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G. Barbiellini and S. Orito: AN EXPERIMENTAL POSSIBILITY TO DETECT THE HIGHER ORDER ELECTROMAGNETIC PROCESSES AT ADONE. -

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G. Barbiellini[(+)] and S. Orito[(o)]: AN EXPERIMENTAL POSSIBILITY TO DETECT THE HIGHER ORDER ELECTROMAGNETIC PROCESSES AT ADONE[(x)].

To detect the almost real $\gamma\gamma$ collisions, we propose to install a tagging system utilizing the bending magnets of ADONE. A main purpose is the experimental check against the contaminations on the 1γ (annihilation) processes coming from the higher order electromagnetic reactions such as $e^+e^- \to e^+e^-e^+e^-$, $e^+e^- \mu^+\mu^-$ or $e^+e^-e^+e^-e^+e^-$. The system also allows us to investigate the hadronic 2γ processes such as $e^+e^- \to e^+e^- \pi^+\pi^-$ or the production of c = +1 resonances like $e^+e^- \to e^+e^- \eta'$. Furthermore it is possible by this scheme to get a clean identification of the radiative vector meson productions.

1. - PURPOSES.

1.1. - Contamination on annihilation processes.

Fig. 1 shows possible diagrams of the higher order electromagnetic processes in the $e^\pm$ collison. Recent calculations[(1, 2, 3, 4)] show relatively large cross sections of these 2γ and 3_γ processes already at GeV region. This implies a possibility to investigate the almost real $\gamma\gamma$ collisions by using the existing or coming $e^\pm$ colliding beam machines.

(x) - Invited paper to the Intern. Conf. on Meson Resonances and Related Electromagnetic Phenomena, Bologna (April, 1971).

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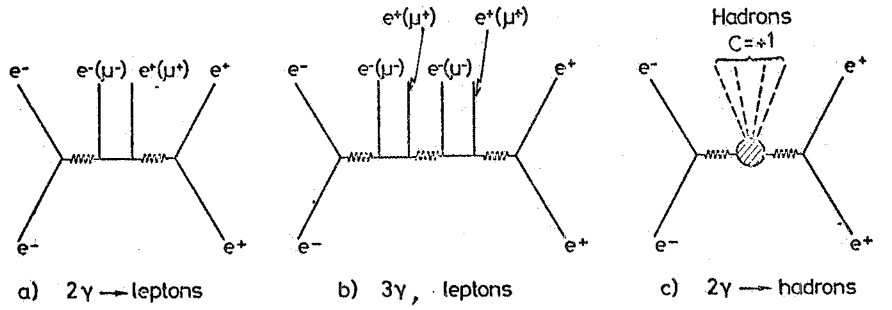

FIG. 1 - Higher order electromagnetic processes in e^+e^- collision.

At the same time, it also indicates some danger of contaminations coming from these 2γ (or 3γ) processes on the 1γ (annihilation) processes. For example, the 2γ process $e^+e^- \rightarrow e^+e^- \mu^+\mu^-$ is expected to have a total cross section of 70 nb at beam energy of 1.5 GeV. This contributes to an effective cross section of 2 nb(5) for the muon pairs with each kinetic energy larger than 150 MeV to be detected by a wide angle detector covering $\theta = 90^o \pm 40^o$, $\Delta\phi/2\pi = 0.8$(5). About 10 % of them (effective cross section of 0.2 nb) will give the collinear track within $\pm 5^o$. In the same way, we expect a cross section of 0.3 nb(5) for the collinear $e^\pm$ with each kinetic energy larger than 150 MeV coming from the 2γ process $e^+e^- \rightarrow e^+e^-e^+e^-$.

These values are appreciably large if compared to the corresponding effective cross section of 0.4 nb expected for the annihilation process $e^+e^- \rightarrow \pi^+\pi^-$ (6). It should be noticed that there exist some difficulties, in most of the detectors being used at ADONE, to distinguish these low energy muons or electrons from the pions. For the complete rejection of such contaminations, a clean experimental identification of the 2γ (3γ) processes would be valuable.

1.2. - Hadronic 2γ processes.

The investigation of the hadron production by $\gamma\gamma$ collision is extremely interesting in itself, since essentially no experimental information is available at this moment. For the reaction $e^+e^- \rightarrow e^+e^-\pi^+\pi^-$, a total cross section of 4 nb is expected at beam energy of 1.5 GeV (assuming the point like pion). This corresponds to an effective cross section of 0.1 nb for the pion pairs with each kinetic energy more than 150 MeV to be detected by the wide angle detector covering(5) $\theta = 90^o \pm 40^o$, $\Delta\phi/2\pi = 0.8$. This will give about 20 events for 100 days assuming an average luminosity of $10^{32}cm^{-2}hr^{-1}$. It would be also worthwhile to notice that some calculation(7) give even twice as large cross section as for the point like pion due to the hadronic corrections.

Other hadronic processes which can be investigated are the production of c = +1 resonances through $\gamma\gamma$ collision. For example, the cross section for the reaction $e^+e^- \rightarrow e^+e^-\eta'$ (960) is expected to be[4] $1.2 \times 10^{-35}\ cm^2 (KeV)^{-1}\ \Gamma_{2\gamma}$ at beam energy of 1.5 GeV where $\Gamma_{2\gamma}$ is the 2γ decay width of the resonance. Putting the branching ratio $\Gamma_{2\gamma}/\Gamma = 0.1$[8] and the upper limit 4 MeV for the total width Γ, we can get a cross section of 5 nb, which results into an event rate similar to the $e^+e^- \to e^+e^-\pi^+\pi^-$. Therefore, we have a good chance, at least, to reduce the upper limit for Γ by a factor 10.

1.3. - Radiative production of the vector mesons.

Recent calculation by Carlo Bernardini[9] demonstrates a cross section of $1 \sim 10$ nb for the reactions $e^+e^- \to \rho\gamma,\ \omega\gamma,\ \phi\gamma$. It would be interesting to detect this kind of events.

2. - EXPERIMENTAL METHOD.

A characteristic kinematical feature of the 2γ (or 3γ) processes is the extremely small angle (typically an order of mrad) between the surviving $e^\pm$ and the beams. In order to tag the almost real γ's by these forward-going $e^\pm$, we propose to use the bending magnet of ADONE as the momentum analyzer.

Fig. 2 shows the experimental arrangement, which consists of two scintillation counters (F_1, F_2) inside the magnet, two lead glass counters set at zero degree (γ_1, γ_2) and a wide angle detector (W).

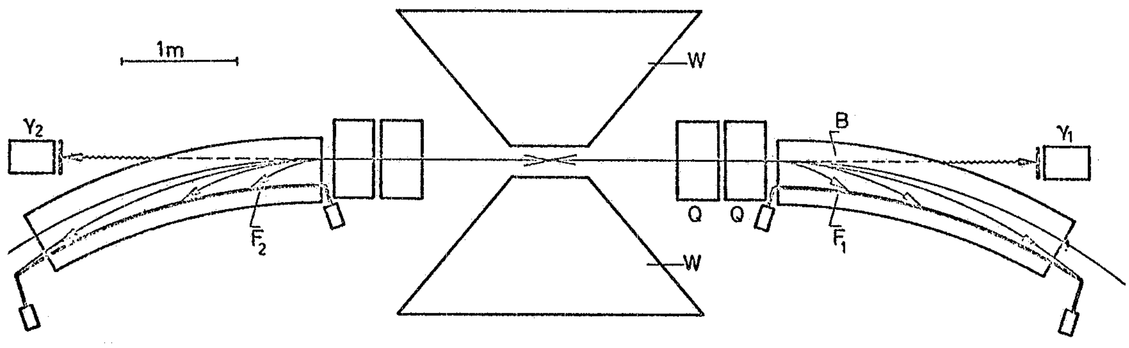

FIG. 2 - Experimental arrangement.

The $e^\pm$ which has lost the energy by the irradiation of almost real photon travels essentially in the beam direction, passing through the quadrupole magnets, swept out by the bending magnet of ADONE, and is detected by the scintillation counter inside the magnet. The scintillator will be 2.7 m long, 7 cm high, 3 cm thick, viewed by two photomultipliers from both sides. The time difference measurement between the tubes gives us a position accuracy of $\pm$ 5 cm, which corresponds to a momentum accuracy of $\pm$ 2%. The small but non-zero angular spread of $e^\pm$ causes a slight difference of orbit even for the same momentum. Considering all these, a typical momentum accuracy is estimated to be of $\pm$ 3%. The momentum range covered is between 0. 2 and 0. 85 E, where E is the beam energy. The range can be extended up to 0. 9 E by adding a small counter at the exit of the magnet.

For the wide angle detector, any apparatus existing or being prepared at ADONE can be used, although a lower threshold energy for the trigger and a larger solid angle is preferable.

Block diagram of the logic is shown in Fig. 3. We take the coincidence $F_1 \overline{\gamma}_1 F_2 \overline{\gamma}_2$ 2W for the 2γ (3γ) processes. The coincidence requirement for the forward going $e^{\pm}$ will be necessary for the clean identification of the events. The background will mainly come from the beam $e^{\pm}$ which loses energy by the real bremsstrahlung with the residual gas. This contribution for the accidental rate is expected to be about 1 % for the normal operating condition of ADONE[10]. The anti-coincidence requirement for the lead glass counter γ_1 or γ_2 will finally avoid any ambiguity coming from this kind of backgrounds.

For the $2\gamma \rightarrow 2$ body processes such as $e^+e^- \rightarrow e^+e^-\pi^+\pi^-$, approximate coplanarity can be used for the identification.

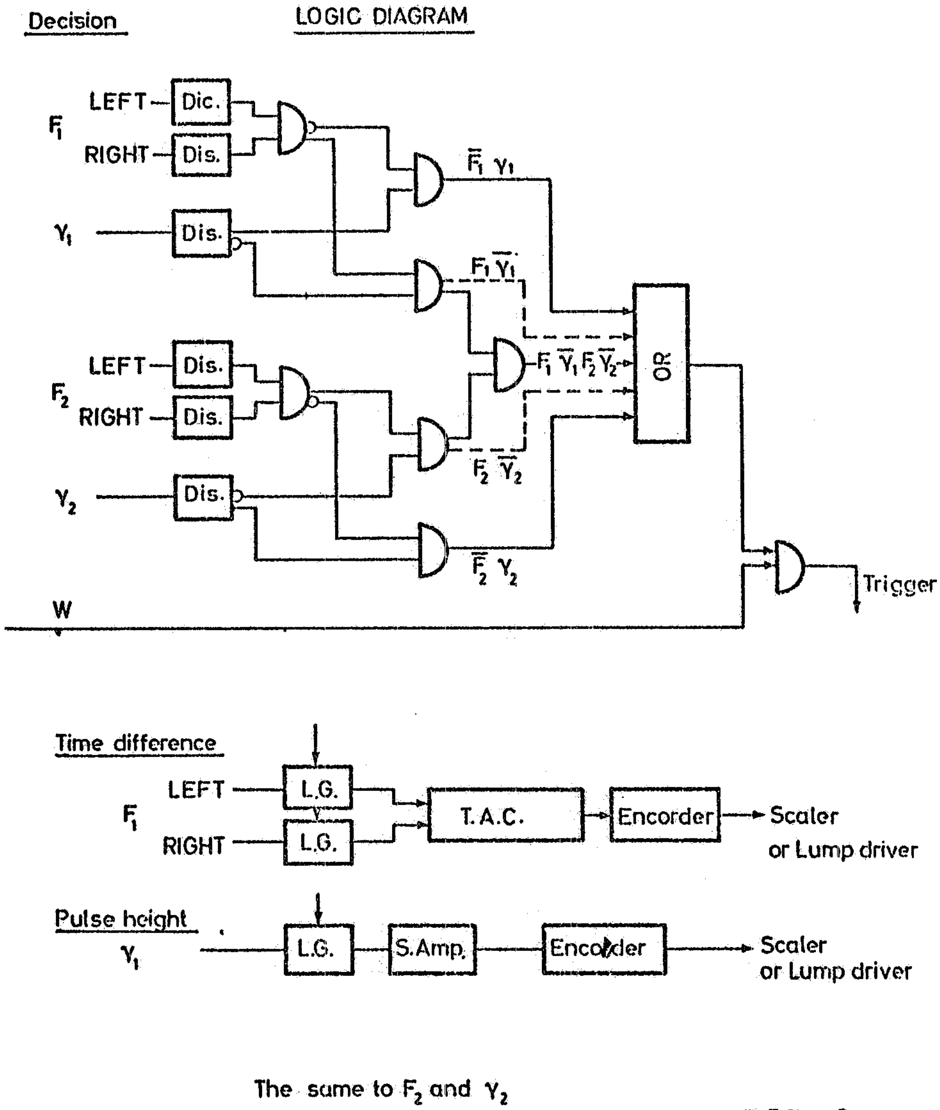

FIG. 3

The invariant mass M and the velocity β of the 2γ system are well determined from the measured momentum of the forward going $e^{\pm}$. Typical accuracies are $\Delta M = \pm 40$ MeV and $\Delta\beta = \pm 0.07$. This also serves a kinematical constraint for the angle and energies of the two final state particles. The resonance production by 2γ process would be clearly recognized by the peak in the invariant mass.

For the radiative production of the vector mesons, we require the logic signal $\gamma_1 W \overline{F_1}$ or $\gamma_2 W \overline{F_2}$. The anticoincidence requirement for F_1 and F_2 will be essential since otherwise the accidental rate would be as high as 10 %(10) which mainly comes from the beam gas bremsstrahlung. The energy of the γ-ray can be measured with an accuracy of $\pm$ 10 %, which will be sufficient to identify this kind of event through the kinematical constraints.

3. - INSTALLATION.

Fig. 4 shows the position of the scintillator inside the magnet. For the installation, the vacuum pipe has to be taken out. This can be done during the shut-down of ADONE scheduled from mid--March of this year for about one month. No significant difficulty is foreseen. The scintillator can be ready mid-March, and the test with the electron beam will be finished before the end of March.

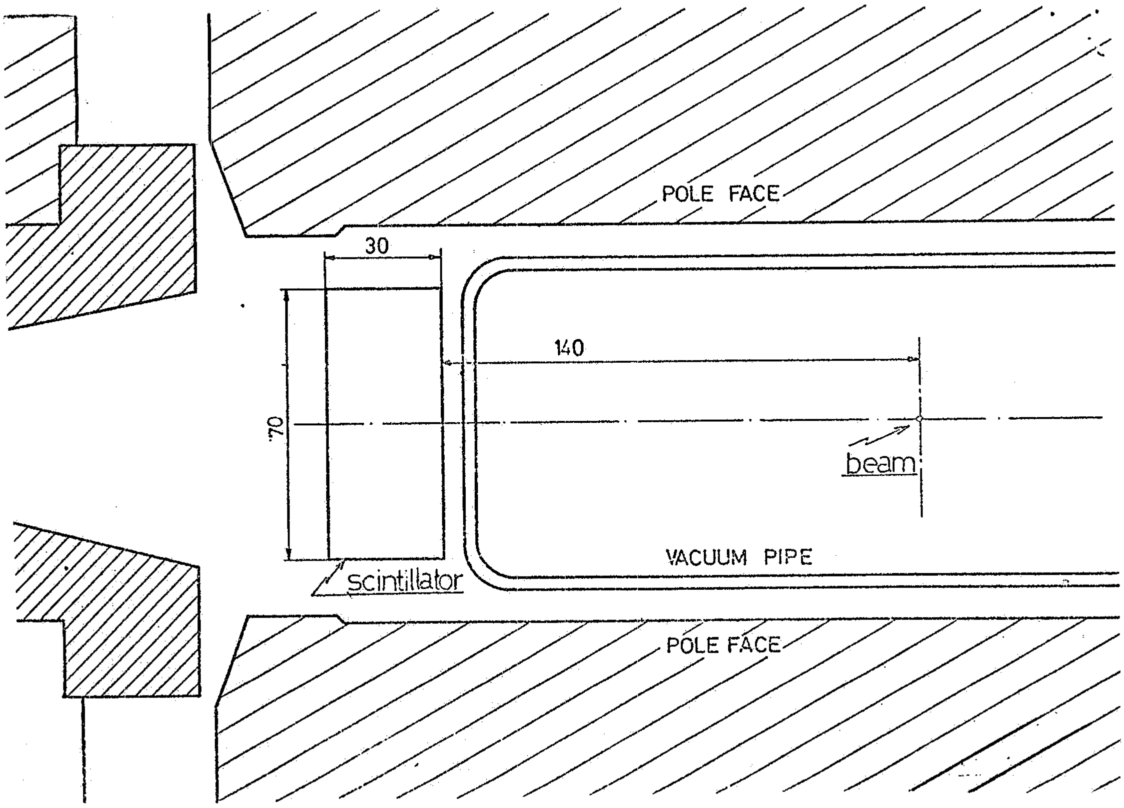

FIG. 4

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REFERENCES AND FOOTNOTES.

(1) - N. A. Romero, A. Jaccarini, P. Kessler and J. Parisi, Paris preprint (1970).
(2) - V. M. Budnev and I. F. Ginzburg, Novosibirsk report TF-55 (1955).
(3) - S. J. Brodsky, T. Kinoshita and H. Terezawa, Phys. Rev. Letters 25, 992 (1970).
(4) - M. Greco, Frascati report LNF-71/1 (1971).
(5) - Inefficiency of 0.5 due to the source spread is taken into account.
(6) - Assumed one half of the point-like cross section.
(7) - J. T. Manassah and S. Matsuda, Princeton preprint (1971).
(8) - M. Roos et al., Phys. Letters 33B, 1 (1971).
(9) - C. Bernardini, INFN report INFN/AE-71/2 (1971).
(10) - We assume the beam intensity 50 mA (10^{11} particles circulating), lifetime of 3 hours. The loss rate is $\sim 10^{11}/10^4$ sec $\sim$ $\sim 10^7$ sec. This corresponds to 1 particle lost per bunch per turn. Since our tagging system is looking about 10% of the whole circumference of ADONE, we expect 0.1 background for each bunch for each tagging system, that means 10% accidentals for each wide angle event. Requiring the coincidence for the two forwardgoing $e^{\pm}$, the accidental rate is expected to be 0.1 x x 0.1 = 0.01.

A magnetic analysis of the forward e^+e^- in ADONE has also been suggested by another group of Adone ($\gamma\gamma$ group) which has done some preliminary measurements looking at 0.9 E electron or positron in coincidence with the angle apparatus. At DESY, Kessler and a DESY group have also studied the way to detect the forward scattered electron and positron.