Diffraction at HERA*

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The diffractive dijet cross sections for photoproduction and deep inelastic scattering were studied with emphasis of studying of factorisation properties of diffractive processes. The production of isolated prompt photons in diffractive photoproduction was measured for the first time. The measurement of exclusive dijet production was compared to predictions from models based on different assumptions about the nature of diffractive exchange.

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1. Introduction

At HERA a substantial part of the *ep* cross section (up to 10%) is represented by diffractive scattering processes initiated by a virtual photons. The observation of jets in diffractive *pp* scattering [1] opened the possibility to study diffraction in the framework of quantum chromodynamics (QCD). Then the hard scattering coefficient functions can be calculated in in perturbative QCD. The diffractive deep inelastic scattering (DIS) process $ep \to eXY$ factorises in QCD and it was proven to hold for inclusive and dijet diffractive processes, assuming high enough photon virtuality such that higher twist effects can be neglected. Then the diffractive parton distribution functions (DPDFs) have to be determined from QCD fits to the measured inclusive DIS diffractive cross sections. The concept of DPDFs plays an important role in the study of diffractive reactions in DIS and can be an essential input to calculations of hard diffractive processes at the LHC.

The diffractive reaction $ep \to eXY$ contains two distinct final state systems, where X is a diffractive hadronic high mass state and Y is an outgoing

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intact proton or its low mass excitation. In many analyses diffractive events have been selected on the basis of a large rapidity gap (LRG) between the leading proton or low-mass system Y and the reminder of the hadronic final state X. The main advantage of this method is its high acceptance. A complementary way to select diffractive events is by direct measurements of the outgoing proton in forward proton spectrometers. This method has a disadvantage of lower acceptance but gives an opportunity to distinguish between the case where the scattered proton remains intact or dissociates into a system of low mass M_Y. These two methods of selection differ partially in the accessible kinematic ranges and substantially in their dominant sources of systematic uncertainties.

2. Diffractive dijet production in DIS and photoproduction

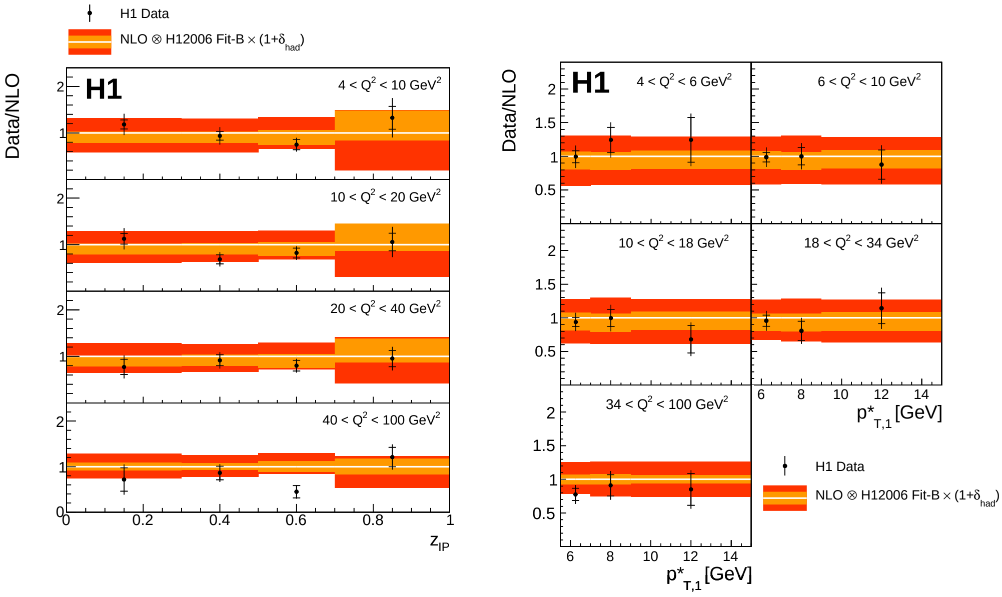

Fig. 1. a) Ratio of the double-differential cross section to the NLO preditions as a function of $z_{I\!P}$ and Q^2 and b) $p^*_{T,1}$ and Q^2. The inner error bars on the data points represent the statistical uncertainties, outer error bars systematic uncertainties added in quadrature.

The new H1 analysis [2] of dijet production in DIS is based on the full HERA-II data sample resulting in significantly increased statistics with respect to previous analyses. Furthermore, the cross sections are determined using a regularised unfolding procedure which fully accounts for efficiencies, migrations and correlations among the measurements. The integrated

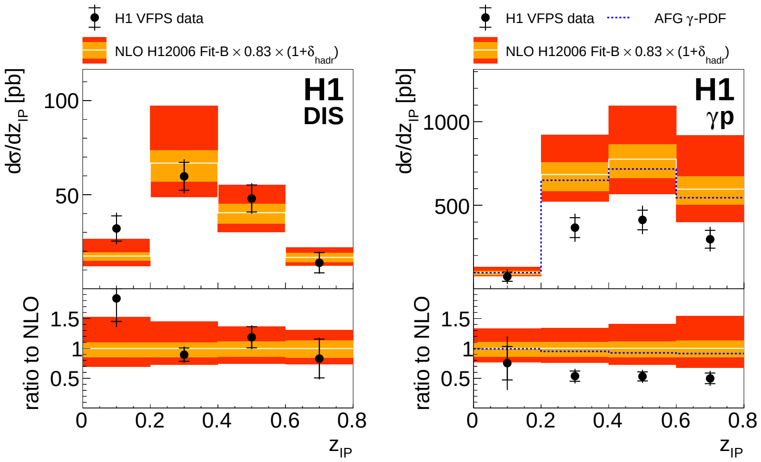

Fig. 2. Diffractive dijet a) DIS and b) photoproduction cross sections differential in $z_{I\!P}$ compared to NLO predictions. The inner error bars represent the statistical errors, outer error bars statistical and systematic uncertainties added in quadrature.

diffractive dijet cross section is found to be well described by the NLO QCD predictions using the H1 2006 Fit-B DPDF set. Both shapes and normalisation of the single-differential cross sections are reproduced by the theory within the experimental and theory uncertainties, as shown in Fig. 1. The measured dijet cross sections are used to extract the strong coupling constant in diffractive DIS processes for the first time. The result $\alpha_s = 0.119 \pm 0.004(exp) \pm 0.012(DPDF, theo)$ is consistent within the uncertainties with the world average.

In the diffractive hadron-hadron interactions, where a hard scale is provided by jets of large transverse momentum, the predictions based on HERA DPDFs however overestimate the data, at Tevatron and LHC, by about one order of magnitude. This breaking of factorisation was theoretically predicted to be present also in *ep* diffractive dijet photoproduction due to contributions of resolved component to photoproduction in LO QCD which resemble hadron-hadron collisions [3]. The contribution of resolved component depends on x_γ (fraction of the photon momentum participating in the hard process) however no significant dependence of data suppression factor [1] on x_γ was observed in previous measurements [4, 5, 6]. The overall data suppression factors measured by two HERA experiments were different, the H1 observed data to be suppressed by a factor of about 0.5-0.6 with respect to the next-to-leading order (NLO) QCD prediction [4, 5], whereas

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[1] The suppression factor is defined as a ratio of data and NLO QCD cross section

the ZEUS data are compatible with the hypothesis of no factorisation breaking [6]. To clarify the situation a new measurement is provided by H1 for both DIS diffractive dijets and dijets produced in photoproduction. The phase space of these two measurements differs only in momentum transfer Q^2 between the incoming and outcoming electron which is defined as $Q^2 < 2$ GeV^2 for photoproduction and $4 < Q^2 < 80$ GeV^2 for DIS events. In contrast to the previous measurements where the LRG method was used, diffractive events were selected using a leading proton spectrometer VFPS. The measured differential cross sections as a function of $z_{I\!P}$ are for DIS and photoproduction dijets shown and compared to NLO predictions in Fig. 2. It is seen that NLO QCD predictions describe properly the DIS data but for photoproduction the measurements are suppressed in comparison with NLO by a factor about 0.5.

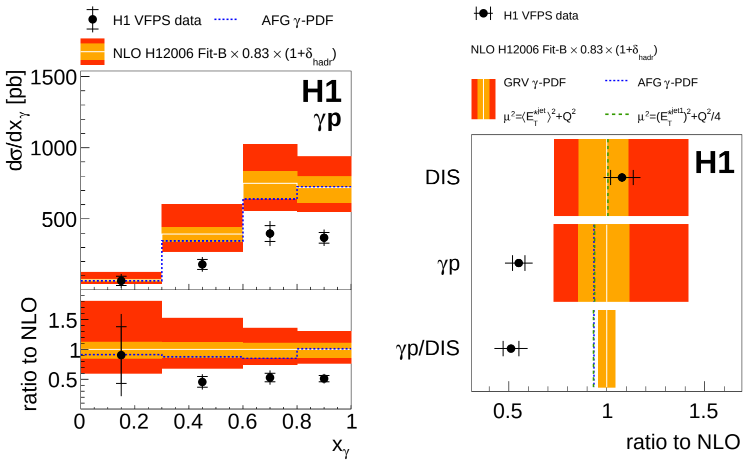

Fig. 3. a) Diffractive dijet ep cross section in the photoproduction differential in x_γ compared to NLO QCD predictions. b) diffractive dijet DIS and photoproduction cross sections normalised to NLO calculation and double ratio of photoproduction to DIS cross sections, normalised to the corresponding ratio of NLO predictions.

In Fig. 3a) the differential cross section is shown as a function of x_γ for dijet photoproduction. Within uncertainties there is clearly no indication of the resolved-part ($x_\gamma < 0.8$) being more suppressed than the direct part ($x_\gamma > 0.8$), which confirms previous measurements at HERA. In a refined method for studying deviations of the NLO QCD predictions from photoproduction data the cross sections measured in this regime are divided by the corresponding cross sections in DIS. In such ratios most of the data and theoretical systematic uncertainties are reduced. The double-ratio of photoproduction to DIS, data to NLO, is shown in Figure 3 b). The observation of factorisation breaking by factor of about 0.5 is in agreement with previous H1 measurements [4, 5], where complementary experimental methods of diffraction selection have been used.

3. Hard photons and exclusive dijet production in diffraction

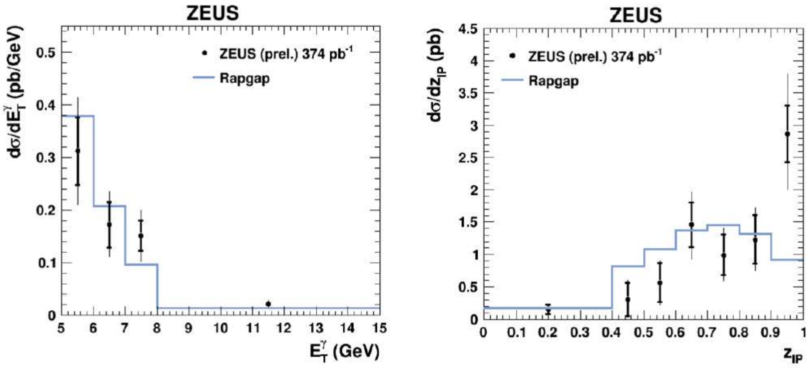

Fig. 4. Differential cross sections as functions of a) E_T^γ and b) $z_{I\!P}$ for events with isolated photon accompanied by a jet compared to normalised prediction of RAPGAP.

A new measurement was provided by ZEUS collaboration for diffractive photoproduction ep events in which a hard isolated prompt photon is detected in the central region of the ZEUS detector and may be accompanied by a jet [8]. In Fig. 4a) differential cross sections are shown as a function of the photon transverse energy E_T^γ for the photon+jet configuration. The shape of these distributions is satisfactorily described by the Rapgap Monte Carlo model [9], normalised to the data. The shape of the $z_{I\!P}$ distribution, see Fig. 4b), however is less well described. In particular, a prominent peak near $z_{I\!P} = 1$ is seen and requires further study. In future it is planed to compare these measurements with NLO QCD calculations to have another handle of factorisation in ep diffractive photoproduction.

The production of exclusive dijets in DIS $e+p \rightarrow e+p+jet_1+jet_2$ which represents a complementary process to the exclusive production of vector mesons was studied by ZEUS collaboration [10]. The differential cross sections were compared to MC predictions for the Resolved-Pomeron model [11] and the Two-Gluon-Exchange model [12] as implemented in Rapgap MC. These two models predict the different shapes in the distribution of Φ, which is the azimuthal angle between lepton and jet planes (definition see Fig. 5 a)). The shapes of the Φ distributions were parameterised in different intervals of β (momentum fraction of the struck parton with respect to the

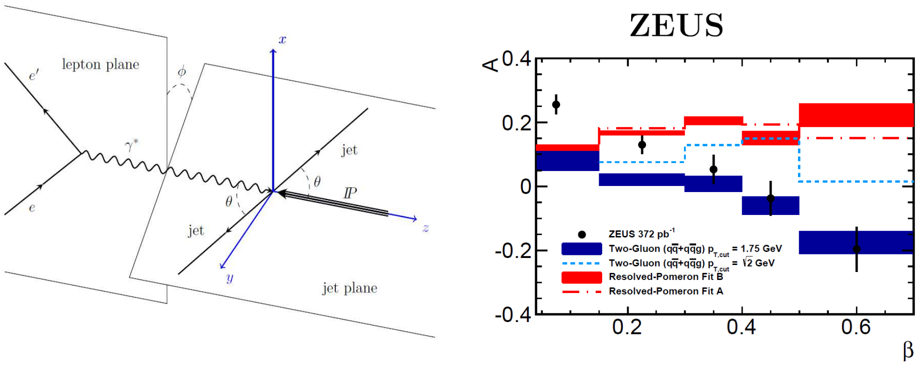

Fig. 5. a) Definition of lepton and jet planes, angle Φ is the angle between these two planes b) the shape parameter A as a function of β in comparison with two models, the bands in model predictions represent statistical uncertainties.

pomeron) with the function $1 + Acos\Phi$ as motivated by theory. The dependence of the parameter A in intervals of β is compared with predictions of two MC models in Fig. 5b). The Two-Gluon-Exchange model predicts reasonably well the measured value of A for $\beta > 0.3$, whereas the Resolved-Pomeron model exhibits a very different trend. In terms of absolute normalisation, both the Resolved- Pomeron and the Two-Gluon-Exchange model are below the data and thus fail to describe the measurement [10].

REFERENCES

[1] R. Bonino *et al.*,the UA8 Collab.,*Phys.Lett.B* **211**, 239 (1988).

[2] V. Andreev *et al.*, the H1 Collab. *JHEP* **1503** , 092 (2015).

[3] A. Kaidalov, V. Khoze, A. Martin, and M. Ryskin,*Eur.Phys.J.* **C66** (2010) 373.

[4] A. Aktas *et al.*, the H1 Collab.*Eur. Phys. J.* **C51**, 549 (2007).

[5] F.D. Aaron *et al.*, the H1 Collab. *Eur.Phys.J.* **C70**, 15 (2010).

[6] S. Chekanov *et al.*, the ZEUS Collab. *Eur.Phys. J.* **C55**, 177 (2008).

[7] V.Andreev *et al.*, the H1 Collab., *JHEP* **1505** 056 (2015).

[8] P. Bussey for the ZEUS Collaboration, Isolated photons in diffraction, Proceedings of DIS 2015 workshop, Dallas (2015).

[9] H. Jung, RAPGAP version 3.1, *Comput. Phys. Commun.* **86** (1995) 147.

[10] H. Abramowicz *et al.*, the ZEUS Collab. DESY-15-070 (May 2015), submitted to EPJ.

[11] G. Ingelman and P.E. Schlein, *Phys. Lett.B* **152**, 256 (1985).

[12] J. Bartels, H. Jung and M. Wuesthoff, *Eur.Phys. J.* **C11** 111 (1999).