Monte Carlo Generators vs Nuclear Model

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India-based neutrino observatory(INO) is planning to study atmospheric neutrino interaction using iron calorimeters[1]. The iron plates will be magnetized to determine the charge of the muon produced by neutrino interaction inside the detector to look at ν_μ and $\bar{\nu}_\mu$ events separately. The plan is to study precisely some of the neutrino oscillation parameters of the neutrino mixing matrix(PMNS matrix) like $|\Delta m^2{}_{atmos}|$, $sin^2 2\theta_{23}$, etc. Presently for the simulation studies at INO, GENIE [2] and NUANCE [3] Monte Carlo generators are being used. Neutrino detection proceeds basically through various channels of interaction with hadronic targets like quasielastic scattering, meson production, resonance excitations, etc. The total νN charged current scattering cross section may be written as

$$\sigma = \sigma_{QEL} + \sigma_{1\pi} + \sigma_{2\pi} + \sigma_{1K} + \sigma_{YK} + ... + \sigma_{DIS}$$

The first term of the right hand side is the cross section from quasielastic scattering, the second term is the one pion production, the third term is two pion production, 1K stands for single kaon production, YK stands for associated production and DIS stands for deep inelastic process. The dotted line shows the contributions from multi pion production, η production, etc. This is usually approximated as $\sigma = \sigma_{QEL} + \sigma_{1\pi} + \sigma_{DIS}$ in the literature. Most of the earlier neutrino event generators like NUANCE, GENEVE, NEUT, NeuGEN and NUX were mainly developed by the experimentalists with the inputs from the earlier neutrino experiments performed either using hydrogen or deuterium targets or heavy nuclear targets like Freon, Freon-Propane, etc. These were developed according to their need and therefore were not applicable for a wide range of energies, nuclear targets or detector specifications.

NUANCE [3] is FORTRAN based event generator. Quasielastic process is modelled using Smith and Moniz gas model with Bosted-1995 form factors for the vector part of the hadronic current. For the axial form factor a dipole form is used. For the inelastic reaction, the production of baryon resonances include the contribution of 18 resonances and the Rein-Sehgal model has been used. FSI effect and some of the medium modification effects have also been included. For the coherent neutrino-nucleus scattering Rein-Sehgal model has been used. The deep inelastic scattering (DIS) cross section is calculated using the modifications suggested by Bodek and Yang to describe scattering at low Q^2. GENIE [2] is C++ based neutrino event generator for predicting the event rates. There are large number of experimental as well as theoretical physicists who are involved in developing a neutrino interaction physics Monte Carlo generator valid for all the nuclear targets and for a wide energy range from MeV to PeV energy scales. Quasielastic process is modelled using Llewellyn-Smith Fermi gas model with BBBA2005 form factors for the vector part of the hadronic current. For the axial form factor a dipole form is used. For the inelastic reaction, in the resonance region ($W < W_{cut}$=1.7GeV) Rein-Sehgal model with 16 resonances have been taken. The non-resonant background has also been included as a small fraction of DIS cross section. It uses INTRANUKE for modeling FSI effects. For the coherent neutrino-nucleus scattering modified Rein-Sehgal model has been used. The deep inelastic scattering (DIS) cross section adopts the same prescription as of NUANCE.

Our Aligarh group is also involved in the study of nuclear effects in neutrino nucleus interactions. We have presented our results for the quasielastic, 1π, 1K, DIS scattering processes in nuclei at the various international conferences and published them in journals [4]-[8]. In Nuint09 [9], the various theoretical work performed by the different groups

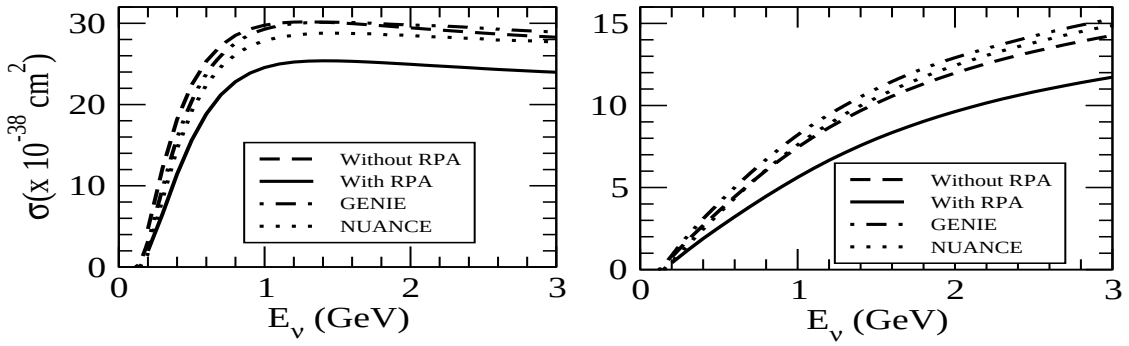

FIG. 1: σ vs E_ν for $\nu_\mu(\bar{\nu}_\mu)$ induced charged current quasielastic process in Iron.

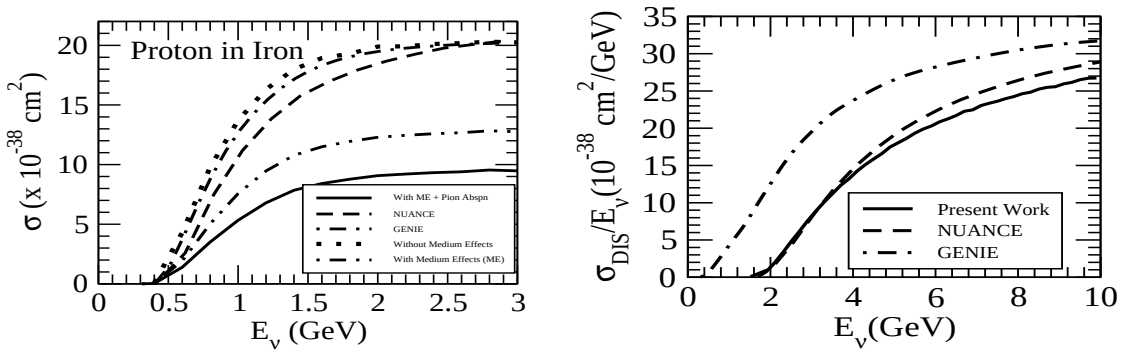

FIG. 2: σ vs E_{ν_μ} for neutrino induced charged current $1\pi^+$ production process(left panel) and deep inelastic scattering process(right panel) in Iron.

were put together towards a better understanding of nuclear models.

In this work, we have performed the calculations for some of these processes like charged current quasielastic(Fig.1), 1π(Fig.2) and DIS scattering(Fig.3) in iron and compared the results obtained with GENIE [2] and NUANCE [3] Monte Carlo generators. The results for the other processes like one kaon production and eta production would also be presented in the Symposium. The comparison of the model with the two Monte Carlo generators would be discussed in the Symposium.

References

[1] Naba K. Mondal, PoS ICHEP-2010 **327** (2010).

[2] C. Andreopoulos et al., Nucl. Instrum. Meth. **A 614** 87 (2010).

[3] D. Casper, Nucl. Phys. (Proc. Suppl.) **B 112** 161 (2002).

[4] M. Sajjad Athar, S. Chauhan and S.K. Singh, Eur. Phys. J. **A 43** 209 (2010).

[5] M. Sajjad Athar, S. Chauhan and S.K. Singh, J. Phys. **G 37** 015005 (2010).

[6] S.K. Singh, M. Sajjad Athar and S. Ahmad, Phys. Rev. Lett. **96** 241801 (2006).

[7] H. Haider, I. Ruiz Simo, M. Sajjad Athar and M.J. Vicente Vacas, arXiv: 1108.3156 [nucl-th] (2011).

[8] M. Rafi Alam, I. Ruiz Simo, M. Sajjad Athar and M.J. Vicente Vacas, Phys. Rev. **D 82** 033001 (2010).

[9] S. Boyd, S. Dytman, E. Hernandez, J. Sobczyk and R. Tacik, A. I. P. Conf. Proc. (NuInt09 Proceedings) **1189** 60 (2009).