Water Cherenkov Test Experiment

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Motivation

- Many existing and next-generation neutrino experiments use water Cherenkov technology
- With increase in collected data reducing systematics is of crucial importance
- Detector systematics are one of the dominant systematic contribution
Water Cherenkov Test Experiment (WCTE)

- Proposed experiment in East Area at CERN
- Small \((d = 4\ m, h = 4\ m)\) water Cherenkov detector that will be used for
  - developing percent level calibration of water Cherenkov detector
  - measuring physical processes (pion scattering in water, Cherenkov light profile, secondary neutron production)
  - testing new technologies: multi-PMT, water based liquid scintillator

WCTE will use electron, muon and hadron beams \((0.2 - 1.2\ GeV/c)\)
  - Secondary beam for electrons and muons
  - Tertiary beam for pions and protons

http://cds.cern.ch/record/2712416/files/?ln=en
Physics goals

● Measurement of Cherenkov light production
  ○ Simulations not consistent
● Study of energy scale calibration
  ○ Defined by muons crossing the detector
  ○ Reduction from 2% to 0.5% needed for Hyper-Kamiokande
● Measurement of secondary neutron production
● Study of pion scattering
East Area T9 beamline

- T9 beamline has been chosen for the experiment
- Max intensity: $5 \times 10^6$
- Secondary beams 0.4 - 15 GeV/c
Water Cherenkov Test Experiment (WCTE)

- Water tank
- Shielding and collimator
- Compact spectrometer and tungsten target (not shown here)

T9 beamline @ East Area (0.4 - 12 GeV/c secondary beam)

Secondary beam trajectory

The tank can slide between secondary and tertiary beams

Low momentum pions decay in secondary beamline
WCTE Tertiary Beam Spectrometer

Spectrometer axis tilted 450 mrad wrt. secondary beam

Tungsten target

~20 cm

~12 cm

~20 cm

16 cm

10 cm

24 cm

Magnet for momentum measurements

Compensation magnet

Bending power (first magnet) = 0.075 Tm

ATLAS SCT (8 modules approved)

Halbach array
WCTE Tertiary Beam Spectrometer

- Tertiary beam particle ID will be done by measuring time-of-flight (with RPCs) and aerogel threshold Cherenkov detectors
  - Aerogel with index of refraction of 1.0026 was produced → it can be used to identify electrons (p > 350 MeV/c)
- RPCs can be used to detect pion decays (kinks in trajectory)

Assuming 100 ps timing resolution
WCTE Tertiary Beam

Tertiary beam spot

Tertiary beam spot without compensation
Water Cherenkov Detector

- ~4 m diameter
- 128 mPMT modules
- Two beam windows
Water tank movement

- Water tank can slide on rails between secondary and tertiary beam position

Two different beam windows → secondary beam window can inject beam particles at different radial positions in the tank
Water system

- Commercially available water purification system
- Micro/nano-filters
- UV system to suppress biological contamination
- Ion exchange resins
- Special resin for Gd loading
Multi-PMT photosensor

- 19 8 cm PMTs (Hamamatsu R14374)
- Less photo-coverage but improved vertex resolution
Hadron interaction measurements in WCTE facility

- WCTE facility can be reconfigured to measure forward hadron-nucleus interactions → elastic and quasi-elastic scattering
- Data is necessary to reduce neutrino flux uncertainty in long-baseline neutrino experiments
- Water tank can be used for muon/pion separation in the secondary beam

Possible spectrometer configuration

- 2 cm thick graphite target
- 32 cm
- 16 cm
- 12 cm
- 7 cm
- 2 cm thick graphite target
- x modules
- y modules
- Two modules combined into one
Hadron interaction measurements in WCTE facility

- We are preparing LOI for an independent experiment that will use WCTE hardware.
- Measurements of forward pion and kaon scattering:
  - $\pi^\pm + C, Al, Fe \rightarrow \pi^\pm + X$ and $K^\pm + C, Al, Fe \rightarrow K^\pm + X$
  - Additional targets are possible.
- Important for T2K, HyperK, DUNE, ...

![Graph showing elastic and quasi-elastic regions for $K^+ + C @ 6\,\text{GeV/c}$]
Conclusion

- Reducing systematics in existing and future water Cherenkov detectors is of crucial importance
- WCTE will use the 50t water Cherenkov detector to study physics processes inside the detector with a well-defined beam and develop calibration techniques
- WCTE is a platform for testing new technologies (multi PMT, WBLS, …)
- WCTE can become a facility for independent experiments such as hadron interaction measurements