203: Production of Vector Meson Pairs in Two-Photon Reactions

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Abstract. A summary is given of the present status of experimental results on two–photon production of pairs of vector mesons. The cross sections for production of all low–energy vector pairs were measured with the only exception of $\phi\phi$. The applicability of various phenomenological models is discussed.

1 Introduction

In the last decade, the two-photon production of pairs of vector mesons has been measured for all possible combinations of mesons ρ, ω, ϕ and K^* in the energy region of a few GeV above the thresholds (see ref.[1] and references cited there). The only exception is the combination $\phi\phi$ that has a so far undetectably small cross section. There exist several models [2, 3, 4, 5, 6] that describe various mechanisms for two–photon production of pairs of vector mesons. At this stage it was felt useful to summarize the existing experimental results and compare them to model predictions.

The talk is organized as follows. We first present a summary of measured cross sections that includes recent results on $\gamma\gamma \to K^*\overline{K^*}$ from ARGUS. Next we briefly discuss the partial wave analysis, and conclude with a comparison to existing model predictions.

2 Experimental data

Fig. 1 shows a collection of available results of cross section measurements taken from ARGUS data [7, 8, 9]. The $\gamma\gamma \to K^{*+}K^{*-}$ and $\gamma\gamma \to K^{*0}\overline{K^{*0}}$ cross sections come from a recent analysis [9] that combines several reaction channels leading to the same $K^*\overline{K^*}$ states. The results are in excellent agreement with an older analysis [10] that involved only about $\frac{1}{3}$ of the data.

A feature common to all spectra is the peaking of cross sections at the vicinity of reaction thresholds. It is also seen that $\gamma\gamma \to \rho^0\rho^0$ dominates all other cross sections.

For the understanding of two-photon production of pairs of vector mesons it is important to know the partial wave composition of the cross section. Whenever the number of events was sufficient a partial wave analysis was performed based on the maximum likelihood method (see e.g. [7, 9]). This was the case for $\rho^0\rho^0$, $\rho^+\rho^-$ and $K^{*0}\overline{K^{*0}}$ where the wave $(J^P, J_z) = (2^+, 2)$ was found to dominate the cross section.

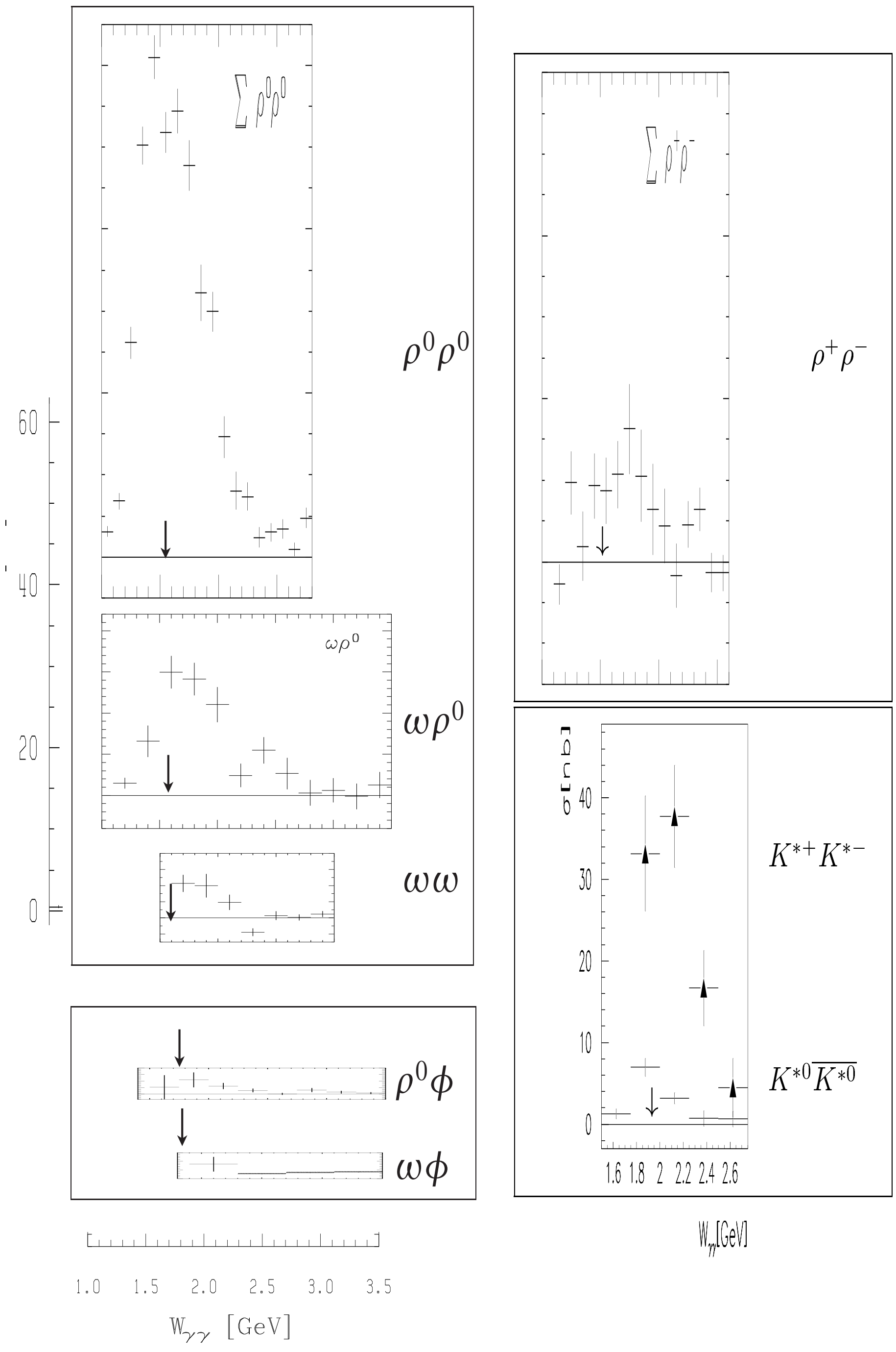

Fig. 1. Collection of all existing cross sections for two–photon production of pairs of vector mesons. Energy and cross section scales are adjusted so that they are equal for all spectra. Arrows indicate reaction thresholds.

We point out two main limitations of the partial wave analysis. Firstly, the final state is assumed to be composed of two isobars (ρ, ϕ, K^*, π, K etc.) and phase space distributed multiparticle states (fig. 2). Secondly, the analysis is usually limited to the partial waves of orbital angular momenta $L = 0, 1, 2$.

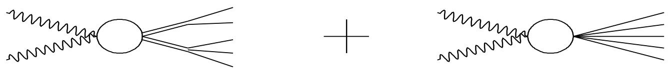

Fig. 2. A schematic drawing representing the isobar model with several particles in the final state. The final state partial waves are treated as being composed of two well defined isobars and phase space distributed parts.

The main origin of systematic errors in the partial wave analysis is a limited knowledge of acceptances for different partial waves. Typically, a relative error in acceptance of 1% may cause an error in cross section of about 10%. Therefore, it is important to have a good knowledge of detector performance. The analysis of the reaction $\gamma\gamma \to \pi^+\pi^-\pi^0$ was used as a test of this kind of systematics. It was found that the $J^P = 2^+$ nature of a_2 was excellently reproduced [11].

3 Interpretation of Experimental Results

Most models for two–photon production of vector meson pairs are based on *vector dominance*. The initial state creation of vector mesons is governed by charge factors for $\rho^0\rho^0 : \rho^0\omega : \omega\omega : \phi\rho^0 : \phi\omega : \phi\phi : \rho^+\rho^- : K^{*+}K^{*-} : K^{*0}\overline{K^{*0}}$ $= 1 : \frac{1}{9} : \frac{1}{81} : \frac{2}{9} : \frac{2}{81} : \frac{4}{81} : 0 : 0 : 0$. They are slightly modified due to flavour SU(3) symmetry breaking. As a first guess, one can see a qualitative tendency of integrated cross sections for neutral nonstrange final states to follow the above ratios, with the exception of processes involving ϕ mesons. On the other hand, there is a significant cross section for production of $\rho^+\rho^-$, $K^{*+}K^{*-}$ and $K^{*0}\overline{K^{*0}}$ that can only proceed through the interaction of initial vector mesons.

A simple VMD approach is to relate e.g. $\gamma\gamma \to \rho^0\rho^0$ to $\rho^0\rho^0$ scattering ($\rho^0\rho^0$ scattering being in turn related to high energy pp scattering). It gives a smooth energy variation of the cross section and cannot account for the enhancement at threshold.

Various Regge exchange mechanisms [3] seem to be able to reproduce to some extent two photon production of $\omega\omega$, $\rho^+\rho^-$, $K^{*0}\overline{K^{*0}}$ and $K^{*+}K^{*-}$ (including $J^P = 2^+$ dominance).

Resonance models like the model of Achasov et al. [2] use the MIT bag model to find two degenerate $qq\bar{q}\bar{q}$ states with $I = 2$ and $I = 0$. In VMD they interfere constructively in $\gamma\gamma \to \rho^0\rho^0$ and destructively in $\gamma\gamma \to \rho^+\rho^-$. The intermediate 2^+ states with OZI superallowed decays to ρ pairs may be long-lived enough to be observable if their mass is close or below the $\rho\rho$ threshold. In addition an $I = 1$ $qq\bar{q}\bar{q}$ state should show up in $\gamma\gamma \to \omega\rho$ and another in $\gamma\gamma \to \rho\phi$ channels. Experimentally there is little evidence for any of the latter two.

Alexander et al. [5] estimate the t-channel exchange contributions in a factorization model by extrapolating from high energies to the threshold region. As input they use experimental cross sections from vector meson production in elastic baryon–baryon scattering, and from vector meson photoproduction on baryons. It is not clear whether this model can be applied to the threshold region. Their results cannot account for the steep rise of the $\gamma\gamma \to \rho^0\rho^0$ cross section at threshold. Also, they are unable to reproduce the experimental data on $\gamma\gamma \to \rho^0\omega$ and $\gamma\gamma \to \omega\omega$.

In the perturbative QCD model of Brodsky et al. [6] the main contribution comes from the formation mechanism. The model reproduces the experimentally observed ratio 8 of integrated cross sections $\gamma\gamma \to K^{*+}K^{*-}$ and $\gamma\gamma \to K^{*0}\overline{K^{*0}}$, but fails to account for the large values of the cross sections.

In summary, the mechanism behind the reactions $\gamma\gamma \to V_1V_2$ is too complex to be understood by a single model. In particular, none of the models can explain satisfactorily the cross sections for $\gamma\gamma \to \rho^0\phi$ and $\gamma\gamma \to \omega\phi$.

The two–photon production of pairs of vector mesons appears to be a combination of several processes. Exceptionally it may happen that one of the processes prevails. Such may be the case with the presumably observed $qq\bar{q}\bar{q}$ states in $\gamma\gamma \to \rho\rho$. It is difficult to see how to prove or disprove the existence of such states. There is some hope that a careful analysis of high statistics experimental data may solve the problem.

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