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C. Bernardini: RESULTS ON e^+e^- REACTIONS AT ADONE (1.4 - 2.4 GeV).

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1. - INTRODUCTION. -

Adone became available for experiments in January 1970. Up to now, the energy interval 2 x 0.7 to 2 x 1.2 GeV has been explored : on the low energy side the luminosity drops too much below 0.7 GeV. The higher energies (1.2 to 1.5 GeV) have been obtained these days by operating the second RF cavity.

Operation has been limited to the head-on collision mode because of difficulties in beam crossing at an angle. Therefore, each target region is long, gaussian shaped with r.m.s. length $\simeq 22 \ E_{GeV}^{3/2}$ cm (E = machine energy). The source shape has been reconstructed from the distribution of the source points of reactions (mainly Bhabha scattering). The luminosity at 1 GeV usually exceeds 10^{33} cm^{-2}hr^{-1}, with an average of 3×10^{32} cm^{-2} hr^{-1} over one year (including different energies). The lifetime is of the order of 10 hrs and the total integrated luminosity up to now is about 4×10^{36} cm^{-2}.

About 300 hrs were used for single-beam background measurements. Recently, background was also studied by operation with 2 vertically separated beams[1].

2. - SURVEY OF THE EXPERIMENTS. -

Five groups occupy the 4 available sections (4 out of 6 crossing points). The group labels and their fields of interest are shown in Table I. The headings of columns 2 to 8 in this Table correspond to detected final states.

TABLE I - Group Labels, Names of Authors, Analyzed final states.

Group	e^+e^-	$\mu^+\mu^-$	$\gamma\gamma$	$2e^+2e^-$	$\pi^+\pi^-(K^+K^-)$	$\bar{p}p$	≥ 3 had
BCF[1]	x	x			x		x
Boson[2]	x						x
$\gamma\gamma$[3]			x	x			x
$\mu\pi$[4]	x	x		(x)	x		x
$\bar{p}p$[5]						x	

(1) - V. Alles Borelli, M. Bernardini, D. Bollini, T. Massam, L. Monari, F. Palmonari, A. Zichichi.

(2) - B. Bartoli, B. Coluzzi, F. Felicetti, G. Goggi, G. Marini, F. Massa, A. Nigro, H. Ogren, D. Scannicchio, V. Silvestrini, N. Spinelli, F. Vanoli.

(3) - C. Bacci, R. Baldini, G. Capon, C. Mencuccini, G. P. Murtas, G. Penso, A. Reale, G. Salvini, M. Spinetti, B. Stella.

(4) - G. Barbiellini, B. Borgia, F. Ceradini, M. Conversi, F. Grianti, M. Grilli, A. Mulachiè, G. Nicoletti, M. Nigro, L. Paoluzi, R. Santonico, P. Spillantini, V. Valente, R. Visentin, G. Zorn.

(5) - M. Castellano, G. Di Giugno, J. Humphrey, I. Peruzzi, E. Sassi, U. Troya, G. Troise, S. Vitale.

The set-ups surrounding the beams have similar geometries and consist of counters and spark-chambers in assorted combinations. As for geometry, they can be roughly classified according to their arrangement relative to the ring plane and to the capability of picking-up particles at small angles. The BCF and $\mu\pi$ devices sample events around the ring plane at large angles ; the $\gamma\gamma$ apparatus is in the vertical plane and allows detection of small angle particles ; Boson and $\bar{p}p$ explore large angles in the plane normal to the beam line. The position relative to the ring plane could prove important at high energies where electron and positron polarization is expected.

The major differences are to be found in trigger requirements allowing specialization to the analysis of particular reactions.

In order to compare the main characteristics a summary of parameters of the 5 set-ups is given in Table II.

TABLE II - Characteristics of set-ups.

	$\Delta\Omega/4\pi$	$\langle\Delta\Omega\rangle/4\pi$	$\Delta\phi$	θ_m	$E_m(\pi)$ (MeV)	Trigger
BCF	0.21		120°	50°	100	Chgd
Boson	0.35	0.18	220°	60°	75	Chgd
$\gamma\gamma$	0.27	0.23	60° 100°	20°	95	Chgd Neut
$\mu\pi$	0.23	0.20	70°	36°	90 180	Chgd
$p\bar{p}$	0.64	0.26	324°	45°	---	Chgd

$\Delta\Omega$ Total solid angle for point source at center.
$\langle\Delta\Omega\rangle$ Same, extended source at 1 GeV.
$\Delta\phi$ Angular interval in the plane orthogonal to the beam line.
θ_m Minimum detected angle with respect to the beam line.
$E_m(\pi)$ Minimum energy of a π to trigger (2 values for asymmetric trigger).

3. - MONITORING. -

A Bhabha scattering luminometer has been currently used to monitor the luminosity in terms of the cross section for elastic electron-positron scattering at c. m. angles in the range $3.5° - 6.1°$ ($q^2 \lesssim (100 \text{ MeV}/c)^2$). This device is believed to attain 5% absolute accuracy.

In order to have an independent check of luminosity, the machine group occasionally operates a single and double bremsstrahlung luminometer by observing γ rays at forward angles from

$$e^+e^- \rightarrow e^+e^-\gamma \,, \qquad\qquad e^+e^- \rightarrow e^+e^-\gamma\gamma \,.$$

Typical counting rates at 1 GeV are :

Bhabha scattering	10^4/hr
Single bremsstrahlung	4×10^7/hr (beam-beam)
Single bremsstrahlung	4×10^7/hr (beam-gas).

The two agree to within 10%.'

A current practice after the encouraging QED tests has been to use wide angle Bhabha scattering in the set-ups to monitor hadronic events, the main advantage being to have all information on the same film or tape.

4. - QED TESTS. -

Observation of the following reactions :

$$e^+e^- \longrightarrow e^+e^- \ , \qquad e^+e^- \longrightarrow \gamma\gamma \ , \qquad e^+e^- \longrightarrow \mu^+\mu^-$$

constitutes the basis for QED verification at high momentum transfers with Adone.

a) - The Bhabha scattering cross section is obtained by detecting charged collinear showering particles. Actually, the measured quantity is :

$$\int_{apparatus} \left\{ \frac{d\sigma}{d\Omega}(\theta) + \frac{d\sigma}{d\Omega}(\pi-\theta) \right\} d\Omega \ = \ \sigma_B$$

because no charge recognition is available at present. Therefore, 3 different momentum transfer values enter the cross section σ_B.

$$s = 4E^2 \ , \qquad t_1 = -4E^2 \sin^2\frac{\theta}{2} \ , \qquad t_2 = -4E^2 \cos^2\frac{\theta}{2} \ .$$

Most of the contribution comes from the amplitude in which t_1 is exchanged. A spectrum of t_1 values as determined by the aperture of the Boson apparatus is shown in Fig. 1[2].
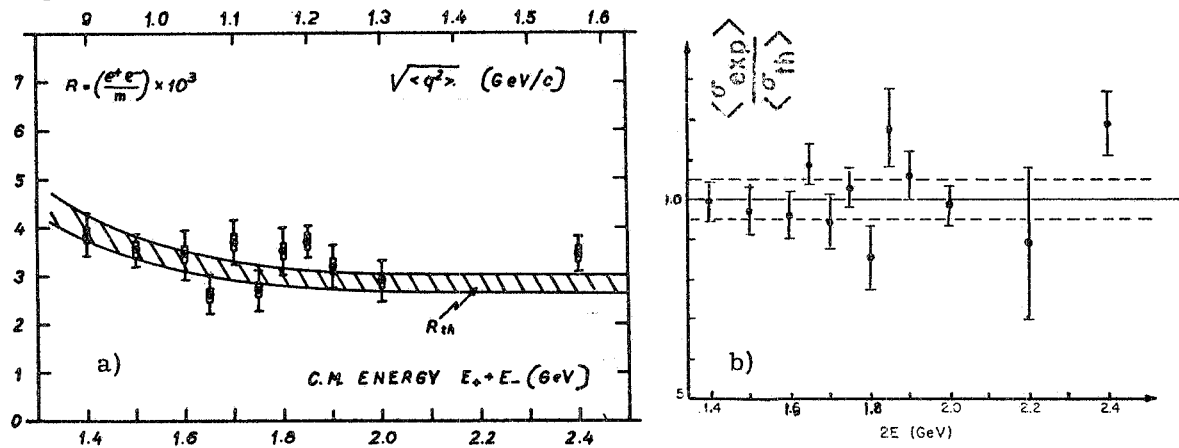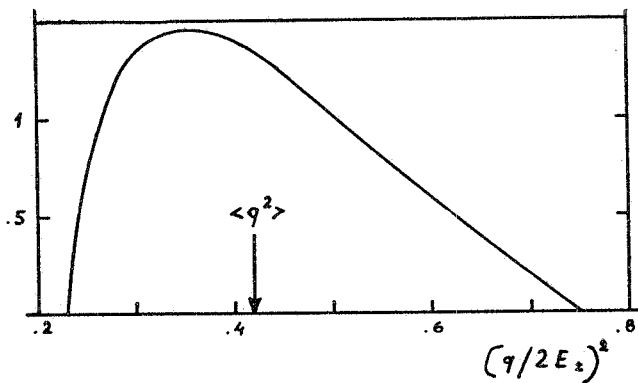

FIG. 1 - a) Ratio of wide angle Bhabha scattering to monitor counts (Boson Group). Band of expected values (QED) includes systematic errors. b) Same ($\mu\pi$ Group).

In Fig. 2 we present the results of different experiments. A total of 1770 events were analyzed by BCF, 5164 by Boson[2] and 3255 by $\mu\pi$[3] ; error bands include a possible $\pm 5\%$ systematic error.

FIG. 2 - Spectrum of $q^2 = -t_1 = 4E^2 \sin^2\theta/2$ in Bhabha scattering (Boson Group).

b) - The reaction $e^+e^- \rightarrow \gamma\gamma$ at high momentum transfers is quite popular because of the huge amount of work   done in the last years on its inverse, occurring in the photoproduction of electron pairs on nuclei. The present direct test at Adone goes up to 1. 6 GeV virtual-lepton 4-momentum and, of course, does not involve any nuclear effect[4]. A total of 597 events have been analyzed (a partial sample of the collected data). Collinear γ rays in the ranges 20°-45° and 70°-110° at energies from 2×0.7 to 2×1.2 GeV are detected; they divide into 443 small angle and 154 wide angle photons.

The QED test consists mainly in the comparison of the measured ratio of wide-angle to small-angle rates with the corresponding prediction. The two agree to within one standard deviation; a possible total systematic error of 5% has been introduced. Details are shown in Fig. 3 where momentum transfer bands due to finite aperture of the apparatus are also indicated.
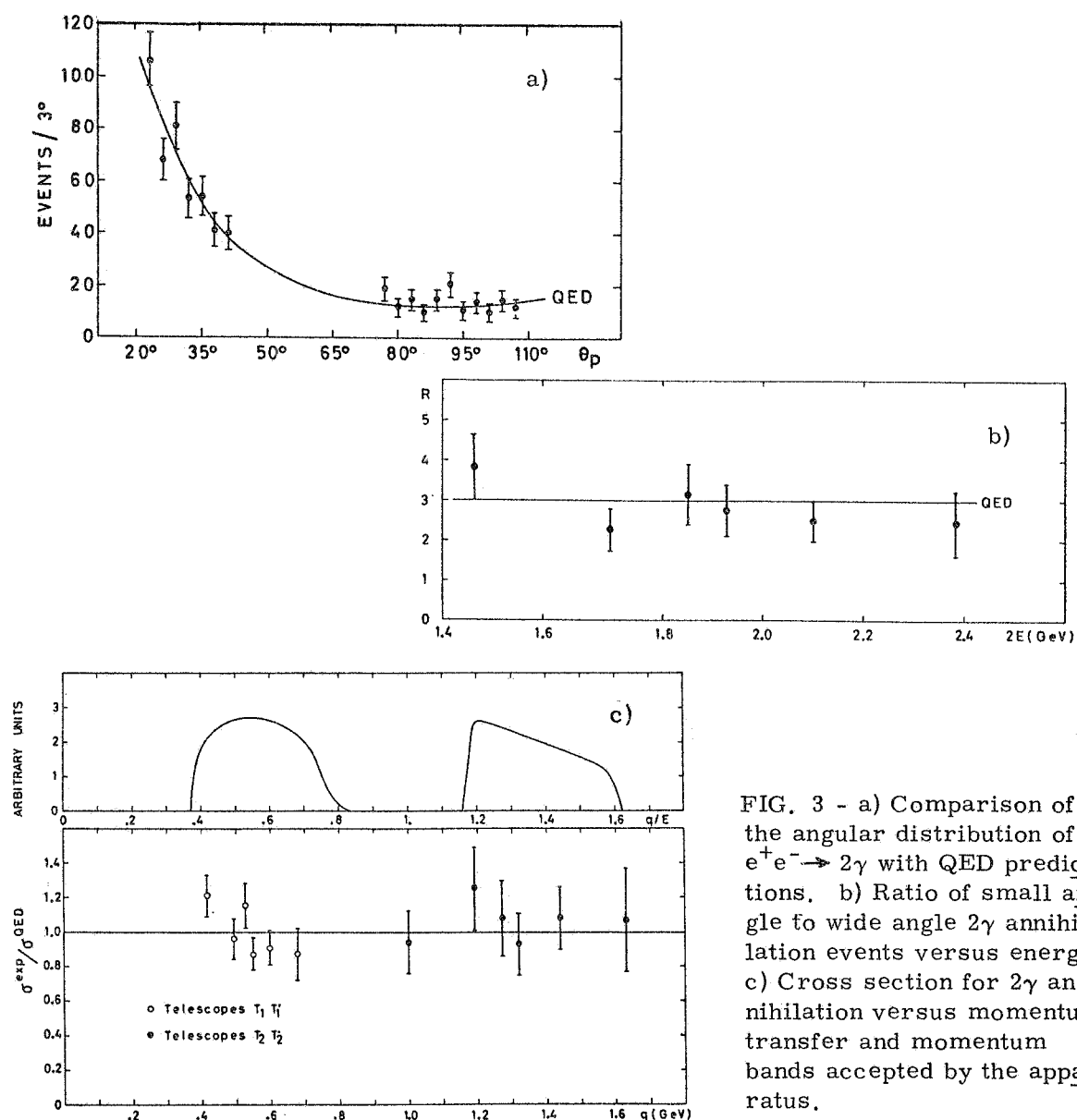

FIG. 3 - a) Comparison of the angular distribution of $e^+e^- \rightarrow 2\gamma$ with QED predictions. b) Ratio of small angle to wide angle 2γ annihilation events versus energy. c) Cross section for 2γ annihilation versus momentum transfer and momentum bands accepted by the apparatus.

c) - Production of μ-pairs proceeds via the annihilation channel only. The single momentum transfer is time-like, angle independent and equals $4E^2 = s$. Absolute monitoring is needed to get the cross section : due to the much higher rate of Bhabha scattering at the corresponding angles, it is safe and convenient to measure the ratio of μ-pairs to Bhabha events.

The BCF group presents[5] the ratio :

$$R = (\frac{e^+e^- \to \mu^+\mu^-}{e^+e^- \to e^+e^-})meas / (\frac{e^+e^- \to \mu^+\mu^-}{e^+e^- \to e^+e^-})QED$$

as a function of energy as shown in Fig. 4. Straight-line interpolation of all the points gives :

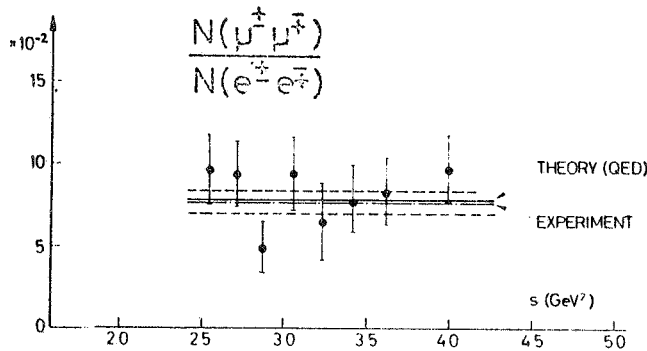$$R = 0.98 \pm 0.08 ; \qquad 2.5 \leqslant s \leqslant 4.0 \ GeV^2.$$

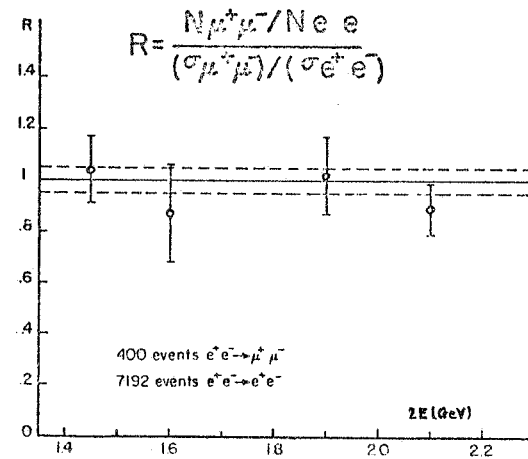FIG. 4 - Ratio of μ-pairs over e-pairs compared to QED predictions (BCF Group).

FIG. 5 - Same as Fig. 4 (μπ Group).

A similar measurement by the μπ group gives the data shown in Fig. 5, based on a total of 400 events.

d) - In conclusion, the available data illustrated in the preceding sections do not show any trend to deviate from the predictions of QED up to 2 GeV momentum transfers (space-like or time-like). This statement is bound to an accuracy which is not better than 10% per point (partly because of systematic errors).

A very popular and perhaps misleading summary is given in terms of cut-off parameters, corresponding to 95% confidence levels in fits. Such parameters (Λ) are listed for completeness (but reluctantly) in Table III. It is understood that Λ enters a factor mutliplying the amplitude corresponding to a Feynman diagram (lowest order) in which t is the momentum exchanged. The type of factor used is shown in the second column.

e) - A nice piece of evidence on the correctness of calculations on radiative corrections has been given by the BCF group[12]. Non-collinearity and non-coplanarity of the outgoing electrons are analyzed in Bhabha scattering ; the resulting distributions are shown in Fig. 6. Comparison with calculations by Bonneau and Martin gives reasonable agreement.
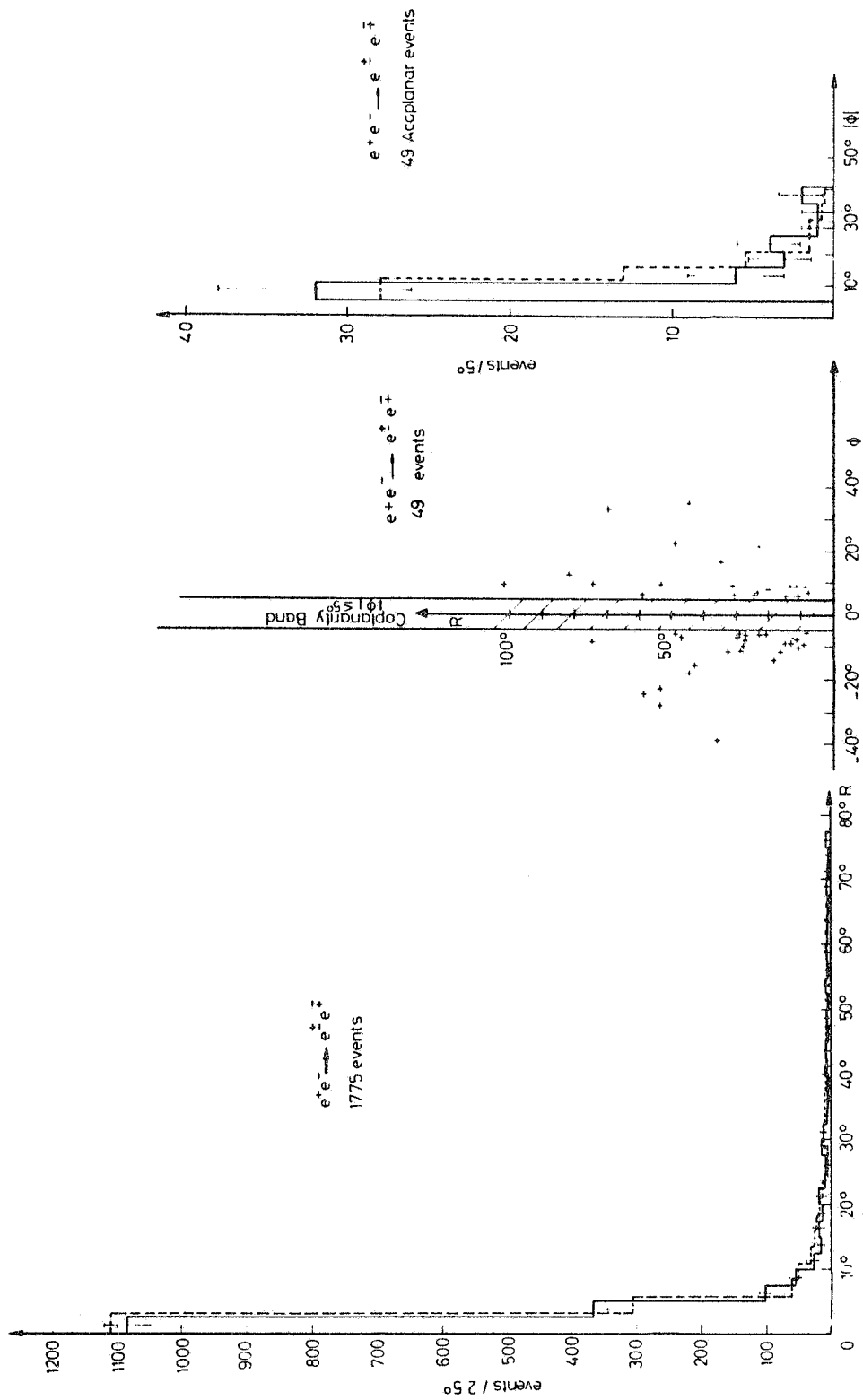
FIG. 6 - a) Distribution of non-collinearity angle R in Bhabha scattering. b) Non-coplanarity ϕ versus non-collinearity, Bhabha events. c) Comparison of non-coplanarity distribution with theory, Bhabha scattering.

TABLE III - QED - Cutoff parameters.   a

Summary of recent data on QED tests with colliding beams.
Λ is a cutoff parameter corresponding to 95 % confidence
level with the indicated amplitude modification.

Reaction	Ampl. correc.	Group	Λ (GeV)
$e^-e^- \rightarrow e^-e^-$	$(1 - \frac{t}{\Lambda^2})^{-1}$	Stanford[6]	4.4
$e^-e^- \rightarrow e^-e^-$	$(1 + \frac{t}{\Lambda^2})^{-1}$	Stanford[6]	3.3
$e^+e^- \rightarrow e^+e^-$	$(1 - \frac{t}{\Lambda^2})^{-1}$	Orsay[7]	2.0
$e^+e^- \rightarrow e^+e^-$	$(1 - \frac{t}{\Lambda^2})^{-1}$	Frascati	6.0
$e^+e^- \rightarrow \gamma\gamma$	$(1 - \frac{t^2}{\Lambda^4})^{-1}$	Novosibirsk[8]	1.1
$e^+e^- \rightarrow \gamma\gamma$	$(1 - \frac{t^2}{\Lambda^4})^{-1}$	Frascati	2.0
$e^+e^- \rightarrow \gamma\gamma$	$(1 + \frac{t^2}{\Lambda^4})^{-1}$	Frascati	2.6
$e^+e^- \rightarrow \mu^+\mu^-$	$(1 - \frac{t}{\Lambda^2})^{-1}$	Frascati	5.0
$\big($ g-2 of μ	$(1 - \frac{t}{\Lambda^2})^{-1}$	CERN[9]	5.0$\big)$

The relevance of the non-coplanarity distribution is in that it allows one to figure out how much of the background originating from Bhabha tails can affect the ha dronic channels.

5. - TWO PHOTON REACTIONS. -

Since the Kiev conference, reactions of the type :

$$e^+e^- \rightarrow e^+e^- + x$$

have been revived[11] and given the attention of experimentalists. At moderate energies, as in the Adone case, the most plausible check of two-photon calculations concerns the case in which $x = e^+e^-$ (having relatively high rates).

By searching for wide-angle non-collinear electron pairs in coincidence with beam electrons that suffer a large energy loss, a peculiar velocity distribution of the center of mass of the pair is expected.

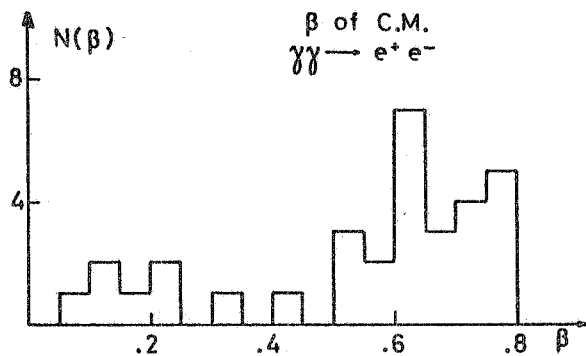Preliminary results by the $\gamma\gamma$ group are shown in Fig. 7.

FIG. 7 - Spectrum of β, the c.m. velocity of wide angle non-collinear pairs from $e^+e^- \rightarrow e^+e^-e^+e^-$ associated with a 0° electron having 76-88% of the beam energy.

The data shown correspond to a total of 35 events. Comparison with predic tion has not yet been possible because of some efficiency problems with soft electrons.

The reaction $e^+e^- \rightarrow e^-e^+\mu^+\mu^-$ could contribute 4 events to the analyzed sample according to the calculated cross section value. Actually, 2 non-showering coplanar non-collinear tracks are seen which could be interpreted as μ-pairs.

Preliminary background analysis seems to exclude contamination from beam-gas reactions.

6. - BOSON PAIRS. -

To my knowledge, no serious attempt has been made to separate π^+ from K^+ particles(x). Therefore, the cross section for minimum ionizing collinear parti- cles must be interpreted as the sum of the two contributions

$$\frac{\pi\alpha^2}{3} \frac{1}{s} \left\{ \left| F_\pi(s) \right|^2 \beta_\pi^3 + \left| F_K(s) \right|^2 \beta_K^3 \right\} \int_{apparatus} \sin^2\theta \, d\theta$$

Here

$$s = 4E^2 , \quad \beta_{\pi,K}^2 \quad 1 - \frac{4m_{\pi,K}^2}{s} .$$

Usually, however, $\left| F_\pi(s) \right|^2$ is read in place of $\left\{ \ \right\}$ and results are quoted as concerning the pion form factor.

The counting rates are slower than in the μ-pair case by more than a fac- tor 10 (a factor 4 because of spin zero even for point pions or kaons).

The BCF group presented[12] points based on a total of 41 events at 4 ener gies. The points are shown in Fig. 8.

(x) - Actually, the $\mu\pi$ group was able to distinguish one K^+K^- pair against 16 $\pi^+\pi^-$ pairs at 1.4 GeV. This would correspond to F_K two to three times smaller than F_π at this energy.
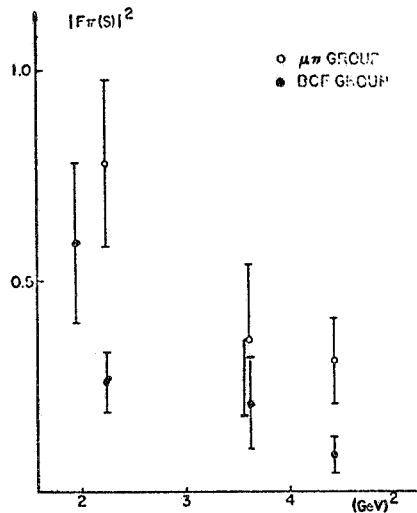
FIG. 8 - "Pion" form factor squared (BCF and $\mu\pi$ Groups).

Also, the $\mu\pi$ group has a total of 39 boson pairs corresponding to 3 energies, as shown in Fig. 8.

It is very hard to relate these data to those at lower energies where the ρ dominates. Should $ReF_\pi(s)$ be naively accounted for by the ρ contribution in dispersion relations, one would expect

$$\left| F_\pi(s) \right|^2 \gtrsim \frac{m_\rho^4}{s^2} \qquad (s \gg m_\rho^2)$$

which does not satisfactorily compare to the experimental results.

A compelling indication is that measurements in the energy range 2×0.5 to 2×0.7 are needed.

7. - PROTON-ANTIPROTON PAIRS. -

A big effort has been made by the group from Napoli University to observe $e^+e^- \rightarrow \bar{p}p$ at 2×1.05 GeV, that is to measure proton form factors at $s = 4.3$ GeV^2. The experiment is feasible near threshold by searching for very highly ionizing colli near particles. Stars at antiproton stops help in further characterizing good events.

Unwanted collinear protons can occur mainly because of

i - cosmic rays ,
ii - electron-nucleus interactions in the gas.

To illustrate the situation it is better to refer to Fig. 9 where the criteria used to select candidates are shown as they work in practice.

After close examination of the selected sample, the authors conclude that 8 ± 4 events could well be $\bar{p}p$ pairs. Evidence is actually better for the partial sample in which $\bar{p}$ is accompanied by a detected star (5 events).

Assuming that the angular distribution is isotropic (which is nearly true in practice), 8 events would correspond to a cross section of 0.4×10^{-33} cm^2. The cross section for point Dirac protons is 1.8×10^{-32} at this energy.

Model-independent comparison with previous upper limit at CERN and Brookhaven[13] is not possible because of large differences in momentum transfers (5.1 GeV^2 at Brookhaven, 6.8 GeV^2 at CERN, 4.3 GeV^2 here). The relatively high cross section observed at Adone could perhaps be related to the recently discovered[13] bump at 1968 MeV in $\bar{p}p \rightarrow K_L K_S$ with a width of the order of 50 MeV.

8. - REACTIONS WITH MORE THAN TWO FINAL PARTICLES AT WIDE ANGLES. -

All groups observe a wealth of events with at least 3 detected particles. The tracks are generally wide-angle and both charged and neutrals are seen.
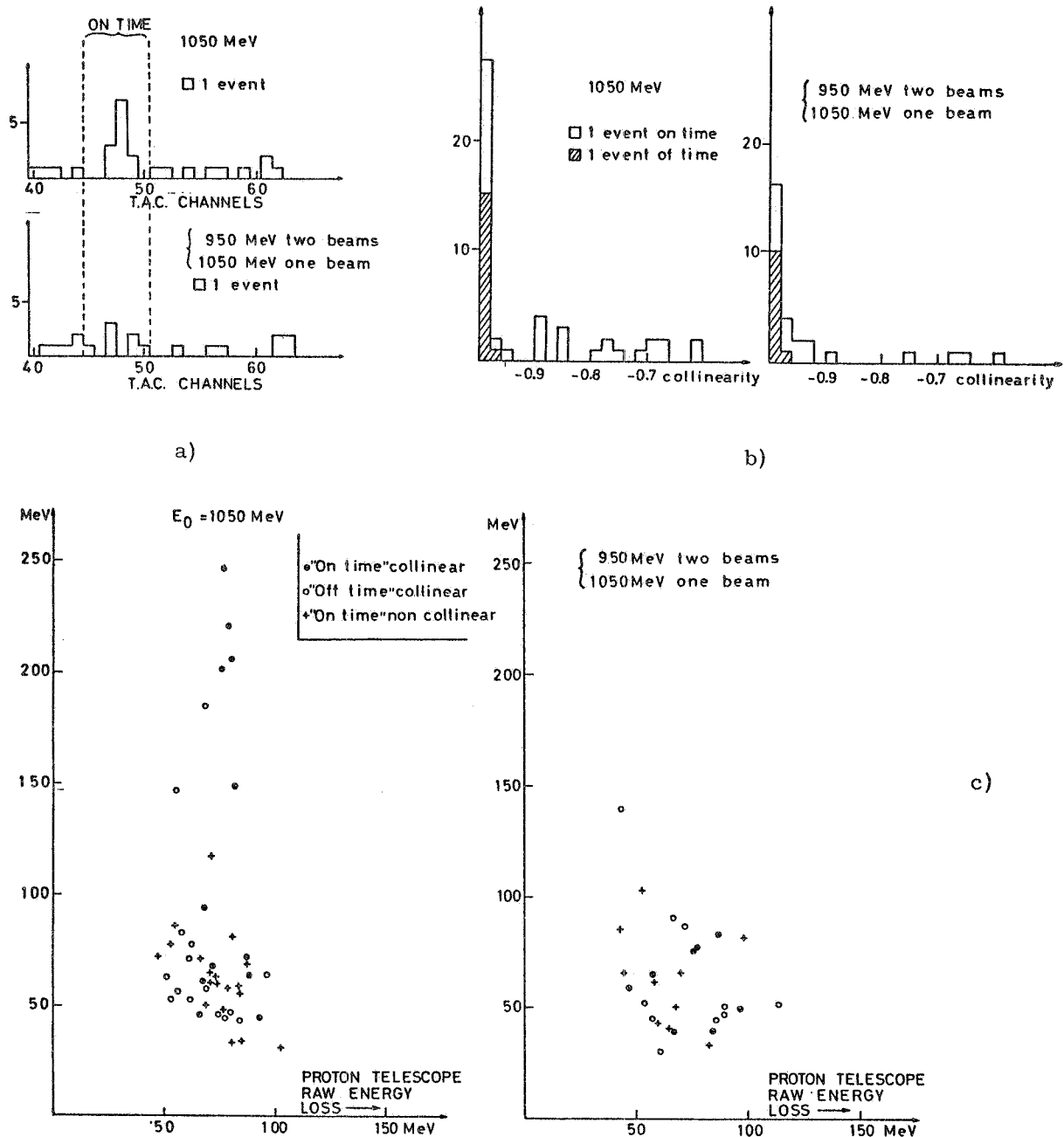
FIG. 9 - a) Time distribution (relative to brunch passage) of collinear "pp̄ " events. Left histogram : events above threshold (1050). Right histogram : background events below trigger threshold (950 MeV) + single beam events at 1050 MeV. Background corresponds to 0. 6 of the total integrated luminosity of 1050 MeV events. b) Collinearity distribution (abscissa is cosine of angle) for on time and off time (shaded area) "pp̄" events. 1050 MeV events (upper histogram) and background (lower histogram) are shown. c) Energy seen in the " p̄ " arm (ordinate) versus energy in the p arm for events at 1050 MeV (left) and for background (right). The expected total proton energy loss in the counters is 80 MeV. The loss in " p̄." arm is larger because of star secondaries.

Also, the Boson group analyzes events in which only 2 non-coplanar charged particles are seen (the plane of the tracks does not contain the beam line). This provides a richer sample, but makes the background problem a bit worse; on the contrary, no serious background affects the case in which at least 3 particles are detected.

The hadronic nature of observed particles has been made secure by calibration of the telescopes with appropriate π and e beams. It is now excluded that low energy electrons simulate hadrons to any relevant extent.

The goal obviously is to give cross sections. Since, however, the many-particle events presumably occur in a large variety of channels and only partial information is picked up (few particles are seen out of many in each event) the analysis is necessarily model dependent.

To be precise, one is forced to assume two kinds of a priori choices :

i - which are the channels occuring in the final states (zoology),
ii - which are the correlations among particles in each channel (dynamics).

Up to now, the type of analysis mostly used is based on phase-space distribution with up to 7 or 8 pions produced.

Since, however, there are many indications of the inadequacy of such approach, a preliminary alternative analysis has been provided in which 2-body channels like $\pi^0 \omega^0$, $\pi^{\pm} A_1^{\mp}$, $\pi^- A_2^{\mp}$, $\rho \eta'$ are considered. The choice of these two-body channels originates in the fact that many theoretical papers[14] suggest (on different grounds) that the 4 indicated should contribute a large part of the cross section.

Before quasi-theoretical pollution, let us review the data circulated up to now in their less refined form. A summary is given in Fig. 10.
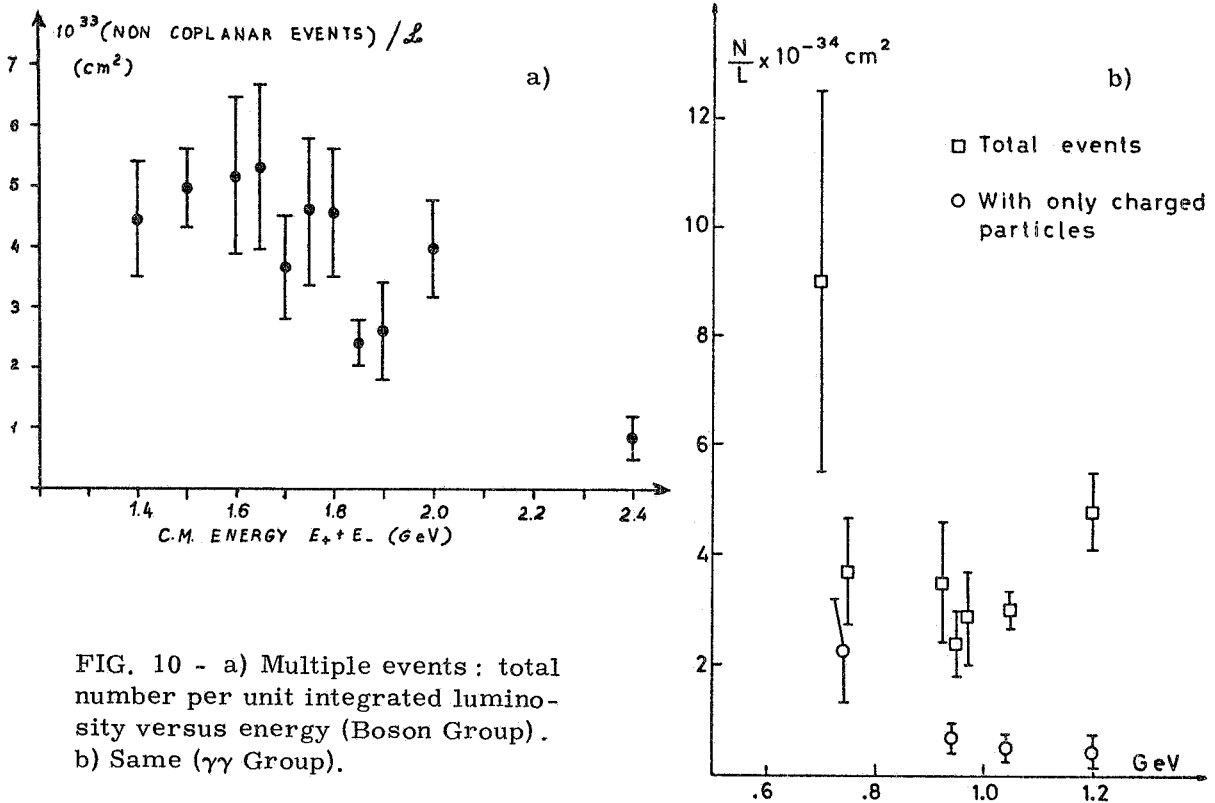

FIG. 10 - a) Multiple events : total number per unit integrated luminosity versus energy (Boson Group).
b) Same (γγ Group).

The data here shown have no obvious meaning; Montecarlo calculations have been used to analyze them, given a model of the many-particle final states. The procedure is to calculate overall efficiencies for detection of a specific event from a given channel (e. g. : $\varepsilon_{2N_c, N_n}(n_c, n_n)$ for the efficiency corresponding to detection of n_c charged, n_n neutrals from $e^+e^- \rightarrow N_c\pi^+ + N_c\pi^- + N_n\pi^0$). Since these efficiencies vary in a wide range, model independent reconstruction of the total cross section is not reasonably possible.

A common feature of the different set-ups is that the overall efficiency for detection of a given final state does not depend very much on dynamics, that is on an gular and mass correlations. However, some simple parameters depending on coarse features of the angular distributions are indeed quite sensitive.

We refer again to Table II in order to appreciate the differences among the set-ups.

a) Boson Group[15]. - A large number of events (about 700) has been collected. Most of them correspond to 2 non-coplanar charged tracks (530 events, $\Delta\phi \geq 13^\circ$). A frac tion of about 9% corresponds to 3 detected charged tracks and 13% of events with 2 charged + 1 neutral are observed.

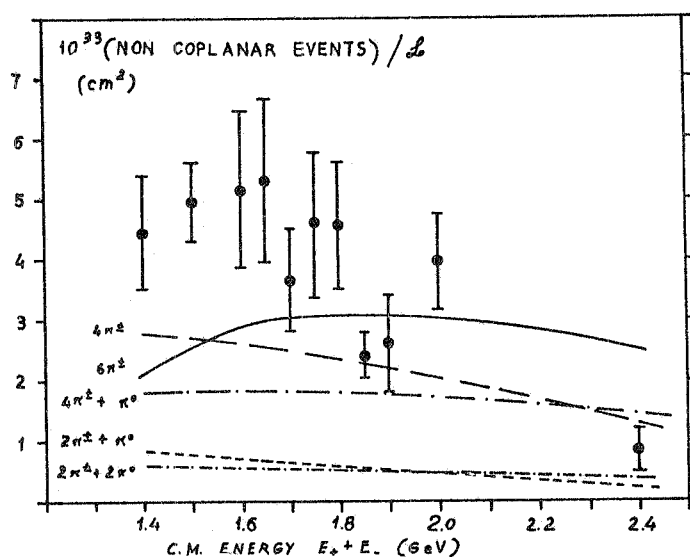Events with 2 charged + 2 neutrals, 3 charged + 1 neutral and 4 charged occur, in negligible amounts ($\leq$ 1%).

FIG. 11 - Same as Fig. 10a), with curves cor responding to a constant cross section of 30 nb for specific channels and phase-space model.

No important energy struc ture is seen in the interval $1.4 \leq \leq 2E \leq 2.4$ GeV.

The simplest channel with high efficiency (phase-space only) corresponds to

$$e^+e^- \rightarrow 2\pi^+2\pi^-$$

which helps in putting a lower limit of about 30 nb for the total cross section.

The detailed data, including the fraction with neutrals, are not satisfactorily consistent with a do minance of
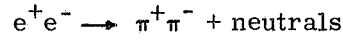
$$e^+e^- \rightarrow 2\pi^+2\pi^- , \quad \pi^+\pi^-2\pi^0$$
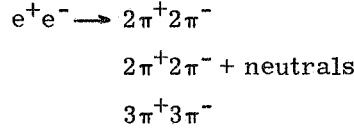
and a substantial contribution of

$$e^+e^- \rightarrow 2\pi^+2\pi^- + \text{neutrals}$$

is required to get a plausible fit.

In Fig. 11 it is shown how a constant cross section of 30 nb would compare with the data assuming a single final state dominance.

b) $\gamma\gamma$ Group[16]. - On the basis of 147 events distributed among several categories ac cording to the nature and number of detected particles (3 at least), the main conclu-

sions are : σ_2, the cross section for

$$e^+e^- \longrightarrow \pi^+\pi^- + \text{neutrals}$$

and σ_4, the cross section for

$$e^+e^- \longrightarrow 2\pi^+2\pi^-$$
$$2\pi^+2\pi^- + \text{neutrals}$$
$$3\pi^+3\pi^-$$

can be determined by assuming phase space distributions. Results are shown in Fig. 12.
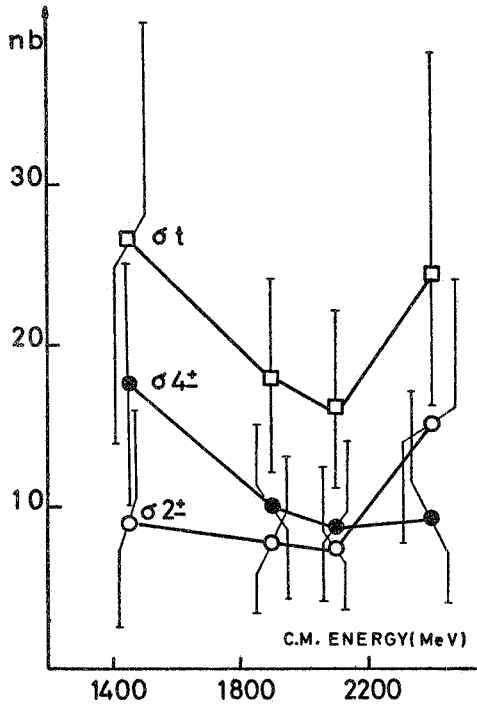

FIG. 12 - The cross sections

σ_2 for $e^+e^- \longrightarrow \pi^+\pi^- + \text{neutrals (phase space)}$

σ_4 for $e^+e^- \longrightarrow 2\pi^+2\pi^-$

$\qquad\qquad\qquad 2\pi^+2\pi^- + \text{neutrals} \qquad \text{(ph. sp.)}$

$\qquad\qquad\qquad 3\pi^+3\pi^-$

$\sigma_t = \sigma_2 + \sigma_4$

versus energy ($\gamma\gamma$ Group).

Also, the data allow setting the limit

$$\sigma(\pi^+\pi^-\pi^o) + \sigma(\pi^+\pi^-\gamma) \leq 2 \text{ nb}.$$

At $2E = 2.1$ GeV, where most of the data have been collected,

$$\frac{\sigma(2\pi^+2\pi^-) + \sigma(3\pi^+3\pi^-)}{\sigma(2\pi^+2\pi^- + \text{neutrals})} = 0.5$$

indicating a large contribution from events with neutrals and high multiplicity.

Some information is obtained, with poor statistics, by the analysis of configurations (n, n') in which n tracks are in a hemisphere, n' in the opposite. For 5 events with 4 detected charged particles

$$\frac{(2,2)}{(3,1)} = 3:2 \qquad \begin{cases} 21 \text{ expected for } A_1^{\pm} \pi^{\mp} \\ \\ 3 \text{ expected for } 2\pi^+2\pi^- \text{ phase space.} \end{cases}$$

For 15 events with 2 charged + 2 neutrals detected

$$\frac{(2,2)}{(3,1)} = 13:2 \qquad \begin{cases} 40 & \text{expected for } \pi^o \omega^o \\ 4.2 & \text{expected for } \pi^+ \pi^- 2\pi^o \text{ phase space.} \end{cases}$$

c) $\mu\pi$ Group. - The analysis, based on 118 events with at least 3 detected charged tracks, leads to the following conclusions :

The distribution of the angles between tracks in events with 3 detected charged particles agrees with phase-space for $2\pi^+ 2\pi^-$ + neutrals as shown in Fig. 13.

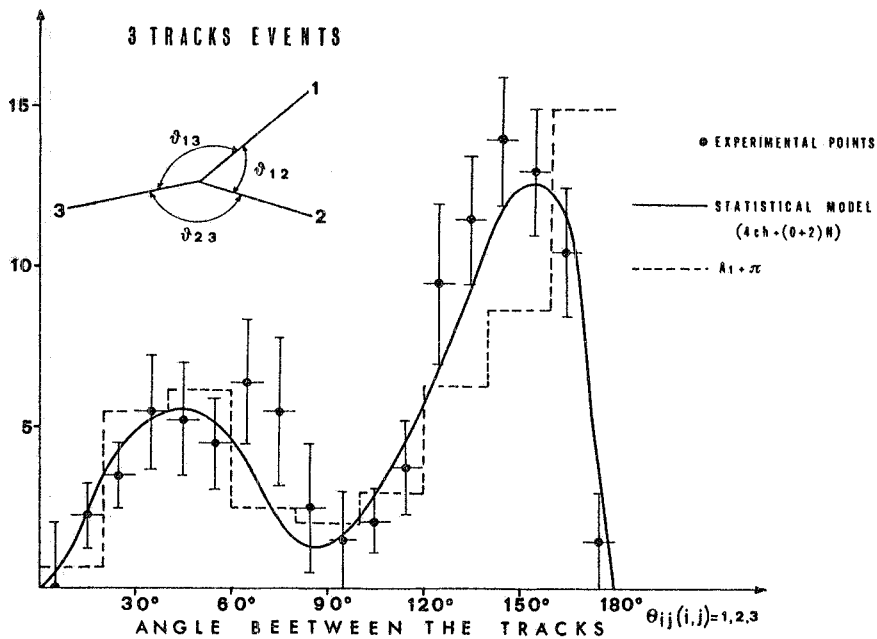FIG. 13 - Distribution of the relative angles of 3 detected charged tracks. Curve is the prediction based on phase-space ($\mu\pi$ Group).

The analysis of configurations (n, n') with n tracks in a hemisphere, n' in the opposite, gives for 34 events with 4 detected charged particles

$$\frac{(2,2)}{(3,1)} = 30:4 .$$

This ratio must be compared with

2.5 expected for $2\pi^+ 2\pi^-$, $2\pi^+ 2\pi^- \pi^o$, phase-space

1 expected for $2\pi^+ 2\pi^- 2\pi^o$, $3\pi^+ 3\pi^-$, phase-space

10 expected for $A_1^{\pm} \pi^{\mp}$.

The observation of 2 events with 5 detected charged particles at $2E = 2.0$ GeV indicates that

$$\sigma(3\pi^+ 3\pi^-) \lesssim 2.0 \pm 1.4 \text{ nb} .$$

This limit is in accord with the other circumstance that the number of events with 3 detected charged particles is larger than the number with 4 detected charged particles by a factor 4.3 ± 1.5. A charged multiplicity of 6 or more would favor a factor of order 1.

As for cross sections, values are found depending on the channels selected for the analysis. A summary of the results is shown in Fig. 14.
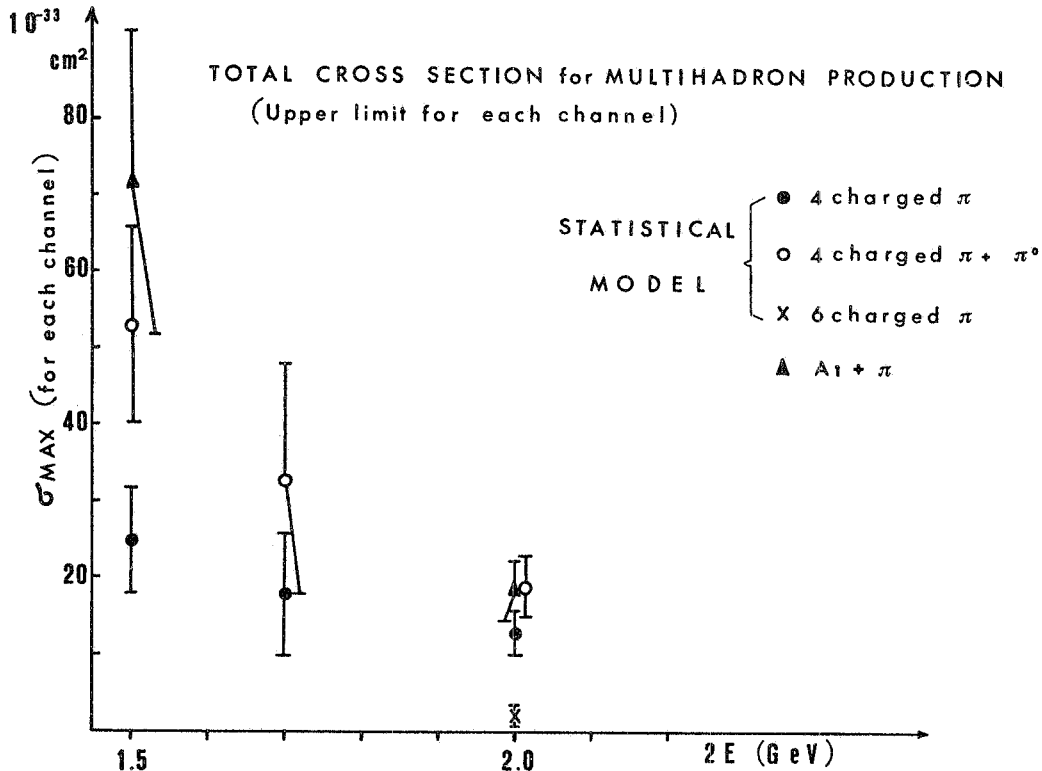

FIG. 14 - Cross sections corresponding to some multiparticle channels versus energy ($\mu\pi$ Group).

d) Conclusions. - No simple conclusion can be drawn from the above results. I would say tentatively that the most abundant final states are

$$2\pi^+ 2\pi^-, \quad \pi^+ \pi^- 2\pi^0, \quad 2\pi^+ \pi^- + \text{neutrals}$$

but this statement is somewhat arbitrary.

No clear indication came out favoring quasi-2-body channels against statistical models, but a trend corresponding to production of pairs like $A_1^- \pi^+$ can be seen in the data. Since the separation of a specific reaction is not simply possible, the presence of high mulitplicity channels tends to smooth the data.

Finally, concerning cross sections, I am inclined to conclude that particles at small θ are less probable than particles around $90°$. However, the explicit inclusion of $\sin^2\theta$ distributions in quasi-2-body final states did not change the results to an appreciable extent.

9. - NEXT STEPS. -

My last remark concerns the installation of an analyzing magnet next spring. Larger solid angle, charge recognition and momentum analysis offer a lot of new possibilities : among others, I want to mention that of studying structure func tions in

$$e^+e^- \longrightarrow h + stuff$$

by single charged track reconstruction. To my opinion, the structure functions of the pion will be of some interest because they possibly approach their asymptotic form in this energy range. However, the study of baryonic resonances near thres-hold ($\bar{p}N^*$, $\bar{N}^*N^*$ etc.) will also be interesting from the form-factors point of view.

In summary, the next major steps at Adone will be :

- Energy up to 2×1.5 GeV (Now);
- Magnetic analysis (Spring 1972);
- Luminosity improvement by a factor 10 (?).

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