FIRST MEASUREMENT OF $F_2^{D(3)}$ IN DEEP INELASTIC SCATTERING AT HERA AND ITS RELATION TO F_2

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1 Introduction

Using a selection of deep-inelastic events with a rapidity gap in the H1 experiment at HERA has enabled the measurement of the diffractive structure function $F_2^{D(3)}(x, Q^2, x_{I\!P})$ and the diffractive contribution to the proton structure function F_2.

2 Rapidity Gap Events

A normal Deep Inelastic Scattering (DIS) event has energy deposited in the forward (proton) direction from interactions of proton fragments. A class of "rapidity gap" events is also observed which have no energy in the forward direction.

The rapidity gap is defined by the variable η_{max}, which is the pseudorapidity ($\eta = -\ln\tan\frac{\theta}{2}$) of the most forward energy cluster in the calorimeter. Events with a low value of η_{max} have a large rapidity gap, and are not reproduced by standard DIS Monte Carlos. These events are identified with interactions where the virtual photon scatters from a colourless component of the proton (Pomeron). Thus there is no colour string to fragment between the proton and the struck quark.

The kinematic variables Q^2, x and t are defined in the usual way. For rapidity gap events further variables $x_{I\!P}$ and β are defined; in the limits of small proton mass and small t then $x_{I\!P}$ is approximately equal to the fraction of the proton's momentum carried by the Pomeron and β is the fraction of the Pomeron's momentum carried by the struck quark. These variables are measured using the relations

$$x_{I\!P} \approx \frac{Q^2 + M_X^2}{Q^2} \cdot x \qquad (1)$$

and

$$\beta \approx \frac{Q^2}{Q^2 + M_X^2} \qquad (2)$$

where M_X is the mass of the hadronic system excluding the proton. We define a structure function $F_2^{D(3)}(x, Q^2, x_{I\!P})$ by analogy with the usual F_2:

$$\frac{d^3\sigma}{dx dQ^2 dx_{I\!P}} = \frac{4\pi\alpha^2}{xQ^4}\left\{1 - y + \frac{y^2}{2}\right\} F_2^{D(3)}. \qquad (3)$$

3 Extraction of $F_2^{D(3)}$

The basic kinematic cuts are $7.5 < Q^2 < 70\,\mathrm{GeV}^2$ and $0.03 < y < 0.7$, giving 16366 events with $\int \mathcal{L}\,dt = 271 \pm 14\,\mathrm{nb}^{-1}$ from the 1993 data-taking period. Rapidity gap events are selected to have $\eta_{max} < 3.2$ and no energy in the forward detectors (extending to $\eta = 6.6$). This implies the limits $|t| \lesssim 7\,\mathrm{GeV}^2$ and $x_{I\!P} < 0.05$. This gives 1723 rapidity gap events. The result, as a function of $x_{I\!P}$ in bins of x and Q^2, is given in[1].

$F_2^{D(3)}$ can be fitted to the factorised form $A(Q^2, \beta)\, x_{I\!P}^{-n}$ with $n = 1.19 \pm 0.06\,(stat.) \pm 0.07\,(syst.)$ over a range $0.0003 < x_{I\!P} < 0.05$, with $\chi^2/dof = 32/46$. The Regge prediction for $x_{I\!P}$ dependence is $x_{I\!P}^{-[2\alpha(t)-1]}$ giving (ignoring t dependence) $\alpha(t=0) = 1.10 \pm 0.03 \pm 0.04$, compared with $\alpha(t=0) = 1.085$ for the Pomeron, and $\alpha(t=0) \approx 0.5$ for vector meson exchange. This is consistent with the behaviour expected from diffraction, and inconsistent with meson exchange.

The cross section is therefore factorisable into a Pomeron flux factor $f_{I\!P/p}(x_{I\!P}) \propto x_{I\!P}^{-n}$ and an electron-Pomeron cross section, so the structure function also factorises:

$$F_2^{D(3)}(\beta, Q^2, x_{I\!P}) = f_{I\!P/p}(x_{I\!P}).F_2^{I\!P}(\beta, Q^2). \qquad (4)$$

However, the normalisation of the Pomeron flux is theoretically undefined, so we define

$$\tilde{F}_2^D(\beta, Q^2) = \int_{0.0003}^{0.05} F_2^{D(3)}(\beta, Q^2, x_{I\!P})\, dx_{I\!P} \qquad (5)$$

where $\tilde{F}_2^D(\beta, Q^2) \propto F_2^{I\!P}(\beta, Q^2)$. This is shown in Fig. 1. Notable features are:

- Approximate Q^2 independence (scaling) is seen, so the interaction is with pointlike constituents.
- $\tilde{F}_2^D(\beta, Q^2)$ is non-zero for a wide range of β, so there are partons in the Pomeron.
- There is a suggestion of a rise with $\ln Q^2$ at all β, implying QCD evolution with a significant "valence" gluon content.

The superimposed curves are the result of QCD fits, which take a z dependence (z ($= x_{i/I\!P}$) is the fraction of the Pomeron's momentum taken by the parton) for

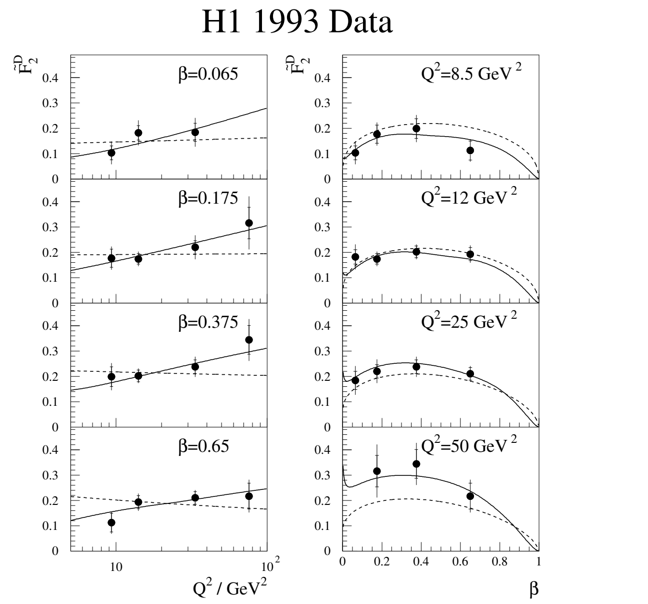

Figure 1: QCD fits to the Pomeron structure function $\tilde{F}_2^D(\beta, Q^2)$

quark and gluon components of the form $z^a(1-z)^b$ at $Q^2 = 4\,\mathrm{GeV}^2$, with QCD (DGLAP) evolution in Q^2.

With quarks only (at $Q^2 = 4\,\mathrm{GeV}^2$) the fit is acceptable and gives a rise with Q^2 at small β but a fall at large β (dotted lines). Including gluons (full lines) gives a better fit; only a hard gluon can give a rise at all β. The estimated gluon content is 70–90% at $Q^2 = 4\,\mathrm{GeV}^2$.

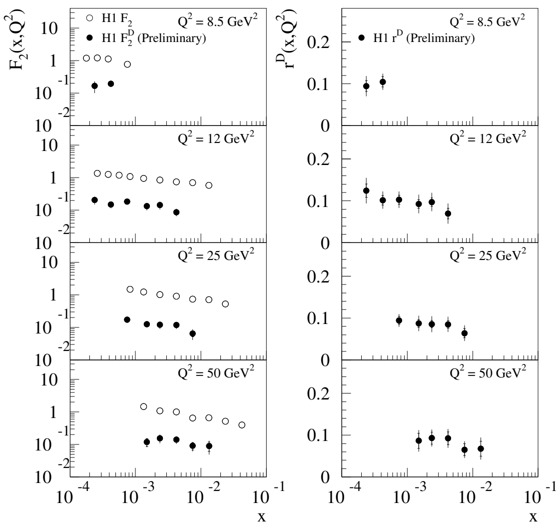

Figure 2: The diffractive contribution to F_2

4 The Diffractive Contribution to F_2

We have also measured $F_2^D(x, Q^2)$, the diffractive contribution to F_2 (Fig. 2):

$$F_2^D(x, Q^2) = \int_x^{0.05} F_2^{D(3)}(x, Q^2, x_{I\!P})\,dx_{I\!P} \qquad (6)$$

and

$$r_D(x, Q^2) = F_2^D(x, Q^2)/F_2(x, Q^2). \qquad (7)$$

The diffractive contribution is about 10% for all x, Q^2 except for x near 0.05 (the kinematic limit for $x_{I\!P} < 0.05$). Therefore diffractive events are not responsible for the rise in F_2 at low x.

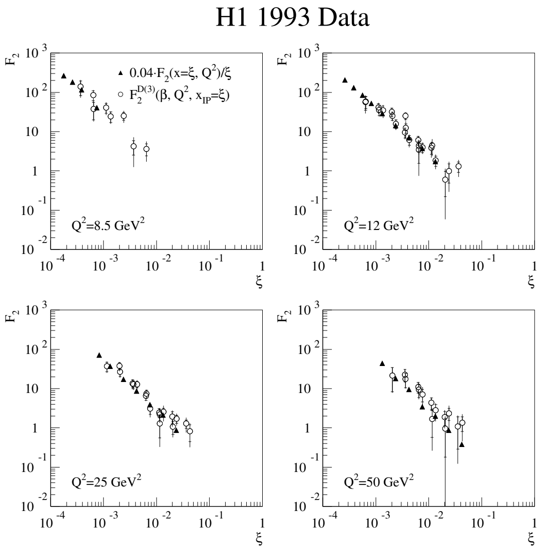

Figure 3: Comparison with the Buchmüller prediction

A model by Buchmüller et al.[2] of the partonic structure of diffractive events assumes that a $q\bar{q}$ pair (initially in a colour octet state) can evolve by non-perturbative interactions with the colour field of the proton into a colour-singlet state. This predicts 1/9 of events with a rapidity gap, and a scaling relationship between $F_2^{D(3)}$ and F_2:

$$\xi F_2^{D(3)}(\beta, Q^2, x_{I\!P} = \xi)|_{Q^2} = 0.04\, F_2(x = \xi, Q^2)|_{Q^2} \qquad (8)$$

(see Fig. 3). The data are consistent with this prediction.

References

1. T. Ahmed at al., *Phys. Lett.* **B348** (1995) 681.
2. W. Buchmüller et al., DESY Report DESY 95-077, 1995.