# ELASTIC $J/\psi$ PRODUCTION AT HERA

Y. C. ZHU, FOR THE H1 COLLABORATION
*DESY, D-22607 Hamburg, Germany*
*E-mail: yczhu@mail.desy.de*

Cross sections for elastic production of $J/\psi$ mesons are measured for photon virtualities $Q^2$ up to 80 GeV$^2$. The center-of-mass energy $W_{\gamma p}$ covers the range $40-305$ GeV in photoproduction and $40-160$ GeV in electroproduction. Data are presented on the $Q^2$, $W_{\gamma p}$ and $t$ dependence of the cross sections. Effective Pomeron trajectories are determined. The $J/\psi$ production and decay angular distributions are measured and yield consistency with s-channel helicity conservation (SCHC). The ratio of the cross sections for longitudinal and transverse photons is measured as a function of $Q^2$ and can be described by perturbative QCD models.

## 1. Introduction

Quantum Chromodynamics (QCD) is expected to describe the strong force between hadrons. QCD is a successful theory in the limit of short distances, corresponding to small values of the strong coupling constant $\alpha_s$, where perturbative methods can be applied (perturbative QCD, pQCD). The bulk of the scattering cross section of hadrons, however, is dominated by long-range forces ("soft interactions"), where a satisfactory understanding of QCD still remains a challenge. A large fraction of these soft interactions is mediated by vacuum quantum number exchange and is termed "diffractive". In hadronic interactions, diffraction is well described by Regge theory, which is mediated by the exchange of "Pomeron" trajectory. In the high energy limit, Pomeron exchange dominates over all other contributions to the scattering amplitude and predicts an almost energy-independent cross section. Elastic photoproduction of vector mesons, $\gamma p \to \mathrm{VM}\ p$, is a particular example for a diffractive process. Measurements of the cross sections for the elastic production of light vector mesons ($\rho$, $\omega$ and $\phi$) in low $Q^2$ as fuction of $W_{\gamma p}$ have verified the expected universal Regge behaviour. The cross section for elastic $J/\psi$ photoproduction, however, rises steeply with $W_{\gamma p}$, incompatible with a universal Pomeron. Due to the large mass of $J/\psi$ meson, providing a "hard" scale, the elastic $J/\psi$ production is expected to be described by pQCD. This is even more so in electroproduction, where $Q^2$ can provide a second hard scale. The presence of two hard scales makes $J/\psi$ production particularly interesting for comparisons with pQCD.

## 2. Data Analysis

The data were recorded with the H1 detector in the years 1999 and 2000 when HERA was operated mostly with positrons. The $J/\psi$ mesons are detected via their decays into $\mu^+\mu^-$ or $e^+e^-$ pairs. They are selected from data corresponding to an integrated luminosity of 55 $\mathrm{pb}^{-1}$. Four data sets are selected covering different regions of $Q^2$ and $W_{\gamma p}$, as described in table 1. Further details of this analysis may be found in the document[1].

Table 1. Summary of the most important event selection criteria for the four data sets.

| Data set | I | II | III | IV |
|---|---|---|---|---|
| Kinematic region | Electroproduction | Photoproduction | | |
| $Q^2$ range [GeV$^2$] | 2-80 | $< 1$ | | |
| $< Q^2 >$ [GeV$^2$] | 8.9 | 0.05 | | |
| $W_{\gamma p}$ [GeV] | 40-160 | | 135-235 | 205-305 |
| $\|t\|$ [GeV$^2$] | $< 1.2$ | | | |
| Decay channel | $J/\psi \rightarrow \mu^+\mu^-$ | | $J/\psi \rightarrow e^+e^-$ | |
| Lepton signature | Track-Track | | Track-Cluster | Cluster-Cluster |
| Lepton polar angle [$^o$] | 20-160 | | $\theta_1$: 80-155<br>$\theta_2$: 160-177 | $\theta_1$: 160-174<br>$\theta_2$:160-175.5 |
| Lepton energy [GeV] | $p_t > 0.8$ | | $p_{t1} > 0.7$,$p_1 > 0.8$<br>$E_2 > 4.2$ | $E_{1,2} > 4.2$<br>$max(E1, E2) > 6$ |
| Elastic selection | No signal in forward detectors | | | |
| $\int \mathcal{L}$ dt [$pb^{-1}$] | 54.79 | | 30.26 | 26.90 |

Monte Carlo simulations are used to calculate the acceptances and efficiencies for triggering, event selection and lepton identification. The systematic uncertainties on the cross sections are dominated by detector effects which are not perfectly modelled in the Monte Carlo simulation. Most uncertainties are obtained by comparisons of data with simulation after tuning the detector simulation with independent data sets.

## 3. Results

Cross sections for elastic production of $J/\psi$ mesons in photoproduction and electroproduction are measured.

$Q^2$ **dependence**: The $\gamma p$ cross section is measured as a function of $Q^2$ in the range $0 < Q^2 < 80$ GeV$^2$, and a fit of the form $\sigma_{\gamma p} \propto (M_\psi^2 + Q^2)^{-n}$

yields a value of $n = 2.486 \pm 0.080 \pm 0.068$. Recent results from the ZEUS collaboration agree well[3,4] with the present data in the entire range of $Q^2$.

$W_{\gamma p}$ **dependence**: In figure 1 the photoproduction data are shown with the result of a fit of the form $\sigma \propto W_{\gamma p}^{\delta}$. The fit yields a value of $\delta = 0.75 \pm 0.03 \pm 0.03$, which is in agreement with our previous measurement[2] and the result from ZEUS collaboration[4]. Different theoretical predictions are compared with the data and shown in figure 1b. Predictions of the $W_{\gamma p}$ dependence of the cross section in pQCD-based models depend strongly on the gluon distribution. A good description of the shape of the data can currently be achieved only with some gluon parameterisations. This demonstrates the potential to constrain the gluon distribution with the elastic $J/\psi$ data in a kinematic region (low $x$, low $Q^2$) where fits from inclusive data yield gluon distributions with large uncertainties. The $W_{\gamma p}$ dependences are also studied in electroproduction, but are not shown here. Similar conclusions as for photoproduction are drawn.

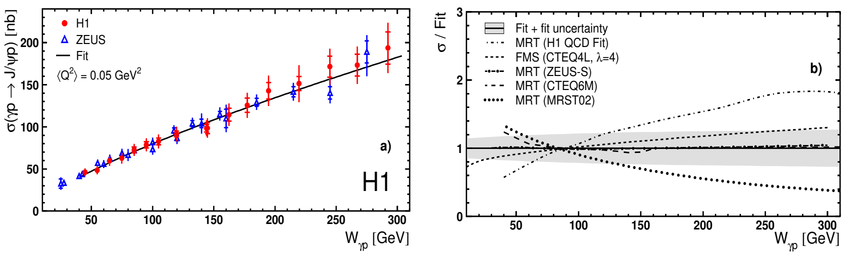


Figure 1. a) Total cross section as a function of $W_{\gamma p}$ in the range $|t| < 1.2$ GeV$^2$ in photoproduction. The solid line shows a fit to the H1 data of the form $\sigma \propto W_{\gamma p}^{\delta}$. b) The ratio of different theoretical predictions to the fit result. The shaded band indicates the uncertainties of the fit result.

**Differential Cross Section** $d\sigma/dt$: The $t$ dependence of differential cross section $d\sigma/dt$ is measured for photoproduction and for electroproduction. A single exponential function $d\sigma/dt \propto e^{bt}$ gives a good description of $d\sigma/dt$, while a dipole function form $d\sigma/dt \propto (1 - t/m_{2g}^2)^{-4}$ is strongly disfavoured by the data. The slope parameter values $b$ are seen to increase with $W_{\gamma p}$ for photoproduction, i.e., shrinkage of the diffractive peak.

**Effective Pomeron Trajectories**: Effective Pomeron trajectories $\alpha_0 + \alpha' t$ for elastic $J/\psi$ photoproduction and electroproduction are determined from a simultaneous analysis of $d\sigma/dt$ as a function of $W_{\gamma p}$ and $|t|$. Figure 2 shows the effective trajectory $\alpha(t)$ as a function of $|t|$. The photoproduction and electroproduction results are consistent with each other within errors. The trajectory for photoproduction has a $t$ slope which is two standard deviations below the soft Pomeron values but four standard deviations above zero.

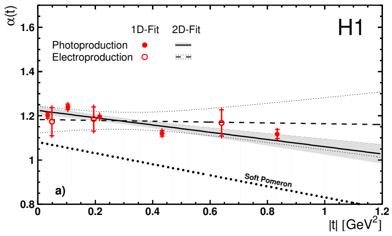


Figure 2. The effective trajectory $\alpha(t)$ as a function of $|t|$. The solid and dashed lines show the results of two-dimensional fits together with $1\sigma$-error bands.

**Helicity Studies**: The helicity structure is analysed as a function of $Q^2$ and $|t|$. No evidence is found for a violation of SCHC within errors. Assuming SCHC, the ratio of the longitudinal to the transverse polarised photon cross sections is determined as a function of $Q^2$ and is found to be consistent with QCD calculations.

## 4. Summary

Measurements of elastic $J/\psi$ photoproduction and electroproduction are presented in the range $40 \leq W_{\gamma p} \leq 305$ GeV and $40 \leq W_{\gamma p} \leq 160$ GeV, respectively. The $W_{\gamma p}$ dependences of the cross sections do not change significantly with $Q^2$ and can be described by models based on pQCD. Within such models, the data show a high sensitivity to the gluon density of the proton in the domain of low $x$ and low $Q^2$. Differential cross sections $d\sigma/dt$ are measured as functions of $W_{\gamma p}$ and $Q^2$. Effective Pomeron trajectories are determined. The helicity structure studies support SCHC. The ratio of the cross section for longitudinally and transversely polarised photons is found to be described by pQCD based models.

## References

1. A. Aktas et al., *DESY-05-161*, **hep-ex/0510016**.
2. C. Adloff et al., *Phys. Lett.* **B 483**, 23 (2000).
3. S. Chekanov et al., *Nucl. Phys.* **B 695**, 3 (2004).
4. S. Chekanov et al., *Eur. Phys. J.* **C 24**, 345 (2002).