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IN SEARCH OF $Q^2\bar{Q}^2$ MESONS IN $\gamma\gamma$ REACTIONS*

Bing An Li†
Stanford Linear Accelerator Center
Stanford University, Stanford, California 94305

and

K. F. Liu
Department of Physics and Astronomy
University of Kentucky, Lexington, Kentucky 40506

ABSTRACT

The structure observed in the reaction $\gamma\gamma \to \rho^0\rho^0$ is interpreted as due to 2^{++} ($I = 0,2$) $Q^2\bar{Q}^2$ states with a background contribution from 0^{++} ($I = 0,2$) $Q^2\bar{Q}^2$ states. Both states decay predominantly via two vector mesons. The predictions of the other two vector channels are presented, and the possibilities of search for $Q^2\bar{Q}^2$ in hadron scattering processes and J/ψ radiative decay are discussed briefly.

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† Permanent address: Institute of High Energy Physics, Academica Sinica, Beijing, China.

Recent experimental measurements [1,2] of the cross section for the reaction $e^+e^- \to e^+e^-\pi^+\pi^-\pi^+\pi^-$ have revealed a dominating process $\gamma\gamma \to \rho^0\rho^0 \to \pi^+\pi^-\pi^+\pi^-$ which exhibits a large enhancement around the $\rho^0\rho^0$ threshold. The possible channels for this reaction $\gamma\gamma \to \rho^0\rho^0$ to occur with lower spins are $J^{PC}(I^G) = 0^{\pm+}\ (0^+,2^+)$ and $2^{\pm+}\ (0^+,2^+)$, since the two real photons do not couple to $J = 1$.

An analysis in terms of the $Q\bar{Q}$ mesons has been performed by Goldberg and Weiler [3]. The possibility of a 0^{-+} or 2^{++} gluonium resonance at 1660 MeV has been suggested by Layssac, Renard [4] and Brodsky [5]. In this letter, we consider the possibility that $Q^2\bar{Q}^2$ type of four-quark mesons may account for this structure.†

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†After this work was finished, B. A. Li learned from the talk given by M. Chanowitz in the Summer Institute at SLAC. He proposed a search for a second observable $\bar{Q}\bar{Q}QQ$ 0^+ state $(I = 0,\ u\bar{d}d\bar{u}\ M(1450) \to \rho\rho, \omega\omega)$ in $\gamma\gamma \to \rho^0\rho^0$.

The existence of the S-wave $Q^2\bar{Q}^2$ states have been considered by Johnson and Jaffe [6 7] in the MIT bag model. A tentative interpretation of the structure observed in the process $\gamma\gamma \to \rho^0\rho^0$ due to $2^{++}\ (0^+,2^+)$ $Q^2\bar{Q}^2$ states and $0^{++}\ (0^+,2^+)$ $Q^2\bar{Q}^2$ states is based on the following properties of these states.

(1) The masses of these $Q^2\bar{Q}^2$ states as calculated by Jaffe [7] in the MIT bag model, are 1.65 GeV, 1.45 GeV and 1.8 GeV, respectively. They are right in the energy domain of the $\gamma\gamma \to \rho^o\rho^o$ enhancement.

(2) The wave functions of the $Q^2\bar{Q}^2$ states have two parts: a color singlet-color singlet part and a color octet-color octet part. Their decays obey the OZI rule. The 2^{++} $Q^2\bar{Q}^2$ states only decay into two vector mesons (zeroth order), and the 0^{++} states which are flavor SU(3) 9^*-plet, 36^*-plet decay into two vector mesons predominantly.

The $\gamma\gamma \to \rho^o\rho^o$ enhancement can be understood in this picture: the real photons form $Q^2\bar{Q}^2$ states which decay into $\rho^o\rho^o$ predominantly. In fact, the threshold enhancement in the VV chanels have been predicted by Jaffe [7].

The $Q^2\bar{Q}^2$ states which contribute to the process $\gamma\gamma \to \rho^o\rho^o$ and their recoupling coefficients which are taken from ref. 8 are shown in table 1. We use Jaffe's symbols to indicate $Q^2\bar{Q}^2$ states.

We start by considering the diagram in fig. 1 as the physical process for $\gamma\gamma \to \rho^o\rho^o$. The two photons collide to produce $Q^2\bar{Q}^2$ mesons via the vector meson dominance. The intermediate $Q^2\bar{Q}^2$ states in turn decay into $\rho^o\rho^o$. As shown in table 1, there are six $Q^2\bar{Q}^2$ states which contribute to this process.

The S-matrix in this picture can be written as

$$\langle \rho^o_{\lambda_1} \rho^o_{\lambda_2} | S | \gamma\gamma \rangle = (2\pi)^4 \, i\delta^4 \, (k_1 + k_2 - p_1 - p_2) \times \sum_i \frac{1}{W - m_{A_i} + \frac{i}{2}\,\Gamma_{A_i}} \langle \rho^o_{\lambda_1} \rho^o_{\lambda_2} | T | A_i \rangle \langle A_i | T | \gamma\gamma \rangle \tag{1}$$

where k_1, k_2 are the momenta of the incoming photons and p_1, p_2 are the momenta of two ρ^o. λ_1, λ_2 are the helicities of two ρ respectively. W is the total energy of the two photons in center-of-mass frame. m_{A_i} is the mass of the $Q^2\bar{Q}^2$ state A_i. Γ_{A_i} is the total width of the $Q^2\bar{Q}^2$ state A_i. The summation is over the intermediate $Q^2\bar{Q}^2$ states A_i.

According to the Bag model [6,7], these $Q^2\bar{Q}^2$ states are in the S-wave, their decay obeys OZI rule, hence they are S-wave decays. For a 2^+ intermediate state A_i, the transition amplitudes can be written as follows

$$\langle \rho^o_{\lambda_1} \rho^o_{\lambda_2} | T | A_i^\lambda(2^+) \rangle = \frac{m_{A_i} \, a^i_{\rho^o\rho^o}(0^+)}{(8m_{A_i} \omega_{\rho_1} \omega_{\rho_2})^{1/2}} \tag{2}$$

$$\times \sum_{m_1 m_2} C^{2\lambda}_{1m_1 1m_2} \, e^{m_1}_{\mu_1} \, e^{m_2}_{\mu_2} \, \varepsilon^{*\lambda_1 \mu_1}(p_1) \, \varepsilon^{*\lambda_2 \mu_2}(p_2)$$

and

$$\langle A_i^\lambda(2^+) | T | \gamma\gamma \rangle = \frac{m_{A_i} \, b^i(2^+)}{(8m_{A_i} \omega_{\gamma_1} \omega_{\gamma_2})^{1/2}} \sum_{m_1 m_2} C^{2\lambda}_{1m_1 1m_2} \, e^{*m_1}_{\mu_1} \, e^{*m_2}_{\mu_2} \tag{3}$$

$$\times \; \{\varepsilon^{\mu_1}(1) - \frac{k_1^{\mu_1}}{k_1 \cdot k_2} k_2 \cdot \varepsilon(1)\} \{\varepsilon^{\mu_2}(2) - \frac{k_2^{\mu_2}}{k_1 \cdot k_2} k_1 \cdot \varepsilon(2)\}$$

where λ is the helicity of $Q^2\bar{Q}^2$ state $A_i(2^+)$. ω_{ρ_1} and ω_{ρ_2} are the energy of the two ρ mesons respectively. ω_{γ_1} and ω_{γ_2} are the energies of the photons respectively. e^m_μ is a spherical vector. $\varepsilon^{\lambda\mu}(p)$ is the polarization vector of the vector mesons. $\varepsilon(1)$ and $\varepsilon(2)$ are photon's polarization vectors. $a^i_{\rho^o\rho^o}(2^+)$ and $b^i(2^+)$ are dimensionless amplitudes respectively.

For a 0^+ state A_i, the transition amplitude is

$$\langle\rho^o_{\lambda_1}\rho^o_{\lambda_2}|T|A_i(0^+)\rangle = \frac{m_{A_i}\, a^i_{\rho^o\rho^o}(0^+)}{\left(8m_{A_i}\omega_{\gamma_1}\omega_{\gamma_2}\right)^{1/2}}\ \varepsilon^{\lambda_1^*}(p_1)\cdot\varepsilon^{\lambda_2^*}(p_2) \tag{4}$$

and

$$\langle A_i(0^+)|T|\gamma\gamma\rangle = \frac{m_{A_i}\, b^i(0^+)}{\left(8m_{A_i}\omega_{\gamma_1}\omega_{\gamma_2}\right)^{1/2}}\left\{\varepsilon(1)\cdot\varepsilon(2) - \frac{1}{k_1\cdot k_2}\ k_1\cdot\varepsilon(2)\ k_2\cdot\varepsilon(1)\right\} \tag{5}$$

We have taken the center-of-mass frame of two photons in which $\vec{k}_1$ and $\vec{k}_2$ are along the z-axis.

The amplitudes $a^i_{\rho^o\rho^o}(2^+)$ and $a^i_{\rho^o\rho^o}(0^+)$ depend on the flavor representation, and the recoupling coefficients to color-singlet VV. For the six states in table 1, they are

$$
\begin{aligned}
a^{9}_{\rho^o\rho^o}(2^+) &= -\frac{1}{2} \times \left(\frac{2}{3}\right)^{1/2} a \\
a^{36,I=0}_{\rho^o\rho^o}(2^+) &= \frac{1}{2\sqrt{3}} \times \frac{1}{\sqrt{3}} a \\
a^{36,I=2}_{\rho^o\rho^o}(2^+) &= \left(\frac{2}{3}\right)^{1/2} \times \frac{1}{\sqrt{3}} a \\
a^{36^*,I=0}_{\rho^o\rho^o}(0^+) &= \frac{1}{2\sqrt{3}} \times 0.743\ a \\
a^{36^*,I=2}_{\rho^o\rho^o}(0^+) &= \left(\frac{2}{3}\right)^{1/2} \times 0.743\ a \\
a^{9^*}_{\rho^o\rho^o}(0^+) &= -\frac{1}{2} \times 0.644\ a
\end{aligned}
\tag{6}
$$

Because the mass difference between the 0^{++} states and the 2^{++} states are smaller, we take the parameter a to be the same for 0^{++} and 2^{++} states. The first numbers on the right hand side are the coefficients of $\rho^o\rho^o$ in the flavor representation and the second numbers are the recoupling coefficients for color-singlet VV in table 1. a is then defined as the reduced amplitude for the process $A_i \to VV$. We take it to be a parameter.

According to VDM, b^i is related to a^i_{VV} as follows

$$
b^i = \sum_{j,k} \frac{e^2}{f_{v_j} f_{v_k}} a^i_{V_j V_k} \tag{7}
$$

for the corresponding $Q^2\bar{Q}^2$ state A_i. f_{V_i} is the coupling constant of photon and vector meson V_i.

Specifically

$$b^{9}(2^+) = a^{9}_{\rho^o\rho^o}(2^+)\,\frac{\alpha}{4}\left(\frac{4\pi}{\gamma_\rho^2}-\frac{4\pi}{\gamma_\omega^2}\right)$$

$$b^{36,I=0}(2^+) = a^{36,I=0}_{\rho^o\rho^o}(2^+)\,\frac{\alpha}{4}\left(\frac{4\pi}{\gamma_\rho^2}+3\,\frac{4\pi}{\gamma_\omega^2}\right)$$

$$b^{36,I=2}(2^+) = a^{36,I=2}_{\rho^o\rho^o}(2^+)\,\frac{\alpha}{4}\,\frac{4\pi}{\gamma_\rho^2}$$

$$b^{36^*,I=0}(0^+) = a^{36^*,I=0}_{\rho^o\rho^o}(0^+)\,\frac{\alpha}{4}\left(\frac{4\pi}{\gamma_\rho^2}+3\,\frac{4\pi}{\gamma_\omega^2}\right) \tag{8}$$

$$b^{36^*,I=2}(0^+) = a^{36^*,I=2}_{\rho^o\rho^o}(0^+)\,\frac{\alpha}{4}\,\frac{4\pi}{\gamma_\rho^2}$$

$$b^{9*}(0^+) = a^{9*}_{\rho^o\rho^o}(0^+)\,\frac{\alpha}{4}\left(\frac{4\pi}{\gamma_\rho^2}-\frac{4\pi}{\gamma_\omega^2}\right)$$

where

$$\frac{\alpha}{4}\,\frac{4\pi}{\gamma_V^2} = \frac{e^2}{f_V^2}\ . \tag{9}$$

We take [9]

$$\frac{\gamma_\rho^2}{4\pi} = 0.61\ ,\quad \frac{\gamma_\omega^2}{4\pi} = 5.49\ ,\quad \frac{\gamma_\phi^2}{4\pi} = 4.3 \tag{10}$$

By using formulas (1)-(8), and (10) we obtain the differential cross section

$$\frac{d\sigma}{d\cos\theta} = \frac{|\vec{p}_1|}{256\pi W^3} \{ 4[1 + \frac{1}{8m_1^2 m_2^2} (W^2 - m_1^2 - m_2^2)^2] \, |A_{0^+}|^2$$

$$+ \frac{1}{3} |\vec{p}_1|^2 [\frac{1}{m_1^2} + \frac{1}{m_2^2} + \frac{1}{2m_1^2 m_2^2} (W^2 - m_1^2 - m_2^2)] \, (1 - 3\cos^2\theta)$$

$$\times (A_{0^+} A^*_{2^+} + A^*_{0^+} A_{2^+}) + [\frac{7}{3} + |\vec{p}_1|^2 (\frac{1}{m_1^2} + \frac{1}{m_2^2}) (\frac{19}{18} - \frac{5}{6}\cos^2\theta)$$

$$+ \frac{|\vec{p}_1|^4}{m_1^2 m_2^2} (\frac{5}{9} - \frac{4}{3} \cos^2\theta + \cos^4\theta)] \, |A_{2^+}|^2 \} \qquad (11)$$

and the total cross section

$$\sigma = \frac{|\vec{p}_1|}{128\pi W^3} \{ 4[1 + \frac{1}{8m_1^2 m_2^2} (W^2 - m_1^2 - m_2^2)^2] \, |A_{0^+}|^2$$

$$+ \frac{7}{3} [1 + \frac{|\vec{p}_1|^2}{3} (\frac{1}{m_1^2} + \frac{1}{m_2^2}) + \frac{2}{15} \frac{|\vec{p}_1|^4}{m_1^2 m_2^2}] \, |A_{2^+}|^2 \} \qquad (12)$$

where m_1 and m_2 are the masses of the two vector mesons respectively. For the reaction $\gamma\gamma \to \rho^0\rho^0$, we have $m_1 = m_2 = m_\rho$. θ is the angle between the directions of a photon and a ρ-meson. A_{0^+} and A_{2^+} are the amplitudes of 0^+ and 2^+ $Q^2\bar{Q}^2$ states respectively.

$$A_{2^+} = \frac{\alpha}{4} a^2 \left\{ \frac{0.4}{W - 1.65 + \frac{i}{2}\Gamma_{2^+}(9)} + \frac{0.1}{W - 1.65 + \frac{i}{2}\Gamma_{2^+}(36)^{I=0}} + \frac{0.6}{W - 1.65 + \frac{i}{2}\Gamma_{2^+}(36)^{I=2}} \right\}$$

$$A_{0^+} = \frac{\alpha}{4} a^2 \left\{ \frac{0.4}{W - 1.45 + \frac{i}{2}\Gamma_{0^+}(9^*)} + \frac{0.18}{W - 1.8 + \frac{i}{2}\Gamma_{0^+}(36^*)^{I=0}} + \frac{1.9}{W - 1.8 + \frac{i}{2}\Gamma_{0^+}(36^*)^{I=2}} \right\} \tag{13}$$

From table 1 it is known that 2^+ states decay into two vector mesons, and 0^+ states (36^*) decay into two vector mesons predominantly. Therefore, the total widths of those states are readily calculable. By using eqs. (2) and (4) we obtain

$$\Gamma_{2^+}(9) = \frac{|\vec{p}_1| m_{2^+} a^2}{8\pi W} \left\{ 1 + \frac{2|\vec{p}_1|^2}{3m_\rho^2} + \frac{2}{15}\frac{|\vec{p}_1|^4}{m_\rho^4} \right\}$$

$$\Gamma_{2^+}(36)^{I=0} = 0.39\,\Gamma_{2^+}(9) \quad , \quad \Gamma_{2^+}(36)^{I=2} = 0.44\,\Gamma_{2^+}(9) \tag{14}$$

and

$$\Gamma_{0^+}(36^*)^{I=0} = 0.64\,\frac{|\vec{p}_1| m_{0^+} a^2}{8\pi W} \left\{ 2 + \left(\frac{W^2}{2m_\rho^2} - 1 \right)^2 \right\}$$

$$\Gamma_{0^+}(36^*)^{I=2} = 1.156\,\Gamma_{0^+}(36^*)^{I=0} \tag{15}$$

Here the mass difference between ρ and ω are neglected.

The mass of the state $(0^+,9^*)$ is below the threshold of two mesons. Therefore, it cannot decay into two vector mesons. The width of this state is expected to be narrower than those of other states. Therefore we choose $\Gamma_{0^+}(9^*)$ to be 150 MeV to calculate the cross section.

We have chosen $a^2 = 45$ to fit the data [1]. The cross sections are plotted in fig. 2. From fig. 2 it is seen that the contribution of the 0^{++} state are fairly small. The major contribution is from three 2^+ states. If only the three 2^+ states are considered we have

$$\sigma_{W=1.65\ \mathrm{GeV}} = 55\ \mathrm{nb} \tag{16}$$

which is independent of the parameter a^2. This is quite compatible with the experimental data of 77 ± 12 nb [1] at this energy range. The angular distribution defined as an averaged over the photon's total energy

$$f(\theta) = \int_{1.54}^{2.5} dW \, \frac{\frac{d\sigma}{d\cos\theta}}{\sigma} \tag{17}$$

is given in fig. 3. The results are rather insensitive to the parameter a^2. The downward behavior with $\cos\theta$ agrees with the Tasso data [1] except at very small angle, but it seems inconsistent with SPEAR data [2].

We have also calculated the cross section of the process

$$\gamma\gamma \to \rho^+\rho^-$$

The I=0 part of the amplitudes A_{0^+} and A_{2^+} of the $\rho^+\rho^-$ channel is twice of those of the $\rho^o\rho^o$ channel, and both of I=2 the parts of these two channels are the same. The peaks of both of them are at W = 1.6 GeV but because of the reasons mentioned above the cross sections at peak are different. The calculation shows

$$\sigma(\rho^+\rho^-)_{\text{at peak}} = 1.69\ \sigma(\rho^o\rho^o)_{\text{at peak}} \qquad (18)$$

The cross section of the process $\gamma\gamma \to \rho^+\rho^-$ is plotted in fig. 2. The distribution of ρ^+ (or ρ^-) production angle is the same as that of ρ^o in $\gamma\gamma \to \rho^o\rho^o$.

The total widths of the $Q^2\bar{Q}^2$ states which contribute to the process $\gamma\gamma \to \rho\rho$ can be calculated by using formulas (14) and (15), and by considering the corresponding coefficients. The widths decaying into two photons can also be calculated. They are as follows

$$\begin{aligned} \Gamma^i_{0^+} &= \frac{m_{0^+} a^2}{8\pi} \left(\frac{\alpha}{4}\right)^2 b^{i^2}(0^+) \quad , \\ \Gamma^i_{2^+} &= \frac{7m_{2^+} a^2}{240\pi} \left(\frac{\alpha}{4}\right)^2 b^{i^2}(2^+) \quad . \end{aligned} \qquad (19)$$

The subscript i indicates different $Q^2\bar{Q}^2$ states. The numerical results of the widths are listed in table 2.

Similarly we have calculated the cross sections of the processes $\gamma\gamma \to \phi\phi,\ \phi\rho^o,\ \phi\omega,\ \rho^o\omega,\ \omega\omega,\ K^{+*}K^{-*},\ \bar{K}^{o*}K^{o*},\ J/\psi\rho^o,\ D^{+*}D^{-*},\ \bar{D}^{o*}D^{o*}$ The values of these cross sections are shown in table 3. In the calculation of the cross sections of the channels $J/\psi\rho^o$, $D^{+*}D^{-*}$ and $\bar{D}^{o*}D^{o*}$ we have used the results of ref. 10, and we have taken

$$\frac{\gamma_J^2}{4\pi} = 3.12 \tag{20}$$

from e^+e^- annihilation.

In conclusion, we find:

1. The enhancement of the process $\gamma\gamma \to \rho^o\rho^o$ can be understood in terms of the $Q^2\bar{Q}^2$states and VDM. The major contribution is from the 2^{++} states. The three 0^{++} states provide a background. If $\varepsilon(700)$ can be considered as a $Q^2\bar{Q}^2$ state [7] we can use the parameter a^2 to estimate the width of $\varepsilon(700)$. It is about 400 MeV. The angle distribution of the ρ-meson production is quite insensitive to the parameter a^2.

2. The isospins of the $Q^2\bar{Q}^2$ states which contribute to the process $\gamma\gamma \to \rho\rho$ are 0 and 2 respectively. Because of this point we obtain the ratio in eq. (18). It is different from the other models [3,4,5]. When the isospin of the intermediate state is zero, and they predict

$$\sigma\ (\ \rho^+\rho^-\ ) = 4\sigma\ (\ \rho^o\rho^o\ ) \tag{21}$$

Hopefully, these predictions in eqs (18) and (21) can be tested in the future.

3. As shown in table 3 the cross sections of other $\gamma\gamma \to V_1V_2$ are much smaller than $\gamma\gamma \to \rho\rho$. This is due to VDM assumptions and detailed properties of the $Q^2\bar{Q}^2$ states. Especially, the cross sections of channel $K^{o*}\bar{K}^{o*}$ and $D^{o*}\bar{D}^{o*}$ are much smaller than of $K^{+*}K^{-*}$ and $D^{+*}D^{-*}$ respectively. This is because both isospin 0 and 1 are contributing to these processes ($\gamma\gamma \to K^*\bar{K}^*, D^*\bar{D}^*$).

4. As predicted by Jaffe [7], there are some $Q^2\bar{Q}^2$ states whose major decay channels are two vector mesons, and whose masses are a little bit heavier than the sum of two vector mesons masses. They can be found in other processes; for instance, two hadron scattering processes

$$h_1 + h_2 \to (Q^2\bar{Q}^2) + \ldots$$
$$\hookrightarrow V_1 + V_2$$

The data [11,12] of the reaction $\pi^- p \to \phi\phi n$ shows that there is a threshold enhancement between 2.1 and 2.5 GeV in the $\phi\phi$ mass spectrum. In the MIT bag model [7] there is a 2^{++} state whose mass is 2.25 GeV and which only decays into $\phi\phi$.

Another possible process which can be used to search for $Q^2\bar{Q}^2$ states is J/ψ radiative decay. In QCD, this process can be described [13] as

$$J/\psi \to \gamma + \underbrace{g + g}$$
$$\hookrightarrow (Q^2\bar{Q}^2) \to M + M$$

The gluons can directly couple to the color octet vector-color octet vector ($\underline{v}\cdot\underline{v}$) part of the $Q^2\bar{Q}^2$ state. The $Q^2\bar{Q}^2$ states which have bigger $\underline{v}\cdot\underline{v}$ components can be found easily. From the recoupling coefficients it can be seen that 2^{++} states and $0^{++}(\underline{9},\underline{36})$ can be found easier. The 2^{++}states decay into two vector mesons and the $0^{++}(\underline{9},\underline{36})$ states decay into two pseudoscalar mesons. The $\rho\rho$ resonance (2^{++}) can be seen in this process (peak at about 1.65 GeV) and the ratio (21) is also valuable.

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Table 1

The masses and recoupling coefficients of the states which contribute to the process $\gamma\gamma \to \rho\rho$. P and V are color-singlet pseudoscalar and vector $Q\bar{Q}$ mesons, $\underline{P}$ and $\underline{V}$ are color-octet of the same.

SU(3) Multiplet	J^{PC} (I)	Mass (GeV)	PP	VV	$\underline{P}\cdot\underline{P}$	$\underline{V}\cdot\underline{V}$
9^*	0^{++} (0)	1.45	−0.177	0.644	0.623	0.407
36^*	0^{++} (0,2)	1.80	0.041	0.743	−0.646	−0.169
9	2^{++} (0)	1.65		$\sqrt{2/3}$		$-1/\sqrt{3}$
36	2^{++} (0,2)	1.65		$1/\sqrt{3}$		$\sqrt{2/3}$

Table 2

The total widths and the two-photon annihilation widths

State $J^{PC}(I,N)$	$\Gamma_{\gamma\gamma}$ (keV)	Γ (GeV)
$0^{++}(0,9^{*})$	1.9	0.15 (input)
$0^{++}(0,36^{*})$	2.36	2.54
$0^{++}(2,36^{*})$	10.6	2.93
$2^{++}(0,9)$	0.81	0.55
$2^{++}(0,36)$	0.3	0.21
$2^{++}(2,36)$	1.37	0.24

Table 3

Channel	Peak Position (GeV)	σ (nb)$_{\text{at peak}}$
$\phi\phi$	2.25	0.9
$\phi\rho^o$	1.9	9.8
$\phi\omega$	1.9	1.3
$\rho^o\omega$	1.58	3.
$\omega\omega$	1.6	5.7
$K^{+*}K^{-*}$	1.81	1.
$K^{o*}\bar{K}^{o*}$	1.81	0.12
$J/\psi\rho^o$	4.02	15.
$D^{+*}D^{-*}$	4.3	0.06
$D^{o+}\bar{D}^{o*}$	4.06	0.015

Figure Captions

Fig. 1. Diagram for the reaction $\gamma\gamma \to \rho^o\rho^o, \rho^+\rho^-$ with $Q^2\bar{Q}^2$ mesons as the intermediate states

Fig. 2. The cross sections of the reactions $\gamma\gamma \to \rho^o\rho^o, \rho^+\rho^-$ "0^{++}" denotes the cross section which is only from 0^{++} $Q^2\bar{Q}^2$ states.

Fig. 3. The angular distributrion of ρ-meson of the process $\gamma\gamma \to \rho^o\rho^o$.

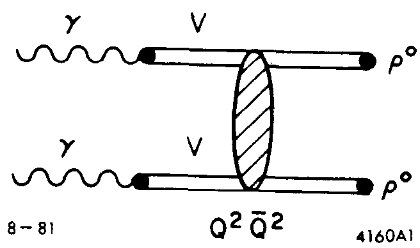

Fig. 1

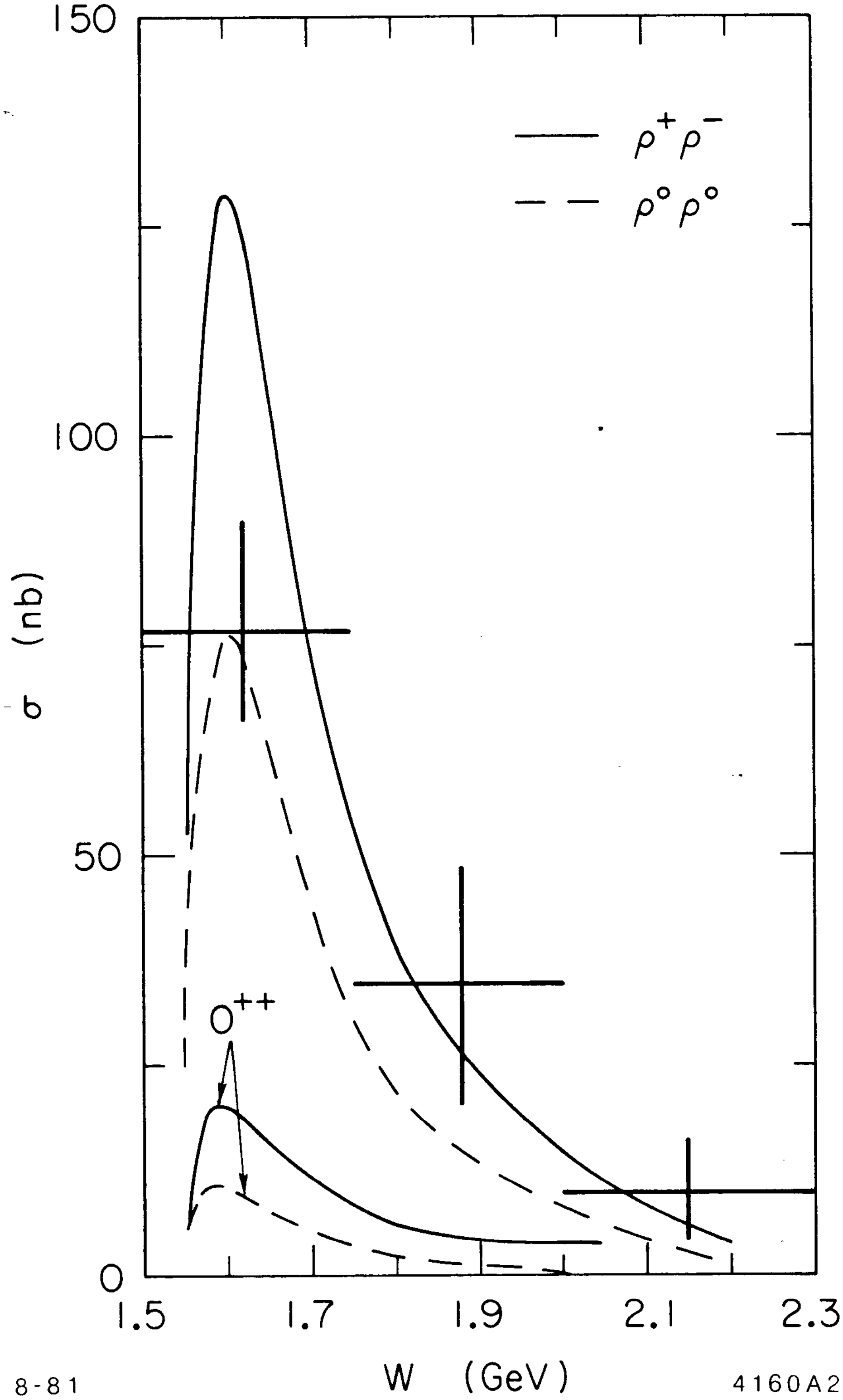
150
100
50
0
σ (nb)
1.5
1.7
1.9
2.1
2.3
W (GeV)
$\rho^+\rho^-$
$\rho^\circ\rho^\circ$
0^{++}
8-81
4160A2

Fig. 2

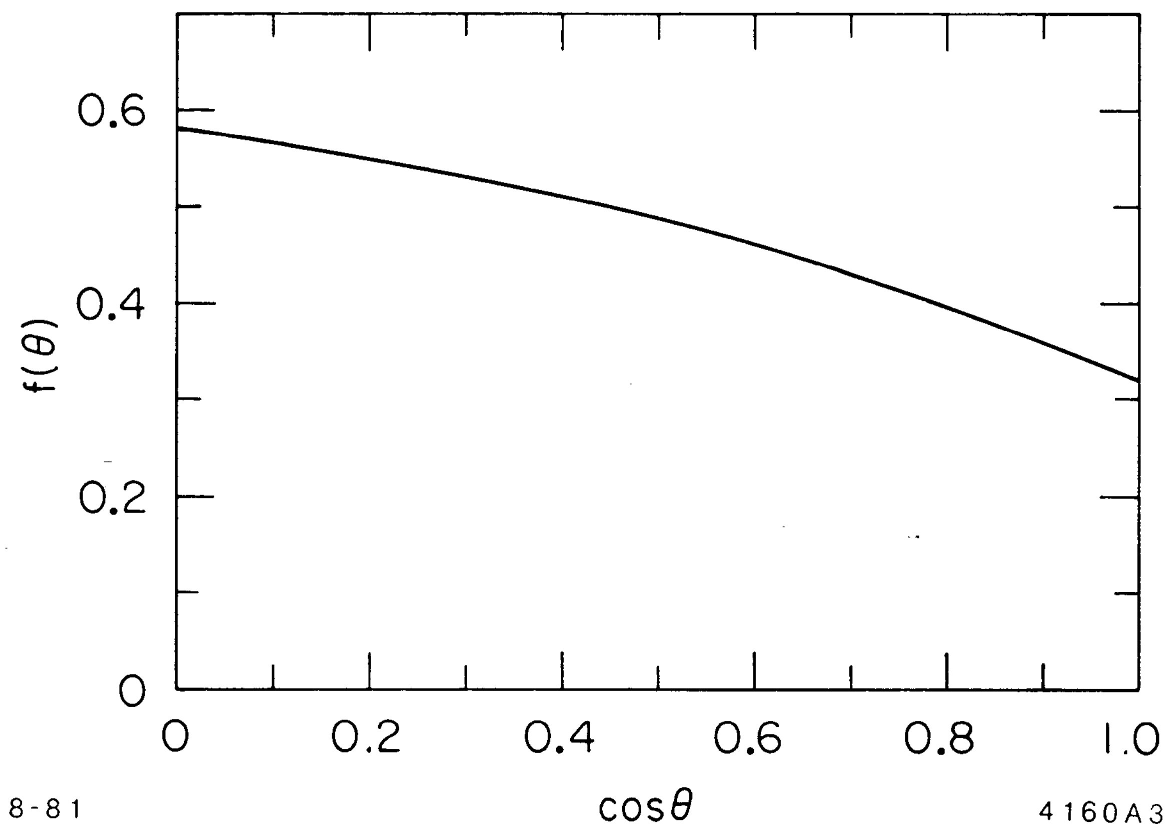

Fig. 3