WCTE and IWCD

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HK local workshop

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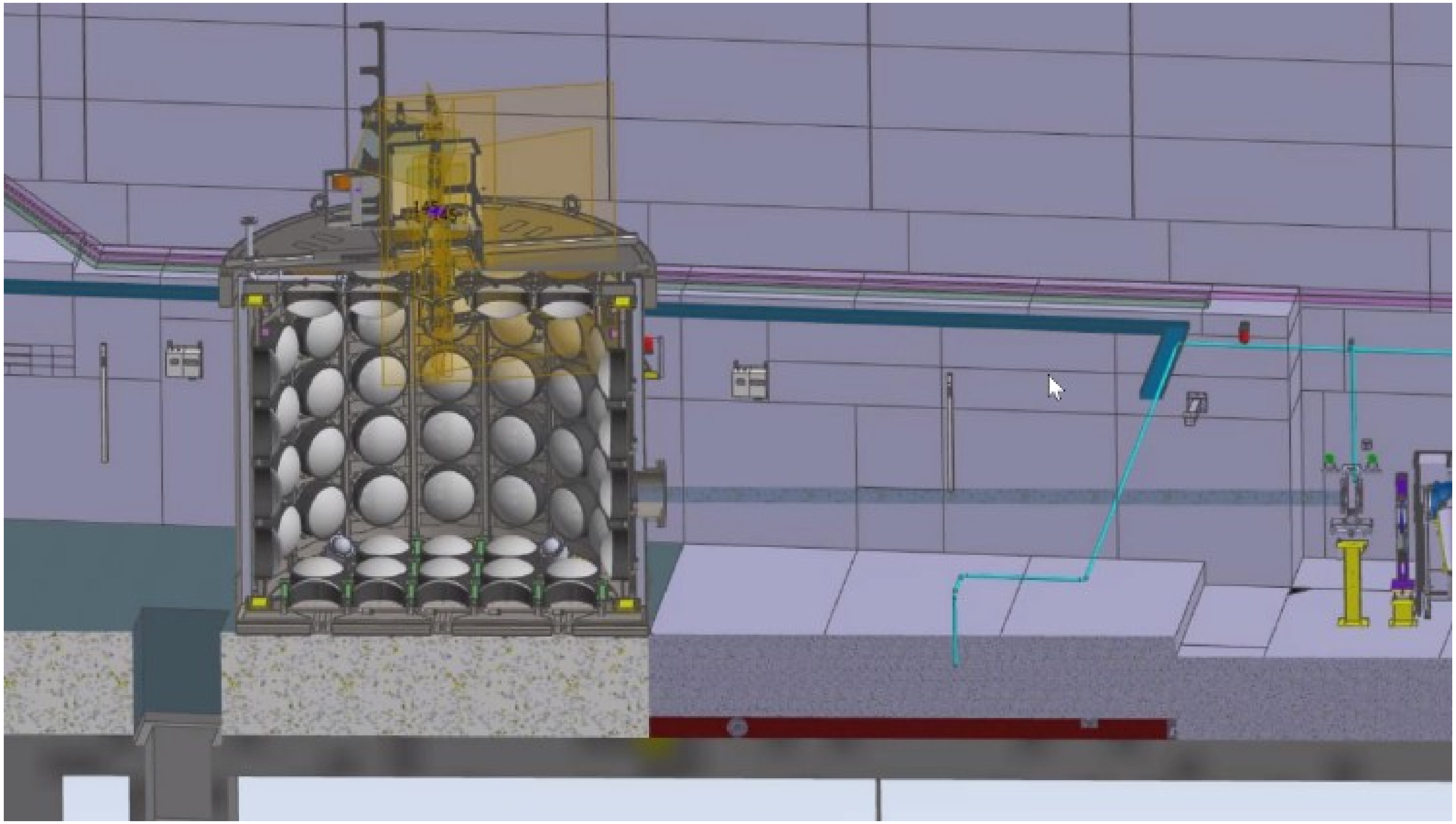
Introduction

- IWCD: Intermediate Water Cherenkov Detector
  - Intermediate water experiment located at around 1 km away from the J-PARC neutrino beam
  - Key detector to improve the neutrino beam sensitivity, mainly to δ_{CP}
    - Canceling several systematic errors
    - Improving key cross-section measurements

- WCTE: Water Cherenkov Test Experiment
  - Prototype (smaller) detector for HK-FD and IWCD
  - Will operate in 2024, taking beam data from CERN SPS from 0.2 GeV/c to 1.2 GeV/c of e, μ, π, p
  - Develop:
    - New calibration and reconstruction techniques, e.g. e/γ separation, neutron production, π/μ separation
    - mPMTs sensors for IWCD and HK-FD

WCTE

- A 40-ton water cherenkov detector instrumented with 104 multi-PMT modules
- 4 m diameter and 4 m high

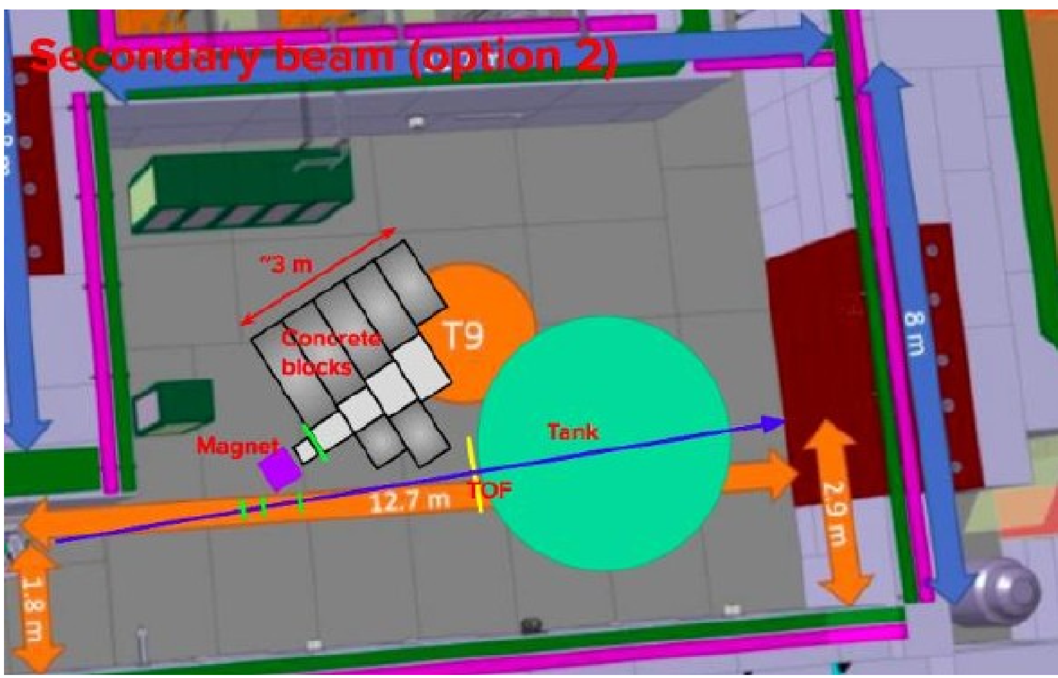


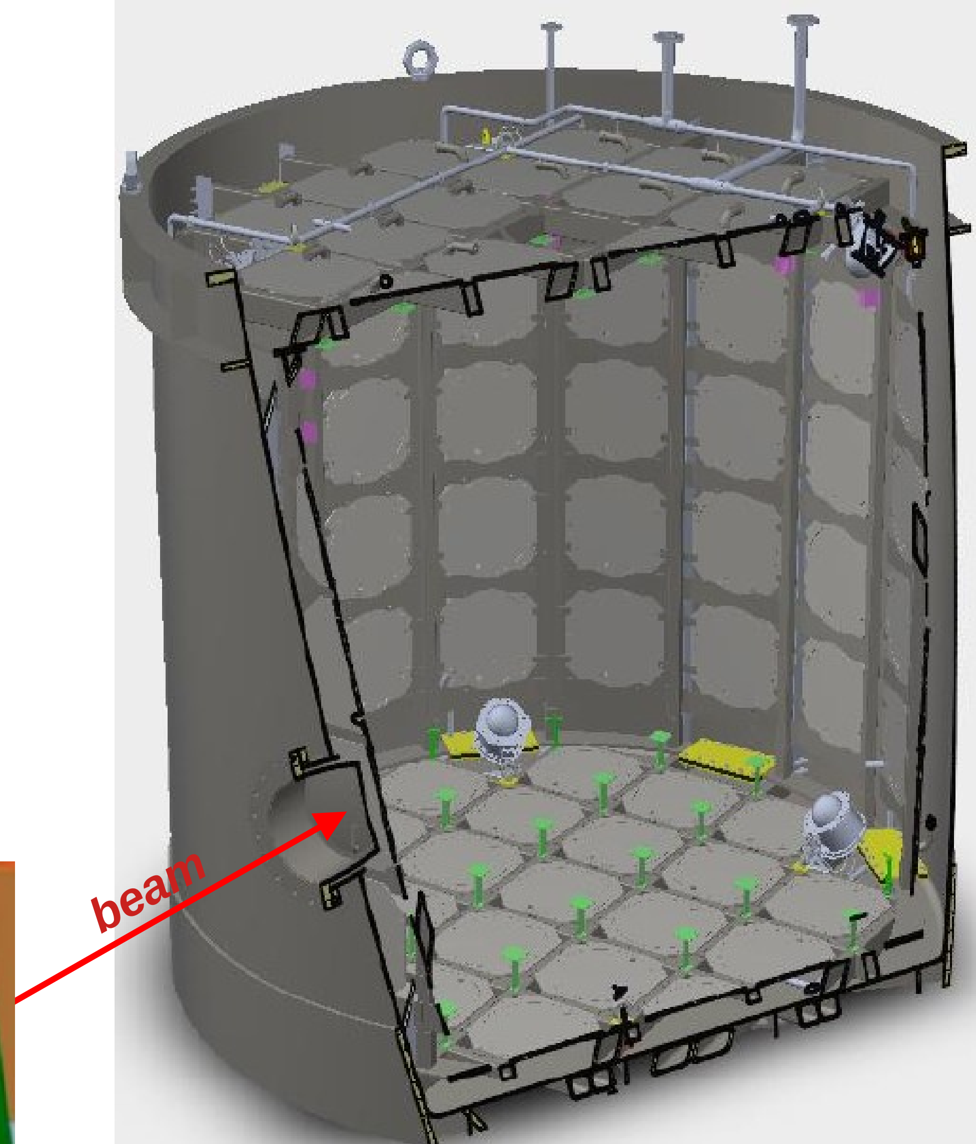
WCTE features

Small detector, but instrumented with mPMTs which allow for better reconstruction of Cherenkov photon directionallity

Additionally, WCTE is instrumented with cameras and lights to know precisely the position of each mPMT

Test for 5 HK-FD mPMTs

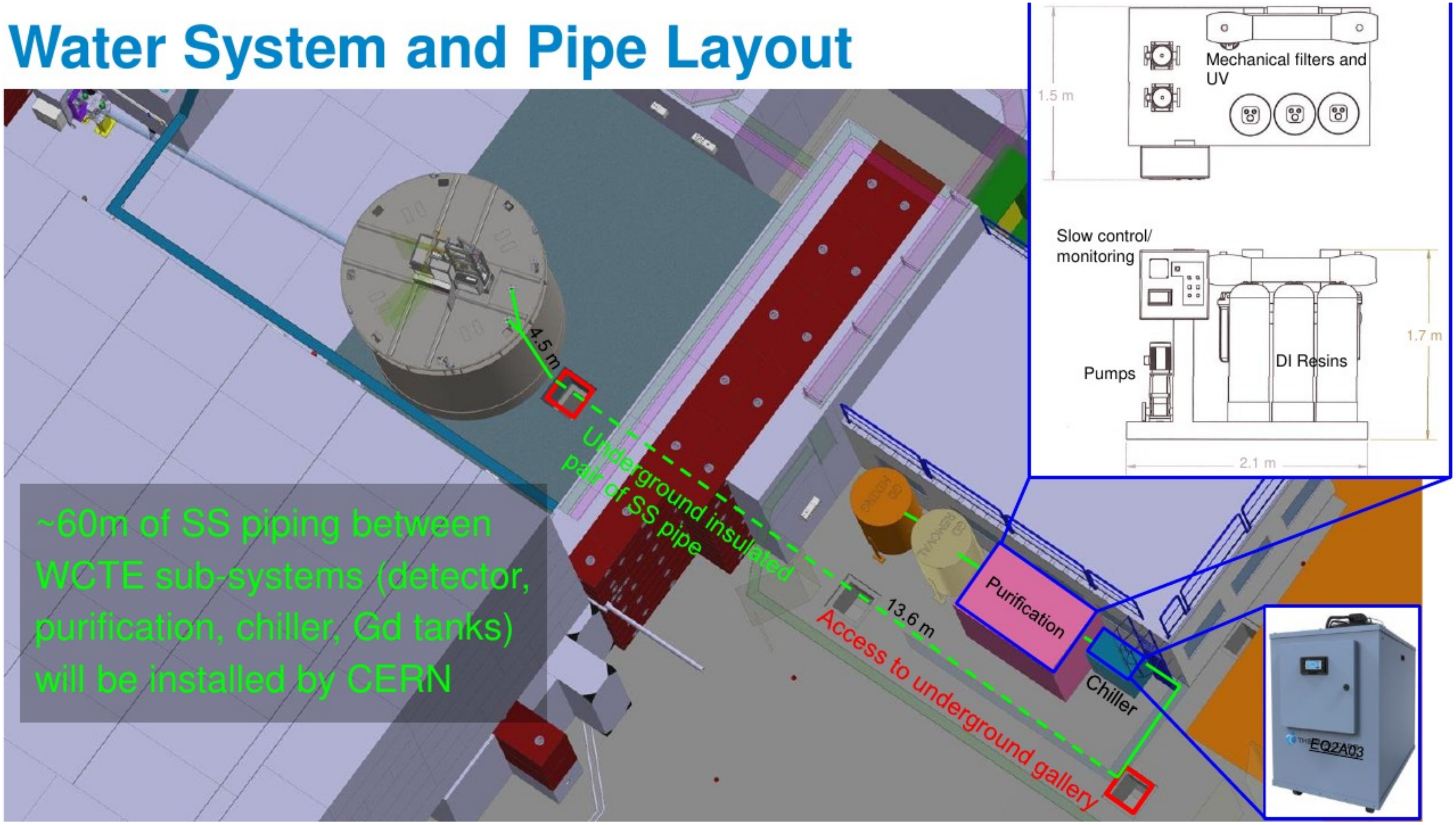




WCTE features

There will be 2 runs, with ultra-pure and Gd-doped water – the latter enabling a very efficient neutron tagging

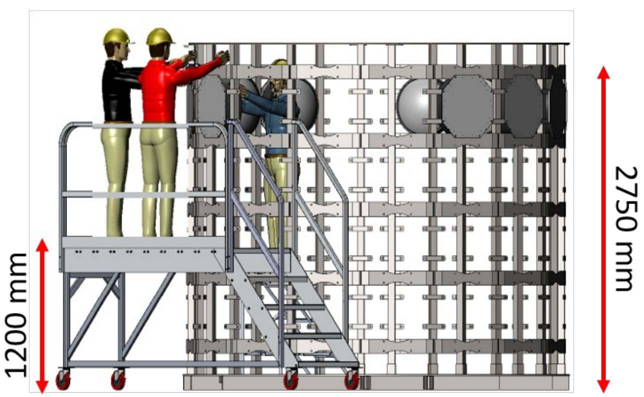
Lot of the technology coming from EGADS, the SuperK-Gd prototype in Kamioka

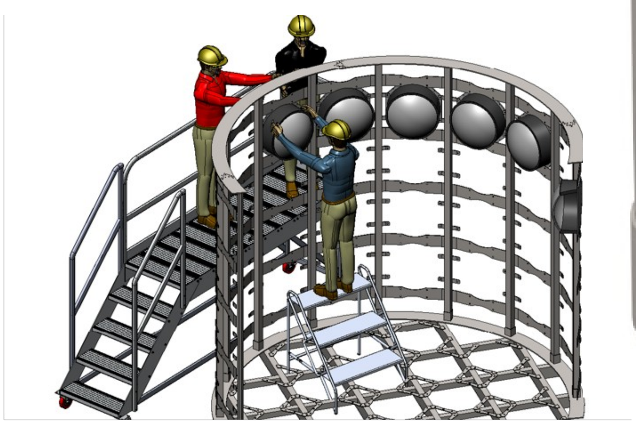


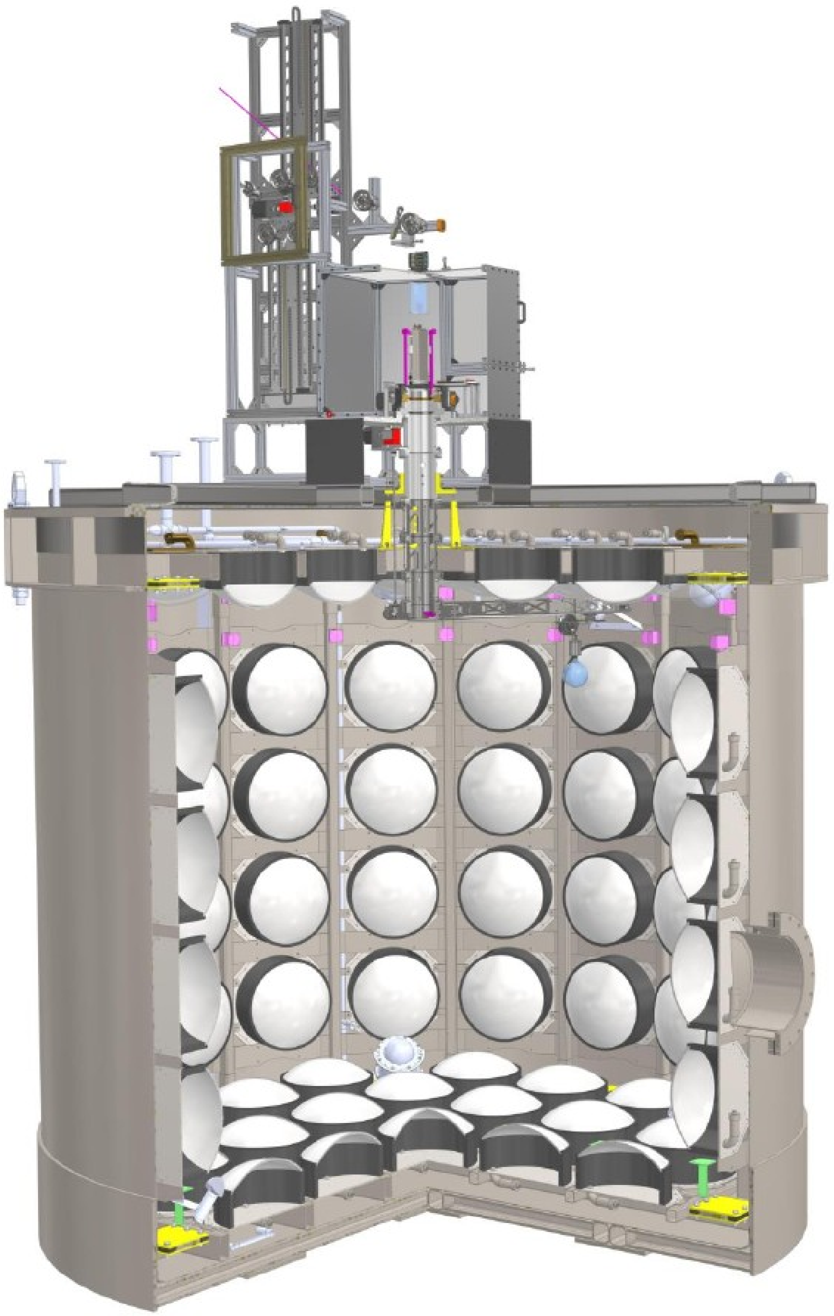
WCTE features

The Central Deployment System will be tested for deploying calibration sources into the detector like Ni-Cf and AmBe radioactive sources (Josh), cameras, diffuse ball

CDS also allows to place the calibration source anywhere in the detector



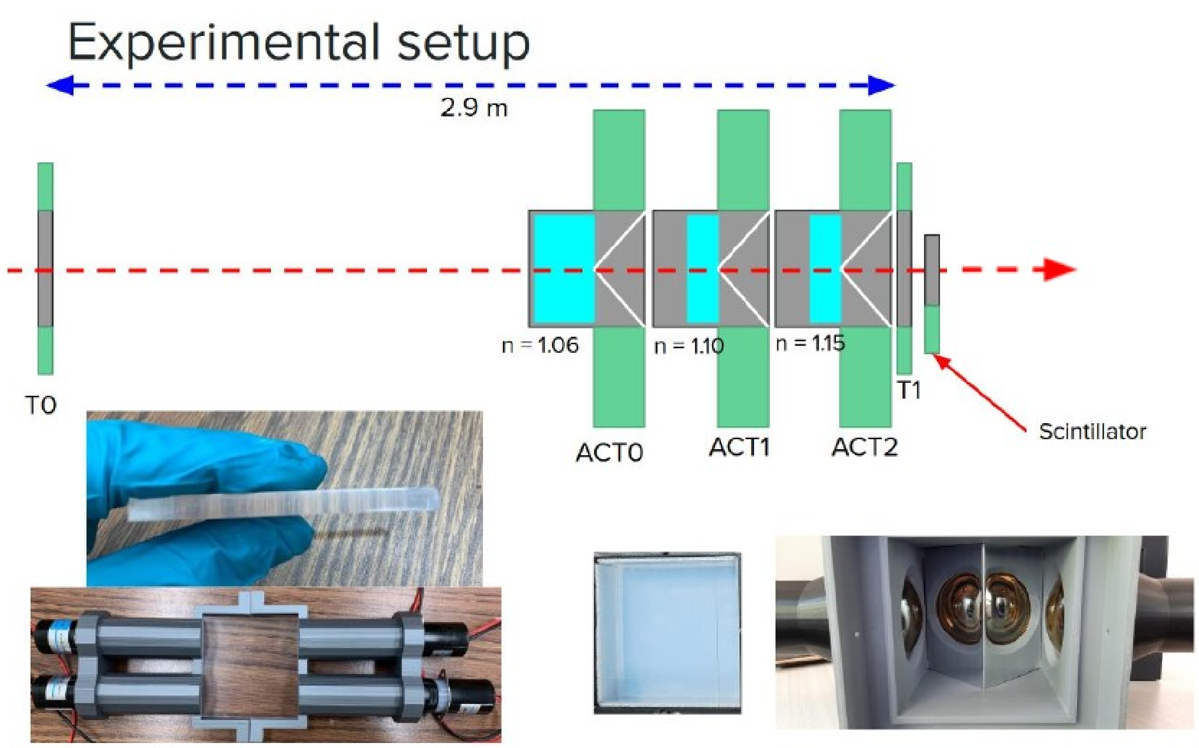




WCTE physics

From target to WCTE the beamline is instrumented to seprate the different incoming particles

T9 Test Beam in July 2022

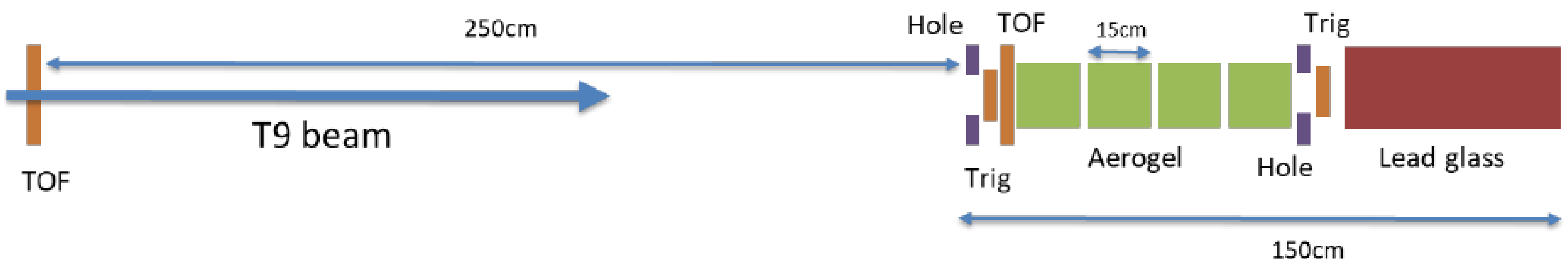


- Test performance of upgraded T9 beamline at low momenta (200 - 300 MeV/c)

WCTE physics

Another test beam next July to check new and improved instrumentation, especially for acquireng photon data

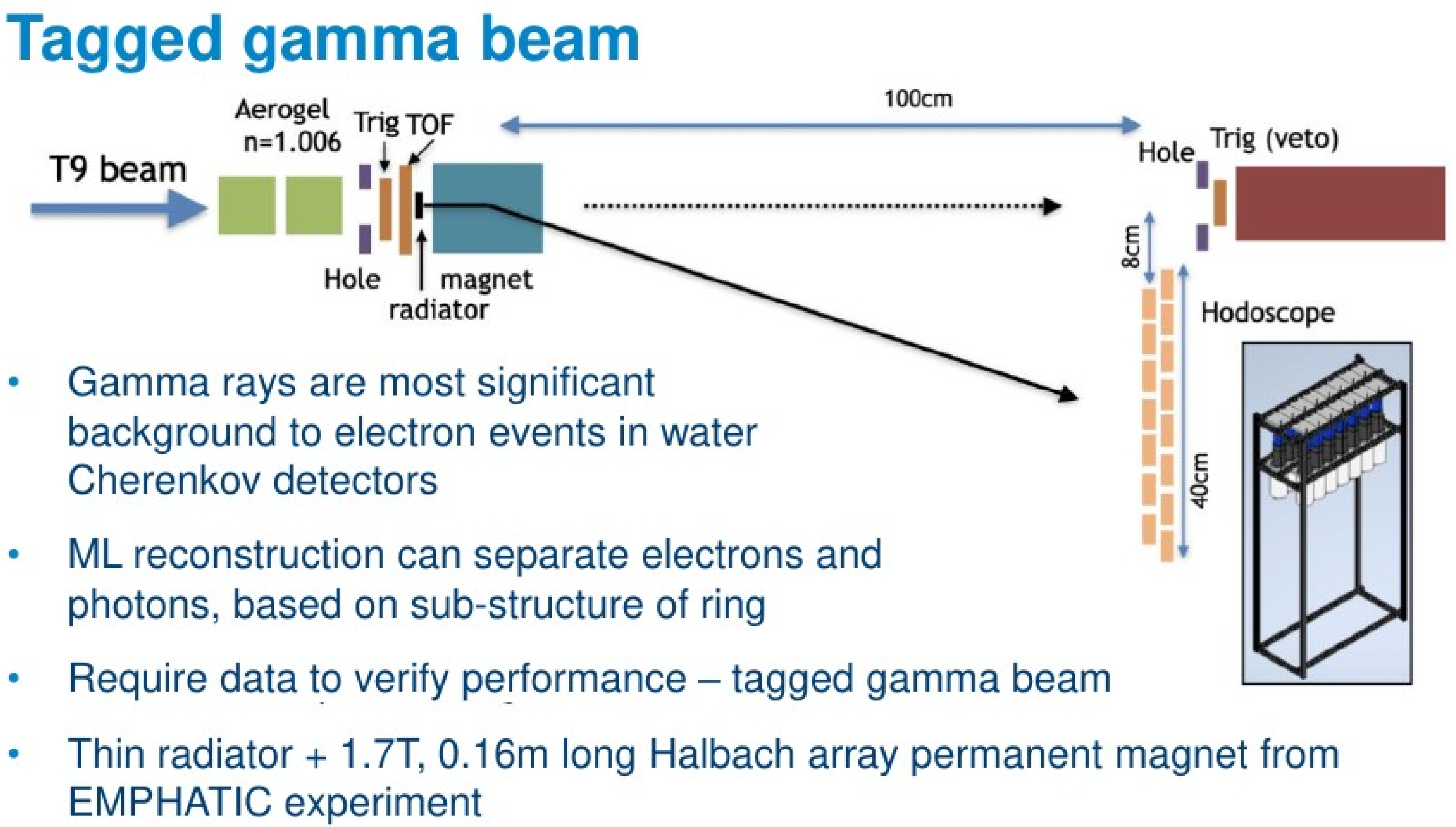
T9 Test Beam in July 2023



- Based on 2022 data we have updated design of ACTs and TOF system, and added hole veto system
  - Better charge + timing resolution, two detectors to reduce fake rate
  - Cut out beam halo
- Will provide >99% pure samples of muons, pions, electrons and protons at momenta from 200MeV/c to 1GeV/c

WCTE physics

Another test beam next July to check new and improved instrumentation, especially for acquireng photon data



WCTE physics

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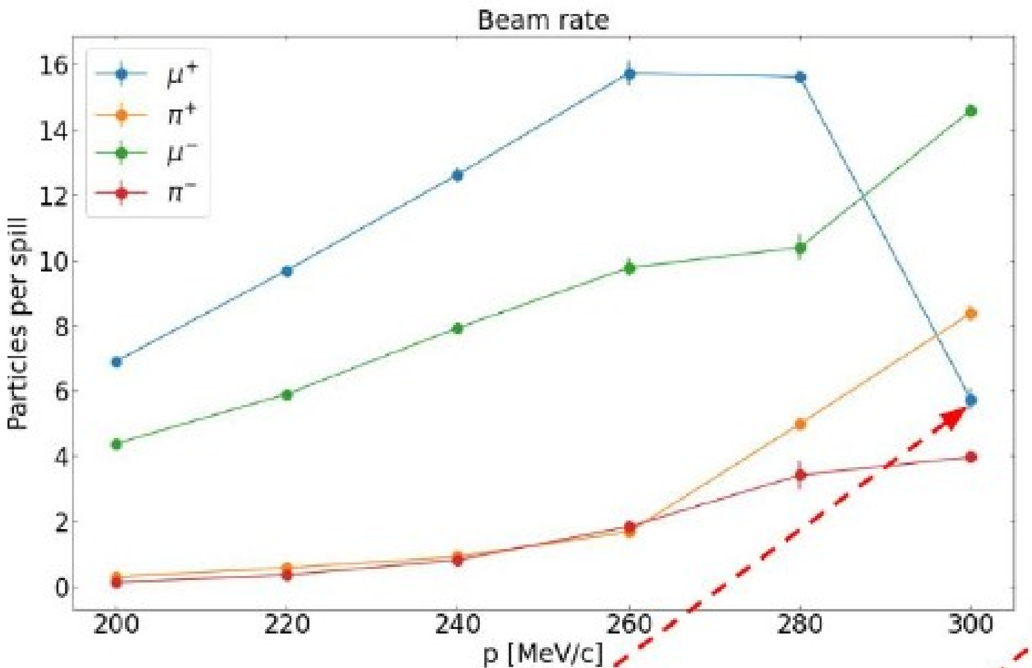
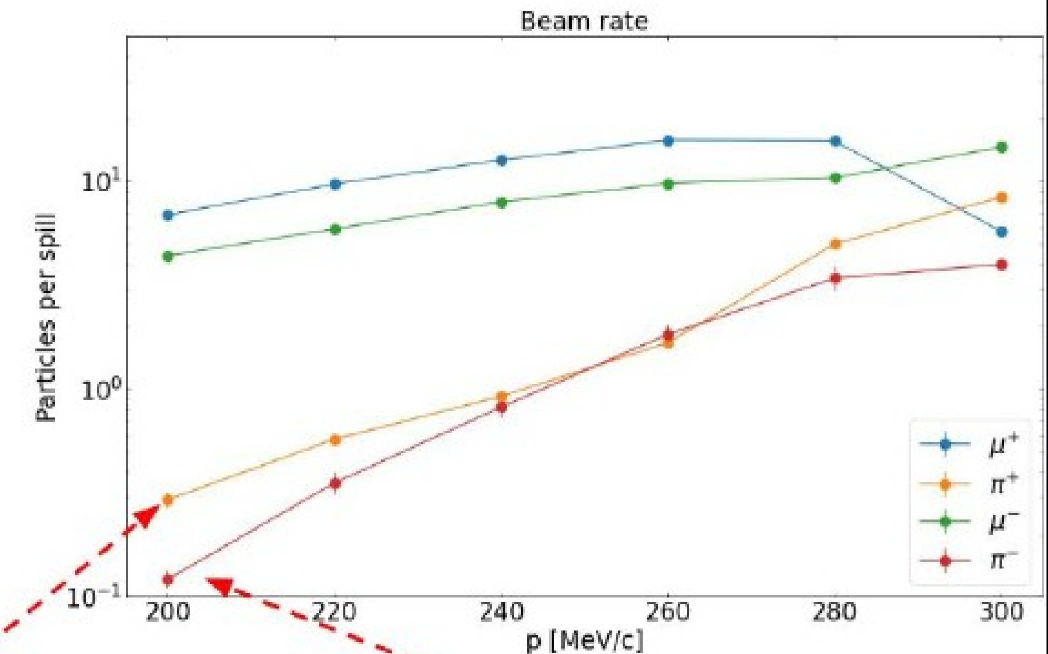




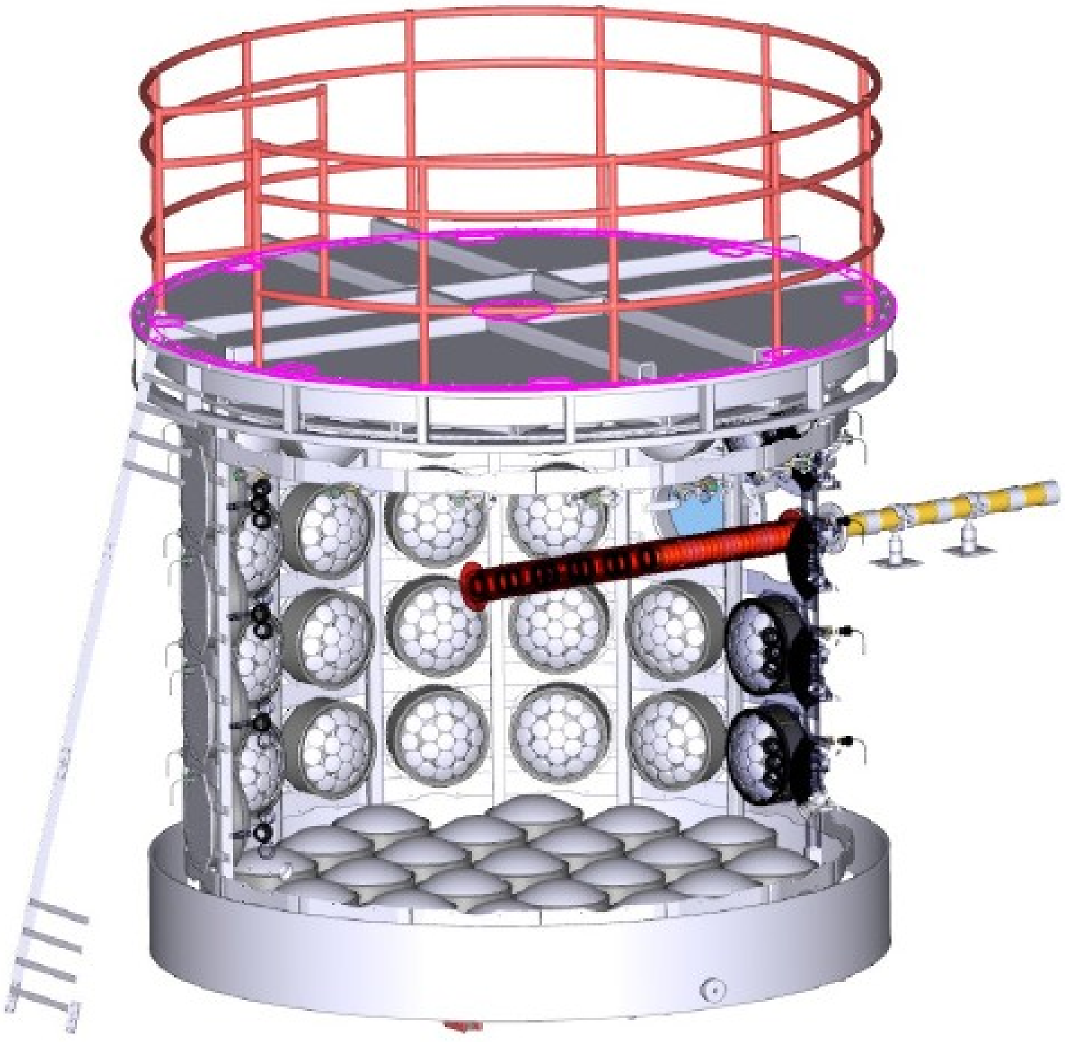
Removed by veto

~1300 per day

~430 per day → based on the beam in July

WCTE physics

Further, there will be an estendable hose getting inside WCTE (Jorge) to reduce the amount of water low momentum particles have to go throw before reaching the fiducial volume

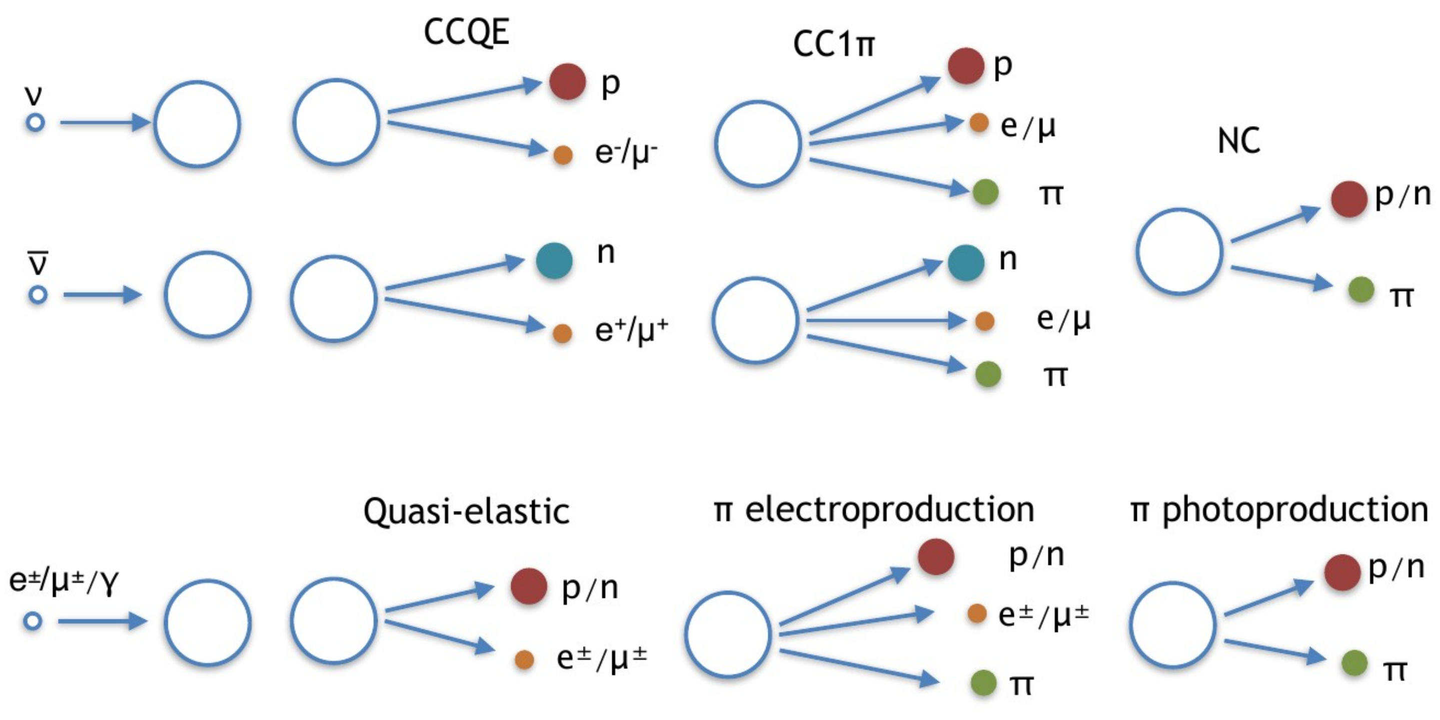


WCTE physics

Some of the most important item we can study:

WC Detector response

sub-GeV e,μ,π, and p
detailed shape of Cherenkov rings → control samples for reconstruction softwares



WCTE physics

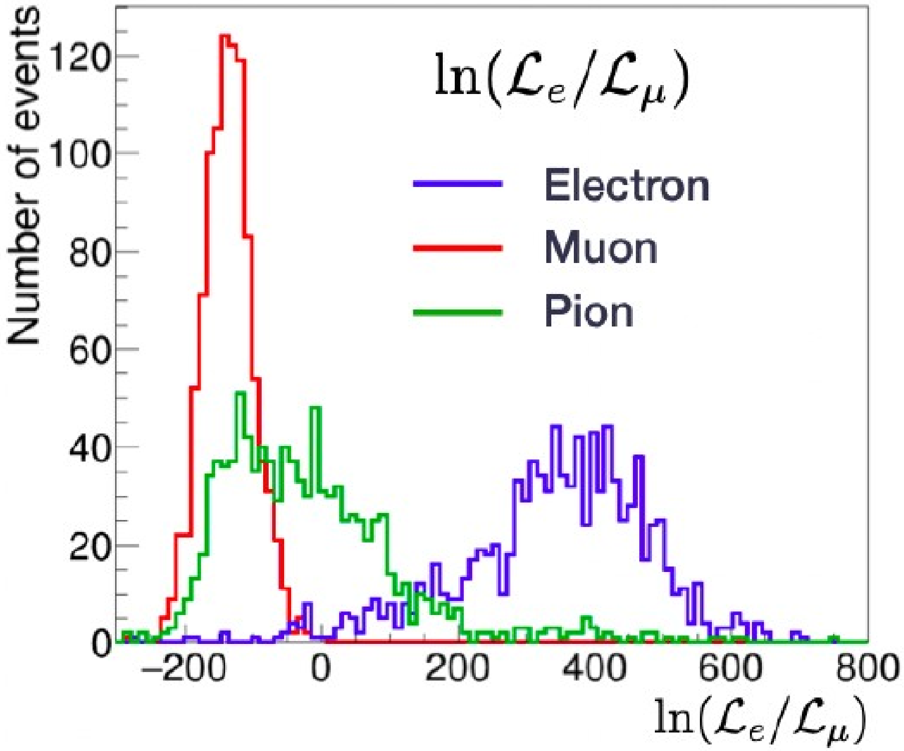
Some of the most important item we can study:

WC Detector response

→ Improve reconstruction and distinction of e μ, π and p with usual software like FiTQun or ne ML methods (Annalise and Loris)

→ Distinguish photons from electrons: this is very important to differenciate CC and NC interactions, crucial for neutrino oscillations (and probably for exotic nucleon decays)

To validate ML methods, it is crucial to acquire data to train them

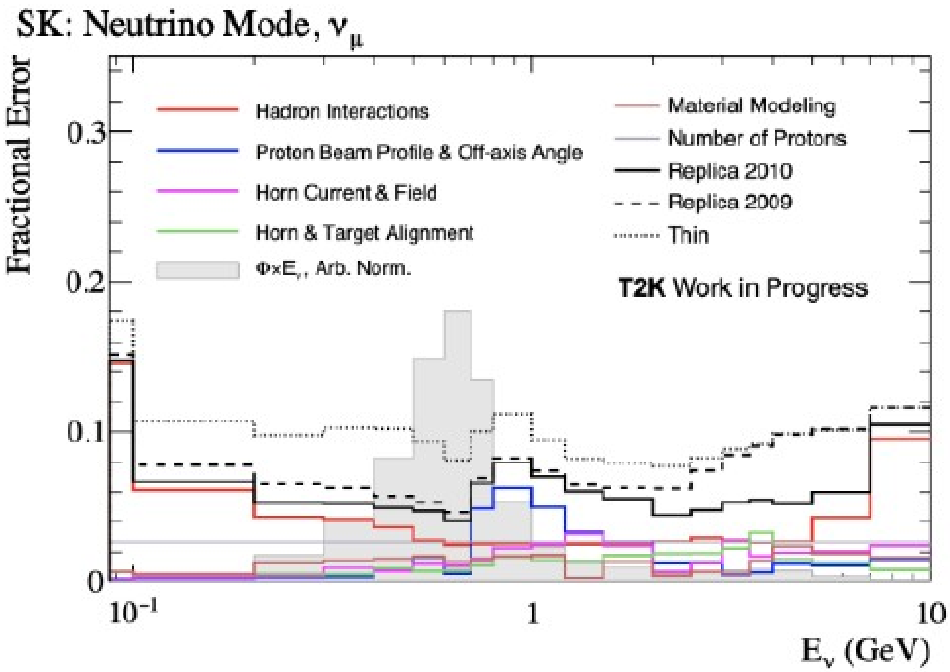


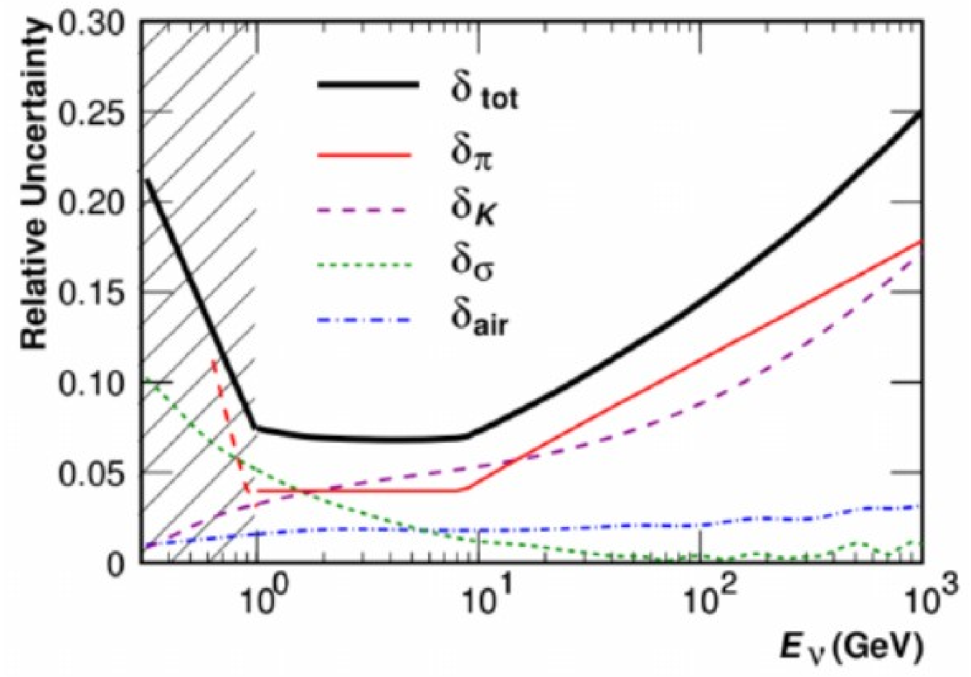
All this is crucial to better understand the neutrino interaction and, therefore, being able to extract its energy, direction and flavor (and interaction mode to some extent).

WCTE physics

Hadronic interactions

Measure particle production at target, relevant for the accelerator neutrino flux predictions and even for the atmospheric neutrino flux predictions

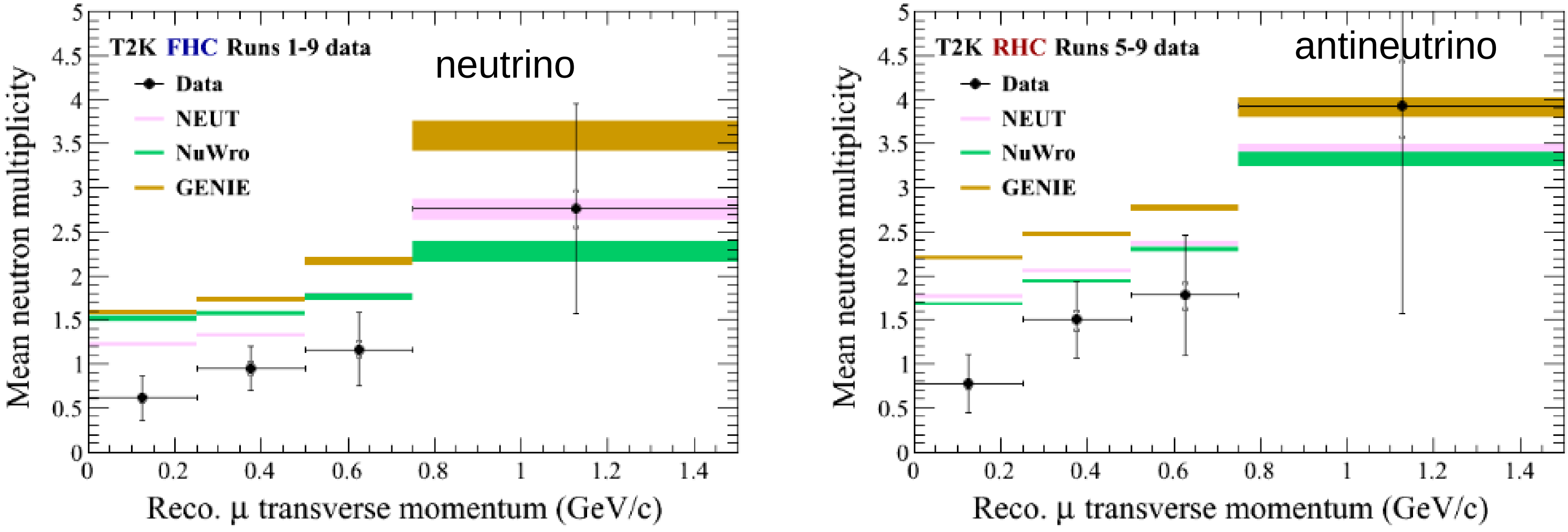




WCTE physics

Neutron production

Sudy neutron production mechanisms in interactions that mimic neutrino secondary interactions in HyperK
→ which will improve neutrino antineutrino separation

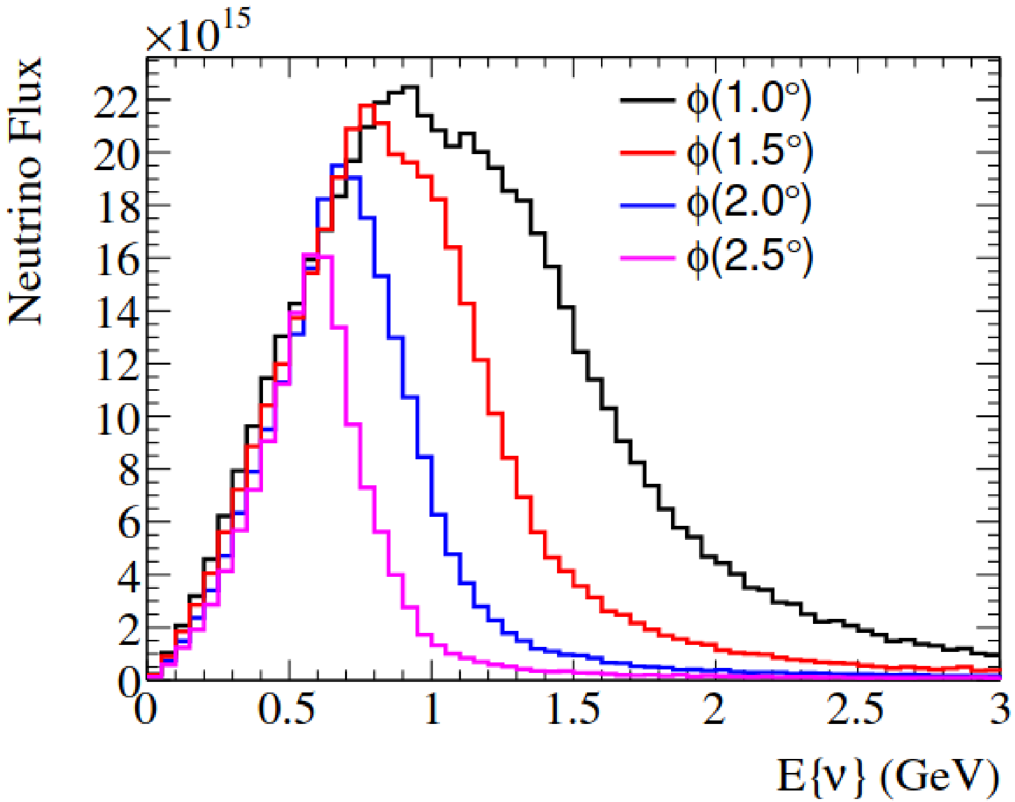


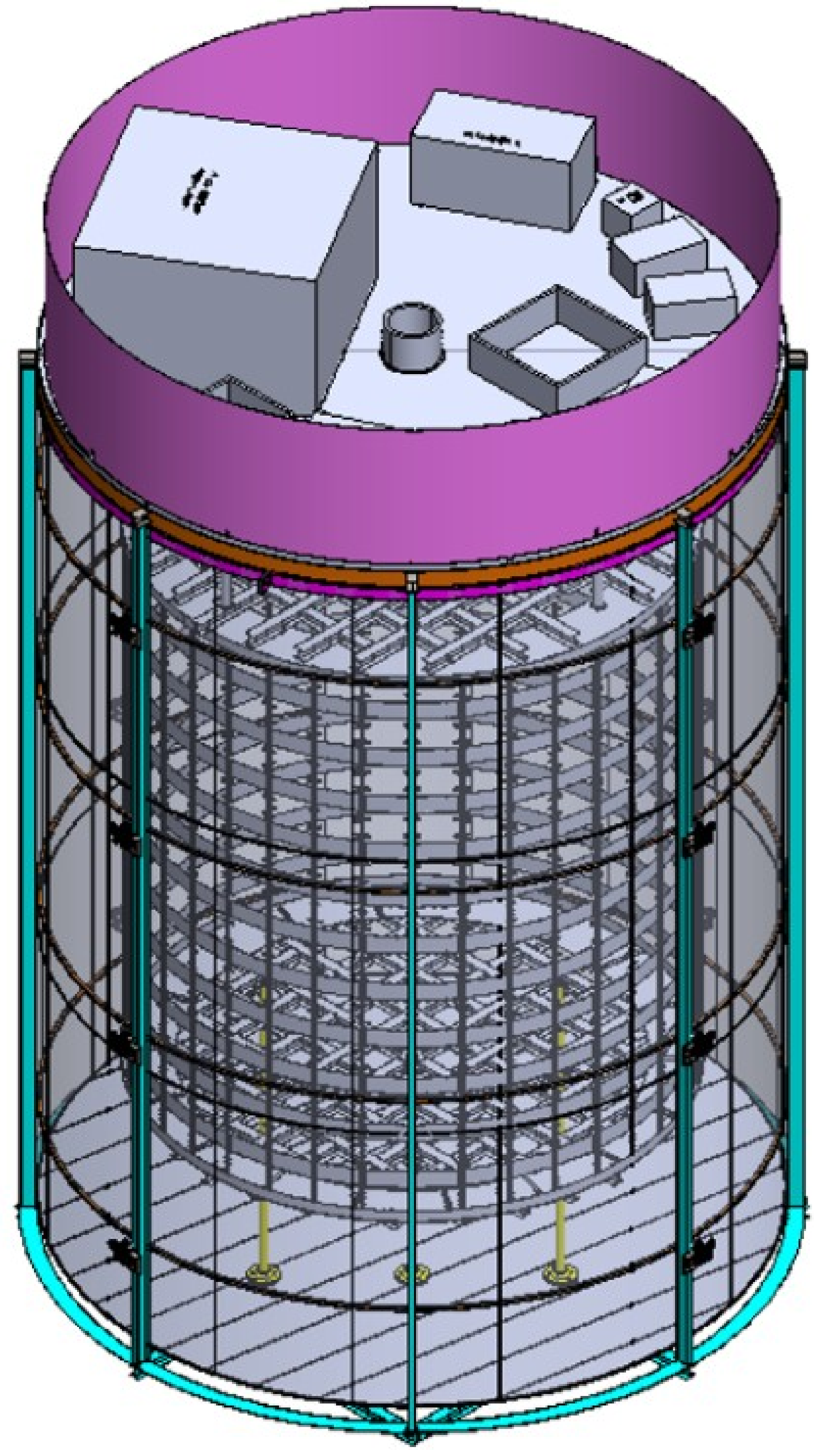
IWCD

Larger tank of around 600 ton place 1km away fı

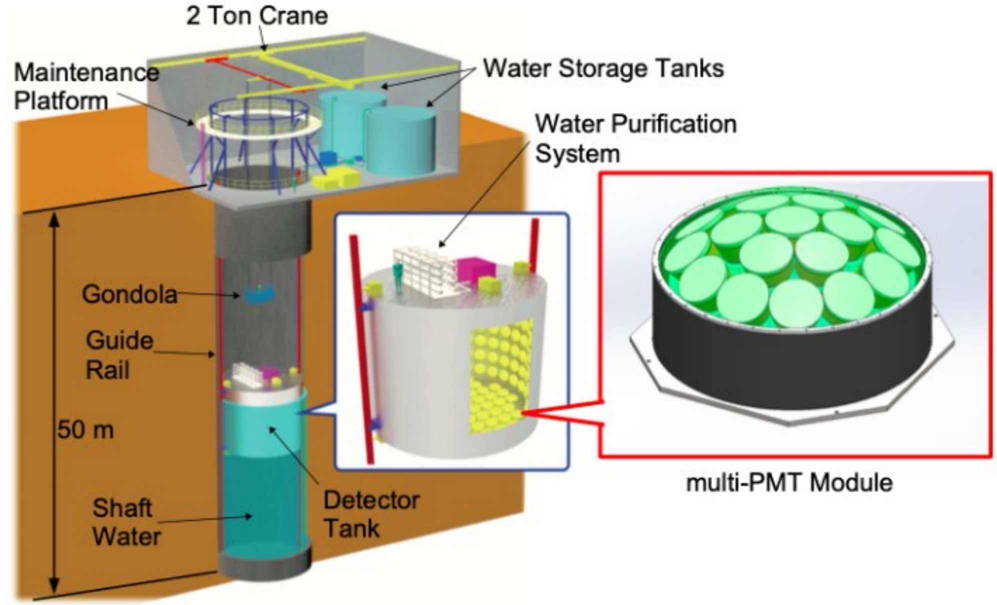
Instrumented with mPMTs and with a CDS, mucl

Further, it will be able to move between different
→ this enables to probe the whole neutrino bear
the vary with the off-axis angle

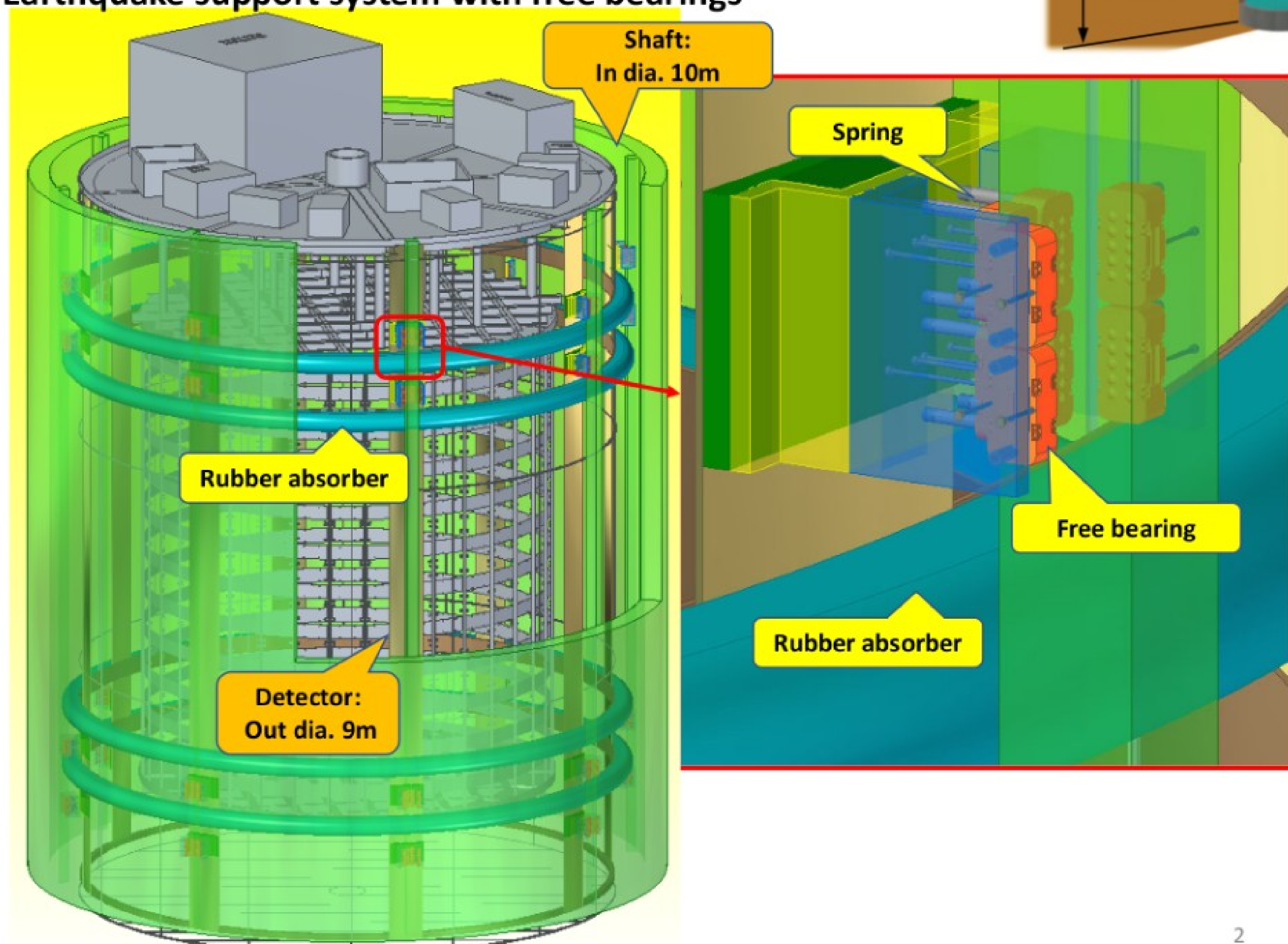


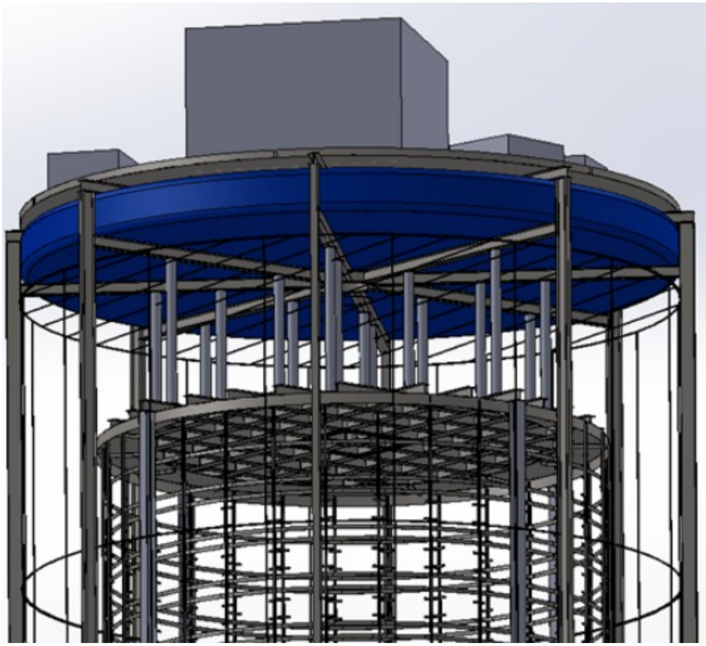


IWCD



Earthquake support system with free bearings

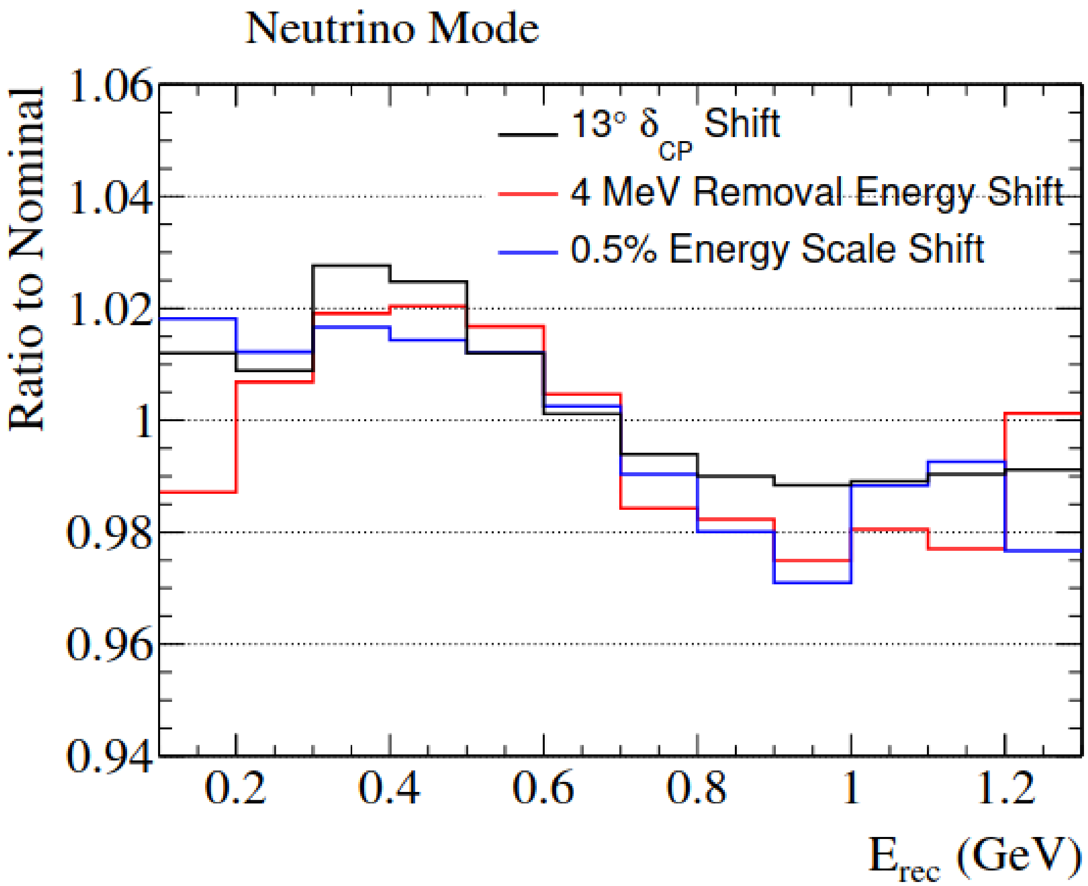


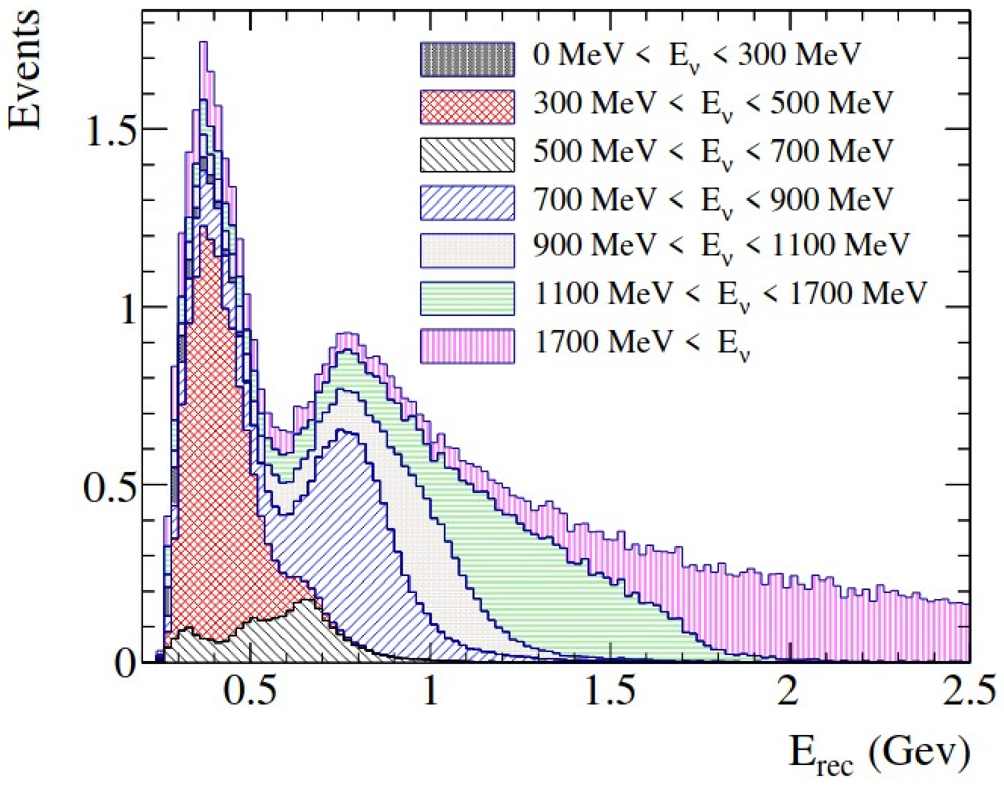


IWCD physics

Flux with detector systematics cancellation

In addition, to ND280, IWCD will measure the beam flux with no (sure?) oscillations on the same target as the FD



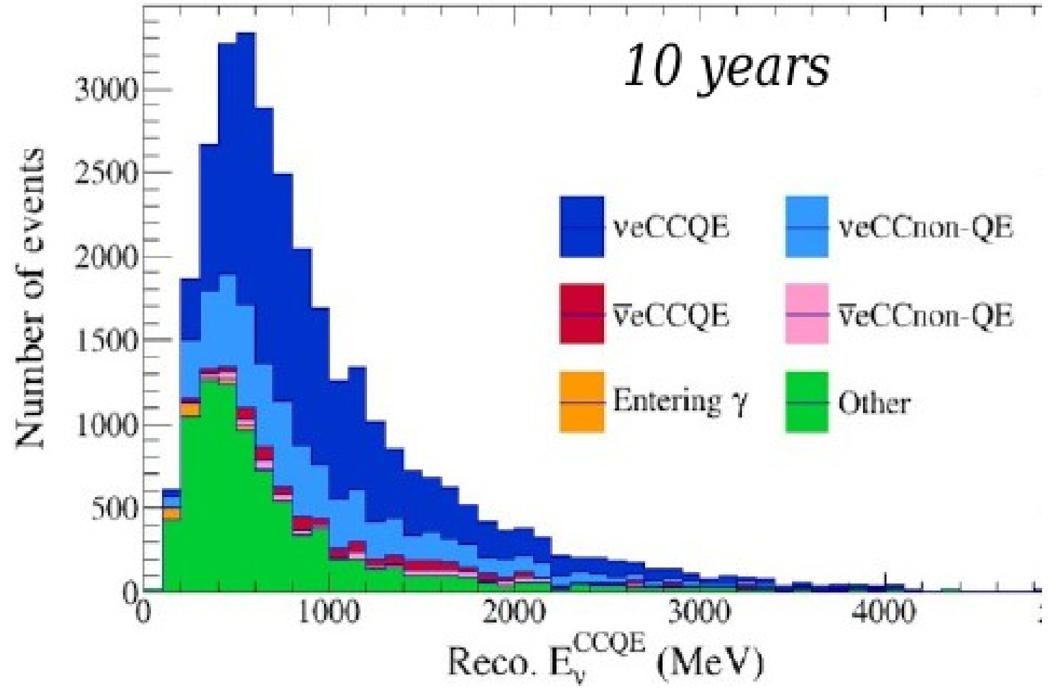


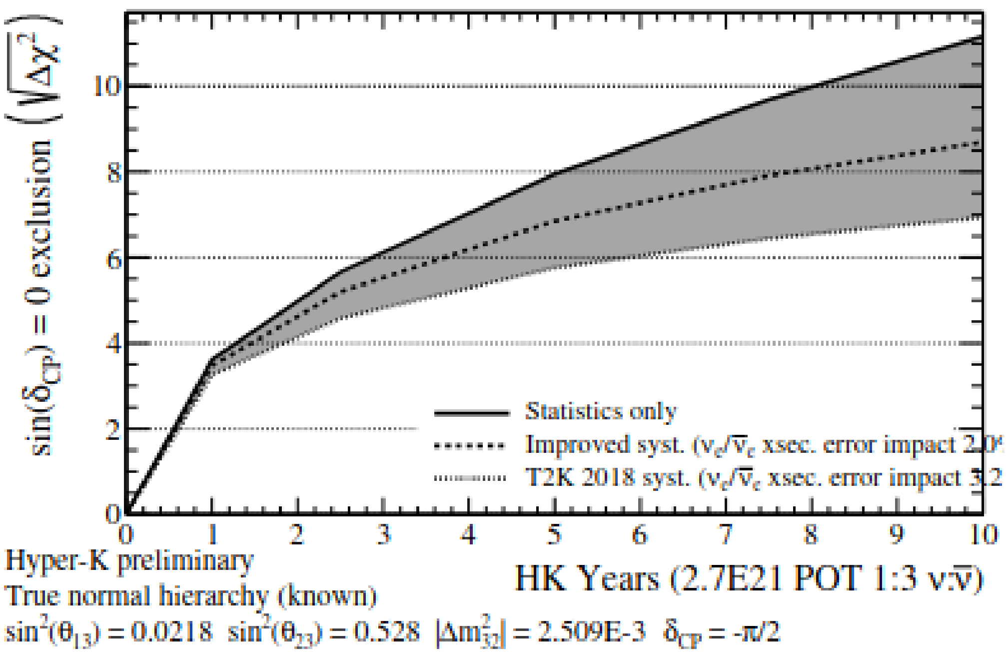
IWCD physics

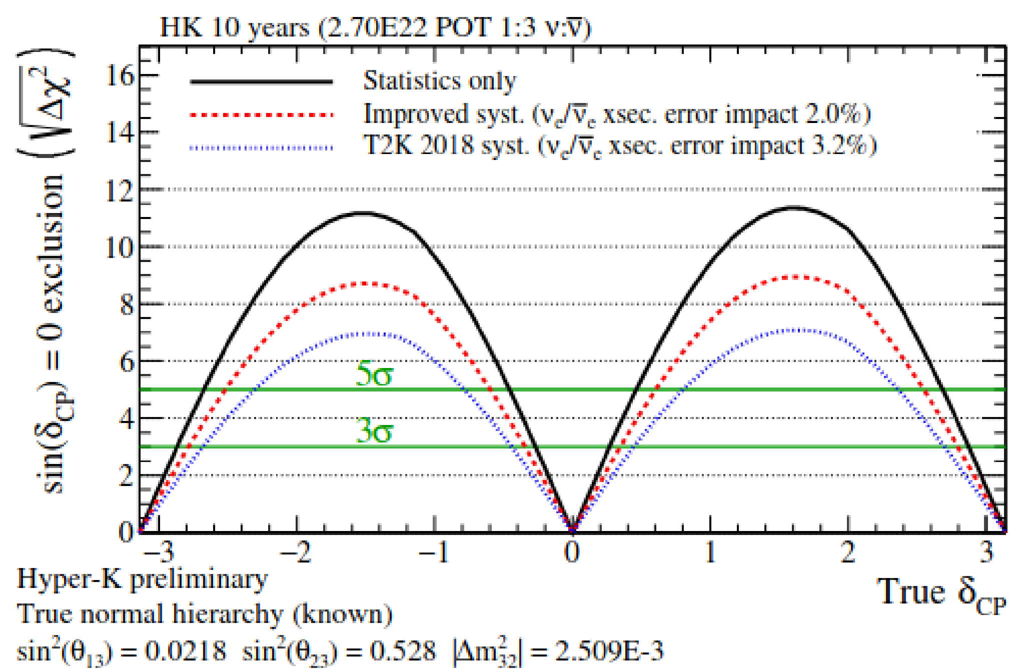
Cross section measurement

the uncertainty on the σνe /σνμ over σ ̄νe /σ ̄νμ cross-section double ratio is the limiting factor in the sensitivity of HK to CPV.

IWCD will measure lots of statistics for the intrinsinc component of νe of the neutrino beam







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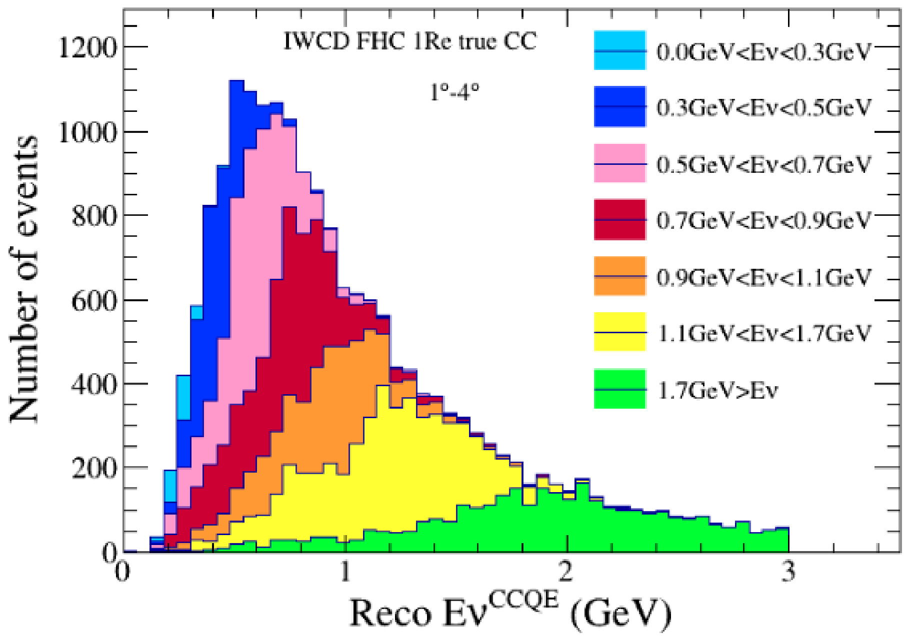
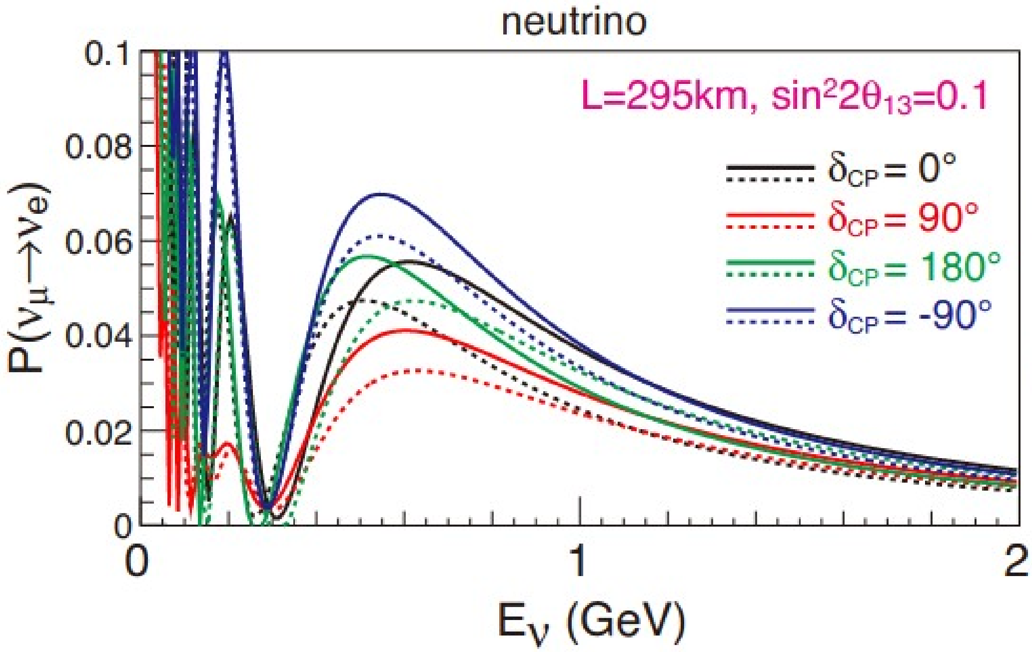
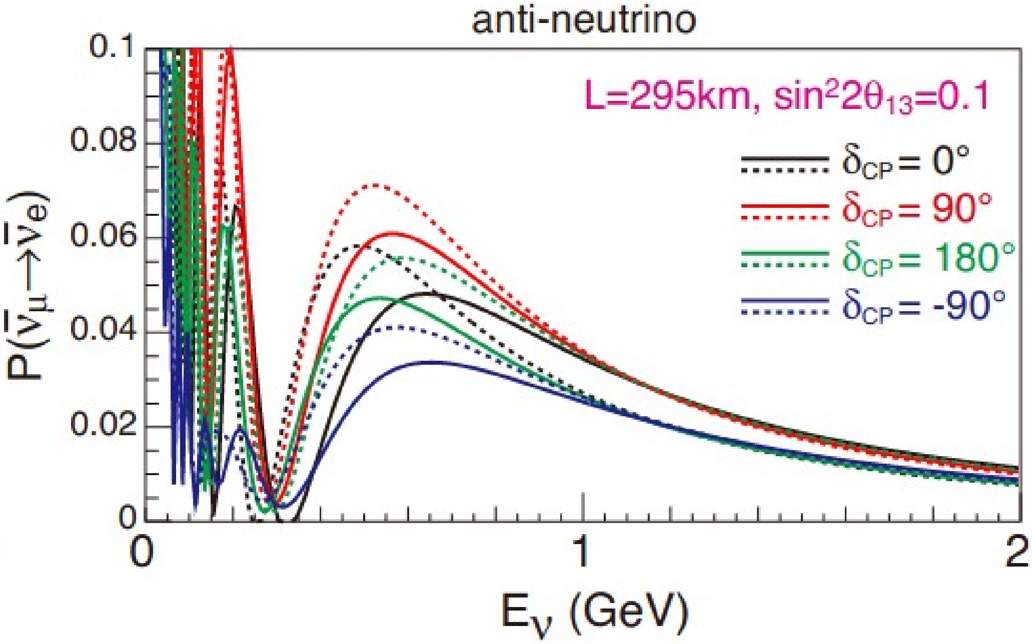




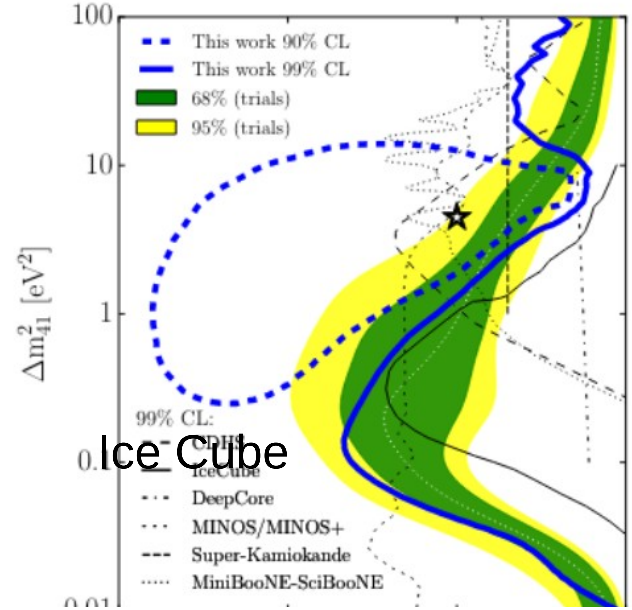


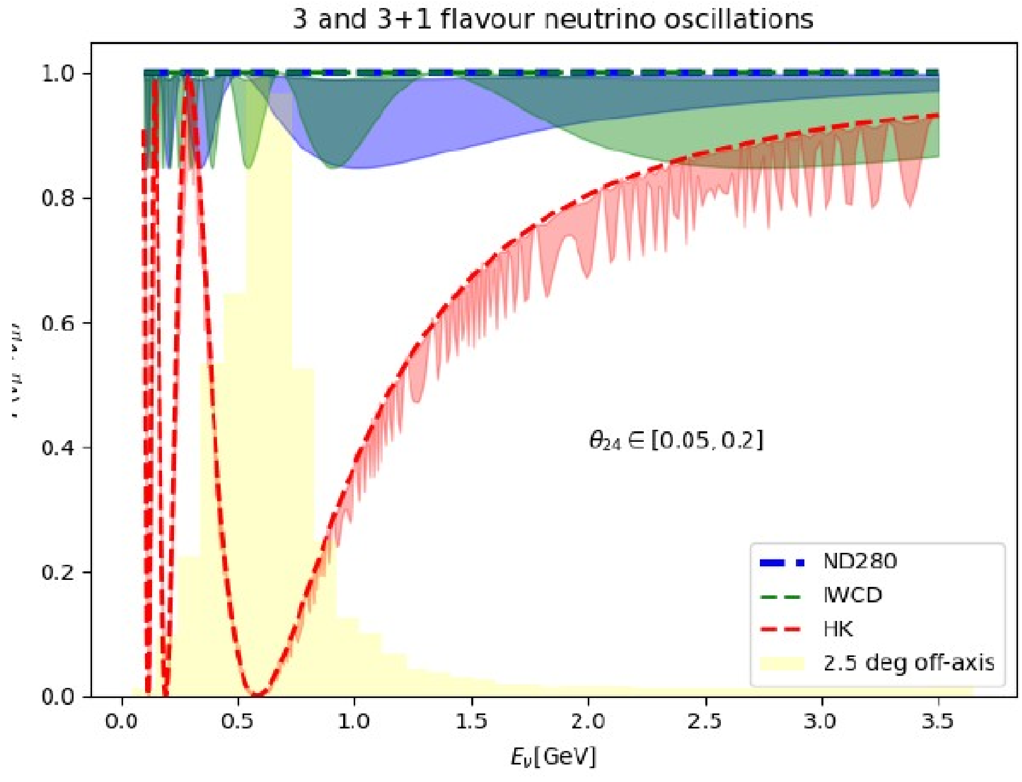
IWCD physics

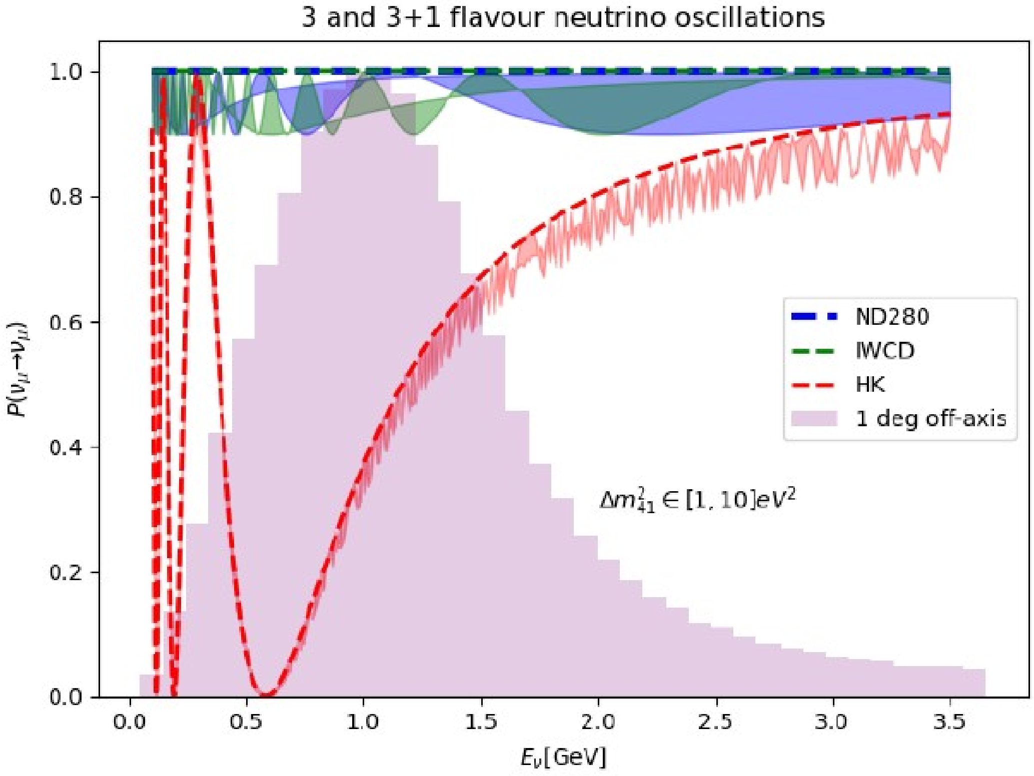
Sterile neutrino searches

Given the location and the beam energy, IWCD is a perfect place to search for steriles neutrinos in the “suspicious” zone of Δm^2_{41}~1 GeV/c^2

(whole HK combined fit?)
(FD of ND280)







Summary

- Both detectors are perfect places for trying new things both in hardware and physics

- Go beyond and the current understanding of WC detectors and try to improve the neutrino physics performance, especially towards the measurement of CP in HyperK
  - Improve knowledge of cross section, systematics, flux
  - Complementary to ND280

- Playground for probing new physics with independent and novel measurements (compare sterile anomalies with microBoone, neutrino decay, neutral heavy leptons)