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1963-06-11

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Submitted to Physics Letters

UCRL-10723-Rev.

UNIVERSITY OF CALIFORNIA
Lawrence Radiation Laboratory
Berkeley, California

Contract No. W-7405-eng-48

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June 11, 1963

PROPERTIES OF THE ω MESON FROM $K^- + p \rightarrow \Lambda + \omega$ †

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June 11, 1963

Events of the type $K^- + p \rightarrow \Lambda + \omega$ were studied in film obtained with the 72-inch hydrogen bubble chamber utilizing a beam of 1.51-BeV/c K^- mesons extracted from the Bevatron[1,2]). Approximately 650 charged ω decays and about 40 neutral decays were analyzed.

The following results are reported here:

a) the branching ratio of neutral to charged (three-pion) decay

b) a limit on the natural width from the predominant three-pion decay

c) evidence for the two-pion decay mode.

At an incident momentum of 1.51 BeV/c (total c.m. energy of 2.025 BeV), approximately 1300 events of the type

$$K^- + p \rightarrow \Lambda + \pi^+ + \pi^- \qquad (1)$$

and a similar number of the type

$$K^- + p \rightarrow \Lambda + \pi^+ + \pi^- + \pi^0 \qquad (2)$$

were analyzed. In addition, some 1400 events of the type

$$K^- + p \rightarrow \Lambda + \text{neutrals} \qquad (3)$$

were processed. At present a systematic study is being made of the reaction $K^- + p \rightarrow \Lambda + \omega$ as a function of K^- momentum; results will appear in a future publication.

For reactions (1), (2), and (3), an upper limit of $\chi^2 = 30$ was imposed in kinematic fitting of the lambda decay. In ambiguous cases, where the vee

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† Work done under the auspices of the U.S. Atomic Energy Commission.

‡ Now at CERN, Geneva, Switzerland.

decay fitted both $\overline{K}^0$ and lambda, a decision was made on the basis of either the goodness of fit of alternate production hypotheses or the ionization of the decay tracks. A production hypothesis [for reaction (1) or (2)] was accepted when its χ^2 value was less than ten times the number of constraints and the χ^2 value for any other hypothesis was higher relative to the number of constraints. The separation of $\Sigma^0\pi^+\pi^-$ from the $\Lambda\pi^+\pi^-$ events removed about 7% of the $\Lambda\pi^+\pi^-$ events, but left a residual of $\Sigma^0\pi^+\pi^-$ events which was only 5% of the $\Lambda\pi^+\pi^-$ sample. [For more details, see the earlier report[1].]

THREE-PION DECAY MODE

The effective-mass spectrum of the three pions in reaction (2) is shown in fig. 1. It is apparent from this spectrum that a large fraction of events result from the two-step process:

$$K^- + p \rightarrow \Lambda + \omega, \quad \omega \rightarrow \pi^+ + \pi^- + \pi^0. \tag{4}$$

For ω mass limits of 760 to 810 MeV, about 650 ω's are observed above background. The background can be estimated as approximately 15% of the events within these mass limits.

The c. m. angular distribution of the recoil lambda for the events satisfying $K^- + p \rightarrow \Lambda + \omega$ kinematics is given in fig. 2. The ω's are produced predominantly in the forward direction.

The cross section for the two-step process (4) has been found by comparing the number of three-pion ω decays with the number of τ decays in the same film sample. After correction for scanning efficiency (about 90%) and for measurement failures (about 15% loss, mostly in kinematic fitting), this cross section is 800 ± 40 μb. The process $K^- + p \rightarrow \Sigma^0 + \omega$ is thought to account for an enhancement on the high-mass side of the ω peak in the mass spectrum of fig. 1. Measurement errors may allow events of this type to fit hypothesis (2).

Detailed study of the $\Sigma^0\omega$ reaction is difficult, since it is not kinematically overdetermined. The number of events of the latter type which give spurious fits to the $\Lambda\omega$ hypothesis is estimated to be less than 5% of the $\Lambda\omega$ events.

NEUTRAL DECAY MODE

The square of the missing neutral mass (or recoil mass) of reaction (3) is shown in fig. 3. Here also the presence of ω production and decay,

$$K^- + p \rightarrow \Lambda + \omega, \quad \omega \rightarrow \text{neutrals}, \tag{5}$$

is apparent in the enhancement occurring approximately at the square of the ω mass. (Instead of the linear mass scale of fig. 1, the square of the missing mass is used as the basic scale of fig. 3; the latter quantity is approximately normally distributed, even in the vicinity of zero mass.) Some 40 events are seen above background.

The cross section for the process given in (5) has also been obtained by comparing these events with the number of τ decays in the same film. With corrections for scanning efficiency (about 90%) and for measurement failures (about 10% loss in track reconstruction, largely from poor measurement, and about 13% loss in kinematic fitting) the value is 83 ± 22 μb.

From the above cross sections, the branching ratio of neutral to three-pion ω decays (i.e., presumably of $\pi^0\gamma$ to $\pi^+\pi^-\pi^0$ final states) is

$$\Gamma(\text{neutral})/\Gamma(3\pi) = 0.11 \pm 0.03. \tag{6}$$

WIDTH OF THE ω MESON

Determination of the true width of the three-pion ω decay is difficult. The mass spread due to measurement error alone, called the "resolution function," is determined from the effective-mass errors calculated by our IBM program EXAMIN; these calculations are based on momentum and angle errors determined by our program PACKAGE, which effects the track reconstruction and kinematic fitting of events. The errors on kinematic quantities determined in track reconstruction appear to be underestimated for the particular film sample considered here. The χ^2 distributions obtained in fitting the events have approximately the correct form, but have median values that are about twice those expected. Underestimation of fitted errors yields a resolution function with too small a width. Thus unfolding the resolution function from the observed mass spectrum gives too large a value for the width of the ω. (Without correction of the resolution function, a sample of the best-measured Λω events yields a value of 14 MeV for the over-estimated width.)

The distribution of errors calculated in the effective mass of any particle system is generally assumed to be Gaussian. This was checked for the $\omega \rightarrow 3\pi$ events by assuming the natural width of the ω to be much smaller than the program-estimated mass errors, and by histogramming the events as a function of $(M-M_\omega)/dM$. This histogram was found to have a Gaussian form and further to have a variance $\overline{(M-M_\omega)^2/dM^2}$ of about 3.0 rather than the value 1.0 expected for correctly estimated errors. The mass spectrum thus was consistent with the χ^2 distribution in that the errors appeared to be underestimated by a factor of $\leq\sqrt{3}$ from the former, and by a factor of $\sqrt{2}$ from the latter.

One possible method of estimating the true ω width would be to utilize only events with small mass errors and to correct the resolution function for these events by the "χ^2 scale factor." Because of the complexity of the error calculations, it is not clear that this χ^2 scale factor is directly applicable to the resolution function.

An alternative method is to divide the data into several samples in accordance with the size of the 3π mass errors and to extrapolate to zero measurement error the width values obtained for the several samples. This method does not necessitate quantitative knowledge of the resolution function nor the "χ^2 scale factor", but does demand the use of the relative variation of this scale factor to correct relative values of the resolution functions. It has the advantage of using more of the available data than the first method and also of providing determination of the absolute value of the scale factor demanded by the resolution function.

The values of effective three-pion mass for the 1361 events of reaction (2) were histogrammed for particular ranges of program-estimated error in the effective mass. The ranges chosen--3 to 5 MeV, 5 to 7 MeV, and 7 to 10 MeV--were narrow enough to permit the assumption that the values of effective mass were Gaussianly distributed with variance equal to the mean value of the squared error in each of the three groups. Events above background in each of the three error-classified samples were fitted with a Gaussian curve. The error on the variance of each of the three Gaussian curves was obtained by using the fact that the variance is distributed like χ^2 with its degrees of freedom equal to the number of events in the peak less one. This error was increased slightly to account for the uncertainty in background estimation.

The three observed widths result from folding a Breit-Wigner resonance curve with a Gaussian measurement-error distribution. These three experimental widths are shown as a function of the mean measurement error in fig. 4. Figure 4a is a plot of the squared quantities, and fig. 4b is a linear plot. [The dM quantity used in fig. 4 is the standard deviation in the Gaussian distribution of effective mass (obtained for a sample of events having similar program-estimated dM error), and is $(1.18)^{-1}$ times the half-width $\Gamma/2$ of this Gaussian distribution.] If we assume that the scale factor required to correct the measurement errors varies inappreciably over the range of errors represented by the three samples of events, the appropriate form of the curve used for width extrapolation to zero measurement error can be taken from fig. 5. The latter presents widths for the folding of Breit-Wigner (S-wave form)* and Gaussian distribution curves, with various Breit-Wigner widths assumed. (The folded distribution is given by

$$N(t) \propto \int_{-\infty}^{\infty} [x^2 + (\Gamma/2)^2]^{-1} \exp^{-(t-x)^2/2(dM)^2} dx).$$

It is evident that the curves of fig. 5a or 5b have similar slopes, which become greater (fig. 5a) or smaller (fig. 5b) in approaching zero.

The experimental-error scale factor could not be assumed to be constant. Examination of the χ^2 distributions for the three samples indicated that the relative scale factors were 1.0, 0.98, and 0.82 for the squared error $(dM)^2$ for points (1), (2), and (3), respectively. Corrections for this variation brought the three points closer to a straight line. The slope of this line indicated that, as in the case of the fitting errors, the program-estimated mass errors are about a factor of $\sqrt{2}$ smaller than they should be.

Because of the difficulty in representing the curves of fig. 5 analytically, straight lines have been drawn through the data in figs. 4a and 4b after correction for scale-factor differences. The intercepts have values of $\Gamma^2 = 50^{+70}_{-50}$ MeV^2 and $\Gamma = 2.5^{+3.5}_{-2.5}$ MeV from figs. 4a and 4b, respectively. The former gives an upper limit of 7±4 MeV on the ω width; the latter is a lower limit. Straight-line extrapolations were also made for the theoretical curves in figs. 5a and 5b; the intercepts so obtained were found to agree nicely with the experimental values of figs. 4a and 4b if the assumed width were Γ=4MeV. The error in the width was determined as 4 MeV by noting that a change of one standard deviation in the experimental Γ^2 or Γ intercepts in fig. 4 could be matched with the calculated curves of figs. 5a and 5b if the assumed Γ were changed from 4 to approximately 8 MeV.

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* For the small width, Γ, of interest here, the $J = 1^-$ resonance shape differs negligibly from the generally used J=0 resonance curve.

(It happens that the 4-MeV error is about equal to the error in either the upper or lower experimental limit. This is probably reasonable, as the difference between the best value of $\Gamma = 4$ MeV and either of the limits is less than the error on each limit.) Thus the value of the ω width, as manifested by the three-pion decay and as determined by the extrapolation method described above, is

$$\Gamma = 4 \pm 4 \text{ MeV}. \tag{7}$$

TWO-PION DECAY

The events of reaction (1) might be expected to show evidence of the well-known resonances, Y_1^{*+}, Y_1^{*-}, and ρ. The Y_1^{*+} and Y_1^{*-} are clearly seen on the

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*The above-described extrapolation technique was used to determine the (near-zero) width of the Λ from the $K^- + p \rightarrow \Lambda + \pi^+ + \pi^- + \pi^0$ events at 1.5 BeV/c fitted as $\pi^- + p + \pi^+ + \pi^- + \pi^0$. Extrapolation of the π^--p effective mass gave $\Gamma(\Lambda \rightarrow \pi^- p) = -1 \pm 1$ MeV. The method also gave the correct answer (within statistics) for the $\overline{K}^0$ width in $K^- + p \rightarrow \overline{K}^0 + \pi^- + p$ events fitted as $K^- + p \rightarrow \pi^- + \pi^+ + \pi^- + p$ at an incident momentum of 1.2 BeV/c.

Dalitz plot of the square of the effective-mass of the $\Lambda\pi^+$ versus that of the $\Lambda\pi^-$ (see fig. 6). Diagonal lines at $M_{\pi\pi}$ = 700 and 800 MeV on the Dalitz plot indicate the expected peak of the two-pion ρ resonance; the ρ is difficult to see because it is a broad resonance, but interference between ρ and Y_1^* is evident in the nonuniform population of the Y_1^* mass bands.

In an attempt to distinguish the ρ, a portion of the Dalitz plot just inside the Y_1^* bands was examined. Two strips with 1430 MeV $\leq (M_{\Lambda\pi^+}$ or $M_{\Lambda\pi^-}) \leq$ 1510 MeV (shaded in fig. 6) were projected onto the 45-degree line which is the two-pion mass axis. Bands rather than the entire sector between the Y_1^*'s were used to make the contribution of the Y_1^* tails uniform along the pion-pion axis outside the region of ρ-Y_1^* interference.

The pion-pion mass spectrum resulting from this projection is shown in fig. 7. A narrow peak is observed near $M^2(2\pi) = 0.6\ \mathrm{BeV}^2$, which is very close to the square of the ω mass. The number of events in the peak is about 15, while the number of ρ events plus background events in the same mass interval is also about 15. Hence the sharp spike is about a three-standard-deviation effect. Its central value is 781 MeV, and its width is about 15 MeV (approximately equal to the resolution function width if corrected for underestimation of measurement errors). It seems very likely that the sharp spike is the result of ω decay into two pions, a mode resulting from the electromagnetic mixing of the ρ^0 and ω states. (See the discussion of theory below.)

The data have been fitted with a constant background, a P-wave Breit-Wigner resonance curve for the ρ meson (with E_0 = 750 MeV and with Γ = 100 MeV), and a Gaussian curve for the "$\omega \rightarrow 2\pi$ decay". A good fit was obtained with parameters for the ω decay of E_0 = 781 MeV and Γ = 11 MeV at half-maximum (mostly measurement error). The total numbers of events assigned to the various hypotheses by this fit are

$$N(\omega) = 15.5 \pm 5.6$$
$$N(\rho) = 93 \pm 19 \qquad (8)$$
$$N(\text{background}) = 224 \pm 22.$$

The possibility that the narrow peak may be a statistical fluctuation due entirely to the ρ decay cannot be completely ruled out. The π-π mass spectrum has been fitted between 300 and 900 MeV with just constant background and the ρ resonance. The fit gives a χ^2 value of about 47 when 35 is expected, in contrast to the value of 38 for the above-mentioned fit with ω included. A fit between 660 and 850 MeV gives $\chi^2 = 12.8$ for 12 degrees of freedom without the ω, and gives $\chi^2 = 5.4$ for 11 degrees of freedom with the ω included (see fig. 8). However, the peak might conceivably be better explained as a ρ mass fluctuation if a mass spectrum enhanced at high mass by ρ-Y^* interference were considered. (The narrowness of the peak, if clearly substantiated, would of course rule out this last objection. Calculations indicate that a peak caused by ρ-Y^* interference would be at least 50-MeV wide.)

Another problem is that the 1660-MeV resonance[3]) has begun to appear in the $\Lambda\pi^+$ mass spectrum. This distorts somewhat the constant background assumed for the π-π study, but it can hardly be expected to cause a narrow peaking.

The 15.5 events that are possible $\omega \to 2\pi$ decays must be increased to 43 to correct for the fact that area selection on the Dalitz plot used 0.36 of the mass band in which ω's could be expected. The density of $\omega \to 2\pi$ events in this mass band is taken to be uniform, since study of the $\omega \to 3\pi$ events in the same film sample indicated isotropic decay*. On comparison with the

* Isotropy is assumed to be undistorted by ρ-ω mixing. Populations of different portions of the $\omega \to 2\pi$ strip of the Dalitz plot are compatible with isotropy; however, even with some anisotropy in the $\omega \to 2\pi$ decay, the density of events in the two strips utilized above appears to be a good average value.

950 three-pion decays expected in the same sample, a branching ratio for two-pion to three-pion decay is estimated to be*:

$$\Gamma(\omega \rightarrow 2\pi)/\Gamma(\omega \rightarrow 3\pi) = 0.045 \pm 0.016. \quad (9)$$

Simple checks have been made to ascertain that there are no spurious $\Lambda\pi^+\pi^-$ fits of actual $\Lambda\pi^+\pi^-\pi^0$ events appearing in the 780-MeV peak. Values of χ^2 used for selection of events were examined more closely. For events under the 780-MeV peak, no χ^2 for $\Lambda\pi^+\pi^-\pi^0$ was lower than 10, and the three events with the $\Lambda 3\pi$ χ^2 between 10 and 20 had χ^2 values for the $\Lambda\pi^+\pi^-$ hypothesis that were much better.

Additional checks have been made. The $\omega \rightarrow 2\pi$ decay was not discernible in the complete π-π mass spectrum. However, the entire sector between the Y^* bands was compared with the π-π spectrum obtained by the incoherent combination of amplitudes for the ρ, the Y_1^* (1385 MeV), and the Y_1^* (1660 MeV) with weighting factors obtained from the fitting of the total sample. The 2π peak at the ω mass was still prominent, again as an approximate three-standard-deviation effect. Further, the angular distribution of the lambda produced with the two pions in the events under the "ω peak" (with about 50% background) was found to have a form closer to the Λ distribution in $K^- + p \rightarrow \Lambda + \omega \rightarrow \Lambda + 3\pi$ than to the Λ distribution in the other $K^- + p \rightarrow \Lambda + 2\pi$ events. Figure 9 shows the π-π mass spectrum for various production angles; the "$\omega \rightarrow 2\pi$" peak is most prominent at forward ω angles.

It seems evident that the experiment $K^- + p \rightarrow \Lambda + 2\pi$ or $\Lambda + 3\pi$ reported here is particularly well-suited to the study of the 2π (or two-lepton) mode of ω decay, as the total number of ρ mesons produced was considerably less than the total number of ω mesons (the ρ yield being 30 to 40% of the ω yield).

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* Subsequent to this analysis, events have been measured at other momentum settings. A similar analysis for all data available (beam momentum of 1.2 to 1.7 BeV/c) gives 32 ± 9 events above background in the ω peak, yielding a branching ratio of 0.034 ± 0.010.

EARLIER STUDY OF THE TWO-PION DECAY MODE

A number of theoretical discussions of the $\omega \rightarrow 2\pi$ decay have appeared in the literature[4]). Two groups of experimentalists have indicated that their data on the ρ mass spectrum showed some evidence for the $\omega \rightarrow 2\pi$ decay[5]).

Theory suggests that the identity of the ρ^0 and ω mesons in all quantum numbers except isotopic spin permits electromagnetic transitions such that an ω meson can become a ρ meson (or vice versa) by passing through a virtual photon state. Another way of stating this is to say that an ω meson (or a ρ^0 meson) can be coupled to any charged pair (e^+e^-, $\mu^+\mu^-$, or $\pi^+\pi^-$) by an intermediate photon, and by virtue of the ρ resonance in the $\pi^+\pi^-$ final state, this mode can be considerably enhanced.

The ratio of the anomalous amplitude to the isotopic–spin–conserving amplitude in ω (or ρ^0 decay) is estimated to be about 1/50; the square of this ratio times the width of the ρ meson gives the rate of $\omega \rightarrow 2\pi$ decay. If the width of the three-pion decay of the ω is about 1 MeV, then the two-pion decay can be expected to be approximately 5% of the dominant three-pion decay. Whether this small rate is detectable in a given experiment and whether it appears as a peak or a dip superimposed on the mass spectrum depends on the relative amplitudes for ρ and for ω production.

OTHER RARE DECAY MODES

We have studied the decay of the ω into $e^+ + e^-$. All vee—two—prong events were fitted for the hypotheses $K^- + p \rightarrow \Lambda + e^+ + e^-$ and also for $K^- + p \rightarrow \Lambda + \omega$, $\omega \rightarrow e^+ + e^-$. As an additional check, colinearity of the charged secondaries was examined after transformation into the ω rest frame (determined solely from the measured K^- momentum and the Λ momentum fitted in decay) under the assumptions that they were e^+e^- and also that they were $\pi^+\pi^-$. On the basis of χ^2 selection criteria and the colinearity check, two good examples and three more possible examples of $\omega \rightarrow e^+ + e^-$ were found in a sample of 4892 $K^- + p \rightarrow \Lambda + 2$-prong events. (The likely e^+e^- candidates were examined for delta rays, but none was found.) The branching ratio thus obtained is

$$\Gamma(\omega \rightarrow e^+e^-)/\Gamma(\omega \rightarrow 3\pi) \leq 0.01. \qquad (10)$$

We are studying the rare decay mode $\omega \rightarrow \pi^+\pi^-\gamma$ by examining missing neutral mass. No definite results have yet been obtained.

CONCLUSIONS

The experiment outlined above has given results for three properties of the ω meson. The neutral-to charged branching ratio of 0.11 ± 0.03 agrees approximately with the estimate of Gell-Mann, Sharp, and Wagner[4]) of 0.17 (considered perhaps the most reliable branching ratio given by their model). The width 4 ± 4 MeV for three-pion decay of the ω is consistent with the estimate of approximately 0.5 MeV by Gell-Mann, Sharp, and Wagner[4]) and by Feld[6]), and with an estimate of the order of 2 MeV by Zemach and Zachariasen[7]). The experimental result does not disagree with smaller estimates, such as 0.05 MeV of Nambu and Sakurai[4]) and 0.15 MeV of Feinberg[8]). It does differ somewhat from the 10- to 20-MeV width calculated by Frazer and Wong[9]). The experimentally determined $2\pi/3\pi$ decay ratio is in very good agreement with the 5% value given by most theoretical estimates; however, since the estimates depend on the absolute 3π rate, this does not support any theoretical model without a more nearly exact determination of the 3π width.

ACKNOWLEDGMENTS

Discussions with Prof. Charles Zemach have been very helpful. Also the interest of Prof. Sheldon Glashow in the evidence for two-pion decay was much appreciated. Thanks are also due Prof. Arthur Rosenfeld for his interest. The assistance of Mr. Daniel Siegel in the $\omega \rightarrow 3\pi$ analysis was greatly appreciated.

Drs. Stanley Wojcicki and Margaret Alston gave assistance in data reduction which was very valuable in this experiment. Discussions with Dr. Ulrich Kruse were helpful in work on rare decay modes. Finally, the encouragement of Prof. Luis Alvarez was very much appreciated.

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FIGURE LEGENDS

Fig. 1. Three-pion effective mass spectrum in the reaction $K^- + p \rightarrow \Lambda + \pi^+ + \pi^- + \pi^0$ at 1.51 BeV/c. About 650 ω's are seen above background. The width of the ω peak is due chiefly to measurement error.

Fig. 2. Production angular distribution for $K^- + p \rightarrow \Lambda + \omega$. The slight backward peaking of the Λ indicates that the ω is produced preferentially in the forward direction.

Fig. 3. Mass of missing neutrals in the reaction $K^- + p \rightarrow \Lambda$ + neutrals at 1.51 BeV/c. About 40 neutral ω decays (presumably $\pi^0 + \gamma$) are seen above background. The observed number of events with the associated statistical error is shown for each interval.

Fig. 4. (a) Square of observed width vs square of estimated mass error for the peak in three samples of events. The dashed curve represents a simple curve through the data. The solid line is a least-squares fit to the data after correction of estimated errors for relative variation in the error "scale factor" (see text for definition). The intercept of the straight-line fit gives an upper limit on the true width of the ω. (The intercept would equal the true width if the measurement error width and the true width could be combined Gaussianly; then Γ^2 (observed) would equal Γ^2 (true) + $K\Gamma^2$ (meas.) = Γ^2 (true) +$K' \langle (dM)^2 \rangle$, where K represents the measurement-error scale factor. See fig. 5 for the calculated results of folding Breit-Wigner and Gaussian curves.) (b) Observed width versus r. m. s. measurement error for the ω peak in three samples of data. The dashed curve is drawn through the data points. The straight line is a least-squares fit to the data after correction for the error "scale factor." The intercept of the straight line

represents a lower limit on the true width of the ω. The estimated mass errors of the samples of events used for these figures are (1) 3 to 5 MeV; (2) 5 to 7 MeV; and (3) 7 to 10 MeV.

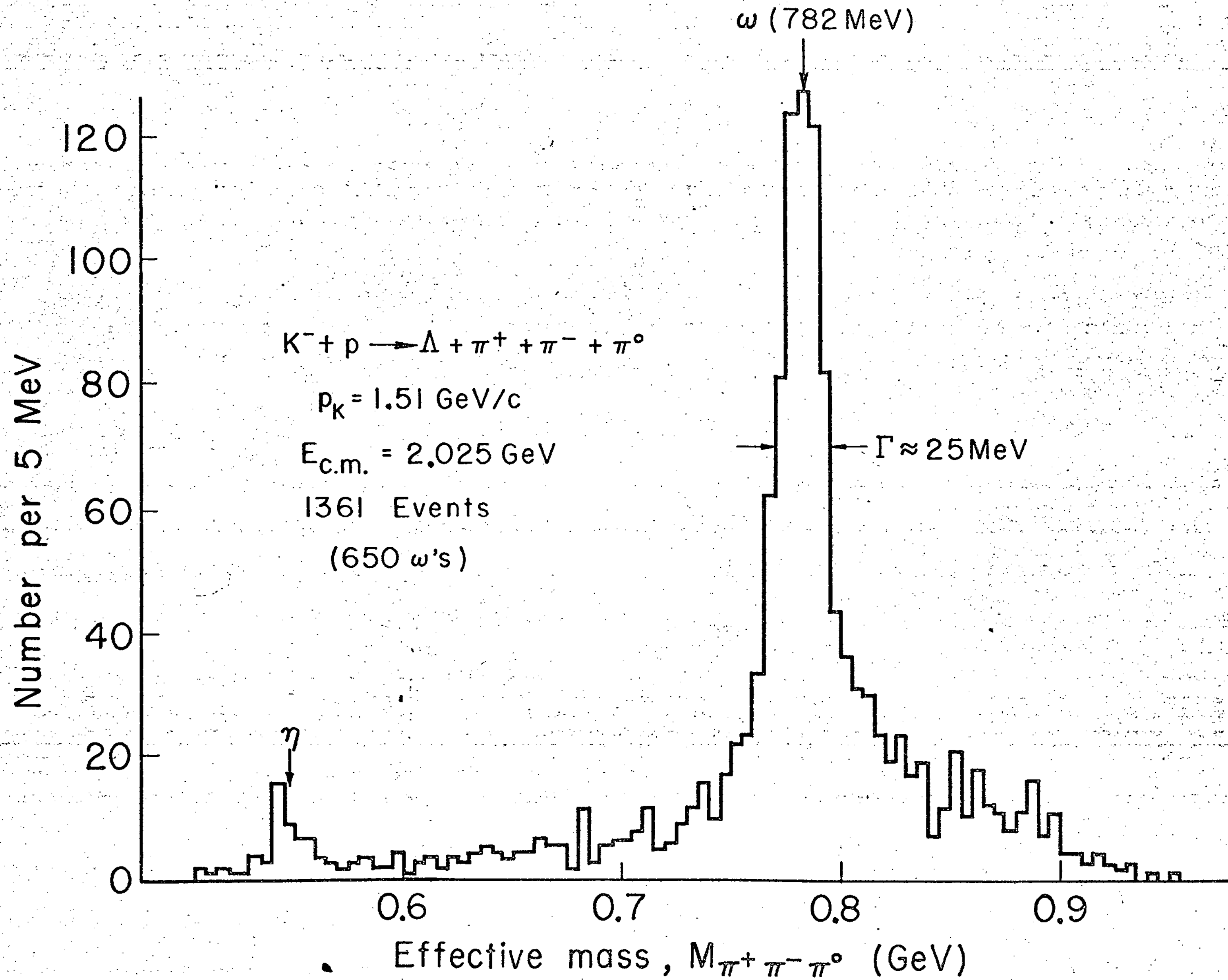
Fig. 5. (a) Square of observed width vs square of mass error, as determined from many calculated curves representing the folding of a Breit-Wigner resonance curve (of specified width Γ) with Gaussian mass error curves of various $\langle (dM)^2 \rangle$ values. (b) Observed width vs mass error for the same calculated curves resulting from the folding of a Breit-Wigner distribution with Gaussian distributions. The Breit-Wigner width appears most significant in the change of slope of the curves as the mass errors approach zero; the slope increases in (a) and decreases in (b) as dM goes to zero, the change being greater for larger Breit-Wigner widths.

Fig. 6. Dalitz plot of 1852 events representing the reaction $K^- + p \rightarrow \Lambda + \pi^+ + \pi^-$ at 1.51 BeV/c. The 45-deg line is the axis for the square of the mass in the π^+-π^- system; lines orthogonal to this axis are shown to indicate 700 and 800 MeV for the π-π mass. Bands between 1340 and 1430 MeV are outlined for the Y^{*+} and Y^{*-} systems; it can be seen that most of the events cluster within these bands. The π-π system was studied by considering two bands parallel to the Y^* bands, between Λ-π masses of 1430 and 1510 MeV. Events within these limits were projected onto the π-π mass axis, with the intention of keeping the Y^* contribution constant as a function of the π-π mass.

Fig. 7. Pion-pion mass spectrum resulting from the projection described in fig. 6. A narrow peak (or a statistical fluctuation) appears superimposed on a broader bump (the ρ meson) in the region of 780 MeV. The width is comparable with the measurement resolution.

Fig. 8. A portion of the pion-pion mass spectrum shown in fig. 7. One of the curves represents a fit to the data with a P-wave ρ meson and constant background; the other curve represents a fit with a P-wave ρ plus background and also a narrow Gaussian centered at 780 MeV to represent the ω meson.

Fig. 9. Pion-pion mass spectra at various production angles for the recoil Λ. The same events are used as in fig. 7. Although the ρ meson also appears to peak forward so that the $\omega \to 2\pi$ decay cannot be separated, it is evident that this peak behaves rather differently from the general $\Lambda - \pi^+ - \pi^-$ "background." (Note: Since the bin of interest, at 780 MeV, is one-fifth as wide as the other bins, the observed number of events and its error were multiplied by five for this bin.)



MU-28528

Fig. 1.

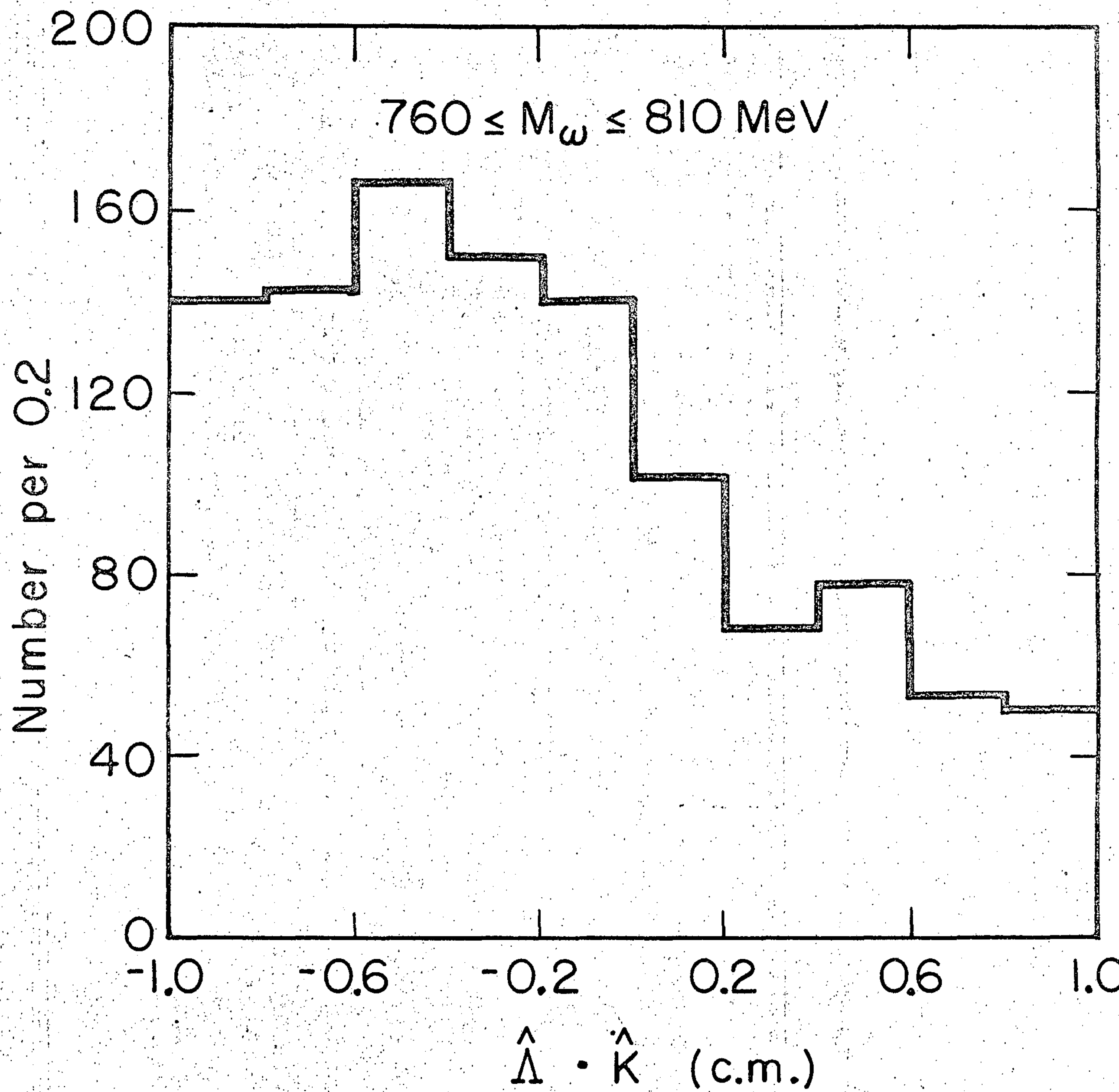


Fig. 2.

MU-30022

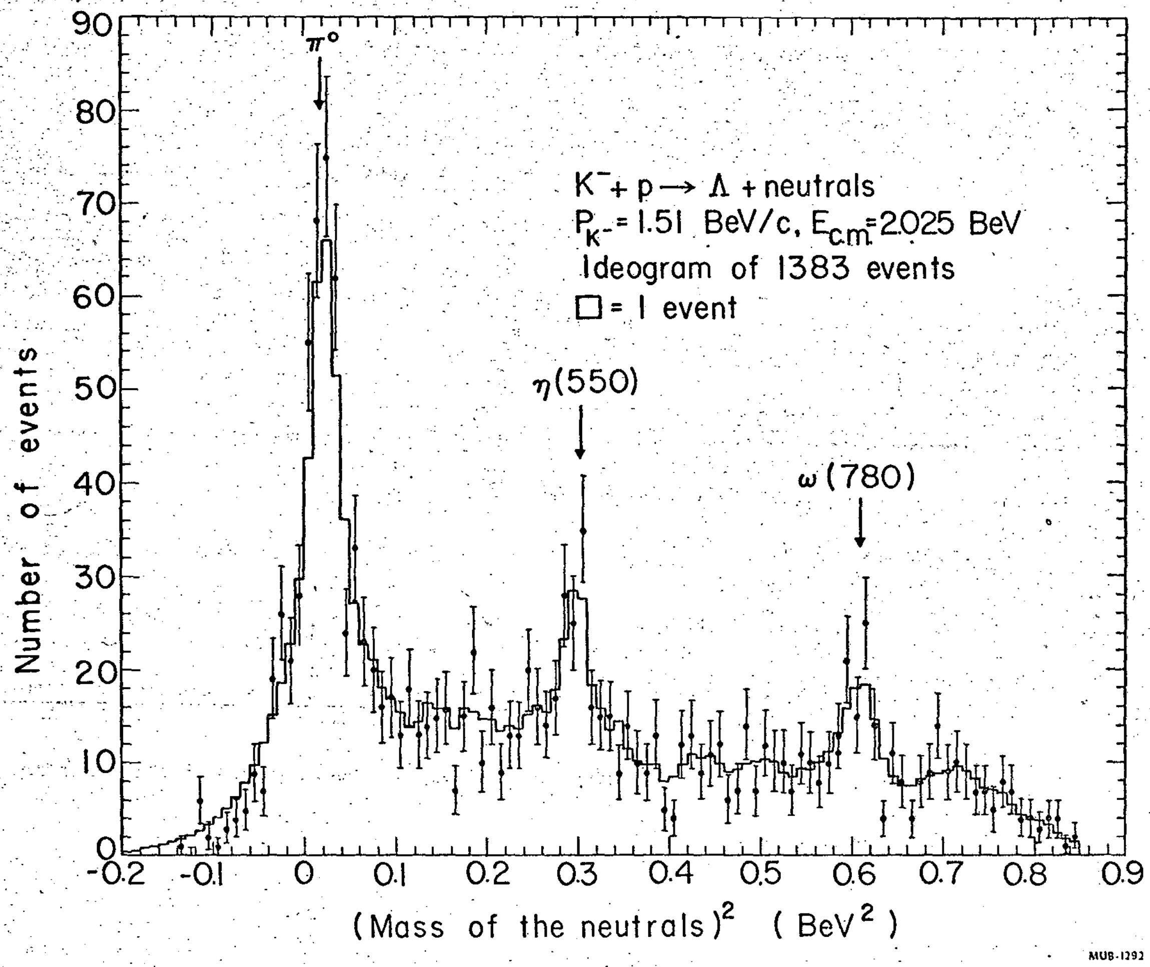

K⁻ + p → Λ + neutrals
P_{K^-} = 1.51 BeV/c, $E_{c.m.}$ = 2.025 BeV
Ideogram of 1383 events
□ = 1 event
π°
η(550)
ω(780)
Number of events
(Mass of the neutrals)² (BeV²)
90
80
70
60
50
40
30
20
10
0
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
MUB-1292

Fig. 3.

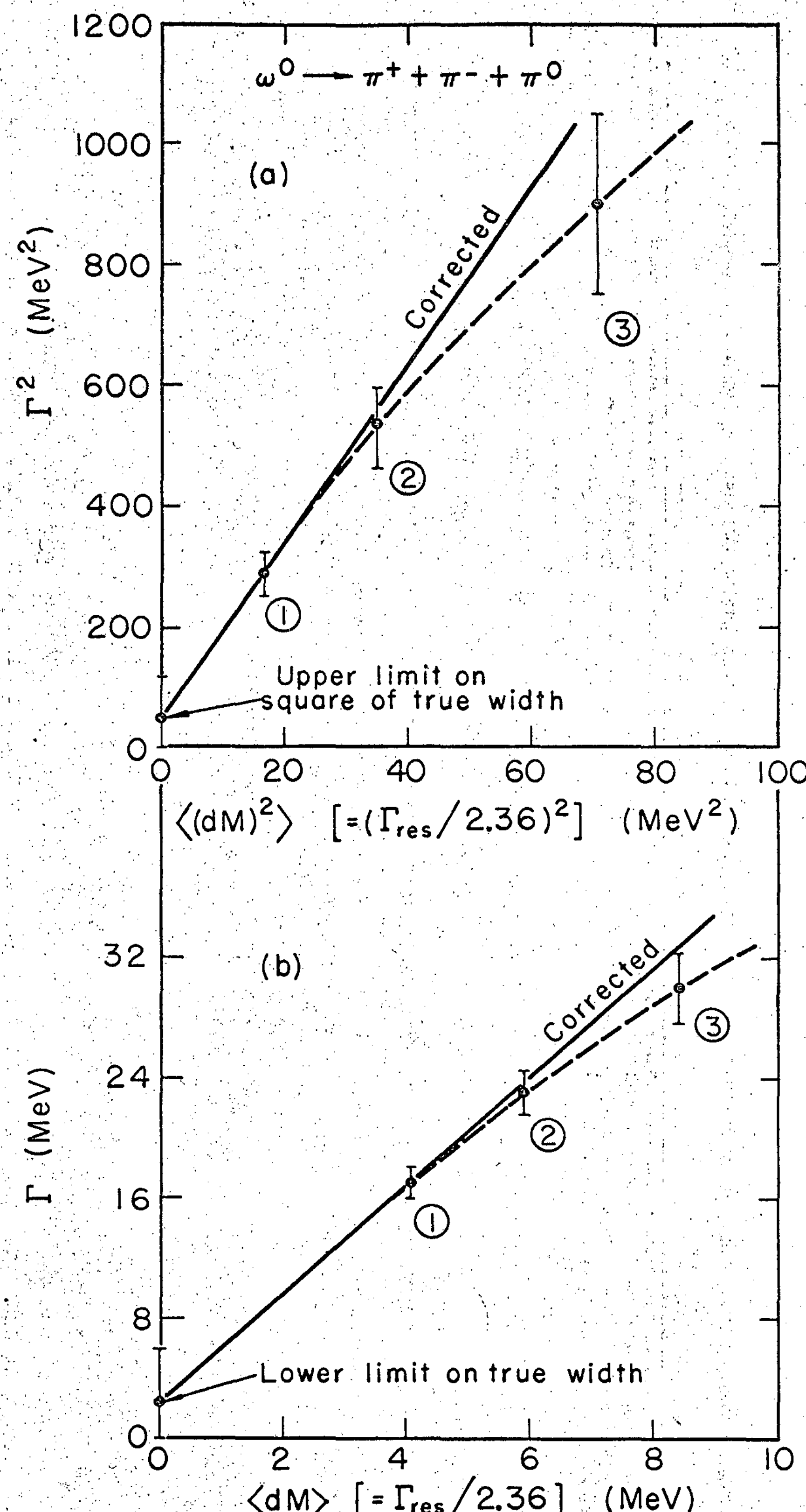


Fig. 4.

MU-30023

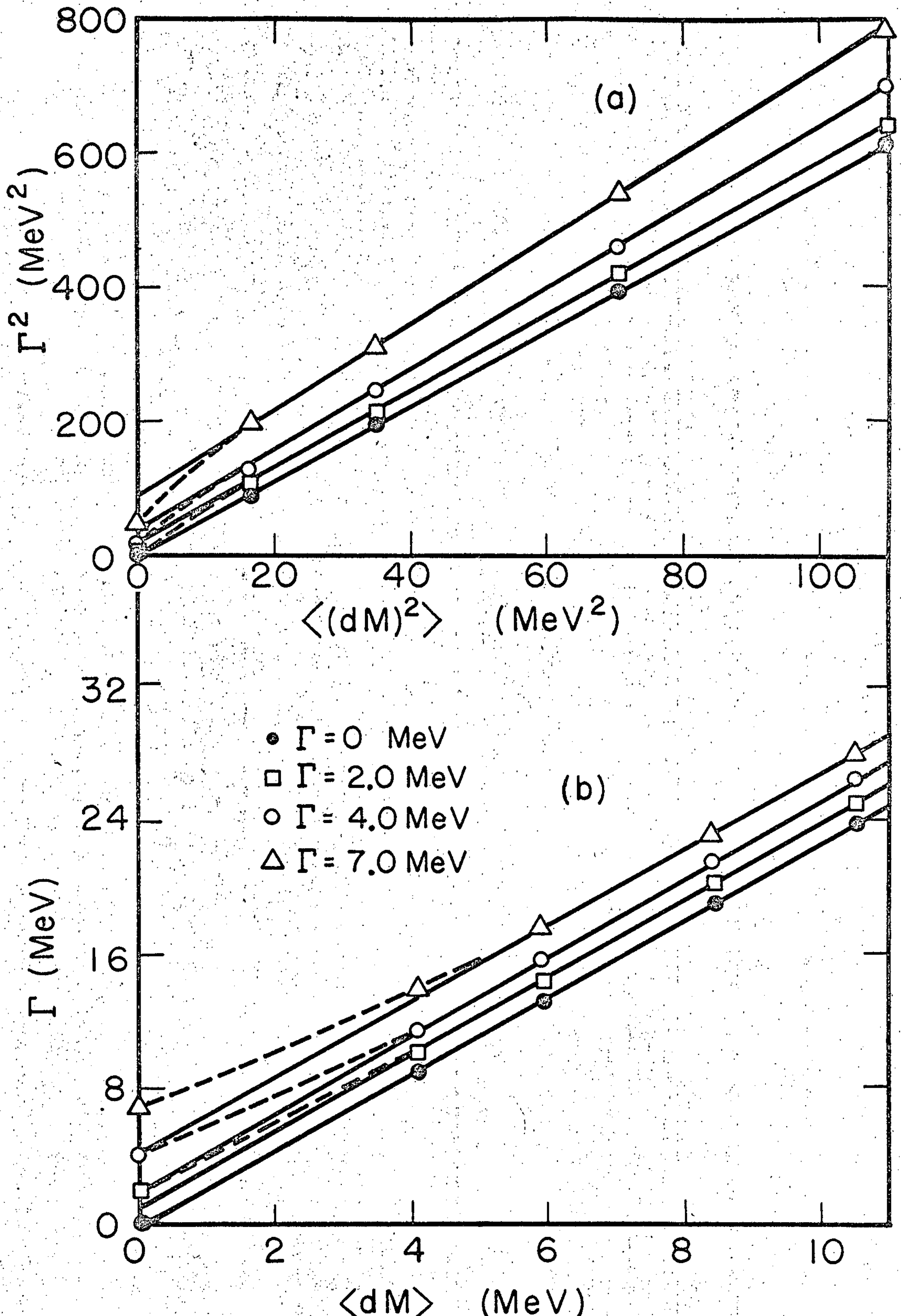


Fig. 5.

MU-30024

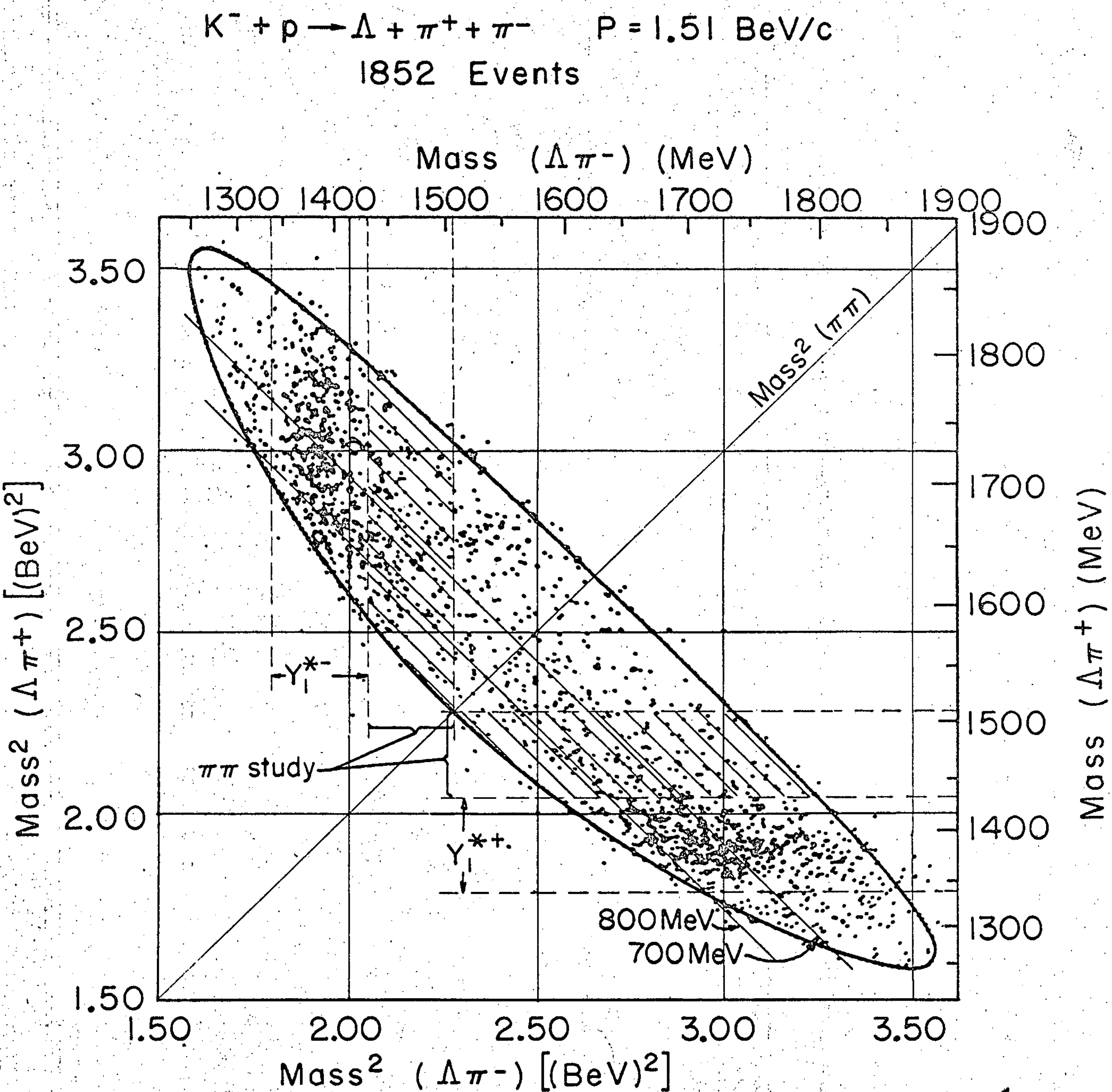


Fig. 6

MU-28877

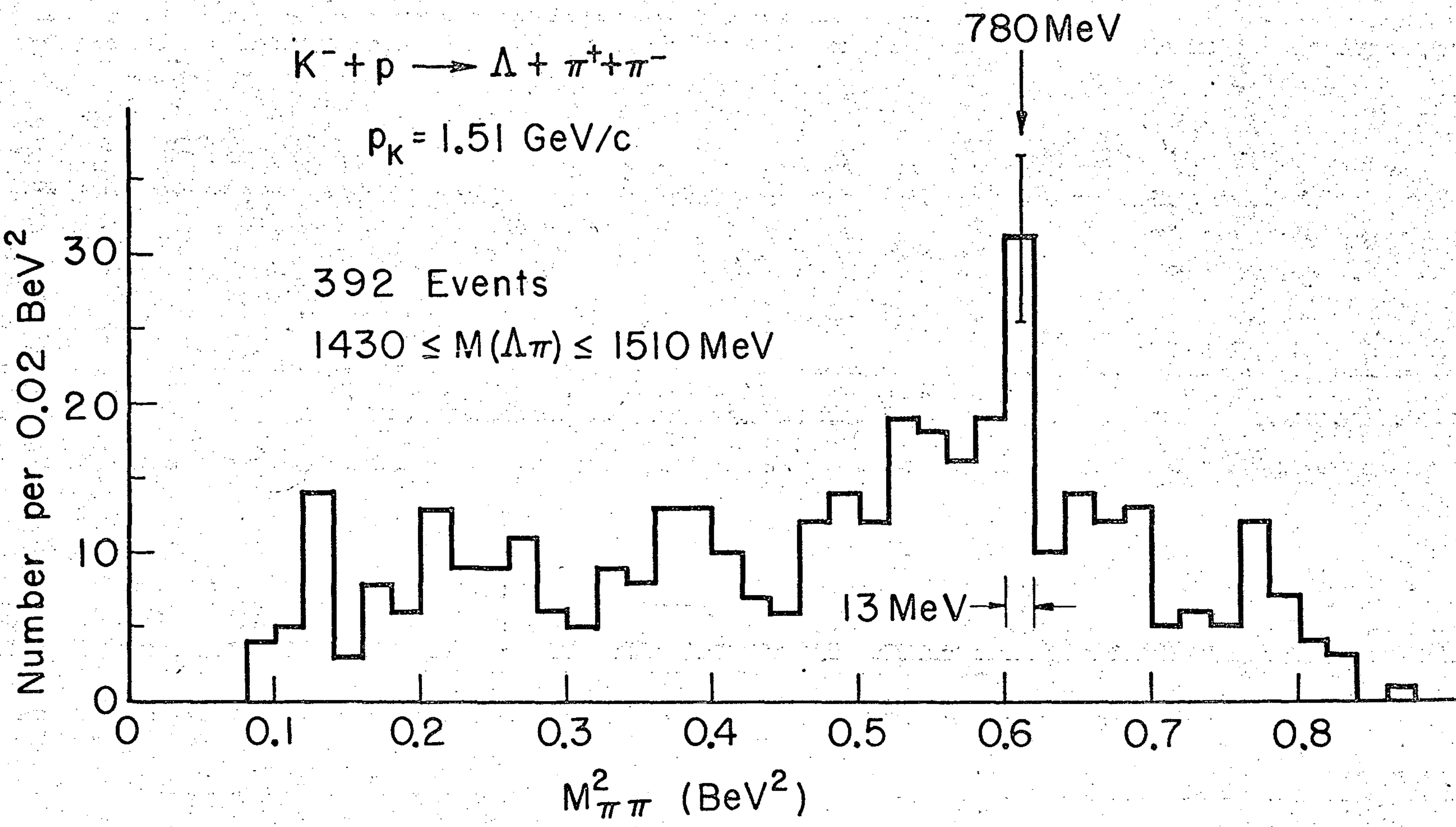


Fig. 7.

MU-28529

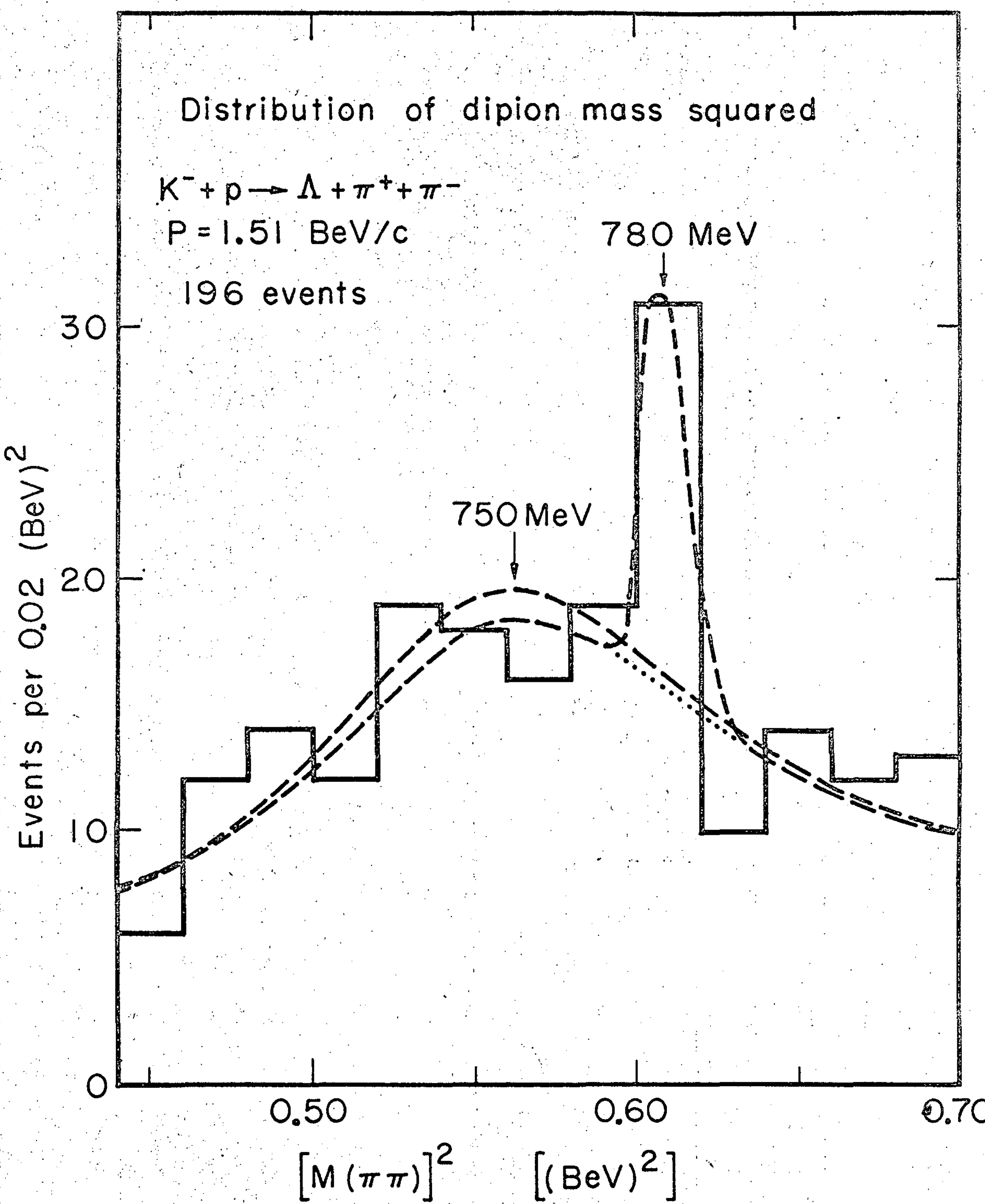
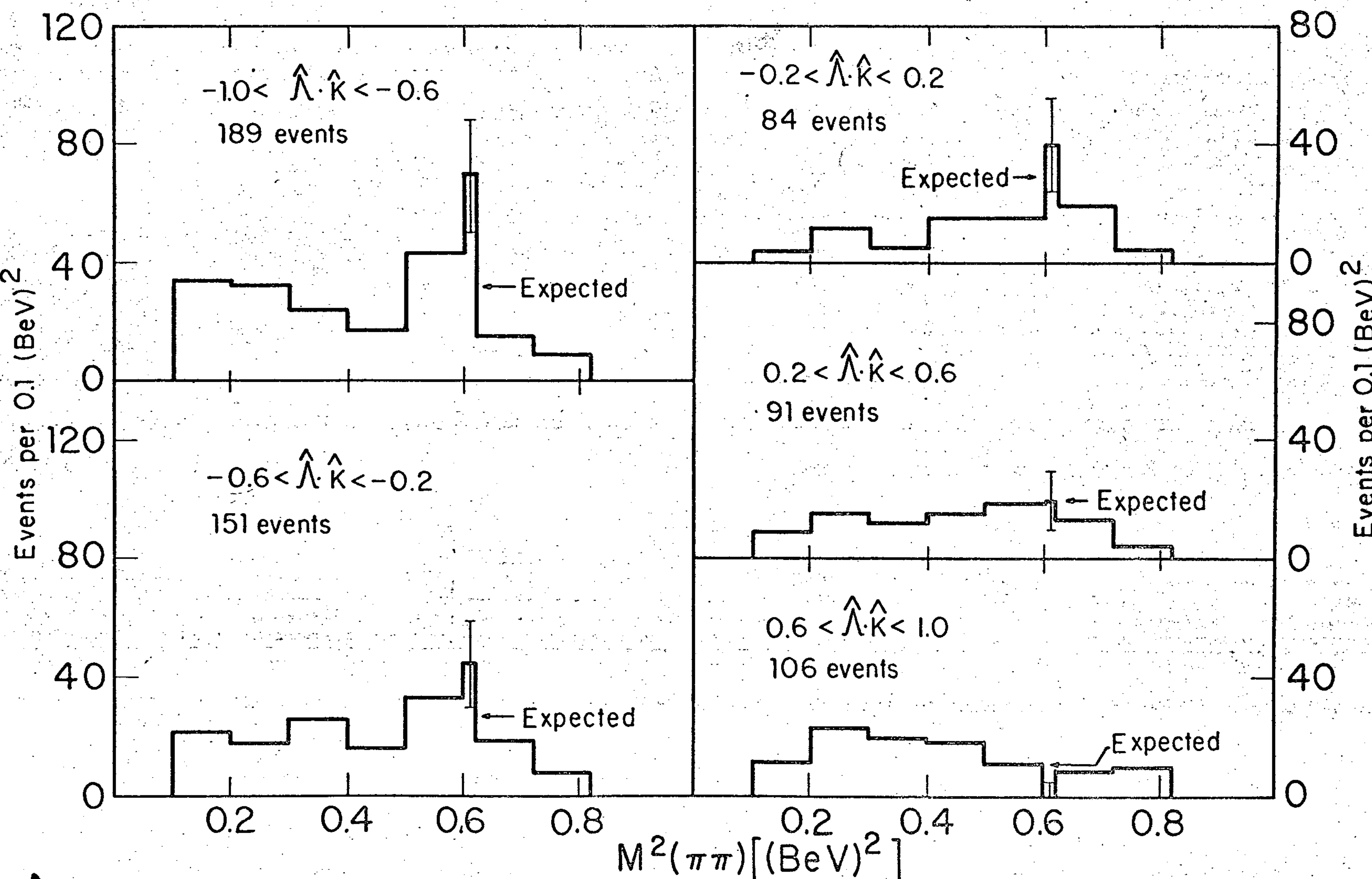


Fig. 8

MU-29054



MU-29074

Fig. 9.

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