

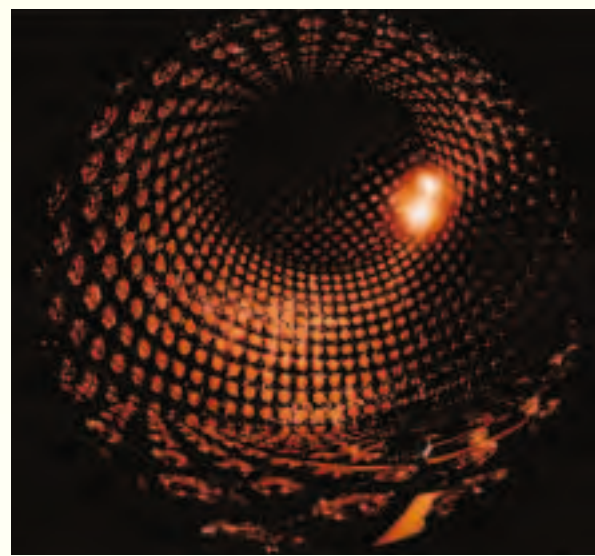
Hyper-Kamiokande



Achievements of (Super-)Kamiokande

Kamiokande
(1983-1996)

→ KamLAND



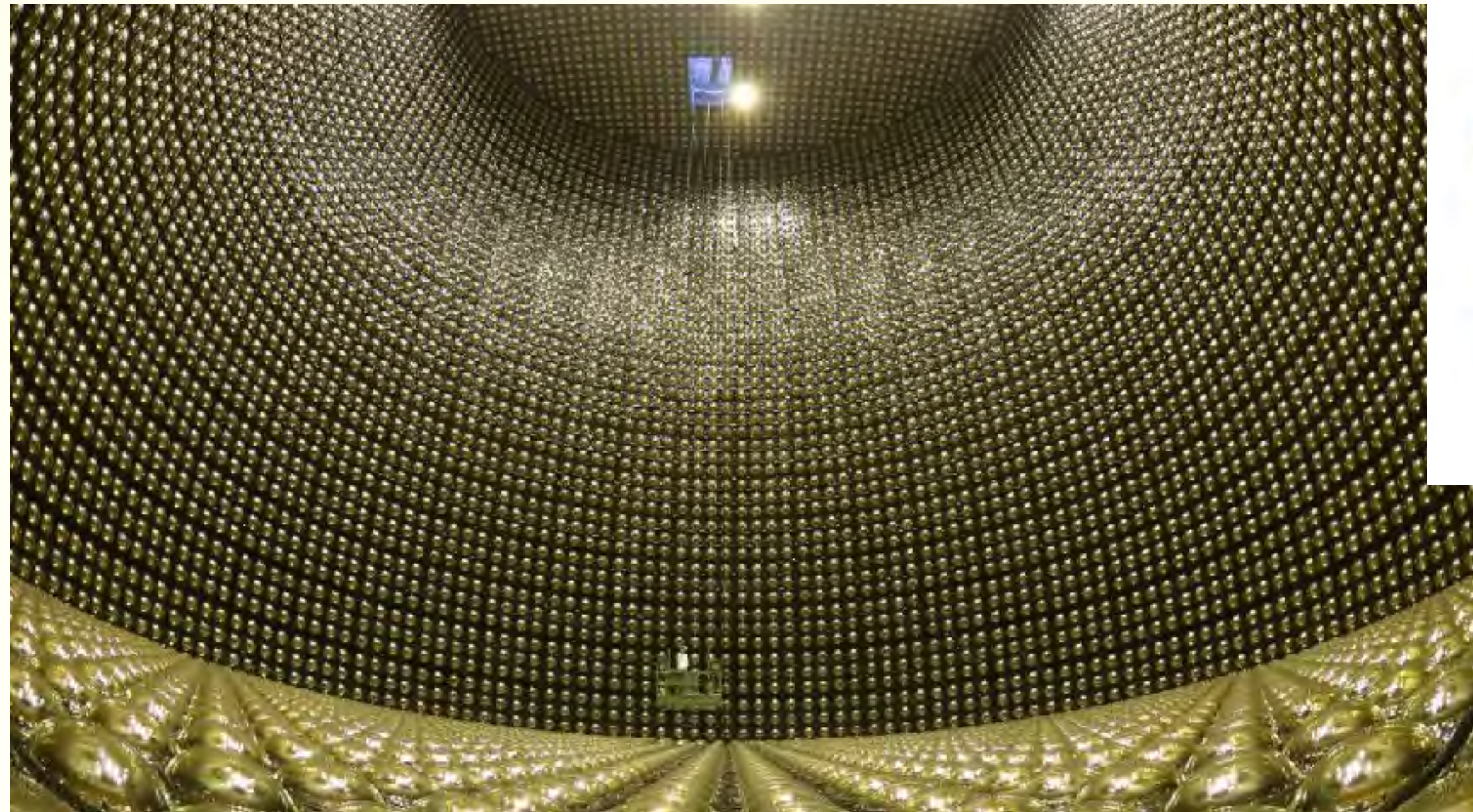
Observation of supernova
neutrino (1987)

Atmospheric neutrino
anomaly (1988)

Real time observation of
solar neutrinos (1989)



Super-Kamiokande (1996-)



Evidence for neutrino oscillations with atmospheric neutrinos (1998)
Solar neutrino flavor change, together with SNO (2001)
First long baseline experiment, K2K (1999-2004)
Discovery of electron neutrino appearance in T2K (2013)
Hint of CP violation in neutrino oscillations (2020)
Indication of diffuse supernova neutrino background (2026)

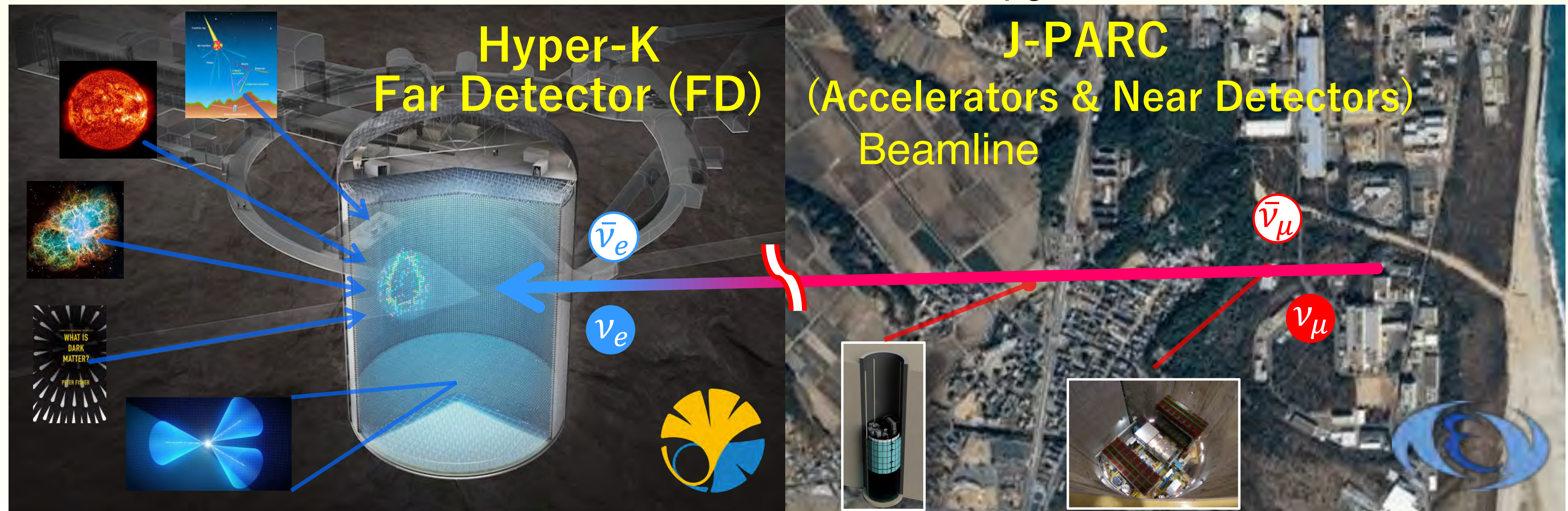


3rd generation: Hyper-Kamiokande

World-largest detector for Nucleon-decay and Neutrino experiment
260kton water Cherenkov detector

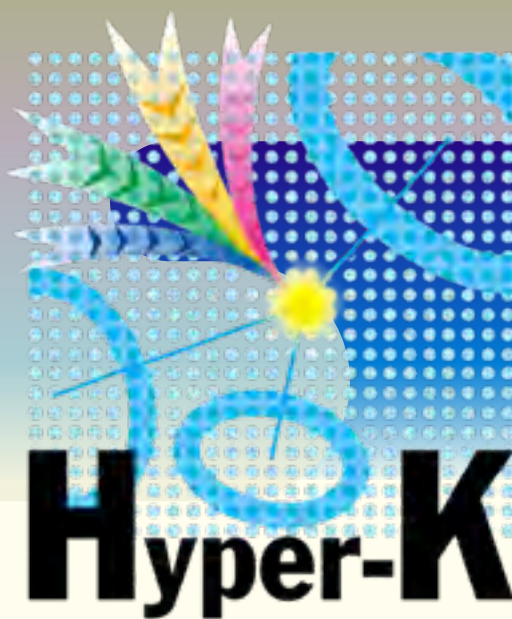
+

World's most intense neutrino beam & new and upgraded near detectors



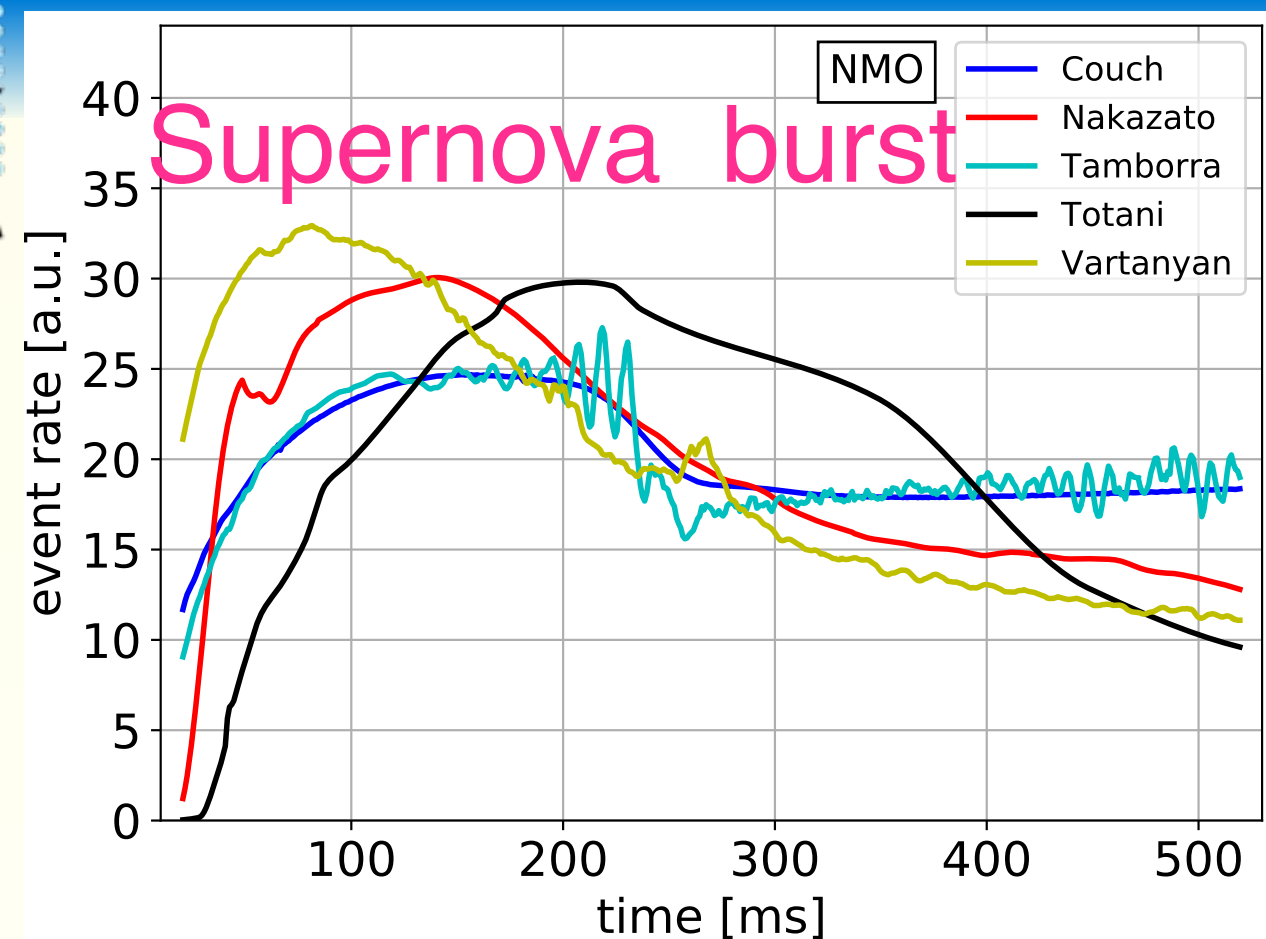
Long baseline experiment and non-accelerator physics in a single project

Building on the strong legacy of success with Super-K and T2K

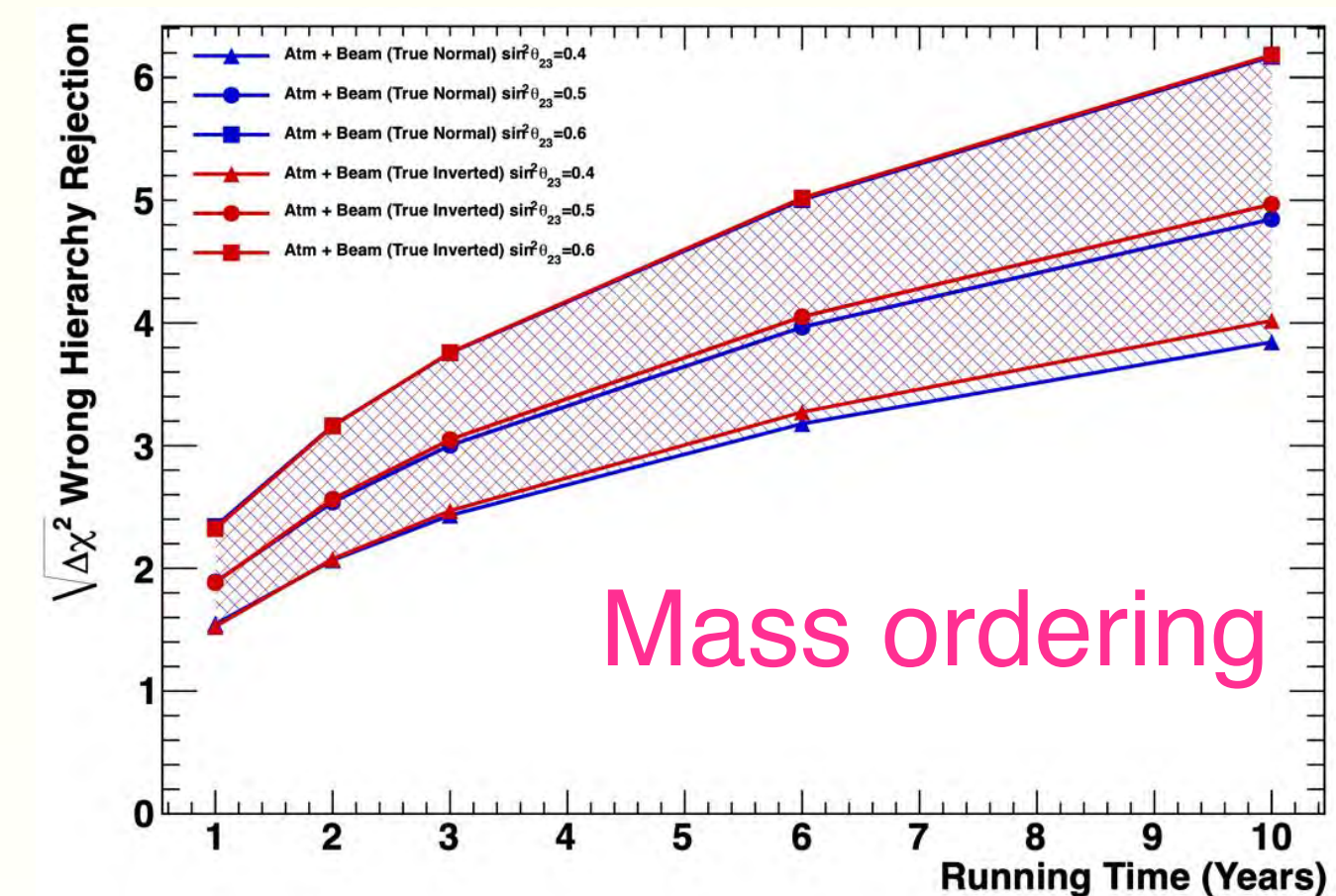
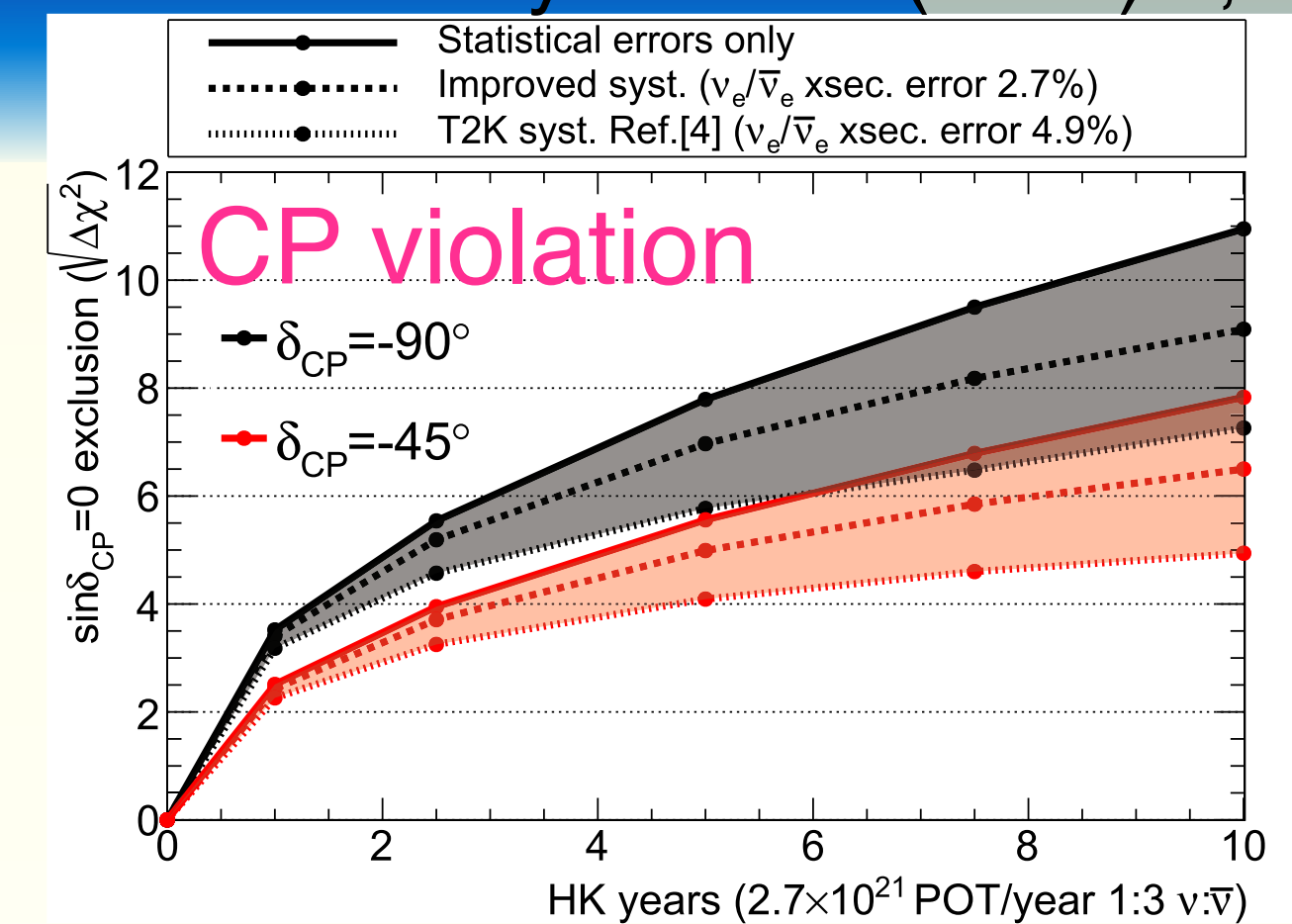
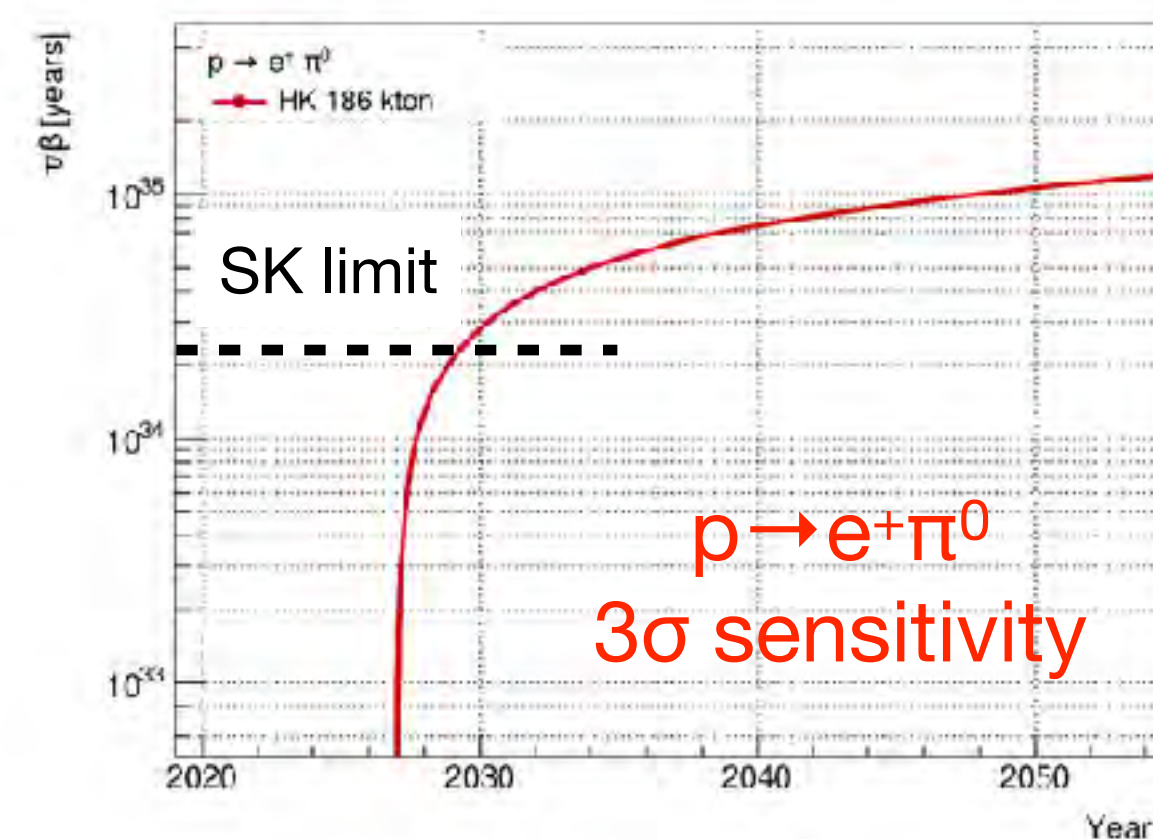
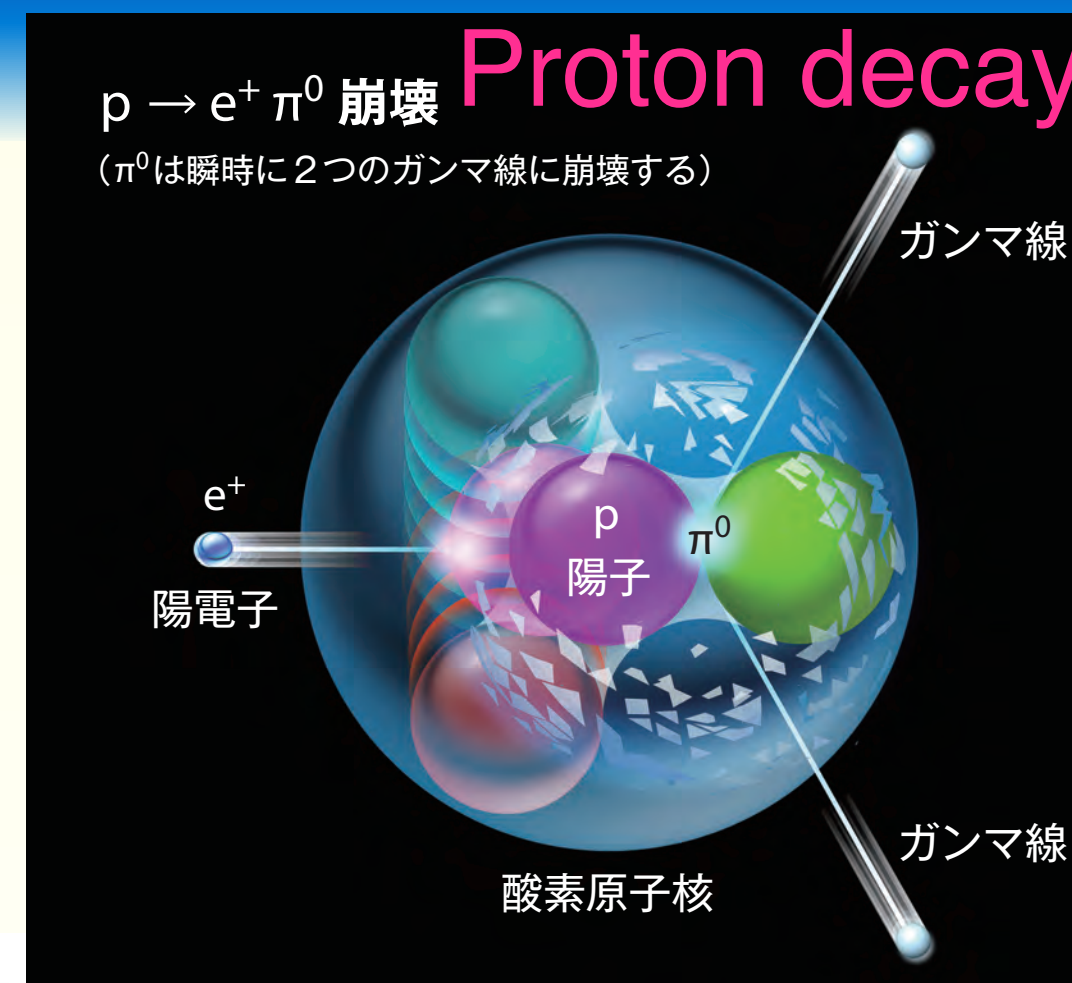
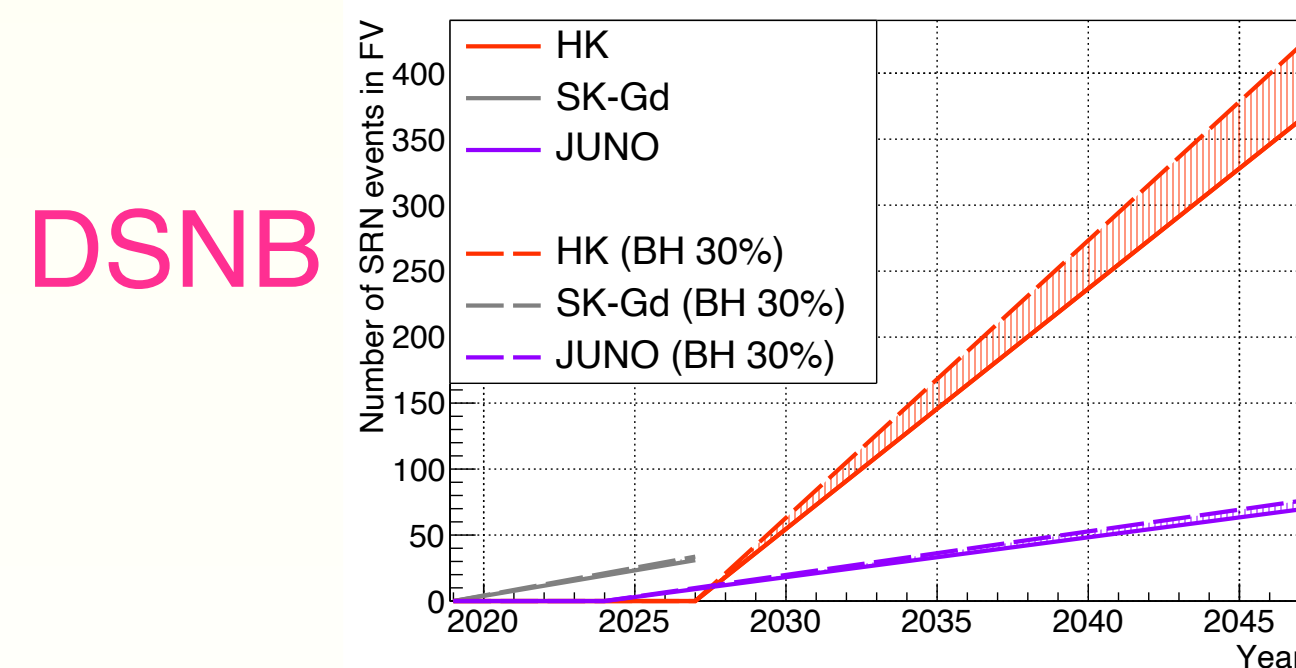


Scientific goals

Hyper-Kamiokande Collaboration,
Eur.Phys.J.C **86** (2026) 2, 170



Hyper-Kamiokande Collaboration,
Astrophys.J. **916** (2021) 1, 15



Solar

Supernova

Accelerator

Nucleon decay

Dark Matter

From MeV to TeV in one experiment

~3.5MeV

~20

~100MeV

~1GeV

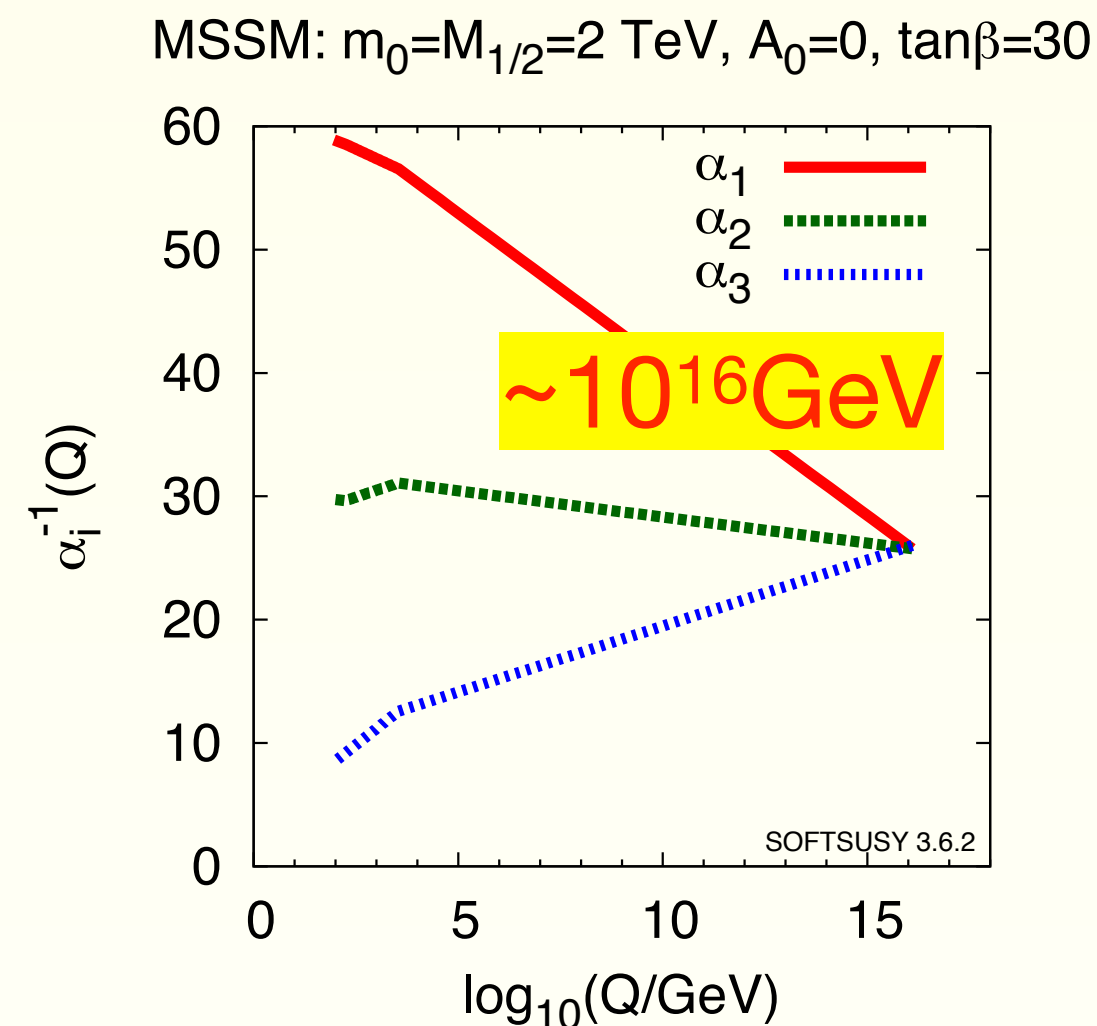
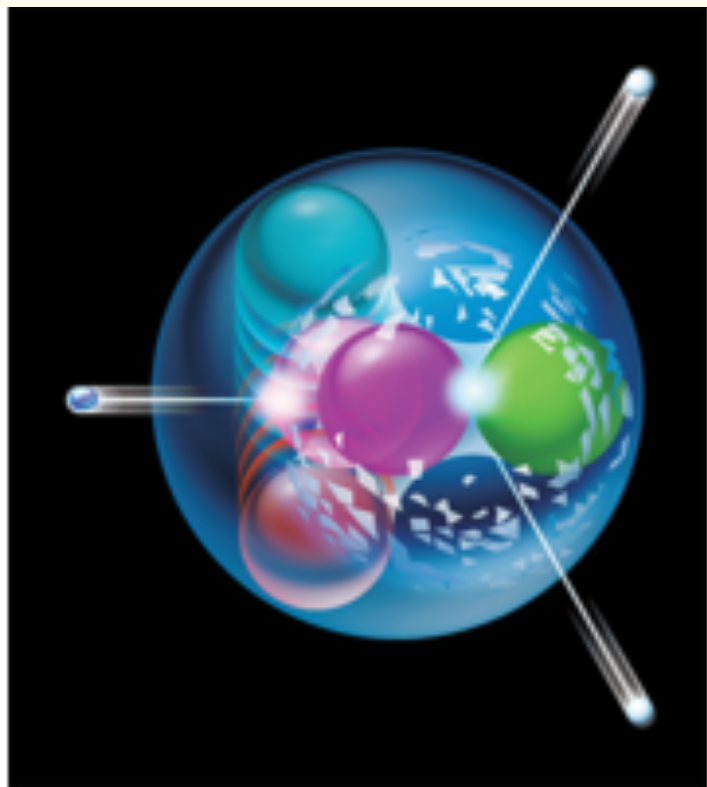
TeV

Atmospheric

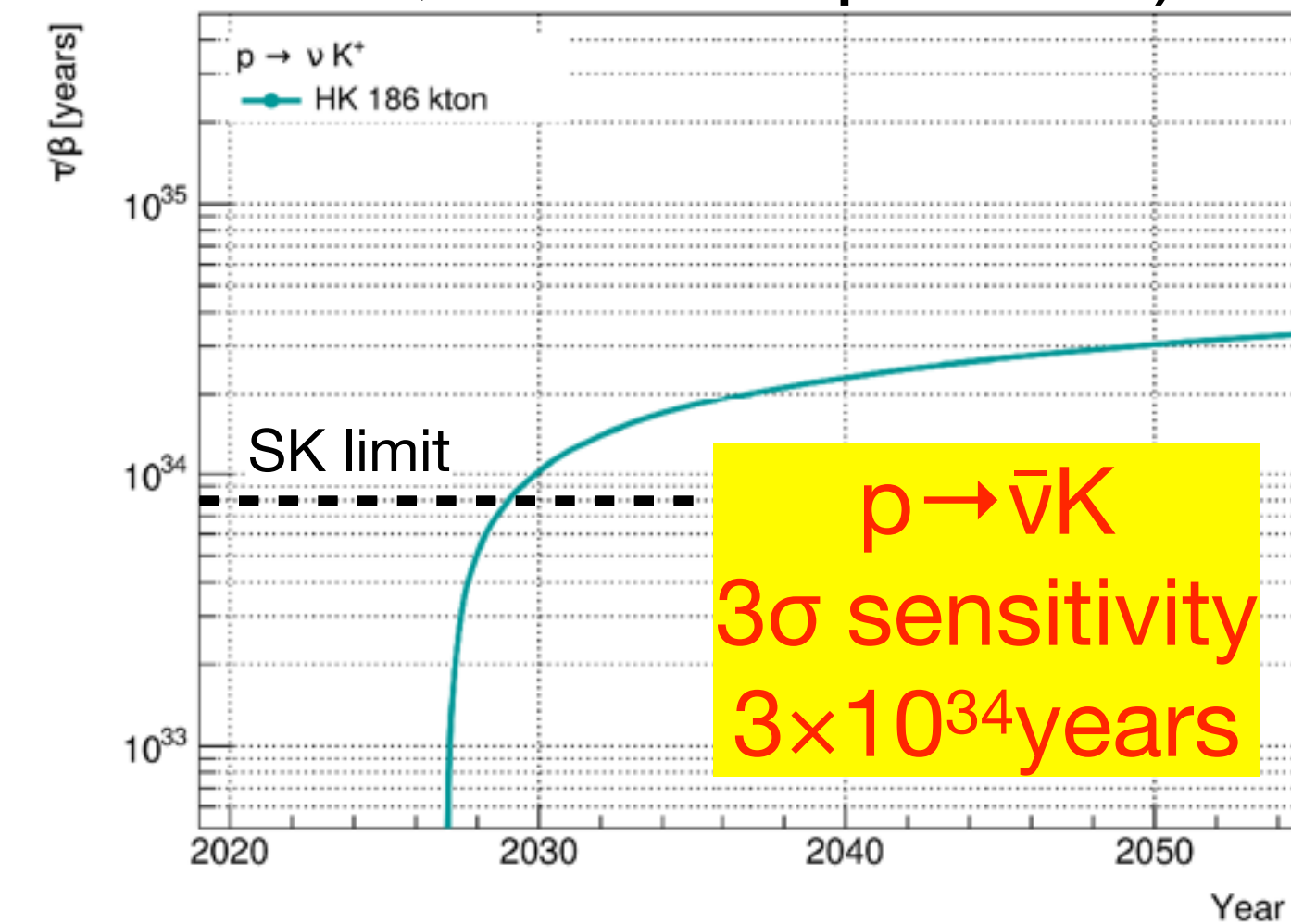
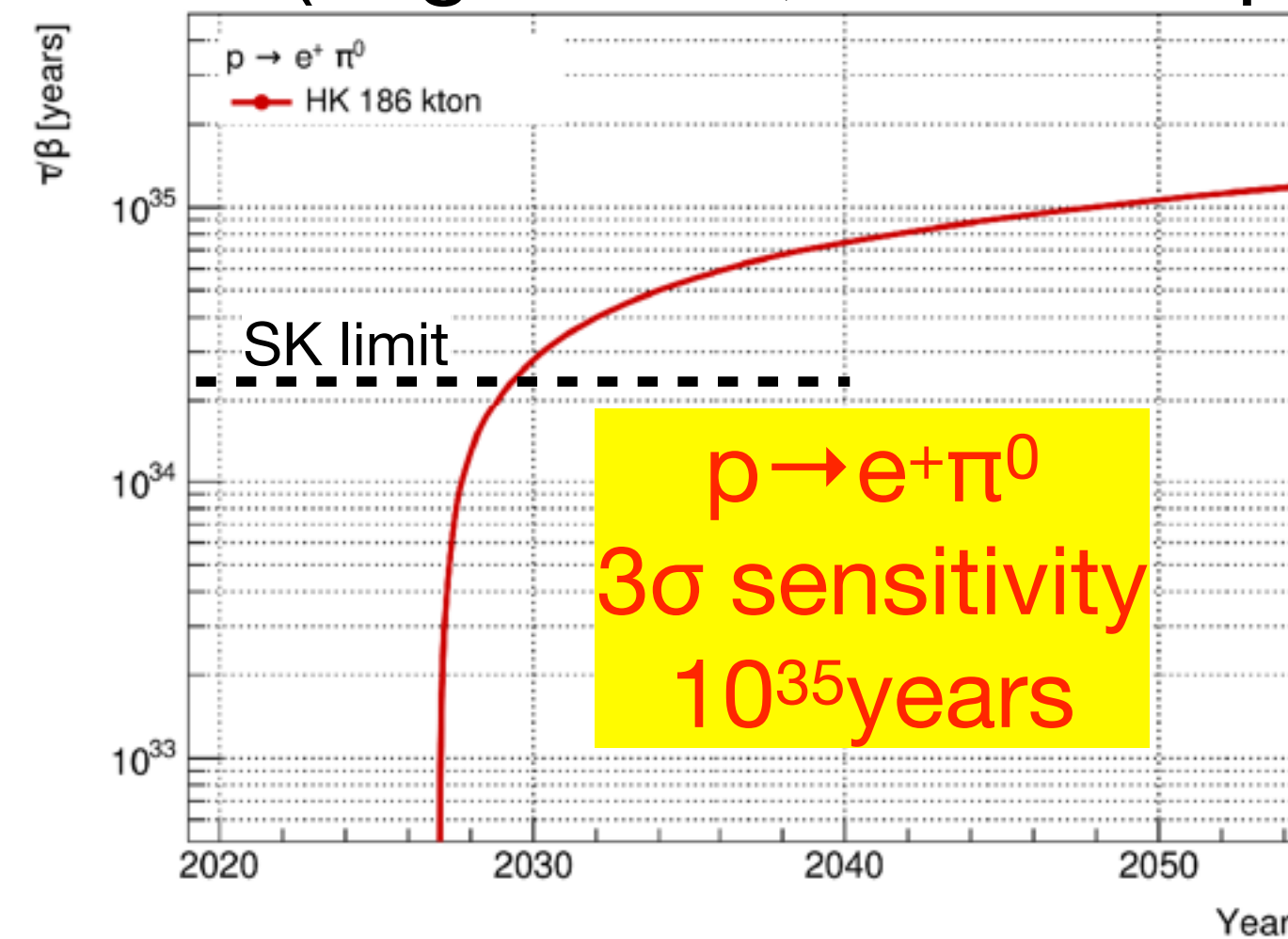


Search for proton decays

Nucleon decay:
clear evidence of
Grand Unification

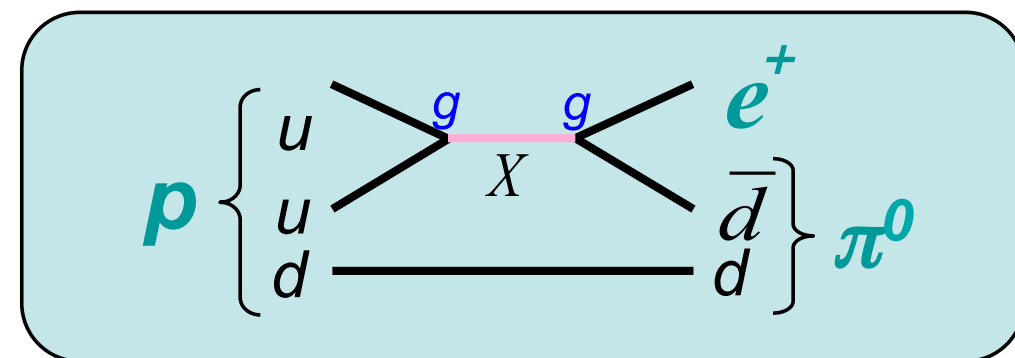


World-best sensitivity for most of possible modes
(huge mass, excellent performance, and free protons)



Two modes as benchmark

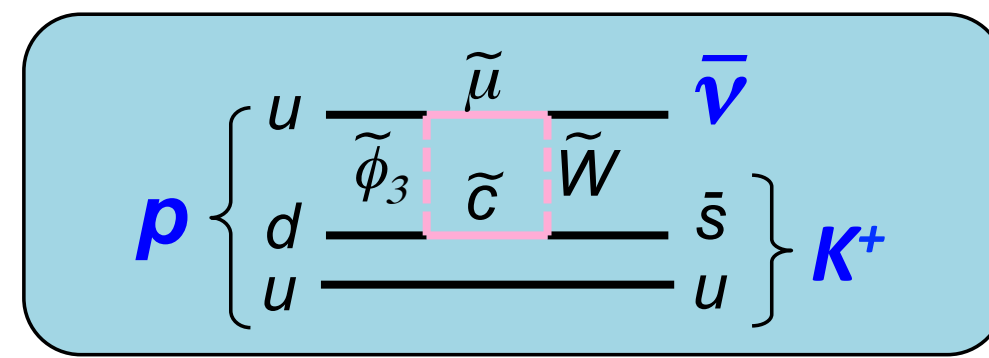
Mediated by gauge bosons



$p \rightarrow e^+ \pi^0$

$$\Gamma(p \rightarrow e^+ \pi^0) \sim \frac{g^4 m_p^5}{M_X^4}$$

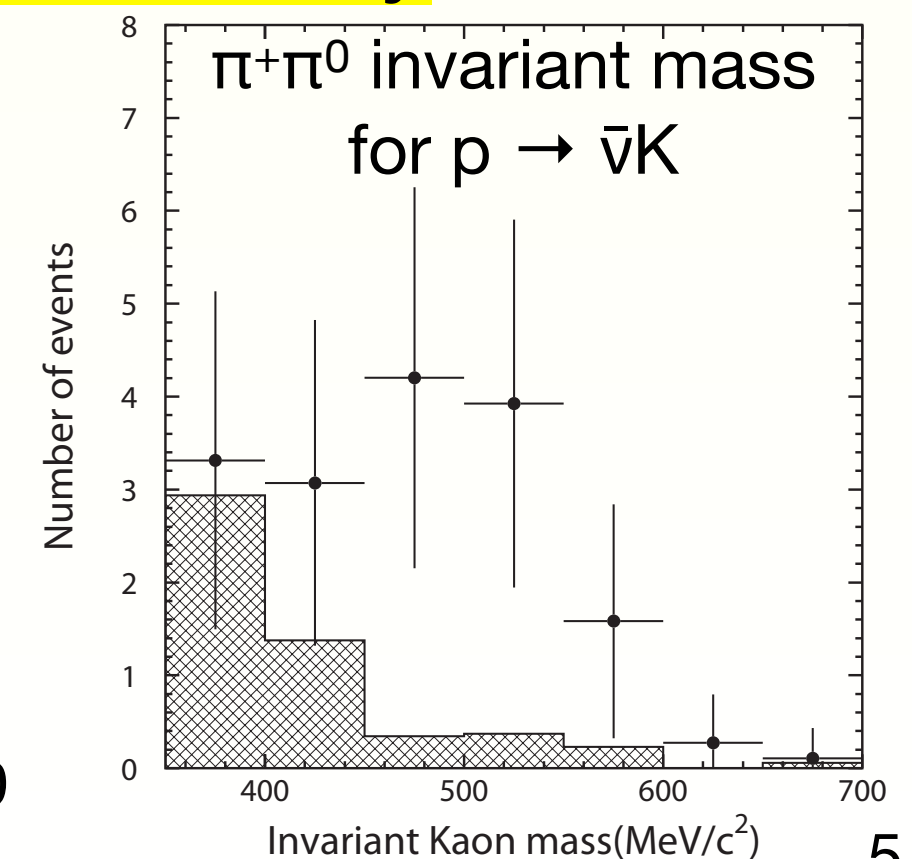
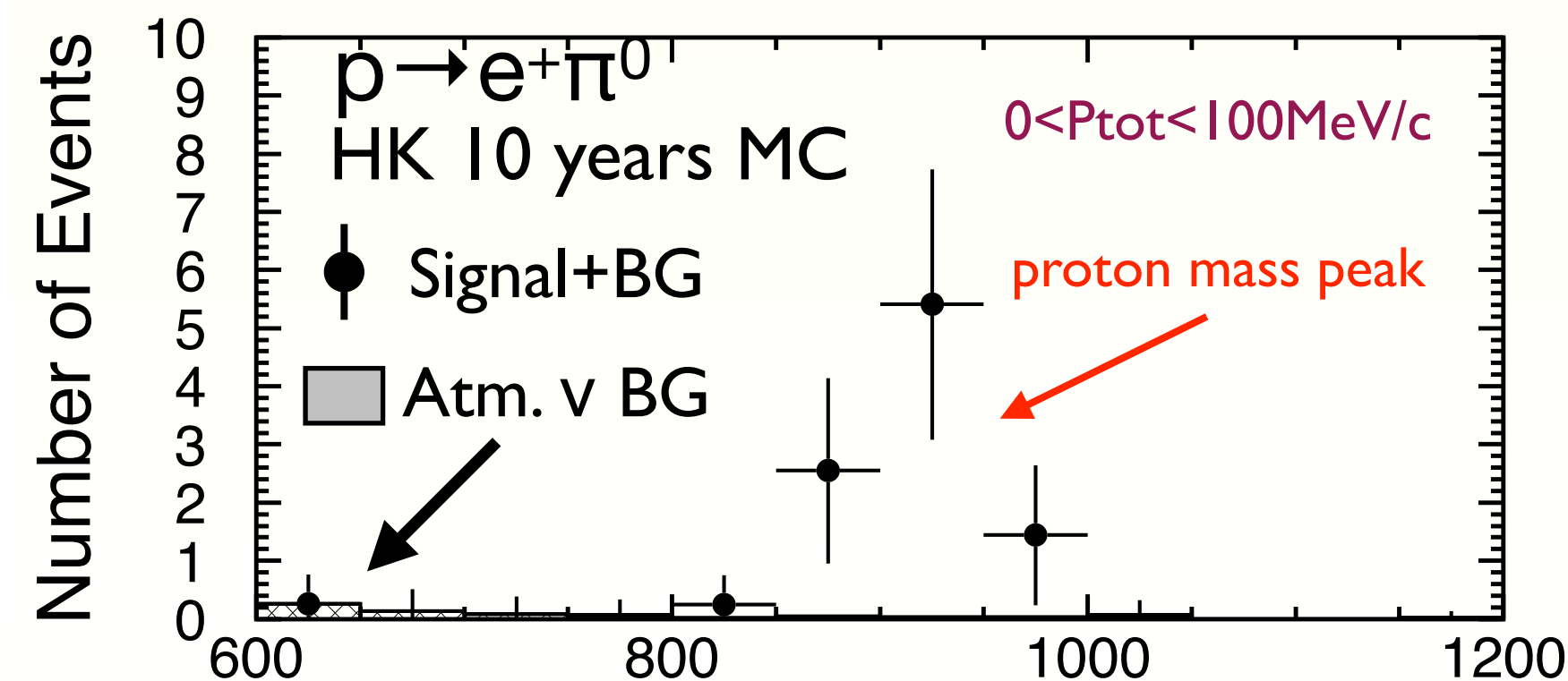
SUSY mediated



$p \rightarrow \bar{\nu} K^+$

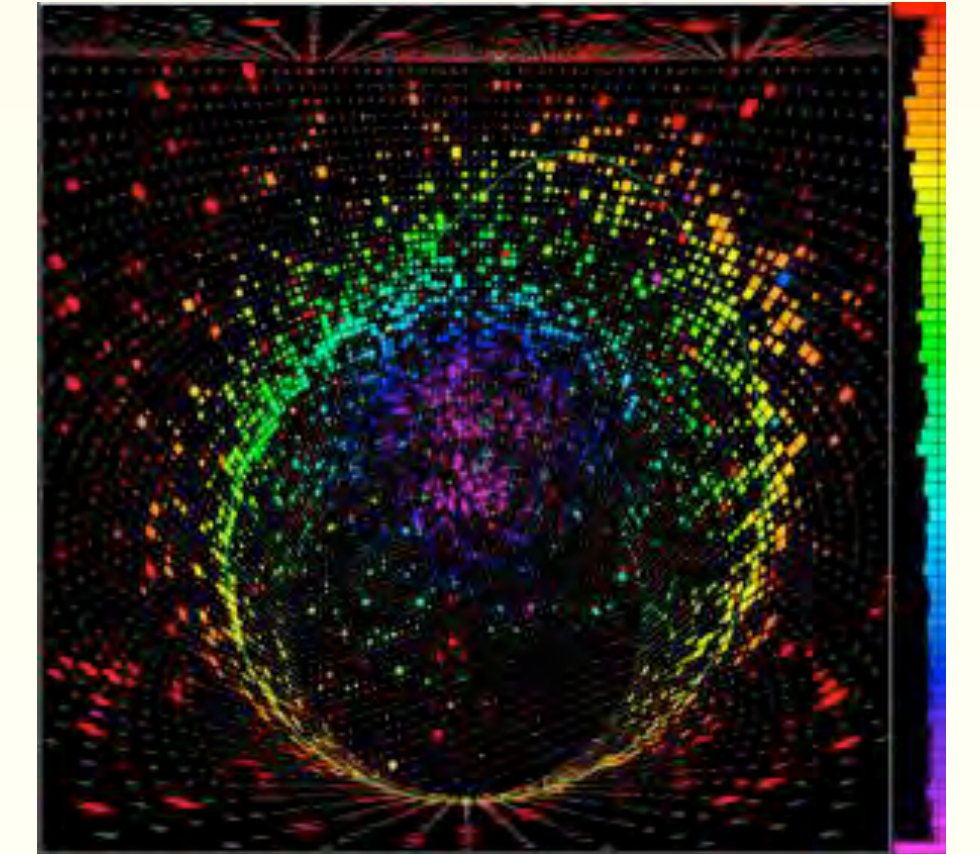
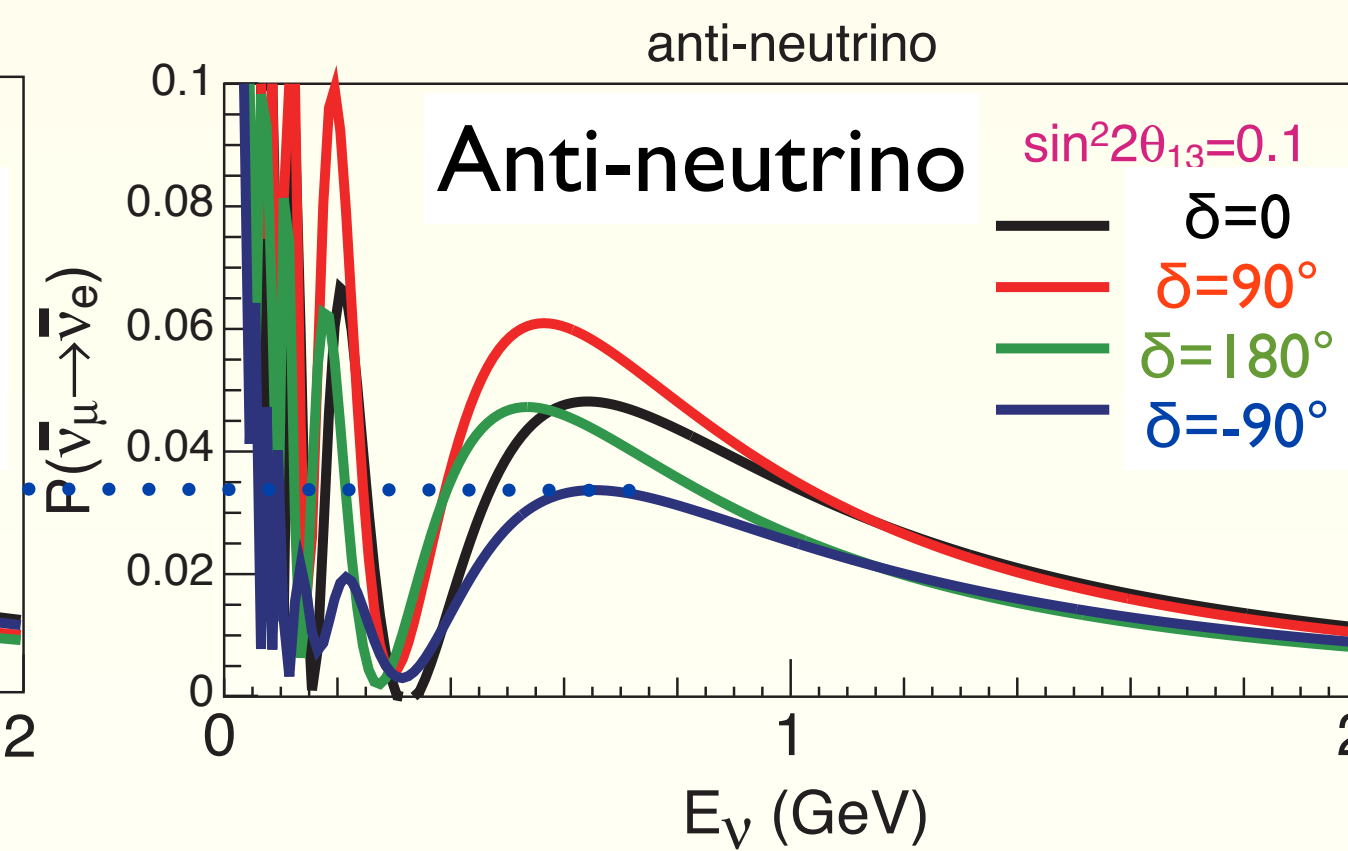
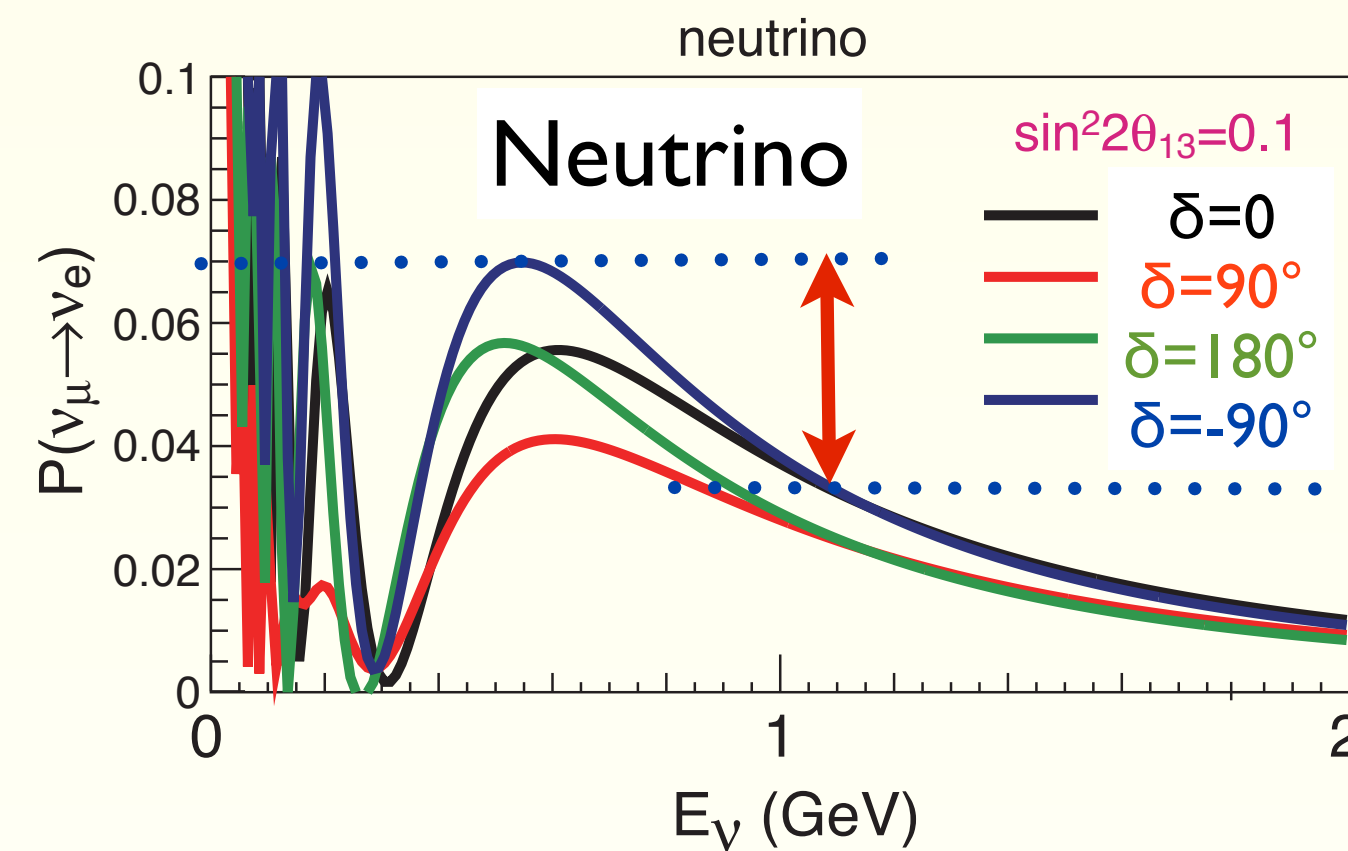
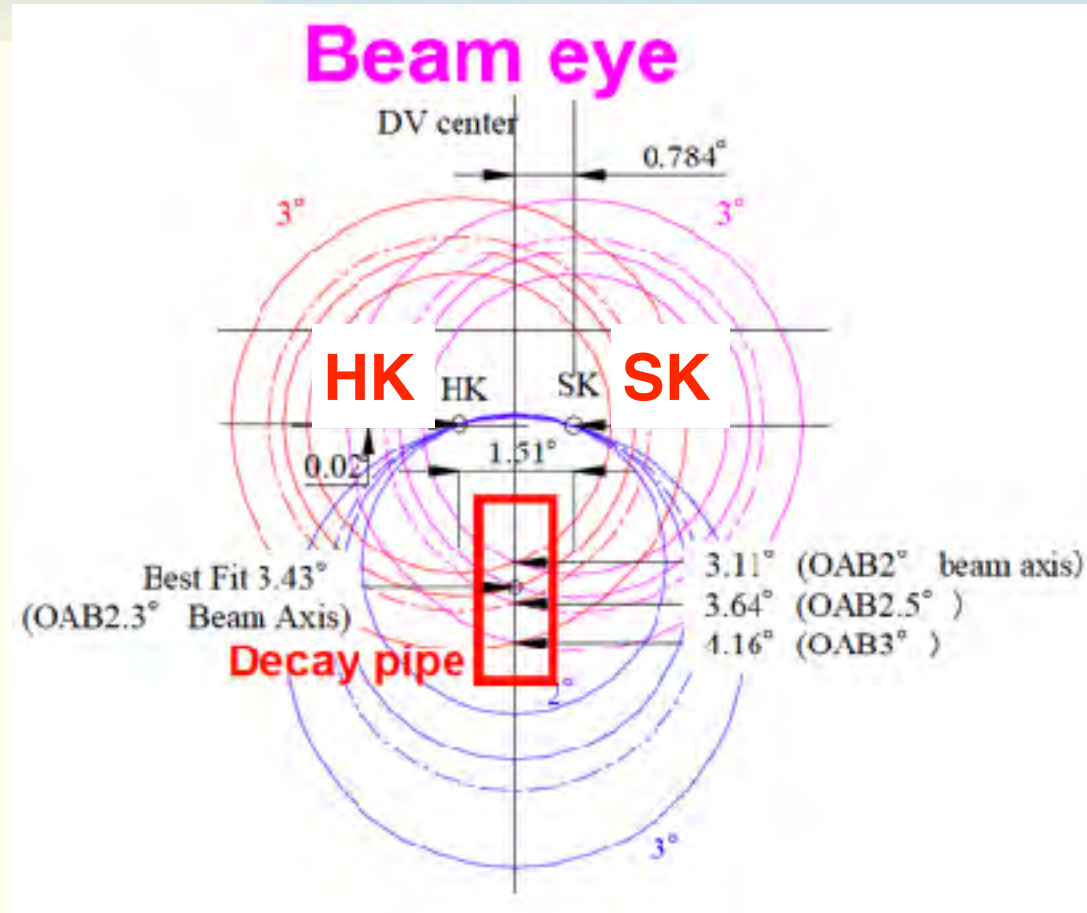
$$\Gamma(p \rightarrow \bar{\nu} K^+) \sim \frac{\tan^2 \beta \times m_p^5}{M_{\tilde{q}}^2 \times M_3^2}$$

Good chance of discovery



Other possible modes are equally important

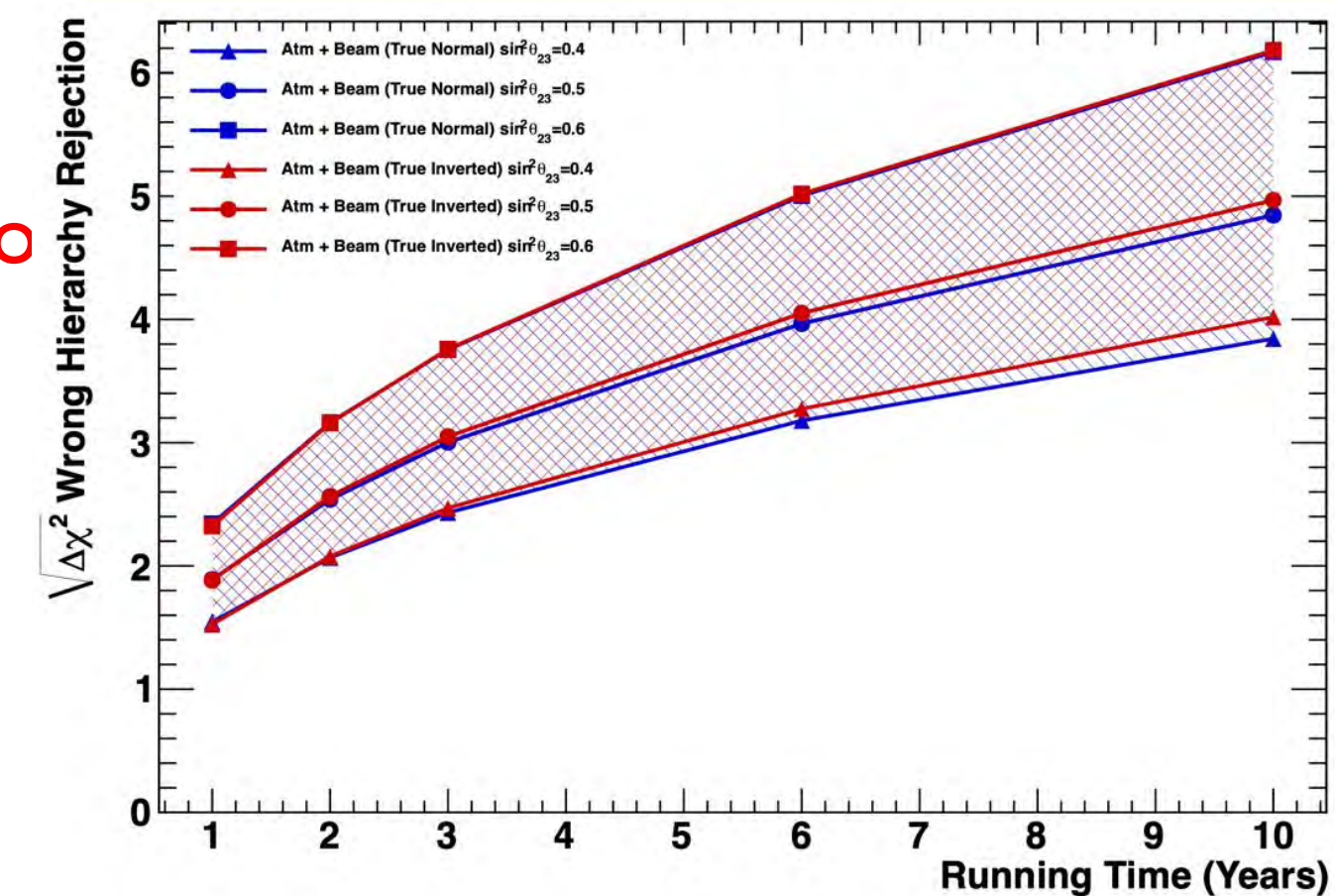
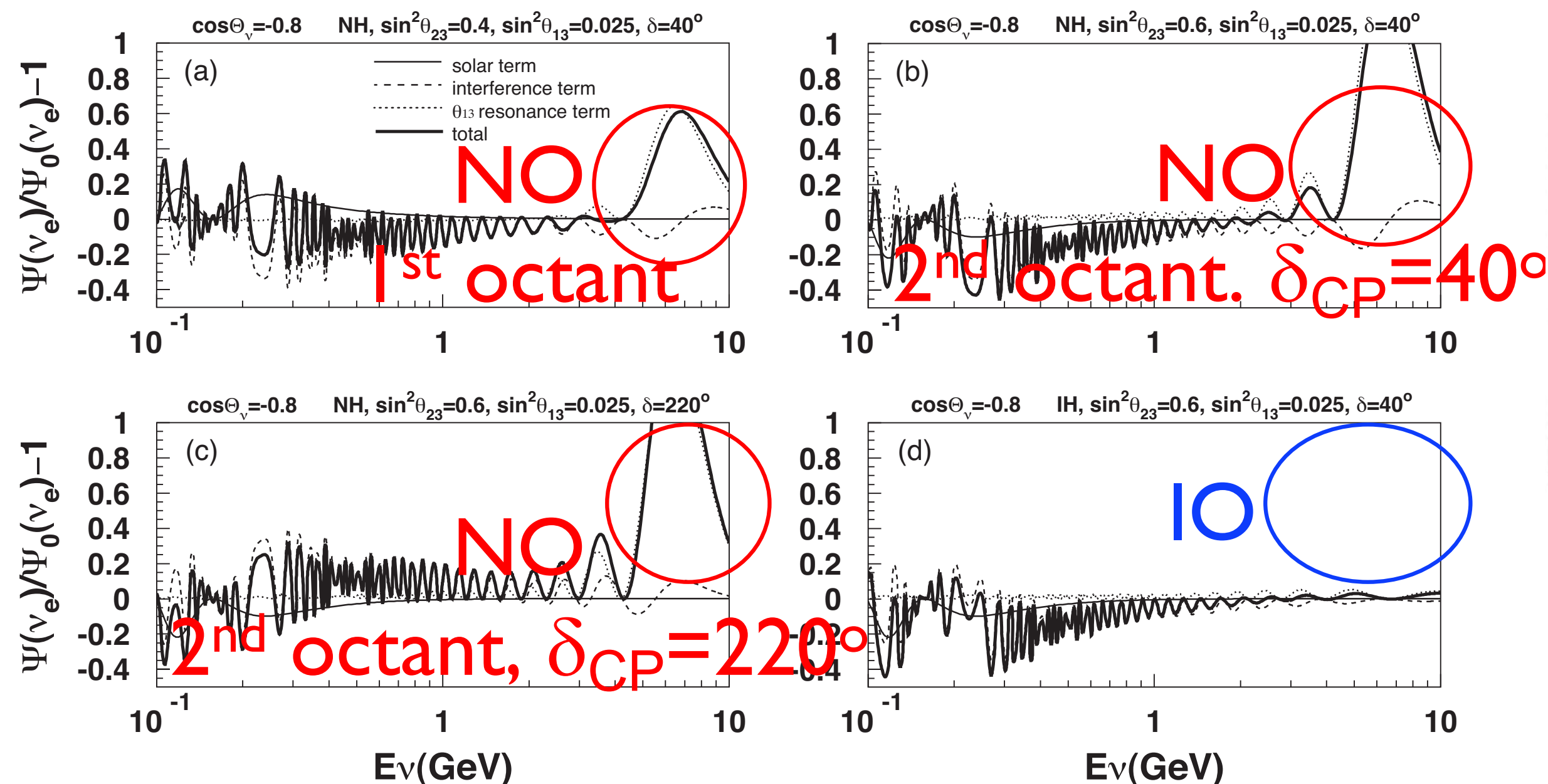
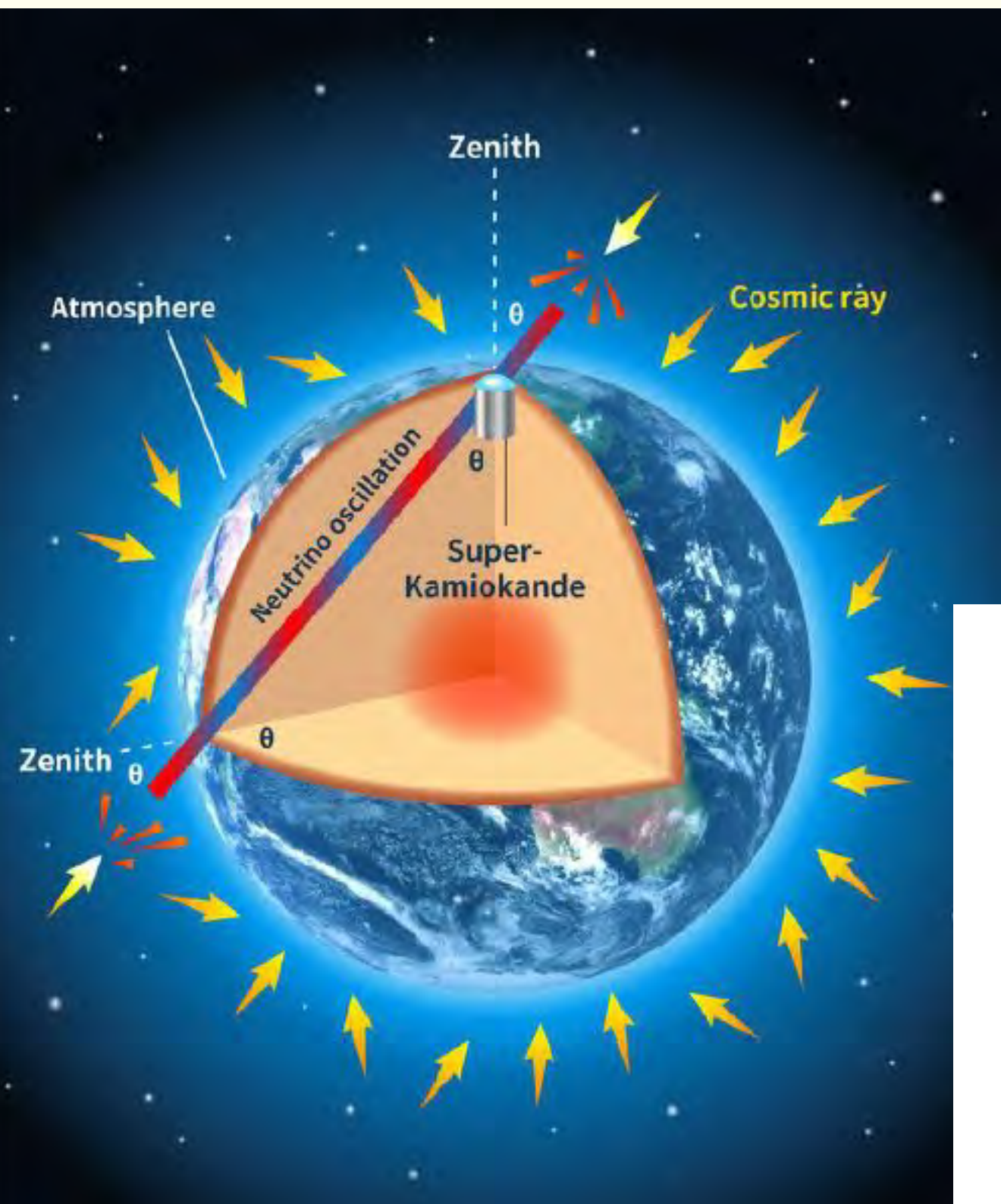
Long baseline experiment with J-PARC neutrino beam



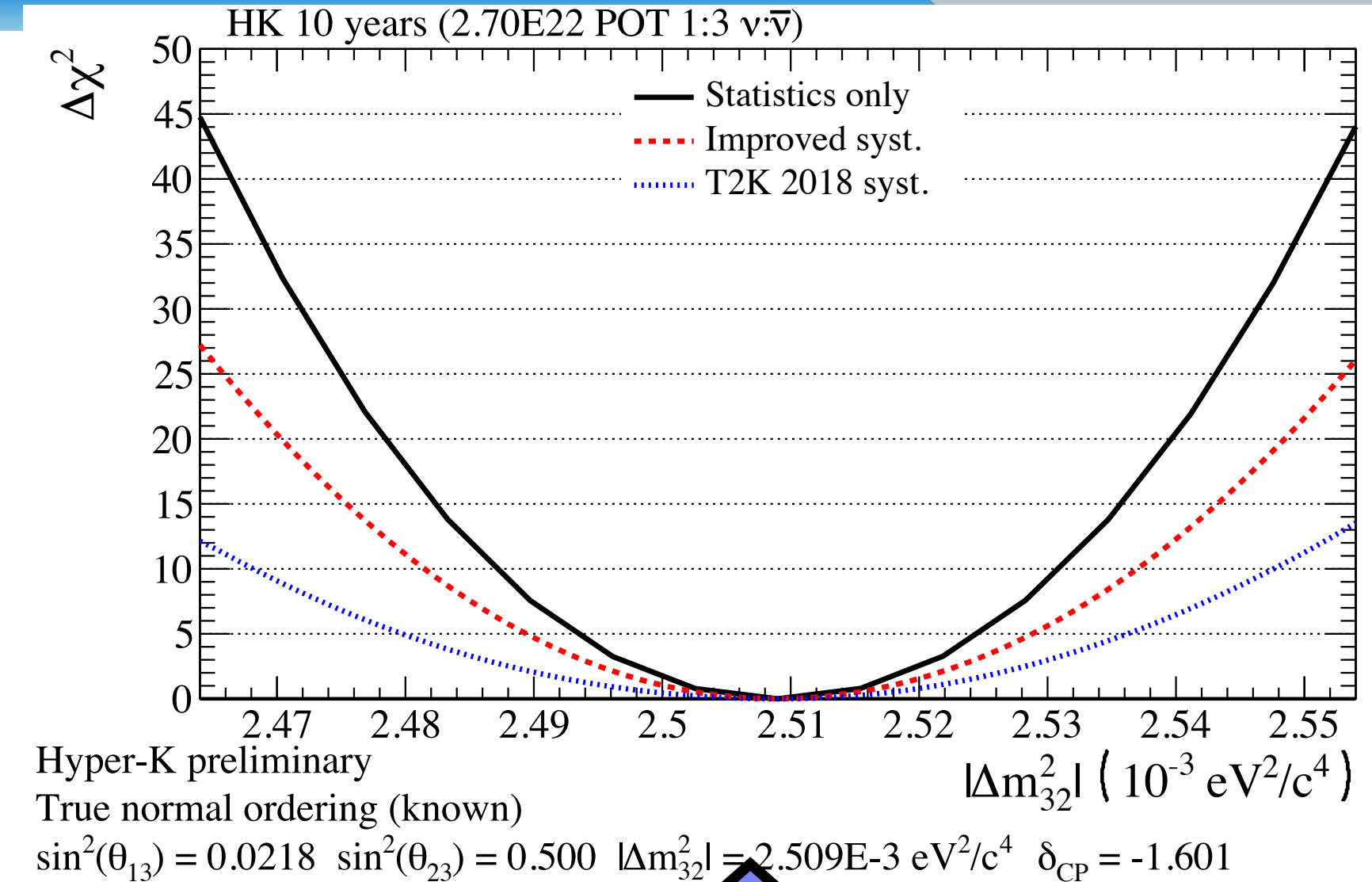
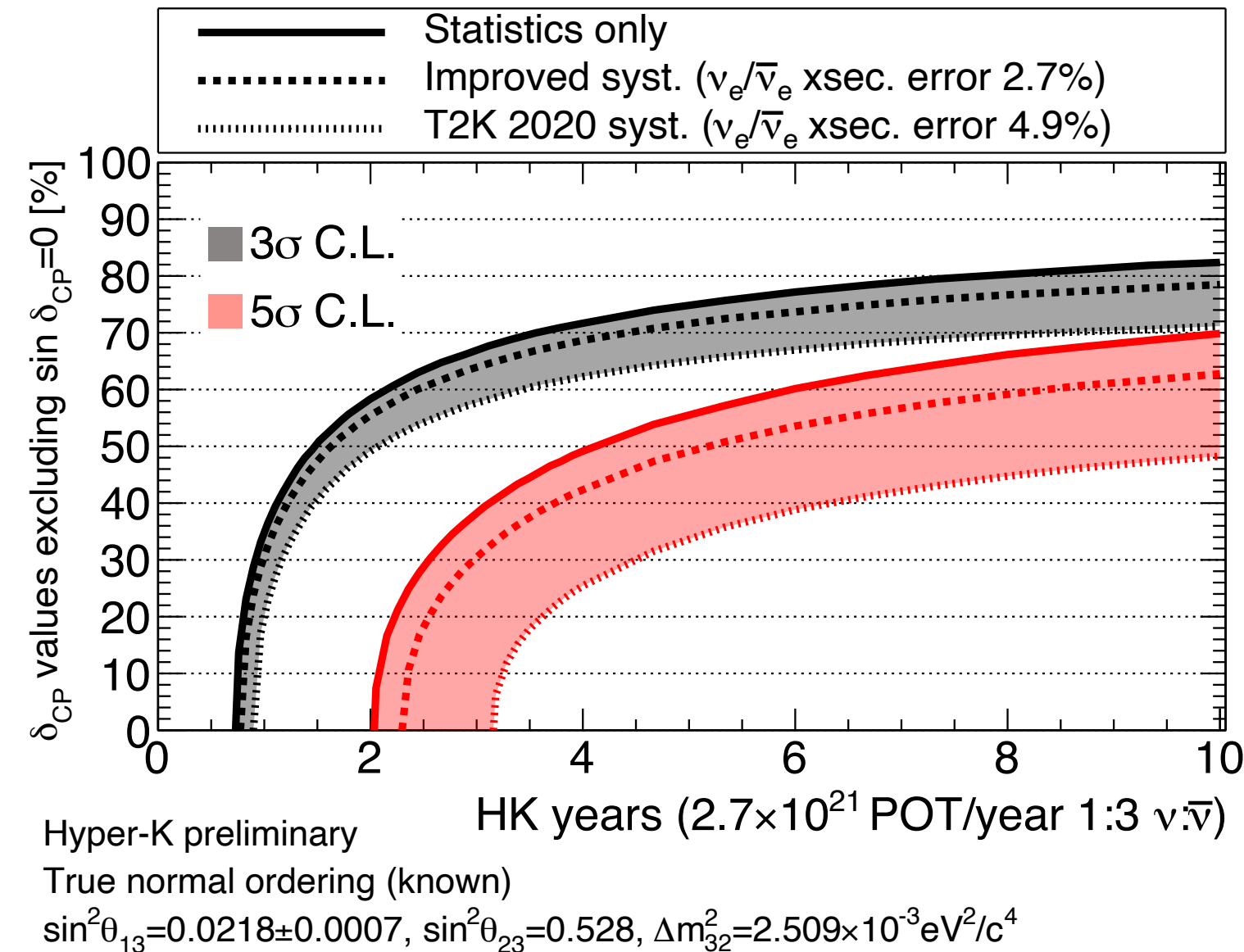
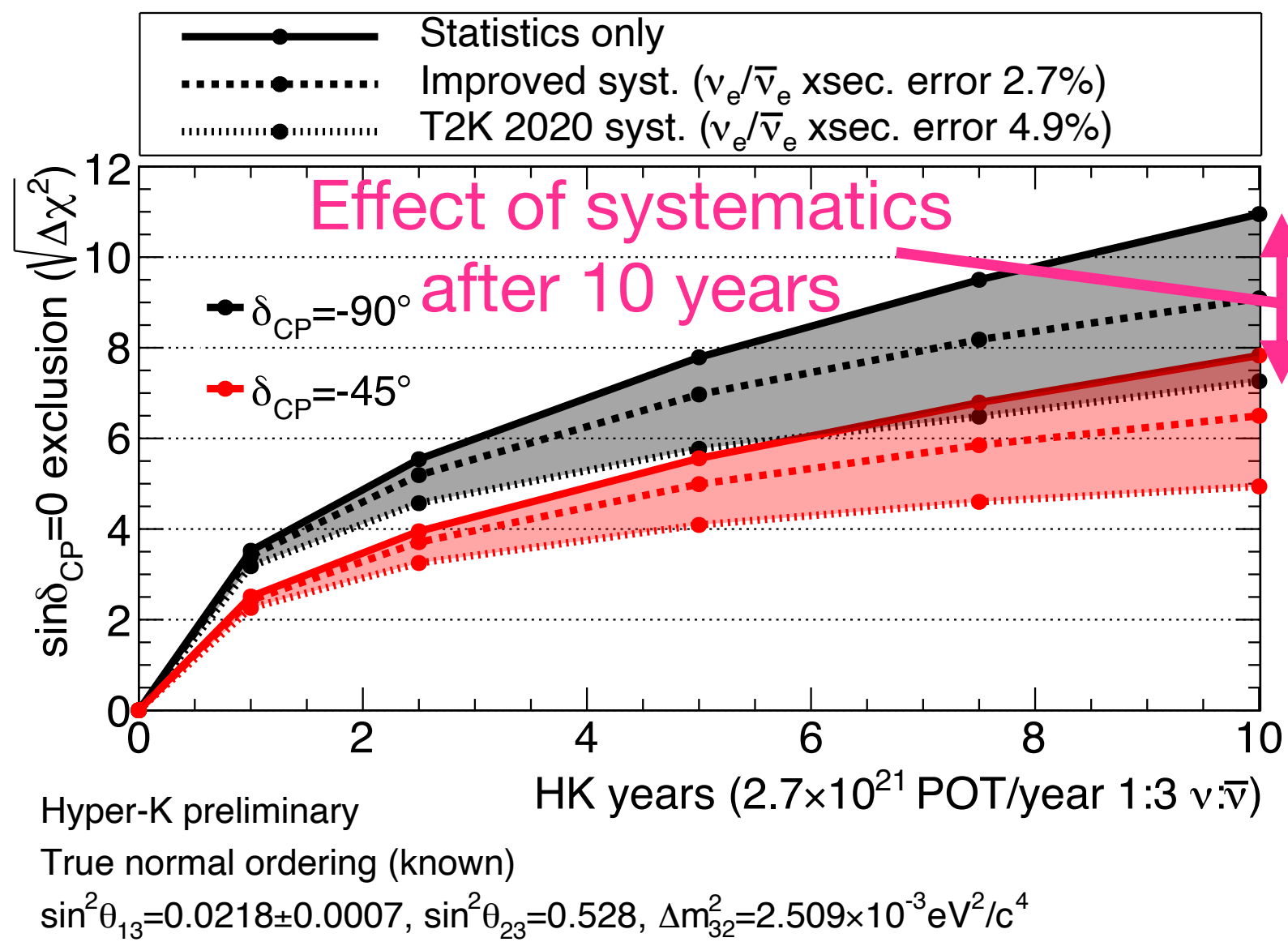
- Generally, the same configuration as T2K
 - **2.5° off-axis beam**, peaked at **0.6 GeV** (oscillation maximum at 295km)
 - Relatively **small matter effect** & **large CP effect**
 - Major interaction channel is CCQE; primary information from (p, θ) of charged lepton
 - CP measurement by comparison of appearance probabilities $P(\nu_\mu \rightarrow \nu_e)$ and $P(\bar{\nu}_\mu \rightarrow \bar{\nu}_e)$
 - **>1000 events each** for ν_e and $\bar{\nu}_e$ signals after 10 years of operation
 - Directly utilize the expertise from T2K + improvements based on experience
 - Beamline and ND280 already exist; improvements with HK + IWCD

Atmospheric neutrinos

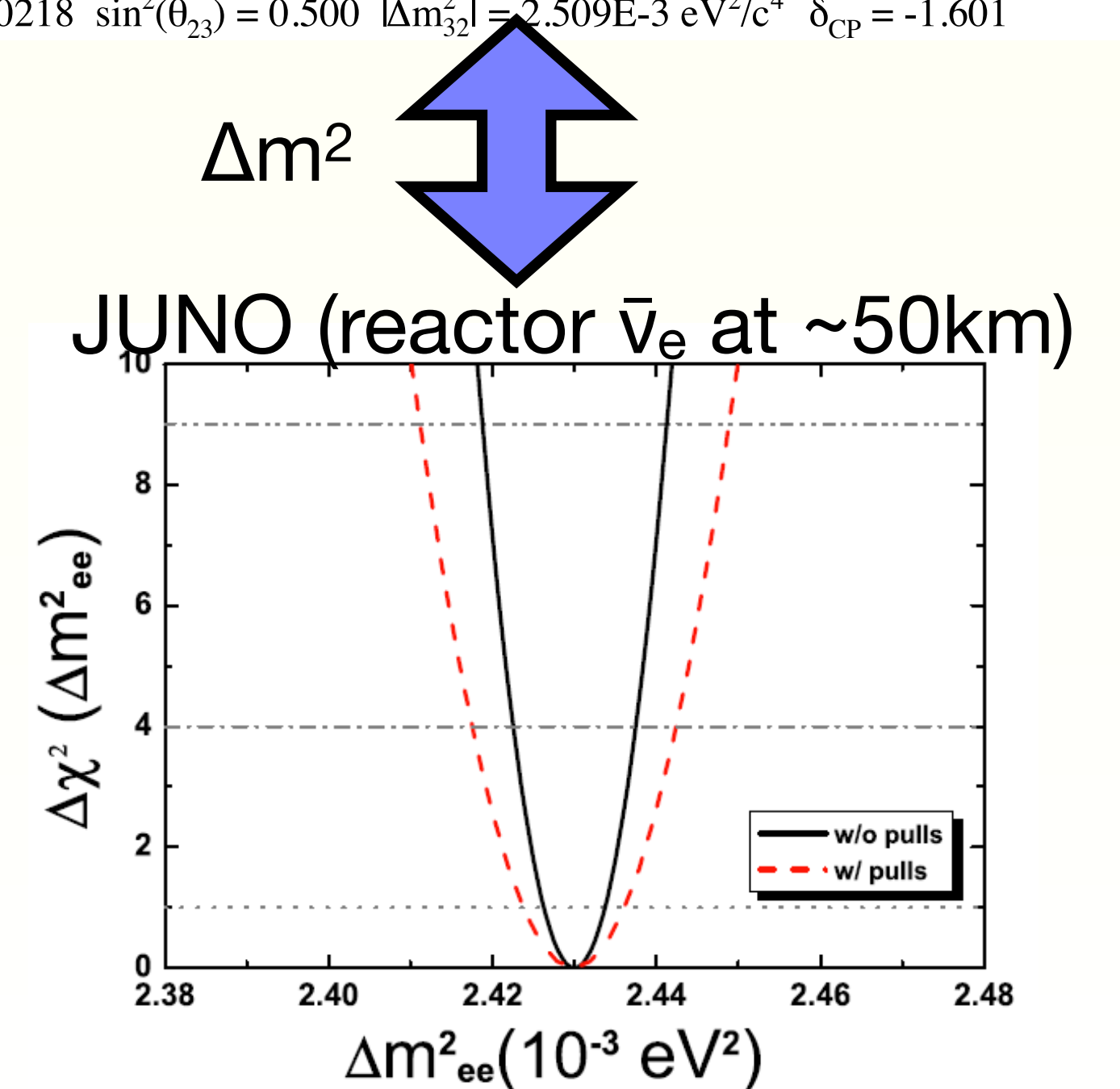
- ~80 events/day
- Wide range of energy and flight length, all flavors of ν and $\bar{\nu}$
- Various studies of neutrino properties, including exotic models
- Good sensitivity to mass ordering with matter effect through the Earth



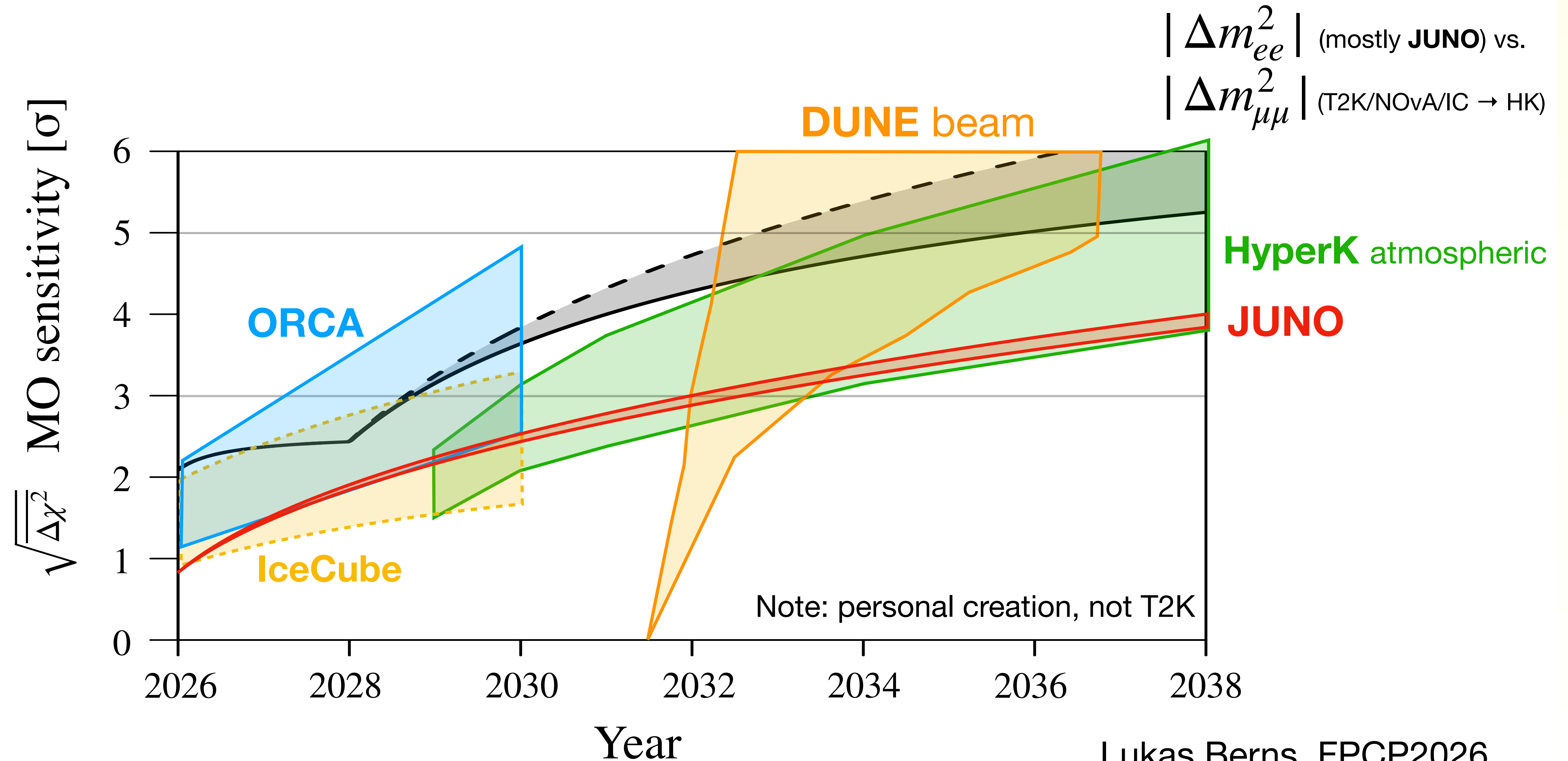
Neutrino Oscillation Measurements



- After 10 years,
 - $>5\sigma$ CPV for $\sim 60\%$ of δ_{CP} values
 - 1σ uncertainty $\sim 20^\circ$ for $\delta_{\text{CP}}=-90^\circ$, $\sim 6^\circ$ for $\delta_{\text{CP}}=0^\circ$
- Precision measurements of parameters and consistency checks of three flavor mixing (together with other experiments)
- Control of systematic uncertainties is important
- Near Detectors (IWCD+ND280), calibration of detectors, external measurements (hadron production, interactions, ..)

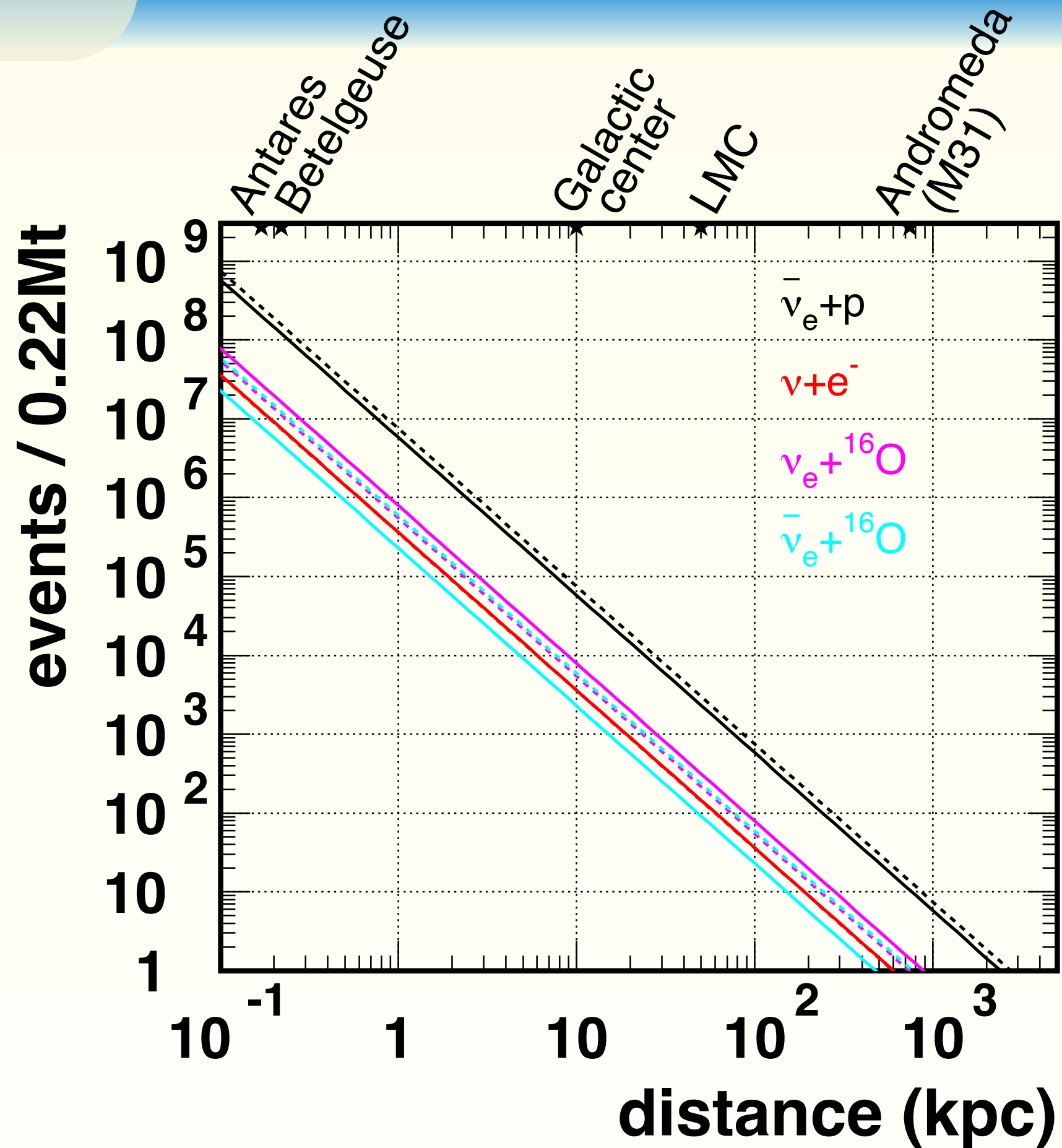


Mass ordering

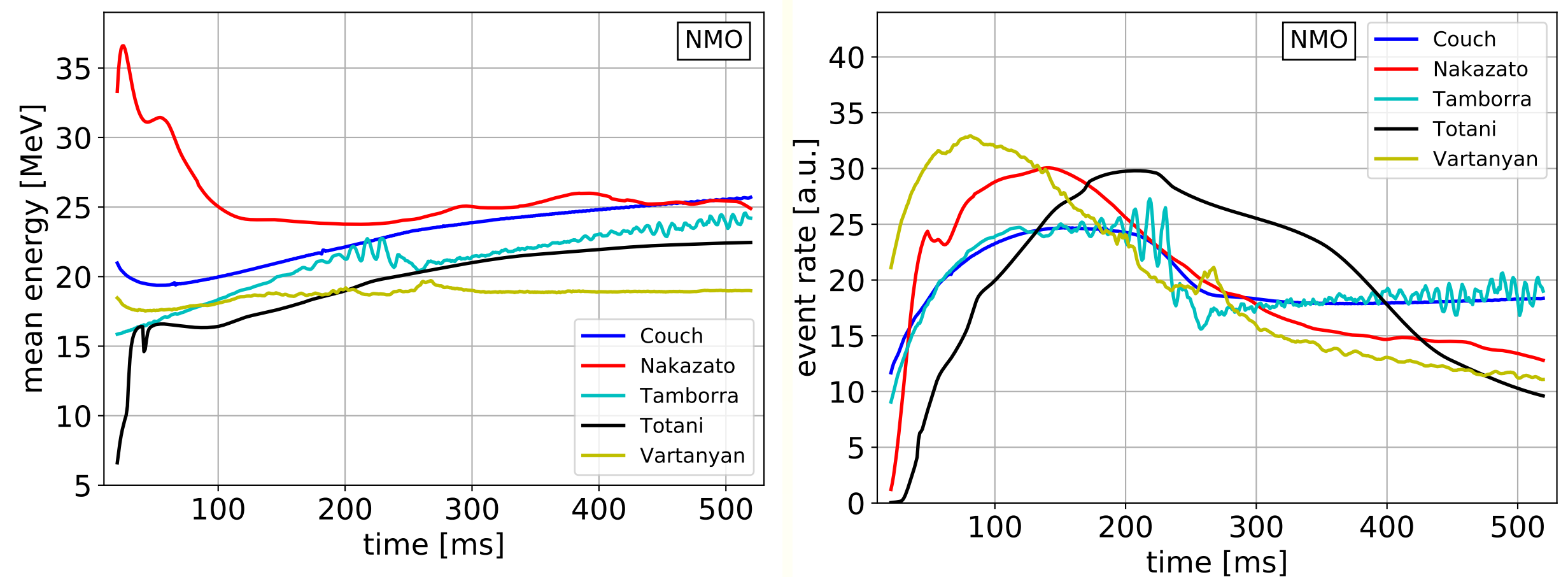


Lukas Berns, FPCP2026

Supernova burst neutrinos

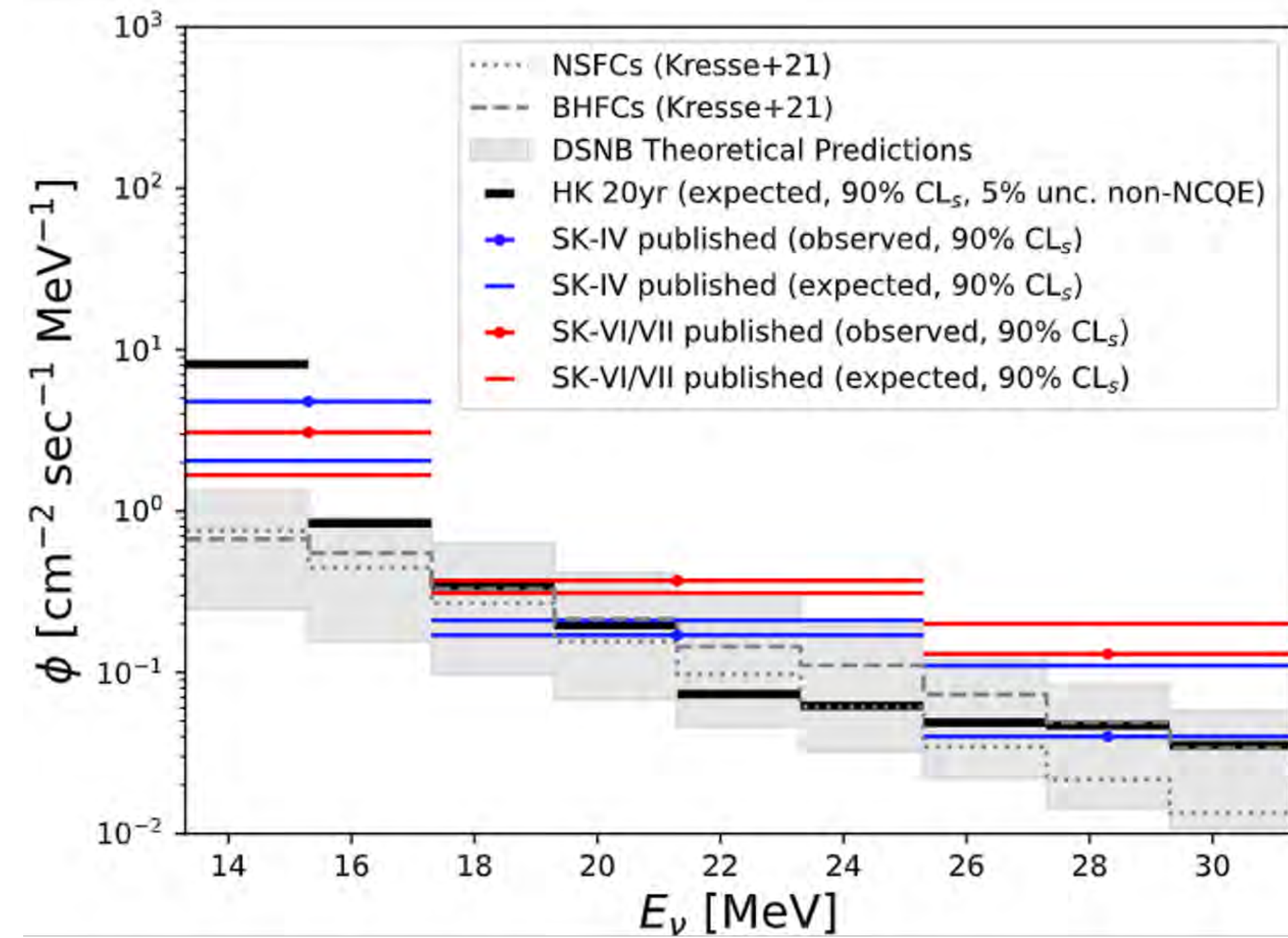
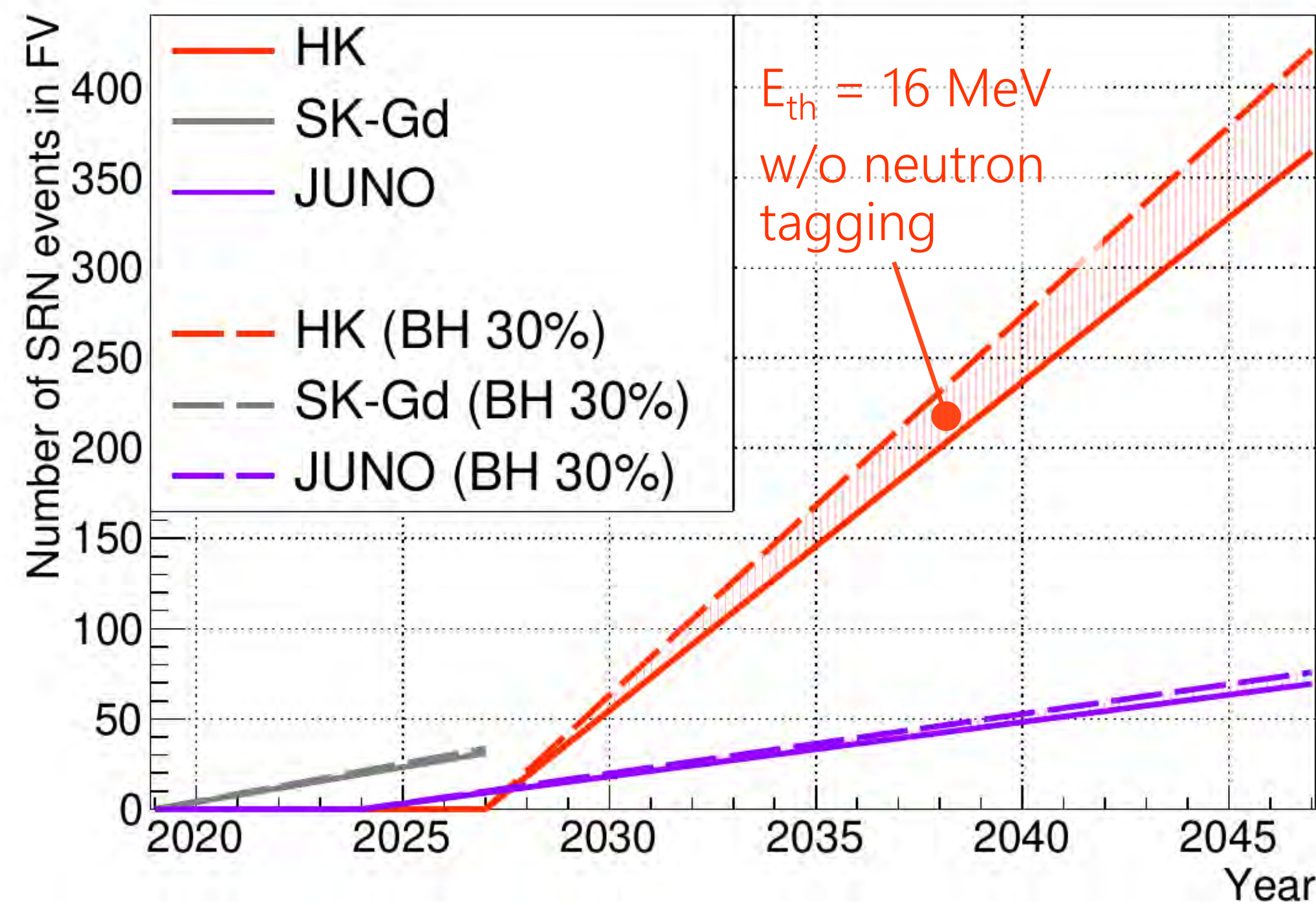


"Supernova Model Discrimination with Hyper-Kamiokande"
Hyper-Kamiokande Collaboration, *Astrophys.J.* **916** (2021) 1, 15

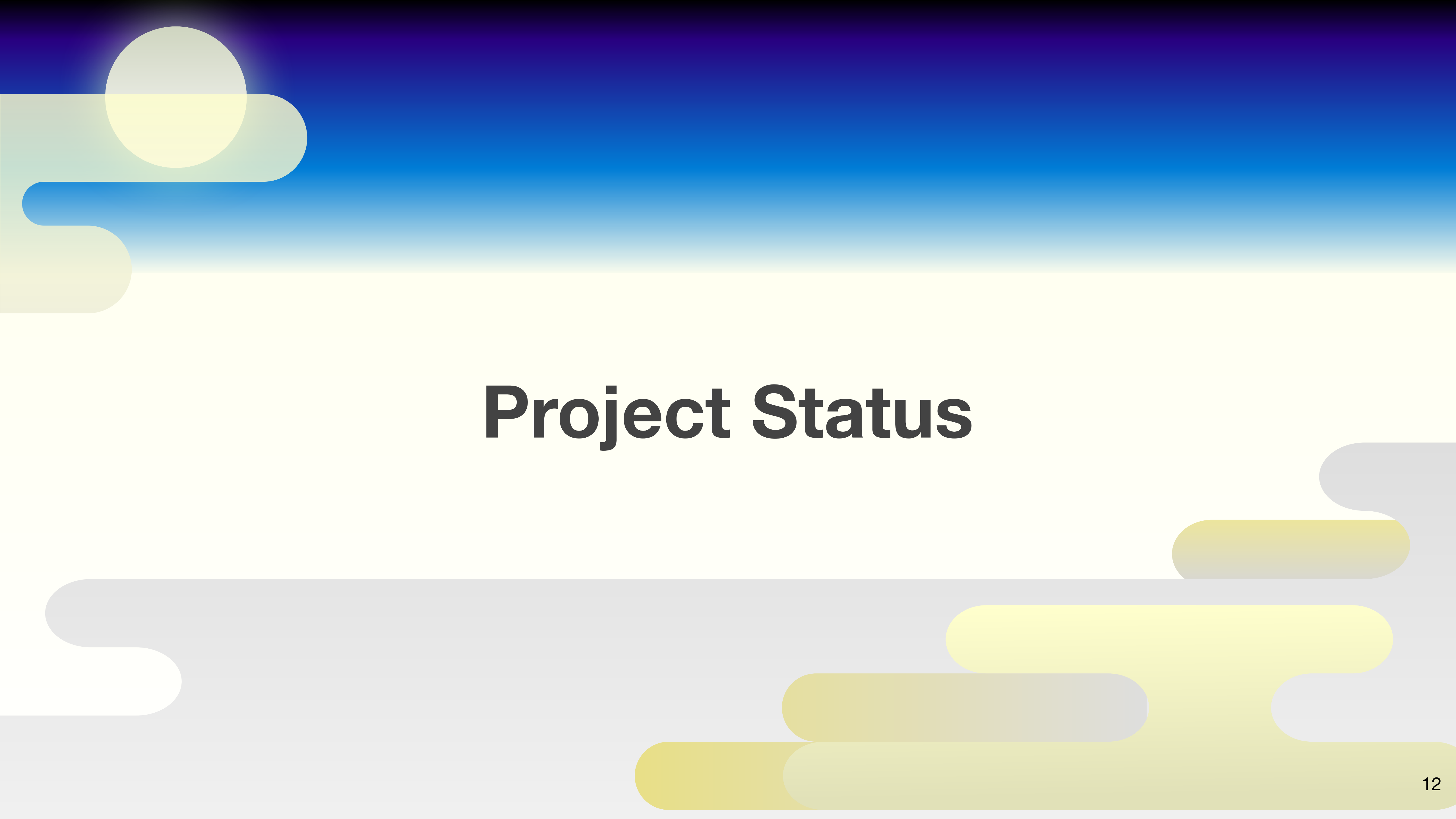


- 50k-80k events expected for an SN at 10kpc
- Time, energy, and direction information
- Detailed information of the explosion mechanism
- Alert with $\sim 1^\circ$ pointing accuracy
- ~ 10 events for a SN in Andromeda

DSNB

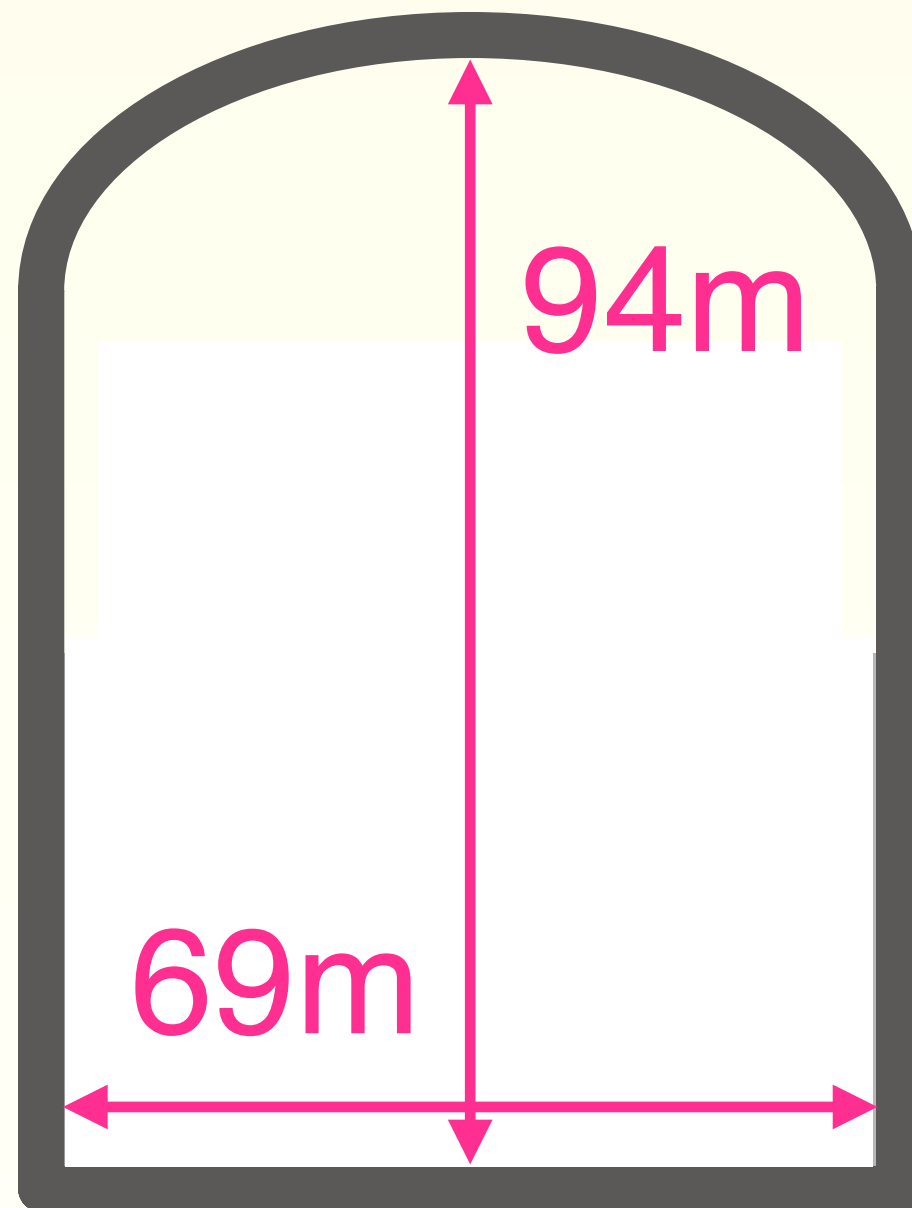


- Sensitivity in rather high energy region
- Expect ~ 4 events / year after selection (w/ pure water)

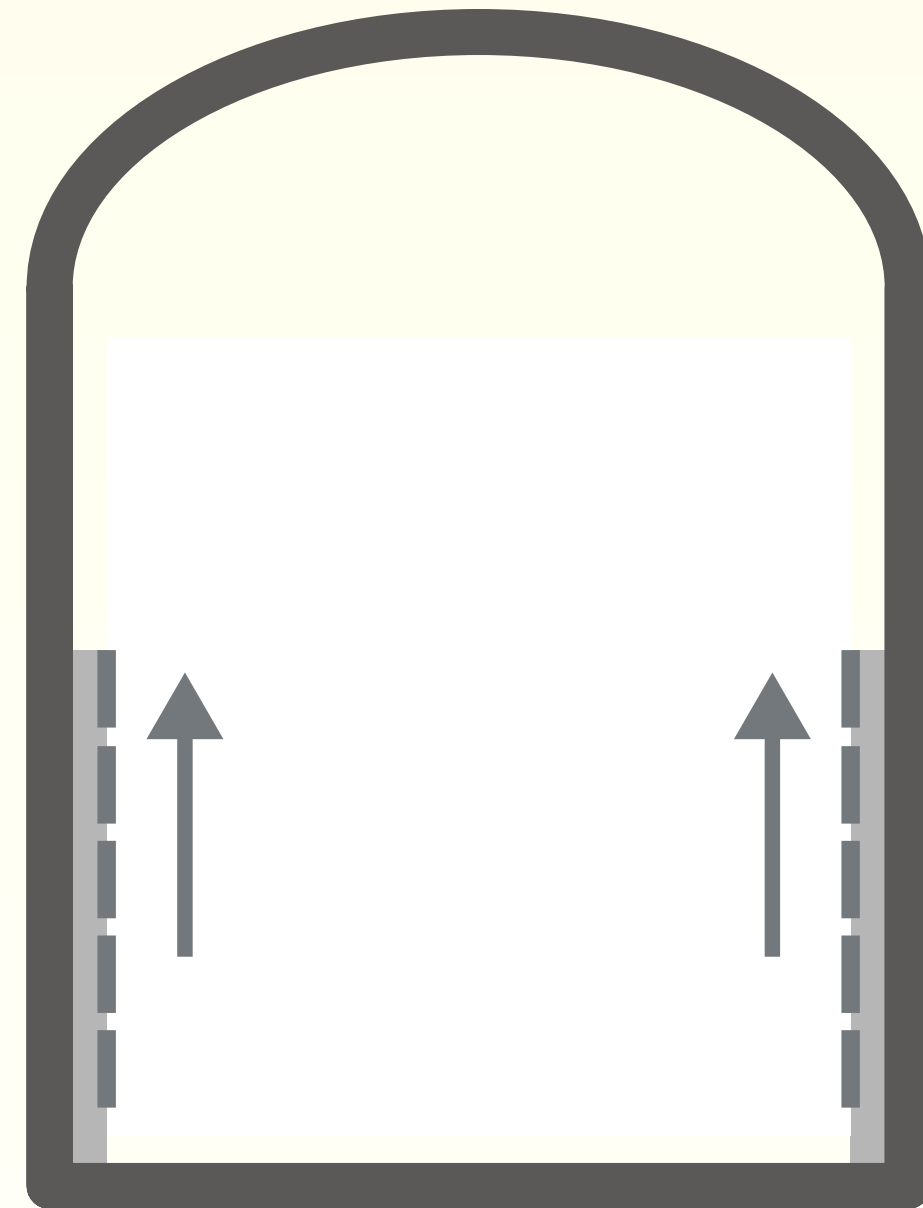


Project Status

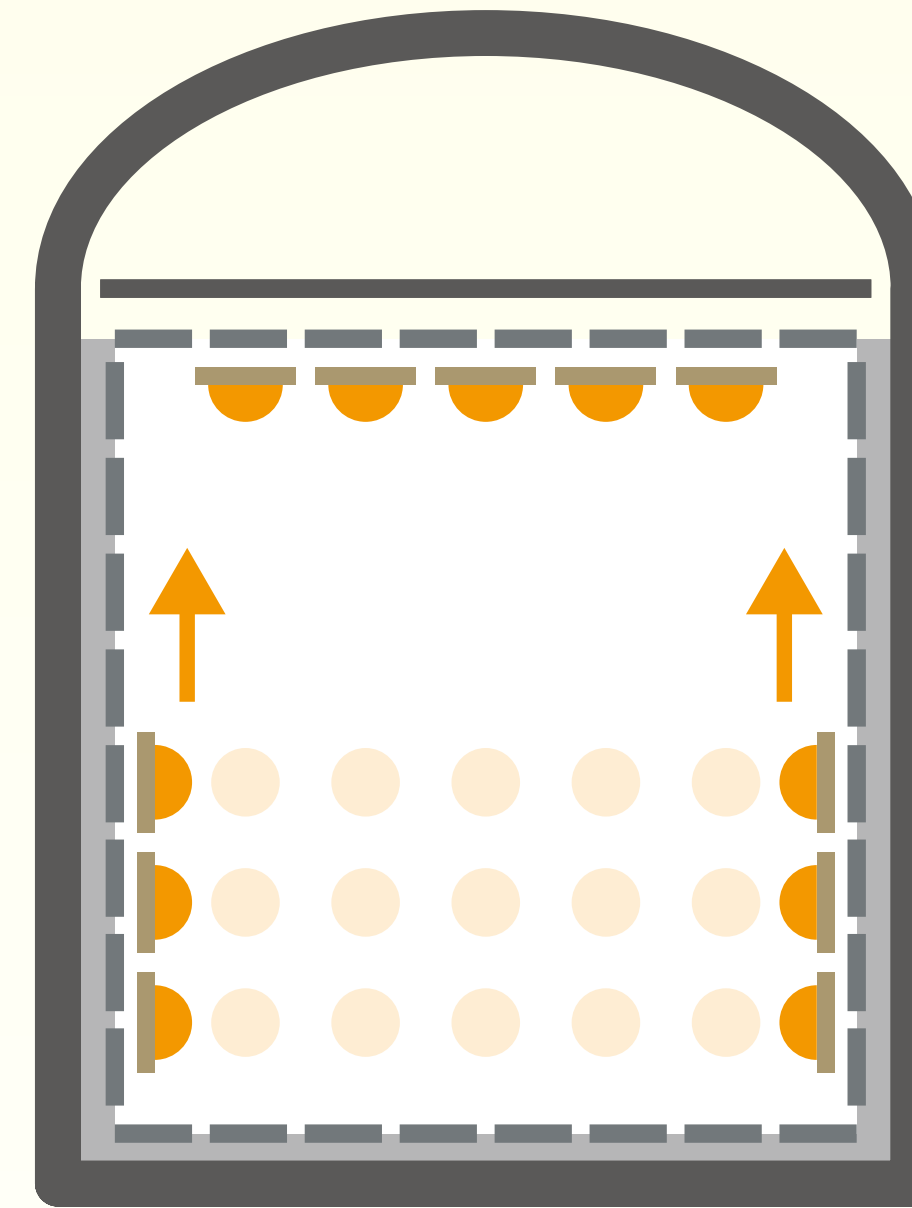
How to construct Hyper-Kamiokande



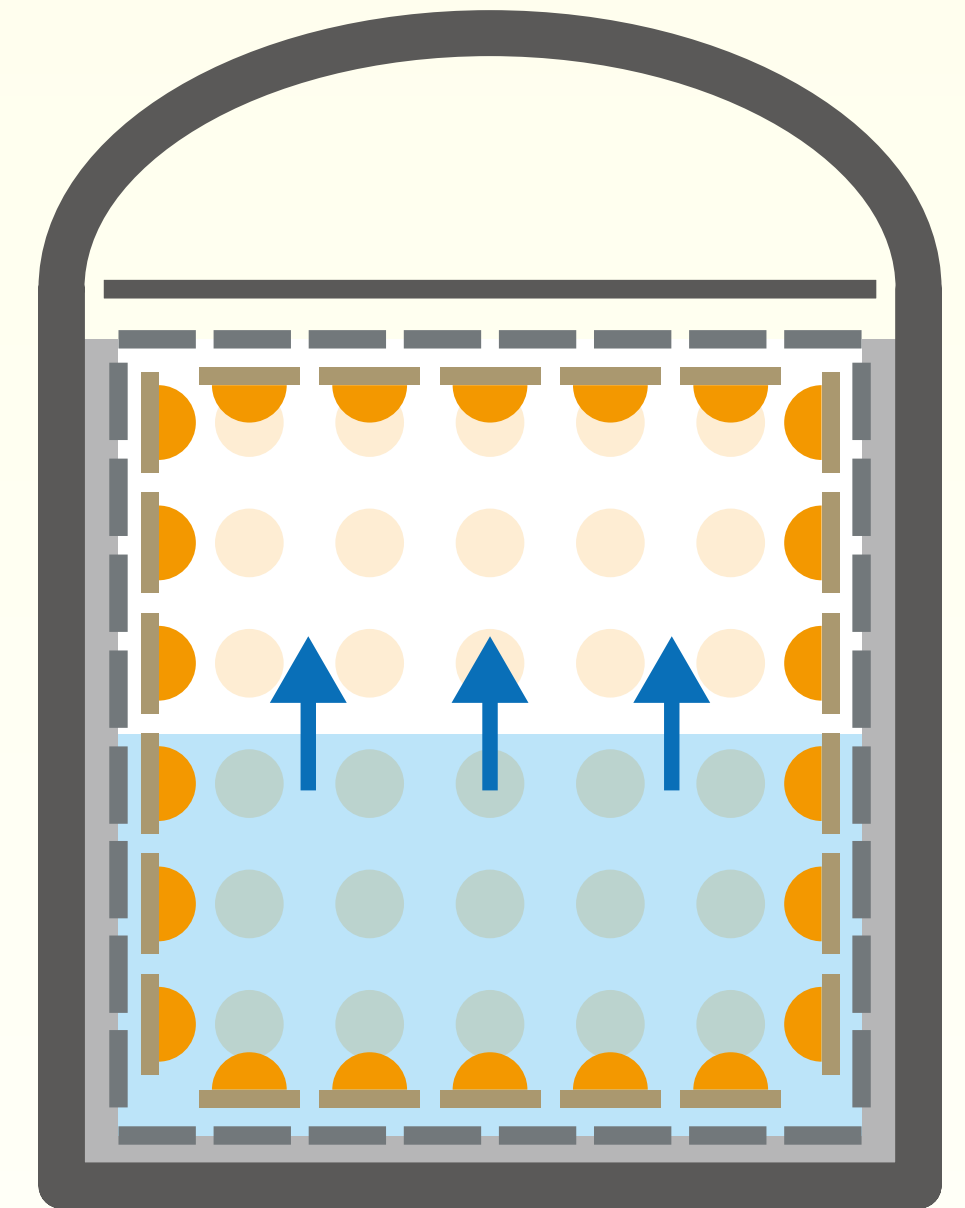
1. Excavate a huge cavern 600m underground



2. Build water tank lining with SUS plates and concrete



3. Intall PMTs and other instruments in parallel to the structure construction



4. Fill with 260kton ultrapure water

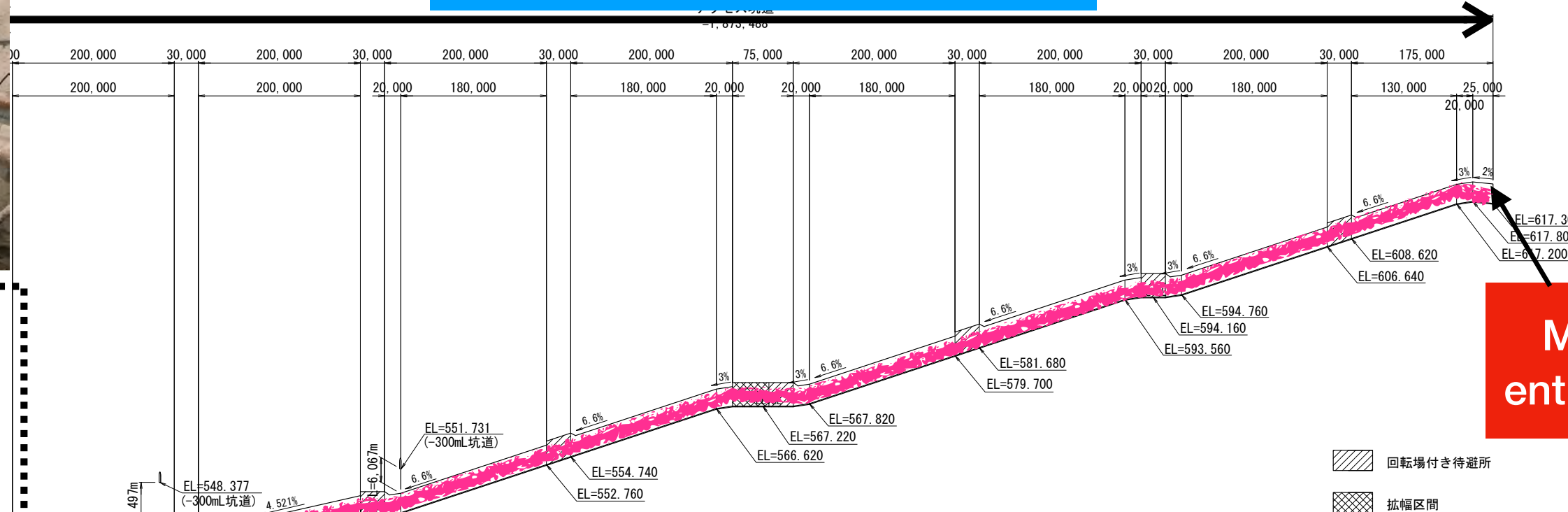
Completed

June 2022

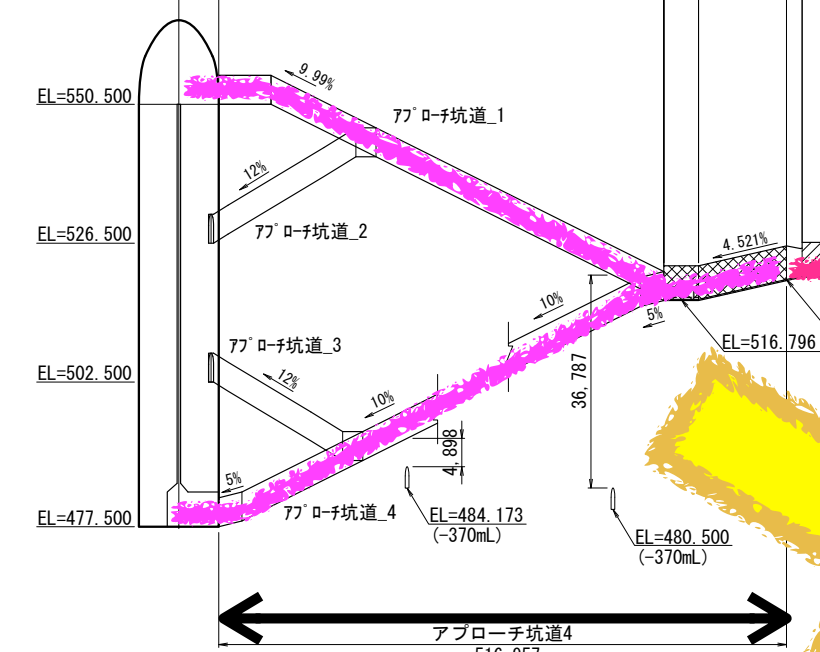
Excavation



Access tunnel (~2km)



HK cavern

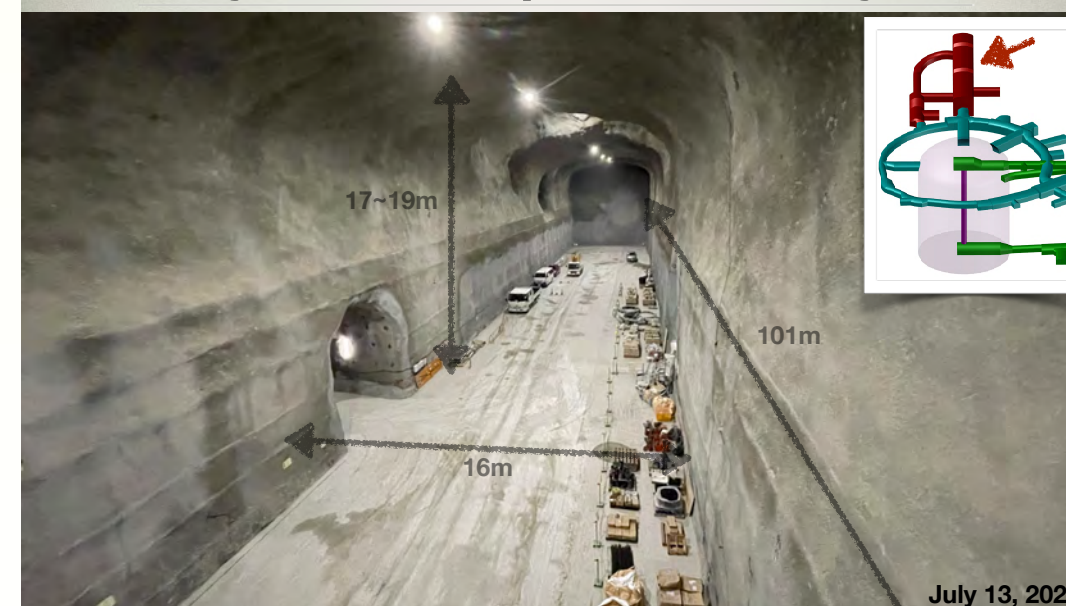


Approach tunnel

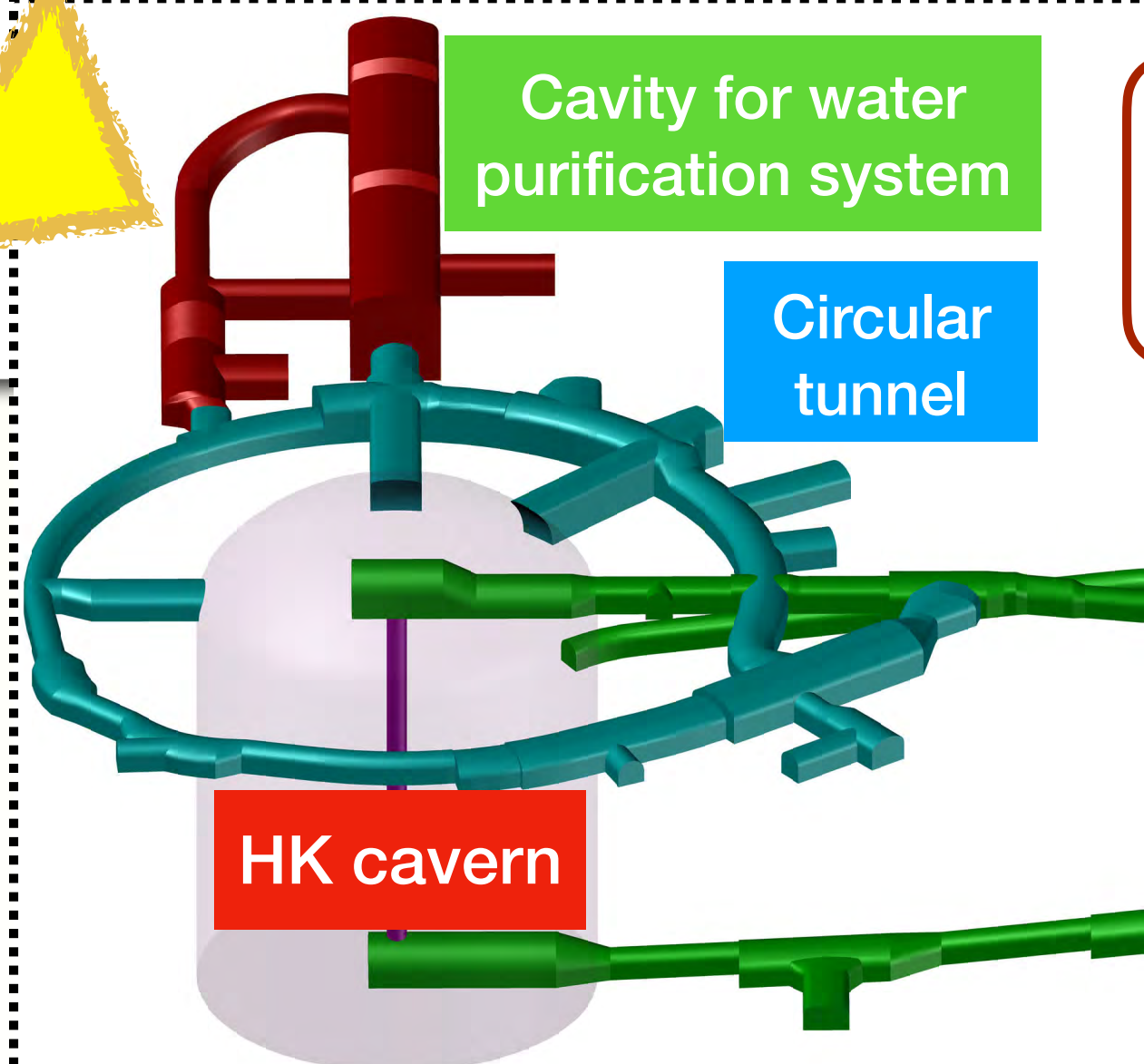
Mine entrance

Around the Hyper-K cavern

Cavity for water purification system



- The size of the cavity for the water purification system is approximately half that of Super-K tank



HK cavern 'dome section' completed



Hyper-K construction began in 2021

Groundbreaking ceremony on May 28th, 2021



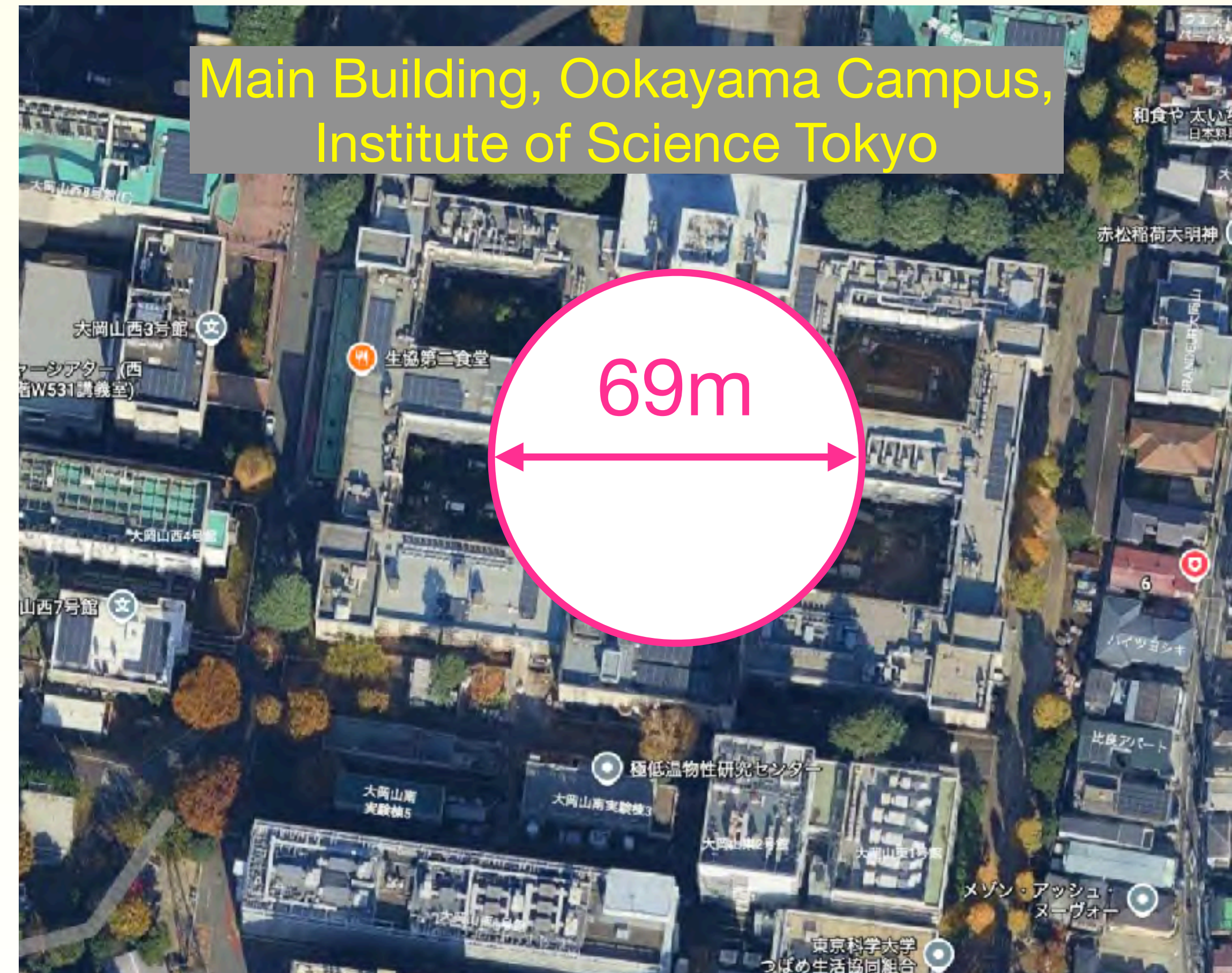
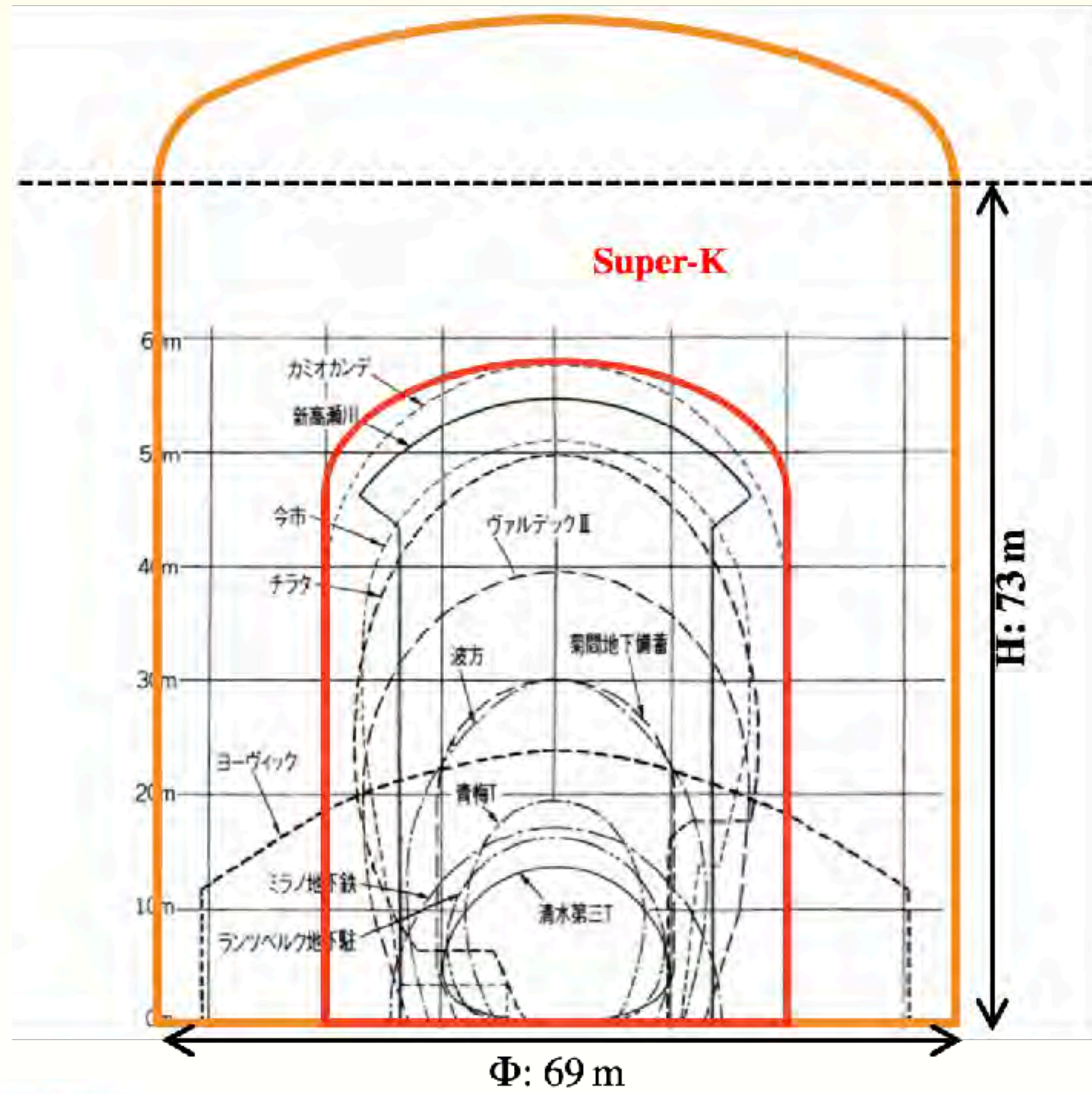
ハイパーカミオカンデ 着工記念式典
Hyper-Kamiokande Groundbreaking Ceremony
—Institute for Cosmic Ray Research, The University of Tokyo—

- Excavation work began in May 2021

May 2021

Oct. 2023

Huge underground cavern



Cavern Excavation Completed: July 2025

Awards received

- The Mining and Materials Processing Institute of Japan
- Japanese Geotechnical Society
- Japan Society of Civil Engineers

Paper published in PTEP:

Y. Asaoka et al., “Excavation of a 69-m diameter and 94-m high cavern for the Hyper-Kamiokande detector,”
Progress of Theoretical and Experimental Physics,
Volume 2026, Issue 7, July 2026, 073H01,
DOI: <https://doi.org/10.1093/ptep/ptag091>



Water tank lining

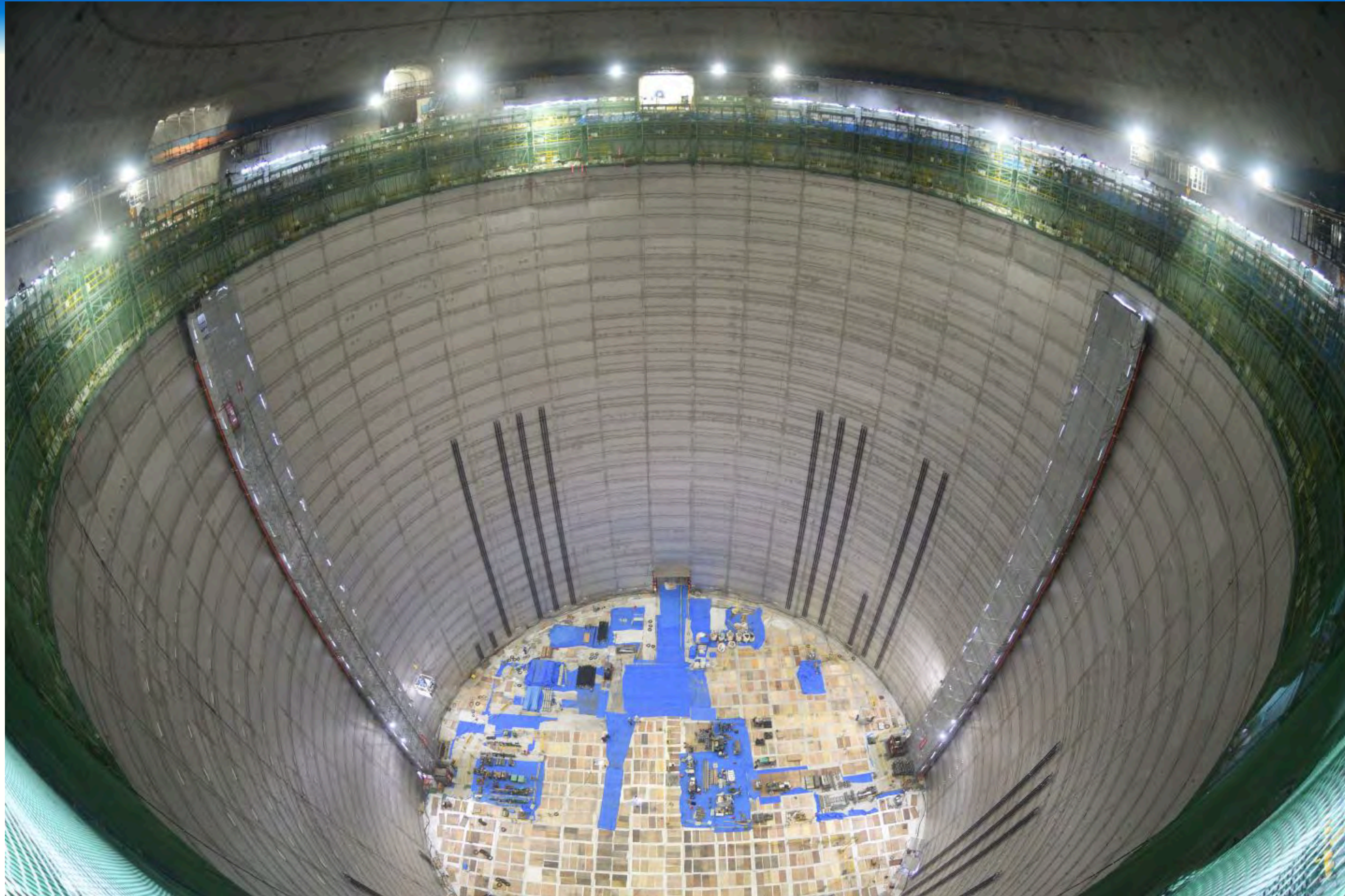


Weld SUS plates to make the water tank
Fill concrete between the plates and bedrock

From bottom to top with a mobile scaffolding
3830 SUS plates, total welding 14.4km



Lining complete: July 2026



Pure water system

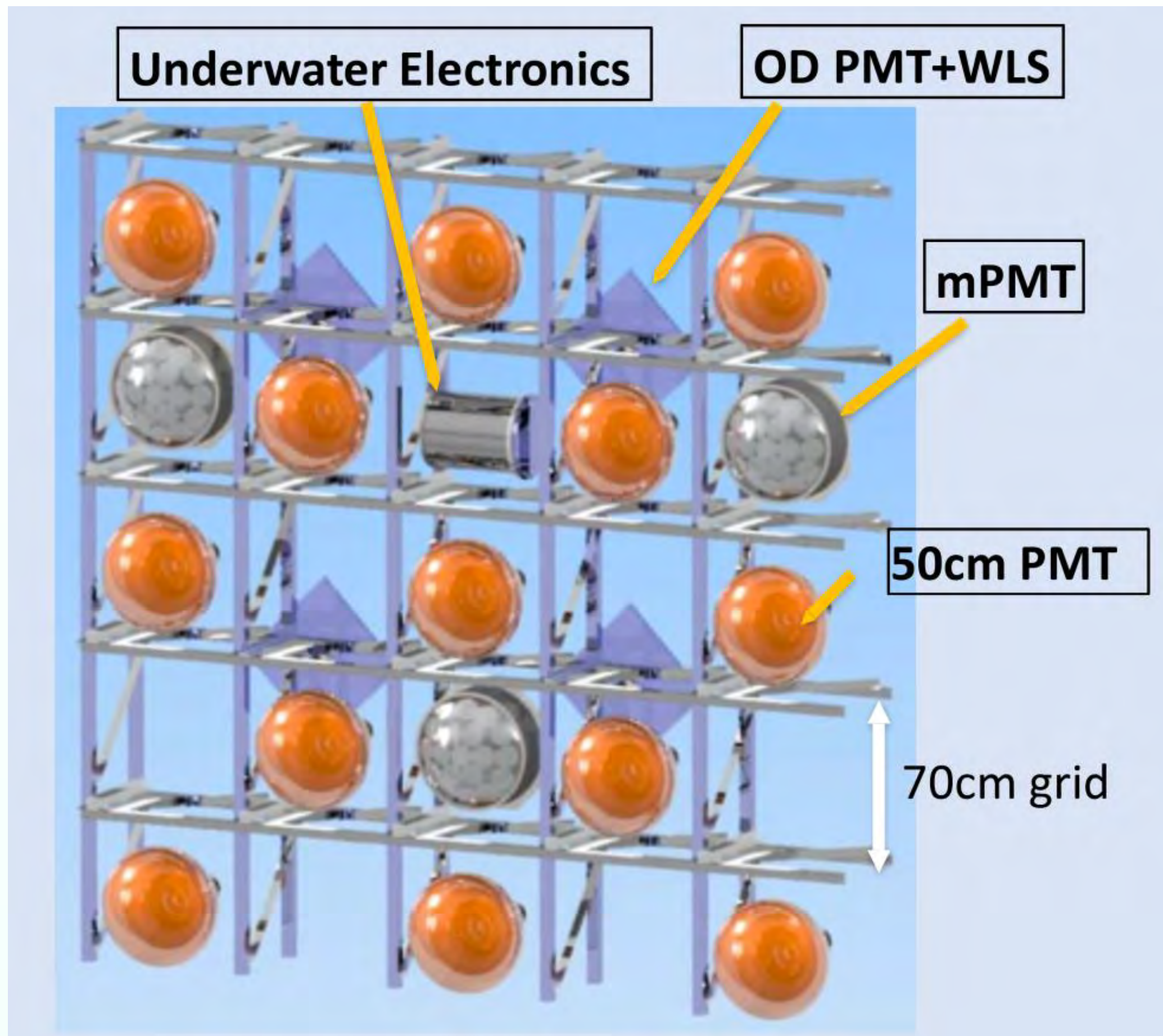


Water system room:
~half of Super-Kamiokande volume



Water system already installed and waiting for operation

Hyper-K detector system

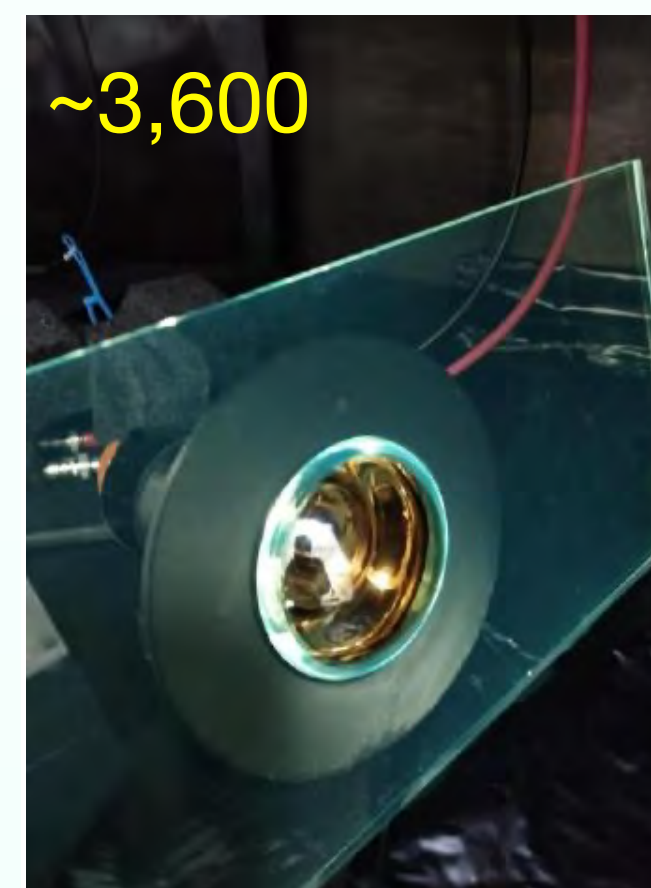


All material is tested to be ultrapure and Gd-loaded water compatible

50cm PMT



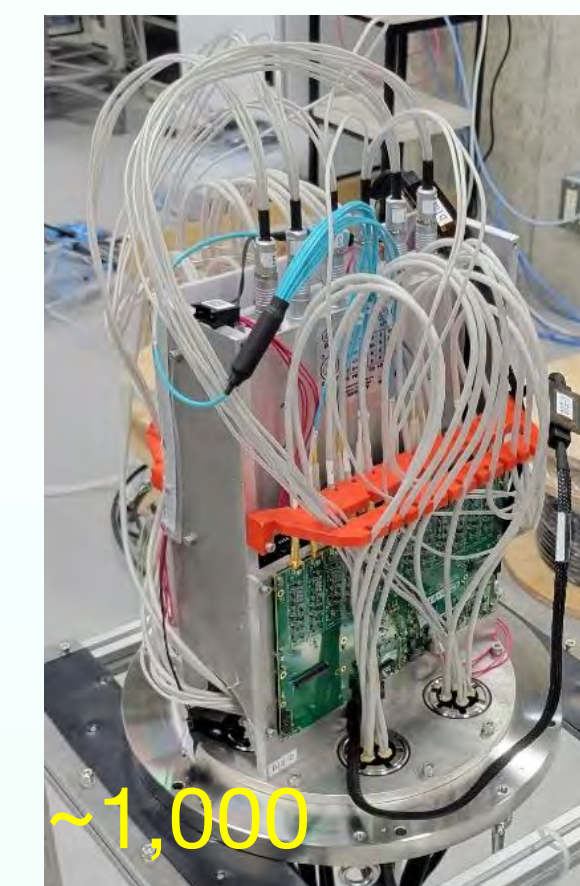
8cm PMT + WLS plate for Outer Detector



multi-PMT module
(ref. KM3NeT)



Underwater electronics



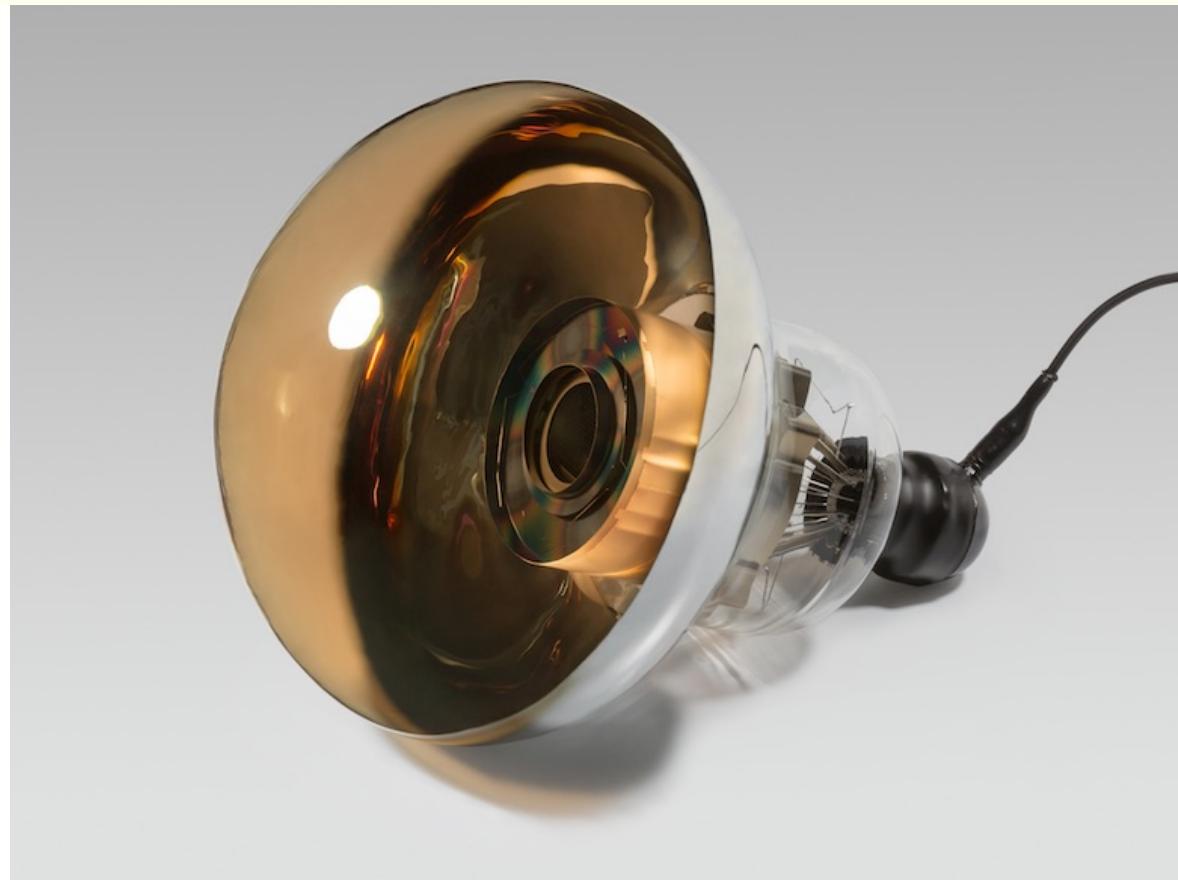
Mockup for integration test



Mass production is ongoing with global collaboration

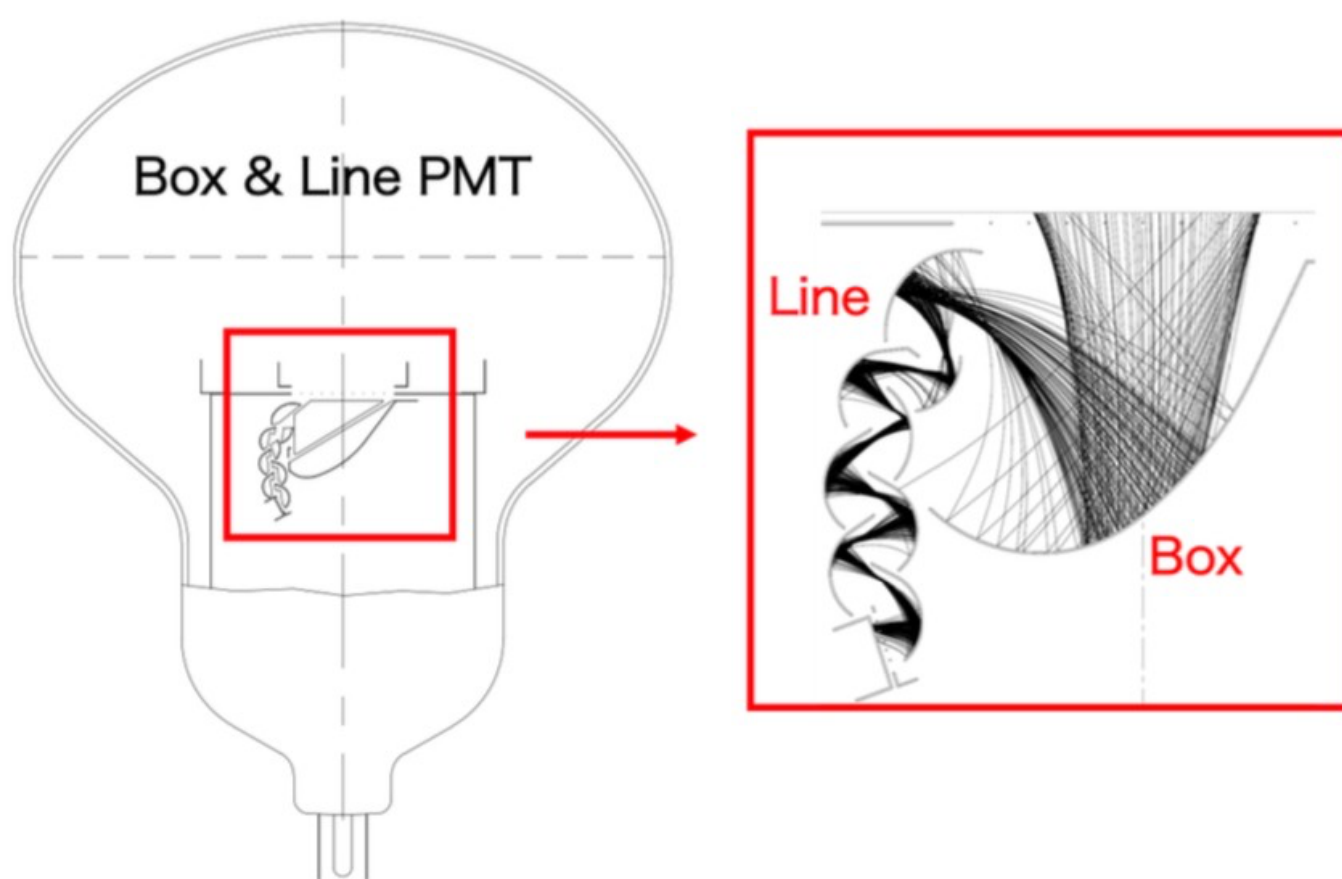
Improved PMT performance

Hamamatsu R12860



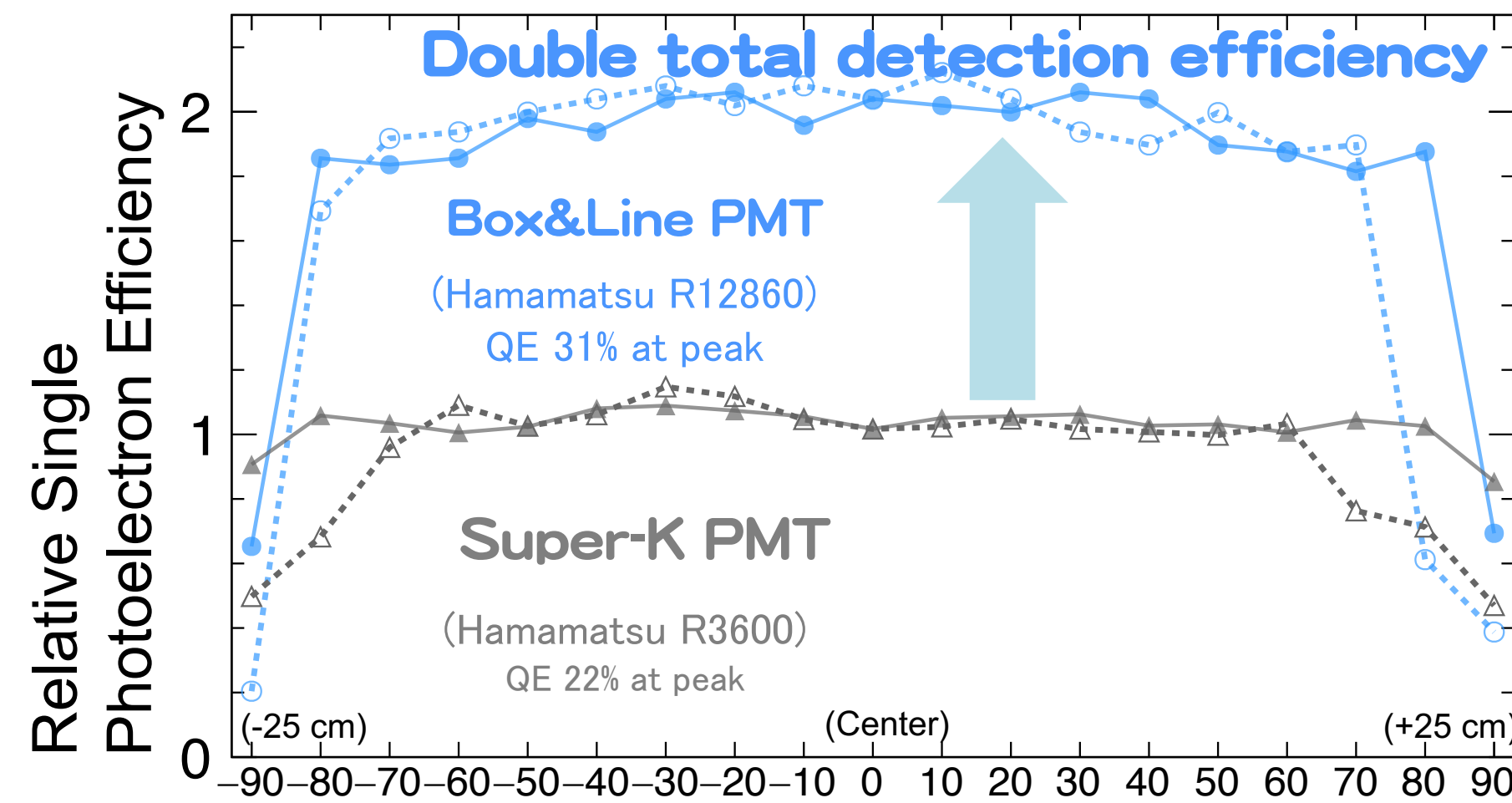
Newly developed for HK

Box&Line dynode



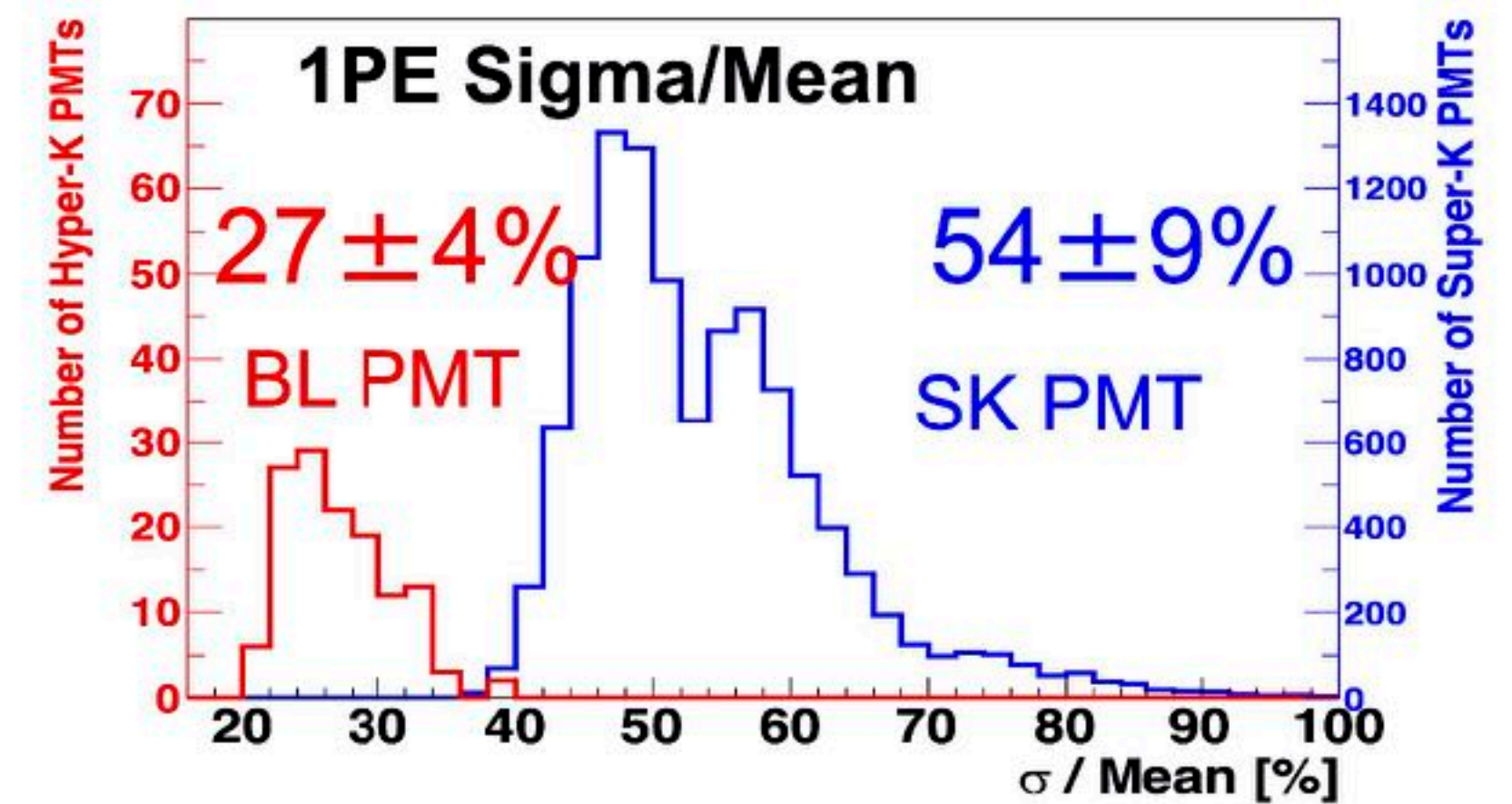
x2 better photodetection efficiency (QE×CE)

→ Even with 20% photocoverage,
similar number of photons with SK(40%)



(Performance in SK tank, $1.7e7$ gain)

x2 better charge resolution



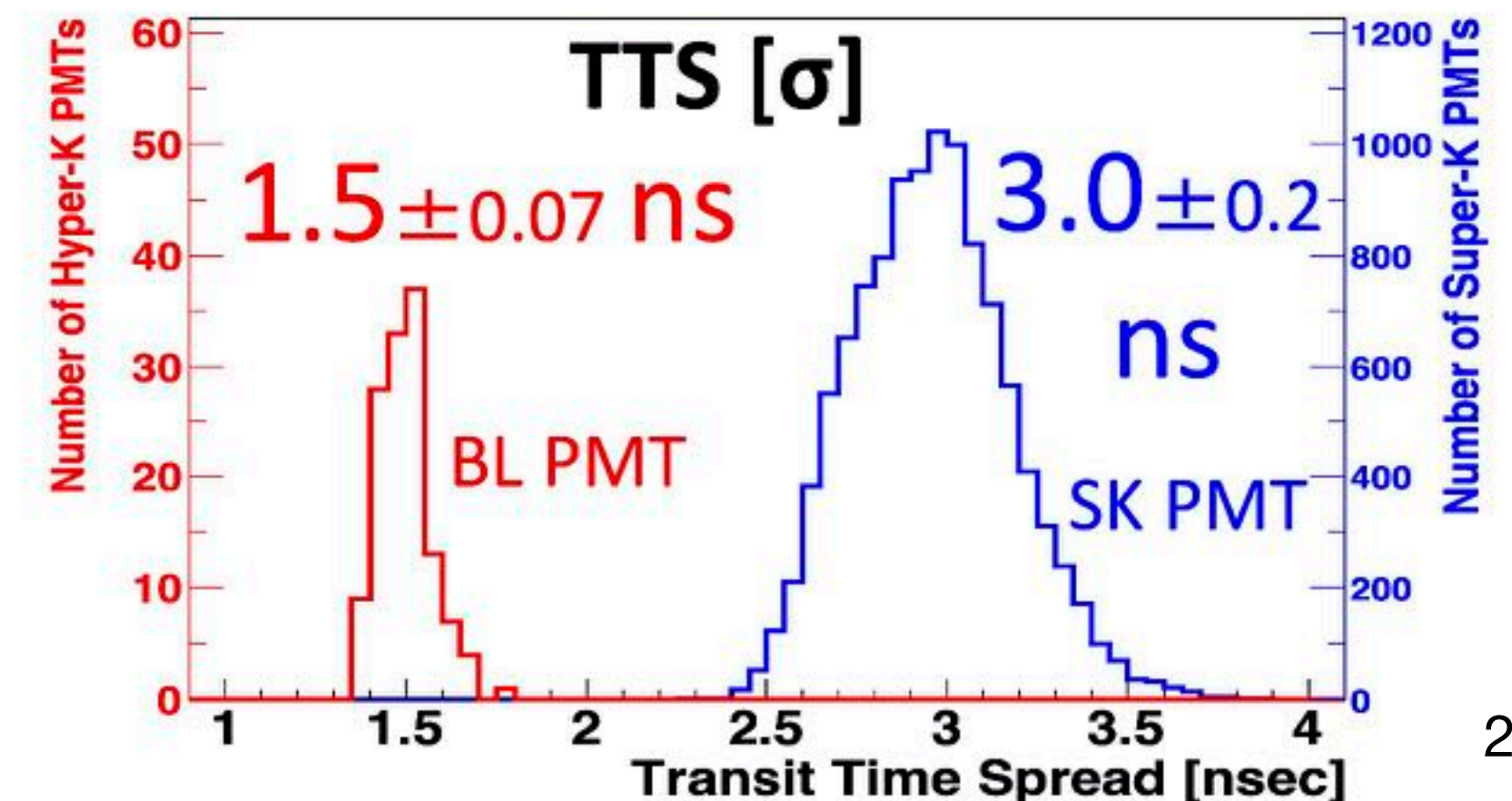
x2 better pressure tolerance

→ enable taller tank,
design optimization

All PMTs will be tested $>0.85\text{MPa}$

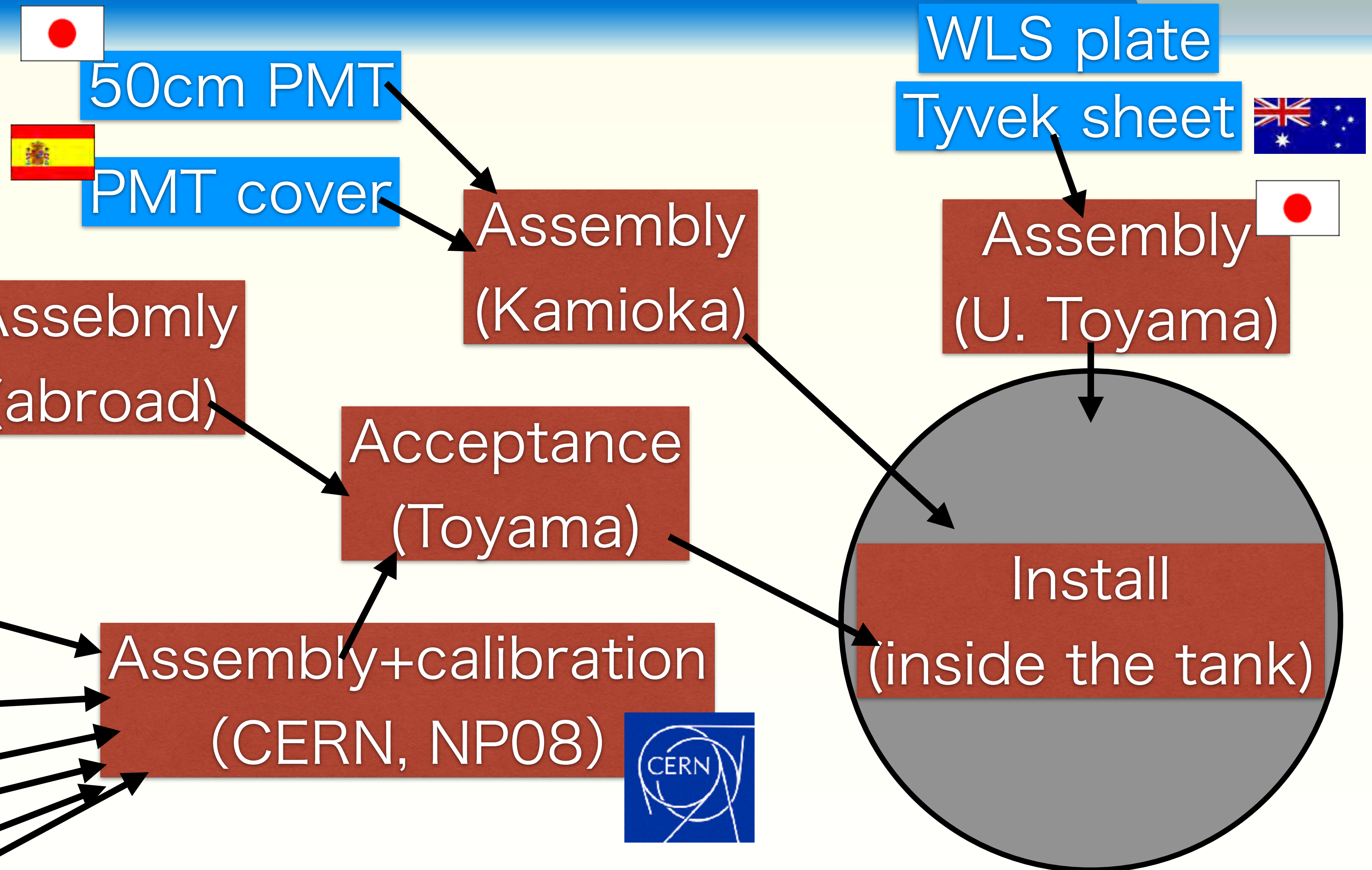
Low dark rate ($\sim 4\text{kHz}$) and RI

x2 better timing resolution



Towards construction

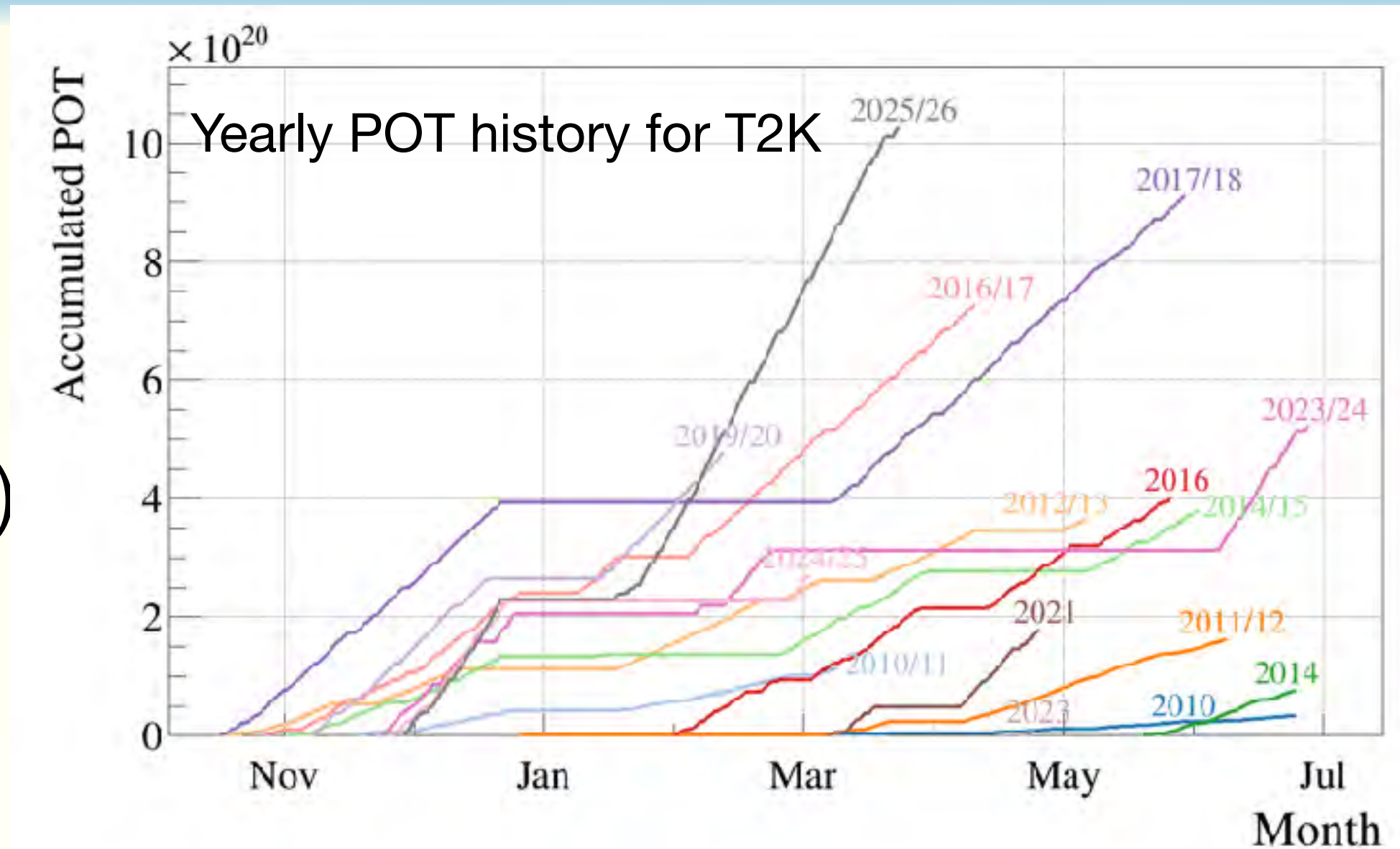
Production and assembly
across the world



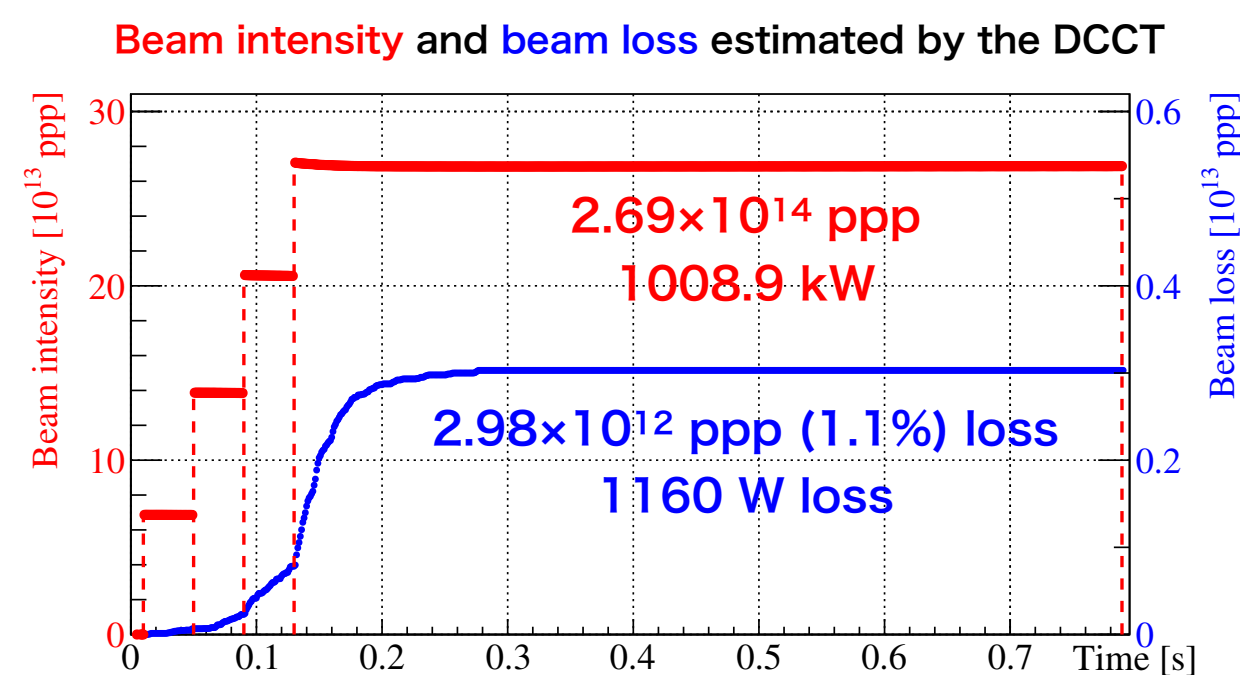
Massive construction work scheduled in 2027
After water filling, operation starts in 2028

Neutrino beam

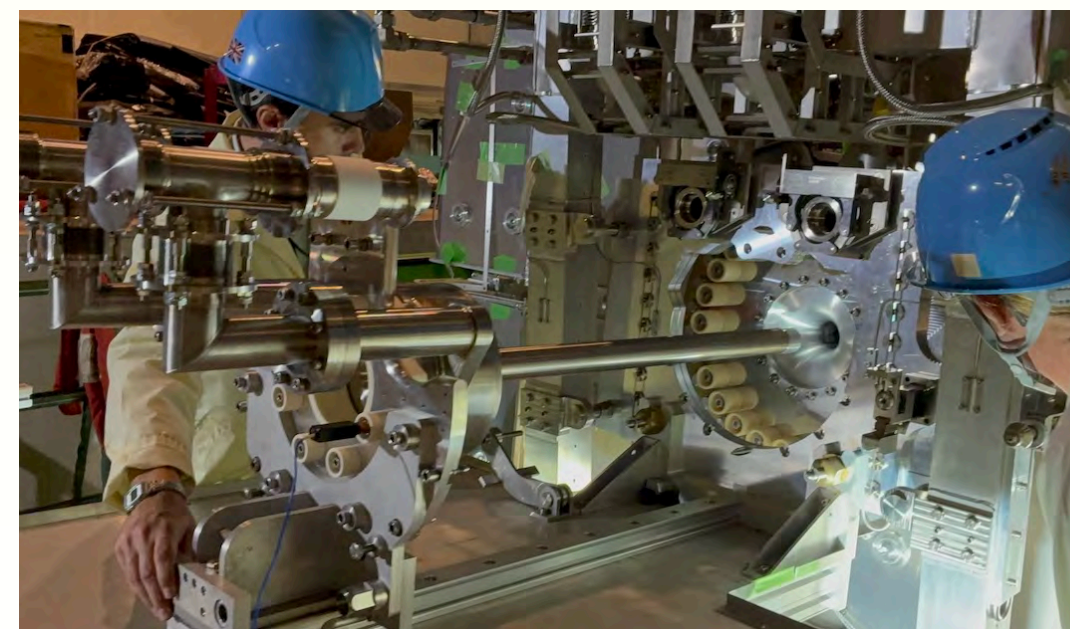
- Increasing the beam power to 1.3MW
 - Increasing protons per pulse
 - Reducing beam cycle
 - Reducing beam loss
- Upgrading beamline (target, coolong, radiation handling, ...)
- Realizing stable operation of 10^7 sec/year
 - Replacement of aged facility/components
 - Upgrade with latest technology
- T2K run is scheduled to finish in May 2027
Commissioning for HK will start



$$\text{Power} = \text{Energy}(30 \text{ GeV}) \times \text{Number of protons} / \text{Cycle time}$$



1MW operation demonstration

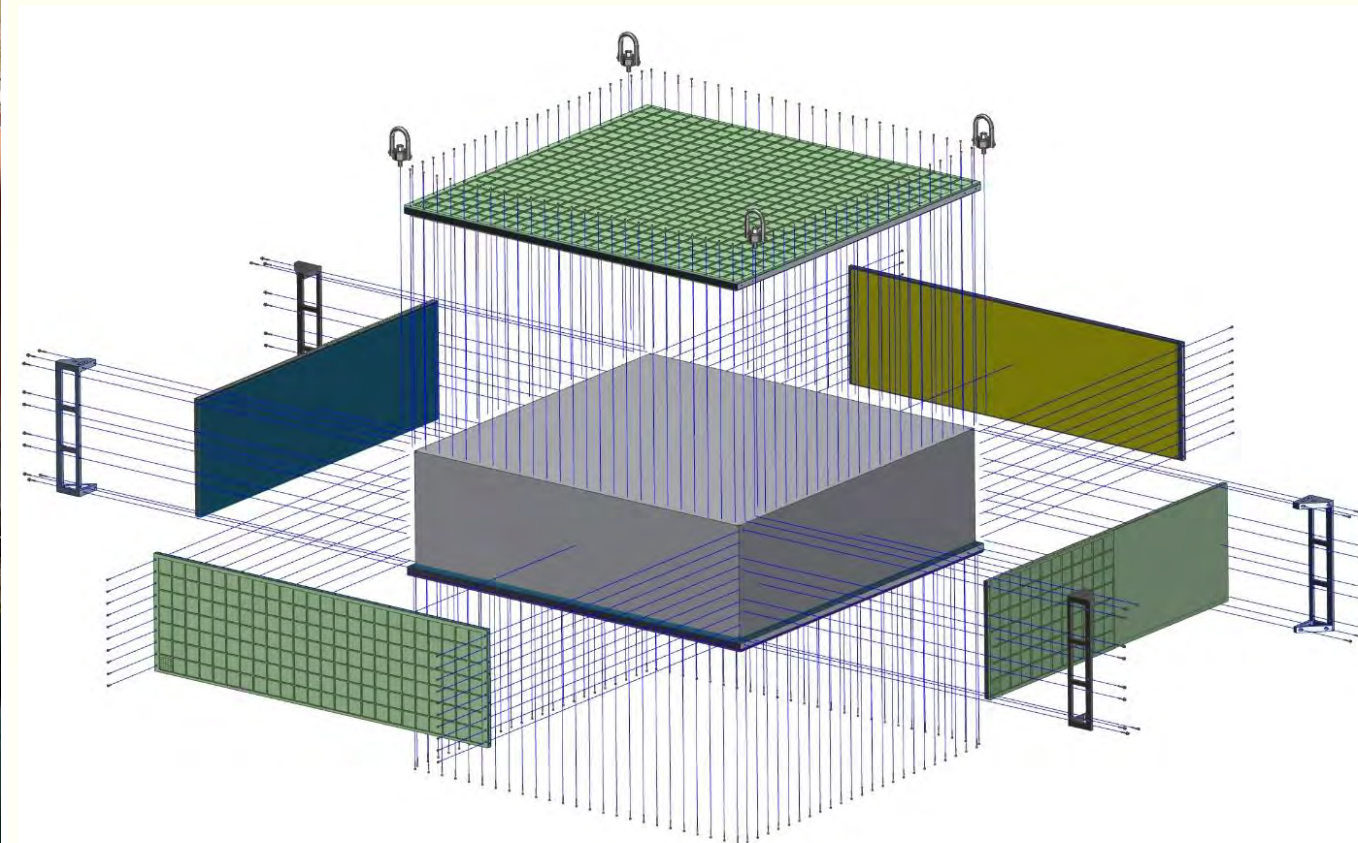
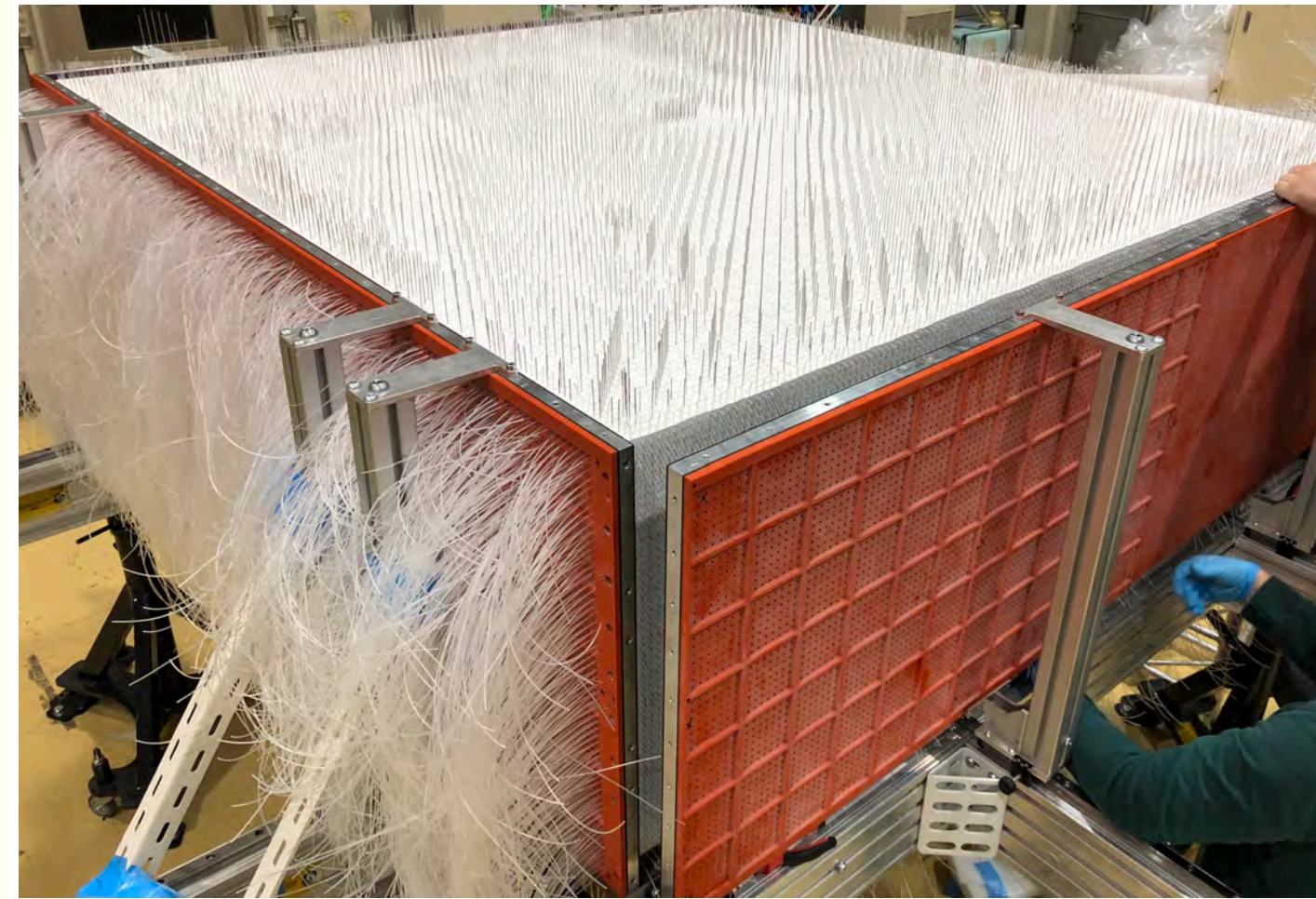


New target

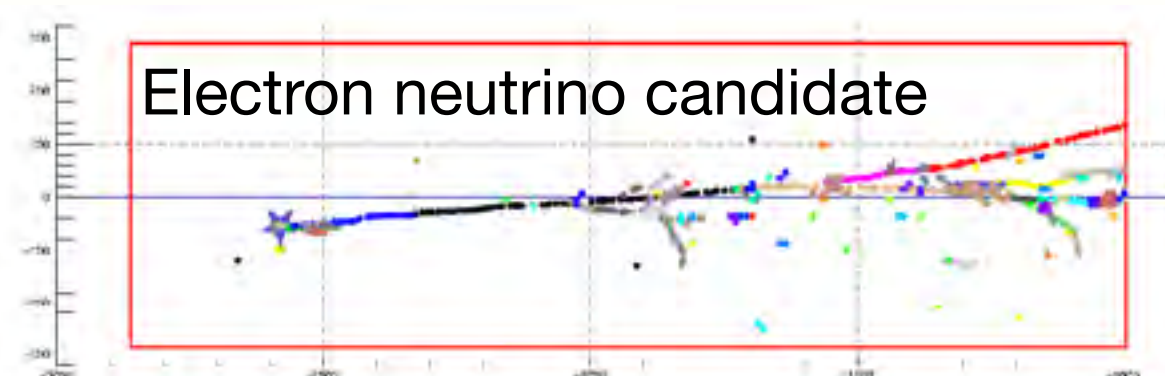
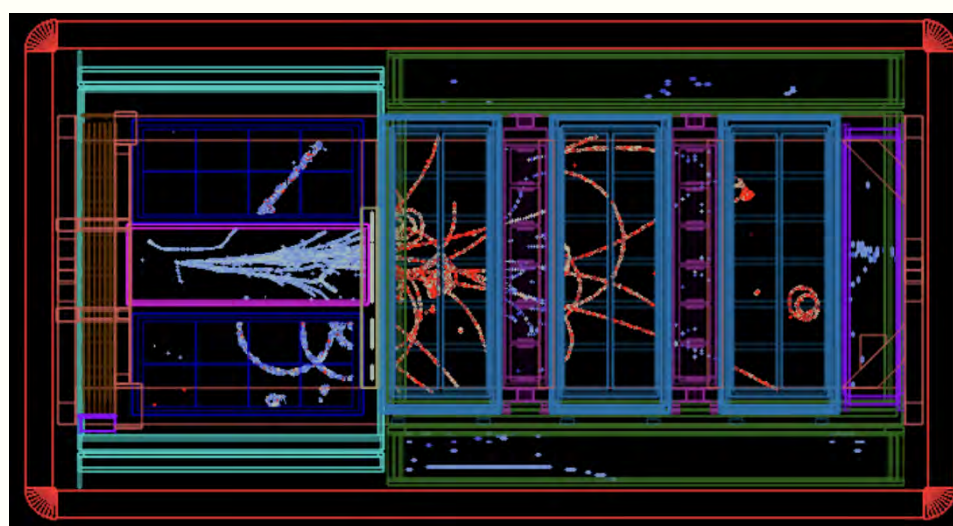
		ppp ... protons per pulse		Beam loss
JFY2021	515kW	2.66×10^{14} ppp	2.48s	2.1%
Feb. 2026	900kW	2.41×10^{14} ppp	1.28s	0.4%
~JFY2028	1300kW	3.3×10^{14} ppp	1.16s	

ND280

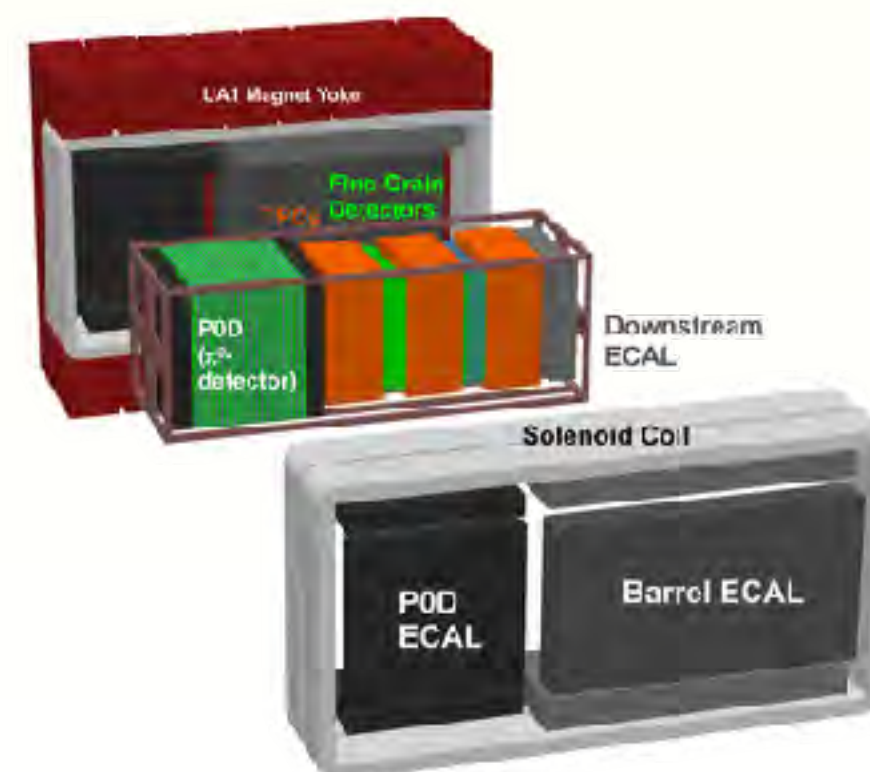
SuperFGD detector with ~2 million scintillator cubes
and ~56,000 WLS fibers+MPPCs



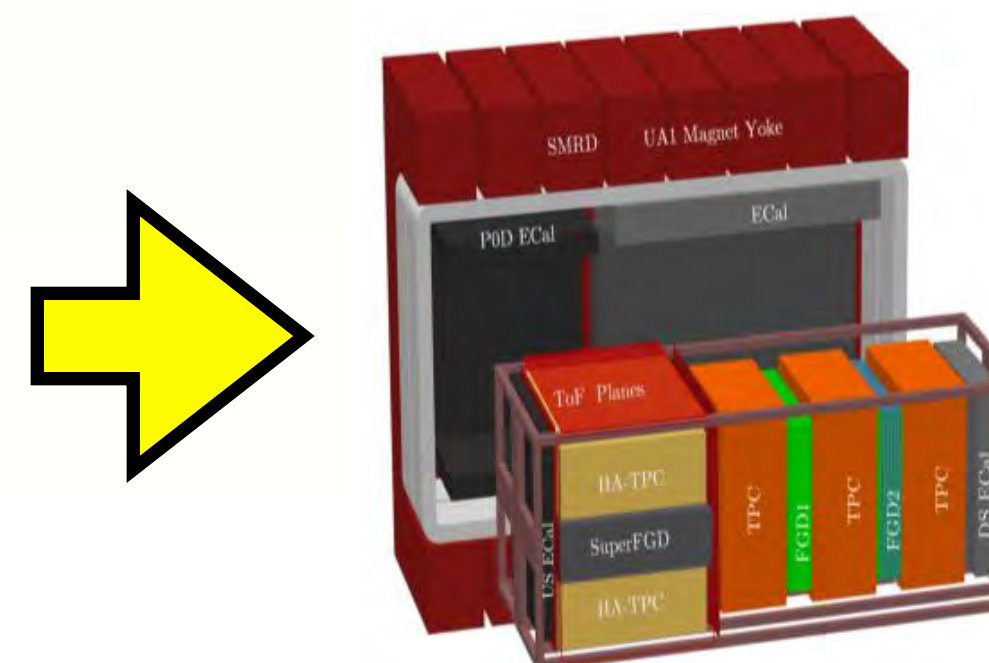
- Upgraded ND280 detector (by T2K) will be inherited and used from Day 1
- Handover activities ongoing
- Further upgrade is also under discussion



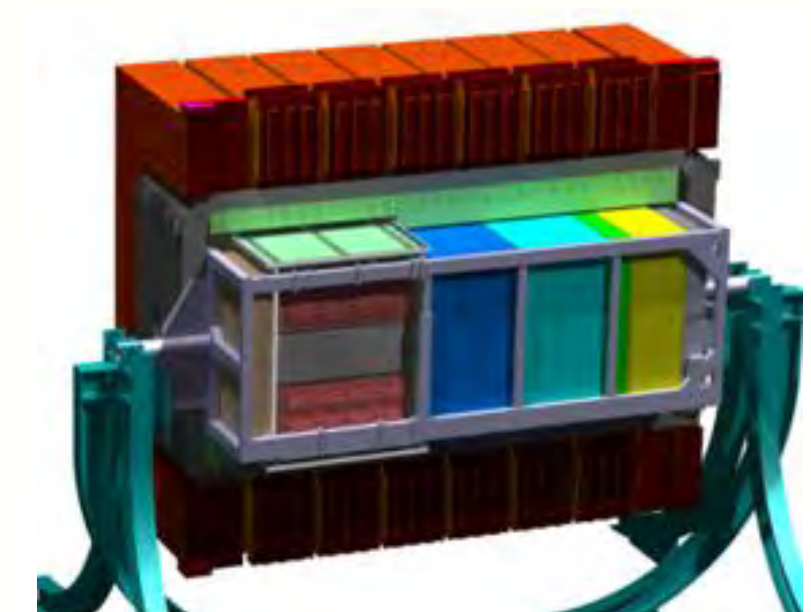
ND280



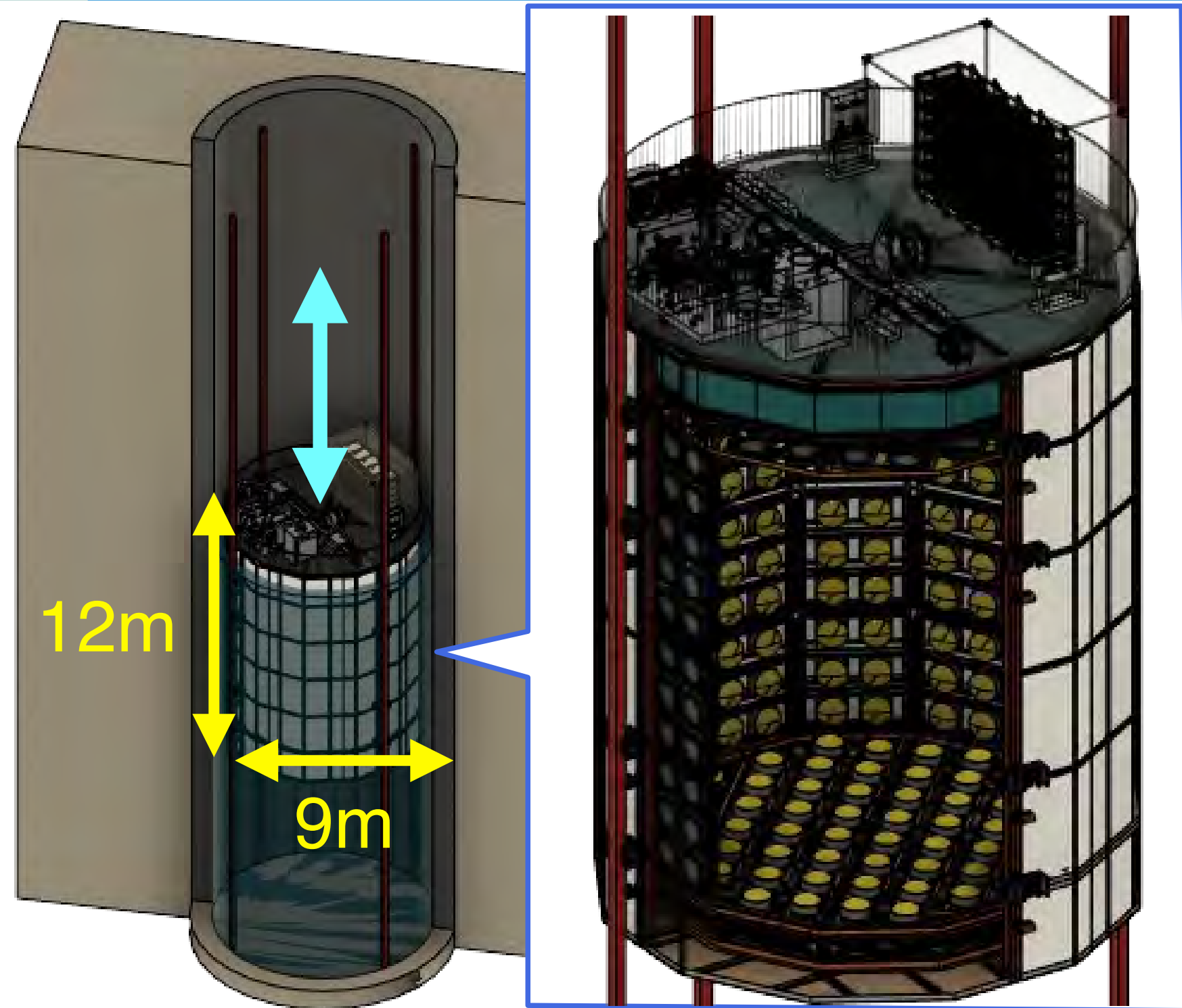
ND280 Upgrade



ND280++ ?

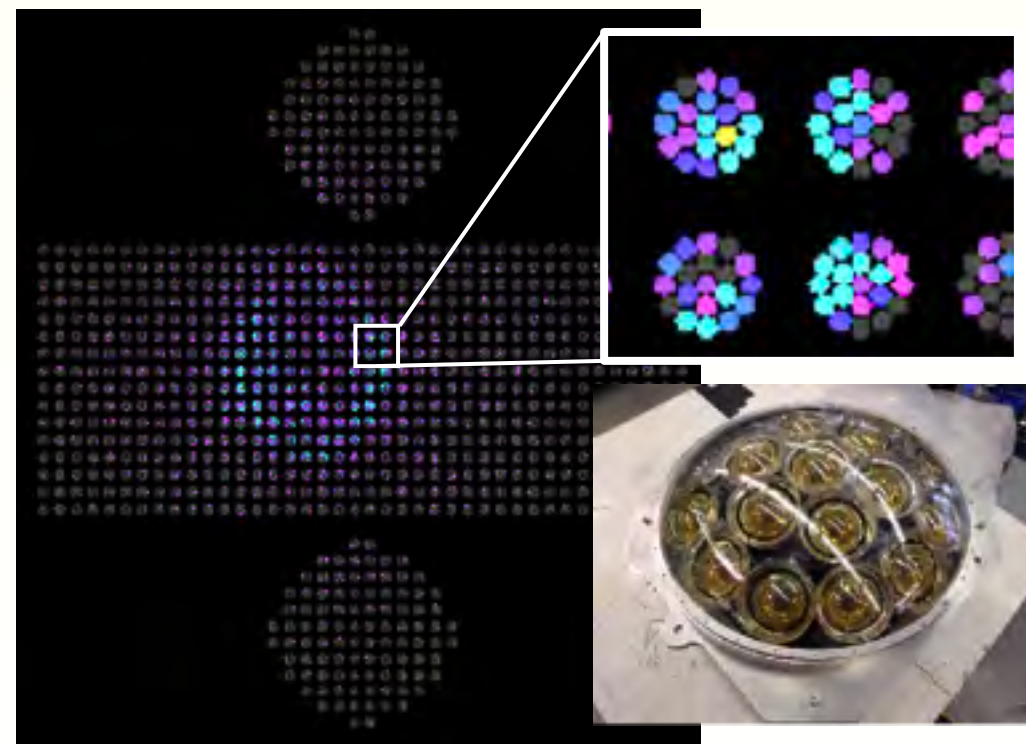
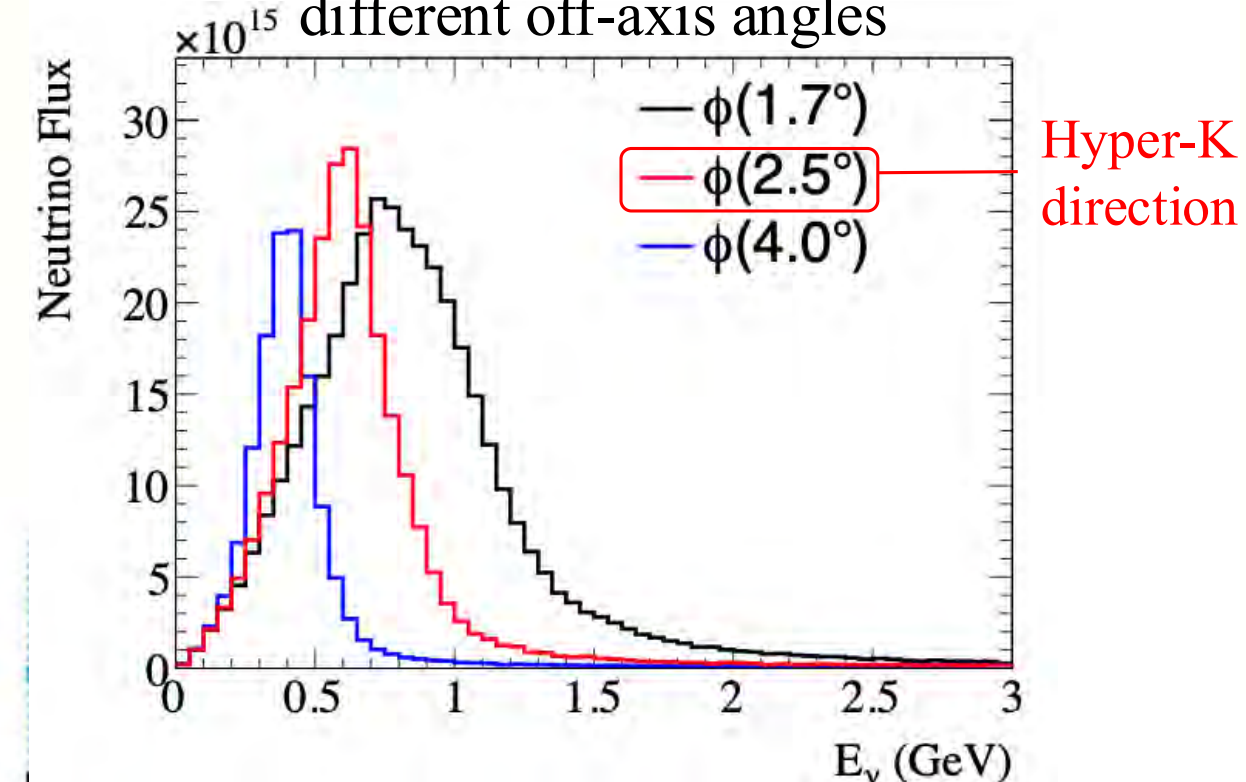


Intermediate Water Cherenkov Detector (IWCD)



- Build a new water Cherenkov detector at $\sim 1\text{km}$ from J-PARC target
- Move the detector by adjusting the water level in the pit
- Changing off-axis angle
→ sample different neutrino energy spectrum
reduction of systematic uncertainties

Neutrino flux at different off-axis angles



Pit excavation started in April 2026

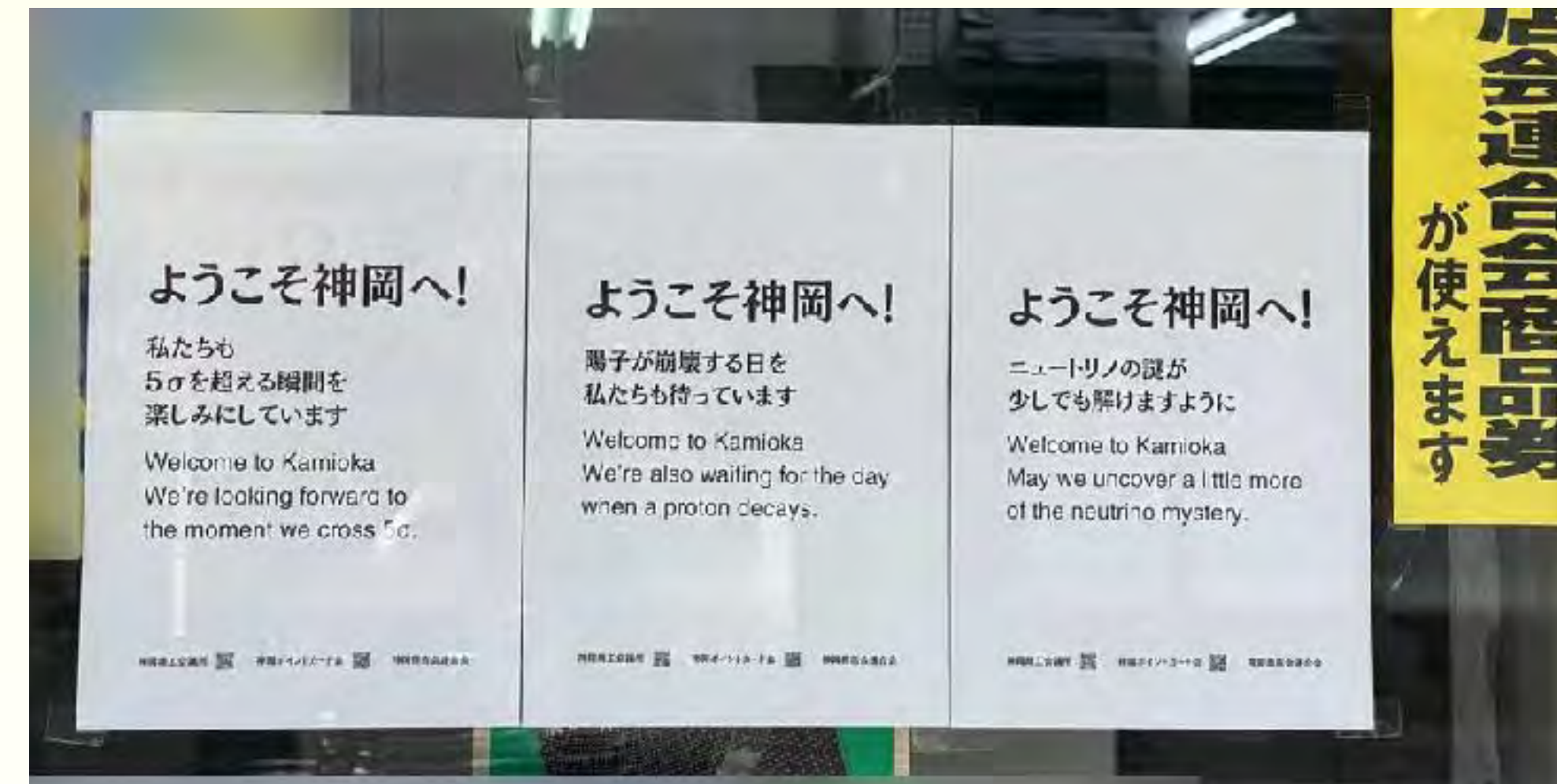
Summary

- Hyper-Kamiokande is under construction
- Massive installation work is scheduled in 2027
- Start of full operation planned for 2028



Collaborators inside tank (June 2026)

Welcome messages displayed on local stores for the first Hyper-K Collaboration Meeting held in the downtown Kamioka (June 2026)



「私たちも 5σ を超える瞬間を楽しみにしています」

「陽子が崩壊する日を私たちも待っています」

「ニュートリノの謎が少しでも解けますように」

"We're looking forward to the moment we cross 5σ ."

"We're waiting for the day when a proton decays."

"May we uncover a little more of the neutrino mystery."