The Water Cherenkov Test Experiment at CERN

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ABSTRACT

The Water Cherenkov Test Experiment (WCTE) is a small scale water Cherenkov detector which will be commissioned over 2022 and 2023, with the aim to be placed in the T9 beam area in CERN. The WCTE will be a test bed for future water Cherenkov technologies, including: performance testing of new multi-PMT (mPMT) modules, testing of automated calibration source deployment systems (CDS), and calibration devices which aim for percent level calibration. A schematic of the proposed detector design with the calibration deployment system can be seen in Figure 1.

WCTE

The data collected from the WCTE project will be used to test the performance of new technologies which are being developed for future water Cherenkov detectors such as new photosensor modules (multi-PMT modules), detector movement systems such as those for the IWCD (see “Future Water Cherenkov Detectors” section), and calibration devices which aim for percent level calibration. A schematic of the proposed detector design with the calibration deployment system can be seen in Figure 1.

PHYSICS STUDIES AT WCTE

Using two potential beam configurations at CERN, WCTE will be able to measure π⁺, p, e and µ fluxes over a momentum range of 300-1200 MeV/c. A schematic of the detector in each of the two beam positions can be seen in Figure 2. Physics capabilities are presented in Figure 3 and the following text.

FIGURE 1

- Proposed WCTE design is approximately 3.5 × 3.5 m.
- Tank and support structure fabricated from stainless steel 304.
- Instrumented with approximately 120 multi-PMT modules.
- Each multi-PMT contains 19 fast 3-inch PMTs.
- Multi-PMT modules also house high voltage and readout circuits.
- A calibration deployment system (CDS) is mounted on the tank lid.
- The CDS will be permanently deployed inside the detector with a laser ball attached.
- A fibre feed system for the CDS will sit on top of the detector.

FIGURE 2

Secondary Beam Configuration

- Electron, muon and proton fluxes

Tertiary Beam Configuration

- Low momentum pion and proton fluxes

The two beam configurations allow for a wide range of physics measurements. Configurations with pure water and Gd₂O₂SO₄ loaded water (0.2% by mass) also allow for neutron tagging.

FIGURE 3

- Neutrons used for neutrino/anti-neutrino tagging in Super-K-Gd and Hyper-K.
- Secondary production can be measured using secondary beam configuration at WCTE.

Pion Scattering

- Reconstruction of pions in final state is challenging due to modelling of hadronic scattering with limited data on Oxygen.
- Directly measure detector response to pions using WCTE in tertiary beam configuration.
- Improve analysis at T2K, Super-K and Hyper-K.

Measurement of Cherenkov Light Production

- Electro-Magnetic models differ in GEANT4 which can lead to systematic errors in event reconstruction.
- Can be measured in a well characterised beam in the secondary beam configuration using WCTE.
- Often difficult to study in larger detectors.

Energy Scale Calibration

- Energy scale in Super-Kamiokande determined using “through-going” muons.
- Current systematic uncertainty of 2% needs to be reduced to 0.5% for Hyper-Kamiokande.
- WCTE can be used to study crossing muons of known energy from secondary beam configuration.

CALIBRATION DEPLOYMENT SYSTEM (CDS)

The CDS is being designed and prototyped at Imperial College London, and will be used to deploy various calibration sources, including a laser ball, also being designed and fabricated at Imperial. A schematic CDS as installed inside WCTE can be seen in Figure 4.

FIGURE 4

- Out of water CDS.
- Rotation around Detector Axis Y
- Out of water CDS.
- Rotation around Detector Axis X
- Feasible CDS system.
- Simulations in WCSim (WCTE).
- Monitors: surface/mid-depth/depth.
- Shadowed events.
- Can be measured with a well characterised beam in the secondary beam configuration using WCTE.
- Often difficult to study in larger detectors.

FIGURE 5

- Simulation of 500 MeV electron in WCTE. The CDS has been included in the simulation by the implementation of the CADMesh software into WCSim, allowing for SOLIDWORKS files to be used in detector construction.

FUTURE WATER CHERENKOV DETECTORS

The large water Cherenkov experiment, Hyper-Kamiokande, will see the addition of an Intermediate Water Cherenkov Detector (IWCD), which is on the same order scale as WCTE. IWCD will also be instrumented with multi-PMT modules (total 11k 3” PMTs) and an adapted version of the CDS. By testing these elements, alongside performing the discussed physics studies at WCTE, we push towards Hyper-K, and other future water Cherenkov experiments reaching their physics goals. For more information about physics studies at IWCD, see Charlie Naseby’s poster.