Spin dependent structure functions of finite nuclei†

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The most famous effect which shows how the nucleon structure responds to the environment inside a nucleus is the EMC effect, which is expressed by the following ratio:

$$R_A = \frac{F_{2A}}{ZF_{2p} + NF_{2n}}, \tag{1}$$

where F_{2A} is the spin independent nuclear structure function, and F_{2p}, F_{2n} are the spin independent free nucleon structure functions. In this paper, we will use a mean field model for the nucleus, which incorporates the quark substructure of the nucleons, to calculate the ratio (1), and also to make predictions for the corresponding polarized EMC ratio:

$$R_{As}^{JH} = \frac{g_{1A}^{JH}}{P_p^{JH} g_{1p} + P_n^{JH} g_{1n}}. \tag{2}$$

Here g_{1A}^{JH} is the spin dependent structure function of a nucleus with spin J and helicity H (along the direction of the incoming electron momentum), g_{1p} and g_{1n} are the spin dependent free nucleon structure functions, and the polarization factors are defined as the expectation values of the proton and neutron spin operators in the polarized nucleus: $P_\alpha^{JH} = < J, H|2S_z^\alpha|J, H >$ $(\alpha = p, n)$. The ratios (1) and (2) are defined so that they reduce to unity in the absence of medium (including Fermi motion) effects. One important difference between the ratios (1) and (2) is that, for the latter case, in order to pin down the medium effects we need the polarization factors, which incorporate the nuclear structure effects and are not known a priori. From the experimental standpoint, if g_{1A} can be measured, one should use the most realistic polarization factors to form the ratio (2). From the theoretical standpoint, one should calculate both the numerator and denominator of (2) in the same framework.

In our calculations, we describe the single nucleon as a bound state of a quark and a scalar or axial vector diquark, following the Faddeev approach to the Nambu-Jona-Lasinio (NJL) model. This allows us to compute the single nucleon structure functions[1]. The nucleus is treated in the mean field approximation where the sources of the mean scalar and vector fields are the quarks inside the nucleons, similar in spirit to the successful quark-meson coupling model. This allows us to compute the momentum distributions of the nucleons in the nucleus. The nuclear structure function is then obtained by the convolution formalism[2].

In Figs. 1 and 2 we show the EMC ratios for the proton-hole nuclei ^{7}Li and ^{27}Al. The line which tends to have a dip for large Bjorken x refers to the ratio (2) for $H = 3/2$, while the other spin dependent ratio refers to the leading multipole ($K = 1$) combination[2] of $H = 3/2$ and $H = 1/2$. Our calculations predict that the polarized EMC effect is stronger than the unpolarized one, with the possible exception of ^{7}Li at large x. This is related to a quenching of the spin sum in the nucleus: Our calculated spin sums for a free nucleon, ^{7}Li, ^{27}Al and infinite nuclear matter are 0.67, 0.62, 0.59 and 0.49.

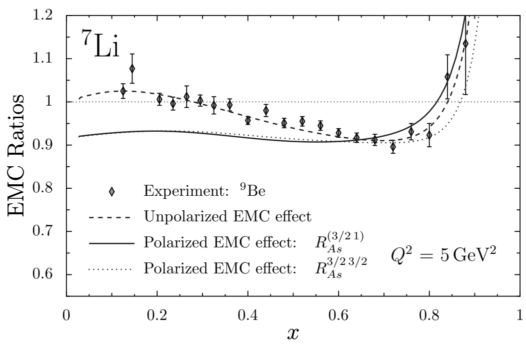

Fig. 1. Polarized (solid and dotted lines) and unpolarized (dashed line) EMC ratios for ^{7}Li.

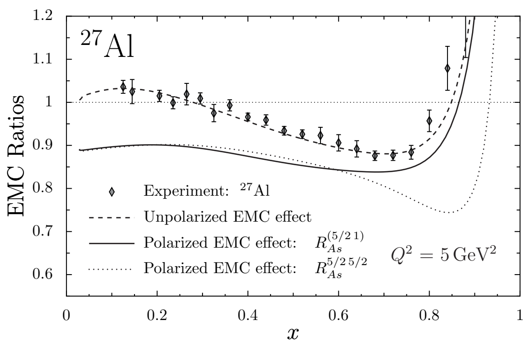

Fig. 2. Same as Fig. 1 for ^{27}Al.

References

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