Gluon EMC effects in nuclear matter†

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The European Muon Collaboration (EMC) effect, which refers to the observation that spin-independent structure functions of nuclei differ from the naive sum of structure functions of their constituents, is still one of the most challenging topics in modern nuclear physics. Previous calculations[1)] have demonstrated that the Nambu-Jona-Lasinio (NJL) model, when used as an effective quark theory of QCD to describe the quark substructure of hadrons, successfully reproduces the unpolarized EMC data across the periodic table. The key mechanism is the in-medium modification of the quark substructure of nucleons arising from scalar and vector mean fields acting on the quarks. The same framework was used to predict a significant medium modification of the polarized structure functions - the polarized EMC effect. An experiment at Jefferson Lab is planned to measure this effect.[2)]

While the EMC effects associated with the quark content of nuclei have been investigated extensively, there have been very few studies of the nuclear modification of the gluon distribution or the "gluon EMC effect." Exploring such changes is one of the primary scientific goals of the planned Electron-Ion-Collider (EIC). In this work we focus on the gluon EMC effect within the framework of the NJL model and the QCD evolution of parton distributions. By evolving our medium modified quark distributions from the NJL model scale ($Q_0^2 = 0.16$ GeV^2) to a scale of $Q^2 = 5$ GeV^2 by using the QCD evolution code of Ref. 3) in next-to-leading order (NLO) and next-to-next-to-leading order (NNLO), we generate the medium modified gluon distributions.

The solid lines in Figs. 1 and 2 show our previous results for the unpolarized EMC ratio F_{2N}^A/F_{2N} and the polarized EMC ratio g_{1p}^A/g_{1p} in nuclear matter. Here F_{2N} is the average of proton and neutron unpolarized structure functions in vacuum while F_{2N}^A is the same quantity in nuclear matter, and g_{1p} is the polarized structure function of the proton in vacuum while g_{1p}^A is the same quantity in nuclear matter. The dashed lines in Figs. 1 and 2 show the ratio g_p^A/g_p for the unpolarized case and $\Delta g_p^A/\Delta g_p$ for the polarized case. Here g_p (Δg_p) is the unpolarized (polarized) gluon distribution in the proton in vacuum while g_p^A (Δg_p^A) is the same quantity in nuclear matter.

It is clear from the figures that our analysis predicts for the first time a sizable gluon EMC effect, both for the unpolarized and the polarized case. We finally mention two points: First, our evolved NJL model results for all quark and gluon distributions agree very well with the phenomenological results of the NNPDF Collaboration.[5)] Therefore the assumption that at the NJL model scale the gluons are frozen into the interactions between quarks is not unreasonable. Second, we obtain almost the same results by using the Q^2 evolution in NLO and NNLO. This reflects the fact that $\alpha_s/4\pi$, which is the relevant parameter for Q^2 evolution, is sufficiently small to apply perturbative QCD to models based on quark degrees of freedom.

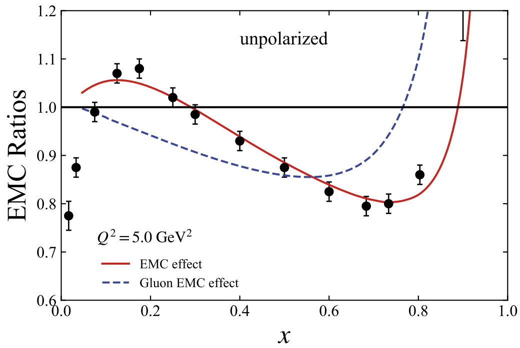

Fig. 1. Unpolarized EMC ratios in nuclear matter for the structure functions (solid line) and the gluon distributions (dashed line) as functions of the Bjorken variable x in NLO. The empirical data points are from Ref. 4).

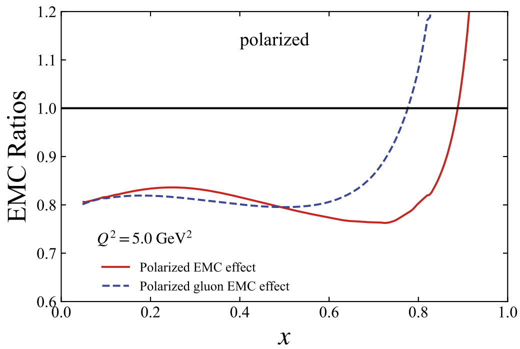

Fig. 2. Polarized EMC ratios in nuclear matter for the structure functions (solid line) and the gluon distributions (dashed line) as functions of x in NLO.

References

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