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Contribution of meson exchange currents to the electromagnetic responses within a relativistic mean-field model

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An unprecedented activity has been unleashed in recent years to determine neutrino properties and their interactions. It has been firmly established that neutrinos oscillate and hence are massive particles. Some of the oscillation parameters, such as the neutrino mixing angles, have been measured with some precision, but other properties remain to be determined, such as their masses or the phase that quantifies the possible charge-parity violation. These are some of the goals of the new generation of accelerator-based neutrino oscillation experiments NOvA, DUNE and HyperKamiokande, with which neutrino physics enters a new 'Precision Era' [1].

The fact that all neutrino oscillation experiments use complex nuclei as target material in the detectors, for example mineral oils, water or liquid argon, complicates the analysis of the results since nuclear effects must be considered. In the energy region covered by the neutrino oscillation experiments, the neutrino-nucleus scattering cross section is not very precisely known, so that it is currently one of the largest contributions to the error [2]. This is what makes the study of neutrino-nucleus interactions a hot topic and brings theoretical nuclear physics to the stage.

Among all the reaction mechanisms that take place in neutrino experiments, we focus on the quasielastic channel (QE), where the scattering off a bound nucleon which is knocked out from the nucleus occurs. This process is studied within a realistic nuclear framework, using a state of the art relativistic mean-field based model for the description of the nuclear dynamics and final state interactions within a quantum mechanical framework (see [3] and references there in). Residual interactions between the bound nucleons through pion exchange are also included. We extend the usual treatment of QE scattering, based on a one-body current operator, by incorporating a two-body meson-exchange current (MEC) one. In this work, MEC include the dominant Delta-resonance mechanism (excitation of the $\Delta(1232)$ resonance and its subsequent decay into $N\pi$) and the background contributions deduced from the chiral perturbation theory Lagrangian of the pion-nucleon system [4].

The connection of electron scattering experiments with neutrino scattering allows to scrutiny the available theoretical models by a first comparison to electron scattering data. Then, in our work [5], we compare our calculation of the electromagnetic responses of the ^{12}C nucleus with the available experimental data. We find that the effect of the two-body currents is only significant in the transverse channel, where the response is increased up to a 34%, leading to an improved description of the data compared to the one-body case. The key contribution of this work is the incorporation of the two-body meson exchange current contribution. The relativistic and quantum mechanical treatment of the process allows its application to heavier nuclei. Therefore, after the success of the model in the scrutiny against ^{12}C electron scattering data, it is in the process of being applied to ^{40}Ca and ^{40}Ar.

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[2] K. Abe et al. (T2K Collaboration), *arXiv:1607.08004* (2016).
[3] R. González-Jiménez et al. *Phys. Rev. D* **97**, 013004 (2018).
[4] S. Scherer and M. R. Schindler, *Quantum Chromodynamics and Chiral Symmetry in A Primer for Chiral Perturbation Theory. Lecture Notes in Physics*, **830**. Springer, Berlin, Heidelberg (2011).
[5] T. Franco-Munoz et al., *arXiv:2203.09996* (2022).

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