Measurement of Dijet Production in Diffractive Deep-Inelastic Scattering with a Leading Proton at HERA

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The latest results from the H1 experiment on the diffractive dijet production in deep-inelastic scattering 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.

1   Introduction

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 provides the possibility to test the QCD factorization in diffractive DIS as well as to look for effects of parton evolution beyond the DGLAP approach. In the following sections, the diffractive jet production with a proton measured with the H1 experiment at the HERA collider will be described and the latest results will be presented.

2   Jets in Diffractive DIS at HERA

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

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

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 for H1, LPS for ZEUS) [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 of the proton $x_{I\!P} = 1 - E'_p/E_p$, 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. In the following analysis, the events tagged by the FPS are analysed. As proven by Collins [3], the diffractive DIS cross section can be factorized 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. The quark densities within the Pomeron are well constrained by the inclusive diffractive DIS measurements, whereas a better constraint on the gluon density in the Pomeron is provided by measurement of jets in the final state. In addition, dijet measurements allow tests of perturbative QCD calculations, various models for modelling diffractive processes and serve as a tool for studying the parton evolution. The measurement of jet production in diffraction with the FPS method has been performed for the first time [4]. The cross section is corrected to the level of stable hadrons with a matrix unfolding. It is compared to pNLO DGLAP QCD calculations, DPDF-based RAPGAP Monte Carlo, two-gluon Pomeron RAPGAP Monte Carlo and soft colour interaction (SCI) model as implemented in the LEPTO Monte Carlo. The jet cross section is measured for two topologies. The 'two central jets' topology (see Table 1) is used for testing the proton vertex factorisation and the DPDFs in processes with a leading proton in the final state, whereas the 'one central + one forward jet' topology is motivated by the search for deviations from DGLAP parton evolution. In contrary to non-diffractive DIS, jets reconstructed in the forward region are not spoiled by the presence of the proton remnant and can be therefore directly related to partons emitted during the interaction.

Selection	two central jets	one central + one forward jet
DIS	$4 < Q^2 < 110$ GeV^2	
	$0.05 < y < 0.7$	
Leading Proton	$x_{I\!P} < 0.1$	
	$|t| < 1$ GeV^2	
Jets	$P_{T,1}^* > 5$ GeV $P_{T,2}^* > 4$ GeV $-1 < \eta_{1,2} < 2.5$	$P_{T,c}^*, P_{T,f}^* > 3.5$ GeV $M_{jj} > 12$ GeV $-1 < \eta_c < 2.5$ $1 < \eta_f < 2.8, \eta_f > \eta_c$

Table 1: Phase space of the diffractive dijet FPS measurements, The asterisk marks variables reconstructed in the hadronic centre-of-mass system while other quantities are reconstructed in the lab frame.

The Figures 1 and 2 present the comparison of the measured hadron level cross sections
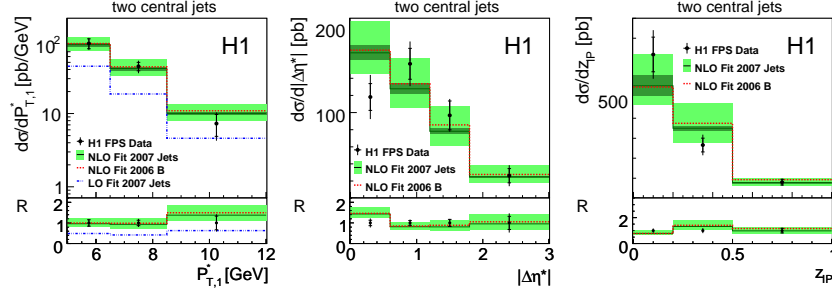
Figure 1: The sinlge differential cross section for the production of two central jets shown as a function of $p^*_{T,1}$, $|\Delta\eta^*|$ and $z_{I\!P}$ (Pomeron momentum fraction which goes into the di-jet system) compared to the NLO QCD DGLAP predictions based on DPDFs H1 2007 Jets and H1 2006 Fit B.

to the NLO QCD DGLAP predictions as well as Monte Carlo Models for the 'two central jets' topology. The NLO predictions describe the data within quoted uncertainties. From the Monte Carlo Models, only the DPDF based RAPGAP MC is able to describe all shape aspects of the kinematic distributions. The Figure 3 left presents the comparison of the *FPS* and *LRG* methods and the extension of the phase space for the *FPS* method. Both methods agree well within errors, the *LRG* measurement is corrected for proton dissociation by a constant factor of 1.2. The measured B slope of the t distribution (middle) is compared to the inclusive *FPS* measurement [1] (right), the result is consistent with the assumption of the proton vertex factorisation being independent on the diffractive final state. Figure 4 presents the comparison of the data to NLO QCD DGLAP in the phase space enhancing effects beyond DGLAP. No deviations were observed within the uncertainties.

3   Conclusion

The latest results on the measurements of diffractive di-jet production with the scattered proton tagged in the Forward Proton Spectrometer at HERA have been presented. The cross sections are well described by the NLO DGLAP QCD predictions even in the phase space enhancing possible deviations from the DGLAP parton evolution. A good agreement between the LRG and FPS methods as well as consistency with proton vertex factorisation assumption has been shown. The DPDF based RAPGAP Monte Carlo describes the kinematical distributions in shape, whereas the two-gluon pomeron and scoft colour interaction models fail.

References

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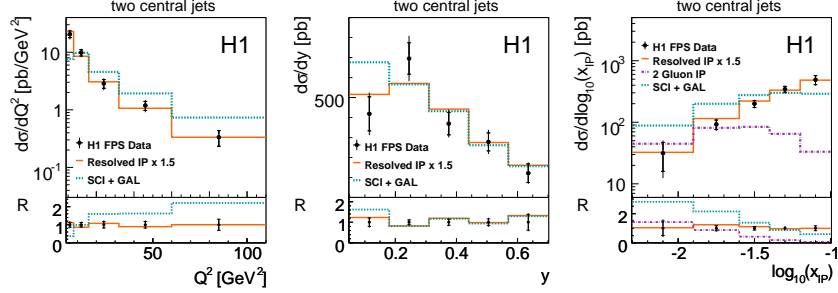[4] F. D. Aaron *et al.* [H1 Collaboration], Eur. Phys. J. **C 72** (2012) 1970 [arXiv:1111.0584].

Figure 2: The sinlge differential cross section for the production of two central jets shown as a function of Q^2, y and $\log(x_{I\!P})$ compared to the DPDF based RAPGAP, 2 gluon $I\!P$ RAPGAP and SCI LEPTO Monte Carlo Models.
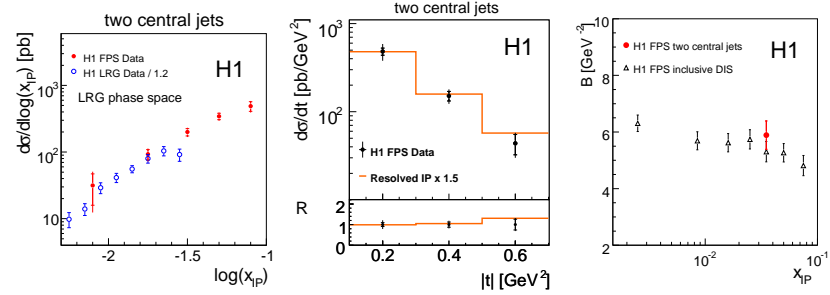

Figure 3: The comparison of the FPS and LRG method as a fuction of $\log(x_{I\!P})$ (left), the sinlge differential cross section for the production of two central jets shown as a function of t (middle) and comparison of the fitted B slope parameter in the inclusive (black open) and dijet (full red) diffractive measurements with tagged leading proton (right).
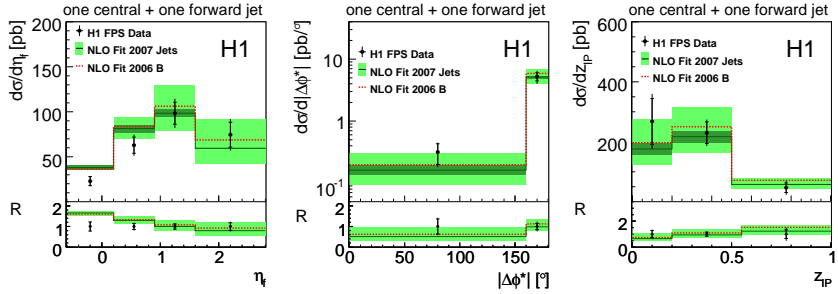

Figure 4: The sinlge differential cross section for the production of one central + one forward jet shown as a function of η_f^*, $|\Delta\phi^*|$ and $z_{I\!P}$ compared to the NLO QCD DGLAP predictions based on DPDFs H1 2007 Jets and H1 2006 Fit B.