10 ³⁰ years) >3.6 $\tau(pp \to \mu)$	90 4 +π0) CL% EVTS 90 0 +π-) CL% EVTS 90 4 0π0) CL% EVTS 90 0 +e+) CL% EVTS 90 0 +μ+) CL% EVTS 90 0 +μ+)	### BKGD EST 0.78 #### DEST 0.78 ###################################	BERGER DOCUMENT ID BERGER DOCUMENT ID BERGER DOCUMENT ID BERGER DOCUMENT ID BERGER	918 FREJ 918 FREJ 918 FREJ 918 FREJ 918 FREJ 918 FREJ 7ECN 918 FREJ	COMMENT T per Iron	763 7 n nucleus 764 7 n nucleus 765 7 n nucleus 765 7 n nucleus 767
>91 $\tau(p \to \mu)$ $timir$ tio^{30} years) >190 • • • We >119 > 10.5 > 44 >190 • • 10.5 > 2.1 42 We hav $\tau(p \to \mu)$ $timir$ tio^{30} years) >21 $\tau(p \to e^{t})$ $timir$ tio^{30} years) >6.0 $\tau(n \to 3i)$ $timir$ tio^{30} years) >0.00049	P PARTICLE P do not use the P P P (free) P P re converted 1 + + + - - - - - - - - - -	200 CL% 90 CL% 9	EVTS 0 EVTS 7 EVTS 0	EKGD EST 0.1 a for averages, fit 0.2 0.7 0.7 0.9 t to 90% CL limit BKGD EST 11.23 BKGD EST 0.7	DOCUMENT ID HAINES S, Ilmits, etc. • • • BERGER PHILLIPS BLEWITT 42 BATTISTONI DOCUMENT ID BERGER DOCUMENT ID PHILLIPS DOCUMENT ID PHILLIPS DOCUMENT ID PHILLIPS	91 89 85 85 85 82	TECN FREJ T52 TECN IMB FREJ HPW IMB IMB NUSX TECN FREJ TECN HPW T55	>0.7 $\tau(pn \to \pi)$ LIMIT (10^{30} years) >2.0 $\tau(nn \to \pi)$ LIMIT (10^{30} years) >0.7 $\tau(nn \to \pi)$ LIMIT (10^{30} years) >3.4 $\tau(pp \to e)$ LIMIT (10^{30} years) >5.6	90 4 +π0) CL% EVTS 90 0 +π-) CL% EVTS 90 4 0π0) CLM EVTS 90 0 +e+) CLM EVTS 90 0 +μ+) CLM EVTS 90 0 +μ+)	### BKGD EST 0.78 #### DEST 0.78 ###################################	BERGER DOCUMENT ID BERGER	918 FREJ 918 FREJ 918 FREJ 918 FREJ 7ECN 918 FREJ 918 FREJ 918 FREJ	COMMENT T per Iron	763 7 n nucleus 764 7 n nucleus 765 7 n nucleus 766 7 n nucleus 767 n nucleus 767 n nucleus
>91 $\tau(p \to \mu)$ $timit$ $tio 30$ years) >190 • • • We >119 > 10.5 > 44 > 190 • • 2.1 42 We hav $\tau(p \to \mu)$ $timit$ $tio 30$ years) >21 $\tau(p \to e^{t})$ $timit$ $tio 30$ years) >6.0 $\tau(n \to 3i)$ 1.1Miff $tio 30$ years) >0.00049 • • • We	PARTICLE P PARTICLE P p p p p p p p p p p re converted 1 + + + p PARTICLE P P PARTICLE P	## 100 CL% 90 90 90 90 90 90 90 9	EVTS 0 EVTS 7 EVTS 0	EKGD EST 0.1 a for averages, fit 0.2 0.7 0.7 0.9 t to 90% CL limit BKGD EST 11.23 BKGD EST 0.7	DOCUMENT ID HAINES S, Ilmits, etc. • • • BERGER PHILLIPS BLEWITT BLEWITT 42 BATTISTONI DOCUMENT ID BERGER DOCUMENT ID PHILLIPS 43 SUZUKI S, Ilmits, etc. • • •	91 89 85 85 82 91B	TECN FREJ HPW IMB IMB NUSX TESS TECN FREJ TOSS TECN FREJ TOSS TECN HPW TOSS TECN KAMI	>0.7 $\tau(pn \rightarrow \pi)$ LIMIT (10 ³⁰ years) >2.0 $\tau(nn \rightarrow \pi)$ LIMIT (10 ³⁰ years) >0.7 $\tau(nn \rightarrow \pi)$ LIMIT (10 ³⁰ years) >3.4 $\tau(pp \rightarrow e)$ LIMIT (10 ³⁰ years) >5.8 $\tau(pp \rightarrow e)$ LIMIT (10 ³⁰ years) >3.6 $\tau(pp \rightarrow \mu)$ LIMIT (10 ³⁰ years)	90 4 +π0) CL% EVTS 90 0 +π-) CL% EVTS 90 4 0π0) CL% EVTS 90 0 +e+) CL% EVTS 90 0 +μ+) CL% EVTS 90 0	### BKGD EST 0.78 #### BKGD EST 0.78 ###################################	BERGER DOCUMENT ID BERGER	918 FREJ 918 FREJ 918 FREJ 918 FREJ 7ECN 918 FREJ 918 FREJ 918 FREJ	COMMENT T per Iron	763 7 n nucleus 764 7 n nucleus 765 7 n nucleus 766 7 n nucleus 767 7 n nucleus 767 7 n nucleus
>91 $\tau(p \to \mu)$ $timir$ tio^{30} years) >190 • • • We >119 > 10.5 > 44 >190 • • 10.5 > 2.1 42 We hav $\tau(p \to \mu)$ $timir$ tio^{30} years) >21 $\tau(p \to e^{t})$ $timir$ tio^{30} years) >6.0 $\tau(n \to 3i)$ $timir$ tio^{30} years) >0.00049	P PARTICLE P do not use the P P P (free) P P re converted 1 + + + - - - - - - - - - -	200 CL% 90 CL% 9	EVTS 1 ing dat 1 1 1 1 1 e even 7 7 EVTS 0	EKGD EST 0.1 a for averages, fit 0.2 0.7 0.7 0.9 t to 90% CL limit BKGD EST 11.23 BKGD EST 0.7	BERGER DOCUMENT ID HAINES S, Ilmits, etc. • • • BERGER PHILLIPS BLEWITT 42 BATTISTONI DOCUMENT ID BERGER DOCUMENT ID PHILLIPS 43 SUZUKI 5, Ilmits, etc. • • • 44 GLICENSTEIN 45 BERGER	91 89 85 85 82 91B	TECN FREJ HPW IMB IMB NUSX TESS TECN FREJ TOSS TECN FREJ TOSS TECN HPW TOSS TECN KAMI	>0.7 $\tau(pn \to \pi)$ LIMIT (10 ³⁰ years) >2.0 $\tau(nn \to \pi)$ LIMIT (10 ³⁰ years) >0.7 $\tau(nn \to \pi)$ LIMIT (10 ³⁰ years) >3.4 $\tau(pp \to e^{-1})$ LIMIT (10 ³⁰ years) >8.8 $\tau(pp \to e^{-1})$ LIMIT (10 ³⁰ years) >3.6 $\tau(pp \to \mu)$ LIMIT (10 ³⁰ years) >3.6	90 4 +π0) <u>CL%</u> <u>EVTS</u> 90 0 +π-) <u>CL%</u> <u>EVTS</u> 90 4 0π0) <u>CL%</u> <u>EVTS</u> 90 0 + e+) <u>CL%</u> <u>EVTS</u> 90 0 + μ+) <u>CL%</u> <u>EVTS</u> 90 0 + μ+) <u>CL%</u> <u>EVTS</u> 90 0	### BKGD EST 0.78 #### BKGD EST 0.78 ###################################	BERGER DOCUMENT ID BERGER	918 FREJ 918 FREJ 7ECN 918 FREJ 7ECN 918 FREJ 7ECN 918 FREJ 7ECN 918 FREJ	COMMENT T per Iron	763 7 n nucleus 764 7 n nucleus 765 7 n nucleus 766 7 n nucleus 767 7 n nucleus 768 7
>91 $\tau(p \rightarrow \mu)$ $timit$ $tio 30$ years) >190 • • • We >119 > 10.5 > 44 > 190 > 2.1 42 We hav $\tau(p \rightarrow \mu)$ $timit$ $tio 30$ years) >21 $\tau(p \rightarrow e^{t})$ $timit$ $tio 30$ years) >6.0 $\tau(n \rightarrow 3i)$ $timit$ $tio 30$ years) >0.00049 • • • We >0.0023 >0.000012	PARTICLE P P PARTICLE P p p p p p p p p re converted 1 + vv) PARTICLE P P PARTICLE P P PARTICLE P P PARTICLE P P PARTICLE N n n n	200 CL% 90 CL% 90 CL% 90 Following Following Following Following Following 90 90 90 90 90 90 90 90 90 90 90 90 90	EVTS 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	EKGD EST 0.1 a for averages, flt 0.2 0.7 0.7 0.9 t to 90% CL limit BKGD EST 11.23 BKGD EST 0.7 BKGD EST 2 a for averages, flt	BERGER DOCUMENT ID HAINES S, Ilmits, etc. • • • BERGER PHILLIPS BLEWITT 42 BATTISTONI DOCUMENT ID BERGER DOCUMENT ID PHILLIPS 43 SUZUKI 5, Ilmits, etc. • • • 44 GLICENSTEIN 45 BERGER 45 BERGER	91 89 85 85 85 82 918 89 938 938 938 919 919	TECN FREJ HPW IMB IMB NUSX TECN FREJ TECN FREJ TECN FREJ TECN KAMI KAMI KAMI FREJ FREJ FREJ	$\begin{array}{c} >0.7 \\ \tau(pn \rightarrow \pi) \\ 1030 \text{ years} \\ >2.0 \\ \tau(nn \rightarrow \pi) \\ 1030 \text{ years} \\ >0.7 \\ \tau(nn \rightarrow \pi) \\ 1030 \text{ years} \\ >0.7 \\ \tau(nn \rightarrow \pi) \\ 1030 \text{ years} \\ >3.4 \\ \tau(pp \rightarrow e) \\ 1030 \text{ years} \\ >3.6 \\ \tau(pp \rightarrow e) \\ 1030 \text{ years} \\ >3.6 \\ \tau(pp \rightarrow \mu) \\ >3.6 \\ \tau(pp \rightarrow \mu) \\ 1030 \text{ years} \\ >3.6 \\ \tau(pp \rightarrow \mu) \\ 1030 \text{ years} \\ >3.6$	90 4 + \(\pi \) 0 \(\frac{\cut_N}{\pi} \) \(\frac{\cut_N}{\cut_N} \) \(\cut	### BKGD EST BKGD EST 2.18	BERGER DOCUMENT ID BERGER	918 FREJ 918 FREJ 7ECN 918 FREJ	COMMENT T per Iron	763 7 n nucleus 764 7 n nucleus 765 7 n nucleus 766 7 n nucleus 767 7 n nucleus 767 7 n nucleus 768 7 n nucleus
>91 τ(p → μ LIMIT (10 ³⁰ years) >190 • • • We >119 > 10.5 > 44 >190 > 2.1 42 We hav τ(p → μ LIMIT (10 ³⁰ years) >21 τ(p → e LIMIT (10 ³⁰ years) >6.0 τ(n → 31 LIMIT (10 ³⁰ years) >0.00049 • • We >0.0023 >0.00012 >0.0005	P PARTICLE P p (free) P p (free) P p (free) P P RE CONVERTED P P PARTICLE P P P PARTICLE P P P PARTICLE P P P P P P P P P P P P P P P P P P P	## 100 ##	EVTS 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	SO.1 BKGD EST 0.1 a for averages, fit 0.2 0.7 0.7 0.9 t to 90% CL limit BKGD EST 11.23 BKGD EST 2 a for averages, fit 6.1 11.2	BERGER DOCUMENT ID HAINES S, Ilmits, etc. • • • BERGER PHILLIPS BLEWITT 42 BATTISTONI DOCUMENT ID BERGER DOCUMENT ID PHILLIPS 43 SUZUKI S, Ilmits, etc. • • • 44 GLICENSTEIN 45 BERGER 45 BERGER LEARNED	91 89 85 85 82 91B 97 91B 97 91B	TECN FREJ T52 TECN IMB FREJ HPW IMB IMB NUSX T53 TECN FREJ T54 TECN HPW T55 TECN KAMI FREJ	>0.7 $\tau(pn \to \pi)$ Limit (10^{30} years) >2.0 $\tau(nn \to \pi)$ Limit (10^{30} years) >0.7 $\tau(nn \to \pi)$ Limit (10^{30} years) >3.4 $\tau(pp \to e)$ Limit (10^{30} years) >3.6 $\tau(pp \to e)$ Limit (10^{30} years) >3.6 $\tau(pp \to \mu)$ Limit (10^{30} years) >1.7 $\tau(pn \to e)$ Limit (10^{30} years) >1.7	90 4 +π0) CL% EVTS 90 0 +π-) CL% EVTS 90 4 0π0) CL% EVTS 90 0 +e+) CL% EVTS 90 0 +μ+) CL% EVTS 90 0 +μ+) CL% EVTS 90 0 +μ+) CL% EVTS 90 0	### BKGD EST BKGD EST 2.18	BERGER DOCUMENT ID BERGER	918 FREJ 7ECN 918 FREJ	COMMENT T per Iron COMMENT	763 7 n nucleus 764 7 n nucleus 765 7 n nucleus 766 7 n nucleus 767 7 n nucleus 767 7 n nucleus 768 7 n nucleus
>91 τ(p → μ LIMIT (10 ³⁰ years) >190 • • • We >119 > 10.5 > 44 >190 > 2.1 42 We hav τ(p → μ LIMIT (10 ³⁰ years) >21 τ(p → e LIMIT (10 ³⁰ years) >6.0 τ(n → 31 LIMIT (10 ³⁰ years) >0.00003 >0.00012 >0.00005 43 The SL	P PARTICLE P p (free) P p (free) P p p (free) P P P R P P P P P P P P P P P P P P P	## 100 ##	EVTS 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	EKGD EST 0.1 a for averages, flt 0.2 0.7 0.7 0.9 t to 90% CL limit BKGD EST 11.23 BKGD EST 2 a for averages, flt 6.1 11.2 ny of ν _e ν _e ν _e ν _e , ν _e	BERGER DOCUMENT ID HAINES S, Ilmits, etc. • • • BERGER PHILLIPS BLEWITT BLEWITT 42 BATTISTONI DOCUMENT ID BERGER DOCUMENT ID PHILLIPS 43 SUZUKI S, Ilmits, etc. • • • 44 GLICENSTEIN 45 BERGER 45 BERGER 45 BERGER LEARNED	918 89 85 85 82 918 918 918 918	TECN FREJ HPW IMB IMB NUSX T53 TECN FREJ T784 TECN HPW T755 TECN KAMI KAMI FREJ FREJ RVUE	>0.7 $\tau(pn \to \pi)$ Limit (10^{30} years) >2.0 $\tau(nn \to \pi)$ Limit (10^{30} years) >0.7 $\tau(nn \to \pi)$ Limit (10^{30} years) >3.4 $\tau(pp \to e)$ Limit (10^{30} years) >3.6 $\tau(pp \to e)$ Limit (10^{30} years) >3.6 $\tau(pp \to \mu)$ Limit (10^{30} years) >1.7 $\tau(pn \to e)$ Limit (10^{30} years) >1.7	90 4 +π0) CL% EVTS 90 0 +π-) CL% EVTS 90 4 0π0) CL% EVTS 90 0 +e+) CL% EVTS 90 0 +μ+) CL% EVTS 90 0 +μ+) CL% EVTS 90 0 +μ+) CL% EVTS 90 0	### BKGD EST BKGD EST 2.18	BERGER DOCUMENT ID BERGER	918 FREJ 918 FREJ 7ECN 918 FREJ	COMMENT T per Iron	763 7 n nucleus 764 7 n nucleus 765 7 n nucleus 766 7 n nucleus 767 7 n nucleus 767 7 n nucleus 768 7 n nucleus
>91 τ (p → μ Limit (10 ³⁰ years) > 190 • • • We > 119 > 10.5 > 44 > 190 • • 10.5 > 44 > 190 • • 2.1 42 We have the first the	PARTICLE P p (free) P p (free) P p (free) P p re converted 1 + \(\nu\) PARTICLE P PARTICLE P PARTICLE P PARTICLE N do not use the n n n n N NUZUKI 938 lim N NUSTEIN 97 us	## 100 ##	EVTS 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	SO.1 BKGD EST O.1 a for averages, fit O.2 O.7 O.7 O.9 t to 90% CL Umit BKGD EST 11.23 BKGD EST O.7 BKGD EST 2 a for averages, fit 6.1 11.2 ny of \(\nu_e\nu_e\nu_e\nu_e\nu_e\nu_e\nu_e\nu_e	BERGER DOCUMENT ID HAINES S, Ilmits, etc. • • • BERGER PHILLIPS BLEWITT 42 BATTISTONI DOCUMENT ID BERGER DOCUMENT ID PHILLIPS 43 SUZUKI 5, Ilmits, etc. • • • 44 GLICENSTEIN 45 BERGER 45 BERGER LEARNED LUMINATION OF UT UT UT That the disappearal	918 85 85 85 82 918 97 918 918 79	TECN FREJ HPW IMB IMB NUSX TECN FREJ TECN FREJ TECN FREJ TECN FREJ TECN KAMI KAMI KAMI KAMI FREJ FREJ RVUE	>0.7 $\tau(pn \to \pi)$ Limit (10^{30} years) >2.0 $\tau(nn \to \pi)$ Limit (10^{30} years) >0.7 $\tau(nn \to \pi)$ Limit (10^{30} years) >3.4 $\tau(pp \to e)$ Limit (10^{30} years) >3.6 $\tau(pp \to e)$ Limit (10^{30} years) >3.6 $\tau(pp \to \mu)$ Limit (10^{30} years) >1.7 $\tau(pn \to e)$ Limit (10^{30} years) >1.7	90 4 + \(\pi \) 0 0 \(\frac{\cut_N}{\pi \cut_N} \) \(\frac{\cut_N}{\cut_N} \) \(\f	### BKGD EST BKGD EST 2.18	BERGER DOCUMENT ID BERGER	918 FREJ 7ECN 918 FREJ	COMMENT T per Iron COMMENT	763 7 n nucleus 764 7 n nucleus 765 7 n nucleus 766 7 n nucleus 767 7 n nucleus 767 7 n nucleus 768 7 n nucleus
>91 τ (p → μ Limit (10 ³⁰ years) > 190 • • • We > 119 > 10.5 > 44 > 190 • • 10.5 > 44 > 190 • • 2.1 42 We have the first the	PARTICLE P p (free) P p (free) P p (free) P p re converted 1 + \(\nu\) PARTICLE P PARTICLE P PARTICLE P PARTICLE N do not use the n n n n N NUZUKI 938 lim N NUSTEIN 97 us	## 100 ##	EVTS 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	SO.1 BKGD EST O.1 a for averages, fit O.2 O.7 O.7 O.9 t to 90% CL Umit BKGD EST 11.23 BKGD EST O.7 BKGD EST 2 a for averages, fit 6.1 11.2 ny of \(\nu_e\nu_e\nu_e\nu_e\nu_e\nu_e\nu_e\nu_e	BERGER DOCUMENT ID HAINES S, Ilmits, etc. • • • BERGER PHILLIPS BLEWITT BLEWITT 42 BATTISTONI DOCUMENT ID BERGER DOCUMENT ID PHILLIPS 43 SUZUKI S, Ilmits, etc. • • • 44 GLICENSTEIN 45 BERGER 45 BERGER 45 BERGER LEARNED	918 85 85 85 82 918 97 918 918 79	TECN FREJ HPW IMB IMB NUSX TECN FREJ TECN FREJ TECN FREJ TECN FREJ TECN KAMI KAMI KAMI KAMI FREJ FREJ RVUE	>0.7 $\tau(pn \to \pi)$ LIMIT (1030 years) >2.0 $\tau(nn \to \pi)$ (1030 years) >0.7 $\tau(nn \to \pi)$ (1030 years) >3.4 $\tau(pp \to e^{-1})$ LIMIT (1030 years) >8.8 $\tau(pp \to e^{-1})$ >3.6 $\tau(pp \to e^{-1})$ (1030 years) >3.6 $\tau(pp \to e^{-1})$ (1030 years) >1.7 $\tau(pn \to e^{-1})$ (1030 years) >1.7 $\tau(pn \to e^{-1})$ LIMIT (1030 years) >2.8	90 4 +π0) CL% EVTS 90 0 +π-) CL% EVTS 90 4 0π0) CL% EVTS 90 0 +e+) CL% EVTS 90 0 +μ+)	### BKGD EST 0.78 ### DEST 0.78 ##	BERGER DOCUMENT ID BERGER	918 FREJ 7ECN 918 FREJ 918 FREJ 7ECN 918 FREJ 7ECN 918 FREJ 7ECN 918 FREJ 918 FREJ	COMMENT T per Iron	Tes
>91 τ (p → μ Limit (10 ³⁰ years) > 190 • • • We > 119 > 10.5 > 44 > 190 • • 10.5 > 44 > 190 • • 2.1 42 We have the first the	PARTICLE P p (free) P p (free) P p (free) P p re converted 1 + \(\nu\) PARTICLE P PARTICLE P PARTICLE P PARTICLE N do not use the n n n n N NUZUKI 938 lim N NUSTEIN 97 us	## 100 ##	EVTS 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	SO.1 BKGD EST O.1 a for averages, fit O.2 O.7 O.7 O.9 t to 90% CL Umit BKGD EST 11.23 BKGD EST O.7 BKGD EST 2 a for averages, fit 6.1 11.2 ny of \(\nu_e\nu_e\nu_e\nu_e\nu_e\nu_e\nu_e\nu_e	BERGER DOCUMENT ID HAINES S, Ilmits, etc. • • • BERGER PHILLIPS BLEWITT 42 BATTISTONI DOCUMENT ID BERGER DOCUMENT ID PHILLIPS 43 SUZUKI 5, Ilmits, etc. • • • 44 GLICENSTEIN 45 BERGER 45 BERGER LEARNED LUMINATION OF UT UT UT That the disappearal	918 85 85 85 82 918 97 918 918 79	TECN FREJ HPW IMB IMB NUSX TECN FREJ TECN FREJ TECN FREJ TECN FREJ TECN KAMI KAMI KAMI KAMI FREJ FREJ RVUE	>0.7 $\tau(pn \to \pi)$ LIMIT (10 ³⁰ years) >2.0 $\tau(nn \to \pi)$ (10 ³⁰ years) >0.7 $\tau(nn \to \pi)$ (10 ³⁰ years) >3.4 $\tau(pp \to e^{-1})$ LIMIT (10 ³⁰ years) >8.8 $\tau(pp \to e^{-1})$ (10 ³⁰ years) >3.6 $\tau(pp \to e^{-1})$ (10 ³⁰ years) >1.7 $\tau(pn \to e^{-1})$ (10 ³⁰ years) >1.7 $\tau(pn \to e^{-1})$ LIMIT (10 ³⁰ years) >1.7 $\tau(pn \to e^{-1})$ LIMIT (10 ³⁰ years) >2.8	90 4 +π0) CL% EVTS 90 0 +π-) CL% EVTS 90 4 0π0) CL% EVTS 90 0 +e+) CL% EVTS 90 0 +μ+) CL% EVTS 90 0	### BKGD EST BKGD EST 2.18	BERGER DOCUMENT ID BERGER	918 FREJ 7ECN 918 FREJ 918 FREJ 7ECN 918 FREJ 7ECN 918 FREJ 7ECN 918 FREJ 918 FREJ	COMMENT T per Iron COMMENT	763 7 n nucleus 764 7 n nucleus 765 7 n nucleus 766 7 n nucleus 767 7 n nucleus 767 7 n nucleus 768 7 n nucleus 769 7 n nucleus

$\tau(nn \to \nu_e \overline{\nu}_e)$		771
(10 ³⁰ years) CL% EVTS BKGD EST	DOCUMENT ID *TECN	COMMENT
>0.000012 90 5 9.7	BERGER 918 FREJ	au per Iron nucleus
$ au(nn o u_{\mu} \overline{ u}_{\mu})$		772
LIMIT (10 ³⁰ years) <u>CL% EVTS BKGD EST</u>	DOCUMENT ID TECN	COMMENT
>0.000006 90 4 4.4	BERGER 91B FREJ	au per iron nucleus

7 PARTIAL MEAN LIVES

The "partial mean life" limits tabulated here are the limits on τ/B_I , where au is the total mean life for the antiproton and B_I is the branching fraction for the mode in question.

$ au(\overline{p} \rightarrow e^- \gamma)$ VALUE (years)	CL%	DOCUMENT ID		TECN	COMMENT	773
>1848	95	GEER	94		8.9 GeV/c 7 beam	_
$ au(\vec{p} \rightarrow e^- \pi^0)$ VALUE (years)	<u>CL</u> %	DOCUMENT ID		TECN	COMMENT	T74
>554	95	GEER	94		8.9 GeV/c p beam.	
$\tau(\overline{p} \rightarrow e^- \eta)$ VALUE (years)	CT.N	DOCUMENT ID		TECN	COMMENT	775
>171	95	GEER	94	CALO	8.9 GeV/c p beam	
$\tau(\overline{p} \to e^- K_S^0)$ VALUE (years)	<u>cl</u> %	DOCUMENT ID		TECN	COMMENT	776
>29	95	GEER	94	CALO	8.9 GeV/c p beam	
$\tau(\overline{p} \rightarrow e^- K_L^0)$ VALUE (years)	CL%.	DOCUMENT ID		TECN	COMMENT	777
>9	95	GEER	94	CALO	8.9 GeV/ <i>c p</i> beam	

p REFERENCES

		,	IVEL FIVEIACES
GLICENSTEIN	97	PL 8411 326	J.F. Glicenstein (SACL)
GABRIELSE	95	PRL 74 3544	+Phillips, Quint+ (HARV, MANZ, SEOUL)
MACGIBBON	95	PR C52 2097	+Garino, Lucas, Nathan+ (ILL, SASK, INRM)
GEER	94	PRL 72 1596	+Marriner, Ray+ (FNAL, UCLA, PSU)
HALLIN	93	PR C48 1497	+Amendt, Bergstrom+ (SASK, BOST, ILL)
SUZUKI	93B	PL B311 357	+Fukuda, Hirata, Inoue+ (KAMIOKANDE Collab.)
HUGHES	92	PRL 69 578	+Deutch (LANL, AARH)
ZIEGER	92	PL B278 34	+Van de Vyver, Christmann, DeGraeve+ (MPCM)
Also	92B) Zieger,, Van den Abeele, Ziegler (MPCM)
BERGER	91	ZPHY C50 385	+Froehlich, Moench, Nisius+ (FREJUS Collab.)
BERGER	91B	PL B269 227	+Froehlich, Moench, Nisius+ (FREJUS Collab.)
	91		
FEDERSPIEL BECKER-SZ		PRL 67 1511	+Eisenstein, Lucas, MacGibbon+ (ILL)
		PR D42 2974	Becker-Szendy, Bratton, Cady, Casper+ (IMB-3 Collab.)
ERICSON	90	EPL 11 295	+Richter (CERN, DARM)
GABRIELSE	90	PRL 65 1317	+Fel, Orozco, Tjoelker+ (HARV, MANZ, WASH, IBS)
BERGER	89	NP B313 509	+Froehlich, Moench+ (FREJUS Collab.)
CHO	89	PRL 63 2559	+Sangster, Hinds (YALE)
HIRATA	89C	PL B220 308	+Kajita, Kifune, Kihara+ (Kamiokande Collab.)
PHILLIPS	89	PL B224 348	+Matthews, Aprile, Cline+ (HPW Collab.)
KREISSL	88	ZPHY C37 \$57	+Hancock, Koch, Koehler, Poth+ (CERN PS176 Collab.)
SEIDEL	88	PRL 61 2522	+Bionta, Blewitt, Bratton+ (IMB Collab.)
BARTELT	87	PR D36 1990	+Courant, Heller+ (Soudan Collab.)
Also	89	PR D40 1701 erratum	Bartelt, Courant, Heller+ (Soudan Collab.)
COHEN	87	RMP 59 1121	+Taylor (RISC, NBS)
HAINES	86	PRL 57 1986	+Bionta, Blewitt, Bratton, Casper+ (IMB Collab.)
KAJITA	86	JPSJ 55 711	+Arlsaka, Koshiba, Nakahata+ (Kamiokande Collab.)
ARISAKA	85	JPSJ 54 3213	+Kajita, Koshiba, Nakahata+ (Kamlokande Collab.)
BLEWITT	85	PRL 55 2114	+LoSecco, Bionta, Bratton+ (IMB Collab.)
DZUBA	85	PL 154B 93	+Flambaum, Silvestrov (NOVO)
PARK	85	PRL 54 22	+Blewitt, Cortez, Foster+ (IMB Collab.)
BATTISTONI	84	PL 133B 454	+Bellotti, Bologna, Campana+ (NUSEX Collab.)
MARINELLI	84	PL 137B 439	+Morpurgo (GENO)
WILKENING	84	PR A29 425	+Ramsey, Larson (HARV, VIRG)
BARTELT	83	PRL 50 651	+Courant, Heller, Joyce, Marshak+ (MINN, ANL)
BATTISTONI	82	PL 118B 461	+Bellotti, Bologna, Campana+ (NUSEX Collab.)
KRISHNA	82	PL 115B 349	Krishnaswamy, Menon+ (TATA, OSKC, INUS)
ALEKSEEV	81	JETPL 33 651	+Bakatanov, Butkevich, Voevodskii+ (PNPI)
		Translated from ZETFF	
CHERRY	81	PRL 47 1507	+Deakyne, Lande, Lee, Steinberg+ (PENN, BNL)
COWSIK	80	PR D22 2204	+Narasimhan (TATA)
BELL	79	PL 86B 215	+Calvetti, Carron, Chaney, Cittolin+ (CERN)
GOLDEN	79	PRL 43 1196	+Horan, Mauger, Badhwar, Lacy+ (NASA, PSLL)
LEARNED	79	PRL 43 907	+Reines, Soni (UCI)
BREGMAN	78	PL 78B 174	+Calvetti, Carron, Cittolin, Hauer, Herr+ (CERN)
ROBERTS	78	PR D17 358	(WILL, RHEL)
EVANS	77	Science 197 989	+Steinberg (BNL, PENN)
ROBERSON	77	PR C16 1945	+King, Kunselman+ (WYOM, CIT, CMU, VPI, WILL)
HU	75	NP A254 403	+Asano, Chen, Cheng, Dugan+ (COLU, YALE)
COHEN	73	JPCRD 2 663	+Taylor (RISC, NBS)
DYLLA	73	PR A7 1224	+King (MIT)
BAMBERGER	70	PL 33B 233	+Lynen, Piekarz+ (MPIH, CERN, KARL)
DIX	70	Thesis Case	(CASE)
HARRISON	69	PRL 22 1263	+Sandars, Wright (OXF)
GURR	67	PR 158 1321	+Kropp, Reines, Meyer (CASE, WITW)
FLEROV	58	DOKL 3 79	+Klochkov, Skobkin, Terentev (ASCI)

n

 $I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$ Status: ***

We have omitted some results that have been superseded by later experiments. See our earlier editions.

The mass is known much more precisely in u (atomic mass units) than in MeV; see the footnotes. The conversion from u to MeV, 1 u = 931.49432±0.00028 MeV, Involves the relatively poorly known electronic charge. The DIFILIPPO 94 value, in u, is by far the best, but when converted to MeV differs only negligibly from the 1986 CODATA value, which, for consistency, we stick with.

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
939.56563±0.00028	¹ COHEN	87	RVUE	1986 CODATA value
• • • We do not use the follow	wing data for averag	es, fits	s, ilmits,	etc. • • •
939.56565±0.00028	2,3 DIFILIPPO	94	TRAP	Penning trap
939.56565±0.00028 939.56564±0.00028	2,3 DIFILIPPO 3,4 GREENE 3 COHEN	86	SPEC	Penning trap $np \rightarrow d\gamma$ 1973 CODATA value

¹ The mass is known much more precisely in u: $m = 1.008664904 \pm 0.000000014$ u.

77 MASS

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
939.485±0.061	59	⁵ CRESTI 8	ь нвс	Pp → Tin
E			_	

 $^5{\rm This}$ is a corrected result (see the erratum). The error is statistical. The maximum systematic error is 0.029 MeV.

$(m_n - m_{\overline{n}}) / m_{\text{average}}$

A test of CPT invariance. Calculated from the n and \overline{n} masses, above.

DOCUMENT ID $(9\pm5)\times10^{-5}$ OUR EVALUATION

 $m_n - m_p$

DOCUMENT ID VALUE (MeV) TECN COMMENT 6 COHEN 1.293318 ±0.000009 87 RVUE 1986 CODATA value 86 SPEC $np \rightarrow d\gamma$ GREENE 1.2933328 ± 0.0000072 73 RVUE 1973 CODATA value COHEN 1.293429 ±0.000036 6 Calculated by us from the COHEN 87 ratio $m_n/m_p=1.001378404\pm0.000000009$. In

 $u, m_D - m_D = 0.001388434 \pm 0.000000009 u.$

n MEAN LIFE

We now compile only direct measurements of the lifetime, not those in-ferred from decay correlation measurements. (Limits on lifetimes for bound neutrons are given in the section "p PARTIAL MEAN LIVES.")

For a review, see EROZOLIMSKII 89 and papers that follow it in an Issue of NIM devoted to the "Proceedings of the International Workshop on Fundamental Physics with Slow Neutrons" (Grenoble 1989). For later reviews and/or commentary, see FREEDMAN 90, SCHRECKENBACH 92, and PENDLEBURY 93.

VALUE (s)	DOCUMENT ID	TECN	COMMENT
886.7± 1.9 OUR AVE	RAGE Error includ	es scale	factor of 1.2.
889.2 ± 3.0 ± 3.8	BYRNE 96	CNTR	Penning trap
882.6 ± 2.7	⁷ MAMPE 93	CNTR	Gravitational trap
888.4 ± 3.1 ± 1.1	NESVIZHEV 92	CNTR	Gravitational trap
878 ±27 ±14	KOSSAKOW 89	TPC	Pulsed beam
887.6± 3.0	MAMPE 89	CNTR	Gravitational trap
877 ±10	PAUL 89	CNTR	Storage ring
876 ±10 ±19	LAST 88	SPEC	Pulsed beam
891 ± 9	SPIVAK 88	CNTR	Beam
903 ±13	KOSVINTSEV 86	CNTR	Gravitational trap
918 ±14	CHRISTENSEN72	CNTR	
• • • We do not use	the following data fo	r average	s, fits, limits, etc. • • •
888.4± 2.9	ALFIMENKOV 90	CNTR	See NESVIZHEVSKII 92
893.6 ± 3.8 ± 3.7	BYRNE 90	CNTR	See BYRNE 96
937 ±18	8 BYRNE 80	CNTR	
875 ±95	KOSVINTSEV 80	CNTR	
881 ± 8	BONDAREN 78	CNTR	See SPIVAK 88
-			

⁷ IGNATOVICH 95 calls into question some of the corrections and averaging procedures used by MAMPE 93. The response, BONDARENKO 96, denies the validity of the

The mass is known much more precisely in u: $m=1.0086649235\pm0.0000000023$ u. We use the conversion factor given above to get the mass in MeV.

³ These determinations are not independent of the m_n-m_p measurements below.

⁴ The mass is known much more precisely in u: $m=1.008664919\pm0.000000014$ u.

⁸ This measurement has been withdrawn (J. Byrne, private communication, 1990).

VALUE (HAI)

n MAGNETIC MOMENT DOCUMENT ID TE

TECN

COMMENT

$-1.91304275 \pm 0.00000045$	COHEN	87	RVUE	1986 CODATA value
• • • We do not use the following	g data for averag	es, fits	i, limits,	etc. • • •
$-1.91304277 \pm 0.00000048$	⁹ GREENE	82	MRS	
⁹ GREENE 82 measures the m magnetons. The value above is 0.000037 (the 1986 CODATA	obtained by mul	tiplyin	g this by	

n ELECTRIC DIPOLE MOMENT

A nonzero value is forbidden by both ${\it T}$ invariance and ${\it P}$ invariance. A number of early results have been omitted. See RAMSEY 90 and GOLUB 94 for reviews.

VALUE (10-25 e	cm) <u>CL%</u>	DOCUMENT ID		TECN	COMMENT
< 0.97	90	ALTAREV	96	MRS	$(+0.26 \pm 0.40 \pm 0.16) \times 10^{-25}$
■ ● ● We do r	not use the fo	llowing data for av-	erag	es, fits,	limits, etc. • • •
< 1.1	95	ALTAREV	92	MRS	See ALTAREV 96
< 1.2	95	SMITH	90		$d = (-0.3 \pm 0.5) \times 10^{-25}$
< 2.6	95	ALTAREV	86	MRS	$d = (-1.4 \pm 0.6) \times 10^{-25}$
0.3 ± 4.8		PENDLEBURY	84	MRS	Ultracold neutrons
< 6	90	ALTAREV	81	MRS	$d = (2.1 \pm 2.4) \times 10^{-25}$
<16	90	ALTAREV	79	MRS	$d = (4.0 \pm 7.5) \times 10^{-25}$

n ELECTRIC POLARIZABILITY α_n

Following is the electric polarizability α_n defined in terms of the induced electric dipole moment by ${\bf D}=4\pi\epsilon_0\alpha_n{\bf E}$. For a review, see SCHMIED-MAYER 89.

VALUE (10-3 fm3)	DOCUMENT ID	TECN	COMMENT
0.98 +0.19 OUR AVERAGE	Error Includes scale fa	ctor of 1.1.	
0.0 ±0.5	¹⁰ KOESTER	95 CNTR	n Pb, n Bl transmission
$1.20 \pm 0.15 \pm 0.20$	SCHMIEDM	91 CNTR	n Pb transmission
$1.07^{+0.33}_{-1.07}$	ROSE	90B CNTR	l γd → γnp
0.8 ±1.0	KOESTER	88 CNTR	n Pb, n Bi transmission
1.2 ± 1.0	SCHMIEDM	88 CNTR	n Pb, n C transmission
• • • We do not use the fo	llowing data for average:	s, fits, limits	i, etc. • • •
$1.17^{+0.43}_{-1.17}$	ROSE	90 CNTR	See ROSE 90B

 $^{^{10}}$ KOESTER 95 uses natural Pb and the isotopes 208, 207, and 206. See this paper for a discussion of methods used by various groups to extract α_n from data.

n CHARGE

See also " $|q_p+q_e|/e$ " in the proton Listings.

VALUE (10 ⁻²¹ e)	DOCUMENT ID	TECN	COMMENT
-0.4 ± 1.1	11 BAUMANN 8	В	Cold n deflection
• • • We do not use the	e following data for averages, i	its, limits	, etc. • • •
-15 ±22	12 GAEHLER 8	2 CNTR	Reactor neutrons
11 The BAUMANN 88	error ± 1.1 gives the 68% CL I	imits abo	ut the the value -0.4.
12 The GAEHLER 82 e	rror ±22 gives the 90% CL lin	its about	the the value 15.

LIMIT ON nn OSCILLATIONS

Mean Time for nn Transition in Vacuum

A test of ΔB =2 baryon number nonconservation. MOHAPATRA 80 and MOHAPATRA 89 discuss the theoretical motivations for looking for $n\bar{n}$ oscillations. DOVER 83 and DOVER 85 give phenomenological analyses. The best limits come from looking for the decay of neutrons bound in nuclei. However, these analyses require model-dependent corrections for nuclear effects. See KABIR 83, DOVER 89, and ALBERICO 91 for discussions. Direct searches for $n \rightarrow \bar{n}$ transitions using reactor neutrons are cleaner but give somewhat poorer limits. We include limits for both free and bound neutrons in the Summary Table.

and bound neut	rons in the	Summary rable.			
VALUE (s)	CL%	DOCUMENT ID		TECN	COMMENT
>1.2 × 10 ⁸	90	BERGER	90	FREJ	n bound in iron
>1.2 × 10 ⁸	90	TAKITA	86	CNTR	Kamiokande
• • • We do not use	the followin	ng data for average	s, fit:	s, limits,	etc. • • •
>8.6 × 10 ⁷	90	BALDO	94	CNTR	Reactor neutrons
>1 × 10 ⁷	90	BALDO	90	CNTR	See BALDO-CEOLIN 94
>4.9 × 10 ⁵	90	BRESSI	90	CNTR	Reactor neutrons
$>4.7 \times 10^{5}$	90	BRESSI	89	CNTR	See BRESSI 90
>1 × 10 ⁶	90	FIDECARO	85	CNTR	Reactor neutrons
>8.8 × 10 ⁷	90	PARK	858	CNTR	
>3 × 10 ⁷		BATTISTONI	84	NUSX	
$> 2.7 \times 10^7 - 1.1 \times 10^7$	В	JONES	84	CNTR	
>2 × 10 ⁷		CHERRY	83	CNTR	

n DECAY MODES

	Mode	Fraction (F_j/Γ)	Confidence level
Γ ₁	pe ⁻ v̄ _e	100 %	
Γ_2	hydrogen-atom $\overline{ u}_{m{e}}$		
	Charge con	servation (Q) violating mode	
Γ3	$p \nu_e \overline{\nu}_e$	$Q < 8 \times 10^{-27}$	68%

n BRANCHING RATIOS

$\Gamma(\text{hydrogen-atom }\overline{\nu}_e)$	/F _{total}				Γ2/Γ
VALUE	<u>CL%</u>	DOCUMENT ID		TECN	
• • • We do not use the	followin	g data for averages	, fits	i, limits, etc. • • •	
$<3 \times 10^{-2}$	95	¹³ GREEN	90	RVUE	

 13 GREEN 90 infers that $\tau({\rm hydrogen\text{-}atom}\,\overline{\nu}_e)>3\times10^4$ s by comparing neutron lifetime measurements made in storage experiments with those made in $\beta{\rm -}decay$ experiments. However, the result depends sensitively on the lifetime measurements, and does not of course take into account more recent measurements of same.

 $\Gamma(p\nu_e\overline{\nu}_e)/\Gamma_{total}$ Forbidden by charge conservation. Γ_3/Γ CL% DOCUMENT ID TECN COMMENT <8 × 10⁻²⁷ 14 NORMAN 96 RVUE ⁷¹Ga → ⁷¹Ge neutrals 68 <9.7 × 10⁻¹⁸ 83 CNTR 113 Cd \rightarrow $^{113}m_{in}$ neut. ROY 90 $< 7.9 \times 10^{-21}$ 83 CNTR 87Rb - 87mSrneut. VAIDYA <9 × 10⁻²⁴ BARABANOV 80 CNTR 71Ga → 71GeX 90 <3 × 10⁻¹⁹ 79 CNTR 87Rb → 87mSrneut. NORMAN 14 NORMAN 96 gets this limit by attributing SAGE and GALLEX counting rates to the charge-nonconserving transition $^{71}\text{Ga}\to ^{71}\text{Ge}+\text{neutrals}$ rather than to solar-neutrino

charge-nonconserving transition **Ga \rightarrow **Ge+neutrals rather than to solar-neutral reactions.

NOTE ON BARYON DECAY PARAMETERS

Written 1996 by E.D. Commins (University of California, Berkeley).

Baryon semileptonic decays

The typical spin-1/2 baryon semileptonic decay is described by a matrix element, the hadronic part of which may be written

$$\overline{B}_f \left[f_1(q^2) \gamma_{\lambda} + i \ f_2(q^2) \sigma_{\lambda\mu} q^{\mu} + g_1(q^2) \gamma_{\lambda} \gamma_5 + g_3(q^2) \gamma_5 q_{\lambda} \right] B_i.$$

Here B_i and \overline{B}_f are spinors describing the initial and final baryons, and $q=p_i-p_f$, while the terms in f_1 , f_2 , g_1 , and g_3 account for vector, induced tensor ("weak magnetism"), axial vector, and induced pseudoscalar contributions [1]. Second-class current contributions are ignored here. In the limit of zero momentum transfer, f_1 reduces to the vector coupling constant g_V , and g_1 reduces to the axial-vector coupling constant g_A . The latter coefficients are related by Cabibbo's theory [2], generalized to six quarks (and three mixing angles) by Kobayashi and Maskawa [3]. The g_3 term is negligible for transitions in which an e^{\pm} is emitted, and gives a very small correction, which can be estimated by PCAC [4], for μ^{\pm} modes. Recoil effects include weak magnetism, and are taken into account adequately by considering terms of first order in

$$\delta = \frac{m_i - m_f}{m_i + m_f} \; ,$$

where m_i and m_f are the masses of the initial and final baryons.

The experimental quantities of interest are the total decay rate, the lepton-neutrino angular correlation, the asymmetry coefficients in the decay of a polarized initial baryon, and the polarization of the decay baryon in its own rest frame for an unpolarized initial baryon. Formulae for these quantities are derived by standard means [5] and are analogous to formulae for nuclear beta decay [6]. We use the notation of Ref. 6 in the Listings for neutron beta decay. For comparison with experiments at higher q^2 , it is necessary to modify the form factors at $q^2 = 0$ by a "dipole" q^2 dependence, and for high-precision comparisons to apply appropriate radiative corrections [7].

The ratio g_A/g_V may be written as

$$g_A/g_V = |g_A/g_V| e^{i\phi_{AV}}.$$

The presence of a "triple correlation" term in the transition probability, proportional to $\text{Im}(g_A/g_V)$ and of the form

$$\sigma_{i}\cdot(\mathbf{p}_{\ell}\times\mathbf{p}_{\nu})$$

for initial baryon polarization or

See key on page 213

$$\sigma_f \cdot (\mathbf{p}_\ell \times \mathbf{p}_\nu)$$

for final baryon polarization, would indicate failure of timereversal invariance. The phase angle ϕ has been measured precisely only in neutron decay (and in ¹⁹Ne nuclear beta decay), and the results are consistent with T invariance.

Hyperon nonleptonic decays

The amplitude for a spin-1/2 hyperon decaying into a spin-1/2 baryon and a spin-0 meson may be written in the form

$$M = G_F m_{\pi}^2 \cdot \overline{B}_f (A - B\gamma_5) B_i ,$$

where A and B are constants [1]. The transition rate is proportional to

$$R = 1 + \gamma \widehat{\omega}_f \cdot \widehat{\omega}_i + (1 - \gamma)(\widehat{\omega}_f \cdot \widehat{\mathbf{n}})(\widehat{\omega}_i \cdot \widehat{\mathbf{n}}) + \alpha(\widehat{\omega}_f \cdot \widehat{\mathbf{n}} + \widehat{\omega}_i \cdot \widehat{\mathbf{n}}) + \beta \widehat{\mathbf{n}} \cdot (\widehat{\omega}_f \times \widehat{\omega}_i),$$

where $\hat{\mathbf{n}}$ is a unit vector in the direction of the final baryon momentum, and $\hat{\omega}_i$ and $\hat{\omega}_f$ are unit vectors in the directions of the initial and final baryon spins. (The sign of the last term in the above equation was incorrect in our 1988 and 1990 editions.) The parameters α , β , and γ are defined as

$$\begin{split} &\alpha = 2\operatorname{Re}(s^*p)/(\,|\,s\,|^2 + \,|\,p\,|^2)\,\,,\\ &\beta = 2\operatorname{Im}(s^*p)/(\,|\,s\,|^2 + \,|\,p\,|^2)\,\,,\\ &\gamma = (\,|\,s\,|^2 - \,|\,p\,|^2)/(\,|\,s\,|^2 + \,|\,p\,|^2)\,\,, \end{split}$$

where s = A and $p = |\mathbf{p}_f| B/(E_f + m_f)$; here E_f and \mathbf{p}_f are the energy and momentum of the final baryon. The parameters α , β , and γ satisfy

$$\alpha^2 + \beta^2 + \gamma^2 = 1 \ .$$

If the hyperon polarization is \mathbf{P}_Y , the polarization \mathbf{P}_B of the decay baryons is

$$\mathbf{P}_B = \frac{(\alpha + \mathbf{P}_Y \cdot \widehat{\mathbf{n}}) \widehat{\mathbf{n}} + \beta (\mathbf{P}_Y \times \widehat{\mathbf{n}}) + \gamma \widehat{\mathbf{n}} \times (\mathbf{P}_Y \times \widehat{\mathbf{n}})}{1 + \alpha \mathbf{P}_Y \cdot \widehat{\mathbf{n}}} \; .$$

Here P_B is defined in the rest system of the baryon, obtained by a Lorentz transformation along $\hat{\mathbf{n}}$ from the hyperon rest frame, in which $\hat{\mathbf{n}}$ and P_Y are defined.

An additional useful parameter ϕ is defined by

$$\beta = (1 - \alpha^2)^{1/2} \sin \phi .$$

In the Listings, we compile α and ϕ for each decay, since these quantities are most closely related to experiment and are essentially uncorrelated. When necessary, we have changed the signs of reported values to agree with our sign conventions. In the Baryon Summary Table, we give α , ϕ , and Δ (defined below) with errors, and also give the value of γ without error.

Time-reversal invariance requires, in the absence of finalstate interactions, that s and p be relatively real, and therefore that $\beta=0$. However, for the decays discussed here, the finalstate interaction is strong. Thus

$$s = |s| e^{i\delta_s}$$
 and $p = |p| e^{i\delta_p}$,

where δ_s and δ_p are the pion-baryon s- and p-wave strong interaction phase shifts. We then have

$$\beta = \frac{-2|s||p|}{|s|^2 + |p|^2}\sin(\delta_s - \delta_p).$$

One also defines $\Delta = -\tan^{-1}(\beta/\alpha)$. If T invariance holds, $\Delta = \delta_s - \delta_p$. For $\Lambda \to p\pi^-$ decay, the value of Δ may be compared with the s- and p-wave phase shifts in low-energy π^-p scattering, and the results are consistent with T invariance.

Radiative hyperon decays

For the radiative decay of a polarized spin-1/2 hyperon, $B_i \to B_f \gamma$, the angular distribution of the direction \widehat{p} of the final spin-1/2 baryon in the hyperon rest frame is

$$\frac{d\Gamma_{\gamma}}{d\Omega} = \frac{\Gamma_{\gamma}}{4\pi} \left(1 + \alpha_{\gamma} \widehat{p} \cdot \mathbf{P}_{i} \right) ,$$

where \mathbf{P}_i is the hyperon polarization and the asymmetry parameter α_{γ} is

$$lpha_{\gamma} = rac{2 \mathrm{Re} \left[g_1'(0) f_M^*(0)
ight]}{|g_1'(0)|^2 + |f_M(0)|^2} \; .$$

Here $f_M=\frac{(m_i-m_f)}{(m_i+m_f)}\left[(m_i+m_f)f_2'-f_1'\right]$, where $f_1'(q^2)$, $f_2'(q^2)$, and $g_1'(q^2)$ are the $\Delta Q=0$ analogs of the $|\Delta Q|=1$ form factors defined above.

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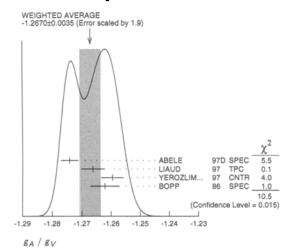
n → pe-v DECAY PARAMETERS

See the above "Note on Baryon Decay Parameters." For discussions of recent results, see the references cited at the beginning of the section on the neutron mean life. For discussions of the values of the weak coupling constants g_A and g_V obtained using the neutron lifetime and asymmetry parameter A, comparisons with other methods of obtaining these constants, and implications for particle physics and for astrophysics, see DUBBERS 91 and WOOLCOCK 91. For tests of the V-A theory of neutron decay, see EROZOLIMSKII 918 and MOSTOVOI 96.

EA / EV

VALUE	DOCUMENT ID	TECN	COMMENT
-1.2670±0.0035 OUR AVERAGE	Error includes s below.	icale factor	of 1.9. See the ideogram
-1.274 ± 0.003	ABELE	97D SPE	C cold n, polarized
-1.266 ±0.004	LIAUD	97 TPC	e mom-n spin corr.
-1.2594±0.0038	^{L5} YEROZLIM	97 CNT	R e mom-n spin corr.
-1.262 ±0.005	BOPP	86 SPE	C e mom-n spin corr.
• • • We do not use the following	data for average	s, fits, limi	ts, etc. • • •
-1.266 ±0.004	SCHRECK	95 TPC	See LIAUD 97
-1.2544 ± 0.0036	EROZOLIM	91 CNT	R See YEROZOLIM- SKY 97
-1.226 ±0.042	MOSTOVOY	83 RVU	
	^{L6} EROZOLIM	79 CNT	R e mom-n spin corr.
-1.259 ±0.017	¹⁶ STRATOWA	78 CNT	R proton recoil spectrum
-1.263 ± 0.015	EROZOLIM	77 CNT	R See EROZOLIMSKII 79
	^{l6} DOBROZE	75 CNT	R See STRATOWA 78
	¹⁷ KROHN	75 CNT	R e mom-n spin corr.
	¹⁸ KROPF	74 RVU	E n decay alone
-1.250 ±0.009	¹⁸ KROPF	74 RVU	E n decay + nuclear ft

 $^{^{15}}$ YEROZOLIMSKY 97 makes a correction to the EROZOLIMSKII 91 value. 16 These experiments measure the absolute value of g_A/g_V only.

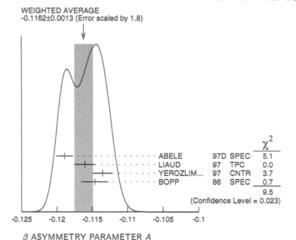


B ASYMMETRY PARAMETER A

rections are small compared to the errors.

This is the neutron-spin electron-momentum correlation coefficient. Unless otherwise

Error includes s below.	cale	factor of	1.8. See the ideogram
ABELE	97D	SPEC	cold n, polarized
LIAUD			e mom-n spin corr.
YEROZLIM	97	CNTR	e mom-n spin corr.
BOPP			
data for average:	i, fits	, limits,	etc. • • •
SCHRECK	95	TPC	See LIAUD 97
EROZOLIM	91	CNTR	See YEROZOLIM- SKY 97
EROZOLIM	79	CNTR	3/(1)
KROHN			
	below. ABELE LIAUD PYEROZLIM BOPP data for average: SCHRECK EROZOLIM PROZOLIM	Delow. ABELE 97D LIAUD 97 PYEROZLIM 97 BOPP 86 data for averages, fits SCHRECK 95 EROZOLIM 91 DEROZOLIM 79 KROHN 75	Delow. ABELE 97D SPEC LIAUD 97 TPC PYEROZLIM 97 CNTR BOPP 86 SPEC data for averages, fits, limits, SCHRECK 95 TPC EROZOLIM 91 CNTR



PASYMMETRY PARAMETER B

This is the neutron-spin antineutrino-momentum correlation coefficient.

VALUE	DOCUMENT ID TECN	COMMENT
0.990 ±0.008 OUR AVERAGE		
0.9894±0.0083	KUZNETSOV 95 CNTR	Cold polarized neutrons
0.995 ±0.034	CHRISTENSEN70 CNTR	
1.00 ± 0.05	EROZOLIM 70C CNTR	

e-V ANGULAR CORRELATION COEFFICIENT a

VALUE	DOCUMENT ID	<u>TECN</u>	COMMENT
-0.102 ±0.005 OUR AVERAGE			
-0.1017 ± 0.0051	STRATOWA	78 CNTR	Proton recoil spectrum
-0.091 ±0.039	GRIGOREV	68 SPEC	Proton recoil spectrum

ϕ_{AV} , PHASE OF g_A RELATIVE TO g_V

Time reversal invariance requires this to be 0 or 180°.

180.07±0.18 OUR EVALUATION	Using the average value for quantity D given in the next data block and $\lambda \equiv g_A/g_V$ in $\sin\phi_{AV} = D(1+3\lambda^2)/2\lambda$.
180.09±0.18 OUR AVERAGE	
179.71±0.39	EROZOLIM 78 CNTR Polarized neutrons
180.35±0.43	EROZOLIM 74 CNTR Polarized neutrons
180.14±0.22	STEINBERG 74 CNTR Polarized neutrons
• • • We do not use the following	data for averages, fits, limits, etc. • • •

²¹ KROPF 181.1 ±1.3 74 RVUE n decay $^{\rm 21}\,\rm KROPF$ 74 reviews all data through 1972.

TRIPLE CORRELATION COEFFICIENT D

These are measurements of the component of n spin perpendicular to the decay plane in β decay. Should be zero if $\mathcal T$ invariance is not violated.

VALUE			DOCUMENT ID		IECN_	COMMENT
(-0.5	±1.4) × 10 ⁻³	OUR AVERAGE			
+ 0.00	0.00±22	30	EROZOLIM	78	CNTR	Polarized neutrons
- 0.00	27±0.00	50	22 EROZOLIM	74	CNTR	Polarized neutrons
- 0.00	0.00 ± 11	17	STEINBERG	74	CNTR	Polarized neutrons

²² EROZOLIMSKII 78 says asymmetric proton losses and nonuniform beam polarization may give a systematic error up to 0.003, thus increasing the EROZOLIMSKII 74 error to 0.005. STEINBERG 74 and STEINBERG 76 estimate these systematic errors to be insignificant in their experiment.

n REFERENCES

We have omitted some papers that have been superseded by later experiments. See our earlier editions.

ABELE	97D	PL B407 212	H. Abele+	(HEIDP, ILLG)
LIAUD	97	NP A612 53	+Schreckenbach, Kossakowski+	(ILLG, LAPP)
YEROZLIM	97	PL B412 240	Yerozolimsky, Kuznetsov, Mosto	
ALTAREV	96	PAN 59 1152	+Borisov, Borovikova+	(PNPI)
	•••	Translated from YAF 59		(,
BONDAREN	96	JETPL 64 416	Bondarenko, Morozov, Panin, Fo	omin+ (KIAE)
		Translated from ZETFP	64 382,	··············
BYRNE	96	EPL 33 187	+Dawber, Habeck, Smidt+	(SUSS, ILLG)
MOSTOVOI	96	PAN 59 968		(KIAE)
		Translated from YAF 59	1013.	
NORMAN	96	PR D53 4086	+Bahcall, Goldhaber	(LBL, IAS, BNL)
IGNATOVICH	95	JETPL 62 1		(JINR)
		Translated from ZETFP	62 3.	, ,
KOESTER	95	PR C51 3363	+Waschkowski, Mitsyna+	(MUNT, JINR, LATV)
KUZNETSOV	95	PRL 75 794	+Serebrov, Stepanenko+	(PNPI, KIAE, HARV, NIST)
SCHRECK	95	PL B349 427	Schreckenbach, Llaud+	(MUNT, ILLG, LAPP)
BALDO	94	ZPHY C63 409	Baido-Ceolin, Benetti+	(HEID, ILLG, PADO, PAVI)
DIFILIPPO	94	PRL 73 1481		(MIT)
Also		PRL 71 1998		
	~		57 77.	(10,000)
PENDLEBURY	93		• • • • • • • • • • • • • • • • • • • •	(ILLG)
			+Rorisov, Rorovikova, Ivanov+	
				(1 141 1, 20141)
MOSTOVOI NORMAN IGNATOVICH KOESTER KUZNETSOV SCHRECK	96 95 95 95 95 94 94 93 94	EPL 33 187 PAN 59 968 Translated from YAF 59 PR D53 4086 JETPL 62 1 Translated from ZETFP PR C51 3363 PRL 75 794 PL B349 427	+Dawber, Habeck, Smidt+ 1013. +Bahcall, Goldhaber 62 3. +Waschkowski, Mitsyna+ +Serebrov, Stepanenko+ Schreckenbach, Llaud+ Baldo-Ceolin, Benettl+ Natarajan, Boyce, Pritchard Natarajan, Boyce, Offilipo, Pri +Lamoreaux +Bondarenko, Morozov+ 57 77. +Borisov, Borovikova, Ivanov+ Nesvizhevskii, Serebrov, Tal'dae	(KIAE) (LBL, IAS, BNL) (JINR) (MUNT, JINR, LATV) (PNPI, KIAE, HARV, NIST) (MUNT, ILLG, LAPP) (HEID, ILLG, PADO, PAVI) tchard (HAHN, WASH) (KIAE) (ILLG) (PNPI)

¹⁷ KROHN 75 includes events of CHRISTENSEN 70. 18 KROPF 74 reviews all data through 1972.

Collaboration Collaboratio	SCHRECK	.92	JPG 18 1	Sebasekanhash Manasa (III.6)
Albo 90	ALBERICO	91	NP A523 488	Schreckenbach, Mampe (ILLG) +de Pace, Pignone (TORI)
EROZOLIM 1			NP A527 239c	(ILLG)
Anio Page	EROZOLIM			Erozolimskii, Kuznetsov, Stepanenko, Kuida+ (PNPI, KIAE)
EROZOLIM		90	S INP \$2 999	Erozolimskii, Kuznetsov, Stepanenko, Kuida+ (PNPI, KIAE)
Schmiedmenny	EROZOLIM	91B	5JNP 53 260	Erozolimskii. Mostovol (KIAE)
WOOLCOCK 91	SCHMIFDM	91	Translated from YAF 53	1 418.
BALDOL	WOOLCOCK	91	MPL A6 2579	(CANR)
BALDD	ALFIMENKOV	90	JETPL 52 373 Translated from ZETER	+Varlamov, Vasil'ev, Gudkov+ (PNPİ, JINR)
## PREEDMAN 90 PRI 65 289 1900			PL B236 95	Baldo-Ceolin Benetti Bitter (PADO PAVI HEIDP III G)
## PREEDMAN 90 PRI 65 289 1900		90	PL B240 237 NC 1034 731	+Froehlich, Moench, Nisius+ (FREJUS Collab.)
GREEN 90	BYRNE	90	PRL 65 289	+Dawber, Spain, Williams+ (SUSS, NBS, SCOT, CBNM)
RAMSEY 90 ARNPS 40 1 ROSE 90 PL B231 460 FOSE	FREEDMAN		CNPP 19 209	(ANL)
ROSE 90 P. 18234 460 +Zurmuelk, Rullhusen, Ludwig+ GOET, MPCM, MANZ SMT P. 18234 191 +Zurmuelk, Rullhusen, Ludwig+ +Zurmuelk, Rullhusen, Ludwigh, Purlik, Rullhusen, Ludwigh +Zurmuelk, Rullhusen, Ludwigh, Purlikk, Rullhusen, Ludwigh, Rullhushush, Rullhushushushushushushushushushushushushush	RAMSEY	90	ARNPS 40 1	(HARV)
Section Sect			PL B234 460	+Zurmuehl, Rullhusen, Ludwig+ (GOET, MPCM, MANZ)
Section Sect			NP A514 621 PL B234 191	+Zurmuehi, Ruilhusen, Ludwig+ (GOET, MPCM) +Crampin+ (SUSS, RAL, HARV, WASH, ILLG, MUNT)
Section Sect	BRESSI	89	ZPHY C43 175	+Calligarich, Cambiaghi+ (INFN, MILA, PAVI, ROMA)
KOSSAKOVW 99 KOSSAKOVW 99 KOSSAKOVW 99 NPA 503 473 MAMPE 99 PRI 56 393 MOHAPATRA 89 PRI 56 393 MOHAPATRA 89 PRI 56 393 MOHAPATRA 89 PRI 56 393 MIM A284 137 SCHMIEDM 89 PRI 57 31307 SCHMIEDM 89 PRI 56 995 SCHMIEDM 89 PRI 56 1055 SCHMIEDM 89 PRI 56 995 Almoid, Dohener, Dubbers+ Almoid, Dohener, Dubbers-			NIM A284 13 NIM A284 89	+Gal, Richard (BNL, HEBR, (SNG)
MOHAPATRA 39	KOSSAKOW	89	NP A503 473	Kossakowski, Grivot+ (LAPP, SAVO, ISNG, ILLG)
PAUL 99 SPHY C45 25 SCHMIEDM. 91 SAZ44 137 Schmiedmayer, Rauch, Ribes (WIEN)			PRL 63 593	+Ageron, Bates, Pendlebury, Steyerl (ILLG, RISL, SUSS, URI)
SCHMIEDM	PAUL	89	ZPHY C45 25	+Anton, Paul, Paul, Mampe (BONN, WUPP, MPIH, ILLG)
KOESTER 88				Schmiedmayer, Rauch, Riehs (WIEN)
SCHMIEDM. 88 PRI. 61 1055 Schmiedmayer, Rauch, Riebs (TUW) SPIVAK 88 PRI. 61 12509 erratum Schmiedmayer, Rauch, Riebs (TUW) SCHMIEDM. 88 PRI. 61 12509 erratum Schmiedmayer, Rauch, Riebs (TUW) SCHMIEDM. 87 RAPP 67 1735 (KIAE) Translated from ZETF 94 1. COHEN 87 RAPP 61 121 Haylor Also 88 JETPL 44 460 TOTAL 121 Haylor Also 89 LEVEL 44 60 TOTAL 121 Haylor Also 89 LEVEL 44 60 TOTAL 121 Haylor Also 89 LEVEL 44 510 TOTAL 121 Haylor Also 89 LEVEL 44 510 TOTAL 121 Haylor Also 89 LEVEL 45 11 TOTAL 121 HAYLOR	KOESTER		ZPHY A329 229	
Also	LAST		PRL 60 995	+Arnold, Doehner, Dubbers+ (HEIDP, ILLG, ANL)
SPIVAK 88			PRL 61 1065 PRL 61 2509 erratum	Schmiedmayer, Rauch, Riehs (TUW) Schmiedmayer, Rauch, Riehs (TUW)
COHEN ALTAREV 86 54 54 54 54 56 519 54 54 56 519 54 56 519 54 56 519 54 56 519 54 56 519 54 56 519 54 56 519 54 56 519 54 56 519 54 56 519 54 56 519 54 56 519 54 54 56 519 54 54 54 56 519 54 54 54 54 54 54 54 54 54 54 54 54 54	SPIVAK		JETP 67 1735	(KIAE)
ALTAREV 85 JETPL 44 460	COHEN	87	RMP 59 1121	±Taylor (DISC NDS)
Also			JETPL 44 460	+Borisov, Borovikova, Brandin, Egorov+ (PNPI)
CRESTI	BOPP	86	PRL 56 919	+Dubbers, Hornig, Klemt, Last+ (HEIDP, ANL, ILLG)
FREENERS 65 FREENERS 6	Also		ZPHY C37 179	Klemt, Bopp, Hornig, Last+ (HEIDP, ANL, ILLG)
FREENERS 65 FREENERS 6			PL B177 206 Pl B200 587 erratum	+Pasquali, Peruzzo, Pinori, Sartori (PADO) Cresti Pasquali Peruzzo Pinori Sartori (PADO)
PL 1568 122				
PL 1568 122	KOSVINTSEV	86	JETPL 44 571 Translated from ZETFP	+Morozov, Terekhov (KIAE)
PL 1568 122	TAKITA		PR D34 902	+Arisaka, Kajita, Kifune+ (KEK, TOKY+)
PARK S5B MP B252 261	FIDECARO		PR C31 1423 PL 156B 122	+Lanceri+ (CERN. II I G. PADO. RAI . SUSS)
JONES 94 PRL 52 720 +Blonta, Blewitt, Bratton+ (Mod Colab.) PRONDLEBURY 84 PL 1868 327 +Blonta, Blewitt, Bratton+ (SUSS, HARV, RAL, ILLG, DVER 83 PRL 50 1354 +Lande, Lee, Steinberg, Cleveland (PENN, BINL) PRL 51 231 (KIAE) Translated from ZETF9 37 162 PRL 52 827	PARK	85B	NP B252 261	+Blewitt, Cortez, Foster+ (IMB Collab.)
PENDLEBURY PL 1368 327 +5mith, Golub, Byrne+ (SUSS, HARV, RAL, ILLG)				+Bellotti, Bologna, Campana+ (NUSEX Collab.) +Bionta Blewitt Bratton+ (IMB Collab.)
CHERRY S3 PRL 50 1354 +Lande, Lee, Steinberg, Cleveland PENN, BNL	PENDLEBURY	84	PL 136B 327	+Smith, Golub, Byrne+ (SUSS, HARV, RAL, ILLG)
MOSTOVOY 83 JETPL 37 196 Translated from 2ETFP 37 162. TATAPA T			PRL 50 1354	+Lande, Lee, Steinberg, Cleveland (PENN, BNL)
MOSTOVOY 83 JETPL 37 196 Translated from 2ETFP 37 162. TATAPA T	KABIR	83		(HARV)
Altarev Standard	MOSTOVOY	83	JETPL 37 196 Translated from ZETER	(KIAE)
Altarev Standard		83	PR D28 1770	+Vaidya, Ephraim, Datar, Bhatki+ (TATA)
GREENE ALTAREV 19 19 19 19 19 19 19 1			PR D27 486 PR D25 2887	+Roy, Ephraim, Datar, Bhattacherjee (TATA)
ALTAREV SI PL 10/28 13	GREENE			+ (YALE, HARV, ILLG, SUSS, ORNL, CENG)
Translated from ZETFP 32 384.	ALTAREV		PL 102B 13	+Borisov, Borovikova, Brandin, Egorov+ (PNPI)
KOSVINTSEV 80			Translated from ZETFF	32 384.
MOHAPATRA 80 ALTAREV 79 SEPTE 29 730 Horizon ZETFP 29 734 Franslated from ZETFP 29 734 Franslated from ZETFP 29 730 Franslated from ZETFP 29 734 Franslated from YAF 30 692 Franslated from YAF 30 692 Franslated from ZETFP 29 328. Also	BYRNE KOSVINTSEV		PL 92B 274	+Morse, Smith, Shaikh, Green, Greene (SUSS, RL)
ALTAREY 79 JETPL 29 730			Translated from ZETFP	31 257.
SINP 30 356	MOHAPATRA ALTAREV		PRL 44 1316 JETPL 29 730	+Marshak (CUNY, VPI) +Borisov, Brandin, Erozov, Exhov, Ivanov L. (DND)
SINP 30 356			Translated from ZETFP	29 794.
NORMAN 79 PRI. 43 1226 +Seamster (WASH)			SJNP 30 356 Translated from YAF 30	Erozolimskii, Frank, Mostovoy+ (KIAE)
Also 82 Smolenice Conf. Bondarenko (KIAE)	NORMAN		PRI 43 1996	⊥Seamster (WASH)
Also 82 Smolenice Conf. Bondarenko (KIAE)	BONDAKEN	/8	Translated from ZETFP	Bondarenko, Kurguzov, Prokofev+ (KIAE) 28 328.
Translated from YAF 28 98.			Smolenice Conf.	Bondarenko (KIAE)
FR D18 3970 Debrozemsky, Weinzlerl SEIB	EROZOLIM	78		Erozolimskii, Mostovoy, Fedunin, Frank+ (KIAE) 3 98.
KROHN 75 ETOZOIII 74 ETPL 20 345 ErozoIII Klingo Fank + Translated from ZETFP 20 745. Fank + Paul (LINZ) CINZ			PR D18 3970	+Dobrozemsky, Weinzierl (SEIB)
KROHN 75 ETOZOIII 74 ETPL 20 345 ErozoIII Klingo Fank + Translated from ZETFP 20 745. Fank + Paul (LINZ) CINZ			Translated from ZETFP	Erozolimskii, Frank, Mostovoy+ (KIAE) 23 720.
KROHN 75 ETOZOIII 74 ETPL 20 345 ErozoIII Klingo Fank + Translated from ZETFP 20 745. Fank + Paul (LINZ) CINZ	STEINBERG		PR D13 2469	+Liaud, Vignon, Hughes (YALE, ISNG)
FETPL 20 345 Femological Process Femol	KROHN	75	PI 55R 175	+Ringo /ANI \
Also 70 NP A154 160 Paul (VIEN)			JETPL 20 345	Erozolimskii, Mostovoy, Fedunin, Frank+
Also 70 NP A154 160 Paul (VIEN)			Iransiated from ZETFP ZPHY 267 129	20 /45. +Paul (LINZ)
COHEN 73 JPCRD 2 663 + Taylor (RISC, NBS) CHRISTENSEN 72 PR D5 1628 +Nielson, Bahnsen, Brown+ (RISC, NBS) CHRISTENSEN 70 PR C1 1693 +Krohn, Ringo (ANL) EROZOLIM 70C PL 33B 351 Erozolimskii, Bondarenko, Mostovoy, Obinyakov + (KIAE) GRIGOREV 68 S.NIP 6 239 Grigori'ev, Grishin, Vladimirsky, Nikolaevskii-+ (KIAE)		70	NP A154 160	Paul (VIEN)
CHRISTENSEN 72 PR D5 1628 +Nilston, Bahnsen, Brown+ (RISO) CHRISTENSEN 79 PK C1 1693 +Krohn, Ringo (ANI.) EROZOLIM 70C PL 338 351 Erozolimskii, Bondarenko, Mostovoy, Obinyakov (KIAE) GRIGOREV 68 S.NIP 6 239 Grizor'sv. Grithin. Valdimirsky. Nikolaevskii-+ (KIAE)	COHEN	73	JPCRD 2 663	+Tavlor (YALE, ISNG) +Tavlor (RISC NIRC)
GRIGOREV 68 SJNP 6 239 Grigor'ev, Grishin, Vladimirsky, Nikolaevskii+ (ITEP)	CHRISTENSEN	72	PR D5 1628	+Nielson, Bahnsen, Brown+ (RISO)
GRIGOREV 68 SJNP 6 239 Grigor'ev, Grishin, Vladimirsky, Nikolaevskii+ (ITEP)	CHRISTENSEN EROZOLIM		PR C1 1693 Pt 33R 351	+Krohn, Ringo (ANL)
Translated from YAF 6 329.	GRIGOREV		SJNP 6 239	Grigor'ev, Grishin, Vladimirsky, Nikolaevskii+ (ITEP)
			Translated from YAF 6	329.

NOTE ON N AND A RESONANCES

Written December 1997 by R.L. Workman (Virginia Polytechnic Institute and State University).

I. Introduction

The excited states of the nucleon have been studied in a large number of formation and production experiments. The conventional (Breit-Wigner) masses, pole positions, widths, and elasticities of the N and Δ resonances in the Baryon Summary Table come almost entirely from partial-wave analyses of πN total, elastic, and charge-exchange scattering data. Partial-wave analyses have also been performed on much smaller data sets to get $N\eta$, ΛK , and ΣK branching fractions. Other branching fractions come from isobar-model analyses of $\pi N \to N\pi\pi$ data. Finally, many $N\gamma$ branching fractions have been determined from photoproduction experiments.

Table 1 lists all the N and Δ entries in the Baryon Listings and gives our evaluation of the status of each, both overall and channel by channel. Only the "established" resonances (overall status 3 or 4 stars) appear in the Baryon Summary Table. We consider a resonance to be established only if it has been seen in at least two independent analyses of elastic scattering and if the relevant partial-wave amplitudes do not behave erratically or have large errors.

Two changes have been made in the Baryon Summary Table: The $\Delta(1900)$ S_{31} state has been downgraded from three stars to two due to its weak signal in speed plots, and thus has been dropped from the Table. More importantly, pole parameters have been added to the Table, as these tend to be less model dependent than parameters found in fits using generalized Breit-Wigner formulas. This point is the subject of the next section.

No new elastic partial-wave analyses have been published since our last *Review*, although some preliminary results were reported at MENU 97 [1], which also contains recent studies of the πN σ term, scattering lengths, and possible isospin-breaking effects.

Several inelastic scattering analyses are now underway [2–5]. Most of them use $\pi N \to N\eta$ data, together with $\pi N \to \pi N$ data, in order to obtain improved values of the properties of the N(1535) S_{11} . The Pittsburgh-ANL [2] and Giessen [3] coupled-channel analyses are similar in scope to that of Manley and Saleski [6], but they differ in theoretical approach and in also using electromagnetic channels.

The interested reader will find further discussions in the proceedings of two recent conferences [7,1], and in two older reviews [8,9].

Baryon Particle Listings N's and Δ 's

Table 1. The status of the N and Δ resonances. Only those with an overall status of *** or **** are included in the main Baryon Summary Table.

							Statu	ıs as se	en in -	_	
Particle	$L_{2I\cdot 2J}$	Overall status	$N\pi$	$N\eta$	ΛK	ΣK	$\Delta\pi$	$N\rho$	$N\gamma$		
N(939)	P_{11}	****									
N(1440)	P_{11}	****	****	*			***	*	***		
N(1520)	D_{13}	****	****	*			****	****	****		
N(1535)	S_{11}	****	****	***			*	**	***		
N(1650)	S_{11}	****	****	*	***	**	***	**	***		
N(1675)	D_{15}	****	****	*	*		***	*	****		
N(1680)	F_{15}	****	****				****	****	****		
N(1700)	D_{13}	***	***	*	**	*	**	*	**		
N(1710)	P_{11}	***	***	**	**	*	**	*	***		
N(1720)	P_{13}	****	****	*	**	*	*	**	**		
N(1900)	P_{13}	**	**					*			
N(1990)	F_{17}	**	**	*	*	*			*		
N(2000)	F_{15}	**	**	*	*	*	*	**			
N(2080)	D_{13}	**	**	*	*				*		
N(2090)	S_{11}	*	*								
N(2100)	P_{11}	*	*	*							
N(2190)	G_{17}	****	****	*	*	*		*	*		
N(2200)	D_{15}	**	**	*	*						
N(2220)	H_{19}	****	****	*							
N(2250)	G_{19}	****	***	*							
N(2600)	I_{111}	***	***								
N(2700)	K_{113}	**	**								
$\Delta(1232)$	P_{33}	****	****	F					***		
$\Delta(1600)$	P_{33}	***	***	o			***	*	**		
$\Delta(1620)$	S_{31}	****	****	r			****	****	***		
$\Delta(1700)$	D_{33}	****	****	b		*	***	**	***		
$\Delta(1750)$	P_{31}	*	*	i							
$\Delta(1900)$	S_{31}	**	**	•	l	*	*	**	*		
$\Delta(1905)$	F_{35}	****	****		d	*	**	**	***		
Δ (1910)	P_{31}	****	***		e	*	*	*	*		
$\Delta(1920)$	P_{33}	***	***		n	*	**		*		
$\Delta(1930)$	D_{35}	***	***			*			**		
$\Delta(1940)$	D_{33}	*	*	\mathbf{F}							
$\Delta(1950)$	F_{37}	****	****	0		*	****	*	****		
$\Delta(2000)$	F_{35}	**		r				**			
$\Delta(2150)$	S_{31}	*	*	b							
$\Delta(2200)$	G_{37}	*	*	i							
$\Delta(2300)$	H_{39}	**	**	Ċ	l						
	D_{35}	*	*		d						
$\Delta(2390)$	F_{37}	*	*		e						
∆(2400)	G_{39}	**	**		n						
4 (0 . 00)	$H_{3.11}$	****	****						*		
$\Delta(2420)$	011										
$\Delta(2420)$ $\Delta(2750)$	$I_{313} K_{315}$	**	**								

- **** Existence is certain, and properties are at least fairly well explored.

 *** Existence ranges from very likely to certain, but further confirmation is desirable and/or quantum numbers, branching fractions, etc. are not well determined.
- ** Evidence of existence is only fair.
- * Evidence of existence is poor.

References for Section I

- Proceedings of the 7th International Symposium on Meson-Nucleon Physics and the Structure of the Nucleon (MENU 97), (Vancouver, July 1997), πN Newsletter No. 13 (1997).
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II. Against Breit-Wigner parameters — a pole-emic

Written December 1997 by G. Höhler (University of Karlsruhe).

(1) All theoretical approaches to the resonance phenomenon have in common that the variation of a partial-wave amplitude T(W), where W is the total c.m. energy, is related to a nearly bound state of the projectile-target system (see e.g., Refs. [1–5]). In πN scattering, this state is an excited state of the nucleon (= isobar). The nearly bound state is described in the framework of S-matrix theory by a pole of the S-matrix element at $W_p = M - i\Gamma/2$ in the lower half of the complex W-plane, close to the real axis; M and Γ are called the mass and width of the resonance. The location of the resonance pole is the same for all reactions to which the resonance couples.

In the inelastic region, a resonance is associated with a cluster of poles on different Riemann sheets. If one of these poles is located near the real axis and sufficiently far from branch points, it will be strongly dominant. If one of the final-state particles itself has a strong decay, one also has to consider branch points in the lower half plane that belong to thresholds for two-particle final states (see e.g., Refs. [6,7]).

- (2) If the formation of an unstable intermediate particle occurs in a scattering process, one expects a time-delay between the arrival of the incident wave packet and its departure from the collision region. Goldberger and Watson [8], starting from earlier work by Wigner, derived for elastic scattering the time-delay Q. Expressed in terms of the amplitude T(W), it is $Q=2\,Sp(W)$, where Sp(W)=|dT/dW| is the speed with which the complex vector T traverses the Argand diagram. If the background can be neglected, a resonance pole leads to a peak of Sp(W) at W=M (see the cited books and Refs. [9-11]).
- (3) It is an old tradition that authors of partial-wave analyses determine conventional resonance parameters from fits to generalized Breit-Wigner formulas. Each group has its own prescription for the treatment of analyticity, the choice of the background, and other details, so the model-dependence is much larger than in the determination of pole parameters. A serious shortcoming is the poor or missing information on inelastic channels. The conventional parameters are the "mass" m, the "width" $\Gamma(W)$ at W=m, and the branching ratios. Following are some problems with these parametrizations.
- (a) The conventional $\Delta(1232)$ parameters come from a fit to the P33 partial wave. It is well known from the Chew-Low plot and dispersion relations [12] that this partial wave

has a large background from the nucleon pole term. The pole position, $1210-50\,i$ MeV, belongs to the Δ -resonance, whereas the conventional parameters, m=1232 MeV and $\Gamma(m)=120$ MeV, belong to the Δ together with the large background in πN scattering.

(b) The N(1535) S_{11} is the only 4-star resonance that does not show a signal in the speed plot. The signal is probably part of the large peak due to the threshold for η production [13]. In this case, poles in other Riemann sheets are expected to give contributions of comparable magnitude. One of these poles produces the threshold cusp [6]. In the 1960's, this problem was treated in many papers (see Ref. 13). In calculations that rely on the conventional mass of 1535 MeV, one cannot see that one has to study a combined resonance plus threshold-cusp phenomenon.

A similar situation of poles in different sheets arises in $\pi\pi$ scattering near the $K\bar{K}$ threshold. See remarks in footnotes to our $f_0(980)$ Listing.

(c) Around 1440 MeV, the VPI group found two poles in the P_{11} amplitude in different Riemann sheets [14]. This was interpreted, by other authors, as evidence for the existence of two nearly degenerate P_{11} resonances, in conflict with the constituent quark model. Cutkosky pointed out that the branch point for $\Delta\pi$ decay is located near the poles, so the poles belong to the same resonance. This was confirmed by a new calculation [15], which also led to conventional parameters of m=1471 MeV and $\Gamma(m)=545$ MeV, which are much different from the pole parameters, 1370-114i and 1360-120i MeV. The speed plot confirms that the formation of the unstable particle N(1440) P_{11} occurs at a considerably lower energy than expected from the conventional parameters.

Conclusion: In contrast to the conventional parameters, the pole positions and speed plots have a well-defined relation to S-matrix theory. They also give more information on the resonances and thresholds and can be used for predictions on other reactions that couple to the excited states.

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III. Electromagnetic interactions

Revised December 1997 by R.L. Crawford (University of Glasgow) and R.L. Workman (Virginia Polytechnic Institute and State University).

Nearly all the entries in the Listings concerning electromagnetic properties of the N and Δ resonances are $N\gamma$ couplings. These couplings, the helicity amplitudes $A_{1/2}$ and $A_{3/2}$, have been obtained in partial-wave analyses of single-pion photoproduction, η photoproduction, and Compton scattering. Most photoproduction analyses take the existence, masses, and widths of the resonances from the $\pi N \to \pi N$ analyses, and only determine the $N\gamma$ couplings. A brief description of the various methods of analysis of photoproduction data may be found in our 1992 edition [1].

Our Listings omit a number of analyses that are now obsolete. Most of the older results may be found in our 1982 edition [2]. The errors quoted for the couplings in the Listings are calculated in different ways in different analyses and therefore should be used with care. In general, the systematic differences between the analyses caused by using different parameterization schemes are probably more indicative of the true uncertainties than are the quoted errors.

Probably the most reliable analyses, for most resonances, are ARAI 80, CRAWFORD 80, AWAJI 81, FUJII 81, CRAWFORD 83, and ARNDT 96. The $\Delta(1232)$ and N(1535) are special cases, discussed separately below. The errors we give are a combination of the stated statistical errors on the analyses and the systematic differences between them. The analyses are given equal weight, except ARNDT 96 is weighted, rather arbitrarily, by a factor of two because its data set is at least 50% larger than those of the other analyses and contains many new high-quality measurements. Again, the $\Delta(1232)$ and N(1535) are discussed separately below.

The Baryon Summary Table gives $N\gamma$ branching fractions for those resonances whose couplings are considered to be reasonably well established. The $N\gamma$ partial width Γ_{γ} is given in terms of the helicity amplitudes $A_{1/2}$ and $A_{3/2}$ by

$$\Gamma_{\gamma} = \frac{k^2}{\pi} \frac{2M_N}{(2J+1)M_R} \left[|A_{1/2}|^2 + |A_{3/2}|^2 \right] . \tag{1}$$

Here M_N and M_R are the nucleon and resonance masses, J is the resonance spin, and k is the photon c.m. decay momentum.

New results for $\Delta(1232) \to p\gamma$: Recent measurements of $\gamma p \to N\pi$ and $\gamma p \to \gamma p$ have fueled a number of new analyses

N's and Δ 's

across the first resonance region [3–7]. A central focus has been the E2/M1 ratio, evaluated at the K-matrix and T-matrix poles. The electric quadrupole (E2) and magnetic dipole (M1) amplitudes are related to our helicity amplitudes by

$$A_{1/2} = -\frac{1}{2}(M1 + 3E2)$$
 and $A_{3/2} = -\frac{\sqrt{3}}{2}(M1 - E2)$. (2)

Most recent estimates of the E2/M1 ratio, evaluated at the K-matrix pole, are considerably larger (in magnitude) than the average, $-1.5\pm0.4\%$, quoted in our 1996 Review. This quantity is quite sensitive to the database being fitted. Fits that exclude a few of the older Bonn measurements [8] tend to fall in the range $-2.5\pm0.5\%$. (Some analyses of the recent Mainz and BNL measurements suggest a central value closer to -3% [3,7].) The E2/M1 ratio appears to be relatively stable when evaluated at the T-matrix pole [9]. This ratio of pole residues has been added to the Full Listings [10].

Values of $A_{1/2}$ and $A_{3/2}$ from the RPI [3] and VPI [4] analyses are in reasonable agreement. However, the BNL [7] results are quite different, due to their larger cross sections for $\pi^0 p$ photoproduction. Previous estimates of the E2 and M1 amplitudes, at the K- and T-matrix poles, should be considered obsolete. Pole parameters given for the $\Delta^+(1232)$ in our 1996 Review are also obsolete (see Ref. [11]).

New results for $N(1535) \to p\gamma$: Properties of the N(1535) are difficult to extract from $\pi N \to \pi N$ and $\gamma N \to \pi N$ due to the nearby ηN threshold (see Sec. III). As a result, a number of recent analyses have been based on data from $\pi^- p \to \eta n$ and $\gamma p \to \eta p$. These studies, and those based on coupled-channel analyses including pion photoproduction data, generally find results [12–15] for $A_{1/2}$ that are significantly different from those based on pion photoproduction alone. In particular, $A_{1/2}$ is sensitive to the N(1535) mass and width, and to its interference with the N(1650) [15].

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IV. Outlook

Revised November 1997 by D.M. Manley (Kent State University).

In May 1997, a new program in baryon spectroscopy was initiated at the Brookhaven National Laboratory AGS with the Crystal Ball Spectrometer [1]. AGS Expt. E913 measures over most of a 4π solid angle the reactions $\pi^-p \to \gamma n$, $\pi^0 n$, ηn , and $\pi^0\pi^0 n$ at 12 momenta between 285 and 750 MeV/c. These measurements will be completed in 1998, and then AGS Expt. E914 will begin a study of hyperon resonances using the reactions $K^-p \to \text{neutrals}$.

Most of the new generation of experiments to study baryon spectroscopy will use electromagnetic probes. Commissioning experiments were carried out for the CEBAF Large Acceptance Spectrometer, CLAS, during mid 1997, using electron beams with energies of 1.6, 2.4, and 4.0 GeV. The first physics run began in December 1997. Initial measurements of $ep \rightarrow eX$ will be performed with 1.6- and 2.4-GeV electrons. Measurements with 4.0-GeV electrons are scheduled for early 1998. Runs with tagged photons are scheduled for early Spring and Summer, 1998. A number of experiments at CEBAF to study baryon resonances have already been completed, including studies of the $(e, e'K^+)$ reactions on hydrogen and deuterium targets [2], and studies of the $e^-p \rightarrow e^-p\eta$ reaction [3]. The E2/M1 ratio is being investigated using new measurements of the $p(e, e'p)\pi^0$ reaction near the $\Delta(1232)$ resonance, and new measurements of $p(e, e'\vec{p})\pi^0$ at the MIT-Bates Lab [4].

Much work is also underway in European facilities. For example, in 1996, studies of η and K photoproduction commenced at GRAAL in Grenoble [5]. This lab currently provides photon beams with energies up to 1.5 GeV, and may later upgrade to 1.8 GeV. Several reactions are under study there, including $\gamma p \to \gamma p$, ηp , $\pi^0 p$, $\pi^+ n$, and $\pi^0 \pi^0 p$. New meson photoproduction data are also being produced from experiments using the 855-MeV CW electron accelerator MAMI at Mainz, which produces photon beams with energies up to 800 MeV [6]. For example, new experiments of pion photoproduction with linearly polarized photons having energies up to 500 MeV are providing data on the E2/M1 ratio for the $\Delta(1232)$ resonance.

Space does not permit a full discussion of the large amount of experimental work now underway at the labs already mentioned, or at other labs such as Bonn. The new experiments have also inspired many new theoretical and phenomenological efforts to understand this particular aspect of nonperturbative QCD. These efforts include techniques such as lattice gauge

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theory, phenomenological Lagrangians, constituent quark-model calculations, and various unitary multichannel approaches.

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V. Non-qqq baryon candidates

The standard quark-model assignments for baryons are outlined in Sec. 13.3, "Baryons: qqq states." Just as with mesons (see the "Note on Non- $q\bar{q}$ mesons"), there have been suggestions that non-qqq baryons might exist, such as hybrid (qqqq) baryons and unstable meson-nucleon bound states [1] (see the "Note on the $\Lambda(1405)$ ").

If non-qqq states exist, they will be more difficult to identify than hybrid mesons: They will not have the clean signature of exotic quantum numbers, and they should also mix with ordinary qqq states. Their identification will depend upon (a) characteristics of their formation and decay, and (b) an over-population of expected qqq states.

Most investigations have focused on the properties of the lightest predicted hybrids. If the first hybrid state lies below 2 GeV, as is suggested by bag-model calculations [2,3,4], it may already exist in our Listings. (However, some estimates put the lightest state well above 2 GeV [5].) At present, there are actually not enough known resonances to fill the known multiplets. If an existing resonance is identified as a hybrid, yet another ordinary qqq state must be found.

The Roper resonance, the N(1440) P_{11} , has been a hybrid candidate based upon its quantum numbers [2] and difficulties with its mass and electromagnetic couplings. If it were a hybrid, our interpretation of the low-lying P_{11} , P_{13} , P_{31} , and P_{33} resonances would change [2,6]. In Ref. 6, both the N(1440) P_{11} and $\Delta(1600)$ P_{33} are hybrid candidates, and N(1540) P_{13} and $\Delta(1550)$ P_{31} states are predicted. One-star P_{13} and P_{31} states were listed in our 1990 Review [7] but were then removed.

Both photoproduction [6,8,9] and electroproduction [9,10] have been considered in the search for a unique hybrid signature. In Ref. 11, QCD counting rules were used to reveal

a characteristic of hybrid electroproduction at high Q^2 . If the N(1440) is a hybrid, its transverse form factor is expected to fall asymptotically $O(1/Q^2)$ faster than for a pure qqq state. However, mixing between qqq and qqqg states will make this identification difficult.

A number of recent experiments have searched for pentaquark $(qqqq\bar{q})$ resonances and H dibaryons (uuddss) states). Narrow structures found in proton-nucleus scattering [12] have been attributed to $qqqs\bar{s}$ states, but these need confirmation. The H-dibaryon experiments, while finding possible candidates [13], have generally quoted upper limits [14] for exotic resonance production. Searches for narrow dibaryons in the nucleon-nucleon interaction are also continuing [15].

Finally, there has been a report [16] of resonances lying below the $\Delta(1232)$. A very weak signal was found using the reaction $pp \to \pi^+ p X^0$. An earlier search [17] for isospin-3/2 states, using $pp \to n X^{++}$, found a null result in the mass range between M_N and $M_N + M_\pi$. At present, there appears to be no evidence for such low-mass states from other reactions.

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N(1440)

N(1440) P₁₁

 $I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$ Status: ***

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters 111B (1982).

N(1440) BREIT-WIGNER MASS

VALUE (MeV)			TECN	COMMENT
1430 to 1470 (≈ 1440)	OUR ESTIMATE			
1462±10	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
1440±30	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
1410±12	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use t	he following data for average	s, fit	s, limits,	etc. • • •
1463± 7	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
1467	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
1421±18	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$
1465	LI	93	IPWA	$\gamma N \rightarrow \pi N$
1471	CUTKOSKY	90	IPWA	$\pi N \rightarrow \pi N$
1411	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
1472	¹ BAKER	79	DPWA	$\pi^- \rho \rightarrow n\eta$
1417	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
1460	BERENDS	77	IPWA	$\gamma N \rightarrow \pi N$
1380	² LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
1390	³ LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

N(1440) BREIT-WIGNER WIDTH

250 to 450 (≈ 350) OUR ESTIM			TECN	COMMENT
200 10 400 (A 300) COK E3 HM	ATE			
391± 34	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
545±170	CUTKOSKY	90	IPWA	$\pi N \rightarrow \pi N$
340 ± 70	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
135± 10	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following	ng data for average	s, fit	s, limits,	etc. • • •
360± 20	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
440	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
250± 63	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$
315	LI	93	IPWA	$\gamma N \rightarrow \pi N$
334	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
113	¹ BAKER	79	DPWA	$\pi^- p \rightarrow n\eta$
331	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
279	BERENDS	77	IPWA	$\gamma N \rightarrow \pi N$
200	² LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
200	3 LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

N(1440) POLE POSITION

REAL PART				
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1345 to 1385 (≈ 1365) OUR	ESTIMATE			
1346	4 ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
1385	⁵ HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
1370	CUTKOSKY	90	IPWA	$\pi N \rightarrow \pi N$
1375±30	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the foll	owing data for average	s, fit	s, limits,	etc. • • •
1360	⁶ ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
1381 or 1379	⁷ LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$
1360 or 1333	² LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
-2×IMAGINARY PART				
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
160 to 260 (≈ 210) OUR ES	TIMATE			
176	4 ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
164	⁵ HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
228	CUTKOSKY	90	IPWA	$\pi N \rightarrow \pi N$
180±40	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the foll	owing data for average	s, flt	s, limits,	etc. • • •
252	⁶ ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
209 or 210	7 LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$
	² LONGACRE	77	1D\A/A	$\pi N \rightarrow N \pi \pi$

N(1440) ELASTIC POLE RESIDUE

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
42	⁴ ARNDT	95	DPWA	$\pi N \rightarrow N\pi$
40	HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
74	CUTKOSKY	90	IPWA	$\pi N \rightarrow \pi N$
52±5	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
	e following data for average			
	6			

PHASE #					
VALUE (°)	DOCUMENT ID		TECN	COMMENT	<u> </u>
- 101	⁴ ARNDT	95	DPWA	$\pi N \rightarrow I$	Vπ
- 84	CUTKOSKY	90	IPWA	$\pi N \rightarrow \pi$	r N
-100 ± 35	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi$	r N
• • • We do not use the fo	illowing data for average	es, fit	s, iimits,	etc. • •	•
- 93	⁶ ARNDT	91	DPWA	$\pi N \rightarrow \tau$	r N Soln SM90

N(1440) DECAY MODES

The following branching fractions are our estimates, not fits or averages.

	Mode	Fraction (Γ_I/Γ)	
Γ ₁	Nπ	60-70 %	
Γ_2	$N\eta$		
۲3	Νππ	30-40 %	
Γ4	$\Delta\pi$	20-30 %	
Γ ₅	$\Delta(1232)\pi$, $ extcolored{P}$ -wave		
۲6	$N\rho$	<8 %	
Γ ₆ Γ ₇	$N\rho$, $S=1/2$, P -wave		
Γ8	$N\rho$, $S=3/2$, P -wave		
Г9	$N(\pi\pi)_{\text{S-wave}}^{I=0}$	5–10 %	
Γ ₁₀	$p\gamma$	0.035-0.048 %	
Γ11	$p\gamma$, helicity= $1/2$	0.035-0.048 %	
Γ ₁₂	$n\gamma$	0.009-0.032 %	
Γ ₁₃	$n\gamma$, helicity= $1/2$	0.009-0.032 %	

N(1440) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$				Γ ₁ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
0.6 to 0.7 OUR ESTIMAT	E			
0.69±0.03	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
0.68±0.04	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
0.51±0.05	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the fo	ollowing data for averag	es, fit	s, limits,	etc. • • •
0.68	ARNDT	95	DPWA	$\pi N \rightarrow N\pi$
0.56±0.08	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N \pi -$	• N(1440) → Nη			(Γ₁Γ₂) ^{1/2} /Γ
VALUE	DOCUMENT ID		TECN_	COMMENT
• • • We do not use the fo	ollowing data for averag	es, fit	s, limits,	etc. • • •
seen	¹ BAKER	79	DPWA	$\pi^- p \rightarrow n\eta$
+0.328	8 FELTESSE	75	DPWA	1488-1745 MeV

Note: Signs of couplings from $\pi N \to N\pi\pi$ analyses were changed in the 1986 edition to agree with the baryon-first convention; the overall phase ambiguity is resolved by choosing a negative sign for the $\Delta(1620)$ S_{31} coupling to $\Delta(1232)\pi$.

(「/「f) ⁷² /「total in /	$V\pi \to N(1440) \to \Delta(1232)\pi$, P-wave $(\Gamma_1\Gamma_5)^{\frac{1}{2}}/\Gamma$
VAI HE	DOCUMENT ID TECN COMMENT
+0.37 to +0.41 OUR	ESTIMATE
$+0.39\pm0.02$	MANLEY 92 IPWA $\pi N \rightarrow \pi N \& N \pi \pi$
+ 0.41	^{2,9} LONGACRE 77 IPWA $\pi N \rightarrow N \pi \pi$
+0.37	³ LONGACRE 75 IPWA $\pi N \rightarrow N \pi \pi$
([,[,c]) ^{1/2} /[,max in /	$V\pi \rightarrow N(1440) \rightarrow N\rho$, S=1/2, P-wave $(\Gamma_1\Gamma_7)^{\frac{1}{2}}/\Gamma$
VALUE	DOCUMENT ID TECN COMMENT
±0.07 to ±0.2	DOCUMENT ID TECN COMMENT 5 OUR ESTIMATE
-0.11	^{2,9} LONGACRE 77 IPWA $\pi N \rightarrow N \pi \pi$
+0.23	³ LONGACRE 75 IPWA $\pi N \rightarrow N \pi \pi$
([,[,c]) ^{1/2} /[$N\pi \rightarrow N(1440) \rightarrow N\rho$, S=3/2, P-wave $(\Gamma_1 \Gamma_0)^{\frac{1}{2}}/\Gamma$
VALUE	DOCUMENT ID TECN COMMENT
+0.18	$\frac{DOCUMENT\ ID}{2.9} \begin{array}{cccc} \underline{TECN} & \underline{COMMENT} \\ \hline 2.9 & \underline{LONGACRE} & 77 & \underline{IPWA} & \pi N \rightarrow N \pi \pi \end{array}$
$(\Gamma_I \Gamma_{i^*})^{\frac{1}{2}} / \Gamma_{\text{total}}$ in I	$V\pi \to N(1440) \to N(\pi\pi)_{S-wave}^{I=0}$ $(\Gamma_1\Gamma_9)^{\frac{1}{2}}/\Gamma$
VALUE	DOCUMENT ID TECN COMMENT
	S OUR ESTIMATE
±0.17 to ±0.2	MANLEY 92 IPWA $\pi N \rightarrow \pi N \& N \pi \pi$
	MANLEY 92 IPWA $\pi N \rightarrow \pi N \& N \pi \pi$ 2,9 LONGACRE 77 IPWA $\pi N \rightarrow N \pi \pi$ 3 LONGACRE 75 IPWA $\pi N \rightarrow N \pi \pi$

N(1440) PHOTON DECAY AMPLITUDES

$N(1440) \rightarrow p\gamma$, helicity-1/2 amplitude $A_{1/2}$

VALUE (GeV ^{-1/2})	DOCUMENT ID		TECN	COMMENT
-0.065 ±0.004 OUR ESTIMATI	E			
-0.063 ±0.005	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
-0.069 ±0.018	CRAWFORD	83	IPWA	$\gamma N \rightarrow \pi N$
-0.063 ±0.008	ILAWA	81	DPWA	$\gamma N \rightarrow \pi N$
-0.069 ±0.004	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
-0.066 ±0.004	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$
-0.079 ±0.009	BRATASHEV	80	DPWA	$\gamma N \rightarrow \pi N$
-0.068 ±0.015	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
-0.0584 ± 0.0148	ISHII	80	DPWA	Compton scattering
	data for averages	, fits	, limits,	etc. • • •
-0.085 ±0.003		93	IPWA	$\gamma N \rightarrow \pi N$
-0.129	¹⁰ WADA	84	DPWA	Compton scattering
-0.075 ±0.015		78	DPWA	$\gamma N \rightarrow \pi N$
-0.125	¹¹ NOELLE	78		$\gamma N \rightarrow \pi N$
_0.076	BERENDS	77	IPWA	~N → πN

FELLER

76 DPWA $\gamma N \rightarrow \pi N$

$N(1440) \rightarrow n\gamma$, helicity-1/2 amplitude A_{1/2}

-0.087 ±0.006

VALUE (GeV ^{-1/2})	DOCUMENT ID		TECN	COMMENT
+0.040±0.010 OUR ESTIMA	NTE			
0.045±0.015	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
0.037±0.010	ILAWA	81	DPWA	$\gamma N \rightarrow \pi N$
0.030 ± 0.003	FUJII	81	DPWA	$\gamma N \rightarrow \pi N$
0.023 ± 0.009	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
0.019 ± 0.012	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$
0.056 ± 0.015	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
-0.029 ± 0.035	TAKEDA	80	DPWA	$\gamma N \rightarrow \pi N$
• • • We do not use the folk	owing data for average	s, fit	s, Ilmits,	etc. • • •
0.085 ± 0.006	LI	93	IPWA	$\gamma N \rightarrow \pi N$
+0.059±0.016	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
0.062	11 NOELLE	78		$\gamma N \rightarrow \pi N$

N(1440) FOOTNOTES

- 1 BAKER 79 finds a coupling of the N(1440) to the N η channel near (but slightly below)
- Threshold. To pole positions are from a search for poles in the unitarized T-matrix; the first (second) value uses, in addition to $\pi N \to N\pi\pi$ data, elastic amplitudes from a Saclay (CERN) partial-wave analysis. The other LONGACRE 77 values are from eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.

 3 From method II of LONGACRE 75: eyeball fits with Breit-Wigner circles to the T-matrix
- ARNDT 95 also finds a second-sheet pole with real part = 1383 MeV, -2×imaginary part = 210 MeV, and residue with modulus 92 MeV and phase = -54°.
- ⁵ See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and Δ resonances as determined from Argand diagrams of πN elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams.
- 6 ARNOT 91 (Soln SM90) also finds a second-sheet pole with real part = 1413 MeV, $-2 \times$ Imaginary part = 256 MeV, and residue = (78–153/) MeV.
- ⁷ LONGACRE 78 values are from a search for poles in the unitarized T-matrix. The first (second) value uses, in addition to $\pi N \to N \pi \pi$ data, elastic amplitudes from a Saclay (CERN) partial-wave analysis.
- An alternative which cannot be distinguished from this is to have a P_{13} resonance with M=1530 MeV, $\Gamma=79$ MeV, and elasticity = +0.271. 9 LONGACRE 77 considers this coupling to be well determined.
- 10 WADA 84 is inconsistent with other analyses; see the Note on N and Δ Resonances,
- 11 Converted to our conventions using M= 1486 MeV, $\Gamma=613$ MeV from NOELLE 78.

N(1440) REFERENCES

For early references, see Physics Letters 111B 70 (1982).

ARNDT	96	PR C53 430	+Strakovsky, Workman		(VPI)	
ARNDT	95	PR C52 2120	+Strakovsky, Workman, Pavan	(VPI.	BRCO	
BATINIC	95	PR C51 2310	+Slaus, Svarc, Nefkens	(BOSK,		
HOEHLER	93	π N Newsletter 9 1	County overcy received		(KARL)	
LI	93	PR C47 2759	+Arndt, Roper, Workman		(VPI)	
MANLEY	92	PR D45 4002	+Saleski	1	(KENT)	
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz		(VPI)	
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI	. TELEÎ	
CUTKOSKY	90	PR D42 235	+Wang		(CMU)	1
WADA	84	NP B247 313	+Egawa, Imanishi, Ishii, Kato, Ukai+		INUS	1
CRAWFORD	83	NP B211 1	+ Morton		(GLAS	í
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT.		í
ILAWA	81	Bonn Conf. 352	+Kajikawa	` ' '	NAGO	i
Also	82	NP B197 365	Fujii, Hayashii, Iwata, Kajikawa+		NAGO	1
FUJII	81	NP B187 53	+Hayashii, Iwata, Kajikawa+	(NAGO.	OSAK	í
ARAI	80	Toronto Conf. 93		• • •	(INUS	í
Also	82	NP B194 251	Arai, Fujii		INUS	1
BRATASHEV		NP 8166 525	Bratashevskii, Gorbenko, Derebchinskii-	+	(KFTI	

CRAWFORD	80	Toronto Conf. 107		(GLAS)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMŮ, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJP
ISHII	80	NP B165 189	+Erawa, Kato, Miyachi+	(KYOT, INUS)
TAKEDA	80	NP B168 17	+Arai, Fuili, Ikeda, Iwasaki+	(TOKY, INUS)
BAKER	79	NP B156 93	+Brown, Clark, Davies, Depagter, Evans+	(RHEL) IJP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) UP
Also	80	Toronto Conf. 3	Koch	(KARLT) UP
BARBOUR	78	NP B141 253	+Crawford, Parsons	(GLAS)
LONGACRE	78	PR D17 1795	+Lasinski, Rosenfeld, Smadia+	(LBL, SLAC)
NOELLE	78	PTP 60 778	,, , , , , , , , , , , , , , , , ,	(NAGO)
BERENDS	77	NP B136 317	+Donnachie	(LEID, MCHS) UP
LONGACRE	77	NP B122 493	+ Dolbeau	(SACL) UP
Also	76	NP B108 365	Dolbeau, Triantis, Neveu, Cadiet	(SACL) IJP
FELLER	76	NP B104 219	+Fukushima, Horikawa, Kalikawa+	(NAGO, OSAK) IJP
FELTESSE	75	NP B93 242	+Ayed, Bareyre, Borgeaud, David+	(SACL) IJP
LONGACRE	75	PL 55B 415	+Rosenfeld, Lasinski, Smadja+	(LBL, SLAC) IJP

 $N(1520) D_{13}$

 $I(J^P) = \frac{1}{2}(\frac{3}{2}^-)$ Status: ***

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters 111B (1982).

N(1520) BREIT-WIGNER MASS

/ALUE (MeV)	DOCUMENT ID		TECN	COMMENT
.515 to 1530 (≈ 1520)	OUR ESTIMATE			
524± 4	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
525 ± 10	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
519± 4	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • We do not use ti	he following data for average	s, fit	s, limits,	etc. • • •
516±10	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
515	ARNDT	95	DPWA	$\pi N \rightarrow N\pi$
526 ± 18	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$
510	น	93	IPWA	$\gamma N \rightarrow \pi N$
504	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
503	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
510	BERENDS	77	IPWA	$\gamma N \rightarrow \pi N$
510	1 LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
520	² LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

N(1520) BREIT-WIGNER WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
110 to 135 (≈ 120) OUR ES	TIMATE			
124± 8	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
120±15	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
114± 7	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the fol	lowing data for average	s, fit	s, limits,	etc. • • •
106± 4	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
106	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
143±32	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$
120	LI	93	IPWA	$\gamma N \rightarrow \pi N$
124	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
183	BAKER	79	DPWA	$\pi^- p \rightarrow n\eta$
135	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
105	BERENDS	77	IPWA	$\gamma N \rightarrow \pi N$
110	¹ LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
150	² LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

N(1520) POLE POSITION

REAL PART				
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1505 to 1515 (≈ 1510) (DUR ESTIMATE			
1515	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
1510	3 HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
1510±5	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the	e following data for average	s, fit	s, limits,	etc. • • •
1511	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
1514 or 1511	⁴ LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$
1508 or 1505	¹ LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
-2×IMAGINARY P	ART			
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
110 to 120 (≈ 115) OUF	RESTIMATE			
110	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
120	³ HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
114±10	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the	e following data for average	s, fit	s, limits,	etc. • • •
108	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soin SM90
146 or 137	⁴ LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$
109 or 107	¹ LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$

Baryon Particle Listings *N*(1520)

N((1520)				
		(1520) ELASTIC POL	E F	RESIDU	E
MO	DULUS r				
	E (MeV)	DOCUMENT ID		TECN	COMMENT
34		ARNDT	95	DPWA	$\pi N \rightarrow N\pi$
32		HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
35±	2	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • •	• We do not use the	following data for average	s, fit	s, limits,	etc. • • •
33		ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
D114	CF 0				
VALU	ISE 0	DOCUMENT ID		TECN	COMMENT
7		ARNDT			$\pi N \rightarrow N\pi$
- 8		HOEHLER			
- 12	+5	CUTKOSKY			
		following data for average			
10		ARNDT	-		$\pi N \rightarrow \pi N \text{ Soln SM90}$
		AMIDI		DI 117	#14 - 7 # 14 SOIII SH150
		N(1520) DECAY	ON	DES	
	The following bra	anching fractions are our e	stim	ates, not	fits or averages.
	Mode		Frac	tion (Γ_I /	r)
$\overline{\Gamma_1}$	Νπ		50-6	0%	
Γ_2	Nη				
۲3	Νππ		40-5	0 %	
Γ_4	$\Delta \pi$		15~2		

	Mode	Fraction (Γ _I /Γ)	
Γ ₁	Νπ	50-60 %	
Γ_2	Nη		
Гз	$N\pi\pi$	40-50 %	
Γ4	$\Delta\pi$	15~25 %	
Γ ₅	Δ (1232) π , S -wave	5-12 %	
Γ6	$\Delta(1232)\pi$, <i>D</i> -wave	10–14 %	
Γ7	$N\rho$	15-25 %	
Гв	$N\rho$, $S=1/2$, D -wave		
Г9	Nρ, 5=3/2, S-wave		
Γ ₁₀	$N\rho$, $S=3/2$, D-wave		
Γ11	$N(\pi\pi)^{I=0}_{S-wave}$	<8 %	
Γ12	Pγ	0.46-0.56 %	
Γ ₁₃	$p\gamma$, helicity=1/2	0.001-0.034 %	
Γ ₁₄	$p\gamma$, helicity=3/2	0.44-0.53 %	
Γ_{15}	$n\gamma$	0.30~0.53 %	
Γ16	$n\gamma$, helicity=1/2	0.04~0.10 %	
r ₁₇	$\pi\gamma$, helicity=3/2	0.25-0.45 %	

N(1520) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$				1	Γ ₁ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT	
0.5 to 0.6 OUR ESTIMAT	TE .				
0.59±0.03	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi 1$	۲.
0.58±0.03	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$	
0.54±0.03	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$	
 • • We do not use the f 	following data for averag	es, fit	s, Ilmits,	etc. • • •	
0.61	ARNDT	95	DPWA	$\pi N \rightarrow N\pi$	
0.46±0.06	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$	
$\Gamma(N\eta)/\Gamma_{\text{total}}$				1	Γ2/Γ
VALUE	DOCUMENT ID		TECN	COMMENT	
• • • We do not use the f	following data for average	es, fit	s, limits,	etc. • • •	
0.001±0.002	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$	
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N_{\pi} -$	→ N(1520) → Nπ			(F ₁ F ₂)	½ /୮
VALUE	DOCUMENT ID		TECN	COMMENT	
• • • We do not use the f	following data for average	es, fit	s, limits,	etc. • • •	
0.02	BAKER	79	DPWA	$\pi^- p \rightarrow n\eta$	
		75	DPWA	Soin A; see BAKER	

Note: Signs of couplings from $\pi\,N \to N\,\pi\,\pi$ analyses were changed in the 1986 edition to agree with the baryon-first convention; the overall phase ambiguity is resolved by choosing a negative sign for the $\Delta(1620)\,S_{31}$ coupling to $\Delta(1232)\,\pi$.

VALUE	$l\pi \rightarrow N(1520) \rightarrow \Delta(123)$				(Γ₁Γ₅) ^⅓ /Γ
-0.26 to -0.20 OUR	ESTIMATE				
-0.18 ± 0.05	MANLEY				πΝ & Νππ
-0.26	^{1,5} LONGACRE				
-0.24	² LONGACRE	75	IPWA	$\pi N \rightarrow$	Νππ
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N$	$l\pi \to N(1520) \to \Delta(123)$	2)π	D-way	re.	(Γ ₁ Γ ₆) ^½ /Γ
	DOCUMENT ID				
VALUE	DOCOMENT ID				<u> </u>
VALUE -0.26 to -0.24 OUR	ESTIMATE		150.1	COMME	"
	ESTIMATE MANLEY		IPWA		πΝ&Νππ
-0.28 to -0.24 OUR	ESTIMATE	92	IPWA	$\pi N \rightarrow$	πΝ&Νππ

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\pi \rightarrow$	$N(1520) \rightarrow N\rho$, $S=3/2$, S-wave $(\Gamma_1\Gamma_9)^3$
VALUE -0.35 to -0.31 OUR ESTI	DOCUMENT ID TECH COMMENT
-0.35±0.03	MANLEY 92 IPWA $\pi N \rightarrow \pi N \& N \pi \pi$
-0.35	^{1,5} LONGACRE 77 IPWA $\pi N \rightarrow N \pi \pi$
-0.24	² LONGACRE 75 IPWA $\pi N \rightarrow N \pi \pi$
$(\Gamma_i \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N \pi \rightarrow$	$N(1520) \rightarrow N(\pi\pi)^{l=0}_{S-wave}$ $(\Gamma_1\Gamma_{11})^{\frac{1}{2}}$
-0.22 to -0.06 OUR EST1	MATE
~0.13	1,5 LONGACRE 77 IPWA $\pi N \rightarrow N \pi \pi$
0.17	² LONGACRE 75 IPWA $\pi N \rightarrow N \pi \pi$
N(1520) PHOTON DECAY AMPLITUDES
$N(1520) \rightarrow p\gamma$, helicity	y-1/2 amplitude A _{1/2}
VALUE (GeV ^{-1/2})	DOCUMENT ID TECN COMMENT
-0.024 ±0.009 OUR EST -0.020 ±0.007	ARNDT 96 IPWA $\gamma N \rightarrow \pi N$
-0.028 ±0.014	CRAWFORD 83 IPWA $\gamma N \rightarrow \pi N$
-0.007 ±0.004	AWAJI 81 DPWA $\gamma N \rightarrow \pi N$
-0.032 ±0.005	ARAI 80 DPWA $\gamma N \rightarrow \pi N$ (fit 1)
-0.032 ±0.004	ARAI 80 DPWA $\gamma N \rightarrow \pi N$ (fit 2)
-0.031 ±0.009	BRATASHEV80 DPWA $\gamma N \rightarrow \pi N$
-0.019 ±0.007 -0.0430±0.0063	CRAWFORD 80 DPWA γ N → π N ISHII 80 DPWA Compton scattering
	llowing data for averages, fits, limits, etc. • •
-0.020 ±0.002 -0.012	LI 93 IPWA $\gamma N \rightarrow \pi N$ WADA 84 DPWA Compton scattering
-0.012 -0.016 ±0.008	BARBOUR 78 DPWA $\gamma N \rightarrow \pi N$
-0.008	6 NOELLE 78 $\gamma N \rightarrow \pi N$
-0.021	BERENDS 77 IPWA $\gamma N \rightarrow \pi N$
0.005 ±0.005	FELLER 76 DPWA $\gamma N \rightarrow \pi N$
$N(1520) \rightarrow p\gamma$, helicity	•
VALUE (GeV-1/2) +0.166 ±0.005 OUR EST	DOCUMENT ID TECN COMMENT
0.167 ±0.005	ARNDT 96 IPWA $\gamma N \rightarrow \pi N$
0.156 ±0.022	CRAWFORD 83 IPWA $\gamma N \rightarrow \pi N$
0.168 ±0.013	AWAJI 81 DPWA $\gamma N \rightarrow \pi N$
0.178 ±0.003	ARAI 80 DPWA $\gamma N \rightarrow \pi N$ (fit 1)
0.162 ±0.003	ARAI 80 DPWA $\gamma N \rightarrow \pi N$ (fit 2)
0.166 ±0.005 0.167 ±0.010	BRATASHEV80 DPWA $\gamma N \rightarrow \pi N$ CRAWFORD 80 DPWA $\gamma N \rightarrow \pi N$
0.1695±0.0014	ISHII 80 DPWA Compton scattering
	llowing data for averages, fits, limits, etc. • • •
0.167 ±0.002	1.1 93 IPWA ~N → πN
0.168	WADA 84 DPWA Compton scattering
+0.157 ±0.007	BARBOUR 78 DPWA $\gamma N \rightarrow \pi N$
0.206	6 NOELLE 78 $\gamma N \rightarrow \pi N$
+0.075 +0.164 ±0.008	BERENDS 77 IPWA $\gamma N \rightarrow \pi N$ FELLER 76 DPWA $\gamma N \rightarrow \pi N$
	,
$N(1520) \rightarrow n\gamma$, helicity	y-1/2 amplitude A _{1/2}
VALUE (GeV ^{-1/2})	DOCUMENT ID TECN COMMENT
-0.059±0.009 OUR ESTIN	MATE -
-0.048±0.008	ARNDT 96 IPWA $\gamma N \rightarrow \pi N$
-0.066±0.013	AWAJI 81 DPWA $\gamma N \rightarrow \pi N$ FUJII 81 DPWA $\gamma N \rightarrow \pi N$
-0.067±0.004 -0.076±0.006	FUJII 81 DPWA $\gamma N \rightarrow \pi N$ ARAI 80 DPWA $\gamma N \rightarrow \pi N$ (fit 1)
-0.070±0.000 -0.071±0.011	ARAI 80 DPWA $\gamma N \rightarrow \pi N$ (fit 2)
-0.056±0.011	CRAWFORD 80 DPWA $\gamma N \rightarrow \pi N$
-0.050 ± 0.014	TAKEDA 80 DPWA $\gamma N \rightarrow \pi N$
• • • We do not use the fo	llowing data for averages, fits, limits, etc. • • •
-0.058±0.003	LI 93 IPWA $\gamma N \rightarrow \pi N$
-0.055±0.014	BARBOUR 78 DPWA $\gamma N \rightarrow \pi N$
- 0.060	⁶ NOELLE 78 $\gamma N \rightarrow \pi N$
$N(1520) \rightarrow n\gamma$, helicity	•
VALUE (GeV ^{-1/2}) -0.139±0.011 OUR ESTIM	DOCUMENT ID TECN COMMENT
-0.140±0.010	ARNDT 96 IPWA $\gamma N \rightarrow \pi N$
-0.124±0.009	AWAJI 81 DPWA $\gamma N \rightarrow \pi N$
-0.158±0.003	FUJII 81 DPWA γN → πN
-0.147 ± 0.008	ARAI 80 DPWA $\gamma N \rightarrow \pi N$ (fit 1)
-0.148±0.009	ARAI 80 DPWA $\gamma N \rightarrow \pi N \text{ (fit 2)}$
-0.144±0.015	CRAWFORD 80 DPWA $\gamma N \rightarrow \pi N$
	TAKEDA 80 DPWA $\gamma N \rightarrow \pi N$
	llowing data for averages fits timits -to
• • We do not use the for	llowing data for averages, fits, limits, etc. • • •
-0.118 ± 0.011 • • • We do not use the fo -0.131 ± 0.003 -0.141 ± 0.015	Howing data for averages, fits, limits, etc. \bullet \bullet \bullet Li 93 IPWA $\gamma N \to \pi N$ BARBOUR 78 DPWA $\gamma N \to \pi N$

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N(1520) FOOTNOTES

- \$\$ LONGACRE 77 pole positions are from a search for poles in the unitarized T-matrix; the first (second) value uses, in addition to \$\pi N \rightarrow N \pi \pi\$ data, elastic amplitudes from a Saclay (CERN) partial-wave analysis. The other LONGACRE 77 values are from eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.
- From method II of LONGACRE 75: eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.
- ³ See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and Δ resonances as determined from Argand diagrams of π N elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams.
- All pilotes aim from a search for poles in the unitarized T-matrix. The first (second) value uses, in addition to $\pi N \to N \pi \pi$ data, elastic amplitudes from a Saclay (CERN) partial-wave analysis.
- 5 LONGACRE 77 considers this coupling to be well determined.
- ⁶ Converted to our conventions using M=1528 MeV, $\Gamma=187$ MeV from NOELLE 78.

N(1520) REFERENCES

For early references, see Physics Letters 111B 70 (1982). For very early references, see Reviews of Modern Physics 37 633 (1965).

			<u> </u>		
ARNDT	96	PR C53 430	+Strakovsky, Workman	(VPI)	
ARNOT	95	PR C52 2120	+Strakovsky, Workman, Pavan	(VPI, BRCO)	
BATINIC	95	PR C51 2310	+Slaus, Svarc, Nefkens	(BOSK, UCLA)	
HOEHLER	93	πN Newsletter 9 1		(KARL)	
LI	93	PR C47 2759	+Arndt, Roper, Workman	(VPI)	
MANLEY	92	PR D45 4002	+Saleski	(KÉNT)	IJP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	(VPI)	
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE)	IJP
WADA	84	NP B247 313	+Egawa, Imanishi, Ishii, Kato, Ukai+	(INUS)	
CRAWFORD	83	NP B211 1	+Morton	(GLAS)	
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)	
ILAWA	81	Bonn Conf. 352	+Kajikawa	(NAGO)	
Also	82	NP B197 365	Fujii, Hayashii, Iwata, Kajikawa+	(NAGO)	
FUJII	81	NP B187 53	+Hayashii, lwata, Kalikawa+	(NAGO, OSAK)	
ARAI	80	Toronto Conf. 93	, , , , , , , , , , , , , , , , , , ,	(INUS)	
Also	82	NP B194 251	Arai, Fujii	(INUS)	
BRATASHEV		NP B166 525	Bratashevskii, Gorbenko, Derebchinskij+		
CRAWFORD	80	Toronto Conf. 107	processing, corpensor, perconsoring	(GLAS)	
CUTKOSKY	BO	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMŮ, LBL)	IIР
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL)	
ISHIL	80	NP B165 189	+Egawa, Kato, Miyachi+	(KYOT, INUS)	
TAKEDA	80	NP B168 17	+Arai, Fujii, Ikeda, Iwasaki+	(TOKY, INUS)	
BAKER	79	NP B156 93	+Brown, Clark, Davies, Depagter, Evans+		LIP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT)	
Also	80	Toronto Conf. 3	Koch	(KARLT)	
BARBOUR	78	NP B141 253	+Crawford, Parsons	(GLAS)	
LONGACRE	78	PR D17 1795	+Lasinski, Rosenfeld, Smadia+	(LBL, SLAC)	
NOELLE	78	PTP 60 778	Transfer, Noscincia, SinsajeT	(NAGO)	
BERENDS	77	NP B136 317	+Donnachie	(LEID, MCHS)	I ID
LONGACRE	77	NP B122 493	+Dolheau	(SACL)	
Also	76	NP B108 365		(SACL)	
FELLER	76	NP B104 219	Dolbeau, Triantis, Neveu, Cadiet		
FELTESSE	/6 75	NP B104 219 NP B93 242	+Fukushima, Horikawa, Kajikawa+	(NAGO, OSAK)	
LONGACRE	75 75	PL 55B 415	+Ayed, Bareyre, Borgeaud, David+	(SACL)	
LUNGACKE	12	PL 330 415	+Rosenfeld, Lasinski, Smadja+	(LBL, SLAC)	IJP

$N(1535) S_{11}$

$$I(J^P) = \frac{1}{2}(\frac{1}{2})$$
 Status: ***

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters 111B (1982).

N(1535) BREIT-WIGNER MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1520 to 1555 (≈ 1535) OU	R ESTIMATE			
1534± 7	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
1550±40	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
1526± 7	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the fo	ollowing data for average	s, fits	i, limits,	etc. • • •
1549± 2	ABAEV	96	DPWA	$\pi^- p \rightarrow \eta n$
1525±10	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
1535	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
1542± 6	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$
1537	BATINIC	95B	DPWA	$\pi N \rightarrow N\pi, N\eta$
1544±13	KRUSCHE	95	DPWA	$\gamma p \rightarrow p \eta$
1518	Li	93	IPWA	$\gamma N \rightarrow \pi N$
1513	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
1511	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
1500	BERENDS	77		$\gamma N \rightarrow \pi N$
1547± 6	BHANDARI	77	DPWA	Uses Nn cusp
1520	1 LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
1510	² LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

N(1535) BREIT-WIGNER WIDTH

VALU	E (MeV)	DOCUMENT ID		TECN	COMME	NT
100	to 250 (≈ 150) OUR ESTIM	IATE				
148.2	2± 8.1	GREEN	97	DPWA	$\pi N \rightarrow$	πN, ηN
151	±27	MANLEY	92	IPWA	$\pi N \rightarrow$	πΝ & Νππ
240	±80	CUTKOSKY	80	IPWA	$\pi N \rightarrow$	πN
120	±20	HOEHLER	79	IPWA	$\piN\to$	πN

• •	 We do not use the follow 	ving data for average	s, fits, limits, etc. • • •
212	±20	³ KRUSCHE	97 DPWA γN → ηN
169	±12	ABAEV	96 DPWA π p → ηn
103	± 5	ARNDT	96 1PWA γN → πN
66		ARNDT	95 DPWA πN → Nπ
150	±15	BATINIC	95 DPWA $\pi N \rightarrow N\pi$, $N\eta$
145		BATINIC	958 DPWA $\pi N \rightarrow N\pi$, $N\eta$
200	±40	KRUSCHE	95 DPWA γp → pη
84		LI	93 IPWA $\gamma N \rightarrow \pi N$
136		CRAWFORD	80 DPWA $\gamma N \rightarrow \pi N$
180		BAKER	79 DPWA $\pi^- p \rightarrow n\eta$
132		BARBOUR	78 DPWA γN → πN
57		BERENDS	77 IPWA γN → πN
139	±33	BHANDARI	77 DPWA Uses N ₇₁ cusp
135	,	¹ LONGACRE	77 IPWA $\pi N \rightarrow N \pi \pi$
100		² LONGACRE	75 IPWA $\pi N \rightarrow N \pi \pi$

N(1535) POLE POSITION

REAL PART VALUE (MeV)	DOCUMENT ID		TCC11	COLUMENT
			TECN	COMMENT
1495 to 1515 (≈ 1506) O	URESTIMATE			
1501	ARNDT		DPWA	$\pi N \rightarrow N \pi$
1487	⁴ HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
1510±50	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the	following data for average	s, fit	s, limits,	etc. • • •
1499	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
1496 or 1499	⁵ LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$
1519± 4			DPWA	Uses Nn cusp
1525 or 1527	¹ LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
-2×IMAGINARY PAI	RT			
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
90 to 250 (≈ 170) OUR	ESTIMATE			
124	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
260 ± 80	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the	following data for average	s, fit	s, ilmits,	etc. • • •
110	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
103 or 105	⁵ LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$
140±32	BHANDARI	77	DPWA	Uses Nn cusp
135 or 123	¹ LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$

N(1535) ELASTIC POLE RESIDUE

MODULUS |r|

VALUE (MEV)	DOCUMENT ID		IEUN	COMMENT
31	ARNDT	95	DPWA	$\pi N \rightarrow N\pi$
120±40	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the follow	ing data for average	es, fit	s, ilmits,	etc. • • •
23	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln \$M90
PHASE 0				
VALUE (°)	DOCUMENT ID		TECN	COMMENT
-12	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
+15±45	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the follow	ing data for average	5, fit:	s, limits,	etc. • • •
-13	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90

N(1535) DECAY MODES

The following branching fractions are our estimates, not fits or averages.

	Mode	Fraction (Γ_I/Γ)	
$\overline{\Gamma_1}$	Νπ	35-55 %	
۲2	Nη	30-55 %	
Гз	$N\pi\pi$	1–10 %	
Γ4	$\Delta\pi$	<1 %	
۲ ₅	$\Delta(1232)\pi$, <i>D</i> -wave		
Γ6	Nρ	<4 %	
Γ7	$N\rho$, $S=1/2$, S -wave		
Γg	$N\rho$, $S=3/2$, D-wave		
Γg	$N(\pi\pi)_{S-\text{wave}}^{I=0}$	<3 %	
Γ10	$N(1440)\pi$	<7 %	
Γ11	Pγ	0.15-0.35 %	
Γ ₁₂	$p\gamma$, helicity=1/2	0.15-0.35 %	
Γ13	$n\gamma$	0.004-0.29 %	
Γ14	$n\gamma$, helicity=1/2	0.004-0.29 %	

Baryon Particle Listings N(1535)

N(1535) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$				Γ;	1/Γ
VALUE	DOCUMENT ID		TECN	COMMENT	
0.35 to 0.55 OUR ESTIMAT	ΓE				
0.394±0.009	GREEN	97	DPWA	$\pi N \rightarrow \pi N, \eta N$	
0.51 ±0.05	MANLEY	92		$\pi N \rightarrow \pi N \& N \pi \pi$	
0.50 ±0.10	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$	
0.38 ±0.04	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$	
 We do not use the foll 	owing data for averag	es, fits	i, limits,	etc. • • •	
0.31	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$	
0.34 ±0.09	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$	
0.297±0.026	BHANDARI	77	DPWA	Uses N η cusp	
$\Gamma(N\eta)/\Gamma_{\text{total}}$				Γ;	2/Γ
VALUE	DOCUMENT ID		TECN	COMMENT	
+0.30 to 0.55 OUR ESTIM	ATE				
 We do not use the foll 	owing data for averag	es, fits	, limits,	etc. • • •	
0.568 ± 0.011	GREEN	97	DPWA	$\pi N \rightarrow \pi N, \eta N$	
0.59 ±0.02	ABAEV	96	DPWA	$\pi^- p \rightarrow \eta n$	
0.63 ±0.07	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$	
$(\Gamma_I \Gamma_f)^{\frac{1}{12}} / \Gamma_{\text{total}} \text{ in } N\pi \rightarrow$	N(1535) → Nn			(Γ ₁ Γ ₂) ^{1/2}	, 2/⊏
VALUE	DOCUMENT ID		TECN		,.
+0.44 to +0.50 OUR ESTIN					_
+0.47±0.02	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$	
• • We do not use the foll	owing data for averag	es, fits	, limits,	etc. • • •	
+0.33	BAKER	79	DPWA	$\pi^- p \rightarrow n\eta$	
+0.48	FELTESSE			1488-1745 MeV	

Note: Signs of couplings from $\pi\,N\to\,N\,\pi\,\pi$ analyses were changed in the 1986 edition to agree with the baryon-first convention; the overall phase ambiguity is resolved by choosing a negative sign for the $\Delta(1620)~S_{31}$ coupling to $\Delta(1232)\pi$.

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N \pi \to N(1)$				
VALUE -0.04 to +0.06 OUR ESTIMATE	DOCUMENT ID		TECN_	COMMENT
+0.00±0.04		92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
	MANLEY 1 LONGACRE			
0.00				
+0.06	² LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N \pi \to N(1)$	535) → Nρ, S	=1/	2, <i>S</i> -wa	ve $(\Gamma_1\Gamma_7)^{\frac{1}{2}}/\Gamma$
<u>VALUE</u> −0.14 to −0.06 OUR ESTIMATE	DOCUMENT ID		TECN	COMMENT
-0.10 ± 0.03				$\pi N \rightarrow \pi N \& N \pi \pi$
-0.10	1 LONGACRE		IPWA	$\pi N \rightarrow N \pi \pi$
-0.09	² LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$
$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \ln N \pi \to N(1)$	535) → N(ππ)/=0 S-w	eve	(Γ₁Γ ₉) ^½ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
+0.03 to +0.13 OUR ESTIMATE				
$+0.07\pm0.04$	MANLEY	92	IPWA	$\pi N \rightarrow \pi N & N \pi \pi$
+0.08	1 LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
+0.09	² LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$
$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \ln N \pi \rightarrow N(1)$	535) → N(144 DOCUMENT ID			(Γ ₁ Γ ₁₀) ^{1/2} /Γ
+0.10±0.05	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$

N(1535) PHOTON DECAY AMPLITUDES

$N(1535) \rightarrow p\gamma$, helicity-1/2 amplitude A_{1/2}

VALUE (GeV ^{-1/2})	DOCUMENT ID		TECN	COMMENT
+0.090 ±0.030 OUR ESTIMATE				
$0.120 \pm 0.011 \pm 0.015$	KRUSCHE	97	DPWA	$\gamma N \rightarrow \eta N$
0.060 ±0.015	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
0.097 ±0.006	BENMERROU.		DPWA	$\gamma N \rightarrow N \eta$
0.095 ±0.011 6	BENMERROU.	.91		$\gamma p \rightarrow p \eta$
0.053 ±0.015	CRAWFORD	83	IPWA	$\gamma N \rightarrow \pi N$
0.077 ±0.021	AWAJI	81	DPWA	$\gamma N \rightarrow \pi N$
0.083 ±0.007	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
0.080 ±0.007	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$
0.029 ±0.007	BRATASHEV	80	DPWA	$\gamma N \rightarrow \pi N$
0.065 ±0.016	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
0.0704 ± 0.0091	ISHII	80	DPWA	Compton scattering
	lata for averages	, fits	, limits,	etc. • • •
0.110 to 0.140	KRUSCHE	95	DPWA	$\gamma p \rightarrow p \eta$
0.125 ±0.025	KRUSCHE	95C	IPWA	$\gamma d \rightarrow \eta N(N)$
0.061 ±0.003	LI	93	IPWA	$\gamma N \rightarrow \pi N$
0.055	WADA	84	DPWA	Compton scattering
+0.082 ±0.019	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
0.046	NOELLE	78		$\gamma N \rightarrow \pi N$
+0.034	BERENDS	77	IPWA	$\gamma N \rightarrow \pi N$
+0.070 ±0.004	FELLER	76	DPWA	$\gamma N \rightarrow \pi N$

VALUE (GeV ^{-1/2})	DOCUMENT ID		TECN	COMMENT
-0.046±0.027 OUR EST	TIMATE			
-0.020 ± 0.035	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
0.035 ± 0.014	ILAWA	81	DPWA	$\gamma N \rightarrow \pi N$
-0.062 ± 0.003	FUJII	81	DPWA	$\gamma N \rightarrow \pi N$
-0.075 ± 0.019	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
-0.075 ± 0.018	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$
-0.098 ± 0.026	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
-0.011 ± 0.017	TAKEDA	80	DPWA	$\gamma N \rightarrow \pi N$
 • • We do not use the 	following data for average	s, fit	s, limits,	etc. • • •
-0.100 ± 0.030	KRUSCHE	950	IPWA	$\gamma d \rightarrow \eta N(N)$
-0.046 ± 0.005	Li	93	IPWA	$\gamma N \rightarrow \pi N$
-0.112 ± 0.034	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
-0.048	7 NOELLE	78		$\gamma N \rightarrow \pi N$
$N(1535) o N\gamma$, rati	o A _{1/2} /A _{1/2}			
VALUE (GeV ^{-1/2})	DOCUMENT ID		TECN	
• • We do not use the	following data for average	s, fit	s, limits,	etc. • • •
-0.84 ± 0.15	MUKHOPAD.	95E	IPWA	

N(1535) FOOTNOTES

- ¹LONGACRE 77 pole positions are from a search for poles in the unitarized T-matrix; the first (second) value uses, in addition to $\pi N \to N \pi \pi$ data, elastic amplitudes from a Saclay (CERN) partial-wave analysis. The other LONGACRE 77 values are from eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.
- ² From method II of LONGACRE 75: eyeball fits with Breit-Wigner circles to the T-matrix

- From method II of LONGACKE 73: eyesian instance $N_{\rm B}$ amplitudes.

 3 KRUSCHE 97 fits with the mass fixed at 1544 MeV.

 4 See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and Δ resonances as determined from Argand diagrams of πN elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams.

 5 LONGACRE 78 values are from a search for poles in the unitarized T-matrix. The first (second) value uses, in addition to $\pi N \to N\pi\pi$ data, elastic amplitudes from a Saclay (CERN) partial-wave analysis.

 6 DENIMEDROLICHE 01 uses an effective Lagrangian approach to analyze η photoproduc-
- 6 BENMERROUCHE 91 uses an effective Lagrangian approach to analyze η photoproduc-
- tion data.
 ⁷ Converted to our conventions using M=1548 MeV, $\Gamma=73$ MeV from NOELLE 78.

N(1535) REFERENCES

For early references, see Physics Letters 111B 70 (1982).

ences		DD 655 DALES		(1)51 5 14819)
GREEN	97	PR C55 R2167	+Wycech	(HELS, WINR)
KRUSCHE	97	PL B397 171	+Mukhopadhyay, Zhang+	(GIES, RPI, SASK)
ABAEV	96	PR C53 385	+Nefkens	(UCLA)
ARNDT	96	PR C53 430	+Strakovsky, Workman	(VPI)
ARNDT	95	PR C52 2120	+Strakovsky, Workman, Pavan	(VPI, BŘCO)
BATINIC	95	PR C51 2310	+Slaus, Svarc, Nefkens	(BOSK, UCLA)
BATINIC	95B		+Slaus, Svarc	(BOSK)
BENMERROU		PR D51 3237	Benmerrouche, Mukhopadhyay, Zhang	(RPI, SASK)
KRUSCHE	95	PRL 74 3736		.AS, BONN, DARM)
KRUSCHE	95C	PL B358 40		.AS, BONN, DARM)
MUKHOPAD			Mukhopadhyay, Zhang, Benmerrouche	(RPI, SASK)
HOEHLER	93	π N Newsletter 9 1		(KARL)
LI	93	PR C47 2759	+Arndt, Roper, Workman	(VPI)
MANLEY	92	PR D45 4002	+Saleski	(KENT) IJP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	(VPI)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
BENMERROU.	91	PRL 67 1070	Benmerrouche, Mukhopadhyay	(RPI)
WADA	84	NP B247 313	+Egawa, Imanishi, Ishii, Kato, Ukai+	(INUS)
CRAWFORD	83	NP B211 1	+ Morton	(GLAS)
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
ILAWA	81	Bonn Conf. 352	+Kajikawa	(NAGO)
Also	82	NP B197 365	Fujii, Hayashii, Iwata, Kajikawa+	(NAGO)
FUJII	81	NP B187 53	+Hayashii, Iwata, Kajikawa+	(NAGO, OSAK)
ARAI	80	Toronto Conf. 93	,	(INUS)
Also	82	NP B194 251	Arai, Fujii	(INUS)
BRATASHEV		NP B166 525	Bratashevskij, Gorbenko, Derebchinskij+	
CRAWFORD	. BO	Toronto Conf. 107	Distancesky, dolbenko, Derebennisky	(GLAS)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMU, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJP
ISHII	80	NP B165 189	+Egawa, Kato, Miyachi+	(KYOT, INUS)
TAKEDA	80	NP B168 17	+Arai, Fujii, Ikeda, Iwasaki+	(TOKY, INUS)
BAKER	79	NP B156 93	+Brown, Clark, Davies, Departer, Evans+	
HOEHLER	79	PDAT 12-1		(KARLT) IJP
			+Kaiser, Koch, Pietarinen	(KARLT) UP
Also	80	Toronto Conf. 3	Koch	
BARBOUR	78	NP B141 253	+Crawford, Parsons	(GLAS)
LONGACRE	78	PR D17 1795	+Lasinski, Rosenfeld, Smadja+	(LBL, SLAC)
NOELLE	78	PTP 60 778		(NAGO)
BERENDS	77	NP B136 317	+Donnachie	(LEID, MCHS) IJP
BHANDARI	77	PR D15 192	+Chao	(CMU) IJP
LONGACRE	77	NP B122 493	+ Dolbeau	(SACL) IJP
Also	76	NP B108 365	Dolbeau, Triantis, Neveu, Cadiet	(SACL) IJP
FELLER	76	NP B104 219	+Fukushima, Horikawa, Kajikawa+	(NAGO, OSAK) IJP
FELTESSE	75	NP B93 242	+Ayed, Bareyre, Borgeaud, David+	(SACL) IJP
LONGACRE	75	PL 55B 415	+Rosenfeld, Lasinski, Smadja+	(LBL, SLAC) IJP
			• •	

$N(1650) S_{11}$

 $I(J^P) = \frac{1}{2}(\frac{1}{2})$ Status: ***

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters 111B (1982).

N(1650) BREIT-WIGNER MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1640 to 1680 (≈ 1650) OUR EST	MATE			
1659± 9	MANLEY	92	IPWA	$\pi N \rightarrow \pi N & N \pi \pi$
1650±30	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
1670± 8	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following	data for averages	, fits	, limits,	etc. • • •
1677± 8	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
1667	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
1712	¹ ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
1669±17	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$
1713±27	² BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$
1674	LI	93	IPWA	$\gamma N \rightarrow \pi N$
1688	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
1672	MUSETTE	80	IPWA	$\pi^- \rho \rightarrow \Lambda K^0$
1680	SAXON -	80	DPWA	$\pi^- p \rightarrow \Lambda K^0$
1680	BAKER	78	DPWA	$\pi^- p \rightarrow \Lambda K^0$
1694	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
1700± 5	3 BAKER	77	IPWA	$\pi^- \rho \rightarrow \Lambda K^0$
1680	3 BAKER	77	DPWA	$\pi^- \rho \rightarrow \Lambda K^0$
1700	⁴ LONGACRE	77		$\pi N \rightarrow N \pi \pi$
1675	KNASEL	75	DPWA	$\pi^- \rho \rightarrow \Lambda K^0$
1660	⁵ LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

N(1650) BREIT-WIGNER WIDTH

VALUE (M	eV)	DOCUMENT ID		TECN	COMMENT
145 to	190 (≈ 150) OUR ESTIMA	ATE			
167.9±	9.4	GREEN	97	DPWA	$\pi N \rightarrow \pi N, \eta N$
173 ±1	.2	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
150 ±4	10	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
180 ±2	:0	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • W	e do not use the following	data for averages	, fits	i, limits,	etc. • • •
160 ±1	.2	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
90		ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
184		¹ ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
215 ±3		BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$
279 ±5	4	² BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$
225		LI	93	IPWA	$\gamma N \rightarrow \pi N$
183		CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
179		MUSETTE	80	IPWA	$\pi^- \rho \rightarrow \Lambda K^0$
120		SAXON	80	DPWA	$\pi^- p \rightarrow \Lambda K^0$
90		BAKER	78	DPWA	$\pi^- p \rightarrow \Lambda K^0$
193		BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
130 ±1	.0	³ BAKER	77	IPWA	$\pi^- p \rightarrow \Lambda K^0$
90		3 BAKER	77		$\pi^- p \rightarrow \Lambda K^0$
170		4 LONGACRE	77		$\pi N \rightarrow N \pi \pi$
170		KNASEL	75	DPWA	$\pi^- \rho \rightarrow \Lambda K^0$
130		5 LONGACRE	75		$\pi N \rightarrow N \pi \pi$

N(1650) POLE POSITION

REAL PART
VALUE (MeV)

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1640 to 1680 (≈ 1660)	OUR ESTIMATE			
1673	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
1689		95	DPWA	$\pi N \rightarrow N \pi$
1670	⁶ HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
1640±20	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use th	e following data for averages	, fit:	s, iimits,	etc. • • •
1657	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
1648 or 1651	⁷ LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$
1699 or 1698	⁴ LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
-2×IMAGINARY P	ART			
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
150 to 170 (≈ 160) OU	R ESTIMATE			
82	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
192	. ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
163	⁶ HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
	HOLHER	"	,,,,,	W 18 - 4 W 18
150±30		80		$\pi N \rightarrow \pi N$
150±30		80	IPWA	$\pi N \rightarrow \pi N$
150±30	CUTKOSKY	80	IPWA s, limits,	$\pi N \rightarrow \pi N$
150±30 • • • We do not use th	CUTKOSKY ie following data for averages _ ARNDT	80 , fit: 91	IPWA s, limits, DPWA	$\pi N \rightarrow \pi N$ etc. • • •
150±30 • • • We do not use the 160	CUTKOSKY te following data for averages _ ARNDT	80 , fit: 91	IPWA s, limits, DPWA IPWA	$\pi N \rightarrow \pi N$ etc. • • • $\pi N \rightarrow \pi N$ Soln SM90

N(1650) ELASTIC POLE RESIDUE

MODULUS |r|

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
22	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
72	¹ ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
39	HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
60±10	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the fo	llowing data for average	es, fit	s, limits,	etc. • • •
54	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
PHASE <i>θ</i>				
VALUE (°)	DOCUMENT ID		TECN	COMMENT
29	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
85	¹ ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
- 37	HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
-75±25	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the fo	llowing data for average	es, fit	s, limits,	etc. • • •
_38	ARNDT	91	D DWA	TN - TN Soln SM90

N(1650) DECAY MODES

The following branching fractions are our estimates, not fits or averages.

	Mode	Fraction (Γ_I/Γ)
Γ ₁	Νπ	55-90 %
Γ ₂ Γ ₃	$N\eta$	3–10 %
Γ3	ΛK	3–11 %
Γ4	ΣΚ	
Γ ₅	$N\pi\pi$	10–20 %
Γ ₆	$\Delta\pi$	1-7 %
Γ_7	Δ (1232) π , D -wave	
Γ8	$N\rho$	4–12 %
Γg	$N\rho$, $S=1/2$, S -wave	
Γ_{10}	$N\rho$, $S=3/2$, D -wave	
Γ_{11}	$N(\pi\pi)_{S-\text{wave}}^{I=0}$	<4 %
Γ_{12}	$N(1440)\pi$	<5 %
Γ ₁₃	$p\gamma$	0.04-0.18 %
Γ14	$p\gamma$, helicity=1/2	0.04-0.18 %
Γ ₁₅	$n\gamma$	0.003~0.17 %
Γ ₁₆	$n\gamma$, helicity=1/2	0.003-0.17 %

N(1650) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$				Γ ₁ /	Г
VALUE	DOCUMENT ID		TECN	COMMENT	
0.85 to 0.90 OUR ESTI	WATE				Τ.
0.735 ± 0.011	GREEN	97	DPWA	$\pi N \rightarrow \pi N, \eta N$	
0.89 ±0.07	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$	
0.65 ±0.10	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$	
0.61 ±0.04	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$	
• • • We do not use the	following data for average	es, fit	s, limits,	etc. • • •	
0.99	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$	
0.27	¹ ARNDT	95	DPWA	$\pi N \rightarrow N\pi$	
0.94 ±0.07	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$	
0.49 ±0.21	² BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$	
Γ(Nη)/Γ _{total}				Γ ₂ /	г

VALUE	DOCUMENT I	D	TECN	COMMEN	<i>T</i>	
• • • We do not use the following	ng data for avera	ges, fit	s, limits,	etc. • •	•	
0.06 ± 0.05	BATINIC	95	DPWA	$\pi N \rightarrow i$	Νπ. Νη	
0.02 ± 0.03	² BATINIC	95	DPWA	$\pi N \rightarrow i$	Νπ, Νη	

$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \ln N\pi \rightarrow$	N(1650) → Nη			(Γ ₁ Γ ₂) ^{1/2} /Γ
VALUE	DOCUMENT	ID TECN	COMMENT	
• • We do not use the following the fol	owing data for avera	ges, fits, limits	, etc. • • •	
-0.09	8 BAKER	79 DPW/	$\pi^- p \rightarrow i$	πη

$(\Gamma_I \Gamma_I)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N$	$\pi \to N(1650) \to \Lambda K$			$(\Gamma_1\Gamma_3)^{\frac{7}{2}}$	1
VALUE	DOCUMENT I	D	TECN	COMMENT	
-0.27 to -0.17 OUR	ESTIMATE				
-0.22	BELL			$\pi^- p \rightarrow \Lambda K^0$	
-0.22	SAXON	80	DPWA	$\pi^- p \rightarrow \Lambda K^0$	
• • • We do not use t	he following data for avera	ges, flt	s, limits,	etc. • • •	
-0.25	9 BAKER	78	DPWA	See SAXON 80	
-0.23 ± 0.01	³ BAKER	77	IPWA	$\pi^- p \rightarrow \Lambda K^0$	
-0.25	3 BAKER	77	DPWA	$\pi^- p \rightarrow \Lambda K^0$	
0.12	KNASEL	75	DPWA	$\pi^- p \rightarrow \Lambda K^0$	

N(1650)

	→ N(1650) → ΣK		TECN	(Γ ₁ Γ ₄) ^{1/2} /Γ
We do not use the f	following data for averages			
0.254	LIVANOS	80	DPWA	$\pi p \rightarrow \Sigma K$
0.066 to 0.137	10 DEANS	75		$\pi N \rightarrow \Sigma K$
0.20	KNASEL	75	DPWA	
0.20				
Note: Signs of co	uplings from $\pi N \rightarrow N \pi \pi$	- ana	lvses we	re changed in the
	gree with the baryon-first			
	ved by choosing a negati			
coupling to $\Delta(123)$			_	· / 31
				-1
Γ _ε Γ _ε) ^½ /Γ _{total} in Nπ –	$\rightarrow N(1650) \rightarrow \Delta(1232)$	2)π,	D-way	e (Γ₁Γ⁊) ^⅓ /Γ
ALUE	DOCUMENT ID			COMMENT
-0.15 to 0.23 OUR ESTIN	AATE			
-0.12±0.04	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
-0.29	4,11 LONGACRE	77		$\pi N \rightarrow N \pi \pi$
0.15	⁵ LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$
1/				14 .
$\Gamma_I \Gamma_I)^{72} / \Gamma_{ ext{total}} \ln N \pi -$	$\rightarrow N(1650) \rightarrow N \rho, S=$	=1/2	2, <i>S</i> -wa	/е (Г ₁ Г ₉) ^½ /Г
ALUE	DOCUMENT ID		<u>TECN</u>	
±0.03 to ±0.19 OU				
0.01±0.09	MANLEY		IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
0.17	4,11 LONGACRE	77		$\pi N \rightarrow N \pi \pi$
0.16	⁵ LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$
14				14
$(\Gamma_I \Gamma_I)^{72} / \Gamma_{ ext{total}} ext{ in } N\pi - 1$	$\rightarrow N(1650) \rightarrow N \rho, S=$	=3/2	2, <i>D</i> -wa	ve $(\Gamma_1\Gamma_{10})^{\frac{1}{2}}/\Gamma$
ALUE	DOCUMENT ID		<u>TECN</u>	COMMENT
-0.17 to +0.29 OUR EST				
-0.16±0.06	MANLEY		IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
-0.29	4,11 LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
1/.				1/
$(\Gamma_I \Gamma_I)^{72} / \Gamma_{\text{total}} \ln N \pi -$	$\rightarrow N(1650) \rightarrow N(\pi\pi)$	/=0 S-4	2140	(Γ₁Γ₁₁) ^⅓ /Γ
ALUE	DOCUMENT ID			COMMENT
-0.04 to +0.18 OUR EST	IMATE			
-0.12±0.08	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
0.00	4,11 LONGACRE	77		$\pi N \rightarrow N \pi \pi$
-0.25	⁵ LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$
.,				· ·
$\Gamma_I \Gamma_f$) $^{4/2} / \Gamma_{\text{total}}$ in $N \pi -$	$\rightarrow N(1650) \rightarrow N(1440)$)) π		(Γ ₁ Γ ₁₂) ^{1/2} /Γ
ALUE	<u>DOCUMENT ID</u>		<u>TECN</u>	COMMENT
-0.11±0.06	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
	·····			
N(165	50) PHOTON DECAY	'AN	APLITU	IDES
//16EA\ ballal	. 1 /2			
• • •	ity-1/2 amplitude A _{1/2}	_		
ALUE (GeV ^{-1/2})	DOCUMENT ID		TECN	COMMENT
	AAATE			
-0.053±0.016 OUR ESTI				
0.063±0.016 OUR ESTI 0.069±0.005	ARNDT		IPWA	$\gamma N \rightarrow \pi N$
0.063±0.016 OUR ESTI 0.069±0.005 0.033±0.015	ARNDT CRAWFORD	83	IPWA	$\gamma N \rightarrow \pi N$
0.063±0.016 OUR ESTI 0.069±0.005 0.033±0.015 0.050±0.010	ARNDT CRAWFORD AWAJI	83 81	IPWA DPWA	$\gamma N \rightarrow \pi N$ $\gamma N \rightarrow \pi N$
0.053±0.016 OUR ESTI 0.069±0.005 0.033±0.015 0.050±0.010 0.065±0.005	ARNDT CRAWFORD AWAJI ARAI	83 81 80	IPWA DPWA DPWA	$\gamma N \rightarrow \pi N$ $\gamma N \rightarrow \pi N$ $\gamma N \rightarrow \pi N \text{ (fit 1)}$
$\begin{array}{l} \textbf{0.053} \!\pm\! \textbf{0.016} \; \textbf{OUR ESTI} \\ \textbf{0.069} \!\pm\! \textbf{0.005} \\ \textbf{0.033} \!\pm\! \textbf{0.015} \\ \textbf{0.050} \!\pm\! \textbf{0.010} \\ \textbf{0.065} \!\pm\! \textbf{0.005} \\ \textbf{0.061} \!\pm\! \textbf{0.005} \end{array}$	ARNDT CRAWFORD AWAJI ARAI ARAI	83 81 80 80	IPWA DPWA DPWA DPWA	$ \begin{array}{l} \gamma N \to \pi N \\ \gamma N \to \pi N \\ \gamma N \to \pi N \text{ (fit 1)} \\ \gamma N \to \pi N \text{ (fit 2)} \end{array} $
0.063±0.016 OUR ESTI 0.069±0.005 0.033±0.015 0.050±0.010 0.065±0.005 0.061±0.005 0.031±0.017	ARNDT CRAWFORD AWAJI ARAI ARAI CRAWFORD	83 81 80 80 80	IPWA DPWA DPWA DPWA DPWA	$\gamma N \rightarrow \pi N$ $\gamma N \rightarrow \pi N$ $\gamma N \rightarrow \pi N$ $\gamma N \rightarrow \pi N$ (fit 1) $\gamma N \rightarrow \pi N$ (fit 2) $\gamma N \rightarrow \pi N$
-0.053±0.016 OUR ESTI 0.069±0.005 0.033±0.015 0.050±0.010 0.065±0.005 0.061±0.005 0.031±0.017	ARNDT CRAWFORD AWAJI ARAI ARAI	83 81 80 80 80 80 s, fits	IPWA DPWA DPWA DPWA DPWA s, limits,	$\begin{array}{ll} \gamma N \rightarrow & \pi N \\ \gamma N \rightarrow & \pi N \\ \gamma N \rightarrow & \pi N \\ \gamma N \rightarrow & \pi N \text{ (fit 1)} \\ \gamma N \rightarrow & \pi N \text{ (fit 2)} \\ \gamma N \rightarrow & \pi N \\ \text{etc.} & \bullet & \bullet \end{array}$
-0.053±0.016 OUR ESTI 0.069±0.005 0.033±0.015 0.050±0.010 0.065±0.005 0.061±0.005 0.031±0.017	ARNDT CRAWFORD AWAJI ARAI ARAI CRAWFORD	83 81 80 80 80 80 5, fits	IPWA DPWA DPWA DPWA DPWA i, limits, IPWA	$\gamma N \rightarrow \pi N$ $\gamma N \rightarrow \pi N$ $\gamma N \rightarrow \pi N$ $\gamma N \rightarrow \pi N$ (fit 1) $\gamma N \rightarrow \pi N$ (fit 2) $\gamma N \rightarrow \pi N$ etc. • • • $\gamma N \rightarrow \pi N$
-0.053±0.016 OUR ESTI 0.069±0.005 0.033±0.015 0.050±0.010 0.065±0.005 0.061±0.005 0.031±0.017 • • We do not use the fi	ARNDT CRAWFORD AWAJI ARAI ARAI CRAWFORD ollowing data for averages	83 81 80 80 80 6, fits 93	IPWA DPWA DPWA DPWA DPWA , limits, IPWA DPWA	$\gamma N \rightarrow \pi N$ $\gamma N \rightarrow \pi N$ $\gamma N \rightarrow \pi N$ $\gamma N \rightarrow \pi N$ (fit 1) $\gamma N \rightarrow \pi N$ (fit 2) $\gamma N \rightarrow \pi N$ etc. • • • $\gamma N \rightarrow \pi N$ Compton scattering
-0.063±0.016 OUR ESTI 0.069±0.005 0.033±0.015 0.050±0.010 0.065±0.005 0.061±0.005 0.031±0.017 • • We do not use the form of the for	ARNDT CRAWFORD AWAJI ARAI ARAI CRAWFORD following data for averages LI WADA BARBOUR	83 81 80 80 80 5, fits 93 84 78	IPWA DPWA DPWA DPWA DPWA , limits, IPWA DPWA DPWA	$\begin{array}{ll} \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \text{ (fit 1)} \\ \gamma N \rightarrow \pi N \text{ (fit 2)} \\ \gamma N \rightarrow \pi N \text{ etc.} \bullet \bullet \bullet \\ \gamma N \rightarrow \pi N \\ \text{Compton scattering} \\ \gamma N \rightarrow \pi N \end{array}$
0.063±0.016 OUR ESTI 0.069±0.005 0.033±0.015 0.050±0.010 0.065±0.005 0.061±0.005 0.031±0.017 • • We do not use the for the control of	ARNDT CRAWFORD AWAJI ARAI ARAI CRAWFORD dollowing data for averages LI WADA	83 81 80 80 80 6, fits 93	IPWA DPWA DPWA DPWA DPWA , limits, IPWA DPWA DPWA	$\gamma N \rightarrow \pi N$ $\gamma N \rightarrow \pi N$ $\gamma N \rightarrow \pi N$ $\gamma N \rightarrow \pi N$ (fit 1) $\gamma N \rightarrow \pi N$ (fit 2) $\gamma N \rightarrow \pi N$ etc. • • • $\gamma N \rightarrow \pi N$ Compton scattering
0.063±0.016 OUR ESTI 0.069±0.005 0.033±0.015 0.050±0.010 0.065±0.005 0.061±0.005 0.031±0.017 • We do not use the form of the form o	ARNDT CRAWFORD AWAJI ARAI ARAI CRAWFORD following data for averages LI WADA BARBOUR FELLER	83 81 80 80 80 5, fits 93 84 78	IPWA DPWA DPWA DPWA DPWA , limits, IPWA DPWA DPWA	$\begin{array}{ll} \gamma N \to \pi N \\ \gamma N \to \pi N \\ \gamma N \to \pi N \text{ (fit 1)} \\ \gamma N \to \pi N \text{ (fit 2)} \\ \gamma N \to \pi N \text{ etc.} \bullet \bullet \bullet \\ \gamma N \to \pi N \\ \text{Compton scattering} \\ \gamma N \to \pi N \end{array}$
0.063±0.016 OUR ESTI 0.069±0.005 0.033±0.015 0.050±0.010 0.065±0.005 0.061±0.005 0.031±0.017 • • We do not use the f 0.068±0.003 0.091 0.048±0.017 0.068±0.009 /(1650) → nγ, helici	ARNDT CRAWFORD AWAJI ARAI ARAI CRAWFORD following data for averages LI WADA BARBOUR FELLER	83 81 80 80 80 5, fits 93 84 78 76	IPWA DPWA DPWA DPWA i, limits, IPWA DPWA DPWA DPWA	$\begin{array}{ll} \gamma N \to \pi N \\ \gamma N \to \pi N \\ \gamma N \to \pi N \text{ (fit 1)} \\ \gamma N \to \pi N \text{ (fit 2)} \\ \gamma N \to \pi N \text{ etc.} \\ \bullet \bullet \bullet \\ \gamma N \to \pi N \\ \text{Compton scattering} \\ \gamma N \to \pi N \\ \gamma N \to \pi N \end{array}$
-0.063±0.016 OUR ESTI 0.069±0.005 0.033±0.015 0.050±0.010 0.065±0.005 0.061±0.005 0.031±0.017 • • We do not use the form of the f	ARNDT CRAWFORD AWAJI ARAI ARAI CRAWFORD following data for averages LI WADA BARBOUR FELLER Ty-1/2 amplitude A _{1/2}	83 81 80 80 80 5, fits 93 84 78 76	IPWA DPWA DPWA DPWA i, limits, IPWA DPWA DPWA DPWA	$\begin{array}{ll} \gamma N \to \pi N \\ \gamma N \to \pi N \\ \gamma N \to \pi N \text{ (fit 1)} \\ \gamma N \to \pi N \text{ (fit 2)} \\ \gamma N \to \pi N \text{ etc.} \\ \bullet \bullet \bullet \\ \gamma N \to \pi N \\ \text{Compton scattering} \\ \gamma N \to \pi N \\ \gamma N \to \pi N \end{array}$
-0.063±0.016 OUR ESTI 0.069±0.005 0.050±0.010 0.065±0.005 0.061±0.005 0.031±0.017 • • We do not use the foundation of the foundati	ARNDT CRAWFORD AWAJI ARAI ARAI CRAWFORD following data for averages LI WADA BARBOUR FELLER AMATE ACCUMENT ID MATE	83 81 80 80 80 80 93 84 78 76	IPWA DPWA DPWA DPWA I, limits, IPWA DPWA DPWA DPWA	$\begin{array}{ll} \gamma N \to \pi N \\ \gamma N \to \pi N \\ \gamma N \to \pi N \\ \gamma N \to \pi N \text{ (fit 1)} \\ \gamma N \to \pi N \text{ (fit 2)} \\ \gamma N \to \pi N \\ \text{etc.} \bullet \bullet \bullet \\ \gamma N \to \pi N \\ \text{Compton scattering} \\ \gamma N \to \pi N \\ \gamma N \to \pi N \\ \end{array}$
-0.063±0.016 OUR ESTI 0.069±0.005 0.033±0.015 0.050±0.010 0.065±0.005 0.061±0.005 0.031±0.017 • • We do not use the found of t	ARNDT CRAWFORD AWAJI ARAI ARAI CRAWFORD following data for averages LI WADA BARBOUR FELLER ARAI DOCUMENT ID ARNDT ARNDT	83 81 80 80 80 80 6, fits 93 84 76 2	IPWA DPWA DPWA DPWA I, limits, IPWA DPWA DPWA DPWA	$\begin{array}{ll} \gamma N \to \pi N \\ \gamma N \to \pi N \\ \gamma N \to \pi N \text{ (fft 1)} \\ \gamma N \to \pi N \text{ (fft 2)} \\ \gamma N \to \pi N \text{ (fft 2)} \\ \gamma N \to \pi N \\ \text{etc.} \bullet \bullet \bullet \\ \gamma N \to \pi N \\ \text{Compton scattering} \\ \gamma N \to \pi N \\ \gamma N \to \pi N \\ \hline \\ \frac{COMMENT}{\gamma N \to \pi N} \end{array}$
-0.053±0.016 OUR ESTI 0.069±0.005 0.033±0.015 0.050±0.010 0.065±0.005 0.061±0.005 0.031±0.017 • We do not use the form of the form	ARNDT CRAWFORD AWAJI ARAI ARAI CRAWFORD following data for averages LI WADA BARBOUR FELLER AMATE ACCUMENT ID MATE	83 81 80 80 80 80 93 84 78 76	IPWA DPWA DPWA DPWA DPWA IPWA DPWA DPWA TECN IPWA DPWA	$\begin{array}{ll} \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \text{ (fit 1)} \\ \gamma N \rightarrow \pi N \text{ (fit 2)} \\ \gamma N \rightarrow \pi N \\ \text{etc.} \bullet \bullet \bullet \\ \gamma N \rightarrow \pi N \\ \text{Compton scattering} \\ \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \\ \\ \hline \\ \frac{COMMENT}{\gamma N \rightarrow \pi N} \\ \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \end{array}$
-0.053±0.016 OUR ESTI 0.069±0.005 0.033±0.015 0.050±0.010 0.065±0.005 0.061±0.005 0.061±0.005 0.031±0.017 • • We do not use the form of the f	ARNDT CRAWFORD AWAJI ARAI ARAI CRAWFORD following data for averages LI WADA BARBOUR FELLER ARAI DOCUMENT ID ARNDT ARNDT	83 81 80 80 80 80 93 84 78 76	IPWA DPWA DPWA DPWA IPWA DPWA DPWA DPWA DPWA DPWA IPWA DPWA DPWA DPWA	$\begin{array}{ll} \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \text{ (fit 1)} \\ \gamma N \rightarrow \pi N \text{ (fit 2)} \\ \gamma N \rightarrow \pi N \\ \text{etc.} \bullet \bullet \bullet \\ \gamma N \rightarrow \pi N \\ \text{Compton scattering} \\ \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \\ \\ \hline \\ \frac{COMMENT}{\gamma N \rightarrow \pi N} \\ \gamma N \rightarrow \pi N \\ $
-0.053±0.016 OUR ESTI 0.069±0.005 0.033±0.015 0.050±0.010 0.065±0.005 0.061±0.005 0.031±0.017 • • We do not use the f 0.068±0.003 0.091 -0.048±0.017 -0.068±0.009 /(1650) → nγ, helich ΔLUE (GeV ^{-1/2}) -0.015±0.005 -0.008±0.005 -0.008±0.005	ARNDT CRAWFORD AWAJI ARAI ARAI CRAWFORD following data for averages LI WADA BARBOUR FELLER Ty-1/2 amplitude A _{1/2} DOCUMENT ID ARNDT AWAJI	83 81 80 80 80 80 5, fits 78 76 2	IPWA DPWA DPWA DPWA IIMIts, IPWA DPWA DPWA IPWA DPWA IPWA DPWA DPWA DPWA	$\begin{array}{ll} \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \text{ (fit 1)} \\ \gamma N \rightarrow \pi N \text{ (fit 2)} \\ \gamma N \rightarrow \pi N \text{ etc.} \bullet \bullet \bullet \\ \gamma N \rightarrow \pi N \\ \text{Compton scattering} \\ \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \\ \\ \hline COMMENT \\ \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \text{ (fit 1)} \\ \end{array}$
-0.053±0.016 OUR ESTI 0.069±0.005 0.033±0.015 0.050±0.010 0.065±0.005 0.061±0.005 0.031±0.017 • We do not use the four of the four	ARNDT CRAWFORD AWAJI ARAI ARAI CRAWFORD following data for averages LI WADA BARBOUR FELLER ity-1/2 amplitude A _{1/2} MATE ARNDT AWAJI FUJII	83 81 80 80 80 80 5, fits 78 76 2	IPWA DPWA DPWA DPWA IIMIts, IPWA DPWA DPWA IPWA DPWA IPWA DPWA DPWA DPWA	$\begin{array}{ll} \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \text{ (fit 1)} \\ \gamma N \rightarrow \pi N \text{ (fit 2)} \\ \gamma N \rightarrow \pi N \\ \text{etc.} \bullet \bullet \bullet \\ \gamma N \rightarrow \pi N \\ \text{Compton scattering} \\ \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \\ \\ \hline \\ \frac{COMMENT}{\gamma N \rightarrow \pi N} \\ \gamma N \rightarrow \pi N \\ $
-0.063±0.016 OUR ESTI 0.069±0.005 0.050±0.010 0.065±0.005 0.061±0.005 0.031±0.017 • • We do not use the following the fol	ARNDT CRAWFORD AWAJI ARAI ARAI CRAWFORD following data for averages LI WADA BARBOUR FELLER ALLER ALLER ARNDT AWAJI FUJII ARAI	83 81 80 80 80 80 5, fits 78 76 2	IPWA DPWA DPWA DPWA I, limits, IPWA DPWA DPWA DPWA IPWA DPWA DPWA DPWA DPWA DPWA DPWA DPWA	$\begin{array}{ll} \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \text{ (fit 1)} \\ \gamma N \rightarrow \pi N \text{ (fit 2)} \\ \gamma N \rightarrow \pi N \text{ etc.} \bullet \bullet \bullet \\ \gamma N \rightarrow \pi N \\ \text{Compton scattering} \\ \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \\ \\ \hline COMMENT \\ \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \text{ (fit 1)} \\ \end{array}$
0.063±0.016 OUR ESTI 0.069±0.005 0.050±0.010 0.065±0.005 0.061±0.005 0.061±0.005 0.061±0.005 0.068±0.003 0.091 0.068±0.009 (1650) → nγ, helici M.UE (GeV ^{-1/2}) 0.015±0.021 OUR ESTI 0.015±0.005 0.008±0.004 0.004±0.004 0.004±0.004 0.010±0.020 0.008±0.019 0.068±0.019 0.068±0.040	ARNDT CRAWFORD AWAJI ARAI ARAI CRAWFORD following data for averages LI WADA BARBOUR FELLER ACTUAL AC	83 81 80 80 80 80 93 84 76 76 2	IPWA DPWA DPWA DPWA IPWA DPWA DPWA DPWA DPWA DPWA DPWA DPWA D	$\begin{array}{ll} \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \text{ (fit 1)} \\ \gamma N \rightarrow \pi N \text{ (fit 2)} \\ \gamma N \rightarrow \pi N \\ \text{etc.} \bullet \bullet \bullet \\ \gamma N \rightarrow \pi N \\ \text{Compton scattering} \\ \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \\ \hline \\ \frac{COMMENT}{\gamma N \rightarrow \pi N} \\ \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \text{ (fit 1)} \\ \gamma N \rightarrow \pi N \text{ (fit 1)} \\ \gamma N \rightarrow \pi N \text{ (fit 2)} \\ \end{array}$
0.063±0.016 OUR ESTI 0.069±0.005 0.033±0.015 0.050±0.010 0.065±0.005 0.031±0.017 • • We do not use the f 0.068±0.003 0.091 0.048±0.017 0.068±0.009 /(1650) → nγ, helici M.UE (GeV ^{-1/2}) 0.015±0.021 OUR ESTI 0.015±0.005 0.008±0.004 0.004±0.004 0.010±0.002 0.008±0.019 0.068±0.040 0.061±0.041	ARNDT CRAWFORD AWAJI ARAI ARAI CRAWFORD following data for averages LI WADA BARBOUR FELLER Ty-1/2 amplitude A _{1/2} MATE ARNDT AWAJI FUJII ARAI ARAI CRAWFORD	83 81 80 80 80 80 93 84 78 76 2 2 96 81 80 80 80 80 80 80	IPWA DPWA DPWA DPWA IPWA DPWA DPWA DPWA DPWA DPWA DPWA DPWA D	$\begin{array}{ll} \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \text{ (fit 1)} \\ \gamma N \rightarrow \pi N \text{ (fit 2)} \\ \gamma N \rightarrow \pi N \text{ (fit 2)} \\ \gamma N \rightarrow \pi N \\ \text{etc.} \bullet \bullet \bullet \\ \gamma N \rightarrow \pi N \\ \text{Compton scattering} \\ \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \\ \hline \\ \frac{COMMENT}{\gamma N \rightarrow \pi N} \\ \gamma N \rightarrow \pi N \text{ (fit 1)} \\ \gamma N \rightarrow \pi N \text{ (fit 1)} \\ \gamma N \rightarrow \pi N \text{ (fit 2)} \\ \gamma N \rightarrow \pi N \\ \gamma $
0.063±0.016 OUR ESTI 0.069±0.005 0.033±0.015 0.050±0.010 0.065±0.005 0.061±0.005 0.031±0.017 • • We do not use the foundation of	ARNDT CRAWFORD AWAJI ARAI ARAI CRAWFORD following data for averages LI WADA BARBOUR FELLER ARNDT AWAJI FUJII ARAI ARAI CRAWFORD TAKEDA	83 81 80 80 80 80 93 84 78 76 2 2 96 81 80 80 80 80 80 80	IPWA DPWA DPWA DPWA IPWA DPWA DPWA DPWA DPWA DPWA DPWA DPWA D	$\begin{array}{ll} \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \text{ (fit 1)} \\ \gamma N \rightarrow \pi N \text{ (fit 2)} \\ \gamma N \rightarrow \pi N \text{ (fit 2)} \\ \gamma N \rightarrow \pi N \\ \text{etc.} \bullet \bullet \bullet \\ \gamma N \rightarrow \pi N \\ \text{Compton scattering} \\ \gamma N \rightarrow \pi N \\ \gamma N \rightarrow \pi N \\ \hline \\ \frac{COMMENT}{\gamma N \rightarrow \pi N} \\ \gamma N \rightarrow \pi N \text{ (fit 1)} \\ \gamma N \rightarrow \pi N \text{ (fit 1)} \\ \gamma N \rightarrow \pi N \text{ (fit 2)} \\ \gamma N \rightarrow \pi N \\ \gamma $

VALUE (units 10 ⁻³)	y → N(1650) → AK		TECN	(<i>E</i> ₀₊ amplitude)
• • • We do not use th	e following data for average	es, fit	s, limits, e	tc. • • •
7.8 ±0.3	WORKMAN	90	DPWA	
8.13	TANABE	89	DPWA	
0.20				
	ΛK^+ phase angle θ			(E ₀₊ amplitude)
$p\gamma \rightarrow N(1650) \rightarrow VALUE (degrees)$	ΛK ⁺ phase angle θ		<u>TECN</u>	(E ₀₊ amplitude)
$p\gamma \rightarrow N(1650) \rightarrow VALUE (degrees)$, •			
$p\gamma \rightarrow N(1650) \rightarrow VALUE (degrees)$	DOCUMENT ID		s, limits, e	

1/

- $^1\!$ ARNDT 95 finds two distinct states. $^2\!$ BATINIC 95 finds two distinct states. This second resonance was associated with the $N(2090) S_{11}$.
- ³ The two BAKER 77 entries are from an IPWA using the Barrelet-zero method and from
- The two DANCE 77 entires are from a search for poles in the unitarized T-matrix; the first (second) value uses, in addition to $\pi N \to N\pi\pi$ data, elastic amplitudes from a Saclay (CERN) partial-wave analysis. The other LONGACRE 77 values are from eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.
- ⁵ From method II of LONGACRE 75: eyeball fits with Breit-Wigner circles to the T-matrix
- From method II of LONGACRE 75: eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.
 6 See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and Δ resonances as determined from Argand diagrams of π N elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams. TLONGACRE 78 values are from a search for poles in the unitarized T-matrix. The first (second) value uses, in addition to π N → Nππ data, elastic amplitudes from a Saclay (CERN) partial-wave analysis.
- 8 BAKER 79 fixed this coupling during fitting, but the negative sign relative to the N(1535)
- 9 The overall phase of BAKER 78 couplings has been changed to agree with previous conventions. Superseded by SAXON 80.

 10 The range given for DEANS 75 is from the four best solutions.

 11 LONGACRE 77 considers this coupling to be well determined.

N(1650) REFERENCES

For early references, see Physics Letters 111B 70 (1982).

GREEN	97	PR C55 R2167	+Wycech	(HELS, WINR)
ARNDT	96	PR C53 K2167	+Strakovsky, Workman	(MELS, WINK)
ARNOT	95	PR C52 2120	+Strakovsky, Workman, Pavan	(VPI, BRCO)
BATINIC	95	PR C51 2310	+Slaus, Svarc, Nefkens	(BOSK, UCLA)
HOEHLER	93	π N Newsietter 9 1	+31aus, Svart, Meinens	(KARL)
LI	93	PR C47 2759		(VPI)
MANLEY		PR D45 4002	+Arndt, Roper, Workman	(KENT) IJP
	92		+Saleski	
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	(VPI)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
WORKMAN	90	PR C42 781		(VPI)
TANABE	89	PR C39 741	+Kohno, Bennhold	(MANZ)
Also	89	NC 102A 193	Kohno, Tanabe, Bennhold	(MANZ)
WADA	84	NP B247 313	+Egawa, Imanishi, Ishii, Kato, Ukai+	(INUS)
BELL	83	NP B222 389	+Blissett, Broome, Daley, Hart, Lintern+	(RL) IJP
CRAWFORD	83	NP B211 1	+ Morton	(GLAS)
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
ILAWA	81	Bonn Conf. 352	+Kajikawa	(NAGO)
Also	82	NP B197 365	Fujii, Hayashii, Iwata, Kajikawa+	(NAGO)
FUJN	61	NP B187 53	+Hayashii, Iwata, Kajikawa+	(NAGO, OSAK)
ARAI	80	Toronto Conf. 93		(INUS)
Also	82	NP B194 251	Arai, Fujii	~ (INUS)
CRAWFORD	60	Toronto Conf. 107		(GLAS)
CUTKOSKY	BO	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMÚ, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJP
LIVANOS	80	Toronto Conf. 35	+Baton, Coutures, Kochowski, Neveu	(SACL) IJP
MUSETTE	80	NC 57A 37		(BRUX) IJP
SAXON	80	NP B162 522	+Baker, Bell, Blissett, Bloodworth+	(RHEL, BRIS) IJP
TAKEDA	80	NP B168 17	+Arai, Fujli, Ikeda, Iwasaki+	(TOKY, INUS)
BAKER	79	NP B156 93	+Brown, Clark, Davies, Depagter, Evans-	
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
BAKER	78	NP B141 29	+Bilssett, Bloodworth, Broome+	(RĹ, CAVE) IJP
BARBOUR	78	NP B141 253	+Crawford, Parsons	(GLAS)
LONGACRE	78	PR D17 1795	+Lasinski, Rosenfeld, Smadja+	(LBL, SLAC)
BAKER	77	NP B126 365	+Blissett, Bloodworth, Broome, Hart+	(RHEL) IJP
LONGACRE	77	NP B122 493	+Dolbeau	(SACL) IJP
Also	76	NP B108 365	Dolbeau, Triantis, Neveu, Cadiet	(SACL) IJP
FELLER	76	NP B104 219	+Fukushima, Horikawa, Kajikawa+	(NAGO, OSAK) IJP
DEANS	75	NP B96 90	+Mitchell, Montgomery+	(SFLA, ALAH) IJP
KNASEL	75	PR D11 1		. WUSL, OSU, ANL JUP
LONGACRE	75	PL 55B 415	+Rosenfeld, Lasinski, Smadja+	(LBL, SLAC) IJP

N(1675) D₁₅

 $I(J^P) = \frac{1}{2}(\frac{5}{2})$ Status: ***

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters 111B (1982).

N(1675) BREIT-WIGNER MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1670 to 1685 (≈ 1675)	OUR ESTIMATE			
1676± 2	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
1675±10	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
1679± 8	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
 • • We do not use th 	e following data for average	s, fit	s, Ilmits,	etc. • • •
1673± 5	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
1673	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
1683±19	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$
1666	LI	93	IPWA	$\gamma N \rightarrow \pi N$
1685	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
1670	SAXON	80	DPWA	$\pi^- p \rightarrow \Lambda K^0$
1680	BARBOUR	78	DPWA	$\gamma_i N \rightarrow \pi N$
1650	1 LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
1660	² LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

N(1675) BREIT-WIGNER WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
140 to 180 (≈ 150) OUR ESTIM/	NTE			
159± 7	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
160±20	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
120±15	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the following	g data for average	s, fit	s, Ilmits,	etc. • • •
154± 7	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
154	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
142±23	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$
136	LI	93	IPWA	$\gamma N \rightarrow \pi N$
191	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
40	SAXON	80	DPWA	$\pi^- p \rightarrow \Lambda K^0$
88	BAKER	79	DPWA	$\pi^- p \rightarrow n\eta$
192	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
130	1 LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
150	² LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

N(1675) POLE POSITION

REAL PART				
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1655 to 1665 (≈ 1660) OUR ESTI	MATE			
1663	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
1656	3 HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
1660±10	CUTKO5KY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following	data for average	s, fit:	s, limits,	etc. • • •
1655	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
1663 or 1668	⁴ LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$
1649 or 1650	¹ LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
-2×IMAGINARY PART				
-2×IMAGINARY PART	DOCUMENT ID		TECN	COMMENT
			TECN	COMMENT
VALUE (MeV)	TE ARNOT	95		$\frac{COMMENT}{\pi N \rightarrow N\pi}$
<u>VALUE (MeV)</u> 125 to 155 (≈ 140) OUR ESTIMA	TE		DPWA	
<u>VALUE (MeV)</u> 125 to 155 (≈ 140) OUR ESTIMA 152	TE ARNOT	93	DPWA ARGD	$\pi N \rightarrow N \pi$
VALUE (MeV) 125 to 155 (≈ 140) OUR ESTIMA 152 126	TE ARNDT 3 HOEHLER CUTKOSKY	93 80	DPWA ARGD IPWA	$ \begin{array}{ccc} \pi N \to & N \pi \\ \pi N \to & \pi N \\ \pi N \to & \pi N \end{array} $
VALUE (MeV) 125 to 155 (≈ 140) OUR ESTIMA 152 152 140±10	TE ARNDT 3 HOEHLER CUTKOSKY	93 80	DPWA ARGD IPWA s, limits,	$ \begin{array}{ccc} \pi N \to N \pi \\ \pi N \to \pi N \\ \pi N \to \pi N \end{array} $
<u>VALUE (MeV)</u> 125 to 155 (≈ 140) OUR ESTIMA 152 126 140±10 • • • We do not use the following	ARNDT ARNDT HOEHLER CUTKOSKY data for average	93 80 s, fit: 91	DPWA ARGD IPWA s, limits,	$\begin{array}{lll} \pi N \to N \pi \\ \pi N \to \pi N \\ \pi N \to \pi N \\ \text{etc.} & \bullet & \bullet \\ \pi N \to \pi N \text{Soin SM90} \end{array}$

N(1675) ELASTIC POLE RESIDUE

MODULUS |r|

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
29	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
23	HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
31±5	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the	following data for average	s, flt	s, limits,	etc. • • •
28	ARNDT	91	DPWA	$\piN \to \piN$ Soln SM90
PHASE €				
VALUE (°)	DOCUMENT ID		TECN	COMMENT
- 6	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
-22	HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
-30±10	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the	following data for average	s, fit	s, ilmits,	etc. • • •
-17	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ Soin SM90}$

N(1675) DECAY MODES

The following branching fractions are our estimates, not fits or averages.

	Mode	Fraction (Γ_I/Γ)	
$\overline{\Gamma_1}$	Νπ	40-50 %	
Γ2	$N\eta$		
Гз	ΛK	<1 %	
Γ_4	ΣΚ		
Γ ₅	$N\pi\pi$	50-60 %	
Γ ₆	$\Delta\pi$	50 ~6 0 %	
Γ_7	$\Delta(1232)\pi$, D -wave		
Г8	$\Delta(1232)\pi$, G-wave		
Г9	$N\rho$	< 1-3 %	
Γ_{10}	$N\rho$, $S=1/2$, D -wave		
Γ_{11}	$N\rho$, $S=3/2$, D-wave		
Γ_{12}	$N\rho$, $S=3/2$, G -wave		
Γ_{13}	$N(\pi\pi)_{S-\text{wave}}^{I=0}$		
Γ ₁₄	$p\gamma$	0.004-0.023 %	
Γ ₁₅	$p\gamma$, helicity= $1/2$	0.0-0.015 %	
Γ ₁₆	$p\gamma$, helicity=3/2	0.0-0.011 %	
Γ ₁₇	$n\gamma$	0.02-0.12 %	
Γ ₁₈	$n\gamma$, helicity=1/2	0.006-0.046 %	
Γ ₁₉	$n\gamma$, helicity=3/2	0.01-0.08 %	

N(1675) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$					Γ ₁ /Γ
VALUE	DOCUMENT ID		<u>TECN</u>	COMMENT	
0.4 to 0.5 OUR ESTIMA					
0.47 ± 0.02	MANLEY			$\pi N \rightarrow \pi N$	& Νππ
0.38±0.05	CUTKOSKY			$\pi N \rightarrow \pi N$	
0.38 ± 0.03	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$	
 • • We do not use the 	following data for average	es, fit	s, limits,	etc. • • •	
0.38	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$	
0.31 ± 0.06	BATINIC	95	DPWA	$\pi N \rightarrow N \pi$	Nη
$\Gamma(N\eta)/\Gamma_{\text{total}}$					Γ2/Γ
VALUE	DOCUMENT ID		TECN	COMMENT	
• • • We do not use the	following data for average	es, fit	s, limits,	etc. • • •	
0.001 ± 0.001	BATINIC	95	DPWA	$\pi N \rightarrow N \pi$	Νη
<u>VALUE</u> • • • We do not use the -0.07	following data for average BAKER	es, fit 79	s, Ilmits, DPWA	etc. • • • $\pi^- p \to n\eta$	
+0.009	FELTESSE		DPWA		
•1					P P 1777 / P
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N \pi$	$\rightarrow N(1675) \rightarrow \Lambda K$				1 1 3 3 7 7 1
$(\Gamma_i \Gamma_f)^{1/2} / \Gamma_{\text{total}} \ln N \pi$	→ N(1675) → AK DOCUMENT ID		<u>TECN</u>	COMMENT	1 1 3) ' / !
$(\Gamma_i \Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\pi$ $\pm 0.04 \text{ to } \pm 0.08$	OUR ESTIMATE			COMMENT	
$(\Gamma_I \Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\pi$ $\frac{\pm 0.04 \text{ to } \pm 0.08}{-0.01}$	OUR ESTIMATE RELL	83	DPWA	$\frac{COMMENT}{\pi^{-1}} p \rightarrow \Lambda k$	
<u>±0.04</u> to ±0.08 −0.01 +0.036	OUR ESTIMATE BELL 5 SAXON	83 80	DPWA DPWA	$ \begin{array}{c} comment \\ \pi^- p \to \Lambda h \\ \pi^- p \to \Lambda h \end{array} $	
<u>±0.04</u> to ±0.08 −0.01	OUR ESTIMATE BELL 5 SAXON	83 80	DPWA DPWA	$ \begin{array}{c} comment \\ \pi^- p \to \Lambda h \\ \pi^- p \to \Lambda h \end{array} $	
<u>±0.04</u> to ±0.08 −0.01 +0.036	OUR ESTIMATE BELL 5 SAXON	83 80 es, fit	DPWA DPWA s, Ilmits,	$ \begin{array}{c} comment \\ \pi^- p \to \Lambda h \\ \pi^- p \to \Lambda h \end{array} $	ζ0 ζ0
± 0.04 to ± 0.08 -0.01 -0.036 • • • We do not use the -0.034 ± 0.006	DOCUMENT ID OUR ESTIMATE BELL 5 SAXON following data for average DEVENISH → N(1675) → ∑ K	83 80 es, fit 746	DPWA DPWA s, limits,	$ \begin{array}{ccc} \pi^{-} p & $	O Coersion rel.
$ \begin{array}{l} $	DOCUMENT ID OUR ESTIMATE BELL 5 SAXON following data for average DEVENISH → N(1675) → ∑ K DOCUMENT ID	83 80 es, fit 74e	DPWA DPWA s, limits,	$ \begin{array}{ccc} \hline comment \\ \pi^- p \rightarrow \Lambda t \\ \pi^- p \rightarrow \Lambda t \\ \text{etc.} \bullet \bullet \bullet \\ \hline Fixed-t dispersion $	O Coersion rel.
$ \begin{array}{c} $	DOCUMENT ID OUR ESTIMATE BELL 5 SAXON following data for average DEVENISH N(1675) -> \(\sum_{DOCUMENT ID} \) following data for average	83 80 es, fit 74e	DPWA DPWA s, limits, i TECN s, limits,	$ \begin{array}{ccc} \hline comment \\ \pi^- p \rightarrow \Lambda t \\ \pi^- p \rightarrow \Lambda t \\ \text{etc.} \bullet \bullet \bullet \\ \hline Fixed-t dispersion $	⁽⁰

Note: Signs of couplings from $\pi N \to N\pi\pi$ analyses were changed in the 1986 edition to agree with the baryon-first convention; the overall phase ambiguity is resolved by choosing a negative sign for the $\Delta(1620)~S_{31}$ coupling to $\Delta(1232)\pi$.

$(\Gamma_I \Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi$	$\rightarrow N(1675) \rightarrow \Delta(123)$	2)π	, D-wav	re (Γ ₁ Γ ₇) ⁷² /Γ
VALUE	DOCUMENT ID			
+0.46 to +0.50 OUR I	STIMATE			
$+0.496\pm0.003$				$\pi N \rightarrow \pi N & N \pi \pi$
+0.46	1,7 LONGACRE			
+0.50	² LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$
• • • We do not use the	e following data for average	s, fit	s, Ilmits,	etc. • • •
+0.5	⁸ NOVOSELLEI	R 78	IPWA	$\pi N \rightarrow N \pi \pi$
				we (Γ ₁ Γ ₁₀) ^{1/2} /Γ
VALUE	DOCUMENT ID	_		COMMENT
+0.04±0.02	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$

Baryon Particle Listings N/1675) N/1680)

N(1675), N(1680)			
	T → N(1675) → N p, S DOCUMENT ID			
-0.12 to -0.06 OUR E				
-0.03 ± 0.02	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$ $\pi N \rightarrow N \pi \pi$
-0.15	1,7 LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
(Γ _Ι Γ _Γ) ^{1/2} /Γ _{total} In Νπ	→ N(1675) → N(ππ)/=0 S-w	ave	(Γ₁Γ₁₅) ^⅓ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
+0.03	1,7 LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
N(1	675) PHOTON DECA	/ AN	APLITU	JDES
$N(1675) \rightarrow p\gamma$, heli	icity-1/2 amplitude A _{1/}	2		
VALUE (GeV ^{-1/2})	DOCUMENT ID		TECN	COMMENT
+0.019±0.008 OUR ES	TIMATE			
0.015±0.010	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
0.021 ± 0.011	CRAWFORD	83	IPWA	$\gamma N \rightarrow \pi N$
0.034 ± 0.005	AWAJI	81	DPWA	$\gamma N \rightarrow \pi N$
0.006 ± 0.005	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
0.006±0.004	ARAI	80		$\gamma N \rightarrow \pi N \text{ (fit 2)}$

CRAWFORD 80 DPWA $\gamma N \rightarrow \pi N$

93 IPWA $\gamma N \rightarrow \pi N$ 78 DPWA $\gamma N \rightarrow \pi N$

76 DPWA $\gamma N \rightarrow \pi N$

$N(1675) \rightarrow p\gamma$, helicity-3/2 amplitude A_{3/2}

 0.023 ± 0.015

 0.012 ± 0.002

 $+0.022 \pm 0.010$

+0.034±0.004

VALUE (GeV ^{-1/2})	DOCUMENT ID		TECN	COMMENT
+0.015±0.009 OUR ESTIMATE				
0.010 ± 0.007	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
0.015 ± 0.009	CRAWFORD	83	IPWA	$\gamma N \rightarrow \pi N$
0.024 ± 0.008	ILAWA	81	DPWA	$\gamma N \rightarrow \pi N$
0.030 ± 0.004	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
0.029 ± 0.004	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$
0.003±0.012	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
	data for average	s, fit	s, iimits,	etc. • • •
0.021 ± 0.002	LI	93	IPWA	$\gamma N \rightarrow \pi N$
$+0.015\pm0.006$	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
$+0.019\pm0.009$	FELLER	76	DPWA	$\gamma N \rightarrow \pi N$

LL BARBOUR

FELLER

$N(1675) \rightarrow n\gamma$, helicity-1/2 amplitude $A_{1/2}$

VALUE (GeV ^{-1/2})	DOCUMENT ID		TECN	COMMENT
-0.043±0.012 OUR ESTIMATE				
-0.049 ± 0.010	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
-0.057 ± 0.024	ILAWA	81	DPWA	$\gamma N \rightarrow \pi N$
-0.033 ± 0.004	FUJII	81	DPWA	$\gamma N \rightarrow \pi N$
-0.039 ± 0.017	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
-0.025 ± 0.027	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$
-0.059 ± 0.015	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
-0.021 ± 0.011	TAKEDA	80	DPWA	$\gamma N \rightarrow \pi N$
• • We do not use the following	data for average	es, fit	s, limits,	etc. • • •
-0.060 ± 0.003	LI	93	IPWA	$\gamma N \rightarrow \pi N$
-0.066 ± 0.020	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$

$N(1675) \rightarrow n\gamma$, helicity-3/2 amplitude A_{3/2}

VALUE (GeV ^{-1/2})	DOCUMENT ID		TECN	COMMENT
-0.068±0.013 OUR ESTIMATE				
-0.051 ± 0.010	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
-0.077 ± 0.018	ILAWA	81	DPWA	$\gamma N \rightarrow \pi N$
-0.069 ± 0.004	FUJII	81	DPWA	$\gamma N \rightarrow \pi N$
-0.066 ± 0.026	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
-0.071 ± 0.022	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$
-0.059 ± 0.020	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
-0.030 ± 0.012	TAKEDA	80	DPWA	$\gamma N \rightarrow \pi N$
• • • We do not use the following	data for average	s, fits	s, Ilmits,	etc. • • •
-0.074 ± 0.003	LI	93	IPWA	$\gamma N \rightarrow \pi N$
-0.073 ± 0.014	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$

N(1675) FOOTNOTES

¹LONGACRE 77 pole positions are from a search for poles in the unitarized T-matrix; the first (second) value uses, in addition to $\pi N \to N \pi \pi$ data, elastic amplitudes from a Saciay (CERN) partial-wave analysis. The other LONGACRE 77 values are from eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.

² From method II of LONGACRE 75: eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.

amplitudes.

3 See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and Δ resonances as determined from Argand diagrams of πN elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams. 4 LONGACRE 78 values are from a search for poles in the unitarized T-matrix. The first (second) value uses, in addition to $\pi N \to N \pi \pi$ data, elastic amplitudes from a Saclay (CERN) partial-wave analysis.

⁵ SAXON 80 finds the coupling phase is near 90°.

⁶The range given is from the four best solutions. DEANS 75 disagrees with π^+p \rightarrow $\Sigma^+ K^+$ data of WINNIK 77 around 1920 MeV. 7 LONGACRE 77 considers this coupling to be well determined.

⁸A Breit-Wigner fit to the HERNDON 75 IPWA.

N(1675) REFERENCES

For early references, see Physics Letters 111B 70 (1982).

ARNDT	96	PR C53 430	+Strakovsky, Workman	(VPI)
ARNDT	95	PR C52 2120	+Strakovsky, Workman, Pavan	(VPI, BŘCO)
BATINIC	95	PR C51 2310	+Staus, Svarc, Nefkens	(BOSK, UCLA)
HOEHLER	93	# N Newsletter 9 1		(KARL)
LI	93	PR C47 2759	+Arndt, Roper, Workman	`(VPI)
MANLEY	92	PR D45 4002	+Saleski	(KĚNT) IJP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	(VPI)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
BELL	83	NP B222 389	+Bilssett, Broome, Daley, Hart, Lintern+	
CRAWFORD	83	NP B211 1	+Morton	(GLAS)
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
ILAWA	81	Bonn Conf. 352	+Kajikawa	(NAGO)
Also	82	NP B197 365	Fujii, Hayashii, Iwata, Kajikawa+	(NAGO)
FUJII	81	NP B187 53	+Hayashii, Iwata, Kajikawa+	(NAGO, OSAK)
ARAI	80	Toronto Conf. 93		` (INUS)
Also	82	NP B194 251	Arai, Fujii	(INUS)
CRAWFORD	80	Toronto Conf. 107	• •	(GLAS)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMŮ, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJP
SAXON	80	NP B162 522	+Baker, Bell, Blissett, Bloodworth+	(RHEL, BRIS) IJP
TAKEDA	BO	NP B168 17	+Arai, Fujii, Ikeda, Iwasaki+	(TOKY, INUS)
BAKER	79	NP B156 93	+Brown, Clark, Davies, Depagter, Evans	
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) LIP
BARBOUR	78	NP B141 253	+Crawford, Parsons	(GLAS)
LONGACRE	78	PR D17 1795	+Lasinski, Rosenfeld, Smadja+	(LBL, SLAC)
NOVOSELLER		NP B13V 509	,, , , , , , , , , , , , , , , , ,	(CIT) UP
Also	78B	NP B137 445	Novoselter	(CIT) IJP
LONGACRE	77	NP B122 493	+Dolbeau	(SACL) IJP
Also	76	NP B108 365	Dolbeau, Triantis, Neveu, Cadiet	(SACL) IJP
WINNIK	77	NP B128 66	+Toaff, Revel, Goldberg, Berny	(HAIF) I
FELLER	76	NP B104 219	+Fukushima, Horikawa, Kajikawa+	(NAGO, OSAK) IJP
DEANS	75	NP B96 90	+Mitchell, Montgomery+	(SFLA, ALAH) IJP
FELTESSE	75	NP B93 242	+Ayed, Bareyre, Borgeaud, David+	(SACL) IJP
HERNDON	75	PR D11 3183	+Longacre, Miller, Rosenfeld+	(LBL, SLAC)
LONGACRE	75	PL 55B 415	+Rosenfeld, Lasinski, Smadja+	(LBL, SLAC) IJP
DEVENISH	74B	NP B81 330		DESY, NORD, LOUC)
DEVENTION	1+0	141 1201 230	Trioggan, mains (2231, 110112, 2000)

 $N(1680) F_{15}$

 $I(J^P) = \frac{1}{2}(\frac{5}{2}^+)$ Status: ***

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters 111B (1982).

N(1680) BREIT-WIGNER MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1675 to 1690 (≈ 1680) OUR	ESTIMATE			
1684± 4	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
1680±10	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
1684± 3	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the follo	wing data for average	s, fit	s, limits,	etc. • • •
1679± 5	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
1678	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
1674±12	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$
1682	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
1680	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
1660	¹ LONGACRE	77		$\pi N \rightarrow N \pi \pi$
1685	KNASEL	75	DPWA	$\pi^- p \rightarrow \Lambda K^0$
1670	² LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

N(1680) BREIT-WIGNER WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
120 to 140 (≈ 130) OU	R ESTIMATE			
139± 8	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
120±10	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
128± 8	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use t	he following data for average	s, fit	s, Ilmits,	etc. • • •
124± 4	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
126	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
126±20	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$
121	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
119	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
150	¹ LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
155	KNASEL	75	DPWA	$\pi^- p \rightarrow \Lambda K^0$
130	² LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

N(1680) POLE POSITION

REAL PART					
VALUE (MeV)	DOCUMENT ID		TECN	COMME	NT
1665 to 1675 (≈ 1670) OU	R ESTIMATE				
1670	ARNDT	95	DPWA	$\pi N \rightarrow$	Nπ
1673	³ HOEHLER	93	ARGD	$\pi N \rightarrow$	πN
1667±5	CUTKOSKY	80	IPWA	$\piN\rightarrow$	πN
• • • We do not use the fo	ollowing data for average	s, fits	s, Ilmits,	etc. • •	•
1670	ARNDT	91	DPWA	$\pi N \rightarrow$	πN Soln SM90
1668 or 1674	⁴ LONGACRE	78	IPWA	$\pi N \rightarrow$	Νππ
1656 or 1653	¹ LONGACRE	77	IPWA	$\pi N \rightarrow$	Nxx
• • • We do not use the fo 1670 1668 or 1674	ollowing data for average ARNDT 4 LONGACRE	s, fit: 91 78	s, ilmits, DPWA IPWA	etc. • • • π N → π N →	τΝ Soln SM Νππ

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
106 to 135 (≈ 120) OU			1001	COMMENT
120	ARNDT		DPWA	$\pi N \rightarrow N \pi$
135	³ HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
110±10	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use t	he following data for average	s, fit	s, ilmits,	etc. • • •
116	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
132 or 137	4 LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$
145 or 143	¹ LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
173 01 473	LONGACKE		IF VVA	N 14 → 14 N N
	N(1680) ELASTIC PO	FF	FSIDII	F

MODULUS |r|

VALUE (MeV)	DOCUMENT ID	_ 7	ECN	COMME	NT
40	ARNDT 9	5 0	PWA	πN →	Νπ
44	HOEHLER 9:	3 A	RGD	$\pi N \rightarrow$	πN
34±2	CUTKOSKY 8)	PWA	$\pi N \rightarrow$	πN
• • • We do not use the	following data for averages, t	its, i	limits,	etc. • •	•
37	ARNDT 9	LD	PWA	$\pi N \rightarrow$	πN Soln SM90

PHASE θ

VALUE (°)	DOCUMENT ID		TECN	COMME	v <i>T</i>
+ 1	ARNDT	95	DPWA	$\pi N \rightarrow$	Νπ
-17	HOEHLER	93	ARGD	$\pi N \rightarrow$	πN
-25±5	CUTKOSKY	80	IPWA	$\pi N \rightarrow$	πN
• • • We do not use the following	data for average	s, fit:	s, limits,	etc. • •	•
-14	ARNDT	91	DPWA	$\pi N \rightarrow$	πN Soln SM90

N(1680) DECAY MODES

The following branching fractions are our estimates, not fits or averages.

	Mode	Fraction (Γ_I/Γ)	
$\overline{\Gamma_1}$	Nπ	60-70 %	
Γ ₂	Νη		
Γ3	ΛŘ		
Γ_4	ΣΚ		
Γ ₅	$N\pi\pi$	30-40 %	
Γ ₆	$\Delta\pi$	5–15 %	
Γ7	Δ (1232) π , P -wave	6–14 %	
Гв	$\Delta(1232)\pi$, F-wave	<2 %	
و۱	Nρ	3–15 %	
Γ ₁₀	Nρ, S =1/2, <i>F</i> -wave		
Γ11	$N\rho$, $S=3/2$, P -wave	<12 %	
Γ12	$N\rho$, $S=3/2$, F -wave	1–5 %	
Γ ₁₃	$N(\pi\pi)_{S-\text{wave}}^{I=0}$	5-20 %	
Γ14	Pγ	0.21-0.32 %	
Γ ₁₅	$p\gamma$, helicity=1/2	0.001-0.011 %	
Γ ₁₆	$p\gamma$, helicity=3/2	0.20-0.32 %	
Γ ₁₇	πγ	0.021-0.046 %	
F ₁₈	$n\gamma$, helicity=1/2	0.004-0.029 %	
Γ19	$n\gamma$, helicity=3/2	0.01-0.024 %	•

N(1680) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$				Γ ₁ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
0.6 to 0.7 OUR ESTIMAT	E			
0.70±0.03	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
0.62±0.05	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
0.65±0.02	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
 • • We do not use the fe 	ollowing data for average	es, fit	s, limits,	etc. • • •
0.68	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
0.69±0.04	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$
$(\Gamma_I \Gamma_I)^{1/2} / \Gamma_{\text{total}} \ln N \pi - VALUE$	DOCUMENT ID			$(\Gamma_1\Gamma_2)^{\frac{1}{2}}/\Gamma$
	DOCUMENT ID		s, limits,	COMMENT
VALUE • • • We do not use the finot seen Γ(Nη)/Γ _{total}	DOCUMENT ID ollowing data for average BAKER	es, fit 79	s, limits, DPWA	COMMENT etc. • • • $\pi^- p \rightarrow n\eta$ Γ_2/Γ
VALUE • • • We do not use the finot seen Γ(Nη)/Γ _{total} VALUE	DOCUMENT ID BAKER DOCUMENT ID	es, fit 79	s, limits, DPWA	COMMENT etc. • • • $\pi^- p \rightarrow n \eta$ COMMENT
VALUE • • • We do not use the finot seen Γ(Nη)/Γ _{total}	DOCUMENT ID BAKER DOCUMENT ID	es, fit 79	s, limits, DPWA	COMMENT etc. • • • $\pi^- p \rightarrow n \eta$ COMMENT
VALUE • • • We do not use the finot seen $\Gamma(N\eta)/\Gamma_{\text{total}}$ VALUE • • • We do not use the fi	DOCUMENT ID Ollowing data for average BAKER DOCUMENT ID Ollowing data for average BATINIC	es, fit 79 es, fit 95	s, limits, DPWA TECN s, limits, DPWA	COMMENT etc. • • • $\pi^- p \rightarrow n \eta$ Γ_2/Γ COMMENT etc. • • • $\pi N \rightarrow N \pi, N \eta$
VALUE • • • We do not use the finot seen $\Gamma(N\eta)/\Gamma_{\text{total}}$ VALUE • • • We do not use the fi	DOCUMENT ID Ollowing data for average BAKER DOCUMENT ID Ollowing data for average BATINIC 5 CARRERAS	es, fit 79 es, fit 95	TECN s, limits, DPWA DPWA MPWA	COMMENT etc. • • • $\pi^- p \rightarrow n \eta$ Γ_2/Γ COMMENT etc. • • • $\pi N \rightarrow N \pi, N \eta$ t pole + resonance
VALUE • • • We do not use the finot seen \[\left(N \eta) / \Gamma_{\text{total}} \] VALUE • • • We do not use the finon to the finon total	DOCUMENT ID Ollowing data for average BAKER DOCUMENT ID Ollowing data for average BATINIC	es, fit 79 es, fit 95	TECN s, limits, DPWA DPWA MPWA	COMMENT etc. • • • $\pi^- p \rightarrow n \eta$ Γ_2/Γ COMMENT etc. • • • $\pi N \rightarrow N \pi, N \eta$

\bullet \bullet We do not use the following data for averages, fits, limits, etc. \bullet \bullet \bullet <0.027 HEUSCH 66 RVUE π^0 , η photoproduction	Γ(Nη)/Γ(Nπ) VALUE	DOCUMENT ID		TECN	COMMENT	Γ_2/Γ_1
<0.027 HEUSCH 66 RVUE π^0 , η photoproduction (Γ ₁ Γ ₂) $\frac{1}{2}$ /Γ _{total} in $N\pi \rightarrow N(1680) \rightarrow \Lambda K$ Coupling to ΛK not required in the analyses of BAKER 77, SAXON 80, or BELL 8 • • • We do not use the following data for averages, fits, limits, etc. • • • 0.01 KNASEL 75 DPWA $\pi^- p \rightarrow \Lambda K^0$ -0.009 ± 0.009 DEVENISH 74B Fixed- t dispersion rel. (Γ ₁ Γ ₂) $\frac{1}{2}$ /Γ _{total} in $N\pi \rightarrow N(1680) \rightarrow \Sigma K$ ALUE DOCUMENT ID TECN COMMENT • • • We do not use the following data for averages, fits, limits, etc. • • • <0.001 DEVENISH 75 DPWA $\pi^- p \rightarrow \Lambda K^0$ Fixed- t dispersion rel. TECN COMMENT • • • We do not use the following data for averages, fits, limits, etc. • • • <0.001 ODEANS 75 DPWA $\pi N \rightarrow \Sigma K$ Note: Signs of couplings from $\pi N \rightarrow N\pi\pi$ analyses were changed in the 1986 edition to agree with the baryon-first convention; the overall phase ambiguity is resolved by choosing a negative sign for the $\Delta(1620)$ S_{31}						
Coupling to ΛK not required in the analyses of BAKER 77, SAXON 80, or BELL 8 DOCUMENT ID TECN COMMENT 0.00 We do not use the following data for averages, fits, limits, etc. • • • 0.01 KNASEL 75 DPWA $\pi^-p \rightarrow \Lambda K^0$ DEVENISH 748 Fixed- t dispersion rel. ($\Gamma_1\Gamma_1$) Γ_2 / Γ_3 / Γ_4 / Γ						oproduction
0.01 KNASEL 75 DPWA $\pi^-p \rightarrow \Lambda K^0$ -0.009 ± 0.009 DEVENISH 748 Fixed- t dispersion rel. ($\Gamma_1\Gamma_1$) $\frac{1}{12}$ / Γ_{total} in $N\pi \rightarrow N(1680) \rightarrow \Sigma K$ ($\Gamma_1\Gamma_4$) $\frac{1}{12}$ / Γ_{total} in $N\pi \rightarrow N(1680) \rightarrow \Sigma K$ ($\Gamma_1\Gamma_4$) $\frac{1}{12}$ / Γ_{total} in $N\pi \rightarrow N(1680) \rightarrow \Sigma K$ ($\Gamma_1\Gamma_4$) Γ_{total} in $N\pi \rightarrow N(1680) \rightarrow \Sigma K$ ($\Gamma_1\Gamma_4$) Γ_{total} in $N\pi \rightarrow N(1680) \rightarrow \Sigma K$ ($\Gamma_1\Gamma_4$) Γ_{total} in $N\pi \rightarrow N(1680) \rightarrow \Sigma K$ ($\Gamma_1\Gamma_4$) Γ_{total} in $N\pi \rightarrow N(1680) \rightarrow \Sigma K$ ($\Gamma_1\Gamma_4$) Γ_{total} in $N\pi \rightarrow N(1680) \rightarrow \Sigma K$ ($\Gamma_1\Gamma_4$) Γ_{total} in $N\pi \rightarrow N(1680) \rightarrow \Sigma K$ Note: Signs of couplings from $\pi N \rightarrow N\pi \pi$ analyses were changed in the 1986 edition to agree with the baryon-first convention; the overall phase ambiguity is resolved by choosing a negative sign for the $\Delta(1620)$ S_{31}	Coupling to AK not	required in the analyses				(Г1Г3)^{1/2}/ D, or BELL 83
-0.009 ± 0.009 DEVENISH 74B Fixed- t dispersion rel. ($\Gamma_1\Gamma_f$) $\frac{1}{2}$ / Γ_{total} in $N\pi \to N(1680) \to \Sigma K$ ($\Gamma_1\Gamma_4$) $\frac{1}{2}$ / N ($\Gamma_1\Gamma_$	 • • We do not use the fe 	ollowing data for average	es, fit	s, limits,	etc. • • •	
$(\Gamma_1\Gamma_1)^{\frac{1}{12}}/\Gamma_{\text{total}}$ in $N\pi \to N(1680) \to \Sigma K$ VALUE DOCUMENT ID • • We do not use the following data for averages, fits, limits, etc. • • • < 0.001 Fig. Comment One of DEANS < 0.001 Note: Signs of couplings from $\pi N \to N\pi\pi$ analyses were changed in the 1986 edition to agree with the baryon-first convention; the overall phase ambiguity is resolved by choosing a negative sign for the $\Delta(1620)$ S_{31}	0.01	KNASEL	75	DPWA	$\pi^- p \rightarrow \ell$	1 <i>K</i> 0
VALUE DOCUMENT ID TECN COMMENT • • • We do not use the following data for averages, fits, limits, etc. • • • <0.001 • DEANS	-0.009 ± 0.009	DEVENISH	748	ı	Fixed-t dis	persion rel.
 • • We do not use the following data for averages, fits, limits, etc. • • • <0.001						· 34 ·-
Note: Signs of couplings from $\pi N \to N \pi \pi$ analyses were changed in the 1986 edition to agree with the baryon-first convention; the overall phase ambiguity is resolved by choosing a negative sign for the $\Delta(1620)$ S_{31}				TECN	COMMENT	(114)"/1
1986 edition to agree with the baryon-first convention; the overall phase ambiguity is resolved by choosing a negative sign for the $\Delta(1620)$ S_{31}	VALUE	DOCUMENT ID				(114)**/1
	• • • We do not use the fo	DOCUMENT ID DISTRIBUTION DISTRI	es, fit	s, limits,	etc. • • •	<u>-</u> -

$(\Gamma_I \Gamma_I)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N_1$	$\pi \to N(1680) \to \Delta(123)$	2)π.	, P-way	e	(Г₁Г ₇) ¹ //Г
VALUE	DOCUMENT ID	_	TECN	COMME	<u>vr</u>
-0.31 to -0.21 OUR E	STIMATE				
-0.26 ± 0.04	MANLEY				
-0.27	1,7 LONGACRE				
-0.25	² LONGACRE	75	IPWA	$\pi N \rightarrow$	Νππ
• • • We do not use th	e following data for average	s, fit	s, limits,	etc. • •	•
-0.38	⁸ NOVOSELLER	₹ 78	IPWA	$\pi N \rightarrow$	$N\pi\pi$

([[[f]) ^{†2} /[total in A	$I\pi \rightarrow N(1680) \rightarrow \Delta(123$	2) π	, F-wav	• (Γ ₁ Γ ₈) ^γ	2/
VALUE	DOCUMENT ID		TECN	COMMENT	Ĺ
+0.03 to +0.11 OUR	ESTIMATE				
$+0.07\pm0.03$	MANLEY			$\pi N \rightarrow \pi N \& N \pi \pi$	
+0.07	1,7 LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$	
+0.08	² LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$	
• • • We do not use	the following data for average	s, fit	s, limits,	etc. • • •	
+0.05	⁸ NOVOSELLEI	78	IPWA	$\pi N \rightarrow N \pi \pi$	

$(\Gamma_I \Gamma_f)^{\frac{1}{12}} / \Gamma_{\text{total}} \ln N$	$\pi \rightarrow N(1680) \rightarrow N\rho, S$	=3/2	2, <i>P</i> -wa	ve (Γ ₁ Γ ₁₁) ^{†2} /!
VALUE	DOCUMENT ID		TECN	COMMENT
-0.30 to -0.10 OUR I	ESTIMATE			
-0.20 ± 0.05	MANLEY			$\pi N \rightarrow \pi N \& N \pi \pi$
-0.23	^{1,7} LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
- 0.30	² LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$
• • • We do not use the	he following data for average	s, fit	s, limits	, etc. • • •
-0.34	⁸ NOVOSELLE	78	IPWA	$\pi N \rightarrow N \pi \pi$

$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N\pi \rightarrow$	$N(1680) \rightarrow N\rho, S=$	3/2, F-wa	we $(\Gamma_1\Gamma_{12})^{\frac{1}{2}}$
VALUE	DOCUMENT ID	<u>TECN</u>	COMMENT
-0.18 to -0.10 OUR ESTI	MATE		
-0.13 ± 0.03			$\pi N \rightarrow \pi N \& N \pi \pi$
-0.15	1,7 LONGACRE	77 IPWA	$\pi N \rightarrow N \pi \pi$

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N_f$	$\pi \to N(1680) \to N(\pi\pi$)/=0 /S-w	ave		(Г₁Г₁₃)^½/ Г
VALUE	DOCUMENT ID		TECN	COMME	NT
+0.25 to +0.35 OUR E	STIMATE				
$+0.29\pm0.04$	MANLEY				
+0.31	1,7 LONGACRE				
+0.30	² LONGACRE	75	IPWA	$\pi N \rightarrow$	Νππ
• • • We do not use the	e following data for average	s, fits	s, limits,	etc. • •	•
+0.42	8 NOVOSELLE	R 78	IPWA	$\pi N \rightarrow$	Νππ

N(1680) PHOTON DECAY AMPLITUDES

$N(1680) \rightarrow p\gamma$, helicity-1/2 amplitude A_{1/2}

VALUE (GeV-1/2)	DOCUMENT ID		TECN	COMMENT
-0.015±0.006 OUR ESTIMATE				
-0.010 ± 0.004	ARNDT	96	IPWA .	$\gamma N \rightarrow \pi N$
-0.017 ± 0.018	CRAWFORD	83	IPWA	$\gamma N \rightarrow \pi N$
-0.009 ± 0.006	ILAWA	81	DPWA	$\gamma N \rightarrow \pi N$
-0.028 ± 0.003	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
-0.026 ± 0.003	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$
-0.018 ± 0.014	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
• • • We do not use the following	data for average	s, fit	s, limits,	etc. • • •
-0.006±0.002	u .	93	IPWA	$\gamma N \rightarrow \pi N$
-0.005 ± 0.015	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
-0.009 ± 0.002	FELLER	76	DPWA	$\gamma N \rightarrow \pi N$

N(1680), N(1700)

VALUE (GeV-1/2)	DOCUMENT ID		TECN	COMMENT
+0.133±0.012 OUR ESTI	MATE			
0.145±0.005	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
0.132 ± 0.010	CRAWFORD	83	IPWA	$\gamma N \rightarrow \pi N$
0.115 ± 0.008	ILAWA	81	DPWA	$\gamma N \rightarrow \pi N$
0.115 ± 0.003	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
0.122 ± 0.003	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (flt 2)}$
0.141 ± 0.014	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
 We do not use the f 	ollowing data for average	s, fit	s, ilmits,	etc. • • •
0.154 ± 0.002	LI	93	IPWA	$\gamma N \rightarrow \pi N$
$+0.138\pm0.021$	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
+0.121 ±0.010	FELLER	76	DPWA	$\gamma N \rightarrow \pi N$

$N(1680) \rightarrow n\gamma$, helicity-1/2 amplitude A_{1/2}

VALUE (GeV ^{-1/2})	DOCUMENT ID		TECN	COMMENT
+0.029±0.010 OUR ESTIMATE				
0.030 ± 0.005	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
0.017 ± 0.014	ILAWA	81	DPWA	$\gamma N \rightarrow \pi N$
0.032 ± 0.003	FUJII	81	DPWA	$\gamma N \rightarrow \pi N$
0.026 ± 0.005	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
0.028 ± 0.014	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$
0.044 ± 0.012	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
0.025 ± 0.010	TAKEDA	80	DPWA	$\gamma N \rightarrow \pi N$
• • • We do not use the following	data for average	s, fit	s, ilmits,	etc. • • •
0.022±0.002	LI	93	IPWA	$\gamma N \rightarrow \pi N$
$+0.037\pm0.010$	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$

$N(1680) \rightarrow n\gamma$, helicity-3/2 amplitude A_{3/2}

VALUE (GeV-1/2)	DOCUMENT ID		TECN	COMMENT
-0.033 ± 0.009 OUR ESTIMATE				
-0.040 ± 0.015	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
-0.033 ± 0.013	ILAWA	81	DPWA	$\gamma N \rightarrow \pi N$
-0.023 ± 0.005	FUJII	81	DPWA	$\gamma N \rightarrow \pi N$
-0.024 ± 0.009	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
-0.029 ± 0.017	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (flt 2)}$
-0.033 ± 0.015	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
-0.035 ± 0.012	TAKEDA	80	DPWA	$\gamma N \rightarrow \pi N$
• • • We do not use the following	g data for average	s, fit	s, limits,	etc. • • •
-0.048±0.002	LI	93	IPWA	$\gamma N \rightarrow \pi N$
-0.038±0.018	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$

N(1680) FOOTNOTES

- ¹ LONGACRE 77 pole positions are from a search for poles in the unitarized T-matrix; the first (second) value uses, in addition to $\pi N \rightarrow N \pi \pi$ data, elastic amplitudes from a Saclay (CERN) partial-wave analysis. The other LONGACRE 77 values are from eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.
- ² From method II of LONGACRE 75: eyeball fits with Breit-Wigner circles to the T-matrix
- ³ See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and Δ resonances as determined from Argand diagrams of πN elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams.
- ⁴ LONGACRE 78 values are from a search for poles in the unitarized T-matrix. The first (second) value uses, in addition to $\pi N \to N \pi \pi$ data, elastic amplitudes from a Saclay (CERN) partial-wave analysis.
- ⁵ The parametrization used may be double counting.
- The parametrization used may be double counting.

 The range given is from 3 of 4 best solutions; not present in solution 1. DEANS 75 disagrees with π⁺p → Σ⁺K⁺ data of WINNIK 77 around 1920 MeV.

 LONGACRE 77 considers this coupling to be well determined.

 A Breit-Wigner fit to the HERNDON 75 IPWA.

N(1680) REFERENCES

For early references, see Physics Letters 1118 70 (1982). For very early references, see Reviews of Modern Physics 37 633 (1965).

ARNDT	96	PR C53 430	+Strakovsky, Workman	(VPI)
ARNDT	95	PR C52 2120	+Strakovsky, Workman, Pavan	(VPI, BRCO)
BATINIC	95	PR C51 2310	+Slaus, Svarc, Nefkens	(BOSK, UCLA)
HOEHLER	93	πN Newsletter 9 1		(KARL)
LI	93	PR C47 2759	+Arndt, Roper, Workman	(VPI)
MANLEY	92	PR D45 4002	+Saleski	(KÈNT) IJP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	(VPI)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
BELL	83	NP B222 389	+Blissett, Broome, Daley, Hart, Lintern+	(RL) IJP
CRAWFORD	83	NP B211 1	+ Morton	(GLAS)
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
ILAWA	81	Bonn Conf. 352	+Kajikawa	(NAGO)
Also	82	NP B197 365	Fujii, Hayashii, Iwata, Kajikawa+	(NAGO)
FUJII	81	NP B187 53	+Hayashii, Iwata, Kajikawa+	(NAGO, OSAK)
ARAI	80	Toronto Conf. 93	•	(INUS)
Also	82	NP B194 251	Arai, Fujii	(INUS)
CRAWFORD	80	Toronto Conf. 107	-	(GLAS)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMÚ, LBL) IJP
Aiso	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJP
SAXON	80	NP B162 522	+Baker, Bell, Blissett, Bloodworth+	(RHEL, BRIS) IJP
TAKEDA	80	NP B168 17	+Arai, Fujii, Ikeda, lwasaki+	(TOKY, INUS)
BAKER	79	NP B156 93	+Brown, Clark, Davies, Depagter, Evans-	(RHEL) IJP

HOEHLER	79	PDAT 12-1	+Kalser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
BARBOUR	78	NP B141 253	+Crawford, Parsons	`(GLAS)
LONGACRE	78	PR D17 1795	+Lasinski, Rosenfeld, Smadja+	(LBL, SLAC)
NOVOSELLER	78	NP B137 509	,,	(CIT) UP
Also	78B	NP B137 445	Novoseller	(CIT) UP
BAKER	77	NP B126 365	+Blissett, Bloodworth, Broome, Ha	
LONGACRE	77	NP B122 493	+Dolbeau	(SACL) UP
Also	76	NP 8108 365	Dolbeau, Triantis, Neveu, Cadlet	(SACL) IJP
WINNIK	77	NP B128 66	+Toaff, Revel, Goldberg, Berny	(HAIF) I
FELLER	76	NP B104 219	+Fukushima, Horikawa, Kajikawa+	
DEANS	75	NP B96 90	+Mitchell, Montgomery+	(SFLA, ALAH) IJP
HERNDON	75	PR D11 3183	+Longacre, Miller, Rosenfeld+	(LBL, SLAC)
KNASEL	75	PR D11 1		(CHIC, WUSL, OSU, ANL) IJP
LONGACRE	75	PL 55B 415	+Rosenfeld, Lasinski, Smadja+	(LBL. SLAC) IJP
DEVENISH	74B	NP B81 330	+Froggatt, Martin	(DESY, NORD, LOUC)
CARRERAS	70	NP B16 35	+Donnachie	(DARE, MCHS)
BOTKE	69	PR 180 1417	Donnecine	(UCSB)
DEANS	69	PR 185 1797	+Wooten	(SFLA)
HEUSCH	66	PRL 17 1019	+Prescott, Dashen	(CIT)
TIEOSCIII	••	1 146 21 2027	Triescott, Danien	(011)

 $N(1700) D_{13}$

 $I(J^P) = \frac{1}{2}(\frac{3}{2})$ Status: ***

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters 111B (1982).

The various partial-wave analyses do not agree very well.

N(1700) BREIT-WIGNER MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1650 to 1750 (≈ 1700) OUR EST	TMATE			
1737 ± 44	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
1675 ± 25	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
1731 ± 15	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following	g data for average	s, flts	s, limits,	etc. • • •
1791 ± 46	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$
1709	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
1650	SAXON	80	DPWA	$\pi^- \rho \rightarrow \Lambda K^0$
1690 to 1710	BAKER	78	DPWA	$\pi^- \rho \rightarrow \Lambda K^0$
1719	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
1670±10	¹ BAKER	77	IPWA	$\pi^- \rho \rightarrow \Lambda K^0$
1690	1 BAKER	77	DPWA	$\pi^- p \rightarrow \Lambda K^0$
1660	² LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
1710	³ LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

N(1700) BREIT-WIGNER WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
50 to 150 (≈ 100) O	UR ESTIMATE			
250 ± 220	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
90 ± 40	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
110± 30	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • We do not use to	the following data for average	s, fit	s, Ilmits,	etc. • • •
215± 60	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$
166	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
70	SAXON	80	DPWA	$\pi^- p \rightarrow \Lambda K^0$
70 to 100	BAKER	78	DPWA	$\pi^- p \rightarrow \Lambda K^0$
126 •	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
90± 25	1 BAKER	77	IPWA	$\pi^- p \rightarrow \Lambda K^0$
100	¹ BAKER	77	DPWA	$\pi^- p \rightarrow \Lambda K^0$
600	² LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
300	³ LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

N(1700) POLE POSITION

DEAL	DADT
REAL	PART

REAL PART				
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1630 to 1730 (≈ 1680) (OUR ESTIMATE			
1700	⁴ HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
1660 ± 30	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the	following data for average	s, fit	s, limits,	etc. • • •
not seen	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
1710 or 1678	⁵ LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$
1616 or 1613	² LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
-2×IMAGINARY PA	ART			
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
50 to 150 (≈ 100) OUF	ESTIMATE			
120	⁴ HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
90 ± 40	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the	following data for average	s, fit	s, Ilmits,	etc. • • •
not seen	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
607 or 567	⁵ LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$
577 or 575	² LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$

. N	(1700) ELASTIC POLE	RESIDL	JE
MODULUS r	DOCUMENT ID	TECN	COMMENT
5	HOEHLER	3 SPED	$\pi N \rightarrow \pi N$
6±3	CUTKOSKY 8	0 IPWA	$\pi N \rightarrow \pi N$
PHASE 0 VALUE (°)	DOCUMENT ID	TECN	COMMENT
0±50	CUTKOSKY 8	0 IPWA	$\pi N \rightarrow \pi N$

N(1700) DECAY MODES

The following branching fractions are our estimates, not fits or averages.

	Mode	Fraction (Γ_I/Γ)	
$\overline{\Gamma_1}$	Nπ	5–15 %	
Γ_2	$N\eta$		
Гз	ΛK	<3 %	
Γ4	ΣΚ		
Γ ₅	$N\pi\pi$	85 -9 5 %	
Γ ₆	$\Delta\pi$		
Γ_7	$\Delta(1232)\pi$, S-wave		
Γ8	$\Delta(1232)\pi$, D-wave		
و٦	$N\rho$	<35 %	
Γ ₁₀	$N\rho$, $S=1/2$, D-wave		
Γ_{11}	Nρ, 5=3/2, <i>S</i> -wave		
Γ ₁₂	$N\rho$, $S=3/2$, D-wave		
Γ13	$N(\pi\pi)_{S-wave}^{I=0}$		
Γ ₁₄	pγ	0.01-0.05 %	
Γ15	$p\gamma$, helicity=1/2	0.0-0.024 %	
Γ ₁₆	$p\gamma$, helicity=3/2	0.002-0.026 %	
Γ ₁₇	$n\gamma$	0.01-0.13 %	
Γ ₁₈	$n\gamma$, helicity=1/2	0.0-0.09 %	
Γ19	$n\gamma$, helicity=3/2	0.01-0.05 %	

N(1700) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$					Γ1/Γ
VALUE	DOCUMENT_ID		TECN	COMMENT	/ -
0.05 to 0.15 OUR ESTIMATE			-		
0.01 ± 0.02	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N 1$	τπ
0.11±0.05	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$	
0.08 ± 0.03	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$	
• • • We do not use the following	data for average	s, fit:	s, limits,	etc. • • •	
0.04±0.05	BATINIC	95	DPWA	$\pi N \rightarrow N \pi_* N \eta$	
$\Gamma(N\eta)/\Gamma_{\text{total}}$					Γ_2/Γ
VALUE	DOCUMENT ID		TECN	COMMENT	
• • • We do not use the following	data for average	s, fit	s, ilmits,	etc. • • •	
0.10±0.06	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$	
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\pi \to N(17)$	700) → <i>ΛK</i>			(Г ₁Г:	ı) ^½ /Γ
VALUE				401114511	
VALUE	DOCUMENT ID		TECN_	COMMENT	
-0.06 to +0.04 OUR ESTIMATE	.			_	
-0.06 to +0.04 OUR ESTIMATE -0.012	BELL	83	DPWA	$\pi^- p \rightarrow \Lambda K^0$	
-0.06 to +0.04 OUR ESTIMATE	.	83	DPWA	_	
-0.06 to +0.04 OUR ESTIMATE -0.012	BELL SAXON	83 80	DPWA DPWA	$\pi^{-} p \rightarrow \Lambda K^{0}$ $\pi^{-} p \rightarrow \Lambda K^{0}$	
-0.06 to +0.04 OUR ESTIMATE -0.012 -0.012	BELL SAXON	83 80 s, fit	DPWA DPWA s, ilmits,	$\pi^{-} p \rightarrow \Lambda K^{0}$ $\pi^{-} p \rightarrow \Lambda K^{0}$	
-0.06 to +0.04 OUR ESTIMATE -0.012 -0.012 • • • We do not use the following	BELL SAXON data for average	83 80 s, fit	DPWA DPWA s, Ilmits, DPWA	$\pi^- p \rightarrow \Lambda K^0$ $\pi^- p \rightarrow \Lambda K^0$ etc. • • •	
-0.06 to +0.04 OUR ESTIMATE -0.012 -0.012 • • • We do not use the following -0.04	BELL SAXON data for average ⁶ BAKER	83 80 s, fit	DPWA DPWA s, ilmits, DPWA IPWA	$\pi^{-} p \rightarrow \Lambda K^{0}$ $\pi^{-} p \rightarrow \Lambda K^{0}$ etc. • • • See SAXON 80	
-0.06 to +0.04 OUR ESTIMATE -0.012 -0.012 • • We do not use the following -0.04 -0.03 ±0.004	BELL SAXON data for average ⁶ BAKER ¹ BAKER	83 80 s, fit 78 77	DPWA DPWA s, ilmits, DPWA IPWA DPWA	$\pi^{-} p \rightarrow \Lambda K^{0}$ $\pi^{-} p \rightarrow \Lambda K^{0}$ etc. • • • See SAXON 80 $\pi^{-} p \rightarrow \Lambda K^{0}$	rel.
-0.06 to +0.04 OUR ESTIMATE -0.012 -0.012 • • • • We do not use the following -0.04 -0.03 ±0.004 -0.03	BELL SAXON data for average BAKER BAKER BAKER BAKER DEVENISH	83 80 es, filt 78 77 77	DPWA DPWA s, ilmits, DPWA IPWA DPWA	$\pi^- p \rightarrow \Lambda K^0$ $\pi^- p \rightarrow \Lambda K^0$ etc. • • • See SAXON 80 $\pi^- p \rightarrow \Lambda K^0$ $\pi^- p \rightarrow \Lambda K^0$ Fixed-t dispersion	rel.
-0.06 to +0.04 OUR ESTIMATE -0.012 -0.012 -0.02 • • We do not use the following -0.04 -0.03 ±0.004 -0.03 +0.026±0.019	BELL SAXON data for average BAKER BAKER BAKER BAKER DEVENISH	83 80 es, filt 78 77 77 746	DPWA DPWA s, ilmits, DPWA IPWA DPWA	$\pi^- p \rightarrow \Lambda K^0$ $\pi^- p \rightarrow \Lambda K^0$ etc. • • • See SAXON 80 $\pi^- p \rightarrow \Lambda K^0$ $\pi^- p \rightarrow \Lambda K^0$ Fixed-t dispersion	.,
-0.06 to +0.04 OUR ESTIMATE -0.012 -0.012 -0.02 • • • We do not use the following -0.04 -0.03 ±0.004 -0.03 +0.026±0.019 $(\Gamma_{j}\Gamma_{r})^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\pi \rightarrow N(17)$	BELL SAXON data for average BAKER BAKER BAKER DEVENISH TOO) → EK DOCUMENT ID	83 80 es, fite 78 77 77 74e	DPWA DPWA s, Ilmits, DPWA IPWA DPWA	$\pi^- p \rightarrow \Lambda K^0$ $\pi^- p \rightarrow \Lambda K^0$ etc. • • • See 5AXON 80 $\pi^- p \rightarrow \Lambda K^0$ $\pi^- p \rightarrow \Lambda K^0$ Fixed-t dispersion	.,
-0.06 to +0.04 OUR ESTIMATE -0.012 -0.012 -0.02 ••• We do not use the following -0.04 -0.03 ±0.004 -0.03 +0.026±0.019 $(\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \rightarrow N(17)$ VALUE	BELL SAXON data for average BAKER BAKER BAKER DEVENISH TOO) → EK DOCUMENT ID	83 80 es, fite 78 77 77 74e	DPWA DPWA s, Ilmits, DPWA IPWA DPWA 3	$\pi^- p \rightarrow \Lambda K^0$ $\pi^- p \rightarrow \Lambda K^0$ etc. • • • See 5AXON 80 $\pi^- p \rightarrow \Lambda K^0$ $\pi^- p \rightarrow \Lambda K^0$ Fixed-t dispersion	.,
-0.06 to +0.04 OUR ESTIMATE -0.012 -0.012 -0.02 ••• We do not use the following -0.04 -0.03 ± 0.004 -0.03 +0.026 ± 0.019 ($\Gamma_{\parallel}\Gamma_{\uparrow}$) $\frac{1}{2}$ / Γ_{total} in $N\pi \rightarrow N(17)$ VALUE •• We do not use the following	BELL SAXON data for average 6 BAKER 1 BAKER 1 BAKER DEVENISH 700) → ∑K DOCUMENT ID c data for average	83 80 es, fit: 78 77 77 74e	DPWA DPWA IPWA DPWA TECN S, limits,	$\begin{array}{ccc} \pi^- p \rightarrow \Lambda K^0 \\ \pi^- p \rightarrow \Lambda K^0 \\ \text{etc.} \bullet \bullet \bullet \\ \text{See 5AXON 80} \\ \pi^- p \rightarrow \Lambda K^0 \\ \pi^- p \rightarrow \Lambda K^0 \\ \text{Fixed-t dispersion} \\ & \Gamma_1 \Gamma_1 \\ \hline \text{comment} \\ \text{etc.} \bullet \bullet \bullet \\ \end{array}$.,

Note: Signs of couplings from $\pi\,N\to N\pi\,\pi$ analyses were changed in the 1986 edition to agree with the baryon-first convention; the overall phase ambiguity is resolved by choosing a negative sign for the $\Delta(1620)~5_{31}$ coupling to $\Delta(1232)\pi$.

coupling to 24(1232)	n .				
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\pi \to I$	N(1700) → Δ(123	2)π	, S-wav	e	(Γ ₁ Γ ₇) ^{1/2} /
VALUE	DOCUMENT ID		TECN	COMME	NT
0.00 to ±0.08 OUR ESTIM	ATE				
$+0.02\pm0.03$	MANLEY	92	IPWA	$\pi N \rightarrow$	π N & N π π
0.00	² LONGACRE	77	IPWA	$\pi N \rightarrow$	Νππ
-0.16	³ LONGACRE	75	IPWA	$\pi N \rightarrow$	Νππ

(Γ _Ι Γ _Γ) ^{1/2} /Γ _{total} in Nπ →	DOCUMENT ID	-/^	TECN	e (Γ ₁ Γ ₈) ¹ /⁄⁄⁄
±0.04 to ±0.20 OUR	ESTIMATE			
$+0.10\pm0.09$	MANLEY			
-0.12			IPWA	
+0.14	³ LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$
$(\Gamma_I \Gamma_I)^{1/2} / \Gamma_{\text{total}}$ in $N\pi \to 0$	N(1700) → N p. S			
±0.01 to ±0.13 QUE	ESTIMATE		7120	COMMENT
-0.04±0.06	MANLEY	92	IPWA	$\pi N \rightarrow \pi N & N \pi \pi$
0.07	² LONGACRE		IPWA	
+0.07	³ LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$
$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N_{\pi} \rightarrow$	N(1700) → N(ππ			$(\Gamma_1\Gamma_{13})^{\frac{1}{12}}$
<u>∀ALUE</u> ±0.02 to ±0.28 OUF	ESTIMATE	_	TECH	COMMENT
+0.02±0.02	MANLEY	92	IPWA	$\pi N \rightarrow \pi N & N \pi \pi$
0.00	² LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
+0.2	³ LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$
$N(1700) \rightarrow p\gamma$, helicit) PHOTON DECAY		APLITU	IDES
	•			
VALUE (GeV ^{-1/2}) 0.018±0.013 OUR ESTIN				
-0.016±0.014	CRAWFORD			$\gamma N \rightarrow \pi N$
-0.002±0.013	ILAWA			$\gamma N \rightarrow \pi N$
-0.028±0.007	ARAI			$\gamma N \rightarrow \pi N \text{ (fit 1)}$
-0.029±0.006	ARAI			$\gamma N \rightarrow \pi N \text{ (fit 2)}$
-0.024±0.019	CRAWFORD			$\gamma N \rightarrow \pi N$
• • We do not use the fo				
-0.033±0.021	BARBOUR			$\gamma N \rightarrow \pi N$
-0.014±0.025	FELLER		DPWA	$\gamma N \rightarrow \pi N$
$N(1700) \rightarrow p\gamma$, helicit		-		
VALUE (GeV ^{-1/2})	DOCUMENT ID		TECN	COMMENT
-0.002±0.024 OUR ESTIN				
-0.009 ± 0.012	CRAWFORD			$\gamma N \rightarrow \pi N$
0.029 ± 0.014	ILAWA			$\gamma N \rightarrow \pi N$
-0.002±0.005	ARAI			$\gamma N \rightarrow \pi N \text{ (fit 1)}$
0.014 ± 0.005	ARAI			$\gamma N \rightarrow \pi N \text{ (flt 2)}$
-0.017±0.014	CRAWFORD			$\gamma N \rightarrow \pi N$
• • We do not use the for				
-0.014 ± 0.025	BARBOUR			$\gamma N \rightarrow \pi N$
0.0 ±0.014	FELLER		DPWA	$\gamma N \rightarrow \pi N$
$N(1700) \rightarrow n\gamma$, helicity	y-1/2 amplitude A _{1/}	2		
VALUE (GeV-1/2)	DOCUMENT ID		TECN	COMMENT
0.000±0.050 OUR ESTIN				
0.006±0.024	AWAJI	81		$\gamma N \rightarrow \pi N$
0.002±0.013	FUJII ~			$\gamma N \rightarrow \pi N$
-0.052±0.030	ARAI			$\gamma N \rightarrow \pi N \text{ (fit 1)}$
-0.055 ±0.030	ARAI	80 80		$\gamma N \rightarrow \pi N \text{ (fit 2)}$ $\gamma N \rightarrow \pi N$
0.052 ± 0.035 • • • We do not use the fo	CRAWFORD			
 • • • We do not use the to +0.050 ±0.042 	BARBOUR			$\gamma N \rightarrow \pi N$
$N(1700) \rightarrow n\gamma$, helicit	v-3/2 amplitude A.	/a		
VALUE (GeV ^{-1/2})	DOCUMENT ID		TECN	COMMENT
-0.003±0.044 OUR ESTIN				
-0.033±0.017	ILAWA	81	DPWA	$\gamma N \rightarrow \pi N$
0.018 ± 0.018	FUJII	81		$\gamma N \rightarrow \pi N$
-0.037±0.036	ARAI	80		$\gamma N \rightarrow \pi N \text{ (fit 1)}$
-0.035±0.024	ARAI	80		$\gamma N \rightarrow \pi N \text{ (fit 2)}$
0.041 ± 0.030	CRAWFORD	80		$\gamma N \rightarrow \pi N$
We do not use the fo				
+0.035±0.030	BARBOUR			$\gamma N \rightarrow \pi N$
N(170	$00) \gamma p \to \Lambda K^+$	AM	PLITU	DES

VALUE (units 10⁻³)

■ • • We do not use the following data for averages, fits, limits, etc. • • TANABE

• • • We do not use the following data for averages, fits, limits, etc. • • TANABE

DOCUMENT ID

 $(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } p \gamma \rightarrow N(1700) \rightarrow \Lambda K^+$ VALUE (units 10^{-3})

DOCUMENT ID

-7.09

89 DPWA

TECN

89 DPWA

(M2_ amplitude)

Baryon Particle Listings N(1700), N(1710)

$p\gamma \rightarrow N(1700) \rightarrow AI$	K ⁺ phase angle θ			(E2 amplitude)
VALUE (degrees)	DOCUMENT IL		TECN	
• • • We do not use the fe	ollowing data for averag	ges, fit	s, limits, et	C. • • •
-35.9	TANABE	89	DPWA	
	-			

N(1700) FOOTNOTES

- ¹ The two BAKER 77 entries are from an IPWA using the Barrelet-zero method and from a conventional energy-dependent analysis.
- a conventional energy-dependent analysis.

 LONGACRE 77 pole positions are from a search for poles in the unitarized T-matrix; the first (second) value uses, in addition to $\pi N \to N\pi\pi$ data, elastic amplitudes from a Saclay (CERN) partial-wave analysis. The other LONGACRE 77 values are from eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.
- any itudes.

 See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and Δ resonances as determined from Argand diagrams of π N elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams.
- SLONGACRE 78 values are from a search for poles in the unitarized T-matrix. The first (second) value uses, in addition to $\pi N \to N \pi \pi$ data, elastic amplitudes from a Saclay (CERN) partial-wave analysis.
- ⁶The overall phase of BAKER 78 couplings has been changed to agree with previous conventions.

 7 The range given is from the four best solutions.

N(1700) REFERENCES

For early references, see Physics Letters 111B 70 (1982).

				•
BATINIC	95	PR C51 2310	+Slaus, Swarc, Nefkens	(BOSK, UCLA)
HOEHLER	93	π N Newsletter 9 1		(KARL)
MANLEY	92	PR D45 4002	+Saleski	(KENT) IJP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	(VPI)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
TANABE	89	PR C39 741	+Kohno, Bennhold	(MANZ)
Also	89	NC 102A 193	Kohno, Tanabe, Bennhold	(MANZ)
BELL	83	NP B222 389	+Blissett, Broome, Daley, Hart, Linters	n+ (RL)IJP
CRAWFORD	83	NP B211 1	+Morton	(GLAS)
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
ILAWA	81	Boan Conf. 352	+Kajikawa	(NAGO)
Also	82	NP B197 365	Fujii, Hayashii, Iwata, Kajikawa+	(NAGO)
FUJH	18	NP B187 53	+Hayashii, Iwata, Kajikawa+	(NAGO, OSAK)
ARAI	80	Toronto Conf. 93		(INUS)
Also	82	NP B194 251	Arai, Fujii	(INUS)
CRAWFORD	80	Toronto Conf. 107	-	(GLAS)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMÚ, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJP
LIVANOS	80	Toronto Conf. 35	+Baton, Coutures, Kochowski, Neveu	(SACL) IJP
SAXON	80	NP B162 522	+Baker, Bell, Blissett, Bloodworth+	(RHEL, BRIS) IJP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
BAKER	78	NP B141 29	+Blissett, Bloodworth, Broome+	(RĽ, CAVE) IJP
BARBOUR	78	NP B141 253	+Crawford, Parsons	(GLAS)
LONGACRE	78	PR D17 1795	+Lasinski, Rosenfeld, Smadja+	(LBL, SLAC)
BAKER	77	NP B126 365	+Blissett, Bloodworth, Broome, Hart+	(RHEL) IJP
LONGACRE	77	NP B122 493	+ Doibeau	(SACL) IJP
Also	76	NP B108 365	Dolbeau, Triantis, Neveu, Cadiet	(SACL) IJP
FELLER	76	NP B104 219	+Fukushima, Horikawa, Kajikawa+	(NAGO, ÖSAK) IJP
DEANS	75	NP B96 90	+Mitchell, Montgomery+	(SFLA, ALAH) IJP
LONGACRE	75	PL 55B 415	+Rosenfeld, Lasinski, Smadja+	(LBL, SLAC) IJP
DEVENISH	74B	NP B81 330	+Froggatt, Martin	(DESY, NORD, LOUC)

$N(1710) P_{11}$

$$I(J^P) = \frac{1}{2}(\frac{1}{2})$$
 Status: ***

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters 111B (1982).

The various partial-wave analyses do not agree very well.

N(1710) BREIT-WIGNER MASS

MATE MANLEY CUTKOSKY	92	IPWA	
	92	ID\A/A	
CUTKOSKY		IL AAW	$\pi N \rightarrow \pi N & N \pi \pi$
	80	IPWA	$\pi N \rightarrow \pi N$
HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
data for average	s, fit	s, limits,	etc. • • •
ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
1 BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$
CUTKOSKY	90	IPWA	$\pi N \rightarrow \pi N$
CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
SAXON	80	DPWA	$\pi^- \rho \rightarrow \Lambda K^0$
BAKER	79	DPWA	$\pi^- \rho \rightarrow \rho \eta$
BAKER	78	DPWA	$\pi^- \rho \rightarrow \Lambda K^0$
BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
² BAKER	77		$\pi^- p \rightarrow \Lambda K^0$
² BAKER	77	DPWA	$\pi^- \rho \rightarrow \Lambda K^0$
³ LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
KNASEL	75	DPWA	$\pi^- \rho \rightarrow \Lambda K^0$
⁴ LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$
	HOEHLER data for average ARNDT BATINIC CUTKOSKY CRAWFORD SAXON BAKER BAKER BARBOUR BAKER BAKER BAKER BAKER BAKER BAKER LONGACRE KNASEL	HOEHLER 79 5 data for averages, fitted ARNDT 96 1 BATINIC 95 CUTKOSKY 90 CRAWFORD 80 SAXON 80 BAKER 79 BAKER 78 BARBOUR 78 2 BAKER 77 3 LONGACRE 77 KNASEL 75	HOEHLER 79 IPWA s data for averages, fits, limits, ARNDT 96 IPWA 1 BATINIC 95 DPWA CUTKOSKY 0 IPWA CRAWFORD 80 DPWA SAXON 80 DPWA SAXON 80 DPWA BAKER 79 DPWA BAKER 78 DPWA BARBOUR 78 DPWA BAKER 77 IPWA 2 BAKER 77 IPWA 3 LONGACRE 77 IPWA KNASEL 75 DPWA

N(1710) BREIT-WIGNER WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
50 to 250 (≈ 100) OU	IR ESTIMATE			
480±230	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
93 ± 30	CUTKOSKY	90	IPWA	$\pi N \rightarrow \pi N$
90 ± 30	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
120± 15	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • We do not use to	he following data for average	s, fit	s, limits,	etc. • • •
105± 10	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
185± 61	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$
540	BELL	83	DPWA	$\pi^- \rho \rightarrow \Lambda K^0$
200	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
550	SAXON	80	DPWA	$\pi^- \rho \rightarrow \Lambda K^0$
97	BAKER	79	DPWA	$\pi^- \rho \rightarrow n\eta$
90 to 150	BAKER	78	DPWA	$\pi^- \rho \rightarrow \Lambda K^0$
167	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
160± 6	² BAKER	77	IPWA	$\pi^- p \rightarrow \Lambda K^0$
95	² BAKER	77	DPWA	$\pi^- p \rightarrow \Lambda K^0$
120	³ LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
174	KNASEL	75	DPWA	$\pi^- p \rightarrow \Lambda K^0$
75	4 LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

N(1710) POLE POSITION

В.	т		
л			

REAL PA

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1670 to 1770 (≈ 1720)	OUR ESTIMATE			
1770	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
1690	⁵ HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
1698	CUTKOSKY	90	IPWA	$\pi N \rightarrow \pi N$
1690±20	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
 We do not use the 	e following data for average	s, fit	s, limits,	etc. • • •
1636	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
1708 or 1712	⁶ LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$
1720 or 1711	³ LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
-2×IMAGINARY P	ART			
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
80 to 380 (≈ 230) OUI	R ESTIMATE			
378	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
200	⁵ HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
88	CUTKOSKY	90	IPWA	$\pi N \rightarrow \pi N$
80 ± 20	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use th	e following data for average	s, fit	s, Ilmits,	etc. • • •
544	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
17 or 22	⁶ LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$
123 or 115	³ LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$

N(1710) ELASTIC POLE RESIDUE

MODULUS |r|

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
37	ARNDT	95	DPWA	$\pi N \rightarrow N\pi$
15	HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
9	CUTKOSKY	90	IPWA	$\pi N \rightarrow \pi N$
8±2	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the fo	Howing data for average	s, fit	s, limits,	etc. • • •
149	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90

PHASE 0

VALUE (°)	DOCUMENT ID		TECN	COMME	NT
- 167	ARNDT	95	DPWA	$\pi N \rightarrow$	Νπ
-167	CUTKOSKY	90	IPWA	$\pi N \rightarrow$	πN
175 ± 35	CUTKOSKY	80	IPWA	$\pi N \rightarrow$	πN
• • We do not use the follow!	ng data for average	es, fit	s, limits,	etc. • •	•
149	ARNDT	91	DPWA	$\pi N \rightarrow$	πN Soln SM90

N(1710) DECAY MODES

The following branching fractions are our estimates, not fits or averages.

	Mode	Fraction (Γ_I/Γ)	
Γ ₁	Νπ	10-20 %	
Γ2	$N\eta$		
Гз	ΛK	5-25 %	
Γ4	ΣΚ		
Γ ₅	Νππ	40 - 9 0 %	
Γ ₆	$\Delta\pi$	15-40 %	
Γ7	Δ (1232) π , P -wave		
Г8	$N\rho$	5–25 %	
Γg	$N\rho$, $S=1/2$, P -wave		
Γ ₁₀	Nρ, S=3/2, P-wave		
Γ11	$N(\pi\pi)^{l=0}_{S-wave}$	10-40 %	
Γ12	Pγ	0.002-0.05%	
Γ ₁₃	$p\gamma$, helicity=1/2	0.002-0.05%	
Γ14	πγ	0.0-0.02%	
Γ ₁₅	$n\gamma$, helicity=1/2	0.0-0.02%	

N(1710) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$				Γ:	1/Г
VALUE	DOCUMENT ID		TECN	COMMENT	
0.10 to 0.20 OUR ESTIMA	TE				
0.09±0.04	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$	
0.20±0.04	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$	
0.12±0.04	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$	
• • • We do not use the fo	ollowing data for averag	es, fit	s, ilmits,	etc. • • •	
0.08±0.14	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$	
$\Gamma(N\eta)/\Gamma_{\text{total}}$				Γ;	2/Γ
VALUE	DOCUMENT ID		TECN	COMMENT	
• • • We do not use the fo	ollowing data for averag	es, fit	s, limits,	etc. • • •	
0.16±0.10	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$	
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N \pi \rightarrow$. 81/1710\ . 8/			(۲ ₁ ۲ ₂) ^{1/}	ر ا
	→ M(1110) → NNT DOCUMENT ID		****		-/1
VALUE					
• • We do not use the form	ollowing data for averag	es, fit	s, limits,	etc. • • •	
0.22	BAKER			$\pi^- p \rightarrow n \eta$	
+0.383	FELTESSE	75	DPWA	Soin A; see BAKER 7	79
+0.383 ([:[-c) ^{1/2} /[DPWA	• • • • • • • • • • • • • • • • • • • •	
$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}}$ in $N\pi - 1$	• N(1710) → AK			(Γ ₁ Γ ₃) ^{1/}	
$(\Gamma_i \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\pi \rightarrow VALUE}$	N(1710) → AK			(Γ ₁ Γ ₃) ^{1/}	
(Γ _I Γ _f) ^{1/2} /Γ _{total} in Nπ <u>VALUE</u> +0.12 to +0.18 OUR ESTI	N(1710) → AK	·	TECN	(Γ ₁ Γ ₃) ^{1/}	
$(\Gamma_1\Gamma_f)^{1/2}/\Gamma_{\text{total}}$ in $N\pi \rightarrow \frac{1}{2}$ VALUE +0.12 to $+0.18$ OUR ESTI +0.16	→ N(1710) → AK	83	TECN DPWA	(Г ₁ Г ₃) ^У	
$(\Gamma_1\Gamma_f)^{1/2}/\Gamma_{\text{total}}$ in $N\pi \rightarrow 4$ VALUE +0.12 to +0.18 OUR ESTI +0.16 +0.14	→ N(1710) → AK DOCUMENT ID MATE BELL SAXON	83 80	TECN DPWA DPWA	$(\Gamma_1\Gamma_3)^{\frac{1}{2}}$ $COMMENT$ $\pi^- p \to \Lambda K^0$ $\pi^- p \to \Lambda K^0$	
$(\Gamma_i \Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}}$ in N π \rightarrow $\frac{VALUE}{+0.12}$ to $+0.18$ OUR ESTI $+0.16$ $+0.14$ \bullet \bullet \bullet We do not use the fo	N(1710) → AK DOCUMENT ID MATE BELL SAXON Sliowing data for average	83 80 es, fit	TECN DPWA DPWA S, limits,	$(\Gamma_1\Gamma_3)^{\frac{1}{2}}$ $\frac{COMMENT}{\pi^- \rho \to \Lambda K^0}$ $\pi^- \rho \to \Lambda K^0$ etc. • • •	
$(\Gamma_{l}\Gamma_{l})^{1/2}/\Gamma_{total}$ in N π — VALUE +0.12 to +0.18 OUR ESTI +0.16 +0.14 ••• We do not use the fo -0.12	► N(1710) → ΛΚ DOCUMENT ID BELL SAXON Ollowing data for averag 7 BAKER	83 80 es, fit	TECN DPWA DPWA s, limits, DPWA	$(\Gamma_1\Gamma_3)^{\frac{1}{2}}$ $\frac{COMMENT}{\pi^- p \to \Lambda K^0}$ $\pi^- p \to \Lambda K^0$ etc. • • • See SAXON 80	
$(\Gamma_{l}\Gamma_{f})^{1/2}/\Gamma_{\text{total}}$ in N π — MALUE +0.12 to +0.18 OUR ESTI +0.16 +0.14 ••• We do not use the fo -0.12 -0.05 ±0.03	N(1710) → ΛΚ DOCUMENT ID MATE BELL SAXON ollowing data for average 7 BAKER 2 BAKER	83 80 es, fit: 78 77	TECN DPWA DPWA s, limits, DPWA IPWA	$(\Gamma_1\Gamma_3)^{\frac{1}{2}}$ $\begin{array}{c} COMMENT \\ \pi^- p \rightarrow \Lambda K^0 \\ \pi^- p \rightarrow \Lambda K^0 \\ \text{etc.} \bullet \bullet \\ \text{See SAXON 80} \\ \pi^- p \rightarrow \Lambda K^0 \end{array}$	
$(\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}}$ in $N\pi \longrightarrow \frac{VALUE}{4}$ +0.12 to +0.18 OUR ESTI +0.16 +0.14 • • • We do not use the for -0.12 -0.05 ± 0.03 -0.10	N(1710) → AK DOCUMENT ID BELL SAXON Ollowing data for averag 7 BAKER 2 BAKER 2 BAKER	83 80 es, fit 78 77	TECN DPWA DPWA s, limits, DPWA IPWA DPWA	$(\Gamma_1\Gamma_3)^{\frac{1}{2}}$ $\frac{COMMENT}{\pi^- p \to \Lambda K^0}$ $\pi^- p \to \Lambda K^0$ etc. • • • See SAXON 80 $\pi^- p \to \Lambda K^0$ $\pi^- p \to \Lambda K^0$	
$(\Gamma_{l}\Gamma_{f})^{1/2}/\Gamma_{\text{total}}$ in N π — MALUE +0.12 to +0.18 OUR ESTI +0.16 +0.14 ••• We do not use the fo -0.12 -0.05 ±0.03	N(1710) → ΛΚ DOCUMENT ID MATE BELL SAXON ollowing data for average 7 BAKER 2 BAKER	83 80 es, fit 78 77	TECN DPWA DPWA s, limits, DPWA IPWA DPWA	$(\Gamma_1\Gamma_3)^{\frac{1}{2}}$ $\begin{array}{c} COMMENT \\ \pi^- p \rightarrow \Lambda K^0 \\ \pi^- p \rightarrow \Lambda K^0 \\ \text{etc.} \bullet \bullet \\ \text{See SAXON 80} \\ \pi^- p \rightarrow \Lambda K^0 \end{array}$	
$(\Gamma_1\Gamma_1)^{1/2}/\Gamma_{\text{total}}$ in N π — MALUE +0.12 to +0.18 OUR ESTI +0.16 +0.16 • • • We do not use the form -0.12 -0.05 ±0.03 -0.10 0.10	N(1710) → AK DOCUMENT ID BELL SAXON Sllowing data for average 7 BAKER 2 BAKER 2 BAKER KNASEL	83 80 es, fit: 78 77 77	TECN DPWA DPWA s, limits, DPWA IPWA DPWA	$(\Gamma_1\Gamma_3)^{\frac{1}{2}}$ $\frac{COMMENT}{\pi^- p \to \Lambda K^0}$ $\pi^- p \to \Lambda K^0$ etc. • • • See SAXON 80 $\pi^- p \to \Lambda K^0$ $\pi^- p \to \Lambda K^0$ $\pi^- p \to \Lambda K^0$ $\pi^- p \to \Lambda K^0$	² /г
$(\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}}$ in $N\pi \rightarrow \frac{VALUE}{+0.12}$ to $+0.18$ OUR ESTI $+0.16$ $+0.14$ • • We do not use the for -0.12 -0.05 ± 0.03 -0.10	N(1710) → AK DOCUMENT ID BELL SAXON SIOWING data for average 7 BAKER 2 BAKER 2 BAKER KNASEL	83 80 es, fit: 78 77 77	DPWA DPWA s, limits, DPWA IPWA DPWA	$(\Gamma_1\Gamma_3)^{\frac{1}{2}}$ $\frac{COMMENT}{\pi^- \rho \to \Lambda K^0}$ $\pi^- \rho \to \Lambda K^0$ etc. • • • See SAXON 80 $\pi^- \rho \to \Lambda K^0$ $\pi^- \rho \to \Lambda K^0$ $\pi^- \rho \to \Lambda K^0$ $(\Gamma_1\Gamma_4)^{\frac{1}{2}}$	² /г
$(\Gamma_{l}\Gamma_{l})^{\frac{1}{2}}/\Gamma_{\text{total}}$ in $N\pi \rightarrow \frac{VALUE}{+0.12}$ to $+0.18$ OUR ESTI $+0.16$ $+0.14$ • • • We do not use the for -0.12 -0.05 ± 0.03 -0.10 0.10 $(\Gamma_{l}\Gamma_{l})^{\frac{1}{2}}/\Gamma_{\text{total}}$ in $N\pi \rightarrow \frac{1}{2}$	→ N(1710) → ΛΚ DOCUMENT ID BELL SAXON SIOWING data for average 7 BAKER 2 BAKER 2 BAKER KNASEL → N(1710) → ΣΚ DOCUMENT ID	83 80 es, fit: 78 77 77 75	DPWA DPWA S, limits, DPWA IPWA DPWA DPWA	$(\Gamma_1\Gamma_3)^{\frac{1}{2}}$ $\frac{COMMENT}{\pi^- p \to \Lambda K^0}$ $\pi^- p \to \Lambda K^0$ etc. • • • See SAXON 80 $\pi^- p \to \Lambda K^0$ $\pi^- p \to \Lambda K^0$ $\pi^- p \to \Lambda K^0$ $\pi^- p \to \Lambda K^0$ $(\Gamma_1\Gamma_4)^{\frac{1}{2}}$ $COMMENT$	² /Γ
$(\Gamma_{I}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}}$ in $N\pi$ — $\frac{VALUE}{+0.12}$ to $+0.18$ OUR ESTI $+0.16$ $+0.16$ 0.14 0.19 We do not use the form -0.12 -0.05 ± 0.03 -0.10 0.10 $(\Gamma_{I}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}}$ in $N\pi$ — $\frac{VALUE}{VALUE}$	HATE BELL SAXON SIOWING data for average 7 BAKER 2 BAKER 2 BAKER KNASEL N(1710) → ∑K DOCUMENT ID DOCUMENT ID DOCUMENT ID	83 80 es, fit: 78 77 77 75	DPWA DPWA S, limits, DPWA IPWA DPWA DPWA DPWA S, limits,	$(\Gamma_1\Gamma_3)^{\frac{1}{2}}$ $\frac{COMMENT}{\pi^- p \to \Lambda K^0}$ $\pi^- p \to \Lambda K^0$ etc. • • • See SAXON 80 $\pi^- p \to \Lambda K^0$ $\pi^- p \to \Lambda K^0$ $\pi^- p \to \Lambda K^0$ $\pi^- p \to \Lambda K^0$ $(\Gamma_1\Gamma_4)^{\frac{1}{2}}$ $COMMENT$	² /Γ

Note: Signs of couplings from $\pi\,N\,\to\,N\,\pi\,\pi$ analyses were changed in the 1986 edition to agree with the baryon-first convention; the overall phase ambiguity is resolved by choosing a negative sign for the $\Delta(1620)$ S_{31} coupling to $\Delta(1232)\pi$.

$(\Gamma_{I}\Gamma_{I})^{\frac{1}{12}}/\Gamma_{\text{total}} \ln N\pi \rightarrow$	$N(1710) \rightarrow \Delta(123)$	2)π	, P-way	e	(Г₁Г ₇) ^{У2} /Г
VALUE	DOCUMENT ID				
±0.16 to ±0.22 OUF	ESTIMATE				
-0.21 ± 0.04	MANLEY				
-0.17	3 LONGACRE	77	IPWA	$\pi N \rightarrow$	Νππ
+0.20	⁴ LONGACRE	75	IPWA	$\pi N \rightarrow$	Νππ
$(\Gamma_I \Gamma_I)^{1/2} / \Gamma_{\text{total}}$ in $N\pi \to$	$N(1710) \rightarrow N\rho$, S	=1/	2, <i>P</i> -wa	ve	(Γ₁Γ϶) ¹ ⁄⁄⁄
VALUE	DOCUMENT ID		TECN	COMME	NT
±0.09 to ±0.19 OUF	RESTIMATE				
+0.05±0.06	MANLEY				πΝ&Νππ
+0.05±0.06 +0.19	MANLEY ³ LONGACRE				

VALUE	π → N(1710) → Nρ, Se DOCUMENT ID 3 LONGACRE		TECN	COMME	NT
+0.31	³ LONGACRE	77	IPWA	$\pi N \rightarrow$	Νππ
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N$	π → N(1710) → N(ππ)	/=0 5-w	eve		(「1「11) ^½ /「
VALUE	DOCUMENT ID		TECN	COMME	NT
±0.14 to ±0.22	OUR ESTIMATE				
$+0.04\pm0.05$	MANLEY	92	IPWA	$\pi N \rightarrow$	πΝ&Νππ
- 0.26	³ LONGACRE	77	IPWA	$\pi N \rightarrow$	Νππ
-0.28	MANLEY 3 LONGACRE 4 LONGACRE	75	IPWA	$\pi N \rightarrow$	Νππ
A.C.	1710) PHOTON DECAY	/ A b	ADI ITI	IDES	

	/	_		
VALUE (GeV-1/2)	DOCUMENT ID		TECN	COMMENT
+0.009±0.022 OUR ESTIMATE				
0.007±0.015	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
0.006 ± 0.018	CRAWFORD	83	IPWA	$\gamma N \rightarrow \pi N$
0.028 ± 0.009	ILAWA	81	DPWA	$\gamma N \rightarrow \pi N$
-0.009 ± 0.006	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
-0.012 ± 0.005	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$
0.015 ± 0.025	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
• • • We do not use the following	data for average	s, fit	s, limits,	etc. • • •
-0.037 ± 0.002	LI	93	IPWA	$\gamma N \rightarrow \pi N$
$+0.001\pm0.039$	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
$+0.053\pm0.019$	FELLER	76	DPWA	$\gamma N \rightarrow \pi N$

$N(1710) \rightarrow n\gamma$, helicity-1/2 amplitude A_{1/2}

		_		
VALUE (GeV-1/2)	DOCUMENT ID		TECN	COMMENT
-0.002±0.014 OUR ES	TIMATE			
-0.002 ± 0.015	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
0.000 ± 0.018	ILAWA	81	DPWA	$\gamma N \rightarrow \pi N$
-0.001 ± 0.003	FUJII	81	DPWA	$\gamma N \rightarrow \pi N$
0.005 ± 0.013	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
0.011 ± 0.021	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$
-0.017 ± 0.020	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
• • • We do not use th	e following data for average	s, fits	s, limits,	etc. • • •
0.052 ± 0.003	LI	93	IPWA	$\gamma N \rightarrow \pi N$
-0.028 ± 0.045	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$

N(1710) $\gamma p \rightarrow \Lambda K^+$ AMPLITUDES

VALUE (units 10 ⁻³)	DOCUMENT ID		TECN	
				ata
• • • we do not use the	following data for average	:s, m	s, mins,	etc. • • •
-10.6 ± 0.4	WORKMAN	90	DPWA	
- 7.21	TANABE	00	DPWA	
		07	DEWA	(M. amplitude
$p\gamma \rightarrow N(1710) \rightarrow N(1710) \rightarrow N(1710)$		67	TECN	(M _{1—} amplitude
$p\gamma \rightarrow N(1710) \rightarrow N(1710) \rightarrow N(1710)$	ΛK^+ phase angle θ		TECN	`
$p\gamma \rightarrow N(1710) \rightarrow N(1710) \rightarrow N(1710)$	ΛK+ phase angle θ DOCUMENT ID		TECN	`

N(1710) FOOTNOTES

 1 BATINIC 95 finds a second state with a 6 MeV mass difference. 2 The two BAKER 77 entries are from an IPWA using the Barrelet-zero method and from

The two BAKER 77 entires are from an Irvax using the Battelet-Zero method and from a conventional energy-dependent analysis.

LONGACRE 77 pole positions are from a search for poles in the unitarized T-matrix; the first (second) value uses, in addition to $\pi N \to N\pi\pi$ data, elastic amplitudes from Saclay (CERN) partial-wave analysis. The other LONGACRE 77 values are from eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.

⁴ From method II of LONGACRE 75: eyeball fits with Breit-Wigner circles to the T-matrix

*From method II of LONGACRE 75: eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.

5 See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and Δ resonances as determined from Argand diagrams of π N elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams. 6 LONGACRE 78 values are from a search for poles in the unitarized T-matrix. The first (second) value uses, in addition to π $N \to N \pi \pi$ data, elastic amplitudes from a Saclay (CERN) partial-wave analysis.

⁷The overall phase of BAKER 78 couplings has been changed to agree with previous

conventions.

8 The range given for DEANS 75 is from the four best solutions.

Baryon Particle Listings N(1710), N(1720)

N(1710) REFERENCES

For early references, see Physics Letters 111B 70 (1982).

ARNDT	96	PR C53 430	+Strakovsky, Workman	(VPI))
ARNDT	95	PR C52 2120	+Strakovsky, Workman, Pavan	(VPI, BRCO))
BATINIC	95	PR C51 2310	+Slaus, Svarc, Nefkens	(BOSK, UCLA)	,
HOEHLER	93	π N Newsletter 9 1		(KARL))
LI	93	PR C47 2759	+Arndt, Roper, Workman	` (VPI))
MANLEY	92	PR D45 4002	+Saleski	(KÈNT)	IJP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	` (VPI))
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE)	
CUTKOSKY	90	PR D42 235	+Wang	` (CMU))
WORKMAN	90	PR C42 781		`(VPI)	,
TANABE	89	PR C39 741	+Kohno, Bennhold	(MÀNZ))
Aiso	89	NC 102A 193	Kohno, Tanabe, Bennhold	(MANZ))
BELL	83	NP B222 389	+Blissett, Broome, Daley, Hart, Lintern+	` (RL)	IJP
CRAWFORD	83	NP B211 1	+ Morton	(GLAS))
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)	,
ILAWA	81	Bonn Conf. 352	+Kajikawa	(NAGO)	
Also	82	NP B197 365	Fujii, Hayashil, Iwata, Kajikawa+	(NAGO))
FUJII	81	NP B187 53	+Hayashii, Iwata, Kajikawa+	(NAGO, OSAK)	i
ARAI	80	Toronto Conf. 93		(INUS)	,
Also	82	NP B194 251	Arai, Fulli	(INUS)	i .
CRAWFORD	80	Toronto Conf. 107		(GLAS)	í
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMŮ, LBL)	IJР
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL)	
LIVANOS	80	Toronto Conf. 35	+Baton, Coutures, Kochowski, Neveu	` (SACL)	
SAXON	80	NP B162 522	+Baker, Bell, Blissett, Bloodworth+	(RHEL, BRIS)	
BAKER	79	NP B156 93	+Brown, Clark, Davies, Departer, Evans-		
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT)	
Also	80	Toronto Conf. 3	Koch	(KARLT)	
BAKER	78	NP B141 29	+Blissett, Bloodworth, Broome+	(RL, CAVE)	
BARBOUR	78	NP B141 253	+Crawford, Parsons	(GLAS)	
LONGACRE	78	PR D17 1795	+Lasinski, Rosenfeld, Smadja+	(LBL, SLAC)	
BAKER	77	NP B126 365	+Blissett, Bloodworth, Broome, Hart+	(RHEL)	
LONGACRE	77	NP B122 493	+Dolbeau	(SACL)	
Also	76	NP B108 365	Dolbeau, Triantis, Neveu, Cadiet	(SACL)	
FELLER	76	NP B104 219	+Fukushima, Horikawa, Kajikawa+	(NAGO, OSAK)	
DEANS	75	NP B96 90	+Mitchell, Montgomery+	(SFLA, ALAH)	
FELTESSE	75	NP B93 242	+Ayed, Bareyre, Borgeaud, David+	(SACL)	
KNASEL	75	PR D11 1		. WUSL, OSU, ANL)	
LONGACRE	75	PL 55B 415	+Rosenfeld, Lasinski, Smadja+	(LBL, SLAC)	
				,,	

$N(1720) P_{13}$

$$I(J^P) = \frac{1}{2}(\frac{3}{2}^+)$$
 Status: ***

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters 111B (1982).

N(1720) BREIT-WIGNER MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1650 to 1750 (≈ 1720) O	UR ESTIMATE			
1717±31	MANLEY	92	IPWA	$\pi N \rightarrow \pi N & N \pi \pi$
1700±50	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
1710±20	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the	following data for averages	s, fits	s, limits,	etc. • • •
1713±10	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
1820	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
1711±26	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$
1720	LI	93	IPWA	$\gamma N \rightarrow \pi N$
1785	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
1690	SAXON	80	DPWA	$\pi^- p \rightarrow \Lambda K^0$
1710 to 1790	BAKER	78	DPWA	$\pi^- p \rightarrow \Lambda K^0$
1809	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
1640±10	¹ BAKER	77	IPWA	$\pi^- p \rightarrow \Lambda K^0$
1710	1 BAKER	77	DPWA	$\pi^- p \rightarrow \Lambda K^0$
1750	² LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
1850	KNASEL	75	DPWA	$\pi^- p \rightarrow \Lambda K^0$
1720	³ LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

N(1720) BREIT-WIGNER WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
100 to 200 (≈ 150) OUR ESTIN	MATE			
380±180	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
125± 70	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
190± 30	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the follow	ing data for average	s, fit	s, limits,	etc. • • •
153± 15	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
354	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
235 ± 51	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$
200	LI	93	IPWA	$\gamma N \rightarrow \pi N$
308	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
120	SAXON	80	DPWA	$\pi^- \rho \rightarrow \Lambda K^0$
447	BAKER	79	DPWA	$\pi^- p \rightarrow n\eta$
300 to 400	BAKER	78	DPWA	$\pi^- p \rightarrow \Lambda K^0$
285	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
200± 50	¹ BAKER	77	IPWA	$\pi^- p \rightarrow \Lambda K^0$
500	¹ BAKER	77	DPWA	$\pi^- p \rightarrow \Lambda K^0$
130	² LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
327	KNASEL	75	DPWA	$\pi^- p \rightarrow \Lambda K^0$
150	³ LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

N(1720) POLE POSITION

REAL PART					
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT	
1650 to 1750 (≈ 1700) (OUR ESTIMATE				
1717	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$	
1686	⁴ HOEHLER	93	SPED	$\pi N \rightarrow \pi N$	
1680±30	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$	
• • We do not use the	e following data for average	s, fit	s, limits,	etc. • • •	
1675	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90	
1716 or 1716	⁵ LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$	
1745 or 1748	² LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$	
-2×IMAGINARY P	ART				
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT	
110 to 390 (≈ 250) OUF	RESTIMATE				
388	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$	
187	⁴ HOEHLER	93	SPED	$\pi N \rightarrow \pi N$	
120±40	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$	
• • We do not use the	e following data for average	s, fit	s, ilmits,	etc. • • •	
114	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ Soln SM90}$	
124 or 126	⁵ LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$	
135 or 123	² LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$	

N(1720) ELASTIC POLE RESIDUE

MODULUS r	
VALUE (MeV)	D

VALUE (MeV)	DOCUMENT ID		TECN	COMME	NT .
39	ARNDT	95	DPWA	$\pi N \rightarrow$	Nπ
15	HOEHLER	93	SPED	$\pi N \rightarrow$	πN
8±2	CUTKOSKY	80	IPWA	$\pi N \rightarrow$	πN
• • • We do not use the following	g data for average	es, fits	s, limits,	etc. • •	•
11	ARNDT	91	DPWA	$\pi N \rightarrow$	πN Soin SM90

11

PHASE 0 VALUE (°)	DOCUMENT ID		TECN	COMMENT	
– 70	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$	
-160 ± 30	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$	
• • We do not use the following	g data for average	s, fit	s, łimits,	etc. • • •	
-130	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90)

N(1720) DECAY MODES

The following branching fractions are our estimates, not fits or averages.

	Mode	Fraction (Γ_I/Γ)
Γ ₁	$N\pi$	10-20 %
	Nη	
Γ ₂ Γ ₃	ΛK	1–15 %
Γ_4	ΣΚ	
Γ ₅	Νππ	>70 %
Γ ₆	$\Delta\pi$	
۲7	$\Delta(1232)\pi$, P -wave	
Γ8	$N\rho$	70-85 %
Γg	Nρ, <i>5</i> =1/2, <i>P</i> -wave	•
Γ ₁₀	$N\rho$, $S=3/2$, P -wave	
Γ_{11}	$N(\pi\pi)_{S-\text{wave}}^{I=0}$	
Γ ₁₂	$p\gamma$	0.003-0.10 %
Γ ₁₃	$p\gamma$, helicity=1/2	0.003-0.08 %
Γ_{14}	$p\gamma$, helicity=3/2	0.001-0.03 %
Γ ₁₅	$n\gamma$	0.002-0.39 %
Γ ₁₆	$n\gamma$, helicity=1/2	0.0-0.002 %
Γ ₁₇	$n\gamma$, helicity=3/2	0.001-0.39 %

N(1720) BRANCHING RATIOS

				Γ_1/Γ
DOCUMENT ID		TECN	COMMENT	
				•
MANLEY	92	IPWA	$\pi N \rightarrow \pi N &$	Νππ
CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$	
HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$	
data for average	s, fit	s, limits,	etc. • • •	
ARNDT	95	DPWA	$\pi N \rightarrow N \pi$	
BATINIC	95	DPWA	$\pi N \rightarrow N \pi$, /	Vη
				Γ_2/Γ
DOCUMENT ID		TECN	COMMENT	
data for average	s, fit	s, limits,	etc. • • •	
BATINIC	95	DPWA	$\pi N \rightarrow N \pi, I$	Vη
	MANLEY CUTKOSKY HOEHLER data for average ARNDT BATINIC DOCUMENT ID data for average	MANLEY 92 CUTKOSKY 80 HOEHLER 79 data for averages, fit ARNDT 95 BATINIC 95	MANLEY 92 IPWA CUTKOSKY 80 IPWA HOEHLER 79 IPWA data for averages, fits, limits, ARNDT 95 DPWA BATINIC 95 DPWA DOCUMENT ID TECN data for averages, fits, limits,	MANLEY 92 IPWA $\pi N \rightarrow \pi N \&$ CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N \&$ HOEHLER 79 IPWA $\pi N \rightarrow \pi N \&$ data for averages, fits, limits, etc. • • • ARNDT 95 DPWA $\pi N \rightarrow N \pi \&$ BATINIC 95 DPWA $\pi N \rightarrow N \pi \&$ DPWA $\pi N \rightarrow N \pi \&$ $\pi M = 0$

Baryon Particle Listings N(1720)

$(\Gamma_i \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N\pi \to N(1)$	720) → Nη DOCUMENT ID		TECN	$(\Gamma_1\Gamma_2)^{\frac{1}{2}}/\Gamma$
• • We do not use the following				
-0.08	BAKER	79	DPWA	$\pi^- p \rightarrow n\eta$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N \pi \rightarrow N(1)$	720) _ AK			(Γ₁Γ₃) ^{1/2} /Γ
VALUE	DOCUMENT ID		TECN	COMMENT (11.3)
-0.14 to -0.06 OUR ESTIMATE	DE: 1		D D14/4	$\pi^- p \rightarrow \Lambda K^0$
0.09 0.11	BELL SAXON	83 80		$\pi^- p \rightarrow \Lambda K^ \pi^- p \rightarrow \Lambda K^0$
• • We do not use the following				
-0.09	6 BAKER			See SAXON 80
-0.06±0.02	1 BAKER	77		$\pi^- \rho \rightarrow \Lambda K^0$
0.09	1 BAKER	77	DPWA	$\pi^- p \rightarrow \Lambda K^0$
$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \ln N \pi \rightarrow N(1)^{1/2}$	720) → Σ K DOCUMENT ID		TECN	$(\Gamma_1\Gamma_4)^{\frac{1}{12}}/\Gamma$
• • We do not use the following				
0.051 to 0.087	7 DEANS	75	DPWA	$\pi N \rightarrow \Sigma K$
Note: Signs of couplings 1986 edition to agree wit ambiguity is resolved by coupling to $\Delta(1232)\pi$.	h the baryon-first	t conv	vention;	the overall phase
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N \pi \rightarrow N(1)$ VALUE	DOCUMENT ID	2)π	, P-wav	e (Γ ₁ Γ ₇) ^{1/2} /Γ
±0.27 to ±0.37 OUR ESTI -0.17	MATE ² LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
14	>			14
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N \pi \rightarrow N(1)$				
VALUE	DOCUMENT ID		IPWA	
+0.34±0.05 -0.26	2 LONGACRE		IPWA	
+0.40	3 LONGACRE	75		$\pi N \rightarrow N \pi \pi$
14			_	14
$(\Gamma_I \Gamma_f)^{\frac{1}{12}} / \Gamma_{\text{total}} \text{ in } N\pi \to N(1)$	720) → Nρ,5 <u>DOCUMENT ID</u>	=3/2	2, <i>P</i> -wa	ve (Γ ₁ Γ ₁₀) ^{1/2} /Γ
+0.15	² LONGACRE		/ECN	COMMENT
	4 LONGACRE	77		$\pi N \rightarrow N \pi \pi$
			IPWA	$\pi N \rightarrow N \pi \pi$ $(\Gamma_1 \Gamma_{21})^{\frac{1}{12}}/\Gamma$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \to N(1)$ VALUE)/=0 S-w	IPWA	$\pi N \rightarrow N \pi \pi$ $(\Gamma_1 \Gamma_{11})^{\frac{1}{12}} / \Gamma$ $COMMENT$
$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \ln N \pi \rightarrow N(1)$	720) → N(##)/=0 S-w	IPWA	$(\Gamma_1\Gamma_{11})^{\frac{1}{2}}/\Gamma$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N \pi \rightarrow N(1)$ VALUE -0.19	720) → N(## DOCUMENT ID)/=0 S-w	IPWA TECN IPWA	$\frac{\left(\Gamma_{1}\Gamma_{11}\right)^{\frac{1}{12}}/\Gamma}{\pi N \to N\pi\pi}$
$\frac{\left(\Gamma_{I}\Gamma_{I}\right)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \to N(1)}{VALUE}$ -0.19 $N(1720) \text{ PH}$	720) → N(ππ DOCUMENT ID LONGACRE OTON DECA)/=0 S-w 77 Y AA	IPWA TECN IPWA	$\frac{\left(\Gamma_{1}\Gamma_{11}\right)^{\frac{1}{12}}/\Gamma}{\pi N \to N\pi\pi}$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N \pi \rightarrow N(1)$ VALUE -0.19	720) → N(## DOCUMENT ID LONGACRE OTON DECA amplitude A ₁)/=0 /5-w 77 Y AN	IPWA TECN IPWA	$\frac{(\Gamma_1\Gamma_{11})^{\frac{1}{2}}/\Gamma}{\pi N \to N\pi\pi}$ UDES
$(\Gamma_I \Gamma_I)^{1/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{N/2} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow$	720) → N(ππ DOCUMENT ID LONGACRE OTON DECA amplitude A ₁ DOCUMENT ID)/=0 /5-w 77 Y AN	IPWA TECN IPWA TECN	$(\Gamma_1\Gamma_{11})^{\frac{1}{2}}/\Gamma$ $\frac{COMMENT}{\pi N \rightarrow N\pi\pi}$ JDES $\frac{COMMENT}{\pi N}$
$\begin{array}{c} (\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{\frac{1}{2}} \\ -0.19 \\ \hline \qquad \qquad N(1720) \text{ PH} \\ N(1720) \rightarrow p \gamma, \text{ helicity-} 1/2 \\ \frac{N L U E (GeV^{-1/2})}{1 + 0.018 \pm 0.030 \text{ OUR ESTIMATE}} \\ -0.015 \pm 0.015 \end{array}$	720) → N(## DOCUMENT ID 2 LONGACRE OTON DECA amplitude A ₁ / DOCUMENT ID ARNDT)/=0 /5-w 77 Y AN /2	TECN IPWA	$(\Gamma_1\Gamma_{11})^{\frac{1}{12}}/\Gamma$ $\frac{COMMENT}{\pi N \to N\pi \pi}$ DES $\frac{COMMENT}{\gamma N \to \pi N}$
$(\Gamma_{l}\Gamma_{r})^{1/2}/\Gamma_{\text{total}} \text{ in } N\pi \rightarrow N(1)^{1/2}/\Gamma_{\text{total}} \text{ in } N\pi \rightarrow N$	720) → N(## DOCUMENT ID 2 LONGACRE OTON DECA' amplitude A ₁ , DOCUMENT ID ARNDT CRAWFORD)/=0 /5-w 77 Y AN /2 96 83	IPWA TECN IPWA IPWA IPWA IPWA	$(\Gamma_{1}\Gamma_{11})^{\frac{1}{12}}/\Gamma$ $COMMENT$ $\pi N \rightarrow N\pi\pi$ UDES $COMMENT$ $\gamma N \rightarrow \pi N$ $\gamma N \rightarrow \pi N$
$(\Gamma_i \Gamma_f)^{1/2}/\Gamma_{\text{total}} \text{ in } N\pi \rightarrow N(1^{-1})^{1/2}/\Gamma_{\text{total}} \text{ in } N\pi \rightarrow N(1^{-1})^{-1}$ $N(1720) \rightarrow N(1720) \rightarrow P\gamma, \text{ helicity-} 1/2$ $VALUE (GeV^{-1/2})$ $+0.018\pm0.030 \text{ OUR ESTIMATE}$ -0.015 ± 0.015 -0.044 ± 0.066 -0.004 ± 0.007	720) → N(## DOCUMENT ID 2 LONGACRE OTON DECA' amplitude A ₁ , DOCUMENT ID ARNOT CRAWFORD AWAJI)/=0 /5-w 77 Y AN /2	IPWA TECN IPWA IPWA IPWA IPWA DPWA	$(\Gamma_{1}\Gamma_{11})^{\frac{1}{12}}/\Gamma$ $\frac{COMMENT}{\pi N \rightarrow N\pi\pi}$ $IDES$ $\frac{COMMENT}{\gamma N \rightarrow \pi N}$ $\gamma N \rightarrow \pi N$ $\gamma N \rightarrow \pi N$ $\gamma N \rightarrow \pi N$
$\begin{array}{c} (\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \pi \rightarrow N(1)^{\frac{1}{2}} \\ -0.19 \\ \hline \qquad \qquad N(1720) \text{ PH} \\ N(1720) \rightarrow p \gamma, \text{ helicity-} 1/2 \\ \frac{N L U E (GeV^{-1/2})}{1 + 0.018 \pm 0.030 \text{ OUR ESTIMATE}} \\ -0.015 \pm 0.015 \end{array}$	720) → N(## DOCUMENT ID 2 LONGACRE OTON DECA' amplitude A ₁ , DOCUMENT ID ARNDT CRAWFORD	77 Y AN /2 96 83 81 80	IPWA IPWA IPWA IPWA IPWA IPWA IPWA IPWA	$(\Gamma_{1}\Gamma_{11})^{\frac{1}{12}}/\Gamma$ $\frac{COMMENT}{\pi N \rightarrow N\pi \pi}$ $DDES$ $\frac{COMMENT}{\gamma N \rightarrow \pi N}$ $\gamma N \rightarrow \pi N$
$(\Gamma_i \Gamma_f)^{1/2}/\Gamma_{\text{total}} \text{ in } N\pi \rightarrow N(1)^{1/2}/\Gamma_{\text{total}} \text{ in } N\pi \rightarrow N(1)$	720) → N(## DOCUMENT ID 2 LONGACRE OTON DECA' amplitude A ₁ , DOCUMENT ID ARNDT CRAWFORD AWAJI ARAI ARAI CRAWFORD)/=0 S-w 77 Y AN /2 96 83 81 80 80 80	TECN IPWA IPWA IPWA IPWA IPWA DPWA DPWA DPWA	$(\Gamma_{1}\Gamma_{11})^{\frac{1}{12}}/\Gamma$ $\frac{COMMENT}{\pi N \rightarrow N\pi\pi}$ DES $\frac{COMMENT}{\gamma N \rightarrow \pi N}$ $\gamma N \rightarrow \pi N$ $\gamma N \rightarrow \pi N$ $\gamma N \rightarrow \pi N \text{ (fit 1)}$ $\gamma N \rightarrow \pi N \text{ (fit 2)}$ $\gamma N \rightarrow \pi N$
$(\Gamma_i \Gamma_f)^{1/2}/\Gamma_{\text{total}} \text{ in } N\pi \rightarrow N(1)^{1/2}/\Gamma_{\text{total}} \text{ in } N\pi \rightarrow N(1)$	720) → N(## DOCUMENT ID 2 LONGACRE OTON DECAY amplitude A ₁ , DOCUMENT ID ARNOT CRAWFORD AWAJI ARAI ARAI CRAWFORD data for average	96 80 80 80 80, fit:	IPWA TECN IPWA IPWA IPWA IPWA DPWA DPWA DPWA DPWA S, Ilmits.	$(\Gamma_{1}\Gamma_{11})^{\frac{1}{12}}/\Gamma$ $\frac{COMMENT}{\pi N \rightarrow N\pi\pi}$ DES $\frac{COMMENT}{\gamma N \rightarrow \pi N}$ $\gamma N \rightarrow \pi N$
$(\Gamma_1\Gamma_T)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \rightarrow N(1)^{\frac{1}{2}}$ -0.19 $N(1720) \rightarrow p\gamma, \text{ helicity-}1/2$ N	720) → N(## DOCUMENT ID 2 LONGACRE OTON DECA amplitude A ₁ , DOCUMENT ID ARNDT CRAWFORD AWAJI ARAI ARAI CRAWFORD data for average LI	77 77 Y AN 96 83 81 80 80 80 80 93	IPWA IPWA IPWA IPWA IPWA IPWA IPWA IPWA	$(\Gamma_1\Gamma_{11})^{\frac{1}{12}}/\Gamma$ $\frac{COMMENT}{\pi N \rightarrow N\pi \pi}$ DES $\frac{COMMENT}{\gamma N \rightarrow \pi N}$ $\gamma N \rightarrow \pi N$
$(\Gamma_1\Gamma_T)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \rightarrow N(1)^{\frac{1}{2}}$ -0.19 $N(1720) \rightarrow p\gamma, \text{ helicity-}1/2$ N	720) → N(## DOCUMENT ID 2 LONGACRE OTON DECA amplitude A ₁ DOCUMENT ID ARNDT CRAWFORD AWAJI ARAI ARAI CRAWFORD data for average LI BARBOUR	96 83 81 80 80 80 80 93 78	IPWA IPWA IPWA IPWA IPWA IPWA IPWA IPWA	$(\Gamma_{1}\Gamma_{11})^{\frac{1}{12}}/\Gamma$ $\frac{COMMENT}{\pi N \rightarrow N\pi\pi}$ DES $\frac{COMMENT}{\gamma N \rightarrow \pi N}$ $\gamma N \rightarrow \pi N$ $\gamma N \rightarrow \pi N$ $\gamma N \rightarrow \pi N \text{ (fit 1)}$ $\gamma N \rightarrow \pi N \text{ (fit 2)}$ $\gamma N \rightarrow \pi N \text{ etc. } \bullet \bullet \bullet$
$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{\text{total}}$ in $N\pi \to N(1)^{1/2}/\Gamma_{\text{total}}$ in $N(1720) \to p\gamma$, helicity-1/2 $N(1720) \to p\gamma$, helicity-3/2	720) → N(## DOCUMENT ID 2 LONGACRE OTON DECAY amplitude A ₁ , DOCUMENT ID ARNOT CRAWFORD AWAJI ARAI ARAI CRAWFORD data for average LI BARBOUR amplitude A ₃ ,	96 83 81 80 80 80 85, fit: 93 78	IPWA TECN IPWA IPWA IPWA IPWA IPWA IPWA IPWA IPWA	$(\Gamma_{1}\Gamma_{11})^{\frac{1}{12}}/\Gamma$ $\frac{COMMENT}{\pi N \rightarrow N\pi\pi}$ DES $\frac{COMMENT}{\gamma N \rightarrow \pi N}$ $\gamma N \rightarrow \pi N$ etc. • • • $\gamma N \rightarrow \pi N$ $\gamma N \rightarrow \pi N$
$(\Gamma_i\Gamma_f)^{1/2}/\Gamma_{\text{total}}$ in $N\pi \to N(1)^{1/2}/\Gamma_{\text{total}}$ in $N(1720) \to p\gamma$, helicity-1/2 $N(1720) \to p\gamma$, helicity-3/2	720) → N(## DOCUMENT ID 2 LONGACRE OTON DECA amplitude A ₁ DOCUMENT ID ARNDT CRAWFORD AWAJI ARAI ARAI CRAWFORD data for average LI BARBOUR	96 83 81 80 80 80 85, fit: 93 78	IPWA TECN IPWA IPWA IPWA IPWA IPWA IPWA IPWA IPWA	$(\Gamma_{1}\Gamma_{11})^{\frac{1}{12}}/\Gamma$ $\frac{COMMENT}{\pi N \rightarrow N\pi\pi}$ DES $\frac{COMMENT}{\gamma N \rightarrow \pi N}$ $\gamma N \rightarrow \pi N$ etc. • • • $\gamma N \rightarrow \pi N$ $\gamma N \rightarrow \pi N$
$(\Gamma_1\Gamma_T)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \rightarrow N(1)^{\frac{1}{2}}/\Gamma_{\text{total}} $	720) → N(## DOCUMENT ID 2 LONGACRE OTON DECAY amplitude A ₁ , DOCUMENT ID ARNOT CRAWFORD AWAJI ARAI ARAI CRAWFORD data for average LI BARBOUR amplitude A ₃ ,	96 83 81 80 80 80 80 87 87 87	IPWA IPWA IPWA IPWA IPWA IPWA IPWA IPWA	$(\Gamma_{1}\Gamma_{11})^{\frac{1}{12}}/\Gamma$ $\frac{COMMENT}{\pi N \rightarrow N\pi\pi}$ DES $\frac{COMMENT}{\gamma N \rightarrow \pi N}$ $\gamma N \rightarrow \pi N$ etc. • • • $\gamma N \rightarrow \pi N$ $\gamma N \rightarrow \pi N$
$(\Gamma_1\Gamma_T)^{1/2}/\Gamma_{\text{total}}$ in $N\pi \to N(1)^{1/2}/\Gamma_{\text{total}}$ in $N(1)^{1/2}/\Gamma_{\text{total}}$ in $N\pi \to N(1)^{1/2}/\Gamma_{\text{total}}$ in $N\pi \to N$	720) → N(## DOCUMENT ID 2 LONGACRE OTON DECA amplitude A ₁ , DOCUMENT ID ARNOT CRAWFORD AWAJI ARAI ARAI CRAWFORD data for average LI BARBOUR amplitude A ₃ , DOCUMENT ID ARNOT CRAWFORD	77 Y AN 77 Y AN 80 80 80 80 80 80 80 80 80 80	IPWA IPWA IPWA IPWA IPWA IPWA IPWA IPWA	$(\Gamma_1\Gamma_{11})^{\frac{1}{12}}/\Gamma$ $\frac{COMMENT}{\pi N \rightarrow N\pi \pi}$ IDES $\frac{COMMENT}{\gamma N \rightarrow \pi N}$ $\gamma N \rightarrow \pi N$ etc. • • • $\gamma N \rightarrow \pi N$ $\gamma N \rightarrow \pi N$ $\gamma N \rightarrow \pi N$ $\gamma N \rightarrow \pi N$ $\gamma N \rightarrow \pi N$ $\gamma N \rightarrow \pi N$ $\gamma N \rightarrow \pi N$
$(\Gamma_1\Gamma_T)^{1/2}/\Gamma_{\text{total}}$ in $N\pi \to N(1)^{1/2}/\Gamma_{\text{total}}$ in $N\pi \to $	720) → N(## DOCUMENT ID LONGACRE OTON DECA amplitude A ₁ , DOCUMENT ID ARNDT CRAWFORD ARAI ARAI CRAWFORD data for average LI BARBOUR amplitude A ₃ , DOCUMENT ID ARNDT CRAWFORD ARNDT CRAWFORD ARNDT CRAWFORD ARNDT CRAWFORD AWAJI	77 Y AN 77 Y AN 80 80 80 80 80 87 78 78 78	IPWA IPWA IPWA IPWA IPWA IPWA IPWA IPWA	$(\Gamma_1\Gamma_{11})^{\frac{1}{12}}/\Gamma$ $\frac{COMMENT}{\pi N \rightarrow N\pi\pi}$ JDES $\frac{COMMENT}{\gamma N \rightarrow \pi N}$ $\gamma N \rightarrow \pi N$
$(\Gamma_1\Gamma_T)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \rightarrow N(1)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N(1)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \rightarrow N(1)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } $	720) → N(** DOCUMENT ID LONGACRE OTON DECA amplitude A ₁ , DOCUMENT ID ARNDT CRAWFORD AWAJI ARAI ARAI CRAWFORD data for average LI BARBOUR amplitude A ₃ , DOCUMENT ID ARNDT CRAWFORD ARNDT CRAWFORD ARNDT CRAWFORD ARNDT CRAWFORD AWAJI ARAI	77 77 77 96 83 81 80 80 80 80 93 78 72	IPWA IPWA IPWA IPWA IPWA IPWA IPWA DPWA DPWA DPWA IPWA IPWA IPWA IPWA IPWA IPWA IPWA I	$(\Gamma_1\Gamma_{11})^{\frac{1}{12}}/\Gamma$ $\frac{COMMENT}{\pi N \rightarrow N\pi\pi}$ JDES $\frac{COMMENT}{\gamma N \rightarrow \pi N}$ $\gamma N \rightarrow \pi N$ etc. • • • $\gamma N \rightarrow \pi N$ $\gamma N \rightarrow \pi N$ $\gamma N \rightarrow \pi N$ $\gamma N \rightarrow \pi N$ $\frac{COMMENT}{\gamma N \rightarrow \pi N}$ $\gamma N \rightarrow \pi N$
$(\Gamma_1\Gamma_T)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \rightarrow N(1)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N(1)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \rightarrow N(1)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } $	720) → N(## DOCUMENT ID LONGACRE OTON DECA amplitude A ₁ , DOCUMENT ID ARNDT CRAWFORD ARAI ARAI CRAWFORD data for average LI BARBOUR amplitude A ₃ , DOCUMENT ID ARNDT CRAWFORD ARNDT CRAWFORD ARNDT CRAWFORD ARNDT CRAWFORD AWAJI	77 77 96 83 81 80 80 80 80 85, fit: 97 78 72	IPWA IPWA IPWA IPWA IPWA IPWA IPWA IPWA	$(\Gamma_1\Gamma_{11})^{\frac{1}{12}}/\Gamma$ $\frac{COMMENT}{\pi N \rightarrow N\pi\pi}$ JDES $\frac{COMMENT}{\gamma N \rightarrow \pi N}$ $\gamma N \rightarrow \pi N$
$(\Gamma_1\Gamma_T)^{1/2}/\Gamma_{\text{total}}$ in $N\pi \rightarrow N(1)^{1/2}/\Gamma_{\text{total}}$ in $N\pi \rightarrow $	720) → N(## DOCUMENT ID LONGACRE OTON DECA amplitude A ₁ , DOCUMENT ID ARNDT CRAWFORD AWAJI ARAI CRAWFORD data for average LI BARBOUR amplitude A ₃ , DOCUMENT ID ARNDT CRAWFORD ARNDT CRAWFORD ARNDT CRAWFORD AWAJI ARAI ARAI CRAWFORD AWAJI ARAI CRAWFORD AWAJI ARAI CRAWFORD AWAJI ARAI CRAWFORD	77 77 77 77 77 77 77 77 77 77 77 77 77	IPWA IPWA IPWA IPWA IPWA IPWA DPWA DPWA DPWA DPWA IPWA IPWA DPWA DPWA DPWA DPWA DPWA DPWA DPWA D	$(\Gamma_1\Gamma_{11})^{\frac{1}{12}}/\Gamma$ $\frac{COMMENT}{\pi N \rightarrow N\pi \pi}$ JDES $\frac{COMMENT}{\gamma N \rightarrow \pi N}$ $\gamma N \rightarrow \pi N$ $\gamma N \rightarrow \pi N$ $\gamma N \rightarrow \pi N \text{ (fit 1)}$ $\gamma N \rightarrow \pi N \text{ (fit 2)}$ $\gamma N \rightarrow \pi N$ text{ (fit 1)}$ $\gamma N \rightarrow \pi N \text{ (fit 1)}$ $\gamma N \rightarrow \pi N \text{ (fit 2)}$
$(\Gamma_1\Gamma_T)^{\frac{1}{2}}/\Gamma_{\text{total}}$ in $N\pi \to N(1)^{\frac{1}{2}}/\Gamma_{\text{total}}$ in $N\pi \to N(1)^{\frac{1}{2}}/\Gamma_{\text{total}$	720) → N(** DOCUMENT ID LONGACRE OTON DECA amplitude A ₁ , DOCUMENT ID ARNDT CRAWFORD AWAJI ARAI CRAWFORD ARNDT CRAWFORD ARNDT CRAWFORD ARNOT CRAWFORD ARNOT CRAWFORD ARNOT CRAWFORD ARNOT CRAWFORD ARNOT CRAWFORD AWAJI ARAI ARAI CRAWFORD data for average LI CRAWFORD	77 Y AN 77 Y AN 77 96 83 80 80 80 80 87 81 80 80 80 80 80 80 80 80 80 80 80 80 80	IPWA IPWA IPWA IPWA IPWA IPWA IPWA DPWA DPWA IPWA IPWA IPWA IPWA IPWA IPWA IPWA I	$(\Gamma_1\Gamma_{11})^{\frac{1}{12}}/\Gamma$ $\frac{COMMENT}{\pi N \rightarrow N\pi\pi}$ JDES $\frac{COMMENT}{\gamma N \rightarrow \pi N}$ $\gamma N \rightarrow \pi N$
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$\begin{array}{c} (\Gamma_1\Gamma_f)^{1/2}/\Gamma_{\text{total}} & \text{in } N\pi \to N(1)^{1/2}/\Gamma_{\text{total}} & \text{in } N(1)^{1/2}/\Gamma_{\text{total}} & \text{in } N\pi \to N(1)^{1/2}/\Gamma_{\text{total}} & $	T20) → N(## DOCUMENT ID LONGACRE OTON DECA amplitude A ₁ , DOCUMENT ID ARNOT CRAWFORD data for average LI BARBOUR amplitude A ₃ , DOCUMENT ID ARNOT CRAWFORD AWAJI ARAI CRAWFORD data for average LI BARBOUR amplitude A ₃ , DOCUMENT ID ARNOT CRAWFORD data for average LI BARBOUR ARAI ARAI ARAI ARAI ARAI ARAI ARAI A	96 83 81 80 80 80 80 80 80 80 80 80 80 80 80 80	IPWA IPWA IPWA IPWA IPWA IPWA IPWA IPWA	$(\Gamma_1\Gamma_{11})^{\frac{1}{2}}/\Gamma$ $\frac{COMMENT}{\pi N \rightarrow N\pi \pi}$ IDES $\frac{COMMENT}{\gamma N \rightarrow \pi N}$ $\gamma N \rightarrow \pi N$ $\gamma N \rightarrow $
$\begin{array}{c} (\Gamma_1\Gamma_1)^{1/2}/\Gamma_{\text{total}} & \text{In } N\pi \to N(1)^{1/2}/\Gamma_{\text{total}} & \text{In } N(1/20) \to p\gamma, \text{ helicity-}1/2 & \text{helicity-}1/2 & helic$	Property of the property of t	96 83 81 80 80 80 80 80 80 80 80 80 80 80 80 80	IPWA IPWA IPWA IPWA IPWA IPWA IPWA IPWA	$(\Gamma_1\Gamma_{11})^{\frac{1}{2}}/\Gamma$ $\frac{COMMENT}{\pi N \rightarrow N\pi \pi}$ JDES $\frac{COMMENT}{\gamma N \rightarrow \pi N}$ $\gamma N \rightarrow \pi N$ $\gamma N \rightarrow $

LI 93 IPWA $\gamma N \rightarrow \pi N$ BARBOUR 78 DPWA $\gamma N \rightarrow \pi N$

 0.050 ± 0.004 $+0.007\pm0.020$

$N(1720) \rightarrow n\gamma$, helicity-	-3/2 amplitude A ₃	/2		
VALUE (GeV-1/2)	DOCUMENT ID		TECN	COMMENT
-0.029±0.061 OUR ESTIMA	ATE			
-0.005±0.025	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
-0.015±0.019	ILAWA	81	DPWA	$\gamma N \rightarrow \pi N$
-0.139 ± 0.039	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
-0.134 ± 0.044	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$
0.018 ± 0.028	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
 We do not use the folk 	owing data for averag	es, fit	s, limits,	etc. • • •
-0.017 ± 0.004	Li	93	IPWA	$\gamma N \rightarrow \pi N$
$+0.051\pm0.051$	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
N(1720	0) $\gamma p \rightarrow \Lambda K^+$	АМ	PLITU	DES
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } p \gamma \rightarrow$	N(1720) → AK	+		(E ₁₊ amplitude)
VALUE (units 10 ⁻³)	DOCUMENT ID		TECN	
 • • We do not use the follow 	owing data for averag	es, fit	s, limits,	etc. • • •
10.2 ±0.2	WORKMAN	90	DPWA	
9.52	TANABE	89	DPWA	
$p\gamma \rightarrow N(1720) \rightarrow \Lambda K^{-}$	+ phase angle θ			$(E_{1+} \text{ amplitude})$
VALUE (degrees)	DOCUMENT ID		TECN	
• • We do not use the folion	-		s. limits.	etc. • • •
-124 ±2	WORKMAN	90	DPWA	
-103.4	TANABE	89	DPWA	
$(\Gamma_I \Gamma_f)^{\frac{1}{12}} / \Gamma_{\text{total}} \ln p \gamma \rightarrow$	N(1720) AK	+		(<i>M</i> ₁₊ amplitude)
(i fi f) /i total iii p j			TECH	(m1+ ampirede)
VALUE (units 10 ⁻³)	DOCUMENT ID			- 4
• • We do not use the folk				
-4.5 ±0.2	WORKMAN	90	DPWA	
3.18	TANABE	89	DPWA	
	N(1720) FOOT	NOT	ES	
1 The two BAKER 77 entric		using	the Barr	elet-zero method and from
	tions are from a search in addition to πN — ive analysis. The other	· No	rπ data, IGACRE	he unitarized T-matrix; the elastic amplitudes from a 77 values are from eyeball
³ From method II of LONG/ amplitudes.				gner circles to the T-matrix
⁴ See HOEHLER 93 for a d of N and △ resonances as	determined from Arg of the speeds with wh	gand o lich th	liagrams e amplit	of πN elastic partial-wave udes traverse the diagrams

5 LONGACRE 78 values are from a search for poles in the unitarized T-matrix. The first (second) value uses, in addition to πN → Nππ data, elastic amplitudes from a Saclay (CERN) partial-wave analysis.
 6 The overall phase of BAKER 78 copulings has been changed to agree with previous conventions.
 7 The range given is from the four best solutions. DEANS 75 disagrees with π+p → Σ+K+ data of WINNIK 77 around 1920 MeV.

N(1720) REFERENCES

For early references, see Physics Letters 111B 70 (1982).

ARNDT	96	PR C53 430	+Strakovsky, Workman	(VPI)
ARNDT	95	PR C52 2120	+Strakovsky, Workman, Pavan	(VPI, BRCO)
BATINIC	95	PR C51 2310	+Slaus. Svarc. Nefkens	(BOSK, UCLA)
HOEHLER	93	π N Newsletter 9 1	Toleus, Start, Heinelis	(KARL)
LI	93	PR C47 2759	+Arndt, Roper, Workman	(VPI)
MANLEY	92	PR D45 4002	+Saleski	(KÈNT) UP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	(VPI)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
WORKMAN	90	PR C42 781	TLI, Nopel, Workillan, Fore	(VPI)
TANABE	89	PR C39 741	+Kohno, Bennhold	(MANZ)
Also	89	NC 102A 193	Kohno, Tanabe, Bennhold	(MANZ)
BELL	83	NP B222 389	+Blissett, Broome, Daley, Hart, Lintern+	(RL) IJP
CRAWFORD	83	NP B211 1	+Morton	(GLAS)
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
ILAWA	81	Bonn Conf. 352	+Kajikawa	(NAGO)
Also	82	NP B197 365	Fujii, Hayashii, Iwata, Kajikawa+	(NAGO)
ARAI	80	Toronto Conf. 93	ruju, mayasiin, mata, majikawa T	(INUS)
Also	82	NP B194 251	Arai, Fujii	(INUS)
CRAWFORD	80	Toronto Conf. 107	Crail i filii	(GLAS)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMU, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJP
SAXON	80	NP B162 522	+Baker, Bell, Blissett, Bloodworth+	(RHEL, BRIS) IJP
BAKER	79	NP B156 93	+Brown, Clark, Davies, Depagter, Evans+	
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) LIP
Aiso	80	Toronto Conf. 3	Koch	(KARLT) IJP
BAKER	78	NP B141 29	+Blissett, Bloodworth, Broome+	(RL, CAVE) UP
BARBOUR	78	NP B141 253	+Crawford, Parsons	(GLAS)
LONGACRE	78	PR D17 1795	+Lasinski, Rosenfeld, Smadia+	(LBL. SLAC)
BAKER	77	NP B126 365	+Blissett. Bloodworth. Broome. Hart+	(RHEL) IJP
LONGACRE	77	NP B122 493	+Dolbeau	(SACL) LIP
Also	76	NP B108 365	Dolbeau, Triantis, Neveu, Cadiet	(SACL) UP
WINNIK	77	NP B128 66	+Toaff, Revel, Goldberg, Berny	(HAIF) I
DEANS	75	NP B96 90	+Mitchell, Montgomery+	(SFLA, ALAH) UP
KNASEL	75 75	PR D11 1		, WUSL, OSU, ANL) IJP
LONGACRE	75	PL 55B 415	+Rosenfeld, Lasinski, Smadia+	(LBL, SLAC) IJP
LUMBACKE	13	FE 33D 413	Troscinou, Lesinski, Sineuja+	(LUL, SERC) IST

REAL PART

-2×IMAGINARY PART

VALUE (MeV)

not seen

 260 ± 60

not seen

VALUE (MeV)

Baryon Particle Listings

M(1000) D	$I(J^P) = \frac{1}{2}(\frac{3}{2}^+)$ Status: **	
$N(1900) P_{13}$	$I(J^*) = \frac{1}{2}(\frac{1}{2})$ Status. $+$	
OMITTED FROM SUMM	ARY TABLE	
N(190	00) BREIT-WIGNER MASS	
VALUE (MeV)	DOCUMENT ID TECN COMMENT	
≈ 1900 OUR ESTIMATE 1879±17	MANLEY 92 IPWA $\pi N \rightarrow \pi N \& N \pi \pi$	
N(190	0) BREIT-WIGNER WIDTH	
VALUE (MeV) 498±78	DOCUMENT ID TECN COMMENT MANLEY 92 IPWA $\pi N \rightarrow \pi N \& N \pi \pi$	
	No.	
•	(1900) DECAY MODES	
Γ_1 $N\pi$		
Γ_2 $N\pi\pi$		
Γ_3 $N\rho$, $S=1/2$, P -wa	ave	
•	00) BRANCHING RATIOS	
Γ(Nπ)/Γ _{total}		1/Г
VALUE 0.26±0.06	DOCUMENT ID TECN COMMENT MANLEY 92 IPWA $\pi N \rightarrow \pi N \& N \pi \pi$	
		,
$(\Gamma_I \Gamma_I)^{1/2} / \Gamma_{\text{total}} \text{ in } N_\pi \to N(1)$	1900) $\rightarrow N_{\rho}$, $S=1/2$, P -wave $(\Gamma_1\Gamma_3)^{\frac{1}{2}}$	5/۲
-0.34±0.03	DOCUMENT IDTECNCOMMENTMANLEY92IPWA $\pi N \rightarrow \pi N \& N \pi \pi$	
	/(1900) REFERENCES	
	(2200) I'M EILEITOM	
MANIEV 92 PP D45 4002	+ Splanki /MENIT	`
MANLEY 92 PR D45 4002 Also 84 PR D30 904	+Saleski (KENT Manley, Arndt, Goradia, Teplitz (VPI	
Also 84 PR D30 904	Manley, Arndt, Goradia, Teplitz (VPI	
N(1990) F ₁₇	Manley, Arndt, Goradia, Teplitz (VPI $I(J^P) = \frac{1}{2}(\frac{7}{2}+)$ Status: **	
N(1990) F ₁₇ OMITTED FROM SUMMA Most of the results pul	Manley, Arndt, Goradia, Teplitz (VPI $I(J^P)=rac{1}{2}(rac{7}{2}+)$ Status: ** ARY TABLE blished before 1975 are now obsolete and have	
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N(1990) F ₁₇ OMITTED FROM SUMMA Most of the results pul been omitted. They Letters 111B (1982). The various analyses of	Manley, Arndt, Goradia, Teplitz (VPI) $I(J^P) = \tfrac{1}{2}(\tfrac{7}{2}^+) \text{ Status: } **$ ARY TABLE blished before 1975 are now obsolete and have may be found in our 1982 edition, Physics	
N(1990) F ₁₇ OMITTED FROM SUMMA Most of the results pul been omitted. They Letters 111B (1982). The various analyses d	Manley, Arndt, Goradia, Teplitz (VPI) $I(J^P) = \frac{1}{2}(\frac{7}{2}^+) \text{ Status: } **$ ARY TABLE blished before 1975 are now obsolete and have may be found in our 1982 edition, Physics do not agree very well with one another.	
N(1990) F ₁₇ OMITTED FROM SUMM/ Most of the results pul been omitted. They Letters 111B (1982). The various analyses of N(199) VALUE (MeV) ≈ 1990 OUR ESTIMATE	Manley, Arndt, Goradia, Teplitz (VPI) $I(J^P) = \frac{1}{2}(\frac{7}{2}^+) \text{ Status: } **$ ARY TABLE blished before 1975 are now obsolete and have may be found in our 1982 edition, Physics do not agree very well with one another. 30) BREIT-WIGNER MASS $\frac{DOCUMENT\ ID}{} \frac{TECN}{} \frac{COMMENT}{} \frac{COMMENT}{}$	
N(1990) F ₁₇ OMITTED FROM SUMM/ Most of the results pul been omitted. They Letters 111B (1982). The various analyses of N(199)	Manley, Arndt, Goradia, Teplitz (VPI) $I(J^P) = \frac{1}{2}(\frac{7}{2}^+) \text{ Status: } **$ ARY TABLE blished before 1975 are now obsolete and have may be found in our 1982 edition, Physics do not agree very well with one another. BO) BREIT-WIGNER MASS $\frac{DOCUMENT\ ID}{CRAWFORD} = \frac{TECN}{80} = \frac{COMMENT}{7N \rightarrow \pi N \& N\pi\pi}$ CRAWFORD 80 DPWA $\gamma N \rightarrow \pi N$	
N(1990) F ₁₇ OMITTED FROM SUMM/ Most of the results pul been omitted. They Letters 111B (1982). The various analyses of N(199 VALUE (MeV) ≈ 1990 OUR ESTIMATE 2086± 28 2018 1970± 50	Manley, Arndt, Goradia, Teplitz (VPI) $I(J^P) = \frac{1}{2}(\frac{7}{2}^+) \text{ Status: } **$ ARY TABLE blished before 1975 are now obsolete and have may be found in our 1982 edition, Physics do not agree very well with one another. BO) BREIT-WIGNER MASS $\frac{DOCUMENT\ ID}{CRAWFORD} = \frac{TECN}{N} \frac{COMMENT}{N} \rightarrow \pi N \& N \pi \pi COTKOSKY = 80 DPWA \gamma N \rightarrow \pi N CUTKOSKY = 80 IPWA \gamma N \rightarrow \pi N$	
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N(1990) F ₁₇ OMITTED FROM SUMM/ Most of the results pul been omitted. They Letters 111B (1982). The various analyses of N(199 VALUE (MeV) ≈ 1990 OUR ESTIMATE 2086 ± 28 2018 1970 ± 50 2005 ± 150 1999	Manley, Arndt, Goradia, Teplitz (VPI) $I(J^P) = \frac{1}{2}(\frac{7}{2}^+) \text{ Status: } **$ ARY TABLE bilished before 1975 are now obsolete and have may be found in our 1982 edition, Physics do not agree very well with one another. 30) BREIT-WIGNER MASS $\frac{DOCUMENT ID}{\text{MANLEY}} = \frac{TECN}{2} \frac{COMMENT}{\text{CRAWFORD}} = \frac{1}{80} \frac{COMMENT}{2}	
N(1990) F ₁₇ N(1990) F ₁₇ OMITTED FROM SUMM/ Most of the results pul been omitted. They Letters 111B (1982). The various analyses of N(1990	Manley, Arndt, Goradia, Teplitz (VPI) $I(J^P) = \frac{1}{2}(\frac{7}{2}^+) \text{ Status: } **$ ARY TABLE bilished before 1975 are now obsolete and have may be found in our 1982 edition, Physics do not agree very well with one another. 30) BREIT-WIGNER MASS $\begin{array}{ccccccccccccccccccccccccccccccccccc$	
N(1990) F ₁₇ OMITTED FROM SUMMA Most of the results pul been omitted. They Letters 111B (1982). The various analyses of N(199 VALUE (MeV) ≈ 1990 OUR ESTIMATE 2086 ± 28 2018 1970 ± 50 2005±150 1999	Manley, Arndt, Goradia, Teplitz (VPI) $I(J^P) = \frac{1}{2}(\frac{7}{2}^+) \text{ Status: } **$ ARY TABLE blished before 1975 are now obsolete and have may be found in our 1982 edition, Physics do not agree very well with one another. 30) BREIT-WIGNER MASS $\begin{array}{ccccccccccccccccccccccccccccccccccc$	
N(1990) F ₁₇ N(1990) F ₁₇ OMITTED FROM SUMM/ Most of the results pul been omitted. They Letters 111B (1982). The various analyses of N(1990 VALUE (MeV) ≈ 1990 OUR ESTIMATE 2086± 28 2018 1970± 50 2005±150 1999 N(1990 VALUE (MeV) 535±120 295 350±120	Manley, Arndt, Goradia, Teplitz $I(J^P) = \frac{1}{2}(\frac{7}{2}^+) \text{ Status: } **$ ARY TABLE bilished before 1975 are now obsolete and have may be found in our 1982 edition, Physics do not agree very well with one another. 30) BREIT-WIGNER MASS $\begin{array}{ccccccccccccccccccccccccccccccccccc$	
N(1990) F ₁₇ N(1990) F ₁₇ OMITTED FROM SUMM/ Most of the results pul been omitted. They Letters 111B (1982). The various analyses of N(1990 VALUE (MeV) ≥ 1990 OUR ESTIMATE 2086± 28 2018 1970± 50 2005±150 1999 N(1990 VALUE (MeV) 535±120 295	Manley, Arndt, Goradia, Teplitz (VPI) $I(J^P) = \frac{1}{2}(\frac{7}{2}^+) \text{ Status: } **$ ARY TABLE blished before 1975 are now obsolete and have may be found in our 1982 edition, Physics do not agree very well with one another. 90) BREIT-WIGNER MASS $\begin{array}{ccccccccccccccccccccccccccccccccccc$	

DOCUMENT ID TECN COMMENT

• • • We do not use the following data for averages, fits, limits, etc. • • •

 \bullet $\,\bullet\,$ We do not use the following data for averages, fits, limits, etc. $\,\bullet\,$ $\,\bullet\,$

ARNDT

ARNDT

DOCUMENT ID

CUTKOSKY 80 IPWA πN → πN

CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$

91 DPWA $\pi N \rightarrow \pi N$ Soln SM90

91 DPWA $\pi N \rightarrow \pi N$ Soln SM90

TECN COMMENT

TECN COMMENT VALUE (°) DOCUMENT ID CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$ -60 ± 30 N(1990) DECAY MODES Mode $N\pi$ Γ₂ Γ₃ Γ₄ Nη ΛK ΣΚ Γ5 $N\pi\pi$ Γ6 $p\gamma$, helicity=1/2 $p\gamma$, helicity=3/2 Γ7 $n\gamma$, helicity=1/2 $n\gamma$, helicity=3/2 N(1990) BRANCHING RATIOS $\Gamma(N\pi)/\Gamma_{\text{total}}$ Γ_1/Γ VALUE DOCUMENT ID TECN COMMENT 0.06±0.02 92 IPWA $\pi N \rightarrow \pi N \& N \pi \pi$ 80 IPWA $\pi N \rightarrow \pi N$ MANLEY CUTKOSKY HOEHLER 79 IPWA $(\Gamma_1\Gamma_2)^{\frac{1}{2}}/\Gamma$ $(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\pi \to N(1990) \to N\eta$ DOCUMENT ID TECN COMMENT VALUE - 0.043 79 DPWA $\pi^- p \rightarrow n\eta$ BAKER ,(Γ₁Γ₃)^{1/2}/Γ $(\Gamma_i \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\pi \to N(1990) \to \Lambda K$ TECN COMMENT DOCUMENT ID 83 DPWA $\pi^- p \rightarrow \Lambda K^0$ 80 DPWA $\pi^- p \rightarrow \Lambda K^0$ +0.01BELL not seen SAXON -0.021 ± 0.033 DEVENISH Fixed-t dispersion rei. $(\Gamma_I \Gamma_I)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\pi \to N(1990) \to \Sigma K$ $(\Gamma_1\Gamma_4)^{\frac{1}{12}}/\Gamma$ DOCUMENT ID TECN COMMENT VALUE 1 DEANS 75 DPWA πN → ΣK 0.010 to 0.023 73 IPWA $\pi N \rightarrow \Sigma K$ (sol. 1) LANGBEIN $(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N \pi \rightarrow N(1990) \rightarrow N \pi \pi$ DOCUMENT ID TECN COMMENT not seen LONGACRE 75 IPWA $\pi N \rightarrow N \pi \pi$ N(1990) PHOTON DECAY AMPLITUDES $N(1990) \rightarrow p\gamma$, helicity-1/2 amplitude A_{1/2} VALUE (GeV-1/2) DOCUMENT ID TECN COMMENT 0.030 ± 0.029 ILAWA 81 DPWA $\gamma N \rightarrow \pi N$ CRAWFORD 80 DPWA $\gamma N \rightarrow \pi N$ 0.001 ± 0.040 ● ● We do not use the following data for averages, fits, limits, etc. ● ● BARBOUR 78 DPWA $\gamma N \rightarrow \pi N$ $N(1990) \rightarrow p\gamma$, helicity-3/2 amplitude A_{3/2} VALUE (GeV -1/2) DOCUMENT ID TECN COMMENT 0.086 ± 0.060 ILAWA 81 DPWA $\gamma N \rightarrow \pi N$ CRAWFORD 80 DPWA $\gamma N \rightarrow \pi N$ 0.004 ± 0.025 BARBOUR 78 DPWA $\gamma N \rightarrow \pi N$ $N(1990) \rightarrow n\gamma$, helicity-1/2 amplitude A_{1/2} VALUE (GeV-1/2) DOCUMENT ID TECN COMMENT -0.001 ILAWA 81 DPWA $\gamma N \rightarrow \pi N$ CRAWFORD 80 DPWA $\gamma N \rightarrow \pi N$ -0.078 ± 0.030 BARBOUR 78 DPWA $\gamma N \rightarrow \pi N$ $N(1990) \rightarrow n\gamma$, helicity-3/2 amplitude A_{3/2} VALUE (GeV-1/2) DOCUMENT ID TECN COMMENT 81 DPWA $\gamma N \rightarrow \pi N$ -0.178 ILAWA -0.116 ± 0.045 CRAWFORD 80 DPWA $\gamma N \rightarrow \pi N$ -- 0.072 BARBOUR 78 DPWA $\gamma N \rightarrow \pi N$

N(1990) ELASTIC POLE RESIDUE

DOCUMENT ID

TECN COMMENT

CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$

MODULUS |r| VALUE (MeV)

9±3

PHASE 0

N(1990) FOOTNOTES

 ${f ^1}$ The range given for DEANS 75 is from the four best solutions.

N(1990) REFERENCES

For early references, see Physics Letters 111B 70 (1982).

MANLEY	92	PR D45 4002	+Saleski	(KENT) IJP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	` (VPI)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
BELL	83	NP B222 389	+Blissett, Broome, Daley, Hart, Lintern	+ ` (RL) IJP
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
ILAWA	81	Bonn Conf. 352	+Kajikawa	` (NAGO)
Also	82	NP B197 365	Fujii, Hayashii, Iwata, Kajikawa+	(NAGO)
CRAWFORD	80	Toronto Conf. 107	• • • • •	(GLAS)
CUTKOSKY	BO	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMÚ, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJP
SAXON	80	NP B162 522	+Baker, Bell, Blissett, Bloodworth+	(RHEL, BRIS) IJP
BAKER	79	NP B156 93	+Brown, Clark, Davies, Depagter, Evans	+ RHEL)IJP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
BARBOUR	78	NP B141 253	+Crawford, Parsons	(GLAS)
DEANS	75	NP B96 90	+Mitchell, Montgomery+	(SFLA, ALAH) IJP
LONGACRE	75	PL 55B 415	+Rosenfeld, Lasinski, Smadja+	(LBL, SLAC) IJP
DEVENISH	748	NP B81 330		DESY, NORD, LOUC)
LANGBEIN	73	NP B53 251	+Wagner	(MUNI) IJP

$N(2000) F_{15}$

 $I(J^P) = \frac{1}{2}(\frac{5}{2}^+)$ Status: **

OMITTED FROM SUMMARY TABLE

Older results have been retained simply because there is little information at all about this possible state.

N(2000) BREIT-WIGNER MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
≈ 2000 OUR ESTIMATE				
1903±87	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
1882±10	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
2025	AYED	76	IPWA	$\pi N \rightarrow \pi N$
1970	¹ LANGBEIN	73	IPWA	$\pi N \rightarrow \Sigma K \text{ (sol. 2)}$
2175	ALMEHED	72	IPWA	$\pi N \rightarrow \pi N$
1930	DEANS	72	MPWA	$\gamma p \rightarrow \Lambda K \text{ (sol. D)}$
• • • We do not use the fol	llowing data for averag	es, fit:	s, limits,	etc. • • •
1814	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$

N(2000) BREIT-WIGNER WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
490±310	MANLEY	92	IPWA	$\pi N \rightarrow \pi N & N \pi \pi$
95± 20	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
157	AYED	76	IPWA	$\pi N \rightarrow \pi N$
170	¹ LANGBEIN	73	IPWA	$\pi N \rightarrow \Sigma K$ (sol. 2)
150	ALMEHED	72	IPWA	$\pi N \rightarrow \pi N$
112	DEANS	72	MPWA	$\lambda \gamma p \rightarrow \Lambda K \text{ (sol. D)}$
• • We do not use the follo	wing data for averag	es, fit	s, limits,	, etc. • • •
176	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$

N(2000) DECAY MODES

	Mode	
Γ ₁	Νπ	
Γ ₂	$N\eta$	
Γ3	ΛK	
Γ4	ΣΚ	
Γ ₅	$N\pi\pi$	
Γ ₆	Δ (1232) π , P -wave	
Γ7	$N\rho$, $S=3/2$, P -wave	
Γ8	$N\rho$, $S=3/2$, F -wave	
Γg	$p\gamma$	

N(2000) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$				Γ ₁ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
0.08±0.05	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
0.04±0.02	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
0.08	AYED	76	IPWA	$\pi N \rightarrow \pi N$
0.25	ALMEHED	72	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the	following data for averag	es, fit	s, iimits,	etc. • • •
0.10	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N \pi$	→ N(2000) → Nη			(Γ ₁ Γ ₂) ^{1/2} /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
+0.03	BAKER	79	DPWA	$\pi^- p \rightarrow n\eta$

(「/「/)'*/「total in / VALUE	$N\pi \rightarrow N(2000) \rightarrow \Lambda K$	k.	TECN	COMMENT	(Г ₁ Г ₃) ^½ /Г
not seen	SAXON	80	DPWA	$\pi^- p \rightarrow$	ΛK ⁰
(CrCe) ^{1/2} /Coopelin/	$N\pi \to N(2000) \to \Sigma K$				(Γ ₁ Γ ₄) ^{1/2} /Γ
VALUE	DOCUMENT ID		TECN	COMMENT	
0.022	² DEANS	75	DPWA	πN → Σ	K
0.05	¹ LANGBEIN	73	IPWA	πN → Σ	K (sol. 2)
(Γ _Ι Γ _Γ) ^{1/2} /Γ _{total} in i	$N\pi \to N(2000) \to \Delta(123)$	32)π	, <i>P</i> -wav	e	(Γ ₁ Γ ₆) ^{1/2} /Γ
	DOCUMENT ID	, -	TECN	COMMENT	
VALUE					
	MANLEY			$\pi N \rightarrow \pi$	Ν & Νππ
+0.10±0.06 (Г,Г г) ^{1/2} /Г _{total} in <i>l</i>	MANLEY $N\pi o N(2000) o N ho$, S	92 ≔3/ 2	IPWA 2, <i>P</i>-wa	ve	(Г ₁ Г ₇) ^½ /І
+0.10±0.06 ([[[]]) ^{1/2} /[_{total} in <i>i</i> value	MANLEY $N\pi o N(2000) o N ho$, S	92 =3/ 2	IPWA 2, P-wa <u>TECN</u>	VE <u>COMMENT</u>	(Γ ₁ Γ ₇) ^½ /Γ
+0.10±0.06 ([[[]]) ^{1/2} /[total in / VALUE -0.22±0.08	MANLEY $N\pi \rightarrow N(2000) \rightarrow N\rho, 5$ $\frac{DOCUMENT ID}{MANLEY}$ $N\pi \rightarrow N(2000) \rightarrow N\rho, 5$	92 =3/2 92 =3/2	IPWA 2, P-wa TECN IPWA 2. F-wa	VC <u>COMMENT</u> π N	(Г1Г7) ^{1/2} /Г
<u>VALUE</u> -0.22±0.08 ((', ',') ^{1/2} / ' _{total} in l VALUE	MANLEY $N\pi \rightarrow N(2000) \rightarrow N\rho, S$ $\frac{DOCUMENT ID}{MANLEY}$ $N\pi \rightarrow N(2000) \rightarrow N\rho, S$ $\frac{DOCUMENT ID}{DOCUMENT ID}$	92 =3/ 2 92 =3/ 2	IPWA 2, P-war TECN IPWA 2, F-war	VE <u>COMMENT</u> π N → π VE <u>COMMENT</u>	(Γ ₁ Γ ₇) ^{1/2} /Γ ν & ν * π (Γ ₁ Γ ₈) ^{1/2} /Γ
+0.10±0.06 ([[, [,]] ^{1/2} / [total in / VALUE -0.22±0.08 ([,[,]] ^{1/2} / [total in / VALUE	MANLEY $N\pi \rightarrow N(2000) \rightarrow N\rho, 5$ $\frac{DOCUMENT ID}{MANLEY}$ $N\pi \rightarrow N(2000) \rightarrow N\rho, 5$	92 =3/ 2 92 =3/ 2	IPWA 2, P-war TECN IPWA 2, F-war	VE <u>COMMENT</u> π N → π VE <u>COMMENT</u>	(Γ ₁ Γ ₇) ^{1/2} /ί ν & νππ (Γ ₁ Γ ₈) ^{1/2} /ί
$+0.10\pm0.06$ $(\Gamma_f \Gamma_f)^{1/2}/\Gamma_{\text{total}}$ in N_{VALUE} -0.22 ± 0.08 $(\Gamma_f \Gamma_f)^{1/2}/\Gamma_{\text{total}}$ in N_{VALUE} $+0.11\pm0.06$	MANLEY $N\pi \rightarrow N(2000) \rightarrow N\rho$, S DOCUMENT ID MANLEY $N\pi \rightarrow N(2000) \rightarrow N\rho$, S DOCUMENT ID MANLEY $N\pi \rightarrow N(2000) \rightarrow N\rho$, S	92 =3/2 92 =3/2 92	IPWA 2, P-wa TECN IPWA 2, F-wa TECN IPWA	VE $\frac{COMMENT}{\pi N \rightarrow \pi}$ VE $\frac{COMMENT}{\pi N \rightarrow \pi}$	(Γ ₁ Γ ₇) ^{1/2} /Γ Ν & Ν * π (Γ ₁ Γ ₈) ^{1/2} /Γ Ν & Ν * π
$+0.10\pm0.06$ $(\Gamma_f \Gamma_f)^{1/2}/\Gamma_{\text{total}}$ in N_{VALUE} -0.22 ± 0.08 $(\Gamma_f \Gamma_f)^{1/2}/\Gamma_{\text{total}}$ in N_{VALUE} $+0.11\pm0.06$	MANLEY $N\pi \rightarrow N(2000) \rightarrow N\rho$, S $OCCUMENT ID$ MANLEY $N\pi \rightarrow N(2000) \rightarrow N\rho$, S $OCCUMENT ID$ MANLEY	92 5=3/ 2 92 5=3/ 2 92	IPWA 2, P-way IPWA 2, F-way IPWA TECN IPWA	VE $\frac{COMMENT}{\pi N \rightarrow \pi}$ VE $\frac{COMMENT}{\pi N \rightarrow \pi}$ $\frac{COMMENT}{\pi N \rightarrow \pi}$	(Γ ₁ Γ ₇) ^{1/2} /Γ ν & ν * π (Γ ₁ Γ ₈) ^{1/2} /Γ

N(2000) FOOTNOTES

 1 Not seen in solution 1 of LANGBEIN 73. 2 Value given is from solution 1 of DEANS 75; not present in solutions 2, 3, or 4.

N(2000) REFERENCES

ovsky, Workman, Pavan (VPI, BRCO)
i (KENT) IJP
y, Arndt, Goradia, Teplitz (VPI)
Bell, Blissett, Bloodworth+ (RHEL, BRIS) IJP
, Clark, Davies, Depagter, Evans+ (RHEL) IJP
, Koch, Pietarinen (KARLT) IJP
(KARLT) IJP
` (SACL) IJP
ell, Montgomery+ (SFLA, ALAH) IJP
er (MUNI) IJP
ice (LUND, RUTG) IJP
s, Lyons, Montgomery (SFLA) IJP

$N(2080) D_{13}$

 $I(J^P) = \frac{1}{2}(\frac{3}{2})$ Status: **

OMITTED FROM SUMMARY TABLE

There is some evidence for two resonances in this wave between 1800 and 2200 MeV (see CUTKOSKY 80). However, the solution of HOEHLER 79 is quite different.

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters 111B (1982).

N(2080) BREIT-WIGNER MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
≈ 2080 OUR ESTIMATE				
1804 ± 55	MANLEY			$\pi N \rightarrow \pi N \& N \pi \pi$
1920	BELL	83	DPWA	$\pi^- p \rightarrow \Lambda K^0$
1880 ± 100	1 CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
2060 ± 80	¹ CUTKOSKY			
1900	SAXON	80	DPWA	$\pi^- p \rightarrow \Lambda K^0$
2081 ± 20	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following	g data for average	es, fit	s, limits,	etc. • • •
1986 ± 75	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$
1880	BAKER	79	DPWA	$\pi^- p \rightarrow n\eta$

N(2080) BREIT-WIGNER WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
450±185	MANLEY			$\pi N \rightarrow \pi N \& N \pi \pi$
320	BELL	83	DPWA	$\pi^- p \rightarrow \Lambda K^0$
180± 60				$\pi N \rightarrow \pi N \text{ (lower } m)$
300±100	1 CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N \text{ (higher } m\text{)}$
240	SAXON	80	DPWA	$\pi^- \rho \rightarrow \Lambda K^0$
265± 40	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the	e following data for average	s, flt	s, limits,	etc. • • •
1050 ± 225	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$
87	BAKER	79	DPWA	$\pi^- p \rightarrow n\eta$

Baryon Particle Listings *N*(2080)

 $\begin{array}{c|c} \left(\Gamma_{I}\Gamma_{f}\right)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \rightarrow N(2080) \rightarrow \Delta(1232)\pi, S\text{-wave} \\ \frac{VALUE}{-0.09\pm0.09} & \frac{DOCUMENT ID}{\text{MANLEY}} & \frac{TECN}{92} & \frac{COMMENT}{\pi N \rightarrow \pi N \& N\pi\pi} \end{array}$

N(2	2080) POLE POSITION			$N(2080) \rightarrow \Delta(1232)\pi$, D-wave $(\Gamma_1\Gamma_7)^{\frac{1}{2}}/\Gamma$
REAL PART	DOCUMENT ID TECH	COMMENT	<u>VALUE</u> +0.22±0.07	DOCUMENT ID TECN COMMENT MANLEY 92 IPWA $\pi N \rightarrow \pi N \& N \pi \pi$
VALUE (MeV) 1880±100	1 CUTKOSKY 80 IPWA			
2050± 70	1 CUTKOSKY 80 IPWA	, ,	$(\Gamma_I \Gamma_{\ell})^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N \pi \rightarrow I$	$N(2080) \rightarrow N \rho$, S=3/2, S-wave $(\Gamma_1 \Gamma_8)^{\frac{1}{2}} / \Gamma_8$
• • We do not use the followin			VALUE	DOCUMENT ID TECN COMMENT
not seen	ARNDT 91 DPW	$\pi N \rightarrow \pi N$ Soln SM90	-0.24 ± 0.06	MANLEY 92 IPWA $\pi N \rightarrow \pi N \& N \pi \pi$
-2×IMAGINARY PART			$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\pi \to I$	$N(2080) \rightarrow N(\pi\pi)_{S-sump}^{I=0}$ $(\Gamma_1 \Gamma_9)^{\frac{1}{2}} / \Gamma_1$
VALUE (MeV)	DOCUMENT ID TECN	COMMENT	VALUE	DOCUMENT ID TECN COMMENT
160±80 200±80		$\pi N \rightarrow \pi N \text{ (lower } m)$ $\pi N \rightarrow \pi N \text{ (higher } m)$	$+0.25\pm0.06$	MANLEY 92 IPWA $\pi N \rightarrow \pi N \& N \pi \pi$
● ● We do not use the followin			14	
not seen		λ πN → πN Soln SM90	$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln p \gamma \to \Lambda$ VALUE	$V(2080) \rightarrow N\eta$ $OCCUMENT ID$ $TECN$ $COMMENT$ $COMMENT$
N(2080)	ELASTIC POLE RESIDU	IF.	0.0037	HICKS 73 MPWA $\gamma p \rightarrow p \eta$
	, LEWING TOLL KLOID	,_	N/2080\	PHOTON DECAY AMPLITUDES
MODULUS r			, ,	
VALUE (MeV)	DOCUMENT ID TECN	COMMENT	$N(2080) \rightarrow p\gamma$, helicity-	1/2 amplitude A _{1/2}
10 ± 5 30 ± 20		$\pi N \rightarrow \pi N \text{ (lower } m)$ $\pi N \rightarrow \pi N \text{ (higher } m)$	VALUE (GeV ^{-1/2})	DOCUMENT ID TECN COMMENT
30 ± 20	COTROSKT OF IT WA	#74 #74 (inglies iii)	-0.020 ± 0.008	AWAJI 81 DPWA $\gamma N \rightarrow \pi N$
PHASE 0			 ◆ ◆ We do not use the follo 	wing data for averages, fits, limits, etc. • • •
VALUE (°)	DOCUMENT ID TECN	COMMENT	0.026 ± 0.052	DEVENISH 74 DPWA $\gamma N \rightarrow \pi N$
100 ± 80 0 ± 100	¹ CUTKOSKY 80 IPWA ¹ CUTKOSKY 80 IPWA	$\pi N \rightarrow \pi N \text{ (lower } m\text{)}$ $\pi N \rightarrow \pi N \text{ (higher } m\text{)}$	$N(2080) \rightarrow p\gamma$, helicity-	3/2 amplitude A
01100				•
N	2080) DECAY MODES		VALUE (GeV ^{-1/2}) 0.017±0.011	AWAJI 81 DPWA $\gamma N \rightarrow \pi N$
				owing data for averages, fits, limits, etc. • • •
Mode			0.128±0.057	DEVENISH 74 DPWA $\gamma N \rightarrow \pi N$
Γ ₁ Νπ				,
$\Gamma_2 = N\eta$			$N(2080) \rightarrow n\gamma$, helicity-	1/2 amplitude A _{1/2}
Γ ₃ ΛΚ			VALUE (GeV ^{-1/2})	DOCUMENT ID TECN COMMENT
$\Gamma_4 \Sigma K$			0.007 ± 0.013	AWAJI 81 DPWA $\gamma N \rightarrow \pi N$
Γ ₅ Νππ				owing data for averages, fits, limits, etc. • • •
$\Gamma_6 \qquad \Delta(1232)\pi$, S-wave			0.053±0.083	DEVENISH 74 DPWA $\gamma N \rightarrow \pi N$
Γ_7 $\Delta(1232)\pi$, D-wave		•	$N(2080) \rightarrow n\gamma$, helicity-	3/2 amplitude A _{2/2}
Γ_8 $N\rho$, $S=3/2$, S-wave			VALUE (GeV ^{-1/2})	DOCUMENT ID TECN COMMENT
$\Gamma_9 N(\pi\pi)_{S-\text{wave}}^{I=0}$			-0.053±0.034	AWAJI 81 DPWA γN → πN
Γ_{10} $p\gamma$, helicity=1/2				owing data for averages, fits, limits, etc. • •
Γ_{11} $p\gamma$, helicity=3/2 Γ_{12} $n\gamma$, helicity=1/2			0.100 ± 0.141	DEVENISH 74 DPWA $\gamma N \rightarrow \pi N$
Γ_{12} $n\gamma$, helicity=1/2 Γ_{13} $n\gamma$, helicity=3/2			· · · · · · · · · · · · · · · · · · ·	
$\Gamma_{14} = \rho \gamma$			N(2080)) $\gamma p \rightarrow \Lambda K^+$ AMPLITUDES
		 	(= = ×4/= = = =	41/2000) 41/2 / C amplitude
N(20	30) BRANCHING RATIOS	i	$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln p \gamma \rightarrow \frac{VALUE \text{ (units } 10^{-3}\text{)}}{}$	$N(2080) \rightarrow \Lambda K^+$ (E ₂ amplitude)
$\Gamma(N\pi)/\Gamma_{\text{total}}$		Γ ₁ /Γ		owing data for averages, fits, ilmits, etc. ● ●
VALUE	DOCUMENT ID TECN	COMMENT	5.5 ±0.3	WORKMAN 90 DPWA
0.23 ± 0.03	MANLEY 92 IPWA		4.09	TANABE 89 DPWA
0.10±0.04	1 CUTKOSKY 80 IPWA 1 CUTKOSKY 80 IPWA	, ,		
0.14±0.07 0.06±0.02		$\pi N \rightarrow \pi N$ (finglier III)	$p\gamma \rightarrow N(2080) \rightarrow \Lambda K^+$	
• • We do not use the following			VALUE (degrees)	DOCUMENT ID TECN
0.09±0.02	BATINIC 95 DPW/	$\lambda \pi N \rightarrow N\pi, N\eta$		owing data for averages, fits, limits, etc. • •
m/a. \ /m		- /r	~48 ±5	WORKMAN 90 DPWA
$\Gamma(N\eta)/\Gamma_{\text{total}}$		Γ ₂ /Γ	35.9	TANABE 89 DPWA
VALUE ■ ■ We do not use the following		COMMENT	$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln p \gamma \rightarrow$	$N(2080) \rightarrow \Lambda K^+$ (M_2 amplitude)
	-		VALUE (units 10 ⁻³)	DOCUMENT ID TECH
0.07 ± 0.04	BATINIC 95 DPW	$\lambda \pi N \rightarrow N\pi, N\eta$		owing data for averages, fits, limits, etc. • •
$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N\pi \to N(2)$	2080) N m	(Γ ₁ Γ ₂) ^{1/2} /Γ	-6.7 ±0.2	WORKMAN 90 DPWA
VALUE		COMMENT	-4.09	TANABE 89 DPWA
0.065		$\pi^- p \rightarrow n \eta$	112	
1/		11.		N(2080) FOOTNOTES
$(\Gamma_I \Gamma_I)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N \pi \rightarrow N(2)$	2080) → <i>ΛK</i>	(Γ₁Γ₃) ^½ /Γ	¹ CUTKOSKY 80 finds a lo	wer mass D_{13} resonance, as well as one in this region. Boti
VALUE	DOCUMENT ID TECN	COMMENT	are listed here	NS 75 is from the four best solutions. Disagrees with π^+p
+0.04		$\lambda \pi^- p \rightarrow \Lambda K^0$	$\Sigma^+ K^+$ data of WINNIK	
+0.03	SAXON 80 DPW	$\lambda \pi^- p \to \Lambda K^0$	Z 7. dete of William	
$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \ln N \pi \rightarrow N(2)$	2080) → ΣK	(Γ ₁ Γ ₄) ^{1/2} /Γ		
		L: 1: 4/ /:		
VALUE / total III re x - re(z		COMMENT		

N(2080) REFERENCES

For early references, see Physics Letters 111B 70 (1982).

BATINIC	95	PR C51 2310	+Slaus, Svarc, Nefkens	(BOSK, UCLA)
MANLEY	92	PR D45 4002	+Saleski	(KENT) IJP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	(VPI)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
WORKMAN	90	PR C42 781	, - , - , , ,	(VPI)
TANABE	89	PR C39 741	+Kohno, Bennhold	(MÀNZ)
Also	89	NC 102A 193	Kohno, Tanabe, Bennhold	(MANZ)
BELL	83	NP B222 389	+Blissett, Broome, Daley, Hart, Lintern	
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
ILAWA	81	Bonn Conf. 352	+Kajikawa	(NAGO)
Also	82	NP B197 365	Fujii, Hayashii, Iwata, Kajikawa+	(NAGO)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMÙ, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJP
SAXON	80	NP B162 522	+Baker, Bell, Blissett, Bloodworth+	(RHEL, BRIS) IJP
BAKER	79	NP B156 93	+Brown, Clark, Davies, Depagter, Evan	s+ ` (RHEL)UP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
WINNIK	77	NP B128 66	+Toaff, Revel, Goldberg, Berny	(HAIF) I
DEANS	75	NP B96 90	+Mitchell, Montgomery+	(SFLA, ÀLAH) IJP
DEVENISH	74	PL 52B 227		DESY, LANC, BONN IJP
HICKS	73	PR D7 2614	+Deans, Jacobs, Lyons+	(CMU, ORNL, SFLA) IJP

 $N(2090) S_{11}$

 $I(J^{P}) = \frac{1}{2}(\frac{1}{2})$ Status: *

OMITTED FROM SUMMARY TABLE

Any structure in the \mathcal{S}_{11} wave above 1800 MeV is listed here. A few early results that are now obsolete have been omitted.

N(2090) BREIT-WIGNER MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
≈ 2090 OUR ESTIMATE				
1928±59	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
2180±80	CUTKOSKY	80 I	IPWA	$\pi N \rightarrow \pi N$
1880±20	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$

N(2090) BREIT-WIGNER WIDTH

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
414±157	MANLEY 92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
350±100	CUTKOSKY 80	IPWA	$\pi N \rightarrow \pi N$
95± 30	HOEHLER 79	IPWA	$\pi N \rightarrow \pi N$

N(2090) POLE POSITION

REAL PART	DOCUMENT ID		TECN	COMMENT
2150±70	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
1937 or 1949	1 LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$
-2×IMAGINARY PART				
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
350±100	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
139 or 131	1 LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$

N(2090) ELASTIC POLE RESIDUE

MODULUS	1	
VALUE (MeV)	٠.	

F(N-1/F

DOCUMENTIO		TECN	COMMENT
CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
DOCUMENT ID		<u>TECN</u>	COMMENT
CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
	CUTKOSKY	DOCUMENT ID	CUTKOSKY 80 IPWA

N(2090) DECAY MODES

	Mode	 	 	
$\overline{\Gamma_1}$	Nπ			
Γ ₂	ΛK			
Γ_3	$N\pi\pi$			

N(2090) BRANCHING RATIOS

! (/∀ <i>*</i> /)/! total				11/1
VALUE	DOCUMENT ID		TECN	COMMENT
0.10 ± 0.10	MANLEY	92	IPWA	$\pi N \rightarrow \pi N & N \pi \pi$
0.18 ± 0.08	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
0.09 ± 0.05	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N \pi$	→ N(2090) → ΛK			(Γ₁Γ₂) ¹ //
VALUE	DOCUMENT ID		TECN	COMMENT
not seen	SAXON	80	DPWA	$\pi^- p \rightarrow \Lambda K^0$

N(2090) FOOTNOTES

 1 LONGACRE 78 values are from a search for poles in the unitarized T-matrix. The first (second) value uses, in addition to $\pi\,N\to\,N\pi\pi$ data, elastic amplitudes from a Saclay (CERN) partial-wave analysis.

N(2090) REFERENCES

MANLEY	92	PR D45 4002	10	+Saleski	(KENT) IJP
Also	84	PR D30 904		Manley, Arndt, Goradia, Teplitz	(VPI)
CUTKOSKY	80	Toronto Conf.		+Forsyth, Babcock, Kelly, Hendrick	(CMU, LBL) IJP
Also	79	PR D20 2839	.,	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL)
SAXON	80	NP B162 522		+Baker, Bell, Blissett, Bloodworth+	(RHEL, BRIS) IJP
HOEHLER	79	PDAT 12-1	3	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf.		Koch	(KARLT) IJP
LONGACRE	78	PR D17 1795		+Lasinski, Rosenfeld, Smadja+	(LBL, SLAC)

 $N(2100) P_{11}$

 $I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$ Status: *

OMITTED FROM SUMMARY TABLE

N(2100) BREIT-WIGNER MASS

VALUE (MeV)	DOCUMENT ID	DOCUMENT ID		COMMENT	
≈ 2100 OUR ESTIMATE					
1885 ± 30	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$	
2125±75	CUTKOSKY	80	JPWA	$\pi N \rightarrow \pi N$	
2050 ± 20	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$	
• • • We do not use the follo	wing data for average	s, fits	i, limits,	etc. • • •	
2203±70	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$	

N(2100) BREIT-WIGNER WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
113± 44	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
260±100	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
200± 30	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following	data for averages	, fits	i, ilmits,	etc. • • •
418±171	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$

N(2100) POLE POSITION

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
2120±40	CUTKOSKY 80	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the form	ollowing data for averages, fit	s, limits,	etc. • • •
not seen	APNOT 01	DPWA	#N → #N Soln SM90

not seen ARNDI 91 DPWA πN → πN SOIN S -2×IMAGINARY PART

VALUE (MEV)	DOCUMENT 1D	7,00,1	COMMENT
240±80	CUTKOSKY	80 IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following	data for averages,	, fits, limits,	etc. • • •
not seen	ARNDT	91 DPWA	$\pi N \to \pi N$ Soln SM90

N(2100) ELASTIC POLE RESIDUE

MODULUS |r|

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
14±7	CUTKOSKY 80	IPWA	$\pi N \rightarrow \pi N$
PHASE 0 VALUE (°)	DOCUMENT ID	TECN	COMMENT
35±25	CUTKOSKY 80	IPWA	$\pi N \rightarrow \pi N$

N(2100) DECAY MODES

_	Mode
Γ ₁	Νπ
Γ ₂	Νη
Γ_3	$N\pi\pi$
Γā	Δ (1232) π . P-wave

N(2100) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$					Γ_1/Γ
VALUE	DOCUMENT ID		TECN	COMMENT	
0.15±0.06	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N$	π
0.12±0.03	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$	
0.10 ± 0.04	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$	
• • We do not use the following the fol	owing data for average	s, flt	s, ilmits,	etc. • • •	
0.11 ± 0.07	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$	

Baryon Particle Listings N(2100), N(2190)

Γ(Νη)/Γ	total		_	DOCUMENT II		TECN	COMMEN	Γ ₂ /Γ
• • • We	do no	t use the follo	wing	data for averag	ges, fit	s, limits,	etc. • •	•
0.86 ± 0.07				BATINIC	95	DPWA	$\pi N \rightarrow$	Νπ, Νη
(F _I F _I) ^{1/2} / <u>VALUE</u> -0.19±0.0	UE <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u>		DOCUMENT ID TECH C					
			N(2100) REFE	RENC	ES		
BATINIC MANLEY Also ARNDT CUTKOSKY Also HOEHLER Also	95 92 84 91 80 79 79	PR C51 2310 PR D45 4002 PR D30 904 PR D43 2131 Toronto Conf. PR D20 2839 PDAT 12-1 Toronto Conf.		+Slaus, Svarc, +Saleski Manley, Arnd +Li, Roper, W +Forsyth, Bab Cutkosky, Fo +Kaiser, Koch Koch	it, Gorac forkman, cock, Ko rsyth, H	lia, Teplitz Ford elly, Hendri endrick, Kr	ick	(BOSK, UCLA) (KENT) IJP (VPI) (VPI, TELE) IJP (CMU, LBL) IJP (CMU, LBL) (KARLT) IJP (KARLT) IJP

$N(2190) G_{17}$

$$I(J^P) = \frac{1}{2}(\frac{7}{2})$$
 Status: ***

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters 111B (1982).

N(2190) BREIT-WIGNER MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
2100 to 2200 (≈ 2190) OUR EST	IMATE			
2127± 9	MANLEY	92	IPWA	$\pi N \rightarrow \pi N & N \pi \pi$
2200±70	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
2140±12	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
2140±40	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following	g data for average	s, fit	s, limits,	etc. • • •
2131	ARNDT	95	DPWA	$\pi N \rightarrow N\pi$
2198±68	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$
2098	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
2180	SAXON	80	DPWA	$\pi^- p \rightarrow \Lambda K^0$
2140	BAKER	79	DPWA	$\pi^- p \rightarrow n\eta$
2117	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$

N(2190) BREIT-WIGNER WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT	
350 to 550 (≈ 450) OUR ESTIMAT	ΤĒ				
550± 50	MANLEY	92	IPWA	$\pi N \rightarrow \pi N & N \pi \pi$	
500±150	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$	
390± 30	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$	
270 ± 50	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$	
• • • We do not use the following	data for average	s, fit	s, limits,	etc. • • •	
476	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$	
805±140	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$	
238	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$	
80	SAXON	80	DPWA	$\pi^- p \rightarrow \Lambda K^0$	
319	BAKER	79	DPWA	$\pi^- p \rightarrow n\eta$	
220	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$	

N(2190) POLE POSITION

REAL	. P	'ΑΙ	₹Т

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1950 to 2150 (≈ 2050) OUR E	STIMATE			
2030	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
2042	¹ HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
2100±50	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the follow	ing data for average	s, fit	s, limits,	etc. • • •
2060	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
A HAAGINIA DAY DA DT				

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
350 to 550 (≈ 450) OUR ES	TIMATE			
460	ARNDT			$\pi N \rightarrow N\pi$
482	¹ HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
400 ± 160	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the foli	owing data for average	s, flt	s, Ilmits,	etc. • • •
464	ARNDT	91	DPWA	$\pi N \to \pi N$ Soln SM90

N(2190) ELASTIC POLE RESIDUE

MODULUS |r|

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
46	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
45	HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
25±10	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following	data for average	s, fit	s, ilmits,	etc. • • •
54	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
PHASE 0				
VALUE (°)	DOCUMENT ID		TECN	COMMENT
-23	ARNDT	95	DPWA	$\pi N \rightarrow N\pi$

VALUE (°)	DOCUMENT ID		TECN	COMME	NT
-23	ARNDT	95	DPWA	$\pi N \rightarrow$	Νπ
-30±50	CUTKOSKY	80	IPWA	$\pi N \rightarrow$	πN
• • • We do not use the following	data for average:	s, fits	s, limits,	etc. • •	•
-44	ARNDT	91	DPWA	$\pi N \rightarrow$	πN Soln SM90

N(2190) DECAY MODES

The following branching fractions are our estimates, not fits or averages.

	Mode	Fraction (F _J /F)	
$\overline{\Gamma_1}$	Νπ	10-20 %	
Γ_2	$N\eta$		
Γ3	ΛK		
Γ4	ΣΚ		
Γ ₅	$N\pi\pi$		
Γ6	$N\rho$		
Γ7	$N\rho$, $S=3/2$, D -wave		
Гв	$p\gamma$, helicity=1/2		
و۲	$p\gamma$, helicity=3/2		
Γ ₁₀	$n\gamma$, helicity=1/2		
Γ11	$n\gamma$, helicity=3/2		

N(2190) BRANCHING RATIOS

Γ(Nπ)/Γ _{total}					Γ ₁ /
VALUE	DOCUMENT ID		TECN	COMMENT	
0.1 to 0.2 OUR ESTIMAT	Έ				
0.22 ± 0.01	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N$	√ππ
0.12±0.06	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$	
0.14±0.02	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$	
0.16±0.04	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$	
• • • We do not use the fe	ollowing data for average	s, fit	s, limits,	etc. • • •	
0.23	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$	
0.19 ± 0.05	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\tau$	7
Γ(Nπ)/Γ					Г2/

VALUE	DOCUMENT ID	<u>TECN</u>	COMMENT	
• • • We do not use the following	data for averages	, fits, limits,	etc. • • •	
0.001 ± 0.003	RATINIC	OF DOWA	- N - N-	

$(\Gamma_I \Gamma_I)^{1/2} / \Gamma_{\text{total}} \ln N \pi \rightarrow N(219)$	90) → Nη			$(\Gamma_1\Gamma_2)^{\frac{1}{2}}/\Gamma$
VALUE	DOCUMENT ID	<u>TECN</u>	COMMENT	

BAKER 79 DPWA $\pi^- p \rightarrow n\eta$ +0.052

$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \ln N \pi \to \Lambda$	/(2190) → <i>ΛK</i>		$(\Gamma_1\Gamma_3)^{\frac{1}{2}}/\Gamma$
VALUE	DOCUMENT ID	TECN	COMMENT
-0.02	BELL 83	DPWA	$\pi^- p \rightarrow \Lambda K^0$
0.00	CAVON OF	DDIA/A	n . AVO

-0.02	SAXON	80	DPWA	$\pi^- p \rightarrow$	ΛK ⁰
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\pi \rightarrow$	N(2190) → ∑K		TECN	COMMEN	_τ (Γ ₁ Γ ₄) ^{1/2} /Γ

ullet ullet We do not use the following data for averages, fits, limits, etc. ullet ullet0.014 to 0.019 ² DEANS 75 DPWA $\pi N \rightarrow \Sigma K$

$(\Gamma_I \Gamma_I)^{\frac{1}{12}} / \Gamma_{\text{total}} \ln N \pi \rightarrow N($	$(2190) \rightarrow N\rho, S=3$	/2, D-wa	we $(\Gamma_1\Gamma_7)^{\frac{1}{12}}/\Gamma$
VALUE			COMMENT
-0.25 ± 0.03	MANLEY 9	2 IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$

N(2190) PHOTON DECAY AMPLITUDES

$N(2190) \rightarrow p\gamma$, helicity-1/2 amplitude A_{1/2}

74(2170) - 7 /, manag-1/2 ampinado 71/2						
VALUE (GeV ^{-1/2}) DOCUMENT ID TECN COMMENT						
-0.055 CRAWFORD 80 DPWA $\gamma N \rightarrow \pi N$						
-0.030 BARBOUR 78 DPWA $\gamma N \rightarrow \pi N$						

					649
	Baryon	P	arti	cle Listii	ngs
	•			90), <i>N</i> (22	_
N(2200) D ₁₅	I(J ^P	') =	1/2(5-) Status: **	
OMITTED FROM SUMMA The mass is not well		Fares d	aziv red	sults have been	
omitted.	determined: A				
N(220	0) BREIT-WIGN	IER	MASS		
VALUE (MeV) ≈ 2200 OUR ESTIMATE	DOCUMENT ID		TECN	COMMENT	—
1900	BELL			$\pi^- p \rightarrow \Lambda K^0$	
2180±80 1920	CUTKOSKY SAXON			$\pi N \rightarrow \pi N$ $\pi^- p \rightarrow \Lambda K^0$	
2228±30	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$	
• • We do not use the following					
2240±65	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$	
N(2200) BREIT-WIGN	ER '	WIDTH	1	
VALUE (MeV)	DOCUMENT ID				
130 400±100	BELL CUTKOSKY			$\pi^- p \rightarrow \Lambda K^0$ $\pi N \rightarrow \pi N$	
220	SAXON			$\pi^- p \rightarrow \Lambda K^0$	
310± 50	HOEHLER			$\pi N \rightarrow \pi N$	
• • We do not use the following	•				
761±139	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$	
N(2200) POLE PO	SIT	ION		
REAL PART	DOCUMENT ID		TECN	COMMENT	
VALUE (MeV) 2100±60	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$	
-2×IMAGINARY PART	DOCUMENT ID		TECN	COMMENT	
360±80	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$	
N(2200) ELASTIC POL	E R	ESIDU		
MODULUS r	,			-	
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT	
20±10	CUTKOSKY	80	IPWA		
PHASE 0					
VALUE (°)	DOCUMENT ID		TECN	COMMENT	
~90±50	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$	
Node Node	(2200) DECAY I	NOE	DES		
$\Gamma_1 N\pi$					
$\Gamma_2 = N\eta$					
Γ ₃ ΛΚ					
N(22	00) BRANCHIN	G R	ATIOS		
$\Gamma(N\pi)/\Gamma_{\text{total}}$,				Γ1/Γ
VALUE	DOCUMENT ID		TECN	COMMENT	
0.10±0.03	CUTKOSKY	80		$\pi N \rightarrow \pi N$	
0.07±0.02 • • • We do not use the following	HOEHLER ng data for average	79 s, fit:		$\pi N \rightarrow \pi N$ etc. • •	
0.08±0.04	BATINIC	95		$\pi N \rightarrow N\pi, N\eta$	
$\Gamma(N\eta)/\Gamma_{\text{total}}$					Γ2/Γ
VALUE	DOCUMENT ID				
• • We do not use the following					
0.001±0.01	BATINIC	95	DPWA	$\pi N \rightarrow N\pi, N\eta$	1/
$(\Gamma_I \Gamma_f)^{\frac{1}{12}} / \Gamma_{\text{total}} \text{ in } N\pi \to N($	2200) → Nη DOCUMENT ID		TECN	(Г ₁ Г	2) ^{1/2} /Γ
0.066	BAKER	79		$\pi^- p \rightarrow n\eta$	

TECN COMMENT 83 DPWA $\pi^- p \rightarrow \Lambda K^0$ 80 DPWA $\pi^- p \rightarrow \Lambda K^0$

BELL

SAXON

DOCUMENT ID

 $(\Gamma_I \Gamma_f)^{1/2}/\Gamma_{\text{total}} \ln N\pi \to N(2200) \to \Lambda K$

-0.03

-0.05

VALUE (GeV-1/2)	DOCUMENT ID		TECN	COMMENT
• • We do not use th	e following data for average	s, fit	s, limits,	etc. • • •
0.081	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
+0.180	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
$N(2190) \rightarrow n\gamma$, he	licity-1/2 amplitude A ₁	/2		
VALUE (GeV-1/2)	DOCUMENT ID	_	TECN	COMMENT
• • We do not use th	e following data for average			
- 0.042	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
- 0.085	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
$N(2190) \rightarrow n\gamma$, he	licity-3/2 amplitude A _{3,}	/2		
VALUE (GeV ^{-1/2})	DOCUMENT ID		TECN	COMMENT
• • We do not use th	e following data for average	s, fit	s, limits,	etc. • •
-0.126	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
+0.007	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \ln \rho^2$ VALUE (units 10^{-3})	(2190) $\gamma p \rightarrow \Lambda K^+$ $\gamma \rightarrow N(2190) \rightarrow \Lambda K^-$ DOCUMENT ID	.	<u>TECN</u>	(E ₄ _ amplitude)
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}}$ in p	$\gamma \rightarrow N(2190) \rightarrow \Lambda K^{-1}$.	<u>TECN</u>	(E ₄ _ amplitude)
$(\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}}$ in p' WALUE (units 10^{-3}) • • • We do not use the	y → N(2190) → AK-	r s, fit	<u>TECN</u>	(E ₄ _ amplitude)
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}}$ in p	$\gamma \rightarrow N(2190) \rightarrow \Lambda K^{-}$ DOCUMENT ID The following data for average	es, fit	TECN s, Ilmits,	(E ₄ _ amplitude)
$(\Gamma_i \Gamma_f)^{1/2}/\Gamma_{\text{total}}$ in p^2 WALUE (units 10^{-3}) • • We do not use the second seco	y → N(2190) → AK ⁻ <u>DOCUMENT ID</u> e following data for average WORKMAN TANABE	es, fit	TECN s, Ilmits, DPWA	(E ₄ _ amplitude)
$(\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}}$ in p . WALUE (units 10^{-3}) • • • We do not use the 2.5 ± 1.0 and 2.04 .	y → N(2190) → ΛK ⁻ <u>DOCUMENT ID</u> The following data for average WORKMAN	es, fit 90 89	TECN s, Ilmits, DPWA	(E4_ amplitude
$(\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}}$ in p' $NALUE \text{ (units 10}^{-3})$ \bullet \bullet We do not use th 2.5 ± 1.0 2.04 $p\gamma \rightarrow N(2190) \rightarrow NLUE \text{ (degrees)}$	y → N(2190) → AK ⁻ DOCUMENT ID THE FORMAN TANABE AK ⁺ phase angle θ	es, fit 90 89	TECN s, limits, DPWA DPWA	$(E_4$ amplitude etc. • • • $(E_4$ amplitude
$(\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}}$ in p' $NALUE (\text{units }10^{-3})$ \bullet \bullet We do not use th 2.5 ± 1.0 2.04 $p\gamma \rightarrow N(2190) \rightarrow NLUE (degrees)$ \bullet \bullet We do not use th	y → N(2190) → AK DOCUMENT ID Re following data for average WORKMAN TANABE AK+ phase angle θ DOCUMENT ID Re following data for average WORKMAN	es, fit 90 89 es, fit	TECN s, Ilmits, DPWA DPWA TECN s, Ilmits,	$(E_4$ amplitude etc. • • • $(E_4$ amplitude
$(\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}}$ in p' $(NLUE (units 10^{-3})$ • • • We do not use the properties of the propertie	y → N(2190) → AK ⁻ DOCUMENT ID THE FORMAN TANABE AK ⁺ phase angle θ DOCUMENT ID THE FORMAN TANABE	es, fit 90 89 es, fit	TECN s, Ilmits, DPWA DPWA TECN s, Ilmits,	$(E_4$ amplitude etc. • • • $(E_4$ amplitude
$(\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}}$ in p' $NALUE (units 10^{-3})$ \bullet \bullet We do not use th 2.5 ± 1.0 0.04 $0.$	y → N(2190) → AK DOCUMENT ID Re following data for average WORKMAN TANABE AK+ phase angle θ DOCUMENT ID Re following data for average WORKMAN TANABE	es, fit 90 89 es, fit 90 89	TECN s, Ilmits, DPWA DPWA TECN s, Ilmits,	$(E_4$ amplitude etc. • • • $(E_4$ amplitude etc. • • •
$(\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}}$ in p . $(NLUE (units 10^{-3})$ \bullet \bullet \bullet We do not use the $0.2.5 \pm 1.0$ 0.04 $0.07 \rightarrow N(2190) \rightarrow 0.00$ $0.04 \rightarrow 0$	y → N(2190) → AK ⁻ DOCUMENT ID WORKMAN TANABE AK ⁺ phase angle θ DOCUMENT ID TO SHOW THE SHOW	90 89 90 90 90 89	TECN s, limits, DPWA DPWA TECN s, limits, DPWA DPWA	$(E_4$ amplitude etc. • • • $(E_4$ amplitude
$(\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}}$ in p . valUE (units 10^{-3}) • • • We do not use th 2.5 ± 1.0 2.04 $p\gamma \rightarrow N(2190) \rightarrow VALUE (degrees)$ • • • We do not use th - 4 ± 9 - 27.5 $(\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}}$ in p . VALUE (units 10^{-3})	y → N(2190) → AK DOCUMENT ID Re following data for average WORKMAN TANABE AK+ phase angle θ DOCUMENT ID Re following data for average WORKMAN TANABE y → N(2190) → AK- DOCUMENT ID	90 89 90 89	s, limits, DPWA DPWA TECN S, limits, DPWA DPWA	$(E_4$ amplitude etc. • • • $(E_4$ amplitude etc. • • • $(M_4$ amplitude
$(\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}}$ in p . valUE (units 10^{-3}) • • • We do not use the 2.5 ± 1.0 2.04 $p\gamma \rightarrow N(2190) \rightarrow VALUE (degrees)$ • • • We do not use the -4 ± 9 -27.5 ($\Gamma_1\Gamma_f$) $\frac{1}{2}/\Gamma_{\text{total}}$ in p . valUE (units 10^{-3}) • • • We do not use the 10^{-3})	y → N(2190) → AK DOCUMENT ID Re following data for average WORKMAN TANABE AK+ phase angle θ DOCUMENT ID Re following data for average WORKMAN TANABE y → N(2190) → AK- DOCUMENT ID Re following data for average	90 89 95, fit 90 89	s, limits, DPWA DPWA TECN s, limits, DPWA DPWA	$(E_4$ amplitude etc. • • • $(E_4$ amplitude etc. • • • $(M_4$ amplitude
$(\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}}$ in p' $NALUE (units 10^{-3})$ \bullet \bullet \bullet We do not use the 2.5 \pm 1.0 2.04 $p\gamma \rightarrow N(2190) \rightarrow N(2190$	y → N(2190) → AK DOCUMENT ID Re following data for average WORKMAN TANABE AK+ phase angle θ DOCUMENT ID Re following data for average WORKMAN TANABE y → N(2190) → AK- DOCUMENT ID	90 89 89 89 89 89	s, limits, DPWA DPWA TECN S, limits, DPWA DPWA	$(E_4$ amplitude etc. • • • $(E_4$ amplitude etc. • • • $(M_4$ amplitude
$(\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}}$ in p . valUE (units 10^{-3}) • • • We do not use th 2.5 ± 1.0 2.04 $p\gamma \rightarrow N(2190) \rightarrow VALUE (degrees)$ • • • We do not use th - 4 ± 9 - 27.5 $(\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}}$ in p . VALUE (units 10^{-3})	y → N(2190) → ΛΚ ⁻ DOCUMENT ID Re following data for average WORKMAN TANABE ΛΚ ⁺ phase angle θ DOCUMENT ID Re following data for average WORKMAN TANABE y → N(2190) → ΛΚ ⁻ DOCUMENT ID Re following data for average WORKMAN	90 89 89 89 89 89	TECN s, Ilmits, DPWA DPWA s, Ilmits, DPWA DPWA TECN s, Ilmits, DPWA	$(E_4$ amplitude etc. • • • $(E_4$ amplitude etc. • • • $(M_4$ amplitude
$(\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}}$ in p' $NALUE (units 10^{-3})$ \bullet \bullet \bullet We do not use the 2.5 \pm 1.0 2.04 $p\gamma \rightarrow N(2190) \rightarrow N(2190$	y → N(2190) → ΛΚ ⁻ DOCUMENT ID Re following data for average WORKMAN TANABE ΛΚ ⁺ phase angle θ DOCUMENT ID Re following data for average WORKMAN TANABE y → N(2190) → ΛΚ ⁻ DOCUMENT ID Re following data for average WORKMAN	90 89 89 89 89 89 89	TECN s, Ilmits, DPWA DPWA s, Ilmits, DPWA DPWA TECN s, Ilmits, DPWA DPWA	$(E_4$ amplitude etc. • • • $(E_4$ amplitude etc. • • • $(M_4$ amplitude
$(\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}}$ in $p^{-\frac{1}{2}}$ in $p^{-\frac{1}{$	y → N(2190) → AK DOCUMENT ID WORKMAN TANABE AK+ phase angle 6 DOCUMENT ID WORKMAN TANABE y → N(2190) → AK- DOCUMENT ID DOCUMENT ID TO DOCUMENT ID TO DOCUMENT ID TO DOCUMENT ID TO DOCUMENT ID TO DOCUMENT ID TO DOCUMENT ID TO STORY TO THE TO TO TO TO TO TO TO TO TO TO TO TO TO	90 89 89 90 89 F	TECN s, Ilmits, DPWA DPWA s, Ilmits, DPWA DPWA TECN s, Ilmits, DPWA S, Ilmits, DPWA ES	$(E_4$ amplitude etc. • • • • $(E_4$ amplitude etc. • • • $(M_4$ amplitude etc. • • •

N(2190) REFERENCES

For early references, see Physics Letters 111B 70 (1982).

				(4m) 00CO)
ARNOT	95	PR C52 2120	+Strakovsky, Workman, Pavan	(VPI, BRCO)
BATINIC	95	PR C51 2310	+Slaus, Svarc, Nefkens	(BOSK, UCLA)
HOEHLER	93	# N Newsletter 9 1		(KARL)
MANLEY	92	PR D45 4002	+Saleski	(KENT) IJP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	(VPI)
ARNOT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
WORKMAN	90	PR C42 781		(VPI)
TANABE	89	PR C39 741	+Kohno, Bennhold	(MANZ)
Also	89	NC 102A 193	Kohno, Tanabe, Bennhold	(MANZ)
BELL	83	NP B222 389	+Blissett, Broome, Daley, Hart, Lintern+	(RL) IJP
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
CRAWFORD	80	Toronto Conf. 107	•	(GLAS)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMÚ, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJP
SAXON	80	NP B162 522	+Baker, Bell, Blissett, Bloodworth+	(RHEL, BRIS) IJP
BAKER	79	NP B156 93	+Brown, Clark, Davies, Depagter, Evans-	- (RHEL) IJP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
BARBOUR	78	NP B141 253	+Crawford, Parsons	(GLAS)
HENDRY	78	PRL 41 222		(IND, LBL) IJP
Also	B1	ANP 136 1	Hendry	(IND)
WINNIK	77	NP B128 66	+Toaff, Revel, Goldberg, Berny	(ĤAIF) I
DEANS	75	NP B96 90	+Mitchell, Montgomery+	(SFLA, ÀLAH) IJP

N(2200), N(2220), N(2250)

N(2200) REFERENCES

BATINIC	95	PR C51 2310	+Slaus, Svarc, Nefkens	(BOSK, UCLA)
BELL	83	NP B222 389	+Blissett, Broome, Daley, Hart, Lintern+	(RL) IJP
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMU, LBL) IAP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL)
SAXON	80	NP B162 522	+Baker, Bell, Bilssett, Bloodworth+	(RHEL, BRIS) IJP
BAKER	79	NP B156 93	+Brown, Clark, Davies, Depagter, Evans+	(RHEL) IJP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP

N(2220) H₁₉

MODULUS |r|

$$I(J^P) = \frac{1}{2}(\frac{9}{2}^+)$$
 Status: ***

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters 111B (1982).

N(2220) BREIT-WIGNER MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
2180 to 2310 (≈ 2220)	OUR ESTIMATE			
2230± 80	CUTKOSKY	80	IPWA	$\pi N \to \pi N$
2205 ± 10	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
2300±100	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$
• • • We do not use the	e following data for average	s, fit	s, Ilmits,	etc. • • •
2258	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
2050	BAKER	79	DPWA	$\pi^- p \rightarrow n\eta$

N(2220) BREIT-WIGNER WIDTH

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
320 to \$80 (≈ 400) OUR ESTIMAT	E		
500±150	CUTKOSKY 80	IPWA	$\pi N \rightarrow \pi N$
365 ± 30	HOEHLER 79	IPWA	$\pi N \rightarrow \pi N$
450±150	HENDRY 78	MPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following	data for averages, fl	ts, limits,	etc. • • •
334	ARNDT 95	DPWA	$\pi N \rightarrow N\pi$

N(2220) POLE POSITION

REAL PART VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
2100 to 2240 (N 2170) OUF	ESTIMATE			
2203	ARNDT			$\pi N \rightarrow N \pi$
2135	¹ HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
2160±80	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the fo	Howing data for average	s, fit	s, limits,	etc. • • •
2253	ARNOT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90

-2×IMAGINARY PART	DOCUMENT ID		TECN	COMME	NT
370 to 570 (≈ 470) OUR ESTIMA		_			
536	ARNDT	95	DPWA	$\pi N \rightarrow$	Nπ
400	1 HOEHLER	93	ARGD	$\pi N \rightarrow$	πN
480±100	CUTKOSKY	80	IPWA	$\pi N \rightarrow$	πN
• • • We do not use the following	data for average	es, fit	s, limits,	etc. • e	•
640	ARNDT	91	DPWA	π N →	πN Soin SM90

N(2220) ELASTIC POLE RESIDUE

DOCUMENT ID

ARNDT

7ECN COMMENT

95 DPWA πN → Nπ

40	HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$	
45±20	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$	
• • • We do not use the following	ng data for average	es, fit	s, limits,	etc. • • •	
85	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soin 5M90	
PHASE 0					
VALUE (°)	DOCUMENT ID		TECN	COMMENT	
-43	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$	
-50	HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$	
-45±25	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$	
• • • We do not use the following	ng data for average	es, fit	s, limits,	etc. • • •	
-62	ARNDT		DPWA	$\pi N \rightarrow \pi N$ Soln SM90	

N(2220) DECAY MODES

The following branching fractions are our estimates, not fits or averages.

	Mode	Fraction (Γ_I/Γ)
Γı	Nπ	10-20 %
Γ ₂ Γ ₃	Νη	
Гз	ΛK	

N(2220) BRANCHING RATIOS

Γ(Nπ)/Γ _{total}					Γ1/Γ
VALUE	DOCUMENT ID		TECN	COMMENT	
0.1 to 0.2 OUR ESTIMATE					
0.15±0.03	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$	
0.18±0.015	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$	
0.12±0.04	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$	
	ing data for averag	es, flt	s, #mlts,	etc. • • •	
0.26	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$	
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N \pi \to N$ VALUE	(2220) → Nη <u>DOCUMENT ID</u>	·	<u>TECN</u>		ιΓ2) ^{1/2} /Γ
• • • We do not use the follow	ing data for averag	es, fit	s, limits,	etc. • • •	
0.034	BAKER	79	DPWA	$\pi^+ p \rightarrow n\eta$	
		1	TECN		ιΓ3) ^{1/2} /Γ
$(\Gamma_i \Gamma_f)^{\frac{1}{12}}/\Gamma_{\text{total}} \text{ in } N_{\pi} \to N$ VALUE not required	(2220) → ΛΚ <u>POCUMENT IP</u> BELL				L ^{T3}) ^{1/2} /F

N(2220) FOOTNOTES

N(2220) REFERENCES

For early references, see Physics Letters 1118 70 (1982).

ARNDT	95	PR C52 2120	+Strakovsky, Workman, Payan	(VPI, BRCO)
HOEHLER	93	x N Newsletter 9 1	•	` (KARL)
ARNDT	91	PR D43 2131	+LI, Roper, Workman, Ford	(VPI, TELE) UP
BELL	83	NP B222 389	+Blissett, Broome, Daley, Hart, Lintern+	(RL) UP
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMU, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJP
SAXON	80	NP B162 522	+Baker, Bell, Blissett, Bloodworth+	(RHEL, BRIS) IJP
BAKER	79	NP B156 93	+Brown, Clark, Davies, Depagter, Evans+	· (RHEL) IJP
HOEHLER	79	PDAT 12-1	+Kalser, Koch, Pietarinen	(KARLT) UP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
HENDRY	78	PRL 41 222		(IND, LBL) UP
Also	81	ANP 136 1	Hendry	(IND)

 $N(2250) G_{19}$

 $I(J^P) = \frac{1}{2}(\frac{9}{2})$ Status: ***

N(2250) BREIT-WIGNER MASS

DOCUMENT ID		TECN	COMMENT
ESTIMATE			
CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
HENDRY	78	MPWA	$\pi N \rightarrow \pi N$
owing data for average:	s, fit	s, ilmits,	etc. • • •
ARNDT	95	DPWA	$\pi N \rightarrow N\pi$
	ESTIMATE CUTKOSKY HOEHLER HENDRY Owing data for average	ESTIMATE CUTKOSKY 80 HOEHLER 79 HENDRY 78 owing data for averages, fit	ESTIMATE CUTKOSKY 80 IPWA HOEHLER 79 IPWA HENDRY 78 MPWA owing data for averages, fits, limits,

N(2250) BREIT-WIGNER WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
290 to 470 (≈ 400) OUR ESTIMAT	TE .			
480±120	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
300 ± 40	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
350±100	HENDRY	76	MPWA	$\pi N \rightarrow \pi N$
 • • We do not use the following 	data for average	s, fit	s, ilmits,	etc. • • •
772	ARNDT	95	DPWA	$\pi N \rightarrow N\pi$

N(2250) POLE POSITION

	• •			
REAL PART	DOCUMENT ID	ı	TECN	COMMENT
2080 to 2200 (≈ 2140) OU	ESTIMATE			
2087	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
2187	¹ HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
2150±50	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the fo	llowing data for averag	es, fits	s, Ilmits,	etc. • • •
2243	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
-2×IMAGINARY PAR	Г			
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
280 to 680 (≈ 480) OUR E	TIMATE			
680	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
388	¹ HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
360±100	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
 • • We do not use the fo 	llowing data for averag	es, fit:	s, limits,	etc. • • •
650	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90

 $^{^{1}}$ See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and Δ resonances as determined from Argand diagrams of π N elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams.

N	(2250) ELASTIC PO	LE RESIDU	ΙE	
MODULUS r				
VALUE (MeV)	DOCUMENT ID	TECN_	COMMENT	
4	ARNDT		$\pi N \rightarrow N \pi$	
1	HOEHLER	93 SPED	$\pi N \rightarrow \pi N$	
:0±6 • • We do not use the	CUTKOSKY		$\pi N \rightarrow \pi N$	
17	ARNDT		$\pi N \rightarrow \pi N$ Soln	SMOO
• •	AMIDI	31 DI WA	# N 1 → N 1 3 3 3 1 1	311130
PHASE 0 VALUE (°)	DOCUMENT ID	TECN	COMMENT	
-44	ARNDT		$\pi N \rightarrow N \pi$	
-50±20	CUTKOSKY		$\pi N \rightarrow \pi N$	
• • We do not use the		es, fits, limits,	, etc. • • •	
-37	ARNDT	91 DPWA	$\pi N \rightarrow \pi N$ Soln	SM90
	N(2250) DECAY	MODES		
The following bra	nching fractions are our		fits or averages.	
_	-		(F)	
Mode		Fraction (Γ_I)	(1)	
		Fraction (Γ_I ,	/!) 	
1 Νπ		Fraction (Γ _I , 5–15 %	(1)	
- 1 Νπ 2 Νη				
Nπ 2 Nη	AVCOTO) DDANGUN	5-15 %		
1 Νπ 2 Νη 3 ΛΚ	N(2250) BRANCHIN	5-15 %		,.
$ \begin{array}{ccc} 1 & N\pi \\ 2 & N\eta \\ 3 & \Lambda K \end{array} $	N(2250) BRANCHIN	5-15 %		Γ1/Γ
$\Gamma_1 N\pi$ $\Gamma_2 N\eta$ $\Gamma_3 \Lambda K$ $\Gamma(N\pi)/\Gamma_{\text{total}}$ ALUE	DOCUMENT ID	5-15 %	COMMENT	Γ1/Γ
1 Nπ 2 Nη 3 ΛΚ	DOCUMENT ID	5-15 % IG RATIOS	COMMENT	Γ ₁ /Γ
$\begin{array}{ccc} 1 & N\pi & & & \\ 2 & N\eta & & & \\ 3 & \Lambda K & & & \\ \hline & & & & & \\ \hline & & & & & \\ \hline & & & &$	DOCUMENT ID CUTKOSKY	5-15 % IG RATIOS	$\frac{COMMENT}{\pi N \to \pi N}$	Γ1/Γ
1 Nπ 2 Nη 3 ΛΚ -(Nπ)/Γtotal ALUE 1.00 to 0.15 OUR ESTIMA 1.01 ± 0.02	DOCUMENT ID CUTKOSKY HOEHLER	5–15 % IG RATIOS TECN 80 IPWA 79 IPWA	$\begin{array}{c} \underline{COMMENT} \\ \pi N \to \pi N \\ \pi N \to \pi N \end{array}$	Γ1/Γ
$7 \times 7 \times$	DOCUMENT ID CUTKOSKY HOEHLER HENDRY	5–15 % IG RATIOS TECN 80 IPWA 79 IPWA 78 MPWA	$\begin{array}{c} \underline{COMMENT} \\ \pi N \to \pi N \\ \pi N \to \pi N \\ \pi N \to \pi N \end{array}$	Γ1/Γ
$7 \times 7 \times$	DOCUMENT ID CUTKOSKY HOEHLER HENDRY	5-15 % IG RATIOS TECN 80 IPWA 79 IPWA 78 MPWA es, fits, limits,	$\begin{array}{c} \underline{COMMENT} \\ \pi N \to \pi N \\ \pi N \to \pi N \\ \pi N \to \pi N \end{array}$	Γ1/Γ
$7 \times 7 \times$	DOCUMENT ID TE CUTKOSKY HOEHLER HENDRY following data for average	5-15 % IG RATIOS TECN 80 IPWA 79 IPWA 78 MPWA es, fits, limits,	$\begin{array}{c} COMMENT \\ \pi N \to \ \pi N \\ \pi N \to \ \pi N \\ \Lambda \pi N \to \ \pi N \\ \text{etc.} \bullet \bullet \\ \pi N \to \ N \pi \end{array}$	
$(N\pi)/\Gamma_{\text{total}}$ 3 ΛK $(N\pi)/\Gamma_{\text{total}}$ ALUE 1.00 to 0.15 OUR ESTIMA 1.10 ± 0.02 1.00 ± 0.02 • • We do not use the 1.10	DOCUMENT ID TTE CUTKOSKY HOEHLER HENDRY following data for average ARNDT → N(2250) → Nη	5-15 % IG RATIOS TECN 80 IPWA 79 IPWA 78 MPWA es, fits, limits, 95 DPWA	$\begin{array}{c} COMMENT \\ \pi N \to \pi N \\ \pi N \to \pi N \\ \pi N \to \pi N \\ etc. \bullet \bullet \\ \pi N \to N\pi \end{array}$	
7 1 1 1 1 1 1 1 1 1 1	DOCUMENT ID TE CUTKOSKY HOEHLER HENDRY following data for average ARNDT → N(2250) → Nη DOCUMENT ID	IG RATIOS TECN 80 IPWA 79 IPWA 78 MPWA es, fits, limits, 95 DPWA	$\begin{array}{c} COMMENT \\ \pi N \to \pi N \\ \pi N \to \pi N \\ \Lambda \pi N \to \pi N \\ \text{etc.} \bullet \bullet \bullet \\ \pi N \to N \pi \end{array}$	
Nπ 2 Nη	DOCUMENT ID TE CUTKOSKY HOEHLER HENDRY following data for average ARNDT → N(2250) → Nη DOCUMENT ID	IG RATIOS TECN 80 IPWA 79 IPWA 78 MPWA es, fits, limits, 95 DPWA TECN res, fits, limits,	$\begin{array}{c} COMMENT \\ \pi N \to \pi N \\ \pi N \to \pi N \\ \Lambda \pi N \to \pi N \\ \text{etc.} \bullet \bullet \bullet \\ \pi N \to N \pi \end{array}$	Γ₁/Γ 2) ^½ /Γ
$ \begin{array}{cccc} 1 & N\pi \\ 2 & N\eta \\ 3 & \Lambda K \end{array} $ $ \begin{array}{ccccc} (N\pi)/\Gamma_{\text{total}} \\ ALUE \\ 0.05 \text{ to 0.15 OUR ESTIMA} \\ 0.10 \pm 0.02 \\ 0.09 $	DOCUMENT ID CUTKOSKY HOEHLER HENDRY following data for average ARNDT N(2250) -> N DOCUMENT ID Tollowing data for average BAKER	IG RATIOS TECN 80 IPWA 79 IPWA 78 MPWA es, fits, limits, 95 DPWA TECN res, fits, limits,	$\begin{array}{c} COMMENT \\ \pi N \to \pi N \\ \pi N \to \pi N \\ \pi N \to \pi N \\ \text{etc.} \bullet \bullet \bullet \\ \pi N \to N\pi \\ \hline \\ COMMENT \\ \text{etc.} \bullet \bullet \bullet \\ \pi^- p \to n\eta \end{array}$	2) ^½ /Γ
$\begin{array}{cccc} & N\pi \\ 2 & N\eta \\ 3 & \Lambda K \end{array}$ $\begin{array}{ccccc} & (N\pi)/\Gamma_{\text{total}} \\ & & & \\ &$	DOCUMENT ID CUTKOSKY HOEHLER HENDRY following data for average ARNDT N(2250) DOCUMENT ID following data for average BAKER N(2250) AK	5-15 % IG RATIOS TECN 80 IPWA 79 IPWA 78 MPWA 95 DPWA 95 DPWA TECN 1 TECN	$\begin{array}{c} \underline{COMMENT} \\ \pi N \to \pi N \\ \pi N \to \pi N \\ \pi N \to \pi N \\ \text{etc.} \bullet \bullet \bullet \\ \pi N \to N \pi \end{array}$ $\begin{array}{c} (\Gamma_1 \Gamma_1 \Gamma_2 \Gamma_3 \Gamma_4 \Gamma_5 \Gamma_5 \Gamma_5 \Gamma_5 \Gamma_5 \Gamma_5 \Gamma_5 \Gamma_5 \Gamma_5 \Gamma_5$	
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	DOCUMENT ID CUTKOSKY HOEHLER HENDRY following data for average ARNDT N(2250) -> N \(\tau \) Following data for average BAKER N(2250) -> \(\tau \) N(2250) -> \(\tau \) DOCUMENT ID DOCUMENT ID	IG RATIOS TECN 80 IPWA 79 IPWA 78 MPWA es, flts, limits, 95 DPWA TECN TECN TECN	$\begin{array}{c} \underline{COMMENT} \\ \pi N \to \pi N \\ \pi N \to \pi N \\ \pi N \to \pi N \\ \text{etc.} \bullet \bullet \bullet \\ \pi N \to N \pi \\ \hline \\ \underline{COMMENT} \\ \text{etc.} \bullet \bullet \bullet \\ \pi^- p \to n \eta \\ \hline \\ \underline{COMMENT} \\ \end{array}$	2) ^½ /Γ
7 1 1 1 1 1 1 1 1 1 1	DOCUMENT ID CUTKOSKY HOEHLER HENDRY following data for average ARNDT N(2250) DOCUMENT ID following data for average BAKER N(2250) AK	5-15 % IG RATIOS TECN 80 IPWA 79 IPWA 78 MPWA es, fits, limits, 95 DPWA TECN 81 DPWA 83 DPWA	$\begin{array}{c} \underline{COMMENT} \\ \pi N \to \pi N \\ \pi N \to \pi N \\ \pi N \to \pi N \\ \text{etc.} \bullet \bullet \bullet \\ \pi N \to N \pi \end{array}$ $\begin{array}{c} (\Gamma_1 \Gamma_1 \Gamma_2 \Gamma_3 \Gamma_4 \Gamma_5 \Gamma_5 \Gamma_5 \Gamma_5 \Gamma_5 \Gamma_5 \Gamma_5 \Gamma_5 \Gamma_5 \Gamma_5$	2) ^{1/2} /I

amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams.

N(2250) REFERENCES

ARNOT	95	PR C52 2120	+Strakovsky, Workman, Pavan	(VPI, BRCO)
HOEHLER	93	π N Newsletter 9 1	•	(KARL)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
BELL	83	NP B222 389	+Blissett, Broome, Daley, Hart, Lintern+	(RL) IJP
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMU, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJP
SAXON	80	NP B162 522	+Baker, Bell, Blissett, Bloodworth+	(RHEL, BRIS) IJP
BAKER	79	NP B156 93	+Brown, Clark, Davies, Depagter, Evans+	(RHEL) IJP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
HENDRY	78	PRL 41 222		(IND, LBL) IJP
Also	81	ANP 136 1	Hendry	(IND)

2600) *l*_{1,11}

 $I(J^P) = \frac{1}{2}(\frac{11}{2})$ Status: ***

DOCUMENT ID		TECN	COMMENT	
TIMATE				
HOEHLER	79	IPWA	$\pi N \rightarrow \pi \Lambda$	1
HENDRY	78	MPWA	$\pi N \rightarrow \pi \Lambda$	1
	TIMATE HOEHLER	TIMATE HOEHLER 79	HOEHLER 79 IPWA	TIMATE HOEHLER 79 IPWA πN → πN

N(2600) BREIT-WIGNER WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT	
500 to 800 (≈ 650) OUR	ESTIMATE				
400 ± 100	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$	
900±100	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$	

N(2600) DECAY MODES

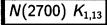
	Mode	Fraction (Γ_I/Γ)
Γ ₁	Νπ	5-10 %

N(2600) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$						Γ_1/Γ
VALUE	DOCUMENT ID		TECN	COMME	VT	
0.05 to 0.1 OUR ESTIMATE						
0.05 ± 0.01	HOEHLER	79	IPWA	$\pi N \rightarrow$	πN	
0.08 ± 0.02	HENDRY	78	MPWA	$\pi N \rightarrow$	πN	

N(2600) REFERENCES

HOEHLER Also HENDRY Also	79 80 78 81	PDAT 12-1 Toronto Conf. 3 PRL 41 222 ANP 136 1	+Kalser, Koch, Pletarinen Koch Hendry	(KARLT) IJI (KARLT) IJI (IND, LBL) IJI (IND)
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 $I(J^P) = \frac{1}{2}(\frac{13}{2}^+)$ Status: **

TED FROM SUMMARY TABLE

N(2700) BREIT-WIGNER MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
≈ 2700 OUR ESTIMATE				
2612 ± 45	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
3000 ± 100	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$

N(2700) BREIT-WIGNER WIDTH

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
350± 50	HOEHLER 79	IPWA	$\pi N \rightarrow \pi N$
900±150	HENDRY 78	MPWA	$\pi N \rightarrow \pi N$

N(2700) DECAY MODES

	Mode	
Γ1	Νπ	

N(2700) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{to}$	tai						Γ ₁ /Γ
VALUE		DOCUMENT ID		<u>TECN</u>	COMME	NT	
0.04 ± 0.01		HOEHLER	79	IPWA	$\pi N \rightarrow$	πN	
0.07 ± 0.02		HENDRY	78	MPWA	$\pi N \rightarrow$	πN	

N(2700) REFERENCES

		,		
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) UP
HENDRY	78	PRL 41 222		(IND, LBL) IJP
Also	81	ANP 136 1	Hendry	(IND)
Also	•••	W44 124 1	(icital y	()

 $N(\sim 3000)$

$N(\sim 3000 \text{ Region})$ Partial-Wave Analyses

OMITTED FROM SUMMARY TABLE

We list here miscellaneous high-mass candidates for isospin-1/2 resonances found in partial-wave analyses.

Our 1982 edition had an N(3245), an N(3690), and an N(3755), each a narrow peak seen in a production experiment. Since nothing has been heard from them since the 1960's, we declare them to be dead. There was also an N(3030), deduced from total cross-section and 180° elastic cross-section measurements; it is the KOCH 80 $L_{1.15}$ state below.

N(~ 3000) BREIT-WIGNER MASS

VALUE (MeV)	DOCUMENT ID	·	TECN	СОММЕ	NT
≈ 3000 OUR ESTIMATE					
2600	KOCH	80	IPWA	$\pi N \rightarrow$	π N D ₁₃
3100	косн	80	IPWA	$\pi N \rightarrow$	$\pi N L_{1,15}$ wave
3500	косн	80	IPWA	$\pi N \rightarrow$	π N M _{1,17} wave
3500 to 4000	косн	80	IPWA	$\piN\rightarrow$	π N N _{1.19} wave
3500 ± 200	HENDRY	78	MPWA	$\pi N \rightarrow$	π N L _{1,15} wave
3800 ± 200	HENDRY	78	MPWA	$\pi N \rightarrow$	$\pi N M_{1,17}$ wave
4100±200	HENDRY	78	MPWA	$\pi N \rightarrow$	π N N $_{1,19}$ wave

N(~ 3000) BREIT-WIGNER WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMME	NT
1300±200	HENDRY	78	MPWA	$\pi N \rightarrow$	$\pi N L_{1,15}$ wave
1600 ± 200	HENDRY	78	MPWA	$\pi N \rightarrow$	* N M _{1,17} wave
1900±300	HENDRY	78	MPWA	$\pi N \rightarrow$	π N N _{1,19} wave

$N(\sim 3000)$ DECAY MODES

	Mode	
Γ1	Nπ	

N(∼ 3000) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$					Γ1/Γ
VALUE	DOCUMENT ID	_	TECN	COMMENT	
0.055 ± 0.02	HENDRY 7	8	MPWA	$\pi N \rightarrow \pi N$	L _{1,15} wave
0.040 ± 0.015	HENDRY 7	8	MPWA	$\pi N \rightarrow \pi N$	M _{1,17} wave
0.030 ± 0.015	HENDRY 7	8	MPWA	$\pi N \rightarrow \pi N$	N _{1,19} wave

N(~ 3000) REFERENCES

OCH	80	Toronto Conf.	3	(KARLT) IJP
ENDRY	78	PRL 41 222		(IND, LBL) IJP
Also	81	ANP 136 1	Hendry	(IND) IJP

Baryon Particle Listings $\Delta(1232)$

91 DPWA $\pi N \rightarrow \pi N$ Soin SM90

△ BARYONS (S = 0, I = 3/2)

 $\Delta^{++} = uuu$, $\Delta^{+} = uud$, $\Delta^{0} = udd$, $\Delta^{-} = ddd$

 $\Delta(1232) P_{33}$

 $I(J^P) = \frac{3}{2}(\frac{3}{2}^+)$ Status: ***

Most of the results published before 1977 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters 111B (1982).

△(1232) BREIT-WIGNER MASSES

MIXED CHARGES VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1230 to 1234 (≈ 1232) O			IECN	COMMENT
1231±1	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
1232±3	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
1233±2	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the	following data for average	es, fit	s, limits	, etc. • • •
1233	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
A(1232)++ MASS				

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
1230.5 ± 0.2	ABAEV	95 IPWA	$\pi N \rightarrow \pi N$
1230.9 ± 0.3	KOCH	808 IPWA	$\pi N \rightarrow \pi N$
1231.1 ± 0.2	PEDRONI	78	$\pi N \rightarrow \pi N 70-370$

△(1232)+ MASS

VALUE (MeV)	DOCUMENT ID	TECI	N COMMENT
• • • We do not use the	following data for averages,	fits, lim	its, etc. • • •
1231.6	CRAWFORD 8	O DPV	$NA \gamma N \rightarrow \pi N$
1234.9 ± 1.4	MIROSHNIC 7	9	Fit photoproduction
1231.2	BARBOUR 7	8 DPV	$NA \gamma N \rightarrow \pi N$
1231.8	BERENDS 7	5 IPW	$^{\prime}A \gamma p \rightarrow \pi N$

△(1232)0 MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1233.1±0.3	ABAEV	95	IPWA	$\pi N \rightarrow \pi N$
1233.6±0.5	косн	80B	1PWA	$\pi N \rightarrow \pi N$
1233.8±0.2	PEDRONI	78		$\pi N \rightarrow \pi N 70-370$ MeV

$m_{\Delta^0} - m_{\Delta^{++}}$

VALUE (MeV)	DOCUMENT ID	TEC	N COMMENT
• • • We do not use the following	data for averages	s, fits, lin	nits, etc. • • •
2.25±0.68 2.6 ±0.4 2.7 ±0.3	BERNICHA ABAEV ¹ PEDRONI	96 95 IPV 78	Fit to PEDRONI 78 VA $\pi N \rightarrow \pi N$ See the masses

△(1232) BREIT-WIGNER WIDTHS

MIXED CHARGES

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
115 to 125 (≈ 120) OUR E	STIMATE			
118±4	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
120±5	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
116±5	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the fo	ollowing data for average	s, fit	s, limits,	etc. • • •
114	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$

△(1232)++ WIDTH

VALUE (MeV)	DOCUMENT IL	TECN_	COMMENT
111.0±1.0	косн	80B IPWA	$\pi N \rightarrow \pi N$
111.3±0.5	PEDRONI	78	$\pi N \rightarrow \pi N 70-370$
			Ma\/

△(1232)+ WIDTH

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
• • • We do not use the following	data for averages, fi	ts, limits	, etc. • • •
111.2	CRAWFORD 80	DPWA	$\gamma N \rightarrow \pi N$
131.1±2.4	MIROSHNIC 79		Fit photoproduction
111.0	BARBOUR 78	DPWA	$\gamma N \rightarrow \pi N$

A/1000\D WIDTH

∆(1232)° WIDTH			
VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
113.0±1.5	косн	808 IPWA	$\pi N \rightarrow \pi N$
117.9±0.9	PEDRONI	78	$\pi N \rightarrow \pi N 70-370$
			Me∨

Δ0-Δ++ WIDTH DIFFERENCE

VALUE (MeV)	DOCUMENT ID	TECI	COMMENT
• • • We do not use the foli	lowing data for averag	es, fîts, limi	its, etc. • • •
8.45 ± 1.11	BERNICHA	96	Fit to PEDRONI 78
5.1 ±1.0	ABAEV	95 IPW	$A \pi N \rightarrow \pi N$
6.6 ±1.0	PEDRONI	78	See the widths

△(1232) POLE POSITIONS

REAL PART, MIXED CHARGES

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT	
1209 to 1211 (≈ 1210) OU	R ESTIMATE				
1211	ARNDT		DPWA	$\pi N \rightarrow N \pi$	
1209	² HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$	
1210±1	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$	
• • • We do not use the f	ollowing data for average	s, fit	s, limits,	etc. • • •	
1210	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM9	0

-2×IMAGINARY PART, MIXED CHARGES

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
96 to 102 (≈ 100) OU	IR ESTIMATE			
100	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
100	² HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
100±2	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use t	he following data for average	s, fit	s, limits,	etc. • • •

REAL PART, △(1232)++

100

VALUE (MeV)	DOCUMENT ID	col	MMENT	
1209.6±0.5	3 VASAN	76B Fit	to CARTER 73	
• • • We do not use the following	g data for average	i, fits, lin	nits, etc. • • •	
1010 E to 1010 B	4 VACAN	760 El+	to CAPTER 73	

ARNDT

-ZXIMAGINART I	MKI, 44(1232)			
VALUE (MeV)	DOCUMENT ID		COMMENT	
100.8 ± 1.0	3 VASAN	76B	Fit to CARTER 73	
• • • We do not use t	he following data for average	es, fits	i, limits, etc. • • •	
00.04-100	4 VACAN	760	Ela to CARTER 72	

REAL PART. △(1232)+

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1208.0±2.0	CAMPBELL.	76		Fit photoproduction
• • We do not use the following	ng data for averages	, fit	s, limits,	etc. • • •
1211 ±1 to 1212 ± 1	HANSTEIN	96	DPWA	$\gamma N \rightarrow \pi N$
1206.9±0.9 to 1210.5 ± 1.8	MIROSHNIC	79		Fit photoproduction

-2×IMAGINARY PART, △(1232)+

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
106 ±4	CAMPBELL	76		Fit photoproduction
■ ■ We do not use the following of	iata for averages	, fits	s, limits,	etc. • • •
102 ±2 to 99 ± 2	HANSTEIN	96	DPWA	$\gamma N \rightarrow \pi N$
111.2 ± 2.0 to 116.6 ± 2.2	MIROSHNIC	79		Fit photoproduction

REAL PART. △(1232)0

-31

VALUE (MeV)	DOCUMENT ID)	COMMENT	
1210.75±0.6	3 VASAN	76B	Fit to CARTER 73	
• • • We do not use the	following data for averag	es, fits	, limits, etc. • • •	
1210.2	4 MASAN	760	Elt to CAPTER 73	

-2×IMAGINARY PART, △(1232)0

VALUE (MeV)	DOCUMENT ID		COMMENT	
105.6±1.2	³ VASAN	76B	Fit to CARTER	73
• • • We do not use the following	g data for averages	i, fits	, limits, etc. • •	•
105.8 to 106.2	4 VASAN	76 8	Fit to CARTER	73

△(1232) ELASTIC POLE RESIDUES

ABSOLUTE VALUE, MIXED CHARGES

VALUE (MeV)			TECN	COMMENT
38	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
50	HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
53±2	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not	use the following data for average	s, fit	s, limits,	etc. • • •
52	ARNOT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90

VALUE (°)	DOCUMENT ID		TECN	COMMENT
- 22	ARNDT	95	DPWA	$\pi N \rightarrow N$
- 48	HOEHLER	93	ARGD	$\pi N \rightarrow \pi i$
-47±1	CUTKOSKY	80	(PWA	$\pi N \rightarrow \pi I$

91 DPWA $\pi N \rightarrow \pi N$ Soln SM90

ARNDT

$\Delta(1232)$

VALUE (MeV)	DOCUMENT IL		COMMENT
 • • We do not use the f 	ollowing data for averag	ges, fits	, limits, etc. • • •
52.4 to 53.2	³ VASAN	76B	Fit to CARTER 73
52.1 to 52.4	4 VASAN	76B	Fit to CARTER 73
PHASE, Δ(1232)++			
VALUE (rad)	DOCUMENT IL		COMMENT
• • • We do not use the f	ollowing data for averag	ges, fits	, limits, etc. • • •
-0.822 to -0.833	3 VASAN	76B	Fit to CARTER 73
-0.823 to -0.830	4 VASAN	768	Fit to CARTER 73
ABSOLUTE VALUE, A	1(1232) ⁰		
VALUE (MeV)			COMMENT
• • • We do not use the f	ollowing data for averag	ges, fits	, limits, etc. • • •
54.8 to 55.0	³ VASAN	76B	Fit to CARTER 73
55.2 to 55.3	4 VASAN	76B	Fit to CARTER 73
PHASE, △(1232) ⁰			
VALUE (rad)	DOCUMENT IL		COMMENT
• • We do not use the f	ollowing data for averag	ges, fits	, limits, etc. • • •
-0.840 to -0.847	3 VASAN	76B	Fit to CARTER 73
-0.848 to -0.856	4 VASAN	76B	Fit to CARTER 73

△(1232) DECAY MODES

The following branching fractions are our estimates, not fits or averages.

	Mode	Fraction (Γ _I /Γ)	
Γı	Νπ	>99 %	
Γ_2	$N\gamma$	0.52-0.60 %	
Γ ₃	$N\gamma$, helicity=1/2	0.11-0.13 %	
Γ_4	$N\gamma$, helicity=3/2	0.41-0.47 %	

△(1232) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$				Γ ₁ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
0.993 to 0.995 OUR ESTIMATE				
1.0	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
1.0	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
1.0	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the following:	data for average	s, fit	s, limits,	etc. • • •
1.0	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$

△(1232) PHOTON DECAY AMPLITUDES

$\Delta(1232) \rightarrow N\gamma$, helicity-1/2 amplitude $A_{1/2}$

VALUE (GeV ^{-1/2})	DOCUMENT ID		TECN	COMMENT
-0.135 ±0.006 OUR ESTIMATE				
-0.135 ±0.005	ARNDT	97	IPWA	$\gamma N \rightarrow \pi N$
-0.1278 ± 0.0012	DAVIDSON	97	DPWA	$\gamma N \rightarrow \pi N$
-0.132 ± 0.002	TIATOR	97	DPWA	$\gamma N \rightarrow \pi N$
-0.141 ±0.005	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
-0.135 ±0.016	DAVIDSON	91B	FIT	$\gamma N \rightarrow \pi N$
-0.145 ±0.015	CRAWFORD	83	IPWA	$\gamma N \rightarrow \pi N$
-0.138 ± 0.004	AWAJI	81	DPWA	$\gamma N \rightarrow \pi N$
-0.147 ± 0.001	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
-0.145 ± 0.001	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$
-0.136 ± 0.006	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
• • • We do not use the following of	data for averages	, fits	i, limits,	etc. • • •
-0.143 ±0.004	LI	93	IPWA	$\gamma N \rightarrow \pi N$
-0.140 ±0.007	DAVIDSON	90	FIT	See DAVIDSON 918
-0.142 ±0.007	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
-0.140	NOELLE	78		$\gamma N \rightarrow \pi N$
-0.141 ±0.004	FELLER	76	DPWA	$\gamma N \rightarrow \pi N$

Δ (1232) $\rightarrow N\gamma$, helicity-3/2 amplitude A_{3/2} VALUE (GeV-1/2)

VALUE (GEV -/-)	DOCUMENT ID		TECN	COMMENT
-0.255 ±0.008 OUR ESTIMATE				
-0.250 ±0.008	ARNDT	97	IPWA	$\gamma N \rightarrow \pi N$
-0.2524 ± 0.0013	DAVIDSON	97	DPWA	$\gamma N \rightarrow \pi N$
-0.253 ±0.003	TIATOR	97	DPWA	$\gamma N \rightarrow \pi N$
-0.261 ± 0.005	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
-0.251 ± 0.033	DAVIDSON	91B	FIT	$\gamma N \rightarrow \pi N$
-0.263 ±0.026	CRAWFORD	83	IPWA	$\gamma N \rightarrow \pi N$
-0.259 ±0.006	ILAWA	81	DPWA	$\gamma N \rightarrow \pi N$
-0.264 ±0.002	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
-0.261 ± 0.002	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$
-0.247 ± 0.010	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
	data for averages	, fits	, limits,	etc. • • •
-0.262 ± 0.004	LI	93	IPWA	$\gamma N \rightarrow \pi N$
-0.254 ±0.011	DAVIDSON	90	FIT	See DAVIDSON 918
-0.271 ±0.010	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
0.247	NOELLE	78		$\gamma N \rightarrow \pi N$.
-0.256 ±0.003	FELLER	76	DPWA	$\gamma N \rightarrow \pi N$

VALUE	DOCUMENT ID TECN COMMENT
-0.025 ±0.005 OUR ES	TIMATE
-0.015 ±0.005	⁶ ARNDT 97 IPWA $\gamma N \rightarrow \pi N$
-0.025 ±0.002 ±0.002	BECK 97 IPWA $\gamma N \rightarrow \pi N$
-0.030 ±0.003 ±0.002	BLANPIED 97 DPWA $\gamma N \rightarrow \pi N$, $\gamma = 0$
-0.0319±0.0024	DAVIDSON 97 DPWA $\gamma N \rightarrow \pi N$
-0.025 ±0.001	TIATOR 97 DPWA $\gamma N \rightarrow \pi N$
-0.015 ±0.005	WORKMAN 92 IPWA $\gamma N \rightarrow \pi N$
-0.0157±0.0072	DAVIDSON 918 FIT $\gamma N \rightarrow \pi N$
• • We do not use the fe	ollowing data for averages, fits, limits, etc. • • •
-0.027 ±0.003 ±0.001	KHANDAKER 95 DPWA γN → πN
-0.0107 ± 0.0037	DAVIDSON 90 FIT $\gamma N \rightarrow \pi N$
-0.015 ±0.002	DAVIDSON 86 FIT $\gamma N \rightarrow \pi N$
+0.037 ±0.004	TANABE 85 FIT $\gamma N \rightarrow \pi N$
$\Delta(1232) \rightarrow N\gamma$, absol	lute value of E ₂ /M ₁ ratio at pole DOCUMENT ID TECN COMMENT
• • We do not use the fe	ollowing data for averages, fits, limits, etc. • • •
- 0.065 ± 0.007	ARNDT 97 DPWA $\gamma N \rightarrow \pi N$
- 0.058	HANSTEIN 96 DPWA $\gamma N \rightarrow \pi N$
	e of E_2/M_1 ratio at pole
	DOCUMENT ID TECN COMMENT
/ALUE	
VALUE • • We do not use the for	ollowing data for averages, fits, limits, etc. • • •
	ollowing data for averages, fits, limits, etc. \bullet \bullet \bullet ARNDT 97 DPWA $\gamma N \rightarrow \pi N$

△(1232)++ MAGNETIC MOMENT

The values are extracted from UCLA and SIN data on $\pi^+\rho$ bremsstrahlung using a variety of different theoretical approximations and methods. Our estimate is only a rough guess of the range we expect the moment to lie

VALUE (µN)	DOCUMENT ID	COMMENT
3.7 to 7.5 OUR EST	IMATE	
• • • We do not use	the following dat	a for averages, fits, limits, etc. ● ●
4.52±0.50±0.45	BOSSHARD	91 $\pi^+ p \rightarrow \pi^+ p \gamma$ (SIN data)
3.7 to 4.2	LIN	91B $\pi^+ p \rightarrow \pi^+ p \gamma$ (from UCLA data)
4.6 to 4.9	LIN	918 $\pi^+ p \rightarrow \pi^+ p \gamma$ (from SIN data)
5.6 to 7.5	WITTMAN	88 $\pi^+ p \rightarrow \pi^+ p \gamma$ (from UCLA data)
6.9 to 9.8	HELLER	87 $\pi^+ p \rightarrow \pi^+ p \gamma$ (from UCLA data)
4.7 to 6.7	NEFKENS	78 $\pi^+ p \rightarrow \pi^+ p \gamma$ (UCLA data)

△(1232) FOOTNOTES

1 Using $\pi^{\pm}d$ as well, PEDRONI 78 determine $(M^{-}-M^{++}) + (M^{0}-M^{+})/3 = 4.6 \pm 0.2$ MeV.
2 See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and Δ resonances as determined from Argand diagrams of π N elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams.
3 This VASAN 76B value is from fits to the coulomb-barrier-corrected CARTER 73 phase shift

shift. 4 This VASAN 76B value is from fits to the CARTER 73 nuclear phase shift without

coulomb barrier corrections. 5 Converted to our conventions using M=1232 MeV, $\Gamma=110$ MeV from NOELLE 78.

⁶ This ARNDT 97 value is very sensitive to the database being fitted. The result is from a fit to the full pion photoproduction database, apart from the BLANPIED 97 cross-section measurements.

△(1232) REFERENCES

For early references, see Physics Letters 111B 70 (1982).

ARNDT	97	PR C56 577	+Strakovsky, Workman	(VPI)
BECK	97	PRL 78 606	+Krahn+	(MANZ, SACL, PAVI, GLAS)
Also	97B	PRL 79 4510	Beck, Krahn	(MANZ)
Also	97C	PRL 79 4512	Beck, Krahn	(MANZ)
Also	97D	PRL 79 4515 (erratum)		(MANZ, SACL, PAVI, GLAS)
BLANPIED	97	PRL 79 4337	+Blecher, Caracappa+	(LEGS Collab.)
DAVIDSON	97	PRL 79 4509	+ Mukhopadhyay	(RPI)
TIATOR	97	π N Newsletter 13, 127	, makilopaanjaj	(MANZ)
ARNDT	96	PR C53 430	+Strakovsky, Workman	(VPI)
BERNICHA	96	NP A597 623	+Lopez Castro, Pestieau	(LOUV, CINV)
HANSTEIN	96	PL 8385 45	+Drechsel, Tiator	(MANZ)
ABAEV	95	ZPHY A352 85	+ Kruglov	(PNPI)
ARNDT	95	PR C52 2120	+Strakovsky, Workman, Pavan	(VPI, BRCO)
KHANDAKER	95	PR D51 3966	+Sandorfi	(BNL, VPI)
HOEHLER	93	π N Newsletter 9 1	(Sandoi ii	(KARL)
LI	93	PR C47 2759	+Arndt, Roper, Workman	(VPI)
MANLEY	92	PR D45 4002	+Saleski	(KENT) IJP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplita	
WORKMAN	92	PR C46 1546	+Arndt. Li	(VPI)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
BOSSHARD	91	PR D44 1962		, VILL, LAUS, UCLA, CATH)
Also	90	PRL 64 2619		US, LBL, VILL, UCLA, ZURI)
DAVIDSON	91B	PR D43 71	+Mukhopadhyay, Wittman	(RPI)
LIN	91B	PR C44 1819	+Liou, Ding	(CUNY, CSOK)
Also	91	PR C43 R930	Lin, Liou	(CUNY)
DAVIDSON	90	PR D42 20	+ Mukhopadhyay	(RPI)
WITTMAN	88	PR C37 2075	Tunninhanklak	(TRIU)
AATT I WANTA	90	FN C31 4013		(: KIO)

HELLER	87	PR C35 718	+Kumano, Martinez, Moniz	(LANL, MIT, ILL)
DAVIDSON	86	PRL 56 804	+ Mukhopadhyay, Wittman	(RPI)
TANABE	85	PR C31 1876	+Ohta	(KOMAB)
CRAWFORD	83	NP B211 1	+ Morton	(GLAS)
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
AWA JI	81	Bonn Conf. 352	+ Kajikawa	(NAGO)
Also	82	NP B197 365	Fujii, Hayashii, Iwata, Kajikawa+	(NAGO)
ARAI	80	Toronto Conf. 93	• • •	`(INUS)
Also	82	NP B194 251	Arai, Fujii	(INUS)
CRAWFORD	80	Toronto Conf. 107		(GLAS)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMŮ, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL)
косн	∙80B	NP A336 331	+Pietarinen	` (KARLT) IJP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
MIROSHNIC	79	SJNP 29 94	Miroshnichenko, Nikiforov, Sanin+	` (KFTI) IJP
		Translated from YAF 29		• •
BARBOUR	78	NP B141 253	+Crawford, Parsons	(GLAS)
NEFKENS	78	PR D18 3911	+Arman, Ballagh, Glodis, Haddock+	(UCLA, CATH) IJP
NOELLE	78	PTP 60 778		(NAGO)
PEDRONI	78	NP A300 321	+Gabathuler, Domingo, Hirt+	(SIN, ISNG, KÄRLE+) IJP
CAMPBELL	76	PR D14 2431	+Shaw, Ball	(BOIS, UCI, UTAH) IJP
FELLER	76	NP B104 219	+Fukushima, Horikawa, Kajikawa+	(NAGO, OSAK) IJP
VASAN	76B	NP B106 535		(CMU) IJP
Also	76	NP B106 526	Vasan	(CMU) IJP
BERENDS	75	NP B84 342	+Donnachie	(LEID, MCHS)
CARTER	73	NP B58 378	+Bugg, Carter	(CAVE, LOQM) IJP

$\Delta(1600) P_{33}$

$$I(J^P) = \frac{3}{2}(\frac{3}{2}^+)$$
 Status: ***

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters 111B (1982).

The various analyses are not in good agreement.

△(1600) BREIT-WIGNER MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1550 to 1700 (≈ 1600)	OUR ESTIMATE			
1706±10	MANLEY	92	IPWA	$\pi N \rightarrow \pi N & N \pi \pi$
1600 ± 50	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
1522±13	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
 • • We do not use t 	he following data for average	s, fit	s, limits,	etc. • • •
1672±15	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
1706	LI	93	IPWA	$\gamma N \rightarrow \pi N$
1690	BARNHAM	80	IPWA	$\pi N \rightarrow N \pi \pi$
1560	¹ LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
1640	² LONGACRE	76	ID\A/A	$\pi N \rightarrow N \pi \pi$

△(1600) BREIT-WIGNER WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
250 to 450 (≈ 350) OUR ESTIMA	ATE			
430 ± 73	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
300±100	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
220 ± 40	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
$\bullet~\bullet~$ We do not use the followin	g data for average	s, fit	s, limits,	etc. • • •
315± 20	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
215	LI	93	IPWA	$\gamma N \rightarrow \pi N$
250	BARNHAM	80	IPWA	$\pi N \rightarrow N \pi \pi$
180	¹ LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
300	² LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

△(1600) POLE POSITION

REAL PART				
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1500 to 1700 (≈ 1600)	OUR ESTIMATE			
1675	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
1550	³ HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
1550 ± 40	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • We do not use to	he following data for averages	s, fit:	s, limits,	etc. • • •
1612	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ Soln SM90}$
1609 or 1610	⁴ LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$
1541 or 1542	1 LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
-2×IMAGINARY F	ART			
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
200 to 400 (≈ 300) OU	R ESTIMATE			
386	ARNDT	95	DPWA	$\pi N \rightarrow N\pi$
200±60	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use ti	he following data for averages	s, fit:	s, limits,	etc. • • •
230	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
323 or 325	⁴ LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$
178 or 178	1 LONGACRE	77	ID\A/A	$\pi N \rightarrow N \pi \pi$

△(1600) ELASTIC POLE RESIDUE

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
52	ARNDT	95	DPWA	$\pi N \rightarrow N\pi$
17 ± 4	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • We do not use ti	he following data for average:	s, fit	s, Ilmits,	etc. • • •
16	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
PHASE θ				
VALUE (°)	DOCUMENT ID		TECN	COMMENT
+ 14	ARNDT	95	DPWA	$\pi N \rightarrow N\pi$
-150 ± 30	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the	he following data for average	s, fit	s, limits,	etc. • • •
	ARNDT			πN → πN Soln SM90

Δ(1600) DECAY MODES

The following branching fractions are our estimates, not fits or averages.

	Mode	Fraction (Γ _I /Γ)	
	Nπ	10-25 %	
:	ΣΚ		
	Νππ	75–90 %	
	$\Delta\pi$	40-70 %	
	Δ (1232) π , P -wave		
	$\Delta(1232)\pi$, F-wave		
	$N\rho$	<25 %	
	$N\rho$, $S=1/2$, P -wave		
	$N\rho$, $S=3/2$, P -wave		
0	$N\rho$, $S=3/2$, F-wave		
1	$N(1440)\pi$	10-35 %	
2	$N(1440)\pi$, P -wave		
3	$N\gamma$	0.001-0.02 %	
4	$N\gamma$, helicity=1/2	0.0-0.02 %	
5	$N\gamma$, helicity=3/2	0.001-0.005 %	

△(1600) BRANCHING RATIOS

VALUE	DOCUMENT ID		<u>TECN</u>	COMMENT
0.10 to 0.25 OUR ESTIM	ATE			
0.12 ± 0.02	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
0.18±0.04	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
0.21 ± 0.06	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \pi$	$\rightarrow \Delta(1600) \rightarrow \Sigma K$			(Γ ₁ Γ ₂) ^½ /Γ
			TECN	COMMENT
VALUE	DOCUMENT ID		7201	
VALUE -0.36 to -0.28 OUR E	STIMATE			
VALUE -0.36 to -0.28 OUR E		s, fit		etc. • • •

Note: Signs of couplings from $\pi\,{\it N} \to {\it N}\,\pi\,\pi$ analyses were changed in the 1986 edition to agree with the baryon-first convention; the overall phase ambiguity is resolved by choosing a negative sign for the $\Delta(1620)~S_{31}$ coupling to $\Delta(1232)\pi$.

	$\pi \to \Delta(1600) \to \Delta(12)$			
VALUE +0.27 to +0.33 OUR E	<u>DOCUMENT ID</u>		TECN	COMMENT
+0.29±0.02		92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
+0.24±0.05	BARNHAM		IPWA	
+0.34	1,6 LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
+0.30	² LONGACRE	75		$\pi N \rightarrow N \pi \pi$
(Γ _I Γ _f) ^{1/2} /Γ _{total} in N	$\pi \to \Delta(1600) \to \Delta(1200)$	32) π ,	F-wav	re (Γ ₁ Γ ₆) ^{1/2} /Ι
-0.15 to -0.03 OUR E	DOCUMENT ID		120/1_	
-0.07	1,6 LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
(「「「」 ^{1/2} /「total in Ne	$\pi o \Delta(1600) o N ho$, S	5 =1/2	. P-wa	ive (Γ ₁ Γ ₈) ^{1/2} /Ι
+0.10	1,6 LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
	$\pi \to \Delta(1600) \to N\rho$, S			

 $\Delta(1600), \Delta(1620)$

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\pi \to \Delta(1)$	600) → N(14	40) <i>π</i>	, P-way	re	$(\Gamma_1\Gamma_{12})^{\frac{1}{2}}$	/Γ
VALUE	DOCUMENT ID		TECN_	COMME	NT.	
+0.15 to +0.23 OUR ESTIMATE						
+0.16±0.02	MANLEY	92	IPWA	$\pi N \rightarrow$	π N & N π π	
+0.23±0.04	BARNHAM	80	IPWA	$\pi N \rightarrow$	Nππ	
						_

△(1600) PHOTON DECAY AMPLITUDES

Δ (1600) $\rightarrow N\gamma$, helicity-1/2 amplitude $A_{1/2}$

VALUE (GeV ^{-1/2})	DOCUMENT ID		TECN	COMMENT
-0.023±0.020 OUR ESTIMATE				
-0.018 ± 0.015	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
-0.039 ± 0.030	CRAWFORD	83	IPWA	$\gamma N \rightarrow \pi N$
-0.046 ± 0.013	ILAWA	81	DPWA	$\gamma N \rightarrow \pi N$
0.005 ± 0.020	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
• • • We do not use the following	data for average	s, fit	s, Ilmits,	etc. • • •
-0.026 ± 0.002	LI	93	IPWA	$\gamma N \rightarrow \pi N$
-0.200	⁷ WADA	84	DPWA	Compton scattering
0.000 ± 0.030	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
0.0 ±0.020	FELLER	76	DPWA	$\gamma N \rightarrow \pi N$

$\Delta(1600) \rightarrow N\gamma$, helicity-3/2 amplitude A_{3/2}

VALUE (GeV-1/2)	DOCUMENT ID	TECN COMMENT
-0.009±0.021 OUR ESTIMATE		
-0.025 ± 0.015	ARNDT	96 IPWA γN → πN
-0.013 ± 0.014	CRAWFORD	83 IPWA $\gamma N \rightarrow \pi N$
0.025 ± 0.031	ILAWA	81 DPWA $\gamma N \rightarrow \pi N$
-0.009 ± 0.020	CRAWFORD	80 DPWA $\gamma N \rightarrow \pi N$
• • • We do not use the following	data for average	es, fits, limits, etc. • • •
-0.016±0.002	LI	93 IPWA γN → πN
0.023	WADA	84 DPWA Compton scattering
0.000 ± 0.045	BARBOUR	78 DPWA $\gamma N \rightarrow \pi N$
0.0 ±0.015	FELLER	76 DPWA $\gamma N \rightarrow \pi N$

△(1600) FOOTNOTES

1 LONGACRE 77 pole positions are from a search for poles in the unitarized T-matrix; the First (second) value uses, in addition to $\pi N \to N \pi \pi$ data, elastic amplitudes from a Saclay (CERN) partial-wave analysis. The other LONGACRE 77 values are from eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.

2 From method II of LONGACRE 75: eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.

From method II of LONGACRE 73: eyeuan its with order region states as amplitudes.

3 See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and Δ resonances as determined from Argand diagrams of π N elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams.

4 LONGACRE 78 values are from a search for poles in the unitarized T-matrix. The first (second) value uses, in addition to $\pi N \to N \pi \pi$ data, elastic amplitudes from a Saclay (CERN) partial-wave analysis.

⁵The range given is from the four best solutions. DEANS 75 disagrees with $\pi^+ p \rightarrow$

 Σ^+K^+ data of WINNIK 77 around 1920 MeV. 6 LONGACRE 77 considers this coupling to be well determined.

 7 WADA 84 is inconsistent with other analyses — see the Note on N and Δ Resonances.

△(1600) REFERENCES

For early references, see Physics Letters 111B 70 (1982).

ARNDT	96	PR C53 430	+Strakovsky, Workman	(VPI)
ARNOT	95	PR C52 2120	+Strakovsky, Workman, Pavan	(VPI, BŘCO)
HOEHLER	93	π N Newsletter 9 1		(KARL)
LI	93	PR C47 2759	+Arndt, Roper, Workman	` (VPI)
MANLEY	92	PR D45 4002	+Saleski	(KĚNT) IJP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	(VPI)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
WADA	84	NP B247 313	+Egawa, Imanishi, Ishii, Kato, Ukai+	(INUS)
CRAWFORD	83	NP B211 1	+ Morton	(GLAS)
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
ILAWA	81	Bonn Conf. 352	+Kajikawa	(NAGO)
Aiso	82	NP B197 365	Fujii, Hayashii, Iwata, Kajikawa+	(NAGO)
BARNHAM	80	NP B168 243	+Glickman, Mier-Jedrzejowicz+	(LOIC)
CRAWFORD	80	Toronto Conf. 107		(GLAS)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMŮ, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
BARBOUR	78	NP B141 253	+Crawford, Parsons	`(GLAS)
LONGACRE	78	PR D17 1795	+Lasinski, Rosenfeld, Smadja+	(LBL, SLAC)
LONGACRE	77	NP B122 493	+Dolbeau	(SACL) IJP
Also	76	NP B108 365	Dolbeau, Triantis, Neveu, Cadlet	(SACL) IJP
WINNIK	77	NP B128 66	+Toaff, Revel, Goldberg, Berny	(HAIF)1
FELLER	76	NP B104 219	+Fukushima, Horikawa, Kajikawa+	(NAGO, ÒSAK) IJP
DEANS	75	NP B96 90	+Mitchell, Montgomery+	(SFLA, ALAH) IJP
LONGACRE	75	PL 55B 415	+Rosenfeld, Lasinski, Smadja+	(LBL, SLAC) IJP

$\Delta(1620) S_{31}$

 $I(J^P) = \frac{3}{2}(\frac{1}{2}^-)$ Status: ***

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics

△(1620) BREIT-WIGNER MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1615 to 1675 (≈ 1620	OUR ESTIMATE	-		
1672 ± 7	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
1620 ±20	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
1610 ± 7	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
 • • We do not use th 	e following data for average	s, fit	s, limits,	etc. • • •
1672 ± 5	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
1617	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
1669	u	93	IPWA	$\gamma N \rightarrow \pi N$
1620	BARNHAM	80	IPWA	$\pi N \rightarrow N \pi \pi$
1712.8± 6.0	¹ CHEW	80	BPWA	$\pi^+ \rho \rightarrow \pi^+ \rho$
1786.7± 2.0	¹ CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$
1657	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
1662	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
1580	² LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
1600	³ LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

△(1620) BREIT-WIGNER WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
120 to 180 (≈ 150) O	UR ESTIMATE			
154 ±37	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
140 ±20	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
139 ±18	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use th	e following data for average	s, flt	s, limits,	etc. • • •
147 ± 8	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
108	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
184	LI	93	IPWA	$\gamma N \rightarrow \pi N$
120	BARNHAM	80	IPWA	$\pi N \rightarrow N \pi \pi$
228.3±18.0	¹ CHEW	80	BPWA	$\pi^+ \rho \rightarrow \pi^+ \rho \text{ (lower mass)}$
30.0± 6.4	¹ CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$ (higher mass)
161	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
180	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
120	² LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
150	3 LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

△(1620) POLE POSITION

RFAI	PART	

DOCUMENT ID		TECN	COMMENT
RESTIMATE			
ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
4 HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
llowing data for average	s, fit	s, limits,	etc. • • • .
ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
5 LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$
² LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
Т			
DOCUMENT_ID		TECN	COMMENT
STIMATE			
ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
4 HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
llowing data for average	s, flt	s, iimits,	etc. • • •
ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soin SM90
5 LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$
² LONGACRE	77	JPWA	$\pi N \rightarrow N \pi \pi$
	ARNDT ARNDT AHOEHLER CUTKOSKY Foliowing data for average ARNDT CUTKOSKY ARNDT STIMATE ARNDT ARNDT ARNDT ARNDT LONGACRE	ARNDT 95 4 HOEHLER 93 CUTKOSKY 80 flowing data for averages, fit ARNDT 91 5 LONGACRE 78 2 LONGACRE 77 T DOCUMENT ID STIMATE ARNDT 95 4 HOEHLER 93 CUTKOSKY 80 flowing data for averages, fit ARNDT 91 5 LONGACRE 78	ARNDT 95 DPWA ARNDT 95 SPED CUTKOSKY 80 IPWA Ilowing data for averages, fits, limits, ARNDT 91 DPWA SLONGACRE 78 IPWA CUTKOSKY 80 IPWA DOCUMENT ID TECN TOCOMENT ID TECN ARNDT 95 DPWA HOEHLER 93 SPED CUTKOSKY 80 IPWA ARNDT 95 IPWA ARNDT 95 DPWA ARNDT 95 DPWA ARNDT 91 DPWA ARNDT 91 DPWA LOWING data for averages, fits, limits, ARNDT 91 DPWA LONGACRE 78 IPWA

△(1620) ELASTIC POLE RESIDUE

MODULUS I

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
14	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
19	HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
15±2	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the followin	g data for average	es, fit:	s, limits,	etc. • • •
15	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soin SM90

PHASE 0	DOCUMENT ID		<u>TECN</u>	COMMENT
-121	ARNDT	95	DPWA	$\pi N \rightarrow N\pi$
- 95	HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
-110±20	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following	g data for average	es, flt	s, limits,	etc. • • •
-125	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90

△(1620) DECAY MODES

The following branching fractions are our estimates, not fits or averages.

	Mode	Fraction (Γ_I/Γ)						
<u>Γ</u> 1	Nπ	20-30 %						
Γ_2	Νππ	70-80 %						
Γ3	$\Delta\pi$	30-60 %						
Γ4	$\Delta(1232)\pi$, D-wave							
Γ ₅	$N\rho$	7-25 %						
Γ6	$N\rho$, $S=1/2$, S-wave							
Γ7	$N\rho$, $S=3/2$, D -wave							
r _s	$N(1440)\pi$							
Γ۵	N_{γ}	0.004-0.044 %						
Γ ₁₀	$N\gamma$, helicity=1/2	0.004-0.044 %						

△(1620) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$				Γ ₁ /Γ
VALUE	DOCUMENT IE		TECN	COMMENT
0.2 to 0.3 OUR ESTIMA	TE			
0.09±0.02	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
0.25±0.03	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
0.35±0.06	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the	following data for averag	ges, fit:	s, limits,	etc. • • •
0.29	ARNDT	95	DPWA	$\pi N \rightarrow N\pi$
0.60	¹ CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$ (lower
0.36	¹ CHEW	80	BPWA	mass) $\pi^+ p \rightarrow \pi^+ p$ (higher mass)

Note: Signs of couplings from $\pi\,N\to N\pi\,\pi$ analyses were changed in the 1986 edition to agree with the baryon-first convention; the overall phase ambiguity is resolved by choosing a negative sign for the $\Delta(1620)~5_{31}$ coupling to $\Delta(1232)\pi$.

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln \Lambda$	$/\pi \rightarrow \Delta(1620) \rightarrow \Delta(123)$	(2)π	, D-way	/e (Γ ₁ Γ ₄) ⁷² /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
-0.36 to -0.28 OUR	ESTIMATE			
-0.24 ± 0.03	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
-0.33 ± 0.06	BARNHAM	80	IPWA	$\pi N \rightarrow N \pi \pi$
-0.39	2,6 LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
0.40	³ LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in A}$	$I\pi o \Delta(1620) o N ho, S$	=1/2	2, S-wa	ve (Γ ₁ Γ ₆) ^{1/2} /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
+0.12 to +0.22 OUR	ESTIMATE			
$+0.15\pm0.02$	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
$+0.40\pm0.10$	BARNHAM		IPWA	$\pi N \rightarrow N \pi \pi$
+0.08	^{2,6} LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
+0.28	³ LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$
$(\Gamma_I \Gamma_{I'})^{\frac{1}{2}} / \Gamma_{\text{total}}$ in A	$I_{\pi} \rightarrow \Delta(1620) \rightarrow N\rho, S$	=3/:	2, <i>D</i> -wa	we (Γ ₁ Γ ₇) ^{1/2} /Γ
VALUE	DOCUMENT ID			
-0.15 to -0.03 OUR	ESTIMATE			
-0.06 ± 0.02	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
-0.13	^{2,6} LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
	$I\pi o \Delta(1620) o N(144$			(Г₁Г ₈) ^{1/} 2/Г
VALUE	DOCUMENT ID		TECN	
0.11±0.05	BARNHAM	80	IPWA	$\pi N \rightarrow N \pi \pi$
	· · · · · · · · · · · · · · · · · · ·			

Δ (1620) PHOTON DECAY AMPLITUDES Δ (1620) $\to N\gamma$, helicity-1/2 amplitude A $_{1/2}$

VALUE (GeV ^{-1/2})	DOCUMENT ID		TECN	COMMENT
+0.027±0.011 OUR ESTIMATE				
0.035 ± 0.020	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
0.035 ± 0.010	CRAWFORD	83	IPWA	$\gamma N \rightarrow \pi N$
0.010 ± 0.015	ILAWA	81	DPWA	$\gamma N \rightarrow \pi N$
-0.022 ± 0.007	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
-0.026 ± 0.008	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$
0.021 ± 0.020	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
0.126 ± 0.021	TAKEDA	80	DPWA	$\gamma N \rightarrow \pi N$

0.042 ± 0.003	LI	93	IPWA $\gamma N \rightarrow \pi N$		
0.066	WADA	84	DPWA Compton scattering		
$+0.034\pm0.028$	BARBOUR	78	DPWA $\gamma N \rightarrow \pi N$		
-0.005 ± 0.016	FELLER	76	DPWA $\gamma N \rightarrow \pi N$		

△(1620) FOOTNOTES

 $^1\,\mathrm{CHEW}$ 80 reports two S_{31} resonances at somewhat higher masses than other analyses. Problems with this analysis are discussed in section 2.1.11 of HOEHLER 83.

Problems with this analysis are discussed in section 2.1.11 of FIGERLEA 03. **2.LONGACRE 77** pole positions are from a search for poles in the unitarized T-matrix; the first (second) value uses, in addition to $\pi N \rightarrow N\pi\pi$ data, elastic amplitudes from a Saclay (CERN) partial-wave analysis. The other LONGACRE 77 values are from eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.

³ From method II of LONGACRE 75: eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.

As See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and Δ resonances as determined from Argand diagrams of π N elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams.

5 LONGACRE 78 values are from a search for poles in the unitarized T-matrix. The first (second) value uses, in addition to $\pi N \to N \pi \pi$ data, elastic amplitudes from a Saclay (CERN) partial-wave analysis.

6 LONGACRE 77 considers this coupling to be well determined.

△(1620) REFERENCES

For early references, see Physics Letters 111B 70 (1982).

ARNDT	96	PR C53 430	+Strakovsky, Workman	(VPI)
ARNDT	95	PR C52 2120	+Strakovsky, Workman, Pavan	(VPI, BŘCO)
HOEHLER	93	π N Newsletter 9 1	•	(KARL)
LI	93	PR C47 2759	+Arndt, Roper, Workman	(VPI)
MANLEY	92	PR D45 4002	+Saleski	(KĖNT) IJP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	` (VPI)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
WADA	84	NP 6247 313	+Egawa, Imanishi, Ishii, Kato, Ukai+	(INUS)
CRAWFORD	83	NP B211 1	+ Morton	(GLAS)
HOEHLER	83	Landolt-Boernstein 1/9	982	(KARLT)
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
ILAWA	81	Bonn Conf. 352	+Kajikawa	(NAGO)
Also	82	NP B197 365	Fujii, Hayashii, Iwata, Kajikawa+	(NAGO)
ARAI	80	Toronto Conf. 93		(INUS)
Also	82	NP B194 251	Arai, Fujii	(INUS)
BARNHAM	80	NP B168 243	+Glickman, Mier-Jedrzejowicz+	(LOIC)
CHEW	80	Toronto Conf. 123		(LBL) IJP
CRAWFORD	80	Torosto Conf. 107		(GLAS)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMÚ, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJP
TAKEDA	80	NP B168 17	+Arai, Fujii, Ikeda, Iwasaki+	(TOKY, INUS)
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
BARBOUR	78	NP B141 253	+Crawford, Parsons	(GLAS)
LONGACRE	78	PR D17 1795	+Lasinski, Rosenfeld, Smadja+	(LBL, SLAC)
LONGACRE	77	NP B122 493	+ Dolbeau	(SACL) IJP
Also	76	NP B108 365	Dolbeau, Triantis, Neveu, Cadiet	(SACL) IJP
FELLER	76	NP B104 219	+Fukushima, Horikawa, Kajikawa+	(NAGO, OSAK) IJP
LONGACRE	75	PL 55B 415	+Rosenfeld, Lasinski, Smadja+	(LBL, SLAC) IJP

$\Delta(1700) D_{33}$

 $I(J^P) = \frac{3}{2}(\frac{3}{2}^-)$ Status: ***

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters 111B (1982).

△(1700) BREIT-WIGNER MASS

VALUE (MeV)	DOCUMENT ID	_	TECN	COMMENT
1670 to 1770 (≈ 1700) OUR ESTIMATE			
1762 ±44	MANLEY	92	IPWA	$\pi N \rightarrow \pi N & N \pi \pi$
1710 ±30	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
1680 ±70	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
 We do not use the 	e following data for average	s, fit	s, limits,	etc. • • •
1690 ±15	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
1680	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
1655	LI	93	IPWA	$\gamma N \rightarrow \pi N$
1650	BARNHAM	80	IPWA	$\pi N \rightarrow N \pi \pi$
$1718.4^{+13.1}_{-13.0}$	¹ CHEW	80	BPWA	$\pi^+ \rho \rightarrow \pi^+ \rho$
1622	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
1629	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
1600	² LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
1680	³ LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

△(1700) BREIT-WIGNER WIDTH

VALU	E (MeV)	DOCUMENT ID		TECN	COMME	NT
200	to 400 (≈ 300) OUR ESTIMA	ATE				
600	±250	MANLEY	92	IPWA	$\pi N \rightarrow$	πΝ & Νππ
280	± 80	CUTKOSKY	80	IPWA	$\pi N \rightarrow$	πN
230	± 80	HOEHLER	79	IPWA	$\pi N \rightarrow$	πN

Baryon Particle Listings $\Delta(1700)$

285 ± 20	ARNDT	96	IPWA 7	$N \rightarrow \pi N$
272	ARNDT	95	DPWA 7	$N \rightarrow N\pi$
348	LI	93	IPWA 7	$N \rightarrow \pi N$
160	BARNHAM	80	IPWA π	$N \rightarrow N \pi \pi$
93.3± 26.0	¹ CHEW	80	BPWA π	r ⁺ ρ → π ⁺ ρ
:09	CRAWFORD	80	DPWA ?	$N \rightarrow \pi N$
216	BARBOUR			$N \rightarrow \pi N$
200	² LONGACRE			
240	³ LONGACRE	75	IPWA π	$N \rightarrow N \pi \pi$

△(1700) POLE POSITION

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1620 to 1700 (≈ 1660)	OUR ESTIMATE			
1655	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
1651	⁴ HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
1675±25	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use th	e following data for average	s, fit	s, limits,	etc. • • •
1646	ARNDT			$\pi N \rightarrow \pi N$ Soin SM90
1681 or 1672	⁵ LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$
1600 or 1594	² LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
-2×IMAGINARY P	ART			
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
150 to 250 (≈ 200) OU	R ESTIMATE			
242	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
159	⁴ HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
220±40	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
 • • We do not use th 	ne following data for average	s, fit	s, limits,	etc. • • •
208	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
245 or 241	⁵ LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$
	² LONGACRE			$\pi N \rightarrow N \pi \pi$

△(1700) ELASTIC POLE RESIDUE

MODULUS |r|

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
16	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
10	HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
13±3	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following	data for average	s, fit	s, limits,	etc. • • •
13	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90

PHASE θ

VALUE (°)	DOCUMENT ID		TECN	COMME	NT
-12	ARNDT	95	DPWA	$\pi N \rightarrow$	Νπ
-20±25	CUTKOSKY	80	IPWA	$\pi N \rightarrow$	πN
• • • We do not use the following	data for averages	, fits	i, limits,	etc. • •	•
-22	ARNDT	91	DPWA	$\pi N \rightarrow$	πN Soln SM90

△(1700) DECAY MODES

The following branching fractions are our estimates, not fits or averages.

	Mode	Fraction (Γ_I/Γ)	
$\overline{\Gamma_1}$	Nπ	10-20 %	
Γ ₂	ΣΚ		
Гз	Νππ	80-90 %	
Γ4	$\Delta\pi$	30-60 %	
Γ_5	$\Delta(1232)\pi$, S-wave	25-50 %	
Γ ₆	$\Delta(1232)\pi$, D-wave	1-7 %	
۲7	$N\rho$	30-55 %	
Гв	$N\rho$, $S=1/2$, D-wave		
Γ̈́	Nρ, \$=3/2, <i>S</i> -wave	5–20 %	
Γ ₁₀	$N\rho$, $S=3/2$, D-wave		
Γ11	Nγ	0.12-0.26 %	
Γ12	N_{γ} , helicity=1/2	0.08-0.16 %	
Γ ₁₃	$N\gamma$, helicity=3/2	0.025~0.12 %	

△(1700) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$				Γ ₁ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
0.10 to 0.20 OUR ESTIMA	ATE			
0.14±0.06	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
0.12±0.03	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
0.20 ± 0.03	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the	following data for average	es, fit	s, limits,	, etc. • • •
0.16	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
0.16	¹ CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$

VALUE	DOCUMENT I		TECN	COMMENT
• • • We do not use th	e following data for avera	ges, fit	s, limits,	etc. • • •
0.002	LIVANOS	80	DPWA	$\pi p \rightarrow \Sigma K$
0.001 to 0.011	⁶ DEANS	75	DPWA	$\pi N \rightarrow \Sigma K$

1986 edition to agree with the baryon-first convention; the overall phase ambiguity is resolved by choosing a negative sign for the $\Delta(1620)$ S_{31} coupling to $\Delta(1232)\pi$.

(f) '~/ total N#	$\rightarrow \Delta(1700) \rightarrow \Delta(123)$	32)#	, 5-wav	e	(Γ ₁ Γ ₅) ^½ /Ι
VALUE	DOCUMENT ID		TECN	COMME	
+0.21 to +0.29 OUR ES	TIMATE				
+0.32±0.06	MANLEY	92	IPWA	$\pi N \rightarrow$	πΝ & Νππ
+0.18±0.04	BARNHAM		1PWA		
+0.30	^{2,7} LONGACRE	77	IPWA	$\pi N \rightarrow$	Νππ
+0.24	³ LONGACRE	75		$\pi N \rightarrow$	
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N_{\pi}$	→ Δ(1700) → Δ(12 3	32)π	, D-wa	⁄e	(Γ ₁ Γ ₆) ^{1/2} /Ι
VALUE	DOCUMENT ID		TECN	COMME	
+0.05 to +0.11 OUR ES	TIMATE				
+0.08±0.03	MANLEY	92	IPWA	$\pi N \rightarrow$	πΝ & Νππ
0.14 ± 0.04	BARNHAM				
	27	77	IPWA	$\pi N \rightarrow$	Νππ
+0.05	^{2,7} LONGACRE				
+0.10	³ LONGACRE	75	IPWA		Νππ
+0.10 (Γ _Ι Γ _Γ) ^{1/2} /Γ _{total} in Νπ	3 LONGACRE → Δ (1700) → $N\rho$, 5 DOCUMENT ID	75 ≔1 /	IPWA 2, D-wa <u>TECN</u>	IVE COMME	Νππ (Γ ₁ Γ ₈) ^{1/2} /
+0.10 (Γ _Ι Γ _Γ) ^{1/2} /Γ _{total} in <i>Νπ</i> <u>value</u>	3 LONGACRE → Δ (1700) → $N\rho$, 5	75 ≔1 /	IPWA 2, D-wa <u>TECN</u>	ive	Νππ (Γ ₁ Γ ₈) ^{1/2} /
$+0.10$ $\left(\Gamma_{l}\Gamma_{r}\right)^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\pi$ $\frac{VALUE}{+0.17\pm0.05}$	3 LONGACRE → Δ (1700) → $N\rho$, 5 $^{DOCUMENT ID}$ BARNHAM	75 ≔1/ 80	IPWA 2, D-wa TECN IPWA	IVE <u>COMME</u> π N →	Nππ (Γ ₁ Γ ₈) ^{1/2} // Nππ (Γ ₁ Γ ₂) ^{1/2} //
$(\Gamma_i \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N\pi$ $VALUE$ $+0.17 \pm 0.05$	3 LONGACRE → Δ (1700) → $N\rho$, 5 $^{DOCUMENT ID}$ BARNHAM	75 ≔1/ 80	IPWA 2, D-wa TECN IPWA	IVE <u>COMME</u> π N →	Nππ (Γ ₁ Γ ₈) ^{1/2} // Nππ (Γ ₁ Γ ₂) ^{1/2} //
$+0.10$ $ \left(\Gamma_{I} \Gamma_{F} \right)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N \pi $ $ \frac{VALUE}{+0.17 \pm 0.05} $	3 LONGACRE → Δ (1700) → $N\rho$, 5 $^{DOCUMENT ID}$ BARNHAM	75 ≔1/ 80	IPWA 2, D-wa TECN IPWA	IVE <u>COMME</u> π N →	Nππ (Γ ₁ Γ ₈) ^{1/2} /(Nππ (Γ ₁ Γ ₂) ^{1/2} /(
+0.10 $ \frac{\left(\Gamma_{i}\Gamma_{f}\right)^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\pi}{VALUE} + 0.17 \pm 0.05 $ $ \frac{\left(\Gamma_{i}\Gamma_{f}\right)^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\pi}{\pm 0.11 \text{ to } \pm 0.19 \text{ O} } $	3 LONGACRE → Δ (1700) → N_P , S DOCUMENT ID BARNHAM → Δ (1700) → N_P , S DOCUMENT ID OUR ESTIMATE MANLEY	75 ≔1/ 80 ≔3/	2, D-wa TECN IPWA 2, S-wa TECN IPWA	COMME π N → COMME COMME π N →	$N\pi\pi$ $\frac{\left(\Gamma_{1}\Gamma_{8}\right)^{\frac{1}{2}}/\left(\Gamma_{1}\Gamma_{8}\right)^{\frac{1}{2}}}{N\pi\pi}$ $\frac{\left(\Gamma_{1}\Gamma_{9}\right)^{\frac{1}{2}}/\left(\Gamma_{1}\Gamma_{9}\right)^{\frac{1}{2}}}{\pi N \& N\pi\pi}$
VALUE +0.17±0.05	3 LONGACRE → Δ (1700) → $N\rho$, 5 $^{DOCUMENT ID}$ BARNHAM	75 ≔1/ 80 ≔3/	2, D-wa TECN IPWA 2, S-wa TECN IPWA	COMME π N → COMME COMME π N →	$N\pi\pi$ $\frac{\left(\Gamma_{1}\Gamma_{8}\right)^{\frac{1}{2}}/\left(\Gamma_{1}\Gamma_{8}\right)^{\frac{1}{2}}}{N\pi\pi}$ $\frac{\left(\Gamma_{1}\Gamma_{9}\right)^{\frac{1}{2}}/\left(\Gamma_{1}\Gamma_{9}\right)^{\frac{1}{2}}}{\pi N \& N\pi\pi}$
$+0.10$ $(\Gamma_{I}\Gamma_{F})^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\pi$ $VALUE$ $+0.17\pm0.05$ $(\Gamma_{I}\Gamma_{F})^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\pi$ $VALUE$ ±0.11 to ±0.19 O $+0.10\pm0.03$ $+0.04$	3 LONGACRE → Δ (1700) → N_P , S DOCUMENT ID BARNHAM → Δ (1700) → N_P , S DOCUMENT ID OUR ESTIMATE MANLEY	75 =1/ 80 =3/ 92 77	IPWA 2, D-wa TECN IPWA 2, S-wa TECN IPWA IPWA	COMME π N → COMME COMME π N →	Nππ (Γ ₁ Γ ₈) ^{1/2} / Nππ (Γ ₁ Γ ₉) ^{1/2} / πN & Nππ Nππ
$+0.10$ $(\Gamma_{I}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\pi$ $\frac{VALUE}{+0.17\pm0.05}$ $(\Gamma_{I}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\pi$ $\frac{VALUE}{\pm0.11}$ to ±0.19 O $+0.10\pm0.03$ $+0.04$	3 LONGACRE → Δ(1700) → Nρ, S DOCUMENT ID BARNHAM → Δ(1700) → Nρ, S DOCUMENT ID FOR ESTIMATE MANLEY 2,7 LONGACRE 3 LONGACRE → Δ(1700) → Nρ, S	75 =1/ 80 =3/ 92 77 75 =3/	IPWA 2, D-wa IPWA 2, S-wa IPWA IPWA IPWA IPWA IPWA	IVE $COMME$ $\pi N \rightarrow COMME$ $\pi N \rightarrow TOMME$ $TOMME$ $TOMM$	Nππ (Γ1Γ8) ^{1/2} /(Nππ (Γ1Γ9) ^{1/2} /(πΝ & Νππ Νππ Νππ (Γ1Γ10) ^{1/2} /(
$+0.10$ $(\Gamma_{1}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\pi$ $\frac{VALUE}{+0.17\pm0.05}$ $(\Gamma_{1}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\pi$ $\frac{VALUE}{\pm0.11} \text{ to } \pm0.19 \text{ O}$ $+0.10\pm0.03$ $+0.04$ -0.30	3 LONGACRE → Δ(1700) → Nρ, \$ DOCUMENT ID BARNHAM → Δ(1700) → Nρ, \$ DOCUMENT ID OUR ESTIMATE MANLEY 2,7 LONGACRE 3 LONGACRE	75 =1/ 80 =3/ 92 77 75 =3/	IPWA 2, D-wa IPWA 2, S-wa IPWA IPWA IPWA IPWA IPWA	IVE $COMME$ $\pi N \rightarrow COMME$ $\pi N \rightarrow TOMME$ $TOMME$ $TOMM$	Nππ (Γ1Γ8) ^{1/2} /(Nππ (Γ1Γ9) ^{1/2} /(πΝ & Νππ Νππ Νππ (Γ1Γ10) ^{1/2} /(

△(1700) PHOTON DECAY AMPLITUDES

$\Delta(1700) \rightarrow N\gamma$, helicity-1/2 amplitude A_{1/2}

	· -	-		
VALUE (GeV ^{-1/2})	DOCUMENT ID		TECN	COMMENT
+0.104±0.015 OUR ESTIMATE				
0.090 ± 0.025	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
0.111 ± 0.017	CRAWFORD	83	IPWA	$\gamma N \rightarrow \pi N$
0.089 ± 0.033	AWAJI	81	DPWA	$\gamma N \rightarrow \pi N$
0.112 ± 0.006	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
0.130 ± 0.006	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$
0.123 ± 0.022	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
• • • We do not use the following	data for average	s, fits	s, limits,	etc. • • •
0.121 ± 0.004	LI	93	IPWA	$\gamma N \rightarrow \pi N$
$+0.130\pm0.037$	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
$+0.072\pm0.033$	FELLER	76	DPWA	$\gamma N \rightarrow \pi N$

VALUE (GeV ^{-1/2})	DOCUMENT ID		TECN	COMMENT
+0.085±0.022 OUR EST	IMATE			
0.097 ± 0.020	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
0.107 ± 0.015	CRAWFORD	83	IPWA	$\gamma N \rightarrow \pi N$
0.060 ± 0.015	ILAWA	81	DPWA	$\gamma N \rightarrow \pi N$
0.047 ± 0.007	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
0.050 ± 0.007	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$
0.102 ± 0.015	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
• • We do not use the	following data for average	s, fit	s, limits,	etc. • • •
0.115 ± 0.004	LI	93	IPWA	$\gamma N \rightarrow \pi N$
+0.098±0.036	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
+ 0.087 ± 0.023	FELLER	76	DPWA	$\gamma N \rightarrow \pi N$

△(1700) FOOTNOTES

Problems with CHEW 80 are discussed in section 2.1.11 of HOEHLER 83.
²LONGACRE 77 pole positions are from a search for poles in the unitarized T-matrix; the first (second) value uses, in addition to $\pi N \to N \pi \pi$ data, elastic amplitudes from a Saclay (CERN) partial-wave analysis. The other LONGACRE 77 values are from eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.
³ From method II of LONGACRE 75: eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.
⁴ See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and Δ resonances as determined from Argand diagrams of πN elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams.

⁵ LONGACRE 78 values are from a search for poles in the unitarized T-matrix. The first (second) value uses, in addition to $\pi N \to N \pi \pi$ data, elastic amplitudes from a Saclay (CERN) partial-wave analysis.
⁶ The range given is from the four best solutions. DEANS 75 disagrees with $\pi^+ \rho \to \Sigma^+ K^+$ data of WiNNIK 77 around 1920 MeV.
⁷ LONGACRE 77 considers this coupling to be well determined.

△(1700) REFERENCES

For early references, see Physics Letters 111B 70 (1982).

ARNDT	96	PR C53 430	+Strakovsky, Workman	(VPI)
ARNDT	95	PR C52 2120	+Strakovsky, Workman, Pavan	(VPI, BRCO)
HOEHLER	93	π N Newsletter 9 1	Constant, Francisco, Caran	(KARL)
Li	93	PR C47 2759	+Arndt, Roper, Workman	(VPI)
MANLEY	92	PR D45 4002	+Saleski	(KÈNT) LIP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	(VPI)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
CRAWFORD	83	NP B211 1	+ Morton	(GLAS)
HOEHLER	83	Landolt-Boernstein 1/		(KARLT)
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
ILAWA	81	Bonn Conf. 352	+ Kalikawa	(NAGO)
Also	82	NP B197 365	Fujii, Hayashii, Iwata, Kajikawa+	(NAGO)
ARAL	80	Toronto Conf. 93		`(INUS)
Also	82	NP B194 251	Arai, Fujii	(inus)
BARNHAM	80	NP B168 243	+Glickman, Mier-Jedrzejowicz+	(LOIC)
CHEW	80	Toronto Conf. 123	•	(LBL) IJP
CRAWFORD	80	Toronto Conf. 107		(GLAS)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMÚ, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJP
LIVANOS	80	Toronto Conf. 35	+Baton, Coutures, Kochowski, Neveu	` (SACL) IJP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
BARBOUR	78	NP B141 253	+Crawford, Parsons	(GLAS)
LONGACRE	78	PR D17 1795	+Lasinski, Rosenfeld, Smadja+	(LBL, SLAC)
LONGACRE	77	NP B122 493	+Dolbeau	(SACL) IJP
Also	76	NP B108 365	Dolbeau, Triantis, Neveu, Cadiet	(SACL) IJP
WINNIK	77	NP B128 66	+Toaff, Revel, Goldberg, Berny	(HAIF) I
FELLER	76	NP B104 219	+Fukushima, Horikawa, Kajikawa+	(NAGO, OSAK) IJP
DEANS	75	NP B96 90	+Mitchell, Montgomery+	`(SFLA, ALAH) IJP
LONGACRE	75	PL 55B 415	+Rosenfeld, Lasinski, Smadja+	`(LBL, SLAC) IJP

$\Delta(1750) P_{31}$

 $I(J^P) = \frac{3}{2}(\frac{1}{2}^+)$ Status: *

OMITTED FROM SUMMARY TABLE

△(1750) BREIT-WIGNER MASS

VALUE (MeV)	DOCUMENT IL	TECN COMMENT
≈ 1750 OUR ESTIMATE		
1744 ±36	MANLEY	92 IPWA $\pi N \rightarrow \pi N \& N \pi \pi$
• • • We do not use the follo	wing data for averag	ges, fits, limits, etc. • • •
1715.2 ± 21.0	¹ CHEW	80 BPWA $\pi^+p \rightarrow \pi^+p$
1778.4± 9.0	¹ CHEW	80 BPWA $\pi^+ p \rightarrow \pi^+ p$

△(1750) BREIT-WIGNER WIDTH

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
300 ±120	MANLEY 92	IPWA	$\pi N \rightarrow \pi N & N \pi \pi$
• • • We do not use the following	data for averages, f	its, limits,	etc. • • •
75.5 1 55.0			$\pi^+ p \rightarrow \pi^+ p$
23.0± 29.0	1 CHEW 80	BPWA	$\pi^+ p \rightarrow \pi^+ p$

△(1750) DECAY MODES

	Mode		
Γ ₁	Νπ	 	
Γ_2	Νππ		
Γ3	$N(1440)\pi$		
_		 	

$\Gamma(N\pi)/\Gamma_{\text{total}}$				Γ ₁ /Γ
VALUE	DOCUMENT ID		<u>TECN</u>	COMMENT
0.08±0.03	MANLEY	92	IPWA	$\pi N \rightarrow \pi N & N \pi \pi$
• • • We do not use t	the following data for average	es, flt	s, limits,	etc. • • •
0.18	¹ CHEW			$\pi^+ \rho \rightarrow \pi^+ \rho$
0.20	¹ CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{total} \ln N$	$l\pi \to \Delta(1700) \to N(144)$	Ю)π		(Γ₁Γ₃) ¹ ⁄2/Γ

$(\lceil j \lceil f \rceil)^{\prime 2} / \lceil \frac{1}{2} \rceil $ total in $N\pi \to \Delta(1/2)$	$(00) \rightarrow N(1440)\pi$		(113)"/
VALUE	DOCUMENT ID	TECN_	COMMENT
$+0.15\pm0.03$	MANLEY 92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$

△(1750) FOOTNOTES

 1 CHEW 80 reports four resonances in the P_{31} wave — see also the $\Delta(1910).$ Problems with this analysis are discussed in section 2.1.11 of HOEHLER 83.

△(1750) REFERENCES

Also 8	PR D45 4002 4 PR D30 904 3 Landolt-Boernstein 0 Toronto Conf. 123		(KENT) (VPI) (KARLT) (LBL)
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$\Delta(1900) S_{31}$

 $I(J^P) = \frac{3}{2}(\frac{1}{2})$ Status: **

OMITTED FROM SUMMARY TABLE

△(1900) BREIT-WIGNER MASS

VALUE	(MeV)	DOCUMENT ID		TECN	COMMENT
1850	to 1960 (≈ 1900) OUR EST	TIMATE			
1920	±24	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
1890	±50	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
1908	±30	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • •	We do not use the following	data for average	s, fit	s, limits,	etc. • • •
1918.	5±23.0	CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$
1803		CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$

△(1900) BREIT-WIGNER WIDTH

<u>VALUI</u>	(MeV)	DOCUMENT ID		TECN	COMMENT
140	to 240 (≈ 200) O	JR ESTIMATE			
263	±39	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
170	±50	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
140	±40	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • •	We do not use the	following data for average	s, fit	s, limits,	, etc. • • •
93.5	±54.0	CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$
137		CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$

△(1900) POLE POSITION

REAL PART VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1780	1 HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
1870 ± 40	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the	following data for average	s, fit	s, ilmits,	etc. • • •
not seen	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
2029 or 2025	² LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$
-2×IMAGINARY PA	ART			
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
180±50	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the	following data for average	s, fit	s, limits,	etc. • • •
not seen	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
164 or 163	² LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$

△(1900) ELASTIC POLE RESIDUE

MODULUS |r|

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
10±3	CUTKOSKY 80	IPWA	$\pi N \rightarrow \pi N$
PHASE 0			
VALUE (°)	DOCUMENT ID	TECN	COMMENT
+20±40	CUTKOSKY 80	IPWA	$\pi N \rightarrow \pi N$

△(1900) DECAY MODES

The following branching fractions are our estimates, not fits or averages.

	Mode	Fraction (Γ_I/Γ)	
Γ ₁	Νπ	10-30 %	
Γ_2	ΣΚ		
Γ3	$N\pi\pi$		
Γ_4	$\Delta\pi$		
Γ ₅	Δ (1232) π , <i>D</i> -wave		
Γ6	$N\rho$		
Γ7	$N\rho$, $S=1/2$, S-wave		
Гв	$N\rho$, $S=3/2$, D-wave		
و٦	$N(1440)\pi$, S-wave		
Γ ₁₀	$N\gamma$, helicity=1/2		

△(1900) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$				Γ ₁ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
0.1 to 0.3 OUR ESTIMA	TE			
0.41±0.04	MANLEY	92	IPWA	$\pi N \rightarrow \pi N & N \pi \pi$
0.10±0.03	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
0.08 ± 0.04	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the	following data for average	es, fit	s, limits,	etc. • • •
0.28	CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$

Baryon Particle Listings $\Delta(1900)$, $\Delta(1905)$

$(\Gamma_i \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N_1$	$r \rightarrow \Delta(1900) \rightarrow \Sigma K$			(Γ₁Γ₂) ^⅓ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
< 0.03	CANDLIN	84	DPWA	$\pi^+ p \rightarrow \Sigma^+ K^+$
 • • We do not use th 	e following data for average	es, fit	s, limits,	etc. • • •
0.076	3 DEANS	75	DPWA	$\pi N \rightarrow \Sigma K$
0.11	LANGBEIN	73	IPWA	$\pi N \rightarrow \Sigma K \text{ (sol. 1)}$
0.12	LANGBEIN	73	IPWA	$\pi N \rightarrow \Sigma K \text{ (sol. 2)}$
$(\Gamma_i \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N_2$	$r \rightarrow \Delta(1900) \rightarrow \Delta(123)$	32) <i>π</i>	, <i>D</i> -wav	re (Г ₁ Г ₅) ^½ /Г
				COMMENT
VALUE	DOCUMENT ID			
+0.25±0.07	MANLEY	92	IPWA	$\pi N \to \pi N \& N \pi \pi$
+0.25±0.07 (Γ _I Γ _I) ^{1/2} /Γ _{total} ln N ₂	MANLEY $r o \Delta(1900) o N ho$, S	92 =1/	IPWA 2 , S-wa	ve (Γ ₁ Γ ₇) ^{1/2} /Γ
VALUE $+0.25\pm0.07$ $\left(\Gamma_{I}\Gamma_{I}\right)^{\frac{1}{2}}/\Gamma_{\text{total}}\ln N_{2}$ VALUE -0.14 ± 0.11	MANLEY $r \rightarrow \Delta(1900) \rightarrow N\rho$, S $\frac{DOCUMENT ID}{r}$	92 =1/	IPWA 2, S-wa	ve (Γ ₁ Γ ₇) ^{1/2} /Γ
$+0.25\pm0.07$ $\left(\Gamma_{f}\Gamma_{f}\right)^{\frac{1}{2}}/\Gamma_{\text{total}}\ln N_{2}$ N_{2} N_{2} N_{3} N_{4} N_{5} N_{5} N_{5} N_{5} N_{5} N_{5}	MANLEY $r \rightarrow \Delta(1900) \rightarrow N\rho, S$ $\frac{DOCUMENT ID}{MANLEY}$ $r \rightarrow \Delta(1900) \rightarrow N\rho, S$	92 =1/3 -92 =3/3	1PWA 2, <i>S</i> -wa <i>TECN</i> 1PWA 2, <i>D</i> -wa	ve $(\Gamma_1\Gamma_7)^{\frac{1}{2}}/\Gamma$ $\frac{COMMENT}{\pi N \rightarrow \pi N \& N\pi\pi}$ ve $(\Gamma_1\Gamma_8)^{\frac{1}{2}}/\Gamma$
+0.25±0.07 (Γ;Γ _f) ^{1/2} /Γ _{total} in N ₂ <u>VALUE</u> -0.14±0.11	MANLEY $T \rightarrow \Delta(1900) \rightarrow N\rho, S$ DOCUMENT ID MANLEY $T \rightarrow \Delta(1900) \rightarrow N\rho, S$ DOCUMENT ID	92 =1/3 92 =3/3	IPWA 2, S-wa TECN IPWA 2, D-wa TECN	ve $(\Gamma_1\Gamma_7)^{\frac{1}{2}}/\Gamma$ $\frac{COMMENT}{\pi N \rightarrow \pi N \& N\pi\pi}$ ve $(\Gamma_1\Gamma_8)^{\frac{1}{2}}/\Gamma$
$+0.25\pm0.07$ $(\Gamma_{i}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N_{2}$ $\frac{VALUE}{C_{i}\Gamma_{f}}$ $\frac{1}{2}/\Gamma_{\text{total}} \ln N_{2}$ $\frac{1}{2}$ $\frac{1}{2}$ $\frac{1}{2}$ $\frac{1}{2}$ $\frac{1}{2}$ $\frac{1}{2}$ $\frac{1}{2}$	MANLEY $T \rightarrow \Delta(1900) \rightarrow N\rho, S$ DOCUMENT ID MANLEY $T \rightarrow \Delta(1900) \rightarrow N\rho, S$ DOCUMENT ID	92 ≔1/3 92 ≔3/3 92	1PWA 2, S-wa 1PWA 1PWA 2, D-wa 1PWA 1PWA 1PWA	ve $(\Gamma_1\Gamma_7)^{\frac{1}{2}}/\Gamma$ $COMMENT$ $\pi N \to \pi N \& N \pi \pi$ ve $(\Gamma_1\Gamma_8)^{\frac{1}{2}}/\Gamma$ $\pi N \to \pi N \& N \pi \pi$ e $(\Gamma_1\Gamma_9)^{\frac{1}{2}}/\Gamma$

△(1900) PHOTON DECAY AMPLITUDES

Δ (1900) $\rightarrow N\gamma$, helicity-1/2 amplitude A_{1/2}

• • • •	-/-	•	
VALUE (GeV ^{-1/2})	DOCUMENT ID	TECN	COMMENT
-0.004 ± 0.016	CRAWFORD	B3 IPWA	$\gamma N \rightarrow \pi N$
0.029 ± 0.008	ILAWA	81 DPWA	$\gamma N \rightarrow \pi N$
• • We do not use the following	data for averages,	fits, limits,	etc. • • •
-0.006 to -0.025	CRAWFORD	80 DPWA	$\gamma N \rightarrow \pi N$

△(1900) FOOTNOTES

¹ See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and Δ resonances as determined from Argand diagrams of π N elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams.

diffipheness and from piots of the species with minimal containing an application of the first Second) value uses, in addition to $\pi N \to N \pi \pi$ data, elastic amplitudes from a Saclay (CERN) partial-wave analysis.

△(1900) REFERENCES

For early references, see Physics Letters 111B 70 (1982).

HOEHLER	93	π N Newsletter 9 1		(KARL)
MANLEY	92	PR D45 4002	+Saleski	(KENT) IJP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	(VPI)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) LIP
CANDLIN	84	NP B238 477	+Lowe, Peach, Scotland+	(EDIN, RAL, LOWC)
CRAWFORD	83	NP B211 1	+ Morton	(GLAS)
ILAWA	81	Bonn Conf. 352	+Kajikawa	(NAGO)
Also	82	NP B197 365	Fujii, Hayashii, Iwata, Kajikawa+	(NAGO)
CHEW	80	Toronto Conf. 123	• • • • • • •	(LBL) IJP
CRAWFORD	80	Toronto Conf. 107		(GLAS)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMŮ, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) LIP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
LONGACRE	78	PR D17 1795	+Lasinski, Rosenfeld, Smadja+	(LBL, SLAC)
DEANS	75	NP B96 90	+Mitchell, Montgomery+	(SFLA, ALAH) IJP
LANGBEIN	73	NP B53 251	+Wagner	QLI (INUM)

Δ (1905) F_{35}

 $I(J^P) = \frac{3}{2}(\frac{5}{2}^+)$ Status: ***

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters 111B (1982).

△(1905) BREIT-WIGNER MASS

VALUE ((MeV)	DOCUMENT ID		TECN	COMMENT
1870	to 1920 (≈ 1905) C	UR ESTIMATE			
1881	±18	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
1910	±30	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
1905	± 20	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • •	We do not use the fo	ollowing data for average	s, fit	s, Ilmits,	etc. • • •
1895	± 8	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
1850		ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
1960	±40	CANDLIN	84	DPWA	$\pi^+ \rho \rightarrow \Sigma^+ K^+$
1787.0	+ 6.0 - 5.7	CHEW	80	BPWA	$\pi^+ \rho \rightarrow \pi^+ \rho$
1880		CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
1892		BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
1830		1 LONGACRE	75	ΙΡ\Λ/Δ	$\pi N \rightarrow N \pi \pi$

△(1905) BREIT-WIGNER WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
280 to 440 (≈ 350) O	UR ESTIMATE			
327 ± 51	MANLEY	92	IPWA	$\pi N \rightarrow \pi N & N \pi \pi$
400 ±100	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
260 ± 20	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
 We do not use the 	e following data for average	s, fit	s, limits,	etc. • • •
354 ± 10	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
294	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
270 ± 40	CANDLIN	84	DPWA	$\pi^+ p \rightarrow \Sigma^+ K^+$
66.0 + 24.0 - 16.0	CHEW	80	BPWA	$\pi^+ \rho \rightarrow \pi^+ \rho$
193	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
159	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
220	1 LONGACRE	75	1504/4	$\pi N \rightarrow N \pi \pi$

△(1905) POLE POSITION

DOCUMENT ID		TECN	COMMENT
RESTIMATE			
ARNDT			$\pi N \rightarrow N \pi$
² HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
llowing data for average	s, fit	s, limits,	etc. • • •
ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ Soln SM90}$
³ LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$
Г			
DOCUMENT ID		TECN	COMMENT
STIMATE			
ARNDT		DPWA	$\pi N \rightarrow N \pi$
² HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
llowing data for average	s, fit	s, limits,	etc. • • •
llowing data for average ARNDT 3 LONGACRE	s, fit 91		etc. • • • $\pi N \rightarrow \pi N$ Soln SM90
	R ESTIMATE ARNDT PHOEHLER CUTKOSKY SHOWING data for average ARNDT CUTKOSKY ARNDT ARNDT DOCUMENT ID STIMATE ARNDT ARNDT ARNDT ARNDT ARNDT ARNDT ARNDT	ARNDT 95 2 HOEHLER 93 CUTKOSKY 80 Ilowing data for averages, fit ARNDT 91 3 LONGACRE 78 T DOCUMENT ID STIMATE ARNDT 95 2 HOEHLER 93	R ESTIMATE

△(1905) ELASTIC POLE RESIDUE

MODULUS |r|

MODULUS [7]				
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
12	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
25	HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
25±8	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
$\bullet~\bullet~$ We do not use the following	data for average	s, fit:	s, limits,	etc. • • •
14	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
PHASE #				
VALUE (°)	DOCUMENT ID		TECN	COMMENT
- 4	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
-50 ± 20	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
$\bullet\bullet$ We do not use the following	data for average	s, fit	s, limits,	etc. • • •
-40	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90

The value given is from solution 1; the resonance is not present in solutions 2, 3, or 4.

△(1905) DECAY MODES

The following branching fractions are our estimates, not fits or averages.

Mode	Fraction (Γ_I/Γ)	
Nπ	5–15 %	
ΣΚ		
$N\pi\pi$	85 -9 5 %	
$\Delta\pi$	<25 %	
$\Delta(1232)\pi$, P -wave		
$\Delta(1232)\pi$, F-wave		
Nρ	>60 %	
$N\rho$, $S=3/2$, P -wave		
$N\rho$, $S=3/2$, F-wave		
$N\rho$, $S=1/2$, F-wave		
$N\gamma$	0.01-0.03 %	
$N\gamma$, helicity=1/2	0.0-0.1 %	
$N\gamma$, helicity=3/2	0.004-0.03 %	
	$N\pi$ Σ K $N\pi\pi$ $\Delta\pi$ $\Delta(1232)\pi$, P -wave $\Delta(1232)\pi$, F -wave $N\rho$ $N\rho$, $S=3/2$, P -wave $N\rho$, $S=3/2$, F -wave $N\rho$, $S=1/2$, F -wave $N\gamma$ $N\gamma$, helicity=1/2	$\begin{array}{llllllllllllllllllllllllllllllllllll$

△(1905) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$				Γ ₁ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
0.06 to 0.15 OUR ESTIMA	ATE			
0.12±0.03	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
0.08±0.03	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
0.15 ± 0.02	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the	following data for average	es, fit	s, limits,	etc. • • •
0.12	ARNDT	95	DPWA	$\pi N \rightarrow N\pi$
0.11	CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N \pi$	$\rightarrow \Delta(1905) \rightarrow \Sigma K$			(Γ ₁ Γ ₂) ^{1/2} /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
-0.015±0.003	CANDLIN	84	DPWA	$\pi^+ \rho \rightarrow \Sigma^+ K^+$
• • • We do not use the	following data for average	es, fit	s, limits,	etc. • • •
	LIVANOS	80	DPWA	$\pi p \rightarrow \Sigma K$
-0.013			DPWA	

Note: Signs of couplings from $\pi\,N\to N\pi\,\pi$ analyses were changed in the 1986 edition to agree with the baryon-first convention; the overall phase ambiguity is resolved by choosing a negative sign for the $\Delta(1620)~S_{31}$ coupling to $\Delta(1232)\pi$.

$(\Gamma_I \Gamma_I)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N_{\pi}$	$\rightarrow \Delta(1905) \rightarrow \Delta(1232)$		
VALUE	DOCUMENT ID	TECN	<u>COMMENT</u>
-0.04 ± 0.05	MANLEY 9	2 IPW	$A \pi N \rightarrow \pi N \& N \pi \pi$
			ave (Γ ₁ Γ ₆) ^{1/2} /Γ
VALUE	DOCUMENT ID	TECH	COMMENT
$+0.02\pm0.03$	MANLEY 9	2 IPW	$A \pi N \rightarrow \pi N \& N \pi \pi$
+0.20	¹ LONGACRE 7	5 IPW	$A \pi N \rightarrow N \pi \pi$
• • • We do not use the	following data for averages,	fits, limi	ts, etc. • • •
+0.17	⁵ NOVOSELLER 7	8 IPW	$A \pi N \rightarrow N \pi \pi$
+0.06	⁶ NOVOSELLER 7	8 IPW	$A \pi N \rightarrow N \pi \pi$

(Γ _/ Γ _f) ^{1/2} /Γ _{total} in Nπ	$\rightarrow \Delta(1905) \rightarrow N\rho, S$	=3/	2, <i>P</i> -wa	ve	(Γ ₁ Γ ₈) ^{1/2} /
VALUE	DOCUMENT ID		TECN	COMME	NT
+0.030 to +0.36 OUR E	STIMATE				
+0.33 ±0.03	MANLEY				
+0.33	1 LONGACRE	75	IPWA	$\pi N \rightarrow$	Νππ
• • • We do not use the	following data for average	s, fit	s, limits,	etc. • •	•
+0.26	⁵ NOVOSELLEI	78	IPWA	$\pi N \rightarrow$	Νππ
+0.11 to +0.33	7 NOVOSELLEI	78	IPWA	$\pi N \rightarrow$	N×x

△(1905) PHOTON DECAY AMPLITUDES

$\Delta(1905) \rightarrow N\gamma$, helicity-1/2 amplitude A_{1/2}

VALUE (GeV-1/2)	DOCUMENT ID		TECN	COMMENT
+0.026±0.011 OUR ESTIMATE				
0.022 ± 0.005	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
0.021 ± 0.010	CRAWFORD	83	IPWA	$\gamma N \rightarrow \pi N$
0.043 ± 0.020	ILAWA	81	DPWA	$\gamma N \rightarrow \pi N$
0.022 ± 0.010	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
0.031 ± 0.009	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$
0.024 ± 0.014	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
• • • We do not use the following	g data for average	s, fit	s, limits,	etc. • • •
0.055 ± 0.004	LI	93	IPWA	$\gamma N \rightarrow \pi N$
+0.033+0.018	BARBOUR	78	DPWA	$\sim N \rightarrow \pi N$

Δ (1905) $\rightarrow N\gamma$, helicity-3/2 amplitude A_{3/2}

VALUE (GeV-1/2)	DOCUMENT ID		TECN	COMMENT
-0.045±0.020 OUR ESTI	MATE			
-0.045 ± 0.005	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
-0.056±0.028	CRAWFORD	83	IPWA	$\gamma N \rightarrow \pi N$
-0.025 ± 0.023	ILAWA	81	DPWA	$\gamma N \rightarrow \pi N$
-0.029 ± 0.007	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
-0.045 ± 0.006	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$
-0.072±0.035	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
• • • We do not use the f	following data for average	s, flt	s, limits,	etc. • • •
0.002 ± 0.003	Li	93	IPWA	$\gamma N \rightarrow \pi N$
-0.055 ± 0.019	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$

△(1905) FOOTNOTES

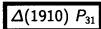
- ¹ From method II of LONGACRE 75: eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.
- ² See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and Δ resonances as determined from Argand diagrams of π N elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams.

 ³ LONGACRE 78 values are from a search for poles in the unitarized T-matrix. The first (second) value uses, in addition to π $N \to N\pi\pi$ data, elastic amplitudes from a Saclay (CERN) partial-wave analysis.
- 4 The range given for DEANS 75 is from the four best solutions.
- ⁵ A Breit-Wigner fit to the HERNDON 75 IPWA.
- 6 A Breit-Wigner fit to the NOVOSELLER 78B IPWA.
- ⁷A Breit-Wigner fit to the NOVOSELLER 78B IPWA; the phase is near 90°.

△(1905) REFERENCES

For early references, see Physics Letters 111B 70 (1982).

ARNDT	96	PR C53 430	+Strakovsky, Workman	(∨PI)
ARNDT	95	PR C52 2120	+Strakovsky, Workman, Pavan	(VPI, BŘCO)
HOEHLER	93	* N Newsletter 9 1	••	(KARL)
LI	93	PR C47 2759	+Arndt, Roper, Workman	(VPI)
MANLEY	92	PR D45 4002	+Saleski	(KÈNT) IJP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	(VPI)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
CANDLIN	84	NP B238 477	+Lowe, Peach, Scotland+	(EDIN, RAL, LOWC)
CRAWFORD	83	NP B211 1	+ Morton	(GLAS)
PDG	82	PL 111B	Roos, Porter, Aguitar-Benitez+	(HELS, CIT, CERN)
ILAWA	81	Bonn Conf. 352	+Kajikawa	(NAGO)
Also	82	NP B197 365	Fujii, Hayashii, Iwata, Kajikawa+	(NAGO)
ARAI	80	Toronto Conf. 93		(INUS)
Also	82	NP B194 251	Arai, Fujii	(INUS)
CHEW	80	Toronto Conf. 123		(LBL) IJP
CRAWFORD	80	Toronto Conf. 107		(GLAS)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMU, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJP
LIVANOS	80	Toronto Conf. 35	+Baton, Coutures, Kochowski, Neveu	(SACL) IJP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
BARBOUR	78	NP B141 253	+Crawford, Parsons	(GLAS)
LONGACRE	78	PR D17 1795	+Lasinski, Rosenfeld, Smadja+	(LBL, SLAC)
NOVOSELLER	78	NP B137 509		(CIT) IJP
NOVOSELLER	788	NP B137 445		(CIT) IJP
DEANS	75	NP B96 90	+Mitchell, Montgomery+	(SFLA, AĹAH) IJP
HERNDON	75	PR D11 3183	+Longacre, Miller, Rosenfeld+	(LBL, SLAC)
LONGACRE	75	PL 55B 415	+Rosenfeld, Lasinski, Smadja+	(LBL, SLAC) UP



$$I(J^P) = \frac{3}{2}(\frac{1}{2}^+)$$
 Status: ***

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters 111B (1982).

△(1910) BREIT-WIGNER MASS

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
1870 to 1920 (≈ 1910) OUR EST	IMATE		
1882 ±10	MANLEY 92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
1910 ±40	CUTKOSKY 80	IPWA	$\pi N \rightarrow \pi N$
1888 ±20	HOEHLER 79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following	data for averages, fl	ts, limits,	etc. • • •
2152	ARNDT 95	DPWA	$\pi N \rightarrow N\pi$
1960.1±21.0	I CHEW 80	BPWA	$\pi^+ \rho \rightarrow \pi^+ \rho$
2121.4+13.0	L CHEW 80	BPWA	$\pi^+ \rho \rightarrow \pi^+ \rho$
1921	CRAWFORD 80	DPWA	$\gamma N \rightarrow \pi N$
1899	BARBOUR 78	DPWA	$\gamma N \rightarrow \pi N$
1790	² LONGACRE 77	IPWA	$\pi N \rightarrow N \pi \pi$

△(1910) BREIT-WIGNER WIDTH

_	E (MeV) to 270 (≈ 250) OUR ESTIMA	DOCUMENT ID		TECN	COMMENT
239	±25	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
225	±50	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
280	±50	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$

Baryon Particle Listings $\Delta(1910)$

• • • We do not use the folio	wing data for average	es, fits, limits, etc. • • •
760	ARNDT	95 DPWA $\pi N \rightarrow N \pi$
152.9±60.0	¹ CHEW	80 BPWA $\pi^+ p \rightarrow \pi^+ p$
172.2±37.0	¹ CHEW	80 BPWA $\pi^+ p \rightarrow \pi^+ p$
351	CRAWFORD	80 DPWA $\gamma N \rightarrow \pi N$
230	BARBOUR	78 DPWA $\gamma N \rightarrow \pi N$
170	² LONGACRE	77 IPWA $\pi N \rightarrow N \pi \pi$

△(1910) POLE POSITION

REAL PART				
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1830 to 1880 (≈ 1855) OUR EST	1MATE			
1810	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
1874	³ HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
1880±30	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the followin	g data for average	s, fit	s, limits,	etc. • • •
1950	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
1792 or 1801	² LONGACRE	77	IPWA	$\pi N \rightarrow N \pi \pi$
-2×IMAGINARY PART				
-2×IMAGINARY PART	DOCUMENT ID		TECN	COMMENT
			<u>TECN</u>	COMMENT
VALUE (MeV)	ATE ARNDT			$\frac{COMMENT}{\pi N \rightarrow N\pi}$
VALUE (MeV) 200 to 500 (≈ 350) OUR ESTIMA	ATE	95	DPWA	
VALUE (MeV) 200 to 800 (≈ 350) OUR ESTIMA 494	ATE ARNDT	95 93	DPWA SPED	$\pi N \rightarrow N \pi$
VALUE (MeV) 200 to 500 (≈ 350) OUR ESTIMA 494 283	ARNDT ARNDT HOEHLER CUTKOSKY	95 93 80	DPWA SPED IPWA	$ \begin{array}{ccc} \pi N \to N \pi \\ \pi N \to \pi N \\ \pi N \to \pi N \end{array} $
VALUE (MeV) 200 to 500 (≈ 350) OUR ESTIMA 494 283 200 ± 40	ARNDT ARNDT HOEHLER CUTKOSKY	95 93 80	DPWA SPED IPWA s, limits,	$ \begin{array}{ccc} \pi N \to N \pi \\ \pi N \to \pi N \\ \pi N \to \pi N \end{array} $

△(1910)) ELASTIC PO	LE F	RESIDU	E
MODULUS r				
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
53	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
38	HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
20±4	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following	ng data for average	es, fit	s, limits,	etc. • • •
37	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
PHASE 0				
VALUE (°)	DOCUMENT ID		TECN_	COMMENT
-176	ARNOT	95	DPWA	$\pi N \rightarrow N\pi$
- 90±30	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following	ng data for average	es, fit	s, limits,	etc. • • •
- 91	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90

△(1910) DECAY MODES

The following branching fractions are our estimates, not fits or averages.

	Mode	Fraction (Γ_I/Γ)	
Γ ₁	Νπ	15-30 %	
Γ ₂	ΣΚ		
Γ̈́3	$N\pi\pi$		
Γ4	$\Delta\pi$		
Γ_5	Δ (1232) π , P -wave		
Γ ₆	$N\rho$		
Γ7	Nρ, S=3/2, P-wave		
Гв	N(1440)π		
Г9	$N(1440)\pi$, P -wave		
Γ ₁₀	$N\gamma$	0.0-0.2 %	
Γ11	$N\gamma$, helicity=1/2	0.0-0.2 %	

△(1910) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$				Г1/Г
VALUE	DOCUMENT ID		TECN	COMMENT
0.15 to 0.3 OUR ESTIMAT	E			
0.23±0.08	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
0.19±0.03	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
0.24±0.06	HOEHLER	79	1PWA	$\pi N \rightarrow \pi N$
• • • We do not use the f	ollowing data for average	es, fit	s, limits,	, etc. • • •
0.26	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
0.17	¹ CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$
0.40	¹ CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$

$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \ln N \pi \rightarrow \Delta \ell$	(1910) → Σ <i>K</i>			(Γ₁Γ₂) ^{1/2} /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
< 0.03	CANDLIN	84	DPWA	$\pi^+ p \rightarrow \Sigma^+ K^+$
• • • We do not use the follow	ing data for averag	es, fit	s, limits,	etc. • • •
-0.019	LIVANOS	80	DPWA	$\pi p \rightarrow \Sigma K$
0.082 to 0.184	⁴ DEANS	75	DPWA	$\pi N \rightarrow \Sigma K$

Note: Signs of couplings from $\pi N \to N \pi \pi$ analyses were changed in the 1986 edition to agree with the baryon-first convention; the overall phase ambiguity is resolved by choosing a negative sign for the $\Delta(1620)$ S_{31} coupling to $\Delta(1232)\pi$.

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\pi$, P-wave (Γ ₁ Γ ₅) ^{1/2} /Γ
	DOCUMENT ID	TECN COMMENT
+0.06	² LONGACRE 77	IPWA $\pi N \rightarrow N \pi \pi$
		2, <i>P</i> -wave $(\Gamma_1\Gamma_7)^{\frac{1}{2}}/\Gamma$
VALUE	DOCUMENT ID	
+0.29	² LONGACRE 77	IPWA $\pi N \rightarrow N \pi \pi$
• • • We do not use the	e following data for averages, fit	s, limits, etc. • • •
+0.17	⁵ NOVOSELLER 78	IPWA $\pi N \rightarrow N \pi \pi$
(Γ _I Γ _I) ^{1/2} /Γ _{total} in Nπ	$r \rightarrow \Delta(1910) \rightarrow N(1440)\pi$	P-wave (\(\Gamma_1 \Gamma_9\)\frac{1}{2}/\Gamma TECN_COMMENT
-0.39±0.04		IPWA $\pi N \rightarrow \pi N & N \pi \pi$
-0.39±0.04	MANLET 92	IPVVA TIV -> TIV 62 IV TT

△(1910) PHOTON DECAY AMPLITUDES

$\Delta(1910) \rightarrow N\gamma$, helicity-1/2 amplitude A_{1/2}

VALUE (GeV-1/2)	DOCUMENT ID		TECN	COMMENT
+0.003 ±0.014 OUR EST	MATE			
-0.002 ± 0.008	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
0.014±0.030	CRAWFORD	83	IPWA	$\gamma N \rightarrow \pi N$
0.025 ± 0.011	ILAWA	81	DPWA	$\gamma N \rightarrow \pi N$
-0.012 ± 0.005	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
-0.031 ± 0.004	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$
-0.005 ± 0.030	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
 • • We do not use the 	following data for average	s, fit	s, limits,	etc. • • •
0.032 ± 0.003	LI	93	IPWA	$\gamma N \rightarrow \pi N$
-0.035 ± 0.021	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$

△(1910) FOOTNOTES

- ¹ CHEW 80 reports four resonances in the P_{31} wave see also the Δ (1750). Problems with this analysis are discussed in section 2.1.11 of HOEHLER 83.

 ² LONGACRE 77 pole positions are from a search for poles in the unitarized T-matrix; the first (second) value uses, in addition to $\pi N \to N\pi\pi$ data, elastic amplitudes from a Saclay (CERN) partial-wave analysis. The other LONGACRE 77 values are from eyeball fits with Breit-Wigner circles to the T-matrix amplitudes.

 ³ See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and Δ resonances as determined from Argand diagrams of πN elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams.

 ⁴ The range fixen for DEANS 78 is from the four host evidence.
- The range given for DEANS 75 is from the four best solutions.
- 5 Evidence for this coupling is weak; see NOVOSELLER 78. This coupling assumes the mass is near 1820 MeV.

△(1910) REFERENCES

For early references, see Physics Letters 111B 70 (1982).

ARNDT	96	PR C53 430	+Strakovsky, Workman	(VPI)
ARNDT	95	PR C52 2120	+Strakovsky, Workman, Pavan	(VPI, BŘCO)
HOEHLER	93	π N Newsletter 9 1	•	(KARL)
LI	93	PR C47 2759	+Arndt, Roper, Workman	` (VPI)
MANLEY	92	PR D45 4002	+Saleski	(KĖNT) IJP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	(VPI)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
CANDLIN	84	NP B238 477	+Lowe, Peach, Scotland+	(EDIN, RAL, LOWC)
CRAWFORD	83	NP B211 1	+Morton	(GLAS)
HOEHLER	83	Landolt-Boernstein 1/	/9B2	(KARLT)
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
ILAWA	81	Bonn Conf. 352	+Kajikawa	(NAGO)
Also	82	NP B197 365	Fujii, Hayashii, Iwata, Kajikawa+	(NAGO)
ARAI	80	Toronto Conf. 93		(INUS)
Also	82	NP B194 251	Arai, Fujii	(INUS)
CHEW	80	Toronto Conf. 123		`(LBL) IJP
CRAWFORD	80	Toronto Conf. 107		(GLAS)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMŮ, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJP
LIVANOS	80	Toronto Conf. 35	+Baton, Coutures, Kochowski, Neveu	(SACL) IJP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
BARBOUR	78	NP B141 253	+Crawford, Parsons	(GLAS)
NOVOSELLER	78	NP B137 509		(CIT) LIP
Also	78B	NP B137 445	Novoseller	(CIT) IJP
LONGACRE	77	NP B122 493	+Doibeau	(SACL) IJP
Also	76	NP B108 365	Dolbeau, Triantis, Neveu, Cadiet	(SACL) IJP
DEANS	75	NP B96 90	+Mitchell, Montgomery+	(SFLA, ALAH) IJP

 Δ (1920) P_{33}

 $I(J^P) = \frac{3}{2}(\frac{3}{2}^+)$ Status: ***

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters 111B (1982).

△(1920) BREIT-WIGNER MASS

VALUE (MeV)		DOCUMENT ID	DOCUMENT ID		COMMENT	
1900	to 1970 (≈ 1920	OUR ESTIMATE				
2014	±16	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$	
1920	±80	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$	
1868	±10	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$	
• • •	We do not use th	e following data for average	s, fit	s, limits,	etc. • • •	
1840	±40	CANDLIN	84	DPWA	$\pi^+ p \rightarrow \Sigma^+ K^+$	
1955.0	0±13.0	¹ CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$	
2065.0	0+13.6 -12.9	¹ CHEW	80	BPWA	$\pi^+ \rho \rightarrow \pi^+ \rho$	

△(1920) BREIT-WIGNER WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
150 to 300 (≈ 200) OUR EST	MATE			
152 ± 55	MANLEY	92	IPWA	$\pi N \rightarrow \pi N & N \pi \pi$
300 ±100	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
220 ± 80	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the follow	ing data for average	s, fit	s, limits,	etc. • • •
200 ± 40	CANDLIN	84	DPWA	$\pi^+ \rho \rightarrow \Sigma^+ K^+$
88.3± 35.0	¹ CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$
62.0 ± 44.0	¹ CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$

△(1920) POLE POSITION

VALUE (MeV)	DOCUMENT ID	DOCUMENT ID		COMMENT
1850 to 1950 (≈ 1900)	OUR ESTIMATE			
1900	² HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
1900 ± 80	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use t	he following data for average	s, fit	s, limits,	etc. • • •
not seen	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ Soln SM90}$

not seen	AKNUT	31	DEWA	π /¥	T N SOIII SIVISU
-2×IMAGINARY PART					
VALUE (MeV)	DOCUMENT ID		TECN	COMME	NT
200 to 400 (≈ 300) OUR ESTIMAT	ΓE				
300 ± 100	CUTKOSKY	80	IPWA	$\pi N \rightarrow$	πN
• • • We do not use the following	data for average	s, fit	s, limits,	etc. •	• •
not seen	ARNDT	91	DPWA	$\pi N \rightarrow$	π N Soln SM90

△(1920) ELASTIC POLE RESIDUE

MODULUS |r|

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
24±4	CUTKOSKY 80		
PHASE 0	DOCUMENT IN		
VALUE (°)	DOCUMENT ID	TECN	COMMENT
-150 ± 30	CUTKOSKY 80	IPWA	$\pi N \rightarrow \pi N$

△(1920) DECAY MODES

The following branching fractions are our estimates, not fits or averages.

	Mode	Fraction (Γ_j/Γ)	
Г	Νπ	5-20 %	
Γ_2	ΣΚ		
Γ₃	Νππ		
Γ_4	Δ (1232) π , P -wave		
Γ_5	$N(1440)\pi$, P -wave		
Γ ₆	$N\gamma$, helicity=1/2		
Γ ₇	$N\gamma$, helicity=3/2		

△(1920) BRANCHING RATIOS

Γ(Nπ)/Γ _{total}				Γ ₁ /Γ
VALUE	DOCUMENT ID	DOCUMENT ID		COMMENT
0.06 to 0.2 OUR ESTIMAT	E			\
0.02 ± 0.02	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
0.20±0.05	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
0.14±0.04	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the fe	ollowing data for averag	es, fit	s, limits,	etc. • • •
0.24	¹ CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$
0.18	¹ CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$

$(\Gamma_i \Gamma_f)^{\gamma_2} / \Gamma_{\text{total}} \ln N \pi$	$\rightarrow \Delta(1920) \rightarrow \Sigma K$				(Г₁Г₂) ^⅓ 2/Г
VALUE	DOCUMENT ID				<u> </u>
-0.052 ± 0.015	CANDLIN	84	DPWA	π ⁺ p	Σ+ K+
• • • We do not use the	following data for averages	, fit	s, limits,	etc. • •	•
-0.049	LIVANOS				
0.048 to 0.120	³ DEANS	75	DPWA	$\pi N \rightarrow$	ΣΚ
(ErEs)1/2/Farmin No	→ △ (1920) → △ (1232	2)π	, P-way	æ	(Γ₁Γ₄) ^½ /Γ
VALUE	DOCUMENT ID				
	DOCUMENT ID MANLEY	92	IPWA	$\frac{COMME}{\pi N} \rightarrow$	VT π N & N π π
VALUE	MANLEY 4 NOVOSELLER	92 78	IPWA IPWA	$\pi N \rightarrow \pi N \rightarrow$	<u>ντ</u> πΝ & Νππ Νππ
<u>VALUE</u> -0.13±0.04	DOCUMENT ID MANLEY	92 78	IPWA IPWA	$\pi N \rightarrow \pi N \rightarrow$	<u>ντ</u> πΝ & Νππ Νππ
$ \frac{VALUE}{-0.13\pm0.04} $ 0.3 0.27 $ (\Gamma_{I}\Gamma_{I})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi $	DOCUMENT ID MANLEY 4 NOVOSELLER 5 NOVOSELLER → Δ(1920) → N(1440	92 78 78	IPWA IPWA IPWA	$ \begin{array}{c} COMMEI\\ \pi N \rightarrow \\ \pi N \rightarrow \\ \pi N \rightarrow \end{array} $	ντ π Ν & Νππ Νππ Νππ (Γ1Γ5) ^{1/2} /Γ
<u>VALUE</u> -0.13±0.04 0.3 0.27	MANLEY 4 NOVOSELLER 5 NOVOSELLER	92 78 78	IPWA IPWA IPWA IPWA	$ \begin{array}{c} COMME \\ \pi N \rightarrow \\ \pi N \rightarrow \\ \pi N \rightarrow \end{array} $	ντ π Ν & Νππ Νππ Νππ (Γ1Γ5) ^{1/2} /Γ

△(1920) PHOTON DECAY AMPLITUDES

Δ (1920) $\rightarrow N\gamma$, helicity-1/2 amplitude A_{1/2}

VALUE (GEV -/-		DUCUMENT ID		1 ECIA	COMME	W /
0.040 ± 0.014		ILAWA	81	DPWA	$\gamma N \rightarrow$	π N
∆ (1920) →	$N\gamma$, helicity-3/2	amplitude A ₃	/2			

21(1920) - 147, Heliaty-3/2	amplitude A3/2		
VALUE (GeV ^{-1/2})	DOCUMENT ID	TECN COMMENT	
0.023±0.017	AWAJI 81	DPWA $\gamma N \rightarrow \pi N$	

△(1920) FOOTNOTES

¹ CHEW 80 reports two P_{33} resonances in this mass region. Problems with this analysis are discussed in section 2.1.11 of HOEHLER 83.
² See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and Δ resonances as determined from Argand diagrams of π N elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams.
³ The traversions for DEANS T is four the fourth of the specific property of the speeds with the solution of the speeds with the speeds wi

³ The range given for DEANS 75 is from the four best solutions. ⁴ A Breit-Wigner fit to the HERNDON 75 IPWA; the phase is near - 90°.

⁵ A Breit-Wigner fit to the NOVOSELLER 78B IPWA; the phase is near -90°.

△(1920) REFERENCES

For early references, see Physics Letters 111B 70 (1982).

(KARL)	
(KENT) IJP	
` (VPI)	
(VPI, TELE) IJP	
RAL, LOWC)	
(KARLT)	
, CIT, CERN)	
(NAGO)	
(NAGO)	
(LBL) IJP	
(CMU, LBL) UP	
(CMU, LBL) IJP	
(SACL) IJP	
(KARLT) IJP	
(KARLT) IJP	
` (CIT)	
(CIT)	
SFLA, ALAH) IJP	
(LBL, SLAC)	
	(LBL) IJP (CMU, LBL) IJP (CMU, LBL) IJP (SACL) IJP (KARLT) IJP (KARLT) IJP (CIT) (CIT) (SFLA, ALAH) IJP

 Δ (1930) D_{35}

$$I(J^P) = \frac{3}{2}(\frac{5}{2}^-)$$
 Status: ***

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters 111B (1982).

The various analyses are not in good agreement.

△(1930) BREIT-WIGNER MASS

VALUE (MeV)	DOCUMENT ID TECN COMMENT
1920 to 19	0 (≈ 1930) OUR ESTIMATE
1956 ±22	MANLEY 92 IPWA $\pi N \rightarrow \pi N \& N \pi$
1940 ±30	CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$
1901 ±15	HOEHLER 79 IPWA $\pi N \rightarrow \pi N$
• • • We d	not use the following data for averages, fits, limits, etc. • • •
1955 ±15	ARNDT 96 IPWA $\gamma N \rightarrow \pi N$
2056	ARNDT 95 DPWA $\pi N \rightarrow N \pi$
1963	LI 93 IPWA $\gamma N \rightarrow \pi N$
1910.0 + 15.0	CHEW 80 BPWA $\pi^+ p \rightarrow \pi^+ p$
2000	CRAWFORD 80 DPWA $\gamma N \rightarrow \pi N$
2024	BARBOUR 78 DPWA $\gamma N \rightarrow \pi N$

 $\Delta(1930), \Delta(1940)$

∆(1930)	BREIT-WIGNER	WIDTH
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VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
250 to 450 (≈ 350) OL	R ESTIMATE			
530 ±140	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
320 ± 60	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
195 ± 60	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the	following data for average	s, fit	s, limits,	etc. • • •
350 ± 20	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
590	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
260	LI	93	IPWA	$\gamma N \rightarrow \pi N$
74.8 ⁺ 17.0 - 16.0	CHEW	80	BPWA	$\pi^+ \rho \rightarrow \pi^+ \rho$
442	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
462	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$

△(1930) POLE POSITION

RE/	NI.	D٨	DT
KE/	٩L	ra	ĸι

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1840 to 1940 (≈ 1890) OUR EST	IMATE			
1913	ARNDT		DPWA	$\pi N \rightarrow N \pi$
1850	1 HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
1890±50	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • We do not use the following	ig data for average	s, fit	s, limits,	etc. • • •
2018	ARNDT	91	DPWA	$\pi N \rightarrow \pi N \text{ Soln SM90}$

-2×IMAGINARY PART					
VALUE (MeV)	DOCUMENT ID		TECN	СОММЕ	NT
200 to 300 (≈ 250) OUR ESTIM	ATE				
246	ARNDT		DPWA	$\pi N \rightarrow$	Νπ
180	¹ HOEHLER	93	SPED	$\pi N \rightarrow$	πN
260 ± 60	CUTKOSKY	80	IPWA	$\pi N \rightarrow$	πN
• • We do not use the following	ig data for average	es, fit	s, limits,	etc. •	• •
398	ARNDT	91	DPWA	$\pi N \rightarrow$	πN Soln SM90

△(1930) ELASTIC POLE RESIDUE

MODULUS |r| VALUE (MeV)

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
8	ARNDT	95	DPWA	$\pi N \rightarrow N\pi$
20	HOEHLER	93	SPED	$\pi N \rightarrow \pi N$
18±6	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following	g data for average	s, fit	s, limits,	etc. • • •
15	ARNDT	91	DPWA	$\piN \to \piN$ Soln SM90
PHASE €				
VALUE (°)	DOCUMENT ID		TECN	COMMENT
- 47	ARNDT	95	DPWA	$\pi N \rightarrow N\pi$
-20 ± 40	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following	g data for average	s, fit	s, limits,	etc. • • •

△(1930) DECAY MODES

The following branching fractions are our estimates, not fits or averages.

	Mode	Fraction (Γ_I/Γ)	
۲	$N\pi$	10–20 %	
Γ_2	ΣΚ		
Γ_3	$N\pi\pi$		
Γ_4	$N\gamma$	0.0-0.02 %	
Γ_5	$N\gamma$, helicity=1/2	0.0-0.01 %	
Γ_6	$N\gamma$, helicity=3/2	0.00.01 %	

△(1930) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$				Γ ₁ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
0.1 to 0.2 OUR ESTIMATE				
0.18 ± 0.02	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
0.14±0.04	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
0.04 ± 0.03	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the follow	ing data for average	es, fit	s, limits,	etc. • • •
0.11	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
0.11	CHEW	80	BPWA	$\pi^+ \rho \rightarrow \pi^+ \rho$

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N\pi \rightarrow 2$	Δ (1930) → Σ <i>K</i>			$(\Gamma_1\Gamma_2)^{\frac{1}{2}}/$
VALUE	DOCUMENT ID	TECN	COMMENT	

< 0.015	CANDLIN	84	DPWA	$\pi^+ p \rightarrow \Sigma^+ K^+$
 ◆ ◆ We do not use the following 	data for average	s, fits	s, limits,	etc. • • •
-0.031	LIVANOS	80	DPWA	$\pi p \rightarrow \Sigma K$
0.018 to 0.035	² DEANS	75	DPWA	$\pi N \rightarrow \Sigma K$

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\pi \to Z$	$\Delta(1930) \rightarrow N\pi\pi$			(F ₁	Γ3) ¹ //Γ
VALUE	DOCUMENT ID		<u>TECN</u>	COMMENT	
not seen	LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$	

△(1930) PHOTON DECAY AMPLITUDES

$\Delta(1930) \rightarrow N\gamma$, helicity-1/2 amplitude A_{1/2}

VALUE (GeV ^{-1/2})	DOCUMENT ID		TECN	COMMENT
-0.009±0.028 OUR ESTIMATE				
-0.007 ± 0.010	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
0.009 ± 0.009	AWAJI	81	DPWA	$\gamma N \rightarrow \pi N$
-0.030 ± 0.047	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
ullet $ullet$ We do not use the following	data for average	s, fit	s, Ilmits,	etc. • • •
-0.019 ± 0.001	LI	93	IPWA	$\gamma N \rightarrow \pi N$
-0.062 ± 0.064	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$

$\Delta(1930) \rightarrow N\gamma$, helicity-3/2 amplitude A_{3/2}

VALUE (GeV-1/2)	DOCUMENT ID		TECN	COMMENT
-0.018±0.028 OUR EST	IMATE			
0.005 ± 0.010	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
-0.025 ± 0.011	ILAWA	81	DPWA	$\gamma N \rightarrow \pi N$
-0.033 ± 0.060	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
• • We do not use the	following data for average	es, fit	s, limits,	etc. • • •
0.009 ± 0.001	LI	93	IPWA	$\gamma N \rightarrow \pi N$
$+0.019\pm0.054$	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$

Δ (1930) FOOTNOTES

¹ See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and Δ resonances as determined from Argand diagrams of πN elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams. ² The range given for DEANS 75 is from the four best solutions.

△(1930) REFERENCES

For early references, see Physics Letters 111B 70 (1982).

ARNDT	96	PR C53 430	+Strakovsky, Workman	(VPI)
ARNDT	95	PR C52 2120	+Strakovsky, Workman, Pavan	(VPI, BŘCO)
HOEHLER	93	π N Newsletter 9 1	•	(KARL)
LI	93	PR C47 2759	+Arndt, Roper, Workman	` (VPI)
MANLEY	92	PR D45 4002	+Saleski	(KÈNT) UP
Also	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	(VPI)
ARNDT	91	PR D43 2131	+Li, Roper, Workman, Ford	(VPI, TELE) IJP
CANDLIN	84	NP B238 477	+Lowe, Peach, Scotland+	(EDIN, RAL, LOWC)
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
AWAJI	81	Bonn Conf. 352	+Kajikawa	(NAGO)
Also	82	NP B197 365	Fujii, Havashii, Iwata, Kajikawa+	(NAGO)
CHEW	80	Toronto Conf. 123	••••••	(LBL) IJP
CRAWFORD	80	Toronto Conf. 107		(GLAS)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMŮ, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJP
LIVANOS	80	Toronto Conf. 35	+Baton, Coutures, Kochowski, Neveu	` (SACL) IJP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
BARBOUR	78	NP B141 253	+Crawford, Parsons	(GLAS)
DEANS	75	NP B96 90	+Mitchell, Montgomery+	(SFLA, ALAH) IJP
LONGACRE	75	PL 55B 415	+Rosenfeld, Lasinski, Smadja+	(LBL, SLAC) IJP

 Δ (1940) D_{33}

 $I(J^{P}) = \frac{3}{2}(\frac{3}{2}^{-})$ Status: *

OMITTED FROM SUMMARY TABLE

△(1940) BREIT-WIGNER MASS

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
≈ 1940 OUR ESTIMATE			
2057 ±110	MANLEY 9	2 IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
2058.1 ± 34.5	CHEW 8	0 BPWA	$\pi^+ p \rightarrow \pi^+ p$
1940 ±100	CUTKOSKY 8	0 IPWA	$\pi N \rightarrow \pi N$

△(1940) BREIT-WIGNER WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
460 ±320	MANLEY 9	92	IPWA	$\pi N \rightarrow \pi N & N \pi \pi$
198.4 ± 45.5	CHEW 8	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$
200 ±100	CUTKOSKY 8	80	IPWA	$\pi N \rightarrow \pi N$

△(1940) POLE POSITION

REAL PART VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1900±100	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
1915 or 1926	¹ LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$
-2×IMAGINARY PART				
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
200±60	CUTKOSKY			$\pi N \rightarrow \pi N$
190 or 186	¹ LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$

	ELASTIC POI	1		-
MODULUS r VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
3±3	CUTKOSKY		IPWA	
PHASE #				
VALUE (°)	DOCUMENT ID			COMMENT
135 ± 45	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
∆ (19	940) DECAY I	MOE	DES	
Mode				· · · · · · · · · · · · · · · · · · ·
Γ ₁ Νπ				
2 ΣΚ				
-3 Nππ - Λ(1030\π S.Waya				
Γ_4 $\Delta(1232)\pi$, S-wave $\Delta(1232)\pi$, D-wave				
N_{ρ} , $S=3/2$, S-wave				
Γ_7 $N\gamma$, helicity=1/2				
$_{8}$ N γ , helicity=3/2				
△(1940) BRANCHIN	G R	ATIOS	
「(Nπ)/Γ _{total}	•			Г1
VALUE	DOCUMENT ID			COMMENT
0.18±0.12	MANLEY			$\pi N \rightarrow \pi N \& N \pi \pi$
0.18 0.05±0.02	CHEW CUTKOSKY			$\pi^+ \rho \rightarrow \pi^+ \rho$
.05±0.02	CUTKOSKY	80	IPWA	
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}}$ in $N\pi o \Delta(19)$	40) → Σ <i>K</i>			(Г₁Г₂) ^½
VALUE	DOCUMENT ID			COMMENT
<0.015	CANDLIN	84	DPWA	$\pi^+ p \rightarrow \Sigma^+ K^+$
1/				•1
$(\Gamma_I \Gamma_I)^{72} / \Gamma_{\text{total}} \text{ in } N_{\pi} \rightarrow \Delta(19)$	$40) \rightarrow \Delta(123)$	2)π	, S-wav	e (Γ₁Γ₄) ^½ 2
ALUE	40) → Δ(123 <u>DOCUMENT ID</u>		<u>TECN</u>	COMMENT
ALUE	HO) → △(123 DOCUMENT ID MANLEY		<u>TECN</u>	
#ALUE" +0.11±0.10	<u>DOCUMENT ID</u> MANLEY 140) → △(123	92 2)π	<u>TECN</u> IPWA , D-wa v	$\frac{COMMENT}{\pi N \to \pi N \& N \pi \pi}$ The $(\Gamma_1 \Gamma_5)^{\frac{1}{2}}$
$_{ ho 1.11\pm0.10}^{ ho LOE}$ $(\Gamma_I\Gamma_f)^{1/2}/\Gamma_{ m total}$ in $N\pi o\Delta(19)$	DOCUMENT ID MANLEY MANLEY MAD → A(123) DOCUMENT ID	92 2) π	TECN IPWA , D-wa v	COMMENT $\pi N \to \pi N \& N \pi \pi$ $\pi R \qquad (\Gamma_1 \Gamma_5)^{\frac{1}{2}}$ COMMENT
$\frac{ALUE}{+0.11\pm0.10}$ $(\Gamma_i\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \to \Delta$ (19) $\frac{ALUE}{+0.27\pm0.16}$	DOCUMENT ID MANLEY 40) → △(123 DOCUMENT ID MANLEY	92 2)π 92	TECN IPWA D-Way TECN IPWA	COMMENT $\pi N \to \pi N \& N \pi \pi$ The $(\Gamma_1 \Gamma_5)^{\frac{1}{2}}$ $\pi N \to \pi N \& N \pi \pi$
$\begin{array}{l} (\Gamma_{f}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \to \Delta(19) \\ \frac{NLUE}{+0.11 \pm 0.10} \\ (\Gamma_{f}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \to \Delta(19) \\ \frac{NLUE}{+0.27 \pm 0.16} \\ (\Gamma_{f}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \to \Delta(19) \end{array}$	DOCUMENT ID MANLEY MANLEY $ \Delta(123) \rightarrow \Delta(123) DOCUMENT ID MANLEY $ MANLEY $ \Delta(123) \rightarrow \Lambda(123) DOCUMENT ID MANLEY $	92 2)π 92 =3/2	TECN IPWA , D-way TECN IPWA 2, S-wa	COMMENT $\pi N \rightarrow \pi N \& N \pi \pi$ The $\frac{(\Gamma_1 \Gamma_5)^{\frac{1}{2}}}{\pi N \rightarrow \pi N \& N \pi \pi}$ The expression of the second s
$(\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{ ext{total}} \text{ in } N\pi o \Delta(19)$ $(\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{ ext{total}} \text{ in } N\pi o \Delta(19)$ $(\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{ ext{total}} \text{ in } N\pi o \Delta(19)$ $(\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{ ext{total}} \text{ in } N\pi o \Delta(19)$ $(ALUE$	DOCUMENT ID MANLEY 140) → ∆(123 DOCUMENT ID MANLEY 140) → Np, S DOCUMENT ID	92 2)π 92 =3/2	TECN IPWA , D-way TECN IPWA 2, S-way	COMMENT $\pi N \to \pi N \& N \pi \pi$ $= (\Gamma_1 \Gamma_5)^{\frac{1}{2}}$ $\pi N \to \pi N \& N \pi \pi$ $ve (\Gamma_1 \Gamma_6)^{\frac{1}{2}}$ $COMMENT$
$\frac{VALUE}{+0.11\pm0.10}$ $(\Gamma_i \Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \to \Delta(19)$ $\frac{VALUE}{+0.27\pm0.16}$	DOCUMENT ID MANLEY MANLEY $ \Delta(123) \rightarrow \Delta(123) DOCUMENT ID MANLEY $ MANLEY $ \Delta(123) \rightarrow \Lambda(123) DOCUMENT ID MANLEY $	92 2)π 92 =3/2	TECN IPWA , D-way TECN IPWA 2, S-way	COMMENT $\pi N \rightarrow \pi N \& N \pi \pi$ The $\frac{(\Gamma_1 \Gamma_5)^{\frac{1}{2}}}{\pi N \rightarrow \pi N \& N \pi \pi}$ The expression of the second s
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$\frac{VALUE}{+0.11\pm0.10}$ $(\Gamma_{I}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \rightarrow \Delta(19)$ $VALUE$ $+0.27\pm0.16$ $(\Gamma_{I}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \rightarrow \Delta(19)$ $VALUE$ $+0.25\pm0.10$ $\Delta(1940) \rightarrow N\gamma, \text{ helicity-1/2}$	DOCUMENT ID MANLEY 40) → \(\Delta(123) \) POCUMENT ID MANLEY 40) → \(N \rho \), So POCUMENT ID MANLEY DOCUMENT ID MANLEY DOTON DECAN amplitude \(A_1 \)	92 2)π 92 -3/2 92 7 AM	TECN IPWA D-way IECN IPWA 2, S-way IECN IPWA	COMMENT $\pi N \to \pi N \& N \pi \pi$ THE $(\Gamma_1 \Gamma_5)^{\frac{1}{2}}$ $\pi N \to \pi N \& N \pi \pi$ THE $(\Gamma_1 \Gamma_6)^{\frac{1}{2}}$ $\pi N \to \pi N \& N \pi \pi$ THE $(\Gamma_1 \Gamma_6)^{\frac{1}{2}}$ $(\Gamma_2 \Gamma_6)^{\frac{1}{2}}$ $(\Gamma_1 \Gamma$
WALUE $+0.11\pm0.10$ $(\Gamma_{\Gamma}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \rightarrow \Delta(19)$ $VALUE$ $+0.27\pm0.16$ $(\Gamma_{\Gamma}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \rightarrow \Delta(19)$ $VALUE$ $+0.25\pm0.10$ $\Delta(1940) \rightarrow N\gamma$, helicity-1/2 $VALUE (\text{GeV}^{-1/2})$	DOCUMENT ID MANLEY 140) A (123 DOCUMENT ID MANLEY 140) N p, S DOCUMENT ID MANLEY DTON DECAY amplitude A ₁ DOCUMENT ID	92 2)π 92 -3/3 92 7 AM	TECN IPWA D-way TECN IPWA 2, S-wa TECN IPWA APLITE TECN	COMMENT $\pi N \rightarrow \pi N \& N \pi \pi$ THE $(\Gamma_1 \Gamma_5)^{\frac{1}{2}}$ $\pi N \rightarrow \pi N \& N \pi \pi$ THE $(\Gamma_1 \Gamma_6)^{\frac{1}{2}}$ $(\Gamma_1 \Gamma_6)^{\frac{1}{2}}$ $(\Gamma_1 \Gamma_6)^{\frac{1}{2}}$ $\pi N \rightarrow \pi N \& N \pi \pi$ THE $\pi N \rightarrow \pi N \& N \pi \pi$ THE $\pi N \rightarrow \pi N \& N \pi \pi$ THE $\pi N \rightarrow \pi N \& N \pi \pi$
$\frac{NALUE}{(\Gamma_{i}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \rightarrow \Delta(19)}{(\Gamma_{i}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \rightarrow \Delta(19)}$ $\frac{(\Gamma_{i}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \rightarrow \Delta(19)}{(2\pi LUE)}$ $\frac{(\Gamma_{i}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \rightarrow \Delta(19)}{(2\pi LUE)}$ $\Delta(1940) \rightarrow N\gamma, \text{ helicity-1/2}$ $\Delta(1940) \rightarrow N\gamma, \text{ helicity-1/2}$ -0.036 ± 0.058	DOCUMENT ID MANLEY 40)	92 2)π 92 3/2 92 7 AM 81	TECN IPWA D-way TECN IPWA 2, S-wa TECN IPWA APLITE TECN	COMMENT $\pi N \to \pi N \& N \pi \pi$ THE $(\Gamma_1 \Gamma_5)^{\frac{1}{2}}$ $\pi N \to \pi N \& N \pi \pi$ THE $(\Gamma_1 \Gamma_6)^{\frac{1}{2}}$ $\pi N \to \pi N \& N \pi \pi$ THE $(\Gamma_1 \Gamma_6)^{\frac{1}{2}}$ $(\Gamma_2 \Gamma_6)^{\frac{1}{2}}$ $(\Gamma_1 \Gamma$
$\begin{array}{c} \frac{NLUE}{+0.11\pm0.10} \\ (\Gamma_{I}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \to \Delta(19) \\ \frac{NLUE}{+0.27\pm0.16} \\ (\Gamma_{I}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \to \Delta(19) \\ \frac{NLUE}{+0.25\pm0.10} \\ \Delta(1940) \to N\gamma, \text{ helicity-1/2} \\ \frac{NLUE}{-0.036\pm0.058} \\ \Delta(1940) \to N\gamma, \text{ helicity-3/2} \end{array}$	DOCUMENT ID MANLEY 40) → \(\Delta(123) \) MANLEY 40) → \(N \rho, S \) DOCUMENT ID MANLEY OTON DECAY amplitude \(A_1 \) DOCUMENT ID AWAJI amplitude \(A_3 \)	92 2)π 92 -3/2 7 AM /2 81	TECN IPWA D-way TECN IPWA 2, S-wa TECN IPWA APLITE TECN	COMMENT $\pi N \rightarrow \pi N \& N \pi \pi$ THE $(\Gamma_1 \Gamma_5)^{\frac{1}{2}}$ $\pi N \rightarrow \pi N \& N \pi \pi$ THE $(\Gamma_1 \Gamma_6)^{\frac{1}{2}}$ $(\Gamma_1 \Gamma_6)^{\frac{1}{2}}$ $(\Gamma_1 \Gamma_6)^{\frac{1}{2}}$ $\pi N \rightarrow \pi N \& N \pi \pi$ THE $\pi N \rightarrow \pi N \& N \pi \pi$ THE $\pi N \rightarrow \pi N \& N \pi \pi$ THE $\pi N \rightarrow \pi N \& N \pi \pi$
$\frac{VALUE}{(\Gamma_i \Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\pi \rightarrow \Delta(19)}{VALUE} + 0.27 \pm 0.16$ $(\Gamma_i \Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\pi \rightarrow \Delta(19)$ $VALUE + 0.25 \pm 0.10$ $\Delta(1940) \rightarrow N\gamma, \text{ helicity-1/2}$ -0.036 ± 0.058	DOCUMENT ID MANLEY A0) - \(\Delta \) (123 \(\Delta \) DOCUMENT ID MANLEY A0) - \(N \rho \), S \(\Delta \) DOCUMENT ID MANLEY DTON DECAY amplitude A1 \(\Delta \) AWAJI amplitude A3 \(\Delta \) DOCUMENT ID	92 2)π 92 -3/2 7 AM /2 81	TECN IPWA 1. D-way 1. IPWA 2. S-way 1. IPWA APLITU TECN IPWA TECN IPWA	COMMENT $\pi N \to \pi N \& N \pi \pi$ $(\Gamma_1 \Gamma_5)^{\frac{1}{2}}$ $\frac{COMMENT}{\pi N \to \pi N \& N \pi \pi}$ $Ve \qquad (\Gamma_1 \Gamma_6)^{\frac{1}{2}}$ $\frac{COMMENT}{\pi N \to \pi N \& N \pi \pi}$ $JDES$ $\frac{COMMENT}{\gamma N \to \pi N}$ $\frac{COMMENT}{\gamma N \to \pi N}$
$\begin{array}{c} \frac{NLUE}{+0.11\pm0.10} \\ (\Gamma_{I}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \to \Delta(19) \\ \frac{NLUE}{+0.27\pm0.16} \\ (\Gamma_{I}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \to \Delta(19) \\ \frac{NLUE}{+0.25\pm0.10} \\ \Delta(1940) \to N\gamma, \text{ helicity-1/2} \\ \frac{NLUE}{-0.036\pm0.058} \\ \Delta(1940) \to N\gamma, \text{ helicity-3/2} \end{array}$	DOCUMENT ID MANLEY 40) → \(\Delta(123) \) MANLEY 40) → \(N \rho, S \) DOCUMENT ID MANLEY OTON DECAY amplitude \(A_1 \) DOCUMENT ID AWAJI amplitude \(A_3 \)	92 2)π 92 -3/2 7 AM /2 81	TECN IPWA 1. D-way 1. IPWA 2. S-way 1. IPWA APLITU TECN IPWA TECN IPWA	COMMENT $\pi N \to \pi N \& N \pi \pi$ THE $(\Gamma_1 \Gamma_5)^{\frac{1}{2}}$ $COMMENT$ $\pi N \to \pi N \& N \pi \pi$ THE $(\Gamma_1 \Gamma_6)^{\frac{1}{2}}$ $COMMENT$ $\pi N \to \pi N \& N \pi \pi$ UNITS $\pi N \to \pi N \& N \pi \pi$ UNITS $T \to T = T = T = T = T = T = T = T = T = $
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VALUE +0.11 ± 0.10 ($\Gamma_1\Gamma_f$) $\frac{1}{2}$ $/\Gamma_{\text{total}}$ Γ_1 N π \rightarrow Δ (19 VALUE +0.27 ± 0.16 ($\Gamma_1\Gamma_f$) $\frac{1}{2}$ $/\Gamma_{\text{total}}$ Γ_1 N π \rightarrow Δ (19 Δ (1940) \rightarrow N π , helicity-1/2 Δ (1940) \rightarrow N π , helicity-1/2 Δ (1940) \rightarrow N π , helicity-3/2 Δ (1940) \rightarrow N π , helicity-3/2 Δ (1940) \rightarrow N π , helicity-3/2 Δ (2003) Δ (2003) Δ (2004) Δ N π , helicity-3/2 Δ (2004) Δ (2004) Δ (2004) Δ (2005) Δ (2005) Δ (2005) Δ (2006) Δ (2007) Δ (20	DOCUMENT ID MANLEY 40) → Δ(123 POCUMENT ID MANLEY 40) → N p, S DOCUMENT ID MANLEY TON DECAY amplitude A ₃ DOCUMENT ID AWAJI 1940) FOOTN a search for pol to π N → Nππ 1940) REFERE + Saleski Manley, Arndt, + Lowe, Peach, S + Kajikawa	92 2) # 92 92 3/2 92 / AM 92 81 OTI es in r dat lwata ackth, H	TECN IPWA DWA TECN IPWA IPWA IPWA IPWA IPWA IPWA IPWA IPWA	COMMENT $\pi N \rightarrow \pi N \& N \pi \pi$ THE $(\Gamma_1 \Gamma_5)^{\frac{1}{2}}$ $COMMENT$ $\pi N \rightarrow \pi N \& N \pi \pi$ THE $(\Gamma_1 \Gamma_6)^{\frac{1}{2}}$ $COMMENT$ $\pi N \rightarrow \pi N \& N \pi \pi$ THE $\pi N \rightarrow \pi N \& N \pi$ THE $\pi N \rightarrow \pi N \& N \pi$ THE $\pi N \rightarrow \pi N \& N \pi$ THE $\pi N \rightarrow \pi N \& N \pi$ THE $\pi N \rightarrow \pi N \& N \pi$ THE $\pi N \rightarrow \pi N \& N \pi$ THE $\pi N \rightarrow \pi N \& N \pi$ THE $\pi N \rightarrow \pi N \& N \rightarrow \pi N$ THE $\pi N \rightarrow \pi N \& N \rightarrow \pi N$ THE $\pi N \rightarrow \pi N \& N \rightarrow \pi N$ THE $\pi N \rightarrow \pi N \& N \rightarrow \pi N$ THE πN

$\Delta(1950) F_{37}$

 $I(J^P) = \frac{3}{2}(\frac{7}{2}^+)$ Status: ***

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters 111B (1982).

△(1950) BREIT-WIGNER MASS

ALUE	(MeV)	DOCUMENT ID		TECN	COMMENT
940	to 1960 (≈ 1950)	OUR ESTIMATE		-	
945	± 2	MANLEY	92	IPWA	$\pi N \rightarrow \pi N & N \pi \pi$
950	± 15	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
913	± 8	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• •	We do not use the	following data for average	s, fit	s, limits,	etc. • • •
947	± 9	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
921		ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
940		LI			$\gamma N \rightarrow \pi N$
925	±20	CANDLIN	84	DPWA	$\pi^+ p \rightarrow \Sigma^+ K^+$
855.0	0+11.0 -10.0	CHEW	80	BPWA	$\pi^+ \rho \rightarrow \pi^+ \rho$
902		CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
912		BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
925		1 LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

△(1950) BREIT-WIGNER WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
290 to 350 (≈ 300) OUR ESTIM	ATE			
300 ± 7	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
340 ±50	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
224 ±10	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following	data for average	s, fit	s, limits,	etc. • • •
302 ± 9	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
232	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
306	LI	93	IPWA	$\gamma N \rightarrow \pi N$
330 ±40	CANDLIN	84	DPWA	$\pi^+ \rho \rightarrow \Sigma^+ K^+$
157.2 ^{+22.0} -19.0	CHEW	80	BPWA	$\pi^+ \rho \rightarrow \pi^+ \rho$
225	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
198	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$
240	¹ LONGACRE	75	IPWA	$\pi N \rightarrow N \pi \pi$

Δ (1950) POLE POSITION

REAL PART VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1880 to 1890 (≈ 1885) C				
1880	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$.
1878	² HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
1890±15	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the	following data for average	s, fit	s, Ilmits,	etc. • • •
1884	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
1924 or 1924	³ LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$
-2×IMAGINARY PA	ART			
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
210 to 270 (≈ 240) OUR	ESTIMATE			
236	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
230	² HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
260 ± 40	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the	following data for average	s, fit	s, limits,	etc. • • •
238	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
258 or 258	³ LONGACRE	78	IPWA	$\pi N \rightarrow N \pi \pi$

△(1950) ELASTIC POLE RESIDUE

MODULUS r				
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
54	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
47	HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
50±7	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following	data for average	s, fit:	s, limits,	etc. • • •
61	ARNDT	91	DPWA	$\pi N \rightarrow \pi N$ Soln SM90
PHASE θ				
PHASE 0	DOCUMENT ID		TECN	COMMENT
	DOCUMENT ID	95		$\frac{COMMENT}{\pi N \to N\pi}$
VALUE (°)		95 93	DPWA	
<u>VALUE</u> (°) -17	ARNDT		DPWA ARGD	$\pi N \rightarrow N\pi$
<u>VALUE (°)</u> - 17 - 32	ARNDT HOEHLER CUTKOSKY	93 80	DPWA ARGD IPWA	$ \begin{array}{cccc} \pi N \to N \pi \\ \pi N \to \pi N \\ \pi N \to \pi N \end{array} $

 $\Delta(1950), \Delta(2000)$

△(1950) DECAY MODES

The following branching fractions are our estimates, not fits or averages.

	Mode	Fraction (Γ_I/Γ)	
Γ ₁	Νπ	35–40 %	
۲2	ΣΚ		
Γ_3	Νππ		
Γ4	$\Delta\pi$	20-30 %	
Γ ₅	$\Delta(1232)\pi$, F-wave		
Γ ₆	$\Delta(1232)\pi$, H-wave		
Γ7	$N\rho$	<10 %	
Гв	$N\rho$, $S=1/2$, F-wave		
وً ٦	$N\rho$, $S=3/2$, F-wave		
Γ10	$N\gamma$	0.08-0.13 %	
Γ11	N_{γ} , helicity=1/2	0.03-0.055 %	
Γ ₁₂	$N\gamma$, helicity=3/2	0.05-0.075 %	

△(1950) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$				Γ ₁ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
0.35 to 0.4 OUR ESTIMAT	TE			
0.38 ± 0.01	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
0.39 ± 0.04	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
0.38±0.02	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
• • • We do not use the	following data for average	s, fit	s, limits,	, etc. • • •
0.49	ARNDT	95	DPWA	$\pi N \rightarrow N \pi$
0.44	CHEW	80	BPWA	$\pi^+ \rho \rightarrow \pi^+ \rho$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N \pi$				(Γ ₁ Γ ₂) ^{1/2} /Γ
VALUE	DOCUMENT ID			COMMENT
-0.053 ± 0.005	CANDLIN	84	DPWA	$\pi^+ \rho \rightarrow \Sigma^+ K^+$
• • We do not use the f	following data for average	es, fit	s, limits	, etc. • • •
0.022 to 0.040	⁴ DEANS	75	DPWA	$\pi N \rightarrow \Sigma K$

Note: Signs of couplings from $\pi N \to N \pi \pi$ analyses were changed in the 1986 edition to agree with the baryon-first convention; the overall phase ambiguity is resolved by choosing a negative sign for the $\Delta(1620)$ 5_{31} coupling to $\Delta(1232)\pi$.

VALUE	$N\pi \to \Delta(1950) \to \Delta(1232)\pi$, F-wave $(\Gamma_1\Gamma_5)^{1/2}$ DOCUMENT ID TECN COMMENT
+0.29 to +0.32 OU	RESTIMATE
$+0.27\pm0.02$	MANLEY 92 IPWA $\pi N \rightarrow \pi N \& N \pi \pi$ 1 LONGACRE 75 IPWA $\pi N \rightarrow N \pi \pi$
+0.32	¹ LONGACRE 75 IPWA $\pi N \rightarrow N \pi \pi$
 • • We do not us 	the following data for averages, fits, limits, etc. • • •
0.21	⁵ NOVOSELLER 78 IPWA $\pi N \rightarrow N \pi \pi$ ⁶ NOVOSELLER 78 IPWA $\pi N \rightarrow N \pi \pi$
0.38	⁶ NOVOSELLER 78 IPWA $\pi N \rightarrow N \pi \pi$
14 .	
(F.F.)½/Fin	Nor A(1950) No. 5-3/2 Europe (C-C-)/2
	$N\pi \to \Delta(1950) \to N\rho$, S=3/2, F-wave $(\Gamma_1 \Gamma_9)^{\frac{1}{2}}$
VALUE	DOCUMENT ID TECN COMMENT
+0.24	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
VALUE +0.24 • • • We do not use	$\frac{\text{DOCUMENT ID}}{\text{1 LONGACRE}} \begin{array}{c cccc} \text{TECN} & \text{COMMENT} \\ \hline & \text{1 LONGACRE} & 75 & \text{IPWA} & \pi N \rightarrow N \pi \pi \\ \hline \text{the following data for averages, fits, limits, etc.} & \bullet & \bullet \\ \hline \end{array}$
+0.24	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$

△(1950) PHOTON DECAY AMPLITUDES

Δ (1950) $\rightarrow N\gamma$, helicity-1/2 amplitude A_{1/2}

VALUE (GeV ^{-1/2})	DOCUMENT ID		TECN	COMMENT
-0.076±0.012 OUR ESTIMATE				
-0.079 ± 0.006	ARNDT	96	IPWA	$\gamma N \rightarrow \pi N$
-0.068 ± 0.007	ILAWA	81	DPWA	$\gamma N \rightarrow \pi N$
-0.091 ± 0.005	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 1)}$
-0.083 ± 0.005	ARAI	80	DPWA	$\gamma N \rightarrow \pi N \text{ (fit 2)}$
-0.067 ± 0.014	CRAWFORD	80	DPWA	$\gamma N \rightarrow \pi N$
	data for average	s, fit	s, limits,	etc. • • •
-0.102 ± 0.003	U	93	IPWA	$\gamma N \rightarrow \pi N$
-0.058 ± 0.013	BARBOUR	78	DPWA	$\gamma N \rightarrow \pi N$

Δ (1950) $\rightarrow N\gamma$, helicity-3/2 amplitude A_{3/2}

•	,	• •	• •	•	J/ -				
VALUE ($GeV^{-1/2}$)			DOCUMENT	ID	TECN	COMME	VT	
-0.097	±0.010 O	UR ESTI	MATE						
-0.103	±0.006			ARNDT	96	IPWA -	$\gamma N \rightarrow$	πÑ	
0.094	± 0.016			ILAWA	81	DPWA	$\gamma N \rightarrow$	πN	
-0.101	± 0.005			ARAI	80	DPWA	$\gamma N \rightarrow$	π N (fit 1)	
-0.100	±0.005			ARAI	80	DPWA	$\gamma N \rightarrow$	πN (fit 2)	
-0.082	±0.017			CRAWFOR	O 80	DPWA	$\gamma N \rightarrow$	πN	
	We do not	use the fo	ollowing d	ata for avera	ges, fits	, limits,	etc. • •	•	
-0.115	±0.003			LI	93	IPWA	$\gamma N \rightarrow$	πN	
0.075	±0.020			BARBOUR	78	DPWA	$\gamma N \rightarrow$	πN	

△(1950) FOOTNOTES

- 1 From method II of LONGACRE 75: eyeball fits with Breit-Wigner circles to the T-matrix
- ² See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and Δ resonances as determined from Argand diagrams of πN elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams. ³LONGACRE 78 values are from a search for poles in the unitarized T-matrix. The first (second) value uses, in addition to $\pi N \to N \pi \pi$ data, elastic amplitudes from a Saclay (CERN) partial-wave analysis.
- The range given is from the four best solutions. DEANS 75 disagrees with $\pi^+ p \rightarrow \Sigma^+ K^+$ data of WINNIK 77 around 1920 MeV.

 5 A Breit-Wigner fit to the HERNDON 75 IPWA; the phase is near -60° .
- ⁶ A Breit-Wigner fit to the NOVOSELLER 788 IPWA; the phase is near -60°.
- A Breit-Wigner fit to the HERNDON 75 IPWA; the phase is near 120°.
 A Breit-Wigner fit to the NOVOSELLER 78B IPWA; the phase is near 120°.

△(1950) REFERENCES

ARNDT	96	PR C53 430	+Strakovsky, Workman	(VPI)
ARNDT	95	PR C52 2120	+Strakovsky, Workman, Pavan	(VPI, BŘCO)
HOEHLER	93	πN Newsletter 9 1		(KARL)
LI	93	PR C47 2759	+Arndt, Roper, Workman	(VPI)
MANLEY	92	PR D45 4002	+Saleski	(KÈNT) IJP
Aiso	84	PR D30 904	Manley, Arndt, Goradia, Teplitz	(VPI)
ARNDT	91	PR D43 2131	+Li. Roper, Workman, Ford	(VPI, TELE) IJP
CANDLIN	84	NP B238 477	+Lowe, Peach, Scotland+	(EDIN, RAL, LOWC)
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
ILAWA	81	Bonn Conf. 352	+Kajikawa	(NAGO)
Aiso	82	NP 8197 365	Fujii, Hayashii, Iwata, Kajikawa+	(NAGO)
ARAI	80	Toronto Conf. 93		`(INUS)
Also	82	NP B194 251	Arai, Fujii	(INUS)
CHEW	80	Toronto Conf. 123	• •	`(LBL\) IJP
CRAWFORD	80	Toronto Conf. 107		(ĠLAS)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMÚ, LBL) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL) IJP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Aiso	80	Toronto Conf. 3	Koch	(KARLT) UP
BARBOUR	78	NP B141 253	+Crawford, Parsons	`(GLAS)
LONGACRE	78	PR D17 1795	+Lasinski, Rosenfeld, Smadja+	(LBL, SLAC)
NOVOSELLER	78	NP B137 509		(CIT) UP
NOVOSELLER	78B	NP B137 445		(CIT) UP
WINNIK	77	NP B128 66	+Toaff, Revel, Goldberg, Berny	(HAIF) I
DEANS	75	NP B96 90	+Mitchell, Montgomery+	(SFLA, ÀLAH) IJP
HERNDON	75	PR D11 3183	+Longacre, Miller, Rosenfeld+	(LBL, SLAC)
LONGACRE	75	PL 55B 415	+Rosenfeld, Lasinski, Smadja+	(LBL, SLAC) IJP

 $\Delta(2000) F_{35}$

 $I(J^P) = \frac{3}{2}(\frac{5}{2}^+)$ Status: **

OMITTED FROM SUMMARY TABLE

△(2000) BREIT-WIGNER MASS

VALUE (MeV) ≈ 2000 OUR ESTIMATE	DOCUMENT ID	-	TECN	COMMENT
1752 ± 32	MANLEY	92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
2200 ± 125	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$

A(2000) BREIT-WIGNER WIDTH

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
251± 93	MANLEY 92	IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
400±125	CUTKOSKY 80	1PWA	$\pi N \rightarrow \pi N$

△(2000) POLE POSITION

REAL PART VALUE (MeV)

DOCUMENT ID TECN COMMENT 2150 ± 100 CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$

-2×IMAGINARY PART

VALUE (MeV) DOCUMENT ID TECN COMMENT 350 ± 100 CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$

△(2000) ELASTIC POLE RESIDUE

MODULUS |r|

VALUE (MeV) DOCUMENT ID TECN COMMENT 16±5 CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$ PHASE 0 DOCUMENT ID TECN COMMENT VALUE (° CUTKOSKY 80 IPWA $\pi N \to \pi N$ 150 ± 90

△(2000) DECAY MODES

	Mode	
<u>Γ</u> 1	Νπ	
Γ_2	$N\pi\pi$	
Γ3	$\Delta(1232)\pi$, P-wave	
Га	$\Delta(1232)\pi$, F-wave	
Γĸ	$N\rho$, $S=3/2$. P-wave	

Δ (2000) BRANCHING i $\Gamma(N\pi)/\Gamma_{ ext{total}}$			A(2150) FOOTNOTES esonances in this mass region. Problems with this analysis
VALUE DOCUMENT ID	Γ ₁ /Γ 	are discussed in section 2.1.11	esonances in this mass region. Problems with this analysi 1 of HOEHLER 83.
0.02±0.01 MANLEY 92	2 IPWA $\pi N \rightarrow \pi N \& N \pi \pi$ 0 IPWA $\pi N \rightarrow \pi N$		(2150) REFERENCES
$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N_{\pi} \rightarrow \Delta(2000) \rightarrow \Delta(1232) \tau$	π , <i>P</i> -wave $(\Gamma_1\Gamma_3)^{\frac{1}{2}}/\Gamma$	CANDLIN 84 NP B238 477 HOEHLER 83 Landolt-Boernstein CHEW 80 Toronto Conf. 12:	
VALUE DOCUMENT ID	$ \frac{TECN}{2} \frac{COMMENT}{\pi N \rightarrow \pi N \& N \pi \pi} $	CUTKOSKY 80 Toronto Conf. 19 Also 79 PR D20 2839	+Forsyth, Babcock, Kelly, Hendrick (CMU, LBL) III Cutkosky, Forsyth, Hendrick, Kelly (CMU, LBL)
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N_{\pi} \rightarrow \Delta(2000) \rightarrow \Delta(1232)_{\pi}$	π , F -wave $(\Gamma_1\Gamma_4)^{1/2}/\Gamma$	1/(222)	P. 3/7->
VALUE DOCUMENT ID	TECN COMMENT 2 IPWA $\pi N \rightarrow \pi N & N \pi \pi$	$\Delta(2200) G_{37}$	$I(J^P) = \frac{3}{2}(\frac{7}{2})$ Status: *
•	•	OMITTED FROM SUMMA	ARY TABLE
$(\Gamma_i \Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N_{\pi} \to \Delta(2000) \to N_{\rho}, S=3$ VALUE DOCUMENT ID	/2, P-wave (F ₁ F ₈) 1/2/F TECN COMMENT	The various analyses a	ere not in good agreement.
	2 IPWA πN → πN & Nππ	△(220	0) BREIT-WIGNER MASS
△(2000) REFERENCE	CES	VALUE (MeV) ≈ 2200 OUR ESTIMATE	DOCUMENT ID TECN COMMENT
MANLEY 92 PR D45 4002 +Saleski	(KENT) IJP	2200 ± 80	CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$
Also 84 PR D30 904 Manley, Arndt, Gor CUTKOSKY 80 Toronto Conf. 19 +Forsyth, Babcock, N	radia, Teplitz (VPI)	2215±60	HOEHLER 79 IPWA $\pi N \rightarrow \pi N$
Also 79 PR D20 2839 Cutkosky, Forsyth,		2280 ± 80	HENDRY 78 MPWA πN → πN
		2280±40	ing data for averages, fits, limits, etc. \bullet \bullet \bullet CANDLIN 84 DPWA $\pi^+p \rightarrow \Sigma^+K^+$
$\Delta(2150) S_{31}$ $I(J^P)$	$= \frac{3}{2}(\frac{1}{2}) \text{ Status: } *$	220V±4U	CAMPLIN 04 DEVAN X ' P → Z ' K '
OMITTED FROM SUMMARY TABLE		△(2200) BREIT-WIGNER WIDTH
		VALUE (MeV)	DOCUMENT ID TECN COMMENT
△(2150) BREIT-WIGNE	R MASS	450±100	CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$
/ALUE (MeV) DOCUMENT ID	TECH COLLEGE	400±100 400±150	HOEHLER 79 IPWA $\pi N \rightarrow \pi N$ HENDRY 78 MPWA $\pi N \rightarrow \pi N$
ALUE (MeV) 2150 OUR ESTIMATE	TECN COMMENT		ng data for averages, fits, limits, etc. • •
	0 BPWA $\pi^+ p \rightarrow \pi^+ p$	400± 50	CANDLIN 84 DPWA $\pi^+p \rightarrow \Sigma^+K^+$
2203.2± 8.4 ¹ CHEW 80 2150 ±100 CUTKOSKY 80	0 BPWA $\pi^+ \rho \rightarrow \pi^+ \rho$ 0 IPWA $\pi N \rightarrow \pi N$		OMAN POLE POSITION
4/2470) ODET 14101171			2200) POLE POSITION
Δ(2150) BREIT-WIGNER	(WID I H	REAL PART VALUE (MeV)	DOCUMENT ID TECN COMMENT
VALUE (MeV) DOCUMENT ID	TECN COMMENT	2100±50	CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$
121.6± 62.0 ¹ CHEW 80	0 BPWA $\pi^+ p \rightarrow \pi^+ p$		
	0 BPWA $\pi^+ p \rightarrow \pi^+ p$	-2×IMAGINARY PART VALUE (MeV)	DOCUMENT ID TECN COMMENT
200 ±100 CUTKOSKY 80	0 IPWA $\pi N \rightarrow \pi N$	340±80	CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$
△(2150) POLE POSI	TION) ELASTIC POLE RESIDUE
REAL PART VALUE (MeV) DOCUMENT ID	TECN COMMENT	MODULUS I-I	•
	0 IPWA $\pi N \rightarrow \pi N$	MODULUS [r]	DOCUMENT ID TECN COMMENT
	, 11 vv.	8±3	CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$
-2×IMAGINARY PART VALUE (MeV) DOCUMENT ID	TECN COMMENT		
	0 IPWA $\pi N \rightarrow \pi N$	PHASE 6 VALUE (°)	DOCUMENT ID TECN COMMENT
		70±40	CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$
△(2150) ELASTIC POLE	RESIDUE		
MODULUS r		Δ((2200) DECAY MODES
VALUE (MeV) DOCUMENT ID 7±2 CUTKOSKY 80	$ \begin{array}{ccc} $	Mode	
) IFVA */V → */V	Γ ₁ Νπ	
PHASE 0 VALUE (°) DOCUMENT ID	TECH COMMENT	Γ_2 ΣK	
<u>VALUE (°)</u> <u>DOCUMENT ID</u> −60±90 CUTKOSKY 80	$ \begin{array}{ccc} $		
		-	00) BRANCHING RATIOS
△(2150) DECAY MO	IDES	$\Gamma(N\pi)/\Gamma_{\text{total}}$	Γ1/
		VALUE 0.06±0.02	DOCUMENT ID TECN COMMENT CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$
Mode			
		0.05 ± 0.02	HOEHLER 79 IPWA $\pi N \rightarrow \pi N$
Γ ₁ Νπ		0.05 ± 0.02 0.09 ± 0.02	HOEHLER 79 IPWA $\pi N \rightarrow \pi N$ HENDRY 78 MPWA $\pi N \rightarrow \pi N$
Γ ₁ Νπ	RATIOS	0.09 ± 0.02 $(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N \pi \rightarrow \Delta ($	HENDRY 78 MPWA $\pi N \rightarrow \pi N$ 2200) $\rightarrow \Sigma K$ $(\Gamma_1 \Gamma_2)^{\frac{1}{2}}/\Gamma_2$
$\Gamma_1 N\pi$ $\Gamma_2 \Sigma K$ Δ (2150) BRANCHING I	RATIOS	0.09±0.02	HENDRY 78 MPWA $\pi N \rightarrow \pi N$
$\Gamma_1 N \pi$ $\Gamma_2 \Sigma K$ Δ (2150) BRANCHING I $\Gamma(N\pi)/\Gamma_{total}$ VALUE DOCUMENT ID	Γ ₁ /Γ	$\begin{array}{c} 0.09 \pm 0.02 \\ \left(\Gamma_i \Gamma_f \right)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N\pi \rightarrow \Delta (1) \\ \frac{VALUE}{-0.014 \pm 0.005} \end{array}$	HENDRY 78 MPWA $\pi N \rightarrow \pi N$ 2200) $\rightarrow \Sigma K$ CANDLIN 84 DPWA $\pi^+ p \rightarrow \Sigma^+ K^+$
	$\begin{array}{ccc} & & & & & & & & & & & & \\ \hline & \underline{TECN} & \underline{COMMENT} & & & & & & & \\ D & BPWA & \pi^+\rho & & \pi^+\rho & & & & \\ \end{array}$	$\begin{array}{c} 0.09 \pm 0.02 \\ \left(\Gamma_i \Gamma_f \right)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N\pi \rightarrow \Delta (1) \\ \frac{VALUE}{-0.014 \pm 0.005} \end{array}$	HENDRY 78 MPWA $\pi N \rightarrow \pi N$ 2200) $\rightarrow \Sigma K$ DOCUMENT ID TECH COMMENT. ($\Gamma_1 \Gamma_2$) $\frac{1}{2}$
	$ \begin{array}{ccc} \Gamma_1/\Gamma \\ \hline \Gamma ESN & SOMMENT \\ \hline D BPWA \pi^+ \rho \rightarrow \pi^+ \rho $	$\begin{array}{c} 0.09\pm0.02 \\ \left(\Gamma_{i}\Gamma_{f}\right)^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\pi \rightarrow \Delta(1) \\ \\ \frac{VALUE}{-0.014\pm0.005} \end{array}$ CANDLIN 84 NP B236 477	HENDRY 78 MPWA $\pi N \rightarrow \pi N$ 2200) $\rightarrow \Sigma K$ CANDLIN 84 DPWA $\pi^+ p \rightarrow \Sigma^+ K^+$ 1(2200) REFERENCES 1-Lowe, Peach, Scotland+ (EDIN, RAL, LOWC)
Γ_1 $N\pi$ Γ_2 Σ K Δ(2150) BRANCHING I $\Gamma(N\pi)/\Gamma_{total}$ $VALUE$ 0.41 Γ_{total} 0.37 Γ_{total} 0.08±0.02 CUTKOSKY 80	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	0.09 \pm 0.02 $ \frac{\left(\Gamma_{i}\Gamma_{f}\right)^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\pi \rightarrow \Delta\left(\frac{1}{2}\right)}{\sqrt{ALUE}} - 0.014 \pm 0.005 $ CANDLIN 84 NP B238 477 17 CUTKOSKY 80 Toronto Conf. 19 R D20 2839	HENDRY 78 MPWA $\pi N \rightarrow \pi N$ 2200) $\rightarrow \Sigma K$ CANDLIN 84 DPWA $\pi^+ p \rightarrow \Sigma^+ K^+$ (C200) REFERENCES +Lowe, Peach, Scotland+ +Forsyth, Baboock, Kelly, Hendrick Cutubsky, Forsyth, Hendrick, Kelly (CMU, LBL)11 (CMU, LBL)11 (CMU, LBL)11
Γ_1 $Nπ$ Γ_2 $Σ K$ Δ (2150) BRANCHING I $\Gamma(Nπ)/\Gamma_{total}$ $VALUE$ 0.41 1 CHEW 80 0.37 1 CHEW 80	$ \begin{array}{ccc} \Gamma_1/\Gamma \\ \hline D BPWA & \pi^+ p \rightarrow & \pi^+ p \\ D BPWA & \pi^+ p \rightarrow & \pi^+ p \end{array} $	0.09 \pm 0.02 $(\Gamma_{f}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\pi \rightarrow \Delta(N)$ VALUE -0.014 ± 0.005 CANDLIN CANDLIN 84 NP B238 477 CUTKOSKY 80 Toronto Conf. 19	HENDRY 78 MPWA $\pi N \rightarrow \pi N$ 2200) $\rightarrow \Sigma K$ DOCUMENT ID CANDLIN 84 DPWA $\pi^+ p \rightarrow \Sigma^+ K^+$ 1(2200) REFERENCES +Lowe, Peach, Scotland+ +Forsyth, Babcock, Kelly, Hendrick (EDIN, RAL, LOWC) (CMU, LBL) IJ

-0.017

CANDLIN CHEW CUTKOSKY Also HOEHLER Also HENDRY Also

Baryon Particle Listings

Δ(2300), Δ(2350)

$\Delta(2300) H_{39}$	I(J	P) =	= 3/2+) Status: *	*
OMITTED FROM SUMM	ARY TABLE				
Δ(23	00) BREIT-WIG	NER	MASS		-
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT	
2300 OUR ESTIMATE	CHEM	-00	D DIA/A	4. 4.	
2204.5± 3.4 2400 ±125	CHEW CUTKOSKY			$\pi^+ p \rightarrow \pi^+ p$ $\pi N \rightarrow \pi N$	
2400 ±125 2217 ± 80	HOEHLER			$\pi N \rightarrow \pi N$ $\pi N \rightarrow \pi N$	
2450 ±100	HENDRY			$\pi N \rightarrow \pi N$	
• • We do not use the follow					
2400	CANDLIN			$\pi^+ p \rightarrow \Sigma^+ K^+$	+
Δ(230	00) BREIT-WIGI	NER	WIDTH	1	-
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT	
32.3± 1.0	CHEW			$\pi^+ \rho \rightarrow \pi^+ \rho$	
425 ±150	CUTKOSKY			$\pi N \rightarrow \pi N$	
300 ±100	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$	
500 ±200	HENDRY			$\pi N \rightarrow \pi N$	
 We do not use the follow 	ing data for averag	es, fit	s, limits,	etc. • • •	
200	CANDLIN	84	DPWA	$\pi^+ \rho \rightarrow \Sigma^+ K^+$	<u> </u>
	(2300) POLE P	OSIT	ION		
REAL PART VALUE (MeV)	DOCUMENT ID		TECN	COMMENT	
2370±80	CUTKOSKY			$\pi N \rightarrow \pi N$	
2310100	COTROSKT	00	11 11/3	# 14 → # 14	
-2×IMAGINARY PART					
VALUE (MeV)	DOCUMENT ID			COMMENT	
420±160	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$	
△(230	0) ELASTIC PO	LE F	RESIDU	E	
MODULUS r					
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT	
10±4	CUTKOSKY			$\pi N \rightarrow \pi N$	
PHASE <i>θ</i>					
VALUE (°)	DOCUMENT ID			COMMENT	
-20±30	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$	
2	1(2300) DECAY	MOI	DES		
Mode					
Γ ₁ Νπ Γ ₂ ΣΚ					
∆ (2	300) BRANCHII	NG R	ATIOS		
Γ(Nπ)/Γ _{total}	DOCUMENT ID		TECN	COMMENT	Γ1/Ι
0.05	CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$	
0.06 ± 0.02	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$	
0.03 ± 0.02	HOEHLER		IPWA	$\pi N \rightarrow \pi N$	
0.08 ± 0.02	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$	
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\pi \to \Delta$	(2300) → ΣK		TECH	(F ₁ I	2)1/2/
VALUE	DOCUMENT ID			COMMENT	+
-0.017	CANDIN	84	SIPWA	# · B) T K -	

CANDLIN 84 DF
Δ(2300) REFERENCES

+Lowe, Peach, Scotland+

+Forsyth, Babcock, Kelly, Hendrick Cutkosky, Forsyth, Hendrick, Kelly +Kaiser, Koch, Pietarinen Koch

NP B238 477 Toronto Conf. 123 Toronto Conf. 19 PR D20 2839 PDAT 12-1 Toronto Conf. 3 PRL 41 222 ANP 136 1 84 DPWA $\pi^+ p \rightarrow \Sigma^+ K^+$

(EDIN, RAL, LOWC)
(LBL) IJP
(CMU, LBL) IJP
(CMU, LBL)
(KARLT) IJP
(KARLT) IJP
(IND, LBL) IJP
(IND, LBL) IJP

$I(J^P) = \frac{3}{2}(\frac{1}{2})$	5 [—]) Status: *
RY TABLE	
D) BREIT-WIGNER MAS	is
DOCUMENT ID TECN	COMMENT
MANUEY OF IDM	A πN → πN & Nππ
CUTKOSKY 80 IPWA	
HOEHLER 79 IPW	$\pi N \rightarrow \pi N$
) BREIT-WIGNER WID	ГН
DOCUMENT ID TECN	COMMENT
MANLEY 92 IPWA	$\pi N \rightarrow \pi N \& N \pi \pi$
HOEHLER 79 IPW/	$\lambda \pi N \rightarrow \pi N$
2350) POLE POSITION	
DOCUMENT ID TECN	COMMENT
CUTKOSKY 80 IPW	
COTTOON OF IT TO	
DOCUMENT IN TECH	COMMENT
	$\frac{COMMENT}{\pi N \rightarrow \pi N}$
) ELASTIC POLE RESID	UE
DOCUMENT ID TECN	COMMENT
CUTKOSKY 80 IPW	
DOCUMENT ID TECN	COMMENT
CUTKOSKY 80 IPW	
2350) DECAY MODES	
50) BRANCHING RATIO	S
	Γ1/
	COMMENT
HOEHLER 79 IPW	
	14
2350) → Σ <i>K</i>	(Г ₁ Г ₂) ^{1/2} /
	$I \longrightarrow COMMENT$ $VA = \pi^+ p \rightarrow \Sigma^+ K^+$
•	
+Saleski Manley Arndt, Goradia, Teo	(KENT) IJ
manicy, Armus, Goradia, Tep	(EDIN. RAL. LOWC)
+Lowe, Peach, Scotland+	added (Charles to the
+Lowe, Peach, Scotland+ +Forsyth, Babcock, Kelly, Her Cutkosky, Forsyth, Hendrick, +Kaiser, Koch, Pietarinen	Altz (VPI) (VPI) (EDIN, RAL, LOWC) (Indrick (CMU, LBL) IJ (KARLT) IJ (KARLT) IJ (KARLT) IJ
	ARY TABLE DO BREIT-WIGNER MASS DOCUMENT ID DOCUMENT ID DOCUMENT ID CUTKOSKY 80 IPW/ HOEHLER 79 IPW/ CUTKOSKY 80 IPW/ HOEHLER 79 IPW/ CUTKOSKY 80 IPW/ HOEHLER 79 IPW/ CUTKOSKY 80 IPW/ CUTKOSKY 80 IPW/ DOCUMENT ID CUTKOSKY 80 IPW/ CUTKOSKY 80 IPW/ DOCUMENT ID CUTKOSKY 80 IPW/ CUTKOSKY 8

P\ 3.7±\ c
$I(J^P) = \frac{3}{2}(\frac{7}{2}^+) \text{ Status: } *$
IARY TABLE
990) BREIT-WIGNER MASS
DOCUMENT ID TECN COMMENT
CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$
HOEHLER 79 IPWA $\pi N \rightarrow \pi N$
00) BREIT-WIGNER WIDTH
DOCUMENT ID TECN COMMENT
CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$
HOEHLER 79 IPWA $\pi N \rightarrow \pi N$
(2390) POLE POSITION
DOCUMENT ID TECH COMMENT
DOCUMENT ID TECN COMMENT CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$
SOTTOMINE OF IT THE PARTY OF
DOCUMENT ID TECN COMMENT
CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$
CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$
DOCUMENT ID TECN COMMENT CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$
1(2390) DECAY MODES
390) BRANCHING RATIOS
Γ ₁ /1
DOCUMENT ID TECN COMMENT CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$
HOEHLER 79 IPWA $\pi N \rightarrow \pi N$
$\lambda(2390) \rightarrow \Sigma K$ $(\Gamma_1 \Gamma_2)^{\frac{1}{2}}/2$
DOCUMENT ID TECN COMMENT
CANDLIN 84 DPWA $\pi^+ p \rightarrow \Sigma^+ K^+$
△(2390) REFERENCES
+Lowe, Peach, Scotland+ +Forsyth, Baboock, Kelly, Hendrick Cuthosky, Forsyth, Hendrick, Kelly +Kaiser, Koch, Pletarinen Koch Koch KARLT) Jif

$\Delta(2400) G_{39}$	$I(J^P) = \frac{3}{2}(\frac{9}{2})$ Status: **
OMITTED FROM SUMMA	ARY TABLE
△(240	00) BREIT-WIGNER MASS
VALUE (MeV)	DOCUMENT ID TECN COMMENT
≈ 2400 OUR ESTIMATE 2300 ± 100	CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$
2468± 50	HOEHLER 79 IPWA $\pi N \rightarrow \pi N$
2200±100	HENDRY 78 MPWA $\pi N \rightarrow \pi N$
△(2400	D) BREIT-WIGNER WIDTH
VALUE (MeV)	DOCUMENT ID TECN COMMENT
330±100	CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$ HOEHLER 79 IPWA $\pi N \rightarrow \pi N$
480±100 450±200	HENDRY 78 MPWA $\pi N \rightarrow \pi N$
Δ(:	2400) POLE POSITION
REAL PART	,
VALUE (MeV)	DOCUMENT ID TECN COMMENT
2260±60	CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$
-2×IMAGINARY PART	DOCUMENT ID TECH CONSEST
VALUE (MeV) 320±160	DOCUMENT ID TECN COMMENT CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$
) ELASTIC POLE RESIDUE
MODULUS r	DOCUMENT ID TECH COMMENT
VALUE (MeV) 8 ± 4	DOCUMENT ID TECN COMMENT CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$
PHASE 0 VALUE (°)	DOCUMENT ID TECN COMMENT
-25±15	CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$
Δ(Mode	(2400) DECAY MODES
- Mode Γ ₁ Νπ	
Γ ₂ ΣΚ	
Δ(24	00) BRANCHING RATIOS
Γ(Nπ)/Γ _{total}	DOCUMENT ID TECN COMMENT
0.05±0.02	CUTKOSKY 80 IPWA $\pi N \rightarrow \pi N$
0.06±0.03	HOEHLER 79 IPWA $\pi N \rightarrow \pi N$
0.06 ± 0.03 0.10 ± 0.03	HOEHLER 79 IPWA $\pi N \rightarrow \pi N$ HENDRY 78 MPWA $\pi N \rightarrow \pi N$
0.10±0.03	HENDRY 78 MPWA $\pi N \rightarrow \pi N$
	HENDRY 78 MPWA $\pi N \rightarrow \pi N$ (2400) $\rightarrow \Sigma K$ DOCUMENT ID TECN COMMENT
0.10±0.03	HENDRY 78 MPWA $\pi N \rightarrow \pi N$ (2400) $\rightarrow \Sigma K$ ($\Gamma_1 \Gamma_2$)
0.10±0.03 $ \frac{(\Gamma_1 \Gamma_7)^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\pi \to \Delta}{(0.015)^{\frac{1}{2}}} $	HENDRY 78 MPWA $\pi N \rightarrow \pi N$ (2400) $\rightarrow \Sigma K$ DOCUMENT ID TECN COMMENT
0.10±0.03 $ \frac{(\Gamma_i \Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \to \Delta}{(\nabla_i \Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\pi \to \Delta} $ $ < 0.015 $ CANDLIN 84 NP B238 477	HENDRY 78 MPWA $\pi N \rightarrow \pi N$ (2400) $\rightarrow \Sigma K$ CANDLIN 84 TECN COMMENT DPWA $\pi^+ p \rightarrow \Sigma^+ K^+$ (CA100) REFERENCES +Lowe, Peach, Scotland+ (EDIN, RAL, LOW)
0.10 ± 0.03 $ \frac{\left(\Gamma_{i}\Gamma_{f}\right)^{\frac{1}{2}}/\Gamma_{total}}{\left(\Gamma_{i}\Gamma_{f}\right)^{\frac{1}{2}}/\Gamma_{total}} \text{ in } N\pi \rightarrow \Delta (\frac{VALUE}{<0.015}) $ CANDLIN 84 NP B238 477 TOORNTO CONF. 19 PR D20 2839 TO POOR TO PO	HENDRY 78 MPWA $\pi N \rightarrow \pi N$ (2400) $\rightarrow \Sigma K$ CANDLIN 84 TECN COMMENT DPWA $\pi^+ p \rightarrow \Sigma^+ K^+$ (EDIN, RAL, LOW- Forsyth, Babcock, Kelly, Hendrick Cutkosky, Forsyth, Hendrick, Kelly (CMU, LBI
0.10 \pm 0.03 $ \frac{\left(\Gamma_{I}\Gamma_{f}\right)^{1/2}/\Gamma_{\text{total}} \text{ in } N\pi \to \Delta}{\left(\Gamma_{I}\Gamma_{f}\right)^{1/2}/\Gamma_{\text{total}} \text{ in } N\pi \to \Delta} $ $ < 0.015 $ CANDLIN 84 NP B238 477 CUTKOSKY 80 Toronto Conf. 19	HENDRY 78 MPWA $\pi N \rightarrow \pi N$ [2400] $\rightarrow \Sigma K$ DOCUMENT ID CANDLIN 84 DPWA $\pi^+ p \rightarrow \Sigma^+ K^+$ [2400] REFERENCES +Lowe, Peach, Scotland+ +Forsyth, Babcock, Kelly, Hendrick (EDIN, RAL, LOW (CMU, LBi

 $\Delta(2420), \Delta(2750), \Delta(2950)$

∆(2420)	$H_{3,11}$
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 $I(J^P) = \frac{3}{2}(\frac{11}{2}^+)$ Status: ***

Most of the results published before 1975 are now obsolete and have been omitted. They may be found in our 1982 edition, Physics Letters 111B (1982).

△(2420) BREIT-WIGNER MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
2300 to 2500 (≈ 2420) OUR ESTIMATE			
2400 ±125	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
2416 ± 17	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
2400 ± 60	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$
 We do not use the 	e following data for averages	, fit	s, limits,	etc. • • •
2400	CANDLIN	84	DPWA	$\pi^+ \rho \rightarrow \Sigma^+ K^+$
2358.0 ± 9.0	CHEW	80	BPWA	$\pi^+ p \rightarrow \pi^+ p$

△(2420) BREIT-WIGNER WIDTH

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
300 to 500 (≈ 400) OUR ESTIN	IATE		
450 ±150	CUTKOSKY 80	IPWA	$\pi N \rightarrow \pi N$
340 ± 28	HOEHLER 79	IPWA	$\pi N \rightarrow \pi N$
460 ±100	HENDRY 78	MPWA	$\pi N \rightarrow \pi N$
• • • We do not use the following	g data for averages, f	its, limits,	etc. • • •
400	CANDLIN 84	DPWA	$\pi^+ p \rightarrow \Sigma^+ K^+$
202.2± 45.0	CHEW 80	BPWA	$\pi^+ p \rightarrow \pi^+ p$

△(2420) POLE POSITION

REAL PART				
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
2260 to 2400 (≈ 2330) OUR EST	TIMATE			
2300	¹ HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
2360±100	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
~2×IMAGINARY PART				
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
350 to 750 (≈ 550) OUR ESTIM	ATE			
620	¹ HOEHLER	93	ARGD	$\pi N \rightarrow \pi N$
420±100	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$

△(2420) ELASTIC POLE RESIDUE

MODULUS r			
VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
39	HOEHLER 93	ARGD	$\pi N \rightarrow \pi N$
18±6	CUTKOSKY 80	IPWA	$\pi N \rightarrow \pi N$
PHASE #			
VALUE (°)	DOCUMENT ID	TECN	COMMENT
-60	HOEHLER 93	ARGD	$\pi N \rightarrow \pi N$
-30 ± 40	CUTKOSKY 80	IPWA	$\pi N \rightarrow \pi N$

△(2420) DECAY MODES

The following branching fractions are our estimates, not fits or averages.

	Mode	Fraction (Γ_I/Γ)
Γ ₁	Νπ	5-15 %
Γ_2^-	ΣΚ	

△(2420) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$				Γ ₁ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
0.05 to 0.15 OUR ESTIMAT	E			
0.08 ± 0.03	CUTKOSKY	80	IPWA	$\pi N \rightarrow \pi N$
0.08 ± 0.015	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$
0.11±0.02	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$
• • We do not use the foll	owing data for average	s, fit	s, limits,	etc. • • •
0.22	CHEW	80	BPWA	$\pi^+ \rho \rightarrow \pi^+ \rho$
$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \ln N\pi \rightarrow$	Δ(2420) → ΣK			(Γ₁Γ₂) ^½ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
-0.016	CANDLIN	84	DPWA	$\pi^+ p \rightarrow \Sigma^+ K^+$

△(2420) FOOTNOTES

△(2420) REFERENCES

Also	81	ANP 136 1	Hendry	` (IND)
HENDRY	78	PRL 41 222		(IND, LBL) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	79	PR D20 2839	Cutkosky, Forsyth, Hendrick, Kelly	(CMU, LBL)
CUTKOSKY	80	Toronto Conf. 19	+Forsyth, Babcock, Kelly, Hendrick	(CMU, LBL) IJP
CHEW	80	Toronto Conf. 123		(LBL) IJP
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
CANDLIN	84	NP B238 477	+Lowe, Peach, Scotland+	(EDIN, RAL, LOWC)
HOEHLER	93	πN Newsletter 9 1		(KARL)

 $\Delta(2750) I_{3,13}$

 $I(J^P) = \frac{3}{2}(\frac{13}{2})$ Status: **

OMITTED FROM SUMMARY TABLE

Δ(2750) BREIT-WIGNER MASS	
---------------------------	--

VALUE (MeV)	DOCUMENT ID		TECN	COMME	v <i>r</i>
≈ 2750 OUR ESTIMATE					
2794 ± 80	HOEHLER	79	IPWA	$\pi N \rightarrow$	πN
2650 ± 100	HENDRY	78	MPWA	$\pi N \rightarrow$	πN

△(2750) BREIT-WIGNER WIDTH

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
350±100	HOEHLER 79	IPWA	$\pi N \rightarrow \pi N$
500±100	HENDRY 78	MPWA	$\pi N \rightarrow \pi N$

Δ(2750) DECAY MODES

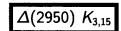
	Mode	
Γ ₁	Νπ	

Δ(2750) BRANCHING RATIOS

Γ(Nπ)/Γ _{total}					Γ_1/Γ
VALUE	DOCUMENT ID		TECN	COMMENT	
0.04±0.015	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$	
0.05 ± 0.01	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$	

△(2750) REFERENCES

HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
HENDRY	78	PRL 41 222		(IND. LBL) IJP
Also	81	ANP 136 1	Hendry	` '(IND)



 $I(J^P) = \frac{3}{2}(\frac{15}{2}^+)$ Status: **

OMITTED FROM SUMMARY TABLE

△(2950) BREIT-WIGNER MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMME	VT
≈ 2950 OUR ESTIMATE					•
2990 ± 100	HOEHLER	79	IPWA	$\pi N \rightarrow$	πN
2850 ± 100	HENDRY	78	MPWA	$\pi N \rightarrow$	πN

△(2950) BREIT-WIGNER WIDTH

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
330±100	HOEHLER 79	9 IPWA	$\pi N \rightarrow \pi N$
700 ± 200	HENDRY 78	B MPWA	$\pi N \rightarrow \pi N$

△(2950) DECAY MODES

	Mode	
Γ ₁	Νπ	

△(2950) BRANCHING RATIOS

$\Gamma(N\pi)/\Gamma_{\text{total}}$					Γ_1/Γ
VALUE	DOCUMENT ID		TECN	COMMENT	
0.04 ± 0.02	HOEHLER	79	IPWA	$\pi N \rightarrow \pi N$	
0.03 ± 0.01	HENDRY	78	MPWA	$\pi N \rightarrow \pi N$	

△(2950) REFERENCES

HOEHLER	79	PDAT 12-1	+Kaiser, Koch, Pietarinen	(KARLT) IJP
Also	80	Toronto Conf. 3	Koch	(KARLT) IJP
HENDRY	78	PRL 41 222	Hendry	(IND, LBL) IJP
Also	81	ANP 136 1		(IND)

¹ See HOEHLER 93 for a detailed discussion of the evidence for and the pole parameters of N and Δ resonances as determined from Argand diagrams of π N elastic partial-wave amplitudes and from plots of the speeds with which the amplitudes traverse the diagrams.

$\Delta (\sim 3000 \text{ Region})$ Partial-Wave Analyses

OMITTED FROM SUMMARY TABLE

We list here miscellaneous high-mass candidates for isospin-3/2 resonances found in partial-wave analyses.

Our 1982 edition also had a $\Delta(2850)$ and a $\Delta(3230)$. The evidence for them was deduced from total cross-section and 180° elastic crosssection measurements. The $\Delta(2850)$ has been resolved into the $\Delta(2750)$ $I_{3,13}$ and $\Delta(2950)$ $K_{3,15}$. The $\Delta(3230)$ is perhaps related to the $K_{3,13}$ of HENDRY 78 and to the $L_{3,17}$ of KOCH 80.

Δ (\sim 3000) BREIT-WIGNER MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
≈ 3000 OUR ESTIMATE				
3300	¹ косн	80	IPWA	$\pi N \rightarrow \pi N L_{3.17}$ wave
3500	¹ косн	80	IPWA	$\pi N \rightarrow \pi N M_{3,19}$ wave
2850±150	HENDRY	78	MPWA	$\pi N \rightarrow \pi N I_{3,11}$ wave
3200 ± 200	HENDRY	78	MPWA	$\pi N \rightarrow \pi N K_{3,13}$ wave
3300 ± 200	HENDRY	78	MPWA	$\pi N \rightarrow \pi N L_{3,17}$ wave
3700 ± 200	HENDRY	78	MPWA	$\pi N \rightarrow \pi N M_{3,19}$ wave
4100±300	HENDRY	78	MPWA	$\pi N \rightarrow \pi N N_{3,21}$ wave

$\Delta (\sim$ 3000) BREIT-WIGNER WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
700 ± 200	HENDRY	78	MPWA	$\pi N \rightarrow \pi N I_{3,11}$ wave
1000 ± 300	HENDRY	78	MPWA	$\pi N \rightarrow \pi N K_{3,13}$ wave
1100±300	HENDRY	78	MPWA	$\pi N \rightarrow \pi N L_{3,17}$ wave
1300 ± 400	HENDRY	78	MPWA	$\pi N \rightarrow \pi N M_{3.19}$ wave
1600 ± 500	HENDRY	78	MPWA	$\pi N \rightarrow \pi N N_{3,21}$ wave

Δ (\sim 3000) DECAY MODES

Δ(-	~ 3000) BRANCH	ING I	RATIOS	5	
$\Gamma(N\pi)/\Gamma_{\text{total}}$					Γ1/Γ
VALUE	DOCUMENT ID		TECN	COMMENT	
0.06 ±0.02	HENDRY	78	MPWA	$\pi N \rightarrow \pi$	N I _{3.11} wave
0.045 ± 0.02	HENDRY	78	MPWA	$\pi N \rightarrow \pi$	N K _{3.13} wave
0.03 ±0.01	HENDRY	78	MPWA	$\pi N \rightarrow \pi$	N L _{3.17} wave
0.025 ± 0.01	HENDRY	78	MPWA	$\pi N \rightarrow \pi$	N M _{3.19} wave
0.018±0.01	HENDRY	78	MPWA	$\pi N \rightarrow \pi$	N N _{3,21} wave
	△(~ 3000) FOOT	LNO.	ΓES		

CH	80	Toronto Conf. 3	Hendry	(KARLT) IJP
NDRY	78	PRL 41 222		· (IND, LBL) IJP
Also	81	ANP 136 1		(IND)

A BARYONS

$$(S=-1, I=0)$$

 $\Lambda^0 = uds$

Λ

$$I(J^P) = O(\frac{1}{2}^+)$$
 Status: ***

We have omitted some results that have been superseded by later experiments. See our earlier editions.

A MASS

The fit uses Λ , Σ^+ , Σ^0 , Σ^- mass and mass-difference measurements.

VALUE (MeV)	EVTS	DOCUMENT ID		TECN COMMENT	
1115.683 ± 0.006 OUR FI	T				
1115.683±0.006 OUR A	/ERAGE				
$1115.678 \pm 0.006 \pm 0.006$	20k	HARTOUNI	94	SPEC pp 27.5 GeV/c	
$1115.690 \pm 0.008 \pm 0.006$	18k	¹ HARTOUNI	94	SPEC pp 27.5 GeV/c	
• • • We do not use the	following	g data for averages	, fits	, limits, etc. • • •	
1115.59 ±0.08	935	HYMAN	72	HEBC	
1115.39 ±0.12	195	MAYEUR	67	EMUL	
1115.6 ±0.4		LONDON	66	нвс	
1115.65 ±0.07	488	² SCHMIDT	65	нвс	
1115.44 ±0.12		³ BHOWMIK	63	RVUE	

 $^{^1}$ We assume $\it CPT$ invariance: this is the $\overline{\it A}$ mass as measured by HARTOUNI 94. See below for the fractional mass difference, testing $\it CPT$.

$$(m_A - m_{\overline{A}}) / m_A$$

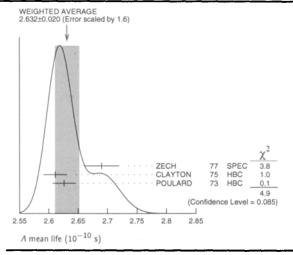
A test of CPT invariance.

VALUE (units 10 ⁻⁵) - 1.0 ± 0.9 OUR AVERAGE	DOCUMENT ID		TECN	COMMENT	
- 1.08 ± 0.90 - 26 ± 13 4.5 ± 5.4	HARTOUNI BADIER CHIEN	67	нвс	pp 27.5 GeV/c 2.4 GeV/c p̄p 6.9 GeV/c p̄p	

1 MEAN LIFE

Measurements with an error $\geq 0.1 \times 10^{-10}$ s have been omitted altogether, and only the latest high-statistics measurements are used for the average.

VALUE (10 ⁻¹⁰ s)	EVTS	DOCUMENT ID		TECN	COMMENT
2.632±0.020 OUR	AVERAGE	Error includes scale	facto	or of 1.6	. See the ideogram below.
2.69 ±0.03	53k	ZECH	77	SPEC	Neutral hyperon beam
2.611 ± 0.020	34k	CLAYTON	75	HBC	0.96-1.4 GeV/c K-p
2.626 ± 0.020	36k	POULARD	73	HBC	0.4-2.3 GeV/c K-p
• • • We do not us	e the followi	ng data for average:	s, fits	i, limits,	etc. • • •
2.69 ±0.05	6582	ALTHOFF	73B	OSPK	$\pi^+ n \rightarrow \Lambda K^+$
2.54 ±0.04	4572	BALTAY	71B	HBC	K [−] p at rest
2.535 ± 0.035	8342	GRIMM	68	HBC	
2.47 ±0.08	2600	HEPP	68	HBC	
2.35 ±0.09	916	BURAN	66	HLBC	
2.452 +0.056 -0.054	2213	ENGELMANN	66	нвс	
2.59 ±0.09	794	HUBBARD	64	HBC	
2.59 ±0.07	1378	SCHWARTZ	64	HBC	
2.36 ±0.06	2239	BLOCK	63	HEBC	



$$(\tau_A - \tau_{\overline{A}}) / \tau_{\text{average}}$$

A test of CPT invariance.

VALUE	DOCUMENT ID	TECN	COMMENT
0.044±0.085	BADIER 67	HBC	2.4 GeV/c pp

BARYON MAGNETIC MOMENTS

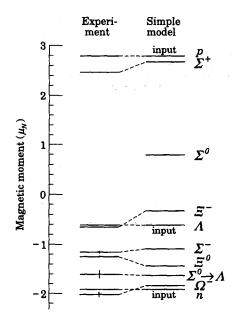
Written 1994 by C.G. Wohl (LBNL).

The figure shows the measured magnetic moments of the stable baryons. It also shows the predictions of the simplest quark model, using the measured p, n, and Λ moments as input. In this model, the moments are [1]

$$\begin{array}{ll} \mu_p = (4\mu_u - \mu_d)/3 & \mu_n = (4\mu_d - \mu_u)/3 \\ \mu_{\Sigma^+} = (4\mu_u - \mu_s)/3 & \mu_{\Sigma^-} = (4\mu_d - \mu_s)/3 \\ \mu_{\Xi^0} = (4\mu_s - \mu_u)/3 & \mu_{\Xi^-} = (4\mu_s - \mu_d)/3 \\ \mu_{\Lambda} = \mu_s & \mu_{\Sigma^0} = (2\mu_u + 2\mu_d - \mu_s)/3 \\ \mu_{\Omega^-} = 3\mu_s \end{array}$$

and the $\Sigma^0 \to \Lambda$ transition moment is

$$\mu_{\varSigma^0\Lambda} = (\mu_d - \mu_u)/\sqrt{3} \ .$$



²The SCHMIDT 65 masses have been reevaluated using our April 1973 proton and K^{\pm} and π^{\pm} masses. P. Schmidt, private communication (1974).

³ The mass has been raised 35 keV to take into account a 46 keV increase in the proton mass and an 11 keV decrease in the π^{\pm} mass (note added Reviews of Modern Physics **39** 1 (1967)).

The quark moments that result from this model are $\mu_u = +1.852 \, \mu_N$, $\mu_d = -0.972 \, \mu_N$, and $\mu_s = -0.613 \, \mu_N$. The corresponding effective quark masses, taking the quarks to be Dirac point particles, where $\mu = q\hbar/2m$, are 338, 322, and 510 MeV. As the figure shows, the model gives a good first approximation to the experimental moments. For efforts to make a better model, we refer to the literature [2].

References

- See, for example, D.H. Perkins, Introduction to High Energy Physics (Addison-Wesley, Reading, MA, 1987), or D. Griffiths, Introduction to Elementary Particles (Harper & Row, New York, 1987).
- See, for example, J. Franklin, Phys. Rev. D29, 2648 (1984);
 H.J. Lipkin, Nucl. Phys. B241, 477 (1984);
 K. Suzuki, H. Kumagai, and Y. Tanaka, Europhys. Lett. 2, 109 (1986);
 S.K. Gupta and S.B. Khadkikar, Phys. Rev. D36, 307 (1987);
 M.I. Krivoruchenko, Sov. J. Nucl. Phys. 45, 109 (1987);
 L. Brekke and J.L. Rosner, Comm. Nucl. Part. Phys. 18, 83 (1988);
 K.-T. Chao, Phys. Rev. D41, 920 (1990) and references

K.-T. Chao, Phys. Rev. **D41**, 920 (1990) and references cited therein Also, see references cited in discussions of results in the experimental papers..

A MAGNETIC MOMENT

See the "Note on Baryon Magnetic Moments" above. Measurements with an error $\geq 0.15~\mu_N$ have been omitted.

VALUE (μ _N)	EVTS	DOCUMENT ID		TECN	COMMENT
-0.613 ± 0.004	OUR AVERAGE				
-0.606 ± 0.015	200k	cox	81	SPEC	
-0.6138 ± 0.0047	3M	SCHACHIN	78	SPEC	
-0.59 ± 0.07	350k	HELLER	77	SPEC	
-0.57 ± 0.05	1.2M	BUNCE	76	SPEC	
-0.66 ± 0.07	1300	DAHL-JENSE	N 71	EMUL	200 kG field

A ELECTRIC DIPOLE MOMENT

A nonzero value is forbidden by both T invariance and P invariance.

VALUE (10 ⁻¹⁶ ecm)	CL%	DOCUMENT ID		<u>TECN</u>
< 1.5	95	⁴ PONDROM	81	SPEC
• • • We do not use t	he followi	ng data for average	es, flt	s, limits, etc. • • •
<100	95	5 BARONI	71	EMUL
<500	95	GIBSON	66	EMUL
⁴ PONDROM 81 me	asures (-	$3.0 \pm 7.4) \times 10^{-1}$	7 e-c	m.
⁵ BARONI 71 measu	res (- 5.9	± 2.9) × 10 ⁻¹⁵ e	-cm.	

A DECAY MODES

	Mode	Fraction (Γ _I /Γ)
$\overline{\Gamma_1}$	ρπ-	(63.9 ±0.5)%
Γ_2	$n\pi^0$	(35.8 ±0.5) %
Γ₃	πγ	$(1.75\pm0.15)\times10^{-3}$
Γ_{4}	$p\pi^-\gamma$	[a] (8.4 \pm 1.4) \times 10 ⁻⁴
Γ ₅	pe [−] ν̄ _e	$(8.32\pm0.14)\times10^{-4}$
Γ ₆	$p\mu^-\overline{\nu}_{\mu}$	$(1.57\pm0.35)\times10^{-4}$

[a] See the Particle Listings below for the pion momentum range used in this measurement.

CONSTRAINED FIT INFORMATION

An overall fit to 5 branching ratios uses 20 measurements and one constraint to determine 5 parameters. The overall fit has a $\chi^2=10.5$ for 16 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\langle \delta x_i \delta x_j \rangle / (\delta x_i \cdot \delta x_j)$, in percent, from the fit to the branching fractions, $x_i \equiv \Gamma_i / \Gamma_{\text{total}}$. The fit constrains the x_i whose labels appear in this array to sum to one.

A BRANCHING RATIOS

$\Gamma(p\pi^-)/\Gamma(N\pi)$					$\Gamma_1/(\Gamma_1+\Gamma_2)$
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.641±0.006 OUR FIT					•
0.640 ± 0.005 OUR AVE	RAGE				
0.646±0.008	4572	BALTAY	718	HBC	K-p at rest
0.635 ± 0.007	6736	DOYLE	69	HBC	$\pi^- p \rightarrow \Lambda K^0$
0.643±0.016	903	HUMPHREY	62	нвс	•
0.624±0.030		CRAWFORD		нвс	$\pi^- p \rightarrow \Lambda K^0$
$\Gamma(n\pi^0)/\Gamma(N\pi)$					$\Gamma_2/(\Gamma_1+\Gamma_2)$
VALUE	EVTS	DOCUMENT ID		TECN	
0.369±0.005 OUR FIT					
0.310±0.028 OUR AVE	ERAGE				
0.35 ±0.05		BROWN	63	HLBC	
0.291 ± 0.034	75	CHRETIEN	63	HLBC	
$\Gamma(n\gamma)/\Gamma_{\text{total}}$					Г3/Г
VALUE (units 10 ⁻³)	EVTS	DOCUMENT ID		TECN	COMMENT
1.75±0.15 OUR FIT					
1.75±0.15	1816	LARSON	93	SPEC	K [←] p at rest
We do not use the	he following	data for average	s, fits	, limits,	etc. • • •
	-	•			
$1.78 \pm 0.24 ^{+0.14}_{-0.16}$	287	NOBLE	92	SPEC	See LARSON 93
$\Gamma(n\gamma)/\Gamma(n\pi^0)$					Γ ₃ /Γ ₂
					-, -
VALUE (units 10 ⁻³)	EVTS	DOCUMENT ID		<u>TECN</u>	COMMENT
• • • We do not use to	he following	r data for average	c fits	. limits.	etc. • • •
		, anto ioi atciabe	-,		
2.86±0.74±0.57	24	BIAGI	86	SPEC	SPS hyperon beam
2.86±0.74±0.57	_				SPS hyperon beam
$2.86\pm0.74\pm0.57$ $\Gamma(\rho\pi^-\gamma)/\Gamma(\rho\pi^-)$	24	BIAGI		SPEC	SPS hyperon beam Γ_4/Γ_1
$2.86 \pm 0.74 \pm 0.57$ $\Gamma(\rho \pi^- \gamma) / \Gamma(\rho \pi^-)$ VALUE (units 10^{-3})	24 <i>EVTS</i>	BIAGI	86	SPEC TECN	SPS hyperon beam Γ ₄ /Γ ₁
$2.86\pm0.74\pm0.57$ $\Gamma(\rho\pi^-\gamma)/\Gamma(\rho\pi^-)$	24	BIAGI	86	SPEC	SPS hyperon beam Γ_4/Γ_1
$2.86 \pm 0.74 \pm 0.57$ $\Gamma(\rho \pi^- \gamma) / \Gamma(\rho \pi^-)$ VALUE (units 10^{-3})	24 <u>EVTS</u> 72	BIAGI	86	SPEC TECN	SPS hyperon beam Γ ₄ /Γ ₁
2.86±0.74±0.57 $\Gamma(\rho\pi^{-}\gamma)/\Gamma(\rho\pi^{-})$ VALUE (units 10 ⁻³) 1.32±0.22	24 <u>EVTS</u> 72	BIAGI	86	SPEC TECN	SPS hyperon beam $\frac{\Gamma_4/\Gamma_1}{comment}$ $\frac{comment}{\pi^- < 95 \text{ MeV}/c}$
2.86 ± 0.74 ± 0.57 $\Gamma(\rho\pi^{-}\gamma)/\Gamma(\rho\pi^{-})$ VALUE (units 10^{-3}) 1.32 ± 0.22 $\Gamma(\rho e^{-}V_{e})/\Gamma(\rho\pi^{-})$	24 EVTS 72 EVTS	BIAGI DOCUMENT ID BAGGETT	86	SPEC TECN HBC	SPS hyperon beam
2.86 \pm 0.74 \pm 0.57 $\Gamma(\rho\pi^{-}\gamma)/\Gamma(\rho\pi^{-})$ 1.32 \pm 0.22 $\Gamma(\rho e^{-}\nu_{e})/\Gamma(\rho\pi^{-})$ 1.44 UE (units 10 ⁻³)	24 EVTS 72 EVTS	BIAGI DOCUMENT ID BAGGETT	86	SPEC TECN HBC	SPS hyperon beam
2.86 \pm 0.74 \pm 0.57 $\Gamma(p\pi^-\gamma)/\Gamma(p\pi^-)$ 1.32 \pm 0.22 $\Gamma(pe^-\nu_e)/\Gamma(p\pi^-)$ VALUE (units 10^{-3}) 1.30 \pm 0.019 OUR FIT 1.301 \pm 0.019 OUR AVI	24 EVTS 72 EVTS	BIAGI DOCUMENT ID BAGGETT	86	SPEC TECN HBC	SPS hyperon beam
$\begin{array}{l} 2.86\pm 0.74\pm 0.57 \\ \Gamma(\rho\pi^-\gamma)/\Gamma(\rho\pi^-) \\ 1.32\pm 0.22 \\ \Gamma(\rho e^-\nu_e)/\Gamma(\rho\pi^-) \\ 1.30\pm 0.019 \text{ CUP FIT} \\ 1.301\pm 0.019 \text{ CUP FIT} \\ 1.301\pm 0.019 \text{ OUR AVI} \\ 1.335\pm 0.056 \end{array}$	EVTS EVTS EVTS	BIAGI DOCUMENT ID BAGGETT DOCUMENT ID	72C	SPEC TECN HBC	SPS hyperon beam
2.86 \pm 0.74 \pm 0.57 $ \Gamma(\rho\pi^-\gamma)/\Gamma(\rho\pi^-) $ 1.32 \pm 0.22 $ \Gamma(\rho e^-\nu_e)/\Gamma(\rho\pi^-) $ 1.301 \pm 0.019 OUR FIT 1.301 \pm 0.019 OUR AVI 1.313 \pm 0.024	EVTS 72 EVTS EVTS EVTS ERAGE 7111 10k	BIAGI DOCUMENT ID BAGGETT DOCUMENT ID BOURQUIN WISE	72C 83 80	SPEC TECN HBC TECN SPEC SPEC	SPS hyperon beam
2.86 \pm 0.74 \pm 0.57 $\Gamma(p\pi^-\gamma)/\Gamma(p\pi^-)$ 1.32 \pm 0.22 $\Gamma(pe^-\nu_e)/\Gamma(p\pi^-)$ 1.301 \pm 0.019 OUR FIT 1.301 \pm 0.019 OUR AVI 1.335 \pm 0.024 1.23 \pm 0.11	EVTS 72 EVTS FRAGE 7111 10k 544	BIAGI DOCUMENT ID BAGGETT DOCUMENT ID BOURQUIN WISE LINDQUIST	72C 83 80 77	SPEC TECN HBC TECN SPEC SPEC SPEC SPEC	SPS hyperon beam
2.86 \pm 0.74 \pm 0.57 $\Gamma(\rho\pi^-\gamma)/\Gamma(\rho\pi^-)$ 1.32 \pm 0.22 $\Gamma(\rho e^-\nu_e)/\Gamma(\rho\pi^-)$ MALUE (units 10^{-3}) 1.301 \pm 0.019 OUR FIT 1.301 \pm 0.019 OUR FIT 1.313 \pm 0.024 1.313 \pm 0.024 1.213 \pm 0.011 1.27 \pm 0.07	24 EVTS 72 EVTS FRAGE 7111 10k 544 1089	BIAGI DOCUMENT ID BAGGETT DOCUMENT ID BOURQUIN WISE LINDQUIST KATZ	83 80 77 73	SPEC TECN HBC TECN SPEC SPEC SPEC SPEC HBC	SPS hyperon beam
2.86 \pm 0.74 \pm 0.57 $\Gamma(\rho\pi^-\gamma)/\Gamma(\rho\pi^-)$ 1.32 \pm 0.22 $\Gamma(\rho e^- V_e)/\Gamma(\rho\pi^-)$ VALUE (units 10^{-3}) 1.301 \pm 0.019 OUR FIT 1.301 \pm 0.019 OUR AVI 1.335 \pm 0.056 1.313 \pm 0.024 1.23 \pm 0.11 1.27 \pm 0.07 1.31 \pm 0.06	24 EVTS 72 EVTS 72 EVTS FRAGE 7111 10k 544 1089 1078	BIAGI DOCUMENT ID BAGGETT DOCUMENT ID BOURQUIN WISE LINDQUIST KATZ ALTHOFF	83 80 77 73 71	SPEC TECN HBC SPEC SPEC SPEC SPEC HBC OSPK	SPS hyperon beam
2.86 \pm 0.74 \pm 0.57 $\Gamma(\rho\pi^-\gamma)/\Gamma(\rho\pi^-)$ 1.32 \pm 0.22 $\Gamma(\rho e^-\nu_e)/\Gamma(\rho\pi^-)$ 1.301 \pm 0.019 OUR FIT 1.301 \pm 0.019 OUR AVI 1.313 \pm 0.024 1.23 \pm 0.11 1.27 \pm 0.07 1.31 \pm 0.06 1.17 \pm 0.13	24 EVTS 72 EVTS ERAGE 7111 10k 544 1089 1078 86	BIAGI DOCUMENT ID BAGGETT DOCUMENT ID BOURQUIN WISE LINDQUIST KATZ ALTHOFF CANTER	72C 83 80 77 73 71 71	SPEC TECN HBC SPEC SPEC SPEC SPEC HBC OSPK HBC	SPS hyperon beam
2.86 \pm 0.74 \pm 0.57 $\Gamma(p\pi^-\gamma)/\Gamma(p\pi^-)$ 1.32 \pm 0.22 $\Gamma(pe^-\nu_e)/\Gamma(p\pi^-)$ 2.301 \pm 0.019 OUR FIT 1.301 \pm 0.019 OUR AVI 1.335 \pm 0.024 1.23 \pm 0.11 1.27 \pm 0.07 1.31 \pm 0.06 1.17 \pm 0.13 1.20 \pm 0.12	EVTS 72 EVTS 72 EVTS FRAGE 7111 10k 544 1089 1078 86 143	BIAGI DOCUMENT ID BAGGETT DOCUMENT ID BOURQUIN WISE LINDQUIST KATZ ALTHOFF 6 CANTER 7 MALONEY	83 80 77 73 71 71 69	SPEC TECN HBC TECN SPEC SPEC SPEC HBC OSPK HBC HBC	SPS hyperon beam
2.86 \pm 0.74 \pm 0.57 $\Gamma(\rho\pi^-\gamma)/\Gamma(\rho\pi^-)$ 1.32 \pm 0.22 $\Gamma(\rho e^- V_e)/\Gamma(\rho\pi^-)$ 1.301 \pm 0.019 OUR FIT 1.301 \pm 0.019 OUR FIT 1.301 \pm 0.019 OUR 1.315 \pm 0.024 1.23 \pm 0.11 1.27 \pm 0.07 1.31 \pm 0.06 1.17 \pm 0.13 1.20 \pm 0.12 1.21 \pm 0.12	EVTS 72 EVTS 72 EVTS FRAGE 7111 10k 544 1089 1078 86 143 120	BIAGI DOCUMENT ID BAGGETT BOURQUIN WISE LINDQUIST KATZ ALTHOFF 6 CANTER 7 MALONEY 7 BAGLIN	83 80 77 73 71 71 69 64	SPEC TECN HBC SPEC SPEC SPEC HBC OSPK HBC HBC FBC	SPS hyperon beam
2.86 \pm 0.74 \pm 0.57 $\Gamma(\rho\pi^-\gamma)/\Gamma(\rho\pi^-)$ 1.32 \pm 0.22 $\Gamma(\rhoe^-\nu_e)/\Gamma(\rho\pi^-)$ 1.301 \pm 0.019 OUR FIT 1.301 \pm 0.019 OUR AVI 1.303 \pm 0.024 1.23 \pm 0.11 1.27 \pm 0.07 1.31 \pm 0.06 1.17 \pm 0.13 1.20 \pm 0.12 1.17 \pm 0.18 1.23 \pm 0.20	24 EVTS 72 EVTS ERAGE 7111 10k 544 1089 1078 86 143 120 150	BIAGI DOCUMENT ID BAGGETT DOCUMENT ID BOURQUIN WISE LINDQUIST KATZ ALTHOFF CANTER MALONEY BAGLIN ELY ELY	83 80 77 73 71 71 69 64 63	SPEC TECN HBC SPEC SPEC SPEC HBC OSPK HBC HBC FBC FBC FBC	SPS hyperon beam
2.86 \pm 0.74 \pm 0.57 $\Gamma(\rho\pi^-\gamma)/\Gamma(\rho\pi^-)$ 1.32 \pm 0.22 $\Gamma(\rho e^- V_e)/\Gamma(\rho\pi^-)$ 1.301 \pm 0.019 OUR FIT 1.301 \pm 0.019 OUR FIT 1.301 \pm 0.019 OUR 1.315 \pm 0.024 1.23 \pm 0.11 1.27 \pm 0.07 1.31 \pm 0.06 1.17 \pm 0.13 1.20 \pm 0.12 1.21 \pm 0.12	24 EVTS 72 EVTS ERAGE 7111 10k 544 1089 1078 86 143 120 150	BIAGI DOCUMENT ID BAGGETT DOCUMENT ID BOURQUIN WISE LINDQUIST KATZ ALTHOFF 6 CANTER 7 MALONEY 7 BAGLIN 7 ELY g data for average	83 80 77 73 71 71 69 64 63 es, fits	SPEC TECN SPEC SPEC SPEC SPEC HBC OSPK HBC HBC FBC FBC FBC FBC Imilts,	SPS hyperon beam
2.86 \pm 0.74 \pm 0.57 $\Gamma(\rho\pi^-\gamma)/\Gamma(\rho\pi^-)$ 1.32 \pm 0.22 $\Gamma(\rhoe^-\nu_e)/\Gamma(\rho\pi^-)$ 1.301 \pm 0.019 OUR FIT 1.301 \pm 0.019 OUR AVI 1.303 \pm 0.024 1.23 \pm 0.11 1.27 \pm 0.07 1.31 \pm 0.06 1.17 \pm 0.13 1.20 \pm 0.12 1.17 \pm 0.18 1.23 \pm 0.20	24 EVTS 72 EVTS ERAGE 7111 10k 544 1089 1078 86 143 120 150	BIAGI DOCUMENT ID BAGGETT DOCUMENT ID BOURQUIN WISE LINDQUIST KATZ ALTHOFF CANTER MALONEY BAGLIN ELY ELY	83 80 77 73 71 71 69 64 63 es, fits	SPEC TECN SPEC SPEC SPEC SPEC HBC OSPK HBC HBC FBC FBC FBC FBC Imilts,	SPS hyperon beam
2.86 \pm 0.74 \pm 0.57 $\Gamma(\rho\pi^-\gamma)/\Gamma(\rho\pi^-)$ 1.32 \pm 0.22 $\Gamma(\rho e^-\nu_e)/\Gamma(\rho\pi^-)$ 1.301 \pm 0.019 OUR FIT 1.301 \pm 0.024 1.23 \pm 0.01 1.27 \pm 0.07 1.31 \pm 0.06 1.17 \pm 0.13 1.20 \pm 0.12 1.17 \pm 0.18 1.23 \pm 0.20 • • • We do not use t 1.32 \pm 0.15 ⁶ Changed by us fror	EVTS 72 EVTS FRAGE 7111 10k 544 1089 1078 86 143 120 150 he following 218	BIAGI DOCUMENT ID BAGGETT DOCUMENT ID BOURQUIN WISE LINDQUIST KATZ ALTHOFF 6 CANTER 7 MALONEY 7 BAGLIN 7 ELIY g data for average 6 LINDQUIST	83 80 77 73 71 71 69 64 63 es, fits	TECN HBC TECN SPEC SPEC SPEC SPEC HBC OSPK HBC HBC FBC FBC FBC S, limits,	SPS hyperon beam
2.86 \pm 0.74 \pm 0.57 $\Gamma(\rho\pi^-\gamma)/\Gamma(\rho\pi^-)$ 1.32 \pm 0.22 $\Gamma(\rho e^- V_e)/\Gamma(\rho\pi^-)$ 1.301 \pm 0.019 1.301 \pm 0.019 1.301 \pm 0.019 1.301 \pm 0.019 1.301 \pm 0.019 1.313 \pm 0.024 1.23 \pm 0.11 1.27 \pm 0.07 1.31 \pm 0.06 1.17 \pm 0.13 1.20 \pm 0.12 1.17 \pm 0.18 1.23 \pm 0.20 ••• We do not use to 2/3.	24 EVTS 72 FENAGE 7111 10k 1089 1078 86 143 120 150 the following 218 m \(\text{F} \) \(\rho e^{-1} BIAGI DOCUMENT ID BAGGETT BOURQUIN WISE LINDQUIST KATZ ALTHOFF 6 CANTER 7 MALONEY 7 BAGLIN 7 ELY 3 data for average 6 LINDQUIST e)/Γ(Nπ) assum	83 80 77 73 71 69 64 63 ss, fits	TECN HBC SPEC SPEC SPEC SPEC HBC OSPK HBC FBC FBC SI limits, i, limits, e author	SPS hyperon beam	

 $\Gamma(\rho\mu^-\overline{\nu}_\mu)/\Gamma(N\pi)$ $\Gamma_6/(\Gamma_1+\Gamma_2)$ VALUE (units 10-4) **EVTS** DOCUMENT ID TECN COMMENT 1.57±0.35 OUR FIT 1.57±0.35 OUR AVERAGE **BAGGETT** 72B HBC 1.4 ±0.5 K-p at rest 718 HBC 2.4 ±0.8 CANTER K-p at rest 1.3 ±0.7 LIND 64 RVUE 1.5 ±1.2 2 RONNE 64 FBC

A DECAY PARAMETERS

See the "Note on Baryon Decay Parameters" in the neutron Listings. Some early results have been omitted.

α_{-} FOR $\Lambda \rightarrow p\pi^{-}$

VALUE	<u>EVTS</u>	DOCUMENT ID		TECN	COMMENT	
0.642±0.013 OUR AV	ERAGE					
0.584 ± 0.046	8500	ASTBURY	75	SPEC		
0.649 ± 0.023	10325	CLELAND	72	OSPK		
0.67 ±0.06	3520	DAUBER	69	HBC	From = decay	
0.645 ± 0.017	10130	OVERSETH	67	OSPK	Λ from $\pi^- p$	
0.62 ±0.07	1156	CRONIN	63	CNTR	Λ from $\pi^- p$	

ANGLE FOR A → BT-

φ ANGLE FOR	$\Lambda \to p\pi^-$				$(\tan\phi=\beta\ /\ \gamma)$
VALUE (°)	EVTS	DOCUMENT ID		TECN	COMMENT
- 6.5± 3.5 OUR	AVERAGE				
-7.0 ± 4.5	10325	CLELAND	72	OSPK	$Λ$ from $π^-p$
-8.0 ± 6.0	10130	OVERSETH	67	OSPK	Λ from $π$ ⁻ $ρ$
13.0 ± 17.0	1156	CRONIN	63	OSPK	$Λ$ from $π^- p$

$\alpha_0 / \alpha_- = \alpha (\Lambda \rightarrow \ \pi \pi^0) / \alpha (\Lambda \rightarrow \ p \pi^-)$

VALUE	EVTS	DOCUMENT I	D	TECN	COMMENT	
1.01 ±0.07 O	UR AVERAGE					
1.000 ± 0.068	4760	⁸ OLSEN	70	OSPK	$\pi^+ n \rightarrow \Lambda K^+$	
1.10 ± 0.27		CORK	60	CNTR		

 $^{^{8}}$ OLSEN 70 compares proton and neutron distributions from $^{\Lambda}$ decay.

$\left[\alpha_{-}(\Lambda) + \alpha_{+}(\overline{\Lambda})\right] / \left[\alpha_{-}(\Lambda) - \alpha_{+}(\overline{\Lambda})\right]$ Zero if *CP* is conserved.

LUE	EVTS	DOCUMENT ID		<u>TECN</u>	COMMENT
0.03±0.06 OUR AVE	RAGE			_	
0.01 ± 0.10	770	TIXIER	88	DM2	$J/\psi \rightarrow \Lambda \overline{\Lambda}$
0.07±0.09	4063	BARNES	87	CNTR	pp → ΛΛ LEAR
0.02±0.14	10k	⁹ CHAUVAT	85	CNTR	pp, pp ISR
	0.03±0.06 OUR AVE 0.01±0.10 0.07±0.09	0.03±0.06 OUR AVERAGE 0.01±0.10 770 0.07±0.09 4063	0.03±0.06 OUR AVERAGE 0.01±0.10 770 TIXIER 0.07±0.09 4063 BARNES	0.03±0.06 OUR AVERAGE 0.01±0.10 770 TIXIER 88 0.07±0.09 4063 BARNES 87	0.03±0.06 OUR AVERAGE 0.01±0.10 770 TIXIER 88 DM2 0.07±0.09 4063 BARNES 87 CNTR

 9 CHAUVAT 85 actually gives $\alpha_+(\overline{\Lambda})/\alpha_-(\Lambda)=-1.04\pm0.29.$ Assumes polarization is same in $\overline{\rho}p\to\overline{\Lambda}X$ and $pp\to\Lambda X$. Tests of this assumption, based on C-invariance and fragmentation, are satisfied by the data.

BA / BV FOR A → pe¬¬¬e

Measurements with fewer than 500 events have been omitted. Where necessary, signs have been changed to agree with our conventions, which are given in the "Note on Baryon Decay Parameters" in the neutron Listings. The measurements all assume that the form factor g₂ = 0. See also the footnote on DWORKIN 90.

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT	
-0.718±0.015 OUR AV	ERAGE					
$-0.719\pm0.016\pm0.012$	37k	¹⁰ DWORKIN	90	SPEC	ev angular corr.	
-0.70 ± 0.03	7111	BOURQUIN	83	SPEC	$\Xi \rightarrow \Lambda \pi^-$	
-0.734 ± 0.031	10k	¹¹ WISE	81	SPEC	ev angular correl.	
• • • We do not use th	e followii	ng data for average	s, fits	s, limits,	etc. • • •	
-0.63 ± 0.06	817	ALTHOFF	73	OSPK	Polarized A	

A REFERENCES

We have omitted some papers that have been superseded by later experiments. See our earlier editions.

HARTOUNI	94	PRL 72 1322	+ Jensen, Kreisler+ (BNL E766 Collab.)
Also	94B	PRL 72 2821 (erratum)	Hartouni, Jensen+ (BNL E766 Collab.)
LARSON	93	PR D47 799	+Noble, Bassalleck+ (BNL-811 Collab.)
NOBLE DWORKIN	92 90	PRL 69 414	+ (BIRM, BOST, BRCO, BNL, CASE, BUDA, LANL+)
TIXIER	90 88	PR D41 780 PL B212 523	+Cox, Dukes, Overseth+ (MICH, WISC, RUTG, MINN) +Ajaltouni, Falvard, Jousset+ (DM2 Collab.)
BARNES	87	PL B199 147	+ (CMU, SACL, LANL, VIEN, FREIB, ILL, UPPS+)
BIAGI	86	ZPHY C30 201	+ (BRIS, CERN, GEVA, HEIDP, LAUS, LOQM, RAL)
CHAUVAT	85	PL 163B 273	+Erhan, Haves+ (CERN, CLER, UCLA, SACL)
BOURQUIN	83	ZPHY C21 1	+Brown+ (BRIS, GEVA, HEIDP, LALO, RL, STRB)
COX	81	PRL 46 877	+Dworkin+ (MICH, WISC, RUTG, MINN, BNL)
PONDROM	81	PR D23 814	+Handler, Sheaff, Cox+ (WISC, MICH, RUTG, MINN)
WISE	81	PL 98B 123	+Jensen, Kreisler, Lomanno, Poster+ (MASA, BNL)
WISE	80	PL 91B 165	+Jensen, Kreisler, Lomanno, Poster+ (MASA, BNL)
SCHACHIN	78	PRL 41 1348	Schachinger, Bunce, Cox+ (MICH, RUTG, WISC)
HELLER	77	PL 68B 480	+Overseth, Bunce, Dydak+ (MICH, WISC, HEIDH)
LINDQUIST	77	PR D16 2104	+Swallow, Sumner+ (EFI, OSU, ANL)
Also	76	JPG 2 L211	Lindquist, Swallow+ (EFI, WUSL, OSU, ANL)
ZECH	77	NP B124 413	+Dydak, Navarria+ (SIEG, CERN, DORT, HEIDH)
BUNCE	76	PRL 36 1113	+Handler, March, Martin+ (WISC, MICH, RUTG)
ASTBURY	75	NP B99 30	+Gallivan, Jafar+ (LOIC, CERN, ETH, SACL)
CLAYTON	75	NP B95 130	+Bacon, Butterworth, Waters+ (LOIC, RHEL)
ALTHOFF	73	PL 43B 237	+Brown, Freytag, Heard, Heintze+ (CERN, HEID)
ALTHOFF	73B	NP B66 29	+Brown, Freytag, Heard, Heintze+ (CERN, HEID)
KATZ	73	Thesis MDDP-TR-74-04	(UMD)
POULARD	73	PL 46B 135	+Givernaud, Borg (SACL)
BAGGETT	72B	ZPHY 252 362	+Baggett, Eisele, Filthuth, Frehse+ (HEID)
BAGGETT	72C	PL 42B 379	+Baggett, Eisele, Filthuth, Frehse, Hepp+ (HEID)
CLELAND	72	NP B40 221	+Conforto, Eaton, Gerber+ (CERN, GEVA, LUND)
HYMAN	72	PR D5 1063	+Bunnell, Derrick, Fields, Katz+ (ANL, CMU)
ALTHOFF	71	PL 37B 531	+Brown, Freytag, Heard, Heintze+ (CERN, HEID)
BALTAY	71B	PR D4 670	+Bridgewater, Cooper, Habibi+ (COLU, BING)
BARONI	71	LNC 2 1256	+Petrera, Romano (ROMA)
CANTER	71	PRL 26 868	+Cole, Lee-Franzini, Loveless+ (STON, COLU)
CANTER	718	PRL 27 59	+Cole, Lee-Franzini, Loveless+ (STON, COLU)
DAHL-JENSEN		NC 3A 1	+ (CERN, ANKA, LAUS, MPIM, ROMA)
LINDQUIST	71	PRL 27 612	+Summer+ (EFI, WUSL, OSU, ANL)
OLSEN	70 69	PRL 24 843	+Pondrom, Handler, Limon, Smith+ (WISC, MICH)
DAUBER	69	PR 179 1262 Thesis UCRL 18139	+Berge, Hubbard, Merrill, Miller (LRL) (LRL)
DOYLE MALONEY	69	PRL 23 425	+Sechi-Zorn (UMD)
GRIMM	68	NC 54A 187	(HEID)
HEPP	68	ZPHY 214 71	+Schleich (HEID)
BADIER	67	PL 258 152	+Bonnet, Briandet, Sadoulet (EPOL)
MAYEUR	67	U.Libr.Brux.Bul. 32	+Tompa, Wickens (BELG, LOUC)
OVERSETH	67	PRL 19 391	+Roth (MICH, PRIN)
PDG	67	RMP 39 1	Rosenfeld, Barbaro-Galtleri, Podolsky+ (LRL, CERN, YALE)
BURAN	66	PL 20 318	+Eivindson, Skjeggestad, Tofte+ (OSLO)
CHIEN	66	PR 152 1171	+Lach, Sandweiss, Taft, Yeh, Oren+ (YALE, BNL)
ENGELMANN	66	NC 45A 1038	+Filthuth, Alexander+ (HEID, REHO)
GIBSON	66	NC 45A 882	+Green (BRIS)
LONDON	66	PR 143 1034	+Rau, Goldberg, Lichtman+ (BNL, SYRA)
SCHMIDT	65	PR 140B 1328	(COLU)
BAGLIN	64	NC 35 977	+Bingham+ (EPOL, CERN, LOUC, RHEL, BERG)
HUBBARD	64	PR 135B 183	+Berge, Kalbfleisch, Shafer+ (LRL)
LIND	64	PR 135B 1483	+Binford, Good, Stern (WISC)
RONNE	64	PL 11 357	+ (CERN, EPOL, LOUC, BERG+)
SCHWARTZ	64	Thesis UCRL 11360	(LRL)
BHOWMIK	63	NC 28 1494	+Goyal (DELH)
BLOCK	63	PR 130 766	+Gessaroli, Ratti+ (NWES, BGNA, SYRA, ORNL)
BROWN	63	PR 130 769	+Kadyk, Trilling, Roe+ (LRL, MICH)
CHRETIEN	63	PR 131 2208	+ (BRAN, BROW, HARV, MIT)
CRONIN	63	PR 129 1795	+Overseth (PRIN)
ELY	63	PR 131 868	+Gidal, Kalmus, Oswald, Powell+ (LRL)
HUMPHREY	62	PR 127 1305	+Ross (LRL)
CORK	60	PR 120 1000	+Kerth, Wenzel, Cronin+ (LRL, PRIN, BNL)
CRAWFORD	59B	PRL 2 266	+Cresti, Douglass, Good, Ticho+ (LRL)

¹⁰ The tabulated result assumes the weak-magnetism coupling $w\equiv g_W(0)/g_V(0)$ to be 0.97, as given by the CVC hypothesis and as assumed by the other listed measurements. However, DWORKIN 90 measures w to be 0.15 \pm 0.30, and then $g_A/g_V=-0.731$ \pm 0.016.

^{0.016.} 11 This experiment measures only the absolute value of g_A/g_V .

Baryon Particle Listings Λ 's and Σ 's

Λ AND Σ RESONANCES

Introduction: There are no new results at all on Λ and Σ resonances. The field remains at a standstill and will only be revived if a kaon factory is built. What follows is a much abbreviated version of the note on Λ and Σ Resonances from our 1990 edition. In particular, see that edition for some representative Argand plots from partial-wave analyses.

Table 1 is an attempt to evaluate the status, both overall and channel by channel, of each Λ and Σ resonance in the Particle Listings. The evaluations are of course partly subjective. A blank indicates there is no evidence at all: either the relevant couplings are small or the resonance does not really exist. The main Baryon Summary Table includes only the established resonances (overall status 3 or 4 stars). A number of the 1- and 2-star entries may eventually disappear, but there are certainly many resonances yet to be discovered underlying the established ones.

Sign conventions for resonance couplings: In terms of the isospin-0 and -1 elastic scattering amplitudes A_0 and A_1 , the amplitude for $K^-p \to \overline{K}^0n$ scattering is $\pm (A_1 - A_0)/2$, where the sign depends on conventions used in conjunction with the Clebsch-Gordan coefficients (such as, is the baryon or the meson the "first" particle). If this reaction is partial-wave analyzed and if the overall phase is chosen so that, say, the $\mathcal{L}(1775)D_{15}$ amplitude at resonance points along the positive imaginary axis (points "up"), then any \mathcal{L} at resonance will point "up" and any \mathcal{L} at resonance will point "up" and any \mathcal{L} at resonance determines the isospin. The above ignores background amplitudes in the resonating partial waves.

That is the basic idea. In a similar but somewhat more complicated way, the phases of the $\overline{K}N \to \Lambda\pi$ and $\overline{K}N \to \Sigma\pi$ amplitudes for a resonating wave help determine the SU(3) multiplet to which the resonance belongs. Again, a convention has to be adopted for some overall arbitrary phases: which way is "up"? Our convention is that of Levi-Setti [1] and is shown in Fig. 1, which also compares experimental results with theoretical predictions for the signs of several resonances. In the Listings, a + or - sign in front of a measurement of an inelastic resonance coupling indicates the sign (the absence of a sign means that the sign is not determined, not that it is positive). For more details, see Appendix II of our 1982 edition [2].

Table 1. The status of the Λ and Σ resonances. Only those with an overall status of *** or **** are included in the main Baryon Summary Table.

				Stat	in —	
Particle	$L_{I\cdot 2J}$	Overall status	$N\overline{K}$	Λπ	$\Sigma\pi$	Other channels
Λ(1116)	P_{01}	****		F		$N\pi$ (weakly)
$\Lambda(1405)$	S_{01}	****	****	o	****	, -,
$\Lambda(1520)$	D_{03}	****	****	г	****	$\Lambda\pi\pi,\Lambda\gamma$
$\Lambda(1600)$	P_{01}	***	***	b	**	
$\Lambda(1670)$	S_{01}	****	****	i	****	$\Lambda\eta$
A(1690)	D_{03}	****	****	d	****	$\Lambda\pi\pi, \Sigma\pi\pi$
$\Lambda(1800)$	S_{01}	***	***	d	**	$N\overline{K}^*, \Sigma(1385)\pi$
A(1810)	P_{01}	***	***	e	**	$N\overline{K}^*$
A(1820)	F_{05}	****	****	n	****	$\Sigma(1385)\pi$
A(1830)	D_{05}	****	***	F	****	$\Sigma(1385)\pi$
A(1890)	P_{03}	****	****	0	**	$N\overline{K}^*, \Sigma(1385)\pi$
A(2000)	-	*		r	*	$\Lambda\omega, N\overline{K}^*$
$\Lambda(2020)$	F_{07}	*	*	b	*	, - :
$\Lambda(2100)$	G_{07}	****	****	i	***	$arLambda\omega, N\overline{K}^*$
$\Lambda(2110)$	F_{05}	***	**	d	*	$\Lambda\omega$, $N\overline{K}^*$
$\Lambda(23110)$ $\Lambda(2325)$	D_{03}	*	*	u d	*	$\Lambda\omega$, $\Lambda\kappa$
$\Lambda(2350)$	D_{03}	***	***	e	*	7100
$\Lambda(2585)$		**	**	п	•	
		**				
$\Sigma(1193)$	P_{11}	****				$N\pi(ext{weakly})$
$\Sigma(1385)$	P_{13}	****		****	****	
$\Sigma(1480)$		*	*	*	*	
$\Sigma(1560)$	_	**		**	**	
$\Sigma(1580)$		**	*	*		
$\Sigma(1620)$	S_{11}	**	**	*	*	
$\Sigma(1660)$		***	***	*	**	1 41
$\Sigma(1670)$	D_{13}	****	****	****	****	several others
$\Sigma(1690)$		**	*	**	*	$\Lambda\pi\pi$
$\Sigma(1750)$	S_{11}	***	***	**	*	$\Sigma\eta$
$\Sigma(1770)$		*				several others
$\Sigma(1775)$		****	****	****	***	several others
$\Sigma(1840)$		*	*		*	$N\overline{K}^*$
$\Sigma(1880)$		**	**	**		*
$\Sigma(1915)$		****	***	****	***	$\Sigma(1385)\pi$
$\Sigma(1940)$		***	*	***	**	quasi-2-body
$\Sigma(2000)$		*		*		$N\overline{K}^*$, $\Lambda(1520)\pi$
$\Sigma(2030)$		****	****	***	**	several others
$\Sigma(2070)$		*	*		*	
$\Sigma(2080)$		**		**		
$\Sigma(2100)$	G_{17}	*		*	*	
$\Sigma(2250)$		***	***	*	*	
$\Sigma(2455)$		**	*			
$\Sigma(2620)$		**	*			
$\Sigma(3000)$		*	*	*		1,11
$\Sigma(3170)$		*				multi-body

^{****} Existence is certain, and properties are at least fairly well explored.

*** Existence ranges from very likely to certain, but further confirmation is desirable and/or quantum numbers, branching fractions, etc. are not well determined.

Errors on masses and widths: The errors quoted on resonance parameters from partial-wave analyses are often only statistical, and the parameters can change by more than these errors when a different parametrization of the waves is used.

^{**} Evidence of existence is only fair.

^{*} Evidence of existence is poor

Λ 's and Σ 's, Λ (1405)

Furthermore, the different analyses use more or less the same data, so it is not really appropriate to treat the different determinations of the resonance parameters as independent or to average them together. In any case, the spread of the masses, widths, and branching fractions from the different analyses is certainly a better indication of the uncertainties than are the quoted errors. In the Baryon Summary Table, we usually give a range reflecting the spread of the values rather than a particular value with error.

For three states, the $\Lambda(1520)$, the $\Lambda(1820)$, and the $\Sigma(1775)$, there is enough information to make an overall fit to the various branching fractions. It is then necessary to use the quoted errors, but the errors obtained from the fit should not be taken seriously.

Production experiments: Partial-wave analyses of course separate partial waves, whereas a peak in a cross section or an invariant mass distribution usually cannot be disentangled from background and analyzed for its quantum numbers; and more than one resonance may be contributing to the peak. Results from partial-wave analyses and from production experiments are generally kept separate in the Listings, and in the Baryon Summary Table results from production experiments are used only for the low-mass states. The $\Sigma(1385)$ and $\Lambda(1405)$ of course lie below the $\overline{K}N$ threshold and nearly everything about them is learned from production experiments; and production and formation experiments agree quite well in the case of $\Lambda(1520)$ and results have been combined. There is some disagreement between production and formation experiments in the 1600-1700 MeV region: see the note on the $\Sigma(1670)$.

References

- R. Levi-Setti, in Proceedings of the Lund International Conference on Elementary Particles (Lund, 1969), p. 339.
- 2. Particle Data Group, Phys. Lett. 111B (1982).

 $\Lambda(1405) S_{01}$

 $I(J^P) = 0(\frac{1}{2})$ Status: ***

NOTE ON THE $\Lambda(1405)$

Revised March 1998 by R.H. Dalitz (Oxford University).

It is generally accepted that the $\Lambda(1405)$ is a well-established $J^P = 1/2^-$ resonance. It is assigned to the lowest L = 1supermultiplet of the 3-quark system and paired with the $J^P = 3/2^- \Lambda(1520)$. Lying about 30 MeV below the $N\overline{K}$ threshold, the $\Lambda(1405)$ can be observed directly only as a resonance bump in the $(\Sigma\pi)^0$ subsystem in final states of production experiments. It was first reported by ALSTON 61B in the reaction $K^-p \to \Sigma \pi \pi \pi$ at 1.15 GeV/c and has since been seen in at least eight other experiments. However, only two of them had enough events for a detailed analysis: THOMAS 73, with about 400 $\Sigma^{\pm}\pi^{\mp}$ events from $\pi^{-}p \to K^{0}(\Sigma\pi)^{0}$ at 1.69 GeV/c; and HEMINGWAY 85, with 766 $\Sigma^{+}\pi^{-}$ and 1106 $\Sigma^-\pi^+$ events from $K^-p \to (\Sigma\pi\pi)^+\pi^-$ at 4.2 GeV/c, after the selections $1600 \le M(\Sigma \pi \pi)^+ \le 1720$ MeV and momentum transfer $\leq 1.0 \; (\text{GeV}/c)^2$ to purify the $\Lambda(1405) \to (\Sigma \pi)^0$ sample. These experiments agree on a mass of about 1395-1400 MeV and a width of about 60 MeV. (Hemingway's mass of 1391 \pm 1 MeV is from his best, but unacceptably poor, Breit-Wigner fit.)

The Byers-Fenster tests on these data allow any spin and either parity: neither J nor P has yet been determined directly. The early indications for $J^P=1/2^-$ came from finding Re $A_{I=0}$ to be large and negative in a constant-scattering-length analysis of low-energy $N\overline{K}$ reaction data (see KIM 65, SAKITT 65, and earlier references cited therein). The first multichannel energy-dependent K-matrix analysis (KIM 67) strengthened the case for a resonance around 1400–1420 MeV strongly coupled to the I=0 S-wave $N\overline{K}$ system.

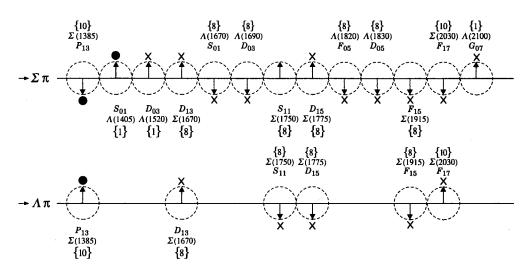


Figure 1. The signs of the imaginary parts of resonating amplitudes in the $\overline{K}N \to \Lambda\pi$ and $\Sigma\pi$ channels. The signs of the $\Sigma(1385)$ and $\Lambda(1405)$, marked with a \bullet , are set by convention, and then the others are determined relative to them. The signs required by the SU(3) assignments of the resonances are shown with an arrow, and the experimentally determined signs are shown with an \times .

Λ(1405)

THOMAS 73 and HEMINGWAY 85 both found the $\Lambda(1405)$ bump to be asymmetric and not well fitted by a Breit-Wigner resonance function with constant parameters. The asymmetry involves a rapid fall in intensity as the $N\overline{K}$ threshold energy is approached from below. This is readily understood as due to a strong coupling of the $\Lambda(1405)$ to the S-wave $N\overline{K}$ channel (see DALITZ 81). This striking S-shaped cusp behavior at a new threshold is characteristic of S-wave coupling; the other below-threshold hyperon, the $\Sigma(1385)$, has no such threshold distortion because its $N\overline{K}$ coupling is P-wave. For the $\Lambda(1405)$, this asymmetry is the sole direct evidence that $J^P=1/2^-$.

Following the early work cited above, a considerable literature has developed on proper procedures for phenomenological extrapolation below the $N\overline{K}$ threshold, partly in order to strengthen the evidence for the spin-parity of the $\Lambda(1405)$, and partly to provide an estimate for the amplitude $f(N\overline{K})$ in the unphysical domain below the $N\overline{K}$ threshold; the latter is needed for the evaluation of the dispersion relation for $N\overline{K}$ and NK forward scattering amplitudes. For recent reviews, see MILLER 84 and BARRETT 89. In most recent work, the $(\Sigma\pi)^0$ production spectrum is included in the data fitted (see, e.g., CHAO 73, MARTIN 81).

It is now accepted that the data can be fitted only with an S-wave pole in the reaction amplitudes below $N\overline{K}$ threshold (see, however, FINK 90), but there is still controversy about the physical origin of this pole (for a review, see DALITZ 81 and DALITZ 82). Two extreme possibilities are: (a) an L=1 SU(3)-singlet uds state coupled with the S-wave meson-baryon systems; or (b) an unstable $N\overline{K}$ bound state, analogous to the (stable) deuteron in the NN system. The problem with (a) is that the $\Lambda(1405)$ mass is so much lower than that of its partner, the $\Lambda(1520)$. This requires, in the QCD-inspired quark model, rather large spin-orbit couplings, whether or not one uses relativistic kinetic energies. CAPSTICK 86 and CAPSTICK 89 conclude that a proper QCD calculation leads only to small energy splittings, whereas LEINWEBER 90, using QCD sum rules, obtains a good fit to this splitting.

On the other hand, the problem with (b) is that then another $J^P=1/2^-\Lambda$ is needed to replace the $\Lambda(1405)$ in the L=1 supermultiplet, and it would have to lie close to the $\Lambda(1520)$, a region already well explored by $N\overline{K}$ experiments without result. Intermediate structures are possible; for example, the cloudy bag model allows the configurations (a) and (b) to mix and finds the intensity of (a) in the $\Lambda(1405)$ to be only 14% (VEIT 84, VEIT 85, JENNINGS 86). Such models naturally predict a second $1/2^-\Lambda$ close to the $\Lambda(1520)$.

The determination of the mass and width of the resonance from $(\Sigma\pi)^0$ data is usually based on the "Watson approximation," which states that the production rate $R(\Sigma\pi)$ of the $(\Sigma\pi)^0$ state has a mass dependence proportional to $(\sin^2\delta_{\Sigma\pi})/q$, q being the $\Sigma\pi$ c.m. momentum, in a $\Sigma\pi$ mass range where $\delta_{\Sigma\pi}$ is not far from $\pi/2$ and only the $\Sigma\pi$ channel is open, i.e., between the $\Sigma\pi$ and the $N\overline{K}$ thresholds. Then $qR(\Sigma\pi)$ is proportional to $\sin^2\delta_{\Sigma\pi}$, and the mass M may be defined as the energy at

which $\sin^2 \delta_{\Sigma\pi} = 1$. The width Γ may be determined from the rate at which $\delta_{\Sigma\pi}$ goes through $\pi/2$, or from the FWHM; this is a matter of convention.

This determination of M and Γ from the data suffers from the following defects:

- (i) The determination of $\sin^2 \delta_{\Sigma\pi}$ requires that $R(\Sigma\pi)$ be scaled to give $\sin^2 \delta_{\Sigma\pi} = 1$ at the peak for the best fit to the data; *i.e.*, the bump must be assumed to arise from a resonance. However, this assumption is supported by the analysis of the low-energy $N\overline{K}$ data and its extrapolation below threshold.
- (ii) Owing to the nearby $N\overline{K}$ threshold, the shape of the best fit to the $M(\Sigma\pi)$ bump is uncertain. For energies below this threshold at $E_{N\overline{K}}$, the general form for $\delta_{\Sigma\pi}$ is

$$q \cot \delta_{\Sigma\pi} = \frac{1 + \kappa\alpha}{\gamma + \kappa(\alpha\gamma - \beta^2)} \ . \tag{1}$$

Here α, β , and γ are the (generally energy-dependent) NN, $N\Sigma$, and $\Sigma\Sigma$ elements of the I=0 S-wave K-matrix for the $(\Sigma\pi, N\overline{K})$ system, and κ is the magnitude of the (imaginary) c.m. momentum k_K for the $N\overline{K}$ system below threshold. The elements α, β, γ are real functions of E; they have no branch cuts at the $\Sigma\pi$ and $N\overline{K}$ thresholds, but they are permitted to have poles in E along the real E axis. The resonance asymmetry arises from the effect of κ on $\delta_{\Sigma\pi}$. We note that $\delta_{\Sigma\pi}=\pi/2$ when $\kappa=-1/\alpha$.

Accepting this close connection of $\delta_{\Sigma\pi}$ with the low-energy $N\overline{K}$ data, it is natural to analyze the two sets of data together (e.g., MARTIN 81), and there is now a large body of accurate $N\overline{K}$ data for laboratory momenta between 100 and 300 MeV/c (see MILLER 84). The two sets of data span c.m. energies from 1370 MeV to 1490 MeV, and the K-matrix elements will not be energy independent over such a broad range. For the I =0 channels, a linear energy dependence for K^{-1} has been adopted routinely ever since the work of KIM 67, and it is essential when fitting the $qR(\Sigma\pi)$ and $N\overline{K}$ data together. However, $qR(\Sigma\pi)$ is not always well fitted in this procedure; the value obtained for the $\Lambda(1405)$ mass M varies a good deal with the type of fit, not a surprising result when the $\Sigma\pi$ mass spectrum below the pK^- threshold contributes only nine data points in a total of about 200. The value of M obtained from an overall fit is not necessarily much better than from one using only the $qR(\Sigma\pi)$ data; and M may be a function of the representation— K-matrix, K⁻¹-matrix, relativistic-separable or nonseparable potentials, etc.— used in fitting over the full energy range. DALITZ 91 fitted the $qR(\Sigma^+\pi^-)$ Hemingway data with each of the first three representations just mentioned, constrained to the I=0 $N\overline{K}$ threshold scattering length from low-energy $N\overline{K}$ data. The (nonseparable) meson-exchange potentials of MÜLLER-GROELING 90, fitted to the low-energy $N\overline{K}$ (and NK) data, predicted an unstable $N\overline{K}$ bound state with mass and width compatible with the $\Lambda(1405)$.

From the measurement of $2p \to 1s$ x rays from kaonic-hydrogen, the energy-level shift ΔE and width Γ of its 1s state can give us two further constraints on the $(\Sigma \pi, N\overline{K})$

Baryon Particle Listings $\Lambda(1405)$

system, at an energy roughly midway between those from the low-energy hydrogen bubble chamber studies and those from $q R(\Sigma \pi)$ observations below the pK^- threshold. IWASAKI 97 have reported the first convincing observation of this x ray, with a good initial estimate:

$$\Delta E - i\Gamma/2 = (-323 \pm 63 \pm 11) - i(204 \pm 104 \pm 50) \text{ eV}$$
. (2)

The errors here encompass about half of the predictions made following the various analyses and/or models for the in-flight K^-p and sub-threshold $q\,R(\varSigma\pi)$ data. Better measurements will be needed to discriminate between the analyses and predictions. Now that ΔE is known with some certainty, we can anticipate much-improved data on kaonic-hydrogen, perhaps from the DA Φ NE storage ring at Frascati, information vital for our quantitative understanding of the $(\varSigma\pi, N\overline{K})$ system in this region. This will lead to better knowledge of kaonic coupling strengths and to more reliable dispersion-theoretic arguments concerning strange-particle processes.

The present status of the $\Lambda(1405)$ thus depends heavily on theoretical arguments, a somewhat unsatisfactory basis for a four-star rating. Nevertheless, there is no known reason to doubt its existence or quantum numbers. The 3-quark model for baryons has been broadly successful in accounting for all of the $L^P = 1^-$ excited baryonic states (CAPSTICK 89), apart from the relatively large mass separation between the $\Lambda(1405)$ and $\Lambda(1520)$. Quark model builders have no reservations about accepting the $\Lambda(1405)$ as a 3-quark state. However, calculations with broken-chiral-symmetric models, which combine internal 3-quark configurations with external meson-baryon states (e.g.,VEIT 85, KAISER 95) end up with descriptions of the $\Lambda(1405)$ dominated by the meson-baryon terms in the wavefunctions. Models using meson-baryon potentials readily fit its mass, and give ΔE negative, as is found empirically. The problem is not so much one of "either (a) or (b)," but rather how to achieve "both (a) and (b)." Theoreticians have not yet been able to deal with the full coupled-channels system, with qqq and $qqqq\overline{q}$ configurations (at the least) being treated on the same footing. On the experimental side, better statistics are needed, both above and below the pK^- threshold. To disentangle the physics, the I = 1 channels also need more attention. For example, low-energy pK_L^0 interactions have not been studied at all in the last 25 years.

A(1405) MASS

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
1406.5± 4.0		¹ DALITZ	91		M-matrix fit
• • • We do not us	e the followin	ng data for averages	, fits	, limits,	etc. • • •
1391 ± 1	700	1 HEMINGWAY	85	нвс	K-p 4.2 GeV/c
~ 1405	400	² THOMAS	73	HBC	π p 1.69 GeV/c
1405	120	BARBARO	688	DBC	K- d 2.1-2.7 GeV/c
1400 ± 5	67	BIRMINGHAM	66	HBC	K-p 3.5 GeV/c
1382 ± 8		ENGLER	65	HDBC	$\pi^- \rho$, $\pi^+ d$ 1.68 GeV/
1400 ±24		MUSGRAVE	65	HBC	pp 3-4 GeV/c
1410		ALEXANDER	62	HBC	$\pi^- p 2.1 \text{ GeV}/c$
1405		ALSTON	62	HBC	K-ρ 1.2-0.5 GeV/c
1405		ALSTON	61B	HBC	$K^- p 1.15 \text{ GeV}/c$

0 ±20 5 ± 5		ANDER 62	HBC	
0 0	ALST(HBC HBC	
EXTRAPOLATIONS B				
ALUE (MeV) ■ • We do not use the f	-			COMMENT etc. • • •
0	3 MART			K-matrix fit
5 0	^{4,6} CHAO MART			0-range fit (sol. B) Constant K-matrix
9 ±6	MART		HBC	Constant K-matrix
0 ±5	KIM	67	HBC	K-matrix fit
4.1±4.1	⁵ KITTE KIM	EL 66 65	HBC HBC	
7.0±3.2 8.2±4.1	5 SAKIT		HBC	
	∧(1405) Di	CAY MOI	DES	
Mode		Frac	tion (Γ ₁ /	' (T)
1 Σπ		100		
2 Λγ				
$\Sigma^0 \gamma$				
4 NK				
	Λ(1405) PAF	RTIAL WIE	THS	
$(\Lambda \gamma)$				
ALUE (keV) • • We do not use the f			COMME s limits	
7±8	-	HARDT 91		
	Вокк	HANDI 31	130001	-
$(\Sigma^0 \gamma)$				r
ALUE (keV)		MENT ID		
• We do not use the f	ollowing data for	averages, fit	s, limits,	etc. • • •
0 ± 4 or 23 ± 7	BURK	HARDT 91	Isobar	model fit
	A(1405) BRAI	NCHING R	ATIOS	***************************************
$\Gamma(N\overline{K})/\Gamma(\Sigma\pi)$	/·(=100) D/0 !!			Γ4/Γ
	L% DOCUM	4ENT ID	<u>TECN</u>	
• We do not use the f	ollowing data for	averages, flt	s, limits,	etc. • • •
<3 9	5 HEMII	NGWAY 85	нвс	K- p 4.2 GeV/c
		OOTNOT		

⁶ An asymmetric shape, with $\Gamma/2 = 41$ MeV below resonance, 14 MeV above.

A(1405) REFERENCES

BURKHARDT	91	PR C44 607	+Lowe .	(NOTT, UNM, BIRM)
DALITZ	91	JPG 17 289	+ Deloff	(OXFTP, WINR)
HEMINGWAY	85	NP B253 742		(CERN) J
MARTIN	81	NP B179 33		(DURH)
CHAO	73	NP B56 46	+Kraemer, Thomas, Martin	(RHEL, CMU, LOUC)
THOMAS	73	NP B56 15	+Engler, Fisk, Kraemer	(CMU)
MARTIN	70	NP B16 479	+Ross	(DURH)
MARTIN	69	PR 183 1352	+Sakitt	(LOUC, BNL)
Also	69B	PR 183 1345	Martin, Sakitt	(LOUC, BNL)
BARBARO	68B	PRL 21 573	Barbaro-Galtieri, Chadwick+	(LRL, SLAC)
KIM	67	PRL 19 1074	,,	(YALE)
BIRMINGHAM	66	PR 152 1148	(BIRM GL	AS, LOIC, OXF, RHEL)
KITTEL	66	PL 21 349	+Otter, Wacek	(VIEN)
ENGLER	65	PRL 15 224	+Fisk, Kraemer, Meltzer, Westgard+	
KIM	65	PRL 14 29	i i i i i i i i i i i i i i i i i i i	(COLU)
MUSGRAVE	65	NC 35 735	+Petmezas+ (BIRM. CER)	N, EPOL, LOIC, SACL)
SAKITT	65	PR 139B 719	+Day, Glasser, Seeman, Friedman+	(UMD. LRL)
ALEXANDER	62	PRL 8 447	+Kalbfleisch, Miller, Smith	(LRL)
ALSTON	62	CERN Conf. 311	+Alvarez, Ferro-Luzzi+	(LRL) i
ALSTON	61B	PRL 6 698	+Alvarez, Eberhard, Good+	(LRL) I
	-20		(raverez, Escindia, Good+	(LRL) I

- OTHER RELATED PAPERS -

*****		DD1		
IWASAKI	97	PRI. 78 3067	+Hayano, Ito, Nakamura+	(KEK-228 Collab.)
FINK	90	PR C41 2720	+He, Landau, Schnick	(IBMY, ORST, ANSM)
LEINWEBER	90	ANP 198 203		(MCMS)
MUELLER-GR.		NP A513 557	Mueller-Groeling, Holinde, Speth	(JULI)
BARRETT	89	NC 102A 179		(SURR)
BATTY	89	NC 102A 255	+Gai	(RAL, HEBR)
CAPSTICK	89.	Excited Baryons '88, p	o. 32	(GUEL)
LOWE	89	NC 102A 167		(BIRM)
WHITEHOUSE		PRL 63 1352	 + (BIRM, BOST, BRCO, B 	NL, CASE, BUDA, TRIU)
SIEGEL	88	PR C38 2221	+Weise	(REGE)
WORKMAN	88	PR D37 3117	+Fearing	(TRIU)
SCHNICK	87	PRL 58 1719	+Landau	(ÒRST)
CAPSTICK	86	PR D34 2809	+lsgur	(TNTO)
JENNINGS	86	PL B176 229	· •	`(TRIU)
MALTMAN	86	PR D34 1372	+lsgur	(LANL, TNTO)
ZHONG	86	PL B171 471	+Thomas, Jennings, Barrett	(ADLD, TRIU, SURR)
BURKHARDT	85	NP A440 653	+Lowe, Rosenthal	(NOTT, BIRM, WMIU)
DAREWYCH	85	PR D32 1765	+Koniuk, Isgur	(YORKC, TNTO)
VEIT	85	PR D31 1033	+Jennings, Thomas, Barrett	(TRIÙ, ADLD, SURR)
KIANG	84	PR C30 1638	+Kumar, Nogami, VanDiik	(DALH, MCMS)
MILLER	84		, riaman, respansi, remedic	(LOUC)
Conf. Inte	rsectio	ins between Particle and	l Nuclear Physics, p. 783	(2000)
VANDIJK	84	PR D30 937		(MCMS)
VEIT	84	PL 137B 415	+Jennings, Barrett, Thomas	(TRIU, SURR, CERN)
DALITZ	82		+McGinley, Belyea, Anthony	(OXFTP)
Heidelberg		, p. 201		. ,
DALITZ	81	-diata Fassas V 11	+McGinley	(OXFTP)
		ediate Energy Kaon-Nucl		4
MARTIN	81B	Low and Intermediate	Energy Kaon-Nucleon Phys., p. 97	(DURH)
OADES	77	NC 42A 462	+Rasche	(AARH, ZURI)
SHAW	73	Purdue Conf. 417		(UCI)
BARBARO	72	LBL-555	Barbaro-Galtieri	(LBL)
DOBSON	72	PR D6 3256	+McElhaney	(HAWA)
RAJASEKA	. 72	PR D5 610 so cited in RAJASEKAF	Rajasekaran	(TATA)
CLINE	71	PRL 26 1194		(huce)
MARTIN	71	PL 35B 62	+Laumann, Mapp	(MISC)
DALITZ	67	PR 153 1617	+ Martin, Ross	(DURH, LOUC, RHEL)
DONALD	66		+Wong, Rajasekaran	(OXFTP, BOMB)
KADYK	66	PL 22 711	+Edwards, Lys, Nisar, Moore	(LIVP)
ABRAMS	65	PRL 17 599	+Oren, Goldhaber, Goldhaber, Tril	
CMANAN	65	PR 139B 454	+Sechi-Zorn	(UMD)

$\Lambda(1520) D_{03}$

$$I(J^P) = O(\frac{3}{2}^-)$$
 Status: ***

Discovered by FERRO-LUZZI 62; the elaboration in WATSON 63 is the classic paper on the Breit-Wigner analysis of a multichannel

The measurements of the mass, width, and elasticity published before 1975 are now obsolete and have been omitted. They were last listed in our 1982 edition Physics Letters 111B (1982).

Production and formation experiments agree quite well, so they are listed together here.

A(1520) MASS							
VALUE (MeV) 1519.5 ±1.0 OUI 1519.50±0.18 OUI		DOCUMENT ID		<u>TECN</u>	COMMENT		
1517.3 ±1.5 1519 ±1	300	BARBER GOPAL			$\begin{array}{ccc} \gamma p \to & \Lambda(1520) K^+ \\ \overline{K} N \to & \overline{K} N \end{array}$		
1517.8 ±1.2 1520.0 ±0.5	5k	BARLAG ALSTON			K ⁻ p 4.2 GeV/c KN → KN		
1519.7 ±0.3 1519 ±1	4k	CAMERON GOPAL			$\frac{K^-p}{K}$ 0.96–1.36 GeV/c		
1519.4 ±0.3	2000	CORDEN	75	DBC	K-d 1.4-1.8 GeV/c		

A(1520) WIDTH

	(MeV) E1.0 OUR ESTIN		DOCUMENT ID		TECN	COMMENT
10.07	EUZI OUK MERU	-UE				
16.3	£3.3	300	BARBER	800	SPEC	$\gamma p \rightarrow \Lambda(1520)K^+$
16	±1		GOPAL	80	DPWA	KN→ KN
14 ±	±3	677 1	BARLAG	79	HBC	K-p 4.2 GeV/c
15.4	-0.5					KN → KN
16.3	£0.5	4k	CAMERON	77	HBC	K-p 0.96-1.36 GeV/c
15.0 ⅓	±0.5		GOPAL	77	DPWA	KN multichannel
15.5 ±	⊦1.6	2000	CORDEN	75	DBC	K- d 1.4-1.8 GeV/c
						,

A(1520) DECAY MODES

	Mode	Fraction (F_I/Γ)	
Γ ₁	NK	45 ± 1%	
Γ_2	$\Sigma\pi$	42 ± 1%	
Γ̈́3	$\Lambda \pi \pi$	10 ± 1%	
Γ_4	Σ (1385) π		
Γ_5	$\Sigma(1385)\pi(\rightarrow \Lambda\pi\pi)$		
Γ ₆	$\Lambda(\pi\pi)_{S\text{-wave}}$		
Γ7	$\Sigma \pi \pi$	$0.9 \pm 0.1\%$	
Γ8	$\Lambda\gamma$	$0.8 \pm 0.2\%$	
Γ ₈ Γ ₉	$\Sigma^0\gamma$		

CONSTRAINED FIT INFORMATION

An overall fit to 9 branching ratios uses 24 measurements and one constraint to determine 6 parameters. The overall fit has a $\chi^2=$ 16.5 for 19 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\langle \delta x_i \delta x_j \rangle / (\delta x_i \cdot \delta x_j)$, in percent, from the fit to the branching fractions, $x_i \equiv \Gamma_i / \Gamma_{\text{total}}$. The fit constrains the x_i whose labels appear in this array to sum to one.

A(1520) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on Λ and Σ

$\Gamma(N\overline{K})/\Gamma_{\text{total}}$				Γ ₁ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
0.45 ±0.01 OUR ESTIMA				
0.448 ± 0.007 OUR FIT E		of 1.	2.	
0.455±0.011 OUR AVERA				
0.47 ±0.02	GOPAL			
0.45 ±0.03	ALSTON			$\overline{K}N \rightarrow \overline{K}N$
0.448±0.014	CORDEN			K - d 1.4-1.8 GeV/c
 We do not use the formula 	ollowing data for average	s, fit	s, Ilmits,	etc. • • •
0.47 ±0.01	GOPAL	77	DPWA	See GOPAL 80
0.42	MAST	76	нвс	$K^- p \rightarrow \overline{K}^0 n$
$\Gamma(\Sigma\pi)/\Gamma_{ ext{total}}$				Γ ₂ /Γ
VALUE	DOCUMENT ID		TECN	
0.42 ±0.01 OUR ESTIMA	NTE			
0.421±0.007 OUR FIT E	rror includes scale factor	of 1.	2.	
0.423±0.011 OUR AVERA	GE			
0.426±0.014	CORDEN	75	DBC	K- d 1.4-1.8 GeV/c
0.418±0.017	BARBARO	69B	HBC	K-p 0.28-0.45 GeV/c
 • • We do not use the fo 	ollowing data for average	s, fit:	s, limits,	etc. • • •
0.46	KIM	71	DPWA	K-matrix analysis
$\Gamma(\Sigma\pi)/\Gamma(N\overline{K})$				Γ_2/Γ_1
VALUE	DOCUMENT ID		TECN	COMMENT
0.940±0.026 OUR FIT E				
0.95 ±0.04 OUR AVERA	GE Error includes scale	facto	or of 1.7.	. See the ideogram below.
0.98 ±0.03	² GOPAL	77	DPWA	KN multichannel
0.82 ±0.08	BURKHARDT	69	HBC	K-p 0.8-1.2 GeV/c
1.06 ±0.14	SCHEUER	68	DBC	K-N 3 GeV/c
0.96 ±0.20	DAHL	67	HBC	π~ p 1.6-4 GeV/c
0.73 ±0.11	DAUBER	67		K-p 2 GeV/c
144 1 4 41 4		_		

 \bullet \bullet \bullet We do not use the following data for averages, fits, limits, etc. \bullet \bullet

BERTHON

MUSGRAVE 65 HBC

74 HBC Quasi-2-body σ

 1.06 ± 0.12

1.72 ±0.78

 $\Gamma(\Lambda\gamma)/\Gamma_{\text{total}}$

 0.0080 ± 0.0014

VALUE EVTS
0.008 ±0.002 OUR ESTIMATE

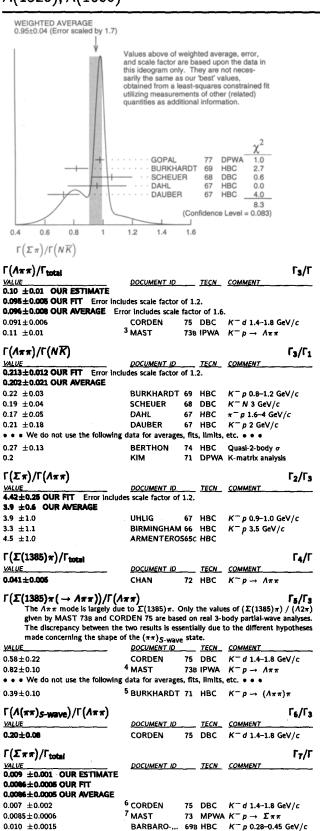
238

MAST

0.0079±0.0014 OUR FIT

Baryon Particle Listings

 $\Lambda(1520), \Lambda(1600)$



$\Gamma(\Sigma^0\gamma)/\Gamma_{\text{total}}$			Γ9/Γ
0.0196±0.0034 OUR FIT	DOCUMENT ID	TECN	COMMENT
0.02 ±0.0035	8 MAST	68B HBC	Not measured; see note

A(1520) FOOTNOTES

- I From the best-resolution sample of $A\pi\pi$ events only.
- ² The $\vec{K}N \rightarrow \Sigma \pi$ amplitude at resonance is +0.46 ± 0.01.
- ³ Assumes $\Gamma(N\overline{K})/\Gamma_{\text{total}} = 0.46 \pm 0.02$.
- ⁴ Both $\Sigma(1385)\pi$ DS_{03} and $\Sigma(\pi\pi)$ DP_{03} contribute.
- 5 The central bin (1514–1524 MeV) gives 0.74 \pm 0.10; other bins are lower by 2-to-5 standard deviations. 6 Much of the $\Sigma \pi \pi$ decay proceeds via $\Sigma (1385)\pi$.
- ⁷ Assumes $\Gamma(N\overline{K})/\Gamma_{\text{total}} = 0.46$.
- 8 Calculated from $\Gamma(\Lambda\gamma)/\Gamma_{total}$, assuming SU(3). Needed to constrain the sum of all the branching ratios to be unity.

A(1520) REFERENCES

PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+ (HELS, CIT, CERN)
BARBER	80D	ZPHY C7 17	+Dainton, Lee, Marshall+ (DARE, LANC, SHEF)
GOPAL	80	Toronto Conf. 159	(RHEL) IJP
BARLAG	79	NP B149 220	+Blokziji, Jongejans+ (AMST, CERN, NIJM, OXF)
ALSTON	78	PR D18 182	Alston-Garnjost, Kenney+ (LBL, MTHO, CERN) IJP
Also	77	PRL 38 1007	Alston-Garnjost, Kenney+ (LBL, MTHO, CERN) IJP
CAMERON	77	NP B131 399	+Franek, Gopal, Kalmus, McPherson+ (RHEL, LOIC) IJP
GOPAL	77	NP B119 362	+Ross, VanHorn, McPherson+ (LOIC, RHEL) IJP
MAST	76	PR D14 13	+Aiston-Garnjost, Bangerter+ (LBL)
CORDEN	75	NP B84 306	+Cox, Dartnell, Kenyon, O'Neale+ (BIRM)
BERTHON	74	NC 21A 146	+Tristram+ (CDEF, RHEL, SACL, STRB)
MAST	73	PR D7 3212	+Bangerter, Alston-Garnjost+ (LBL) IJP
MAST	73B	PR D7 5	+Bangerter, Alston-Garnjost+ (LBL) IJP
CHAN	72	PRL 28 256	+Button-Shafer, Hertzbach, Kofler+ (MASA, YALE)
BURKHARDT	71	NP B27 64	+Filthuth, Kluge+ (HEID, CERN, SACL)
KIM	71	PRL 27 356	(HARV) IJP
Also	70	Duke Conf. 161	Kim (HARV) IJP
BARBARQ	69B	Lund Conf. 352	Barbaro-Galtieri, Bangerter, Mast, Tripp (LRL)
Also	70	Duke Conf. 95	Tripp (LRL)
BURKHARDT	69	NP B14 106	+Filthuth, Kluge+ (HEID, EFI, CERN, SACL)
MAST	68B	PRL 21 1715	+Alston-Garnjost, Bangerter, Galtieri+ (LRL)
SCHEUER	68	NP B8 503	+Merrill, Verglas, DeWitt+ (SABRE Collab.)
DAHL	67	PR 163 1377	+Hardy, Hess, Kirz, Miller (LRL)
DAUBER	67	PL 24B 525	+Malamud, Schlein, Slater, Stork (UCLA)
UHLIG	67	PR 155 1448	+Charlton, Condon, Glasser, Yodh+ (UMD, NRL)
BIRMINGHAM	66	PR 152 1148	(BIRM, GLAS, LOIC, OXF, RHEL)
ARMENTEROS	65C	PL 19 338	+Ferro-Luzzi+ (CERN, HEID, SACL)
MUSGRAVE	65	NC 35 735	+Petmezas+ (BIRM, CERN, EPOL, LOIC, SACL)
WATSON	63	PR 131 2248	+Ferro-Luzzi, Tripp (LRL) IJP
FERRO-LUZZI	62	PRL 8 28	+Tripp, Watson (LRL) IJP

 $\Lambda(1600) P_{01}$

r_e/r

DOCUMENT ID TECN COMMENT

688 HBC Using $\Gamma(N\overline{K})/\Gamma_{\text{total}} = 0.45$

 $I(J^P) = O(\frac{1}{2}^+)$ Status: ***

See also the $\Lambda(1810)$ P_{01} . There are quite possibly two P_{01} states in this region.

A(1600) MASS

DOCUMENT ID		TECN	COMMENT
OUR ESTIMATE			
GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
ALSTON	78	DPWA	$RN \rightarrow RN$
GOPAL	77	DPWA	KN multichannel
KANE	74	DPWA	$K^-p \rightarrow \Sigma \pi$
LANGBEIN	72	IPWA	KN multichannel
following data for average	s, fits	s, limits,	etc. • • •
¹ MARTIN	77	DPWA	KN multichannel
· 2 CARROLL	76	DPWA	Isospin-0 total σ
KIM	71	DPWA	K-matrix analysis
	OUR ESTIMATE GOPAL ALSTON GOPAL KANE LANGBEIN FOllowing data for average: 1 MARTIN 2 CARROLL	OUR ESTIMATE GOPAL 80 ALSTON 78 GOPAL 77 KANE 74 LANGBEIN 72 following data for averages, fit: 1 MARTIN 77 2 CARROLL 76	GOPAL 80 DPWA ALSTON 78 DPWA GOPAL 77 DPWA KANE 74 DPWA LANGBEIN 72 IPWA following data for averages, fits, llimits, 1 MARTIN 77 DPWA 2 CARROLL 76 DPWA

Λ(1600) WIDTH

DOCUMENT ID		TECN	COMMENT
TE			
GOPAL	80	DPWA	RN → RN
ALSTON	78	DPWA	RN → RN
GOPAL.	77	DPWA	KN multichannel
KANE	74	DPWA	$K^-p \rightarrow \Sigma \pi$
LANGBEIN	72	IPWA	KN multichannel
g data for average	s, fit	s, limits,	etc. • • •
1 MARTIN	77	DPWA	KN multichannel
² CARROLL	76	DPWA	Isospin-O total o
KIM	71	DPWA	K-matrix analysis
	GOPAL ALSTON GOPAL KANE LANGBEIN 3 data for average 1 MARTIN 2 CARROLL	GOPAL 80 ALSTON 78 GOPAL 77 KANE 74 LANGBEIN 72 g data for averages, fitt 1 MARTIN 77 2 CARROLL 76	GOPAL 80 DPWA ALSTON 78 DPWA GOPAL 77 DPWA KANE 74 DPWA LANGBEIN 72 IPWA d data for averages, fits, limits, 1 MARTIN 77 DPWA 2 CARROLL 76 DPWA

A(1600) DECAY MODES

	Mode	Fraction (Γ_I/Γ)
$\overline{\Gamma_1}$	NK	15-30 %
Γ ₂	Σπ	10-60 %
	The above branching fractions are ou	ir estimates, not fits or averages.

A(1600) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on \varLambda and \varSigma Resonances.

DOCUMENT ID		TECN		Γ1/
MATE		1201-	COMMENT	
GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$	
ALSTON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$	
LANGBEIN	72	IPWA	KN multichannel	
following data for average	es, fit	s, limits,	etc. • • •	
GOPAL	77	DPWA	See GOPAL 80	
1 MARTIN	77	DPWA	KN multichannel	
	GOPAL ALSTON LANGBEIN following data for average	GOPAL 80 ALSTON 78 LANGBEIN 72 following data for averages, fit GOPAL 77	GOPAL 80 DPWA ALSTON 78 DPWA LANGBEIN 72 IPWA following data for averages, fits, limits, GOPAL 77 DPWA	GOPAL 80 DPWA $\overline{K}N \rightarrow \overline{K}N$ ALSTON 78 DPWA $\overline{K}N \rightarrow \overline{K}N$ LANGBEIN 72 IPWA $\overline{K}N$ multichannel following data for averages, fits, limits, etc. • • • GOPAL 77 DPWA See GOPAL 80

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K}$	$\rightarrow \Lambda(1600) \rightarrow \Sigma \pi$			(Γ₁Γ₂) ¹ ⁄2
VALUE	DOCUMENT ID		TECN	COMMENT
-0.16 ± 0.04	GOPAL	77	DPWA	KN multichannel
-0.33 ± 0.11	KANE	74	DPWA	$K^- p \rightarrow \Sigma \pi$
0.28 ± 0.09	LANGBEIN	72	IPWA	K N multichannel
• • • We do not use the	following data for average	es, fit	s, limits,	etc. • • •
-0.39 or -0.39	¹ MARTIN	77	DPWA	KN multichannel
not seen	HEPP	76E	DPWA	$K^- N \rightarrow \Sigma \pi$

A(1600) FOOTNOTES

 ${}^{1}_{}$ The two MARTIN 77 values are from a T-matrix pole and from a Breit-Wigner fit.

²A total cross-section bump with $(J+1/2) \Gamma_{el} / \Gamma_{total} = 0.04$.

A(1600) REFERENCES

GOPAL ALSTON Also GOPAL MARTIN Also Also CARROLL HEPP KANE LANGBEIN KIM	80 78 77 77 77 77B 77C 76 76B 74 72	Toronto Conf. 15 PR D18 182 PRL 38 1007 NP B119 362 NP B127 349 NP B126 265 NP B126 265 NP B126 285 PRL 37 806 PL 65B 487 LBL-2452 NP B47 477 PRL 27 356	Alston-Garnjost, Kenney+ Alston-Garnjost, Kenney+ +Ross, VanHorn, McPherson+ +Pidcock, Moorhouse Martin, Pidcock Martin, Pidcock +Chlang, Kycla, Li, Mazur, Michael	(RHEL) IJP (LBL, MTHO, CERN) IJP (LBL, MTHO, CERN) IJP (LOUC, RHEL) IJP (LOUC) (LOUC) (LOUC) (LOUC) (COUC) (CERN, HEIDH, MPIM) IJP (MPIM) IJP (HARV) IJP
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Λ(1670) S₀₁

$$I(J^P) = O(\frac{1}{2})$$
 Status: ***

The measurements of the mass, width, and elasticity published before 1974 are now obsolete and have been omitted. They were last listed in our 1982 edition Physics Letters 111B (1982).

Λ(1670) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1660 to 1680 (≈ 1670) (OUR ESTIMATE			
1670.8 ± 1.7	KOISO	85	DPWA	$K^-p \rightarrow \Sigma \pi$
1667 ±5	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
1671 ±3	ALSTON	78	DPWA	KN → KN
1670 ±5	GOPAL	77	DPWA	KN multichannel
1675 ±2	HEPP	76B	DPWA	$K^-N \rightarrow \Sigma \pi$
1679 ±1	KANE	74	DPWA	$K^-p \rightarrow \Sigma \pi$
1665 ±5	PREVOST	74	DPWA	$K^- N \rightarrow \Sigma(1385)\pi$
• • • We do not use the	following data for average			
1669 ±2	ABAEV	96	DPWA	$\pi^- p \rightarrow \eta n$
1664	¹ MARTIN			K N multichannel

Λ(1670) WIDTH

VALE	JE (MeV)	DOCUMENT ID		TECN	COMMENT
25	to 50 (≈ 35) OUR ESTIMATE		-		
34.1	± 3.7	KOISO	85	DPWA	$K^- \rho \rightarrow \Sigma \pi$
29	± 5	GOPAL	80	DPWA	KN → KN
29	± 5	ALSTON	78	DPWA	K̃N→ K̄N
45	±10	GOPAL	77	DPWA	KN multichannel
46	± 5	HEPP	76B	DPWA	$K^-N \rightarrow \Sigma \pi$
40	± 3	KANE	74	DPWA	$K^- p \rightarrow \Sigma \pi$
19	± 5	PREVOST	74	DPWA	$K^-N \rightarrow \Sigma(1385)\pi$
• •	• We do not use the following of	lata for averages	i, fits	, limits,	etc. • • •
21	± 4	ABAEV	96	DPWA	$\pi^- p \rightarrow \eta n$
12	1	MARTIN			KN multichannel

A(1670) DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ ₁	Ν̈́Κ	15–25 %
Γ_2	$\Sigma\pi$	20-60 %
Γ3	$\Lambda\eta$	15-35 %
Γ_4	$\Sigma(1385)\pi$	
	The above branching fraction	ns are our estimates, not fits or averages.

A(1670) BRANCHING RATIOS

See "Sign conventions for resonance couplings" In the Note on \varLambda and \varSigma Resonances.

Γ(NK)/Γ _{total}					Γ_1/Γ
VALUE	DOCUMENT ID		TECN	COMMENT	
0.15 to 0.25 OUR ESTIM	ATE				
0.18±0.03	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$	
0.17±0.03	ALSTON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$	
ullet $ullet$ $ullet$ We do not use the	following data for averag	es, fit	s, limits,	etc. • • •	
0.20 ± 0.03	GOPAL	77	DPWA	See GOPAL 80	
0.15	¹ MARTIN	77	DPWA	KN multichanne	:l

$(\Gamma_I \Gamma_I)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N^{\frac{1}{2}}$	$\overline{\zeta} \to \Lambda(1670) \to \Sigma \pi$			(Γ ₁ Γ ₂) ^½ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
-0.26 ± 0.02	KOISO	85	DPWA	$K^- p \rightarrow \Sigma \pi$
-0.31 ± 0.03	GOPAL	77	DPWA	KN multichannel
-0.29 ± 0.03	HEPP	76B	DPWA	$K^- N \rightarrow \Sigma \pi$
-0.23 ± 0.03	LONDON	75	HLBC	$K^- p \rightarrow \Sigma^0 \pi^0$
-0.27 ± 0.02	KANE	74	DPWA	$K^- p \rightarrow \Sigma \pi$
• • • We do not use th	e following data for average	es, fits	, limits,	etc. • • •
-0.13	¹ MARTIN	77	DPWA	KN multichannel

(「「「「」) ^{1/2} /「total in NK /ALUE	$0 \rightarrow \Lambda(1670) \rightarrow \Lambda\eta$ $0 \rightarrow \Lambda \eta$		TECN	(Γ ₁ Γ ₃) ^{1/2} /Γ
+0.20±0.05	BAXTER	73	DPWA	$K^-p \rightarrow \text{neutrals}$
 We do not use the 	following data for average	s. fit:	s. limits.	etc. • • •
	•			
0.06 0.24	ABAEV KIM	96	DPWA	$\pi^- p \rightarrow \eta n$ K-matrix analysis
0.06	ABAEV	96 71	DPWA DPWA	$\pi^- p \rightarrow \eta n$

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\overline{K} \to A$	$\Lambda(1670) \rightarrow \Sigma(1385)$	T		(Г₁Г₄) ^½ /Г
VALUE	DOCUMENT ID	TECN	COMMENT	
-0.18 ± 0.05	PREVOST 7	I DPWA	$K^- N \rightarrow$	$\Sigma(1385)\pi$

A(1670) FOOTNOTES

 $^{1}\,\mathrm{MARTIN}$ 77 obtains Identical resonance parameters from a T-matrix pole and from a Breit-Wigner fit.

A(1670) REFERENCES

ABALV 96 PR CS3 385 + Nelkens KOISO 85 NP A433 619 + Sai, Yamamoto, Kofler GOPAL 80 Toronto Conf. 159 ALSTON 78 PR D18 182 Alston-Garnjost, Kenney+ (LBL, MTHO, CERN) IJP GOPAL 77 NP B119 362 Alston-Garnjost, Kenney+ (LBL, MTHO, CERN) IJP Also 778 NP B112 349 + Pidcock, Moorhouse (LOUC, GLAS) IJP Also 776 NP B126 266 Martin, Pidcock (LOUC, GLAS) IJP LONDON 75 NP B85 289 + Yu, Boyd (LOUC, GLAS) IJP LONDON 75 NP B85 289 + Yu, Boyd (SNH, CERN, EPOL, ORSAY, TORI) (LOUC, GLAS) IJP REVOST 74 NP B69 266 + Barloutaud+ (SACL, CERN, HEID), MPM) IJP PREVOST 74 NP B69 266 + Barloutaud+ (SACL, CERN, HEID), MPM BAXTER 73 NP B67 125 + Buckingham, Corbett, Dunn+ (HARV) IJP Also 70 Duke Conf. 161 AMENTEROS 69C Lund Paper 229 Values are quoted in LEVI-SETTI 69. BERKLEY 65 PRI 15 641 + Connolly, Hart, Rahm, Stonehill+ (BNL) IJP					
PDG 82	ABAEV	96	PR C53 385	+Nefkens	(UCLA)
GOPAL 80 Toronto Conf. 159 (RHEL) 1JP	KOISO	85	NP A433 619	+Sai, Yamamoto, Kofler	(TOKY, MASA)
Alson-Garnjost, Kenney+ (LBL, MTHO, CERN) IJP	PDG	82	PL 1118	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
Also 77 PR. 38 1007 Alston-Garnjost, Kennery (LBL, MTHO, CERN) IJP	GOPAL	80	Toronto Conf. 159		(RHEL) IJP
GOPAL 77 NP B119 362	ALSTON	78	PR D18 182	Aiston-Garnjost, Kenney+	(LBL, MTHO, CERN) IJP
MARTIN 77	Aiso	77	PRL 38 1007	Alston-Garnjost, Kenney+	(LBL, MTHO, CERN) IJP
Also 778 NP B126 266	GOPAL	77	NP B119 362	+Ross, VanHorn, McPherson+	
Also 77C NP B126 285	MARTIN	77	NP B127 349	+Pidcock, Moorhouse	(LOUC, GLAS) IJP
HEPP	Also	77B	NP B126 266	Martin, Pidcock	(LOUC)
LONDON 75 NP B85 289	Also	77C	NP B126 285	Martin, Pidcock	(LOUC) IJP
KANE 74	HEPP	76B	PL 65B 487	+Braun, Grimm, Strobele+	(CERN, HEIDH, MPIM) IJP
PREVOST 74 NP 869 246 +Barloutaud+ (SACL, CERN, ĤEID) BAXTER 73 NP 867 125 +Buckingham, Corbett, Dunn+ (OXF) IJP KIM 71 PRL 27 336 (HARV) IJP ASD 70 Duke Conf. 161 Kim (HARV) IJP ARMENTEROS 69C Lund Paper 229 +Ballion+ (CERN, HEID, SACL) IJP	LONDON	75	NP B85 289	+Yu, Boyd+ (BNL, CERN,	EPOL, ORSAY, TORI)
BAXTER 73 NP B67 125 +Buckingham, Corbett, Dunn+ (OXF) IJP KIM 71 PRL 27 356 (HARV) IJP Also 70 Duke Conf. 161 Kim (HARV) IJP ARMENTEROS 69C Lund Paper 229 +Ballion+ (CERN, HEID, SACL) IJP Values are quoted in LeVS-ETT1 69. (CERN, HEID, SACL) IJP	KANE	74	LBL-2452		(LBL) IJP
KIM 71 PRL 27 356 (HARV) IJP Also 70 Duke Conf. 161 Kim (HARV) IJP ARMENTEROS 69C Lund Paper 229 +Baillon+ (CERN, HEID, SACL) IJP Values are quoted in LEVI-SETTI 69.	PREVOST	74	NP B69 246	+Barloutaud+	(SACL, CERN, HEID)
Also 70 Duke Conf. 161 Kim (HARV) IJP ARMENTEROS 69C Lund Paper 229 + Ballion+ (CERN, HEID, SACL) IJP Values are quoted in LEVI-SETTI 69.	BAXTER	73	NP B67 125	+Buckingham, Corbett, Dunn+	(OXF) IJP
ARMENTEROS 69C Lund Paper 229 +Baillon+ (CERN, HEID, SACL) IJP Values are quoted in LEVI-SETTI 69.	KIM	71	PRL 27 356	•	(HARV) IJP
Values are quoted in LEVI-SETTI 69.	Also	70	Duke Conf. 161	Kim	(HARV) IJP
	ARMENTEROS	5 69C	Lund Paper 229	+Baillon+	(CERN, HEID, SACL) IJP
BERLEY 65 PRL 15 641 +Connolly, Hart, Rahm, Stonehill+ (BNL) IJP	Values are	quote	d in LEVI-SETTI 69.		•
	BERLEY	65	PRL 15 641	+Connolly, Hart, Rahm, Stonehill+	(BNL) LIP

Λ(1690), Λ(1800)

 $\Lambda(1690) D_{03}$

 $I(J^P) = O(\frac{3}{2}^-)$ Status: ***

The measurements of the mass, width, and elasticity published before 1974 are now obsolete and have been omitted. They were last listed in our 1982 edition Physics Letters 111B (1982).

Λ(1690) MASS

	(MeV)	DOCUMENT ID		TECN	COMMENT
1685	to 1695 (≈ 1690)	OUR ESTIMATE			
1695.	7 ± 2.6	KOISO	85	DPWA	$K^-p \rightarrow \Sigma \pi$
1690	±5	GOPAL	80	DPWA	$KN \rightarrow KN$
1692	±5	ALSTON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$
1690	±5	GOPAL	77	DPWA	KN multichannel
1690	±3	HEPP	76B	DPWA	$K^-N \rightarrow \Sigma \pi$
1689	±1	KANE	74	DPWA	$K^- \rho \rightarrow \Sigma \pi$
• • •	We do not use the	following data for average	s, fits	, limits,	etc. • • •
1687	or 1689	¹ MARTIN	77	DPWA	KN multichannel
1692	±4	CARROLL	76	DPWA	Isospin-0 total σ

Λ(1690) WIDTH

VAL	UE (MeV)	DOCUMENT ID		TECN	COMMENT
50	to 70 (≈ 60) OUR ESTIMATE				
67.2	2± 5.6	KOISO	85	DPWA	$K^- \rho \rightarrow \Sigma \pi$
61	± 5	GOPAL	80	DPWA	$KN \rightarrow KN$
64	±10	ALSTON	78	DPWA	KN → KN
60	± 5	GOPAL	77	DPWA	KN multichannel
82	± 8	HEPP	76B	DPWA	$K^- N \rightarrow \Sigma \pi$
60	± 4	KANE	74	DPWA	$K^- \rho \rightarrow \Sigma \pi$
	• We do not use the following	data for average:	s, fits	, limits,	etc. • • •
62	or 62	¹ MARTIN	77	DPWA	KN multichannel
38		CARROLL	76	DPWA	Isospin-0 total σ

A(1690) DECAY MODES

	Mode	Fraction (Γ_I/Γ)	
$\overline{\Gamma_1}$	NK	20–30 %	
Γ_2	Σπ	20-40 %	
Гз	Λππ	∼ 25 %	
Γ ₅	$\Sigma \pi \pi$ $\Lambda \eta$	~ 20 %	
16	$\Sigma(1385)\pi$, <i>S</i> -wave		

The above branching fractions are our estimates, not fits or averages.

1/(1690) BRANCHING RATIOS

The sum of all the quoted branching ratios is more than 1.0. The two-body ratios are from partial-wave analyses, and thus probably are more reliable than the three-body ratios, which are determined from bumps in cross sections. Of the latter, the $\Sigma\pi\pi$ bump looks more significant. (The error given for the $\Lambda\pi\pi$ ratio looks unreasonably small.) Hardly any of the $\Sigma\pi\pi$ decay can be via Σ (1385), for then seven times as much $\Lambda\pi\pi$ decay would be required. See "Sign conventions for resonance couplings" in the Note on Λ and Σ Resonances.

$\Gamma(N\overline{K})/\Gamma_{\text{total}}$				Γ1/Γ
VALUE	DOCUMENT ID		<u>TECN</u>	COMMENT
0.2 to 0.3 OUR ESTIMATE				
0.23 ± 0.03	GOPAL			$\overline{K}N \to \overline{K}N$
0.22 ± 0.03	ALSTON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$
• • We do not use the following	data for average	s, fits	, limits,	etc. • • •
0.24 ± 0.03	GOPAL	77	DPWA	See GOPAL 80
0.28 or 0.26	¹ MARTIN	77	DPWA	KN multichannel
$(\Gamma_{I}\Gamma_{I})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow \Lambda(1)$	690) → Σπ DOCUMENT ID		TECN	$(\Gamma_1\Gamma_2)^{\frac{1}{2}}/\Gamma$
-0.34±0.02	KOISO	85	DPWA	$K^-p \rightarrow \Sigma \pi$
-0.25 ± 0.03	GOPAL	77	DPWA	K N multichannel
-0.29±0.03	HEPP	768	DPWA	$K^-N \rightarrow \Sigma \pi$
-0.28 ± 0.03	LONDON	75	HLBC	$K^- p \rightarrow \Sigma^0 \pi^0$
-0.28 ± 0.02	KANE	74	DPWA	$K^-p \rightarrow \Sigma \pi$
• • • We do not use the following	data for average	s, fits	s, limits,	etc. • • •
-0.30 or -0.28	¹ MARTIN	77	DPWA	K N multichannel
$(\Gamma_{I}\Gamma_{I})^{\frac{1}{2}}/\Gamma_{total}$ in $N\overline{K} \to \Lambda(1)$	690) → An		TECN	$(\Gamma_1\Gamma_5)^{\frac{1}{12}}/\Gamma$
0.00±0.03	BAXTER	73		K p → neutrals
0.00 1 0.03	DANTER	, ,	D: WA	N p → incutials

$(\Gamma_I \Gamma_I)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\overline{K}$	$\rightarrow \Lambda(1690) \rightarrow \Lambda \pi \pi$			(Г₁Г₃) ^½ /Г
VALUE	DOCUMENT ID	TECN	COMMENT	
• • • We do not use the f	following data for averages, fits	, limits,	etc. • •	•
0.25 ± 0.02	² BARTLEY 68	HDBC	K-p →	$\Lambda \pi \pi$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N \overline{K}$	<i>→ Λ</i> (1690) <i>→ Σππ</i>			(Γ ₁ Γ ₄) ^{1/2} /Γ
VALUE	DOCUMENT ID	<u>TEÇN</u>	COMMENT	<u> </u>
0.21	ARMENTEROS68C	HDBC	K-N→	Σππ
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N \overline{K}$	$\rightarrow \Lambda(1690) \rightarrow \Sigma(1385)\pi,$ $DOCUMENT ID$	S-wav	COMMENT	(Γ ₁ Γ ₆) ^½ /Γ
+0.27±0.04	PREVOST 74			
	A(1690) FOOTNOTE	S		

 $^{^1}$ The two MARTIN 77 values are from a T-matrix pole and from a Brelt-Wigner flt. Another \textit{D}_{03} $\textit{\Lambda}$ at 1966 MeV is also suggested by MARTIN 77, but is very uncertain.

A(1690) REFERENCES

Also 77 CARROLL 76 HEPP 76 LONDON 75 KANE 74 PREVOST 75 PREVOST 75	22 PL 100 Torons 17 PR 17 NP 17 NP 17 NP 17 NP 17 NP 17 NP 17 NP 17 NP 17 NP 18 N	A433 619 1118 0nto Conf. 159 D18 182 L 38 1007 B119 362 B127 349 B126 266 B126 285 L 37 806 65B 487 B85 289 L-2452 B69 246 B67 125 sterdam Conf.	+Yu, Boyd+ (BNL, CERN, +Barloutaud+ +Buckingham, Corbett, Dunn+	(CERN, HEIDH, MPIM) IJP EPOL, ORSAY, TORI) (LBL) IJP (SACL, CERN, HEID) (OXF) IJP (CERN, HEID, SACL)
			+Buckingham, Corbett, Dunn+	
		B8 216	+Baillon+	(CERN, HEID, SACL) I
BARTLEY 6	8 PR	L 21 1111	+Chu, Dowd, Greene+	(TUFTS, FSU, BRAN)I

 $\Lambda(1800) S_{01}$

 $I(J^P) = O(\frac{1}{2}^-) \text{ Status: } ***$

This is the second resonance in the S_{01} wave, the first being the $\Lambda(1670)$.

Λ(1800) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1720 to 1850 (≈ 1800)	OUR ESTIMATE			
1841±10	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
1725 ± 20	ALSTON	78	DPWA	KN → KN
1825 ± 20	GOPAL	77	DPWA	KN multichannel
1830 ± 20	LANGBEIN	72	IPWA	KN multichannel
• • We do not use th	e following data for averag	es, fits	i, limits,	etc. • • •
1767 or 1842	1 MARTIN	77	DPWA	KN multichannel
1780	KIM	71	DPWA	K-matrix analysis
1872±10	BRICMAN	70B	DPWA	KN → KN

Λ(1800) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
200 to 400 (≈ 300) OUR ESTIMAT	E			
228±20	GOPAL			Kn → Kn
185 ± 20	ALSTON	78	DPWA	KN → KN
230 ± 20	GOPAL	77	DPWA	KN multichannel
70±15	LANGBEIN	72	IPWA	KN multichannel
• • • We do not use the following	data for averages	s, fits	i, Ilmits,	etc. • • •
435 or 473	1 MARTIN	77	DPWA	KN multichannel
40	KIM	71	DPWA	K-matrix analysis
100±20	BRICMAN	70B	DPWA	KN → KN

A(1800) DECAY MODES

	Mode	Fraction (Γ_I/Γ)
$\overline{\Gamma_1}$	NK	25-40 %
Γ_2	$\Sigma \pi$	seen
Γ_3	$\Sigma(1385)\pi$	seen
Γ_4	NK*(892)	seen
Γ_5	$N\overline{K}^*$ (892), $S=1/2$, S -wave	
Γ6	$N\overline{K}^*$ (892), $S=3/2$, D -wave	
	The above branching fractions are	our estimates, not fits or averages.

²BARTLEY 68 uses only cross-section data. The enhancement is not seen by PRE-

A(1800) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on \varLambda and \varSigma Resonances.

$\Gamma(NK)/\Gamma_{\text{total}}$				Γ ₁ /
VALUE	DOCUMENT ID		TECN	COMMENT
0.25 to 0.40 OUR ESTIM				
0.36±0.04	GOPAL			
0.28 ± 0.05	ALSTON			
0.35 ± 0.15				KN multichannel
• • We do not use the	following data for average	es, fits	i, limits,	etc. • • •
0.37±0.05	GOPAL	77	DPWA	See GOPAL 80
1.21 or 0.70	¹ MARTIN	77	DPWA	See GOPAL 80 KN multichannel
0.80				K-matrix analysis
0.18±0.02	BRICMAN	70B	DPWA	$\overline{K}N \to \overline{K}N$
[Γ _Ι Γ _Γ) ^{1/2} /Γ _{total} in N K	→ Λ(1800) → Σπ DOCUMENT ID		TECN	$(\Gamma_1\Gamma_2)^{\frac{1}{2}}$
-0.08±0.05	GOPAL	77	DPWA	KN multichannel
	following data for average			
-0.74 or -0.43				KN multichannel
0.24				K-matrix analysis
0.24				
		35)π 	TECN	(\(\Gamma_1 \Gamma_3 \)\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
		3 5)π	TECN_ DPWA	$\frac{(\Gamma_1\Gamma_3)^{\frac{1}{2}}}{K^-\rho \to \Sigma(1385)\pi}$
([, f,]	$ \frac{1}{1000} \rightarrow \Lambda(1800) \rightarrow \Sigma(138) $ $ \frac{DOCUMENT ID}{2} $ CAMERON $ \frac{1}{1000} \rightarrow \Lambda(1800) \rightarrow N\overline{K}^{*}(1800) $	892)	, 5 =1/:	2, S-wave (Γ ₁ Γ ₅) ^{1/2} /
(「「「「」) ^{1/2} / 「total in NK <u>MUE</u> +0.056±0.028 (「「「「」) ^{1/2} / 「total in NK MUE	→ Λ(1800) → Σ(138	892)	, 5 =1/:	2, S-wave (Γ ₁ Γ ₅) ^{1/2} /
$(\Gamma_i \Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\overline{K}$ $VALUE$ $+0.056\pm0.028$ $(\Gamma_i \Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\overline{K}$ $VALUE$ -0.17 ± 0.03	$ \frac{1}{1000} \rightarrow \Lambda(1800) \rightarrow \Sigma(138) $ $ \frac{DOCUMENT ID}{2} $ CAMERON $ \frac{1}{1000} \rightarrow \Lambda(1800) \rightarrow N\overline{K}^{*}(1800) $	892) 788	, S=1/: TECN DPWA , S=3/:	2, S-wave $(\Gamma_1\Gamma_5)^{\frac{1}{2}}/$ $\frac{COMMENT}{K^-\rho \to N\overline{K}^+}$ 2, D-wave $(\Gamma_1\Gamma_6)^{\frac{1}{2}}/$

A(1800) FOOTNOTES

1 The two MARTIN 77 values are from a T-matrix pole and from a Breit-Wigner fit.

²The published sign has been changed to be in accord with the baryon-first convention.

A(1800) REFERENCES

BRICMAN	70B	PL 33B 511	+Ferro-Luzzi, Lagnaux	(CERN) IJP
Also	70	Duke Conf. 161	Kim	(HARV) IJP
KIM	71	PRL 27 356		(HARV) IJP
LANGBEIN	72	NP B47 477	+Wagner	(MPIM) IJP
Also	77C	NP B126 285	Martin, Pidcock	(LOUC) IJP
Also	77B	NP B126 266	Martin, Pidcock	(LOUC)
MARTIN	77	NP B127 349	+Pidcock, Moorhouse	(LOUC, GLAS) IJP
GOPAL	77	NP B119 362	+Ross, VanHorn, McPherson+	(LOIC, RHEL) IJP
CAMERON	78B	NP B146 327	+Franek, Gopal, Kalmus, McPherson+	(RHEL, LOIC) IJP
CAMERON	78	NP B143 189	+Franek, Gopal, Bacon, Butterworth+	(RHEL, LOIC) IJP
Also	77	PRL 38 1007		L, MTHO, CERN) IJP
ALSTON	78	PR D18 182		L, MTHO, CERN) IJP
GOPAL	80	Toronto Conf. 159		(RHEL) IJP

 $\Lambda(1810) P_{01}$

$$I(J^{P}) = O(\frac{1}{2}^{+})$$
 Status: ***

Almost all the recent analyses contain a P_{01} state, and sometimes two of them, but the masses, widths, and branching ratios vary greatly. See also the $\Lambda(1600)$ P_{01} .

Λ(1810) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1750 to 1850 (≈ 1810)	OUR ESTIMATE			
1841±20	GOPAL	80	DPWA	RN → RN
1853±20	GOPAL	77	DPWA	KN multichannel
1735± 5	CARROLL	76	DPWA	Isospin-0 total σ
1746±10	PREVOST	74	DPWA	$K^-N \rightarrow \Sigma(1385)\pi$
1780±20	LANGBEIN	72	IPWA	KN multichannel
• • • We do not use th	e following data for average	s, fit	s, limits,	etc. • • •
1861 or 1953	¹ MARTIN	77	DPWA	KN multichannel
1755	KIM	71	DPWA	K-matrix analysis
1800	ARMENTERO	S70	HBC	RN→ RN
1750	ARMENTERO	S70	HBC	$\overline{K}N \rightarrow \Sigma \pi$
1690±10	BARBARO	70	HBC	$\overline{K}N \rightarrow \Sigma \pi$
1740	BAILEY	69	DPWA	$\overline{K}N \rightarrow \overline{K}N$
1745	ARMENTERO	S68E	HBC	$\overline{K}N \rightarrow \overline{K}N$

A(1810) WIDTH

VALUE (MeV)	DOCUMENT ID TECN COMMENT
50 to 250 (≈ 150) OU	R ESTIMATE
164±20	GOPAL 80 DPWA $\overline{K}N \rightarrow \overline{K}N$
90 ± 20	CAMERON 788 DPWA $K^-p \rightarrow N\overline{K}^*$
166 ± 20	GOPAL 77 DPWA $\overline{K}N$ multichannel
46 ± 20	PREVOST 74 DPWA $K^-N \rightarrow \Sigma(1385)\pi$
120±10	LANGBEIN 72 IPWA KN multichannel
• • • We do not use the	ne following data for averages, fits, limits, etc. • • •
535 or 585	1 MARTIN 77 DPWA KN multichannel
28	CARROLL 76 DPWA Isospin-0 total σ
35	KIM 71 DPWA K-matrix analysis
30	ARMENTEROS70 HBC $\overline{K}N \rightarrow \overline{K}N$
70	ARMENTEROS70 HBC $\overline{K}N \rightarrow \Sigma \pi$
22	BARBARO 70 HBC $\overline{K}N \to \Sigma \pi$
300	BAILEY 69 DPWA $\overline{K}N \rightarrow \overline{K}N$
147	ARMENTEROS68B HBC

A(1810) DECAY MODES

	Mode	Fraction (Γ_I/Γ)	
Γ ₁	NK	20-50 %	
Γ_2	$\Sigma \pi$	10-40 %	
Γ3	Σ (1385) π	seen	
Γ_4	NK*(892)	30-60 %	
Γ ₅	$N\overline{K}^*(892), S=1/2, P$ -wave		
Γ ₆	$N\overline{K}^*(892)$, $S=3/2$, P -wave		

The above branching fractions are our estimates, not fits or averages.

A(1810) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on Λ and Σ Resonances

$\Gamma(N\overline{K})/\Gamma_{\text{total}}$					Γ_1/Γ
VALUE	DOCUMENT ID		TECN	COMMENT	
0.2 to 0.5 OUR ESTIMATE					
0.24±0.04	GOPAL	80	DPWA	RN → RN	
0.36±0.05	LANGBEIN	72	IPWA	KN multichannel	
• • • We do not use the follow	owing data for average	s, fit	s, limits,	etc. • • •	
0.21±0.04	GOPAL	77	DPWA	See GOPAL 80	
0.52 or 0.49	¹ MARTIN	77	DPWA	KN multichannel	
0.30	KIM	71	DPWA	K-matrix analysis	
0.15	ARMENTERO	570	DPWA	$\overline{K}N \rightarrow \overline{K}N$	
0.55	BAILEY	69	DPWA	$\overline{K}N \rightarrow \overline{K}N$	
0.4	ARMENTERO	S68B	DPWA	$\overline{K}N \rightarrow \overline{K}N$	

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N \overline{K}$	(۲ ₁ ۲ ₂)			
VALUE	DOCUMENT ID		TECN	COMMENT
-0.24 ± 0.04	GOPAL	77	DPWA	KN multichannel
• • • We do not use the f	following data for average	es, fits	s, limits,	etc. • • •
+0.25 or +0.23	¹ MARTIN	77	DPWA	KN multichannel
< 0.01	LANGBEIN	72	IPWA	RN multichannel
0.17	KIM			K-matrix analysis
+0.20	² ARMENTERO	570	DPWA	$\overline{K}N \rightarrow \Sigma \pi$
-0 13+0 03	RARRARO-	70	DPWA	$\overline{K}N \rightarrow \Sigma \pi$

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K} \to \Lambda(1810) \to \Sigma(1385) \pi$						/г
VALUE	DOCUMENT ID		TECN	COMMENT		_
+0.18+0.10	PREVOST	74	DPWA	K-N →	$\Sigma(1385)_{\pi}$	

 $\begin{array}{c|c} \left(\Gamma_{i}\Gamma_{f}\right)^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\overline{K} \rightarrow A (1810) \rightarrow N\overline{K}^{\bullet}(892), S=1/2, P\text{-wave} & \left(\Gamma_{1}\Gamma_{5}\right)^{\frac{1}{2}}/\Gamma_{\text{total}} \\ \hline POCUMENT ID & TECN & COMMENT \\ \hline -0.14 \pm 0.03 & 2 \text{ CAMERON} & 788 \text{ DPWA} & K^{-}p \rightarrow N\overline{K}^{*} \end{array}$

 $\begin{array}{c|c} (\Gamma_{I}\Gamma_{f})^{\frac{1}{12}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow A(1810) \rightarrow N\overline{K}^{\bullet}(892), S=3/2, P\text{-wave} & (\Gamma_{1}\Gamma_{6})^{\frac{1}{12}}/\Gamma_{1} \\ \hline \text{VALUE} & \underline{DOCUMENT ID} & \underline{TECN} & \underline{COMMENT} \\ +0.35\pm0.06 & \underline{CAMERON} & 78B & \underline{DPWA} & K^{-}\rho \rightarrow N\overline{K}^{*} \end{array}$

A(1810) FOOTNOTES

 $^{1}\,\text{The two MARTIN 77 values are from a T-matrix pole and from a Breit-Wigner fit. <math display="inline">^{2}\,\text{The published sign has been changed to be in accord with the baryon-first convention.}$

 $\Lambda(1810), \Lambda(1820), \Lambda(1830)$

A(1810) REFERENCES

GOPAL CAMERON	80 78B	Toronto Conf. 159 NP B146 327	+Franck, Gopal, Kalmus, McPherson-	(RHEL) IJP (RHEL, LOIC) IJP
GOPAL	77	NP B119 362		
			+Ross, VanHorn, McPherson+	(LOIC, RHEL) IJP
MARTIN	77	NP B127 349	+Pidcock, Moorhouse	(LOUC, GLAS) IJP
Also	77B	NP B126 266	Martin, Pidcock	(LOUC)
Afso	77C	NP B126 285	Martin, Pidcock	(LOUC) IJP
CARROLL	76	PRL 37 806	+Chiang, Kycia, Li, Mazur, Michael+	(BNL) I
PREVOST	74	NP B69 246	+Barloutaud+	(SACL, CERN, HEID)
LANGBEIN	72	NP B47 477	+Wagner	(MPIM) LIP
KIM	71	PRL 27 356	-	(HARV) IJP
Also	70	Duke Conf. 161	Kim	(HARV) IJP
ARMENTEROS	70	Duke Conf. 123	+Baillon+	(CERN, HEID, SACL) IJP
BARBARO	70	Duke Conf. 173	Barbaro-Galtieri	(LRL) IJP
BAILEY	69	Thesis UCRL 50617		(LLL) UP
ARMENTEROS	68B	NP B8 195	+Baillon+	(CERN, HEID, SACL) IJP

Λ(1820) F₀₅

$$I(J^P) = O(\frac{5}{2}^+)$$
 Status: ***

This resonance is the cornerstone for all partial-wave analyses in this region. Most of the results published before 1973 are now obsolete and have been omitted. They may be found in our 1982 edition Physics Letters 111B (1982).

Most of the quoted errors are statistical only; the systematic errors due to the particular parametrizations used in the partial-wave analyses are not included. For this reason we do not calculate weighted averages for the mass and width.

Λ(1820) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1815 to 1825 (≈ 1820) (OUR ESTIMATE			
1823±3	GOPAL	80	DPWA	KN → KN
1819±2	ALSTON	78	DPWA	RN → RN
1822±2	GOPAL	77	DPWA	KN multichannel
1821±2	KANE	74	DPWA	$K^-p \rightarrow \Sigma \pi$
• • • We do not use the	following data for average	es, flt	s, limits,	etc. • • •
1830	DECLAIS	77	DPWA	$\overline{K}N \to \overline{K}N$
1817 or 1819	¹ MARTIN	77	DPWA	KN multichannel

A(1820) WIDTH

VALUE (MeV) 70 to 90 (≈ 80) OUR ESTIMATE	DOCUMENT ID		TECN	COMMENT
77±5	GOPAL	80	DPWA	RN→ RN
72±5	ALSTON	78	DPWA	KN → KN
81±5	GOPAL	77	DPWA	KN multichannel
87±3	KANE	74	DPWA	$K^- \rho \rightarrow \Sigma \pi$
• • • We do not use the following	data for average	s, flt	s, limits,	etc. • • •
82	DECLAIS	77	DPWA	KN → KN
76 or 76	1 MARTIN	77	DPWA	K N multichannel

A(1820) DECAY MODES

	Mode	Fraction (Γ_J/Γ)	
Γ ₁	NK	55-65 %	
Γ_2	$\Sigma \pi$	8-14 %	
Γ3	$\Sigma(1385)\pi$	5-10 %	
Γ4	$\Sigma(1385)\pi$, P-wave		
Γ5	$\Sigma(1385)\pi$, F-wave		
۲6	$\Lambda\eta$		
Γ ₇	Σππ		

The above branching fractions are our estimates, not fits or averages.

A(1820) BRANCHING RATIOS

Errors quoted do not include uncertainties in the parametrizations used in the partial-wave analyses and are thus too small. See also "Sign conventions for resonance couplings" in the Note on Λ and Σ Resonances.

$\Gamma(N\overline{K})/\Gamma_{\text{total}}$					Γ1/Γ
VALUE	DOCUMENT ID		TECN	COMMENT	
0.55 to 0.65 OUR ESTIM	MTE				
0.58±0.02	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$	
0.60 ± 0.03	ALSTON	78	DPWA	KN → KN	
• • • We do not use the	following data for averag	es, fit	s, limits,	etc. • • •	
0.51	DECLAIS	77	DPWA	$\overline{K}N \rightarrow \overline{K}N$	
0.57±0.02	GOPAL	77	DPWA	See GOPAL 80	
0.59 or 0.58	¹ MARTIN	77	DPWA	KN multichannel	ı

(Γ,Γ _f) ^{1/2} /Γ _{total} in NK →					(Г ₁ Г ₂) ^⅓ /Г
VALUE	DOCUMENT ID		TECN .	COMMENT	
-0.28 ± 0.03	GOPAL		D	KN multi	
-0.28 ± 0.01	KANE			$K^-p \rightarrow$	
 We do not use the fo 	•				
-0.25 or -0.25	¹ MARTIN	77	DPWA	KN multi	ichannel
$(\Gamma_I\Gamma_I)^{1/2}/\Gamma_{ m total}$ in $N\overline{K}$ –	+ Λ(1820) → Λη				(Γ ₁ Γ ₆) ^{1/2} /Γ
VALUE	DOCUMENT ID		TECN		
-0.096 ^{+0.040} -0.020	RADER	73	MPWA		
Γ(Σππ)/Γ _{total}					Γ ₇ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT	·
no clear signal	² ARMENTER	O S68 c	новс	$K^-N \rightarrow$	Σππ
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\overline{K} -$					(Γ ₁ Γ ₄) ^{1/2} /Γ
VALUE	DOCUMENT ID				
-0.167 ± 0.054	³ CAMERON				
+0.27 ±0.03	PREVOST	74	DPWA	K-N→	Σ (1385)π
(「「「「」) ^{1/2} /「total in NK -	+ Λ(1820) → Σ(130				(Γ ₁ Γ ₅) ^{1/2} /Γ
+0.065 ±0.029	3 CAMERON				

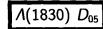
A(1820) FOOTNOTES

1 The two MARTIN 77 values are from a T-matrix pole and from a Breit-Wigner fit. There is a suggestion of a bump, enough to be consistent with what is expected from $\Sigma(1385) \to \Sigma \pi$ decay.

³ The published sign has been changed to be in accord with the baryon-first convention.

A(1820) REFERENCES

PDG	82	PL 1118	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
GOPAL	80	Toronto Conf. 159		(RHEL) IJP
ALSTON	78	PR D18 182	Alston-Garnjost, Kenney+	(LBL, MTHO, CERN) IJP
Also	77	PRL 38 1007	Alston-Garnjost, Kenney+	(LBL, MTHO, CERN) IJP
CAMERON	78	NP B143 189	+Franck, Gopal, Bacon, Butterworth+	(RHEL, LOIC) IJP
DECLAIS	77	CERN 77-16	+Duchon, Louvel, Patry, Seguinot+	(CAEN, CERN) IJP
GOPAL.	77	NP B119 362	+Ross, VanHorn, McPherson+	(LOIC, RHEL) IJP
MARTIN	77	NP B127 349	+Pidcock, Moorhouse	(LOUC, GLAS) IJP
Also	77B	NP B126 266	Martin, Pidcock	(Louc)
Also	77C	NP B126 285	Martin, Pidcock	(LOUC) IJP
KANE	74	LBL-2452		`(LBL) IJP
PREVOST	74	NP B69 246	+Barloutaud+	(SACL, CERN, HEID)
RADER	73	NC 16A 178	+Barloutaud+ (SACL, HEID.	CERN, RHEL, CDEF)
ARMENTEROS	68C	NP B8 216		(CERN, HEID, SACL) I



$$I(J^P) = O(\frac{5}{2}^-)$$
 Status: ****

For results published before 1973 (they are now obsolete), see our 1982 edition Physics Letters 111B (1982).

The best evidence for this resonance is in the $\Sigma\pi$ channel.

A(1830) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1810 to 1830 (≈ 1830) (OUR ESTIMATE			•
1831 ± 10	GOPAL			KN → KN
1825 ± 10	GOPAL	77	DPWA	KN multichannel
1825 ± 1	KANE	74	DPWA	$K^- p \rightarrow \Sigma \pi$
• • We do not use the	e following data for averag	es, fit	s, limits,	etc. • • •
1817 or 1818	¹ MARTIN	77	DPWA	KN multichannel

Λ(1830) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
60 to 110 (≈ 95) OUR	ESTIMATE			
100±10	GOPAL	80	DPWA	RN → RN
94 ± 10	GOPAL	77	DPWA	KN multichannel
119± 3	KANE	74	DPWA	$K^-p \rightarrow \Sigma \pi$
• • • We do not use the	following data for averag	es, fits	s, limits,	etc. • • •
56 or 56	1 MARTIN	77	DPWA	K N multichannel

A(1830) DECAY MODES

	Mode	Fraction (Γ_i/Γ)	_
Γ1	NK	3-10 %	
Γ_2	$\Sigma\pi$	35-75 %	
Γ ₃ Γ ₄	$\Sigma(1385)\pi$ $\Sigma(1385)\pi$, <i>D</i> -wave	>15 %	
Γ ₅	Δη Δ-wave		

The above branching fractions are our estimates, not fits or averages.

A(1830) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on Λ and Σ

$\Gamma(N\overline{K})/\Gamma_{\text{total}}$					Γ1/Γ
VALUE	DOCUMENT ID		TECN	COMMENT	
0.03 to 0.10 OUR ESTIMA	ATE				
0.08±0.03	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$	
0.02 ± 0.02	ALSTON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$	
ullet $ullet$ We do not use the	following data for average	s, fit	s, limits,	etc. • • •	
0.04±0.03	GOPAL	77	DPWA	See GOPAL 80)
0.04 or 0.04	¹ MARTIN	77	DPWA	KN multichar	inel
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\overline{K}$	$\rightarrow \Lambda(1830) \rightarrow \Sigma \pi$			(r	1 Г2) ¹ /2/Г
VALUE	DOCUMENT ID		TECN		
-0.17±0.03	GOPAL	77	DPWA	KN multichar	nel
-0.15 ± 0.01	KANE	74	DPWA	$K^- p \rightarrow \Sigma \pi$	
• • • We do not use the					
-0.17 or -0.17	¹ MARTIN	77	DPWA	KN multichar	inel
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N \overline{K}$				(r	1Γ ₈) ^{1/2} /Γ
VALUE			TECN		
-0.044 ± 0.020	RADER	73	MPWA		
$(\Gamma_l\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}}$ in $N\overline{K}$				(r	1√3) ¹ //
VALUE					
$+0.141\pm0.014$	² CAMERON				
+0.13 ±0.03	PREVOST	74	DPWA	$K^-N \rightarrow \Sigma($	1385)π

A(1830) FOOTNOTES

A(1830) REFERENCES

		-		
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
GOPAL	80	Toronto Conf. 159		(RHEL) IJP
ALSTON	78	PR D18 182	Alston-Garnjost, Kenney+	(LBL, MTHO, CERN) IJP
Aiso	77	PRL 38 1007	Alston-Garnjost, Kenney+	(LBL, MTHO, CERN) IJP
CAMERON	78	NP B143 189	+Franek, Gopal, Bacon, Butterworth	+ (RHEL, LOIC) IJP
GOPAL	77	NP B119 362	+Ross, VanHorn, McPherson+	(LOIC, RHEL) IJP
MARTIN	77	NP B127 349	+Pidcock, Moorhouse	(LOUC, GLAS) IJP
Also	77B	NP B126 266	Martin, Pidcock	(LOUC)
Also	77C	NP B126 285	Martin, Pidcock	(LOUC) IJP
KANE	74	LBL-2452		(LBL) IJP
PREVOST	74	NP B69 246	+Barloutaud+	(SACL, CERN, HEID)
RADER	73	NC 16A 178 .	+Barloutaud+ (SACL, HEII), CERN, RHEL, CDEF)

 $\Lambda(1890) P_{03}$

$$I(J^P) = O(\frac{3}{2}^+)$$
 Status: ****

For results published before 1974 (they are now obsolete), see our 1982 edition Physics Letters 111B (1982).

The $J^P=3/2^+$ assignment is consistent with all available data (including polarization) and recent partial-wave analyses. The dominant inelastic modes remain unknown.

Λ(1890) MASS

VALUE (MeV)			TECN	COMMENT
1850 to 1910 (≈ 1890)	OUR ESTIMATE			
1897± 5	GOPAL	.80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
1908±10	ALSTON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$
1900± 5	GOPAL	77	DPWA	KN multichannel
1894±10	HEMINGWAY	75	DPWA	$K^-p \rightarrow \overline{K}N$
• • • We do not use the	ne following data for average:	, fit	s, limits,	etc. • • •
1856 or 1868	¹ MARTIN	77	DPWA	KN multichannel
1900	² NAKKASYAN			

Λ(1890) WIDTH

VALUE (MeV)	DOCUMENT ID	DOCUMENT ID 1		COMMENT
60 to 200 (≈ 100) OU	R ESTIMATE			
74±10	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
119±20	ALSTON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$
72±10	GOPAL	77	DPWA	KN multichannel
107±10	HEMINGWAY	75	DPWA	$K^-p \rightarrow \overline{K}N$
• • • We do not use t	he following data for average	s, fit:	s, limits,	etc. • • •
191 or 193	¹ MARTIN	77	DPWA	KN multichannel
100	² NAKKASYAN	75	DPWA	$K^- \rho \rightarrow \Lambda \omega$

A(1890) DECAY MODES

	Mode	Fraction (Γ_I/Γ)
Г1	NK	20-35 %
Γ_2	$\Sigma \pi$	3–10 %
Γ3	$\Sigma(1385)\pi$	seen
Γ_4	$\Sigma(1385)\pi$, P-wave	
Γ ₅	$\Sigma(1385)\pi$, F-wave	
۲6	NK*(892)	seen
Γ ₇	$N\overline{K}^*(892), S=1/2, P$ -wave	
Γ8	$\Lambda \omega$	

The above branching fractions are our estimates, not fits or averages.

A(1890) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on A and Σ

$\Gamma(N\overline{K})/\Gamma_{\text{total}}$				Г ₁ /Г
VALUE	DOCUMENT ID		TECN	COMMENT
0.20 to 0.35 OUR ESTIM				
0.20 ± 0.02				$\overline{K}N \rightarrow \overline{K}N$
0.34 ± 0.05	ALSTON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$
0.24 ± 0.04	HEMINGWAY	75	DPWA	$K^- p \rightarrow \overline{K} N$
 • • We do not use the 	following data for averages	s, flt:	s, limits,	etc. • • •
0.18±0.02				See GOPAL 80
0.36 or 0.34	¹ MARTIN	77	DPWA	KN multichannel
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\overline{K}$	→ Λ(1890) → Σπ			(┌₁┌₂) ^½ /┌
VALUE	DOCUMENT ID		TECN	COMMENT
~0.09±0.03	GOPAL	77	DPWA	KN multichannel
 • • We do not use the 	following data for averages	s, fit:	s, limits,	etc. • • •
+0.15 or +0.14	¹ MARTIN	77	DPWA	KN multichannel
(「「「「」 ^{1/2} /「total in NK VALUE	$\rightarrow \Lambda(1890) \rightarrow \Lambda \omega$ DOCUMENT ID		TECN	(Γ ₁ Γ ₈) ^{1/2} /[

VALUE	$NK \rightarrow \Lambda(1890) \rightarrow \Lambda\omega$ DOCUMENT ID	_	TECN	COMMENT	(Г ₁ Г ₈) ⁷² /Г
seen	BACCARI	77	IPWA	$K^-p \rightarrow$	Λω
0.032	² NAKKASYAN	75	DPWA	$K^- p \rightarrow$	$\Lambda \omega$
(F.F.)1/2/Fin	$N\overline{K} \rightarrow A(1890) \rightarrow \Sigma(1385)$	١	P-way		([1[A] ¹ /[

<0.03	CAMERON			$K^-p \rightarrow$	Σ(1385)π
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\overline{K} \to K$	(1890) → Σ (1385))π, F	-wav	2	(Γ ₁ Γ ₅) ^{1/2} /Γ
VALUE	DOCUMENT ID	I	<u>ECN</u>	COMMENT	<u> </u>
~0.126±0.055	3 CAMERON	78 D	PWA	$K^- \rho \rightarrow$	$\Sigma(1385)\pi$

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\overline{K} \to \Lambda$	$(1890) \rightarrow N\overline{K}^{\bullet}(892)$			$(\Gamma_1\Gamma_6)^{\frac{1}{2}}$
VALUE	DOCUMENT ID	TECN	COMMENT	
-0.07±0.03	3,4 CAMERON 788	DPWA	$K^-p \rightarrow$	N K *

Λ(1890) FOOTNOTES

¹ The two MARTIN 77 values are from a T-matrix pole and from a Breit-Wigner fit.

² Found in one of two best solutions.

³ The published sign has been changed to be in accord with the baryon-first convention. 4 Upper limits on the P_3 and F_3 waves are each 0.03.

A(1890) REFERENCES

		-	·	
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
GOPAL	80	Toronto Conf. 159		(RHEL) IJP
ALSTON	78	PR D18 182	Alston-Garnjost, Kenney+	(LBL, MTHO, CERN) IJP
Also	77	PRL 38 1007	Alston-Garnjost, Kenney+	(LBL, MTHO, CERN) IJP
CAMERON	78	NP B143 189	+Franek, Gopal, Bacon, Butterwort	h+ (RHEL, LOIC) IJP
CAMERON	78B	NP B146 327	+Franek, Gopal, Kalmus, McPherso	n+ (RHEL, LOIC) IJP
BACCARI	77	NC 41A 96	+Poulard, Revel, Tallini+	(SACL, CDEF) IJP
GOPAL	77	NP B119 362	+Ross, VanHorn, McPherson+	(LOIC, RHEL) IJP
MARTIN	77	NP B127 349	+Pidcock, Moorhouse	(LOUC, GLAS) IJP
Also	77B	NP B126 266	Martin, Pidcock	(LOUC)
Aiso	77C	NP B126 285	Martin, Pidcock	(LOUC) IJP
HEMINGWAY	75	NP B91 12	+Eades, Harmsen+	(CERN, HEIDH, MPIM) IJP
NAKKASYAN	75	NP R93 85		(CERN) LIP

 $^{^{1}\,\}text{The}$ two MARTIN 77 values are from a T-matrix pole and from a Breit-Wigner fit. $^{2}\,\text{The}$ CAMERON 78 upper limit on G-wave decay is 0.03. The published sign has been changed to be in accord with the baryon-first convention.

Λ(2000), Λ(2020)

Λ(2000)

 $I(J^{p}) = 0(?^{?})$ Status: *

OMITTED FROM SUMMARY TABLE

We list here all the ambiguous resonance possibilities with a mass around 2 GeV. The proposed quantum numbers are D_3 (BARBARO-GALTIERI 70 in $\Sigma\pi$), $D_3+F_5,\,P_3+D_5,$ or P_1+D_3 (BRANDSTETTER 72 in $\Lambda\omega$), and S_1 (CAMERON 78B in $N\overline{K}^*$). The first two of the above analyses should now be considered obsolete. See also NAKKASYAN 75.

1(2000) MASS

VALUE (MeV)	DOCUMENT ID TECN COMMENT
≈ 2000 OUR ESTIMATE	
2030±30	CAMERON 788 DPWA $K^- p \rightarrow N \overline{K}^*$
1935 to 1971	¹ BRANDSTET72 DPWA $K^-p \rightarrow \Lambda \omega$
1951 to 2034	¹ BRANDSTET72 DPWA $K^-p \rightarrow \Lambda \omega$
2010±30	BARBARO 70 DPWA K ⁻ p → Σπ
	

A(2000) WIDTH

VALUE (MeV) 125±25 180 to 240 73 to 154	DOCUMENT ID TECN COMMENT CAMERON 78B DPWA $K^-p \rightarrow N\overline{K}^*$ BRANDSTET72 DPWA (lower mass) BRANDSTET72 DPWA (higher mass)
130±50	BARBARO 70 DPWA $K^-p \rightarrow \Sigma \pi$

A(2000) DECAY MODES

	Mode
۲,	NK
Γ_2^-	Σπ
Γ3	$\Lambda \omega$
Γ4	$N\overline{K}^*(892)$, $S=1/2$, S-wave
r _s	$N\overline{K}^*(892)$, $S=3/2$, D-wave

Λ(2000) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on A and Σ Resonances.

(total in N K →	Λ(2000) → Σπ DOCUMENT ID TECH COMI	(Γ ₁ Γ ₂) ^{1/2} /Γ
-0.20±0.04	BARBARO 70 DPWA K-	
(Γ _I Γ _f) 1/2 /Γ _{total} in NK →	Λ(2000) → Λω DOCUMENT ID TECH COM	([15])1/2/[
0.17 to 0.25	1 BRANDSTET72 DPWA (lower 1 BRANDSTET72 DPWA (high	er mass)
0.04 to 0.15	¹ BRANDSTET72 DPWA (high	ier mass)
•1		_
$(\Gamma_I\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}}$ in $N\overline{K} \rightarrow \frac{VALUE}{2}$	Λ(2000) → NK+(892), S=1/2, S+ DOCUMENT ID TECN COMI	MENT
		MENT

A(2000) FOOTNOTES

A(2000) REFERENCES

CAMERON	78B	NP B146 327	+Franck, Gopal, Kalmus, McPherson+	(RHEL, LOIC) UP
NAKKASYAN	75	NP B93 85		(CERN) UP
BRANDSTET	.72	NP B39 13	Brandstetter, Butterworth+ (RHEL	, CDEF, SACL)
BARBARO		Duke Conf. 173	Barbaro-Galtieri	(LRL) IJP

 $\Lambda(2020) F_{07}$

< 0.05

 $I(J^P) = O(\frac{7}{2}^+)$ Status: *

OMITTED FROM SUMMARY TABLE

In LITCHFIELD 71, need for the state rests solely on a possibly inconsistent polarization measurement at 1.784 GeV/c. HEMING-WAY 75 does not require this state. GOPAL 77 does not need it in either $N \overline{K}$ or $\Sigma \pi$. With new $K^- n$ angular distributions included, DECLAIS 77 sees it. However, this and other new data are included in GOPAL 80 and the state is not required. BACCARI 77 weakly supports it.

A(2020)	MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
≈ 2020 OUR ESTIMATE				
2140	BACCARI	77	DPWA	$K^- p \rightarrow \Lambda \omega$
2117	DECLAIS	77	DPWA	KN → KN
2100±30	LITCHFIELD	71	DPWA	$K^-p \rightarrow \overline{K}N$
2020±20	BARBARO	70	DPWA	$K^-p \rightarrow \Sigma \pi$

Λ(2020) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
128	BACCARI	77	DPWA	$K^-p \rightarrow \Lambda \omega$
167	DECLAIS	77	DPWA	Kn → Kn
120±30	LITCHFIELD	71	DPWA	K-p → KN
160±30	BARBARO	70	DPWA	$K^-p \rightarrow \Sigma \pi$

A(2020) DECAY MODES

	Mode		 	
<u></u>	NK	 		
ΓŽ	Σπ			
Γ3	Λω			

A(2020) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on \varLambda and \varSigma Resonances.

Γ(NR)/Γ _{total}					Γ_1/Γ
VALUE	DOCUMENT ID		TECN	COMMENT	
0.05	DECLAIS	77	DPWA	$\overline{K}N \rightarrow \overline{K}N$	
0.05 ± 0.02	LITCHFIELD	71	DPWA	$K^-p \rightarrow \overline{K}N$	
$(\Gamma_{\ell}\Gamma_{\ell})^{\frac{1}{2}}/\Gamma_{mod}$ in $N\overline{K} \rightarrow \Lambda(20)$	20) → Σπ			([1]	ο)*⁄/Γ

() () () () () total III to \ \to \ \tag{20}	(1112) /1			
VALUE	DOCUMENT ID	TECN	COMMENT	
-0.15 ± 0.02	BARBARO 70	DPWA	$K^-p \rightarrow$	Σπ
$(\Gamma_I \Gamma_f)^{\frac{1}{12}} / \Gamma_{\text{total}} \text{ in } N\overline{K} \to \Lambda(20)$	20) → Λω	TECN	COMMENT	(Γ ₁ Γ ₃) ^{1/2} /Γ

A(2020) REFERENCES

BACCARI

77 DPWA K-p → Aw

GOPAL BACCARI DECLAIS GOPAL HEMINGWAY LITCHFIELD	80 77 77 77 75 71	Toronto Conf. 159 NC 41A 96 CERN 77-16 NP B119 362 NP B91 12 NP B30 125	+Poulard, Revel, Tallini+ +Duchon, Louvel, Patry, Seguinot+ +Ross, VanHorn, McPherson+ +Eades, Harmsen+ +, Lesquoy+	(LOIC, RHEL) (CERN, HEIDH, MPIM) LIP (RHEL, CDEF, SACL) IJP
	70	Duke Conf. 173	Barbaro-Galtieri	(LRL) IJP

 $^{^1}$ The parameters quoted here are ranges from the three best fits; the lower state probably has $J \leq 3/2$, and the higher one probably has $J \leq 5/2$.

 $^{^{\}rm 2}\,{\rm The}$ published sign has been changed to be in accord with the baryon-first convention.

 $\Lambda(2100) G_{07}$

 $I(J^P) = 0(\frac{7}{2}^-)$ Status: ***

Discovered by COOL 66 and by WOHL 66. Most of the results published before 1973 are now obsolete and have been omitted. They may be found in our 1982 edition Physics Letters 111B (1982).

This entry only includes results from partial-wave analyses. Parameters of peaks seen in cross sections and in invariant-mass distributions around 2100 MeV used to be listed in a separate entry immediately following. It may be found in our 1986 edition Physics Letters

Λ(2100) MASS

VALUE (MeV)	DOCUMENT ID		TECN COMMENT
2090 to 2110 (≈ 2100) OUR ES	TIMATE		
2104±10	GOPAL	80	DPWA $\overline{K}N \rightarrow \overline{K}N$
2106±30	DEBELLEFON	78	DPWA $\overline{K}N \rightarrow \overline{K}N$
2110±10	GOPAL	77	DPWA KN multichannel
2105 ± 10	HEMINGWAY	75	DPWA $K^-p \rightarrow \overline{K}N$
2115±10	KANE	74	DPWA $K^-p \rightarrow \Sigma \pi$
• • • We do not use the follow	ing data for averages,	, fits	s, limits, etc. • • •
2094	BACCARI	77	DPWA $K^-p \rightarrow \Lambda \omega$
2094	DECLAIS	77	DPWA $\overline{K}N \rightarrow \overline{K}N$
2110 or 2089	¹ NAKKASYAN	75	DPWA $K^-p \rightarrow \Lambda \omega$

Λ(2100) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN COMMENT
100 to 250 (≈ 200) OUR ESTIN	MATE		
157±40	DEBELLEFON	78	DPWA $\overline{K}N \rightarrow \overline{K}N$
250±30	GOPAL	77	DPWA $\overline{K}N$ multichannel
241±30	HEMINGWAY	75	DPWA $K^-p \rightarrow \overline{K}N$
152±15	KANE	74	DPWA $K^-p \rightarrow \Sigma \pi$
• • • We do not use the follow	ing data for average	s, flt	s, limits, etc. • • •
98	BACCARI	77	DPWA $K^- p \rightarrow \Lambda \omega$
250			DPWA $\overline{K}N \rightarrow \overline{K}N$
244 or 302	¹ NAKKASYAN	75	DPWA $K^-p \rightarrow \Lambda \omega$

A(2100) DECAY MODES

	Mode	Fraction (Γ_i/Γ)	
$\overline{\Gamma_1}$	NK	25-35 %	
Γ_2	$\Sigma\pi$	~ 5 %	
Γ_3	$\Lambda\eta$	<3 %	
Γ_4	ΞK	<3 %	
Γ_5	$\Lambda \omega$	<8 %	
Γ ₆	NK*(892)	10–20 %	
Γ7	$N\overline{K}^*$ (892), $S=1/2$, G -wave		
Γ ₈	<i>N K</i> *(892), <i>S</i> =3/2, <i>D</i> -wave		

The above branching fractions are our estimates, not fits or averages.

A(2100) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on Λ and Σ Resonances.

$\Gamma(N\overline{K})/\Gamma_{\text{total}}$	4				Γ1/
VALUE	DOCUMENT ID		TECN	COMMENT	
0.25 to 0.35 OUR ESTIMA	NTE	-			
0.34±0.03	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$	
0.24±0.06	DEBELLEFON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$	
0.31 ± 0.03	HEMINGWAY	75	DPWA	$K^-p \rightarrow \overline{K}N$	
• • • We do not use the f	following data for average:	s, fit	s, limits,	etc. • • •	
0.29	DECLAIS	77	DPWA	$\overline{K}N \rightarrow \overline{K}N$	
0.30 ± 0.03	GOPAL	77	DPWA	See GOPAL 80	
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\overline{K}$	$\rightarrow \Lambda(2100) \rightarrow \Sigma \pi$			(r ₁ r;	2) ^{1/2} /
VALUE	DOCUMENT ID		TECN	COMMENT	
$+0.12 \pm 0.04$	GOPAL	77	DPWA	KN multichannel	

$+0.11 \pm 0.01$	KANE	74	DPWA	$K^- p \rightarrow \Sigma \pi$
$(\Gamma_I \Gamma_f)^{\frac{1}{12}} / \Gamma_{\text{total}} \ln N \overline{K} \rightarrow \Lambda(21)$				(Γ₁Γ₃) ^½ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
-0.050±0.020	RADER	73	MPWA	$K^- \rho \rightarrow \Lambda \eta$

VALUE	DOCUMENT ID		TECN_	COMMENT
0.035 ± 0.018	LITCHFIELD	71	DPWA	$K^-p \rightarrow \Xi K$
• • We do not use the	following data for average:	s, fits	, limits,	etc. • • •
0.003	MULLER	69B	DPWA	$K^-p \rightarrow \Xi K$
0.05	TRIPP	67	RVUE	$K^-p \rightarrow \Xi K$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\overline{K}$	$\rightarrow \Lambda(2100) \rightarrow \Lambda \omega$			(「1「5) ^½ /i
VALUE	<u>DOCUMENT ID</u>			COMMENT
-0.070	² BACCARI	77	DPWA	GD ₃₇ wave
+0.011	² BACCARI	77	DPWA	GG ₁₋₇ wave
+0.008	² BACCARI	77	DPWA	GG ₃₇ wave
0.122 or 0.154	¹ NAKKASYAN			$K^-p \rightarrow \Lambda \omega$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\overline{K}$				
VALUE	<u>DOCUMENT ID</u>		<u>TECN</u>	COMMENT
$+0.21\pm0.04$	CAMERON	78B	DPWA	$K^- \rho \rightarrow N \overline{K}^*$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N\overline{K}$	$\rightarrow \Lambda(2100) \rightarrow N\overline{K}^{\bullet}(8)$ $\underline{DOCUMENT ID}$			
-0.04±0.03	3 CAMERON			

 1 The NAKKASYAN 75 values are from the two best solutions found. Each has the $\Lambda(2100)$ and one additional resonance $(P_3$ or $F_5)$. 2 Note that the three for BACCARI 77 entries are for three different waves. 3 The published sign has been changed to be in accord with the baryon-first convention. The upper limit on the G_3 wave is 0.03.

A(2100) REFERENCES

PDG PDG	86 82	PL 170B PL 111B	Aguilar-Benitez, Porte Roos, Porter, Aguilar-		(CERN, CIT+) (HELS, CIT, CERN)
GOPAL	80	Toronto Conf. 159			(RHEL) UP
CAMERON	78B	NP B146 327	+Franek, Gopal, Kalmu	is, McPherson+	(RHEL, LOIC) UP
DEBELLEFON	78	NC 42A 403	De Bellefon, Berthon,	Billoir+	(CDEF, SACL) IJP
BACCARI	77	NC 41A 96	+Poulard, Revel, Tallini	i +	(SACL, CDEF) IJP
DECLAIS	77	CERN 77-16	+Duchon, Louvel, Patry	y, Seguinot+	(CAEN, CERN) UP
GOPAL	77	NP B119 362	+Ross, VanHorn, McPh	terson+	(ŁOIC, RHEL) IJP
HEMINGWAY	75	NP B91 12	+Eades, Harmsen+	(CI	ERN, HÈIDH, MPIM) IJP
NAKKASYAN	75	NP B93 85	r		(CERN) IJP
KANE	74	LBL-2452			(LBL) IJP
RADER	73	NC 16A 178	+Barloutaud+	(SACL, HEID,	CERN, RHEL, CDEF)
LITCHFIELD	71	NP B30 125	+, Lesquoy+	` ' (RHEL, CDEF, SACL) IJP
MULLER	69B	Thesis UCRL 19372	• • • •	•	(LRL)
TRIPP	67	NP B3 10	+Leith+	(LRL, SLAC,	CERN, HEID, SACL)
COOL	66	PRL 16 1228	+Giacomelli, Kycia, Lec	ontic. Lundby+	(BNL)
WOHL	66	PRL 17 107	+Solmitz, Stevenson		(LRL) IJP

 $\Lambda(2110) F_{05}$

$$I(J^P) = O(\frac{5}{2}^+)$$
 Status: ***

For results published before 1974 (they are now obsolete), see our 1982 edition Physics Letters 111B (1982). All the references have

This resonance is in the Baryon Summary Table, but the evidence for it could be better.

A(2110) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
2090 to 2140 (≈ 2110) OU	R ESTIMATE			
2092 ± 25	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
2125 ± 25	CAMERON	78B	DPWA	$K^- p \rightarrow N \overline{K}^*$
2106±50	DEBELLEFON	78	DPWA	$\overline{K}N \to \overline{K}N$
2140±20	DEBELLEFON	77	DPWA	$K^- \rho \rightarrow \Sigma \pi$
2100±50	GOPAL	77	DPWA	KN multichannel
2112± 7	KANE	74	DPWA	$K^- p \rightarrow \Sigma \pi$
• • We do not use the form	ollowing data for averages	i, fits	, limits,	etc. • • •
2137	BACCARI	77	DPWA	$K^- p \rightarrow \Lambda \omega$
2103	¹ NAKKASYAN	75	DPWA	$K^- p \rightarrow \Lambda \omega$

A(2110) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
150 to 250 (≈ 200) OUR ESTIMA	TE			
245 ± 25	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
160±30	CAMERON	78B	DPWA	$K^- p \rightarrow N \overline{K}^*$
251±50	DEBELLEFON	78	DPWA	$\overline{K}N \to \overline{K}N$
140±20	DEBELLEFON	77	DPWA	$K^-p \rightarrow \Sigma \pi$
200 ± 50	GOPAL	77	DPWA	KN multichannel
190±30	KANE	74	DPWA	$K^-p \rightarrow \Sigma \pi$
	data for averages	i, fits	i, limits,	etc. • • •
132	BACCARI			
391	¹ NAKKASYAN	75	DPWA	$K^-p \rightarrow \Lambda \omega$

 $\Lambda(2110), \Lambda(2325), \Lambda(2350)$

A(2110) DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ ₁	NK	5-25 %
Γ_2	$\Sigma \pi$	10-40 %
Γ3	Λω	seen
Γ_4	$\Sigma(1385)\pi$	seen
Γ ₅	$\Sigma(1385)\pi$, <i>P</i> -wave	
Γ ₅ Γ ₆	N K*(892)	10-60 %
Γ7	$N\overline{K}^*(892), S=1/2, F$ -wave	
	The above branching fractions are	our estimates, not fits or averages.

Λ(2110) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on Λ and Σ

		Γ ₁ /Γ
	TECN	COMMENT

ollowing data for averages,	fits, limits,	etc. • • •
GOPAL 7	7 DPWA	See GOPAL 80
		(Γ₁Γ₂) ^½ /Γ
DOCUMENT ID	<u>TECN</u>	COMMENT
DEBELLEFON 7	7 DPWA	$K^- p \rightarrow \Sigma \pi$
KANE 7	4 DPWA	$K^-p \rightarrow \Sigma \pi$
ollowing data for averages,	fits, limits,	etc. • • •
GOPAL 7	7 DPWA	KN multichannel
→ Λ(2110) → Λω	TECH	(Γ ₁ Γ ₃) ^{1/2} /Γ
DOCUMENT ID		COMMENT
DOCUMENT ID BACCARI 7	7 DPWA	$COMMENT$ $K^-p \rightarrow \Lambda \omega$
DOCUMENT ID	7 DPWA	$COMMENT$ $K^-p \rightarrow \Lambda \omega$
DOCUMENT ID BACCARI 7 1 NAKKASYAN 7 → A(2110) → Σ(1385)	7 DPWA 5 DPWA	$ \begin{array}{c} COMMENT \\ K^- p \to \Lambda \omega \\ K^- p \to \Lambda \omega \end{array} $ $ (\Gamma_1 \Gamma_4)^{\frac{1}{2}}/\Gamma$
DOCUMENT ID BACCARI 7 1 NAKKASYAN 7 → A(2110) → Σ(1385)	7 DPWA 5 DPWA	$ \begin{array}{c} COMMENT \\ K^- p \to \Lambda \omega \\ K^- p \to \Lambda \omega \end{array} $ $ (\Gamma_1 \Gamma_4)^{\frac{1}{2}}/\Gamma$
<u>DOCUMENT ID</u> BACCARI 7 ¹ NAKKASYAN 7	7 DPWA 5 DPWA	$ \begin{array}{c} COMMENT \\ K^- p \to \Lambda \omega \\ K^- p \to \Lambda \omega \end{array} $ $ (\Gamma_1 \Gamma_4)^{\frac{1}{2}}/\Gamma$
DOCUMENT ID BACCARI 7 1 NAKKASYAN 7 → A(2110) → Σ(1385) DOCUMENT ID 3 CAMERON 7 → A(2110) → NK*(89:	7 DPWA 5 DPWA 7 TECN 8 DPWA	$ \begin{array}{c} COMMENT \\ K^- p \to \Lambda \omega \\ K^- p \to \Lambda \omega \end{array} $ $ (\Gamma_1 \Gamma_4)^{\frac{1}{2}}/\Gamma$
	GOPAL 8 2 DEBELLEFON 7 collowing data for averages, 1 GOPAL 7 → A(2110) → ∑π DOCUMENT ID DEBELLEFON 7 KANE 7 collowing data for averages, 1	GOPAL 80 DPWA 2 DEBELLEFON 78 DPWA billowing data for averages, fits, limits, GOPAL 77 DPWA → A(2110) → ∑π DOCUMENT ID TECN DEBELLEFON 77 DPWA

A(2110) FOOTNOTES

A(2110) REFERENCES

PDG	82	PL 1118	*	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
GOPAL	80	Toronto Conf.	159		(RHEL) IJP
CAMERON	78	NP B143 189		+Franck, Gopal, Bacon, Butterworth+	(RHEL, LOIC) IJP
CAMERON	78B	NP B146 327		+Franek, Gopai, Kalmus, McPherson+	(RHEL, LOIC) IJP
DEBELLEFON	78	NC 42A 403		De Bellefon, Berthon, Billoir+	(CDEF, SACL) IJP
BACCARI	77	NC 41A 96		+Poulard, Revel, Tallini+	(SACL, CDEF) IJP
DEBELLEFON	77	NC 37A 175		De Bellefon, Berthon, Billoir+	(CDEF, SACL) IJP
GOPAL	77	NP B119 362		+Ross, VanHorn, McPherson+	(LOIC, RHEL) IJP
NAKKASYAN	75	NP B93 85			(CERN) IJP
KANE	74	LBL-2452			(LBL) IJP

$\Lambda(2325) D_{03}$

 $I(J^P) = O(\frac{3}{2})$ Status: *

OMITTED FROM SUMMARY TABLE

BACCARI 77 finds this state with either $J^P = 3/2^-$ or $3/2^+$ in a energy-dependent partial-wave analyses of $K^-p \to \Lambda \omega$ from 2070 to 2436 MeV. A subsequent semi-energy-independent analysis from threshold to 2436 MeV selects 3/2". DEBELLEFON 78 (same group) also sees this state in an energy-dependent partial-wave analysis of $K^-p\to \overline{K}\,N$ data, and finds $J^P=3/2^-$ or $3/2^+$. They again prefer $J^P=3/2^-$, but only on the basis of model-dependent considerations.

Λ(2325) MASS

	,
VALUE (MeV)	DOCUMENT ID TECN COMMENT
≈ 2325 OUR ESTIMATE	DEDELLESON TO DOWN THE TAX
2342±30	DEBELLEFON 78 DPWA $\overline{K}N \rightarrow \overline{K}N$
2327 ± 20	BACCARI 77 DPWA $K^-p \rightarrow \Lambda \omega$
	∧(2325) WIDTH
VALUE (MeV)	DOCUMENT ID TECN COMMENT
177±40	DEBELLEFON 78 DPWA $\overline{K}N \rightarrow \overline{K}N$

A(2325) DECAY MODES

	Mode				
Γ ₁	NK	100.000		 	_
Γ_2	$\Lambda \omega$				

A(2325) BRANCHING RATIOS

TALUL	DOCOMENT ID		1201	COMMENT	_
0.19 ± 0.06	DEBELLEFON	78	DPWA	KN→ KN	
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N$	$\mathcal{R} \to \Lambda(2325) \to \Lambda \omega$			(Γ ₁ Γ ₂) ^{1/2} /	r
VALUE	DOCUMENT ID		TECN	COMMENT	_
0.06 ± 0.02	¹ BACCARI	77	IPWA	DS ₃₃ wave	
0.05 ± 0.02	¹ BACCARI	77	DPWA	DD ₁₃ wave	
0.08 ± 0.03	¹ BACCARI	77	DPWA	DD ₃₃ wave	

A(2325) FOOTNOTES

A(2325) REFERENCES

DEBELLEFON 78 NC 42A 403 BACCARI 77 NC 41A 96

 $\Gamma(N\overline{K})/\Gamma_{total}$

De Bellefon, Berthon, Billoir+ +Poulard, Revel, Tallini+

(CDEF, SACL) IJP (SACL, CDEF) IJP

 Γ_1/Γ

Λ(2350) H₀₉

$$I(J^P) = O(\frac{9}{2}^+)$$
 Status: ***

DAUM 68 favors $J^{P} = 7/2^{-}$ or $9/2^{+}$. BRICMAN 70 favors $9/2^{+}$. LASINSKI 71 suggests three states in this region using a Pomeron + resonances model. There are now also three formation experiments from the College de France-Saclay group, DEBELLEFON 77, BACCARI 77, and DEBELLEFON 78, which find 9/2+ in energydependent partial-wave analyses of $\overline{K}N \to \Sigma \pi$, $\Lambda \omega$, and $N\overline{K}$.

A(2350) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
2340 to 2370 (≈ 2350)	OUR ESTIMATE			
2370 ± 50	DEBELLEFON	78	DPWA	KN → KN
2365 ± 20	DEBELLEFON	77	DPWA	$K^-p \rightarrow \Sigma \pi$
2358± 6	BRICMAN	70	CNTR	Total, charge exchange
 • • We do not use th 	e following data for average	s, flt	s, limits,	etc. • • •
2372	BACCARI	77	DPWA	$K^- p \rightarrow \Lambda \omega$
2344±15	COOL			K^-p , K^-d total
2360 ± 20	LU	70	CNTR	$\gamma p \rightarrow K^+ Y^*$
2340 ± 7	BUGG	68	CNTR	K^-p , K^-d total

¹ Found in one of two best solutions. ² The published error of 0.6 was a misprint.

The CAMERON 78 upper limit on F-wave decay is 0.03. The sign here has been changed to be in accord with the baryon-first convention.

⁴The published sign has been changed to be in accord with the baryon-first convention. The CAMERON 78B upper limits on the *P*₃ and *F*₃ waves are each 0.03.

¹ Note that the three BACCARI 77 entries are for three different waves.

A(2350) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
100 to 250 (≈ 150) OUR	ESTIMATE			
204±50	DEBELLEFO	N 78	DPWA	$\overline{K}N \rightarrow \overline{K}N$
110 ± 20	DEBELLEFO	N 77	DPWA	$K^- p \rightarrow \Sigma \pi$
324±30	BRICMAN	70	CNTR	Total, charge exchange
• • • We do not use the	following data for averag	es, fit	s, limits,	etc. • • •
257	BACCARI	77	DPWA	$K^- p \rightarrow \Lambda \omega$
190	COOL	70	CNTR	K^-p , K^-d total
55	LU	70	CNTR	$\gamma p \rightarrow K^+ Y^*$
140±20	BUGG	68	CNTR	$K^- p$, $K^- d$ total

1(2350) DECAY MODES

	Mode	Fraction (Γ _I /Γ)
$\overline{\Gamma_1}$	NK	~ 12 %
Γ_2	Σπ	~ 10 %
Γ_3	$\Lambda \omega$	

The above branching fractions are our estimates, not fits or averages.

A(2350) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on \varLambda and \varSigma Resonances.

$\Gamma(N\overline{K})/\Gamma_{\text{total}}$			Γ1/Γ
VALUE	DOCUMENT ID	TECN	COMMENT
~ 0.12 OUR ESTIMATE 0.12±0.04	DEBELLEFON 78	DPWA	$\overline{K}N \rightarrow \overline{K}N$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\overline{K} \to \Lambda(23)$	50) → Σπ DOCUMENT ID	TECN	$(\Gamma_1\Gamma_2)^{\frac{1}{2}}/\Gamma$
-0.11±0.02	DEBELLEFON 77		
$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \ln N \overline{K} \rightarrow \Lambda(23)$	50) → Λω		(Γ₁Γ₃) ^½ /Γ
VALUE	DOCUMENT ID	TECN	COMMENT
< 0.05	BACCARI 77	DPWA	$K^- p \rightarrow \Lambda \omega$

A(2350) REFERENCES

DEBELLEFON	78	NC 42A 403	De Bellefon, Berthon, Billoir+ (CDEF, SACL) IJF
BACCARI	77	NC 41A 96	+Poulard, Revel, Tallini+ (SACL, CDEF) IJF
DEBELLEFON	77	NC 37A 175	De Bellefon, Berthon, Billoir+ (CDEF, SACL) IJF
LASINSKI	71	NP B29 125	(EFI) IJF
BRICMAN	70	PL 31B 152	+Ferro-Luzzi, Perreau+ (CERN, CAEN, SACL)
COOL	70	PR D1 1887	+Giacomelli, Kycia, Leontic, Li+ (BNL) I
Also	66	PRL 16 1228	Cool, Giacomelli, Kycia, Leontic, Lundby+ (BNL) I
LU	70	PR D2 1846	+Greenberg, Hughes, Minehart, Mori+ (YALE)
BUGG	68	PR 168 1466	+Gilmore, Knight+ (RHEL, BIRM, CAVE) I
DAUM	68	NP B7 19	+Erne, Lagnaux, Sens, Steuer, Udo (CERN) JP

 $I(J^P) = 0(?^?)$ Status: **

OMITTED FROM SUMMARY TABLE

Λ(2585) MASS (BUMPS)

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
≈ 2585 OUR ESTIMATE				
2585 ± 45	ABRAMS	70	CNTR	K^-p , K^-d total
2530±25	LU	70	CNTR	$\gamma p \rightarrow K^+ Y^*$

Λ(2585) WIDTH (BUMPS)

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
300	ABRAMS	70	CNTR	K-p, K-d total
150	LU	70	CNTR	$\gamma p \rightarrow K^+ Y^*$

A(2585) DECAY MODES (BUMPS)

	Mode			
Γ ₁	ΝK		 	

Λ(2585) BRANCHING RATIOS (BUMPS)

$(J+\frac{1}{2})\times\Gamma(N\overline{K})/\Gamma_{\text{total}}$ <i>J</i> is not known, so only $(J+\frac{1}{2})\times\Gamma(N\overline{K})/\Gamma_{\text{total}}$ can be given.							
VALUE	DOCUMENT ID		TECN:	COMMENT			
1	ABRAMS	70	CNTR	K^-p , K^-d total			
0.12±0.12	¹ BRICMAN	70	CNTR	Total, charge exchange			

A(2585) FOOTNOTES (BUMPS)

¹ The resonance is at the end of the region analyzed — no clear signal.

Λ(2585) REFERENCES (BUMPS)

ABRAMS Also BRICMAN LU	66 70	PR D1 1917 PRL 16 1228 PL 31B 152 PR D2 1846	+Cool, Glacomelli, Kycia, Leontic, Ll+ Cool, Giacomelli, Kycia, Leontic, Lundby+ +Ferro-Luzzi, Perreau+ (CERN, +Greenberg, Hughes, Minehart, Mori+	(BNL) I (BNL) I CAEN, SACL) (YALE)
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Σ BARYONS (S=-1, I=1)

 $\Sigma^+ = uus$, $\Sigma^0 = uds$, $\Sigma^- = dds$



$$I(J^P) = 1(\frac{1}{2}^+)$$
 Status: ***

We have omitted some results that have been superseded by later experiments. See our earlier editions.

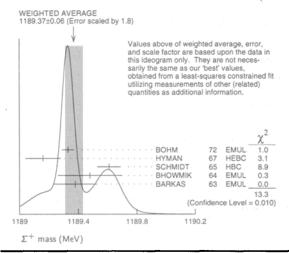
Σ+ MASS

The fit uses Σ^+ , Σ^0 , Σ^- , and Λ mass and mass-difference measurements.

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
1189.37±0.07 OUR	FIT Error in	cludes scale fact	or of	2.2.	
1189.37±0.06 OUR	AVERAGE	Error Includes sca below.	ile fac	tor of 1.	8. See the ideogram
1189.33 ± 0.04	607	¹ вонм	72	EMUL	
1189.16 ± 0.12		HYMAN	67	HEBC	
1189.61 ± 0.08	4205	SCHMIDT	65	HBC	See note with A mass
1189.48 ± 0.22	58	² BHOWMIK	64	EMUL	
1189.38 + 0.15	144	² BARKAS	63	EMUI	

¹BOHM 72 is updated with our 1973 K^- , π^- , and π^0 masses (Reviews of Modern Physics 45 No. 2 Pt. II (1973)).

 $^{^2}$ These masses have been raised 30 keV to take into account a 46 keV increase in the proton mass and a 21 keV decrease in the π^0 mass (note added 1967 edition, Reviews of Modern Physics 39 1 (1967)).



Σ+ MEAN LIFE

Measurements with an error $\geq 0.1 \times 10^{-10}$ s have been omitted.

VALUE (10 ⁻¹⁰ s)	EVTS	DOCUMENT ID		TECN	COMMENT
0.799±0.004 OUR AV	ERAGE		_		
0.798 ± 0.005	30k	MARRAFFINO	80	HBC	K-p 0.42-0.5 GeV/c
0.807 ± 0.013	5719	CONFORTO	76	HBC	K-p 1-1.4 GeV/c
0.83 ±0.04	526	BAKKER	71	DBC	$K^- n \rightarrow \Sigma^+ \pi^- \pi^-$
0.795 ± 0.010	20k	EISELE	70	HBC	K^-p at rest
0.803 ± 0.008	10664	BARLOUTAUD	69	HBC	K-p 0.4-1.2 GeV/c
0.83 ±0.032	1300	³ CHANG	66	HBC	
0.80 ±0.07	381	соок	66	OSPK	
0.84 ±0.09	181	BALTAY	65	HBC	
0.76 ±0.03	900	CARAYAN	65	HBC	
$0.749^{+0.056}_{-0.052}$	192	GRARD	62	нвс	
0.765 ± 0.04	456	HUMPHREY	62	нвс	
•					

 $^{^3\,\}mbox{We}$ have increased the CHANG 66 error of 0.018; see our 1970 edition, Reviews of Modern Physics 42 No. 1 (1970).

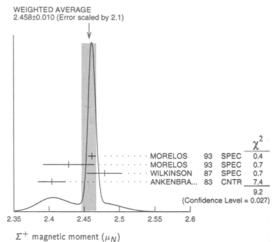
Σ+ MAGNETIC MOMENT

See the "Note on Baryon Magnetic Moments" in the A Listings. Measurements with an error $\geq 0.1 \,\mu_N$ have been omitted.

VALUE	(μ_N)		EVTS		DOCUMENT ID		TECN	COMMENT
2.458	±0.010	OUR AVERAGE	Error		ides scale facto below.	r of	2.1. See	the ideogram
2.4613	±0.0034	±0.0040	250k		MORELOS	93	SPEC	pCu 800 GeV
2.428	± 0.036	±0.007	12k	4	MORELOS	93	SPEC	pCu 800 GeV
2.479	± 0.012	±0.022	137k		WILKINSON	87	SPEC	pBe 400 GeV
2.4040	±0.0198		44k	5	ANKENBRA	83	CNTR	pCu 400 GeV

⁴We assume CPT invariance: this is (minus) the $\overline{\Sigma}^-$ magnetic moment as measured by

MORELOS 93. See below for the moment difference testing CPT. 5 ANKENBRANDT 83 gives the value 2.38 \pm 0.02 μ_N . MORELOS 93 uses the same hyperon magnet and channel and claims to determine the field integral better, leading to the revised value given here.



 $(\mu_{\Sigma^+} + \mu_{\overline{\Sigma}^-}) / |\mu|_{\text{average}}$

A test of CP / Hivariance.			
VALUE	DOCUMENT ID	TECN	COMMENT
0.014±0.015	6 MORELOS 93	SPEC	pCu 800 GeV

⁶This is our calculation from the MORELOS 93 measurements of the Σ^+ and $\overline{\Sigma}^$ magnetic moments given above. The statistical error on $\mu_{\overline{\Sigma}^-}$ dominates the error here.

Σ+ DECAY MODES

	Mode	Fraction (Γ_j/Γ) Confidence level
Γ ₁	$p\pi^0$	(51.57±0.30) %
Γ_2	$n\pi^+$	(48.31±0.30) %
Гз	$p\gamma$	$(1.23\pm0.05)\times10^{-3}$
Γ4	$n\pi^+\gamma$	[a] $(4.5 \pm 0.5) \times 10^{-4}$
Γ ₅	$\Lambda e^+ \nu_e$	$(2.0 \pm 0.5) \times 10^{-5}$

$\Delta S = \Delta Q$ (SQ) violating modes or $\Delta S = 1$ weak neutral current (S1) modes

Γ6	$ne^+\nu_e$	5Q	< 5	× 10 ⁻⁶	90%
Γ ₇	$n\mu^+ u_\mu$	5Q	< 3.0	× 10 ⁻⁵	90%
	pe+ e ^{'-}	51	< 7	× 10 ⁻⁶	

[a] See the Particle Listings below for the pion momentum range used in this measurement.

CONSTRAINED FIT INFORMATION

An overall fit to 2 branching ratios uses 14 measurements and one constraint to determine 3 parameters. The overall fit has a χ^2 7.7 for 12 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\langle \delta x_i \delta x_j \rangle / (\delta x_i \cdot \delta x_j)$, in percent, from the fit to the branching fractions, $x_i \equiv$ $\Gamma_i/\Gamma_{\rm total}$. The fit constrains the x_i whose labels appear in this array to sum to

$$\begin{array}{c|cccc} x_2 & -100 & \\ x_3 & 12 & -14 \\ \hline & x_1 & x_2 \end{array}$$

	Σ+	BRANCHING F	RAT	OS	
$\Gamma(n\pi^+)/\Gamma(N\pi)$					$\Gamma_2/(\Gamma_1+\Gamma_2)$
VALUE 0.4836±0.0030 OI		DOCUMENT ID	_	TECN	COMMENT
0.4836±0.0030 O I 0.4828±0.0036	10k	7 MARRAFFINO	80	нвс	K ⁻ p 0.42-0.5 GeV/c
0.488 ±0.008	1861	NOWAK	78	HBC	N p 0.42-0.5 GeV/C
0.484 ±0.015	537	TOVEE	71	EMUL	
0.488 ±0.010	1331	BARLOUTAUE		HBC	K-p 0.4-1.2 GeV/c
0.46 ±0.02	534	CHANG	66	HBC	
0.490 ±0.024 7 MARRAFFING	308 308 actually given	HUMPHREY ves Γ(ρπ ⁰)/Γ(total	62 } =	HBC 0.5172	+ 0.0036
$\Gamma(p\gamma)/\Gamma(p\pi^0)$	o actually 8.	, oo , (p)/ , (total	, –		
$(P7)/(P\pi^2)$ VALUE (units 10^{-3})	EVTS	DOCUMENT ID		TECN	F3/F1
2.38±0.10 OUR F	iT				
2.32±0.11±0.10	32k	TIMM	95	E761	Σ+ 375 GeV
$2.81 \pm 0.39 ^{+0.21}_{-0.43}$	408	HESSEY	89	CNTR	$K^-p \rightarrow \Sigma^+\pi^-$ at rest
2.52 ± 0.28	190	⁸ KOBAYASHI	87	CNTR	$\pi^+ \rho \rightarrow \Sigma^+ K^+$
2.46 ^{+ 0.30} - 0.35	155	BIAGI	85	CNTR	CERN hyperon beam
2.11±0.38	46	MANZ	80	нвс	$K^-p \rightarrow \Sigma^+\pi^-$
2.1 ±0.3	45	ANG		HBC	K p at rest
2.76±0.51	31	GERSHWIN		HBC	$K-p \rightarrow \Sigma^+\pi^-$
3.7 ±0.8	24	BAZIN		HBC	K p at rest
		$\Gamma(p\gamma)/\Gamma(\text{total}) =$			•
		0 // (/			
·(ππ+γ)/Γ(ππ				46-	F4/F2
	mentum cuts d In the Summar		aver	age the	results but simply use the
ALUE (units 10 ⁻³)	EVTS	DOCUMENT ID		TECN	COMMENT
0.93±0.10	180	EBENHOH	72	HBC	π^+ < 150 MeV/c
		g data for averages			
		•			
0.27±0.05 - 1.8	29	ANG BAZIN		HBC HBC	$\pi^+ < 110 \text{ MeV/}c$ $\pi^+ < 116 \text{ MeV/}c$
		DAZIN	935	пьс	A. < 110 MIGALC
$\Gamma(\Lambda e^+ \nu_e) / \Gamma_{\text{tot}}$	al le				Γ ₅ /Γ
VALUE (units 10 ⁻⁵)					
	EVTS	DOCUMENT ID		TECN	COMMENT
	<u>EVTS</u> ERAGE	DOCUMENT ID		TECN	COMMENT
2.0±0.5 OUR AV		DOCUMENT ID	69	<u>TECN</u> HBC	COMMENT K-p at rest
2.0±0.5 OUR AVI	ERAGE		69 69		
2.0±0.5 OUR AVI 1.6±0.7 2.9±1.0	ERAGE 5	BALTAY		нвс	K ⁻ p at rest
2.0±0.5 OUR AVI 1.6±0.7 2.9±1.0 2.0±0.8 Γ(ne ⁺ ν _e)/Γ(n	5 10 6 x ⁺)	BALTAY EISELE BARASH	69 67	HBC HBC HBC	K^-p at rest K^-p at rest K^-p at rest F_0/Γ_2
2.0 \pm 0.5 OUR AVI 1.6 \pm 0.7 2.9 \pm 1.0 2.0 \pm 0.8 $\Gamma(ne^+\nu_e)/\Gamma(ne^+\nu_e)$ Test of ΔS : have been o	ERAGE 5 10 6 π^+) = ΔQ rule. Exmitted.	BALTAY EISELE BARASH periments with an o	69 67 effect	HBC HBC HBC	K^-p at rest K^-p at rest K^-p at rest F_6/Γ_2 ominator less than 100,000
2.0±0.5 OUR AVI 1.6±0.7 2.9±1.0 2.0±0.8 T (ne+ν _e)/Γ(n Test of Δ5: have been o EFFECTIVE DENOM.	5 10 6 π ⁺) = Δ Q rule. Exmitted. EVTS D	BALTAY EISELE BARASH periments with an o	69 67 effect	HBC HBC HBC	K^-p at rest K^-p at rest K^-p at rest pminator less than 100,000
2.0 \pm 0.5 OUR AVI 1.6 \pm 0.7 2.9 \pm 1.0 2.0 \pm 0.8 $\Gamma(ne^+\nu_e)/\Gamma(ne^+\nu_e)/\Gamma(ne^+\nu_e)$ Test of Δ 5 have been o	5 10 6 π ⁺) = Δ Q rule. Exmitted. EVTS D	BALTAY EISELE BARASH periments with an o OCUMENT ID 90% CL limit = (2 sum). [Numbe	69 67 effect TECA 2.3 ev	HBC HBC HBC ive deno	K^-p at rest K^-p at rest K^-p at rest F_6/Γ_2 ominator less than 100,000
2.0 \pm 0.5 OUR AVI 1.6 \pm 0.7 2.9 \pm 1.0 2.0 \pm 0.8 $\Gamma(ne^+\nu_e)/\Gamma(ne^+\nu_e)/\Gamma(ne^+\nu_e)/\Gamma(ne^+\nu_e)/\Gamma(ne^+\nu_e)/\Gamma(ne^+\nu_e)$ have been of the periods of the contract of the cont	5 10 6 π+) = ΔQ rule. Ex. mittedEVTS Ω R LIMIT Our	BALTAY EISELE BARASH periments with an of the confidence level BARASH OCUMENT IO Sum). [Numbe confidence level	69 67 Effect TECA 2.3 ev r of e	HBC HBC HBC ive deno cents)/(events in	K-p at rest K-p at rest K-p at rest F6/F2 cominator less than 100,000 MENT effective denominator icreased to 2.3 for a 90%
2.0±0.5 OUR AVI .6±0.7 2.9±1.0 2.0±0.8 (ne+ν _e)/Γ(n Test of ΔS have been o EFFECTIVE DENOM. < 1.1 × 10 ⁻⁸ OU	5 10 6 π ⁺) = ΔQ rule. Exmitted. EVTS D R LIMIT Our	BALTAY EISELE BARASH Deciments with an officer of the second of the sec	69 67 effect TECA 2.3 ev r of e	HBC HBC HBC ive deno	K-p at rest K-p at rest K-p at rest K-p at rest pminator less than 100,000 MENT effective denominator a 90% p at rest
2.0±0.5 OUR AVI 2.0±0.7 2.9±1.0 2.0±0.8 (ne+ν _e)/Γ(n Test of ΔS have been o 2.1.1 × 10 ⁻⁵ OU 111000 105000	5 10 6 π ⁺) = ΔQ rule. Exmitted. EVTS D R LIMIT Our 0 9 E 0 9 S	BALTAY EISELE BARASH Deciments with an office of the confidence leve BENHOH 74 ECHI-ZORN 73	69 67 Effect TECA 2.3 ev r of e	HBC HBC HBC ive deno	K-p at rest K-p at rest K-p at rest F6/F2 cominator less than 100,000 MENT effective denominator icreased to 2.3 for a 90%
2.0±0.5 OUR AVI .6±0.7 2.9±1.0 2.0±0.8 (ne+ν _e)/Γ(n Test of ΔS have been o EFFECTIVE DENOM. < 1.1 × 10 ⁻⁸ OU	5 10 6 π ⁺) = ΔQ rule. Exmitted. EVTS D R LIMIT Our 0 9 E 0 9 S	BALTAY EISELE BARASH Deciments with an office of the confidence leve BENHOH 74 ECHI-ZORN 73	69 67 effect TECA 2.3 ev r of e	HBC HBC HBC ive deno	K-p at rest K-p at rest K-p at rest K-p at rest pminator less than 100,000 MENT effective denominator a 90% p at rest
2.0 \pm 0.5 OUR AVI 1.6 \pm 0.7 2.9 \pm 1.0 2.0 \pm 0.8 $\Gamma (ne^+\nu_e)/\Gamma (n$	5 10 6 π+) = Δ Q rule. Ex mitted. EVTS D R LIMIT Our 0 9 E 0 9 S minator calcula	BALTAY EISELE BARASH Deciments with an office of the confidence leve BENHOH 74 ECHI-ZORN 73	69 67 effect TECA 2.3 ev r of e	HBC HBC HBC ive deno	K-p at rest K-p at rest K-p at rest Fg/F2 cominator less than 100,000 MENT effective denominator coreased to 2.3 for a 90% p at rest p at rest
2.0 \pm 0.5 OUR AVI 6. \pm 0.7 2.9 \pm 1.0 1.0 \pm 0.8 $\Gamma(ne^+\nu_e)/\Gamma(ne^+\nu_e)/\Gamma(ne^+\nu_e)/\Gamma(ne^+\nu_e)/\Gamma(ne^+\nu_e)/\Gamma(ne^+\nu_e)$ 1.11000 1.11000 9 Effective denoinable of $\Gamma(n\mu^+\nu_\mu)/\Gamma(ne^+\nu_\mu)/\Gamma(ne^+\nu_\mu)/\Gamma(ne^+\nu_e)$	ERAGE 5 10 6 π^+) = ΔQ rule. Exmitted. EVIS Q R LIMIT Our 0 9 E 0 9 S minator calcular π^+) = ΔQ rule.	BALTAY EISELE BARASH periments with an of the control of the control of the control of the confidence levels BENHOH 74 ECHI-ZORN 73 ted by us.	69 67 TECA 2.3 ev r of e i.] HBC	HBC HBC HBC ive deni COM vents)/(vents ir K- K-	K-p at rest K-p at rest K-p at rest K-p at rest pminator less than 100,000 MENT effective denominator a 90% p at rest
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2.0 \pm 0.5 OUR AVI 1.6 \pm 0.7 2.9 \pm 1.0 2.0 \pm 0.8 $\Gamma(ne^+\nu_e)/\Gamma(ne$	ERAGE 5 10 6 π^+) = ΔQ rule. Exmitted. EYIS \underline{D} 0 9 S minator calcula π^+) = ΔQ rule. EVIS \underline{D} ΔQ rule. EVIS \underline{D} 0 11 C 0 11 G minator calcula minator taken f tal	BALTAY EISELE BARASH periments with an of OCUMENT ID 90% CL limit = (2 sum). [Numbe confidence levels and Electric General State of Stat	69 67 Effect FECA HBC HBC HBC HBC HBC HBC HBC H	HBC HBC HBC ive deni V V V V V V V V V V V V V V V V V V V	K-p at rest K-p at rest K-p at rest K-p at rest F6/F2 cominator less than 100,000 IMENT effective denominator coreased to 2.3 for a 90% p at rest p at rest F7/F2 effective denominator coreased to 6.7 for a 90%
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2.0 \pm 0.5 OUR AVI 1.6 \pm 0.7 2.0 \pm 1.0 2.0 \pm 0.8 $\Gamma(ne^+\nu_e)/\Gamma(ne$	FRAGE 5 10 6 π+) = AQ rule. Exmitted. EVIS 0 9 S minator calcula π+) = AQ rule. EVIS 0 11 C 0 11 N 1 G minator calcula minator taken f tai d three pe+e CLS EVIS IT Our 90% use the following 10 10 11 11 12 13 14 15 16 17 17 18 18 18 18 18 18 18 18 18 18 18 18 18	BALTAY EISELE BARASH Deriments with an of the confidence lever the conf	69 67 Effect TECA A 3.3 ever of e HBC HBC HBC HBC HBC HBC HBC HB	HBC HBC HBC HBC HBC HBC HBC HBC Ive denic K- K- Iverents)/(I Verents)/(I IECN P)/(I IECN III III IECN III III III II	K ⁻ p at rest K ⁻ p at rest K ⁻ p at rest K ⁻ p at rest F ₆ /Γ ₂ cominator less than 100,000 IMENT effective denominator coreased to 2.3 for a 90% p at rest p at rest coreased to 6.7 for a 90% F ₆ /Γ COMMENT K ⁻ p at rest comment K ⁻ p at rest comment K ⁻ p at one comment
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\Gamma(\Sigma^+ \to n \mu^+ \nu_\mu)/\Gamma(\Sigma^- \to n \mu^- \overline{\nu}_\mu)
VALUE EVTS DOCUMENT ID TECH COMMENT < 0.12 OUR LIMIT Our 90% CL limit, using \Gamma(n\mu^+\nu_\mu)/\Gamma(n\pi^+) above.
                       EVTS
• • • We do not use the following data for averages, fits, limits, etc. • • •
  0.06^{+0.045}_{-0.03}
                                     EISELE
                                                    698 HBC K-p at rest
\Gamma(\Sigma^+ \to n\ell^+\nu)/\Gamma(\Sigma^- \to n\ell^-\nu)
Test of \Delta S = \Delta Q rule.

VALUE EVTS
                       EVTS
                                    DOCUMENT ID
                                                       TECN
<0.043 OUR LIMIT Our 90% CL limit, using \left[\Gamma(ne^+\nu_e) + \Gamma(n\mu^+\nu_\mu)\right]/\Gamma(n\pi^+).
• • • We do not use the following data for averages, fits, limits, etc. • • •
                                     NORTON
                                                    69 HBC
< 0.08
< 0.034
                            0
                                     BAGGETT
                                                    67 HBC
                            Y+ DECAY PARAMETERS
         See the "Note on Baryon Decay Parameters" in the neutron Listings. A
         few early results have been omitted.
\alpha_0 FOR \Sigma^+ \rightarrow \rho \pi^0
                                     DOCUMENT ID TECN COMMENT
                      <u>EVTS</u>
VALUE
-0.900 +0.017 OUR FIT
-0.900 +0.017 OUR AVERAGE
-0.945 +0.055
-0.042
                                13 LIPMAN
                         1259
                                                     73 OSPK \pi^+ p \rightarrow \Sigma^+
                                     BELLAMY 72 ASPK \pi^+ p \rightarrow \Sigma^+ K^+
~0.940±0.045
                         16k
-0.98 +0.05
-0.02
                        1335 14 HARRIS
                                                    70 OSPK \pi^+p \rightarrow \Sigma^+K^+
-0.999±0.022
                         32k
                                     BANGERTER 69 HBC K-p 0.4 GeV/c
 13 Decay protons scattered off aluminum.
 14 Decay protons scattered off carbon.
\phi_0 ANGLE FOR \Sigma^+ \rightarrow p\pi^0
                                                                         (\tan\phi_0=\beta/\gamma)
VALUE (°)
                         EVTS
                                     DOCUMENT ID TECN COMMENT
36 ±34 OUR AVERAGE
                                15 LIPMAN
                         1259
                                                     73 OSPK \pi^+ p \rightarrow \Sigma^+ K^+
                                  16 HARRIS
22 ±90
                                                     70 OSPK \pi^+ \rho \rightarrow \Sigma^+ K^+
 15 Decay proton scattered off aluminum.
 16 Decay protons scattered off carbon.
Older results have been omitted.
                                     DOCUMENT ID TECN COMMENT
-0.069±0.013 OUR FTT
-0.073\pm0.021
                                     MARRAFFINO 80 HBC K-p 0.42-0.5 GeV/c
\alpha_+ FOR \Sigma^+ \rightarrow \pi \pi^+
VALUE EVTS
0.068±0.013 OUR FIT
                                     DOCUMENT ID TECH COMMENT
0.066±0.016 OUR AVERAGE
0.037 \pm 0.049
                         4101
                                      BERLEY
                                                   708 HBC
                                     BANGERTER 69 HBC K-p 0.4 GeV/c
0.069 \pm 0.017
                          35k
\phi_+ ANGLE FOR \Sigma^+ \rightarrow n\pi^+
                                                                        (\tan\phi_+=\beta/\gamma)
VALUE (°) EVTS DOCUMENT ID TECH
167±20 OUR AVERAGE Error includes scale factor of 1.1.
                                                         TECN COMMENT
                                  17 BERLEY
                                                    70B HBC
184±24
                         1054
                                     BANGERTER 698 HBC K-p 0.4 GeV/c
                         560
143±29
 ^{17} Changed from 176 to 184° to agree with our sign convention.
\alpha_{\gamma} FOR \Sigma^{+} \rightarrow p\gamma
VALUE
                                     DOCUMENT ID TECN COMMENT
                         EVTS
 -0.76 ±0.08 OUR AVERAGE
                                 ^{18} FOUCHER 92 SPEC \Sigma^+ 375 GeV
-0.720±0.086±0.045 35k
-0.86 ±0.13 ±0.04
                         190
                                     KOBAYASHI 87 CNTR \pi^+p \rightarrow \Sigma^+K^+
-0.53 +0.38
-0.36
                           46
                                     MANZ
                                                     80 HBC K<sup>-</sup>p → Σ<sup>+</sup>π<sup>-</sup>
-1.03 \begin{array}{l} +0.52 \\ -0.42 \end{array}
                                     GERSHWIN 698 HBC K^-p \rightarrow \Sigma^+\pi^-
                           61
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 $^{18}\,\mathrm{See}$ TIMM 95 for a detailed description of the analysis.

Σ⁺ REFERENCES

We have omitted some papers that have been superseded by later experiments. See our earlier editions.

MORELOS 93 PRL 71 3417 Habuquerque, Bondar, Carrigan + (FNAL E761 Collab.) FOUCHER 92 PRL 68 3004 Habuquerque, Bondar, Carrigan + (FNAL E761 Collab.) FOUCHER 93 PRL 69 3004 Habuquerque, Bondar, Carrigan + (FNAL E761 Collab.) FOUCHER 94 PRL 59 868 Haba, Homma, Kawai, Miyake + (RNL 817 Collab.) FOUCHER 95 PRL 59 868 Haba, Homma, Kawai, Miyake + (RNL 817 Collab.) FOUCHER PRL 59 868 Haba, Homma, Kawai, Miyake + (RNL 817 Collab.) FOUCHER PRL 59 869 Haba, Homma, Kawai, Miyake + (RNL 817 Collab.) FOUCHER PRL 59 869 Haba, Homma, Kawai, Miyake + (RNL 81 Collab.) FOUCHER PRL 59 869 Haba, Homma, Kawai, Miyake + (RNL 81 Collab.) FOUCHER PRL 59 869 Haba, Homma, Kawai, Miyake + (RNL 81 Collab.) FOUCHER PRL 59 869 Haba, Homma, Kawai, Miyake + (RNL 81 Collab.) FOUCHER PRL 59 869 Haba, Homma, Kawai, Miyake + (RNL 81 Collab.) FOUCHER PRL 59 869 Haba, Homma, Kawai, Miyake + (RNL 81 Collab.) FOUCHER PRL 59 869 Haba, Homma, Kawai, Miyake + (RNL 81 Collab.) FOUCHER PRL 59 869 Haba, Homma, Kawai, Miyake + (RNL 81 Collab.) FOUCHER PRL 59 869 Haba, Homma, Kawai, Miyake + (RNL 81 Collab.) FOUCHER PRL 59 869 Haba, Homma, Kawai, Miyake + (RNL 81 Collab.) FOUCHER PRL 59 869 Haba, Homma, Kawai, Miyake + (RNL 81 Collab.) FOUCHER PRL 59 869 Haba, Homma, Kawai, Miyake + (RNL 81 Collab.) FOUCHER PRL 59 869 Haba, Homma, Kawai, Miyake + (RNL 81 Collab.) FOUCHER PRL 59 869 Haba, Homma, Kawai, Miyake + (RNL 81 Collab.) FOUCHER PRL 59 869 Haba, Homma, Kawai, Miyake + (RNL 81 Collab.) FOUCHER PRL 59 869 Haba, Homma, Kawai, Miyake + (RNL 81 Collab.) FOUCHER PRL 59 869 FOUCHER PRL 59	TIMM	95	PR D51 4638	+Albuquerque, Bondar+ (FNAL E761 Collab.)
FOULÉTR 92 PRL 58 3004 Halbuquerque, Bondari + (FNAL Erist Collab.) HESSEY 89 ZPHY C42 175 FNEL 59 868 Haba, Homma, Kawai, Miyake+ (KYOT) Haba, Haba, Homma, Kawai, Miyake+ (KYOT) Haba, Haba, Homma, Kawai, Miyake+ (KYOT) Haba, Haba, Homma, Kawai, Miyake+ (KYOT) Haba, Homma, Kawai, Miyake+ (KYOT) Haba, Haba, Homma, Kawai, Miyake+ (KYOT) Haba, Haba, Haba, Haba, Haba, Haba, Haba, Haba, Haba, Haba, Homma, Kawai, Miyake+ (KYOT) Haba,				
HESSEY 89				
NOBAYASHI 87 PRL 59 868 Haba, Homma, Kawai, Miyake+ (WISC, MICH, RUTG, MINH) BIAGI 95 ZPHY C28 495 Handler+ (WISC, MICH, RUTG, MINH) RANKENBRA 83 PRL 51 863 Ankenbrand, Berge+ (FNAL, IOWA, ISU, YALE) Handler+ (RMFIM, YANE) Handler+ (RMFIM,				
WILKINSON 87				
BIAGI 85 ZPHY C28 495 Ankenbrandt, Berge+ (FNAL, IOWA, ISU, VABLE) ANKENBRA. 83 PRL 51 863 Ankenbrandt, Berge+ (FNAL, IOWA, ISU, VABLE) Ankenbrandt, Berge+ (FNAL, IOWA, ISU, ISU, ISU, ISU, ISU, ISU, ISU, ISU		87		
ANKENBRA 83 PRL 51 863 Ankenbrandt, Berge+ (FNAL, IOWA, ISU, VALE)				
MANZ 80 PL 968 217 +Reuroft, Settles, Wolf+ (MPIM, XND)	ANKENBRA	83	PRL 51 863	
NOWAK 78	MANZ	80	PL 96B 217	
CONFORTO 76 NP B105 189	MARRAFFINO	80	PR D21 2501	+Reucroft, Roos, Waters+ (VAND, MPIM)
EBENHOH	NOWAK	78	NP B139 61	+Armstrong, Davis+ (LOUC, BELG, DURH, WARS)
EBENHOH 73	CONFORTO	76	NP B105 189	+Gopal, Kalmus, Litchfield, Ross+ (RHEL, LOIC)
PDG				
PDG 73				
SECHL-ZORN 73 PR D8 12 +Snow (UMD)				
BELLAMY 72 Pl. 398 299 +Anderson, Crawford+ (LOWC, RHEL, SUSS) BOHM 72 NP B48 1 + (BERL, KIDR, BRUX, IASD, DUUC, LOUC+) BAKKER 71 LNC 1 37 +Hoogland, Kluyver, Massard+ (SABRE Collab.) COLE 71 PR D4 631 +Lee-Francii, Loveless, Baltay+ (STON, COLD TOVEE 71 NP B33 493 + (LOUC, KIDR, BERL, BRUX, DUUC, WARS) ERILEY 708 PR D1 2015 +Yamin, Hertzbach, Koffer+ (BNL, MASA, YARS) Proposition Pr				
BOHM 72 NP B48 1 + (BERL, KIDR, BRUX, IASD, DIUC, LOUC+) Also 73 IIHE-73.2 Nov Bohm (BERL, KIDR, BRUX, IASD, DIUC, LOUC+) BAKKER 71 LNC 1 37 +Hoogland, Kluyver, Massard+ (SABRE Collad) COLE 71 PR D4 631 +Lee-Franzini, Loveless, Baltay+ (STON, COLU) TOVEE 71 NP B33 493 + (LOUC, KIDR, BERL, BRUX, DUUC, WARS) BERLEY 708 PR D1 2015 +Yamin, Hertzbach, Koffer+ (BNL, MASA, YALE)				
Also 73 IHE-73.2 Nov Bohm (BERL, KIDR, BRUX, IASD, DUUC, LOUC+) BAKKER 71 LNC 1 37 +Hoogland, Kluyver, Massard+ (SABRE Collab.) COLE 71 PR D4 631 +Lee-Franzini, Loveless, Baltay+ (STON, COLU) TOVEE 71 NP B33 493 +Lee-Franzini, Loveless, Baltay+ (STON, COLU) ERRIEY 708 PR D1 2015 +Yamin, Hertzbach, Koffer+ (BNL, MASA, YADRA)				
BAKKER 71 LNC 1 37 +Hoogland, Kluyver, Massard+ (SABRE Collab.) COLE 71 PR D4 631 +Lee-Franzini, Loveless, Baltay+ (STON, COLU) TOVEE 71 NP B33 493 + (LOUC, KIDR, BERL, BRUX, DUUC, WARS) BERLEY 708 PR D1 2015 +Yamin, Hertzbach, Kofler+ (BNL, MASA, YALE)				
COLE 71 PR D4 631 +Lee-Franzini, Loveless, Baltay+ (STON, COLU) TOVEE 71 NP B33 493 + (LOUC, KIDR, BERL, BRUX, DUUC, WARS) BERLEY 708 PR D1 2015 +Yamin, Hertzbach, Koffer+ (BNL, MASA, YAS)				
TOVEE 71 NP B33 493 + (LOUC, KIDR, BERL, BRUX, DUUC, WARS) BERLEY 70B PR D1 2015 +Yamin, Hertzbach, Kofler+ (BNL, MASA, YALE)				
BERLEY 70B PR D1 2015 +Yamin, Hertzbach, Kofler+ (BNL, MASA, YALE)				
EISELE (0 ZPMY 238 3/2 +Fifthuth, Mepp, Presser, Zech (HEID)				
HARRIS 70 PRL 24 165 +Overseth, Pondrom, Dettmann (MICH, WISC)				
PDG 70 RMP 42 No. 1 Barbaro-Galtieri, Derenzo, Price+ (LRL, BRAN, CERN+) ANG 69B ZPHY 228 151 +Ebenhoh, Eisele, Engelmann, Filthuth+ (HEID)				
ANG 69B ZPHY 228 151 +Ebenhoh, Eisele, Engelmann, Filthuth+ (HEID) BAGGETT 69B Thesis MDDP-TR-973 (UMD)				
BALTAY 69 PRL 22 615 +Franzini, Newman, Norton+ (COLU, STON)				
BANGERTER 69 Thesis UCRL 19244 (LRL) BANGERTER 69B PR 187 1821 +Alston-Garnjost, Galtieri, Gershwin+ (LRL)				
BARLOUTAUD 69 NP B14 153 +DeBellefon, Granet+ (SACL, CERN, HEID)				
EISELE 69 ZPHY 221 1 +Engelmann, Filthuth, Fohlisch, Hepp+ (HEID)				
Also 64 PRL 13 291 Willis, Courant+ (BNL, CERN, HEID, UMD)				
EISELE 69B ZPHY 221 401 +Engelmann, Filthuth, Fohlisch, Hepp+ (HEID)				
GERSHWIN 69B PR 188 2077 +Alston-Garnjost, Bangerter+ (LRL)				
Also 69 Thesis UCRL 19246 Gershwin (LRL)				
NORTON 69 Thesis Nevis 175 (COLU)				
BAGGETT 67 PRL 19 1458 +Day, Glasser, Kehoe, Knop+ (UMD)	BAGGETT	67	PRL 19 1458	
Also 68 Vienna Abs. 374 Baggett, Kehoe (UMD)				
Also 68B Private Comm. Baggett (UMD)	Also	68B		
BARASH 67 PRL 19 181 +Day, Glasser, Kehoe, Knop+ (UMD)	BARASH	67	PRL 19 181	
EISELE 67 ZPHY 205 409 +Engelmann, Filthuth, Folish, Hepp+ (HEID)	EISELE	67	ZPHY 205 409	+Engelmann, Filthuth, Folish, Hepp+ (HEID)
HYMAN 67 PL 25B 376 +Loken, Pewitt, McKenzie+ (ANL, CMU, NWES)	HYMAN	67		+Loken, Pewitt, McKenzie+ (ANL, CMU, NWES)
PDG 67 RMP 39 1 Rosenfeld, Barbaro-Galtieri, Podolsky+ (LRL, CERN, YALE)	PDG	67	RMP 39 1	Rosenfeld, Barbaro-Galtieri, Podolsky+ (LRL, CERN, YALE)
CHANG 66 PR 151 1081 (COLU)	CHANG	66	PR 151 1081	(COLU)
Also 65 Thesis Nevis 145 Chang (COLU)				
COOK 66 PRL 17 223 +Ewart, Masek, Orr, Platner (WASH)				
BALTAY 65 PR 140B 1027 +Sandweiss, Culwick, Kopp+ (YALE, BNL)				
BAZIN 65 PRL 14 154 +Blumenfeld, Nauenberg+ (PRIN, COLU)				
BAZIN 65B PR 140B 1358 +Plano, Schmidt+ (PRIN, RUTG, COLU)				
CARAYAN 65 PR 138B 433 Carayannopoulos, Tautfest, Willmann (PURD)				
SCHMIDT 65 PR 140B 1328 (COLU)				
BHOWMIK 64 NP 53 22 + Jain, Mathur, Lakshmi (DELH)				
COURANT 64 PR 136B 1791 +Filthuth+ (CERN, HEID, UMD, NRL, BNL)				
NAUENBERG 64 PRL 12 679 + Marateck+ (COLU, RUTG, PRIN)				
BARKAS 63 PRL 11 26 +Dyer, Heckman (LRL)				
Also 61 Thesis UCRL 9450 Dyer (LRL) GALTIERI 62 PRL 9 26 +Barkas, Heckman, Patrick, Smith (LRL)				
GALTIERI 62 PRL 9 26 +Barkas, Heckman, Patrick, Smith (LRL) GRARD 62 PR 127 607 +Smith (LRL)				
HUMPHREY 62 PR 127 1305 +Ross (LRL)				
(LRL)				(ERL)



 $I(J^P) = 1(\frac{1}{2}^+)$ Status: ***

Σ⁰ MASS

The fit uses Σ^+ , Σ^0 , Σ^- , and Λ mass and mass-difference measurements.

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
1192.642±0.024 OUR FI	г			
• • • We do not use the	following	lata for averages,	fits, limits, et	C. • • •
1192.65 ±0.020±0.014	3327	¹ WANG	97 SPEC	$\Sigma^0 \rightarrow \Lambda \gamma \rightarrow$
				$(p\pi^{-})(e^{+}e^{-})$
¹ This WANG 97 result	is redunda	nt with the $oldsymbol{\Sigma}^{oldsymbol{0}}$ - $oldsymbol{arLambda}$	mass-differen	ce measurement below.

$m_{\Sigma^-}-m_{\Sigma^0}$

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
4.807±0.035 C	OUR FIT Error	includes scale factor	of 1.1	ι.	
4.86 ±0.08 C	OUR AVERAGE	Error includes scale	facto	r of 1.2.	
4.87 ± 0.12	37	DOSCH	65	HBC	
5.01 ± 0.12	12	SCHMIDT	65	HBC	See note with A mass
4.75 ± 0.1	18	BURNSTEIN	64	HBC	

$m_{\Sigma^0} - m_{\Lambda}$

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
76.959±0.023 OUR FIT					
76.966±0.020±0.013	3327	WANG	97	SPEC	$\Sigma^0 \to \Lambda \gamma \to$
• • • We do not use th	e following	data for average	. ei+	c limite	$(p\pi^{-})(e^{+}e^{-})$
• • • we do not use th	e ionowing	uata ioi average			
76.23 ±0.55	109	COLAS	75	HLBC	$\Sigma^0 \rightarrow \Lambda \gamma$
76.63 ±0.28	208	SCHMIDT	65	HBC	See note with A mass

Σ⁰ MEAN LIFE

These lifetimes are deduced from measurements of the cross sections for the Primakoff process $\Lambda \to \Sigma^0$ in nuclear Coulomb fields. An alternative expression of the same information is the Σ^0 - Λ transition magnetic moment given in the following section. The relation is $(\mu_{\Sigma} \Lambda/\mu_N)^2 \tau =$ 1.92951×10^{-19} s (see DEVLIN 86).

VALUE (10 ⁻²⁰ s)	DOCUMENT ID		TECN	COMMENT			
7.4±0.7 OUR EVALUATION	Using $\mu_{\sum \Lambda}$ (see the above note).						
$6.5^{+1.7}_{-1.1}$	² DEVLIN	86	SPEC	Primakoff effect			
7.6±0.5±0.7	³ PETERSEN	86	SPEC	Primakoff effect			
• • • We do not use the follow	wing data for averag	es, flt	s, limits,	etc. • • •			
5.8±1.3	² DYDAK	77	SPEC	See DEVLIN 86			
$^2\text{DEVLIN}$ 86 is a recalculation of the results of DYDAK 77 removing a numerical approximation made in that work.							

³An additional uncertainty of the Primakoff formalism is estimated to be < 5%.

$|\mu(\Sigma^0 o \Lambda)|$ Transition magnetic moment

See the note in the Σ^0 mean-life section above. Also, see the "Note on Baryon Magnetic Moments" in the Λ Listings.

VALUE (μ _N)	DOCUMENT ID		TECN	COMMENT			
1.61±0.08 OUR AVERAGE							
$1.72^{+0.17}_{-0.19}$	4 DEVLIN	86	SPEC	Primakoff effect			
$1.59 \pm 0.05 \pm 0.07$	⁵ PETERSEN	86	SPEC	Primakoff effect			
$1.82^{+0.25}_{-0.18}$	4 DYDAK	77	SPEC	See DEVLIN 86			

 4 DEVLIN 86 is a recalculation of the results of DYDAK 77 removing a numerical approximation made in that work. 5 An additional uncertainty of the Primakoff formalism is estimated to be < 2.5%.

Σ⁰ DECAY MODES

	Mode	Fraction (Γ_j/Γ)	Confidence level
Γ1	$\Lambda\gamma$	100 %	
Γ_2	$\Lambda \gamma \gamma$	< 3%	90%
Γ_3	Λe ⁺ e ⁻	[a] 5×10^{-3}	

[a] A theoretical value using QED.

∑⁰ BRANCHING RATIOS

0.00645		FEINBERG	58	Theoretical QED of	alculation
Γ(Λe ⁺ e ⁻)/Γ _{total}		DOCUMENT ID		COMMENT	Г3/Г
Γ(Λγγ)/Γ _{total} VALUE <0.03	<u>CL%</u> 90	DOCUMENT ID	75	TECN HLBC	Γ ₂ /Γ

∑⁰ REFERENCES

WANG	97	PR D56 2544	+Hartouni, Kreisler+ (BNL-E766 Collab.)
DEVLIN	86	PR D34 1626	+Petersen, Beretvas (RUTG)
PETERSEN	86	PRL 57 949	+Beretvas, Devlin, Luk+ (RUTG, WISC, MICH, MINN)
DYDAK	77	NP B118 1	+Navarria, Overseth, Steffen+ (CERN, DORT, HEIDH)
COLAS	75	NP B91 253	+Farwell, Ferrer, Six (ORSAY)
DOSCH	65	PL 14 239	+Engelmann, Filthuth, Hepp, Kluge+ (HEID)
SCHMIDT	65	PR 140B 1328	(corn)
BURNSTEIN	64	PRL 13 66	+Day, Kehoe, Zorn, Snow (UMD)
FEINBERG	58	PR 109 1019	`(BNL)
			• •



 $I(J^P) = 1(\frac{1}{2}^+)$ Status: ***

We have omitted some results that have been superseded by later experiments. See our earlier editions.

Σ- MASS

The fit uses Σ^+ , Σ^0 , Σ^- , and Λ mass and mass-difference measurements.

VALUE (MeV)	EVTS	DOCUMENT ID	<u> </u>	TECN	COMMENT
1197.449±0.030 OU	R FIT Erro	r includes scale f	actor c	of 1.2.	
1197.45 ±0.04 OU	R AVERAGE	Error includes	scale 1	actor of	1.2.
1197.417±0.040		GUREV	93	SPEC	Σ^- C atom, crystal diff.
1197.532±0.057		GALL	88	CNTR	Σ^- Pb, Σ^- W atoms
1197.43 ±0.08	3000	SCHMIDT	65	HBC	See note with A mass
• • • We do not use	the followin	g data for averag	es, fit	s, limits,	etc. • • •
1197.24 ±0.15		1 DUGAN	75	CNTR	Exotic atoms
¹ GALL 88 conclud	es that the I	OUGAN 75 mass	needs	to be re	evaluated.

$m_{\Sigma^-} - m_{\Sigma^+}$

VALUE (MeV)	EVTS	DOCUMENT I	DOCUMENT ID						
8.08±0.08 OUR FIT	Error Inclu								
8.09±0.16 OUR AVE	8.09±0.16 OUR AVERAGE								
7.91 ± 0.23	86	вонм	72	EMUL					
8.25 ± 0.25	2500	DOSCH	65	HBC					
8.25±0.40	87	BARKAS	63	EMUL					

$m_{\Sigma^-} - m_{\Lambda}$

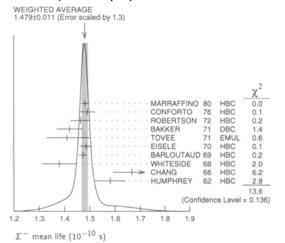
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
81.766±0.030	OUR FIT Error	includes scale facto	rof	1.2.	
81.69 ±0.07	OUR AVERAGE				
81.64 ±0.09	2279	HEPP	68	HBC	
81.80 ±0.13	85	SCHMIDT	65	HBC	See note with / mass
81.70 ±0.19		BURNSTEIN	64	нвс	

Σ- MEAN LIFE

Measurements with an error $\geq 0.2 \times 10^{-10}$ s have been omitted.

VALUE (10 ⁻¹⁰ s)	EVTS	DOCUMENT ID		TECN	COMMENT
1.479±0.011 OUR	AVERAGE	Error includes scale	fact	or of 1.3	See the Ideogram below.
1.480 ± 0.014	16k	MARRAFFING	80	HBC	K-p 0.42-0.5 GeV/c
1.49 ±0.03	8437	CONFORTO	76	HBC	K- p 1-1.4 GeV/c
1.463±0.039	2400	ROBERTSON	72	HBC	K-p 0.25 GeV/c
1.42 ±0.05	1383	BAKKER	71	DBC	$K^-N \rightarrow \Sigma^-\pi\pi$
$1.41 \begin{array}{c} +0.09 \\ -0.08 \end{array}$		TOVEE	71	EMUL	
1.485±0.022	100k	EISELE	70	HBC	K ⁻ p at rest
1.472±0.016	10k	BARLOUTAU)69	HBC	K-p 0.4-1.2 GeV/c
1.38 ±0.07	506	WHITESIDE	68	HBC	K p at rest
1.666 ± 0.075	3267	² CHANG	66	HBC	K p at rest
1.58 ±0.06	1208	HUMPHREY	62	нвс	K p at rest

 $^2\,\mbox{We}$ have increased the CHANG 66 error of 0.018; see our 1970 edition, Reviews of Modern Physics 42 No. 1 (1970).

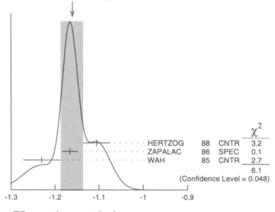


Y- MAGNETIC MOMENT

See the "Note on Baryon Magnetic Moments" in the Λ Listings. Measurements with an error \geq 0.3 μ_N have been omitted.

VALUE (µN)	EVTS	DOCUMENT ID		TECN	COMMENT
-1.160±0.025 OUR AVERAGE	E Error inc	ludes scale factor below.	rof	1.7. See	the ideogram
$-1.105\pm0.029\pm0.010$		HERTZOG	88	CNTR	Σ-Pb, Σ-W atoms
$-1.166 \pm 0.014 \pm 0.010$	671k	ZAPALAC	86	SPEC	ne ν, nπ de- cays
-1.23 ±0.03 ±0.03 • • • We do not use the follow	ving data fo				$\rho Cu \rightarrow \Sigma^- X$
-0.89 ±0.14	516k	•	83		<i>ρ</i> Be → Σ ⁻ X

WEIGHTED AVERAGE -1.160±0.025 (Error scaled by 1.7)



 Σ^- magnetic moment (μ_N)

Σ− DECAY MODES

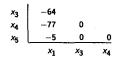
	Mode	Fraction (Γ _I /Γ)
$\overline{\Gamma_1}$	ηπ-	(99.848±0.005) %
Γ_2	$n\pi^-\gamma$	[a] $(4.6 \pm 0.6) \times 10^{-4}$
Γ3	ne−⊽ _e	$(1.017\pm0.034)\times10^{-3}$
Γ_4	$n\mu^-\overline{ u}_\mu$	$(4.5 \pm 0.4) \times 10^{-4}$
Γ_5	Λe ⁻ ν̄ _e	$(5.73 \pm 0.27) \times 10^{-5}$

[a] See the Particle Listings below for the pion momentum range used in this measurement.

CONSTRAINED FIT INFORMATION

An overall fit to 3 branching ratios uses 16 measurements and one constraint to determine 4 parameters. The overall fit has a $\chi^2=8.7$ for 13 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\left\langle \delta x_i \delta x_j \right\rangle / (\delta x_i \cdot \delta x_j)$, in percent, from the fit to the branching fractions, $x_i \equiv \Gamma_i / \Gamma_{\text{total}}$. The fit constrains the x_i whose labels appear in this array to sum to one



Σ^- BRANCHING RATIOS

 $\Gamma(n\pi^-\gamma)/\Gamma(n\pi^-)$ Γ_2/Γ_1 The π^+ momentum cuts differ, so we do not average the results but simply use the

latest value to	or the Summa	ry lable.		
VALUE (units 10-3)	EVTS	DOCUMENT ID	TECN	COMMENT
0.46±0.06	292	EBENHOH	73 HBC	$\pi^+ < 150 \text{ MeV/}c$
• • • We do not u	se the followin	g data for averag	es, fits, limits	, etc. • • •
0.10 ± 0.02	23	ANG	69B HBC	$\pi^- < 110~\text{MeV/c}$
. 11		DATIN	CED UDC	166 MaV/c

$\Gamma(ne^-\overline{\nu}_e)/\Gamma(ne^-\overline{\nu}_e)$				Γ ₃ /Γ ₁
Measuremen	ts with an erro	or \geq 0.2 $ imes$ 10 $^{-3}$ h:	ave been om	ltted.
VALUE (units 10-3)	EVTS	DOCUMENT ID	TECN	COMMENT
1.019±0.034 OUR	FIT			
1.019 ^{+0.031} _{-0.036} OUR	AVERAGE			
0.96 ±0.05	2847	BOURQUIN	83C SPEC	SPS hyperon beam
1.09 +0.06 -0.08	601	³ EBENHOH	74 HBC	K [−] p at rest
1.05 ^{+0.07} -0.13	455	³ SECHI-ZORN	73 HBC	K ⁻ p at rest
0.97 ±0.15	57	COLE	71 HBC	K [−] p at rest
1.11 ±0.09	180	BIERMAN	68 HBC	

³ An additional negative systematic error is included for internal radiative corrections and latest form factors; see BOURQUIN 83C.

$\Gamma(n\mu^-\overline{\nu}_\mu)/\Gamma(n\pi^-)$					Γ4/Γ1
VALUE (units 10-3)	EVTS	DOCUMENT ID		TECN	COMMENT
0.45±0.04 OUR FIT					
0.45 ± 0.04 OUR AVER	AGE				
0.38 ± 0.11	13	COLE	71	HBC	K [−] p at rest
0.43 ± 0.06	72	ANG	69	HBC	K-p at rest
0.43 ± 0.09	56	BAGGETT	69	HBC	K-p at rest
0.56 ± 0.20	11	BAZIN	65B	HBC	K ⁻ p at rest
0.66 ± 0.15	22	COURANT	64	HBC	
$\Gamma(\Lambda e^- \overline{\nu}_e) / \Gamma(n\pi^-)$					Γ ₅ /Γ ₁
VALUE (units 10 ⁻⁴)	EVTS	DOCUMENT ID		TECN	COMMENT
0.574±0.027 OUR FIT					
0.574±0.027 OUR AVE	RAGE				
0.561 ± 0.031	1620	4 BOURQUIN	82	SPEC	SPS hyperon beam
0.63 ±0.11	114	THOMPSON	80	ASPK	Hyperon beam
0.52 ±0.09	31	BALTAY	69	HBC	K [−] p at rest
0.69 ±0.12	31	EISELE	69	HBC	K-p at rest
0.64 ±0.12	35	BARASH	67	HBC	K p at rest
0.75 ±0.28	11	COURANT	64	HBC	K p at rest
⁴ The value is from E	BOURQU	IN 83B, and include	s rac	liation o	orrections and new accep-

Σ[−] DECAY PARAMETERS

See the "Note on Baryon Decay Parameters" in the neutron Listings. Older, outdated results have been omitted.

α_- FOR $\Sigma^- \rightarrow n\pi^-$

tance.

VALUE	<u>EVT5</u>	DOCUMENT ID	TEC	Y COMMENT
-0.068±0.008 OUF	AVERAGE			
-0.062 ± 0.024	28k	HANSL	78 HBC	$K^- \rho \rightarrow \Sigma^- \pi^+$
-0.067 ± 0.011	60k	BOGERT	70 HBC	K = p 0.4 GeV/c
-0.071 ± 0.012	51k	BANGERTER	69 HBC	C K [™] p 0.4 GeV/c
φ ANGLE FOR Σ	_ → nπ	-		$(\tan\phi=\beta\ /\ \gamma)$
VALUE (°)	EVTS	DOCUMENT ID	TEC	N COMMENT
10±15 OUR AVE	RAGE			
+ 5±23	1092	5 BERLEY	70B HB0	n rescattering
14±19	1385	BANGERTER	69B HB0	C K ⁻ ρ 0.4 GeV/c
5 RERIEV 708 ch	anged from	-5 to +5° to agree	with our	sign convention.

g_A/g_V FOR Σ⁻ → ne⁻ν_e

Measurements with fewer than 500 events have been omitted. Where necessary, signs have been changed to agree with our conventions, which are given in the "Note on Baryon Decay Parameters" in the neutron Listings. What is actually listed is $|g_1/f_1-0.237g_2/f_1|$. This reduces to $g_A/g_V\equiv g_1(0)/f_1(0)$ on making the usual assumption that $g_2=0$. See also the note on HSUEH 88.

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT		
0.340±0.017 OUR A	/ERAGE						
$+0.327\pm0.007\pm0.019$	50k	6 HSUEH	88	SPEC	Σ~ 250 GeV		
+0.34 ±0.05					SPS hyperon beam		
0.385 ± 0.037	3507	8 TANENBAUM	74	ASPK			
• • • We do not use the following data for averages, fits, limits, etc. • •							
0.29 ±0.07	25k	HSUEH	85	SPEC	See HSUEH 88		
$0.17 \begin{array}{l} +0.07 \\ -0.09 \end{array}$	519	DECAMP	77	ELEC	Hyperon beam		

⁶ The sign is, with our conventions, unambiguously positive. The value assumes, as usual, that $g_2=0$. If g_2 is included in the fit, than (with our sign convention) $g_2=-0.56\pm0.37$, with a corresponding reduction of g_A/g_V to $+0.20\pm0.08$.

7 BOURQUIN 83C favors the positive sign by at least 2.6 standard deviations.

 8 TANENBAUM 74 gives 0.435 \pm 0.035, assuming no q^2 dependence in g_A and g_V . The listed result allows q^2 dependence, and is taken from HSUEH 88.

 $f_2(0)/f_1(0)$ FOR $\Sigma^- \to ne^- \overline{\nu}_e$ The signs have been changed to be in accord with our conventions, given in the "Note on Barvon Decay Parameters" in the neutron Listings.

	on Baryon Decay	Parameters	in the neutron	Listin	gs.	
VALU	<u>E</u>	EVTS	DOCUMENT ID		TECN	COMMENT
0.9	7±0.14 OUR AVE	RAGE				
+0.9	6±0.07±0.13	50k	HSUEH	88	SPEC	Σ- 250 GeV
+1.0	02±0.34	4456	BOURQUIN	83C	SPEC	SPS hyperon beam

TRIPLE CORRELATION COEFFICIENT D for $\Sigma^- \to ne^- \overline{\nu}_e$

The coefficient D of the term D $P \cdot (P_e \times P_v)$ in the $\Sigma^- \to ne^- v$ decay angular distribution. A nonzero value would indicate a violation of time-reversal invariance.

EVTS DOCUMENT ID TECN COMMENT

50k HSUEH 88 SPEC Σ^- 250 GeV

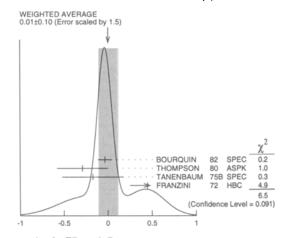
 0.11 ± 0.10

gv/g_A FOR $\Sigma^- \to \Lambda e^- \mathcal{V}_e$ For the sign convention, see the "Note on Baryon Decay Parameters" in the neutron Listings. The value is predicted to be zero by conserved vector current theory. The values averaged assume CVC-SU(3) weak magnetism term.

VALUE	<u>EVTS</u>	DOCUMENT ID	<u>TI</u>	ECN	COMMENT
0.01 ±0.10	OUR AVERAGE	below.	le facto	r of 1.	5. See the ideogram
-0.034 ± 0.080	1620	⁹ BOURQUIN	82 SI	PEC	SPS hyperon beam
-0.29 ± 0.29	114	THOMPSON	80 A	SPK	BNL hyperon beam
-0.17 ± 0.35	55		758 SI	PEC	BNL hyperon beam
$+0.45 \pm 0.20$	186	^{9,10} FRANZINI	72 H	вс	

⁹The sign has been changed to agree with our convention.

10 The FRANZINI 72 value includes the events of earlier papers.



 g_V/g_A for $\Sigma^- \to \Lambda e^- \overline{\nu}_e$

SWM/SA FOR $\Sigma^- \to \Lambda e^- \nu_e$ The values quoted assume the CVC prediction $g_V = 0$.

VALUE	EVTS	DOCUMENT ID TECN COMMENT	
2.4 ±1.7 OUR A	/ERAGE		
1.75 ± 3.5	114	THOMPSON 80 ASPK BNL hyperon beam	
3.5 ±4.5	55	TANENBAUM 75B SPEC BNL hyperon beam	
2.4 ± 2.1	186	FRANZINI 72 HBC	

Σ[−] REFERENCES

We have omitted some papers that have been superseded by later experiments. See our earlier editions.

GUREV	93	JETPL 57 400 Translated from ZETFF	Gur'ev, Denisov, Zhelamkov, Ivanov+	(PNPI)
GALL	88	PRL 60 186		. CIT. CMU. WYOM)
HERTZOG	88	PR D37 1142		CIT, CMU, WYOM)
HSUEH	88	PR D38 2056	+ (CHIC, ELMT, FNAL, IOW	
ZAPALAC	86	PRL 57 1526	+ (EFI. ELMT. FNAL, IOW	
HSUEH	85	PRL 54 2399		L, ISU, PNPI, YALE)
WAH	85	PRL 55 2551	+Cardello, Cooper, Teig+	(FNAL, IOWA, ISU)
BOURQUIN	83B	ZPHY C21 27		P. LALO. RL. STRB)
BOURQUIN	83C	ZPHY C21 17		P. LALO, RL. STRB)
DECK	83	PR D28 1		WISC, MICH, MINN)
BOURQUIN	82	ZPHY C12 307		P. LALO, RL, STRB)
MARRAFFINO		PR D21 2501	+Reucroft, Roos, Waters+	(VAND, MPIM)
THOMPSON	80	PR D21 2501	+Cleiand, Cooper, Dris, Engels+	(PITT, BNL)
HANSL	78	NP B132 45	+Manz, Matt, Reucroft, Settles+	(MPIM, VAND)
DECAMP	77	PL 66B 295	+Badier, Bland, Chollet, Gaillard+	(LALO, EPOL)
CONFORTO	76	NP B105 189	+Gopal, Kalmus, Litchfield, Ross+	(RHEL, LOIC)
DUGAN	75	NP A254 396	+Asano, Chen, Cheng, Hu, Lidofsky+	(COLU, YALE)
TANENBAUM	75B	PR D12 1871	+Hungerbuhler+	(YALE, FNAL, BNL)
EBENHOH	74	ZPHY 266 367	+Eisele, Engelmann, Filthuth, Hepp+	(HEIDT)
TANENBAUM	74	PRL 33 175		(YALE, FNAL, BNL)
	73	ZPHY 264 413	+Hungerbuhler+ +Eisele, Filthuth, Hepp, Leitner, Thouw-	
EBENHOH	73			
SECHI-ZORN		PR D8 12	+Snow	(UMD)
вонм	72	NP B48 1	+ (BERL, KIDR, BRUX, IA	
FRANZINI	72	PR D6 2417	+ (COLO,	HEID, UMD, STON)
ROBERTSON	72	Thesis UMI 78-00877		(IIT)
BAKKER	71	LNC 1 37	+Hoogland, Kluyver, Massard+	(SABRE Collab.)
COLE	71	PR D4 631	+Lee-Franzini, Loveless, Baltay+	(STON, COLU)
Also	69	Thesis Nevis 175	Norton	(COLU)
TOVEE	71	NP B33 493	+ (LOUC, KIDR, BERL, B	
BERLEY	70B	PR D1 2015	+Yamin, Hertzbach, Kofler+	(BNL, MASA, YALE)

BOGERT	70	PR D2 6	+Lucas, Taft, Willis, Berley+ (BNL, MASA, YALE)
EISELE	70	ZPHY 238 372	+Filthuth, Hepp, Presser, Zech (HEID)
PDG	70	RMP 42 No. 1	Barbaro-Galtieri, Derenzo, Price+ (LRL, BRAN, CERN+)
ANG	69	ZPHY 223 103	+Eisele, Engelmann, Filthuth+ (HEID)
ANG	69B	ZPHY 228 151	+Ebenhoh, Eisele, Engelmann, Filthuth+ (HEID)
BAGGETT	69	PRL 23 249	+Kehoe, Snow (UMD)
BALTAY	69	PRL 22 615	+Franzini, Newman, Norton+ (COLU, STON)
BANGERTER	69	Thesis UCRL 19244	(LRL)
BANGERTER	69B	PR 187 1821	+Alston-Garnjost, Galtieri, Gershwin+ (LRL)
BARLOUTAUD	69	NP B14 153	+DeBellefon, Granet+ (SACL, CERN, HEID)
EISELE	69	ZPHY 221 1	+Engelmann, Filthuth, Fohlisch, Hepp+ (HEID)
BIERMAN	68	PRL 20 1459	+Kounosu, Nauenberg+ (PRIN)
HEPP	68	ZPHY 214 71	+Schleich (HEID)
WHITESIDE	68	NC 54A 537	+Gollub (OBER)
BARASH	67	PRL 19 181	+Day, Glasser, Kehoe, Knop+ (UMD)
CHANG	66	PR 151 1081	(COLU)
BAZIN	65B	PR 140B 1358	+Plano, Schmidt+ (PRIN, RUTG, COLU)
DOSCH	65	PL 14 239	+Engelmann, Filthuth, Hepp, Kluge+ (HEID)
Also	66	PR 151 1081	Chang (COLU)
SCHMIDT	65	PR 140B 1328	(COLU)
BURNSTEIN	64	PRL 13 66	+Day, Kehoe, Zorn, Snow (UMD)
COURANT	64	PR 136B 1791	+Filthuth+ (CERN, HEID, UMD, NRL, BNL)
BARKAS	63	PRL 11 26	+Dyer, Heckman (LRL)
HUMPHREY	62	PR 127 1305	+Ross (LRL)
			(Litt)

$\Sigma(1385) P_{13}$

$$I(J^P) = 1(\frac{3}{2}^+)$$
 Status: ***

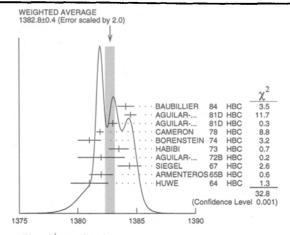
Discovered by ALSTON 60. Early measurements of the mass and width for combined charge states have been omitted. They may be found in our 1984 edition Reviews of Modern Physics **56** No. 2 Pt. II (1984).

We average only the most significant determinations. We do not average results from inclusive experiments with large backgrounds or results which are not accompanied by some discussion of experimental resolution. Nevertheless systematic differences between experiments remain. (See the ideograms in the Listings below.) These differences could arise from interference effects that change with production mechanism and/or beam momentum. They can also be accounted for in part by differences in the parametrizations employed. (See BORENSTEIN 74 for a discussion on this point.) Thus BORENSTEIN 74 uses a Breit-Wigner with energyindependent width, since a P-wave was found to give unsatisfactory fits. CAMERON 78 uses the same form. On the other hand HOLM-GREN 77 obtains a good fit to their $\Lambda\pi$ spectrum with a P-wave Breit-Wigner, but includes the partial width for the $\Sigma\pi$ decay mode in the parametrization. AGUILAR-BENITEZ 81D gives masses and widths for five different Breit-Wigner shapes. The results vary considerably. Only the best-fit S-wave results are given here.

Σ(1385) MASSES

Σ(1385)+ MASS

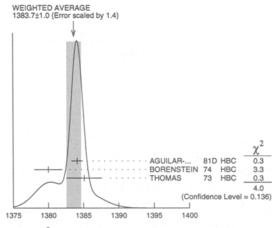
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
1382.8±0.4	OUR AVERAGE	Error includes scale	facto	or of 2.0.	See the ideogram below.
1384.1±0.7	1897	BAUBILLIER	84	HBC	K ρ 8.25 GeV/c
1384.5±0.5	5256	AGUILAR	81 D	нвс	$K^- p \rightarrow \Lambda \pi \pi 4.2$ GeV/c
1383.0±0.4	9361	AGUILAR	81 D	нвс	$K^- p \rightarrow \Lambda 3\pi 4.2$ GeV/c
1381.9 ± 0.3	6900	CAMERON	78	HBC	K-p 0.96-1.36 GeV/c
1381 ±1	6846	BORENSTEIN	74	HBC	K-p 2.18 GeV/c
1383.5 ± 0.85	2300	HABIBI	73	HBC	$K^- \rho \rightarrow \Lambda \pi \pi$
1382 ±2	400	AGUILAR	728	HBC	$K^- \rho \rightarrow \Lambda \pi$'s
1384.4 ± 1.0	1260	SIEGEL	67	HBC	K - p 2.1 GeV/c
1382 ±1	. 750	ARMENTEROS	65B	HBC	K ⁻ ρ 0.9-1.2 GeV/c
1381.0 ± 1.6	859	HUWE	64	HBC	K-p 1.22 GeV/c
• • • We do	not use the follow	ing data for averages	, fits	, limits,	etc. • • •
1385.1 ± 1.2	600	BAKER	80	HYBR	$\pi^+ p$ 7 GeV/c
1383.2 ± 1.0	750	BAKER	80	HYBR	K - p 7 GeV/c
1381 ±2	7k	¹ BAUBILLIER	79B	HBC	K-p 8.25 GeV/c
1391 ±2	2k	CAUTIS	79	HYBR	$\pi^{+} p/K^{-} p$ 11.5 GeV
1390 ±2	100	¹ SUGAHARA	79B	HBC	π – p 6 GeV/c
1385 ±3	22k	^{1,2} BARREIRO	77B	HBC	K-p 4.2 GeV/c
1385 ±1	2594	HOLMGREN	77	HBC	See AGUILAR 81D
1380 ±2		¹ BARDADIN	75	HBC	K-p 14.3 GeV/c
1382 ±1	3740	3 BERTHON	74	HBC	K-p 1263-1843 MeV/c
1390 ±6	46	AGUILAR	70B	HBC	$K^- p \rightarrow \Sigma \pi$'s 4 GeV/c
1383 ±8	62	⁴ BIRMINGHAM	66	HBC	K-p 3.5 GeV/c
1378 ±5	135	LONDON	66	HBC	K-p 2.24 GeV/c
1384.3 ± 1.9	250	4 SMITH	65	HBC	K-p 1.8 GeV/c
1382.6 ± 2.1	250	⁴ SMITH	65	нвс	K-p 1.95 GeV/c
1375.0±3.9	170	COOPER	64	нвс	K-p 1.45 GeV/c
1376.0±3.9	154	⁴ ELY	61	HLBC	K-p 1.11 GeV/c



 Σ (1385)⁺ mass (MeV)

Σ(1385)0 MASS

VALUE	(MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
1383.7	±1.0 OUR	WERAGE Erro	r includes scale f	actor	of 1.4.	See the Ideogram below.
1384.1	8.0±	5722	AGUILAR	81D	нвс	$K^- p \rightarrow \Lambda 3\pi 4.2$ GeV/c
1380	±2	3100	⁵ BORENSTEIN	74	нвс	$K^- p \rightarrow \Lambda 3\pi \ 2.18$ GeV/c
1385.1	L±2.5	240	⁴ THOMAS	73	нвс	$\pi^- p \rightarrow \Lambda \pi^0 K^0$
	We do not u	ise the following	data for averages	, fits	, limíts,	etc. • • •
1389	±3	500	6 BAUBILLIER	79B	нвс	K-p8.25 GeV/c

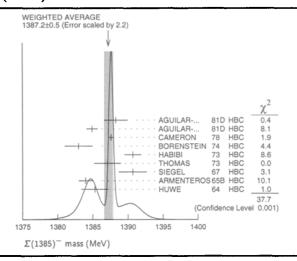


 Σ (1385)⁰ mass (MeV)

Σ(1385)- MASS

Z(1303)	MV			
VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
1387.2±0.5	OUR AVERAGE	Error includes scale facto	of 2.2.	See the ideogram below.
1388.3 ± 1.7	620	AGUILAR 810	HBC	$K^- p \rightarrow \Lambda \pi \pi 4.2$ GeV/c
1384.9±0.8	3346	AGUILAR 810	HBC	$K^- p \rightarrow \Lambda 3\pi 4.2$ GeV/c
1387.6±0.3	9720	CAMERON 78	HBC	K-p 0.96-1.36 GeV/c
1383 ±2	2303	BORENSTEIN 74	HBC	$K^- \rho$ 2.18 GeV/c
1390.7±1.2	1900	HABIBI 73	HBC	$K^-p \rightarrow \Lambda \pi \pi$
1387.1±1.9	630	⁴ THOMAS 73	HBC	$\pi^- p \rightarrow \Lambda \pi^- K^+$
1390.7±2.0	370	SIEGEL 67	HBC	K [−] p 2.1 GeV/c
1384 ±1	1380	ARMENTEROS65	HBC	K ρ 0.9-1.2 GeV/c
1385.3±1.9	1086	⁴ HUWE 64	HBC	K-p 1.15-1.30 GeV/c
• • • We d	o not use the follo	wing data for averages, fit	s, limits	, etc. • • •
1383 ±1	4.5k	¹ BAUBILLIER 798	HBC	K-p 8.25 GeV/c
1380 ±6	150	¹ SUGAHARA 796	HBC	π – p 6 GeV/c
1387 ±3	12k	1,2 BARREIRO 776	HBC	K-p 4.2 GeV/c
1391 ±3	193	HOLMGREN 77	HBC	See AGUILAR 81D
1383 ±2		¹ BARDADIN 75	HBC	K-p 14.3 GeV/c
1389 ±1	3060	³ BERTHON 74	HBC	K-p 1263-1843 MeV/c
1389 ±9	15	LONDON 66	HBC	K ⁻ ρ 2.24 GeV/c
1391.5 ± 2.6	120	⁴ SMITH 65	HBC	K [−] p 1.8 GeV/c
1399.8 ± 2.2	58	⁴ SMITH 65	HBC	K [−] p 1.95 GeV/c
1392.0±6.2	200	COOPER 64	HBC	K-p 1.45 GeV/c
1382 ±3	93	DAHL 61	DBC	K- d 0.45 GeV/c
1376.0±4.4	224	⁴ ELY 61	HLBC	K [−] p 1.11 GeV/c

Baryon Particle Listings $\Sigma(1385)$



$m_{\Sigma(1385)^-} - m_{\Sigma(1385)^+}$

VALUE (MeV)	CL%	DOCUMENT ID		TECN	COMMENT
	se the followin	g data for averages	, fits	, limits,	etc. • • •
- 2 to +6	95	7 BORENSTEIN	74	HBC	K [™] p 2.18 GeV/c
7.2 ± 1.4		⁷ HABIBI	73	HBC	$K^- p \rightarrow \Lambda \pi \pi$
6.3±2.0		⁷ SIEGEL	67	HBC	K-p 2.1 GeV/c
11 ±9		⁷ LONDON	66	HBC	K-p 2.24 GeV/c
9 ±6		LONDON	66	HBC	Λ3π events
2.0 ± 1.5		7 ARMENTERO	S65B	HBC	K p 0.9−1.2 GeV/c
7.2 ± 2.1		⁷ sмітн	65	HBC	K p 1.8 GeV/c
17.2 ± 2.0		⁷ SMITH	65	HBC	K-p 1.95 GeV/c
17 ±7		7 COOPER	64	HBC	K- p 1.45 GeV/c
4.3±2.2		⁷ HUWE	64	HBC	K-p 1.22 GeV/c
0.0 ± 4.2		7 ELY	61	HLBC	K-p 1.11 GeV/c

$m_{\Sigma(1385)^0} - m_{\Sigma(1385)^+}$

VALUE (MeV)	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do not use the	following	data for averages, fits	, limits,	etc. • • •
-4 to +4	95	BORENSTEIN 74	HBC	K-p 2.18 GeV/c

$m_{\Sigma(1385)^-} - m_{\Sigma(1385)^0}$

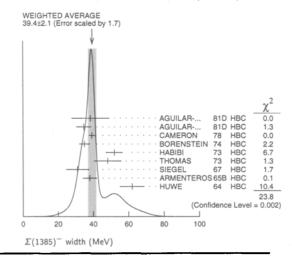
VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
	data for averages, fi	ts, limits,	etc. • • •
2.0±2.4	⁷ THOMAS 73	HBC	$\pi^- p \rightarrow \Lambda \pi^- K^+$

Σ(1385) WIDTHS

Σ(1385)+ WIDTH					
VALUE (MeV)	EVT5	DOCUMENT ID		TECN	COMMENT
35.8± 0.8 OUR AVER	AGE				
37.2± 2.0	1897	BAUBILLIER	84	HBC	K [−] p 8.25 GeV/c
35.1± 1.7	5256	AGUILAR	81 D	HBC	$K^- p \rightarrow \Lambda \pi \pi 4.2$ GeV/c
37.5± 2.0	9361	AGUILAR	81 D	нвс	$K^- p \rightarrow \Lambda 3\pi 4.2$ GeV/c
35.5± 1.9	6900	CAMERON	78	HBC	K-p 0.96-1.36 GeV/c
34.0± 1.6	6846	8 BORENSTEIN	74	HBC	K-p 2.18 GeV/c
38.3 ± 3.2	2300	⁹ HABIBI	73	HBC	$K^- p \rightarrow \Lambda \pi \pi$
32.5 ± 6.0	400	AGUILAR	72B	HBC	$K^- p \rightarrow \Lambda \pi$'s
36 ± 4	1260	9 SIEGEL	67	HBC	K-p 2.1 GeV/c
32.0 ± 4.7	750	9 ARMENTEROS	65B	HBC	K-p 0.95-1.20 GeV/c
46.5± 6.4	859	⁹ HUWE	64		K-p 1.15-1.30 GeV/c
• • We do not use the	e followi	ng data for averages	, fits	i, limits,	etc. • • •
40 ± 3	600	BAKER	80	HYBR	$\pi^+ p$ 7 GeV/c
37 ± 2	750	BAKER	80	HYBR	K = p 7 GeV/c
37 ± 2	7k	¹ BAUBILLIER	79B	HBC	K-p 8.25 GeV/c
30 ± 4	2k	CAUTIS	79	HYBR	$\pi^+ p/K^- p$ 11.5 GeV
30 ± 6	100	¹ SUGAHARA	79B	HBC	π p 6 GeV/c
43 ± 5	22k	^{1,2} BARREIRO	77B	HBC	K [−] p 4.2 GeV/c
34 ± 2	2594	HOLMGREN	77	HBC	See AGUILAR 81D
40.0 ± 3.2		1 BARDADIN	75	HBC	K [—] р 14.3 GeV/с
48 ± 3	3740	3 BERTHON	74	HBC	K-p 1263-1843 MeV/c
33 ±20	46	9 AGUILAR	70в	нвс	$K^- p \rightarrow \Sigma \pi$'s 4 GeV/c
25 ±32	62	9 BIRMINGHAM	66	HBC	K-p 3.5 GeV/c
30.3± 7.5	250	9 SMITH	65	HBC	K ⁻ p 1.8 GeV/c
33.1 ± 8.3	250	⁹ SMITH	65	HBC	K- p 1.95 GeV/c
51 ±16	170	⁹ COOPER	64	HBC	K- p 1.45 GeV/c
48 ±16	154	9 ELY	61	HLBC	K-p 1.11 GeV/c

Σ(1385)0 WID	TH				
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
6 ± 5 OUR	WERAGE				
34.8± 5.6	5722				$K^- p \rightarrow \Lambda 3\pi 4.2$ GeV/c
39.3 ± 10.2	240	⁹ THOMAS	73	HBC	$\pi^- p \rightarrow \Lambda \pi^0 K^0$
• • We do not	use the followi	ing data for averages	, fits	i, limits,	etc. • • •
53 ± 8	3100	¹⁰ BORENSTEIN	74	нвс	$K^- p \rightarrow \Lambda 3\pi \ 2.18$ GeV/c
30 ± 9	106	CURTIS	63	OSPK	$\pi^- \rho$ 1.5 GeV/c
Σ(1385) ⁻ WID	тн				

Σ(1385)- WID	ТН				
VALUE (MeV)	EVTS	DOCUMENT: ID		TECN	COMMENT
39.4± 2.1 OUR A	VERAGE Er	ror includes scale fac	tor c	of 1.7.	See the ideogram below.
38.4±10.7	620	AGUILAR	81D	нвс	$K^- p \rightarrow \Lambda \pi \pi 4.2$ GeV/c
34.6± 4.2	3346	AGUILAR	81 D	нвс	$K^- p \rightarrow \Lambda 3\pi 4.2$ GeV/c
39.2± 1.7	9720	CAMERON	78	HBC	K-p 0.96-1.36 GeV/c
35 ± 3	2303	8 BORENSTEIN	74	HBC	K [™] p 2.18 GeV/c
51.9± 4.8	1900	9 HABIBI	73	HBC	$K^- \rho \rightarrow \Lambda \pi \pi$
48.2± 7.7	630	⁹ THOMAS	73	HBC	$\pi^- \rho \rightarrow \Lambda \pi^- K^0$
31.0± 6.5	370	9 SIEGEL	67	нвс	K ⁻ p 2.1 GeV/c
38.0± 4.1	1382	9 ARMENTERO	565в	HBC	K-p 0.95-1.20 GeV/c
62 ± 7	1086	HUWE	64	HBC	K-p 1.15-1.30 GeV/c
• • • We do not	use the followi	ing data for average:	s, fits	, Ilmits	, etc. • • •
44 ± 4	4.5k	¹ BAUBILLIER	79B	HBC	K~ p 8.25 GeV/c
58 ± 4	150	¹ SUGAHARA	79B	HBC	π ⁻ p 6 GeV/c
45 ± 5	12k	^{1,2} BARREIRO	77B	HBC	K-p 4.2 GeV/c
35 ±10	193	HOLMGREN	77	HBC	See AGUILAR 81D
47 ± 6		¹ BARDADIN	75	нвс	K [™] p 14.3 GeV/c
40 ± 3	3060	3 BERTHON	74	HBC	K~p 1263-1843 MeV/
29.2±10.6	120	⁹ SMITH	65	HBC	K~ p 1.80 GeV/c
17.1 ± 8.9	58	⁹ SMITH	65	HBC	K-p 1.95 GeV/c
88 ±24	200	9 COOPER	64	HBC	K-p 1.45 GeV/c
40		DAHL	61	DBC	K d 0.45 GeV/c
66 ±18	224	⁹ ELY	61	HLBC	K~ p 1.11 GeV/c



Σ (1385) POLE POSITIONS

Σ(1385)+ REAL PART

22.5±1.5

VALUE	DOCUMENT ID	COMMENT
1379±1	LICHTENBERG74	Extrapolates HABIBI 73
Σ(1385)+ -IMAGIN	IARY PART	
VALUE	DOCUMENT ID	COMMENT
17.5 ± 1.5	LICHTENBERG74	Extrapolates HABIBI 73
Σ(1385)- REAL PA	RT	
VALUE	DOCUMENT ID	COMMENT
1383±1	LICHTENBERG74	Extrapolates HABIBI 73
Σ(1385)" - IMAGIN	IARY PART	
VALUE	DOCUMENT ID	COMMENT

LICHTENBERG74 Extrapolates HABIBI 73

Σ(1385) DECAY MODES

	Mode	Fraction (Γ ₁ /Γ)
Γı	Λπ	88±2 %
Γ_2	$\Sigma \pi$	12±2 %
Γ_3	Λγ	
Γ_4	$\Sigma\gamma$	
Γ ₄ Γ ₅	ΝŔ	
	The above branching f	ractions are our estimates, not fits or averages.

Σ (1385) BRANCHING RATIOS						
$\Gamma(\Sigma\pi)/\Gamma(\Lambda\pi)$						Γ_2/Γ_1
VALUE		DOCUMENT ID		TECN	CHG	COMMENT
0.135±0.011 OUR AV	ERAGE					
0.20 ± 0.06		DIONISI	78B	HBC	±	$K^- p \rightarrow Y^* K \overline{K}$
0.16 ±0.03		BERTHON	74	нвс	+	K ⁻ p 1.26-1.84 GeV/c
0.11 ±0.02		BERTHON	74	HBC	-	K-p 1.26-1.84 GeV/c
0.21 ±0.05		BORENSTEIN	74	нвс	+	$K^- p \rightarrow \Lambda \pi^+ \pi^-, \Sigma^0 \pi^+ \pi^-$
0.18 ±0.04		MAST	73	MPWA	±	$K^{-}p \xrightarrow{\pi}$ $\Lambda \pi^{+} \pi^{-}$, $\Sigma^{0} \pi^{+} \pi^{-}$
0.10 ±0.05		THOMAS	73	HBC	-	$\pi^{-}p \rightarrow \Lambda K\pi$, $\Sigma K\pi$
0.16 ±0.07		AGUILAR	72B	нвс	+	K p 3.9, 4.6 GeV/c
0.13 ±0.04		COLLEY	71B	DBC	-0	K-N 1.5 GeV/c
0.13 ±0.04		PAN	69	нвс	+	$\pi^+ p \rightarrow \Lambda K \pi$, $\Sigma K \pi$
0.08 ±0.06		LONDON	66	HBC	+	K-p 2.24 GeV/c
0.163±0.041		ARMENTERO	5 65 8	нвс	±	K ⁻ p 0.95-1.20 GeV/c
0.09 ± 0.04		HUWE	64	HBC	±	K - p 1.2-1.7 GeV
• • We do not use the	following	data for averages	i, fits	, ilmits,	etc. •	• •
< 0.04		ALSTON	62	HBC	±ο	K-p 1.15 GeV/c
0.04 ±0.04		BASTIEN	61	нвс	±	•
$\Gamma(\Lambda\gamma)/\Gamma_{\text{total}}$						Г3/Г
	<u>EVTS</u>	DOCUMENT ID				
• • We do not use the	_	•				
0.17±0.17	1	MEISNER	72	HBC	1 eve	nt only
$\Gamma(\Lambda\gamma)/\Gamma(\Lambda\pi)$						Γ ₃ /Γ ₁
VALUE	CL%	DOCUMENT ID				
• • We do not use the	following o	data for averages	, fits	, limits,	etc. •	• •
<0.06	90	COLAS	75	HLBC	K- p	575-970 MeV
$\Gamma(\Sigma\gamma)/\Gamma(\Lambda\pi)$						Γ_4/Γ_1
VALUE	CL%	DOCUMENT ID		<u>TECN</u>		
• • • We do not use the	following	data for average:	i, fits	i, limits,	etc. •	• •
<0.05	90	COLAS	75	HLBC	K- p	575-970 MeV
(F/F/) ^{1/2} /F _{total} in N K	? → Σ(13	85) → Λπ ·	,	CHG C	OMME	(Γ ₅ Γ ₁) ^{1/2} /Γ
+0.586±0.319	11	DEVENISH	74B			dispersion rel.

Σ(1385) FOOTNOTES

Σ(1385) REFERENCES

BAUBILLIER 84	ZPHY C23 213	+ (BIRM, CERN, GLAS, MSU, CURIN)
PDG 84		Wohl, Cahn, Rittenberg+ (LBL, CIT, CERN)
AGUILAR 81D		Aguilar-Benitez, Salicio (MADR)
BAKER 80	NP B166 207	+Chima, Dornan, Gibbs, Hall, Miller+ (LOIC)
BAUBILLIER 79B	NP B148 18	+ (BIRM, CERN, GLAS, MSU, CURIN)
CAUTIS 79	NP B156 507	+Ballam, Bouchez, Carroll, Chadwick+ (5LAC)
SUGAHARA 79B	NP B156 237	+Ochiai, Fukul, Cooper+ (KEK, OSKC, KINK)
CAMERON 78	NP B143 189	+Franek, Gopal, Bacon, Butterworth+ (RHEL, LOIC)
DIONISI 78B	PL 78B 154	+Armenteros, Diaz (CERN, AMST, NIJM, OXF)
BARREIRO 77B	NP B126 319	+Berge, Ganguli, Blokziji+ (CERN, AMST, NIJM)
HOLMGREN 77	NP B119 261	+Aguilar-Benitez, Kluyver+ (CERN, AMST, NIJM)
BARDADIN 75	NP B98 418	Bardadin-Otwinowska+ (SACL, EPOL, RHEL)
COLAS 75	NP B91 253	+Farwell, Ferrer, Six (ORSAY)
BERTHON 74	NC 21A 146	+Tristram+ (CDEF, RHEL, SACL, STRB)
BORENSTEIN 74	PR D9 3006	+Kalbfleisch, Strand+ (BNL, MICH)
DEVENISH 74B	NP B81 330	+Froggatt, Martin (DESY, NORD, LOUC)
LICHTENBERG 74	PR D10 3865	(IND)
Also 74B	Private Comm.	Lichtenberg (IND)
HABIBI 73	Thesis Nevis 199	(còlu)
Also 73	Purdue Conf. 387	Baltay, Bridgewater, Cooper+ (COLU, BING)
MAST 73	PR D7 3212	+Bangerter, Alston-Garnjost+ (LBL) IJP
Also 73B	PR D7 5	Mast, Bangerter, Alston-Garnjost+ (LBL) IJP
THOMAS 73	NP B56 15	+Engler, Fisk, Kraemer (CMU) JP
AGUILAR 72B	PR D6 29	Aguilar-Benitez, Chung, Eisner, Samios (BNL)
MEISNER 72	NC 12A 62	(UNC, LBL)
COLLEY 71B	NP B31 61	+Cox, Eastwood, Fry+ (BIRM, EDIN, GLAS, LOIC)
AGUILAR 70B	PRL 25 58	Aguilar-Benitez, Barnes, Bassano+ (BNL, SYRA)
PAN 69	PRL 23 808	+Forman (PENN) I
SIEGEL 67	Thesis UCRL 18041	`(LRL)
BIRMINGHAM 66	PR 152 1148	(BIRM, GLAS, LOIC, OXF, RHEL)
LONDON 66	PR 143 1034	+Rau, Goldberg, Lichtman+ (BNL, SYRA) J
ARMENTEROS 65B	PL 19 75	+ (CERN, HEID, SACL)
SMITH 65	Thesis UCLA	(UCLA)
COOPER 64	PL 8 365	+Filthuth, Fridman, Malamud+ (CERN, AMST)
HUWE 64	Thesis UCRL 11291	(LRL) JP
Also 69	PR 180 1824	Huwe (LRL)
CURTIS 63	PR 132 1771	+Coffin, Meyer, Terwilliger (MICH) J
ALSTON 62	CERN Conf. 311	+Alvarez, Ferro-Luzzi+ (LRL)
BASTIEN 61	PRL 6 702	+Ferro-Luzzi, Rosenfeld (LRL)
DAHL 61	PRL 6 142	+Horwitz, Miller, Murray, White (LRL)
ELY 61	PRL 7 461	+Fung, Gidal, Pan, Powell, White (LRL) J
ALSTON 60	PRL 5 520	+Alvarez, Eberhard, Good, Graziano+ (LRL) I

Σ (1480) Bumps

 $I(J^P) = 1(??)$ Status: *

OMITTED FROM SUMMARY TABLE

These are peaks seen in $\Lambda\pi$ and $\Sigma\pi$ spectra in the reaction $\pi^+p\to$ $(Y\pi)K^+$ at 1.7 GeV/c. Also, the Y polarization oscillates in the same region.

MILLER 70 suggests a possible alternate explanation in terms of a reflection of $N(1675) \rightarrow \Lambda K$ decay. However, such an explanation for the $(\Sigma^+ \pi^0) K^+$ channel in terms of $\Delta(1650) \rightarrow \Sigma K$ decay seems unlikely (see PAN 70). In addition such reflections would also have to account for the oscillation of the Y polarization in the 1480 MeV region.

HANSON 71, with less data than PAN 70, can neither confirm nor deny the existence of this state. MAST 75 sees no structure in this region in $K^-p \rightarrow \Lambda \pi^0$.

ENGELEN 80 performs a multichannel analysis of $K^-p \to p \overline{K}{}^0\pi^$ at 4.2 GeV/c. They observe a 3.5 standard-deviation signal at 1480 MeV in $p\overline{K}^0$ which cannot be explained as a reflection of any competing channel.

Σ(1480) MASS (PRODUCTION EXPERIMENTS)

VALUE (MeV) ≈ 1480 OUR EST	<u>EVTS</u>	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT
1480	120	ENGELEN	80	нвс	+	$K^- p \rightarrow (p \overline{K}^0) \pi^-$
1485±10		CLINE	73	MPWA	-	$K^{-}d \rightarrow (\Lambda \pi^{-})p$
1479±10		PAN	70	нвс	+	-+ n -
1465±15		PAN	70	нвс	+	$(\Lambda \pi^{+}) K^{+}$ $\pi^{+} p \rightarrow (\Sigma \pi) K^{+}$

Σ(1480) WIDTH (PRODUCTION EXPERIMENTS)

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
80±20	120	ENGELEN	80	нвс	+	$K^- p \rightarrow (p \overline{K}^0) \pi^-$
40±20		CLINE	73	MPWA		$K^{-}d \rightarrow (\Lambda \pi^{-})p$
31 ± 15		PAN	70	нвс	+	-to-
30±20		PAN	70	нвс	+	$(\Lambda \pi^{+})K^{+}$ $\pi^{+}\rho \rightarrow (\Sigma \pi)K^{+}$

¹ From fit to inclusive $\Lambda\pi$ spectrum.

² Includes data of HOLMGREN 77. ³ The errors are statistical only. The resolution is not unfolded. ⁴ The error is enlarged to Γ/\sqrt{N} . See the note on the $K^*(892)$ mass in the 1984 edition.

⁵ From a fit to $\Lambda\pi^0$ with the width fixed at 34 MeV. 6 From fit to inclusive $\Lambda\pi^0$ spectrum with the width fixed at 40 MeV.

 $^{^7}$ Redundant with data in the mass Listings. 8 Results from $\Lambda\pi^+\pi^-$ and $\Lambda\pi^+\pi^-\pi^0$ combined by us.

⁹ The error is enlarged to $4\Gamma/\sqrt{N}$. See the note on the $K^*(892)$ mass in the 1984 edition.

 $^{^{10}}$ Consistent with +, 0, and - widths equal.

¹¹ An extrapolation of the parametrized amplitude below threshold.

 $\Sigma(1480)$ Bumps, $\Sigma(1560)$ Bumps, $\Sigma(1580)$

Σ(1480) DECAY MODES (PRODUCTION EXPERIMENTS)

	Mode	
Γ ₁	NK	
Γ_2	$\Lambda\pi$	
Γ3	$\Sigma \pi$	
		Σ(1480) BRANCHING RATIOS

	RODUCTION EXPERIM		
$\Gamma(\Sigma\pi)/\Gamma(\Lambda\pi)$ VALUE 0.82 ± 0.51	DOCUMENT ID PAN 70	Γ <u>3</u> /0 - <u>TECN CHG</u> - HBC +	Γ ₂
$\Gamma(N\overline{K})/\Gamma(\Lambda\pi)$ $VALUE$ 0.72 ± 0.50	DOCUMENT ID PAN 70	Γ <u>1</u> /(_ <u>TECN CHG</u>) HBC +	Γ ₂
Γ(NK)/Γ _{total}	DOCUMENT ID	TECN COMMENT	/F
small	CLINE 73	MPWA $K^-d \rightarrow (\Lambda \pi^-)p$	

Σ(1480) REFERENCES (PRODUCTION EXPERIMENTS)

ENGELEN	80	NP B167 61	+Jongejans, Dionisi+	(NIJM, AMST, CERN, C	OXF)
MAST	75	PR D11 3078	+Alston-Garniost, Bangerter+		LBL)
CLINE	73	LNC 6 205	+Laumann, Mapp	(Ŵ	/ISC) IJI
HANSON	71	PR D4 1296	+Kalmus, Louie	. ((LBL) I
MILLER	70	Duke Conf. 229		(Pi	JRD)
PAN	70	PR D2 49	+Forman, Ko, Hagopian, Selov	e (PE	ENN)
Also	69	PRL 23 808	Pan, Forman		ENN) I
Also	69B	PRL 23 806	Pan, Forman	(PE	ENN) I

$\Sigma(1560)$ Bumps

 $I(J^P) = 1(??)$ Status: **

OMITTED FROM SUMMARY TABLE

This entry lists peaks reported in mass spectra around 1560 MeV without implying that they are necessarily related.

DIONISI 78B observes a 6 standard-deviation enhancement at 1553 MeV in the charged $\Lambda/\Sigma\pi$ mass spectra from $K^-p\to$ $(\Lambda/\Sigma)\pi K\overline{K}$ at 4.2 GeV/c. In a CERN ISR experiment, LOCK-MAN 78 reports a narrow 6 standard-deviation enhancement at 1572 MeV in $\Lambda \pi^{\pm}$ from the reaction $pp \to \Lambda \pi^+ \pi^- X$. These enhancements are unlikely to be associated with the $\Sigma(1580)$ (which has not been confirmed by several recent experiments - see the next entry in the Listings).

CARROLL 76 observes a bump at 1550 MeV (as well as one at 1580 MeV) in the isospin-1 $\overline{K}N$ total cross section, but uncertainties in cross section measurements outside the mass range of the experiment preclude estimating its significance.

See also MEADOWS 80 for a review of this state.

Σ(1560) MASS (PRODUCTION EXPERIMENTS)

VALUE (MeV) ≈ 1560 OUR ESTIN	EVTS	DOCUMENT ID	TECN	CHG	COMMENT
1553±7	121	DIONISI	78B HBC	±	$K^- p \rightarrow (Y\pi)K\overline{K}$
1572±4	40	LOCKMAN	78 SPEC	±	$pp \rightarrow \Lambda \pi^+ \pi^- X$

Σ(1560) WIDTH (PRODUCTION EXPERIMENTS)

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
79±30	121	DIONISI	78B	нвс	±	$K^-p \rightarrow (Y\pi)K\overline{K}$
15± 6	40	1 LOCKMAN	78	SPEC	±	$pp \rightarrow \Lambda \pi^+ \pi^- X$

Σ(1560) DECAY MODES (PRODUCTION EXPERIMENTS)

	Mode	Fraction (Γ_I/Γ)
Γ ₁	Λπ	seen
Γ ₂	Σπ	

Σ (1560) BRANCHING RATIOS (PRODUCTION EXPERIMENTS)

$\Gamma(\Sigma\pi)/[\Gamma(\Lambda\pi)+\Gamma(\Sigma\pi)]$	DOCUMENT ID		TECN	<u>CHG</u>	$\Gamma_2/(\Gamma_1+\Gamma_2)$
0.35±0.12	DIONISI	78B	нвс	±	$K^-p \to (Y\pi)K\overline{K}$
Γ(Λπ)/Γ _{total}	DOCUMENT ID		<u>TECN</u>	<u>CHG</u>	Γ ₁ /Γ
seen	LOCKMAN	78	SPEC	±	$pp \rightarrow \Lambda \pi^+ \pi^- X$

Σ(1560) FOOTNOTES (PRODUCTION EXPERIMENTS)

 $^{1}\mathrm{The}$ width observed by LOCKMAN 78 is consistent with experimental resolution.

Σ(1560) REFERENCES (PRODUCTION EXPERIMENTS)

MEADOWS	80	Toronto Conf. 283	+Armenteros, Diaz (CERN,	(CINC)
DIONISI	78B	PL 78B 154		AMST, NIJM, OXF) I
LOCKMAN	78	Saclay DPHPE 78-01	+Meyer, Rander, Poster, Schlein+	(UCLA, SACL)
CARROLL	76	PRL 37 806	+Chiang, Kycia, Li, Mazur, Michael+	(BNL) I

$\Sigma(1580) D_{13}$

 $I(J^P) = 1(\frac{3}{2})$ Status: **

OMITTED FROM SUMMARY TABLE

Seen in the isospin-1 \overline{K} N cross section at BNL (LI 73, CARROLL 76) and in a partial-wave analysis of $K^-p \to \Lambda\pi^0$ for c.m. energies 1560–1600 MeV by LITCHFIELD 74. LITCHFIELD 74 finds $J^P=$ 3/2". Not seen by ENGLER 78 or by CAMERON 78C (with larger statistics in $K_L^0 p \to \Lambda \pi^+$ and $\Sigma^0 \pi^+$).

Σ(1580) MASS DOCUMENT ID

VALUE (MeV)	DOCUMENT ID		IECN	COMMENT	
≈ 1580 OUR ESTIMATE					
1583±4				Isospin-1 total σ	
1582±4	² LITCHFIELD	² LITCHFIELD 74		$K^- \rho \rightarrow \Lambda \pi^0$	
	Σ(1580) WID	TL			
	Z(1560) WID	1111			
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT	
15	¹ CARROLL	76	DPWA	Isospin-1 total σ	
11+4	2 LITCHEIELD	74	DPWA	$K^- n \rightarrow \Lambda \pi^0$	

Σ(1580) DECAY MODES

	Mode	
Γ ₁	NK Λπ	
Γ_2	$\Lambda\pi$	
Γ3	$\Sigma \pi$	

Σ(1580) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on Λ and Σ

$\Gamma(N\overline{K})/\Gamma_{\text{total}}$				Γ ₁ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
$+0.03\pm0.01$	² LITCHFIELD	74	DPWA	KN multichannel
$(\Gamma_I \Gamma_I)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N^{\frac{1}{2}}$	$\overline{\zeta} \to \Sigma(1580) \to \Lambda \pi$			(Γ₁Γ₂) ^½ /Γ
VALUE	DOCUMENT ID		TECN_	COMMENT
not seen	CAMERON	78C	HBC	$K_{i}^{0}p \rightarrow \Lambda \pi^{+}$
not seen	ENGLER	78	нвс	$K_i^{\bar{0}} \rho \rightarrow \Lambda \pi^+$
+0.10±0.02	CAMERON ENGLER ² LITCHFIELD	74	DPWA	$\kappa^{-} p \rightarrow \Lambda \pi^{0}$
$(\Gamma_I \Gamma_I)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N^7$	$ abla \to \Sigma(1580) \to \Sigma \pi$			(Γ₁Γ₃) ^{1/2} /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
not seen	CAMERON	78 C	HBC	$\begin{array}{ccc} \kappa_L^0 p \to & \Sigma^0 \pi^+ \\ \kappa_L^0 p \to & \Sigma^0 \pi^+ \end{array}$
not seen	ENGLER	78	HBC	$K_I^0 p \rightarrow \Sigma^0 \pi^+$
+0.03±0.04	² LITCHFIELD		DPWA	KN multichannel

Σ(1580) FOOTNOTES

¹CARROLL 76 sees a total-cross-section bump with $(J+1/2) \Gamma_{el} / \Gamma_{total} = 0.06$.

 2 The main effect observed by LITCHFIELD 74 is in the $\Lambda\pi$ final state; the $\overline{K}N$ and couplings are estimated from a multichannel fit including total-cross-section data of

$\Sigma(1580)$, $\Sigma(1620)$, $\Sigma(1620)$ Production Experiments

Σ(1580) REFERENCES

CAMERON ENGLER CARROLL LITCHFIELD LI NP B132 189 PR D18 3061 PRL 37 806 PL 51B 509 Purdue Conf. 283 +Capiluppi+ (BGNA, EDIN, GLAS, PISA, RHEL) I +Keyes, Kraemer, Tanaka, Cho+ +Chiang, Kycia, Li, Mazur, Michael+ (CMU, ANL) (CERN) LIP (CERN) LIP

 Σ (1620) S_{11}

 $I(J^P) = 1(\frac{1}{2})$ Status: **

OMITTED FROM SUMMARY TABLE

The S_{11} state at 1697 MeV reported by VANHORN 75 is tentatively listed under the $\Sigma(1750)$. CARROLL 76 sees two bumps in the isospin-1 total cross section near this mass.

Production experiments are listed separately in the next entry.

$\Sigma(1620)$	MASS
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DOCUMENT ID		<u>TECN</u>	COMMENT
1 MODBIE	70	DD\A/A	K-n . 4
KIM	71	DPWA	K-matrix analysis
	DOCUMENT ID 1 MORRIS 2 CARROLL 3 CARROLL LANGBEIN KIM	1 MORRIS 78 2 CARROLL 76 3 CARROLL 76 LANGBEIN 72	1 MORRIS 78 DPWA 2 CARROLL 76 DPWA 3 CARROLL 76 DPWA LANGBEIN 72 IPWA

Σ(1620) WIDTH

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
87±19	1 MORRIS 7	8 DPWA	$K^- n \rightarrow \Lambda \pi^-$
15	² CARROLL 7	6 DPWA	Isospin-1 total σ
10	3 CARROLL 7	6 DPW	Isospin-1 total σ
65 ± 20	LANGBEIN	2 IPWA	KN multichannel
40	KIM 7	1 DPW	K-matrix analysis

Σ(1620) DECAY MODES

	Mode	 	 	 	
Γ1	NK			 	
	$\Lambda\pi$				
Г	$\Sigma \pi$,			

Σ (1620) BRANCHING RATIOS

I (NK)/I total				11/
VALUE	DOCUMENT ID	TECN	COMMENT	
0.22 ± 0.02	LANGBEIN 7	2 IPW	KN multichannel	
0.05	KIM 7	1 DPW	A K-matrix analysis	

$(\Gamma_I \Gamma_I)^{\dagger 2} / \Gamma_{\text{total}} \ln N \overline{K} \rightarrow$	$\Sigma(1620) \rightarrow \Lambda \pi$			$(\Gamma_1\Gamma_2)^{72}$
VALUE	DOCUMENT ID		TECN_	COMMENT
0.12 ± 0.02	¹ MORRIS	78	DPWA	$K^- n \rightarrow \Lambda \pi^-$
not seen	BAILLON	75	IPWA	$\overline{K}N \rightarrow \Lambda\pi$
0.15	KIM	71	DPWA	K-matrix analysis

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N \overline{K} \rightarrow \Sigma$	(1620) → Σπ		(Γ ₁ Γ ₃) ^{1/2} /
VALUE	DOCUMENT ID	TECN	COMMENT
not seen	HEPP	76B DPWA	$K^-N \rightarrow \Sigma \pi$
0.40 ± 0.06	LANGBEIN	72 IPWA	KN multichannel
0.08	KIM	71 DPWA	K-matrix analysis

Σ (1620) FOOTNOTES

- $^{1}\,\mathrm{MORRIS}$ 78 obtains an equally good fit without including this resonance.
- ² Total cross-section bump with (J+1/2) $\Gamma_{\rm el}$ / $\Gamma_{\rm total}$ is 0.06 seen by CARROLL 76.

Σ(1620) REFERENCES

MORRIS	78	PR D17 55	+Albright, Colleraine, Kimel, Lannutti	(FSU) IJP
CARROLL	76	PRL 37 806	+Chiang, Kycia, Li, Mazur, Michael+	(BNL) I
HEPP	76B	PL 658 487	+Braun, Grimm, Strobele+ (C	ERN, HEIDH, MPIM) IJP
BAILLON	75	NP B94 39	+Litchfield	(CERN, RHEL) IJP
VANHORN	75	NP B87 145		(LBL) IJP
Also	75B	NP B87 157	VanHorn	(LBL) IJP
LANGBEIN	72	NP B47 477	+Wagner	(MPIM) IJP
KIM	71	PRL 27 356		(HARV) IJP
Also	70	Duke Conf. 161	Kim	(HARV) IJP

$\Sigma(1620)$ Production Experiments

 $I(J^P) = 1(??)$

OMITTED FROM SUMMARY TABLE

Formation experiments are listed separately in the previous entry.

The results of CRENNELL 69B at 3.9 ${
m GeV}/c$ are not confirmed by SABRE 70 at 3.0 GeV/c. However, at 4.5 GeV/c, AMMANN 70 sees a peak at 1642 MeV which on the basis of branching ratios they do not associate with the $\Sigma(1670)$. See MILLER 70 for a review of these conflicts.

Σ(1620) MASS (PRODUCTION EXPERIMENTS)

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
≈ 1620 OUR ESTI	MATE					
1642 ± 12		AMMANN	70	DBC		K-N 4.5 GeV/c
1618± 3	20	BLUMENFELD	69	HBC	+	K ⁰ _L p
1619± 8		CRENNELL	69 B	DBC	±	$K^{-}N \rightarrow \Lambda\pi\pi\pi$
• • • We do not u	ise the following	data for averages	, fits	, limits	etc.	• •
1616± 8		CRENNELL	68	DBC	±	See CREN- NELL 698

Σ(1620) WIDTH (PRODUCTION EXPERIMENTS)

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
55 ± 24		AMMANN	70	DBC		K-N 4.5 GeV/c
30 ± 10	20	BLUMENFELD	69	HBC	+	
72 ⁺²² ₋₁₅		CRENNELL	69B	DBC	±	
• • • We do not	use the following	data for averages	, fits	, limits,	etc. •	• •
66±16		CRENNELL	68	DBC	±	See CREN-

Σ(1620) DECAY MODES (PRODUCTION EXPERIMENTS)

	Mode	
Гı	NK	
Γ_2	$\Lambda\pi$	
$\bar{\Gamma_3}$	Σπ	
Γ4	Λππ	
Γ ₅	$\Sigma(1385)\pi$	
Γ6	$\Lambda(1405)\pi$	

Σ(1620) BRANCHING RATIOS (PRODUCTION EXPERIMENTS)

$\Gamma(\Lambda\pi\pi)/\Gamma(\Lambda\pi)$					Γ_4/Γ_2
VALUE	<u>EVTS</u>	DOCUMENT ID		TECN	<u>CHG</u>
~ 2.5	14	BLUMENFELD	69	HBC	+
$\Gamma(N\overline{K})/\Gamma(\Lambda\pi)$					Γ_1/Γ_2
VALUE		DOCUMENT ID		TECN_	CHG COMMENT
0.4±0.4		AMMANN	70	DBC	K p 4.5 GeV/c
0.0±0.1		CRENNELL	68	DBC	+ See CREN- NELL 69B
$\Gamma(\Lambda\pi)/\Gamma_{\text{total}}$					Γ ₂ /Γ
VALUE		DOCUMENT ID		TECN	<u>CHG</u>
large		CRENNELL	68	DBC	±
$\Gamma(\Sigma(1385)\pi)/\Gamma(\Lambda\pi)$					Γ_5/Γ_2
VALUE	CL%	DOCUMENT ID		TECN	CHG COMMENT
< 0.3	95	AMMANN	70	DBC	K - p 4.5 GeV/c
0.2 ± 0.1		CRENNELL	68	DBC	±
$\Gamma(\Sigma\pi)/\Gamma(\Lambda\pi)$					Γ ₃ /Γ ₂
VALUE	CL%	DOCUMENT ID		TECN	COMMENT
<1.1	95	AMMANN .	70	DBC	K-N 4.5 GeV/c
$\Gamma(\Lambda(1405)\pi)/\Gamma(\Lambda\pi)$					Γ_6/Γ_2
VALUE		DOCUMENT ID		TECN	COMMENT
0.7±0.4		AMMANN	70	DBC	K [™] p 4.5 GeV/c

 $^{^3}$ Total cross-section bump with (J+1/2) $\Gamma_{\mbox{el}}$ / $\Gamma_{\mbox{total}}$ is 0.04 seen by CARROLL 76.

 $\Sigma(1620)$ Production Experiments, $\Sigma(1660)$, $\Sigma(1670)$

Σ(1620) REFERENCES (PRODUCTION EXPERIMENTS)

AMMANN	70	PRL 24 327	+Garfinkel, Carmony, Gutay+	(PURD, IND)
Also	73	PR D7 1345	Ammann, Carmony, Garfinkel+	(PURD, IUPU)
MILLER	70	Duke Conf. 229	,	(PURD)
SABRE	70	NP B16 201	Barloutaud, Merril, Schever+	(SABRE Collab.)
BLUMENFELD	69	PL 29B 58	+Kalbfleisch	(BNL) I
CRENNELL	69B	Lund Paper 183	+Karshon, Lai, O'Neil, Scarr+	(BNL, CUNY) I
Results are	quot	ed in LEVI-SETTI 69C.		,,
Also	69C	Lund Conf.	Levi-Setti	(EFI)
CRENNELL	68	PRL 21 648	+Delaney, Flaminio, Karshon+	(BNL, CÙNY) I

Σ (1660) P_{11}

$$I(J^P) = 1(\frac{1}{2}^+)$$
 Status: ***

For results published before 1974 (they are now obsolete), see our 1982 edition Physics Letters 111B (1982).

	Σ(1660) MA	SS		
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1630 to 1690 (≈ 1660) OUR ES	TIMATE			
1665.1±11.2	1 KOISO	85	DPWA	$K^-p \rightarrow \Sigma \pi$
1670 ±10	GOPAL	80	DPWA	KN → KN
1679 ±10	ALSTON	78	DPWA	KN → KN
1676 ±15	GOPAL	77	DPWA	RN multichannel
1668 ±25	VANHORN	75	DPWA	$K^- p \rightarrow \Lambda \pi^0$
1670 ±20	KANE	74	DPWA	$K^- p \rightarrow \Sigma \pi$
• • • We do not use the following	g data for average	s, fit	s, limits,	etc. • • •
1565 or 1597	² MARTIN	77	DPWA	KN multichannel
1660 ±30	3 BAILLON	75	IPWA	$\overline{K}N \rightarrow \Lambda \pi$
1671 ± 2	4 PONTE	75	DPWA	$K^- p \rightarrow \Lambda \pi^0$

Σ(1660) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
40 to 200 (≈ 100) OUR ESTIN	AATE			
81.5± 22.2	¹ KOISO	85	DPWA	$K^- p \rightarrow \Sigma \pi$
152 ± 20	GOPAL	80	DPWA	RN → RN
38 ± 10	ALSTON	78	DPWA	KN → KN
120 ± 20	GOPAL	77	DPWA	KN multichannel
230 +165 - 60	VANHORN	75	DPWA	$K^-p \rightarrow \Lambda \pi^0$
250 ±110	KANE	74	DPWA	$K^- p \rightarrow \Sigma \pi$
• • • We do not use the following	g data for average	s, fit	s, iimits,	etc. • • •
202 or 217	² MARTIN	77	DPWA	KN multichannel
80 ± 40				$\overline{K}N \rightarrow \Lambda_{\overline{\pi}}$
81 ± 10	4 PONTE	75	DPWA	$K^-p \rightarrow \Lambda \pi^0$

Σ(1660) DECAY MODES

	Mode	Fraction (Γ _I /Γ)
Γ ₁	ΝK	10–30 %
Γ_2	$\Lambda\pi$	seen
Гз	$\Sigma \pi$	seen

Σ(1660) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on Λ and Σ

$\Gamma(N\overline{K})/\Gamma_{\text{total}}$				Г1/Г
VALUE	DOCUMENT ID		TECN	COMMENT
0.1 to 0.3 OUR ESTIN	MATE			
0.12 ± 0.03	GOPAL ,	80	DPWA	$RN \rightarrow RN$
0.10 ± 0.05	ALSTON	78	DPWA	$RN \rightarrow RN$
• • • We do not use the	following data for averag	es, flt	s, limits,	etc. • • •
<0.04	GOPAL	77	DPWA	See GOPAL 80
0.27 or 0.29	² MARTIN	77	DPWA	KN multichannel
(F ₁ F ₁)½/F _{total} in NK	$\rightarrow \Sigma(1660) \rightarrow \Lambda \pi$			(Γ ₁ Γ ₂) ^½ /Γ
			TECN	
<u>VALUE</u> < 0.04	<u>DOCUMENT ID</u> GOPAL	77		COMMENT /
VALUE	DOCUMENT ID	77	DPWA	COMMENT
<u>VALUE</u> < 0.04	DOCUMENT ID GOPAL VANHORN	77 75	DPWA DPWA	$\frac{COMMENT}{K N \text{ multichannel}}$ $K^- p \to \Lambda \pi^0$
< 0.04 0.12+0.12 0.04	<u>DOCUMENT ID</u> GOPAL VANHORN following data for averag	77 75 es, flt	DPWA DPWA s, limits,	$\frac{COMMENT}{K N \text{ multichannel}}$ $K^- p \to \Lambda \pi^0$
VALUE < 0.04 0.12+0.12 - 0.04 • • • We do not use the	DOCUMENT ID GOPAL VANHORN following data for averag 2 MARTIN 3 BAILLON	77 75 es, flt: 77 75	DPWA DPWA s, limits, DPWA iPWA	$\frac{COMMENT}{KN \text{ multichannel}}$ $K^- p \rightarrow \Lambda \pi^0$ etc. • • •

(Γ _I Γ _I) ^{1/2} /Γ _{total} In N λ				(Γ₁Γ₃) ¹ ⁄2/
VALUE	DOCUMENT I	<u> </u>	TECN	COMMENT
-0.13 ± 0.04	¹ koiso			$K^-p \rightarrow \Sigma \pi$
-0.16 ± 0.03	GOPAL	77	DPWA	KN multichannel
-0.11 ± 0.01	KANE	74	DPWA	$K^-p \rightarrow \Sigma \pi$
• • • We do not use the	following data for avera	ges, fits	s, Umits,	etc. • • •
-0.34 or -0.37	² MARTIN	77	DPWA	KN multichannel
not seen	HEPP	76B	DPWA	$K^-N \rightarrow \Sigma \pi$

Σ(1660) FOOTNOTES

 $\frac{1}{2}$ The evidence of KOISO 85 is weak.

⁴ From solution 2 of PONTE 75; not present in solution 1.

Σ(1660) REFERENCES

KOISO	85	NP A433 619	+Sai, Yamamoto, Kofler	(TOKY, MASA)
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
GOPAL	80	Toronto Conf. 159	· · · · •	(RHEL) LIP
ALSTON	78	PR D18 182	Alston-Garnjost, Kenney+	(LBL, MTHO, CERN) UP
Also	77	PRL 38 1007	Aiston-Garnjost, Kenney+	(LBL, MTHO, CERN) IJP
GOPAL	77	NP B119 362	+Ross, VanHorn, McPherson+	(LOIC, RHEL) IJP
MARTIN	77	NP B127 349	+Pidcock, Moorhouse	(LOUC, GLAS) IJP
Also	77B	NP B126 266	Martin, Pidcock	` (LOUCÍ
Also	77C	NP B126 285	Martin, Pidcock	(LOUC) UP
HEPP	76B	PL 65B 487	+Braun, Grimm, Strobele+	(CERN, HEIDH, MPIM) IJP
BAILLON	75	NP B94 39	+Litchfield	(CERN, RHEL) IJP
PONTE	75	PR D12 2597	+Hertzbach, Button-Shafer+	(MASA, TENN, UCR) IJP
VANHORN	75	NP B87 145		(LBL) IJP
Also	75B	NP B87 157	VanHorn	(LBL) IJP
KANE	74	LBL-2452		(LBL) IJP

THE $\Sigma(1670)$ REGION

Production experiments: The measured $\Sigma \pi / \Sigma \pi \pi$ branching ratio for the $\Sigma(1670)$ produced in the reaction $K^-p \to \pi^- \Sigma (1670)^+$ is strongly dependent on momentum transfer. This was first discovered by EBERHARD 69, who suggested that there exist two Σ resonances with the same mass and quantum numbers: one with a large $\Sigma\pi\pi$ (mainly $\Lambda(1405)\pi$) branching fraction produced peripherally, and the other with a large $\Sigma\pi$ branching fraction produced at larger angles. The experimental results have been confirmed by AGUILAR-BENITEZ 70, ASPELL 74, ESTES 74, and TIMMERMANS 76. If, in fact, there are two resonances, the most likely quantum numbers for both the $\Sigma\pi$ and the $\Lambda(1405)\pi$ states are D_{13} . There is also possibly a third Σ in this region, the $\Sigma(1690)$ in the Listings, the main evidence for which is a large $\Lambda\pi/\Sigma\pi$ branching ratio. These topics have been reviewed by EBERHARD 73 and by MILLER 70.

Formation experiments: Two states are also observed near this mass in formation experiments. One of these, the $\Sigma(1670)D_{13}$, has the same quantum numbers as those observed in production and has a large $\Sigma \pi / \Sigma \pi \pi$ branching ratio; it may well be the $\Sigma(1670)$ produced at larger angles (see TIM-MERMANS 76). The other state, the $\Sigma(1660)P_{11}$, has different quantum numbers, its $\Sigma \pi / \Sigma \pi \pi$ branching ratio is unknown, and its relation to the produced $\Sigma(1670)$ states is obscure.

² The two MARTIN 77 values are from a T-matrix pole and from a Breit-Wigner fit.

³ From solution 1 of BAILLON 75; not present in solution 2.

$\Sigma(1670) D_{13}$

 $I(J^P) = 1(\frac{3}{2}^-)$ Status: ***

For most results published before 1974 (they are now obsolete), see our 1982 edition Physics Letters 111B (1982).

Results from production experiments are listed separately in the next

Σ(1670) MASS

VALUE	(MeV)	DOCUMENT ID		TECN	COMMENT
1665	to 1685 (≈ 1670) OUR EST	IMATE			
1665.1	± 4.1	KOISO	85		$K^- p \rightarrow \Sigma \pi$
1682	± 5	GOPAL	80	DPWA	KN → KN
1679	±10	ALSTON	78	DPWA	KN → KN
1670	± 5	GOPAL	77	DPWA	KN multichannel
1670	± 6	HEPP	76B	DPWA	$K^- N \rightarrow \Sigma \pi$
1685	±20	BAILLON	75	IPWA	$\overline{K}N \rightarrow \Lambda \pi$
1659	+12 - 5	VANHORN	75	DPWA	$\kappa^- \rho \rightarrow \Lambda \pi^0$
1670	± 2	KANE	74	DPWA	$K^- p \rightarrow \Sigma \pi$
• • •	We do not use the following	data for averages	s, fits	, limits,	etc. • • •
1667	or 1668	¹ MARTIN	77	DPWA	KN multichannel
1650		DEBELLEFON	76	IPWA	$K^- p \rightarrow \Lambda \pi^0$
1671	± 3	PONTE			$K^- p \rightarrow \Lambda \pi^0$ (sol. 1)
1655	± 2	PONTE	75	DPWA	$K^-p \rightarrow \Lambda \pi^0$ (sol. 2)

Σ(1670) WIDTH

VALI	JE (MeV)	DOCUMENT ID		TECN	COMMENT
40	to 80 (≈ 60) OUR ESTIMATE	:			
65.0	± 7.3	KOISO	85		$K^- p \rightarrow \Sigma \pi$
79	±10	GOPAL	80	DPWA	KN → KN
56	±20	ALSTON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$
50	± 5	GOPAL	77	DPWA	KN multichannel
56	± 3	HEPP	76B	DPWA	$K^- N \rightarrow \Sigma \pi$
85	±25	BAILLON	75	IPWA	$\overline{K}N \rightarrow \Lambda \pi$
32	±11	VANHORN	75	DPWA	$K^- p \rightarrow \Lambda \pi^0$
79	± 6	KANE	74	DPWA	$K^- p \rightarrow \Sigma \pi$
• •	• We do not use the following	data for averages	i, fits	, limits,	etc. • • •
46	or 46	¹ MARTIN	77	DPWA	KN multichannel
80		DEBELLEFON	76	IPWA	$K^- p \rightarrow \Lambda \pi^0$
44	±11	PONTE	75	DPWA	$K^-p \rightarrow \Lambda \pi^0$ (sol. 1)
76	± 5	PONTE			$K^-p \rightarrow \Lambda \pi^0$ (sol. 2)

Σ(1670) DECAY MODES

	Mode	Fraction (Γ_I/Γ)	
Γ ₁	NK	7–13 %	
Γ_2	$\Lambda\pi$	5–15 %	
Γ3	$\Sigma \pi$	30-60 %	
Γ4	Λππ	r.	
	Σππ	*	
Γ ₅ Γ ₆	Σ (1385) π		
Γ ₇	Σ (1385) π , S-wave		
Γ̈́8	$\Lambda(1405)\pi$		
Γ٩	Λ(1520) π		
-	•		

The above branching fractions are our estimates, not fits or averages.

Σ(1670) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on \varLambda and \varSigma Resonances.

Γ(NR)/Γ _{total}				Γ ₁ /
VALUE	DOCUMENT ID		TECN	COMMENT
0.07 to 0.13 OUR ESTIM	ATE			
0.10±0.03	GOPAL	80		$\overline{K}N \rightarrow \overline{K}N$
0.11 ± 0.03	ALSTON	78	DPWA	KN → KN ·
 • • We do not use the 	following data for averag	es, fit	s, limits,	etc. • • •
0.08±0.03	GOPAL	77	DPWA	See GOPAL 80
0.07 or 0.07	¹ MARTIN	77	DPWA	KN multichannel
(5 5 1/5 1- NP	T(1670) . A-			(F F 1/2)
$(\Gamma_I \Gamma_I)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\overline{K}$	-→ Σ(1670) → Λπ			$(\Gamma_1\Gamma_2)^{\frac{1}{2}}$
VALUE	DOCUMENT ID		<u>TECN</u>	COMMENT
0.17 ±0.03	2 MORRIS	78	DPWA	$\begin{array}{c} COMMENT \\ K^- n \to \Lambda \pi^- \end{array}$
VALUE	DOCUMENT ID		DPWA	COMMENT
0.17 ±0.03	2 MORRIS	78	DPWA DPWA	$\begin{array}{c} COMMENT \\ K^- n \to \Lambda \pi^- \end{array}$
0.17 ±0.03 0.13 ±0.02	2 MORRIS 2 MORRIS 2 MORRIS	78 78	DPWA DPWA DPWA IPWA	$\begin{array}{ccc} \underline{COMMENT} \\ K^- n \to & \Lambda \pi^- \\ K^- n \to & \Lambda \pi^- \\ \hline K N \text{ multichannel} \\ \hline K N \to & \Lambda \pi \end{array}$
VALUE 0.17 ±0.03 0.13 ±0.02 +0.10 ±0.02	² MORRIS ² MORRIS ² MORRIS GOPAL	78 78 77	DPWA DPWA DPWA IPWA	$\begin{array}{c} COMMENT \\ K^- n \to \Lambda \pi^- \\ K^- n \to \Lambda \pi^- \\ \overline{K} N \text{ multichannel} \end{array}$
0.17 ±0.03 0.13 ±0.02 +0.10 ±0.02 +0.06 ±0.02	2 MORRIS 2 MORRIS 4 MORRIS 5 GOPAL 6 BAILLON	78 78 77 75	DPWA DPWA DPWA IPWA DPWA	$\begin{array}{ccc} \underline{COMMENT} \\ K^- n \to & \Lambda \pi^- \\ K^- n \to & \Lambda \pi^- \\ \hline K N \text{ multichannel} \\ \hline K N \to & \Lambda \pi \end{array}$

Γ(Λ(1405)π)/Γ(Σ(1385)π					Г
<0.03	BERLEY	69	HBC	K ⁻ p 0.6-0.82 G	eV/
• • We do not use the follow	ing data for averag	es, fit	s, limits,	etc. • • •	
0.007 ± 0.002	⁵ BRUCKER		DBC	$K^-N \to \Sigma \pi \pi$	
VALUE	DOCUMENT ID				
$\Gamma_I \Gamma_f / \Gamma_{\text{total}}^2 \text{ in } N \overline{K} \to \Sigma (16)$	$IUJ \rightarrow I(1405)$ 1	π			ιΓa
(-) 1 NT	-0) 4(440-1			_	_
<0.06	ARMENTER	OS68E	HBC	$K^- p$, $K^- d$ (Γ_1 :	=0.
• • • We do not use the follow	ing data for averag	es, fit	s, limits,	etc. • • •	
VALUE	DOCUMENT ID				
$\Gamma(\Lambda(1405)\pi)/\Gamma_{\text{total}}$					Γ
m/ Adv \ /m					_
<0.14	4 ARMENTER	OS68E	НВС	K^-p , K^-d (Γ_1	=0.
• • • We do not use the follow	ing data for averag	es, fit	s, limits,	etc. • • •	
VALUE	DOCUMENT ID				
, ,,	00000000		TECH	COMMENT	•
$\Gamma(\Sigma_{\pi\pi})/\Gamma_{\text{total}}$					Γ
0.17±0.02	3 SIMS	68	DBC	$N \rightarrow \Lambda \pi \pi$	
				$K^-N \rightarrow \Lambda \pi \pi$	
• • • We do not use the follow!					- ,
+0.11±0.03	PREVOST			$K^- N \rightarrow \Sigma(138)$	51-
(f / - / total	DOCUMENT ID				"
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K} \to \Sigma$	/1670\ , \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\	8E/-	Cum	e (Г ₁ Г;	١,
V.11	MUMERIER	J300E	. IDC	p (11-0.03)	
<0.11	-			$K^- p (\Gamma_1 = 0.09)$	
• • We do not use the follow!					
VALUE	DOCUMENT ID		<u>TECN</u>	COMMENT	
Γ(Λππ)/Γ _{total}					Γ
TU.10 01 TU.11	IMALIM	"	DF WA	TO THE INVIDENTINE	
+0.18 or +0.17	1 MARTIN	77		KN multichannel	
• • • We do not use the follow!				•	
+0.21±0.03	KANE			$K^-p \rightarrow \Sigma \pi$	
+0.20±0.01	HEPP			$K^-N \rightarrow \Sigma \pi$	
+0.21±0.02	GOPAL			K N multichannel	
+0.20±0.02	KOISO			$K^-p \rightarrow \Sigma \pi$	_
VALUE	DOCUMENT ID		TECN		3,
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N \overline{K} \to \Sigma$	/1670\ → ∑e			(Γ ₁ Γ ₂	٠,
0.17 ±0.01	TONTE	,,,	UI WA	$N \rightarrow NN$ (so	JI.
0.08 ±0.01 0.17 ±0.01	PONTE PONTE			$K^- p \rightarrow \Lambda \pi^0$ (so	
				$K^- p \rightarrow \Lambda \pi^0$ (so	
+0.05	1 MARTIN			$\overline{K}N$ multichannel $K^- p \rightarrow \Lambda \pi^0$	

Σ(1670) FOOTNOTES

- 1 The two MARTIN 77 values are from a T-matrix pole and from a Breit-Wigner fit.
- ² Results are with and without an S_{11} $\Sigma(1620)$ in the fit.
- ³ SIMS 68 uses only cross-section data. Result used as upper limit only.
- **RMS be uses only cross-section data. Results used to E Γ (1385).

 **Assuming the Λ (1405) π cross-section bump is due only to 3/2 $^-$ resonance.
- ⁶ The CAMERON 77 upper limit on F-wave decay is 0.03.

Σ(1670) REFERENCES

KOISO	85	NP A433 619	+Sai, Yamamoto, Kofler	(TOKY, MASA)
₽DG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
GOPAL	80	Toronto Conf. 159		(RHEL) IJP
ALSTON	78	PR D18 182	Aiston-Garnjost, Kenney+	(LBL, MTHO, CERN) IJP
Also	77	PRL 38 1007	Aiston-Garnjost, Kenney+	(LBL, MTHO, CERN) IJP
MORRIS	78	PR D17 55	+Albright, Colleraine, Kimel, Lannut	tti (FSU) IJP
CAMERON	77	NP B131 399	+Franck, Gopal, Kalmus, McPherso	n+ (RHEL, LOIC) IJP
GOPAL	77	NP B119 362	+Ross, VanHorn, McPherson+	(LOIC, RHEL) IJP
MARTIN	77	NP B127 349	+Pidcock, Moorhouse	(LOUC, GLAS) UP
Also	77B	NP B126 266	Martin, Pidcock	` (Louci
Also	77C	NP B126 285	Martin, Pidcock	(LOUC) NP
DEBELLEFON	76	NP B109 129	De Beliefon, Berthon	(CDEF) UP
HEPP	76B	PL 65B 487		(CERN, HEIDH, MPIM) IJP
BAILLON	75	NP B94 39	+Litchfield	(CERN, RHEL) IJP
PONTE	75	PR D12 2597	+Hertzbach, Button-Shafer+	(MASA, TENN, UCR) IJP
VANHORN	75	NP B87 145	The about Dation Chart	(LBL) IJP
Also	75B	NP B87 157	VanHorn	(LBL) IJP
DEVENISH	74B	NP B61 330	+Froggatt, Martin	(DESY, NORD, LOUC)
KANE	74	LBL-2452	+11088acci martin	(LBL) IJP
PREVOST	74	NP B69 246	+Barloutaud+	(SACL, CERN, HEID)
BRUCKER	70	Duke Conf. 155	+Harrison, Sims, Albright, Chandler	
				(BNL)
BERLEY	69	PL 30B 430	+Hart, Rahm, Willis, Yamamoto	(CERN, HEID, SACL)
ARMENTEROS		PL 28B 521	+Baillon+	
SIMS	68	PRL 21 1413	+Albright, Bartley, Meer+	(FSU, TUFTS, BRAN)

Baryon Particle Listings Σ (1670) Bumps

Σ (1670) Bumps

 $I(J^P) = 1(??)$

OMITTED FROM SUMMARY TABLE

Formation experiments are listed separately in the preceding entry.

Probably there are two states at the same mass with the same quantum numbers, one decaying to $\Sigma \pi$ and $\Lambda \pi$, the other to $\Lambda(1405)\pi$. See the note in front of the preceding entry.

Σ (1670) MASS (PRODUCTION EXPERIMENTS)

VALUE (MeV)	EVTS	DOCUMENT ID	_	TECN	<u>CHG</u>	COMMENT
1670± 4	1	CARROLL	76	DPWA		Isospin-1 total σ
1675±10	2	HEPP	76	DBC	-	K-N 1.6-1.75 GeV/c
1665± 1		APSELL	74	нвс		K ⁻ p 2.87 GeV/c
1688 \pm 2 or 1683 \pm 5	1200	BERTHON	74	HBC	0	Quasi-2-body σ
1670± 6		AGUILAR	70B	нвс		$K^- p \rightarrow \Sigma \pi \pi$ 4 GeV
1668±10		AGUILAR	70B	нвс		$K^- p \rightarrow \Sigma 3\pi$ 4 GeV
1660±10		ALVAREZ	63	HBC	+	K [™] p 1.51 GeV/c
• • • We do not use the	following da	ta for averages,	fits, !	ilmits, et	tc. • •	•
1668±10	150	FERRERSORIA	81	OMEG	-	π p 9,12 GeV/c
1655 to 1677		TIMMERMANS	576	HBC	+	K- p 4.2 GeV/c
1665± 5		BUGG	68	CNTR		K^-p , d total σ
1661± 9	70	PRIMER	68	HBC	+	See BARNES 69E
1685		ALEXANDER	62 C	нвс	-0	π ρ 2-2.2 GeV/c

Σ(1670) WIDTH (PRODUCTION EXPERIMENTS)

VALU	E (MeV)	EVTS	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT
67.	0± 2.4		APSELL	74	HBC		K ⁻ p 2.87 GeV/c
110	±12		AGUILAR	70B	нвс		$K^-p \rightarrow \Sigma \pi \pi 4$ GeV
135	+40 -30		AGUILAR	70B	нвс		$K^- p \rightarrow \Sigma 3\pi 4$ GeV
40	±10		ALVAREZ	63	HBC	+	
• •	 We do not use the 	following o	data for averages	, fits	, limits,	etc. •	• •
90	±20	150	FERRERSORIA	81	OMEG	_	π p 9,12 GeV/c
52		1	CARROLL	76	DPWA		Isospin-1 total σ
48	to 63		TIMMERMANS	576	HBC	+	K - p 4.2 GeV/c
30	±15		BUGG	68	CNTR		
60	±20	70	PRIMER	68	HBC	+	See BARNES 69E
45			ALEXANDER	62 C	нвс	-0	

Σ(1670) DECAY MODES (PRODUCTION EXPERIMENTS)

	Mode	 	 	
Γ ₁	NK			
Γ_2	$\Lambda\pi$			
Гз	$\sum \pi$			
Γ_4	Λππ			
Γ ₅	Σππ			
Γ ₅ Γ ₆	$\Sigma(1385)\pi$			
Γ ₇	$\Sigma(1385)\pi$ $\Lambda(1405)\pi$			

∑(1670) BRANCHING RATIOS (PRODUCTION EXPERIMENTS)

$\Gamma(N\overline{K})/\Gamma(\Sigma\pi)$						Γ_1/Γ_3
VALUE	EVTS	DOCUMENT ID		<u>TECN</u>	<u>CHG</u>	COMMENT
< 0.03		TIMMERMAN	1576	HBC	+	K- p 4.2 GeV/c
< 0.10		BERTHON	74	HBC	0	Quasl-2-body σ
<0.2		AGUILAR	70B	HBC		
<0.26		BARNES	69E	нвс	+	K ⁻ p 3.9-5 GeV/c
0.025		BUGG	68	CNTR	0	Assuming $J = 3/2$
<0.24	0	PRIMER	68	нвс	+	K [—] p 4.6-5 GeV/c
< 0.6		LONDON	66	HBC	+	K ⁻ ρ 2.25 GeV/c
<0.19	0	ALVAREZ	63	HBC	+	K-p 1.15 GeV/c
≥ 0.5 ±0.25		SMITH	63	HBC	0	

$\Gamma(\Lambda\pi)/\Gamma(\Sigma\pi)$		-				Γ ₂ /Γ ₃
VALUE	EVTS	DOCUMENT ID		TECN	<u>CHG</u>	
0.76±0.09		ESTES	74	HBC	0	K p 2.1,2.6 GeV/c
0.45±0.15		BARNES	69E	нвс	+	K ⁻ p 3.9-5 GeV/c
0.15 ± 0.07		HUWE	69	нвс	+	
0.11±0.06 • • • We do not use the	33 e following	BUTTON data for averages	68 s. fits	HBC . limits.	+ etc. •	K ⁻ p 1.7 GeV/c
< 0.45±0.07		TIMMERMAN		нвс	+	K - p 4.2 GeV/c
0.55±0.11	_	BERTHON	74	HBC	0	Quasi-2-body σ
0 <0.6	0	PRIMER LONDON	68 66	нвс нвс	+	See BARNES 69£ K-p 2.25 GeV/c
1.2	130	ALVAREZ	63	нвс	+	K-p 1.15 GeV/c
1.2		SMITH	63	нвс	-0	
$\Gamma(\Lambda\pi\pi)/\Gamma(\Sigma\pi)$						Γ ₄ /Γ ₃
VALUE <0.6	EVTS	DOCUMENT ID	66	TECN HBC	<u>снс</u> +	COMMENT K-p 2.25 GeV/c
0.56	. 90	ALVAREZ	63	HBC	+	K-p 1.15 GeV/c
0.17		SMITH	63	нвс	-0	
Γ(Σππ)/Γ(Σπ)	EVTE	DOCUMENT ID		TECN	<u>CHG</u>	Γ _B /Γ ₃
VALUE largest at small angles	<u>EVT\$</u>	ESTES	74	HBC	0	K ⁻ p 2.1,2.6
• • We do not use th	e following	data for average	s, fit	s, limits	etc. =	GeV/c
<0.2		2 HEPP	76	DBC	_	K-N 1.6-1.75
						GeV/c
0.56	180	ALVAREZ	63	нвс	+	K-p 1.15 GeV/c
$\Gamma(\Lambda(1405)\pi)/\Gamma(\Sigma\pi)$	•					Γ ₇ /Γ ₃
VALUE 1.8 ± 0.3 to 0.02 ±	_ <u>EVT\$</u> 3,	DOCUMENT ID 4 TIMMERMAN	576	TECN HBC	<u>CHG</u> +	COMMENT K p 4.2 GeV/c
0.07 largest at small angles		ESTES	74	нвс	±	K-p 2.1,2.6
3.0 ±1.6	50 5 following	LONDON	66	HBC	+	GeV/c K = p 2.25 GeV/c
• • • We do not use th 0.58±0.20	17	PRIMER	68	HBC	+	See BARNES 69E
$\Gamma(\Sigma\pi)/\Gamma(\Sigma\pi\pi)$						Γ ₃ /Γ ₅
VALUE		DOCUMENT ID		<u>TECN</u>	CHG	
varies with prod. angle 1.39±0.16		⁵ APSELL BERTHON	74 74	HBC HBC	+	$K^- p$ 2.87 GeV/c Quasi-2-body σ
2.5 to 0.24		⁴ EBERHARD	69	нвс	-	K - p 2.6 GeV/c
<0.4 0.30±0.15		BIRMINGHAM LONDON	66 I	HBC HBC	+	K - p 3.5 GeV/c K - p 2.25 GeV/c
		LONDON	•	1100	г	
$\Gamma(\Lambda(1405)\pi)/\Gamma(\Sigma\pi)$	·π)	DOCUMENT ID		<u>TECN</u>	CHG	Γ <mark>7/Γ</mark> 8 COMMENT
0.97±0.08		TIMMERMAN	576	HBC	5110	K- p 4.2 GeV/c
1.00±0.02		APSELL	74	HBC		K⁻p 2.87 GeV/c
$0.90^{+0.10}_{-0.16}$		EBERHARD	65	нвс	+	K- p 2.45 GeV/c
Γ(Λ(1405)π)/Γ(Σ(1	(385)#ì					Γ ₇ /Γ ₆
VALUE		DOCUMENT ID				COMMENT
<0.8		EBERHARD	65	нвс	+	K- p 2.45 GeV/c
$\Gamma(\Lambda\pi\pi)/\Gamma(\Sigma\pi\pi)$						Γ4/Γ5
VALUE		DOCUMENT ID				
0.35±0.2		BIRMINGHAM	90	пвс	+	K p 3.5 GeV/c
						Γ2/Γ5
$\Gamma(\Lambda\pi)/\Gamma(\Sigma\pi\pi)$		000000000000000000000000000000000000000		****	~	COMMENT
VALUE		DOCUMENT ID				
<u>VALUE</u> <0.2	 (Σπ)]	<u>DOCUMENT ID</u> BIRMINGHAN			<u>CHG</u> +	K [−] p 3.5 GeV/c
$\frac{VALUE}{<0.2}$ $\Gamma(\Lambda\pi)/[\Gamma(\Lambda\pi)+\Gamma(VALUE)]$	(Σπ)]	BIRMINGHAN	1 66	HBC <u>TECN</u>	+	K [−] p 3.5 GeV/c
$\frac{\text{VALUE}}{<0.2}$ $\Gamma(\Lambda\pi)/[\Gamma(\Lambda\pi) + \Gamma(\Lambda\pi)]$ $\frac{\text{VALUE}}{<0.6}$		BIRMINGHAN	1 66	HBC <u>TECN</u>	+	K ⁻ p 3.5 GeV/c Γ2/(Γ2+Γ3)
$\frac{VALUE}{<0.2}$ $\Gamma(\Lambda\pi)/[\Gamma(\Lambda\pi)+\Gamma(VALUE)]$		BIRMINGHAN	70£	HBC TECN HBC	+	K−ρ 3.5 GeV/c Γ2/(Γ2+Γ3) Γ6/Γ3
$ \frac{\text{VALUE}}{<0.2} \Gamma(\Lambda\pi)/[\Gamma(\Lambda\pi) + \Gamma(\Lambda\pi)] \frac{\text{VALUE}}{<0.6} \Gamma(\Sigma(1385)\pi)/\Gamma(\Sigma_1^2) $		BIRMINGHAN <u>DOCUMENT ID</u> AGUILAR	70£	HBC TECN HBC	+ 	K−ρ 3.5 GeV/c Γ2/(Γ2+Γ3) Γ6/Γ3
YALUE <0.2 $\Gamma(\Lambda\pi)/[\Gamma(\Lambda\pi)+\Gamma(M\pi)]$ YALUE <0.6 $\Gamma(\Sigma(1385)\pi)/\Gamma(\Sigma_{1345})$ YALUE	r) Σ(1670	DOCUMENT ID AGUILAR DOCUMENT ID TIMMERMAN) QUANTUM	70s 1576	HBC TECN HBC HBC	+ 	K [−] ρ 3.5 GeV/c Γ2/(Γ2+Γ3) Γ6/Γ3
$\frac{\text{VALUE}}{<0.2}$ $\Gamma(\Lambda\pi)/[\Gamma(\Lambda\pi) + \Gamma(\frac{1}{2})]$ $\frac{\text{VALUE}}{<0.6}$ $\Gamma(\Sigma(1385)\pi)/\Gamma(\Sigma_{\frac{1}{2}})$ $\frac{\text{VALUE}}{\leq 0.21 \pm 0.05}$	Σ(1670 (PRODU	DOCUMENT ID AGUILAR DOCUMENT ID TIMMERMAN) QUANTUM JCTION EXPE	70E 1576 NUI	TECN HBC TECN HBC	+ <u>com</u> <u>K-</u> (K = p 3.5 GeV/c Γ2/(Γ2+Γ3) Γ6/Γ3 MENT p 4.2 GeV/c
$\frac{\text{VALUE}}{<0.2}$ $\Gamma(\Lambda\pi)/[\Gamma(\Lambda\pi) + \Gamma(\frac{\text{VALUE}}{<0.6})$ $\Gamma(\Sigma(1385)\pi)/\Gamma(\Sigma_1)$ $\frac{\text{VALUE}}{\text{VALUE}}$	r) Σ(1670	DOCUMENT ID AGUILAR DOCUMENT ID TIMMERMAN) QUANTUM	70£	TECN TECN HBC MBER:	+ <u>com</u> K - j	K ⁻ p 3.5 GeV/c Γ ₂ /(Γ ₂ +Γ ₃) Γ ₆ /Γ ₃ MENT p 4.2 GeV/c

VALUE	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
$J^P = 3/2^-$	400	BUTTON	68	нвс	±	$\Sigma^0\pi$
$J^P = 3/2^-$		EBERHARD	67	HBC	+	$\Lambda(1405)\pi$
$J^P=3/2^+$		LEVEQUE	65	HBC		$\Lambda(1405)\pi$

1	Total cross-section	bump with	(J+1/2) Γ _{α1}	/ [total	= 0.23.

 2 Enhancements in $\Sigma\pi$ and $\Sigma\pi\pi$ cross sections. 3 Backward production in the $\Lambda\pi^ K^+$ final state.

Depending on production angle.

APSELL 74, ESTES 74, and TIMMERMANS 76 find strong branching ratio dependence on production angle, as in earlier production experiments.

Σ(1670) REFERENCES (PRODUCTION EXPERIMENTS)

FERRERSORIA 81	NP B178 373	+Treille, Rivet, Volte+ (CERN, CDEF, EPOL, LALO)
CARROLL 76	PRL 37 806	+Chiang, Kycia, Li, Mazur, Michael+ (BNL	١í
HEPP 76	NP B115 82	+Braun, Grimm, Stroebele+ (CERN, HEID, MPIM	
TIMMERMANS 76	NP B112 77	+Engelen+ (NIJM, CERN, AMST, OXF	
APSELL 74	PR D10 1419	+Ford, Gourevitch+ (BRAN, UMD, SYRA, TUFTS)	
BERTHON 74	NC 21A 146	+Tristram+ (CDEF, RHEL, SACL, STRB	
ESTES 74	Thesis LBL-3827	(LBL	
AGUILAR 70B	PRL 25 58	Aguilar-Benitez, Barnes, Bassano+ (BNL, SYRA)	
BARNES 69E	BNL 13823	+Chung, Eisner, Flaminio+ (BNL, SYRA	
EBERHARD 69	PRL 22 200	+Friedman, Pripstein, Ross (LRL	
HUWE 69	PR 180 1824	+rneuman, rnpstem, Ross (ERE	
BUGG 68	PR 168 1466	+Gilmore, Knight+ (RHEL, BIRM, CAVE) (
BUTTON 68	PRL 21 1123	Button-Shafer (MASA, LRL	ĺJΡ
PRIMER 68	PRL 20 610	+Goldberg, Jaeger, Barnes, Dornan+ (SYRA, BNL	<u>ا</u>
EBERHARD 67	PR 163 1446	+Pripstein, Shively, Kruse, Swanson (LRL, ILL	S LJP
BIRMINGHAM 66	PR 152 1148	(BIRM, GLAS, LOIC, OXF, RHEL	
LONDON 66	PR 143 1034	+Rau, Goldberg, Lichtman+ (BNL, SYRA	
EBERHARD 65	PRL 14 466	+Shively, Ross, Siegal, Ficenec+ (LRL, ILL	
LEVEQUE 65	PL 18 69	+ (SACL, EPOL, GLAS, LOIC, OXF, RHEL	
ALVAREZ 63	PRL 10 184		
		+Alston, Ferro-Luzzi, Huwe+ (LRL	
SMITH 63	Athens Conf. 67	(LRL	
ALEXANDER 62C	CERN Conf. 320	+Jacobs, Kalbfleisch, Milter+ (LRL	١(

Σ (1690) Bumps

 $I(J^{P}) = 1(?^{?})$ Status: **

OMITTED FROM SUMMARY TABLE

See the note preceding the $\Sigma(1670)$ Listings. Seen in production experiments only, mainly in $\Lambda\pi$.

Σ(1690) MASS (PRODUCTION EXPERIMENTS)

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
≈ 1690 OUR ESTIN	MATE					
1698 ± 20	70	¹ GODDARD	79	HBC	+	$\pi^{+}p$ 10.3 GeV/c
1707 ± 20	40	² GODDARD	79	HBC	+	$\pi^{+} p$ 10.3 GeV/c
1698 ± 20	15	ADERHOLZ	69	HBC	+	π+ p 8 GeV/c
1682± 2	46	BLUMENFELD	69	HBC	+	K ⁰ P
1700 ± 20		MOTT	69	HBC	+	K ⁻ ρ 5.5 GeV/c
1694±24	60	3 PRIMER	68	нвс	+	K-p 4.6-5 GeV/c
1700 ± 6		⁴ SIMS	68	HBC	-	$K^-N \rightarrow \Lambda\pi\pi$
1715±12	30	COLLEY	67	нвс	+	K-p6 GeV/c

Σ(1690) WIDTH (PRODUCTION EXPERIMENTS)

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT
240± 60	70	¹ GODDARD	79	нвс	+	$\pi^{+}p$ 10.3 GeV/c
130 + 100 - 60	40	² GODDARD	79	нвс	+	$\pi^+ p$ 10.3 GeV/c
142± 40	15	ADERHOLZ	69	HBC	+	π ⁺ ρ 8 GeV/c
25± 10	46	BLUMENFELD	69	HBC	+	K ⁰ _P
130± 25		MOTT	69	нвс	+	κ ⁻ ρ 5.5 GeV/c
105 ± 35	60	³ PRIMER	68	нвс	+	K-p 4.6-5 GeV/c
62± 14		⁴ SIMS	68	HBC	-	$K^-N \rightarrow \Lambda \pi \pi$
100± 35	30	COLLEY	67	HBC	+	K-p6 GeV/c

Σ(1690) DECAY MODES (PRODUCTION EXPERIMENTS)

	Mode		
$\overline{\Gamma_1}$	NK	 	
Γ ₂	$\Lambda\pi$		•
Γ3	$\Sigma \pi$		
Γ_4	$\Sigma(1385)\pi$		
Γ ₅	$\Lambda\pi\pi$ (including $\Sigma(1385)\pi$)		

Σ(1690) BRANCHING RATIOS (PRODUCTION EXPERIMENTS)

$\Gamma(N\overline{K})/\Gamma(\Lambda\pi)$						Γ_1/Γ_2
VALUE	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
small		GODDARD	79	HBC	+	$\pi^{+}p$ 10.2 GeV/c
< 0.2		MOTT	69	HBC	+	K - p 5.5 GeV/c
0.4 ± 0.25	18	COLLEY	67	HBC	+	6/30 events

$\Gamma(\Sigma\pi)/\Gamma(\Lambda\pi)$	CL%.	DOCUMENT ID		TECH		Γ ₃ /Γ ₂
small	<u>u.a.</u>	GODDARD	79	TECN HBC	CHG	COMMENT
					+	$\pi^{+} p$ 10.2 GeV/c
<0.4	90	MOTT	69	HBC	+	K p 5.5 GeV/c
0.3 ± 0.3		COLLEY	67	HBC	+	4/30 events
$\Gamma(\Sigma(1385)\pi)/\Gamma($	$\Lambda\pi$)					Γ_4/Γ_2
VALUE		DOCUMENT ID	2	TECN	<u>CHG</u>	COMMENT
<0.5		MOTT	69	HBC	+	K ⁻ ρ 5.5 GeV/c
Γ(Λππ(including	Σ(1385)π))/ Г (А я)				$\Gamma_{\rm B}/\Gamma_{\rm 2}$
VALUE		DOCUMENT ID		TECN	CHG	COMMENT
2.0±0.6		BLUMENFE	LD 69	нвс	+	31/15 events
0.5 ± 0.25		COLLEY	67	нвс	+	15/30 events
Γ(Σ(1385)π)/Γ(Λππ (includ	$\dim \mathcal{L}(1385)\pi$))			Γ_4/Γ_5
VALUE		DOCUMENT ID	<u> </u>	TECN	CHG	COMMENT
large		SIMS	68	HBC	-	$K^- N \rightarrow \Lambda \pi \pi$
small		COLLEY	67	HBC	+	K-p6 GeV/c

Σ (1690) FOOTNOTES (PRODUCTION EXPERIMENTS)

 1 From $\pi^+p \to (A\pi^+)K^+$. J > 1/2 is not required by the data. 2 From $\pi^+p \to (A\pi^+)(K\pi)^+$. J > 1/2 is indicated, but large background precludes a definite conclusion. 3 See the $\Sigma(1670)$ Listings. AGUILAR-BENITEZ 70B with three times the data of PRIMER 68 find no evidence for the $\Sigma(1690)$.

⁴ This analysis, which is difficult and requires several assumptions and shows no unambiguous $\Sigma(1690)$ signal, suggests $J^P=5/2^+$. Such a state would lead all previously known Y* trajectories.

Σ(1690) REFERENCES (PRODUCTION EXPERIMENTS)

GODDARD	79	PR D19 1	250	+Key, Luste, Prentice, Yoon, Gordon+	(TNTO, BNL) IJ
AGUILAR	70B	PRL 25 58		Aguilar-Benitez, Barnes, Bassano+	(BNL, SYRA)
ADERHOLZ	69	NP B11 2	59	+Bartsch+ (AACH3, BERL, CERN,	JAGL, WARS) I
BLUMENFELD	69	PL 29B 56	8	+Kalbfleisch	(BNL) I
MOTT	69	PR 177 19	966	+Ammar, Davis, Kropac, Slate+	(NWES, ANL) I
Also	67	PRL 18 26	66	Derrick, Fields, Loken, Ammar+	(ANL, NWES) I
PRIMER	68	PRL 20 61	10	+Goldberg, Jaeger, Barnes, Dornan+	(SYRA, BNL) I
SIMS	68	PRL 21 14	413	+Albright, Bartley, Meer+ (FSU, T	UFTS, BRAN) I
COLLEY	67	PL 24B 46	89	(BIRM, GLAS, LOIC, MUNI	, OXF, RHEL) I

 Σ (1750) S_{11}

 $I(J^{P}) = 1(\frac{1}{2})$ Status: ***

For most results published before 1974 (they are now obsolete), see our 1982 edition Physics Letters 111B (1982).

There is evidence for this state in many partial-wave analyses, but with wide variations in the mass, width, and couplings. The latest analyses indicated significant couplings to $N\overline{K}$ and $\Lambda\pi$, as well as to $\Sigma \eta$ whose threshold is at 1746 MeV (JONES 74).

Σ(1750) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1730 to 1800 (≈ 1750) OUR ESTI	MATE			
1756±10	GOPAL	80	DPWA	$KN \rightarrow KN$
1770±10	ALSTON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$
1770±15	GOPAL	77	DPWA	KN multichannel
• • • We do not use the following	data for averages	, fit	s, limits,	etc. • • •
1800 or 1813	1 MARTIN	77	DPWA	RN multichannel
1715±10	² CARROLL	76	DPWA	Isospin-1 total σ
1730	DEBELLEFON	76	IPWA	$K^- p \rightarrow \Lambda \pi^0$
1780±30	BAILLON	75	IPWA	$\overline{K}N \rightarrow \Lambda\pi$ (sol. 1)
1700±30	BAILLON	75	IPWA	$\overline{K}N \rightarrow \Lambda \pi \text{ (sol. 2)}$
1697 ⁺²⁰ -10	VANHORN	75	DPWA	$K^- p \rightarrow \Lambda \pi^0$
1785±12	CHU	74	DBC	Fits $\sigma(K^- n \to \Sigma^- \eta)$
1760± 5	3 JONES	74	HBC	Fits $\sigma(K^-\rho \to \Sigma^0\eta)$
1739±10	PREVOST	74	DPWA	$K^-N \rightarrow \Sigma(1385)\pi$

Σ(1750) WIDTH

VALUE (MeV) 60 to 160 (≈ 90) OUR ESTIMATE	DOCUMENT ID		<u>TECN</u>	COMMENT
64±10		80	DPWA	$\overline{K}N \to \overline{K}N$
161±20	ALSTON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$
60 + 10	GOPAL	77	DPWA	K N multichannel

Baryon Particle Listings $\Sigma(1750), \Sigma(1770)$

• • • We do not use the followin	g data for average	s, fit	s, limits,	etc. • • •
117 or 119				KN multichannel
10	² CARROLL	76	DPWA	Isospin-1 total σ
110	DEBELLEFON	76	IPWA	$K^- p \rightarrow \Lambda \pi^0$
140±30	BAILLON	75	IPWA	$\overline{K}N \rightarrow \Lambda \pi$ (sol. 1)
160±50	BAILLON	75	IPWA	$\overline{K}N \rightarrow \Lambda \pi \text{ (sol. 2)}$
66 ⁺¹⁴ -12	VANHORN	75	DPWA	$K^- p \rightarrow \Lambda \pi^0$
89±33	CHU		DBC	Fits $\sigma(K^- n \rightarrow \Sigma^- \eta)$
92± 7	3 JONES	74	HBC	Fits $\sigma(K^-p \to \Sigma^0\eta)$
108±20	PREVOST	74	DPWA	$K^- N \rightarrow \Sigma(1385)\pi$

Σ(1750) DECAY MODES

	Mode	Fraction (Γ_I/Γ)					
<u></u>	NK	10-40 %					
Γ_2^-	$\Lambda\pi$	seen					
Γ3	$\Sigma \pi$	<8 %					
Γ ₄	$\Sigma \eta$	15-55 %					
Γs	$\Sigma(1385)\pi$						
۲ ₆	$\Lambda(1520)\pi$						
	The above branching fractions are our estimates, not fits or averages.						

Σ(1750) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on Λ and Σ

Γ(NK)/Γ _{total}				[1/ [
VALUE	DOCUMENT ID		TECN	COMMENT
0.1 to 0.4 OUR ESTIMATE				T T.
0.14±0.03	GOPAL			KN → KN
0.33±0.05	ALSTON			
• • We do not use the following	-			
0.15±0.03	GOPAL			See GOPAL 80
0.06 or 0.05	¹ MARTIN	77	DPWA	KN multichannel
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N \overline{K} \rightarrow \Sigma (17)$	750) → A=			(Γ₁Γ₂) ^½ /Γ
VALUE	DOCUMENT ID		TECN	
0.04 ±0.03	GOPAL	77	DPWA	K N multichannel
• • We do not use the following	data for averages	, flts	, limits,	etc. • • •
	1 MARTIN			KN multichannel
-0.12				$K^- p \rightarrow \Lambda \pi^0$
-0.12 ±0.02				$\overline{K}N \rightarrow \Lambda\pi$ (sol. 1)
-0.13 ±0.03	BAILLON	75	IPWA	$\overline{K}N \rightarrow \Lambda \pi$ (sol. 2)
~0.13 ±0.04	VANHORN	75	DPWA	$K^-p \rightarrow \Lambda \pi^0$
~0.120±0.077	DEVENISH	74B		Fixed-t dispersion rel.
	DOCUMENT ID			
-0.09 ± 0.05	GOPAL			KN multichannel
• • We do not use the following	_			
,, ,	1 MARTIN			K N multichannel
0.13±0.02	LANGBEIN	72	IPWA	KN multichannel
$(\Gamma_i \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\overline{K} \to \Sigma(1)^{\frac{1}{2}}$	750) → Ση		TEĆN	$(\Gamma_1\Gamma_4)^{\frac{1}{2}}/\Gamma$
	3 JONES			
	- JUNES data for average	fitte Effe	Ilmits	$PICSO(N P \rightarrow Z^{-1}I)$
·				Threshold bump
seen	CLINE	03	~~~	i iresnoid bump
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\overline{K} \to \Sigma(1)$	750) → Σ (138	5)π		$(\Gamma_1\Gamma_5)^{\frac{1}{2}}/\Gamma$
$(\Gamma_i \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N \overline{K} \to \Sigma(1)$	750) → Σ(138	5)π	TECN	(Γ ₁ Γ ₅) ^{1/2} /Γ
$(\Gamma_{l}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\overline{K} \rightarrow \Sigma(1)$ $VALUE$ $+0.18\pm0.15$ $(\Gamma_{l}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\overline{K} \rightarrow \Sigma(1)$ $VALUE$	750) → ∑(138 DOCUMENT ID PREVOST 750) → ∧(1520 DOCUMENT ID	5)π 74 0)π	TECN DPWA	$\frac{(\Gamma_1\Gamma_5)^{\frac{1}{2}}/\Gamma}{\kappa^- N \to \Sigma^{(1385)\pi}}$ $\frac{(\Gamma_1\Gamma_6)^{\frac{1}{2}}/\Gamma}{(\Gamma_1\Gamma_6)^{\frac{1}{2}}/\Gamma}$ COMMENT
<u>VALUE</u> +0.18±0.15	750) → ∑(138 DOCUMENT ID PREVOST 750) → ∧(1520 DOCUMENT ID	5)π 74 0)π	TECN DPWA	$\frac{(\Gamma_1\Gamma_5)^{\frac{1}{2}}/\Gamma}{\kappa^- N \to \Sigma(1385)\pi}$ $\frac{(\Gamma_1\Gamma_6)^{\frac{1}{2}}/\Gamma}{COMMENT}$

Σ(1750) FOOTNOTES

Σ(1750) REFERENCES

GOPAL 80 Toronto Conf. 159 ALSTON 78 PR D18 182 Alston-Garnjost, Kenney+ (LBL, MTHO, CERN) LII Also 77 PRL 38 1007 Alston-Garnjost, Kenney+ (LBL, MTHO, CERN) LII
CAMERON 77 NP B131 399 +Franck, Gopal, Kalmus, McPherson+ (RHEL, LOIC) LI
GOPAL 77 NP B119 362 +Ross, VanHorn, McPherson+ (LOIC, RHEL) IJ
MARTIN 77 NP B127 349 +Pidcock, Moorhouse (LOUC, GLAS) IJI
Also 77B NP B126 266 Martin, Pidcock (LOUC)
Also 77C NP B126 285 Martin, Pidcock (LOUC) IJ
CARROLL 76 PRL 37 806 +Chlang, Kycia, Li, Mazur, Michael+ (BNL) I
DEBELLEFON 76 NP B109 129 De Bellefon, Berthon (CDEF) IJ
BAILLON 75 NP B94 39 +Litchfield (CERN, RHEL) IJ
VANHORN 75 NP B87 145 (LBL) U
Also 75B NP B87 157 VanHorn (LBL) U
CHU 74 NC 20A 35 +Bartley+ (PLAT, TUFTS, BRAN) LI
DEVENISH 74B NP BB1 330 +Froggatt, Martin (DESY, NORD, LOUC)
JONES 74 NP B73 141 (CHIC) IJ
PREVOST 74 NP B69 246 +Barloutaud+ (SACL, CERN, HEID)
LANGBEIN 72 NP B47 477 +Wagner (MPIM) IJ
CLINE 69 LNC 2 407 +Laumann, Mapp (WISC)

$\overline{\Sigma(1770)} P_{11}$

F(NK)/Frotal

 $I(J^P) = 1(\frac{1}{2}^+)$ Status: *

OMITTED FROM SUMMARY TABLE

Evidence for this state now rests solely on solution 1 of BAILLON 75, (see the footnotes) but the $\Lambda\pi$ partial-wave amplitudes of this solution are in disagreement with amplitudes from most other $\Lambda\pi$ analyses.

Σ(1770) MASS

VALUE (MeV) № 1770 OUR ESTIMATE	DOCUMENT ID		TECN	COMMENT
1738±10 1770±20	¹ GOPAL ² BAILLON	75	IPWA	$\overline{K}N$ multichannel $\overline{K}N \to \Lambda \pi$
1772	3 KANE	72	DPWA	K ⁻ p → Σπ

Σ(1770) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
72±10	1 GOPAL	77	DPWA	RN multichannel
80±30	² BAILLON	75	IPWA	$KN \rightarrow \Lambda \pi$
80	3 KANE	72	DPWA	$K^-p \rightarrow \Sigma \pi$

Σ(1770) DECAY MODES

	Mode		 	
Γ ₁	NK			
Γ2	$\Lambda\pi$			
Γ ₂ Γ ₃	$\sum \pi$			

Σ(1770) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on Λ and Σ

 Γ_1/Γ

VALUE	DOCUMENT ID		TECN	COMMENT
0.14 ± 0.04	¹ GOPAL	77	DPWA	ドル multichannel
$(\Gamma_f \Gamma_f)^{1/2} / \Gamma_{\text{total}} \ln N \overline{K}$	$\Sigma \to \Sigma(1770) \to \Lambda \pi$		TECN.	(\(\Gamma_1\Gamma_2\)\frac{1}{2}/\Gamma
VALUE				
< 0.04				KN multichannel
-0.08 ± 0.02	² BAILLON	75	IPWA	KN → Ax
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\overline{K}$	$Z \to \Sigma(1770) \to \Sigma \pi$			(Γ₁Γ₃) ^½ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
< 0.04	GOPAL	77	DPWA	KN multichannel
-0.108	3 KANE	72	DPWA	$K^-p \rightarrow \Sigma \pi$
-0.108	3 KANE	72	DPWA	K ⁻ p → Σπ

Σ(1770) FOOTNOTES

- 1 Required to fit the isospin-1 total cross section of CARROLL 76 in the $\overline{\textit{K}}$ N channel. The addition of new K^-p polarization and K^-n differential cross-section data in GOPAL 80 find it to be more consistent with the Σ (1660) P_{11} .

 From solution 1 of BAILLON 75; not present in solution 2.

 Not required in KANE 74, which supersedes KANE 72.

Σ(1770) REFERENCES

			_(-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,	
GOPAL GOPAL CARROLL BAILLON KANE KANE	80 77 76 75 74 72	Toronto Conf. NP B119 362 PRL 37 806 NP B94 39 LBL-2452 PR D5 1583	159 +Ross, VanHorn, McPherson+ +Chiang, Kycia, Li, Mazur, Michael+ +Litchfield	(RHEL) (LOIC, RHEL) UP (BNL) I (CERN, RHEL) UP (LBL) UP (LBL)

¹ The two MARTIN 77 values are from a T-matrix pole and from a Brelt-Wigner fit.

 $^{^2}$ A total cross-section bump with (J+1/2) Γ_{el} / Γ_{total} = 0.30.

An S-wave Breit-Wigner fit to the threshold cross section with no background and errors statistical only.

 $I(J^P) = 1(\frac{5}{2}^-)$ Status: ****

Discovered by GALTIERI 63, this resonance plays the same role as cornerstone for isospin-1 analyses in this region as the $\Lambda(1820)$ does in the isospin-0 channel.

For most results published before 1974 (they are now obsolete), see our 1982 edition Physics Letters 111B (1982).

Σ(1775) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1770 to 1780 (≈ 1775) OUR EST	1MATE			
1778± 5	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
1777 ± 5	ALSTON	78	DPWA	KN → KN
1774± 5	GOPAL	77	DPWA	KN multichannel
1775±10	BAILLON	75	IPWA	$\overline{K}N \rightarrow \Lambda \pi$
1774±10	VANHORN	75	DPWA	$K^- p \rightarrow \Lambda \pi^0$
1772± 6	KANE	74	DPWA	$K^-p \rightarrow \Sigma \pi$
	g data for averages	s, fit	s, limits,	etc. • • •
1772 or 1777	¹ MARTIN	77	DPWA	KN multichannel
1765	DEBELLEFON	76	IPWA	$K^- p \rightarrow \Lambda \pi^0$

Σ(1775) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
105 to 135 (≈ 120) OUR ESTIMA	TE			
137±10	GOPAL	80	DPWA	RN → RN
116±10	ALSTON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$
130±10	GOPAL	77	DPWA	KN multichannel
125±15	BAILLON	75	IPWA	$\overline{K}N \rightarrow \Lambda \pi$
146±18	VANHORN	75	DPWA	$K^- \rho \rightarrow \Lambda \pi^0$
154±10	KANE	74	DPWA	$K^-p \rightarrow \Sigma \pi$
	data for averages	, fit	s, limits,	etc. • • •
102 or 103	¹ MARTIN	77	DPWA	K N multichannel
120	DEBELLEFON	76	IPWA	$K^- p \rightarrow \Lambda \pi^0$

Σ(1775) DECAY MODES

	Mode	Fraction (Γ_I/Γ)	
$\overline{\Gamma_1}$	NK	37-43%	
Γ_2	$\Lambda\pi$	14-20%	
Гз	$\Sigma \pi$	2–5%	
Γ ₄ Γ ₅	$\Sigma(1385)\pi$ $\Sigma(1385)\pi$, <i>D</i> -wave	8–12%	
Γ ₆ Γ ₇	$\Lambda(1520) \pi$ $\Sigma \pi \pi$	17-23%	

The above branching fractions are our estimates, not fits or averages.

CONSTRAINED FIT INFORMATION

An overall fit to 8 branching ratios uses 16 measurements and one constraint to determine 5 parameters. The overall fit has a χ^2 = 63.9 for 12 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\langle \delta x_i \delta x_j \rangle / (\delta x_i \cdot \delta x_j)$, in percent, from the fit to the branching fractions, $x_i \equiv$ Γ_i/Γ_{total} . The fit constrains the x_i whose labels appear in this array to sum to

Σ(1775) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on Λ and Σ Resonances. Also, the errors quoted do not include uncertainties due to the parametrization used in the partial-wave analyses and are thus too

$\Gamma(NK)/\Gamma_{\text{total}}$					Γ1/Γ
VALUE	DOCUMENT ID		TECN	COMMENT	
0.37 to 0.43 OUR ESTIM. 0.45 ±0.04 OUR FIT E 0.391±0.017 OUR AVERA	rror includes scale facto	r of 3	.1.		
0.40 ±0.02	GOPAL	80	DPWA	$RN \rightarrow RN$	
0.37 ±0.03	ALSTON	78	DPWA	$\overline{K}N \rightarrow \overline{K}N$	
• • • We do not use the fe	ollowing data for averag	es, fit	s, limits,	etc. • • •	
0.41 ±0.03	GOPAL	7,7	DPWA	See GOPAL 80	
0.37 or 0.36	¹ MARTIN	77	DPWA	See GOPAL 80 KN multichanne	1

(「「「f」) 1/2 / 「total in NK -	DOCUMENT ID		TECN	$(\Gamma_1\Gamma_2)^{\frac{1}{12}}$
0.305±0.018 OUR FIT	Error includes scale fact	or of	2.4.	
-0.262±0.015 OUR AVEF -0.28 ±0.03	RAGE GOPAL		B. B. L. A.	
-0.25 ±0.03	BAILLON			$\overline{K}N$ multichannel $\overline{K}N \rightarrow \Lambda \pi$
$-0.28 \begin{array}{l} +0.04 \\ -0.05 \end{array}$	VANHORN	75	DPWA	$K^-p \rightarrow \Lambda \pi^0$
-0.259±0.048	DEVENISH	74B		Fixed-t dispersion rel.
• • We do not use the f		es, fits		
-0.29 or -0.28	¹ MARTIN	77		KN multichannel
- 0.30	DEBELLEFON	1 76	IPWA	$K^- \rho \rightarrow \Lambda \pi^0$
$(\Gamma_I \Gamma_{I'})^{\frac{1}{2}} / \Gamma_{\text{total}}$ in $N\overline{K}$ -	→ Σ(1775) → Σπ			(Γ ₁ Γ ₃) ^{1/2} /
VALUE	DOCUMENT ID		TECN	COMMENT
0.105±0.025 OUR FIT				
0.098±0.016 OUR AVER				
+0.13 ±0.02	GOPAL			KN multichannel
0.09 ±0.01	KANE	74		$K^-p \rightarrow \Sigma \pi$
• • We do not use the f				
+0.08 or +0.08	¹ MARTIN	77	DPWA	KN multichannel
(「「「f) ^{1/2} /「total in NK - ^{VALUE}	$\rightarrow \Sigma(1775) \rightarrow \Lambda(152)$:0)π	TECH	(Γ ₁ Γ ₆) ^{1/2} ,
0.315±0.010 OUR FIT		or of	1.5.	
0.303 ± 0.009 OUR AVER - 0.305 ± 0.010	_*		•	
-0.305 ±0.010	~ CAMERON	"	DPWA	$K^- p \rightarrow \Lambda(1520)\pi^0$
0.21 0.00			D D1444	
0.31 ±0.02 0.27 ±0.03 (Г _Г Г _Г)	BARLETTA ARMENTERO) 565 C	НВС	$\begin{array}{ccc} K^- p \to \Lambda(1520) \pi^0 \\ K^- p \to \Lambda(1520) \pi^0 \end{array}$ $\left(\Gamma_1 \Gamma_4 \right)^{\frac{1}{2}}$
0.27 ±0.03 (「「「「」 ^{1/2} /「 _{total} In <i>NK</i> - _{VALUE}	BARLETTA ARMENTERO → Σ(1775) → Σ(136 DOCUMENT ID	0565c 85)π	HBC TECN	$K^- p \rightarrow \Lambda(1520) \pi^0$ $(\Gamma_1 \Gamma_4)^{\frac{1}{2}}$
0.27 ±0.03	BARLETTA ARMENTERO → Σ(1775) → Σ(138 DOCUMENT ID Error includes scale fact	0S65c B5)π or of	HBC <u>TECN</u> 2.8.	$K^- p \rightarrow \Lambda(1520) \pi^0$ $(\Gamma_1 \Gamma_4)^{\frac{1}{2}}$ COMMENT
0.27 ±0.03 (Γ _I Γ _I) ^{1/2} /Γ _{total} in NK - VALUE 0.211±0.022 OUR FIT	BARLETTA ARMENTERO → Σ(1775) → Σ(138 DOCUMENT ID Error includes scale fact RAGE Signs on measure	BS65c	HBC TECN 2.8. ts were ig	$K^- p \rightarrow \Lambda(1520) \pi^0$ $\frac{(\Gamma_1 \Gamma_4)^{\frac{1}{2}}}{COMMENT}$ gnored.
0.27 \pm 0.03 $(\Gamma_i \Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \ln NK - \frac{N}{N}$ 0.211 \pm 0.022 OUR FIT 0.188 \pm 0.010 OUR AVER	BARLETTA ARMENTERO → Σ(1775) → Σ(138 DOCUMENT ID Error includes scale fact RAGE Signs on measure	S65c B5) π for of ement 78	HBC TECN 2.8. ts were lg	$K^- p \rightarrow \Lambda(1520) \pi^0$ $(\Gamma_1 \Gamma_4)^{\frac{1}{2}}$ COMMENT
0.27 ±0.03 (\(\(\right)_{f}\)\(\frac{1}{2}\)/\(\right)_{\text{total}}\) In NK - \(\right)_{\text{2.01}}\) 0.211±0.022 OUR FIT 0.188±0.010 OUR AVER -0.184±0.011	BARLETTA ARMENTERC → ∑(1775) → ∑(136 DOCUMENT ID Error includes scale fact RAGE Signs on measure 3 CAMERON PREVOST	0565c 85) π or of ement 78 74	TECN 2.8. ts were le DPWA DPWA	$K^-p \rightarrow \Lambda(1520)\pi^0$ $\frac{(\Gamma_1\Gamma_4)^{1/2}}{COMMENT}$ gnored. $K^-p \rightarrow \Sigma(1385)\pi$ $K^-N \rightarrow \Sigma(1385)\pi$
0.27 \pm 0.03 ($\Gamma_I \Gamma_f$) $\frac{1}{2}$ / Γ_{total} in NK - VALUE 0.211 \pm 0.022 OUR FIT 0.184 \pm 0.010 OUR AVER -0.184 \pm 0.011 +0.20 \pm 0.02 • • • We do not use the form	BARLETTA ARMENTERC → ∑(1775) → ∑(136 DOCUMENT ID Error includes scale fact RAGE Signs on measure 3 CAMERON PREVOST Ollowing data for average	S65c B5) π or of ement 78 74 es, fits	TECN 2.8. ts were lg DPWA DPWA s, limits,	$K^-p \rightarrow \Lambda(1520)\pi^0$ $\frac{(\Gamma_1\Gamma_4)^{1/2}}{COMMENT}$ gnored. $K^-p \rightarrow \Sigma(1385)\pi$ $K^-N \rightarrow \Sigma(1385)\pi$ etc. • • •
0.27 \pm 0.03 $(\Gamma_I\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \ln NK$ - $\frac{VALUE}{0.211\pm0.022}$ OUR FIT 0.184 \pm 0.010 OUR AVER -0.184 ± 0.011 $+0.20$ ±0.02	BARLETTA ARMENTERC → ∑(1775) → ∑(136 DOCUMENT ID Error includes scale fact RAGE Signs on measure 3 CAMERON PREVOST	85) π cor of ement 78 74 es, fits	TECN 2.8. ts were ig DPWA DPWA s, limits,	$K^- p \rightarrow \Lambda(1520) \pi^0$ $\frac{(\Gamma_1 \Gamma_4)^{1/2}}{COMMENT}$ gnored. $K^- p \rightarrow \Sigma(1385) \pi$ $K^- N \rightarrow \Sigma(1385) \pi$
0.27 \pm 0.03 $(\Gamma_{I}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \ln NK$ - $\frac{VALUE}{0.211 \pm 0.022}$ OUR FIT 0.188 \pm 0.010 OUR AVER - 0.184 \pm 0.011 + 0.20 \pm 0.02 • • • We do not use the for 0.32 \pm 0.06 0.24 \pm 0.03	BARLETTA ARMENTERO → ∑(1775) → ∑(136 DOCUMENT ID Error Includes scale fact RAGE Signs on measure 3 CAMERON PREVOST Ollowing data for average	85) π cor of ement 78 74 es, fits	TECN 2.8. ts were ig DPWA DPWA s, limits,	$K^-p \rightarrow \Lambda(1520)\pi^0$ $\frac{(\Gamma_1\Gamma_4)^{1/2}}{COMMENT}$ gnored. $K^-p \rightarrow \Sigma(1385)\pi$ $K^-N \rightarrow \Sigma(1385)\pi$ etc. • • • $K^-N \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$
0.27 \pm 0.03 $(\Gamma_{i}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \ln NK$ - $\frac{1}{2}$ \(\text{Value}\) 0.211 \(\perp 0.022\) OUR FIT 0.188\(\perp 0.010\) OUR AVER - 0.184\(\perp 0.011\) + 0.20 \(\perp 0.02\) • • • We do not use the for 0.24 \(\perp 0.03\) \(\perp 0.03\) \(\perp 0.03\) \(\perp 0.03\) \(\perp 0.07K\) \(\perp 0.07K\)	BARLETTA ARMENTERC → ∑(1775) → ∑(136 DOCUMENT ID Error includes scale fact RAGE Signs on measure 3 CAMERON PREVOST ollowing data for average SIMS ARMENTERO	S65C B5) π or of ement 78 74 es, fits 68 OS67C	TECN 2.8. ts were lg DPWA DPWA s, limits, DBC HBC	$K^-p \rightarrow \Lambda(1520)\pi^0$ $\frac{(\Gamma_1\Gamma_4)^{1/2}}{COMMENT}$ gnored. $K^-p \rightarrow \Sigma(1385)\pi$ $K^-N \rightarrow \Sigma(1385)\pi$ etc. • • • $K^-N \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$
0.27 \pm 0.03 ($\Gamma_i \Gamma_f$) $\frac{1/2}{2} / \Gamma_{\text{total}} \ln N K$ - VALUE 0.211 \pm 0.022 OUR FIT 0.188 \pm 0.010 OUR AVER -0.184 \pm 0.011 +0.20 \pm 0.02 • • We do not use the for 0.32 \pm 0.06 0.24 \pm 0.03 $\Gamma(\Lambda \pi) / \Gamma(N K)$	BARLETTA ARMENTERO → ∑(1775) → ∑(138 DOCUMENT ID Error includes scale fact RAGE Signs on measure 3 CAMERON PREVOST following data for average SIMS ARMENTERO	2565c 250 of of the second of	TECN 2.8. ts were lg DPWA DPWA s, limits, DBC HBC	$K^-p \rightarrow \Lambda(1520)\pi^0$ $\frac{(\Gamma_1\Gamma_4)^{1/2}}{COMMENT}$ gnored. $K^-p \rightarrow \Sigma(1385)\pi$ $K^-N \rightarrow \Sigma(1385)\pi$ etc. • • • $K^-N \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$
0.27 \pm 0.03 ($\Gamma_i \Gamma_f \gamma_i^{1/2} / \Gamma_{\text{total}} \ln N K - \frac{VALUE}{2}$ 0.211 \pm 0.022 OUR FIT 0.188 \pm 0.010 OUR AVER -0.184 \pm 0.011 +0.20 \pm 0.02 • • We do not use the form of	BARLETTA ARMENTERO → ∑(1775) → ∑(138 DOCUMENT ID Error includes scale fact RAGE Signs on measure 3 CAMERON PREVOST following data for average SIMS ARMENTERO DOCUMENT ID or includes scale factor of	S65c 85) π or of ement 78 74 es, fits 68 OS67c	TECN 2.8. ts were Ig DPWA DPWA s, Hmits, DBC HBC	$K^-p \rightarrow \Lambda(1520)\pi^0$ $(\Gamma_1\Gamma_4)^{1/2}$ gnored. $K^-p \rightarrow \Sigma(1385)\pi$ $K^-N \rightarrow \Sigma(1385)\pi$ etc. • • • $K^-N \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$
0.27 \pm 0.03 ($\Gamma_1\Gamma_f$) $\frac{1}{2}/\Gamma_{\text{total}} \ln NK$ - $\frac{1}{2}$	BARLETTA ARMENTERO → ∑(1775) → ∑(138 DOCUMENT ID Error includes scale fact RAGE Signs on measure 3 CAMERON PREVOST following data for average SIMS ARMENTERO	S65c 85) π or of ement 78 74 es, fits 68 OS67c	TECN 2.8. ts were lg DPWA DPWA s, limits, DBC HBC	$K^-p \rightarrow \Lambda(1520)\pi^0$ $\frac{(\Gamma_1\Gamma_4)^{1/2}}{COMMENT}$ gnored. $K^-p \rightarrow \Sigma(1385)\pi$ $K^-N \rightarrow \Sigma(1385)\pi$ etc. • • • $K^-N \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$
0.27 \pm 0.03 ($\Gamma_i \Gamma_f$) $\frac{1/2}{2} / \Gamma_{\text{total}} \ln NK$ - $\frac{1}{2} \times 10^{-12} = 0.211 \pm 0.022$ OUR FIT 0.188 \pm 0.010 OUR AVER - 0.184 \pm 0.011 \pm 0.20 \pm 0.02 \bullet 0.40 do not use the form of 0.32 \pm 0.06 0.24 \pm 0.03 $\Gamma(A\pi)/\Gamma(NK)$ VALUE 0.45 \pm 0.09 OUR FIT Error 0.33 \pm 0.05 $\Gamma(\Sigma \pi \pi)/\Gamma_{\text{total}}$	BARLETTA ARMENTERO → ∑(1775) → ∑(134) DOCUMENT ID Error includes scale fact RAGE Signs on measure 3 CAMERON PREVOST Ollowing data for average SIMS ARMENTERO DOCUMENT ID Or includes scale factor of UHLIG	85) π or of ement 78 74 es, fits 68 9567c	TECN 2.8. ts were lg DPWA DPWA DPWA DPWA DPWA TECN HBC	$K^-p \rightarrow \Lambda(1520)\pi^0$ $(\Gamma_1\Gamma_4)^{1/2}/2$ gnored. $K^-p \rightarrow \Sigma(1385)\pi$ $K^-N \rightarrow \Sigma(1385)\pi$ etc. • • • $K^-N \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$
0.27 \pm 0.03 ($\Gamma_i \Gamma_f)^{1/2}_{2} / \Gamma_{\text{total}} \ln N K - \frac{VALUE}{2}$ 0.211 \pm 0.022 OUR FIT 0.188 \pm 0.010 OUR AVER -0.184 \pm 0.011 +0.20 \pm 0.02 • • We do not use the form of the form	BARLETTA ARMENTERO → ∑(1775) → ∑(138 DOCUMENT ID Error includes scale fact RAGE Signs on measure 3 CAMERON PREVOST following data for average SIMS ARMENTERO DOCUMENT ID DOCUMENT ID	0565c 85) π or of ement 78 74 68 0567c	TECN 2.8. Is were ig DPWA DPWA s, limits, DBC HBC TECN HBC	$K^-p \rightarrow \Lambda(1520)\pi^0$ $(\Gamma_1\Gamma_4)^{1/2}/\Gamma_4$ gnored. $K^-p \rightarrow \Sigma(1385)\pi$ $K^-N \rightarrow \Sigma(1385)\pi$ etc. • • • $K^-N \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$
0.27 \pm 0.03 ($\Gamma_i \Gamma_f$) $\frac{1/2}{2} / \Gamma_{\text{total}} \ln NK$ - $\frac{1}{2} \times 10^{-12} = 0.211 \pm 0.022$ OUR FIT 0.188 \pm 0.010 OUR AVER - 0.184 \pm 0.011 \pm 0.20 \pm 0.02 \bullet 0.40 do not use the form of 0.32 \pm 0.06 0.24 \pm 0.03 $\Gamma(A\pi)/\Gamma(NK)$ VALUE 0.45 \pm 0.09 OUR FIT Error 0.33 \pm 0.05 $\Gamma(\Sigma \pi \pi)/\Gamma_{\text{total}}$	BARLETTA ARMENTERO → ∑(1775) → ∑(138 DOCUMENT ID Error includes scale fact RAGE Signs on measure 3 CAMERON PREVOST following data for average SIMS ARMENTERO DOCUMENT ID DOCUMENT ID	0565c 85) π or of ement 78 74 68 0567c	TECN 2.8. Is were ig DPWA DPWA s, limits, DBC HBC TECN HBC	$K^-p \rightarrow \Lambda(1520)\pi^0$ $(\Gamma_1\Gamma_4)^{1/2}/\Gamma_4$ gnored. $K^-p \rightarrow \Sigma(1385)\pi$ $K^-N \rightarrow \Sigma(1385)\pi$ etc. • • • $K^-N \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$
0.27 \pm 0.03 ($\Gamma_i \Gamma_f)^{1/2}_{2} / \Gamma_{\text{total}} \ln N K - \frac{VALUE}{2}$ 0.211 \pm 0.022 OUR FIT 0.188 \pm 0.010 OUR AVER -0.184 \pm 0.011 +0.20 \pm 0.02 • • We do not use the form of the form	BARLETTA ARMENTERO → ∑(1775) → ∑(138 DOCUMENT ID Error includes scale fact RAGE Signs on measure 3 CAMERON PREVOST following data for average SIMS ARMENTERO DOCUMENT ID OT includes scale factor of UHLIG	0565c 85) π or of ement 78 74 ess, fits 68 0567c	TECN 2.8. Is were lg DPWA DPWA s, limits, DBC HBC TECN HBC	$K^-p \rightarrow \Lambda(1520)\pi^0$ $(\Gamma_1\Gamma_4)^{1/2}/\Gamma_4$ gnored. $K^-p \rightarrow \Sigma(1385)\pi$ $K^-N \rightarrow \Sigma(1385)\pi$ etc. • • • $K^-N \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$
0.27 \pm 0.03 ($\Gamma_1\Gamma_f$) $\frac{1/2}{2}/\Gamma_{\text{total}} \ln NK$ - $\frac{1}{2}\sqrt{N}$ $\frac{1}{2}\sqrt{\Gamma_{\text{total}}} \ln NK$ - 0.211 \pm 0.022 OUR FIT 0.188 \pm 0.010 OUR AVER - 0.184 \pm 0.011 \pm 0.02 \bullet 0.04 \pm 0.03 \pm 0.06 0.24 \pm 0.03 ($\Lambda\pi$)/ Γ (NK) VALUE 0.46 \pm 0.09 OUR FIT Erro 0.33 \pm 0.05 (Γ ($\Sigma\pi\pi$)/ Γ_{total} VALUE \bullet • • We do not use the form 0.12	BARLETTA ARMENTERO → ∑(1775) → ∑(138 DOCUMENT ID Error includes scale fact RAGE Signs on measure 3 CAMERON PREVOST following data for average SIMS ARMENTERO DOCUMENT ID OT includes scale factor of UHLIG	0565c 85) π or of ement 78 74 ess, fits 68 0567c	TECN 2.8. Is were lg DPWA DPWA s, limits, DBC HBC TECN HBC	$K^-p \rightarrow \Lambda(1520)\pi^0$ ($\Gamma_1\Gamma_4$) ($\Gamma_1\Gamma_4$
0.27 \pm 0.03 ($\Gamma_1\Gamma_f$) $\frac{1/2}{2}/\Gamma_{\text{total}} \ln NK$ - $\frac{1}{2}$ \(\text{VALUE}\) 0.211 \pm 0.022 OUR FIT 0.188 \pm 0.010 OUR AVER -0.184 \pm 0.011 +0.20 \pm 0.02 • • • We do not use the form of the foliation of th	BARLETTA ARMENTERO Total State of the second of the secon	9565c 85) π or of ement 78 74 es, filts 68 9567c 67 67	TECN 2.8. ts were ig DPWA DPWA S, limits, DBC HBC TECN HBC	$K^-p \rightarrow \Lambda(1520)\pi^0$ ($\Gamma_1\Gamma_4$) ^{1/2} / gnored. $K^-p \rightarrow \Sigma(1385)\pi$ $K^-N \rightarrow \Sigma(1385)\pi$ etc. • • • $K^-N \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$
0.27 \pm 0.03 ($\Gamma_i \Gamma_f \gamma_i^{1/2} / \Gamma_{\text{total}} \ln N K - \frac{N}{2} + \frac{N}{2} = \frac{N}{2} $	BARLETTA ARMENTERO FITO Includes scale fact 3 CAMERON PREVOST Collowing data for average SIMS ARMENTERO DOCUMENT ID OF INCLUDES SCALE factor of UHLIG DOCUMENT ID COLLOWING data for average 4 ARMENTERO DOCUMENT ID COLLOWING data for average 4 ARMENTERO DOCUMENT ID COLLOWING DOCUMENT ID COLOWING DOCUMENT ID COLLOWING DOCUMEN	9565c 85) π cor of ement 78 78 78 68 9567c 67 67 67	TECN 2.8. ts were ig DPWA DPWA S, limits, DBC HBC TECN HBC	$K^-p \rightarrow \Lambda(1520)\pi^0$ $(\Gamma_1\Gamma_4)^{1/2}/\Gamma_4$ gnored. $K^-p \rightarrow \Sigma(1385)\pi$ $K^-N \rightarrow \Sigma(1385)\pi$ etc. • • • $K^-N \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$
0.27 \pm 0.03 ($\Gamma_1\Gamma_f$) $\frac{1/2}{2}/\Gamma_{\text{total}} \ln NK$ - $\frac{1}{2}$ \(\text{VALUE}\) 0.211 \pm 0.022 OUR FIT 0.188 \pm 0.010 OUR AVER -0.184 \pm 0.011 +0.20 \pm 0.02 • • • We do not use the form of the foliation of th	BARLETTA ARMENTERO FITO Includes scale fact 3 CAMERON PREVOST Collowing data for average SIMS ARMENTERO DOCUMENT ID OF INCLUDES SCALE factor of UHLIG DOCUMENT ID COLLOWING data for average 4 ARMENTERO DOCUMENT ID COLLOWING data for average 4 ARMENTERO DOCUMENT ID COLLOWING DOCUMENT ID COLOWING DOCUMENT ID COLLOWING DOCUMEN	9565c 85) π or of ement 78 74 68 9567c 67 67 67	TECN 2.8. ts were ig DPWA DPWA S, limits, DBC HBC TECN HBC	$K^-p \rightarrow \Lambda(1520)\pi^0$ ($\Gamma_1\Gamma_4$) ^{1/2} / gnored. $K^-p \rightarrow \Sigma(1385)\pi$ $K^-N \rightarrow \Sigma(1385)\pi$ etc. • • • $K^-N \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$
0.27 \pm 0.03 ($\Gamma_i \Gamma_f \gamma_i^{1/2} / \Gamma_{\text{total}} \ln N K - \frac{V \times U E}{2}$ 0.211 \pm 0.022 OUR FIT 0.188 \pm 0.010 OUR AVER -0.184 \pm 0.011 +0.20 \pm 0.02 • • • We do not use the form of the foliation	BARLETTA ARMENTERO FITO Includes scale fact 3 CAMERON PREVOST Collowing data for average SIMS ARMENTERO DO Includes scale factor of UHLIG DOCUMENT ID Collowing data for average 4 ARMENTERO DOCUMENT ID COLLOWING DOCUMENT ID COLOWING DOCUMENT ID COLLOWING DOCUMENT ID COLOWING DOCUMENT	9565c 85) π or of ement 78 74 68 9567c 67 67 67	TECN 2.8. ts were Ig DPWA 5, Ilmits, HBC TECN 5, Ilmits, HDBC TECN TECN TECN TECN TECN	$K^-p \rightarrow \Lambda(1520)\pi^0$ $(\Gamma_1\Gamma_4)^{1/2}/2$ COMMENT GRORED. $K^-p \rightarrow \Sigma(1385)\pi$ $K^-N \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$
0.27 \pm 0.03 ($\Gamma_i \Gamma_f \Gamma_f^{1/2} / \Gamma_{\text{total}} \ln N K - \frac{N}{2} + \frac{N}{2} = \frac{N}{2} + \frac{N}{2} = \frac{N}{2} $	BARLETTA ARMENTERO FITO Includes scale fact 3 CAMERON PREVOST Collowing data for average SIMS ARMENTERO DO Includes scale factor of UHLIG DOCUMENT ID Collowing data for average 4 ARMENTERO DOCUMENT ID COLLOWING DOCUMENT ID COLOWING DOCUMENT ID COLLOWING DOCUMENT ID COLOWING DOCUMENT	9565c 85) π or of ement 78 74 68 9567c 67 67 67	TECN 2.8. ts were Ig DPWA 5, Ilmits, HBC TECN 5, Ilmits, HDBC TECN TECN TECN TECN TECN	$K^-p \rightarrow \Lambda(1520)\pi^0$ $(\Gamma_1\Gamma_4)^{1/2}/2$ gnored. $K^-p \rightarrow \Sigma(1385)\pi$ etc. • • • $K^-N \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow K^-p
0.27 \pm 0.03 ($\Gamma_1\Gamma_1$) $\frac{1}{12}/\Gamma_{\text{total}} \ln NK$ - $\frac{1}{12}$	BARLETTA ARMENTERO ***\sum_{100} \sum_{100}	0565c 85) x or of rement 78 74 68 9567c 67 67 67	TECN 2.8. ts were ig DPWA DPWA S, limits, HBC TECN HBC TECN HBC TECN HBC TECN HBC	$K^-p \rightarrow \Lambda(1520)\pi^0$ $(\Gamma_1\Gamma_4)^{1/2}/2$ COMMENT GRORED. $K^-p \rightarrow \Sigma(1385)\pi$ $K^-N \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$
0.27 \pm 0.03 ($\Gamma_1\Gamma_1$)\frac{1}{2}/\Gamma_{total} \leftin N\overline{K}- \text{value} 0.211\pm 0.022 \text{ OUR FIT} 0.188\pm 0.010 \text{ OUR AVER} -0.184\pm 0.011 +0.20\pm 0.02 • • • We do not use the form 0.32 \pm 0.06 0.24 \pm 0.03 \text{\$\Gamma_{A}/\Gamma_{K}} \text{VALUE} 0.45\pm 0.09 \text{ OUR FIT} \text{ Error} 0.33\pm 0.05 \text{\$\Gamma_{A}/\Gamma_{total}} \text{VALUE} 0.12 \text{\$\Gamma_{A}/\Gamma_{total}} \text{\$\O_{A}/\Gamma_{total}} \text{\$\O_{A}/\O_{A}}	BARLETTA ARMENTERO FIGURENT ID Error Includes scale fact Signs on measure CAME Signs on measure CAME Signs on measure CAMERON PREVOST Collowing data for average SIMS ARMENTERO DOCUMENT ID COLOR OF ARMENTERO ARMENTERO DOCUMENT ID OR INCLUDES SCALE factor of UHLIG	0565c 0565c 0576c 0576c 0567c 05	TECN TECN TECN TECN TECN TECN HBC TECN HBC	$K^-p \rightarrow \Lambda(1520)\pi^0$ ($\Gamma_1\Gamma_4$) ^{1/2} gnored. $K^-p \rightarrow \Sigma(1385)\pi$ $K^-N \rightarrow \Sigma(1385)\pi$ etc. • • • $K^-N \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Sigma\pi\pi$
0.27 \pm 0.03 ($\Gamma_1\Gamma_1$) $\frac{1}{12}/\Gamma_{\text{total}} \ln NK$ - $\frac{1}{12}$	BARLETTA ARMENTERO ***\sum_{100} \sum_{100}	0565c 0565c 0576c 0576c 0567c 05	TECN 2.8. ts were ig DPWA DPWA S, limits, HBC TECN HBC TECN HBC TECN HBC TECN HBC	$K^-p \rightarrow \Lambda(1520)\pi^0$ $(\Gamma_1\Gamma_4)^{1/2}/2$ COMMENT GRORED. $K^-p \rightarrow \Sigma(1385)\pi$ $K^-N \rightarrow \Sigma(1385)\pi$ etc. • • • $K^-N \rightarrow \Lambda\pi\pi$ $K^-p \rightarrow \Lambda\pi\pi$

Σ(1775) FOOTNOTES

1 The two MARTIN 77 values are from a T-matrix pole and from a Breit-Wigner fit.

2 This rate combines *P*-wave and *F*-wave decays. The CAMERON 77 results for the separate *P*-wave and *F*-wave decays are -0.303 ± 0.010 and -0.037 ± 0.014. The published signs have been changed here to be in accord with the baryon-first convention.

3 The CAMERON 78 upper limit on *G*-wave decay is 0.03.

⁴ For about 3/4 of this, the $\Sigma\pi$ system has I=0 and is almost entirely $\Lambda(1520)$. For the rest, the $\Sigma\pi$ has I=1, which is about what is expected from the known $\Sigma(1775) \to \Sigma(1385)\pi$ rate, as seen in $\Lambda\pi\pi$.

Σ(1775) REFERENCES

PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
GOPAL	80	Toronto Conf. 159		(RHEL) UP
ALSTON	78	PR D18 182	Alston-Garnjost, Kenney+	(LBL, MTHO, CERN) IJP
Also	77	PRL 38 1007	Aiston-Garnjost, Kenney+	(LBL, MTHO, CERN) IJP
CAMERON	78	NP B143 189	+Franek, Gopal, Bacon, Butterworth+	(RHEL, LOIC) IJP
CAMERON	77	NP B131 399	+Franek, Gopal, Kalmus, McPherson+	RHEL, LOIC) IJP
GOPAL	77	NP B119 362	+Ross, VanHorn, McPherson+	(LOIC, RHEL) IJP
MARTIN	77	NP B127 349	+Pidcock, Moorhouse	(LOUC, GLAS) IJP
Also	77B	NP B126 266	Martin, Pidcock	(LOUC)
Also	77C	NP B126 285	Martin, Pidcock	(LOUC) IJP
DEBELLEFON	76	NP B109 129	De Bellefon, Berthon	(CDEF) IJP
BAILLON	75	NP B94 39	+Litchfield	(CERN, RHEL) IJP
VANHORN	75	NP B87 145		(LBL) IJP
Aiso	75B	NP B87 157	VanHorn	(LBL) IJP

Γ₁ Γ₂

NK

 $\Lambda\pi$ $\Sigma \pi$

Baryon Particle Listings $\Sigma(1775), \Sigma(1840), \Sigma(1880)$

DEVENISH	74B	NP B81 330	+Froggatt, Martin	(DESY, NORD, LOUC)
KANE	74	LBL-2452	== '	(LBL) IJP
PREVOST	74	NP B69 246	+Barloutaud+	(SACL, CERN, HEID)
BARLETTA	72	NP B40 45		(EFI) IJP
Also	66	PRL 17 841	Fenster, Gelfand, Harmsen+	(CHIC, ANL, CÈRN) IJP
ARMENTEROS	68C	NP B8 216	+Baitlon+	(CERN, HEID, SACL) I
SIMS	68	PRL 21 1413	+Albright, Bartley, Meer+	(FSU, TUFTS, BRAN)
ARMENTEROS	67C	ZPHY 202 486	+Ferro-Luzzi+	(CERN, HEID, SACL)
UHLIG	67	PR 155 1448	+Charlton, Condon, Glasser, Yodh+	
ARMENTEROS	65C	PL 19 338	+Ferro-Luzzi+	(CERN, HEID, SACL) IJP
GALTIERI	63	PL 6 296	+Hussain, Tripp	(LRL) IJ

$\Sigma(1840) P_{13}$

 $I(J^P) = 1(\frac{3}{2}^+)$ Status: *

OMITTED FROM SUMMARY TABLE

For the time being, we list together here all resonance claims in the P_{13} wave between 1700 and 1900 MeV.

	Σ(1840) MA	SS		
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
≈ 1840 OUR ESTIMATE				
1798 or 1802	1 MARTIN	77		KN multichannel
1720± 30	² BAILLON	75		$\overline{K}N \rightarrow \Lambda \pi$
1925±200	VANHORN	75		$K^- p \rightarrow \Lambda \pi^0$
1840± 10	LANGBEIN	72	IPWA	KN multichannel
	Σ(1840) WID	TH		
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
93 or 93	¹ MARTIN	77	DPWA	KN multichannel
	² BAILLON	75	IPWA	$\overline{K}N \rightarrow \Lambda \pi$
120±30				
120±30 65+50 -20	VANHORN	75	DPWA	$K^- p \rightarrow \Lambda \pi^0$

Σ(1840) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on \varLambda and Σ

$\Gamma(N\overline{K})/\Gamma_{\text{total}}$				Γ ₁ /Γ		
VALUE	DOCUMENT ID		TECN	COMMENT		
0 or 0	1 MARTIN	77	DPWA	KN multichannel		
0.37 ± 0.13	LANGBEIN	72	IPWA	KN multichannel		
$(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N \overline{K} -$				(Γ ₁ Γ ₂) ^{1/2} /Γ		
VALUE	DOCUMENT ID		<u>TECN</u>	COMMENT		
+0.03 or +0.03	1 MARTIN	77		KN multichannel		
$+0.11 \pm 0.02$	² BAILLON	75		$\overline{K}N \rightarrow \Lambda \pi$		
+0.06 ±0.04	VANHORN	75	DPWA	$K^-p \rightarrow \Lambda \pi^0$		
$+0.122\pm0.078$	DEVENISH	74B		Fixed-t dispersion rel.		
0.20 ±0.04	LANGBEIN	72	1PWA	KN multichannel		
$(\Gamma_{1}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow \Sigma (1840) \rightarrow \Sigma \pi$ VALUE DOCUMENT ID TECH COMMENT ($\Gamma_{1}\Gamma_{3}$) 1/2 / Γ_{2}						
-0.04 or -0.04	<u>DOCUMENT ID</u> 1 MARTIN	77		K N multichannel		
0.15±0.04	LANGBEIN	72		K N multichannel		
Σ(1840) FOOTNOTES						

 1 The two MARTIN 77 values are from a T-matrix pole and from a Breit-Wigner fit.

² From solution 1 of BAILLON 75; not present in solution 2.

Σ(1840) REFERENCES

MARTIN	77	NP B127 349	+Pidcock, Moorhouse	(LOUC, GLAS) IJP
Also	77B	NP B126 266	Martin, Pidcock	` (LOUC)
Also	77C	NP B126 285	Martin, Pidcock	(LOUC) IJP
BAILLON	75	NP B94 39	+Litchfield	(CERN, RHEL) IJP
VANHORN	75	NP B87 145		(LBL) IJP
Also	75B	NP B87 157	VanHorn	(LBL) IJP
DEVENISH	74B	NP B81 330	+Froggatt, Martin	(DESY, NORD, LÒUC)
LANGBEIN	72	NP B47 477	+Wagner	(MPIM) IJP

$\Sigma(1880) P_{11}$

 $I(J^P) = 1(\frac{1}{2}^+)$ Status: **

OMITTED FROM SUMMARY TABLE

A P_{11} resonance is suggested by several partial-wave analyses, but with wide variations in the mass and other parameters. We list here all claims which lie well above the P_{11} $\Sigma(1770)$.

2(1660)	MASS
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VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
≈ 1880 OUR ESTIMATE		-		
1826 ± 20	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
1870±10	CAMERON	78B	DPWA	$K^- p \rightarrow N \overline{K}^*$
1847 or 1863	¹ MARTIN	77	DPWA	KN multichannel
1960±30	² BAILLON	75	IPWA	$\overline{K}N \rightarrow \Lambda\pi$
1985 ± 50	VANHORN	75	DPWA	$K^- p \rightarrow \Lambda \pi^0$
1898	³ LEA	73	DPWA	Multichannel K-matrix
~ 1850	ARMENTERO	570	IPWA	$\overline{K}N \rightarrow \overline{K}N$
1950±50	BARBARO	70	DPWA	$K^- N \rightarrow \Lambda \pi$
1920±30	LITCHFIELD	70	DPWA	$K^-N \rightarrow \Lambda \pi$
1850	BAILEY	69	DPWA	RN → RN
1882 ± 40	SMART	68	DPWA	$K^- N \rightarrow \Lambda \pi$

Σ(1880) WIDTH

VALUE (MeV)	DOCUMENT ID TECN COMMENT
86 ± 15	GOPAL 80 DPWA $\overline{K}N \rightarrow \overline{K}N$
80 ± 10	CAMERON 788 DPWA $K^-p \rightarrow N\overline{K}^*$
216 or 220	¹ MARTIN 77 DPWA KN multichannel
260± 40	² BAILLON 75 IPWA $\overline{K}N \rightarrow \Lambda \pi$
220±140	VANHORN 75 DPWA $K^-p \rightarrow \Lambda \pi^0$
222	³ LEA 73 DPWA Multichannel K-matrix
~ 30	ARMENTEROS70 IPWA $\overline{K}N \rightarrow \overline{K}N$
200± 50	BARBARO 70 DPWA $K^-N \rightarrow \Lambda \pi$
170± 40	LITCHFIELD 70 DPWA $K^-N \rightarrow \Lambda \pi$
200	BAILEY 69 DPWA $\overline{K}N \to \overline{K}N$
222 ± 150	SMART 68 DPWA $K^-N \rightarrow \Lambda \pi$

Σ(1880) DECAY MODES

	Mode
Γ_1	NK
Γ_2	Λπ
Γ3	$\Sigma\pi$
Γ4	$N\overline{K}^*(892), S=1/2, P$ -wave
Γ ₅	$N\overline{K}^*(892)$, $S=3/2$, P -wave

Σ(1880) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on \varLambda and \varSigma

$\Gamma(N\overline{K})/\Gamma_{\text{total}}$				Γ ₁ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
0.06±0.02	GOPAL	80	DPWA	KN → KN
0.27 or 0.27	¹ MARTIN	77	DPWA	KN multichannel
0.31	³ LEA	73	DPWA	Multichannel K-matrix
0.20	ARMENTERO	570	IPWA	$\overline{K}N \to \overline{K}N$
0.22	BAILEY	69	DPWA	$\overline{K}N \rightarrow \overline{K}N$

$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N \overline{K} \rightarrow$	$\Sigma(1880) \rightarrow \Lambda\pi$			(Γ₁Γ₂) ^{1/2} /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
-0.24 or -0.24	¹ MARTIN	77	DPWA	KN multichannel
-0.12 ± 0.02	² BAILLON	75	IPWA	$\overline{K}N \rightarrow \Lambda \pi$
+0.05 +0.07 -0.02	VANHORN	75	DPWA	$K^-p \rightarrow \Lambda \pi^0$
-0.169 ± 0.119	DEVENISH	74B		Fixed-t dispersion rel.
-0.30	³ LEA	73	DPWA	Multichannel K-matrix
-0.09 ±0.04	BARBARO	70	DPWA	$K^- N \rightarrow \Lambda \pi$
-0.14 ±0.03	LITCHFIELD	70	DPWA	$K^- N \rightarrow \Lambda \pi$
0.14 1.000	CLAADT		D D14/4	1/ 11 4

-0.11 ±0.03		SMART	 	K-N→	
$(\Gamma_I\Gamma_f)^{\frac{1}{2}}/\Gamma_{to}$	tal in $N \overrightarrow{K} \rightarrow \Sigma$	1880) → Σπ			(Γ ₁ Γ ₃) ^{1/2} /Γ
VALUE		DOCUMENT ID	 TECN	COMMENT	
+0.30 or +0.2 not seen		¹ MARTIN ³ LEA		KN multi Multichan	channel nel K-matrix

$(\Gamma_i\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}}$ in	$V\overline{K} \rightarrow \Sigma(1880) \rightarrow N\overline{K}^{\bullet}(892), S=1/2, P-wave (\Gamma_1\Gamma_4)^{\frac{1}{2}}/\Gamma$
VALUE	DOCUMENT ID TECN COMMENT
_ 0.05±0.03	4 CAMEDON 700 DOWN K- n - NK+

$(\Gamma_I \Gamma_I)^{1/2} / \Gamma_{\text{total}} \ln N \overline{K} \rightarrow \Sigma(18)$	380) → NK*(8	892), <i>5</i> =3/	/2, <i>P</i> -wave (Γ ₁ Γ ₅) ^{1/2} /Γ
VALUE	DOCUMENT ID	TECN	COMMENT
$+0.11\pm0.03$	CAMERON	788 DPWA	$K^- \rho \rightarrow N \overline{K}^*$

Σ(1880) FOOTNOTES

- ¹ The two MARTIN 77 values are from a T-matrix pole and from a Breit-Wigner flt.
 ² From solution 1 of BAILLON 75; not present in solution 2.
 ³ Only unconstrained states from table 1 of LEA 73 are listed.

- ⁴ The published sign has been changed to be in accord with the baryon-first convention.

Σ(1880) REFERENCES

GOPAL CAMERON MARTIN Also	80 78B 77 77B	Toronto Conf. 159 NP B146 327 NP B127 349 NP B126 266	+Franek, Gopal, Kalmus, N +Pidcock, Moorhouse Martis. Pidcock	(RHEL) IJP McPherson+ (RHEL, LOIC) IJP (LOUC, GLAS) IJP (LOUC)
Also	77C	NP B126 285	Martin, Pidcock	(LOUC) LIP
BAILLON	75	NP B94 39	+Litchfield	(CERN, RHEL) IJP
VANHORN	75	NP B87 145		(LBL) IJP
Also	75B	NP B87 157	VanHorn	(LBL) IJP
DEVENISH	74B	NP B81 330	+Froggatt, Martin	(DESY, NORD, LOUC)
LEA	73	NP B56 77	+Martin, Moorhouse+	(RHEL, LOUC, GLAS, AARH) IJP
ARMENTEROS	70	Duke Conf. 123	+Baillon+	(CERN, HEID, SACL) IJP
BARBARO	70	Duke Conf. 173	Barbaro-Galtieri	(LRL) IJP
LITCHFIELD	70	NP B22 269		(RHEL) IJP
BAILEY	69	Thesis UCRL 50617		`(LLL) IJP
SMART	68	PR 169 1330		(LRL) IJP

$\Sigma(1915) F_{15}$

 $I(J^P) = 1(\frac{5}{2}^+)$ Status: ***

Discovered by COOL 66. For results published before 1974 (they are now obsolete), see our 1982 edition Physics Letters 111B (1982).

This entry only includes results from partial-wave analyses. Parameters of peaks seen in cross sections and invariant-mass distributions in this region used to be listed in in a separate entry immediately following. They may be found in our 1986 edition Physics Letters 170B (1986).

Σ(1915) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
1900 to 1935 (≈ 1915) OUR ESTI	MATE			
1937±20	ALSTON	78	DPWA	KN → KN
1894± 5	1 CORDEN	77C		$K^- n \rightarrow \Sigma \pi$
1909 ± 5	¹ CORDEN	77C		$K^- n \rightarrow \Sigma \pi$
1920±10		77	DPWA	KN multichannel
1900± 4	² CORDEN	76	DPWA	$K^- n \rightarrow \Lambda \pi^-$
1920±30	BAILLON	75	IPWA	$\overline{K}N \rightarrow \Lambda \pi$
1914±10	HEMINGWAY	75	DPWA	$K^- p \rightarrow \overline{K} N$
1920 + 15 - 20	VANHORN	75	DPWA	$K^- \rho \rightarrow \Lambda \pi^0$
1920± 5	KANE	74	DPWA	$K^- \rho \rightarrow \Sigma \pi$
• • • We do not use the following	data for averages	, fits	, limits,	etc. • • •
not seen	DECLAIS	77	DPWA	KN → KN
1925 or 1933	3 MARTIN	77	DPWA	KN multichannel
1915	DEBELLEFON	76	IPWA	$K^-p \rightarrow \Lambda \pi^0$

Σ(1915) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN_	COMMENT
80 to 160 (≈ 120) OUR ESTIMA	TE			
161±20	ALSTON	78	DPWA	RN → RN
107±14	1 CORDEN	77c		$K^- n \rightarrow \Sigma \pi$
85±13	¹ CORDEN	77C		$K^- n \rightarrow \Sigma \pi$
130±10	GOPAL	77	DPWA	KN multichannel
75±14	² CORDEN	76	DPWA	$K^- n \rightarrow \Lambda \pi^-$
70±20	BAILLON	75	IPWA	$\overline{K}N \rightarrow \Lambda \pi$
85±15	HEMINGWAY	75	DPWA	$K^-p \rightarrow \overline{K}N$
102±18	VANHORN	75	DPWA	$K^- \rho \rightarrow \Lambda \pi^0$
162±25	KANE	74	DPWA	$K^- p \rightarrow \Sigma \pi$
• • • We do not use the following	data for averages	, fits	, Ilmits,	etc. • • •
171 or 173	3 MARTIN	77	DPWA	KN multichannel
60	DEBELLEFON	76	IPWA	$K^- p \rightarrow \Lambda \pi^0$

Σ(1915) DECAY MODES

	Mode	Fraction (Γ_I/Γ)	
Γ ₁	NK	5-15 %	
Γ_2	Λπ	seen	
Гз	$\Sigma \pi$	seen	
Γ_4	Σ (1385) π	<5 %	
Γ ₅	$\Sigma(1385)\pi$, P-wave		
Γ_6	$\Sigma(1385)\pi$, F-wave		

The above branching fractions are our estimates, not fits or averages.

Σ(1915) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on \varLambda and \varSigma

Γ(NK)/Γ _{total}				Γ1/1
VALUE	DOCUMENT ID		TECN	COMMENT
0.05 to 0.15 OUR ESTIMATE				
0.03±0.02				KN → KN
0.14±0.05				$KN \rightarrow KN$
0.11±0.04				K ⁻ p → KN
 • • We do not use the following 	ing data for average	s, fits	i, limits,	etc. • • •
0.05±0.03	GOPAL			See GOPAL 80
0.08 or 0.08	³ MARTIN	77	DPWA	KN multichannel
$(\Gamma_i \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K} \to \Sigma$				$(\Gamma_1\Gamma_2)^{\frac{1}{2}}$
VALUE	DOCUMENT ID			
-0.09 ±0.03	GOPAL			KN multichannel
-0.10 ±0.01				$K^- n \rightarrow \Lambda \pi^-$
-0.06 ±0.02	BAILLON	75	IPWA	$\overline{K}N \rightarrow \Lambda \pi$ $K^{-}p \rightarrow \Lambda \pi^{0}$
-0.09 ±0.02	VANHORN	75	DPWA	$K^-p \rightarrow \Lambda \pi^0$
-0.087±0.056	DEVENISH	74B		Fixed-t dispersion rel.
 ◆ ◆ We do not use the follow 			s, Ilmits,	etc. • • •
-0.09 or -0.09	3 MARTIN	77	DPWA	KN multichannel
-0.10	DEBELLEFON	1 76	IPWA	$K^- p \rightarrow \Lambda \pi^0$
1/				1/
$(\Gamma_i \Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N \overline{K} \to \Sigma$	(1915) → Σπ DOCUMENT ID		<u>TECN</u>	(\(\Gamma_1 \Gamma_3 \)^{\frac{1}{2}}/2
VALUE	DOCUMENT ID 1 CORDEN			COMMENT
<u>VALUE</u> -0.17±0.01	DOCUMENT ID	77C		$ \begin{array}{c} COMMENT \\ K^- n \to \Sigma \pi \\ K^- n \to \Sigma \pi \end{array} $
VALUE - 0.17±0.01 - 0.15±0.02	DOCUMENT ID 1 CORDEN 1 CORDEN	77c 77c 77	DPWA	$\begin{array}{c} \underline{COMMENT} \\ K^- n \to \Sigma \pi \\ K^- n \to \Sigma \pi \\ \overline{K} N \text{multichannel} \end{array}$
VALUE -0.17±0.01 -0.15±0.02 -0.19±0.03	DOCUMENT ID 1 CORDEN 1 CORDEN GOPAL KANE	77C 77C 77 74	DPWA DPWA	$\begin{array}{l} \underline{COMMENT} \\ K^- n \to \Sigma \pi \\ K^- n \to \Sigma \pi \\ \hline K N \text{multichannel} \\ K^- \rho \to \Sigma \pi \end{array}$
VALUE -0.17 ± 0.01 -0.15 ± 0.02 -0.19 ± 0.03 -0.16 ± 0.03	DOCUMENT ID 1 CORDEN 1 CORDEN GOPAL KANE	77C 77C 77 74 es, fits	DPWA DPWA s, limits,	$\begin{array}{l} \underline{COMMENT} \\ K^- n \to \; \Sigma \pi \\ K^- n \to \; \Sigma \pi \\ \overline{K} N \; \text{multichannel} \\ K^- \rho \to \; \Sigma \pi \end{array}$
VALUE -0.17±0.01 -0.15±0.02 -0.19±0.03 -0.16±0.03 • • • We do not use the follow -0.05 or -0.05 (Γ _I Γ _I) $\frac{1}{2}$ /Γ _{total} in NK → Σ	DOCUMENT ID 1 CORDEN 1 CORDEN GOPAL KANE ling data for average	77C 77C 77 74 es, fits 77	DPWA DPWA s, limits, DPWA	$\begin{array}{ll} \underline{COMMENT} \\ K^- n \to \Sigma \pi \\ K^- n \to \Sigma \pi \\ \overline{K} N \text{ multichannel} \\ K^- \rho \to \Sigma \pi \\ \text{etc.} \bullet \bullet \bullet \\ \overline{K} N \text{ multichannel} \\ \text{re} & \left(\Gamma_1 \Gamma_5 \right)^{\frac{1}{2}} \end{array}$
VALUE -0.17±0.01 -0.15±0.02 -0.19±0.03 -0.16±0.03 • • • We do not use the follow	DOCUMENT ID 1 CORDEN 1 CORDEN GOPAL KANE ling data for average 3 MARTIN 1 (1915) → Σ(138)	77C 77C 77 74 es, fits 77	DPWA DPWA s, limits, DPWA TECN	COMMENT $K^- n \to \Sigma \pi$ $K^- n \to \Sigma \pi$ $\overline{K} N \text{ multichannel}$ $K^- \rho \to \Sigma \pi$ etc. • • • $\overline{K} N \text{ multichannel}$ $K^- \rho \to \Gamma \pi$
VALUE -0.17 ± 0.01 -0.15 ± 0.02 -0.15 ± 0.03 -0.16 ± 0.03 -0.16 ± 0.03 \bullet • • We do not use the follow -0.05 or -0.05 $(\Gamma_{\ell}\Gamma_{\ell})^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\overline{K} \rightarrow \Sigma_{VALUE}$	DOCUMENT ID 1 CORDEN 1 CORDEN GOPAL KANE ling data for average 3 MARTIN (1915) → Σ(13) DOCUMENT ID CAMERON	77c 77c 77 74 es, fits 77 85) #	DPWA DPWA s, limits, DPWA TECN DPWA	COMMENT $K^- n \to \Sigma \pi$ $K^- n \to \Sigma \pi$ $K^- n \to \Sigma \pi$ $K \in P \to E \pi$ etc. • • • $K \in R \to E \pi$ etc. • • • etc. • • • $K \in R \to E \pi$ etc. • • • etc. • • etc. • • • etc. • • • etc. • • • etc. • • • etc. • • • etc. • • • etc. • • • etc. • • • etc. • • • etc. • • • etc. • • • etc. • • • etc. • • • etc. • • etc. • • • etc. • • • etc. • • • etc. • • • etc. • • • etc. • • • etc. • • • etc. • • • etc. • • • etc. • • • etc. • • • etc. • • • etc. • • • etc. • • • etc. • • • etc. • • • etc. • • • etc. • • • etc. • • etc. • • • etc. • • • et

Σ(1915) FOOTNOTES

- 1 The two entries for CORDEN 77C are from two different acceptable solutions.
- 2 Preferred solution 3; see CORDEN 76 for other possibilities.

 3 The two MARTIN 77 values are from a T-matrix pole and from a Breit-Wigner fit.
- ⁴ The mass and width are fixed to the GOPAL 77 values due to the low elasticity.
- ⁵ The published sign has been changed to be in accord with the baryon-first convention.

Σ(1915) REFERENCES

PDG	86	PL 1708	Aguilar-Benitez, Porter+	(CERN, CIT+)
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
GOPAL	80	Toronto Conf. 159	11004 1 01111, 1 (6000)	(RHEL) UP
ALSTON	78	PR D18 182	Alston-Garnjost, Kenney+	(LBL, MTHO, CERN) UP
Also	77	PRL 38 1007	Alston-Garnjost, Kenney+	(LBL, MTHO, CERN) UP
CAMERON	78	NP B143 189	+Franck, Gopal, Bacon, Butterworth	
CORDEN	77C	NP B125 61	+Cox, Kenyon, O'Neale, Stubbs, Su	
DECLAIS	77	CERN 77-16	+Duchon, Louvel, Patry, Seguinot+	(CAEN, CERN) IJP
GOPAL	77	NP B119 362	+Ross, VanHorn, McPherson+	(LOIC, RHEL) IJP
MARTIN	77	NP B127 349	+Pidcock, Moorhouse	(LOUC, GLAS) IJP
Also	77B	NP B126 266	Martin, Pidcock	(LOUC)
Also	77C	NP B126 285	Martin, Pidcock	(LOUC) UP
CORDEN	76	NP B104 382	+Cox, Dartnell, Kenyon, O'Neale+	(BIRM) IJP
DEBELLEFON	76	NP B109 129	De Bellefon, Berthon	(CDEF) IJP
BAILLON	75	NP B94 39	+Litchfield	(CERN, RHEL) IJP
HEMINGWAY	75	NP B91 12	+Eades, Harmsen+	(CERN, HEIDH, MPIM) IJP
VANHORN	75	NP 887 145		` (LBL) IJP
Also	75B	NP B87 157	VanHorn	(LBL) IJP
DEVENISH	74B	NP BB1 330	+Froggatt, Martin	(DESY, NORD, LOUC)
KANE	74	LBL-2452		(LBL) IJP
COOL	66	PRL 16 1228	+Giacomelli, Kycia, Leontic, Lundby	+ (BNL)

Baryon Particle Listings $\Sigma(1940), \Sigma(2000)$

 $\Sigma(1940) D_{13}$

 $I(J^P) = 1(\frac{3}{2}^-)$ Status: ***

For results published before 1974 (they are now obsolete), see our 1982 edition Physics Letters 111B (1982).

Not all analyses require this state. It is not required by the GOYAL 77 analysis of $K^- n \to (\Sigma \pi)^-$ nor by the GOPAL 80 analysis of $K^- n \rightarrow K^- n$. See also HEMINGWAY 75.

Σ(1940) MASS

VALUE (MeV)			TECN	COMMENT
1900 to 1950 (≈ 1940)	OUR ESTIMATE			
1920±50	GOPAL	77	DPWA	K N multichannel
1950±30	BAILLON	75	IPWA	$\overline{K}N \rightarrow \Lambda \pi$
1949 + 40 - 60	VANHORN	75	DPWA	$K^- p \rightarrow \Lambda \pi^0$
1935±80	KANE	74	DPWA	$K^-p \rightarrow \Sigma \pi$
1940±20	LITCHFIELD	74B	DPWA	$K^- p \rightarrow \Lambda(1520) \pi^0$
1950±20	LITCHFIELD	74C	DPWA	$K^-p \rightarrow \Delta(1232)\overline{K}$
• • • We do not use th	e following data for averages	, fits	, limits,	etc. • •
1886 or 1893	¹ MARTIN	77	DPWA	K N multichannel
1940	DEBELLEFON	76	IPWA	$K^- p \rightarrow \Lambda \pi^0, F_{17}$ wave

Σ(1940) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
150 to 300 (≈ 220) OUR EST	TIMATE			
170±25	CAMERON	78B	DPWA	$K^-p \rightarrow N\overline{K}^*$
300±80	GOPAL	77	DPWA	KN multichannel
150±75	BAILLON	75	IPWA	$\overline{K}N \rightarrow \Lambda\pi$
160 ⁺⁷⁰ -40	VANHORN	75	DPWA	$K^- p \rightarrow \Lambda \pi^0$
330±80	KANE	74	DPWA	$K^-p \rightarrow \Sigma \pi$
60±20	LITCHFIELD	74B	DPWA	$K^-p \rightarrow \Lambda(1520)\pi^0$
70 ⁺³⁰ -20	LITCHFIELD	74 C	DPWA	$K^- p \rightarrow \Delta(1232)\overline{K}$
• • • We do not use the folk	owing data for average	s, fits	, limits,	etc. • • •
157 or 159	¹ MARTIN	77	DPWA	KN multichannel

Σ(1940) DECAY MODES

	Mode	Fraction (Γ_I/Γ)
Γ ₁	NK	<20 %
Γ2	$\Lambda\pi$	seen
Гз	Σπ	seen
Γ4	$\Sigma(1385)\pi$	seen
۲5	$\Sigma(1385)\pi$, S-wave	
Γ ₆	$\Lambda(1520)\pi$	seen
Γ7	$\Lambda(1520)\pi$, P-wave	
Γ8	$\Lambda(1520)\pi$, F-wave	
Γg	$\Delta(1232)\overline{K}$	seen
Γ ₁₀	$\Delta(1232)\overline{K}$, S-wave	
Γ11	$\Delta(1232)\overline{K}$, D-wave	
Γ ₁₂	N <i>K</i> *(892)	seen
Γ ₁₃	$N\overline{K}^*(892)$, $S=3/2$, S-wave	

Σ(1940) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on \varLambda and \varSigma

$\Gamma(N\overline{K})/\Gamma_{\text{total}}$					Γ_1/Γ
VALUE	DOCUMENT ID		TECN	COMMENT	
<0.2 OUR ESTIMATE					
<0.04	GOPAL	77		KN multichannel	
0.14 or 0.13	1 MARTIN	77	DPWA	KN multichannel	
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\overline{K} \to .$				(F ₁ F ₂) ^½ /୮
VALUE	DOCUMENT ID		TECN	COMMENT	
-0.06 ±0.03	GOPAL	77	DPWA	KN multichannel	
-0.04 ± 0.02	BAILLON	75	IPWA	$\overline{K}N \rightarrow \Lambda \pi$	
$-0.05 \begin{array}{c} +0.03 \\ -0.02 \end{array}$	VANHORN	75	DPWA	$K^- p \rightarrow \Lambda \pi^0$	
-0.153 ± 0.070	DEVENISH	74B		Fixed-t dispersion	rel.
• • We do not use the follow	wing data for average	s, fits	i, limits,	etc. • • •	
-0.15 or -0.14	¹ MARTIN	77	DPWA	$\overline{K}N$ multichannel	

(「「「」) ^{1/2} /「total in NK VALUE	DOCUMENT ID		TECN	COMMENT	([15])1/2
-0.08±0.04				KN mult	
-0.14 ± 0.04	KANE				
• • • We do not use the	following data for average	s, fits	, limits,	etc. • • •	,
+0.16 or +0.16	¹ MARTIN	77	DPWA	₹N mult	ichannel
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N \overline{K}$	$I \to \Sigma(1940) \to \Lambda(152)$	0) x	P-wav	e	(Г1Г7) ¹ / ₂
VALUE	DOCUMENT ID		TECN	COMMENT	, ,
< 0.03	CAMERON	77	DPWA	$K^-p \rightarrow$	$\Lambda(1520)\pi^{0}$
-0.11 ± 0.04	LITCHFIELD	74B	DPWA	K- p →	$\Lambda(1520)\pi^0$
	' → Σ(1940) → Λ(152	0)π,	F-wav	e	(Γ ₁ Γ ₈) ^{1/2} ,
VALUE	DOCUMENT ID				
0.000 0.004	CAMEDON	77	DPWA	$K^- D \rightarrow$	$\Lambda(1520)\pi^{0}$
0.062 ± 0.021					
-0.08 ±0.04	LITCHFIELD	748	DPWA	κ-'p →	
-0.08 ±0.04 (「/「/) ^{1/2} /「total in NK VALUE	LITCHFIELD $ \Delta = \Sigma(1940) \rightarrow \Delta(123) $ DOCUMENT ID	748 32) K	DPWA , S-wav TECN	K ⁻ p → ve <u>COMMENT</u>	(Г ₁ Г ₁₀) ^{1/2}
-0.08 ± 0.04 $(\Gamma_I \Gamma_f)^{1/2} / \Gamma_{total}$ in N K	LITCHFIELD $\Sigma \to \Sigma (1940) \to \Delta (123)$	748 32) K	DPWA , S-wav TECN	K ⁻ p → ve <u>COMMENT</u>	(Г ₁ Г ₁₀) ^{1/2}
-0.08 ± 0.04 $(\Gamma_i \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } NK$ $\frac{VALUE}{C}$ -0.16 ± 0.05 $(\Gamma_i \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } NK$	LITCHFIELD $T o \Sigma(1940) o \Delta(123) o DOCUMENT ID LITCHFIELD$ $T o \Sigma(1940) o \Delta(123) o \Delta(123)$	748 32) K 740	DPWA , S-wav TECN DPWA	$K^{-}p \rightarrow Ve$ $\frac{COMMENT}{K^{-}p \rightarrow Ve}$	$(\Gamma_1\Gamma_{10})^{\frac{1}{2}}$ $\Delta(1232)\overline{K}$
-0.08 ± 0.04 $(\Gamma_i \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } NK$ $\frac{VALUE}{C}$ -0.16 ± 0.05 $(\Gamma_i \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } NK$	LITCHFIELD $T o \Sigma(1940) o \Delta(123) o DOCUMENT ID LITCHFIELD$ $T o \Sigma(1940) o \Delta(123) o \Delta(123)$	748 32) K 740	DPWA , S-wav TECN DPWA	$K^{-}p \rightarrow Ve$ $\frac{COMMENT}{K^{-}p \rightarrow Ve}$	$(\Gamma_1\Gamma_{10})^{\frac{1}{2}}$ $\Delta(1232)\overline{K}$
-0.08 ± 0.04 $(\Gamma_i \Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \ln NK$ $VALUE$ -0.16 ± 0.05 $(\Gamma_i \Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \ln NK$ $VALUE$ -0.14 ± 0.05	LITCHFIELD $ A \rightarrow \Sigma(1940) \rightarrow \Delta(122) $ $ DOCUMENT ID $ LITCHFIELD $ A \rightarrow \Sigma(1940) \rightarrow \Delta(122) $ $ DOCUMENT ID $ LITCHFIELD $ A \rightarrow \Sigma(1940) \rightarrow \Sigma(134) $ $ DOCUMENT ID $ $ DOCUMENT ID $ $ DOCUMENT ID $	748 32) K 74c 32) K 74c 74c	DPWA TECN DPWA TECN DPWA TECN DPWA	$K^-p \rightarrow$ ve $COMMENT$ $K^-p \rightarrow$ ve $COMMENT$ $K^-p \rightarrow$ $COMMENT$	$(\Gamma_1\Gamma_{10})^{\frac{1}{2}}$ $\Delta(1232)\overline{K}$ $(\Gamma_1\Gamma_{11})^{\frac{1}{2}}$ $\Delta(1232)\overline{K}$ $(\Gamma_1\Gamma_4)^{\frac{1}{2}}$
-0.08 ± 0.04 $(\Gamma_{I}\Gamma_{I})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K}$ $\frac{VALUE}{-0.16 \pm 0.05}$ $(\Gamma_{I}\Gamma_{I})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K}$ $\frac{VALUE}{-0.14 \pm 0.05}$ $(\Gamma_{I}\Gamma_{I})^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K}$	LITCHFIELD $ A \rightarrow \Sigma(1940) \rightarrow \Delta(122) $ $ DOCUMENT ID $ LITCHFIELD $ A \rightarrow \Sigma(1940) \rightarrow \Delta(122) $ $ DOCUMENT ID $ LITCHFIELD	748 32) K 74c 32) K 74c 74c	DPWA TECN DPWA TECN DPWA TECN DPWA	$K^-p \rightarrow$ ve $COMMENT$ $K^-p \rightarrow$ ve $COMMENT$ $K^-p \rightarrow$ $COMMENT$	$(\Gamma_1\Gamma_{10})^{\frac{1}{2}}$ $\Delta(1232)\overline{K}$ $(\Gamma_1\Gamma_{11})^{\frac{1}{2}}$ $\Delta(1232)\overline{K}$ $(\Gamma_1\Gamma_4)^{\frac{1}{2}}$
-0.08 ± 0.04 $(\Gamma_i \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N\overline{K}$ $VALUE$ -0.16 ± 0.05 $(\Gamma_i \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N\overline{K}$ $VALUE$ -0.14 ± 0.05 $(\Gamma_i \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N\overline{K}$ $VALUE$ $+0.066 \pm 0.025$	LITCHFIELD $ A \rightarrow \Sigma(1940) \rightarrow \Delta(123) $ DOCUMENT ID LITCHFIELD $ A \rightarrow \Sigma(1940) \rightarrow \Delta(123) $ DOCUMENT ID LITCHFIELD $ A \rightarrow \Sigma(1940) \rightarrow \Sigma(134) $ DOCUMENT ID $ A \rightarrow \Sigma(1940) \rightarrow \Sigma(134) $ CAMERON	748 32) Κ 740 32) Κ 740 85) π	, S-way TECN_DPWA TECN_DPWA TECN_DPWA	$K^-p \rightarrow$ ve <u>COMMENT</u> $K^-p \rightarrow$ ve <u>COMMENT</u> $K^-p \rightarrow$	$\frac{(\Gamma_{1}\Gamma_{10})^{\frac{1}{2}}}{\Delta(1232)\overline{K}}$ $\frac{(\Gamma_{1}\Gamma_{11})^{\frac{1}{2}}}{\Delta(1232)\overline{K}}$ $\frac{(\Gamma_{1}\Gamma_{4})^{\frac{1}{2}}}{(\Gamma_{1}\Gamma_{4})^{\frac{1}{2}}}$ $\frac{\Gamma(1385)\pi}{K}$
-0.08 ± 0.04 $(\Gamma_i \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N\overline{K}$ $VALUE$ -0.16 ± 0.05 $(\Gamma_i \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N\overline{K}$ $VALUE$ -0.14 ± 0.05 $(\Gamma_i \Gamma_f)^{1/2} / \Gamma_{\text{total}} \text{ in } N\overline{K}$ $VALUE$ $+0.066 \pm 0.025$	LITCHFIELD $ A \rightarrow \Sigma(1940) \rightarrow \Delta(122) $ $ DOCUMENT ID $ LITCHFIELD $ A \rightarrow \Sigma(1940) \rightarrow \Delta(122) $ $ DOCUMENT ID $ LITCHFIELD $ A \rightarrow \Sigma(1940) \rightarrow \Sigma(134) $ $ DOCUMENT ID $ $ DOCUMENT ID $ $ DOCUMENT ID $	748 32) K 74c 74c 74c 74c 78 85) π 78	, S-war TECN DPWA TECN DPWA TECN DPWA	$K^-p \rightarrow$ ve <u>COMMENT</u> $K^-p \rightarrow$ ve <u>COMMENT</u> $K^-p \rightarrow$ <u>COMMENT</u> $K^-p \rightarrow$	$\frac{(\Gamma_{1}\Gamma_{10})^{\frac{1}{2}}}{\Delta(1232)\overline{K}}$ $\frac{(\Gamma_{1}\Gamma_{11})^{\frac{1}{2}}}{\Delta(1232)\overline{K}}$ $\frac{(\Gamma_{1}\Gamma_{4})^{\frac{1}{2}}}{\Gamma(1385)\pi}$ $\frac{(\Gamma_{1}\Gamma_{12})^{\frac{1}{2}}}{\Gamma(1\Gamma_{12})^{\frac{1}{2}}}$

¹ The two MARTIN 77 values are from a T-matrix pole and from a Breit-Wigner fit.

² The published sign has been changed to be in accord with the baryon-first convention. 3 Upper limits on the D_1 and D_3 waves are each 0.03.

Σ(1940) REFERENCES

PDG GOPAL	82	PL 111B	Roos, Porter, Aguilar-Benitez+	(HELS, CIT, CERN)
CAMERON	80 78	Toronto Conf. 159 NP B143 189	+Franck, Gopal, Bacon, Butterworth	(RHEL) + (RHEL, LOIC) IJP
CAMERON	78B	NP B146 327	+Franck, Gopal, Kalmus, McPherson	
CAMERON	77	NP B131 399	+Franck, Gopal, Kalmus, McPherson	
GOPAL	77	NP B119 362	+Ross, VanHorn, McPherson+	(LOIC, RHEL) IJP
GOYAL	77	PR D16 2746	+Sodhi	(DELH)
MARTIN	77	NP B127 349	+Pidcock, Moorhouse	(LOUC, GLAS) IJP
Also	77B	NP B126 266	Martin, Pidcock	(LOUC)
Also	77C	NP B126 285	Martin, Pidcock	(LOUC) IJP
DEBELLEFON	76	NP B109 129	De Bellefon, Berthon	(CDEF) IJP
BAILLON	75	NP B94 39	+Litchfield	(CERN, RHEL) IJP
HEMINGWAY	75	NP B91 12	+Eades, Harmsen+ (CERN, HEIDH, MPIM) UP
VANHORN	75	NP B87 145		(LBL) IJP
Also	75B	NP B87 157	VanHorn	(LBL) IJP
DEVENISH	74B	NP B81 330	+Froggatt, Martin	(DESY, NORD, LÒUC)
KANE	74	LBL-2452		(LBL) IJP
LITCHFIELD	74B	NP 874 19	+Hemingway, Baillon+	(CERN, HÈIDH) IJP
LITCHFIELD	74C	NP B74 39	+Hemingway, Baillon+	(CERN, HEIDH) IJP

 Σ (2000) S_{11}

 $I(J^P) = 1(\frac{1}{2})$ Status: *

OMITTED FROM SUMMARY TABLE

We list here all reported S_{11} states lying above the $\Sigma(1750)$ S_{11} .

	Σ(2000) MA	SS		
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
≈ 2000 OUR ESTIMATE				
1944±15	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
1955±15	GOPAL	77	DPWA	KN multichannel
1755 or 1834	1 MARTIN	77	DPWA	KN multichannel
2004 ± 40	VANHORN	75	DPWA	$K^-p \rightarrow \Lambda \pi^0$
	Σ(2000) WID	тн		•
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
215±25	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
170±40	GOPAL	77	DPWA	KN multichannel
413 or 450	1 MARTIN	77	DPWA	KN multichannel
116±40	VANHORN	75	DPWA	$K^- \rho \rightarrow \Lambda \pi^0$

Σ(2000) DECAY MODES

	Mode
$\overline{\Gamma_1}$	NK
Γ_2	$\Lambda\pi$
Гз	$\Sigma\pi$
Γ4	$\Lambda(1520)\pi$
Γs	$N\overline{K}^*$ (892), $S=1/2$, S-wave
Γ ₆	$N\overline{K}^*(892)$, $S=3/2$, D -wave

Σ(2000) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on \varLambda and \varSigma Resonances.

			Γ ₁ ,
DOCUMENT ID		TECN	COMMENT
GOPAL	80	DPWA	KN → KN
GOPAL	77	DPWA	See GOPAL 80
¹ MARTIN	77	DPWA	KN multichannel
→ Σ(2000) → Λπ		T= C++	$(\Gamma_1\Gamma_2)^{\frac{1}{12}}$
			KN multichannel
BAILLON			
VANHORN	75	DPWA	$K^- p \rightarrow \Lambda \pi^0$
→ Σ(2000) → Σπ		TECN	(Γ ₁ Γ ₃) ^{1/2}
GOPAL	77	DPWA	KN multichannel
¹ MARTIN	77	DPWA	KN multichannel
$\rightarrow \Sigma(2000) \rightarrow \Lambda(152)$ DOCUMENT ID	:0)π	TECN	$(\Gamma_1\Gamma_4)^{\frac{1}{2}}$
² CAMERON	77	DPWA	P-wave decay
$\rightarrow \Sigma(2000) \rightarrow N\overline{K}^{\circ}($	(892)), <i>5</i> =3/	/2, <i>D</i> -wave (Γ ₁ Γ ₆) ^{1/2}
DOCUMENT ID		TECN_	COMMENT
	GOPAL GOPAL 1 MARTIN → F (2000) → Λπ DOCUMENT ID GOPAL 1 MARTIN BAILLON VANHORN → F (2000) → F π DOCUMENT ID GOPAL 1 MARTIN 3 COPAL 1 MARTIN 2 CAMERON → F (2000) → Λ(152 DOCUMENT ID 2 CAMERON → F (2000) → N F (4)	GOPAL 80 GOPAL 77 1 MARTIN 77 → F(2000) → A π DOCUMENT ID GOPAL 77 1 MARTIN 77 BAILLON 75 VANHORN 75 → F(2000) → F π DOCUMENT ID GOPAL 77 1 MARTIN 77 → F(2000) → A(1520) π DOCUMENT ID 2 CAMERON 77 → F(2000) → NK* (892) DOCUMENT ID 2 CAMERON 788	GOPAL 80 DPWA GOPAL 77 DPWA 1 MARTIN 77 DPWA → \(\mathcal{F}(2000)\) → \(\lambda\pi\) GOPAL 77 DPWA 1 MARTIN 77 DPWA 1 MARTIN 77 DPWA BAILLON 75 IPWA VANHORN 75 DPWA → \(\mathcal{F}(2000)\) → \(\mathcal{F}\pi\) DOCUMENT ID TECN TECN TECN TECN TECN TECN TECN TECN TECN TECN TECN TECN TECN

Σ(2000) FOOTNOTES

 1 The two MARTIN 77 values are from a T-matrix pole and from a Breit-Wigner flt.

²The published sign has been changed to be in accord with the baryon-first convention.

Σ(2000) REFERENCES

GOPAL CAMERON CAMERON GOPAL	80 78B 77 77	Toronto Conf. 159 NP B146 327 NP B131 399 NP B119 362	+Franek, Gopal, Kalmus, McPherson+ +Franek, Gopal, Kalmus, McPherson+ +Ross, VanHorn, McPherson+	(RHEL) IJP (RHEL, LOIC) IJP (RHEL, LOIC) IJP (LOIC, RHEL) IJP
MARTIN	77	NP B127 349	+Pidcock, Moorhouse	(LOUC, GLAS) IJP
Also	77B	NP B126 266	Martin, Pidcock	(LOUC)
Also	77C	NP B126 285	Martin, Pidcock	(LOUC) IJP
BAILLON	75	NP B94 39	+Litchfield	(CERN, RHEL) IJP
VANHORN	75	NP B87 145		(LBL) IJP
Also	75B	NP B87 157	VanHorn	(LBL) IJP

 $\Sigma(2030) F_{17}$

 $I(J^P) = 1(\frac{7}{2}^+)$ Status: ***

Discovered by COOL 66 and by WOHL 66. For most results published before 1974 (they are now obsolete), see our 1982 edition Physics Letters 111B (1982).

This entry only includes results from partial-wave analyses. Parameters of peaks seen in cross sections and invariant-mass distributions around 2030 MeV may be found in our 1984 edition, Reviews of Modern Physics **56** No. 2 Pt. II (1984).

Σ(2030) MASS

VALUE (MeV)	DOCUMENT ID TECN COMMENT
2025 to 2040 (≈ 2030)	OUR ESTIMATE
2036 ± 5	GOPAL 80 DPWA $\overline{K}N \rightarrow \overline{K}N$
2038±10	CORDEN 77B $K^- N \rightarrow N \overline{K}^*$
2040 ± 5	GOPAL 77 DPWA KN multichannel
2030± 3	¹ CORDEN 76 DPWA $K^- n \rightarrow \Lambda \pi^-$
2035±15	BAILLON 75 IPWA $\overline{K}N \rightarrow \Lambda \pi$
2038 ± 10	HEMINGWAY 75 DPWA $K^-p \rightarrow \overline{K}N$
2042 ± 1·1	VANHORN 75 DPWA $K^-p \rightarrow \Lambda \pi^0$
2020 ± 6	KANE 74 DPWA $K^-p \rightarrow \Sigma \pi$
2035 ± 10	LITCHFIELD 74B DPWA $K^-p \rightarrow \Lambda(1520)\pi^0$
2020 ± 30	LITCHFIELD 74c DPWA $K^-p \rightarrow \Delta(1232)\overline{K}$
2025 ± 10	LITCHFIELD 74D DPWA $K^-p \rightarrow \Lambda(1820)\pi^0$
• • • We do not use th	e following data for averages, fits, limits, etc. • • •
2027 to 2057	GOYAL 77 DPWA $K^-N \rightarrow \Sigma \pi$
2030	DEBELLEFON 76 IPWA $K^-p \rightarrow \Lambda \pi^0$

Σ(2030) WIDTH

VALUE (MeV)	DOCUMENT_ID		TECN_	COMMENT
150 to 200 (≈ 180) OUR ESTIMA	TE			
172±10	GOPAL	80	DPWA	$\overline{K}N \rightarrow \overline{K}N$
137±40	CORDEN	77B		$K^- N \rightarrow N \overline{K}^*$
190±10	GOPAL	77	DPWA	KN multichannel
201± 9	¹ CORDEN	76	DPWA	$K^- n \rightarrow \Lambda \pi^-$
180±20	BAILLON	75	IPWA	$\overline{K}N \rightarrow \Lambda \pi$
172±15	HEMINGWAY	75	DPWA	$K^- p \rightarrow \overline{K} N$
178±13	VANHORN	75	DPWA	$K^-p \rightarrow \Lambda \pi^0$
111± 5	KANE	74	DPWA	$K^- \rho \rightarrow \Sigma \pi$
160±20	LITCHFIELD	74B	DPWA	$K^- \rho \rightarrow \Lambda(1520)\pi^0$
200±30	LITCHFIELD	74C	DPWA	$K^- p \rightarrow \Delta(1232)\overline{K}$
• • • We do not use the following	g data for average	s, fits	, limits,	etc. • • •
260	DECLAIS	77	DPWA	$\overline{K}N \rightarrow \overline{K}N$
126 to 195	GOYAL	77	DPWA	$K^-N \rightarrow \Sigma \pi$
160	DEBELLEFON	76	IPWA	$K^-p \rightarrow \Lambda \pi^0$
70 to 125	LITCHFIELD	74D	DPWA	$K^- p \rightarrow \Lambda(1820)\pi^0$

Σ(2030) DECAY MODES

	Mode	Fraction (Γ_f/Γ)
Γ ₁	NK	17-23 %
Γ_2	$\Lambda\pi$	17-23 %
Γ_3	$\Sigma \pi$	5-10 %
Γ4	ΞK	<2 %
Γ5	$\Sigma(1385)\pi$	5~15 %
Γ6	$\Sigma(1385)\pi$, F-wave	
Γ7	$\Lambda(1520)\pi$	10-20 %
Γg	$\Lambda(1520)\pi$, D-wave	
و٦	$\Lambda(1520)\pi$, G-wave	
Γ10	$\Delta(1232)\overline{K}$	10-20 %
Γ11	$\Delta(1232)\overline{K}$, F-wave	
Γ12	$\Delta(1232)\overline{K}$, H-wave	
Γ ₁₃	N <i>K</i> *(892)	<5 %
Γ14	$N\overline{K}^*(892)$, $S=1/2$, F_{-} wave	
Γ15	$N\overline{K}^*$ (892), $S=3/2$, F -wave	
Γ ₁₆	$\Lambda(1820)\pi$, P -wave	
	The above branching fractions are	our estimates, not fits or averages.

 $\Sigma(2030), \Sigma(2070)$

Σ(2030) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on Λ and Σ

$ \begin{array}{c c c c c c c c c c c c c c c c c c c $,
DOLUMENT ID TECH COMMENT 1.9 ± 0.03 • • • We do not use the following data for averages, fits, limits, etc. • • • 0.15 0.24 ± 0.02 ($\Gamma_i \Gamma_f \gamma_i^{1/2} / \Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow A\pi$ MALUE 0.02 ($\Gamma_i \Gamma_f \gamma_i^{1/2} / \Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow A\pi$ ($\Gamma_i \Gamma_f \gamma_i^{1/2} / \Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow A\pi$ ($\Gamma_i \Gamma_f \gamma_i^{1/2} / \Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow A\pi$ ($\Gamma_i \Gamma_f \gamma_i^{1/2} / \Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow A\pi$ ($\Gamma_i \Gamma_f \gamma_i^{1/2} / \Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow A\pi$ ($\Gamma_i \Gamma_f \gamma_i^{1/2} / \Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow A\pi$ ($\Gamma_i \Gamma_f \gamma_i^{1/2} / \Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow K\pi$ ($\Gamma_i \Gamma_f \gamma_i^{1/2} / \Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow \Sigma\pi$ ($\Gamma_i \Gamma_f \gamma_i^{1/2} / \Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow \Sigma\pi$ ($\Gamma_i \Gamma_f \gamma_i^{1/2} / \Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow \Sigma\pi$ ($\Gamma_i \Gamma_f \gamma_i^{1/2} / \Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow \Sigma\pi$ ($\Gamma_i \Gamma_f \gamma_i^{1/2} / \Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow \Sigma\pi$ ($\Gamma_i \Gamma_f \gamma_i^{1/2} / \Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow \Sigma\pi$ ($\Gamma_i \Gamma_f \gamma_i^{1/2} / \Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow \Sigma\pi$ ($\Gamma_i \Gamma_f \gamma_i^{1/2} / \Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow \Sigma\pi$ ($\Gamma_i \Gamma_f \gamma_i^{1/2} / \Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow \Sigma\pi$ ($\Gamma_i \Gamma_f \gamma_i^{1/2} / \Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow \Sigma\pi$ ($\Gamma_i \Gamma_f \gamma_i^{1/2} / \Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow \Sigma\pi$ ($\Gamma_i \Gamma_f \gamma_i^{1/2} / \Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow \Sigma\pi$ ($\Gamma_i \Gamma_f \gamma_i^{1/2} / \Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow \Sigma\pi$ ($\Gamma_i \Gamma_f \gamma_i^{1/2} / \Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow \Sigma\pi$ ($\Gamma_i \Gamma_f \gamma_i^{1/2} / \Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow \Sigma\pi$ ($\Gamma_i \Gamma_f \gamma_i^{1/2} / \Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow \Sigma\pi$ ($\Gamma_i \Gamma_f \gamma_i^{1/2} / \Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow \Sigma\pi$ ($\Gamma_i \Gamma_f \gamma_i^{1/2} / \Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow \Sigma\pi$ ($\Gamma_i \Gamma_f \gamma_i^{1/2} / \Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow \Sigma\pi$ ($\Gamma_i \Gamma_f \gamma_i^{1/2} / \Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow \Sigma\pi$ ($\Gamma_i \Gamma_f \gamma_i^{1/2} / \Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow \Sigma\pi$ ($\Gamma_i \Gamma_f \gamma_i^{1/2} / \Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow \Sigma\pi$ ($\Gamma_i \Gamma_f \gamma_i^{1/2} / \Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow \Sigma\pi$ ($\Gamma_i \Gamma_f \gamma_i^{1/2} / \Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow \Sigma\pi$ ($\Gamma_i \Gamma_f \gamma_i^{1/2} / \Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow \Sigma\pi$ ($\Gamma_i \Gamma_f \gamma_i^{1/2} / \Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow \Sigma\pi$ ($\Gamma_i \Gamma_f \gamma_i^{1/2} / \Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow \Sigma\pi$ ($\Gamma_i $	Γ(NK)/Γ······				Γ ₁ /Γ
0.17 to 0.25 OUR ESTIMATE 0.19 ± 0.03 0.19 ± 0.03 0.18 ± 0.03 0.18 ± 0.02 0.24 ± 0.02 0.24 ± 0.02 0.27 0.24 ± 0.02 0.27 0.28 ± 0.02 0.28 ± 0.02 0.28 ± 0.02 0.29 ± 0.01 0.29 ± 0.01 0.29 ± 0.01 0.29 ± 0.01 0.29 ± 0.01 0.20 ± 0.02 0.20	VALUE	DOCUMENT ID		TECN	
HEMINGWAY 75 DPWA $K^-p - K$ N • • We do not use the following data for averages, fits, limits, etc. • • • 0.15 DECLAIS 77 DPWA $K N - K$ N 0.24 ± 0.02 GOPAL 77 DPWA $K N - K$ N Fig. 10.18 ± 0.02 GOPAL 77 DPWA $K N - K$ N 10.18 ± 0.02 GOPAL 77 DPWA $K N - K$ N 10.18 ± 0.02 GOPAL 77 DPWA $K N - K$ N 10.18 ± 0.02 GOPAL 77 DPWA $K N - M$ N 10.18 ± 0.02 GOPAL 77 DPWA $K N - M$ N 10.19 ± 0.03 JC ORDEN 76 DPWA $K N - M$ N 10.19 ± 0.053 DEVENISH 74s Fixed-dispersion rel. 10.20 DEBELLEFON 76 IPWA $K - p - A \pi^0$ 10.20 ± 0.01 JC ORDEN 77c $K - n - K - K$ 10.20 ± 0.01 JC ORDEN 77c $K - n - K - K - M$ 10.20 ± 0.01 JC ORDEN 77c $K - n - K - K - M$ 10.20 ± 0.01 JC ORDEN 77c $K - n - K - K - M$ 10.20 ± 0.01 JC ORDEN 77c $K - n - K - K - M$ 10.20 ± 0.01 JC ORDEN 77c $K - n - K - K - M$ 10.20 ± 0.01 JC ORDEN 77c $K - n - K - K - M - K - M$ 10.21 ± 0.03 GOPAL 77 DPWA $K - p - K - M - M$ 10.22 ± 0.03 GOPAL 77 DPWA $K - p - K - M - M$ 10.23 GOPAL 77 DPWA $K - p - K - M - M - M$ 10.24 ± 0.03 GOPAL 77 DPWA $K - p - K - M - M - M - M - M - M - M - M - M$	0.17 to 0.23 OUR ESTIMATE				
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DOCUMENT ID TECN COMMENT +0.18 ± 0.02 +0.20 ± 0.01 +0.18 ± 0.02 BAILLON 75 IPWA $K = h \to h = h \to h \to h \to h \to h \to h \to h \to h$	0.24±0.02	GOPAL	"	DPWA	See GOPAL 80
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+0.20 ±0.01 +0.18 ±0.02 +0.18 ±0.02 +0.19 ±0.03 +0.19 ±0.03 +0.19 ±0.03 +0.19 ±0.03 +0.19 ±0.03 +0.19 ±0.03 +0.19 ±0.03 +0.19 ±0.03 -0.20 DEBELLEFON 76 IPWA $K \cap p \to \Lambda_{\pi^0}$ DEVENISH 748 Fixed-t dispersion rel. Fixed-tolog (Fixed-tile) Fixed-tolog (Fixed-tile) Fixed-tolog (Fixed-tile) Fixed-tolog (Fixed-tile) Fixed-tolog (Fixed-tile) Fixed-tolog (Fixed-tile) Fixed-tolog (Fixed-tile) Fixed-tolog (Fixed-til	VALUE				COMMENT
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+0.20 ±0.01 +0.195±0.053 • • • We do not use the following data for averages, fits, limits, etc. • • • 0.20 DEBELLEFON 76 IPWA $K^-p \rightarrow \Lambda \pi^0$ (Γ ₁ Γ ₁) ^{1/2} /Γ _{total} in $N\overline{K} \rightarrow \Sigma(2030) \rightarrow \Sigma \pi$ MALUE -0.09 ±0.01 -0.06 ±0.01 -0.06 ±0.01 -0.10 ±0.01 -0.15 ±0.03 GOPAL 77 DPWA \overline{K} N multichannel KANE 74 DPWA \overline{K} N \overline{K} N \overline{K} • • We do not use the following data for averages, fits, limits, etc. • • • -0.085±0.02 3 GOYAL 77 DPWA \overline{K} N \overline{K} N \overline{K} (Γ ₁ Γ ₄) ^{1/2} /Γ MALUE -0.023 MULLER 698 DPWA \overline{K} P → $\overline{E}\overline{K}$ (Γ ₁ Γ ₄) ^{1/2} /Γ MALUE 0.023 MULLER 698 DPWA \overline{K} P → $\overline{E}\overline{K}$ (Γ ₁ Γ ₄) ^{1/2} /Γ MALUE 0.023 MULLER 698 DPWA \overline{K} P → $\overline{E}\overline{K}$ (Γ ₁ Γ ₄) ^{1/2} /Γ MALUE 0.023 MULLER 698 DPWA \overline{K} P → $\overline{E}\overline{K}$ (Γ ₁ Γ ₄) ^{1/2} /Γ MALUE 0.024 COND 1.17 ECN. COMMENT 0.025 BURGUN 68 DPWA \overline{K} P → $\overline{E}\overline{K}$ (Γ ₁ Γ ₄) ^{1/2} /Γ MALUE 0.14±0.02 0.16±0.04 LITCHFIELD 1.12 COMMENT 1.12 COMME					
0.20 DEVENISH 748 Fixed-t dispersion rel. • • • • We do not use the following data for averages, fits, limits, etc. • • • • • • We do not use the following data for averages, fits, limits, etc. • • • (Γ ₁ Γ ₂) ^{1/2} /Γ _{total} in NK → Σ(2030) → Σπ (Γ ₁ Γ ₂) ^{1/2} /Γ _{total} in NK → Σ(2030) → Σπ (Γ ₁ Γ ₃) ^{1/2} /Γ -0.09 ±0.01 2 CORDEN 77C K⁻ n → Σπ -0.06 ±0.01 2 CORDEN 77C K⁻ n → Σπ -0.05 ±0.03 GOPAL 77 DPWA K ¬ p → Σπ -0.10 ±0.01 KANE 74 DPWA K⁻ p → Σπ -0.085±0.02 3 GOYAL 77 DPWA K⁻ N → Σπ (Γ ₁ Γ ₄) ^{1/2} /Γ _{total} in NK → Σ(2030) → ≡ K -0.085±0.02 3 GOYAL 77 DPWA K⁻ N → Σπ (Γ ₁ Γ ₄) ^{1/2} /Γ _{total} in NK → Σ(2030) → ≡ K -0.05 MULLER 698 DPWA K⁻ p → ≡ K -0.05 BURGUN 69 DPWA K⁻ p → ≡ K -0.05 TRIPP 67 RVUE K⁻ p → ≡ K (Γ ₁ Γ ₄) ^{1/2} /Γ total in NK → Σ(2030) → Λ(1820)π, P-wave -0.14±0.02 CORDEN 758 DBC K⁻ n → NKπ⁻ -0.14±0.03 TITCHFIELD 740 DPWA K⁻ p → Λ(1820)π ⁰ -0.14±0.03 TITCHFIELD 740 DPWA K⁻ p → Λ(1820)π ⁰ -0.10±0.03 5 CORDEN 758 DBC K⁻ n → NKπ⁻ (Γ ₁ Γ ₁) ^{1/2} /Γ total in NK → Σ(2030) → Λ(1520)π, G-wave -0.10±0.03 5 CORDEN 758 DBC K⁻ n → NKπ⁻ (Γ ₁ Γ ₁) ^{1/2} /Γ total in NK → Σ(2030) → Λ(1520)π, G-wave -0.10±0.03 5 CORDEN 758 DBC K⁻ n → NKπ⁻ (Γ ₁ Γ ₁) ^{1/2} /Γ total in NK → Σ(2030) → Λ(1520)π, G-wave -0.10±0.03 5 CORDEN 758 DBC K⁻ n → NKπ⁻ (Γ ₁ Γ ₁) ^{1/2} /Γ total in NK → Σ(2030) → Λ(1520)π, G-wave -0.10±0.03 5 CORDEN 758 DBC K⁻ n → NKπ⁻ (Γ ₁ Γ ₁) ^{1/2} /Γ total in NK → Σ(2030) → Λ(1520)π, G-wave -0.17±0.03 5 CORDEN 758 DBC K⁻ n → NKπ⁻ (Γ ₁ Γ ₁) ^{1/2} /Γ total in NK → Σ(2030) → Λ(1232)K, F-wave -0.17±0.03 5 CORDEN 758 DBC K⁻ n → NKπ⁻ (Γ ₁ Γ ₁) ^{1/2} /Γ total in NK → Σ(2030) → Λ(1232)K, F-wave -0.17±0.03 5 CORDEN 78 DPWA K⁻ p → Λ(1520)π ⁰ -0.17±0.03 5 TECN COMMENT -0.16±0.03 TECN COMMENT -0.16±0.03 TECN COMMENT -0.16±0.03 TECN COMMENT -0.16±0.03 TECN COMMENT -0.16±0.03 TECN COMMENT -0.16±0.03 TECN COMMENT -0.16±0.03 TECN COMMENT -0.16±0.03 TECN COMMENT -0.16±0.03 TECN COMMENT -0.16±0.03 TECN COMMENT -0.16±0.03 TECN COMMENT -0.16±0.03 TECN COMMENT -0.16±0.03 TECN COMMENT		BAILLON			
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0.20 DEBELLEFON 76 IPWA $K - p \rightarrow \Lambda \pi^0$ $ (\Gamma_1 \Gamma_f)^{\frac{1}{2}}/\Gamma_{total} \ln N \overrightarrow{K} \rightarrow \Sigma(2030) \rightarrow \Sigma \pi $					
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$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	0.20	DEBELLEFON	10	IPVVA	$K p \rightarrow \Lambda \pi^{-}$
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$ \begin{array}{c} -0.9 \pm 0.01 \\ -0.06 \pm 0.01 \\ -0.06 \pm 0.01 \\ -0.05 \pm 0.03 \\ -0.10 \pm 0.01 \\ \bullet \bullet \bullet \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \$		DOCUMENT ID		TECN	COMMENT ('1'3)
$ \begin{array}{c} -0.06 \pm 0.01 \\ -0.15 \pm 0.03 \\ -0.10 \pm 0.01 \\ +$					
$-0.15 \pm 0.03 \qquad \text{GOPAL} \qquad 77 \text{DPWA} \overline{K} N \text{ multichannel} \\ -0.10 \pm 0.01 \qquad \text{KANE} \qquad 74 \text{DPWA} K^- p \to \Sigma^- \pi$ •• •• We do not use the following data for averages, fits, limits, etc. •• •• $-0.085 \pm 0.02 \qquad \qquad ^3 \text{ GOYAL} \qquad 77 \text{DPWA} K^- P \to \Sigma^- \pi$ $(\Gamma_1 \Gamma_1)^{\frac{1}{12}} / \Gamma_{\text{total}} \ln N \overline{K} \to \Sigma (2030) \to \Xi K \qquad \qquad COMMENT$ $0.023 \qquad \qquad \text{MULLER} \qquad 698 \text{DPWA} K^- p \to \Xi K$ $<0.05 \qquad \qquad \text{BURGUN} \qquad 68 \text{DPWA} K^- p \to \Xi K$ $<0.05 \qquad \qquad \text{TRIPP} \qquad 67 \text{RVUE} K^- p \to \Xi K$ $<0.05 \qquad \qquad \text{TRIPP} \qquad 67 \text{RVUE} K^- p \to \Xi K$ $(\Gamma_1 \Gamma_1)^{\frac{1}{12}} / \Gamma_{\text{total}} \ln N \overline{K} \to \Sigma (2030) \to A (1820) \pi, P \text{-wave} \qquad (\Gamma_1 \Gamma_{16})^{\frac{1}{12}} / \Gamma_{\frac{1}{12}}					
• • • We do not use the following data for averages, fits, limits, etc. • • • • • • • • • • • • • • • • • • •		GOPAL			
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0.023 MULLER 698 DPWA $K^-p \rightarrow \Xi K$ 8URGUN 68 DPWA $K^-p \rightarrow \Xi K$ 8URGUN 75 BDBC $K^-n \rightarrow NK\pi^-$ 8ULUE 8DCCUMENT ID 758 DBC $K^-n \rightarrow NK\pi^-$ 8ULUE 9DCCUMENT ID 758 DBC $K^-n \rightarrow NK\pi^-$ 8ULUE 9DCCUMENT ID 758 DBC $K^-n \rightarrow NK\pi^-$ 8ULUE 9DCCUMENT ID 7DPWA $K^-p \rightarrow \Lambda(1520)\pi^0$ 8 • • We do not use the following data for averages, fits, limits, etc. • • • • • • • • • • • • • • • • • • •				TECN	
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$(\Gamma_{1}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow A(1820)\pi, P-wave \qquad (\Gamma_{1}\Gamma_{16})^{\frac{1}{2}}/\Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow A(1820)\pi, P-wave \qquad (\Gamma_{1}\Gamma_{16})^{\frac{1}{2}}/\Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow A(1820)\pi, P-wave \qquad (\Gamma_{1}\Gamma_{16})^{\frac{1}{2}}/\Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow A(1520)\pi, D-wave \qquad (\Gamma_{1}\Gamma_{16})^{\frac{1}{2}}/\Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow A(1520)\pi, D-wave \qquad (\Gamma_{1}\Gamma_{16})^{\frac{1}{2}}/\Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow A(1520)\pi, D-wave \qquad (\Gamma_{1}\Gamma_{16})^{\frac{1}{2}}/\Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow A(1520)\pi, D-wave \qquad (\Gamma_{1}\Gamma_{16})^{\frac{1}{2}}/\Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow A(1520)\pi, D-wave \qquad (\Gamma_{1}\Gamma_{16})^{\frac{1}{2}}/\Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow A(1520)\pi, G-wave \qquad (\Gamma_{1}\Gamma_{1})^{\frac{1}{2}}/\Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow A(1520)\pi, G-wave \qquad (\Gamma_{1}\Gamma_{1})^{\frac{1}{2}}/\Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow A(1520)\pi, G-wave \qquad (\Gamma_{1}\Gamma_{1})^{\frac{1}{2}}/\Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow A(1232)K, F-wave \qquad (\Gamma_{1}\Gamma_{1})^{\frac{1}{2}}/\Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow A(1232)K, F-wave \qquad (\Gamma_{1}\Gamma_{1})^{\frac{1}{2}}/\Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow \Delta(1232)K, F-wave \qquad (\Gamma_{1}\Gamma_{1})^{\frac{1}{2}}/\Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow \Delta(1232)K, F-wave \qquad (\Gamma_{1}\Gamma_{1})^{\frac{1}{2}}/\Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow \Delta(1232)K, F-wave \qquad (\Gamma_{1}\Gamma_{12})^{\frac{1}{2}}/\Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow \Delta(1232)K, F-wave \qquad (\Gamma_{1}\Gamma_{12})^{\frac{1}{2}}/\Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow \Delta(1232)K, F-wave \qquad (\Gamma_{1}\Gamma_{12})^{\frac{1}{2}}/\Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow \Sigma(1385)\pi \qquad (\Gamma_{1}\Gamma_{12})^{\frac{1}{2}}/\Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow \Sigma(1385)\pi \qquad (\Gamma_{1}\Gamma_{12})^{\frac{1}{2}}/\Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow NK^*(892), S=1/2, F-wave \qquad (\Gamma_{1}\Gamma_{14})^{\frac{1}{2}}/\Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow NK^*(892), S=1/2, F-wave \qquad (\Gamma_{1}\Gamma_{14})^{\frac{1}{2}}/\Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow NK^*(892), S=1/2, F-wave \qquad (\Gamma_{1}\Gamma_{14})^{\frac{1}{2}}/\Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow NK^*(892), S=1/2, F-wave \qquad (\Gamma_{1}\Gamma_{14})^{\frac{1}{2}}/\Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow NK^*(892), S=1/2, F-wave \qquad (\Gamma_{1}\Gamma_{14})^{\frac{1}{2}}/\Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow NK^*(892), S=1/2, F-wave \qquad (\Gamma_{1}\Gamma_{14})^{\frac{1}{2}}/\Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow NK^*(892), S=1/2, F-wave \qquad (\Gamma_{1}\Gamma_{14})^{\frac{1}{2}}/\Gamma_{total} \ln NK \rightarrow \Sigma(2030) \rightarrow NK^*(892), S=1/2, F-wave \qquad (\Gamma_{1}\Gamma_{14})^{\frac{1}{2}}/\Gamma_{total} \ln NK \rightarrow \Sigma(2$					
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$\begin{array}{c ccccccccccccccccccccccccccccccccccc$		*****			
0.14 \pm 0.02 0.18 \pm 0.04 CORDEN 75B DBC $K^- n \rightarrow N\overline{K}\pi^-$ 0.18 \pm 0.04 CORDEN 74D DPWA $K^- p \rightarrow \Lambda(1820)\pi^0$ $ \begin{pmatrix} (\Gamma_1 \Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\overline{K} \rightarrow \Sigma(2030) \rightarrow \Lambda(1520)\pi, D\text{-wave} \\ DOCUMENT ID TECN COMMENT \\ -0.114 \pm 0.010 \\ 0.14 \pm 0.03 \\ \bullet \bullet \bullet \text{We do not use the following data for averages, fits, limits, etc.} \bullet \bullet \bullet \bullet \bullet \bullet \bullet \bullet \bullet \bullet \bullet \bullet \bullet \bullet \bullet \bullet \bullet \bullet \bullet$					
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	0.14±0.02				
VALUE 0.14 ± 0.010 0.14 ± 0.03 0.10 ± 0.010 0.10 ± 0.010 0.10 ± 0.02 0.10 ± 0.02 0.10 ± 0.02 0.10 ± 0.02 0.10 ± 0.03 0.10	0.18 ± 0.04	LITCHFIELD	740	DPWA	$K^- p \rightarrow \Lambda(1820)\pi^0$
VALUE 0.14 ± 0.010 0.14 ± 0.03 0.10 ± 0.010 0.10 ± 0.010 0.10 ± 0.02 0.10 ± 0.02 0.10 ± 0.02 0.10 ± 0.02 0.10 ± 0.03 0.10	(E E) 1/2 E 1/2 E 1/2		٠.		
+0.114 ± 0.010 0.14 ± 0.03 • • • We do not use the following data for averages, fits, limits, etc. • • • 0.10 ± 0.03 • • \(\text{CAMERON} \) 75B DBC \(K^- n \to N \overline{K} \pi^{1/2} / \rac{1}{\text{Fotal}} \] In $N \overline{K} \rightarrow \Sigma(2030) \rightarrow \Lambda(1520) \pi$, G-wave (\(\Gamma_1 \Gamma_1 \cdot \cdo \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdot \cdo	(! /) f) "/! total in WK → 2 (2)	$(152) \rightarrow N(152)$	υ)π	, D-Wav	(118)"/I
0.14 \pm 0.03 LITCHFIELD 74B DPWA $K^-p \rightarrow \Lambda(1520)\pi^0$ • • • We do not use the following data for averages, fits, limits, etc. • • • • 0.10 \pm 0.03 5 CORDEN 75B DBC $K^-n \rightarrow N\overline{K}\pi^-$ $ (\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow \Sigma(2030) \rightarrow \Lambda(1520)\pi, G\text{-wave} \qquad (\Gamma_1\Gamma_9)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow \Sigma(2030) \rightarrow \Lambda(1520)\pi, G\text{-wave} \qquad (\Gamma_1\Gamma_9)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow \Sigma(2030) \rightarrow \Lambda(1520)\pi, G\text{-wave} \qquad (\Gamma_1\Gamma_9)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow \Sigma(2030) \rightarrow \Lambda(1520)\pi, G\text{-wave} \qquad (\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow \Sigma(2030) \rightarrow \Lambda(1232)\overline{K}, F\text{-wave} \qquad (\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow \Sigma(2030) \rightarrow \Lambda(1232)\overline{K}, F\text{-wave} \qquad (\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow \Sigma(2030) \rightarrow \Lambda(1232)\overline{K}, F\text{-wave} \qquad (\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow \Sigma(2030) \rightarrow \Lambda(1232)\overline{K}, F\text{-wave} \qquad (\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow \Sigma(2030) \rightarrow \Sigma(1385)\pi \qquad (\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow \Sigma(2030) \rightarrow \Sigma(1385)\pi \qquad (\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow \Sigma(2030) \rightarrow \Sigma(1385)\pi \qquad (\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow \Sigma(2030) \rightarrow \Sigma(1385)\pi \qquad (\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow \Sigma(2030) \rightarrow N\overline{K}^*(892), S=1/2, F\text{-wave} \qquad (\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow \Sigma(2030) \rightarrow N\overline{K}^*(892), S=1/2, F\text{-wave} \qquad (\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow \Sigma(2030) \rightarrow N\overline{K}^*(892), S=1/2, F\text{-wave} \qquad (\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow \Sigma(2030) \rightarrow N\overline{K}^*(892), S=1/2, F\text{-wave} \qquad (\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_1 \rightarrow 0.00\pm0.03 \qquad (\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_1 \rightarrow 0.00\pm0.03 \qquad (\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_1 \rightarrow 0.00\pm0.03 \qquad (\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_1 \rightarrow 0.00\pm0.03 \qquad (\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_1 \rightarrow 0.00\pm0.03 \qquad (\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_1 \rightarrow 0.00\pm0.03 \qquad (\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_1 \rightarrow 0.00\pm0.03 \qquad (\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_1 \rightarrow 0.00\pm0.03 \qquad (\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_1 \rightarrow 0.00\pm0.03 \qquad (\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_1 \rightarrow 0.00\pm0.03 \qquad (\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_1 \rightarrow 0.00\pm0.03 \qquad (\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_1 \rightarrow 0.00\pm0.03 \qquad (\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_1 \rightarrow 0.00\pm0.03 \qquad (\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_1 \rightarrow 0.00\pm0.03 \qquad (\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_1 \rightarrow 0.00\pm0.03 \qquad (\Gamma_1\Gamma_1)$	+0.114+0.010	4 CAMERON	77	D D W/A	K- n - A(1520)=0
• • • We do not use the following data for averages, fits, limits, etc. • • • • • • 0.10 \pm 0.03		LITCHEIELD	749	DPWA	$K^- \eta \rightarrow \Lambda(1520)\pi^0$
0.10 \pm 0.03					
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$					
VALUE $+0.146\pm0.010 \qquad 4 \text{ CAMERON } \qquad 77 \text{ DPWA } \qquad K^-p \rightarrow \Lambda(1520)\pi^0$ $0.02\pm0.02 \qquad \text{LITCHFIELD } \qquad 748 \text{ DPWA } \qquad K^-p \rightarrow \Lambda(1520)\pi^0$ $(\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ In } N\overline{K} \rightarrow \Sigma(2030) \rightarrow \Delta(1232)\overline{K}, F\text{-wave} \qquad (\Gamma_1\Gamma_{11})^{\frac{1}{2}}/\Gamma_{\text{NALUE}} \qquad DOCUMENT :D \qquad TECN \qquad COMMENT$ $0.16\pm0.03 \qquad \text{LITCHFIELD } \qquad 74c \text{ DPWA } \qquad K^-p \rightarrow \Delta(1232)\overline{K}$ $\bullet \bullet \text{ We do not use the following data for averages, fits, limits, etc. } \bullet \bullet \bullet$ $0.17\pm0.03 \qquad 5 \text{ CORDEN } \qquad 758 \text{ DBC } \qquad K^-n \rightarrow N\overline{K}\pi^-$ $(\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ In } N\overline{K} \rightarrow \Sigma(2030) \rightarrow \Delta(1232)\overline{K}, H\text{-wave} \qquad (\Gamma_1\Gamma_{12})^{\frac{1}{2}}/\Gamma_{\text{NALUE}} \qquad DOCUMENT :D \qquad TECN \qquad COMMENT$ $0.00\pm0.02 \qquad \text{LITCHFIELD } \qquad 74c \text{ DPWA } \qquad K^-p \rightarrow \Delta(1232)\overline{K}$ $(\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow \Sigma(2030) \rightarrow \Sigma(1385)\pi \qquad (\Gamma_1\Gamma_5)^{\frac{1}{2}}/\Gamma_{\text{NALUE}} \qquad DOCUMENT :D \qquad TECN \qquad COMMENT$ $+0.153\pm0.026 \qquad 4 \text{ CAMERON } \qquad 78 \text{ DPWA } \qquad K^-p \rightarrow \Sigma(1385)\pi$ $(\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow \Sigma(2030) \rightarrow N\overline{K}^*(892), S=1/2, F\text{-wave}$ $(\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow \Sigma(2030) \rightarrow N\overline{K}^*(892), S=1/2, F\text{-wave}$ $(\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow \Sigma(2030) \rightarrow N\overline{K}^*(892), S=1/2, F\text{-wave}$ $(\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow \Sigma(2030) \rightarrow N\overline{K}^*(892), S=1/2, F\text{-wave}$ $(\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow \Sigma(2030) \rightarrow N\overline{K}^*(892), S=1/2, F\text{-wave}$ $(\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow \Sigma(2030) \rightarrow N\overline{K}^*(892), S=1/2, F\text{-wave}$ $(\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow \Sigma(2030) \rightarrow N\overline{K}^*(892), S=1/2, F\text{-wave}$ $(\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow \Sigma(2030) \rightarrow N\overline{K}^*(892), S=1/2, F\text{-wave}$ $(\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow \Sigma(2030) \rightarrow N\overline{K}^*(892), S=1/2, F\text{-wave}$					_
VALUE $+0.146\pm0.010 \qquad 4 \text{ CAMERON } 77 \text{ DPWA } K^-p \rightarrow \Lambda(1520)\pi^0$ $0.02\pm0.02 \qquad \text{LITCHFIELD } 748 \text{ DPWA } K^-p \rightarrow \Lambda(1520)\pi^0$ $(\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\overline{K} \rightarrow \Sigma(2030) \rightarrow \Delta(1232)\overline{K}, F\text{-wave} \qquad (\Gamma_1\Gamma_{11})^{\frac{1}{2}}/\Gamma_{\text{DOCUMENT }1D} \qquad \text{TECN} \qquad \text{COMMENT}$ $0.16\pm0.03 \qquad \text{LITCHFIELD } 74c \text{ DPWA } K^-p \rightarrow \Delta(1232)\overline{K}$ $\bullet \bullet \text{ We do not use the following data for averages, fits, limits, etc. } \bullet \bullet \bullet$ $0.17\pm0.03 \qquad 5 \text{ CORDEN } 758 \text{ DBC } K^-n \rightarrow N\overline{K}\pi^-$ $(\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\overline{K} \rightarrow \Sigma(2030) \rightarrow \Delta(1232)\overline{K}, H\text{-wave} \qquad (\Gamma_1\Gamma_{12})^{\frac{1}{2}}/\Gamma_{\text{NALUE}} \qquad DOCUMENT 1D \qquad IECN \qquad COMMENT$ $0.00\pm0.02 \qquad \text{LITCHFIELD } 74c \text{ DPWA } K^-p \rightarrow \Delta(1232)\overline{K}$ $(\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\overline{K} \rightarrow \Sigma(2030) \rightarrow \Sigma(1385)\pi \qquad (\Gamma_1\Gamma_5)^{\frac{1}{2}}/\Gamma_{\text{NALUE}} \qquad DOCUMENT 1D \qquad IECN \qquad COMMENT$ $+0.153\pm0.026 \qquad 4 \text{ CAMERON } 78 \text{ DPWA } K^-p \rightarrow \Sigma(1385)\pi$ $(\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\overline{K} \rightarrow \Sigma(2030) \rightarrow N\overline{K}^*(892), S=1/2, F\text{-wave}$ $(\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\overline{K} \rightarrow \Sigma(2030) \rightarrow N\overline{K}^*(892), S=1/2, F\text{-wave}$ $(\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\overline{K} \rightarrow \Sigma(2030) \rightarrow N\overline{K}^*(892), S=1/2, F\text{-wave}$ $(\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\overline{K} \rightarrow \Sigma(2030) \rightarrow N\overline{K}^*(892), S=1/2, F\text{-wave}$ $(\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\overline{K} \rightarrow \Sigma(2030) \rightarrow N\overline{K}^*(892), S=1/2, F\text{-wave}$ $(\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\overline{K} \rightarrow \Sigma(2030) \rightarrow N\overline{K}^*(892), S=1/2, F\text{-wave}$ $(\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\overline{K} \rightarrow \Sigma(2030) \rightarrow N\overline{K}^*(892), S=1/2, F\text{-wave}$ $(\Gamma_1\Gamma_1)^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\overline{K} \rightarrow \Sigma(2030) \rightarrow N\overline{K}^*(892), S=1/2, F\text{-wave}$	$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N \overline{K} \to \Sigma(2)$	030) → <i>1</i> (152	0)π	, G-wav	•e (Γ ₁ Γ ₉) ^⅓ /Γ
0.02 \pm 0.02 LITCHFIELD 74B DPWA $K^-p \rightarrow \Lambda(1520)\pi^0$ $ (\Gamma_1\Gamma_f)^{\frac{1}{12}}/\Gamma_{\text{total}} \ln N\overline{K} \rightarrow \mathcal{E}(2030) \rightarrow \Delta(1232)\overline{K}, F\text{-wave} \qquad (\Gamma_1\Gamma_{11})^{\frac{1}{12}}/\Gamma_{\text{value}} \qquad DOCUMENT ID IECN COMMENT ID ITCH IN INTERPOLATION I$	VALUE	DOCUMENT ID		TECN	COMMENT
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$					
VALUE DOCUMENT ID LITCHFIELD TECN COMMENT LITCHFIELD TACL DPWA $K^-p \rightarrow \Delta(1232)\overline{K}$ * • • We do not use the following data for averages, fits, limits, etc. • • • 0.17 ± 0.03 5 CORDEN 758 DBC $K^-n \rightarrow N\overline{K}\pi^-$ ($\Gamma_1\Gamma_1$) ^{1/2} / Γ_{total} in $N\overline{K} \rightarrow \Sigma(2030) \rightarrow \Delta(1232)\overline{K}$, H -wave $(\Gamma_1\Gamma_1)^{1/2}/\Gamma_{total}$ $\frac{DOCUMENT ID}{1}$ $\frac{TECN}{1}$ $\frac{COMMENT}{1}$ $\frac{TECN}{1}$ $\frac{COMMENT}{1}$ $\frac{TECN}{1}$ $\frac{COMMENT}{1}$ $\frac{VALUE}{1}$ $\frac{DOCUMENT ID}{1}$ $\frac{TECN}{1}$ $\frac{COMMENT}{1}$ $\frac{VALUE}{1}$ $\frac{DOCUMENT ID}{1}$ $\frac{TECN}{1}$ $\frac{COMMENT}{1}$ $\frac{TECN}{1}$ $\frac{COMMENT}{1}$ $\frac{VALUE}{1}$ $\frac{TECN}{1}$ $\frac{COMMENT}{1}$ $\frac{TECN}{1}$ $\frac{TECN}{1}$ $\frac{COMMENT}{1}$ $\frac{TECN}{1}$ \frac	0.02 ±0.02	LITCHFIELD	748	DPWA	$K^- p \rightarrow \Lambda(1520) \pi^0$
VALUE DOCUMENT ID LITCHFIELD TECN COMMENT O.16 \pm 0.03 • • • We do not use the following data for averages, fits, limits, etc. • • • 0.17 \pm 0.03 5 CORDEN 758 DBC $K^- n \rightarrow N\overline{K}\pi^-$ ($\Gamma_1\Gamma_1$) $\frac{1}{2}$ / Γ_{total} in $N\overline{K} \rightarrow \Sigma$ (2030) $\rightarrow \Delta$ (1232) \overline{K} , \overline{H} -wave ($\Gamma_1\Gamma_1$) $\frac{1}{2}$ / Γ_{total} in $N\overline{K} \rightarrow \Sigma$ (2030) $\rightarrow \Sigma$ (1385) π COUMENT ID LITCHFIELD TECN COMMENT ($\Gamma_1\Gamma_1$) $\frac{1}{2}$ / Γ_{total} ($\Gamma_1\Gamma_1$) $\frac{1}{2}$ / Γ_1 TECN COMMENT ($\Gamma_1\Gamma_1$) $\frac{1}{2}$ / Γ_1 TECN COMMENT ($\Gamma_1\Gamma_1$) $\frac{1}{2}$ / Γ_2 TECN COMMENT ($\Gamma_1\Gamma_1$) $\frac{1}{2}$ / Γ_3 TECN COMMENT ($\Gamma_1\Gamma_1$) $\frac{1}{2}$ / Γ_4 TECN COMMENT TECN COMMENT ($\Gamma_1\Gamma_1$) $\frac{1}{2}$ / Γ_4 TECN COMMENT TECN COMMENT ($\Gamma_1\Gamma_1$) $\frac{1}{2}$ / Γ_4 TECN COMMENT TECN COMMENT ($\Gamma_1\Gamma_1$) $\frac{1}{2}$ / Γ_4 TECN COMMENT TECN TECN TECN TECN TECN TECN TECN	(F F) 1/2 - 1/2 - 1/2	000\ 4/100	no\T	7 F	··· (F 5 1/2 /F
0.16 \pm 0.03		DOCUMENT IO	14 J	TECN	VG (1111)'-/
• • • We do not use the following data for averages, fits, limits, etc. • • • • • • • • • • • • • • • • • • •		DOCUMENT ID		IECN	COMMENT
0.17 \pm 0.03 5 CORDEN 75B DBC $K^-n \rightarrow N\overline{K}\pi^-$ $(\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\overline{K} \rightarrow \Sigma(2030) \rightarrow \Delta(1232)\overline{K}, H\text{-wave} \qquad (\Gamma_1\Gamma_{12})^{\frac{1}{2}}/\Gamma_{\text{DOCUMENT } D } \qquad \underline{\text{TECN}} \qquad \underline{\text{COMMENT}}$ 0.00 \pm 0.02 LITCHFIELD 74C DPWA $K^-p \rightarrow \Delta(1232)\overline{K}$ $(\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\overline{K} \rightarrow \Sigma(2030) \rightarrow \Sigma(1385)\pi \qquad (\Gamma_1\Gamma_5)^{\frac{1}{2}}/\Gamma_{\text{DOCUMENT } D } \qquad \underline{\text{TECN}} \qquad \underline{\text{COMMENT}}$ +0.153 \pm 0.026 4 CAMERON 78 DPWA $K^-p \rightarrow \Sigma(1385)\pi$ $(\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\overline{K} \rightarrow \Sigma(2030) \rightarrow N\overline{K}^*(892), S=1/2, F\text{-wave}$ $\frac{VALUE}{+0.06\pm0.03} \qquad \frac{DOCUMENT D }{4} \qquad \underline{\text{TECN}} \qquad \underline{\text{COMMENT}}$ +0.06 \pm 0.03 4 CAMERON 78B DPWA $K^-p \rightarrow N\overline{K}^*$	0.16+0.03	LITCHEIEID	740	DD\A/A	K=n → A(1232)¥
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$			740	DPWA	$K^-p \rightarrow \Delta(1232)\overline{K}$
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	• • • We do not use the following	data for average	740 s, flt	DPWA s, limits,	$K^- p \rightarrow \Delta(1232)\overline{K}$ etc. • • •
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	• • • We do not use the following 0.17 ± 0.03	data for average 5 CORDEN	740 s, fit 758	DPWA s, limits, DBC	$K^- p \rightarrow \Delta(1232)\overline{K}$ etc. • • • $K^- n \rightarrow N\overline{K}\pi^-$
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	• • • We do not use the following 0.17 ± 0.03	data for average 5 CORDEN	740 s, fit 758	DPWA s, limits, DBC	$K^- p \rightarrow \Delta(1232)\overline{K}$ etc. • • • $K^- n \rightarrow N\overline{K}\pi^-$
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	• • • We do not use the following 0.17 ± 0.03 $(\Gamma_1 \Gamma_T)^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N \overline{K} \rightarrow \Sigma(2)$	data for average 5 CORDEN $030) \rightarrow \Delta(123)$	740 s, fit 758 32)7	DPWAs, limits, DBC	$K^- p \rightarrow \Delta(1232) \overline{K}$ etc. • • • $K^- n \rightarrow N \overline{K} \pi^-$ eve $(\Gamma_1 \Gamma_{12})^{\frac{1}{2}} / \Gamma$
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	• • • We do not use the following 0.17 ± 0.03 $ (\Gamma_{I}\Gamma_{I})^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\overline{K} \rightarrow \Sigma(2) $ YALUE	data for average ⁵ CORDEN 030) → Δ(123 DOCUMENT ID	740 s, fit: 758 32) 7	DPWA s, limits, DBC , H-wa TECN_	$K^- p \rightarrow \Delta(1232) \overline{K}$ etc. • • • $K^- n \rightarrow N \overline{K} \pi^-$ eve $(\Gamma_1 \Gamma_{12})^{\frac{1}{2}} / \Gamma$ $COMMENT$
+0.153±0.026 4 CAMERON 78 DPWA $K^-p \rightarrow \Sigma(1385)\pi$ $(\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow \Sigma(2030) \rightarrow N\overline{K}^*(892), S=1/2, F-\text{wave}$ $(\Gamma_1\Gamma_f)^{\frac{1}{2}}/\Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow \Sigma(2030) \rightarrow N\overline{K}^*(892), S=1/2, F-\text{wave}$ $(\Gamma_1\Gamma_{14})^{\frac{1}{2}}/\Gamma_{\text{total}}$ +0.06±0.03 4 CAMERON 78B DPWA $K^-p \rightarrow N\overline{K}^*$	• • • We do not use the following 0.17 ± 0.03 $ \frac{\left(\Gamma_{I}\Gamma_{F}\right)^{\frac{1}{2}}}{\Gamma_{\text{total}} \ln NK} \rightarrow \Sigma(24) \times 24 \times 100 \times 1$	data for average 5 CORDEN 030) → △(123 DOCUMENT ID LITCHFIELD	740 s, fit: 758 32) 7	DPWA s, limits, DBC , H-wa TECN	$\begin{array}{ccc} K^-p \to \Delta(1232)\overline{K} \\ \text{etc.} \bullet \bullet \bullet \\ K^-n \to N\overline{K}\pi^- \end{array}$ $\begin{array}{ccc} K^-n \to N\overline{K}\pi^- \\ \text{owe} & (\Gamma_1\Gamma_{12})^{\frac{1}{2}}/\Gamma \\ \frac{COMMENT}{K^-p \to \Delta(1232)\overline{K}} \end{array}$
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	• • • We do not use the following 0.17 ± 0.03 $ \frac{\left(\Gamma_{l}\Gamma_{f}\right)^{\frac{1}{2}}}{\Gamma_{total}\ln NK} \to \mathcal{E}(2t) $ $ \frac{VALUE}{0.00\pm0.02} $ $ \frac{\left(\Gamma_{l}\Gamma_{f}\right)^{\frac{1}{2}}}{\Gamma_{total}\ln NK} \to \mathcal{E}(2t) $ $ \frac{VALUE}{VALUE} $	data for average ⁵ CORDEN 030) → Δ(123 <u>DOCUMENT ID</u> LITCHFIELD 030) → Σ(136 DOCUMENT ID	740 s, fit: 758 32) 7 740	DPWA s, limits, DBC 7, H-wa TECN TECN	$K^- p \rightarrow \Delta(1232)\overline{K}$ etc. • • • $K^- n \rightarrow N\overline{K}\pi^-$ $K^- p \rightarrow \Delta(1232)\overline{K}$ $K^- p \rightarrow \Delta(1232)\overline{K}$ $(\Gamma_1 \Gamma_5)^{1/2}/\Gamma$ $COMMENT$ $COMMENT$
YALUE DOCUMENT ID TECN COMMENT $+0.06\pm0.03$ CAMERON 78B DPWA $K^-p \rightarrow N\overline{K}^*$	• • • We do not use the following 0.17 ± 0.03 $ \frac{\left(\Gamma_{l}\Gamma_{f}\right)^{\frac{1}{2}}}{\Gamma_{total}\ln NK} \to \mathcal{E}(2t) $ $ \frac{VALUE}{0.00\pm0.02} $ $ \frac{\left(\Gamma_{l}\Gamma_{f}\right)^{\frac{1}{2}}}{\Gamma_{total}\ln NK} \to \mathcal{E}(2t) $ $ \frac{VALUE}{VALUE} $	data for average ⁵ CORDEN 030) → Δ(123 <u>DOCUMENT ID</u> LITCHFIELD 030) → Σ(136 DOCUMENT ID	740 s, fit: 758 32) 7 740	DPWA s, limits, DBC 7, H-wa TECN TECN	$K^- p \rightarrow \Delta(1232)\overline{K}$ etc. • • • $K^- n \rightarrow N\overline{K}\pi^-$ $K^- p \rightarrow \Delta(1232)\overline{K}$ $K^- p \rightarrow \Delta(1232)\overline{K}$ $(\Gamma_1 \Gamma_5)^{1/2}/\Gamma$ $COMMENT$ $COMMENT$
+0.06±0.03 $\frac{DOCUMENT\ ID}{4}$ CAMERON 78B DPWA $K^-p \rightarrow N\overline{K}^*$	• • • We do not use the following 0.17 ± 0.03 $(\Gamma_{I}\Gamma_{I})^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\overline{K} \rightarrow \Sigma(2)$ $\frac{VALUE}{0.00 \pm 0.02}$ $(\Gamma_{I}\Gamma_{I})^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\overline{K} \rightarrow \Sigma(2)$ $\frac{VALUE}{VALUE}$ + 0.153 \pm 0.026	data for average ⁵ CORDEN 030) → Δ(123 <u>DOCUMENT ID</u> LITCHFIELD 030) → Σ(136 <u>DOCUMENT ID</u> ⁴ CAMERON	740 5, fit: 756 32) 740 35) π	DPWA TECN DPWA DPWA	$K^- p \rightarrow \Delta(1232)\overline{K}$ etc. • • • $K^- n \rightarrow N\overline{K}\pi^-$ $K^- p \rightarrow \Delta(1232)\overline{K}$ $K^- p \rightarrow \Delta(1232)\overline{K}$ $(\Gamma_1 \Gamma_5)^{1/2}/\Gamma$ $COMMENT$ $K^- p \rightarrow \Sigma(1385)\pi$
+0.06±0.03 $\frac{DOCUMENT\ ID}{4}$ CAMERON 78B DPWA $K^-p \rightarrow N\overline{K}^*$	• • • We do not use the following 0.17 ± 0.03 $(\Gamma_{I}\Gamma_{I})^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\overline{K} \rightarrow \Sigma(2t)$ $\frac{VALUE}{0.00\pm0.02}$ $(\Gamma_{I}\Gamma_{I})^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\overline{K} \rightarrow \Sigma(2t)$ $\frac{VALUE}{VALUE}$ +0.153±0.026	data for average ⁵ CORDEN 030) → Δ(123 <u>DOCUMENT ID</u> LITCHFIELD 030) → Σ(136 <u>DOCUMENT ID</u> ⁴ CAMERON	740 5, fit: 756 32) 740 35) π	DPWA TECN DPWA DPWA	$K^-p \rightarrow \Delta(1232)\overline{K}$ etc. • • • $K^-n \rightarrow N\overline{K}\pi^-$ $K^-n \rightarrow N\overline{K}\pi^ K^-p \rightarrow \Delta(1232)\overline{K}$ $K^-p \rightarrow \Delta(1232)\overline{K}$ $K^-p \rightarrow \Sigma(1385)\pi$ $K^-p \rightarrow \Sigma(1385)\pi$
$+0.06\pm0.03$ 4 CAMERON 788 DPWA $K^-p \rightarrow N\overline{K}^*$	• • • We do not use the following 0.17 ± 0.03 $(\Gamma_{I}\Gamma_{I})^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\overline{K} \rightarrow \Sigma(2t)$ $\frac{VALUE}{0.00\pm0.02}$ $(\Gamma_{I}\Gamma_{I})^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\overline{K} \rightarrow \Sigma(2t)$ $\frac{VALUE}{VALUE}$ +0.153±0.026	data for average 5 CORDEN 030) → ∆(123 DOCUMENT ID. LITCHFIELD 030) → ∑(138 DOCUMENT ID. 4 CAMERON 030) → N¼*(74c 75e 75e 74c 74c 78 78	DPWA TECN DPWA TECN DPWA TECN DPWA	$K^-p \rightarrow \Delta(1232)\overline{K}$ etc. • • • $K^-n \rightarrow N\overline{K}\pi^ K^-n \rightarrow N\overline{K}\pi^ K^-p \rightarrow \Delta(1232)\overline{K}$ $K^-p \rightarrow \Delta(1232)\overline{K}$ $K^-p \rightarrow \Sigma(1385)\pi$ $K^-p \rightarrow \Sigma(1385)\pi$ $K^-p \rightarrow \Sigma(1385)\pi$
-0.02 ± 0.01 CORDEN 77B $K^-d \rightarrow NN\overline{K}^*$	• • • We do not use the following 0.17 ± 0.03 $ \frac{(\Gamma_{I}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\overline{K} \rightarrow \Sigma(2)}{NALUE} = 0.00\pm0.02$ $ \frac{(\Gamma_{I}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\overline{K} \rightarrow \Sigma(2)}{NALUE} = 0.153\pm0.026$ $ \frac{(\Gamma_{I}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\overline{K} \rightarrow \Sigma(2)}{(\Gamma_{I}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\overline{K} \rightarrow \Sigma(2)} = 0.153\pm0.026$	data for average 5 CORDEN 030) → ∆(123 DOCUMENT ID. LITCHFIELD 030) → ∑(138 DOCUMENT ID. 4 CAMERON 030) → N¼*(74cc 758 74cc 758 74cc 758 74cc 758 78 78 78	DPWA TECN DPWA TECN DPWA TECN DPWA TECN DPWA	$K^-p \rightarrow \Delta(1232)\overline{K}$ etc. • • • $K^-n \rightarrow N\overline{K}\pi^ K^-n \rightarrow N\overline{K}\pi^ K^-p \rightarrow \Delta(1232)\overline{K}$ $K^-p \rightarrow \Delta(1232)\overline{K}$ $K^-p \rightarrow \Sigma(1385)\pi$ $K^-p \rightarrow \Sigma(1385)\pi$ $K^-p \rightarrow \Sigma(1385)\pi$
	• • • We do not use the following 0.17 ± 0.03 $(\Gamma_{I}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\overline{K} \rightarrow \Sigma(2t)$ $\frac{VALUE}{0.00 \pm 0.02}$ $(\Gamma_{I}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\overline{K} \rightarrow \Sigma(2t)$ $\frac{VALUE}{VALUE}$ + 0.153 \pm 0.026 $(\Gamma_{I}\Gamma_{f})^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\overline{K} \rightarrow \Sigma(2t)$ $\frac{VALUE}{VALUE}$	data for average 5 CORDEN 030) → ∆(122 DOCUMENT ID LITCHFIELD 030) → ∑(136 DOCUMENT ID 4 CAMERON 030) → NK*(DOCUMENT ID 4 CAMERON	74cc 75e 75e 75e 74cc 75e 74cc 75e 74cc 76e 78e 78e 78e 78e 78e 78e 78e 78e 78e 78	DPWA DBC TECN DPWA TECN DPWA TECN DPWA TECN DPWA TECN DPWA	$K^- p \rightarrow \Delta(1232)\overline{K}$ etc. • • • $K^- n \rightarrow N\overline{K}\pi^-$ $K^- p \rightarrow \Delta(1232)\overline{K}$ $(\Gamma_1\Gamma_2)^{\frac{1}{2}}/\Gamma$ $\frac{COMMENT}{K^- p \rightarrow \Sigma(1385)\pi}$ $\frac{(\Gamma_1\Gamma_4)^{\frac{1}{2}}/\Gamma}{K^- p \rightarrow N\overline{K}^+}$
	• • • We do not use the following 0.17 ± 0.03 $(\Gamma_{I}\Gamma_{I})^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\overline{K} \rightarrow \Sigma(2t)$ $\frac{VALUE}{0.00\pm0.02}$ $(\Gamma_{I}\Gamma_{I})^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\overline{K} \rightarrow \Sigma(2t)$ $\frac{VALUE}{+0.153\pm0.026}$ $(\Gamma_{I}\Gamma_{I})^{\frac{1}{2}}/\Gamma_{\text{total}} \ln N\overline{K} \rightarrow \Sigma(2t)$ $\frac{VALUE}{+0.06\pm0.03}$	data for average 5 CORDEN 030) → ∆(122 DOCUMENT ID LITCHFIELD 030) → ∑(136 DOCUMENT ID 4 CAMERON 030) → NK*(DOCUMENT ID 4 CAMERON	74cc 75e 75e 75e 74cc 75e 74cc 75e 74cc 76e 78e 78e 78e 78e 78e 78e 78e 78e 78e 78	DPWA DBC TECN DPWA TECN DPWA TECN DPWA TECN DPWA TECN DPWA	$K^- p \rightarrow \Delta(1232)\overline{K}$ etc. • • • $K^- n \rightarrow N\overline{K}\pi^-$ $K^- p \rightarrow \Delta(1232)\overline{K}$ $(\Gamma_1\Gamma_2)^{\frac{1}{2}}/\Gamma$ $\frac{COMMENT}{K^- p \rightarrow \Sigma(1385)\pi}$ $\frac{(\Gamma_1\Gamma_4)^{\frac{1}{2}}/\Gamma}{K^- p \rightarrow N\overline{K}^+}$

(, , , , , , , , , , , , , , , , , , ,	$ abla \rightarrow \Sigma(2030) \rightarrow N\overline{K}^*($,,		$(\Gamma_1\Gamma_{18})^{\frac{1}{2}}/\Gamma_1$
VALUE	DOCUMENT ID	TECN	COMMENT	
$+0.04\pm0.03$	⁶ CAMERON	78B DPWA	$K^-p \rightarrow$	NK*
-0.12 ± 0.02	CORDEN	77B	$K^-d \rightarrow$	NNK*

- ² The two entries for CORDEN 77C are from two different acceptable solutions.
- ³This coupling is extracted from unnormalized data.
- ⁴ The published sign has been changed to be in accord with the baryon-first convention. ⁵ An upper limit.
- 6 The upper limit on the G_3 wave is 0.03.

Σ(2030) REFERENCES

PDG	84	RMP 56 No. 2 Pt. II	Wohl, Cahn, Rittenberg+ (LBL, CIT, CERN)
PDG	82	PL 111B	Roos, Porter, Aguilar-Benitez+ (HELS, CIT, CERN)
GOPAL	80	Toronto Conf. 159	(RHEL) UP
CAMERON	78	NP. B143 189	+Franek, Gopal, Bacon, Butterworth+ (RHEL, LOIC) UP
CAMERON	78B	NP B146 327	+Franek, Gopal, Kalmus, McPherson+ (RHEL, LOIC) IJP
CAMERON	77	NP B131 399	+Franck, Gopal, Kalmus, McPherson+ (RHEL, LOIC) IJP
CORDEN	77B	NP B121 365	+Cox, Kenyon, O'Neale, Stubbs, Sumorok+ (BIRM) IJP
CORDEN	77C	NP B125 61	+Cox, Kenyon, O'Neale, Stubbs, Sumorok+ (BIRM) IJP
DECLAIS	77	CERN 77-16	+Duchon, Louvel, Patry, Seguinot+ (CAEN, CERN) IJP
GOPAL	77	NP B119 362	+Ross, VanHorn, McPherson+ (LOIC, RHEL) IJP
GOYAL	77	PR D16 2746	+Sodhi (DELH) IJP
CORDEN	76	NP B104 382	+Cox, Dartnell, Kenyon, O'Neale+ (BIRM) IJP
DEBELLEFON	76	NP B109 129	De Bellefon, Berthon (CDEF) IJP
BAILLON	75	NP B94 39	+Litchfield (CERN, RHEL) IJP
CORDEN	75B	NP B92 365	+Cox, Dartnell, Kenyon, O'Neale+ (BIRM) IJP
HEMINGWAY	75	NP B91 12	+Eades, Harmsen+ (CERN, HEIDH, MPIM) IJP
VANHORN	75	NP B87 145	(LBL) IJP
Also	75B	NP B87 157	VanHorn (LBL) IJP
DEVENISH	74B	NP B81 330	+Froggatt, Martin (DESY, NORD, LOUC)
KANE	74	LBL-2452	(LBL) IJP
LITCHFIELD	74B	NP B74 19	+Hemingway, Baillon+ (CERN, HEIDH) IJP
LITCHFIELD	74C	NP B74 39	+Hemingway, Bailton+ (CERN, HEIDH) IJP
LITCHFIELD	74D	NP B74 12	+Hemingway, Bailton+ (CERN, HEIDH) IJP
MULLER	69B	Thesis UCRL 19372	(LRL)
BURGUN	68	NP B8 447	+Meyer, Pauli, Tallinl+ (SACL, CDEF, RHEL)
TRIPP	67	NP B3 10	+Leith+ (LRL, SLAC, CERN, HEID, SACL)
COOL	66	PRL 16 1228	+Giacomelli, Kycia, Leontic, Lundby+ (BNL)
WOHL	66	PRL 17 107	+Solmitz, Stevenson (LRL) IJP

$\Sigma(2070) F_{15}$

906

140±20

 $I(J^P) = 1(\frac{5}{2}^+)$ Status: *

72 DPWA $K^-p \rightarrow \Sigma \pi$

708 DPWA $K^-p \rightarrow \Sigma \pi$

OMITTED FROM SUMMARY TABLE

This state suggested by BERTHON 70B finds support in GOPAL 80 with new K^-p polarization and K^-n angular distributions. The very broad state seen in KANE 72 is not required in the later (KANE 74) analysis of $\overline{K}\,N\to\Sigma\pi$.

Σ(2070) MASS

VALUE (MeV) ≈ 2070 OUR ESTIMATE	DOCUMENT ID		TECN	COMMENT	
2051 ± 25	GOPAL			$RN \rightarrow RN$	
2057 2070±10	KANE BERTHON			$K^-p \rightarrow \Sigma \pi$ $K^-p \rightarrow \Sigma \pi$	
	Σ(2070) WID	тн		-	
VALUE (MeV)	DOCUMENT ID		TECN	COMMENT	
300±30	GOPAL	80	DPWA	$\overline{K}N \to \overline{K}N$	

Σ(2070) DECAY MODES

KANE

BERTHON

	Mode				
Γ ₁	ΝK				
	$\Sigma \pi$				

Σ(2070) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on \varLambda and \varSigma Resonances.

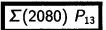
Γ(NK)/Γ _{total}				Г1/Г
VALUE	DOCUMENT ID	<u>TECN</u>	COMMENT	
0.08 ± 0.03	GOPAL 80	DPWA	$\overline{K}N \to \overline{K}$	N ·
-1				•/
(\(\Gamma_I\Gamma_f\)\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\	$\rightarrow \Sigma(2070) \rightarrow \Sigma \pi$			$(\Gamma_1\Gamma_2)^{\frac{1}{2}}/\Gamma$
(\(\Gamma_I\Gamma_f\)\ship\footal in N\(\overline{K}\)	$' \rightarrow \Sigma(2070) \rightarrow \Sigma \pi$ DOCUMENT ID	TECN	COMMENT	(Г₁Г₂) ^⅓ 2/Г
	DOCUMENT ID			

Σ(2070) REFERENCES

GOPAL	80	Toronto Conf.
KANE	74	LBL-2452
KANE	72	PR DS 1583
BERTHON	70B	NP B24 417

+Vrana, Butterworth+

(RHEL) IJP (LBL) (LBL) (CDEF, RHEL, SACL) IJP



$$I(J^P) = 1(\frac{3}{2}^+)$$
 Status: **

OMITTED FROM SUMMARY TABLE

Suggested by some but not all partial-wave analyses across this re-

Σ(2080) MASS

VALUE (MeV)	DOCUMENT ID		TECN	COMMENT
≈ 2080 OUR ESTIMATE				
2091± 7	¹ CORDEN	76	DPWA	$K^- n \rightarrow \Lambda \pi^-$
2070 to 2120	DEBELLEFON	76	IPWA	$K^- p \rightarrow \Lambda \pi^0$
2120±40	BAILLON	75	IPWA	$\overline{K}N \rightarrow \Lambda\pi$ (sol. 1)
2140±40	BAILLON	75	IPWA	$\overline{K}N \rightarrow \Lambda \pi \text{ (sol. 2)}$
2082± 4	COX .	70	DPWA	See CORDEN 76
2070 ± 30	LITCHFIELD	70	DPWA	$K^-N \rightarrow \Lambda \pi$

Σ(2080) WIDTH

VALUE (MeV)	DOCUMENT ID TECN COMMENT
186±48	¹ CORDEN 76 DPWA $K^- n \rightarrow \Lambda \pi^-$
100	DEBELLEFON 76 IPWA $K^-p \rightarrow \Lambda \pi^0$
240±50	BAILLON 75 IPWA $\overline{K}N \rightarrow \Lambda\pi$ (sol. 1)
200±50	BAILLON 75 IPWA $\overline{K}N \rightarrow \Lambda \pi$ (sol. 2)
87±20	COX 70 DPWA See CORDEN 76
250±40	LITCHFIELD 70 DPWA $K^- N \rightarrow \Lambda \pi$

Σ(2080) DECAY MODES

		-	•		
	Mode	 			
$\overline{\Gamma_1}$	NK				
Γ2	$\Lambda\pi$				

∑(2080) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on \varLambda and \varSigma

$(\Gamma_I \Gamma_I)^{\frac{1}{2}} / \Gamma_{\text{total}} \text{ in } N\overline{K} \rightarrow$		(Γ ₁ Γ ₂) ^{1/2} /Γ	
VALUE	DOCUMENT ID	TECN	COMMENT
-0.10 ± 0.03			$K^- \pi \rightarrow \Lambda \pi^-$
-0.10	DEBELLEFON 76		
-0.13 ± 0.04	BAILLON 75	IPWA	$\overline{K}N \rightarrow \Lambda\pi$ (sol. 1 and 2)
-0.16 ± 0.03	COX 70	DPWA	See CORDEN 76
-0.09 ± 0.03	LITCHFIELD 70	DPWA	$K^- N \rightarrow \Lambda \pi$

Σ(2080) FOOTNOTES

 $^{
m 1}$ Preferred solution 3; see CORDEN 76 for other possibilities, including a D_{15} at this

Σ(2080) REFERENCES

CORDEN DEBELLEFON Also BAILLON COX LITCHFIELD	76 76 75 75 70 70	NP B104 382 NP B109 129 NP B90 1 NP B94 39 NP B19 61 NP B22 269	+Cox, Dartnell, Kenyon De Bellefon, Berthon De Bellefon, Berthon, +Litchfield +Islam, Colley+	Brunet+	(BIRM) LIF (CDEF) LIF (CDEF, SACL) LIF (CERN, RHEL) LIF EDIN, GLAS, LOIC) LIF (RHEL) LIF
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$\Sigma(2100)$	G ₁₇
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 70 ± 30 135±30

$$I(J^P) = 1(\frac{7}{2})$$
 Status: *

BARBARO-... 70 DPWA $K^-p \rightarrow \Lambda \pi^0$ BARBARO-... 70 DPWA $K^-p \rightarrow \Sigma \pi$

OMITTED FROM SUMMARY TABLE

	Σ(2100) MASS			
VALUE (MeV)	DOCUMENT ID	TECN	COMMENT	•
≈ 2100 OUR ESTIMATE			_	
2060 ± 20	BARBARO 70) DPWA	$K^-p \rightarrow \Lambda \pi^0$	
2120±30	BARBARO 70	DPWA	$K^- p \rightarrow \Sigma \pi$	
	Σ(2100) WIDTH	ı		
VALUE (MeV)	DOCUMENT ID	TECN	COMMENT	

Σ(2100) DECAY MODES

	Mode		 	
Γ ₁	NK			
	$\Lambda\pi$			
Γ_3	$\Sigma \pi$			

Σ(2100) BRANCHING RATIOS

See "Sign conventions for resonance couplings" in the Note on \varLambda and \varSigma Resonances.

(F _I F _f) ^{1/2} /F _{total} in NK	$\rightarrow \Sigma(2100) \rightarrow \Lambda \pi$			$(\Gamma_1\Gamma_2)^{\frac{1}{2}}/\Gamma$
VALUE		TECN	COMMENT	
-0.07 ± 0.02	BARBARO 70	DPWA	$K^-p \rightarrow$	$\Lambda \pi^0$
$(\Gamma_I \Gamma_f)^{\frac{1}{2}} / \Gamma_{\text{total}} \ln N \overline{K}$	$\rightarrow \Sigma(2100) \rightarrow \Sigma \pi$ DOCUMENT ID	TECN	COMMENT	(Γ ₁ Γ ₃) ^{1/2} /Γ
+0.13±0.02	BARBARO 70			

Σ(2100) REFERENCES

BARBARO-... 70 Duke Conf. 173

Barbaro-Galtieri

(LRL) (JP

 Σ (2250)

$$I(J^P) = 1(??)$$
 Status: ***

Results from partial-wave analyses are too weak to warrant separating them from the production and cross-section experiments. LASINSKI 71 in $\overline{K}N$ using a Pomeron + resonances model, and DEBELLEFON 76, DEBELLEFON 77, and DEBELLEFON 78 in energy-dependent partial-wave analyses of $\overline{K}N \to \Lambda\pi$, $\Sigma\pi$, and $N\overline{K}$, respectively, suggest two resonances around this mass.

Σ(2250) MASS

VALUE (MeV)	DOCUMENT ID TECN COMMENT						
2210 to 2280 (~ 2250) OUR ESTIMATE							
2270 ± 50	DEBELLEFON 78 DPWA D ₅ wave						
2210±30	DEBELLEFON 78 DPWA Gg wave						
2275±20	DEBELLEFON 77 DPWA D ₅ wave						
2215 ± 20	DEBELLEFON 77 DPWA G wave						
2300±30	¹ DEBELLEFON 75B HBC $K^-p \rightarrow \Xi^{*0}K^0$						
2251 ^{+ 30} - 20	VANHORN 75 DPWA $K^-p \rightarrow \Lambda \pi^0$, F_5 wave						
2280±14	AGUILAR 708 HBC K-p 3.9, 4.6 GeV/c						
2237±11	BRICMAN 70 CNTR Total, charge exchange						
2255 ± 10	COOL 70 CNTR K^-p , K^-d total						
2250± 7	BUGG 68 CNTR K^-p , K^-d total						
• • • We do not use the	following data for averages, fits, limits, etc. • • •						
2260	DEBELLEFON 76 IPWA D ₅ wave						
2215	DEBELLEFON 76 IPWA Gg wave						
2250 ± 20	LU 70 CNTR $\gamma p \rightarrow K^+ Y^*$						
2245	BLANPIED 65 CNTR $\gamma p \rightarrow K^+ Y^*$						
2299± 6	BOCK 65 HBC $\vec{p}p$ 5.7 GeV/c						

Baryon Particle Listings Σ (2250), Σ (2455) Bumps

		Σ(2250) WIDTH
ALUE	(MeV)	DOCUMENT ID TECN COMMENT
	o 150 (≈ 100) OUR	
20±		DEBELLEFON 78 DPWA D ₅ wave
80±		DEBELLEFON 78 DPWA Gg wave
70± 60∎±		DEBELLEFON 77 DPWA D_5 wave DEBELLEFON 77 DPWA G_9 wave
30±		¹ DEBELLEFON 75B HBC $K^-p \rightarrow \Xi^{*0}K^0$
92±		VANHORN 75 DPWA $K^- p \rightarrow \Lambda \pi^0$, F_5 wave
00±		AGUILAR 708 HBC K p 3.9, 4.6 GeV/c
64± 30±		BRICMAN 70 CNTR Total, charge exchange BUGG 68 CNTR K-p, K-d total
		following data for averages, fits, limits, etc. • • •
00		DEBELLEFON 76 IPWA D ₅ wave
40		DEBELLEFON 76 IPWA G ₉ wave
70 25		COOL 70 CNTR K ⁻ p, K ⁻ d total
25 50		LU 70 CNTR $\gamma p \rightarrow K^+ Y^*$ BLANPIED 65 CNTR $\gamma p \rightarrow K^+ Y^*$
21 <u>+</u>	-17	BOCK 65 HBC pp 5.7 GeV/c
	21	
		Σ(2250) DECAY MODES
	Mode	Fraction (Γ_j/Γ)
1	NK	<10 %
2	$\Lambda\pi$	se e n
3	$\Sigma_{\underline{\pi}}$	seen
4	$NK\pi$	
5	<i>Ξ</i> (1530) <i>K</i>	
	The above branc	ching fractions are our estimates, not fits or averages.
		Σ(2250) BRANCHING RATIOS
	See "Sign conve	intions for resonance couplings" in the Note on Λ and Σ
	Resonances.	antions for resonance couplings in the Note on A and 2
	Resonances.	
	Resonances. \overline{K})/ Γ_{total}	Г1/
ALUE	Resonances. \overline{K})/ Γ_{total}	
0.0	Resonances. K)/\Gamma_total OUR ESTIMATE 8±0.02	$\Gamma_1/$ DOCUMENT ID TECN COMMENT DEBELLEFON 78 DPWA D_5 wave
0.0	Resonances. K)/\Gamma_total OUR ESTIMATE	T1/
0.0 0.0	Resonances. K)/\Gamma_total E OUR ESTIMATE 8±0.02 12±0.01	$\Gamma_1/$ DOCUMENT ID TECN COMMENT DEBELLEFON 78 DPWA G_9 wave DEBELLEFON 78 DPWA G_9 wave
0.0 0.0 0.0 4LUI	Resonances. K)/Γ _{total} E OUR ESTIMATE 8±0.02 2±0.01 1)×Γ(NK)/Γ _{total}	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
0.0 0.0 0.0 J +	Resonances. K)/Γ _{total} E OUR ESTIMATE 8±0.02 2±0.01 1)×Γ(NK)/Γ _{total}	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$
0.0 0.0 0.0 4-1 16:	Resonances. K)/Γ _{total} E OUR ESTIMATE 8±0.02 2±0.01 1)×Γ(NK)/Γ _{total}	DEBELLEFON 78 DPWA D ₅ wave DEBELLEFON 78 DPWA G ₉ wave DOCUMENT ID TECN COMMENT DOCUMENT ID TECN COMMENT Following data for averages, fits, limits, etc. • • • BRICMAN 70 CNTR Total, charge exchange
16: 42	Resonances. K)/\Gamma _{total} COUR ESTIMATE 18±0.02 12±0.01 L)×Γ(NK)/Γ _{total} We do not use the	DEBELLEFON 78 DPWA D_5 wave DEBELLEFON 78 DPWA G_9 wave DOCUMENT ID TECN COMMENT DOCUMENT ID TECN COMMENT Following data for averages, fits, limits, etc. • • • BRICMAN 70 CNTR Total, charge exchange COOL 70 CNTR K^-p , K^-q d total
16: 42	Resonances. K)/\Gamma _{total} COUR ESTIMATE 18±0.02 12±0.01 L)×Γ(NK)/Γ _{total} We do not use the	DEBELLEFON 78 DPWA D_5 wave DEBELLEFON 78 DPWA G_9 wave DEBELLEFON 78 DPWA G_9 wave DEBELLEFON 78 DPWA G_9 wave
0.0 0.0 0.0 41 16: 42 47	Resonances. K)/Ftotal COUR ESTIMATE 18±0.02 12±0.01 2)×F(NK)/Ftotal We do not use the ±0.12	DEBELLEFON 78 DPWA D_5 wave DEBELLEFON 78 DPWA G_9 wave DEBELLEFON 78 DPWA G_9 wave DEBELLEFON 78 DPWA G_9 wave
16: 42	Resonances. K)/\Gamma_total OUR ESTIMATE 8±0.02 12±0.01 2)×\Gamma(NK)/\Gamma_total We do not use the ±0.12	DEBELLEFON 78 DPWA D_5 wave DEBELLEFON 78 DPWA G_9 wave DEBELLEFON 78 DPWA G_9 wave DEBELLEFON 78 DPWA G_9 wave following data for averages, fits, limits, etc. • • • BRICMAN 70 CNTR Total, charge exchange COOL 70 CNTR K^-p , K^-d total BUGG 68 CNTR K^-p , K^-d total DOCUMENT ID TECN COMMENT
16: 42 47	Resonances. K)/\Gamma_total OUR ESTIMATE 8±0.02 12±0.01 2)×\Gamma\G	DEBELLEFON 78 DPWA D_5 wave DEBELLEFON 78 DPWA G_9 wave DEBELLEFON 78 DPWA G_9 wave DEBELLEFON 78 DPWA G_9 wave
16: 42 47	Resonances. K)/\Gamma_total OUR ESTIMATE 8±0.02 2±0.01 2)×\Gamma(NK)/\Gamma_total We do not use the ±0.12 f)\frac{1/2}{\Gamma_total} \text{ In NK} E 6±0.03 We do not use the	DEBELLEFON 78 DPWA D_5 wave DEBELLEFON 78 DPWA G_9 wave DEBELLEFON 78 DPWA G_9 wave DEBELLEFON 78 DPWA G_9 wave G_9 wave following data for averages, fits, limits, etc. • • • • BRICMAN 70 CNTR Total, charge exchange COOL 70 CNTR K^-p , K^-d total BUGG 68 CNTR G_9 COMMENT G_9 COMENT G_9 COMMENT G_9 COM
16: 42 47 0.1	Resonances. K)/\Gamma_total OUR ESTIMATE 8±0.02 12±0.01 120 We do not use the ±0.12 Thotal in NK 6±0.03 We do not use the	DEBELLEFON 78 DPWA D_5 wave DEBELLEFON 78 DPWA G_9 wave $G_$
16: 42 47 0.1 0.1 0.1	Resonances. K)/\Gamma_total OUR ESTIMATE 8±0.02 12±0.01 2)\Gamma\Gamma(NK)/\Gamma_total We do not use the ±0.12 1/2/\Gamma_total We do not use the 500.03 We do not use the	DEBELLEFON 78 DPWA D_5 wave DEBELLEFON 78 DPWA G_9 wave DEBELLEFON 78 DPWA G_9 wave DEBELLEFON 78 DPWA G_9 wave
16: 42 47 0.1 0.1 0.1	Resonances. K)/\Gamma_total OUR ESTIMATE 8±0.02 12±0.01 2±0.01 We do not use the ±0.12 F)\frac{1/2}{\Gamma_t}/\Gamma_t\text{total in NK}} We do not use the 1 0 8	DEBELLEFON 78 DPWA D_5 wave DEBELLEFON 78 DPWA G_9 wave DEBELLEFON 78 DPWA G_9 wave DEBELLEFON 78 DPWA G_9 wave
16: 42 47 7 [] [0.1 0.1 0.1	Resonances. K)/\Gamma\text{Ftotal} OUR ESTIMATE 8\pm \ 0.02 2\pm \ 0.01 2\pm \ \Gamma\text{(NK)}/\Gamma\text{total} \text{b} \text{ We do not use the } \frac{1}{2}/\Gamma\text{/Ttotal in NK} 6\pm \ 0.03 We do not use the 1 0 8 7)\frac{1}{2}/\Gamma\text{/Ttotal in NK}	DEBELLEFON 78 DPWA D_5 wave DEBELLEFON 78 DPWA G_9 wave DEBELLEFON 78 DPWA G_9 wave DEBELLEFON 78 DPWA G_9 wave
16: 42 47 	Resonances. K)/\Gamma_total OUR ESTIMATE 18±0.02 12±0.01 21±0.01 We do not use the ±0.12 F)\frac{1/2}{\Gamma_t}/\Gamma_t\text{total} \text{ in NK}} We do not use the 1 0 8 1 0 8	DEBELLEFON 78 DPWA D_5 wave DEBELLEFON 78 DPWA G_9 wave DEBELLEFON 70 CNTR K^-p , K^-d total BUGG 68 CNTR K^-p , K^-d total DEBELLEFON 75 DPWA $K^-p \rightarrow \Lambda \pi^0$, F_5 wave DEBELLEFON 76 IPWA G_9 wave DEBELLEFON 76 IPWA G_9 wave BARBARO 70 DPWA $K^-p \rightarrow \Lambda \pi^0$, G_9 wave DEBELLEFON 76 IPWA G_9 wave G_9 w
16= 42 47 7	Resonances. K)/\Gamma\text{Ftotal} OUR ESTIMATE 8±0.02 12±0.01 12)\\Gamma\Gamma\text{F(NK)/\Gamma\text{Ftotal}} We do not use the ±0.12 12/\Gamma\text{Ttotal} in NK 6±0.03 We do not use the 1 0 8 7)\frac{1}{1/2}/\Gamma\text{Ttotal} in NK 6±0.02	DEBELLEFON 78 DPWA D_5 wave DEBELLEFON 78 DPWA G_9 wave DEBELLEFON 78 DPWA G_9 wave DEBELLEFON 78 DPWA G_9 wave
16= 42 47 	Resonances. K)/\Gamma\text{Footal} Belono2 2\pma 2\pma 12 2\pma 12 2\pma 14 15 16 16 16 16 16 16 16 17 17 17 17 17 17 17 17 17 17 17 17 17	DEBELLEFON 78 DPWA D_5 wave DEBELLEFON 78 DPWA G_9 wave DEBELLEFON 70 CNTR K^-p , K^-d total BUGG 68 CNTR K^-p , K^-d total DEBELLEFON 75 DPWA $K^-p \rightarrow \Lambda \pi^0$, F_5 wave DEBELLEFON 76 IPWA G_9 wave DEBELLEFON 76 IPWA G_9 wave BARBARO 70 DPWA $K^-p \rightarrow \Lambda \pi^0$, G_9 wave DEBELLEFON 76 IPWA G_9 wave G_9 w
16: 42 47 0.1 0.1 0.1 0.1 0.1 0.0 0.0 0.0	Resonances. K)/\Gamma\text{Ftotal} Beloo2 2±0.01 2)\times\Gamma\text{(NK)}/\Gamma\text{total} beloo2 2±0.01 2)\times\Gamma\text{(NK)}/\Gamma\text{total} beloo3 We do not use the 1 0 8 1 0 8 7 1 7 1 7 1 7 1 7 1 7	DEBELLEFON 78 DPWA D_5 wave DEBELLEFON 78 DPWA G_9 wave Pollowing data for averages, fits, limits, etc. • • • BRICMAN 70 CNTR K^-p , K^-d total BUGG 68 CNTR TOUCHMENT ID TECN COMMENT VANHORN 75 DPWA $K^-p \rightarrow \Lambda \pi^0$, F_5 wave DEBELLEFON 76 IPWA G_9 wave DEBELLEFON 76 IPWA G_9 wave BARBARO 70 DPWA $K^-p \rightarrow \Lambda \pi^0$, G_9 wave DEBELLEFON 77 DPWA G_9 wave DEBELLEFON 77 DPWA G_9 wave DEBELLEFON 77 DPWA G_9 wave DEBELLEFON 77 DPWA G_9 wave DEBELLEFON 77 DPWA G_9 wave DEBELLEFON 77 DPWA G_9 wave DEBELLEFON 77 DPWA G_9 wave DEBELLEFON 77 DPWA G_9 wave DEBELLEFON 77 DPWA G_9 wave DEBELLEFON 77 DPWA G_9 wave DEBELLEFON 77 DPWA G_9 wave DEBELLEFON 77 DPWA G_9 wave DEBELLEFON 77 DPWA G_9 wave DEBELLEFON 77 DPWA G_9 wave DEBELLEFON 77 DPWA G_9 wave DEBELLEFON 77 DPWA G_9 wave DEBELLEFON 77 DPWA G_9 wave DEBELLEFON 77 DPWA G_9 wave
16: 42 47 16: 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1	Resonances. K)/ Γ total Superstimate 8±0.02 9±0.01 12)× Γ (NK)/ Γ total 12)× Γ (NK)/ Γ total 13) We do not use the 140 150 160 170 170 170 170 170 170 17	DEBELLEFON 78 DPWA D_5 wave DEBELLEFON 78 DPWA G_9 wave $G_$
16: 42 47 16: 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1	Resonances. K)/ Γ_{total} OUR ESTIMATE 8±0.02 12±0.01 2)× $\Gamma(NK)/\Gamma_{\text{total}}$ We do not use the ±0.12 f) $\frac{1}{2}/\Gamma_{\text{total}}$ in NK E 6±0.03 We do not use the 1 0 8 P_{total} P_{total} N/ $\Gamma(\Sigma \pi)$	DEBELLEFON 76 DPWA D_5 wave DEBELLEFON 77 DPWA D_5 wave DEBELLEFON 78 DPWA D_5 wave DEBELLEFON 78 DPWA D_5 wave DEBELLEFON 78 DPWA D_5 wave DEBELLEFON 78 DPWA D_5 wave DEBELLEFON 76 DPWA D_5 wave D_5 wave DEBELLEFON 76 DPWA D_5 wave DEBELLEFON 76 DPWA D_5 wave DEBELLEFON 76 DPWA D_5 wave DEBELLEFON 77 DPWA D_5 wave
16: 42 47 7 F U 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1	Resonances. K)/ Γ_{total} OUR ESTIMATE 8±0.02 12±0.01 2)× $\Gamma(NK)/\Gamma_{\text{total}}$ We do not use the ±0.12 f) $\frac{1}{2}/\Gamma_{\text{total}}$ in NK 6±0.03 We do not use the 1 0 8 6±0.03 We do not use the 7 K)/ $\Gamma(\Sigma\pi)$ We do not use the	DEBELLEFON 78 DPWA D_5 wave DEBELLEFON 78 DPWA G_9 wave MI DOCUMENT ID TECN COMMENT Tollowing data for averages, fits, limits, etc. • • • BRICMAN 70 CNTR Total, charge exchange COOL 70 CNTR K^-p , K^-d total BUGG 68 CNTR TOLLOWING DEBELLEFON 75 DPWA $K^-p \rightarrow \Lambda \pi^0$, F_5 wave following data for averages, fits, limits, etc. • • • DEBELLEFON 76 IPWA G_9 wave DEBELLEFON 76 IPWA G_9 wave DEBELLEFON 77 DPWA G_9 wave DEBELLEFON 79 DPWA G_9 wave DEBELLEFON 79 DPWA G_9 wave DEBELLEFON 79 DPWA G_9
ALUI 0.0 16: 42 47 -0.1 -0.1 -0.1 -0.0 -0.0 (N ALUI -0.0 -0.0 -0.0	Resonances. K)/ Γ_{total} Suppose the second of the	DEBELLEFON 76 DPWA D_5 wave DEBELLEFON 77 DPWA D_5 wave DEBELLEFON 78 DPWA D_5 wave DEBELLEFON 78 DPWA D_5 wave DEBELLEFON 78 DPWA D_5 wave DEBELLEFON 78 DPWA D_5 wave DEBELLEFON 76 DPWA D_5 wave D_5 wave DEBELLEFON 76 DPWA D_5 wave DEBELLEFON 76 DPWA D_5 wave DEBELLEFON 76 DPWA D_5 wave DEBELLEFON 77 DPWA D_5 wave
ALUI 0.0 16: 42 47 -0.1 -0.1 -0.1 -0.0 -0.0 (N ALUI -0.0 -0.0 -0.0	Resonances. K)/ Γ_{total} OUR ESTIMATE 8±0.02 12±0.01 2)× $\Gamma(NK)/\Gamma_{\text{total}}$ We do not use the ±0.12 f) $\frac{1}{2}/\Gamma_{\text{total}}$ in NK 6±0.03 We do not use the 1 0 8 6±0.03 We do not use the 7 K)/ $\Gamma(\Sigma\pi)$ We do not use the	DEBELLEFON 78 DPWA D_5 wave DEBELLEFON 78 DPWA G_9 wave MI DOCUMENT ID TECN COMMENT Tollowing data for averages, fits, limits, etc. • • • BRICMAN 70 CNTR Total, charge exchange COOL 70 CNTR K^-p , K^-d total BUGG 68 CNTR TOLLOWING DEBELLEFON 75 DPWA $K^-p \rightarrow \Lambda \pi^0$, F_5 wave following data for averages, fits, limits, etc. • • • DEBELLEFON 76 IPWA G_9 wave DEBELLEFON 76 IPWA G_9 wave DEBELLEFON 77 DPWA G_9 wave DEBELLEFON 79 DPWA G_9 wave DEBELLEFON 79 DPWA G_9 wave DEBELLEFON 79 DPWA G_9
16: 42 47	Resonances. K)/ Γ_{total} OUR ESTIMATE 8±0.02 12±0.01 2)× $\Gamma(NK)/\Gamma_{\text{total}}$ We do not use the ±0.12 f) $\frac{1}{2}/\Gamma_{\text{total}}$ in NK E 6±0.03 We do not use the 1 0 8 $\frac{1}{2}/\Gamma_{\text{total}}$ in NK E 6±0.02 3±0.02 7 K)/ $\Gamma(\Sigma\pi)$ We do not use the 18 π)/ $\Gamma(\Sigma\pi)$	DEBELLEFON 78 DPWA D_5 wave DEBELLEFON 78 DPWA G_9 wave MRICMAN 70 CNTR Total, charge exchange COOL 70 CNTR Total, charge exchange COOL 70 CNTR K^-p , K^-d total BUGG 68 CNTR TOUCHMENT ID TECN COMMENT VANHORN 75 DPWA $K^-p \rightarrow \Lambda \pi^0$, F_5 wave following data for averages, fits, limits, etc. • • • DEBELLEFON 76 IPWA G_9 wave DEBELLEFON 76 IPWA G_9 wave BARBARO 70 DPWA $K^-p \rightarrow \Lambda \pi^0$, G_9 wave DEBELLEFON 77 DPWA G_9 wave G_9 w
16: 42 47	Resonances. K)/ Γ_{total} OUR ESTIMATE 8±0.02 12±0.01 2)× $\Gamma(NK)/\Gamma_{\text{total}}$ We do not use the ±0.12 f) $\frac{1}{2}/\Gamma_{\text{total}}$ in NK E 6±0.03 We do not use the 1 0 8 $\frac{1}{2}/\Gamma_{\text{total}}$ in NK E 6±0.02 3±0.02 7 K)/ $\Gamma(\Sigma\pi)$ We do not use the 18 π)/ $\Gamma(\Sigma\pi)$	DEBELLEFON 78 DPWA D_5 wave DEBELLEFON 78 DPWA G_9 wave MRICMAN 70 CNTR Total, charge exchange COOL 70 CNTR Total, charge exchange COOL 70 CNTR K^-p , K^-d total BUGG 68 CNTR TOUCHMENT ID TECN COMMENT VANHORN 75 DPWA $K^-p \rightarrow \Lambda \pi^0$, F_5 wave following data for averages, fits, limits, etc. • • • DEBELLEFON 76 IPWA G_9 wave DEBELLEFON 76 IPWA G_9 wave BARBARO 70 DPWA $K^-p \rightarrow \Lambda \pi^0$, G_9 wave DEBELLEFON 77 DPWA G_9 wave G_9 w
16: 42 47	Resonances. K)/ Γ_{total} OUR ESTIMATE 8±0.02 12±0.01 2)× $\Gamma(NK)/\Gamma_{\text{total}}$ We do not use the ±0.12 f) $\frac{1}{2}/\Gamma_{\text{total}}$ in NK 6±0.03 We do not use the 10 8 $\frac{1}{2}/\Gamma_{\text{total}}$ in NK 6±0.02 3±0.02 7 K)/ $\Gamma(\Sigma\pi)$ We do not use the 8 $\pi/\Gamma(\Sigma\pi)$	DEBELLEFON 78 DPWA D_5 wave DEBELLEFON 78 DPWA G_9 wave MRICMAN 70 CNTR Total, charge exchange COOL 70 CNTR Total, charge exchange COOL 70 CNTR K^-p , K^-d total BUGG 68 CNTR TOUCHMENT ID TECN COMMENT VANHORN 75 DPWA $K^-p \rightarrow \Lambda \pi^0$, F_5 wave following data for averages, fits, limits, etc. • • • DEBELLEFON 76 IPWA G_9 wave DEBELLEFON 76 IPWA G_9 wave BARBARO 70 DPWA $K^-p \rightarrow \Lambda \pi^0$, G_9 wave DEBELLEFON 77 DPWA G_9 wave G_9 w
ALUI 0.0.0 0.0 0.0 0.0 0.0 0.1 0.1 0	Resonances. K)/ Γ_{total} Belong 2 2 ± 0.01 2)× $\Gamma(NK)/\Gamma_{\text{total}}$ We do not use the ± 0.12 $f^{1/2}/\Gamma_{\text{total}}$ in NK 6 ± 0.03 We do not use the 10 8 $f^{1/2}/\Gamma_{\text{total}}$ in NK 6 ± 0.02 3 ± 0.02 7 K)/ $\Gamma(\Sigma\pi)$ We do not use the 18 π)/ $\Gamma(\Sigma\pi)$ E We do not use the 18	DEBELLEFON 78 DPWA D_5 wave DEBELLEFON 78 DPWA G_9 wave DEBELLEFON 78 DPWA G_9 wave DEBELLEFON 78 DPWA G_9 wave
ALUI 0.0.0 0.0 0.0 0.0 0.0 0.1 0.1 0	Resonances. K)/ Γ total Superstimate 8±0.02 2±0.01 2)× Γ (NK)/ Γ total We do not use the ±0.12 We do not use the 5 We do not use the 6±0.03 We do not use the 6±0.02 3±0.02 7 K)/ Γ ($\Sigma \pi$) We do not use the 8 π)/ Γ ($\Sigma \pi$) We do not use the 8 π / Γ ($\Sigma \pi$) We do not use the 8 π / Γ ($\Sigma \pi$) We do not use the 8 π / Γ ($\Sigma \pi$) We do not use the 8	DEBELLEFON 78 DPWA D_5 wave DEBELLEFON 78 DPWA G_9 wave MRICMAN 70 CNTR Total, charge exchange COOL 70 CNTR Total, charge exchange COOL 70 CNTR K^-p , K^-d total BUGG 68 CNTR TOUCHMENT ID TECN COMMENT VANHORN 75 DPWA $K^-p \rightarrow \Lambda \pi^0$, F_5 wave following data for averages, fits, limits, etc. • • • DEBELLEFON 76 IPWA G_9 wave DEBELLEFON 76 IPWA G_9 wave BARBARO 70 DPWA $K^-p \rightarrow \Lambda \pi^0$, G_9 wave DEBELLEFON 77 DPWA G_9 wave G_9 w

Σ(2250) FOOTNOTES

 1 Seen in the (initial and final state) \mathcal{D}_{5} wave. Isospin not determined.

NC 42A 403 NC 37A 175 NP 8109 129 NP 890 1 NC 28A 289 NP 887 157 NP 887 157 NP 829 125 PRL 25 58 Duke Conf. 173 PR D1 1897 PR D1 1897 PR D1 21846 PR D2 1846 PR D4 187 PR D1 187 PR D1 187 PR D1 187 PR D1 187 PR D1 187 PR D1 187 PR D1 187 PR D1 187 PR D1 187 PR D1 187

Σ(2250) REFERENCES

(CDEF, SACL) LIP
(CDEF, SACL) LIP
(CDEF, SACL) LIP
(CDEF, SACL) LIP
(CDEF, SACL) LIP
(LIB, LIP
(LIB, LIP)
(ERI) LIP
(ERI) LIP
(CERN, CAEN, SACL)
+
(GRNL, SACL)
+
(BNL, SYRA)
(RHEL, BIRM, CAVE)
(VALE, CEA)
(CERN, SACL) De Bellefon, Berthon, Billoir+ De Bellefon, Berthon, Billoir+ De Bellefon, Berthon De Bellefon, Berthon, Brunet+ De Bellefon, Berthon, Billoir+ Agullar-Benitez, Barnes, Bassano+ Barbaro-Galtieri
+Ferro-Luzzi, Perreau+ (CERN, Giacomelli, Kycia, Leontic, Li+ Cool, Giacomelli, Kycia, Leontic, Lundby+ +Greenberg, Hughes, Minehart, Mori+ +Flaminio, Montanet, Samios+ +Gilmore, Knight+ (RHEL +Greenberg, Hughes, Kitching, Lu+ +Cooper, French, Kinson+

Σ (2455) Bumps

DEBELLEFON 78
DEBELLEFON 77
DEBELLEFON 75
DEBELLEFON 75
AISO 75
AISO 75
AISO 71
AGUILAR-... 70
BRICMAN 70
COOL 70
AISO 66
DEBELEFON 70
BRICMAN 70
DRICMAN
 $I(J^P) = 1(??)$ Status: **

OMITTED FROM SUMMARY TABLE

There is also some slight evidence for Y* states in this mass region from the reaction $\gamma p \rightarrow K^+ X$ — see GREENBERG 68.

Σ(2455) MASS

VALUE (MeV) ≈ 2455 OUR ESTIMATE	DOCUMENT ID	TECN	COMMENT
2455 ± 10	ABRAMS 70	CNTR	K^-p , K^-d total
2455 ± 7	BUGG 68	CNTR	K^-p , K^-d total

Σ(2455) WIDTH

VALUE (MeV)	DOCUMENT ID		TECN_	COMMENT
140	ABRAMS	70	CNTR	K-p, K-d total
100±20	BUGG	68	CNTR	

Σ(2455) DECAY MODES

Mode Γ_1 ΝK

Σ(2455) BRANCHING RATIOS

$(J+\frac{1}{2})\times\Gamma(N\overline{K})/\Gamma_{\text{total}}$				Γ ₁ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
0.39	ABRAMS	70	CNTR	K^-p , K^-d total
0.05 ± 0.05	¹ BRICMAN	70	CNTR	Total, charge exchange
0.3	BUGG	68	CNTR	

E(2455) FOOTNOTES

 $^{f 1}$ Fit of total cross section given by BRICMAN 70 is poor in this region.

Σ(2455) REFERENCES

ABRAMS 70 PR D1 1917 Also 67E PRL 19 678 BRICMAN 70 PL 31B 152 BUGG 68 PR 168 1466 GREENBERG 68 PRL 20 221	+Cool, Giacomelli, Kycia, Leontic, Li Abrams, Cool, Giacomelli, Kycia, Li +Ferro-Luzzi, Perreau+ +Gilmore, Knight+ +Hughes, Lu, Minehart+	
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EHRLICH

66 PR 152 1194

$\Sigma(2620)$ Bumps, $\Sigma(3000)$ Bumps, $\Sigma(3170)$ Bumps

E(2620) MASS DOCUMENT ID TECN COMMENT DOCUMENT ID TECN COMMENT DIBIANCA T5 DBC K¬N → ΞKπ ABRAMS T0 CNTR K¬p, K¬d total E(2620) WIDTH DOCUMENT ID TECN COMMENT DIBIANCA T5 DBC K¬N → ΞKπ ABRAMS T0 CNTR K¬p, K¬d total E(2620) DECAY MODES Mode F1 F2(2620) DECAY MODES Mode F2 DOCUMENT ID TECN COMMENT DIBIANCA T0 CNTR K¬p, K¬d total E(2620) DECAY MODES Mode F2 ABRAMS T0 CNTR K¬p, K¬d total BRICMAN T0 CNTR Total, charge exchange E(2620) REFERENCES DIBIANCA T5 NP B98 137 ABRAMS T0 CNTR K¬p, K¬d total BRICMAN T0 CNTR Total, charge exchange E(2620) REFERENCES DIBIANCA T5 NP B98 137 ABRAMS T0 CNTR K¬p, K¬d total BRICMAN T0 CNTR Total, charge exchange E(2620) REFERENCES DIBIANCA T5 NP B98 137 ABRAMS T0 CNTR K¬p, K¬d total BRICMAN T0 CNTR Total, charge exchange E(2620) REFERENCES DIBIANCA T0 PR D1 1917 ABRAMS T0 PR D1 1917 ABRAMS T0 PR D1 1917 ABRAMS T0 PR D1 1917 ABRAMS T0 PR D1 1917 ABRAMS T0 PR D1 1917 ABRAMS T0 PR D1 1917 ABRAMS T0 PR D1 1917 ABRAMS T0 PR D1 1917 ABRAMS T0 PR D1 1917 ABRAMS T0 PR D1 1917 ABRAMS T0 PR D1 1917 ABRAMS T0 PR D1 1917 ABRAMS T0 PR D1 1917 ABRAMS T0 PR D1 1917 ABRAMS T0 PR D1 1917 ABRAMS T0 CNTR K¬p, K¬d total E(CMU) (ENL) E(13000) Bumps I(JP) = 1(?²) Status: * DOMITTED FROM SUMMARY TABLE Seen as an enhancement in Aπ and KN invariant mass spectra and in the missing mass of neutrals recoiling against a K ⁰ . E(3000) MASS E(3000) MASS E(3000) MASS E(3000) DECAY MODES Mode F1 NK	DMITTED FROM SUMMARY TABLE \[\begin{align*} \be		
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Γ ₁ NK	Γ ₁ Ν K Γ ₂ Λ π	Mode	
· 1	$\Gamma_2 = \Lambda \pi$		
₹	T(3000) DECEDENCES	-	

+Selove, Yuta

$\Sigma(3170)$	Bump	$I(J^P) = 1(?^?)$ Status: >	*
hancemei dependen 6.5 GeV/ final stat Isospin 1	AMIRZADEH and in the reac thigh statist c. The dominal es and the prais is favored.	ARY TABLE 179 as a narrow 6.5-standard-deviation ention $K^-p \to Y^{*+}\pi^-$ using data from in ics bubble chamber experiments at 8.25 and ant decay modes are multibody, multistrang oduction is via isospin-3/2 baryon exchange periment in LASS at 11 GeV/c (ASTON 85B)	i- d ge
VALUE (MeV)	(PROD	E'(3170) MASS DUCTION EXPERIMENTS) DOCUMENT ID TECH COMMENT	
≈ 3170 OUR ESTI 3170±5		AMIRZADEH 79 HBC $K^-p \rightarrow Y^{*+}$	π-
VALUE (MeV)	(PROD	Σ(3170) WIDTH DUCTION EXPERIMENTS) DOCUMENT ID TECN COMMENT	
<20	35	1 AMIRZADEH 79 HBC K ⁻ p → Y*+	π
		3170) DECAY MODES DUCTION EXPERIMENTS)	
Mode		Fraction (Γ_f/Γ)	

Σ (3170) BRANCHING RATIOS (PRODUCTION EXPERIMENTS)

seen

seen

Γ(ΛΚΚπ's)/Γ _{total}	DOCUMENT ID	TECN	Γ ₁ /Γ
seen	AMIRZADEH 7	9 HBC	$K^- \rho \rightarrow Y^{*+} \pi^-$
Γ(ΣΚΚπ's)/Γ _{total}	DOCUMENT ID	TECN	Γ ₂ /Γ
seen	AMIRZADEH 7	9 HBC	$K^- p \rightarrow Y^{*+} \pi^-$
Γ(ΞΚπ's)/Γ _{total}	DOCUMENT ID	TECN	Γ ₃ /Γ
poen			$K^- p \rightarrow Y^{*+} \pi^-$

Σ(3170) FOOTNOTES (PRODUCTION EXPERIMENTS)

 $^{1}\,\mbox{Observed}$ width consistent with experimental resolution.

Γ₁ Γ₂ Γ₃

(PENN) I

ΛΚΚπ's

 $\Sigma K \overline{K} \pi$'s

ΞΚπ's

Σ (3170) REFERENCES (PRODUCTION EXPERIMENTS)

ASTON AMIRZADEH		PR D32 2270 PL 89B 125		+Carnegie+	(SLAC, CARL, CNRC, CINC) (BIRM, CERN, GLAS, MSU, CURIN, CAVE+) I
AMIKZADEH	80	Toronto Conf.	263	+ Kinson+	(BIRM, CERN, GLAS, MSU, CURIN, CAVE+))

E BARYONS (S=-2, I=1/2)

$$\Xi^0 = uss$$
, $\Xi^- = dss$



$$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$$
 Status: ***

The parity has not actually been measured, but + is of course expected.

= MASS

The fit uses the Ξ^0 , Ξ^- , and Ξ^+ mass and mass difference measure-

VALUE (MeV)	EVTS	DOCUMENT ID		TECN
1314.9±0.6 OUR FIT				
1314.8±0.8 OUR AVE	RAGE			
1315.2±0.92	49	WILQUET	72	HLBC
1313.4 ± 1.8	1	PALMER	68	HBC

$$m_{\Xi^-} - m_{\Xi^0}$$

The fit uses the Ξ^0 , Ξ^+ , and $\overline{\Xi}^+$ mass and mass difference measure-

VALUE (MeV)	EVTS	DOCUMENT ID	3	TECN	COMMENT
6.4±0.6 OUR FIT					
6.3±0.7 OUR AVE	ERAGE				
6.9±2.2	29	LONDON	66 H	IBC	
6.1±0.9	88	PJERROU	65B H	HBC	
6.8 ± 1.6	23	JAUNEAU	63 F	ВС	
• • • We do not t	use the followin	g data for averag	es, fits,	iimits	, etc. • • •
6.1±1.6	45	CARMONY	64B 1	1BC	See PJERROU 658

≅ MEAN LIFE

VALUE (10 ⁻¹⁰ s)	EVTS	DOCUMENT ID		TECN	COMMENT
2.90±0.09 OUR AV	ERAGE				
2.83±0.16	6300	1 ZECH	77	SPEC	Neutral hyperon beam
2.88 ^{+0.21} -0.19	652	BALTAY	74	нвс	1.75 GeV/c K-p
$2.90^{+0.32}_{-0.27}$	157	² MAYEUR	72	HLBC	2.1 GeV/c K-
3.07 ^{+0.22} _{-0.20}	340	DAUBER	69	нвс	
3.0 ±0.5	80	PJERROU	65B	нвс	
$2.5 \begin{array}{c} +0.4 \\ -0.3 \end{array}$	101	HUBBARD	64	нвс	
3.9 ^{+1.4} -0.8	24	JAUNEAU	63	FBC	
• • We do not use	the followin	g data for average	s, fits	s, limits,	etc. • • •
3.5 ^{+1.0} -0.8	45	CARMONY	64B	нвс	See PJERROU 658
1 The ZECH 77 re $^{2.63} \times 10^{-10}$ s. 2 The MAYEUR 72	_			10 ⁻¹⁰	s, in which we use $ au_{A}=$

See the "Note on Baryon Magnetic Moments" in the Λ Listings.

= MAGNETIC MOMENT

VALUE (µN)	EVTS	DOCUMENT ID		TECN
-1.250±0.014 OUR	AVERAGE			
-1.253 ± 0.014	270k	cox	81	SPEC
-1.20 ± 0.06	42k	BUNCE	79	SPEC

=0 DECAY MODES

	Mode	Fraction (Γ _/ /Γ)	Confide	ence level
r ₁	Λπ ⁰	(99.54±0.05)	%	
Γ_2	Λ_{γ}	(1.06±0.16)	× 10 ⁻³	
Γ_3^-	$\Sigma^{\dot{0}}\gamma$	(3.5 ±0.4)	< 10 ^{−3}	
Γ_{4}	$\Sigma^+e^-\overline{\nu}_e$	< 1.1	< 10 ⁻³	90%
Γ5	$\Sigma^+\mu^-\overline{\nu}_{\mu}$	< 1.1	< 10 ⁻³	90%

$\Delta S = \Delta Q$ (SQ) violating modes or $\Delta S = 2$ forbidden (S2) modes $\Sigma^-e^+ u_e \ \Sigma^-\mu^+ u_\mu$ × 10⁻⁴ SQ 90% × 10⁻⁴ SQ 90% $\times 10^{-5}$ 52 < 4 90% × 10⁻³ pe−₽e 52 < 1.3 \times 10⁻³ $\rho\mu^-\overline{\nu}_{\mu}$ 52 < 1.3

CONSTRAINED FIT INFORMATION

An overall fit to 2 branching ratios uses 2 measurements and one constraint to determine 3 parameters. The overall fit has a χ^2 = 0.0 for 0 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\langle \delta x_i \delta x_j \rangle / (\delta x_i \delta x_j)$, in percent, from the fit to the branching fractions, $x_i \equiv$ Γ_i/Γ_{total} . The fit constrains the x_i whose labels appear in this array to sum to one.

$$\begin{array}{c|cccc}
x_2 & -35 \\
x_3 & -94 & 0 \\
\hline
& x_1 & x_2
\end{array}$$

Γ₆ Γ₇ Γ₈ Γ₉

Γ10

 $p\pi^-$

₹ BRANCHING RATIOS

	=-	BRANCHING	KA I	103			
$\Gamma(\Lambda\gamma)/\Gamma(\Lambda\pi^0)$							Γ_2/Γ_1
VALUE (units 10 ⁻³) 1.06±0.16 OUR FIT	<u>EVTS</u>	DOCUMENT ID		TECN	<u>co</u>	MMENT	
1.06±0.12±0.11	116	JAMES	90	SPEC	FN	AL hyperons	
• • • We do not us	e the following	data for average	es, fit	s, limits	, etc.	• • •	
5 ±5	1	YEH	74	нвс	Effe	ective denom	.=200
$\Gamma(\Sigma^0\gamma)/\Gamma(\Lambda\pi^0)$							Γ_3/Γ_1
VALUE (units 10 ⁻³) 3.6 ±0.4 OUR	CL% EVTS	DOCUMEN	T ID	<u>T</u>	ECN	COMMENT	
3.56±0.42±0.10		TEIGE		89 S	PEC	FNAL hype	tons
• • • We do not us			es, fit				
< 8 <65	90 90 0–1	BENSING YEH	ER		IPS2 BC	K~W 6 G Effective de nom.=6	
$\Gamma(\Sigma^+e^-\overline{\nu}_e)/\Gamma(e^+e^-\overline{\nu}_e)$	$\Lambda \pi^0$)						Γ ₄ /Γ ₁
VALUE (units 10-3)	L% EVTS	DOCUMENT ID		TECN	<u>co</u>	MMENT	
<1.1 9	0 0	YEH	74	HBC	Eff	ective denom	.=2100
• • • We do not us	e the following	g data for average	es, fit	s, limits	, etc.		
<1.5		DAUBER	69	HBC			
<7		HUBBARD	66	HBC			
$\Gamma(\Sigma^+\mu^-\overline{\nu}_\mu)/\Gamma($	$\Lambda \pi^0$)						Γ ₅ /Γ ₁
VALUE (units 10 ⁻³)	L% EVTS	DOCUMENT ID		TECN	co	MMENT	
<1.1 9	ю 0	YEH	74	нвс	Eff	ective denom	.=2100
• • • We do not us	e the following	g data for average	es, fit	s, limits	, etc.		
<1.5		DAUBER	69	нвс			
<7		HUBBARD	66	нвс		•	
$\Gamma(\Sigma^-e^+\nu_e)/\Gamma(A^-)$ Test of $\Delta S = -1$	4π ⁰)						Γ_6/Γ_1
VALUE (units 10 ⁻³) (DOCUMENT ID		TECN	co	MMENT	
	0 0	YEH	74	HBC		ective denom	=2500
• • • We do not us	-						2555
<1.5		DAUBER	69	нвс			
<6		HUBBARD	66	HBC			
$\Gamma(\Sigma^{-}\mu^{+}\nu_{\mu})/\Gamma(\Sigma^{-}\mu^{+}\nu_{\mu})$ Test of $\Delta S = 0$							Γ ₇ /Γ ₁
VALUE (units 10-3)	L% EVTS	DOCUMENT ID		TECN	<u>co</u>	MMENT	
<0.9	0 0	YEH	74	нвс	Eff	ective denom	.=2500
• • • We do not us	se the following	g data for average	es, fit	s, limits	, etc.	• • •	
<1.5		DAUBER	69	HBC			
<6		HUBBARD	66	HBC			
$\Gamma(p\pi^-)/\Gamma(\Lambda\pi^0)$		der weak interact	·lan				Γ ₈ /Γ ₁
	iden in first-or L <u>% EVTS</u>	der weak interact DOCUMENT ID	JUII.	TECN	co	MMENT	
	10 10	GEWENIGER	75		. ==		
• • • We do not us	-				, etc.		
	0 0	YEH	74	нвс		ective denom	.=1300
< 90	. •	DAUBER	69	нвс			
<500		HUBBARD	66	HBC			

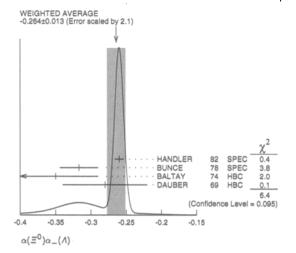
			rder weak interac	tion.		
VALUE (units 10-3) <u>CL%</u>	EVTS	DOCUMENT ID		TECN	COMMENT
<1.3			DAUBER	69	HBC	
● ● ● We do n	ot use the	followin	g data for averag	es, fit	s, limits	etc. • • •
<3.4	90	0	YEH	74	HBC	Effective denom.=670
<6			HUBBARD	66	HBC	
Γ(ρ μ [—] ν _μ)/Γ Δ5=2. F	(Λπ ⁰) orbidden	in first-o	der weak Interac	tion.		Γ ₁₀ /Γ
VALUE (units 10 ⁻³) CL%	EVTS	DOCUMENT ID		TECN	COMMENT
<1.3			DAUBER	69	нвс	
	ot use the	followin	g data for averag	es, flt	s, limits,	etc. • • •
● ● ● We do n			YEH	74	нвс	Effective denom.=664
● ● ● We do no <3.5	90	0				CHECKIAE DEMONIT004

≡⁰ DECAY PARAMETERS

See the "Note on Baryon Decay Parameters" in the neutron Listings.

$\alpha(\Xi^0) \alpha_-(\Lambda)$

VALUE -0.264±0.013 OUR AVER	EVTS	<u>DOCUMENT IE</u> ncludes scale fac		TECN	COMMENT
0.204 T 0.029 OOK WATE	AGE CHOIL	below.	101 01	2.1. 366	the lucogram
$-0.260\pm0.004\pm0.005$	300k	HANDLER	82	SPEC	FNAL hyperons
-0.317 ± 0.027	6075	BUNCE	78	SPEC	FNAL hyperons
-0.35 ±0.06	505	BALTAY	74	нвс	K ⁻ p 1.75 GeV/c
-0.28 ±0.06	739	DAUBER	69	нвс	K = p 1.7-2.6 GeV/c



α FOR \equiv 0 $\rightarrow \Lambda\pi^0$

The above average, $\alpha(\Xi^0)\alpha_-(\Lambda)=-0.264\pm0.013$, where the error includes a scale factor of 2.1, divided by our current average $\alpha_-(\Lambda)=0.642\pm0.013$, gives the following value for $\alpha(\Xi^0)$.

<u>VALUE</u> <u>DOCUMENT ID</u> <u>-0.411±0.022 OUR EVALUATION</u> Error Includes scale factor of 2.1.

# ANGLE FOR E	$^{0} \rightarrow \Lambda \pi^{0}$				$(\tan\phi=\beta/\gamma)$
VALUE (°)	EVTS	DOCUMENT ID		TECN	COMMENT
21±12 OUR AVER	AGE				
16 ± 17	652	BALTAY	74	HBC	1.75 GeV/c K-p
38 ± 19	739	3 DAUBER	69	HBC	•
- 8±30	146	⁴ BERGE	66	HBC	
_					

 $^{^3}$ DAUBER 69 uses $\alpha_{\Lambda}=0.647\pm0.020$.

⁴ The errors have been multiplied by 1.2 due to approximations used for the ≡ polarization; see DAUBER 69 for a discussion.

α FOR $\equiv^0 \rightarrow \Lambda\gamma$		•			
VALUE	EVTS	DOCUMENT ID	TECN	COMMENT	
+0.43±0.44	87	JAMES	90 SPEC	FNAL hyperons	
α FOR $\Xi^0 \to \Sigma^0$	Y				
VALUE	_EVTS	DOCUMENT ID	TECN	COMMENT	
+0.20±0.32±0.05	85	TEIGE	89 SPEC	FNAL hyperons	

=0 REFERENCES

JAMES	90	PRL 64 843	+Heller, Border, Dworkin+ (MINN, MICH, WISC, RUTG)
TEIGE	89	PRL 63 2717	+Beretvas, Caracappa, Devlin+ (RUTG, MICH, MINN)
BENSINGER	88	PL B215 195	+Fortner, Kirsch, Piekarz+ (BRAN, DUKE, NDAM, MASD)
HANDLER	82	PR D25 639	+Grobel, Pondrom+ (WISC, MICH, MINN, RUTG)
COX	81	PRL 46 877	+Dworkin+ (MICH, WISC, RUTG, MINN, BNL)
BUNCE	79	PL 86B 386	+Overseth, Cox+ (BNL, MICH, RUTG, WISC)
BUNCE	78	PR D18 633	+Handler, March, Martin+ (WISC, MICH, RUTG)
ZECH	77	NP B124 413	+Dydak, Navarria+ (SIEG, CERN, DORT, HEIDH)
GEWENIGER	75	PL 57B 193	+Gjesdal, Presser+ (CERN, HEIDH)
BALTAY	74	PR D9 49	+Bridgewater, Cooper, Gershwin+ (COLU, BING) J
YEH	74	PR D10 3545	+Gaigalas, Smith, Zendle, Baltay+ (BING, COLU)
MAYEUR	72	NP B47 333	+VanBinst, Wilquet+ (BRUX, CERN, TUFTS, LOUC)
Also	73	NP 853 268 erratum	Mayeur
WILQUET	72	PL 42B 372	+Fliagine, Guy+ (BRUX, CERN, TUFTS, LOUC)
DAUBER	69	PR 179 1262	+Berge, Hubbard, Merrill, Miller (LRL)
PALMER	68	PL 26B 323	+Radojicic, Rau, Richardson+ (BNL, SYRA)
BERGE	66	PR 147 945	+Eberhard, Hubbard, Merrill+ (LRL)
HUBBARD	66	Thesis UCRL 11510	(LRL)
LONDON	66	PR 143 1034	+Rau, Goldberg, Lichtman+ (BNL, SYRA)
PJERROU	65B	PRL 14 275	+Schlein, Slater, Smith, Stork, Ticho (UCLA)
Also	65	Thesis	Pjerrou (UCLA)
CARMONY	64B	PRL 12 482	+Pjerrou, Schlein, Slater, Stork+ (UCLA)
HUBBARD	64	PR 135B 183	+Berge, Kalbfleisch, Shafer+ (LRL)
JAUNEAU	63	PL 4 49	+ (EPOL, CERN, LOUC, RHEL, BERG)
Also	63C	Siena Conf. 1 1	Jauneau+ (EPOL, CERN, LOUC, RHEL, BERG)



$$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$$
 Status: ***

The parity has not actually been measured, but + is of course expected.

We have omitted some results that have been superseded by later experiments. See our earlier editions.

E" MASS

The fit uses the \mathcal{Z}^- , $\overline{\mathcal{Z}}^+$, and \mathcal{Z}^0 mass and mass difference measurements. It assumes the \mathcal{Z}^- and $\overline{\mathcal{Z}}^+$ masses are the same.

VALUE (MeV) 1321.32±0.13 OUR F 1321.34±0.14 OUR A		DOCUMENT ID		TECN	COMMENT
1321.46±0.34	632	DIBIANCA	75	DBC	4.9 GeV/c K - d
1321.12 ± 0.41	268	WILQUET	72	HLBC	•
1321.87±0.51	195	¹ GOLDWASSER	70	HBC	5.5 GeV/c K - p
1321.67±0.52	6	CHIEN	66	HBC	6.9 GeV/c 7p
1321.4 ±1.1	299	LONDON	66	HBC	1 1
1321.3 ±0.4	149	PJERROU	65B	HBC	
1321.1 ±0.3	241	² BADIER	64	HBC	
1321.4 ±0.4	517	² JAUNEAU	63D	FBC	
1321.1 ±0.65	62	² SCHNEIDER	63	HBC	

 $^{^{1}}$ GOLDWASSER 70 uses $m_{\Lambda}=$ 1115.58 MeV.

T+ MACC

The fit uses the Ξ^- , Ξ^+ , and Ξ^0 mass and mass difference measurements, it assumes the Ξ^- and Ξ^+ masses are the same.

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
1321.32±0.13 OUR	FIT				
1321.20±0.33 OUR	AVERAGE				
1321.6 ± 0.8	35	VOTRUBA	72	HBC	10 GeV/c K+p
1321.2 ±0.4	34	STONE	70	HBC	
1320.69 ± 0.93	5	CHIEN	66	HBC	6.9 GeV/ <i>c ₱p</i>
1320.69 ± 0.93	5	CHIEN	66	HBC	6.9 GeV/ <i>c ₱p</i>

$$(m_{\Xi^-} - m_{\Xi^+}) / m_{\text{average}}$$

A test of *CPT* invariance. We calculate it from the average Ξ^- and Ξ^+ masses above.

VALUE DOCUMENT ID

(1.1±2.7) × 10⁻⁴ OUR EVALUATION

² These masses have been increased 0.09 MeV because the A mass increased.

≡ MEAN LIFE

Measurements with an error $>0.2\times 10^{-10}~\text{s}$ or with systematic errors not included have been omitted.

VALUE (10 ⁻¹⁰ s)	EVTS	DOCUMENT ID		TECN	COMMENT
1.639±0.015 OUR	AVERAGE				
1.652 ± 0.051	32k	BOURQUIN	84	SPEC	Hyperon beam
1.665±0.065	41k	BOURQUIN	79	SPEC	Hyperon beam
1.609 ± 0.028	4286	HEMINGWAY	78	HBC	4.2 GeV/c K ⁻ p
1.67 ±0.08		DIBIANCA	75	DBC	4.9 GeV/c K-d
1.63 ±0.03	4303	BALTAY	74	HBÇ	1.75 GeV/c K-p
1.73 +0.08	680	MAYEUR	72	HLBC	2.1 GeV/c K-
1.61 ±0.04	2610	DAUBER	69	HBC	
1.80 ±0.16	299	LONDON	66	HBC	
1.70 ±0.12	246	PJERROU	65B	HBC	
1.69 ±0.07	794	HUBBARD	64	HBC	
1.86 +0.15	517	JAUNEAU	63D	FBC	

E+ MEAN LIFE

VALUE (10 ⁻¹⁰ s)	EVTS	DOCUMENT ID		TECN	COMMENT
1.6 ±0.3	34	STONE	70	нвс	
• • • We do not use	the following	ng data for averag	es, fit	s, limits,	etc. • • •
$1.55^{+0.35}_{-0.20}$	35	³ VOTRUBA	72	нвс	10 GeV/ <i>c K</i> + <i>p</i>
$1.9 \begin{array}{c} +0.7 \\ -0.5 \end{array}$	12	3 SHEN	67	нвс	
1.51 ± 0.55	5	3 CHIEN	66	нвс	6.9 GeV/ <i>c p̄p</i>
³ The error is statis	tical only.				

$(au_{\Xi^-} - au_{\Xi^+}) / au_{ ext{average}}$

A test of CPT invariance. Calculated from the Ξ^+ and Ξ^+ mean lives, above.

VALUE
0.02±0.18 OUR EVALUATION

DOCUMENT ID

=" MAGNETIC MOMENT

See the "Note on Baryon Magnetic Moments" in the $\ensuremath{\varLambda}$ Listings.

VALUE (·N)	EVTS	DOCUMENT ID		TECN	COMMENT
- 0.650	7±0.0025 OUR AVER	AGE				
- 0.650	5±0.0025	4.36M	DURYEA	92	SPEC	800 GeV p Be
-0.661	±0.036 ±0.036	44k	TROST	89	SPEC	.Ξ- ~ 250 GeV
-0.69	±0.04	218k	RAMEIKA	84	SPEC	400 GeV pBe
• • • V	Ve do not use the folk	owing data 1	for averages, fits,	limits	, etc. •	• • • • • • •
-0.674	±0.021 ±0.020	122k	но	90	SPEC	See DURYEA 92
-2.1	±0.8	2436	COOL	74	OSPK	1.8 GeV/c K-p
0.1	±2.1	2724	BINGHAM	708	OSPK	1.8 GeV/c K-p

E+ MAGNETIC MOMENT

See the "Note on Baryon Magnetic Moments" in the Λ Listings.

VALUE (µN)	EVTS	DOCUMENT ID T		TECN	COMMENT
+0.657±0.028±0.020	70k	но	90	SPEC	800 GeV pBe

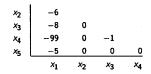
= DECAY MODES

	Mode	•	Fraction (Γ_i/Γ)	Confide	nce level
Γ ₁	Λπ-		(99.887±0.03	35) %	
Γ_2	$\Sigma^-\gamma$		(1.27 ±0.23	3)×10 ⁻⁴	
Γ3	Λe ⁻ $\overline{ u}_e$		(5.63 ±0.31) × 10 ⁻⁴	
Γ ₄	$\Lambda \mu^- \overline{ u}_{\mu}$		$(3.5 \begin{array}{c} +3.5 \\ -2.2 \end{array}$) × 10 ⁻⁴	
Γ_5	$\Sigma^0 e^- \overline{ u}_e$		(8.7 ±1.7) × 10 ⁻⁵	
Γ ₆	$\Sigma^0 \mu^- \overline{ u}_{\mu}$		< 8	× 10 ⁻⁴	90%
Γ ₇	$\Xi^0 e^- \overline{\nu}_e$		< 2.3	× 10 ⁻³	90%
		$\Delta S = 2$ forbidden	(<i>52</i>) modes		
Γ8	$n\pi^-$	52	< 1.9	× 10 ⁻⁵	90%
Г9	ne−⊽ _e	52	< 3.2	× 10 ⁻³	90%
Γ ₁₀	$n\mu^-\overline{ u}_{\mu}$	52	< 1.5	%	90%
Γ_{11}	$\rho \pi^- \pi^-$	52	< 4	× 10 ⁻⁴	90%
Γ ₁₂	$p\pi^-e^-\overline{\nu}_e$	52	< 4	× 10 ⁻⁴	90%
Γ ₁₃	$p\pi^-\mu^-\overline{\nu}_{\mu}$	52	< 4	× 10 ⁻⁴	90%
Γ ₁₄	ρμ-μ- ΄	L	< 4	× 10 ⁻⁴	90%

CONSTRAINED FIT INFORMATION

An overall fit to 4 branching ratios uses 5 measurements and one constraint to determine 5 parameters. The overall fit has a $\chi^2=1.0$ for 1 degrees of freedom.

The following off-diagonal array elements are the correlation coefficients $\langle \delta x_i \delta x_j \rangle / (\delta x_i \cdot \delta x_j)$, in percent, from the fit to the branching fractions, $x_i \equiv \Gamma_i / \Gamma_{\rm total}$. The fit constrains the x_i whose labels appear in this array to sum to one.



<1.1

= BRANCHING RATIOS

A number of early results have been omitted.

	•				
$\Gamma(\Sigma^-\gamma)/\Gamma(\Lambda\pi^-)$					Γ_2/Γ_1
VALUE (units 10-4)	EVTS	DOCUMENT ID	1	ECN	COMMENT
1.27±0.24 OUR FIT 1.27±0.23 OUR AVEF	ACE				
1.22 ± 0.23 ± 0.06	211	⁴ DUBBS	94 E	761	Ξ- 375 GeV
2.27±1.02	211	BIAGI	87B S		SPS hyperon beam
	-				
$= 1.0 \pm 1.3$).	ids weak	evidence that the a	symme	try pai	rameter $lpha_{m{\gamma}}$ is positive $(lpha_{m{\gamma}}$
$\Gamma(\Lambda e^- \overline{\nu}_e) / \Gamma(\Lambda \pi^-$	•				Γ ₃ /Γ ₁
VALUE (units 10 ⁻³) 0.564±0.031 OUR FIT	EVTS	DOCUMENT ID		TECN	COMMENT
0.564±0.031	2857	BOURQUIN	02	SPEC	SPS hyperon beam
• • • We do not use		•			•••
0.30 ±0.13	11	THOMPSON			Hyperon beam
$\Gamma(\Lambda\mu^-\overline{\nu}_\mu)/\Gamma(\Lambda\pi^-$.)				Γ_4/Γ_1
VALUE (units 10 ⁻³) CL9		DOCUMENT ID		TECN	COMMENT
0.35 +0.35 OUR F					
0.35 _ 0.22 OUR F	11				
0.35±0.35	1	YEH		HBC	Effective denom.=2859
• • We do not use to	the follow	ing data for average	es, fits,	limits	, etc. • • •
< 2.3 90	0	THOMPSON		ASPK	Effective denom.=1017
< 1.3		DAUBER		HBC	
<12		BERGE	66	нвс	
$\Gamma(\Sigma^0 e^- \overline{\nu}_e) / \Gamma(\Lambda \pi$	-)				Γ_5/Γ_1
VALUE (units 10 ⁻³)	EVTS	DOCUMENT ID		TECN	COMMENT
0.087±0.017 OUR FIT 0.087±0.017	T 154	BOURQUIN	83	SPEC	SPS hyperon beam
$\Gamma(\Sigma^0\mu^-\overline{\nu}_\mu)/\Gamma(\Lambda\pi$	-)				Γ ₆ /Γ ₁
VALUE (units 10 ⁻³) CLS		DOCUMENT ID		TECN	COMMENT
<0.76 90	1 1 1 1	YEH		HBC	Effective denom.=3026
• • • We do not use	•				
<5		BERGE	66		·
$[\Gamma(\Lambda e^{-} V_e) + \Gamma(\Sigma$	$^{0}e^{-}\overline{\nu}_{e})$]/ Г (//# ⁻)			$(\Gamma_3+\Gamma_5)/\Gamma_1$
VALUE (units 10 ⁻³)	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use		-			
0.651±0.031 0.68 ±0.22	3011 17	5 BOURQUIN 6 DUCLOS	83	SPEC OSPK	SPS hyperon beam
					(4) and E/=0 \/
	BOOKQO	in 65 values for i	(Ne	e)/'	$(\Lambda\pi^-)$ and $\Gamma(\Sigma^0e^-\overline{ u}_e)/$
$\Gamma(\Lambda\pi^-)$ above. 6 DUCLOS 71 cannot is about a factor 6	t distingu smaller t	ish Σ^0 's from Λ 's. Than the Λ rate.	The Ca	bibbo	theory predicts the $oldsymbol{\Sigma}^{oldsymbol{0}}$ rate
$\Gamma(\Xi^0 e^- \overline{\nu}_e) / \Gamma(\Lambda \pi$					Γ ₇ /Γ ₁
VALUE (units 10-3) CLS		DOCUMENT ID		TECN	COMMENT
<2.3 90	0	YEH		HBC	Effective denom.=1000
m/ _\					_ ·-
$\Gamma(n\pi^-)/\Gamma(\Lambda\pi^-)$ $\Delta S=2$. Forbidden in first-order weak interaction.					
VALUE (units 10 ⁻³) CLS		DOCUMENT ID		TECN	COMMENT
<0.019 90		BIAGI		SPEC	SPS hyperon beam
• • • We do not use	the follow	ing data for average	es, fits,	limits	
<3.0 90	0	YEH	74	нвс	Effective denom.=760

DAUBER

FERRO-LUZZI 63 HBC

$\Gamma(ne^-\overline{\nu}_e)/\Gamma(ne^-\overline{\nu}_e)$		in first or	der weak interact	lon		Γ9/Γ1	
VALUE (units 10 ⁻³)			DOCUMENT ID		TECN	COMMENT	
< 3.2	90		YEH		нвс	Effective denom.=715	
• • • We do not	use th	e following	g data for average	es, fits	, limits,	etc. • • •	
<10	90		BINGHAM	65	RVUE	•	
$\Gamma(n\mu^- u_\mu)/\Gamma(n\mu^- u_\mu)$	Λπ [—]) bidden	in first-or	der weak interact	ion.		Γ ₁₀ /Γ ₁	
VALUE (units 10 ⁻³)			DOCUMENT ID		TECN	COMMENT	
<15.3	90	0	YEH	74	нвс	Effective denom.=150	
$\Gamma(p\pi^-\pi^-)/\Gamma(\Lambda\pi^-)$ $\Delta S=2$. Forbidden in first-order weak interaction.							
VALUE (units 10 ⁻⁴)	CL%	EVT5	DOCUMENT ID		<u>TECN</u>	COMMENT	
<3.7	90	0	YEH	74	нвс	Effective denom.=6200	
Γ(pπ ⁻ e ⁻ ν _e), ΔS=2. For			der weak interact	ion.		Γ ₁₂ /Γ ₁	
VALUE (units 10 ⁻⁴)	CL%	EVTS	DOCUMENT ID		TECN	COMMENT	
<3.7	90	0	YEH	74	нвс	Effective denom.=6200	
$\Gamma(p\pi^-\mu^-\overline{\nu}_\mu)/\Gamma(\Lambda\pi^-)$ ΔS=2. Forbidden in first-order weak interaction.							
VALUE (units 10 ⁻⁴)	CL%	EVTS	DOCUMENT ID		TECN	COMMENT	
<3.7	90	0	YEH	74	HBC	Effective denom.=6200	
Γ(ρμ ⁻ μ ⁻)/Γ(Α Δ <i>L</i> =2 de			y total lepton nur	n ber d	onserva	Γ_{14}/Γ_{1}	
VALUE (units 10-4)		CL%	DOCUMENT ID		TECN	COMMENT	
<3.7		90	7 LITTENBERG	3 92B	HBC	Uses YEH 74 data	
						Its for the preceding three of the Ξ^- . One could as	

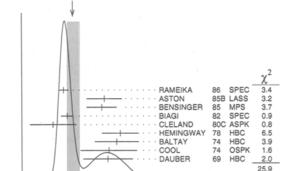
≡ DECAY PARAMETERS

See the "Note on Baryon Decay Parameters" in the neutron Listings.

well apply the limit to the sum of the four modes.

$\alpha(\Xi^{-})\alpha$ (A)

u(-)u-(/')				
VALUE	EVTS	DOCUMENT ID	<u>TECN</u>	COMMENT
-0.293±0.007 OUR AVER	AGE Error in	ncludes scale facto below.	r of 1.8. S	ee the ideogram
$-0.303\pm0.004\pm0.004$	192k	RAMEIKA	86 SPEC	400 GeV pBe
-0.257 ± 0.020	11k	ASTON	85B LASS	11 GeV/c K - p
-0.260±0.017	21k	BENSINGER	85 MPS	5 GeV/c K-p
-0.299 ± 0.007	150k	BIAGI	82 SPEC	SPS hyperon beam
-0.315 ± 0.026	9046	CLELAND	80c ASPI	
-0.239 ± 0.021	6599	HEMINGWAY	78 HBC	4.2 GeV/c K p
-0.243±0.025	4303	BALTAY	74 HBC	1.75 GeV/c K-p
-0.252 ± 0.032	2436	COOL	74 OSPI	K 1.8 GeV/c K - p
-0.253 ± 0.028	2781	DAUBER	69 HBC	



α FOR $\Xi^- \to \Lambda \pi^-$

-0.3

-0.35

WEIGHTED AVERAGE -0.293±0.007 (Error scaled by 1.8)

The above average, $\alpha(\Xi^-)$ $\alpha_-(\Lambda) = -0.293 \pm 0.007$, where the error includes a scale factor of 1.8, divided by our current average $\alpha_{-}(\Lambda)=0.642\pm0.013$, gives the following value for $\alpha(\Xi^+)$.

-0.2

-0.15

(Confidence Level = 0.001)

-0.25

φ AN	NGLE	FOR $\Xi^- \to \Lambda \pi^-$				$(\tan\phi=\beta/\gamma)$
VALUE	(°)	EVT5	DOCUMENT ID		TECN	COMMENT
4	± 4	OUR AVERAGE				
5	±10	11k	ASTON	85B	LASS	K-p
14.7	7 ± 16.0	21k	⁸ BENSINGER	85	MPS	5 GeV/c K-p
11	± 9	4303	BALTAY	74	HBC	1.75 GeV/c K-p
5	±16	2436	COOL	74	OSPK	1.8 GeV/c K-p
- 26	±30	2724	BINGHAM	70B	OSPK	•
14	±11	2781	DAUBER	69	HBC	Uses $\alpha_A = 0.647 \pm 0.020$
0	±12	1004	⁹ BERGE	66	HBC	,
0	±20.4	364	9 LONDON	66	HBC	Using $\alpha_A = 0.62$
54	±30	356	⁹ CARMONY	64B	HBC	- //

 $^{^8}_{-}$ BENSINGER 85 used $\alpha_{\mbox{$\Lambda$}} = 0.642 \pm 0.013$.

SA / SV FOR = → Ae Pe DOCUMENT ID TECN COMMENT 10 BOURQUIN 83 SPEC SPS hyperon beam -0.25±0.05 1992

$10\,\mathrm{BOURQUIN}$ 83 assumes that $g_2=0$. Also, the sign has been changed to agree with our conventions, given in the "Note on Baryon Decay Parameters" in the neutron Listings.

=- REFERENCES

We have omitted some papers that have been superseded by later experiments. See our earlier editions.

DUBBS	94	PRL 72 808	+Albuquerque, Bondar+ (FNAL E761 Collab.)
DURYEA	92	PRL 68 768	+Guglielmo, Heller+ (MINN, FNAL, MICH, RUTG)
LITTENBERG	92B	PR D46 R892	+Shrock (BNL, STON)
но	90	PRL 65 1713	+Longo, Nguyen, Luk+ (MICH, FNAL, MINN, RUTG)
Aiso	91	PR D44 3402	Ho, Longo, Nguyen, Luk+ (MICH, FNAL, MINN, RUTG)
TROST	89	PR D40 1703	+McCliment, Newsom, Hseuh, Mueller+ (FNAL-715 Collab.)
BIAGI	87B	ZPHY C35 143	 + (BRIS, CERN, GEVA, HEIDP, LÄUS, LOQM, RAL)
RAMEIKA	86	PR D33 3172	+Beretvas, Deck+ (RUTG, MICH, WISC, MINN)
ASTON	85B	PR D32 2270	+Carnegie+ (SLAC, CARL, CNRC, CINC)
BENSINGER	85	NP B252 561	+ (CHIC, ELMT, FNAL, ISU, PNPI, MASD)
BOURQUIN	84	NP B241 1	 + (BRIS, GEVA, HEIDP, LALO, RAL, STRB)
RAMEIKA	84	PRL 52 581	+Beretvas, Deck+ (RUTG, MICH, WISC, MINN)
BOURQUIN	83	ZPHY C21 1	+Brown+ (BRIS, GEVA, HEIDP, LALO, RL, STRB)
BIAGI	82	PL 112B 265	 + (BRIS, CAVE, GEVA, HEIDP, LAUS, LOQM, RL)
BIAGI	82B	PL 1128 277	 + (LOQM, GEVA, RL, HEIDP, CAVE, LAUS, BRIS)
CLELAND	80C	PR D21 12	+Cooper, Dris, Engels, Herbert+ (PITT, BNL)
THOMPSON	80	PR D21 25	+Cleland, Cooper, Dris, Engels+ (PITT, BNL)
BOURQUIN	79	PL 87B 297	 + (BRIS, GEVA, HEIDP, ORSAY, RHEL, STRB)
HEMINGWAY	78	NP B142 205	+Armenteros+ (CERN, ZEEM, NIJM, OXF)
DIBIANCA	75	NP B98 137	+Endorf (CMU)
BALTAY	74	PR D9 49	+Bridgewater, Cooper, Gershwin+ (COLU, BING) J
COOL	74	PR D10 792	+Giacomelli, Jenkins, Kycia, Leontic, Li+ (BNL)
Also	72	PRL 29 1630	Cool, Giacomelli, Jenkins, Kycia, Leontic+ (BNL)
YEH	74	PR D10 3545	+Gaigalas, Smith, Zendle, Baltay+ (BING, COLU)
MAYEUR	72	NP B47 333	+VanBinst, Wilquet+ (BRUX, CERN, TUFTS, LOUC)
VOTRUBA	72	NP B45 77	+Safder, Ratcliffe (BIRM, EDIN)
WILQUET	72	PL 42B 372	+Fliagine, Guy+ (BRUX, CERN, TUFTS, LOUC)
DUCLOS	71	NP B32 493	+Freytag, Heintze, Heinzelmann, Jones+ (CERN)
BINGHAM	70B	PR D1 3010	+Cook, Humphrey, Sander+ (UC5D, WASH)
GOLDWASSER		PR D1 1960	+Schultz (ILL)
STONE	70	PL 32B 515	+Berlinghieri, Bromberg, Cohen, Ferbel+ (ROCH)
DAUBER	69	PR 179 1262	+Berge, Hubbard, Merrill, Miller (LRL) J
SHEN	67	PL 25B 443	+Firestone, Goldhaber (UCB, LRL)
BERGE	66	PR 147 945	+Eberhard, Hubbard, Merrill+ (LRL) +Lach, Sandweiss, Taft, Yeh, Oren+ (YALE, BNL)
CHIEN	66	PR 152 1171	
LONDON	66	PR 143 1034	+Rau, Goldberg, Lichtman+ (BNL, SYRA) (CERN)
BINGHAM	65 65B	PRSL 285 202	+Schlein, Slater, Smith, Stork, Ticho (UCLA)
PJERROU		PRL 14 275 Thesis	
Also BADIER	65 64	Dubna Conf. 1 593	Pjerrou (UCLA) +Demoulin, Barloutaud+ (EPOL, SACL, ZEEM)
CARMONY	64B	PRL 12 482	+Pierrou, Schiein, Slater, Stork+ (UCLA) J
HUBBARD	64	PR 135B 183	+Berge, Kalbfleisch, Shafer+ (LRL)
FERRO-LUZZI	63	PR 130 1568	+Alston-Garnjost, Rosenfeld, Wojcicki (LRL)
JAUNEAU	63D	Siena Conf. 4	+ (EPOL, CERN, LOUC, RHEL, BERG)
Also	63B	PL 5 261	Jauneau+ (EPOL, CERN, LOUC, RHEL, BERG)
SCHNEIDER	63	PL 4 360	(CERN)
SCHILLIDEN			(cent)

<u>POCUMENT ID</u>
-0.456±0.014 OUR EVALUATION Error includes scale factor of 1.8.

The errors have been multiplied by 1.2 due to approximations used for the Ξ polarization; see DAUBER 69 for a discussion.

 Ξ 's, Ξ (1530)

E RESONANCES

The accompanying table gives our evaluation of the present status of the Ξ resonances. Not much is known about Ξ resonances. This is because (1) they can only be produced as a part of a final state, and so the analysis is more complicated than if direct formation were possible, (2) the production cross sections are small (typically a few μ b), and (3) the final states are topologically complicated and difficult to study with electronic techniques. Thus early information about Ξ resonances came entirely from bubble chamber experiments, where the numbers of events are small, and only in the 1980's did electronic experiments make any significant contributions. However, there has not been a single new piece of data on Ξ resonances since our 1988 edition.

For a detailed earlier review, see Meadows [1].

Table 1. The status of the Ξ resonances. Only those with an overall status of *** or **** are included in the Baryon Summary Table.

		_			Status	as seen in	
Particle	$L_{2I\cdot 2J}$	Overall status	Ξπ	ΛK	ΣK	$\Xi(1530)\pi$	Other channels
Ξ(1318)	$\overline{P_{11}}$	****					Decays weakly
Ξ(1530)	P_{13}	****	****				
$\Xi(1620)$		*	*				
E(1690)		***		***	**		
三(1820)	D_{13}	***	**	***	**	**	
E(1950)		***	**	**		*	
$\Xi(2030)$	1	***		**	***		
$\Xi(2120)$		*		*			
$\Xi(2250)$		**					3-body decays
$\Xi(2370)$	1	**					3-body decays
E(2500)	_	*		*	*		3-body decays

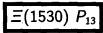
- **** Existence is certain, and properties are at least fairly well explored.

 *** Existence ranges from very likely to certain, but further confirmation is desirable and/or quantum numbers, branching fractions, etc. are not well determined.
- etc. are not well determined.

 ** Evidence of existence is only fair.
- * Evidence of existence is poor.

Reference

 B.T. Meadows, in Proceedings of the IVth International Conference on Baryon Resonances (Toronto, 1980), ed. N. Isgur, p. 283.



$$I(J^P) = \frac{1}{2}(\frac{3}{2}^+)$$
 Status: ***

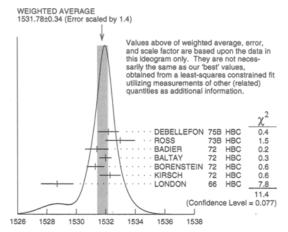
This is the only Ξ resonance whose properties are all reasonably well known. Spin-parity $3/2^+$ is favored by the data.

We use only those determinations of the mass and width that are accompanied by some discussion of systematics and resolution.

≡(1530) MASSES

≡(1530)0 MAS	S			
VALUE (MeV)	EVT5	DOCUMENT ID	TECN	COMMENT
1531.80±0.32 OU	R FIT Error in	cludes scale factor	of 1.3.	
1531.78±0.34 OU	R AVERAGE E	rror includes scale below.	factor of 1.	4. See the Ideogram
1532.2 ±0.7		DEBELLEFON	758 HBC	$K^-p \rightarrow \Xi^- \overline{K} \pi$
1533 ±1		ROSS	73B HBC	$K^- p \rightarrow \Xi \overline{K} \pi(\pi)$
1531.4 ±0.8	59	BADIER	72 HBC	K-p 3.95 GeV/c
1532.0 ±0.4	1262	BALTAY	72 HBC	K~ p 1.75 GeV/c
1531.3 ±0.6	324	BORENSTEIN	72 HBC	K = p 2.2 GeV/c
1532.3 ±0.7	286	KIRSCH	72 HBC	K-p 2.87 GeV/c
1528.7 ±1.1	76	LONDON	66 HBC	K - p 2.24 GeV/c

• • • '	We do not	use the following	data for average	s, fits, limits	etc. • • •	
1532.1	±0.4	1244	ASTON	85B LASS	K~ p 11 GeV/c	
1532.1	±0,6	2700	1 BAUBILLIER	81B HBC	K - p 8.25 GeV/c	
1530	±1	450	BIAGI	81 SPEC	SPS hyperon beam	
1527	±6	80	SIXEL	79 HBC	K - p 10 GeV/c	
1535	±4	100	SIXEL	79 HBC	K- p 16 GeV/c	
1533.6	±1.4	97	BERTHON	74 HBC	Quasi-2-body σ	



Ξ(1530) [−] MASS					
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
1.535.0±0.6 OUR FT	Τ				
1535.2±0.8 OUR AV	/ERAGE				
1534.5±1.2		DEBELLEFON	75B	HBC	K ⁻ p → Ξ ⁻ Kπ
1535.3 ± 2.0		ROSS	738	HBC	$K^- p \rightarrow \Xi \overline{K} \pi(\pi)$
1536.2±1.6	185	KIRSCH	72	HBC	K-p 2.87 GeV/c
1535.7±3.2	38	LONDON	66	HBC	K p 2.24 GeV/c
• • We do not use	e the followin	g data for averages	, fits	i, Ilmits	, etc. • • •
1540 ±3	48	BERTHON	74	нвс	Quasi-2-body σ
1534.7±1.1	334	BALTAY	72	HBC	K- p 1.75 GeV/c

VALUE (MeV) DOCUMENT ID TECN COMMENT 3.2±0.6 OUR FIT 2.9±0.9 OUR AVERAGE BALTAY 72 HBC K-p 1.75 GeV/c 2.7 ± 1.0 MERRILL 66 HBC K- p 1.7-2.7 GeV/c 2.0±3.2 **PJERROU** 65B HBC K D 1.8-1.95 GeV/c 5.7±3.0 • • • We do not use the following data for averages, fits, limits, etc. • • • 3.9±1.8 2 KIRSCH 72 HBC K- p 2.87 GeV/c ² LONDON HBC K- p 2.24 GeV/c

 $m_{\Xi(1530)^-} - m_{\Xi(1530)}$

Ξ(1530) WIDTHS

Ξ(1530) WIDT	Н			
VALUE (MeV)	EVTS	DOCUMENT ID	TE	CN COMMENT
9.1±0.5 OUR AV	RAGE			
9.5 ± 1.2		DEBELLEFON	758 HE	$SC K^-p \rightarrow \Xi^- \overline{K}\pi$
9.1 ± 2.4		ROSS	73B H	$SC K^-p \rightarrow \Xi \overline{K}\pi(\pi)$
11 ±2		BADIER	72 HE	3C K p 3.95 GeV/c
9.0±0.7		BALTAY	72 HE	3C K p 1.75 GeV/c
8.4±1.4		BORENSTEIN	72 H	3C <i>Ξ</i> − π ⁺
11.0±1.8		KIRSCH	72 H	3C Ξ-π ⁺
7 ±7		BERGE	66 HE	3C K-p 1.5-1.7 GeV/c
8.5 ± 3.5		LONDON	66 H	3C K = p 2.24 GeV/c
7 ±2		SCHLEIN	63B HE	3C K-p 1.8, 1.95 GeV/
 • • We do not u 	se the followi	ng data for average	s, fits, il:	mits, etc. • • •
12.8±1.0	2700	1 BAUBILLIER	818 H	3C K - p 8.25 GeV/c
19 ±6	80	3 SIXEL	79 H	3C K = p 10 GeV/c
14 ±5	100	³ SIXEL	79 H	3C K - p 16 GeV/c
≡(1530) − WID7	гн			
VALUE (MeV)		DOCUMENT ID	TE	CN COMMENT
9.9 ^{+1.7} OUR AV	ERAGE			
9.6 ± 2.8		DEBELLEFON	758 H	$SC K^-p \rightarrow \Xi^- \overline{K}\pi$
8.3 ± 3.6		ROSS	73B H	$SC K^-p \rightarrow \Xi \overline{K} \pi(\pi)$
7.8 + 3.5 - 7.8		BALTAY	72 H	BC K = p 1.75 GeV/c
16.2+4.6		KIRSCH	72 H	3C =- \pi^0, \pi^0\pi^-

Ξ(1530) POLE POSITIONS

Ξ(1530)⁰ REAL PART <u>VALUE</u> 1531.6 ± 0.4	DOCUMENT ID LICHTENBERG74	COMMENT Using HABIBI 73
Ξ(1530)⁰ IMAGINARY PART <u>VALUE</u> 4.45±0.35	DOCUMENT ID LICHTENBERG74	COMMENT Using HABIBI 73
E(1530) REAL PART <u>VALUE</u> 1534.4±1.1	DOCUMENT ID LICHTENBERG74	COMMENT Using HABIBI 73
E(1530) IMAGINARY PART <u>VALUE</u> 3.9 ^{+1.75} -3.9	DOCUMENT ID LICHTENBERG74	COMMENT Using HABIBI 73

≡(1530) DECAY MODES

	Mode	Fraction (Γ_I/Γ)	Confidence level
Γ_1	Ξπ	100 %	
Γ_2	$\equiv \gamma$	<4 %	90%

Ξ(1530) BRANCHING RATIOS

$\Gamma(\Xi\gamma)/\Gamma_{\text{total}}$				Г2/Г
VALUE	CL%	DOCUMENT ID	TECN_	COMMENT
<0.04	90	KALBFLEISCH 75	HBC	K-p 2.18 GeV/c

≡(1530) FOOTNOTES

¹ BAUBILLIER 81B is a fit to the inclusive spectrum. The resolution (5 MeV) is not unfolded.

Redundant with data in the mass Listings.

³SIXEL 79 doesn't unfold the experimental resolution of 15 MeV.

≡(1530) REFERENCES

BAUBILLIER 8 BIAGI 8 SIXEL 7 DEBELLEFON 7 KALBFLEISCH 7 BERTHON 7 LICHTENBERG 7 AISO 7 HABIBI 77 ROSS 7 BADIER 7 BALTAY 7 BORENSTEIN 7 KIRSCH 8 EERGE 6	31B 31 79 75B 75 74 74 74B 73 73B 72 72 72	PR D32 2270 NP B192 1 ZPHY C9 305 NP B159 125 NC 28A 289 PR D11 987 NC 21A 146 PR D10 3865 Private Comm. Thesis Nevis 199 Purdue Conf. 355 NP B37 429 PR D5 1559 NP B40 349 PR D4 349 PR D4 349 PR D4 349 PR 143 1034	+Tristram+ (CDEF, RHEL, SACL Lichtenberg +Lloyd, Radojicic +Barrelet, Charlton, Videau +Bridgewater, Cooper, Gershwin+ (COLL +Danburg, Kalbfleisch+ (BNL +Schmidt, Chang+ (BRAN, UMD, SYRA, +Eberhard, Hubbard, Merrill+	CURIN) , RHEL) , VIEN) , SACL) , MICH) , STRB) (IND) (OXF) (EPOL) , BING)	
BERGE 6	66	PR 147 945	+Eberhard, Hubbard, Merrill+	(LRL)	11
MERRILL 6	6	Thesis UCRL 16455	•	(LRL)	JP
		PRL 14 275 PRL 11 167	+Schlein, Slater, Smith, Stork, Ticho +Carmony, Pjerrou, Slater, Stork, Ticho	(UCLA)	
	-	OTHER	R RELATED PAPERS	·	

MAZZUCATO 81 NP B178 1 +Pennino+ BRIEFEL 77 PR D16 2706 +Gourevitch, Chang+ HUNGERBU 74 PR D10 2051 Hungerbailer, Majka+ BUTTON 66 PR 142 883 Button-Shafer, Lindsey, Mr	(AMST, CERN, NIJM, OXF) (BRAN, UMD, SYRA, TUFTS) (BRAN, UMD, SYRA, TUFTS) (YALE, FNAL, BNL, PITT) lurray, Smith (LRL)
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 $\Xi(1620)$

 $I(J^P) = \frac{1}{2}(?^?)$ Status: * J, P need confirmation.

OMITTED FROM SUMMARY TABLE

What little evidence there is consists of weak signals in the $\Xi\pi$ channel. A number of other experiments (e.g., BORENSTEIN 72 and HASSALL 81) have looked for but not seen any effect.

Ξ(1620) MASS

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
≈ 1620 OUR ESTII	MATE				
1624± 3	31	BRIEFEL	77	HBC	K-p 2.87 GeV/c
1633 ± 12	34	DEBELLEFON	758	HBC	K ⁻ ρ → Ξ ⁻ Kπ
1606 ± 6	29	ROSS	72	HBC	K-p 3.1-3.7 GeV/c

Ξ(1620) WIDTH

¹ BRIEFI	EL 77	HBC	K-p 2.87 GeV/c
			N P 2.01 GCV/C
DEBEL	LEFON 758	в нвс	$K^{-}p \rightarrow \Xi^{-}\overline{K}\pi$
ROSS	72	HBC	$K^-\rho \rightarrow$
			DEBELLEFON 758 HBC ROSS 72 HBC

Ξ(1620) DECAY MODES

	Mode	
Γ ₁	Ξπ	

Ξ(1620) FOOTNOTES

¹ The fit is insensitive to values between 15 and 30 MeV.

≡(1620) REFERENCES

HASSALL BRIEFEL Also Also DEBELLEFON BORENSTEIN	75B		Briefel+ (Briefel, Gourevitch+ (De Bellefon, Berthon, Billoi	BRAN, U BRAN, U	(CAVE, MSU) MD, SYRA, TUFTS) MD, SYRA, TUFTS) MD, SYRA, TUFTS) (CDEF, SACL) (RNI, MICH)
BORENSTEIN ROSS		PR D5 1559 PL 38B 177	+Danburg, Kalbfleisch+ +Buran, Lloyd, Mulvey, Rado		(BNL, MICH) I (OXF) I

OTHER RELATED PAPERS -

HUNGERBU SCHMIDT KALBFLEISCH	73	PR D10 2051 Purdue Conf. 363 Duke Conf. 331	Hungerbuhler,	Majka+ (YALE, FNAL, BNL, PITT) (BRAN) (BNL) I
APSELL	69	PRL 23 884	+	(BRAN, UMD, SYRA, TÚFTS)
BARTSCH	69	PL 28B 439	+	(AACH, BERL, CERN, LOIC, VIEN)

Ξ(1690)

 $I(J^P) = \frac{1}{2}(?^?)$ Status: ***

DIONISI 78 sees a threshold enhancement in both the neutral and negatively charged $\Sigma \overline{K}$ mass spectra in $K^- p \to (\Sigma \overline{K}) K \pi$ at 4.2 GeV/c. The data from the ΣK channels alone cannot distinguish between a resonance and a large scattering length. Weaker evidence at the same mass is seen in the corresponding $\Lambda \overline{K}$ channels, and a coupled-channel analysis yields results consistent with a new \varXi .

BIAGI 81 sees an enhancement at 1700 MeV in the diffractively produced ΛK^- system. A peak is also observed in the $\Lambda \overline{K}{}^0$ mass spectrum at 1660 MeV that is consistent with a 1720 MeV resonance decaying to $\Sigma^0\overline{K}^0$, with the γ from the Σ^0 decay not detected.

BIAGI 87 provides further confirmation of this state in diffractive dissociation of Ξ^- into ΛK^- . The significance claimed is 6.7 standard deviations.

≡(1690) MASSES

MIXED CHARGES

DOCUMENT ID

1690±10 OUR ESTIMATE This is only an educated guess; the error given is larger than the error on the average of the published values.

Ξ(1690)⁰ MASS

VALUE (MeV)	<u>EVT5</u>	DOCUMENT ID		TECN	COMMENT
1699±5	175	¹ DIONISI	78	нвс	K- p 4.2 GeV/c
1684±5	183	² DIONISI	78	нвс	K p 4.2 GeV/c
 Ξ(1690) − MASS	51.55	000000000000000000000000000000000000000			201115117
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
1691.1± 1.9±2.0	104	BIAGI	87	SPEC	∃ [−] Be 116 GeV
1700 ±10	150	³ BIAGI	81	SPEC	Ξ−H 100, 135 GeV
1694 ± 6	45	⁴ DIONISI	78	HBC	K- p 4.2 GeV/c

 $\Xi(1690), \Xi(1820)$

3	E(1690) WIDTHS						
MIXED CHARGES VALUE (MeV)	DOCUMENT ID						
<50 OUR ESTIMATE							
 (1690) ⁰ WIDTH							
<u>VALUE (MeV)</u> <u>EVTS</u> 44±23 175	DOCUMENT ID DIONISI 78	TECN HBC	COMM K-D	4.2 GeV/c			
	DIONISI 78	нвс		4.2 GeV/c			
<i>≣</i> (1690) [—] WIDTH							
VALUE (MeV) CL% EVTS	DOCUMENT ID	TECN	сомм	IENT			
< 8 90 104	BIAGI 87			e 116 GeV			
	³ BIAGI 81 ⁴ DIONISI 78	SPEC HBC		100, 135 GeV 4.2 GeV/c			
E(1690) DECAY MODES							
• •							
Mode		tion (F ₁ /	(1)				
Γ ₁ Λ Κ Γ ₂ Σ Κ	seen seen						
Γ ₃ ≅π	Seen						
$\Gamma_4 = \pi^+ \pi^0$							
$\Gamma_5 = \Xi^- \pi^+ \pi^- $ $\Gamma_6 = \Xi(1530)\pi$	poss	ibly seen					
) BRANCHING R	ATIOS					
Γ(ΛK)/Γ _{total}) DIONICHING K	A1103		r./r			
VALUE EVTS	DOCUMENT ID	TECN	CHG	Γ ₁ /Γ			
seen 104	BIAGI 87		_	≅ Be 116 GeV			
$\Gamma(\Sigma \overrightarrow{K})/\Gamma(\Lambda \overrightarrow{K})$				Γ_2/Γ_1			
VALUE	DOCUMENT ID	TECN	CHG	COMMENT			
2.7±0.9	DIONISI 78 DIONISI 78	НВС НВС	0	K p 4.2 GeV/c K p 4.2 GeV/c			
3.1±1.4 [(=-)/[(\(\nabla\)\)]	DIOIVISI 16	nac	_				
Γ(Ξπ)/Γ(Σ K)	DOCUMENT ID	TECN	CHG	Γ ₃ /Γ ₂			
<0.09	DIONISI 78		0	K- p 4.2 GeV/c			
$\Gamma(\Xi^-\pi^+\pi^0)/\Gamma(\Sigma \overrightarrow{K})$				Γ_4/Γ_2			
VALUE	DOCUMENT ID	TECN	CHG	COMMENT			
<0.04	DIONISI 78	HBC	0	K~ p 4.2 GeV/c			
$\Gamma(\Xi^-\pi^+\pi^-)/\Gamma_{\text{total}}$				Γ ₅ /Γ			
VALUE EVTS			CHG	COMMENT			
possibly seen 4	BIAGI 87	SPEC	-	Ξ Be 116 GeV			
Γ(Ξ¯π ⁺ π¯)/Γ(Σ ¯ Κ)				Γ_5/Γ_2			
<0.03	DIONISI 78	TECN_ HBC	<u>CHG</u>	K- p 4.2 GeV/c			
Γ(Ξ(1530)π)/Γ(Σ K)	Diomai 10	1100		Γ ₆ /Γ ₂			
(=(1930)*)/1 (2 K)	DOCUMENT ID	TECN	CHG	COMMENT COMMENT			
<0.06	DIONISI 78	нвс	-	K-p 4.2 GeV/c			
$\Xi($ 1 From a fit to the Σ^+K^- spect	≡(1690) FOOTNOTES						
2 From a coupled-channel analysi		Λ Κ ⁰ sp	ectra.				
³ A fit to the inclusive spectrum from $\Xi^- N \to \Lambda K^- X$. ⁴ From a coupled-channel analysis of the $\Sigma^0 K^-$ and ΛK^- spectra.							
			ectra.				
Ξ (:	1690) REFERENC	ES					
BIAGI 87 ZPHY C34 15 BIAGI 81 ZPHY C9 305 DIONISI 78 PL 80B 145	 + (BRIS, CAVE, 	GEVA, HE	IDP, LA	AUS, LOQM, RAL) I US, LOQM, RHEL)			
010-143	+Diaz, Armenteros+	,	curit, F	MST, NIJM, OXF) I			

$\Xi(1820) D_{13}$

 $I(J^P) = \frac{1}{2}(\frac{3}{2}^-)$ Status: ***

The clearest evidence is an 8-standard-deviation peak in ΛK^- seen. by GAY 76. TEODORO 78 favors J=3/2, but cannot make a parity discrimination. BIAGI 87C is consistent with J=3/2 and favors negative parity for this J value.

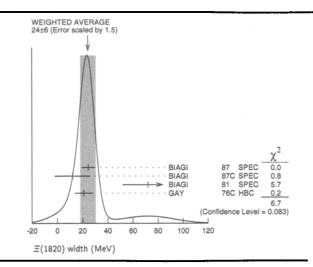
Ξ(1820) MASS

We only average the measurements that appear to us to be most significant and best determined. $\label{eq:continuous} % \begin{subarray}{ll} \end{subarray} \begin{subarray}{$

VALUE (MeV)	EVTS	DOCUMENT ID	TEC	N CHG	COMMENT
1823 ± 5 OUR E	STIMATE				
1823.4± 1.4 OUR A	WERAGE				
1819.4± 3.1±2.0	280	1 BIAGI	87 SPE	C 0	Ξ ⁻ Be → (ΛΚ ⁻) X
$1826 \pm 3 \pm 1$	54	BIAGI	87C SPE	C 0	Ξ^- Be $\to (\Lambda \overline{K}^0)$
1822 ± 6		JENKINS	83 MP	S ~	$K^{-}p \rightarrow K^{+}$ (MM)
1830 ± 6	300	BIAGI	81 SPE	C -	SPS hyperon beam
1823 ± 2	130	GAY	76C HB	c –	K p 4.2 GeV/c
• • • We do not use	e the following	g data for average	es, fits, lim	its, etc. o	• • •
1797 ±19	74	BRIEFEL	77 HB	C 0	K- p 2.87 GeV/c
1829 ± 9	68	BRIEFEL	77 HB	C -0	$\Xi(1530)\pi$
1860 ±14	39	BRIEFEL	77 HB	c –	$\Sigma = \overline{K}^0$
1870 ± 9	44	BRIEFEL	77 HB	C 0	$\Lambda \overline{K}^0$
1813 ± 4	57	BRIEFEL	77 HB	c -	ΛK-
1807 ±27		DIBIANCA	75 DB	C -0	$\Xi \pi \pi, \Xi^* \pi$
1762 ± 8	28	² BADIER	72 HB	C -0	$\Xi \pi$, $\Xi \pi \pi$, YK
1838 ± 5	38	² BADIER	72 HB	C -0	$\Xi\pi, \Xi\pi\pi, YK$
1830 ±10	25	3 CRENNELL	708 DB	C -0	3.6, 3.9 GeV/c
1826 ±12	**	4 CRENNELL	708 DB	C -0	3.6, 3.9 GeV/c
1830 ±10	40	ALITTI	69 HB	c –	Λ, ΣK
1814 ± 4	30	BADIER	65 HB	C 0	$\Lambda \overline{K}^0$
1817 ± 7	29	SMITH	65c HB	C -0	$\Lambda \overline{K}^0$, ΛK^-
1770		HALSTEINSL	ID63 FB0	C -0	K freon 3.5 GeV/c

Ξ(1820) WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
24	+15 -10	OUR ESTIMATE					
24	± 6	OUR AVERAGE	Error includes scale below.	fact	or of 1.	5. See	the ideogram
24.0	5± 5.3	280	¹ BIAGI	87	SPEC	0	Ξ Be → (ΛΚ) X
12	±14	±1.7 54	BIAGI	87C	SPEC	0	Ξ^- Be $\rightarrow (\Lambda \overline{K}^0)$
72	±20	300	BIAGI	81	SPEC	~	SPS hyperon beam
21	± 7	130	GAY	76 C	нвс	~	K p 4.2 GeV/c
• • •	We do	not use the following	ig data for averages	, fits	, limits,	etc. •	• •
99	±57	74	BRIEFEL	77	HBC	0	K-p 2.87 GeV/c
52	±34	68	BRIEFEL	77	HBC	~0	Ξ(1530)π
72	±17	39	BRIEFEL	77	HBC	-	$\Sigma - \underline{K}_0$
44	±11	44	BRIEFEL	77	HBC	0	$\Lambda \overline{K}^0$
26	±11	57	BRIEFEL	77	HBC	-	AK-
85	±58		DIBIANCA	75	DBC	-0	Ξππ, Ξ*π
51	±13		² BADIER	72	нвс	-0	Lower mass
58	±13		² BADIER	72	HBC	-0	Higher mass
103	+38 -24		³ CRENNELL	70B	DBC	-0	3.6, 3.9 GeV/c
48	+ 36 - 19		4 CRENNELL	70B	DBC	-0	3.6, 3.9 GeV/c
55	+40 -20		ALITTI	69	нвс	-	A, EK
12	± 4		BADIER	65	HBC	0	$\Lambda \overline{K}^0$
30	± 7		SMITH	65 6	HBC	-0	ΛK
< 80			HALSTEINSLI	263	FBC	-0	K⁻ freon 3.5 GeV/c



≡(1820) DECAY MODES

	Mode	Fraction (Γ_i/Γ)	
Γ ₁ Γ ₂	Λ <u>K</u>	large	
	$\Sigma \overline{K}$	smalt	
Γ3	$\Xi\pi$	smali	
Γ4	$\Xi(1530)\pi$	small	
۲5	$\Xi\pi\pi(\operatorname{not}\Xi(1530)\pi)$		

Ξ(1820) BRANCHING RATIOS

The dominant modes seem to be $A\overline{K}$ and (perhaps) $\Xi(1530)\pi$, but the branching fractions are very poorly determined.

r(Λ̄K)/r _{total}	•				Г1/Г
VALUE	DOCUMENT ID		TECN_	CHG	COMMENT
0.30±0.15	ALITTI	69	нвс	-	K ⁻ p 3. 9- 5 GeV/c
Γ(Ξπ)/Γ _{total}					Γ ₃ /Γ
VALUE			TECN	CHG	COMMENT
0.10±0.10	ALITTI	69	нвс	-	K ⁻ p 3. 9- 5 GeV/c
Γ(Ξπ)/Γ(Λ K)					Γ ₃ /Γ ₁
VALUE CL	<u>DOCUMENT ID</u>		TECN	CHG	COMMENT
<0.36 95	GAY	76 C	HBC	_	K-p 4.2 GeV/c
0.20±0.20	BADIER	65	нвс	0	K−p 3 GeV/c
$\Gamma(\Xi\pi)/\Gamma(\Xi(1530)\pi)$					Γ_3/Γ_4
VALUE	DOCUMENT ID		TECN	CHG	COMMENT
1.5 ^{+0.6} -0.4	APSELL	70	нвс	0	K [−] p 2.87 GeV/c
$\Gamma(\Sigma \overline{K})/\Gamma_{\text{total}}$					Γ ₂ /Γ
VALUE	DOCUMENT ID		TECN	CHG	COMMENT
0.30±0.15	ALITTI	69	нвс	-	K p 3.9-5 GeV/c
• • • We do not use the fol	lowing data for average	s, fits	, limits,	etc. •	
<0.02	TRIPP	67	RVUE		Use SMITH 65C
$\Gamma(\Sigma \overline{K})/\Gamma(\Lambda \overline{K})$					Γ_2/Γ_1
VALUE	DOCUMENT ID		<u>TECN</u>	CHG	COMMENT
0.24±0.10	· GAY	7 6 C	нвс	-	K-p 4.2 GeV/c
$\Gamma(\Xi(1530)\pi)/\Gamma_{\text{total}}$					Γ4/Γ
VALUE	DOCUMENT ID		<u>TECN</u>	<u>CHG</u>	COMMENT
0.30±0.15	ALITTI	69	нвс	-	K ⁻ p 3.9-5 GeV/c
• • • We do not use the for	lowing data for average	s, fits	, limits,	etc. •	
seen	ASTON	85B	LASS		K - p 11 GeV/c
not seen	5 HASSALL	81	HBC		K-p 6.5 GeV/c
<0.25	6 DAUBER	69	нвс		K-p 2.7 GeV/c
$\Gamma(\Xi(1530)\pi)/\Gamma(\Lambda \overline{K})$					Γ_4/Γ_1
VALUE	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT
0.36±0.27 OUR AVERAGE					K= - 42 C-V/-
1.0 ±0.3	GAY		HBC	_	K = p 4.2 GeV/c
0.26±0.13	SMITH	65 C	НВС	-0	K p 2.45-2.7 GeV/c

VALUE	DOCUMENT ID		TECN	CHG	Γ _δ /Γ ₁
0.30±0.20	BIAGI	87	SPEC	_	= Be 116 GeV
• • • We do not use the fo	ollowing data for averag	es, fits	, limits	etc. •	
<0.14	7 BADIER	65	HBC	0	1 st. dev. limit
>0.1	SMITH	65C	HBC	-0	K ⁻ p 2.45-2.7 GeV/c
					201/2
Γ(Ξππ(notΞ(1530)π))/Γ(Ξ(1530)π)				Гв/Гл
)/Γ(Ξ(1530)π) 		TECN	<u>CHG</u>	•
$\Gamma(\Xi\pi\pi(\text{not}\Xi(1530)\pi))$ VALUE consistent with zero			TECN HBC	<u>снс</u> –	Г _Б /Га
VALUE	DOCUMENT ID	7 6 C	нвс	_	Γ _B /Γ _c <u>COMMENT</u> K ⁻ p 4.2 GeV/c

Ξ(1820) FOOTNOTES

- 1 BIAGI 87 also sees weak signals in the in the $\Xi^-\pi^+\pi^-$ channel at 1782.6 \pm 1.4 MeV ($\Gamma=6.0\pm1.5$ MeV) and 1831.9 \pm 2.8 MeV ($\Gamma=9.6\pm9.9$ MeV).
- 2 BADIER 72 adds all channels and divides the peak into lower and higher mass regions.

 The data can also be fitted with a single Breit-Wigner of mass 1800 MeV and width 150 MeV. ³ From a fit to inclusive $\Xi\pi$, $\Xi\pi\pi$, and ΛK^- spectra.
- ⁴ From a fit to inclusive $\Xi \pi$ and $\Xi \pi \pi$ spectra only.
- ⁵ Including $\Xi \pi \pi$.
- 6 DAUBER 69 uses in part the same data as SMITH 65C. 7 For the decay mode $\Xi^-\pi^+\pi^0$ only. This limit includes $\Xi(1530)\pi$.
- ⁸ Or less. Upper limit for the 3-body decay.

≡(1820) REFERENCES

BIAGI	87	ZPHY C34 15	 + (BRIS, CERN, GEVA, HEIDP, LAUS, LOQM, RAL)
BIAGI	87C	ZPHY C34 175	+ (BRIS, CERN, GEVA, HEIDP, LAUS, LOQM, RAL) JP
ASTON	85B	PR D32 2270	+Carnegie+ (SLAC, CARL, CNRC, CINC)
JENKINS	83	PRL 51 951	+Albright, Diamond+ (FSU, BRAN, LBL, CINC, MASD)
BIAGI	81	ZPHY C9 305	+ (BRIS, CAVE, GEVA, HEIDP, LAUS, LOQM, RHEL)
HASSALL	81	NP B189 397	+Ansorge, Carter, Neale+ (CAVE, MSU)
TEODORO	78	PL 77B 451	+Diaz, Dionisi, Blokzijl+ (AMST, CERN, NIJM, OXF) JP
BRIEFEL	77	PR D16 2706	+Gourevitch, Chang+ (BRAN, UMD, SYRA, TUFTS)
Also	69	PRL 23 884	Apseli+ (BRAN, UMD, SYRA, TUFTS)
GAY	76	NC 31A 593	+Jeanneret, Bogdanski+ (NEUC, LAUS, LIVP, CURIN)
GAY	76C	PL 62B 477	+Armenteros, Berge+ (AMST, CERN, NIJM) IJ
DIBIANCA	75	NP B98 137	+Endorf (CMU)
BADIER	72	NP B37 429	+Barrelet, Charlton, Videau (EPOL)
APSELL	70	PRL 24 777	+ (BRAN, UMD, SYRA, TUFTS) I
CRENNELL	70B	PR D1 847	+Karshon, Lai, O'Neall, Scarr, Schumann (BNL)
ALITTI	69	PRL 22 79	+Barnes, Flaminio, Metzger+ (BNL, SYRA) I
DAUBER	69	PR 179 1262	+Berge, Hubbard, Merrill, Miller (LRL)
TRIPP	67	NP B3 10	+Leith+ (LRL, SLAC, CERN, HEID, SACL)
BADIER	65	PL 16 171	+Demoulin, Goldberg+ (EPOL, SACL, AMST) I
SMITH	65B	Athens Conf. 251	+Lindsey (LRL)
SMITH	65C	PRL 14 25	+Lindsey, Button-Shafer, Murray • (LRL) IJP
HALSTEINSLI	D 63	Siena Conf. 1 73	 + (BERG, CERN, EPOL, RHEL, LOUC) !

OTHER RELATED PAPERS

TEODORO BRIEFEL SCHMIDT	78 75 73	PL 77B 451 PR D12 1859 Purdue Conf. 363	+Diaz, Dionisi, Blokzijl+ +Gourevitch+	(AMST, CERN, NI (BRAN, UMD, SYRA	
MERRILL	68	PR 167 1202	+Shafer	afer+	(LRL)
SMITH	64	PRL 13 61	+Lindsey, Murray, Button-Sha		(LRL) IJ

Ξ(1950)

$$I(J^P) = \frac{1}{2}(?^?)$$
 Status: ***

We list here everything reported between 1875 and 2000 MeV. The accumulated evidence for a E near 1950 MeV seems strong enough to include a $\Xi(1950)$ in the main Baryon Table, but not much can be said about its properties. In fact, there may be more than one Ξ near this mass.

Ξ(1950) MASS

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
1950±15 OUR EST		DOCOMENT 10	_	TECH	COMMENT
1944 ± 9	129	BIAGI	87	SPEC	Ξ- Be →
					$(\Xi^-\pi^+)\pi^-\times$
1963 ± 5 ± 2	63	BIAGI	87 C	SPEC	Ξ^- Be $\rightarrow (\Lambda \overline{K}^0) X$
1937 ± 7	150	BIAGI	81	SPEC	SPS hyperon beam
1961 ± 18	139	BRIEFEL	77	HBC	$2.87 K^- p \rightarrow \Xi^- \pi^+ X$
1936 ± 22	44	BRIEFEL	77	HBC	2.87 $K^- p \to \Xi^0 \pi^- X$
1964±10	56	BRIEFEL	77	HBC	$\Xi(1530)\pi$
1900±12		DIBIANCA	75	DBC	Ξπ
1952±11	25	ROSS	730		(Ξπ) [—]
1956± 6	29	BADIER	72	HBC	$\Xi \pi$, $\Xi \pi \pi$, $Y K$
1955 ± 14	21	GOLDWASSER	70	HBC	Ξπ
1894±18	66	DAUBER	69	HBC	Ξπ .
1930 ± 20	27	ALITTI	68	нвс	<i>=</i> -π ⁺
1933±16	35	BADIER	65	HBC	Ξ-π+

 $\Xi(1950), \Xi(2030)$

	WIDT	

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
60±20 OUR ES	TIMATE				
100±31	129	BIAGI	87	SPEC	Ξ^- Be \to $(\Xi^-\pi^+)\pi^-$ X
$25 \pm 15 \pm 1.2$	63	BIAGI	87c	SPEC	Ξ^- Be $\rightarrow (\Lambda \overline{K}^0)$ X
60± 8	150	BIAGI	81	SPEC	SPS hyperon beam
159±57	139	BRIEFEL	77	HBC	$2.87 K^{-}p \rightarrow \Xi^{-}\pi^{+}X$
87±26	44	BRIEFEL	77	HBC	$2.87 \ K^- p \to \Xi^0 \pi^- X$
60±39	56	BRIEFEL	77	HBC	Ξ (1530) π
63±78		DIBIANCA	75	DBC	Ξπ
38±10		ROSS	73C		(Ξπ) ⁻
35 ± 11	29	BADIER	72	HBC	$\Xi\pi$, $\Xi\pi\pi$, YK
56 ± 26	21	GOLDWASSER	70	HBC	Ξπ
98 ± 23	66	DAUBER	69	HBC	$\equiv \pi$
80±40	27	ALITTI	68	HBC	Ξ-π+
140±35	35	BADIER	65	нвс	<i>Ξ</i> ~ π +

Ξ(1950) DECAY MODES

	Mode	Fraction (Γ_I/Γ)	
Γ ₁ Γ ₂ Γ ₃ Γ ₄ Γ ₅	$ \Lambda \overline{K} $ $\Sigma \overline{K}$ $\Xi \pi$ $\Xi (1530) \pi$ $\Xi \pi \pi (\text{not } \Xi (1530) \pi)$	seen possibly seen seen	

Ξ(1950) BRANCHING RATIOS

$\Gamma(\Sigma R)/\Gamma(\Lambda)$	R)						Γ_2/Γ_1
VALUE	CLN.	EVTS	DOCUMENT ID		TECN	COMMENT	
<2.3	90	0	BIAGI	87 C	SPEC	Ξ — Be 116 GeV	
$\Gamma(\Sigma \overline{K})/\Gamma_{\text{tota}}$	ı						Γ_2/Γ
VALUE		EVTS	DOCUMENT ID		TECN	COMMENT	
possibly seen		17	HASSALL	81	HBC	K-p 6.5 GeV/c	:
Γ(Ξπ)/Γ(Ξ (1530) π)					Γ_3/Γ_4
VALUE			DOCUMENT ID		TECN		
$2.8^{+0.7}_{-0.6}$			APSELL	70	нвс		
Γ(Ξππ(not:	E(15 30)	π))/Γ(Ξ(1530)π)				Γ_8/Γ_4
VALUE			DOCUMENT ID		TECN	•	
0.0 ± 0.3			APSELL	70	HBC		

≡(1950) REFERENCES

BIAGI BIAGI	87 87C	ZPHY C34 15 ZPHY C34 175	+ (BRIS, CERN, GEVA, HEID + (BRIS, CERN, GEVA, HEID	P, LAUS, LOOM, RAL)
BIAGI	81	ZPHY C9 305	+ (BRIS, CAVE, GEVA, HEIDP,	
HASSALL	81	NP B189 397	+Ansorge, Carter, Neale+	(CAVE, MSU)
BRIEFEL	77	PR D16 2706		UMD, SYRA, TUFTS)
Also	70	Duke Conf. 317		UMD, SYRA, TUFTS)
DIBIANCA	75	NP B98 137	+Endorf	(CMU)
ROSS	73C	Purdue Conf. 345	+Lloyd, Radojicic	(OXF)
BADIER	72	NP B37 429	+Barrelet, Charlton, Videau	(ÈPOL)
APSELL	70	PRL 24 777	+ (BRAN,	UMD, SYRA, TUFTS) I
GOLDWASSER	70	PR D1 1960	+Schultz	(ILL)
DAUBER	69	PR 179 1262	+Berge, Hubbard, Merrili, Miller	(LRL) I
ALITTI	68	PRL 21 1119	+Flaminio, Metzger, Radolicic+	(BNL, SYRA) I
BADIER	65	PL 16 171	+Demoulin, Goldberg+	(EPOL, SACL, AMST)

Ξ(2030)

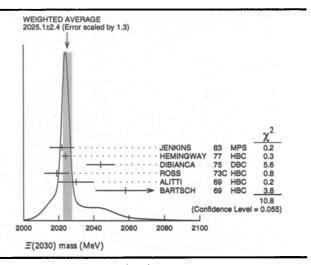
$$I(J^P) = \frac{1}{2} (\geq \frac{5}{2})^{\frac{1}{2}}$$
 tatus: ***

The evidence for this state has been much improved by HEMING-WAY 77, who see an eight standard deviation enhancement in $\Sigma\overline{K}$ and a weaker coupling to $\Lambda\overline{K}$. ALITTI 68 and HEMINGWAY 77 observe no signals in the $\Xi\pi\pi$ (or $\Xi(1530)\pi$) channel, in contrast to DIBIANCA 75. The decay $(\Lambda/\Sigma)\overline{K}\pi$ reported by BARTSCH 69 is also not confirmed by HEMINGWAY 77.

A moments analysis of the HEMINGWAY 77 data indicates at a level of three standard deviations that $J \geq 5/2$.

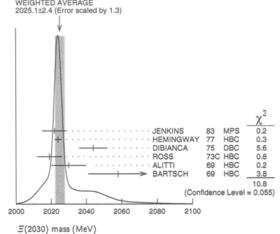
≡(2030) MASS

VALUE			EVTS	DOCUMENT ID		TECN	CHG	COMMENT
			OUR ESTIMATE					
2025.	1±	2.4	OUR AVERAGE	Error includes scale	facto	or of 1.3	. See	the ideogram below.
2022	±	7		JENKINS	83	MPS	-	$K^-p \rightarrow K^+$ MM
2024	±	2	200	HEMINGWAY	77	HBC	_	K - p 4.2 GeV/c
2044	±	8		DIBIANCA	75	DBC	-0	$\Xi \pi \pi$, $\Xi^* \pi$
2019	±	7	15	ROSS	73C	HBC	-0	ΣK
2030	±	10	42	ALITTI	69	нвс	-	K [−] p 3.9–5 GeV/c
2058	_	17	An.	RAPTSCH	60	HRC	_0	K n 10 GeV/c



Ξ(2030) WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
20 + 15 OUR ESTIMATE	ŀ					
21± 6 OUR AVERAGE	Error in	cludes scale factor	of 1	.3. See	the Ide	eogram below.
16 ± 5	200	HEMINGWAY	77	HBC	_	K- p 4.2 GeV/c
60 ± 24		DIBIANCA	75	DBC	-0	Ξ κ π, Ξ* π
33±17	15	ROSS	73C	HBC	-0	ΣK
45 ⁺⁴⁰ ₋₂₀		ALITTI	69	нвс	-	K [−] p 3.9–5 GeV/c
57 ± 30		BARTSCH	69	HBC	-0	K - p 10 GeV/c
WEIGHTED AVE	DAGE					



Ξ(2030) DECAY MODES

Mode	Fraction (Γ_I/Γ)	
ΛK	~ 20 %	
ΣK	~ 80 %	
$\Xi \pi$	small	
$\Xi(1530)\pi$	small	
	smail	
$\Lambda \overline{K} \pi$	small	
$\Sigma \overline{K} \pi$	small	
	$ \begin{array}{l} \Lambda \overline{K} \\ \Sigma \overline{K} \\ \Xi \pi \\ \Xi(1530) \pi \\ \Xi \pi \pi (\text{not } \Xi(1530) \pi) \end{array} $	$\begin{array}{lll} \Lambda\overline{K} & \sim 20 \% \\ \Sigma\overline{K} & \sim 80 \% \\ \Xi\pi & \text{small} \\ \Xi(1530) \pi & \text{small} \\ \Xi\pi\pi \left(\cot\Xi(1530)\pi \right) & \text{small} \\ \Lambda\overline{K}\pi & \text{small} \end{array}$

Ξ(2030) BRANCHING RATIOS

$\Gamma(\Xi\pi)/[\Gamma(\Lambda K) + VALUE)$	-Γ(Σ /K) +	- Γ(Ξπ) + Γ(- <u>ροсимент</u>				
• • • We do not use	the followin					
<0.30		ALITTI	69	нвс	-	1 standard dev. limit
$\Gamma(\Xi\pi)/\Gamma(\Sigma\overline{K})$						Γ ₃ /Γ ₂
VALUE	CL%	DOCUMENT	D	TECN	CHG	COMMENT
<0.19	95	HEMINGWA	Y 77	нвс	-	K [−] p 4.2 GeV/c

VALUE	$+\Gamma(\Xi\pi)+\Gamma(\Xi(1530)\pi)$ $\Gamma_1/(\Gamma_1+\Gamma_2+\Gamma_3+\Gamma_4)$ DOCUMENT ID TECN CHG COMMENT
0.25±0.15	ALITTI 69 HBC — K ⁻ p 3.9-5 GeV/c
$(\Lambda \overline{K})/\Gamma(\Sigma \overline{K})$	Γ ₁ /Γ ₂
ALUE 0.22±0.09	DOCUMENT ID TECN CHG COMMENT HEMINGWAY 77 HBC - K ⁻ p 4.2 GeV/c
$(\Sigma \overline{K})/[\Gamma(\Lambda \overline{K}) + \Gamma(\Sigma \overline{K})]$	$+\Gamma(\Xi\pi)+\Gamma(\Xi(1530)\pi)$] $\Gamma_2/(\Gamma_1+\Gamma_2+\Gamma_3+\Gamma_4)$
0.75 ± 0.20	ALITTI 69 HBC - K-p 3.9-5
- -(Ξ(1530)π)/[Γ(Λ Ҡ) + Γ	$(\Sigma \overline{K}) + \Gamma(\Xi \pi) + \Gamma(\Xi(1530)\pi)$
ALUE	Γ4/(Γ1+Γ2+Γ3+Γ4) DOCUMENT ID TECN CHG COMMENT
• • We do not use the following	ing data for averages, fits, limits, etc. • • •
<0.15	ALITTI 69 HBC — 1 standard dev. limit
[Γ(Ξ(1530)π) + Γ(Ξππ(n /ALUE	$ \text{not } \Xi(1530)\pi))]/\Gamma(\Sigma\overline{K}) \qquad $
<0.11 95	¹ HEMINGWAY 77 HBC - K ⁻ p 4.2 GeV/c
$(\Lambda \overline{K}\pi)/\Gamma_{\text{total}}$	F6/I
• We do not use the follow!	DOCUMENT ID TECN COMMENT Ing data for averages, fits, limits, etc. ● ●
een	BARTSCH 69 HBC KT p 10 GeV
$(\Lambda \overline{K}\pi)/\Gamma(\Sigma \overline{K})$	Γ ₆ /Γ:
<0.32 95	HEMINGWAY 77 HBC - K p 4.2 GeV/c
$(\Sigma \overline{K}\pi)/\Gamma_{\text{total}}$	Γ ₇ /Ι
• We do not use the follow!	DOCUMENT ID TECN COMMENT Ing data for averages, fits, limits, etc. • • •
ееп	BARTSCH 69 HBC K-p 10 GeV
$\Gamma(\Sigma \overline{K}\pi)/\Gamma(\Sigma \overline{K})$	Γ ₇ /Γ ₃
<u>CL%</u> <0.04 95	DOCUMENT ID TECN CHG COMMENT HEMINGWAY 77 HBC - K p 4.2 GeV/c
	≡(2030) FOOTNOTES
¹ For the decay mode $\Xi^-\pi^+$ ² For the decay mode $\Sigma^\pm K^-$	
	≡(2030) REFERENCES
	+Albright, Diamond+ (FSU, BRAN, LBL, CINC, MASD) +Armenteros+ (AMST, CERN, NIJM, OXF) IJ
ENKINS 83 PRL 51 951	
HEMINGWAY 77 PL 68B 197 Also 76C PL 62B 477	Gay, Armenteros, Berge+ (AMST, CERN, NIJM)
IEMINGWAY 77 PL 68B 197 Also 76C PL 62B 477 DIBIANCA 75 NP B98 137 ICOSS 73C Purdue Conf. 34 LITTI 69 PRL 22 79	Gay, Armenteros, Berge+ (AMST, CERN, NIJM) + Endorf (CMU) 5
HEMINGWAY 77 PL 68B 197 Also 76C PL 62B 477 DIBIANCA 75 NP B98 137 COSS 73C Purdue Conf. 34 LITTI 69 PRL 22 79 JARTSCH 69 PL 28B 439	Gay, Armenteros, Berge+ (AMST, CERN, NIJM) +Endorf (CMU) 45 +Lloyd, Radojicic (OXF)
IEMINGWAY 77	Gay, Armenteros, Berge+ (AMST, CERN, NIJM) +Endorf (CMU) 15 +Lloyd, Radojlcic +Barnes, Fiaminio, Metzger+ (BNL, SYRA) + (AACH, BERL, CERN, LOIC, VIEN) +Fiaminio, Metzger, Radojlcic+ (BNL, SYRA)
IEMINGWAY 77 PL 68B 197 Also 76C PL 62B 477 OIBLANCA 75 NP B98 137 OISS 73C Purdue Conf. 34 LITTI 69 PRL 22 79 ARTSCH 69 PL 28B 439 LITTI 68 PRL 21 1119	Gay, Armenteros, Berge+ (AMST, CERN, NIJM) + Endorf (CMU) (CMU) (CMU) (CMU) (CMU) + Holyd, Radolicic (OXF) + Barnes, Flaminio, Metzger+ (BNL, SYRA) + Flaminio, Metzger, Radolicic+ (BNL, SYRA) $I(J^P) = \frac{1}{2}(?^7) \text{Status:} * J, P \text{ need confirmation.}$
IEMINGWAY 77 PL 68B 197 Also 76C PL 62B 477 OIBLANCA 75 NP B98 137 OISS 73C Purdue Conf. 34 LITTI 69 PRL 22 79 ARTSCH 69 PL 28B 439 LITTI 68 PRL 21 1119	Gay, Armenteros, Berge+ (AMST, CERN, NIJM) + Endorf (CMU) (CMU) (CMU) (CMU) (CMU) + Holyd, Radolicic (OXF) + Barnes, Flaminio, Metzger+ (BNL, SYRA) + Flaminio, Metzger, Radolicic+ (BNL, SYRA) $I(J^P) = \frac{1}{2}(?^7) \text{Status:} * J, P \text{ need confirmation.}$
HEMINGWAY	Gay, Armenteros, Berge+ (AMST, CERN, NIM) + Endorf (CMU) (CMU) (SMU) + Lloyd, Radojicic + Barnes, Fiaminio, Metzger+ (BNL, SYRA) + Fiaminio, Metzger, Radojicic+ (BNL, SYRA) + $I(J^P) = \frac{1}{2}(?^7)$ Status: * J , P need confirmation.
IEMINGWAY 77	Gay, Armenteros, Berge+ (AMST, CERN, NIM) (EMU) (AMST, CERN, NIM) (EMU)
IEMINGWAY 77	Gay, Armenteros, Berge+ (AMST, CERN, NIM) (EMO) (EMO) (AMST, CERN, NIM) (EMO)
HEMINGWAY 77	Gay, Armenteros, Berge+ (AMST, CERN, NIM) + Endorf (CMU) + Hendorf (CMC) + He
IEMINGWAY 77	Gay, Armenteros, Berge+ (AMST, CERN, NIM) (CMU) (CMU) (CMU) (CMV) (CMV) (CMV) (CMV) (CMV) (CMV) (CMV) (AACH, BERL, CERN, LOIC, VIEN) (BNL, SYRA) (BNL
IEMINGWAY 77	Gay, Armentros, Berge+ (AMST, CERN, NIM) (CMU) (CMU) (CMV) (ST) (CMF) (CMV) (CMV) (CMF) (CMV) (CMF) (
IEMINGWAY 77	Gay, Armentros, Berge+ (AMST, CERN, NIM) + Endorf (CMU) + Hander (CMU) + Lloyd, Radojicic (CMF) + Harnes, Flaminio, Metzger+ (BNL, SYRA) - (AACH, BERL, CERN, LOIC, VIEN) + Flaminio, Metzger, Radojicic+ (BNL, SYRA) - (BNL, SYR
HEMINGWAY 77	Gay, Armentros, Berge+ (AMST, CERN, NIM) + Endorf (CMU) (CMU) + Holod, Radojicic (CMF) + Holod, Radojicic (AACH, BERL, CERN, LOIC, VIEN) + Flaminio, Metzger+ (BNL, SYRA) + Flaminio, Metzger, Radojicic+ (BNL, SYRA) + Flaminio, Metzger, Radoji

Ξ(2120) BRANCHING RATIOS

Γ(ΛK)/Γ _{total}				Γ ₁ /Γ
VALUE	DOCUMENT ID		TECN	COMMENT
SOCI		79	HBC	$K^+p \rightarrow (\overline{\Lambda}K^+)X$
908f1	² GAY	76 C	HBC	K-p 4.2 GeV/c

≡(2120) FOOTNOTES

¹CHLIAPNIKOV 79 does not uniquely identify the K^+ in the $(\overline{A}K^+)$ X final state. It also reports bumps with fewer events at 2240, 2540, and 2830 MeV.

²GAY 76c sees a 4-standard deviation signal. However, HEMINGWAY 77, with more events from the same experiment points out that the signal is greatly reduced if a cut is made on the 4-momentum v. This suggests an anomalous production mechanism if the $\Xi(2120)$ is real.

Ξ(2120) REFERENCES

CHLIAPNIK	77	NP B158 253	Chliapnikov, Gerdyukov+	(CERN, BELG, MONS)
HEMINGWAY		PL 68B 197	+Armenteros+	(AMST, CERN, NIJM, OXF)
GAY		PL 62B 477	+Armenteros, Berge+	(AMST, CERN, NIJM)

三(2250)

 $I(J^P) = \frac{1}{2}(?^?)$ Status: ** J, P need confirmation.

OMITTED FROM SUMMARY TABLE

The evidence for this state is mixed. BARTSCH 69 sees a bump of not much statistical significance in $\Lambda \overline{K}\pi$, $\Sigma \overline{K}\pi$, and $\Xi \pi \pi$ mass spectra. GOLDWASSER 70 sees a narrower bump in $\Xi \pi \pi$ at a higher mass. Not seen by HASSALL 81 with 45 events/ μ b at 6.5 GeV/c. Seen by JENKINS 83. Perhaps seen by BIAGI 87.

=(2250) !	MASS
------------------	------

VALUE (MeV) ≈ 2250 OUR ESTIM	EVTS	DOCUMENT ID	<u>TECN</u>	CHG	COMMENT
2189± 7	66	BIAGI 87	SPEC	-	Ξ-Be → (Ξ-π+π-)
2214± 5		JENKINS 83	MPS	-	$K^- \rho \rightarrow K^+$ MM
2295 ± 15	18	GOLDWASSER 70	HBC	_	K-p 5.5 GeV/c
2244±52	35	BARTSCH 69	HBC		K- p 10 GeV/c

Ξ(2250) WIDTH

VALUE (MeV)	EVTS	DOCUMENT ID	_	TEÇN	CHG	COMMENT
46 ± 27	66	BIAGI	87	SPEC	-	$\begin{array}{c} \Xi^- \operatorname{Be} \to \\ (\Xi^- \pi^+ \pi^-) \\ X \end{array}$
< 30 130±80		GOLDWASSER BARTSCH	70 69	HBC HBC	-	K p 5.5 GeV/c

Ξ(2250) DECAY MODES

	Mode			
Γ ₁ Γ ₂	Ξππ ΛΚπ ΣΚπ			
Γ3	$\Sigma \overline{K} \pi$			

≡(2250) REFERENCES

BIAGI	87	ZPHY C34 15	+ (BRIS, CERN, GEVA, HEIDP, LAUS, LOQM, RAL) +Albright, Diamond+ (FSU, BRAN, LBL, CINC, MASD) +Ansorge, Carter, Neale+ (CAVE, MSU) +Schultz (ALCH, BERL, CERN, LOIC, VIEN)
JENKINS	83	PRL 51 951	
HASSALL	81	NP B189 397	
GOLDWASSER	70	PR D1 1960	
BARTSCH	69	PL 28B 439	

 Ξ (2370), Ξ (2500)

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 $I(J^P) = \frac{1}{2}(?^?)$ Status: ** J, P need confirmation.

		≘(2370) MA	SS			
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
≈ 2370 OUR EST	IMATE					
2356 ± 10		JENKINS	83	MPS	-	$K^- \rho \rightarrow K^+$ MM
2370	50	HASSALL	81	HBC	-0	K p 6.5 GeV/c
2373± 8	94	AMIRZADEH	80	HBC	-0	K- p 8.25 GeV/c
2392±27		DIBIANCA	75	DBC		Ξ2π
		<i>Ξ</i> (2370) WID	TH			
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
80	50	HASSALL	81	нвс	-0	K-p 6.5 GeV/c
80 ± 25	94	AMIRZADEH	80	HBC	-0	K- p 8.25 GeV/c
75±69		DIBIANCA	75	DBC		Ξ2π

	Mode	Fraction (Γ_I/Γ)	
$\overline{\Gamma_1}$	$\Lambda \overline{K} \pi$ Includes $\Gamma_4 + \Gamma_6$.	seen	
Γ2	$\Sigma \overline{K} \pi$ Includes $\Gamma_5 + \Gamma_6$.	seen	
Гз	Ω-K		
Γ4	Λ Κ *(892)		
Γ ₄ Γ ₅	$\Sigma \overline{K}^*$ (892)		
Γ6	$\Sigma(1385)\overline{K}$		

Ξ(2370) BRANCHING RATIOS

$\Gamma(\Lambda \overline{K}\pi)/\Gamma_{\text{total}}$					Г1/Г
VALUE	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT
seen	AMIRZADEH	80	HBC	-0	K⁻p 8.25 GeV/c
$\Gamma(\Sigma \overline{K}\pi)/\Gamma_{\text{total}}$					Γ ₂ /Γ
VALUE	DOCUMENT_ID		TECN	<u>CHG</u>	COMMENT
seen	AMIRZADEH	80	HBC	-0	K [−] p 8.25 GeV/c
$[\Gamma(\Lambda \overline{K}\pi) + \Gamma(\Sigma \overline{K}\pi)]/\Gamma_{\text{tota}}$	əl				(「1+「2)/「
VALUE EVTS	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT
sten 50	HASSALL	81	HBC	-0	K-ρ 6.5 GeV/c
$\Gamma(\Omega^-K)/\Gamma_{\text{total}}$					Γ ₃ /Γ
Γ(Ω [—] K)/Γ _{total}	DOCUMENT ID		<u>TECN</u>	<u>CHG</u>	Γ ₃ /Γ
	DOCUMENT ID 1 KINSON	80	TECN HBC	<u>снд</u> 	-,
VALUE	1 KINSON	80		<u>снд</u> 	COMMENT
<u>VALUE</u> 0.09±0.04	1 KINSON			<u>сн</u>	COMMENT K - p 8.25 GeV/c (Γ4+Γ5)/Γ
$\frac{VALUE}{0.09\pm0.04}$ $\left[\Gamma(\Lambda\overline{K}^{\bullet}(892)) + \Gamma(\Sigma\overline{K}^{\bullet}(892))\right]$	¹ κinson (2))]/Γ _{total}		НВС	_	COMMENT K - p 8.25 GeV/c (Γ4+Γ5)/Γ
$\frac{VALUE}{0.09\pm0.04}$ $\left[\Gamma(\Lambda \overline{K}^{\bullet}(892)) + \Gamma(\Sigma \overline{K}^{\bullet}(892))\right]$ VALUE	1 KINSON (2))]/F _{total} DOCUMENT ID		HBC TECN	_	COMMENT K - p 8.25 GeV/c (Γ4+Γ5)/Γ COMMENT
$\frac{VALUE}{0.09\pm0.04}$ $\left[\Gamma(\Lambda \overline{K}^{\bullet}(892)) + \Gamma(\Sigma $	1 KINSON (2))]/F _{total} DOCUMENT ID		HBC TECN	_	COMMENT K = p 8.25 GeV/c (Γ4+Γ5)/Γ COMMENT K = p 8.25 GeV/c Γ6/Γ

Ξ(2370) FOOTNOTES

≡(2370) REFERENCES

JENKINS HASSALL AMIRZADEH KINSON DIBIANCA	83 81 80 80 75	PRL 51 951 NP B189 397 PL 90B 324 Toronto Conf. 263 NP B98 137	+Albright, Diamond+ (FSU, BRAN, LBL +Ansorge, Carter, Neale+ + (BIRM, CERN, GLAS, + (BIRM, CERN, GLAS,	(CAVE, MSU) MSU, CURIN) I
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 $\Xi(2500)$

 $I(J^P) = \frac{1}{2}(?^?)$ Status: * J, P need confirmation.

OMITTED FROM SUMMARY TABLE

	: Ξ (2370) no					
		<i>≡</i> (2500) MA	NSS			
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT
≥ 2500 OUR ESTIM 2505 ± 10	IATE	JENKINS	83	MPS	_	$K^-p \rightarrow K^+$
2430 ± 20	30	ALITTI	69	нвс	_	MM K = p 4.6-5
2500 ± 10	45	BARTSCH	69	нвс	-0	GeV/c K p 10 GeV/c
		<i>≣</i> (2500) WI	TH			
VALUE (MeV)		DOCUMENT ID	<u> </u>	TECN	СНG	
150 ⁺⁶⁰ -40		ALITTI	69	нвс	_	
59±27		BARTSCH	69	нвс	-0	
	=(2500) DECAY	MO	DES		
Mode			Fract	tion (Γ_I	/ r)	
$ \Gamma_1 = \pi $ $ \Gamma_2 = \Lambda \overline{K} $ $ \Gamma_3 = \Sigma \overline{K} $ $ \Gamma_4 = \Xi \pi \pi $			seen			
Γ ₅ Ξ(1530)π Γ ₆ ΛΚπ + Σ	$\overline{K}\pi$		seen			
	Ξ(250	00) BRANCHIN	NG R	ATIOS		
Γ(Ξπ)/[Γ(Ξπ) · VALUE	+	Γ(ΣK)+Γ(Ξ DOCUMENT ID		10)π)] TECN		(「1+「2+「3+「5 MENT
<0.5		ALITTI	69	нвс	1 sta	ndard dev. limit
Γ(Λ Κ)/[Γ(Ξπ)	+ Γ(//K) +	$\Gamma(\Sigma \overrightarrow{K}) + \Gamma(\Xi$	E(153	(π(00	Γ2/	$(\Gamma_1 + \Gamma_2 + \Gamma_3 + \Gamma_5)$
VALUE 0.5±0.2		<u>DOCUMENT ID</u> ALITTI		TECN HBC	<u>CHG</u>	
Γ(Σ <i>K</i>)/[Γ(Ξπ)	⊥ Γ(Λ Τ Γ) ⊐	. Γ/3-1₹\ → Γ/3	=/15 [.]	301-1]	Га/	(「1+「2+「3+「5
VALUE		DOCUMENT ID				V-4112113118
0.5±0.2		ALITTI		HBC	-	
r/≈/1530\~\/[r	(Ξ π) + Γ($(\Lambda \overline{K}) + \Gamma(\Sigma \overline{K})$	+ [(<i>≡</i> (153		 (「 ₁ +「 ₂ +「 ₃ +「 ₅
· (~(1330) *)/[i						
		DOCUMENT ID		TECN	<u>сом</u> і	MENT
VALUE <0.2		<u>DOCUMENT ID</u> ALITTI	69	HBC		<i>MENT</i> ndard dev. limit
VALUE						

≡(2500) REFERENCES

DOCUMENT ID

TECN CHG 69 HBC -0

 Γ_6/Γ

JENKINS 83 PRL 51 951 +Albright, Diamond+ (FSU, BRAN, LBL, CINC, MA ALITTI 69 PRL 22 79 +Barnes, Flaminio, Metzger+ (BNL, SYF BARTSCH 69 PL 28B 439 + (AACH, BERL, CERN, LOIC, VIE
--

 $[\Gamma(\Lambda \overline{K}\pi) + \Gamma(\Sigma \overline{K}\pi)]/\Gamma_{\text{total}}$

 $^{^{1}\}mbox{KINSON}$ 80 is a reanalysis of AMIRZADEH 80 with 50% more events.

Ω BARYONS (S = -3, I = 0)

 $\Omega^-=sss$

 Ω^-

 $I(J^P) = O(\frac{3}{2}^+)$ Status: ****

The unambiguous discovery in both production and decay was by BARNES 64. The quantum numbers have not actually been measured, but follow from the assignment of the particle to the baryon decuplet. DEUTSCHMANN 78 and BAUBILLIER 78 rule out J=1/2 and find consistency with J=3/2.

We have omitted some results that have been superseded by later experiments. See our earlier editions.

Ω- MASS

The fit assumes the Ω^- and $\overline{\Omega}^+$ masses are the same.

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
1672.45±0.29 OUR	FIT				
1672.43±0.32 OUR	AVERAGE				
1673 ±1	100	HARTOUNI	85	SPEC	80-280 GeV KOC
1673.0 ±0.8	41	BAUBILLIER	78	HBC	8.25 GeV/c K ⁻ p
1671.7 ±0.6	27	HEMINGWAY	78	HBC	4.2 GeV/c K ⁻ p
1673.4 ±1.7	4	¹ DIBIANCA	75	DBC	4.9 GeV/c K-d
1673.3 ±1.0	3	PALMER	68	HBC	K ⁻ ρ 4.6, 5 GeV/c
1671.8 ±0.8	3	SCHULTZ	68	HBC	K-p 5.5 GeV/c
1674.2 ±1.6	5	SCOTTER	68	HBC	K-p6 GeV/c
1672.1 ±1.0	1	² FRY	55	EMUL	
• • • We do not us	e the following	g data for average	s, fit:	s, limits,	etc. • • •
1671.43±0.78	13	3 DEUTSCH	73	HBC	K-p 10 GeV/c
1671.9 ±1.2	. 6	³ SPETH	69	HBC	See
1570.0 1.0.0	_	4004140		unc	DEUTSCHMANN 73 → Ξ π ⁰
1673.0 ±8.0	1	ABRAMS		HBC	$\rightarrow = \pi^{\circ}$
1670.6 ±1.0	1	² FRY	558	EMUL	
1615	1	⁴ EISENBERG	54	EMUL	

¹ DIBIANCA 75 gives a mass for each event. We quote the average.

 2 The FRY 55 and FRY 558 events were identified as \varOmega^- by ALVAREZ 73. The masses assume decay to ΛK^- at rest. For FRY 558, decay from an atomic orbit could Doppler shift the K^- energy and the resulting \varOmega^- mass by several MeV. This shift is negligible for FRY 55 because the \varOmega decay is approximately perpendicular to its orbital velocity, as is known because the \varLambda strikes the nucleus (L.Alvarez, private communication 1973). We have calculated the error assuming that the orbital n is 4 or larger.

 3 Excluded from the average; the \varOmega^- lifetimes measured by the experiments differ significantly from other measurements.

The EISENBERG 54 mass was calculated for decay in flight. ALVAREZ 73 has shown that the Ω interacted with an Ag nucleus to give $K^- \Xi Ag$.

Ω+ MASS

The fit assumes the \varOmega^- and $\overline{\varOmega}^+$ masses are the same.

VALUE (MeV)	EVTS OUR FIT	DOCUMENT ID	TECN	COMMENT
	OUR AVERAGE			
1672 ±1	72	HARTOUNI	85 SPEC	80-280 GeV K10 C
1673.1 ±1.0	1	FIRESTONE	71B HBC	12 GeV/c K+d

$(m_{\Omega^-} - m_{\overline{\Omega}^+}) / m_{\text{average}}$

A test of CPT invariance. Calculated from the average Ω^- and $\overline{\Omega}{}^+$ masses, above.

VALUE	DOCUMENT ID
$(0+5) \times 10^{-4}$ OUR EVALUATION	

Ω- MEAN LIFE

Measurements with an error $> 0.1 \times 10^{-10}$ s have been omitted.

VALUE (10 ⁻¹⁰ s)	EVT5	DOCUMENT ID		TECN	COMMENT
0.822±0.012 OUR	AVERAGE				
0.811 ± 0.037	1096	LUK	88	SPEC	pBe 400 GeV
0.823 ± 0.013	12k	BOURQUIN	84	SPEC	SPS hyperon beam
• • • We do not u	se the following	g data for average	es, fit	s, limits.	, etc. • • •
0.822 ± 0.028	2437	BOURQUIN	79E	SPEC	See BOURQUIN 84

Ω- MAGNETIC MOMENT

VALUE (μ _N) -2.02 ±0.05 OUR	EVTS AVERAGE	DOCUMENT ID	<u> </u>	TECN	COMMENT
-2.024 ± 0.056 -1.94 ±0.17 ±0.1	235k 4 25k	WALLACE DIEHL			Ω^- 300–550 GeV Spin-transfer production

Ω- DECAY MODES

	Mode	Fraction (Γ_I/Γ) Confidence leve
Γ ₁	ΛK-	(67.8±0.7) %
Γ_2	<u>=</u> 0π-	(23.6±0.7) %
Гз	$\underline{\Xi}^{0}\pi^{-}$ $\underline{\Xi}^{-}\pi^{0}$	(8.6±0.4) %
Γ4	$\equiv -\pi^+\pi^-$	$(4.3^{+3.4}_{-1.3}) \times 10^{-4}$
۲5	Ξ(1530) ⁰ π−	$(6.4^{+5.1}_{-2.0}) \times 10^{-4}$
Γ ₆	$\Xi^0 e^- \overline{\nu}_e$	$(5.6\pm2.8)\times10^{-3}$
	$\equiv -\gamma$	< 4.6 × 10 ⁻⁴ 90%
		$\Delta S = 2$ forbidden (S2) modes
Γ8	$\Lambda\pi^-$	$52 < 1.9 \times 10^{-4}$ 90%

Ω^- BRANCHING RATIOS

The BOURQUIN 84 values (which include results of BOURQUIN 79B, a separate experiment) are much more accurate than any other results, and so the other results have been omitted.

		much more accurate been omitted.	tnan any	other results, and
$\Gamma(\Lambda K^-)/\Gamma_{\text{total}}$				Γ1/Γ
VALUE	EVTS	DOCUMENT ID		COMMENT
0.678±0.007	14k		SPEC	
		g data for averages, f		
0.686 ± 0.013	1920	BOURQUIN 79	B SPEC	See BOURQUIN 84
Γ(Ξ ⁰ π [−])/Γ _{total}				Γ ₂ /Γ
VALUE	<u>EVTS</u> 1947	DOCUMENT ID		
0.236±0.007		BOURQUIN 8- ig data for averages, f		SPS hyperon beam
0.234±0.013	317	-		See BOURQUIN 84
		BOUNQUIN	36 SFEC	See BOOKQUIA 64
Γ(Ξ-π ⁰)/Γ _{total}	 <i>_EVTS</i>	DOCUMENT ID	TECN	COMMENT.
0.086±0.004	759		4 SPEC	
		g data for averages, f		
0.080±0.008	145	•		See BOURQUIN 84
Γ(Ξ ⁻ π ⁺ π ⁻)/Γ				Γ ₄ /Γ
VALUE (units 10-4)	EVTS	DOCUMENT ID	TECN	COMMENT
4.3 ^{+3.4} -1.3	4	BOURQUIN 8	4 SPEC	SPS hyperon beam
Γ(Ξ(1530) ⁰ π ⁻)				Γ ₅ /Γ
VALUE (units 10 ⁻⁴)	<u>EVTS</u>	DOCUMENT ID	TECN	COMMENT
$6.4^{+5.1}_{-2.0}$	4			SPS hyperon beam
• • • We do not i	ise the followin	ig data for averages, i		
~ 20	1	BOURQUIN 7	9B SPEC	See BOURQUIN 84
5 The same 4 even Ξ (1530) 0 →			e Isospin	factor to take into account
$\Gamma(\Xi^0e^-\overline{\nu}_e)/\Gamma_{\rm tr}$	otal			Γ ₆ /Γ
VALUE (units 10 ⁻³)	EVTS	DOCUMENT ID	TECN	COMMENT
5.6±2.8	14		4 SPEC	
• • • We do not i	use the following	ng data for averages, 1		
~ 10	3	BOURQUIN 7	98 SPEC	See BOURQUIN 84
$\Gamma(\Xi^-\gamma)/\Gamma_{ m total}$				Γ ₇ /Γ
VALUE (units 10 ⁻⁴)	CL% EVTS	DOCUMENT ID	TECN	COMMENT
< 4.6	90 0	ALBUQUERQ9		Ω = 375 GeV
• • • We do not i	use the following	ng data for averages, 1	its, limits	, etc. • • •
<22	90 9		4 SPEC	• •
<31	90 0	BOURQUIN 7	98 SPEC	See BOURQUIN 84
$\Gamma(\Lambda\pi^-)/\Gamma_{\text{total}}$ $\Delta S=2$. Forb	idden in first-o	rder weak interaction.		Γ ₈ /Γ

DOCUMENT ID

• • We do not use the following data for averages, fits, limits, etc. • • •

TECN COMMENT

BOURQUIN 84 SPEC SPS hyperon beam

BOURQUIN 798 SPEC See BOURQUIN 84

VALUE (units 10-4) CL% EVTS

90

90

0

< 1.9

<13

 Ω^{-} , $\Omega(2250)^{-}$, $\Omega(2380)^{-}$, $\Omega(2470)^{-}$

Ω^- DECAY PARAMETERS

αF	OR	Ω^{-}	-+	AK-
----	----	--------------	----	-----

Some early results have been omitted. YALUE EYTS -0.026±0.026 OUR AVERAGE DOCUMENT ID TECN COMMENT LUK 88 SPEC pBe 400 GeV BOURQUIN 84 SPEC SPS hyperon beam -0.034±0.079 1743 ~0.025±0.028 α FOR $\Omega^- \to \Xi^0 \pi^-$ DOCUMENT ID TECN COMMENT $+0.09\pm0.14$ 1630 BOURQUIN 84 SPEC SPS hyperon beam α FOR $\Omega^- \to \Xi^- \pi^0$ EVTS DOCUMENT ID TECN COMMENT +0.05±0.21 BOURQUIN 84 SPEC SPS hyperon beam

Ω^- REFERENCES

We have omitted some papers that have been superseded by later experiments. See our earlier editions.

WALLACE	95	PRL 74 3732	+Border+ (MINN, ARIZ, MICH, FNAL)
ALBUQUERQ.		PR D50 R18	Albuquerque, Bondar, Carrigan+ (FNAL E761 Collab.)
DIEHL	91	PRL 67 804	+Teige, Thompson, Zou+ (RUTG, FNAL, MICH, MINN)
LUK	88	PR D38 19	
			+Beretvas, Deck+ (RUTG, WISC, MICH, MINN)
HARTOUNI	85	PRL 54 628	+Atiya, Holmes, Knapp, Lee+ (COLU, ILL, FNAL)
BOURQUIN	84	NP B241 1	 + (BRIS, GEVA, HEIDP, LALO, RAL, STRB)
Also	79	PL 87B 297	Bourquin+ (BRIS, GEVA, HEIDP, ORSAY, RHEL, STRB)
BOURQUIN	79B	PL 88B 192	+ (BRIS, GEVA, HEIDP, LALO, RAL)
BAUBILLIER	78	PL 78B 342	+ (BIRM, CÈRN, GLAS, MSU, CURIN, PARIN).
DEUTSCH	78	PL 73B 96	Deutschmann+ (AACH3, BERL, CERN, INNS, LOIC+) J
HEMINGWAY	78	NP B142 205	+Armenteros+ (CERN, ZEEM, NIJM, OXF)
DIBIANCA	75	NP 898 137	+Endorf (CMU)
ALVAREZ	73	PR D8 702	`(LBL)
DEUTSCH	73	NP B61 102	Deutschmann, Kaufmann, Besliv+ (ABCLV Collab.)
FIRESTONE	71B	PRL 26 410	+Goldhaber, Lissauer, Sheldon, Trilling (LRL)
SPETH	69	PL 29B 252	+ (AACH, BERL, CERN, LOIC, VIEN)
PALMER	68	PL 26B 323	+Radojicic, Rau, Richardson+ (BNL, SYRA)
SCHULTZ	68	PR 168 1509	+ (ILL, ANL, NWES, WISC)
SCOTTER	68	PL 26B 474	+ (BIRM, GLAS, LOIC, MUNI, OXF)
ABRAMS	64	PRL 13 670	
BARNES	64	PRL 12 204	+Connolly, Crennell, Culwick+ (BNL)
FRY	55	PR 97 1189	+Schneps, Swami (WISC)
FRY	55B	NC 2 346	+Schneps, Swami (WISC)
EISENBERG	54	PR 96 541	(CORN)

$\Omega(2250)^-$

 $I(J^P) = 0(??)$ Status: ***

$\Omega(2250)^-$ MASS

VALUE (MeV) 2252± 9 OUR AVERAGE	VTS	DOCUMENT ID	<u>TECN</u>	COMMENT
2253±13	44	ASTON	878 LASS	K ⁻ p 11 GeV/c
2251± 9±8	78	BIAGI	86B SPEC	SPS <i>Ξ</i> − beam

$\Omega(2250)^-$ WIDTH

VALUE (MeV) 55±18 OUR AVERAGE	<u>EVTS</u>	DOCUMENT ID	<u>TECN</u>	COMMENT
81 ± 38	44	ASTON	878 LASS	K - p 11 GeV/c
48 ± 20	78	BIAGI	868 SPEC	SPS = beam

Ω(2250)- DECAY MODES

	Mode	Fraction (Γ_I/Γ)	
Γ1	Ξ-π+K-	seen	
Γ_2	Ξ(1530) ⁰ K−	seen	

$\Omega(2250)^-$ BRANCHING RATIOS

$\Gamma(\Xi(1530)^0 K^-)/$	T(=- + +	(-)		Γ2/Γ	
VALUE	EVTS	DOCUMENT ID	TECN	COMMENT	
~ 1.0	44	ASTON	878 LASS	K- p 11 GeV/c	
0.70 ± 0.20	49	BIAGI	86B SPEC	Ξ Be 116 GeV/c	

$\Omega(2250)^-$ REFERENCES

ASTON		PL B194 579			(SLAC, NAGO, CINC, INUS)
BIAGI	86B	ZPHY C31 33	+ (LOQM, GEVA, RAL,	HEIDP, LAUS, BRIS, CERN)

 $\Omega(2380)^-$

 26 ± 23

Status: **

868 SPEC SPS E- beam

OMITTED FROM SUMMARY TABLE

Ω(2380)- MASS

VALUE (MeV) ≈ 2380 OUR ESTI	<u>EVTS</u>	DOCUMENT ID	TECN	COMMENT	
2384±9±8	45	BIAGI	868 SPEC	SPS = beam	
		Ω(2380) ⁻ WII	тн		
VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT	

$\Omega(2380)^-$ DECAY MODES

BIAGI

 Mode	
$\Xi^{-}\pi^{+}K^{-}$ $\Xi(1530)^{0}K^{-}$ $\Xi^{-}\overline{K}^{*}(892)^{0}$	

Ω(2380) BRANCHING RATIOS

Γ(Ξ(1530) ⁰ K⁻	·)/Γ(≅	$-\pi^+I$	(-)		Γ_2/Γ_1
VALUE	CL%	VTS	DOCUMENT ID	TECN	COMMENT
<0.44	90	9	BIAGI	868 SPEC	Ξ - Be 116 GeV/c
Γ(Ξ ⁻ \(\bar{K}\)*(892) ⁰)/r(<i>=</i>	-π+ <i>i</i>	(-)		Γ ₃ /Γ ₁
VALUE		VTS	DOCUMENT ID	TECN	COMMENT
0.5±0.3		21	BIAGI	86B SPEC	= Be 116 GeV/c

Ω(2380) - REFERENCES

BIAGI 86B ZPHY C31 33 + (LOQM, GEVA, RAL, HEIDP, LAUS, BRIS, CERN)



Status: **

OMITTED FROM SUMMARY TABLE

A peak in the $\Omega^-\pi^+\pi^-$ mass spectrum with a signal significance claimed to be at least 5.5 standard deviations. There is no reason to seriously doubt the existence of this state, but unless the evidence is overwhelming we usually wait for confirmation from a second experiment before elevating peaks to the Summary Table.

$\Omega(2470)^-$ MASS

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT	
2474±12	59	ASTON	88G LASS	K [−] p 11 GeV/c	
		Ω(2470) WI	DTH		
VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT	
72±33	59	ASTON	88G LASS	K-p 11 GeV/c	

Ω(2470) DECAY MODES

	Mode					
Γ ₁	$\Omega^-\pi^+\pi^-$					
		2(2470) REFERENCES				
ACTOR		(Aughl Diana Died)	(C) AC	NACO	CINC	MILES

CHARMED BARYONS (C = +1)

 $\begin{array}{lll} \varLambda_c^+ = u\,d\,c, & \varSigma_c^{++} = u\,u\,c, & \varSigma_c^+ = u\,d\,c, & \varSigma_c^0 = d\,d\,c, \\ \varXi_c^+ = u\,s\,c, & \varXi_c^0 = d\,s\,c, & \varOmega_c^0 = s\,s\,c \end{array}$

CHARMED BARYONS

Figure 1 shows the SU(4) multiplets that have as their lowest levels (a) the SU(3) octet that contains the nucleon, and (b) the SU(3) decuplet that contains the $\Delta(1232)$. All the particles in a given SU(4) multiplet have the same spin and parity. The only known charmed baryons each contain one charmed quark and thus belong to the second level of an SU(4) multiplet. Figure 2 shows this level for the SU(4) multiplet of Fig. 1(a). The level splits apart into two SU(3) multiplets, a $\overline{3}$ that contains the $\Lambda_c(2285)$ and the $\Xi_c(2470)$, both of which decay weakly, and a 6 that contains the $\Sigma_c(2455)$, which decays strongly to $\Lambda_c \pi$, and the $\Omega_c(2710)$, which decays weakly. A second Ξ_c remains to be discovered to fill out the 6, and a host of other baryons with one or more charmed quarks are needed to fill out the full SU(4) multiplets. Furthermore, every N or Δ baryon resonance "starts" another SU(4) multiplet, so the woods are full of charmed baryons, most of which no doubt will forever remain undiscovered. The only candidates so far to belong to more massive multiplets are the $\Lambda_c(2593)$ and the $\Lambda_c(2625)$, and perhaps a $\Xi_c(2645)$; see the Listings.

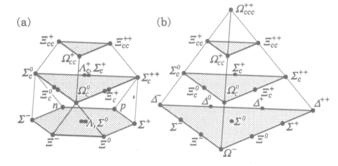


Fig. 1. SU(4) multiplets of baryons made of u, d, s, and c quarks. (a) The 20-plet with an SU(3) octet on the lowest level. (b) The 20-plet with an SU(3) decuplet on the lowest level.

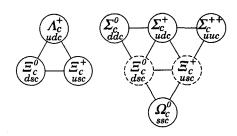


Fig. 2. The SU(3) multiplets on the second level of the SU(4) multiplet of Fig. 1(a). The particles in dashed circles have yet to be discovered.

The states of the $\overline{3}$ multiplet in Fig. 2 are antisymmetric under interchange of the two light quarks (the u, d, and s quarks), whereas the states of the 6 multiplet are symmetric under interchange of these quarks. Actually, there may be some mixing between the pure $\overline{3}$ and 6 Ξ_c states (they have the same I, J, and P quantum numbers) to form the physical Ξ_c states.

It need hardly be said that the flavor symmetries Fig. 1 displays are very badly broken, but the figure is the simplest way to see what charmed baryons should exist.

For a review of theory and experiment, see Ref. 1.

References

 J.G. Körner, M. Krämer, and D. Pirjol, Prog. in Part. Nucl. Phys. 33, 787 (1994).



$$I(J^P) = O(\frac{1}{2}^+)$$
 Status: ***

J has not actually been measured yet. Results of an analysis of $\rho K^-\pi^+$ decays (JEZABEK 92) are consistent with the expected J=1/2. The quark content is udc.

We have omitted some results that have been superseded by later experiments. The omitted results may be found in earlier editions.

A+ MASS

Measurements with an error greater than 5 MeV or that are otherwise obsolete have been omitted.

The fit also includes Σ_c - Λ_c^+ and Λ_c^{*+} - Λ_c^+ mass-difference measurements.

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
2284.9±0.6 OUR FT	<u>T</u>			
2284.9±0.6 OUR AV	/ERAGE			
2284.7±0.6±0.7	1134	AVERY	91 CLEC	Six modes
2281.7±2.7±2.6	29	ALVAREZ	908 NA14	ι <i>pK</i> −π ⁺
2285.8 ± 0.6 ± 1.2	101	BARLAG	89 NA32	2 pK-π+
2284.7±2.3±0.5	5	AGUILAR	88B LEBO	pK-π+
2283.1±1.7±2.0	628	ALBRECHT	88c ARG	$pK^-\pi^+$, $p\overline{K}^0$, $\Lambda 3\pi$
2286.2 ± 1.7 ± 0.7	97	ANJOS	88B E691	$pK^-\pi^+$
2281 ±3	2	JONES	87 HBC	$pK^-\pi^+$
2283 ±3	3	BOSETTI	82 HBC	$pK^-\pi^+$
2290 ±3	1	CALICCHIO	80 HYB	R ρK-π+

At MEAN LIFE

Measurements with an error $\geq 0.1 \times 10^{-12}$ s or with fewer than 20 events have been omitted.

VALUE (10 ⁻¹² s) 0.206±0.012 OUR AV	EVTS ERAGE	DOCUMENT ID	<u>TECN</u>	COMMENT
0.215±0.016±0.008	1340	FRABETTI	93D E687	$\gamma Be, \Lambda_c^+ \rightarrow pK^-\pi^+$
0.18 ±0.03 ±0.03	29	ALVAREZ	90 NA14	$\gamma, \Lambda_c^+ \rightarrow \rho K^- \pi^+$
$0.20 \pm 0.03 \pm 0.03$	90	FRABETTI	90 E687	$\gamma Be, \Lambda_c^+ \rightarrow \rho K^- \pi^+$
$0.196^{+0.023}_{-0.020}$	101	BARLAG	89 NA32	$pK^-\pi^+$ + c.c.
0.22 ±0.03 ±0.02	97	SOLNA	88B E691	$pK^-\pi^+$ + c.c.

Λ_c^+

A+ DECAY MODES

Nearly all branching fractions of the Λ_c^+ are measured relative to the $\rho\,K^-\pi^+$ mode, but there are no model-independent measurements of this branching fraction. We explain how we arrive at our value of $\mathrm{B}(\Lambda_c^+\to\rho\,K^-\pi^+)$ in a Note at the beginning of the branching-ratio measurements, below. When this branching fraction is eventually well determined, all the other branching fractions will slide up or down proportionally as the true value differs from the value we use here.

```
Scale factor/
                                                                                                Confidence level
         Mode
                                                                  Fraction (\Gamma_I/\Gamma)
                               Hadronic modes with a p and one \overline{K}
         p\overline{K}^0
\Gamma_1
                                                                     (2.5 \pm 0.7)\%
\Gamma_2
         pK- π+
                                                                    (5.0 \pm 1.3)\%
            p\overline{K}^*(892)^0
Γ3
                                                                    (1.8 \pm 0.6)\%
             \Delta(1232)^{++}K^{-}
                                                                     (8 \pm 5) \times 10^{-3}
Г4
                                                               [b] (4.5 + 2.5 \times 10^{-3}) \times 10^{-3}
\Gamma_5
             \Lambda(1520)\pi^{+}
Γ<sub>6</sub>
             pK^-\pi^+ nonresonant
                                                                     (2.8 \pm 0.9)\%
Γ7
         p\overline{K}^0\eta
                                                                      (1.3 \pm 0.4)\%
         p \overline{K}{}^{0} \pi^{+} \pi
Γ8
                                                                     (2.4 \pm 1.1)\%
         pK^{-}\pi^{+}\pi^{0}
Γ٩
Γ<sub>10</sub>
             pK*(892)^{-}\pi^{+}
                                                              [b] (1.1 \pm 0.6)\%
             p(K^-\pi^+)_{\text{nonresonant}}\pi^0
\Delta(1232)\overline{K}^*(892)
Γ11
                                                                      (3.6 \pm 1.2)\%
Γ<sub>12</sub>
                                                                     (1.1 \pm 0.8) \times 10^{-3}
Γ<sub>13</sub>
         pK^-\pi^+\pi^+\pi^-
         pK^{-}\pi^{+}\pi^{0}\pi^{0}
                                                                     (8 \pm 4 ) \times 10<sup>-3</sup>
Γ<sub>14</sub>
         pK^{-}\pi^{+}\pi^{0}\pi^{0}\pi^{0}
                                                                     ( 5.0~\pm~3.4 ) \times~10^{-3}
                        Hadronic modes with a p and zero or two K's
         p\pi^+\pi^-
                                                                     ( 3.5 \pm 2.0 ) \times\,10^{-3}
\Gamma_{16}
                                                                     (2.8 \pm 1.9) \times 10^{-3}
Γ17
            pf_0(980)
                                                                      ( 1.8 \pm 1.2 ) \times 10<sup>-3</sup>
Γ<sub>18</sub>
         p\pi^+\pi^+\pi^-
         pK+K-
                                                                     ( 2.3 \pm 0.9 ) \times 10 ^{-3}
Γ<sub>19</sub>
                                                               [b] ( 1.2 \pm 0.5 ) \times 10<sup>-3</sup>
\Gamma_{20}
             рφ
                                  Hadronic modes with a hyperon
\Gamma_{21} \Lambda\pi^+
                                                                     (9.0 \pm 2.8) \times 10^{-3}
         \Lambda\pi^{+}\pi^{0}
                                                                      ( 3.6 \pm 1.3 ) %
            \Lambda \rho^+
\Gamma_{23}
                                                                    < 5
                                                                                                         CL=95%
        \Lambda\pi^{+}\pi^{+}\pi^{-}
                                                                     (3.3 \pm 1.0)\%
Γ24
        \Lambda \pi^+ \eta
Γ<sub>25</sub>
                                                                      (1.7 \pm 0.6)\%
                                                                     (8.5 \pm 3.3) \times 10^{-3}
            \Sigma(1385)^{+}\eta
Γ<sub>26</sub>
        1K+KO
                                                                      (6.0 \pm 2.1) \times 10^{-3}
Γ27
Γ<sub>28</sub>
        \Sigma^0\pi^+
                                                                      (9.9 \pm 3.2) \times 10^{-3}
       \Sigma^+\pi^0
                                                                      (1.00 \pm 0.34)\%
Γ29
       \Sigma^+\eta
                                                                      (5.5 \pm 2.3) \times 10^{-3}
Γ30
        \Sigma^+\dot{\pi}^+\pi
۲31
                                                                      (3.4 \pm 1.0)\%
\Gamma_{32}
                                                                                                          CL=95%
                                                                    < 1.4
                                                                      (1.8 \pm 0.8)\%
Γ<sub>34</sub>
                                                                      (1.8 \pm 0.8)\%
                                                                      (1.1 \pm 0.4)\%
 Γ35
Γ<sub>36</sub>
             \Sigma^+\omega
                                                               [b] (2.7 \pm 1.0)\%
Γ37
                                                                      (3.0 + 4.1 \times 10^{-3}) \times 10^{-3}
          \Sigma^{+}\pi^{+}\pi^{+}\pi^{-}\pi^{-}
                                                                      (3.5 \pm 1.2) \times 10^{-3}
Γ39
          Σ+ K+ K-
Γ40
              \Sigma^+\phi
                                                                     (3.5 \pm 1.7) \times 10^{-3}
         \Sigma^+ K^+ \pi^-
                                                                      (7 + \frac{6}{4}) \times 10^{-3}
 ۲41
         Ξ0 K+
                                                                      ( 3.9 \pm 1.4 ) \times 10<sup>-3</sup>
Γ42
          \Xi^-K^+\pi^+
                                                                       (4.9 \pm 1.7) \times 10^{-3}
\Gamma_{43}
             \Xi(1530)^0K^+
                                                                     (2.6 \pm 1.0) \times 10^{-3}
                                            Semileptonic modes
         \Lambda \ell^+ \nu_\ell \ \Lambda e^+ \nu_e
\Gamma_{45}
                                                               [c] (2.0 \pm 0.6)\%
\Gamma_{46}
                                                                      (2.1 \pm 0.6)\%
                                                                      (2.0 \pm 0.7)\%
 Γ47
             \Lambda \mu^+ \nu_{\mu}
Γ<sub>48</sub>
        e<sup>+</sup> anything
                                                                      (4.5 \pm 1.7)\%
        pe+ anything
                                                                      (1.8 \pm 0.9)\%
 Γ<sub>50</sub>
         ∧e<sup>+</sup> anything
 \Gamma_{51} \Lambda \mu^+ anything
        \Lambda \ell^+ \nu_\ell anything
```

```
Inclusive modes
\Gamma_{53} p anything
                                                         (50 ±16
                                                                      1%
          p anything (no \Lambda)
                                                         (12
                                                              ±19
                                                                       ) %
       p hadrons
Γ55
       n anything
                                                              ±16
Γ<sub>56</sub>
          n anything (no \Lambda)
                                                              ±17
Γ<sub>57</sub>
                                                        (29
                                                                       )%
       / anything
Γ<sub>58</sub>
                                                        (35
                                                               \pm 11
                                                                       ) %
                                                                                        S=1.4
       Σ<sup>±</sup> anything
                                                       (10
```

$\Delta C = 1$ weak neutral current (C1) modes, or Lepton number (L) violating modes

Γ60	$p\mu^+\mu^- \ \Sigma^-\mu^+\mu^+$	C1	< 3.4	× 10 ⁻⁴	CL=90%
F61	$\Sigma^-\mu^+\mu^+$	L	< 7.0	× 10 ⁻⁴	CL=90%

- [a] See the "Note on Λ_c^+ Branching Fractions" below.
- [b] This branching fraction includes all the decay modes of the final-state resonance.
- [c] An ℓ indicates an e or a μ mode, not a sum over these modes.
- [d] The value is for the sum of the charge states of particle/antiparticle states indicated

NOTE ON Λ_{c}^{+} BRANCHING FRACTIONS

Written 1998 by P.R. Burchat (Stanford University).

Most Λ_c^+ branching fractions are measured relative to the decay mode $\Lambda_c^+ \to pK^-\pi^+$. However, there are no model-independent measurements of the absolute branching fraction for $\Lambda_c^+ \to pK^-\pi^+$. Here, we describe the measurements that have been used to extract $B(\Lambda_c^+ \to pK^-\pi^+)$, the model-dependence of the results, and the method we have used to average the results.

ARGUS (ALBRECHT 88C) and CLEO (CRAWFORD 92) measure $B(\overline{B} \to \Lambda_c^+ X) \times B(\Lambda_c^+ \to pK^-\pi^+)$ to be $(0.30 \pm 0.12 \pm 0.06)\%$ and $(0.273 \pm 0.051 \pm 0.039)\%$. Under the assumptions that decays of \overline{B} mesons to baryons are dominated by $\overline{B} \to \Lambda_c^+ X$ and that $\Lambda_c^+ X$ final states other than $\Lambda_c^+ \overline{N} X$ can be neglected, they also measure $B(\overline{B} \to \Lambda_c^+ X)$ to be $(6.8 \pm 0.5 \pm 0.3)\%$ (ALBRECHT 92O) and $(6.4 \pm 0.8 \pm 0.8)\%$ (CRAWFORD 92). Combining these results, we get $B(\Lambda_c^+ \to pK^-\pi^+) = (4.14 \pm 0.91)\%$. However, the assumption that \overline{B} decay modes to baryons other than $\Lambda_c^+ \overline{N} X$ are negligible is not on solid ground experimentally or theoretically. Therefore, the branching fraction for $\Lambda_c^+ \to pK^-\pi^+$ given above may be low by some undetermined amount.

The second type of model-dependent determination of $B(\Lambda_c^+ \to pK^-\pi^+)$ is based on measurements by AR-GUS (ALBRECHT 91G) and CLEO (BERGFELD 94) of $\sigma(e^+e^- \to \Lambda_c^+X) \cdot B(\Lambda_c^+ \to \Lambda \ell^+\nu_\ell) = (4.15 \pm 1.03 \pm 1.18)$ pb and $(4.77 \pm 0.25 \pm 0.66)$ pb. ARGUS (ALBRECHT 96E) and CLEO (AVERY 91) have also measured $\sigma(e^+e^- \to \Lambda_c^+X) \cdot B(\Lambda_c^+ \to pK^-\pi^+)$. The weighted average is (11.2 ± 1.3) pb.

From these measurements, we extract $R \equiv \mathrm{B}(\Lambda_c^+ \to p K^- \pi^+)/\mathrm{B}(\Lambda_c^+ \to \Lambda \ell^+ \nu_\ell) = 2.40 \pm 0.43$. We estimate the $\Lambda_c^+ \to p K^- \pi^+$ branching fraction from the equation

$$B(\Lambda_c^+ \to pK^-\pi^+) = R f F \frac{\Gamma(D \to X\ell^+\nu_{\ell})}{1 + |V_{cd}/V_{cs}|^2} \cdot \tau(\Lambda_c^+) , \quad (1)$$

where $f = B(\Lambda_c^+ \to \Lambda \ell^+ \nu_\ell)/B(\Lambda_c^+ \to X_s \ell^+ \nu_\ell)$ and $F = \Gamma(\Lambda_c^+ \to X_s \ell^+ \nu_\ell)/\Gamma(D^0 \to X_s \ell^+ \nu_\ell)$. When we use

 $1+|V_{cd}/V_{cs}|^2=1.05$ and the world averages $\Gamma(D\to \mathrm{X}\ell^+\nu_\ell)=(0.163\pm0.006)\times10^{-12}~\mathrm{s}^{-1}$ and $\tau(\Lambda_c^+)=(0.206\pm0.012)\times10^{-12}~\mathrm{s},$ we calculate $\mathrm{B}(\Lambda_c^+\to pK^-\pi^+)=(7.7\pm1.5)\%\cdot f\,F.$ Theoretical estimates for f and F are near 1.0 with significant uncertainties.

So, we have two results with significant model-dependence: $\mathrm{B}(\Lambda_c^+ \to pK^-\pi^+) = (4.14\pm0.91)\%$ from \overline{B} decays, and $\mathrm{B}(\Lambda_c^+ \to pK^-\pi^+) = (7.7\pm1.5)\% \cdot f\,F$ from semileptonic Λ_c^+ decays. If we set $f\,F=1.0$ in the second result, and assign an uncertainty of 30% to each result to account for the unknown model-dependence, we get the consistent results $\mathrm{B}(\Lambda_c^+ \to pK^-\pi^+) = (4.14\pm0.91\pm1.24)\%$ and $\mathrm{B}(\Lambda_c^+ \to pK^-\pi^+) = (7.7\pm1.5\pm2.3)\%$. The weighted average of these two results is $\mathrm{B}(\Lambda_c^+ \to pK^-\pi^+) = (5.0\pm1.3)\%$, where the uncertainty contains both the experimental uncertainty and the 30% estimate of model dependence in each result.

This procedure is clearly rather arbitrary, but so is any other procedure until good measurements of the absolute branching fraction are made. Therefore, we have assigned the value $(5.0 \pm 1.3)\%$ to the $\Lambda_c^+ \to p K^- \pi^+$ branching fraction (given as PDG 98 below). As was noted earlier, most of the other modes are measured relative to this mode.

A+ BRANCHING RATIOS

—— Hadronic modes with a p and one \overline{K} ———		Hadronic	modes v	with a	p and	one \mathcal{R}	
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Hadronic modes with a p and one K						
$\Gamma(p\overline{K}^0)/\Gamma(pK^-\pi$	+)				Γ_1/Γ_2	
VALUE	<u>EVTS</u>	DOCUMENT ID	TECN	COMMENT		
0.49±0.07 OUR AVE				A		
0.44±0.07±0.05	133	AVERY	91 CLEO			
$0.55 \pm 0.17 \pm 0.14$ $0.62 \pm 0.15 \pm 0.03$	45 73	ANJOS ALBRECHT	90 E691 88c ARG	γ Be 70-260 GeV e+e- 10 GeV		
U.02 ± U.13 ± U.U3	13	ALBRECHI	ooc And	e e 10 dev		
$\Gamma(pK^-\pi^+)/\Gamma_{\text{total}}$					Γ_2/Γ	
See the "Note of	on $arLambda_c^+$ Brand	ching Fractions"	above.			
VALUE	poc	UMENT ID	TECN COMM	IENT		
0.050 ± 0.013	PDC			ote at top of ratios		
• • • We do not use	the followin	g data for averag	ges, fits, limits	s, etc. • • •		
0.041 ± 0.010		RECHT 920				
0.044 ± 0.012	1,3 CRA	WFORD 92	CLEO e+e	10.5 GeV		
CLEO (CRAWFO	the average RD 92).	of measuremen	ts from ARG	US (ALBRECHT 8	(0.28 ± 88C) and	
² ALBRECHT 920						
³ CRAWFORD 92 r	neasures B($\overline{B} \rightarrow \Lambda_c^+ X) = ($	6.4 ± 0.8 ± 0	0.8)%.		
Γ(<i>p\</i> K*(892) ⁰)/Γ(ρK ⁻ π ⁺)				Γ_3/Γ_2	
		₹*(892) ⁰ are lr	cluded.		-, -	
VALUE	EVTS	<u>DOCÚMENT ID</u>		COMMENT		
0.36+0.06 OUR AVE	RAGE					
$0.35^{+0.06}_{-0.07}\pm0.03$	39	BOZEK	93 NA32	π^- Cu 230 GeV		
0.42±0.24	12	BASILE	818 CNTF	$R pp \rightarrow \Lambda_c^+ e^- X$		
• • • We do not use	the followin	g data for averag	ges, fits, limit	s, etc. • • •		
0.35 ± 0.11		BARLAG	90D NA32	See BOZEK 93		
Γ(Δ(1232) ⁺⁺ K ⁻)/Γ(pK-	•			Γ_4/Γ_2	
<u>VALUE</u> 0.16±0.10 OUR AVE	RAGE Fro	<u>DOCUMENT II</u> or Includes scale		COMMENT		
	14	BOZEK		π - Cu 230 GeV		
$0.12^{+0.04}_{-0.05}\pm0.05$						
0.40 ± 0.17	17	BASILE	81B CNTF	$R pp \rightarrow \Lambda_c^+ e^- X$		

DOCUMENT ID

BOZEK

 Γ_5/Γ_2

TECN COMMENT

93 NA32 π Cu 230 GeV

 $\Gamma(\Lambda(1520)\pi^+)/\Gamma(pK^-\pi^+)$ Unseen decay modes of the $\Lambda(1520)$ are included.

EVTS

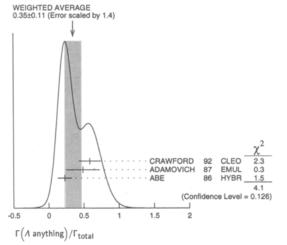
12

0.09 +0.04 ±0.02

						
(pK-π+ nonresonar		(- _# +) DOCUMENT ID		TECN	COMMENT	Γ ₆ /Γ
0.56 ^{+0.07} _{-0.09} ±0.05	71	BOZEK		NA32	π Cu 230 GeV	,
	`					
「(pK ⁰ η)/Γ(pK ⁻ π ⁺ VALUE) EVTS	DOCUMENT ID		TECN	COMMENT	Γ_7/Γ_2
0.25±0.04±0.04	57	AMMAR		CLE2		5)
$\Gamma(ho \overline{K}{}^0\pi^+\pi^-)/\Gamma(ho K$	·-π+)					Γ8/Γ
<u>E</u> 0.49±0.17 OUR AVERAG		DOCUMENT ID			COMMENT	
0.43±0.12±0.04					e+e- 10.5 Ge\	,
0.98±0.36±0.08			90 D	NA32	π ⁻ 230 GeV	
$\Gamma(pK^-\pi^+\pi^0)/\Gamma_{\text{total}}$						Г9/
	EVTS	DOCUMENT ID		TECN	COMMENT	. 3/
icen _.	44	AMENDOLIA	87	SPEC	γGe-Si	
$\Gamma(pK^*(892)^-\pi^+)/\Gamma($	(p Κ 0π+	π~)				Γ ₁₀ /Γ
Unseen decay mode					COMMENT	
VALUE	<u>5713</u> 17	DOCUMENT ID		BIS2	nN 20-70 GeV	
	0) (= (F /F
Γ(ρ(K ⁻ π ⁺)nonresonal	nt 🗝) / I (<i>EVTS</i>	PK π τ) DOCUMENT ID		TECN	COMMENT	Γ ₁₁ /Γ
0.73±0.12±0.05	67	BOZEK		NA32		,
Γ(Δ(1232) Ҡ* (892))/	/F					Γ ₁₂ /
	EVTS	DOCUMENT ID		TECN	COMMENT	1 12/
seen	35	AMENDOLIA				
$\Gamma(\rho K^-\pi^+\pi^+\pi^-)/\Gamma$	(nK=++	٠١				Γ ₁₃ /Γ
VALUE	(<i>p</i> · · ·	DOCUMENT ID		TECN	COMMENT	. 13/ .
0.022±0.015		BARLAG	900	NA32	π^- 230 GeV	
$\Gamma(pK^-\pi^+\pi^0\pi^0)/\Gamma(pK^-\pi^+\pi^0\pi^0)$	pK-π+))				Γ ₁₄ /1
VALUE	<u>EVTS</u>	DOCUMENT ID				
0.16±0.07±0.03	15	BOZEK	93	NA32	π Cu 230 Ge ¹	v
Γ(ρK ⁻ π ⁺ π ⁰ π ⁰ π ⁰)/	/Γ(pK=1	r ⁺)				Γ ₁₅ /Γ
	EVT\$	DOCUMENT ID				
0.10±0.06±0.02	8	BOZEK		NA32		v
На	dronic m	odes with a p	and	0 or 2	! K's	
Γ(pπ+π ⁻)/Γ(pK ⁻ π	r ⁺)					F ₁₆ /[
VALUE		DOCUMENT ID			π 230 GeV	
0.0 69 ±0.036		BARLAG	901) NA32	π 230 GeV	
Γ(ρf ₀ (980))/Γ(ρ <i>K</i> ⁻	π ⁺)	(000) are leady				Γ ₁₇ /Ι
Unseen decay mod	es or the <i>r</i>	DOCUMENT ID		TECN	COMMENT	
0.055±0.036				NA32		
Γ(ρπ ⁺ π ⁺ π ⁻ π ⁻)/Γ	(pK==+	.)				Γ ₁₈ /Ι
VALUE		DOCUMENT ID		TECN	COMMENT	
0.036±0.023		BARLAG	900	NA32	π^- 230 GeV	
Γ(ρK ⁺ K ⁻)/Γ(ρK ⁻	$\pi^+)$					Γ19/
VALUE	EVTS	DOCUMENT ID			COMMENT	
0.046±0.012 OUR AVEF 0.039±0.009±0.007	RAGE Err 214	or includes scale ALEXANDER	960	CLE2	$e^+e^-\approx T(4$	\$ 5)
0.096±0.029±0.010	30	FRABETTI	93	E687	γ Be, \overline{E}_{γ} 220	GeV
0.048±0.027		BARLAG			π = 230 GeV	
$\Gamma(p\phi)/\Gamma(pK^-\pi^+)$	lan a <i>t</i> 22	فالمناج والمساور				Γ ₂₀ /1
Unseen decay mod	les of the ¢ <u>EVT\$</u>	DOCUMENT ID		TECN	COMMENT	
0.024±0.006±0.003	54	ALEXANDER	960	CLE2	$e^+e^-\approx r(4$	\$ 5)
• • We do not use the	e following					
0.040±0.027		BARLAG	901	NA32	π 230 GeV	
$\Gamma(p\phi)/\Gamma(pK^+K^-)$	lac of the	Care Included				Γ ₂₀ /Γ
Unseen decay mod		DOCUMENT ID	:	TECN	COMMENT	
• • • We do not use the						
<0.58	ю	FRABETTI	93H I	E687	γ Be, \overline{E}_{γ} 220 Ge	٧
•						

Under	only modes with a hyperon		$\Gamma(\Sigma^0\pi^+\pi^+\pi^-)/\Gamma(\mu^0\pi^+\pi^-)$	+\				/C-
	onic modes with a hyperon ———	F /F-	VALUE	EVTS	DOCUMENT ID	TECN	COMMENT	Γ ₃₅ /Γ ₂
Γ(Λπ ⁺)/Γ(ρΚ ⁻ π ⁺) VALUECL%_EVI	S DOCUMENT ID TECH COMME	Γ ₂₁ /Γ ₂	0.21±0.05±0.05	90	AVERY	94 CLE2	e+e-≈ 7(35), T(4S)
0.180±0.032 OUR AVERAGE			$\Gamma(\Sigma^+\omega)/\Gamma(pK^-\pi^+)$	-)				Γ_{37}/Γ_2
0.18 ±0.03 ±0.04 0.18 ±0.03 ±0.03	ALBRECHT 92 ARG e ⁺ e ⁻ 7 AVERY 91 CLEO e ⁺ e ⁻	≈ 10.4 GeV	Unseen decay mod	des of the ω			COLUMNIT	
	ng data for averages, fits, limits, etc. • • •	10.5 GeV	VALUE 0.54±0.13±0.06	<u>EVTS</u> 107	DOCUMENT ID KUBOTA		$e^+e^-\approx \Upsilon$	45)
<0.33 90 <0.16 90	ANJOS 90 E691 γ Be 70	0260 GeV 10 GeV	Γ(Σ+π+π+π-π-)			93 CLL2	e e ~ //	Γ ₃₈ /Γ ₂
			VALUE	EVTS	DOCUMENT ID	TECN	COMMENT	
$(\Lambda \pi^+ \pi^0)/\Gamma(pK^- \pi^+)$ VALUE EVTS	DOCUMENT ID TECN COMMENT	Γ ₂₂ /Γ ₂	0.06 ^{+0.08} -0.04	1	BARLAG	92 NA32	π [—] Cu 230 G	eV
.73±0.09±0.16 464	AVERY 94 CLE2 e ⁺ e ⁻ ≈	T(3S),T(45)	$\Gamma(\Sigma^+ K^+ K^-)/\Gamma(p)$	K-*+)				Γ39/Γ2
$\Gamma(\Lambda \rho^+)/\Gamma(\rho K^-\pi^+)$		Γ_{23}/Γ_2	VALUE	EVTS	DOCUMENT ID	TECN	COMMENT	. 35/ . 2
ALUE CL%	DOCUMENT ID TECN COMMENT		$0.070 \pm 0.011 \pm 0.011$	59	AVERY	93 CLE2	$e^+e^-\approx 10.9$	5 GeV
<0.95 95	AVERY 94 CLE2 $e^+e^-\approx$	T(35), T(45)	$\Gamma(\Sigma^+\phi)/\Gamma(pK^-\pi^+$	٠,				Γ40/Γ2
$(\Lambda \pi^+ \pi^+ \pi^-)/\Gamma_{\text{total}}$		Γ ₂₄ /Γ	Unseen decay mod		are included.			140/12
ALUE EVTS	DOCUMENT ID TECN COMMENT		VALUE	EVTS	DOCUMENT ID		COMMENT	
We do not use the following	ng data for averages, fits, limits, etc. • • •		$0.069 \pm 0.023 \pm 0.016$	26	AVERY	93 CLE2	$e^+e^-\approx 10.$	5 GeV
.028±0.007±0.011 70	4 BOWCOCK 85 CLEO e+e- 10.5	5 GeV	$\Gamma(\Sigma^+K^+\pi^-)/\Gamma(pK$	(- _x +)				Γ_{41}/Γ_{2}
⁴ See BOWCOCK 85 for assum	ptions made on charm production and Λ_{C} pro-	oduction from	VALUE	EVTS	DOCUMENT ID	TECN	COMMENT	
charm to get this result.	•		$0.13^{+0.12}_{-0.07}$	2	BARLAG	92 NA32	π ⁻ Cu 230 G	eV
$(\Lambda \pi^+ \pi^+ \pi^-)/\Gamma(pK^-\pi^+)$		Γ_{24}/Γ_{2}			• • •			
ALUE EVTS	DOCUMENT ID TECN COMMENT	-	$\Gamma(\Xi^0K^+)/\Gamma(pK^-\pi$	+)				Γ_{42}/Γ_2
.66±0.11 OUR AVERAGE	AVEDY 04 5150 ±	Cal	VALUE	<u>EVTS</u>	DOCUMENT ID		COMMENT	
65±0.11±0.12 289 82±0.29±0.27 44	AVERY 91 CLEO e ⁺ e ⁻ 10.5 ANJOS 90 E691 γBe 70-260		$0.078 \pm 0.013 \pm 0.013$	56 ·	AVERY	93 CLE2	$e^+e^-\approx 10.$	5 GeV
94±0.41±0.13 10	BARLAG 900 NA32 π ⁻ 230 GeV		Γ(Ξ~K+π+)/Γ(pK	(- +)				Γ43/Γ2
61±0.16±0.04 105	ALBRECHT 88C ARG e+e-10 G		VALUE	<u>EVTS</u>	DOCUMENT ID	TECN	COMMENT	143/12
$(ho K^0 \pi^+ \pi^-) / \Gamma (\Lambda \pi^+ \pi^+ \pi^-) / \Gamma (\Lambda \pi^+ \pi^+ \pi^-) / \Gamma (\Lambda \pi^+ \pi^+ \pi^-) / \Gamma (\Lambda \pi^+ \pi^+ \pi^-) / \Gamma (\Lambda \pi^+ \pi^+ \pi^-) / \Gamma (\Lambda \pi^+ \pi^+ \pi^-) / \Gamma (\Lambda \pi^+ \pi^+ \pi^-) / \Gamma (\Lambda \pi^+ \pi^+ \pi^-) / \Gamma (\Lambda \pi^-) / \Gamma (\Lambda \pi^-$	1	r. /r	0.098±0.021 OUR AVE		or includes scale			gram below
LUEEVTS	DOCUMENT ID TECN COMMENT	Γ ₈ /Γ ₂₄	0.14 ±0.03 ±0.02	34	ALBRECHT		$e^+e^-\approx 10.$	
	ig data for averages, fits, limits, etc. • • •		0.079±0.013±0.014	60	AVERY		$e^+e^-\approx 10.1$	
1±1.2	ALEEV 96 SPEC n nucleus, !	50 GeV/c	0.15 ±0.04 ±0.03	30	AVERY	91 CLEO	e ⁺ e ⁻ 10.5 0	ieV
3±1.2 130	ALEEV 84 BIS2 nC 40-70 0		WEIGHTED AVERAGE					
4 1 1/2/_ 1/2 11		- /-	0.098±0.021 (Error scale	ed by 1.3)				
$(\Lambda \pi^+ \eta)/\Gamma(pK^- \pi^+)$		Γ ₂₅ /Γ ₂	ı					
NLUE EVTS 35±0.05±0.06 116	AMMAR 95 CLE2 $e^+e^-\approx$	7(45)	\wedge					
	0	1 (43)						
$(\Sigma(1385)^+\eta)/\Gamma(\rho K^-\pi^+)$	1	Γ_{26}/Γ_{2}						
Unseen decay modes of the	$\Sigma(1385)^+$ are included.							
ALUE EVTS	DOCUMENT ID TECN COMMENT	2(46)						
17±0.04±0.03 54	AMMAR 95 CLE2 e ⁺ e [−] ≈	1 (45)						
$(\Lambda K^+ \overline{K}^0)/\Gamma(\rho K^- \pi^+)$		Γ_{27}/Γ_2						
ALUE EVTS	DOCUMENT ID TECN COMMENT							
12 ±0.02 ±0.02 59	AMMAR 95 CLE2 $e^+e^-\approx$	T(4S)					×2	
$(\Sigma^0\pi^+)/\Gamma(pK^-\pi^+)$		Γ_{28}/Γ_{2}		<u></u>	· · · ALBRECHT	95B AR	IG 1.3	
ALUE EVTS	DOCUMENT ID TECN COMMENT	' 26/ ' 2		\	···AVERY	93 CL	E2 1.0	
20±0.04 OUR AVERAGE					···AVERY	91 CL	EO 1.1 3.4	
21±0.02±0.04 196	AVERY 94 CLE2 e ⁺ e ⁻ ≈			/	(C	onfidence Le	3.4 evel = 0.180)	
17±0.06±0.04	ALBRECHT 92 ARG e ⁺ e ⁻ ≈1	.0.4 GeV			1			
$(\Sigma^+\pi^0)/\Gamma(pK^-\pi^+)$		Γ ₂₉ /Γ ₂	0 0.05 0.1 0.15		0.25 0.3 0.3	10		
LUE EVTS	DOCUMENT ID TECN COMMENT		$\Gamma(\Xi^-K^+\pi^+)/\Gamma(\rho K$	(-π ⁺)				
20±0.03±0.03 93	KUBOTA 93 CLE2 $e^+e^-\approx$	Υ(4S)						
(F+=)/[(= k-=+)		r /r-	Γ(Ξ(1530) ⁰ K ⁺)/Γ($pK^-\pi^+$				Γ ₄₄ /Γ;
$(\Sigma^+\eta)/\Gamma(pK^-\pi^+)$	DOCUMENT ID TECH CONSESSE	Γ ₃₀ /Γ ₂	Unseen decay mod					
LUE EVTS 11±0.03±0.02 26	AMMAR 95 CLE2 $e^+e^-\approx$	T(45)	VALUE	EVTS	DOCUMENT ID	IECN_	COMMENT	
	23 CEEZ 8.6 ≅	. (33)	0.052±0.014 OUR AVE	RAGE 11	ALBRECHT	95B ARG	e ⁺ e ⁻ ≈10.	4 Ge\/
$(\Sigma^+\pi^+\pi^-)/\Gamma(pK^-\pi^+)$		Γ_{31}/Γ_2	0.053 ± 0.016 ± 0.010	24	AUERY		e+e ≈ 10. e+e-≈ 10.	
LUE EVTS	DOCUMENT ID TECN COMMENT			_				
68±0.09 OUR AVERAGE 74±0.07±0.09 487	KUBOTA 93 CLE2 e+e-≈	T(45)	-	S	emileptonic mo	des		
		· ·	$\Gamma(\Lambda \ell^+ \nu_\ell)/\Gamma(pK^-\pi$	+)				Γ ₄₅ /Γ:
54 ^{+0.18} -0.15	BARLAG 92 NA32 π Cu 230	GEV	VALUE		DOCUMENT ID	соммы	ENT	
$(\Sigma^+ ho^0)/\Gamma(pK^-\pi^+)$		Γ_{32}/Γ_2	0.41±0.05 OUR AVERA	IGE				السد
LUE CL%	DOCUMENT ID TECN COMMENT	· Ja; · 6	0.42 ± 0.07		PDG	98 Our F($\Lambda e^+ \nu_e) / \Gamma(p)$	(~ **) ~~ -±\
0.27 95	KUBOTA 93 CLE2 e+e-≈	Υ(4S)	0.39±0.08		PDG	98 Our F($(\Lambda \mu^+ \nu_\mu)/\Gamma(\rho)$	√ π [™])
(Σ ⁻ π ⁺ π ⁺)/Γ(Σ ⁺ π ⁺ π ⁻		Γ_{33}/Γ_{31}						
LUE EVTS	DOCUMENT ID TECH COMMENT	20. Ce\/						
83±0.15±0.07 56	FRABETTI 948 E687 γ Be, \overline{E}_{γ} 25	∠∪ GeV						
$(\Sigma^0\pi^+\pi^0)/\Gamma(pK^-\pi^+)$		Γ_{34}/Γ_{2}						
ALUE EVTS	DOCUMENT ID TECN COMMENT							
.36±0.09±0.10 117	AVERY 94 CLE2 e+e-≈	T(35),T(45)						

MAZE-DOT OUR AVERAGE ANSE-DOS OUR AVERAGE ANSE-DOS OUR AVERAGE ANSE-DOS OUR AVERAGE ANSE-DOS OUR AVERAGE ANSE-DOS OUR AVERAGE ANSE-DOS OUR AVERAGE 5.6 BERGFELD 94 CLE2 $e^+e^- \approx 7(4S)$ 3.08 ± 0.14 5.6 TO extract $(A_c^+ \rightarrow Ae^+\nu_e)$)/ $((A_c^+ \rightarrow PK^- \pi^+))$, we use $a(e^+e^- \rightarrow A_c^+ X)$. B($A_c^- \rightarrow Ae^+\nu_e)$ = (1.2 ± 1.3) pb, which is the weighted average of measurements from ACMSUS (ALBRECHT 96c) and CLEO (AVERY 91). 7 ALBRECHT 915 one sessures $a(e^+e^- \rightarrow A_c^+ X)$. B($A_c^+ \rightarrow Ae^+\nu_e)$) = (4.20 ± 1.28 ± 0.71) pb. $(A\mu^+\nu_\mu)$ / $(\mu K^-\pi^+)$ ANUE DOCUMENT ID TECN COMMENT F47/F2 ANUE DOCUMENT ID TECN COMMENT F47/F2 ANUE DOCUMENT ID TECN COMMENT F47/F2 ANUE DOCUMENT ID TECN COMMENT F47/F2 ANUE DOCUMENT ID TECN COMMENT F47/F2 ANUE DOCUMENT ID TECN COMMENT TAT/F2 ANUE DOCUMENT ID TECN COMMENT TAT/F2 TAT		
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but account is taken of this in the systematic error. \[\begin{align*} \begin{align*} \limits \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \	0.50±0.08±0.14	13 CRAWFORD 92 CLEO e ⁺ e ⁻ 10.5 GeV
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DOCUMENT ID 14 CRAWFORD 92 CLEO e ⁺ e ⁻ 10.5 GeV 14 This CRAWFORD 92 value includes neutrons from Λ decay. The value is model dependent, but account is taken of this in the systematic error. [(n anything (no Λ))/\(\Gamma\) (Total \\ \text{VALUE} \\ \text{DOCUMENT ID} \\ \text{TECN} \\ \text{COMMENT} \\ \text{COMMENT} \\ \text{DOCUMENT ID} \\ \text{TECN} \\ \text{COMMENT} \\ \text{COMMENT} \\ \text{DOCUMENT ID} \\ \text{TECN} \\ \text{COMMENT} \\ \text{COMMENT} \\ \text{DOCUMENT ID} \\ \text{TECN} \\ \text{COMMENT} \\ \text{COMMENT} \\ \text{DOCUMENT ID} \\ \text{TECN} \\ \text{COMMENT} \\ \text{COMMENT} \\ \text{DOCUMENT ID} \\ \text{TECN} \\ \text{COMMENT} \\ \text{COMMENT} \\ \text{DOCUMENT ID} \\ \text{TECN} \\ \text{COMMENT} \\ \text{COMMENT} \\ \text{DOCUMENT ID} \\ \text{TECN} \\ \text{COMMENT} \\ \text{COMMENT} \\ \text{DOSS-1.11 OUR AVERAGE} \\ \text{Error includes scale factor of 1.4. See the ideogram below.} \\ \text{D.35±0.10±0.12} \\ \text{DAMOVICH 87 EMUL} \\ \text{ADAMOVICH 87 EMUL} \\ ADAMOVI	0.12±0.10±0.16	CRAWFORD 92 CLEO e ⁺ e 10.5 GeV
DOCUMENT ID 14 CRAWFORD 92 CLEO e ⁺ e ⁻ 10.5 GeV 14 This CRAWFORD 92 value includes neutrons from Λ decay. The value is model dependent, but account is taken of this in the systematic error. (n anything (no Λ))/\(\Gamma\) (n anything	r/a amablaa\/r	F /F
14 CRAWFORD 92 CLEO e ⁺ e ⁻ 10.5 GeV 14 This CRAWFORD 92 value includes neutrons from Λ decay. The value is model dependent, but account is taken of this in the systematic error. Γ(π anything (no Λ))/Γ _{total} VALUE DOCUMENT ID CRAWFORD 92 CLEO e ⁺ e ⁻ 10.5 GeV Γ(p hadrons)/Γ _{total} VALUE DOCUMENT ID TECN COMMENT F\$5/I VALUE DOCUMENT ID TECN COMMENT F\$5/I VALUE DOCUMENT ID TECN COMMENT F\$5/I VALUE DOCUMENT ID TECN COMMENT F\$5/I VALUE POCUMENT ID TECN COMMENT F\$5/I VALUE O.41±0.24 ADAMOVICH 87 EMUL γA 20-70 GeV/c T(Λ anything)/Γ _{total} VALUE CRAWFORD 92 CLEO e ⁺ e ⁻ 10.5 GeV CRAWFORD 92 CLEO e ⁺ e ⁻ 10.5 GeV CRAWFORD 92 CLEO e ⁺ e ⁻ 10.5 GeV ADAMOVICH 87 EMUL γA 20-70 GeV/c	· · · · · · · · · · · · · · · · · · ·	
14 This CRAWFORD 92 value includes neutrons from Λ decay. The value is model dependent, but account is taken of this in the systematic error. Γ(η anything (no Λ))/Γtotal VALUE DOCUMENT ID TECN COMMENT CRAWFORD 92 CLEO e ⁺ e ⁻ 10.5 GeV F55/I VALUE DOCUMENT ID TECN COMMENT F55/I VALUE T(Λ anything)/Γtotal VALUE FVTS DOCUMENT ID TECN COMMENT F58/I VALUE T(Λ anything)/Γtotal VALUE EVTS DOCUMENT ID TECN COMMENT F58/I VALUE T(Λ anything)/Γtotal VALUE T(Λ anything)/Γtotal VALUE EVTS DOCUMENT ID TECN COMMENT TECN COMMENT TO TECN COMMENT TO S8/I VALUE T(Λ anything)/Γtotal VALUE EVTS DOCUMENT ID TECN COMMENT TO S8/I VALUE TO ADAMOVICH 87 EMUL γA 20-70 GeV/c		
Total DOCUMENT ID TECN COMMENT		
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CRAWFORD 92 CLEO e^+e^- 10.5 GeV $\Gamma(p \text{ hadrons})/\Gamma_{\text{total}} \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad $		
$\Gamma(p \text{ hadrons})/\Gamma_{\text{total}}$ P_{total} P_{tota	$\Gamma(n \text{ anything (no } \Lambda))/\Gamma_{tot}$	Γ ₅₇ /[
VALUE DOCUMENT ID TECN COMMENT ••• We do not use the following data for averages, fits, limits, etc. ••• 0.41 \pm 0.24 ADAMOVICH 87 EMUL γ A 20–70 GeV/c $\Gamma(\Lambda \text{ anything})/\Gamma_{\text{total}} \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad \qquad $	VALUE	F ₈₇ /[DOCUMENT ID TECN. COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • • • • • • • • • • • • • • • • • •	VALUE	F ₈₇ /[DOCUMENT ID TECN. COMMENT
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	0.29±0.09±0.15 (p hadrons)/\(\Gamma_{\text{total}}\)	T ₅₇ /I - <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT</u> CRAWFORD 92 CLEO e ⁺ e ⁻ 10.5 GeV
<u>NALUE</u> <u>EYTS</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT ID</u> <u>10.35 ± 0.11 OUR AVERAGE</u> Error Includes scale factor of 1.4. See the Ideogram below. D.59 ± 0.10 ± 0.12 CRAWFORD 92 CLEO e ⁺ e [−] 10.5 GeV 20.49 ± 0.23 ± 0.10 8 15 ABE 86 HYBR 20 GeV γ p	VALUE 0.29±0.09±0.15 「(p hadrons)/Γ _{total} VALUE	T 57/1 CRAWFORD 92 CLEO e ⁺ e [−] 10.5 GeV DOCUMENT ID TECN COMMENT TECN TECN COMMENT TECN
<u>VALUE</u> <u>EYTS</u> <u>DOCUMENT ID</u> <u>TECN</u> <u>COMMENT T</u> 0.35±0.11 OUR AVERAGE Error Includes scale factor of 1.4. See the Ideogram below. 0.59±0.10±0.12	<u>γαίυε</u> 0.29±0.09±0.15 Γ (<i>p</i> hadrons) / Γ _{total} <u>γαίυε</u> • • • • We do not use the folio	Tech Comment ID TECN COMMENT TECN COMMENT TECN COMMENT TECN TECN TECN TECN COMMENT TECN COMMENT TECN COMMENT TECN COMMENT TECN COMMENT TECN TECN TECN TECN TECN TECN TECN T
0.35±0.11 OUR AVERAGE Error includes scale factor of 1.4. See the ideogram below. 0.59±0.10±0.12 CRAWFORD 92 CLEO e+e- 10.5 GeV 0.49±0.24 ADAMOVICH 87 EMUL γA 20-70 GeV/c 0.23±0.10 8 15 ABE 86 HYBR 20 GeV γp	2.29±0.09±0.15 (p hadrons)/Γ _{total} 2.41∪E • • • We do not use the folio 0.41±0.24	TECN COMMENT ID CRAWFORD 92 CLEO e ⁺ e ⁻ 10.5 GeV CRAWFORD 92 CLEO c e ⁺ e ⁻ 10.5 GeV TECN COMMENT Wing data for averages, flts, limits, etc. • • • ADAMOVICH 87 EMUL γ A 20–70 GeV/c
0.49 ± 0.24 ADAMOVICH 87 EMUL γ A 20-70 GeV/ c 0.23 \pm 0.10 8 15 ABE 86 HYBR 20 GeV γ p	$VALUE$ 0.29 \pm 0.09 \pm 0.15 $\Gamma(p \text{ hadrons})/\Gamma_{\text{total}}$ $VALUE$ 0.41 \pm 0.24 $\Gamma(A \text{ anything})/\Gamma_{\text{total}}$	Tech Comment ID TECH COMMENT CRAWFORD 92 CLEO e ⁺ e ⁻ 10.5 GeV CRAWFORD 92 CLEO comment DOCUMENT ID TECH COMMENT wing data for averages, fits, limits, etc. • • • ADAMOVICH 87 EMUL γ A 20–70 GeV/c
0.23±0.10 8 ¹⁵ ABE 86 HYBR 20 GeV γ p	$VALUE$ 0.29 \pm 0.09 \pm 0.15 $\Gamma(p \text{ hadrons})/\Gamma_{\text{total}}$ $VALUE$ • • • We do not use the folion 0.41 \pm 0.24 $\Gamma(A \text{ anything})/\Gamma_{\text{total}}$ $VALUE$ $VALUE$ $VALUE$ $VALUE$ $VALUE$	TECN COMMENT CRAWFORD 92 CLEO e ⁺ e ⁻ 10.5 GeV CRAWFORD 92 CLEO e ⁺ e ⁻ 10.5 GeV TECN COMMENT DOCUMENT ID TECN COMMENT Wing data for averages, flts, limits, etc. • • • ADAMOVICH 87 EMUL γ A 20-70 GeV/c TECN COMMENT
and the second s	\(\(\pi\)\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\	CRAWFORD 92 CLEO e ⁺ e ⁻ 10.5 GeV DOCUMENT ID TECN COMMENT
¹⁵ ABE 86 Includes Λ 's from Σ^0 decay.	VALUE 0.29±0.09±0.15 Γ(p hadrons)/Γtotal VALUE • • • • We do not use the folio 0.41±0.24 Γ(A anything)/Γtotal VALUE EVTS 0.35±0.11 OUR AVERAGE 0.55±0.10±0.12 0.49±0.24	TECN COMMENT CRAWFORD 92 CLEO e ⁺ e ⁻ 10.5 GeV CRAWFORD 92 CLEO c ⁺ e ⁻ 10.5 GeV TECN COMMENT Wing data for averages, fits, limits, etc. • • • ADAMOVICH 87 EMUL γ A 20-70 GeV/c TECN COMMENT Error includes scale factor of 1.4. See the ideogram below. CRAWFORD 92 CLEO e ⁺ e ⁻ 10.5 GeV ADAMOVICH 87 EMUL γ A 20-70 GeV/c



$\Gamma(\Sigma^{\pm} \text{ anything})/\Gamma_{to}$	tal				Γ_{59}/Γ
VALUE	EVTS	DOCUMENT ID	TECN	COMMENT	
0.1 ±0.06	5	ABE	86 HYBR	20 GeV γ p	

Rare or forbidden modes CL% EVTS VALUE DOCUMENT ID TECN COMMENT <3.4 × 10⁻⁴ 90 95 E653 π^{--} emulsion 600 GeV KODAMA $\Gamma(\Sigma^-\mu^+\mu^+)/\Gamma_{\text{total}}$ A test of lepton-number conservation. Γ_{61}/Γ CL% EVTS DOCUMENT ID TECN COMMENT <7.0 × 10⁻⁴ KODAMA 95 E653 π^- emulsion 600 GeV

A+ DECAY PARAMETERS

See the "Note on Baryon Decay Parameters" in the neutron Listings.

$\alpha \text{ FOR } \Lambda_{\Gamma}^{r} \rightarrow \Lambda_{\pi}^{r}$	•				
VALUE	EVTS	DOCUMENT ID	TE	CN C	COMMENT
-0.98±0.19 OUR AV	ERAGE				
$-0.94 \pm 0.21 \pm 0.12$	414	¹⁶ BISHAI	95 CL	LE2 ($e^+e^-\approx T(45)$
-0.96 ± 0.42		ALBRECHT	92 AF	RG (e ⁺ e [−] ≈ 10.4 GeV
-1.1 ± 0.4	86	AVERY	90B CL	LEO (e ⁺ e [−] ≈ 10.6 GeV

¹⁶BISHAl 95 actually gives $\alpha=-0.94^{+}0.21^{+}0.12$, chopping the errors at the physical limit -1.0. However, for $\alpha\approx-1.0$, some experiments should get unphysical values ($\alpha<-1.0$), and for averaging with other measurements such values (or errors that extend below -1.0) should not be chopped.

α FOR $\Lambda_c^+ \rightarrow \Sigma^+$	F 0			
VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
$-0.45\pm0.31\pm0.06$	89	BISHAI 9	CLE2	$e^+e^-pprox \Upsilon(4S)$

The experiment we average then			r same incon	nplete) $M(A\ell^+)$ range, but
VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
-0.82 ^{+0.11} _{-0.07} OUR AV	ERAGE			
$-0.82^{+0.09}_{-0.06}^{+0.06}_{-0.03}$	700	¹⁷ CRAWFORD	95 CLE2	$e^+e^- \approx T(45)$
$-0.91\pm0.42\pm0.25$		18 ALBRECHT	94B ARG	e^+e^-pprox 10 GeV
• • • We do not use	the follow	ing data for average	es, fits, limits	s, etc. • • •
$-0.89^{+0.17}_{-0.11}^{+0.09}_{-0.05}$	350	¹⁹ BERGFELD	94 CLE2	See CRAWFORD 95
¹⁷ CRAWFORD 95 m	neasures th	e form-factor ratio	$R \equiv f_2/f_1$ for	or $\Lambda_c^+ o \Lambda_e^+ \nu_e$ events to

be $-0.25\pm0.14\pm0.08$ and from this calculates α , averaged over q^2 , to be the above. 18 ALBRECHT 948 uses Λe^+ and $\Lambda \mu^+$ events in the mass range 1.85 < $M(\Lambda \ell^+)<$ 2.20 GeV. 19 BERGFELD 94 uses Λe^+ events.

 Λ_c^+ , $\Lambda_c(2593)^+$, $\Lambda_c(2625)^+$

A+ REFERENCES

We have omlitted some papers that have been superseded by later exper-Iments. The omitted papers may be found in our 1992 edition (Physical Review **D45**, 1 June, Part II) or in earlier editions.

DD.C	98	EDI CO I	C. Caso+
PDG		EPJ C3 1	
ALBRECHT	96E	PRPL 276 223	+Andam, Binder, Bockmann+ (ARGUS Collab.) +Balandin+ (Serpukhov EXCHARM Collab.)
ALEEV	96 96C	JINRRC 3 31	
ALEXANDER	95B	PR D53 R1013 PL B342 397	
ALBRECHT AMMAR	95	PRL 74 3534	
BISHAL	95	PL B350 256	
CRAWFORD	95	PRL 75 624	
KODAMA	95	PL B345 85	+Ushida, Mokhtarani+ (FNAL E653 Collab.)
ALBRECHT	94B	PL B326 320	+Ehrlichmann, Hamacher+ (ARGUS Collab.)
ALEEV	94	PAN 57 1370	+Batandin+ (Serpukhov BIS-2 Collab.)
AVERY	94	Translated from YF PL B325 257	+Freyberger, Rodriguez+ (CLEO Collab.)
		PL B323 219	+Eisenstein, Gollin, Ong+ (CLEO Collab.)
BERGFELD	94		
FRABETTI	94E	PL B328 193	
AVERY	93	PRL 71 2391	
BOZEK	93	PL B312 247	
FRABETTI	93D	PRL 70 1755	+Cheung, Cumalat+ (FNAL E687 Collab.)
FRABETTI	93H	PL B314 477	+Cheung, Cumalat+ (FNAL E687 Collab.)
KUBOTA	93	PRL 71 3255	+Lattery, Nelson, Patton+ (CLEO Collab.)
ALBRECHT	92	PL B274 239	+Ehrlichmann, Hamacher, Krueger+ (ARGUS Collab.)
ALBRECHT	920	ZPHY C56 1	+Cronstroem, Ehrlichmann+ (ARGUS Collab.)
BARLAG	92	PL B283 465	+Becker, Bozek, Boehringer+ (ACCMOR Collab.)
CRAWFORD	92	PR D45 752	+Fulton, Jensen, Johnson+ (CLEO Collab.)
JEZABEK	92	PL B286 175	+Rybicki, Rylko (CRAC)
ALBRECHT	91G	PL B269 234	+Ehrlichmann, Hamacher+ (ARGUS Collab.)
AVERY	91	PR D43 3599	+Besson, Garren, Yelton+ (CLEO Collab.)
ALVAREZ	90	ZPHY C47 539	+Barate, Bloch, Bonamy+ (CERN NA14/2 Collab.)
ALVAREZ	90B	PL B246 256	+Barate, Bloch, Bonamy+ (CERN NA14/2 Collab.)
ANJOS	90	PR D41 801	+Appel, Bean+ (FNAL E691 Collab.)
AVERY	90B	PRL 65 2842	+Besson, Garren, Yelton, Kinoshita+ (CLEO Collab.)
BARLAG	90D	ZPHY C48 29	+Becker, Boehringer, Bosman+ (ACCMOR Collab.)
FRABETTI	90	PL B2\$1 639	+Bogart, Cheung, Coteus+ (FNAL E687 Collab.)
BARLAG	89	PL B218 374	+Becker, Boehringer, Bosman+ (ACCMOR Collab.)
AGUILAR	88B	ZPHY C40 321	Aguilar-Benitez, Allison, Bailty+ (LEBC-EHS Collab.)
Also	87	PL B189 254	Aguilar-Benitez, Allison, Bailly+ (LEBC-EHS Collab.)
Also	87B	PL B199 462	Aguilar-Benitez, Allison, Bailly+ (LEBC-EHS Collab.)
Also	88	SJNP 48 833	Begalli, Otter, Schulte, Gensch+ (LEBC-EHS Collab.)
		Translated from YA	F 48 1310.
ALBRECHT	88C	PL B207 109	+ (ARGUS Collab.)
ANJOS	88B	PRL 60 1379	+Appel+ (FNAL E691 Collab.)
ADAMOVICH	87	EPL 4 887	+ Alexandrov, Bolta+ (Photon Emulsion Collab.)
Also	87	SJNP 46 447	Viaggi, Gessaroli+ (Photon Emulsion Collab.)
		Translated from YA	
AMENDOLIA	87	ZPHY C36 513	+Bagliesi, Batignani, Beck+ (CERN NA1 Collab.)
JONES	87	ZPHY C36 593	+ Jones, Kennedy, O'Neale+ (CERN WA21 Collab.)
ABE	86	PR D33 1	+ (SLAC Hybrid Facility Photon Collab.)
BOWCOCK	85	PRL 55 923	+Giles, Hassard, Kinoshita+ (CLEO Collab.)
ALEEV	84	ZPHY C23 333	+Arefiev, Balandin, Berdyshev+ (BIS-2 Collab.)
BOSETTI	82	PL 109B 234	+Graessler+ (AACH3, BONN, CERN, MPIM, OXF)
VELLA	82	PRL 48 1515	+Trilling, Abrams, Alam+ (SLAC, LBL, UCB)
BASILE	81B	NC 62A 14	+Romeo+ (CERN, BGNA, PGIA, FRAS)
CALICCHIO	80	PL 93B 521	 + (BARI, BIRM, BRUX, CERN, EPOL, RHEL+)

$\Lambda_c(2593)^+$

$$I(J^P) = O(\frac{1}{2}) \text{ Status: } ***$$

Seen in $\Lambda_c^+\pi^+\pi^-$ but not in $\Lambda_c^+\pi^0$, so this is indeed an excited Λ_c^+ rather than a Σ_c^+ . The $\Lambda_c^+\pi^+\pi^-$ mode is largely, and perhaps entirely, $\Sigma_c\pi$, which is just at threshold; thus (assuming, as has not yet been proven, that the Σ_c has $J^P=1/2^+$) the J^P here is almost certainly $1/2^-$. This result is in accord with the theoretical expectation that this is the charm counterpart of the strange A(1405).

$\Lambda_c(2593)^+$ MASS

The mass is obtained from the $m_{\Lambda_c(2593)^+} - m_{\Lambda_c^+}$ mass-difference measurements below.

VALUE (MeV)
2593.9±0.8 OUR FIT

DOCUMENT ID

$m_{\Lambda_c(2593)^+}-m_{\Lambda_c^+}$						
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT	
308.9±0.6 OUR FIT	Error inclu	ides scale factor o	f 1.1.			
308.9±0.6 OUR AV	ERAGE Err	or includes scale f	actor	of 1.1.		
309.7±0.9±0.4	19	ALBRECHT	97	ARG	$e^+e^-\approx 10 \text{ GeV}$	
309.2±0.7±0.3	14	1 FRABETTI	96	E687	γ Be, $\overline{E}_{\gamma} \approx 220 \text{ GeV}$	
307.5±0.4±1.0	112				e ⁺ e [−] ≈ 10.5 GeV	

 1 FRABETTI 96 claims a signal of 13.9 \pm 4.5 events. ²EDWARDS 95 claims a signal of 112.5 \pm 16.5 events in $\Lambda_c^+\pi^+\pi^-$.

Λ_c(2593)⁺ WIDTH

VALUE (MeV) 3.6+2.0 OUR AVE	EVTS RAGE	DOCUMENT ID		TECN	COMMENT
$2.9^{+2.9}_{-2.1}^{+1.8}_{-1.4}$	19	ALBRECHT	97	ARG	e^+e^-pprox 10 GeV
$3.9^{+1.4}_{-1.2}^{+2.0}_{-1.0}$	112	EDWARDS	95	CLE2	$e^+e^-pprox~10.5~GeV$

Ac(2593)+ DECAY MODES

 $\Lambda_{C}^{+}\pi\pi$ and its submode Σ_{C} (2455) π — the latter just barely — are the only strong decays allowed to an excited Λ_c^+ having this mass; and the $\Lambda_c^+\pi^+\pi^-$ mode seems to be largely via $\Sigma_c^{++}\pi^-$ or $\Sigma_c^0\pi^+$.

	Mode	Fraction (Γ_{I}/Γ)	
$\overline{\Gamma_1}$	$\Lambda_{c}^{+}\pi^{+}\pi^{-}$	[a] ≈ 67 %	
Γ_2	$\Sigma_c(2455)^{++}\pi^-$	24 ± 7 %	
Γ3	$\Sigma_c^{\circ}(2455)^0\pi^+$	24 ± 7 %	
Γ_4	$\Lambda_c^+ \pi^+ \pi^-$ 3-body	18 ± 10 %	
Γ_5	$\Lambda_c^+ \pi^0$	not seen	
Γ ₆	$\Lambda_c^{\frac{1}{2}}\gamma$	not seen	
	•		

[a] Assuming isospin conservation, so that the other third is $\Lambda_c^+ \pi^0 \pi^0$.

Ac(2593)+ BRANCHING RATIOS

$\Gamma(\Sigma_c(2455)^{++}\pi^-)$,, , (, .c	DOCUMENT ID		TECH	COMMENT	Γ_2/Γ_1
VALUE 0.36±0.10 OUR AVER	RAGE	DOCUMENT ID		IECIY	COMMENT	
0.37±0.12±0.13	- 1	ALBRECHT	97	ARG	e ⁺ e ⁻ ≈	10 GeV
0.36±0.09±0.09		EDWARDS	95	CLE2	e ⁺ e ⁻ ≈	10.5 GeV
$\Gamma(\Sigma_c(2455)^0\pi^+)/\Gamma$	Γ(Λ ' π+	π-)				Г3/Г
VALUE		DOCUMENT ID		TECN	COMMENT	
0.37±0.10 OUR AVER	RAGE					
				ADC	-+	10 CeV/
0.29±0.10±0.11		ALBRECHT	97	ARG	€ € ≈	In dea
0.29±0.10±0.11 0.42±0.09±0.09		ALBRECHT EDWARDS			e+e-≈ e+e-≈	
$0.42 \pm 0.09 \pm 0.09$ $\Gamma(\Sigma_c(2455)^{++}\pi^{-}$		EDWARDS [c(2455) ⁰ π ⁺)]/	95 Γ(Λ	CLE2	e+e-≈ -)	10.5 GeV (Γ ₂ +Γ ₃)/Γ ₁
$[\Gamma(\Sigma_c(2455)^{++}\pi^{-})]$	<u>crx</u>	EDWARDS c(2455) ⁰ \(\pi^+\)]/I	95 Г(Л	CLE2 ### TECN	e ⁺ e ⁻ ≈) <u>COMMENT</u>	10.5 GeV (Γ ₂ +Γ ₃)/Γ ₁
$0.42 \pm 0.09 \pm 0.09$ $\Gamma(\Sigma_c(2455)^{++}\pi^{-}$	<u>crx</u>	EDWARDS c(2455) ⁰ \(\pi^+\)]/I	95 Г(Л	CLE2 ### TECN	e ⁺ e ⁻ ≈) <u>COMMENT</u>	10.5 GeV (Γ ₂ +Γ ₃)/Γ ₁
$[\Gamma(\Sigma_c(2455)^{++}\pi^{-})]$	<u>CL%</u> the followi	EDWARDS C(2455) ⁰ \(\pi + \) \] / \(\frac{DOCUMENT ID}{\text{ing data for average}}\) ALBRECHT	95 Г(/ / / es, fit	CLE2 ### TECN s, limits ARG	$e^+e^- \approx$ $\frac{COMMENT}{e^+e^- \approx}$	10.5 GeV (\(\Gamma_2 + \Gamma_3\)/\Gamma_1 10 GeV
$[\Gamma(\Sigma_c(2455)^{++}\pi^{-})]$ WALUE •• • We do not use 1	<u>CL%</u> the followi	EDWARDS $\frac{1}{C}(2455)^0\pi^+)]/0$ DOCUMENT ID ing data for average	95 Г(/ / / es, fit	CLE2 ### TECN s, limits ARG	$e^+e^- \approx$ $\frac{COMMENT}{e^+e^- \approx}$	10.5 GeV (\(\Gamma_2 + \Gamma_3\)/\Gamma_1 10 GeV
$[\Gamma(\Sigma_c(2455)^{++}\pi^{-}VALUE]$ • • • We do not use to $0.66^{+0.13}_{-0.16} \pm 0.07$	<u>CL%</u> the followi	EDWARDS Cc(2455) ⁰ π+)]/ DOCUMENT ID Ing data for average ALBRECHT 3 FRABETTI	95 Г (/ / / / / / / / / /	TECN s, limits ARG E687	$e^+e^- \approx$ COMMENT etc. • • • $e^+e^- \approx$ γ Be, \overline{E}_{γ}	10.5 GeV (\(\Gamma_2 + \Gamma_3\)/\Gamma_1 10 GeV

A_c(2593)+ REFERENCES

DOCUMENT ID

EDWARDS

DOCUMENT ID

CLN

ላ_c(2625)+

 $\Gamma(\Lambda_c^+ \gamma) / \Gamma(\Lambda_c^+ \pi^+ \pi^-)$

VALUE

<0.98

$$I(J^P) = 0(??)$$
 Status: ***

TECN COMMENT

TECN COMMENT

95 CLE2 $e^+e^-\approx 10.5~\text{GeV}$

95 CLE2 $e^+e^-\approx 10.5$ GeV

 Γ_6/Γ_1

Seen in $\Lambda_c^+ \pi^+ \pi^-$ but not in $\Lambda_c^+ \pi^0$ so this is indeed an excited Λ_c^+ rather than a Σ_c^+ . The spin-parity is expected to be $3/2^-$: this is presumably the charm counterpart of the strange $\Lambda(1520)$.

$\Lambda_{c}(2625)^{+}$ MASS

The mass is obtained from the $m_{\Lambda_c(2625)^+}-m_{\Lambda_c^+}$ mass-difference measurement below.

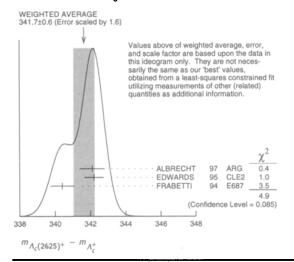
EVTS DOCUMENT ID TECN COMMENT 2626.6±0.8 OUR FIT Error includes scale factor of 1.2. 1 ALBRECHT 93F ARG See ALBRECHT 97 2626.6±0.5±1.5 42 1 ALBRECHT 93F claims a signal of 42.4 \pm 8.8 events.

$m_{\Lambda_c(2625)^+} - m_{\Lambda_c^+}$

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
341.7±0.6 OUR FIT	Error Inclu	des scale factor of	1.6.	
341.7±0.6 OUR AVE	RAGE Erro	r includes scale fac	ctor of 1.6.	See the ideogram below.
$342.1 \pm 0.5 \pm 0.5$	51	ALBRECHT	97 ARG	e ⁺ e ⁻ ≈ 10 GeV
342.2±0.2±0.5	245		95 CLE2	e ⁺ e [−] ≈ 10.5 GeV
340.4±0.6±0.3	40	³ FRABETTI	94 E687	γ Be, $\overline{\it E}_{m{\gamma}}=$ 220 GeV

²EDWARDS 95 claims a signal of 244.6 \pm 19.0 events in $\Lambda_c^+\pi^+\pi^-$.

 $^{^3\,\}text{FRABETTI}$ 94 claims a signal of 39.7 \pm 8.7 events.



$\Lambda_c(2625)^+$ WIDTH

VALUE (MeV)	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
<1.9	90	245	EDWARDS	95	CLE2	e ⁺ e ⁻ ≈ 10.5 GeV
• • • We do n	ot use the	following	g data for average	s, fits	, limits,	etc. • • •
<3.2	90		ALBRECHT	93F	ARG	$e^+e^-pprox \Upsilon(45)$

$\Lambda_c(2625)^+$ DECAY MODES

 Λ_c^+ $\pi\pi$ and its submode $\Sigma(2455)\pi$ are the only strong decays allowed to an excited Λ_c^+ having this mass.

	Mode	Fraction (Γ_i/Γ)	
Γ ₁	$\Lambda_c^+\pi^+\pi^-$	seen	_
Γ2 ·	$\Sigma_c(2455)^{++}\pi^- \Sigma_c(2455)^0\pi^+$	small	
Гз	Σ_c (2455) $^0\pi^+$	small	
Γ_4	$\Lambda_c^+ \pi^+ \pi^-$ 3-body	large	
Γ ₅	$\Lambda_c^+ \pi^0$	not seen	
Γ ₆	$\Lambda_c^+ \gamma$	not seen	

$\Lambda_c(2625)^+$ BRANCHING RATIOS

$\Gamma(\Sigma_c(2455)^+$	$^+\pi^-)/\Gamma(\Lambda_c^+\pi^+$	π^-)			Γ_2/Γ_1
VALUE	CL%	DOCUMENT ID	TEC	N COMMENT	
<0.08	90	EDWARDS	95 CLI	E2 e ⁺ e ⁻ ≈	10.5 GeV
$\Gamma(\Sigma_c(2455)^0$	$(\pi^+)/\Gamma(\Lambda_c^+\pi^+\pi^-)$	-)		•	Γ_3/Γ_1
VALUE	CL%	DOCUMENT ID	TEC	N COMMENT	
<0.07	90	EDWARDS	95 CL	E2 e ⁺ e [−] ≈	10.5 GeV
$[\Gamma(\Sigma_c(2455)^{-1})]$	$^{++}\pi^{-})+\Gamma(\Sigma_c($	[2455) ⁰ π ⁺)]/Γ	$(\Lambda_c^+\pi^+$	π-)	$(\Gamma_2+\Gamma_3)/\Gamma_1$
VALUE	CL% EVTS	DOCUMENT ID	<u>TEC</u>	N COMMENT	
• • • We do no	ot use the following	data for average:	s, fits, lin	nits, etc. • • •	l ,
< 0.36	90	FRABETTI	94 E68	37 γ Be, \overline{E}_{γ}	= 220 GeV
0.46 ± 0.14	21	ALBRECHT	93F AR	G e ⁺ e [−] ≈	T(45)
$\Gamma(\Lambda_c^+\pi^+\pi^-3$	-body)/Γ(Λ _c +π	+π-)			Γ_4/Γ_1
VALUE	<u>EVTS</u>	DOCUMENT ID	TEC	CN COMMENT	
• • • We do no	ot use the following	data for averages	s, fits, lin	nits, etc. • • •	•
0.54 ± 0.14	16	ALBRECHT	93F AR	G e ⁺ e [−] ≈	T(45)

$\Gamma(\Lambda_c^+\pi^0)/\Gamma(\Lambda_c^+\pi^0)$		v Isospin conservat	ion if	this sta	$\Gamma_{m{5}}/\hbar$ te is in fact a $\Lambda_{m{c}}.$	Γ1
VALUE	CL%_	DOCUMENT ID		TECN	COMMENT	
<0.91	90	EDWARDS	95	CLE2	e^+e^-pprox 10.5 GeV	
$\Gamma(\Lambda_c^+ \gamma)/\Gamma(\Lambda_c^+$	$\pi^{+}\pi^{-}$)				Γ ₆ /	Г1
VALUE	<u>CL%</u>	DOCUMENT ID		TECN	COMMENT	
<0.52	90	EDWARDS	95	CLE2	$e^+e^-pprox~10.5~{\rm GeV}$	

A_c(2625)+ REFERENCES

ALBRECHT	97	PL B402 207	+Hamacher, Hofmann+	(ARGUS Collab.)
EDWARDS	95	PRL 74 3331	+Ogg, Bellerive, Britton+	(CLEO Collab.)
FRABETTI	94	PRL 72 961	+Cheung, Cumalat+	(FNAL E687 Collab.)
ALBRECHT	93F	PL B317 227	+Ehrlichmann, Hamacher+	(ARGUS Collab.)

 $\Sigma_c(2455)$

m___ _ m ...

$$I(J^P) = 1(\frac{1}{2}^+)$$
 Status: ***

 $\overline{J^P}$ is not confirmed. $1/2^+$ is the quark model prediction.

Σ_c (2455) MASSES

The masses are obtained from the mass-difference measurements that follow.

Σ_c (2455) ⁺⁺ MASS	
VALUE (MeV)	DOCUMENT ID
2452.8±0.6 OUR FIT	
Σ_c (2455)+ MASS	
VALUE (MeV)	DOCUMENT ID
2453.6±0.9 OUR FIT	
Σ_c (2455) 0 MASS	
VALUE (MeV)	DOCUMENT ID
2452.2±0.6 OUR FIT	

$m_{\Sigma_c(2455)} - m_{\Lambda_c^+}$

ALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
67.87± 0.19 OUR FI	т—		_		
67.87± 0.20 OUR AV	/ERAGE				
67.76± 0.29±0.15	122	AITALA	96B	E791	π - N, 500 GeV
$.67.6 \pm 0.6 \pm 0.6$	56	FRABETTI	96	E687	γ Be, $\overline{E}_{\gamma} \approx 220 \text{ GeV}$
.68.2 ± 0.3 ±0.2	126	CRAWFORD	93	CLE2	$e^+e^-\stackrel{'}{pprox} \varUpsilon(45)$
$.67.8 \pm 0.4 \pm 0.3$	54	BOWCOCK	89	CLEO	e ⁺ e ⁻ 10 GeV
$.68.2 \pm 0.5 \pm 1.6$	92	ALBRECHT	88D	ARG	e ⁺ e ⁻ 10 GeV
$67.4 \pm 0.5 \pm 2.0$	46	DIESBURG	87	SPEC	nA ∼ 600 GeV
.67 ± 1	2	JONES	87	HBC	νρ in BEBC
.68 ± 3	6	BALTAY	79	HLBC	ν Ne-H In 15-ft
• • We do not use t	he followin	g data for average	s, fits	, limits,	etc. • • •
.66 ± 1	1	BOSETTI	82	HBC	See JONES 87
.66 ±15	1	CAZZOLI	75	HBC	νρ in BNL 7-ft
$m_{\Sigma_c^+} - m_{\Lambda_c^+}$					
ALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
68.7±0.6 OUR FIT					
.68 ±3	1	CALICCHIO	80	нвс	νp in BEBC-TST
• • We do not use t	he followin	g data for average	s, fits	i, limits,	etc. • • •
68.5 ± 0.4 ± 0.2	111	¹ CRAWFORD	93	CLE2	$e^+e^-pprox \Upsilon(45)$
¹ This result enters t	ha fit thro	unh m m	halo	.,	

	r. me	000000000000000000000000000000000000000		TECH	COMMENT
VALUE (MeV) 167.30 ± 0.20 OUR FT	EVTS	DOCUMENT ID		<u>TECN</u>	COMMENT
167.31±0.21 OUR AV	•				
167.38±0.29±0.15	143	AITALA	96B	E791	π^- N, 500 GeV
167.8 ±0.6 ±0.2		ALEEV	96	SPEC	n nucleus, 50 GeV/c
166.6 ±0.5 ±0.6	69	FRABETTI	96	E687	γ Be, $\overline{E}_{\gamma} \approx 220 \text{ GeV}$
167.1 ±0.3 ±0.2	124	CRAWFORD	93	CLE2	$e^+e^-\stackrel{'}{pprox} \Upsilon(45)$
168.4 ±1.0 ±0.3	14	ANJOS	89D	E691	γ Be 90-260 GeV
• • We do not use	the followi	ng data for average	es, fits	, limits,	etc. • • •
167.9 ±0.5 ±0.3	48	² BOWCOCK	89	CLEO	e ⁺ e ⁻ 10 GeV
167.0 ±0.5 ±1.6	70	² ALBRECHT	880	ARG	$e^{+}e^{-}$ 10 GeV
178.2 ±0.4 ±2.0	85	3 DIESBURG	87	SPEC	nA ∼ 600 GeV
163 ±2	1	AMMAR	86	EMUL	νΑ

 $^{^2}$ This result enters the flt through $m_{\Sigma_c^{++}} - m_{\Sigma_c^0}$ given below.

³ See the note on DIESBURG 87 in the $m_{\sum_{c}^{++}} - m_{\sum_{c}^{0}}$ section below.

1.4±0.5±0.3

 $\Sigma_c(2455)$, $\Sigma_c(2520)$, Ξ_c^+

Σ_c(2455) MASS DIFFERENCES

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
0.57±0.23 OUR FIT 0.66±0.28 OUR AVERA	GE Error Includes scal	e factor of 1.	.1.
+ 0.38±0.40±0.15	AITALA	96B E791	π - N, 500 GeV
$1.1 \pm 0.4 \pm 0.1$	CRAWFORD	93 CLE2	$e^+e^-pprox \Upsilon(4S)$
- 0.1 ±0.6 ±0.1	BOWCOCK	89 CLEO	e ⁺ e ⁻ 10 GeV
+ 1.2 ±0.7 ±0.3	ALBRECHT	88D ARG	$e^+e^-\sim 10~\text{GeV}$
• • • We do not use the fo	flowing data for average	s, fits, limits	, etc. • • •
-10.8 ±2.9	4 DIESBURG	87 SPEC	nA ~ 600 GeV
⁴ DIESBURG 87 is comple since it agrees with then	etely incompatible with to about $^{m}\Sigma_{c}(2455)^{++}$	he other expe $-m_{\Lambda_{+}^{+}}$. We	eriments, which is surprising go with the majority here

		′°c		
$m_{\Sigma_c^+} - m_{\Sigma_c^0}$				
VALUE (MeV)	DOCUMENT ID	TECN	COMMENT	
1.4±0.6 OUR FIT				

CRAWFORD 93 CLE2 $e^+e^- \approx \Upsilon(45)$

Σ_c (2455) DECAY MODES

 $\Lambda_c^+\pi$ is the only strong decay allowed to a Σ_c having this mass.

	Mode	Fraction (Γ_I/Γ)
Γ ₁	$\Lambda_c^+\pi$	≈ 100 %

$\Sigma_c(2455)$ REFERENCES

AITALA	96B	PL B379 292	+Amato, Anjos+ (FNAL E791 Collab.)
ALEEV	96	JINRRC 3 31	+Balandin+ (Serpukhov EXCHARM Collab.)
FRABETTI	96	PL B365 461	+Cheung, Cumalat+ (FNAL E687 Collab.)
CRAWFORD	93	PRL 71 3259	+Daubenmier, Fulton+ (CLEO Collab.)
ANJOS	89D	PRL 62 1721	+Appel, Bean, Bracker, Browder+ (FNAL E691 Collab.)
BOWCOCK	89	PRL 62 1240	+Kinoshita, Pipkin, Procarlo, Wilson+ (CLEO Collab.)
ALBRECHT	88D	PL B211 489	+Boeckmann, Glaeser+ (ARGUS Collab.)
DIESBURG	87	PRL 59 2711	+Ladbury, Binkley+ (FNAL E400 Collab.)
JONES	87	ZPHY C36 593	+ Jones, Kennedy, O'Neale+ (CERN WA21 Collab.)
AMMAR	86	JETPL 43 515 Translated from ZETFF	+Ammosov, Bakic, Baranov, Burnett+ (ITEP)
BOSETTI	82	PL 109B 234	+Graessier+ (AACH3, BONN, CERN, MPIM, OXF)
CALICCHIO	80	PL 93B 521	+ (BARI, BIRM, BRUX, CERN, EPOL, RHEL+)
BALTAY	79	PRL 42 1721	+Caroumballs, French, Hibbs+ (COLU, BNL) !
CAZZOLI	75	PRL 34 1125	+Cnops, Connolly, Louttit, Murtagh+ (BNL)

$\Sigma_c(2520)$

 $I(J^P) = 1(?^?)$ Status: ***

Seen in the $\Lambda_c^+\pi^\pm$ mass spectrum. The natural assignment is that this is the $J^P=3/2^+$ excitation of the $\Sigma_c(2455)$, the charm counterpart of the $\Sigma(1385)$.

$\Sigma_c(2520)$ MASSES

The masses are obtained from the mass-difference measurements that fol-

Σ_c(2520)++ MASS

VALUE (MeV) 2519.4±1.5 OUR FIT	_EVTS	DOCUMENT ID	TECN	COMMENT	
2519.4±1.5 OUR FIT		···			
• • • We do not use	the following	data for averag	es, fits, ilmits,	etc. • • •	
2530 ±5 ±5	6	1 AMMOSOV	93 HLBC	$\nu p \rightarrow \mu^- \Sigma$	· (2530)++
¹ AMMOSOV 93 se	es a cluster o	of 6 events and e	stimates the b	ackground to	be 1 event.

$\Sigma_{\rm c}(2520)^0$ MASS

VALUE (MeV)
2517.5±1.4 OUR FIT DOCUMENT ID

	$\Sigma_c(25)$	20) MASS DIFFERI	ENCES		
$m_{\Sigma_c(2520)^{++}} - m$	A±				
VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT	
234.5±1.4 OUR FIT					
234.5±1.1±0.5	677	BRANDENB 97	CLE2	$e^+e^-\approx T(45)$	
$m_{\Sigma_c(2520)^0} - m_A$	÷				
VALUE (MeV)	EVT5	DOCUMENT ID	TECN	COMMENT	
232.6±1.3 OUR FIT					
232.6±1.0±0.8	504	BRANDENB 97	CLE2	$e^+e^-\approx \Upsilon(45)$	
$m_{\Sigma_c(2520)^{++}} - m$	Σ _c (2520) ⁰				
VALUE (MeV)		DOCUMENT ID	TECN	COMMENT	
1.9±1.9 OUR FIT					
• • • We do not use	the followin	g data for averages, fit	s, limits	, etc. • • •	
1.9±1.4±1.0		² BRANDENB 97	CLE2	$e^+e^-pprox \Upsilon(45)$	

²This BRANDENBURG 97 result is redundant with measurements in earlier entries.

Σ_c (2520) WIDTHS

$\Sigma_c(2520)^{++}$ WID	TH		
VALUE (MeV)	EVTS	DOCUMENT ID TECN COMMENT	
$17.9^{+3.8}_{-3.2}\pm4.0$	677	BRANDENB 97 CLE2 $e^+e^-\approx T(4S)$	
$\Sigma_c(2520)^0$ WIDTH		DOCUMENT ID TECH COMMENT	
VALUE (MeV)	EVTS	DOCUMENT ID TECN COMMENT	
13.0 ^{+3.7} ±4.0	504	BRANDENB 97 CLE2 $e^+e^-\approx \Upsilon(45)$	

Σ_c (2520) REFERENCES

BRANDENB	97	PRL 78 2304	Brandenburg, Briere, Kim, Llu+	(CLEO Collab.)
AMMOSOV	93	JETPL 58 247	+Vasil'ev, Ivanilov, Ivanov+	(SERP)
Aminosor			ZETFP 58 241.	()



 $I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$ Status: ***

According to the quark model, the Ξ_c^+ (quark content usc) and Ξ_c^0 form an isospin doublet, and the spin-parity ought to be $J^P =$ 1/2+. None of I, J, or P has actually been measured.

=+ MASS

The fit uses the Ξ_c^+ and Ξ_c^0 mass and mass-difference measurements.

VALUE (MeV)	EVTS	DOCUMENT ID		ECN	COMMENT
2465.6± 1.4 OUR FIT	-				
2465.9± 1.4 OUR AV	ERAGE				
2467.0± 1.6± 2.0	147	EDWARDS	96 C	LE2	$e^+e^- \approx T(45)$
2464.4± 2.0± 1.4	30	FRABETTI	938 E	687	γ Be, $\overline{E}_{\gamma} = 220 \text{ GeV}$
2465.1± 3.6± 1.9	30	ALBRECHT	90F A	RG	e+e- at 7(45)
2467 ± 3 ± 4	23	ALAM	89 C	LEO	e+e- 10.6 GeV
2466.5± 2.7± 1.2	5	BARLAG	89C A	ССМ	π Cu 230 GeV
• • • We do not use t	he followin	ng data for average	es, fits, l	lmits,	etc. • • •
2459 ± 5 ±30	56	¹ COTEUS	87 S	PEC	nA ≃ 600 GeV
2460 ±25	82	BIAGI	83 S	PEC	Σ - Be 135 GeV

1 Although COTEUS 87 claims to agree well with BIAGI 83 on the mass and width, there appears to be a discrepancy between the two experiments. BIAGI 83 sees a single peak (stated significance about 6 standard deviations) in the $\Lambda K^-\pi^+\pi^+$ mass spectrum. COTEUS 87 sees two peaks in the same spectrum, one at the $\Xi_{\mathbf{c}}^+$ mass, the other 75 MeV lower. The latter is attributed to $\Xi_c^+ \to \Sigma^0 K^- \pi^+ \pi^+ \to (\Lambda \gamma) K^- \pi^+ \pi^+$, with the γ unseen. The *combined* significance of the double peak is stated to be 5.5 standard deviations. But the absence of any trace of a lower peak in BIAGI 83 seems to us to throw into question the interpretation of the lower peak of COTEUS 87.

ET MEAN LIFE

VALUE (10 ⁻¹² s) 0.35 ^{+0.07} OUR AVE	EVTS RAGE	DOCUMENT ID	TECN	COMMENT
$0.41^{+0.11}_{-0.08}\pm0.02$	30	FRABETTI	93B E687	$_{\gamma}$ Be, \overline{E}_{γ} = 220 GeV
0.20 + 0.11	6	BARLAG	89C ACCM	π^- (K^-) Cu 230 GeV
$0.40^{+0.18}_{-0.12}\pm0.10$	102	COTEUS	87 SPEC	πA ≃ 600 GeV
$\substack{0.48 + 0.21 + 0.20 \\ - 0.15 - 0.10}$	53	BIAGI	85C SPEC	Σ~ Be 135 GeV

E DECAY MODES

	Mode	Fraction (Γ_I/Γ)
$\overline{\Gamma_1}$	$\Lambda K^-\pi^+\pi^+$	seen
Γ ₂	Λ Κ* (892) ⁰ π ⁺	not seen
Γ ₃ Γ ₄ Γ ₅ Γ ₆ Γ ₇ Γ ₈ Γ ₁₀ Γ ₁₁ Γ ₁₂	$\Sigma(1385)^{+}K^{-}\pi^{+}$	not seen
Γ4	$\Sigma^+K^-\pi^+$	seen
Γ ₅	$\Sigma^+\overline{\mathcal{K}}^*(892)^0$	seen
Γ6	$\Sigma^0 K^- \pi^+ \pi^+$	seen
Γ7	≘ 0π+	seen
Гв	$\Xi^-\pi^+\pi^+$	seen
و۱	$\Xi(1530)^{0}\pi^{+}$	not seen
Γ ₁₀	$\equiv^0 \pi^+ \pi^0$	seen
Γ11	$\equiv^{\circ}\pi^{+}\pi^{+}\pi^{-}$	seen
Γ ₁₂	$\Xi^0 e^+ \nu_e$	seen

E BRANCHING RATIOS

\equiv_{c}^{+} Branching ratios						
$\Gamma(\Lambda K^-\pi^+\pi^+)/\Gamma$	Tental					Γ ₁ /Γ
VALUE	EVTS	DOCUMENT ID		<u>TECN</u>	COMMENT	
seen	56	COTEUS		SPEC	nA ≃ 600 GeV	
seen	82	² BIAGI		SPEC		 0 ±,
² BIAGI 85B look	(S for but doe	is not see the .	= ¿	IN PK	- Κ ⁰ π (Γ(pK - 2π ⁺) / Γ(ΛK	K π τ) -+ -+)
/ I (ΛΚ π'π' <0.03, 90% CL)	0.08 with 9 0.08 with 9	$\Lambda K^{*0}\pi^+$, and Σ	2π (138	(1 (<i>p2K</i> 5) ⁺ <i>K</i> ⁻	π^+ .	π'π')
$\Gamma(\Lambda K^-\pi^+\pi^+)/2$	Γ(Ξ-π+π+))				Γ1/Γ8
VALUE	EVTS	DOCUMENT ID			COMMENT	
0.58±0.16±0.07	61	BERGFELD	96	CLE2	$e^+e^-\approx T(45)$	
Γ(Λ Κ *(892) ⁰ π ⁺						Γ_2/Γ_1
		₹*(892) ⁰ are inc			COMMENT	
<u>VALUE</u> <0.5	<u>CL%</u> 90	DOCUMENT ID BERGFELD		CLE2	$\frac{COMMENT}{e^+e^-\approx T(4S)}$	
					,	- /-
Γ(Σ(1385)+ K-		π'π') Σ(1385) ⁺ are inc	-luda			Γ ₃ /Γ ₁
VALUE VALUE	CL%	DOCUMENT ID			COMMENT	
<0.7	90	BERGFELD	96	CLE2	$e^+e^-\approx \Upsilon(4S)$	
$\Gamma(\Sigma^{+}K^{-}\pi^{+})/\Gamma$	(=- + + + + + + + + + + + + + + + + + + +					Γ ₄ /Γ ₈
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT	
1.18±0.26±0.17	119	BERGFELD	96	CLE2		
• • • We do not us						
$0.09^{+0.13}_{-0.06}^{+0.03}_{-0.02}$	5	BARLAG	890	ACCM	$2 \Sigma^{+} K^{-} \pi^{+}, 3$ = $\pi^{+} \pi^{+}$	
Γ(Σ ⁺ K *(892) ⁰)	/r/=+-	+1				F- /F-
		`) K*(892) ⁰ are inc	luded	1.		Γ ₅ /Γ ₈
VALUE	EVTS	DOCUMENT ID		TECN		
0.92±0.27±0.14	61	BERGFELD		CLE2	, ,	
• • • We do not us	se the following 59	AVERY		s, iimits, CLE2	$e^+e^-pprox~ \Upsilon(4S)$	
			70	CLEZ	€ € ≈ 7(43)	
$\Gamma(\Sigma^0 K^- \pi^+ \pi^+)$				T EC.	501415WT	Γ_6/Γ_1
<u>VALUE</u> 0.84±0.36	<u>EVTS</u> 47	3 COTEUS		SPEC	nA ≃ 600 GeV	
³ See, however, th	e note on the					
		C				- /-
Γ(Ξ ⁰ π+)/Γ(Ξ <u>VALUE</u>	π'π') 	DOCUMENT ID		TECN	COMMENT	Γ7/Γ8
0.55±0.13±0.09	39	EDWARDS		CLE2)
Γ(Ξ ⁻ π ⁺ π ⁺)/Γ ₁	total					Г8/Г
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT	
soon 	131	BERGFELD AVERY	96 95		$e^+e^-\approx \Upsilon(45)$ $e^+e^-\approx \Upsilon(45)$	
SCCN	160 30	FRABETTI		E687		GeV
9000	30	ALBRECHT		ARG	e+e- at 7(45))
SOCI	23	ALAM	89	CLEO	e ⁺ e ⁻ 10.6 GeV	,
$\Gamma(\Xi(1530)^0\pi^+)$	/「(<i>Ξ</i> ־ѫ+ѫ ⁻	⁺)				Г9/Г8
Unseen decay	modes of the .	Ξ(1530)⁰ are i nc				
<u>VALUE</u> <0.2	<u>CL%</u> 90	DOCUMENT ID BERGFELD			$e^+e^-\approx \Upsilon(45)$	
-		DENO! EED	,,,		c c ~ /(43)	
Γ(Ξ ⁰ π ⁺ π ⁰)/Γ(.	<u>Ξ¯πтπт)</u> <u>EVTS</u>	DOCUMENT ID		TECH	COMMENT	Γ ₁₀ /Γ ₈
VALUE 2.34±0.57±0.37	81	EDWARDS			$e^+e^-\approx \Upsilon(45)$:)
Γ(Ξ(1530) ⁰ π ⁺)	/r/=0_+_0				•	, F- /F
(=(1530)-#*)	/1 (= · * · *) DOCUMENT ID		TECN	COMMENT	Γ ₉ /Γ ₁₀
<0.3	90	EDWARDS		CLE2		;)
Γ(Ξ ⁰ π ⁺ π ⁺ π ⁻)	/r(=~ * + *-	+)				Γ ₁₁ /Γ ₈
VALUE	EVTS	DOCUMENT ID				
1.74±0.42±0.27	57	EDWARDS	96	CLE2	$e^+e^-\approx \Upsilon(45)$	i)
$\Gamma(\Xi^0 e^+ \nu_e)/\Gamma(\Xi^0 e^+ \nu_e)$	Ξ-π ⁺ π ⁺)					Γ_{12}/Γ_{8}
VALUE	<u>EVTS</u>	DOCUMENT ID		TECN	COMMENT	
- 0.3						
$2.3\pm0.6^{+0.3}_{-0.6}$	41	ALEXANDER	951	CLE2	$e^+e^-\approx \Upsilon(45)$)

= REFERENCES

BERGFELD	96	Pl. B365 431	+Eisenstein, Ernst+	(CLEO	Collab.)
EDWARDS	96	PL B373 261	+McLean, Ogg+	(CLEO	Collab.)
ALEXANDER	95B	PRL 74 3113	+ Bebek, Berkelman+	(CLEO	Collab.)
Also	95E	PRL 75 4155 (erratum)	!	•	•
AVERY	95	PRL 75 4364	+Freyberger, Lingel+	(CLEO	Collab.)
FRABETTI	93B	PRL 70 1381	+Cheung, Cumalat+	(FNAL E687	Collab.)
ALBRECHT	90F	PL B247 121	+Ehrlichmann, Harder, Kruger, Nau+	(ARGUS	Collab.)
ALAM	89	PL B226 401	+Katayama, Kim, Li, Lou, Sun+	(CLEO	Collab.)
BARLAG	89C	PL B233 522	+Boehringer, Bosman+	(ACCMOR	Collab.)
COTEUS	87	PRL 59 1530	+Binkley+	(FNAL E400	Collab.)
BIAGI	85B	ZPHY C28 175	+Bourquin, Britten+	(ČERN WA62	Collab.)
BIAGI	85C	PL 150B 230	+Bourquin, Britten+	(CERN WA62	Collab.)
BIAGI	83	PL 122B 455	+Bourquin, Britten+	(CERN WA62	Collab.)



$$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$$
 Status: ***

According to the quark model, the Ξ_c^0 (quark content dsc) and Ξ_c^+ form an isospin doublet, and the spin-parity ought to be $J^P=1/2^+$. None of I, J, or P has actually been measured.

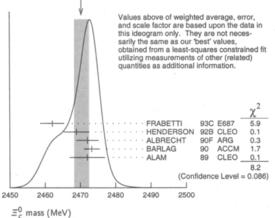
≡⁰ MASS

The fit uses the Ξ_c^0 and Ξ_c^+ mass and mass-difference measurements.

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
2470.3±1.8 OUR FT	F Error Inc	ludes scale factor o	f 1.3.		-
2470.4±2.0 OUR AV	ERAGE E				See the ideogram below.
$2462.1 \pm 3.1 \pm 1.4$	42	¹ FRABETTI	93C	E687	γ Be, \overline{E}_{γ} = 220 GeV
2469 ±2 ±3	9	HENDERSON			
2472.1 ± 2.7 ± 1.6	54	ALBRECHT	90F	ARG	e^+e^- at \varUpsilon (45)
2473.3±1.9±1.2	4	BARLAG	90	ACCM	π^- (K^-) Cu 230 GeV
2472 ±3 ±4	19	ALAM	89	CLEO	e ⁺ e ⁻ 10.6 GeV
• • • We do not use	the followli	ng data for average:	s, fits	, limits,	etc. • • •
2471 ±3 ±4	14	AVERY	89	CLEO	See ALAM 89

¹ The FRABETTI 93C mass is well below the other measurements.

WEIGHTED AVERAGE 2470.4±2.0 (Error scaled by 1.4)



$m_{\Xi_c^0} - m_{\Xi_c^+}$

VALUE (MeV)	DOCUM	ENT ID	TECN	COMMENT
4.7±2.1 OUR FIT	Error Includes scale fa	ctor of 1.2.		
6.3 ± 2.3 OUR AVE	RAGE			
$+7.0\pm4.5\pm2.2$	ALBRE	CHT 90F	ARG	$e^{+}e^{-}$ at $T(45)$
$+6.8\pm3.3\pm0.5$	BARLA	G 90	ACCM	π (K -) Cu 230 GeV
+5 ±4 ±1	ALAM	89	CLEO	$\Xi_c^0 \rightarrow \Xi^-\pi^+, \Xi_c^+ \rightarrow$
				`=- _# + _# +

≡0 MEAN LIFE

VALUE (10 ⁻¹² s) 0.098 + 0.023 OUR AVE	EVTS RAGE	DOCUMENT ID	TECN	COMMENT
$0.101^{+0.025}_{-0.017} \pm 0.005$	42	FRABETTI	93C E687	γ Be, $\overline{E}_{\gamma} =$ 220 GeV
$0.082^{+0.059}_{-0.030}$	4	BARLAG	90 ACCM	π^- (K^-) Cu 230 GeV

 $\Xi_c^0, \Xi_c(2645)$

	=° DECAY MODES	$\Xi_c(2645)$ $I(J^P) = ?(??)$ Status: *:	k *
Mode	Fraction (Γ_I/Γ)	-c(2043)	
1 Λ Κ 0	seen	A narrow peak seen in the $\Xi_c \pi$ mass spectrum. The natural assign-	
1 /Λ. 2 Ξ~π ⁺	seen	ment is that this is the $J^P = 3/2^+$ excitation of the Ξ_c in the same	
$\Xi^{-}\pi^{+}\pi^{+}\pi^{-}$	seen	SU(4) multiplet as the Δ (1232).	
$pK^{-}\overline{K}^{*}(892)^{0}$	seen	T (0/4F) MASSES	
Ω^-K^+	seen	Ξ_c (2645) MASSES	
$\Xi^-e^+\nu_e$	seen	The masses are obtained from the mass-difference measurements that fol-	
$\Xi^-\ell^+$ anything	seen	low.	
	=0 BRANCHING RATIOS	=c(2645)+ MASS VALUE(Mey) DOCUMENT ID	
		2644.6±2.1 OUR FIT Error includes scale factor of 1.2.	
「(∧Ҡ ⁰)/Г _{total}	Γ ₁ /Γ	- (near)0 hade	
ALUE EVT:		=c(2645) ⁰ MASS	
een 7	ALBRECHT 958 ARG e ⁺ e ⁻ ≈ 10.4 GeV	VALUE (MeV) DOCUMENT ID 2643.8±1.8 OUR FIT	
·(=- \pi +)/\(\(\varphi - \pi + \pi	r) Γ ₂ /Γ ₃		
ALUE	DOCUMENT ID TECN COMMENT	M <u>= (2645)</u> — M <u>=</u> ,	
.30±0.12±0.05	ALBRECHT 90F ARG e^+e^- at $\Upsilon(45)$		
·(ρΚ ⁻ Κ̄*(892) ⁰)/Γ _{total}	r. /r	$m_{\Xi_c(2645)^+} - m_{\Xi_c^0}$	
(PN N (092) // total	POCUMENT ID TECH COMMENT	VALUE (MeV) EVTS DOCUMENT ID TECN COMMENT	
DEN .	BARLAG 90 ACCM π^- (K^-) Cu 230 GeV	174.3±1.1 OUR FIT 174.3±0.5±1.0 34 GIBBONS 96 CLE2 $e^+e^- \approx T(45)$	
$\Gamma(\Omega^-K^+)/\Gamma(\Xi^-\pi^+)$	Γ ₈ /Γ ₂	M M .	
ALUE EVT		$m_{\Xi_c(2645)^0} - m_{\Xi_c^+}$	
.50±0.21±0.05	HENDERSON 928 CLEO e+e- ≈ 10.6 GeV	VALUE (MeV) EVTS DOCUMENT ID TECN COMMENT 178.2±1.1 QUR FIT	
		178.2 ± 1.1 OUR 711 178.2 ± 0.5 ± 1.0 55 AVERY 95 CLE2 $e^+e^- \approx \Upsilon(4S)$	
$(\Xi^-e^+\nu_e)/\Gamma(\Xi^-\pi^+)$	Γ ₆ /Γ ₂	11012 100 11 10 10 10 10 10 10 10 10 10 10 10	
ALUE EVT		Ξ_c (2645) WIDTHS	
3.1±1.0 ^{+0.3} -0.5	ALEXANDER 95B CLE2 $e^+e^-\approx T(4S)$	The said sames	
$\Gamma(\Xi^-\ell^+$ anything)/ $\Gamma(\Xi^-$	·_+\	≅ _c (2645) ⁺ WIDTH	
		value (MeV) CL% DOCUMENT ID TECN COMMENT <3.1 90 GIBBONS 96 CLE2 $e^+e^- \approx \Upsilon(45^-)$	
modes.	gge (not the sum) of the Ξ^-e^+ anything and $\Xi^-\mu^+$ anything	•	
ALUE EVT.		Ξ _c (2645) ⁰ WIDTH	
.96±0.43±0.18	ALBRECHT 93B ARG e ⁺ e ≈ 10.4 GeV	VALUE (MeV) CL% EVTS DOCUMENT ID TECN COMMENT	
$(\Xi^-\ell^+$ anything)/ $\Gamma(\Xi^-$	Γ_7/Γ_3	<5.8 90 55 AVERY 95 CLE2 e ⁺ e ⁻ ≈ \(\tau(4.5)\)	
	age (not the sum) of the Ξ^-e^+ anything and $\Xi^-\mu^+$ anything	E _c (2645) DECAY MODES	
VALUE EVT.	DOCUMENT ID TECN COMMENT	$\Xi_{C}\pi$ is the only strong decay allowed to a Ξ_{C} resonance having this mass.	
0.29±0.12±0.04	ALBRECHT 93B ARG $e^+e^-\approx 10.4$ GeV		
	=0 DECEDENCES	Mode Fraction (Γ ₁ /Γ)	
	=° REFERENCES	$\Gamma_1 = \Xi_c^0 \pi^+$ seen	
ALBRECHT 95B PL B342 397 ALEXANDER 95B PRL 74 3113	+Hamacher, Hofmann+ (ARGUS Collab.) +Bebek, Berkelman+ (CLEO Collab.)	$\Gamma_2 = \Xi_c^+ \pi^-$ seen	
Also 95E PRL 75 4155 ALBRECHT 93B PL B303 368 RABETTI 93C PRL 70 2058	(erratum) +Cronstroem, Ehrlichmann+ (ARGUS Collab.) +Cheung, Cumalat+ (FNAL E687 Collab.)	E _c (2645) REFERENCES	
HENDERSON 92B PL B283 161 ALBRECHT 90F PL B247 121	+Kinoshita, Pipkin, Saulnier+ (CLEO Collab.) +Ehrlichmann, Harder, Kruger, Nau+ (ARGUS Collab.)	CIPDONE OF DRI TT BYO Inhance Kross I	alah 1
3ARLAG 90 PL B236 495	+Becker, Boehringer, Bosman+ (ACCMOR Collab.)	GIBBONS 96 PRL 77 810 + Johnson, Kwon+ (CLEO Co AVERY 95 PRL 75 4364 + Freyberger, Lingel+ (CLEO Co	nav.) llab.)
ALAM 89 PL B226 401 EVERY 89 PRL 62 863	+Katayama, Kim, Li, Lou, Sun+ (CLEO Collab.) +Besson, Garren, Yelton, Bowcock+ (CLEO Collab.)		_

 Ω_c^0

$$I(J^P) = 0(\frac{1}{2}^+)$$
 Status: ***

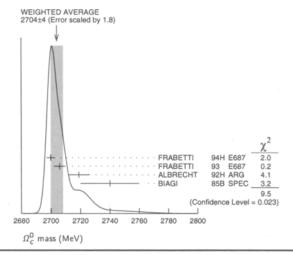
The quantum numbers have not been measured, but are simply assigned in accord with the quark model, in which the $\boldsymbol{\varOmega}_c^0$ is the ssc ground state.

Ω_c^0 MASS

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
2704 ± 4 OUR A	VERAGE	Error includes scale	factor of 1.8	. See the ideogram below.
2699.9± 1.5±2.5	42	1 FRABETTI	94H E687	$_{m{\gamma}}$ Be, $m{ar{E}}_{m{\gamma}} =$ 221 GeV
2705.9± 3.3±2.0	10	² FRABETTI	93 E687	γ Be, $\overline{E}_{\gamma}^{\prime} =$ 221 GeV
2719.0± 7.0±2.5	11	3 ALBRECHT	92H ARG	e^+e^-pprox 10.6 GeV
2740 ±20	3	BIAGI	85B SPEC	Σ- Be 135 GeV/c

- ¹ FRABETTI 94H claims a signal of 42.5 \pm 8.8 $\Sigma^+ K^- K^- \pi^+$ events. The background is about 24 events.

 ² FRABETTI 93 claims a signal of 10.3 \pm 3.9 $\Omega^- \pi^+$ events above a background of 5.8
- events. 3 ALBRECHT 92H claims a signal of $11.5 \pm 4.3 \equiv -K \pi^+ \pi^+$ events. The background is about 5 events.



Ω_c^0 MEAN LIFE

VALUE (10 ⁻¹² s)	<u>EVTS</u>	DOCUMENT ID	TECN	COMMENT
$0.055 + 0.013 + 0.018 \\ -0.011 - 0.023$	86	ADAMOVICH	95B WA89	$\Omega^{-}\pi^{-}\pi^{+}\pi^{+},$ $\Xi^{-}K^{-}\pi^{+}\pi^{+}$
$0.086^{+0.027}_{-0.020}\pm0.028$	25	FRABETTI	95D E687	Σ+κ-κ-π+

Ω_c^0 DECAY MODES

	Mode	Fraction (Γ_I/Γ)	
Γ ₁	Σ+ Κ- Κ- π+	seen	
Γ_2	$\Xi^-K^-\pi^+\pi^+$	seen	
Γ3	$\Xi^- K^- \pi^+ \pi^+$ $\Omega^- \pi^+$	seen	
Γ4	$\Omega^-\pi^-\pi^+\pi^+$	seen	

Ω_c^0 BRANCHING RATIOS

$\Gamma(\Sigma^+K^-)$	K-1	r ⁺)/Γ _{total}					Γ_1/Γ
VALUE		EVTS	DOCUMENT ID		<u>TECN</u>	COMMENT	
seen		42	FRABETTI	94H	E687	γ Be, $\overline{E}_{\gamma} = 221$	GeV
$\Gamma(\Xi^-K^-\pi^+\pi^+)/\Gamma_{\text{total}}$						Γ_2/Γ	
VALUE		EVTS	DOCUMENT ID		TECN_	COMMENT	
seen		11	ALBRECHT	92H	ARG	$e^+e^-\approx 10.6 \text{ G}$	eV
900N		3	BIAGI	85B	SPEC	Σ- Be 135 GeV	/c
$\Gamma(\Omega^-\pi^+)$	/r _{to}	tal					Γ ₃ /Γ
VALUE		EVTS	DOCUMENT ID		TECN	COMMENT	
seen		10	FRABETTI	93	E687	γ Be, $\overline{E}_{\gamma} = 221$	GeV
Γ(Ξ-K-	π ⁺ π	+)/Γ(Ω-π+)					Γ_2/Γ_3
VALUE		<u> CL%</u>	DOCUMENT ID		TECN_	COMMENT	
• • • We d	o not	use the following	data for average	s, fits	s, limits,	, etc. • • •	
<2.8		90	FRABETTI	93	E687	γ Be, $\overline{E}_{\gamma} = 221$	GeV
Γ(Ω-π-1	r+π	⁺)/Γ(Ω ⁻ π ⁺)					Γ_4/Γ_3
VALUE		<u>C1%</u>	DOCUMENT ID		TECN	COMMENT	
seen			ADAMOVICH	958	WA89	Σ^- 340 GeV	
• • • We d	o not	use the following	data for average	s, fit	s, limits	, etc. • • •	
<1.6		90	FRABETTI	93	E687	γ Be, \overline{E}_{γ} = 221	GeV
Ω° REFERENCES							
ADAMOVICH FRABETTI FRABETTI FRABETTI ALBRECHT BIAGI	95B 95D 94H 93 92H 85B	PL B358 151 PL B357 678 PL B338 106 PL B300 190 PL B288 367 ZPHY C28 175	+Albertson, Alex +Cheung, Cuma +Cheung, Cuma +Cheung, Cuma +Cronstroem, El +Bourquin, Britt	lat+ lat+ lat, Da rdichm	allapiccola		Collab.) Collab.) Collab.) Collab.)

BOTTOM BARYONS

(B=-1)

 $\Lambda_b^0 = udb$, $\Xi_b^0 = usb$, $\Xi_b^- = dsb$



$$I(J^{p}) = O(\frac{1}{2}^{+})$$
 Status: ***

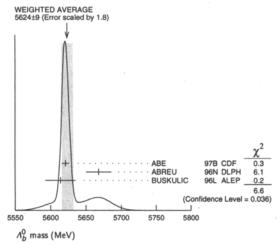
In the quark model, a Λ_b^0 is an isospin-0 udb state. The lowest Λ_b^0 ought to have $J^P = 1/2^+$. None of I, J, or P have actually been measured.

AD MASS

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
5624± 9 OUR AVI	ERAGE Err	or includes scale t	factor of 1.8.	See the ideogram below.
5621± 4± 3		1 ABE		$p\overline{p}$ at 1.8 TeV
5668± 16± 8	4			$e^+e^- \rightarrow Z$
5614± 21± 4	4	² BUSKULIC	96L ALEP	$e^+e^- \rightarrow Z$
 • • We do not us 	e the followir	ng data for averag	ges, fits, limits,	etc. • • •
not seen		3 ABE	93B CDF	Sup. by ABE 978
5640 ± 50 ± 30	16	⁴ ALBAJAR	91E UA1	p p 630 GeV
5640 ⁺¹⁰⁰ -210	52	BARI	91 SFM	$\Lambda_b^0 \rightarrow p D^0 \pi^-$
5650 + 150 - 200	90	BARI	91 SFM	$\Lambda_b^0 \rightarrow \Lambda_c^+ \pi^+ \pi^- \pi^-$

 $^{^1}$ ABE 97B observed 38 events above a background 18 \pm 1.6 events in the mass range 5.60–5.65 GeV/ c^2 , a significance of > 3.4 standard deviations.

 $^{^4}$ ALBAJAR 91E claims 16 \pm 5 events above a background of 9 \pm 1 events, a significance of about 5 standard deviations.



10 MEAN LIFE

These are actually measurements of the average lifetime of weakly decaying b baryons weighted by generally unknown production rates, branching fractions, and detection efficiencies. Presumably, the mix is mainly \varLambda_b^0 , with some Ξ_b^0 and Ξ_b^- .

See b-baryon Admixture section for data on b-baryon mean life average over species of b-baryon particles.

"OUR EVALUATION" is an average of the data listed below performed by the LEP B Lifetimes Working Group as described in our review "Production and Decay of b-flavored Hadrons" in the B^{\pm} Section of the Listings. The averaging procedure takes into account correlations between the measurements and asymmetric lifetime errors.

VALUE (10-12 s)	EVTS	DOCUMENT ID	TECN	COMMENT
1.24±0.08 OUR EVALU				
$1.29^{+0.24}_{-0.22}\pm0.06$		⁵ ACKERSTAFF	98G OPAL	$e^+e^- \rightarrow Z$
1.21 ± 0.11		5 BARATE	98D ALEP	$e^+e^- \rightarrow Z$
$1.32 \pm 0.15 \pm 0.07$		ABE	96м CDF	Excess $\Lambda_C \ell^-$, decay lengths
$1.19^{+0.21}_{-0.18}^{+0.07}_{-0.08}$		ABREU	960 DLPH	Excess $\Lambda_c \ell^-$, decay

 ^{• • •} We do not use the following data for averages, fits, limits, etc. • • •

$1.14^{+0.22}_{-0.19}\pm0.07$	69	AKERS	95K OPAL	Repl. by ACKER- STAFF 98G		
$1.02^{+0.23}_{-0.18} \pm 0.06$	44	BUSKULIC	95L ALEP	Repl. by BARATE 98D		
⁵ Measured using $\Lambda_c \ell^-$ and $\Lambda \ell^+ \ell^-$.						

AD DECAY MODES

These branching fractions are actually an average over weakly decaying b-baryons weighted by their production rates in Z decay (or high-energy $p\bar{p}$), branching ratios, and detection efficiencies. They scale with the LEP Λ_b production fraction $B(b \to \Lambda_b)$ and are evaluated for our value $B(b \to \Lambda_b) = (10.1 + \frac{3.9}{3.1})\%$.

The branching fractions B(b-baryon $\rightarrow \Lambda \ell^- \bar{\nu}_\ell$ anything) and B($\Lambda_b^0 \rightarrow \Lambda_c^+ \ell^- \bar{\nu}_\ell$ anything) are not pure measurements because the underlying measured products of these with B($b \rightarrow \Lambda_b$) were used to determine B($b \rightarrow \Lambda_b$), as described in the note "Production and Decay of b-Flavored Hadrons."

	Mode	Fraction (Γ_i/Γ)	Confidence level
Γ ₁ Γ ₂	$J/\psi(1S)\Lambda$ $pD^0\pi^-$	$(4.7\pm2.8)\times10^{-4}$	
Γ_2	$\rho D^0 \pi^-$		
Γ_3	$\Lambda_{c}^{+}\pi^{-}$	seen	
Γ4	$\Lambda_{c}^{+} a_{1}(1260)^{-}$	seen	
Γ_5	$\Lambda_c^+ \pi^+ \pi^- \pi^-$		
Γ ₆	$\Lambda K^{0} 2\pi^{+} 2\pi^{-}$		
Γ7	$\Lambda_c^+ \ell^- \overline{\nu}_\ell$ anything	[a] $(9.0^{+3.1}_{-3.8})$ %	
Гв	ρπ-	< 5.0 × 10 ⁻⁵ < 5.0 × 10 ⁻⁵	90%
Γ̈́g	pK-	$< 5.0 \times 10^{-5}$	90%

[a] Not a pure measurement. See note at head of Λ_h^0 Decay Modes.

 $\Gamma(J/\psi(1S)A)/\Gamma_{\text{total}}$

AD BRANCHING RATIOS

 Γ_1/Γ

· (~/ +(~~//·// tt	74					. 17.
VALUE (units 10 ⁻⁴)	EVTS	DOCUMENT ID		TECN	COMMENT	
4.7± 2.1± 1.9		⁶ ABE	97B	CDF	pp at 1.8 TeV	
• • • We do not use	e the followin	g data for average	s, fits	, ilmits,	etc. • • •	
$178.2 \pm 108.9 ^{+54.7}_{-68.8}$	16	⁷ ALBAJAR	91E	UA1	$J/\psi(15) \rightarrow \mu$	+ μ-
⁶ ABE 97B reports	(0.037 ± 0	.017(stat)±0.007(s	sys))%	for B	$(b \rightarrow \Lambda_b) = 0$.1 and for
$B(B^0 \rightarrow J/\psi(1$	$s)K_c^0) = 0.0$	037%. We rescale	to ou	PDG	97 best value Bí	$b \rightarrow \Lambda_b$
~ (10.1+3.9)%	and B/B ⁰ ~	$\rightarrow J/\psi(15)K_S^0) =$	- (0.0	144 + n	006)%. Our fi	rst error is
their experiments	s's error and o	our second error is	the sv	stemati	c error from usin	g our best
value						
ALBAJAR 91E re	ports 180 ±	110 for B($\overline{b} \rightarrow \Lambda_l$	b) = (0.10. W	e rescale to our	best value
$B(\overline{b} \to \Lambda_b) = ($	(10.1 + 3.9) ×	10 ⁻² . Our first o	error l	s their	experiment's err	or and our
second error is th	ne systematic	error from using o	our be	st value	·-	
$\Gamma(pD^0\pi^-)/\Gamma_{\text{total}}$	1					Γ_2/Γ
VALUE	EVTS	DOCUMENT ID		TECN_	COMMENT	
• • • We do not us		g data for average				
seen	52	BARI	91		$D^0 \rightarrow K^-\pi^+$	-
seen		BASILE	81	SFM	$D^0 \rightarrow K^-\pi^+$	-
$\Gamma(A_c^+\pi^-)/\Gamma_{\text{total}}$						Γ_3/Γ
VALUE	EVTS	DOCUMENT ID		<u>TECN</u>		
seen	3	ABREU	96N	DLPH	$\Lambda_c^+ \rightarrow pK^-$	
2000	4	BUSKULIC	96L	ALEP	$\Lambda_c^{\frac{1}{2}} \rightarrow pK^{-1}$	r^+ , $p\overline{K}^0$,
					$\lambda_{\pi^+\pi^+\pi^-}$	-
F/A+ - /1060\-\	/r .					F. /F
Γ(Λ+ a1(1260)-)				T56	CO.4145WT	Γ4/Γ
VALUE	EVTŞ	DOCUMENT ID			COMMENT	
seen	1	ABREU	96N	DLPH	$\Lambda_c^+ \to pK^-$	τ',
					$a_1^- \rightarrow \rho^0 \tau$, [_] →
					π ⁺ π ⁻ π ⁻	
$\Gamma(\Lambda_c^+\pi^+\pi^-\pi^-)$	/Farani					Γ_5/Γ
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT	. 9/ .
• • • We do not us						
		-			$\Lambda_c^+ \rightarrow pK^-1$	-+
seen	90	BARI	41	JEM	"c → pk 1	
$\Gamma(\Lambda K^0 2\pi^+ 2\pi^-)$	/Fames					Γ_6/Γ
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT	. 0/
• • • We do not us						
seen	A	8 ARENTON			$\Lambda K_S^0 2\pi^+ 2\pi^-$	
20011	4	- ALENION	90	I IMPS	775 2 T 2 T	

⁸ See the footnote to the ARENTON 86 mass value.

 $^{^2}$ Uses 4 fully reconstructed \varLambda_b events.

 $^{^3}$ ABE 93B states that, based on the signal claimed by ALBAJAR 91E, CDF should have found 30 \pm 23 $\Lambda_D^0 \to J/\psi(15)\Lambda$ events. Instead, CDF found not more than 2 events.

Λ_b^0 , Ξ_b^0 , Ξ_b^- , b-baryon ADMIXTURE $(\Lambda_b, \Xi_b, \Sigma_b, \Omega_b)$

assun under	nes our	r B(b product t the not	(Λ_b)	this section servant. They cannot be not fractions were production and D DOCUMENT ID	e thought of a also used to d	es measurement eterminine B(b ored Hadrons."	s since the
0.090 + 0.01 0.03 + 0.03	11 18 OUI	R AVER	NGE				
0.085±0.01				9 BARATE	980 ALEP	$e^+e^- \rightarrow Z$	ı
0.12 +0.04 -0.03			29	10 ABREU	955 DLPH	$e^+e^- \rightarrow Z$	
			followia	ng data for averag	ges, fits, limits	, etc. • • •	
.075±0.01	18 ^{+0.0}	923 929	55	¹¹ BUSKULIC	95L ALEP	Repl. by BAR	ATE 98D
.15 ±0.06	+0.0)5)6	21	¹² BUSKULIC	92E ALEP	$\Lambda_c^+ \rightarrow pK^-$	π^+
0.0014. Is their best val	We di experi lue. M	vide by o ment's e easured	our bes rror an using /	$ ightarrow \Lambda_c^+ \ell^- \overline{\nu}_\ell$ anyth t value B($\overline{b} ightarrow \Lambda_c$ and our second errow $\Lambda_c \ell^-$ and $\Lambda \ell^+ \ell^-$	$(b) = (10.1 + \frac{3}{3})$ or is the syste	$^{.9}_{.1}$) × 10 ² . Ou matic error fron	r first error n using our
0.0026 Our firs	+0.003 -0.002 st error sing ou	11. We 11. We Is their I best va	divide experi	$\rightarrow \Lambda_c^+ \ell^- \overline{\nu}_\ell$ are by our best valuement's error and	ie B $(\overline{b} \rightarrow \Lambda_{\overline{b}})$ our second e	$(10.1^{+3.9}_{-3.1}) = (10.1^{+3.9}_{-3.1})$ From is the system) × 10 ⁻² . matic error
0.0014	± 0.00 or is t	12. We heir exp	divide l	$A_b^0 \rightarrow A_c^+ \ell^- \nu_\ell$ by our best value t's error and our	$B(\overline{b} \rightarrow \Lambda_b) =$	= (10.1 + 3.9) ×	10 ² . Our
12 BUSKU	ILIC 9	2E repor	ts /B(/	$\Lambda_b^0 \rightarrow \Lambda_c^+ \ell^- \overline{\nu}_\ell$	anything) x	B(b → Ab)	= 0.015 ±
		heir evo	erim en 1	t's error and our	second error le	= (10.1 +3.9) ×	error from
using or $(p\pi^-)/l$	ur best	value.	Superse	t's error and our eded by BUSKUL	second error Is IC 95L.	the systematic	error from
using or (p x -)/l	urbest F _{total}	value,	eriment Superse <u>CL%</u> 90	t's error and our eded by BUSKUL	second error is IC 95L.	the systematic	error from
using or (p\pi^)/\(\frac{1}{\rho}\)/\(\frac{1}{\rho}\) \tag{5.0 \times 10}	Ttotal	value.	Superse <u>CL%</u> 90	t's error and our eded by BUSKUL <u>DOCUMENT II</u>	second error Is IC 95L. D <u>TECN</u> 96V ALEP	the systematic $\frac{COMMENT}{e^+e^- \rightarrow Z}$	Γ ₈ /Γ
using of (p\pi^)/\(\frac{1}{2}\) \(\frac{5.0 \times 10^{\times}}{13}\) BUSKU (pK^-)/\(\frac{1}{2}\)	ur best Ftotal -5 PLIC 96 Ftotal	value, :	Superse <u>CL%</u> 90	L's error and our eded by BUSKUL DOCUMENT II 13 BUSKULIC G 96 production to	second error is IC 95L. D TECN 96V ALEP Fractions for B	the systematic $\frac{COMMENT}{e^{+}e^{-}\rightarrow Z}$ $0, B^{+}, B_{S}, b = 0$	Γ ₈ /Γ
using of (p\pi^-)/\(\frac{1}{2}\) <5.0 \times 10^- 13 BUSKU (pK^-)/\(\frac{1}{2}\) <5.0 \times 10^- <5.0 \times 10^-	Ur best Ttotal -8 ULIC 96 Ttotal -5	SV assum	CL% 90 nes PD CL% 90	13 BUSKULIC G 96 production f DOCUMENT II 13 BUSKULIC G 96 production f DOCUMENT II 14 BUSKULIC	second error Is IC 95L. D TECN 96V ALEP fractions for B D TECN 96V ALEP	comment $e^+e^- \rightarrow Z$ 0 , B^+ , B_S , b by COMMENT $e^+e^- \rightarrow Z$	Γ ₈ /Γ
using of (p\(\pi^-\))/\(\lambda\)/\(\lambd	Ttotal -5 ULIC 96 Ttotal -5 do not	5V assum	CL% 90 nes PD CL% 90	L's error and our eded by BUSKUL DOCUMENT II 13 BUSKULIC G 96 production to	second error is IC 951. D IECN 96V ALEP Fractions for B D IECN 96V ALEP ges, fits, limits	comment $e^+e^- \rightarrow Z$ 0 , B^+ , B_S , b by COMMENT $e^+e^- \rightarrow Z$	Γ ₈ /Γ
using out (px -) /	Ttotal Ttotal Ttotal Ttotal Ttotal Ttotal Ttotal	ovalue.	CL% 90 nes PD 6010win 90 nes PD	DOCUMENT II DOCUMENT II DOCUMENT II DOCUMENT II DOCUMENT II DOCUMENT II ABUSKULIC DOCUMENT II ABUSKULIC Register of the second of the	second error Is IC 95L. D TECN 96V ALEP fractions for B D TECN 96V ALEP ges, fits, limits 96D DLPH fractions for B	$\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow Z \\ 0, B^+, B_S, b \text{ b:} \\ \\ \underline{COMMENT} \\ e^+e^- \rightarrow Z \\ \text{, etc.} \bullet \bullet \bullet \\ e^+e^- \rightarrow Z \\ \end{array}$	Γ ₈ /Γ aryons. Γ ₉ /Γ
using of (pm ⁻)///ALUE <5.0 × 10 ⁻ 13 BUSKU (pK ⁻)//ALUE <5.0 × 10 ⁻ <5.0 × 10 ⁻ < 3.6 × 10 ⁻ 14 BUSKU	Ttotal Ttotal Ttotal Ttotal Ttotal Ttotal Ttotal	ovalue.	CL% 90 nes PD 6010win 90 nes PD	1's error and our edded by BUSKUL DOCUMENT II 13 BUSKULIC G 96 production if DOCUMENT II 14 BUSKULIC ng data for averal 15 ADAM G 96 production if	second error is IC 95L. D TECN 96V ALEP fractions for B 0 TECN 96V ALEP ges, fits, limits 96D DLPH fractions for B $f_{B_g} = 0.12$.	$\begin{array}{c} \underline{COMMENT} \\ e^+e^- \rightarrow Z \\ 0, B^+, B_S, b \text{ b:} \\ \\ \underline{COMMENT} \\ e^+e^- \rightarrow Z \\ \text{, etc.} \bullet \bullet \bullet \\ e^+e^- \rightarrow Z \\ \end{array}$	Γ ₈ /Γ aryons. Γ ₉ /Γ
using of (px ⁻)/(24,000 × 10 ⁻) 13 BUSKU (pK ⁻)/(24,000 × 10 ⁻) 45.0 × 10 ⁻ 45.0 × 10 ⁻ 14 BUSKU	Total Total Total Total Total Total Total Total Total Total Total Total Total Total Total Total Total Total	use the	CL½ 990 90 90 followin 90 nes PD 161 197 1119 1119 1119 11 199 35 207 442 4471	13 BUSKULIC G 96 production 1 14 BUSKULIC Ing data for Live a 15 ADAM G 96 production 1 A BUSKULIC R BOT ADAM G 96 production 1 A BUSKULIC R BOT ADAM G 96 production 1 K. Ackerstaff R. Barate+ + Aklimoto, Ak + Adam, Adye, + Adam, Adye, - W. Adam, Adye, W. Adam+	second error is IC 95L. 96V ALEP fractions for B 96V ALEP ges, fits, limits 96D DLPH fractions for B Figs = 0.12. NCES 14 Opian, Albrow+ Agasi+ Agasi+ Agasi+ ecamp, Ghez+	is the systematic $\frac{COMMENT}{e^+e^- \rightarrow Z}$ $e^+e^- \rightarrow Z$ 0 , B^+ , B_S , b is $\frac{COMMENT}{e^+e^- \rightarrow Z}$, etc. • • • $e^+e^- \rightarrow Z$ 0 , B^+ , B_S , b is $\frac{COMMENT}{e^+e^- \rightarrow Z}$ 0 , B^+ , B_S , b is $\frac{COMENT}{e^-e^- \rightarrow Z}$ 0 , 0	Γ ₈ /Γ aryons. Γ ₉ /Γ

Ξ_{b}^{0}, Ξ_{b}^{-}

 $I(J^P) = O(\frac{1}{2}^+)$ Status: *

OMITTED FROM SUMMARY TABLE

ABREU 95V observe an excess of same-sign $\Xi^{\mp} \ell^{\mp}$ events in jets, which they interpret as $\Xi_b \to \Xi^- \ell^- \overline{\nu}_\ell X$. They find that the probability for these events to come from non-b-baryon decays is less than 5×10^{-4} and that Λ_b decays can account for less than 10% of these events.

In the quark model, Ξ_b^0 and Ξ_b^- are an isodoublet (usb, dsb) state; the lowest Ξ_b^0 and Ξ_b^- ought to have $J^P=1/2^+$. None of I, J, or P have actually been measured.

E, MEAN LIFE

This is actually a measurement of the average lifetime of *b*-baryons that decay to a jet containing a same-sign $\Xi^\mp \ell^\mp$ pair. Presumably the mix is mainly Ξ_b , with some Λ_b .

"OUR EVALUATION" is an average of the data listed below performed by the LEP B Lifetimes Working Group as described in our review "Production and Decay of b-flavored Hadrons" in the B^\pm Section of the Listings. The averaging procedure takes into account correlations between the measurements and asymmetric lifetime errors.

VALUE (10 ⁻¹² s) E	VTS DOCUMENT IL	<u>TECN</u>	COMMENT
1.39 ^{+0.34} OUR EVALUAT	TION		
$1.35^{+0.37}_{-0.28}^{+0.15}_{-0.17}$	BUSKULIC	96T ALEP	Excess == ℓ=, impact parameters
$1.5 \begin{array}{l} +0.7 \\ -0.4 \end{array} \pm 0.3$	8 ABREU	95v DLPH	Excess $\mathcal{Z}^-\ell^-$, decay lengths

5 DECAY MODES

	Mode	Fraction (Γ_I/Γ)
Г	$\Xi^-\ell^-\overline{\nu}_\ell$ anything	seen

∑_b BRANCHING RATIOS

$\Gamma(\Xi^-\ell^-\overline{\nu}_\ell \text{ anything})/\Gamma_{\text{total}}$			Γ1/Γ
VALUE	DOCUMENT ID	TECN	COMMENT
seen	¹ BUSKULIC	96T ALEP	Excess = l over
9987	ABREU	95V DLPH	Excess = l over
1 BUSKULIC 96T measures [B(t 0.8) \times 10 $^{-4}$ per lepton specie	$b \to \Xi_b) \times B(\Xi_b)$ s, averaged over a	$ ightarrow$ \equiv $^{-}\ell^{-}\overline{\nu}$ and μ .	ℓ anything)] = (5.4 \pm 1.1 \pm

E REFERENCES

BUSKULIC ABREU 96T PL B384 449 95V ZPHY C68 541 +De Bonis, Decamp, Ghez+ +Adam, Adye, Agasi+

b-baryon ADMIXTURE $(\Lambda_b, \Xi_b, \Sigma_b, \Omega_b)$

b-baryon ADMIXTURE MEAN LIFE

Each measurement of the b-baryon mean life is an average over an admixture of various b baryons which decay weakly. Different techniques emphasize different admixtures of produced particles, which could result In a different b-baryon mean life.

"OUR EVALUATION" is an average of the data listed below performed by the LEP B Lifetimes Working Group as described in our review "Production and Decay of b-flavored Hadrons" in the B^{\pm} Section of these Listings. The averaging procedure takes into account correlations between the measurements and asymmetric lifetime errors.

VALUE (10 ⁻¹² s) EVTS 1.20±0.07 OUR EVALUATION	DOCUMENT ID	TECN	COMMENT
$1.20 \pm 0.08 \pm 0.06$	1 BARATE	98D ALEP	$e^+e^- \rightarrow Z$
$1.46^{+0.22}_{-0.21}^{+0.07}_{-0.09}$	ABREU	960 DLPH	Excess $\Lambda \ell^- \pi^+$, decay lengths
$1.10^{+0.19}_{-0.17}\pm0.09$	ABREU	96D DLPH	Excess $\Lambda \mu^-$ Impact parameters
$1.16 \pm 0.11 \pm 0.06$	AKERS	96 OPAL	Excess Al—, decay lengths and impact parameters
$1.27^{+0.35}_{-0.29}\pm0.09$	ABREU	95s DLPH	Excess $p\mu^-$, decay lengths

Baryon Particle Listings

b-baryon ADMIXTURE $(\Lambda_b, \Xi_b, \Sigma_b, \Omega_b)$

$1.25 \pm 0.11 \pm 0.05$		² ABREU	960 DLPH	Combined result
$1.05^{+0.12}_{-0.11}\pm0.09$	290	BUSKULIC	95L ALEP	Repl. by BARATE 98D
$1.04^{+0.48}_{-0.38}\pm0.10$	11	³ ABREU	93F DLPH	Excess $\Lambda \mu^-$, decay lengths
$1.05^{+0.23}_{-0.20}\pm0.08$	157	⁴ AKERS	93 OPAL	Excess $\Lambda \ell^-$, decay lengths
$1.12^{+0.32}_{-0.29}\pm0.16$	101	⁵ BUSKULIC	921 ALEP	Excess Al , Impact pa-

- ¹ Measured using the excess of $\Lambda \ell^-$, lepton impact parameter.
- ² Combined result of the three ABREU 96D methods and ABREU 95S. ³ ABREU 93F superseded by ABREU 96D.
- ⁴ AKERS 93 superseded by AKERS 96.
- ⁵ BUSKULIC 921 superseded by BUSKULIC 95L.

b-baryon ADMIXTURE $(\Lambda_b,\Xi_b,\Sigma_b,\Omega_b)$

These branching fractions are actually an average over weakly decaying b-baryons weighted by their production rates in Z decay (or high-energy $p\overline{p}$), branching ratios, and detection efficiencies. They scale with the LEP Λ_b production fraction B($b o \Lambda_b$) and are evaluated for our value B(b o Λ_b) = (10.1 $^{+3.9}_{-3.1}$)%.

The branching fractions B(b-baryon $\rightarrow \Lambda \ell^- \bar{\nu}_{\ell}$ anything) and B($\Lambda_h^0 \rightarrow$ $\Lambda_c^+ \ell^- \overline{\nu}_\ell$ anything) are not pure measurements because the underlying measured products of these with $B(b \rightarrow \Lambda_b)$ were used to determine $B(b \rightarrow \Lambda_b)$, as described in the note "Production and Decay of b-Flavored Hadrons."

	Mode	Fraction (Γ_I/Γ)	
r ₁	$p\mu^-\overline{\nu}$ anything	(4.9± 2.4)%	_
	$\Lambda \ell^- \overline{ u}_\ell$ anything	$(3.1^{+}_{-}1.0^{1})\%$	
Γ ₃ Γ ₄ Γ ₅	$\Lambda \ell^* \nu_\ell$ anything $\Lambda_c^{+} \ell^- \overline{\nu}_\ell$ anything		
Γ ₆	$\Lambda/\overline{\Lambda}$ anything	$(35 \begin{array}{c} +12 \\ -14 \end{array}) \%$	
Γ ₇	$\Xi^-\ell^-\overline{\nu}_\ell$ anything	$(5.5^{+}_{-2.4}) \times 10^{-3}$	

b-baryon ADMIXTURE (Λ_b , Ξ_b , Σ_b , Ω_b) BRANCHING RATIOS

$\Gamma(p\mu^- u)$ anything)/	r _{total}			Γ1/Γ
VALUE	EVTS	DOCUMENT ID	TECN	COMMENT
$0.049 ^{igoplus 0.018 + 0.015}_{-0.015 - 0.019}$	125	6 ABREU	95s DLPH	$e^+e^- \rightarrow Z$

⁶ ABREU 95s reports [B(b-baryon $\rightarrow p\mu^-\overline{\nu}$ anything) \times B($\overline{b} \rightarrow \Lambda_b$)] = 0.0049 \pm 0.0011 $^{+}$ 0.0015. We divide by our best value B($\overline{b} \rightarrow \Lambda_b$) = (10.1 $^{+}$ 3.9) \times 10 $^{-2}$. Our first error is their experiment's error and our second error is the systematic error from

 $\Gamma(\Lambda \ell^- \nu_\ell \text{anything}) / \Gamma_{\text{total}}$ The values and averages in this section serve only to show what values result if one assumes our $\mathsf{B}(b\to \Lambda_b)$. They cannot be thought of as measurements since the underlying product branching fractions were also used to determinine $\mathsf{B}(b\to \Lambda_b)$ as described in the note on "Production and Decay of b-Flavored Hadrons."

acacinoca ili tito i	.010	1 TOURCESON WITH DO	cuj oi bil lavi	orca Hadrons,
VALUE	<u>EVTS</u>	DOCUMENT ID	TECN_	COMMENT
0.031+0.010 OUR AVI	ERAGE	•		
$0.032 \pm 0.004 ^{+0.010}_{-0.012}$		7 BARATE	98D ALEP	$e^+e^- \rightarrow Z$
$0.029 \pm 0.003 ^{+0.009}_{-0.011}$		8 AKERS	96 OPAL	Excess of $\Lambda \ell^-$ over $\Lambda \ell^+$
$0.030 \pm 0.007 ^{+0.009}_{-0.011}$	262	9 ABREU	95s DLPH	Excess of $\Lambda\ell^-$ over $\Lambda\ell^+$
$0.060 \pm 0.012 ^{+0.019}_{-0.023}$	290	¹⁰ BUSKULIC	95L ALEP	Excess of $\Lambda\ell^-$ over $\Lambda\ell^+$
• • • We do not use the	he follow	Ing data for averag	es, fits, limits,	etc. • • •
seen	157	11 AKERS	93 OPAL	Excess of $\Lambda\ell^-$ over $\Lambda\ell^+$
$0.069 \pm 0.020 + 0.021$	101	¹² BUSKULIC	921 ALEP	Excess of $\Lambda \ell^-$ over $\Lambda \ell^+$

⁷BARATE 980 reports $[B(b\text{-baryon} \rightarrow \Lambda \ell^- \overline{\nu}_{\ell} \text{anything}) \times B(\overline{b} \rightarrow \Lambda_b)] = 0.00326 \pm 10^{-10}$ 0.00016 ± 0.00039 . We divide by our best value B($\overline{b}\to \Lambda_b$) = $(10.1^{+3.9}_{-3.1})\times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value. Measured using the excess of $\Lambda\ell^-$, lepton impact parameter. AKERS 96 reports $[B(b\text{-baryon} \to A\ell^- \overline{\nu}_\ell \text{ anything}) \times B(\overline{b} \to \Lambda_b)] = 0.00291 \pm 0.00023 \pm 0.00025$. We divide by our best value $B(\overline{b} \to \Lambda_b) = (10.1 + \frac{3}{3}, \frac{9}{1}) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value

⁹ ABREU 95s reports [B(b-baryon $\rightarrow \Lambda \ell^- \overline{\nu}_\ell$ anything) \times B($\overline{b} \rightarrow \Lambda_b$)] = 0.0030 \pm 0.0006 \pm 0.0004. We divide by our best value B($\overline{b} \rightarrow \Lambda_b$) = (10.1 $^{+3.9}_{-3.1}$) \times 10 $^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

10 BUSKULIC 95L reports [8(b-baryon $\rightarrow \Lambda \ell^- \overline{\nu}_\ell$ anything) \times 8($\overline{b} \rightarrow \Lambda_b$)] = 0.0061 \pm 0.0006 \pm 0.0010. We divide by our best value 8($\overline{b} \rightarrow \Lambda_b$) = (10.1 $^{+3.9}_{-3.1}$) \times 10 $^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

11 AKERS 93 superseded by AKERS 96.

12 BUSKULIC 921 reports $[B(b\text{-baryon} \to A\ell^-\overline{\nu}_\ell \text{anything}) \times B(\overline{b} \to \Lambda_b)] = 0.0070 \pm 0.0010 \pm 0.0018$. We divide by our best value $B(\overline{b} \to \Lambda_b) = (10.1 \pm \frac{3.9}{3.1}) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value. Superseded by BUSKULIC 95L.

VALUE	DOCUMENT	D TECN	COMMENT	
0.070±0.012±0.007	ACKERSTA	FF 97N OPA	L e ⁺ e [−] →	Z
Γ(Λ/⊼anything)/Γ _{total}	DOCUMENT	ID TECN	COMMENT	Γ ₆ /Γ
0.35 ^{+0.12} OUR AVERAGE				
$0.39 \pm 0.06 ^{+0.12}_{-0.15}$	13 ACKERSTA	FF 97N OPA	L e ⁺ e ⁻ →	z
$0.22^{+0.12}_{-0.08}^{+0.12}_{-0.09}$	¹⁴ ABREU	95C DLP	H e ⁺ e ⁻ →	z

0.0046 \pm 0.0037. We divide by our best value B($\overline{b} \rightarrow \Lambda_b$) = $(10.1^{+3.9}_{-3.1}) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

using our best value. 14 ABREU 95c reports $0.28^{+0.17}_{-0.12}$ for $B(\overline{b} \rightarrow \Lambda_b) = 0.08 \pm 0.02$. We rescale to our best value $B(\overline{b} \rightarrow \Lambda_b) = (10.1^{+3.9}_{-3.1}) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

$\Gamma(\Xi^-\ell^-\overline{\nu}_\ell \text{ anything})/\Gamma_{\text{total}}$	DOCUMENT ID	<u>TECN</u>	Γ ₇ /Γ
0.0055 +0.0020 OUR AVERAGE			,
$0.0053 \pm 0.0013 ^{+0.0016}_{-0.0021}$	¹⁵ BUSKULIC	96T ALEP	Excess = - l - over = - l +
$0.0058 \pm 0.0023 {+0.0018 \atop -0.0023}$	¹⁶ ABREU		Excess = - e over

¹⁵ BUSKULIC 96T reports $[B(b\text{-baryon} \rightarrow \bar{\Xi}^-\ell^-\bar{\nu}_\ell\text{anything}) \times B(\bar{b} \rightarrow \Lambda_b)] = 0.00054 \pm 0.00011 \pm 0.00008$. We divide by our best value $B(\bar{b} \rightarrow \Lambda_b) = 0.00054$ $(10.1^{+3.9}_{-3.1}) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

16 ABREU 95v reports $[B(\overline{b}-baryon \rightarrow \overline{z}^{-1}\overline{\nu}_{\overline{b}}anything) \times B(\overline{b} \rightarrow \Lambda_{\overline{b}})] = 0.00059 \pm 10.00021 \pm 0.0001$. We divide by our best value $B(\overline{b} \rightarrow \Lambda_{\overline{b}}) = (10.11 \pm 3.9 \pm 1) \times 10^{-2}$. Our first error is their experiment's error and our second error is the systematic error from using our best value.

b-baryon ADMIXTURE $(\Lambda_b, \Xi_b, \Sigma_b, \Omega_b)$ REFERENCES

BARATE	98D	EPJ C2 197	R. Barate+	(ALEPH Collab.)
ACKERSTAFF	97N	ZPHY C74 423	K. Ackerstaff+	(OPAL Collab.)
ABREU	96D	ZPHY C71 199	+Adam, Adye, Agasi+	(DELPHI Collab.)
AKERS	96	ZPHY C69 195	+Alexander, Allison, Altekamp+	(OPAL Collab.)
BUSKULIC	96T	PL B384 449	+De Bonis, Decamp, Ghez+	(ALEPH Collab.)
ABREU	95C	PL B347 447	+Adam, Adye, Agasi+	(DELPHI Collab.)
ABREU	955	ZPHY C68 375	+Adam, Adye, Agasi+	(DELPHI Collab.)
ABREU	95V	ZPHY C68 541	+Adam, Adye, Agasi+	(DELPHI Collab.)
BUSKULIC	95L	PL B357 685	+Casper, De Bonis, Decamp+	(ALEPH Collab.)
ABREU	93F	PL B311 379	+Adam, Adye, Agasi+	(DELPHI Collab.)
AKER5	93	PL B316 435	+Alexander, Allison, Anderson+	(OPAL Collab.)
BUSKULIC	921	PL B297 449	+Decamp, Goy, Lees+	(ALEPH Collab.)

SEARCHES*

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^{*} See the Boson Particle Listings for searches for Higgs bosons, other heavy bosons, and axions and other very light bosons; the Lepton Particle Listings for searches for heavy leptons and for neutrino mixing; the Quark Particle Listings for free quark searches; and the Meson Particle Listings for searches for top and fourth-generation hadrons.

SEARCHES FOR MONOPOLES, SUPERSYMMETRY, COMPOSITENESS, etc.

Magnetic Monopole Searches

MAGNETIC MONOPOLE SEARCHES

Revised December 1997 by D.E. Groom (LBNL).

"At the present time (1975) there is no experimental evidence for the existence of magnetic charges or monopoles, but chiefly because of an early, brilliant theoretical argument by Dirac, the search for monopoles is renewed whenever a new energy region is opened up in high energy physics or a new source of matter, such as rocks from the moon, becomes available [1]." Dirac argued that a monopole anywhere in the universe results in electric charge quantization everywhere, and leads to the prediction of a least magnetic charge $g = e/2\alpha$, the Dirac charge [2]. Recently monopoles have become indispensable in many gauge theories, which endow them with a variety of extraordinarily large masses. The discovery by a candidate event in a single superconducting loop in 1982 [6] stimulated an enormous experimental effort to search for supermassive magnetic monopoles [3,4,5].

Monopole detectors have predominantly used either induction or ionization. Induction experiments measure the monopole magnetic charge and are independent of monopole electric charge, mass, and velocity. Monopole candidate events in single semiconductor loops [6,7] have been detected by this method, but no two-loop coincidence has been observed. Ionization experiments rely on a magnetic charge producing more ionization than an electrical charge with the same velocity. In the case of supermassive monopoles, time-of-flight measurements indicating $v \ll c$ has also been a frequently sought signature.

Cosmic rays are the most likely source of massive monopoles, since accelerator energies are insufficient to produce them. Evidence for such monopoles may also be obtained from astrophysical observations.

Jackson's 1975 assessment remains true. The search is somewhat abated by the lack of success in the 1980's and the decrease of interest in grand unified gauge theories.

References

- J. D. Jackson, Classical Electrodynamics, 2nd edition (John Wiley & Sons, New York, 1975).
- 2. P.A.M. Dirac, Proc. Royal Soc. London A133, 60 (1931).
- 3. J. Preskill, Ann. Rev. Nucl. and Part. Sci. 34, 461 (1984).
- G. Giacomelli, La Rivista del Nuovo Cimento 7, N. 12, 1 (1984).
- 5. Phys. Rep. 140, 323 (1986).
- 6. B. Cabrera, Phys. Rev. Lett. 48, 1378 (1982).
- 7. A.D. Caplin et al., Nature 321, 402 (1986).

Monopole	Production	Cross S	ection -	- Acce	elerator	Searches		
X-SECT	MASS		ENERGY					
(cm ²)	(GeV)	(g)	(GeV)	BEAM	_EVTS	DOCUMENT ID		TECN
<0.65E-33		≥ 2	11 <i>A</i>	197 _{Au}	0	1 HE	97	
<1.90E-33	<8.1	≥ 2	160 <i>A</i>	208 _{Pb}	0	¹ HE	97	
<3.E-37	<45.0	1.0	88 -9 4	e+e-	0	PINFOLD	93	PLAS
<3.E-37	<41.6	2.0	88 -9 4	e+e-	0	PINFOLD	93	PLAS
<7.E-35	<44.9	0.2-1.0	89-93	e+ e-	0	KINOSHITA	92	PLAS
<2.E-34	<850	≥ 0.5	1800	$p \overline{p}$	0	BERTANI	90	PLAS
<1.2E-33	<800	≥ 1	1800	ρÞ	0	PRICE	90	PLAS
<1.E-37	<29	1	50-61	e^+e^-	0	KINOSHITA	89	PLAS
<1.E-37	<18	2	50-61	e^+e^-	0	KINOSHITA	89	PLAS
<1.E-38	<17	<1	35	e^+e^-	0	BRAUNSCH	88B	CNTR
<8.E-37	<24	1	50-52	e^+e^-	0	KINOSHITA	88	PLAS
<1.3E-35	<22	2	50-52	e+ e-	0	KINOSHITA	88	PLAS
<9.E-37	<4	< 0.15	10.6	e^+e^-	0	GENTILE	87	CLEO
<3.E-32	<800	≥ 1	1800	₽₽	0	PRICE	87	PLAS
<3.E-38		<3	29	e+ e-	0	FRYBERGER	84	PLAS
<1.E-31		1,3	540	ρF	0	AUBERT	83B	PLAS
<4.E-38	<10	<6	34	e^+e^-	0	MUSSET	83	PLAS
<8.E-36	<20		52	PP	0	² DELL	82	CNTR
<9.E-37	<30	<3	29	e+e-	. 0	KINOSHITA	82	PLAS
<1.E-37	<20	<24	63	pр	0	CARRIGAN	78	CNTR
<1.E-37	<30	. <3	56	pр	0	HOFFMANN	78	PLAS
			62	pр	0	² DELL	76	SPRK
<4.E-33			300	P	0	2 STEVENS	76B	SPRK
<1.E-40	<5	<2	70	P	0	3 ZRELOV	76	CNTR
<2.E-30			300	п	0	² BURKE	75	OSPK
<1.E-38			8	ν	0	4 CARRIGAN	75	HLBC
<5.E-43	<12	<10	400	P	0	EBERHARD		INDU
<2.E 36	<30	<3	60	pр	0	GIACOMELLI	75	PLAS
<5.E-42	<13	<24	400	P	0	CARRIGAN	74	CNTR
<6.E 42	<12	<24	300	p	0	CARRIGAN	73	CNTR
<2.E-36		1	0.001	γ	0	3 BARTLETT	72	CNTR
<1.E-41	<5		70	P	0	GUREVICH	72	EMUL
<1.E-40	<3	<2	28	P	0	AMALDI	63	EMUL
<2.E-40	<3	<2	30	P	0	PURCELL	63	CNTR
<1.E-35	<3	<4	28	p	0	FIDECARO	61	CNTR
<2.E-35	<1	1	6	P	0	BRADNER	59	EMUL
1								

¹ HE 97 used a lead target and barium phosphate glass detectors. Cross-section limits are well below those predicted via the Drell-Yan mechanism.

Monopole Production — Other Accelerator Searches

(GeV)	 (GeV)	BEAM	DOCUMENT ID	TECN
>510	88~94	e ⁺ e ⁻	⁵ ACCIARRI 950	L3

 $^{^5}$ ACCIARRI 95C finds a limit B(Z $\rightarrow ~\gamma\gamma\gamma) < 0.8 \times 10^{-5}$ (which is possible via monopole loop) at 95% CL and sets the mass limit via a cross section model.

Managada Flore Casada Bara Casada a									
	Monopole Flux — Cosmic Ray Searches								
FLUX (cm-2 _{sr} -1 _s -1	MASS YGN/)		COMMENTS $(\beta = v/c) \qquad EV$	rs	DOCUMENT ID		TECN		
				_					
<1E-15		1	1.1 × 10 ⁻⁴ -0.1	0	⁶ AMBROSIO ⁷ AMBROSIO	97	MCRO MCRO		
<4.1E-15		1	(0.18-2.7)E-3	0		97			
<1.0E-15		1		0	8 AMBROSIO	97	MCRO		
<0.87E-15			(0.11-5)E-3	0	9 AMBROSIO	97	MCRO		
<6.8E-15		_	4.0E-5	0	10 AMBROSIO	97	MCRO		
<2.8E-15			0.1-1	0	11 AMBROSIO	97	MCRO		
<4.4E-15		1		0	12 AMBROSIO	97	MCRO		
<5.6E-15		1	(0.18-3.0)E-3	0	13 AHLEN	94	MCRO		
<2.7E-15		1	$\beta \sim 1 \times 10^{-3}$	0	14 BECKER-SZ	94	IMB		
<8.7E-15		1	>2.E-3	0	THRON	92	SOUD		
<4.4E-12		1	all $oldsymbol{eta}$	0	GARDNER	91	INDU		
<7.2E-13		1	all $oldsymbol{eta}$	0	HUBER	91	INDU		
<3.7E-15	>E12	1	β=1.E-4	0	15 ORITO	91	PLAS		
<3.2E-16	>E10	1	$\beta > 0.05$	0	15 ORITO	91	PLAS		
<3.2E-16	>E10-E12	2,3		0	15 ORITO	91	PLAS		
<3.8E-13		1	all β	0	BERMON	90	INDU		
<5.E~16		1	$\beta < 1.E - 3$	0	14 BEZRUKOV	90	CHER		
<1.8E-14		1	$\beta > 1.1E - 4$	0	16 BUCKLAND	90	HEPT		
<1E-18			$3.E-4 < \beta < 1.5E-3$	0	17 GHOSH	90	MICA		
<7.2E-13		1	all β	0	HUBER	90	INDU		
<5.E-12	>E7	1	$3.E-4 < \beta < 5.E-3$	0	BARISH	87	CNTR		
<1.E-13			$1.E-5 < \beta < 1$	0	14 BARTELT	87	SOUD		
<1.E-10		1	all β	0	EBISU	87	INDU		
<2.E-13			$1.E-4 < \beta < 6.E-4$	0	MASEK	87	HEPT		
<2.E-14			$4.E-5 < \beta < 2.E-4$	0	NAKAMURA	87	PLAS		
<2.E-14			1.E−3 < β <1	0	NAKAMURA	87	PLAS		
<5.E-14			9.E-4 < β < 1.E-2	0	SHEPKO	87	CNTR		
<2.E-13			$4.E-4 < \beta < 1$	0	TSUKAMOTO	87	CNTR		
<5.E-14		1	all β	1	18 CAPLIN	86	INDU		
<5.E-12		1		ō	CROMAR	86	INDU		
<1.E-13			$7.E-4 < \beta$	0	HARA	86	CNTR		

² Multiphoton events.

³ Cherenkov radiation polarization.

⁴ Re-examines CERN neutrino experiments.

Searches Particle Listings

Magnetic Monopole Searches

<7.E 11		1	ali β	0		INCANDELA	86	INDU
<1.E-18			$4.E-4 < \beta < 1.E-3$	0	17	PRICE	86	MICA
<5.E-12		1		0		BERMON	85	INDU
<6.E-12		1		0		CAPLIN	85	INDU
<6.E-10		1		0		EBISU	85	INDU
<3.E-15			$5.E-5 \le \beta \le 1.E-3$	0	14	KAJITA	85	KAMI
<2.E-21			β <1.E-3	•	1,19		85	KAMI
<3.E-15			$1.E-3 < \beta < 1.E-1$	0	14	PARK	85B	CNTR
<5.E-12		1	1.E−4 < β <1	0		BATTISTONI	84	NUSX
<7.E-12		1		0		INCANDELA	84	INDU
<7.E-13		1	3.E−4 < β	0	16	KAJINO	84	CNTR
<2.E-12		1	$3.E-4 < \beta < 1.E-1$	٥		KAJINO	848	CNTR
<6.E-13		1	5.E−4 < β <1	0		KAWAGOE	84	CNTR
<2.E-14			1.E−3 < β	0	14	KRISHNA	84	CNTR
<4.E 13		1	$6.E-4 < \beta < 2.E-3$	0		LISS	84	CNTR
<1.E~16			$3.E-4 < \beta < 1.E-3$	0	17	PRICE	84	MICA
<1.E 13		1	1.E−4 < β	0		PRICE	84B	PLAS
<4.E-13		1	$6.E-4 < \beta < 2.E-3$	0		TARLE	84	CNTR
				7	20	ANDERSON	83	EMUL
<4.E-13		1	$1.E-2 < \beta < 1.E-3$	0		BARTELT	83B	CNTR
<1.E-12		1	7.E−3 < β <1	0		BARWICK	83	PLAS
<3.E-13		1	$1.E-3 < \beta < 4.E-1$	0		BONARELLI	83	CNTR
<3.E-12			5.E-4 < β < 5.E-2	0	14	BOSETTI	83	CNTR
<4.E-11		1		0		CABRERA	83	INDU
<5.E-15		1	1.E−2 < β <1	0		DOKE	83	PLAS
<8.E-15			1.E-4 < β <1.E-1	0	14	ERREDE	83	IMB
<5.E-12		1	$1.E-4 < \beta < 3.E-2$	0		GROOM	83	CNTR
<2.E-12			6.E−4 < β <1	0		MASHIMO	83	CNTR
<1.E-13		1	β=3.E-3	٥		ALEXEYEV	82	CNTR
<2.E-12			7.E-3 < \$ < 6.E-1	Q		BONARELLI	82	CNTR
6.E-10			all β	1	21	CABRERA	82	INDU
<2.E-11		_	1.E-2 < β <1.E-1	0		MASHIMO	82	CNTR
<2.E-15			concentrator	ō		BARTLETT	81	PLAS
<1.E~13	>1		1.E−3 < β	Ó		KINOSHITA		PLAS
<5.E-11	<e17< td=""><td></td><td>3.E-4 < β <1.E-3</td><td>ō</td><td></td><td>ULLMAN</td><td>81</td><td>CNTR</td></e17<>		3.E-4 < β <1.E-3	ō		ULLMAN	81	CNTR
<2.E~11	·		concentrator	ō		BARTLETT	78	PLAS
1.E-1	>200	2		ĭ	22	PRICE	75	PLAS
<2.E~13		>2		ō		FLEISCHER	71	PLAS
<1.E~19			obsidian, mica	ō		FLEISCHER		PLAS
<5.E~15	<15		concentrator	ō		CARITHERS		ELEC
<2.E-11	•		concentrator	0		MALKUS	51	
6				15				

⁶ AMBROSIO 97 global MACRO 90%CL is 0.78×10^{-15} at $\beta=1.1\times10^{-4}$, goes through a minimum at 0.61×10^{-15} near $\beta=(1.1-2.7)\times10^{-3}$, then rises to 0.84×10^{-15} at β =0.1. The global limit in this region is below the Parker bound at 10^{-15} . Less stringent limits are established for $4\times 10^{-5}<\beta<1$. Limits set by various triggers in the detector are listed below. All limits assume a catalysis cross section smaller than

7 AMBROSIO 97 "Scintillator D" (low velocity) 90%CL increases from 4.1 \times 10⁻¹⁵ at β =2.7 \times 10⁻³ to 14.6 \times 10⁻¹⁵ at β =0.006.

⁸ AMBROSIO 97 "Scintillator B" 90%CL (single medium-velocity trigger with two analysis criteria).

criteria).

9 AMBROSIO 97 streamer tube 90%CL. Tubes contain helium, and hence trigger is sensitive via the atomic induction mechanism.

10 AMBROSIO 97 CR39 90%CL improves to 4.3×10^{-15} at $\beta = 1.0 \times 10^{-4}$. CR39 is sensitive for $4 \times 10^{-5} < \beta < 1$ except for a window at $0.25 \times 10^{-3} < \beta < 2.1 \times 10^{-3}$. In the middle region other triggers set better limits.

11 AMBROSIO 97 CR39 90%CL falls to 2.7×10^{-15} at $\beta = 1$ and increases at lower velocities. Provides better limit than "Scintillator C" for $0.1 < \beta < 1.0$.

12 AMBROSIO 97 "Scintillator C" 0.0×10^{-15} has do no high absolute energy loss in two

12 AMBROSIO 97 "Scintillator C" 90%CL, based on high absolute energy loss in two scintillator layers.

scintillator layers.

13 AHLEN 94 limit for dyons extends down to β =0.9E-4 and a limit of 1.3E-14 extends to β =0.8E-4. Also see comment by PRICE 94 and reply of BARISH 94. One loophole in the AHLEN 94 result is that in the case of monopoles catalyzing nucleon decay, relativishic particles could veto the events. See AMBROSIO 97 for additional results.

14 Catalysis of nucleon decay; sensitive to assumed catalysis cross section.

15 ORITO 91 limits are functions of velocity. Lowest limits are given here.

16 Used DKMPR mechanism and Penning effect.

17 Assumes monopole attaches fermion nucleus.

** Assumes monopole attacnes termion nuceus.

**B Limit from combining data of CAPLIN 86, BERMON 85, INCANDELA 84, and CABRERA 83. For a discussion of controversy about CAPLIN 86 observed event, see GUY 87.

**Also see SCHOUTEN 87.

**Based on lack of high- energy solar neutrinos from catalysis in the sun.

 20 Anomalous long-range α (4 He) tracks.

 21 CABRERA 82 candidate event has single Dirac charge within $\pm 5\%$.

22 AUAREZ 75, FLEISCHER 75, and FRIEDLANDER 75 explain as fragmenting nucleus. EBERHARD 75 and ROSS 76 discuss conflict with other experiments. HAGSTROM 77 reinterprets as antinucleus. PRICE 78 reassesses.

молорою н	UX — A:	πгор	nysics				
FLUX	MA55		COMMENTS				
$(cm^{-2}sr^{-1}s^{-1})$	(GeV)	<u>_(a)</u>	$(\beta = v/c)$	EVTS	DOCUMENT ID		TECN
<1.E-16	E17	1	galactic field	0	²³ ADAMS	93	COSM
<1.E-23			Jovian planets		²⁴ ARAFUNE	85	COSM
<1.E-16	E15		solar trapping	0	BRACCI	85B	COSM
<1.E-18		1		0	24 HARVEY	84	COSM
<3.E-23			neutron stars		KOLB	84	COSM
<7.E-22			pulsars	0	²⁴ FREESE	83B	COSM

<1.E-18	<£18	1	intergalactic fleid		24 REPHAELI		COSM
<1.E-23			neutron stars	0	²⁴ DIMOPOUL	82	COSM
<5.E-22			neutron stars	0	²⁴ KOLB	82	COSM
<5.E-15	>E21		galactic halo		SALPETER	82	COSM
<1.E-12	E19	1	β=3.E-3	0	²⁵ TURNER	82	COSM
<1.E-16		1	galactic field	0	PARKER	70	COSM

 23 ADAMS 93 limit based on "survival and growth of a small galactic seed field" is $10^{-16}~(m/10^{17}~{\rm GeV})~{\rm cm}^{-2}~{\rm s}^{-1}~{\rm sr}^{-1}$. Above $10^{17}~{\rm GeV}$, limit $10^{-16}~(10^{17}~{\rm GeV}/m)$ cm⁻² s⁻¹ sr⁻¹ (from requirement that monopole density does not overclose the universe) is more stringent.

24 Catalysis of nucleon decay. 25 Re-evaluates PARKER 70 limit for GUT monopoles.

Monopole Density - Matter Searches

DENSITY	(<u>k</u>)	MATERIAL	EVTS	DOCUMENT ID		TECN
<6.9E-6/gram	>1/3	Meteorites and other	0	JEON	95	INDU
<2.E-7/gram	>0.6	Fe ore	0	²⁶ EBISU	87	INDU
<4.6E-6/gram	> 0.5	deep schist	0	KOVALIK	86	INDU
<1.6E-6/gram	> 0.5	manganese nodules	0	²⁷ KOVALIK	86	INDU
<1.3E~6/gram	> 0.5	seawater	0	KOVALIK	86	INDU
>1.E $+$ 14/gram	>1/3	iron aerosois	>1	MIKHAILOV	83	SPEC
<6.E-4/gram		air, seawater	0	CARRIGAN	76	CNTR
<5.E-1/gram	>0.04	11 materials	0	CABRERA	75	INDU
<2.E-4/gram	>0.05	moon rock	0	ROSS	73	INDU
<6.E-7/gram	<140	seawater	0	KOLM	71	CNTR
<1.E-2/gram	<120	manganese nodules	0	FLEISCHER	69	PLAS
<1.E-4/gram	>0	manganese	0	FLEISCHER	69B	PLAS.
<2.E-3/gram	<1-3	magnetite, meteor	0	GOTO	63	EMUL
<2.E-2/gram		meteorite	0	PETUKHOV	63	CNTR
26	4 4 . 1	7 0.24				

 26 Mass 1 \times 10 14 –1 \times 10 17 GeV. 27 KOVALIK 86 examined 498 kg of schist from two sites which exhibited clear minearalogic evidence of haiving been buried at least 20 km deep and held below the Curie temperature.

Monopole Density - Astrophysics

DENSITY	CHG (g)	MATERIAL	EVTS	DOCUMENT ID	TECN
<1.E-9/gram	1	sun, catalysis	0	²⁸ ARAFUNE 83	COSM
<6.E-33/nucl	1	moon wake	0	SCHATTEN 83	ELEC
<2.E-28/nucl		earth heat	0	CARRIGAN 80	COSM
<2.E-4/prot		42cm absorption	0	BRODERICK 79	COSM
<2.E~13/m ³		moon wake	0	SCHATTEN 70	ELEC
²⁸ Catalysis of n	ucleon de	cay.			

REFERENCES FOR Magnetic Monopole Searches

AMBROSIO	97	PL 8406 249	M. Ambrosio+	(MACRO Collab.)
HE	97	PRL 79 3134	Y.D. He	(UCB)
ACCIARRI	95C	PL B345 609	+Adam, Adriani, Aguilar-Benitez+	(L3 Collab.)
JEON	95	PRL 75 1443	Jeon, Longo	(MICH)
Also	96	PRL 76 159 (errata)		
AHLEN	94	PRL 72 608	+Ambrosio, Antolini, Auriemma+	(MACRO Collab.)
BARISH	94	PRL 73 1306	+Giacomelli, Hong	(CIT, BGNA, BOST)
BECKER-SZ	94	PR D49 2169	Becker-Szendy, Bratton, Breault, Co	
PRICE	94	PRL 73 1305		(UCB)
ADAMS	93	PRL 70 2511	+Fatuzzo, Freese, Tarle+	(MICH, FNAL)
PINFOLD	93	PL B316 407		, HARV, MONT, UCB)
KINOSHITA	92	PR D46 R881		(HARV, BGNA, REHO)
THRON	92	PR D46 4846	+Allison, Alner, Ambats+	(SOUDAN-2 Collab.)
GARDNER	91	PR D44 622	+Cabrera, Huber, Taber	(STAN)
HUBER	91	PR D44 636	+Cabrera, Taber, Gardner	(STAN)
ORITO	91	PRL 66 1951		WASCR, NIHO, ICRR)
BERMON	90	PRL 64 839	+Chi, Tsuei+	(IBM, BNL)
BERTANI	90	EPL 12 613	+Giacomelli, Mondardini, Pal+	(BGNA, INFN)
BEZRUKOV	90	SJNP 52 54	+Belolaptikov, Bugaev, Budnev+	(INRM)
BUCKLAND	90	Translated from YAF 5		(uccn)
	90	PR D41 2726	+Masek, Vernon, Knapp, Stronsi	(UCSD)
GHOSH HUBER		EPL 12 25	+Chatterjea	(JADA)
PRICE	90 90	PRL 64 835	+Cabrera, Tabor, Gardner	(STAN)
		PRL 65 149	+Guiru, Kinoshita	(UCB, HARV)
KINOSHITA	89	PL B228 543		ISA, KEK, UCB, GIFU)
BRAUNSCH	888	ZPHY C38 543	Braunschweig, Gerhards, Kirschfink-	
KINOSHITA	88	PRL 60 1610		ISA, KEK, UCB, GIFU)
BARISH	87	PR D36 2641	+Liu, Lane	(CIT)
BARTELT	87	PR D36 1990	+Courant, Heller+	(Soudan Collab.)
Also	89	PR D40 1701 erratum	Bartelt, Courant, Heller+	(Soudan Collab.)
EBISU	87	PR D36 3359	+Watanabe	(KOBE)
Also	85	JPG 11 883	Ebisu, Watanabe	(KOBE)
GENTILE	87	PR D35 1081	+Haas, Hempstead+	(CLEO Collab.)
GUY	87	Nature 325 463		(LOIC)
MASEK	87	PR D35 2758	+Knapp, Miller, Stronski, Vernon, W.	
NAKAMURA	87	PL B183 395		(INUS, WASCR, NIHO)
PRICE	87	PRL 59 2523	+Guoxiao, Kinoshita	(UCB, HARV)
SCHOUTEN	87	JPE 20 850	+Caplin, Guy, Hardiman+	(LOIC)
SHEPKO TSUKAMOTO	87	PR D35 2917	+Gagliardi, Green, McIntyre+	(TAMU)
CAPLIN		EPL 3 39	+Nagano, Anraku+	(ICRR)
Also	86	Nature 321 402	+Hardiman, Koratzinos, Schouten	(LOIC)
Aiso	87 87	JPE 20 850 Nature 325 463	Schouten, Caplin, Guy, Hardiman+	(LOIC)
CROMAR	86	PRL 56 2561	Guy +Clark, Fickett	(NBSB)
HARA	96 86	PRL 56 553		
INCANDELA	86	PR D34 2637	+Frisch. Somalwar. Kuchnir+	, KEK, KOBE, ICEPP)
KOVALIK	86	PR A33 1183	J.M. Kovalik, J.L. Kirschvink	(CHIC, FNAL, MICH)
PRICE	86			(CIT) (UCB)
ARAFUNE	85	PRL 56 1226 PR D32 2586	+Salamon +Fukugita, Yanagita	
BERMON	85	PRL 55 1850		(ICRR, KYOTU, IBAR)
BRACCI	85B	NP B258 726	+Chaudhari, Chi, Tesche, Tsuei +Fiorentini, Mezzorani	(IBM) (PISA, CAGL, INFN)
Aiso CAPLIN	85 85	LNC 42 123 Nature 317 234	Bracci, Florentini	(PISA) (LOIC)
EBISU	85	JPG 11 883	+Guy, Hardiman, Park, Schouten +Watanabe	(KOSE)
KAJITA	85	JPSJ 54 4065	+vvatanabe +Arisaka, Koshiba, Nakahata+	(ICRR, KEK, NIIG)
PARK	85B	NP B252 261	+ Arisaka, Kosniba, Nakanaka+ + Blewitt, Cortez, Foster+	(ICRR, KER, NIIG) (IMB Collab.)
BATTISTONI	83D	PL 133B 454	+Bellotti, Bologna, Campana+	(NUSEX Collab.)
DALLIGION	04	FL 1330 434	Todiviu, bologia, Campana+	(MOSEV COMBD.)

Magnetic Monopole Searches, Supersymmetric Particle Searches

FRYBERGER	84	PR D29 1524	+Coan, Kinoshita, Price (SLAC, UCB)
HARVEY		NP B236 255	+Coan, Kinoshita, Price (SLAC, UCB) (PRIN) +Campbell, Frisch+ (CHIC, FNAL, MICH)
INCANDELA	84 84	PRL 53 2067	+Campbell, Frisch+ (CHIC, FNAL, MICH)
ONILAN	84 -	PRI 52 1373	+Matsuno, Yuan, Kitamura (ICRR)
KAJINO	84B	JPG 10 447 LNC 41 315 APJ 286 702 PL 142B 99	+Matsuno, Kitamura, Aoki, Yuan, Mitsui+ (ICRR)
KAWAGOE KOLB	84 84	LNC 41 315	+ Mashimo, Nakamura, Nozaki, Orito (TOKY) + Turner Krishnaswamy, Menon+ (TATA, OSKC, INUS) + Ahlen, Tarie (UCB, IND, MICH, IND, GESC) (CERN) + Ahlen, Lisa (UCB, MICH, IND) + Lord, Strausz, Wilkes (UCB, MICH, IND) + Fukugita (ICRR, KYOTU) - Musser, Price, Vialle (CERN, LAPP)
KRISHNA	84	PI 142R 99	+ IUINEI (FNAL, CHIC) + IUINEI (FNAL, CHIC)
LISS	84	PR D30 884	+Ahlen, Tarle (UCB, IND, MICH)
PRICE	84	PR D30 884 PRL 52 1265	+Guo, Ahlen, Fleischer (ROMA, UCB, IND, GESC)
PRICE	84B	PL 140R 112	(CERN)
TARLE	84	PRL 52 90 PR D28 2308	+Ahlen, Liss (UCB, MICH, IND)
ANDERSON	83 83	PR D28 2308	+Lord, Strausz, Wilkes (WASH)
ARAFUNE AUBERT	83B	PL 133B 380 PL 120B 465	+Musset, Price, Vialle (CERN, LAPP)
BARTELT	83B	PRL 50 655	+Courant, Heller, Joyce, Marshak+ (MINN, ANL)
BARWICK	83	PR D28 2338	+Kinoshita, Price (UCB)
BONARELLI	83	PL 126B 137	+Capiluppi, Dantone (BGNA)
BOSETTI	83	PL 133B 265	+Gorham, Harris, Learned+ (AACH3, HAWA, TOKY)
CABRERA DOKE	83 83	PRL 51 1933 PL 129B 370	+ Capiluppi, Dantone (BGNA) + Gorham, Harris, Learned+ (AACH3, HAWA, TOKY) + Taber, Gardner, Bourg (STAN) + Hayashi, Hamasaki+ (WASU, RIKK, TTAM, RIKEN) + Stone, Vander Velde, Bionta+ (IMB Collab.)
ERREDE	83	PRL 51 245	+Stone, Vander Velde, Bionta+ (IMB Collab.)
FREESE	83B	PRL 51 1625	+Hayashi, Hamasaki+ (WASU, RIKK, TTAM, RIKEN) +Stone, Vander Velde, Bionta+ (IMB Collab.) +Turner, Schramm (CHIC)
GROOM	83	PRL 51 245 PRL 51 1625 PRL 50 573	+Lon, Nelson, Kitson (UIAH, SIAN)
MASHIMO	83	PL 128B 327	+Orito, Kawagoe, Nakamura, Nozaki (ICEPP)
MIKHAILOV MUSSET	83 83	PL 130B 331 PL 128B 333	(KAZA) +Price, Lohrmann (CERN, HAMB)
REPHAELI SCHATTEN	83	PL 121B 115	+Turner (CHIC)
SCHATTEN	83	PR D27 1525	+Turner (CHIC) (NASA)
ALEXEYEV	82	LNC 35 413	+Bolley, Chudakov, Makoev, Mikheyev+ (INRM)
BONARELLI	82	Pt 112B 100	+Capiluppi, Dantone+ (BGNA)
CABRERA	82	PRL 48 1378	(STAN)
DELL DIMOPOUL	82 82	NP B209 45 PL 119B 320	+Yuan, Roberts, Dooher+ (BNL, ADEL, ROMA) Dimopoulos, Preskill, Wilczek (HARV, UCSBT)
KINOSHITA	82	PDI 48 77	+Price, Fryberger (UCB, SLAC)
KOLB	82	PRL 48 77 PRL 49 1373	+Colgate, marvey (LASL, PRIN)
MASHIMO	82	JPSJ 51 3067 PRL 49 1114	+Kawagoe, Koshiba (INUS) +Shapiro, Wasserman (CORN)
KOLB MASHIMO SALPETER	82	PRL 49 1114	+Kawagoe, Koshiba (INUS) +Shapiro, Wasserman (CORN) +Parker, Bogdan (CHIC)
IURIVER	82	PR D26 1296	+Parker, Bogdan (CHIC) +Soo, Fleischer, Hart+ (COLO, GESC)
BARTLETT KINOSHITA	81 81B	PR D24 612	+Soo, Fleischer, Hart+ (COLO, GESC) +Price (UCB)
ULLMAN	81	PR D24 1707 PRL 47 289	+Price (UCB) (LEHM, BNL)
CARRIGAN	80		
BRODERICK	79	PR D19 1046	+Ficenec, Teplitz, Teplitz (VPI)
BARTLETT CARRIGAN	78	PR D19 1046 PR D18 2253 PR D17 1754 LNC 23 357	+Ficenec, Teplitz, Teplitz (TVP) +Soo, White (COLO, PRIN) +Strauss, Giacomelii (FNAL, BGNA) +Kantardjian, Diliberto, Meddi+ +Kantardjian, Diliberto, Meddi+ -Kantardjian, Diliberto, Meddi+ -Kihird, Cohorne Pinsky
CARRIGAN HOFFMANN	78 78	PR D17 1754	+Strauss, Giacomelli (FNAL, BGNA) +KantardJian, Diliberto, Meddl+ (CERN, ROMA)
PRICE	78	PR D18 1382	+Shirk, Osborne, Pinsky (UCB, HOUS)
HAGSTROM	77	PR D18 1382 PRL 38 729	
CARRIGAN	76	PR D13 1823 LNC 15 269	(LBL) +Nezrick, Strauss +Uto, Yuan, Amaldi+ (CERN, BNL, ROMA, ADEL)
DELL	76	LNC 15 269	+Uto, Yuan, Amaldi+ (CERN, BNL, ROMA, ADEL)
ROSS	76	LBL-4665	(LBL)
STEVENS ZRELOV ALVAREZ	76B 76	PR D14 2207 CZJP B26 1306	+Collins, Ficenec, Trower, Fischer+ (VPI, BNL) +Kollarova, Kollar, Lupiltsev, Pavlovic+ (JINR)
ALVARE7	75	LBI -4260	(IBL)
BURKE	75	PL 60B 113	+Gustafson, Jones, Longo (MICH)
CABRERA	75	Thesis	(STAN)
CARRIGAN	75	NP B91 279	+Nezrick (FNAL)
Also EBERHARD	71 75	PR D3 56 PR D11 3099	Carrigan, Nezrick (FNAL) +Ross, Taylor, Alvarez, Oberlack (LBL, MPIM)
EBERHARD	75B	I RI -4289	+ROSS, Taylor, Advarez, Oberlack (LDL, MFIM)
FLEISCHER	75	LBL-4289 PRL 35 1412	(LBL) +Walker (GESC, WUSL)
FRIEDLANDER	₹ 75	PRL 35 1167	(WUSL)
GIACOMELLI	75	NC 28A 21 PRL 35 487	
PRICE CARRIGAN	75 74	PRL 35 487 PR D10 3867	+Shirk, Osborne, Pinsky (UCB, HOUS)
CARRIGAN	73	PR DR 3717	+Nezrick, Strauss (FNAL) +Nezrick, Strauss (FNAL)
ROSS	73	PR D10 3867 PR D8 3717 PR D8 698 PR D4 3260	+Shirk, Osborne, Pinsky +Nezrick, Strauss +Nezrick, Strauss +Reirick, Strauss +Eberhard, Ross, Alvarez, Watt Eberhard, Ross, Alvarez, Watt Lahana +Lahana +Khakimow, Martemyanov+ Barkov, Gurevich, Zolotorev (KIAE, NOVO, SERP) 61 1721.
Also	71	PR D4 3260 *	+Eberhard, Alvarez, Watt (LBL, SLAC) Eberhard, Ross, Alvarez, Watt (LBL, SLAC) Alvarez, Eberhard, Ross, Watt (LBL, SLAC)
Also BARTLETT	70	Science 167 701 PR D6 1817	Alvarez, Eberhard, Ross, Watt (LBL, SLAC)
GUREVICH	72 72	PR D6 1817 PL 38B 549	+Lahana (COLO)
Aiso	72B		+Khakimov, Martemyanov+ (KIAE, NOVO, SERP)
		Translated from ZETF	
Also	70	PL 31B 394	Gurevich, Khakimov+ (KIAE, NOVO, SERP)
FLEISCHER KOLM		PR D4 24 PR D4 1285	+Hart, Nichols, Price (GESC) +Villa, Odian (MIT, SLAC)
	71		+Villa, Odian (MIT, SLACT
	71	API 160 383	(CHIC)
PARKER	71 70 70	APJ 160 383 PR D1 2245	(CHIC) (NASA)
PARKER SCHATTEN FLEISCHER	71 70 70 69	APJ 160 383 PR D1 2245	(CHIC) (NASA) + Jacobs, Schwartz, Price (GESC, FSU)
PARKER SCHATTEN FLEISCHER FLEISCHER	71 70 70 69 69B	APJ 160 383 PR D1 2245 PR 177 2029 PR 184 1393	(CHIC) (NASA) + Jacobs, Schwartz, Price (GESC, FSU) + Hart. Jacobs+ (GESC, UNCS, GSCO)
PARKER SCHATTEN FLEISCHER FLEISCHER FLEISCHER	71 70 70 69 69B 69C	APJ 160 383 PR D1 2245 PR 177 2029 PR 184 1393 PR 184 1398	(CHIC) (NASA) + Jacobs, Schwartz, Price (GESC, FSU) + Hart. Jacobs+ (GESC, UNCS, GSCO)
PARKER SCHATTEN FLEISCHER FLEISCHER FLEISCHER Also	71 70 70 69 69B 69C 70C	APJ 160 383 PR D1 2245 PR 177 2029 PR 184 1393 PR 184 1398 JAP 41 958	(CHIC) (NASA) Hart, Jacobs, Schwartz, Price (GESC, FSU) Hart, Lacobs+ (GESC, UNCS, GSC) (CESC) (CESC) (CESC)
PARKER SCHATTEN FLEISCHER FLEISCHER FLEISCHER	71 70 70 69 69B 69C 70C 66	APJ 160 383 PR D1 2245 PR 177 2029 PR 184 1393 PR 184 1398 JAP 41 958	(CHIC) (NASA) Hart, Jacobs, Schwartz, Price (GESC, FSU) Hart, Lacobs+ (GESC, UNCS, GSC) (CESC) (CESC) (CESC)
PARKER SCHATTEN FLEISCHER FLEISCHER FLEISCHER Also CARITHERS AMALDI GOTO	71 70 70 69 69B 69C 70C 66 63	APJ 160 383 PR D1 2245 PR 177 2029 PR 184 1393 PR 184 1398 JAP 41 958 PR 149 1070 NC 28 773 PR 132 387	(CHIC) + Jacobs, Schwartz, Price + Hart, Jacobs+ + Price, Woods Fleischer, Hart, Jacobs, Price+ + Stefanski, Adair + Baroni, Manfredini+ + Kolm. Ford (TOKY, MIT, BRN)
PARKER SCHATTEN FLEISCHER FLEISCHER FLEISCHER Also CARITHERS AMALDI GOTO PETUKHOV	71 70 70 69 69B 69C 70C 66 63 63	APJ 160 383 PR D1 2245 PR 177 2029 PR 184 1393 PR 184 1398 JAP 41 958 PR 149 1070 NC 28 773 PR 132 387 NP 49 87	(CHIC) + Jacobs, Schwartz, Price + Hart, Jacobs+ + Price, Woods Fleischer, Hart, Jacobs, Price+ + Stefanski, Adair + Baroni, Manfredini+ + Kolm. Ford (TOKY, MIT, BRN)
PARKER SCHATTEN FLEISCHER FLEISCHER FLEISCHER Also CARITHERS AMALDI GOTO PETUKHOV PURCELL	71 70 70 69 69B 69C 70C 66 63 63 63	APJ 160 383 PR D1 2245 PR 177 2029 PR 184 1393 PR 184 1398 JAP 41 958 PR 149 1070 NC 28 773 PR 132 387 NP 49 87 PR 129 2326	(CHIC) (NASA) Hart, Jacobs, Price Hart, Jacobs+ (GESC, FSU) Price, Woods Fleischer, Hart, Jacobs, Price+ Stefanski, Adair HBaroni, Manfredini+ HSdom, Ford (TOKY, MIT, BRAN) (LEBD) (HARV, BBNL) (HARV, BBNL)
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Supersymmetric Particle Searches

SUPERSYMMETRY

Written October 1997 by Howard E. Haber (Univ. of California, Santa Cruz) Part I, and by M. Schmitt (CERN*) Part II

This review is divided into two parts:

Supersymmetry, Part I (Theory)

- I.1. Introduction
- I.2. Structure of the MSSM
- I.3. Parameters of the MSSM
- I.4. The Higgs sector of the MSSM
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- I.6. Reducing the MSSM parameter freedom
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Supersymmetry, Part II (Experiment)

- II.1. Introduction
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- II.7. Conclusions

SUPERSYMMETRY, PART I (THEORY)

(by H.E. Haber)

I.1. Introduction: Supersymmetry (SUSY) is a generalization of the space-time symmetries of quantum field theory that transforms fermions into bosons and vice versa. It also provides a framework for the unification of particle physics and gravity [1-3], which is governed by the Planck scale, $M_P \approx 10^{19} \text{ GeV}$ (defined to be the energy scale where the gravitational interactions of elementary particles become comparable to their gauge interactions). If supersymmetry were an exact symmetry of nature, then particles and their superpartners (which differ in spin by half a unit) would be degenerate in mass. Thus, supersymmetry cannot be an exact symmetry of nature, and must be broken. In theories of "low-energy" supersymmetry, the effective scale of supersymmetry breaking is tied to the electroweak scale [4-6], which is characterized by the Standard Model Higgs vacuum expectation value v = 246 GeV. It is thus possible that supersymmetry will ultimately explain the origin of the large hierarchy of energy scales from the W and Z masses to the Planck scale.

At present, there are no unambiguous experimental results that require the existence of low-energy supersymmetry. However, if experimentation at future colliders uncovers evidence for supersymmetry, this would have a profound effect on the study of TeV-scale physics and the development of a more fundamental theory of mass and symmetry-breaking phenomena in particle physics.

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I.2. Structure of the MSSM: The minimal supersymmetric extension of the Standard Model (MSSM) consists of taking the Standard Model and adding the corresponding supersymmetric partners [7]. In addition, the MSSM contains two hypercharge $Y=\pm 1$ Higgs doublets, which is the minimal structure for the Higgs sector of an anomaly-free supersymmetric extension of the Standard Model. The supersymmetric structure of the theory also requires (at least) two Higgs doublets to generate mass for both "up"-type and "down"-type quarks (and charged leptons) [8,9]. All renormalizable supersymmetric interactions consistent with (global) B-L conservation (B =baryon number and L =lepton number) are included. Finally, the most general soft-supersymmetry-breaking terms are added [10].

If supersymmetry is relevant for explaining the scale of electroweak interactions, then the mass parameters introduced by the soft-supersymmetry-breaking terms must be of order 1 TeV or below [11]. Some bounds on these parameters exist due to the absence of supersymmetric-particle production at current accelerators [12]. Additional constraints arise from limits on the contributions of virtual supersymmetric particle exchange to a variety of Standard Model processes [13,14]. The impact of precision electroweak measurements at LEP and SLC on the MSSM parameter space is discussed briefly in Section I.8.

As a consequence of B-L invariance, the MSSM possesses a multiplicative R-parity invariance, where $R=(-1)^{3(B-L)+2S}$ for a particle of spin S [15]. Note that this formula implies that all the ordinary Standard Model particles have even R-parity, whereas the corresponding supersymmetric partners have odd R-parity. The conservation of R-parity in scattering and decay processes has a crucial impact on supersymmetric phenomenology. For example, starting from an initial state involving ordinary (R-even) particles, it follows that supersymmetric particles must be produced in pairs. In general, these particles are highly unstable and decay quickly into lighter states. However, R-parity invariance also implies that the lightest supersymmetric particle (LSP) is absolutely stable, and must eventually be produced at the end of a decay chain initiated by the decay of a heavy unstable supersymmetric particle.

In order to be consistent with cosmological constraints, a stable LSP is almost certainly electrically and color neutral [16]. Consequently, the LSP in a R-parity-conserving theory is weakly-interacting in ordinary matter, i.e. it behaves like a stable heavy neutrino and will escape detectors without being directly observed. Thus, the canonical signature for conventional R-parity-conserving supersymmetric theories is missing (transverse) energy, due to the escape of the LSP. Moreover, the LSP is a prime candidate for "cold dark matter", a potentially important component of the non-baryonic dark matter that is required in cosmologies with a critical mass density [17].

In the MSSM, supersymmetry breaking is accomplished by including the most general renormalizable soft-supersymmetry-breaking terms consistent with the $SU(3)\times SU(2)\times U(1)$ gauge symmetry and R-parity invariance. These terms parameterize our ignorance of the fundamental mechanism of supersymmetry

breaking. If supersymmetry breaking occurs spontaneously, then a massless Goldstone fermion called the goldstino (\widetilde{G}) must exist. The goldstino would then be the LSP and could play an important role in supersymmetric phenomenology [18]. However, the goldstino is a physical degree of freedom only in models of spontaneously broken global supersymmetry. If the supersymmetry is a local symmetry, then the theory must incorporate gravity; the resulting theory is called supergravity. In models of spontaneously broken supergravity, the goldstino is "absorbed" by the gravitino $(\widetilde{g}_{3/2})$, the spin-3/2 partner of the graviton [19]. By this super-Higgs mechanism, the goldstino is removed from the physical spectrum and the gravitino acquires a mass $(m_{3/2})$.

It is very difficult (perhaps impossible) to construct a model of spontaneously-broken low-energy supersymmetry where the supersymmetry breaking arises solely as a consequence of the interactions of the particles of the MSSM. A more viable scheme posits a theory consisting of at least two distinct sectors: a "hidden" sector consisting of particles that are completely neutral with respect to the Standard Model gauge group, and a "visible" sector consisting of the particles of the MSSM. There are no renormalizable tree-level interactions between particles of the visible and hidden sectors. Supersymmetry breaking is assumed to occur in the hidden sector, and then transmitted to the MSSM by some mechanism. Two theoretical scenarios have been examined in detail: gravity-mediated and gauge-mediated supersymmetry breaking.

All particles feel the gravitational force. In particular, particles of the hidden sector and the visible sector can interact via the exchange of gravitons. Thus, supergravity models provide a natural mechanism for transmitting the supersymmetry breaking of the hidden sector to the particle spectrum of the MSSM. In models of gravity-mediated supersymmetry breaking, gravity is the messenger of supersymmetry breaking [20,21]. In this scenario, the gravitino mass is of order the electroweak-symmetry-breaking scale, while its couplings are roughly gravitational in strength [1,22]. Such a gravitino would play no role in supersymmetric phenomenology at colliders.

In gauge-mediated supersymmetry breaking, supersymmetry breaking is transmitted to the MSSM via gauge forces. The canonical structure of such models involves a hidden sector where supersymmetry is broken, a "messenger sector" consisting of particles (messengers) with SU(3)×SU(2)×U(1) quantum numbers, and the visible sector consisting of the fields of the MSSM [23,24]. The direct coupling of the messengers to the hidden sector generates a supersymmetry breaking spectrum in the messenger sector. Finally, supersymmetry breaking is transmitted to the MSSM via the virtual exchange of the messengers. If this approach is extended to incorporate gravitational phenomena, then supergravity effects will also contribute to supersymmetry breaking. However, in models of gauge-mediated supersymmetry breaking, one usually chooses the model parameters in such a way that the virtual exchange

of the messengers dominates the effects of the direct gravitational interactions between the hidden and visible sectors. In this scenario, the gravitino mass is typically in the eV to keV range, and is therefore the LSP. The helicity $\pm\frac{1}{2}$ components of $\tilde{g}_{3/2}$ behave approximately like the goldstino; its coupling to the particles of the MSSM is significantly stronger than a coupling of gravitational strength.

I.3. Parameters of the MSSM: The parameters of the MSSM are conveniently described by considering separately the supersymmetry-conserving sector and the supersymmetry-breaking sector. A careful discussion of the conventions used in defining the MSSM parameters can be found in Ref. 25. For simplicity, consider the case of one generation of quarks, leptons, and their scalar superpartners. The parameters of the supersymmetry-conserving sector consist of: (i) gauge couplings: g_s , g, and g', corresponding to the Standard Model gauge group $SU(3)\times SU(2)\times U(1)$ respectively; (ii) a supersymmetry-conserving Higgs mass parameter μ ; and (iii) Higgs-fermion Yukawa coupling constants: λ_u , λ_d , and λ_e (corresponding to the coupling of one generation of quarks, leptons, and their superpartners to the Higgs bosons and higgsinos).

The supersymmetry-breaking sector contains the following set of parameters: (i) gaugino Majorana masses M_3 , M_2 and M_1 associated with the SU(3), SU(2), and U(1) subgroups of the Standard Model; (ii) five scalar squared-mass parameters for the squarks and sleptons, $M_{\widetilde{O}}^2$, $M_{\widetilde{U}}^2$, $M_{\widetilde{D}}^2$, $M_{\widetilde{L}}^2$, and $M_{\widetilde{E}}^2$ [corresponding to the five electroweak gauge multiplets, i.e., superpartners of $(u, d)_L$, u_L^c , d_L^c , $(\nu, e^-)_L$, and e_L^c , (iii) Higgssquark-squark and Higgs-slepton-slepton trilinear interaction terms, with coefficients A_u , A_d , and A_e (these are the so-called "A-parameters"); and (iv) three scalar Higgs squared-mass parameters-two of which contribute to the diagonal Higgs squared-masses, given by $m_1^2 + |\mu|^2$ and $m_2^2 + |\mu|^2$, and one offdiagonal Higgs squared-mass term, $m_{12}^2 \equiv B\mu$ (which defines the "B-parameter"). These three squared-mass parameters can be re-expressed in terms of the two Higgs vacuum expectation values, v_d and v_u , and one physical Higgs mass. Here, v_d (v_u) is the vacuum expectation value of the Higgs field which couples exclusively to down-type (up-type) quarks and leptons. (Another notation often employed in the literature is $v_1 \equiv v_d$ and $v_2 \equiv v_u$.) Note that $v_d^2 + v_u^2 = (246 \text{ GeV})^2$ is fixed by the W mass (or equivalently by the Fermi constant G_F), while the $\tan \beta = v_u/v_d$

is a free parameter of the model.

The total number of degrees of freedom of the MSSM is quite large, primarily due to the parameters of the soft-supersymmetry-breaking sector. In particular, in the case of three generations of quarks, leptons, and their superpartners, $M_{\widetilde{Q}}^2$, $M_{\widetilde{D}}^2$, $M_{\widetilde{D}}^2$, $M_{\widetilde{L}}^2$, and $M_{\widetilde{E}}^2$ are hermitian 3×3 matrices, and the A-parameters are complex 3×3 matrices. In addition, M_1 , M_2 , M_3 , B and μ are in general complex. Finally, as in the Standard Model, the Higgs-fermion Yukawa couplings, λ_f (f=u, d, and e), are complex 3×3 matrices which are related to the quark

and lepton mass matrices via: $M_f = \lambda_f v_f / \sqrt{2}$, where $v_e \equiv v_d$ (with v_u and v_d as defined above). However, not all these parameters are physical. Some of the MSSM parameters can be eliminated by expressing interaction eigenstates in terms of the mass eigenstates, with an appropriate redefinition of the MSSM fields to remove unphysical degrees of freedom. The analysis of Ref. 26 shows that the MSSM possesses 124 truly independent parameters. Of these, 18 parameters correspond to Standard Model parameters (including the QCD vacuum angle $\theta_{\rm QCD}$), one corresponds to a Higgs sector parameter (the analogue of the Standard Model Higgs mass), and 105 are genuinely new parameters of the model. The latter include: five real parameters and three CP-violating phases in the gaugino/higgsino sector, 21 squark and slepton masses, 36 new real mixing angles to define the squark and slepton mass eigenstates and 40 new CP-violating phases that can appear in squark and slepton interactions. The most general R-parityconserving minimal supersymmetric extension of the Standard Model (without additional theoretical assumptions) will be denoted henceforth as MSSM-124 [27].

I.4. The Higgs sector of the MSSM: Before describing the supersymmetric-particle sector, let us consider the Higgs sector of the MSSM [8,9,28]. Despite the large number of potential CP-violating phases among the MSSM-124 parameters, one can show that the tree-level MSSM Higgs sector is automatically CP-conserving. That is, unphysical phases can be absorbed into the definition of the Higgs fields such that $\tan \beta$ is a real parameter (conventionally chosen to be positive). Moreover, the physical neutral Higgs scalars are CP eigenstates. There are five physical Higgs particles in this model: a charged Higgs boson pair (H^\pm) , two CP-even neutral Higgs bosons (denoted by H_1^0 and H_2^0 where $m_{H_1^0} \leq m_{H_2^0}$) and one CP-odd neutral Higgs boson (A^0) .

The properties of the Higgs sector are determined by the Higgs potential which is made up of quadratic terms [whose squared-mass coefficients were mentioned above Eq. (1)] and quartic interaction terms. The strengths of the interaction terms are directly related to the gauge couplings by supersymmetry (and are not affected at tree-level by supersymmetry breaking). As a result, $\tan \beta$ [defined in Eq. (1)] and one Higgs mass determine the tree-level Higgs-sector parameters. These include the Higgs masses, an angle α [which measures the component of the original $Y=\pm 1$ Higgs doublet states in the physical CP-even neutral scalars], and the Higgs boson couplings.

When one-loop radiative corrections are incorporated, additional parameters of the supersymmetric model enter via virtual loops. The impact of these corrections can be significant [29,30]. For example, at tree-level, MSSM-124 predicts $m_{H_1^0} \leq m_Z |\cos 2\beta| \leq m_Z$ [8,9]. If this prediction were accurate, it would imply that H_1^0 must be discovered at the LEP-2 collider (running at its maximum energy and luminosity); otherwise MSSM-124 would be ruled out. However, when radiative

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corrections are included, the light Higgs-mass upper bound may be significantly increased. For example, in Ref. 29, the following approximate upper bound was obtained for $m_{H_1^0}$ (assuming $m_{A^0} > m_Z$) in the limit of $m_Z \ll m_t \ll M_{\widetilde{t}}$ [where top-squark $(\widetilde{t}_L - \widetilde{t}_R)$ mixing is neglected]

$$m_{H_1^0}^2 \lesssim m_Z^2 + \frac{3g^2 m_Z^4}{16\pi^2 m_W^2} \bigg\{ \bigg[\frac{2m_t^4 - m_t^2 m_Z^2}{m_Z^4} \bigg] \ln \bigg(\frac{M_t^2}{m_t^2} \bigg) + \frac{m_t^2}{3m_Z^2} \bigg\}. \tag{2}$$

More refined computations (which include the effects of top-squark mixing, renormalization group improvement, and the leading two-loop contributions) yield $m_{H^0} \lesssim 125$ GeV for $m_t = 175$ GeV and a top-squark mass of $M_{\tilde{t}} \lesssim 1$ TeV [31]. Clearly, the radiative corrections to the Higgs masses can have a significant impact on the search for the Higgs bosons of the MSSM at LEP [32].

I.5. The supersymmetric-particle sector: Consider the sector of supersymmetric particles (sparticles) in the MSSM. The supersymmetric partners of the gauge and Higgs bosons are fermions, whose names are obtained by appending "ino" at the end of the corresponding Standard Model particle name. The gluino is the color octet Majorana fermion partner of the gluon with mass $M_{\widetilde{g}} = |M_3|$. The supersymmetric partners of the electroweak gauge and Higgs bosons (the gauginos and higgsinos) can mix. As a result, the physical mass eigenstates are model-dependent linear combinations of these states, called charginos and neutralinos, which are obtained by diagonalizing the corresponding mass matrices. The chargino-mass matrix depends on M_2 , μ , tan β and m_W [33].

The corresponding chargino-mass eigenstates are denoted by $\widetilde{\chi}_1^+$ and $\widetilde{\chi}_2^+$, with masses

$$\begin{split} M_{\widetilde{\chi}_{1}^{+},\widetilde{\chi}_{2}^{+}}^{2} &= \frac{1}{2} \left\{ |\mu|^{2} + |M_{2}|^{2} + 2m_{W}^{2} \right. \\ &+ \left[\left(|\mu|^{2} + |M_{2}|^{2} + 2m_{W}^{2} \right)^{2} - 4|\mu|^{2} |M_{2}|^{2} \right. \\ &\left. - 4m_{W}^{4} \sin^{2} 2\beta + 8m_{W}^{2} \sin 2\beta \operatorname{Re}(\mu M_{2}) \right]^{1/2} \right\}, (3) \end{split}$$

where the states are ordered such that $M_{\widetilde{\chi}_1^+} \leq M_{\widetilde{\chi}_2^+}$. If CP-violating effects are ignored (in which case, M_2 and μ are real parameters), then one can choose a convention where $\tan \beta$ and M_2 are positive. (Note that the relative sign of M_2 and μ is meaningful. The sign of μ is convention-dependent; the reader is warned that both sign conventions appear in the literature.) The sign convention for μ implicit in Eq. (3) is used by the LEP collaborations [12] in their plots of exclusion contours in the M_2 vs. μ plane derived from the non-observation of $e^+e^- \to \widetilde{\chi}_1^+\widetilde{\chi}_1^-$.

The neutralino mass matrix depends on M_1 , M_2 , μ , $\tan \beta$, m_Z , and the weak mixing angle θ_W [33]. The corresponding neutralino eigenstates are usually denoted by $\widetilde{\chi}_i^0$ ($i=1,\ldots 4$), according to the convention that $M_{\widetilde{\chi}_1^0} \leq M_{\widetilde{\chi}_2^0} \leq M_{\widetilde{\chi}_3^0} \leq M_{\widetilde{\chi}_3^0}$. If a chargino or neutralino eigenstate approximates a particular

gaugino or Higgsino state, it may be convenient to use the corresponding nomenclature. For example, if M_1 and M_2 are small compared to m_Z (and $|\mu|$), then the lightest neutralino $\widetilde{\chi}_1^0$ will be nearly a pure photino, $\widetilde{\gamma}$ (the supersymmetric partner of the photon).

The supersymmetric partners of the quarks and leptons are spin-zero bosons: the squarks, charged sleptons, and sneutrinos. For simplicity, only the one-generation case is illustrated below (using first-generation notation). For a given fermion f, there are two supersymmetric partners \tilde{f}_L and \tilde{f}_R which are scalar partners of the corresponding left and right-handed fermion. (There is no $\tilde{\nu}_R$ in the MSSM.) However, in general, \tilde{f}_L and \tilde{f}_R are not mass-eigenstates since there is \tilde{f}_L - \tilde{f}_R mixing which is proportional in strength to the corresponding element of the scalar squared-mass matrix [34]

$$M_{LR}^2 = \begin{cases} m_d(A_d - \mu \tan \beta), & \text{for "down"-type } f \\ m_u(A_u - \mu \cot \beta), & \text{for "up"-type } f, \end{cases}$$
(4)

where m_d (m_u) is the mass of the appropriate "down" ("up") type quark or lepton. The signs of the A-parameters are also convention-dependent; see Ref. 25. Due to the appearance of the fermion mass in Eq. (4), one expects M_{LR} to be small compared to the diagonal squark and slepton masses, with the possible exception of the top-squark, since m_t is large, and the bottom-squark and tau-slepton if $\tan \beta \gg 1$.

The (diagonal) L- and R-type squark and slepton squared-masses are given by [2]

$$\begin{split} M_{\widetilde{f}_{L}}^{2} &= M_{\widetilde{F}}^{2} + m_{f}^{2} + (T_{3f} - e_{f} \sin^{2} \theta_{W}) m_{Z}^{2} \cos 2\beta , \\ M_{\widetilde{f}_{R}}^{2} &= M_{\widetilde{R}}^{2} + m_{f}^{2} + e_{f} \sin^{2} \theta_{W} m_{\widetilde{\Phi}}^{2} \cos 2\beta , \end{split}$$
 (5)

where $M_{\widetilde{F}}^2=M_{\widetilde{Q}}^2$ $[M_L^2]$ for \widetilde{u}_L and \widetilde{d}_L $[\widetilde{\nu}_L$ and $\widetilde{e}_L]$, and $M_{\widetilde{R}}^2=M_{\widetilde{U}}^2$, $M_{\widetilde{D}}^2$ and $M_{\widetilde{E}}^2$ for \widetilde{u}_R , \widetilde{d}_R , and \widetilde{e}_R , respectively. In addition, $e_f=\frac{2}{3}$, $-\frac{1}{3}$, 0, -1 for f=u, d, ν , and e, respectively, $T_{3f}=\frac{1}{2}$ $[-\frac{1}{2}]$ for up-type [down-type] squarks and sleptons, and m_f is the corresponding quark or lepton mass. Squark and slepton mass eigenstates, generically called \widetilde{f}_1 and \widetilde{f}_2 (these are linear combinations of \widetilde{f}_L and \widetilde{f}_R) are obtained by diagonalizing the corresponding 2 × 2 squared-mass matrices.

In the case of three generations, the general analysis is more complicated. The scalar squared-masses $[M_{\widetilde{F}}^2$ and $M_{\widetilde{R}}^2$ in Eq. (5)], the fermion masses m_f and the A-parameters are now 3×3 matrices as noted in Section I.3. Thus, to obtain the squark and slepton mass eigenstates, one must diagonalize 6×6 mass matrices. As a result, intergenerational mixing is possible, although there are some constraints from the nonobservation of FCNC's [14]. In practice, because off-diagonal scalar mixing is appreciable only for the third generation, this additional complication can usually be neglected.

It should be noted that all mass formulae quoted in this section are tree-level results. One-loop corrections will modify all these results, and eventually must be included in any precision study of supersymmetric phenomenology.

I.6. Reducing the MSSM parameter freedom: Even in the absence of a fundamental theory of supersymmetry breaking, one is hard-pressed to regard MSSM-124 as a fundamental theory. For example, no fundamental explanation is provided for the origin of electroweak symmetry breaking. Moreover, MSSM-124 is not a phenomenologically viable theory over most of its parameter space. Among the phenomenologically deficiencies are: (i) no conservation of the separate lepton numbers L_e , L_μ , and L_τ ; (ii) unsuppressed FCNC's; and (iii) new sources of CP-violation that are inconsistent with the experimental bounds. As a result, almost the entire MSSM-124 parameter space is ruled out! This theory is viable only at very special "exceptional" points of the full parameter space.

MSSM-124 is also theoretically deficient since it provides no explanation for the origin of the supersymmetry-breaking parameters (and in particular, why these parameters should conform to the exceptional points of the parameter space mentioned above). Moreover, the MSSM contains many new sources of CP violation. For example, some combination of the complex phases of the gaugino-mass parameters, the A-parameters, and μ must be less than of order 10^{-2} – 10^{-3} (for a supersymmetry-breaking scale of 100 GeV) to avoid generating electric dipole moments for the neutron, electron, and atoms in conflict with observed data [35].

There are two general approaches for reducing the parameter freedom of MSSM-124. In the low-energy approach, an attempt is made to elucidate the nature of the exceptional points in the MSSM-124 parameter space that are phenomenologically viable. Consider the following two possible choices. First, one can assume that $M_{\widetilde{Q}}^2$, $M_{\widetilde{U}}^2$, $M_{\widetilde{D}}^2$, $M_{\widetilde{L}}^2$, $M_{\widetilde{E}}^2$ and the matrix A-parameters are generation-independent (horizontal universality [5,26,36]). Alternatively, one can simply require that all the aforementioned matrices are flavor diagonal in a basis where the quark and lepton mass matrices are diagonal (flavor alignment [37]). In either case, L_e , L_μ , and L_τ are separately conserved, while tree-level FCNC's are automatically absent. In both cases, the number of free parameters characterizing the MSSM is substantially less than 124. Both scenarios are phenomenologically viable, although there is no strong theoretical basis for either scenario.

In the high-energy approach, one treats the parameters of the MSSM as running parameters and imposes a particular structure on the soft-supersymmetry-breaking terms at a common high-energy scale [such as the Planck scale (M_P)]. Using the renormalization group equations, one can then derive the low-energy MSSM parameters. The initial conditions (at the appropriate high-energy scale) for the renormalization group equations depend on the mechanism by which supersymmetry breaking is communicated to the effective low energy theory. Examples of this scenario are provided by models of gravity-mediated and gauge-mediated supersymmetry breaking (see Section I.2). One bonus of such an approach is that one of the diagonal Higgs squared-mass parameters is typically driven negative by renormalization group evolution. Thus, electroweak

symmetry breaking is generated radiatively, and the resulting electroweak symmetry-breaking scale is intimately tied to the scale of low-energy supersymmetry breaking.

One of the most common predictions of the high-energy approach is the unification of gaugino mass parameters at some high-energy scale M_X , *i.e.*,

$$M_1(M_X) = M_2(M_X) = M_3(M_X) = m_{1/2}.$$
 (6)

This is a common prediction of both grand unified supergravity models and gauge-mediated supersymmetry-breaking models. Consequently, the effective low-energy gaugino mass parameters (at the electroweak scale) are related:

$$M_3 = (g_s^2/g^2)M_2$$
, $M_1 = (5g'^2/3g^2)M_2 \simeq 0.5M_2$. (7)

In this case, the chargino and neutralino masses and mixing angles depend only on three unknown parameters: the gluino mass, μ , and $\tan \beta$. However, the assumption of gaugino-mass unification could prove false and must eventually be tested experimentally. For example, the phenomenology of neutralinos in a model with $M_1 \simeq M_2$ can differ in some interesting ways from the standard phenomenology based on Eq. (7), as shown in Ref. 38.

1.7. The constrained MSSMs: mSUGRA, GMSB, and SGUTs: One way to guarantee the absence of significant FCNC's mediated by virtual supersymmetric-particle exchange is to posit that the diagonal soft-supersymmetry-breaking scalar squared-masses are universal at some energy scale. In models of gauge-mediated supersymmetry breaking, scalar squared-masses are expected to be flavor independent since gauge forces are flavor-blind. In the minimal supergravity (mSUGRA) framework [1,2], the soft-supersymmetry breaking parameters at the Planck scale take a particularly simple form in which the scalar squared-masses and the A-parameters are flavor diagonal and universal [20]:

$$\begin{split} M_{\widetilde{Q}}^2(M_{\rm P}) &= M_{\widetilde{U}}^2(M_{\rm P}) = M_{\widetilde{D}}^2(M_{\rm P}) = m_0^2 \mathbf{1} \,, \\ M_{\widetilde{L}}^2(M_{\rm P}) &= M_{\widetilde{E}}^2(M_{\rm P}) = m_0^2 \mathbf{1} \,, \\ m_1^2(M_{\rm P}) &= m_2^2(M_{\rm P}) = m_0^2 \,, \\ A_U(M_{\rm P}) &= A_D(M_{\rm P}) = A_L(M_{\rm P}) = A_0 \mathbf{1} \,, \end{split} \tag{8}$$

where 1 is a 3×3 identity matrix in generation space. Renormalization group evolution is then used to derive the values of the supersymmetric parameters at the low-energy (electroweak) scale. For example, to compute squark and slepton masses, one must use the low-energy values for $M_{\widetilde{F}}^2$ and $M_{\widetilde{R}}^2$ in Eq. (5). Through the renormalization group running with boundary conditions specified in Eq. (7) and Eq. (8), one can show that the low-energy values of $M_{\widetilde{F}}^2$ and $M_{\widetilde{R}}^2$ depend primarily on m_0^2 and $m_{1/2}^2$. A number of useful approximate analytic expressions for superpartner masses in terms of the mSUGRA parameters can be found in Ref. 39.

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Clearly, in the mSUGRA approach, the MSSM-124 parameter freedom has been sharply reduced. For example, typical mSUGRA models give low-energy values for the scalar mass parameters that satisfy $M_{\widetilde{L}} \approx M_{\widetilde{E}} < M_{\widetilde{Q}} \approx M_{\widetilde{U}} \approx M_{\widetilde{D}}$ with the squark mass parameters somewhere between a factor of 1–3 larger than the slepton mass parameters (e.g., see Ref. 39). More precisely, the low-energy values of the squark mass parameters of the first two generations are roughly degenerate, while $M_{\widetilde{Q}_3}$ and $M_{\widetilde{U}_3}$ are typically reduced by a factor of 1–3 from the values of the first and second generation squark mass parameters because of renormalization effects due to the heavy top quark mass.

As a result, one typically finds that four flavors of squarks (with two squark eigenstates per flavor) and \tilde{b}_R are nearly mass-degenerate. The \tilde{b}_L mass and the diagonal \tilde{t}_L and \tilde{t}_R masses are reduced compared to the common squark mass of the first two generations. (If $\tan \beta \gg 1$, then the pattern of third generation squark masses is somewhat altered; e.g., see Ref. 40.) In addition, there are six flavors of nearly mass-degenerate sleptons (with two slepton eigenstates per flavor for the charged sleptons and one per flavor for the sneutrinos); the sleptons are expected to be somewhat lighter than the mass-degenerate squarks. Finally, third generation squark masses and tau-slepton masses are sensitive to the strength of the respective $\tilde{f}_L - \tilde{f}_R$ mixing as discussed below Eq. (4).

Due to the implicit $m_{1/2}$ dependence in the low-energy values of $M_{\widetilde{Q}}^2$, $M_{\widetilde{U}}^2$ and $M_{\widetilde{D}}^2$, there is a tendency for the gluino in mSUGRA models to be lighter than the first and second generation squarks. Moreover, the LSP is typically the lightest neutralino, $\widetilde{\chi}_1^0$, which tends to be dominated by its gaugino components. However, there are some regions of mSUGRA parameter space where the above conclusions do not hold. For example, one can reject those mSUGRA parameter regimes in which the LSP is a chargino.

One can count the number of independent parameters in the mSUGRA framework. In addition to 18 Standard Model parameters (excluding the Higgs mass), one must specify m_0 , $m_{1/2}$, A_0 , and Planck-scale values for μ and B-parameters (denoted by μ_0 and B_0). In principle, A_0 , B_0 and μ_0 can be complex, although in the mSUGRA approach, these parameters are taken (arbitrarily) to be real. As previously noted, renormalization group evolution is used to compute the low-energy values of the mSUGRA parameters, which then fixes all the parameters of the low-energy MSSM. In particular, the two Higgs vacuum expectation values (or equivalently, m_Z and $\tan \beta$) can be expressed as a function of the Planck-scale supergravity parameters. The simplest procedure is to remove μ_0 and B_0 in favor of m_Z and $\tan \beta$ (the sign of μ_0 is not fixed in this process). In this case, the MSSM spectrum and its interaction strengths are determined by five parameters: m_0 , A_0 , $m_{1/2}$, $\tan \beta$, and the sign of μ_0 , in addition to the 18 parameters of the Standard Model. However, the mSUGRA approach is probably too simplistic. Theoretical considerations suggest that the universality

of Planck-scale soft-supersymmetry-breaking parameters is not generic [41].

In the minimal gauge-mediated supersymmetry-breaking (GMSB) approach, there is one effective mass scale, Λ , that determines all low-energy scalar and gaugino mass parameters through loop-effects (while the resulting Λ -parameters are suppressed). In order that the resulting superpartner masses be of order 1 TeV or less, one must have $\Lambda \sim 100$ TeV. The origin of the μ and B-parameters is quite model dependent and lies somewhat outside the ansatz of gauge-mediated supersymmetry breaking. The simplest models of this type are even more restrictive than mSUGRA, with two fewer degrees of freedom. However, minimal GMSB is not a fully realized model. The sector of supersymmetry-breaking dynamics can be very complex, and it is fair to say that no complete model of gauge-mediated supersymmetry yet exists that is both simple and compelling.

It was noted in Section I.2 that the gravitino is the LSP in GMSB models. Thus, in such models, the next-to-lightest supersymmetric particle (NLSP) plays a crucial role in the phenomenology of supersymmetric particle production and decay. Note that unlike the LSP, the NLSP can be charged. In GMSB models, the most likely candidates for the NLSP are $\widetilde{\chi}_1^0$ and $\widetilde{\tau}_R^{\pm}$. The NLSP will decay into its superpartner plus a gravitino (e.g., $\widetilde{\chi}_1^0 \to \gamma \widetilde{g}_{3/2}$, $\widetilde{\chi}_1^0 \to Z \widetilde{g}_{3/2}$ or $\widetilde{\tau}_R^{\pm} \to \tau^{\pm} \widetilde{g}_{3/2}$), with lifetimes and branching ratios that depend on the model parameters.

Different choices for the identity of the NLSP and its decay rate lead to a variety of distinctive supersymmetric phenomenologies [42]. For example, a long-lived $\widetilde{\chi}_1^0$ -NLSP that decays outside collider detectors leads to supersymmetric decay chains with missing energy in association with leptons and/or hadronic jets (this case is indistinguishable from the canonical phenomenology of the $\widetilde{\chi}_1^0$ -LSP). On the other hand, if $\widetilde{\chi}_1^0 \to \gamma \widetilde{g}_{3/2}$ is the dominant decay mode, and the decay occurs inside the detector, then nearly all supersymmetric particle decay chains would contain a photon. In contrast, the case of a $\widetilde{\tau}_R^\pm$ -NLSP would lead either to a new long-lived charged particle (i.e., the $\widetilde{\tau}_R^+$) or to supersymmetric particle decay chains with τ -leptons.

Finally, grand unification can impose additional constraints on the MSSM parameters. Perhaps one of the most compelling hints for low-energy supersymmetry is the unification of SU(3)×SU(2)×U(1) gauge couplings predicted by models of supersymmetric grand unified theories (SGUTs) [5,43] (with the supersymmetry-breaking scale of order 1 TeV or below). Gauge coupling unification, which takes place at an energy scale of order 10¹⁶ GeV, is quite robust (i.e., the unification depends weakly on the details of the theory at the unification scale). Current low-energy data is in fair agreement with the predictions of supersymmetric grand unification as discussed in Section I.8.

Additional SGUT predictions arise through the unification of the Higgs-fermion Yukawa couplings (λ_f) . There is some

evidence that $\lambda_b = \lambda_\tau$ leads to good low-energy phenomenology [44], and an intriguing possibility that $\lambda_b = \lambda_\tau = \lambda_t$ may be phenomenologically viable [45,40] in the parameter regime where $\tan \beta \simeq m_t/m_b$. Finally, grand unification imposes constraints on the soft-supersymmetry-breaking parameters. For example, gaugino-mass unification leads to the relations given in Eq. (7). Diagonal squark and slepton soft-supersymmetry-breaking scalar masses may also be unified, which is analogous to the unification of Higgs-fermion Yukawa couplings.

In the absence of a fundamental theory of supersymmetry breaking, further progress will require a detailed knowledge of the supersymmetric-particle spectrum in order to determine the nature of the high-energy parameters. Of course, any of the theoretical assumptions described in this section could be wrong and must eventually be tested experimentally.

I.8. The MSSM and precision of electroweak data: The MSSM provides a framework that can be tested by precision electroweak data. The level of accuracy of the measured Z decay observables at LEP and SLC is sufficient to test the structure of the one-loop radiative corrections of the electroweak model [46]. Thus the precision electroweak data is potentially sensitive to the virtual effects of undiscovered particles. Combining the most recent LEP and SLC electroweak results (including the limits obtained from the direct Higgs search at LEP) with the recent top-quark mass measurement at the Tevatron, a preference is found [47,48] for a light Higgs boson mass of order m_Z , which is consistent with the MSSM Higgs mass upper bound discussed in Section I.4. [More precisely, in Ref. 48, the best fit value for the mass of the Standard Model Higgs boson ranges from about 83 to 140 GeV, while the 95% CL upper limit ranges from 287 to 361 GeV, depending on the value used for $\alpha(m_Z)$. (Similar results have been obtained in Ref. 47). Moreover, for Z decay observables, the effects of virtual supersymmetric-particle exchange are suppressed by a factor of $m_Z^2/M_{\rm SUSY}^2$, and therefore decouple in the limit of large supersymmetric-particle masses. It follows that for $M_{\rm SUSY} \gg m_Z$ (in practice, it is sufficient to have all supersymmetric-particle masses above 200 GeV), the MSSM yields an equally good fit to the precision electroweak data as compared to the Standard Model fit.

At present, a global fit of the electroweak data by Erler and Langacker (EL) [48] is in excellent agreement with the predictions of the Standard Model. If some supersymmetric particles are light (say, below 200 GeV but above present experimental bounds deduced from direct searches), then it is possible that the EL fit could be modified in the MSSM. A few years ago, when the rate for $Z \to b\bar{b}$ was four standard deviations above the Standard Model prediction, the possibility that the MSSM could improve the global electroweak fit was taken quite seriously. However, it is hard to imagine that the MSSM could significantly improve the quality of the current EL fit (given that the Standard Model fit is already quite good, and a global fit in the context of the MSSM would

necessarily involve more degrees of freedom). On the other hand, the MSSM could significantly decrease the goodness of the Standard Model fit. This possibility has been explored recently in Ref. 49. Their analysis shows that one can slightly reduce the allowed region of mSUGRA and GMSB model parameter spaces beyond the region already ruled out by the non-observation of direct supersymmetric particle production.

Electroweak observables are also sensitive to the strong coupling constant through the QCD radiative corrections. The EL global fit extracts a value of $\alpha_s(m_Z) = 0.1214 \pm 0.0031$, which is in good agreement with the world average of $\alpha_s(m_Z)$ 0.1191 ± 0.0018 [48]. This result has important implications for the viability of supersymmetric unification. Given the lowenergy values of the electroweak couplings $q(m_Z)$ and $q'(m_Z)$, one can predict $\alpha_s(m_Z)$ by using the MSSM renormalization group equations to extrapolate to higher energies and imposing the unification condition on the three gauge couplings at some high-energy scale, M_X . This procedure (which fixes M_X) can be successful (i.e., three running couplings will meet at a single point) only for a unique value of $\alpha_s(m_Z)$. The extrapolation depends somewhat on the low-energy supersymmetric spectrum (so-called low-energy "threshold effects") and on the SGUT spectrum (high-energy threshold effects), which can somewhat alter the evolution of couplings. For example, allowing for lowenergy threshold effects but neglecting threshold corrections near the unification scale, Ref. 50 finds that SGUT unification in the mSUGRA model predicts that $\alpha_s(m_Z) > 0.126$, which is only in slight disagreement with the results of the EL fit. (Similar results have been obtained in Ref. 51.) Taking SGUT threshold effects into account could either slightly increase or decrease the predicted value of $\alpha_s(m_Z)$, depending on the details of the model. In contrast, the corresponding result for the Standard Model extrapolation, $\alpha_s(m_Z) \simeq 0.073 \pm 0.002$ [52], is many standard deviations away from the experimentally observed result.

1.9. Beyond the MSSM: Non-minimal models of low-energy supersymmetry can also be constructed. One approach is to add new structure beyond the Standard Model at the TeV scale or below. The supersymmetric extension of such a theory would be a non-minimal extension of the MSSM. Possible new structures include: (i) the supersymmetric generalization of the see-saw model of neutrino masses [53,54]; (ii) an enlarged electroweak gauge group beyond $SU(2) \times U(1)$ [55]; (iii) the addition of new, possibly exotic, matter multiplets [e.g., a vector-like color triplet with electric charge $\frac{1}{3}e$; such states sometimes occur as low-energy remnants in E₆ grand unification models]; and/or (iv) the addition of low-energy $SU(3) \times SU(2) \times U(1)$ singlets [56]. A possible theoretical motivation for such new structure arises from the study of phenomenologically viable string theory ground states [57].

A second approach is to retain the minimal particle content of the MSSM but remove the assumption of R-parity invariance. The most general R-parity-violating (RPV) theory

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involving the MSSM spectrum introduces many new parameters to both the supersymmetry-conserving and the supersymmetry-breaking sectors. Each new interaction term violates either B or L conservation. For example, consider new scalar-fermion Yukawa couplings derived from the following interactions:

$$(\lambda_L)_{pmn}\widehat{L}_p\widehat{L}_m\widehat{E}_n^c + (\lambda_L')_{pmn}\widehat{L}_p\widehat{Q}_m\widehat{D}_n^c + (\lambda_B)_{pmn}\widehat{U}_p^c\widehat{D}_m^c\widehat{D}_n^c , \tag{9}$$

where $p,\ m$, and n are generation indices, and gauge group indices are suppressed. In the notation above, $\widehat{Q},\ \widehat{U}^c,\ \widehat{D}^c,\ \widehat{L}$, and \widehat{E}^c respectively represent $(u,d)_L,\ u^c_L,\ d^c_L,\ (\nu,\ e^-)_L$, and e^c_L and the corresponding superpartners. The Yukawa interactions are obtained from Eq. (9) by taking all possible combinations involving two fermions and one scalar superpartner. Note that the term in Eq. (9) proportional to λ_B violates B, while the other two terms violate L.

Phenomenological constraints on various low-energy B- and L-violating processes yield limits on each of the coefficients $(\lambda_L)_{pmn}$, $(\lambda_L')_{pmn}$ and $(\lambda_B)_{pmn}$ taken one at a time [58]. If more than one coefficient is simultaneously non-zero, then the limits are in general more complicated. All possible RPV terms cannot be simultaneously present and unsuppressed; otherwise the proton decay rate would be many orders of magnitude larger than the present experimental bound. One way to avoid proton decay is to impose B- or L-invariance (either one alone would suffice). Otherwise, one must accept the requirement that certain RPV coefficients must be extremely suppressed.

If R-parity is not conserved, supersymmetric phenomenology exhibits features that are quite distinct from that of the MSSM. The LSP is no longer stable, which implies that not all supersymmetric decay chains must yield missing-energy events at colliders. Both $\Delta L = 1$ and $\Delta L = 2$ phenomena are allowed (if L is violated), leading to neutrino masses and mixing [59], neutrinoless double beta decay [60], sneutrino-antisneutrino mixing [54,61], and s-channel resonant production of the sneutrino in e^+e^- collisions [62]. Since the distinction between the Higgs and matter multiplets is lost, R-parity violation permits the mixing of sleptons and Higgs bosons, the mixing of neutrinos and neutralinos, and the mixing of charged leptons and charginos, leading to more complicated mass matrices and mass eigenstates than in the MSSM.

Squarks can be regarded as leptoquarks since if $\lambda_L' \neq 0$, the following processes are allowed: $e^+\overline{u}_m \to \overline{\tilde{d}}_n \to e^+\overline{u}_m$, $\overline{\nu}\overline{d}_m$ and $e^+d_m \to \widetilde{u}_n \to e^+d_m$. (As above, m and n are generation labels, so that $d_2=s$, $d_3=b$, etc.) These processes have received much attention during the past year as a possible explanation for the HERA high Q^2 anomaly [63].

The theory and phenomenology of alternative low-energy supersymmetric models (such as models with R-parity violation) and its consequences for collider physics have only recently begun to attract significant attention. Experimental and theoretical constraints place some restrictions on these approaches, although no comprehensive treatment has yet appeared in the literature.

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SUPERSYMMETRY, PART II (EXPERIMENT) (by M. Schmitt)

II.1. Introduction: The theoretical strong points of supersymmetry (SUSY) have motivated many searches for supersymmetric particles. Most of these have been guided by the MSSM and are based on the canonical missing-energy signature caused by the escape of the LSP's ('lightest supersymmetric particles'). More recently, other scenarios have received considerable attention from experimenters, widening the range of topologies in which new physics might be found.

Unfortunately, no convincing evidence for the production of supersymmetric particles has been found. The most far reaching laboratory searches have been performed at the Tevatron and at LEP, and these are the main topic of this review. In addition, there are a few special opportunities exploited by HERA and certain fixed-target experiments.

In order to keep this review as current as possible, the most recent results have been used, including selected preliminary results reported at the High Energy Conference of the European Physical Society, held in Jerusalem during August 1997.

Theoretical aspects of supersymmetry have been covered in Part I of this review by H.E. Haber (see also Ref. 1, 2); we use his notations and terminology.

II.2. Common supersymmetry scenarios: In the 'canonical' scenario [1], supersymmetric particles are pair-produced and decay directly or via cascades to the LSP. For most typical choices of model parameters, the lightest neutralino is the LSP. Conservation of R-parity is assumed, so the LSP's do not decay and escape detection, causing an apparent transverse momentum imbalance, $p_T^{\rm miss}$ (also referred to as missing transverse energy, E_T), and missing energy, $E^{\rm miss}$. There are always two LSP's per event. The searches demand significant $p_T^{\rm miss}$ as the main discriminant against Standard Model (SM) processes; collimated jets, isolated leptons or photons, and appropriate kinematic cuts provide additional handles to reduce backgrounds.

The conservation of R-parity is not required in supersymmetry, however, and in some searches it is assumed that supersymmetric particles decay via interactions which violate R-parity (RPV), and hence, lepton and/or baryon number. For the most part the production of superpartners is unchanged, but in general the missing-energy signature is lost. Depending on the choice of the R-parity-breaking interaction, SUSY events are characterized by excess leptons or hadronic jets, and in many cases it is relatively easy to suppress SM backgrounds [3]. In this scenario the pair-production of LSP's, which need not be $\widetilde{\chi}_1^0$'s or $\widetilde{\nu}$'s, is a significant SUSY signal.

In models assuming gauge-mediated supersymmetry breaking (GMSB) [4], the gravitino $\tilde{g}_{3/2}$ is a weakly-interacting fermion with a mass so small that it can be neglected when considering the event kinematics. It is the LSP, and the lightest neutralino decays to it radiatively, possibly with a very long lifetime. For the most part the decays and production of other superpartners are the same as in the canonical scenario, so when the $\tilde{\chi}_1^0$ lifetime is not too long, the event topologies are augmented by the presence of photons which can be energetic and isolated. If the $\tilde{\chi}_1^0$ lifetime is so long that it decays outside of the detector, the event topologies are the same as in the canonical scenario. In some variants of this theory the right-sleptons are lighter than the lightest neutralino, and they decay to a lepton and a gravitino. This decay might occur after the slepton exits the apparatus, depending on model parameters.

Finally, in another scenario the gluino \tilde{g} is assumed to be very light $(M_{\tilde{g}} < 5 \text{ GeV}/c^2)$ [5]. It is a color-octet fermion which can saturate the decays of charginos and neutralinos. In this scenario the decay of the gluino to the lightest neutralino is

kinematically suppressed, so long-lived supersymmetric hadrons $(\tilde{g} + g)$ bound states called R^0 's) are formed [6]. These will produce hadronic showers in the calorimeters, thus spoiling the canonical missing-energy signature on which most SUSY searches rely. The exclusion of a light gluino is not settled (see the Listings), however, given recent experimental and theoretical developments, this issue may well be settled in the near future.

II.3. Experimental issues: Before describing the results of the searches, a few words about the issues facing the experimenters are in order.

Given no signal for supersymmetric particles, experimenters are forced to derive limits on their production. The most general formulation of supersymmetry is so flexible that few universal bounds can be obtained. Often more restricted forms of the theory are evoked for which predictions are more definite—and exclusions more constraining. The most popular of these is minimal supergravity ('mSUGRA'). As explained in the Part I of this review, parameter freedom is drastically reduced by requiring related parameters to be equal at the unification scale. Thus, the gaugino masses are equal with value $m_{1/2}$, and the slepton, squark, and Higgs masses depend on a common scalar mass parameter, m_0 . In the individual experimental analyses, only some of these assumptions are necessary. For example, the gluon and squark searches at proton machines constrain mainly M_3 and a scalar mass parameter m_0 for the squark masses, while the chargino, neutralino, and slepton searches at e^+e^- colliders constrain M_2 and a scalar mass parameter m_0 for the slepton masses. In addition, results from the Higgs searches can be used to constrain $m_{1/2}$ and m_0 as a function of $\tan \beta$. (The full analysis involves large radiative corrections coming from squark mixing, which is where the dependence on $m_{1/2}$ and m_0 enter.) In the mSUGRA framework, all the scalar mass parameters m_0 are the same and the three gaugino mass parameters are proportional to $m_{1/2}$, so limits from squarks, sleptons, charginos, gluinos, and Higgs all can be used to constrain the parameter space.

While the mSUGRA framework is convenient, it is based on several theoretical assumptions which are highly specific, so limits presented in this framework cannot easily be applied to other supersymmetric models. Serious attempts to reduce the model dependence of experimental exclusions have been made recently. When model-independent results are impossible, the underlying assumptions and their consequences are carefully delineated. This is easier to achieve at e^+e^- colliders than at proton machines.

The least model-dependent result from any experiment is the upper limit on the cross section. It requires only the number N of candidate events, the integrated luminosity \mathcal{L} , the expected backgrounds b, and the acceptance ϵ for a given signal. The upper limit on the number of signal events for a

given confidence level N^{upper} is computed from N and b (see review of Statistics). The experimental bound is simply

$$\epsilon \cdot \sigma < N^{\text{upper}}/\mathcal{L}.$$
 (1)

This information is nearly always reported, but some care is needed to understand how the acceptance was estimated, since it is often sensitive to assumptions about masses and branching ratios. Also, in the more complicated analyses, $N^{\rm upper}$ also changes as a result of the optimization for a variety of possible signals.

The theoretical parameter space is constrained by computing $\epsilon \cdot \sigma$ of Eq. (1) in terms of the relevant parameters while $N^{\text{upper}}/\mathcal{L}$ is fixed by experiment. Even after the theoretical scenario and assumptions have been specified, some choice remains about how to present the constraints. The quantity $\epsilon \cdot \sigma$ may depend on three or more parameters, yet in a printed page one usually can display limits only in a two-dimensional space. Three rather different tactics are employed by experimenters:

- Select "typical" values for the parameters not shown. These may be suggested by theory, or values giving more conservative—or more powerful results may be selected. Although the values are usually specified, one sometimes has to work to understand the possible 'loopholes.'
- Scan the parameters not shown. The lowest value for $\epsilon \cdot \sigma$ is used in Eq. (1), thereby giving the weakest limit for the parameters shown. As a consequence, the limit applies for all values of the parameters not shown.
- Scan parameters to find the lowest acceptance ε and
 use it as a constant in Eq. (1). The limits are then
 safe from theoretical uncertainties but may be overconservative, hiding powerful constraints existing in
 more typical cases.

Judgement is exercised: the second option is the most correct but may be impractical or uninteresting; most often representative cases are presented. These latter become standard, allowing a direct comparison of experiments, and also the opportunity to combine results.

Limits reported here are derived for 95% C.L. unless noted otherwise.

II.4. Supersymmetry searches in e^+e^- colliders: The center-of-mass energy of the large electron-positron collider (LEP) at CERN has been raised well above the Z peak in recent years. After collecting approximately 150 pb⁻¹ at LEP 1, each experiment (ALEPH, DELPHI, L3, OPAL) has accumulated the first data at LEP 2: about 5.7 pb⁻¹ at $\sqrt{s} \sim 133$ GeV (1995) [7], 10 pb⁻¹ at 161 GeV and 11 pb⁻¹ at 172 GeV (1996). This review emphasizes the most recent LEP 2 results.

At LEP experiments and SLD at SLAC excluded all visible supersymmetric particles up to about half the Z mass (see the Listings for details). These limits come mainly from the

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comparison of the measured Z widths to the SM expectations, and depend less on the details of the SUSY particle decays than do the results of direct searches [8]. The new data taken at higher energies allow much stronger limits to be set, although the complex interplay of masses, cross sections, and branching ratios makes simple general limits impossible to specify.

The main signals come from SUSY particles with charge, weak isospin, or large Yukawa couplings. The gauge fermions (charginos and neutralinos) generally are produced with large cross sections, while the scalar particles (sleptons and squarks) are suppressed near threshold by kinematic factors.

Charginos are produced via γ^* , Z^* , and $\widetilde{\nu}_e$ exchange. Cross sections are in the 1–10 pb range, but can be an order of magnitude smaller when $M_{\widetilde{\nu}_e}$ is less than 100 GeV/ c^2 due to the destructive interference between s- and t-channel amplitudes. Under the same circumstances, neutralino production is enhanced, as the t-channel \widetilde{e} exchange completely dominates the s-channel Z^* exchange. When Higgsino components dominate the field content of charginos and neutralinos, cross sections are large and insensitive to slepton masses.

Sleptons and squarks are produced via γ^* and Z^* exchange; for selectrons there is an important additional contribution from t-channel neutralino exchange which generally increases the cross section substantially. Although the Tevatron experiments have placed general limits on squark masses far beyond the reach of LEP, a light top squark (stop) could still be found since the flavor eigenstates can mix to give a large splitting between the mass eigenstates. The coupling of the lightest stop to the Z^* will vary with the mixing angle, however, and for certain values, even vanish, so the limits on squarks from LEP depend on the mixing angle assumed.

The various SUSY particles considered at LEP usually decay directly to SM particles and LSP's, so signatures commonly consist of some combination of jets, leptons, possibly photons, and missing energy. Consequently the search criteria are geared toward a few distinct topologies. Although they may be optimized for one specific signal, they are often efficient for others. For example, acoplanar jets are expected in both $\widetilde{t_1} \widetilde{t_1}$ and $\widetilde{\chi}^0_1 \widetilde{\chi}^0_2$ production, and acoplanar leptons for both $\widetilde{\ell}^+ \widetilde{\ell}^-$ and $\widetilde{\chi}^+ \widetilde{\chi}^-$.

The major backgrounds come from three sources. First, there are the so-called 'two-photon interactions,' in which the beam electrons emit photons which combine to produce a low mass hadronic or leptonic system leaving little visible energy in the detector. Since the electrons are seldom deflected through large angles, $p_T^{\rm miss}$ is low. Second, there is difermion production, usually accompanied by a large initial-state radiation induced by the Z pole, which gives events that are well balanced with respect to the beam direction. Finally, there is four-fermion production through states with one or two resonating bosons $(W^+W^-, ZZ, We\nu, Ze^+e^-, \text{etc.})$ which can give events with large $E^{\rm miss}$ and $p_T^{\rm miss}$ due to neutrinos and electrons lost down the beam pipe.

In the canonical case, E^{miss} and p_T^{miss} are large enough to eliminate most of these backgrounds. The e^+e^- initial state is

well defined so searches utilize both transverse and longitudinal momentum components. It is possible to measure the missing mass $(M_{\rm miss} = \{(\sqrt{s} - E_{\rm vis})^2 - \vec{p}^{\;2}_{\rm vis}\}^{1/2})$ which is small if $p_T^{\rm miss}$ is caused by a single neutrino or undetected electron or photon, and can be large when there are two massive LSP's. The four-fermion processes cannot be entirely eliminated, however, and a non-negligible irreducible background is expected. Fortunately, the uncertainties for these backgrounds are not large.

High efficiencies are easily achieved when the mass of the LSP is lighter than the parent particle by at least $10~{\rm GeV}/c^2$ and greater than about $10~{\rm GeV}/c^2$. Difficulties arise when the mass difference ΔM between the produced particle and the LSP is smaller than $10~{\rm GeV}/c^2$ as the signal resembles background from two-photon interactions. A very light LSP is challenging also since, kinematically speaking, it plays a role similar to a neutrino, so that, for example, a signal for charginos of mass $80~{\rm GeV}/c^2$ is difficult to distinguish from the production of W^+W^- pairs.

Since the start of LEP 2, experimenters have made special efforts to cover a wide range of mass differences. Also, since virtual superpartners exchanged in decays can heavily influence branching ratios to SM particles, care has been taken to ensure that the search efficiencies are not strongly dependent on the final state. This ability to cover a wide range of topologies has driven the push for bounds with a minimum of model dependence.

Charginos have been excluded up to 86 GeV/ c^2 [9] except in cases of low acceptance ($\Delta M = M_{\widetilde{\chi}^\pm} - M_{\widetilde{\chi}^0_1} \lesssim 5 \text{ GeV}/c^2$) or low cross section ($M_{\widetilde{\nu}_e} \lesssim M_W$). When $|\mu| \ll M_2$, the Higgsino components are large for charginos and neutralinos. In this case the associated production of neutralino pairs $\widetilde{\chi}_1^0 \widetilde{\chi}_2^0$ is large and the problem of small mass differences ($M_{\widetilde{\chi}^0_2} - M_{\widetilde{\chi}^0_1}$) less severe. Experimental sensitivity now extends down to mass differences of 4 GeV/ c^2 , corresponding to M_2 well above 1 TeV/ c^2 . The strong variation of the efficiency with ΔM makes it difficult to derive absolute bounds on the masses of charginos and neutralinos. The problem of low cross sections will be less severe after higher integrated luminosities have been delivered.

The limits from chargino and neutralino production are most often used to constrain M_2 and μ for fixed $\tan \beta$. An example from the OPAL Collaboration is shown in Fig. 1, where excluded regions in the (μ, M_2) plane are shown for $\tan \beta = 1.5$ and 35 for $\sqrt{s} = 172$ GeV. The case of heavy sneutrinos is illustrated by the plots with $m_0 = 1$ TeV/ c^2 . The plots also provide a gluino mass scale, valid assuming gaugino mass unification, which implies that the mass of gluinos hypothetically produced in proton machines is proportional to the mass of charginos with a large gaugino component.

When the sleptons are light, two important effects must be considered for charginos: the cross section is significantly reduced and the branching ratio to leptons is enhanced, especially to τ 's via $\tilde{\tau}$'s which can have non-negligible mixing. These effects are greatest when the chargino has a large gaugino component. The weakest bounds are found for $\mu \sim -70~{\rm GeV}/c^2$

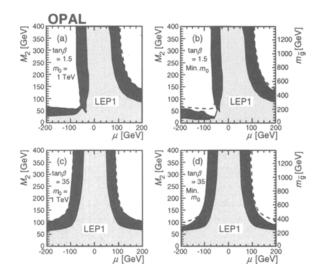


Figure 1: Regions in the (μ, M_2) plane excluded by chargino and neutralino searches performed by the OPAL Collaboration, for two values of $\tan \beta$ [9]. The light shaded region shows the limits derived from the Z width, while the dark region shows the additional exclusion obtained by the direct searches at LEP 2. The dashed line shows the kinematic bound for charginos; exclusions beyond this come from the searches for neutralinos. m_0 is the universal mass parameter for sleptons and sneutrinos, so when $m_0 = 1 \text{ TeV}/c^2$ the sneutrino is very heavy and cross sections are as large as possible. The curves labeled 'minimal m_0 ' give an indication of how much the exclusions weaken when light sneutrinos are considered. The gluino scale is shown for comparison to Tevatron results; it is valid assuming the unification of gaugino masses.

and $\tan \beta < 2$, as the cross section is reduced with respect to larger $|\mu|$, the impact of $\tilde{\tau}$ mixing can be large, and the efficiency is not optimal because ΔM is large. The erosion in the bounds when sneutrinos are light is illustrated clearly by the so-called 'minimal m_0 ' case (Fig. 1). Here m_0 is a universal mass for sleptons and sneutrinos at the GUT scale; for this analysis the smallest value of m_0 consistent with OPAL slepton limits has been taken.

If the sneutrino is lighter than the chargino, then two-body decays $\widetilde{\chi}^+ \to \ell^+ \widetilde{\nu}$ dominate, and in the 'corridor' $0 < M_{\widetilde{\chi}^\pm} - M_{\widetilde{\nu}} \lesssim 3 \text{ GeV}/c^2$ the acceptance is so low that no exclusion is possible [10]. An example of this is shown in Fig. 2, from the ALEPH Collaboration. Since the chargino cross-section and field content varies with μ , two values were tested: in both cases the corridor $M_{\widetilde{\chi}^\pm} \lesssim M_{\widetilde{\nu}}$ persists, and strictly speaking the lower limit on $M_{\widetilde{\chi}^\pm}$ is the one from LEP 1. Searches for charged sleptons can be used to cover this corridor, as shown in the figure, but this coverage is effective only for low $\tan \beta$. The

searches for neutralinos alleviate the problem in some regions of parameter space, but they cannot close the corridor.

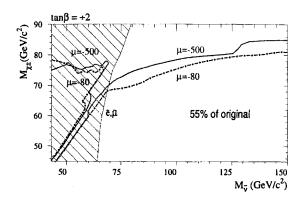


Figure 2: Limit on a gaugino-like chargino as a function of the sneutrino mass, from the ALEPH Collaboration [9]. The open corridor $0 < M_{\widetilde{\chi}^{\pm}} - M_{\widetilde{\nu}} \lesssim 3 \text{ GeV}/c^2$ is evident. $\tan \beta = \sqrt{2}$ is fixed and two values of μ are shown. The hatched region is excluded by slepton searches, but at higher $\tan \beta$ this exclusion is much weaker.

The limits on slepton masses [11] are well below the kinematic limit due to a strong p-wave phase space suppression near threshold. A variety of limits have been derived, considering right-sleptons only (which is conservative), or degenerate right/left-sleptons (which is optimistic), or relying on a universal slepton mass m_0 (which is model-dependent). For individual experiments, the limits on selectrons reach 80 GeV/c^2 due to contributions from t-channel neutralino exchange; they depend slightly on μ and an eta. For the extreme case $M_{\widetilde{\mathcal{V}}^0} o 0$, the AMY Collaboration at TRISTAN obtained a result which reaches 79 GeV/ c^2 for degenerate selectrons at 90% CL [12]. Limits on smuons reach approximately 60 GeV/c^2 , and staus, 55 GeV/c^2 . For selectrons and smuons the dependence on $\Delta M = M_{\widetilde{\ell}} - M_{\widetilde{\Sigma}^0}$ is weak for $\Delta M \gtrsim 10~{
m GeV}/c^2$ unless parameters are chosen which lead to a large branching ratio for $\widetilde{\ell}_R \to \ell \widetilde{\chi}^0_2$, possible when $M_{\widetilde{\chi}^0_1}$ is very small. Preliminary results from the combination of the four LEP experiments have been derived, leading to significantly stronger bounds [13]: $M_{\widetilde{e}_R} > 80 \text{ GeV}/c^2$ and $M_{\widetilde{\mu}_R} > 74 \text{ GeV}/c^2$ for $M_{\widetilde{\chi}_1^0} = 45 \text{ GeV}/c^2$. Bounds on the parameters M_2 and m_0 also have been derived.

In some GMSB models, sleptons may decay to $\ell^{\pm} \, \widetilde{g}_{3/2}$ outside the detector, so the experimental signature is a pair of colinear, heavily ionizing tracks. Searches for such events [14] have placed mass limits of 66 GeV/ c^2 (combined: 68 GeV/ c^2 [13]) for $\widetilde{\mu}_R$ and $\widetilde{\tau}_R$.

Limits on stop and sbottom masses [15], like the slepton mass limits, do not extend to the kinematic limit. The stop

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decay $\tilde{t}_1 \to c \widetilde{\chi}_1^0$ proceeds through loops, giving a lifetime long enough to allow the top squark to form supersymmetric hadrons which provide a pair of jets and missing energy. If sneutrinos are light the decay $\tilde{t}_1 \to b \ell \tilde{\nu}$ dominates, giving two leptons in addition to the jets. Access to very small ΔM is possible due to the visibility of the decay products of the c and b quarks. Limits vary from 75 GeV/ c^2 for an unrealistic pure \tilde{t}_L state to 60 GeV/ c^2 if the coupling of \tilde{t}_1 to the Z vanishes. The DELPHI result is shown in Fig. 3 as an example. The combination of results from all four experiments, shown in Fig. 4, is significantly stronger: for example, $M_{\tilde{t}} > 75$ GeV/ c^2 is obtained for $\Delta M > 10$ GeV/ c^2 and any mixing [13]. Limits on sbottoms are weaker due to their smaller electric charge.

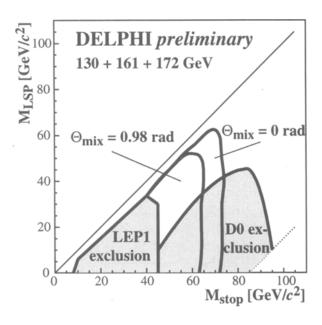
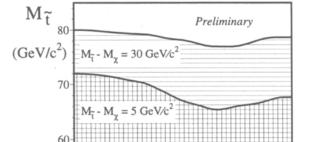


Figure 3: Ranges of excluded stop and neutralino masses reported by the DELPHI Collaboration [15]. Two values of mixing angle are shown: $\theta_{\text{mix}} = 0$ gives pure \tilde{t}_L and $\theta_{\text{mix}} = 0.98$ rad gives a stop with no coupling to the Z. The range excluded by DØ is also shown.

In canonical SUSY scenarios the lightest neutralino leaves no signal in the detector. Nonetheless, the tight correspondences among the neutralino and chargino masses allow an indirect limit on $M_{\widetilde{\chi}_1^0}$ to be derived [9,10]. The key assumption is that the gaugino mass parameters M_1 and M_2 unify at the GUT scale, which leads to a definite relation between them at the electroweak scale: $M_1 = \frac{5}{3} \tan^2 \theta_W M_2$. Assuming slepton masses to be at least 200 GeV/ c^2 , the bound on $M_{\widetilde{\chi}_1^0}$ is derived from the results of chargino and neutralino searches and certain bounds from LEP 1, as illustrated in Fig. 5, from DELPHI. The various contours change as $\tan \beta$ is increased, with the result that the lower limit on $M_{\widetilde{\chi}_1^0}$ increases also.



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95% C.L. Exclusion OPAL, ALEPH, and DELPHI

Figure 4: Lower bound on the stop mass as a function of the mixing angle for two values of $\Delta M = M_{\widetilde{t}} - M_{\widetilde{\chi}_1^0}$, derived from the combined results of the LEP experiments. These results are preliminary [13].

 $\Theta_{\widetilde{t}}$

(Degrees)

When sleptons are lighter than 80 GeV/ c^2 , all the effects of light sneutrinos on both the production and decay of charginos and heavier neutralinos must be taken into account. Although the bounds from charginos are weakened substantially, useful additional constraints from the slepton searches rule out the possibility of a massless neutralino. The current preliminary limit, shown in Fig. 6, is $M_{\widetilde{\chi}_1^0} > 25~{\rm GeV}/c^2$ for $\tan\beta > 1$ and $M_{\widetilde{\nu}} > 200~{\rm GeV}/c^2$ (effectively, $m_0 \gtrsim 200~{\rm GeV}/c^2$). Allowing the universal slepton mass m_0 to have any value, the limit is $M_{\widetilde{\chi}_1^0} > 14~{\rm GeV}/c^2$ [10]. These bounds can be evaded by dropping gaugino mass unification or R-parity conservation, or by assuming the gluino is very light.

If R-parity is not conserved, the lightest neutralino decays to SM particles and is visible inside the detector. Searches for supersymmetry with R-parity violation [16] usually assume that one of three possible interaction terms $(LL\overline{E}, LQ\overline{D}, \overline{U}\,\overline{D}\,\overline{D})$ dominates. The relevant term can cause R-parity violation directly in the decay of the produced particle, or it can be manifested indirectly in the decay of the LSP, which need no longer be neutral or colorless. Rather exotic topologies can occur, such as six-lepton final states in slepton production with $LL\overline{E}$ dominating, or ten-jet final states in chargino production with $\overline{U}\,\overline{D}\,\overline{D}$ dominating; and, for the most part, entirely new search criteria keyed to an excess of leptons and/or jets must be devised. Although not all possibilities have been tested yet, searches with a wide scope have found no evidence for supersymmetry with R-parity violation, and limits are usually

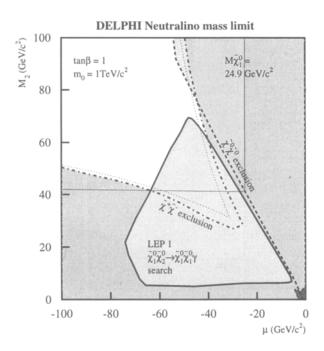


Figure 5: Excluded regions in the (μ, M_2) plane obtained by the DELPHI Collaboration, for $\tan \beta = 1$ and $m_0 = 1 \text{ TeV}/c^2$ [9]. (This very high value for m_0 is tantamount to setting all slepton masses to 1 TeV/c^2 .) The combination of LEP 2 chargino search (dotdash line) and the neutralino search (dashed line) with the single-photon limits from LEP 1 (thick solid line) give the limit on $M_{\widetilde{\chi}_1^0}$. The thin solid line shows the values of μ and M_2 giving $M_{\widetilde{\chi}_1^0} = 24.9 \text{ GeV}/c^2$, and the dotted line gives the kinematic limit for charginos at $\sqrt{s} = 172 \text{ GeV}$.

as constraining as in the canonical scenario. In fact, the direct exclusion of pair-produced $\tilde{\chi}_1^0$'s rules out some parameter space not accessible in the canonical case.

R-parity violation can lead to new production processes, such as s-channel sneutrino production, which also are being investigated [17].

Visible signals from the lightest neutralino are also realized in special cases of GMSB which predict $\widetilde{\chi}_1^0 \to \gamma \, \widetilde{g}_{3/2}$ with a lifetime short enough for the decay to occur inside the detector. The most promising topology consists of two energetic photons and missing energy resulting from $e^+e^- \to \widetilde{\chi}_1^0 \widetilde{\chi}_1^0$. (In the canonical scenario, such events also would appear for $e^+e^- \to \widetilde{\chi}_2^0 \widetilde{\chi}_2^0$ followed by $\widetilde{\chi}_2^0 \to \gamma \widetilde{\chi}_1^0$ which can be expected in certain regions of parameter space.) The LEP experiments have observed no excess over the expected number of background events [18], leading to a bound on the neutralino mass of about 70 GeV/ c^2 . As an example, the L3 upper limit on the number of signal events is plotted as a function of neutralino mass

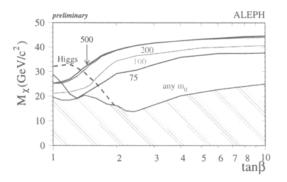


Figure 6: Lower limit on the mass of the lightest neutralino, derived by the ALEPH Collaboration using constraints from chargino, neutralino, and slepton searches [10]. The values $500, \ldots, 75$ show the bound obtained when fixing the universal scalar mass and taking slepton bounds into account; including also limits from Higgs for $m_0 = 75 \text{ GeV}/c^2$ gives the dashed line. Allowing m_0 to vary freely independently of $\tan \beta$ gives the curve labelled 'any m_0 .'

in Fig. 7. When the results are combined [13], the limit is $M_{\widetilde{\chi}_1^0} > 75~{\rm GeV}/c^2$. Single-photon production has been used to constrain the process $e^+e^- \to \widetilde{g}_{3/2}\widetilde{\chi}_1^0$.

At the time of this writing, LEP was colliding beams at $\sqrt{s}=183$ GeV. No signals for supersymmetry were reported in conferences; rather, preliminary limits $M_{\widetilde{\chi}^{\pm}} \gtrsim 91$ GeV/ c^2 were shown [19]. In coming years the center of mass energy will be increased in steps up to a maximum of 200 GeV.

II.5. Supersymmetry searches at proton machines: Although the LEP experiments can investigate a wide range of scenarios and cover obscure corners of parameter space, they cannot match the mass reach of the Tevatron experiments (CDF and $D\emptyset$). Each experiment has logged approximately 110 pb⁻¹ of data at $\sqrt{s} = 1.8$ TeV—ten times the energy of LEP 2. Although the full energy is never available for annihilation, the cross sections for supersymmetric particle production are large due to color factors and the strong coupling.

The main source of signals for supersymmetry are squarks (scalar partners of quarks) and gluinos (fermionic partners of gluons), in contradistinction to LEP. Pairs of squarks or gluinos are produced in s, t and u-channel processes, which decay directly or via cascades to at least two LSP's. The key distinction in the experimental signature is whether the gluino is heavier or lighter than the squarks, with the latter occurring naturally in mSUGRA models. The u, d, s, c, and b squarks are assumed to have similar masses; the search results are reported in terms of their average mass $M_{\widetilde{q}}$ and the gluino mass $M_{\widetilde{q}}$.

The classic searches [20] rely on large missing transverse energy E_T caused by the escaping neutralinos. Jets with high

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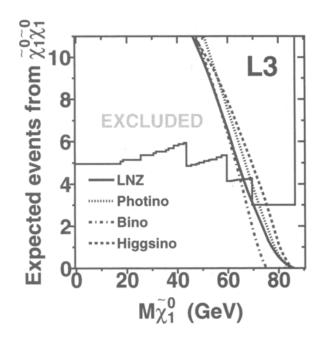
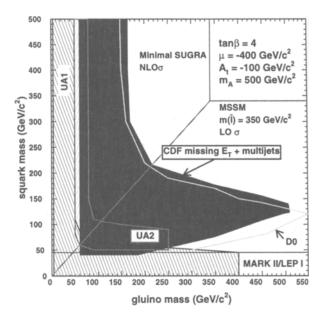


Figure 7: Upper limit on the number of acoplanar photon events as a function of the neutralino mass, from the L3 Collaboration [18]. The theoretical cross section depends on the field content of the neutralino, shown here for pure photinos, binos, and Higgsinos. 'LNZ' refers to a particular model [4].

transverse energy are also required as evidence of a hard interaction; care is taken to distinguish genuine E_T from fluctuations in the jet energy measurement. Backgrounds from W, Z and top production are reduced by rejecting events with identified leptons. Uncertainties in the rates of these processes are minimized by normalizing related samples, such as events with two jets and one or more leptons. The tails of more ordinary hard-scattering processes accompanied by multiple gluon emission are estimated directly from the data.

The bounds are displayed in the $(M_{\widetilde{g}},M_{\widetilde{q}})$ plane and have steadily improved with the integrated luminosity. The latest result from the CDF Collaboration is shown in Fig. 8, which also shows a recent result from DØ. If the squarks are heavier than the gluino, then $M_{\widetilde{g}} \gtrsim 180~{\rm GeV}/c^2$. If they all have the same mass, then that mass is at least 260 ${\rm GeV}/c^2$, according to the DØ analysis. If the squarks are much lighter than the gluin (in which case they decay via $\widetilde{q} \to q \widetilde{\chi}_1^0$), the bounds from UA1 and UA2 [21] play a role giving $M_{\widetilde{g}} \gtrsim 300~{\rm GeV}/c^2$. All of these bounds assume there is no gluino lighter than 5 ${\rm GeV}/c^2$.

Since these results are expressed in terms of the physical masses relevant to the production process and experimental signature, the excluded region depends primarily on the assumption of nearly equal squark masses with only a small dependence on other parameters such as μ and $\tan \beta$. Direct constraints on



the theoretical parameters m_0 and $m_{1/2}\approx 0.34\,M_3$, shown in Fig. 9, have been obtained by the DØ Collaboration assuming the mass relations of the mSUGRA model. In particular, m_0 is keyed to the squark mass and $m_{1/2}$ to the gluino mass, while for the LEP results these parameters usually relate to slepton and chargino masses.

Charginos and neutralinos may be produced directly by annihilation $(q\overline{q} \to \widetilde{\chi}_i^{\pm} \widetilde{\chi}_j^0)$ or in the decays of heavier squarks $(\widetilde{q} \to q' \widetilde{\chi}_i^{\pm}, q \widetilde{\chi}_j^0)$. They decay to energetic leptons (for example, $\widetilde{\chi}^{\pm} \to \ell \nu \widetilde{\chi}_1^0$ and $\widetilde{\chi}_2^0 \to \ell^+ \ell^- \widetilde{\chi}_1^0$) and the branching ratio can be high for some parameter choices. The presence of energetic leptons has been exploited in two ways: the 'trilepton' signature and the 'dilepton' signature.

The search for trileptons is most effective for the associated production of $\widetilde{\chi}_1^{\pm}\widetilde{\chi}_2^0$ [22]. The requirement of three energetic leptons reduces backgrounds to a very small level, but is efficient for the signal only in special cases. The results reported to date are not competitive with the LEP bounds.

The dilepton signal is geared more for the production of charginos in gluino and squark cascades [23]. Jets are required as expected from the rest of the decay chain; the leptons should be well separated from the jets in order to avoid backgrounds from heavy quark decays. Drell-Yan events are rejected with simple cuts on the relative azimuthal angles of the leptons and their transverse momentum. In some analyses the Majorana nature of the gluino is exploited by requiring two leptons with

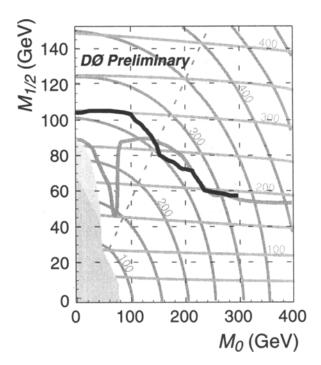


Figure 9: Bounds in the $(m_0, m_{1/2})$ plane obtained by the DØ Collaboration from their searches for squarks and gluinos [20]. The dark solid line shows the result from the jets+ E_T selection, and the grey solid line shows the result from the dielectron selection. The radial contours give the squark mass in this plane, and the nearly horizontal lines give the gluino mass. Parameter values in the shaded region lead to unphysical conditions.

the same charge, thereby greatly reducing the background. In this scenario limits on squarks and gluinos are almost as stringent as in the classic jets+ E_T case.

It should be noted that the dilepton search complements the multijet+ E_T search in that the acceptance for the latter is reduced when charginos and neutralinos are produced in the decay cascades—exactly the situation in which the dilepton signature is most effective.

A loophole in the squark-gluino bounds has recently been addressed using dijet mass distributions [24]. If gluinos are lighter than about 5 GeV/c^2 , E_T is very small and the classic jets+ E_T searches are no longer effective. Resonant production of squarks would have a large cross section, however, and if the squarks are not very heavy, broad peaks in the dijet mass distributions are expected. Comparison of the observed spectrum with theoretical estimates rules out light gluinos if squarks are lighter than about 600 GeV/c^2 .

The top squark is different from the other squarks because its SM partner is so massive: large off-diagonal terms in the squared-mass matrix lead to large mixing effects and a possible light mass eigenstate, $M_{\widetilde{t}_1} \ll M_{\widetilde{q}}$. Analyses designed to find

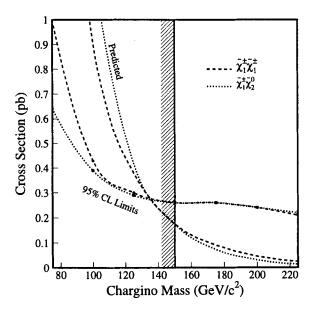


Figure 10: Comparison of the DØ upper limits on chargino and neutralino cross sections with theory in a GMSB scenario, plotted as a function of the chargino mass [28]. The vertical line shows the result obtained from the combined chargino and neutralino exclusions. It corresponds to $M_{\widetilde{\chi}_1^0} \gtrsim 75 \text{ GeV/}c^2$.

light stops have been performed by DØ [25]. The first of these was based on the jets+ E_T signature expected when the the stop is lighter than the chargino. A powerful limit $M_{\widetilde{t}} \gtrsim 90~{\rm GeV/c^2}$ was obtained, provided the neutralino was at least 30 ${\rm GeV/c^2}$ lighter than the stop as depicted in Fig. 3. (These searches are sensitive to the $c\widetilde{\chi}_1^0$ channel which does not apply below the dotted line.) More recently a search for the pair-production of light stops decaying to $b\widetilde{\chi}_1^\pm$ was performed. The presence of two energetic electrons was required; backgrounds from W's were greatly reduced. Regrettably this experimental bound does not yet improve existing bounds on stop masses.

An anomalous event observed by the CDF Collaboration [26] sparked much theoretical speculation [27]. It contains two energetic electrons, two energetic photons, large E_T , and little else. Since it is difficult to explain this event with SM processes, theorists have turned to SUSY. While some models are based on canonical MSSM scenarios (without gaugino mass unification), others are based on GMSB models with selectron production followed by $\tilde{e} \to e \tilde{\chi}^0_1$ and $\tilde{\chi}^0_1 \to \gamma \tilde{g}_{3/2}$. These models predict large inclusive signals for $p\bar{p} \to \gamma\gamma + X$ given kinematic constraints derived from the properties of the CDF event. The Tevatron experiments have looked for such events, and have found none [28], aside from the one anomalous event. These results have been translated into the bound $M_{\tilde{\chi}^0_1} > 75 \text{ GeV}/c^2$, as shown in Fig. 10 from the DØ Collaboration. This bound is

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Table 1: Lower limits on supersymmetric particle masses. 'GMSB' refers to models with gauge	-
mediated supersymmetry breaking, and 'RPV' refers to models allowing R-parity violation.	

particle		Condition	Lower limit (GeV/c^2)	Source
$\overline{\widetilde{\chi}_1^{\pm}}$	gaugino	$M_{\widetilde{ u}} > 200~{ m GeV}/c^2$	86	LEP 2
		$M_{\widetilde{ u}} > M_{\widetilde{ u}}^{\pm}$	67	LEP 2
		any $M_{\widetilde{\nu}}$	45	Z width
	Higgsino	$M_2 < 1 { m TeV}/c^2$	79	LEP 2
	GMSB		150	DØ isolated photons
	RPV	$LL\overline{E}$ worst case	73	LEP 2
		$LQ\overline{D} \ m_0 > 500 \ \mathrm{GeV}/c^2$	83	LEP 2
$\overline{\widetilde{\chi}_{1}^{0}}$	indirect	any $\tan \beta$, $M_{\widetilde{\nu}} > 200 \text{ GeV}/c^2$	25	LEP 2
		any $\tan \beta$, any m_0	14	LEP 2
	GMSB		75	DØ and LEP 2
	RPV	$LL\overline{E}$ worst case	23	LEP 2
\widetilde{e}_R	$e\widetilde{\chi}_1^0$	$\Delta M > 10 \mathrm{GeV}/c^2$	75	LEP 2 combined
$\widetilde{\mu}_R$	$\mu \widetilde{\chi}_1^0$	$\Delta M > 10~{ m GeV}/c^2$	75	LEP 2 combined
$ ilde{ au}_R$	$ au \widetilde{\chi}_1^0$	$M_{\widetilde{\chi}_1^0} < 20 \mathrm{GeV}/c^2$	53	LEP 2
$\widetilde{ u}$		~1	43	Z width
$\widetilde{\mu}_R,\widetilde{ au}_R$		stable	76	LEP 2 combined
$\overline{\widetilde{t}_1}$	$c\widetilde{\chi}_1^0$	any $\theta_{\rm mix}$, $\Delta M > 10~{ m GeV}/c^2$	70	LEP 2 combined
		any $\theta_{ m mix},M_{\widetilde{\chi}_1^0}<rac{1}{2}M_{\widetilde{t}}$	86	DØ
	$b\ell\widetilde{ u}$	any $\theta_{\rm mix}$, $\Delta M > 7 { m GeV}/c^2$	64	LEP 2 combined
$\overline{\widetilde{g}}$	any $M_{\widetilde{a}}$		190	DØ jets+ E_T
	•		180	CDF dileptons
$\widetilde{m{q}}$	$M_{\widetilde{q}} = M_{\widetilde{q}}$		260	DØ jets+ $\not\!\!E_T$
	. ,		230	CDF dileptons

as good as that derived from the combination of the four LEP experiments.

II.6. Supersymmetry searches at HERA and fixed-target experiments: The electron-proton collider (HERA) at DESY runs at $\sqrt{s} = 310$ GeV and, due to its unique beam types, can be used to probe certain channels more effectively than LEP or the Tevatron.

The first of these is associated selectron-squark production [29] through t-channel neutralino exchange. Assuming the conservation of R-parity, the signal consists of an energetic isolated electron, a jet, and missing transverse momentum. No signal was observed in 20 pb⁻¹ of data and limits were placed on the sum $\frac{1}{2}(M_{\widetilde{e}}+M_{\widetilde{q}})$. They are weaker than the latest ones from LEP.

A more interesting opportunity comes in SUSY models with R-parity violation, in particular, with a dominant $LQ\overline{D}$ interaction [30]. Squarks would be produced directly in the s-channel, decaying either directly to a lepton and a quark via R-parity violation or to a pair of fermions and a chargino or neutralino, with the latter possibly decaying via R-parity violation. Less than 3 pb⁻¹ were used to look for a squark resonance above SM backgrounds. All possible topologies were

considered, so model-independent bounds on the R-parity-violating parameter λ'_{111} could be derived as a function of the squark mass. The special case of a light \widetilde{t}_1 was also considered, and limits derived on λ'_{131} as a function of $M_{\widetilde{t}}$. These were improved by considering also the pair-production of stops via photon-gluon fusion (see the Listings for more information).

Limits from SUSY searches in fixed-target or beam-dump experiments were surpassed long ago by the colliders. An important exception is the search for the light gluino, materializing as a long-lived supersymmetric hadron called the R^0 [6]. These could be produced in fixed-target experiments with hadron beams and observed via their decay in flight to a low mass hadronic state: $R^0 \to \pi^+\pi^-\widetilde{\chi}^0_1$ or $\eta\widetilde{\chi}^0_1$. The KTeV Collaboration at Fermilab have searched for R^0 's in their neutral-kaon data and found no evidence for this particle in the $\pi^+\pi^-\widetilde{\chi}^0_1$ channel, deriving strong limits on its mass and lifetime [31], as shown in Fig. 11. A complementary search for supersymmetric baryons was performed by the E761 Collaboration with a charged hyperon beam [32].

II.7. Conclusions: A huge variety of searches for supersymmetry have been carried out at LEP, the Tevatron, and HERA. Despite all the effort, no signal has been found, forcing the

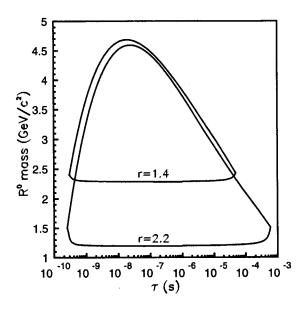


Figure 11: Ranges of R^0 mass and lifetime excluded at 90% CL by the KTeV Collaboration [31]. The ratio of the R^0 to the $\tilde{\chi}_1^0$ mass is r

experimenters to derive limits. We have tried to summarize the interesting cases in Table 1. At the present time there is little room for SUSY particles lighter than M_W . The LEP collaborations will analyze more data taken at higher energies, and the Tevatron collaborations will begin a high luminosity run in a couple of years. If still no sign of supersymmetry appears, definitive tests will be made at the LHC.

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MINIMAL SUPERSYMMETRIC STANDARD MODEL ASSUMPTIONS

All results shown below (except where stated otherwise) are based on the Minimal Supersymmetric Standard Model (MSSM) as described in the Note on Supersymmetry. This includes the assumption that R-parity is conserved. In addition the following assumptions are made in most cases:

- 1) The $\tilde{\chi}_1^0$ (or $\tilde{\gamma}$) is the lightest supersymmetric particle (LSP).
- 2) $m_{\widetilde f_L}=m_{\widetilde f_R}$ where $\widetilde f_L$ and $\widetilde f_R$ refer to the scalar partners of left-and right-handed fermions.

Limits involving different assumptions either are identified with comments or are in the miscellaneous section.

When needed, specific assumptions of the eigenstate content of neutralinos and charginos are indicated (use of the notation $\widetilde{\gamma}$ (photino), \widetilde{H} (Higgsino), \widetilde{W} (w-ino), and \widetilde{Z} (z-ino) indicates the approximation of a pure state was made).

$\widetilde{\chi}_1^0$ (Lightest Neutralino) MASS LIMIT

 $\widetilde{\chi}_1^0$ is likely to be the lightest supersymmetric particle (LSP). See also the $\widetilde{\chi}_2^0$, $\widetilde{\chi}_3^0$, $\widetilde{\chi}_4^0$ section below.

We have divided the $\widetilde{\chi}_1^0$ listings below into three sections: 1) Accelerator limits for $\widetilde{\chi}_1^0$, 2) Bounds on $\widetilde{\chi}_1^0$ from dark matter searches, and 3) Other bounds on $\widetilde{\chi}_1^0$ from astrophysics and cosmology.

Accelerator limits for $\tilde{\chi}_1^0$

These papers generally exclude regions in the $M_2-\mu$ parameter plane based on accelerator experiments. Unless otherwise stated, these papers assume minimal supersymmetry and GUT relations (gaugino-mass unification condition). $\Delta m_0=m_{\widetilde{\chi}_0^0}-m_{\widetilde{\chi}_0^0}-m_{\widetilde{\chi}_0^0}$

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
>24.9	95	¹ ABREU	98	DLPH	
>10.9	95	² ACCIARRI	98F	L3	$tan \beta > 1$
>13.3	95	3 ACKERSTAFF			$tan \beta > 1$
>12.5	95	4 ALEXANDER	96L	OPAL	$tan \beta > 1.5$
>12.8	95	⁵ BUSKULIC	96A	ALEP	$m_{\widetilde{\nu}} > 200 \text{ GeV}$
>23	95	⁶ ACCIARRI	95E	L3	$\tan \beta > 3$
• • • We do not use the	e followir	ng data for averages	i, fits	, limits,	etc. • • •
>17	95	7 ELLIS	97c	RVUE	All $tan \beta$
		⁸ ABREU	960	DLPH	
		9 ACCIARRI	96F		
>12.0	95	10 ALEXANDER	961	OPAL	$1.5 < \tan \beta < 35$
≥ 0		¹¹ FRANKE	94	RVUE	$\widetilde{\chi}_1^0$ mixed with a singlet
>20	95	12 DECAMP	92	ALEP	tan eta > 3
>5	90	13 HEARTY	89	ASP	γ̃; for m ₂ <55 GeV

- 1 ABREU 98 bound combines the chargino and neutralino searches at $\sqrt{s}{=}161,\,172$ GeV with single-photon-production results at LEP-1 from ABREU 97J. The limit is based on the same assumptions as ALEXANDER 96J except $m_0{=}1$ TeV.
- ² ACCIARRI 98F evaluates production cross sections and decay branching ratios within the MSSM, and includes in the analysis the effects of gaugino cascade decays. The limit is obtained for $0 < M_2 < 2000$, $|\mu| < 500$, and $1 < \tan \beta < 40$, but remains valid outside this domain. No dependence on the trilinear-coupling parameter A is found. The limit holds for all values of m_0 consistent with scalar lepton contraints. It improves to 24.6 GeV for $m_{\widetilde{\nu}} > 200$ GeV. Data taken at $\sqrt{s} = 130$ –172 GeV.
- 3 ACKERSTAFF 98L evaluates production cross sections and decay branching ratios within the MSSM, and includes in the analysis the effects of gaugino cascade decays. The bound is determined indirectly from the $\tilde{\chi}_1^+$ and $\tilde{\chi}_2^0$ searches within the MSSM. The limit is obtained for $0 < M_2 < 1500$, $|\mu| < 500$ and $\tan\beta > 1$, but remains valid outside this domain. The limit holds for the smallest value of m_0 consistent with scalar lepton constraints (ACKERSTAFF 97H). It improves to 24.7 GeV for $m_0{=}1$ TeV. Data taken at $\sqrt{s}{=}130{-}172$ GeV.
- ⁴ ALEXANDER 96L bound for $tan \beta = 35$ is 26.0 GeV.
- ⁵ BUSKULIC 96A puts a lower limit on $m_{\widetilde{\chi}_1^0}$ from the negative search for neutralinos,
- tharginos. The bound holds for $m_{\widetilde{\nu}} > 200^{\circ}$ GeV. A small region of (μ, M_2) still allows $m_{\widetilde{\lambda}0} = 0$ if sneutrino is lighter. This analysis combines data from e^+e^- collisions at $\frac{1}{\sqrt{3}} = 91.2$ and at 130–136 GeV.
- 6 ACCIARRI 95E limit for $an\!eta$ >2 is 20 GeV, and the bound disappears if $an\!eta$ \sim 1.
- 7 ELLIS 97c uses constraints on X^\pm , X^0 , and $\tilde{\ell}$ production obtained by the LEP experiments from e^+e^- collisions at $\sqrt{s}=130$ –172 GeV. It assumes a universal mass m_0 for scalar leptons at the grand unification scale.
- ABREU 960 searches for possible final states of neutralino pairs produced in e^+e^- collisions at $\sqrt{s}=130$ –140 GeV. See their Fig. 3 for excluded regions in the (μ,M_2) plane.
- plane.

 9 ACCIARRI 96F searches for possible final states of neutralino pairs produced in e^+e^- collisions at \sqrt{s} = 130–140 GeV. See their Fig. 5 for excluded regions in the (μ, M_2) plane.
- 10 ALEXANDER 96) bound is determined indirectly from the $\widetilde{\chi}_1^{\pm}$ and $\widetilde{\chi}_2^0$ searches within MSSM. A universal scalar mass m_0 at the grand unification scale is assumed. The bound is for the smallest possible value of m_0 allowed by the LEP $\overline{\ell},\,\widetilde{\nu}$ mass limits. Branching fractions are calculated using minimal supergravity. The bound is for $m_{\widetilde{\chi}_2^0} m_{\widetilde{\chi}_2^0} > 10$

GeV. The limit improves to 21.4 GeV for m_0 =1 TeV. Data taken at \sqrt{s} = 130-136

- GeV. ACKERSTAFF 96C, using data from $\sqrt{s}=$ 161 GeV, improves the limit for $m_0=$
- 11 FRANKE 94 reanalyzed the LEP constraints on the neutralinos in the MSSM with an additional singlet.
- ¹² DECAMP 92 limit for $\tan \beta > 2$ is m>13 GeV.
- 13 HEARTY 89 assumed pure $\widetilde{\gamma}$ eigenstate and $m_{\widetilde{e}_L}=m_{\widetilde{e}_R}$. There is no limit for $m_{\widetilde{e}}>$ 58 GeV. Uses $e^+e^- \to \gamma \tilde{\gamma} \tilde{\gamma}$. No GUT relation assumptions are made.

Bounds on $\widetilde{\chi}_1^0$ from dark matter searches

These papers generally exclude regions in the $M_2-\mu$ parameter plane assuming that $\widetilde{\chi}^0_1$ is the dominant form of dark matter in the galactic halo. These limits are based on the lack of detection in laboratory experiments or by the absence of a signal in underground neturino detectors. The latter signal is expected if $\tilde{\chi}_1^0$ accumiates in the Sun or the Earth and annihilates into high-energy ν 's.

VALUE	DOCUMENT ID		<u>TECN</u>
• • • We do not use th	e following data for averages	, fits	, limits, etc. • • •
	14 BOTTINO	97	DAMA
	15 LOSECCO	95	RVUE
	¹⁶ MORI	93	KAMI
	17 BOTTINO	92	соѕм
	¹⁸ BOTTINO	91	RVUE
	¹⁹ GELMINI	91	COSM
	²⁰ KAMIONKOW	91	RVUE
	²¹ MORI		KAMI
none 4-15 GeV	²² OLIVE	88	COSM

- 14 BOTTINO 97 points out that the current data from the dark-matter detection experiment DAMA are sensitive to neutralinos in domains of parameter space not excluded by terrestrial laboratory searches.
- ¹⁵LOSECCO 95 reanalyzed the IMB data and places lower limit on $m_{\widetilde{\chi}_1^0}$ of 18 GeV if the LSP is a photino and 10 GeV if the LSP is a higgsino based on LSP annihilation in the sun producing high-enery neutrinos and the limits on neutrino fluxes from the IMB
- 16 MORI 93 excludes some region in M_2 - μ parameter space depending on $\tan\beta$ and lightest scalar Higgs mass for neutralino dark matter $m_{\widetilde{\chi}0} > m_W$, using limits on upgoing muons produced by energetic neutrinos from neutralino annihilation in the Sun and the Earth.
- Produced by energetic neutrinos from neutralino diministron in the son and the Latin.

 18 OTTINO 92 excludes some region M₂-μ parameter space assuming that the lightest neutralino is the dark matter, using upgoing muons at Kamiokande, direct searches by Ge detectors, and by LEP experiments. The analysis includes top radiative corrections on Higgs parameters and employs two different hypotheses for nucleon-Higgs coupling. Effects of rescaling in the local neutralino density according to the neutralino relic abundance are taken into account.

 18 DOTTINO 31 excluded 3 region in M₂-μ plane using upgoing muon data from Kamioka
- 18 BOTTINO 91 excluded a region in $M_2-\mu$ plane using upgoing muon data from Kamloka experiment, assuming that the dark matter surrounding us is composed of neutralinos and that the Higgs boson is not too heavy.
- 19 GELMINI 91 exclude a region in $M_2-\mu$ plane using dark matter searches
- 20 KAMIONKOWSKI 91 excludes a region in the M_2 - μ plane using IMB limit on upgoing muons originated by energetic neutrinos from neutralino annihilation in the sun, assuming that the dark matter is composed of neutralinos and that $m_{H_1^0}\lesssim$ 50 GeV. See Fig. 8
- 21 MORI 91B exclude a part of the region in the M_2 – μ plane with $m_{\widetilde{\chi}^0_1}\lesssim 80$ GeV using a limit on upgoing muons originated by energetic neutrinos from neutralino annihilation in the earth, assuming that the dark matter surrounding us is composed of neutralinos and that $m_{H_1^0} \lesssim 80 \text{ GeV}$.
- 22 OLIVE 88 result assumes that photinos make up the dark matter in the galactic halo. Limit is based on annihilations in the sun and is due to an absence of high energy neutrinos detected in underground experiments. The limit is model dependent.

Other bounds on $\tilde{\chi}_1^0$ from astrophysics and cosmology

Most of these papers generally exclude regions in the $M_2-\mu$ parameter plane by requiring that the $\widetilde{\chi}_1^0$ contribution to the overall cosmological density is less than some maximal value to avoid overclosure of the Universe. Those not based on the cosmological density are indicated. Many of these papers also include LEP and/or other bounds.

VALUE	<u>CL%</u>	DOCUMENT ID		TECN	COMMENT
>40		²³ ELLIS	97 C	RVUE	
• • We do not	use the followi	ng data for average:	s, fits	, Ilmits,	etc. • • •
>21.4	95	²⁴ ELLIS	96B	RVUE	$tan\beta > 1.2, \mu < 0$
		²⁵ FALK	95	COSM	CP-violating phases
		DREES	93	COSM	Minimal supergravity
		FALK	93	COSM	Sfermion mixing
		KELLEY	93	COSM	Minimal supergravity
		MIZUTA	93	COSM	Co-annihilation
		ELLIS	92F	COSM	Minimal supergravity
		KAWASAKI	92	COSM	Minimal supergravity, m ₀ =A=0
		LOPEZ	92	соѕм	Minimal supergravity, m ₀ =A=0
		MCDONALD	92	COSM	•
		NOJIRI	91	COSM	Minimal supergravity
		²⁶ OLIVÉ	91	COSM	
		ROSZKOWSKI	91	COSM	

	ELLIS	90 COSM
	27 GRIEST	90 COSM
	28 GRIFOLS	90 ASTR 7; SN 1987A
	KRAUSS	90 COSM
	²⁶ OLIVE	89 COSM
> 100 eV	²⁹ ELLIS	88B ASTR ~; SN 1987A
none 100 eV - (5-7) GeV	SREDNICKI	88 COSM $\tilde{\gamma}$; $m_{\tilde{f}}$ =60 GeV
none 100 eV - 15 GeV	SREDNICKI	88 COSM γ̃; m _¥ =100 GeV
none 100 eV-5 GeV	ELLIS	84 COSM $\tilde{\gamma}$; for $m_{\tilde{f}} = 100 \text{ GeV}$
	GOLDBERG	83 COSM ₹
	³⁰ KRAUSS	83 COSM 7
	VYSOTSKII	83 COSM ≈

- 23 ELLIS 97C uses in addition to cosmological constraints, data from e^+e^- collisions at 170–172 GeV. It assumes a universal scalar mass for both the Higgs and scalar leptons, as well as radiative supersymmetry breaking with universal gaugino masses. ELLIS 97c also uses the absence of Higgs detection (with the assumptions listed above) to set a limit on $\tan\beta > 1.7$ for $\mu < 0$ and $\tan\beta > 1.4$ for $\mu > 0$. This paper updates ELLIS 96B. ²⁴ ELLIS 96B uses, in addition to cosmological constraints, data from BUSKULIC 96K and
- SUGIMOTO 96. It assumes a universal scalar mass m_0 and radiative Supersymmetry breaking, with universal gaugino masses.
- 25 Mass of the bino (=LSP) is limited to $m_{\widetilde{B}} \lesssim 350$ GeV for $m_{\widetilde{t}} = 174$ GeV.
- ²⁶ Mass of the bino (=LSP) is limited to $m_{\widetilde{B}}\lesssim 350$ GeV for $m_t\leq 200$ GeV. Mass of the higgsino (=LSP) is limited to $m_{\widetilde{H}}\lesssim 1$ TeV for $m_t\leq 200$ GeV.
- 27 Mass of the bino (=LSP) is limited to $m_{\widetilde{B}} \lesssim$ 550 GeV. Mass of the higgsino (=LSP) is limited to $m_{\widetilde{H}} \lesssim$ 3.2 TeV.
- 28 GRIFOLS 90 argues that SN1987A data exclude a light photino ($\lesssim 1$ MeV) if $m_{\widetilde{q}} < 1.1$ TeV, $m_{\widetilde{\mu}} < 0.83$ TeV.
- ²⁹ ELLIS 88b argues that the observed neutrino flux from SN 1987A is inconsistent with a light photino if 60 GeV $\lesssim m_{\widetilde{q}} \lesssim 2.5$ TeV. If m(higgsino) is O(100 eV) the same argument leads to limits on the ratio of the two Higgs v.e.v.'s. LAU 93 discusses possible relations of ELLIS 88b bounds.
- 30 KRAUSS 83 finds $m_{\widetilde{\gamma}}$ not 30 eV to 2.5 GeV. KRAUSS 83 takes into account the gravitino decay. Find that limits depend strongly on reheated temperature. For example a new allowed region $m_{\widetilde{\gamma}}=$ 4–20 MeV exists if $m_{\rm gravitino}$ <40 TeV. See figure 2.

$\tilde{\chi}_{2}^{0}$, $\tilde{\chi}_{3}^{0}$, $\tilde{\chi}_{4}^{0}$ (Neutralinos) MASS LIMITS

CL%

VALUE (GeV)

Neutralinos are unknown mixtures of photinos, z-inos, and neutral higgsinos (the supersymmetric partners of photons and of Z and Higgs bosons). The limits here apply only to $\widetilde{\chi}_{0}^{0}$, $\widetilde{\chi}_{0}^{0}$, and $\widetilde{\chi}_{0}^{0}$, $\widetilde{\chi}_{0}^{0}$ is the lightest supersymmetric particle (LSP); see $\widetilde{\chi}_{0}^{0}$ Mass Limits. It is not possible to quote rigorous mass limits because they are extremely model dependent; i.e. they depend on branching ratios of various $\widetilde{\chi}^{0}$ decay modes, on the masses of decay products $(\tilde{e},\,\tilde{\gamma},\,\tilde{q},\,\tilde{g})$, and on the \tilde{e} mass exchanged in $e^+e^- ou \tilde{\chi}^0_1\tilde{\chi}^0_2$. Often limits are given as contour plots in the $m_{\tilde{\chi}^0_1}-m_{\tilde{e}}$ plane vs other parameters. When specific assumptions are made, e.g., the neutralino is a pure photino $(\widetilde{\gamma})$, pure z-ino (\widetilde{Z}) , or pure neutral higgsino (\widetilde{H}^0) , the neutralinos will be labelled as such.

TECN COMMENT

DOCUMENT ID

TALUE (UCT)		DOCOMENTID		COMMENT
> 45.3	95	31 ACKERSTAFF	98L OPAL	$\tilde{\chi}_2^0$, $\tan \beta > 1$
> 75.8	95	31 ACKERSTAFF	98L OPAL	$\tilde{\chi}_{3}^{0}$, $\tan \beta > 1$
>127	95	³² ACCIARRI	95E L3	$\tilde{\chi}_{4}^{0}$, tan $eta >$ 3
• • • We do not use	e the follow	ing data for average:	s, fits, limits	, etc. • • •
> 92	95	33 ACCIARRI	98F L3	\widetilde{H}_{2}^{0} , tan β =1.41, M_{2} < 500 GeV
		34 ABACHI	96 D0	$\begin{array}{c} {}^{2}500 \text{ GeV} \\ p\overline{p} \rightarrow \widetilde{\chi}^{\pm}_{1}\widetilde{\chi}^{0}_{2} \end{array}$
		35 ABE	96K CDF	$p\overline{p} \rightarrow \tilde{\chi}_1^{\pm} \tilde{\chi}_2^{\bar{0}}$
		³⁶ ACCIARRI	96F L3	$\tilde{\chi}_2^0$
> 86.3	95	37 ACKERSTAFF	96c OPAL	$\tilde{\chi}_{0}^{0}$
> 45.3	95	38 ALEXANDER	96J OPAL	$\widetilde{\chi}_{2}^{0}$ $\widetilde{\chi}_{2}^{0}$ $\widetilde{\chi}_{3}^{0}$ $\widetilde{\chi}_{2}^{0}$ 1.5 $<$ tan β $<$ 35
> 33.0	95	39 ALEXANDER	96L OPAL	
> 68	95	⁴⁰ BUSKULIC	96ĸ ALEP	\tilde{x}_{2}^{0}
> 52	95	32 ACCIARRI	95E L3	$\tilde{\chi}_{2}^{0}$, $\tan \beta > 3$
> 84	95	32 ACCIARRI	95E L3	$\tilde{\chi}_{3}^{0}$, $\tan \beta > 3$
> 45	95	41 DECAMP	92 ALEP	$\tilde{\chi}_{2}^{0}$, $\tan \beta > 3$
		⁴² ABREU	90g DLPH	$Z \rightarrow \tilde{\chi}^0 \tilde{\chi}^0$
		43 AKRAWY	90N OPAL	$Z \rightarrow \tilde{\chi}^0 \tilde{\chi}^0$
> 57	90	⁴⁴ BAER	90 RVUE	$\widetilde{\chi}^0_3$; $\Gamma(Z)$; $ aneta>1$
		⁴⁵ BARKLOW	90 MRK2	$ \begin{array}{ccc} z \to \tilde{\chi}_1^0 \tilde{\chi}_2^0, \tilde{\chi}_2^0 \tilde{\chi}_2^0 \\ z \to \tilde{\chi}_1^0 \tilde{\chi}_2^0 \end{array} $
		46 DECAMP	90K ALEP	$Z \rightarrow \tilde{\chi}^{\dot{0}} \tilde{\chi}^{\dot{0}}$
> 41	95	⁴⁷ SAKAI	90 AMY	
				$(\widetilde{H}_2^0 \rightarrow f\widetilde{\widetilde{f}}\widetilde{H}_1^{\widetilde{0}})$
> 31	95	⁴⁸ BEHREND	87B CELL	$e^+e^- \rightarrow \tilde{\gamma}\tilde{Z}$
				$(\widetilde{Z} \rightarrow q \overline{q} \widetilde{\gamma}), m_{\widetilde{e}} <$
				70 GeV

Supersymmetric Particle Searches

	_			
> 30	95	⁴⁹ BEHREND	87B CELL	$e^+e^- \rightarrow \tilde{\gamma}\tilde{Z}$
> 31.3	95	⁵⁰ BEHREND	878 CELL	$e^+e^- ightarrow \widetilde{H}_1^0\widetilde{H}_2^0$
> 22	95	⁵¹ BEHREND	878 CELL	$(\widetilde{H}_2^0 \rightarrow f \widetilde{f} \widetilde{H}_1^0)$ $e^+ e^- \rightarrow \gamma \widetilde{\gamma} \widetilde{Z}$
		⁵² AKERLOF	85 HRS	$e^+e^{\sim 2} ightarrow \widetilde{\gamma}\widetilde{\chi}^0$
none 1~21	95	53 BARTEL	85L JADE	$e^+e^- ightarrow \widetilde{q}\widetilde{q}\widetilde{\gamma})$ $e^+e^- ightarrow \widetilde{H}_1^0\widetilde{H}_2^0$,
		54 BEHREND	85 CELL	$\widetilde{H}_{2}^{0} \rightarrow f \overline{f} \widetilde{H}_{1}^{0}$ $e^{+}e^{-} \rightarrow \text{monojet X}$
> 35	95	55 ADEVA	848 MRKJ	e+e- → γŽ
> 28	95	56 BARTEL	84c JADE	$(\tilde{Z} \to t\bar{t}\tilde{\gamma})$ $e^+e^- \to \gamma \tilde{Z}$ $(\tilde{Z} \to t\bar{t}\tilde{\gamma})$
		⁵⁷ ELLIS	84 COSM	$(Z \rightarrow ff\gamma)$

 31 ACKERSTAFF 98L is obtained from direct searches in the $e^+\,e^-\,\to\,\widetilde\chi^0_1\widetilde\chi^0_{2,3}$ production channels, and Indirectly from $\tilde{\chi}^{\pm}_{1}$ and $\tilde{\chi}^{0}_{1}$ searches within the MSSM. See footnote to ACKERSTAFF 98L in the chargino Section for further details on the assumptions. Data taken at $\sqrt{s}=130-172$ GeV.

 32 ACCIARRI 95E limits go down to 0 GeV $(\tilde{\chi}_2^0)$, 60 GeV $(\tilde{\chi}_3^0)$, and 90 GeV $(\tilde{\chi}_4^0)$ for $\tan\beta=1$.

³³ ACCIARRI 98F is obtained from direct searches in the $e^+e^- \to \tilde{\chi}_{1,2}^0 \dot{\tilde{\chi}}_2^0$ production channels, and indirectly from $\widetilde{\chi}_1^\pm$ and $\widetilde{\chi}_1^0$ searches within the MSSM. See footone to ACCIARRI 98F in the chargino Section for futher details on the assumptions. Data taken at $\sqrt{s} = 130-172$ GeV.

at $\sqrt{s}=130-1/2$ GeV. 34 ABACHI 96 searches for 3-lepton final states. Efficiencies are calculated using mass relations and branching ratios in the Minimal Supergravity scenario. Results are presented as lower bounds on $\sigma(\widetilde{\chi}_1^{\pm}\widetilde{\chi}_2^0) \times \mathrm{B}(\widetilde{\chi}_1^{\pm} \to \ell \nu_\ell \widetilde{\chi}_1^0) \times \mathrm{B}(\widetilde{\chi}_2^0 \to \ell^+ \ell^- \widetilde{\chi}_1^0)$ as a function of $m_{\widetilde{\chi}_1^0}$. Limits range from 3.1 pb $(m_{\widetilde{\chi}_1^0}=45~\mathrm{GeV})$ to 0.6 pb $(m_{\widetilde{\chi}_1^0}=100~\mathrm{GeV})$.

³⁵ ABE 96K looked for tripleton events from chargino-neutralino production. They obtained lower bounds on $m_{\widetilde{\chi}^0_2}$ as a function of μ . The lower bounds are in the 45–50 GeV range

for gaugino-dominant $\widetilde{\chi}_2^0$ with negative μ , if aneta <10. See paper for more details of the assumptions.

³⁶ ACCIARRI 96F looked for associated production $e^+e^- \rightarrow \tilde{\chi}_1^0 \tilde{\chi}_2^0$. See the paper for upper bounds on the cross section. Data taken at $\sqrt{s} = 130-136$ GeV.

 37 ACKERSTAFF 96C is obtained from direct searches in the $e^+e^-
ightarrow \, \widetilde{\chi}^0_1 \, \widetilde{\chi}^0_{2.3}$ production channel, and indirectly from $\widetilde{\chi}_1^\pm$ searches within MSSM. Data from $\sqrt{s}=130,136,$ and 161 GeV are combined. The same assumptions and constraints of ALEXANDER 961 apply. The limit improves to 94.3 GeV for $m_0=1$ TeV. 38 ALEXANDER 961 looked for associated $e^+e^- \to \widetilde{\chi}_0^0\widetilde{\chi}_0^0$. A universal scalar mass m_0 at

the grand unification scale is assumed. The bound is for the smallest possible value of m_0 alowed by the LEP $\tilde{\ell},\,\tilde{\nu}$ mass limits, 1.5 < $an\!eta$ <35. Branching fractions are calculated using minimal supergravity. The bound is for $m_{\widetilde{\chi}0} > 10$ GeV. The limit improves to 47.5 GeV for $m_0=1$ TeV. Data taken at $\sqrt{s}=130$ –136 GeV. ACKERSTAFF 96c, using data from $\sqrt{s}=161$ GeV, improves the limit for $m_0=1$ TeV to 51.9 GeV.

³⁹ ALEXANDER 96L bound for $\tan\beta$ =35 is 51.5 GeV. ⁴⁰ BUSKULIC 96K looked for associated $e^+e^- \rightarrow \widetilde{\chi}_1^0\widetilde{\chi}_2^0$ and assumed the dominance of off-shell Z-exchange in the $\overline{\chi}_2^0$ decay. The bound is for $m_{\widetilde{\chi}_2^0} - m_{\widetilde{\chi}_1^0} > 9$ GeV. Data taken at $\sqrt{s} = 130-136$ GeV.

41 For $\tan \beta > 2$ the limit is >40 GeV; and it disappears for $\tan \beta < 1.6$. 42 ABREU 90G exclude $B(Z \to \widetilde{\chi}_1^0 \widetilde{\chi}_2^0) \ge 10^{-3}$ and $B(Z \to \widetilde{\chi}_2^0 \widetilde{\chi}_2^0) \ge 2 \times 10^{-3}$ assuming $\tilde{\chi}_2^0 \to \tilde{\chi}_1^0$ f \tilde{f} via virtual Z. These exclude certain regions in model parameter space, see their Fig. 5.

space, see time rig. 3. 43 AKRAWY 90N exclude B($Z \to \tilde{\chi}_1^0 \tilde{\chi}_2^0$) $\gtrsim 3-5 \times 10^{-4}$ assuming $\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 f \tilde{r}$ or $\tilde{\chi}_1^0 f$ for most accessible masses. These exclude certain regions in model parameter space, see

 44 BAER 90 is independent of decay modes. Limit from analysis of supersymmetric parameter space restrictions implied by $\Delta\Gamma(Z)<120$ MeV. These result from decays of Z to all combinations of $\tilde{\chi}_I^\pm$ and $\tilde{\chi}_I^0$. Minimal supersymmetry with $\tan\!\beta > 1$ is assumed.

 $^{45}\,\mathrm{See}$ Figs. 4, 5 in BARKLOW 90 for the excluded regions.

46 DECAMP 90K exclude certain regions in model parameter space, see their figures.

47 SAKAI 90 assume $m_{\widetilde{H}_1^0}=0$. The limit is for $m_{\widetilde{H}_2^0}$.

48 Pure $\tilde{\gamma}$ and pure \tilde{Z} eigenstates. B($\tilde{Z} \rightarrow q \bar{q} \tilde{\gamma}$) = 0.60 and B($\tilde{Z} \rightarrow e^+ e^- \tilde{\gamma}$) = 0.13. $m_{\widetilde{e}_L} = m_{\widetilde{e}_R} < 70 \text{ GeV. } m_{\widetilde{\gamma}} < 10 \text{ GeV.}$

⁴⁹ Pure $\widetilde{\gamma}$ and pure \widetilde{Z} eigenstates. B($\widetilde{Z} \to q \overline{q} \widetilde{g}) = 1$. $m_{\widetilde{e}_L} = m_{\widetilde{e}_R} < 70$ GeV. $m_{\widetilde{\gamma}} = 0$.

⁵⁰ Pure higgsino. The LSP is the other higgsino and is taken massless. Limit degraded if

 $\tilde{\chi}^{Q}$ not pure higgsino or if LSP not massless. 51 Pure $\tilde{\gamma}$ and pure \tilde{Z} eigenstates. B($\tilde{Z} \rightarrow \tilde{\nu}\nu$) = 1. $m_{\tilde{e}_L} = m_{\tilde{e}_R} = 26$ GeV. $m_{\tilde{\gamma}} = 10$ GeV. No excluded region remains for $m_{\widetilde{e}} >$ 30 GeV.

52 AKERLOF 85 is e+e-monojet search motivated by UA1 monojet events. Observed only one event consistent with $e^+e^- \to \widetilde{\gamma} + \widetilde{\chi}^0$ where $\widetilde{\chi}^0 \to \text{monojet}$. Assuming that missing- $p_{\widetilde{X}}$ is due to $\widetilde{\gamma}$, and monojet due to $\widetilde{\widetilde{\chi}}{}^0$, limits dependent on the mixing and $m_{\widetilde{e}}$ are given, see their figure 4.

53 BARTEL 85L assume $m_{\widetilde{H}_1^0}=$ 0, $\Gamma(Z\to\widetilde{H}_1^0\widetilde{H}_2^0)\gtrsim \frac{1}{2}$ $\Gamma(Z\to \nu_e\overline{\nu}_e)$. The limit is

for $m_{\widetilde{H}_2^0}$.

⁵⁴BEHREND 85 find no monojet at $E_{
m cm}=$ 40–46 GeV. Consider $ilde{\chi}^0$ pair production via Z^0 . One is assumed as massless and escapes detector. Limit is for the heavier one, decaying into a jet and massless $\widetilde{\chi}^0$. Both $\widetilde{\chi}^0$'s are assumed to be pure higgsino. For these very model-dependent results, BEHREND 85 excludes m=1.5–19.5 GeV. 55 ADEVA 84B observed no events with signature of acoplanar lepton pair with missing energy. Above example limit is for $m_{\widetilde{\gamma}}$ <2 GeV and $m_{\widetilde{e}}$ <40 GeV, and assumes $B(\tilde{Z} \to \mu^+ \mu^- \tilde{\gamma}) = B(\tilde{Z} \to e^+ e^- \tilde{\gamma}) = 0.10$. BR = 0.05 gives 33.5 GeV limit.

56 BARTEL 84C search for $e^+e^- \rightarrow \tilde{Z} + \tilde{\gamma}$ with $\tilde{Z} \rightarrow \tilde{\gamma} + e^+e^-$, $\mu^+\mu^-$, $q\overline{q}$, etc. They see no acoplanar events with missing- p_T due to two $\tilde{\gamma}$'s. Above example limit is for $m_{\widetilde{e}}$ = 40 GeV and for light stable $\tilde{\gamma}$ with $B(\tilde{Z} \rightarrow e^+e^-\tilde{\gamma}) = 0.1$.

⁵⁷ ELLIS 84 find if lightest neutralino is stable, then $m_{\widetilde{\chi}0}$ not 100 eV - 2 GeV (for $m_{\widetilde{q}}$ = 40 GeV). The upper limit depends on $m_{\widetilde{q}}$ (similar to the $\widetilde{\gamma}$ limit) and on nature of $\widetilde{\widetilde{\chi}}^0$. For pure higgsino the higher limit is 5 GeV.

Unstable $\widetilde{\chi}_1^0$ (Lightest Neutralino) MASS LIMIT

Unless stated otherwise, the limits below assume that the $\tilde{\gamma}$ decays either into γ \tilde{G} (goldstino) or into $\gamma \widetilde{H}^0$ (Higgsino).

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do	not use			fits, limits, etc. • • •
>77	95	58 ABBOTT	98 DO	$\begin{array}{cccccccccccccccccccccccccccccccccccc$
		⁵⁹ ABREU	98 DLPH	$e^+e^- \rightarrow \widetilde{\chi}_1^0\widetilde{\chi}_1^0 \ (\widetilde{\chi}_1^0 \rightarrow \gamma \widetilde{G})$
		60 ACKERSTAFF	981 OPAL	$e^+e^- \rightarrow \widetilde{\chi}_1^0\widetilde{\chi}_1^0 \ (\widetilde{\chi}_1^0 \rightarrow \gamma \widetilde{G})$
	95	61 ACCIARRI	97∨ L3	$e^+e^- \rightarrow \widetilde{\chi}_1^0\widetilde{\chi}_1^0 \ (\widetilde{\chi}_1^0 \rightarrow \gamma \widetilde{G})$
		62 ELLIS	97 THEO	$e^+e^- \rightarrow \tilde{\chi}_1^0 \tilde{\chi}_1^0, \tilde{\chi}_1^0 \rightarrow \gamma \tilde{G}$
		63 BUSKULIC	96U ALEP	$e^+e^- \rightarrow \tilde{\chi}_1^0 \tilde{\chi}_1^0$
				$(\tilde{x}_1^0 \rightarrow \nu \ell \tilde{\ell}')$
>40	95	64 BUSKULIC	95E ALEP	$e^+e^- \rightarrow \tilde{\chi}_1^0\tilde{\chi}_1^0$
				$(\widetilde{\chi}_1^0 \to \nu \ell \overline{\ell}')$
		⁶⁵ BUSKULIC	95E ALEP	$e^+e^- \rightarrow \tilde{\gamma}\tilde{\gamma}$
		66		$(\tilde{\gamma} \rightarrow \nu \ell \tilde{\ell}')$
		⁶⁶ ACTON	93G OPAL	$e^+e^- \rightarrow \tilde{\gamma}\tilde{\gamma}$
		67 ABE	901 MME	$(\widetilde{\gamma} \to \tau^{\pm} \ell^{\mp} \nu_{\ell'})$ $e^{+}e^{-} \to \widetilde{\gamma} \widetilde{\gamma}$
		- ADE	991 AM2	$(\tilde{\gamma} \rightarrow \gamma \tilde{G} \text{ or } \gamma \tilde{H}^0)$
>15	95	68 BEHREND	87B CELL	$e^+e^- \rightarrow \tilde{\gamma}\tilde{\gamma}$
				$(\tilde{\gamma} \rightarrow \gamma \tilde{G} \text{ or } \gamma \tilde{H}^0)$
		⁶⁹ ADEVA ⁷⁰ BALL	85 MRKJ	
		71	84 CALO 84B JADE	Beam dump
		71 BEHREND		
		72 CABIBBO	81 COSM	

⁵⁸ABBOTT 98 studied the chargino and neutralino production, where the lightest neutralino in their decay products further decays into $\gamma \, \widetilde{G}$. The limit assumes the gaugino nass unification.

⁵⁹ ABREU 98 uses data at \sqrt{s} =161 and 172 GeV. Upper bounds on $\gamma\gamma E$ cross section are obtained. Similar limits on γE are also given, relevant for ${
m e}^+ \, {
m e}^- \to \, \widetilde{\chi}_1^0 \, \widetilde{{
m G}}$ production,

 60 ACKERSTAFF 98J looked for $\gamma\gamma E$ final states at \sqrt{s} =161–172 GeV. They set limits on $\sigma(e^+e^- o ilde{\chi}_1^0 ilde{\chi}_1^0)$ In the range 0.22–0.50 pb for $m_{\widetilde{\chi}_1^0}$ in the range 45–86 GeV. Mass limits for explicit models from the literature are given in Fig. 19 of their paper. Similar limits on $\gamma+$ missing energy are also given, relevant for $\widetilde{\chi}_1^0$ \widetilde{G} production.

⁶¹ ACCIARRI 97V looked for $\gamma\gamma E$ final states at \sqrt{s} =161 and 172 GeV. They set limits on $\sigma(e^+e^- \to \tilde{\chi}_1^0 \tilde{\chi}_1^0)$ In the range 0.25–0.50 pb for masses in the range 45–85 GeV. The lower limits on $m_{\tilde{\chi}_1^0}$ vary in the range of 64.8 GeV (pure bino with 90 GeV slepton) to 75.3 GeV (pure higgsino). There is no limit for pure zino case.

 62 ELLIS 97 reanalyzed the LEP2 (\sqrt{s} =161 GeV) limits of $\sigma(\gamma\gamma + E_{miss})$ < 0.2 pb to exclude $m_{\widetilde{\chi}_1^0} <$ 63 GeV if $m_{\widetilde{e}_L} = m_{\widetilde{e}_R} <$ 150 GeV and $\widetilde{\chi}_1^0$ decays to γ \widetilde{G} inside detector.

 63 BUSKULIC 960 extended the search for $e^+e^- \rightarrow \widetilde{\chi}_1^0 \widetilde{\chi}_1^0$ in BUSKULIC 95E under

the same assumptions. See their Fig. 5 for excluded region in the neutralino-chargino parameter space. Data taken at $\sqrt{s}=130-136$ GeV. ⁶⁴ BUSKULIC 95E looked for $e^+e^- \rightarrow \widetilde{\chi}_1^0\widetilde{\chi}_1^0$, where $\widetilde{\chi}_1^0$ decays via *R*-parity violating interaction into one neutrino and two opposite-charge leptons. The bound applies provided that $B(Z \rightarrow \widetilde{\chi}_1^0\widetilde{\chi}_1^0) > 3 \times 10^{-5}\beta^3$, β being the final state $\widetilde{\chi}_1^0$ velocity.

65 BUSKULIC 95E looked for $e^+e^- \to \widetilde{\gamma}\widetilde{\gamma}$, where $\widetilde{\gamma}$ decays via R-parity violating interaction into one neutrino and two opposite-charge leptons. They extend the domain in the $(m_{\widetilde{e}}, m_{\widetilde{\gamma}})$ plane excluded by ACTON 93G to $m_{\widetilde{e}} >$ 220 GeV/ c^2 (for $m_{\widetilde{\gamma}} =$ 15 GeV/ c^2) and to $m_{\widetilde{\gamma}} > 2 \text{ GeV}/c^2$ (for $m_{\widetilde{e}} < 220 \text{ GeV}/c^2$).

66 ACTON 93G assume R-parity violation and decays $\tilde{\gamma} \to \tau^{\pm} \ell^{\mp} \nu_{\ell}$ ($\ell = e$ or μ). They exclude $m_{\tilde{\gamma}} = 4$ -43 GeV for $m_{\widetilde{e}_{\ell}} <$ 42 GeV, and $m_{\tilde{\gamma}} = 7$ -30 GeV for $m_{\widetilde{e}_{\ell}} <$ 100 GeV (95% CL). Assumes \tilde{e}_{R} much heavier than \tilde{e}_{ℓ} , and lepton family number violation but L_e - L_μ conservation.

 67 ABE 891 exclude $m_{\widetilde{\gamma}}=0.15$ –25 GeV (95%CL) for $d=(100~{
m GeV})^2$ and $m_{\widetilde{e}}=40~{
m GeV}$ In the case $\tilde{\gamma} \to \gamma \tilde{G}$, and $m_{\tilde{\gamma}}$ up to 23 GeV for $m_{\tilde{e}} =$ 40 GeV in the case $\tilde{\gamma} \to \gamma \tilde{H}^0$.

⁶⁸ BEHREND 87B limit is for unstable photinos only. Assumes B($\tilde{\gamma} \rightarrow \gamma(\tilde{G} \text{ or } \tilde{H}^0)$) =1, $m_{\tilde{G} \text{ or } \tilde{H}^0} \ll m_{\tilde{\gamma}}$ and pure $\tilde{\gamma}$ eigenstate. $m_{\tilde{e}_L} = m_{\tilde{e}_R} < 100 \text{ GeV}$.

⁶⁹ ADEVA 85 is sensitive to $\tilde{\gamma}$ decay path <5 cm. With $m_{\tilde{e}}=50$ GeV, limit (CL = 90%) is $m_{\tilde{\gamma}}>$ >20.5 GeV. Assume $\tilde{\gamma}$ decays to photon + goldstino and search for acoplanar photons with large missing p_T .

70 BALL 84 is FNAL beam dump experiment. Observed no $\tilde{\gamma}$ decay, where $\tilde{\gamma}$'s are expected to come from \tilde{g} 's produced at the target. Three possible $\tilde{\gamma}$ lifetimes are considered.

Gluino decay to goldstino + gluon is also considered 71 BEHREND 83 and BARTEL 84B look for 2γ events from $\widetilde{\gamma}$ pair production. With supersymmetric breaking parameter d = $(100~{\rm GeV})^2$ and $m_{\widetilde{e}}=40~{\rm GeV}$ the excluded regions at CL = 95% would be $m_{\widetilde{\gamma}}=$ 100 MeV - 13 GeV for BEHREND 83 $m_{\widetilde{\gamma}}=$ 80 MeV - 18 GeV for BARTEL 84B. Limit is also applicable if the $\widetilde{\gamma}$ decays radiatively within the detector.

within the detector. Within the detector $\tilde{\gamma} \rightarrow \gamma +$ goldstino. Photino must be either light enough (<30 eV) to satisfy cosmology bound, or heavy enough (>0.3 MeV) to have disappeared at early universe.

$\tilde{\chi}_1^{\pm}$, $\tilde{\chi}_2^{\pm}$ (Charginos) MASS LIMITS

Charginos $(\widetilde{X}^{\pm}$'s) are unknown mixtures of w-inos and charged higgsinos (the supersymmetric partners of W and Higgs bosons). Mass limits are relatively model dependent, so assumptions concerning branching ratios need to be specified. When specific assumptions are made, e.g. the chargino is a pure w-ino (\widetilde{W}) or pure charged higgsino (\widetilde{H}^{\pm}) , the charginos will be labelled as such.

In the Listing below, we use $\Delta m_+ = m_{\widetilde{\chi}^\pm_1} - m_{\widetilde{\chi}^0_1} \Delta m_{\nu} = m_{\widetilde{\chi}^\pm_1} - m_{\widetilde{\nu}^*}$ or simply Δm to indicate that the constraint applies to both Δm_+ and Δm_{ν} .

VALUE (GeV)	CL%		DOCUMENT ID		TECN	COMMENT
> 67.6	95	73	ABREU	98	DLPH	Δm> 10 GeV
> 69.2	95		ACCIARRI	98F		tan eta < 1.41
> 65.7	95	75	ACKERSTAFF	98L	OPAL	$\Delta m_+ > 3 \text{ GeV}$
> 56.3	95		ABREU	96L	DLPH	$e^+e^- \rightarrow \tilde{\chi}^+\tilde{\chi}^-$
> 64	95	77	ACCIARRI	96F	L3	$e^+e^- \rightarrow \tilde{\chi}^+\tilde{\chi}^-,$ $m_{\tilde{\chi}0} < 43 \text{ GeV}$
>4/	. 6 -11					
• • We do not use the						
>150	95		ABBOTT	98	D0	$p\overline{p} \rightarrow \gamma \gamma E_T + X$
			ABBOTT	98C	D0	$p\vec{p} \rightarrow \tilde{\chi}_1^{\pm} \tilde{\chi}_2^0$
> 71.8	95	80	ABREU	98	DLPH	$e^+e^- \rightarrow \tilde{\chi}^+\tilde{\chi}^-,$ $\tilde{\chi}^0_1 \rightarrow \tilde{G}\gamma$
		81	ACKERSTAFF	98ĸ	OPAL	$\tilde{\chi}^+ \xrightarrow{1} \ell^+ E$
		82	CARENA	97	THEO	$g_{\mu}-2$
			KALINOWSKI	97	THEO	$W \rightarrow \tilde{\chi}_1^{\pm} \tilde{\chi}_1^0$
		84	ABE	96K	CDF	$p\overline{p} \rightarrow \widetilde{\chi}_{1}^{\pm}\widetilde{\chi}_{2}^{0}$
> 62	95	85	ACKERSTAFF	96c	OPAL	$e^+e^- \rightarrow \tilde{\chi}^+\tilde{\chi}^-$
> 58.7	95		ALEXANDER			
> 63	95	87	BUSKULIC		ALEP	
		88	BUSKULIC	96U	ALEP	$e^+e^- \rightarrow \tilde{\chi}_1^+\tilde{\chi}_1^-; R$
> 44.0	95	89	ADRIANI	93M	L3	parity violation $Z \rightarrow \tilde{\chi}^+ \tilde{\chi}^-, \Gamma(Z)$
> 45.2	95		DECAMP	92		$Z \rightarrow \tilde{\chi} + \tilde{\chi}^-$, all $m_{\tilde{\chi}0}$
> 47			DECAMP			$Z \rightarrow \tilde{\chi}^+ \tilde{\chi}^-,$
> 41	95	-	DECAMP	92	ALEP	$m_{\widetilde{\chi}0}$ <41 GeV
> 99	95	91	HIDAKA	Q1	RVUE	1
> 44.5			ABREU			$\tilde{Z} \rightarrow \tilde{\chi} + \tilde{\chi}^-$
> 44.5	95		ABREU	90G	DLPH	$m_{\widetilde{\gamma}} < 20 \text{ GeV}$
> 45	95	93	AKESSON	90B	UA2	p p → ZX
		0.4				$(Z \rightarrow \widetilde{W}^+\widetilde{W}^-)$
> 45	95	74	AKRAWY	90 D	OPAL	$e^+e^- \rightarrow \tilde{\chi}^+\tilde{\chi}^-;$ $m_{\tilde{\gamma}} < 20 \text{ GeV}$
> 45	95	95	BARKLOW	90	MRK2	$z \rightarrow \widetilde{W} + \widetilde{W} -$
> 42	95		BARKLOW	90	MRK2	$Z \rightarrow \tilde{H}^+ \tilde{H}^-$
> 44.5	95		DECAMP		ALEP	$e^+e^- \rightarrow \tilde{\chi}^+\tilde{\chi}^-$
		•				$m_{\widetilde{\gamma}} < 28 \; { m GeV}$
> 25.5	95		ADACHI	89	TOPZ	$e^+e^- \rightarrow \tilde{\chi}^+\tilde{\chi}^-$
> 44	95	99	ADEVA	89B	L3	$e^+e^- \rightarrow \widetilde{W}^+\widetilde{W}^-$
> 45	90	100	ANSARI	87D	UA2	$\widetilde{W} \rightarrow \ell \widetilde{\nu} \text{ or } \ell \nu \widetilde{\gamma}$ $p \overline{p} \rightarrow Z X$
						$(Z \rightarrow \widetilde{W}^+\widetilde{W}^-,$
						$\widetilde{W}^{\pm} \rightarrow e^{\pm} \widetilde{\nu}$)

 73 ABREU 98 uses data at $\sqrt{s}{=}161$ and 172 GeV. The universal scalar mass at the GUT scale is assumed to compute branching fractions and mass spectrum. The limit is for 41 $<\!m_{\widetilde{\nu}}<100$ GeV, and $\tan\beta\!=\!1{-}35$. The limit improves to 84.3 GeV for $m_{\widetilde{\nu}}>300$ GeV. For Δm_+ below 10 GeV, the limit is independent of $m_{\widetilde{\nu}}$, and is given by 80.3 GeV for $\Delta m_+=5$ GeV, and by 52.4 GeV for $\Delta m_+=3$ GeV.

74 ACCIARRI 98F evaluates production cross sections and decay branching ratios within the MSSM, and includes in the analysis the effects of gaugino cascade decays. The limit is obtained for $0 < M_2 < 2000$, $\tan \beta < 1.41$, $\tan \mu = -200$ GeV, and holds for all values of m_0 . No dependence on the trillinear-coupling parameter A is found. It improves to 84 GeV for large sneutrino mass, at μ =-200 GeV. See the paper for limits obtained with specific assumptions on the gaugino/higgsino composition of the state. Data taken at \sqrt{s} = 130-172 GeV.

 75 ACKERSTAFF 98L evaluates production cross sections and decay branching ratios within the MSSM, and includes in the analysis the effects of gaugino cascade decays. The limit is obtained for 0 c M_2 c 1500, $|\mu|$ < 500 and $\tan\beta$ > 1, but remains valid outside this domain. The dependence on the trilinear-coupling parameter A is studied, and found neglibible. The limit holds for the smallest value of m_0 consistent with scalar lepton constraints (ACKERSTAFF 97H) and for all values of m_0 where the condition $\Delta m_{\widetilde{\nu}} > 2.0$ GeV is satisfied. $\Delta m_{\nu} > 10$ GeV if $\widetilde{x}^{\pm} \rightarrow \ell \widetilde{\nu}_{\ell}$. The limit improves to 84.5 GeV for $m_0 = 1$ TeV. Data taken at $\sqrt{s} = 130 - 172$ GeV.

76 ABREU 96L assumes the dominance of off-shell W-exchange in the chargino decay and $\Delta(m)>10$ GeV. The bound is for the smallest $\tilde{\ell},\,\tilde{\nu}$ mass allowed by LEP, provided either $m_{\widetilde{\nu}}>m_{\widetilde{\chi}\pm}$ or $m_{\widetilde{\chi}\pm}-m_{\widetilde{\nu}}>10$ GeV. $1<\tan\beta<35$. For a mostly higgsino $\tilde{\chi}^+$ ($m_{\widetilde{\chi}\pm}-m_{\widetilde{\chi}0}=5$ GeV) the limit is 63.8 GeV, independently of the $\tilde{\ell}$ masses. Data taken at $\sqrt{s}=130-136$ GeV.

- 77 ACCIARRI 96F assume $m_{\widetilde{\nu}} >$ 200 GeV and $m_{\widetilde{\chi}_{1}^{\pm}} < m_{\widetilde{\chi}_{0}^{0}}$. See their Fig. 4 for excluded regions in the $(m_{\widetilde{\chi}_{2}^{\pm}}, m_{\widetilde{\chi}_{0}^{0}})$ plane. Data taken at $\sqrt{s} = 130$ –136 GeV.
- 78 ABBOTT 98 studied the chargino and neutralino production, where the lightest neutralino in their decay products further decays into γ \tilde{G} . The limit assumes the gaugino mass unification.
- 79 Mass unincation. 79 Mass unincation. The Mass unincation of the Mass unincation of the Mass are calculated using mass relations and branching ratios in the Minimal Supergravity scenario. Results are presented in Fig. 1 of their paper as lower bounds on $\sigma(p\overline{p} \to \widetilde{\chi}^{\pm}\widetilde{\chi}^{0}_{2}) \times B(3\ell)$. Limits range from 0.66 pb $(m_{\widetilde{\chi}^{\pm}_{1}}=45 \text{ GeV})$ to 0.10 pb $(m_{\widetilde{\chi}^{\pm}_{1}}=124 \text{ GeV})$.
- 80 ABREU 98 uses data at \sqrt{s} =161 and 172 GeV. The universal scalar mass at the GUT scale is assumed to compute branching fractions and mass spectrum, and the radiative decay of the lightest neutralino into gravitino is assumed. The limit is for $\Delta m > 10$ GeV, at $4 < m_{\widetilde{\nu}} < 100$ GeV, and $4 < m_{\widetilde{\nu}} < 100$ GeV, and $4 < m_{\widetilde{\nu}} < 100$ GeV and $4 < m_{\widetilde{\nu}} < 100$ GeV. and $4 < m_{\widetilde{\nu}} < 100$ GeV. The second of the limit is for $2 < m_{\widetilde{\nu}} < 100$ GeV. The second of the limit is $2 < m_{\widetilde{\nu}} < 100$ GeV. The second of the limit is $2 < m_{\widetilde{\nu}} < 100$ GeV. The second of the limit is $2 < m_{\widetilde{\nu}} < 100$ GeV. The second of the limit is $2 < m_{\widetilde{\nu}} < 100$ GeV. The second of the limit is $2 < m_{\widetilde{\nu}} < 100$ GeV. The second of the limit is $2 < m_{\widetilde{\nu}} < 100$ GeV. The second of the limit is $2 < m_{\widetilde{\nu}} < 100$ GeV. The second of the limit is $2 < m_{\widetilde{\nu}} < 100$ GeV. The second of the limit is $2 < m_{\widetilde{\nu}} < 100$ GeV. The second of the limit is $2 < m_{\widetilde{\nu}} < 100$ GeV. The second of the limit is $2 < m_{\widetilde{\nu}} < 100$ GeV. The second of the limit is $2 < m_{\widetilde{\nu}} < 100$ GeV. The second of the limit is $2 < m_{\widetilde{\nu}} < 100$ GeV. The second of the limit is $2 < m_{\widetilde{\nu}} < 100$ GeV. The second of the limit is $2 < m_{\widetilde{\nu}} < 100$ GeV. The second of the limit is $2 < m_{\widetilde{\nu}} < 100$ GeV. The second of the limit is $2 < m_{\widetilde{\nu}} < 100$ GeV. The second of the limit is $2 < m_{\widetilde{\nu}} < 100$ GeV. The second of the limit is $2 < m_{\widetilde{\nu}} < 100$ GeV. The second of the limit is $2 < m_{\widetilde{\nu}} < 100$ GeV. The second of the limit is $2 < m_{\widetilde{\nu}} < 100$ GeV. The second of the limit is $2 < m_{\widetilde{\nu}} < 100$ GeV. The second of the limit is $2 < m_{\widetilde{\nu}} < 100$ GeV. The second of the limit is $2 < m_{\widetilde{\nu}} < 100$ GeV. The second of the limit is $2 < m_{\widetilde{\nu}} < 100$ GeV. The second of the limit is $2 < m_{\widetilde{\nu}} < 100$ GeV. The second of the limit is $2 < m_{\widetilde{\nu}} < 100$ GeV. The second of the limit is $2 < m_{\widetilde{\nu}} < 100$ GeV. The second of the limit is $2 < m_{\widetilde{\nu}} < 100$ GeV. The second of the limit is $2 < m_{\widetilde{\nu}$
- 81 ACKERSTAFF 98K looked for dilepton+ E_T final states at \sqrt{s} =130-172 GeV. Limits on $\sigma(e^+e^- \to \widetilde{\chi}_1^+\widetilde{\chi}_1^-) \times B^2(\ell)$, with B(ℓ)=B($\chi^+ \to \ell^+ \nu_\ell \chi_1^0$) (B(ℓ)=B($\chi^+ \to \ell^+ \widetilde{\nu}_\ell$)), are given in Fig. 16 (Fig. 17).
- 82 CARENA 97 studied the constraints on chargino and sneutrino masses from muon g-2. The bound can be important for large $\tan \beta$.
- 83 KALINOWSKI 97 studies the constraints on the chargino-neutralino parameter space from limits on $\Gamma(W \to \widetilde{\chi}_1^\pm \widetilde{\chi}_1^0)$ achievable at LEP2. This is relevant when $\widetilde{\chi}_1^\pm$ is "invisible," i.e., if $\widetilde{\chi}_1^\pm$ dominantly decays into $\widetilde{\nu}_\ell \ell^\pm$ with little energy for the lepton. Small otherwise allowed regions could be excluded.
- 84 ABE 96K looked for tripleton events from chargino-neutralino production. The bound on $m_{\widetilde{\chi}^{\pm}_1}$ can reach up to 47 GeV for specific choices of parameters. The limits on the combined production cross section times 3-lepton branching ratios range between 1.4 and 0.4 pb, for $45 < m_{\widetilde{\chi}^{\pm}_1} (\text{GeV}) < 100$. See the paper for more details on the parameter dependence of the results.
- 85 ACKERSTAFF 96c assumes the dominance of off-shell W-exchange in the chargino decay and applies for $\Delta m > 10$ GeV in the region of parameter space defined by: $M_2 < 1500$ GeV, $|\mu| < 500$ GeV and $\tan \beta > 1.5$. The bound is for the smallest $\tilde{\ell}, \tilde{\nu}$ mass allowed by LEP, with the efficiency for $\tilde{\chi}^{\pm} \rightarrow \tilde{\nu} \nu$ decays set to zero. The limit improves to 78.5 GeV for $m_0 = 1$ TeV. Data taken at $\sqrt{s} = 130,136$, and 161 GeV.
- ⁸⁶ ALEXANDER 96J assumes a universal scalar mass m_0 at the grand unification scale. The bound is for the smallest possible value of m_0 alowed by the LEP $\tilde{\ell},\,\tilde{\nu}$ mass limits. 1.5 <tan/ β <35. Branching fractions are calculated using minimal supergravity. The bound is for $\Delta(m)$ >10 GeV. The limit improves to 65.4 GeV for m_0 =1 TeV. Data taken at $\sqrt{s}=130$ -136 GeV.
- 87 BUSKULIC 96K assumes the dominance of off-shell W-exchange in the chargino decay and applies throughout the (M_2,μ) plane for 1.41 <tan β <35 provided either $m_{\widetilde{\nu}} > m_{\widetilde{\chi}\pm}$ and $m_{\widetilde{\chi}\pm} m_{\widetilde{\chi}0}^{2} >$ 4 GeV, or $m_{\widetilde{\chi}\pm} m_{\widetilde{\nu}} >$ 4 GeV. The limit improves to 67.8 GeV for
 - a pure gaugino $\vec{\hat{\chi}}^{\pm}$ and $m_{\widetilde{\nu}} > 200$ GeV. Data taken at $\sqrt{s} = 130$ –136 GeV.
- 88 BUSKULIC 960 searched for pair-produced charginos which decay into $\widetilde{\chi}^0_1$ with either leptons or hadrons, where $\widetilde{\chi}^0_1$ further decays leptonically via *R*-parity violating interactions. See their Fig. 5 for excluded region in the neutralino-chargino parameter space. Data taken at $\sqrt{s}=130\text{-}136$ GeV.
- ⁸⁹ ADRIANI 93M limit from $\Delta\Gamma(Z)$ < 35.1 MeV. For pure wino, the limit is 45.5 GeV.
- ⁹⁰ DECAMP 92 limit is for a general $\tilde{\chi}^{\pm}$ (all contents).
- 91 HIDAKA 91 limit obtained from LEP and preliminary CDF limits on the gluino mass (as analyzed in BAER 91).
- 92 ABREU 90G limit is for a general $\widetilde{\chi}^{\pm}$. They assume charginos have a three-body decay such as $\ell^{+}\nu\widetilde{\gamma}$.
- 93 AKESSON 908 assume $\widetilde{W}\to e\widetilde{\nu}$ with B > 20% and $m_{\widetilde{\nu}}=$ 0. The limit disappears if $m_{\widetilde{\nu}}>$ 30 GeV.
- 94 AKRAWY 90D assume charginos have three-body decay such as $\ell^+ \nu \widetilde{\gamma}$ (i.e. $m_{\widetilde{\nu}} > m_{\widetilde{\chi}+}$). A two-body decay, $\widetilde{\chi}^+ \to \ell \widetilde{\nu}$ would have been seen by their search for acoplanar leptons. The result is independent of the hadronic branching ratio. They search for acoplanar electromagnetic clusters and quark jets.
- electromagnetic cubsters and quain jets. 95 BARKLOW 90 assume 100% $\widetilde{W} \to W^* \widetilde{\chi}_1^0$. Valid up to $m_{\widetilde{\chi}_1^0} \lesssim [m_{\widetilde{W}} 5 \text{ GeV}]$.
- ⁹⁶ BARKLOW 90 assume 100% $\widetilde{H} \to H^* \widetilde{\chi}_1^0$. Valid up to $m_{\widetilde{\chi}_1^0} \lesssim [m_{\widetilde{H}} 8 \text{ GeV}]$.
- 97 DECAMP 90C assume charginos have three-body decay such as $\ell^+ \nu \widetilde{\gamma}$ (i.e. $m_{\widetilde{\nu}} > m_{\widetilde{\chi}^+}$), and branching ratio to each lepton is 11%. They search for acoplanar dimuons, dielectrons, and μe events. Limit valid for $m_{\widetilde{\gamma}} <$ 28 GeV.
- 98 ADACHI 89 assume only single photon annihilation in the production. The limit applies for arbitrary decay branching ratios with $\mathrm{B}(\widetilde{\chi} \to e \nu \widetilde{\gamma}) + \mathrm{B}(\widetilde{\chi} \to \mu \nu \widetilde{\gamma}) + \mathrm{B}(\widetilde{\chi} \to \nu \widetilde{\gamma}) + \mathrm{B}(\widetilde{\chi} \to \mu \nu \widetilde{\gamma$
- 99 ADEVA 898 assume for $\ell \nu \tilde{\gamma}$ ($\ell \tilde{\nu}$) mode that B(e) = B(μ) = B(τ) = 11% (33%) and search for acoplanar dimuons, dielectrons, and μe events. Also assume $m_{\tilde{\gamma}} <$ 20 GeV and for $\ell \tilde{\nu}$ mode that $m_{\tilde{\nu}} =$ 10 GeV.
- 100 ANSARI 87D looks for high p_T e^+e^- pair with large missing p_T at the CERN $p\widetilde{p}$ collider at $E_{\rm CM}=546-630$ GeV. The limit is valid when $m_{\widetilde{\nu}}\lesssim 20$ GeV, ${\sf B}(\widetilde{W}\to e\widetilde{\nu}_e)=1/3$, and ${\sf B}(Z\to \widetilde{W}^+\widetilde{W}^-)$ is calculated by assuming pure gaugino eigenstate. See their Fig. 3(b) for excluded region in the $m_{\widetilde{W}}-m_{\widetilde{\nu}}$ plane.

Supersymmetric Particle Searches

Long-lived \tilde{X}^{\pm}	(Chargino)	MASS	LIMITS
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Limits on charginos which leave the detector before decaying. VALUE (GeV) CL% DOCUMENT ID TECN • • • We do not use the following data for averages, fits, limits, etc. • • • 101 ABREU >80 95 970 DLPH 102 BARATE >83 95 97k ALEP >45 ABREU 90G DLPH 95 >28.2 **ADACHI** 90c TOPZ 101 ABREU 97D bound applies only to masses above 45 GeV. Data collected in e^+ collisions at \sqrt{s} =130–172 GeV. The limit improves to 84 GeV for $m_{\widetilde{\nu}} >$ 200 GeV. 102 BARATE 97k uses e^+e^- data collected at $\sqrt{s}=130$ –172 GeV. Limit valid for $\tan\beta=\sqrt{2}$ and $m_{\widetilde{\nu}}>100$ GeV. The limit improves to 86 GeV for $m_{\widetilde{\nu}}>250$ GeV.

ν̃ (Sneutrino) MASS LIMIT

The limit depends on the number, $N(\tilde{\nu})$, of sneutrinos assumed to be degenerate in mass. Only $\tilde{\nu}_{\ell}$ (not $\tilde{\nu}_{R}$) exist. It is possible that $\tilde{\nu}$ could be the lightest supersymmetric particle (LSP).

VALUE (GeV)	<u>CL%</u>	DOCUMENT ID	TECN	COMMENT	_
> 43.1	95	103 ELLIS	968 RVUE	$\Gamma(Z \to \text{invisible}); N(\widetilde{\nu})=3$	٦
> 41.8	95	¹⁰⁴ ADRIANI	93M L3	$\Gamma(Z \rightarrow \text{invisible}); N(\tilde{\nu})=3$	•
> 37.1	95	104 ADRIANI	93M L3	$\Gamma(Z \rightarrow \text{invisible}); N(\widetilde{\nu})=1$	
> 41	95	105 DECAMP	92 ALEP	$\Gamma(Z \rightarrow \text{invisible}); N(\tilde{\nu})=3$	
> 36	95	ABREU	91F DLPH	$\Gamma(Z \rightarrow \text{Invisible}); N(\widetilde{\nu})=1$	
> 32	95			$\Gamma(Z)$; $N(\tilde{\nu}) \approx 1$	
> 31.2	95	107 ALEXANDER	91F OPAL	$\Gamma(Z \rightarrow \text{invisible}); N(\tilde{\nu})=1$	
• • • We do	not use	the following data for	or averages,	flts, limits, etc. • • •	
≠ m ₇	95	108 ACCIARRI	97u L3	R-parity violation	ı
none 125-180	95	108 ACCIARRI	97u L3	R-parity violation	- [
		109 CARENA	97 THEO	$g_{\mu} - 2$	ı
> 46.0	95	110 BUSKULIC	95E ALEP		
none 20~25000)	111 BECK	94 COSM	Stable $\tilde{\nu}$, dark matter	
<600		112 FALK	94 COSM	ν LSP, cosmic abundance	
none 3-90	90	113 SATO		Stable $\tilde{\nu}_e$ or $\tilde{\nu}_\mu$,	
none 4-90	90	113 SATO		dark matter Stable $\tilde{\nu}$, dark matter	

90i L3 $^{103}\, ext{ELLIS}$ 968 uses combined LEP data available in the Summer 1995, which constrain the number of neutrino species to N_{ν} =2.991 \pm 0.016.

90i L3

 $\Gamma(Z \rightarrow \text{Invisible}); N(\tilde{\nu})=1$

 $\Gamma(Z \rightarrow \text{invisible}); N(\widetilde{\nu})=3$

104 ADRIANI 93M limit from $\Delta\Gamma(Z)$ (invisible) < 16.2 MeV.

114 ADEVA

114 ADEVA

95

95

> 31.4

> 39.4

- 105 DECAMP 92 limit is from $\Gamma({\rm invisible})/\Gamma(\ell\ell)=5.91\pm0.15$ (N $_{\nu}=2.97\pm0.07$).
- 106 ABREU 91F limit (>32 GeV) is independent of sneutrino decay mode.
- 107 ALEXANDER 91F limit is for one species of $\tilde{\nu}$ and is derived from $\Gamma(\text{invisible, new})/\Gamma(\ell\ell)$
- < 0.38. 108 ACCIARRI 970 studied the effect of the s-channel tau-sneutrino exchange in $e^+e^$ e⁺e⁻ at $\sqrt{s}=m_Z$ and $\sqrt{s}=130-172$ GeV, via the *R*-parity violating coupling $\lambda_{131} L_1 L_1 e_1$. The limits quoted here hold for $\lambda_{131}>0.05$. Similar limits were studied in e⁺e⁻ $\rightarrow \mu^+\mu^-$ together with $\lambda_{232} L_2 L_3 e_2$ coupling.
- 109 CARENA 97 studled the constraints on chargino and sneutrino masses from muon g = 2. The bound can be important for large tanβ.
- 110 BUSKULIC 95E looked for $Z \to \widetilde{\nu} \overline{\widetilde{\nu}}$, where $\widetilde{\nu} \to \nu \chi_1^0$ and χ_1^0 decays via *R*-parity
- violating interactions into two leptons and a neutrino. 111 BECK 94 limit can be inferred from limit on Dirac neutrino using $\sigma(\tilde{\nu})=4\sigma(\nu)$. Also private communication with H.V. Klapdor-Kleingrothaus.
- ¹¹²FALK 94 puts an upper bound on $m_{\widetilde{
 u}}$ when $\widetilde{
 u}$ is LSP by requiring its relic density does ot overclose the Universe.
- 113 SATO 91 search for high-energy neutrinos from the sun produced by annihilation of sneutrinos in the sun. Sneutrinos are assumed to be stable and to constitute dark matter in our galaxy. SATO 91 follow the analysis of NG 87, OLIVE 88, and GAISSER 86.
- $^{114} \, \rm ADEVA$ 90: limit is from $\Delta \textit{N}_{\nu}~<~0.19$.

ẽ (Selectron) MASS LIMIT

Limits assume $m_{\widetilde{e}_l}=m_{\widetilde{e}_R}$ unless otherwise stated. When the assumption of a universal scalar mass parameter m_0 for \tilde{e}_l and \tilde{e}_R is mentioned, the relation between $m_{\widetilde{e}_l}$ and $m_{\widetilde{e}_l}$ can be found in the "Note on Supersymmetry."

In the Listings below, we use $\Delta m = m_{\widetilde{e}} - m_{\widetilde{\chi}_1^0}$.

<u>VA</u>	LUE (GeV)	CL%	DOCUMENT ID	<u>TECN</u>	COMMENT
>	56	95 1	¹⁵ ACCIARRI	98F L3	$\Delta m > 5$ GeV, $\tilde{e}_R^+ \tilde{e}_R^-$, $\tan \beta > 1.41$
>	58.0	95 1	¹⁶ ACKERSTAFF	98K OPAL	$\Delta(m) > 5$ GeV, $\tilde{e}_R^+ \tilde{e}_R^-$
>	55	95 1	¹⁷ ACKERSTAFF	97H OPAL	$\Delta(m) > 5$ GeV, $\tilde{e}_R^+ \tilde{e}_R^-$
>	58	95 1	¹⁸ BARATE	97N ALEP	$\Delta(m) > 3 \text{ GeV}, \ \tilde{e}_R^+ \tilde{e}_R^-$
•	 We do not use the 	following	g data for averages	, fits, limits,	etc. • • •
<- >	35		¹⁹ BARATE	97N RVUE	\tilde{e}_R , $\Gamma^{\text{inv}}(Z)$
>	57		²⁰ ABREU	960 DLPH	$\Delta(m) > 5 \text{ GeV}, \tilde{e}^+ \tilde{e}^-$
>	50	95 1	²¹ ACCIARRI	96F L3	$\Delta(m) > 5 \text{ GeV}, \ \tilde{e}^+ \tilde{e}^-$
. >	63	95 ¹	²² AID	960 H1	$m_{\widetilde{q}} = m_{\widetilde{e}}, m_{\widetilde{\chi}_{i}^{0}} = 35 \text{ GeV}$
>	50	95 1	²³ BUSKULIC	96K ALEP	$\Delta(m) > 10 \text{ GeV}, \ \tilde{e}_R^+ \tilde{e}_R^-, \ \mu = 1 \text{ TeV}$
>	63	90 1	²⁴ sugimoto	96 AMY	$m_{\widetilde{\gamma}} < 5 \text{ GeV}, \gamma \widetilde{\gamma} \widetilde{\gamma}$

> 77	90		SUGIMOTO	96	RVUE	$m_{\widetilde{\gamma}}$ <5 GeV, $\gamma \widetilde{\gamma} \widetilde{\gamma}$
> 46	90	126	ABE	95A	TOPZ	$m_{\widetilde{\gamma}} < 5 \text{ GeV}, \gamma \widetilde{\gamma} \widetilde{\gamma}$
> 45.6	95	127	BUSKULIC	95E	ALEP	e → evel
> 51.9	90		HOSODA	94	VNS	$m_{\widetilde{\gamma}}=0; \gamma \widetilde{\gamma} \widetilde{\gamma}$
> 45	95	128	ADRIANI	93м	L3	$\Delta(m) > 5 \text{ GeV}, \ \tilde{e}_R^+ \tilde{e}_R^-$
> 45	95	129	DECAMP	92	ALEP	$\Delta(m) > 4 \text{ GeV}, \ \tilde{e}_{R}^{+} \tilde{e}_{R}^{-}$
> 42	95		ABREU	90G	DLPH	m_{\approx} < 40 GeV; $\tilde{e}^{+}\tilde{e}^{-}$
> 38	95	130	AKESSON	90B	UA2	$m_{\widetilde{\gamma}} = 0; p\overline{p} \rightarrow ZX$
						$(Z \rightarrow \tilde{e}^+\tilde{e}^-)$
> 43.4	95	131	AKRAWY	90D	OPAL	$m_{\widetilde{\gamma}} < 30 \text{ GeV}; \ \widetilde{e}^{+} \widetilde{e}^{-}$
> 38.1	90	132	BAER	90	RVUE	\tilde{e}_L ; $\Gamma(Z)$; $\tan \beta > 1$
> 43.5	95	133	DECAMP	90C	ALEP	$m_{\widetilde{\gamma}}$ < 36 GeV; $\widetilde{e}^+\widetilde{e}^-$
>830			GRIFOLS	90	ASTR	$m_{\widetilde{\gamma}}^{'} < 1 \; {\sf MeV}$
> 29.9	95		SAKAI	90	AMY	$m_{\widetilde{\gamma}}^{'} < 20$ GeV; $\widetilde{e}^{+}\widetilde{e}^{-}$
> 29	95		TAKETANI	90	VNS	$m_{\widetilde{\gamma}} < 25 \text{ GeV}; \widetilde{e}^+\widetilde{e}^-$
> 60		134	ZHUKOVSKII	90	ASTR	$m_{\widetilde{\gamma}} = 0$
> 28	95	135	ADACHI	89	TOPZ	$m_{\widetilde{\gamma}} \lesssim 0.85 m_{\widetilde{e}}; \ \widetilde{e}^+ \widetilde{e}^-$
> 41	95	136	ADEVA	89B	L3	$m_{\widetilde{\gamma}}$ < 20 GeV; $\widetilde{e}^+\widetilde{e}^-$
> 32	90	137	ALBAJAR	89	UA1	$\rho \overline{p}' \rightarrow W^{\pm} X$
						$(W^{\pm} \rightarrow \tilde{e}_L \tilde{\nu})$
		120				$(\tilde{e}_L \rightarrow e\tilde{\gamma})$
> 14	90	140	ALBAJAR HEARTY		UA1	$Z \rightarrow \tilde{e}^+\tilde{e}^-$
> 53		,			ASP	$m_{\widetilde{\gamma}}=0; \gamma \widetilde{\gamma} \widetilde{\gamma}$
> 50	95		HEARTY		ASP	$m_{\widetilde{\gamma}} < 5 \text{ GeV}; \gamma \widetilde{\gamma} \widetilde{\gamma}$
> 35	95	142	HEARTY	89	ASP	$m_{\widetilde{\gamma}} < 10 \text{ GeV}; \gamma \widetilde{\gamma} \widetilde{\gamma}$
> 51.5		,142	BEHREND		CELL	$m_{\widetilde{\gamma}}=0$ GeV; $\gamma\widetilde{\gamma}\widetilde{\gamma}$
> 48	90		BEHREND	88B	CELL	$m_{\widetilde{\gamma}} < 5$ GeV; $\gamma \widetilde{\gamma} \widetilde{\gamma}$

 115 ACCIARRI 98F looked for acoplanar dielectron+ E_T final states at \sqrt{s} =130–172 GeV. The limit assumes $\mu=-200$ GeV, and zero efficiecny for decays other than $\tilde{e}_R \to e \tilde{\chi}_1^0$. See their Fig. 6 for the dependence of the limit on Δm .

116 ACKERSTAFF 98K looked for dielectron+ E_T final states at \sqrt{s} =130–172 GeV. The limit assumes $\mu < -100$ GeV, aneta = 35, and zero efficiency for decays other than $\tilde{e}_R \to$ $e\widetilde{\chi}_1^0$. The limit improves to 66.5 GeV for $\tan\!eta\!=\!1.5$.

 117 ACKERSTAFF 97H searched for acoplanar e^+e^- , assuming the MSSM with universal scalar mass and $an\!eta\!=\!1.5$ but conservatively did not take the possible $ilde{e}_L$ production into account. The limit improves to 68 GeV for the lightest allowed $\widetilde{\chi}_1^0$, while it disappears for $\Delta(m) < 3$ GeV. The study includes data from e^+e^- collisions at \sqrt{s} =161 GeV, as well as 130–136 GeV (ALEXANDER 97B).

118 BARATE 97N uses e^+e^- data collected at \sqrt{s} =161 and 172 GeV. The limit is for $\tan\beta$ =2. It improves to 75 GeV if $\Delta(m)$ >35 GeV.

BARATE 97N limit from ALCARAZ 96 limit on Z Invisible-decay width and N_{ν} =3, independent of decay mode. Limit improves to 41 GeV for degenerate right-handed

120 ABREU 960 bound assumes $|\mu|>$ 200 GeV. The limit on $m_{\widetilde{e}_R}$ obtained by assuming a heavy \tilde{e}_L reduces to below 48 GeV. Data taken at $\sqrt{s} = 130-136$ GeV.

121 ACCIARRI 96F searched for acoplanar electron pairs. The limit is on $m_{\widetilde{e}_R}$, under the assumption of a universal scalar mass in the range 0 < m < 100 GeV. It assumes 0 < M < 200 GeV, $-200 < \mu < 0$ GeV, $\tan \beta = 1.5$. The corresponding limit for for $m_{\widetilde{e}_L}$ is 64 GeV. The bound on $m_{\widetilde{e}_R}$ ($m_{\widetilde{e}_L}$) improves to 58 GeV (70 GeV) for $m_{\widetilde{\chi}_1^0} = 0$. Data taken at $\sqrt{s} = 130-136$ GeV.

122 AID 96C used electron+jet events with missing energy and momentum to look for $eq \rightarrow \tilde{eq}$ via neutralino exchange with decays into $(e\tilde{\chi}_1^0)(q\tilde{\chi}_1^0)$. See the paper for dependences

123 BUSKULIC 1 96K searched for acoplanar electron pairs. The bound disappears for $\Delta(m)$ <10 GeV, while it improves to 59 GeV for $m_{\widetilde{\chi}0}^{-}$ =0. If μ is small and the LSP

hlggsino-dominated, no bound beyond $m_Z/2$ exists. Data taken at $\sqrt{\tilde{s}}=130$ –136 GeV. 124 SUGIMOTO 96 looked for single photon production from e^+e^- annihilation at \sqrt{s} = 57.8 GeV. The lower bound improves to 65.5 GeV for a massless photino.

125 SUGIMOTO 96 combined FORD 86, BEHREND 88B, HEARTY 89, HOSODA 94, ABE 95A, and SUGIMOTO 96 results. The lower bound improves to 79.3 GeV for a massless photino.

 126 ABE 95A looked for single photon production from e^+e^- annihilation at $\sqrt{s}=$ 58 GeV. The lower bound improves to 47.2 GeV for a massless photino.

127 BUSKULIC 95E looked for $Z \to \overline{e_R^+} \overline{e_R^-}$ where $\overline{e_R} \to e \chi_1^0$ and χ_1^0 decays via R-parity violating interactions into two leptons and a neutrino.

128 ADRIANI 93M used acolinear di-lepton events.

129 DECAMP 92 limit improves for equal masses. They looked for acoplanar electrons.

 $^{130}\,\mathrm{AKESSON}$ 90B assume $m_{\widetilde{\gamma}}=0.$ Very similar limits hold for $m_{\widetilde{\gamma}}\lesssim$ 20 GeV.

131 AKRAWY 90D look for acoplanar electrons. For $m_{\widetilde{e}_L} \gg m_{\widetilde{e}_R}$, limit is 41.5 GeV, for m_{\approx} < 30 GeV.

132 BAER 90 limit from $\Delta\Gamma(Z)$ (nonhadronic) < 53 MeV. Independent of decay modes. Mininal supersymmetry and $\tan\beta>1$ assumed.

133 DECAMP 90C look for acoplanar electrons. For $m_{\widetilde{e}_L} \gg m_{\widetilde{e}_R}$ limit is 42 GeV, for $m_{\widetilde{\gamma}}$ < 33 GeV.

134 ZHUKOVSKII 90 set limit by saying the luminosity of a magnetized neutron star due to massiess photino emission by electrons be small compared with its neutrino luminosity.

135 ADACHI 89 assume only photon and photino exchange and $m_{\widetilde{e}_L}=m_{\widetilde{e}_R}$. The limit for the nondegenerate case is 26 GeV.

136 ADEVA 89B look for acoplanar electrons.

- 137 ALBAJAR 89 limit applies for \tilde{e}_L when $m_{\tilde{e}_L}=m_{\tilde{\nu}_L}$ and $m_{\tilde{\gamma}}=0$. See their Fig. 55 for the 90% CL excluded region in the $m_{\widetilde e_L}-m_{\widetilde
 u_L}$ plane. For $m_{\widetilde
 u}=m_{\widetilde \gamma}=$ 0, limit is 50 138 ${\mbox{GeV}}$. ALBAJAR 89 assume $m_{\widetilde{\gamma}}=0.$
- 139 HEARTY 89 assume $m_{\widetilde{\gamma}}^{'}=$ 0. The limit is very sensitive to $m_{\widetilde{\gamma}}$; no limit can be placed for $m_{\widetilde{\gamma}} \gtrsim$ 13 GeV.
- $^{140}\mathrm{The}$ limit is reduced to 43 GeV if only one \tilde{e} state is produced (\tilde{e}_L or \tilde{e}_R very heavy).
- 141 BEHREND 888 limits assume pure photino eigenstate and $m_{\widetilde{e}_L}=m_{\widetilde{e}_R}$. 142 The 95% CL limit for BEHREND 888 is 47.5 GeV for $m_{\widetilde{\gamma}}=0$. The limit for $m_{\widetilde{e}_L}\gg$ $m_{\widetilde{e}_R}$ is 40 GeV at 90% CL.

$\tilde{\mu}$ (Smuon) MASS LIMIT

Limits assume $m_{\widetilde{\mu}_L} = m_{\widetilde{\mu}_R}$ unless otherwise stated.

In the Listings below, we use $\Delta(m)=m_{\widetilde{\mu}}-m_{\widetilde{\chi}0}$. When limits on $m_{\widetilde{\mu}_R}$ are quoted, it is understood that limits on $m_{\widetilde{\mu}_L}$ are usually at least as strong.

VALUE (GeV)	CL%	DOCUMENT ID TE	CN COMMENT
>55	95	143 ACCIARRI 98F L3	$\Delta m > 5$ GeV, $\tilde{\mu}_R^+ \tilde{\mu}_R^-$
>55.6	95	144 ACKERSTAFF 98K OF	
>59	95	145 BARATE 97N AL	
• • • We do not use th	e follow	ng data for averages, fits, ili	mits, etc. • • •
>51	95	146 ACKERSTAFF 97H OF	
>35	95	147 BARATE 97N RV	$IUE \ \widetilde{\mu}_R, \Gamma^{lnv}(Z)$
>51	95	148 ABREU 960 DI	LPH $\Delta(m) > 5$ GeV, $\tilde{\mu}^+ \tilde{\mu}^-$
>45.6	95	149 BUSKULIC 95E AL	
>45	95	ADRIANI 93M L3	$m_{\widetilde{\chi}_i^0}$ <40 GeV, $\widetilde{\mu}_R^+\widetilde{\mu}_R^-$
>45	95	DECAMP 92 AL	EP $m_{\widetilde{\chi}_{0}^{0}}$ <41 GeV, $\widetilde{\mu}_{R}^{+}\widetilde{\mu}_{R}^{-}$
>36	95	ABREU 906 DI	LPH $m_{\widetilde{\gamma}}$ < 33 GeV; $\widetilde{\mu}^+\widetilde{\mu}^-$
>43	95	150 AKRAWY 90D OF	PAL $m_{\widetilde{\gamma}} < 30 \text{ GeV}; \widetilde{\mu}^+ \widetilde{\mu}^-$
>38.1	90	151 BAER 90 R\	/UE $\tilde{\mu}_L$; $\Gamma(Z)$; $\tan \beta > 1$
>42.6	95	152 DECAMP 90c Al	EP $m_{\widetilde{\gamma}} < 34$ GeV; $\widetilde{\mu}^+ \widetilde{\mu}^-$
>27	95	SAKAI 90 AI	MY $m_{\widetilde{\gamma}} < 18$ GeV; $\widetilde{\mu}^+ \widetilde{\mu}^-$
>24.5	95	TAKETANI 90 VI	NS $m_{\widetilde{\gamma}} < 15$ GeV; $\widetilde{\mu}^+ \widetilde{\mu}^-$
>24.5	95		OPZ $m_{\widetilde{\gamma}} \lesssim 0.8 m_{\widetilde{\mu}}$; $\widetilde{\mu}^+ \widetilde{\mu}^-$
>41	95	154 ADEVA 898 L3	$m_{\widetilde{\gamma}} <$ 20 GeV; $\widetilde{\mu}^+\widetilde{\mu}^-$

 143 ACCIARRI 98F looked for dimuon+ E_T final states at \sqrt{s} =130–172 GeV. The limit assumes $\mu=-$ 200 GeV, and zero efficiecny for decays other than $\widetilde{\mu}_R \to ~\mu \widetilde{\chi}_1^0$. See their Fig. 6 for the dependence of the limit on Δm .

144 ACKERSTAFF 98k looked for dimuon+ E_T final states at \sqrt{s} =130–172 GeV. The limit assumes $\mu < -100$ GeV, $\tan \beta$ =1.5, and zero efficiency for decays other than $\widetilde{\mu}_R \to$ $\mu\widetilde{\chi}_1^0$. The limit improves to 62.7 GeV for B($\widetilde{\mu}_R \to \mu\widetilde{\chi}_1^0$)=1.

¹⁴⁵BARATE 97N uses e^+e^- data collected at \sqrt{s} =161 and 172 GeV. The limit assumes $B(\widetilde{\mu} \to \mu \widetilde{\chi}_1^0) = 1.$

 $^{146}\,\mathrm{ACKERSTAFF}$ 97H limit is for $m_{\widetilde{\chi}_1^0}$ >12 GeV allowed by their chargino, neutralino search, and for $an\!eta\geq 1.5$ and $|\mu|>200$ GeV. The study includes data from e^+e^-

collisions at \sqrt{s} =161 GeV, as well as at 130-136 GeV (ALEXANDER 97B). ¹⁴⁷BARATE 97N limit from ALCARAZ 96 limit on Z invisible-decay width and N_{ν} =3, independent of decay mode. Limit improves to 41 GeV for degenerate right-handed

¹⁴⁸ Data taken at $\sqrt{s} = 130-136$ GeV.

149 BUSKULIC 95E looked for $Z \to \widetilde{\mu}_R^+ \widetilde{\mu}_R^-$, where $\widetilde{\mu}_R \to \mu \chi_1^0$ and χ_1^0 decays via *R*-parity violating interactions into two leptons and a neutrino.

150 AKRAWY 90D look for acoplanar muons. For $m_{\widetilde{\mu}_L} \gg m_{\widetilde{\mu}_R}$, limit is 41.0 GeV, for m_{\approx} < 30 GeV.

151 BAER 90 limit from $\Delta\Gamma(Z)$ (nonhadronic) < 53 MeV. Independent of decay modes. Mininal supersymmetry and $\tan\beta>1$ assumed. 152 DECAMP 90C look for acoplanar muons. For $m_{\widetilde{\mu}_L}\gg m_{\widetilde{\mu}_R}$ limit is 40 GeV, for $m_{\widetilde{\gamma}}<$

153 GeV. 153 ADACHI 89 assume only photon exchange, which gives a conservative limit. $m_{\widetilde{\mu}_L}$ $m_{\widetilde{\mu}_R}$ assumed. The limit for nondegenerate case is 22 GeV.

154 ADEVA 898 look for acoplanar muons.

$\tilde{\tau}$ (Stau) MASS LIMIT

Limits assume $m_{\widetilde{ au}_L} = m_{\widetilde{ au}_R}$ unless otherwise stated.

In the Listings below, we use $\Delta(m)=m_{\widetilde{\tau}}-m_{\widetilde{\chi}_{\bullet}^0}$. The limits depend on the potentially large mixing angle of the lightest mass eigenstate $\tilde{\tau}_1 = \tilde{\tau}_R \sin\!\theta_{ au} + \tilde{\tau}_L \sin\!\theta_{ au}$. The coupling to the Z vanishes for $\theta_{\tau}=0.82$.

VALUE (GeV)	<u>CL%</u>	DOCUMENT ID	TECN	COMMENT	
>53	95	155 BARATE	97N ALEP	$\Delta(m) > 30 \text{ GeV},$	
>47	95	155 BARATE	97N ALEP	$\theta_{\tau} = \pi/2$ $\Delta(m) > 30 \text{ GeV},$ $\theta_{\tau} = 0.82$	ı
>35	95	156 BARATE	97N RVUE	$\theta_{\tau} = 0.82$ $\tilde{\tau}_{R}, \Gamma^{\text{inv}}(Z)$	Į
>44	95	¹⁵⁷ ADRIANI	93M L3	$m_{\widetilde{\chi}^0_1}$ <38 GeV, $\widetilde{\tau}^+\widetilde{\tau}^-$	
>45	95	158 DECAMP	92 ALEP	$m_{\widetilde{\chi}_0^0}^{-1}$ <38 GeV, $\widetilde{\tau}^+\widetilde{\tau}^-$	
>43.0	95	159 AKRAWY	90D OPAL	$m_{\widetilde{\gamma}}^{-1}$ < 23 GeV; $\widetilde{\tau}^+\widetilde{\tau}^-$	

 ● We do not use the following data for averages, fits, limits, etc. 								
>45.6	95	160 BUSKULIC	95E ALEP	$\tilde{\tau} \rightarrow \tau \nu \ell \bar{\ell}'$				
>35	95	ABREU	90G DLPH	$m_{\widetilde{\gamma}} <$ 25 GeV; $\widetilde{\tau}^+\widetilde{\tau}^-$				
>38.1	90	161 BAER	90 RVUE	$\tilde{\tau}_L$; $\Gamma(Z)$; $\tan \beta > 1$				
>40.4	95	162 DECAMP	90C ALEP	$m_{\widetilde{\gamma}} < 15 \text{ GeV}; \widetilde{\tau}^+ \widetilde{\tau}^-$				
>25	95	SAKAI	90 AMY	$m_{\widetilde{\gamma}} < 10$ GeV; $\widetilde{\tau}^+ \widetilde{\tau}^-$				
>25.5	95	TAKETANI	90 VNS	$m_{\widetilde{\gamma}} < 15 \text{ GeV}; \widetilde{\tau}^+ \widetilde{\tau}^-$				
>21.7	95	163 ADACHI		$m_{\widetilde{\gamma}}=0; \widetilde{\tau}^+ \widetilde{\tau}^-$				

¹⁵⁵BARATE 97N uses e^+e^- data collected at \sqrt{s} =161 and 172 GeV.

 156 BARATE 97N limit from ALCARAZ 96 limit on Z invisible-decay width and $N_{\nu}=3$, Independent of decay mode. Limit improves to 41 GeV for degenerate right-handed sleptons.

157 ADRIANI 93M limit is for $m_{\widetilde{\tau}_L} \gg m_{\widetilde{\tau}_R}$.

158 DECAMP 92 limit is for $m_{\widetilde{\tau}_L} \gg m_{\widetilde{\tau}_R}$; for equal masses the limit would improve. They looked for acoplanar particles.

159 AKRAWY 90D look for acoplanar particles. For $m_{\widetilde{ au}_L} \gg m_{\widetilde{ au}_R}$, limit is 41.0 GeV, for

160 BUSKULIC 95E looked for $Z \to \tau_R^+ \tau_R^-$, where $\tau_R \to \tau \chi_1^0$ and χ_1^0 decays via R-parity violating interactions into two leptons and a neutrino.

161 BAER 90 limit from $\Delta\Gamma(Z)$ (nonhadronlc) < 53 MeV. Independent of decay modes. Mininal supersymmetry and $\tan\beta > 1$ assumed.

¹⁶²DECAMP 90C look for acoplanar charged particle pairs. Limit is for $m_{\widetilde{\tau}_l}=m_{\widetilde{\tau}_R}$. For $m_{\widetilde{\gamma}} \leq$ 24 GeV, the limit is 37 GeV. For $m_{\widetilde{\tau}_L} \gg m_{\widetilde{\tau}_R}$ and $m_{\widetilde{\gamma}} <$ 15 GeV, the limit

is 33 GeV. 163 ADACHI 89 assume only photon exchange, which gives a conservative limit. $m_{\widetilde{\tau}_L}$ $m_{\widetilde{ au}_R}$ assumed.

Stable & (Slepton) MASS LIMIT

Limits on scalar leptons which leave detector before decaying. Limits from Z decays are independent of lepton flavor. Limits from continuum e^+e^- annihilation are also independent of flavor for smuons and staus. However, selectron limits from continuum e^+e^- annihilation depend on flavor because there is an additional contribution from neutralino exchange that in general yields stronger limits. All limits assume $m_{\widetilde{\ell}_I}=$ $m_{\widetilde{\ell}_R}$ unless otherwise stated.

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>65	95	164 ABREU	97D DLPH	$\tilde{\mu}_r$ or $\tilde{\tau}_R$
>67	95	165 BARATE	97K ALEP	$\tilde{\mu}_{R}$, $\tilde{\tau}_{R}$
• • • We do not	use the follow	ving data for averag	es, fits, limits,	etc. • • •
>40	95	ABREU	90G DLPH	
>26.3	95	ADACHI	90c TOPZ	$\tilde{\mu}$, $\tilde{\tau}$
>38.8	95	AKRAWY	900 OPAL	$\tilde{\ell}_R$
>27.1	95	¹⁶⁶ SAKAI	90 AMY	
>32.6	95	SODERSTRO	M90 MRK2	
>24.5	95	167 ADACHI	89 TOPZ	
164				

164 ABREU 97D bound applies only to masses above 45 GeV. The mass limit improves to 68 GeV for $\tilde{\mu}_L$, $\tilde{\tau}_L$. Data collected in e^+e^- collisions at \sqrt{s} =130–172 GeV.

165 BARATE 97K uses e^+e^- data collected at $\sqrt{s}=$ 130–172 GeV. The mass limit improves to 69 GeV for $\tilde{\mu}_L$ and $\tilde{\tau}_L$.

166 SAKAI 90 limit improves to 30.1 GeV for \tilde{e} if $m_{\tilde{\gamma}} \approx m_{\tilde{e}}$.

167 ADACHI 89 assume only photon (and photino for $\tilde{\epsilon}$) exchange. The limit for $\tilde{\epsilon}$ improves to 26 GeV for $m_{\widetilde{\gamma}} \approx m_{\widetilde{\delta}}$.

q̃ (Squark) MASS LIMIT

> 63

For $\dot{m_{\widetilde{q}}} >$ 60-70 GeV, it is expected that squarks would undergo a cascade decay via a number of neutralinos and/or charginos rather than undergo a direct decay to photinos as assumed by some papers. Limits obtained when direct decay is assumed are usually higher than limits when cascade decays are included. The limits from ${\cal Z}$ decay do not assume GUT relations and are more model independent.

VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
> 224	95	168 ABE	96D	CDF	$m_{\widetilde{g}} \leq m_{\widetilde{q}}$; with cas-
> 176	95	¹⁶⁹ ABACHI	95 C	D0	cade decays Any $m_{\widetilde{g}}$ <300 GeV;
> 212	95	¹⁶⁹ ABACHI	95 C	D0	with cascade decays $m_{\widetilde{g}} \leq m_{\widetilde{q}}$; with cascade decays
• • • We do not use	the follow	ving data for average	s, fits	, limits,	etc. • • •
		170 DATTA	97	THEO	\widetilde{v} 's lighter than $\widetilde{\chi}_1^{\pm}$, $\widetilde{\chi}_2^0$
> 216	95	171 DERRICK			$ep \rightarrow \widetilde{q}, \widetilde{q} \rightarrow \mu j$ or $\tau j, R$ -parity violation
none 130-573	95	172 HEWETT	97	THEO	$q\tilde{g} \rightarrow \tilde{q}, \tilde{q} \rightarrow q\tilde{g},$ with a light gluino
none 190-650	95	173 TEREKHOV	97	THEO	$qg \rightarrow \tilde{q}\tilde{g}, \tilde{q} \rightarrow q\tilde{g},$ with a light gluino
> 215	95	¹⁷⁴ AID	96	H1	$ep \rightarrow \tilde{q}$, R -parity viola-
> 150	95	174 AID	96	H1	tion, λ =0.3 $ep \rightarrow \tilde{q}$, R -parity violation, λ =0.1
~ 63	QE	175 AID	960	H1	m==m= m===35 GeV

96C H1

 $m_{\widetilde{q}} = m_{\widetilde{e}}, \; m_{\widetilde{\chi}_1^0} = 35 \; \mathrm{GeV}$

175 AID

Supersymmetric Particle Searches

none	e 330–400	95	176	TEREKHOV	96	THEO	
	*		177	ABE	95T	CDF	with a light gluino $\widetilde{q} \rightarrow \widetilde{\chi}_2^0 \rightarrow \widetilde{\chi}_1^0 \gamma$
_	45.3	95	178	BUSKULIC	95E	ALEP	q → qvll'
- 2		95	179	AHMED	94B		
-	239	90		ADMED	940	пī	ep → q; R-parity viola-
> 1	135	9 5	179	AHMED	948	H1	tion, $\lambda = 0.30$ $ep \rightarrow \tilde{q}$; R-parity violation, $\lambda = 0.1$
>	35.3	95	180	ADRIANI	93M	13	tion, $\lambda=0.1$ $Z \rightarrow \widetilde{u}\widetilde{u}$, $\Gamma(Z)$
-	36.8	95	180	ADRIANI			
>			191	ABE	93M	_	$Z \rightarrow dd, \Gamma(Z)$
>	90	90		ABE	92L	CDF	Any $m_{\widetilde{g}}$ <410 GeV;
							with cascade decay
> 2	218	90	182	ABE	92L	CDF	$m_{\tilde{g}} = m_{\tilde{q}}$; with cascade
							decay
> 1	180	90	181	ABE	92L	CDF	$m_{\widetilde{g}} < m_{\widetilde{q}}$; with cas-
							cade decay
> 1	100		183	ROY	92	RVUE	
	LUU			NO I	72	KVUE	pp → qq; R-parity vio- lating
			184	NOJIRI	91	COSM	in the same
_	45	95	185	ABREU		DLPH	7 . 27
>	45	95		ADREU	901	DLPH	$Z \rightarrow \tilde{q}\tilde{q}$,
							$m_{\widetilde{\gamma}} \lesssim 20 \text{ GeV}$
>	43	95	186	ABREU	90F	DLPH	Z → ďď,
							$m_{\widetilde{\gamma}} < 20 \text{ GeV}$
>	42	95	187	ABREU	90F	DLPH	$Z \rightarrow \widetilde{v}\widetilde{\widetilde{u}}$,
•		••			•••		$m_{\widetilde{\gamma}} < 20 \text{ GeV}$
->	27.0	95		ADACHI	900	TOPZ	Stable \tilde{u} , \tilde{u}
>	74	90	188	ALITTI		UA2	
>	14	90		ALITI	90	UAZ	Any $m_{\tilde{q}}$;
							B(q̃ → qg̃or qγ̃)
	106	90	188	ALITTI	~~	1140	_ = 1
> :	100	90		ALITI	90	UA2	$m_{\tilde{q}} = m_{\tilde{g}}$;
			100				$B(\tilde{q} \rightarrow q\tilde{\gamma}) = 1$
>	39.2	90	199	BAER	90	RVUE	\tilde{d}_L ; $\Gamma(Z)$
>	45	95 190),191	BARKLOW	90	MRK2	Z → ĝĝ
>	40	95 190	7,192	BARKLOW	90	MRK2	$Z \rightarrow \tilde{d}\tilde{d}$
>	39	95 190	193	BARKLOW	90	MRK2	Z → ũū
>1		,,,		GRIFOLS	90	ASTR	
71.	100			GKIFOL3	90	MOIR	$m_{\widetilde{\gamma}} < 1 \text{ MeV}$
>	24	95		SAKAI	90	AMY	$e^+e^- \rightarrow \tilde{d}\bar{d} \rightarrow d\bar{d}\tilde{\gamma}\tilde{\gamma};$ $m_{\tilde{\gamma}} < 10 \text{ GeV}$
>	26	95		SAKAI	90	AMY	$e^+e^- \rightarrow \widetilde{u}\overline{\widetilde{u}} \rightarrow u\overline{u}\widetilde{\gamma}\widetilde{\gamma}$;
							$m_{\widetilde{\gamma}} < 10 \; { m GeV}$
>	26.3	95	194	ADACHI	89	TOPZ	e ⁺ e [→] → q̃q̃ →
							$q \overline{q} \widetilde{\gamma} \widetilde{\gamma}$
			195	NATH	88	THEO	$\tau(p \rightarrow \nu K)$ in super-
			100				gravity GUT
>	45	90	146	ALBAJAR	87 D	UA1	Any $m_{\tilde{g}} > m_{\tilde{q}}$
>	75	90	196	ALBAJAR	870	UA1	$m_{\widetilde{R}} = m_{\widetilde{a}}$
168							q

168 ABE 96D searched for production of gluinos and five degenerate squarks in final states containing a pair of leptons, two jets, and missing E_T . The two leptons arise from the semileptonic decays of charginos produced in the cascade decays. The limit is derived for fixed $\tan\beta=4.0$, $\mu=-400$ GeV, and $m_{H^+}=500$ GeV, and with the cascade decays of the squarks and gluinos calculated within the framework of the Minimal Supergravity scenario.

scenario. 169 ABACHI 95c assume five degenerate squark flavors with $m_{\widetilde{Q}_L} = m_{\widetilde{Q}_R}$. Sleptons are assumed to be heavier than squarks. The limits are derived for fixed $\tan\beta = 2.0~\mu = -250~{\rm GeV}$, and $m_{H^+}{=}500~{\rm GeV}$, and with the cascade decays of the squarks and gluinos calculated within the framework of the Minimal Supergravity scenario. The bounds are weakly sensitive to the three fixed parameters for a large fraction of parameter space. No limit is given for $m_{\rm gluino} > 547~{\rm GeV}$.

170 DATTA 97 argues that the squark mass bound by ABACHI 95C can be weakened by 10–20 GeV if one relaxes the assumption of the universal scalar mass at the GUT-scale so that the $\widetilde{\chi}_1^{\pm}$, $\widetilde{\chi}_2^{0}$ in the squark cascade decays have dominant and invisible decays to

171 DERRICK 97 looked for lepton-number violating final states via R-parity violating couplings $\lambda'_{IJk}L_IQ_Jd_k$. When $\lambda'_{11k}\lambda'_{IJk}\neq 0$, the process $eu\to \overline{d}_k^*\to \ell_Iu_J$ is possible. When $\lambda'_{1J1}\lambda'_{IJk}\neq 0$, the process $e\overline{d}\to \widetilde{u}_J^*\to \ell_I\overline{d}_k$ is possible. 100% branching fraction $\widetilde{q}\to\ell_J$ is assumed. The limit quoted here corresponds to $\widetilde{t}\to \tau q$ decay, with $\lambda'=0.3$. For different channels, limits are slightly better. See Table 6 in their paper.

172 HEWETT 97 reanalyzed the limits on possible resonances in di-jet mode $(\tilde{q} \to q\tilde{g})$ from ALITTI 93 quoted in "Limits for Excited q (q^*) from Single Production," ABE 96 in "SCALE LIMITS for Contact Interactions: $\Lambda(q\,q\,q\,q)$," and unpublished CDF, DØ bounds. The bound applies to the gluino mass of 5 GeV, and improves for lighter gluino. The analysis has gluinos in parton distribution function.

173 TEREKHOV 97 improved the analysis of TEREKHOV 96 by including di-jet angular distributions in the analysis.

174 AID 96 looked for first-generation squarks as s-channel resonances singly produced in ep collision via the R-parity violating coupling in the superpotential $W = \lambda L_1 Q_1 d_1$. The degeneracy of squarks \widetilde{Q}_1 and \widetilde{d}_1 is assumed. Eight different channels of possible squark decays are considered.

175 AID 96c used electron-jet events with missing energy and momentum to look for $eq \rightarrow \tilde{e}\tilde{q}$ via neutralino exchange with decays into $(e\tilde{\chi}_1^Q)(q\tilde{\chi}_1^Q)$. See the paper for dependences on $m_{\tilde{e}}$, $m_{\tilde{\chi}0}$.

176 TEREKHOV 96 reanalyzed the limits on possible resonances in dI-jet mode $(\tilde{u} \rightarrow u\tilde{g})$ from ABE 95n quoted in "MASS LIMITS for g_A (axigluon)." The bound applies only to the case with a light gluino.

177 ABE 95T looked for a cascade decay of five degenerate squarks into $\widetilde{\chi}^0_2$ which further decays into $\widetilde{\chi}^0_1$ and a photon. No signal is observed. Limits vary widely depending on

the choice of parameters. For $\mu=-40$ GeV, $\tan\beta=1.5$, and heavy gluinos, the range $50{<}m_{\widetilde{o}}$ (GeV) ${<}110$ is excluded at 90% CL. See the paper for details.

178 BUSKULIC 95E looked for $Z \to \tilde{q}\tilde{q}$, where $\tilde{q} \to q \chi_1^0$ and χ_1^0 decays via *R*-parity violating interactions into two leptons and a neutrino.

violating interactions into two leptons and a neutrino. 179 AHMED 948 looked for squarks as s-channel resonance in ep collision via R-parity violating coupling in the superpotential $W=\lambda I_1 Q_1 d_1$. The degeneracy of all squarks Q_1 and d_1 is assumed. The squarks decay dominantly via the same R-violating coupling into eq or νq if $\lambda \gtrsim 0.2$. For smaller λ , decay into photino is assumed which subsequently decays into eq \overline{q} , and the bound depends on $m_{\overline{q}}$. See paper for excluded region on $(m_{\overline{q}}, \lambda)$ plane.

180 ADRIANI 93M limit from $\Delta\Gamma(Z)$ < 35.1 MeV and assumes $m_{\widetilde{q}_L}\gg m_{\widetilde{q}_R}$

181 ABE 92L assume five degenerate squark flavors and $m_{\widetilde{q}_L} = m_{\widetilde{q}_R}^2$. ABE 92L includes the effect of cascade decay, for a particular choice of parameters, $\mu = -250$ GeV, $\tan\beta = 2$. Results are weakly sensitive to these parameters over much of parameter space. No limit for $m_{\widetilde{q}} \leq 50$ GeV (but other experiments rule out that region). Limits are 10–20 GeV higher if $B(\widetilde{q} \to q\widetilde{\gamma}) = 1$. Limit assumes GUT relations between gaugino masses and the gauge coupling: in particular that for $|\mu|$ not small, $m_{\widetilde{\chi}_1^0} \approx m_{\widetilde{g}}/6$. This last

relation implies that as $m_{\widetilde{g}}$ increases, the mass of $\widetilde{\chi}^0_1$ will eventually exceed $m_{\widetilde{g}}$ so that no decay is possible. Even before that occurs, the signal will disappear; in particular no bounds can be obtained for $m_{\widetilde{g}} >$ 410 GeV. $m_{H^+} =$ 500 GeV.

 $^{182}\,\mathrm{ABE}$ 92L bounds are based on similar assumptions as ABACHI 95c. No limits for $m_{gluino} >$ 410 GeV.

183 ROY 92 reanalyzed CDF limits on di-lepton events to obtain limits on squark production in *R*-parity violating models. The 100% decay $\tilde{q} \to q \tilde{\chi}$ where $\tilde{\chi}$ is the LSP, and the LSP decays either into $\ell q \bar{d}$ or $\ell \ell \bar{e}$ is assumed.

184 NOJIRI 91 argues that a heavy squark should be nearly degenerate with the gluino in minimal supergravity not to overclose the universe.

185 ABREU 90F assume six degenerate squarks and $m_{\widetilde{q}_L}=m_{\widetilde{q}_R}$. $m_{\widetilde{q}}<$ 41 GeV is excluded at 95% CL for $m_{\rm LSP}< m_{\widetilde{q}}$ –2 GeV.

 $^{186}\,\mathrm{ABREU}$ 90F exclude $m_{\widetilde{d}}$ < 38 GeV at 95% for m_{LSP} < $m_{\widetilde{d}}$ $^{-}$ 2 GeV.

187 ABREU 90F exclude $m_{\widetilde{u}}$ < 36 GeV at 95% for $m_{\rm LSP}$ < $m_{\widetilde{u}}$ -2 GeV.

188 ALITTI 90 searched for events having ≥ 2 jets with $E_T^1 > 25$ GeV, $E_T^2 > 15$ GeV, $|\eta| < 0.85$, and $\Delta \phi < 160^\circ$, with a missing momentum > 40 GeV and no electrons. They assume $\tilde{q} \to q \tilde{\gamma}$ (if $m_{\tilde{q}} < m_{\tilde{g}}$) or $\tilde{q} \to q \tilde{g}$ (if $m_{\tilde{q}} > m_{\tilde{g}}$) decay and $m_{\tilde{q}} \lesssim 20$ GeV. Five degenerate squark flavors and $m_{\tilde{q}_L} = m_{\tilde{q}_R}$ are assumed. Masses below 50 GeV are not excluded by the analysis.

189 BAER 90 limit from $\Delta \Gamma(Z) < 120$ MeV, assuming $m_{\widetilde{d}_L} = m_{\widetilde{p}_L} = m_{\widetilde{e}_L} = m_{\widetilde{p}_L}$. Independent of decay modes. Minimal supergravity assumed.

¹⁹⁰BARKLOW 90 assume 100% $\tilde{q} \rightarrow q\tilde{\gamma}$.

 191 BARKLOW 90 assume five degenerate squarks (left- and right-handed). Valid up to $m_{\widetilde\chi_0^0} \lesssim [m_{\widetilde q} - 4~{\rm GeV}].$

 192 BARKLOW 90 result valid up to $m_{\widetilde{\chi}^0_1} \lesssim [m_{\widetilde{d}} - 5 \text{ GeV}].$

¹⁹³BARKLOW 90 result valid up to $m_{\widetilde{\chi}_1^0} \lesssim [m_{\widetilde{u}} - 6 \text{ GeV}].$

194 ADACHI 89 assume only photon exchange, which gives a a conservative limit. The limit is only for one flavor of charge 2/3 \tilde{q} . $m_{\widetilde{q}_L} = m_{\widetilde{q}_{\widetilde{R}}}$ and $m_{\widetilde{\gamma}} = 0$ assumed. The limit decreases to 26.1 GeV for $m_{\widetilde{\gamma}} = 15$ GeV. The limit for nondegenerate case is 24.4 GeV.

195 NATH 88 uses Kamioka limit of $\tau(p \to \overline{\nu}K^+) > 7 \times 10^{31}$ yrs to constrain squark mass $m_{\widetilde{q}} > 1000$ GeV by assuming that the proton decay proceeds via an exchange of a color-triplet Higgsino of mass $< 10^{16}$ GeV in the supersymmetric SU(5) GUT. The limit applies for $m_{\widetilde{\gamma}} \equiv (8/3) \sin^2 \theta_W \widetilde{m}_2 > 10$ GeV (\widetilde{m}_2) is the SU(2) gaugino mass) and for a very conservative value of the three-quark proton wave function, barring cancellation between second and third generations. Lower squark mass is allowed if $m_{\widetilde{\gamma}}$ as defined above is smaller.

above is smaller. 196 The limits of ALBAJAR 87D are from $p\overline{p} \to \widetilde{q}\overline{\overline{q}} X$ ($\overline{q} \to q\widetilde{\gamma}$) and assume 5 flavors of degenerate mass squarks each with $m_{\widetilde{q}_L} = m_{\widetilde{q}_R}$. They also assume $m_{\widetilde{g}} > m_{\widetilde{q}}$. These limits apply for $m_{\widetilde{\gamma}} \lesssim$ 20 GeV.

\tilde{b} (Sbottom) MASS LIMIT

Limits in e⁺ e⁻ depend on the mixing angle of the mass eigenstate $\tilde{b}_1 = \tilde{b}_L \cos\theta_b + \tilde{b}_R \sin\theta_b$. Coupling to the Z vanishes for $\theta_b \sim$ 1.17. In the Listings below, we use $\Delta m = m_{\widetilde{b}_1} - m_{\widetilde{\chi}_1^0}$.

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do not us	e the follow	ing data for averages	, fits, limits,	etc. • • •
>69.7	95	197 ACKERSTAFF	97Q OPAL	$\tilde{b} \rightarrow b\tilde{\chi}_{1}^{0}, \theta_{b}=0,$
>73	95	198 BARATE	97Q ALEP	$\Delta(m) > 8 \text{ GeV}$ $\tilde{b} \rightarrow b \tilde{\chi}_{1}^{0}, \theta_{b} = 0,$
>53	95	199 ABREU	960 DLPH	$\Delta(m) > 10 \text{ GeV}$ $\tilde{b} \to b\tilde{X}^0, \theta_b = 0,$
>61.8	95	200 ACKERSTAFF	96 OPAL	$\Delta(m) > 20 \text{ GeV}$ $\tilde{b} \rightarrow b \tilde{\chi}^{0}, \theta_{b} = 0,$ $\Delta(m) > 8 \text{ GeV}$
				$\Delta(m) > 8 \text{ GeV}$

197 ACKERSTAFF 97Q data taken at $\sqrt{s}{\approx}130{-}172$ GeV. See paper for dependence on θ_b . No limit for $\theta_b\approx 1.17$.

 $198\, \rm BARATE$ 970 uses data at $\sqrt{s}{=}161,$ 170, and 172 GeV. The limit disappears when $\theta_b\approx 1.17.$

¹⁹⁹ Data taken at $\sqrt{s} \approx 130-136$ GeV.

²⁰⁰ACKERSTAFF 96 also studied θ_b dependence when there is a mixing $\tilde{b}_1 = \tilde{b}_L \cos\theta_b +$ $\tilde{b}_R \sin \theta_b$. Data taken at $\sqrt{s}=130$, 136, and 161 GeV. See the paper for dependence on θ_b . No limit for $\theta_b \approx 1.17$.

t (Stop) MASS LIMIT

Limit depends on decay mode. In e^+e^- collisions they also depend on the mixing angle of the mass eigenstate $\tilde{t}_1=\tilde{t}_L\cos\theta_t+\tilde{t}_R\sin\theta_t$. Coupling to Z vanishes when $\theta_t=0.98$. In the Listings below, we use $\Delta m\equiv m_{\tilde{t}_1}-m_{\tilde{\chi}_0}$ or $\Delta m\equiv m_{\tilde{t}_1}-m_{\tilde{\nu}}$. depending on relevant decay mode. See also bounds in "q (Squark) MASS LIMIT."

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
> 73.3	95	²⁰¹ ACKERSTAFF	97Q OPAL	$\tilde{t} \rightarrow c\tilde{\chi}_1^0, \theta_t = 0, \Delta(m) > 10$
> 65.0	95	²⁰¹ ACKERSTAFF	97Q OPAL	GeV $\tilde{t} \rightarrow c\tilde{\chi}_{1}^{0}, \theta_{t}=0.98, \Delta(m) > 1$
> 67.9	95	²⁰¹ ACKERSTAFF	97Q OPAL	$\tilde{t} \to b\ell\tilde{\nu}, \theta_t = 0, \Delta(m) > 10$
> 56.2	95	²⁰¹ ACKERSTAFF	970 OPAL	$\tilde{t} \to b\ell\tilde{\nu}, \theta_t = 0.98, \Delta(m) > $
> 66.3	95	²⁰¹ ACKERSTAFF	97Q OPAL	$\tilde{t} \stackrel{10 \text{ GeV}}{\rightarrow} b\tau \tilde{\nu}_{\tau}, \ \theta_{t} = 0, \ \Delta(m) > 10$
> 54.4	95	²⁰¹ ACKERSTAFF	97Q OPAL	$\tilde{t} \to b\tau \tilde{\nu}_{\tau}, \ \theta_{t} = 0.98, \ \Delta(m) > $
> 67	95	202 BARATE	97Q ALEP	$\tilde{t} \to c\tilde{\chi}_1^0, \text{ any } \theta_t, \Delta(m) > 10$
> 70	95	202 BARATE	97Q ALEP	$\tilde{t} \to b\ell\tilde{\nu}$, any θ_t , $\Delta(m) > 10$
> 64	95	202 BARATE	97Q ALEP	$\widetilde{t} \to b\tau \widetilde{\nu}_{\tau}$, any $\theta_{\widetilde{t}}$, $\Delta(m) > 10 \text{ GeV}$
 ● ● We do not 	use the	following data for a	verages, fits,	
попе 61 -9 1	95	²⁰³ ABACHI	96B D0	$\tilde{t} \rightarrow c \tilde{\chi}_1^0, m_{\tilde{\chi}_1^0} < 30 \text{ GeV}$
> 54	95	²⁰⁴ ABREU	960 DLPH	$\tilde{t} \rightarrow c\tilde{\chi}_1^0, \theta_t = 0, \Delta(m) > 5$
> 52	95	²⁰⁴ ACCIARRI	96F L3	$\tilde{t} \stackrel{GeV}{\to} c\tilde{\chi}_{1}^{0}, \theta_{t} = 0, \Delta(m) > 8$
> 65.4	95	²⁰⁵ ACKERSTAFF	96 OPAL	$\tilde{t} \to c\tilde{\chi}_1^0, \theta_t = 0, \Delta(m) > 10$
> 56.8	95	²⁰⁵ ACKERSTAFF	96 OPAL	$\widetilde{t} \to c\widetilde{\chi}_1^0, \theta_t = 0.98,$
> 60.6	95	²⁰⁵ ACKERSTAFF	96 OPAL	$\Delta(m) > 10 \text{ GeV}$ $\tilde{t} \to b\ell\tilde{\nu}, \theta_{\tilde{t}} = 0, \Delta(m) > 10$
none 9-24.4	95	206 AID	96 H1	$e p \xrightarrow{\widetilde{t} \widetilde{t}}$, R-parity violating
>138	95	²⁰⁷ AID	96 H1	decays $e p \rightarrow t$, R-parity violation,
> 48	95	²⁰⁴ BUSKULIC	96K ALEP	$\lambda \cos\theta_t > 0.03$ $t \to c\tilde{\chi}_1^0, \theta_t = 0, \Delta(m) > 18$
> 57	95	²⁰⁴ BUSKULIC	96K ALEP	$t \to c\tilde{\chi}_1^0, \theta_t = \pi/2, \Delta(m) > 14$
> 45		²⁰⁸ CHO	96 RVUE	$B^0 - \overline{B^0}$ and ϵ , $\theta_t = 0.98$, $\tan \beta < 2$
none 11-41	95	²⁰⁹ BUSKULIC	95E ALEP	$\theta_t = 0.98, \ \tilde{t} \rightarrow c \nu \ell \tilde{\ell}'$
none 6.0-41.2	95	AKERS	94K OPAL	$\tilde{t} \rightarrow c\tilde{\chi}_1^0, \theta_t = 0, \Delta(m) > 2$
none 5.0-46.0	95	AKERS	94K OPAL	$\tilde{t} \to c\tilde{\chi}_1^0, \theta_t = 0, \Delta(m) > 5$
none 11.2-25.5	95	AKERS	94K OPAL	$\tilde{t} \rightarrow c\tilde{\chi}_1^0, \theta_t = 0.98, \Delta(m) > 2$
none 7.9-41.2	95	AKERS	94K OPAL	GeV $\tilde{t} \to c\tilde{\chi}_1^0, \theta_t = 0.98, \Delta(m) > 5$
none 7.6-28.0	95	²¹⁰ SH I RAI	94 VNS	$\widetilde{t} \to c\widetilde{\chi}_1^0$, any θ_t , $\Delta(m) > 10$
none 10-20	95	²¹⁰ SHIRAI	94 VNS	$\widetilde{t} \rightarrow c\widetilde{\chi}_{1}^{0}$, any $\theta_{\widetilde{t}}$, $\Delta(m) > 2.5$ GeV
201				

- 201 ACKERSTAFF 97Q looked for \tilde{t} pair production. Data taken at \sqrt{s} =130, 136, 161, 170, and 172 GeV. Unless the ℓ = τ decay mode is explicitly indicated, the same branching fractions to ℓ =e, μ , and τ are assumed for $b\ell\tilde{\nu}_{\ell}$ modes. See Table 7 and Figs. 8–10 for other choices of θ_{ℓ} , $\Delta(m)$, and leptonic branching ratios.
- 202 BARATE 970 uses e^+e^- data at \sqrt{s} =161, 170, and 172 GeV. Unless the ℓ = τ decay mode is explicitly indicated, the same branching fractions to ℓ =e, μ , and τ are assumed for $b\ell\bar{\nu}_\ell$ modes. See their Figs. 4 and 5 for other choices of θ_{ℓ} , $\Delta(m)$, and leptonic branching ratios.
- 203 ABACHI 968 searches for final states with 2 jets and missing E_T . Limits on $m_{\widetilde{\tau}}$ are given as a function of $m_{\widetilde{\chi}_1^0}$. See Fig. 4 for details.
- ²⁰⁴ Data taken at $\sqrt{s}=130^{-1}36$ GeV.
 ²⁰⁵ ACKERSTAFF 96 looked for \tilde{t} pair production. See the paper for $\theta_{\tilde{t}}$ and $\Delta(m)$ dependece of the limits. Data taken at $\sqrt{s}=130$, 136, and 161 GeV.
- 206 AID 96 considers photoproduction of \widetilde{tt} pairs, with 100% R-parity violating decays of \widetilde{t} to eq, with q=d, s, or b quarks.
- 207 AID 96 considers production and decay of \tilde{t} via the *R*-parity violating coupling in the superpotential $W=\lambda L_1 \, Q_3 \, d_1$.
- 208 CHO 96 studied the consistency among the $B^0-\overline{B}^0$ mixing, ϵ in $K^0-\overline{K}^0$ mixing, and the measurements of V_{cb} , V_{ub}/V_{cb} . For the range 25.5 GeV $< m_{\widetilde{t}_1} < m_Z/2$ left by AKERS 94K for $\theta_{\ell}=0.98$, and within the allowed range in M_2 - μ parameter space from chargino, neutralino searches by ACCIARRI 95E, they found the scalar top contribution to $B^0 - \overline{B}{}^0$ mixing and ϵ to be too large if $\tan \beta <$ 2. For more on their assumptions, see the paper and their reference 10.
- ²⁰⁹ BUSKULIC 95E looked for $Z \to \tilde{t}\tilde{t}$, where $\tilde{t} \to c \chi_1^0$ and χ_1^0 decays via R-parity violating interactions into two leptons and a neutrino.
- 210 SHIRAI 94 bound assumes the cross section without the s-channel Z-exchange and the QCD correction, underestimating the cross section up to 20% and 30%, respectively. They assume $m_c=1.5$ GeV.

Heavy 👸 (Gluino) MASS LIMIT

For $m_{\widetilde{R}} > 60$ –70 GeV, it is expected that gluinos would undergo a cascade decay via a number of neutralinos and/or charginos rather than undergo a direct decay to photinos as assumed by some papers. Limits obtained when direct decay is assumed are usually higher than limits when cascade decays are included.

1/ALUE /C-\/\	CI W	DOCUMENT ID	TECH	COMMENT
VALUE (GeV)	<u> </u>	DOCUMENT ID	TECN_	COMMENT
>173	95	211 ABE	97K CDF	Any $m_{\widetilde{q}}$; with cascade decays
>216	95	²¹¹ ABE	97K CDF	$m_{\tilde{q}} = m_{\tilde{g}}$; with cascade decays
>224	95	²¹² ABE	96D CDF	$m_{\widetilde{q}} = m_{\widetilde{g}}$; with cascade decays
>154	95	²¹² ABE	96D CDF	$m_{\widetilde{\mathbf{g}}} < m_{\widetilde{\mathbf{q}}}$; with cascade
>212	95	²¹³ ABACHI	95c D0	decays $m_{\widetilde{g}} \geq m_{\widetilde{q}}$; with cascade
>144	95	²¹³ ABACHI	95c D0	decays Any $m_{\widetilde{q}}$; with cascade
• • • We do not u	se the follow	ving data for average	s, fits, limits.	decays
		214 ABE		
				$\tilde{\mathbf{g}} \to \tilde{\chi}_2^0 \to \tilde{\chi}_1^0 \gamma$
		215 HEBBEKER		e ⁺ e ⁻ jet analyses
>218	90	²¹⁶ ABE	92L CDF	$m_{\widetilde{q}} \leq m_{\widetilde{g}}$; with cascade decay
>100	90	²¹⁶ ABE	92L CDF	Any $m_{\widetilde{q}}$; with cascade decay
>100		²¹⁷ ROY	92 RVUE	pp → gg; R-parity vio- lating
>132	90	218 HIDAKA	91 RVUE	
•		²¹⁹ NOJIRI	91 COSM	
> 79	90	220 ALITTI	90 UA2	Any $m_{\widetilde{g}}$; $B(\widetilde{g} \rightarrow q \overline{q} \widetilde{\gamma}) = 1$
>106	90	220 ALITTI	90 UA2	$m_{\widetilde{q}} = m_{\widetilde{g}};$
		²²¹ NAKAMURA	89 SPEC	$B(\tilde{g} \to q \bar{q} \tilde{\gamma}) = 1$ $R \cdot \Delta^{++}$
none 4-53	90	222 ALBAJAR	870 UA1	
				Any $m_{\widetilde{q}} > m_{\widetilde{g}}$
none 4-75	90	222 ALBAJAR	87D UA1	$m_{\widetilde{q}} = m_{\widetilde{g}}$
none 16-58	90	223 ANSARI	87D UA2	$m_{\widetilde{q}} \lesssim 100 \text{ GeV}$
011				7

- ²¹¹ABE 97k searched for production of gluinos and five degenerate squarks in events with three or more jets but no electrons or muons and missing transverse energy $E_T > 60$ GeV. The limit for any $m_{\widetilde{q}}$ is for μ =-200 GeV and $\tan \beta$ =2, and that for $m_{\widetilde{q}}$ = $m_{\widetilde{g}}$ is for μ =-400 GeV and $\tan \beta$ =4. Different choices for $\tan \beta$ and μ lead to changes of the order of \pm 10 GeV in the limits. See Footnote [16] of the paper for more details on the assumptions.
- 212 ABE 96D searched for production of gluinos and five degenerate squarks in final states containing a pair of leptons, two jets, and missing $E_{\mathcal{T}}$. The two leptons arise from the semileptonic decays of charginos produced in the cascade decays. The limits are derived for fixed $\tan\beta=4.0$, $\mu=-400$ GeV, and $m_{H^+}=500$ GeV, and with the cascade decays of the squarks and gluinos calculated within the framework of the Minimal Supergravity scenario. The bounds are weakly sensitive to the values of the three fixed parameters for a large fraction of parameter space. See Fig. 2 for the limits corresponding to different parameter choices.
- parameter cnoices. 213 ABACHI 95c assume five degenerate squark flavors with with $m_{\widetilde{q}_L}=m_{\widetilde{q}_R}$. Sleptons are assumed to be heavier than squarks. The limits are derived for fixed $\tan\beta=2.0~\mu=-250~{\rm GeV}$, and $m_{H^\pm}=500~{\rm GeV}$, and with the cascade decays of the squarks and gluinos calculated within the framework of the Minimal Supergravity scenario. The bounds are
- weakly sensitive to the three fixed parameters for a large fraction of parameter space. ^214 ABE 95T looked for a cascade decay of gluino into \widetilde{x}_2^0 which further decays into \widetilde{x}_1^0 and a photon. No signal is observed. Limits vary widely depending on the choice of parameters. For $\mu=-40$ GeV, $\tan\beta=1.5$, and heavy squarks, the range $50 < m_{\widetilde{g}}$ (GeV)<140 is excluded at 90% CL. See the paper for details.
- 215 HEBBEKER 93 combined jet analyses at various e^+e^- colliders. The 4-jet analyses at TRISTAN/LEP and the measured α_S at PEP/PETRA/TRISTAN/LEP are used. A constraint on effective number of quarks N=6.3 \pm 1.1 is obtained, which is compared to that with a light gluino, N=8.
- 216 ABE 92L bounds are based on similar assumptions as ABACHI 95C. Not sensitive to $m_{\rm gluino}$ <40 GeV (but other experiments rule out that region).
- 217 ROY 92 reanalyzed CDF limits on di-lepton events to obtain limits on gluino production in R-parity violating models. The 100% decay $\widetilde{g} \to q \overline{q} \widetilde{\chi}$ where $\widetilde{\chi}$ is the LSP, and the LSP decays either into $\ell q \overline{d}$ or $\ell \ell \overline{e}$ is assumed.
- 218 HIDAKA 91 limit obtained from LEP and preliminary CDF results within minimal supersymmetry with gaugino-mass unification condition. HIDAKA 91 limit extracted from BAER 91 analysis.
- 219 NOJIRI 91 argues that a heavy gluino should be nearly degenerate with squarks in minimal supergravity not to overclose the universe.
- 220 ALITTI 90 searched for events having \geq 2 jets with E_T^1 > 25 GeV, E_T^2 > 15 GeV, $|\eta|~<~0.85$, and $\Delta\phi~<~160^{\circ}$, with a missing momentum >~40 GeV and no electrons. They assume $\widetilde{g} o q \overline{q} \widetilde{\gamma}$ decay and $m_{\widetilde{\gamma}} \lesssim$ 20 GeV. Masses below 50 GeV are not excluded by the analysis.
- 221 NAKAMURA 89 searched for a long-lived ($au \gtrsim 10^{-7}$ s) charge-(± 2) particle with mass 1.6 GeV in proton-Pt interactions at 12 GeV and found that the yield is less than 10^{-8} times that of the pion. This excludes R- Δ^{++} (a $\tilde{g}uuu$ state) lighter than 1.6
- GeV. 222 The limits of ALBAJAR 87D are from $\rho \overline{\rho} \to \widetilde{g} \widetilde{g} \times (\widetilde{g} \to q \overline{q} \widetilde{\gamma})$ and assume $m_{\widetilde{q}} >$ $m_{\widetilde{g}}$. These limits apply for $m_{\widetilde{\gamma}} \lesssim$ 20 GeV and $\tau(\widetilde{g}) < 10^{-10}$ s.
- 223 The limit of ANSARI 87D assumes $m_{\widetilde{q}} > m_{\widetilde{g}}$ and $m_{\widetilde{\gamma}} \approx 0$.

Supersymmetric Particle Searches

NOTE ON LIGHT GLUINO

Written March 1998 by H. Murayama (UC Berkeley).

It is controversial if a light gluino of mass below 5 GeV is phenomenologically allowed. Below we list some of the most important and least controversial constraints which need to be met for a light gluino to be viable. For reviews on the subject, see, e.g., Ref. 1.

- 1. Either $m_{\tilde{g}} \lesssim 1.5$ GeV or $m_{\tilde{g}} \gtrsim 3.5$ GeV to avoid the CAKIR 94 limit. See also Ref. 2 for similar quarkonium constraints on lighter masses.
- 2. The lifetime of the gluino or the ground state gluino-containing hadron (typically, $g\tilde{g}$) must be $\gtrsim 10^{-10}$ s in order to evade beam-dump and missing energy limits [1.2].
- Charged gluino-containing hadrons (e.g. ḡud̄) must decay into neutral ones (e.g. R⁰(ḡg)π⁺ or (ḡuū̄)e⁻v̄_e) with a lifetime shorter than about 10⁻⁷ s to avoid the AKERS 95R limit. Older limits for lower masses and shorter lifetimes are summarized in Ref. 1.
- 4. The lifetime of $R^0 \to \rho^0 \tilde{\gamma}$, if allowed, must be outside the ADAMS 97B range. The $R_p^+(\tilde{g}uud)$ state, which is believed to decay weakly into $S^0(\tilde{g}uds)\pi^\pm$ (FARRAR 96), must be heavier than 2 GeV or have lifetime $\tau_{R_p} \gtrsim 1$ ns or $\tau_{R_p} \lesssim 50$ ps (e.g. if the strong decay into S^0K^\pm is allowed), or its production cross sections must be at least a factor of 5 smaller than those of hyperons, to avoid ALBUQUERQUE 97
- 5. $m_{\tilde{g}} \geq 6.8$ GeV (95% CL) if the "experimental optimization" method of fixing the renormalization scale is valid and if the hadronization and resummation uncertainties are as estimated in BARATE 97L, from the D_2 event shape observable in Z^0 decay. The 4-jet angular distribution is less sensitive to renormalization scale ambiguities and yields a 90%CL exclusion of a light gluino (DEGOUVEA 97). A combined LEP analysis based on all the Z^0 data and using the recent NLO calculations [3] is warranted.
- 6. Constraints from the effect of light gluinos on the running of α_s apply independently of the gluino lifetime and are insensitive to renormalization scale. They disfavor a light gluino at 70% CL (CSIKOR 97), which improves to more than 99% with jet analysis.

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Long-lived/light \tilde{g} (Gluino) MASS LIMIT

Limits on light gluinos ($m_{\widetilde{g}}$ < 5 GeV), or gluinos which leave the detector before

decaying.					
VALUE (GeV)	CL%_	DOCUMENT ID		TECN	COMMENT
• • • We do not use	e the followin	ng data for averages	, fits	limits,	etc. • • •
		224 ADAMS	97B	KTEV	$\rho N \rightarrow R^0 \rightarrow \rho^0 \tilde{\gamma}$
		225 ALBUQUERQ	.97	E761	$R^+(uud\tilde{g}) \rightarrow$
		• •			$S^0(uds\widetilde{g})\pi^+$,
					X - (ssdg̃)→
					50π ⁻
>6.3	95	226 BARATE		ALEP	Color factors
>5		227 CSIKOR	97	RVUE	β function, $Z \rightarrow$ jets
>1.5	90	228 DEGOUVEA	97		Z →]]]] -0
	_	229 FARRAR	96	RVUE	$R^{0} \rightarrow \pi^{0} \tilde{\gamma}$
none 1.9-13.6		230 AKERS		OPAL	Z decay into a long-lived $(\tilde{g} q \bar{q})^{\pm}$
<0.7		231 CLAVELLI	95	RVUE	quarkonia
none 1.5-3.5		232 CAKIR	94	RVUE	$T(1S) \rightarrow \gamma + \text{gluinon-}$
not 3-5		233 LOPEZ		RVUE	LEP
≈ 4		234 CLAVELLI	92	RVUE	α _s running
		235 ANTONIADIS 236 ANTONIADIS	91	RVUE	α_s running $pN \rightarrow \text{missing energy}$
>1		237 ARNOLD	91 87	EMUL	π^{-} (350 GeV). $\sigma \simeq A^{1}$
>3.8	90	237 ARNOLD		EMUL	π (350 GeV). σ ⊆ Α· π (350 GeV). σ ≃
>3.2	90		87		A0.72
none 0.6-2.2	90	238 TUTS	87	CUSB	$\gamma(15) \rightarrow \gamma + \text{gluinon-}$
none 1 -4.5	90	²³⁹ ALBRECHT	8 6 C	ARG	$1 \times 10^{-11} \lesssim \tau \lesssim 1 \times 10^{-9} \text{s}$
none 1-4	90	240 BADIER	86	BDMP	$1 \times 10^{-10} < \tau < 1 \times 10^{-7}$ s
none 3-5		²⁴¹ BARNETT	86	RVUE	
none		²⁴² VOLOSHIN	86	RVUE	
none 0.5-2		²⁴³ COOPER	85B	BDMP	For $m_{\tilde{q}}$ =300 GeV
none 0.5-4		243 COOPER	858	вомр	
none 0.5-3		243 COOPER	85B	BDMP	For $m_{\tilde{q}}=150 \text{ GeV}$
none 2-4		244 DAWSON	85	RVUE	$\tau > 10^{-7} \text{ s}$
none 1-2.5		244 DAWSON	85	RVUE	For $m_{\tilde{q}}=100 \text{ GeV}$
none 0.5~4.1	90	245 FARRAR	85	RVUE	FNAL beam dump
>1		246 GOLDMAN	85	RVUE	Gluononium
>1-2		247 HABER	85	RVUE	
		248 BALL	84	CALO	
		249 BRICK	84	RVUE	
		250 FARRAR	84	RVUE	
>2		251 BERGSMA		RVUE	For $m_{\widetilde{q}} < 100 \text{ GeV}$
		252 CHANOWITZ		RVUE	gud, guud
>2-3		253 KANE	82	RVUE	Beam dump
>1.5-2		FARRAR	78	RVUE	R-hadron

224 ADAMS 978 looked for $\rho^0 \to \pi^+\pi^-$ as a signature of $R^0 = (\tilde{g}\,g)$ bound states. The experiment is sensitive to an R^0 mass range of 1.2–4.5 GeV and to a lifetime range of $10^{-10}-10^{-3}$ sec. Precise limits depend on the assumed value of $m_{R^0}/m_{\widetilde{\gamma}}$. See Fig. 7 for the excluded mass and lifetime region.

for the excluded mass and inetime region.

225 ALBUQUERQUE 97 looked for weakly decaying baryon-like states which contain a light giulno, following the suggestions in FARRAR 96. See their Table 1 for limits on the production fraction. These limits exclude gluino masses in the range 100–600 MeV for the predicted lifetimes (FARRAR 96) and production rates, which are assumed to be comparable to those of strange or charmed baryons.

226 BARATE 97L studied the QCD color factors from four-jet angular correlations and the differential two-jet rate in Z decay. Limit obtained from the determination of $n_f=4.24\pm0.29\pm1.15$, assuming $T_F/C_F=3/8$ and $C_A/C_F=9/4$.

227 CSIKOR 97 combined the α_s from $\sigma(e^+e^- \to \text{hadron})$, τ decay, and jet analysis in Z decay. They exclude a light gluino below 5 GeV at more than 99.7%CL.

228 DEGOUVEA 97 reaanalyzed AKERS 95A data on Z decay into four jets to place constraints on a light stable gluino. The mass limit corresponds to the pole mass of 2.8 GeV. The analysis, however, is limited to the leading-order QCD calculation.

- 229 FARRAR 96 studied the possible $R^0 = (\tilde{g}g)$ component in Fermilab E799 experiment and used its bound $B(K_L^0 \to \pi^0 \nu \bar{\nu}) \leq 5.8 \times 10^{-5}$ to place constraints on the combination of R^0 production cross section and its lifetime.
- 230 AKERS 95R looked for Z decay into $q \bar{q} \tilde{g} \tilde{g}$, by searching for charged particles with dE/dx consistent with \tilde{g} fragmentation into a state $(\tilde{g} q \bar{q})^{\pm}$ with lifetime $\tau > 10^{-7}$ sec. The fragmentation probability into a charged state is assumed to be 25%.
- fragmentation probability into a charged state is assumed to be 20%.

 231 CLAVELLI 95 updates the analysis of CLAVELLI 93, based on a comparison of the hadronic widths of charmonium and bottomonium 5-wave states. The analysis includes a parametrization of relativisitic corrections. Claims that the presence of a light gluino improves agreement with the data by slowing down the running of α₅.
- 232 CAKIR 94 reanalyzed TUTS 87 and later unpublished data from CUSB to exclude pseudo-scalar gluinonium $\eta_{\widetilde{g}}(\widetilde{g})$ of mass below 7 GeV. It was argued, however, that the perturbative QCD calculation of the branching fraction $\tau \to \eta_{\widetilde{g}} \gamma$ is unreliable for $m_{\eta_{\widetilde{g}}} < 3$ GeV. The gluino mass is defined by $m_{\widetilde{g}} = (m_{\eta_{\widetilde{q}}})/2$. The limit holds for any gluino lifetime.
- 233 LOPEZ 93C uses combined restraint from the radiative symmetry breaking scenario within the minimal supergravity model, and the LEP bounds on the (M_2,μ) plane. Claims that the light gluino window is strongly disfavored.
- 234 CLAVELLI 92 claims that a light gluino mass around 4 GeV should exist to explain the discrepancy between $\alpha_{\rm S}$ at LEP and at quarkonia (Υ), since a light gluino slows the running of the QCD coupling.
- 235 ANTONIADIS 91 argue that possible light gluinos (< 5 GeV) contradict the observed running of α_s between 5 GeV and m_Z . The significance is less than 2 s.d.
- 236 ANTONIADIS 91 intrepret the search for missing energy events in 450 GeV/c pN collisions, AKESSON 91, in terms of light gluinos.
- ²³⁷ The limits assume $m_{\widetilde{q}}=$ 100 GeV. See their figure 3 for limits vs. $m_{\widetilde{q}}.$
- 238 The gluino mass is defined by half the bound $\tilde{g}\tilde{g}$ mass. If zero gluino mass gives a $\tilde{g}\tilde{g}$ of mass about 1 GeV as suggested by various glueball mass estimates, then the low-mass bound can be replaced by zero. The high-mass bound is obtained by comparing the data with nonrelativistic potential-model estimates.
- 239 ALBRECHT 86c search for secondary decay vertices from $\chi_{b1}(1P) \rightarrow \tilde{g}\,\tilde{g}\,g$ where \tilde{g} 's make long-lived hadrons. See their figure 4 for excluded region in the $m_{\tilde{g}} m_{\tilde{g}}$ and $m_{\tilde{g}} m_{\tilde{g}}$ plane. The lower $m_{\tilde{g}}$ region below ~ 2 GeV may be sensitive to fragmentation effects. Remark that the \tilde{g} -hadron mass is expected to be ~ 1 GeV (glueball mass) in the zero \tilde{g} mass limit.
- 240 BADIER 86 looked for secondary decay vertices from long-lived \tilde{g} -hadrons produced at 300 GeV π^- beam dump. The quoted bound assumes \tilde{g} -hadron nucleon total cross section of 10 μ b. See their figure 7 for excluded region in the $m_{\widetilde{g}}-m_{\widetilde{q}}$ plane for several section of 10 μ b.
- assumed total cross-section values. 241 BARNETT 86 rule out light gluinos (m=3–5 GeV) by calculating the monojet rate from gluino gluino gluon events (and from gluino gluino events) and by using UA1 data from $p\bar{p}$ collisions at CERN.
- 242 VOLOSHIN 86 rules out stable gluino based on the cosmological argument that predicts too much hydrogen consisting of the charged stable hadron g̃ uud. Quasi-stable (τ > 1.×10⁻⁷s) light gluino of m_{g̃} <3 GeV is also ruled out by nonobservation of the stable charged particles, g̃ uud, in high energy hadron collisions.</p>
- charged particles, g uua, in right energy naturon compositions. 243 COOPER-SARKAR 85B is BEBC beam-dump. Glulnos decaying in dump would yield $\tilde{\gamma}$'s in the detector giving neutral-current-like interactions. For $m_{\widetilde{q}} > 330$ GeV, no limit is set.
- 244 DAWSON 85 first limit from neutral particle search. Second limit based on FNAL beam dump experiment.
- dump experiment. 245 FARRAR 85 points out that BALL 84 analysis applies only if the \tilde{g} 's decay before interacting, i.e. $m_{\tilde{q}} < 80 m_{\tilde{g}}^{-1.5}$. FARRAR 85 finds $m_{\tilde{g}} < 0.5$ not excluded for $m_{\tilde{q}} = 30$ –1000 GeV and $m_{\tilde{g}} < 1.0$ not excluded for $m_{\tilde{q}} = 100$ –500 GeV by BALL 84 experiment.
- ²⁴⁶ GOLDMAN 85 use nonobservation of a pseudoscalar \tilde{g} - \tilde{g} bound state in radiative ψ decay.
- 247 HABER 85 is based on survey of all previous searches sensitive to low mass \(\tilde{g}' \)'s. Limit makes assumptions regarding the lifetime and electric charge of the lightest supersymmetric particle.
- 248 BALL 84 is FNAL beam dump experiment. Observed no interactions of $\widetilde{\gamma}$ in the calorimeter, where $\widetilde{\gamma}$'s are expected to come from pair-produced \widetilde{g} 's. Search for long-lived $\widetilde{\gamma}$ interacting in calorimeter 56m from target. Limit is for $m_{\widetilde{q}}=$ 40 GeV and production cross section proportional to A $^{0.72}$. BALL 84 find no \widetilde{g} allowed below 4.1 GeV at CL = 90%. Their figure 1 shows dependence on $m_{\widetilde{q}}$ and A. See also KANE 82.
- ²⁴⁹ BRICK 84 reanalyzed FNAL 147 GeV HBC data for R- Δ (1232)⁺⁺ with $\tau > 10^{-9}$ s and $\rho_{\rm lab} > 2$ GeV. Set CL = 90% upper limits 6.1, 4.4, and 29 microbarns in ρp , $\pi^+ p$, $K^+ p$ collisions respectively. R- Δ^{++} is defined as being \tilde{g} and 3 up quarks. If mass =
- 1.2–1.5 GeV, then limits may be lower than theory predictions.
 250 FARRAR 84 argues that $m_{\widetilde{g}} < 100$ MeV is not ruled out if the lightest R-hadrons are long-lived. A long lifetime would occur if R-hadrons are lighter than $\widetilde{\gamma}$'s or if $m_{\widetilde{q}} > 100$
- GeV. 251 BERGSMA 83C is reanalysis of CERN-SPS beam-dump data. See their figure 1.
- ²⁵² CHANOWITZ 83 find in bag-model that charged s-hadron exists which is stable against strong decay if $m_{\widetilde{g}} < 1$ GeV. This is important since tracks from decay of neutral s-hadron cannot be reconstructed to primary vertex because of missed $\widetilde{\gamma}$. Charged s-hadron leaves track from vertex.
- leaves track from vertex.

 253 KANE 82 Inferred above \tilde{g} mass limit from retroactive analysis of hadronic collision and beam dump experiments. Limits valid if \tilde{g} decays inside detector.

Supersymmetry Miscellaneous Results

Results that do not appear under other headings or that make nonminimal assumptions.

VALUE	DOCUMENT ID		<u>TECN</u>	COMMENT
• • • We do not use the	following data for average	es, fits	i, limits,	, etc. • • •
	254 ABACHI	97	D0	77X
	²⁵⁵ BARBER	84B	RVUE	
	256 HOFFMAN	83	CNTR	$\pi p \rightarrow n(e^+e^-)$

- 254 ABACHI 97 searched for pp̄ → γγ ₽_T+X as supersymmetry signature. It can be caused by selectron, sneutrino, or neutralino production with a radiative decay of their decay products. They placed limits on cross sections.
- 255 BARBER 84B consider that $\tilde{\mu}$ and \tilde{e} may mix leading to $\mu \to e \tilde{\gamma} \tilde{\gamma}$. They discuss mass-mixing limits from decay dist asym in LBL-TRIUMF data and e^+ polarization in SIN data.
- 256 HOFFMAN 83 set CL = 90% limit $d\sigma/dt$ B(e⁺e⁻) < 3.5 × 10⁻³² cm²/GeV² for spin-1 partner of Goldstone fermions with 140 < m <160 MeV decaying $\rightarrow e^+e^-$ pair.

REFERENCES FOR Supersymmetric Particle Searches

			D 415-41 (DA C-11-1	
	98 98C	PRL 80 442 PRL 80 1591	B. Abbott+ (DO Collab	
ABBOTT ABREU		EPJ C1 1	B. Abbott+ (D6 Collab P. Abreu+ (DELPHI Collab	Υ.
		EPJ C (to be publ.)	M. Acciarri+ (L3 Collab	
		n	MI. ALGERIT (ES CONED	٠,
CERN-PPE, ACKERSTAFF	981	EPJ C (to be publ.)	K. Ackerstaff+ (OPAL Collab	. 1
CERN-PPE	/97-13	2	N. Meneratan I	-,
ACKERSTAFE	98K	EPJ C (to be publ.)	K. Ackerstaff+ (OPAL Collab	
CERN-PPE			(4	٠,
ACKERSTAFF	981	FP1 C2 213	K. Ackerstaff+ (OPAL Collab	
ABACHI	97	PRL 78 2070	S. Abachi+ (D0 Collab	Υ.
ABE		PR D56 R1357	S. Abachl+ (D0 Collab F. Abe+ (CDF Collab	Υ.
		PL 8396 315	P. Abreu+ (DELPHI Collab	Υ.
ABREU	97J	ZPHY C74 577	P. Abreu+ (DELPHI Collab	7
ACCIARRI ACCIARRI ACKERSTAFF	970	PL D414 3/3	M. Acciarri+ (L3 Collab	·į
ACCIARRI	977	PL B415 299	III. FICEIEIT	./
ACKERSTAFF	9/11	PL B396 301	K. Ackerstaff+ (OPAL Collab	٠,
ACKERSTAFF	97Q	ZPHY C75 409	K. Ackerstaff+ (OPAL Collab	٠.)
ADAMS	97B	PRL 79 4083	J. Adams+ (KTeV Collab	
ALBUQUERQ	97_	PRL 78 3252	I.F. Albuquerque+ (FNAL E761 Collab	ı.)
ALEXANDER	97B	ZPHY C73 201	G. Alexander+ (OPAL Collab R. Barate+ (ALEPH Collab	1.)
	97K	PL B405 379	R. Barate+ (ALEPH Collab	.)
		ZPHY C76 1	R. Barate+ (ALEPH Collab	.)
BARATE	97N	PL B407 377	R. Barate+ (ALEPH Collab	.)
BARATE	97Q	PL B413 431	R. Barate+ (ALEPH Collab	
BOTTINO	97		+ (TORI, LAPP, GENO, ROMA, ROMA2, INFR M. Carena, G.F. Giudice, C.E.M. Wagner	۷)
CARENA	97	PL B390 234	M. Carena, G.F. Gludice, C.E.M. Wagner	•
	97	PRI 78 4335	F Csikor 7 Fodor (EOTV. CFR)	()
DATTA	97	PL B395 54	F. Csikor, Z. Fodor A. Datta, M. Guchait, N. Parua (ICTP, TATA	٩Ś
		PL B400 117	A. de Gouvea, H. Murayama	•
DERRICK	97	ZPHY C73 613	A. Datta, M. Guchait, N. Parua (ICTP, TAT/ A. de Gouvea, H. Murayama M. Derrick+ (ZEUS Collab	.)
ELLIS	97	PL B394 354	J. Ellis, J.L. Lopez, D.V. Nanopoulos	•
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		PL B400 112	J. Kalinowski, P. Zerwas	
TEREKHOV	97	PL 8400 112 PL 8412 86	J. Kailnowski, P. Zerwas I. Terekhov (ALAT	F)
ABACHI	96	PRL 76 2228	I. Terekhov (ALAT +Abbott, Abolins, Acharya+ (D0 Collab	3
		PRL 76 2222	+Abbott, Abolins, Acharya+ (DO Collab	7
	96	DDI 77 439	+Abbott, Abolins, Acharya+ (DO Collab +Akimoto, Akopian, Albrow+ (CDF Collab +Akimoto, Akopian, Albrow+ (CDF Collab	
	96D	PRL 77 438 PRL 76 2006	Abimata Abasian Albrows (CDE Callab	"(
ABE	96 P	PRL 76 4307	+Akimoto, Akopian, Albrow+ (CDF Collab +Akimoto, Akopian, Albrow+ (CDF Collab	``(
ABE		PRL /6 430/	+Akimoto, Akopian, Albrow+ (CDF Collab	ŀį
ABREU	96L	PL B382 323	+Adam, Adye, Agasi+ (DELPHI Collab	٠Į
ABREU		PL B387 651	+Adam, Adye, Agasi+ (DELPHI Collab	ı.į
ACCIARRI	96F	PL B377 289	+Adam, Adriani, Aguilar-Benitez+ +Alexander, Allison, Altekamp+ (L3 Collab	L)
ACKERSTAFF	96	PL B389 197	+Alexander, Allison, Altekamp+ (OPAL Collab +Alexander, Allison, Altekamp+ (OPAL Collab	ı.)
ACKERSTAFF		PL B389 616	+Alexander, Allison, Altekamp+ (OPAL Collab	١.)
AID	96	ZPHY C71 211	+Andreev, Andrieu, Appuhn+ (H1 Collab	
AID	96C	PL B380 461	+Andreev, Andrieu, Appuhn+ (H1 Collab	1.)
ALCARAZ	96	CERN-PPE/96-183	J. Alcaraz+ LD Collaborations and the LEP Electroweak Working Group	
The ALEPI	1, DEI	LPHI, L3, OPAL, and SI	LD Collaborations and the LEP Electroweak Working Group	Ρ.
ALEXANDER	96J	PL B377 181	+Allison, Altekamp, Ametewee+ (OPAL Collab).)
ALEXANDER		PL B377 273	+Allison, Altekamp, Ametewee+ (OPAL Collab	ı.)
BUSKULIC			D. Buskulic+ (ALEPH Collab +De Bonis, Decamp, Ghez+ (ALEPH Collab	1.)
BUSKULIC		PL B373 246	+De Bonis, Decamp, Ghez+ (ALEPH Collab	١.)
BUSKULIC		PL B384 461	+De Bonis, Decamp, Ghez+ +De Bonis, Decamp, Ghez+ +Kizukuri, Oshimo (TOKAH, OCK	1.)
СНО	96	PL B372 101	+Kizukuri, Oshimo (TOKAH, OCI	1)
ELLIS				u)
	968	PL B388 97	+Falk, Olive, Schmitt (CERN, MINI	٠,
FARRAR	96	PRL 76 4111	+Falk, Olive, Schmitt (CERN, MINI G.R. Farrar (RUT)	G)
FARRAR SUGIMOTO		PRL 76 4111	+Faik, Olive, Schmitt (CERN, MINI G.R. Farrar +Abe, Fujii, Igarashi+ (AMY Collab	5) 5.)
FARRAR	96 96 96	PRL 76 4111	+Faik, Olive, Schmitt (CERN, MINI G.R. Farrar +Abe, Fujii, Igarashi+ (AMY Collab	5) 5.)
FARRAR SUGIMOTO TEREKHOV ABACHI	96 96 96	PL B388 97 PRL 76 4111 PL B369 86 PL B385 139 PRL 75 618	+Faix, Olive, Schmitt G.R. Farrar +Abe, Fujii, Igarashi+ I. Terkhov, L. Clavell -Abbott. Abolins. Acharva+ (DO Collab	G) 5.) T)
FARRAR SUGIMOTO TEREKHOV ABACHI	96 96 96 95C	PL B388 97 PRL 76 4111 PL B369 86 PL B385 139 PRL 75 618	+Faik, Olive, Schmitt G.R. Farrar G.R. Farrar +Abe, Fujii, Igarashi+ (AMY Collab I. Terkhov, L. Claveli (ALA' +Abbott, Abolins, Acharya+ (DO Collab Eulit (ALA') - Collab Eulit (ALA') - Collab Eulit (ALA') - Collab Eulit (ALA') - Collab - Collab Eulit (ALA') - Collab - Collab - Collab	G) 5.) T)
FARRAR SUGIMOTO TEREKHOV ABACHI ABE	96 96 96 95C 95A	PL B388 97 PRL 76 4111 PL B369 86 PL B385 139 PRL 75 618	+Faik, Olive, Schmitt G.R. Farrar G.R. Farrar +Abe, Fujii, Igarashi+ (AMY Collab I. Terkhov, L. Claveli (ALA' +Abbott, Abolins, Acharya+ (DO Collab Eulit (ALA') - Collab Eulit (ALA') - Collab Eulit (ALA') - Collab Eulit (ALA') - Collab - Collab Eulit (ALA') - Collab - Collab - Collab	G) 5.) T)
FARRAR SUGIMOTO TEREKHOV ABACHI	96 96 96 95C 95A	PL B388 97 PRL 76 4111 PL B369 86 PL B385 139 PRL 75 618 PL B361 199 PRL 74 3538	+Falk, Olive, Schmitt G.R. Farrar +Abe, Fujii, Igarashi+ 1, Terkhov, L. Clavell +Abbott, Abolins, Acharya+ +Fujii, Sugryama, Fujimoto+ +Fujii, Sugryama, Fujimoto+ -Albrow, Amendoila, Amidej, Antos+ (CDP Coliab	6) 2, 17, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2,
FARRAR SUGIMOTO TEREKHOV ABACHI ABE ABE ABE	96 96 95 95C 95A 95N 95T	PL 8388 97 PRL 76 4111 PL 8369 86 PL 8385 139 PRL 75 618 PL 8361 199 PRL 74 3538 PRL 75 613	+Falk, Olive, Schmitt G.R. Farrar +Abe, Fujii, Igarashi+ I, Terkhov, L. Clavelil +Abbott, Abolins, Acharya+ +Fujii, Sugiyama, Fujimoto+ +Albrow, Amedolia, Amidel, Antos+ +Albrow, Amidel, Anway-Wiese+ +Adam, Adrain, Azuliar-Benitz+ (L3 Colais	
FARRAR SUGIMOTO TEREKHOV ABACHI ABE ABE ABE ACCIARRI	96 96 95C 95A 95N 95T 95E	PL 8388 97 PRI, 76 4111 PL 8369 86 PL 8385 139 PRI, 75 618 PL 8361 199 PRI, 74 3538 PRI, 75 613 PL 8350 109	+Falk, Olive, Schmitt G.R. Farrar +Abe, Fujii, Igarashi+ I, Terkhov, L. Clavelil +Abbott, Abolins, Acharya+ +Fujii, Sugiyama, Fujimoto+ +Albrow, Amedolia, Amidel, Antos+ +Albrow, Amidel, Anway-Wiese+ +Adam, Adrain, Azuliar-Benitz+ (L3 Colais	
FARRAR SUGIMOTO TEREKHOV ABACHI ABE ABE ABE ACCIARRI AKERS	96 96 95C 95A 95N 95T 95E	PL 8388 97 PRI, 76 4111 PL 8369 86 PL 8385 139 PRI, 75 618 PL 8361 199 PRI, 74 3538 PRI, 75 613 PL 8350 109	+Falk, Olive, Schmitt G.R. Farrar +Abe, Fujii, Igarashi+ I, Terkhov, L. Clavelil +Abbott, Abolins, Acharya+ +Fujii, Sugiyama, Fujimoto+ +Albrow, Amedolia, Amidel, Antos+ +Albrow, Amidel, Anway-Wiese+ +Adam, Adrain, Azuliar-Benitz+ (L3 Colais	
FARRAR SUGIMOTO TEREKHOV ABACHI ABE ABE ABE ACCIARRI AKERS AKERS	96 96 95C 95A 95N 95T 95E 95A 95R	PL 8388 97 PRL 76 4111 PL 8369 86 PL 8365 139 PRL 75 618 PL 8361 199 PRL 74 3538 PRL 75 613 PL 8350 109 ZPHY C65 367 ZPHY C65 203	+Falk, Olive, Schmitt GR, Farrar +Abe, Fujii, Igarashi+ (Aut Colab I, Terkhov, L. Clavell +Abbott, Abolins, Acharya+ +Alipii, Sughyans, Fujimoto+ +Allrow, Amediolia, Amidel, Antos+ +Albrow, Amidel, Amway-Wisser+ +Adam, Adralani, Aguilar-Benitez+ R. Akers+ +Alexander, Allison, Ametewee, Anderson+ (CPAL Colab +Casper, Depois, Decamber, Casper, Depois, Deca	03632222223
FARRAR SUGIMOTO TEREKHOV ABACHI ABE ABE ABE ACCIARRI AKERS AKERS BUSKULIC	96 96 95C 95A 95N 95T 95E 95A 95R 95E	PL 8388 97 PRL 76 4111 PL 8369 86 PL 8361 139 PRL 75 618 PL 8361 199 PRL 74 3539 PRL 75 613 PRL 75 613 PL 8350 109 ZPHY C67 203 PPL 8349 238	+Falk, Olive, Schmitt GR, Farrar +Abe, Fujii, Igarashi+ (Aut Colab I, Terkhov, L. Clavell +Abbott, Abolins, Acharya+ +Alipii, Sughyans, Fujimoto+ +Allrow, Amediolia, Amidel, Antos+ +Albrow, Amidel, Amway-Wisser+ +Adam, Adralani, Aguilar-Benitez+ R. Akers+ +Alexander, Allison, Ametewee, Anderson+ (CPAL Colab +Casper, Depois, Decamber, Casper, Depois, Deca	03632222223
FARRAR SUGIMOTO TEREKHOV ABACHI ABE ABE ACCIARRI AKERS AKERS BUSKULIC CLAVELLI	96 96 95C 95A 95T 95E 95A 95R 95E 95	PL 5388 97 PRL 76 4111 PL 8369 86 PL 8365 139 PRL 75 618 PL 8361 199 PRL 74 3538 PRL 75 613 PL 8350 109 ZPHY C65 367 ZPHY C67 203 PL 8349 238 PR D51 11117	+Falk, Olive, Schmitt GR. Farrar +Abe, Fujii, Igarashi+ (AUY Colab. I, Terkhov, L. Clavell +Abbott, Abolins, Acharya+ +Fujii, Sugyham, Fujimoto+ +Albrow, Amendolia, Amidei, Antos+ +Albrow, Adam, Adriani, Aguilar-Benitez+ R. Akers+ -Alexander, Allison, Amettewee, Anderson+ (DPAL Colab +Casper, DeBonis, Decamp+ -Coulter ALEPH Colab	0202222222
FARRAR SUGIMOTO TEREKHOV ABACHI ABE ABE ACCIARRI AKERS AKERS BUSKULIC CFALK	96 96 95 C 95 A 95 N 95 T 95 E 95 A 95 E 95 E 95 S	PL 8388 97 PRL 76 4111 PL 8369 86 PL 8365 139 PRL 75 518 PL 8361 199 PRL 75 613 PRL 75 613 PL 8369 109 ZPHY C65 367 ZPHY C67 203 PL 8349 238 PR D51 1117 PL 8349 99	+Falk, Olive, Schmitt GR. Farrar +Abe, Fujii, Igarashi+ (ALY Collab 1, Terkhov, L. Clavell +Abbott, Abolins, Acharya+ +Allorow, Amedolia, Amidel, Antos+ +Albrow, Ameldel, Amvay-Wisse+ +Aldram, Adralani, Aguilar-Benitez+ +Alemaner, Allison, Ametewee, Anderson+ +Casper, Debonis, Decamp+ +Coulter +Coulter (ALA' (MINN. UCS)	02F22222222
FARRAR SUGIMOTO TEREKHOV ABACHI ABE ABE ABE ACCIARRI AKERS BUSKULIC CLAVELLI FALK LOSECCO	96 96 95 C 95 A 95 N 95 T 95 E 95 A 95 E 95 E 95 S 95 S	PL 8388 97 PRL 75 4111 PL 8369 86 PRL 75 618 PRL 75 618 PRL 75 613 PRL 75 613 PL 8350 109 ZPHY C65 367 ZPHY C67 203 PL 8349 238 PL 8354 939 PL 8344 939	+Falk, Olive, Schmitt GR. Farrar +Abe, Fujii, Igarashi+ (ALY Collab I. Terkhov, L. Clavell +Abbott, Abolins, Acharya+ +Allorow, Amedolia, Amidel, Antos+ +Albrow, Ameldel, Amvay-Wisse+ +Aldram, Adralani, Aguilar-Benitez+ +Alarander, Allison, Ametewee, Anderson+ +Casper, Debonis, Decamp+ +Coulter +Coulter (ALA' (MINN. UCS)	02F22222222
FARRAR SUGIMOTO TEREKHOV ABACHI ABE ABE ACCIARRI AKERS AKERS BUSKULIC CLAVELLI FALK LOSECCO AHMED	96 96 95 95A 95N 95T 95E 95A 95E 95 95 95 95	PL 8388 97 PRL 75 4111 PL 8369 86 PRL 75 618 PRL 75 618 PRL 75 613 PL 8350 109 PRL 75 613 PL 8350 109 ZPHY C67 203 ZPHY C67 203 PR D51 1117 PL 8349 238 PR D51 1117 PL 8349 238 PR D51 1117 PL 8345 99 PL 8342 392 ZPHY C64 545	+Falk, Olive, Schmitt GR. Farrar +Abe, Fujii, Igarashi+ (ALY Collab I. Terkhov, L. Clavell +Abbott, Abolins, Acharya+ +Allorow, Amedolia, Amidel, Antos+ +Albrow, Ameldel, Amvay-Wisse+ +Aldram, Adralani, Aguilar-Benitez+ +Alarander, Allison, Ametewee, Anderson+ +Casper, Debonis, Decamp+ +Coulter +Coulter (ALA' (MINN. UCS)	02F22222222
FARRAR SUGIMOTO TEREKHOV ABACHI ABE ABE ACCIARRI AKERS AKERS BUSKULIC CLAVELLI FALK LOSECCO AHMED AKERS	96 96 95 95 95 95 95 95 95 95 95 95 95 95 95 9	PL 8388 97 PRL 76 4111 PL 8369 86 PRL 75 618 PRL 75 618 PRL 75 618 PRL 75 613 PRL 8350 109 PRL 75 613 PL 8350 109 ZPHY C67 203 PL 8349 238 PL 8364 939 PL 8347 264 ZPHY C64 549 PL 8347 207	+Falk, Olive, Schmitt GR. Farrar +Abe, Fujii, Igarashi+ (RUT' +Abe, Fujii, Igarashi+ (AAY Colab I. Terkhov, L. Clavelii (ALA' +Abbott, Abolins, Acharya+ +Fujii, Sugyyama, Fujimoto+ +Albrow, Amedolia, Amidel, Antos+ +Albrow, Amidel, Amay-Wisse+ +Adam, Adralani, Aguilar-Benitez+ (CPF Coliab +Alexander, Allison, Ametewee, Anderson+ (CPAL Coliab +Coulter -Alexander, Allison, Ametewon+ -Alexander, Allison, Anderson+ -Alexander, Allison, Anderson+	G 2 T 2 2 2 2 2 2 2 2 T B (2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FARRAR SUGIMOTO TEREKHOV ABACHI ABE ABE ABE ACCIARRI AKERS BUSKULIC CLAVELLI FALK LOSECCO AHMED AKERS BECK	96 96 95 95 95 95 95 95 95 95 95 95 95 95 95 9	PL 8388 97 PRL 76 4111 PL 8369 86 PRL 75 618 PRL 75 618 PRL 75 618 PRL 73 538 PRL 75 613 PRL 350 109 ZPHY C65 367 ZPHY C65 7203 PL 8389 238 PL 8389 238 PL 8384 939 ZPHY C64 545 PL 8337 207 PL 8337 207 PL 8337 207 PL 8337 207	+Falk, Olive, Schmitt GR. Farrar +Abe, Fujii, Igarashi+ (RUT' +Abe, Fujii, Igarashi+ (AAY Colab I. Terkhov, L. Clavelii (ALA' +Abbott, Abolins, Acharya+ +Fujii, Sugyyama, Fujimoto+ +Albrow, Amedolia, Amidel, Antos+ +Albrow, Amidel, Amay-Wisse+ +Adam, Adralani, Aguilar-Benitez+ (CPF Coliab +Alexander, Allison, Ametewee, Anderson+ (CPAL Coliab +Coulter -Alexander, Allison, Ametewon+ -Alexander, Allison, Anderson+ -Alexander, Allison, Anderson+	G 2 T 2 2 2 2 2 2 2 2 T B (2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FARRAR SUGIMOTO TEREKHOV ABACHI ABE ABE ACCIARRI AKERS AKERS BUSKULIC CLAVELLI FALK LOSECCO AHMED AKERS BECK CAKIR	96 96 95 95 95 95 95 95 95 95 95 95 95 95 95 9	PL 8388 97 PRL 75 4111 PL 8369 86 PRL 75 618 PRL 75 618 PRL 75 618 PRL 75 613 PRL 8350 109 PRL 75 613 PL 8350 109 PRL 75 613 PL 8350 109 PRL 849 238 PR DS1 1117 PL 8364 99 PL 8342 392 PRP CS5 1117 PL 8342 392 PRP CS5 236	+Falk, Olive, Schmitt GR. Farrar +Abe, Fujii, Igarashi+ (RUT' +Abe, Fujii, Igarashi+ (AAY Colab I. Terkhov, L. Clavelii (ALA' +Abbott, Abolins, Acharya+ +Fujii, Sugyyama, Fujimoto+ +Albrow, Amedolia, Amidel, Antos+ +Albrow, Amidel, Amay-Wisse+ +Adam, Adralani, Aguilar-Benitez+ (CPF Coliab +Alexander, Allison, Ametewee, Anderson+ (CPAL Coliab +Coulter -Alexander, Allison, Ametewon+ -Alexander, Allison, Anderson+ -Alexander, Allison, Anderson+	G 2 T 2 2 2 2 2 2 2 2 T B (2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FARRAR SUGIMOTO TEREKHOV ABACHI ABE ABE ACCIARE AKERS BUSKULIC CLAVELLI FALK LOSECCO AHMED AKERS BECK CAKIR FALK	96 96 95 95 N 95 P 95 P 95 P 95 P 95 P 95 P 95 P 94 P 94 P 94 P	PL 8388 97 PRL 76 4111 PL 8369 86 PRL 75 618 PRL 75 618 PRL 75 618 PRL 74 3539 PRL 75 613 PL 8350 109 ZPHY C65 367 ZPHY C65 367 ZPHY C65 367 ZPHY C65 367 PR D51 11117 PL 8354 99 PL 8349 392 ZPHY C64 545 PL 8337 207 PL 8336 141 PR D50 3268	+Falk, Olive, Schmitt GR. Farrar +Abe, Fujii, Igarashi+ (RUT' +Abe, Fujii, Igarashi+ (AAY Colab I. Terkhov, L. Clavelii (ALA' +Abbott, Abolins, Acharya+ +Fujii, Sugyyama, Fujimoto+ +Albrow, Amedolia, Amidel, Antos+ +Albrow, Amidel, Amay-Wisse+ +Adam, Adralani, Aguilar-Benitez+ (CPF Coliab +Alexander, Allison, Ametewee, Anderson+ (CPAL Coliab +Coulter -Alexander, Allison, Ametewon+ -Alexander, Allison, Anderson+ -Alexander, Allison, Anderson+	G 2 T 2 2 2 2 2 2 2 2 T B (2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FARRAR SUGIMOTO TEREKHOV ABACHI ABE ABE ABE ACCIARRI AKERS BUSKULIC CLAVELLI FALK LOSECCO AHMED AKERS BECK CAKIR FALK	96 96 95 95 N 95 P 95 P 95 P 95 P 95 P 95 P 95 P 94 P 94 P 94 P 94 P	PL 8388 97 PRL 75 4111 PL 8369 86 PRL 75 618 PRL 75 618 PRL 75 618 PRL 75 613 PL 8350 109 PRL 75 613 PL 8350 109 PRL 75 613 PL 8350 109 PRL 75 613 PL 8350 109 PL 8342 238 PR D51 1117 PL 8342 392 PR D51 1117 PL 8342 392 PR D51 3137 207 PL 8342 392 PR PR 9353 614 PR 9393 248 PR 98 939 248 PR 98 939 248	+Falk, Olive, Schmitt GR. Farrar +Abe, Fujii, Igarashi+ (RUT' +Abe, Fujii, Igarashi+ (AAY Colab I. Terkhov, L. Clavelii (ALA' +Abbott, Abolins, Acharya+ +Fujii, Sugyyama, Fujimoto+ +Albrow, Amedolia, Amidel, Antos+ +Albrow, Amidel, Amay-Wisse+ +Adam, Adralani, Aguilar-Benitez+ (CPF Coliab +Alexander, Allison, Ametewee, Anderson+ (CPAL Coliab +Coulter -Alexander, Allison, Ametewon+ -Alexander, Allison, Anderson+ -Alexander, Allison, Anderson+	G 2 T 2 2 2 2 2 2 2 2 T B (2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FARRAR SUGIMOTO TEREKHOV ABACHI ABE ABE ACCIARRI AKERS BUSKULIC CLAVELLI FALK LOSECCO AHMED AKERS BECK CAKIR FRANKE FRANKE FRANKE	96 96 95 95 95 95 95 95 95 95 95 95 95 95 95	PL 8388 97 PRL 75 4111 PL 8369 86 PRL 75 618 PRL 75 618 PRL 75 618 PRL 75 613 PL 8350 109 PRL 75 613 PL 8350 109 PRH 76 203 PPH 765 367 PPH 765 367 PPH 765 367 PR D51 1111 PL 8349 238 PR D51 1111 PL 8345 499 PL 8349 614 PR D50 3266 PL 8349 128 PPH 764 545 PL 8345 141 PR D50 3266 PR B336 415 PR D53 3264 PR B336 415 PR D53 3264 PL 8336 415 PR D53 3264	+Falk, Olive, Schmitt GR. Farrar +Abe, Fujii, Igarashi+ (RUT' +Abe, Fujii, Igarashi+ (AMY Colab I. Terkhov, L. Clavell +Abbott, Abolins, Acharya+ (DO Colab +Albrow, Amedolia, Amidel, Antos+ +Albrow, Amedolia, Amidel, Antos+ +Albrow, Amidel, Anway-Wiese+ +Albrow, Amidel, Anway-Wiese+ +Adam, Adralani, Agullar-Benitez+ R. Akers+ +Adam, Adralani, Agullar-Benitez+ R. Akers+ -Alexander, Allison, Ametewee, Anderson+ -Copiter -Coulter -Cou	G 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FARRAR SUGIMOTO TEREKHOV ABACHI ABE ABE ACCIARRI AKERS AKERS AKERS CLAVELLI FALK LOSECCO AHMED AKERS BECK CANIR FALK HOSODA SHIRAI HOSODA SHIRAI SHIR	96 96 95 95 95 95 95 95 95 95 95 95 95 95 95	PL 8388 97 PRL 75 4111 PL 8369 86 PL 8365 139 PRL 75 618 PRL 8361 199 PRL 75 613 PL 8360 109 PRL 75 613 PL 8360 109 PRL 75 613 PL 8360 109 PL 837 203 PL 8369 238 PL 8369 238 PL 8369 292 PPLY C65 456 PL 8337 207 PL 8347 207 PL 8342 399 PL 8349 296 PL 8339 248 PL 8339 248 PL 8339 248 PL 8339 248 PL 8339 248 PL 8339 248 PL 8339 248 PL 8339 248	+Falk, Olive, Schmitt GR. Farrar +Abe, Fujii, Igarashi+ (RUT' +Abe, Fujii, Igarashi+ (AAY Colab I. Terkhov, L. Clavell +Abbott, Abolins, Acharya+ +Fujii, Sugyham, Fujimoto+ +Altrow, Ameldei, Amvay-Wiese+ +Aldrow, Ameldei, Amvay-Wiese+ +Aldrow, Adralani, Aguilar-Benitez+ +Aldram, Adralani, Aguilar-Benitez+ +Alexander, Allison, Ametewee, Anderson+ +Coulter +Coulter +Coulter +Coulter +Coulter +Coulter +Coulter +Aldi, Andreev, Andrieu, Appuhn, Arpagaus+ +Aid, Andreev, Andrieu, Appuhn, Arpagaus+ +Aid, Andreev, Andrieu, Appuhn, Arpagaus+ +Mid. Cakir, GR. Farrar +Olive, Srednicki +Pass, Bard +Coulter +Coul	0 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FARRAR SUGIMOTO TEREKHOV ABACHI ABACHI ABE ABE ABE ACCIARRI AKERS BUSKULIC CLAVELI FALK LOSECCO AHMED AKERS BCCK CAKIR FRANKE HOSODA SHIRAI ACTON NATON	96 96 95 95 95 95 95 95 95 95 95 95 95 95 95	PL 8388 97 PRL 75 4111 PL 8369 86 PL 8365 139 PRL 75 618 PL 8365 139 PRL 75 613 PL 8360 109 PRL 75 613 PL 8360 109 PRL 75 613 PL 8360 109 PR 8349 238 PR D51 1117 PL 8345 99 PL 8345 99 PL 8347 99 PL 8347 99 PL 8342 392 PR D51 141 PR D50 3266 PL 8337 207 PL 8358 141 PR D50 3266 PL 8339 248 PL 8336 415 PR D53 3264 PL 8339 248 PL 8336 415 PR 1539 248 PL 8336 415 PR 1539 248 PL 8336 415 PR 1539 248 PL 8331 211 PRL 72 3313 PRL 72 3313	+Falk, Olive, Schmitt G.R. Farrar +Abe, Fujil, Igarashi+ (RUT' +Abe, Allison, Anderson+ +Allrow, Amdiel, Annay- +Albrow, Amdiel, Annay- +Albrow, Amdiel, Annay- +Blow, Amendolia, Amidel, Antos+ +Aldrow, Amdiel, Annay- +Blow, Amendolia, Amidel, Antos+ +Aldrow, Amdiel, Amay- +Blow, Amendolia, Amidel, Antos+ +Aldrow, Amdiel, Amay- +Blow, Amander, Allison, Anderson+ +Coulter -Coulter -Coulter -Ald, Andreev, Andrieu, Appuhn, Arpagaus+ -Alid, Andreev, Andrieu, Appuhn, Arpagaus+ -Alexander, Allison, Anderson+ -Bensch, Bockhoit+ M.B. Cakir, G.R. Farrar -Colive, Srednicki -Fraas, Bartl -Coulter -Coul	0.2.2.2.2.2.2.2.2.2.0.0.2.2.2.2.2.2.2.2
FARRAR SUGIMOTO TEREKHOV ABACHI ABE ABE ACCIARRI AKERS AKERS AKERS AKERS CLAVELLI FALK LOSECCO AHMED AKERS BECK CAKIR FRANKE HOSODA SHIRAI ACTON ADRIANI	96 96 95 95 95 95 95 95 95 95 95 95 95 95 95	PL 8388 97 PRL 75 4111 PL 8369 86 PL 8365 139 PRL 75 618 PL 8365 139 PRL 75 613 PL 8360 109 PRL 75 613 PL 8360 109 PRL 75 613 PL 8360 109 PR 8349 238 PR D51 1117 PL 8345 99 PL 8345 99 PL 8347 99 PL 8347 99 PL 8342 392 PR D51 141 PR D50 3266 PL 8337 207 PL 8358 141 PR D50 3266 PL 8339 248 PL 8336 415 PR D53 3264 PL 8339 248 PL 8336 415 PR 1539 248 PL 8336 415 PR 1539 248 PL 8336 415 PR 1539 248 PL 8331 211 PRL 72 3313 PRL 72 3313	+Falk, Olive, Schmitt G.R. Farrar +Abe, Fujil, Igarashi+ (RUT' +Abe, Allison, Anderson+ +Allrow, Amdiel, Annay- +Albrow, Amdiel, Annay- +Albrow, Amdiel, Annay- +Blow, Amendolia, Amidel, Antos+ +Aldrow, Amdiel, Annay- +Blow, Amendolia, Amidel, Antos+ +Aldrow, Amdiel, Amay- +Blow, Amendolia, Amidel, Antos+ +Aldrow, Amdiel, Amay- +Blow, Amander, Allison, Anderson+ +Coulter -Coulter -Coulter -Ald, Andreev, Andrieu, Appuhn, Arpagaus+ -Alid, Andreev, Andrieu, Appuhn, Arpagaus+ -Alexander, Allison, Anderson+ -Bensch, Bockhoit+ M.B. Cakir, G.R. Farrar -Colive, Srednicki -Fraas, Bartl -Coulter -Coul	0.2.2.2.2.2.2.2.2.2.0.0.2.2.2.2.2.2.2.2
FARRAR SUGIMOTO TEREKHOV ABACHI ABE ABE ABE ACCIARRI AKERS BUSKULIC CLAVELLI FALK LOSECCO AHMED AKERS BCK CANIR FALK HOSODA SHIRAI ACTON ADRIANI ALITTI	96 96 95 95 95 95 95 95 95 95 95 95 95 95 95	PL 8388 97 PRL 76 4111 PL 8369 86 PL 8369 86 PRL 75 618 PRL 75 618 PRL 75 618 PRL 75 613 PL 8350 109 PRL 75 613 PL 8350 109 PRL 75 613 PL 8350 109 PRL 75 623 PPH C65 367 PPH C65 367 PPH C65 367 PPH C65 367 PR D51 1111 PL 8349 238 PL 8349 238 PL 8349 236 PL 8349 236 PL 8349 237 PRP C64 545 PL 8349 247 PR D50 3268 PL 8339 248 PL 8336 415 PL 8339 248 PL 8336 415 PL 8331 211 PRL 72 3313 PRPL 236 1 PRL 72 3313 PRPL 236 1 PRL 72 3313 PRPL 236 1	+Falk, Olive, Schmitt GR. Farrar +Abe, Fujii, Igarashi+ (RUT' +Abe, Albrow, Amfale, Amaya- +Albrow, Amfale, Albrow, Al	G2F22222222CB4220G2222222
FARRAR SUGIMOTO TEREKHOV ABACHI ABACHI ABE ABE ACCIARRI AKCRS AKCRS AKCRS AKCRS AKCRS CLAVELLI FALK LOSECCO AHMED AKCRS BECK CAKIR FRANKE HOSODA SHIRAI NACTON ADRIANI ALITTI	96 96 95 95 95 95 95 95 95 95 95 95 94 94 94 94 93 93 93 93 93 93 93 93 93 93 93 94 94 94 95 95 95 95 95 95 95 95 95 95 95 95 95	PL 8388 97 PRL 75 4111 PL 8369 86 PL 8365 139 PRL 75 618 PL 8361 199 PRL 75 613 PL 8350 109 PR 9361 111 PR 9361 111 PR 9361 111 PR 9361 111 PR 950 3268 PL 8339 248 PL 8339 111 PR 9361 111 P	+Falk, Olive, Schmitt GR. Farrar +Abe, Fujii, Igarashi+ (ALY Coliab I. Terkhov, L. Clavelil +Abbott, Abolins, Acharya+ +Fujii, Sugypam, Fujimoto+ +Albrow, Ameldolia, Amidel, Antos+ +Albrow, Ameldo, Amelderson+ +Casper, Debonis, Decamp+ +Coulter -Olive, Srednicki -Ald, Andreev, Andrieu, Appuhn, Arpagaus+ -Ald, Andreev, Andrieu, Appuhn, Arpagaus+ -HI Coliab -Alexander, Allison, Anderson+ -Bensch, Bockholt+ -Will, Srednicki -Holmoto, Abe, Amako+ -Akers, Alexander, Allison, Anderson+ -Aguilar-Benitz, Ahlen, Alcaraz, Aloislo+ -Ambroolni, Ansari, Autlero, Bareyre+ -Coulter, Yuan -Coliat, Yung, Millon -Coliat, Coliat -Coliat, Coliat -Coliat, Coliat -Coliat, Coliat -Coliat, Coliat -Coliat -Coliat, Coliat -Coliat -Col	G 2 C 2 C 2 C C C C C C C C C C C C C C
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Supersymmetric Particle Searches, Quark and Lepton Compositeness

ANTONIADIS 91	PL B262 109	+Ellis, Nanopoulos (EPOL, CERN, TAMU, HARC)
BAER 91	PR D44 207	+Tata, Woodside (FSU, HAWA, ISU)
BOTTINO 91	PR D44 207 PL B265 57	+de Alfaro, Fornengo, Mignola+ (TORI, INFN)
GELMINI 91 HIDAKA 91	NP B351 623	+Gondolo, Roulet (ÚCLA, TRST)
KAMIONKOW91	PR D44 927 PR D44 3021	(TGAK) Kamionkowski (CHIC, FNAL) +Nojiri, Oyama, Suzuki+ (Kamiokande Collab.)
MORI 91B	PL B270 89	+Nojiri, Oyama, Suzuki+ (Kamiokande Collab.)
NOJIRI 91 OLIVE 91	PL B261 76 NP B355 208	(KEK) +Srednicki (MINN, UC5B)
ROSZKOWSKI 91	PL B262 59	(CERN)
SATO 91 ABREU 90F	PR D44 2220 PL B247 148	+Hirata, Kajita, Kifune, Kihara+ (Kamloka Collab.) +Adam, Adami, Adye, Alekseev+ (DELPHI Collab.)
ABREU 90G	PL B247 157 PL B244 352	+Adam, Adami, Adye, Alekseev+ (DELPHI Collab.) +Aihara, Doser, Enomoto+ (TOPAZ Collab.)
ADACHI 90C	PL B244 352	+Adam, Adami, Adye, Alekseev+ (DELPHI Collab.) +Aihara, Doser, Enomoto+ (TOPAZ Collab.) +Adriani, Aguilar-Benitez, Akbari, Alcarez+ (L3 Collab.)
ADEVA 901 AKESSON 90B	PL B249 341 PL B238 442	+Adriani, Aguilar-Benitez, Akbari, Alcarez+ (L3 Collab.) +Alitti, Ansari, Ansorge+ (UA2 Collab.)
AKRAWY 90D	PL B240 261	+Alexander Allison Allnort+ (OPAL Collab.)
AKRAWY 90N	Pl B248 211	+Alexander, Allison, Allport, Anderson+ +Alexander, Allison, Allport, Anderson+ +Ansari, Ansorge, Bagnaia, Bareyre+ (UA2 Collab.)
AKRAWY 900 ALITTI 90	PL B252 290 PL B235 363	+Alexander, Allison, Alliport, Anderson+ (UPAL Collab.) +Ansari Ansorge, Bagnaia, Barevre+ (UA2 Collab.)
BAER 90	PR D41 3414	+Alexander, Alison, Allport, Anderson+ -Alexander, Alison, Allport, Anderson+ (OPAL Collab, -Ansari, Ansorge, Bagnaia, Bareyre+ -Ores, Tata -Pores, Tata -Abrams, Adolphsen, Averill, Ballam+ -Deschizeaux, Lees, Minard, CrespoDeschizeaux, Goy, Lees+ -Deschizeaux, Goy, Lees+
BARKLOW 90 DECAMP 90C	PRL 64 2984 PL B236 86	+Abrams, Adolphsen, Averill, Ballam+ (Mark II Collab.)
DECAMP 90K	PL B244 541	+Deschizeaux, Lees, Minard, Crespo+ (ALEPH Collab.) +Deschizeaux, Gov. Lees+ (ALEPH Collab.)
ELLIS 90	PL B244 541 PL B245 251	+Deschizeaux, Goy, Lees+ (ALEPH Collab.) +Nanopoulos, Roszkowski, Schramm (CERN, HARC, TAMU) +Kamionkowski, Turner (UCB, CHIC, FNAL)
GRIEST 90 GRIFOLS 90	PR D41 3565 NP B331 244	+Kamionkowski, Turner (UCB, CHIC, FNAL) +Masso (BARC)
KRAUSS 90	PRL 64 999	(YALE)
SAKAI 90	PI B234 534	(YALE) +Gu, Low, Abe, Fujii+ (AMY Collab.)
SODERSTROM 90 TAKETANI 90	PRL 64 2980 PL B234 202	+McKenna, Abrams, Adolphsen, Averill+ (Mark II Collab.) +Odaka, Abe, Amako+ (VENUS Collab.)
ZHUKOVSKII 90	SJNP 52 931	+Eminov (MOSU)
ABE 89J	Translated from YAF ZPHY C45 175	52 1477
ADACHI 89	PL B218 105	+Amako, Arai, Fukawa+ (VENUS Collab.) +Aihara, Dijkstra, Enomoto, Fujii+ (TOPAZ Collab.) +Adriani, Aguilar-Benitez, Akbari+ (L3 Collab.)
ADEVA 89B	PL B218 105 PL B233 530	+Adriani, Aguilar-Benitez, Akbari+ (L3 Collab.)
ALBAJAR 89 HEARTY 89	ZPHY C44 15 PR D39 3207	
Also 87	PRL 58 1711	+Albrow, Allkofer, Arnison, Astbury+ +Rothberg, Young, Johnson, Whitaker+ Hearty, Rothberg, Young, Johnson+ (ASP Collab.)
Also 86	PRL 56 685	Bartha, Burke, Extermann+ (ASP Collab.)
NAKAMURA 89 OLIVE 89		+Kobayashi, Konaka, Imai, Masaike+ (KYOT, TMTC) +Srednicki (MINN, UCSB)
BEHREND 88B	PL B230 78 PL B215 186 PL B215 404	+Criegee, Dainton, Field+ (CELLO Collab.)
ELLIS 88B	PL B215 404	
NATH 88 OLIVE 88	PR D38 1479 PL B205 553 NP B310 693	+Arnowitt (NEAS, TAMU) +Srednicki (MINN, UCSB) +Watkins, Olive (MINN, UCSB)
SREDNICKI 88	NP B310 693	+Watkins, Olive (MINN, UCSB)
ALBAJAR 87D ANSARI 87D	PL B198 261	+Albrow, Allkoter+ (UA1 Collab.)
ANSARI 87D ARNOLD 87	PL B195 613 PL B186 435	+Bagnaia, Banner+ +Barth+ (BRUX, DUUC, LOUC, BARI, AICH, CERN+) +Buerger, Criegee, Dainton+ +Olive, Srednicki (MINN, UCSB) +Franzini, Youssef, Zhao+ (CUSB Collab.)
BEHREND 87B	ZPHY C35 181	+Barth+ (BRUX, DUUC, LOUC, BARI, AICH, CERN+) +Buerger, Criegee, Dainton+ (CELLO Collab.)
NG 87 TUTS 87	PL B188 138 PL B186 233	+Olive, Srednicki (MINN, UCSB)
ALBRECHT 86C	PL 167B 360	+Franzini, Youssef, Zhao+ +Binder, Harder+ +Bemporad, Boucrot, Callot+ +Haber, Kane +Qi, Read+ +Steigman, Tilav (LBL, UCSC, MICH) +MAC Collab, +Steigman, Tilav (BART, DELA)
BADIER 86	ZPHY C31 21 NP B267 625	+Bemporad, Boucrot, Callot+ (NA3 Collab.)
BARNETT 86 FORD 86	NP B267 625	+Haber, Kane (LBL, ÚCSC, MICH) +Qi, Read+ (MAC Collab.)
GAISSER 86	PR D33 3472 PR D34 2206	+Steigman, Tilav (BART, DELA)
VOLOSHIN 86	SJNP 43 495	+Okun (IIEP)
ADEVA 85	Translated from YAF PL 152B 439	+Recker Recker-Szendy+ (Mark-1 Collah)
Also 84C	PRPL 109 131	Adeva, Barber, Becker+ (Mark-J Collab.)
AKERLOF 85 BARTEL 85L	PL 156B 271 PL 155B 288	+Bonvicini, Chapman, Errede+ (HRS Collab.) +Becker, Cords, Felst, Hagiwara+ (JADE Collab.)
BEHREND 85	PL 161B 182	+Burger, Criegee, Fenner+ (CELLO Collab.)
COOPER 85B	PL 160B 212	Cooper-Sarkar, Parker, Sarkar+ (WA66 Collab.)
DAWSON 85 FARRAR 85	PR D31 1581 PRL 55 895	+Eichten, Quigg (LBL, FNAL) (RUTG)
GOLDMAN 85	Physica 15D 181	+Haber (LANL, UCSC) +Kane (UCSC, MICH) +Barber, Becker, Berdugo+ (Mark-J Collab.)
HABER 85 ADEVA 84B	PRPL 117 75 PRL 53 1806	+Kane (UCSC, MICH)
BALL 84	PRL 53 1314	
BARBER 84B	PL 139B 427	+Shrock (STON)
BARTEL 84B BARTEL 84C	PL 139B 327 PL 146B 126	+ Becker, Bowdery, Cords+ (JADE Collab.)
BRICK 84	PR D30 1134	+ (BROW, CAVE, IIT, IND, MIT, MONS, NIJM+)
ELLIS 84	NP B238 453	+Hagelin, Nanopoulos, Olive, Srednicki (CERN) (RUTG)
FARRAR 84 BEHREND 83	PRL 53 1029 PL 123B 127	+Chen, Fenner, Gumpel+ (CELLO Collab.)
BERGSMA 83C	PL 121B 429	+Dorenbosch, Jonker+ (CHARM Collab.)
CHANOWITZ 83	PL 126B 225	+Sharpe (UCB, LBL)
GOLDBERG 83 HOFFMAN 83	PRL 50 1419 PR D28 660	(NEAS) +Frank, Mischke, Moir, Schardt (LANL, ARZS)
KRAUSS 83	NP B227 556 SJNP 37 948	(HARV)
VYSOTSKII 83	SJNP 37 948 Translated from YAF	(ITEP)
KANE 82	PL 112B 227	+Leveille (MICH)
CABIBBO 81 FARRAR 78	PL 105B 155	+Farrar, Maiani (ROMA, RUTG) +Favet (CIT)
Also 78B	PL 76B 575 PL 79B 442	+Fayet (CIT) Farrar, Fayet (CIT)

Quark and Lepton Compositeness, Searches for

SEARCHES FOR QUARK AND LEPTON COMPOSITENESS

Written 1994 by K. Hagiwara (KEK) and K. Hikasa (Tohoku Univ.).

If quarks and leptons are made of constituents, then at the scale of constituent binding energies, there should appear new interactions among quarks and leptons. At energies much below the compositeness scale (Λ) , these interactions are suppressed by inverse powers of Λ . The dominant effect should come from

the lowest dimensional interactions with four fermions (contact terms), whose most general chirally invariant form reads [1]

$$L = \frac{g^2}{2\Lambda^2} \left[\eta_{LL} \overline{\psi}_L \gamma_\mu \psi_L \overline{\psi}_L \gamma^\mu \psi_L + \eta_{RR} \overline{\psi}_R \gamma_\mu \psi_R \overline{\psi}_R \gamma^\mu \psi_R + 2\eta_{LR} \overline{\psi}_L \gamma_\mu \psi_L \overline{\psi}_R \gamma^\mu \psi_R \right] . \tag{1}$$

Chiral invariance provides a natural explanation why quark and lepton masses are much smaller than their inverse size Λ . We may determine the scale Λ unambiguously by using the above form of the effective interactions; the conventional method [1] is to fix its scale by setting $g^2/4\pi = g^2(\Lambda)/4\pi = 1$ for the new strong interaction coupling and by setting the largest magnitude of the coefficients $\eta_{\alpha\beta}$ to be unity. In the following, we denote

$$\begin{split} & \Lambda = \Lambda_{LL}^{\pm} \ \, \text{for} \ \, (\eta_{LL},\, \eta_{RR},\, \eta_{LR}) = (\pm 1,\, 0,\, 0) \;, \\ & \Lambda = \Lambda_{RR}^{\pm} \ \, \text{for} \ \, (\eta_{LL},\, \eta_{RR},\, \eta_{LR}) = (0,\, \pm 1,\, 0) \;, \\ & \Lambda = \Lambda_{VV}^{\pm} \ \, \text{for} \ \, (\eta_{LL},\, \eta_{RR},\, \eta_{LR}) = (\pm 1,\, \pm 1,\, \pm 1) \;, \\ & \Lambda = \Lambda_{AA}^{\pm} \ \, \text{for} \ \, (\eta_{LL},\, \eta_{RR},\, \eta_{LR}) = (\pm 1,\, \pm 1,\, \mp 1) \;, \end{split} \label{eq:lambda}$$

as typical examples. Such interactions can arise by constituent interchange (when the fermions have common constituents, e.g., for $ee \rightarrow ee$) and/or by exchange of the binding quanta (whenever binding quanta couple to constituents of both particles).

Another typical consequence of compositeness is the appearance of excited leptons and quarks (ℓ^* and q^*). Phenomenologically, an excited lepton is defined to be a heavy lepton which shares leptonic quantum number with one of the existing leptons (an excited quark is defined similarly). For example, an excited electron e^* is characterized by a nonzero transition-magnetic coupling with electrons. Smallness of the lepton mass and the success of QED prediction for g-2 suggest chirality conservation, *i.e.*, an excited lepton should not couple to both left- and right-handed components of the corresponding lepton.

Excited leptons may be classified by $SU(2)\times U(1)$ quantum numbers. Typical examples are:

1. Sequential type

$$\left(egin{array}{c}
u^* \\ \ell^* \end{array}
ight)_L \,, \qquad \left[
u^*_R
ight] \,, \qquad \ell^*_R \,.$$

 ν_R^* is necessary unless ν^* has a Majorana mass.

2. Mirror type

$$\left[
u_L^*
ight], \qquad \ell_L^*, \qquad \left(egin{array}{c}
u^* \ \ell^* \end{array}
ight)_R \,.$$

3. Homodoublet type

$$\begin{pmatrix} \nu^* \\ \ell^* \end{pmatrix}_L \,, \qquad \begin{pmatrix} \nu^* \\ \ell^* \end{pmatrix}_R \,.$$

Similar classification can be made for excited quarks.

Excited fermions can be pair produced via their gauge couplings. The couplings of excited leptons with Z are listed

	Sequential type	Mirror type	Homodoublet type
$V^{\ell^*} A^{\ell^*}$	$-\frac{1}{2}+2\sin^2\theta_W$	$-\frac{1}{2} + 2\sin^2\theta_W$	$-1+2\sin^2\!\theta_W$
A^{ℓ^*}	$-\frac{1}{2}$	$+\frac{1}{2}$	0
$V^{ u_D^*}$	$+\frac{\overline{1}}{2}$	$+\frac{1}{2}$	+1
$A^{ u_D^*}$	$+\frac{1}{2}$	$-\frac{1}{2}$	0
$V^{ u_M^*}$	0	0	
$A^{ u_M^*}$	+1	-1	

in the following table (for notation see Eq. (1) in "Standard Model of Electroweak Interactions"):

Here ν_D^* (ν_M^*) stands for Dirac (Majorana) excited neutrino. The corresponding couplings of excited quarks can be easily obtained. Although form factor effects can be present for the gauge couplings at $q^2 \neq 0$, they are usually neglected.

In addition, transition magnetic type couplings with a gauge boson are expected. These couplings can be generally parametrized as follows:

$$\mathcal{L} = \frac{\lambda_{\gamma}^{(f^{*})} e}{2m_{f^{*}}} \overline{f}^{*} \sigma^{\mu\nu} (\eta_{L} \frac{1-\gamma_{5}}{2} + \eta_{R} \frac{1+\gamma_{5}}{2}) f F_{\mu\nu}
+ \frac{\lambda_{Z}^{(f^{*})} e}{2m_{f^{*}}} \overline{f}^{*} \sigma^{\mu\nu} (\eta_{L} \frac{1-\gamma_{5}}{2} + \eta_{R} \frac{1+\gamma_{5}}{2}) f Z_{\mu\nu}
+ \frac{\lambda_{W}^{(\ell^{*})} g}{2m_{\ell^{*}}} \overline{\ell}^{*} \sigma^{\mu\nu} \frac{1-\gamma_{5}}{2} \nu W_{\mu\nu}
+ \frac{\lambda_{W}^{(\nu^{*})} g}{2m_{\nu^{*}}} \overline{\nu}^{*} \sigma^{\mu\nu} (\eta_{L} \frac{1-\gamma_{5}}{2} + \eta_{R} \frac{1+\gamma_{5}}{2}) \ell W_{\mu\nu}^{\dagger}
+ \text{h.c.},$$
(3)

where $g=e/\sin\theta_W$, $F_{\mu\nu}=\partial_\mu A_\nu-\partial_\nu A_\mu$ is the photon field strength, $Z_{\mu\nu}=\partial_\mu Z_\nu-\partial_\nu Z_\mu$, etc. The normalization of the coupling is chosen such that

$$\max(|\eta_L|, |\eta_R|) = 1.$$

Chirality conservation requires

$$\eta_L \eta_R = 0 \ . \tag{4}$$

These couplings can arise from $SU(2)\times U(1)$ -invariant higher-dimensional interactions. A well-studied model is the interaction of homodoublet type ℓ^* with the Lagrangian [2,3]

$$\mathcal{L} = \frac{1}{2\Lambda} \overline{L}^* (g f \frac{\tau^a}{2} W_{\mu\nu}^a + g' f' Y B_{\mu\nu}) \frac{1 - \gamma_5}{2} L + \text{h.c.} , \qquad (5)$$

where L denotes the lepton doublet (ν, ℓ) , Λ is the compositeness scale, g, g' are SU(2) and U(1) $_Y$ gauge couplings, and $W^a_{\mu\nu}$ and $B_{\mu\nu}$ are the field strengths for SU(2) and U(1) $_Y$ gauge fields. The same interaction occurs for mirror-type excited leptons. For sequential-type excited leptons, the ℓ^* and ν^* couplings become unrelated, and the couplings receive the extra

suppression of $(250\,{\rm GeV})/\Lambda$ or m_{L^*}/Λ . In any case, these couplings satisfy the relation

$$\lambda_W = -\sqrt{2}\sin^2\theta_W(\lambda_Z \cot\theta_W + \lambda_\gamma) \ . \tag{6}$$

Additional coupling with gluons is possible for excited quarks:

$$\mathcal{L} = \frac{1}{2\Lambda} \overline{Q}^* \sigma^{\mu\nu} \left(g_s f_s \frac{\lambda^a}{2} G^a_{\mu\nu} + g f \frac{\tau^a}{2} W^a_{\mu\nu} + g' f' Y B_{\mu\nu} \right)$$

$$\times \frac{1 - \gamma_5}{2} Q + \text{h.c.} , \qquad (7)$$

where Q denotes a quark doublet, g_s is the QCD gauge coupling, and $G^a_{\mu\nu}$ the gluon field strength.

Some experimental analyses assume the relation $\eta_L = \eta_R = 1$, which violates chiral symmetry. We encode the results of such analyses if the crucial part of the cross section is proportional to the factor $\eta_L^2 + \eta_R^2$ and the limits can be reinterpreted as those for chirality conserving cases $(\eta_L, \eta_R) = (1,0)$ or (0,1) after rescaling λ .

Several different conventions are used by LEP experiments to express the transition magnetic couplings. To facilitate comparison, we reexpress these in terms of λ_Z and λ_γ using the following relations and taking $\sin^2 \theta_W = 0.23$. We assume chiral couplings, i.e., |c| = |d| in the notation of Ref. 2.

1. ALEPH (charged lepton and neutrino)

$$\lambda_Z^{\text{ALEPH}} = \frac{1}{2} \lambda_Z$$
 (1990 papers) (8a)

$$\frac{2c}{\Lambda} = \frac{\lambda_Z}{m_{\ell^*}[\text{or } m_{\nu^*}]} \quad \text{(for } |c| = |d|)$$
 (8b)

2. ALEPH (quark)

$$\lambda_u^{\text{ALEPH}} = \frac{\sin \theta_W \cos \theta_W}{\sqrt{\frac{1}{4} - \frac{2}{3} \sin^2 \theta_W + \frac{8}{9} \sin^4 \theta_W}} \lambda_Z = 1.11 \lambda_Z \quad (9)$$

3. L3 and DELPHI (charged lepton)

$$\lambda^{\text{L3}} = \lambda_Z^{\text{DELPHI}} = -\frac{\sqrt{2}}{\cot \theta_W - \tan \theta_W} \lambda_Z = -1.10\lambda_Z \quad (10)$$

4. L3 (neutrino)

$$f_Z^{L3} = \sqrt{2}\lambda_Z \tag{11}$$

5. OPAL (charged lepton)

$$\frac{f^{\text{OPAL}}}{\Lambda} = -\frac{2}{\cot \theta_W - \tan \theta_W} \frac{\lambda_Z}{m_{\ell^*}} = -1.56 \frac{\lambda_Z}{m_{\ell^*}}$$
(12)

6. OPAL (quark)

$$\frac{f^{\text{OPAL}}c}{\Lambda} = \frac{\lambda_Z}{2m_{\sigma^*}} \quad (\text{for } |c| = |d|)$$
 (13)

7. DELPHI (charged lepton)

$$\lambda_{\gamma}^{\rm DELPHI} = -\frac{1}{\sqrt{2}} \, \lambda_{\gamma} \tag{14}$$

If leptons are made of color triplet and antitriplet constituents, we may expect their color-octet partners. Transitions

Quark and Lepton Compositeness

between the octet leptons (ℓ_8) and the ordinary lepton (ℓ) may take place via the dimension-five interactions

$$\mathcal{L} = \frac{1}{2\Lambda} \sum_{\ell} \left\{ \overline{\ell}_{8}^{\alpha} g_{S} F_{\mu\nu}^{\alpha} \sigma^{\mu\nu} \left(\eta_{L} \ell_{L} + \eta_{R} \ell_{R} \right) + h.c. \right\}$$
 (15)

where the summation is over charged leptons and neutrinos. The leptonic chiral invariance implies $\eta_L \ \eta_R = 0$ as before.

References

- 1. E.J. Eichten, K.D. Lane, and M.E. Peskin, Phys. Rev. Lett. **50**, 811 (1983).
- 2. K. Hagiwara, S. Komamiya, and D. Zeppenfeld, Z. Phys. C29, 115 (1985).
- N. Cabibbo, L. Maiani, and Y. Srivastava, Phys. Lett. 139B, 459 (1984).

SCALE LIMITS for Contact Interactions: A(eeee)

Limits are for Λ_{LL}^{\pm} only. For other cases, see each reference.

$\Lambda_{LL}^{+}(\text{TeV})$	$\Lambda_{LL}^{-}(TeV)$	CL%	DOCUMENT ID		TECN	COMMENT
> 2.4	>2.2	95	ACKERSTAFF	97C	OPAL	E _{cm} = 130-136, 161 GeV
	>3.6	95	¹ KROHA	92	RVUE	
• • • W	e do not us	e the fo	llowing data for aver	ages,	, fits, lin	nits, etc. • • •
>1.7	>2.3	95	² ARIMA	97	VNS	E _{cm} = 57.77 GeV
>1.6	>2.0	95	³ BUSKULIC	93Q	ALEP	
>1.6		95	3,4 BUSKULIC	93Q	RVUE	cin
	>2.2	95	BUSKULIC	93Q	RVUE	
>1.3		95	¹ KROHA	92	RVUE	
>0.7	>2.8	95	BEHREND	910	CELL	E _{cm} =35 GeV
>1.3	>1.3	95	KIM	89	AMY	E _{cm} =50-57 GeV
>1.4	>3.3	95	⁵ BRAUNSCH	88	TASS	E _{cm} =12-46.8 GeV
>1.0	>0.7	95	⁶ FERNANDEZ	87B	MAC	E _{cm} =29 GeV
>1.1	>1.4	95	⁷ BARTEL	86 C	JADE	E _{cm} =12-46.8 GeV
>1.17	>0.87	95	8 DERRICK	86	HRS	E _{cm} =29 GeV
>1.1	>0.76	95	⁹ BERGER	85B	PLUT	E _{cm} =34.7 GeV

¹ KROHA 92 limit is from fit to BERGER 85B, BARTEL 86c, DERRICK 86B, FERNAN-DEZ 87B, BRAUNSCHWEIG 88, BEHREND 91B, and BEHREND 91c. The fit gives $\eta/\Lambda_{LL}^2 = +0.230 \pm 0.206 \text{ TeV}^{-2}$

 $\frac{2}{Z}Z - Z^{T}$ mixing is assumed to be zero.

⁵ BRAUNSCHWEIG 88 assumed $m_Z = 92$ GeV and $\sin^2 \theta_W = 0.23$.

⁶ FERNANDEZ 87B assumed $\sin^2 \theta_W = 0.22$.

 $^7\,\mathrm{BARTEL}$ 86c assumed $m_Z=93~\mathrm{GeV}$ and $\mathrm{sin}^2\theta_W=0.217.$

 9 BERGER 85B assumed $m_Z=93$ GeV and $\sin^2\!\theta_W=0.217$.

SCALE LIMITS for Contact Interactions: $\Lambda(ee\mu\mu)$

Limits are for Λ_{LL}^{\pm} only. For other cases, see each reference.

ALL (TeV)	A_L (TeV)	CL%		DOCUMENT ID		TECN	COMMENT
>2.4	> 2.9	95		ACKERSTAFF	97c	OPAL	E _{cm} = 130-136, 161 GeV
> 2.6	>1.9	95	10,11	BUSKULIC	93Q	RVUE	City
• • • We	do not us	e the	followi	ng data for aver	ages	, fits, lin	nits, etc. • • •
>1.7	>2.2	95	11	VELISSARIS	94	AMY	E _{cm} =57.8 GeV
>1.3	>1.5	95	11	BUSKULIC	93Q	ALEP	E _{Cm} =88.25-94.25 GeV
>2.3	>2.0	95		HOWELL	92	TOPZ	E _{cm} =52-61.4 GeV
	>1.7	95	12	KROHA	92	RVUE	C
>2.5	>1.5	95		BEHREND	91¢	CELL	E _{cm} =35-43 GeV
>1.6	>2.0	95	13	ABE	90ı	VNS	E _{CD} =50-60.8 GeV
>1.9	>1.0	95		KIM	89	AMY	E _{cm} =50−57 GeV
>2.3	>1.3	95.		BRAUNSCH	88D	TASS	E _{cm} =30-46.8 GeV
>4.4	>2.1	95	14	BARTEL	86C	JADE	E _{cm} =12-46.8 GeV
>2.9	>0.86	95	15	BERGER	85	PLUT	E _{cm} =34.7 GeV

¹⁰ This BUSKULIC 93Q value is from ALEPH data plus PEP/PETRA/TRISTAN data reanalyzed by KROHA 92.

SCALE LIMITS for Contact Interactions: $\Lambda(ee\tau\tau)$

Limits are for Λ_{LL}^{\pm} only. For other cases, see each reference.

$\Lambda_{LL}^+(\text{TeV})$	A _{LL} (TeV)	CL%	DOCUMENT ID		TECN	COMMENT
>1.9	>3.0	95	ACKERSTAFF	97c	OPAL	E _{cm} = 130-136, 161 GeV
• • • W	e do not us	e the	following data for ave			
>1.4	>2.0	95	16 VELISSARIS	94	AMY	E _{cm} =57.8 GeV
>1.0	>1.5	95	¹⁶ BUSKULIC			E _{cm} =88.25-94.25 GeV
>1.8	>2.3	95	16,17 BUSKULIC	93Q	RVUE	
>1.9	>1.7	95	HOWELL	92	TOPZ	Ecm=52-61.4 GeV
>1.9	>2.9	95	¹⁸ KROHA	92	RVUE	
>1.6	>2.3	95	BEHREND	91 C	CELL	E _{cm} =35-43 GeV
>1.8	>1.3	95	19 ABE	901	VNS	E _{cm} =50-60.8 GeV
>2.2	>3.2	95	²⁰ BARTEL	86	JADE	E _{cm} =12-46.8 GeV

¹⁶ BUSKULIC 93Q and VELISSARIS 94 use the following prescription to obtain the limit: when the naive 95%CL limit is better than the statistically expected sensitivity for the limit, the latter is adopted for the limit.

This BUSKULIC 93Q value is from ALEPH data plus PEP/PETRA/TRISTAN data reanalyzed by KROHA 92.

18 KROHA 92 limit is from fit to BARTEL 86C BEHREND 89B, BRAUNSCHWEIG 89C, ABE 901, and BEHREND 91c. The fit gives $\eta/\Lambda_{LL}^2 = +0.095 \pm 0.120 \text{ TeV}^{-2}$.

 19 ABE 901 assumed m_Z =91.163 GeV and $\sin^2\!\theta_W = 0.231$.

SCALE LIMITS for Contact Interactions: A(LLLL)

Lepton universality assumed. Limits are for Λ^{\pm}_{LL} only. For other cases, see each

ALL(TeV)	^_L(TeV)	CL%	DOCUMENT ID		TECN	COMMENT
>2.7	> 3.8	95	ACKERSTAFF	97c	OPAL	E _{cm} = 130-136, 161 GeV
> 3.5	>2.8	95	^{21,22} BUSKULIC	93Q	RVUE	
• • • V	Ve do not us	e the	following data for ave	rages	, fits, lin	nits, etc. • • •
>3.0	>2.3	95	22,23 BUSKULIC	93Q	ALEP	E _{cm} =88.25-94.25 GeV
>2.5	>2.2	95	²⁴ HOWELL			E _{cm} =52-61.4 GeV
>3.4	>2.7	95	²⁵ KROHA		RVUE	

 21 This BUSKULIC 93Q value is from ALEPH data plus PEP/PETRA/TRISTAN data reanalyzed by KROHA 92.

analyzed by KKUTIA 92.

22 BUSKULIC 930 uses the following prescription to obtain the limit: when the naive 95%CL limit is better than the statistically expected sensitivity for the limit, the latter is adopted

for the limit. 23 From $e^+e^- \rightarrow e^+e^-$, $\mu^+\mu^-$, and $\tau^+\tau^-$. 24 HOWELL 92 limit is from $e^+e^- \rightarrow \mu^+\mu^-$ and $\tau^+\tau^-$.

²⁵ KROHA 92 limit is from fit to most PEP/PETRA/TRISTAN data. The fit gives η/Λ_{II}^2 $= -0.0200 \pm 0.0666 \text{ TeV}^{-2}$.

SCALE LIMITS for Contact Interactions: $\Lambda(eeqq)$

Limits are for Λ_{LL}^{\pm} only. For other cases, see each reference.

LL (TeV)	$\Lambda_{LL}^{-}(TeV)$	CL%	DOCUMENT ID		TECN	COMMENT
>2.5	>3.7	95	26 ABE	971	CDF	(eeqq) (isosinglet)
>3.1	>2.9	95	27 ACKERSTAFF	97C	OPAL	(eebb)
• • W	e do not us	e the fo	llowing data for aver	ages	, fits, lir	nits, etc. • • •
>2.5	>2.1	95	28 ACKERSTAFF	97c	OPAL	(eegg)
>7.4	>11.7	95	²⁹ DEANDREA			eeuu, atomic parity viola- tion
>2.3	>1.0	95	30 AID	95	H1	(eeqq) (u, d quarks)
1.7	>2.2	95	31 ABE	91D	CDF	(eeqq) (u, d quarks)
>1.2		95	³² ADACHI	91	TOPZ	(e e q q) (flavor-universal)
	>1.6	95	32 ADACHI	91	TOPZ	(e e q q) (flavor-universal)
>0.6	>1.7	95	33 BEHREND	91 C	CELL	(eecc)
>1.1	>1.0	95	33 BEHREND	91 C	CELL	(eebb)
>0.9		95	³⁴ ABE	89L	VNS	(e e q q) (flavor-universal)
	>1.7	95	34 ABE	89L	VNS	(e e q q) (flavor-universal)
>1.05	>1.61	95	³⁵ HAGIWARA	89	RVUE	(eecc)
>1.21	>0.53	95	36 HAGIWARA	89	RVUE	(eebb)

27 ACKERSTAFF 97C limits are from e^+e^- mass distribution in $pp \to e^+e^-$ A at $E_{\rm cm}=1.0$ teV. 28 ACKERSTAFF 97C limits are from $e^+e^- \to q\overline{q}$ cross section at $E_{\rm cm}=130-136$ GeV

and 161 GeV.

29 DEANDREA 97 limits is from atomic parity violation of cesium. The limit is eluded if the contact interactions are parity conserving.

30 AID 95 limits are from the Q^2 spectrum measurement of $ep \rightarrow eX$.

31 ABE 910 limits are from e^+e^- mass distribution in $p\bar{p} \rightarrow e^+e^-X$ at $E_{cm} = 1.8$ TeV.

 32 ADACHI 91 limits are from differential jet cross section. Universality of $\Lambda(eeqq)$ for five

flavors is assumed.

33 BEHREND 91C is from data at $E_{cm} = 35-43$ GeV.

³⁴ABE 89L limits are from jet charge asymmetry. Universality of $\Lambda(eeqq)$ for five flavors

BUSKULIC 930 uses the following prescription to obtain the limit: when the naive 95%CL limit is better than the statistically expected sensitivity for the limit, the latter is adopted

⁴ This BUSKULIC 93Q value is from ALEPH data plus PEP/PETRA/TRISTAN data reanalyzed by KROHA 92.

⁸ DERRICK 86 assumed $m_Z^2 = 93$ GeV and $g_V^2 = (-1/2 + 2\sin^2\theta_W)^2 = 0.004$.

¹¹ BUSKULIC 93Q and VELISSARIS 94 use the following prescription to obtain the limit: when the naive 95%CL limit is better than the statistically expected sensitivity for the limit, the latter is adopted for the limit.

¹² KROHA 92 limit is from fit to BARTEL 86C, BEHREND 87C, BRAUNSCHWEIG 88D, BRAUNSCHWEIG 89C, ABE 90I, and BEHREND 91C. The flt gives $\eta/\Lambda_{LL}^2=-0.155\pm$

^{0.095} TeV $^{-2}$. 13 ABE 901 assumed m_Z =91.163 GeV and $\sin^2\!\theta_W \approx$ 0.231.

 $^{^{14}\,\}mathrm{BARTEL}$ 86C assumed $m_Z=93~\mathrm{GeV}$ and $\mathrm{sin}^2\theta_W=0.217.$

¹⁵ BERGER 85 assumed $m_Z = 93$ GeV and $\sin^2 \theta_W = 0.217$.

²⁰ BARTEL 86 assumed $m_Z = 93$ GeV and $\sin^2 \theta_W = 0.217$.

35 The HAGIWARA 89 limit is derived from forward-backward asymmetry measurements of D/D* mesons by ALTHOFF 83c, BARTEL 84E, and BARINGER 88.

The HAGIWARA 89 limit is derived from forward-backward asymmetry measurement of b hadrons by BARTEL 84D.

SCALE LIMITS for Contact Interactions: $\Lambda(\mu\mu qq)$

$\Lambda_{LL}^{+}(TeV)$	Λ _{LL} (TeV)	CL%	DOCUMENT I	D	TECN	COMMENT
>2.9 • • • W	>4.2 e do not us	95 e the f	37 ABE ollowing data for a	97T verages,	CDF fits, li	(μμqq) (isosinglet) mits, etc. • • •
,	>1.6	95	ABE			$(\mu\mu q q)$ (isosinglet)
37 ABE	97T limits a	re fron	$\mu^+\mu^-$ mass dist	ribution	in $\overline{\rho} \rho$	$\rightarrow \mu^{+}\mu^{-}X$ at $\mathcal{E}_{cm}=1.8$ TeV.

SCALE LIMITS for Contact interactions: $\Lambda(\ell\nu\ell\nu)$

CL%	DOCUMENT ID		TECN	COMMENT					
90	38 JODIDIO	86	SPEC	$\Lambda_{LR}^{\pm}(\nu_{\mu}\nu_{e}\mu_{e})$					
	³⁹ DIAZCRUZ	94	RVUE	$\Lambda_{LL}^+(au u_ aue u_e)$					
	⁴⁰ DIAZCRUZ	94	RVUE	$\Lambda_{LL}^{+}(\tau \nu_{\tau} \mu \nu_{\mu})$					
	⁴⁰ DIAZCRUZ	94	RVUE	$\Lambda_{LL}^-(au u_{ au}\mu u_{\mu})$					
	90	90 38 JODIDIO e following data for averages 39 DIAZCRUZ 39 DIAZCRUZ 40 DIAZCRUZ	90 38 JODIDIO 86 e following data for averages, fit: 39 DIAZCRUZ 94 39 DIAZCRUZ 94 40 DIAZCRUZ 94	90 38 JODIDIO 86 SPEC e following data for averages, fits, limits, 39 DIAZCRUZ 94 RVUE 40 DIAZCRUZ 94 RVUE					

³⁸ JODIDIO 86 limit is from $\mu^+ \to \overline{\nu}_{\mu} \, e^+ \nu_e$. Chirality invariant interactions $L = (g^2/\Lambda^2)$ $\left[\eta_{LL}\left(\overline{\nu}_{\mu L}\gamma^{\alpha}\mu_{L}\right)\left(\overline{e}_{L}\gamma_{\alpha}\nu_{eL}\right)+\eta_{LR}\left(\overline{\nu}_{\mu L}\gamma^{\alpha}\nu_{eL}\left(\overline{e}_{R}\gamma_{\alpha}\mu_{R}\right)\right]\text{ with }g^{2}/4\pi=1\text{ and }g^{2}/4\pi=1$ $(\eta_{LL},\eta_{LR})=(0,\pm 1)$ are taken. No limits are given for Λ_{LL}^\pm with $(\eta_{LL},\eta_{LR})=(\pm 1,0)$. For more general constraints with right-handed neutrinos and chirality nonconserving contact interactions, see their text.

39 DIAZCRUZ 94 limits are from $\Gamma(\tau \to e \nu \nu)$ and assume flavor-dependent contact interactions with $\Lambda(\tau \nu_{\tau} e \nu_{e}) \ll \Lambda(\mu \nu_{\mu} e \nu_{e})$.

40 DIAZCRUZ 94 limits are from $\Gamma(\tau \to \mu \nu \nu)$ and assume flavor-dependent contact

interactions with $\Lambda(\tau \nu_{\tau} \mu \nu_{\mu}) \ll \Lambda(\mu \nu_{\mu} e \nu_{e})$.

SCALE LIMITS for Contact Interactions: $\Lambda(qqqq)$

Limits are for Λ_{LL}^{\pm} with color-singlet isoscalar exchanges among u_L 's and d_L 's only. See EICHTEN 84 for details.

VALUE (TeV)	C1%	DOCUMENT ID		COMMENT	_
		41 ABE	96 CDF	$p\overline{p} \rightarrow \text{jets inclusive}$	
>1.6	95	⁴² ABE	965 CDF	$\rho \overline{\rho} \rightarrow \text{dijet angl.; } \Lambda_{LL}^+$	- 1
• • • We do not	use the followi	ng data for averag	es, fits, limit	s, etc. • • •	
>1.3	95	43 ABE	93G CDF	$\rho \overline{\rho} \rightarrow \text{dijet mass}$	
>1.4	95	44 ABE	92D CDF	$p\overline{p} \rightarrow \text{jets Inclusive}$	
>1.0	99	⁴⁵ ABE	92M CDF	$p\overline{p} \rightarrow dijet angl.$	
>0.825	95	⁴⁶ ALITTI	91B UA2	$p\overline{p} \rightarrow jets inclusive$	
>0.700	95	⁴⁴ ABE	89 CDF	$p\overline{p} \rightarrow \text{jets inclusive}$	
>0.330	95	47 ABE	89H CDF	$p\overline{p} \rightarrow \text{dijet angl.}$	
>0.400	95	48 ARNISON	86C UA1	pp → jets inclusive	
>0.415	95	⁴⁹ ARNISON	860 UA1	$p\overline{p} \rightarrow dljet angl.$	
>0.370	95	50 APPEL	85 UA2	$p\overline{p} \rightarrow \text{jets inclusive}$	
>0.275	95	⁵¹ BAGNAIA	84C UA2	Repl. by APPEL 85	

⁴¹ ABE 96 finds that the inclusive jet cross section for E_T >200 GeV is significantly higher than the $\mathcal{O}(\alpha_s^3)$ perturbative QCD prediction. This could be interpreted as the effect of a contact interaction with $\Lambda_{LL} \sim$ 1.6 TeV. However, ABE 96 state that uncertainty in the parton distribution functions, higher-order QCD corrections, and the detector calibration may possibly account for the effect.
42 ABE 96s limit is from dijet angular distribution in $p\bar{p}$ collisions at $E_{\rm Cm}=1.8$ TeV. The

limit for Λ_{II}^- is $> 1.4\,\text{TeV}$. ABE 965 also obtain limits for flavor symmetric contact

interactions among all quark flavors: $\Lambda_{LL}^+~>1.8$ TeV and $\Lambda_{LL}^-~>1.6$ TeV.

 43 ABE 93G limit is from dijet mass distribution in $p\overline{p}$ collisions at $E_{\rm Cm}=1.8$ TeV. The limit is the weakest from several choices of structure functions and renormalization scale. 44 Limit is from inclusive jet cross-section data in $p\overline{p}$ collisions at $E_{\rm Cm}=1.8$ TeV. The limit takes into account uncertainties in choice of structure functions and in choice of

45 ABE 92M limit is from dijet angular distribution for $m_{\text{dijet}} > 550 \text{ GeV}$ in $p\overline{p}$ collisions at E_{cm}=1.8 TeV.

46 ALITTI 91B limit is from inclusive jet cross section in $p\overline{p}$ collisions at $E_{\rm CM}=630$ GeV. The limit takes into account uncertainties in choice of structure functions and in choice

of process scale.

47 ABE 89H limit is from dijet angular distribution for $m_{\rm dijet} > 200$ GeV at the Fermilab Tevatron Collider with $E_{\rm CM} = 1.8$ TeV. The QCD prediction is quite insensitive to choice of structure functions and choice of process scale.

48 ARNISON 86C limit is from the study of inclusive high- p_T jet distributions at the CERN \bar{p} p collider ($E_{\rm CM} = 546$ and 630 GeV). The QCD prediction-renormalized to the low- p_T region gives a good fit to the data.

49 ARNISON 860 limit is from the study of dijet angular distribution in the range 240 < m(dijet) < 300 GeV at the CERN \bar{p} p collider ($E_{\rm CM} = 630$ GeV). QCD prediction using

EHLQ structure function (EICHTEN.84) with $\Lambda_{QCD}=0.2$ GeV for the choice of $Q^2=$ p_T^2 gives the best fit to the data.

⁵⁰ APPEL 85 limit is from the study of inclusive high- p_T let distributions at the CERN p_T collider ($E_{Cm} = 630$ GeV). The QCD prediction renormalized to the low- p_T region gives a good description of the data.

gives a good description of the data. 5 BAGNAIA 84C limit is from the study of jet p_T and dijet mass distributions at the CERN $\bar{p}p$ collider ($E_{\rm CM}=540$ GeV). The limit suffers from the uncertainties in comparing the data with the QCD prediction.

MASS LIMITS for Excited e (e*)

Most e^+e^- experiments assume one-photon or Z exchange. The limits from some e^+e^- experiments which depend on λ have assumed transition couplings which are chirality violating $(\eta_L=\eta_R)$. However they can be interpreted as limits for chirality-conserving interactions after multiplying the coupling value λ by $\sqrt{2}$; see Note.

Excited leptons have the same quantum numbers as other ortholeptons. See also the searches for ortholeptons in the "Searches for Heavy Leptons"

Limits for Excited e (e*) from Pair Production

These limits are obtained from $e^+e^- \rightarrow e^{*+}e^{*-}$ and thus rely only on the (electroweak) charge of e*. Form factor effects are ignored unless noted. For the case of limits from Z decay, the e^* coupling is assumed to be of sequential type. Possible t channel contribution from transition magnetic coupling is neglected. All limits assume $e^* \rightarrow e\gamma$ decay except the limits from $\Gamma(Z)$.

For limits prior to 1987, see our 1992 edition (Physical Review D45, 1 June, Part II

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>85.0	95	52 ACKERSTAFF	98C OPAL	$e^+e^- \rightarrow e^*e^*$ Homodoublet type
 ● ● We do 	not ı	ise the following data t	for averages,	fits, limits, etc. • • •
>79.6	95	53,54 ABREU	97B DLPH	$e^+e^- \rightarrow e^*e^*$ Homodoublet type
>77.9	95	^{53,55} ABREU	97B DLPH	e ⁺ e ⁻ → e [*] e [*] Sequential type
>79.7	95	53 ACCIARRI	97G L3	$e^+e^- \rightarrow e^*e^*$ Sequential type
>79.9	95		97 OPAL	$e^+e^- \rightarrow e^*e^*$ Homodoublet type
>62.5	95	57 ABREU	96K DLPH	$e^+e^- \rightarrow e^*e^*$ Homodoublet type
>64.7	95	⁵⁸ ACCIARRI	96D L3	$e^+e^- \rightarrow e^*e^*$ Sequential type
>66.5	95	⁵⁸ ALEXANDER	96Q OPAL	$e^+e^- \rightarrow e^*e^*$ Homodoublet type
>65.2	95	⁵⁸ BUSKULIC	96w ALEP	$e^+e^- ightarrow e^*e^*$ Sequential type
>45.6	95	ADRIANI	93M L3	$Z \rightarrow e^* e^*$
>45.6	95	ABREU		$Z \rightarrow e^* e^*$
>29.8	95	59 BARDADIN	92 RVUE	Γ(<i>Z</i>)
>26.1	95	60 DECAMP	92 ALEP	$Z \rightarrow e^* e^*; \Gamma(Z)$
>46.1	95	DECAMP	92 ALEP	$Z \rightarrow e^* e^*$
>33	95	60 ABREU	91F DLPH	$Z \rightarrow e^* e^*; \Gamma(Z)$
>45.0	95	⁶¹ ADEVA	90F L3	$Z \rightarrow e^* e^*$
>44.9	95	AKRAWY	901 OPAL	
>44.6	95	62 DECAMP	90G ALEP	
>30.2	95	ADACHI	89B TOPZ	$e^+e^- \rightarrow e^*e^*$
>28.3	95	KIM	89 AMY	e ⁺ e ⁻ → e*e*
>27.9	95	63 ABE	888 VNS	e ⁺ e ⁻ → e*e*
F0 .		_		

52 From e^+e^- collisions at \sqrt{s} =170–172 GeV. ACKERSTAFF 98c also obtain limit from $e^* \rightarrow \nu W$ decay mode: $m_{e^*} >$ 81.3 GeV.

⁵³ From e^+e^- collisions at $\sqrt{s}=$ 161 GeV.

⁵⁴ ABREU 97B also obtain limit from charged current decay mode $e^* \rightarrow \nu W$, $m_{e^*} > 70.9$

GeV. SS ABREU 978 also obtain limit from charged current decay mode $e^* \to \nu W$, $m_{e^*} >$ 44.6

56 GeV. SACKERSTAFF 97 also obtain limit from charged current decay mode $e^{\bf k} \to \nu W, \, m_{\nu_e^{\bf k}}$ >

77.1 GeV. 57 From e^+e^- collisions at $\sqrt{s}=$ 130–136 GeV.

⁵⁸ From e^+e^- collisions at \sqrt{s} = 130–140 GeV.

⁵⁹BARDADIN-OTWINOWSKA 92 limit is independent of decay modes. Based on $\Delta\Gamma(Z)$ <36 MeV.

 60 Limit is independent of e^* decay mode.

61 ADEVA 90F is superseded by ADRIANI 93M.

62 Superseded by DECAMP 92.

63 ABE 888 limits assume $e^+e^- \rightarrow e^{*+}e^{*-}$ with one photon exchange only and $e^* \rightarrow$ eγ giving eeγγ.

Limits for Excited $e(e^*)$ from Single Production

These limits are from $e^+e^- \to e^*e$, $W \to e^*\nu$, or $ep \to e^*X$ and depend on transition magnetic coupling between e and e^* . All limits assume $e^* \to e\gamma$ decay except as noted. Limits from LEP, UA2, and H1 are for chiral coupling, whereas all other limits are for nonchiral coupling, $\eta_L=\eta_R=1$. In most papers, the limit is expressed in the form of an excluded region in the $\lambda-m_{e^*}$ plane. See the original

For limits prior to 1987, see our 1992 edition (Physical Review D45, 1 June, Part II

(1992)	,.				
VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT	
none 30-200	95	64 BREITWEG	97C ZEUS	ep → e*X	
>89	95	ADRIANI	93M L3	$Z \rightarrow ee^*, \lambda_Z > 0.5$	
>88	95	ABREU	92c DLPH	$Z \rightarrow ee^*, \lambda_Z > 0.5$	
>91	95	DECAMP	92 ALEP	$Z \rightarrow ee^*, \lambda_Z > 1$	
>87	95	AKRAWY	90i OPAL	$Z \rightarrow ee^*, \lambda_Z > 0.5$	

Quark and Lepton Compositeness

• • • '	We do no	t use the	following data	for a	erages,	fits, limits, etc. • • •
	9:	5 65	ACKERSTAFF	98C	OPAL	e+e- → ee*
		66,67	ABREU	97B	DLPH	e+e- → ce*
		66,68	ACCIARRI	97G		$e^+e^- \rightarrow ee^*$
		69	ACKERSTAFF	97	OPAL	e+e- → ee*
		70	ADLOFF	97	H1	Lepton-flavor violation
		71	ABREU	96K	DLPH	e+e- → ce*
		72	ACCIARRI		L3	e+e- → ee*
		73	ALEXANDER			e ⁺ e ⁻ → ee*
		74	BUSKULIC		ALEP	e+e- → ee*
		75	DERRICK		ZEUS	-r -
			ABT		H1	$ep \rightarrow e^* X$
>86	9:		ADRIANI		L3	$\lambda_{\gamma} > 0.04$
		"	DERRICK		ZEUS	Superseded by DERRICK 95B
>86	9		ABREU	92C	DLPH	$e^+e^- \rightarrow ee^*, \lambda_{\gamma} > 0.1$
>88	9		ADEVA	90F	L3	$Z \rightarrow ee^*, \lambda_Z > 0.5$
>86	9		ADEVA	90F	L3	$Z \rightarrow ee^*, \lambda_Z > 0.04$
>81	9	5 79	DECAMP		ALEP	$Z \rightarrow ee^*, \lambda_Z^- > 1$
>50	9	5	ADACHI	89B	TOPZ	$e^+e^- \rightarrow e\bar{e^*}, \lambda_{\gamma} > 0.04$
>56	9	5	KIM	89	AMY	$e^+e^- \rightarrow ee^*$, $\lambda_{\gamma} > 0.03$
none 2	3-54 9	5 80	ABE	88B	VNS	$e^+e^- \rightarrow ee^* \lambda_{\gamma} > 0.04$
>75	9		ANSARI	87D	UA2	$W \rightarrow e^* \nu$; $\lambda_W > 0.7$
>63	9		ANSARI	87D	UA2	$W \rightarrow e^* \nu; \lambda_W > 0.2$
>40	9	5 81	ANSARI	87Đ	UA2	$W \rightarrow e^* \nu; \lambda_W > 0.09$
64						••

- ⁶⁴ BREITWEG 97C search for single e^* production in ep collisions with the decays $e^* o$ $e\gamma$, eZ, νW . $f=-f'=2\Lambda/m_{e^*}$ is assumed for the e^* coupling. See their Fig. 9 for the exclusion plot in the mass-coupling plane.
- 65 ACKERSTAFF 98C from e^+e^- collisions at \sqrt{s} =170–172 GeV. See their Fig. 11 for the exclusion limit in the mass-coupling plane.
- 66 From e^+e^- collisions at $\sqrt{s}=$ 161 GeV.
- 67 See Fig. 4a and Fig. 5a of ABREU 97B for the exclusion limit in the mass-coupling plane. 68 See Fig. 2 and Fig. 3 of ACCIARRI 97G for the exclusion limit in the mass-coupling plane.
- ⁶⁹ ACKERSTAFF 97 result is from e^+e^- collisions at \sqrt{s} = 161 GeV. See their Fig. 3 for the exclusion limit in the mass-coupling plane.
- To ADLOFF 97 search for single e^* production in ep collisions with the decays $e^* \rightarrow e\gamma$, eZ, νW . See their Fig. 4 for the rejection limits on the product of the production cross section and the branching ratio into a specific decay channel.
- 71 ABREU 96K result is from e $^+$ e $^-$ collisions at \sqrt{s} = 130–136 GeV. See their Fig. 4 for the exclusion limit in the mass-coupling plane.
- 72 ACCIARRI 96D result is from e^+e^- collisions at \sqrt{s} = 130–140 GeV. See their Fig. 2 for
- the exclusion limit in the mass-coupling plane. 73 ALEXANDER 96Q result is from e^+e^- collisions at $\sqrt{s}=$ 130–140 GeV. See their Fig. 3a
- for the exclusion limit in the mass-coupling plane. 74 BUSKULIC 96w result is from e^+e^- collisions at $\sqrt{s}=$ 130–140 GeV. See their Fig. 3 for the exclusion limit in the mass-coupling plane.
- 75 DERRICK 958 search for single e* production via e* e γ coupling in e ρ collisions with the decays $e^* \rightarrow e\gamma$, eZ, νW . See their Fig. 13 for the exclusion plot in the $m_{e^*} - \lambda \gamma$
- plane. 76 ABT 93 search for single e^* production via $e^*e\gamma$ coupling in ep collisions with the m - λ , plane. decays $e^* \to e \gamma$, e Z, νW . See their Fig. 4 for exclusion plot in the $m_{e^*} - \lambda_{\gamma}$ plane.
- 77 DERRICK 93B search for single e^* production via e^*e_γ coupling in e_P collisions with the decays $e^* \to e\gamma$, eZ, νW . See their Fig. 3 for exclusion plot in the $m_{\rho *} - \lambda_{\gamma}$ plane.
- ⁷⁸ Superseded by ADRIANI 93M.
- ⁷⁹ Superseded by DECAMP 92.
- 80 ABE 888 limits use $e^+e^-\to ee^*$ where t-channel photon exchange dominates giving $e\gamma(e)$ (quasi-real compton scattering).
- 81 ANSARI 87D is at $E_{\rm cm}=546-630$ GeV.

Limits for Excited e (e^*) from $e^+e^- \rightarrow \gamma\gamma$

These limits are derived from indirect effects due to e^* exchange in the t channel and depend on transition magnetic coupling between e and e^* . All limits are for $\lambda_{\gamma}=1$. All limits except ABE 89J are for nonchiral coupling with $\eta_L=\eta_R=1$.

For limits prior to 1987, see our 1992 edition (Physical Review D45, 1 June, Part II (1992)).

VALUE (GeV)	CL%	DOCUMENT ID TECN COMMENT	_
>194	95	ACKERSTAFF 98 OPAL √s=130-172 GeV	
• • • We do not	use the following	ng data for averages, fits, limits, etc. • • •	
>129	95	ACCIARRI 96L L3 √5≔133 GeV	
>147	95	ALEXANDER 96K OPAL	
>136	95	BUSKULIC 96Z ALEP √s=130, 136 GeV	
>146	95	ACCIARRI 95G L3	
		82 BUSKULIC 93Q ALEP	
>127	95	83 ADRIANI 928 L3	
>114	95	84 BARDADIN 92 RVUE	
> 99	95	DECAMP 92 ALEP	
		⁸⁵ SHIMOZAWA 92 TOPZ	
>100	95	ABREU 91E DLPH	
>116	95	AKRAWY 91F OPAL	
> 83	95	ADEVA 90K L3	
> 82	95	AKRAWY 90F OPAL	
> 68	95	86 ABE 891 VNS $\eta_L=1, \eta_R=0$	
> 90.2	95	ADACHI 898 TOPZ	
> 65	95	KIM 89 AMY	

- 82 BUSKULIC 93Q obtain Λ^+ >121 GeV (95%CL) from ALEPH experiment and Λ^+ >135 GeV from combined TRISTAN and ALEPH data. These limits roughly correspond to limits on m_{e^*} .
- 83 ADRIANI 92B superseded by ACCIARRI 95G.
- 84 BARDADIN-OTWINOWSKA 92 limit from fit to the combined data of DECAMP 92, ABREU 91E, ADEVA 90K, AKRAWY 91F.
- ASKEU 91E, ADEVA 90E, ANKAWY 91F. 85 SHIMOZAWA 92 fit the data to the limiting form of the cross section with $m_{e^*}\gg E_{CM}$ and obtain $m_{e^*}>168$ GeV at 95%CL. Use of the full form would reduce this limit by a few GeV. The statistically unexpected large value is due to fluctuation in the data.
- ⁸⁶ The ABE 891 limit assumes chiral coupling. This corresponds to $\lambda_{\gamma}=$ 0.7 for nonchiral counting.

Indirect Limits for Excited e (e*)

These limits make use of loop effects involving e^* and are therefore subject to theoretical uncertainty.

VALUE (GeV)	DOCUMENT ID		TECN	COMMENT
• • • We do not use the	e following data for average	s, fit	s, Ilmits,	etc. • • •
	87 DORENBOS	89	CHRM	$egin{array}{l} \overline{ u}_{\mu} e ightarrow \overline{ u}_{\mu} e ightarrow u_{\mu} e \end{array}$
	⁸⁸ GRIFOLS			$\nu_{\mu}e \rightarrow \nu_{\mu}e$
	⁸⁹ RENARD	82	THEO	g-2 of electron

- 87 DORENBOSCH 89 obtain the limit $\lambda_{\gamma}^2 \Lambda_{\text{Cut}}^2 / m_{e^*}^2 < 2.6$ (95% CL), where Λ_{Cut} is the cutoff scale, based on the one-loop calculation by GRIFOLS 86. If one assumes that $\Lambda_{\text{cut}} = 1$ TeV and $\lambda_{\gamma} = 1$, one obtains $m_{e^*} > 620$ GeV. However, one generally expects $\lambda_{\gamma} \approx m_{e^*} / \Lambda_{\text{cut}}$ in composite models.
- 88 GRIFOLS 86 uses $\nu_{\mu}e \rightarrow \nu_{\mu}e$ and $\overline{\nu}_{\mu}e \rightarrow \overline{\nu}_{\mu}e$ data from CHARM Collaboration to derive mass limits which depend on the scale of compositeness.
- 89 RENARD 82 derived from g-2 data limits on mass and couplings of e^* and μ^* . See figures 2 and 3 of the paper.

MASS LIMITS for Excited μ (μ *)

Limits for Excited μ (μ *) from Pair Production

These limits are obtained from $e^+\,e^-\,
ightarrow\,\mu^{*+}\,\mu^{*-}$ and thus rely only on the (electroweak) charge of μ^* . Form factor effects are ignored unless noted. For the case of limits from Z decay, the μ^* coupling is assumed to be of sequential type. All limits assume $\mu^* \to \mu \gamma$ decay except for the limits from $\Gamma(Z)$.

For limits prior to 1987, see our 1992 edition (Physical Review D45, 1 June, Part II (1992)). (GeV) CL%

(1772)	٫.					
VALUE (GeV)	CL%		DOCUMENT ID		TECN	COMMENT
>85.3	95	90	ACKERSTAFF	98C	OPAL	$e^+e^- \rightarrow \mu^*\mu^*$ Homodoublet type
• • • We do	not i	ise the	following data	for a	verages,	fits, limits, etc. • • •
>79.6	95		ABREU	97B	DLPH	$e^+e^- \rightarrow \mu^*\mu^*$ Homodoublet type
>78.4	95		ABREU	97B	DLPH	$e^+e^- \rightarrow \mu^*\mu^*$ Sequential type
>79.9	95	91	ACCIARRI	97G	L3	$e^+e^- \rightarrow \mu^*\mu^*$ Sequential type
>80.0	95	91,94	ACKERSTAFF	97	OPAL	$e^+e^- \rightarrow \mu^*\mu^*$ Homodoublet type
>62.6	95	95	ABREU	96K	DLPH	$e^+e^- \rightarrow \mu^*\mu^*$ Homodoublet type
>64.9	95		ACCIARRI	96 D	L3	$e^+e^- \rightarrow \mu^*\mu^*$ Sequential type
>66.8	95		ALEXANDER	96Q	OPAL	$e^+e^- \rightarrow \mu^*\mu^*$ Homodoublet type
>65.4	95	96	BUSKULIC	96W	ALEP	$e^+e^- \rightarrow \mu^*\mu^*$ Sequential type
>45.6	95		ADRIANI	93M	L3	$Z \rightarrow \mu^* \mu^*$
>45.6	95		ABREU			$Z \rightarrow \mu^* \mu^*$
>29.8	95		BARDADIN	92	RVUE	Γ(Z)
>26.1	95	98	DECAMP	92	ALEP	$Z \rightarrow \mu^* \mu^*; \Gamma(Z)$
>46.1	95		DECAMP	92	ALEP	$Z \rightarrow \mu^* \mu^*$
>33	95		ABREU	91F	DLPH	$Z \rightarrow \mu^* \mu^*; \Gamma(Z)$
>45.3	95	99	ADEVA	90F	L3	$Z \rightarrow \mu^* \mu^*$
>44.9	95		AKRAWY	9 0ı	OPAL.	$Z \rightarrow \mu^* \mu^*$
>44.6	95	100	DECAMP	90G	ALEP	$e^+e^- \rightarrow \mu^*\mu^*$
>29.9	95		ADACHI			$e^+e^- \rightarrow \mu^*\mu^*$
>28.3	95		KIM	89	AMY	$e^+e^- \rightarrow \mu^*\mu^*$
90 From a+	a c	Mision	e at . /cm170.11	72 C	W ACH	EDETAEE ORG also obtain limit from

- 90 From e⁺e⁻⁻ collisions at √s=170-172 GeV. ACKERSTAFF 980 also obtain limit from $\mu^*
 ightarrow \
 u \, W$ decay mode: $m_{\mu^*} >$ 81.3 GeV.
- 91 From e^+e^- collisions at $\sqrt{s}\approx$ 161 GeV.
- 92 ABREU 978 also obtain limit from charged current decay mode $\mu^* \rightarrow \nu W$, $m_{\mu^*} > 70.9$
- 93 GeV. 93 ABREU 978 also obtain limit from charged current decay mode $\mu^* \to \nu W, \, m_{\mu^*} >$ 44.6
- GeV. 94 ACKERSTAFF 97 also obtain limit from charged current decay mode $\mu^* \to \nu W$, $m_{\nu_{\mu}^{\bullet}} > 77.1$ GeV.
- 95 From e^+e^- collisions at $\sqrt{s}\approx$ 130-136 GeV.
- ⁹⁶ From e^+e^- collisions at $\sqrt{s}\approx$ 130–140 GeV.
- 97 BARDADIN-OTWINOWSKA 92 limit is independent of decay modes. Based on $\Delta\Gamma(Z)$ <36 MeV
- 98 Limit is independent of μ^* decay mode.
- 99 Superseded by ADRIANI 93M.
- 100 Superseded by DECAMP 92.

Limits for Excited μ (μ *) from Single Production

These limits are from $e^+e^-\to \mu^*\mu$ and depend on transition magnetic coupling between μ and μ^* . All limits assume $\mu^*\to \mu\gamma$ decay. Limits from LEP are for chiral coupling, whereas all other limits are for nonchiral coupling, $\eta_L=\eta_R=1$. In most papers, the limit is expressed in the form of an excluded region in the $\lambda - m_{\mu^*}$ plane. See the original papers.

For limits prior to 1987, see our 1992 edition (Physical Review D45, 1 June, Part II

(1992))).			
VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>89	95	ADRIANI	93M L3	$Z \rightarrow \mu \mu^*, \lambda_Z > 0.5$
>88	95	ABREU	92C DLPH	$Z \rightarrow \mu \mu^*, \lambda_Z > 0.5$
>91	95	DECAMP	92 ALEP	$Z \rightarrow \mu \mu^*, \lambda_Z > 1$
>87	95	AKRAWY	901 OPAL	$Z \rightarrow \mu \mu^*, \lambda_Z > 1$
 ● ● We de 	o not use th	e following data	for averages,	fits, limits, etc. • • •
	95 10	ACKERSTAFF		
	102,10	3 ABREU	978 DLPH	$e^+e^- \rightarrow \mu\mu^*$
	102,10	4 ACCIARRI	97G L3	$e^+e^- \rightarrow \mu\mu^*$
	10	5 ACKERSTAFF	97 OPAL	$e^+e^- \rightarrow \mu\mu^*$
	10	6 ABREU		$e^+e^- \rightarrow \mu\mu^*$
	10	ACCIARRI	96D L3	$e^+e^- \rightarrow \mu\mu^*$
	10	8 ALEXANDER		$e^+e^- \rightarrow \mu\mu^*$
	- 11	9 BUSKULIC		$e^+e^- \rightarrow \mu\mu^*$
>85		O ADEVA		$Z \rightarrow \mu \mu^*, \lambda_Z > 1$
>75		O ADEVA	90F L3	$Z \rightarrow \mu \mu^*, \lambda_Z > 0.1$
>80		¹ DECAMP		$e^+e^- \rightarrow \mu\mu^*, \lambda_Z=1$
>50	95	ADACHI		$e^+e^- \rightarrow \mu\mu^*, \lambda_{\gamma}=0.7$
>46	95	KIM	89 AMY	$e^+e^- \rightarrow \mu\mu^*, \lambda_{\gamma}^{\prime}=0.2$
exclusion	n limit in th	from e^+e^- collise mass-coupling points at $\sqrt{s}=161$ (olane.	:170-172 GeV. See their Fig. 11 for the
103 See Fig.	4a and Fig.	5a of ABREU 97	B for the excl	lusion limit in the mass-coupling plane.
				lusion limit in the mass-coupling plane.
				at \sqrt{s} = 161 GeV. See their Fig. 3 for
		n the mass-coupl		s = 130-136 GeV. See their Fig. 4 for
		n the mass-coupl		3= 130-136 GeV. See their Fig. 4 to
				\sqrt{s} = 130–140 GeV. See their Fig. 2 for
		n the mass-coupl		
				at \sqrt{s} = 130–140 GeV. See their Fig. 3a
		ilt in the mass-co		
				at \sqrt{s} = 130–140 GeV. See their Fig. 3
110 Superse		it in the mass-co	urbuilg hique	•
111 Superse	ded by DEC	AMP 92.		
Superso	occ of Dec	,		

Indirect Limits for Excited μ (μ *)

These limits make use of loop effects involving μ^* and are therefore subject to theoretical uncertainty.

VALUE (GeV)	DOCUMENT ID	TECN	COMMENT
• • We do not use the following	ng data for averages, fi	ts, limits,	etc. • • •
	112 RENARD 82	THEO	g-2 of muon

 112 RENARD 82 derived from g-2 data limits on mass and couplings of e^* and μ^* . See figures 2 and 3 of the paper.

MASS LIMITS for Excited τ (τ *)

Limits for Excited au (au^*) from Pair Production

These limits are obtained from $e^+e^- \rightarrow \tau^{*+}\tau^{*-}$ and thus rely only on the (electroweak) charge of au^* . Form factor effects are ignored unless noted. For the case of limits from Z decay, the au^* coupling is assumed to be of sequential type. All limits assume $\tau^* \to \tau \gamma$ decay except for the limits from $\Gamma(Z)$.

For limits prior to 1987, see our 1992 edition (Physical Review D45, 1 June, Part II

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>84.6	95	113 ACKERSTAFF	98c OPAL	$e^+e^- \rightarrow \tau^*\tau^*$ Homodoublet type
• • • We do	not use	the following data t	for averages,	fits, limits, etc. • • •
>79.4		115 ABREU	97B DLPH	$e^+e^- \rightarrow \tau^*\tau^*$ Homodoublet type
>77.4		116 ABREU	97B DLPH	$e^+e^- \rightarrow \tau^*\tau^*$ Sequential type
>79.3		¹¹⁴ ACCIARRI	97G L3	$e^+e^- \rightarrow \tau^*\tau^*$ Sequential type
>79.1		117 ACKERSTAFF	97 OPAL	$e^+e^- \rightarrow \tau^*\tau^*$ Homodoublet type
>62.2		¹¹⁸ ABREU	96K DLPH	$e^+e^- \rightarrow \tau^*\tau^*$ Homodoublet type
>64.2		¹¹⁹ ACCIARRI	96D L3	$e^+e^- \rightarrow \tau^*\tau^*$ Sequential type
>65.3		¹¹⁹ ALEXANDER	96Q OPAL	$e^+e^- \rightarrow \tau^*\tau^*$ Homodoublet type
>64.8	95	¹¹⁹ BUSKULIC	96W ALEP	$e^+e^- \rightarrow \tau^*\tau^*$ Sequential type
>45.6	95	ADRIANI	93M L3	$Z \rightarrow \tau^* \tau^*$
>45.3	95	ABREU	92c DLPH	$Z \rightarrow \tau^* \tau^*$
>29.8		120 BARDADIN	92 RVUE	Γ(Z)
>26.1	9 5	121 DECAMP	92 ALEP	$Z \rightarrow \tau^* \tau^*; \Gamma(Z)$
>46.0	95	DECAMP	92 ALEP	$Z \rightarrow \tau^* \tau^*$
>33	95	¹²¹ ABREU	91F DLPH	$Z \rightarrow \tau^* \tau^*; \Gamma(Z)$
>45.5	95	122 ADEVA	90L L3	$Z \rightarrow \tau^* \tau^*$
>44.9	95	AKRAWY	901 OPAL	$Z \rightarrow \tau^* \tau^*$
>41.2	95	123 DECAMP	90G ALEP	$e^+e^- \rightarrow \tau^*\tau^*$
>29.0	95	ADACHI	898 TOPZ	$e^+e^- \rightarrow \tau^*\tau^*$

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^{113}From e^+e^- collisions at \sqrt{s}=170–172 GeV. ACKERSTAFF 98C also obtain limit from
   	au^* 
ightarrow \ 
u \, W decay mode: m_{	au^*} > 81.3 GeV.
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- ¹¹⁴ From e^+e^- collisions at $\sqrt{s}=$ 161 GeV.
- 115 ABREU 978 also obtain limit from charged current decay mode $r^* \rightarrow \nu W$, $m_{\tau^*} > 70.9$
- GeV. 116 ABREU 97B also obtain limit from charged current decay mode $au^*
 ightarrow
 u W$, $m_{ au^*} >$ 44.6
- GeV. 117 ACKERSTAFF 97 also obtain limit from charged current decay mode $au^*
 ightarrow
 u W$, $m_{\nu_{-}^{*}} > 77.1 \text{ GeV}.$
- 118 From e^+e^- collisions at \sqrt{s} = 130–136 GeV.
- ¹¹⁹ From e^+e^- collisions at \sqrt{s} = 130–140 GeV.
- 120 BARDADIN-OTWINOWSKA 92 limit is independent of decay modes. Based on
- 121 Limit is independent of τ^* decay mode.
- 122 Superseded by ADRIANI 93M.
- 123 Superseded by DECAMP 92.

VALUE (GeV) CL%

Limits for Excited τ (τ *) from Single Production

DOCUMENT ID

These limits are from $e^+e^-\to \tau^*\tau$ and depend on transition magnetic coupling between τ and τ^* . All limits assume $\tau^*\to \tau\gamma$ decay. Limits from LEP are for chiral coupling, whereas all other limits are for nonchiral coupling, $\eta_L=\eta_R=1$. In most papers, the limit is expressed in the form of an excluded region in the $\lambda-m_{\tau^+}$ plane. See the original papers.

TECN COMMENT

>88	95	ADRIANI	93M L3	$Z \rightarrow \tau \tau^*$, $\lambda_Z > 0.5$
>87	95	ABREU	92C DLPH	$Z \rightarrow \tau \tau^*, \lambda_Z > 0.5$
>90	95	DECAMP	92 ALEP	$Z \rightarrow \tau \tau^*, \lambda_Z > 0.18$
>86.5	95	AKRAWY	901 OPAL	$Z \rightarrow \tau \tau^*, \lambda_Z > 1$
• • • We do	not use th	e following data	for averages,	fits, limits, etc. • • •
		4 ACKERSTAFF	98C OPAL	$e^+e^- \rightarrow \tau \tau^*$
		⁶ ABREU	97B DLPH	$e^+e^- \rightarrow \tau \tau^*$
	125,12	⁷ ACCIARRI	97G L3	$e^+e^- \rightarrow \tau \tau^*$
		⁸ ACKERSTAFF	97 OPAL	$e^+e^- \rightarrow \tau \tau^*$
		⁹ ABREU	96k DLPH	$e^+e^- \rightarrow \tau \tau^*$
		¹⁰ ACCIARRI		$e^+e^- \rightarrow \tau \tau^*$
		11 ALEXANDER	96Q OPAL	$e^+e^- \rightarrow \tau \tau^*$
		¹² BUSKULIC	96W ALEP	$e^+e^- \rightarrow \tau \tau^*$
>88		¹³ ADEVA	90L L3	$Z \rightarrow \tau \tau^*, \lambda_Z > 1$
>59		³⁴ DECAMP	90G ALEP	$Z \rightarrow \tau \tau^*, \lambda_Z = 1$
>40	95 ¹³	³⁵ BARTEL	86 JADE	$e^+e^- \rightarrow \tau \tau^*, \lambda_{\gamma}=1$
>41.4	95 ¹³	³⁶ BEHREND	86 CELL	$e^+e^- \rightarrow r\tau^*, \lambda_{\gamma}=1$
>40.8	95 13	³⁶ BEHREND	86 CELL	$e^+e^- \rightarrow \tau \tau^*, \lambda_{\gamma}=0.7$

- 124 ACKERSTAFF 98C from e^+e^- collisions at \sqrt{s} =170–172 GeV. See their Fig. 11 for the exclusion limit in the mass-coupling plane.
- ¹²⁵ From e^+e^- collisions at $\sqrt{s}=$ 161 GeV.
- 126 See Fig. 4a and Fig. 5a of ABREU 97B for the exclusion limit in the mass-coupling plane.
- 127 See Fig. 2 and Fig. 3 of ACCIARRI 97G for the exclusion limit in the mass-coupling plane.
- 128 ACKERSTAFF 97 result is from e^+e^- collisions at \sqrt{s} = 161 GeV. See their Fig. 3 for the exclusion limit in the mass-coupling plane.
- ¹²⁹ABREU 96K result is from e^+e^- collisions at \sqrt{s} = 130–136 GeV. See their Fig. 4 for the exclusion limit in the mass-coupling plane.
- 130 ACCIARRI 96D result is from e⁺e[−] collisions at √s= 130–140 GeV. See their Fig. 2 for the exclusion limit in the mass-coupling plane.
- 131 ALEXANDER 96Q result is from e^+e^- collisions at $\sqrt{s}=$ 130–140 GeV. See their Fig. 3a for the exclusion limit in the mass-coupling plane.
- 132 BUSKULIC 96w result is from e+ e- collisions at \sqrt{s} = 130–140 GeV. See their Fig. 3 for the exclusion limit in the mass-coupling plane.
- 133 Superseded by ADRIANI 93M.
- 134 Superseded by DECAMP 92.
- 135 BARTEL 86 is at $E_{\rm cm} = 30$ –46.78 GeV.
- 136 BEHREND 86 limit is at $E_{\rm cm}=$ 33–46.8 GeV.

MASS LIMITS for Excited Neutrino (ν^*)

Limits for Excited ν (ν^{+}) from Pair Production

These limits are obtained from $e^+e^- \rightarrow \nu^*\nu^*$ and thus rely only on the (electroweak) charge of ν^* . Form factor effects are ignored unless noted. The ν^* coupling is assumed to be of sequential type unless otherwise noted. Limits assume $\nu^* \to \nu \gamma$ decay except for the $\Gamma(Z)$ measurement which makes no assumption about decay mode.

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DOCUMENT ID TECN COMMENT
VALUE (GeV) CL%
                   ^{137} ACKERSTAFF 98C OPAL e^+e^- \rightarrow \nu^*\nu^* Homodoublet type
             95
• • • We do not use the following data for averages, fits, limits, etc. • •
              95 138,139 ABREU
                                        978 DLPH e^+e^- \rightarrow \nu^* \nu^* Homodoublet type
>77.6
              95 138,140 ABREU
                                        97B DLPH e^+e^- \rightarrow \nu^*\nu^* Sequential type
>64.4
              95 138,141 ACCIARRI
                                                    e^+e^- \rightarrow \nu^*\nu^* Sequential type
>71.2
                                        97G L3
              95 ^{138,142} ACKERSTAFF 97 OPAL e^+e^- 
ightarrow 
u^* 
u^* Homodoublet type
>77.8
              95 143,144 ACCIARRI
>61.4
                                        96D L3
                                                    e^+e^- \rightarrow \nu^*\nu^* Sequential type
              95 145,146 ALEXANDER
                                       960 OPAL e^+e^- \rightarrow \nu^*\nu^* Homodoublet type
>65.0
                    143 BUSKULIC
                                        96W ALEP e^+e^- \rightarrow \nu^*\nu^* Sequential type
 >63.6
                    147 BARDADIN-...
                                       92 RVUE Γ(Z)
>43.7
              95
                    148 DECAMP
                                        92 ALEP
>47
              95
                    149 DECAMP
                                        92 ALEP
>42.6
              95 150,151 DECAMP
>35.4
                                        900 ALEP
                                                    \Gamma(Z)
              95 151,152 DECAMP
                                        900 ALEP
 >46
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Quark and Lepton Compositeness

- 137 From e^+e^- collisions at \sqrt{s} =170–172 GeV. ACKERSTAFF 98C also obtain limit from charged decay modes: $m_{\nu_e^*}$ > 84.1 GeV, $m_{\nu_\mu^*}$ > 83.9 GeV, and $m_{\nu_\tau^*}$ > 79.4 GeV.
- 138 From e^+e^- collisions at $\sqrt{s}\approx$ 161 GeV.
- $^{139}\,\mathrm{ABREU}$ 978 also obtain limits from charged current decay modes, $m_{\nu^*} >$ 56.4 GeV.
- 140 ABREU 97B also obtain limits from charged current decay modes, $m_{\nu^{*}}^{-} >$ 44.9 GeV.
- 141 ACCIARRI 97G also obtain limits from charged current decay mode $u_{m{e}}^*
 ightarrow e\, W$, $m_{
 u^*} >$ $^{64.5}$ GeV. 142 ACKERSTAFF 97 also obtain limits from charged current decay modes $m_{\nu_s^{\bullet}} > 78.3$
- GeV, $m_{\nu_{\mu}^{*}} > 78.9$ GeV, $m_{\nu_{\tau}^{*}} > 76.2$ GeV.
- ¹⁴³ From e^+e^- collisions at \sqrt{s} = 130–140 GeV.
- 144 ACCIARRI 96D also obtain limit from $\nu^* \rightarrow eW$ decay mode: $m_{\nu^*} >$ 57.3 GeV.
- ¹⁴⁵ From e^+e^- collisions at \sqrt{s} = 130–136 GeV.
- 146 ALEXANDER 96Q also obtain limits from charged current decay modes: $m_{
 u^*} > 66.2$ GeV, $m_{\nu_{ii}^*} >$ 66.5 GeV, $m_{\nu_{\tau}^*} >$ 64.7 GeV.
- 147 BARDADIN-OTWINOWSKA 92 limit is for Dirac ν^* . Based on $\Delta\Gamma(Z){<}36$ MeV. The
- limit is 36.4 GeV for Majorana ν^* , 45.4 GeV for homodoublet ν^* . 148 Limit is based on B($Z \to \nu^* \bar{\nu}^*$)×B($\nu^* \to \nu \gamma$)² < 5 × 10⁻⁵ (95%CL) assuming Dirac ν^* , B($\nu^* \rightarrow \nu \gamma$) = 1.
- 149 Limit is for Dirac ν^* . The limit is 34.6 GeV for Majorana ν^* , 45.4 GeV for homodoublet
- 150 DECAMP 900 limit is from excess $\Delta\Gamma(Z)<$ 89 MeV. The above value is for Dirac u^* ; 26.6 GeV for Majorana ν^* ; 44.8 GeV for homodoublet ν^* .
- 151 Superseded by DECAMP 92.
- ¹⁵²DECAMP 900 limit based on B($Z \rightarrow \nu^* \nu^*$)·B($\nu^* \rightarrow \nu \gamma$)² < 7 × 10⁻⁵ (95%CL), assuming Dirac ν^* , B($\nu^* \rightarrow \nu \gamma$) = 1.

Limits for Excited ν (ν *) from Single Production

These limits are from $Z \to \nu \nu^*$ or $ep \to \nu^* X$ and depend on transition magnetic coupling between ν/e and ν^* . Assumptions about ν^* decay mode are given in

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
none 40-96	95	153 BREITWEG	97c ZEUS	ep → ν*X
>91	95	ADRIANI	93M L3	$\lambda_Z > 1, \nu^* \rightarrow \nu \gamma$
>89	95	ADRIANI	93M L3	$\lambda_Z > 1, \nu_a^* \rightarrow eW$
>91	95	154 DECAMP	92 ALEP	$\lambda_{Z}^{-} > 1$

• • We do not use the following data for averages, fits, limits, etc. • • •

	95 155	ACKERSTAFF	98c OPAL	ep → ν*ν*
	156,157	ABREU		$e^+e^- \rightarrow \nu \nu^*$
	158	ABREU	971 DLPH	$\nu^* \rightarrow \ell W, \nu Z$
	159	ABREU	97」DLPH	$\nu^* \rightarrow \nu \gamma$
	156,160	ACCIARRI ·		$e^+e^- \rightarrow \nu \nu^*$
	161	ACKERSTAFF	97 OPAL	$e^+e^- \rightarrow \nu \nu^*$
	162	ADLOFF		Lepton-flavor violation
	163	ACCIARRI		e ⁺ e ⁻ → νν*
	164	ALEXANDER	96Q OPAL	$e^+e^- \rightarrow \nu \nu^*$
	165	BUSKULIC	96W ALEP	
	166	DERRICK	95B ZEUS	ep → ν*X
	167	ABT	93 H1	ep → ν*X
>87	95	ADRIANI	93M L3	$\lambda_Z > 0.1, \nu^* \rightarrow \nu \gamma$
>74	95	ADRIANI	93M L3	$\lambda_Z > 0.1, \nu_a^* \rightarrow eW$
	168	BARDADIN	92 RVUE	- •
>74	95 154	DECAMP	92 ALEP	$\lambda_7 > 0.034$
>91	95 169,170		900 L3	$\lambda_{Z}^{-} > 1$
>83	95 170	ADEVA	900 L3	$\lambda_Z > 0.1, \nu^* \rightarrow \nu \gamma$
>74	95 170	ADEVA	900 L3	$\lambda_Z > 0.1, \nu_a^* \rightarrow eW$
>90	95 171,172	DECAMP	900 ALEP	$\lambda_{7} > 1$
>74.7	95 171,172	DECAMP	900 ALEP	$\lambda_{Z} > 0.06$
				-

- 153 BREITWEG 97C search for single ν^* production in ep collisions with the decay ν^* ightharpoonup $\nu\gamma$. $f=-f'=2\Lambda/m_{\nu^*}$ is assumed for the ν^* coupling. See their Fig. 10 for the exclusion plot in the mass-coupling plane.
- ¹⁵⁴DECAMP 92 limit is based on B($Z \rightarrow \nu^* \overline{\nu}$)×B($\nu^* \rightarrow \nu \gamma$) < 2.7 × 10⁻⁵ (95%CL)
- assuming Dirac ν^* , B($\nu^* \rightarrow \nu \gamma$) = 1. 155 ACKERSTAFF 98c from e⁺ e⁻ collisions at \sqrt{s} =170–172 GeV. See their Fig. 11 for the exclusion limit in the mass-coupling plane.
- 156 From e^+e^- collisions at $\sqrt{s}=$ 161 GeV.
- 157 See Fig. 4b and Fig. 5b of ABREU 97B for the exclusion ilmit in the mass-coupling plane. 158 ABREU 971 limit is from $Z \to \nu \nu^*$. See their Fig. 12 for the exclusion limit in the mass-coupling plane.
- 159 ABREU 971 limit is from $Z \rightarrow \nu \nu^*$. See their Fig. 5 for the exclusion limit in the mass-coupling plane.
- 160 See Fig. 2 and Fig. 3 of ACCIARRI 97G for the exclusion limit in the mass-coupling plane. ¹⁶¹ ACKERSTAFF 97 result is from e^+e^- collisions at $\sqrt{s}\approx$ 161 GeV, for homodoublet ν^* . See their Fig. 3 for the exclusion limit in the mass-coupling plane.
- 162 ADLOFF 97 search for single e^* production in ep collisions with the decays $e^* \rightarrow e\gamma$, eZ, νW . See their Fig. 4 for the rejection limits on the product of the production cross section and the branching ratio.
- ¹⁶³ ACCIARRI 96D result is from e^+e^- collisions at $\sqrt{s}=$ 130-140 GeV. See their Fig. 2 for
- the exclusion limit in the mass-coupling plane.

 164 ALEXANDER 960 result is from e⁺e⁻ collisions at \sqrt{s} = 130-140 GeV for homedoublet ν^* . See their Fig. 3b and Fig. 3c for the exclusion limit in the mass-coupling
- 165 BUSKULIC 96w result is from e^+e^- collisions at $\sqrt{s}=$ 130–140 GeV. See their Fig. 4 for the exclusion limit in the mass-coupling plane.

- 166 DERRICK 958 search for single ν^* production via ν^*eW coupling in ep collisions with the decays $\nu^* \to \nu \gamma$, νZ , eW. See their Fig. 14 for the exclusion plot in the $m_{\nu^*} - \lambda \gamma$ plane.
- 167 ABT 93 search for single ν^* production via ν^*eW coupling in ep collisions with the decays $\nu^* \to \nu \gamma$, νZ , eW. See their Fig. 4 for exclusion plot in the m_{ν^*} - λ_W plane.
- 168 See Fig. 5 of BARDADIN-OTWINOWSKA 92 for combined limit of ADEVA 900, DE-CAMP 900, and DECAMP 92.
- 169 Limit is either for $\nu^* \rightarrow \nu \gamma$ or $\nu^* \rightarrow eW$.
- 170 Superseded by ADRIANI 93M.
- 171 DECAMP 900 limit based on B(Z $\rightarrow \nu \nu^*$)·B($\nu^* \rightarrow \nu \gamma$) < 6×10^{-5} (95%CL), assuming $B(\nu^* \rightarrow \nu \gamma) = 1$.
- 172 Superseded by DECAMP 92.

MASS LIMITS for Excited $q(q^*)$

Limits for Excited $q(q^*)$ from Pair Production

CL%

These limits are obtained from $e^+e^- \rightarrow q^* \overline{q}^*$ and thus rely only on the (electroweak) charge of the q^* . Form factor effects are ignored unless noted. Assumptions about the q^* decay are given in the comments and footnotes. VALUE (GeV)

TECN

DOCUMENT ID

>45.6	95	173 ADRIANI	93M	L3	u or d type, $Z \rightarrow q^*q^*$
 • • We do not 	use the follow	ing data for average:	s, fits,	ilmits,	etc. • • •
		174 ADRIANI	92F ($Z \rightarrow q^*q^*$
>41.7	95	175 BARDADIN	92	RVUE	u-type, Γ(Z)
>44.7	95	175 BARDADIN	92 1	RVUE	d -type, $\Gamma(Z)$
>40.6	95	176 DECAMP		ALEP	
>44.2	95	176 DECAMP	92	ALEP	d -type, $\Gamma(Z)$
>45	95	177 DECAMP	92 /	ALEP	u or d type,
					$Z \rightarrow q^*q^*$
>45	95	176 ABREU	91F	DLPH	<i>u</i> -type, Γ(Z)
>45	95	176 ABREU	91F 1	DLPH	d-type, Γ(Z)
>21.1	95	178 BEHREND	86C (CELL	$e(q^*) = -1/3, q^* \rightarrow$
		470			98
>22.3	95	178 BEHREND	86C (CELL	$e(q^*)=2/3, q^*\to qg$
>22.5	95	178 BEHREND	86C (CELL	
>23.2	95	178 BEHREND	86C (CELL	$e(q^*) = 2/3, q^* \rightarrow q\gamma$
170					

- 173 ADRIANI 93M limit is valid for B($q^* \rightarrow qg$)> 0.25 (0.17) for up (down) type.
- 174 ADRIANI 92F search for $Z \to q^* \overline{q}^*$ followed with $q^* \to q \gamma$ decays and give the limit $\sigma_Z + \mathsf{B}(Z \to q^* \overline{q}^*) + \mathsf{B}^2(q^* \to q \gamma) < 2\,\mathrm{pb}$ at 95%CL. Assuming five flavors of degenerate q^* of homodoublet type, B($q^* \rightarrow q \gamma$) <4% is obtained for m_{q^*} <45 GeV.
- 175 BARDADIN-OTWINOWSKA 92 limit based on $\Delta\Gamma(Z)$ <36 MeV.
- ${\bf 176}\,{\rm These}$ limits are independent of decay modes.
- 177 Limit is for B($q^* \rightarrow qg$)+B($q^* \rightarrow q\gamma$)=1. 178 BEHREND 86C search for $e^+e^- \rightarrow q^*\overline{q}^*$ for $m_{q^*} > 5$ GeV. But m < 5 GeV excluded by total hadronic cross section. The limits are for point-like photon couplings of excited

Limits for Excited $q(q^*)$ from Single Production

These limits are from $e^+e^- \to q^*\bar{q}$ or $p\bar{p} \to q^*X$ and depend on transition magnetic couplings between q and q^* . Assumptions about q^* decay mode are given in the footnotes and comments.

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>570 (CL = 95%) O	UR EVAI	LUATION		
none 200~520 and 580~760	95	¹⁷⁹ ABE	97G CDF	pp → q*X, q* → 2 lets
none 40-169	95	180 BREITWEG	97c ZEUS	ep → q*X
none 80-570	95	¹⁸¹ ABE	95N CDF	$p\overline{p} \rightarrow q^*X, q^* \rightarrow qg$ $q\gamma, qW$
>288	90	182 ALITTI	93 UA2	pp → a*X, a* → ag
> 88	95	183 DECAMP	92 ALEP	$Z \rightarrow qq^*, \lambda_Z > 1$
> 86	95	183 AKRAWY		$Z \rightarrow qq^*, \lambda_Z > 1.2$
• • • We do not use	the follo		es, fits, limits	

		184 ADLOFF	97 H1	Lepton-flavor violation
		185 DERRICK	95B ZEUS	ep → g*X
none 80-540	95	¹⁸⁶ ABE	94 CDF	$p\overline{p} \xrightarrow{q} q^* X, q^* \rightarrow q\gamma$
> 79	95	¹⁸⁷ ADRIANI	93M L3	λ ₇ (L3)> 0.06
		¹⁸⁸ ABREU	920 DLPH	Z → qq*
		¹⁸⁹ ADRIANI	92F L3	$Z \rightarrow qq^*$
> 75	95	187 DECAMP	92 ALEP	$Z \rightarrow qq^*, \lambda_Z > 1$
		¹⁹⁰ ALBAJAR	89 UA1	$p\overline{p} \rightarrow q^*X$
				$q^* \rightarrow qW$
> 39	95	191 BEHREND	86C CELL	$e^+e^- \rightarrow q^*\overline{q} (q^* \rightarrow$
		*		$qg,q\gamma$), $\lambda_{\gamma} \approx 1$

- 179 ABE 97G search for new particle decaying to dijets.
- 180 BREITWEG 97C search for single q^* production in ep collisions with the decays q^* $q\gamma$, qW. $f_s=0$, and $f=-f'=2\Lambda/m_{q^*}$ is assumed for the q^* coupling. See their Fig. 11
- for the exclusion plot in the mass-coupling plane. 181 ABE 95N assume a degenerate u^* and d^* with $f_s = f = f' = \Lambda/m_{Q^*}$. See their Fig. 4 for the excluded region in $m_{q^*} - f$ plane.
- 182 ALITTI 93 search for resonances in the two-jet invariant mass. The limit is for $f_{\rm S}=f$ $=f'=\Lambda/m_{q^*}$. u^* and d^* are assumed to be degenerate. If not, the limit for u^* (d^*) is 277 (247) GeV if $m_{d^*}\gg m_{u^*}$ $(m_{u^*}\gg m_{d^*}).$

Quark and Lepton Compositeness

- ¹⁸³ Assumes B($q^* \rightarrow q\gamma$) = 0.1.
- 184 ADLOFF 97 search for single q^* production in ep collisions with the decay $q^* \rightarrow q\gamma$. See their Fig. 6 for the rejection limits on the product of the production cross section and the branching ratio.
- 185 DERRICK 95B search for single q^* production via $q^*\,q\,\gamma$ coupling in $e\,p$ collisions with the decays $q^* \rightarrow qW$, qZ, qg, $q\gamma$. See their Fig. 15 for the exclusion plot in the
- 186 ABE 94 search for resonances in jet- γ and jet-W invariant mass in $p\overline{p}$ collisions at $E_{\rm cm}$ = 1.8 TeV. The limit is for $f_s = f = f' = \Lambda/m_{q^*}$ and u^* and d^* are assumed to be degenerate. See their Fig. 4 for the excluded region in $m_{q^{\bullet}}f$ plane.
- ¹⁸⁷ Assumes B($q^* \rightarrow qg$) = 1.
- 188 ABREU 920 give $\sigma(e^+e^- \rightarrow Z \rightarrow q^*\overline{q} \text{ or } q\overline{q}^*) \times \text{B}(q^* \rightarrow q\gamma) < 15 \text{ pb (95\% CL)}$ for m_{a^*} <80 GeV.
- ¹⁸⁹ADRIANI 92F search for $Z \to q q^*$ with $q^* \to q \gamma$ and give the limit $\sigma_Z \cdot \mathsf{B}(Z \to q \gamma)$ $q\,q^*)\cdot \mathrm{B}(q^*\,\to\,q\,\gamma)<$ (2–10) pb (95%CL) for $m_{q^*}=$ (46–82) GeV.
- ¹⁹⁰ ALBAJAR 89 give $\sigma(q^* \rightarrow W + \text{jet})/\sigma(W) < 0.019$ (90% CL) for $m_{q^*} > 220$ GeV.
- 191 BEHREND 86C has $E_{
 m cm}=42.5$ -46.8 GeV. See their Fig. 3 for excluded region in the $m_{a^*} - (\lambda_{\gamma}/m_{a^*})^2$ plane. The limit is for $\lambda_{\gamma} = 1$ with $\eta_L = \eta_R = 1$.

MASS LIMITS for Color Sextet Quarks (96)

VALUE (GeV)	CL%	DOCUMENT ID	TECN	COMMENT
>84	95	¹⁹² ABE 8	39D CDF	$p\overline{p} \rightarrow q_6\overline{q}_6$

192 ABE 89D look for pair production of unit-charged particles which leave the detector before decaying. In the above limit the color sextet quark is assumed to fragment into a unit-charged or neutral hadron with equal probability and to have long enough lifetime not to decay within the detector. A limit of 121 GeV is obtained for a color decuplet.

MASS LIMITS for Color Octet Charged Leptons (48)

$\lambda \equiv m_{\ell_B}/\Lambda$					
VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT
>86	95	193 ABE	89D	CDF	Stable $\ell_8: p\overline{p} \rightarrow \ell_8\overline{\ell}_8$
• • • We do not use	the follow	ving data for average	es, fits	, limits	, etc. • • •
		¹⁹⁴ ABT	93	H1	$e_{\mathbf{R}}: e_{\mathcal{P}} \rightarrow e_{\mathbf{R}} X$
none 3.0-30.3	95	¹⁹⁵ KIM	90	AMY	e_8 : $e^p \rightarrow e_8 \times e_8$: $e^+e^- \rightarrow ee + ee$
none 3.5-30.3	95	195 KIM	90	AMY	$\mu_8: e^+e^- \rightarrow \mu\mu +$ lets
		196 KIM	90	AMY	e ₈ : e ⁺ e ⁻ → gg; R
>19.8	95	197 BARTEL	87B	JADE	
none 5-23.2	95	197 BARTEL	87B	JADE	$\mu_8: e^+e^- \rightarrow \mu\mu +$ lets
		198 BARTEL	85K	JADE	e ₈ : e ⁺ e ⁻ → gg; R

- 193 ABE 89D look for pair production of unit-charged particles which leave the detector before decaying. In the above limit the color octet lepton is assumed to fragment into a unit-charged or neutral hadron with equal probability and to have long enough lifetime not to decay within the detector. The limit improves to 99 GeV if it always fragments into a unit-charged hadron.
- 194 ABT 93 search for e_8 production via e-gluon fusion in e_p collisions with $e_8 \rightarrow e_g$. See their Fig. 3 for exclusion plot in the m_{e_8} - Λ plane for $m_{e_8} = 35$ -220 GeV.
- 195 KIM 90 is at $E_{\rm cm} =$ 50–60.8 GeV. The same assumptions as in BARTEL 878 are used.
- 196 KIM 90 result (m_{eg} Λ_M)^{1/2} > 178.4 GeV (95%CL, α_S = 0.16 used) is subject to the same restriction as for BARTEL 85K.
 197 BARTEL 878 is at E_{CM} = 46.3-46.78 GeV. The limits assume ℓ₈ pair production cross sections to be eight times larger than those of the corresponding heavy lepton pair
- production. 198 in BARTEL 85K, R can be affected by $e^+e^- o gg$ via e_q exchange. Their limit $m_{\rm e_8}$ >173 GeV (CL=95%) at $\lambda=m_{\rm e_8}/\Lambda_{\rm M}=1$ ($\eta_L=\eta_R=1$) is not listed above because the cross section is sensitive to the product $\eta_L\eta_R$, which should be absent in

ordinary theory with electronic chiral invariance.

MASS LIMITS for Color Octet Neutrinos (va)

$\lambda \equiv m_{\ell_0}/\Lambda$		•				
VALUE (GeV)	CL%	DOCUMENT ID		TECN	COMMENT	
>110	90	199 BARGER	89	RVUE	$\nu_8: \rho \overline{\rho} \rightarrow$	ν ₈ ν 8
• • • We do not use t	he follo	wing data for average				
none 3.8-29.8	95	200 KIM	90	AMY	ν ₈ : e ⁺ e ⁻	→ acoplanar
none 9–21.9	95	²⁰¹ BARTEL	878	JADE	ν ₈ : e ⁺ e ⁻	→ acoplanar

- 199 BARGER 89 used ABE 898 limit for events with large missing transverse momentum. Two-body decay $\nu_8 \rightarrow \nu_g$ is assumed.
- $200\,\rm KIM$ 90 is at $E_{\rm cm}=50\text{--}60.8$ GeV. The same assumptions as in BARTEL 878 are used. 201 BARTEL 87B is at $E_{\rm cm}=$ 46.3–46.78 GeV. The limit assumes the $\nu_{\rm 8}$ pair production cross section to be eight times larger than that of the corresponding heavy neutrino pair production. This assumption is not valid in general for the weak couplings, and the limit can be sensitive to its ${\rm SU}(2)_L \times {\rm U}(1)_Y$ quantum numbers.

MASS LIMITS for Wa (Color Octet W Boson)

VALUE (GeV)	DOCUMENT ID		COMMENT
• • • We do not use the	following data for averages,	fits, limits	, etc. • • •
	²⁰² ALBAJAR 8	9 UA1	$p\overline{p} \rightarrow W_8 X, W_8 \rightarrow W_g$
202 ALBAJAR 89 give σ($W_0 \rightarrow W + \text{jet})/\sigma(W) < 0$.019 (90%	CL) for $m_{M/L} > 220$ GeV.

Limits on $ZZ\gamma$ Coupling

Limits are for the electric dipole transition form factor for $Z\to \gamma Z^*$ parametrized as $f(s')=\beta(s'/m_Z^2-1)$, where s' is the virtual Z mass. In the Standard Model

VALUE	CL%	DOCUMENT ID	TECN	COMMENT
• • • We do not use the	following	data for average:	s, fits, limits,	etc. • • •
<0.80	95	ADRIANI	92J L3	$Z \rightarrow \gamma \nu \overline{\nu}$

REFERENCES FOR Searches for Quark and Lepton Compositeness

ACKERSTAFF	98	EPJ C1 21 EPJ C1 45	K. Ackerstaff+ (OPAL Collab.)
ACKERSTAFF	98C	EPJ C1 45	K. Ackerstaff+ (OPAL Collab.)
ABE	97G	PR D55 R5263	+Akimoto, Akopian, Albrow, Amendolia+ (CDF Collab.) +Akimoto, Akopian, Albrow, Amendolia+ (CDF Collab.)
ABE ABREU	97T 97B	PRL 79 2198 PL B393 245	+Adam, Adye, Ajinenko, Alekseev+ (DELPHI Collab.)
ABREU	971	ZPHY C74 57	+Adam, Adye, Ajinenko, Alekseev+ (DELPHI Collab.)
Also	97L	ZPHY C75 580 erratum	Abreu, Adam, Adye, Ajinenko+ (DELPHI Collab.)
ABREU	97 J	ZPHY C74 577	Abreu, Adam, Adye, Ajinenko+ (DELPHI Collab.) P. Abreu+ (DELPHI Collab.)
ACCIARRI	97G	PL B401 139	+Adriani, Aguilar-Benitez, Ahlen, Alpat+ (L3 Collab.)
ACKERSTAFF	97	PL B391 197	+Alexander, Allison, Altekamp, Ametewee+ (OPAL Collab.)
ACKERSTAFF	97C	PL B391 221 NP B483 44	+Alexander, Allison, Altekamp, Ametewee+ (OPAL Collab.) +Aid, Anderson, Andreev, Andrieu, Arndt+ (H1 Collab.)
ADLOFF ARIMA	97 97	PR D55 19	+Aid, Anderson, Andreev, Andrieu, Arndt+ (H1 Collab.) +Odaka, Ogawa, Shirai, Tsuboyama+ (VENUS Collab.)
BREITWEG	97C	ZPHY C76 631	+Derrick, Krakauer, Marill+ (ZEUS Collab.)
DEANDREA	97	PL B409 277	(MARS)
ABE	96	PRL 77 438 PRL 77 5336	+Akimoto, Akopian, Albrow+ (CDF Collab.)
ABE	965	PRL 77 5336	+Akimoto, Akopian, Albrow, Amendolia+ (CDF Collab.)
ABREU	96K	PL B380 480	+Adam, Adye, Agasi, Ajinenko+ (DELPHI Collab.)
ACCIARRI ACCIARRI	96D 96L	Pl. B370 211 Pl. B384 323	+Adam, Adriani, Aguilar-Benitez, Ahlen+ (L3 Collab.) +Adam, Adriani, Aguilar-Benitez+ (L3 Collab.)
ALEXANDER	96K	PL B377 222	+ (OPAL Collab.)
ALEXANDER	96Q	PL B386 463	LANGEON Alteksons Ameteures (OPA) Collab)
BUSKULIC	96W	PL B385 445	+De Bonis, Decamo, Ghez, Gov. Lees+ (ALEPH Collab.)
BUSKULIC	96Z	PL B384 333	+De Bonis, Decamp, Ghez+ (ALEPH Collab.)
ABE	95N	PRL 74 3538	+Albrow, Amendolia, Amidei, Antos+ (CDF Collab.)
ACCIARRI	95G	PL 8353 136	+Adam, Adriani, Aguilar-Benitez, Ahlen+ (L3 Collab.)
AID	95 95B	PL B353 578	+ Andreev, Andrieu, Appuhn, Arpagaus+ (H1 Collab.) + Krakauer, Magill, Musgrave, Repond+ (ZEUS Collab.)
DERRICK ABE	956	ZPHY C65 627 PRL 72 3004	+Andreev, Andrieu, Appuhn, Arpagaus+ +Krakauer, Magill, Musgrave, Repond+ +Albrow, Amidei, Anway-Wiese, Apollinari+ (CDF Collab.)
DIAZCRUZ	94	PR D49 R2149	Diaz Cruz, Sampayo (CINV)
VELISSARIS	94	PL B331 227	+Lusin, Chung, Park, Cho, Bodek, Kim+ (AMY Collab.)
ABE	93G	PRL 71 2542	+Albrow, Akimoto, Amidel, Anway-Wiese+ (CDF Collab.)
ABT	93	NP 8396 3	+Andreev, Andrieu, Appuhn, Arpagaus+ (H1 Collab.)
ADRIANI	93M	PRPL 236 1	+Aguilar-Benitez, Ahlen, Alcaraz, Aloisio+ (L3 Collab.)
ALITTI	93	NP B400 3	+Ambrosini, Ansari, Autiero, Bareyre+ (UA2 Collab.)
BUSKULIC	93Q	ZPHY C59 215	+Decamp, Goy, Lees, Minard, Mours+ +Krakauer, Magill, Musgrave, Repond+ (ZEUS Collab.)
DERRICK ABE	93B 92B	PL B316 207	
ABE	92D	PRL 68 1463 PRL 68 1104	+Amidei Anollinari Atac Auchincloss+ (CDF Collab.)
ABE	92M	PRL 69 2896	+Amidei, Anway-Wiese, Apollinari, Atac+ (CDF Collab.)
ABREU	92C	ZPHY C53 41	+Adam, Adami, Adye, Akesson+ (DELPHI Collab.)
ABREU	92D	ZPHY C53 555	+Adam, Adami, Adye, Akesson, Alekseev+(DELPHI Collab.)
ADRIANI	92B	PL B288 404	+Aguitar-Benitez, Ahlen, Akbari, Alcaraz+ (L3 Collab.)
ADRIANI	92F	PL B292 472	+Amicel, Apolimari, Atac, Auchincloss+ +Amicel, Apolimari, Atac, Auchincloss+ +Amicel, Anway-Wiese, Apollinari, Atac (CDF Collab.) +Adam, Adami, Adye, Akesson-I (DELPHI Collab.) +Adam, Adami, Adye, Akesson, Alekseev+(DELPHI Collab.) +Aguliar-Bentez, Ahlen, Akbari, Akaraz-t (L3 Collab.) +Aguliar-Bentez, Ahlen, Akbari, Akaraz-t (L3 Collab.)
ADRIANI	92.	PL B297 469	
BARDADIN	92	ZPHY C55 163 PRPL 216 253	Bardadin-Otwinowska (CLER) +Deschizeaux, Goy, Lees, Minard+ (ALEPH Collab.)
DECAMP HOWELL	92 92	PL B291 206	+Deschizeaux, Goy, Lees, Minard+ (ALEPH Collab.) +Koltick, Tauchi, Miyamoto, Kichimi+ (TOPAZ Collab.)
KROHA	92	PR D46 58	(ROCH)
PDG	92	PR D45, 1 June, Part	II Hikasa, Barnett, Stone+ (KEK, LBL, BOST+)
SHIMOZAWA	92	PL B284 144	+Fuirmoto, Abe. Adachi, Doser+ {TOPAZ Collab.}
ABE	91D	PRL 67 2418	+Amidei, Apollinari, Atac, Auchincloss+ +Adam, Adami, Adye, Akesson+ (CDELPHI Collab.)
ABREU	91E	PL B268 296	+Adam, Adami, Adye, Akesson+ (DELPHI Collab.) +Adam, Adami, Adye, Akesson+ (DELPHI Collab.)
ABREU ADACHI	91F 91	NP B367 511	+Adam, Adami, Adye, Akesson+ (DELPHI Collab.) +Anazawa, Doser, Enomoto+ (TOPAZ Collab.)
AKRAWY	91F	PL B255 613 PL B257 531	+Alexander, Allison, Allport, Anderson+ (OPAL Collab.)
ALITTI	91B	PL B257 232	+Ansari, Autiero, Bareyre, Blaylock+ (UA2 Collab.)
BEHREND	91B	ZPHY C51 143	+Criegee, Field, Franke, Jung+ (CELLO Coliab.)
BEHREND	91C	ZPHY C51 143 ZPHY C51 149	Criegge Field Franke Jung Meuer (CFLLO Collab.)
Also	91B	ZPHY C51 143	Behrend, Criegee, Field, Franke, Jung+ (CELLO Collab.)
ABE	901	ZPHY C48 13	
ADEVA	90F	PL B247 177	+Adriani, Aguilar-Benitez, Akbari, Alcaraz+ (L3 Collab.)
ADEVA ADEVA	90K 90L	PL B250 199 PL B250 205	+Adriani, Aguilar-Benitez, Akbari, Alcarez+ (L3 Collab.) +Adriani, Aguilar-Benitez, Akbari, Alcarez+ (L3 Collab.)
ADEVA	90L 90O	PL 8250 205 PL 8252 525	+Adriani, Aguilar-Benitez, Akbari, Alcaraz+ +Adriani, Aguilar-Benitez, Akbari, Alcaraz+ (L3 Collab.)
AKRAWY	90F	PL B241 133	+Alexander, Allison, Allport+ (OPAL Collab.)
AKRAWY	901	PL B244 135	+Alexander, Allison, Allport+ (OPAL Collab.) +Alexander, Allison, Allport, Anderson+ +Alexander, Allison, Allport, Anderson+ (OPAL Collab.)
AKRAWY	90 J	PL B244 135 PL B246 285	+Alexander, Allison, Allport, Anderson+ (OPAL Collab.)
DECAMP	90G	PL B236 501	+Deschizeaux, Lees, Minard+ (ALEPH Collab.)
DECAMP	900	PL B250 172 PL B240 243	+Deschizeaux, Goy, Lees+ (ALEPH Collab.) +Breedon, Ko, Lander, Maeshima, Malchow+(AMY Collab.)
KIM	90	PL B240 243	+Breedon, Ko, Lander, Maeshima, Malchow+(AMY Collab.)
ABE	89	PRL 62 613	+Amidei, Apollinari, Ascori, Atac+ (CDF Collab.) +Amidei, Apollinari, Ascoli, Atac+ (CDF Collab.)
ABE ABE	89B 89D	PRL 62 1825	+Amidei, Apollinari, Ascoli, Atac+ (CDF Collab.) +Amidei, Apollinari, Ascoli, Atac+ (CDF Collab.) +Amidei, Apollinari, Ascoli, Atac+ (CDF Collab.)
ABE	89H		
ABE	89J	ZPHY C45 175	+Amako, Arai, Fukawa+ (VENUS Collab.)
ABE	89L	PL B232 425	+Amako, Arai, Asano, Chiba+ (VENUS Collab.)
ADACHI	89B	PL B228 553	+Ajnara, Doser, Enomoto, ruje+ (10rAz Collab.)
ALBAJAR	89	ZPHY C44 15	+Albrow, Allkofer, Arnison, Astbury+ +Hagiwara, Han, Zeppenfeld (WISC, KEK)
BARGER	89	PL B220 464	+Hagiwara, Han, Zeppenfeld (WISC, KEK) +Criegee, Dainton, Field, Franke+ (CELLO Collab.)
BEHREND	89B	PL B222 163	+Criegee, Dainton, Field, Franke+ (CELLO Collab.) Braunschweig, Gerhards, Kirschfink+ (TASSO Collab.)
BRAUNSCH DORENBOS		ZPHY C43 549 ZPHY C41 567	Dorenhosch Lido Allahy Amaldi+ (CHARM Collab.)
HAGIWARA	. 89	PL B219 369	+Sakuda, Terunuma (KEK, DURH, HIRO)
KIM	89	PL B223 476	+Kim, Kang, Lee, Myung, Bacala (AMY Collab.)
ABE	88B	PL B213 400	+Amako, Arai, Asano, Chiba, Chiba+ (VENUS Collab.)
BARINGER	88	PL B206 551	+Bylsma, De Bonte, Koltick, Low+ (HRS Collab.)
BRAUNSCH	. 88	ZPHY C37 171	Braunschweig, Gerhards+ (TASSO Collab.)

Quark and Lepton Compositeness, WIMPs and Other Particle Searches

BRAUNSCH	880	ZPHY C40 163	Braunschweig, Gerhards, Kirschfink+	(TASSO Collab.)
ANSARI	87D	PL B195 613	+Bagnaia, Banner+	` (UA2 Collab.)
BARTEL	87B	ZPHY C36 15	+Becker, Felst+	(JADE Collab.)
BEHREND	87C	PL B191 209	+Buerger, Criegee, Dainton+	(ČELLO Collab.)
FERNANDEZ	87B	PR D35 10	+Ford, Qi, Read, Smith, Camporesi+	(MAC Collab.)
ARNISON	86C	PL B172 461	+Albrow, Allkofer+	(UA1 Collab.)
ARNISON	86D	PL B177 244	+Albajar, Albrow+	(UA1 Collab.)
BARTEL	86	ZPHY C31 359	+Becker, Felst, Haidt+	(JADE Collab.)
BARTEL	86C	ZPHY C30 371	+Becker, Cords, Felst, Haidt+	(JADE Collab.)
BEHREND	86	PL 168B 420	+Buerger, Criegee, Fenner+	(ČELLO Collab.)
BEHREND	86C	PL B181 178	+Buerger, Criegee, Dainton+	(CELLO Collab.)
DERRICK	86	PL 166B 463	+Gan, Kooijman, Loos+	(HRS Collab.)
Also	86B	PR D34 3286	Derrick, Gan, Kooijman, Loos, Muse	rave+ (HRS Collab.)
DERRICK	86B	PR D34 3286	+Gan, Kooijman, Loos, Musgrave+	(HRS Collab.)
GRIFOLS	86	PL 168B 264	+Peris	(BARC)
JODIDIO	86	PR D34 1967	+Balke, Carr, Gidal, Shinsky+	(LBL, NWES, TRIU)
Also	88	PR D37 237 erratum	Jodidio, Balke, Carr+	(LBL, NWES, TRIU)
APPEL	85	PL 160B 349	+Bagnaia, Banner+	(UA2 Collab.)
BARTEL	85K	PL 160B 337	+Becker, Cords, Eichler+	(JADE Collab.)
BERGER	85	ZPHY C28 1	+Genzel, Lackas, Pielorz+	(PLUTO Collab.)
BERGER	85B	ZPHY C27 341	+Deuter, Genzel, Lackas, Pielorz+	(PLUTO Collab.)
BAGNAIA	84C	PL 138B 430	+Banner, Battiston+	(UA2 Collab.)
BARTEL	84D	PL 146B 437	+Becker, Bowdery, Cords+	(JADE Collab.)
BARTEL	84E	PL 146B 121	+Becker, Bowdery, Cords, Felst+	(JADE Collab.)
EICHTEN	84	RMP 56 579	+Hinchliffe, Lane, Quigg	(FNAL, LBL, OSU)
ALTHOFF .	83C	PL 126B 493	+Fischer, Burkhardt+	(TASSO Collab.)
RENARD	82	PL 116B 264		(CERN)

WIMPs and Other Particle Searches

OMITTED FROM SUMMARY TABLE WIMPS AND OTHER PARTICLE SEARCHES

Revised October 1997 by K. Hikasa (Tohoku University).

We collect here those searches which do not appear in any of the above search categories. These are listed in the following order:

- 1. Galactic WIMP (weakly-interacting massive particle) searches
- 2. Concentration of stable particles in matter
- 3. Limits on neutral particle production at accelerators
- 4. Limits on jet-jet resonance in hadron collisions
- 5. Limits on charged particles in e^+e^- collisions
- 6. Limits on charged particles in hadron reactions
- 7. Limits on charged particles in cosmic rays

Note that searches appear in separate sections elsewhere for Higgs bosons (and technipions), other heavy bosons (including W_R, W', Z' , leptoquarks, axigluons), axions (including pseudo-Goldstone bosons, Majorons, familons), heavy leptons, heavy neutrinos, free quarks, monopoles, supersymmetric particles, and compositeness. We include specific WIMP searches in the appropriate sections when they yield limits on hypothetical particles such as supersymmetric particles, axions, massive neutrinos, monopoles, etc.

We omit papers on CHAMP's, millicharged particles, and other exotic particles. We no longer list for limits on tachyons and centauros. See our 1994 edition for these limits.

GALACTIC WIMP SEARCHES Cross-Section Limits for Dark Matter Particles (X^0) on Nuclei

These limits are for weakly-interacting stable particles that may constitute the invisible mass in the galaxy. Unless otherwise noted, a local mass density of 0.3 GeV/cm³ is assumed; see each paper for velocity distribution assumptions. In the papers the limit is given as a function of the X^0 mass. Here we list limits only for typical mass values of 20 GeV, 100 GeV, and 1 TeV. Specific limits on supersymmetric dark matter particles may be found in the Supersymmetry section.

For $m_{\chi 0} = 20 \text{ GeV}$

VALUE (nb)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not	use the following	g data for average	s, flts	i limits,	etc. • • •
		1 BERNABEI	97	CNTR	F
< 0.8		ALESSAND	96	CNTR	0
< 6		ALESSAND	96	CNTR	Te
< 0.02	90				129Xe, inel.
		3 BELLI	96C	CNTR	¹²⁹ Xe

< 0.004	90	⁴ BERNABEI	96	CNTR	Na
< 0.3	90	⁴ BERNABEI	96	CNTR	į.
< 0.2	95	⁵ SARSA	96	CNTR	Na
< 0.015	90	⁶ SMITH	96	CNTR	Na
< 0.05	95	⁷ GARCIA	95	CNTR	Natural Ge
< 0.1	95	QUENBY	95	CNTR	Na
<90	90	8 SNOWDEN	95	MICA	16 _O
$< 4 \times 10^3$	90	8 SNOWDEN	95	MICA	³⁹ K
< 0.7	90	BACCI	92	CNTR	Na
< 0.12	90	⁹ REUSSER	91	CNTR	Natural Ge
< 0.06	95	CALDWELL	88	CNTR	Natural Ge

 1 BERNABEI 97 give $\sigma < 12$ pb (90%CL) for the spin-dependent X^0 -proton cross section. 2 BELLI 96 limit for inelastic scattering X^0 $^{129}{\rm Xe} \rightarrow~X^0$ $^{129}{\rm Xe}^*(39.58$ keV).

 3 BELLI 96C use background subtraction and obtain $\sigma <$ 150 pb (< 1.5 fb) (?%CL) for spin-dependent (Independent) X⁰-proton cross section.

⁴ BERNABEI 96 use pulse shape discrimination to enhance the possible signal. The limit here is from R. Bernabel, private communication, September 19, 1997.

5 SARSA 96 search for annual modulation of WIMP signal. See SARSA 97 for details of the analysis. The limit here is from M.L. Sarsa, private communication, May 26, 1997. 6 SMITH 96 use pulse shape discrimination to enhance the possible signal. A dark matter density of 0.4 GeV cm $^{-3}$ is assumed.

7 GARCIA 95 limit is from the event rate. A weaker limit is obtained from searches for

diurnal and annual modulation.

8 SNOWDEN-IFFT 95 look for recoil tracks in an ancient mica crystal. Similar limits are also given for ²⁷Al and ²⁸Si. See COLLAR 96 and SNOWDEN-IFFT 96 for discussion on potential backgrounds.

⁹ REUSSER 91 limit here is changed from published (0.04) after reanalysis by authors. L. Vullieumier, private communication, March 29, 1996.

For $m_{\chi^0} = 100 \text{ GeV}$

VALUE (nb)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use	the follow	ing data for average	s, fits	, limits,	etc. • • •
		¹⁰ BERNABEI	97	CNTR	F
< 4		ALESSAND	96	CNTR	0
<25		ALESSAND	96	CNTR	
< 0.006	90	¹¹ BELLI	96	CNTR	¹²⁹ Xe, inel.
		12 BELLI	96C	CNTR	
< 0.001	90	13 BERNABEI	96	CNTR	Na
< 0.3	90	¹³ BERNABEI	96	CNTR	1
< 0.7	95	¹⁴ SARSA	96	CNTR	Na
< 0.03	90	¹⁵ SMITH	96	CNTR	Na
< 0.8	90	¹⁵ SMITH	96	CNTR	1
< 0.35	95	¹⁶ GARCIA	95	CNTR	Natural Ge
< 0.6	95	QUENBY	95	CNTR	Na
< 3	95	QUENBY	95	CNTR	1
$< 1.5 \times 10^2$	90	17 SNOWDEN	95	MICA	¹⁶ O
$< 4 \times 10^{2}$	90	17 SNOWDEN	95	MICA	³⁹ K
< 0.08	90	18 BECK	94	CNTR	⁷⁶ Ge
< 2.5	90	BACCI	92	CNTR	Na
< 3	90	BACCI	92	CNTR	1
< 0.9	90	19 REUSSER	91	CNTR	Natural Ge
< 0.7	95	CALDWELL	88	CNTR	Natural Ge
10					•

 10 BERNABEI 97 give $\sigma < 5$ pb (90%CL) for the spin-dependent X^0 -proton cross section. ¹¹BELLI 96 limit for inelastic scattering $X^{0.129} \text{Xe} \rightarrow X^{0.129} \text{Xe*}(39.58 \text{ keV})$.

 12 BELLI 96C use background subtraction and obtain $\sigma <$ 0.35 pb (< 0.15 fb) (?%CL) for spin-dependent (independent) X^0 -proton cross section.

13 BERNABEI 96 use pulse shape discrimination to enhance the possible signal. The limit here is from R. Bernabel, private communication, September 19, 1997.

14 SARSA 96 search for annual modulation of WIMP signal. See SARSA 97 for details of the analysis. The limit here is from M.L. Sarsa, private communication, May 26, 1997. $^{15}\,\mathrm{SMITH}$ 96 use pulse shape discrimination to enhance the possible signal. A dark matter

density of 0.4 GeV cm⁻³ is assumed.

16 GARCIA 95 limit is from the event rate. A weaker limit is obtained from search urnal and annual modulation.

17 SNOWDEN-IFFT 95 look for recoil tracks in an ancient mica crystal. Similar limits are also given for ²⁷Al and ²⁸SI. See COLLAR 96 and SNOWDEN-IFFT 96 for discussion on potential backgrounds

18 BECK 94 uses enriched 76 Ge (86% purity).

19 REUSSER 91 limit here is changed from published (0.3) after reanalysis by authors. J.L. Vullleumler, private communication, March 29, 1996.

For $m_{\chi^0} = 1 \text{ TeV}$

VALUE (nb)	CL%	DOCUMENT ID		TECN	COMMENT	
• • • We do not	use the followi	ing data for average	s, fits	, ilmits,	etc. • • •	
		²⁰ BERNABEI	97	CNTR	F	
< 40		ALESSAND	96	CNTR	0	
<700		ALESSAND	96			
< 0.05	90	²¹ BELLi	96	CNTR	¹²⁹ Xe, inel.	
< 1.5	90	22 BELLI	96	CNTR	129 Xe, Inel.	
		23 BELLI	960	CNTR	129 _{Xe}	
< 0.01	90	24 BERNABEI		CNTR		
< 9	90	24 BERNABEI	96	CNTR	1	
< 7	95	²⁵ SARSA	96	CNTR	Na	
< 0.3	90	²⁶ SMITH	96	CNTR	Na	

LIMITS ON NEUTRAL PARTICLE PRODUCTION

Production Cross Section of Radiatively-Decaying Neutral Particle

VALUE (pb)	CL%	DOCUMENT ID TECN COMMENT
• • • We do not	use the followir	ng data for averages, fits, limits, etc. • • •
<(2.5-0.5)	95	³⁶ ACKERSTAFF 97B OPAL $e^+e^- \rightarrow X^0 Y^0$, $X^0 \rightarrow Y^0 \gamma$
<(1.6-0.9)	95	³⁷ ACKERSTAFF 97B OPAL $e^+e^- \rightarrow X^0X^0$, $X^0 \rightarrow Y^0\gamma$

³⁶ ACKERSTAFF 97B associated production limit is for $m_{\chi 0} =$ 80–160 GeV, $m_{\gamma 0} =$ 0 from 10.0 pb⁻¹ at $\sqrt{s} = 161$ GeV. See their Fig. 3(a).

 37 ACKERSTAFF 97B pair production limit is for $m_{\chi^0}=40$ –80 GeV, $m_{\gamma^0}=0$ from 10.0 pb⁻¹ at $\sqrt{s} = 161$ GeV. See their Fig. 3(b).

Heavy Particle Production Cross Section

VALUE (cm ² /N)	CL%	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not u	se th	e followin	g data for averages	, fits	, limits,	etc. • • •
$< 10^{-36} - 10^{-33}$			38 GALLAS	95	TOF	m= 0.5-20 GeV
$<(4-0.3)\times10^{-31}$ $<2\times10^{-36}$	95		³⁹ AKESSON	91	CNTR	m = 0-5 GeV
	90	0	⁴⁰ BADIER	86	BDMP	$\tau = (0.05-1.) \times 10^{-8}$ s
<2.5 × 10 ⁻³⁵		0	⁴¹ GUSTAFSON	76	CNTR	$\tau > 10^{-7} \text{ s}$

 38 GALLAS 95 limit is for a weakly interacting neutral particle produced in 800 GeV/c pN interactions decaying with a lifetime of 10^{-4} – 10^{-8} s. See their Figs. 8 and 9. Similar limits are obtained for a stable particle with interaction cross section 10^{-29} – 10^{-33} cm².

 39 AKESSON 91 limit is from weakly interacting neutral long-lived particles produced in pN reaction at 450 GeV/c performed at CERN SPS. Bourquin-Gaillard formula is used as the production model. The above limit is for $\tau > 10^{-7}\,\mathrm{s}$. For $\tau > 10^{-9}\,\mathrm{s}$, $\sigma < 10^{-30} \, \text{cm}^{-2} / \text{nucleon is obtained.}$

 40 BADIER 86 looked for long-lived particles at 300 GeV π^- beam dump. The limit applies for nonstrongly interacting neutral or charged particles with mass >2 GeV. The limit applies for particle modes, $\mu^+\pi^-$, $\mu^+\mu^-$, $\pi^+\pi^-$ X, $\pi^+\pi^-\pi^\pm$ etc. See their figure 5 for the contours of limits in the mass- τ plane for each mode.

 41 GUSTAFSON 76 is a 300 GeV FNAL experiment looking for heavy (m>2 GeV) long-lived neutral hadrons in the M4 neutral beam. The above typical value is for m=3GeV and assumes an interaction cross section of 1 mb. Values as a function of mass and interaction cross section are given in figure 2.

Production of New Penetrating Non-v Like States in Beam Dump

VALUE	DOCUMENT ID	_	TECN_	COMMENT
• • • We do not use the following	data for averages,	, fits	, Ilmits,	etc. • • •
•	12 LOSECCO	81	CALO	28 GeV protons

⁴²No excess neutral-current events leads to σ (production) $\times \sigma$ (interaction) \times acceptance < 2.26 \times 10⁻⁷¹ cm⁴/nucleon² (CL = 90%) for light neutrals. Acceptance depends on models (0.1 to 4. \times 10⁻⁴).

LIMITS ON JET-JET RESONANCES

Heavy Particle Production Cross Section in pp

Limits are for a particle decaying to two hadronic jets. DOCUMENT ID TECN COMMENT Units(pb) _CL% Mass(GeV) • • • We do not use the following data for averages, fits, limits, etc. • • •

		⁴³ ABE	97G CDF	1.8 TeV pp → 2 jets
<2603	95 200	44 ABE	93G CDF	1.8 TeV pp → 2jets
< 44	95 400	44 ABE	93G CDF	1.8 TeV pp → 2jets
< 7	95 600	⁴⁴ ABE	93G CDF	1.8 TeV pp → 2jets

43 ABE 97G search for narrow dijet resonances in $p\bar{p}$ collisions with 106 pb⁻¹ of data at $\sqrt{s} = 1.8$ TeV. Limits on $\sigma(p\bar{p} \to X + \text{anything}) B(X \to Jj)$ in the range $10^4 - 10^{-1}$ pb (95%CL) are given for dijet mass m=200–1150 GeV with both jets having $|\eta| <$ 2.0 and the dijet system having $|\cos\!\theta^*|<$ 0.67. See their Table I for the list of limits. Supersedes

44 ABE 93c gives cross section times branching ratio into light (d, u, s, c, b) quarks for Γ = 0.02 M. Their Table II gives limits for M = 200–900 GeV and Γ = (0.02-0.2) M.

LIMITS ON CHARGED PARTICLES IN e+e~

Heavy Particle Production Cross Section in e+e-

Ratio to $\sigma(e^+e^-\to \mu^+\mu^-)$ unless noted. See also entries in Free Quark Search and Magnetic Monopole Searches.

VALUE	CL% EVTS	DOCUMENT ID	<u>TECN</u>	COMMENT
• • • We do no	t use the follo	wing data for averag	es, fits, limits,	etc. • • •
		⁴⁵ ABREU	970 DLPH	Q=1,2/3, m=45-84 GeV
		⁴⁶ BARATE	97K ALEP	Q=1, m=45-85 GeV
$< 2 \times 10^{-5}$	95	47 AKERS	95R OPAL	Q=1, m= 5-45 GeV
$< 1 \times 10^{-5}$	95	47 AKERS	95R OPAL	Q=2, m= 5-45 GeV
$< 2 \times 10^{-3}$	90	48 BUSKULIC	93C ALEP	Q=1, m=32-72 GeV
<(10 ⁻² -1)	95	⁴⁹ ADACHI	90c TOPZ	Q = 1, m = 1-16, 18-27 GeV
$< 7 \times 10^{-2}$	90	⁵⁰ ADACHI	90E TOPZ	Q = 1, m = 5-25 GeV
$< 1.6 \times 10^{-2}$	95 0		82 PLAS	Q=3-180, m <14.5 GeV
$< 5.0 \times 10^{-2}$	90 0	F0	80 JADE	Q=(3,4,5)/3 2-12 GeV

 45 ABREU 97D search for pair production of long-lived particles and give limits $\sigma<(0.4-2.3)$ pb (95%CL) for various center-of-mass energies $\sqrt{s}\!\approx\!130\!-\!136,\ 161,\$ and 172 GeV, assuming an almost flat production distribution in $\cos\theta.$

< 6	90	26 SMITH 96 CNTR I
< 6	95	27 GARCIA 95 CNTR Natural Ge
< 8	95	QUENBY 95 CNTR Na
< 50	95	QUENBY 95 CNTR I
$< 7 \times 10^2$	90	²⁸ SNOWDEN 95 MICA ¹⁶ O
$< 1 \times 10^3$	90	²⁸ SNOWDEN 95 MICA ³⁹ K
< 0.8	90	²⁹ BECK 94 CNTR ⁷⁶ Ge
< 30	90	BACCI 92 CNTR Na
< 30	90	BACCI 92 CNTR I
< 15	90	30 REUSSER 91 CNTR Natural Ge
< 6	95	CALDWELL 88 CNTR Natural Ge

- 20 BERNABEI 97 give $\sigma <$ 32 pb (90%CL) for the spin-dependent X^0 -proton cross section.
- 21 BELLI 96 limit for inelastic scattering X^0 129 $Xe \rightarrow X^0$ 129 Xe^* (39.58 keV). 22 BELLI 96 limit for inelastic scattering X^0 129 $Xe \rightarrow X^0$ 129 Xe^* (236.14 keV).
- 23 BELLI 96C use background subtraction and obtain $\sigma <$ 0.7 pb (< 0.7 fb) (?%CL) for spin-dependent (independent) X^0 -proton cross section.
- 24 BERNABEI 96 use pulse shape discrimination to enhance the possible signal. The limit here is from R. Bernabei, private communication, September 19, 1997.
- 25 SARSA 96 search for annual modulation of WIMP signal. See SARSA 97 for details of the analysis. The limit here is from M.L. Sarsa, private communication, May 26, 1997.
- 26 SMITH 96 use pulse shape discrimination to enhance the possible signal. A dark matter density of 0.4 GeV cm⁻³ is assumed.
- 27 GARCIA 95 limit is from the event rate. A weaker limit is obtained from searches for
- diurnal and annual modulation.

 28 SNOWDEN-IFFT 95 look for recoil tracks in an ancient mica crystal. Similar limits are also given for ²⁷Al and ²⁸SI. See COLLAR 96 and SNOWDEN-IFFT 96 for discussion on potential backgrounds.

 29 BECK 94 uses enriched ⁷⁶Ge (86% purity).
- 30 REUSSER 91 limit here is changed from published (5) after reanalysis by authors. J.L. Vuilleumier, private communication, March 29, 1996.

CONCENTRATION OF STABLE PARTICLES IN MATTER

Concentration of Heavy (Charge +1) Stable Particles in Matter

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use	the follow	ing data for average	s, fits	, limits,	etc. • • •
<4 × 10 ⁻¹⁷	95	31 YAMAGATA	93	SPEC	Deep sea water, m=5-1600m _p
$< 6 \times 10^{-15}$	95	32 VERKERK			Water, m= 10 ⁵ to 3 ×
$< 7 \times 10^{-15}$	95	32 VERKERK	92	SPEC	Water, $m = 10^4$, 6×10^7 GeV
$< 9 \times 10^{-15}$	95	32 VERKERK	92	SPEC	Water, m= 10 ⁸ GeV
$< 3 \times 10^{-23}$	90	33 HEMMICK	90	SPEC	Water, $m = 1000 m_D$
$< 2 \times 10^{-21}$	90	³³ HEMMICK			Water, $m = 5000 m_D$
$< 3 \times 10^{-20}$	90	33 HEMMICK			Water, $m = 10000 m_p$
<1. × 10 ⁻²⁹		SMITH	82B	SPEC	Water, m=30-400m _p
<2. × 10 ⁻²⁸		SMITH	82B	SPEC	Water, m=12-1000mp
<1. × 10 ⁻¹⁴		SMITH			Water, m >1000 mp
<(0.2–1.) × 10 ⁻²¹		SMITH			Water, m=6-350 m _p

31 YAMAGATA 93 used deep sea water at 4000 m since the concentration is enhanced in deep sea due to gravity.

32 VERKERK 92 looked for heavy isotopes in sea water and put a bound on concentration of stable charged massive particle in sea water. The above bound can be translated into into a bound on charged dark matter particle (5 imes 10 6 GeV), assuming the local density, ρ =0.3 GeV/cm³, and the mean velocity $\langle v \rangle$ =300 km/s.

 $^{\rm 33}\,{\rm See}$ HEMMICK 90 Fig. 7 for other masses 100–10000 m_{p}

Concentration of Heavy (Charge -1) Stable Particles

 35 Bound valid up to $m_{\chi^+} \sim 100$ TeV.

VALUE	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use the fo	ollowing da	ta for averages, fits	s, Ilmi	ts, etc.	• • •
<4 × 10 ⁻²⁰	90	34 HEMMICK	90	SPEC	C, $M = 100 m_D$
<8 × 10 ⁻²⁰	90	34 HEMMICK			C, $M = 1000 m_D$
<2 × 10 ⁻¹⁶	90	34 HEMMICK	90	SPEC	C, $M = 10000 m_D$
<6 × 10 ⁻¹³	90	34 HEMMICK	90	SPEC	Li, $M = 1000 m_D^2$
<1 × 10 ⁻¹¹	90	34 HEMMICK			Be, M = 1000mp
<6 × 10 ⁻¹⁴	90	34 HEMMICK			B, $M = 1000 m_D^2$
<4 × 10 ⁻¹⁷	90	34 HEMMICK	90	SPEC	$O, M = 1000 m_D$
<4 × 10 ⁻¹⁵	90	34 HEMMICK	90	SPEC	F, $M = 1000 m_D$
$< 1.5 \times 10^{-13}$ /nucleon	68	35 NORMAN	89	SPEC	206 _{PbX} -
$< 1.2 \times 10^{-12}$ /nucleon	68	35 NORMAN	87	SPEC	56,58 _{Fe X} -

WIMPs and Other Particle Searches

- 46 BARATE 97K search for pair production of long-lived charged particles at $\sqrt{s}=130,\,136,\,161,\,$ and 172 GeV and give limits $\sigma<(0.2\text{-}0.4)$ pb (95%CL) for spin-0 and spin-1/2 particles with m=45-65 GeV. The limit is translated to the cross section at $\sqrt{s}=172$ GeV with the \sqrt{s} dependence described in the paper. See their Figs. 2 and 3 for limits on J=1/2 and J=0 cases.
- 47 AKERS 95R is a CERN-LEP experiment with W $_{
 m cm}~\sim~m_Z$. The limit is for the production of a stable particle in multihadron events normalized to $\sigma(e^+e^- \to \text{hadrons})$. Constant phase space distribution is assumed. See their Fig. 3 for bounds for $Q=\pm 2/3$,
- 48 BUSKULIC 93C is a CERN-LEP experiment with W_{CM} = m_Z. The limit is for a pair or single production of heavy particles with unusual ionization loss in TPC. See their Fig. 5
- 49 ADACHI 90C is a KEK-TRISTAN experiment with W_{cm} = 52–60 GeV. The limit is for pair production of a scalar or spin-1/2 particle. See Figs. 3 and 4.
- 50 ADACHI 90E is KEK-TRISTAN experiment with $W_{cm} = 52-61.4$ GeV. The above limit is for inclusive production cross section normalized to $\sigma(e^+e^-\to \mu^+\mu^-)\cdot\beta(3-\beta^2)/2$, where $\beta=(1-4m^2/W_{\rm cm}^2)^{1/2}$. See the paper for the assumption about the production prochairs
- 51 KINOSHITA 82 is SLAC PEP experiment at $W_{cm} = 29$ GeV using lexan and 39 Cr plastic
- Sheets sensitive to highly lonizing particles.
 BARTEL 80 is DESY-PETRA experiment with W_{cm} = 27-35 GeV. Above limit is for inclusive pair production and ranges between 1. x 10⁻¹ and 1. x 10⁻² depending on mass and production momentum distributions. (See their figures 9, 10, 11).

Branching Fraction of Z^0 to a Pair of Stable Charged Heavy Fermions

VALUE			TECN	•
• • • We do not us	se the follow	ing data for averag	ges, fits, limits,	etc. • • •
$< 5 \times 10^{-6}$	95	53 AKERS	95R OPAL	m= 40.4-45.6 GeV
$< 1 \times 10^{-3}$	95	AKRAWY	900 OPAL	m = 29-40 GeV

⁵³ AKERS 95R give the 95% CL limit $\sigma(X\overline{X})/\sigma(\mu\mu) < 1.8 \times 10^{-4}$ for the pair production of singly- or doubly-charged stable particles. The limit applies for the mass range 40.4–45.6 GeV for X^{\pm} and < 45.6 GeV for $X^{\pm\pm}$. See the paper for bounds for $Q=\pm 2/3, \pm 4/3$.

900 OPAL m = 29-40 GeV

LIMITS ON CHARGED PARTICLES IN HADRONIC REACTIONS

Heavy Particle Production Cross Section

 $<1 \times 10^{-3}$

VALUE (nb)	CL% EV7	S DOCUMENT ID	TECN	COMMENT
• • • We do	not use the fol	iowing data for averag	es, fits, limits	etc. • • •
< 0.05	95	54 ABE	92J CDF	m=50-200 GeV
<30-130		55 CARROLL	78 SPEC	m=2-2.5 GeV
<100		O ⁵⁶ LEIPUNER	73 CNTR	m=3-11 GeV

- ⁵⁴ ABE 92J look for pair production of unit-charged particles which leave detector before decaying. Limit shown here is for $m{\approx}50$ GeV. See their Fig. 5 for different charges and stronger limits for higher mass.
- 55 CARROLL 78 look for neutral, S=-2 dihyperon resonance in $pp\to 2K^+$ section varies within above limits over mass range and $p_{\rm lab}=5.1$ –5.9 GeV/c.
- 56 LEIPUNER 73 is an NAL 300 GeV p experiment. Would have detected particles with lifetime greater than 200 ns.

Heavy Particle Production Differential Cross Section

VALUE							
$(cm^2sr^{-1}GeV^{-1})$	CL% E	<u>vrs</u>	DOCUMENT ID		TECN	CHG	COMMENT
• • • We do not	use the f	ollowin	g data for average:	s, fits	, limits,	etc. •	• •
$< 2.6 \times 10^{-36}$	90	0	⁵⁷ BALDIN	76	CNTR	-	Q= 1, m=2.1-9.4 GeV
$< 2.2 \times 10^{-33}$	90	0	⁵⁸ ALBROW	75	SPEC	±	Q= ±1, m=4-15 GeV
$<1.1 \times 10^{-33}$	90	0	⁵⁸ ALBROW	75	SPEC	±	Q= ±2, m=6-27 GeV
$< 8. \times 10^{-35}$	90	0	⁵⁹ JOVANOV	75	CNTR	±	m=15-26 GeV
$<1.5 \times 10^{-34}$	90	0	⁵⁹ JOVANOV	75	CNTR	±	Q= ±2, m=3-10 GeV
<6. × 10 ⁻³⁵	90	0	VONAVOL ⁶²	75	CNTR	±	Q= ±2, m=10-26 GeV
$<1. \times 10^{-31}$	90	0	60 APPEL	74	CNTR	±	m=3.2-7.2 GeV
$< 5.8 \times 10^{-34}$	90	0	61 ALPER	73	SPEC	±	m=1.5-24 GeV
$< 1.2 \times 10^{-35}$	90	0	62 ANTIPOV	71B	CNTR	_	Q=-, m=2.2-2.8
$< 2.4 \times 10^{-35}$	90	0	63 ANTIPOV	71C	CNTR	-	Q=-, m=1.2-1.7, 2.1-4
<2.4 × 10 ⁻³⁵	90	0	BINON	69	CNTR	-	Q=-, m=1-1.8 GeV
$<1.5 \times 10^{-36}$		0	⁶⁴ DORFAN	65	CNTR		Be target m=3-7 GeV
$< 3.0 \times 10^{-36}$		0	⁶⁴ DORFAN	65	CNTR		Fe target m=3-7

- ⁵⁷ BALDIN 76 is a 70 GeV Serpukhov experiment. Value is per AI nucleus at $\theta=0$. For other charges in range -0.5 to -3.0, CL =90% limit is $(2.6\times10^{-36})/|(\text{charge})|$ for mass range (2.1–9.4 GeV) \times |(charge)|. Assumes stable particle interacting with matter
- ⁵⁸ ALBROW 75 is a CERN ISR experiment with $E_{\rm cm} =$ 53 GeV. $\theta =$ 40 mr. See figure 5 for mass ranges up to 35 GeV.
- ⁵⁹ JOVANOVICH 75 is a CERN ISR 26+26 and 15+15 GeV pp experiment. Figure 4 covers ranges Q=1/3 to 2 and m=3 to 26 GeV. Value is per GeV momentum.
- 60 APPEL 74 is NAL 300 GeV pW experiment. Studies forward production of heavy (up to 24 GeV) charged particles with momenta 24-200 GeV (-charge) and 40-150 GeV (+charge). Above typical value is for 75 GeV and is per GeV momentum per nucleon.
- 61 ALPER 73 is CERN ISR 26+26 GeV pp experiment. p >0.9 GeV, 0.2 < β <0.65.
- 62 ANTIPOV 71B is from same 70 GeV p experiment as ANTIPOV 71C and BINON 69.
- 63 ANTIPOV 71C limit inferred from flux ratio. 70 GeV p experiment.
- 64 DORFAN 65 is a 30 GeV/c p experiment at BNL. Units are per GeV momentum per

Long-Lived Heavy Particle Invariant Cross Section

VALUE							
(cm ² /GeV ² /N)	CL%	EVTS	DOCUMENT ID		TECN	<u>CHG</u>	COMMENT
• • • We do not us	se the follow	ing dat	a for averages, fits,	limit	ts, etc. •	• •	
$< 5 \times 10^{-35} - 7 \times 10^{-35}$		0	⁶⁵ BERNSTEIN	88	CNTR		
$< 5 \times 10^{-37} - 7 \times 10^{-37}$	0 ⁻³⁵ 90	0	65 BERNSTEIN	88	CNTR		
$< 2.5 \times 10^{-36}$	90	0	⁶⁶ THRON	85	CNTR	~	Q= 1, m=4-12
<1. × 10 ⁻³⁵	90	1	66 THRON	85	CNTR	+	GeV Q= 1, m=4-12
$<6. \times 10^{-33}$	- 90	0	67 ARMITAGE	79	SPEC		GeV m=1.87 GeV
$< 1.5 \times 10^{-33}$	90	0	67 ARMITAGE	79	SPEC		m=1.5-3.0 GeV
		0	68 BOZZOLI	79	CNTR	±	Q = (2/3, 1, 4/3, 2)
$<1.1 \times 10^{-37}$	90	0	⁶⁹ CUTTS	78	CNTR		m=4−10 GeV
$< 3.0 \times 10^{-37}$	90	0	⁷⁰ VIDAL	78	CNTR		m=4.5-6 GeV

- 65 BERNSTEIN 88 limits apply at x=0.2 and $p_T=0$. Mass and lifetime dependence of limits are shown in the regions: m=1.5-7.5 GeV and $\tau=10^{-8}-2\times10^{-6}$ s. First number is for hadrons; second is for weakly interacting particles.
- 66 THRON 85 is FNAL 400 GeV proton experiment. Mass determined from measured velocity and momentum. Limits are for $\tau>3\times 10^{-9}$ s.
- ⁶⁷ ARMITAGE 79 Is CERN-ISR experiment at $E_{\rm cm}=53$ GeV. Value is for x=0.1 and $p_{T}=0.15$. Observed particles at m=1.87 GeV are found all consistent with being antideuterons.
- 68 BOZZOLI 79 is CERN-SPS 200 GeV pN experiment. Looks for particle with au larger than 10^{-8} s. See their figure 11–18 for production cross-section upper limits vs mass.
- for Cutts 78 is pile experiment at FNAL sensitive to particles of $\tau > 5 \times 10^{-8}$ s. Value is for -0.3 < x < 0 and $p_T = 0.175$.
- 70 VIDAL 78 is FNAL 400 GeV proton experiment. Value is for x=0 and $p_{T}=0$. Puts lifetime limit of < 5 $\times\,10^{-8}\,\text{s}$ on particle in this mass range.

Long-Lived Heavy Particle Production

 $(\sigma(\text{Heavy Particle}) / \sigma(\pi))$

VALUE	EVTS	DOCUMENT ID		<u>TECN</u>	CHG	COMMENT
● ● ● We do no	t use the following	data for average	s, fit	s, limits,	etc. •	• •
<10-8	;	⁷¹ NAKAMURA	89	SPEC	±	$Q=(-5/3,\pm 2)$
	0	72 BUSSIERE	80	CNTR	±	Q=(2/3.1.4/3.2)

- 71 NAKAMURA 89 is KEK experiment with 12 GeV protons on Pt target. The limit applies for mass \lesssim 1.6 GeV and lifetime \gtrsim 10⁻⁷ s.
- 72 BUSSIERE 80 is CERN-SP5 experiment with 200-240 GeV protons on Be and Al target. See their figures 6 and 7 for cross-section ratio vs mass.

Production and Capture of Long-Lived Massive Particles

VALUE (10-36 cm ²)	EVTS	DOCUMENT ID	TECN	COMMENT
• • • We do not use	the following	g data for average	s, fits, limits,	etc. • • •
<20 to 800				τ =5 ms to 1 day
<200 to 2000			76B ELEC	τ=100 ms to 1 day
<1.4 to 9		74 FRANKEL	75 CNTR	τ =50 ms to 10 hours
<0.1 to 9	0	⁷⁵ FRANKEL	74 CNTR	τ =1 to 1000 hours

- 73 ALEKSEEV 76 and ALEKSEEV 76B are 61-70 GeV p Serpukhov experiment. Cross section is per Pb nucleus.
- FRANKEL 75 is extension of FRANKEL 74.
- 75 FRANKEL 74 looks for particles produced in thick Al targets by 300–400 GeV/c protons.

Long-Lived Particle Search at Hadron Collisions

Limits are for cross section times branching ratio.

(pb/nucleon)	CL%	EVTS	DOCUMENT IE	TECN	COMMENT	
• • • We do	not use th	e followi	ng data for avera	ages, fits, limits	s, etc. • • •	
<2°	90	0	76 BADIER	86 BDMP	$\tau = (0.05-1.)$	× 10 ⁻⁸ s

 76 BADIER 86 looked for long-lived particles at 300 GeV π^- beam dump. The limit applies for nonstrongly interacting neutral or charged particles with mass >2 GeV. The limit applies for particle modes, $\mu^+\pi^-, \, \mu^+\mu^-, \, \pi^+\pi^- X, \, \pi^+\pi^-\pi^\pm$ etc. See their figure 5 for the contours of limits in the mass- τ plane for each mode.

Long-Lived Heavy Particle Cross Section

VALUE (pb/sr)	CL%	DOCUMENT ID		TECN	COMMENT
• • • We do not use th	e following	data for averages	, fits	, limits,	etc. • • •
<34	95 7	⁷ RAM	94	SPEC	1015 <m<sub>X++ <1085</m<sub>
<75	95 7	7 RAM	94	SPEC	MeV 920 <m<sub>X++ <1025</m<sub>

77 RAM 94 search for a long-lived doubly-charged fermion X^{++} with mass between m_N and $m_N + m_\pi$ and baryon number +1 in the reaction $pp \to X^{++}n$. No candidate is found. The limit is for the cross section at 15° scattering angle at 460 MeV incident energy and applies for $\tau(X^{++}) \gg 0.1 \,\mu$ s.

LIMITS ON CHARGED PARTICLES IN COSMIC RAYS

Heavy	Particle	Flux in	Cosmic	Rays
				•

(cm - 2 _{sr} - 1		CL% E		DOCUMENT ID		TECN	CHG	
• • • W	do not use	the folio	wing	data for averages, fl	its, li	mits, etc		•
~ 6	× 10 ⁻⁹		2	⁷⁸ SAITO	90			$Q \simeq 14, m \simeq 370 m_p$
< 1.4	× 10 ⁻¹²	90	0	⁷⁹ MINCER ⁸⁰ SAKUYAMA	85 836	CALO PLAS		$m \ge 1 \text{ TeV}$ $m \sim 1 \text{ TeV}$
< 1.7	$\times 10^{-11}$	99	0	81 BHAT	82	CC		
< 1.	× 10 ⁻⁹	90	0	82 MARINI	82	CNTR	±	$Q=1, m \sim 4.5 m_p$
2.	× 10 ⁻⁹		3	83 YOCK	81	SPRK	±	$Q=1, m \sim 4.5 m_p$
			3	⁸³ YOCK	81	SPRK		Fractionally charged
3.0	× 10 ⁻⁹		3	⁸⁴ YOCK	80	SPRK		$m \sim 4.5 m_p$
(4 ±1	$) \times 10^{-11}$		3	GOODMAN	79	ELEC		m ≥ 5 GeV
< 1.3	× 10 ⁻⁹	90		85 BHAT	78	CNTR	±	m >1 GeV
< 1.0	× 10 ⁻⁹		0	BRIATORE	76	ELEC		
< 7.	× 10 ⁻¹⁰	90	0	YOCK	75	ELEC	±	Q >7e or < -7e
> 6.	× 10 ⁻⁹		5	86 YOCK	74	CNTR		m >6 GeV
< 3.0	× 10 ⁻⁸		0	DARDO	72	CNTR		
< 1.5	× 10 ⁻⁹		0	TONWAR	72	CNTR		m >10 GeV
< 3.0	× 10 ⁻¹⁰		0	BJORNBOE	68	CNTR		m >5 GeV
< 5.0	× 10 ⁻¹¹	90	0	JONES	67	ELEC		<i>m</i> =5−15 GeV

78 SAITO 90 candidates carry about 450 MeV/nucleon. Cannot be accounted for by conventional backgrounds. Consistent with strange quark matter hypothesis.

ventional backgrounds. Consistent with strange quark matter hypothesia.

79 MINCER 85 is high statistics study of calorimeter signals delayed by 20–200 ns. Callbration with AGS beam shows they can be accounted for by rare fluctuations in signals from low-energy hadrons in the shower. Claim that previous delayed signals including BJORNBOE 68, DARDO 72, BHAT 82, SAKUYAMA 838 below may be due to this fake effect.

enerct.

80 SAKUYAMA 83B analyzed 6000 extended air shower events. Increase of delayed particles and change of lateral distribution above 10¹⁷ eV may indicate production of very heavy parent at top of atmosphere.

B1 BHAT 82 observed 12 events with delay $> 2. \times 10^{-8}$ s and with more than 40 particles. 1 eV has good hadron shower. However all events are delayed in only one of two detectors in cloud chamber, and could not be due to strongly interacting massive particle.

82 MARINI 82 applied PEP-counter for TOF. Above limit is for velocity = 0.54 of light. Limit is inconsistent with YOCK 80 YOCK 81 events if isotropic dependence on zenith angle is assumed.

83 YOCK 81 saw another 3 events with $Q=\pm 1$ and m about 4.5 m_p as well as 2 events with $m>5.3m_p$, $Q=\pm 0.75\pm 0.05$ and $m>2.8m_p$, $Q=\pm 0.70\pm 0.05$ and 1 event with $m=(9.3\pm 3.)m_p$, $Q=\pm 0.89\pm 0.06$ as possible heavy candidates.

84 YOCK 80 events are with charge exactly or approximately equal to unity.

 85 BHAT 78 is at Kolar gold fields. Limit is for $au > 10^{-6}$ s.

86 YOCK 74 events could be tritons.

Superheavy Particle (Quark Matter) Flux in Cosmic Rays

VALUE (cm ⁻² sr ⁻¹ s ⁻¹)	<u>CL%</u>	EVTS	DOCUMENT ID		TECN	COMMENT
THE WE GO HOL	use u	ie ioliowii	ilk data ioi avciake	3, 111	5, 111111113,	etc. • • •
$< 1.8 \times 10^{-12}$	90		87 ASTONE			$m \ge 1.5 \times 10^{-13} \text{gram}$
$< 1.1 \times 10^{-14}$	90		⁸⁸ AHLEN			$10^{-10} < m < 0.1 \text{ gram}$
$< 3.2 \times 10^{-11}$	90	0	⁸⁹ NAKAMURA	85	CNTR	$m > 1.5 \times 10^{-13}$ gram
$< 3.5 \times 10^{-11}$	90	0	⁹⁰ ULLMAN	81	CNTR	Planck-mass 10 ¹⁹ GeV
<7. × 10 ⁻¹¹	90	0	⁹⁰ ULLMAN	81	CNTR	$m \le 10^{16} \text{ GeV}$

87 ASTONE 93 searched for quark matter ("nuclearites") in the velocity/c range = 10^{-3} -1. Their Table 1 gives a compilation of searches for nuclearites.

88 AHLEN 92 searched for quark matter ("nuclearites"). The bound applies to velocity/c $< 2.5 \times 10^{-3}$. See their Fig. 3 for other velocity/c and heavier mass range.

 89 NAKAMURA 85 at KEK searched for quark-matter. These might be lumps of strange quark matter with roughly equal numbers of u, d, s quarks. These lumps or nuclearites were assumed to have velocity/c of 10^{-4} – 10^{-3} .

90 ULLMAN 81 is sensitive for heavy slow singly charge particle reaching earth with vertical velocity 100–350 km/s.

Highly Ionizing Particle Flux

VALUE (m ⁻² yr ⁻¹)		/TS	DOCUMENT ID	TECN	COMMENT
• • • We do not use	the follow	wing data	for averages, fit:	s, limits, etc	. • • •
<0.4	95	0	KINOSHITA	81B PLAS	Z/β 30-100

REFERENCES FOR WIMPs and Other Particle Searches

ABE	97G	PR D55 R5263	+Akimoto, Akopian, Albrow, Amendolia+ (CDF Collab.)
ABREU	97D	PL B396 315	P. Abreu+ (DELPHI Collab.)
ACKERSTAFF BARATE	97B 97K	PL B391 210 PL B405 379	K. Ackerstaff+ (OPAL Collab.) R. Barate+ (ALEPH Collab.)
BERNABEI	97	ASP 7 73	R. Bernabei+
SARSA ALESSAND	97 96	PR D56 1856 PL B384 316	M.L. Sarsa+ (ZARA) Alessandrello, Brofferio, Camin+ (MILA, MILAI, SASSO)
BELLI	96	PL 8387 222	+ {ROMA2, ROMAI, ROMA, ROMA3, BHEP}
Also	96B	PL B389 783 (erratum)) P. Belli+
BELLI BERNABEI	96C 96	NC 19C 537 PL B389 757	P. Belli+ (ROMA2, ROMAI, ROMA3, SASSO, BHEP) + (ROMA2, ROMAI, ROMA, ROMA3, BHEP+)
COLLAR	96	PRL 76 331	(SCUC)
SARSA Also	96 97	PL B386 458 PR D56 1856	+Morales, Morales, Garcia+ (ZARA) M.L. Sarsa+ (ZARA)
SMITH	96	PL B379 299	+Arnison+ (RAL, SHEF, LOIC, BIRK, NOTT)
SNOWDEN	96	PRL 76 332	Snowden-Ifft, Freeman, Price (UCB)
AKERS GALLAS	95R 95	ZPHY C67 203 PR D52 6	+Alexander, Allison, Ametewee, Anderson+ (OPAL Collab.) +Abolins, Brock, Cobau+ (MSU, FNAL, MIT, FLOR)
GARCIA	95	PR D51 1458	+Morales, Morales, Sarsa+ (ZARA, SCUC, PNL)
QUENBY SNOWDEN	95 95	PL B351 70 PRL 74 4133	+Sumner+ (LOIC, RAL, SHEF, BIRK, NOTT, RHBL) Snowden-lift, Freeman, Price (UCB)
Also	96	PRL 76 331	Collar (SCUC)
Also	96	PRL 76 332	Snowden-Ifft, Freeman, Price (UCB)
BECK RAM	94 94	PL B336 141 * PR D49 3120	+Bensch, Bockholt+ (MPIH, KIAE, SÁSSO) +Abegg, Ashery, Frekers, Helmer+ (TELA, TRIU)
ABE	93G	PRL 71 2542	+Albrow, Akimoto, Amidei, Anway-Wiese+ (CDF Collab.)
ASTONE BUSKULIC	93 93C	PR D47 4770 PL B303 198	+Bassan, Bonifazi, Coccia+(ROMA, ROMAI, CATA, FRAS) +Decamp, Goy, Lees, Minard+ (ALEPH Collab.)
YAMAGATA	93	PR D47 1231	+Takamori, Utsunomiya (KONAN)
ABE	92J	PR D46 R1889	+Amidel, Anway-Weiss+ (CDF Collab.)
AHLEN BACCI	92 92	PRL 69 1860 PL B293 460	+Ambrosio, Antolini, Auriemma, Baker+ (MACRO Collab.) +Belli, Bernabei+ (Beijing-Roma-Saclay Collab.)
VERKERK	92	PRL 68 1116	+Grynberg, Pichard, Spiro, Zylberajch+(ENSP, SACL, PAST)
AKESSON REUSSER	91 91	ZPHY C52 219 PL B255 143	+Aimehed, Angelis, Atherton, Aubry+ +Treichel, Boehm, Broggini+ (NEUC, CIT, PSI)
ADACHI	90C	PL B244 352	+Aihara, Doser, Enomoto+ (TOPAZ Collab.)
ADACHI	90E	PL B249 336	+Anazawa, Doser, Enomoto, Fujii+ (TOPAZ Collab.)
AKRAWY HEMMICK	90O 90	PL B252 290 PR D41 2074	+Alexander, Allison, Allport, Anderson+ (OPAL Collab.) +Elmore+ (ROCH, MICH, OHIO, RAL, LANL, STON)
SAITO	90	PRL 65 2094	+Hatano, Fukada, Oda (ICRR, KOBE)
NAKAMURA NORMAN	89 89	PR D39 1261 PR D39 2499	+Kobayashi, Konaka, Imai, Masaike+ (KYOT, TMTC)
BERNSTEIN	88	PR D37 3103	+Chadwick, Lesko, Larimer, Hoffman (LBL) +Shea, Winstein, Cousins, Greenhalgh+ (STAN, WISC)
CALDWELL	88	PRL 61 510	+Eisberg, Grumm, Witherell+ (UCSB, UCB, LBL)
NORMAN BADIER	87 86	PRL 58 1403 ZPHY C31 21	+Gazes, Bennett (LBL) +Bemporad, Boucrot, Callot+ (NA3 Collab.)
MINCER	85	PR D32 541	+Freudenreich, Goodman+ (UMD, GMAS, NSF)
NAKAMURA THRON	85 85	PL 161B 417 PR D31 451	+Horie, Takahashi, Tanimori +Cardello, Cooper, Teig+ (YALE, FNAL, IOWA)
SAKUYAMA	83B	LNC 37 17	+Nuzuki (MEIS)
Also	83	LNC 36 389	Sakuyama, Watanabe (MEIS)
Also Also	83D 83C	NC 7BA 147 NC 6C 371	Sakuyama, Watanabe (MEIS) Sakuyama, Watanabe (MEIS)
BHAT	82	PR D25 2820	+Gupta, Murthy, Sreekantan+ (TATA)
KINOSHITA MARINI	82 82	PRL 48 77 PR D26 1777	+Price, Fryberger +Peruzzi, Piccolo+ (FRAS, LBL, NWES, STAN, HAWA)
SMITH	82B	NP B206 333	+Bennett, Homer, Lewin, Walford, Smith (RAL)
KINOSHITA LOSECCO	81B 81	PR D24 1707	+Price (UCB)
ULLMAN	81	PL 102B 209 PRL 47 289	+Sulak, Galik, Horstkotte+ (MICH, PENN, BNL) (LEHM, BNL)
YOCK	81	PR D23 1207	(AUCK)
BARTEL BUSSIERE	80 80	ZPHY C6 295 NP B174 1	+Canzler, Lords, Drumm+ (JADE Collab.) +Giacomelli, Lesquoy+ (BGNA, SACL, LAPP)
YOCK	80	PR D22 61	(AUCK)
ARMITAGE	79	NP B150 87	+Benz, Bobbink+ (CERN, DARE, FOM, MCHS, UTRE)
BOZZOLI GOODMAN	79 79	NP 8159 363 PR D19 2572	+Bussiere, Giacomelli+ (BGNA, LAPP, SACL, CERN) +Ellsworth, Ito, Macfall, Siohan+ (UMD)
SMITH	79	NP B149 525	+Bennett (RHEL)
BHAT CARROLL	78 78	Pramana 10 115 PRL 41 777	+Murthy (TATA) +Chiang, Johnson, Kycia, Ki+ (BNL, PRIN)
CUTTS	78	PRL 41 363	+Dulude+ (BROW, FNAL, ILL, BARI, MIT, WARS)
VIDAL	78	PL 77B 344 SJNP 22 531	+Herb, Lederman+ (COLU, FNAL, STON, UCB)
ALEKSEEV	76	Translated from YAF 2	+Zaitsev, Kalinina, Kruglov+ (JINR) 12 1021.
ALEKSEEV	76B	SJNP 23 633 Translated from YAF 2	+Zaitsev, Kalinina, Kruglov+ (JINR)
BALDIN	76	SJNP 22 264	+Vertogradov, Vishnevsky, Grishkevich+ (JINR)
BRIATORE	76	Translated from YAF 2 NC 31A 553	2 512. +Dardo, Piazzoli, Mannocchi+ (LCGT, FRAS, FREIB)
GUSTAFSON	76	PRL 37 474	+Avre, Jones, Longo, Murthy (MICH)
ALBROW FRANKEL	75 75	NP B97 189 PR D12 2561	+Barber+ (CERN, DARE, FOM, LANC, MCHS, UTRE) +Frati, Resvanis, Yang, Nezrick (PENN, FNAL)
JOVANOV	75	PL 56B 105	+Frati, Resvanis, Yang, Nezrick (PENN, FNAL) Jovanovich+ (MANI, AACH, CERN, GENO, HARV+)
YOCK	75	NP B86 216	(AUCK, SLAC)
APPEL FRANKEL	74 74	PRL 32 428 PR D9 1932	+Bourquin, Gaines, Lederman+ (COLU, FNAL) +Frati, Resvanis, Yang, Nezrick (PENN, FNAL)
YOCK	74	NP B76 175	(AUCK)
ALPER LEIPUNER	73 73	PL 46B 265 PRL 31 1226	+ (CERN, LIVP, LUND, BOHR, RHEL, STOH, BERG+) +Larsen, Sessoms, Smith, Williams+ (BNL, YALE)
DARDO	72	NC 9A 319	+Navarra, Penengo, Sitte (TORI)
TONWAR	72	JPA 5 569	+Naranan, Sreekantan (TATA)
ANTIPOV ANTIPOV	71B 71C	NP B31 235 PL 34B 164	+Denisov, Donskov, Gorin, Kachanov+ (SERP) +Denisov, Donskov, Gorin, Kachanov+ (SERP)
BINON	69	PL 30B 510 NC B53 241	+Duteil, Kachanov, Khromov, Kutyin+ (SERP)
BJORNBOE JONES	68 67	NC B53 241 PR 164 1584	+Damgard, Hansen+ (BOHR, TATA, BERN, BERG) (MICH, WISC, LBL, UCLA, MINN, COSU, COLO+)
DORFAN	65	PRL 14 999	+Eades, Lederman, Lee, Ting (COLU)