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Shadowing and antishadowing in the rescaling model

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The study of deep inelastic scattering (DIS) of leptons on nuclei shows the appearance of a significant effect of nucleon interaction in the nucleus, which eliminates the naive idea of the nucleus as a system of quasi-free nucleons (see, for example, review [1–5]. This effect was first discovered [6] by the European Muon Collaboration (EMC) in the domain of valence quark dominance, therefore it was called the EMC effect. Influence of nuclear effects on parton distribution functions (PDFs) meets a lot of interest from both theoretical and experimental points of view. In particular, detailed knowledge of PDFs in a nuclei (nPDFs) is necessary for any theoretical description of pA and AA processes studied at modern (LHC, RHIC) and future colliders (FCC-he, EiC, EicC, NICA).

Usually the nuclear modification factor, defined as a ratio of per-nucleon structure functions in nuclei A and deuteron, $R = F_2^A(x,Q^2)/F_2^D(x,Q^2)$, or rather ratio of corresponding parton densities, is introduced and its behavior in the shadowing ($x \leq 0.1$), anti-shadowing ($0.1 \leq x \leq 0.3$), valence quarks and Fermi motion dominance regions ($0.3 \leq x \leq 0.7$ and $x \geq 0.7$, respectively) is investigated. Unfortunately, up to now there is no commonly accepted framework to describe this nuclear modification of PDFs in a whole kinematical range. Two main approaches are used by different groups at present. In the first, which is currently seems to be more popular, nPDFs are extracted from a global fit to nuclear data using some empirical parametrization of corresponding intitial parton densities. Then, numerical solution of Dokshitzer–Gribov–Lipatov–Altarelli–Parisi (DGLAP) equations [7–11] is applied to describe their QCD evolution (see review [12] and references therein). The second strategy is based on special nPDF models (see, for example, [13–19] and review [20]).

The aim of this Letter is to study the nuclear modification of DIS structure function (SF) $F_2(x,Q^2)$ in the framework of the rescaling model [15–17]. The rescaling model is based on the assumption [18, 19] that the effective size of gluon and quark confinement in nucleus is greater than in a free nucleon. Within the framework of perturbative QCD this confinement rescaling predicts [15–19] that ordinary PDFs and nPDFs can be connected by simply shifting the values of the kinematic variable Q^2 (see also review [21]). Thus, the rescaling model demonstrates the features inherent in both approaches: there is the relationship between PDFs and nPDFs that arises as a result of shifting in the scale Q^2 and, at the same time, both PDFs and nPDFs obey the DGLAP equations. In a sence, the rescaling model corresponds to the first strategy with empirical nPDFs obtained from the corresponding PDFs by x-independent shift. Initially, it was proposed for the domain of valence quarks dominance and expanded recently to a low x range [22–25].

In the framework of rescaling model, we fitted the NMC experimental data for the ratios of the DIS structure functions $F_2(x,Q^2)$ in nuclear targets and deuteron at low and intermediate x values, $x \leq 0.7$. Our analysis is based on the analytical expressions for proton PDFs derived previously in [26]. Using the obtained resuls for rescaling values, we derive predictions for nPDFs for several nuclear targets and, thus, for shadowing and antishadowing effects. We find that shadowing effect for gluons is less than for quarks, which is consistent with many other studies. There is no antishadowing for gluons, and it is better pronounced for antiquarks than for quarks. This is a rather interesting result, since different groups give very different results on the antishadowing effect with large uncertainties.

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