To be submitted to
Physics Letters

ISTITUTO NAZIONALE DI FISICA NUCLEARE
Laboratori Nazionali di Frascati

LNF-79/33(P)
8 Giugno 1979

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EXPERIMENTAL RESULTS ON PHOTON-PHOTON INTERACTIONS AT ADONE.

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EXPERIMENTAL RESULTS ON PHOTON-PHOTON INTERACTIONS AT ADONE.

ABSTRACT.

Experimental results for the reactions $e^+e^- \to e^+e^- + X$ are presented for $X = e^+e^-$, $\mu^+\mu^-$, $\pi^+\pi^-$, η'.

Tagging technique has been used to detect final electron and positron. A QED test is performed and an upper limit of 20 KeV is derived for the partial width $\Gamma(\eta' \to \gamma\gamma)$.

We present experimental results for the reactions

$$e^+e^- \longrightarrow e^+e^- + X \tag{1}$$

obtained at the Adone e^+e^- storage ring ($\gamma\gamma$2 experiment), in the single beam energy range 750-1500 MeV. Previous results[1] on this reaction have been obtained with a different set-up.

In reaction (1) the following C = +1 final states have now been considered:

$$X = e^+e^- \tag{2}$$
$$X = \mu^+\mu^- \tag{3}$$
$$X = \pi^+\pi^- \tag{4}$$
$$X = \eta'(958) \tag{5}$$

As is well known[2] reaction (1) is described by the interaction of two quasi-real photons, travelling along the beam line and producing the final state X. The incident electron (positron) comes out in the final state with a lowered energy and with an angular distribution peaked in the very forward directions.

The experimental set-up (Fig. 1) consists of a wide angle detector and two tagging counters.

(+) Now at Istituto di Fisica, Università dell'Aquila
(x) Now at Istituto di Fisica, Università di Napoli
(o) Istituto di Fisica, Università di Roma, and INFN, Sezione di Roma.

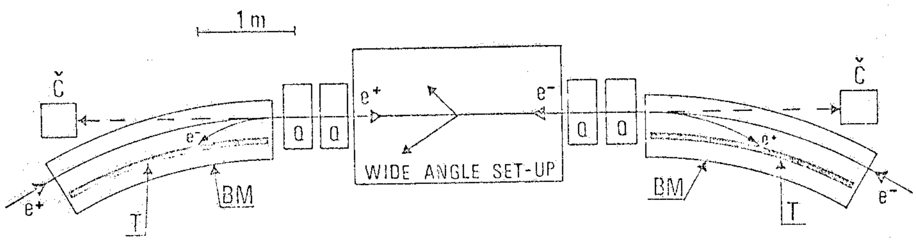

FIG. 1 - Experimental set-up. T = tagging counter; BM = Adone bending magnet; Q = Adone quadrupole; C = Total absorption lead glass Čerenkov counter.

The wide angle set-up has been described in detail elsewhere(3). It consists of two large semicylindrical telescopes placed above and below the interaction region, with their axes perpendicular to the beam line. These telescopes, designed for charged particle and photon detection, are sandwiches of optical spark chambers and lead converters for a total thickness of 5.5 r.l.. The solid angle covered by the triggering counters is $0.41 \times 4\pi$ sr and that covered by the optical spark chambers is $0.66 \times 4\pi$ sr. The two tagging counters are placed(4) close to the doughtnut, inside the Adone bending magnets adjacent to the wide angle set up (Fig. 1).

These magnets are used as momentum analysers for the secondary electron and positron of reaction (1).

The tagging counters accept(5) electrons or positrons with a momentum ranging from 0.1E to 0.9E, E being the single beam energy, and with an emission angle less than ~ 15 mrad.

Each tagging counter is viewed by the photomultiplier tubes placed at the ends of a long plastic scintillator. Delay time measurements between these two photomultipliers is used to determine the impact position of the electron or positron on the scintillator and therefore to deduce its momentum. The emitted photon energy is calculated as the difference between the incident and the tagged electron energy.

Delay time calibration vs. electron (positron) momentum has been performed by looking(4) at the reaction $e^+e^- \rightarrow e^+e^-\gamma$ in the configuration where the electron (positron) and the photon are detected in the wide angle set-up, while the positron (electron) is detected by one of the tagging counters. Typical momentum resolution of these counters turns out to be $\Delta p/p \simeq \pm 8\%$.

Detection efficiency of tagging counters has been measured by looking at the beam-gas bremsstrahlung events; in this measurement the total absorption lead glass Čerenkov counter Č (Fig. 1) has been used in coincidence with the respective tagging counter, to detect the bremsstrahlung photon.

The trigger logic accept two tagging counters in coincidence with: a) at least one charged particle in both the upper and lower telescope of the wide angle set-up: b) one or more photons in both the upper and lower telescope; c) at least one charged particle in the upper (lower) telescope and one more photons in the lower (upper) one.

In order to fire a telescope, a pion must have a kinetic energy of at least 100 MeV; if photons convert in the telescope this limit can be lowered to 35 MeV. The photon detection efficiency vs. photon energy has been calculated(6) by Monte-Carlo method. Luminosity has been measured by looking at Bhabha scattering in the wide angle set-up.

The present results are relative to 60 events corresponding to a total accumulated luminosity of 270 nb^{-1}.

These events have been divided in two categories: a) 58 events with one charged particle in each wide angle telescope; b) 2 events with at least three particles in the wide angle set-up. No events were found with only photons. The expected number of accidental coincidences with the tagging counters is ~ 0.5 events for category a) and ~ 1 event for category b). Furthermore in ~ 4% of the events an accidental electron or positron is detected by one of the tagging counters simultaneously with a true one coming from reaction (1) (pile-up). Of course in this case the momentum of the electron or positron, determined by delay time between the two photomultipliers, is wrong.

Let us now consider reaction (1) with final state (2), (3) or (4). In this case it can be considered as two body reactions $\gamma\gamma \longrightarrow e^+e^-, \mu^+\mu^-, \pi^+\pi^-$ with the final particles being approximately coplanar with the incident beam. Taking into account the energy and the energy and angular acceptance of the tagging counters, we expect to have a maximum acoplanarity angle[7] $\Delta\varphi_{max} \simeq 12^o$.

In Fig. 2 we report the $\Delta\varphi$ spectrum of the 58 events of category a), which are neutral candidates for the considered reactions. This spectrum is in good agreement with what was expected,

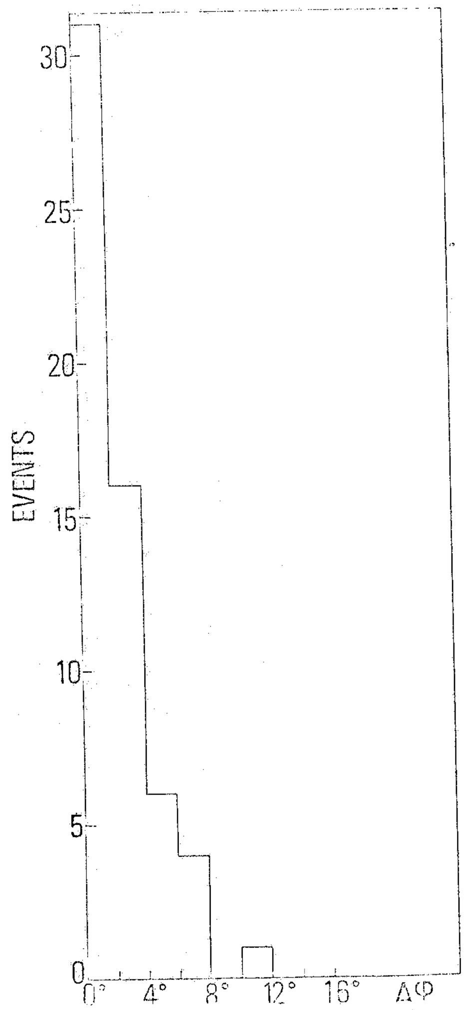

FIG. 2 - Acoplanarity angle distribution for the events of category a) (see text and Ref. (7)).

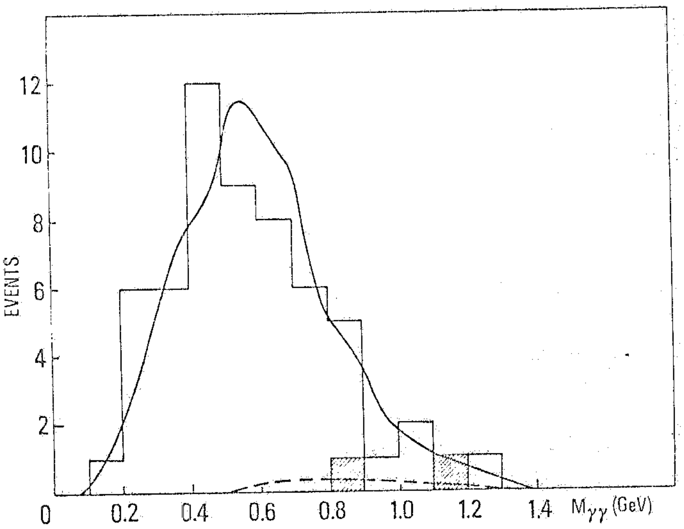

FIG. 3- Effective mass spectrum of the two photon system for the events of category a) (see text) The full line is absolute Monte Carlo prediction for the sum of the reaction $\gamma\gamma \longrightarrow e^+e^-, \mu^+\mu^-, \pi^+\pi^-$. The dashed events are the two $\pi^+\pi^-$ candidates. Dashed line is absolute Monte Carlo prediction for the reaction $\gamma\gamma \longrightarrow \pi^+\pi^-$, usign Born approximation[2].

giving confidence that these events come from reaction (1) with $X = e^+e^-, \mu^+\mu^-, \pi^+\pi^-$. According to the behaviour of the two final particles in the wide angle set-up, these 58 events are divided in: 30 ± 5 events with two showering particles; 28 ± 5 events with two non-showering particles. The quoted errors are an estimate of the uncertainty in shower recognition, especially for low energy particles. The 30 showering events are candidate for $X = e^+e^-$. By looking at the scattering angle distribution of the two tracks in the wide angle set-up, the 28 non-showering events can be divided in: 26 events candidates for $X = \mu^+\mu^-$ and 2 events for $X = \pi^+\pi^-$. According to a Monte Carlo calculation based[2] on QED for final states (2), (3) and Born approximation for final state (4), the expected number of events is 27.5 for e^+e^-, 26.7 for $\mu^+\mu^-$ and 2.2 for $\pi^+\pi^-$ in good agreement with the experimental one. Equivalent photon approximation[2] has been used in all the calculations.

From the momentum of the secondary electron and positron, measured by tagging counters, we deduce the energy of the corresponding emitted photons, and therefore their effective mass

$M_{\gamma\gamma}$.

In Fig. 3 the experimental $M_{\gamma\gamma}$ spectrum is reported: here all the 58 two body events have been lumped together to overcome the uncertainty in the assignement of some of them to a given subgroup, and also because of low statistics.

For each event we also measure the angle, with respect to the beam line, of the two particles detected in the wide angle set-up. This allows us to make a consistency check with the momentum of the secondary electron and positron measured by tagging counters. For 48 events this check was satisfied. For the remaining 10 events one of the tagging counter gave a "wrong" value of the electron or positron momentum. For these events the two angles measured in the wide angle set-up were used in order to calculate $M_{\gamma\gamma}$. It has to be noted that these 10 events with a "wrong" tagging are perfectly compatible with what we expect is we take into account pile-up in tagging counters and the emission of radiative photons by incident and final electrons and positrons.

The full line of Fig. 3 is an absolute prediction calculated by Monte Carlo method for reaction (1) with final state (2), (3) and (4) using QED and Born approximation respectively. Experimental resolution has been taken into account.

In Fig. 3 we have also indicated the two events (dashed) which are $\pi^+\pi^-$ candidated, together with the absolute Monte Carlo prediction (dashed line) for the process $\gamma\gamma \longrightarrow \pi^+\pi^-$. The agreement between the experimental spectrum and the calculated one is quite good. In conclusion, the observed two body reactions allows us to check that QED and equivalent photon approximation are valid for the reaction $\gamma\gamma \longrightarrow e^+ e^-$, $\mu^+\mu^-$ and that at these energies Born approximation gives the correct order of magnitude cross section for the reaction $\gamma\gamma \longrightarrow \pi^+\pi^-$.

Let us now consider the two events of category b). For one of them, the momentum of the electron detected by one tagging has a value which is kinematically not allowed, and therefore is a candidate for the expected 1 accidental event. The other event of category b) is the only true multihadron candidate for reaction (1).

For this event the two-photon effective mass turns out to be $M_{\gamma\gamma} = 1430 \pm 200$ MeV which is incompatible with the $\eta'(958)$ mass. We conclude that no candidate for the reaction $e^+e^- \longrightarrow e^+e^-\eta'$ has been observed. Taking into account for the branching ratios[8] of η' decays, the detection efficiency for the reaction $e^+e^- \longrightarrow e^+e^-\eta'$ has been evaluated by a Monte Carlo method. From the well known[2] cross section $\sigma(e^+e^- \longrightarrow e^+e^-\eta')$ we can therefore deduce an upper limit for the partial decay width $\Gamma(\eta' \longrightarrow \gamma\gamma) \leq 20$ KeV (95% c.l.). This result, together with other similar[9], favours the fractionally charged quarks model, which predicts $\Gamma(\eta' \longrightarrow \gamma\gamma) = 6$ KeV, with respect to the integer charged one, which predicts $\Gamma(\eta' \longrightarrow \gamma\gamma) = 25.6$ KeV. This conclusion seems to be confirmed by very recent measurement[11] of the $\eta' \longrightarrow \gamma\gamma$ partial width.

We would like to thank A. Courau, E. Etim, G. Pancheri-Srivastava and Y. Srivastava for very helpfull discussions.

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