Spin dependent nuclear structure functions†

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[NUCLEAR STRUCTURE FUNCTIONS, Spin dependence, Effective Quark Theories]

One of the most prominent phenomena in deep inelastic scattering of leptons off nuclei is the EMC effect, which concerns the spin-independent nuclear structure functions[1)]. In a recent work[2)], this effect has been successfully described in terms of the self consistent scalar and vector fields which couple to the quarks inside the nucleons. Concerning the spin-dependent nuclear structure functions, on the other hand, only little is known about them both experimentally and theoretically, except for very light nuclei. In this work we will investigate the medium modifications of the spin-dependent structure functions of a nucleon bound in the nuclear medium, and present a simple model calculation of the spin-dependent counter part of the EMC ratio.

As an effective chiral quark theory, we use the Nambu-Jona-Lasinio model to describe the single nucleon as a bound state of a quark and a scalar diquark, and to describe nuclear matter in terms of self consistent scalar and vector mean fields which act on the quarks within the nucleons[3)]. It has been shown that this approach describes the nuclear matter saturation properties. By using the quark-diquark wave function and the density dependent effective masses obtained in this model, we calculate the spin-dependent light-cone momentum distributions of the quarks in the nuclear medium by using the familiar convolution approach. In principle, the spin-dependent smearing function representing the Fermi motion of the nucleons should be calculated for a given valence nucleon orbit, but as a first step we employ the same function as for the spin-independent case. In the pure quark-scalar diquark description, only the up quark contributes to the polarization of the proton. In order to describe also the down quark contribution, one should include also the axial vector diquark channel.

The results for the polarized up quark distribution ($\Delta u(x)$) at the saturation density of our nuclear matter equation of state are shown in Fig.1 for the low energy scale $Q_0 = 0.4$ GeV. The dotted line shows the distribution in a free nucleon, the dashed line shows the result including the mean scalar field, the dotted-dashed line shows the result including the Fermi motion of nucleons, and the solid line also includes the mean vector field. It is clear from this figure that the mean vector field plays an important role to deplete the distribution in the medium, which is reminiscent of the spin-independent case. Figure 2 shows the ratio of the in-medium $\Delta u(x)$ to the free nucleon value at $Q^2 = 10\,\mathrm{GeV}^2$, which represents a first estimate of the "spin-dependent EMC effect" in this simple model. It is interesting to observe that there is a plateau for $0.2 < x < 0.8$ with an average value of about 0.7, which is smaller than the well known spin-independent EMC ratio. We can therefore expect that the medium modifications are more important for the case of the spin-dependent structure functions than for the spin-independent ones.

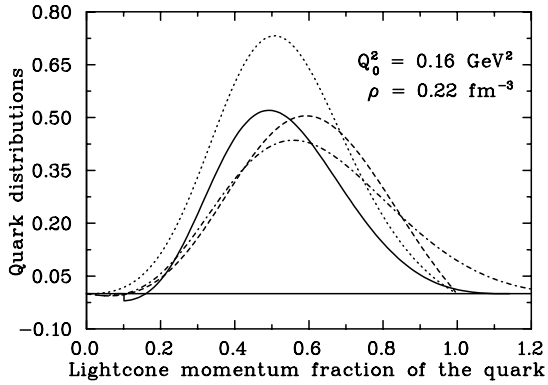

Fig. 1. Medium modifications of the polarized up quark distribution. For explanation of the lines, see text.

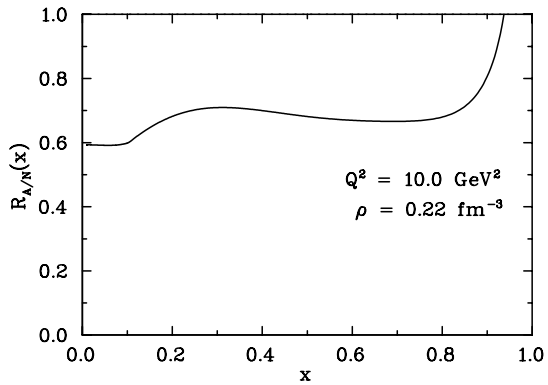

Fig. 2. Ratio of the in-medium polarized up quark distribution to the free nucleon value.

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