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Comments on structure functions at low-x

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Abstract. We present further analysis of the structure functions at low-x using the approximate solutions of Altarelli-Parisi equations recently reported by us. We also compare our results with non-perturbative and non-linear evolutions.

Keywords. Structure functions; Altarelli-Parisi equations; low-x.

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In a recent paper (Choudhury and Sarma 1992) we have shown that at low-x, the Altarelli–Parisi (AP) equations (Altarelli and Parisi 1977) have simple possible approximate solutions:

$$F_2^{NS}(x,t) = F_2^{NS}(x,t_0)(t/t_0) \tag{1}$$

$$F_2^{S}(x,t) = F_2^{S}(x,t_0)(t/t_0). \tag{2}$$

In deriving (2), we needed the extra assumption that the t-evolution of gluon and singlet structure functions are identical (Choudhury and Saikia 1989) and we tested only (2) through the relation of the deuterium structure function

$$F_2^{D} = \frac{5}{18}F_2^{S} \tag{3}$$

where the small-x small -Q^2 EMC data (Arneodo *et al* 1989) were used. We then compared our result with the non-perturbative (Donnachie and Landshoff 1984) as well as non-linear evolutions (Kim and Ryskin 1991) as given below.

Non-perturbative evolution

$$\mathrm{V} = F_2^{\text{valence}} = 1{\cdot}33X^{0{\cdot}56}(1-x)^3\left(\frac{Q^2}{Q^2+0{\cdot}85}\right)^{0{\cdot}44} \tag{4}$$

$$S = F_2^{\text{non-valence}} = 0{\cdot}17x^{-0{\cdot}8}(1-x)^7\left(\frac{Q^2}{Q^2+0{\cdot}36}\right)^{1{\cdot}08} \tag{5}$$

Non-linear evolution

$$F_2^{S}(x,Q^2) = F_2^{S}(x,Q_0^2)\left(\frac{Q^2}{Q_0^2}\right)^{24/7} \tag{6}$$

In the present note we show the corresponding comparison for proton structure function defined by the relation,

$$F_2^p(x,t) = F_2^p(x,t_0)(t/t_0) \tag{7}$$

where,

$$F_2^p(x,t_0) = \frac{5}{18}F_2^{NS}(x,t_0) + \frac{3}{18}F_2^{NS}(x,t_0).$$

Low-x data are taken from Fermilab E 98 experiment (Gordon *et al* 1979).

While comparing the non-perturbative evolutions defined by (4) and (5), we take all the three options for singlet, viz. with (u,d), (u,d,s) and (u,d,s,c) sea components as noted earlier (Choudhury and Sarma 1992). They will respectively yield the following form of the structure function:

$$F_2^p(x,t) = V + \left\{\frac{10}{9}S, \frac{12}{9}S, \frac{20}{9}S\right\}. \tag{8}$$

In testing any evolution one always faces the problem of inputs. This is more so in the case of low-x, low-Q^2 structure functions. In our earlier communication, we tested our evolution taking inputs directly from data without the use of phenomenological inputs. Such strategy seemed safer than to evolve the structure functions down to $Q^2 < Q_0^2$. However in recent times (Kwiecinski and Strozik-Koltorz 1991), plausible parametrization of parton distributions at low-x has been suggested which have got even correct backward QCD evolution ($Q^2 < Q_0^2$).

In the present work, we therefore explore both the possibilities: inputs from data as well as their low-x parametrization. For the latter, we assume that the structure function is dominated by sea and the low-x sea components (Kwiecinski and Strozik-Koltorz 1991) at $Q_0^2 = 5\,\text{GeV}^2$ are given by

$$\begin{aligned} xq_s^{(i)}(x,Q_0^2) &= x\bar{q}_s^{(i)}(x,Q_0^2) \\ &= C^{(i)}(3{\cdot}25 \times 10^{-2}x^{-0{\cdot}5} + 0{\cdot}845)(1-x)^{8{\cdot}54} \end{aligned} \tag{9}$$

with $C^{(1,2)} = 0{\cdot}182$ for u, d quarks and $C^{(3)} = 0{\cdot}081$ for s quark. To incorporate the charm contribution, we further assume its value to be equal to the s quark. We also report the prediction of the non-linear evolution (Kim and Ryskin 1991), equation (6) for the singlet structure function.

In figure 1(a–d) we present our results (solid lines) for proton targets for representative values of x:$x = 0{\cdot}00125, 0{\cdot}002, 0{\cdot}00312, 0{\cdot}005$. Data at $Q^2 = 0{\cdot}25\,\text{GeV}^2$, $0{\cdot}25\,\text{GeV}^2$, $0{\cdot}35\,\text{GeV}$, $0{\cdot}45\,\text{GeV}^2$ are respectively taken as inputs to test the evolution (7). Agreement is again found to be excellent. In the same figures, we also plot the non-perturbative evolutions (dashed lines 1, 2, 3). We find that the non-perturbative results are in agreement with experiment without c quark for low-Q^2 while higher -Q^2 data require c. The corresponding results of the non-linear evolutions are also shown in the figures (dot dashed lines). In the same figures, we also plot the predictions of our formalism (dotted curves 1, 2, 3) with the low-x inputs given by equation (9). It conforms to experiment with (u, d, s, c) components in the sea.

In figure 2 we also plot $F_2^p(x,Q^2)$ vs Q^2 for relatively higher x, $x = 0{\cdot}16667$. The labels I and II correspond to the choices of data inputs at $Q^2 = 1{\cdot}375\,\text{GeV}^2$ and $1{\cdot}875\,\text{GeV}^2$ respectively. It shows that the agreement of the theory with experiment is poor specially at high -Q^2, indicating that the present approximation breaks down in kinematic regime of high-x and high-Q^2. It seems quite natural as our formalism was developed under low-x approximation.

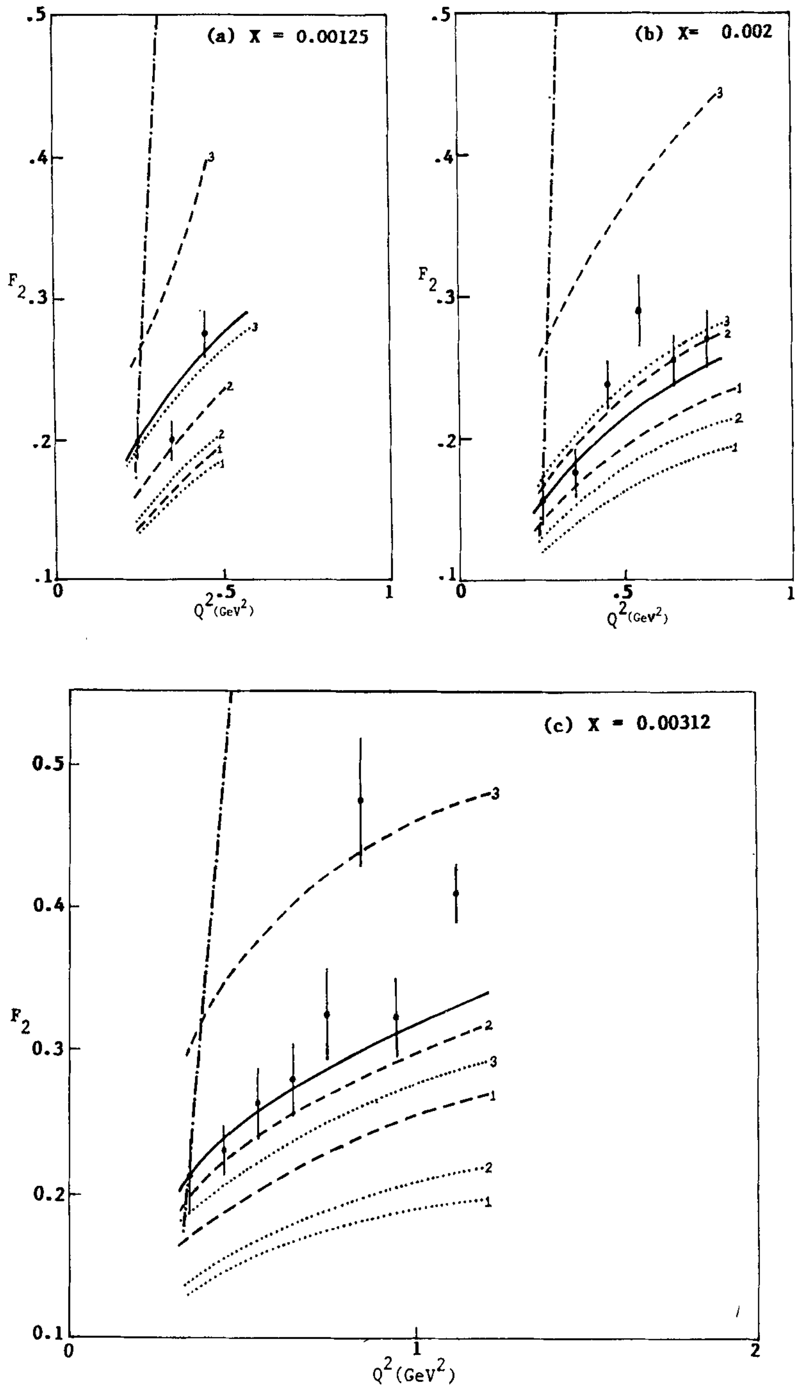

Figure 1 (a–c).

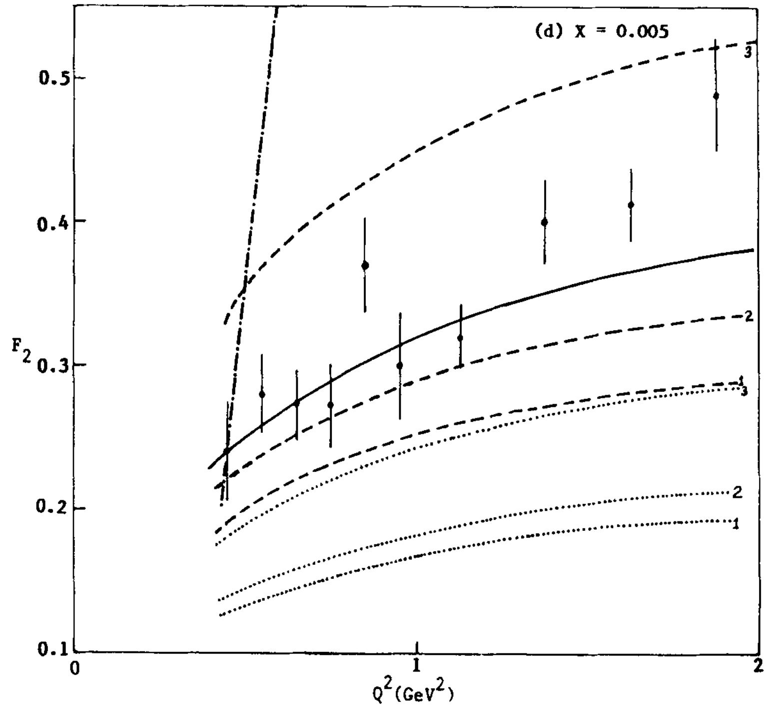

Figure 1(d).

Figure 1(a–d). $F_2^p(X, Q^2)$ vs Q^2 for $X = 0{\cdot}00125, 0{\cdot}002, 0{\cdot}00312$ and $0{\cdot}005$ respectively. Solid lines represent the predictions of the perturbative evolution while the dashed ones represent those of non-perturbative evolutions. Curves 1, 2 and 3 indicate contributions of (u, d), (u, d, s) and (u, d, s, c) in the sea respectively. Data are taken from Gordon *et al* (1979). Dot-dashed ones are the predictions of non-linear evolutions. Dotted ones correspond to the prediction of the perturbative evolution with low-X inputs.

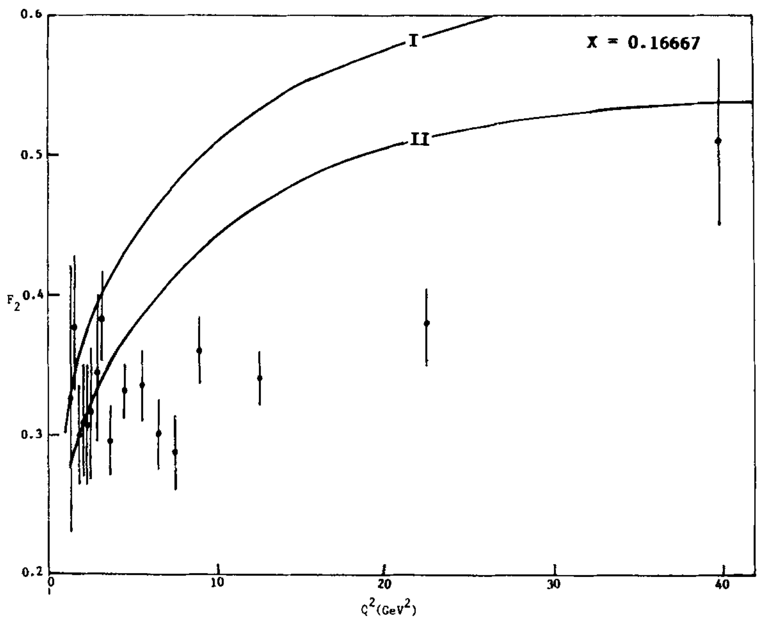

Figure 2. $F_2^p(X, Q^2)$ for $X = 0{\cdot}16667$. Curves I and II correspond to the choices of data inputs at $Q^2 = 1{\cdot}375\,\text{GeV}^2$ and $1{\cdot}875\,\text{GeV}^2$ respectively.

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