Quark Hadron Duality and DIS modeling

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In Collaboration with Prof. Mary Hall Reno(University of Iowa) , Dr. Steven Gardiner(Fermilab) , Prof. Md. Sajjad Athar(AMU), Vanya Ansari(AMU)

Need of Genie Tuning in DIS region

1. In GENIE, Deep inelastic scattering (DIS) is calculated in an effective leading order model using the modifications prescribed by Bodek and Yang.
2. No A(mass number) Scaling in GENIE.
3. Use GRV98 LO parton distributions.
4. GENIE uses Whitlow's parameterization to obtain $F_{1N}(x, Q^2)$.

$$2xF_{1N}(x,Q^2) = \frac{\gamma^2\ F_{2N}(x,Q^2)}{1+R(x,Q^2)}; \qquad \gamma^2 = 1 + \frac{4M_N^2x^2}{Q^2}$$

where

$$R(x,Q^2) = \frac{0.0635}{ln(Q^2/0.04)}\,\Theta(x,Q^2) + \frac{0.5747}{Q^2} - \frac{0.3534}{Q^4+0.3^2}$$

$$\Theta(x,Q^2) = 1 + 12\left(\frac{Q^2}{Q^2+1}\right)\left(\frac{0.125^2}{0.125^2+x^2}\right)$$

AMU DIS

- Our group at AMU has studied the nuclear medium effects in the electromagnetic structure functions $F_1^{EM}(x, Q^2)$ and $F_2^{EM}(x, Q^2)$ and the weak structure functions $F_1^{Weak}(x, Q^2)$, $F_2^{Weak}(x, Q^2)$, $F_3^{Weak}(x, Q^2)$ in the deep inelastic charged lepton- and neutrino-nucleus scattering for wide range of x and Q^2.
- This model has been applied to various electromagnetic and weak interaction processes in a wide range of x and Q^2. For details: Nucl. Phys. A 857 (2011) 29, Phys.Rev. C84 (2011) 054610, Phys.Rev. C85 (2012) 055201, Nucl.Phys. A943 (2015) 58, Nucl. Phys. A955 (2016) 58.
- Also we have applied this model to study nuclear medium effects in Drell-Yan process (J.Phys. G44 (2017) 045111) and Parity violating asymmetry with nuclear medium effects in deep inelastic $\vec{e}$ scattering (Nucl.Phys. A940 (2015) 138).

Structure function at the nucleon level

1. The free nucleon structure functions $F_{iN}(x, Q^2)$ (i = 1, 2, 3) are expressed in terms of the nucleon PDFs and for the numerical calculations we have used Martin, Motylinski, Harland-Lang, Thorne (MMHT) 2014 NLO and NNLO nucleon PDFs.
2. For the evolution of PDFs at NLO and NNLO from the leading order, we have followed the works of Vermaseren et al., Moch et al. and Vogt et al. and obtain the nucleon structure functions $F_{iN}(x, Q^2)$ (i = 1, 2, 3) in an independent manner.
3. The target mass correction effect which is found to be more pronounced in the region of large x and moderate Q^2 has been taken into account following the method by Georgi and Politzer Schienbein et al.
4. The dynamical higher twist correction has been taken into account following the methods of Dasgupta et al. and Stein et al. as well as with the phenomenological approach given by Virchaux et al.

What is available for Genie

1. C++ code is ready to go for free nucleon where Target Mass Correction (TMC) and Next-to-Leading Order (NLO) have been included. In the present code of C++ we have used LHAPDF 6 for the nucleon parton distribution functions.
2. Nuclear Medium Effects in our calculations:
   1. Fermi motion, Pauli Blocking, Nucleon Correlation and binding .
   2. Pion and Rho meson cloud contribution in $F_2(x, Q^2)$ structure function
   3. Shadowing and AntiShadowing
3. Steven Gardiner already added our DIS model in Genie (in my and his area not yet public). Presently, incorporated model is for free nucleon and iron which will be modified for several nucleus in future once we finish the validation and comparison with Bodek-Yang DIS model.

Recent calculations we have(Phys.Rev.D 102 (2020) 113007)

$$\frac{d^2\sigma}{dxdy} = \frac{G_F^2 M_N E_\nu}{\pi(1+\frac{Q^2}{M_W^2})^2}\Big\{\Big[y^2 x + \frac{m_l^2 y}{2E_\nu M_N}\Big]F_{1N}(x,Q^2) + \Big[\Big(1-\frac{m_l^2}{4E_\nu^2}\Big) - \Big(1+\frac{M_N x}{2E_\nu}\Big)y\Big]F_{2N}(x,Q^2)$$
$$\pm \Big[xy\Big(1-\frac{y}{2}\Big) - \frac{m_l^2 y}{4E_\nu M_N}\Big]F_{3N}(x,Q^2) + \frac{m_l^2(m_l^2+Q^2)}{4E_\nu^2 M_N^2 x}F_{4N}(x,Q^2) - \frac{m_l^2}{E_\nu M_N}F_{5N}(x,Q^2)\Big\}.$$

1. We have obtained the nucleon structure functions $F_4(x,Q^2)$ and $F_5(x,Q^2)$. Present calculations are in Fortran, plan is to convert them in to c++ for Genie.
2. The lepton mass effect has been shown explicitly by comparing ν_μ vs ν_τ induced differential and the total scattering cross sections.
3. The effect of W cuts on the differential and the total scattering cross sections has been studied.

Recent work in Collaboration Prof. Mary Hall Reno(University of Iowa)

1. Theoretical and phenomenological study of quark-hadron duality in electron proton scattering and in future neutrino scattering as well.
2. Phenomenolgically, we can use parametrized structure functions of ep scattering by Capella, Kaidalov, Merino, and Thanh Van (CKMT).
3. We are comparing our theoretical and phenomenological calculations with the JLAB results available for inclusive ep scattering to see the scaling behaviour between resonances and DIS.
4. Minoo's MK model may be useful for SIS study.
5. In future we would like to apply our understanding of ep duality to neutrino scattering calculations, eventually to Genie.

1. Need to validate and compare our AMUValDIS model with the Bodek Yang. We need a few months to do this validation.
2. SIS calculations with Hallsie are ongoing. Since, we have recently started this less explored region, therefore, we can't say about the timeline for this project.