PROCEEDINGS OF SCIENCE

Neutrino-nucleus scattering in the SuSAv2 model including Meson-Exchange Currents

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A brief review of scaling based models for neutrino-nucleus scattering is presented. In particular, it is stressed the importance of a coherent description of the electromagnetic and weak nuclear reactions extended from the quasi elastic to the inelastic region. The study is relevant for the analysis of neutrino oscillation for the next generation experiments Hyper-Kamiokande and DUNE. Perspectives for two-particles–two-holes ($2p2h$) semi-inclusive cross-sections are also discussed. This excitation channel constitutes a crucial ingredient for correctly modeling the lepton-nucleus scattering for semi-inclusive measurements.

12th Neutrino Oscillation Workshop (NOW2024)
2-8, September 2024
Otranto, Lecce, Italy

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ISSN 1824-8039. Published by SISSA Medialab.

PoS(NOW2024)051

1. Introduction

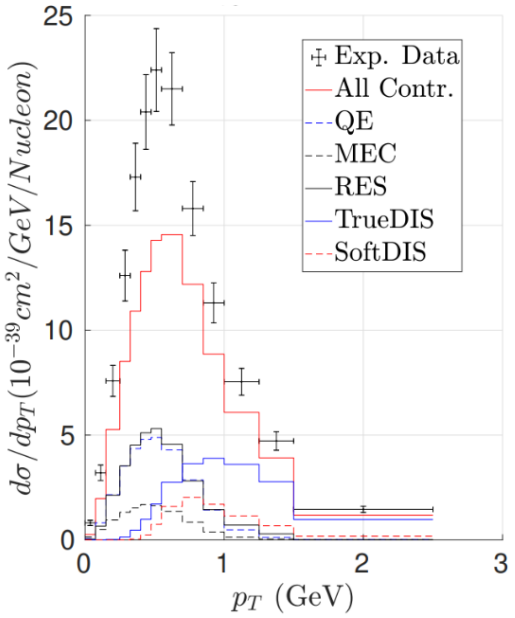
High-precision measurements in neutrino oscillation experiments require a very accurate description of the lepton-nucleus scattering process. Current and future accelerator-based neutrino experiments use neutrino beams with energy from hundreds of MeV to tens of GeV. Thus a reliable description of all the active interaction channels is strongly required. The cross-sections are fundamental quantities for the correct analysis and interpretation of the collected data, but their evaluation is challenging [1]. The neutrino community is advancing toward a deeper understanding of inclusive processes -where only the final lepton is detected-, from the Quasi-Elastic (QE) to the inelastic regions, as well as exploring more exclusive reactions -where hadrons are detected in coincidence with the lepton in the final state-, which could provide further insights into nuclear properties due to their increased sensitivity to them.

2. SuSAv2

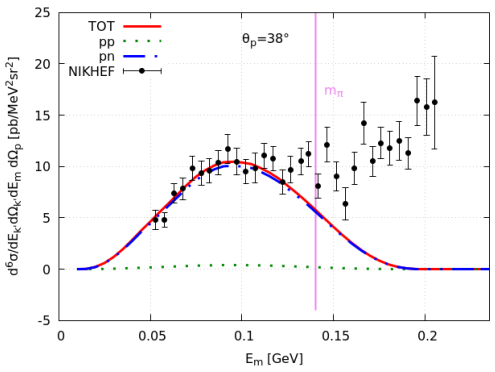
The SuperScaling Approach (SuSA) is a phenomenological model based on the scaling behaviour exhibited by the nuclear QE responses in the inclusive electron nucleus scattering. In fact, nuclear responses can be related to the single nucleon responses times the scaling function f, that accounts for the nuclear dynamics. The SuSAv2 [2] represents a step further, being based on a set of scaling functions microscopically computed within the Relativistic Mean Field. This model has been generalized to also describe weak neutrino reactions. Extension to the inelastic channels has been recently developed in Ref. [3]: resonances contributions are included defining a generalized scaling function for each invariant mass, while Deep Inelastic Scattering (DIS) is computed by folding the nucleon elementary inelastic response with the scaling functions. The model was built up for the electron-nucleus scattering and then generalized to the weak sector. The strength of SuSAv2-inelastic model is mainly related to the simultaneous and coherent description of several interaction channels. This way, no double counting occurs. The model has also been implemented in a Monte Carlo event generator, and tested against available T2K, MINERνA and MicroBooNE data. An example of the results of Ref. [3] is reported in Fig. (1a).

3. Meson-Exchange Currents

The importance of the nucleons double knockout is well established in the inclusive predictions, and several calculations exist [1]. However, for semi-inclusive processes, in which the lepton and one or more hadrons are detected in the final state, the impact of the two body Meson-Exchange Currents (MEC) has not yet been investigated correctly. For instance, the common approach consist of 'extracting' more exclusive predictions from inclusive results, forcibly using assumptions whose reliability is difficult to control. This way, the interpretation of the semi-inclusive data is limited by the high uncertainties associated to the $2p2h$ contributions. A promising study aimed at addressing this gap is presented in Ref. [4], where the relativistic microscopic approach, already implemented in SuSAv2, has been generalized for semi-inclusive predictions and tested against available electron-carbon data. An example of the obtained results is shown in Fig. (1b). The calculation employs relativistic two-body currents involving the one pion exchange and the excitation of an intermediate Δ resonance in the Relativistic Fermi Gas framework.



(a) MINERvA CC inclusive ν_μ $-^{12}C$ flux-averaged single-differential cross-section per target nucleon as function of the muon transverse momentum p_T. Figure from Ref. [3].



(b) The 2p2h contribution to the $^{12}C(e,e'p)$ cross-section is displayed versus the proton missing energy E_m for electron energy ϵ=478 MeV, energy transfer ω=263 MeV, momentum transfer q=303 MeV/c and proton scattering angle θ_p=38°, degrees. The separate contributions of pp and pn emission to total cross-section are shown. The vertical line in violet represents the π production threshold: to its right, mesons production starts to contribute. Figure from Ref. [4].

4. Conclusion

SuSAv2-inelastic model represents an important step for a coherent description of the inclusive lepton-nucleus scattering over a wide energy range, encompassing all the interaction channels active above hundreds of MeV incident energy leptons.

Concerning more exclusive reactions, $2p2h$ relativistic MEC contributions to one proton emission in electron scattering have been recently evaluated, representing a novelty in this sector. The strongly demanded extension to the weak sector is currently underway. It is crucial to assess the $2p2h$ impact in present and future semi-inclusive neutrino cross-section measurements.

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