Presented at "The Flaine Meeting on Storage Ring Physics", Feb. 22-28, 1976

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G. Bellettini: THE FLAINE MEETING ON STORAGE RING PHYSICS. CONCLUSIONS.

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THE FLAINE MEETING ON STORAGE RING PHYSICS
February 22-28, 1976

CONCLUSIONS

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Abstract: A number of results presented at the Meeting are summarized. The following topics are covered: 1) New particles from $e^{+}e^{-}$ storage rings; 2) Hadron production of J/ψ and e/π ratio, and possible 6 GeV particle at FNAL; 3) $\mu^{+}\mu^{-}$ and $\mu^{-}e^{+}V^{o}$ events from ν_{μ} beams and charm searches; 4) Hadron jets in $e^{+}e^{-}$ and pp collisions.

I will summarize data that are in part new or that I found particu larly interesting. I will cover the following items:

1 - New particles from e^+e^- storage rings;

2 - Hadron production of J/ψ and e/π ratio, and possible 6 GeV particle at FNAL;

3 - $\mu^+\mu^-$ and $\mu^-e^+V^o$ events from ν_μ beams and charm searches;

4 - Hadron jets in e^+e^- and pp collisions.

1. - e^+e^- DATA. -

1.1. - Region of the "new physics" ($3.9 \lesssim E_{c.m.} \lesssim 4.6$ GeV) at SPEAR. - (reported by R.F. Schwitters).

A new energy scan of σ_h at SPEAR between the $\psi'(3684)$ and $E_{c.m.} = 3.9$ GeV has shown that there is no new narrow structure with $\sigma \cdot \Gamma \gtrsim 100$ nb x MeV.

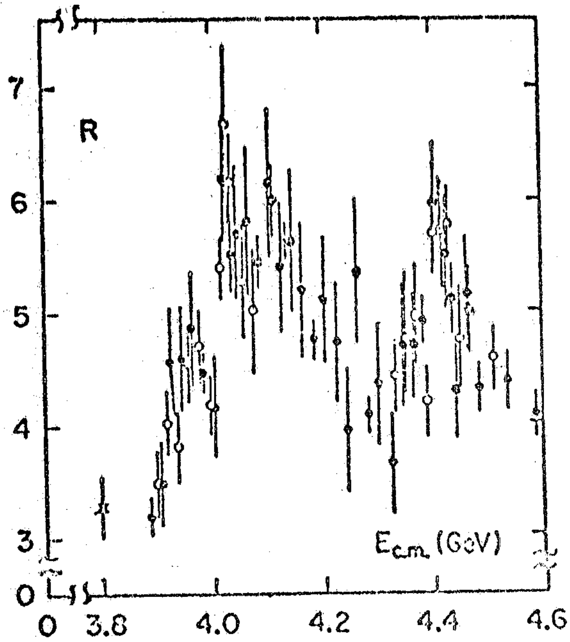


FIG. 1

In the region $3.9 \lesssim E_{c.m.} \lesssim 4.6$ GeV new data have been collected (Fig. 1, open circles) which confirm the existence of the following structures:

- A peak at ~ 3.95 GeV;
- a possible peak at ~ 4.05 GeV;
- a possible peak at ~ 4.11 GeV;
- a peak at 4.41 GeV, which is so clearly separated to be called by the authors $\psi(4414)$.

The Breit-Wigner fit to $\psi(4414)$ is shown in Fig. 2 and the resonance parameters are listed in Table I. Notice that $\psi(4414)$ has full width over 100 times that of $\psi'(3684)$ but its coupling Γ_{ee} to e^+e^- pair is only 1/5 of the ψ'.

Dispite these structures, $\langle n_{ch} \rangle$ and $\langle p_{obs} \rangle$ vary smoothly in the region $3.8 < E_{c.m.} \lesssim 4.6$ GeV (Fig. 3).

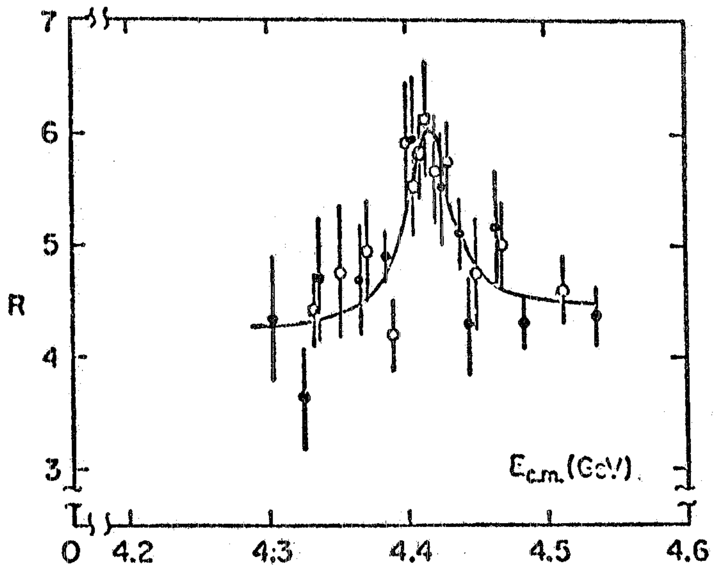


FIG. 2

TABLE I - Resonance parameters for ψ's.

STATE	$J/\psi(3095)$	$\psi'(3684)$	$\psi(4414)$
MASS (MeV)	3095 ± 4	3684 ± 5	4414 ± 7
Γ(MeV)	0.069 ± 0.015	0.228 ± 0.056	33 ± 10
Γ_{ee}(keV)	4.8 ± 0.6	2.1 ± 0.3	0.44 ± 0.14
B_{ee}	0.069 ± 0.009	0.0093 ± 0.0016	$(1.3 \pm 0.3) 10^{-5}$

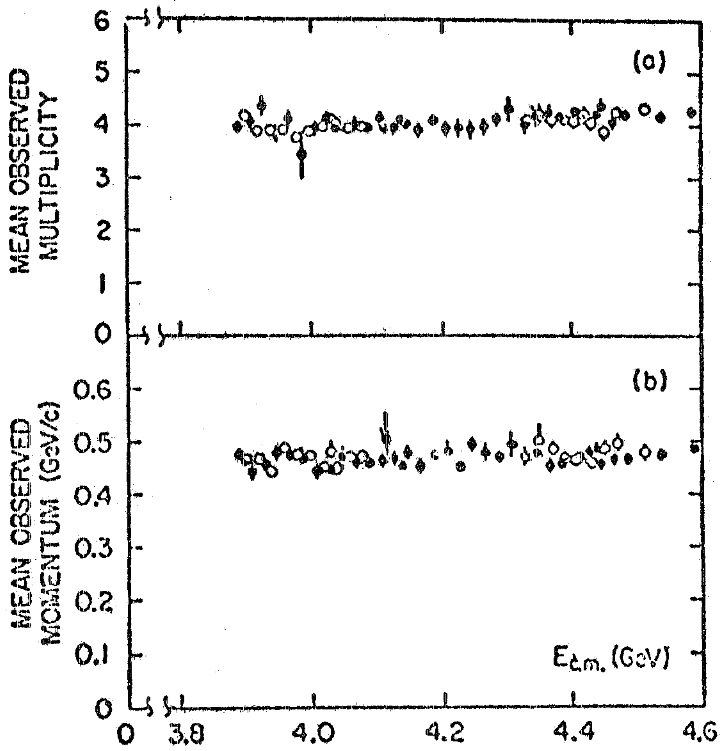


FIG. 3

1.2. - Search for the 6 GeV particle at SPEAR. -

(reported by R. F. Schwitters).

Because of the indications for a new particle Y decaying into e^+e^-, with mass ~ 6 GeV, found at FNAL (see later), an accurate energy scan was made at SPEAR in the region

$$5.8 \lesssim W \lesssim 6.04 \text{ GeV}$$

(up to the date of this Conference).

No narrow structure was found as seen in Fig. 4. The maximum magnitude of any possible signal below the "waves" in this data is of the order of 100 nb x MeV (to be compared to the ψ' signal $\int \sigma_{\psi'} dW \sim$ ~ 5000 nb x MeV).

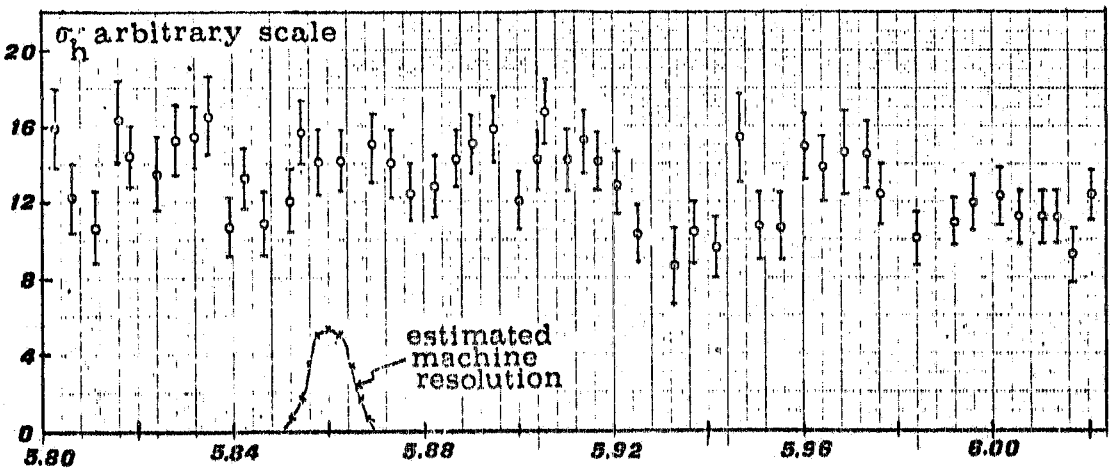


FIG. 4

1.3. - The μe events at SPEAR. -

(reported by M. Perl - see also P.R.L. 35, 1489 (1975).

The definition of μe events from the process

$$e^+ + e^- \rightarrow \mu^{\pm} + e^{\mp} + \text{missing energy}$$

is:

a) No other charged particles or photons detected;

b) $P_e > 0.65$ GeV/c, $P_\mu > 0.65$ GeV/c ;

c) $\theta_{copl} \geq 20^o$.

The cross section for these μe events is given in Fig. 5 as a function of $E_{c.m.}$.

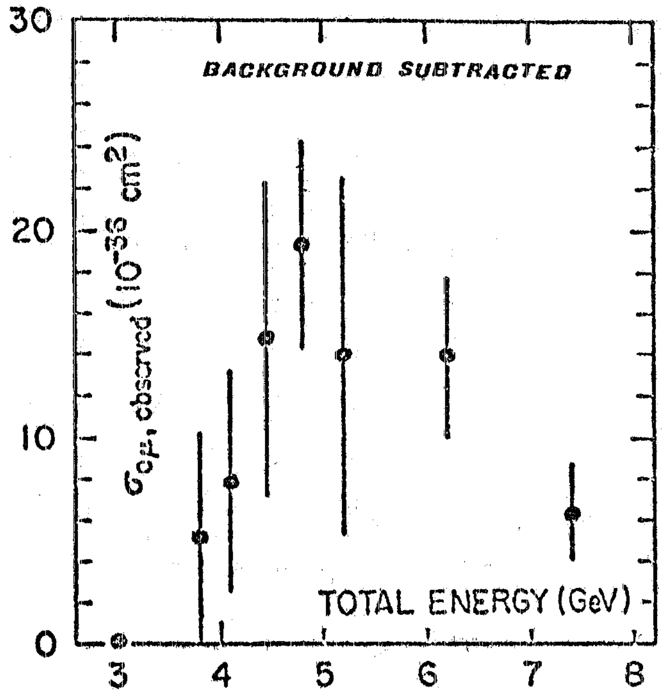


FIG. 5

The new data give a better definition of the threshold. More events were obtained as shown in Fig. 6.

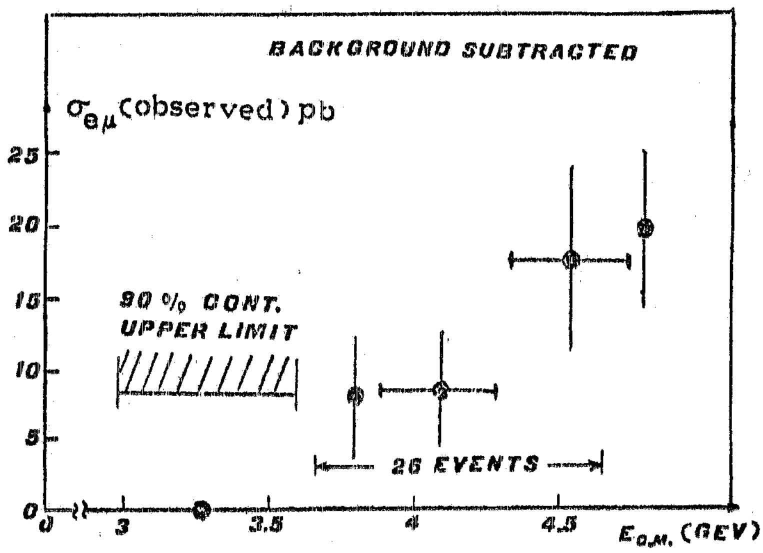


FIG. 6

These events are tentatively interpreted to be due to pair production of new particles

$$e^+e^- \rightarrow U^+U^- .$$

Since mass of U $\approx$ $E_{c.m.}$ threshold/2, one estimates

$$1.6 \leq M_U \leq 2.0 \quad \mathrm{GeV}/c^2 .$$

The momentum spectrum of leptons shows that the decay of U's is not likely to be two-body. This is shown in Fig. 7. The variable ρ is

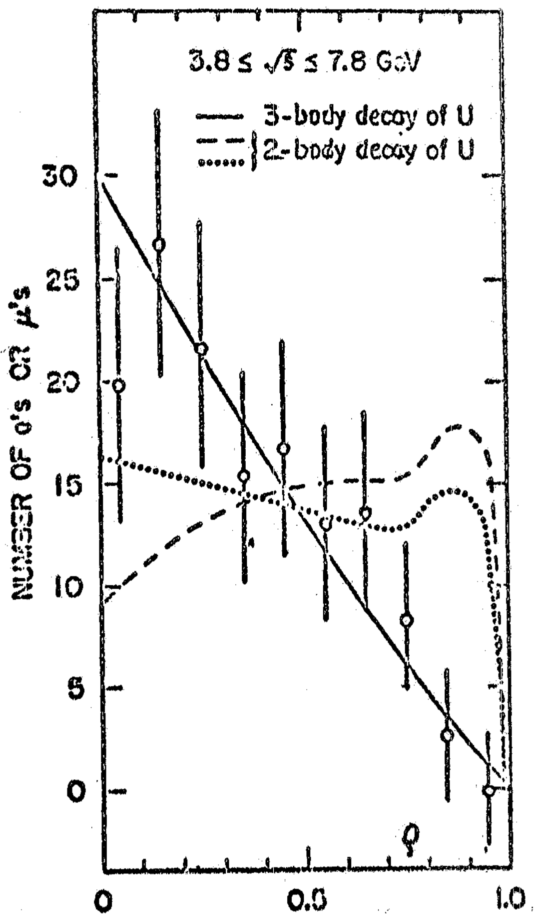


FIG. 7

$\frac{p - 0.65}{p_{max} - 0.65}$, when p, p_{max} are in GeV/c and 0.65 is the momentum cut. Expected distributions for two--body decay of U's (assumed mass 1.8 GeV) have been estimated with two different models.

To understand wether the U's are charmed mesons, they have searched for typical semi-leptonic hadron decays :

$$c \rightarrow e\,\nu_e (n\pi^0)$$
$$\rightarrow \mu\,\nu_\mu (n\pi^0)$$

by studying photons converted in the detector and found none. They concluded that < 9 % of μe events contain π^0's.

They have also searched for

$$c \rightarrow e\,\nu_e\,K^0_L$$
$$\rightarrow \mu\,\nu_\mu\,K^0_L$$

by looking for $e\,\mu\,K^0_S$ ($K^0_S \rightarrow \pi^+\pi^-$) events and found none. They concluded that < 5 % of the μe events contain K^0's.

One also finds that the μe events are not related to the rich structures that appear in the "new physics region". This is shown in Fig. 8. Alltogether, it seems unlikely that the U's are charmed mesons.

If U's are heavy leptons, since

$$e^+e^- \longrightarrow U^+ + U^-$$

$$U^- \longrightarrow \mu^-\bar{\nu}_\mu\nu_U, \quad e^-\bar{\nu}_e\nu_U$$

$$U^+ \longrightarrow e^+\nu_e\bar{\nu}_U, \quad \mu^+\nu_\mu\bar{\nu}_U$$

then one should also observe e^+e^- and $\mu^+\mu^-$ events, with

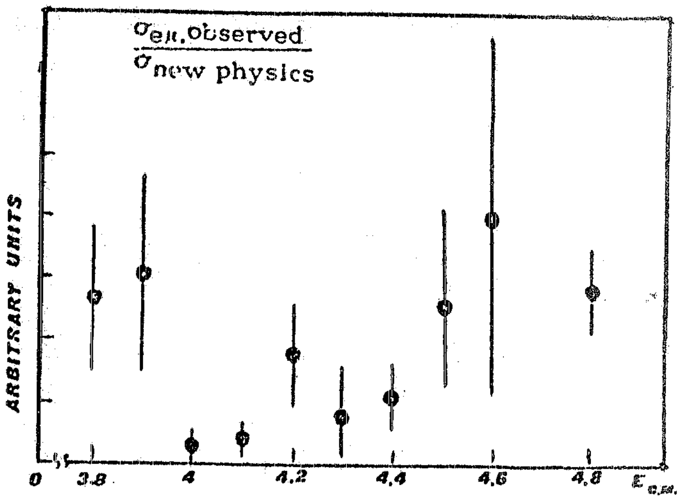


FIG. 8

$$\frac{e^+e^- \text{ events}}{e^\pm\mu^\mp \text{ events}} = 0.5\,, \qquad \frac{\mu^+\mu^- \text{ events}}{e^\pm\mu^\mp \text{ events}} = 0.5\,.$$

The data shown in Fig. 9 are consistent with this ratio 0.5.

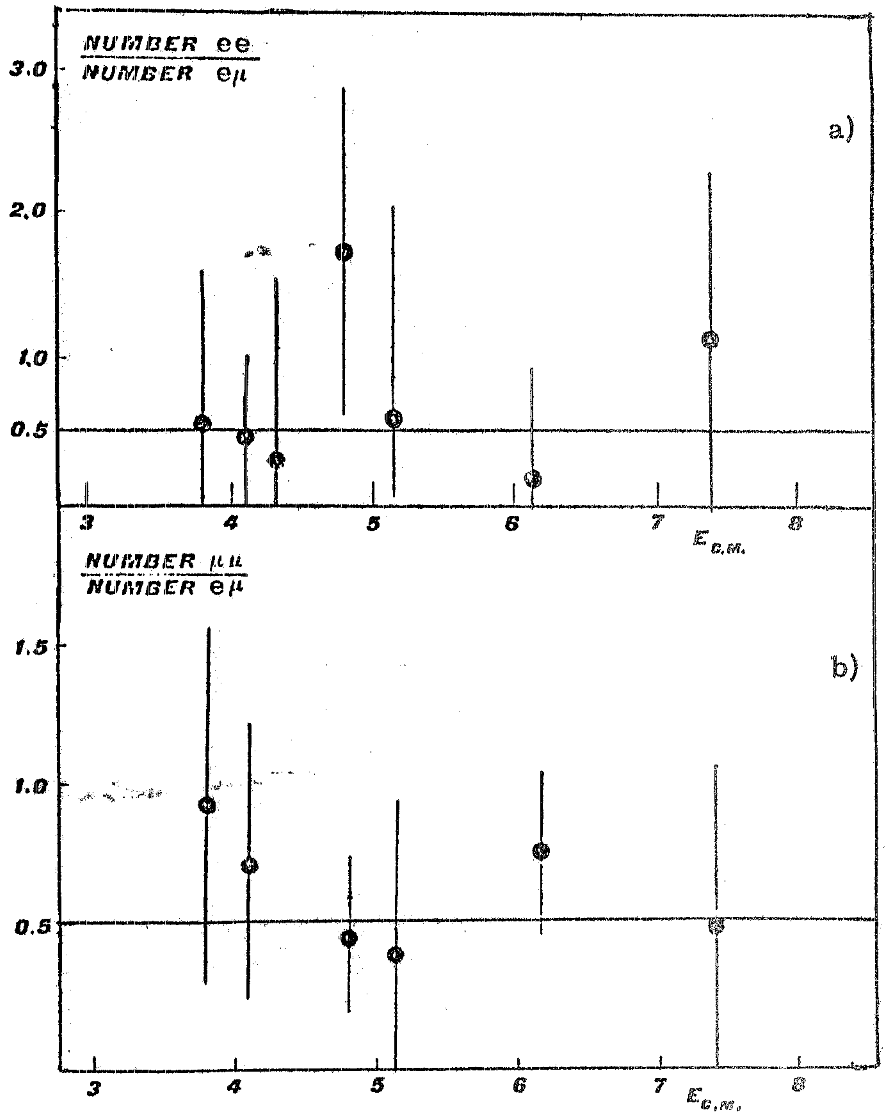


FIG. 9

Thus one interprets these events to come from heavy lepton production:

$$e^+ + e^- \rightarrow U^+ \quad U^-$$
$$U^- \rightarrow \nu_U + \mu^- + \bar{\nu}_\mu$$
$$U^+ \rightarrow \bar{\nu}_U + e^+ + \nu_e \; .$$

Out of the many(e μX) events, some could be due to inelastic production of U^+U^- pairs. The data are 715(e μ hadrons)found, with 646(e μ hadrons)expected background. The excess rate (69 events) cannot be taken as a signal for inclusive U^+U^- production, because the background calculations (based on a $\sim$ 20 % probability for hadrons to simulate either e or μ) have a $\pm$ 20 % systematic uncertainty.

However, with a μ-detector with clean μ-signature one can hope to isolate these events.

1.4. - μX events from the Princeton-Pavia-Maryland experiment at SPEAR. -

(reported by M. Cavalli Sforza).

The Princeton-Pavia-Maryland group detected at SPEAR one muon in the 90° spectrometer and one track in the central chambers, and found 13 non-coplanar events (see Fig. 10).

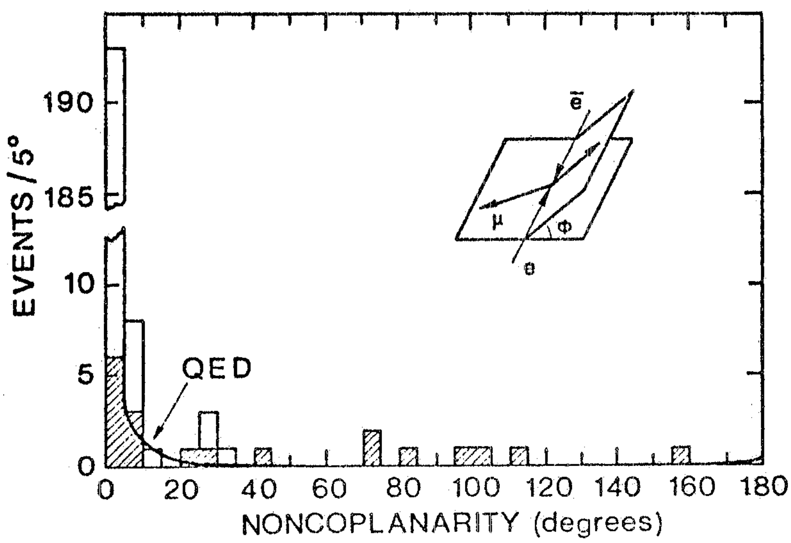


FIG. 10

13 events are observed with $\phi > 20^{\circ}$ where only ≈ 4 are expected (see Table II). The probability for this to be a statistical fluctuation is very small. One can derive the following cross-section:

$$\left.\frac{d\sigma(\mu X)}{d\Omega}\right|_{90^{\circ}} = 23^{+12}_{-9} \text{ pb/sr} \qquad (\varphi > 20^{\circ},\ p_{\mu} > 1.05 \text{ GeV/c}).$$

TABLE II - μX (X is 1 charged particle).

Expected No. of events ("Background")			
Hadron misidentification		Expected muons	
Hadron penetration	0.4	QED μ pairs	3.0
π, K decay	0.5	$e^+e^- \rightarrow e^+e^-\mu^+\mu^-$	---
Total	0.9	Total	3.0

From the $p_{\parallel}$ vs $p_{\perp}$ distribution of observed μ's (Fig. 11) one concludes

$$1.6 \lesssim \underset{\llcorner\!\rightarrow\ \mu + \cdots}{M} \lesssim 2.0 \text{ GeV.}$$

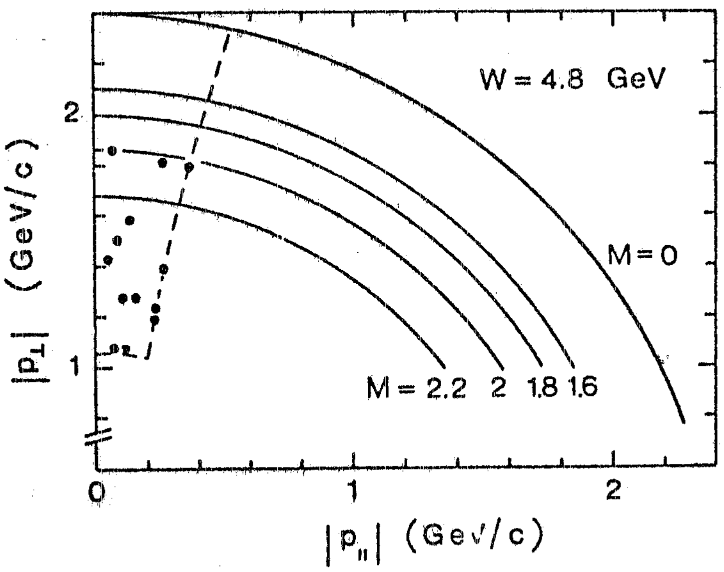


FIG. 11

In the figure the curves enclose the regions within which the representative points must lie, if the primary mass is as labeled. The p_{μ} distribution of events might favour M to be a lepton, but it is too early to say. It is hoped that future extended measurements will clarify wether these are the same μe events observed in the SLAC-LBL detector.

1.5. - J/ψ and ψ' decays leading to new states. -

(reported by E. T. Whittaker).

The SLAC-LBL group has chosen a ψ' data sample with even number of prongs and total charge zero, and has searched for the particular mass choice ($\pi\pi$, KK, $\pi\pi\pi\pi$, $\pi\pi$KK, $\pi\pi\pi\pi\pi\pi$, etc.) if anyone giving zero missing mass. By plotting the effective mass of the observed prongs for each sample, they found a number of structures. Although these structures are not fully consistent from one sample to another, one concludes that there is

	1 state at $E_{c.m.}$	$= 3.41$ GeV,
maybe	1 state at $E_{c.m.}$	~ 3.49 GeV,
maybe	1 state at $E_{c.m.}$	~ 3.55 GeV.

The $\pi\pi$, KK and 4π spectra are shown in Figs. 12 and 13. In this last figure the results from a similar analysis performed on a J/ψ sample is shown, which contains no evidence for structures. The branching ratio for

$$\psi' \rightarrow \gamma X(3.41) \;\; \llcorner\!\rightarrow \pi^+\pi^- \text{ or } K^+K^-$$

is $(6.5 \pm 1.8) \times 10^{-4}$, and for

$$\psi' \rightarrow \gamma X(3.41 \text{ or } 3.49 \text{ or } 3.55) \;\; \llcorner\!\rightarrow 4\pi^{\pm},\ 6\pi^{\pm},\ \pi^+\pi^-K^+K^-$$

is $\sim (0.1 \text{ to } 0.2) \times 10^{-2}$.

We recall that at DESY with DASP one has found decays of the type

$$\psi' \rightarrow \gamma + P_c \;\; \llcorner\!\rightarrow \gamma + J/\psi .$$

One possible solution (when γ_1 is emitted first) is that there are two P_c's with mass 3.51 and 3.42 GeV, as shown in Fig. 14. These may be related to the states found at SPEAR

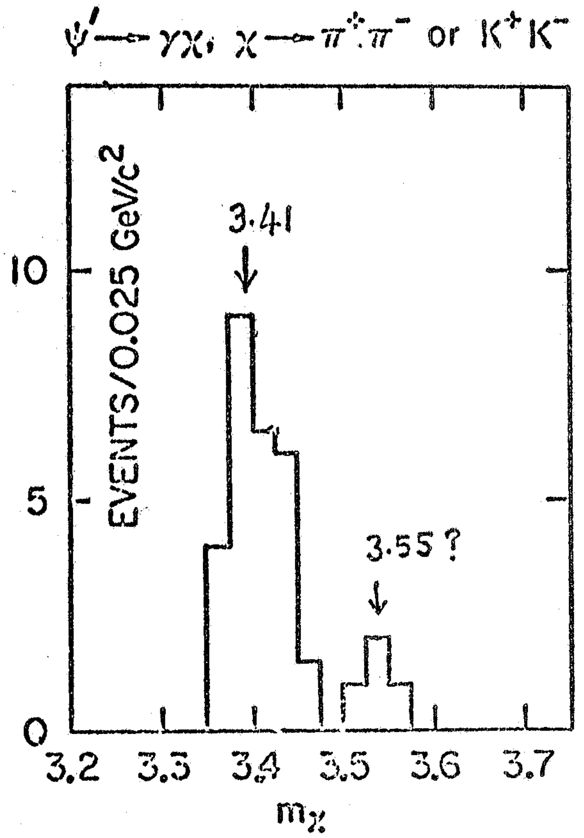


FIG. 12

as mentioned above.

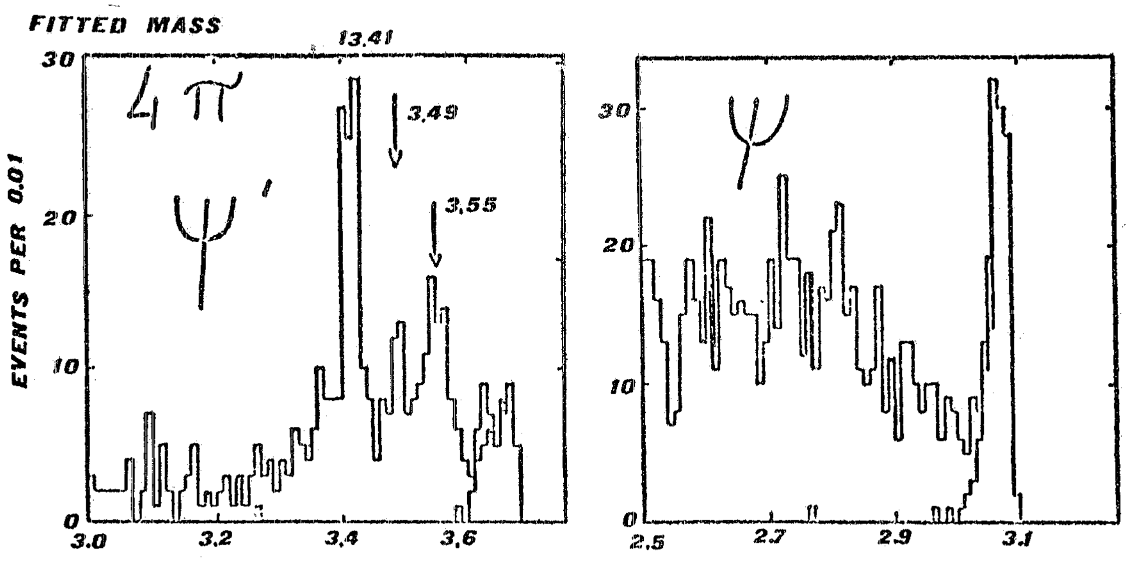


FIG. 13

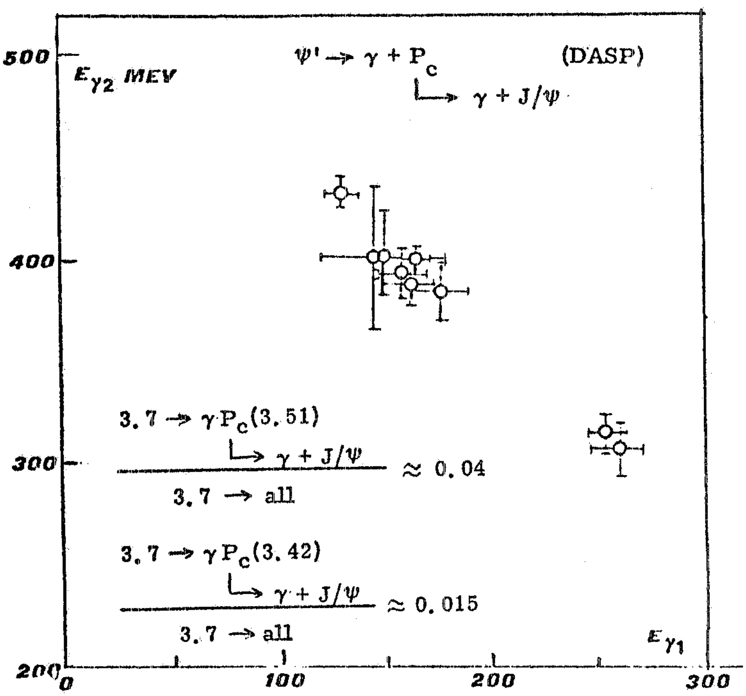
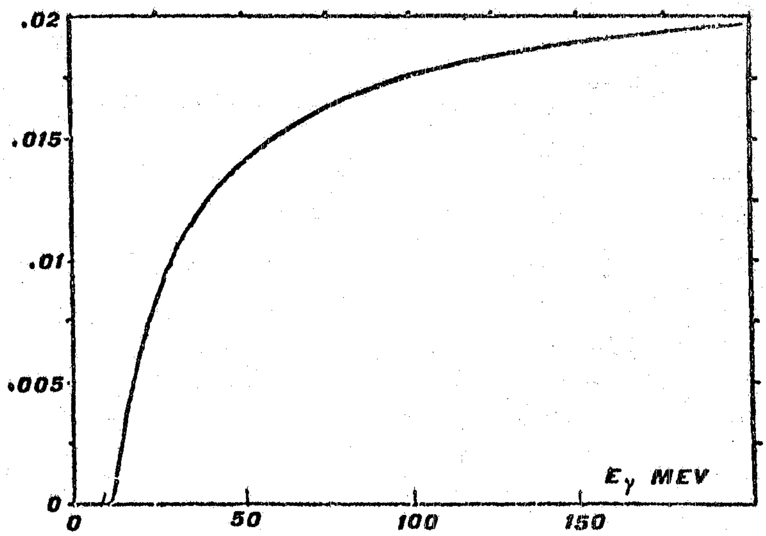


FIG. 14

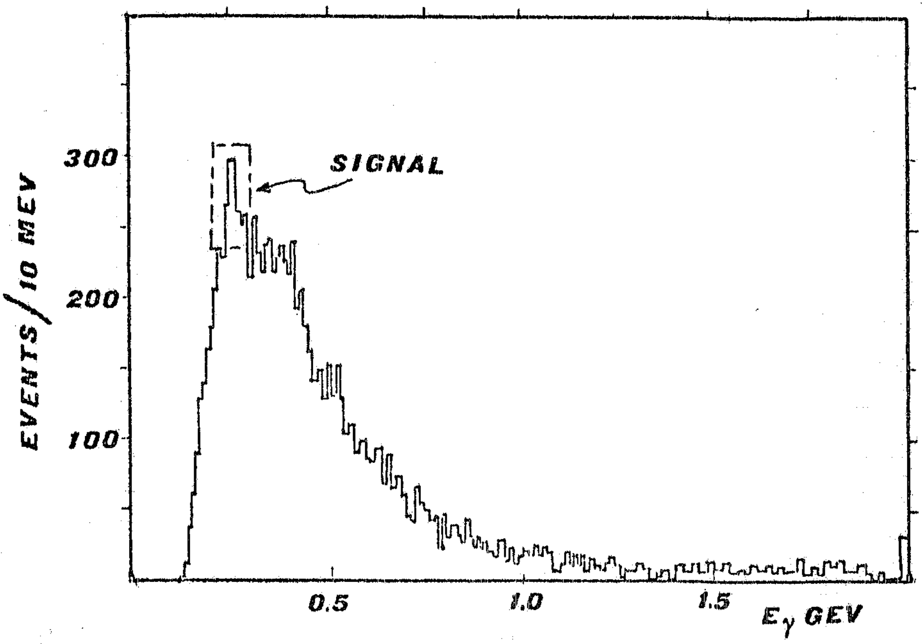
Only a few $\psi' \to$ hadron decay modes are reconstructed ($p\bar{p}, \Lambda\bar{\Lambda}$..) and $\sim 28\,\%$ are not understood. However, by studying the inclusive γ-spectrum from photons converted inside the detector with efficiency $\sim 2\,\%$ (see Fig. 15) and $\Delta E_\gamma / E_\gamma = \pm$ 3-5 %, they find a peak at $E_\gamma \sim 260$ MeV, as shown in Fig. 16, which can be attributed to

$$\psi' \to \gamma X(3.410).$$



Photon conversion efficiency for $|\cos\theta| < 0.6$. Isotropic production was assumed with momentum at $p_\perp > 55$ MeV/track.

FIG. 15

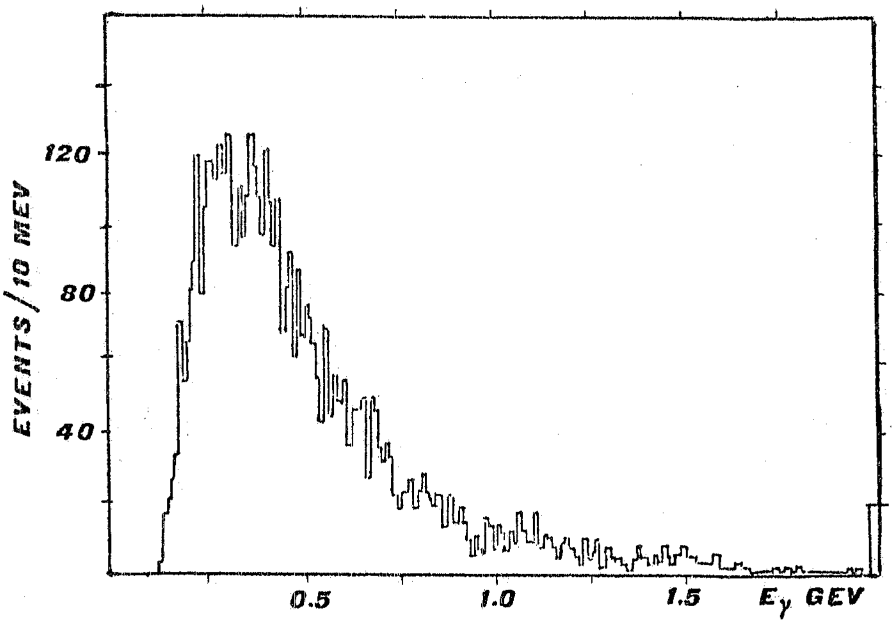


ψ' inclusive γ-spectrum, for $|\cos\theta| < 0.6$ and $p_\perp > 55$ MeV/track

FIG. 16

From a signal of 199 ± 37 events thay deduce that the branching ratio is $\sim 8\%$. The inclusive γ-ray spectrum for J/ψ decays is shown in Fig. 17, but no peaks are observed.

Similar decays leading to X(3.49) and X(3.55) with $E_\gamma = 180$ and $E_\gamma = 120$ MeV would not be detectable because of limited acceptance. Are these the additional ψ' decays which are not understood ?



J/Ψ inclusive γ-spectrum, from a similar analysis as in Fig. 16.

FIG. 17

1.6. - The problem of the X (2.8) particle. -

In the SLAC-LBL detector a sample of $J/\Psi \rightarrow \gamma 4\pi$ decays was studied, and no signal in the 4π-mass spectrum was found at $M(4\pi) \sim 2.8$ GeV; they conclude

$$BR\left[J/\psi \longrightarrow \gamma X(2.8) \atop \quad\quad\quad \hookrightarrow 4\pi\right] < 5 \times 10^{-3} .$$

Evidence for the existence of X(2.8) was found at DORIS by studying the radiative decays $J/\psi \rightarrow X\gamma$, $X \rightarrow \gamma\gamma$ or $p\bar{p}$. The 1975 data contained 33 events of type $J/\psi \rightarrow 3\gamma$ (for 210 nb^{-1}) and off resonance 3 similar events $e^+e^- \rightarrow 3\gamma$ (for 60 nb^{-1}). In the J/Ψ sample, after removing the $J/\psi \rightarrow \eta\gamma$ events an excess over the computed QED background was found at $M_{\gamma\gamma} \sim$ ~ 2.8 GeV. At the resonance, two events were also separately found of the type $e^+e^- \rightarrow \gamma p\bar{p}$, with $M(p\bar{p}) \sim 2.8$ GeV. The authors concluded that

$BR(J/\Psi \longrightarrow \gamma X) \simeq 2$ to 8×10^{-4} and $BR(J/\Psi \longrightarrow \gamma X) \simeq 2 \times 10^{-4}$
$\hookrightarrow \gamma\gamma$ $\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad\quad$ $\hookrightarrow pp$

About 200 nb^{-1} of new data are at present being analyzed, and preliminary results look similar but with some background problems. The present statement is

$$\mathrm{BR}\,(J/\psi \longrightarrow \gamma \underset{\hookrightarrow \gamma\gamma}{X(2.8)}) = (0 \div 8) \times 10^{-4} \ .$$

It is also observed that the two events attributed to $J/\psi \longrightarrow \gamma \underset{\hookrightarrow p\bar{p}}{X(2.8)}$ in the 1975 analysis are consistent with $J/\psi \longrightarrow \pi^0 p\bar{p}$, such that the authors prefer to give an upper limit

$$\mathrm{BR}\left[J/\psi \longrightarrow \gamma \underset{\hookrightarrow p\bar{p}}{X(2.8)}\right] \lesssim 2 \times 10^{-4} \ .$$

It is clear that this hypothetical particle deserves further accurate study.

1.7. - Search for new particles at Frascati. -

After the 1975 SLAC Conference, the serach for narrow resonances at Frascati has been repeated between 2150 and 2200 MeV and has been continued from 2540 MeV up to ~ 2750 MeV.

No narrow resonance with integrated cross-section $\gtrsim 1/10$ of J/ψ has been found. The spectrum for the 1975 energy scan is shown in Fig. 18.

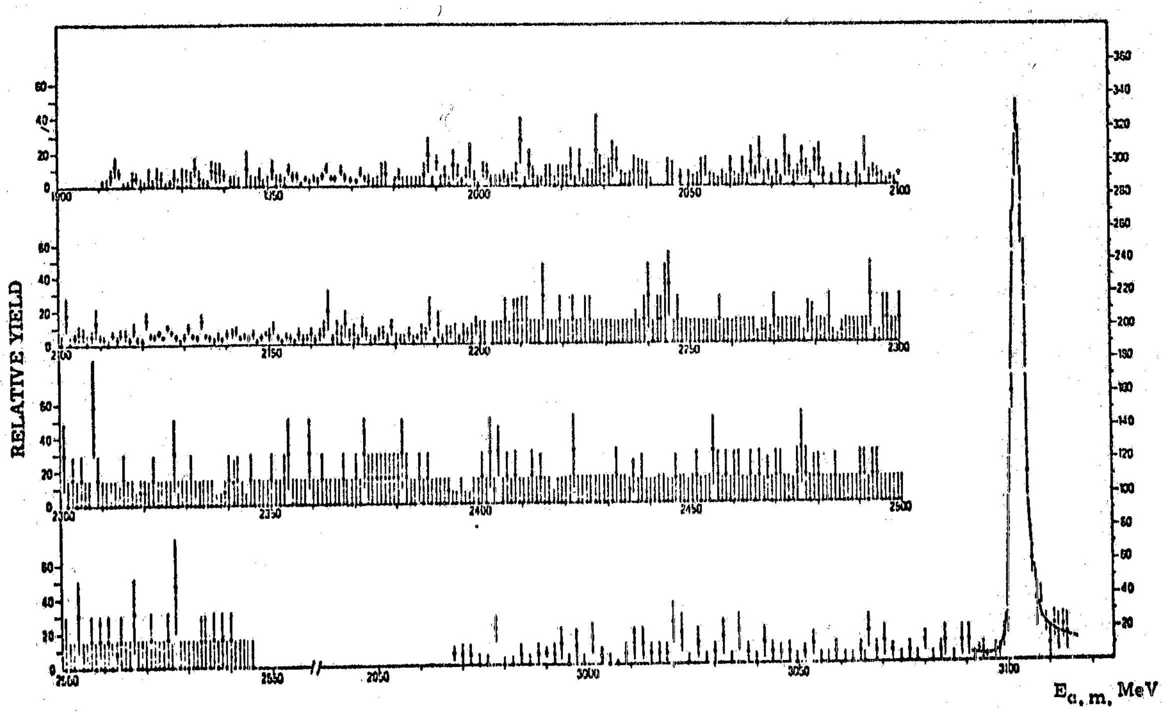


FIG. 18

1. 8. - <u>Search for new particles at Novosibirsk.</u> -

At VEPP 2' a search for narrow resonances in the channel ($\pi^+\pi^-$ neutrals) has been made from 770 MeV up to above 1030 MeV and no signal (besides ω and ϕ) has been found with integrated cross-section $\gtrsim 20\%$ of ω, ϕ (see Fig. 19). At VEPP 2' they also have a beautiful scan of $\phi \rightarrow K_S^o K_L^o$ (Fig. 20), leading to the result

$$M_\phi = 1019.4 \pm 0.3 \text{ MeV}.$$

More physics is expected to come out of these data in the near future.

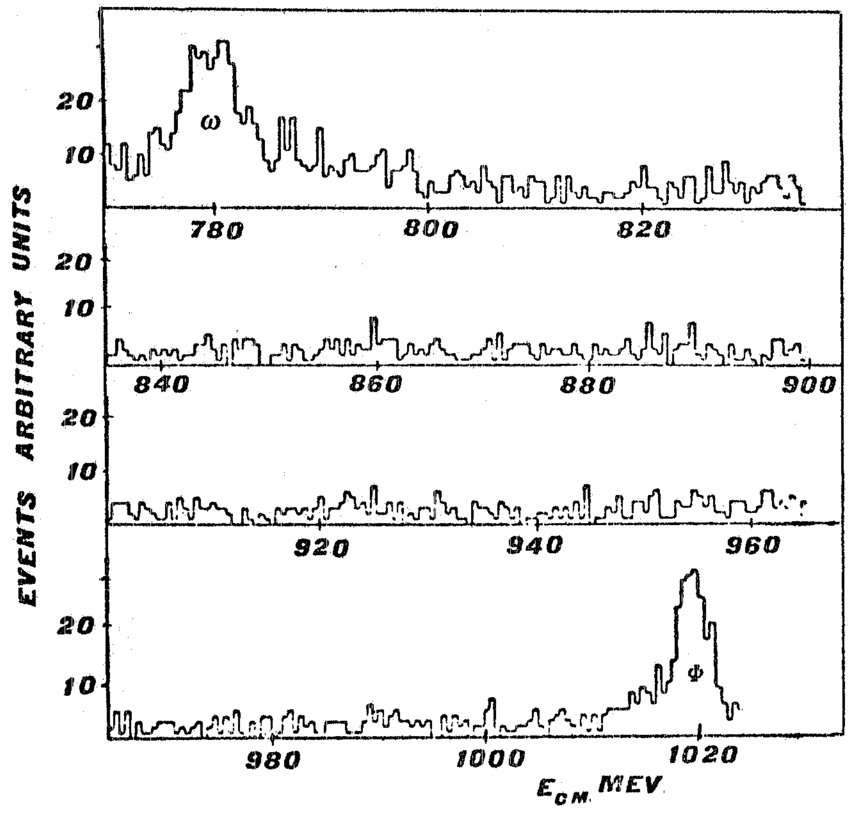


FIG. 19

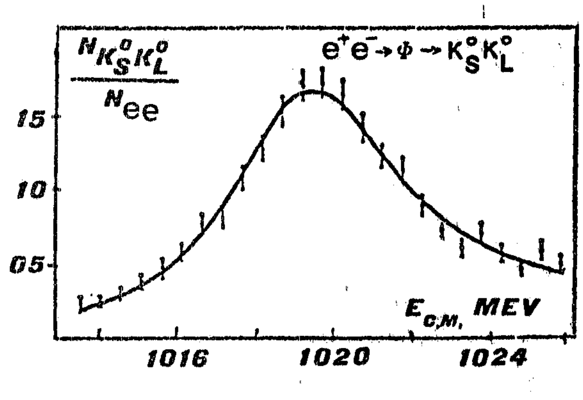


FIG. 20

1.9. - e^+e^- physics at ACO. -

As an example to illustrate that e^+e^- physics below $\omega = 3$ GeV has still a lot to say, we show some recent ACO data in Fig. 21. By studying

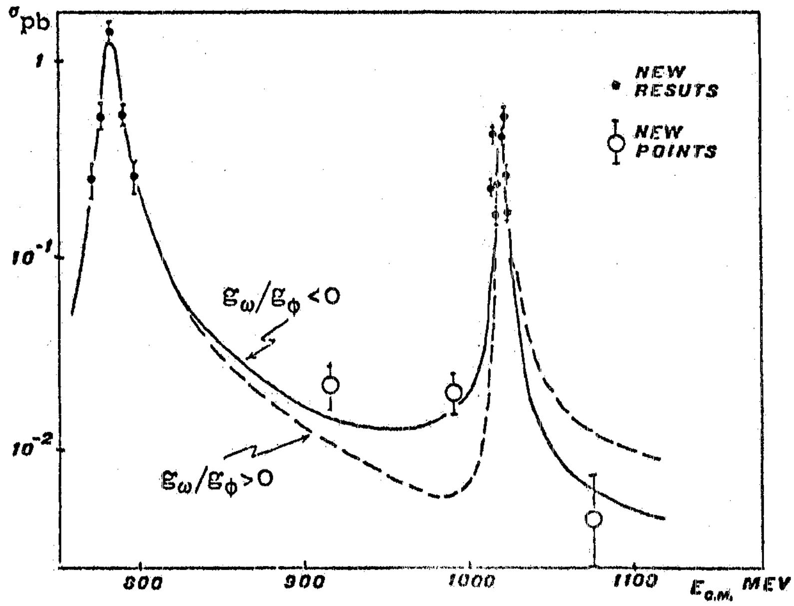


FIG. 21

the $\omega - \phi$ interference into the $\pi^+\pi^-\pi^0$ channel it was concluded that

$$g_{\phi \to 3\pi} / g_{\omega \to 3\pi} < 0 .$$

2. - THE PRODUCTION OF J/ψ PARTICLES AND POSSIBLE DISCOVERY OF A NEW PARTICLE Y AT 6 GeV AT FNAL. -

2.1. - J/ψ production at FNAL. -

(reported by L. Lederman).

The Columbia-FNAL Group with a double arm spectrometer studies:

$$P + Be \longrightarrow e^+e^- + \text{anything}$$

at 400 GeV/c beam momentum. The mass resolution is ≈ 40 MeV at the J/ψ mass and ≈ 70 MeV at 6 GeV.

The following results on J/ψ production have been obtained:

a) $P_\perp$ distribution at $x = 0$: $e^{-1.1\, p_\perp^2}$ (see Fig. 22);

b) $\left.\frac{d\sigma}{dx}\right|_{x=0} \cdot B = (2.6 \pm 0.7) \times 10^{-31}$ cm^2/Be nucleus;

c) assuming

$$E\frac{d^3\sigma}{dp^3} \propto (1-|x|)^{4.3}\, e^{-1.6\, p_\perp}$$

$$-1 \leq x \leq 1$$

and that the cross-section is proportional to the Berillium mass number they obtained $\sigma \cdot B = (1.1 \pm 0.3) \times 10^{-32}$ cm^2/nucleon. The cross-section for J/ψ production is increased by a factor of 10 between FNAL and Serpukhov energies and by a factor of 100 between FNAL and BNL.

d) $\psi'(3684)$ production is also observed with

$$\left.\frac{(\sigma\cdot B)_{\psi'(3.7)}}{(\sigma\cdot B)_{J/\psi(3.1)}}\right|_{y=0} = (1.7 \pm 0.5)\,\% .$$

e) The yield of direct leptons resulting from J/ψ decay was computed, and it was concluded that for $P_\perp \gtrsim 2.3$ GeV/c a substantial fraction, if not all, of the direct single leptons comes from J/ψ decay. In Fig. 23 it is shown the predicted single lepton rate from J/ψ decay, for two different extrapolations of the $p_\perp$ dependence of the production cross-section ($e^{-1.1\, p_\perp^2}$ or $e^{-2\, p_\perp}$), which fit equally well the measured data.

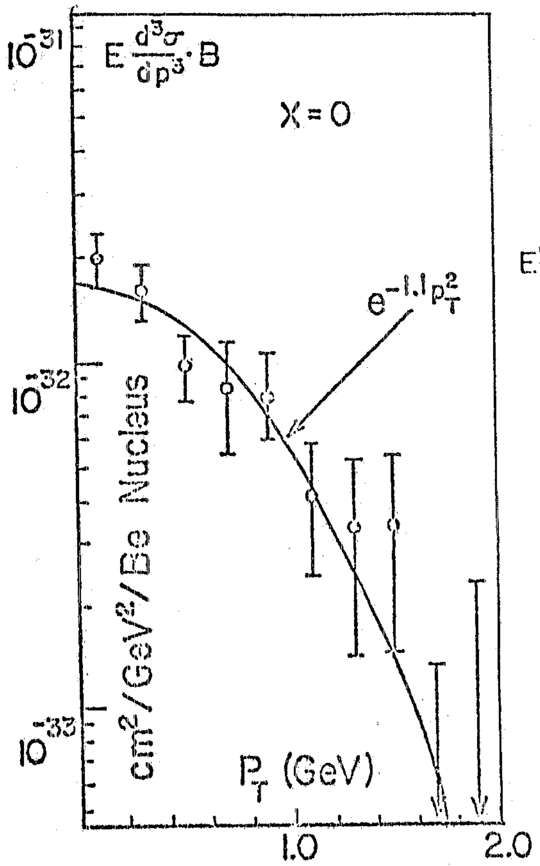


FIG. 22

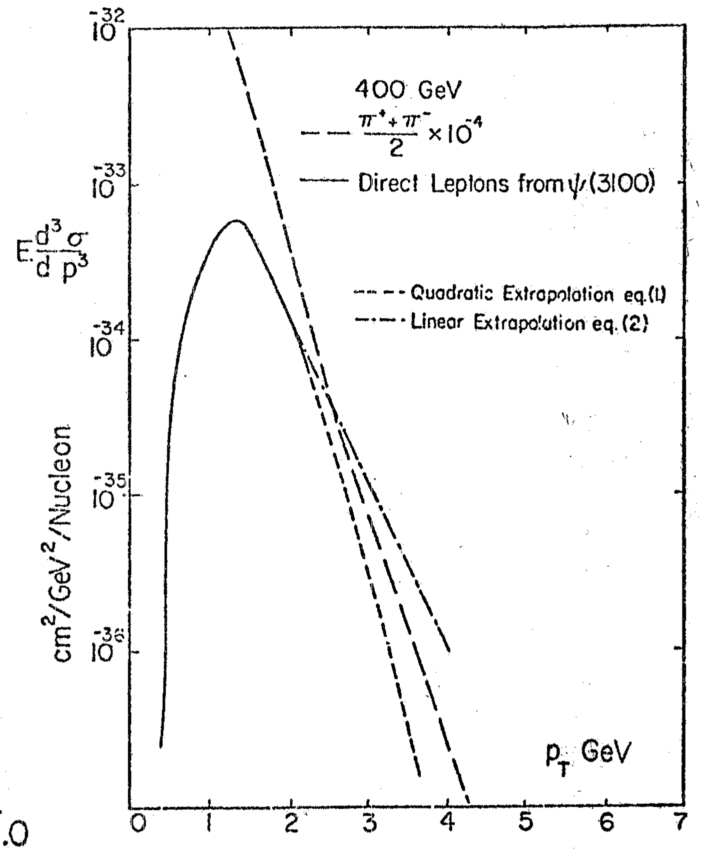


FIG. 23

2.2. - The particle Υ at 6 GeV. -

(reported by L. Lederman).

The data from the Columbia-FNAL experiment are shown in Fig. 24.

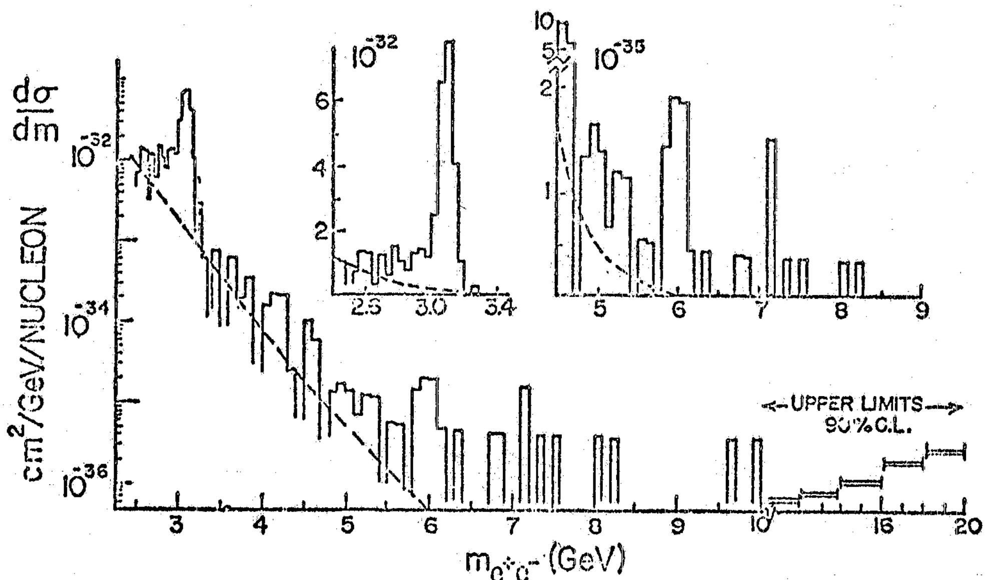


FIG. 24

It is found that the peak containing 11 events at $5.8 < M_{ee} < 6.1$ GeV has a 2% chance of being a statistical fluctuation when one throws events according to smooth distributions like $d\sigma/dm \sim 1/m^5$.

Figure 25 gives the $(E/P)_{up}$ versus $(E/P)_{down}$ plot (E = energy deposited in the lead-glass, p = measured momentum) which shows that there is

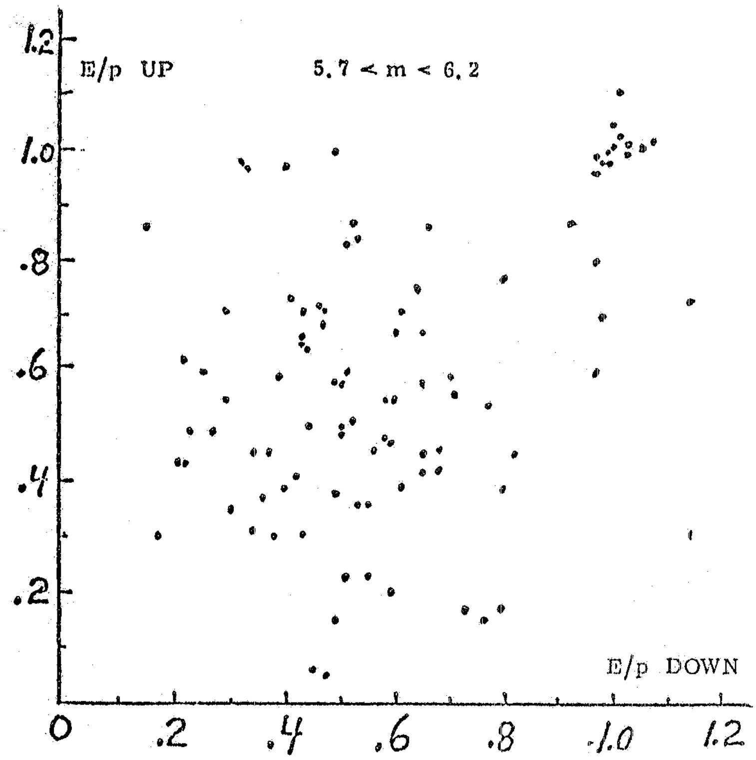


FIG. 25

an appreciable contribution of real e^+e^- pairs in the appropriate mass region.

Using the same $p_\perp$ and x dependence as for J/ψ production, the authors find

$$\sigma \cdot BR(Y) = (5.2 \pm 2.0) \times 10^{-36}\ \mathrm{cm}^2/\mathrm{nucleon} \sim \frac{1}{2000}\ \sigma \cdot BR(J/\psi)\ .$$

2.3. - Beam dump experiment at FNAL. -

At FNAL Eartly, Giacomelli and Pretzl have studied the reaction

$$P + N \longrightarrow \mu^+ \mu^- + \cdots\cdots$$

with 300 GeV/c protons incident on a beam dump. An integral $M_{\mu\mu}$ mass spectrum was measured, in which they have seen a shoulder at 3.1 GeV and a similar indication for a structure around $M^2_{\mu\mu} \simeq 36\ \mathrm{GeV}^2$. Figure 26 shows the integrated spectra versus $M^2_{\mu\mu}$. There is some difficulty in normalization and they can only get a rough order of magnitude for the cross sections.

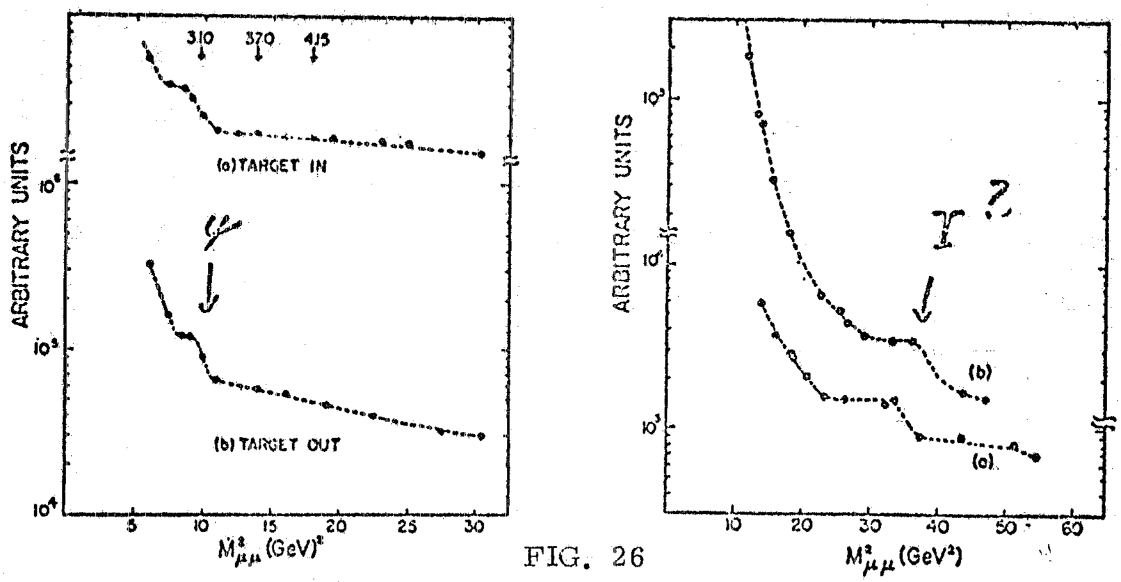


FIG. 26

For the J/ψ (3.1 GeV) they obtained one event/10^8 proton interactions, giving $\sigma_{J/\psi} > 10^{-33}\ \mathrm{cm}^2$. For the 6 GeV structure they obtained one event/2×10^9 proton interactions.

2.4. - The $e, \mu/\pi$ ratio. -

The energy and $P_\perp$ dependence of e/π, μ/π ratio for directly produced leptons is still unclear. The preliminary data presented by various groups at the 1975 SLAC Conference (see Fig. 27) have not been given out

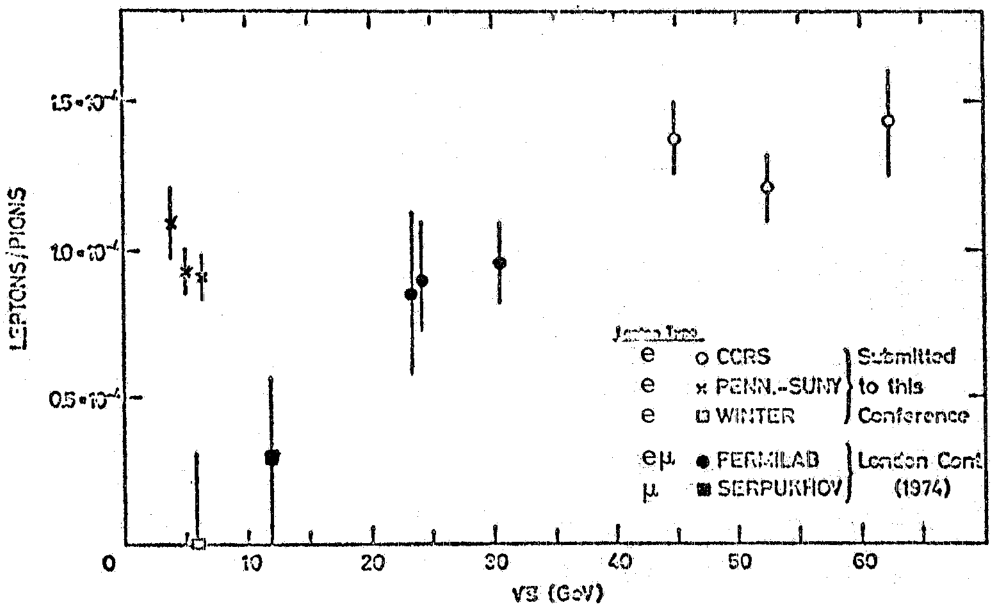


FIG. 27

in final form. Some of that data is being revised. For example, the CCRS ISR data at $p_\perp \gtrsim 1$ GeV/c contain more background from Dalitz pairs than originally estimated, such that the direct lepton rate will turn out to be smaller (by ~ 30%) than reported at SLAC. This source of background makes all experiments at $p_\perp \lesssim 1$ GeV/c particularly delicate. Figure 28 shows the new estimates of Dalitz decay background in the CCRS experiment. Thebroken line is the previous estimate.

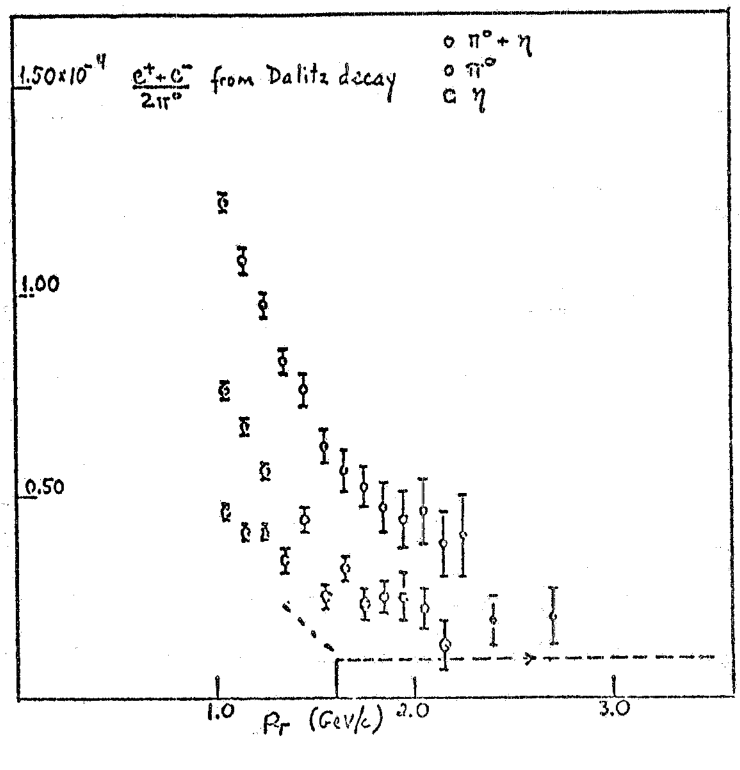


FIG. 28

3. - THE $\mu^-\mu^+$ AND $\mu^- e^+ V^o$ NEUTRINO EVENTS, AND CHARM SEARCHES.

3.1. - ν_μ interactions with counter experiments at NAL.

(reported by A. Mann).

The HPWF at FNAL experiment reports

$$7\ \mu^-\mu^-$$
$$5\ \mu^+\mu^+$$
$$\sim 100\ \mu^-\mu^+$$

in ν_μ interactions above 30 GeV.

The events are found to be produced with equal probability both in a diluted hadron calorimeter and in a dense slab in front of the muon spectrometer, and thus appear to be direct (not coming from π, K decay).

The mechanisms that one can considers to explain the observed rate are

a) W^+ production (Fig. 29a).

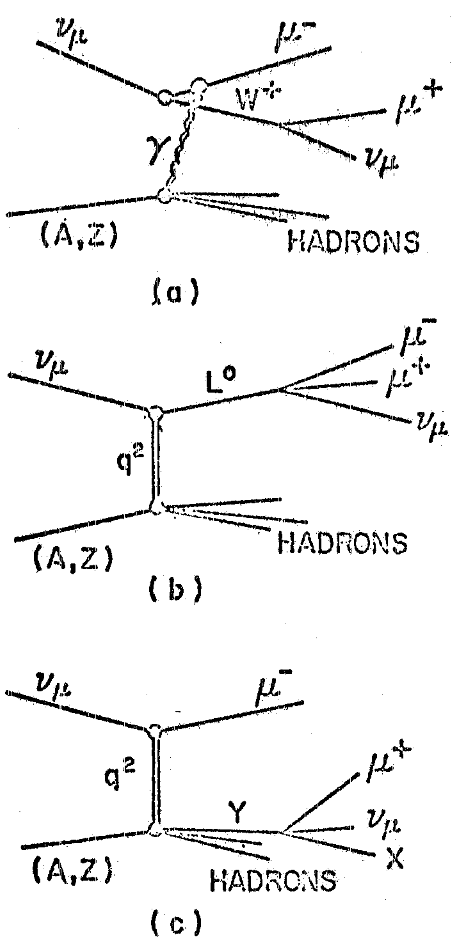


FIG. 29

However, this is unfavoured by the observed linear dependence of $\langle Q^2 \rangle$ on E_ν (see Fig. 30), which is consistent with $\Lambda = M_W \sim \infty$, wiz no w.

b) Heavy lepton (L^o) production (Fig. 29b) which is unfavoured by the large ratio $\frac{\langle p_{\mu^-} \rangle}{\langle p_{\mu^+} \rangle}$ observed (3.7 ± 0.7) even in presence of $\bar{\nu}_\mu$ background, while one would expect a ratio of 1 for L^o production and decay. Also, one cannot easily explain how the observed $\sim 10\%$ of μ-pairs of equal sign could be generated in this mechanism.

c) Production of a new hadron y at the hadron vertex (Fig. 29c). This mechanism is consistent with the data.

The $p_\perp$-dependence of μ^+ rate indicates $M_y \sim 2$ GeV (Figure 31). Also the visible ener gy of events indicates a threshold of 20 - 30 GeV neutrino energy.

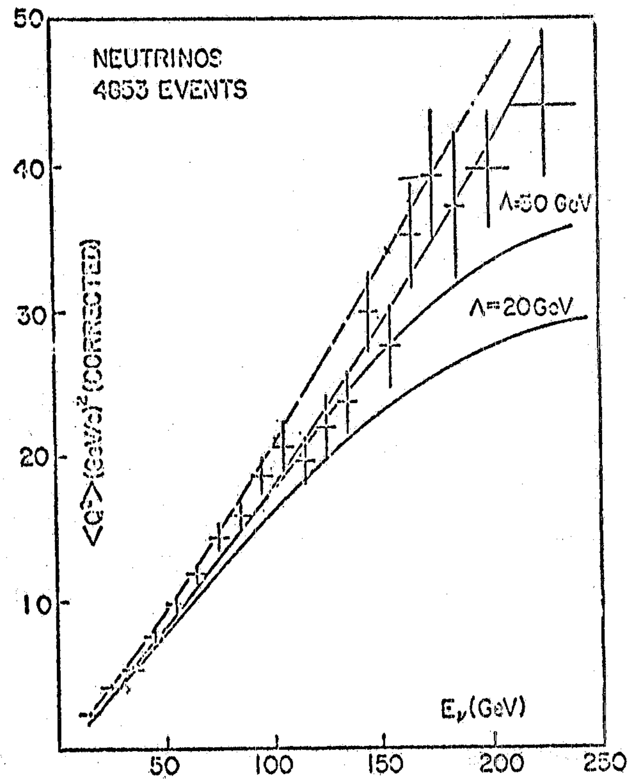


FIG. 30

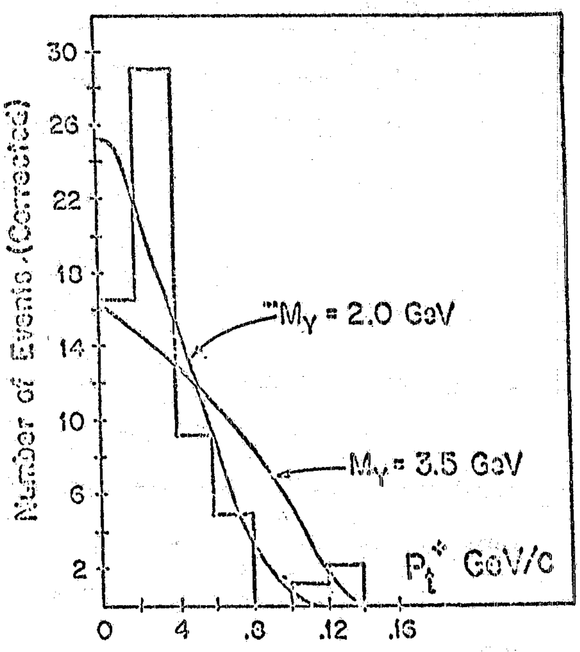


FIG. 31

3.2. - $\mu^- e^+ V^o$ events from Gargamelle.

(reported by P. Musset).

3 events have been observed in Gargamelle :

$$\nu_\mu + N \rightarrow \mu^- + e^+ + V^o + \cdots\cdots$$

$$\left.\begin{array}{l} V^o \; : \; K^o \\ \quad\text{or } \Lambda^o \end{array}\right\} \text{ not identified}$$

These events can be interpreted as semileptonic decay of charmed hadrons for instance

$$\nu_\mu + N \rightarrow \mu^- + C + \text{hadrons}$$
$$\qquad\qquad\qquad\quad \hookrightarrow K^o \; e^+ \; \nu_e$$

The details of these events are given in Table III.

TABLE III - 3 $\mu^- e^+ V^o$ events from Gargamelle.

	I	II	III
p_{μ^-} (MeV)	150 (decays)	1060 (leaves)	900 (leaves)
p_{e^+} (MeV)	250	900	750
p_{V^o} $\Lambda^o(\pi p)$	1095 ± 8 MeV	1100 ± 13	1100 ± 10
$K^o(\pi\pi)$ (MeV)	454 ± 43	427 ± 36	460 ± 40
Others	π^- $\pi^+/p/K^+$ $\pi^+/p/K^+$	$\pi^+/p/K^+$	$\pi^+/p/K^+$
E_{vis}(*) (GeV)	3.1 GeV	3.4 GeV	$\sim$5 GeV
W (GeV)	2.1 GeV	2.4 GeV	2.7 GeV
x	0.04	0.3	0.4
y	0.94	0.7	0.8
Mass ($\Lambda^o e^+$) (GeV)	1.24 ± 0.02	1.91 ± 0.17 ← favored	
Mass ($K^o e^+$) (GeV)	0.65 ± 0.03	1.57 ± 0.20	

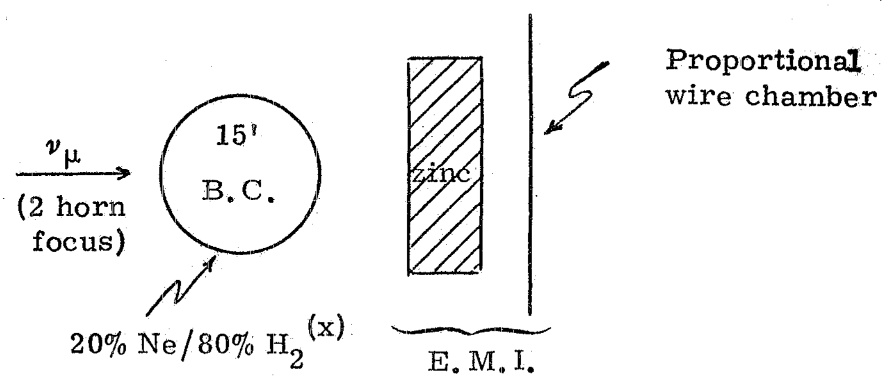
(*) W = invariant mass of hadrons ; $x = \dfrac{Q^2}{2M_p(E_\nu - E_\mu)}$,

$Q^2 = 2E_\nu E_\mu(1 - \cos\theta_\mu)$; $y = \dfrac{E_\nu - E_\mu}{E_\nu}$.

3.3. - $\mu^- e^+ V^o$ events from FNAL 15' Bubble Chamber.

(reported by B. Reeder).

The bubble chamber was implemented with an external muon identifier as sketched below



They study: $\nu_\mu + N \rightarrow \mu^- + e^+ + \cdots\cdots$

The procedures which were followed are :

a) Professional scanners located ν interactions ;

(x) Radiation length = 110 cm, interaction length = 200 cm.

b) For each interaction, physicists examine for e^+, e^- or both (this was the only criterion for selection).

The details of the events found are listed in Table IV.

TABLE IV

	1	2	3	4	5	6	7	8	9	10	11
Evis(GeV)	34.	11.	26	28	100	95	11		30	29	
P_{μ^-}(GeV/c)	14.3 EMI	3.4	21.9 EMI	9.3	9.3 EMI	57 EMI	1.3 EMI		6.0 EMI	μ^+ 7.3 EMI	μ?
P_{e^+}(GeV/c)	2.0	1.1	2.2	5.3	5.3	2.1	1.3		0.6	e^- 2.2	e^-
V^o	K^o_S	K^o_S	K^o_S	K^o_S	K^o_S K^o_L K^{*o}_{892}	K^o_S K^o_L K^o_L $(K_S \to 2\pi^o)$	-	K^o_S K^o_S K^o_L	K^-	-	K^o_S
P (GeV/c)	6.3	3.1	1.8	5.6	38	4	-		2.6		
y	0.6	0.7	0.2	0.6	0.9	0.4	0.9		0.8		
x	0.003	0.09	0.9	0.2	0.05	0.003	0.3				
W	6.0	4.0	1.3	5.0	12.3	8.3	4.0				
Q^2(GeV^2)	0.1	1.4	6.0	7.0	8.4	0.2	5.0				
P_{te}(GeV/c)	0.4	0.7	0.4	0.7							

P = momentum of V^o ; $y = \dfrac{E_\nu - E_\mu}{E_\nu}$; $x = \dfrac{Q^2}{2M_p(E_\nu - E_\mu)}$,

$Q^2 = 2E_\nu E_\mu(1 - \cos\theta_\mu)$; W = invariant mass of hadrons.

The main features of these events can be summerized as follows :

a) Expected background $\simeq 10\%$;

b) The e^+ energy is small, therefore it is unlikely that the events come from $\bar{\nu}_e$ interaction ;

c) Since $p_\perp$ is not balanced, there is probably missing ν ;

d) $\langle N_K \rangle \approx 2$ to 4 for K^o only, but probably more because of $K^\pm$ (which in general cannot be distinguished from charged pions);

e) No Λ^o observed ! ;

f) $\dfrac{\mu^- e^+ X}{\mu^- X} \sim 1\%$.

Are these events from charm ?

3.4. - Many negative charm searches.

All direct charm searches at FNAL, BNL and CERN have given negative results, although many mass-spectra of hadron pairs have been measured. Even an attempt to increase the charm signal by tagging the events with J/ψ production (the Zweig's rule suggests that in these events the charmed meson production is enhanced):

$$h + N \to J/\psi + c + c + x, \quad J/\psi \to \mu^+\mu^-$$

has failed to give a signal (reported by J. People). They looked for events with a J/ψ produced ($J/\psi \to \mu^+\mu^-$) and an additional μ meson. Their efficiency for the 3rd μ was $\sim 50\%$ provided the charmed parent was within $\pm$ 1 unity of rapidity of the J/ψ. Out of 3670 J/ψ events obtained, 4 cases of extra $-\mu$ were observed, which are consistent with estimated background. It is concluded that

(probability that a c is produced with J/) x (leptonic branching ratio of c)

$$\lesssim 10^{-3} .$$

An addition piece of information which is relevant in this contest is that no increase in (low momentum) K's at SPEAR is found in the 4 GeV region (reported by C. Moorhouse). In order to associate the step in R to some charm production (whose decay would produce in average one kaon per event), one needs to invoke an appreciable heavy lepton production to take place at the same energy (kaons are very rare in the heavy lepton decay products)!

The latest charm serach results from the BNL-MIT group was reported by S. Ting. They look for a μ trigger in addition to a hadron pairs, chasing the reaction

$$p + Be \to c\bar{c} + \cdots\cdots, \quad \bar{c} \to \mu\,\nu_\mu K, \quad c \to \text{hadron pair.}$$

The results can be illustrated as an example by the $pBe \to K^-\pi^+\mu x$ data.

For $p + Be \rightarrow K^-\pi^+ + x$ it was obtained

$$\left.\frac{d\sigma}{dm\,dp_\perp dx}\right|_{\substack{p_\perp = 0 \\ x = 0}} \simeq 10^{-29}\ \mathrm{cm}^2/\mathrm{GeV}/c^2/\mathrm{GeV}/c/\mathrm{nucleon}$$

assuming $e^{-2p_\perp}$, e^{-5x} dependence

$$\sigma\,(p + Be \rightarrow K^-\pi^+X) \sim 10^{-30}\ \mathrm{cm}^2/\mathrm{GeV}/c^2/\mathrm{nucleon}.$$

When tagging an associated muon, they found

$$\sigma\,(p + Be \rightarrow K^-\pi^+\mu X) \sim 10^{-32}\ \mathrm{cm}^2/\mathrm{GeV}/c^2/\mathrm{nucleon}.$$

If all direct μ's are from charm mesons which decay into $K^-\pi^+\mu X$, and $\mu/\pi \sim 10^{-4}$, one derives from this data that the cross section of $K^-\pi^+\mu$ should be $\sim 10^{-29}$ cm^2. On the other hand, since they don't see structures in $m_{K^-\pi^+}$, they can derive an upper limit for charm production into $K^-\pi^+\mu$ of about 10^{-31} $\mathrm{cm}^2/\mathrm{GeV}/c^2$/nucleon (the limit is derived assuming that the minimum observable signal was 10 events within a 10 MeV mass bin, which is the resolution of the experiment).

4. - HADRON JETS IN e^+e^- AND pp COLLISIONS. -

4.1. - Jets at SPEAR.

(reported by G. Feldman).

Above the region of the "new physics" at SPEAR ($E_{c.m.} \gtrsim 4.5$ GeV) one has found increasing evidence with increasing energy for a front-back jet structure of the events. By definition, jets is an event in which $p_\perp$ is limited with respect to some axis. The existence of such jets and the jet axis are found by finding the axis which minimizes $\Sigma p_\perp^2$; then to the event one attributes a sphericity,

$$S = \frac{3\,(\Sigma p_\perp^2)_{min}}{2\,\Sigma p^2}$$

and one compares the event distribution in sphericity with Montecarlo simulations. One finds that only by assuming $\langle p_\perp \rangle_{min} = 300$ MeV/c and $1 + \cos^2\theta$ distribution for jet axis one can explain both the S-distribution of the data (Fig. 32) and the single particle inclusive spectra at large x (Fig. 33).

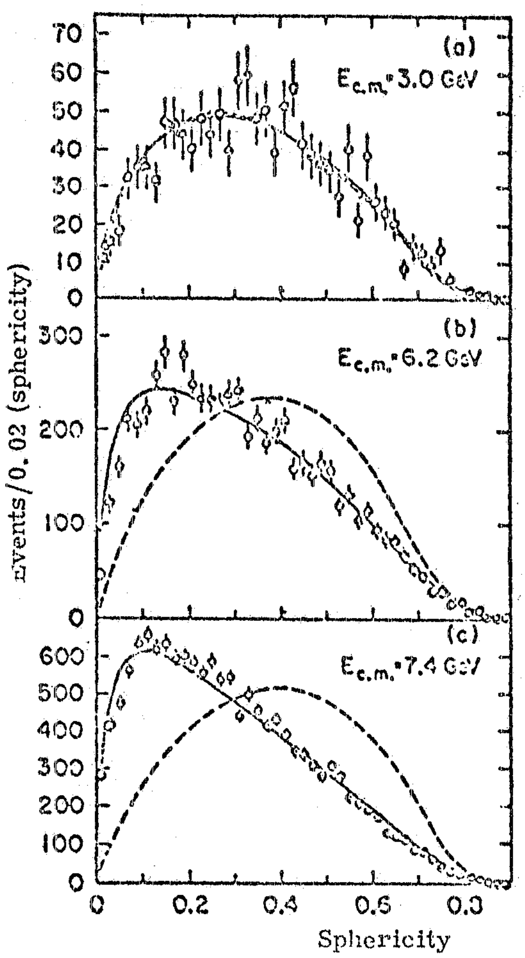


FIG. 32

Observed sphericity distributions

Hadron events, ≥ 3 Prongs

o Data

--- Montecarlo, Phase Space

—— Montecarlo, Limited Transverse Momentum

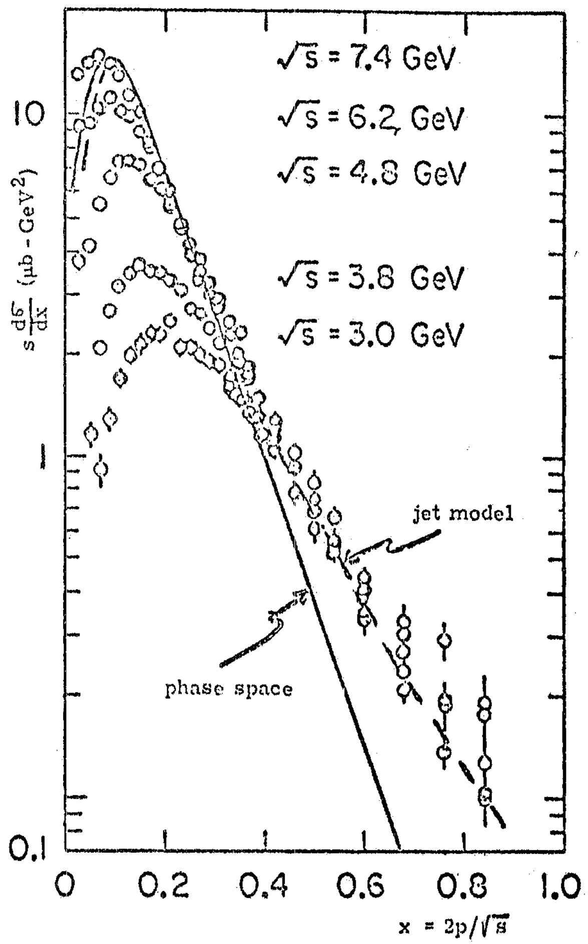


FIG. 33

It is interesting to observe that the Montecarlo jet model predicts very narrow jets at PETRA/PEP energies. The expected sphericity and secondary opening angle distributions at $E_{c.m.}$ = 30 GeV are shown in Fig. 34 and 35.

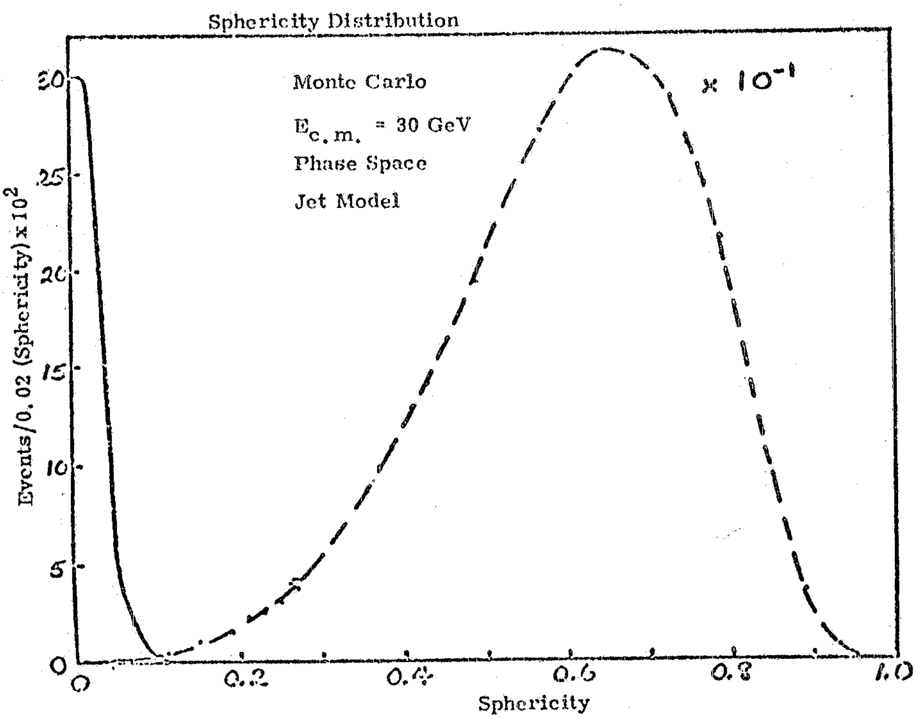


FIG. 34

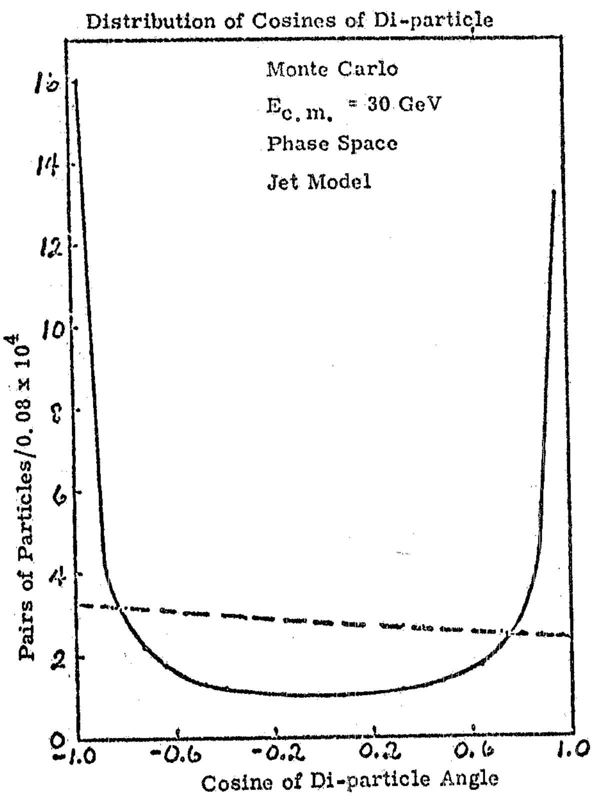


FIG. 35

4.2. - Jets at the ISR.

(reported by M. Jacob and A. Navarria).

Jet searches at the ISR have led to a picture of large $p_\perp$ events as a superposition of jets like at SPEAR, on top of additional "normal" low $p_\perp$ production. However, because of the motion of constitutens inside the primary protons, the two branches of jets are not expected to be back-to-back as in e^+e^- annihilation (see Fig. 36).

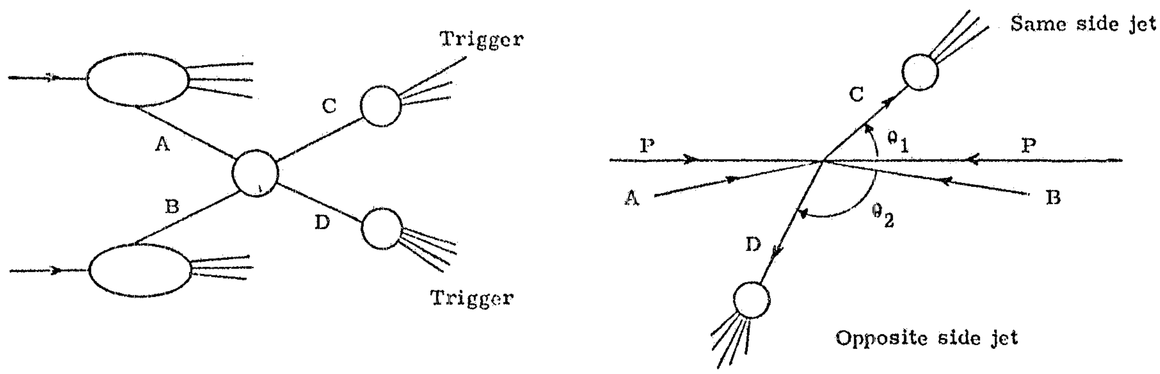


FIG. 36

One finds :

a) Front-back azimuthal correlation between large $p_\perp$ triggering particle and excess of multiplicity in opposite azimuthal hemisphere ;

b) Average momentum transverse to azimuthal plane containing one jet branch is $\langle p_{out} \rangle \sim 500$ MeV (excess over $\langle p_\perp \rangle_{min} \sim 300$ MeV at SPEAR can be understood in terms of transverse motion of constituents inside protons) ;

c) Tendency of particles to cluster around the axis of jet branch, which increases with increasing component of particle momentum along the branch axis.

Alltogether, when account is made for parton motion inside the protons, the jet-like component which is found in large $p_\perp$ events at the ISR can be thought of as being qualitatively the same as the SPEAR jets.

ACKNOWLEDGMENTS. -

On behalf of all participants, I would like to express to Tran our deepest friendship and appreciation.