RECENT RESULTS IN DIFFRACTIVE *ep* SCATTERING AT HERA

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Recent diffractive results from the H1 and ZEUS experiments and their comparisons to pQCD models are presented. In particular results on inclusive diffraction as well as exclusive final states such as the diffractive production of D^* mesons, dijets and vector mesons are discussed.

1. Introduction

Deep inelastic diffractive scattering at HERA, the process $ep \to eXY$ where the final state systems X and Y are well separated in rapidity, provides a unique probe of the diffractive interaction and its interpretation within QCD. For the inclusive process, a hard scale is present when the virtuality of the exchanged photon, Q^2, is large - this is also the case for Deeply Virtual Compton Scattering (DVCS), $ep \to ep\gamma$. Diffractive vector meson production, $ep \to eVY$, may also provide a hard scale from a large vector meson mass or large four-momentum transfer at the the proton vertex, $|t|$. When such hard scales are present the data may be interpreted within perturbative QCD (pQCD).

2. Inclusive Diffraction

The inclusive diffractive DIS cross section may be defined as

$$\frac{d^3\sigma^{ep\to eXY}}{dx_{I\!P}\,d\beta\,dQ^2} = \frac{4\pi\alpha^2}{\beta Q^4}\left(1 - y + \frac{y^2}{2}\right)\sigma_r^{D(3)}(x_{I\!P}, \beta, Q^2), \tag{1}$$

*On behalf of the H1 and ZEUS collaborations where t is integrated over, as the proton system Y is usually not detected. The reduced diffractive cross section, $\sigma_r^{D(3)}$, is expressed in terms of the diffractive and longitudinal diffractive structure functions, $F_2^{D(3)}(x_{I\!P}, \beta, Q^2)$ and $F_L^{D(3)}(x_{I\!P}, \beta, Q^2)$ respectively, as

$$\sigma_r^{D(3)} = F_2^{D(3)} - \frac{y^2}{1+(1-y)^2} F_L^{D(3)}, \tag{2}$$

such that $\sigma_r^{D(3)} \sim F_2^{D(3)}$ at all but large values of y. QCD hard scattering factorisation states that the reduced cross section can be expressed in terms of a product of diffractive parton density functions (DPDFs), f_i^D, and partonic hard scattering matrix elements, $\sigma^{\gamma^* i}$, as $\sigma_r^{D(3)} \sim \sum \sigma^{\gamma^* i} \otimes f_i^D$.

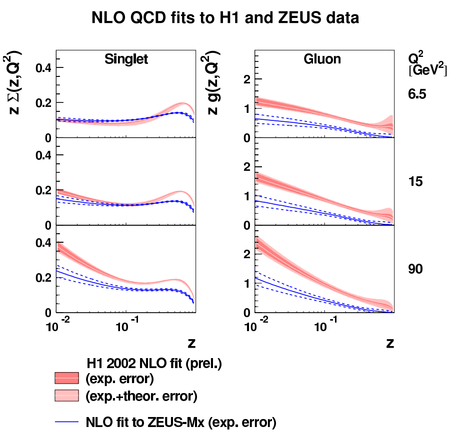

Figure 1. Diffractive quark singlet and gluon PDFs, as obtained from NLO DGLAP fits to the H1-LRG and ZEUS-M_X data.

Results have been released recently on inclusive diffraction by both the H1 and ZEUS collaborations. These each use one of three methods to identify diffractive events - by demanding a large rapidity gap (LRG) between the two hadronic systems in the final state, by using the distribution of events in the mass of the X system, M_X, or by tagging the proton system in Roman Pot detectors within the HERA beampipe.

A recent analysis[1] for the HERA-LHC workshop has extracted DPDFs by applying the same approach as used for the H1-2002-prelim NLO QCD fit (made to the H1 LRG data) to the inclusive diffractive data from ZEUS (using the M_X method). Figure 1 shows that while the singlet distributions agree reasonably at low Q^2, differences occur at larger Q^2. The gluon distribution from the ZEUS data is seen to be significantly smaller than that from H1. Both of these observations follow from the fits reflecting the different Q^2 dependences of the H1 LRG and ZEUS M_X data.

3. Diffractive Dijet and D^* Production

The universality of the DPDFs extracted from inclusive diffractive data, and hence factorisation in diffraction, may be tested by comparison to exclusive diffractive processes. Of particular interest are the diffractive production of dijets and D^* mesons, as these processes are directly sensitive to the gluon component of the diffractive exchange - the dominant contribution to the DPDFs.

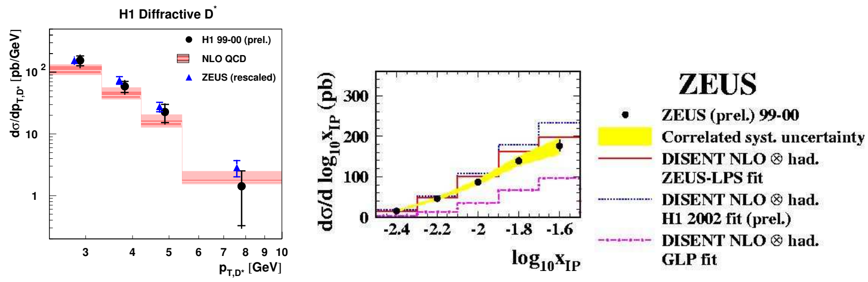

Figure 2. Diffractive production of D^* mesons (a), and dijets (b) in photoproduction

Figure 2a shows the differential cross section for diffractive D^* production in DIS[2] as a function of transverse momentum p_{T,D^*}. The ZEUS data are extrapolated to the H1 kinematic range for comparison. Both measurements agree and are described by the NLO QCD prediction using the H1 DPDFs. The differential cross section for diffractive dijets in DIS[3] as a function of $x_{I\!P}$ (Fig. 2b) is described reasonably by the predictions from both the H1 2002 fit and the ZEUS-LPS (Leading Proton Spectrometer) fit. However the prediction from the ZEUS GLP fit (using the M_X method) lies below the data. The description of the diffractive dijet and D^* cross sections by some of the DPDFs may show that factorisation holds in DIS. However, the differences between the DPDF predictions show that further understanding is needed. In particular, including diffractive dijet data in the DPDF fits will help to further constrain the diffractive gluon density.

Figure 3 shows the differential cross section for diffractive photoproduction of dijets[4] as a function of x_γ^{jets}, which, in a leading order approach, estimates the fractional momentum of the partons from the photon that enter the hard subprocess. The new prediction using the H1 2002 NLO DPDFs lies above the data. Figure 3a shows that when only the resolved photon is suppressed ($x_\gamma^{jets} < 0.9$) the H1 2002 NLO fit is unable to describe the data. However, Fig.3b shows the data are described by the H1 2002 NLO fit when scaled by a factor of 0.5. Figure 3c shows the differential cross section for diffractive photoproduction of D^* mesons[5] as a function

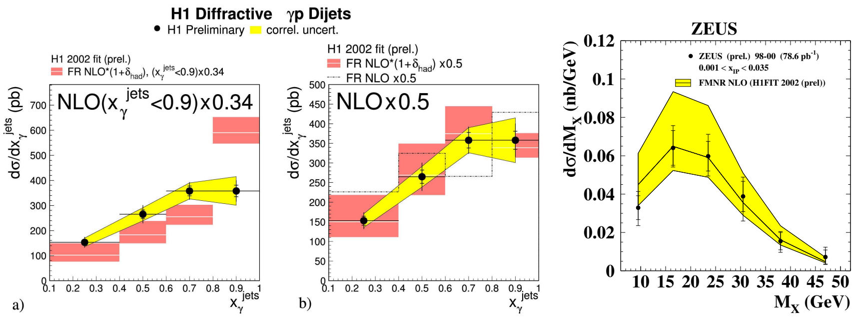

Figure 3. Diffractive production of dijets (a), (b) and D^* mesons (c) in photoproduction

of M_X, where this process is dominated by direct interactions. The data are described by the DPDFs from the H1 fit 2002, but within a large error band. That diffractive photoproduction of D^* mesons is described may suggest that factorisation also holds in direct photoproduction. However, the diffractive photoproduction of dijets is described by a global suppression, rather than by only a suppression due to the hadronic interaction of the photon, suggesting that factorisation is broken. Again, a better understanding of the DPDFs is need before firm conclusions are made.

4. Diffractive Vector Meson Production and DVCS

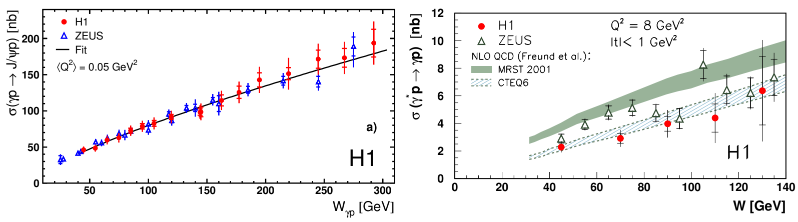

Figure 4. Elastic diffractive J/Ψ production (a) and (b) DVCS

Figure 4a shows the cross section for diffractive elastic J/Ψ photoproduction[6] as a function of the photon-proton centre of mass energy, W. The steep rise for all W, seen at both high and low Q^2, shows the importance of the vector meson mass as a hard scale. A steep rise with W is also seen in the W dependence of the DVCS cross section[7] (Fig. 4b).

Here the only hard scale present is Q^2. The steep rises with W for both cross sections show the sensitivity of diffractive vector meson and DVCS measurements to the gluon PDFs of the proton. For instance, Fig. 4b shows the sensitivity of an NLO prediction to inputs from two generalised parton densities derived from different input PDFs.

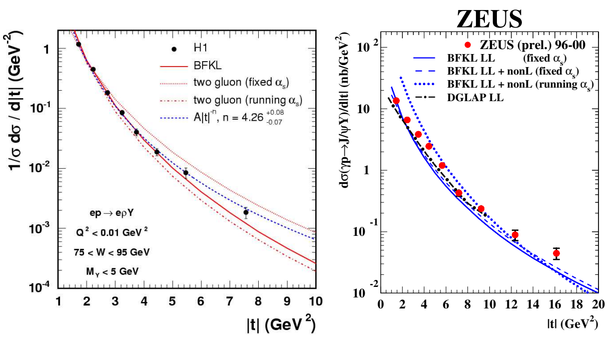

Figure 5. Diffractive photoproduction of (a) ρ and (b) J/Ψ mesons at high $|t|$.

New measurements of the diffractive photoproduction of ρ mesons[8] and J/Ψ mesons[9] at large momentum transfer (high $|t|$) confirm that $|t|$ can provide a hard scale at which to probe the diffractive exchange with vector mesons. The $|t|$ dependence of the diffractive photoproduction of high $|t|$ ρ (Fig. 5a) and J/Ψ (Fig. 5b) mesons are reasonably described by different BFKL models. However, two gluon models give a worse description of the ρ data and the J/Ψ data can only be described by the DGLAP model in the range of validity ($|t| < M_{J/\Psi}$).

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