Nuclear medium effects in $R = \sigma_L/\sigma_T$ in $\nu_l - A$ DIS

F. Zaidi* and H. Haider
Aligarh Muslim University, Aligarh - 202002, INDIA

Introduction

Since the discovery of the nucleon substructure in the electron-proton scattering experiment at SLAC, efforts are continuously going on to understand the distribution of partons inside the nucleon as well as their nuclear modifications. Therefore, the nucleon structure functions $F_{iN}(x,Q^2)$; $(i = 1-3)$ have been studied theoretically as well as experimentally. It has been found that $F_{1N}(x,Q^2)$ has contribution only from the transverse component while $F_{2N}(x,Q^2)$ has an admixture of both longitudinal as well as transverse components. Presently, the longitudinal structure function $F_{LN}(x,Q^2)$ which is directly related to the gluon distribution is not well determined unlike the nucleon structure function $F_{1N}(x,Q^2)$ and $F_{2N}(x,Q^2)$ because of the limited data availability. Furthermore, it has been argued that various nuclear medium effects arising due to the Fermi motion of nucleons, mesons, gluons distributions and higher twist effects in nuclei would contribute differently in the longitudinal and transverse structure functions in the various regions of x and Q^2 and induce nuclear dependence on the ratio of longitudinal to transverse structure functions in nuclei. The nuclear dependence of this ratio has been the topic of investigation in some experiments like CCFR, NuTeV, CDHSW, CHORUS, etc., for weak interaction induced DIS process but very few theoretical studies are available for this investigation. Therefore in this work, we have theoretically studied the nuclear dependence of $R_{LA}(x,Q^2)$ for $\nu_l - A$ deep inelastic scattering(DIS) process by using a microscopic model.

*Electronic address: zaidi.physics@gmail.com

Formalism

The expression of differential scattering cross section for the charged current $\nu_l - A$ DIS is given by

$$\frac{d^2\sigma_A}{dxdy} = \frac{G_F^2 M_N E}{\pi}\Big[F_{2A}(x,Q^2)\Big(1 - y\times \left\{1+\frac{M_N x}{2E}\right\} + \frac{y^2}{2}\,\frac{\gamma^2}{1+R_{LA}(x,Q^2)}\Big) \pm \left(y-\frac{y^2}{2}\right) xF_{3A}(x,Q^2)\Big],$$

where G_F is the Fermi coupling constant, M_N is the nucleon mass, $\gamma = \sqrt{1+\frac{4M_N^2x^2}{Q^2}}$ and $R_{LA}(x,Q^2) = \frac{F_{LA}(x,Q^2)}{2xF_{1A}(x,Q^2)}$. The longitudinal structure function is defined as

$$F_{LA}(x) = F_{2A}(x)\left(1+\frac{4M_N^2x^2}{Q^2}\right) - 2xF_{1A}(x).$$

$F_{iA}(x,Q^2)$; $(i = 1-3)$ are the nuclear structure functions and are evaluated at NLO with a microscopic model which uses a relativistic nucleon spectral function to describe the target nucleon momentum distribution incorporating Fermi motion, binding energy effects and nucleon correlations in a field theoretical model. The nucleon spectral function is obtained by using the Lehmann's representation for the relativistic nucleon propagator and nuclear many body theory is used to calculate it for an interacting Fermi sea in the nuclear matter. A local density approximation is then applied to translate these results to a finite nucleus. We have also incorporated the effects due to the meson contribution, shadowing and target mass correction [1]. For the parton distribution functions(PDFs), we have used the parameterization of CTEQ6.6 for nucleons and the parameterization of Gluck et al. for mesons [2]. The formalism has been described in detail in our recent papers [3].

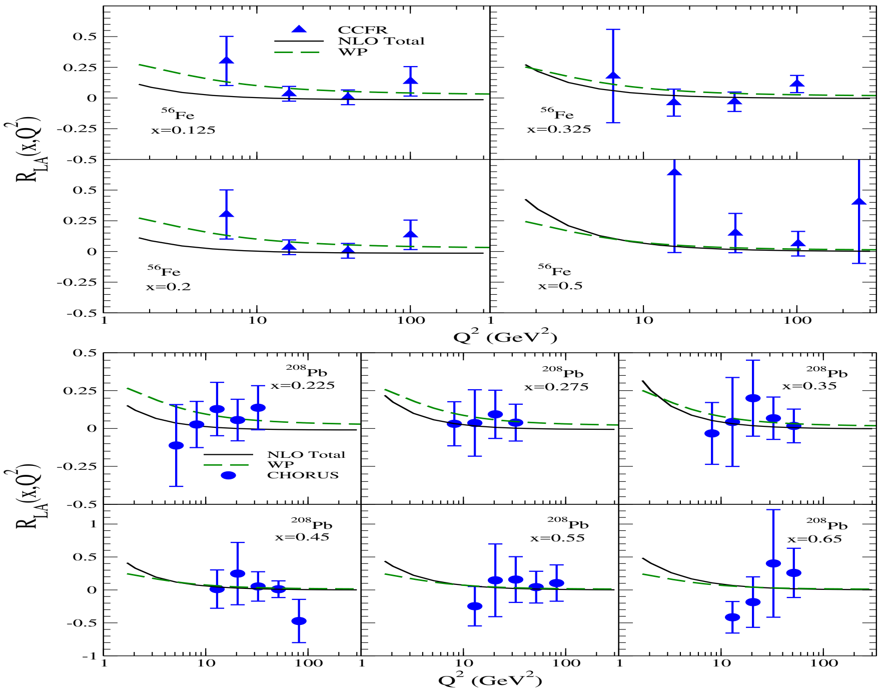

FIG. 1: Results for the ratio $R_{LA}(x,Q^2) = \frac{F_{LA}(x,Q^2)}{2xF_{1A}(x,Q^2)}$ vs Q^2 in ^{56}Fe(top panel) and ^{208}Pb(bottom panel) nuclei. The results are compared with the experimental data of CCFR [5] and CHORUS [6].

Results and Discussion

We have obtained the ratio $R_{LA}(x,Q^2)$ in ^{56}Fe and ^{208}Pb nuclei which are considered to be isoscalar in the present calculation as the data are available with the isoscalarity corrections. The numerical calculations are performed using the full model at NLO and are labeled as NLO Total. These results are compared with the results of $R_N(x,Q^2) = \frac{F_{LN}(x,Q^2)}{2xF_{1N}(x,Q^2)}$ obtained using the phenomenological parameterization of Whitlow et al.(WP) [4].

In Fig. 1, the results of the ratio $R_{LA}(x,Q^2)$ versus Q^2 are presented at the fixed values of x for iron(top panel) and lead(bottom panel). We have observed that $R_{LA}(x,Q^2)$ shows significant deviation from zero for low Q^2 and high x, however, for high Q^2 and low x this deviation is very small. The deviation of $R_{LA}(x,Q^2)$ also implies that Callan-Gross relation gets modified inside the nuclear medium in the region of high x and low Q^2. We have compared the numerical results with the experimental data of CCFR [5] and CHORUS [6] for iron and lead nuclei, respectively. These theoretical results would help to understand the nuclear dependence of the ratio in the future experiments.

References

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