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NLO QCD FIT TO H1 DIFFRACTIVE DIS DATA*

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A new NLO DGLAP QCD fit to recent inclusive diffractive DIS data from the H1 collaboration is presented. Diffractive parton distributions are extracted, including their experimental and theoretical uncertainties. The parton distributions are used for comparisons with recent diffractive final state data from HERA and the Tevatron.

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1. Introduction

Measurements of the cross section $\sigma^{\rm D}(x_{\mathbb{P}}, \beta, Q^2)$ for diffractive Deep Inelastic Scattering (DIS) processes of the type $ep \to eXp$ by H1 at HERA have reached high precision [1]. Here, Q^2 is the photon virtuality, $x_{\mathbb{P}}$ is the longitudinal momentum fraction of the diffractive exchange with respect to the proton and $\beta = x/x_{\mathbb{P}}$ is the exchange's longitudinal momentum fraction of the quark which couples to the virtual photon. The recent H1 data are presented in terms of a reduced cross section $\sigma_{\rm r}^{\rm D}$, integrated over t, the 4-momentum transfer squared at the proton vertex,

$$\frac{d^3\sigma^{\rm D}}{dx_{\mathbb{P}}\; d\beta\; dQ^2} = \frac{4\pi\alpha^2}{\beta Q^4}\left(1 - y + \frac{y^2}{2}\right)\sigma_{\rm r}^{\rm D(3)}(x_{\mathbb{P}}, \beta, Q^2)\ , \tag{1}$$

($y = Q^2/xs$ is the inelasticity) which is expressed in terms of the diffractive structure functions $F_2^{\rm D}$ and the longitudinal $F_{\rm L}^{\rm D}$ as

$$\sigma_{\rm r}^{\rm D(3)} = F_2^{\rm D(3)} - \frac{y^2}{1+(1-y)^2} F_{\rm L}^{\rm D(3)}\ . \tag{2}$$

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The proof [2] of QCD hard scattering factorisation in diffractive DIS justifies to express $\sigma_{\rm r}^{\rm D(3)}$, at fixed $x_{\mathbb{P}}$, as a convolution of diffractive parton distributions (dpdf's) $f_i^{\rm D}$ and partonic cross sections $\hat{\sigma}^{\gamma^* i}$:

$$\frac{d\sigma_{\rm r}^{\rm D(3)}(x,Q^2,x_{\mathbb{P}})}{dx_{\mathbb{P}}} = \sum_i \int_x^{x_{\mathbb{P}}} d\xi \ \hat{\sigma}^{\gamma^* i}(x,Q^2,\xi) \ f_i^{\rm D}(\xi,Q^2,x_{\mathbb{P}}) \ . \tag{3}$$

The $f_i^{\rm D}$ should obey the DGLAP evolution equations and the $\hat{\sigma}^{\gamma^* i}$ are the same as for standard DIS. In a Next-to-Leading Order (NLO) DGLAP QCD fit, dpdf's are determined from the recent $\sigma_{\rm r}^{\rm D(3)}$ data from H1. Factorisation in diffraction is tested by using these dpdf's for comparisons with diffractive final state data from HERA and the Tevatron.

2. The NLO QCD fit

In the fit to the H1 $\sigma_{\rm r}^{\rm D(3)}$ data, the shapes of the dpdf's are assumed to be independent of $x_{\mathbb{P}}$ ("Regge factorisation"), which is supported by the data. The $x_{\mathbb{P}}$ dependence is parameterised as

$$f_{\mathbb{P}}(x_{\mathbb{P}}) = \int dt \ x_{\mathbb{P}}^{1-2\alpha_{\mathbb{P}}(t)} {\rm e}^{B_{\mathbb{P}}} t \ ; \qquad \alpha_{\mathbb{P}}(t) = \alpha_{\mathbb{P}}(0) + \alpha'_{\mathbb{P}} t \ , \tag{4}$$

where $\alpha_{\mathbb{P}}(0) = 1.173 \pm 0.018$ as obtained from a fit to the $x_{\mathbb{P}}$ dependence of the data[1]. A sub-leading exchange contribution (parameterised using a pion pdf) is included but found to be negligibly small for $x_{\mathbb{P}} < 0.01$. The diffractive exchange is parameterised by a light flavour singlet[2] and a gluon distribution at a starting scale $Q_0^2 = 3$ GeV^2 using Chebychev polynomials. No momentum sum rule is imposed. Heavy quarks are treated in the massive scheme with $m_c = 1.5 \pm 0.1$ GeV. The strong coupling is set via $\Lambda_{\rm QCD}^{\overline{MS}} = 200 \pm 30$ MeV.

The NLO DGLAP evolution equations are used. The QCD fit program is the one used in [4], extended for diffraction. In the fit, the experimental systematic errors of the data points and their correlations are propagated to obtain error bands for the resulting dpdf's. In addition, a theory error is estimated by variations of $\Lambda_{\rm QCD}$, m_c and the parameterisation of the $x_{\mathbb{P}}$ dependences.

The data used in the fit cover $x_{\mathbb{P}} < 0.05$, $0.01 \leq \beta \leq 0.9$ and $M_X > 2$ GeV, where the latter cut on the diffractive mass M_X is applied to justify a leading twist approach. The NLO fit is performed to $\sigma_{\rm r}^{\rm D}$. However, due

[1] For the values of $\alpha'_{\mathbb{P}}$ and $B_{\mathbb{P}}$ and the assumed uncertainties see [3].

[2] $u = d = s = \bar{u} = \bar{d} = \bar{s}$ is assumed.

to the y range of the data there is presently no direct sensitivity to F_L^D. Two data sets are used in the fit: (1) the recent H1 preliminary data [3] in the range $6.5 \leq Q^2 \leq 120$ GeV^2 (284 points) and (2) H1 preliminary data at higher Q^2 [5] ($200 \leq Q^2 \leq 800$ GeV^2, 29 points). The χ^2 for the central NLO fit is 308.7 for 306 degrees of freedom and 7 free parameters (3+3 parameters for the singlet and gluon distributions, 1 normalisation for the sub-leading exchange contribution).

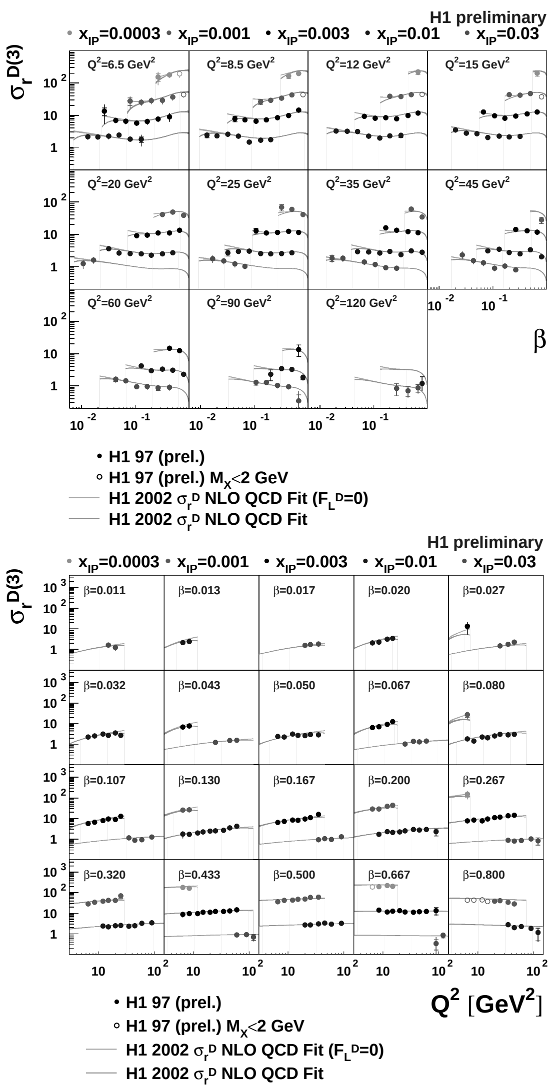

Fig. 1. The diffractive reduced cross section data as a function of β (top) and Q^2 (bottom), compared with the result of the NLO QCD fit.

The result of the fit is compared with the data in Fig. 1. The diffractive parton distributions are presented in Fig. 2, where the inner error bands correspond to the experimental error and the outer error bands include in addition the theory error. The parton distributions extend to large fractional momenta z (or β). The gluon distribution is dominant. Fits at leading order (LO) have been performed as well and are compared with previous H1 fits [6] in Fig. 2 (right). Taking the uncertainties, especially of the old fits, into account, the agreement is reasonable.

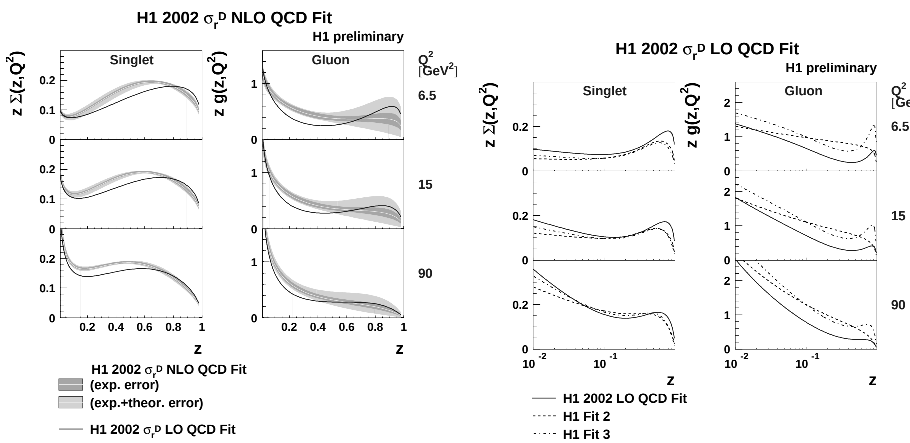

Fig. 2. The dpdf's resulting from the NLO (left) and LO (right) QCD fits.

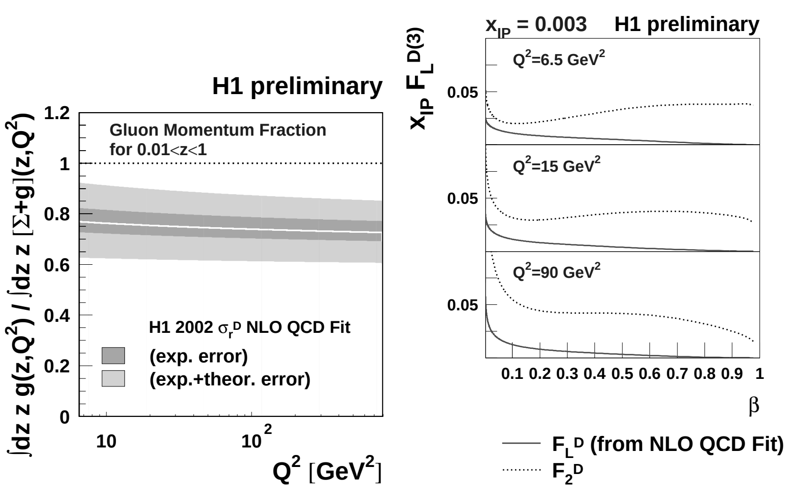

Fig. 3. Momentum fraction of the colour singlet exchange carried by gluons (left) and the perturbative, leading twist part of $F_{\mathrm{L}}^{\mathrm{D}}$ (right) resulting from the NLO QCD fit.

Integrating the parton distributions over the measured kinematic range ($0.01 < z < 1$), the momentum fraction of the colour singlet exchange carried by gluons is obtained (Fig. 3 left). At $Q^2 = 10$ GeV^2, it amounts to $75 \pm 15\%$. At NLO QCD, the perturbative leading twist component of the longitudinal diffractive structure function F_L^D is predicted (Fig. 3 right). F_L^D is found to increase relative to F_2^D towards low Q^2 and β.

3. Comparison with diffractive final state data

QCD factorisation in diffraction can be tested by using the dpdf's extracted from σ_r^D in DIS to predict the cross sections for diffractive final states such as jet and charm production. Both processes are strongly sensitive to the diffractive gluon distribution. Fig. 4 presents comparisons of H1 data for diffractive dijet [7] and D^* meson [8] production in DIS based on the LO dpdf's of the present as well as the previous QCD fits[3]. The D^* data are well described using the new fit. Taking the uncertainties in the dpdf's and also the scale uncertainties due to the LO comparison into account, the data are consistent with QCD factorisation.

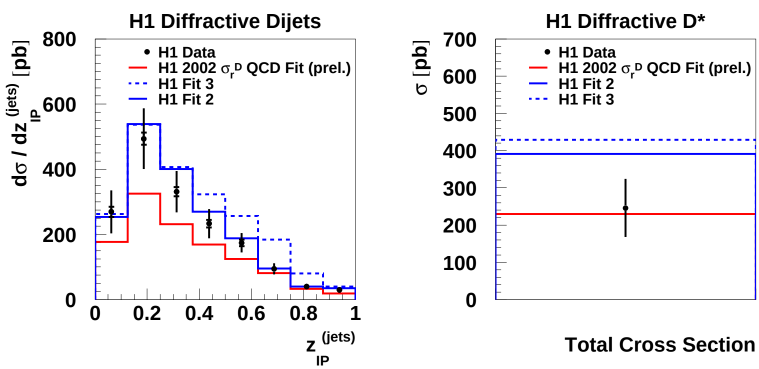

Fig. 4. Comparison of H1 measurements of dijet (left) and D^* (right) cross sections in diffractive DIS with predictions based on the new LO dpdf's.

Fig. 5 shows a comparison of CDF data for diffractive dijet production at the Tevatron with a prediction based on the dpdf's obtained at HERA. The new QCD fit confirms the serious breakdown of factorisation in diffraction observed at hadron-hadron colliders, often interpreted as being due to additional spectator interactions which suppress rapidity gaps (absorptive corrections, "rapidity gap survival").

[3] For more detailed comparisons, see [9].

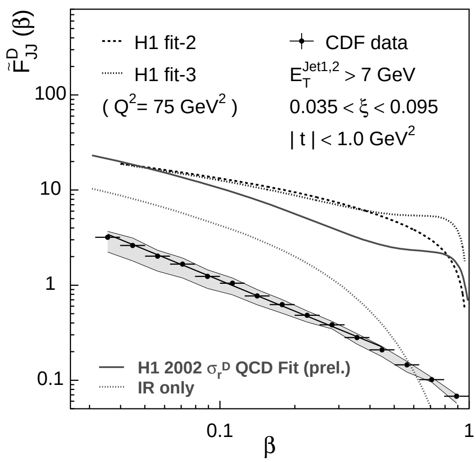

Fig. 5. Comparison of CDF diffractive dijet data with a prediction based on the new dpdf's and assuming factorisation to hold.

4. Conclusions

Diffractive parton distributions were extracted from a NLO QCD fit to recent H1 inclusive diffractive DIS data. For the first time in diffraction, the uncertainties of these pdf's were evaluated. Comparisons with diffractive final state data show, within the present uncertainties, consistency with QCD factorisation in diffractive DIS and confirm the breakdown of factorisation at the Tevatron.

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