

# Benchmarking intra-nuclear cascade models for neutrino scattering with relativistic optical potentials

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The description of final-state interactions (FSI) in the large phase space probed in neutrino experiments poses a great challenge. In neutrino experiments, which operate under semi-inclusive conditions, cascade models are commonly used for this task, while under exclusive conditions FSI can be treated with relativistic optical potentials (ROP). We formulate conditions under which the ROP approach and cascade model can be directly compared. We feed the NEUT cascade with events from a relativistic distorted-wave impulse approximation calculation that uses the real part of an optical potential. Cuts on the missing energy of the resulting events are applied to define a set of events that can be directly compared to RDWIA calculations with the full optical potential. The NEUT cascade and ROP agree for proton kinetic energies  $T_p > 150$  MeV for carbon, oxygen and calcium nuclei when a realistic nuclear density is used to introduce events in the cascade. For  $T_p < 100$  MeV the ROP and NEUT cross sections differ in shape and differences in magnitude are larger than 50 %. Single transverse variables allow to distinguish different approaches to FSI, but due to a large non-QE contribution the comparison to T2K data does not give an unambiguous view of FSI. We discuss electron scattering and argue that with a cut in missing energy FSI can be studied with minimal confounding factors in e.g.  $e4\nu$ . The agreement of the ROP and NEUT for T2K conditions lends confidence to these models as a tool in oscillation analyses for sufficiently large nucleon kinetic energies. These results urge for caution when a cascade model is applied for small nucleon energies. The assessment of model assumptions relevant to this region are strongly encouraged. This paper provides novel constraints on cascade models from proton-nucleus scattering that can be easily applied to other neutrino event generators.

## Attendance type

In-person presentation

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