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G. P. Murtas: TWO PHOTON ANNIHILATION. -

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TWO PHOTON ANNIHILATION

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I will consider in my talk the so called two photon processes in colliding electron-positron beams

$$e^+e^- \longrightarrow (e^+e^-\gamma\gamma) \longrightarrow e^+e^-X$$

in which the virtual photons annihilate into a C = + leptonic or hadronic state:

$X \rightarrow e^+e^-$ $\qquad$ $X \rightarrow \pi^o$

$X \rightarrow \mu^+\mu^-$ $\qquad$ $X \rightarrow \eta^o$.

$X \rightarrow \pi^+\pi^-$

I recall that this kind of reaction has been extensively considered also because of their interest since from the annihilation of the virtual photons, states with C = + are produced.

Furthermore an interesting feature of these processes is their energy dependence: it happens in fact that above certain energies they become predominant with respect to one photon exchange mechanism.

For a general reference on the theoretical works on this subject see Brodsky report at the 1971 Intern. Symposium on Electron and Photon Interactions, Cornell.

The Feynmann diagram for these e. m. fourth order processes is shown in the Fig. 1.

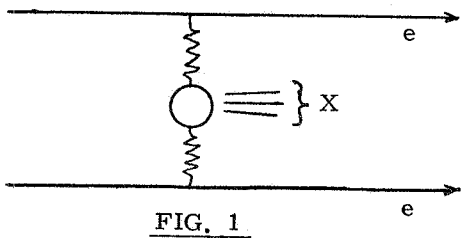


FIG. 1

The first theoretical approach to this problem is the "equivalent photon approximation", E. P. A.

This technique gives a general connection between electroproduction and photon cross-section and it is valid when primary electrons are both scattered into small forward angles (see Fig. 2)

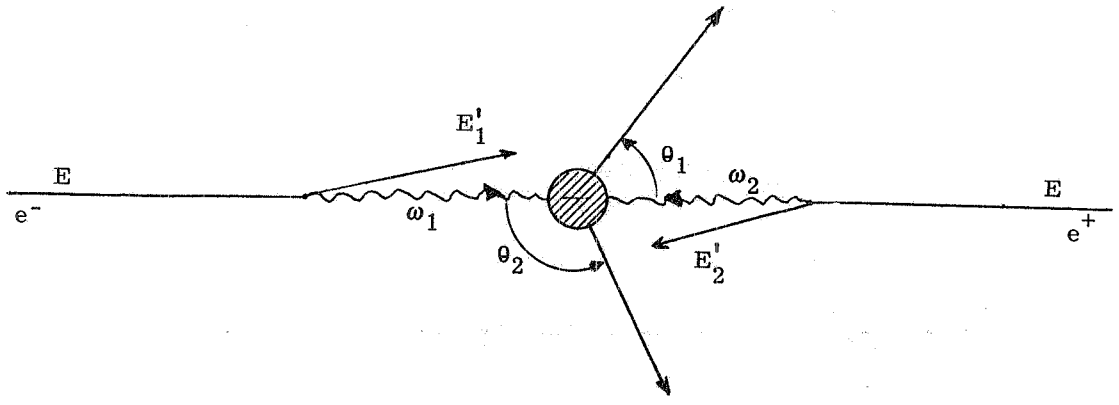


FIG. 2

Following the notation of Fig. 2

$$d\sigma_{ee \to eeX}(E) = \int^{E} \left(\frac{d\omega_1}{\omega_1}\ \frac{2\alpha}{\pi}\ \frac{E^2+E_1'^2}{2E}\ \ln\frac{E}{m_e}\right)\left(\frac{d\omega_2}{\omega_2}\ \frac{2\alpha}{\pi}\ \frac{E+E_2'^2}{2E}\ \ln\frac{E}{m_e}\right) d\sigma_{\gamma\gamma \to X}(S)$$

where $S = 4\,\omega_1\omega_2$, and $d\sigma_{\gamma\gamma}$ is the differential cross-section for the annihilation of two opposite-direct real unpolarized photons in to a state X. Expressions in brackets represent the equivalent photon spectrum of an electron of energy E.

According to the E. P. A. the simplest examples of the two photons cross section are shown in Fig. 3. (In the case of pion pair cross section the Born approximation is used). In Fig. 3 it is also shown the cross section of one photon exchange cross section for muon pair production.

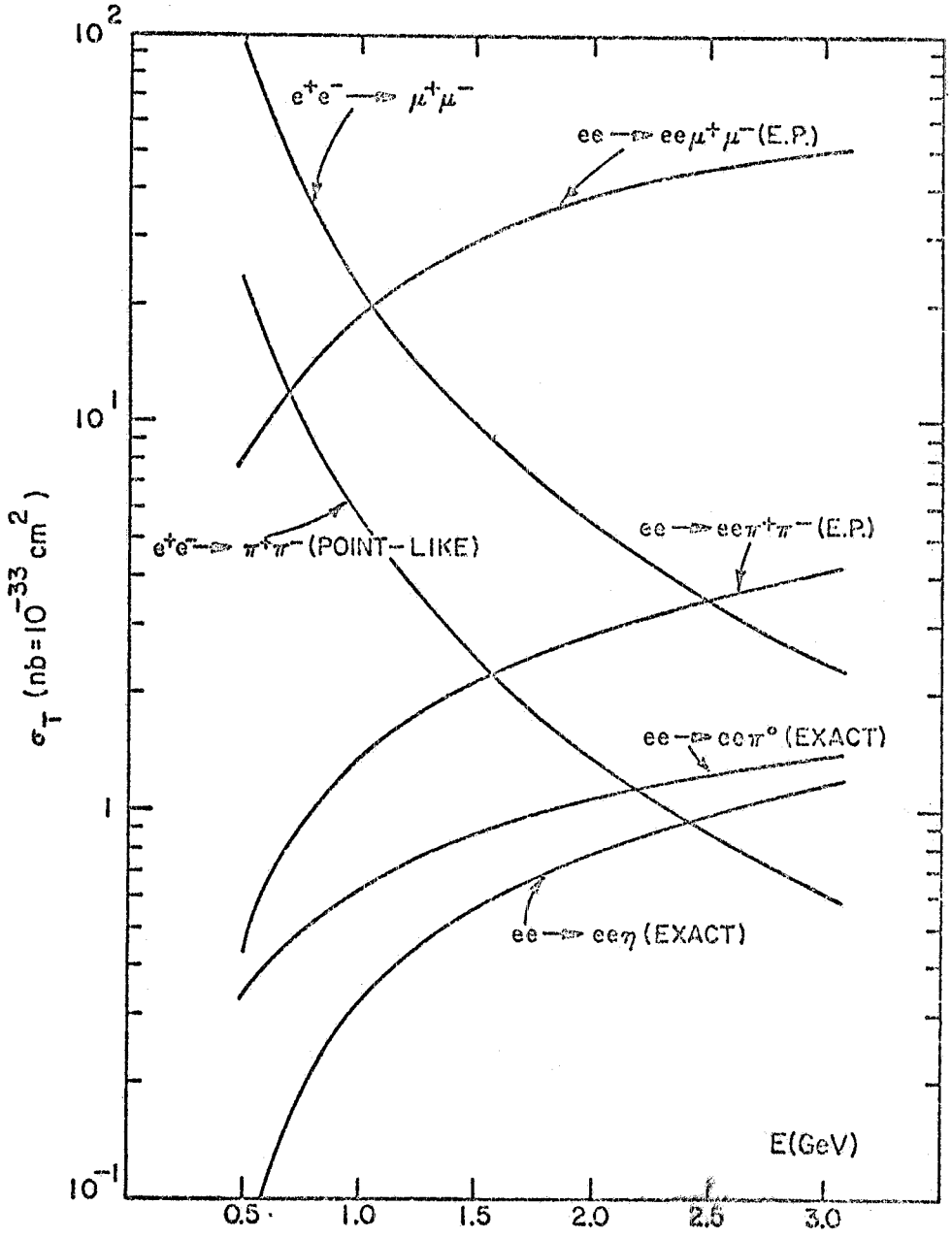


FIG. 3

It is worth noticing that the energy dependence of the two reactions goes like $\ln^3 E$ for the $ee \rightarrow eeX$ whereas the one photon exchange reactions goes like $1/E^2$.

Before going on with the discussion of the experimental results obtained in this field we should note some kinematical features of the two photon processes.

- Since the photons are roughly collinear with the electron-positron beam, the produced pair is approximately coplanar with the incident beam;
- Since the momenta of the two photons are generally different, the c.m. frame is moving relative to the lab and the produced pair will generally be not collinear.

Experimental results. -

Two experiments on $\gamma\gamma$ process have been so far performed and their results published.

The first work has been done with the colliding beam machine VEPP 2 in Novosibirsk at 2x510 MeV by V. E. Balakin et al. (Phys. Letters 34B, 663).

The observed reaction is

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

Only the two wide angle electrons are detected with the experimental set up shown in Fig. 4.

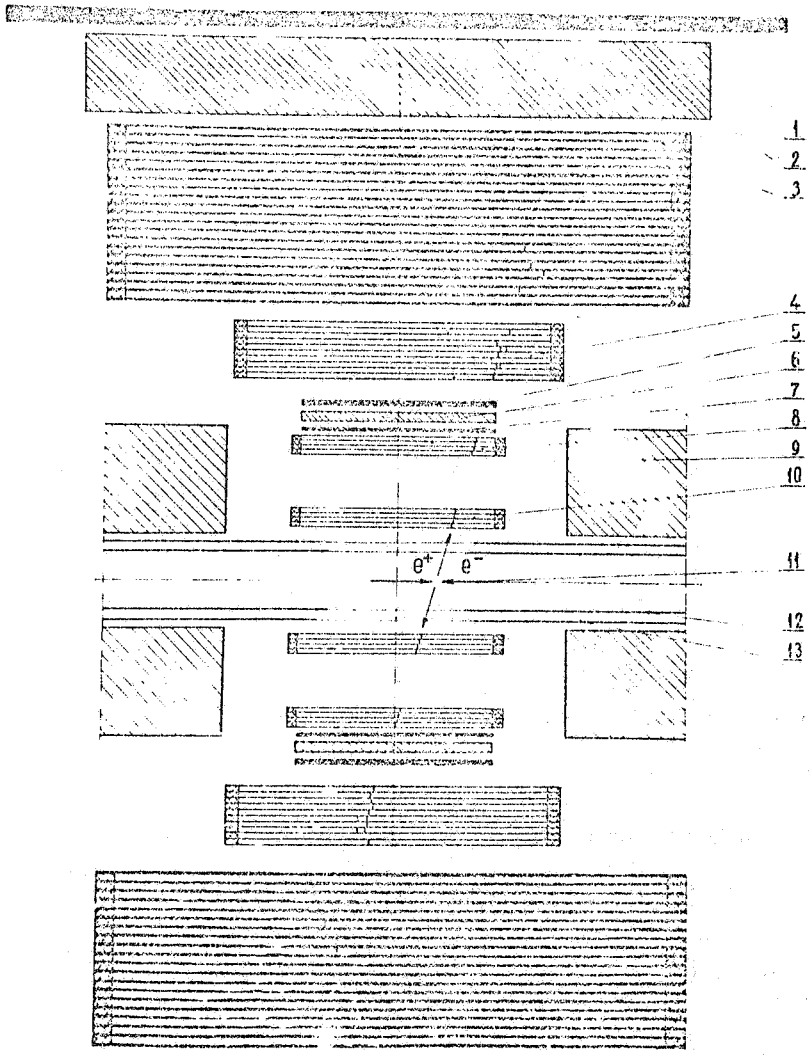


FIG. 4

Results are shown in Table I.

TABLE I

$\|\Delta\theta\|$ interval (degrees)	0 - 40	40 - 90
Effect	150	71
Background (normalization factor 0.30)	16	21
Admixture of the other processes considered	13 ± 5	0.2
"Clean" effect	84 ± 19	1 ± 18
Calculation according to Baier and Fadin paper[5]	65 ± 13	22 ± 5

E = 510 MeV $\quad L_{int} = 8.5 \pm 0.4$ nb^{-1}

$\Delta\theta$ is the non collinearity angle between the two wide angle electrons. The electronic nature of the detected particles is established on the basis of multiple scattering argum ents.

In Fig. 5 is shown the distribution of events with respect to the no-coplanarity angle.

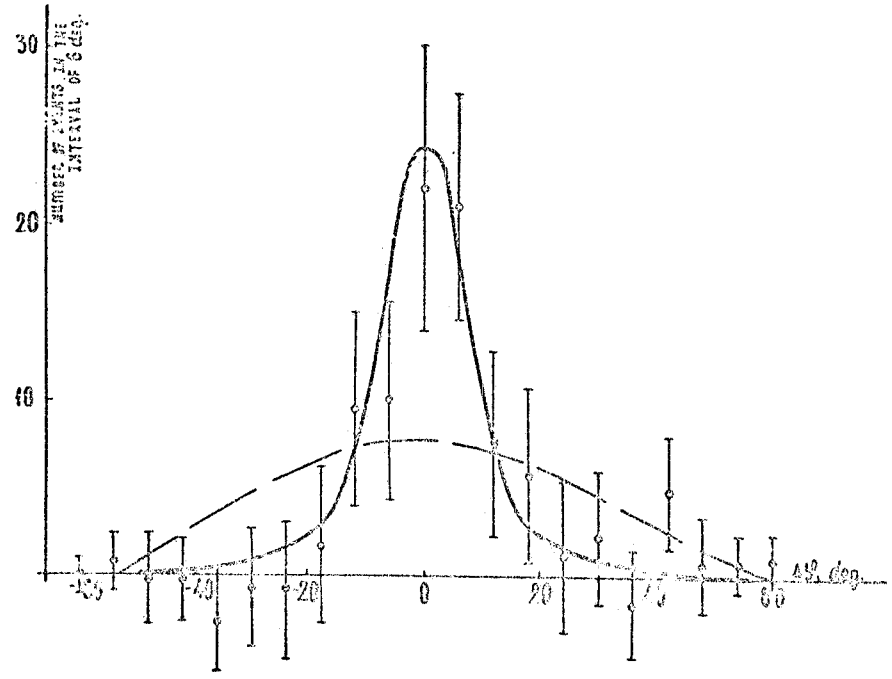


FIG. 5 - Pair electroproduction events distribution with respect to angle $\Delta\varphi$. Solid curve is obtained with the Baier and Fadin formulas. Dashed one represents the computed distribution for the process with independent and isotropic particle distribution.

Other measurements have been performed by the same group in the 1970 with better discrimination between electrons and other particles obtained with the help of Cerenkov counter. All experimental results are in agreement with Baier-Fadin calculation.

The second experiment was made in Frascati from the $\gamma\gamma$ group (C. Bacci, R. Baldini-Celio, G. Capon, C. Mencuccini, G. P. Murtas, G. Penso, A. Reale, G. Salvini, M. Spinetti and B. Stella) at an average beam energy E of 1 GeV.

The observed reaction is

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

and at least 3 final particles are detected in this experiment.

The experimental set up is shown in Fig. 6. One forward emitted electron or positron is bent by the magnets of the storage ring with an angular acceptance of 20 mr and a fraction of them is detected by the counters C_e or C_p. The energy of the electrons and positrons accepted by the C_e or C_p counters covers the range 0.7 - 0.9 GeV. The corresponding virtual photons have energies in the interval 0.1 - 0.3 GeV.

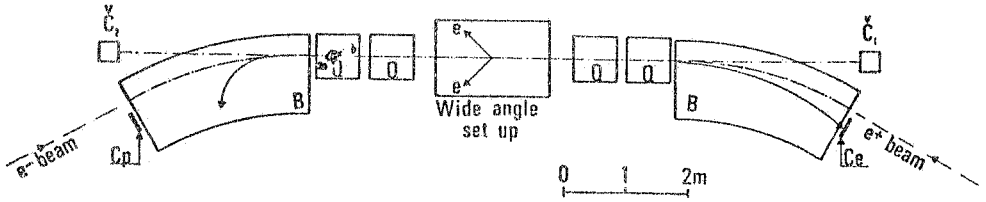


FIG. 6

The two wide angle electrons are detected in the apparatus shown in Fig. 7, with a threshold energy of 50 MeV and with a detection efficiency ε_2 shown in Fig. 8.

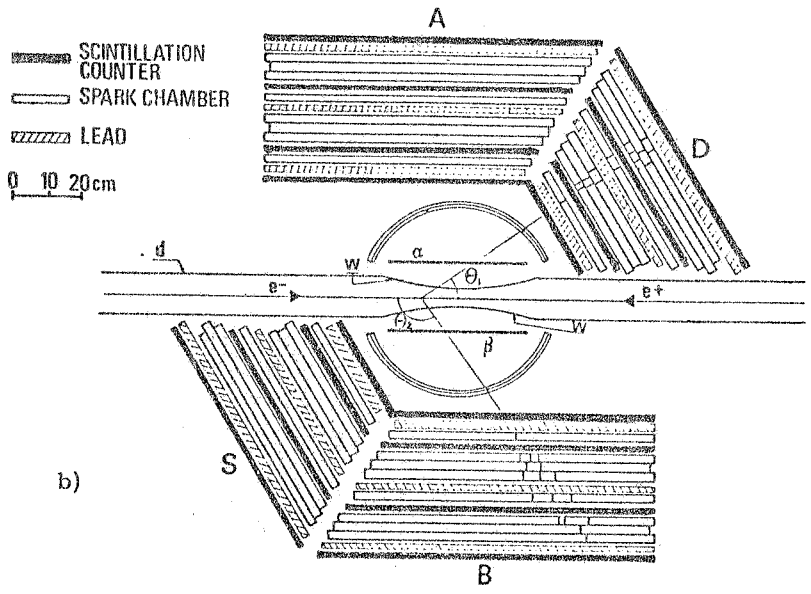


FIG. 7

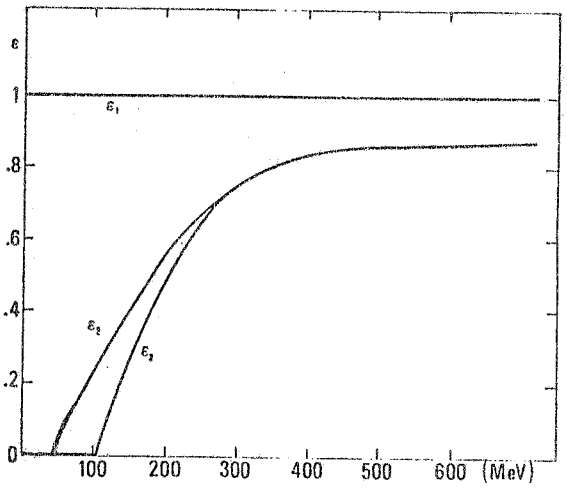


FIG. 8

The four telescopes A, B, D, S, each made of plastic scintillator, optical spark chambers, and lead converters allow a good discrimination between showering and no-showering particles.

Events are selected requiring a no-collinearity angle $> 10^{o}$ to avoid accidentals due for istance to Bhabha scattering. No event due to beam-gas interaction was found.

29 events have been found for an integral luminosity of 123 nb^{-1}. Fig. 9 reports the distribution of the C. M. velocity of the two wide angle electrons

$$|\beta| = \frac{\text{sen}\,|\theta_1 - \theta_2|}{\text{sen}\,\theta_1 + \text{sen}\,\theta_2}$$

β is defined as negative when C. M. move in the same direction with respect to the forward

detected particles. In this case the wide angle electrons have lowest energies ; and their detection is critically dependent on the efficiency ε of the four telescopes. Thus the fact that events with $\beta < 0$ was not observed could be not significant.

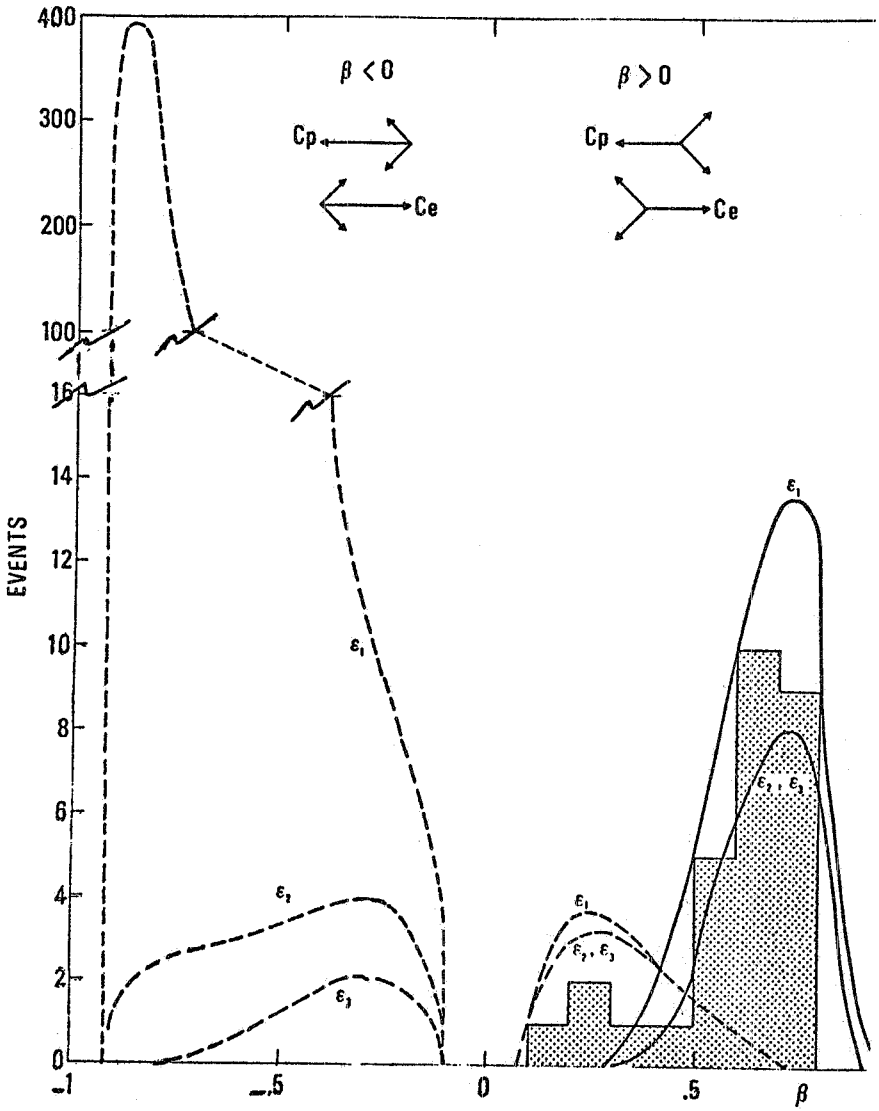


FIG. 9

All detected events have β 0 and experimental results are in disagreement with values of β as calculated by using E. P. A. with the hypothesis previously cited (dotted curves ; forsake of comparison are also shown the predictions obtained assuming electron detection efficiencies ε_1, ε_3 different from the measured one ε_2). Values of β obtained by using calculation performed by N. Cabibbo and G. Parisi in the hypothesis that one of the scattered electron goes at wide angle is shown also in Fig. 9 (solid curves).

In this case the two electrons or positrons with small transverse momentum are mostly emitted in the same direction (see Fig. 10), and the events must concentrate in the region with positive values of β.

The corresponding absolute predictions are in good agreement with the experimental results.

During this experiment this group has also collected a few events with no showering tracks in the spark chambers.

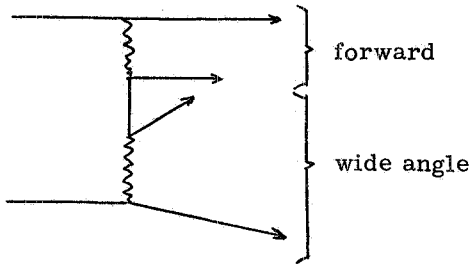


FIG. 10

These events could be interpret as due to reaction:

$$ee \longrightarrow ee\mu\mu \qquad \text{or} \qquad ee \longrightarrow ee\pi\pi .$$

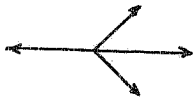
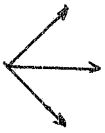
Last moment data obtained by $\gamma\gamma$ group and $\mu\pi$ group (G. Barbiellini, G. Barbarino, F. Ceradini, M. Conversi, M. Grilli, E. Iarocci, N. Nigro, L. Paoluzi, R. Santonico, P. Spillantini, L. Trasatti, V. Valente, R. Visentin and G. T. Zorn) at Adone.

Tagging counters have been mounted between Adone vacuum chamber and magnet by these two groups.

Energy of forward electrons are measured detecting the impact point by means of time flight in the range of $(5 \times 10^{-2} - 0.8)\,E$.

Preliminary results are shown in Table II.

TABLE II

	$\gamma\gamma$ group	$\mu\pi$ group
Events ee → eeee	30	23
Luminosity	35 nb^{-1}	30 nb^{-1}
W. A. apparatus	"$\gamma\gamma$"	"$\mu\pi$"
Angular acceptance of W. A. apparatus	$15^o - 140^o$	$45^o - 135^o$
Threshold of W. A. electr.	As first exp. 150 MeV 1/2 eff.	30 MeV
Type of events:		
	29	14
	1	1
	0	8