Water Cherenkov Test Experiment

Matej Pavin,
on behalf of the WCTE collaboration

CAP 2021,
June 10, 2021

Outline

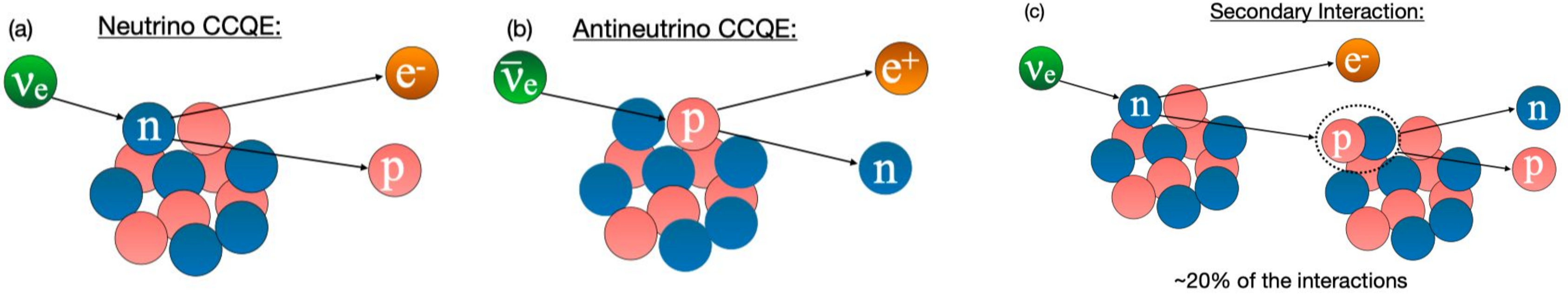
- Motivation for Water Cherenkov Test Experiment
- What is WCTE?
- Proposed experimental setup

Motivation

- Many existing and next-generation neutrino experiments use water Cherenkov technology
- With increase in collected data reducing systematics is of crucial importance
- Hyper Kamiokande will achieve 3% statistical error for CP violation measurements ➔ current systematic uncertainty in T2K is 6%
- Detector systematics are one of the dominant systematic contributions ➔ calibration of water Cherenkov detector

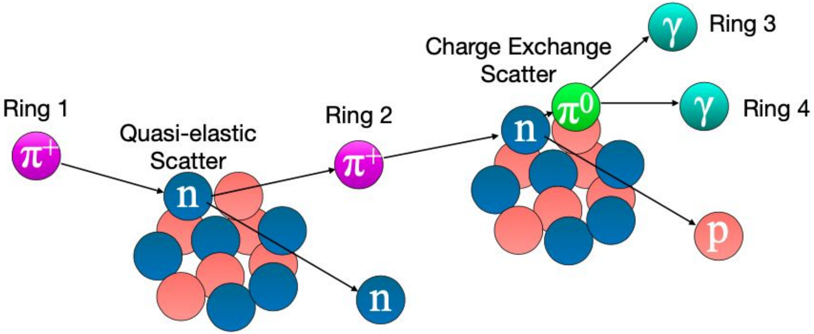
Secondary neutron production

- Super Kamiokande is starting to use water with 0.2% $Gd_2(SO_3)_4$ to capture neutrons produced in (anti)neutrino interactions
- Hyper Kamiokande will also use $Gd_2(SO_3)_4$ loaded water
- Charged current quasi elastic antineutrino interaction produce neutrons
- Secondary production of neutrons by protons and pions (20% of neutrino interactions) ➜ not constrained by data



Pion scattering in water

- Sensitivity of neutrino oscillation measurements can be improved by including neutrino events with pions in the final state
- Pions can undergo hadronic scattering on oxygen ➔ can introduce systematic biases in analysis
- Data is sparse



Testing new technologies

- New photo-sensor technologies (multi-PMT)
- Water based liquid scintillator ➜ possibility to separate scintillation and Cherenkov light
    - THEIA, ANNIE and WATCHMAN

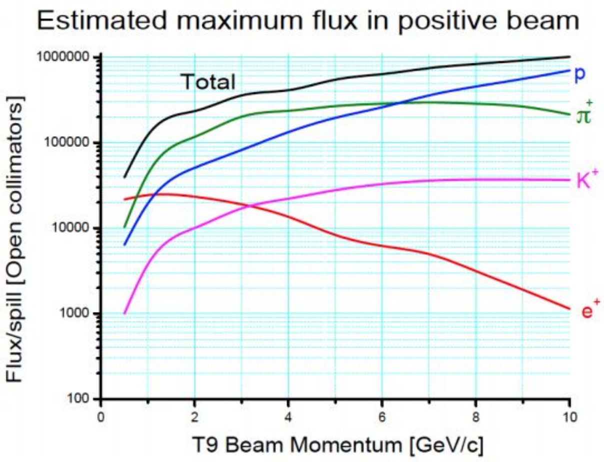
Water Cherenkov Test Experiment (WCTE)

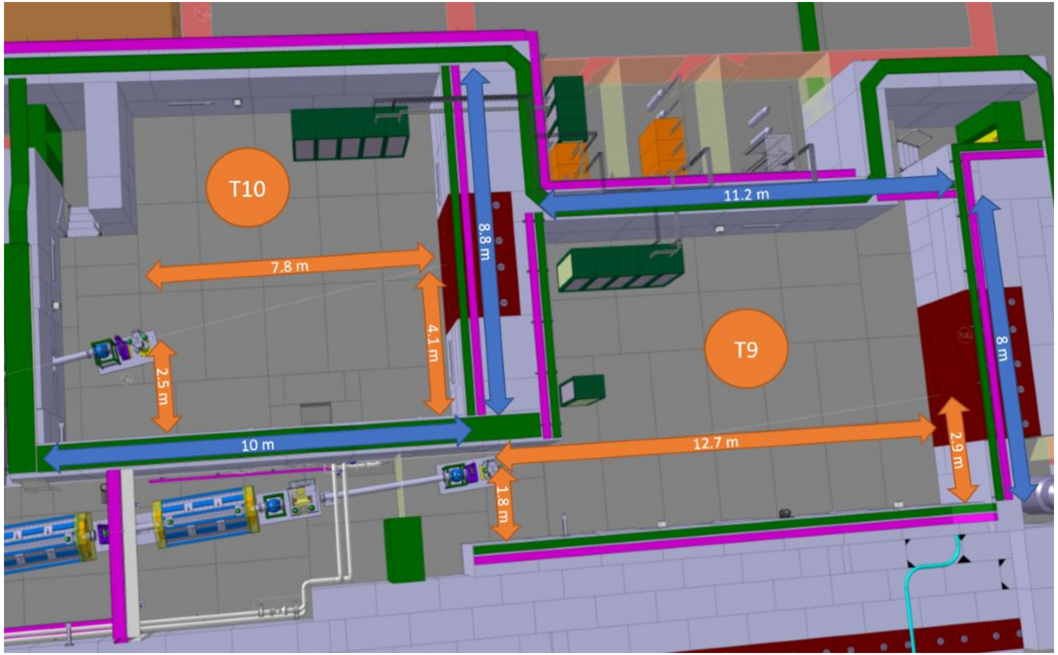
- Proposed experiment in East Area at CERN
- Small (d = 4 m, h = 4 m) water Cherenkov detector that will be used for
  - developing percent level calibration of water Cherenkov detector
  - measuring physical processes (pion scattering in water, Cherenkov light profile, secondary neutron production)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

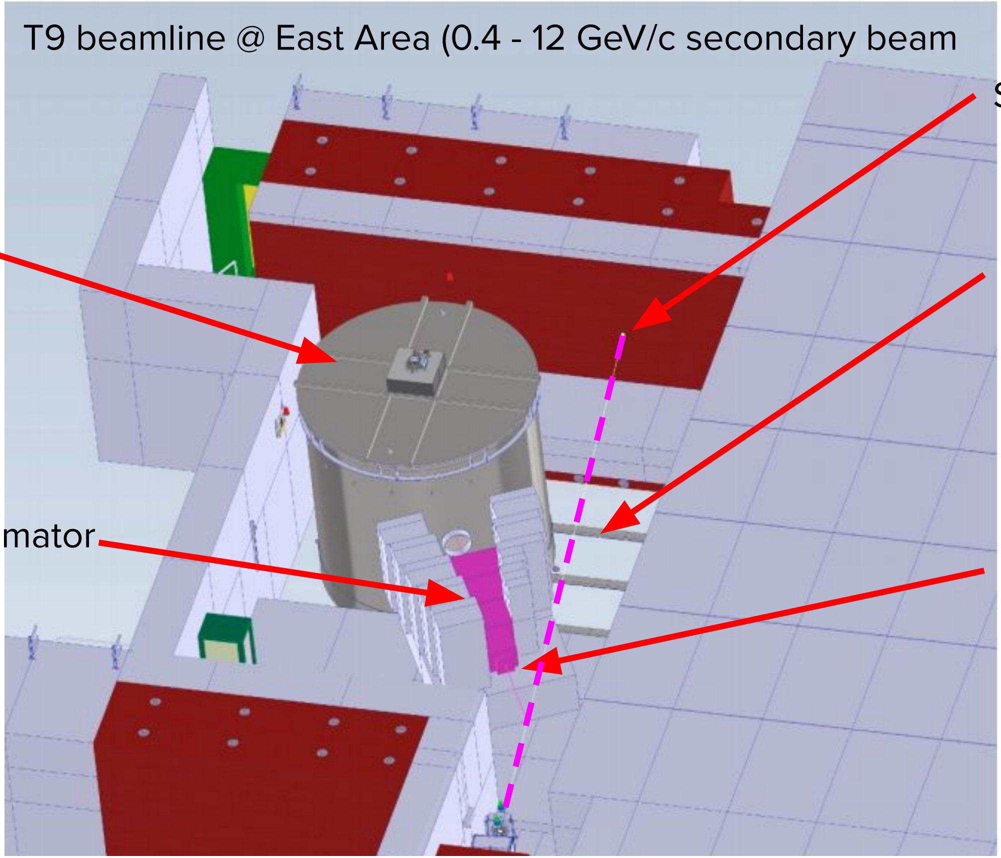
East Area T9 beamline

- T9 beamline has been chosen for the experiment
- Max intensity: $5x10^6$
- Secondary beams 0.4 - 15 GeV/c





Water Cherenkov Test Experiment (WCTE)



Water tank

Shielding and collimator

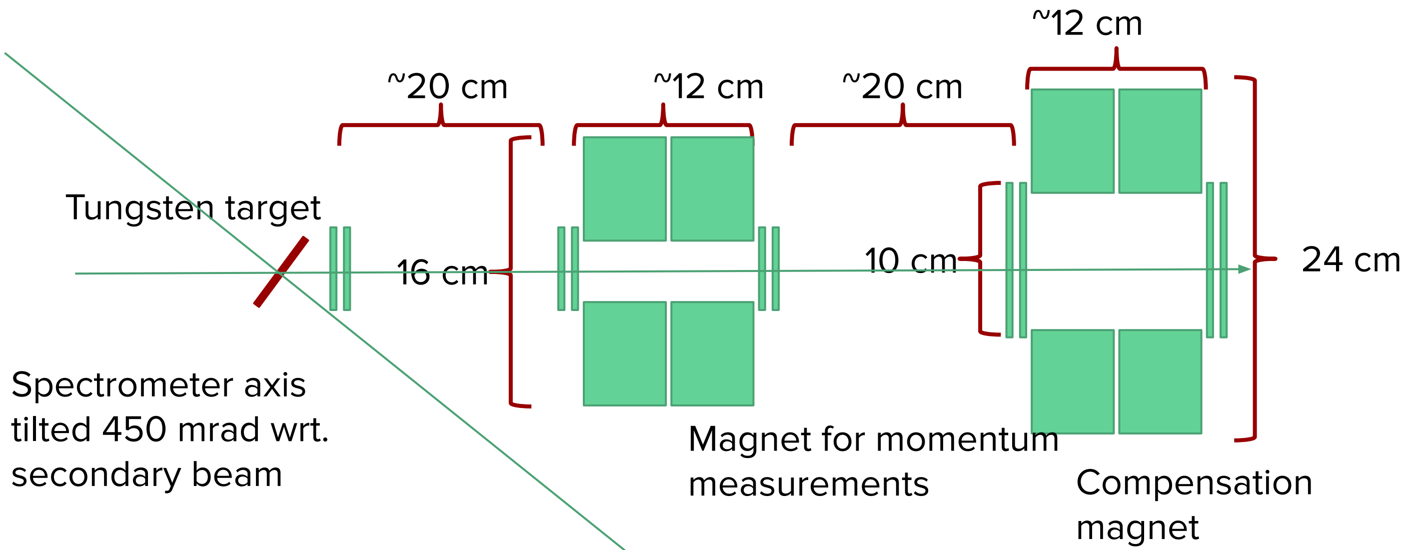
Low momentum pions decay in secondary beamline

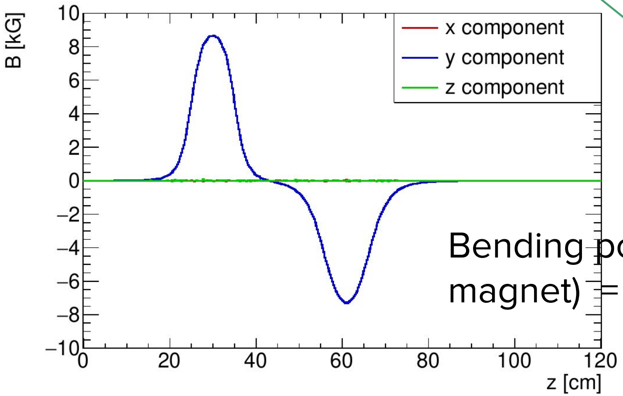
Secondary beam trajectory

The tank can slide between secondary and tertiary beams

Compact spectrometer and tungsten target (not shown here)

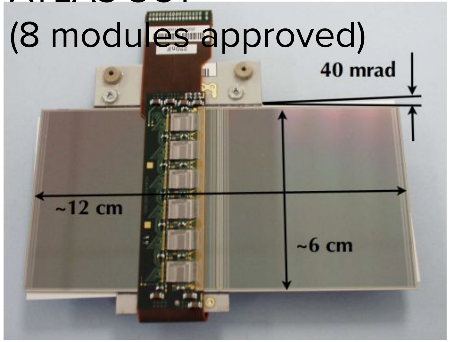
WCTE Tertiary Beam Spectrometer



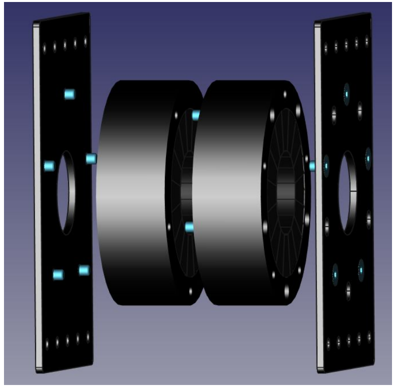


Bending power (first magnet) = 0.075 Tm

ATLAS SCT
(8 modules approved)

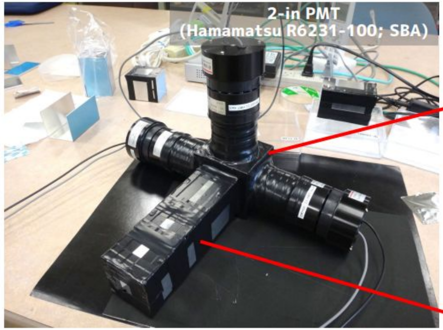


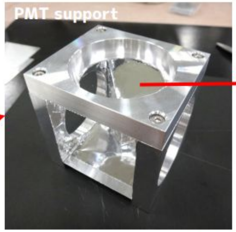
Halbach array

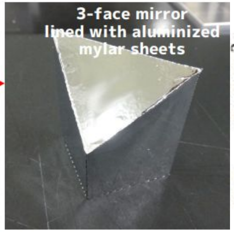


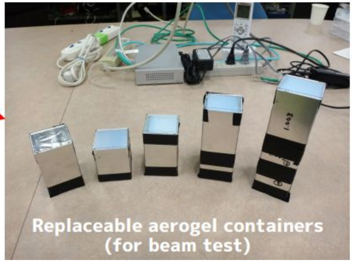
WCTE Tertiary Beam Spectrometer

- 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)

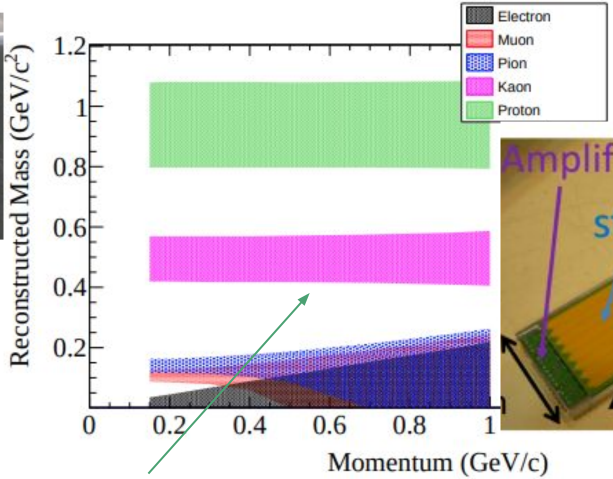






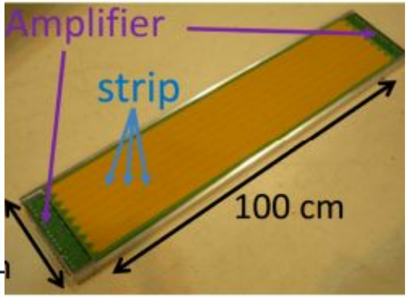


Aerogel threshold Cherenkov detector

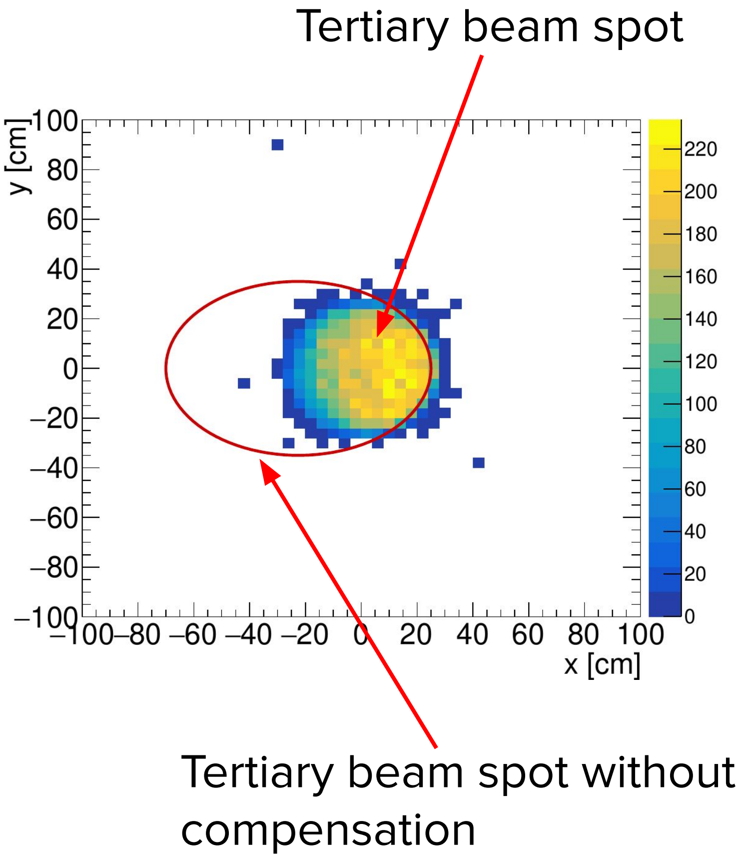


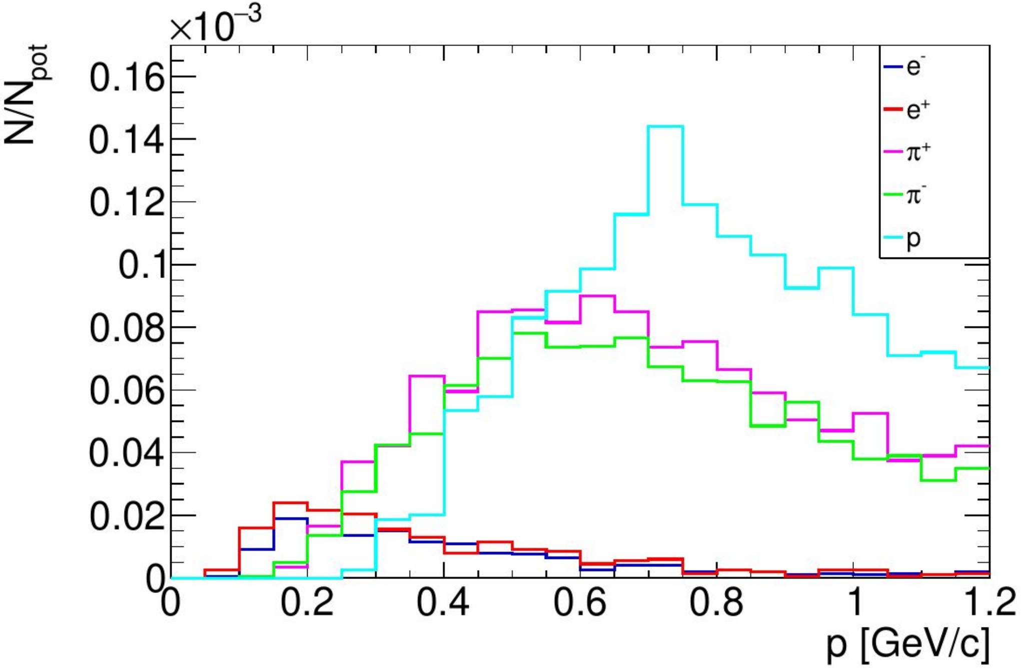
Assuming 100 ps timing resolution

RPCs



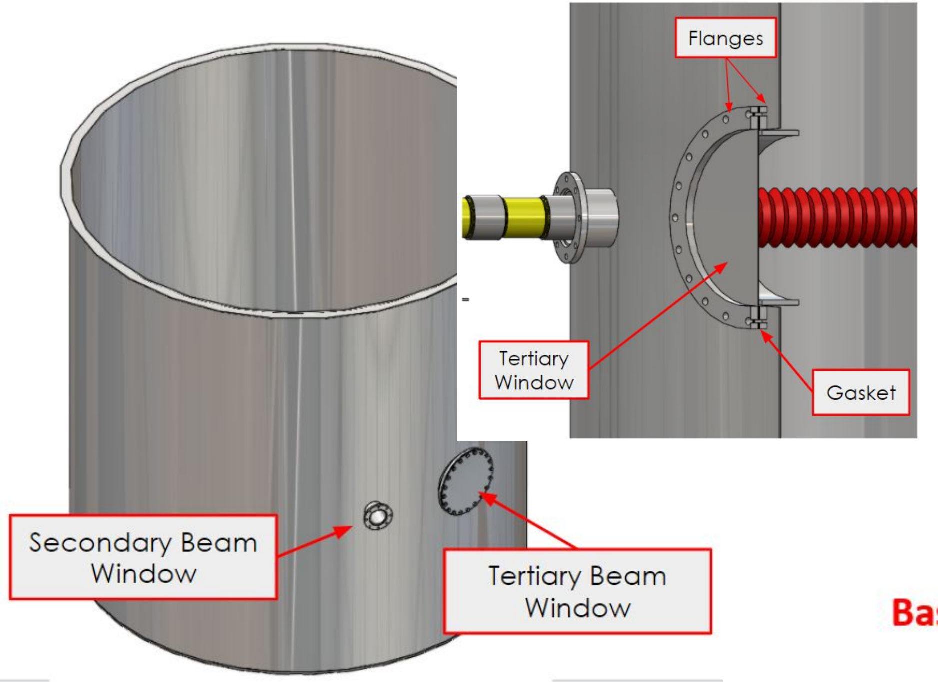
WCTE Tertiary Beam





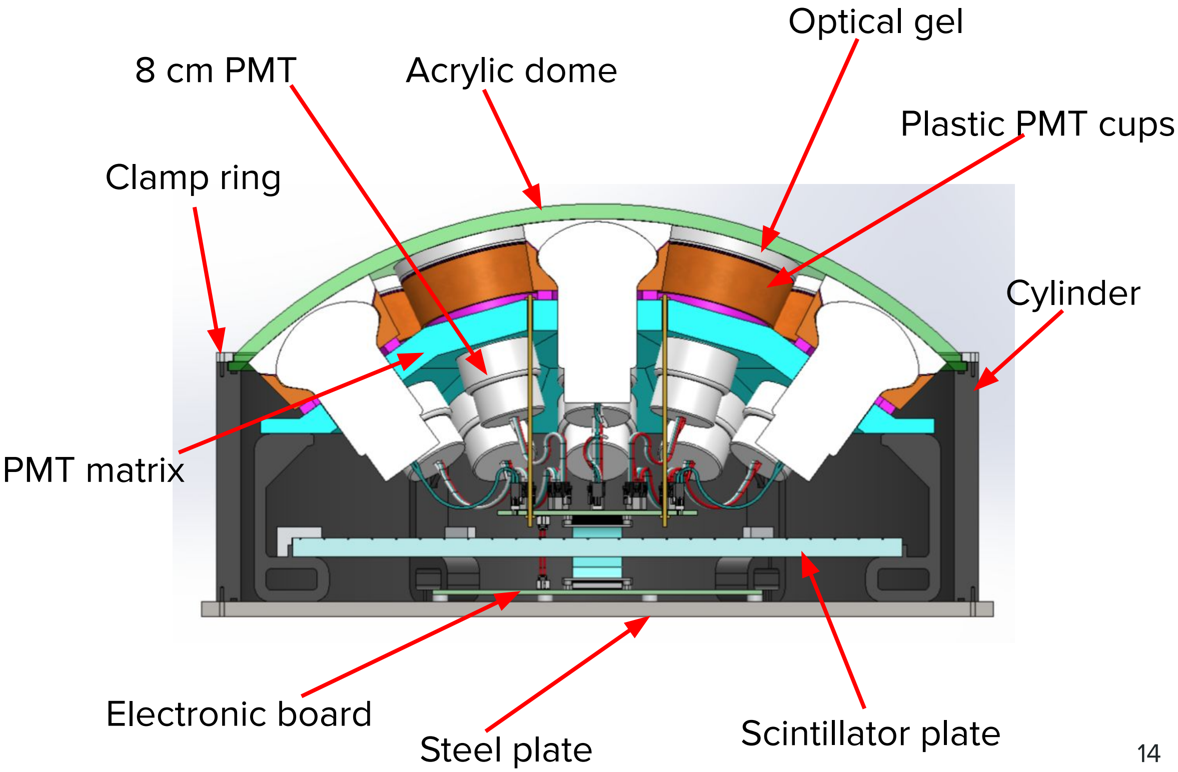
Water Cherenkov Detector

- ~4 m diameter
- 128 mPMT modules
- Two beam windows



Multi-PMT photosensor

- 19 8 cm PMTs (Hamamatsu R14374)
- Less photo-coverage but improved vertex resolution



Conclusions

- 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 ➜ independent experiments