Nuclear effects in neutrino scattering

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We have developed a model to describe the interactions of neutrinos with nuclei, focusing on the region of the quasielastic and Delta(1232) peaks. We describe neutrino nucleon collisions with a fully relativistic formalism which incorporates state-of-the-art parameterizations of the form factors for both the nucleon and the N-Δ transition. The model has then been extended to finite nuclei, by taking into account nuclear effects such as Fermi motion, Pauli blocking (both within the local density approximation), nuclear binding and final state interactions (FSI). The in-medium modification of the $\Delta(1232)$ resonance due to Pauli blocking and collisional broadening have also been included. FSI are implemented by means of the Boltzmann-Uehling-Uhlenbeck (BUU) coupled-channel semiclassical transport model. Pions and nucleons undergo elastic and charge exchange scattering with the nucleons in the medium. Pions can also be absorbed or created in secondary collisions. The propagation of particles between collisions is influenced by momentum dependent mean-field potentials.

Motivated by the advent of new experiments like MiniBooNE and MINERνA, we have calculated inclusive double differential cross sections $d\sigma/dQ^2dE_\mu$ for charge and neutral current processes on C and Fe targets. We have also considered exclusive channels, namely pion production and nucleon knockout. We find that FSI modify considerably the distributions through rescattering, side feeding and absorption. In the case of pions, there is a strong absorption associated with in-medium pionless decay modes of the Δ (like $\Delta N \to N N$), while nucleon knockout exhibits a considerable enhancement of low energy nucleons due to rescattering, as well as a strong $p \to n$ side-feeding. Finally, we have investigated the role of polarization effects (nuclear RPA correlations) in quasielastic neutrino-nucleus scattering on the specific conditions of the MiniBooNE experiment. They cause a considerable reduction of the cross section at low Q^2, in line with the reported discrepancies between data and Monte-Carlo simulations which do not include this important nuclear effect.