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C. Bemporad: EXPERIMENTAL RESULTS OF e^+e^- ANNIHILATION AT ENERGIES 3 GeV AND LOWER.

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EXPERIMENTAL RESULTS OF e^+e^- ANNIHILATION AT ENERGIES 3 GeV AND LOWER(*)

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In this talk I will summarize the new experimental results that have become available since 1973. The papers submitted to this conference come from ACO[1,2,3] and ADONE[4,5,6,7] plus an important contribution from CERN.[8]

Most of the ADONE data were obtained after the installation of three new experiments in three different interaction regions (the fourth region being used for the Bhabha luminometer). These large solid angle experiments have been designed to cope with the high multihadronic production and the rather long source ($47 \pm 5\ E^{3/2}_{GeV\,beam}$ cm FWHM), both phenomena unforseen in the first generation experiments, ended in 1972.

I. - ADONE RESULTS ON THE J/ψ

The natural ADONE energy range, where it was planned to exploit the new facilities for investigating multihadron production, new resonances, proton-antiproton production, etc , is from I GeV to the maximum design energy of 3 GeV[9].

But here comes the J/ψ discovery with all its excitement[10,11]!

The successful effort by the Machine Staff, to make the machine work reliably somewhat over its design maximum energy allowed the ADONE groups to grasp the J/ψ and to contribute in defining its properties[12÷17]

Allow me then to stretch also the energy limit stated in the title so as to present the J/ψ data obtained at ADONE.

The experiments now in operation at ADONE are:

- The $\gamma\gamma$ exp. ($\gamma\gamma$). Covered solid angle for point like source and for tracking $0.66 \times 4\pi$ sr.
  Good γ detection efficiency.
- The magnet experiment (MEA). Covered solid angle for point like source and for tracking $0.4 \times 4\pi$ sr.
  Magnetic field perpendicular to the beams
- The Barion-antibarion exp. (B $\bar{B}$). Covered solid angle for point like source $0.71 \times 4\pi$ sr.
  Good identification of low energy protons.

This last experiment was installed only recently; nevertheless it was able to collect J/ψ decay collinear events by a very reduced version of the final set up; the bulk of the recent ADONE results were contributed by the $\gamma\gamma$ and MEA groups.

The reactions which have been studied are

1) $e^+ + e^- \rightarrow$	hadrons	($\gamma\gamma$, MEA);
2) $e^+ + e^- \rightarrow$	$e^+ + e^-$	($\gamma\gamma$, MEA, $B\bar{B}$);
3) $e^+ + e^- \rightarrow$	$\mu^+ + \mu^-$	($\gamma\gamma$, MEA, $B\bar{B}$);
4) $e^+ + e^- \rightarrow$	neutrals	($\gamma\gamma$);

the absolute luminosity of the machine was measured by the small angle Bhabha scattering and the double bremsstrahlung monitors.

I. 1. - $e^+ + e^- \rightarrow$ HADRONS

Events are classified as hadronic if they have proper timing with the beams and show at least two noncollinear ($\theta > 20^o$) charged tracks ($\gamma\gamma$, MEA) or at least one charged particle and one photon ($\gamma\gamma$); the two particles are requested to be one in each of the two opposite parts of the apparatus.

A charge pion must have a minimum energy of 120 MeV (MEA) and 140 MeV ($\gamma\gamma$) to provide a trigger; this last value is generally reduced by a factor of 3 if a γ is present.

The Montecarlo method was used to estimate the detection efficiency for different multiplicity pion final states, generated according to a Lorentz-invariant phase space.

The possible presence of a kaon contamination of about 20% was checked to have a small effect on the calculated efficiency.

The $\gamma\gamma$ group analysed a sample of about one thousand hadronic events. For each event the number of charged prongs N_{ch} and converted photons N_γ was determined. The experimental results and the calculated efficiencies were inserted in a system of simultaneous equations relating true and observed multiplicities. From the maximum likelihood solution of the system, for events with $N_\gamma + N_{ch} > 2$, it was possible to extract the weight of the topological cross sections $\sigma_2(\pi^+\pi^- + n\pi^o)$, $\sigma_4(2\pi^+ 2\pi^- + n\pi^o)$ etc., and the average multiplicity $\langle n_{\pi^o} \rangle_2$, $\langle n_{\pi^o} \rangle_4$ etc., associated to σ_2, σ_4, etc. respectively.

It is important to remark at this point that the calculated triggering efficiency for the different charged configurations is only weakly dependent on the number of associated π^o's; the accuracy with which the weight of the topological cross section is determined is therefore unaffected by the uncertainty on the photon detection efficiency.

Some systematic uncertainties do affect the determination of the number of low energy photons associated with high multiplicity events.

The results for the weights of the topological cross sections are

$$w_2 = (32 \pm 5)\% \qquad w_4 = (49 \pm 8)\%$$
$$w_6 = (18 \pm 3)\% \qquad w_8 = (1 \pm 0.6)\%$$

the average charged multiplicity is

$$\langle N_{ch} \rangle = 3.8 \pm 0.3 ;$$

the average neutral pion multiplicities associated to the topological channels are

$$\langle n_{\pi^o} \rangle_2 = 3.6 \pm 0.9 \qquad \langle n_{\pi^o} \rangle_4 = 3.1 \pm 0.7 \qquad \langle n_{\pi^o} \rangle_6 = 2.3 \pm 0.6$$

The average total neutral pion multiplicity is therefore

$$\langle N_{\pi^o} \rangle = 3.1 \pm 0.8$$

The quoted errors take into account both the statistical and the systematic uncertainties.

The results on the pion average multiplicities lead to the ratio

$$\langle N_{ch} \rangle / \langle N_{\pi^o} \rangle = 1.2 \pm 0.4$$

in the J/ψ decay.

What one would expect, in the hypothesis of a I=0 resonance and by neglecting intermediate states electromagnetically decaying into pions (such as η's), is a ratio larger than 2; this estimate takes into account the presence of kaonic decays and of the photon mediated decays.

The total hadronic cross section has been measured as a function of the C.M. energy; the excitation curve is shown in Fig. 1a. The full line represents a fit to the experimental points; the effects of the finite energy spread of the machine and of the radiative corrections are included. The best fit results are

$$\Gamma_w = (3.1 \pm 0.2)\ \text{MeV} \qquad \text{F.W.H.M.} \qquad (\gamma\gamma)$$

$$\frac{\Gamma_e \Gamma_h}{\Gamma} = (4.8 \pm 0.8)\ \text{KeV} \qquad (\gamma\gamma),$$

$$\frac{\Gamma_e \Gamma_h}{\Gamma} = (3.9 \pm 0.8)\ \text{KeV} \qquad (\text{MEA}).$$

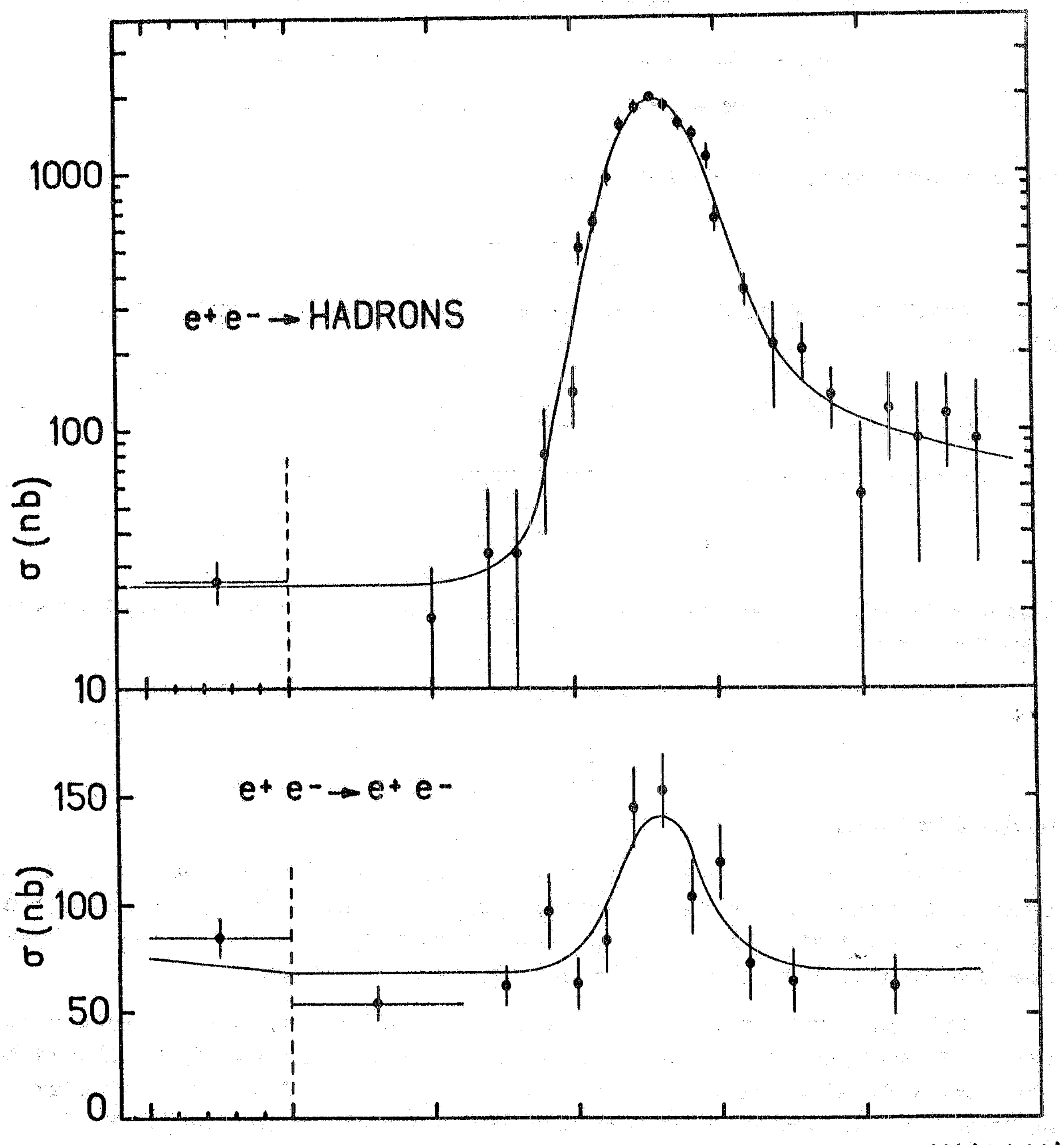

FIG. 1 - Excitation curves for the reactions $e^+ + e^- \rightarrow$ hadrons, a) and $e^+ + e^- \rightarrow e^+ + e^-$, b). The full line represents the best fit to the data. ($\gamma\gamma$ group).

I.2. - $e^+ + e^- \rightarrow e^+ + e^-$

Events are classified as e^+e^- is they have:

a) two collinear tracks within 10^o;
b) proper timing with the beam, origin within the source, proper time of flight in the apparatus;
c) showers present in shower detector ($\gamma\gamma$), or in the external heavy spark chambers (MEA), or ionization ≥ 2 times the minimum after 3.5 r.l. in one of two opposite telescopes ($B\bar{B}$);
d) secondaries of proper momenta (MEA).

One excitation curve is shown in Fig. 1b ($\gamma\gamma$).

In the evaluation of Γ_e^2/Γ from the data, monitoring and detection efficiency uncertainties are bypassed by normalizing to the QED level outside the resonance.

By using the Γ_W the following results, inclusive of radiative corrections,[18] were obtained:

$$\Gamma_e^2/\Gamma = 0.32 \pm 0.07 \text{ KeV} \quad (\gamma\gamma)$$
$$= 0.34 \pm 0.09 \quad (\text{MEA})$$
$$= 0.34 \pm 0.14 \quad (B\bar{B});$$

the associated error is only statistical for the $\gamma\gamma$ and MEA groups; it includes systematic uncertainties on the QED level subtraction for the BB group.

I.3. - $e^+e^- \longrightarrow \mu^+\mu^-$

Events are classified as $\mu^+\mu^-$ if they have the signature a) + b) + d) and moreover:

e) no electromagnetic shower present ($\gamma\gamma$, MEA, $B\bar{B}$);
f) no nuclear interaction in the thick plate spark chambers (MEA);
g) secondaries of proper momenta (MEA).

Cosmic ray rejection is obtained by time of flight technique.

The obtained $\Gamma_e \Gamma_\mu / \Gamma$ are:

$$\Gamma_e \Gamma_\mu / \Gamma = 0.38 \pm 0.05 \text{ (MEA)}$$
$$= 0.31 \pm 0.09 \text{ } (B\bar{B})$$

These results are in good agreement with the ones by SPEAR[19] and DORIS[20].

Possible energy effects on the asymmetry, which were indicated by preliminary data of the MEA group[21], are still under study.

I.4. - $e^+e^- \rightarrow$ NEUTRALS

The $\gamma\gamma$ group has already published the results relative to the decays $J/\psi \rightarrow \pi^o \gamma$, $J/\psi \rightarrow \eta^o \gamma$, $J/\psi \rightarrow \gamma\gamma$. They are:

$$\Gamma_{\pi^o \gamma}/\Gamma < 0.5\% \qquad 90\%\ \text{C.L.}$$

$$\Gamma_{\eta^o \gamma}/\Gamma < 1.6\% \qquad 90\%\ \text{C.L.}$$

$$R = \frac{\gamma\gamma\ \text{YIELD}\ 3098 < \text{ECM} < 3104\ \text{MeV}}{\gamma\gamma\ \text{YIELD}\ E_{CM} < 3098,\ E_{CM} < 3104\ \text{MeV}} = 1.6 \pm 0.6 \quad [16]$$

The new result is about the decay $\psi \rightarrow \eta'(958) + \gamma$[4] searched in the channel

$$J/\psi \rightarrow \eta'\gamma$$
$$\quad \hookrightarrow \varrho\gamma$$
$$\qquad \hookrightarrow \pi^+\pi^-$$

A sample of hadronic events, corresponding to an integrated luminosity of 9 nb^{-1}, was taken at the peak energy of the J/ψ. A subsample was selected satisfying the configurations:

1) 2 charged prongs + 2 γ's

or

2) 2 charged prongs + 1γ , where, in this case, the two prongs are both in one of the semicylindrical part of the apparatus.

A rough estimate of the energy of the detected γ is possible from the track length and spark pattern of the shower in the spark chambers. The energy calibration can be continuously checked by events like $e^+e^- \rightarrow \gamma\gamma$, $e^+e^- \rightarrow e^+e^-$, simultaneously collected by the set up.

10 events of type 1) and 0 events of type 2) were obtained. 5 of the 10 events satisfied momentum balance, thus showing that no particle escaped detection. For these remaining 5 events the effective masses $M(\pi^+\pi^-)$ and $M(\pi^+\pi^-\gamma_2)$ (where γ_2 is the lower energy γ) were evaluated and compared with the ϱ and the η' masses, taking into account the angular resolution of the measurement and the ϱ mass width.

Any candidate for the decay $\psi \rightarrow \eta'\gamma$ should appear with 95% probability in the dashed area of the scatter plot in Fig. 2; the only candidate was rejected because of the clear inconsistency between the calculated energy (50 MeV) and the shower pattern in the detector. The limit derived is:

$$\frac{\Gamma_{\psi \rightarrow \eta'\gamma}}{\Gamma_h} < 1.7\% \qquad 90\%\ \text{C.L.}$$

or using the known ratio Γ_h/Γ

$$\Gamma_{\psi\to\eta'\gamma} < 1\,\mathrm{KeV} \qquad 90\% \quad \mathrm{C.L.}$$

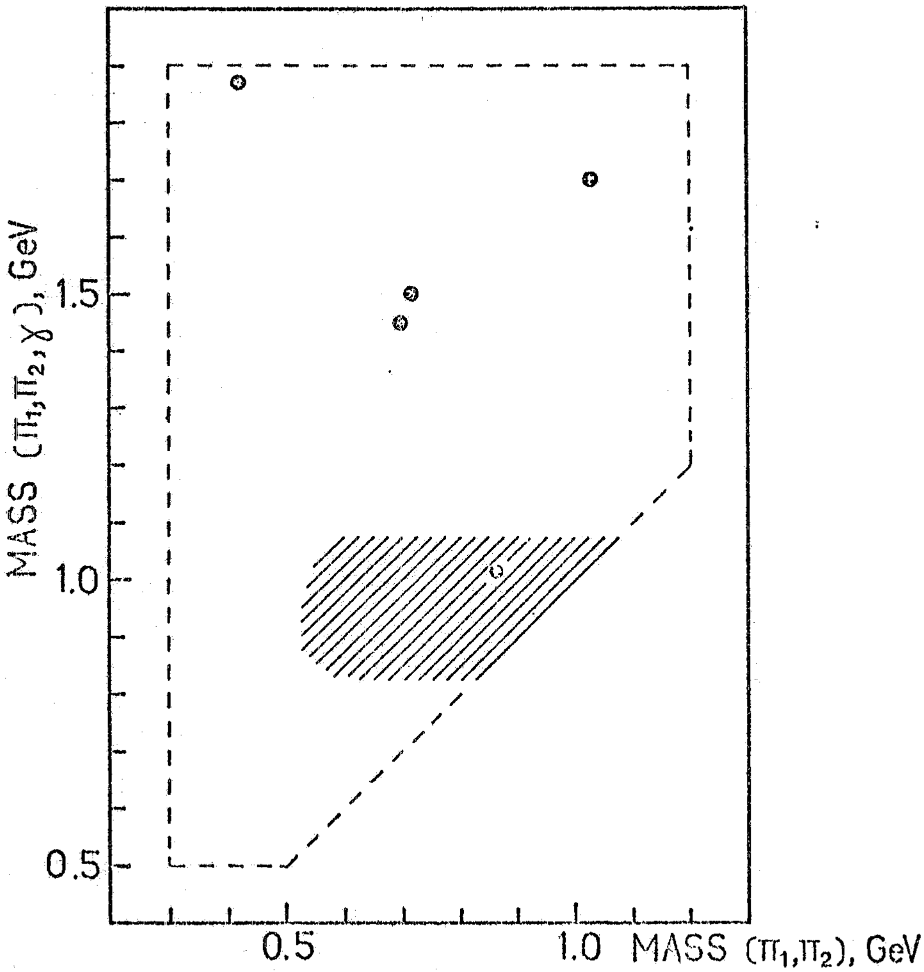

FIG. 2 - Scatter plot of the invariant mass $M(\pi^+, \pi^-)$ of the pion pair versus the invariant mass $M(\pi^+, \pi^-, \gamma)$, γ being the less energetic detected photon, for the events satisfying the momentum balance. The area limited by the dashed line represents the geometrical and trigger acceptance of the apparatus for two prongs and two photons isotropically distributed. The dashed area represents the acceptance of apparatus for 95% of the events from the decay $J/\psi\,(3100) \to \eta'\gamma$, with $\eta' \to \rho\gamma$, taking into account the experimental angular resolution and the ρ width.

A summary of the ψ properties as measured at ADONE is presented in Table I.

TABLE I

PROPERTIES OF THE J/Ψ (3100)

(MASS = 3103 ± 6 MeV)

GROUPS	$\gamma\gamma$	MEA	$B\bar{B}$
$\Gamma_e \Gamma_h / \Gamma$	4.8 ± 0.8 KeV	3.9 ± 0.8 KeV	-
Γ_e^2 / Γ	0.32 ± 0.07 KeV	0.34 ± 0.09 KeV	0.34 ± 0.14 KeV
$\Gamma_e \Gamma_\mu / \Gamma$	--	0.38 ± 0.05 KeV	0.31 ± 0.09 KeV
Γ_e	4.6 ± 0.8 KeV	4.6 ± 1.0 KeV	--
Γ_μ	--	5.0 ± 1.0 KeV	--
Γ_h	59 ± 24 KeV	50 ± 23 KeV	--
$\Gamma = \Gamma_e + \Gamma_\mu + \Gamma_h$	68 ± 26 KeV	60 ± 25 KeV	--
$\Gamma_{\pi^0\gamma} / \Gamma$	< 0.5% 90% C.L.	--	--
$\Gamma_{\eta^0\gamma} / \Gamma$	< 1.6% 90% C.L.	--	--
$\Gamma_{\eta'\gamma} / \Gamma$	< 1.7% 90% C.L.	--	--
$R_{\gamma\gamma/QED}$	1.6 ± 0.6	--	--

II. - SEARCH FOR POSSIBLE OTHER NARROW RESONANCES -

On the wake of the J/ψ discovery, a systematic search for narrow resonances decaying into hadrons has been made. The C.M. energy intervals were 1910-2545 MeV explored in I MeV steps and 2970-3090 explored in 2 MeV steps. Portions of these energy regions were studied more than once.

Since the F.W.H.M. C.M. energy resolution of ADONE varies according to $\Gamma_w(\text{MeV}) = 0.32\, w^2\, (\text{GeV})^2$ the chosen steps were adequate to detect resonances narrower than Γ_w.

The raw data of the scan are presented in Fig. 3 (MEA)[7] and 4 ($\gamma\gamma$)[5].

The search, corresponding to a total luminosity of 153 nb^{-1}, had a sensitivity to narrow resonances well summarized in Table II ($\gamma\gamma$).

No narrow resonance is present with an integrated cross section exceeding 10% of the corresponding J/Ψ value. No limit has yet been derived from the data, for resonances of width larger than Γ_w. The narrow reso-

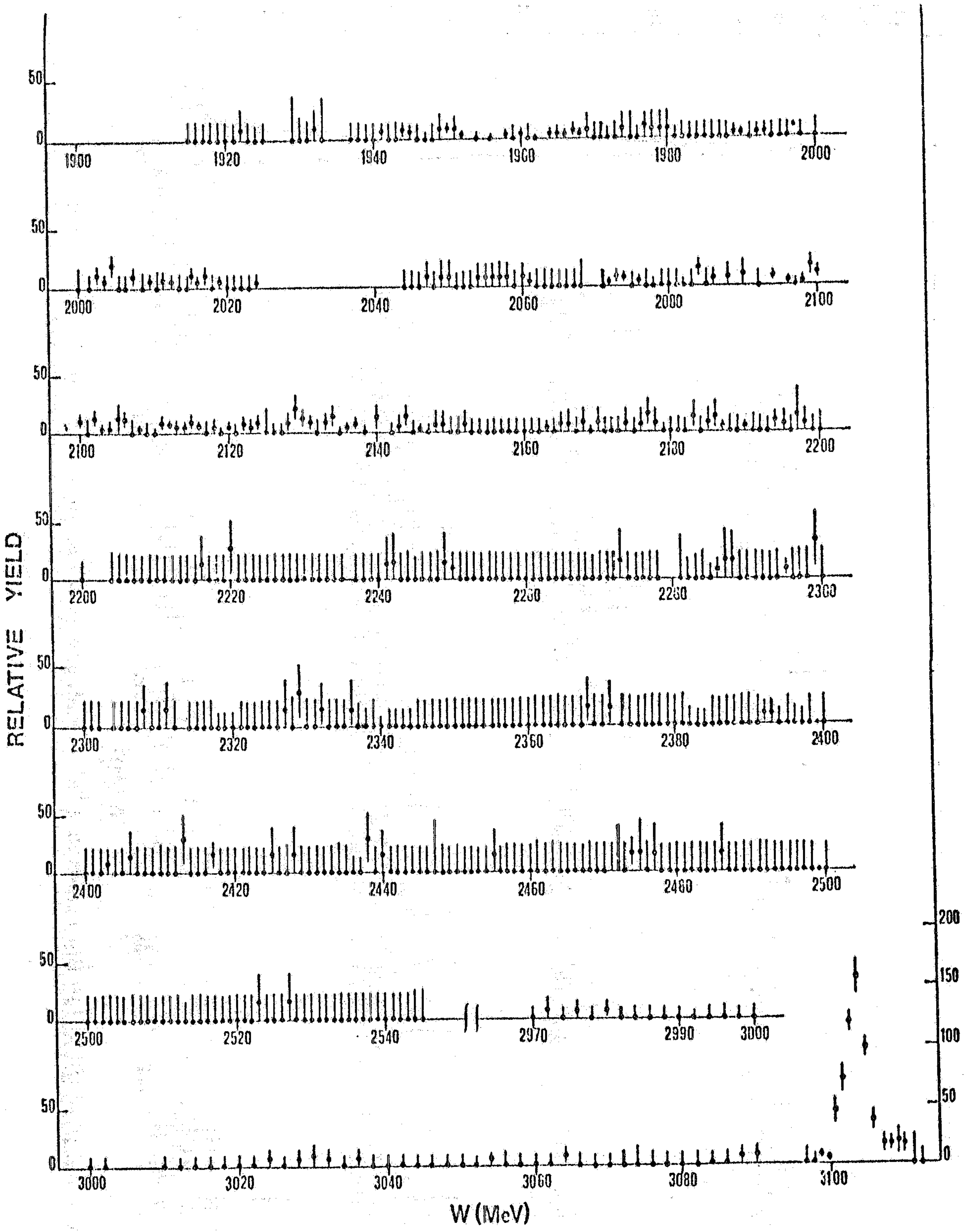

FIG. 3 - Relative yield for the reaction $e^+e^- \rightarrow$ hadrons as a function of the total C.M. energy W.

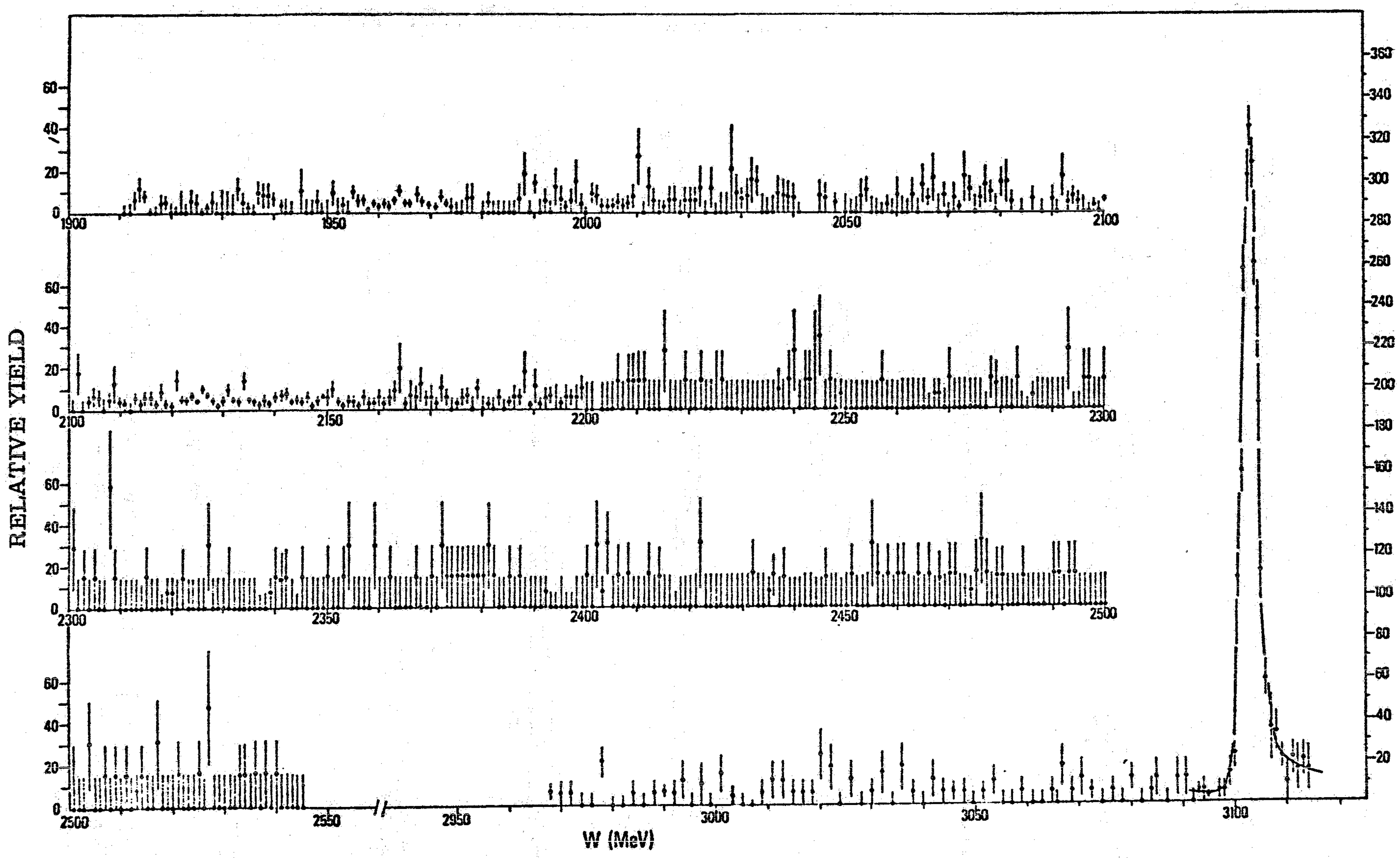

FIG. 4 - Relative yield for the reaction $e^+e^- \rightarrow$ hadrons as a function of the total c. m. energy W.

nance search is being pursued to cover yet unexplored energy regions.

TABLE II - Upper limits at the 90% confidence level for the integrated resonant cross section for a resonance whose width is less than the mass resolution. The radiative corrections have been taken into account.

Total c.m. energy range W (MeV)	ΔW (MeV)	$\int_{\Delta W} [\sigma(W)-\sigma_{NR}(W)]\,dW$ upper limit (90% c.l.) (nb · MeV)	Non resonant background σ_{NR} (nb)
1910 - 2200	2	950	29 ± 9
2200 - 2545	2	660	30 ± 9
2970 - 3090	4	830	25 ± 8

III. - PROTON FORM FACTORS IN THE TIME LIKE REGION.

An important result, coming from CERN[8], enters this presentation via time reversal; it is the first experimental evidence for the reaction

$$p + \bar{p} \longrightarrow e^+ + e^-$$

Two previous attempts at CERN[22] and BNL[23] gave upper limits for the process at $Q^2 = -6.8, -6.6, -5.1\ (\mathrm{GeV}/c)^2$.

The inverse reaction

$$e^+ + e^- \longrightarrow p + \bar{p}$$

studied at ADONE[24], measured a cross section $\sigma = 0.91 \pm 0.22$ nb at $Q^2 = 4.3\ (\mathrm{GeV}/c)^2$. This corresponds to $|G_E| = |G_M| = 0.27 \pm 0.04$ in the hypothesis of equal electric and magnetic proton form factors.

The new CERN result is for antiprotons at rest ($Q^2 = -3.5\ (\mathrm{GeV}/c)^2$), so complementary to the ones of any experiment on ($e^+ + e^- \longrightarrow p + \bar{p}$): such low Q^2 value cannot be reached if the produced proton has to be detected.

The $\bar{p}$'s of an electrostatistically separated beam are moderated and brought to rest in a 50 cm long H_2 target. The target is surrounded by 4 equal parts composed of kinematical thin foil optical spark chambers followed by lead-scintillator shower detectors followed by heavy plate optical spark chambers (Fig. 5a, 5b).

29 electron pairs with energy above 700 MeV were found; 10 are collinear within 1°; the remaining 19 events are well separated from the others and are probably due to annihilation in flight and to high mass vector mesons from processes like

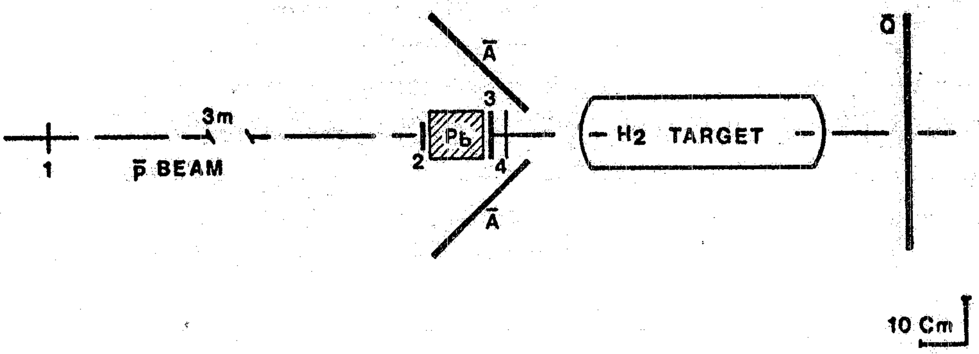

FIG. 5a)

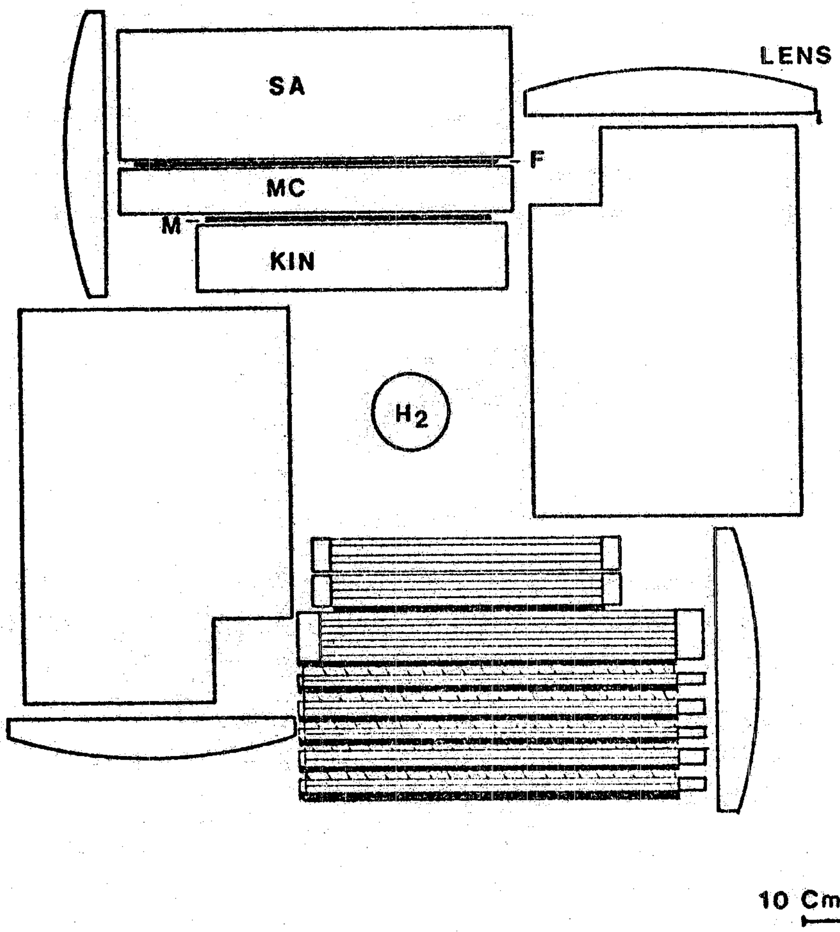

FIG. 5b)

FIG. 5 - Experimental apparatus for the study of $\overline{p} + p \rightarrow e^+e^-$.

$$\bar{p} + p \longrightarrow V + \pi^o$$
$$\hookrightarrow e^+ + e^-$$

The contamination in the sample of e^+e^- collinear events is estimated to be less than 1%.

The authors give the preliminary result of their experiment in the form of the branching ratio

$$B_{e/h} = \frac{\Gamma(p\bar{p} \to e^+e^-)}{\Gamma(p\bar{p} \to h^+h^-)} = (1.2^{+0.6}_{-0.4})10^{-4} \qquad h^\pm = \pi^\pm,\ k^\pm$$

Since the ratios[25]

$$\Gamma\ (p\bar{p} \to \pi^+\pi^-)/\Gamma\ (p\bar{p} \to \text{TOTAL}) = (3.2 \pm 0.3)10^{-3}$$

$$\Gamma\ (p\bar{p} \to k^+k^-)/\Gamma\ (p\bar{p} \to \text{TOTAL}) = (1.1 \pm 0.1)10^{-3}$$

the result can also be given in the form

$$B_e = \frac{\Gamma\ (p\bar{p} \to e^+e^-)}{(p\bar{p} \to \text{TOTAL})} = (5.1\ ^{+2.5}_{-1.7})10^{-7}$$

But how can we extract the form factor G_E and G_M from B_e?

The total cross section for $p\bar{p} \to e^+e^-$ is[26]

$$\sigma_{p\bar{p} \to e^+e^-} = \frac{\pi\ \alpha^2}{3Mp}\ \frac{1}{\eta}\left[(G_E|^2 - 2\eta|G_M|^2\right]$$

$$\eta = Q^2/4M^2$$

At the threshold the angular distribution should be isotropic; this and the hypothesis of non singular Dirac and Pauli form factors F_1 and F_2, give the equality

$$G_E(-4M^2) = G_M(-4M^2) = G(-4M^2)$$

The simplified expression for $\sigma_{p\bar{p} \to e^+e^-}$ cannot be used to extract G due to the momentum p vanishing as $Q^2 \to -4M^2$.

One possible approach to circumvent the problem is to make use of the relation

$$B_e = \frac{\Gamma_{ee}}{\Gamma_{TOT}} = \frac{\Gamma_{ee}}{\Gamma_{hh}}\ \frac{\Gamma_{hh}}{\Gamma_{TOT}}$$

from which

$$\Gamma_{ee} = B_e \frac{\Gamma_{TOT}}{\Gamma_{hh}} \Gamma_{hh}$$

B_e is the quantity already measured at CERN, Γ_{hh}/Γ_{TOT} is known. Since $\Gamma_{hh}(-4M^2) = \lim_{v \to 0} \sigma_{hh} v$, Γ_{hh} can be determined by extrapolating to zero the experimental curve of $\sigma_{\bar{h}h} v$ vs. the $\bar{p}$ kinetic energy. This information can be obtained by the CERN experiment and is the still missing piece needed to extract $|G|$ from the data.

An important conclusion can already be derived from the now known B_e. The relation

$$|G_E(-4M^2)| = |G_M(-4M^2)|$$

might not be the only constraint satisfied by G_E and G_M ; in fact the "scaling law" $G_E = G_M/\mu$ is valid in the space-like region up to $Q^2 \approx 5\,(\mathrm{GeV}/c)^2$.

Were this relation to be valid also in the time-like region up to $Q^2 = -4M^2$, it would follow that to satisfy $|G_E| = |G_M|$, $G_E = G_M/\mu$ it should be $G_E = G_M = 0$.

The CERN exp. says $G \neq 0$, so the scaling law is certainly not valid at $Q^2(-4M^2)$.

We shall wait for the determination of Γ_{hh} to derive $G(-4M^2)$ from the CERN data, but let me remark that using a generalised vector dominance model suggested by Benvenuti and Cline[27] and applied to the reaction

$$p\bar{p} \to \pi^+\pi^-$$

the following relation follows

$$B_e \simeq \frac{6\alpha^2}{\beta_\pi^3} \frac{|G(-4M^2)|^2}{|F_\pi(-4M^2)|^2} \frac{\Gamma_{TOT}}{\Gamma_{\pi\pi}}$$

Since pion form factor is $|F_\pi| = 0.367^{+0.0728}_{-0.084}$ at $Q^2 = -3.61(\mathrm{GeV}/c)^2$ the relation predicts a G value not in contradiction with the existing measurements[22, 23, 24].

IV. - INTERFERENCE EFFECTS IN ω AND ϕ PRODUCTION.

If the production of ω and ϕ is studied through the same decay channel, one should observe the interference between ω and ϕ amplitudes; this effect should be maximum at energies where the amplitude A_ω and A_ϕ are roughly equal .

Parrour et al. at ACO[2] have measured the cross section $e^+ + e^- \rightarrow \pi^+ \pi^- \pi^o$ from 900 to 1100 MeV C.M. energy and in particular at 915, 990, 1076 MeV, energies far from the ω and ϕ peaks. The total luminosity at the ϕ was more than ten times the one collected during the previous ACO experiment.

The reaction $e^+ + e^- \rightarrow K^o_L + K^o_S$ was also studied to determine, from the known ϕ energy position, the energy calibration of the storage ring and to determine the width of the ϕ resonance (best fit value $\Gamma_\phi = 4.25 \pm 0.5$ MeV).

I have no possibility to enter into the thorough and convincing analysis performed to separate the reaction $e^+ + e^- \rightarrow \pi^+ \pi^- \pi^o$ from the many background channels.

The data from the previous ACO experiment[29,30] were added to the recent ones therefore allowing a fit to the theoretical predictions in the C.M. energy range from 770 to 1076 MeV.

For the A_ω and A_ϕ amplitudes, the authors used the forms suggested by Renard[31], which keep into account the many effects to be considered when interpreting data far from the resonance peaks where the Breit and Wigner form is inadequate.

The results of the fit are presented in Fig. 6 for the same and the op

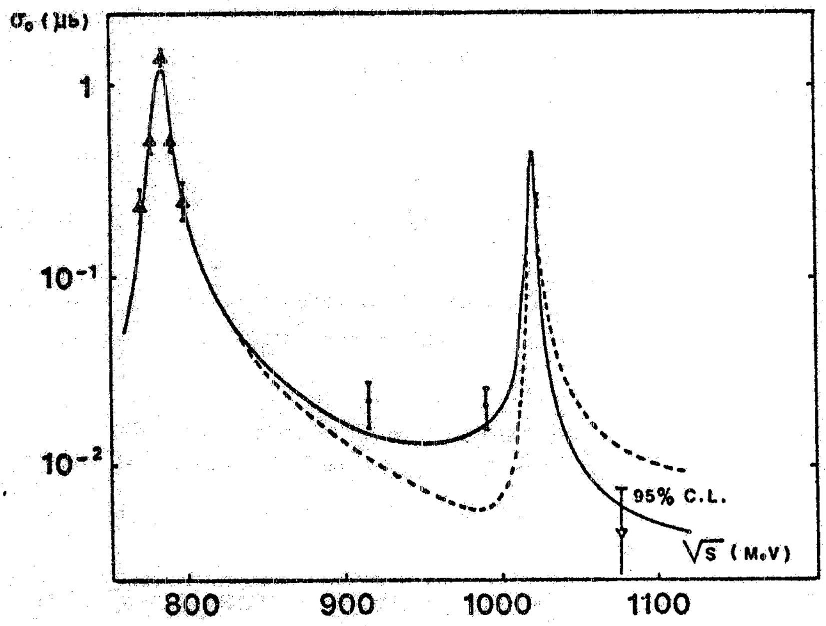

FIG. 6 - Cross section for $e^+e^- \rightarrow \pi^+\pi^-\pi^o$. Full curve: opposite sign between $g_{\omega \rightarrow 3\pi}$ and $g_{\phi \rightarrow 3\pi}$; dotted curve: same sign.

posite signs of the coupling constants $g_{\omega \rightarrow 3\pi}$ $g_{\phi 3\pi}$.

The opposite sign and the positive interference between the ω and ϕ peaks is the chosen solution, as suggested by Renard.

All fits without the use of the ω - ϕ interference are rejected (probability $< 1\%$) both if performed in the full 770 ÷ 1076 MeV energy span or in the region from 1015 to 1025 MeV near to the ϕ peak.

A last fit, leaving the interference phase free, finds the value $155^{\circ} \pm 29^{\circ}$ for this parameter.

It appears that experiments of this type might provide, in the future and by the measurement of the interference between amplitudes, extra constraints to the theories willing to accomodate data on vector meson decays.

V. - ϕ RADIATIVE DECAYS.

At ACO the same group has also obtained an improved determination of the ϕ meson radiative decays[1] through the measurement of the processes

$$e^+ + e^- \rightarrow \phi \rightarrow \eta^0 \gamma \rightarrow 3\gamma$$

$$e^+ + e^- \rightarrow \phi \rightarrow \pi^0 \gamma \rightarrow 3\gamma$$

The difficult analysis which extracts few tens of $\pi^0\gamma$ and $\eta^0\gamma$ events from 1400 3γ's candidates, in turn selected from 10^6 photographs, is very similar to the one already tuned in the previous study of these reactions[32] ; a combination of the following criteria:

I) selection of safety "zones" for $\pi^0\gamma$ and $\eta^0\gamma$ in the Dalitz plot of 3γ events;
2) comparison of the expected γ energies and the ones roughly measured in heavy spark chambers;
3) request for 3γ coplanarity (the reaction plane is defined by the γ conversion points; one studies how the showers develop in respect of this plane).

An important factor in the reduction of uncertainties in the separation of good events from background is the larger available statistics of the new experiment; this allows safer cuts in the 3γ Dalitz plot with now bearable good events losses.

Two remarkable excitation curves were obtained in the $\eta^0\gamma$ and $\pi^0\gamma$ channels (Fig. 7a, 7b).

The newly determined branching ratios $B_{\phi \rightarrow \eta^0\gamma}$ and $B_{\phi \rightarrow \pi^0\gamma}$

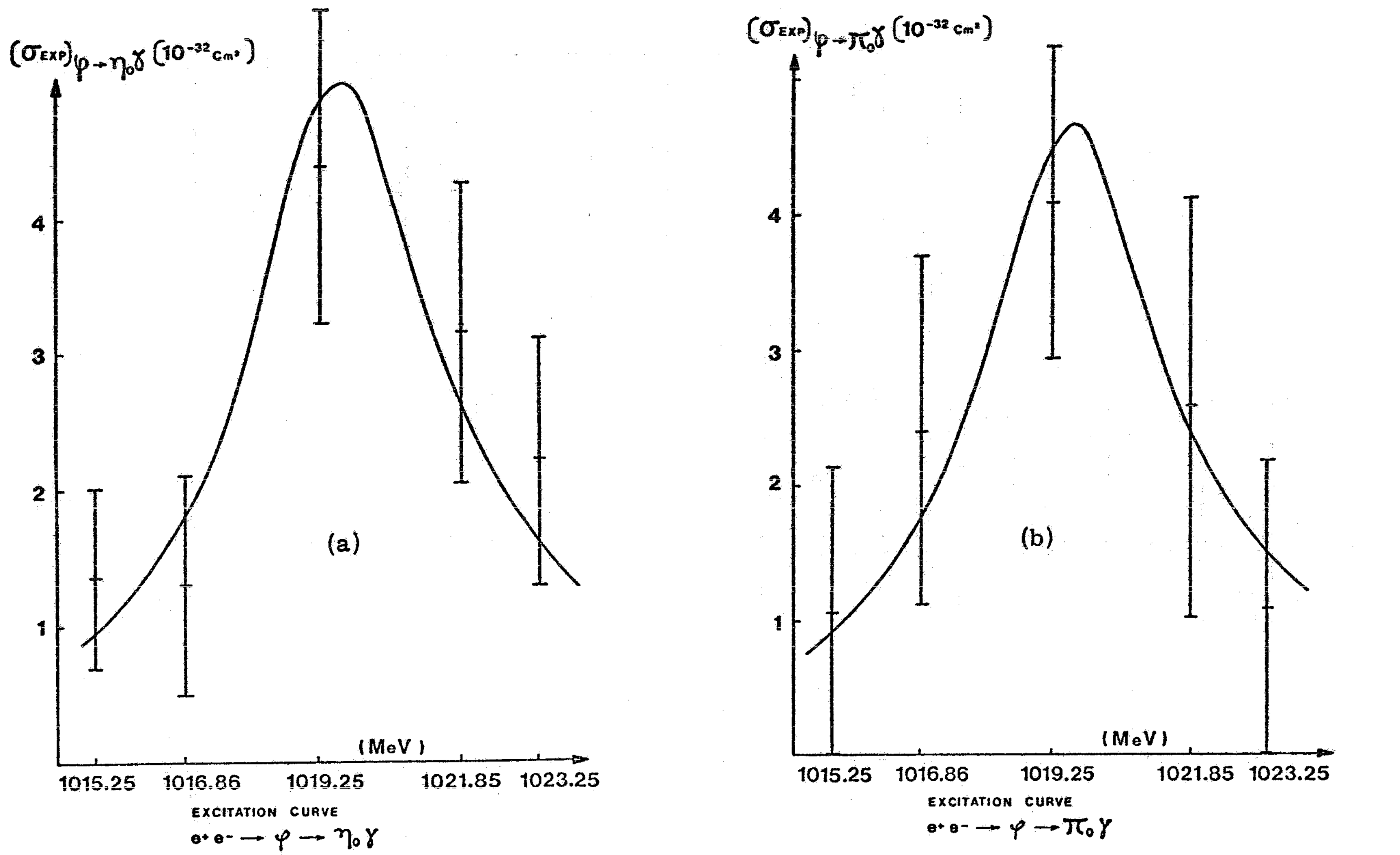

FIG. 7 - a), b) - Excitation curve for $e^+e^- \to \phi \to \eta_0 \gamma$; a) and $e^+e^- \to$ $\to \phi \to \pi^0 \gamma$; b) Experimental points and Breit and Wigner fit.

have the value

$$B_{\phi \to \eta^{o} \gamma} = (1.5 \pm 0.4)10^{-2}$$

$$B_{\phi \to \pi^{o} \gamma} = (1.4 \pm 0.5)10^{-3}$$

to be compared with the published values

$$B_{\phi \to \eta^{o} \gamma} = (7.3 \pm 1.8)10^{-2} \quad 33$$
$$(2.6 \pm 0.7)10^{-2} \quad 32$$

$$B_{\phi \to \pi^{o} \gamma} < 0.35\ 10^{-2} \quad 34$$
$$= (0.25 \pm 0.12)10^{-2} \quad 32$$

I want to mention that during the last few years a certain number of new results on radiative vector meson decays has become available.

Apart from the results presented to this Conference other upper limits and branching ratio determinations are available for $K^{*+} \to K^{+}\gamma$ [35]; $K^{*o} \to K^{o}\gamma$ [36]; $\rho^{-} \to \pi^{-}\gamma$ [38]; $\rho^{o} \to \eta^{o}\gamma$ [37], in Table III.

TABLE III

RADIATIVE DECAYS OF VECTOR MESONS.

	Quark model	Exper.	
$\phi \to\ ^{o}$	240 KeV	65 ± 15 KeV	This Conf.
$\phi \to \pi^{o}\gamma$	15 KeV	5.9 ± 2.1	This Conf.
$\rho^{-} \to \pi^{-}\gamma$	120 KeV	35 ± 10	P.R.L. 33, 1450 (1974)
$\rho^{o} \to \eta^{o}\gamma$	70 KeV	<160	Nordberg, August (1973)
$K^{*+} \to K^{+}\gamma$	70 KeV	<80	NP B51 1 (1973)
$K^{*o} \to K^{o}\gamma$	270 KeV	75 ± 35	Muhlemann et al. Prepr. Rochester (1975)

It does not appear that the quoted values are in such good agreement with the leading theoretical predictions.

VI. - PION FORM FACTOR IN THE TIME LIKE REGION NEAR THE THRESHOLD.

An interesting result was obtained at ACO[3] by using the solenoid and MWPC system recently installed.

The apparatus consists of a 9 KG solenoid containing 4 thin (10^{-3} R. L.) cylindrical MWPC's with anode wires parallel to the beam and two families of cathode wires at 45° in respect of the beam.

Cosmic rays are vetoed by counters placed on the top and sides of the magnet behind a lead shield.

The experimental result derives from measurement of the reaction

$$e^{+} + e^{-} \rightarrow \pi^{+} + \pi^{-}$$

at the minimum available ACO C.M. energy i.e. 480 MeV; a difficult measurement because of the small cross section, the vanishing ACO luminosity at this low energy and the cosmic ray background one has to fight with.

To make the investigation possible the magnetic structure of the machine had to be modified gaining so a factor of 2 in luminosity (5×10^{30} cm^{-2} h^{-1}).

Being the beam lifetime very brief, 200 injections were needed to collect the final 60 $\pi^{+}\pi^{-}$ events (Fig. 8)!

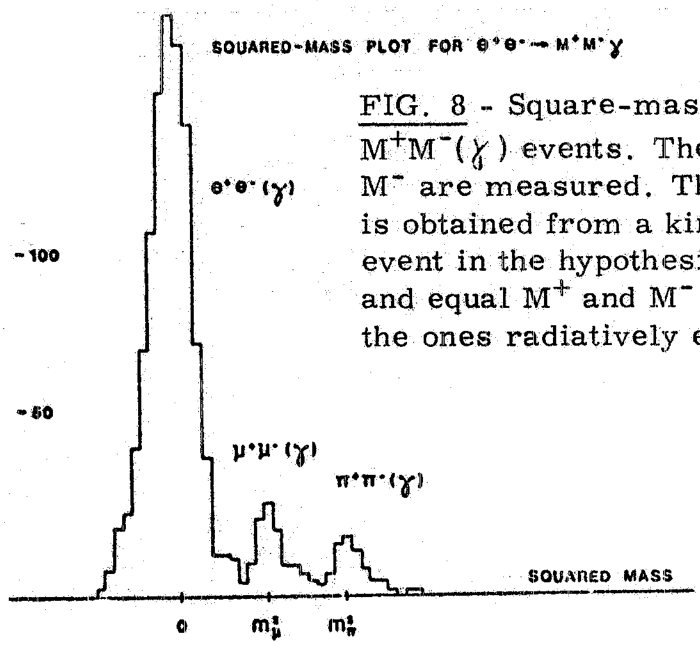

FIG. 8 - Square-mass plot for the M of $M^{+}M^{-}(\gamma)$ events. The momenta of M^{+} and M^{-} are measured. The γ ray momentum is obtained from a kinematical fit to each event in the hypothesis of single γ emission and equal M^{+} and M^{-} masses. The γ's are the ones radiatively emitted.

The authors found a cross section at C.M. energy 484 MeV.

$$\sigma = (0.169 \pm 0.025)\ \mu b$$

from which

$$|F_\pi| = 1.83 \pm 0.13$$

in good agreement with the Gounaris-Sakurai fit to the ACO Π^0 results[39].

This new experimental information gives extra confidence in the evaluation of the hadronic contribution to the muon anomalous magnetic moment, based on a Gounaris-Sakurai expression for the pion form factor[40].

FOOTNOTE AND REFERENCES -

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