The polarized EMC effect

W. Bentz*, I. C. Cloet†,** and A. W. Thomas**

*Department of Physics, Tokai University, Hiratsuka-shi, Kanagawa 259-1292, Japan
†Special Research Centre for the Subatomic Structure of Matter and
Department of Physics and Mathematical Physics, University of Adelaide, SA 5005, Australia
**Jefferson Lab, 12000 Jefferson Avenue, Newport News, VA 23606, U.S.A.

Abstract. We calculate both the spin independent and spin dependent nuclear structure functions in an effective quark theory. The nucleon is described as a composite quark-diquark state, and the nucleus is treated in the mean field approximation. We predict a sizable polarized EMC effect, which could be confirmed in future experiments.

Keywords: Spin-dependence, medium modifications, structure functions
PACS: 12.39Fe, 14.20Dh, 25.30Fj

In this paper we determine the structure functions for both unpolarized and polarized deep inelastic scattering of leptons on nuclear targets. The basic quantities are the light-cone quark distributions in a nucleus, which have the following form for the polarized case: [1]

$$\Delta q_A^H(x_A) = \frac{P_-}{A}\int \frac{d\omega^-}{2\pi} e^{iP_- x_A \omega^-/A} \langle A,P,H|\overline{\psi}_q(0)\,\gamma^+\gamma_5\,\psi_q(\omega^-)|A,P,H\rangle, \qquad (1)$$

where ψ_q is the quark field (flavor q) and A, P^μ, H are the mass number, 4-momentum, and helicity (along the direction of the incoming lepton momentum) of the nucleus with spin J. We evaluate these distributions using the convolution formalism.

In our model, we describe the nucleon as a bound state of a quark and a diquark (scalar and axial vector) in the Nambu-Jona-Lasinio model[2]. The nucleus is treated in the mean field approximation, where we assume scalar and vector potentials of Woods-Saxon shape and depth parameters given by our earlier self consistent nuclear matter calculations[3]. Using the resulting Dirac spinors for the nucleons, we calculate the light cone momentum distribution of nucleons in the nucleus, and convolute them with the quark distributions in the bound nucleon. The essential point in our calculation is that these quark distributions in the bound nucleon are calculated in the presence of the nuclear scalar and vector mean fields, i.e., they respond to the nuclear environment.

By using the QCD evolution equations up to the next-to-leading order[4], we can obtain the nuclear structure functions F_{2A} and g_{1A}^H, where for the latter we indicate the dependence on the helicity H of the nucleus. Alternatively, we can express the spin dependent structure functions in terms of K-multipoles $g_{1A}^{(K)}$, which are linear combinations of the helicity structure functions[1]. We present our results for the structure functions in terms of the following EMC ratios:

$$R_A = \frac{F_{2A}}{ZF_{2p}+NF_{2n}}, \qquad R_{As}^H = \frac{g_{1A}^H}{P_p^H g_{1p} + P_n^H g_{1n}} \qquad (2)$$

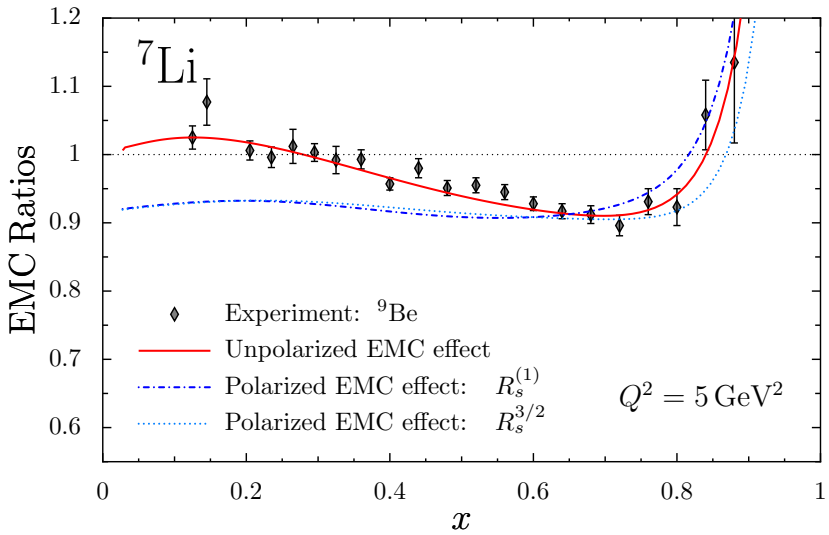

FIGURE 1. The solid line is the unpolarized EMC ratio for ^{7}Li, which is compared to experimental data[6]. The dash-dotted line is the prediction of the polarized EMC ratio for the dominant $K = 1$ multipole, and the dotted line refers to helicity $H = 3/2$ of the nucleus.

Here $P_p^H \equiv < J,H|2S_z^p|J,H >$ is the polarization factor for protons, and similar for the neutrons. These EMC ratios are such that in the extreme nonrelativistic limit, with no medium modifications, they are unity. For the spin dependent case, we will denote the EMC ratio for the leading multipole ($K = 1$) by $R_{As}^{(1)}$.

Our results for the EMC ratios for ^{7}Li, ^{11}Be and ^{27}Al are shown in Figs.1 to 3[5]. We have chosen these nuclei because their polarization is determined mainly by the protons, which avoids uncertainties associated with g_{1n} (see Eq.(2)), and because they are not too heavy, which is desirable in view of the approximate $1/A$ suppression of g_{1A} relative to F_{2A}.

Because our calculation includes the important medium modifications of the single nucleon structure functions, we are readily able to explain the unpolarized EMC data. These medium modifications also lead to a decrease of the fraction of the nucleon spin carried by the quarks, i.e., some part of the spin is converted into orbital angular momentum. This leads to a decrease of the spin dependent light cone momentum distributions and structure functions in the medium, and the resulting polarized EMC effect is larger than, or at least comparable to, the unpolarized one. Experimental confirmation would give important insights into in-medium quark dynamics, thereby helping to quantify the role of quark degrees of freedom in the nuclear environment.

This work was supported by the Australian Research Council and DOE contract DE-AC05-84150, under which JSA operates Jefferson Lab, and by the Grant in Aid for Scientific Research of the Japanese Ministry of Education, Culture, Sports, Science and Technology, Project No. C2-16540267.

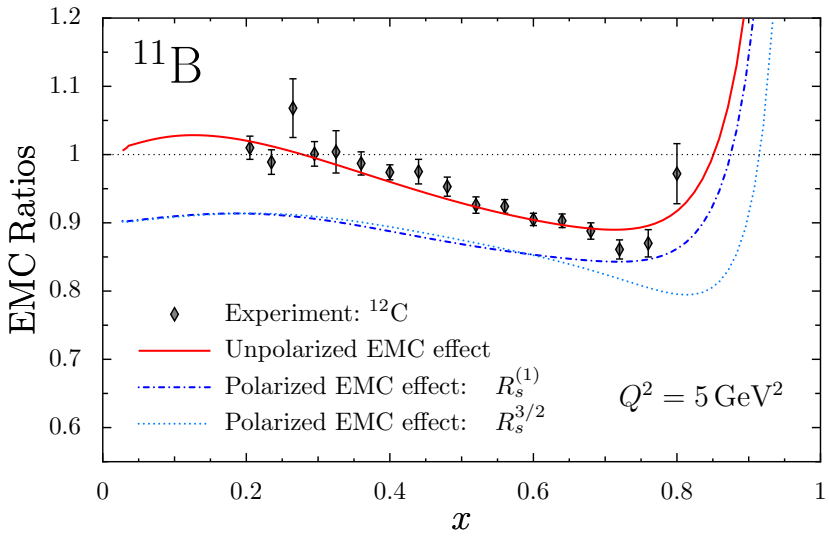

FIGURE 2. Same as Fig.1 for the nucleus ^{11}B.

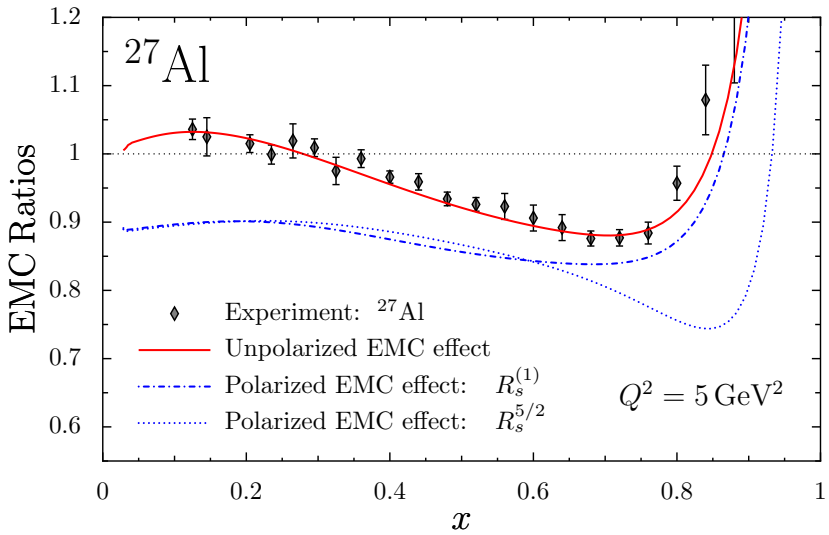

FIGURE 3. Same as Fig.1 for the nucleus ^{27}Al. Here the dotted line refers to the helicity $H = 5/2$.

REFERENCES

1. R. L. Jaffe and A. Manohar, Nucl. Phys. B **321**, 343 (1989).
2. N. Ishii, W. Bentz and K. Yazaki, Nucl. Phys. A **587**, 617 (1995).
3. I. C. Cloet, W. Bentz and A. W. Thomas, Phys. Rev. Lett. **95**, 052302 (2005).
4. M. Hirai, S. Kumano and M. Miyama, Comput. Phys. Commun. **108**, 38 (1998).
5. I. C. Cloet, W. Bentz and A. W. Thomas, to be published in Phys. Lett. **B**.
6. J. Gomez, et et., Phys. Rev. D **49**, 4348 (1994).