MEASUREMENTS OF DVCS AND HIGH |t| VECTOR MESON PRODUCTION AT HERA

D.P. BROWN

ON BEHALF OF THE H1 AND ZEUS COLLABORATIONS

DESY, Notkestr. 85, D-22607 HAMBURG. GERMANY.

Measurements of Deeply Virtual Compton Scattering (DVCS) are presented using data collected by the H1 and ZEUS experiments at HERA. The transition from a virtual photon to an on-shell particle is expected to necessitate the use of skewed parton distributions for a theoretical description. The results are compared to theoretical predictions. Diffractive vector meson production measurements from H1 and ZEUS are also presented in which the magnitude of the four-momentum transfer squared $|t|$ at the proton vertex is large. A large $|t|$ is expected to make it possible to perform a perturbative calculation. The results are compared to recent theoretical predictions performed within the framework of perturbative QCD.

1 Introduction

Measurements of the diffractive production of a photon and of the diffractive production of vector mesons cover a wide kinematic region at HERA. In perturbative QCD (pQCD) diffractive interactions can be modelled in the proton rest frame in which the incoming photon is assumed to fluctuate into a quark-antiquark pair before interacting with the proton. The interaction of the pair with the proton is via the exchange of a colour-singlet system. The detailed internal dynamical structure of the system is studied in Deeply Virtual Compton Scattering (DVCS) and in diffractive meson production processes in which the four-momentum transfer squared $|t|$ at the proton vertex is large. DVCS measurements are expected to offer a particularly suitable channel for studying the behaviour of skewed parton distributions. The theoretical uncertainties associated with the meson wavefunction which is not completely calculable in pQCD are also avoided. Due to the experimentally clean signatures diffractive meson production processes at large $|t|$ have been proposed as ideal testing grounds for the dynamics of BFKL evolution.[1,2]

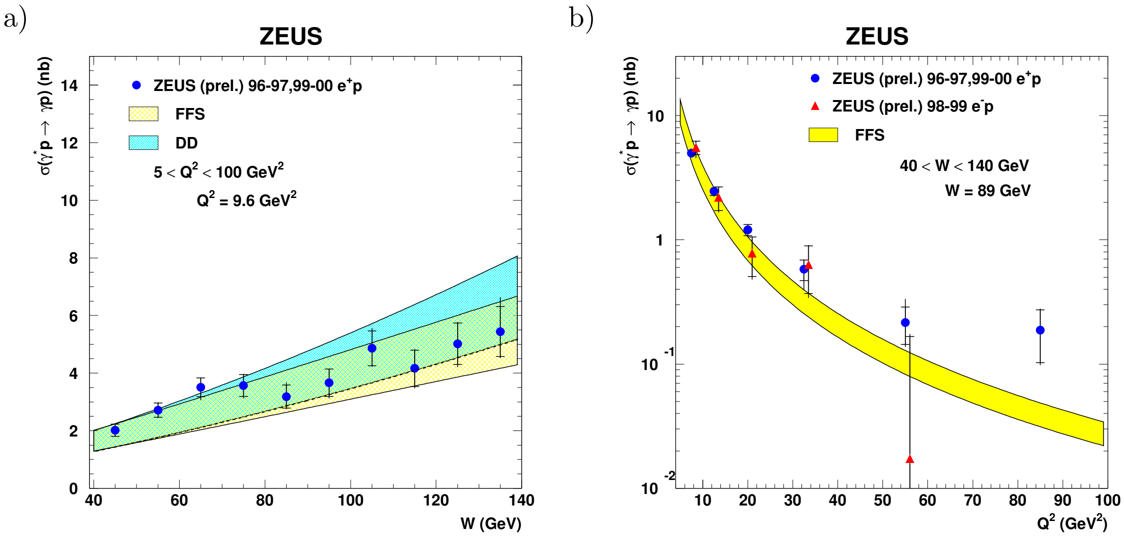

Figure 1: The DVCS cross section $\sigma(\gamma^* p \rightarrow \gamma p)$ as a function of a) the photon-proton centre-of-mass energy $W_{\gamma p}$ and b) the incoming photon virtuality Q^2. The measurements are compared to DVCS models. The bands show the variations in the assumed $|t|$ dependence.

2 Deeply Virtual Compton Scattering Measurements

To enhance the ratio of selected DVCS events to Bethe-Heitler events, which have the same experimental signature ($ep \rightarrow e\gamma p$), the outgoing photon is selected in the forward, or outgoing proton, region.[3] Large values of the incoming photon virtuality Q^2 are selected by detecting the scattered electron in the main detectors. The outgoing proton escapes down the beam-pipe in the forward direction. The remaining Bethe-Heitler contribution is subtracted using a theoretical calculation.

The cross section[4] for Deeply Virtual Compton Scattering $\sigma(\gamma^* p \rightarrow \gamma p)$ extracted from positron-proton data is shown in figure 1a) as a function of the initial photon-proton centre-of-mass energy $W_{\gamma p}$. The measurement covers the kinematic region $40 < W_{\gamma p} < 140$ GeV and $5 < Q^2 < 100$ GeV^2. A fit of the form $\sigma \sim W_{\gamma p}^{\delta}$ gives a similar steep rise $\delta = 0.78 \pm 0.10$ as measured for elastic J/ψ photoproduction.[5,6] The data are compared to theoretical predictions.[7,8] Both models include soft and hard contributions and in both cases the bands show variations in the assumed $|t|$ dependence. Both models give a good description of the data. In figure 1b) the cross section is shown as a function of the incoming photon virtuality Q^2. The e^+ and e^- analyses, both shown in the figure, are based on integrated luminosities of 95 pb^{-1} and 17 pb^{-1} respectively. A fit of the form $(Q^2)^{-n}$ yields an exponent $n = 1.47 \pm 0.07$. The data are compared to the one of the models [8], extrapolated under the assumption of a Q^2 independent $|t|$-dependence. The data lie above the prediction at large values of Q^2.

3 Diffractive Vector Meson Production Measurements at Large |t|

The mesons are selected via their decays into two-prong decay signatures. The four-momentum transfer squared $|t|$ at the proton vertex is reconstructed using the meson decay products. At large values of the $|t|$, the proton dissociates and the products typically leave energy deposits in the forward detectors. The differential cross section $d\sigma/dt$ for the diffractive photoproduction of the J/ψ is shown as a function of $|t|$ extending to very large $|t| < 21$ GeV^2 in figure 2a).[9]

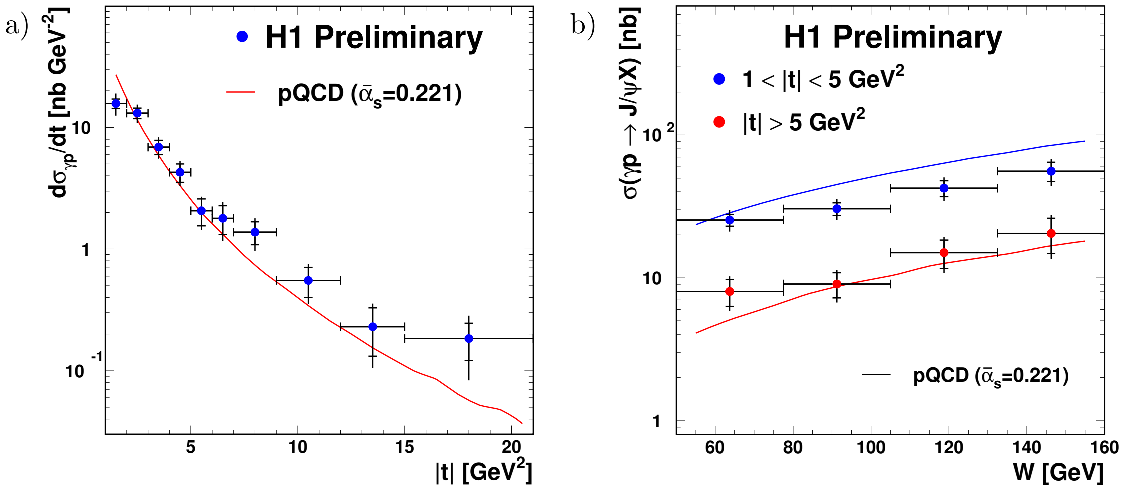

Figure 2: The photon-proton differential cross-section a) $d\sigma/d|t|$ as a function of $|t|$ and b) $\sigma(\gamma p \to J/\psi X)$ as a function of $W_{\gamma p}$ for two different intervals of $|t|$ for J/ψ production with proton dissociation in the kinematic range $Q^2 < 1.0$ GeV^2, $50 < W_{\gamma p} < 160$ GeV, $|t| > 1.0$ GeV^2. The results are compared to a BFKL model.

In figure 2b) the total cross section $\sigma(\gamma p \to J/\psi Y)$ is also presented as a function of $W_{\gamma p}$ in two $|t|$ regions. Fits of the form $\sigma \sim W_{\gamma p}^{\delta}$ yield a similar steep rise ($\delta \sim 1$) as for elastic J/ψ photoproduction at smaller values of $|t|$.[5,6] The data are compared to a pQCD prediction which uses BFKL evolution and a simple non-relativistic treatment of the meson wavefunction.[1,2] The model gives a reasonable simultaneous description of the $W_{\gamma p}$ and $|t|$ distributions, when the parameter $\bar{\alpha}_s$, treated as a free parameter in this model, is chosen to be about $\bar{\alpha}_s = 0.2$.

The measured differential cross section $d\sigma/dt$ for the proton dissociative production of the ρ and the ϕ meson are shown in figure 3a) and b) respectively for the kinematic region $80 < W_{\gamma p} < 120$ GeV, $Q^2 < 0.02$ GeV^2, based on an integrated luminosity of 25 pb^{-1}. The dependence at large $|t|$ is approximately power-like $|t|^{-n}$ with an exponent $n \sim 3$ for both the ρ and the ϕ.[10] The $|t|$ dependence of the ρ and the ϕ are fitted simultaneously [11] together with J/ψ data at low values of $|t|$ to the BFKL model [1,2] and a good description is obtained.

4 Electroproduction Measurements at High $|t|$

In electroproduction the normalised production and angular decay distribution in the $\gamma^* p$ centre-of-mass system is a function of fifteen linear combinations of the spin density matrix elements.

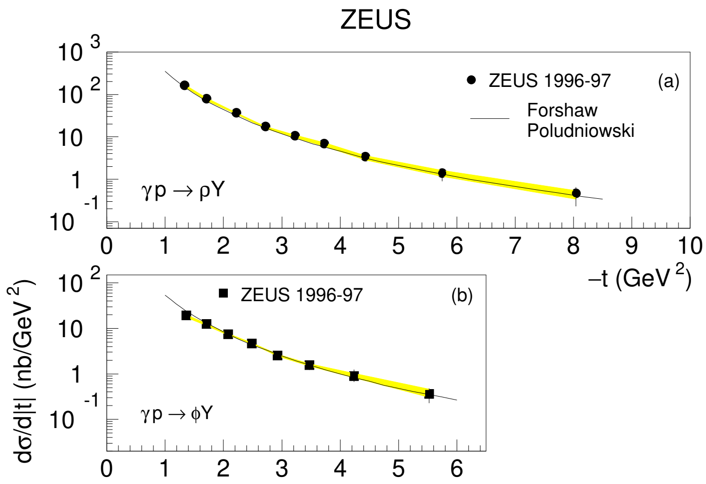

Figure 3: The differential cross section $d\sigma/dt$ as a function of $|t|$ for the proton dissociative production of a) the ρ and b) the ϕ meson. The result of a simultaneous fit of a BFKL model is shown by the solid line.

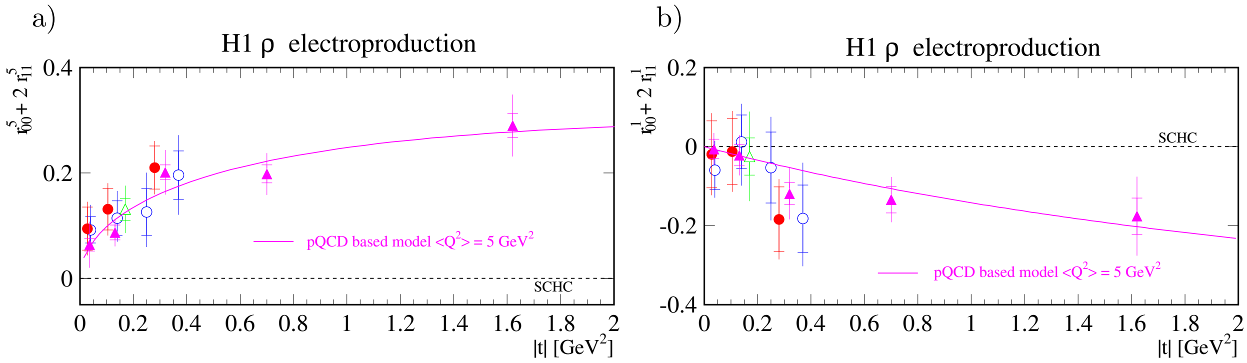

Figure 4: High $|t|$ electroproduction ρ measurements of a) $r^5_{00} + 2r^5_{11}$ and b) $r^1_{00} + 2r^1_{11}$ as a function of $|t|$. The solid line shows the result of a simultaneous fit to the data (closed triangles) for all 15 linear combinations of the spin density matrix elements.

The combinations $r^5_{00}+2r^5_{11}$ and $r^1_{00}+2r^1_{11}$ are presented as a function of $|t|$ in figures 4a) and b) respectively.[12] In pQCD the $|t|$ dependence of the parameters r^5_{00} and r^5_{11} are both expected to be proportional to $\sqrt{|t|}$ and the parameters r^1_{00} and r^1_{11} proportional to $|t|$ differing only in their sign. The result of a simultaneous fit to all 15 linear combinations is shown by the solid line. In figure 4a) the violation of SCHC increases proportional to $\sqrt{|t|}$ as expected. In figure 4b) the violation is proportional to $|t|$ as expected. The parameter r^1_{00} (which depends on the single-flip amplitude T_{01}) dominates due to the negative proportionality.

5 Summary

The DVCS cross section exhibits a similar steep rise as a function of the interaction energy $W_{\gamma p}$ as measured for elastic J/ψ photoproduction. The cross section is described by models, including those incorporating effects of skewed parton distributions, however when the Q^2 dependence is extrapolated assuming a Q^2 independent $|t|$ dependence these models lie below the data at large Q^2. A similar steep energy dependence is measured in diffractive J/ψ photoproduction at large $|t|$ in two $|t|$ regions. The leading-order BFKL model gives a reasonable simultaneous description of the $W_{\gamma p}$ and $|t|$ dependences. The high $|t|$ dependence of the proton dissociative ρ and ϕ production cross sections are approximately power-like $|t|^{-n}$ with an exponent $n \sim 3$ for both the ρ and the ϕ. Measurements of the $|t|$ dependences of spin density matrix elements in electroproduction ρ measurements agree with pQCD expectations showing significant deviations from s-channel helicity conservation.

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