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SUMMARY TALK

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XIXth RENCONTRE DE MORIOND ON ELECTROWEAK INTERACTIONS AND UNIFIED THEORIES

SUMMARY TALK

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Abstract

A summary of some of the highlights of the conference is presented.

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Introduction

Since last year's Moriond meeting we have seen considerable progress in our field.

The W and Z are now well established from both the UA1 and UA2 experiments. Their measured masses are in excellent agreement with the parameters obtained from low energy experiments within the framework of the standard model. However, the missing particles--in particular the Higgs scalars and the top quark--are still missing.

The PETRA groups have pushed the search for a $t\bar{t}$, heavy vector meson successor to the J/ψ and Υ, up to a mass of 46 GeV/c^2 without finding any evidence for such a state.

Some people have tried to consider the ξ (2.2) - the narrow state observed by the MARK III collaboration at SPEAR - as a possible "light Higgs". However, we have heard evidence at this Conference, based on an analysis by M. Ogg from Cornell, that such an assignment is very unlikely.

While the standard model appears tremendously successful, Guido Altarelli pointed out, however, that in spite of its experimental and theoretical successes the standard model does not look like the *ultimate* theory.
The reasons are:

- Too many parameters, namely:

Couplings $g_s, g_w, \sin\Theta_W$	3
Fermion mass ratios	8+(3 for ν's)
Mixing angles	4+(4 for ν's)
Higgs $m_H, <\phi>$	2
Θ (strong CP viol.)	1
Total number of parameters	18 (25)

- The Θ problem: ($\Theta_{exp} < 10^{-9}$), why is the Θ parameter so small?
- Higgs sector is ad hoc and untested (but for $M_W^2/M_Z^2 \cos^2\Theta_W \approx 1$).
- Charge quantization is unexplained.
- $m_\nu = 0$ (?) is unexplained.
- Baryon and lepton number conservation is not gauge protected.
- The iteration of families is unexplained.
- P and C violation are unexplained.
- No unification of forces.
- No gravity included.
- The hierarchy problem.

Altarelli gave a very eloquent discussion on why he favors super symmetry, SUSY, as the next step in a theoretical model. An important feature of SUSY is that one has to introduce a super symmetric companion particle--which differs by spin 1/2--for each known and even some of the not yet known particles! This doubling of particles is required to keep a sum over all particles, in the renormalization of the mass terms, from diverging. In this sum the bosons and fermions come in with opposite signs due to a factor $(-1)^{2J}$ when J is the particle spin. Thus the effect of the introduction of the SUSY partners is to cancel the contribution of each boson with that of the corresponding fermion, and vice versa. At first sight the introduction of so many new particles is mind boggling to an experimentalist like myself.

However, if we look back at the history of particle physics, the introduction of new particles to cancel an apparent infinity or explain a puzzling result has been extremely successful. Thus the Z^0--a favorite particle of this decade--was first introduced to remove divergencies in $\nu\nu$ scattering. Furthermore, the charmed quark--a favorite particle of the last decade--was introduced by Glashow, Iliopoulos and Maiani, GIM, to explain the absence of strangeness changing neutral currents. It remains to be seen whether this latest doubling of the number of particles will or will not be verified.

I have organized this Summary into 5 sections:

1. What happened since last year at Moriond?
   Principal new results.
2. What did not happen?
   Limits on processes and masses.
3. What may have happened?
   Hints and "Zukunfts Musik."
4. What did we learn about known phenomena?
   Improved measurements, parameter fits.
5. What is planned for the future?
   Plans and Construction, and Experiments in Progress.

1. Principal new results

1.1 W decay into $e\nu_e$ and $\mu\nu_\mu$ final states

The W is now clearly established in experiments by the UA1 and UA2 collaborations. D. Kryn of UA1 presented the evidence for $W \to \mu\nu_\mu$ and gave comparisons between the $e\,\nu$ and $\mu\,\nu$ decay modes. C. Conta presented the $W \to e\nu_e$ data from the UA2 collaboration.

1.2 The discovery of the Z°

This year saw the discovery of the Z°. C. Conta presented the UA2 results on 8 $Z^\circ \to e^+e^-$ decays, while E. Ellis presented UA1 evidence for $Z^\circ \to \mu^+\mu^-$ decays. Furthermore, he also showed data on other μ pairs of mass around 15 GeV which I will discuss later. See Fig. 1.21.

1.3 The observation of Z° events of the type $Z^\circ \to l^+l^-\gamma$

There are three such events from both UA1 and UA2. These events were the subject of intense speculation and discussion. The probability that the individual events are radiative Z° decays varies from a few percent to 0.5%. This could still be the simplest explanation for this phenomenon! Table 1.31 gives some of the details on the 3 events. Composite models were discussed by Renard and Schildknecht in part inspired by these events. The speculation is that these events could either represent a scalar particle of mass $\approx$ 45 GeV decaying into e^+e^- or an excited electron e^* of mass $\approx$ 80 GeV. The former hypothesis was tested and ruled out by the PETRA groups as reported by G. Flügge. It should be noted that the $Z^\circ \to \mu^+\mu^-\gamma$ event from UA1 fits these hypotheses very poorly; however, this is also the event with the largest measurement errors, since muon energies are not as well determined as electron energies.

1.4 The observation of a narrow resonance $\xi(2.2) \to K\bar{K}$

A narrow resonance $\Gamma \leq 40$ MeV, $M = 2.22 \pm 0.01$ GeV has been observed in the MARK III experiment at SPEAR. In view of the unexpectedly narrow width it was speculated that this could be a light Higgs particle. In a search for the $\xi(2.2)$ in the upsilon region M. Ogg gave a series of elegant arguments which demonstrated that this cannot be so.

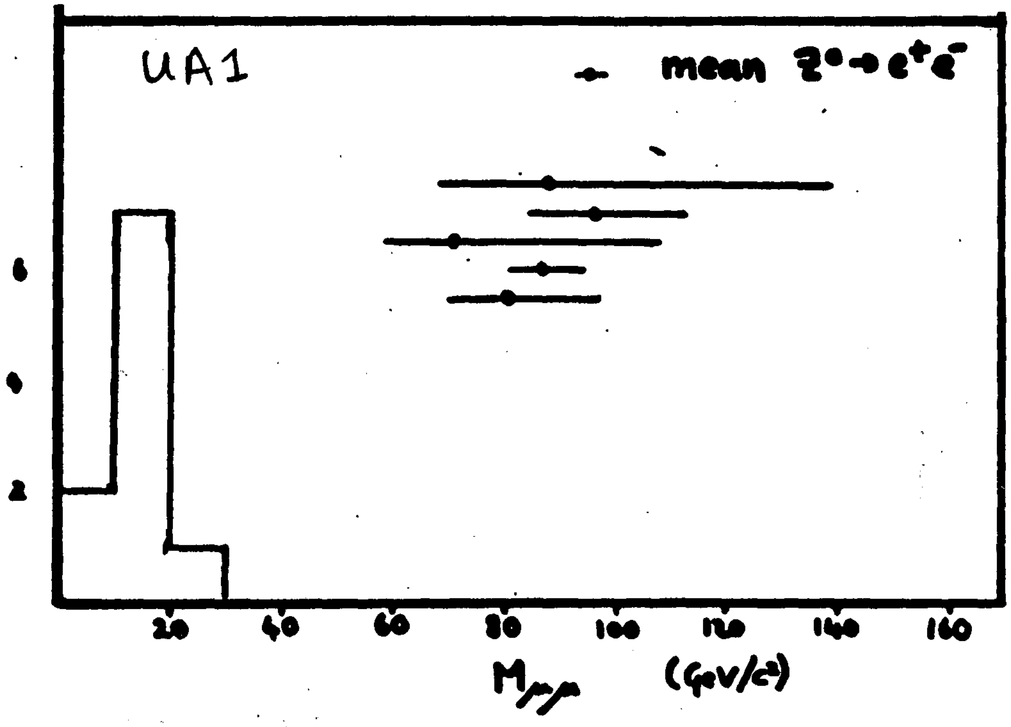


Fig. 1.21 UA1 result on μ pair masses. Mean mass of Z from $e^+ e^-$ decay 95.6 ± 1.6 GeV/c^2

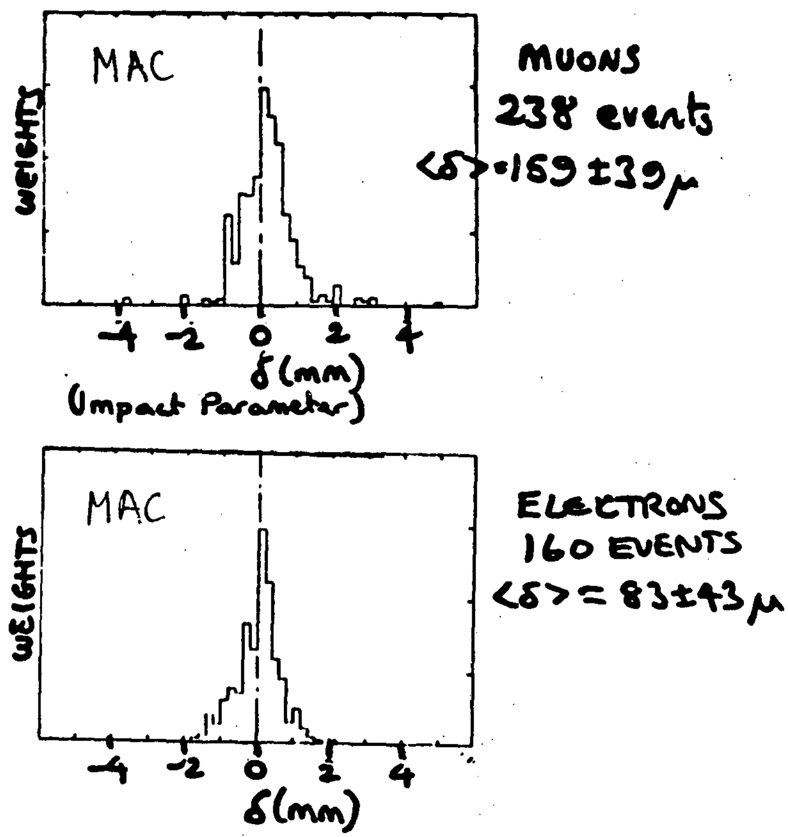


Fig. 1.61 New preliminary results on impact parameter distributions for B enhanced samples from MAC.

Table 1.31

$L^+L^-\gamma$ events from CERN

	UA1		UA2
	$\mu^+\mu^-\gamma$	$e^+e^-\gamma$	$ee\gamma$
E_γ (GeV)	30	38.8±1.5	24.4±1.4
E_{L_1} (GeV)	--	61.0±1.2	11.4±0.9
E_{L_2} (GeV)	--	9±1	68.5±1.6
$\Delta\varphi(L_2\gamma)^\circ$	7.9°	14.4°±4°	30°
$M(L_1L_2)$	$70.9^{+37.2}_{-14.2}$	42.7±2.4	49.8
$M(L_1L_2\gamma)$	$88.4^{+46.1}_{-15.2}$	98.8±5.0	83.7±2.8
$M(L_1\gamma)$	$52.4^{+23.1}_{-3.3}$	89.0±2.5	9.0
$M(L_2\gamma)$	5.0±0.4	3.6±1.0	74.1

1.5 The observation of $F \to \Phi\pi^+$ at a mass 1970 MeV

While this result belongs into the Moriond Conference on New Particle Production at High Energies (M1), I feel it should be mentioned here as one of the important new observations. The resonance of mass ≈ 1970 MeV was reported by the CLEO, ARGUS, TASSO and ACCMOR collaborations (M1). Here the ARGUS experiment also sees $F \to \Phi 3\pi$. One point which needs clarification is that the observed mass (1970 MeV) differs significantly from earlier observations which gave masses ≈ 2020 MeV which had been identified with the F. See Particle Data Group compilations (PDG1).

1.6 Measurement of the B lifetime

Two observations of the B lifetime, which turned out to be surprisingly long, were recently published by E. Fernandez et al (F1) from MAC and N. Lockyer et. al. (L1) from the MARK II. A new preliminary value from MAC was reported by J. Yelton. The MAC group reanalyzed the track reconstruction for their μ events and thus, together with higher statistics, obtained greater accuracy in their measurement of the μ impact parameter for B decay. The lifetimes are: $\tau_B = (1.20^{+0.45}_{-0.36} \pm 0.30)\times 10^{-12}$ sec from MARK II (L1), $\tau_B = (1.8 \pm 0.6 \pm 0.4)\times 10^{-12}$ sec from MAC (F1) and the new preliminary value from MAC: $\tau_B = (1.6 \pm 0.4 \pm 0.3) \times 10^{-12}$ sec. See Fig. 1.61

1.7 Proton decay: Limit or observation?

Results from 3 experiments in progress were reported. For the NUSEX experiments located in the side of the tunnel through Monti Bianca, S. Ragazzi reported the observation of a proton decay candidate $p \to \mu + K^0$ among 18 fully contained events. Fig. 1.71. The other 17 events are consistent with ν_e or ν_μ interactions in the NUSEX detector. Furthermore he reported a limit on $n-\bar{n}$ oscillations--based on 2 events consistent with π^0 emission. $\tau_{n\bar{n}} > 0.6 \times 10^{31}$ yrs. in Fe at 90% CL. This can be connected to $\tau_{n\bar{n}} > 3-4 \times 10^7$ sec for free neutrons, although the nuclear physics calculations

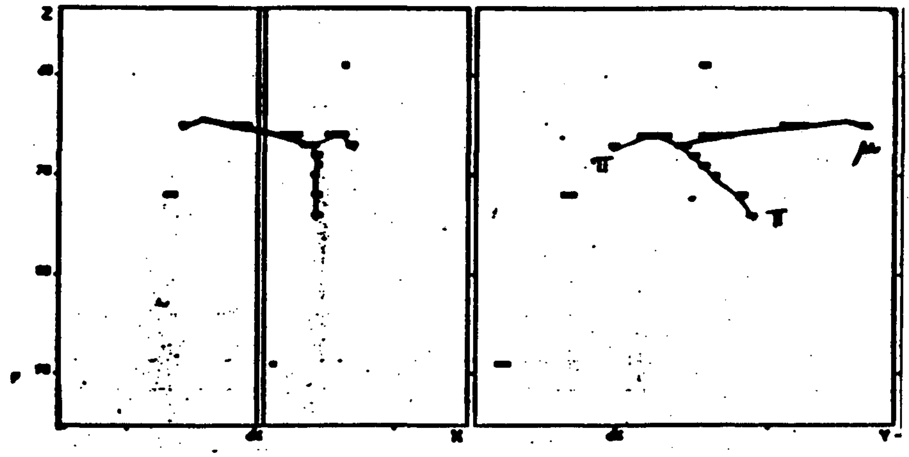
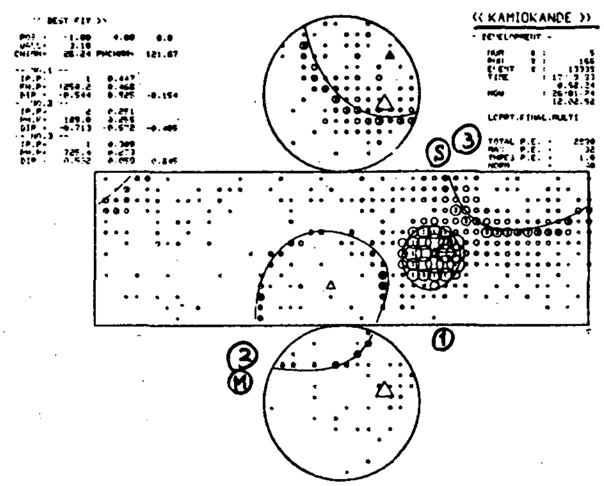


Fig. 1.71 Tracks corresponding to the proton decay candidate from the NUSEX experiment.

Fig. 1.72 Čerenkov rings corresponding to a proton decay candidate from the KAMIOKANDE experiment.



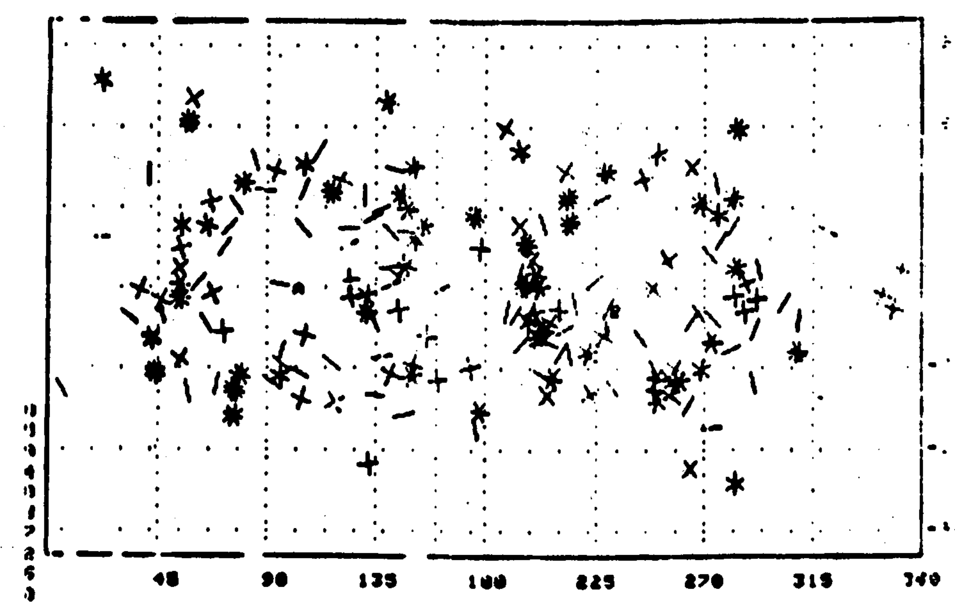


Fig. 1.73 Čerenkov rings corresponding to a fully contained two prong event from the IMB experiment. The 2 prongs make a 135^{0} angle and one is identified as a muon from its observed decay. The event is interpreted as a background to proton decay.

involved are still subject to some questions. For the KAMIOKANDE Experiment located in the KAMIOKANDE mine in Japan Y. Totsuka reported one candidate which corresponds either to

$$p \to \mu^+ \eta^o$$
$$\to \gamma\gamma$$

or

$$p \to \mu^+ K^o$$
$$\to \pi^o\pi^o$$

or possibly

$$n \to e^+ \rho^-$$
$$\to \pi^+\pi^o$$

See Fig. 1.72. They estimate background for this event at 10^{-2}. They have also observed a second possible proton decay candidate $p \to e^+\omega^o$. The IMB experiment operating in the Morton-Thiokol Salt mine near Cleveland was reported by E. Shumard. This experiment was run for 202 days which corresponds to 2300 ton years. During this period 148 contained events were observed, a handful of which could be proton decay candidates. The IMB group states, however, that all the observed events may be consistent with ν induced background.

They show distributions of the number of photo tubes that fired for these events, compared with a simulation based on 5000 ν events obtained from data tapes in the Gargamelle Bubble chamber. Fig. 1.73 shows an example of a 2 prong event with observed μ^+ decay which they however rule out as possible p decay candidate because the two tracks make a 135° angle with each other, which is too small to pass their acceptance criteria. Table 1.71 is a summary of the results from the 3 experiments prepared by J. Van der Velde.

2. Searches and Limits

2.1 The search for the top quark

Work at PETRA

We heard from G. Flügge about the heroic effort at PETRA to search for the top quark. All four PETRA Detectors CELLO, JADE, MARK J and TASSO have pooled their data in the search which has proceeded in 30 MeV steps, taking about 60 nb^{-1} per point and about 1 point per day. Thus the average $\int$ Ldt for all four detectors combined is 224 nb^{-1}, which yields a combined sum of 45 hadrons per point. See Fig. 2.11.

In this manner they have covered the region from $\sqrt{s}$ = 39.5 GeV to 46.2 GeV which is nearly the end of their range. However, PETRA is still managing to go higher for a few more steps, and this was in progress in March 1984.

The search was made so as to be able to observe a peak due to a $Q = \frac{1}{3}e$ quark, an estimated increase of $\Delta R \approx 1$, as well as the effect of a $Q = \frac{2}{3}e$ quark, $\Delta R \approx 4$.

One anomaly was observed at 44 GeV which could be of the order expected for a $Q = \frac{1}{3}e$ quark, however, a preliminary attempt to repeat one point did not show any enhancement. It is the intention of the PETRA groups to return to this energy region, after the total scan is completed, for a more careful look.

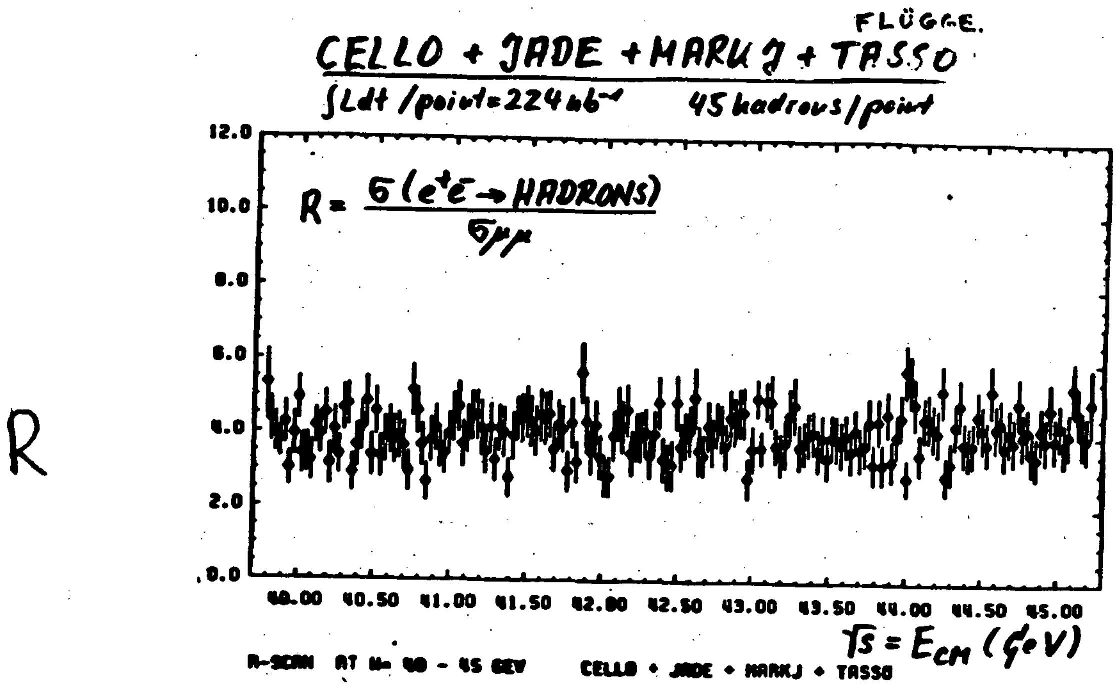


Fig. 2.11 Results on toponium search from the PETRA groups.

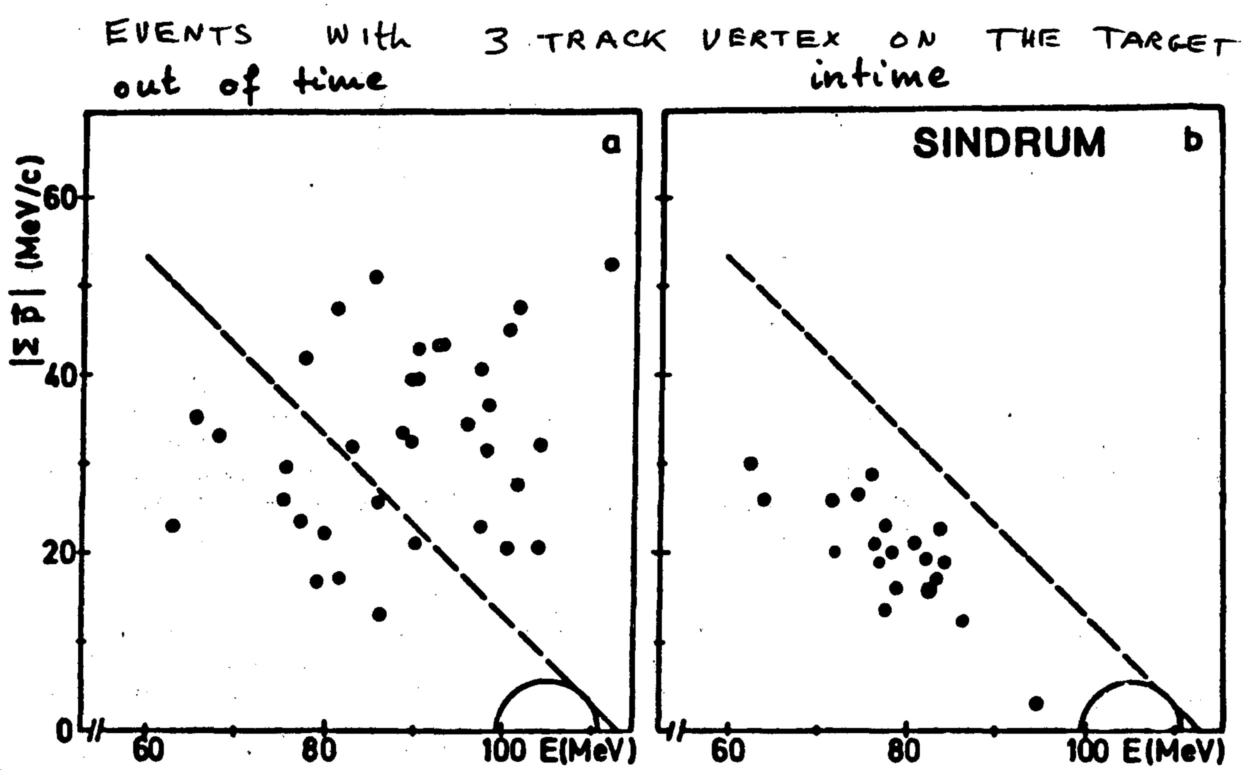


Fig. 2.41 Search for lepton nonconserving muon decay in SINDRUM detector.

(a) Out of time events corresponding to chance coincidences.

(b) In time events corresponding to $\mu^+ \to e^+ e^+ e^- \nu \bar{\nu}$ decays for which the theoretically expected decay rate is observed.

The expected decays would lie inside the small semicircles on figure.

Table 1.71

90% CL τ/B limits in units of 10^{30} years for various decay modes.
Also number of baryon decay candidates N_c observed.
Compilation by Jack Van der Velde.

Decay mode	NUSEX 180 t.y. τ/B	N_c	IMB 2300 t.y. τ/B	N_c	Kamiokande 324 t.y. τ/B	N_c
$p \to e^+\pi^0$	10		200		26	
$\mu^+\pi^0$	7		200		18	
$e^+\gamma$	-		220		-	
$\mu^+\gamma$	-		220		-	
$e^+\eta^0$	-		130		18	
$\mu^+\eta^0$	-		40		8	either 1
e^+K^0	-		31		18	
μ^+K^0	13	1	20	1*	8	or 1
$e^+\omega^0$	-		41	1*	6	1
$\mu^+\omega^0$	-		51	2*	-	
νK^+	5		12	3*	7	3*
$\nu\pi^+$	4		-		3	5*
$n \to e^+\pi^-$	19		-		9	
$\mu^+\pi^-$	4		-		11	
$\nu\pi^0$	10		-		15	
νK^0	6		8	3*	8	

*consistent with expected ν background

Work at CERN in the UA2 detector

R. Battiston reported on an effort in the UA2 detector to look for the reaction $W^+ \to t\bar{b}$ with $t \to e\nu b$. This reaction is expected to yield events with an electron plus two jets and a neutrino, i.e. the topology (e, j_1, j_2, ν) of three visible jets and missing transverse energy. For $25 < M_t < 50$ GeV they found 4 candidates of this topology -- these events are however consistent with background.

2.2 The search for SUSY particles

As summarized by Altarelli our theoretical friends are actively studying avenues for excursions beyond the standard model through SUSY theories. This in turn has stimulated considerable experimental activity -- particularly at e^+e^- colliders -- in a search for SUSY particles. During the past year we have seen considerable effort in ferreting out mechanisms and diagrams which are amenable to experimental tests. We have seen numerous experimental results from this pursuit. Unfortunately though one knows where and how to look for SUSY particles, we have no idea as yet whether we have explored 1%, 10% or perhaps even 99% of the region in which such particles may occur. Table 2.21 gives a representative sample of some of the limits achieved at PETRA and PEP and reported at this conference.

Table 2.21

Summary on sleptons.
Excluded region shown.
From acoplanarity measurements unless noted otherwise.

95% C.L. limits in GeV

	$\tilde{e}$	$\tilde{\mu}$	$\tilde{\tau}$
CELLO	<21.3	3 - 16	6 - 15.5
JADE	<20.5 <25*	<20.5	4 - 14
MARK J	--	3 - 18	3 - 16.5
TASSO	<16.6	<16.4	--
MARK II	<21.5*	90% C.L. (MARK II, MAC, MAC)	
MAC	<23.4*		
MAC	<35.0**		

*single e
**single γ

2.3 Limits on right handed currents

R. Tripp reported on the update of the LBL-Northwestern-TRIUMF experiment with a "surface μ beam". This elegant experiment utilizes the end point of the μ decay spectrum for highly polarized as well as precessed muons. The data analysis sets a limit of $M(W_R) > 380$ GeV for the mass of a possible right handed W. A new limit on the δ parameter in μ decay is in progress.

2.4 The search for lepton number violating μ decays

R. Eichler reported on an experiment at SIN using the SINDRUM detector. This experiment also utilizes a "surface μ beam" to look for the decay

$$\mu^+ \to e^+e^-e^+ . \tag{1}$$

The principal background to this reaction is radiative μ^+ decay

$$\mu^+ \to e^+\gamma\bar{\nu}_\mu\nu_e . \tag{2}$$

with internal (or external) $\gamma \to e^+e^-$ conversion. They have actually observed this allowed, but very rare, decay mode and can distinguish it clearly from (1). Another source of background are multiple, and hence out of time, μ decays. This experiment has pushed the limit for (1) from $< 1.9\times10^{-9}$ to $< 1.6\times10^{-10}$ and they hope to decrease this limit to $< 10^{-12}$. See Fig. 2.41.

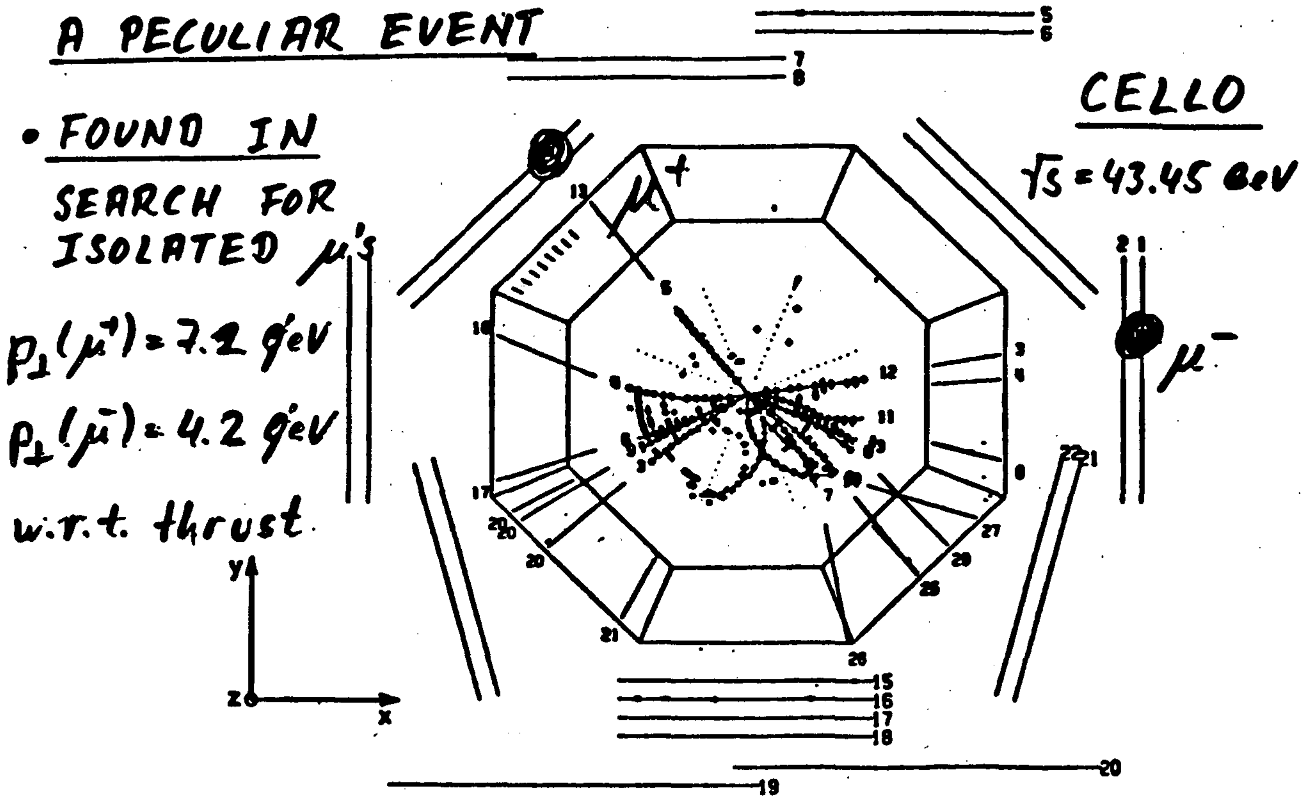


Fig. 3.11 Peculiar $\mu^+\mu^-$ jet 1 jet 2 event found in CELLO detector.

• Remarkably planar:
$\langle p_\perp^{OUT} \rangle = 270$ MeV

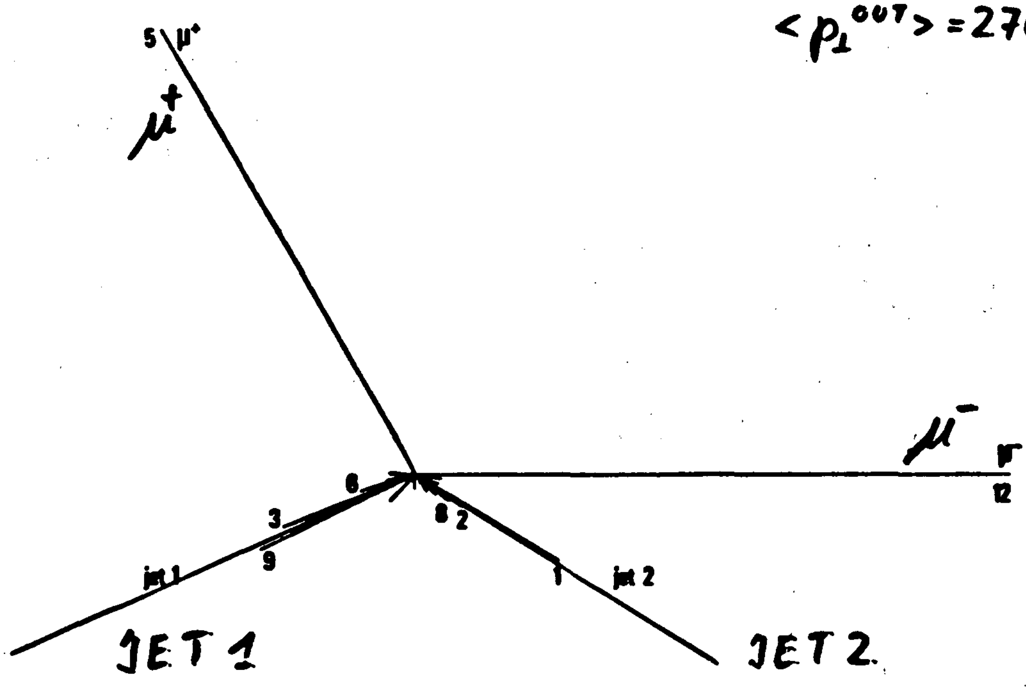
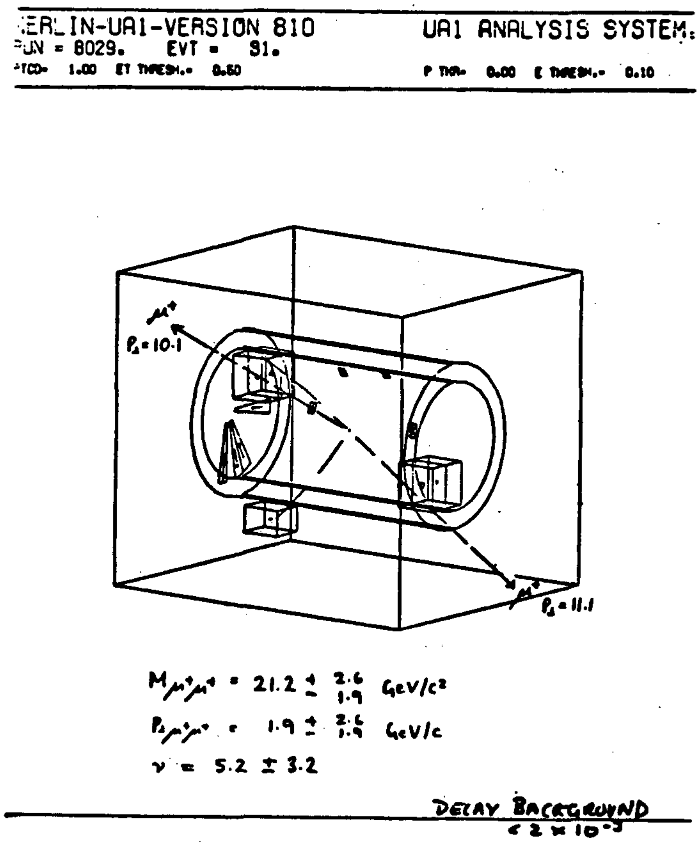
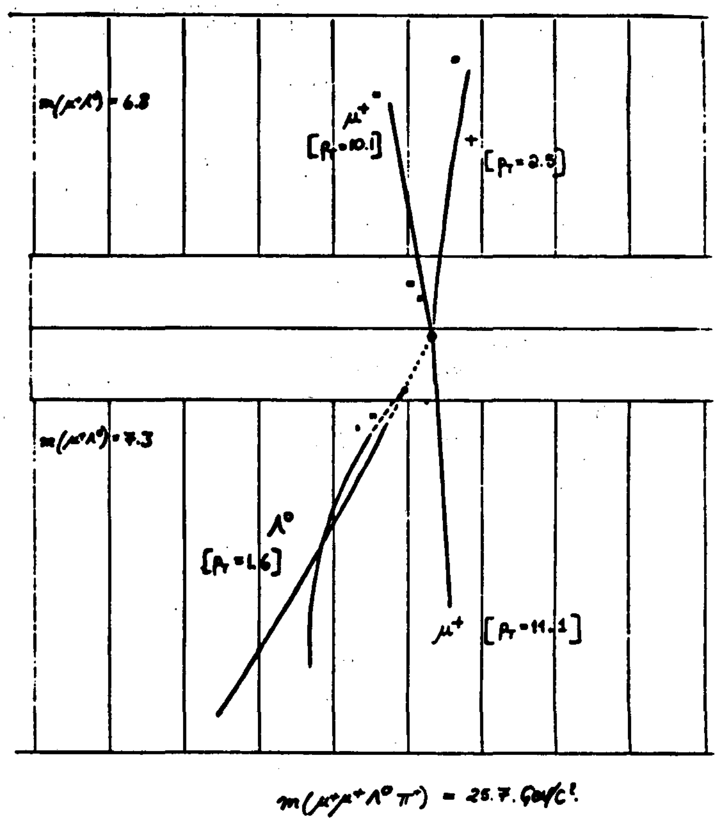


Fig. 3.12 Momentum diagram for CELLO event.





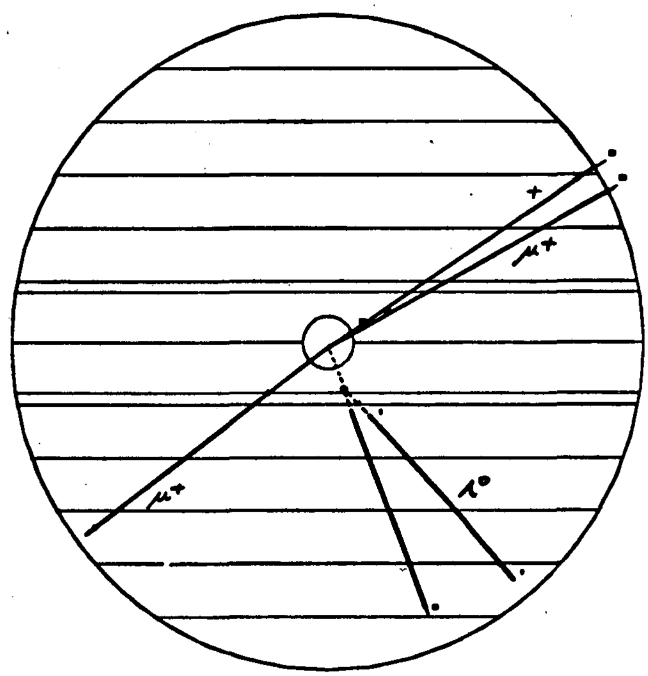
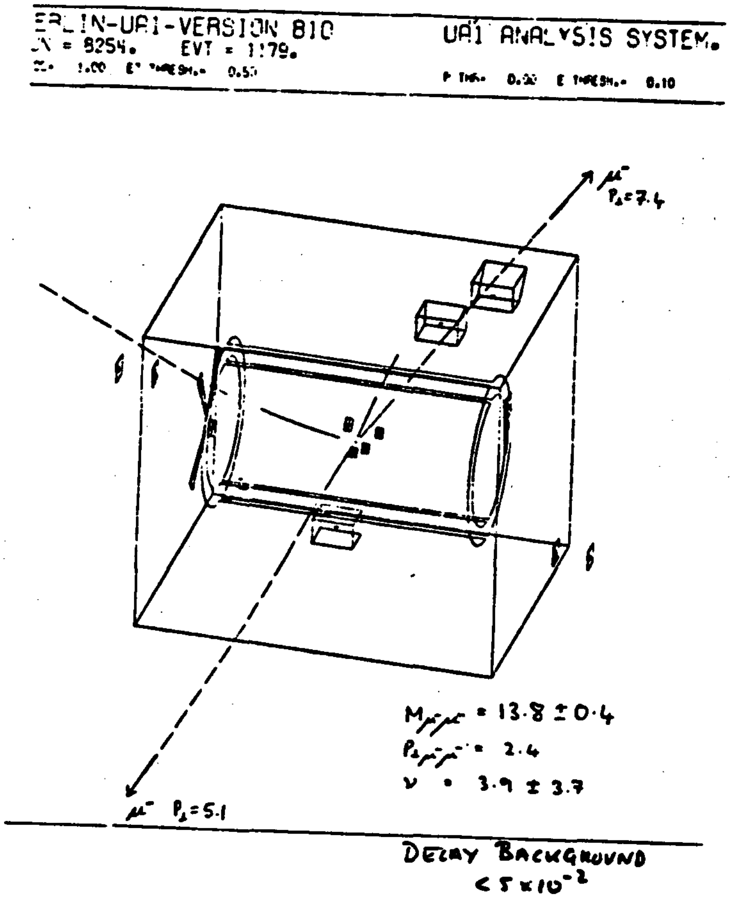


Fig. 3.21 UA1 $\mu^+\mu^+$ Λ event.



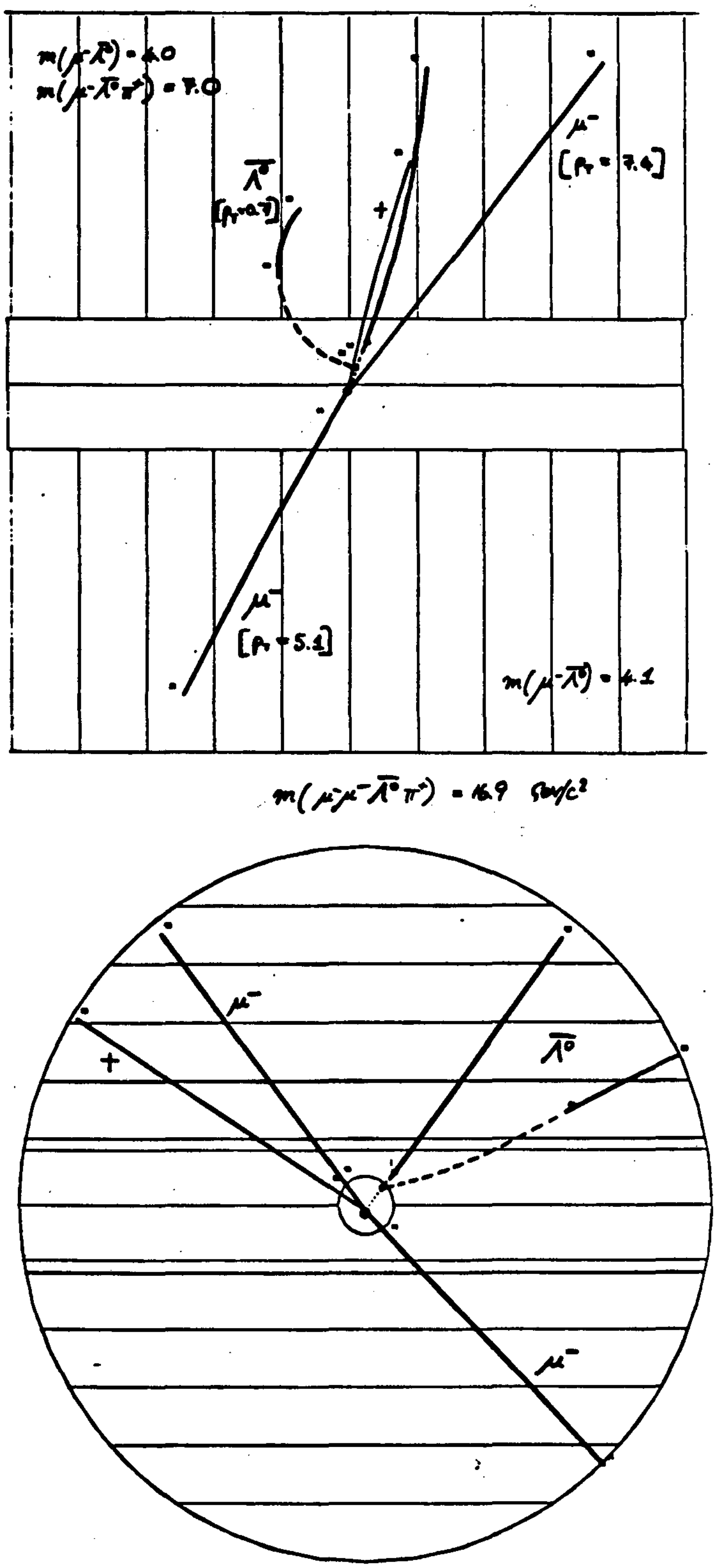


Fig. 3.22 UA1 $\mu^- \mu^- \bar{\Lambda}$ event.

3. New hints and interesting events

3.1 A $\mu^+\mu^-$ jet-jet event from CELLO

As reported by G. Flügge, the CELLO detector at PETRA running at E_{CM} = 43.45 GeV has observed an event containing a pair of muons as well as two distinct jets (j_1,j_2). Events with a μ pair and additional hadrons are not uncommon. These are either of QED origin or due to a heavy quark pair. The CELLO event, however, has exceptionally large masses (>9.5 GeV/c^2) between any combination of pairs $\mu^+\mu^-$, μj and j_1j_2. Table 3.11 shows the measured masses. So far there is no definite interpretation for this event. The probability that this event is due to conventional processes is 10^{-3}. See Figs. 3.11 and 3.12.

3.2 Like sign muon pairs observed in the UA1 experiment

Ellis reported on the observation of 3 like sign μ pairs. Two of these are very similar. They show no jet activity and consist of $\mu^+\mu^+\Lambda$ and $\mu^-\mu^-\bar{\Lambda}$ each with one additional π^+ and some (3-5 GeV) missing transverse energy. The third like muon pair event is different in that it shows considerable jet activity. There is no definite interpretation for these events as yet. See Figs. 3.21 and 3.22.

4. Improved measurements and parameter fits

I will just mention a few selected highlights very briefly.

4.1 B meson studies at CESR

Juliet Lee-Franzini reported on results from CLEO and CUSB. In particular, she gave:

- a limit on $\Upsilon(4S) \to B^*B$ of $\leq 8\%$ at 90% C.L. for E_γ = 20−135 MeV from CUSB. See Fig. 4.11.
- a ratio of decay probabilities of $(B \to e\bar{\nu}Xu)/(B \to e\bar{\nu}Xc) < 0.045$ which places a very low upper limit on the $|U_{bu}|$ K−M matrix element. See Fig. 4.12.
- indication for additional resonance structure above the $\Upsilon(4S)$ mass.

Table 3.11

Invariant masses from the CELLO $\mu\mu$ jet jet event

(GeV)	μ^+	μ^-	JET 1
JET 2	19.4±1.3	9.5±0.5	17.3±0.3
JET 1	14.1±1.0	22.2±1.6	--
μ^-	20.4±1.1	--	--

SEARCH FOR 20-135 MeV PHOTONS FROM B* DECAY

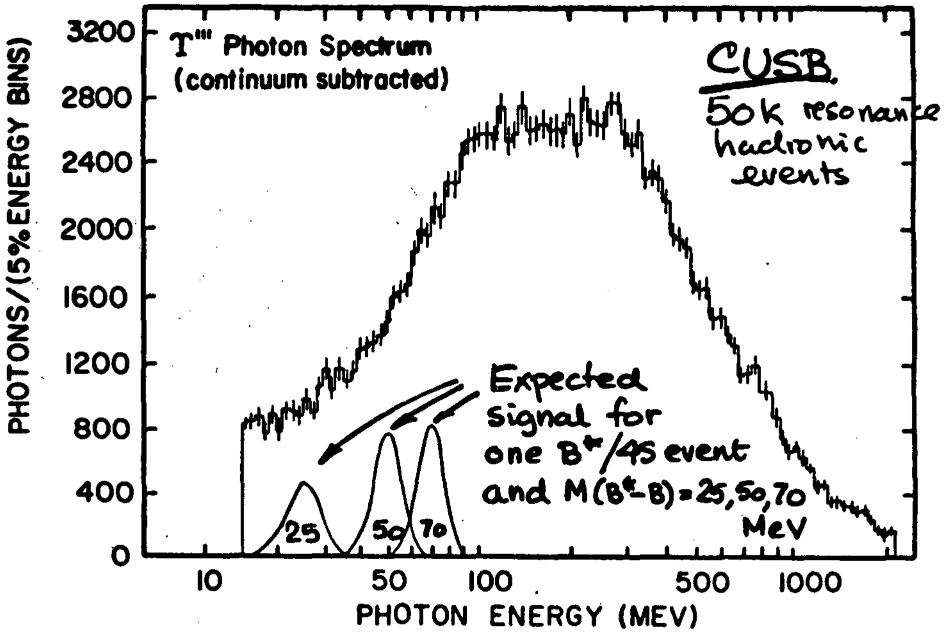
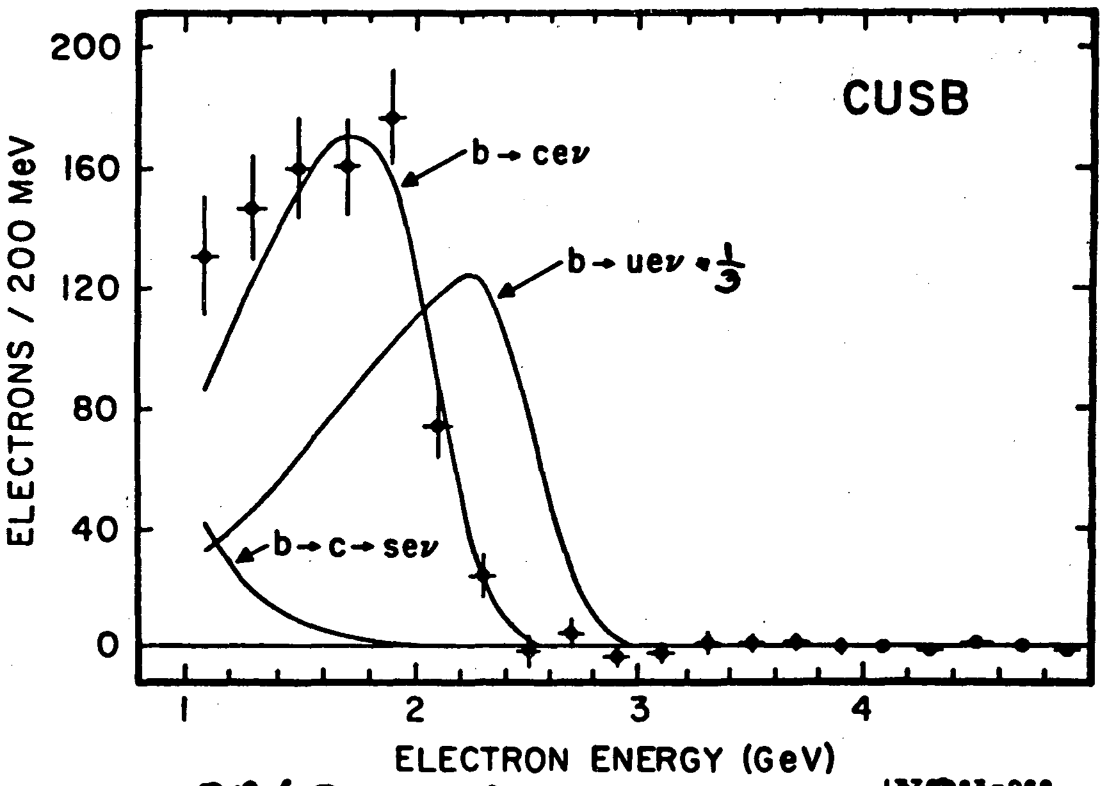


Fig. 4.11 Search for T(4S) → B B*



BR(B→e ν̄ X) = (13.2 ± .8 ± .5)%

Γ(B→e ν̄ X_u)/Γ(B→e ν̄ X_c) < .045

Fig. 4.12 Electron spectrum from semileptonic B decay.

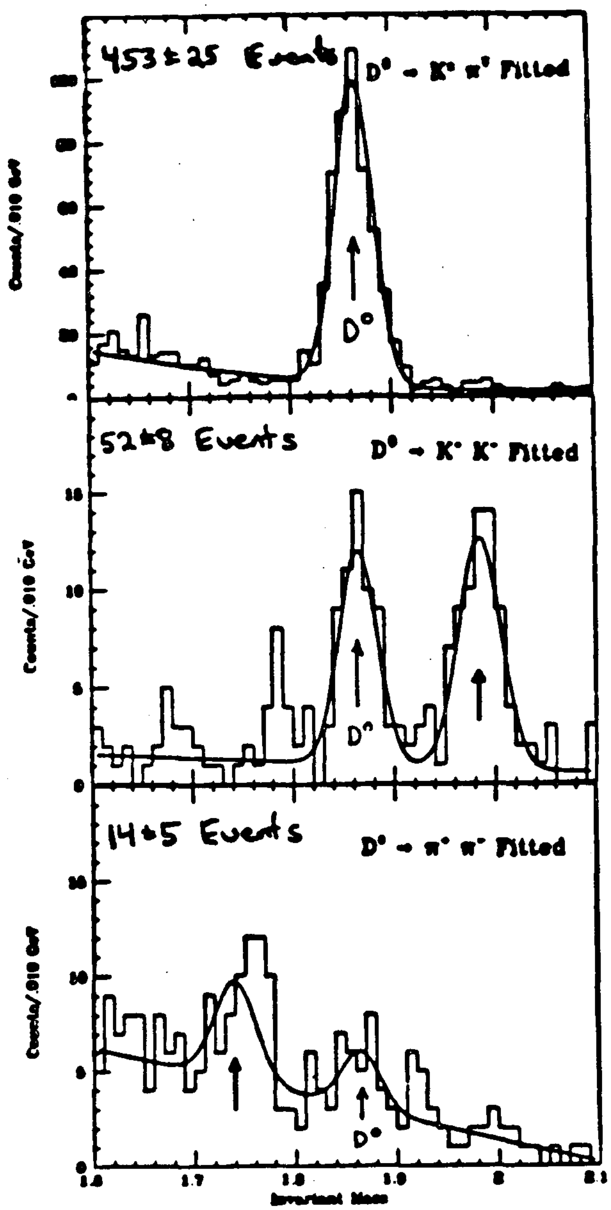


Fig. 4.21

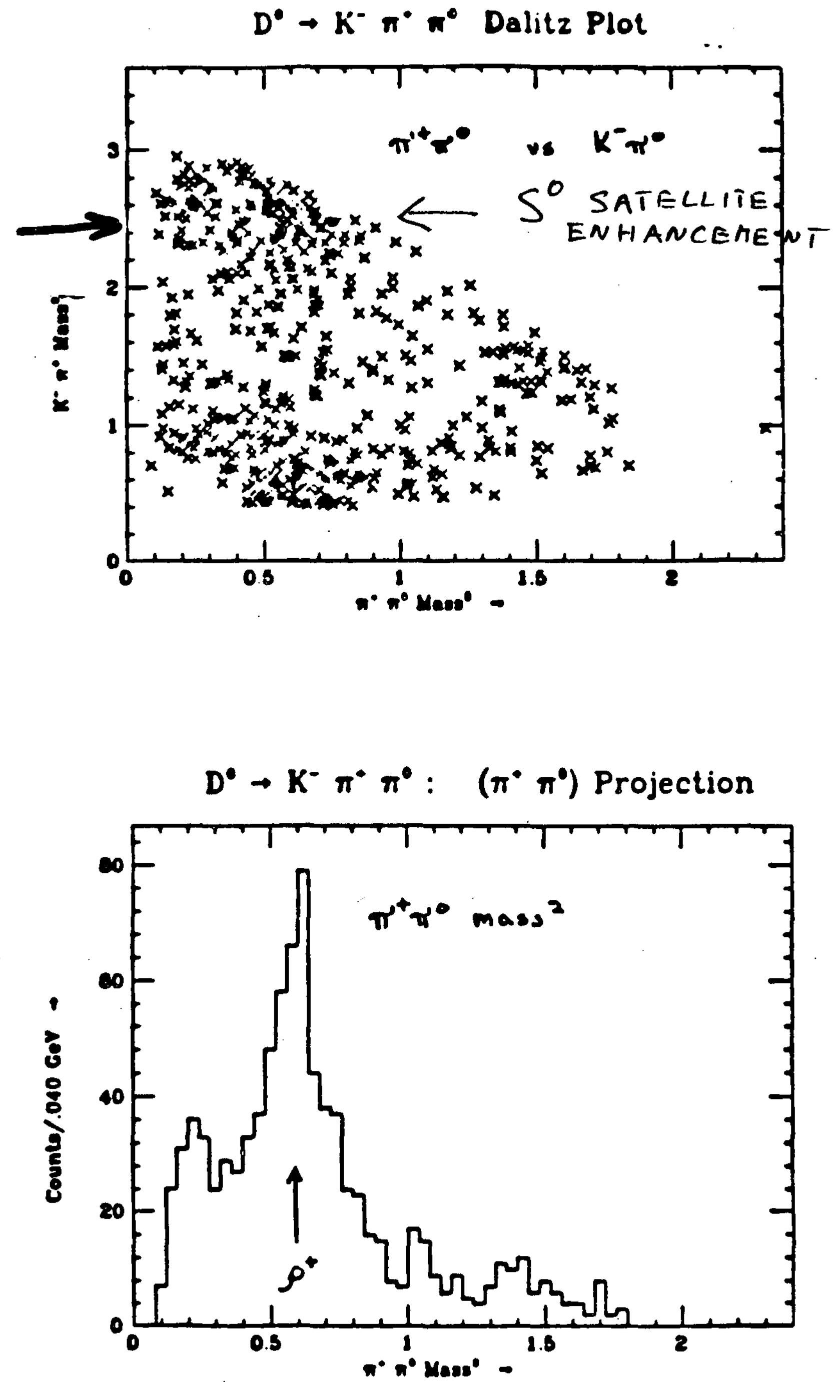


Fig. 4.22

Fig. 4.21 Results from MARK III. Cabibbo allowed and suppressed two body D^0 decay. The "off mass" peaks in the K^+K^- and $\pi^+\pi^-$ distributions are due to K/π misidentifications. No efficiency corrections applied.

Fig. 4.22 Results from MARK III. Dalitz plot and projection for $D^0 \rightarrow K^-\pi^+\pi^0$. The location of the "$S^0$ satellite peak" is indicated.

Results on the S^0 Satellite Peak from
MARK II at SPEAR
Reprinted from Moriond 1983

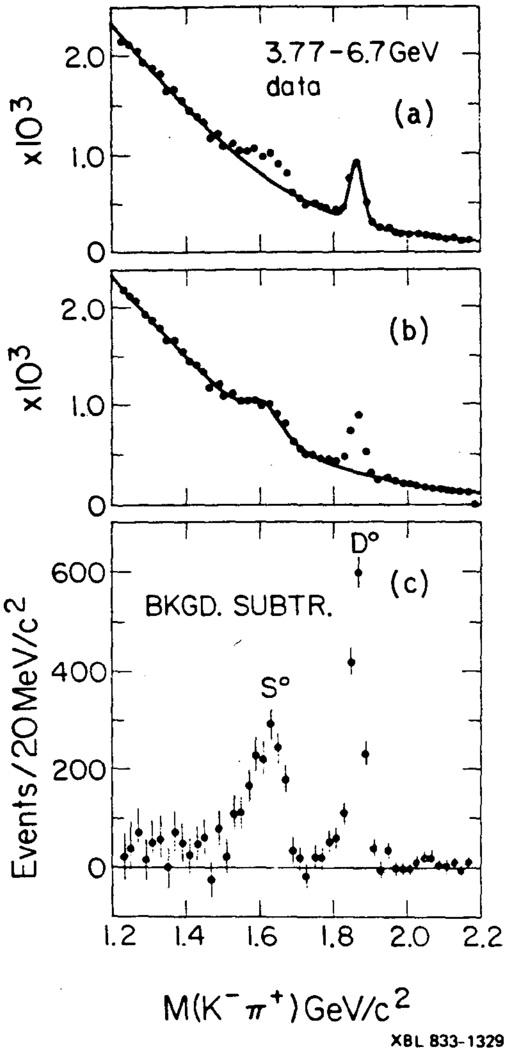


Fig. 4.23

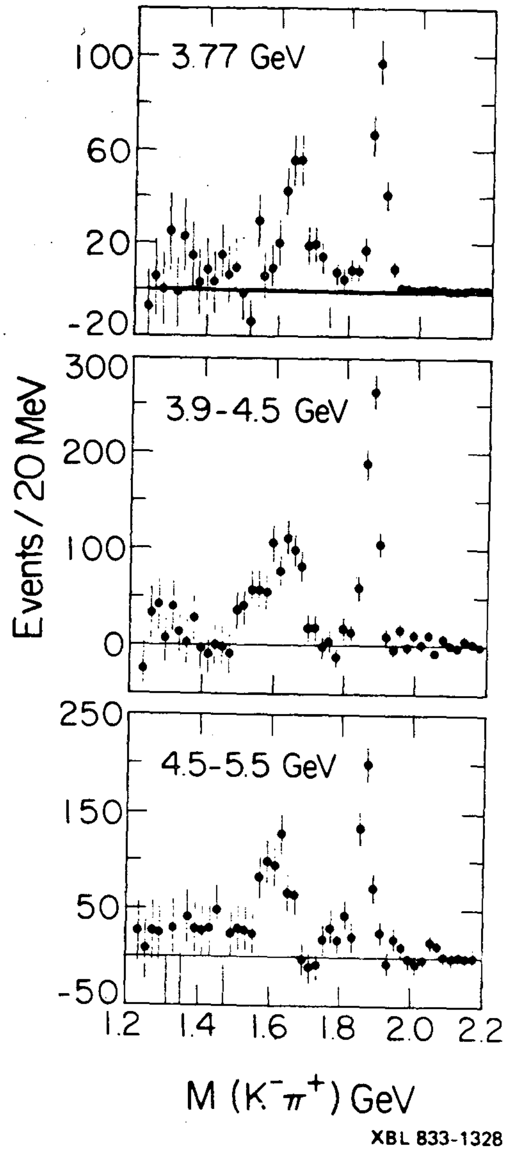
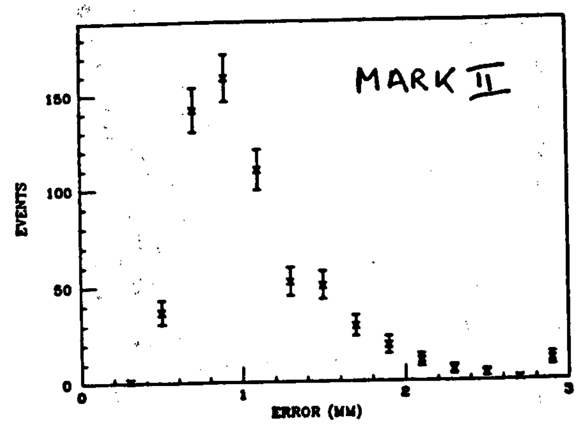
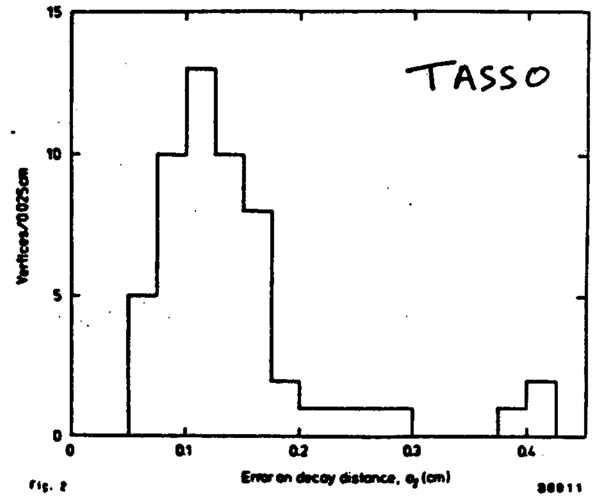


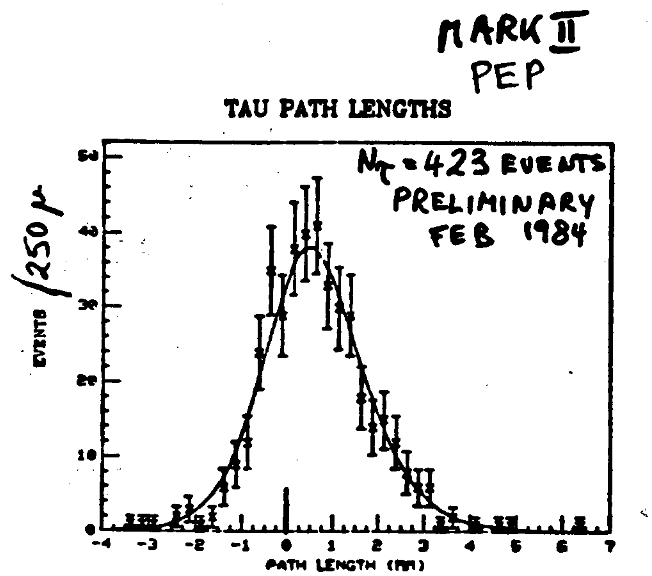
Fig. 4.24

Fig.4.23 The D° resonance and S° enhancement. The signals correspond to 1340 D° events and 1470 S° events. The S° signal thus more then doubles the number of charm tags for the $K^-\pi^+$ decay mode. (a) The curves is a fit to background and the D° signal. (b) The curve is a fit to background and the S° signal. (c) The data with background (as determined from the above fits) subtracted. Mark II at SPEAR.

Fig.4.24 The D° and S° signals for 3 energy regions as noted with background subtracted. Mark II at SPEAR.







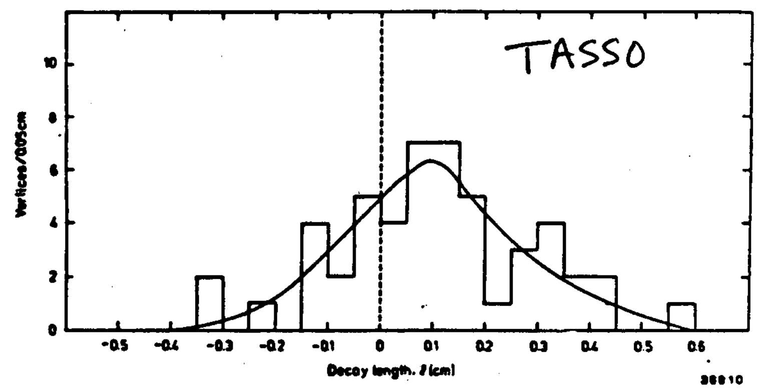
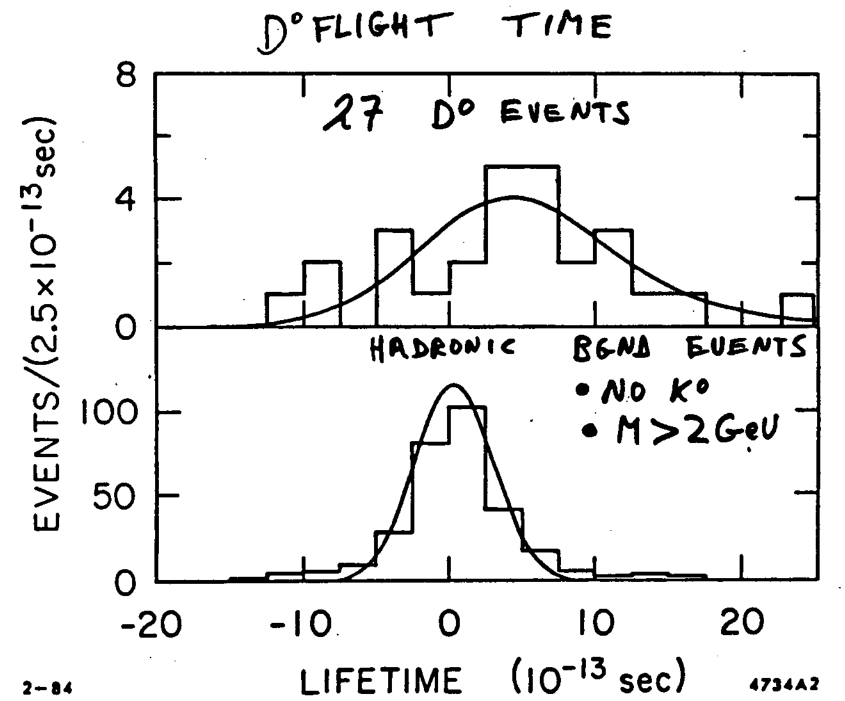


Fig. 4.33 τ path length errors. TASSO

Fig. 4.34 τ path length measurements. TASSO

Fig. 4.31 τ - path length errors. MARK II.

Fig. 4.32 τ - path length measurements. MARK II.



$\tau_{D^0} = (4.2^{+1.3}_{-1.0} \pm 1.0) \times 10^{-13}$ sec

Fig. 4.35

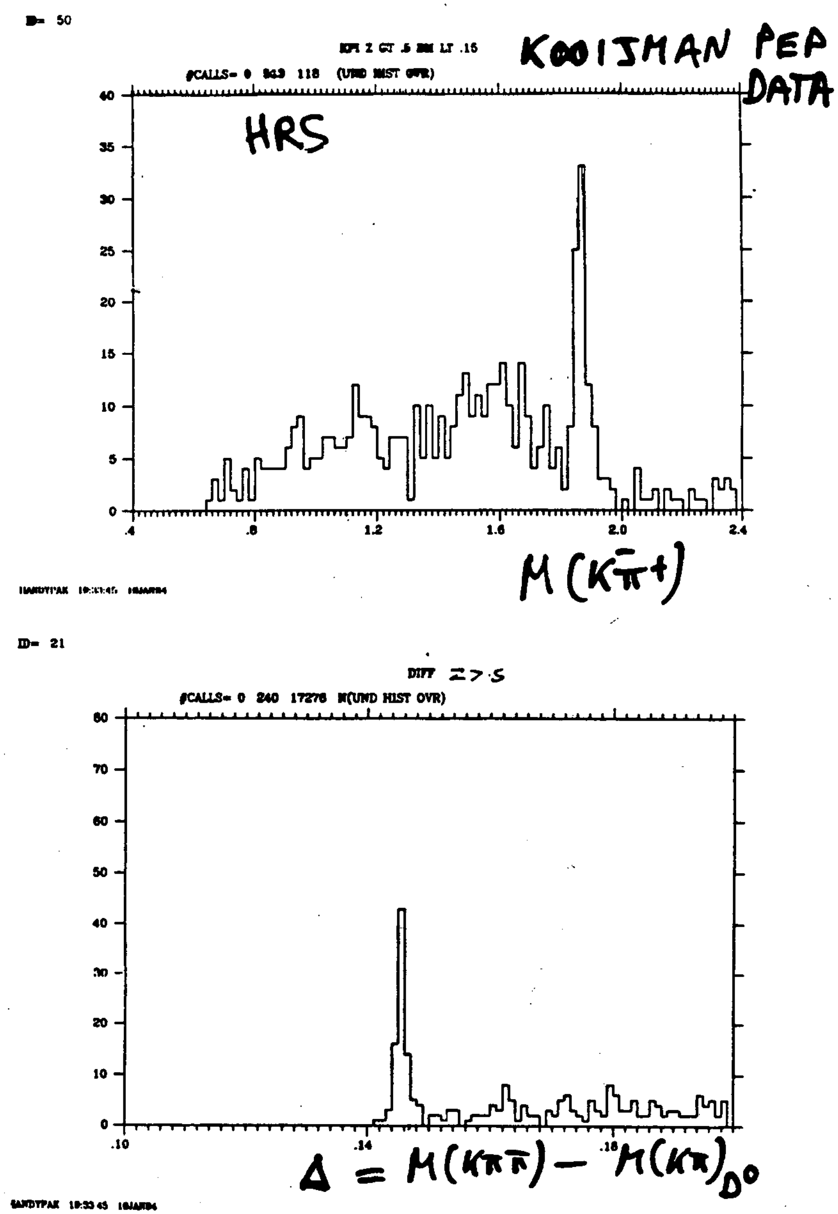


Fig. 4.41

Fig. 4.35 D^0 flight time distribution and distribution for background events.

Fig. 4.41 D^0 signal and mass difference signal from HRS at PEP. Note that high resolution is very valuable!

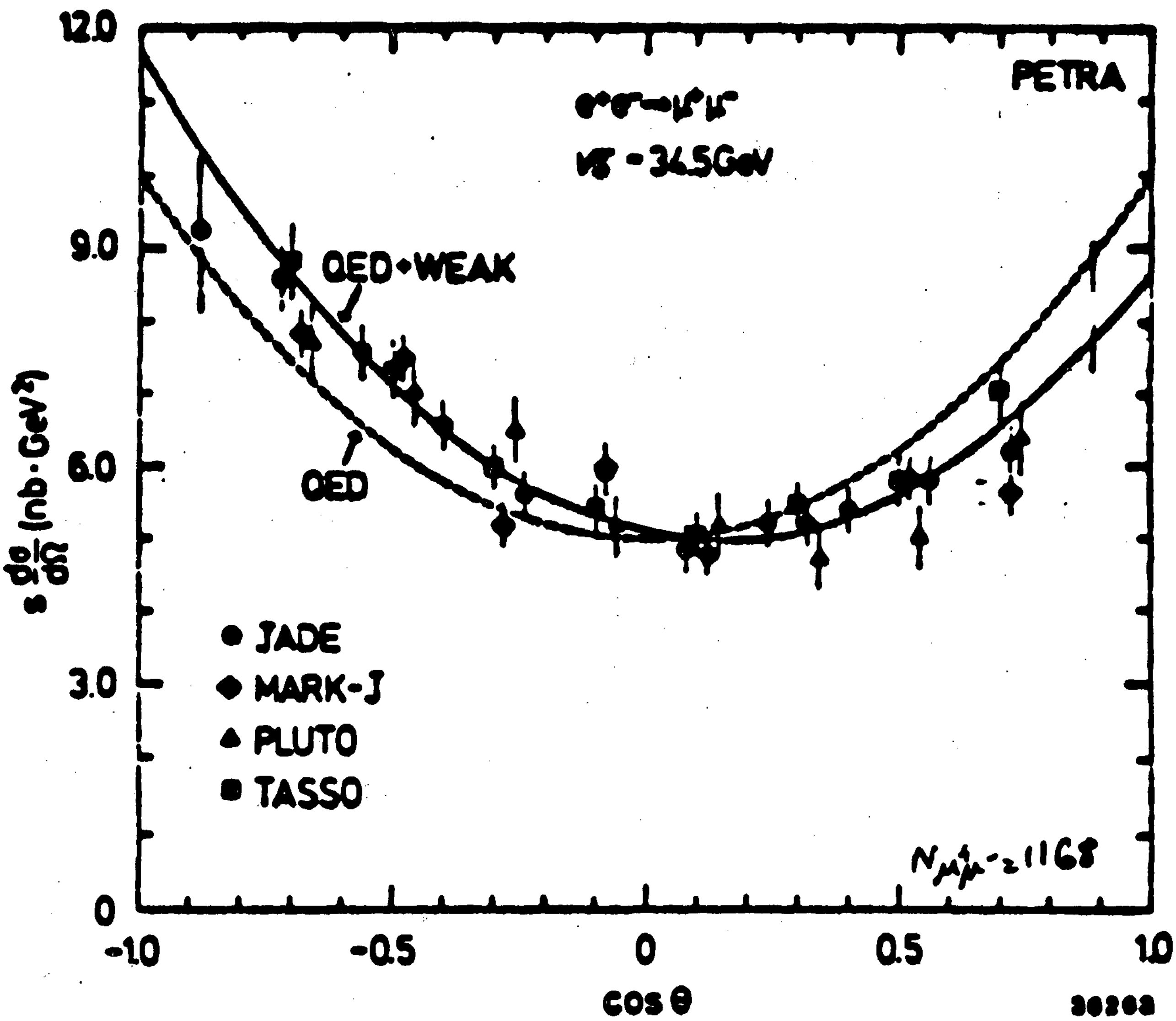


Fig. 4.42 Asymmetry in μ pairs. Combined data from PETRA groups. $A\mu\mu$ = (-10.8 ± 1.1)% at $\sqrt{S}$ = 34.5 GeV.

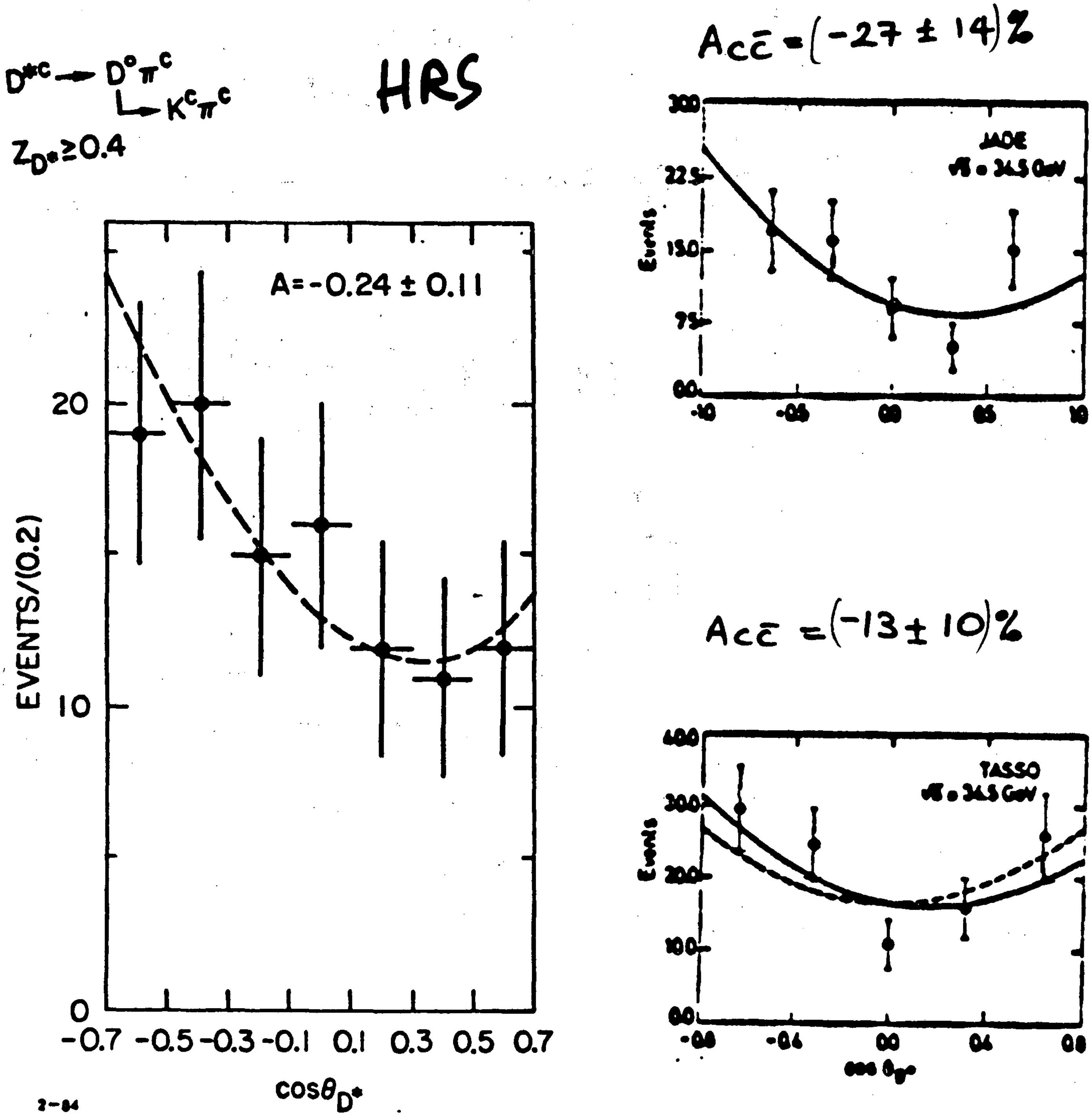


Fig. 4.43 Asymmetry due to Electroweak interference in D^* production. HRS and JADE and TASSO.

4.2 Charmed meson studies with the Mark III detector at SPEAR

J. Hauser reported new D° and D^+ data obtained at the Ψ'' resonance. In particular he showed preliminary results on the Cabibbo suppressed D° decays. $D^\circ \to K^+K^-$ and $D^\circ \to \pi^+\pi^-$ and confirmed the earlier Mark II results that the former decay rate is considerably larger than the latter. He also showed a $D^\circ \to K^-\pi^+\pi^\circ$ Dalitz plot which shows strong and highly aligned ρ^+ production. This confirms the assumption for the origin of the charmed meson Satellite peak ($S^\circ \to K^-\pi^+$, $M \simeq 1.61$ GeV $\Gamma \sim 0.12$ GeV) I presented at the 1983 Moriond Conference (G1)--namely, that it is an enhancement that occurs due to the combination of the K^- with the π^+ from a highly aligned ρ^+. See Figs. 4.21-4.24.

4.3 τ and D° lifetime studies with vertex chambers

J. Yelton reported on results from the Mark II detector at PEP giving a preliminary value of the τ lifetime of

$$\tau_\tau = (2.81 \pm 0.24 \pm 0.30) \times 10^{-13} \text{ sec}$$

based on 423 events. He also reported a new TASSO result of

$$\tau_\tau = (3.18 \pm ^{0.59}_{0.75} \pm 0.56) \times 10^{-13} \text{ sec}$$

based on about 50 events. Furthermore, he quoted a Mark II result on the D° lifetime

$$\tau_{D^\circ} = (4.2^{+1.3}_{-1.0} \pm 1.0) \times 10^{-13} \text{ sec}$$

based on 27 events identified via the $D^{*+} \to D^+\pi^\circ$ decay with $Z(D^*) > 0.6$. See Figs. 4.31-4.35.

4.4 Electroweak interference effects

P. Kooijman from PEP and C. Youngman from PETRA reported on interference results for $\mu^+\mu^-$, $\tau^+\tau^-$ and $c\bar{c}$ pairs. See Figs. 4.41-4.43.

4.5 New $\sin^2\Theta_W$ determinations and compilations

C. Geweniger and Van der Bij gave compilations and comparisons of $\sin^2\Theta_W$ determinations from both high and low energy experiments. They emphasized the importance of understanding the radiative corrections in comparing such results. A. Böhm showed that by using the now known Z mass, consistent and fairly accurate $\sin^2\Theta_W$ values can be obtained from the electroweak asymmetry measurements mentioned above (4.4), $\sin^2\Theta_W = 0.18 \pm 0.02$ with $M_Z = 93 \pm 2$ GeV. See Folio 4.51, Figs. 4.51-4.53, and Table 4.51.

4.6 K-M matrix element determinations

C. Jarlskog gave a very beautiful and colorful description of the Kobayashi-Maskawa mixing matrix and considered the possible extension to more than 6 quarks. K. Kleinknecht gave a detailed evaluation of the absolute value of the matrix elements from the experimental input. This entire subject has been explored in great detail at the Erice Conference on Flavor Mixing in Weak Interactions organized by Ling-Lie Chau (C1). See Table 4.61.

5. Plans, construction and work in progress

5.1 ν astronomy

The large proton decay experiments are also starting to study ν astronomy--by studying upwards produced muons--and ν oscillations (J. Van der Velde for IMB and P. Galleotti for NUSEX). Furthermore, a new 1 Kton high resolution detector is under construction in the FREJUS tunnel (C. Longuemare).

Folio 4.51 Equations for $\sin^2\Theta_W$ evaluations.

Measurement of $\sin^2\vartheta_W$ from $e^+e^- \to \mu^+\mu^-$

A. Böhm DESY+Aachen

Cross-section:

$$R_{\mu\mu} = \frac{\sigma_{\mu\mu}}{\sigma_{pt}} = 1 - 2\chi\, g_V^e g_V^\mu + \ldots$$

where $\sigma_{pt} = \dfrac{4\pi\alpha^2}{3s}$

$$g_V^e \cdot g_V^\mu = \frac{1}{4}\left(1 - 4\sin^2\vartheta_W\right)^2 \qquad SU(2)_L \times U(1)$$

$$\chi = \frac{1}{4\sin^2\vartheta_W\cos^2\vartheta_W}\,\frac{s}{m_Z^2 - s} = \frac{\rho G_F\, m_Z^2}{2\sqrt{2}\,\pi\alpha}\,\frac{s}{m_Z^2 - s}$$

Asymmetry:

$$A_{\mu\mu} = -\frac{3}{2}\chi\, g_A^e g_A^\mu + \ldots$$

where $g_A^e \cdot g_A^\mu = \frac{1}{4}$ in $SU(2)_L \times U(1)$

Two methods to determine $\sin^2\vartheta_W$:

2 parameters $\sin^2\vartheta_W$ and m_Z	3 (2) parameters $\sin^2\vartheta_W$ and ρ
⇓	$m_Z = \dfrac{1}{\rho}\,\dfrac{\pi\alpha}{\sqrt{2}\,G_F}\,\dfrac{1}{\sin^2\vartheta_W\cos^2\vartheta_W}$
independent of ρ	⇓
m_Z is measured ⇒	very weekly dependent of m_Z
measure $\sin^2\vartheta_W$ from $A_{\mu\mu}$ (and $R_{\mu\mu}$)	$A_{\mu\mu}$ independent of $\sin^2\vartheta_W$; measure $\sin^2\vartheta_W$ from $R_{\mu\mu}$

Table 4.51 $\sin^2 \Theta_W$ and ρ evaluations.

Measurements of $\sin^2\vartheta_W$ and ρ — Böhm

Reaktion	$\sin^2\vartheta_W$	ρ	remarks
νN	0.220 ± 0.015 (exp.) ± 0.010 (theor.)	ρ = 1	Ch. Geweniger rad. corr. incl.
	0.232 ± 0.027	0.999 ± 0.025	Kim et al. no rad. corr. $\Delta\sin^2\vartheta_W \approx -0.01$
e-d	0.224 ± 0.020	ρ = 1	no rad corr. $\Delta\sin^2\vartheta_W \approx -0.007$
	$0.293 \pm^{0.033}_{0.100}$	1.74 ± 0.36	"
	0.216 ± 0.008 (stat.) ± 0.008 (syst.)	independent	for $m_Z = 93 \pm 2$ GeV no rad. corr.
μ-C	0.23 ± 0.07 ± 0.04	ρ = 1	only QED rad. corr.
CHARM * ν_μ-e, $\bar{\nu}_\mu$-e	0.215 ± 0.04 ± 0.015	1.12 ± 0.12 ± 0.11	no rad. corr.
$e^+e^- \to \mu^+\mu^-$ PETRA + PEP	0.18 ± 0.02	independent	for $m_Z = 93 \pm 2$ GeV el. w. rad. corr. incl.
	≈ 0.3 ± 0.1	1.08 ± 0.08 (exp) ± 0.03 (theor)	using G_F, α rad. corr. included
UA1	0.226 ± 0.008 ± 0.014	independent	from $\sin\vartheta_W = \frac{38.5\ \text{GeV}}{m_W}$
UA2	0.218 ± 0.010 ± 0.007		
Combined	0.221 ± 0.010		
UA1		0.925 ± 0.050	$\rho = \frac{m_W^2}{m_Z^2 \cos^2\vartheta}$
UA2		1.013 ± 0.050	
combined		0.97 ± 0.04	

* Also BNL LANOU PRELIM RESULT

Radiative Corr Van der Bij

GEWENIGER

Fig. 4.51 Compilation of $R_{\bar{\nu}}$ vs. R_ν yielding $\sin^2\Theta_W$ values (Geweniger).

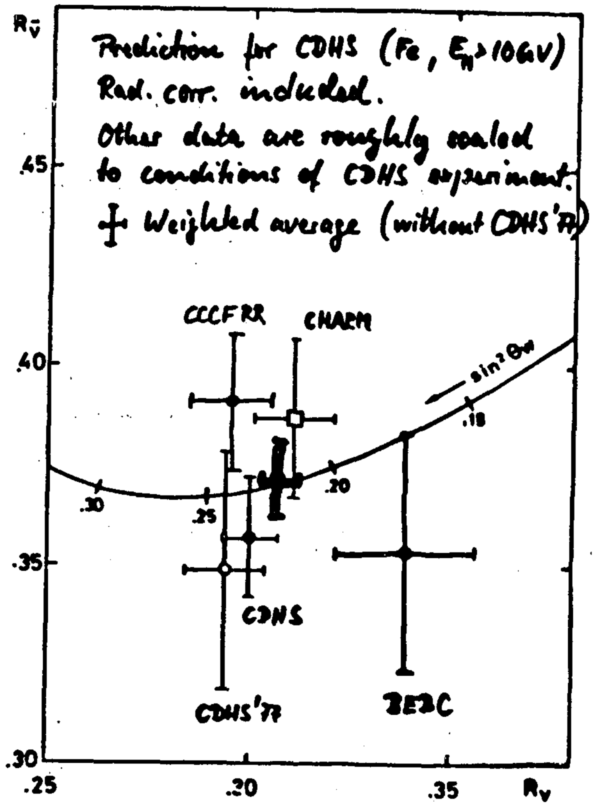
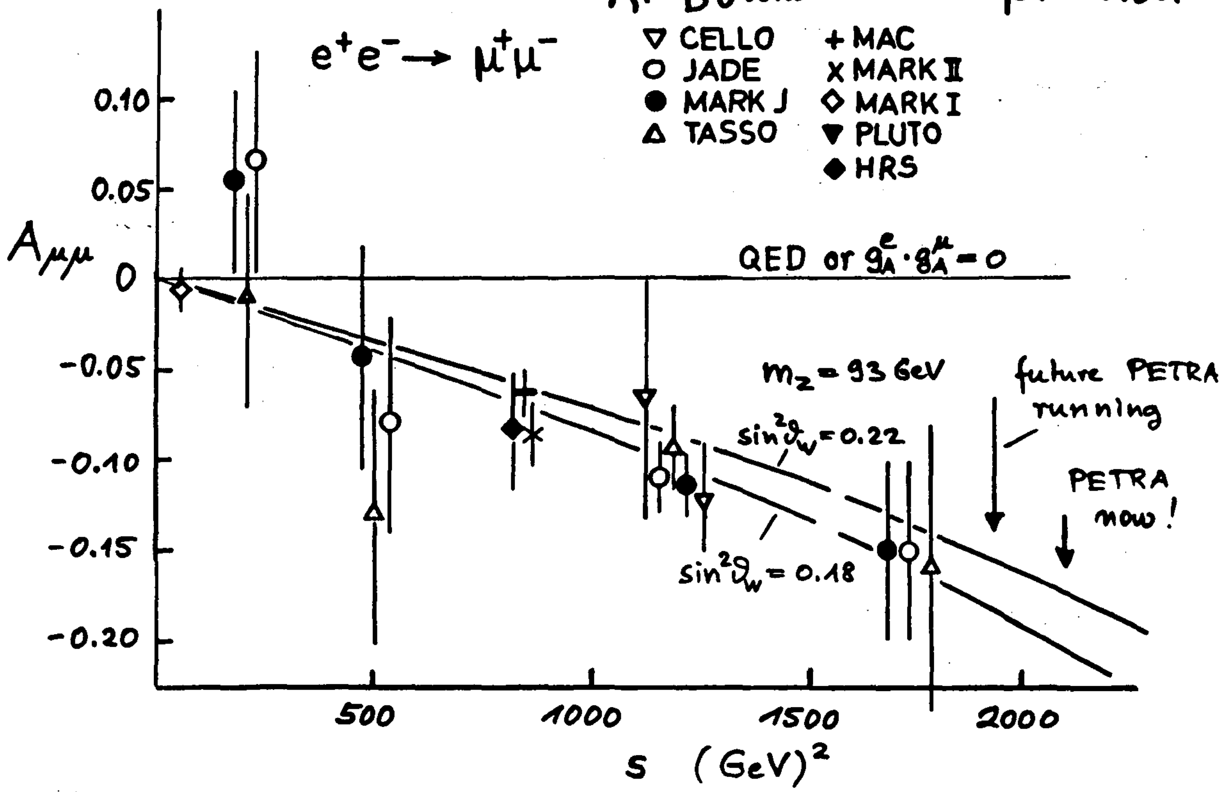


Fig. 4.52 Compilation to asymmetry measurements in $e^+e^- \to \mu^+\mu^-$. Fit by A. Böhm using M_Z value.

$$R_\nu = \frac{\sigma(\bar{\nu}N \to \bar{\nu}X)}{\sigma(\bar{\nu}N \to \mu^- X)}$$

A. Böhm Compilation



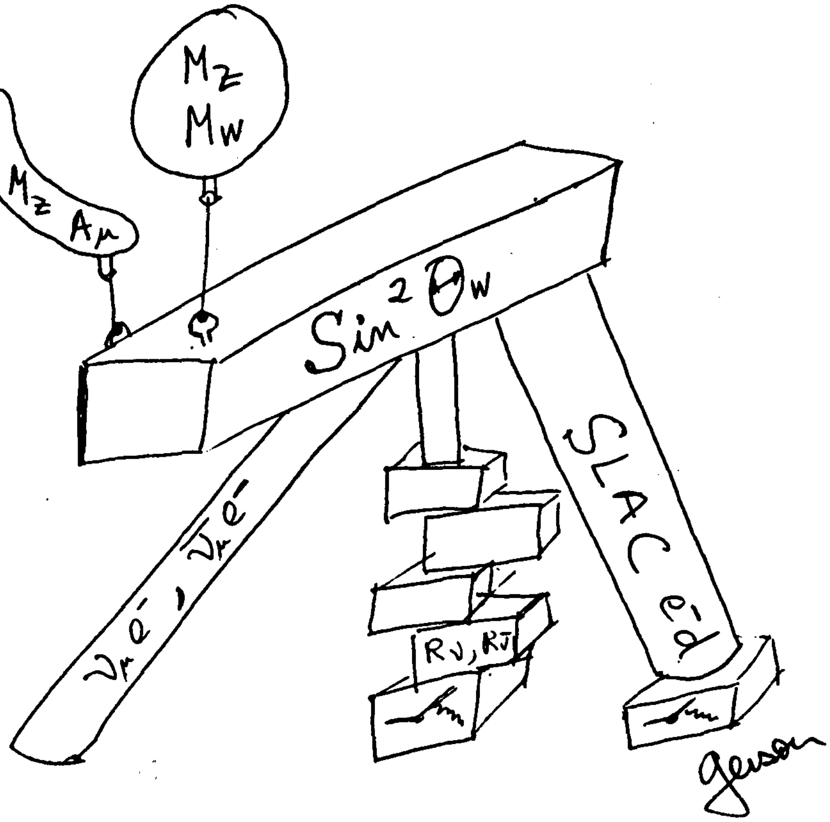


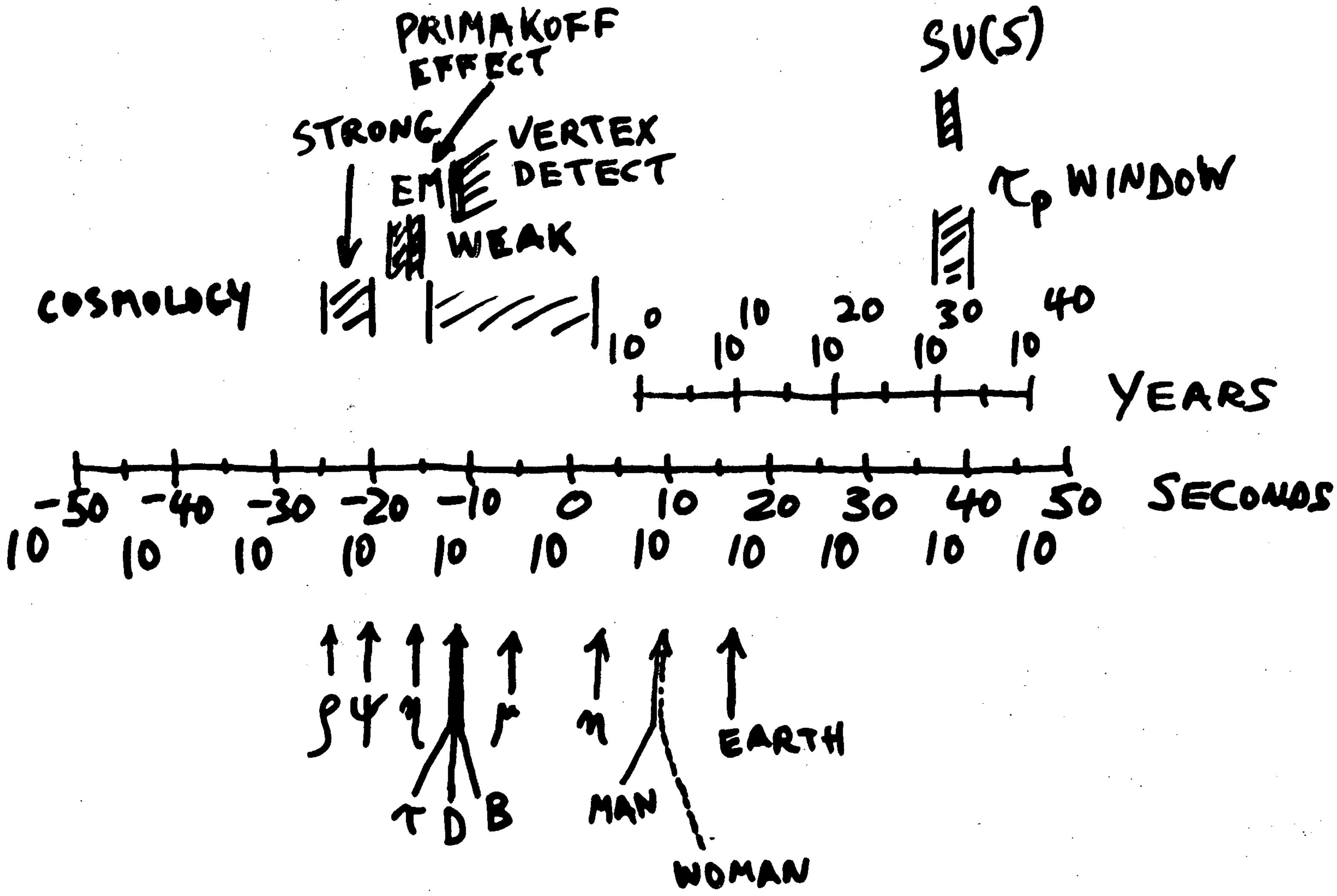
Fig. 4.53 The $\sin^2 \Theta_w$ "edifice".

Table 4.61 Evaluation of the Kobayashi Maskawa Matrix

KLEIN KNECHT COMPILATION

Elements of quark mixing matrix $|U_{ik}|$ from fit of experimental constraints (1 standard deviation range)

	d	s	b
u	0.9723 - 0.9737	0.228 - 0.234	0.000 - 0.008
c	0.228 - 0.234	0.9704 - 0.9726	0.042 - 0.067
t	0.003 - 0.016	0.041 - 0.066	0.9977 - 0.9991



Concluding figure. The time scales discussed at this conference.

5.2 New work on $\sin^2\Theta_W$ determination

New improved $\nu_\mu e$ and $\bar{\nu}_\mu e$ measurements are in progress to deduce $\sin^2\Theta_W$ in purely leptonic reactions (R. Lanou for BNL work and Niebergal for CHARM II). Also a new type of Čerenkov detector is being designed and tested for such an experiment (J. Feltesse).

Conclusion

The year 1983 was a great year for particle physics in general and for CERN in particular. Thanks to this, and last but not least, thanks to the weather, Moriond 1984 was a great conference!

I will end with a quote from Maurice Goldhaber:

> We are looking for proton decay and neutron oscillations. What we know so far for sure is that the neutron decays and the proton does not oscillate.

Acknowledgment

I am very grateful to Dr. J. Tran Thanh Van for providing a hospitable and stimulating environment at La Plagne for preparing and presenting my summary talk. I wish to thank Mme Francine Le Fèvre for help in compiling my transparencies and Mrs. Marian Golden and Ms. Valerie Heatlie for their efforts and help in producing this manuscript.

References

Whenever the name of a speaker is given without further reference, I am referring to a paper presented at this conference and reproduced in this volume.

C1. Ling-Lie Chau, Conference Chairman, "Ettore Majorana" Center, A. Zichichi, Director, Topical Conference on Flavor Mixing in Weak Interactions, March 4-11, 1984.

F1. E. Fernandez et al., Phys. Rev. Lett. *51*, 1022 (1983).

G1. G. Goldhaber, p. 137, XIIXth Rencontre de Moriond, J. Tran Thanh Van, editor, "Beyond the Standard Model". 1983 Editions Frontières, France.

L1. N.S. Lockyer et al., Phys. Rev. Lett. *51*, 1316 (1983).

M1. XIX Rencontre de Moriond. Conference on New Particle Production at High Energies. 1984 Companion Volume.

PDG1. Review of Particle Properties, Rev. Mod. Phys. *56*, Part II (1984).

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