HIGH $|t|$ DIFFRACTIVE PHOTOPRODUCTION OF VECTOR MESONS AND PHOTONS AT HERA

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Diffractive vector meson photoproduction measurements from H1 and ZEUS are presented in which the magnitude of the four-momentum transfer squared $|t|$ at the proton vertex is large. H1 has also studied the process $\gamma p \rightarrow \gamma Y$ in which the outgoing photon has transverse momentum $p_{t(\gamma)} > 2$ GeV and there is a large rapidity gap between the proton dissociation system Y and the outgoing photon. In both cases, the large transverse momentum transfer ensures that perturbative QCD can be applied. The results are compared to predictions from perturbative QCD models based on the leading logarithmic approximation of the BFKL evolution equation.

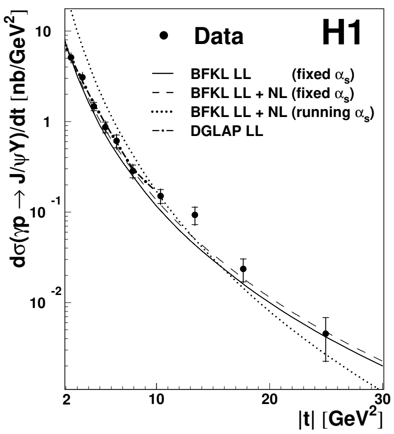

Figure 1. The photon-proton differential cross section $d\sigma/dt$ for J/ψ production in the kinematic range $Q^2 < 1$ GeV^2, $50 < W < 150$ GeV and $|t| > 2$ GeV^2 from the H1 collaboration. The results are compared to a BFKL model and to a DGLAP model for $|t| < m^2_{J/\psi}$.

1 Introduction

We present results on the diffractive photoproduction of vector mesons in ep scattering at high energy and large magnitude of the four-momentum transfer squared $|t|$ at the proton vertex: $\gamma p \rightarrow VY$, where V is a vector meson (ρ or J/ψ) and Y is a hadronic system of mass M_Y, where M_Y is much lower than the $\gamma^* p$ centre of mass energy W. For high $|t|$, perturbative QCD (pQCD) is expected to apply and diffractive vector meson 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 exchange of color singlet state, and the $q\bar{q}$ pair recombination into a real vector meson. The color singlet is realised in lowest order QCD by the exchange of a pair of gluons with opposite color. In the leading logarithmic (LL) approximation, the diffractive interaction can be described by the effective exchange of a gluonic ladder. At high $|t|$, the gluon ladder is expected to include contributions from BFKL evolution, where DGLAP evolution is expected to fail.

The process $\gamma p \rightarrow \gamma Y$, where the final state photon has a high transverse momentum $p_{t(\gamma)}$ and there is a large rapidity gap between the system Y and the outgoing photon, also provides a clean channel in which to search for evidence of BFKL evolution. As the experimental measurements can be performed in an extended pseudorapidity (η) range compared with high $|t|$ vector meson production, a larger range in $\hat{s}$, the centre of mass energy of the hard subprocess, is reached (the separation in pseudorapidity between the struck parton and the outgoing photon is $\Delta\eta \simeq log(\hat{s}/p^2_{t(\gamma)})$), the LL BFKL

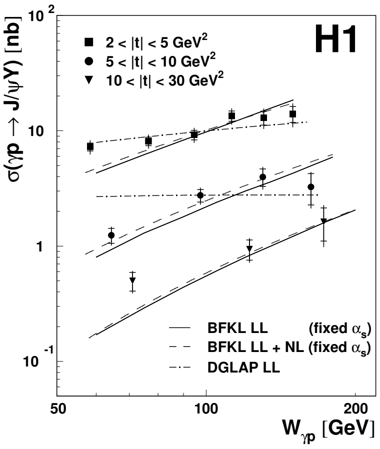

Figure 2. The photon-proton cross section dσ/dW in three bins of $|t|$ for J/ψ pproduction from the H1 collaboration. The results are compared to a BFKL model and to a DGLAP model.

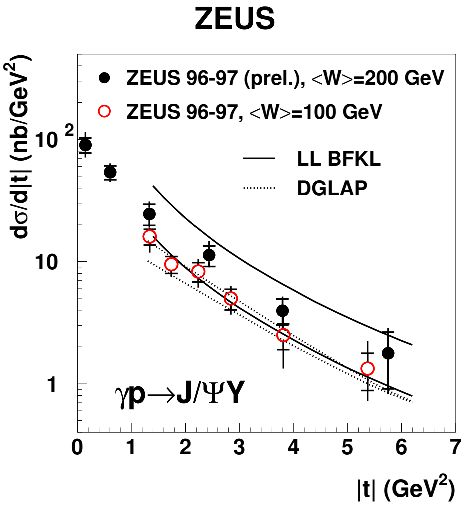

Figure 3. The differential cross-section dσ/dt for diffractive J/ψ photoproduction at $W \simeq 200$ GeV (full circles) and at $W \simeq 100$ GeV (open circles) as measured by the ZEUS experiment. The solid lines represent the results of the BFKL calculations and the dashed ones the results of the DGLAP calculations at both energies.

approximation being only valid in the large $\hat{s}$ limit. Furthermore, the theoretical uncertainties associated with the meson wavefunction, which is not completely calculable in pQCD, are avoided in that case.

2 Diffractive Vector Meson Photoproduction at Large $|t|$

The differential cross section dσ/dt for the diffractive photoproduction of J/ψ measured by H1[1], based on data collected in 1999 and 2000 and corresponding to an integrated luminosity of 78 pb^{-1}, is shown as a function of $|t|$ in figure 1. The covered kinematic range is $Q^2 < 1$ GeV^2, $50 < W < 150$ GeV and $|t| > 2$ GeV^2, where Q^2 is the virtuality of the exchanged photon. The results are compared to a BFKL model[2] and a DGLAP model[3]: the solid line shows the prediction from the BFKL calculation in the leading logarithmic approximation for fixed α_s, the dashed (dotted) curve corresponds to the BFKL calculation including an estimation of non-leading (NL) corrections and using a fixed (running) α_s, and the dashed-dotted curve shows the calculation based on the DGLAP equation in the leading logarithmic approximation. The t dependence and normalization of the data are well described by the LL BFKL approximation when α_s is fixed to 0.18, according to a fit performed to various vector meson proton data at HERA in a smaller $|t|$ range[4]. The inclusion of NL corrections with fixed α_s leads to a small difference respecting to LL, but with a running α_s the prediction is unable to describe the data. The DGLAP model reproduces the data well in shape and normalisation in its range of validity ($|t| < m^2_{J/\psi}$).

In figure 2, the cross section $\sigma_{\gamma p \to J/\psi Y}$ is presented as a function of W for three ranges of t. A Regge-like fit to the form dσ/dt $\propto$ W$^{4(\alpha(t)-1)}$, with the parametrisation $\alpha(t) = \alpha(0) + \alpha' t$, yields a slope of $\alpha' = -0.0135 \pm 0.0074(\text{stat.}) \pm 0.0051(\text{syst.})$ GeV^{-2} and an intercept of $\alpha(0) = 1.167 \pm 0.048(\text{stat.}) \pm 0.024(\text{syst.})$, i.e. a steep rise with energy compared to hadron-hadron interactions. The value of the slope parameter α' is lower than that observed in J/ψ photoproduction[5] at low $|t|$ and the value of

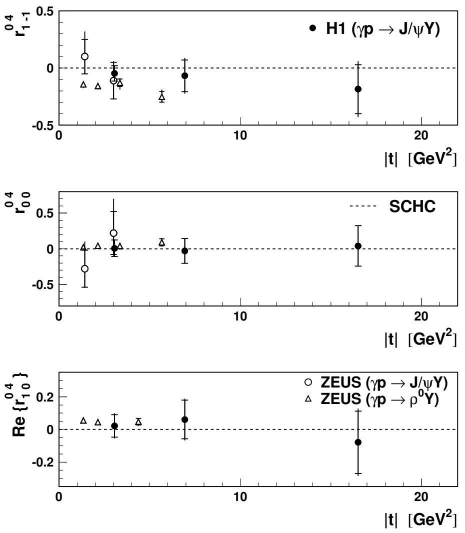

Figure 4. The three spin density matrix elements a) r^{04}_{1-1}, b) r^{04}_{00} and c) Re$\{r^{04}_{10}\}$ for J/ψ and ρ diffractive photoproduction as a function of $|t|$ as measured by the H1 and ZEUS collaborations. The dashed line shown the expectation from SCHC.

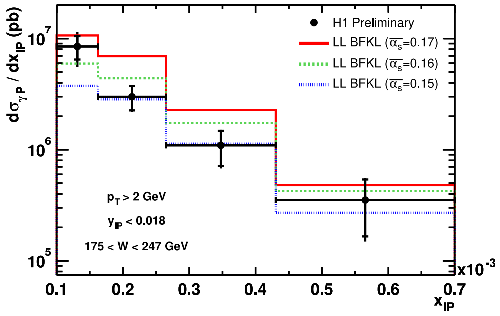

Figure 5. The differential cross section $\gamma p \to \gamma p$ in $x_{I\!P}$ as measured by the H1 experiment. The results are compared with predictions of the leading logarithmic approximation of BFKL for three values of the strong coupling α_s.

$\alpha' = 0.26 \pm 0.02$ GeV^{-2} obtained at low $|t|$ in hadron-hadron scattering. The data are well described by the BFKL theoretical predictions for the LL approximation (solid curve) and the LL+NL predictions with fixed α_s (dashed curve). The DGLAP LL model describes the energy dependence in the lowest $|t|$ range but the description becomes worse in the region $5 < |t| < 10$ GeV^2, where $|t|$ approaches $m^2_{J/\psi}$.

The ZEUS collaboration has studied diffractive photoproduction of J/ψ mesons in two W ranges[6,7], namely $80 < W < 180$ GeV and $185 < W < 245$ GeV, for $Q^2 < 0.02$ GeV^2 and up to a value of 7 GeV^2 in $|t|$. The high W sample allows to access very low values of x Bjorken where the BFKL dynamic is relevant. The data were collected in 1996 and 1997 and correponds to an integrated luminosity of 36 pb^{-1}. Figure 3 shows the obtained differential cross section dσ/dt together with predictions from the DGLAP and BFKL models in the LL approximation. The BFKL LL prediction (solid curves), which was tuned to the low W ZEUS data for ρ, ϕ and J/ψ photoproduction[6], reproduces well the shape of the t distribution at the two different values of W, but overestimates the magnitude of its rise with W. On the other hand, the DGLAP LL calculations (dashed curves) clearly underestimate the observed rise of the cross section with energy.

The measurement of the production and decay angular distribution provides access to the spin density matrix elements (SDME), which characterise the helicity states of the photon and the vector meson. The matrix elements r^{04}_{1-1}, r^{04}_{00} and Re$\{r^{04}_{10}\}$ have been measured by the H1 collaboration for diffractive J/ψ photoproduction[1] and by the ZEUS collaboration for diffractive ρ, ϕ and J/ψ photoproduction[6]. The results are shown in figure 4 as a function of $|t|$ for the ρ and J/ψ mesons. In contrast to the ρ meson, the measured SDME of the J/ψ meson are compatible with zero, within experimental errors, and thus compatible with the s-channel helicity conservation (SCHC) hypothesis, i.e. that the helicity of the vector meson and the photon are the same. The J/ψ results are therefore consistent with the longitudinal momen-

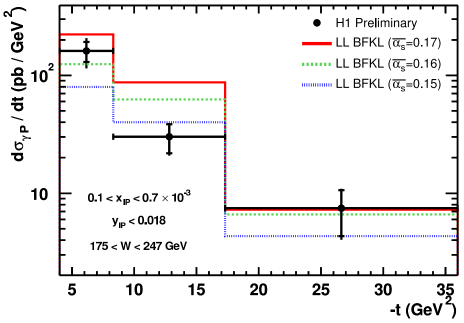

Figure 6. The differential cross section $\gamma p \to \gamma p$ in t as measured by the H1 experiment. The results are compared with predictions of the leading logarithmic approximation of BFKL for three values of the strong coupling α_s.

tum of the photon being shared symmetrically between the two heavy quarks. Hence, the approximation made in the pQCD models for the J/ψ wavefunction is satisfactory for the present data.

3 Diffractive Photoproduction of High-p_t Photons

The diffractive photoproduction of photons with high transverse momentum $p_{t(\gamma)}$ has been studied by the H1 collaboration[8]. The analysis is based on data collected during the 1999-2000 running period and corresponding to an integrated luminosity of 47.6 pb^{-1}. The measurement is performed in the kinematic range $Q^2 < 0.01$ GeV^2, $174 < W < 247$ GeV, $p_{t,\gamma} > 2$ GeV and $y_{I\!P} < 0.018$, where $y_{I\!P} = p.(q-X)/q.p$ with p, q and X being the 4-vectors of the incoming proton and photon and of the scattered photon respectively. As $y_{I\!P} \simeq e^{-\Delta\eta}$, this last cut ensures that there is a large rapidity gap between the outgoing photon and the proton dissociative system.

Figure 5 shows the differential γp cross section with respect to $x_{I\!P}$, the fraction of the proton's momentum carried by the diffractive exchange. The data are compared to a calculation based on the leading logarithmic approximation of the BFKL evolution equation[9] for values of α_s between 0.15 and 0.17. The basic features of the cross section are described by the model but, within the errors, it is difficult to distinguish between the three choices of α_s. The same conclusions may be drawn from the measured differential γp cross section with respect to t, which is shown in figure 6.

4 Summary

The diffractive photoproduction of vector mesons at high $|t|$ has been studied in ep collisions at HERA with the H1 and ZEUS detectors. A steep energy dependence is observed in J/ψ photoproduction at large $|t|$. The leading logarithmic BFKL model describes both the W and the t dependences. Measurements of the t dependence of spin density matrix elements of the J/ψ agree with s-channel helicity conservation. The results from the diffractive photoproduction of high p_t photons from H1 are also found to be in reasonable agreement with the predictions of the leading logarithmic approximation of BFKL.

References

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