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FSI Uncertainties in DUNE-PRISM at various off-axis angles.

Neutrino experiments often utilize heavy nuclear targets to achieve high-statistics neutrino-nucleus interaction event rates. However, this approach introduces systematic uncertainties in oscillation parameters due to nuclear effects and cross-section uncertainties. A precise understanding of neutrino-nucleus interactions is thus crucial for accurately determining oscillation parameters. The Deep Underground Neutrino Experiment Precision Reaction-Independent Spectrum Measurement (DUNE-PRISM) is an advanced component of the DUNE experiment, designed to provide precise measurements of neutrino interactions and enhance the sensitivity to oscillation parameters. DUNE-PRISM employs a movable near detector that samples neutrino interactions at various off-axis angles, enabling the measurement of a wide range of neutrino energy spectra from the same beamline. This study investigates the uncertainty in neutrino energy reconstruction of quasi-elastic (QE) events at different off-axis positions using the calorimetric method. As we move away from the on-axis beam position, the uncertainties in the reconstruction increase in the QE region (˜1 - 2 GeV), resulting in significant uncertainties at 41.81 and 52.26 milliradian off-axis beam positions. We quantify the uncertainties due to nuclear effects at these off-axis angles. Our findings indicate that final state interaction (FSI) effects create substantial uncertainties in the same energy region at these two off-axis angles. These results underscore the importance of accounting for FSI effects in neutrino energy reconstruction to enhance the precision of oscillation parameter measurements in future neutrino experiments.

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