ON THE ENERGY DEPENDENCE OF THE DEEP–INELASTIC DIFFRACTIVE CROSS SECTION

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Abstract

The importance of the dependence on Bjorken–x of the cross section for deep–inelastic ep diffraction is emphasised. It is proposed that an accurate measurement of a comparison of the Bjorken–x dependence of this cross section with that of the totally inclusive ep cross section may well be the best way of determining the properties of the pomeron and whether they are universal and thus consistent with factorisation. Results of such a comparison in the form of a measurement of the ratio $r^{D(3)}(\beta, x, Q^2)$ of the deep–inelastic diffractive and total cross sections are reviewed and discussed. The x dependence of the measure $r^D(x, Q^2)$ of the total contribution of diffraction to deep–inelastic scattering is also presented and its significance stated.

1 Introduction

Diffractive deep–inelastic scattering offers a unique possibility of testing QCD dynamics at low x and of elucidating the origin of the pomeron ($I\!P$). The $I\!P$ is a generic name to whose exchange may be attributed the mechanism responsible for production of final states with large rapidity gaps. In the Regge formalism the $I\!P$ is represented by a trajectory [1] $\alpha_{I\!P}(t) = 1 + 0.08 + 0.25t$, where t is the four-momentum transfer squared between the interacting particles. The parameters of this trajectory, nowadays called the "soft pomeron", determine in soft hadronic interactions the energy dependence of the total, elastic and diffractive cross sections. In soft interactions the $I\!P$ trajectory turns out to be universal.

Within perturbative QCD, the $I\!P$ is expected to be non-universal. In deep–inelastic scattering $ep \to eXp$, low mass diffraction with $M_X^2 \ll Q^2$ can be considered as two-gluon exchange [2]. The expected Q^2 dependence is that of a QCD higher twist contribution while the cross section at fixed Q^2 is expected to rise like $[xg(x, Q^2)]^2$, where $xg(x, Q^2)$ is the gluon momentum density in the proton. In the large mass regime, $M_X^2 \gg Q^2$, the triple Regge formalism is expected to be valid leading to a Q^2 dependence typical of a leading twist contribution and an energy dependence typical of the soft $I\!P$ [3]. Should this picture be valid, one would expect a very different energy and Q^2 dependence for large and small M_X.

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2 Formalism for the x dependence of the Deep–Inelastic Diffractive Cross Section

It is necessary to explain carefully the basic formalism in terms of the appropriate variables. We introduce the two variables used to described diffractive scattering: the fraction of the proton momentum carried by the (generic) $I\!P$, $x_{I\!P}$, and the fraction of the $I\!P$ momentum carried by the struck quark, $\beta = x/x_{I\!P}$, where x is the usual Bjorken variable. Assuming $t \simeq 0$ and neglecting the mass of the proton

$$x_{I\!P} = \frac{Q^2 + M_X^2}{W^2 + M_X^2}, \qquad \beta = \frac{Q^2}{Q^2 + M_X^2}.$$

Following the original procedure of [4, 5], the differential diffractive ep cross section expressed in terms of x, Q^2 and $x_{I\!P}$ is

$$\frac{\mathrm{d}^3\sigma^D}{\mathrm{d}x\mathrm{d}Q^2\mathrm{d}x_{I\!P}} = \frac{2\pi\alpha^2}{xQ^4}\left\{1 + (1-y)^2\right\} F_2^{D(3)}(x, Q^2, x_{I\!P})$$

where $y = Q^2/(xs)$ and s is the ep center of mass energy squared. $F_2^{D(3)}$ denotes the contribution of diffractive events with a given $x_{I\!P}$ integrated over t to the proton structure function F_2 for a given Q^2 and x. For simplicity the contribution from the longitudinal proton structure function F_L is omitted in the considerations presented here. First measurements of $F_2^{D(3)}$have already been made [6, 7, 8, 9]. In terms of x, Q^2 and β, the x, Q^2 and $x_{I\!P}$ dependence transforms into

$$\begin{aligned} \frac{d^3\sigma^D}{d\,x d\,Q^2 d\,\beta} &= \frac{x}{\beta^2}\frac{d^3\sigma^D}{d\,x_{I\!P} d\,Q^2 d\,\beta} \\ &= \frac{2\pi\alpha^2}{\beta^2 Q^4}\left[1 + (1-y)^2\right] F_2^{D(3)}(\beta, Q^2, x_{I\!P}), \end{aligned} \tag{1}$$

where $x = \beta \cdot x_{I\!P}$. It will also be useful to have in mind explicitly the ratio of the deep–inelastic diffractive and total cross sections in the form

$$r^{D(4)}(\beta, x, Q^2, t) = \frac{\mathrm{d}^4\sigma^D}{\mathrm{d}x\mathrm{d}Q^2\mathrm{d}\beta\mathrm{d}t} / \frac{\mathrm{d}^2\sigma^{ep\to eX}}{\mathrm{d}x\mathrm{d}Q^2}$$

acknowledging the dependence on t, and the integral of this over t, namely

$$\begin{aligned} r^{D(3)}(\beta, x, Q^2) = \int_t r^{D(4)}(\beta, x, Q^2, t)\mathrm{d}t &= \frac{\mathrm{d}^3\sigma^D}{\mathrm{d}x\mathrm{d}Q^2\mathrm{d}\beta} / \frac{\mathrm{d}^2\sigma^{ep\to eX}}{\mathrm{d}x\mathrm{d}Q^2} \\ &= \frac{1}{\sigma^{\gamma^* p\to X}} \cdot \frac{\mathrm{d}\sigma^{\gamma^* p\, D}}{\mathrm{d}\beta} = \frac{x}{\beta^2} \cdot \frac{F_2^{D(3)}(\beta, x, Q^2)}{F_2(x, Q^2)}. \end{aligned} \tag{2}$$

Here $r^{D(3)}(\beta, x, Q^2)$ is written also in terms of virtual photon proton ($\gamma^* p$) cross sections, which are related directly to $F_2^{D(3)}$and F_2 according to

$$\frac{\mathrm{d}\sigma^{\gamma^* p\, D}}{\mathrm{d}\beta} = \frac{4\pi^2\alpha}{Q^2(1-x)}\frac{x}{\beta^2} \cdot F_2^{D(3)} \qquad \sigma^{\gamma^* p\to X}(x, Q^2) = \frac{4\pi^2\alpha}{Q^2(1-x)} F_2.$$

Obviously α here is the fine structure constant.

3 Bjorken–x Dependence for the ZEUS Data

Assume that for a given β and Q^2, $F_2^{D(3)}$ can be expressed as

$$F_2^{D(3)} = \frac{1}{x_{I\!P}^{\delta}} F_2^{I\!P}(\beta, Q^2)\,.$$

Then

$$\frac{d^3\sigma^D}{dx\,dQ^2\,d\beta} = \frac{2\pi\alpha^2}{Q^4 x}\frac{1}{x^{\delta-1}}\beta^{\delta-2}F_2^{I\!P}(\beta, Q^2)\left[1+(1-y)^2\right]\,,$$

and the ratio

$$r^{D(3)}(\beta, x, Q^2) = \frac{\mathrm{d}^3\sigma^D}{\mathrm{d}x\mathrm{d}Q^2\mathrm{d}\beta} / \frac{\mathrm{d}^2\sigma^{ep\to eX}}{\mathrm{d}x\mathrm{d}Q^2} = \frac{1}{x^{\delta-1}}\frac{\beta^{\delta-2}F_2^{I\!P}(\beta, Q^2)}{F_2(x, Q^2)}\,.$$

From measurements of the proton structure function we know that the F_2 structure function of the proton can be expressed as $F_2(x, Q^2) = f(Q^2)x^{-\lambda}$, with $\lambda \simeq 0.25$ and rising slightly with Q^2 [10]. Thus for fixed β and Q^2 we expect

$$r^{D(3)} \propto x^{1-\delta+\lambda}\,. \tag{3}$$

If factorization indeed holds and δ is independent of β, the same should hold for the diffractive cross section integrated over a range of β as long as the low β range is not too close to the kinematical boundary, within the x range studied.

Let's assume that the $I\!P$ observed in deep–inelastic scattering is the same as the one governing soft interactions. In that case $\delta = 1.06$ (after including the shrinkage of the t distribution) and $r^{D(3)} \propto x^{.19}$. The ratio would be expected to rise by factor 1.5 when going from $x = 10^{-4}$ to $x = 10^{-3}$.

Should the perturbative QCD scenario prevail than we would expect $r^{D(3)}(M_X^2 \ll Q^2) \propto x^{-\lambda} \propto x^{-0.25}$, that is to decrease by factor 1.8 from $x = 10^{-4}$ to $x = 10^{-3}$, while it would be rising for $M_X^2 \gg Q^2$.

Present ZEUS data are compatible with factorization but do not allow a clear interpretation of the nature of the $I\!P$. The results, based on the quoted universal values for δ, are summarized in table 1 in the form of the universal x dependence of $r^{D(3)}$. The ZEUS II analysis follows a different, and possibly superior, procedure in handling background from non–diffractive interactions than does ZEUS I. The result is shown in figure 1 in the form of the measured W dependences $[W^2 = Q^2(\frac{1}{x}-1)]$ at fixed Q^2 of $\frac{\mathrm{d}\sigma^{\gamma^* p\, D}}{\mathrm{d}M_X}$. The superimposed curves show the expectation assuming the dependence $\frac{\mathrm{d}\sigma^{\gamma^* p\, D}}{\mathrm{d}M_X} \propto (W^2)^{2\overline{\alpha_{I\!P}}-2} = (W^2)^{\delta-1}$ with a universal $\overline{\alpha_{I\!P}} = 1.23 + -.02 + -.04$ or $\delta = 1.46 \pm .04 \pm .08$. A significant rise is observed with increasing W which at face value (3.3 s.d.) is not obviously attributable to the "soft" $I\!P$ and is indicative of exciting physics ahead.

It should be noted that it may well be possible to determine the x dependence of $r^{D(3)}$ with much better precision than the flux of the $I\!P$ itself as many of the systematic errors cancel out. This in turn may be a more precise way of addressing the issue of factorization.

4 Bjorken–x Dependence for the H1 Data

Following their 1993 measurements of $F_2^{D(3)}$ and F_2 [6, 13], comparison of the x dependences in the form of $r^{D(3)}(\beta, x, Q^2)$ in equation 2 has already been made by the H1 collaboration [11, 12]. The result is shown in figure 2. At different β and Q^2 there is no significant evidence yet for

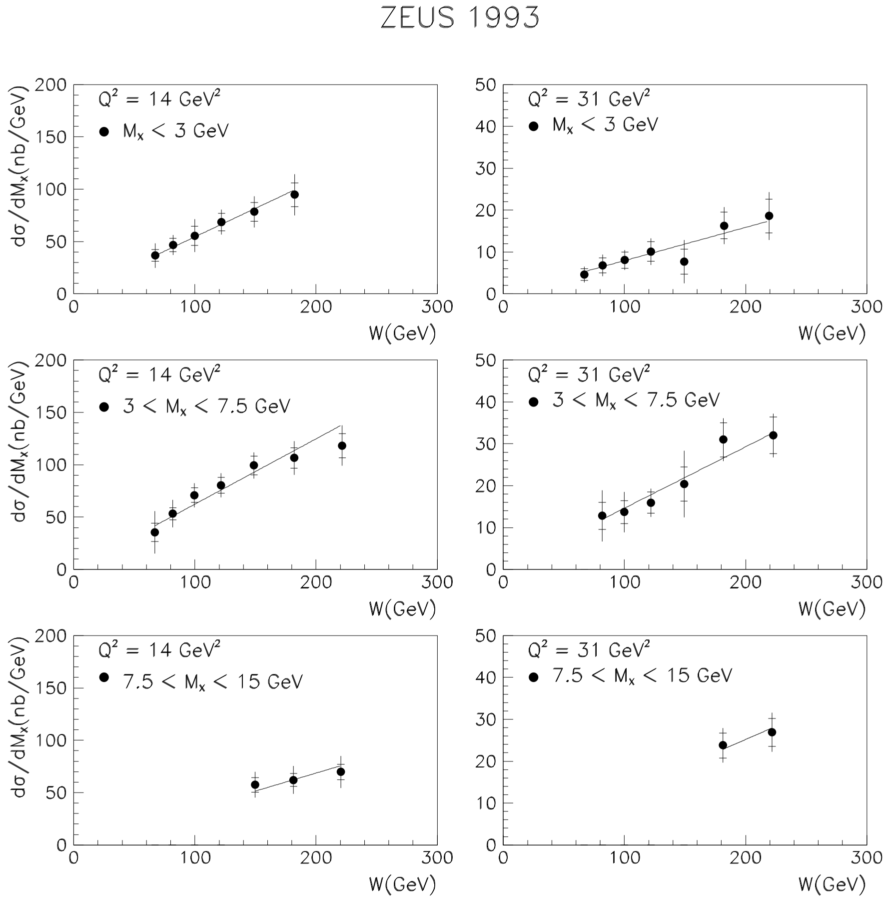

Figure 1: The differential cross sections $\mathrm{d}\sigma^{\gamma^* p\, D}/\mathrm{d}M_X$ as a function of W averaged over the M_X intervals $2m_\pi$ - 3, 3 - 7.5 and 7.5 - 15 GeV at $Q^2 = 14$ and 31 GeV^2. The inner error bars show the statistical errors and the full bars the statistical and systematic errors added in quadrature. The overall normalization uncertainty of 3.5% is not included. The curves show the results from fitting all cross sections to the form $\mathrm{d}\sigma^{\gamma^* p\, D}/\mathrm{d}M_X \propto (W^2)^{(2\overline{\alpha_{I\!P}}-2)}$ with a common value of $\overline{\alpha_{I\!P}}$, see text.

any differences between the observed x dependences of the cross sections for deep–inelastic diffraction and deep–inelastic scattering, that is for any variation of $r^{D(3)}(\beta, x, Q^2)$. The x dependence of the deep–inelastic diffractive cross section is thus consistent with the rise with decreasing x of the deep–inelastic scattering cross section (that is of F_2), namely $\propto x^{-\lambda}$ with $\lambda \sim 0.19$ to 0.25 [13]. However the experimental precision of this first measurement of $F_2^{D(3)}$is limited – superimposed is a best fit of a universal dependence $r^{D(3)} \propto x^{-m}$ for which $m = -0.06 \pm 0.06(\mathrm{stat.}) \pm 0.08(\mathrm{syst.})$. The acceptability of this fit of a universal dependence to the measurements implies factorisability of the $I\!P$ flux at the level of experimental precision of this measurement, restating the result in [6] expressed in terms of $x_{I\!P}$. The consistency of m with 0 quantifies the lack evidence for any significant difference between the x dependences of the diffractive and total deep–inelastic cross sections.

Interpreting the result in figure 2 in terms of the manifestation of the $I\!P$ in deep–inelastic diffraction (DIF) and in deep–inelastic scattering (DIS) requires use of the following equations, which arise in simple Regge phenomenology [12] applied to diffractive and total $\gamma^* p$ cross

Analysis	δ	$r^{D(3)}$
ZEUS I	$1.30 \pm .08^{+.08}_{-.14}$	$x^{-.05 \pm .08^{+.14}_{-.08}}$
ZEUS II	$1.46 \pm .04 \pm .08$	$x^{-.21 \pm .04 \pm .08}$

Table 1: Summary of the values of δ as measured by ZEUS and the expected x dependence of the $r^{D(3)}$. ZEUS I [7] and ZEUS II [8] denote results obtained with two different methods for subtracting background.

sections,

$$\frac{\mathrm{d}^2\sigma^{\gamma^* p\, D}}{\mathrm{d}M_X^2\,\mathrm{d}t} \propto \frac{f(M_X^2, t)}{x^{2\alpha_{I\!P}^{DIF}(t)-2}}, \tag{4}$$

where $f(M_X^2, t)$ is a function which need not here be specified, and

$$\sigma^{\gamma^* p \to X}(x, Q^2) \quad \propto \quad \frac{1}{x^{\alpha_{I\!P}^{DIS}(t=0)-1}} \qquad (\frac{Q^2}{W^2} \to 0)$$

to write (in obvious notation)

$$r^{D(4)}(\beta, x, Q^2, t) \propto \frac{1}{x^{2\alpha_{I\!P}^{DIF}(t)-2-\varepsilon^{DIS}}},$$

in which distinction is made between the $I\!P$ trajectories $\alpha_{I\!P}^{DIF}(t)$ and $\alpha_{I\!P}^{DIS}(t)$ of deep–inelastic diffraction and scattering, DIF and DIS respectively. Here $\varepsilon = \alpha_{I\!P}(t=0) - 1$. If the effect of the t integration, namely correction for any shrinkage of the t dependence, is ignored so that $\varepsilon^{DIF} = \alpha_{I\!P}^{DIF}(t=0) - 1 \approx \alpha_{I\!P}^{DIF}(t) - 1$, then

$$r^{D(3)}(\beta, x, Q^2) \propto \frac{1}{x^{2\varepsilon^{DIF}-\varepsilon^{DIS}}}. \tag{5}$$

Note that equation 5 is equivalent to equation 3 above in which, ignoring shrinkage, $\delta = 2\alpha_{I\!P}^{DIF}(t=0) - 1$.

The presence or not of any shrinkage depends on the t dependence of $\alpha_{I\!P}(t)$. Its effect on this expression for $r^{D(3)}$ depends also on the t dependence of the cross section $\frac{\mathrm{d}^4\sigma^D}{\mathrm{d}x\mathrm{d}Q^2\mathrm{d}\beta\mathrm{d}t}$, or equivalently $\frac{\mathrm{d}^2\sigma^{\gamma^* p\, D}}{\mathrm{d}\beta\mathrm{d}t}$. Perturbative QCD calculations of the $I\!P$ seem to find little or no dependence of $\alpha_{I\!P}$ on t [14, 15], and thus little or no modification to equation 5. As mentioned above, hadron phenomenology finds $\alpha'_{I\!P} = 0.25\,\mathrm{GeV}^{-2}$ [1], and thus a modification to equation 5 which, for a given ε^{DIF}, will reduce the contribution of DIF to the power of the resulting $1/x^m$ dependence of $r^{D(3)}$ on x.

At fixed β the sensitivity of the x dependence of $F_2^{D(3)}$to ε^{DIF} is roughly twice that of the x dependence of F_2 to ε^{DIS} in equation 5. Thus, and always with the complications for equation 5 of shrinkage in mind, the description in terms of a universal dependence $r^{D(3)} \propto x^{-m}$ may be cast into the equivalent form $\varepsilon^{DIF} \approx \varepsilon^{DIS}/2 - 0.03 \pm 0.03(\mathrm{stat.}) \pm 0.04(\mathrm{syst.})$. Given that the

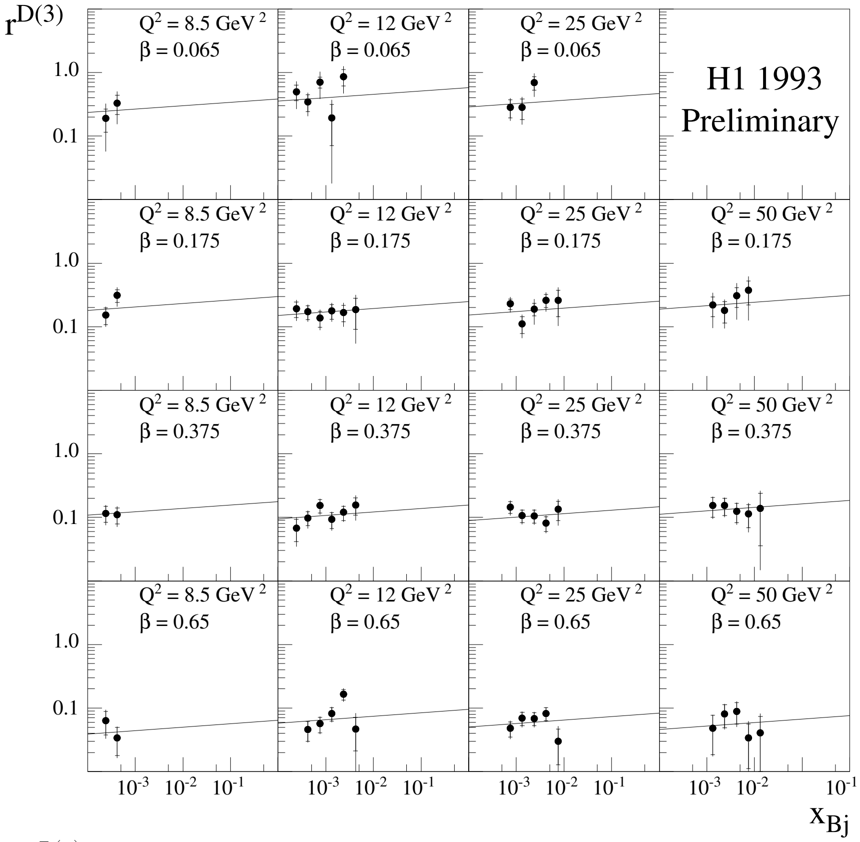

Figure 2: Ratio $r^{D(3)}(\beta, x, Q^2)$ (see text) which compares the x dependences of the deep–inelastic diffractive cross section $\mathrm{d}^3\sigma^D/\mathrm{d}x\mathrm{d}Q^2\mathrm{d}\beta$ with the total cross section $\mathrm{d}^2\sigma^{ep\to eX}/\mathrm{d}x\mathrm{d}Q^2$.

x dependence of F_2 corresponds to $\varepsilon^{DIS} \sim 0.19$ to 0.25 [13] (the $x^{-\lambda}$ dependence of F_2 on x mentioned above), then ε^{DIF} lies between 0.07 and 0.10 with an error $\pm 0.03(\mathrm{stat.}) \pm 0.04(\mathrm{syst.})$. Therefore it is not yet possible to conclude that the $I\!P$ in DIF is "softer" than, or as "hard" as, it seems to be in DIS until the accuracy of the measurements of $F_2^{D(3)}$improve and their scope includes t dependence. This conclusion is of course no different from that to be found in [6] which is based on the equivalent extraction of ε^{DIF} from the $x_{I\!P}$ dependence of $F_2^{D(3)}$.

Thus the identification of any contribution to deep–inelastic diffraction which may be attributed to a $I\!P$ which is harder than the universal $I\!P$ of soft hadronic physics requires more accurate measurements of the Bjorken–x dependences of $r^{D(3)}$ (or $F_2^{D(3)}$) and a careful analysis of them using the appropriate Regge phenomenology. However this present result, which is no more than a reworking in terms of the Bjorken–x dependence of $r^{D(3)}$ instead of the analysis of the $x_{I\!P}$ dependence of $F_2^{D(3)}$published in [6], may be the way to gain insight, when experimental accuracy improves, into the details of the nature of deep–inelastic diffraction and the $I\!P$. In turn, this may lead to better ways of analysing the QCD structure of diffraction than hitherto has been achieved, namely by using the variables β and $x_{I\!P}$ in a picture involving the structure of the (more or less factorisable) $I\!P$ [12, 16, 17].

5 The Total Contribution of Proton Diffraction to Deep–Inelastic ep Scattering

The simplest question that can be asked concerning the Bjorken–x dependence of the contribution of diffraction to deep–inelastic ep scattering is that of its sum total. Such a measurement, which is also of course just the W^2 dependence of the total diffractive $\gamma^* p$ cross section at fixed Q^2, is especially important for the interpretation of QCD analyses of the totally inclusive deep–inelastic cross section, that is of F_2 [18, 19, 20].

The definition of a "sum total" of diffraction is a matter of convention. For all deep–inelastic ep scattering, the presence of a leading particle or cluster of particles (of relatively low mass) in the overall hadronic final state specifies an $x_{I\!P}$. The choice of a diffractive interpretation of this scattering is a matter of definition of a range in $x_{I\!P}$, namely that it be small, usually $\lesssim 0.1$. There is also a lower kinematic limit in $x_{I\!P}$ arising because $x = \beta \cdot x_{I\!P}$ so that $x \leq x_{I\!P}$. This lower limit has an important effect in any quantification of a sum total of diffraction as a function of x.

The measurement of $F_2^{D(3)}$by H1 has been used to determine the sum total contribution of diffraction to F_2 as a function of x and Q^2. Diffraction is defined to be for $x \leq x_{I\!P} \leq 0.05$ so that the contribution can be expressed as $F_2^D(x, Q^2)$ which is related to $F_2^{D(3)}$according to

$$F_2^D(x, Q^2) = \int_x^{0.05} F_2^{D(3)}(x, Q^2, x_{I\!P}) \mathrm{d}x_{I\!P}$$

The results are shown in figure 3, both as $F_2^D(x, Q^2)$ and as the proportion $r^D(x, Q^2) = F_2^D/F_2$ – unlike for $r^{D(3)}$ in equation 2 there are now no perplexing Jacobian–like factors because both F_2 and F_2^D are total $\gamma^* p$ cross sections. Because of the lower kinematic limit in $x_{I\!P}$, both F_2^D and r^D tend to zero as x tends to the upper limit in $x_{I\!P}$ (here 0.05). Away from this limit, r^D is rather insensitive to x and Q^2 and is about 10%. However the x dependences of both $F_2^D(x, Q^2)$ and $r^D(x, Q^2)$ are everywhere influenced by it.

It is important to note that the x dependence of $F_2^D(x, Q^2)$, or $r^D(x, Q^2)$, does *not* have a simple interpretation in terms of the nature of the $I\!P$ in deep–inelastic diffraction, as does $F_2^{D(3)}$or equivalently $r^{D(3)}$. This is because $F_2^D(x, Q^2)$ does not correspond to the differential cross section $\frac{\mathrm{d}^2\sigma^{\gamma^* p\, D}}{\mathrm{d}M_X^2 \mathrm{d}t}$, or integration of it over t, and thereby to its parametrisation as in equation 4. The integration over $x_{I\!P}$ to obtain r^D at a particular x corresponds to an integration over M_X^2 from threshold to the upper limit specified by $x_{I\!P} = 0.05$. Such a cross section is not amenable to the simple Regge parametrisation of equation 4, namely of W dependence at fixed M_X^2.

Either of $F_2^D(x, Q^2)$ or $r^D(x, Q^2)$ quantify the total contribution to deep–inelastic ep scattering due to proton diffraction. The interesting question which now arises is exactly how this diffractive contribution should be taken into account in DGLAP (or otherwise) based QCD analyses of the proton structure function F_2 at low x and the extraction of parton distribution functions (pdf's) of the proton [18]. There as yet seems to be no conclusive answer [19, 20].

6 Conclusion

The expectations for the Bjorken–x dependence of the diffractive deep–inelastic cross section have been outlined with reference to their sensitivity to pomeron dynamics. They are discussed in terms of a measurement of the comparison of the x dependence of this cross section with that for the total deep–inelastic cross section. The ratio $r^{D(3)}(\beta, x, Q^2)$ of these cross sections may be the most precise way of establishing both the nature and the uniformity of pomeron dynamics, and thus the degree to which the diffractive deep–inelastic cross section may include a term describing a universal pomeron flux.

Using measurements at HERA of the $x_{I\!P}$ dependence of $F_2^{D(3)}$by the ZEUS I analysis and of $r^{D(3)}(\beta, x, Q^2)$ by the H1 experiment, it has been shown that the accuracy of present measurements of deep–inelastic diffraction are not yet sufficient to establish a distinction between the "hard" pomeron, as manifest in the x dependence of the proton structure function F_2, and

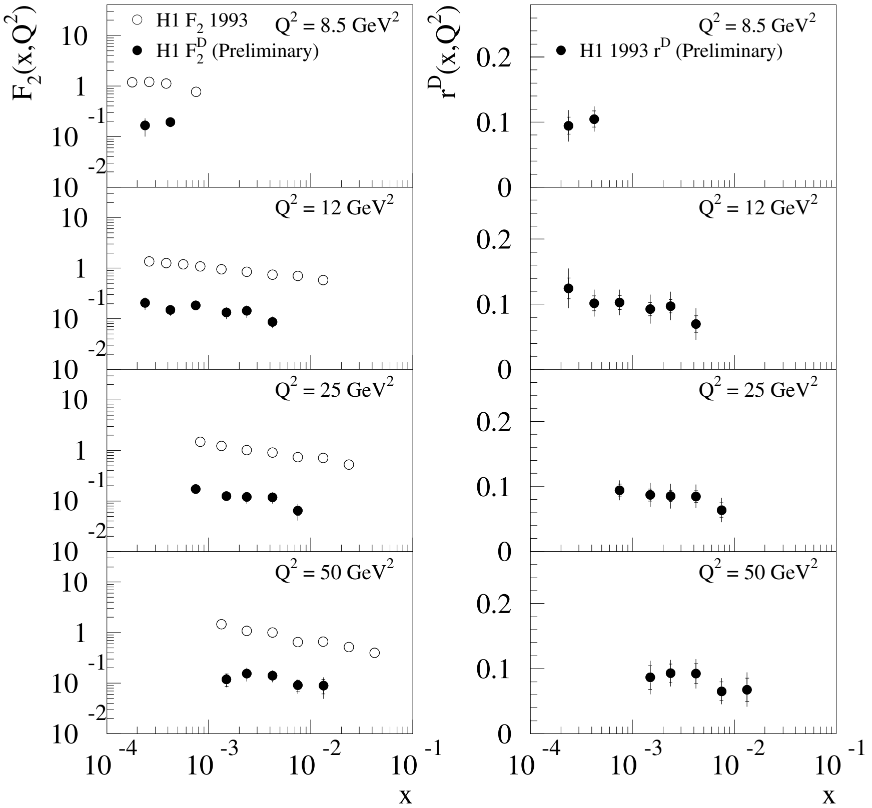

Figure 3: The structure function $F_2^D(x,Q^2)$ and the ratio $r^D = F_2^D(x,Q^2)/F_2(x,Q^2)$ for $x_{I\!P} < 0.05$; the result is for deep–inelastic diffraction in which the proton does not dissociate; about a third of deep–inelastic diffractive interactions are consistent with proton dissociation.

the "soft" pomeron of hadronic physics. However, the result of the ZEUS II analysis may be an important hint for the presence of a hard component in deep–inelastic diffraction. Already measurements of the cross sections for of exclusive ρ [21, 22], ϕ [23] and J/ψ [24] meson production at similar Q^2 and of J/ψ in photoproduction [25, 26] show a rise with W in excess of that expected from a "soft" pomeron [9].

The measurement by H1 of the total contribution of diffraction, in the forms of both $F_2^D(x,Q^2)$ and $r^D(x,Q^2)$, to deep–inelastic scattering as a function of Bjorken–x is rather insensitive to x and Q^2 and is about 10%. Any interpretation of it in terms of the nature of the pomeron is complicated by the the kinematic effect of integration over the diffractive range of $x_{I\!P}$.

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References

[1] A. Donnachie and P. V. Landshoff, Phys. Lett. **202B** (1988) 131; Phys Lett. **B296** (1992) 227; Nucl. Phys. **B303** (1988) 634.

[2] S. J. Brodsky et al., Phys. Rev. **D50** (1994) 3134.

[3] N. N. Nikolaev and B. G. Zakharov, Zeit. Phys. **C53** (1992) 331.

[4] G. Ingelman and K. Janson–Prytz, "The Pomeron Structure Function and QCD at Small–x", in Proceedings of the Workshop "Physics at HERA", p. 233, October 1991, ed. W. Buchmüller and G. Ingelman.

[5] G. Ingelman and K. Prytz, Zeit. Phys. **C58** (1993) 285.

[6] H1 Collab., T. Ahmed et al., Phys. Lett. **B348** (1995) 681.

[7] ZEUS Collab., M. Derrick et al., Zeit. Phys. **C68** (1995) 569.

[8] ZEUS Collab., M. Derrick et al., DESY 96-018, submitted to Zeit. Phys. **C**.

[9] A. Doyle, these proceedings.

[10] A. Levy, "Soft Interactions at High Energies", in Proc International Europhysics Conference on High Energy Physics, Brussels, July 1995, in litt. and DESY 95-204.

[11] A. Mehta, "Comparison of Diffractive and non-Diffractive Deep–Inelastic Scattering", in Proc. of the International Workshop on Photon–Photon and Photon–Hadron Interactions "Photon95", Sheffield, UK, April 1995, ed. S. L. Cartwright and D. J. Miller, in litt.

[12] J. B. Dainton, "Deep–Inelastic Electron–Proton Diffraction", in Proc. VI Blois Workshop "Frontiers in Strong Interactions", Château de Blois, France, June 1995, in litt., and DESY 95-228.

[13] T. Ahmed et al. (H1 Collaboration), Nucl. Phys. **B439** (1995) 471.

[14] L. N. Lipatov, Sov. Phys. JETP **63** (1986) 904.

[15] É. A. Kuraev, L. N. Lipatov, and V. S. Fadin, Sov. Phys. JETP **45** (1977) 199.
Ya. Ya. Balitskiĭ and L. N. Lipatov, Sov. J. Nucl. Phys. **28** (1978) 822.

[16] J. P. Phillips, "Rapidity Gap Events at HERA and the Structure of the Pomeron", in Proc. of the International Workshop on Deep–Inelastic Scattering and Related Topics, Paris, France, April 1995, ed. J-F. Laporte and Y. Sirois, in litt.

[17] H1 Collaboration, "The Partonic Structure of Proton Diffraction", paper EPS-0491 submitted to the International Europhysics Conference on High Energy Physics, Brussels, July 1995, and to the International Symposium on Lepton–Photon Interactions, Beijing 1995.

[18] T. Ahmed et al. (H1 Collaboration), Phys. Lett. **B354** (1995) 494.

[19] A. Caldwell, J. B. Dainton, W. J. Stirling et al., Report of the Working Group on Structure Functions, in Proc. of the Int. Workshop on Deep–Inelastic Scattering and Related Topics, Eilat, Israel, 1994, ed. Aharon Levy, World Scientific, **ISBN 981–02–2053–7**, p.315.

[20] B. Badelek, N. Brook, A. De Roeck, A. D. Martin et al., Report of the Working Group on Structure Functions, in these proceedings.

[21] ZEUS Collaboration, M. Derrick et al., Phys. Lett. **B356** (1995) 601.

[22] H1 Collaboration, "Exclusive ρ^0 Production in Deep–Inelastic Scattering Events at HERA", paper EPS-0490 submitted to the International Europhysics Conference on High Energy Physics, Brussels, July 1995, and to the International Symposium on Lepton–Photon Interactions, Beijing 1995.

[23] ZEUS Collaboration, M. Derrick et al., paper EPS-0397 submitted to the International Europhysics Conference on High Energy Physics, Brussels, July 1995, and to the International Symposium on Lepton–Photon Interactions, Beijing 1995.

[24] H1 Collaboration, "J/ψ Production inf Deep Inelastic Scattering at HERA", paper EPS-0469 submitted to the International Europhysics Conference on High Energy Physics, Brussels, July 1995, and to the International Symposium on Lepton–Photon Interactions, Beijing 1995.

[25] H1 Collaboration, "Photoproduction of J/ψ Mesons at HERA", paper EPS-0468 submitted to the International Europhysics Conference on High Energy Physics, Brussels, July 1995, and to the International Symposium on Lepton–Photon Interactions, Beijing 1995.

[26] ZEUS Collaboration, M. Derrick et al., paper EPS-0386 submitted to the International Europhysics Conference on High Energy Physics, Brussels, July 1995, and to the International Symposium on Lepton–Photon Interactions, Beijing 1995.