Diffractive photoproduction of ρ mesons with large momentum transfer at HERA

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Abstract. The diffractive photoproduction of ρ mesons with large momentum transfer, $ep \rightarrow e\rho Y$, is studied at HERA in the kinematic range $Q^2 < 0.01$ GeV^2, $75 < W < 95$ GeV, $1.5 < |t| < 10.0$ GeV^2 and $M_Y < 5$ GeV. The t dependence of the cross section is measured, as well as the spin density matrix elements. All results are compared to BFKL model predictions.

Keywords: H1, DIFFRACTION, PHOTOPRODUCTION, VECTOR MESON, RHO, HELICITY ANGLES, HIGH T
PACS: 14.40.C5

INTRODUCTION

Results are presented on the diffractive photoproduction of ρ mesons at large momentum transfer in high energy ep collisions: $ep \rightarrow e\rho Y$; $\rho \rightarrow \pi^+\pi^-$. The scattered proton is mainly excited into a system Y of mass M_Y, which is much lower than the γp centre of mass (cms) energy W ("proton dissociative" scattering). There is also a small contribution from "proton elastic" scattering where the proton remains intact.

For $|t|$ larger than a few GeV^2, t being the square of the four momentum transferred at the proton vertex, 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 fluctuates into a $q\bar{q}$ pair; the $q\bar{q}$ pair is involved in a hard interaction with the proton via the exchange, at lowest order, of two gluons in a colour singlet state and the $q\bar{q}$ pair recombine to form a bound ρ meson. In the leading logarithm approximation the process is represented by the effective exchange of a gluonic ladder, which, in the low x region of interest, is described by BFKL evolution.

The data are taken with the H1 detector [1] in the year 2000 and correspond to an integrated luminosity of 20.1 pb^{-1}. A selection is performed based on the requirement of two tracks (pion candidates) in the central H1 detector along with an energy deposit in the electron tagger situated 44 m along the beam pipe in the electron direction (electron candidate). The kinematic range is restricted to is $1.5 < |t| < 10.0$ GeV^2, $75 < W < 95$ GeV and $Q^2 < 0.01$ GeV^2, where Q^2 is the modulus squared of the four momentum carried by the intermediate photon, in order to ensure high acceptance over all the distributions studied. The further requirement of no additional energy deposits, not associated to the two decay pions, detected within the liquid argon calorimeter (LAr) limits the dissociative proton system to $M_Y \lesssim 5$ GeV.

THEORETICAL MODEL

The process of interest is described by the non-forward BFKL equation for which a complete analytical solution, in the leading logarithm approximation, is presented by Poludniowski *et al.* in [2, 3]. Their prescription is to factorise the meson production from the hard subprocess using a set of meson wavefunctions expanded on the light-cone. All expansions are performed up to twist-3, i.e. next-to-leading twist, which is the lowest order able to accommodate a non-zero r^{04}_{10} matrix element (see below). The constituent, as opposed to current, quark mass is used to enhance the coupling of the photon to chiral odd $q\bar{q}$ configurations; thereby producing a strong transverse polarisation as supported by previous data [4, 5].

At leading log accuracy there are three free parameters α_s^{IF} (0.21) , α_s^{BFKL} (0.2) and γ (1.0): where α_s^{IF} is the coupling of the two gluons to each impact factor, α_s^{BFKL} is the coupling within the BFKL ladder and γ determines the scale $\Lambda^2 = m_\rho^2 - \gamma t$. The numbers in parenthesis refer to the parameter values chosen to provide the best description of the previous ZEUS measurements [4] and are used to describe the results that follow.

The spin density matrix elements characterise the helicity states of the ρ meson and the photon. They are defined as bilinear combinations of the helicity amplitudes $M_{\lambda_\rho \lambda_\gamma}$, where $\lambda_\rho, \lambda_\gamma = -, 0, +$ represent the respective helicities of the ρ meson and the photon [6]. In the assumption of s-channel helicity conservation (SCHC), whereby the ρ meson retains the helicity of the photon, both the single-flip and double-flip dependent matrix elements are expected to be zero. In contrast, the model of Poludniowski *et al.* predicts violation of SCHC with a hierarchy of helicity amplitudes given by: non-flip (M_{++}) > double-flip (M_{+-}) > single-flip (M_{+0})[1].

The theoretical challenge is to provide a simultaneous description of both the t spectra of the vector mesons and the spin density matrix elements; in particular the largeness of the double-flip dependent matrix element r^{04}_{1-1} and the smallness of the single-flip dependent matrix element r^{04}_{00}.

DEPENDENCE ON t

The t dependence of the $\gamma p \to \rho Y$ cross section is presented in Fig. 1. Both the experimental result and the theoretical prediction are normalised to unity by dividing by their respective integrated cross-section over the range of interest. The dependence is well described by the BFKL model of Poludniowski *et al.* Further, it can be fitted by a power law distribution of the form $d\sigma/dt \propto |t|^{-n}$, where $n = 4.41 \pm 0.07$ (stat.) $^{+0.07}_{-0.05}$ (syst.), over the measured range of t. It should be noted that the dependence is steeper than that observed in [4] as is expected theoretically due to the different M_Y range.

[1] There are also the corresponding amplitudes M_{--}, M_{-+} and M_{-0}, which satisfy $M_{--} = M_{++}$, $M_{+-} = M_{-+}$ and $M_{-0} = M_{+0}$.

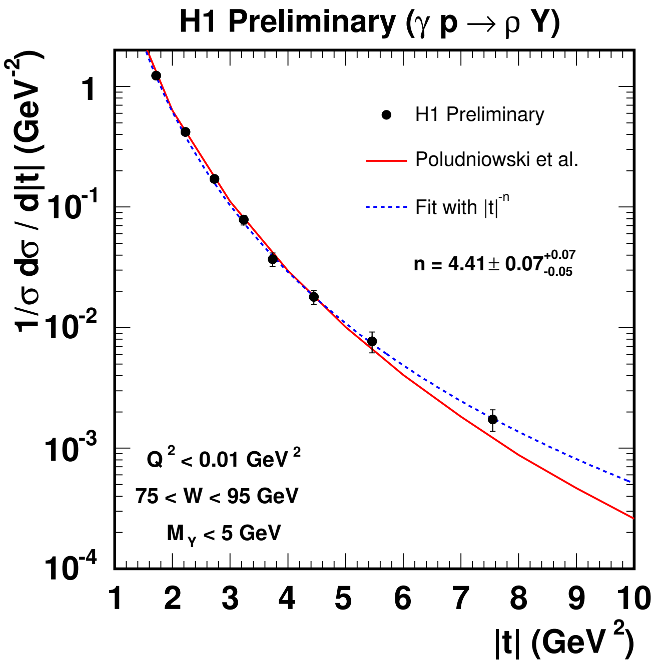

FIGURE 1. The t dependence of the $\gamma p \to \rho Y$ cross section. The inner error bars show the statistical errors, while the outer ones represent the sum of the statistical and non-correlated systematic errors added in quadrature. The dashed line represents a power law fit $|t|^{-n}$, which results in a power $n = 4.41 \pm 0.07\,(\text{stat.})\,^{+0.07}_{-0.05}\,(\text{syst.})$. The full line shows the result from the BFKL model of Poludniowski *et al.*

SPIN DENSITY MATRIX ELEMENTS

The measurement of the production and decay angular distributions provides access to the spin density matrix elements. Here the angles $\cos\theta^*$ and ϕ^* (where θ^* and ϕ^* represent, respectively, the polar and azimuthal angles of the π^+ in the ρ rest frame, the quantisation axis being taken as the direction opposite to that of the scattered photon) are fitted to extract the matrix elements r^{04}_{00} and r^{04}_{1-1} respectively. The fitting procedure is performed separately in three bins of t and the corresponding t dependencies are presented in Fig. 2. Also shown are the results of the ZEUS collaboration [4], with which there is excellent agreement. The single-flip dependent element r^{04}_{00} is consistent with zero indicating that the production is dominated by transversely polarised ρ mesons. The non-zero double-flip dependent matrix element r^{04}_{1-1} confirms the expected SCHC violation. The matrix element r^{04}_{00} agrees well with the BFKL model of Poludniowski *et al.*, while the prediction for r^{04}_{1-1}, although qualitatively able to reproduce the data, is too large at low values of $|t|$.

CONCLUSIONS

The photoproduction of ρ mesons with large momentum transfer has been studied using the H1 detector at HERA. The t dependence of the γp cross sec-

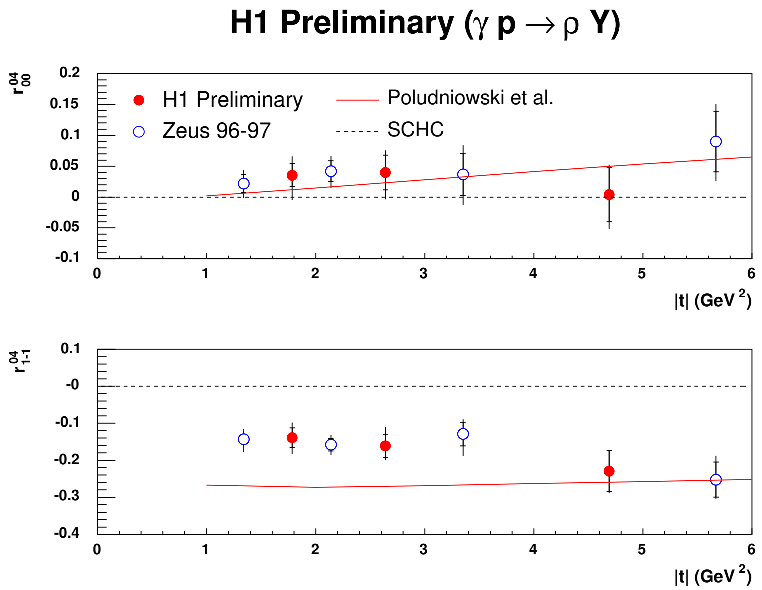

FIGURE 2. Measurements of r^{04}_{00} and r^{04}_{1-1} as a function of $|t|$ (full points) together with the previous measurement [4] (open points). The inner error bars show the statistical errors, while the outer ones represent the sum of the statistical and systematic errors added in quadrature. The full line shows the result from the BFKL model of Poludniowski *et al.*, while the dashed line shows the prediction from SCHC

tion is measured and fitted with a power law of the form $|t|^{-n}$, which results in $n = 4.41 \pm 0.07$ (stat.) $^{+0.07}_{-0.05}$ (syst.). Moreover, it is well described by BFKL model predictions. The spin density matrix elements r^{04}_{00} and r^{04}_{1-1} are measured as a function of t. The r^{04}_{00} matrix element is consistent with zero while the r^{04}_{1-1} matrix element differs significantly from zero and thus confirms violation of SCHC. BFKL model predictions well describe r^{04}_{00} but the prediction for r^{04}_{00}, although qualitatively able to reproduce the data, is too large at low $|t|$.

ACKNOWLEDGMENTS

We would like to thank J. Forshaw and R. Enberg for providing the theoretical model calculations used throughout.

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