TRIUMF

THE WATER CHERENKOV TEST EXPERIMENT: INVESTIGATING PARTICLE DETECTION IN SMALL-SCALE WATER CHERENKOV DETECTORS

Mohit Gola,[1] mgola@triumf.ca
On behalf of WCTE collaboration
[1]TRIUMF: Canada's particle accelerator centre

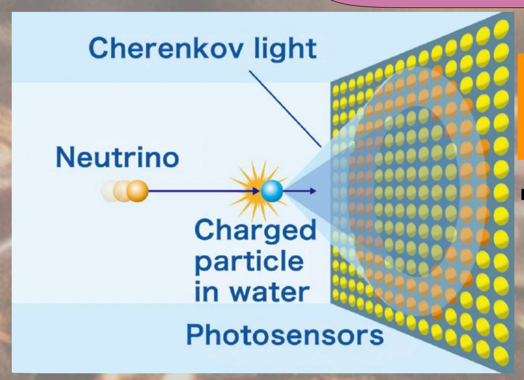
Development of a novel photon detection system to precisely measure the CP violation among neutrinos.

ABSTRACT

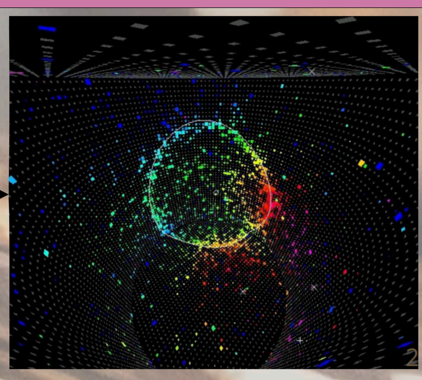
The multi-PMT (mPMT) photosensor has been developed for use in the Intermediate Water Cherenkov Detector (IWCD) detector due to its better timing and spatial resolution compared to the Super-K or Hyper-K 50-cm diameter PMTs. This will facilitate precise event reconstruction in the small-scale detector like the IWCD. To validate the performance of the mPMTs and event reconstruction using mPMTs in a small water Cherenkov detector, we are currently in the process of constructing a ~40-ton scale Water Cherenkov Test Experiment (WCTE) as a prototype for IWCD, with plans for operation in late 2024.

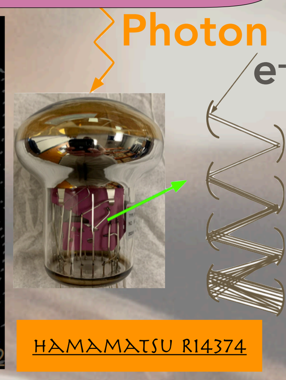
PRINCIPLE

Water Cherenkov detectors use the Cherenkov light produced from the resultant charged particle in a neutrino interaction to reconstruct the event



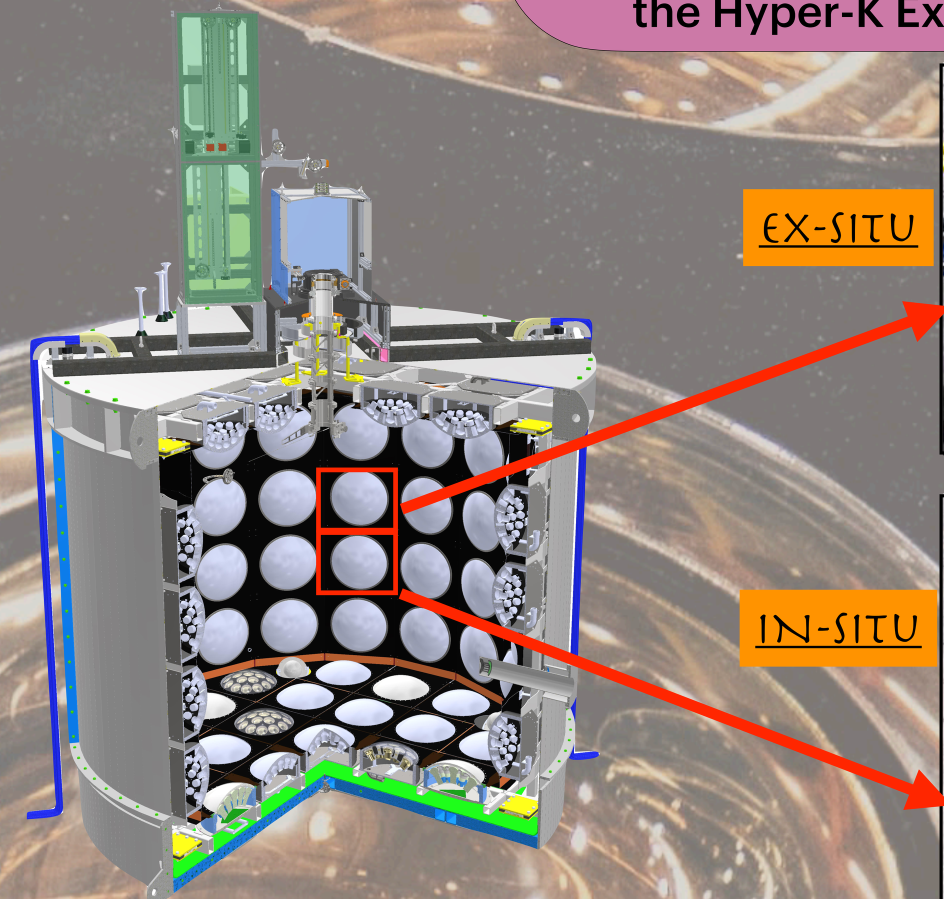
WHAT WE OBSERVE





WATER CHERENKOV TEST EXPERIMENT (WCTE)

The WCTE will act as a technology demonstrator for new water Cherenkov detector technologies being developed for the Hyper-K Experiment and IWCD.

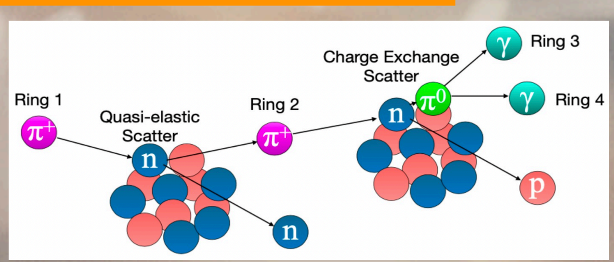


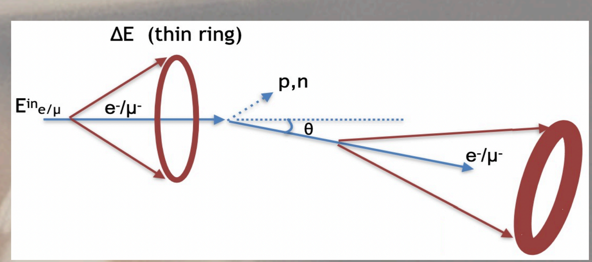
EX-SITU

IN-SITU

- The WCTE has a tank with a height and diameter of ~4 m, with the capacity to house 100 mPMT modules during operation.
- The WCTE will operate in the CERN East Area T9 beam line with low momentum charged particle fluxes.
- The WCTE has a 10 cm beam pipe in the middle with the ability to extend to inject the beam at different positions.

WCTE PHYSICS GOALS





- Incomplete simulation details of electromagnetic processes cause uncertainties in backward-going light generation.
- Improve the systematic uncertainty in vertex reconstruction, particularly the study of the backward-going light generation: *Important for the CP violation measurement.*
- Energy scale calibration by precision measurement of the total Cherenkov light ratio between muons and electrons: *Important for neutrino mass ordering.*
- The scattering of electrons and muons on nuclei can be used to constrain nuclear models that are also inputs for *neutrino interaction modelling.*
- Hadronic interactions lack first-principles simulation, leading to typical uncertainties of tens of percent.
- Measure pion interaction cross-sections and their response in water Cherenkov detectors: *Help the measurement of pionic neutrino interaction modes (CC1π, NCπ) in water Cherenkov.*
- Demonstrate particle identifications in water Cherenkov: *e/γ separation by the highly granular mPMT using the newly developed tagged γ beam*

EX-SITU STYLE MPMT

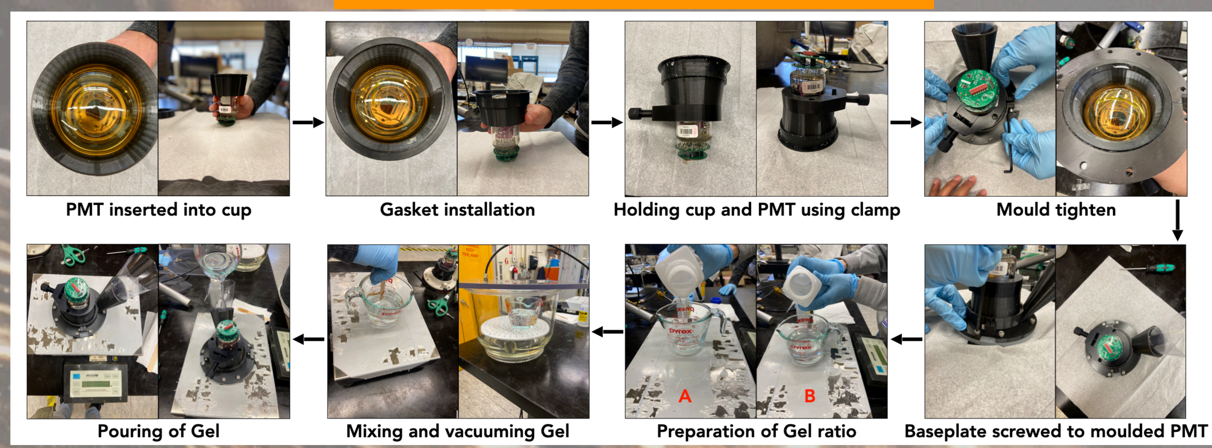
IN-SITU STYLE MPMT

Each mPMT module consists of 19 8 cm PMTs and electronics to generate high voltage and digitized signals for each PMT.

The 8 cm PMTs will be used for detecting the Cherenkov radiations by simple photoelectric effect and electron amplification method.

Two different mPMT construction strategies has been developed for the WCTE experiment namely Ex-situ and In-situ.

PMT GELLING PROCEDURE



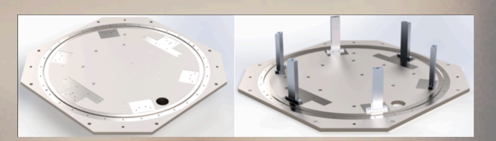
MPMT MECHANICAL COMPONENTS


Support Matrix


PVC Cylinder

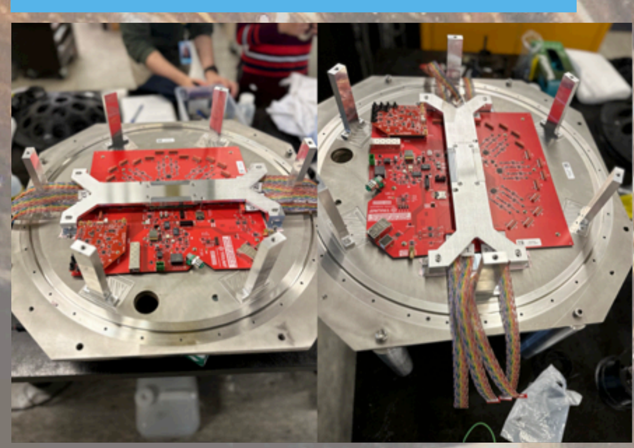

Fully Assembled PMT


Acrylic Dome


stainless steel backplate and pillars

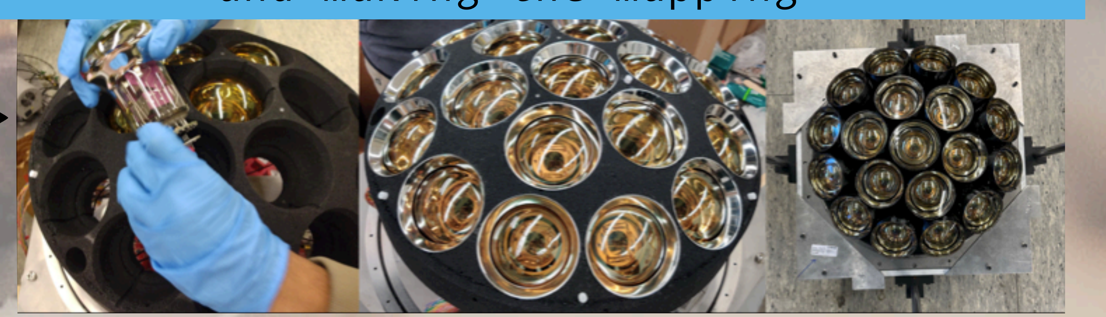
MPMT ASSEMBLY PROCEDURE

Install Mainboard

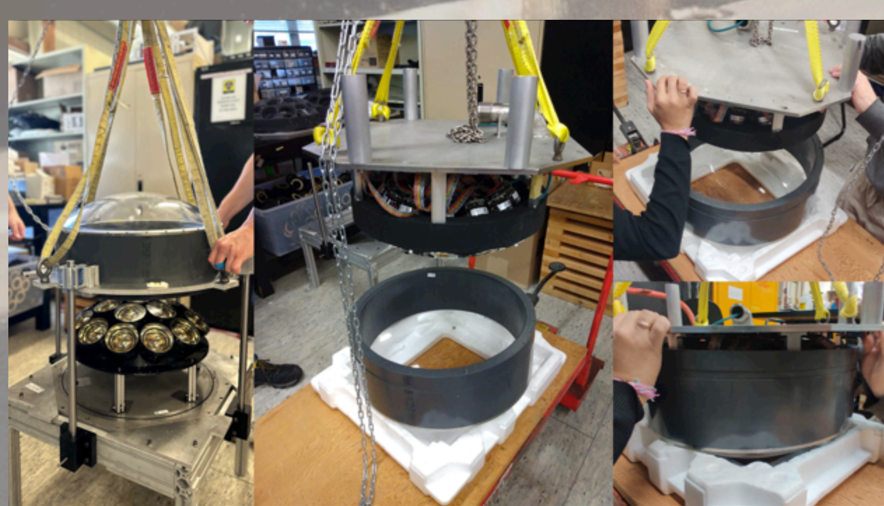


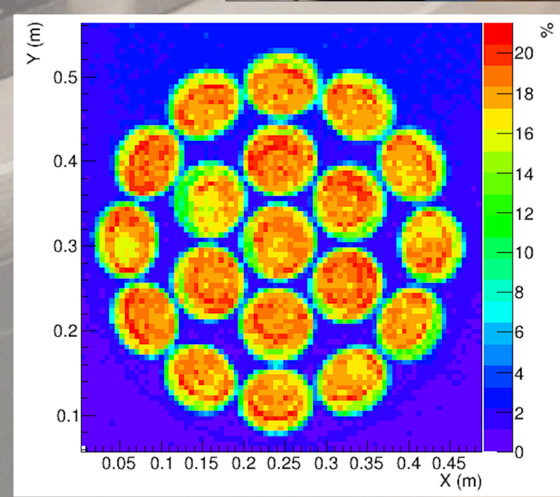
Connect cables

Placing PMTs and reflectors on the matrix and making the mapping



Screw Pillars

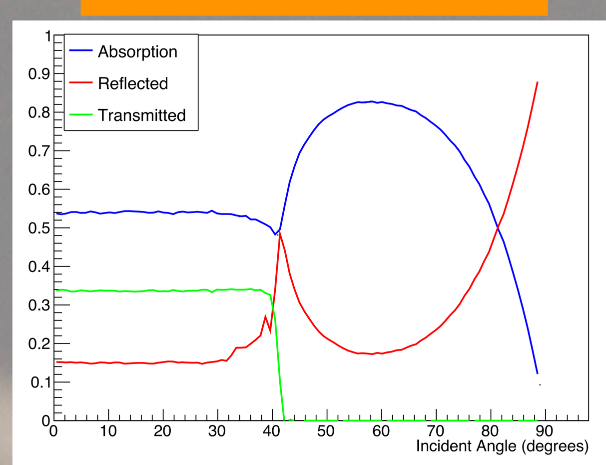


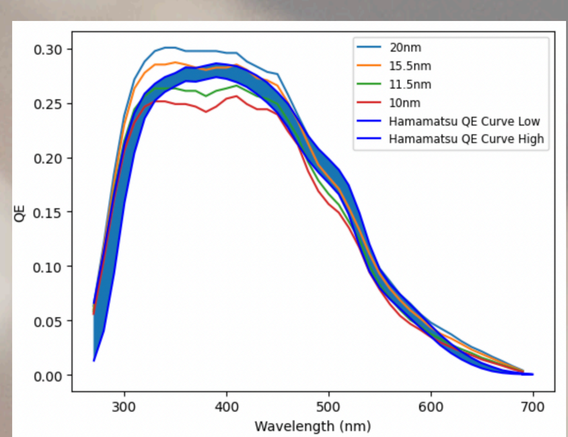


Clean/ lubricate the PMTs

Lower the dome/backplate substructure

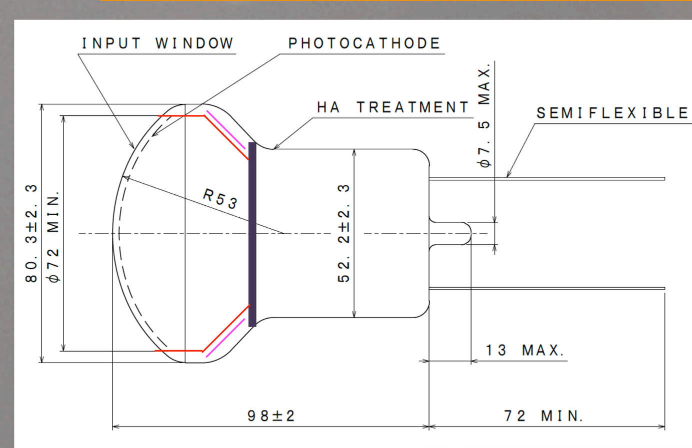
PROBABILITY CURVE



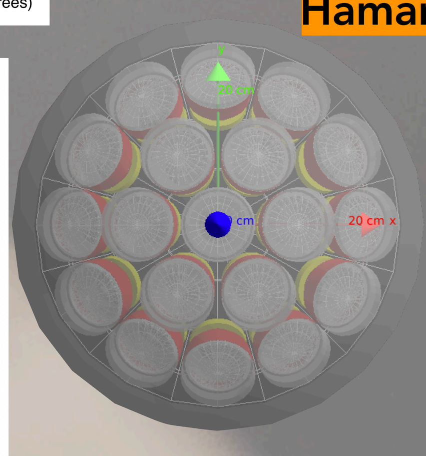


QE CURVE

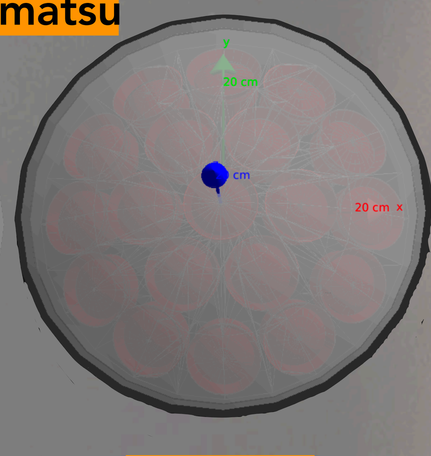
MPMT GEANT4 SIMULATION



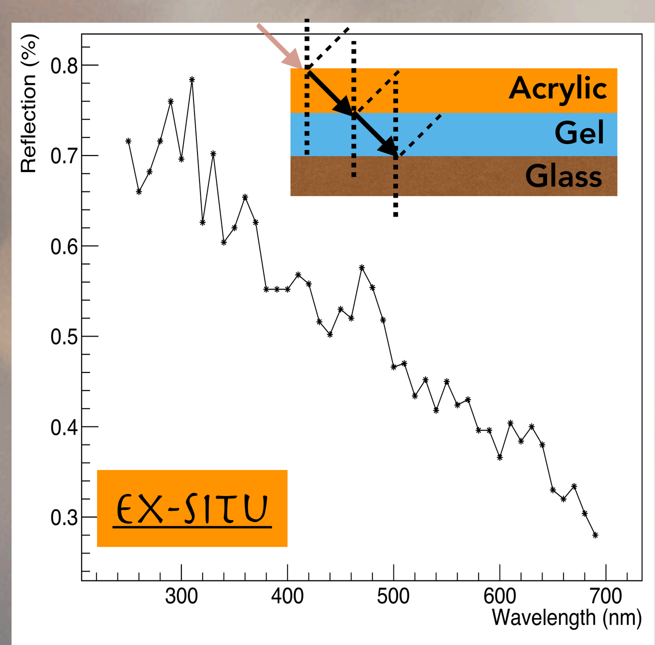
Hamamatsu

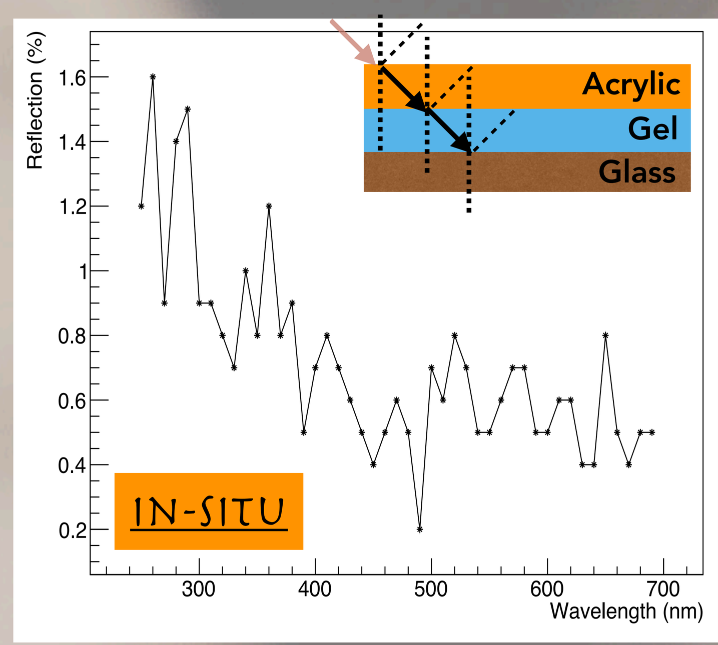


EX-SITU



IN-SITU





- Construction of an accurate PMT as well as mPMT model in GEANT4.
- Implementation of the new photocathode model, allowing the propagation of photons entering the PMT. In the current model, photons were killed upon entering the PMT.
- Ensuring precise geometry and accurate material definitions as well as properties.
- Creating separate models for in-situ and ex-situ style mPMT.
- Produced the probability curve for different incident angles.
- Generated the QE curve and attempted to compare it with the Hamamatsu given curve.
- The use of gel to minimize reflections at the different boundaries is confirmed by the simulation.

SUMMARY

The WCTE has been approved by the CERN research board and is currently under construction, with data collection scheduled for late 2024.

WCTE will measure the charged particle processes in the water Cherenkov detectors to reduce the systematic uncertainties in detector calibrations.

WCTE simulation uses WCSim, a GEANT4-based water Cherenkov Monte Carlo simulation package to simulate the detector and response

The construction of approximately 110 mPMTs is underway in Canada, Poland, and Italy, with installation scheduled to begin in June of this year.