DO L3 DATA INDICATE THE EXISTENCE OF AN ISOTENSOR MESON?*

I.V. Anikin, O.V. Teryaev

Bogoliubov Laboratory of Theoretical Physics, 141980 Dubna, Russia

B. Pire

CPhT†, École Polytechnique, 91128 Palaiseau, France

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The QCD analysis of the hard exclusive production of $\rho^+\rho^-$ and $\rho^0\rho^0$ mesons in two photon collisions shows that the recent experimental data obtained by the L3 Collaboration at LEP can be understood as a signal for the existence of an exotic isotensor resonance with a mass around 1.5 GeV.

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1. Introduction

Exclusive reactions $\gamma^*\gamma \to A + B$ which may be accessed in e^+e^- collisions have been shown [1] to have a partonic interpretation in the kinematical region of large virtuality of one photon and of small center of mass energy. The scattering amplitude factorizes in a long distance dominated object — the generalized distribution amplitude (GDA) — and a short distance perturbatively calculable scattering matrix. Data on the $\rho^0\rho^0$ and $\rho^+\rho^-$ channels have now been published [2]. Their analysis [3] firstly shows the compatibility of the QCD leading order analysis with experiment down to quite modest values of Q^2, and secondly enables to separate a twist-4 signal which may be interpreted as an isotensor contribution of potential great interest for the hadron spectroscopy.

2. Framework

Photon–photon collisions may create a pair of isovector meson with total isospin 0 or 2. Twist decomposition of meson production separates two quark operators from four quark operators. The $\rho\rho$ state with $I = 0$ can be

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† Unité mixte C7644 du CNRS.

projected on both the two and four quark operators, while the state with $I = 2$ on the four quark operator only. Production of an exotic isotensor meson is thus a good probe of the validity of the twist expansion. This may be contrasted with exotic hybrid meson production (with $J^{\rm PC} = 1^{-+}$) which has a leading twist component [4]. The flavor decomposition of correlators show this explicitly. For instance the vacuum-to-$\rho\rho$ matrix element reads

$$\langle \rho^a \rho^b | \bar{\psi}_{\rm f}(0) \Gamma \psi_g(z) | 0 \rangle = \delta^{ab} I_{fg} \Phi^{I=0} + i \varepsilon^{abc} \tau^c_{fg} \Phi^{I=1} \,, \tag{1}$$

where the quark fields are shown with flavor indices and Γ stands for the corresponding γ-matrix. The isoscalar and isovector GDA's Φ^I in (1) are unknown (see, however, [5] for their structure). The four quark GDA's $\tilde{\Phi}^{I,\,I_z=0}$ can be defined in an analogous way as the two quark GDA's. Hence, the amplitudes for $\rho^0\rho^0$ and $\rho^+\rho^-$ production in photon–photon collisions can be written under the form of the decomposition:

$$\mathcal{A}_{(+,+)} = \mathcal{A}^{I=0,\,I_z=0}_{(+,+)\,2} + \mathcal{A}^{I=0,\,I_z=0}_{(+,+)\,4} + \mathcal{A}^{I=2,\,I_z=0}_{(+,+)\,4} \,, \tag{2}$$

where the subscripts 2 and 4 indicate that the given amplitudes are associated with the two and four quark correlators, respectively. The crucial point is that the amplitudes corresponding to $\rho^+\rho^-$ and $\rho^0\rho^0$ production are not independent:

$$\begin{aligned} \mathcal{A}^{I=0,\,I_z=0}_{(+,+)\,k}(\gamma\gamma^* \to \rho^+\rho^-) &= \mathcal{A}^{I=0,\,I_z=0}_{(+,+)\,k}(\gamma\gamma^* \to \rho^0\rho^0)\,, \qquad \text{for } k = 2,\, 4 \\ \mathcal{A}^{I=2,\,I_z=0}_{(+,+)\,4}(\gamma\gamma^* \to \rho^+\rho^-) &= -\frac{1}{2}\mathcal{A}^{I=2,\,I_z=0}_{(+,+)\,4}(\gamma\gamma^* \to \rho^0\rho^0)\,. \end{aligned} \tag{3}$$

3. Cross sections and fitting procedure

The production cross section $\frac{d\sigma_{ee\to ee\rho^0\rho^0}}{dQ^2 dW^2}$ may be written as:

$$\begin{aligned} &\frac{100\alpha^4}{9} G(S_{ee}, Q^2, W^2)\beta \Bigg(f_0(W) \left[\boldsymbol{S}_2^{I=0,I_3=0} + \frac{\alpha_S(Q^2) M^2_{R^0}}{Q^2} \boldsymbol{S}_4^{I=0,I_3=0} \right]^2 \\ &+ f_2(W) \left[\frac{\alpha_S(Q^2) M^2_{R^2}}{Q^2} \boldsymbol{S}_4^{I=2,I_3=0} \right]^2 \\ &+ f_{02}(W) \left[\boldsymbol{S}_2^{I=0,I_3=0} + \frac{\alpha_S(Q^2) M^2_{R^0}}{Q^2} \boldsymbol{S}_4^{I=0,I_3=0} \right] \frac{\alpha_S(Q^2) M^2_{R^2}}{Q^2} \boldsymbol{S}_4^{I=2,I_3=0} \Bigg), \end{aligned} \tag{4}$$

where $f_i(W)$ stand for the unknown but very interesting W-dependence of the GDAs [6], which we will parameterize with Breit–Wigner forms. The dimension-full structure constants $\boldsymbol{S}_4^{I,I_3=0}$ and $\boldsymbol{S}_2^{I=0,I_3=0}$ are related to the nonperturbative vacuum-to-meson matrix elements and their relative magnitudes measure the importance of different twist components. The function G in (4) is the usual Weizsacker–Williams function. The differential cross section corresponding to $\rho^+\rho^-$ production can be obtained using Eq. (3). The different weights of the twist-2 and twist-4 components then enable to fit the parameters $\boldsymbol{S}_4^{I,I_3=0}$ and $\boldsymbol{S}_2^{I=0,I_3=0}$ and the related functions $f_i(W)$.

We then fit the parameters associated with the different twist contributions; we get for the isoscalar sector a background described as an "effective" resonance with mass and width equal to $M_{R^0} = 1.8\,\mathrm{GeV}$, $\Gamma_{R^0} = 1.00\,\mathrm{GeV}$. To describe data with $0.2 < Q^2 < 0.85\,\mathrm{GeV}^2$ (see Fig. 1) we definitely need an isotensor component which we parameterize with a Breit–Wigner

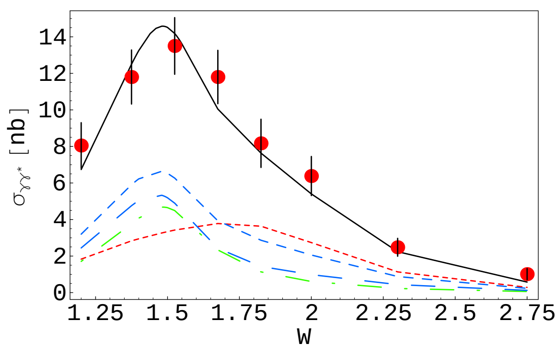

Fig. 1. W-dependence of the cross section $\sigma_{\gamma^*\gamma\to\rho^0\rho^0}$ in the $0.2<Q^2<0.85$ region. The short-dashed (dash-dotted) line corresponds to the twist-2 (twist-4) contribution, the middle-dashed and long-dashed lines to interference terms. Experimental data have been taken from [2].

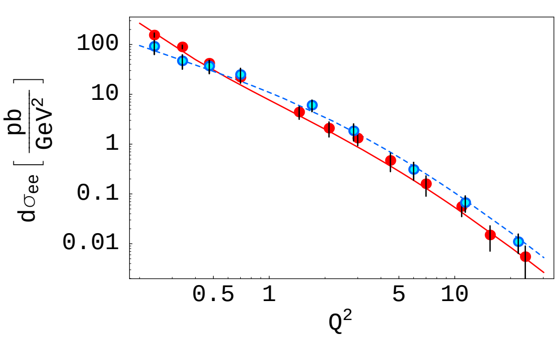

Fig. 2. The Q^2-dependence of the differential cross sections $d\sigma_{ee\to ee\rho^0\rho^0}/dQ^2$ and $d\sigma_{ee\to ee\rho^+\rho^-}/dQ^2$. The solid line corresponds to the case of $\rho^0\rho^0$ production; the dashed line to the case of $\rho^+\rho^-$ production. Experimental data have been taken from [2].

representation of a resonance. The mass and widths of this resonance are then fitted as $M_{R^2} = 1.5\,\mathrm{GeV}$, $\Gamma_{R^2} = 0.4\,\mathrm{GeV}$, while the parameters which measure the relative magnitudes of the amplitudes come out as $\boldsymbol{S}_4^{I=0,I_3=0} \in (0.002,\ 0.006)$ and $\boldsymbol{S}_4^{I=2,I_3=0} \in (0.012,\ 0.018)$, to be compared with $\boldsymbol{S}_2^{I=0,I_3=0} \in (0.12,\ 0.16)$. As seen on Fig. 2, the Q^2-dependence of both $\rho^0\rho^0$ and $\rho^+\rho^-$ production cross sections is then fairly well described on a wide range of values of Q^2. The leading twist amplitude is dominant almost down to $Q^2 = 1\mathrm{GeV}^2$ and the interference of twist-2 and twist-4 amplitudes is needed at lower values.

4. Conclusion

The reaction $\gamma^*\gamma \to \rho\rho$ and its QCD analysis thus proves its efficiency to reveal facts on hadronic physics which would remain quite difficult to explain in a quantitative way otherwise. Other aspects of QCD may be revealed in different kinematical regimes through the same reaction [7]. Its detailed experimental analysis at present intense electron colliders and in a future linear collider is thus extremely promising.

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