DIFFRACTIVE CROSS SECTIONS AND PARTON DENSITIES FROM RAPIDITY GAP AND LEADING PROTON MEASUREMENTS

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Highlights are presented from two recent measurements of the total diffractive DIS cross section at HERA. In the first, the process $ep \to eXp$ is studied by tagging the leading final state proton. In the second, events of this type are selected by requiring a large gap in the rapidity distribution of the final state hadrons. The two measurements are compared in detail and the kinematic dependences are interpreted in the framework of a factorisable diffractive exchange. A set of diffractive parton distribution functions corresponding to this exchange is obtained, which may be applied to the prediction of other diffractive DIS processes.

1. Introduction

This report summarises two recent H1 publications on measurements of the cross section for diffactive deep-inelastic scattering and associated phenomenology, which cover an unprecedented kinematic range up to $Q^2 = 1600$ GeV^2 with unprecedented precision (5% statistical, 5% systematic and 6% normalisation errors in the best-measured region). In the first paper[1], the Forward Proton Spectrometer (FPS) is used to detect and measure the four-momentum of the outgoing proton in the process $ep \to eXp$. This selection method has the advantages that the proton unambiguously scatters elastically and that the squared four-momentum transfer at the proton vertex t can be reconstructed. However, the available statistics are limited by the FPS acceptance. A higher statistics sample of diffractive DIS events[2] is selected on the basis of a large rapidity gap (LRG) in the outgoing proton direction. The measured process is $ep \to eXY$ where Y corresponds to any leading baryonic state with mass $M_Y < 1.6$ GeV.

Together, the FPS and LRG data provide a means of studying inclusive diffraction as a function of all relevant kinematic variables. In addition to t and the usual DIS variables x and Q^2, measurements are made as a function of the fractional proton longitudinal momentum loss $x_{I\!P}$ and of $\beta = x/x_{I\!P}$, which corresponds to the fraction of the exchanged longitudinal momentum which is carried by the quark coupling to the virtual photon.

The data exhibit a remarkable consistency with 'proton vertex' factorisation[3], whereby the dependences on the variables $x_{I\!P}$, t and M_Y describing the proton vertex are completely independent of the variables β and Q^2, which describe the hard interaction with the photon. The dependences on $x_{I\!P}$ and t can then be expressed in terms of an 'effective pomeron flux' of colourless exchange, whilst the β and Q^2 dependences can be interpreted in terms of Diffractive Parton Distribution Functions (DPDFs), which describe the partonic structure of that exchange[4].

Only a short commentary on a few highlights is possible in the space available here. Much more detail, including the cross section measurements themselves, can be found in[1,2]. The first charged current diffractive measurement is also presented in [2], but is not covered here.

2. Comparison between Data Sets

Since the LRG and FPS data sets are statistically independent and have very different systematics, the two measurements constitute a powerful mutual cross-check. Compatibility between them is established in detail in [1], where it is shown that there is no significant dependence of the ratio of the two cross section measurements on β, Q^2 or $x_{I\!P}$. The ratio of overall normalisations, LRG / FPS, is $\sigma(M_Y < 1.6$ GeV$)$ / $\sigma(Y = p) = 1.23 \pm 0.03$ (stat.) $\pm$ 0.16 (syst.), consistent with predictions for the proton-elastic cross section and the proton dissociation cross section with $M_Y < 1.6$ GeV[1]. The FPS data are also consistent with the corresponding measurement obtained with the ZEUS Leading Proton Spectrometer[5].

3. Dependences on $x_{I\!P}$ and t: the diffractive flux factor

The t dependences of diffractive cross sections are commonly parameterised with an exponential, $\mathrm{d}\sigma/\mathrm{d}t \propto e^{Bt}$. Fits of this form to the FPS data at low $x_{I\!P}$ are compatible with a constant slope parameter, $B \simeq 6$ GeV^2. In a Regge approach with a single linear exchanged pomeron trajectory, $\alpha_{I\!P}(t) = \alpha_{I\!P}(0) + \alpha'_{I\!P} t$, the slope parameter decreases with increasing $x_{I\!P}$ according to $B = B_0 - 2\alpha'_{I\!P} \ln x_{I\!P}$. The low $x_{I\!P}$ data thus favour a small value of $\alpha'_{I\!P} \simeq 0.06$ GeV^{-2}, though $\alpha'_{I\!P} \simeq 0.25$, as obtained from soft hadronic interactions, cannot be excluded.

The $x_{I\!P}$ dependences of both measurements are interpreted in terms of effective pomeron intercepts. The two results are consistent, the more precise value of $\alpha_{I\!P}(0) = 1.118 \pm 0.008$ (exp.) $^{+0.029}_{-0.010}$ (model) coming from the LRG data. The dominant error arises from the strong positive correlation between $\alpha_{I\!P}(0)$ and $\alpha'_{I\!P}$, such that $\alpha_{I\!P}(0)$ increases to around 1.15 if $\alpha'_{I\!P}$ is set to 0.25 GeV^{-2} rather than 0.06 GeV^{-2}. The extracted $\alpha_{I\!P}(0)$ is slightly higher than the 'soft pomeron' value of $\alpha_{I\!P}(0) \simeq 1.08$, from long distance hadronic interactions.

The values of both $\alpha_{I\!P}(0)$ and $\alpha'_{I\!P}$ describing diffractive DIS are compatible with the results obtained for soft exclusive photoproduction of ρ^0 mesons[6]. This similarity supports the picture of diffractive DIS as probing the structure of a 'soft' pomeron. 'Hard' perturbative 2-gluon exchange contributions[7] are likely to be small, as is also suggested by the lack of a strong signal for exclusive dijet production in diffractive DIS[8].

Further analysis in which either the slope B or the intercept $\alpha_{I\!P}(0)$ is allowed to vary with β or Q^2 shows no significant dependences, confirming the validity of proton vertex factorisation for the present data. This contrasts with the Q^2 dependent effective pomeron intercept extracted in a Regge approach to inclusive low x proton structure function data, as studied in detail via the ratio of diffractive to inclusive cross sections in[2].

4. Dependences on β and Q^2: diffractive parton densities

In[2], the cross section is presented differentially in β, Q^2 and $x_{I\!P}$. After dividing out the $x_{I\!P}$ dependence using a flux factor with parameters obtained as described in section 3, the results from different $x_{I\!P}$ values are compatible, as expected where proton vertex factorisation holds.

The β and Q^2 dependences of the data are interpreted in a NLO DGLAP QCD fit[2] in order to extract DPDFs. For the first time, experimental and theoretical uncertainties are evaluated for these partons. The results are shown in figure 1. The singlet quark density is very closely related to the measured diffractive cross section and is thus well constrained, with a typical error of 5%. According to the DGLAP evolution equations, the derivative of the cross section with respect to $\ln Q^2$ contains contributions due to the splittings $g \to q\bar{q}$ and $q \to qg$, convoluted with the diffractive gluon and quark densities, respectively. The Q^2 evolution is driven almost entirely by the gluon density up to $\beta \simeq 0.3$. The relatively strong dependence on $\ln Q^2$ in this region can thus be attributed to a large gluonic component in the DPDFs. For $\beta \gtrsim 0.3$, the contribution to the Q^2 evolution from quark splittings $q \to qg$ becomes increasingly important and the inclusive cross section becomes correspondingly less sensitive to the gluon density. The diffractive gluon density is thus determined to around 15% at low β, with an uncertainty that grows quickly for $\beta \gtrsim 0.3$. The DPDFs in figure 1 provide important input to the understanding of less inclusive diffractive measurements such as those involving jets and charm[8], which may also provide important additional constraints on the gluon at high β.

Integrated over β, the gluon density carries around 70% of the total momentum. A similar fraction of the total proton momentum is carried by the inclusive gluon density in the low x region where valence quark effects are small. This similarity of the ratio of quarks to gluons in the DPDFs and the inclusive proton parton densities is reflected[2] in a ratio of the two cross sections which, to good approximation, is flat as a function of Q^2 at fixed x and $x_{I\!P}$.

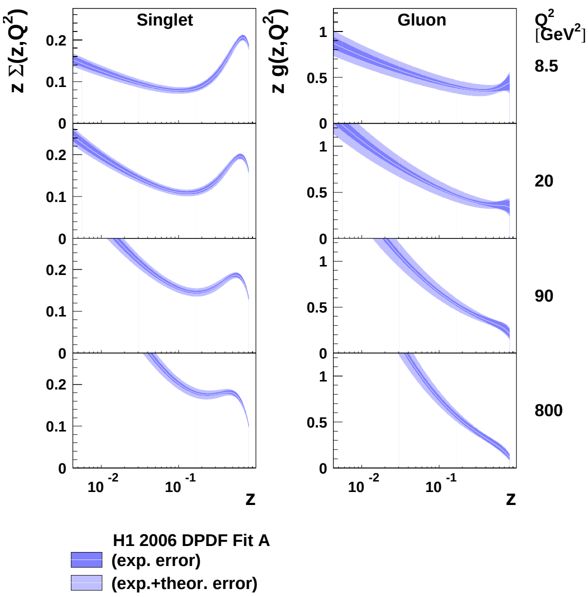

Figure 1. The total quark singlet and gluon distributions from the NLO QCD 'H1 2006 DPDF Fit A', as a function of the momentum fraction z carried by the relevant parton.

References

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