Diffractive ρ Meson Electroproduction at High Q^2 and High $|t|$

Xavier Janssen [†],
on behalf of the H1 collaboration

Université Libre de Bruxelles, Bd du Triomphe, CP 230,
B-1050 Brussels, Belgium.
e-mail: janssen@hep.iihe.ac.be

The electroproduction of ρ mesons is studied at HERA with the H1 detector at high Q^2 and high $|t|$. Cross sections are measured as a function of Q^2, W and t. The W dependence of the $\gamma^* p$ cross section is observed to increase with Q^2 from values compatible with soft Pomeron exchange at low Q^2 to a hard dependence at large Q^2. Spin density matrix elements are measured and their dependence is compared with a two gluon exchange model.

PACS numbers: PACS numbers come here

1. Introduction

We present results on the diffractive electroproduction of ρ mesons in ep scattering at high energy: $ep \to e\rho Y$, $\rho \to \pi^+\pi^-$, where Y is either a proton ("elastic" scattering) or a baryonic system of mass M_Y much lower than the $\gamma^* p$ center of mass (cms) energy W ("proton dissociative" scattering.)

At low Q^2, the modulus of the intermediate photon four-momentum squared, the $\gamma^* p$ cross section is characterized by a "soft" energy dependence due to pomeron ($I\!P$) exchange with $\mathrm{d}\sigma/\mathrm{d}t \propto W^{4(\alpha_{I\!P}(t)-1)}$, where the soft pomeron trajectory is parametrized [1] as $\alpha_{I\!P}(t) = \alpha_{I\!P}(0) - \alpha' \cdot |t| \simeq 1.08 - 0.25 \cdot |t|$, t being the square of the four-momentum transfer to the proton.

For Q^2 larger than a few GeV^2, perturbative QCD (pQCD) is expected to apply and diffractive ρ production is viewed in the proton rest frame as a sequence of three processes well separated in time : the photon fluctuation into a $q\bar{q}$ pair, the hard interaction of the $q\bar{q}$ pair with the proton via the

[†] The author is supported by the F.R.I.A (Belgium)

exchange of two gluons in a color-singlet state, and the the $q\bar{q}$ pair recombination into a real ρ meson. The cross section is then proportional to the square of the gluon density in the proton, which provides a fast increase of the $\gamma^* p$ cross section with the energy ("hard" behavior) [2].

The data, taken with the H1 detector in 1997 and 2000, correspond to integrated luminosities of 6 pb^{-1} and 42 pb^{-1}, respectively. The 1997 data are dedicated to the study of the "high $|t|$" regime [3] in the kinematic domain $|t| < 3$ GeV^2, $2.5 < Q^2 < 30$ GeV^2 and $40 < W < 120$ GeV. This sample includes both elastic and proton dissociative events. The "high Q^2" regime is investigated using the 2000 data in the kinematic domain $2.5 < Q^2 < 60$ GeV^2, $40 < W < 180$ GeV and $|t| < 0.5$ GeV^2 (elastic channel only).

2. Cross sections

The Q^2 dependence of the $\gamma^* p \to \rho p$ cross section for $W = 95$ GeV is presented in Fig. 1a. A fit of the form $\mathrm{d}\sigma/\mathrm{d}Q^2 \propto 1/(Q^2 + m_\rho^2)^n$ for the range $8 < Q^2 < 60$ GeV^2 results in $n = 2.60 \pm 0.04$ (full line).

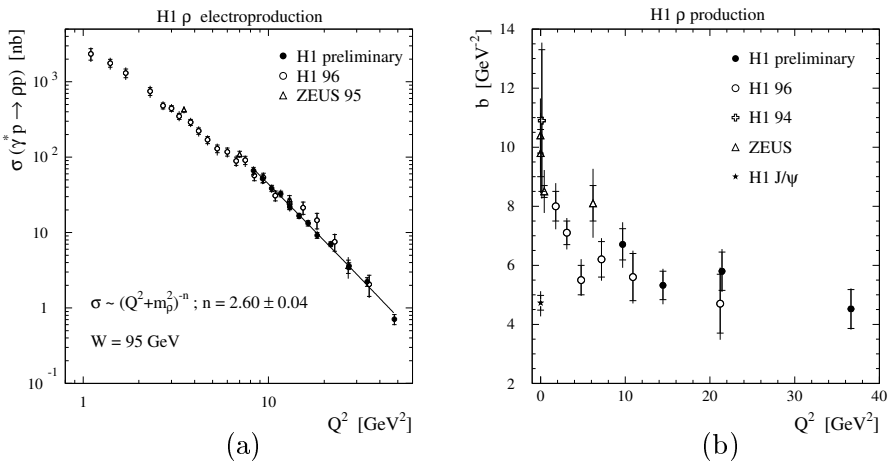

Fig. 1. (a) $\sigma(\gamma^* p \to \rho p)$ as a function of Q^2 for $W = 95$ GeV, together with previous measurements [4, 5]. Full line: see text. (b) Results of fits to exponential distributions of the t dependence of $\sigma(\gamma^* p \to \rho p)$, presented as a function of Q^2 together with previous results from ρ [4, 5, 6] and J/ψ [7] measurements.

The t dependence of the cross section is parametrized as $\mathrm{d}\sigma/\mathrm{d}t \propto exp(-b|t|)$. Measured values of the b parameter are shown as a function of Q^2 in Fig. 1b: b decreases as Q^2 increases, reflecting the decrease of the transverse size of the $q\bar{q}$ pair, down to values close to that of the J/ψ in photoproduction [7].

The W dependence of the $\gamma^* p \to \rho p$ cross section, parametrised as $\sigma(W) \propto W^{\delta}$, has been measured in four Q^2 intervals (Fig. 2). A clear transition from a "soft" to a "hard" behavior is observed when Q^2 increases, reaching values similar to the J/ψ in photoproduction [7], where the charm quark mass acts as a hard scale in pQCD.

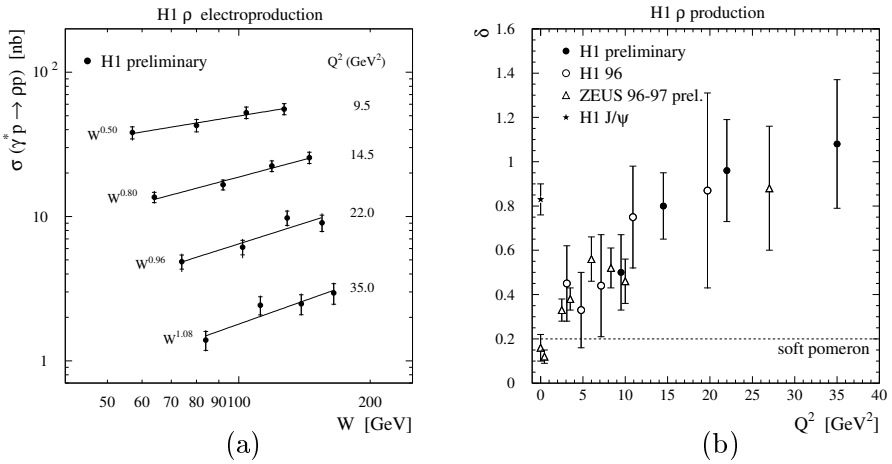

Fig. 2. (a) $\sigma(\gamma^* p \to \rho p)$ as a function of W in four Q^2 intervals. (b) Results of fits of the form W^{δ} to the W dependence of $\sigma(\gamma^* p \to \rho p)$ (full lines in (a)), presented as a function of Q^2 together with previous ρ [4, 8] and J/ψ [7] measurements.

3. Spin density matrix elements

The measurement of the production and decay angular distibutions gives access to the spin density matrix elements, which characterise the helicity states of the photon and the ρ meson, and which are bilinear combinations of the helicity amplitudes $T_{\lambda_\rho \lambda_\gamma}$ [9], where λ_ρ,$\lambda_\gamma = -1, 0, 1$ stand for the helicities of the ρ meson and the photon, respectively. The matrix element r^{04}_{00} and the combinations $r^5_{00} + 2r^5_{11}$ and $r^1_{00} + 2r^1_{11}$ have been measured for the "high $|t|$" and the "high Q^2" data samples.

Assuming s-channel helicity conservation (SCHC), the helicity of the ρ meson and the photon are the same and the combinations $r^5_{00} + 2r^5_{11}$ and $r^1_{00} + 2r^1_{11}$ vanish. Calculations based on pQCD [10, 11] predict SCHC violations with the following qualitative t dependences: a ratio constant with t for the helicity conserving amplitudes (T_{00} and T_{11}), a $\sqrt{|t|}$ dependence for the ratio of the single helicity flip (T_{01} and T_{10}) to the non-flip amplitudes and a linear dependence for the ratio of the double flip (T_{1-1}) to the non-flip amplitudes. The matrix element r^{04}_{00} is related to the ratio of the longitudinal to transverse non-flip amplitudes; the t dependence of the $r^5_{00} + 2r^5_{11}$

combination is dominated by the T_{01} amplitude, and that of the $r^1_{00} + 2r^1_{11}$ combination by $|T_{01}|^2$.

Fig. 3a presents $R = \sigma_L/\sigma_T$ as a function of Q^2, extracted from the measurement of the r^{04}_{00} matrix element. The significant increase of R with Q^2 is compatible with a pQCD based prediction [13], shown as a full line.

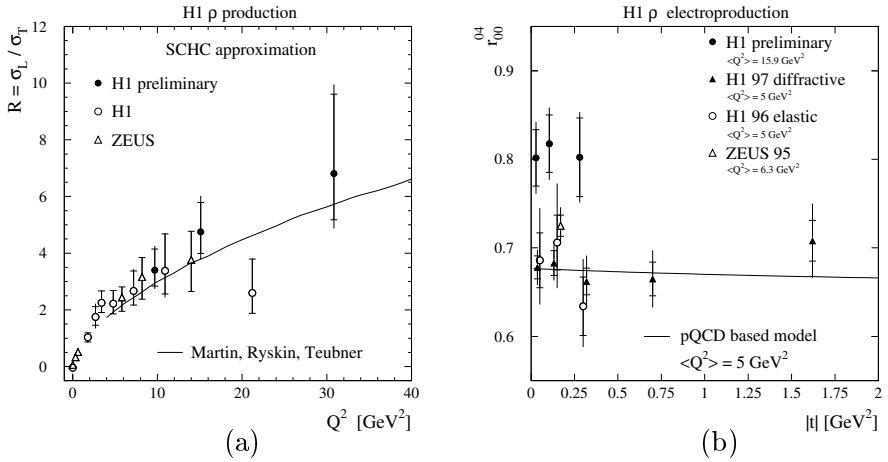

Fig. 3. Measurements of (a) $R = \sigma_L/\sigma_T$ as a function of Q^2, together with previous measuments [4, 6, 5, 12] (b) r^{04}_{00} as a function of $|t|$, together with previous measuments [4, 14] Full lines: see text.

The t dependence of the r^{04}_{00} matrix element and of the combinations $r^5_{00} + 2r^5_{11}$ and $r^1_{00} + 2r^1_{11}$ are presented in Figs. 3b and 4. The expected SCHC violation is confirmed. The "high $|t|$" sample is well described by the prediction based on the model from ref. [10]. The very weak dependence of r^{04}_{00} with $|t|$ indicates that, in the measured range, the longitudinal and the transverse cross sections have similar t dependences.

4. Conclusions

The electroproduction of ρ mesons has been studied at HERA with the H1 detector at high $|t|$ and high Q^2. The W dependence of the $\gamma^* p$ cross section is observed to evolve with Q^2 from a behaviour compatible with soft Pomeron exchange at low Q^2 to a hard dependence at large Q^2. At high Q^2, the W and the t dependences for ρ electroproduction become similar to J/ψ photoproduction. The r^{04}_{00} spin density matrix elements and the combinations $r^5_{00} + 2r^5_{11}$ and $r^1_{00} + 2r^1_{11}$ have been measured as a function of t. No significant t dependence is observed for r^{04}_{00}, and the t dependences of the $r^5_{00} + 2r^5_{11}$ and $r^1_{00} + 2r^1_{11}$ combinations are in agreement with perturbative QCD predictions.

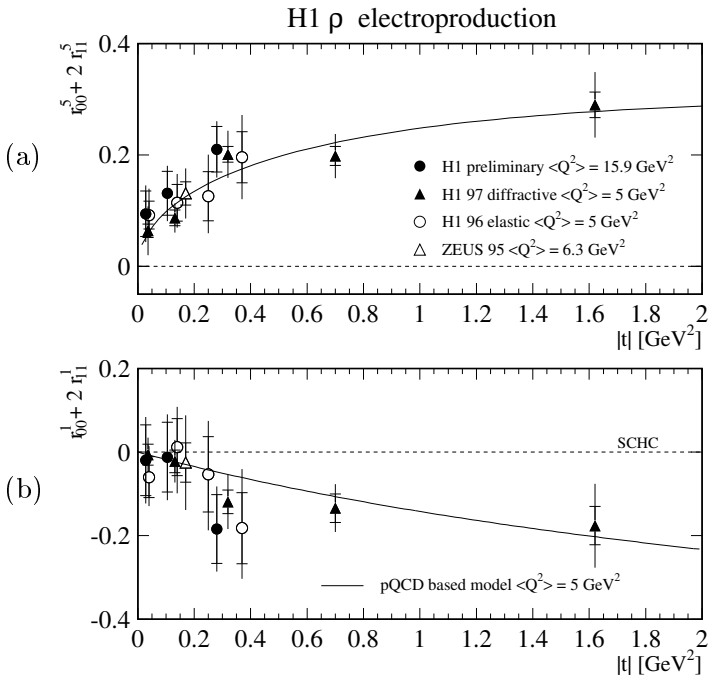

Fig. 4. Measurements of (a) $r^5_{00} + 2r^5_{11}$ and (b) $r^1_{00} + 2r^1_{11}$ as a function of $|t|$, together with previous measuments [4, 14]. Full lines: see text

REFERENCES

[1] A. Donnachie and P.V. Landshoff, Phys. Lett. **B395** (1997) 311.

[2] M.G. Ryskin *et al.*, Z. Phys. **C76** (1997) 231.

[3] C. Adloff *et al.* [H1 Collaboration], accepted by Phys Lett. B [hep-ex/0203022].

[4] C. Adloff *et al.* [H1 Collaboration], Eur. Phys. J. **C13** (2000) 371.

[5] J. Breitweg *et al.* [ZEUS Collaboration], Eur. Phys. J. **C6** (1999) 603.

[6] S. Aid *et al.* [H1 Collaboration], Nucl. Phys. **B463** (1996) 3.

[7] C. Adloff *et al.* [H1 Collaboration], Phys. Lett. **B483** (2000) 23.

[8] ZEUS Collaboration, "Exclusive electroproduction of ρ^0 mesons at HERA", Contrib. pap. 594 to the Eur. Phys. Soc. Conference, Budapest 2001.

[9] K. Schilling and G. Wolff, Nucl. Phys. **B61** (1973) 381.

[10] D.Yu. Ivanov and R. Kirschner, Phys. Rev. **D58** (1998) 114026.

[11] E.V. Kuraev, N.N. Nikolaev and B.G. Zakharov, JETP Lett. **68** (1998) 696.

[12] J. Breitweg *et al.* [ZEUS Collaboration], Eur. Phys. J. **C2** (1998) 247.

[13] A. D. Martin, M. G. Ryskin and T. Teubner, Phys. Rev. **D55** (1997) 4329.

[14] J. Breitweg *et al.* [ZEUS Collaborations], Eur. Phys. J. C **12** (2000) 393.