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The nuPRISM detector: An experimental solution to the neutrino energy measurement problem

The frequency with which a neutrino oscillates is dictated by its energy. Therefore, in order to determine neutrino oscillation parameters, experiments must accurately measure the energy of each neutrino. Unfortunately, the neutrino energy is not directly observable, and, instead, experiments can only measure the outgoing charged lepton from a charged current neutrino interaction, and perhaps some constraint on the energy of the final state hadrons. To translate these measurements to neutrino energy, it is necessary to rely on theoretical models of neutrino interactions with atomic nuclei.

In recent years, neutrino interaction models have undergone drastic modifications. Many models now predict that neutrinos interact with correlated sets of nucleons within the nucleus, which causes large biases in reconstructed neutrino energy for 20-30% of interactions at neutrino energies near 1 GeV. These effects were not included in the state of the art neutrino models just 5 years ago. These nucleon correlation effects are difficult to calculate, and large discrepancies exist between currently available models. Existing neutrino experiments cannot uniquely determine the cross section and final state kinematics for these correlated nucleon processes, hence uncertainties on the modeling of these effects are a potentially dominant systematic uncertainty for future precision oscillation parameter measurements.

In the nuPRISM concept, a detector is placed ~1 km from the neutrino production source and spans a range of off-axis angles relative to the neutrino beam direction. As the off-axis angle changes, the beam energy changes, which can provide a direct, data-driven constraint on the relationship between neutrino energy and experimental observables. This technique is currently being pursued as a near detector upgrade for the T2K experiment, but it is generally applicable to all long-baseline neutrino experiments.

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