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NEW RESULTS ON INCLUSIVE DIFFRACTION*

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Two new measurements of diffractive DIS events ($ep \to eXp$) where there is a large gap in rapidity between the hadronic system X and the leading proton p are presented, measured with the H1 detector at HERA. The first technique measures the full final state including the leading proton. The t dependence of the data, parameterised by $d\sigma/dt \propto \mathrm{e}^{Bt}$ gives a value of $B = 5.0 \pm 0.3\,(\mathrm{stat}) \pm 0.8\,(\mathrm{syst})\,\mathrm{GeV}^{-2}$. The second, higher statistics, measurement technique selects diffractive events on the basis of a large rapidity gap separating X and p. The reduced cross section $\sigma_{\mathrm{r}}^{\mathrm{D}(3)}$ ($= F_2^{\mathrm{D}(3)}$ if $F_{\mathrm{L}}^{\mathrm{D}(3)} = 0$) is extracted and good agreement is found between the two techniques. A value of $\alpha_{\mathbb{P}}(0) = 1.173 \pm 0.018\,(\mathrm{stat}) \pm 0.017\,(\mathrm{syst})^{+0.063}_{-0.035}\,(\mathrm{model})$ is measured for the effective pomeron intercept and the Q^2 and β dependence of the data are described by a NLO QCD fit to the data including a Regge factorisation hypothesis. The logarithmic Q^2 derivative of the ratio of the diffractive to the inclusive cross section is measured and found to be consistent with zero in the bulk of phase space.

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1. Introduction

Diffractive DIS, $\gamma^* p \to Xp$, uses the point-like virtual photon as a probe to study the QCD structure of colour-singlet exchanges. The reduced cross section $\sigma_{\mathrm{r}}^{\mathrm{D}(4)}$ is defined using:

$$\frac{d\sigma^{ep\to eXp}}{d\beta dQ^2 dx_{\mathbb{P}} dt} = \frac{4\pi\alpha^2}{\beta Q^4}\left(1 - y + \frac{y^2}{2}\right)\sigma_{\mathrm{r}}^{\mathrm{D}(4)}\,, \tag{1}$$

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where Q^2 is the virtuality of the photon and t is the 4-momentum transfer squared at the proton vertex. In the infinite momentum frame of the proton $x_{\mathbb{P}}$ is the longitudinal momentum fraction of the diffractive exchange with respect to the proton and $\beta(= x/x_{\mathbb{P}})$ is the diffractive equivalent of the Bjorken x scaling variable, *i.e.* the longitudinal momentum fraction of the struck quark[1]. $\sigma_{\mathrm{r}}^{\mathrm{D}(4)}$ is related to the more familiar structure functions by

$$\sigma_{\mathrm{r}}^{\mathrm{D}(4)} = F_2^{\mathrm{D}(4)} - \frac{y^2}{1+(1-y)^2} F_{\mathrm{L}}^{\mathrm{D}(4)} . \quad (2)$$

Thus $\sigma_{\mathrm{r}}^{\mathrm{D}(4)} = F_2^{\mathrm{D}(4)}$ if $F_{\mathrm{L}}^{\mathrm{D}(4)} = 0$, and, as can be seen in Eq. (2), $\sigma_{\mathrm{r}}^{\mathrm{D}(4)} \approx F_2^{\mathrm{D}(4)}$ is an approximation valid at all but the highest y.

Following the proof of QCD hard scattering factorisation for diffractive DIS by Collins [2] it is now possible to define diffractive parton density functions (pdfs) $p(x, Q^2, x_{\mathbb{P}}, t)$ with no additional assumptions. At fixed $x_{\mathbb{P}}$ and t these pdfs should obey the DGLAP evolution equations, allowing a test of the dynamics of diffraction purely within the framework of perturbative QCD. An additional assumption which is often made is that the $x_{\mathbb{P}}$ and t dependencies factorise from the hard scatter. This is referred to as the Regge factorisation scheme.

2. Analysis and results

Two analysis methods are employed, the first of which measures the complete final state using the Forward Proton Spectrometer (FPS) of H1 to detect the leading proton [3]. All 4 of the kinematic variables are measured in the range $2 < Q^2 < 50$ GeV^2, $5 \times 10^{-3} < \beta < 1$, $x_{\mathbb{P}} < 0.09$ and $-0.45 < t < -0.08\,\mathrm{GeV}^2$. The t dependence of the data can be fitted with an exponential parameterisation $d\sigma/dt \propto \mathrm{e}^{Bt}$ and a value of $B = 5.0 \pm 0.3\,(\mathrm{stat}) \pm 0.8\,(\mathrm{syst})$ GeV^{-2} averaged over the full measured range is obtained. A prediction of Regge factorisation is that B will have the form $B = B_0 + 2\alpha' \ln(1/x_{\mathbb{P}})$, resulting in a phenomenon known as "shrinkage" if α' is non-zero. As shown in Fig. 1(a) the data are inconclusive on this subject.

The second analysis method selects events on the basis of a rapidity gap separating the leading proton, which escapes undetected, from the hadronic final state system X [1]. The measurement covers the kinematic range $6.5 < Q^2 < 120$ GeV^2, $0.01 < \beta < 0.9$, $10^{-4} < x_{\mathbb{P}} < 0.05$. In the rapidity gap selection t is not measured and so an integration is performed over the kinematically allowed range ($-1.0\,\mathrm{GeV}^2 < t < t_{\mathrm{min}}$), and the results are presented as the three dimensional quantity $\sigma_{\mathrm{r}}^{\mathrm{D}(3)}(\beta, Q^2, x_{\mathbb{P}})$. A flux factor,

[1] See [1] for more formal definitions.

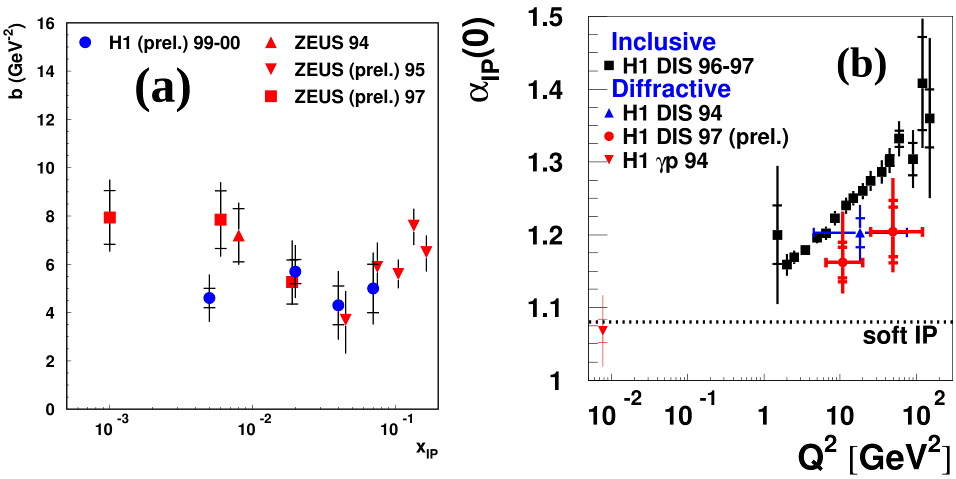

Fig. 1. t-dependence using the FPS selection technique (a). The Pomeron intercept $\alpha_{\mathbb{P}}(0)$ (b).

$f_{\mathbb{P}}(x_{\mathbb{P}}) = \int_{-1.0}^{t_{\min}} \frac{e^{Bt}}{x_{\mathbb{P}}^{2\alpha(t)-1}}$, motivated by Regge theory is used to incorporate the $x_{\mathbb{P}}$ dependence of the reduced cross section[2]. A direct comparison of all $x_{\mathbb{P}}$ bins is then possible by simply dividing $\sigma_{\rm r}^{\rm D(3)}$ by $f_{\mathbb{P}}(x_{\mathbb{P}})$.

The β and Q^2 dependencies of $\sigma_{\rm r}^{\rm D(3)}$ with the $x_{\mathbb{P}}$ dependence factored out can be seen in Fig. 2. The Q^2 distributions show large positive scaling violations persisting to $\beta \simeq 0.6$, consistent with gluon dominated diffractive pdfs extending to large β. Comparison of the different $x_{\mathbb{P}}$ bins shows that there is no remaining $x_{\mathbb{P}}$ dependence in the data, supporting the Regge factorisation hypothesis. The β distributions also show no remaining $x_{\mathbb{P}}$ dependence of the data, allowing the full β structure to be seen. The β distributions are seen to be quite flat across the full measured range of β. The NLO QCD fit to the rapidity gap data [4] assumes that the shape of the pdfs are independent of $x_{\mathbb{P}}$ and is seen to be able to describe the data.

Fig. 1(b) shows a comparison of the effective pomeron intercept $\alpha_{\mathbb{P}}(0)$ as extracted[3] from inclusive neutral current data and rapidity gap diffractive data. The value of $\alpha_{\mathbb{P}}(0)$ for diffraction at high Q^2 is significantly higher than that measured for the soft pomeron and there is evidence that the dependence on Q^2 is weaker in the diffractive case than in the inclusive case. The value of $\alpha_{\mathbb{P}}(0)$ is found to be consistent with previous measurements and is $\alpha_{\mathbb{P}}(0) = 1.173 \pm 0.018({\rm stat}) \pm 0.017({\rm syst})^{+0.063}_{-0.035}({\rm model})$.

[2] Details of the values of the parameters used can be found in [1].
[3] Details of the $\alpha_{\mathbb{P}}$ extraction procedure can be found in [1].

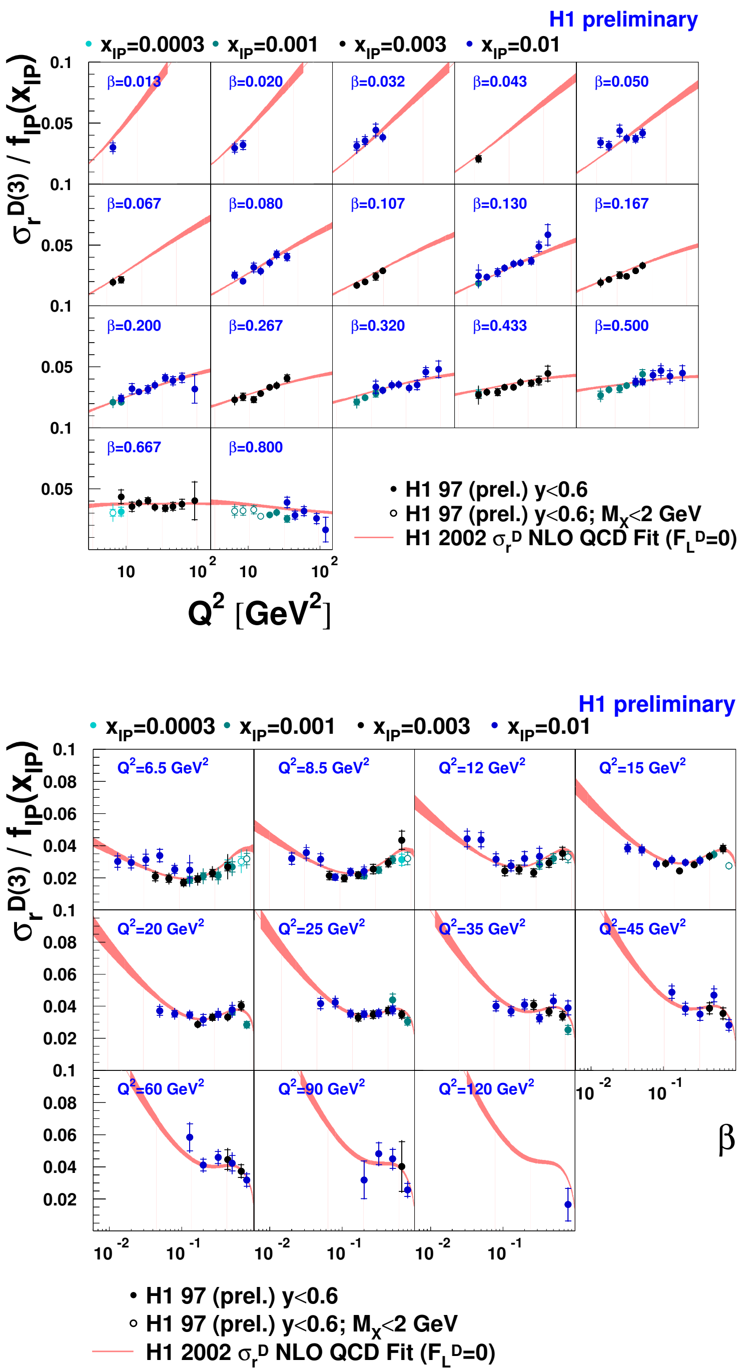

Fig. 2. Q^2 and β dependencies of the data compared with the NLO QCD fit.

The ratio of the diffractive to the inclusive reduced cross section, $\sigma_{\mathrm{r}}^{\mathrm{D}}/\sigma_{\mathrm{r}}$, is measured for the rapidity gap data, and the logarithmic Q^2 derivative of this ratio is studied, again comparing all $x_{\mathbb{P}}$ bins by dividing the ratio by $f_{\mathbb{P}}(x_{\mathbb{P}})$. The results are shown in Fig. 3 and it is found that this quantity is consistent with zero across the bulk of the measured phase space, which suggests that the dynamics of the structures being probed arise from closely related physical mechanisms. The ratio clearly becomes negative as $\beta \to 1$, *i.e.*, as $x_{\mathbb{P}} \to x$.

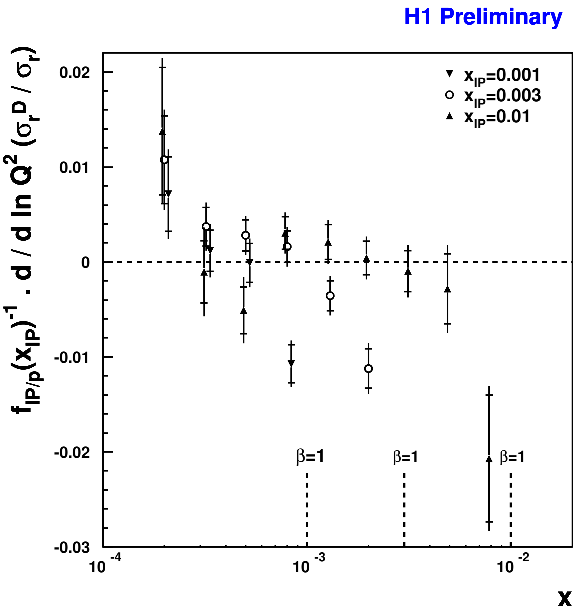

Fig. 3. Logarithmic Q^2 derivative of ratio $\sigma_{\mathrm{r}}^{\mathrm{D}}/\sigma_{\mathrm{r}}$.

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