To be submitted to
Lett. Nuovo Cimento

COMITATO NAZIONALE PER L'ENERGIA NUCLEARE
Laboratori Nazionali di Frascati

LNF-74/10(P)
6 Marzo 1974

G. Barbiellini, F. Ceradini, M. L. Ferrer, S. Orito, L. Paoluzi,
R. Santonico and T. Tsuru: MULTI-HADRONS PRODUCTION THROUGH THE PHOTON-PHOTON INTERACTION.

Servizio Documentazione
dei Laboratori Nazionali di Frascati del CNEN
Casella Postale 70 - Frascati (Roma)

Laboratori Nazionali di Frascati del CNEN
Servizio Documentazione

LNF-74/10(P)
6 Marzo 1974

G. Barbiellini, F. Ceradini[x], M.L. Ferrer[x], S. Orito, L. Paoluzi[x], R. Santonico[x] and T. Tsuru: MULTI-HADRONS PRODUCTION THROUGH THE PHOTON-PHOTON INTERACTION. -

ABSTRACT. -

The process $\gamma\gamma \rightarrow$ multi-hadrons has been investigated in the Frascati electron positron storage ring Adone, via the reaction $e^+e^- \rightarrow e^+e^-$ mh, where $m > 2$ is the number of hadrons h in the final state. The equivalent mass of the hadronic system has been measured with two counters tagging the final state electrons.

One event was observed in the η' mass region; depending on the evaluation of non resonant contribution of $\gamma\gamma \rightarrow$ mh, the value of $\Gamma_{\eta' \rightarrow \gamma\gamma} = 11^{+8}_{-6}$ keV or alternatively an upper limit $\Gamma_{\eta' \rightarrow \gamma\gamma} \lesssim 33$ keV with 95 % confidence level is obtained.

(x) - Istituto di Fisica dell'Università di Roma and Istituto Nazionale di Fisica Nucleare, Sezione di Roma, Roma (Italy).

The reaction $e^+e^- \rightarrow e^+e^- X$, where X is an hadronic system, provides a powerful method to study the coupling of the C = +1 mesonic states with two photons. In particular if the hadronic system is a resonance R of mass M and spin J its decay width in two gammas $\Gamma_{R\rightarrow\gamma\gamma}$ can be obtained by measuring the cross section σ of the process $e^+e^- \rightarrow e^+e^- R$ that in the equivalent photon approximation[1, 2, 3] is given by the equation

$$\sigma = \frac{8(2J+1)}{M^3} \alpha^2 \, \Gamma_{R\rightarrow\gamma\gamma} f(E) \tag{1}$$

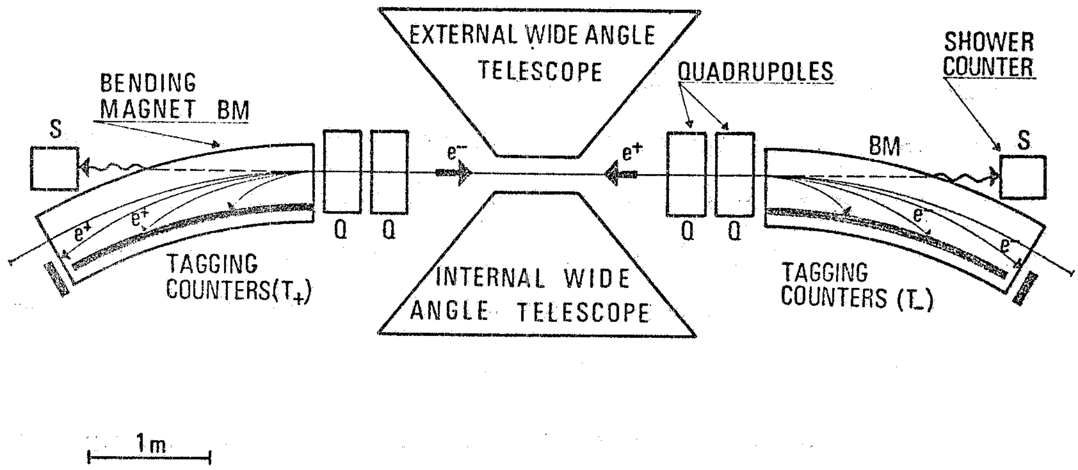
In this relationship α is the fine structure constant and the function f(E) takes into account the virtual photons energy spectrum at the energy E of the colliding beams.

In this paper, we study the interaction $\gamma\gamma \rightarrow$ multihadrons through the process

$$e^+e^- \rightarrow e^+e^- \, mh$$

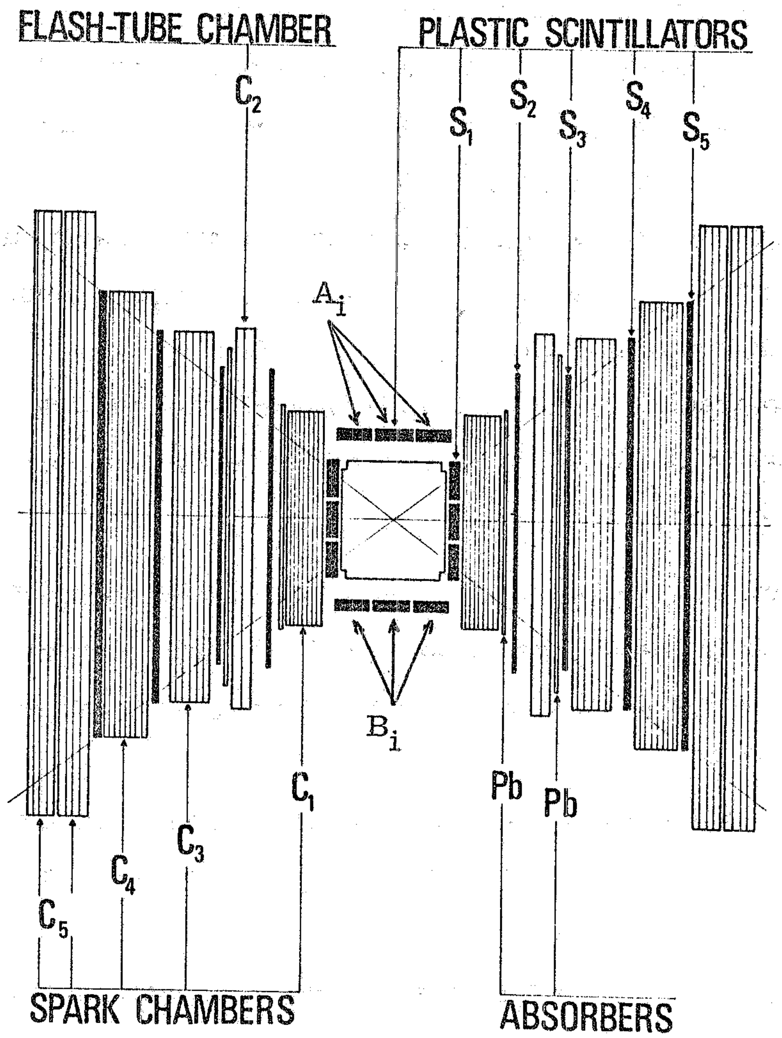
The experiment was performed with Adone, the Frascati e^+, e^- storage ring. The experimental set-up is shown schematically in Fig. 1. It consists of two tagging systems[4] T_+ and T_- used to detect the outgoing forward emitted e^+ and e^-, and of two wide angle telescopes, forming the "main apparatus"[5], used here to detect the particles produced in the photon-photon collisions. $T_{+(-)}$ consists of two plastic scintillators whose geometrical acceptance is approximately 50% for the scattered $e^\pm$ with momentum in the interval (0.2 E-0.85 E). The tagging technique adopted[4] utilizes the machine bending magnets as momentum analyzers, correlating the momentum p_e of the detected $e^{+(-)}$ with the impact point in $T_{+(-)}$. Typical momentum resolution is $\Delta p_e \gtrsim 60$ MeV.

The relevant part of the wide angle detector[5] as shown in Fig. 2, consists essentially of two counter and optical chamber telescopes covering a solid angle of about $0.25 \times 4\pi$. In addition six scintillation counters, three above (A_i) and three below the vacuum chamber (B_i), increase



EXTERNAL WIDE ANGLE TELESCOPE
BENDING MAGNET BM
QUADRUPOLES
SHOWER COUNTER
S
BM
S
e⁻
e⁺
e⁺
e⁺
Q Q
Q Q
e⁻
e⁻
TAGGING COUNTERS(T₊)
INTERNAL WIDE ANGLE TELESCOPE
TAGGING COUNTERS (T₋)
1m

FIG. 1



FLASH-TUBE CHAMBER
PLASTIC SCINTILLATORS
C2
S1
S2
S3
S4
S5
Ai
Bi
C1
Pb
Pb
C3
C4
C5
SPARK CHAMBERS
ABSORBERS

FIG. 2

the solid angle covered to about $0.5 \times 4\pi$.

Finally two shower detectors[6], S, are used to veto the real photons from beam-beam and beam-gas bremsstrahlung.

Runs were carried out at beam energies E = 1.3, 1.4 and 1.5 GeV for a total integrated luminosity $\int L\, dt = 350\ nb^{-1}$. The chambers were triggered by a master coincidence requiring:

1) A 5-fold coincidence among the counters of the main apparatus, which implied a minimum penetration of 10 g cm^{-2} of iron equivalent in one telescope and 22 g cm^{-2} in the other;

2) coincident pulses in both tagging systems, T_+ and T_-;

3) time coincidence with the instant of beam-beam collision.

The events candidates for process $e^+e^- \to e^+e^-$ mh are required, in addition, to fulfil the following criteria:

4) at least two tracks, one in each telescope, converging within $\pm$ 3 cm at a common origin in the e^+e^- interaction region, must be found in the thin-foil "kinematical" spark chambers C1;

5) for two-track events the non-coplanarity angle $\Delta\varphi$, defined as the angle between two planes containing the beam and each of the tracks, must be $\Delta\varphi > 8^o$.

Only two events passed the criteria 1)...5), one with M = 800 MeV and the other with M = 1400 MeV, where M is the two interacting photons equivalent mass, which is measured by the tagging system with a typical accuracy $\Delta M = \pm 90$ MeV.

The event with M = 800 MeV exibits two tracks with $\Delta\varphi = 30^o$ and a pulse from one of the three counters A_i. The event with M = 1400 MeV shows two tracks with $\Delta\varphi = 24^o$.

The background simulating these events is negligible for the following reasons.

a) The events due to beam-gas interaction give signals in at most one tagging counter. These events are rejected by the condition 2. Events due to accidental double tagging give a negligible background, as estimated from the rate of the tagging counters. No event satisfying requirements 1...5 has been found during the runs with separated beams.

b) No background is expected from the processes $\gamma\gamma \to$ two bodies, such as $\gamma\gamma \to \mu^+\mu^-$ or $\pi^+\pi^-$ or e^+e^-, because the double tagging at forward angle implies $\Delta\varphi \leq 5^o$ for two-body events[7].

Therefore the two selected events provide evidence for the process $\gamma\gamma \to$ multihadrons.

The event with the equivalent mass of the hadronic system M = = 800 MeV is compatible within the uncertainty in the mass determination with the hypothesis that it is originated from the process

$$(2) \qquad e^+e^- \to e^+e^- \eta'$$

Contributions to this event, due to other known resonances are excluded because these have either a much smaller wide angle detection efficiency or a mass value far away from the detected one. The contribution of the non resonant production cannot be excluded because of the uncertainty on the value of the cross section.

The detection efficiency for the process $e^+e^- \to e^+e^-\eta'$ has been calculated by a Montecarlo simulation of the experiment based on the equivalent photon approximation. The validity of this approximation has been checked in a previous experiment[7] in which the processes $e^+e^- \to e^+e^- e^+e^-$ and $e^+e^- \to e^+e^- \mu^+\mu^-$ were investigated.

In Table I are shown the calculated experimental efficiencies for the apparatus to detect the relevant decay modes of the η'.

The total efficiency of the experimental apparatus to detect the η' is $\varepsilon = \sum B_i \varepsilon_i = (0.53 \pm 0.03)\%$. The calculated value of the cross section of the process $e^+e^- \to e^+e^- \eta'$ properly averaged over the different energies involved in the experiment is $\sigma = 4.8\ 10^{-35}\ \Gamma_{\eta' \to \gamma\gamma}\ cm^2\ KeV^{-1}$[3].
If the multi-hadron event with M = (800 ± 90 MeV) is interpreted as an η'

production, the $\gamma\gamma$ decay width of the η' is $\Gamma_{\eta' \to \gamma\gamma} = (11 {}^{+15}_{-8})$ KeV; if the event is coming from a non resonant contribution of $\gamma\gamma \to m\,\pi$ the upper limit of $\Gamma_{\eta' \to \gamma\gamma}$ is 33 KeV with 95% confidence level.

TABLE I

η' Decay-channels (i)	Branching ratio B_i	Efficiency ε_i
$\pi^+ \pi^- \gamma$	26%	$(1.45 \pm 0.07)\%$
$\pi\pi\eta \to 2\,\pi^+ 2\,\pi^-$ + neutral	14%	$(0.89 \pm 0.06)\%$
$\pi\pi\eta \to \pi^+ \pi^-$ + neutral	41%	$(0.06 \pm 0.01)\%$

The total width obtained through the known branching ratio[8] is respectively

$$\Gamma_{\eta' \to \text{all}} = (0.6 {}^{+0.8}_{-0.4})\ \text{MeV}\ .$$

$$\Gamma_{\eta' \to \text{all}} \leq 1.8\ \text{MeV}$$

The value of $\Gamma_{\eta'}$ is in agreement with the recent experimental determination[9] and with the theoretical estimate[10]. The analysis of the event with M = 1400 MeV could be carried out in a similar way. However, the interpretation of this event as due to a high-mass resonance decay, is made more complicate by the number of resonances that in a mass interval around M = = 1400 MeV as large as the experimental mass resolution.

We are grateful to Professor M. Conversi, Dr. S. D'Angelo and Dr. R. Visentin for their contributions to the present work. Dr. A. Bramon and Dr. M. Greco have contributed many clarifying discussions on the theoretical implications of this research. We acknowledge the cooperation of the machine group and especially of Dr. M. Placidi. Finally we want to thank Prof. M. Conversi and Dr. C. Spencer for their critical reading of the manuscript.

REFERENCES. -

(1) - N. A. Romero, A. Jaccarini, P. Kessler and J. Parisi, C. R. Acad. Sci. Sez. 296 (1969); Lett. Nuovo Cimento 4, 933 (1970); 1, 936 (1971);

(2) - S. J. Brodsky, T. Kinoshita and H. Terazawa, Phys. Rev. Letters 25, 972 (1970); Phys. Rev. D4 , 1532 (1971).

(3) - M. Greco, Nuovo Cimento 4, 689 (1971); A. Bramon and M. Greco, Lett. Nuovo Cimento 2, 522 (1971).

(4) - G. Barbiellini and S. Orito, Frascati LNF-71/17 (1971); and Proc. First Conf. on Meson Resonances and Related Electromagnetic Phenomena, Bologna (1971).

(5) - F. Ceradini, M. Conversi, S. D'Angelo, L. Paoluzi, R. Santonico and R. Visentin, Phys. Letters 47B, 80 (1973).

(6) - H. C. Dehne, M. Preger, S. Tazzari and G. Vignola, Frascati report LNF-72/75 (1972).

(7) - G. Barbiellini, S. Orito, T. Tsuru, R. Visentin, F. Ceradini, M. Conversi, S. D'Angelo, M. L. Ferrer, L. Paoluzi and R. Santonico, Phys. Rev. Letters 32, 385 (1974).

(8) - Particle Data Group, Rev. Mod. Phys. 45, n. 2 Part. II (1973) (Review of Particle Properties), for references to the original papers.

(9) - D.M. Binnie, L. Camilleri, A. Duane, D.A. Garbutt, J.R. Holmes, W.G. Jones, J. Keyne, M. Lewis, I. Siotis, P.N. Upadhyay, I.F. Burton and J.G. McEwen, Phys. Letters 39B, 275 (1972); A. Duane, D.M. Binnie, L. Camilleri, J. Carr, N.C. Debenham, D.A. Garbutt, W.G. Jones, J. Keyne, I. Siotis, J.C. McEwen, Phys. Rev. Letters 32, 425 (1974) For other value see ref. (8).

(10) - A. Bramon and M. Greco, Phys. Letters 48B, 137 (1974).