# 1 Water Cherenkov Detector Calibration Tasks

## 1.1 Scope of work

We propose to significantly contribute to the design of the calibration and monitoring systems for the large Water Cherenkov Detector option for LBNE. These systems are an essential feature in a Water Cherenkov detector because the properties of the water change with time and position due to temperature and water quality variations. In fact, in the Super-Kamiokande experiment the water attenuation length was observed to vary as much as 20 m within a month and even twice that when comparing year to year [**?**]. It is possible that in a larger water Cherenkov detector the water circulation of a larger mass of water will make this a more significant issue. In addition, the attenuation coefficient is a function of wavelength as it is subject to Rayleigh and Mie scattering as well as absorption terms.

These variations potentially have an impact on physics quantities such as vertex and angular resolution and consequently particle identification efficiency. Every effort will be made to measure each factor individually and eventually input it into the simulation, in addition measuring the physical quantities for different particles types provides more direct access to the final uncertainties as a function of time and position in the detector. These uncertainties have direct consequences on the final sensitivity of this experiment.

## 1.2 Interested Groups

The work here proposed is organized within the calibration task for the water Cherenkov detector option for LBNE. The goal of the group is to develop all of the calibration systems required to achieve the level of uncertainties needed to obtain the desired sensitivity of this experiment given other design constraints such as the size of the detector, the PMT density and quantum efficiency, etc. The group includes the following sub-tasks: measurement of transparency of the water, the calibration of photomultiplier tubes (both timing and pulse height), the calibration of the energy scale and resolution, the calibration of particle identification efficiencies, vertex reconstruction accuracy and angular resolution of the WCD, and the monitoring of the environment within the WCD. Groups that are participating in these tasks from the EPSCOR proposers are: Hawaii, ISU, LSU and SDSMT.

### 1.3 Specific Goals

The specific goals are to design (aspects of) the Water Cherenkov calibration system:

- **Energy Calibration:** The development of the system that calibrates the energy scale of the detector. This includes systems to determine the energy scale and resolution as functin of position and at high energies applicable to the neutrino beam events.

  – High-energy calibration: The development of the system that calibrates the energy scale between 100 MeV and 1-2 GeV based on naturally occurring sources. This system must determine the energy scale to within 2% and determination of the energy resolution to within xx% between 100 MeV and 2 GeV.

- **Particle Vertex and ID Calibration:** The development and investigation of the systems and procedures to calibrate vertex and angular resolution and particle identification efficiency as function of position and at high energies applicable to the neutrino beam events.

  – High-Energy Particle Vertex and ID: The development of the system that establishes the effectiveness of the particle vertex and identification performance in the detector for energies between 100 MeV and 2 GeV.

- **Photomultiplier Calibration:** The development and investigation of the systems that calibrate the response of the photomultipliers including any light collectors that may part of the optical system.

  – Timing calibration: The development of a system that calibrates the timing response of the photomultipliers to better than 1 ns. This system includes the laser, the electronics to trigger the laser, the fiber optic system used to introduce light into the detector.

  – Pulseheight calibration: The development of the system that calibrates the gain of the photomultipliers to 1%. The system includes a laser, a system to vary the light level introduced in the detector, the fiber optic system and the electronics to trigger the laser.

- **Water Transparency Monitoring:** The development and investigation of systems that monitors the transparency of water.

  – In-situ water monitoring: This would include measurements of the stratification within the Water Cherenkov Detector. The measure-

ment of the effective attenuation length and the monitoring of overall optical quality using relative measurements of cosmic muons.

- **Detector Environmental Monitoring:** The development of the system that monitors the environment within the detector volume.

  – Water Parameter monitoring: The development of the system that monitors temperature, level, pH, total dissolved solids, resistivity, biologics, flow rate and flow pattern within the detector.

### 1.4 Relationship to the Simulation Effort

At this stage of the experiment most of the calibration design is based on assumptions of scalability and transferability from the Super-Kamiokande detector to the LBNE detectors. However, there are significant differences in the design that need to be addressed to confirm such assumptions, such as larger detector size, different PMT type, density, granularity, etc. Another potential concern is the low muon rate at 4850 feet depth of the DUSEL cavern. Thus this effort requires extensive simulation work using the LBNE proposed design as well as the development of dedicated software algorithms to reconstruct, identify, analyze and select suitable subsets of events that can verify and improve the uncertainty in the vertex reconstruction and contribute to improved, more robust particle identification. The water Cherenkov simulation developed by LBNE collaborators at Duke University, which is based on the T2K 2-km water Cherenkov detector as well as the GLoBES framework , will be used as a starting point. We expect to contribute significantly to the simulation effort and to provide the main link between the LBNE calibration and simulation groups.

### 1.5 Water Cherenkov Calibration Requirements (current status)

To be filled from CDR document.