Nuclear medium modification of $F_2^N(x,Q^2)$ in ^{12}C

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In this work, we have studied nuclear effect in electromagnetic structure function of nucleon $F_2^N(x,Q^2)$ in ^{12}C in the deep inelastic lepton nucleus scattering process by taking into account Fermi motion, binding, pion and rho meson cloud contributions, target mass correction, shadowing and anti-shadowing corrections. The calculations have been done in a local density approximation using a relativistic nuclear spectral function which include nucleon correlations for nuclear matter. The ratio $R^C_{F2}(x,Q^2) = \frac{F_2^C(x,Q^2)}{12F_{2N}^{Deut}(x,Q^2)}$ is obtained and compared with the recent results reported at JLab [1] and also with some of the older experiments available in the literature [2–5].

We use a theoretical spectral function [6] to describe the momentum distribution of nucleons in the nucleus. The spectral function has been calculated 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 nuclear matter. A local density approximation is then applied to translate these results in finite nuclei. The contribution of pion and rho meson cloud contributions are taken into account in a many body field theoretical approach [7]. We have taken the effect of nuclear shadowing and anti-shadowing from the works of Kulagin and Petti [8]. For the numerical calculations, NLO parton distribution functions for the nucleons have been taken from the parameterization of Martin et al.(MSTW) [9] and in the case of pions we have taken the pionic parton distribution functions given by Gluck et al.[10]. For the rho mesons, we have applied the same PDFs as for the pions. The NLO evolution of the deep inelastic structure functions has been taken from the works of van Neerven and Vogt [11]. The effect of target mass correction has been taken from the works of Schienbein et al. [12]. We have presented the results for F_2 in nucleon bound inside deuterium i.e. $F_{2N}^{Deut}(x,Q^2)$ by taking the deuterium effect studied by Atti et al. [13].

Our base equation for the nuclear structure function F_2^A is written as:

$$F_2^A(x,Q^2) = 4\int d^3r \int \frac{d^3p}{(2\pi)^3} \int_{-\infty}^{\mu} d\omega \times S_h(\omega,\mathbf{p},\rho(\mathbf{r})) \frac{\left(1-\gamma\frac{p_z}{M}\right)}{\gamma^2} \times \left(\gamma'^2 + \frac{6x'^2(\mathbf{p}^2-p_z^2)}{Q^2}\right) F_2^N(x',Q^2) \quad (1)$$

where $S_h(\omega,\mathbf{p},\rho(\mathbf{r}))$ is the nuclear spectral function, normalized to the number of nucleons in the nucleus and taken from Ref. [6], p is the four momentum of the bound nucleon and is written as p=$(M+\omega,\mathbf{p})$, where the nucleon mass M has been separated from the energy p_0. $\gamma = (1+4x^2M^2/Q^2)^{\frac{1}{2}}$, $x = \frac{Q^2}{2Mq^0}$, $\gamma'^2 = 1+4x'^2p^2/Q^2$ and $x' = \frac{Q^2}{2p.q} = \frac{Q^2}{2(p_0q_0-p_zq_z)}$ [8]. Here we have considered the momentum transfer lying on the z-axis with $q_z = |\mathbf{q}|$.

The nuclear structure function for the deuteron has the following form [13]:

$$F_{2N}^{Deut}(\ x\ ,Q^2) \simeq F_{2N}(x,Q^2) + xF'_{2N}(x,Q^2) \times \frac{<E> - |\epsilon_A| - \frac{2}{3}<T> + <T_R>}{M} + \left[xF'_{2N}(x,Q^2) + \frac{x^2}{2} \times F''_{2N}(x,Q^2)\right] \frac{2<T>}{3M}. \quad (2)$$

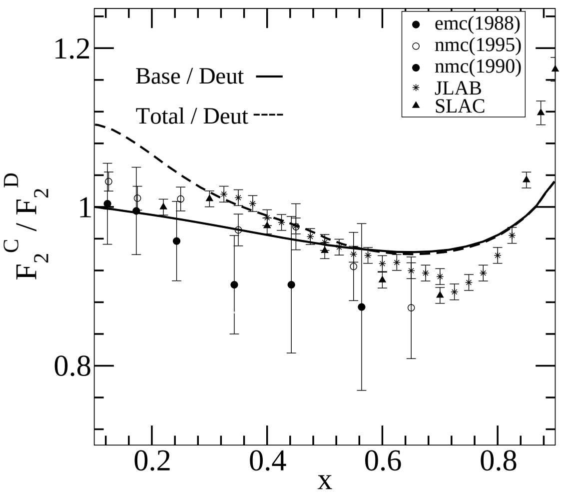

FIG. 1: Results for the ratio R(x,Q^2)=$\frac{F_{2A}^{Carbon}}{AF_{2N}^{Deut}}$ when the numerator is calculated using Eq.(1) (solid line) and with pion and rho cloud contributions and shadowing & antishadowing corrections from the works of Kulagin and Petti [8] (dashed line), and the denominator is calculated using Eq.(2). The experimental points are the EMC results of Seely et al. [1], Gomez et al. [2] and by NMC [3] and EMC [4, 5] collaborations.

where $< T >$ is the mean kinetic energy, $< E >$ is the removal energy, $|\epsilon_A|$ is the binding energy per nucleon, $< T_R > \simeq \left\langle \mathbf{p}^2 \right\rangle /2M$ with $\left\langle \mathbf{p}^2 \right\rangle$ as the average of the square of nucleon momentum [13].

We present the results for the ratio $R_{F2}^{Carbon}(x,Q^2) = \frac{F_2^{Carbon}(x,Q^2)}{12F_{2N}^{Deut}(x,Q^2)}$ in Fig.1, as a function of x using electrons of energy 5.767GeV and the scattering angle of 40^0 corresponding to the JLab [1] kinematics. Our results have been presented for $F_{2A}(x)$ calculated in the numerator by using Eq.(1) with target mass correction and when we also include the pion and rho cloud contributions and the shadowing & antishadowing corrections. The denominator $F_{2N}^{Deut}(x,Q^2)$ has been calculated by using Eq.(2) with the target mass correction. In Fig.1, the experimental results obtained by JLab [1], SLAC [2], NMC [3] and EMC [4, 5] collaborations have also been presented. The details [14] of the formalism and results will be presented in the conference.

References

[1] J. Seely et al., nucl-ex:0904.4448 (2009).
[2] J. Gomez et al., Phys. Rev. D **49** (1994) 4348.
[3] M. Arneodo et al., Nucl. Phys. B **441** (1995) 12.
[4] M. Arneodo et al., Nucl. Phys. B **333** (1990) 1.
[5] J. Ashman et al., Phys. Lett. B **202** (1988) 603.
[6] P. Fernandez de Cordoba and E. Oset, Phys. Rev. C **46** (1992) 1697.
[7] E. Marco, E. Oset and P. Fernandez de Cordoba, Nucl. Phys. A **611** (1996) 484.
[8] S. A. Kulagin and R. Petti, Nucl. Phys. A **765** (2006) 126; Phys. Rev. D **76** (2007) 094033.
[9] A. D. Martin, W.J. Stirling, R. S. Thorne and G. Watt, hep-ph:0901.0002 (2009).
[10] M. Gluck, E. Reya and I. Schienbein, Eur. Phys. J. C **10** (1999) 313.
[11] W. L. van Neerven and A. Vogt, Nucl. Phys. B **568** (2000) 263; ibid **588** (2000) 345.
[12] I. Schienbein et al. J. Phys. G **35** (2008) 053101.
[13] C. Ciofi degli Atti et al., Phys. Rev. C **76** (2007) 055206.
[14] M. Sajjad Athar, I. Ruiz Simo and M.J. Vicente Vacas, Paper in preparation.