EMC effect for parity-violating DIS†

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[NUCLEAR PARTON DISTRIBUTIONS, Flavor dependence, Parity violating deep inelastic electron scattering]

In the deep inelastic scattering (DIS) of longitudinal polarized electrons on unpolarized nuclear targets (A), parity violating (PV) effects due to the interference between the photon exchange and Z^0 boson exchange lead to a non-zero spin asymmetry $A_{PV} = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L}$. Here $\sigma_{R,L}$ denote the double differential cross sections for DIS of right and left-hand polarized electrons. In the Bjorken limit, we have[1)]

$$A_{PV} = \frac{G_F Q^2}{4\pi\alpha\sqrt{2}} \left[a_2(x_A) + \frac{1-(1-y)^2}{1+(1-y)^2} a_3(x_A) \right] .$$

Here x_A is the Bjorken variable of the nucleus multiplied by the mass number A, G_F is the Fermi coupling constant, and $y = \nu/E$ is the energy transfer divided by the incident electron energy. The term a_2 comes from the product of the electron weak axial current and the quark weak vector current, and is given by

$$a_2(x_A) = \frac{F_{2A}^{\gamma Z}(x_A)}{F_{2A}^{\gamma}(x_A)} = \frac{2\sum_q e_q\, g_v^q\, q_{A+}(x_A)}{\sum_q e_q^2\, q_{A+}(x_A)} .$$

Here $q_{A+}(x_A) = q_A(x_A) + \overline{q}_A(x_A)$ are the nuclear parton distributions, and for the definitions of the nuclear structure functions (F_{2A}^{γ} and $F_{2A}^{\gamma Z}$) and the quark weak vector couplings (g_v^q) we follow the conventions of Ref.[2)]. The term a_3, which comes from the product of the electron weak vector current and the quark weak axial vector current, makes only a small contribution to the asymmetry, and will not be discussed here.

Because the structure functions $F_{2A}^{\gamma Z}$ and F_{2A}^{γ} have different flavor dependences, they will receive different medium modifications in isospin asymmetric nuclear systems ($N \neq Z$). This is clearly seen if we consider the isovector correction to first oder:

$$a_2(x_A) \simeq \left(\frac{9}{5} - 4\sin^2\Theta_W \right) - \frac{12}{25} \frac{u_{A+}(x_A) - d_{A+}(x_A)}{u_{A+}(x_A) + d_{A+}(x_A)} ,$$

where Θ_W is the Weinberg angle. It follows that a measurement of a_2 would give information on the flavor dependence of nuclear parton distributions. Conversely, if one can make reliable estimates of the isovector correction term, the spin asymmetry provides an independent method to determine the Weinberg angle.

Here we use the quark distributions in isospin asymmetric nuclear matter, calculated in our previous work in the Nambu-Jona-Lasinio model[3)], to show the isospin dependent medium modifications of the spin asymmetry term a_2. In Figs. 1 and 2, a_2^{naive} is the result without medium modifications (obtained by assuming that the target nucleus is composed of free nucleons), and a_2 is our full model result. The Standard Model value $\sin^2\Theta_W = 0.223$ is used. The results, which refer to the NJL model associated with a low energy scale, do not change much under Q^2 evolution in the valence quark region. We see that the medium modifications enhance the spin asymmetry for large x_A. The reason for this is that the isovector-vector mean field (ρ^0) leads to an additional binding of u quarks, which results in a softening of u_A compared to d_A in the valence quark region[3)].

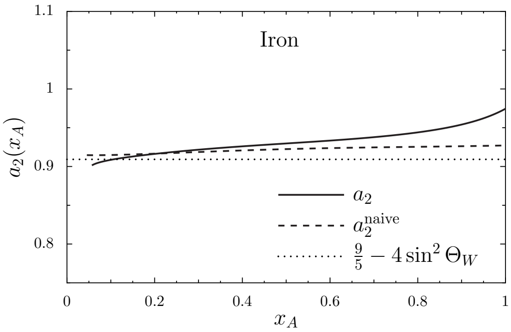

Fig. 1. Spin asymmetry a_1 for $Z/N = 26/30$.

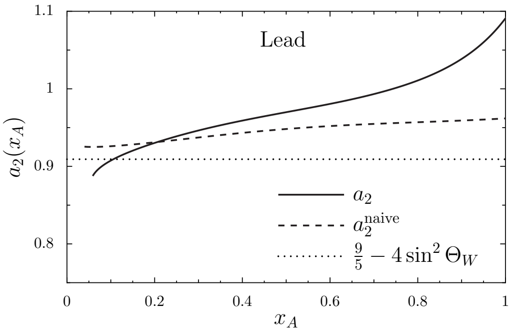

Fig. 2. Spin asymmetry for $Z/N = 82/126$.

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