A-dependence of weak nuclear structure functions

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INTRODUCTION

In the deep inelastic region, both experimentally as well as theoretically, limited efforts have been made to understand the medium effects for weak interaction induced processes. In the case of experimental measurements performed for $F_{2,3}^A$ weak structure functions the error bars are large and need better precision. MINERvA is using muon neutrinos in the energy region of 1-20 GeV and aim is to study medium effects by taking various nuclear targets like helium, carbon, oxygen, iron and lead.

This paper is aimed to study weak structure functions F_2^A, F_3^A, in a nuclear model using relativistic nuclear spectral function which describes the momentum distribution of nucleons in the nucleus within a field-theoretical approach where nucleon propagators are written in terms of this spectral function, 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 to finite nuclei[1,2]. The contributions of the pion and rho meson clouds are taken into account in a many-body field-theoretical approach. We have also taken target mass correction and shadowing effects into account. The details of the model are given in Refs.[1-3].

FORMALISM

The expressions for $F_2^A(x,Q^2)$ and $F_3^A(x,Q^2)$ in the nuclear medium are written as[1]:

$$F_2^A(x_A,Q^2) = 4\int d^3r \int \frac{d^3p}{(2\pi)^3}\frac{M}{E(\mathbf{p})}\int_{-\infty}^{\mu} dp^0\, S_h(p^0,\mathbf{p},\rho(\mathbf{r}))\frac{x}{x_N}\left(1+\frac{2x_N p_x^2}{M\nu_N}\right)F_2^N(x_N,Q^2)$$

$$F_3^A(x_A,Q^2) = 4\int d^3r \int \frac{d^3p}{(2\pi)^3}\frac{M}{E(\mathbf{p})}\int_{-\infty}^{\mu} dp^0\, S_h(p^0,\mathbf{p},\rho(\mathbf{r}))\frac{p^0\gamma-p_z}{(p^0-p_z\gamma)\gamma}F_3^N(x_N,Q^2)$$

where F_2^N and F_3^N are the nucleon structure functions written in terms of parton distribution functions, q is the four momentum transfer, $q^2 = -Q^2$, x is the Bjorken variable, v is the energy transfer. M is the mass of nucleon. S_h is the spectral hole taken from Ref.[4]:

$$S_h(\omega,\mathbf{p}) = \frac{1}{\pi}\frac{\frac{M}{E(\mathbf{p})}Im\Sigma^N(p^0,p)}{(p^0-E(\mathbf{p})-\frac{M}{E(\mathbf{p})}Re\Sigma^N(p^0,p))^2+(\frac{M}{E(\mathbf{p})}Im\Sigma^N(p^0,p))^2}$$ and $$\gamma = \frac{q_z}{q^0} = \left(1+\frac{4M^2x^2}{Q^2}\right)^{1/2}, x_N = \frac{Q^2}{2(p^0q^0-p_zq_z)}$$

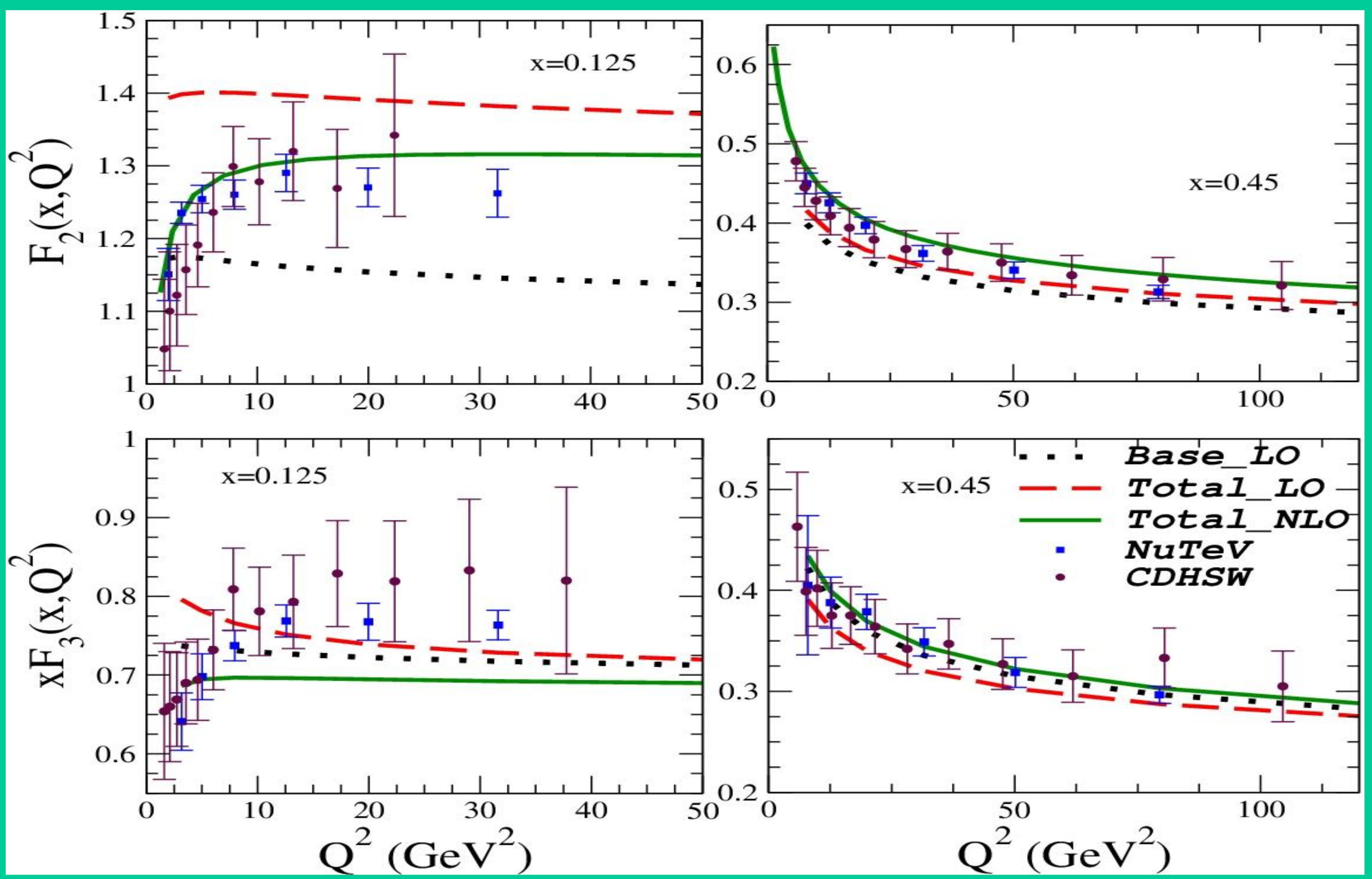

Fig1: $F_i^A(x,Q^2)$ vs Q^2 (i=2,3). Upper panel is for F_2^A and lower panel is for xF_3^A.

RESULTS AND DISCUSSION

In Fig1. we have presented the results for F_2^A and F_3^A weak structure functions in iron target for different values of x and Q^2 at LO and NLO. In our calculations, base results include Fermi motion, nucleon correlation, Pauli blocking and target mass correction and the results with full calculation are when we incorporate shadowing and anti-shadowing effects for F_2^A and F_3^A as well as including pion and rho cloud contributions for F_2^A. Numerical results have been compared with the NuTeV and CDHSW data. Calculations at NLO make results more closer to the experimental data. Using the results of weak structure functions F_2^A,F_3^A, we have obtained the ratio of structure functions F_i^A/F_i^p and F_i^A/F_i^d, where the deuteron structure functions have been obtained using the same formulas but performing the convolution with the deuteron wave function squared instead of the nuclear spectral function.

RESULTS AND DISCUSSION contd.

We have presented the results for the ratio F_i^A/F_i^p and F_i^A/F_i^D(i=2,3) in Figs.2-4. We find that nature for F_2^A structure function is different from F_3^A structure function. In Fig.2, we have compared our results for F_i^{Fe}/F_i^D with some of the phenomenological studies. It may be observed from Figs. 3 and 4 that medium effects are not the same in different nuclear targets[2]. This study may be useful in the analysis of MINERvA experiment.

RATIOS

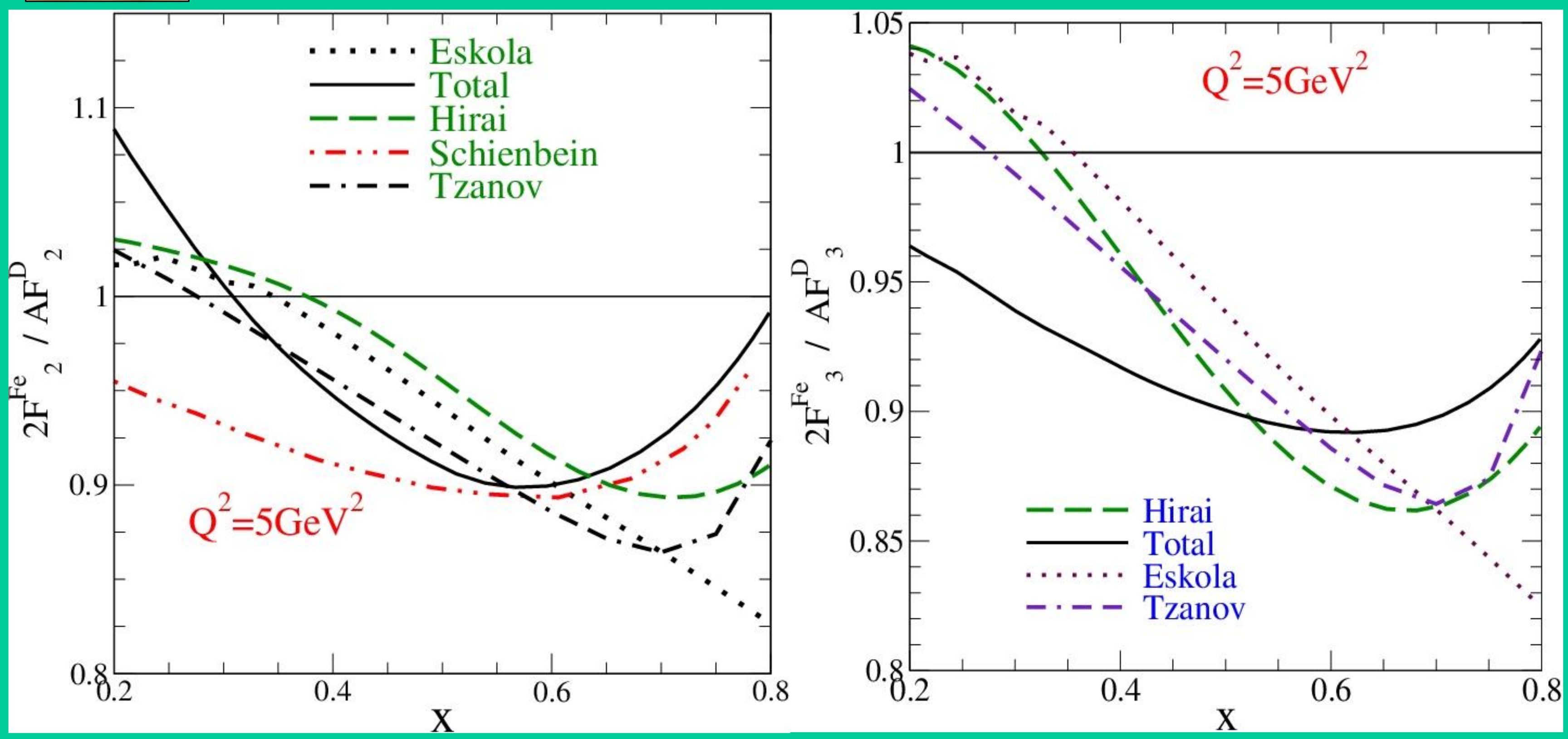

Fig.2: Ratio $R(x,Q^2)=2F_i^{Fe}/AF_i^D$ (i=2,3) with full calculation has been shown by the solid line. Calculations have been done for Q^2=5 GeV^2 using CTEQ PDFs at NLO. The results from Tzanov et al.(PRD74,012008), Hirai et al.(PRC76,065207) , Eskola et al.(EPJC9,61) and Schienbein et al.(PRD80,094004) have also been shown.

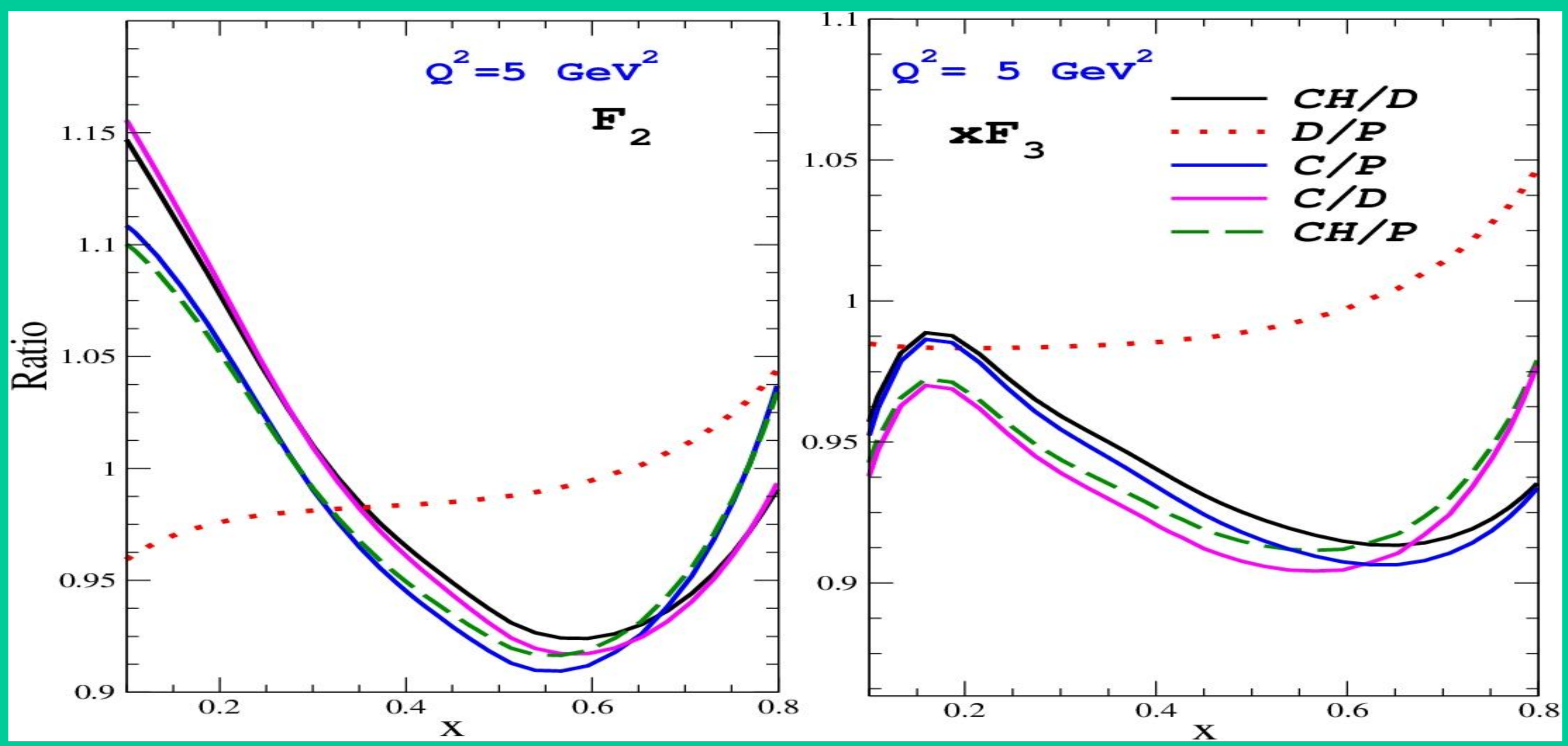

Fig.3:Ratio $R(x,Q^2)=F_i^{CH}/F_i^p$, F_i^{CH}/F_i^D, F_i^D/F_i^p, F_i^C/F_i^p, F_i^C/F_i^D(i=2(left) and 3(right)) using full model at NLO.

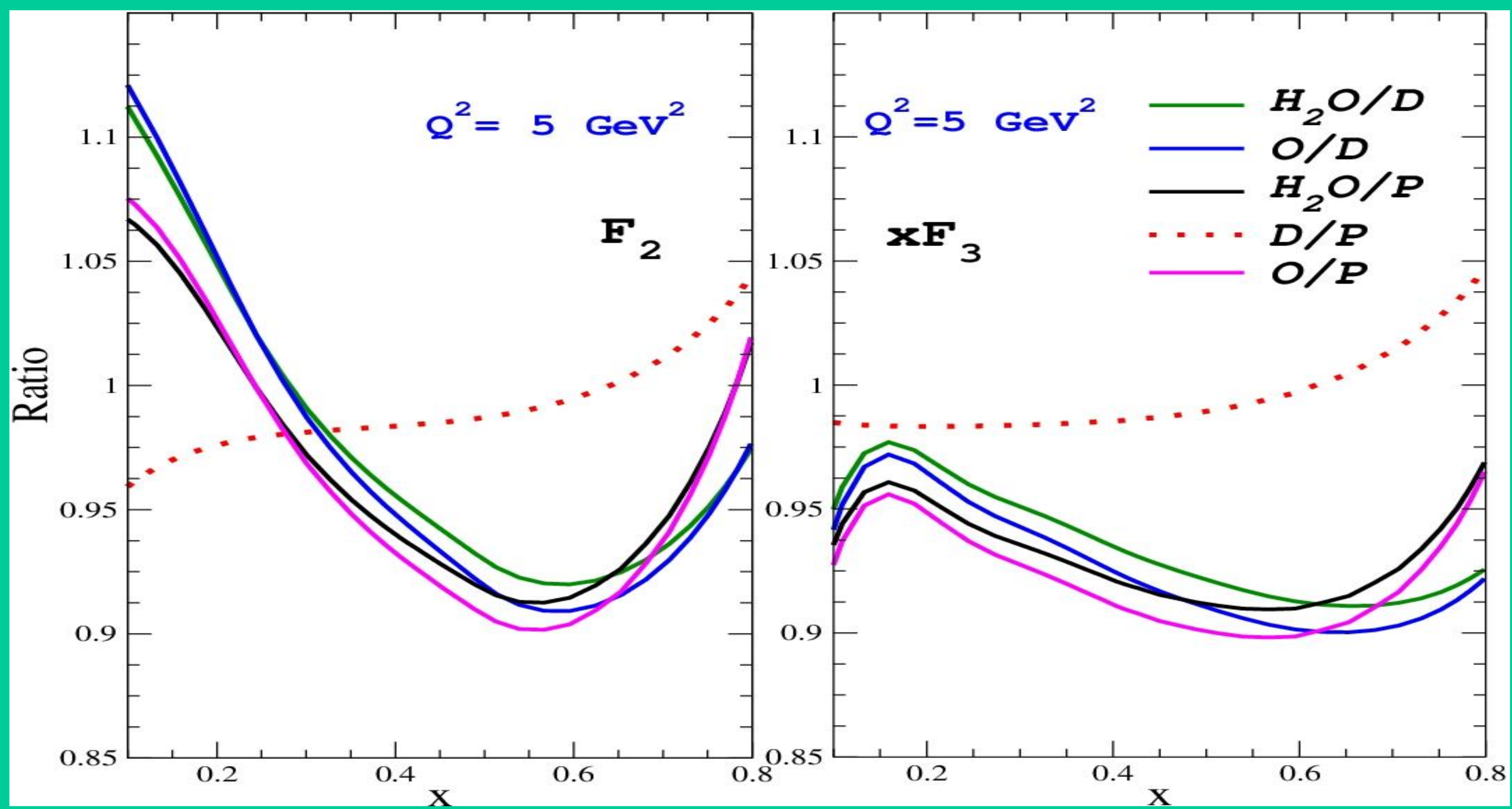

Fig.4:Ratio $R(x,Q^2)=F_i^{H_2O}/F_i^p$, $F_i^{H_2O}/F_i^D$, F_i^D/F_i^p, F_i^O/F_i^p, F_i^O/F_i^D(i=2(left) and 3(right)) using full model at NLO.

CONCLUSIONS

1.We find that the effect of the nuclear medium is quite important even for deep inelastic scattering, and the ratio of the structure functions in nuclei to deuteron or free nucleon is different in F_2^A and F_3^A.

2. We have found that the mesonic cloud (basically pion) contribution modulates the structure functions in the low region of x(x<0.5).

3. We find that the results of the full calculations at NLO are, in general, in good agreement with the experimental observations.

4. The ratio of structure functions F_i^A/F_i^p and F_i^A/F_i^D(i=2,3) is not the same for the different nuclei as well as for the same nucleus the ratio of F_2^A and F_3^A are different.

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