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# Parton distributions and EMC ratios of the $^6$Li nucleus in the constituent quark exchange model

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**Abstract**

While the constituent quark model (CQM), in which the quarks are assumed to be the complex objects, is used to calculate the parton distribution functions of the iso-scalar lithium-6 ($^6$Li) nucleus, the *u–d* constituent quark distribution functions of the $^6$Li nucleus are evaluated from the valence quark exchange formalism (VQEF) for the $\mathcal{A} = 6$ iso-scalar system. After computing the valence quark, sea quark, and gluon distribution functions in the constituent quark exchange model (CQEM, i.e., CQM + VQEF), the nucleus structure function is calculated for the $^6$Li nucleus at the leading order (*LO*) and the next-to-leading-order (*NLO*) levels to extract the European muon collaboration (EMC) ratio, at different hard scales, using the standard Dokshitzer–Gribov–Lipatov–Altarelli–Parisi (DGALP) evolution equations. The outcomes are compared with those of our previous works and the available NMC experimental data, and various physical points are discussed. It is observed that the present EMC ratios are considerably improved compared with those of our previous works, in which only the valence quark distributions were considered to calculate the EMC ratio, and are closer to the NMC data. Finally, it is concluded that at a given appropriate hard scale, the *LO* approximation may be enough for calculating the nucleus EMC ratio.


*Keywords:* Quark exchange; Structure function; Fermi motion effect; EMC effect; Constituent quark model

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## 1. Introduction

The outcome of a pioneering 1969 SLAC deep inelastic electron proton scattering experiment (DIS) [1,2] has resulted in tremendous efforts by both the theoretical and the experimental physicists, to understand the structure of hadrons, nuclei, and nuclear matter, in terms of partons, i.e., valence quarks, sea quarks, and gluons [3–14]. In the recent years, many deep inelastic scattering experiments have been performed on hadrons and nuclear targets such as protons, deuterium, tritium, helium 3, and so on[15–44]. To clarify the consequences of these experiments, various theoretical models have been proposed by different groups [3–7,45–65].

The question of how the properties of hadrons bound in the nuclear medium differ from the properties of free nucleons has been one of the hot topics during the last three decades. The fact that the nucleon structure functions of the bound and the free nucleons are not the same was first discovered in 1983 by the European Muon collaboration (EMC) group, i.e., Aubert et al. [8]. At first, the "nuclear structure" physics was proposed for these unexpected differences [3–7,49–59]. Later, while the parton exchange between the bound nucleons and the role of $\Delta$ particle were suggested for the medium $x$ ($x$ is the fraction of the momentum of nucleons carried by each quark) region, i.e., $0.3 \leq x \leq 0.8$, the Fermi motion effect and the shadowing phenomena were proposed for large ($x \to 1$) and small ($x \leq 0.05$) values of $x$. It was found that the latter, i.e., the shadowing effect, is important for heavy nuclei.

The valence quark exchange formalism (VQEF) was primordially introduced by Hoodbhoy and Jaffe, in the $\mathcal{A} = 3$ mirror nuclei [10,12], to calculate the valence quark distributions, and structure function and to justify the deviation of the ratio of the nuclear structure function to that of the free nucleon (EMC ratio), from unity. The applications of the VQEF to different nucleus systems, such as the nuclear matter, were successfully reproduced by us, and it was shown that the results were in agreement with both the experimental data and those of other theoretical works [13,14,66–70]. Recently, this formalism was also developed by us to evaluate the valence quark distribution function, the structure function, and the EMC ratio of the $\mathcal{A} = 6$ iso-scalar system, i.e., the lithium-6 ($^6$Li) nucleus [70]. However, it becomes very complicated to consider the roles of sea quarks and gluons in the VQEF directly. To overcome this complication, one can use "the constituent quark model" (CQM) to consider the above degrees of freedom in the quark exchange formalism (e.g., see reference [68]) and to calculate the lithium-6 nucleus structure function.

In the constituent quark framework, the "constituent quarks" are assumed to be the complex objects with point-like quarks, anti-quarks, and gluons as their constituents. This model was initially introduced by Feynman [52–54] and others, [71–79] and it was then applied by different groups [71,72,80,81] to calculate the structure function of hadrons.

However, recently, it has been shown that especially in the very small $x$ region, the unintegrated parton distribution function (UPDF) may be important in the calculations of the hadron structure functions [63–65,82–86]. The application of UPDF to the nuclei was investigated by the Martin group [65], and it was shown that the application of UPDF can improve the nucleus structure function in the very small $x$ region ($x \ll 0.1$). However, in this paper, we intend to focus on the small and the middle $x$ regions ($0.07 \leq x \leq 0.7$). However, in our future works, we hope to investigate the $^6$Li structure function in the very small $x$ values by the application of UPDF to the lithium structure function and its EMC ratio.

In this report, according to the constituent quark exchange model (CQEM = CQM + VQEF), we intend to calculate various point-like parton distributions, the structure function, and the EMC ratio of the $^6$Li nucleus. The paper is organized as follows: First, in section 2 and