PROCEEDINGS OF SCIENCE

Diffractive dijet photoproduction in ep collisions with a leading proton at HERA.

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Differential cross sections of the diffractive photoproduction process $e^+p \to eXp$ are measured using the data collected with H1 detector at HERA in 2006 and 2007 which correspondes to an integrated luminosity of $30\,\mathrm{pb}^{-1}$. The system X is required to contain at least 2 jets with a minimum transvers energy $E_T^{\mathrm{jet1(2)}} = 5.5(4)\,\mathrm{GeV}$ and the outgoing proton is tagged in Very Forward Proton Spectrometer (VFPS). The measurement is performed for untagged photoproduction with $Q^2 < 2\,\mathrm{GeV}^2$ in photon virtuality. The results are compared to next-to-leading order QCD calculations based on diffractive parton distribution functions extracted from measurements of inclusive cross sections in diffractive deep-inelastic scattering (DIS).

XXI International Workshop on Deep-Inelastic Scattering and Related Subject -DIS2013,
22-26 April 2013
Marseilles,France

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[†]On behalf of H1 Collaboration, supported by SVV 267309 of Charles University in Prague

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1. Introduction

The factorisation theorem assumes, that the cross section could be expressed as a convolution of non-perturbative universal parton distribution functions and the hard sub-process cross-section calculable within perturbative QCD. For hard diffraction the so called diffractive parton distribution functions (DPDFs) were introduced in analogy to the non-diffractive case. These DPDFs are obtained by fitting of the inclusive diffractive $ep \to ep'X$ data from HERA [1]. The universality of these DPDFs was successfully experimentally tested in the DIS region for processes as dijets, charm or vector meson production.

On the other hand in diffractive hadron-hadron interactions, where the hard scale is provided by presence of jets, the predictions based on HERA DPDFs overestimates the data, at Tevatron by about one order of magnitude [2]. This effect is usually explained as a consequence of additional partonic interactions between both hadrons which destroy the diffractive event signature - the rapidity gap [3]. Similar effect was recently observed at LHC by CMS collaboration [4].

Far from clear, however, is the situation in the photoproduction regime of the ep diffractive scattering. In photoproduction, in the leading order approximation, the small photon virtuality allows for partonic fluctuations that live long enough. The photon may not couple directly to the quarks in the proton, but only a part of its four-momentum participates in the hard interaction. Such interactions are called resolved and photon here has hadronic structure. The photon can still couple directly (with its whole four-momentum) to the quarks and these interactions are called direct. The resolved photon interactions resemble the hadron-hadron ones since two particles with structure scatter on each other. The variable x_γ, which is defined as a four-momentum fraction of the photon taking part in the hard interaction, is usually used to distinguish between these two regimes in photoproduction. Obviously, following relations hold: $x_\gamma = 1$ and $x_\gamma < 1$ for the direct and resolved photon interactions, respectively. Because of the resemblance of the resolved processes with hadron-hadron interactions the presence of the data suppression with respect to the theoretical predictions based on factorisation theorem is here usually assumed [5, 6].

Up to now two analysis from H1 collaboration [7, 8] and one ZEUS measurement [9] of diffractive dijets ep photoproduction exist. In each of these measurement the diffraction is selected using large-rapidity gap (LRG) method and contrary to the theoretical expectations no significant dependence of data suppression factor on x_γ is observed. The overall data suppression factors provided by both collaborations are different, the H1 observed data to be suppressed by a factor of 0.6 with respect to the next-to-leading order (NLO) QCD prediction, the ZEUS data are compatible with the hypothesis of no factorisation breaking. Due to the different phase spaces of H1 and ZEUS analysis, an attempt of extrapolating H1 data into the ZEUS phase space was done in [10]. This study concludes that the disagreement in the suppression factors within both collaborations cannot be explained by the phase space difference only.

To clarify the situation a new measurement of this process is provided by H1. In contrast to the previous measurements the diffractive events were selected using a leading proton spectrometer. Unlike the LRG method direct detection of the leading proton profits from the fact that the measurement is free of contributions of the proton dissociative and non-diffractive processes.

2. Experimental Setup

The H1 detector is described in detail elsewhere [11]. In this measurement, the diffractive protons were directly tagged by Very Forward Proton Spectrometer (VFPS) [12], so no proton dissociative admixture is presented in contrast to LRG method. The VFPS consists of two stations at 220 and 222 m from the interaction point and has a high track reconstruction efficiency and a low beam-halo background contamination. The diffractive kinematic domain specified by relative proton energy loss $x_{I\!P}$ and proton four-momentum transfer t is chosen to be within VFPS acceptance (2.4).

Photoproduction events were selected by using an electron veto. To achieve a good electron rejection efficiency the photon virtuality Q^2 and the inelasticity y are constrained (2.2).

Jets selected by the k_T-algorithm with $R = 1$ [13] are required to have pseudorapidities $\eta^{\mathrm{jet1,2}}$ within Liquid-Argon calorimeter acceptance (2.4). Constrains on transverse jet energies $E_T^{\mathrm{jet1,2}}$ (2.3) are asymmetric [14] to avoid infrared singularities in next-to-leading order QCD predictions (see section 3).

$$Q^2 < 2\,\mathrm{GeV}^2 \quad \& \quad 0.2 < y < 0.8 \tag{2.1}$$

$$E_T^{\mathrm{jet1}} > 5.5\,\mathrm{GeV} \quad \& \quad E_T^{\mathrm{jet2}} > 4\,\mathrm{GeV} \tag{2.2}$$

$$-1 < \eta^{\mathrm{jet1,2}} < 2.5 \tag{2.3}$$

$$0.010 < x_{I\!P} < 0.024 \quad \& \quad |t| < 0.6\,\mathrm{GeV}^2 \tag{2.4}$$

3. Theoretical Calculations

Theoretical calculations based on factorisation theorem were performed by the NLO QCD program of Frixione et. al. [15] adopted for diffractive photoproduction described by the Resolved Pomeron Model [16]. For these calculations the H1 2006 Fit B DPDF [1] and GRV-HO γ-PDF [17] were used. In addition to the Pomeron exchange also the sub-leading Reggeon exchange is taken into account. The renormalization and factorisation scales are both set to the leading jet transverse energy i.e. $\mu_R = \mu_F = E_T^{jet1}$. The NLO calculations are performed with the number of flavours fixed to 5 and $\Lambda_5 = 0.228\,\mathrm{GeV}$, corresponding to a 2-loop α_S of 0.118. This program was successfully compared with an alternative NLO QCD program [18].

The resulting parton-level cross sections are corrected for remove hadronisation effects by means of hadronisation corrections calculated by the leading order Monte Carlo RAPGAP [19]. This Monte Carlo is also used for unfolding measured data to the level of stable hadrons applying single value decomposition method [20].

4. Results

An overall suppression factor of data with respect to NLO QCD predictions of

$$\sigma_{DATA}/\sigma_{NLO} = 0.67 \pm 0.04\,(\mathrm{stat.}) \pm 0.09\,(\mathrm{syst.}) \pm 0.20\,(\mathrm{scale}) \pm 0.14\,(\mathrm{DPDF}) \tag{4.1}$$

is observed consistent with the previous H1 result [7].

The measured differential cross sections as a function of x_γ, $z_{I\!P}$, E_T^{jet1} and $\langle\eta^{\text{jets}}\rangle$ are shown in Figure 1.

The photon's four momenta fraction entering to the hard subprocess x_γ is sensitive to the γ-PDF and is also an experimental discriminator between direct and resolved photoproduction. There is clearly no indication of the resolved-part ($x_\gamma \lesssim 0.8$) being more suppressed than the direct part ($x_\gamma \gtrsim 0.8$), as predicted i.e. by the KKMR model [6].

The differential cross section of Pomeron momentum fraction entering to the hard subprocess $z_{I\!P}$, which is sensitive to the DPDF seems to be less suppressed for high $z_{I\!P}$ which corresponds to jets going to the forward region. However, one should take into account that the H1 DPDF Fit B used in NLO calculations was actually measured only up to $z_{I\!P} = 0.8$ [1] and higher values are only accessed by extrapolation.

The transverse leading-jet energy distribution E_T^{jet1} indicates that the suppression factor could depend on the hard scale involved, a similar effect is observed in [8], but given the large uncertainties definite conclusions cannot be made.

The mean jet's rapidity distribution in the laboratory system $\langle\eta^{\text{jets}}\rangle$ indicates data being more forward "peaked" compared to the theory.

The RAPGAP MC describes the shape of the measured distributions satisfactory however the total data cross section is higher compared to RAPGAP MC.

5. Conclusion

The diffractive dijets cross-sections in photoproduction with leading proton detected by proton spectrometer is measured for the first time. The ratio of the measured cross section to the NLO prediction is 0.67. This suppression factor is consistent with the value observed in the previous analysis [7] in which a (slightly) different phase space has been explored. No dependence of the survival probability as a function of the variables investigated is found, especially no difference is observed in the survival probability for the direct and resolved contributions.

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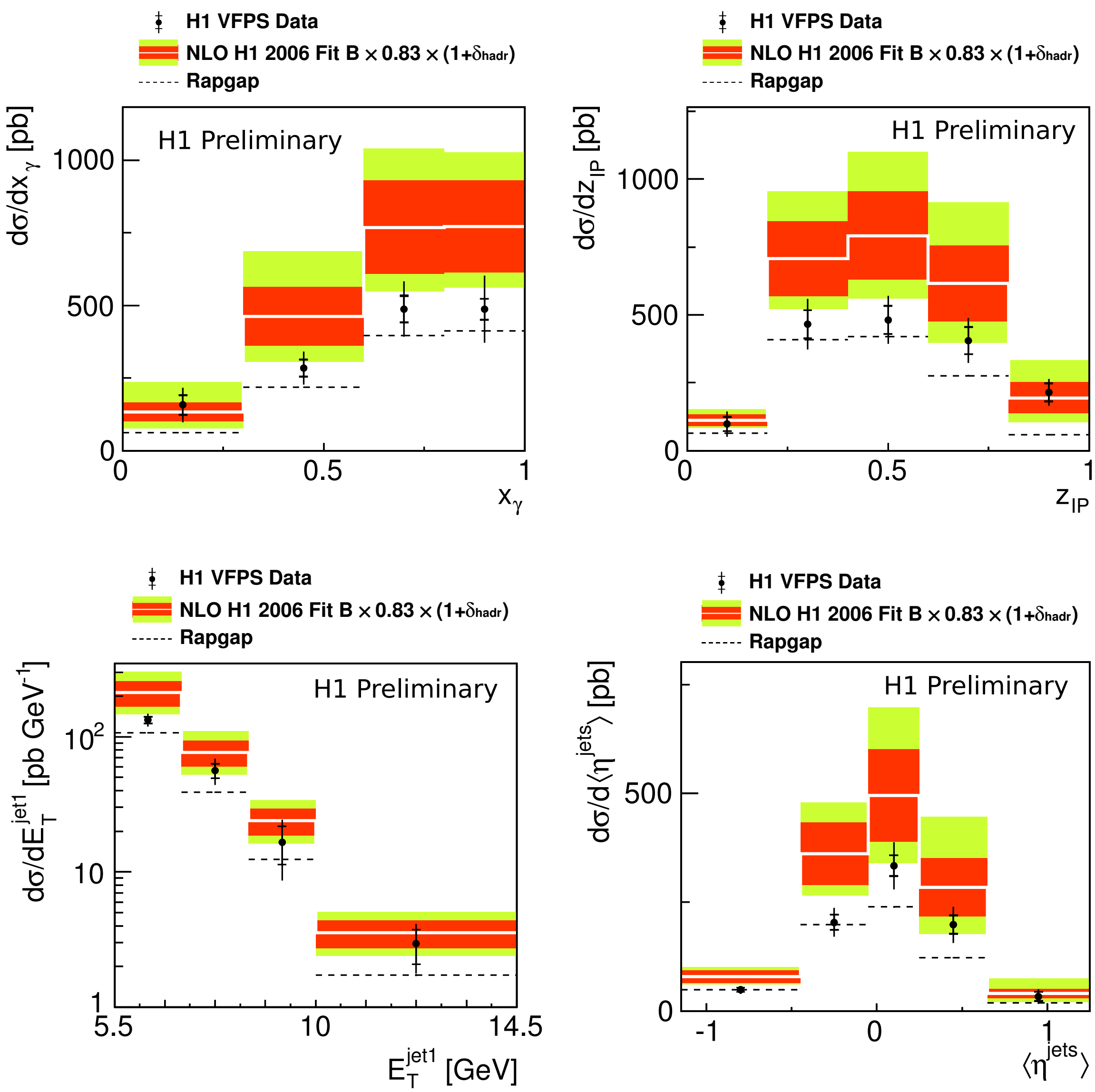

Figure 1: Differential diffractive dijet photoproduction cross sections as a function of x_γ, $z_{I\!P}$, $E_T^{\rm jet1}$ and $\langle\eta^{\rm jets}\rangle$. The inner error bars represent the statistical errors. The outer error bars indicate the statistical and systematic errors added in quadrature. NLO QCD predictions based on the DPDF set H1 2006 Fit B, corrected to the level of stable hadrons, are shown as a white line. The red band indicates the DPDFs uncertainties and light green band indicates the DPDFs and scale uncertainties added in quadrature. The LO QCD predictions from RAPGAP using the same DPDF set are shown by the dashed black line.