

PROTON-DISSOCIATIVE VECTOR MESON PRODUCTION AT HERA*

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The double diffractive photoproduction of J/ψ mesons, $\gamma p \rightarrow J/\psi Y$, has been studied in ep collisions with the ZEUS and H1 detectors at HERA. The differential cross section $d\sigma/dt$, where t is the four-momentum transfer squared at the proton vertex, has been measured for $|t| < 30 \text{ GeV}^2$. The total cross section has been presented as a function of the photon-proton centre-of-mass energy, $W_{\gamma p}$, in the kinematic range $50 < W_{\gamma p} < 245 \text{ GeV}$. The results are compared with perturbative QCD models based on BFKL and DGLAP evolution.

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1. Introduction

The diffractive photoproduction of J/ψ mesons with large negative momentum transfer at the proton vertex t is a powerful mean to probe the parton dynamics of the diffractive exchange. The variable t or the meson mass in the case of J/ψ provide a relevant scale to justify the application of perturbative QCD (pQCD). The proton-dissociative vector meson production, in the proton rest frame, can be factorized into three steps: the almost-real photon fluctuates into a $q\bar{q}$ pair at a long distance from the proton target, which then interact with a single parton in the proton by means of a color singlet exchange. After interaction the $q\bar{q}$ pair forms a bound state, the vector meson. In the leading log (LL) approximation, the color singlet exchange is described by the exchange of a gluon ladder. The ordering of gluons in the ladder is different in DGLAP (resummation of $(\alpha_s \ln Q^2)^n$), where

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they are strongly ordered in k_T , and in BFKL (resummation of $(\alpha_s \ln 1/x)^n$ terms) they are strongly ordered in x , the longitudinal momentum fraction.

The proton-dissociative production of the J/ψ mesons, $ep \rightarrow eJ\psi Y$, is presented in the kinematic region of photoproduction. The incoming lepton is scattered at a small angle emitting an almost real photon. Y represents the proton remnant system. The J/ψ is studied in two leptonic decay channels: $J/\psi \rightarrow \mu^+\mu^-$ and $J/\psi \rightarrow e^+e^-$. The differential cross section $d\sigma/dt$ is presented as a function of t for $|t| < 30 \text{ GeV}^2$. The total cross section is studied as a function of $W_{\gamma p}$ for $50 < W_{\gamma p} < 245 \text{ GeV}$.

2. Results

The proton dissociative J/ψ meson production was studied by the ZEUS and H1 Collaboration. The data were collected in the years 1996–2000 and correspond to an integrated luminosity of 36 pb^{-1} (ZEUS) and 78 pb^{-1} (H1). In this time HERA was operated with positrons/electrons of energy 27.5 GeV and the protons of 820 (920) GeV.

2.1. The $|t|$ dependence of the cross section.

The differential cross section $d\sigma/dt$ measured by the H1 Collaboration [1] is shown in Fig. 1, for the kinematic region $2 < |t| < 30 \text{ GeV}^2$, $50 < W_{\gamma p} < 150 \text{ GeV}$ and $z > 0.95$. For $|t| > 3.45 \text{ GeV}^2$, the data are described by a power-law dependence of the form $A|t|^{-n}$, where $n = 3.00 \pm 0.08$ (stat.) ± 0.05 (syst.). The data are compared to a model [4] based on BFKL evolution, where the parameters $\alpha_s=0.21$ and $s_0 = 0.5 \text{ GeV}^2$ (governing the dynamics of the gluon ladder) are extracted from the fit to the previous ZEUS measurement [2]. The calculations of LL approximation (solid curve) describe the data well. The inclusion of NL corrections with a fixed α_s gives only a small difference with respect to the LL prediction. The LL+NL calculations containing the running α_s becomes steeper (dotted line) and are unable to describe the data across the whole t range. The data are also compared to the DGLAP LL [5] approximation (dashed-dotted curve) in the region of the model validity $|t| < M_{J/\psi}^2$. The data are also well described in shape and normalization.

The cross section, measured by the ZEUS Collaboration [6] in the kinematic range of $|t| < 7 \text{ GeV}^2$ and $185 < W_{\gamma p} < 245 \text{ GeV}$ is shown in Fig. 2 together with the previous ZEUS measurement at $\langle W \rangle = 100 \text{ GeV}$ [2]. The measurements are compared with BFKL calculations in LL approximation (solid curves) and including NL corrections with fixed α_s (dashed curves) in Fig. 2 (left). The LL calculations reproduce well the shape of the t distributions, but overestimate the magnitude of their rise with increasing W . The LL approximation including NL corrections gives t distributions which

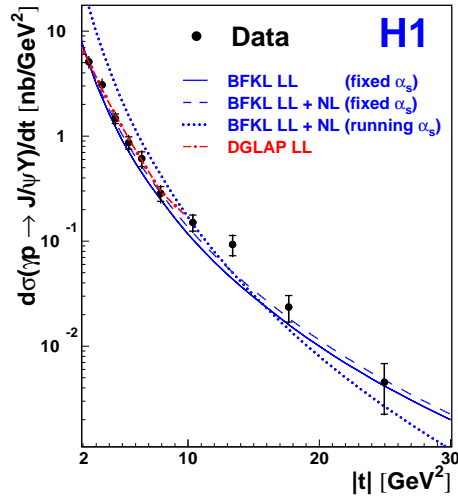


Fig.1. The differential cross section $d\sigma/dt$ of the process $\gamma p \rightarrow J/\psi Y$ in the kinematic range $50 < W_{\gamma p} < 150 \text{ GeV}^2$, $|t| > 2 \text{ GeV}^2$ and $z > 0.95$. The data are compared with the predictions based on BFKL and DGLAP evolution.

are too steep, but reproduce better the relative rise of the cross section with increasing energy. In Fig. 2 (right) the data are compared with DGLAP and BFKL calculations. The prediction of DGLAP LL does not follow the observed rise of the cross section with the energy.

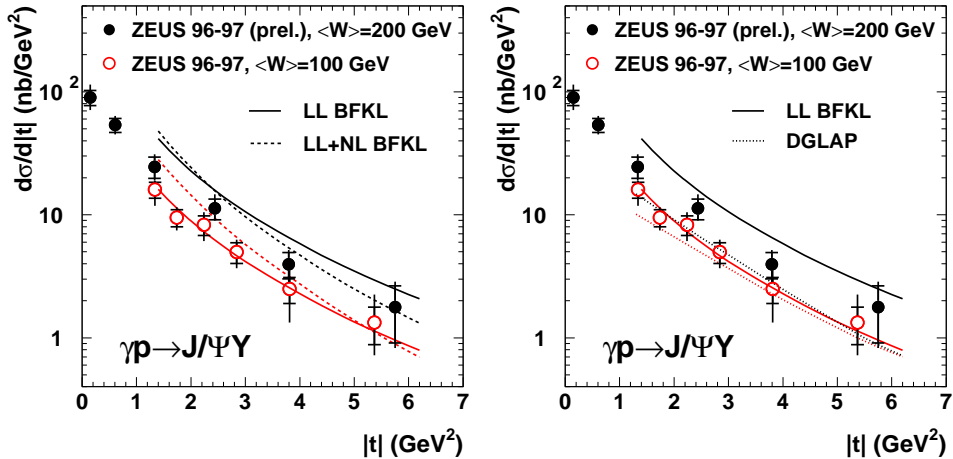


Fig.2. The differential cross section $d\sigma/d|t|$ for the process $\gamma p \rightarrow J/\psi Y$ at $W \simeq 200 \text{ GeV}$ (full circles) and at $W \simeq 100 \text{ GeV}$ (open circles). The comparison with QCD models is presented.

2.2. The $W_{\gamma p}$ dependence of the total cross section.

In Fig. 3 the cross section $\sigma_{\gamma p \rightarrow J/\psi \, Y}$ is presented as a function of $W_{\gamma p}$ in three bins of $|t|$. A fast rise of the cross section with W is observed for each t bin. The data are well described by a power-like function in the form $\sigma \propto W_{\gamma p}^\delta$ and the results of the fit are as follows: for $2 < |t| < 5 \text{ GeV}^2$ $\delta = 0.77 \pm 0.14 \text{ (stat.)} \pm 0.10 \text{ (syst.)}$, for $5 < |t| < 10 \text{ GeV}^2$ $\delta = 1.29 \pm 0.23 \text{ (stat.)} \pm 0.16 \text{ (syst.)}$ and for $10 < |t| < 30 \text{ GeV}^2$ $\delta = 1.28 \pm 0.39 \text{ (stat.)} \pm 0.36 \text{ (syst.)}$. In each t bin, the cross section was fitted in the form $d\sigma/dt = F(t)W_{\gamma p}^{4\alpha(t)-4}$, where $\alpha(t)$ is the effective Pomeron trajectory. Assuming a linear form for the Pomeron trajectory $\alpha(t) = \alpha(0) + \alpha' \cdot t$, the fit yields a slope $\alpha' = -0.0135 \pm 0.0074 \text{ (stat.)} \pm 0.0051 \text{ (syst.) GeV}^{-2}$ and an intercept $\alpha(0) = 1.167 \pm 0.048 \text{ (stat.)} \pm 0.024 \text{ (syst.)}$. The data are compared with the BFKL calculation in the LL approximation (solid curve) and LL+NL approximation with fixed α_s (dashed curve). BFKL LL+NL predictions give a reasonable description of the energy dependence, except in the lowest $|t|$ range, where they are steeper than the data. The DGLAP LL model, valid for $|t| < M_{J/\psi}^2$, generally describes the energy dependence in the lowest $|t|$ bin. For $5 < |t| < 10 \text{ GeV}^2$, the DGLAP LL prediction do not follow the rise of the cross section with the energy.

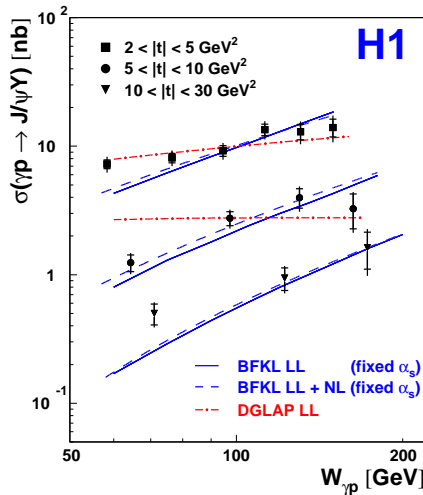


Fig. 3. The photon–proton cross section as a function of $W_{\gamma p}$ measured in three bins of t . The solid lines correspond to the BFKL LL calculations, the dashed lines presents BFKL calculations with non-leading corrections using a fixed α_s . The dashes-dotted line shows the DGLAP LL predictions.

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