INCLUSIVE DIFFRACTION AT HERA

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The H1 and ZEUS Collaborations have measured the inclusive diffractive DIS cross section $ep \to eXp$ with very high precision across a wide kinematic range. Diffractive parton density functions (DPDFs) have been extracted from the data using the DGLAP approach at next-to-leading-order (NLO) of perturbative QCD. Results from diffractive dijets in DIS have also been included in the fit. The first direct measurement of the longitudinal diffractive structure function F_L^D has been compared to the DPDF predictions. Finally, the DPDF predictions have been compared to data on diffractive dijets in photoproduction, where the issue of absorption and gap survival probability in a hadron-hadron environment can be studied.

1 Introduction

Diffractive processes have been studied extensively in deep-inelastic electron-proton scattering (DIS) at the HERA collider. Such interactions are characterised by the presence of a leading proton in the final state carrying most of the initial energy and by the presence of a large gap in rapidity between the proton and the rest of the hadronic system. The kinematic variables used to describe inclusive DIS, $ep \to eX$, are the virtuality of the exchanged boson, Q^2, the Bjorken scaling variable, x, and the inelasticity, y. In addition, the kinematic variables $x_{I\!P}$ and β are specific for diffractive DIS, $ep \to eXp$, with $x_{I\!P}$ the longitudinal fractional momentum of the proton carried by the diffractive exchange and β the longitudinal momentum fraction of the struck parton with respect to the diffractive exchange. They are related by $x = x_{I\!P}\beta$. The inclusive diffractive DIS cross section is usually presented in the form of a diffractive reduced cross section, $\sigma_r^{D(3)}$, integrated over the Mandelstam t variable, here representing the squared four-momentum transferred at the proton vertex, and is related to the experimentally measured differential cross section by

$$\frac{d^3\sigma^{ep\to eXp}}{dx_{I\!P}d\beta dQ^2} = \frac{2\pi\alpha^2}{\beta Q^2} Y_+ \sigma_r^{D(3)}(x_{I\!P},\beta,Q^2) \ , \tag{1}$$

where $Y_+ = 1 + (1-y)^2$. The reduced cross section depends at moderate Q^2 on two diffractive structure functions, $F_2^{D(3)}$ and $F_L^{D(3)}$, according to

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

For y not too close to unity, $\sigma_r^{D(3)} = F_2^{D(3)}$ holds to very good approximation.

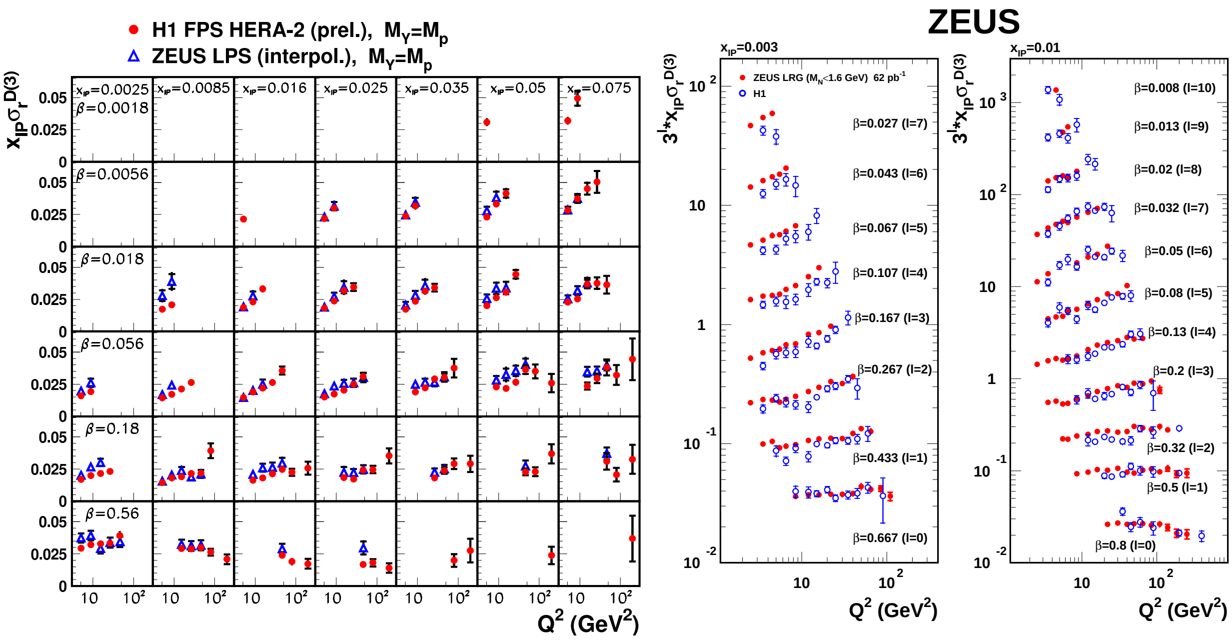

Figure 1: Comparison between the H1 and ZEUS measurements of the diffractive reduced cross section as a function of Q^2, obtained using PS (*left*) or LRG (*right*) samples.

2 Diffractive Cross Section Measurements

Experimentally, diffractive DIS events can be selected by requiring the presence of a large rapidity gap (LRG). A complementary way is the direct measurement of the outgoing proton by using Proton Spectrometers (PS). Whilst the LRG-based techniques yield better statistics than the PS method, they suffer from systematic uncertainties associated with background events due to proton dissociation.

The H1 Collaboration recently released a preliminary proton-tagged measurement using its full available sample from Forward Proton Spectrometer (FPS) data at HERA-II [1]. The measurement agrees in shape and normalization with the previous H1 FPS results from HERA-I [2] and considerably improves the statistical uncertainty and the kinematical coverage, being based on a factor 20 more integrated luminosity than the HERA-I measurement. As shown in Figure 1 (*left*), the new data agree in shape with the recently published final ZEUS results based on Leading Proton Spectrometer (LPS) data from HERA-I [3], but they tend to lie slightly below, still within the combined normalization uncertainty of about 13%.

The recently published ZEUS measurements [3], obtained using the LRG method, substantially improved the statistical precision compared with the older H1 results [4]. Good agreement is observed between the shapes of the H1 and ZEUS cross sections throughout most of the phase space studied, as shown in Figure 1 (*right*). An average 13% normalization difference between the two experiments has been estimated, compatible with the one seen from PS measurements, i.e. the cross sections agree up to a normalization difference between the two Collaborations, independent of experimental method.

3 Diffractive Parton Density Functions

It has been shown by Collins [5] that the NC diffractive DIS process $ep \rightarrow eXp$ factorises into diffractive parton density functions (DPDFs) times a term related to the hard-scattering partonic cross section; a useful additional assumption (proton vertex factorisation) is often made

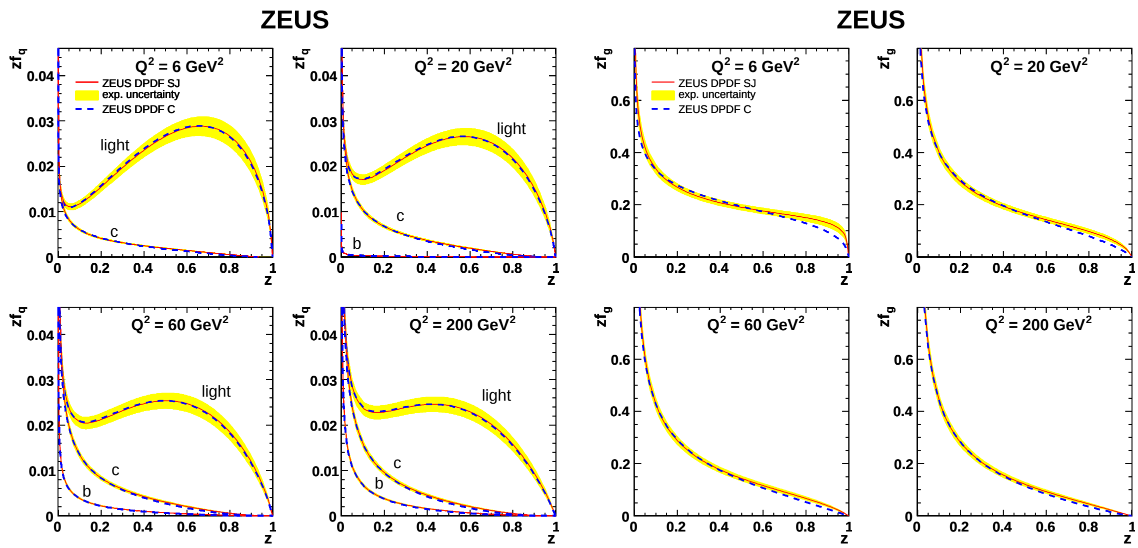

Figure 2: ZEUS singlet (*left*) and gluon (*right*) densities as a function of the momentum fraction, z, for four different values of Q^2. The shaded error bands represent the experimental uncertainty.

whereby the proton vertex dynamics factorise from the vertex of the hard scatter. The β and Q^2 dependences of $\sigma_r^{D(3)}$ may then be subjected to a perturbative QCD analysis based on the DGLAP equations, in order to obtain diffractive PDFs. Whilst F_2^D directly measures the quark density, the gluon density is only indirectly constrained via the scaling violation, $\partial F_2^D/\partial lnQ^2$.

The high statistics ZEUS LRG and LPS data[3] have recently been fitted to extract DPDFs[6]. The method and DPDF parametrisations are similar to the earlier H1 analysis[4], the main difference being in the heavy flavour treatment, which now follows the general mass flavour numbering scheme. In the resulting DPDFs the quark densities are relatively well known throughout the phase space, whilst the theoretical uncertainties on the gluon density are large, in particular at high fractional momentum, z. Indeed, in this region the dominant parton splitting is $q \to qg$ and the sensitivity of $\partial F_2^D/\partial lnQ^2$ to the gluon density becomes poor. Improved large z constraint has been obtained by including in the fit diffractive dijet production data[7], which are directly sensitive to gluons via the boson-gluon fusion process. The resulting quark and gluon densities are presented in Figure 2, showing a comparable precision across the whole z range.

4 The Longitudinal Diffractive Structure Function

At low x and Q^2, the longitudinal diffractive structure function, F_L^D, is closely related to the diffractive gluon density and can thus provide a test of diffractive factorization and of the role of gluons complementarily to jet and charm data. Measurements of F_L^D became possible thanks to the reduced proton beam energy runs at the end of HERA operation.

The H1 Collaboration recently released preliminary F_L^D data[8], shown in Figure 3. When integrated over β, F_L^D is non-zero at 3σ level. It is also clearly incompatible with its maximum possible value, that of F_2^D. The measured F_L^D is in agreement with predictions based on H1 DPDFs[4].

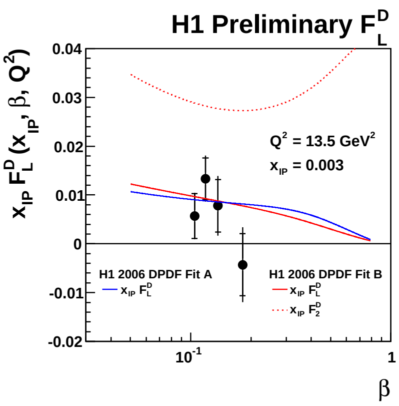

Figure 3: First F_L^D measurement, compared with DPDF predictions.

5 Diffractive Dijets in Photoproduction

DPDFs extracted from inclusive data describe successfully data on dijet in DIS [7,9] and charm [10,11] production. However, predictions obtained with HERA DPDFs grossly overshoot the diffractive dijet cross section at the Tevatron. At HERA, photoproduction events, where $Q^2 \sim 0$, provides an environment similar to a hadron-hadron collider, since the photon can develop an effective partonic structure via $\gamma \to q\bar{q}$ fluctuations and further subsequent splitting. In a simple leading order picture, there are thus two classes of hard photoproduction: 'resolved' interactions, where the photon interacts via its partonic structure, and 'direct' interactions, where the photon behaves as a point-like particle. The variable x_γ is the fraction of the four-momentum of the photon transferred to the hard interaction; the lower the value of x_γ the more hadron-like the photon.

Both H1 [12] and ZEUS [13] have measured diffractive dijets in photoproduction. The ratios of data to theory obtained by both experiments show no dependence on x_γ, which is in constrast with theoretical expectations [14,15]. The data are also suggestive of a weak suppression depending on the transverse energy, E_T, of the jet. More differential studies are required to fully unfold the dynamics.

6 Conclusions

The H1 and ZEUS Collaborations are finalising measurements of the inclusive diffractive DIS cross section, $ep \to eXp$, with the full statistics available from HERA. The DPDFs extracted from NLO QCD fits to inclusive and dijets data result in quark and gluon densities constrained with good precision across the whole kinematic range. The first F_L^D measurement, in agreement with DPDF predictions, provides a unique test of factorization. Comparing the DPDF predictions with diffractive dijets in photoproduction data shows evidence of a small suppression of the cross section which is independent on x_γ and slightly dependent on E_T of the jet, a fact which remains under investigation.

References

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