Hyper-Kamiokande Overview

Rencontres de Moriond 2026

Ben Carew for HyperK

Lepton Sector CPV

Neutrinos oscillate

$$|\nu_\alpha\rangle = \sum_i U^*_{\alpha i} |\nu_i\rangle$$

because their interaction basis and their propagation basis are not the same

The Mixing Matrix

$$U_{PMNS} = U(\theta_{12}, \theta_{13}, \theta_{23}, \delta_{CP})$$

contains a CP violating phase

The CPV Mixing Term

is $\propto \sin(\delta_{CP})$

so CPV is maximal at $\delta_{CP} = \pm\, \pi/2$

Oscillation Probability

$$P(\nu_\mu \to \nu_e) - P(\bar{\nu}_\mu \to \bar{\nu}_e) = ?$$

measurements allow us to constrain the CP phase

Neutrino LBL Experiments

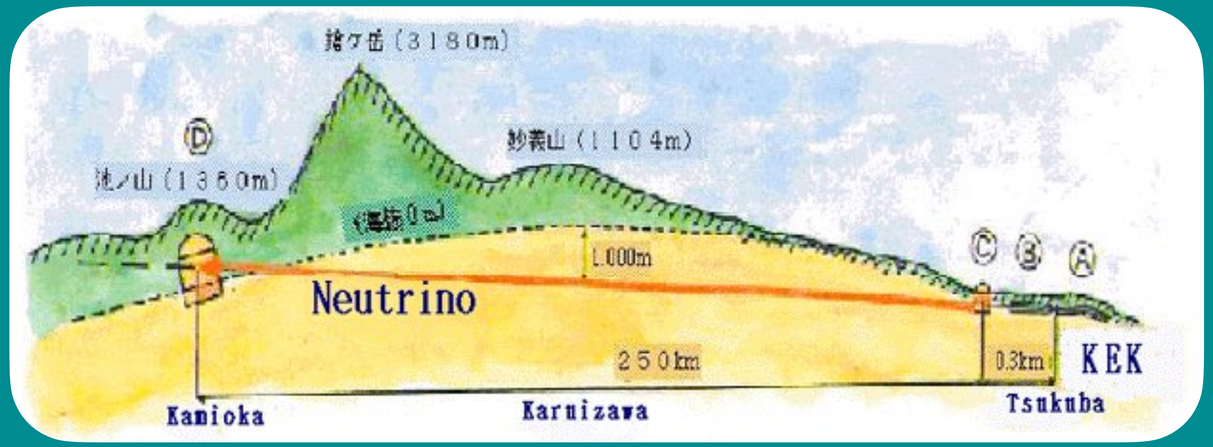


Illustration of the K2K experiment, original LBL in Japan

The T2K experiment has found

<u>2σ</u> evidence for neutrino CPV.

We need more statistics!

Recipe

1. Define asymmetry factor

$$A_{CP} = \frac{P(\nu_\mu \to \nu_e) - P(\bar{\nu}_\mu \to \bar{\nu}_e)}{P(\nu_\mu \to \nu_e) + P(\bar{\nu}_\mu \to \bar{\nu}_e)}$$

2. Count events in Near Detector (ND280)

$$N_{ND}(E_\nu) \propto \Phi_{ND} \times \sigma_{ND} \times \epsilon_{ND}$$

3. Count events in Far Detector (HyperK)

$$N_{FD}(E_\nu) \propto \Phi_{FD} \times \sigma_{FD} \times \epsilon_{FD} \times P_{osc}$$

4. Account for differences in matter effects, fluxes, efficiencies, cross-sections, etc.

Far Detector

Upgrades:
- 8.4x fiducial volume of SK
- Improved PMT efficiency

Status:
- Cavern excavation finished
- PMT testing ongoing

J-PARC ν Beam

Upgrades: 1.3MW Beam Power (2.5x)

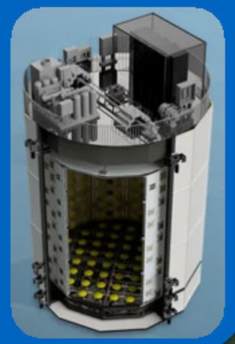
Status: First tests with 1MW beam

295 km

IWCD - 850m

Upgrades: New addition

Status: Excavation underway



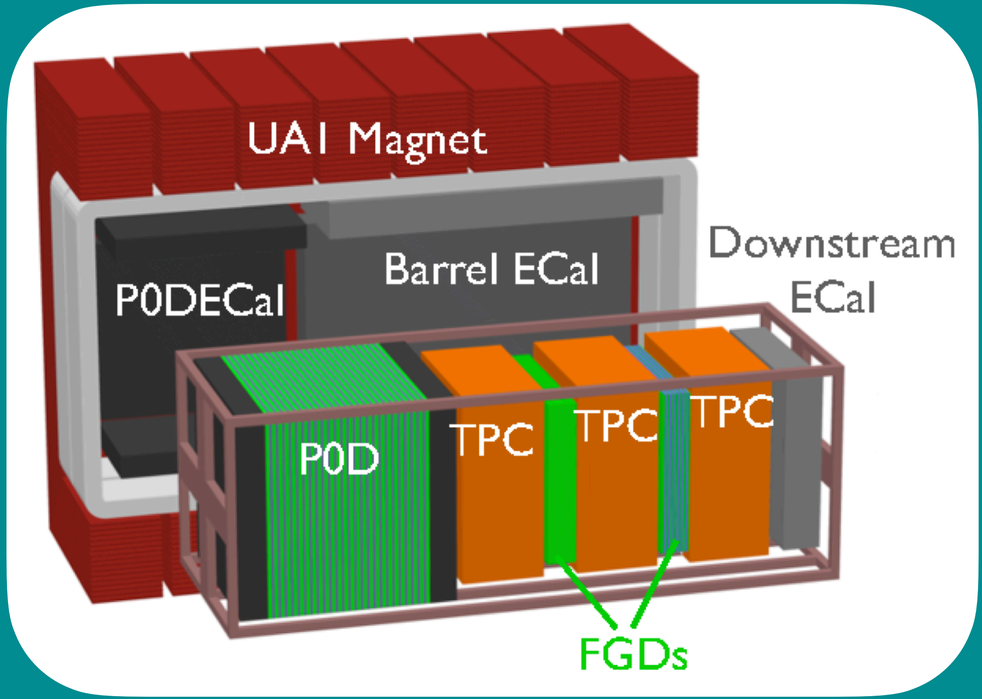
ND280, INGRID

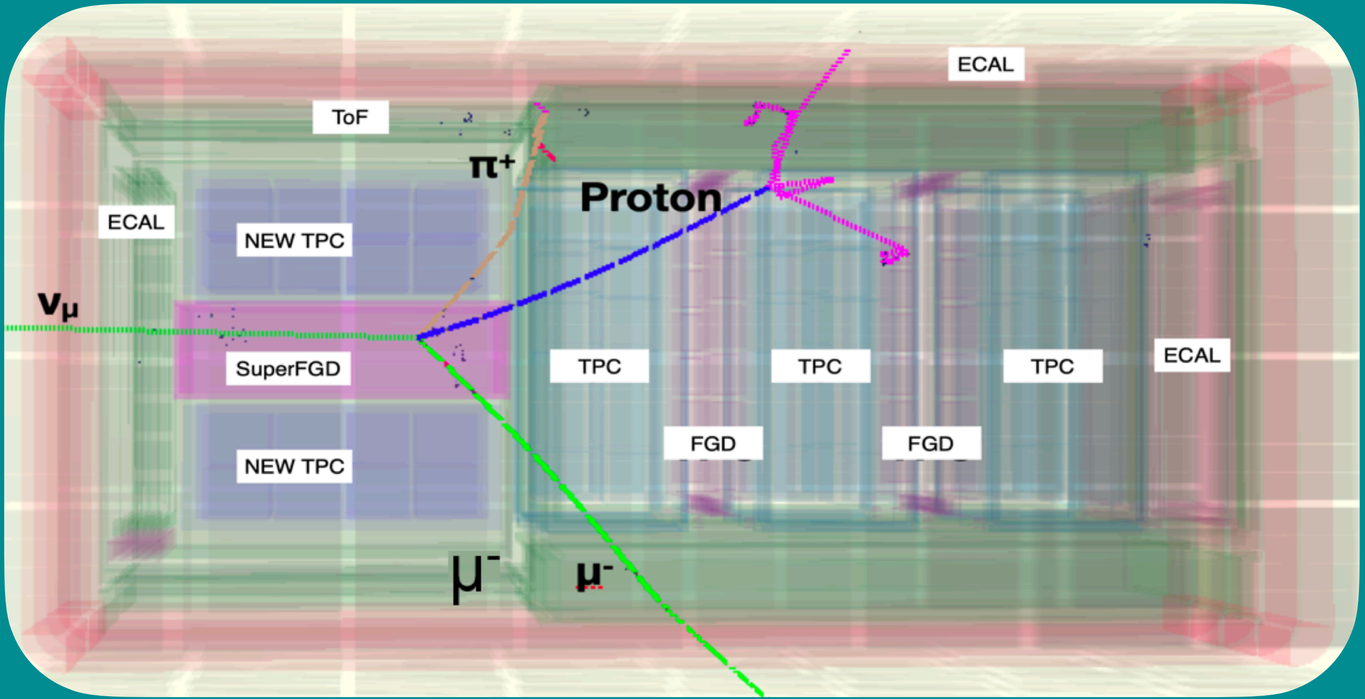
Upgrades: SuperFGD, 2 TPCs and TOF system

Status: Recently completed, ND280++ plans

ND280 Upgrade

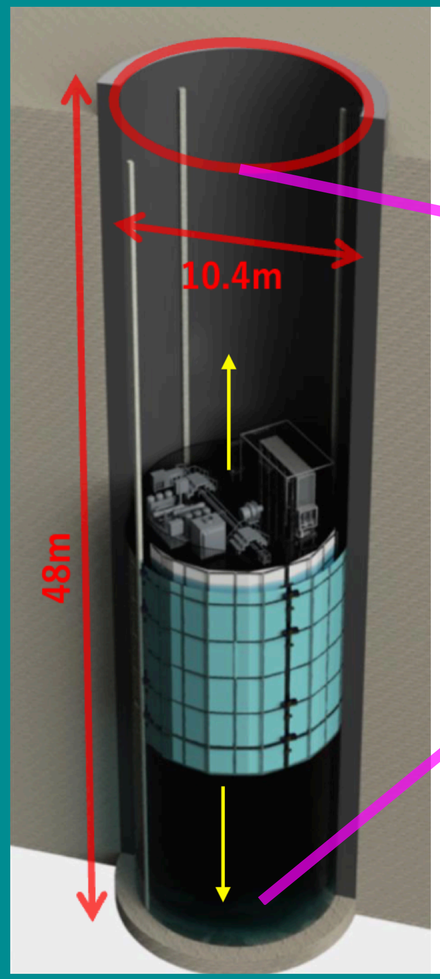
Off-axis (2.5°) Near Detector at 280m from beam

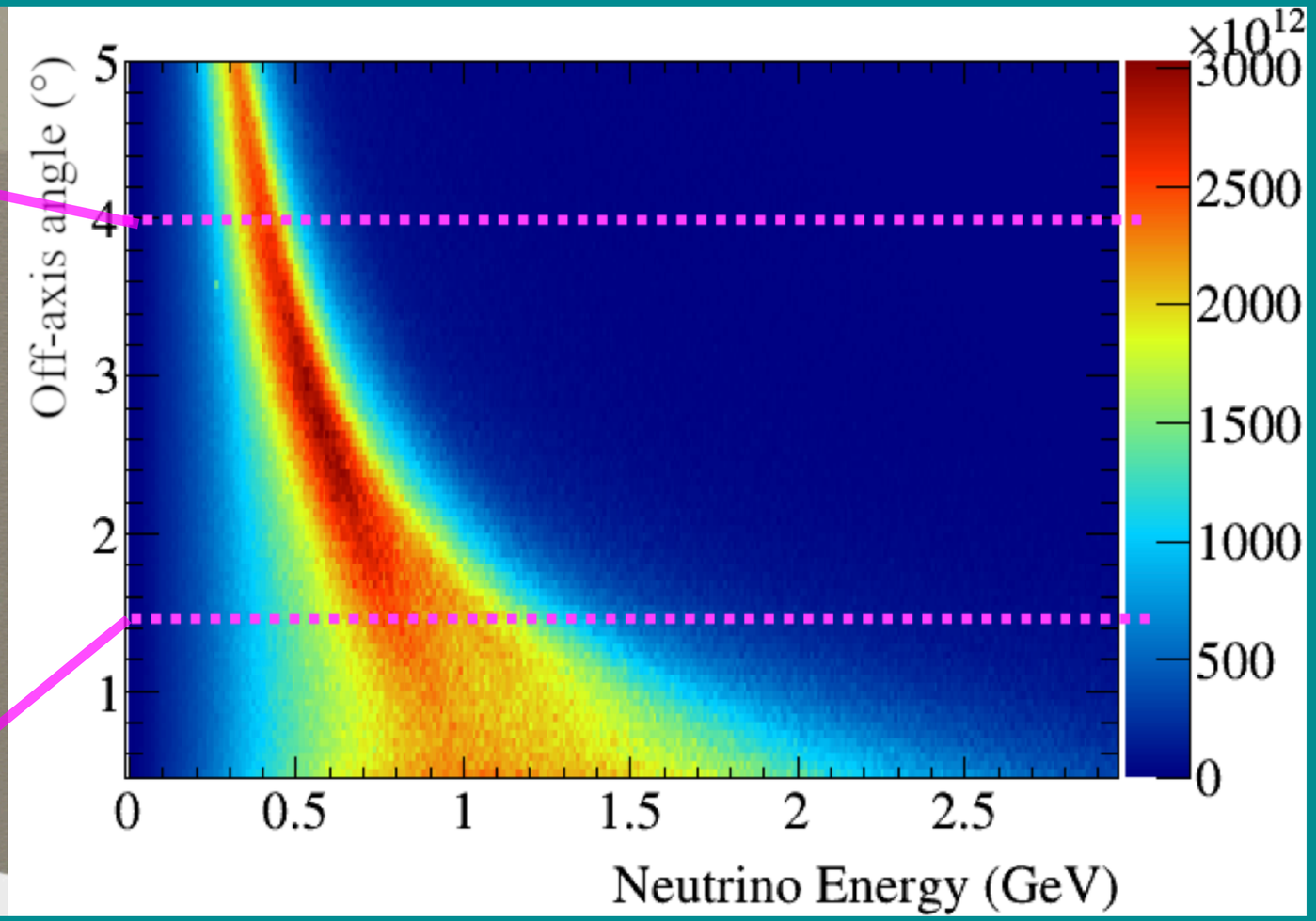




P0D system replaced by **SuperFGD**, **TPCs** and **ToF panels**

Intermediate WC Detector





- **New addition** for HK to control systematics
- Can **move vertically** to measure neutrinos at different energies
- 6x8m detector with **370 multi-PMT** units

Far Detector

Inner Detector

50cm PMTs

- 20,000 total
- 20% photo-coverage
- Upgraded efficiency

Multi-PMTs

- 800 total modules
- Each has 19 x 8cm PMTs
- Inside 50cm sealed vessel

Outer Detector

- Veto region for cosmic rays
- 3,600 8cm PMTs
- WLS plates to maximise photo-coverage

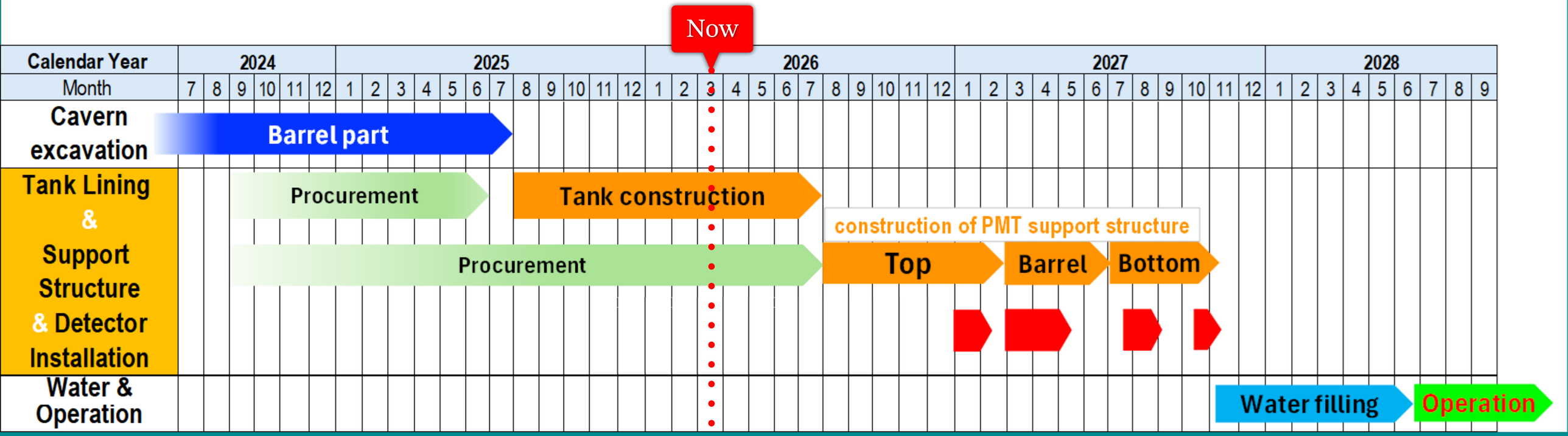
Details in next talk from Shinoda-san!

PMT Delivery Status

89%

January 2026
18.463/20,800

Master Schedule for the Hyper-Kamiokande FD



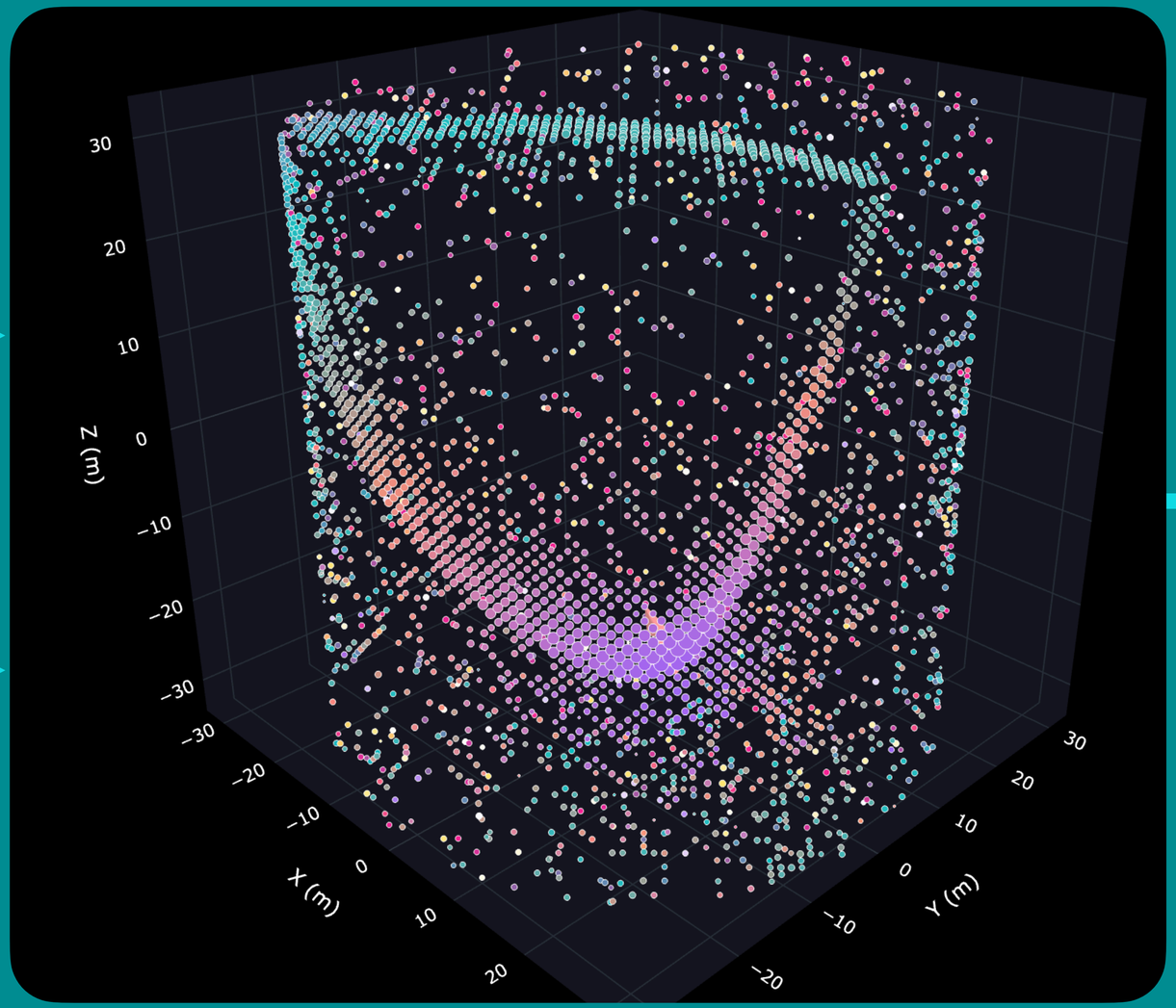
2026 To-Dos:

- **Construction**: Tank lining, water system, PMT delivery and testing, electronics
- Far detector construction shifts begin **end of the year**
- **Software:** Finalise reconstruction algorithms, selection, calibration simulations

Software

Water Cherenkov Simulation

Real Data (from 2028)



Real-Time Analysis
Supernovae, etc.

Trigger and Pre-selection

Event Reconstruction

Offline Analysis
CPV, Proton decay, etc.

Sensitivity Projections

60% of δ_{CP} values **excluded** after 10 years

5σ **CPV** discovery in 5 years if $\delta_{CP} = -\pi/2$

Eur.Phys.J.C, DOI: 10.1140/epjc/s10052-025-14938-9

Lots of other expected or possible phenomenology:

Neutrino Parameters

$\underbrace{\theta_{23}, \Delta m^2_{23}}_{\textit{world-leading}}$, mass ordering

Proton Decay

$p \to e^+\pi^0 : \tau/\beta \approx \mathbf{5 \times 10^{34}}$ years

$p \to \nu K^+ : \tau/\beta \approx \mathbf{2 \times 10^{34}}$ years

from 10 years of data

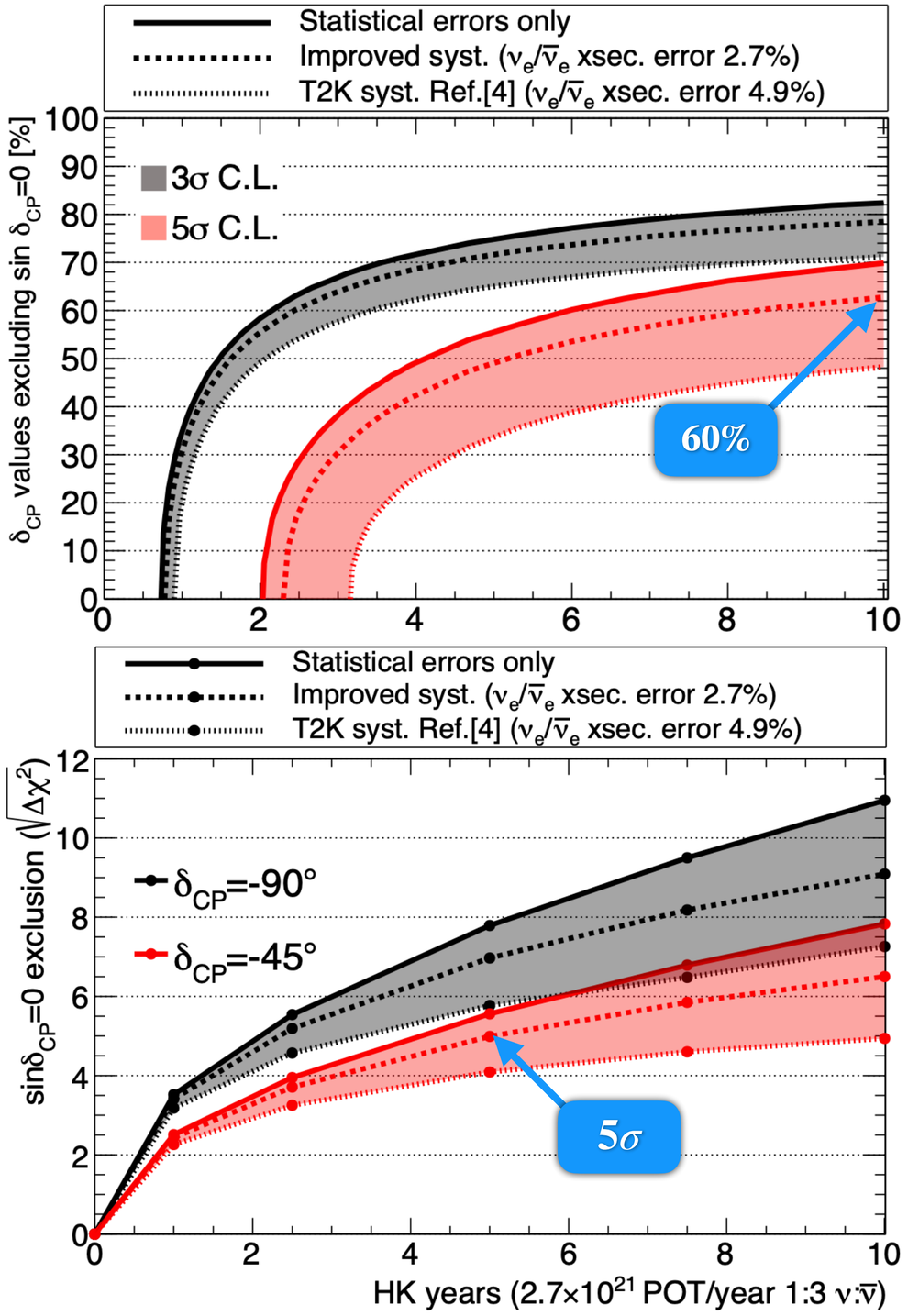
Supernovae

DSNB: **200** events in 10 years

GCC: $\mathbf{10^5}$ events at galactic centre

BSM Searches

Heavy neutral leptons, indirect dark matter, CPT, etc...



Summary

- HyperK is **under construction**
- Data taking scheduled for **2028**
- Neutrino beam, near detectors and far detector all receiving **major upgrades from T2K**
- Major improvements to **software and analysis** over SuperK
- Projected to **exclude half** δ_{CP} values within **5 years**
- Next steps: PMT testing, water system, IWCD excavation, beam testing, construction, calibration