Estimate of $\sigma(\gamma\gamma \to VV')$ at high energies

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(Received 28 October 1994)

Using the factorization model at high energies the estimate for the $\gamma\gamma \to \rho^0\phi$ reaction cross section is obtained in the $W_{\gamma\gamma}$ energy region from 11.5 to 18.4 GeV: $\sigma(\gamma\gamma \to \rho^0\phi) = 1.2$–$2.4$ nb. A comparison of this estimate with the recent ARGUS data, $\sigma(\gamma\gamma \to \rho^0\phi) = 0.16 \pm 0.16$ nb for $3.25 \leq W_{\gamma\gamma} \leq 3.5$ GeV, shows that between 3.5 and 18.4 GeV the $\gamma\gamma \to \rho^0\phi$ reaction cross section can increase by an order of magnitude. A similar increase would be a real challenge for our current knowledge about the dynamics of quasi-two-body reactions and would also signify that in the reaction $\gamma\gamma \to \rho^0\phi$ at $W_{\gamma\gamma} \approx 3.5$ GeV we encountered a new unknown phenomenon. The cross sections for other VV' final states at high energies, calculated assuming factorization, do not differ so dramatically from what has been measured so far at lower energies.

PACS number(s): 13.60.Le, 13.85.Fb

I. INTRODUCTION

Intense experimental studies of the processes $\gamma\gamma \to VV'$ $[V(V') = \rho, \omega, \phi, K^*]$ began in 1980 with an experiment of the TASSO group [1] in which they found a large cross section for the reaction $\gamma\gamma \to \rho^0\rho^0$ near the $\rho^0\rho^0$ threshold. At present, owing to the outstanding efforts of the TASSO [1–3], Mark II [4], CELLO [5–7], JADE [8,9], PLUTO [10,11], TPC/2γ [12,13], and ARGUS [14–22] groups, investigations of all nine $\gamma\gamma \to VV'$ channels in the low energy region ($W_{\gamma\gamma} = \sqrt{s} < 3$–$3.5$ GeV) have been, in the first approximation, completed. These experiments have revealed a good number of new physical phenomena near the VV' thresholds. For example, a great resonance-type enhancement was observed near the threshold of the reaction $\gamma\gamma \to \rho^0\rho^0$ [1,2,4,5,10,13,14], while the absence of a similar enhancement was established in the $\gamma\gamma \to \rho^+\rho^-$ channel [6,8,15,20]. This fact is in agreement with predictions obtained in the very early 1980s in Refs. [23,24], where the program to search for four-quark states ($q^2\bar{q}^2$) [25] in the reactions $\gamma\gamma \to VV'$ was formulated. While the TASSO data [2] indicate sizable contributions of both $J^P = 0^+$ and $J^P = 2^+$ waves in $\gamma\gamma \to \rho^0\rho^0$ near threshold, the data from the PLUTO [10], TPC/2γ [13], and CELLO [5,26] are consistent with the production of $J^P = 2^+$ states with a small admixture of $J^P = 0^+$. At last, with the high statistics collected by the ARGUS detector, the analysis of the $\gamma\gamma \to \rho^0\rho^0$ enhancement shows a clear dominance of the $J^P = 2^+$ wave [14]. This important fact also agrees well with the predictions of the $q^2\bar{q}^2$ model [23,25–27]. Thus, there are weighty arguments in favor of the formation of an exotic $q^2\bar{q}^2$ resonance (or resonances) with an isospin of $I = 2$ and $I_3 = 0$ in the reactions $\gamma\gamma \to \rho^0\rho^0$ and $\gamma\gamma \to \rho^+\rho^-$ [26–28]. To resolve finally the issue of the existence of such a state, a search for its doubly charged partners, for example, in the reactions $\pi^+p \to \rho^+\rho^+n$, $\pi^-p \to \rho^-\rho^-\Delta^{++}$, $pp \to n(\rho^+\rho^+)n$, and $\bar{p}n \to \rho^-\rho^-\pi^+$, is necessary [29]. Furthermore, the data on the reaction $\gamma\gamma \to \rho^0\omega$ [7,9,16,21,30] cannot be described by known $q\bar{q}$ resonances and agree qualitatively with the predicted, in the $q^2\bar{q}^2$ model, four-quark state with $I = 1$ in the $\rho^0\omega$ channel [23,25,27,31]. For a long time there was actually no consensus on whether the observed enhancement in $\gamma\gamma \to \rho^0\omega$ had specific spin and parity. However, it was recently found that, just like in the $\gamma\gamma \to \rho^0\rho^0$ reaction, $J^P = 2^+$ [21].

Of course, the resonance explanation of some threshold phenomena in $\gamma\gamma \to VV'$, although possible, is considered highly controversial and is not yet well established. Detailed discussions of the whole results on the reactions $\gamma\gamma \to VV'$ at low energies can be found, for example, in Refs. [8,27,30–36].

It is evident that now is an appropriate time to study the reactions $\gamma\gamma \to VV'$ at high energies. More precisely, we keep in mind the $W_{\gamma\gamma}$ energy range from 3.5 to 20 GeV in which the total cross section of $\gamma\gamma \to$hadrons was already measured [37]. In this connection we would like especially to attract the attention of experimentalists to the reaction $\gamma\gamma \to \rho^0\phi$. The first data on the cross section for this reaction were quite recently obtained by the ARGUS group [22]. The measurements covered the $W_{\gamma\gamma}$ interval between 1.5 and 3.5 GeV. An expected significant signal due to the production of tensor $q^2\bar{q}^2$ states near the $\rho^0\phi$ threshold [27] was not found [22]. Nevertheless, the $\gamma\gamma \to \rho^0\phi$ cross section has a broad maximum in the region of the nominal $\rho^0\phi$ threshold and reaches 2–3 nb. For $W_{\gamma\gamma} > 2$ GeV the cross section falls smoothly and turns out to be as low as 0.16 ± 0.16 nb at maximally reached energies $3.25 \leq W_{\gamma\gamma} \leq 3.5$ GeV (see Fig. 1). At high energies the $\gamma\gamma \to \rho^0\phi$ cross section can be estimated through the known cross sections of the processes $\gamma p \to \rho^0 p$, $\gamma p \to \phi p$, and $pp \to pp$, by using the factorization model for the main asymptotical (Pomeron) contributions to the reaction amplitudes. This estimate shows that the cross section for $\gamma\gamma \to \rho^0\phi$ in the $W_{\gamma\gamma}$ energy region between 11.5 and 18.4 GeV can be, by an order of magnitude, larger than the ARGUS data for $3.25 \leq W_{\gamma\gamma} \leq 3.5$ GeV.

As is known, when increasing $\sqrt{s}$ from 3.5 to 11.5 GeV the cross sections of the elastic processes $\pi^\pm p \to \pi^\pm p$,

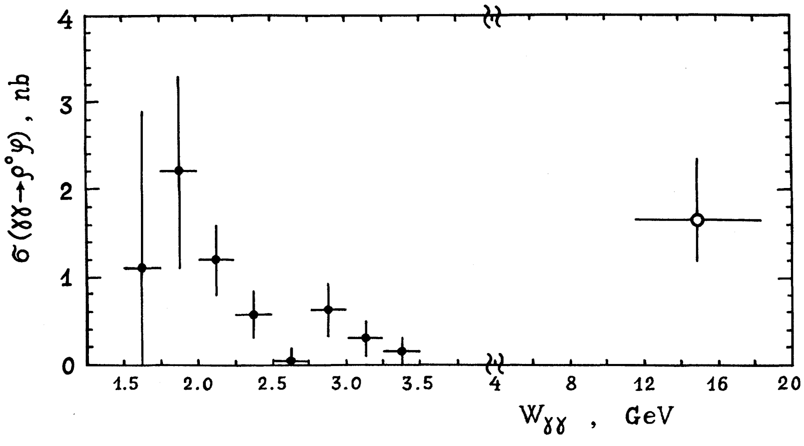

FIG. 1. Cross section for $\gamma\gamma \to \rho^0\phi$: the ARGUS data for $1.5 \le W_{\gamma\gamma} \le 3.5$ GeV [22] (●) and the prediction of the factorization model for the high energy region (○).

$K^\pm p \to K^\pm p$, $pp \to pp$, $\bar{p}p \to \bar{p}p$ [38], and also the reactions $\gamma p \to \rho^0 p$ and $\gamma p \to \omega p$ [39] fall smoothly going to an asymptotic, and only the $\gamma p \to \phi p$ cross section slowly rises in this energy range by approximately a factor of 1.5 [39]. When increasing $\sqrt{s}$ from 11.5 to 18.4 GeV (this corresponds to the variation of $P_{\rm lab}$ for π, K, p, and γ beams from 70 to 180 GeV/c) all the above mentioned cross sections are constant to within the experimental uncertainties [38,39]. Let us note that the reaction $\gamma p \to \phi p$ is dominated by a so-called "pure Pomeron" exchange [40,41]. Indeed, according to the Okubo-Zweig-Iizuka (OZI) rule, there are forbidden both the qqq resonance production at low energies and the ideally mixed f and f' Regge trajectory exchanges at high energies in $\gamma p \to \phi p$ with $\phi = s\bar{s}$. Therefore, in a general qualitative agreement with the dual picture the $\gamma p \to \phi p$ reaction exhibits an asymptotic behavior at lower energies than all other reactions [40–44]. Using the vector meson dominance model [40] and the results [41,42] for the $\phi p \to \phi p$ reaction amplitude, according to which $\sigma_{\rm tot}(\phi p) = \sigma_{\rm tot}(K^+p) + \sigma_{\rm tot}(K^-p) - [\sigma_{\rm tot}(\pi^-p) + \sigma_{\rm tot}(\pi^+p)]/2$ is a linearly rising function of $\ln(s)$ from an incident momentum of 6 to 200 GeV/c, and also the slope of the diffractive peak for the reaction $\gamma p \to \phi p$ from Ref. [43], $B_{\gamma p\to\phi p}(s) = 4.66 + 0.38\ln(s)$, the energy dependence of $\sigma(\gamma p \to \phi p)$ can be found from the relation [40–44]

$$\sigma(\gamma p \to \phi p) = \frac{4\pi\alpha}{f_\phi^2}\,\frac{P_\phi^2}{P_\gamma^2}\,\frac{\sigma_{\rm tot}^2(\phi p)}{B_{\gamma p\to\phi p}}\,\exp(B_{\gamma p\to\phi p}\,t_{\rm min})\,, \tag{1}$$

where f_ϕ is the γ-ϕ coupling constant, and P_ϕ and P_γ are the momenta of the ϕ meson and the incident photon respectively in the c.m. system (c.m.s.). According to Eq. (1), when increasing $P_{\rm lab}$ from 6 to 70 GeV/c (or $\sqrt{s}$ from 3.5 to 11.5 GeV) the $\gamma p \to \phi p$ cross section smoothly rises by approximately a factor 1.7, which agrees with the available data, to within their uncertainties [39,43–46]. It would be quite reasonable if a similar situation could also take place in the reaction $\gamma\gamma \to \rho^0\phi$. However, if the ARGUS data [22] are correct (of course, they have yet to be confirmed by extra measurements), then the factorization model permits one to expect an increase of the $\gamma\gamma \to \rho^0\phi$ reaction cross section by an order of magnitude in the region $3.5 \le W_{\gamma\gamma} \le 18.4$ GeV. Nothing of the kind has yet happened in elastic and quasielastic reactions with the Pomeron exchange and with particles involving light quarks.

In Sec. II, the detailed estimate for the $\gamma\gamma \to \rho^0\phi$ reaction cross section at high energies obtained with the help of the factorization model is presented. In Sec. III, analogous estimates are briefly discussed for other reactions $\gamma\gamma \to VV'$. Our conclusions are summarized in Sec. IV.

II. ESTIMATE OF THE $\gamma\gamma \to \rho^0\phi$ REACTION CROSS SECTION AT HIGH ENERGIES

Let us write the factorization assumption [47,48] for the differential cross section of the reaction $\gamma\gamma \to \rho^0\phi$. The usual approximation in the small t region, $d\sigma/dt = A\exp(Bt)$ [where $A = (d\sigma/dt)_{t=0}$, and B is the slope of the diffractive peak at $t \approx 0$ (see below)], gives

$$\frac{d\sigma(\gamma\gamma \to \rho^0\phi)}{dt} = \frac{[d\sigma(\gamma p \to \rho^0 p)/dt]_{t=0}\,[d\sigma(\gamma p \to \phi p)/dt]_{t=0}}{[d\sigma(pp \to pp)/dt]_{t=0}}\exp(B_{\gamma\gamma\to\rho^0\phi}\,t)\,, \tag{2}$$

$$B_{\gamma\gamma\to\rho^0\phi} = B_{\gamma p\to\rho^0 p} + B_{\gamma p\to\phi p} - B_{pp\to pp}\,. \tag{3}$$

Hence for the integrated cross section we get

$$\sigma(\gamma\gamma \to \rho^0\phi) = 2\frac{[d\sigma(\gamma p \to \rho^0 p)/dt]_{t=0}\,[d\sigma(\gamma p \to \phi p)/dt]_{t=0}}{B_{\gamma\gamma\to\rho^0\phi}\,[d\sigma(pp \to pp)/dt]_{t=0}}\,. \tag{4}$$

The factor 2 in Eq. (4) is explained by existing two identical Pomeron peaks at the forward and backward directions in the reactions $\gamma\gamma \rightarrow VV'$ [where $V(V') = \rho^0, \omega, \phi$], and therefore, for the different vector mesons ($V \neq V'$) in the final state, $\sigma(\gamma\gamma \rightarrow VV') = 2[d\sigma(\gamma\gamma \rightarrow VV')/dt]_{t=0} / B_{\gamma\gamma\rightarrow VV'}$.

For the estimates we use the available data on the reactions $\gamma p \rightarrow \rho^0 p$ [45,49,50], $\gamma p \rightarrow \phi p$ [45,46], and $pp \rightarrow pp$ [42] in the region of $P_{\rm lab}$ from 70 to 180 GeV/c ($11.5 \leq \sqrt{s} \leq 18.4$ GeV). Evidently it is an asymptotical region in which the Pomeron contribution dominates and where differences in the kinematics of the reactions (for example, the differences of $t_{\rm min}$ for $\gamma\gamma \rightarrow \rho^0\phi$ and $\gamma p \rightarrow Vp$) are negligible. At higher $P_{\rm lab}$ the data on the three reactions simultaneously are not available.

The experimental data on the differential cross sections of the processes $\pi^\pm p \rightarrow \pi^\pm p$, $pp \rightarrow pp$, $\gamma p \rightarrow \rho^0 p$, $\gamma p \rightarrow \phi p$, ... in a wide t range ($0 < |t| < 1$ GeV^2, where practically all cross sections concentrate) are parametrized, as a rule, by the quadratic exponential form $d\sigma/dt = A\exp(Bt + Ct^2)$ [39,42,46,49]. We use the results of such parametrization for the reactions $pp \rightarrow pp$, $\gamma p \rightarrow \rho^0 p$, and $\gamma p \rightarrow \phi p$ and also the parametrization of the form $d\sigma/dt = A\exp(Bt)$, which is appropriate in the small t region ($|t| \leq 0.1$ GeV^2). Therefore, the slope $B_{\gamma\gamma\rightarrow\rho^0\phi}$ defined by Eq. (3) applies to $t \approx 0$. As seen from Eqs. (2) and (4), we use this slope for all t. At the same time, it is natural to suppose that the slope of the diffractive cone in $\gamma\gamma \rightarrow \rho^0\phi$ is maximal at $t \approx 0$ and decreases with $|t|$ increasing, as it takes place in other reactions. For example, an observed decrease of the slopes in the reactions $pp \rightarrow pp$, $\gamma p \rightarrow \rho^0 p$, and $\gamma p \rightarrow \phi p$ leads to an increase of the integrated cross sections by 5–10% in comparison with an estimate $\sigma = (d\sigma/dt)_{t=0} / B$ in which the slope at $t \approx 0$ is used. So one can hope that, using Eq. (4) with the slope $B_{\gamma\gamma\rightarrow\rho^0\phi}$ determined at $t \approx 0$, we, at least, do not overestimate $\sigma(\gamma\gamma \rightarrow \rho^0\phi)$.

In Ref. [42], the differential cross section for the reaction $pp \rightarrow pp$ was measured in the range $0.0375 \leq |t| \leq 0.75$ GeV^2 at $P_{\rm lab} = 50$, 70, 100, 140, and 175 GeV/c and the parameters A, B, and C from a fit to the t distributions of the form $d\sigma/dt = A\exp(Bt + Ct^2)$ were obtained. The average values of the parameters for $70 \leq P_{\rm lab} \leq 175$ GeV/c are given in Table I. For the reaction $\gamma p \rightarrow \rho^0 p$ Table I gives the results of the three experiments [49,50,45]. In the first of them [49], the measurement was made in the $P_{\rm lab}$ range from 20 to 70 GeV/c, which adjoins directly to the $P_{\rm lab}$ interval of interest to us, and for $0.06 < |t| < 1$ GeV^2. This is the most detailed experiment at high energies, and below we use the information about slope parameters obtained therein. In the second experiment [50], the ρ^0 photoproduction was studied in the range $75 \leq P_{\rm lab} \leq 148$ GeV/c, and the $(d\sigma/dt)_{t=0}$ and also the parameter B in the small t region ($0.02 \leq |t| \leq 0.1$ GeV^2) were found. The statistical accuracy of this experiment is very high. However, an overall normalization of the cross section has a $\pm 13\%$ uncertainty [50]. In the third experiment [45], the total $\gamma p \rightarrow \rho^0 p$ cross section was only measured in the nine overlapping $P_{\rm lab}$ intervals covering the range from 30 to 180 GeV/c. Within $\pm(5$–$6)\%$ statistical errors, the found cross section is approximately constant with photon energy. Table I gives the value of $\sigma(\gamma p \rightarrow \rho^0 p)$ averaged over the region $68 \leq P_{\rm lab} \leq 180$ GeV/c. In this experiment [45], the cross section for the reaction $\gamma p \rightarrow \phi p$ was also measured at the same values of $P_{\rm lab}$. Here statistical errors are approximately $\pm(10$–$15)\%$. The cross section $\sigma(\gamma p \rightarrow \phi p)$ averaged over the region $68 \leq P_{\rm lab} \leq 180$ GeV/c is shown in Table I, too. Up to now, only an experiment on the reaction $\gamma p \rightarrow \phi p$ exists [46] in which the differential cross section was measured for $P_{\rm lab} > 40$ GeV/c; the studied t range was from 0 to -1 GeV^2. The parameters A, B, and C (see Table I), which were obtained from the fit to the data in this experiment [46], are related to the whole $P_{\rm lab}$ range (35–165 GeV/c). At the same time, the total $\gamma p \rightarrow \phi p$ cross section was determined for the nine smaller intervals of $P_{\rm lab}$. Table I shows the average values of $\sigma(\gamma p \rightarrow \phi p)$ both for the

TABLE I. Results of measurements of the cross sections and of fits of $d\sigma/dt$ to the forms $d\sigma/dt = A\exp(Bt + Ct^2)$ and $d\sigma/dt = A\exp(Bt)$ for the reactions $pp \rightarrow pp$, $\gamma p \rightarrow \rho^0 p$ and $\gamma p \rightarrow \phi p$. Values in parentheses are explained in the text.

			$pp \rightarrow pp$		
Ref.	$P_{\rm lab}$ (GeV/c)	σ (mb)	A (mb/GeV^2)	B (GeV^{-2})	C (GeV^{-4})
[42]	70–175	7.135 ± 0.305	75.35 ± 1.35	10.875 ± 0.150	2.025 ± 0.250
			$\gamma p \rightarrow \rho^0 p$		
Ref.	$P_{\rm lab}$ (GeV/c)	σ (μb)	A (μb/GeV^2)	B (GeV^{-2})	C (GeV^{-4})
[49]	20–70	9.4 ± 0.1	—	9.1 ± 0.1	3.1 ± 0.2
[50]	75–148	—	114.2	9.6 ± 1	—
[45]	68–180	8.95 ± 0.51	—	—	—
			(74.15 ± 4.23)	(9.1)	(3.1)
			(79.13 ± 4.51)	(9.6)	(3.1)
			$\gamma p \rightarrow \phi p$		
[45]	68–180	0.670 ± 0.075	—	—	—
			(4.31 ± 0.48)	(6.8)	(1.2)
[46]	35–165	0.550 ± 0.093	3.11 ± 0.33	6.8 ± 0.8	1.2 ± 1.1
	75–165	0.604 ± 0.109	(3.88 ± 0.70)	(6.8)	(1.2)

whole P_{lab} range and for the P_{lab} region from 75 to 165 GeV/c.

In the cases that the total cross sections for $\gamma p \to \phi p$ and $\gamma p \to \rho^0 p$ are available only, we estimate the values of $A = (d\sigma/dt)_{t=0}$ from the relation

$$A = \left(\frac{d\sigma}{dt}\right)_{t=0} = \sigma\left(\int_0^{1\ \text{GeV}^2} \exp(Bt + Ct^2)dt\right)^{-1},$$

using central values of the parameters B and C found in other experiments. The results are given in Table I in parentheses.

Taking into account nine possible combinations of the data on the reactions $\gamma p \to \rho^0 p$, $\gamma p \to \phi p$, and $pp \to pp$ in the P_{lab} range from 70 to 180 GeV/c from Table I, and using Eqs. (3) and (4), we get for the $W_{\gamma\gamma}$ energy range between 11.5 and 18.4 GeV a cross section

$$\sigma(\gamma\gamma \to \rho^0\phi) \approx 1.18\text{–}2.36 \text{ nb} \qquad (5)$$

and its average value of 1.66 nb (see Fig. 1), which is an order of magnitude larger than the ARGUS data for $3.25 \le W_{\gamma\gamma} \le 3.5$ GeV [22]. A low bound of the estimate (5) is more than the data by 6.4 their standard deviations. This bound can be considered as a lower limit of $\sigma(\gamma\gamma \to \rho^0\phi)$ because using Eqs. (3) and (4) we took care especially lest the cross section be overestimated.

Let us note that an estimate combining the vector meson dominance model with the additive quark model [such as Eq. (1)] gives, at high energies, $\sigma(\gamma\gamma \to \rho^0\phi) \approx$ 4.1–4.5 nb and $\sigma(\gamma\gamma \to \rho^0\phi) \approx$ 2–2.2 nb with the γ-ρ^0 and γ-ϕ coupling constants determined from e^+e^- annihilation [38] and photoproduction on nuclei [39], respectively.

III. FACTORIZATION AND OTHER REACTIONS $\gamma\gamma \to VV'$

In Table II, we present a comparison of the estimates based on the factorization model for the $\gamma\gamma \to \rho^0\rho^0$, $\gamma\gamma \to \rho^0\omega$, $\gamma\gamma \to \omega\omega$, $\gamma\gamma \to \omega\phi$, and $\gamma\gamma \to \phi\phi$ reaction cross sections at high energies ($11.5 < W_{\gamma\gamma} < 18.4$ GeV) with the available data on these reactions at maximally reached energies. In addition to the data on $\gamma p \to \rho^0 p$, $\gamma p \to \phi p$, and $pp \to pp$, we used here the data on $\gamma p \to \omega p$ from three experiments [46,51,52] covering the P_{lab} region from 46 to 225 GeV/c. As seen from Table II, the available experimental results are not yet sufficient to allow definite conclusions from this comparison (owing to large experimental errors and distinctions between the data from the different groups). For example, the PLUTO data on the reaction $\gamma\gamma \to \rho^0\rho^0$ are close to our estimate of $\sigma(\gamma\gamma \to \rho^0\rho^0)$ at high energies, but the TPC/2γ data are not. Let us also note that the cross section of the reaction $\gamma\gamma \to \omega\omega$ at not too high energies is dominated by the one-pion exchange contribution [53]. For example, at $W_{\gamma\gamma} \approx 3$ GeV, this mechanism can provide the $\gamma\gamma \to \omega\omega$ cross section at a level of some nanobarns and is quite competitive with the Pomeron and other natural parity exchanges up to $W_{\gamma\gamma} \approx 10$ GeV.

IV. CONCLUSION

The factorization model is one of the most well-grounded and good working phenomenological models in high energy physics. Therefore, an unusually strong rise of the $\gamma\gamma \to \rho^0\phi$ reaction cross section expected from this model and the ARGUS data would be a real challenge for our current knowledge about the dynamics of quasi-two-body reactions. Why is the cross section $\sigma(\gamma\gamma \to \rho^0\phi)$ so small near 3.5 GeV? Here either we encounter a new physical phenomenon or the ARGUS data [22] have been

TABLE II. Experimental data on the $\gamma\gamma \to VV'$ reaction cross sections at maximal reached energies and estimates derived from the factorization model for the cross sections of these reactions at high energies.

Ref.	Reaction	$(W_{\gamma\gamma})_{\max}$ (GeV)	$\sigma(\gamma\gamma \to VV')$ at $(W_{\gamma\gamma})_{\max}$ (nb)	$\sigma(\gamma\gamma \to VV')$ from factorization at high energies (nb)
PLUTO [10]	$\gamma\gamma \to \rho^0\rho^0$	3.0–3.2	7 ± 2	9.9–21
TPC/2γ [13]		2.8–3.2	1.1 ± 0.9	
JADE [9]		2.4–3.0	0.6 ± 0.6	
TPC/2γ [30]	$\gamma\gamma \to \rho^0\omega$	2.5–2.75	1.3 ± 1.2	1.9–3.8
CELLO [7]		2.5–3.0	0.0 ± 4.2	
ARGUS [16]		2.2–2.5	1.8 ± 1.0	
ARGUS [17]	$\gamma\gamma \to \omega\omega$	2.2–3.0	0.3 ± 1.2	0.1–0.22
ARGUS [18]	$\gamma\gamma \to \omega\phi$	2.3–3.5	< 0.7	0.1–0.28
ARGUS [18]	$\gamma\gamma \to \phi\phi$	2.5–3.4	< 0.8	0.047–0.09

underestimated for some reason.[1] In any case direct measurements of the $\gamma\gamma \to \rho^0\phi$ reaction cross section at high energies and a further study of the $W_{\gamma\gamma}$ energy region around 3.5 GeV are extremely important problems. At present, electron-positron colliders at DESY and at SLAC and also the detector KEDR at the Budker Institute of Nuclear Physics (BINP), CLEO II at the Cornell Electron Storage Ring (CESR), TRISTAN at KEK, and the e^+e^- collider LEP at CERN have considerable opportunity to advance in the region above 3.5 GeV.

[1]In Ref. [54] the factorization model was applied to the reaction $\gamma\gamma \to \rho^0\phi$ in the $W_{\gamma\gamma}$ range of 2–3 GeV and the cross section about 0.4–0.5 nb was predicted. Unfortunately, the authors lost a factor of 2 which is needed in the factorization relation for this reaction [see Eq. (4) and the following discussion]. After such a correction, $\sigma(\gamma\gamma \to \rho^0\phi) \approx 0.8$–1.0 nb, which is essentially larger than the ARGUS measurements. However, this cannot be argued too definitely for the difficulties of extracting a pure Pomeron-exchange contribution from the experimental data on $\gamma p \to \rho^0 p$ and $pp \to pp$ at low energies [55]. At the same time our estimate (5) gives a reliable lower limit for $\sigma(\gamma\gamma \to \rho^0\phi)$ at high energies.

ACKNOWLEDGMENT

This work was supported partly by the Russian Foundation for Fundamental Sciences, Grant No. 94-02-05 188.

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