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Calibrating for Precision Physics in LArTPCs at ICARUS

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The Short-Baseline Neutrino (SBN) Program at Fermilab consists of multiple Liquid Argon Time Projection Chamber (LArTPC) detectors in a single neutrino beam. SBN will have a broad physics program that includes GeV-scale neutrino cross section measurements and Beyond Standard Model physics searches including a search for short-baseline neutrino oscillations. Especially for the oscillation program at SBN (and, looking ahead, at DUNE) it is imperative to have accurate and precise energy measurements that can be related to the true neutrino energy. In addition to GeV-scale accelerator neutrino physics, MeV-scale physics is also possible at SBN and DUNE such as in searches for millicharged particles, solar and supernova neutrino detection, and a proposed modification of DUNE to enable a search for neutrinoless double beta decay. These measurements will require further leveraging of the calorimetric information from ionization charge beyond the traditional needs of GeV-scale physics. In this talk, I will review the limits on calorimetric energy precision in a LArTPC. I will also discuss a path for calibrations to improve the accuracy of track-like energy measurements in a LArTPC to the sub-percent level. Two innovations are important here. First, diffusion plays a role in determining the energy scale in LArTPC calibration in a way unappreciated by previous experiments. Second, calibrating from digitized charge to energy directly instead of through a determination of the electronics gain can eliminate the otherwise irreducible systematic uncertainty from existing recombination measurements. We are implementing these techniques now at ICARUS, the far detector in SBN, which has already begun data collection. Looking forward, improved measurements of LAr properties are needed to unlock the best possible energy reconstruction at SBN and DUNE.

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