Diffractive Deep-Inelastic Scattering with a Leading Proton at HERA-2 H1 FPS Data

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Abstract. The new measurement of the cross section for diffractive deep-inelastic scattering process $ep \to eXp$ with the leading final state proton detected in the H1 Forward Proton Spectrometer is presented using data collected at HERA-2 in the 2005-2007 years. The data are compared to QCD predictions at next-to-leading order based on diffractive parton distribution functions previously extracted from measurements of inclusive diffractive deep-inelastic scattering with a large gap in the rapidity distribution of the final state hadrons.

1. Introduction

The understanding at fundamental level of diffractive processes such as $ep \to eXp$ in deep-inelastic electron-proton scattering (DIS) is crucial for the development of quantum chromodynamics (QCD) at high parton densities. In a number of previous analyses, including [1], diffractive DIS events were selected on the basis of the presence of a large rapidity gap (LRG) between the leading proton and the remainder of the hadronic final state X. A complementary way to study diffractive processes is by direct measurement of the outgoing proton using Forward Proton Spectrometer (FPS) [2]. The FPS method of studying diffraction has several advantages over the LRG method, although the FPS acceptance is low. In contrast to the LRG case, the squared four-momentum transfer at the proton vertex t can be reconstructed. The FPS method also selects events in which the proton scatters elastically, whereas the LRG method does not distinguish the elastic case from dissociation to excited systems Y with small masses M_Y . The FPS also allows measurements up to higher values of the fractional proton longitudinal momentum loss x_{IP} than is possible with the LRG method, extending into regions where the sub-leading trajectory is the dominant exchange. Together, the FPS and LRG data thus provide a means of testing in detail whether the variables x_{IP}, t and M_Y associated with the proton vertex can be factorized from the variables $\beta = x/x_{IP}$ and Q^2 describing the hard interaction with the photon. Here β is the longitudinal momentum fraction of the colour singlet carried by the struck quark, x is the Bjorken scaling variable and Q^2 is the photon virtuality.

2.Results

A new measurement of the reduced cross section σ_r^D for the diffractive DIS process $ep \to eXp$ is presented, using the FPS data collected with the H1 detector at HERA-2. The σ_r^D is related to the diffractive structure functions F_2^D and F_L^D by:

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

where y is the inelasticity. Thus $\sigma_r^D \cong F_2^D$ is a good approximation except at the highest y. The analyzed data sample corresponds to an integrated luminosity of 156 pb^{-1}. The data cover the range $x_{IP} < 0.1$, $4 < Q^2 < 700 GeV^2$ and $0.001 < \beta < 1$. The FPS HERA-2 measurements extend the kinematic range to higher Q^2. The diffractive reduced cross section $\sigma_r^{D(3)}$ is measured differentially in x_{IP}, β and Q^2. The data are integrated over the range $|t| < 1 GeV^2$ which is the region covered by H1 using the LRG method [1]. The measurement of $x_{IP}\sigma_r^{D(3)}$ is presented in Fig.1 as a function of β for selected values of x_{IP} and Q^2.

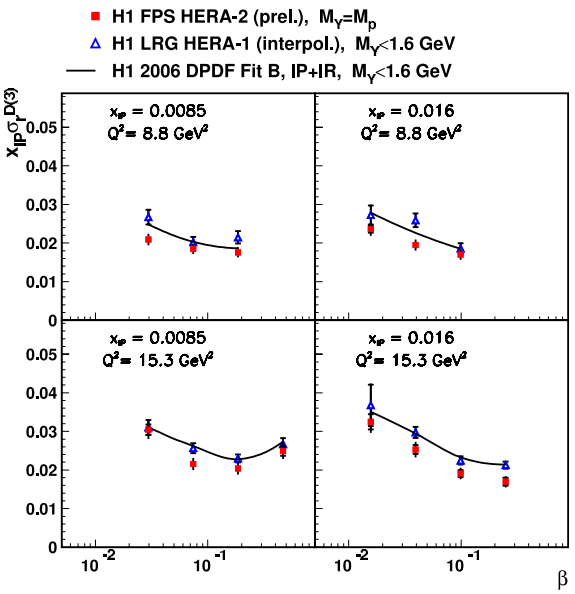

Figure 1: The diffractive reduced cross section, shown as a function of β for selected values of Q^2 and x_{IP}. The H1 FPS data are compared to the H1 LRG results [1]. The solid curves represent the results of the 'H1 2006 DPDF Fit B' to the LRG data [1].

The data are compared to the H1 LRG data interpolated to the FPS β, Q^2 and x_{IP} values. Predictions derived from the 'H1 2006 DPDF (Diffractive Parton Distribution Function) Fit B' [1] performed to the H1 LRG data in the framework of NLO (next-to-leading order) DGLAP (*Dokshitzer-Gribov-Lipatov-Altarelli-Parisi*) evolution are also shown. The statistical precision of the FPS measurement

reached that of the published H1 LRG data. The difference in the normalization is attributed to the proton dissociation contribution to the LRG sample. The FPS HERA-2 data are measured with an averaged systematic uncertainty of 8% and a normalization uncertainty of 6%, $\sigma_r^{D(3)}$ is decreasing with β over most of the measured kinematic range, but rises at high β and low Q^2 and x_{IP}. Within the framework of DPDFs, this can be explained by the shape of diffractive quark densities [1].

The FPS data are compared directly to the LRG measurement in order to test the compatibility between the results obtained with the two measurement techniques and to quantify the proton dissociation contribution to the LRG data. The diffractive cross section measured with the LRG data is defined to include proton dissociation to any system Y with a mass in the range M_Y <1.6 GeV, whereas Y is defined to be a proton in the cross section measured with the FPS. The LRG results are interpolated to the Q^2, β, and x_{IP} bin center values of the FPS data using a parameterization of the 'H1 2006 DPDF Fit B'. Since the two data sets are statistically independent and the dominant sources of systematic errors are very different, correlations between the uncertainties on the FPS and LRG data are neglected.

The ratio of the LRG to the FPS cross section is plotted in Fig.2 as a function of Q^2, β, and x_{IP} , after averaging over the other kinematic variables. The combined normalization error is 8.5 % within the remaining uncertainties of typically 6% per data point. No significant dependence of the ratio on Q^2, β or x_{IP} is observed.

The ratio of overall normalizations, LRG/FPS, is $\sigma(M_Y < 1.6GeV)/\sigma(Y = p) = 1.18 \pm 0.01(\text{stat.}) \pm 0.06(\text{syst.}) \pm 0.10(\text{norm.})$ the dominant uncertainties arising from the normalizations of the FPS and LRG data. This result is in agreement within the uncertainties with the value of $1.23 \pm 0.03(\text{stat.}) \pm 0.16(\text{syst.})$ obtained from comparison of the H1 LRG and FPS data at HERA-1 [2].

3. Conclusions

The good agreement, after accounting for proton dissociation, between the LRG and the FPS data confirms that the two measurement methods lead to compatible results, despite having very different systematics. The lack of a strong kinematic dependence of the ratio of the two cross sections shows, within uncertainties, that proton dissociation with M_Y <1.6 GeV can be treated similarly to the elastic proton case. This supports the factorization in terms of M_Y, for both the pomeron and the sub-leading exchange contributions, of processes occurring at the proton vertex from those describing the hard interaction. It also confirms that contributions from proton dissociation in the LRG measurement do not significantly alter the measured Q^2, β or x_{IP} dependences and hence cannot have a large influence on the diffractive gluon density or other information extracted from the LRG data. The results have been presented at H1 meetings at DESY (Hamburg) during the 2008 and 2009 years and at the DIS2009, XVII International Workshop on Deep Inelastic Scattering (Madrid, April 2009).

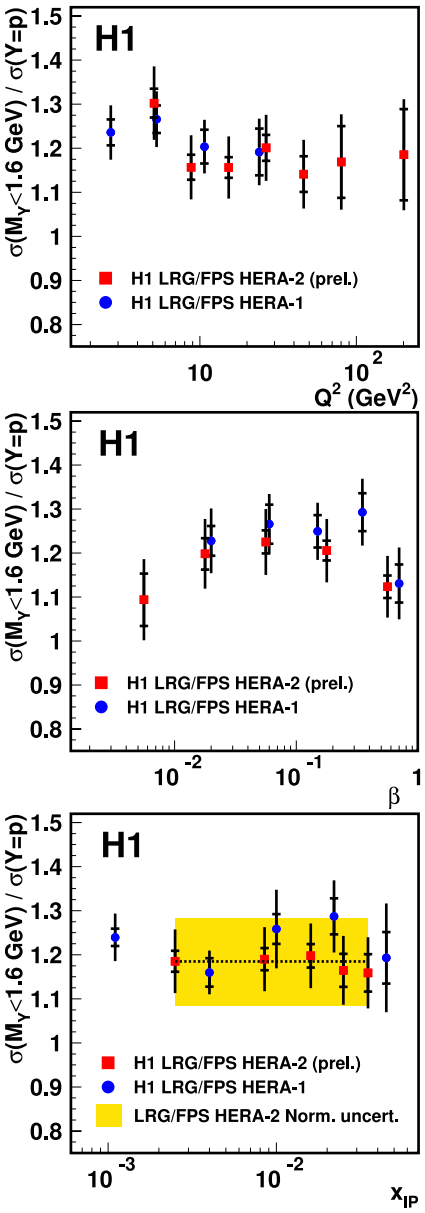

Figure 2: The ratio of the diffractive cross section for M_Y <1.6 GeV and $|t|$ <1 GeV^2 to that for $\boldsymbol{Y = p}$ obtained from $\sigma_r^{D(3)}$ measurements using the H1 LRG data [1] and the FPS data at HERA-1 [2] and HERA-2. The results are shown as a function of Q^2, β and x_{IP}, after averaging over two other variables. Normalization uncertainty of 8.5% is shown on the down picture. The dash line represents the result of a fit to the data assuming no dependence on x_{IP}.

References

[1] H1 Collaboration, Eur. Phys. J. C 48 (2006) 715.
[2] H1 Collaboration, Eur. Phys. J. C 48 (2006) 749.