DEUTSCHES ELEKTRONEN-SYNCHROTRON DESY

DESY 85-079
August 1985

t-CHANNEL FACTORIZATION DESCRIPTION OF $\gamma\gamma \to V_1V_2$

by

G. Alexander, A. Levy, U. Maor

Deutsches Elektronen-Synchrotron DESY, Hamburg

and

School of Physics and Astronomy, Tel Aviv University

ISSN 0418-9833

NOTKESTRASSE 85 · 2 HAMBURG 52

DESY 85-079
August 1985

ISSN 0418-9833

t-Channel Factorization Description of $\gamma\gamma \to V_1V_2$

G. Alexander, A. Levy, U. Maor

Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany

and

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

Abstract

A t-channel factorization model is used to estimate cross sections for the processes $\gamma\gamma \to V_1V_2$. Whenever $V = \rho$, the width of the ρ has been included in the calculations. The channels $\gamma\gamma \to \rho^\circ\rho^\circ$, $\rho^\circ\varphi$, $\varphi\varphi$, $\omega\omega$, $\rho^\circ\omega$ and $\rho^+\rho^-$ are calculated for two quasi-real photons. Predictions are also given for the process $\gamma^*\gamma \to \rho^\circ\rho^\circ$ for virtual photon mass squared $Q^2 <$ 5 GeV^2. Our results are consistent with all available experimental data.

I) Introduction

A large cross section for the quasi-real photons (no tag) reaction $\gamma\gamma \to \rho^\circ\rho^\circ$ near threshold has been observed[1-3]. This threshold enhancement is considerably bigger than a simple asymptotic VDM prediction[1] and therefore has triggered several interpretations. Among them are those studies which attempted to understand the large $\rho^\circ\rho^\circ$ cross section as a signature of a new phenomena in the direct $\gamma\gamma$ channel; the production of a new resonance[4] or the exotic formation of interfering four-quark bound states with $I = 0$ and $I = 2$[5,6]. A more conservative approach has been to accomodate the observed $\rho^\circ\rho^\circ$ enhancement by the factorization properties of the hadron-like (VDM) two photon interaction[7]. The relevance of this approach is self-evident. If it does provide, as indeed we claim, satisfactory estimates for the observed rates of vector meson production in $\gamma\gamma$ collisions, then it defines a large background over which any signal of a more exotic nature should be verified.

In this paper we wish to elaborate on the factorization model defined in ref. (7). The model assumptions remain unchanged. We apply the factorization relation for the crossed t-channel natural and unnatural parities at fixed outgoing c.m. momenta, correcting for the flux factors (denoted by Fij) arising from the different masses involved. Thus we get:

$$\sigma(\gamma\gamma \to V_1V_2) = \sum_i \frac{\sigma^i(\gamma N \to V_1 N)\ \sigma^i(\gamma N \to V_2 N)\ F^2_{\gamma N}}{\sigma^i(NN \to NN)\ F_{NN}\ F_{\gamma\gamma}} \qquad (1)$$

where the summation is over the various t-channel processes contributing to $\gamma\gamma \to V_1V_2$. As we shall see the actual processes of interest are the diffractive and the one pion exchange (OPE) contributions. Thus our summation is equivalent to summing over the isoscalar and isovector photon components. Eq. (1) has the advantage that it approaches the standard asymptotic factorization relation in the high energy limits, while providing a sensible low energy continuation close to threshold.

The applicability of this model crucially depends on several elements:

a) that the quality of the input data is satisfactory,
b) that a reliable separation of the input data to t-channel contributions with well defined quantum numbers is possible,
c) that our main assumption is viable, i.e. that a t-channel model, when continued to the low energy limit, provides nevertheless a reasonable average description of the data.

In the following we shall apply the model to estimate the diffractive production of $\rho^\circ\rho^\circ$, $\varphi\varphi$ and $\rho^\circ\varphi$ by two quasi-real photons. We improve on our previous calculation[7] by taking the ρ width into account. We proceed to predict the $\rho^\circ\rho^\circ$ cross sections when one of the initial photons is off shell. The model is then applied to estimate the cross sections of $\gamma\gamma \to \omega\omega$ and $\gamma\gamma \to \rho^\circ\omega$. We conclude by discussing the estimate of $\gamma\gamma \to \rho^+\rho^-$.

II) Diffractive production of vector mesons

The reactions $\gamma\gamma \to \rho^\circ\rho^\circ$, $\gamma\gamma \to \varphi\varphi$ and $\gamma\gamma \to \rho^\circ\varphi$ are very suitable for the application of Eq. (1). The input reactions are either purely or predominantly diffractive for which we have reliable cross sections close to threshold[8-10]. There is, however, a certain ambiguity with regard to the ρ° photoproduction input data resulting from different model dependent handlings of the ρ° resonance. The cross sections obtained with a standard Breit-Wigner analysis, the Söding[11] or Ross-Stodolsky[12] models differ by as much as 15%. This together with the statistical errors are the sources of uncertainty in our input reflected in the wide band of our $\rho^\circ\rho^\circ$ cross section output.

Our earlier estimate neglected the ρ° width, which may affect the results for $W_{\gamma\gamma} \lesssim 1.7$ GeV. Following ref. (1), we present here a simple Breit-Wigner procedure to unfold the ρ° width:

$$\sigma(\gamma\gamma\to\rho^\circ\rho^\circ) = \frac{\int_{m_1}^{M} \frac{\sigma^2(\gamma p \to \rho^\circ p)\ F_{\gamma p}^2}{\sigma(pp \to pp)\ F_{pp}\ F_{\gamma\gamma}} |BW(m)|^2\ dm}{\int_{m_1}^{m_2} |BW(m)|^2\ dm} \qquad (2)$$

where $m_1 = 0.6$ GeV, $m_2 = 0.9$ GeV and $M = \min(\frac{W_{\gamma\gamma}}{2}, 0.9\text{ GeV})$. The numerical results are insensitive to our particular choice of m_1 and m_2. The Breit-Wigner amplitude is given by

$$BW(m) = \frac{\sqrt{m_\rho \Gamma_\rho m/p^*}}{\pi(m_\rho^2 - m^2 - i m_\rho \Gamma_\rho)}$$

with

$$\Gamma_\rho = \Gamma_o \left(\frac{p^*}{p_o^*}\right)^3 \frac{2\, p_o^{*2}}{p_o^{*2} + p^{*2}}$$

$$p^* = \frac{1}{2}\sqrt{m^2 - 4m_\pi^2} \text{ and } p_o^* = \frac{1}{2}\sqrt{m_\rho^2 - 4m_\pi^2}$$

The ρ° nominal parameters used are $m_\rho = 0.776$ GeV and $\Gamma_o = 0.155$ GeV. To compare our prediction with the data below $W_{\gamma\gamma} = 1.5$ GeV we have followed ref. (1) and have subtracted 50 MeV from the input m_ρ for every decrease of 100 MeV in $W_{\gamma\gamma}$.

For the actual application of Eq. (2), we have used numerical extrapolations, including error propagations, through the data points of refs. (8-10). Our results for $\gamma\gamma \to \rho^\circ\rho^\circ$ in the final state are shown in Fig. 1 where we compare our estimates with the no-tag data of TASSO[1], CELLO[2] and TPC[3]. As can be seen, we reproduce the observed threshold enhancement of $\gamma\gamma \to \rho^\circ\rho^\circ$ including the observation[1] of a big cross section below the nominal $\rho^\circ\rho^\circ$ threshold. We predict a very small cross section for $\gamma\gamma \to \varphi\varphi$. For $2 < W_{\gamma\gamma} < 5$ GeV our predicted cross

sections range from 0.001 to 0.05 nb respectively. This estimate is far below the current experimental upper limits[13,14], where φ + 2 charged tracks are observed in the final state, but no $\varphi\varphi$ signal has been detected thus far. Our prediction for $\sigma(\gamma\gamma \to \rho^\circ\varphi)$ in the energy range $2 < W_{\gamma\gamma} < 3$ GeV is 0.4-0.5 nb. Once again no $\rho^\circ\varphi$ signal has been detected in the φ + 2 charged tracks sample and the published upper limits[13,14] are well above our estimate.

III. The reaction $\gamma^*\gamma \to \rho^\circ\rho^\circ$

It is of interest to check the predictions of our model for single tag production of $\rho^\circ\rho^\circ$. Whereas our treatment of the no-tag, almost real photons, as hadron-like is rather sensible, one may, however, question the validity of this treatment for off mass photons. We rely here on a similar model[15] applied to deep inelastic e-γ scattering which was compared with the data[16]. The conclusions of that comparison are that whereas a factorizable estimate reproduces the data at small Q^2, it is severely deficient when compared with the high Q^2 data. This conclusion is not surprising in view of the fact that the point-like photon contribution increases with Q^2.

Our estimates are thus confined to $Q^2 < 5$ GeV^2, where we have taken the $ep \to e\rho^\circ p$ input data from ref. (17). Our results for two representative $W_{\gamma\gamma}$ values are displayed in Fig. 2. An interesting point should be noted. If we compare our results with a ρ-dominance form factor $(m_\rho^2/(m_\rho^2 + Q^2))^2$, we observe that our predictions rise above the ρ-dominance values as Q^2 increases. This behaviour is similar to the one observed in the total cross section studies[15,16]. However, at the same time our input cross sections[17] are lower than the ρ-dominance expectations. This apparent difference between input and output relation to ρ-dominance is typical for our model which is applied at fixed outgoing c.m. momenta rather than fixed energies.

IV) Non diffractive channels

The application of Eq. (1) to $\gamma\gamma \to \omega\omega$ is somewhat more complicated and less reliable than the previous analysis of diffractive channels. When we examine the input reactions of interest we realize that $\gamma p \to \omega p$ is dominated at low energies by an OPE mechanism in addition to a much smaller diffractive contribution. Separation between those channels can be done by either utilizing SU(3) relations between $\gamma p \to V^\circ p$ or by comparing the energy dependences of these reactions. These two methods provide results which are not very different from each other. In any case the OPE contribution contains strong absorptive corrections which make the isolation of t-channel contributions rather crude. Thus, the application of factorization is only justified on a very approximate level. Moreover, the isolation of the appropriate OPE contribution to elastic pp scattering is very difficult. We overcome this by taking the np charge exchange data[19] which is dominated by OPE[20]. We then replace $\sigma^{OPE}(pp \to pp)$ by $\frac{1}{4}\,\sigma(np \to pn)$ using the appropriate Glebsh-Gordan coefficients.

Keeping these limitations in mind, we proceed to show in Fig. 3 our predicted bands for $\sigma(\gamma\gamma \to \omega\omega)$ and $\sigma(\gamma\gamma \to \rho^\circ\omega)$ together with the experimental upper limits[21]. Our diffractive + OPE analysis turns out to yield OPE contributions to $\omega\omega$ production which are much bigger than the diffractive ones. For $\rho^\circ\omega$ we cannot ignore either of these contributions. Our present estimates are considerably lower than those we have obtained previously[7]. The reasons for this difference are not due to any change in our basic assumptions but rather to a more careful treatment of the input data. Previously, we have used an extrapolation formula for $\sigma(\gamma p \to \omega p)$ suggested by Eisenberg et al.[18]. This approximation severely overestimates the ω photoproduction cross section close to its threshold. In our present analysis we have used the same procedure as in the diffractive channels, i.e. a multi-

parameter extrapolation between the data points with an error propagation which was omitted in our early estimate. Another problem with our previous analysis has been an underestimate of the np charge exchange cross sections input. These were obtained in ref. 7 by integrating $\frac{d\sigma}{du}$ over a very narrow cone, namely $|u| < m_\pi^2$. Reconsidering we find this unjustified, as it is known that the OPE contribution to np charge exchange extends to much higher $|u|$ values[20]. In our present estimate we have integrated $\frac{d\sigma}{du}$ over the backward hemisphere and obtain cross sections which we consider more realistic. Our results are compatible with the appropriate upper limits published recently[21]. We note that an examination of the SU(3) relations:

$$\sigma^{OPE}(\gamma\gamma \to \omega\omega) = 81\,\sigma^{OPE}(\gamma\gamma \to \rho\rho)$$

$$81\,\sigma^{Diff}(\gamma\gamma \to \omega\omega) = \sigma^{Diff}(\gamma\gamma \to \rho\rho)$$

is not very instructive as both estimates of $\sigma^{OPE}(\gamma\gamma \to \rho\rho)$ and $\sigma^{Diff}(\gamma\gamma \to \omega\omega)$ are very small and associated with large errors.

Next we turn to the reaction $\gamma\gamma \to \rho^+\rho^-$. This channel is crucially important in the search for possible direct channel $\gamma\gamma$ phenomena. Unfortunately, the application of factorization to this reaction is least reliable as the input data[22] is of relatively poor quality and separation into well defined t-channel contributions is virtually impossible. If we resort to the assumption that $\gamma\gamma \to \rho^+\rho^-$ is OPE dominated, we obtain a cross section of 6 nb at $W_{\gamma\gamma} = 2$ GeV, which drops to 1 nb at $W_{\gamma\gamma} = 3$ GeV.

V) Conclusions

The basic approach of our analysis is that we treat an almost real virtual photon as if it were a hadron. This point of view is supported by the Q^2 dependence studies of total $\gamma\gamma$ reactions[16], and we assume that $\gamma\gamma \to V_1V_2$ behaves in a similar manner.

The basis of our analysis is the assumption that t-channel factorization can be applied close to threshold provided reasonable kinematical corrections are made. Our experience from two-body hadron reactions supports this assumption in particular when applied to diffractive channels. Our results should be considered, thus, as an overall approximation where we did not attempt to examine more refined properties of $\gamma\gamma$ reactions.

We conclude by restating our motive. The search for exotic explanations of $\gamma\gamma$ phenomena should be done above the background of conventional processes. In our judgement, factorization can serve as a good estimate of this background.

Acknowledgements

We would like to thank the DESY Directorate for their kind hospitality and the Minerva Foundation for financial support.

References

1) TASSO Coll., R. Brandelik et al., Phys.Lett. 97B (1980), 448
M. Althoff et al., Z.Phys. C18 (1982), 13

2) CELLO Coll., H.-J. Behrend et al., Z.Phys. C21 (1984), 205

3) TPC Coll., J.G. Layter et al., submitted to the Leipzig Conf. on High Energy Physics, 1984
MARK II Coll., D.L. Burks et al., Phys.Lett. 103B (1981), 153

4) H. Goldberg and T. Weiler, Phys.Lett. 102B (1961), 63

5) N.N. Achasov et al., Phys.Lett. 108B (1982), 134; Z.Phys. C16 (1982), 55; Ibid C27 (1985), 99

6) B.A. Li and K.F. Liu, Phys.Lett. 118B (1982), 435; Phys.Rev. D30 (1984), 613

7) G. Alexander, U. Maor and P.G. Williams, Phys.Rev. D26 (1982), 1198

8) ABBHHM Coll., Phys.Rev. 175 (1968), 1669;
Y. Eisenberg et al., Phys.Rev. D5 (1972), 15;
W. Struczinski et al., Nucl.Phys. B108 (1976), 45

9) D.G. Cassel et al., Phys.Rev. D24 (1981), 2787

10) O. Benary, L.R. Price, G. Alexander, NN and ND interactions (above 0.5 GeV/c) - a compilation, UCRL-20000 (1971)

11) P. Söding, Phys.Lett. 19B (1965), 702

12) M. Ross and L. Stodolsky, Phys.Rev. 149 (1966), 1172

13) TPC Coll., H. Aihara, Phys.Rev.Lett. 54 (1985), 2564

14) TASSO Coll., submitted to EPS BARI Conference, July 1985

15) G. Alexander, U. Maor and C. Milstene, Phys.Lett. 131B (1983), 224

16) PLUTO Coll., Ch. Berger et al., Z.Phys. C26 (1984), 353

17) I. Cohen et al., Phys.Rev. D25 (1982), 634

18) Y. Eisenberg et al., Phys.Lett. 34B (1971), 439;
J. Ballam et al., Phys.Rev. D7 (1973), 3150;
D.P. Barber et al., Z.Phys. C26 (1984), 343

19) See ref. 10. The np charge exchange total cross sections were obtained from $d\sigma/d(\cos\Theta)$ data integrated over the backward hemisphere.

20) A complete reproduction of the np charge exchange data requires also small non OPE contributions. See e.g. E. Gotsman and U. Maor, Nucl.Phys. B145 (1978), 459

21) JADE Coll., J. Olsson, contributed paper to Int. Europhysics Conf. on High Energy Physics, Brighton 1983;
PLUTO Coll., J. Grunhaus, DESY report 84-099 and Int.Symp. on Multiparticle Dynamics, Lund 1984

22) ABHHM Coll., Nucl.Phys. B23 (1970), 45

Figure Captions

Fig. 1 Compilation of $\sigma(\gamma\gamma \to \rho^o\rho^o)$ data taken from references 1-3 as a function of $W_{\gamma\gamma}$. The shaded band represents the predictions of the t-channel factorization model.

Fig. 2 Prediction of the t-channel factorization model for the $\rho^o\rho^o$ cross section produced by $\gamma^*\gamma$ as a function of Q^2, the invariant mass squared of the virtual photon γ^*, for two $W_{\gamma\gamma}$ values.

Fig. 3 Upper limits at 95% confidence level for the cross section values of the channels
a) $\gamma\gamma \to \omega\omega$ and b) $\gamma\gamma \to \rho^o\omega$. The shaded bands are predictions of the t-channel factorization model.

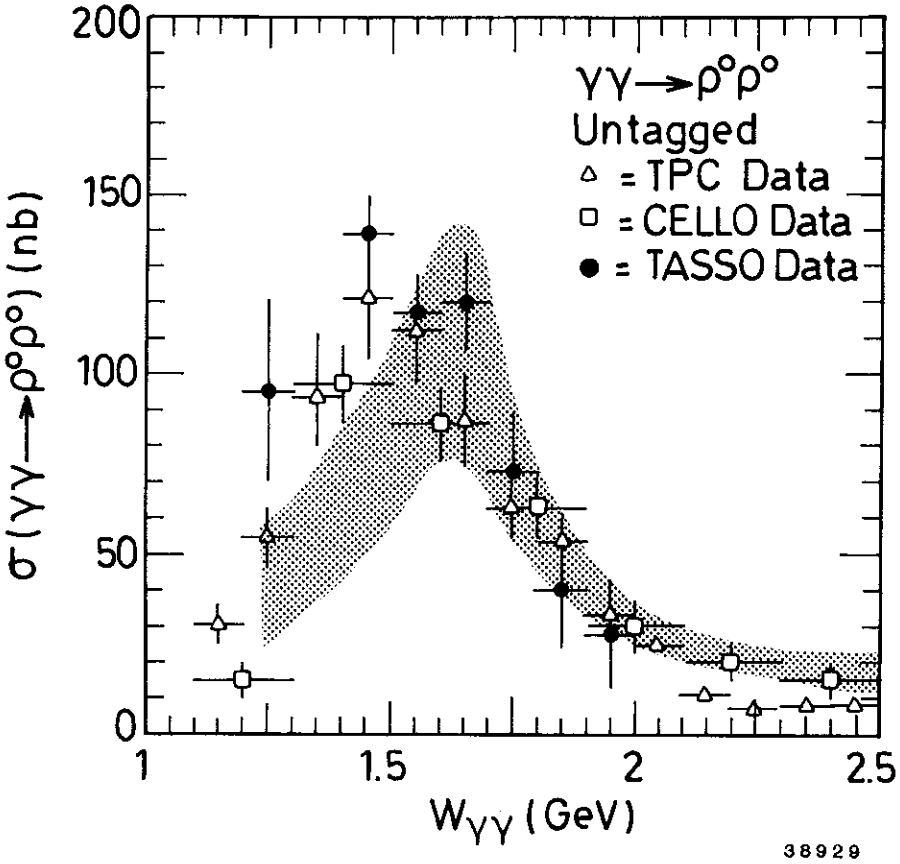
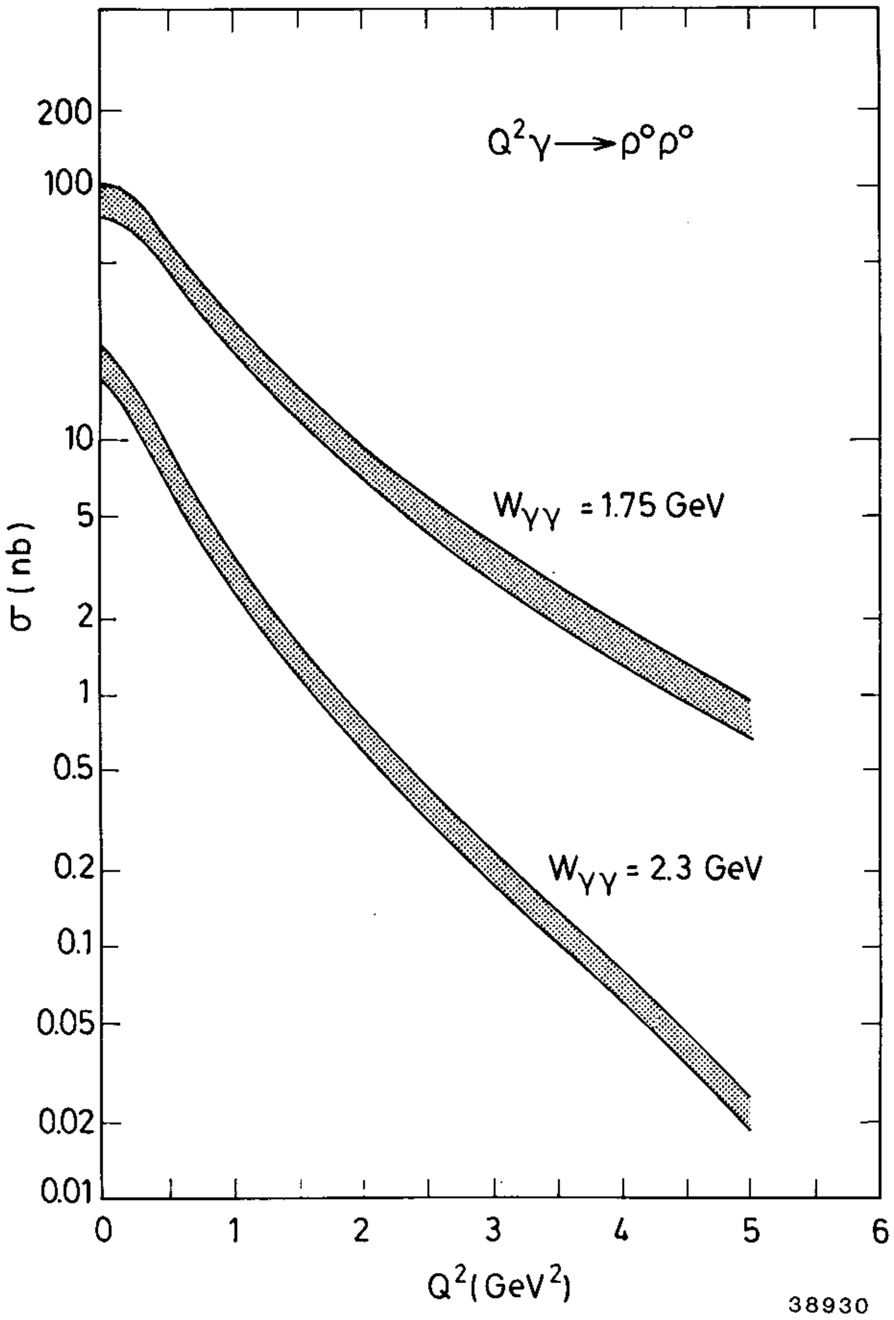
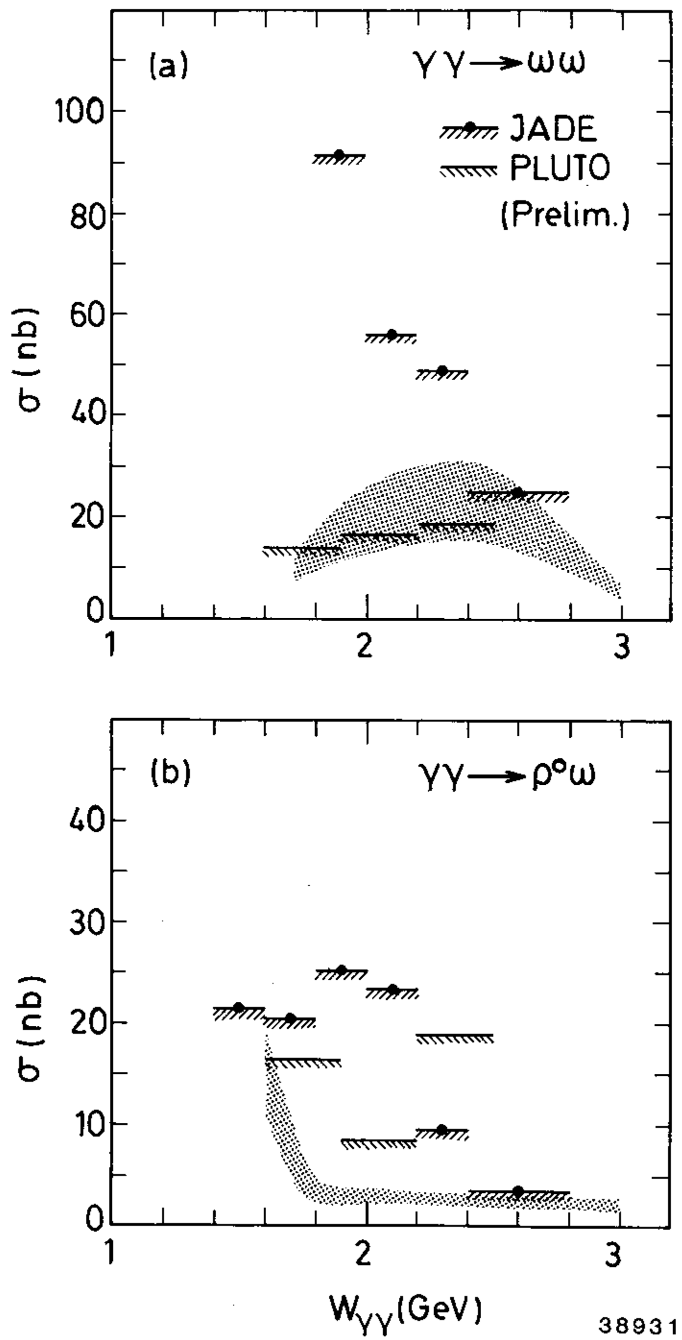


Fig. 1



$Q^2\gamma \rightarrow \rho^o\rho^o$
$W_{\gamma\gamma}$ = 1.75 GeV
$W_{\gamma\gamma}$ = 2.3 GeV
σ (nb)
Q^2(GeV^2)
38930

Fig. 2



(a)
$\gamma\gamma \rightarrow \omega\omega$
JADE
PLUTO
(Prelim.)
σ (nb)
(b)
$\gamma\gamma \rightarrow \rho^o\omega$
σ (nb)
$W_{\gamma\gamma}$(GeV)
38931

Fig. 3