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JETS AND E_t FLOW IN DIFFRACTION AT HERA*

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Recent measurements of diffractive multi-jet production and transverse energy flow in Deep-Inelastic Scattering (DIS) at HERA are presented. The data are used to investigate the factorisation properties of diffractive DIS and to examine its quantum chromodynamic (QCD) structure.

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1. Introduction

The study of energy flow and jet production in diffraction allows the nature of the strong interaction at high energy to be investigated. The aims of the measurements include testing QCD factorisation and, in processes where the transverse momentum $p_{\rm T}$ is large, the data can be compared with perturbative QCD calculations.

The kinematics of diffractive Deep Inelastic Scattering (DIS) at HERA ($ep \to eXp$) are illustrated in figure 1. A photon of virtuality Q^2, coupled to

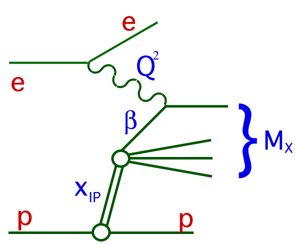

Fig. 1. Illustration of the kinematic variables used to describe diffractive DIS.

the electron, undergoes a strong interaction with the proton to form a final state hadronic system X (mass M_X) separated by a large rapidity gap from

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the leading proton. A fraction $x_{\mathbb{P}}$ of the proton longitudinal momentum is transferred to the system X. The virtual photon couples to a quark carrying a fraction β of the exchanged momentum. The squared four-momentum transfer at the proton vertex is denoted t.

2. The factorisable Pomeron model

The theorem of QCD hard scattering factorisation [1] in diffraction states that at fixed values of $x_{\mathbb{P}}$ and t diffractive parton density functions (PDFs) may be defined which evolve in x and Q^2 according to the DGLAP evolution equations. In addition to this proof it may be assumed that the $x_{\mathbb{P}}$ and t dependence factorises from the (β, Q^2) dependence and has a form described by a flux factor based on Regge phenomenology [2]. The diffractive PDFs can be obtained from fits to the diffractive structure function $F_2^{D(3)}(\beta, Q^2, x_{\mathbb{P}})$ [3]. The parton densities of the diffractive exchange are found to be dominated by gluons. These parton densities may be used in Monte Carlo programs to give predictions on the properties of the hadronic final state in diffraction.

3. Colour dipole models

An alternative approach in describing diffractive interactions is to consider, in the proton rest frame, the scattering of $q\bar{q}$ and $q\bar{q}g$ fluctuations of the virtual photon, as colour dipoles scattering off the proton target. The interaction of the dipole with the proton is described by the exchange of 2 gluons and the cross section is related to the gluon density within the proton. At large M_X the $q\bar{q}g$ contribution is expected to dominate. Colour dipole models include the "saturation" model [4] and the model of Ryskin [5]. In diffractive final states with high transverse momentum *e.g.* high p_{T} jets the data may be compared with perturbative calculations such as those performed by Bartels *et al.* [6].

4. Measurements of event topology

In figure 2 (left) the average p_{T}^2 is plotted as a function of $x_{\mathrm{F}} = p_{\mathrm{L}}/p_{\mathrm{L}}^{\mathrm{max}}$. In the figure, commonly referred to as the 'seagull distribution', it can be seen that there is an increasing asymmetry with M_X between the photon hemisphere (positive x_{F}) and the Pomeron hemisphere (negative x_{F}). This asymmetry is well described both by the resolved Pomeron model which incorporates a Pomeron remnant and by colour dipole models in which $q\bar{q}g$ final states are the dominant contribution at large M_X. Measurements of thrust, the thrust angle, sphericity and energy flow confirm this picture [7].

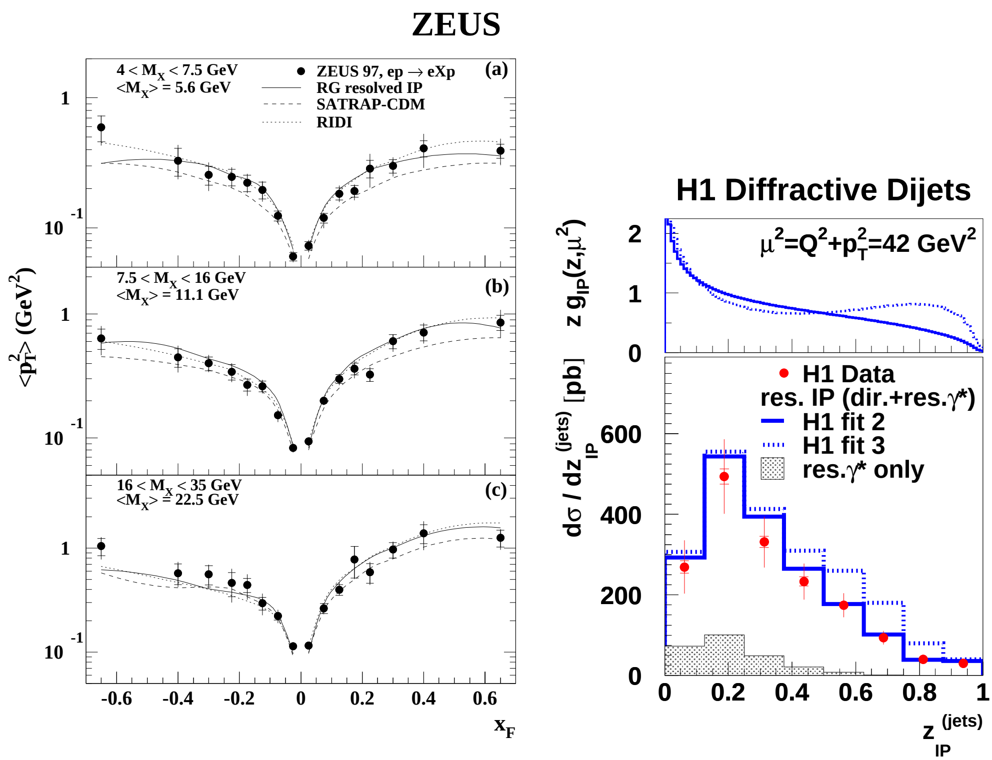

Fig. 2. (left) The 'seagull' distribution at three different values of M_X The data are compared with the resolved $\mathbb{P}$ and colour dipole models. (right) $z_{\mathbb{P}}$ in dijet events. The data are compared with different parton densities of the resolved Pomeron model.

5. Jet production

The measurement of high $p_{\rm T}$ jet production is sensitive to both the shape and the magnitude of the gluon distribution of the diffractive exchange. A hadron level estimate $z_{\mathbb{P}}^{\rm jets}$ of the partonic fraction of the Pomeron's momentum which couples with the virtual photon can be constructed from the final state. In figure 2(right) the resolved Pomeron model gives a good description of the shape and normalisation of the $z_{\mathbb{P}}$ distribution. In figure 3 the data are also compared with colour dipole models in the region of applicability($x_{\mathbb{P}} < 0.01$) as a function of Q^2, $p_{\rm T,\,jets}$, $z_{\mathbb{P}}^{\rm jets}$ and the $p_{\rm T}$ of the Pomeron remnant. The perturbative calculation of Bartels *et al.* [6] provides a better description than the "saturation" model [4] suggesting the importance of $k_{\rm T}$ ordering of the gluons and higher order QCD contributions in the modeling of jet data.

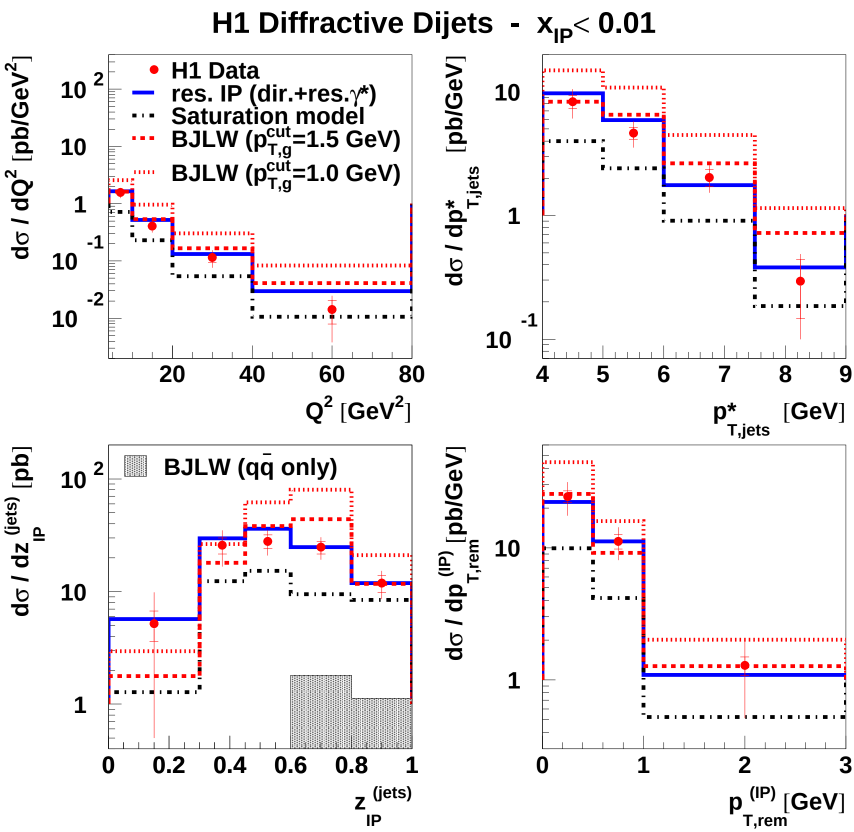

Fig. 3. The diffractive dijet cross section in the region $x_{\mathbb{P}} < 0.01$. The data are compared with resolved $\mathbb{P}$ and colour dipole models.

Higher order effects can be further investigated in the measurement of diffractive three jet production [8]. In figure 4(left) the differential jet shape of the most forward jet (the forward direction is defined as the $\mathbb{P}$ direction) and the most backward jet (the jet closest to the γ direction) are shown in diffractive three jet events. The jet in the $\mathbb{P}$ direction is observed to be broader than that in the γ direction. This is consistent with the Pomeron remnant jet being initiated by a gluon. In figure 4(right) the cross section for the most forward jet is shown as a function of p_{T}. The resolved Pomeron and the saturation model provide a better description of the data when the Colour Dipole Model, as opposed to parton showers, is used to model higher order effects. The colour dipole model of Ryskin(labeled RIDI) is unable to produce enough momentum to describe the $p_{\mathrm{T,\,jet}}$ distribution.

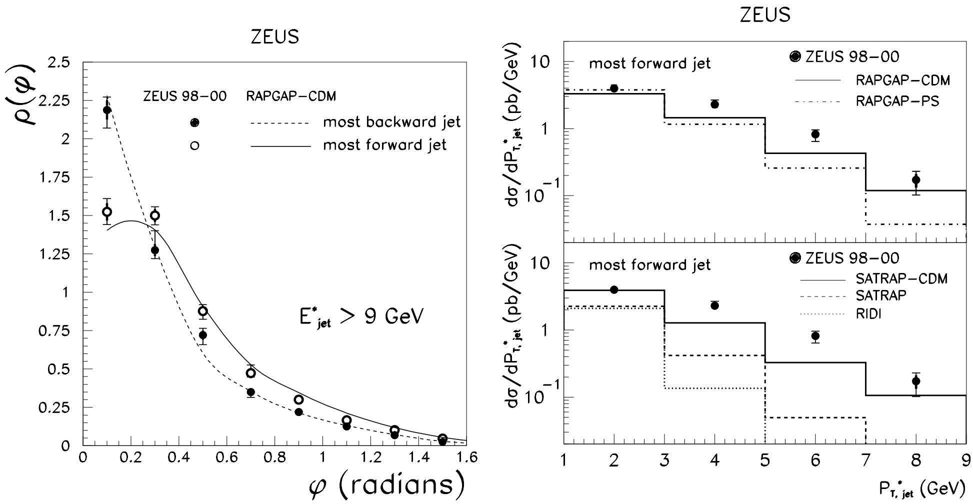

Fig. 4. (left) The differential jet shape of the most forward and backward jets in three jet events. (right) The transverse momentum of the most forward jet. The data are compared with the resolved Pomeron model and colour dipole models.

6. New QCD fits and the final state

The H1 Collaboration recently released new preliminary $F_2^{D(3)}$ data [9] based on a factor of 5 more luminosity than previous measurements. New LO and NLO QCD fits have been performed to this data [10] within the framework of the resolved Pomeron model. The fit constitutes the first evaluation of experimental and theoretical uncertainties of the diffractive parton density functions. When the new LO parton densities are compared with dijet data the shape continues to be well described but the normalisation is somewhat lower than that obtained from fits to earlier data. However, the fit remains consistent within the combined uncertainties of the model parameters, scales and PDFs.

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