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Enhancing the LBNF/DUNE Physics Program

The Long-Baseline Neutrino Facility (LBNF) offers a unique opportunity for neutrino physics due to the high intensity (anti)neutrino beam with a broad energy spectrum. The possibility to collect unprecedented exposures alleviates one of the primary limitations of past neutrino experiments. An experimental technique has been recently proposed to achieve a control of the configuration, chemical composition, size, and mass of the neutrino targets comparable to the electron scattering experiments. In particular, this technique allows precise measurements of high statistics samples of (anti)neutrino-hydrogen (H) interactions.

The availability of high statistics samples of $\nu(\bar{\nu})$-H interactions addresses three main systematic uncertainties affecting the Deep Underground Neutrino Experiment (DUNE) long-baseline oscillation analyses:
(a) determination of the neutrino and antineutrino fluxes $\Phi(E_\nu)$;
(b) constraint of the nuclear smearing in Ar (response function) entering the event unfolding;
(c) calibration of the reconstructed (anti)neutrino energy scale.
Neutrino flux can be potentially measured at the percent level using various exclusive $\nu(\bar{\nu})$-H topologies. Such a precision cannot be achieved by other techniques.

A control of the neutrino target(s) similar to the one achieved in electron scattering experiments together with an accurate determination of the (anti)neutrino fluxes from $\nu(\bar{\nu})$-H and the unprecedented statistics would enable a sensible program of precision tests of fundamental interactions in the DUNE Near Detector (ND). This program includes a broad mixture of measurements of electroweak parameters, QCD and hadron structure of nucleons and nuclei, form factors, structure functions and cross-sections, as well as searches for new physics or verification of existing outstanding inconsistencies. It would produce hundreds of papers of varying importance and potentially add a substantial discovery potential to the DUNE physics program. This ND program would not require any additional cost with respect to what is needed to address the systematics of the long-baseline analyses. Such a program of precision measurements and searches would nicely complement the ongoing efforts in the collider, fixed-target and nuclear physics communities. In turn, it would elevate the near site of DUNE to a general physics facility much needed for a project of the size and duration of the DUNE experiment.

We propose to integrate the capability to obtain accurate $\nu(\bar{\nu})$-H measurements into the design of the ND complex currently considered in DUNE. The core technology needed for this enhancement of the physics potential is well established and has enough flexibility to be adapted to different detector geometries and configurations. This addition to the ND system can be accomplished either with a new self-contained complementary detector or an integrated sub-detector with minimal variations of the magnetized detector being considered. In particular, an interesting low-cost solution currently being studied for the former option includes the reuse of an existing magnet and electromagnetic calorimeter.

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