DIFFRACTIVE PHOTOPRODUCTION OF ρ MESONS WITH LARGE MOMENTUM TRANSFER AT HERA

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The diffractive photoproduction of ρ mesons with large momentum transfer, $ep \to e\rho Y$, 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 and is well described by a power law, $\mathrm{d}\sigma/\mathrm{d}|t| \propto |t|^{-n}$. The spin density matrix elements are extracted via measurements of angular distributions of the ρ decay products. The data indicate a violation of s-channel helicity conservation, with contributions from both single and double helicity-flip observed. The results are compared to the predictions of perturbative QCD models.

1. Introduction

Results are presented on the diffractive photoproduction of ρ mesons in ep interactions, $ep \to e\rho Y$ ($\rho \to \pi^+\pi^-$), in the case where the negative four momentum transfer squared at the proton vertex, t, is large[1]. Here, the system Y represents either an elastically scattered proton or a low mass dissociated system of mass M_Y, which is much less than the γp centre of mass energy, W.

The data are taken with the H1 detector[2] 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 $1.5 < |t| < 10.0$ 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. 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. The invariant mass of the two-pion system is restricted

to the range $0.6 < M_{\pi\pi} < 1.1$ GeV.

The large momentum transfer provides the hard scale necessary for the application of perturbative QCD (pQCD) models. Here the results are compared to two theoretical predictions: a fixed order calculation in which the hard interaction is approximated by the exchange of two gluons [3,4] and a LL calculation in which it is described according to the BFKL evolution [4].

2. Dependence on $|t|$

The t dependence of the $ep \to e\rho Y$ 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. Over the measured t range, the data are well described by a power-law dependence of the form $\mathrm{d}\sigma/\mathrm{d}|t| \propto |t|^{-n}$ (dashed line), which results in $n = 4.26 \pm 0.06$ (stat.) $^{+0.06}_{-0.04}$ (syst.). The data in Fig. 1 are compared with the predictions of the two-gluon model both with fixed (dotted line) and running (dashed-dotted line) α_s and with those of the BFKL model (solid line)[4]. The BFKL model provides a reasonable description of the t dependence, in contrast to both the two-gluon model predictions.

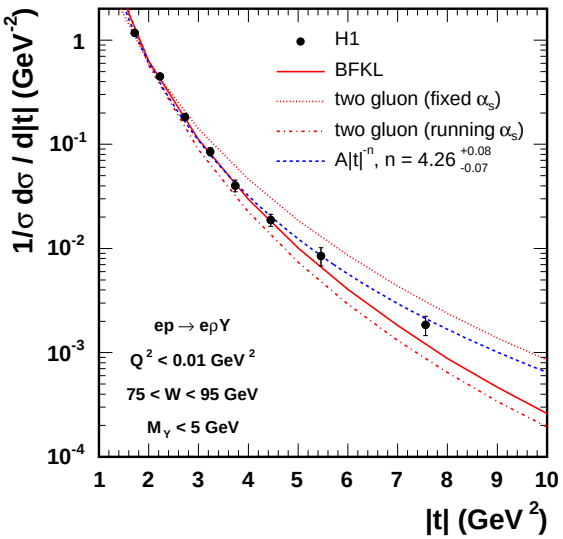

Figure 1. The t dependence of the $ep \to e\rho Y$ cross section. The inner error bars show the dominating statistical errors and the outer error bars show the sum of the statistical and systematic errors added in quadrature. The lines show the results of the power-law fit and the various pQCD models described in the text.

3. Spin Density Matrix Elements

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[5]. Here, the matrix elements r^{04}_{00}, Re $\left[r^{04}_{10}\right]$ and r^{04}_{1-1} are extracted via a two-dimensional fit to the decay angular distributions $\cos\theta^*$ 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). Under the assumption of s-channel helicity conservation (SCHC), whereby the ρ meson retains the helicity of the photon, all three spin density matrix elements are expected to be zero. The fitting procedure is performed separately in three bins of t and the resulting t dependencies are presented in Fig. 2. The results of the ZEUS Collaboration[6] are also shown and there is a reasonable agreement between the two experiments.

The small values of r^{04}_{00} indicate that the probability of producing a longitudinally polarised ρ meson from a transversely polarised photon is low. The non-zero values of Re $\left[r^{04}_{10}\right]$ confirm that, although small, a single-flip contribution is present. The production of transversely polarised ρ mesons must, therefore, dominate and the finite negative values of r^{04}_{1-1} show clear evidence for a helicity double-flip contribution. Both these observations indicate a violation of the SCHC hypothesis (dashed lines).

The two-gluon model predictions[4] (dotted lines) are unable to describe the measured spin density matrix elements. In particular, the model predicts too high values of r^{04}_{00}, i.e. too high probabilities for producing longitudinally polarised ρ mesons. For the BFKL predictions[4] (solid lines), r^{04}_{00} is well described but the prediction for r^{04}_{1-1} is too negative and the wrong sign for Re $\left[r^{04}_{10}\right]$ is predicted. The inability to describe the Re $\left[r^{04}_{10}\right]$ matrix element is the major obstacle for the BFKL model.

4. Summary

The diffractive photoproduction of ρ mesons with large momentum transfer has been studied using the H1 detector at HERA. The t dependence of the cross section is measured and fitted with a power law of the form $|t|^{-n}$, which fits the data well and results in $n = 4.26 \pm 0.06$ (stat.) $^{+0.06}_{-0.04}$ (syst.). It is reasonably described by a BFKL-based model while two-gluon predictions, with both fixed and running α_s, fail to describe the data. The accessible spin density matrix elements are measured as a function of t. The

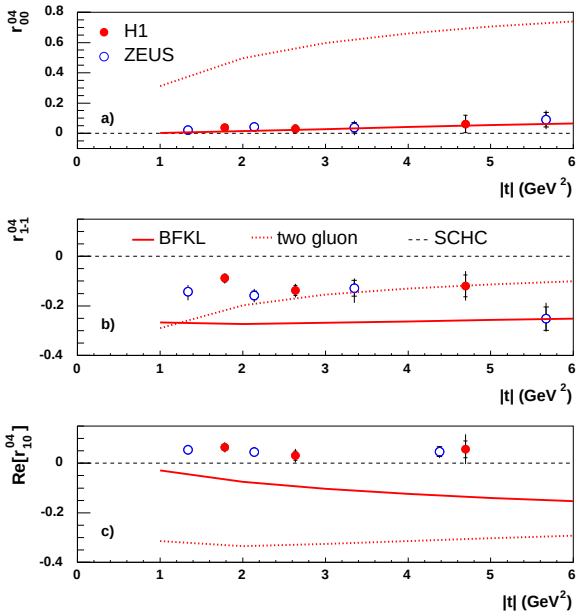

Figure 2. The spin density matrix elements a) r^{04}_{00}, b) r^{04}_{1-1} and c) Re $[r^{04}_{10}]$ for ρ meson photoproduction as a function of $|t|$ (full points) together with ZEUS measurements[6] (open points). The inner error bars show the statistical errors and the outer error bars show the sum of the statistical and systematic errors added in quadrature. The lines show the results of the pQCD models described in the text.

r^{04}_{1-1} and Re $[r^{04}_{10}]$ matrix elements differ significantly from zero, confirming the violation of s-channel helicity conservation (SCHC), with contributions from both single and double helicity-flip observed. Although, unlike the two-gluon models, the BFKL model is able to describe a predominantly longitudinal ρ meson production, both models considered here fail to adequately describe the full set of spin density matrix elements.

References

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