Do L3 data indicate the existence of an isotensor meson ? *

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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.

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.

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 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 $J^{PC} = 1^{-+}$) which has a leading twist component [4]. The flavour decomposition of correlators show this explicitly. For instance the vacuum–to–$\rho\rho$ matrix element reads

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

where the quark fields are shown with flavour 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 :

$$\mathcal{A}^{I=0, I_z=0}_{(+,+)\,k}(\gamma\gamma^* \to \rho^+\rho^-) = \mathcal{A}^{I=0, I_z=0}_{(+,+)\,k}(\gamma\gamma^* \to \rho^0\rho^0) \quad \text{for } k = 2,\, 4$$

$$\mathcal{A}^{I=2, I_z=0}_{(+,+)\,4}(\gamma\gamma^* \to \rho^+\rho^-) = -\frac{1}{2}\mathcal{A}^{I=2, I_z=0}_{(+,+)\,4}(\gamma\gamma^* \to \rho^0\rho^0). \tag{3}$$

CROSS SECTIONS AND FITTING PROCEDURE

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

$$\frac{100\alpha^4}{9}G(S_{ee},Q^2,W^2)\beta\left(f_0(W)\left[\mathbf{S}_2^{I=0,I_3=0}+\frac{\alpha_S(Q^2)M_{R^0}^2}{Q^2}\mathbf{S}_4^{I=0,I_3=0}\right]^2\right.$$
$$+f_2(W)\left[\frac{\alpha_S(Q^2)M_{R^2}^2}{Q^2}\mathbf{S}_4^{I=2,I_3=0}\right]^2+ \tag{4}$$
$$\left.f_{02}(W)\left[\mathbf{S}_2^{I=0,I_3=0}+\frac{\alpha_S(Q^2)M_{R^0}^2}{Q^2}\mathbf{S}_4^{I=0,I_3=0}\right]\frac{\alpha_S(Q^2)M_{R^2}^2}{Q^2}\mathbf{S}_4^{I=2,I_3=0}\right),$$

where $f_i(W)$ stand for the unknown but much interesting $W-$dependence of the GDAs [6], which we will parameterize with Breit-Wigner forms. The dimensionful structure constants $\mathbf{S}_4^{I,I_3=0}$ and $\mathbf{S}_2^{I=0,I_3=0}$ are related to the nonperturbative vacuum–to–meson matrix elements and their relative magnitudes measures 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 $\mathbf{S}_4^{I,I_3=0}$ and $\mathbf{S}_2^{I=0,I_3=0}$ 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 $0.2<Q^2<0.85$ GeV^2 (see Fig. 1) we definitely need an isotensor component which we parameterize with a Breit-Wigner 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 $\mathbf{S}_4^{I=0,I_3=0}\in(0.002,0.006)$ and $\mathbf{S}_4^{I=2,I_3=0}\in(0.012,0.018)$, to be compared with $\mathbf{S}_2^{I=0,I_3=0}\in(0.12,0.16)$.
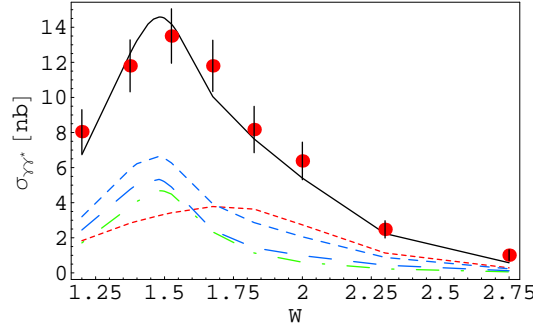

Figure 1: W dependence of the cross section $\sigma_{\gamma^*\gamma\to\rho^0\rho^0}$ in the $0.2<Q^2<0.85$ region. The short-dashed (dash-dotted) line corresponds to the twist 2 (twist 4) contribution, the middle-dashed and long-dashed lines to interference terms. Experimental data have been taken from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

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.

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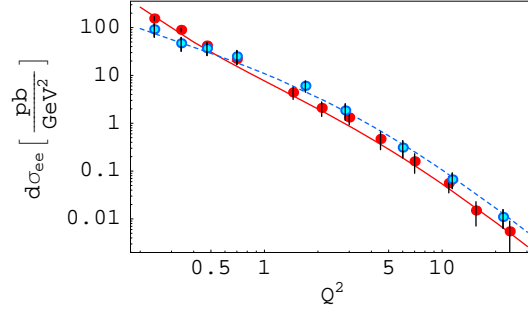
Figure 2: The Q^2 dependence of the differential cross sections $d\sigma_{ee\to ee\rho^0\rho^0}/dQ^2$ and $d\sigma_{ee\to ee\rho^+\rho^-}/dQ^2$. The solid line corresponds to the case of $\rho^0\rho^0$ production; the dashed line to the case of $\rho^+\rho^-$ production. Experimental data have been taken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

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