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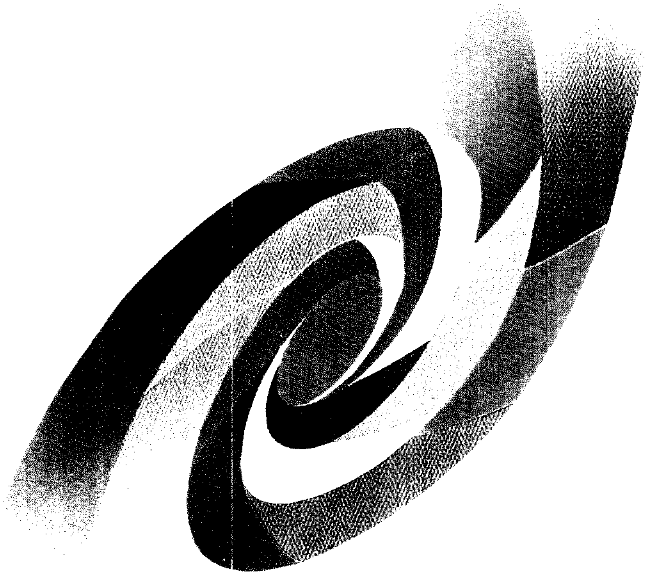

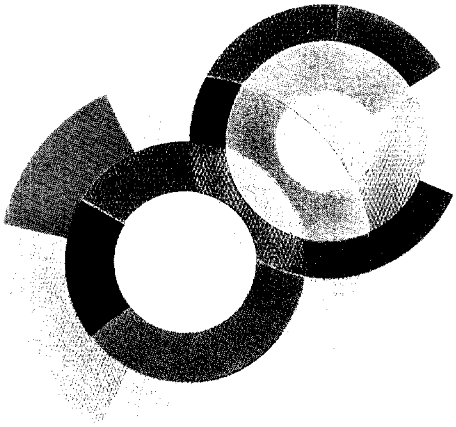

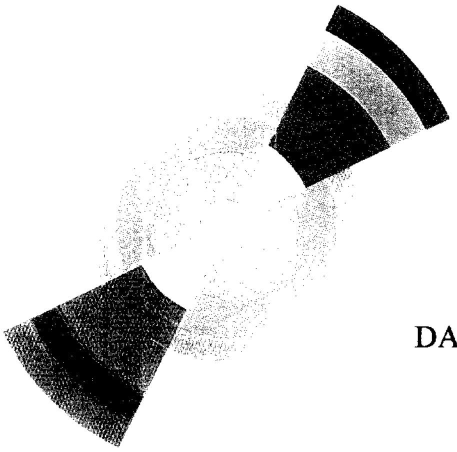

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QCD DIPOLE DESCRIPTION OF TOTAL AND DIFFRACTIVE PROTON STRUCTURE FUNCTIONS

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Talk given at the International Conference on High Energy Physics (HEP97)
Jerusalem (Israel), 19-26 August 1997

Couverture Sylvie Cabrit et Marc Sauvage

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QCD dipole description of total and diffractive proton structure functions

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Abstract. It is argued that the QCD dipole picture allows to build an unified theoretical description -based on BFKL dynamics- of the total and diffractive nucleon structure functions. This description is in qualitative agreement with the present collection of data obtained by the H1 collaboration. [1]

1 BFKL dynamics in the framework of the QCD dipole model and F_2 fit

The quest for an unifying picture of total and diffractive structure functions based on a perturbative QCD framework is a challenge. The interest of using the QCD dipole approach [1] for deep-inelastic structure functions is to deal with an unified approach based on the BFKL resummation properties of perturbative QCD [2]. Indeed, starting from an unique non-perturbative input in terms of a primordial proton distribution of dipoles at low scale Q_0, it is possible to compute the theoretical predictions [3] for the (transverse and longitudinal) quark and the gluon distributions as functions of x and Q^2. In the same framework it is also possible to compute the two components of the dipole-model predictions for hard diffractive structure functions, namely the inelastic component and the quasi-elastic one [4].

To obtain the proton structure function F_2, we use the k_T factorisation theorem [5], valid at high energy (small x), to factorise the $(\gamma\ g(k) \rightarrow q\ \bar{q})$ cross section and the unintegrated gluon distribution of an onium state which contains the physics of the BFKL pomeron [1]. One can show that

$$F_2 = \mathcal{N} a^{1/2} e^{(\alpha_P - 1)\ln\frac{c}{x}} \frac{Q}{Q_0} e^{-\frac{a}{2}\ln^2\frac{Q}{Q_0}} \qquad (1)$$

where $\alpha_P - 1 = \frac{4\bar{\alpha}N_C \ln 2}{\pi}$ and $a = \left(\frac{\bar{\alpha}N_c}{\pi}7\zeta(3)\ln\frac{c}{x}\right)^{-1}$. The detailed calculations can be found in [3]. It can be shown that the approximations are valid when $\ln Q/Q_0/\ln(c/x) << 1$, that is in the kinematic domain of small x, and moderate Q/Q_0. The free parameters for the fit of the H1 data are $\mathcal{N}$, α_P, Q_0, and c. Finally, we get parameter free predictions for R, the ratio of the longitudinal and transverse structure functions, and the gluon density in the proton [3].

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[1] Invited talk given at the International Conference on High Energy Physics (HEP97), Jerusalem, 19-26 August 1997

In order to test the accuracy of the F_2 parametrisation obtained in formula (1), a fit using the recently published data from the H1 experiment [6] has been performed [3]. We have only used the points with $Q^2 \leq 150 GeV^2$ to remain in a reasonable domain of validity of the QCD dipole model. The result of the fit is given in detail in reference [3]. The χ^2 is 88.7 for 130 points, and the values of the parameters are $Q_0 = 0.522 GeV$, $\mathcal{N} = 0.059$, and $c = 1.750$, while $\Delta_P = 0.282$. Commenting on the parameters, let us note that the effective coupling constant extracted using (3) from Δ_P is $\alpha = 0.11$, close to $\alpha(M_Z)$ used in the H1 QCD fit. It is an acceptable value for the small fixed value of the coupling constant required by the BFKL framework. The running of the coupling constant is not taken into account in the present BFKL scheme. This could explain the rather low value of the effective Δ_P which is expected to be reduced by the next to leading corrections.

2 Diffractive structure functions

The success of the dipole model applied to the proton structure function motivates its extension to the investigations to other inclusive processes, in particular to diffractive dissociation. We can distinguish two different components:
- the "elastic" term which represents the elastic scattering of the onium on the target proton;
- the "triple-pomeron" term which represents the sum of all dipole-dipole interactions (it is dominant at large masses of the excited system).
Let us describe in more detail each of the two components. The "triple-pomeron" term dominates at low β, where $\beta = x/x_P$, x_P is the proton momentum fraction carried by the "pomeron" [4]. This component, integrated over t, the momentum transfer, is factorisable in a part depending only on x_p (flux factor) and on a part depending only on β and Q^2 ("pomeron" structure function F) [4]:

$$F_2^{D(3),I} \simeq x_P^{-1-2\Delta_P} \left(\frac{2a}{\pi}\right)^3 \left(\frac{Q}{Q_0}\right) (\beta)^{-\Delta_P} \left(\frac{2a\,(\beta)}{\pi}\right)^{1/2} \exp\left\{-\frac{1}{2}a\,(\beta)\ln^2\left(\frac{Q}{Q_0}\right)\right\} \qquad (2)$$

The important point to notice is that $a(x_p)$ is proportional of $ln 1/x_p$. The effective exponent (the slope of lnF_2^D in lnx_p) is found to be dependent on x_p because of the term in $ln^3(x_p)$ coming from a, and is sizeably smaller than the BFKL exponent. This is why we can describe an apparently soft behaviour (a small exponent in x_p) with the BFKL equation, which predicts a hard behaviour (the exponent in x_p is close to 0.35). This is due to the fact that the effective exponent is smaller then the real one. It should be also noticed that the structure function F is directly proportional to the proton structure function.

The elastic component behaves quite differently [4]. The explicit formulae used in the prediction can be found in reference [8]. First it dominates at $\beta \sim 1$. It is also factorisable like the inelastic component, but with a different flux factor, which means that the sum of the two components will not be factorisable. This means that in this model, factorisation breaking is coming from the fact that we sum up two factorisable components with different flux factors. The β dependence is quite flat at large β, due to the interplay between the longitudinal and transverse components. The sum remains almost independent of β, whereas the ratio $R = F_L/F_T$ is strongly β dependent. Once more, a R measurement in diffractive processes will be an interesting way to distinguish the different models, as the dipole model predicts different β and Q^2 behaviours.

The sum of the two components shown in the figure describes quite well the H1 data [7]. There is no further fit of the data as we chose to take the different parameters (Q_0, α_P, c) from the F_2 fit. In this study, the normalisation is let free. The most striking point is that we describe quite well the factorisation breaking due to the resummation of the two components at low and large β [8]. The full line is the sum of the two components, the dashed line the inelastic one (which dominates at low β), and the dotted line the elastic one (which dominates at high β).

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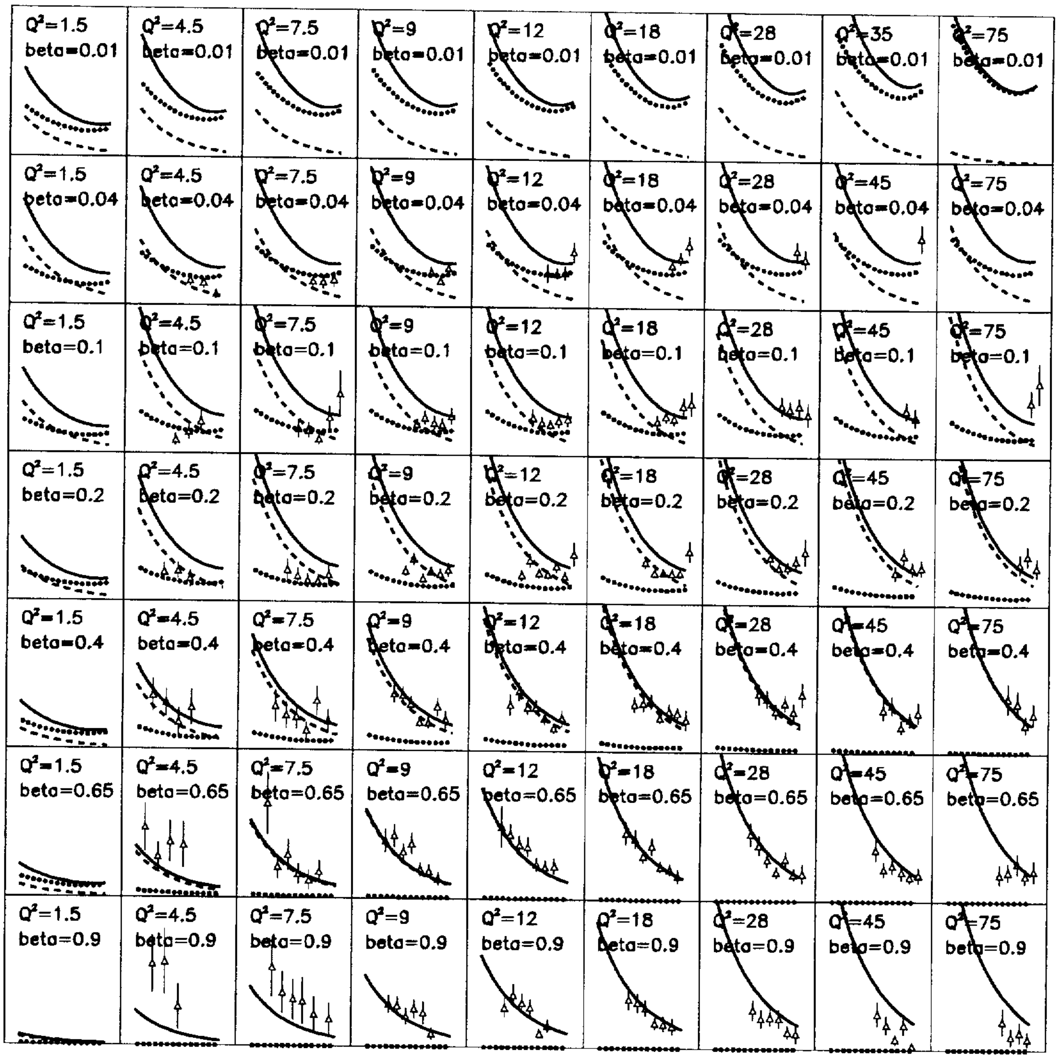

Fig. 1. Prediction on F_2^D and comparison with the H1 measurement. The full line is the sum of the two components, the dashed line the inelastic one (which dominates at low β), and the dotted line the elastic one (which dominates at high β).