Elastic ρ meson production at HERA

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Results on elastic electroproduction of ρ mesons are presented for a photon virtuality in the range $1 < Q^2 < 60$ GeV^2 and for a hadronic center of mass energy in the range $30 < W < 140$ GeV. The shape of the $(\pi\pi)$ mass distribution is discussed and measurements of the cross section dependences on Q^2, W and t (the four-momentum transfer squared to the proton) are presented. The full set of ϱ spin density matrix elements is measured, providing information on the ϱ meson and on the photon polarization states. In particular, the ratio R of longitudinal to transverse $\gamma^* p$ cross section is determined.

1. INTRODUCTION

We present results [1] on elastic electroproduction of ϱ mesons: $e + p \to e + p + \varrho$, the ϱ meson decaying into two pions ($\rho \to \pi^+\pi^-$, BR $\simeq 100$ %). The data were collected in 1995 and 1996 by the H1 detector, corresponding respectively to an integrated luminosity of 125 nb^{-1} and 3.87 pb^{-1}. The kinematical range covered in Q^2, W and t is the following: $1 < Q^2 < 60$ GeV^2, $30 < W < 140$ GeV and $|t| < 0.5$ GeV^2. The ϱ meson having the same quantum numbers as the photon ($J^{PC} = 1^{--}$), the $\gamma^* p$ interaction is mediated by the exchange of a colourless object, called the pomeron in the Regge model. It is important to understand the pomeron in terms of partons in the framework of the QCD theory.

2. MODELS

Quantitative predictions in perturbative QCD are possible when a hard scale is present in the interaction. For ϱ meson production, this scale can be given by Q^2 ($Q^2 \gtrsim$ several GeV^2). Most models rely on the fact that, at high energy in the proton rest frame, the photon fluctuates into a $q\bar{q}$ pair a long time before the interaction, and recombines into a ϱ meson a long time after the interaction. The amplitude $\mathcal{M}$ then factorizes in three terms: $\mathcal{M} \propto \psi^{\rho\,*}_{\lambda_\rho}\ T_{\lambda_\rho\lambda_\gamma}\ \psi^{\gamma}_{\lambda_\gamma}$ where $T_{\lambda_\rho\lambda_\gamma}$ are the interaction helicity amplitudes (λ_γ and λ_ρ being the helicities of the photon and the ϱ meson, respectively) and ψ represent the wave functions. In most models, the $q\bar{q}-p$ interaction is described by 2 gluon exchange. The cross section is then proportional to the square of the gluon density in the proton: $\sigma_{\gamma p} \sim \alpha_s^2(Q^2)/Q^6 \cdot \left|xg(x,Q^2)\right|^2$. The main uncertainties of the models come from the choice of the scale, of the gluon distribution parametrization, of the ϱ meson wave function (Fermi motion), and from the neglect of off-diagonal gluon distributions and of higher order corrections.

3. SIGNAL

The shape of the $(\pi\pi)$ mass distribution has been studied as a function of Q^2. The mass distributions are skewed compared to a relativistic Breit-Wigner profile: enhancement is observed in the low mass region and suppression in the high mass side. This effect has been attributed to an interference between the resonant and the non-resonant production of two pions. The skewing of the mass distribution is observed to decrease with Q^2.

4. CROSS SECTIONS

• t dependence: the data present the characteristic exponential falling off of the t distribution $\sigma \propto \exp(-b|t|)$. The b slope parameter, measured

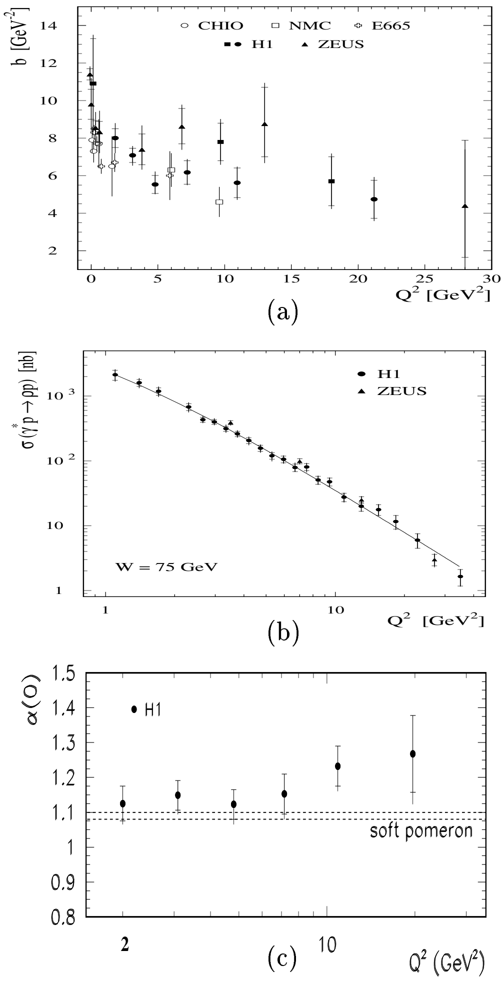

Figure 1. (a) b slope parameter as a function of Q^2; (b) $\sigma(\gamma^* p \to \rho p)$ as a function of Q^2 for W = 75 GeV (full line: see text); (c) the intercept $\alpha(0)$ as a function of Q^2.

for different Q^2 interval, is shown in Fig 1a, confirming the decrease of b when Q^2 increases from photoproduction to the deep-inelastic domain, reflecting the decrease of the transverse size of the virtual photon.

• Q^2 dependence: Fig. 1b presents the Q^2 dependence of the $\sigma(\gamma^* p \to \rho p)$ cross section for W = 75 GeV. The data are well described by the parametrization $(Q^2 + m_\rho^2)^n$, with $n = 2.24 \pm 0.09$ (full line).

• W dependence: the W dependence of $\sigma(\gamma^* p \to \rho p)$ was measured for different Q^2 values, and the parametrization $\sigma \propto W^\delta$ was fitted to the data. In a Regge context, δ can be related to the exchange trajectory [1] and the values of the intercept $\alpha(0)$ are shown in Fig. 1c. The measurements are compared to the values $1.08-1.10$ obtained from fits to the total and elastic hadron–hadron cross sections. They suggest that the intercept of the effective trajectory governing high Q^2 ϱ electroproduction is larger than that describing elastic and total hadronic cross sections. The strong rise of the cross section with W, observed at high Q^2, is in agreement with perturbative QCD prediction $\sigma_{\gamma p} \sim |xg(x,Q^2)|^2$.

5. STUDIES OF HELICITIES

The study of the angular distributions of the production and decay of the ϱ meson gives information on the photon and ϱ polarization states. In the helicity frame, three angles are used: the polar (θ) and azimuthal (φ) angles of the π^+ direction in the ϱ meson center of mass system (cms), and the Φ angle between the electron scattering plane and the ϱ meson production plane, in the hadronic cms. The decay angular distribution $W(\cos\theta, \varphi, \Phi)$ is a function of 15 matrix elements r_{ij}^{α} and $r_{ij}^{\alpha\beta}$, which are related to the helicity amplitudes $T_{\lambda_\rho \lambda_\gamma}$. Figure 2a presents the measurement of the 15 matrix elements (using the "moment method") as a function of Q^2. In case of s-channel helicity conservation (SCHC), the helicity of the vector meson is the same as that of the photon ($T_{\lambda_\rho \lambda_\gamma} = T_{01} = T_{10} = T_{1-1} = T_{-11} = 0$), and 10 of the matrix elements vanish (dotted lines in Figs. 2a and 2b). The measurement of the matrix elements are in agreement which SCHC except for the r_{00}^5 element, which is observed to be significantly different from zero. This element is proportional to the single helicity flip amplitude $T_{\lambda_\rho \lambda_\gamma} = T_{01}$.

Another way to extract the r_{00}^5 matrix element is to study the Φ distribution. Indeed the decay angular distribution $W(\Phi)$ depends on the combination $(2r_{11}^5 + r_{00}^5)$. Figure 2b presents the result of the fits in different Q^2, W and $|t|$ bins. Again, we observe a clear deviation of the r_{00}^5 parameter from the null value expected for SCHC. The ratio of helicity flip to non helicity flip amplitudes is hence estimated to be 8.0 ± 3.0 %.

The ratio of the longitudinal to the transverse cross section, $R = \sigma_L/\sigma_T$, can be extracted using the measurement of the r^{04}_{00} matrix element. R is observed to increase with Q^2, and to reach the value $R = 3 - 4$ for $Q^2 \simeq 20$ GeV^2 (see Fig. 2c). The Q^2 dependence of the ratio R is well described by the perturbative QCD models of Royen and Cudell [2] (full line), and of Martin, Ryskin and Teubner [3] (dashed line) and by the model of Schildknect, Schuler and Surrow [4] (dotted line) based on generalized vector dominance model (GVDM). The following hierarchy between the helicity amplitudes, observed in the data: $|T_{00}| > |T_{11}| > |T_{01}| > |T_{10}|, |T_{1-1}|$, is in agreement with perturbative QCD calculations performed by Ivanov and Kirschner [5].

6. CONCLUSIONS

The elastic electroproduction of ϱ mesons has been studied at HERA with the H1 detector in a wide kinematical domain: $1 < Q^2 < 60$ GeV^2 and $30 < W < 140$ GeV. Measurements of the cross section $\sigma(\gamma^* p \to \rho p)$ show an indication for an increasingly strong energy dependence when Q^2 increases. Full helicity studies have been performed showing a small but significant violation of SCHC. The Q^2 dependence of the ratio $R = \sigma_L/\sigma_T$ was measured and is well described by two models based on perturbative QCD [2,3] and by a model based on GVDM [4].

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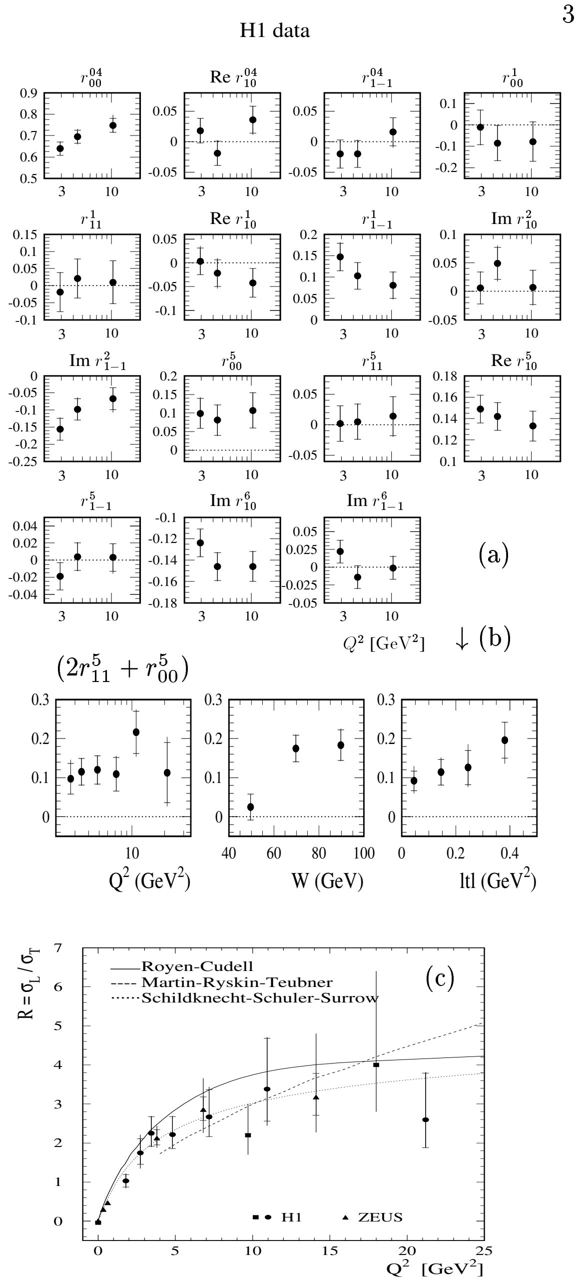

Figure 2. (a) Spin density matrix elements measured for three values of Q^2. (b) Measurements of the combination of matrix elements $2r^5_{11} + r^5_{00}$, as a function of Q^2, W and $|t|$, obtained from fits to the Φ distributions. In both figures, the dashed lines indicate the null values expected in the case of SCHC. (c) The ratio R of the longitudinal to transverse photon cross sections as a function of Q^2. The curves are the predictions of the models (see text).