The Hyper-Kamiokande Experiment

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For the Hyper-Kamiokande Collaboration

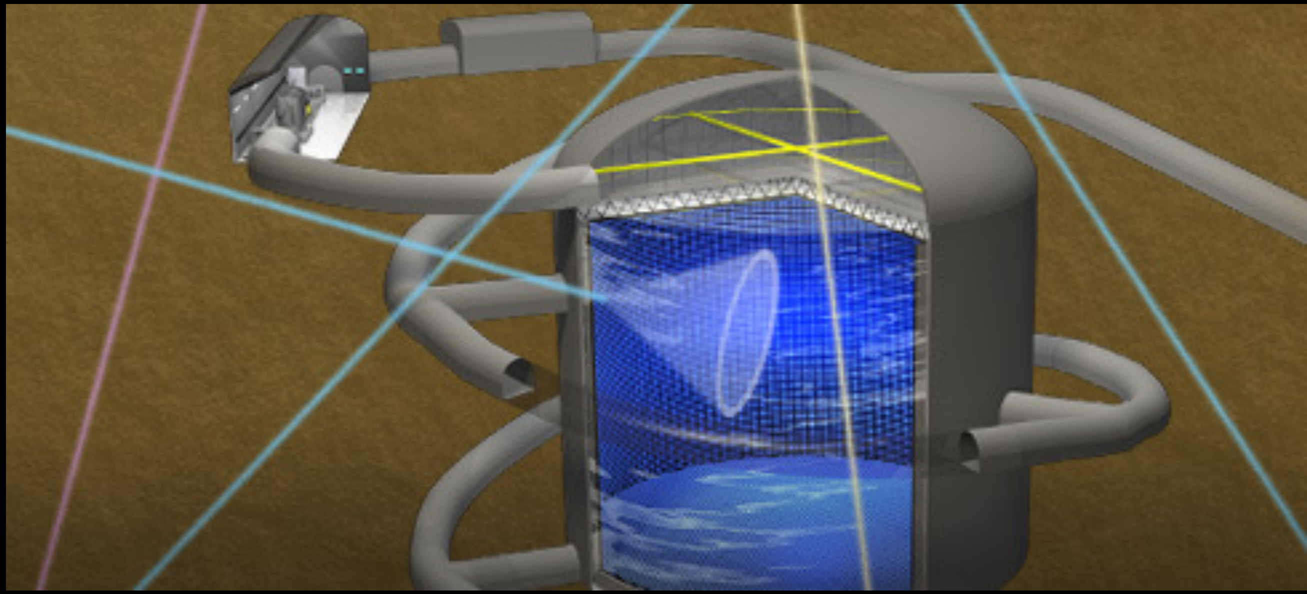
Hyper-Kamiokande

NEUTRINO 2022
XXX International Conference on Neutrino Physics and Astrophysics
May 30 - June 4, 2022 Virtual Seoul

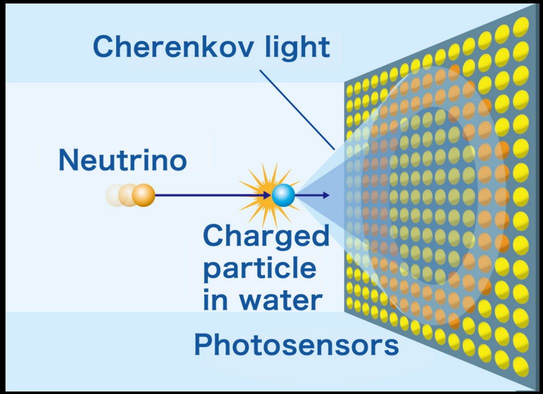
KING'S College LONDON

Outline

- The Hyper-Kamiokande project
  - Hyper-Kamiokande Detector
  - History, physics, collaboration, status
  - Beam
  - Near Detectors
- (selected) Physics Sensitivities
  - δ_{CP}, mass ordering, $\sin^2\theta_{23}, \Delta m^2_{32}$
  - Supernova Bursts
  - Proton Decay
- R&D and construction highlights



Kamioka Water Cherenkov Experiments



Hyper-Kamiokande

- ~2027 onwards
- 260 kton (188 kton FV)

X 8.4

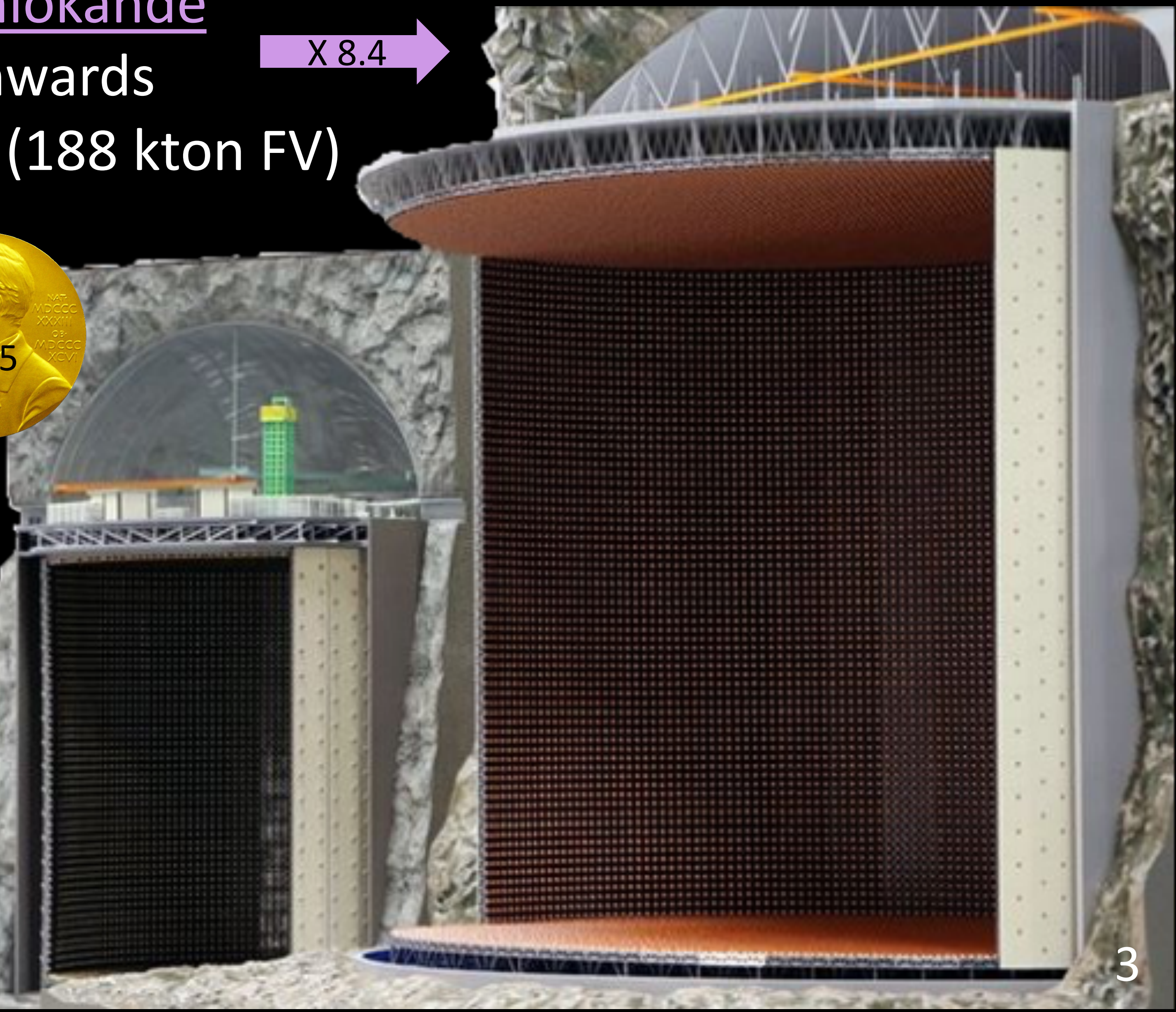
Super-Kamiokande

X 20

- 1996 onwards
- 50 kton (22.5 kton FV)

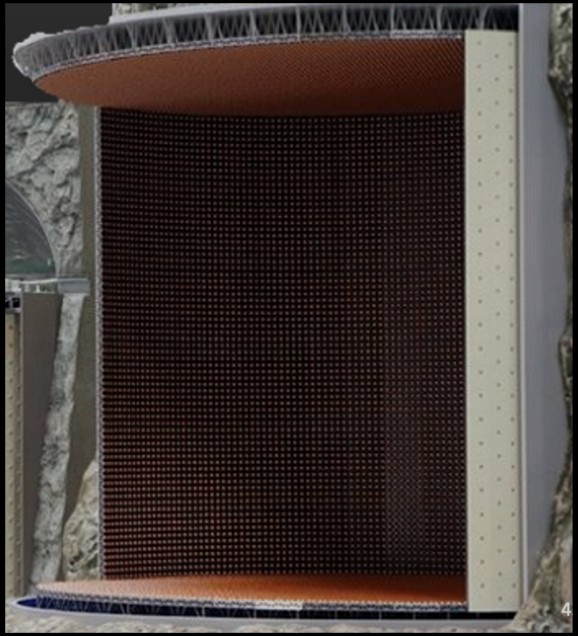
Kamiokande

- 1983 – 1996
- 3 kton



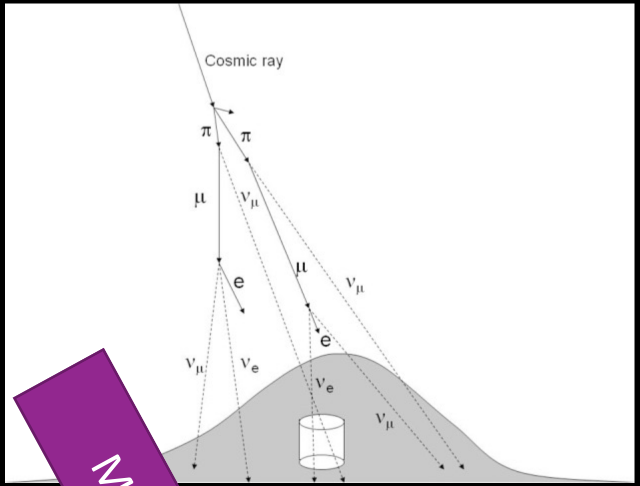
Jongno Tower = 132 m tall

Hyper-K = 71 m tall

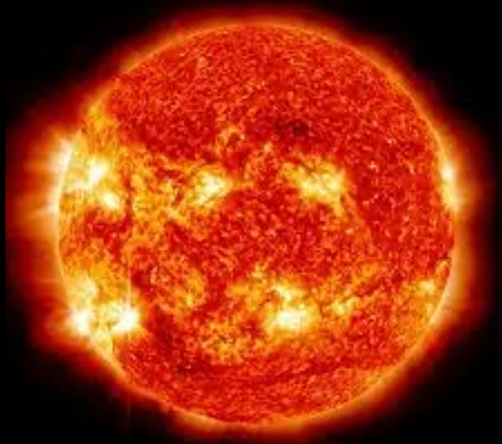


68 m diameter

The Hyper-Kamiokande Project

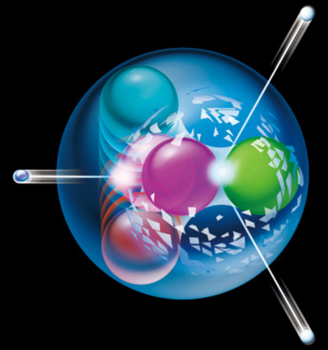


Atmospheric neutrinos:
$\nu_\mu, \bar{\nu}_\mu, \nu_e, \bar{\nu}_e$



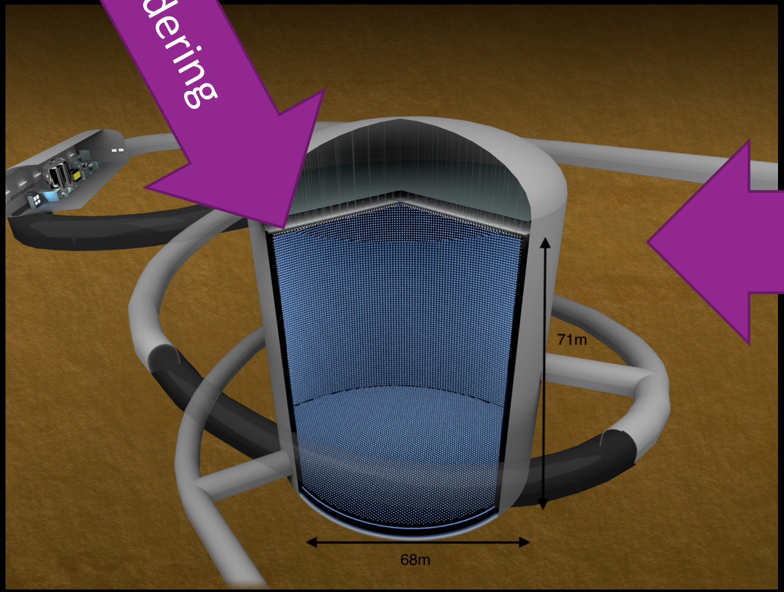
Solar neutrinos, ν_e

Supernova bursts
Diffuse Supernova Background Neutrinos



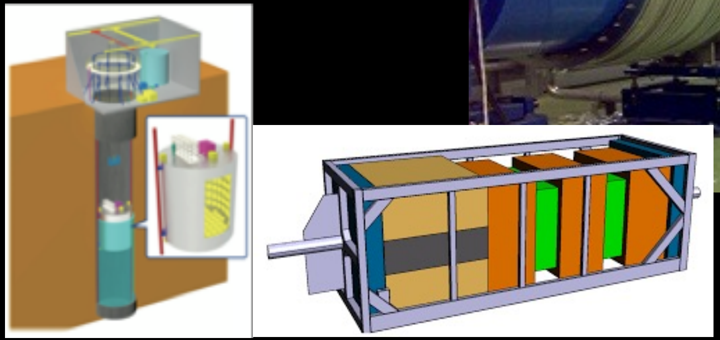
Proton Decay Search

Mass Ordering



CP violation, oscillation parameters

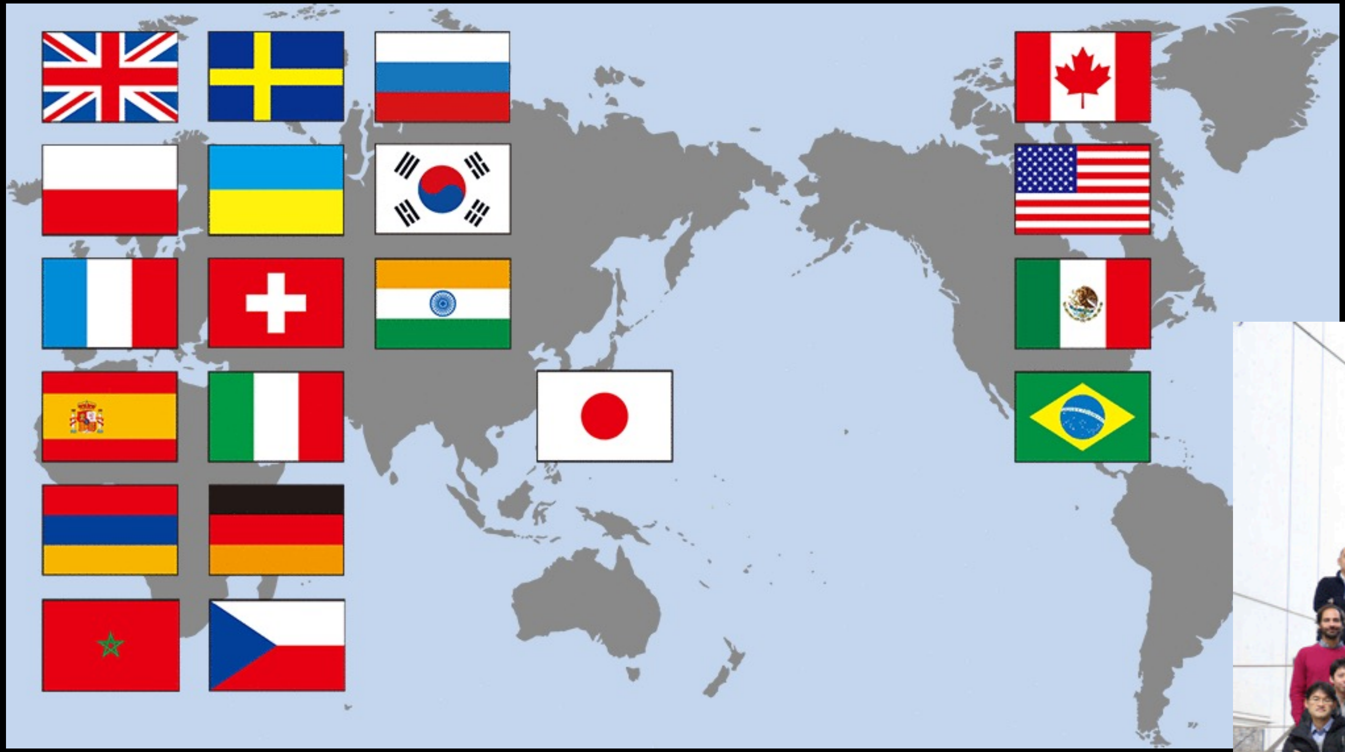
J-PARC neutrino beam: $\nu_\mu, \bar{\nu}_\mu$



Near Detectors

Hyper-Kamiokande Collaboration

~500 researchers from 20 different countries



Last in-person meeting

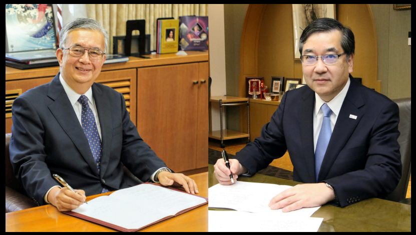
February 2020

Project Status

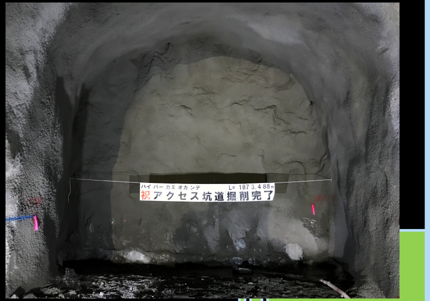
NEUTRINO 2022
XXX International Conference on Neutrino Physics and Astrophysics
May 30 - June 4, 2022 Virtual Seoul

2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027

MOU signed, May 2020



Ground-breaking May 2021



Access tunnel complete, Feb 2022

Approach and Peripheral tunnels, Summer 2022

Operation starts 2027

Cavern Excavation

Tank Construction

Installation

Water filling

PMT production

Project Status

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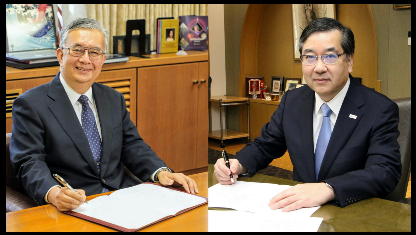

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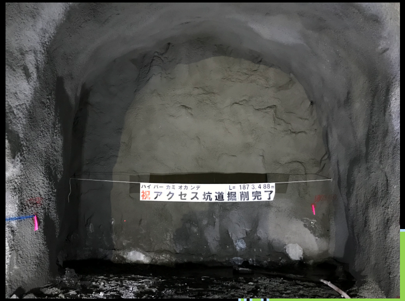

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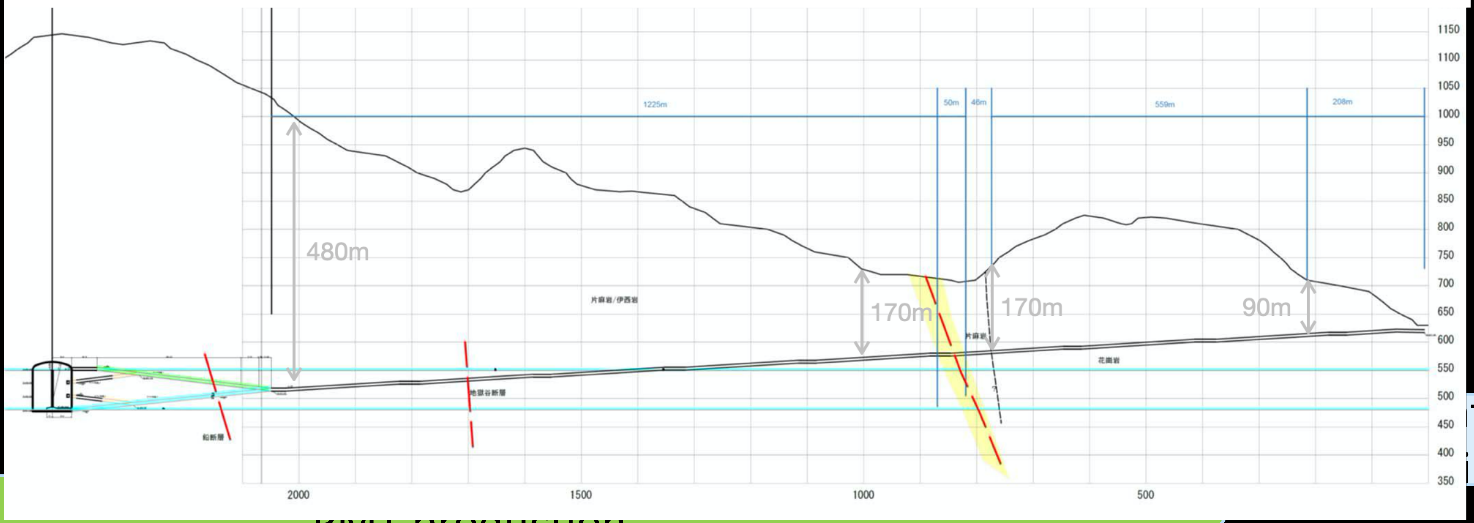

PMT production

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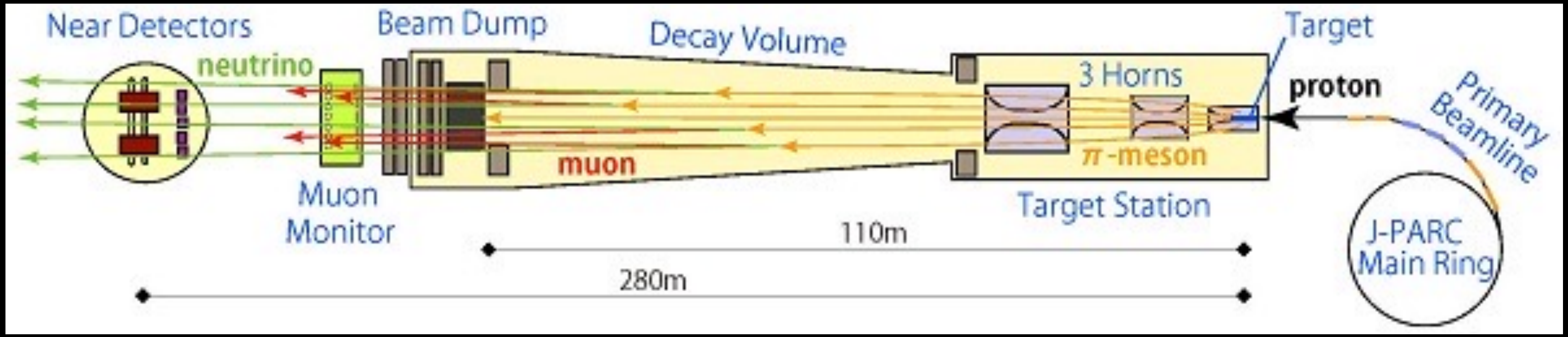
ing

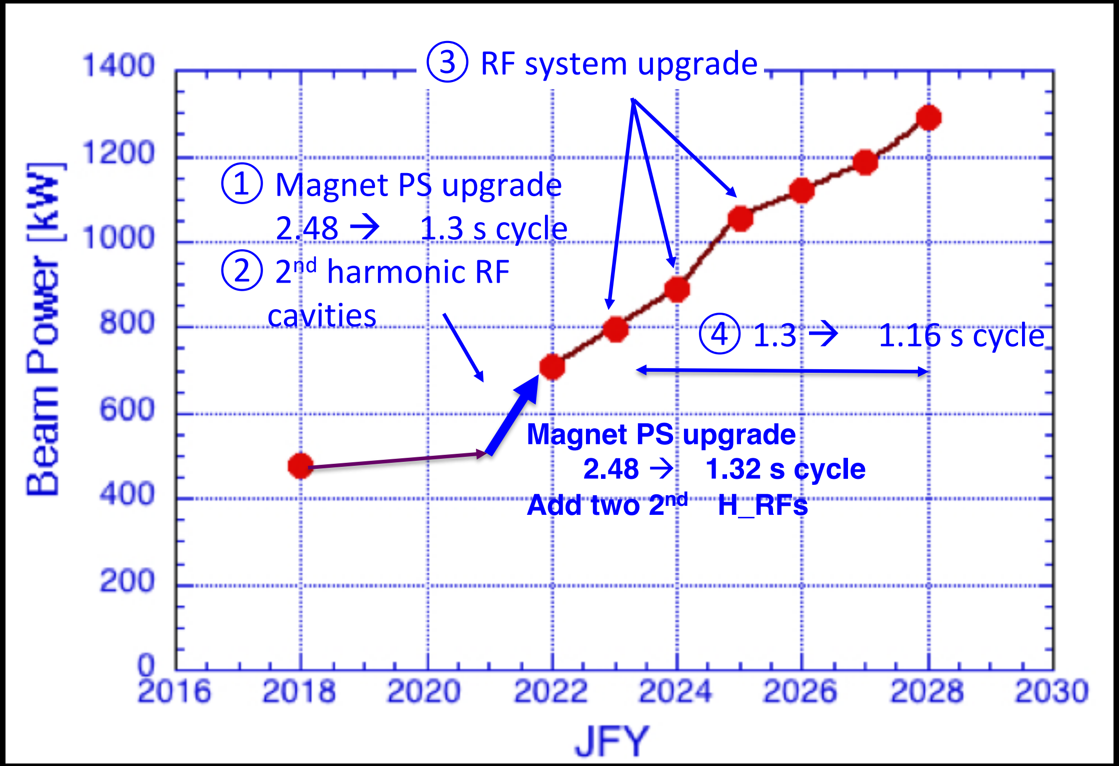
Beam

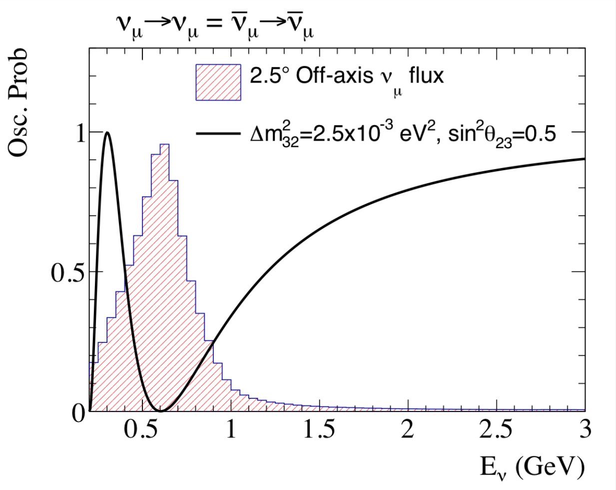
https://j-parc.jp/Neutrino/en/nu-facility.html

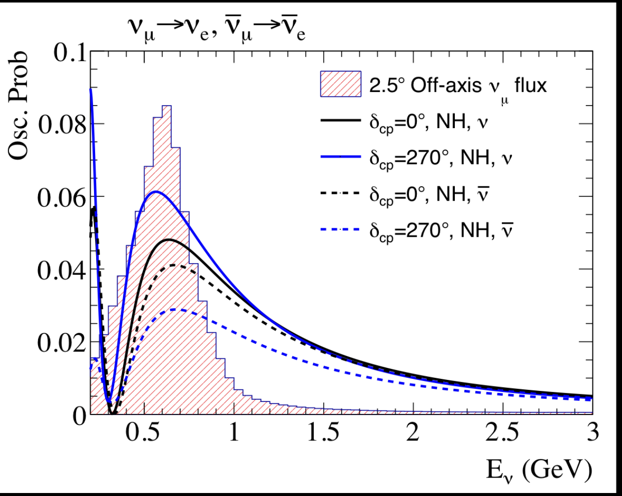


- 295 km baseline
- ν_μ or $\bar{\nu}_\mu$ selected by horn current
- 2.5° off-axis ν / $\bar{\nu}$ beam peaked at 0.6 GeV
- Predominantly QE interactions
- J-PARC upgrade 500kW →1.3 MW

HK Beam Talk on Saturday (S19)- Tetsuro Sekiguchi

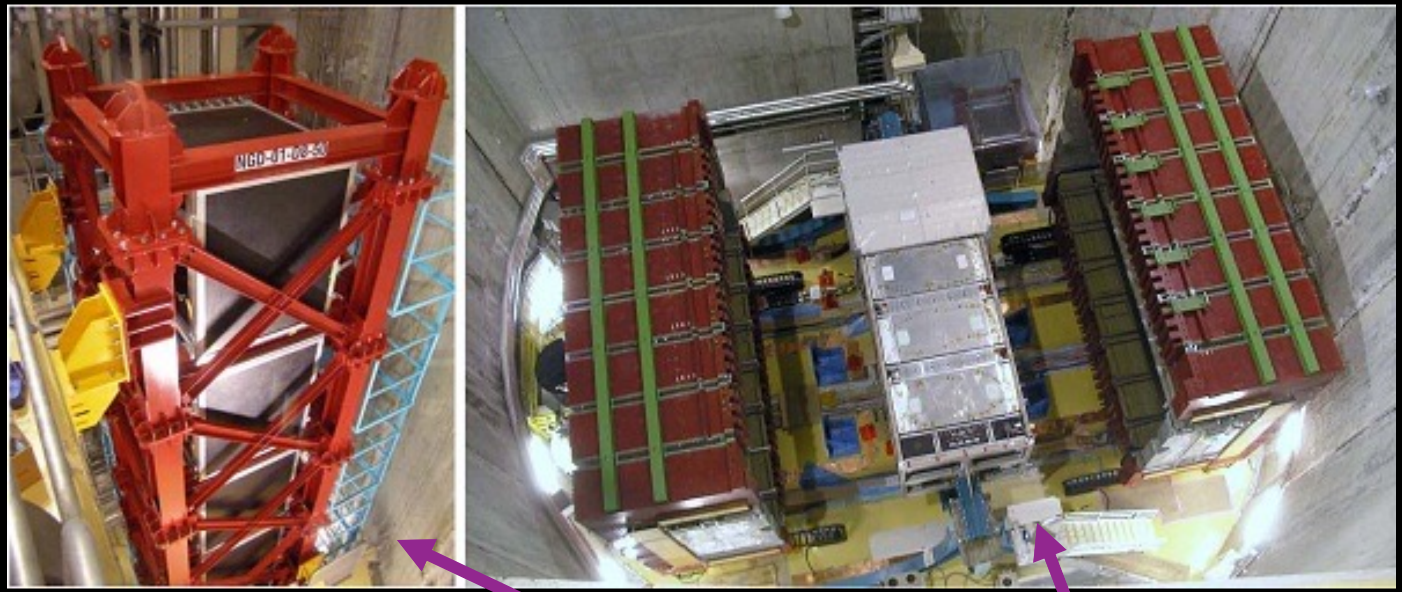


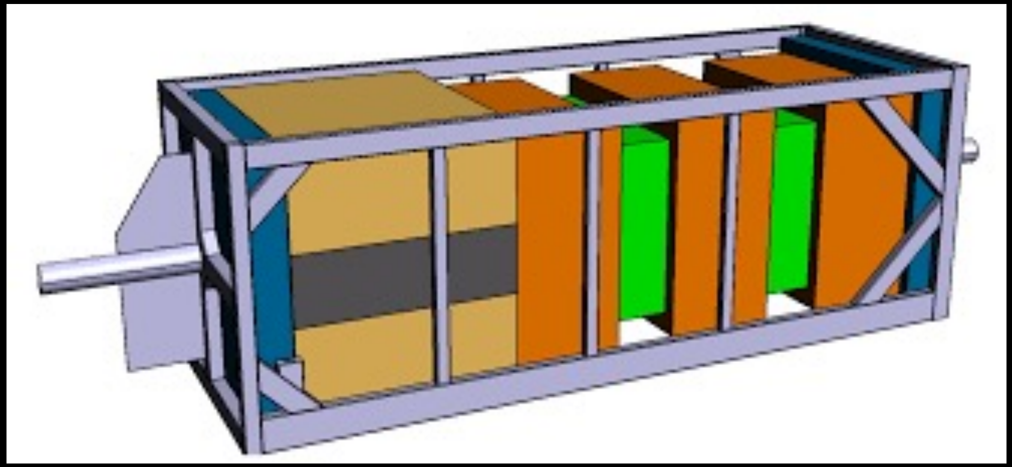




Near Detectors

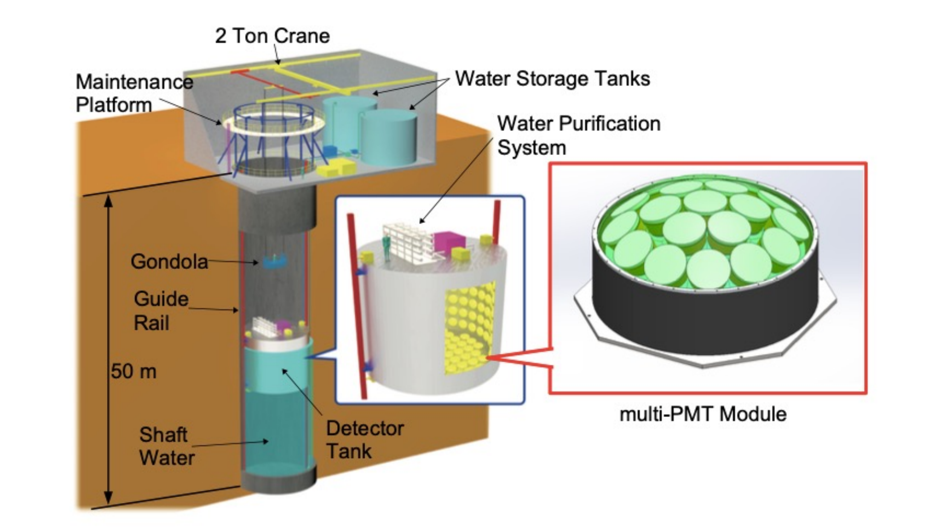
T2K talk, June 1st (S9) Christophe Bronner
ND280 Upgrade Posters: 173, 187, 192, 193, 198, 306, 371, 444

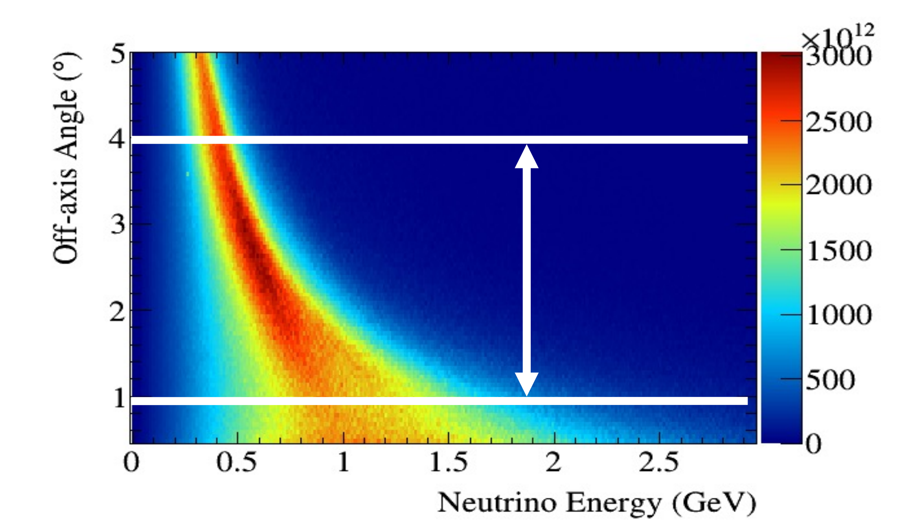




- T2K Near detectors INGRID and ND280 measure beam structure and composition 280 m downstream.
  - Measurements constrain uncertainty on flux and neutrino interaction models
  - Events samples from ND280 used in oscillation fit to near and far detector data
- Upgrades underway in 2022/23 to improve angular acceptance of the ND280 tracking detector

The Intermediate Water Cherenkov Detector (IWCD)

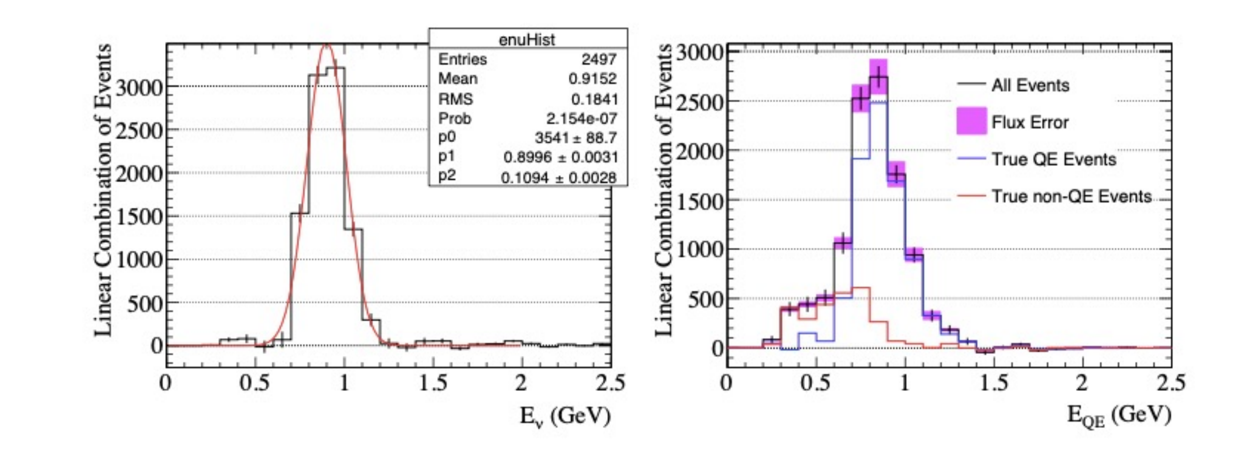




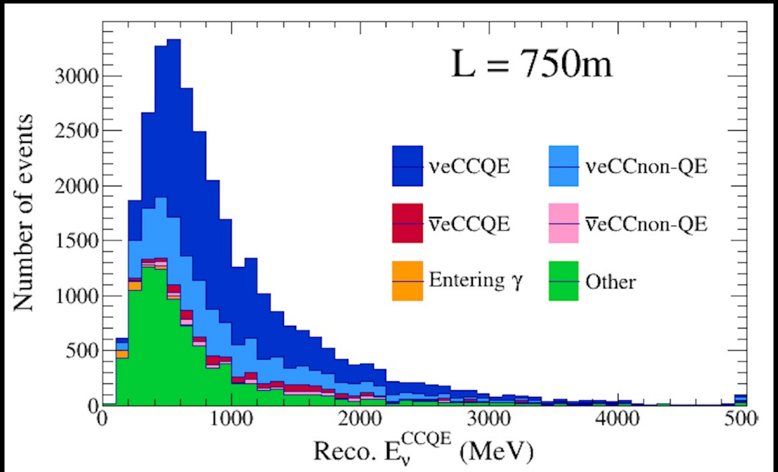
Neutrino Interactions talk
June 3rd (S17)
Xianguo Lu

Posters:
76 – Ryosuku Akutsu
419 – Tailin Zhu

- Moving detector → measurements at different off-axis angles → energy spectrum changes → constrain relationship between reconstructed quantities and neutrino energy



Create "mono-chromatic" spectra to constrain non-QE feed-down with 5% precision



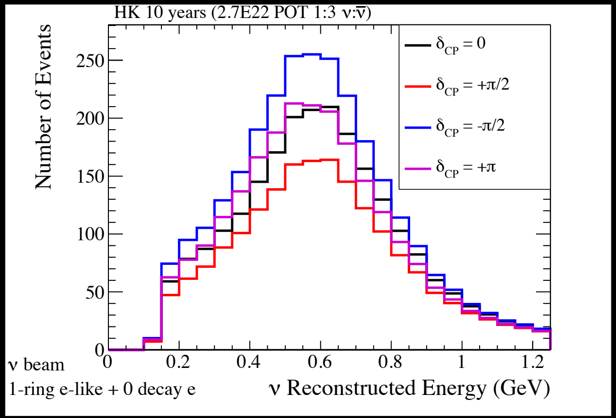
Use intrinsic electron (anti) neutrinos in beam

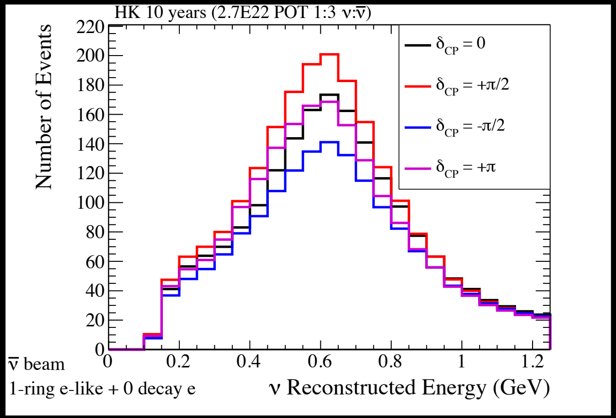
Measure $CC\nu_e/CC\bar{\nu}_e$ ratio with <4% precision

Long Baseline Physics- δ_{CP}

Probe CP-violation through comparison of $P(\nu_\mu \rightarrow \nu_e)$ and $P(\bar{\nu}_\mu \rightarrow \bar{\nu}_e)$

- Select 1 ring e-like events in far detector
- 10 years running, 1:3 $\nu:\bar{\nu}$ run plan

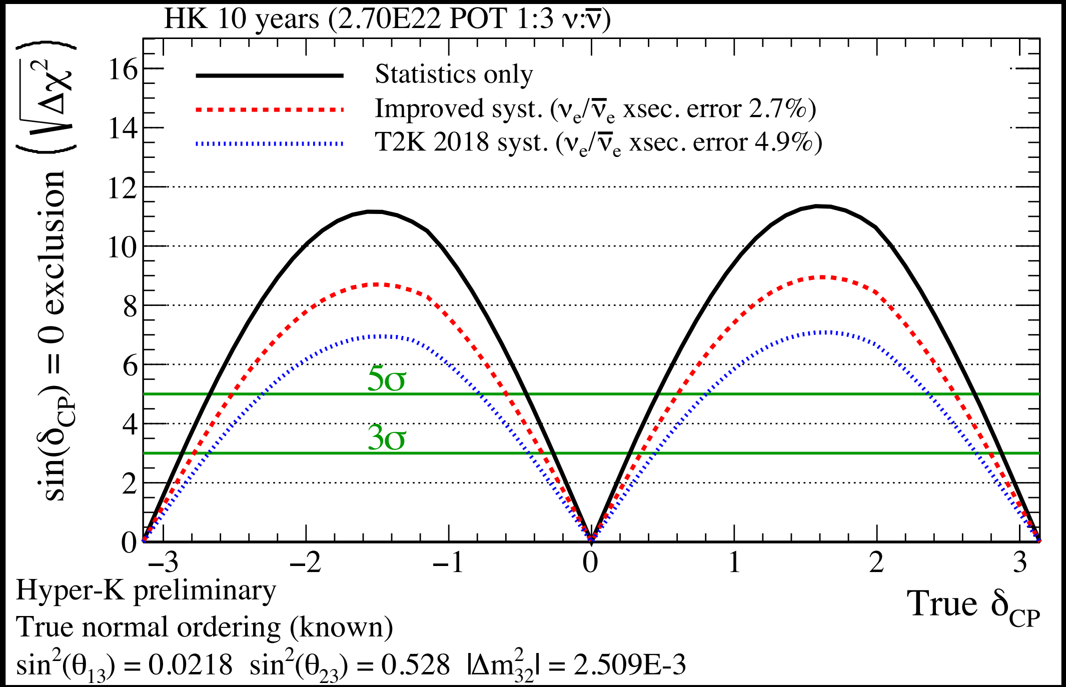


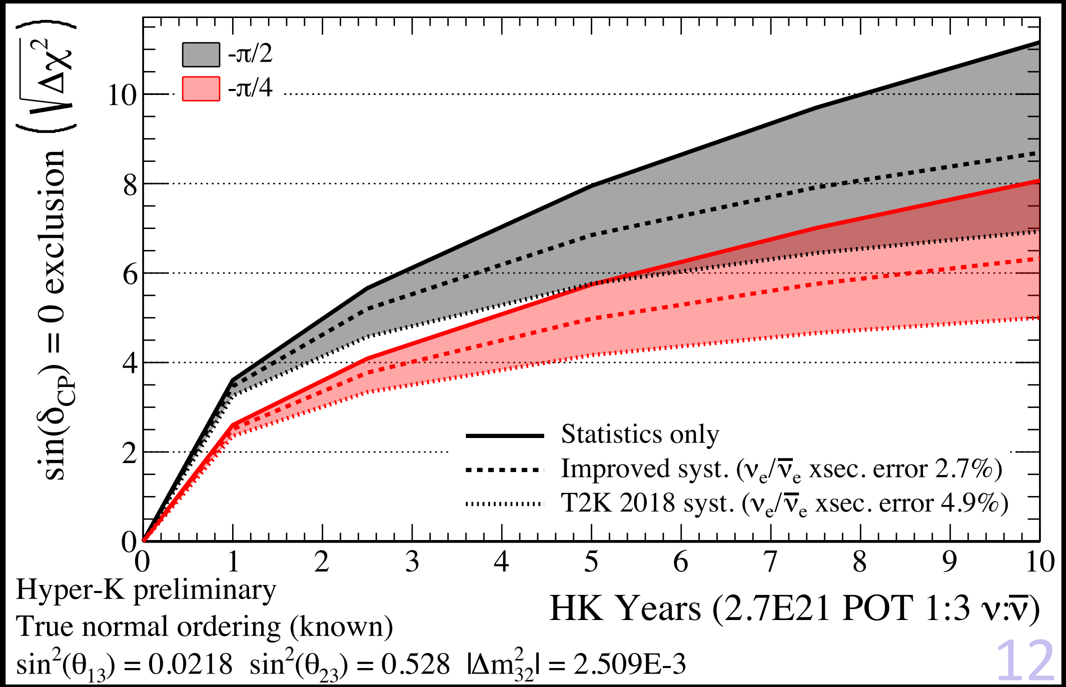


- >1000 ν_e and $\bar{\nu}_e$ signals

Assume normal mass ordering is known → Projected sensitivity based on T2K systematics plus improvements for Hyper-K

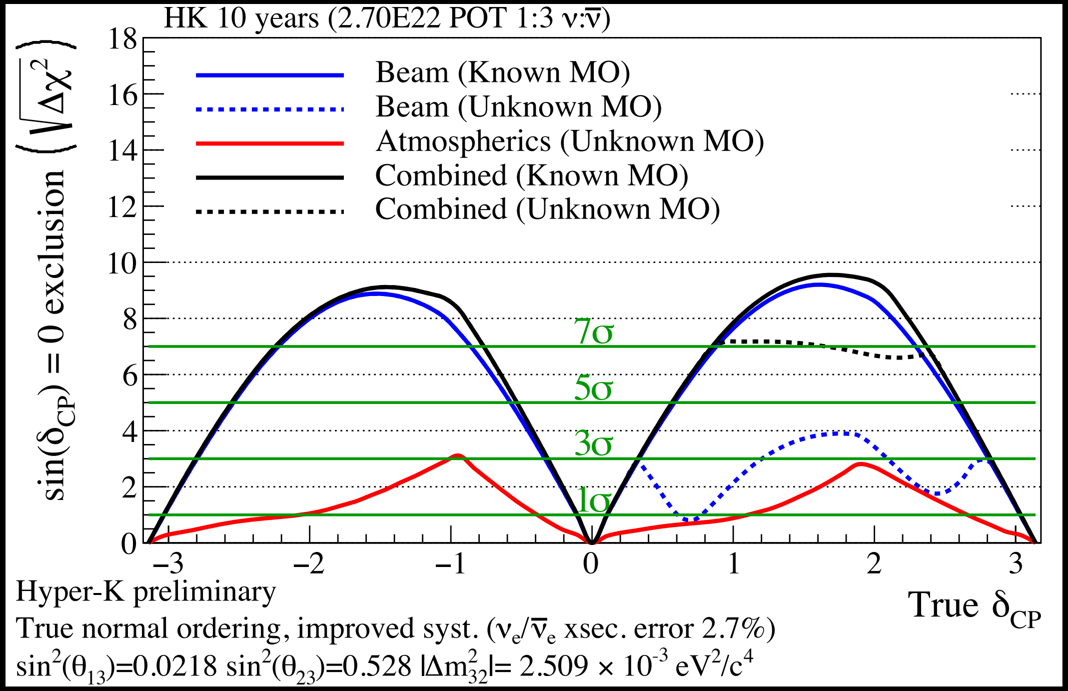
After 10 HK-years, 61% of true δ_{CP} values can be excluded at 5 sigma

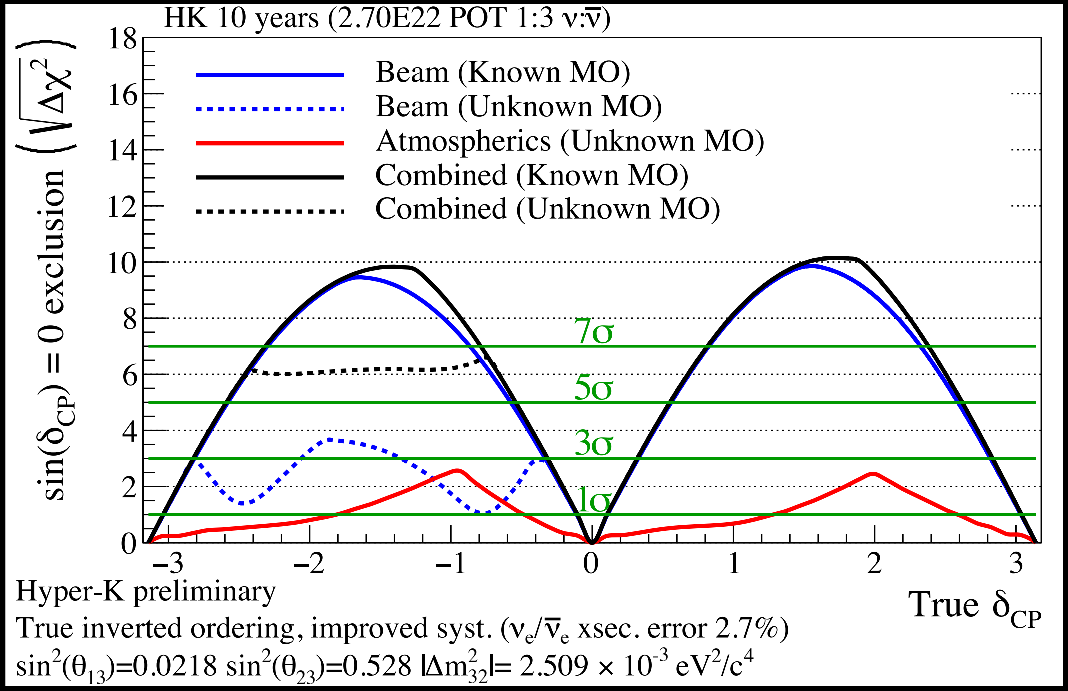




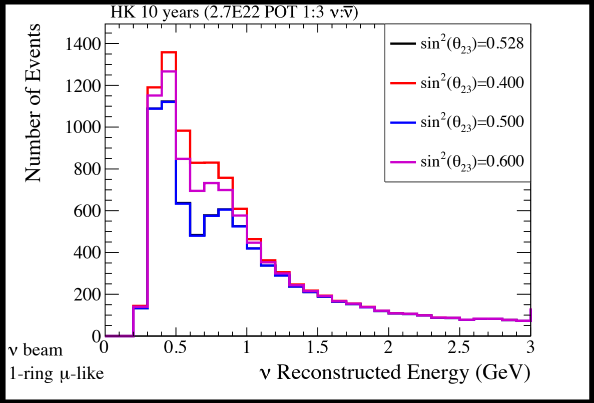
Mass Ordering

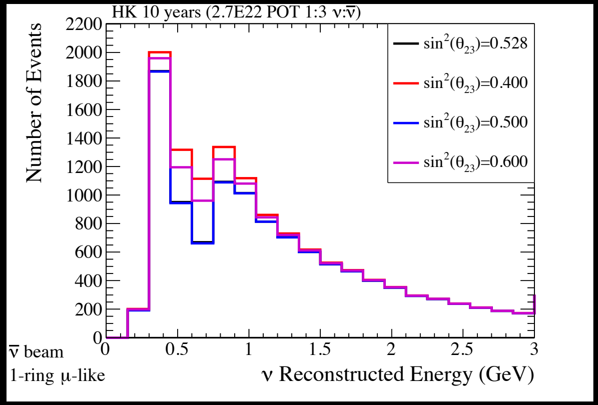
- If mass ordering is not known, combination of beam measurements with atmospheric neutrino observations resolves parameter degeneracy





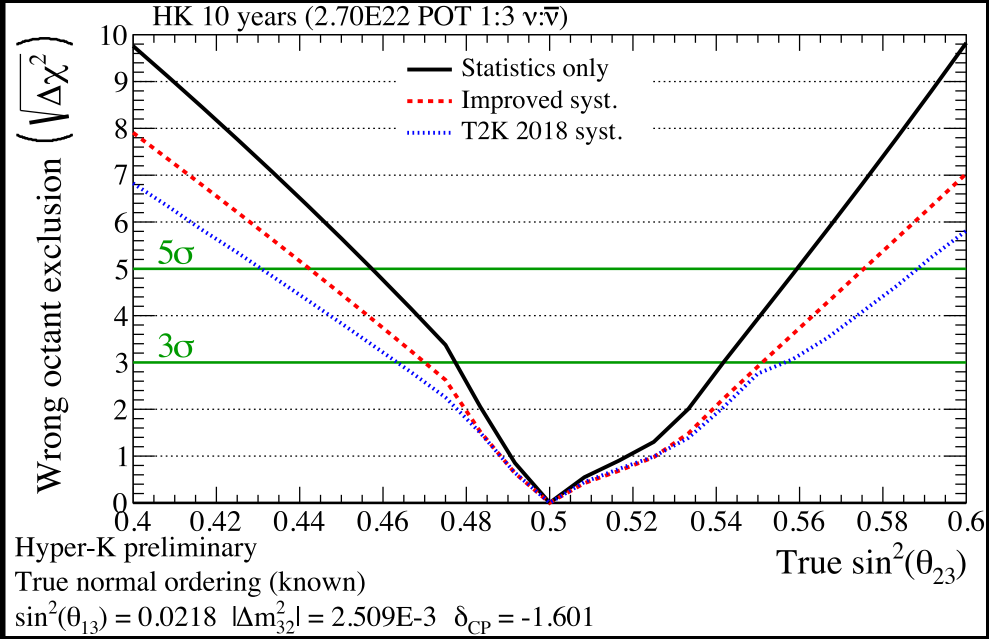
$\sin^2\theta_{23}$ and Δm^2_{32}



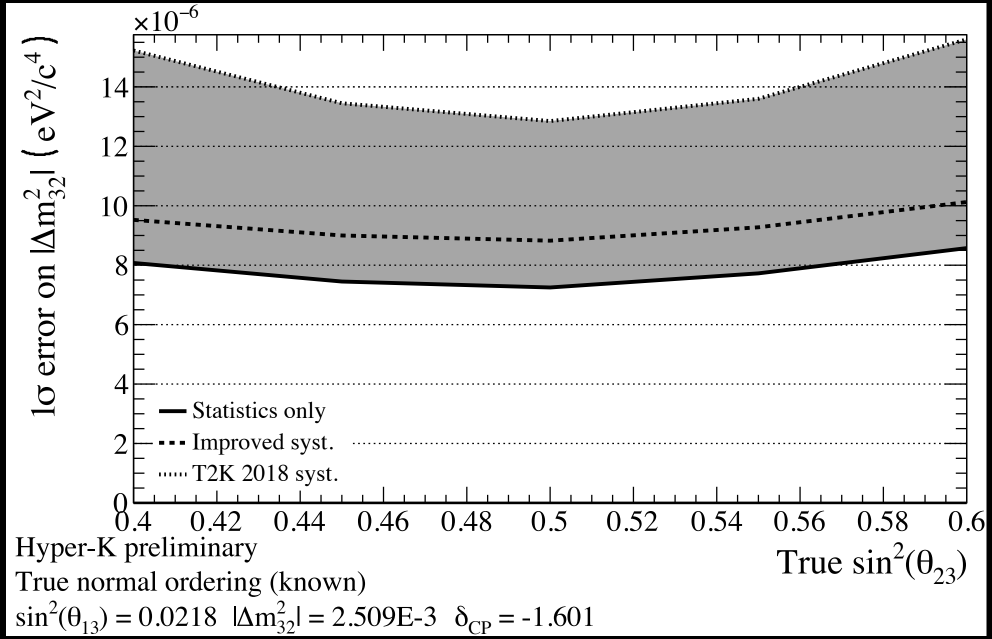


Probe 2-3 mixing through dip in $P(\nu_\mu \rightarrow \nu_\mu)$ and $P(\bar{\nu}_\mu \rightarrow \bar{\nu}_\mu)$

- Select 1 ring μ-like events in far detector
- 10 years running, 1:3 $\nu:\bar{\nu}$ run plan



Wrong octant can be excluded at 3σ for true $\sin^2\theta_{23} < 0.47$ and true $\sin^2\theta_{23} > 0.55$

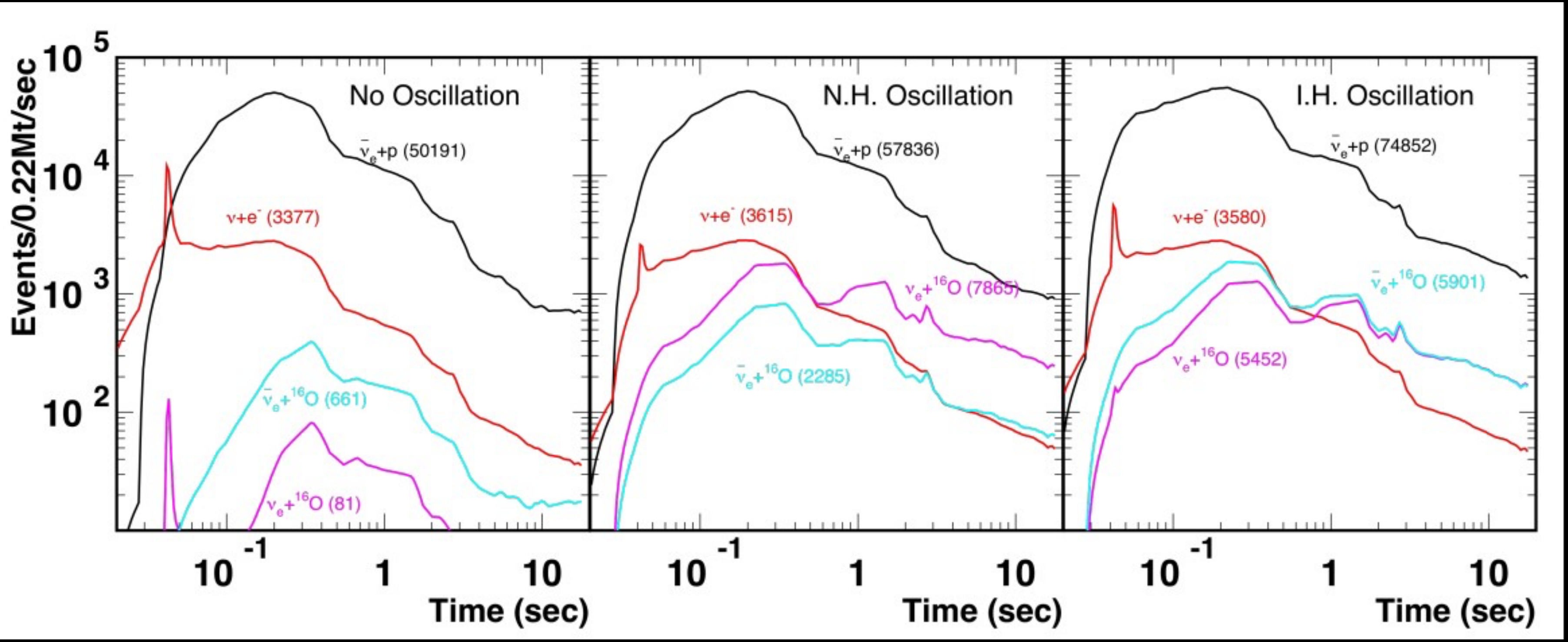


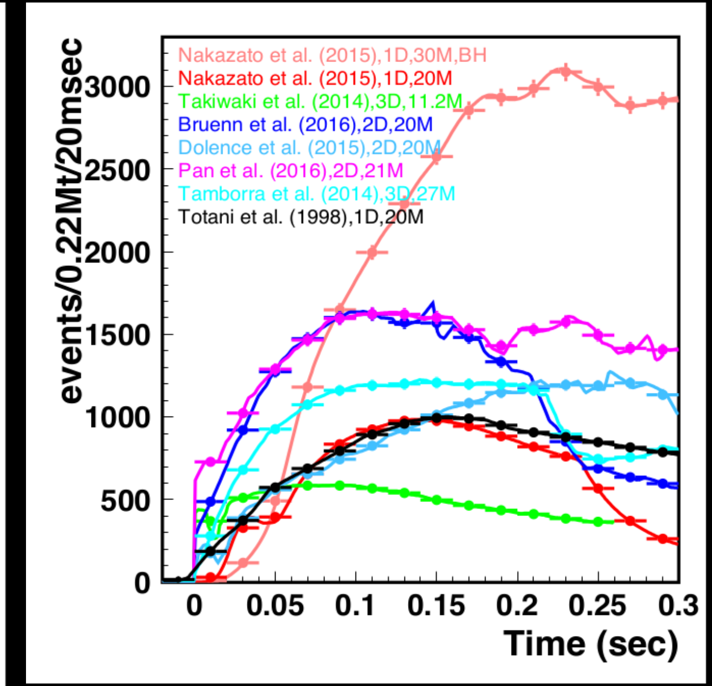
1σ resolution of Δm^2_{32} as a function of true $\sin^2\theta_{23}$

Neutrino Astrophysics – Supernova Bursts

- Expected time profile and event numbers in HK for a supernova at 10 kpc (Livermore simulation)
  - numbers in brackets total interactions integrated over the 10 s burst
  - peak event rate of inverse beta decay events (black) reaches ~50 kHz
  - Model discrimination - **arXiv:2101.05269**

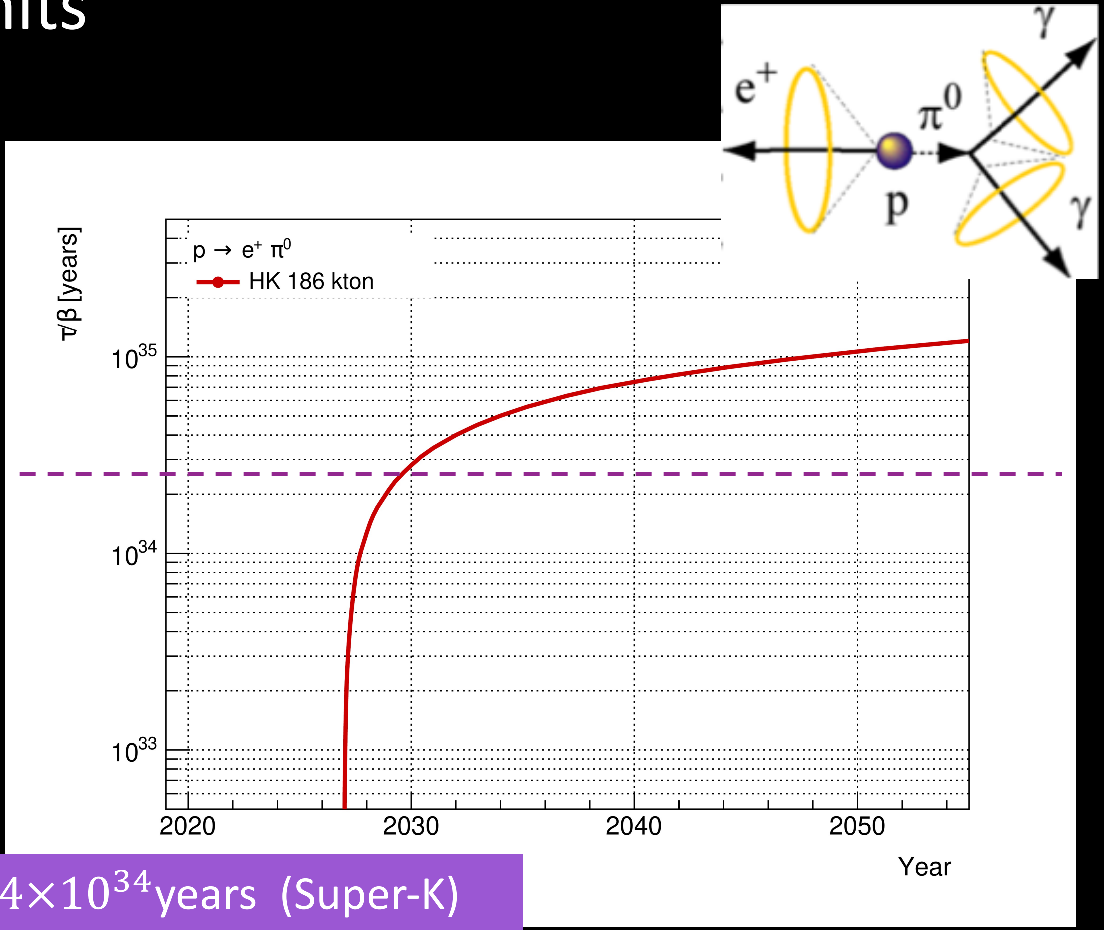
DAQ designed to cope with peak data rates from very close SN (eg. Betelgeuse)



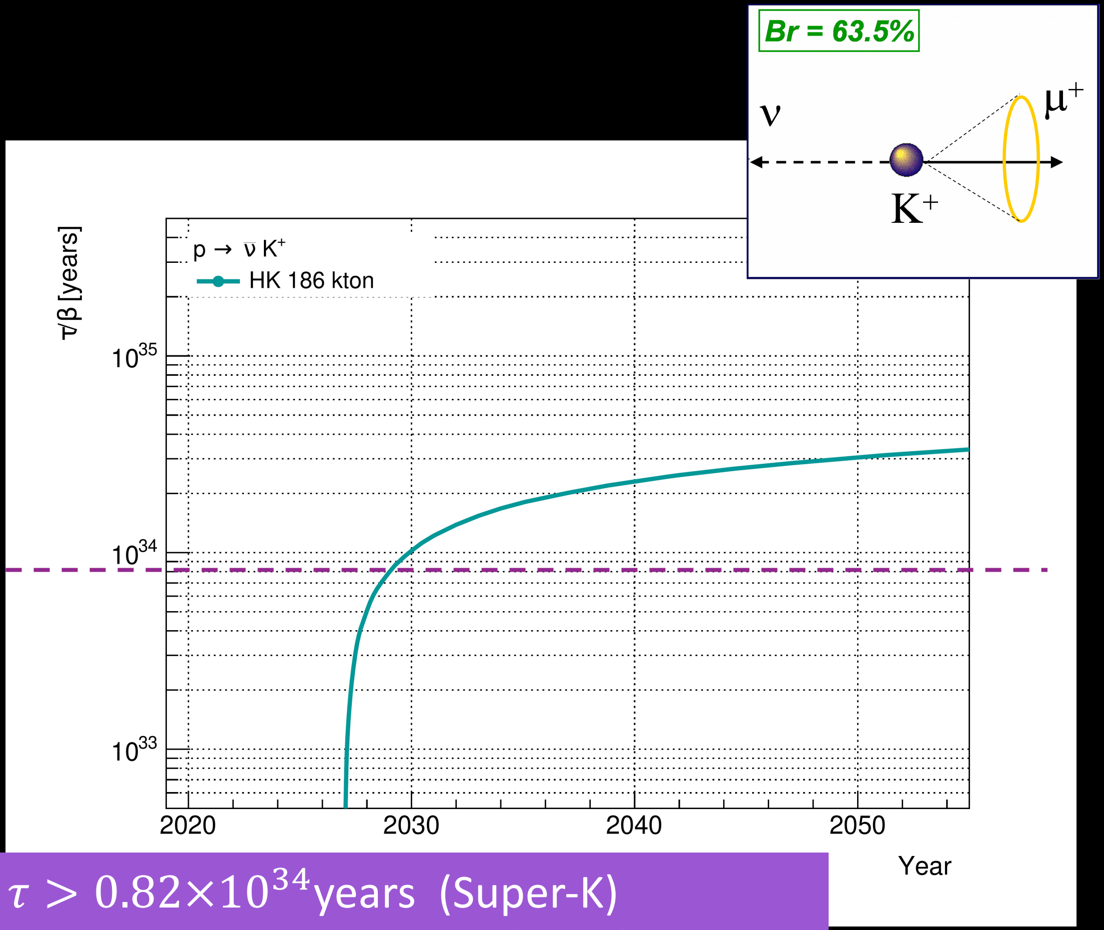


Proton Decay

- Hyper-K far detector has many protons!
- Can extend proton decay search by an order of magnitude beyond current limits



$\tau > 2.4 \times 10^{34}$years (Super-K)
Phys. Rev. D 102, 112011 (2020)

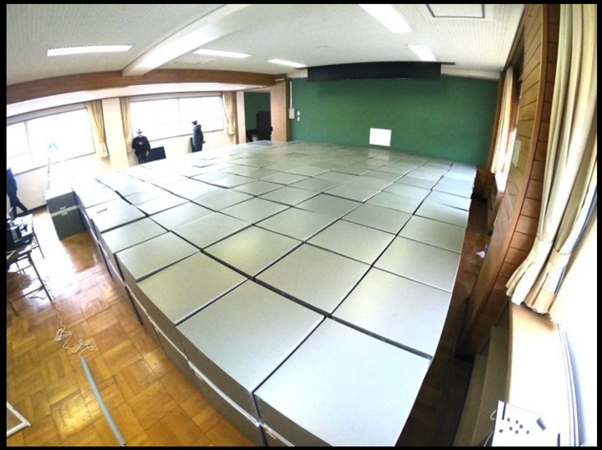


$\tau > 0.82 \times 10^{34}$years (Super-K)
Nucl.Instrum.Meth.A 952 (2020) 161634

Hyper-K Far Detector – R&D highlights

20k 50 cm Box and Line Dynode ID PMTs

- 2.6 ns timing resolution
- 2 × SK PMT efficiency
- Mass production and QA commenced 2021

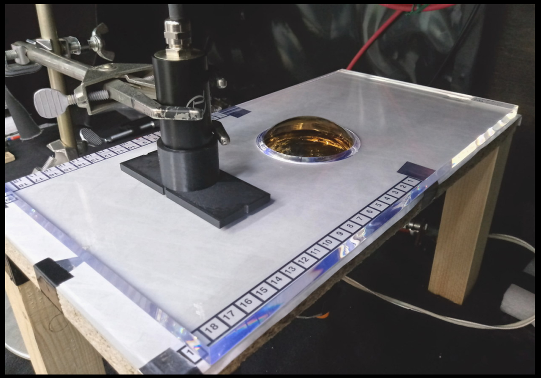


mPMT units

- 19 8 cm PMTs + electronics inside single pressure vessel
- Directional information, improved spatial and timing resolution

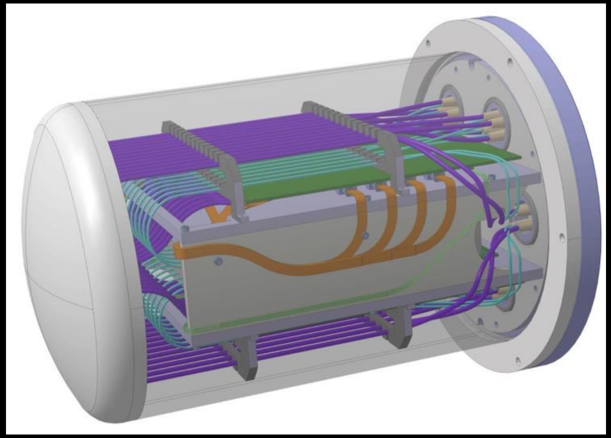
Posters:
97 – Lucas Machado et al
321 – Soniya Samani
401 – Lucile Mellet
424 – Shota Izumiyama

Outer Detector:



8 cm PMTs + WLS plates

Installation mock-up



Underwater electronics

Summary

- Hyper-Kamiokande is the next generation neutrino experiment in Japan
  - 260 kton Underground water Cherenkov far detector
  - 1.3 MW upgraded neutrino beam from JPARC
  - Upgraded and additional near detectors
- Construction is underway, on schedule to begin operation in 2027
- Hyper-K aims to reveal the full picture of neutrino oscillations
  - CP violation, mass ordering, θ_{23} octant…
- Astrophysical observations
  - Supernova bursts, solar neutrinos, supernova relic neutrinos
- Search for proton decay improves on current limits by order of magnitude
- International R&D ongoing to improve physics potential
- New collaborators welcome

Hyper-Kamiokande