POLARIZED DEEP INELASTIC SCATTERING AND THE SPIN STRUCTURE OF THE PROTON*

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ABSTRACT: We reexamine recent data on polarized lepton-proton scattering and we give an estimate of the fraction of the proton spin carried by the light quarks. We also recall some simple ways to measure the missing fraction of the proton spin.

Let us recall that the EMC collaboration has recently obtained a very interesting result on the asymmetry $A_1^p(x)$ in polarized muon-proton deep inelastic scattering.[1] These data extend to very small values of x where they are significantly lower than expected and cover the kinematic range $0.01 \leq x \leq 0.7$ with $\langle Q^2 \rangle$ from 3.5 to 29.5 GeV^2. From this data one can evaluate the integral of the proton structure function $g_1^p(x)$, which is simply related to $A_1^p(x)$, and one finds that it is much smaller than predicted by Ellis and Jaffe.[2] Several recent theoretical papers[3] have tried various arguments to account for this disagreement but none of them is presenting a calculation of $A_1^p(x)$. Although tests of sum rules are important, even more restrictive is the comparison of the distribution itself with experimental observation. We would like to recall a 1984 prediction of $A_1^p(x)$ which describes well this new data and the rather simple physical content attached to it. In this

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approach,[4] deep inelastic scattering proceeds via *two* main mechanisms:

a) The single Fire-String production (Fig. 1a)

b) The double Fire-String production (Fig. 1b).

In a) the initial nucleon N must produce a low-lying baryon B^* and a virtual $q\bar{q}$-pair which, after interaction with the highly virtual photon, will give a high mass state, the Fire-String FS, whose decay will produce ordinary hadrons in the final state. In b) another $q\bar{q}$-pair is created within the color field existing in the virtual $q\bar{q}$-pair and after interaction with the virtual photon, the two pairs will recombine to produce two Fire-Strings, FS_1 and FS_2. One can see that a) dominates for large x because it involves valence quarks coming out from the nucleon and interacting directly with the virtual photon, while b) is dominant at small x because it involves the interaction of the virtual photon with sea quarks. This is clearly seen in Fig. 2 which shows the result of the calculation of $F_2^{\mu p}(x)$ at $Q^2 = 20\ \mathrm{GeV}^2$ and also the two separate contributions coming from the two mechanisms a) and b). From the relative size of a) and b), let us now try to guess what will be, in this model, $A_1^p(x)$ which reflects the helicity correlation between the nucleon N and the incoming virtual photon γ. We expect mechanism a) to give a sizeable A_1^p, of the order of the $SU(6)$ prediction, and a very small effect from mechanism b). Therefore we anticipate $A_1^p(x)$ to be small at low x and large at high x values in agreement with observation. A more detailed calculation has led to the prediction of $A_1^p(x)$ shown in Fig. 3 compared with experimental data. The agreement is remarkably good. On the other hand, if we consider the helicity correlation between the nucleon N and the Fire-String FS_1 produced (or one hadron from its decay product), we expect from this two-component mechanism a large effect at low x and a small effect at high x. This should be made more quantitative and should be checked experimentally. Finally, in this model the neutron asymmetry A_1^n is predicted to be very small and positive, so the light quarks carry, on the average, about one half of the proton spin. The strange sea quarks are also known to carry a small fraction of the proton spin.[6]

In the framework of QCD the fraction of the proton spin carried by gluons is important to know and it is presumably half of it, the rest being carried by the quarks in reasonable agreement with what we know about the sharing of the proton momentum. Therefore it is crucial to propose some ways to measure the spin-dependent distribution of the gluon. In polarized deep inelastic scattering, this is possible in the production of heavy quarkonia because there is an effect, for example in the process $\gamma^* g \to J/\psi g$, which has been calculated in Ref. 7. In polarized hadronic collisions, direct photon production at large p_T seems the best process to uncover a non-zero gluon polarization.[8]

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Figure Captions

Figure 1: The two-component mechanism for deep inelastic scattering: a) single Fire-String production, b) double Fire-String production.

Figure 2: Data and result of the calculation for $F_2^{\mu p}(x)$ versus x at $Q^2 = 20$ GeV^2 (full line) showing also the two contributions a) and b). (Taken from Ref. 4.)

Figure 3: Data on the asymmetry $A_1^p(x)$ versus x from Ref. 1 compared with the calculations of Ref. 4 (dashed line) and Ref. 5 (full line).

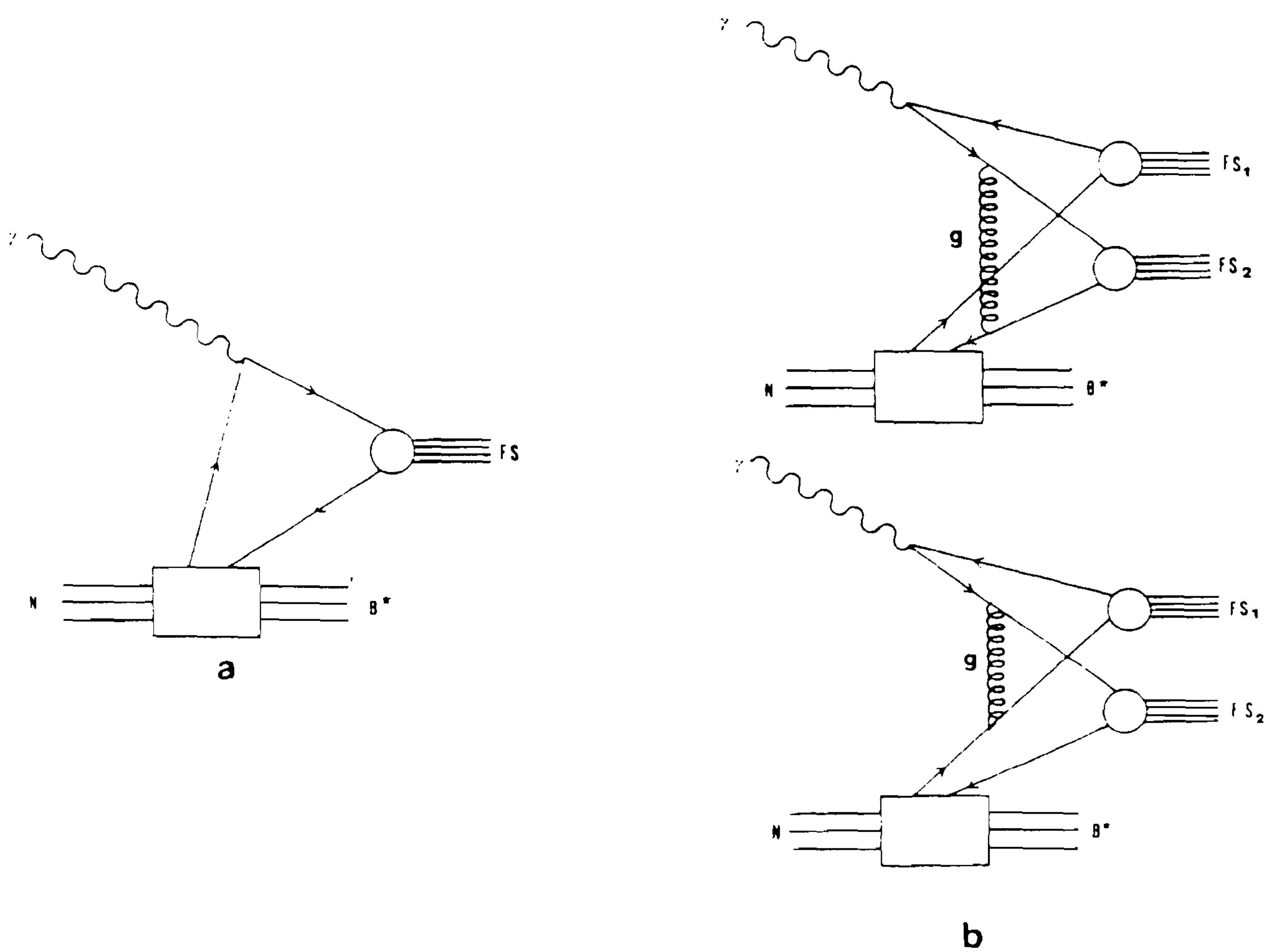

Figure 1

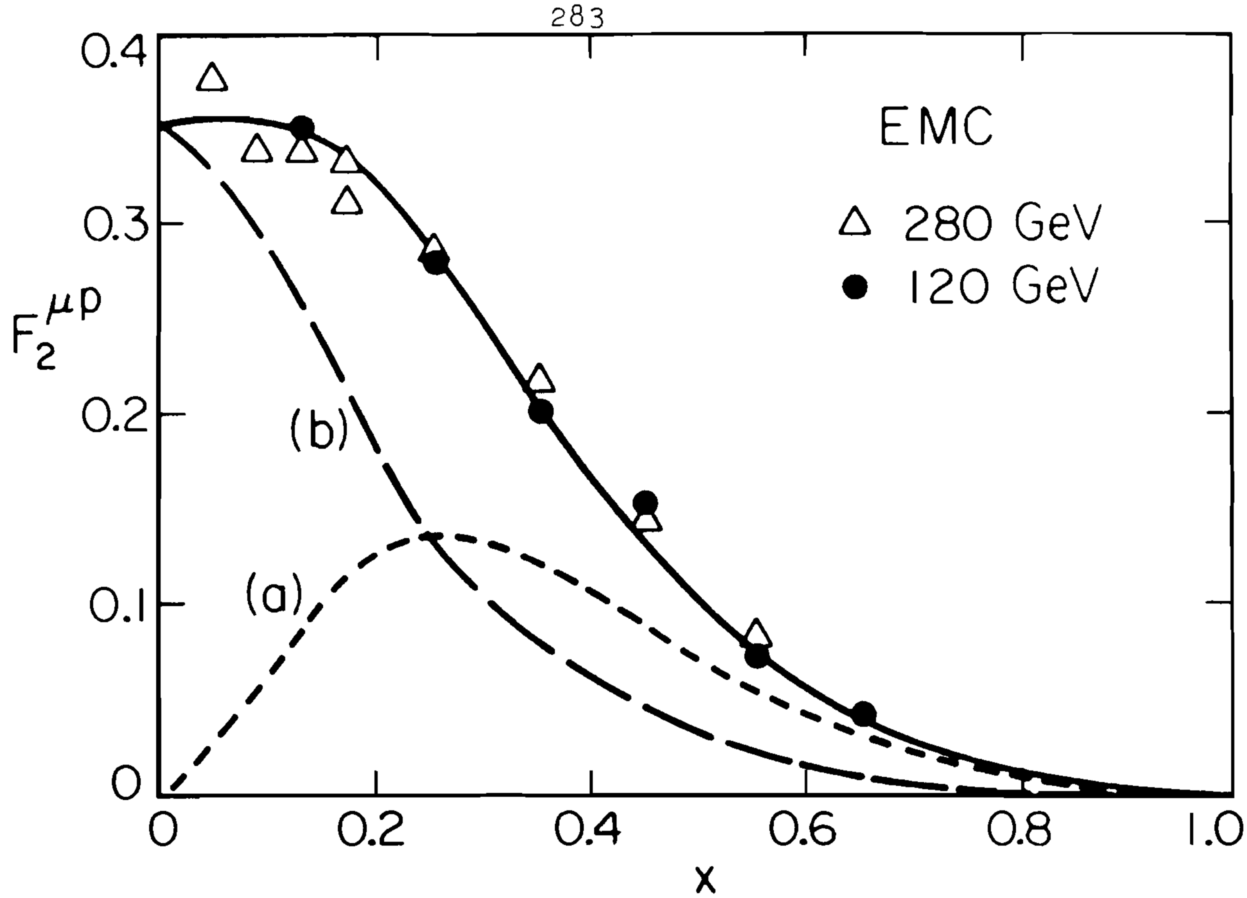

Figure 2

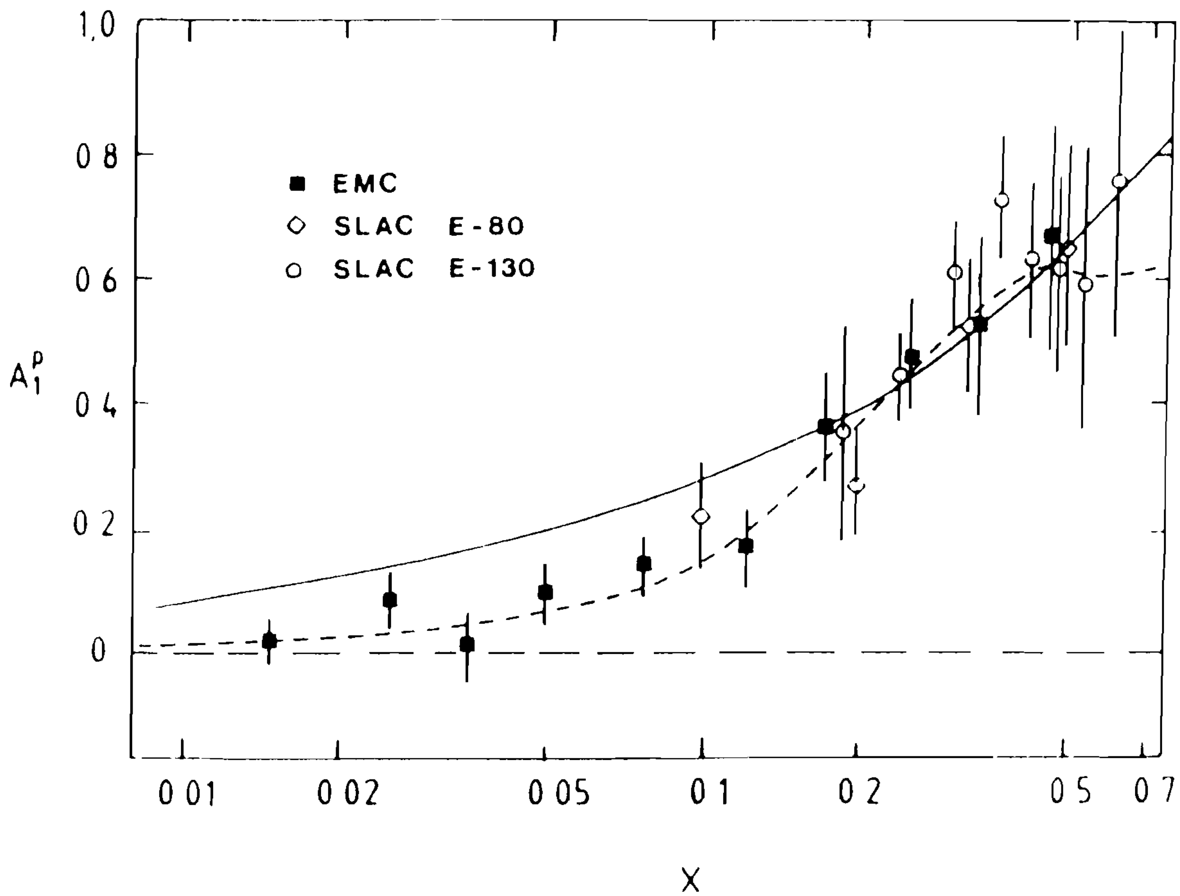

Figure 3