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Diffractive jet production in ep collisions at HERA

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The latest results from the H1 experiment on the diffractive dijet production in deep-inelastic scattering and photoproduction are presented. The first jet measurements with a tagged leading proton are described. The results are discussed in terms of diffractive parton densities and Regge factorisation.

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1. Introduction

The measurements of di-jets in diffractive deep inelastic scattering (DIS) provide an unique tool to investigate the gluonic part of the object exchanged in the diffractive interactions - the Pomeron [1]. The presence of a hard scale - the transverse momenta of the jets - allows to compare the measured data with next-to-leading order QCD calculations. This leads to possibility of testing the QCD factorization in diffractive DIS as well as searching for parton evolution beyond the DGLAP scheme.

In the following sections, the diffractive jet production at the HERA experiment will be described and the latest results obtained with different experimental procedures will be presented.

2. Diffraction at HERA

Events of the type $ep \to eXY$, where the final state consists of two systems X and Y, comprise approximately 10% of all deep-inelastic scattering events (DIS) in the low x_{Bj} region in the high energy electron[1]-proton collisions at HERA.

The products of the interaction with the photon emitted by the electron are contained in the system X, the system Y contains the outgoing proton (elastic processes) or its low mass excitations (proton dissociation). Both systems are clearly separated by a region without energy flow (Large Rapidity Gap). These events are called diffractive. Diffractive interactions are described according to the Regge phenomenology in terms of the exchange of a colourless object which carries the quantum numbers of the vacuum, the so called Pomeron. At HERA, extensive measurements of inclusive diffractive DIS have been performed using two experimental methods of detecting diffraction - the Large Rapidity Gap (*LRG*) method [2] and the tagging of the outgoing proton with dedicated detectors (FPS and VFPS) [1]. In addition to the standard DIS variables Q^2 (photon virtuality) and x_{Bj} (the longitudinal momentum fraction of the interacting parton with respect to the incoming proton), the following additional variables are used to describe diffractive processes: the fractional longitudinal momentum loss $x_{I\!P} = 1 - E'_p/E_p$, the momentum fraction of the interacting parton with respect to the Pomeron β, defined similar to x_{Bj}, and the squared four-momentum transfer at the proton vertex t.

3. Jets in Diffractive DIS

The diffractive DIS cross section can be factorized (as proven by Collins [3]) into a hard process (denoted as $d\hat{\sigma}^{ei}$) calculable within the pQCD framework and the diffractive parton distribution functions f_i^D (DPDF) which have to be determined experimentally: $d\sigma(Q^2, |t|, \beta, x_{I\!P}) = \sum_i f_i^D(Q^2, |t|, \beta, x_{I\!P}) \otimes d\hat{\sigma}^{ei}(Q^2, x_{Bj} = x_{I\!P} \cdot \beta)$, where the sum runs over all partons. Regge factorization (also called proton vertex factorization) is usually assumed in addition, where the dependence on the variables characterizing the proton vertex ($x_{I\!P}$ and t) factorizes from the hard interaction depending on β and Q^2: $f_i^D(Q^2, |t|, \beta, x_{I\!P}) = f_{I\!P/p}(x_{I\!P}, t) \cdot f_i(\beta, Q^2)$, where the $f_{I\!P/p}$ stands for the Pomeron flux and f_i is the probability of finding a parton i in the Pomeron.

[1]The term “electron” is used here to denote both electron and positron.

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The inclusive diffractive DIS measurements constrain the quark densities within the Pomeron well, whereas the measurement of jets in the final state allows a better constraint of the gluon density in the Pomeron. In addition, dijet measurements allow tests of perturbative QCD calculations and serve as a tool for studying of the parton evolution.

The measurement of jets with the *VFPS* method has been performed for the first time, the phase space was defined by asymmetric cuts on the transverse momentum $p^*_{T,1} > 5.5$ *GeV* and $p^*_{T,2} > 4$ *GeV* and pseudorapidity $-3.0 < \eta^*_{1,2} < 0.0$, where asterisk denotes the hadronic centre-of-mass system. The *VFPS* dijet measurement which is shown in Figure 1 left and middle shows a good agreement with the NLO QCD predictions [6] based on the DPDF set H1 2007 Jets which was extracted from the inclusive *LRG* and jets data. The measurement of jets with the *FPS* method has been performed for the first time and is compared with a measurement using the *LRG* method [4] in Figure 1 right [5]. Both methods show a good agreement within errors, while the *FPS* method allows an extension of the phase space towards large $x_{I\!P}$.

A unique measurement of diffractive forward jets with the *FPS* method has been performed in order to test the validity of the DGLAP evolution equations [7]. Diffractive jet production with a tagged elastic proton allows the reconstruction of forward jets close to the outgoing proton. The phase space, defined by a hard jet close to the outgoing proton direction with a transverse momentum squared of the same order as the photon virtuality, suppresses strongly the DGLAP evolution. Within the phase space accessible by the H1 detector and the *FPS*, the DGLAP evolution gives a good description of the production of one central and one forward jet, see Fig. 2.

4. Jets in Diffractive Photoproduction

A test of factorisation has been performed by H1 in the photoproduction regime ($Q^2 \approx 0$ GeV^2) [8]. Two classes of processes contribute to the photoproduction of dijets: resolved and direct processes. In the resolved processes, the photon is considered as a hadron with a partonic structure, and in addition to the interacting parton a photon remnant is present. In the direct process the photon is treated as structureless. The observable $x_\gamma = \sum(E - p_Z)_{jets} / \sum(E - p_Z)_{hadrons}$ is defined to distinguish the direct ($x_\gamma \approx 1$) from the resolved ($x_\gamma < 1$) processes. According to theoretical calculations, in diffraction the resolved processes are expected to be suppressed by the *Gap Survival Probability* factor, whereas the direct processes remain unsuppressed [9]. The measured cross section as a function of x_γ and the ratio to the NLO predictions (based on H1 2006 Fit B and Kaidalov-Khoze-Martin-Ryskin (KKMR) model [10] for gap survival probability) is presented in Fig. 3. The ratio of data to theory is inconsistent with unity except for the lowest x_γ range, the data prefer a suppression for the direct component as well. This fact may hint of a possible breaking of the Regge factorisation in photoproduction, therefore more investigations are necessary.

5. Conclusion

The latest results on the measurements of diffractive di-jet production at HERA have been presented. The first results from the H1 sub-detector Very Forward Proton Spectrometer have been compared with the next-to-leading order calculations based on DPDF fit H1 2007 Jets. The NLO calculations describe the measured spectra within quoted errors. The good agreement between the

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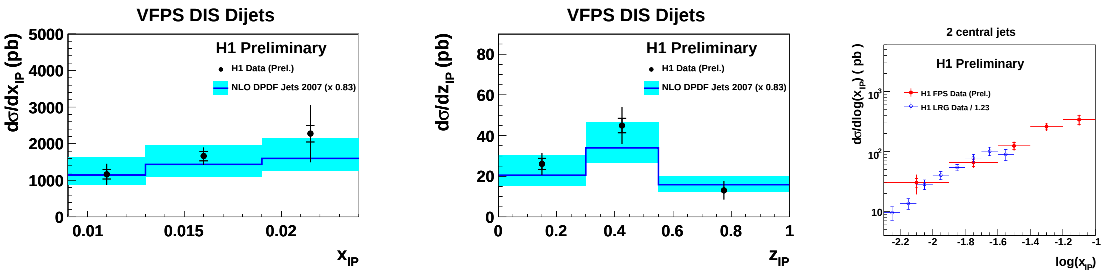

Figure 1: Single differential in the full *VFPS* accessible kinematic range as a function of $x_{I\!P}$ (left) and $z_{I\!P} = (M_{12}^2 + Q^2)/(x_{I\!P} ys)$, where M_{12} is the invariant mass of the jets, y the inelasticity of the event and s the central mass energy (middle). The factor 0.83 has been applied on order to correct for proton dissociation. Single differential cross section of the diffractive DIS dijet production measured in the phase space of [4] (right).

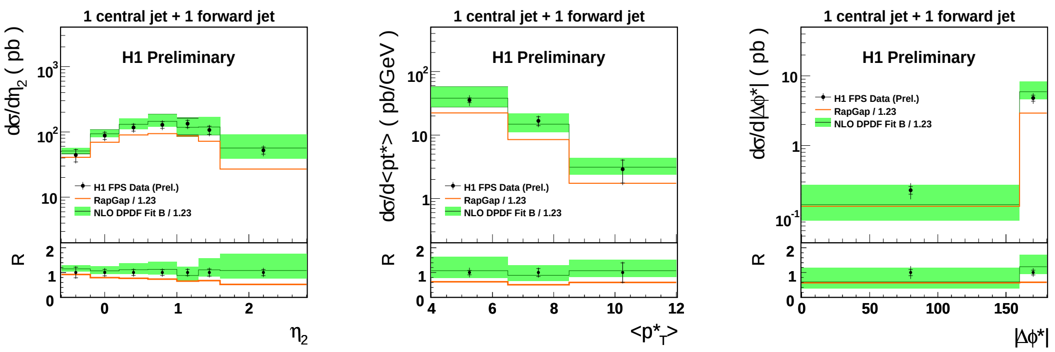

Figure 2: Single differential cross section as a function of pseudorapidity of the forward jet η_2 (left), mean transverse momentum $< p_T^* >$ (middle) and difference in the azimuthal angle $|\Delta\phi^*|$ for the two jets for the *FPS* sample.

different experimental methods of measuring diffractive di-jets has been presented. The search for physics beyond the DGLAP dynamics by means of measuring diffractive forward jets has shown that the DGLAP predictions are describing the region of phase space accessible by the HERA experiment within the theoretical and experimental errors. A measurement of Di-jets in diffractive photoproduction has been performed and the results may hint of a possible breaking of the Regge factorization in this kinematical domain.

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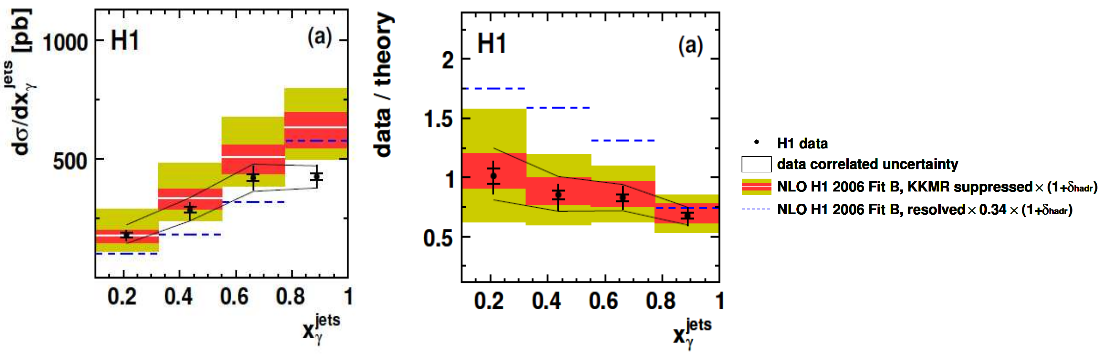

Figure 3: Single differential cross section in diffractive photoproduction measured as a function of x_γ (left) and the comparison of the H1 measured data to the revised KKMR theory (red and beige band) and H1 2006 Fit B (blue dashed line) on the right.

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