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

I.V. Anikin\textsuperscript{a}, B. Pire\textsuperscript{b}, O.V. Teryaev\textsuperscript{a}

\textsuperscript{a}Bogoliubov Laboratory of Theoretical Physics, JINR, 141980 Dubna, Russia
\textsuperscript{b}CPHT, École Polytechnique, 91128 Palaiseau Cedex, France

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 \textsuperscript{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 \textsuperscript{2}. Their analysis \textsuperscript{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 \textsuperscript{4}. The flavour decomposition of correlators show this explicitly. For instance the vacuum–to–$\rho\rho$ matrix element reads

$$\langle \rho^a\rho^b|\bar{\psi}_{f}(0)\Gamma \psi_{g}(z)|0\rangle = \delta^{ab} I_{f g} \Phi^{I=0} + i\epsilon^{abc} \tau^c f_{f g} \Phi^{I=1},$$

where the quark fields are shown with flavour indices and $\Gamma$ stands for the corresponding $\gamma$-matrix. The isoscalar and isovector GDA’s $\Phi^I$ in (1) are unknown (see however \textsuperscript{5} for their structure). The four quark GDA’s $\Phi^{I, I_z=0}$ 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:

$$A_{(+,+)} = A_{(+,+)}^{I=0, I_z=0} + A_{(+,+)}^{I=0, I_z=0} + A_{(+,+)}^{I=2, I_z=0},$$

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:

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

$$A_{(+,+)}^{I=2, I_z=0} (\gamma\gamma^* \to \rho^+\rho^-) = -\frac{1}{2} A_{(+,+)}^{I=2, I_z=0} (\gamma\gamma^* \to \rho^0\rho^0).$$

\textsuperscript{*} Presented at Photon2005, Warsaw, by I.V. Anikin.
\textsuperscript{†} Unité mixte 7644 du CNRS
CROSS SECTIONS AND FITTING PROCEDURE

The production cross section \( \frac{d\sigma}{dQ^2} \) may be written as:

\[
\frac{100\alpha^4}{9} G(S, Q^2, W^2) \beta \left( f_0(W) S_i^1 = 0, I_3 = 0 + \frac{\alpha S(Q^2) M_R^2}{Q^2} S_i^1 = 0, I_3 = 0 \right)^2 + f_2(W) \left[ \frac{\alpha S(Q^2) M_R^2}{Q^2} S_i^1 = 0, I_3 = 0 \right]^2 + f_02(W) \left[ S_i^1 = 0, I_3 = 0 + \frac{\alpha S(Q^2) M_R^2}{Q^2} S_i^1 = 0, I_3 = 0 \right]^2 \frac{\alpha S(Q^2) M_R^2}{Q^2} S_i^1 = 0, I_3 = 0, \right)
\]

where \( f_i(W) \) stand for the unknown but much interesting \( W \)-dependence of the GDAs \( S_i^1 \), which we will parameterize with Breit-Wigner forms. The dimensionful structure constants \( S_i^1 \) and \( S_i^1 = 0, I_3 = 0 \) 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 \( S_i^1 \) and \( S_i^1 = 0, I_3 = 0 \) 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 \( M_R = 1.8 \text{ GeV} \), \( \Gamma_R = 1.00 \text{ GeV} \). To describe data with \( 0.2 < Q^2 < 0.85 \text{ GeV}^2 \) (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 \( M_R = 1.5 \text{ GeV} \), \( \Gamma_R = 0.4 \text{ GeV} \), while the parameters which measure the relative magnitudes of the amplitudes come out as \( S_i^1 = 0, I_3 = 0 \in (0.002, 0.006) \) and \( S_i^1 = 2, I_3 = 0 \in (0.012, 0.018) \), to be compared with \( S_i^1 = 0, I_3 = 0 \in (0.12, 0.16) \).

![Figure 1: \( W \) dependence of the cross section \( \sigma_{\gamma^* \gamma \rightarrow \rho \rho} \) 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.](image)

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 \( Q^2 = 1 \text{ GeV}^2 \) and the interference of twist 2 and twist 4 amplitudes is needed at lower values.

CONCLUSION

The reaction \( \gamma^* \gamma \rightarrow \rho \rho \) 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 3. 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 $d\sigma_{ee\to ee\rho^0}/dQ^2$ 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].

We are grateful to N.N. Achasov, A. Donnachie, J. Field, M. Kienzle, N. Kivel, M.V. Polyakov and I. Vorobiev for useful discussions and correspondence. O.V.T. is indebted to Theory Division of CERN and CPHT, École Polytechnique, for warm hospitality. I.V.A. expresses gratitude to Theory Division of CERN and University of Geneva for financial support of his visit. This work has been supported in part by RFFI Grant 03-02-16816.

[5] The $\rho\rho$ GDAs have the same structure as the deuteron GPDs studied in E. R. Berger et al., Phys. Rev. Lett. 87, 142302 (2001).