VIIth International Workshop on
PHOTON-PHOTON COLLISIONS

Edited by
A COURAU
P KESSLER

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FOREWORD

The VIIth International Workshop on Photon-Photon Collisions was held at the Collège de France, Paris, on April 1-5, 1986. It was financially supported by various French scientific bodies : the Centre National de la Recherche Scientifique (C.N.R.S.), the Institut National de Physique Nucléaire et de Physique des Particules (IN2P3) and the Institut de Recherche Fondamentale du Commissariat à l'Energie Atomique. We warmly thank them.

A generous sponsoring was also provided by two industrial companies, PRANA and RTC COMPELEC, and by the wine producers of Saint-Emilion and Pomerol ; we express our gratitude to all those sponsors.

We are grateful, on the other hand, to the Administration of the Collège de France, which accepted to host the Workshop ; and to both laboratories, the Laboratoire de Physique Corpusculaire (LPC) du Collège de France and the Laboratoire de l'Accélérateur Linéaire (LAL) d'Orsay, who took charge of its organization.

We are particularly indebted to Professeur M. FROISSART, director of the LPC Collège de France, who constantly supported us in the course of all preparatory activities, who welcomed the delegation and honoured the Workshop by his permanent presence ; as well as to Professors J. PEREZ Y JORBA a d M. DAVIER, respectively former and present director of the LAL Orsay, who also provided us with their active support.

We thank the members of the International Advisory Committee for the precious advice they gave us during the entire stage of preparation, and those of the French Organizing Committee who helped us considerably in that same period.

It is a special pleasure for us to pay a tribute to the secretaries of the LAL Orsay, Nicole MATHIEU and Monique BONNAMY, whose effectiveness, devotedness and smiling presence warranted a smooth running of the Workshop. We also wish to express our appreciation to the secretaries of the LPC Collège de France, Chantal BREON and Michèle MANACH, who were involved in the manifold tasks of preparation, and Germaine MASSEI who helped us on many occasions.

We are obliged to the scientific assistants (K. DJAGOURI, L. HOURAYAHOU, E.H. KADA and M. TAMAZOUST) for their help in organizing the sessions ; to P. BONIERBALE, who took care, in the most devoted way, of many material tasks and in particular of the whole xeroxing work ; and to S. NECHAL who was in charge of the coffee breaks.

Last but not least, we thank the chairmen of sessions ; the speakers who presented the review talks, experimental reports and individual contributions ; and all delegates who, by their active and enthusiastic participation, made this Workshop a successful scientific meeting.

A. COURAU P. KESSLER

AVANT-PROPOS

Le VIIème Colloque International sur les Collisions Photon-Photon s'est tenu au Collège de France, Paris, du 1er au 5 avril 1986. Il a bénéficié du soutien financier de différents organismes scientifiques français : le Centre National de la Recherche Scientifique (C.N.R.S.), l'Institut National de Physique Nucléaire et Physique des Particules (IN2P3), et l'Institut de Recherche Fondamentale du Commissariat à l'Energie Atomique. Nous les remercions très vivement.

Une aide matérielle généreuse nous a également été fournie par deux sociétés industrielles, PRANA et RTC COMPELEC, ainsi que par les producteurs de vin de Saint-Emilion et de Pomerol ; aux uns et aux autres, nous exprimons toute notre reconnaissance.

Notre gratitude va d'autre part à l'Administration du Collège de France qui a accepté d'accueillir ce Colloque, ainsi qu'aux deux laboratoires (Laboratoire de Physique Corpusculaire du Collège de France et Laboratoire de l'Accélérateur Linéaire d'Orsay) qui ont assumé son organisation.

Nous sommes particulièrement reconnaissants au Professeur M. FROISSART, directeur du LPC du Collège de France, qui nous a apporté un soutien constant au cours des activités préparatoires du Colloque, qui a souhaité la bienvenue aux délégués et a en permanence honoré le Colloque de sa présence, ainsi qu'aux Professeurs J. PEREZ Y JORBA et M. DAVIER, respectivement ancien et nouveau directeur du LAL d'Orsay, qui nous ont également soutenus activement.

Les membres du Comité Consultatif International nous ont fait bénéficier de leurs conseils précieux au cours des mois de préparation ; qu'ils en soient ici remerciés. Notre reconnaissance va aussi aux membres du Comité d'Organisation Français qui nous ont apporté, tout au long de cette préparation, une aide considérable.

C'est avec un plaisir particulier que nous rendons hommage aux secrétaires du LAL d'Orsay, Nicole MATHIEU et Monique BONNAMY, dont l'efficacité, le dévouement et la présence souriante ont permis le bon déroulement du Colloque. Nous désirons également exprimer notre gratitude aux secrétaires du LPC du Collège de France, Chantal BREON et Michèle MANACH, qui ont été associées aux multiples tâches de préparation, et Germaine MASSEI qui nous a aidé en de nombreuses occasions.

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Enfin, nous remercions les présidents de séance ; les orateurs qui ont présenté les exposés généraux, les rapports expérimentaux et les contributions individuelles ; et l'ensemble des délégués qui, par leur participation active et enthousiaste, ont permis la réussite de ce Colloque sur le plan scientifique.

A. COURAU P. KESSLER

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I
REVIEW TALKS

RESONANCE PRODUCTION IN PHOTON PHOTON COLLISIONS

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1. INTRODUCTION

The experimental study of resonances in photon photon collisions owes its beginning to F. Low, who suggested in 1960 that the determination of the π^0 lifetime could be accomplished by measuring its $\gamma\gamma$ width at e^+e^- storage rings.[1] The production cross section of a resonance R via two photon interactions in e^+e^- collisions can be written as

$$\sigma(ee\rightarrow eeR) = \frac{16\alpha^2(2J+1)}{m^3_R} \cdot \left(\ln \frac{E}{m_e}\right)^2 \cdot f\left(\frac{m_R}{2E}\right) \cdot \Gamma_{R\gamma\gamma}$$

where $f(x) = (2+x^2)\ln(1/x) - (1-x^2)(3+x^2)^2$, J is the spin, and $\Gamma_{R\gamma\gamma}$ is the $\gamma\gamma$ width of R.

It was not until the 1979 η' measurement by MKII[2] that any $\gamma\gamma$ width was determined this way. And $\Gamma_{\pi^0\gamma\gamma}$ was not measured in an e^+e^- storage ring until the 1984 result of the Crystal Ball Collaboration.[3]

The study of resonances produced in $\gamma\gamma$ collisions has many advantages. The formation of resonances can be studied in exclusive final states over a large range of $\gamma\gamma$ energies . These resonances have even C-parity, I=0, 1, or 2. Two real photons can couple to all even-spin states and to all even-parity odd-spin states except J=1. The measured $\gamma\gamma$ widths provide information on the SU(3) mixing and gluon contents of the isoscalar mesons. They can also help to distinguish exotic states such as glueballs and four-quark states ($qq\bar{q}\bar{q}$) from $q\bar{q}$ states.

There are also certain experimental constraints in these studies. The $\gamma\gamma$ luminosity falls rapidly as $\gamma\gamma$ energy increases. The $\gamma\gamma$ center of mass moves with considerable momentum, and the final state particles are Lorentz boosted along the beam directions. Often outgoing particles are inside the beam pipe and cannot be detected. As a result, the acceptance is small and event reconstruction is difficult.

A large number of $\gamma\gamma$ width measurements have been reported since the last International Workshop on Photon-Photon Collisions at Tahoe.[4)] We review, in Sections 2 and 3, the present status of pseudoscalar and tensor mesons. The world averages of the $\gamma\gamma$ width measurements are used in Section 4 to obtain the SU(3) mixing angles, and in Section 5 to determine the gluon contents. The experimental situation of the scalar mesons is discussed in Section 6. The measured limits on the $\gamma\gamma$ widths of various higher mass states are reviewed in Section 7. In section 8, the overall experimental situation is summarized.

2. PSEUDOSCALAR MESONS

η MESON The measurements of JADE and TPC/2γ have been recently published.[5),6)] The data are shown in Figs. 1,2. Preliminary results of Crystal Ball are presented at this Workshop, as shown in Figs. 3 (a),(b).[7)] These measurements are summarized in Fig. 4. The weighted average is $<\Gamma_{\eta\gamma\gamma}> = 0.55 \pm 0.04$ KeV.

η' MESON TPC/2γ has reported recently their studies of η' production in both tagged and untagged data, as shown in Figs. 5(a),(b).[8)] The Q^2 dependence is shown in Fig. 5(c) and is well described by ρ-dominance. This and other measurements are summarized in Fig. 6. The weighted average is $<\Gamma_{\eta'\gamma\gamma}> =$ 4.34 $\pm$ 0.26 KeV.

π^o MESON The data of Crystal Ball with low threshold energy trigger show, in Fig.3(a), a prominent signal of π^o production. However, no width measurement is reported because the background has not been completely understood. From the recent precision measurement of π^o lifeime by Atherton et al.[9)] and earlier measurements, one obtains the present world average $<\Gamma_{\pi^o\gamma\gamma}> = 7.29 \pm 0.20$ eV.

3. TENSOR MESONS

A_2 MESON TASSO has presented at this Workshop an analysis of the A_2

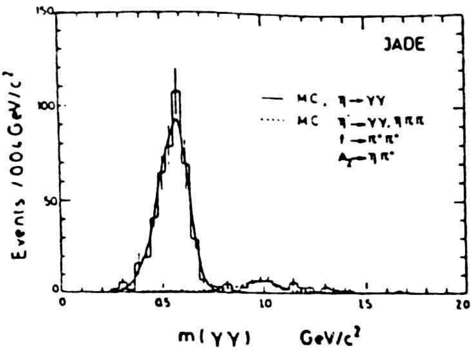


Fig.1 JADE, $M(\gamma\gamma)$ distribution

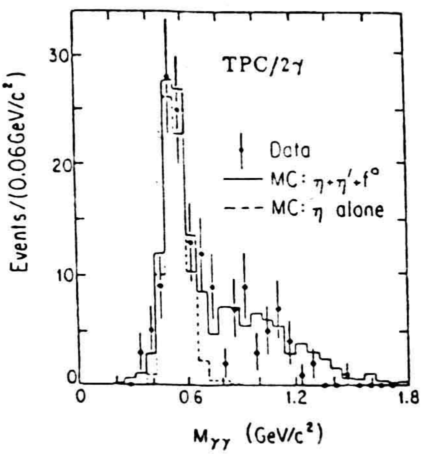


Fig.2 TPC/2γ, $M(\gamma\gamma)$ distribution

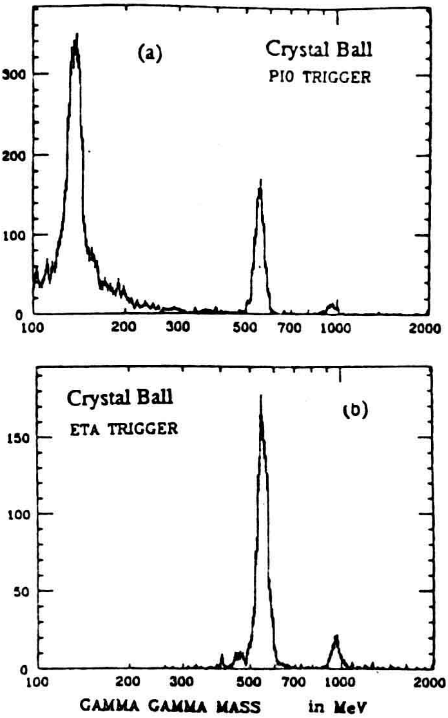


Fig.3 Crystal Ball, $M(\gamma\gamma)$ distribution for (a) π^0 trigger, and (b) η trigger

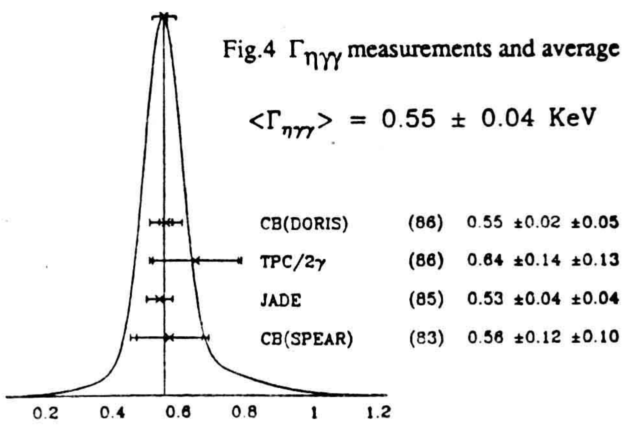
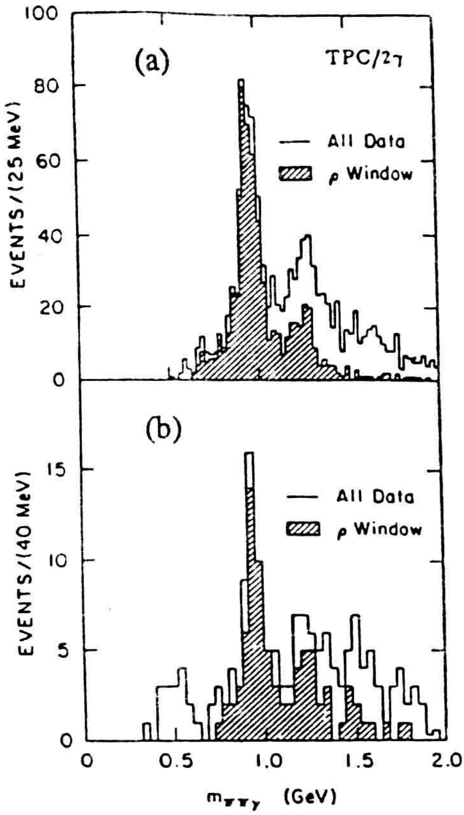


Fig.4 $\Gamma_{\eta\gamma\gamma}$ measurements and average



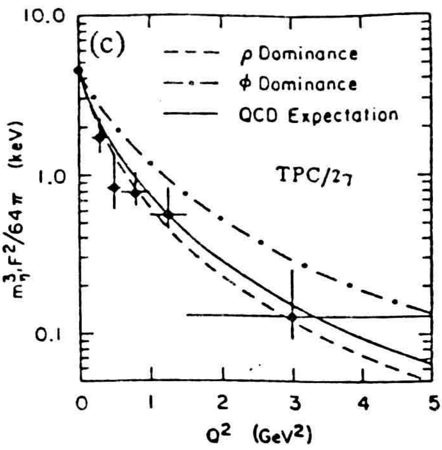
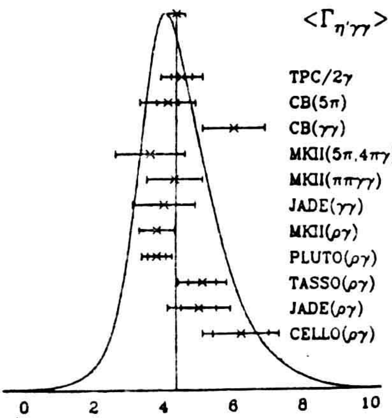


Fig.5 TPC/2γ, $M(\pi\pi\gamma)$ for (a) untagged, (b) single-tagged, and (c) Q^2 distribution for $\gamma\gamma \to \eta' \to \pi\pi\gamma$

Fig.6 $\Gamma_{\eta'\gamma\gamma}$ measurements and average

$\langle\Gamma_{\eta'\gamma\gamma}\rangle$ = 4.34 ± 0.26 KeV



TPC/2γ	(86)	4.50	±0.30	±0.60
CB(5π)	(86)	4.10	±0.31	±0.80
CB(γγ)	(86)	6.00	±0.90	±0.90
MKII(5π,4πγ)	(85)	3.60	±1.00	
MKII(ππγγ)	(85)	4.30	±0.80	
JADE(γγ)	(85)	4.00	±0.90	
MKII(ργ)	(85)	3.80	±0.50	
PLUTO(ργ)	(84)	3.80	±0.26	±0.43
TASSO(ργ)	(84)	5.10	±0.40	±0.70
JADE(ργ)	(82)	5.00	±0.50	±0.90
CELLO(ργ)	(82)	6.20	±1.10	±0.80

meson [10] After removing non-exclusive background, the neutral 3π mass distribution in Fig. 7 shows clear production of the A_2. This and earlier measurements are summarized in Fig. 8. The weighted average is $< \Gamma_{A_2\gamma\gamma} > = 0.90 \pm 0.11$ KeV.

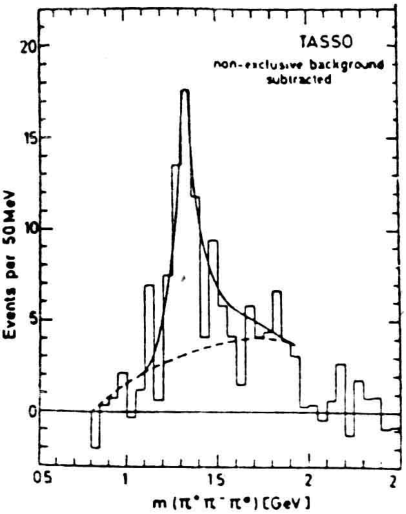
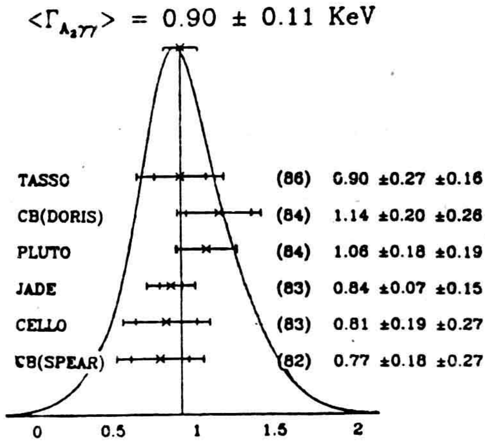


Fig.7 TASSO, $M(\pi^+\pi^-\pi^0)$ distribution

Fig.8 $\Gamma_{A_2\gamma\gamma}$ measurements and average



f MESON Results from a detailed study of f production has been reported by TPC/2γ.[11] Very careful separation of $\pi\pi$ from ee and $\mu\mu$ final states was carried out using the particle identification capabilities of the TPC. Fig. 9(a) shows the cross section $\sigma(\gamma\gamma\rightarrow\pi\pi)$ as a function of $\gamma\gamma$ energy. The decay angular distribution shown in Fig. 9(b) is consistent with pure helicity 2. The $\Gamma_{f\gamma\gamma}$ obtained by TPC/2γ and other

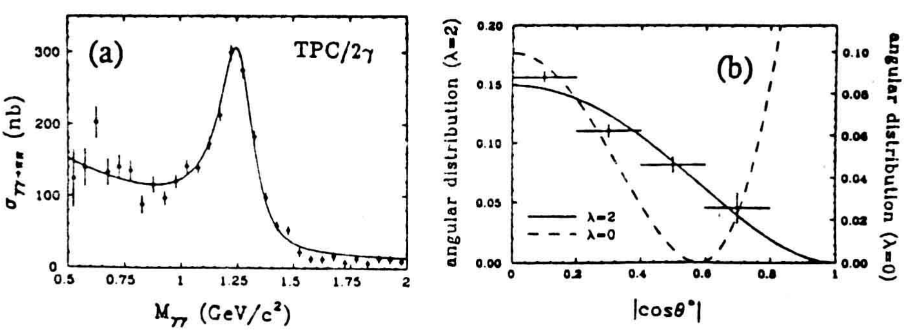


Fig.9 TPC/2γ, (a) $\sigma(\gamma\gamma\rightarrow\pi\pi)$ and (b) decay angular distribution of f