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A Re-evaluation of F_2^n/F_2^p and $F_2^p-F_2^n$

NEW MUON COLLABORATION (NMC)

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Abstract

We present a new determination of the ratio F_2^n/F_2^p and the non-singlet structure function $F_2^p-F_2^n$ based on recently measured values of F_2^d. At low x the ratio does not tend to unity. A new evaluation of the Gottfried sum is also given.

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In 1991 the New Muon Collaboration (NMC) published an evaluation of the Gottfried sum $\int(F_2^p-F_2^n)dx/x$ which showed that the simple quark model expectation of 1/3 was not reached [1]. In that analysis the non-singlet structure function was obtained as

$$F_2^p-F_2^n = 2\,F_2^d\,.(1-F_2^n/F_2^p)/(1+F_2^n/F_2^p) \quad (1)$$

with the ratio F_2^n/F_2^p, defined as $2F_2^d/F_2^p$-1, derived from the NMC data at 90 and 280 GeV and F_2^d from a global fit to the results of several earlier experiments.

Recently the NMC has made a more detailed study of the ratio F_2^n/F_2^p [2] from a slightly extended data set and has derived and published its own values of the proton and deuteron structure functions [3]. These represent the first precise measurements of F_2^p and F_2^d at small x and F_2^d differs significantly from the previous global fit used in ref. [1].

We present here a new determination of F_2^n/F_2^p [4], from the same data as used in ref. [2], but using a new parametrisation of F_2^d for determining the radiative corrections, which are treated here using the method of Akhundov et al. [5]. The F_2^d parametrisation was obtained [3] from a global fit to the NMC, SLAC and BCDMS data. The ratios were evaluated at Q^2 = 4 GeV^2, using a linear fit in log(Q^2) for each interval of x, as in ref. [1]. The value of 4 GeV^2 was chosen since it is covered by our measurements in the range $0.004 < x < 0.5$. The results are presented in table 1, together with the values of F_2^d from the parametrisation.

The differences with respect to the values of ref. [1] are primarily due to the use in the radiative correction procedure of the new values of F_2^d which are significantly larger at low x. The present values of F_2^n/F_2^p at low x are smaller than unity. This may be an indication of shadowing in the deuteron.

We also present a new evaluation of the non-singlet structure function $F_2^p-F_2^n$. This could be obtained from the values of F_2^p and F_2^d listed in the preprint version of ref. [3], but this would not take advantage of the simultaneous measurement on protons and deuterons, which is a crucial feature of the NMC experiment. With the NMC target configuration, acceptance corrections cancel almost entirely in the measurement of structure function ratios. For this reason it was possible to include more data in the determination of the ratio F_2^n/F_2^p than in that of the structure functions, and also to cover a larger kinematic range, making the two measurements almost independent. Consequently, the non-singlet structure function $F_2^p-F_2^n$ is obtained with optimal accuracy from F_2^d and the ratio F_2^n/F_2^p using eq. (1) as is done in ref. [1]. Thus, the values of the non-singlet structure function at Q^2 = 4 GeV^2 presented here are determined from the new global fit to F_2^d [3] and from the re-evaluated F_2^n/F_2^p [4]. No attempt was made to correct for the possible effects of shadowing in the lowest x bins (which would lower the values of $F_2^p - F_2^n$).

The results for $F_2^p - F_2^n$ are given in fig. 1 and in table 1. At low x the new values are slightly larger than those quoted in ref. [1]. This is due mainly to the change of $1 - F_2^n/F_2^p$ factor in eq. (1). The value of the Gottfried sum at $Q^2 = 4$ GeV^2 over the interval $0.004 < x < 0.8$ is found to be

$$S_G(0.004 - 0.8) = 0.236 \pm 0.008 \text{ (stat.)} .$$

Following the same procedure as in ref. [1] to evaluate the contributions from the unmeasured regions at very high and low x, we obtain 0.002 ± 0.001 and 0.020 ± 0.005, respectively. The low x contribution is estimated from a fit of $F_2^p - F_2^n$ to the expression ax^b in the range $0.004 < x < 0.15$ which yields the parameters $a = 0.16 \pm 0.02$ and $b = 0.50 \pm 0.06$. This fit assumes a smooth interpolation of $F_2^p - F_2^n$ between $x = 0.15$, where nuclear effects are thought to be negligible, and $x = 0$. Possible deviations in the lowest x bins from this Regge-like functional form of $F_2^p - F_2^n$, extracted according to eq. (1), have a negligible effect on the value of the extrapolation to $x = 0$.

In total we obtain for the Gottried sum 0.258 ± 0.010 (stat.) ± 0.015 (syst.) where the systematic error taken from ref. [1] should now be considered as an upper limit in view of the improved knowledge of F_2^d. Adding the errors quadratically the sum is

$$S_G = 0.258 \pm 0.017.$$

This new value is 0.018 higher than the one quoted in our earlier paper [1], due to the improved knowledge of F_2^d at low x [3]. The conclusions of ref. [1] are unchanged.

The evaluation of the Gottfried sum at higher Q^2 requires large extrapolations of the measured values of F_2^n/F_2^p at low x. For this reason precise determinations of $F_2^p - F_2^n$ and the Gottfried sum from the present data is restricted to Q^2 around 4 GeV^2.

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Table 1: The values of F_2^n/F_2^p, F_2^d and $F_2^p-F_2^n$ at $Q^2 = 4$ GeV^2. The errors are statistical.

x	F_2^n/F_2^p	F_2^d	$F_2^p-F_2^n$
0.007	0.952 ± 0.017	0.413	0.020 ± 0.007
0.015	0.949 ± 0.011	0.394	0.021 ± 0.004
0.030	0.921 ± 0.007	0.378	0.031 ± 0.003
0.050	0.916 ± 0.007	0.365	0.032 ± 0.003
0.080	0.880 ± 0.006	0.350	0.045 ± 0.002
0.125	0.835 ± 0.007	0.331	0.059 ± 0.003
0.175	0.812 ± 0.009	0.310	0.064 ± 0.003
0.250	0.742 ± 0.008	0.274	0.081 ± 0.003
0.350	0.638 ± 0.012	0.214	0.095 ± 0.004
0.450	0.496 ± 0.020	0.152	0.103 ± 0.005
0.550	0.500 ± 0.039	0.101	0.068 ± 0.007
0.700	0.375 ± 0.061	0.048	0.044 ± 0.006

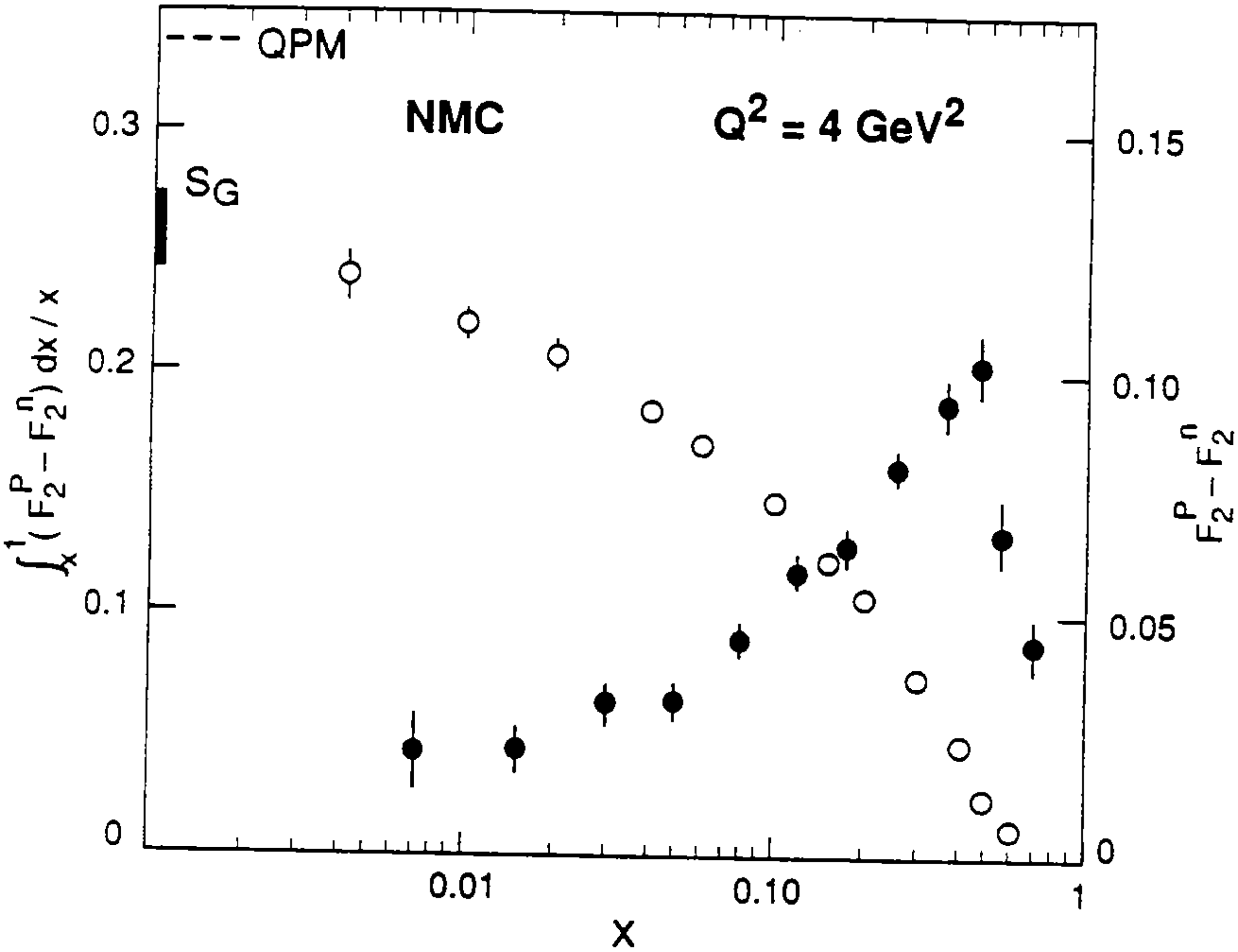

Fig. 1

The difference $F_2^p - F_2^n$ (full symbols and scale to the right) and $\int_x^1 (F_2^p - F_2^n) dx/x$ (open symbols and scale to the left) at $Q^2 = 4\ GeV^2$, as a function of the Bjorken scaling variable x. The extrapolated result S_G and the prediction of the simple quark-parton model (QPM) are also shown.