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RECENT RESULTS ON THE REACTIONS $\gamma\gamma \to \eta'$, A_2, $(5\pi)^0$ AND UPPER LIMITS ON $\gamma\gamma \to \rho^0\omega$ AND $\gamma\gamma \to \omega\omega$ PRODUCTION

by

Jacob Grunhaus

School of Physics and Astronomy, Tel Aviv University, Tel Aviv, Israel

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Recent Results on the Reactions $\gamma\gamma \rightarrow \eta'$, A_2, $(5\pi)^0$ and Upper Limits on $\gamma\gamma \rightarrow \rho^0\omega$ and $\gamma\gamma \rightarrow \omega\omega$ Production

PLUTO COLLABORATION
presented by
Jacob Grunhaus*

School of Physics and Astronomy
Tel Aviv University, Tel Aviv, Israel

Abstract

Values are presented for the radiative widths, $\Gamma_{\gamma\gamma}(\eta')$ and $\Gamma_{\gamma\gamma}(A_2)$ and for the transition form factor of the η' meson. The cross section for the process $\gamma\gamma \rightarrow 2\pi^+2\pi^-\pi^0$ is given. Upper limits for the reactions $\gamma\gamma \rightarrow \rho^0\omega$ and $\gamma\gamma \rightarrow \omega\omega$ are set and the relevance of these limits to models which explain the enhancement at threshold for the process $\gamma\gamma \rightarrow \rho^0\rho^0$ is discussed.

THE η' MESON

We have studied η' meson formation by 2 "quasireal" photons, $\langle Q^2 \rangle \sim 0.0$ GeV^2 via the reaction $e^+e^- \rightarrow e^+e^-\eta'$. The η' meson was identified by its decay into $\rho^0\gamma$. The transition form factor was also determined using "single tag" events up to a $Q^2 = 1.0$ GeV^2.

The study is based on an integrated luminosity of 45 pb^{-1} at an average e^+e^- CM energy of 34.7 GeV. A sample of events of 2 unlike charged tracks and 1 photon having $E_\gamma \geq$ 100 MeV was selected and the standard cuts were applied in order to remove background from beam gas interactions, cosmic rays and the 1 γ annihilation process. The momenta of the 3 final state particles, for the

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no tag sample, were required to be consistent with momentum conservation in the R- ϕ plane by satisfying the condition that the angle between the transverse vectors $\vec{P}_\perp(\pi^+, \pi^-)$ and $\vec{P}_\perp(\gamma)$ deviate from 180^o by at most 28^o. The photon energy was then scaled using the recipe, $E_\gamma = E_\gamma(\text{seen}) \cdot \vec{P}_\perp(\pi^+, \pi^-)$ seen / $\vec{P}_\perp(\gamma)$ seen. The $M(\pi^+\pi^-\gamma)$ plot shown in Fig. 1a exhibits a prominent η' signal and an enhancement at the A_2 mass which arises from the $A_2 \rightarrow \pi^+\pi^-\pi^0$ decay, where only 1 photon was detected. A fit to this mass plot yielded 243 ± 17 η' events, which corresponds to the product $\Gamma_{\gamma\gamma}B(\eta' \rightarrow \rho^0\gamma) = 1.14 \pm 0.08$ keV. Using the value of $B(\eta' \rightarrow \rho^0\gamma) = 30.0 \pm 1.6\%$ (1) we get a partial width value of,

$$\Gamma_{\gamma\gamma}(\eta') = 3.80 \pm 0.26\ (\text{stat}) \pm 0.43\ (\text{syst})\ \text{keV}.$$

Combining our value of $\Gamma_{\gamma\gamma}(\eta')$ with the world value of $B(\eta' \rightarrow \gamma\gamma) = 1.9 \pm 0.2\%$ (1) we get the total width of the η' to be 200 ± 34 keV

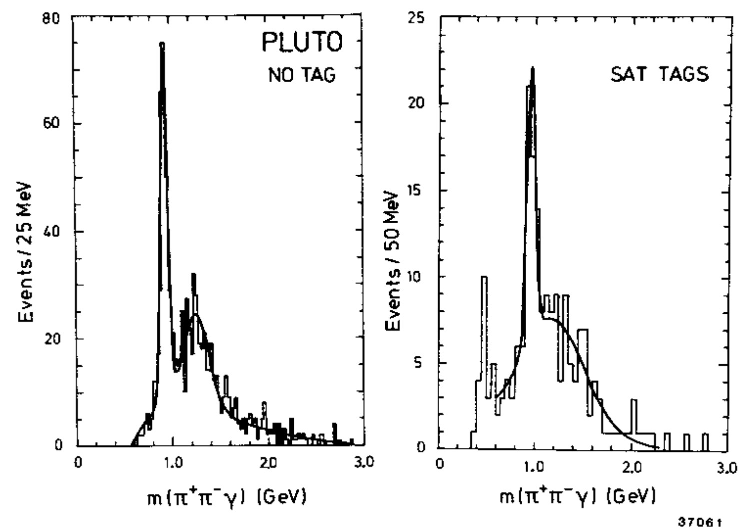

Fig. 1. The distribution $M(\pi^+\pi^-\gamma)$ arising from the collision of a) quasireal photons (no tag) and b) from single tag events with $\langle Q^2 \rangle = 0.4$ GeV^2.

which is the most accurate determination to date of this parameter. Our value of $\Gamma_{\gamma\gamma}(\eta')$ is appreciably lower than the world average value of 5.3 ± 0.6 keV[2]. We attribute our lower value to our including in the Monte Carlo acceptance studies the "p-wave" nature of the $\eta' \to \rho^0\gamma$ decay. Without the inclusion of the proper dynamics of the η' decay we get a value of ~ 5 keV. In the framework of flavor SU(3) assuming nonet symmetry for the 0^{-+} mesons, one obtains the following mixing angle independent relationship:

$$\frac{\Gamma_{\gamma\gamma}(\eta')}{m^3(\eta')} = \frac{3\Gamma_{\gamma\gamma}(\pi^0)}{m^3(\pi^0)} - \frac{\Gamma_{\gamma\gamma}(\eta)}{m^3(\eta)} .$$

Using the recent values of $\Gamma_{\gamma\gamma}(\eta) = 0.56 \pm 0.12 \pm 0.10$ keV[3] and $\Gamma_{\gamma\gamma}(\pi^0) = 7.56 \pm 0.09$ eV[4] this relationship predicts $\Gamma_{\gamma\gamma}(\eta') = 5.13 \pm 0.84$ keV, a value which is consistent with our determination, although, it is on the high side. It has been suggested that a value of $\Gamma_{\gamma\gamma}(\eta')$ smaller than the SU(3) expectation might indicate a glueball admixture in the η' [5]. Using the definition of the transition form factor in terms of $\sigma(\gamma\gamma \to \eta')$ and the width and mass of the η' as given by G. Köpp, T. Walsch and P. Zerwas[6], we have determined its value in the Q^2 range up to 1 GeV^2. Fig. 2 shows the η' form factor along with the expected ρ^0 pole contribution normalized to $Q^2 = 0$.

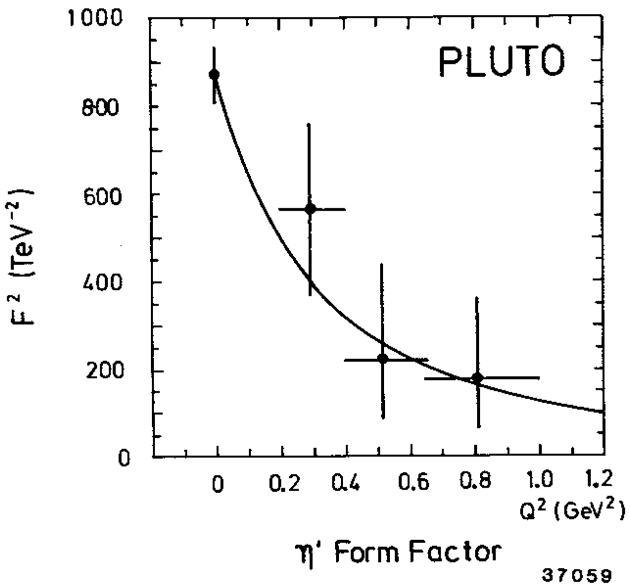

Fig. 2. The transition form factor for $\eta' \to \gamma\gamma$. The expected ρ^0 pole contribution normalized to $Q^2 = 0$ is shown.

THE A_2 MESON

We have studied the formation of the A_2^0 meson by "quasireal" photons in $\gamma\gamma$ collisions. The A_2^0 meson was detected by its decay into $\rho^{\pm}\pi$. In addition to the usual background reduction cuts, the sample of events consisting of 2 charged unlike tracks and 2 shower clusters was also kinematically fitted. Imposition of momentum conservation in the R-ϕ plane and the requirement that the 2 shower clusters form a π^0 meson made possible a 3 constraint fit. Events satisfying the kinematic fit with a χ^2- probability greater than 2% were accepted. The $M(\pi^+\pi^-\pi^0)$ distribution shown in Fig. 3 exhibits a clear A_2 signal which is strongly correlated with the $\pi^{\pm}\pi^0$ mass combination being in the $\rho^{\pm}$ meson mass band. The fit shown in Fig. 3 yielded 97 ± 18 A_2 events.

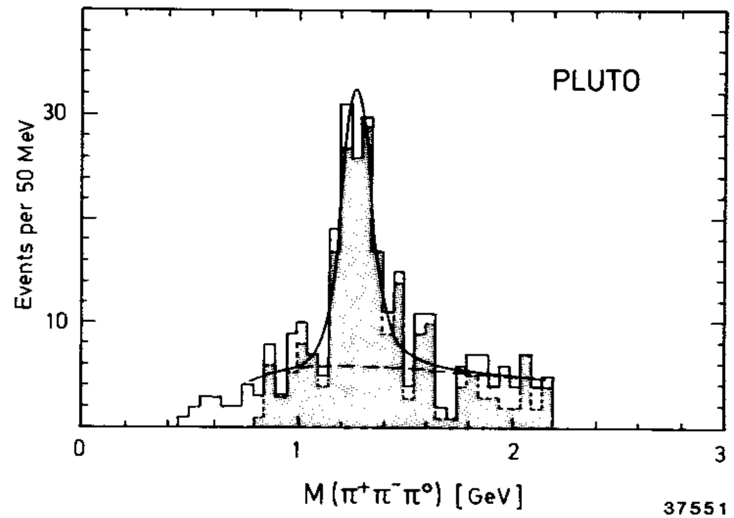

Fig. 3. The $M(\pi^+\pi^-\pi^0)$ distribution for the channel $\gamma\gamma \to \pi^+\pi^-\pi^0$. Entries for which $M(\pi^{\pm}\pi^0) = M(\rho^{\pm})$ ±200 MeV are indicated by the shaded regions. The fit to the A_2 meson is shown.

The detector acceptance was determined from Monte Carlo studies where the events were generated taking into consideration constructive interference between the 2 decay chains, $A_2^0 \to \rho^+\pi^- \to \pi^+\pi^-\pi^0$ and $A_2^0 \to \rho^-\pi^+ \to \pi^+\pi^-\pi^0$ [7].

$$|M|^2 \propto (2J+1)\,\frac{M_{A_2}}{S}\;\frac{\Gamma_{\gamma\gamma}(A_2)}{(M^2_{A_2}-S)^2+M^2_{A_2}\,\Gamma^2_{A_2}}\;*$$

$$*\;\sum_{\lambda}\rho_{\lambda\lambda}\left|\frac{T_\lambda(A_2\to\rho^+\pi^-)}{M^2_\rho-S_{\rho^+}-i\,M_\rho\Gamma_\rho}+\frac{T_\lambda(A_2\to\rho^-\pi^+)}{M^2_\rho-S_{\rho^-}-i\,M_\rho\Gamma_\rho}\right|^2$$

The spin (helicity) of the A_2 is denoted by $J(\lambda)$, $S_{\rho\pm}$, is the $(\pi^\pm\pi^0)$ mass system and $T_\lambda(A_2\to\rho^\pm\pi)$ is the transition amplitude for the decay $A_2\to\rho^\pm\pi$. The widths for the A_2 and ρ meson were described by momentum dependent forms.

In order to ascertain the spin-parity of the 3 pion final state we have calculated the Dalitz plot parameter,

$$\Lambda = \frac{|\vec{P}_{\pi^+}\times\vec{P}_{\pi^-}|^2}{\max\,(|\vec{P}_{\pi^+}\times\vec{P}_{\pi^-}|^2)},$$

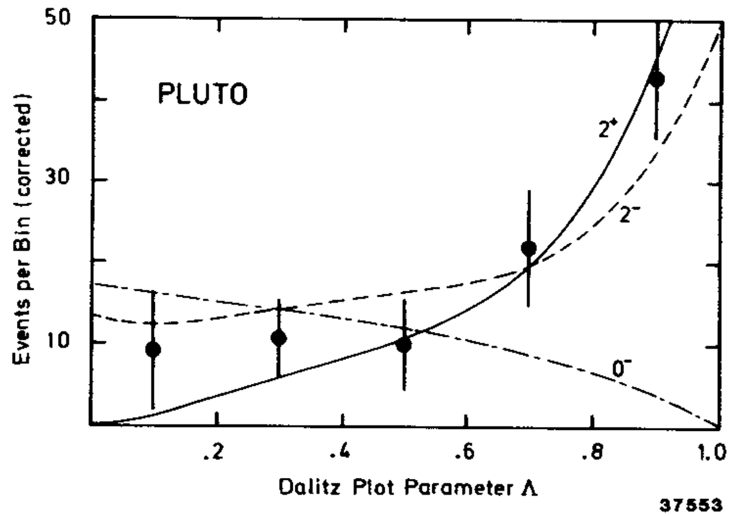

Fig. 4. Distribution of the acceptance corrected value of the Dalitz plot parameter Λ. The expected behaviour for a 2^+ resonance is shown by the full line, for 2^- by the dashed line, and for 0^- by the point-dashed line.

and this is plotted in Fig. 4. The expected behaviour for the J^P values which are consistent with a 3π final state initiated by 2 photons, namely 2^+, 2^- 0^- are also indicated in Fig. 4. The data is best described by the 2^+ curve. We denote the angle between the photon photon axis and the normal to the 3π plane (in the 3π CM) by the symbol α . The distribution of $\cos\alpha$ along with the expected behaviour for the $J^P(\lambda)$ values, $2^+(0)$, $2^+(2)$ and $2^-(0)$ are shown in Fig. 5. The data is well described by $|\lambda| = 2$ with some admixture of $\lambda = 0$. A fit to $\lambda = 2$ and 0 yields an admixture of 39± 38% of $\lambda = 0$. In our Monte Carlo studies we have generated events with $\lambda = 2$ and 0, in the same proportion found in the fit of the data. We have found the radiative width of the A_2 meson, $\Gamma_{\gamma\gamma}(A_2) = 1.06 \pm 0.18 \pm 0.19$ keV, a value consistent with previous measurements of $0.77 \pm 0.18 \pm 0.27$ [8], $0.81 \pm 0.19 \pm 0.27$ [9], and $0.84 \pm 0.07 \pm 0.15$ [10].

In the framework of SU(3) flavour, assuming nonet symmetry, we have the following expression for the radiative widths of the 2^{++} mesons, which is mixing angle independent:

$$\frac{3\,\Gamma_{\gamma\gamma}(A_2)}{m^3_{A_2}} = \frac{\Gamma_{\gamma\gamma}(f')}{m^3_{f'}} + \frac{\Gamma_{\gamma\gamma}(f^0)}{m^3_{f^0}}$$

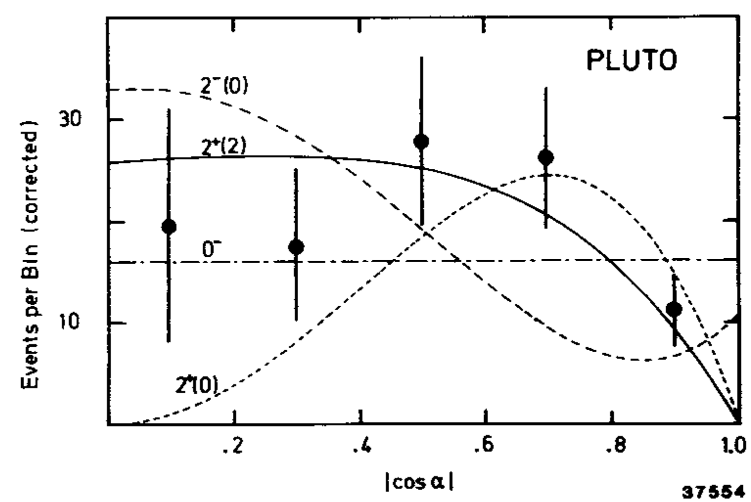

Fig. 5 The acceptance corrected distribution of $|\cos\alpha|$ and the expected behaviour for the $J^P(\lambda)$ values $2^+(2)$ (full line), $2^-(0)$ (----), $2^+(0)$ (....) and 0^- (-.-.-).

Using the world average value $\Gamma_{\gamma\gamma}(f^0) = 2.8 \pm 0.2$ keV and the TASSO[11] measurement of $B(f' \to K\bar{K})$ $\Gamma_{\gamma\gamma}(f') = 0.11 \pm .02 \pm .04$ keV, and if we set $B(f' \to K\bar{K}) = 1$, we obtain a lower limit prediction of $\Gamma_{\gamma\gamma}(A_2) = 1.06 \pm 0.08$ keV in agreement with our measurement.

UPPER LIMITS ON $\gamma\gamma \to \rho^0\omega$ and $\gamma\gamma \to \omega\omega$

In view of the sizeable cross section measured for the channel $\gamma\gamma \to \rho^0\rho^0$ near threshold[12,13,14] which cannot be accounted for by simple VDM expectations, searches have been carried out for other vector meson final states - $\rho^+\rho^-$, $\rho^0\omega$ and $\omega\omega$. Models proposed to explain the $\rho^0\rho^0$ enhancement also make predictions for the production of the other vector meson states. Table I below summarizes these predictions.

The JADE Collaboration [15] has set upper limits on $\gamma\gamma \to \rho^+\rho^-$ which rule out the interpretation of the $\rho^0\rho^0$ enhancement as a non-exotic I=0,1 resonance. The proposed models 4) and 5) in Table I are inconsistent with the $\rho^+\rho^-$ upper limit.

TABLE I

Model	Rate Relative to $\rho^0\rho^0$			
	$\rho^0\rho^0$	$\rho^+\rho^-$	$\omega\omega$	$\rho^0\omega$
* 1) VDM (γV-Coupling)	1	0	1/81	1/9
2) VDM + Regge, Ref. 16	1		5.8	0.5
3) Alexander et al., Ref. 17	1		~1	~ 0.2
4) Quark Model, Ref. 18	1	2	1	~ 1.4
5) Quark Model, Ref. 19	1	~ 1.3		
6) $qq\bar{q}\bar{q}$, Ref. 20	1	~ 0	~ 0.03	~ 0.6
7) $qq\bar{q}\bar{q}$, Ref. 21	1	~ 0	~ 0.06	~ 0.03

* does not explain the $\rho^0\rho^0$ enhancement.

We have carried out a search for $\gamma\gamma \to \rho^0\omega$ using a topological sample of 2 positive tracks, 2 negative tracks and 2 neutral clusters, with $E_\gamma \geq 100$ MeV. The energies of the 2 photons were scaled so that momentum was conserved in the R- ϕ plane. Also the probability that the 2 photons originated from a spin zero particle had

to be greater than 40% as determined from their opening angle[22]. A sample of 52 ± 8 events of the exclusive channel $\gamma\gamma \to 2\pi^+ 2\pi^-\pi^0$ was found. The cross section for this exclusive 5 pion final state was determined as a function of $W_{\gamma\gamma}$, and these values are shown in Fig. 6 along with preliminary values from CELLO[23].

No ρ^0 or ω meson signal was detected in this exclusive channel. The acceptance of the PLUTO detector for the reaction $\gamma\gamma \to \rho^0\omega \to 2\pi^+ 2\pi^-\pi^0$ was studied as a function of $W_{\gamma\gamma}$ using the Monte Carlo simulation program. An isotropic distribution was assumed for the $\rho^0\omega$ production and the subsequent decays $\rho^0 \to \pi^+\pi^-$ and $\omega \to \pi^+\pi^-\pi^0$. The Monte Carlo events when processed through the physics analysis programs yield a clear ω signal recoiling from the ρ^0 meson. Upper limits at the 95% confidence level are given in Fig. 7 along with the upper limits set by the JADE Collaboration[15].

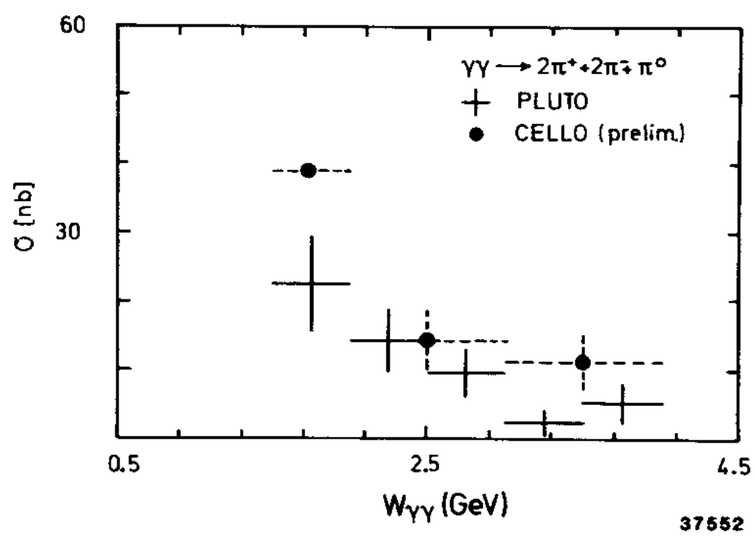

Fig. 6. The value of the cross section of the process $\gamma\gamma \to 2\pi^+ 2\pi^-\pi^0$ as a function of the γ-γ CM energy, $W_{\gamma\gamma}$. Preliminary results from the CELLO Collaboration are also shown.

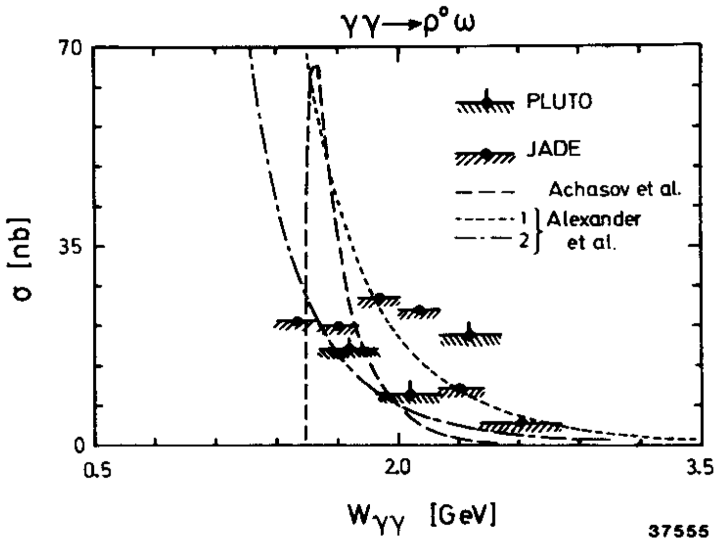

Fig. 7. Upper limits (95% conf. level) for the reaction $\gamma\gamma \rightarrow \rho^0\omega$. Expectations of Achasov, Ref. 20 and Alexander, Ref. 16 and 17 are shown.

THE CHANNEL $\gamma\gamma \rightarrow \omega\omega$

In our study of the channel $\gamma\gamma \rightarrow \omega\omega$ we have considered the sample of events having 2 positive tracks, 2 negative tracks and from one to four neutral clusters with $E_\gamma >$ 40 MeV. We have searched for the ω meson through its dominant decay mode $\pi^+\pi^-\pi^0$. The rather low acceptance of the detector for the complete final state $2\pi^+2\pi^-2\pi^0$ (4 photons) precluded the use of momentum conservation constraints to fit the events. We have, therefore, taken the approach of maximizing the ω-meson signal by reconstructing one ω meson using only 1 photon. We have studied the mass system $\pi^+\pi^-$ "γ", where we approximate the π^0 by one energetic photon, $E_\gamma >$ 135 MeV, which carries almost all the energy and retains quite well the direction of its parent π^0. Extensive Monte Carlo studies show that such a reconstruction yields a mass for the ω meson which is ~ 30 MeV lower. The detector simulation programs give a clear ω signal at a mass of ~ 753 MeV.

The above outlined reconstruction method has been previously used by the CELLO Collaboration in their study of the A_2 meson [9].

Our data show no ω signal. Upper limits at the 95% confidence level are given in Fig. 8 along with previously determined upper limits from the JADE Collaboration[15].

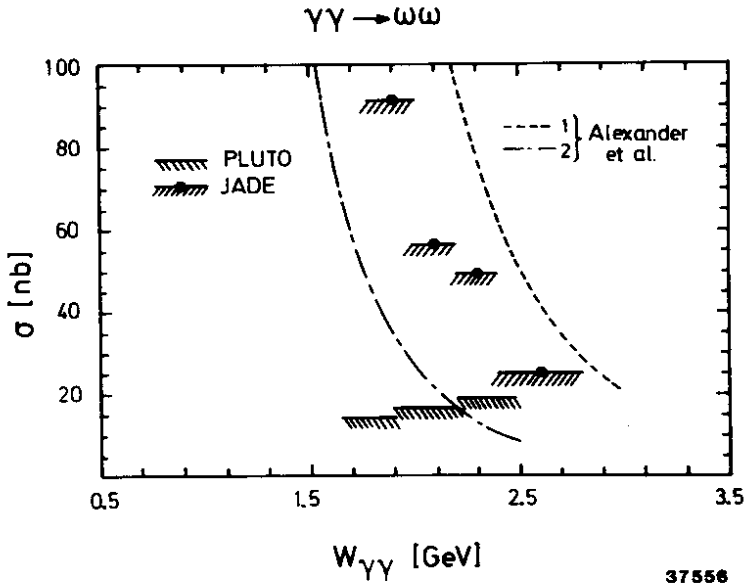

Fig. 8. Upper limits (95% conf. level) for the reaction $\gamma\gamma \rightarrow \omega\omega$. Expectations of Alexander, Ref. 16 and 17 are shown.

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