RIKEN Accel. Prog. Rep. **37** (2004)

The EMC effect in an effective quark theory for nuclear matter†

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[NUCLEAR STRUCTURE FUNCTIONS, EMC Effect, Effective Quark Theories]

In this work we will be concerned with the medium modifications of the spin-independent nuclear structure functions measured in deep inelastic scattering of leptons, that is, the EMC effect. In recent works we have shown that the quark- scalar diquark description of the single nucleon, which is based on the relativistic Faddeev approach to the Nambu-Jona-Lasinio model[1)], can be combined successfully with the mean field description of the nuclear matter equation of state (NMEOS)[2)]. This framework offers a powerful tool for investigating the origin of the EMC effect in terms of binding on the level of quarks. Here we will consider the case of infinite nuclear matter as a first step, and limit ourselves to a valence quark description.

By using the solution to the quark-diquark bound state equation, we calculate the light-cone momentum distributions (LCMDs) of quarks in a single nucleon. The LCMDs in nuclear matter are then obtained by using familiar convolution formalism. Besides the Fermi motion of nucleons, this description takes into account the effect of the mean scalar field via the density-dependent masses according to the NMEOS, and also the effect of the mean vector field (V_0). We found that the direct effect of V_0 on the LCMDs in nuclear matter can be expressed as[3)] $f_{q/A}(x_A) = \dfrac{\epsilon_F}{E_F} f_{q/A0}(x'_A = \dfrac{\epsilon_F}{E_F} x_A - \dfrac{V_0}{E_F})$, where $f_{q/A0}(x'_A)$ is the LCMD for $V_0 = 0$, and $\epsilon_F = E_F + 3V_0$ ($E_F = \sqrt{M_N^2 + p_F^2}$) is the nucleon Fermi energy with M_N the effective nucleon mass. The actual calculations are carried out in the proper time regularization scheme which avoids unphysical quark decay thresholds for the nucleon.

The medium modifications of the isoscalar valence quark distribution at the saturation density of our NMEOS are shown in Figure 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, and also from the scale transformation given above, that the effect of the mean vector field is to narrow the LCMD, leading to a depletion in the valence quark region and to an enhancement at smaller values of the Bjorken variable. Figure 2 shows the resulting EMC ratio in comparison to nuclear data extrapolated to the nuclear matter case. We see that the calculation can reproduce the main features of the EMC effect, namely the suppression at large x and the enhancement at smaller x.

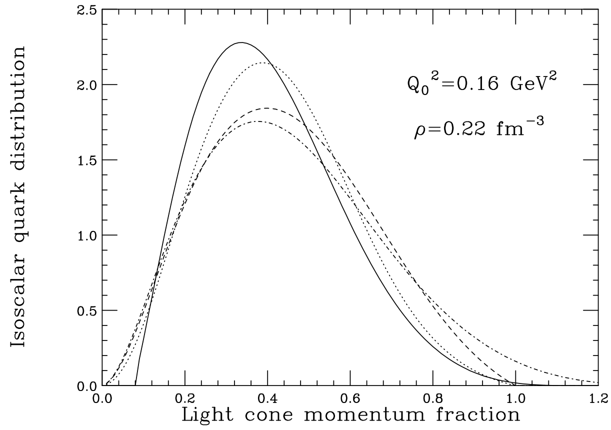

Fig. 1. Isoscalar LCMD of quarks. For explanation of the lines, see text.

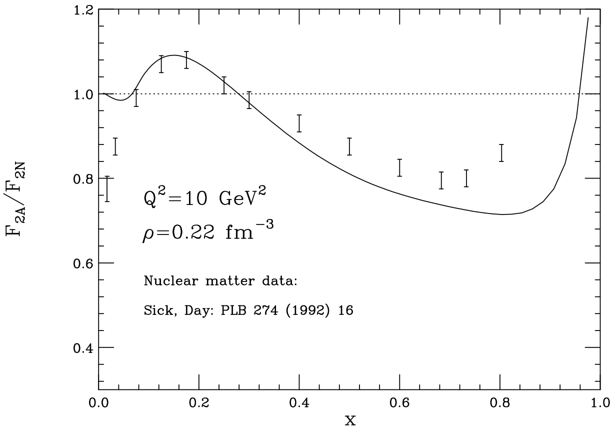

Fig. 2. EMC ratio in isospin symmetric nuclear matter.

† Condensed from an article by H. Mineo, W. Bentz, N. Ishii, A.W. Thomas and K. Yazaki, to be published.

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