Calibration related Simulation Studies for the LBNE Near Detector

1 Overview and Purpose

Precision measurements of neutrino-interactions at the near-detector (ND) is necessary to ensure the highest possible sensitivity to the neutrino oscillation studies (νOSCL) in LBNE. Regardless of the process under study, ν_μ or $\boldsymbol{\bar{\nu}_\mu}$ disappearance or $\boldsymbol{\nu_\mu \rightarrow \nu_e}$ oscillation, the systematic error should be less than the corresponding statistical error. To this end, the goal of the ND is to provide three principal calibrations to the far-detector (FD):

(a): Measurement of the absolute and the relative abundance of the **four** species of neutrinos in the LBNE-beam as a function of energy (E_ν): ν_μ, $\overline{\nu}_\mu$, ν_e and $\overline{\nu}_e$ via the *in situ* identification of their CC-interactions. These are the unoscillated spectra of the neutrinos.

(b): Determination of the absolute E_ν-scale: the scale which determines the νOSCL-parameter Δm^2.

(c) Determination of π^0's and $\pi^\pm$'s produced in the NC and CC interactions: these mesons induce the dominant background to the $\boldsymbol{\nu_\mu \rightarrow \nu_e}$ and ν_μ ($\boldsymbol{\bar{\nu}_\mu}$) disappearance measurements.

We need simulation studies to quantify the needed precision, and to design the ND to meet these. Since the resolution of the ND will be much higher than that of FD, and since ND and FD see different neutrino spectra — both for signal and background — it is necessary to measure at ND neutrino interactions in water for the Water Cerenkov (WC) and in argon for the Liquid Argon (LAr) detectors. Thus a key component of the calibration studies is the quantification of ν-nucleus cross-section.

The simulation studies will involve a high-resolution straw-tube tracker (STT) with a 4π calorimetric and muon coverage. The STT is one of the leading choices for the LBNE-ND. STT will be designed to have finely segmented water target. The STT will also have Ar-traget in thin pressurized tubes. The STT design will be imbricated with a possible MicroBOONE-type LAr detector at the near site.

2 Specific Calibration Related Simulation Studies

We enlist a set of calibration related simulation studies with the ND.

(1) Establishing the Absolute E_ν-Scale: Quantify the error in the absolute E_ν-scale using two processes and determine the detector requirements to accomplish the precision:

(a) ν_μ Induced Quasi-Elastic interactions: The key is the reconstruction of the momentum vector of the recoil proton.

(b) Missing-PT measurement in ν_μ ($\boldsymbol{\bar{\nu}_\mu}$) CC:

(2) π^0's in ν_μ and $\boldsymbol{\bar{\nu}_\mu}$ Beams: Study the π^0-reconstruction in neutrino and anti-neutrino beams in water (Ar) targets

(3) Calibrating the ν-Measurements at FD: The study involves a board umbrella of issues. Some salient topics are:

(a) Energy Scale of the Leading Lepton —- Muon and Electron:

(b) Absolute Energy Scale —- Hadrons:

(c) Pions in the Hadronic Jet:

(d) Events induced by Outside-interactions — Dirt Events: