DIFFRACTION IN *ep* COLLISIONS

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Recent measurements of the diffractive deep-inelastic cross section are used to extract diffractive parton densities of the proton. These are subsequently applied in models to predict the production of jets and open charm in the final state. A rapidity gap suppression factor for dijet production in diffractive photoproduction relative to diffractive deep-inelastic scattering is obtained using a model-independent comparison.

1 Introduction

The measurement of diffractive processes in deep-inelastic scattering (DIS), characterized by the presence of a large rapidity gap in the final state, has been used to extract so-called diffractive parton densities of the proton. According to [1], this is a valid procedure, since the QCD hard scattering factorization theorem should also hold for diffractive *ep* collisions, yielding parton density functions that are conditional on the presence of a proton with fixed four-momentum in the final state. It has also been pointed out, however, that using these conditional parton densities to predict jet rates in $p\overline{p}$ collisions, leads to an overestimation of the cross section by an order of magnitude [2]. This breaking of factorization between *ep* and $p\overline{p}$ interactions is generally attributed to rescattering processes that are present in $p\overline{p}$ but not in *ep* collisions, and has been succesfully parameterized as a "rapidity gap survival probability" [3].

In *ep* collisions mediated by quasi-real photons, one distinguishes (in leading order (LO) QCD) direct processes, where the exchanged photon interacts as a whole, from resolved processes, where the photon is treated as a source of partons, one of which produces a hard scattering with the proton, leaving a photon remnant behind. This last class of processes, where the photon has a hadron-like component, is reminiscent of $p\overline{p}$ collisions and thus naturally leads to the question whether rapidity gap suppression is also observed here.

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This paper first discusses new measurements of the inclusive diffractive deep-inelastic cross section and the extraction of diffractive parton densities. These results are subsequently used to interpret results on dijet and open charm production in diffractive DIS and to look for rapidity gap suppression in diffractive photoproduction of dijet events.

2 Inclusive diffractive deep-inelastic scattering

2.1 Cross section measurements

In addition to the usual DIS kinematic variables, the photon virtuality Q^2 and the Björken scaling variables x and y, one introduces in the case of diffractive DIS the variables $x_{I\!P}$ and β, respectively defined as the longitudinal momentum fraction of the proton carried by the colourless exchange causing the rapidity gap, and the longitudinal momentum fraction of the colourless exchange carried by the struck quark. β has an analogous interpretation in the $\gamma I\!P$ [b] collision as Björken-x in the γp interaction.

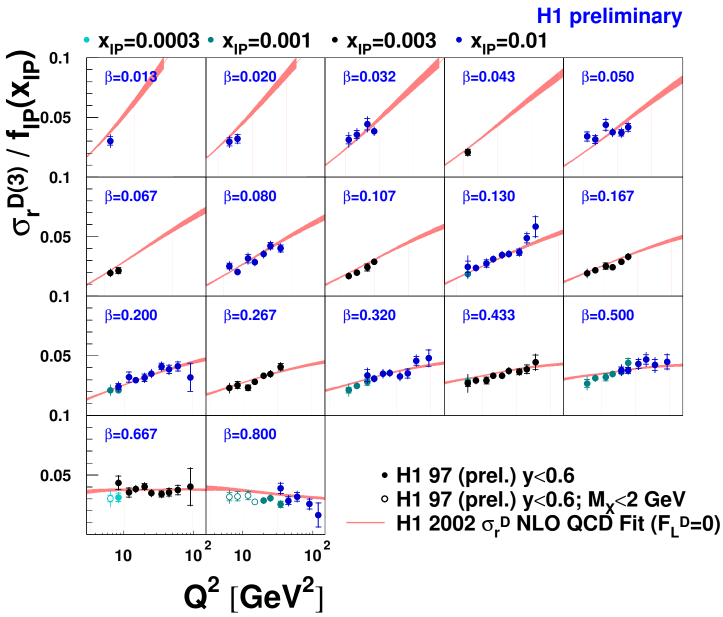

Figure 1: The diffractive cross section divided by the pomeron flux as a function of Q^2 in bins of β and for different $x_{I\!P}$ values. The band represents the result of the NLO QCD fit discussed in Sec. 2.2.

Figure 1 shows recent measurements obtained by the H1 Collaboration [4]. The results are presented as a reduced cross section, $\sigma_r^{D(3)}$, defined through

$$\frac{d^3\sigma^D}{dx_{I\!P}\,dx\,dQ^2} = \frac{4\pi\alpha^2}{xQ^4}\left(1 - y + \frac{y^2}{2}\right) \times \sigma_r^{D(3)}(x_{I\!P}, x, Q^2), \quad (1)$$

and divided by the "pomeron flux" $f_{I\!P}(x_{I\!P})$. This flux factor is obtained from a parameterization of the $x_{I\!P}$ dependence of the cross section inspired by Regge theory. The parameterization works well, as can be seen from the overlap of data points at the same β and Q^2 values obtained for different proton momentum losses $x_{I\!P}$. The intercept of the pomeron trajectory extracted from this data is

$$\alpha_{I\!P} = 1.173 \pm 0.018\ (\text{stat.}) \pm 0.017\ (\text{syst.})^{+0.063}_{-0.035}\ (\text{model}). \quad (2)$$

Positive scaling violations are observed in most of the phase space, suggesting a large gluon content of the diffractive exchange. The ratio of diffractive to inclusive DIS cross sections is found to be reasonably flat at fixed x as function of Q^2, indicating that the same scaling violations occur in both proccesses.

The ZEUS Collaboration has recently installed a new "Forward Plug" calorimeter which covers the range in pseudorapidity $4 < \eta < 5$ and increases the measurable range in mass of the photon dissociation system, M_X, to 35 GeV, while reducing the range in mass of the proton disscociation system, M_Y to 2.3 GeV and hence reducing the background due to proton dissociation. Preliminary results can be found in [5].

[b] $I\!P$ is a generic label used for the colourless exchange, which in some models is identified with the pomeron.

2.2 Next-to-leading order DGLAP fits

Using a parametrization based on Chebychev polynomials at a starting scale of $Q_0^2 = 3$ GeV^2, quark and gluon densities have been fitted to the observed H1 cross section by applying the DGLAP evolution equations. Subleading reggeon exchanges are included assuming the structure function of the pion. The fit, which includes the data shown in Fig. 1 together with data at higher Q^2 ($200 < Q^2 < 800$ GeV^2) [6] yields a $\chi^2/ndf = 308.7/306$.

Figure 2 shows the result of the next-to-leading order (NLO) QCD fit, with full propagation of statistical, systematic experimental and theoretical errors. The momentum fraction carried by gluons is estimated to be $75 \pm 15\%$. The resolved pomeron model used in the subsequent sections uses LO parton densities (also shown in Fig. 2) and LO parton cross sections. NLO effects are then simulated with parton cascades.

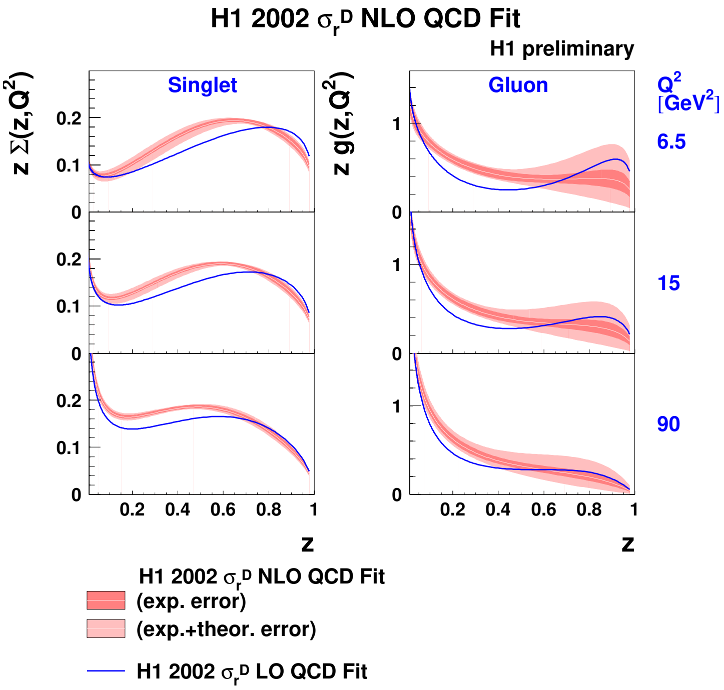

Figure 2: Diffractive quark singlet ($6 * u$ with $u = d = s = \overline{u} = \overline{d} = \overline{s}$) and gluon density. The pomeron flux is normalized to unity at $x_{I\!P} = 0.003$.

3 Factorization tests

The conditional parton densities obtained from the analysis of the inclusive diffractive DIS cross section have been used succesfully to describe the semi-inclusive cross section for dijet and open charm production in diffractive DIS. Both these processes are driven by the large gluon density through boson-gluon fusion.

Figure 3 shows the cross section for diffractive dijet production in DIS obtained by the H1 Collaboration [8] as a function of the fractional momentum of the colourless exchange entering the dijet system, $z_{I\!P}$. The data are compared to the resolved pomeron model. Although the fit based on the latest H1 data yields a smaller gluon content and therefore a lower dijet cross section than previous fits [7], the data are reasonably described given the large uncertainties on the extracted gluon density as well as on the scale for final state predictions, and missing higher order corrections.

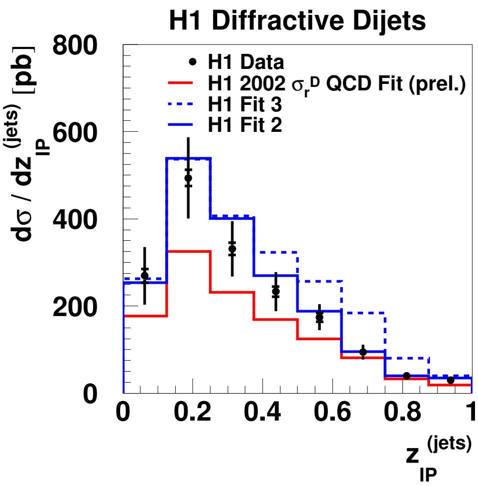

Figure 3: Diffractive DIS dijet cross section compared with the latest LO QCD fit as well as fits to previous data.

The $D^{*\pm}$ DIS production cross section as measured by ZEUS [9] is also well described by the resolved pomeron model. Again, a lower cross section is observed with the model based on the latest H1 fit as compared to previous fits. Within uncertainties, however, no evidence for breakdown of QCD hard scattering factorization is observed between the inclusive and semi-inclusive cross sections for diffractive DIS.

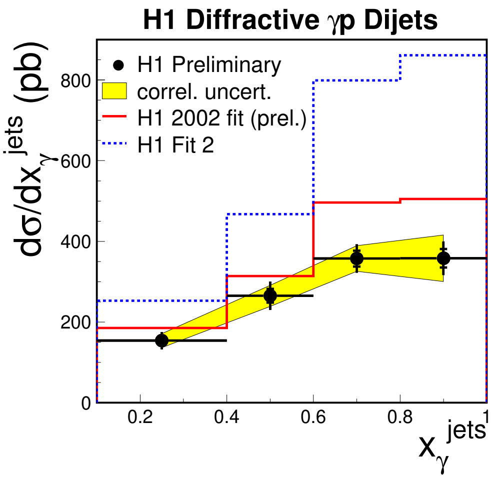

Figure 4: The dijet diffractive photoproduction cross section as function of x_γ^{jets}. The GRV LO parton distributions are used for the photon.

The H1 Collaboration has studied dijets in diffractive photoproduction [10]. Resolved and direct processes are distinguished by reconstructing the variable x_γ, defined as the fractional momentum of the quasi-real photon entering the dijet system. For direct processes x_γ should be unity, while in the case of resolved processes $x_\gamma < 1$ will hold. The hadron level variable is x_γ^{jets}.

Figure 4 displays the measured cross section for diffractive dijet photoproduction as a function of x_γ^{jets}. The data are compared to predictions by the resolved pomeron model using the new H1 fit based on 2002 data and the previous "Fit 2". A model-independent evaluation of the rapidity gap suppression factor in diffractive photoproduction relative to diffractive DIS is obtained by calculating the double ratio of measured data to the model prediction in photoproduction relative to DIS, yielding 1.80 ± 0.45. This factor is found to be the same, within errors, for direct and resolved processes.

4 Conclusion

High precision measurements of the diffractive cross section in DIS have been performed by H1 and ZEUS in an increased region of phase space. The data support Regge factorization (provided subleading trajectories can contribute) with a value of the pomeron intercept which is larger than for the soft pomeron. New NLO QCD fits are available yielding diffractive parton densities that can be used to test QCD hard scattering factorization.

Data on the inclusive cross section and final state (open charm and dijet production) in diffractive DIS in are in agreement with QCD factorization. A study of diffractive photoproduction of dijets finds a suppression with respect to DIS dijets, but cannot confirm different suppression factors for resolved and direct processes.

Acknowledgments

I am indebted to all members of the H1 and ZEUS Collaborations who contributed to these results by collecting and analysing the experimental data.

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