Q^2 evolution of the structure function $F_2(x,Q^2)$ at small values of x

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Under the assumption that the behavior of the structure function $F_2(x,Q^2)$ for deep inelastic scattering is governed by a pomeron at small values of x, the parameters of a parametrization of this function are found on the basis of data from the NMC group at $Q^2=5$ GeV^2. The evolution of the structure function toward larger values of Q^2 is calculated. The results are compared with preliminary data obtained at the HERA accelerator.

Simple asymptotic regimes (Bjorken scaling, the perturbative regime, or the Regge behavior) in the structure functions for deep inelastic scattering continue to attract much interest. Some data on deep inelastic lepton–hadron scattering at small values of the Bjorken variable x recently found by the NMC group[1] represent the first penetration into the range of applicability of Regge phenomenology. The value $Q^2=5$ GeV^2 corresponding to these results is large enough that one can assume that Bjorken scaling applies. In addition, this value is close to hadron-mass values (~ 1 GeV), so one can expect a behavior typical of hadron cross sections for the structure functions. As was pointed out in Ref. 2, the NMC data reproduce well the diffraction component which can be seen in high-energy ($\sqrt{s}\sim 1$ TeV) pp and $\bar{p}p$ scattering, which is determined by pomeron exchange in the t channel.

The diffraction component can be fitted well by the formula

$$\sigma_t=A(1+\epsilon\ln s)\quad(\epsilon\approx 0.1),$$

which is also reproduced from the standpoint of s-channel unitarity. It corresponds to the exchange of a double Pomeranchuk pole and can be found from QCD.[3] It was suggested in Ref. 4 that the behavior of the structure functions at small values of x is also determined by a dipole pomeron (we recall that we have $x\sim Q^2/s$ in this kinematic region), i.e.,

$$F_2(x,Q^2)=B(1+\epsilon\ln x^{-1}). \tag{1}$$

A Q^2 evolution of the structure functions of a fairly general type, which includes the behavior in (1), was analyzed in our earlier paper.[5] In the present letter we use a technique developed in that earlier paper to exactly calculate the Q^2 evolution of the structure functions at small values of x. We start with the value $Q_0^2=5$ GeV^2, for

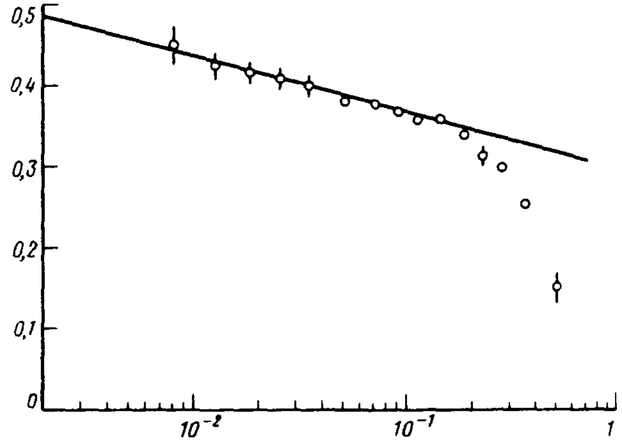

FIG. 1. Plot of the structure function $F_2(x,Q^2)$ versus x for $Q^2=5$ GeV^2. Data reported by the NMC group are shown. The solid line corresponds to Eq. (1) of the text.

which we believe that the structure function is of the form in (1) with parameter values fixed by the NMC data. We find a simple behavior for $F_2(x, Q^2)$ (the complete analysis is given in a preprint[6]):

$$F_2(x,\xi)=Be^{-4.64\xi}\left[x^{-1.44\xi}+\epsilon\ln\frac{1}{x}\,e^{3\xi}x^{-0.72\xi}\right]\quad\left(\xi=\ln\frac{\ln(Q^2/\Lambda^2)}{\ln(Q_0^2/\Lambda^2)}\right). \tag{2}$$

This behavior satisfies the GLAP equation[7] (we are working with four types of quarks) with condition (1) at $Q^2=Q_0^2$.

Under the assumption of a logarithmic behavior for the structure functions at small values of x and under the assumption $Q_0^2=5$ GeV^2, we find a power-law behavior in x at $Q^2>Q_0^2$. We can thus describe the transition, at small values of x, from a "nonperturbative" regime (i.e., a logarithmic behavior in x) at small values of Q^2 to a perturbative regime (i.e., a power-law behavior in x) at larger values of Q^2.

We can compare our results with some new experimental data obtained at the HERA accelerator. Preliminary data are available[8] for $Q^2=15$ and 30 GeV^2. To determine B and ϵ we use the NMC data (Fig. 1), finding

$$B\approx 0.3,\quad \epsilon\approx 0.1.$$

The value found for ϵ here supports the suggestion that the high-energy scattering is similar to the structure functions for deep inelastic scattering at small values of x.

The result of a comparison of expression (2) with the HERA data is shown in Fig. 2 (we are using $\Lambda_{QCD}=200$ MeV). We see a good agreement between our calculations and experiment. We introduced no additional parameters in making this comparison with the HERA data.

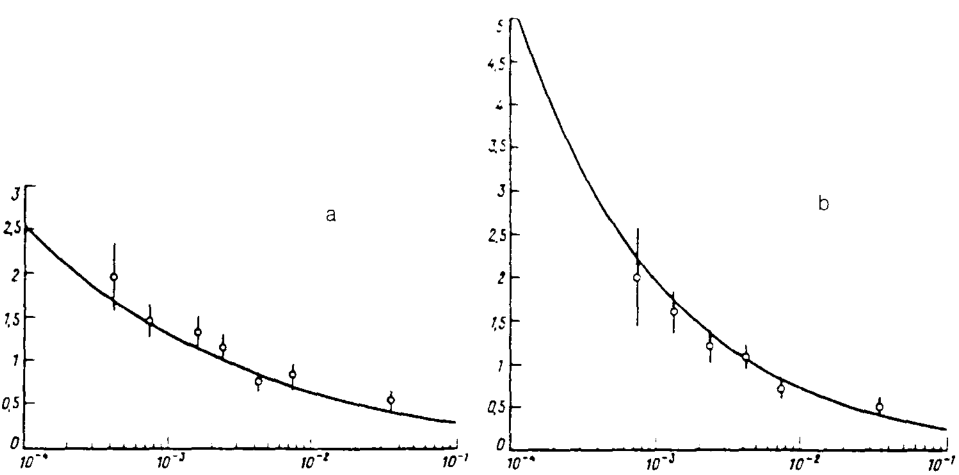

FIG. 2. Plots of the structure function $F_2(x,Q^2)$ versus x for $Q^2=15$ GeV^2 (a) and 30 GeV^2. Data obtained by the H1 group (at the HERA accelerator) are shown. The solid curves correspond to Eq. (2) of the text.

A model based on the exchange of a dipole pomeron not only explains the behavior of the cross section for pp scattering at large values of s but also predicts the behavior of the structure function F_2 at small values of x and various values of Q^2. The quantitative agreement with experimental data supports our ansatz in (1) with Q_0^2. In addition, the Q^2 evolution has the consequence that a model based on the exchange of a dipole pomeron becomes consistent with a power-law x dependence of the structure functions at large values of Q^2 and thus with the predictions of field-theory models.[9]

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[1] P. Amaudrus *et al.*, Phys. Lett. B **295**, 159 (1992).

[2] L. Jenkovszky, "Small-x extrapolation of the recent NMC data," *Proceedings of Rencontres de Physique de Valle d'Aosta, La Thuile, 1993,* M. Greco (editor), Proc. in preparation; P. Desgrolard, M. Giffon, L. Jenkovszky *et al.*, "The Pomeron and small-x extrapolation of the structure function" (Lyon Preprint, 1993), in preparation.

[3] F. Paccanoni, *Phenomenological Consequences of the Dipole Gluon Propagator. Proceedings of the Workshop on Elastic and Diffractive Scattering. Hadrons 92,* L. Jenkovzky and E. Martynov (editors), p. 39.

[4] L. Jenkovszky, E. Paccanoni, and E. Predazzi, Nucl Phys. B **25**, 80 (1992).

[5] L. L. Enkovskiĭ, A. V. Kotikov, and F. Paccanoni, Yad. Fiz. **55**, 2205 (1992).

[6] L. L. Jenkovszky, A. V. Kotikov, and F. Paccanoni, Padova Preprint (1993), in preparation.

[7] V. N. Gribov and L. N. Lipatov, Yad. Fiz. **15**, 1218 (1972) [Sov. J. Nucl. Phys. **15**, 675 (1972)]; L. N. Lipatov, Yad. Fiz. **20**, 181 (1974) [Sov. J. Nucl. Phys. **20**, 94 (1974)]; G. Altaralli and G. Parisi, Nucl. Phys. B **126**, 298 (1977).

[8] C. Vallee, "DIS cross section (F_2) in H_1," presented at Les Rencontres de Moriond, 1993, proceedings in preparation.

[9] L. N. Lipatov, Zh. Eksp. Teor. Fiz. **90**, 1536 (1986) [Sov. Phys. JETP **63**, 906 (1986)].

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