Status of the Hyper-Kamiokande Experiment

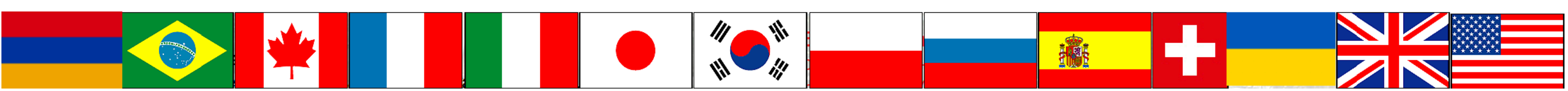
Erin O’Sullivan, on behalf of the Hyper-Kamiokande proto-collaboration
Stockholm University

NuFACT 2017

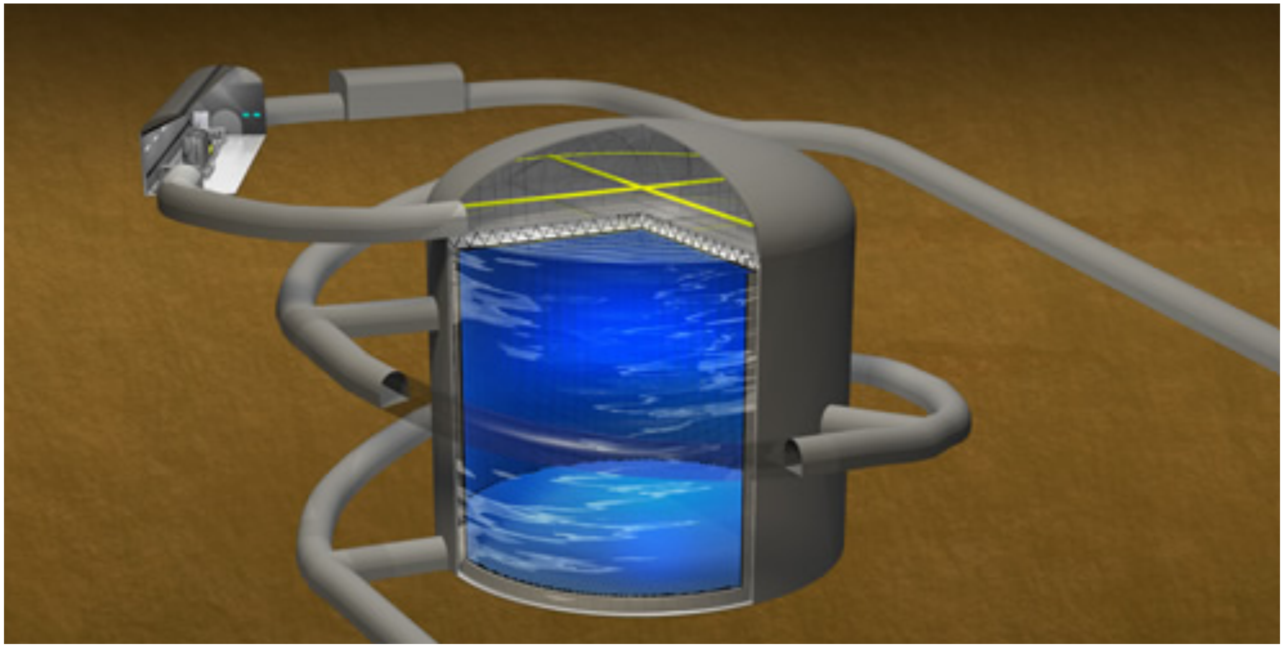
Hyper-Kamiokande collaboration

Proto-collaboration formed in 2015

~ 300 members from 14 countries (71 institutes)

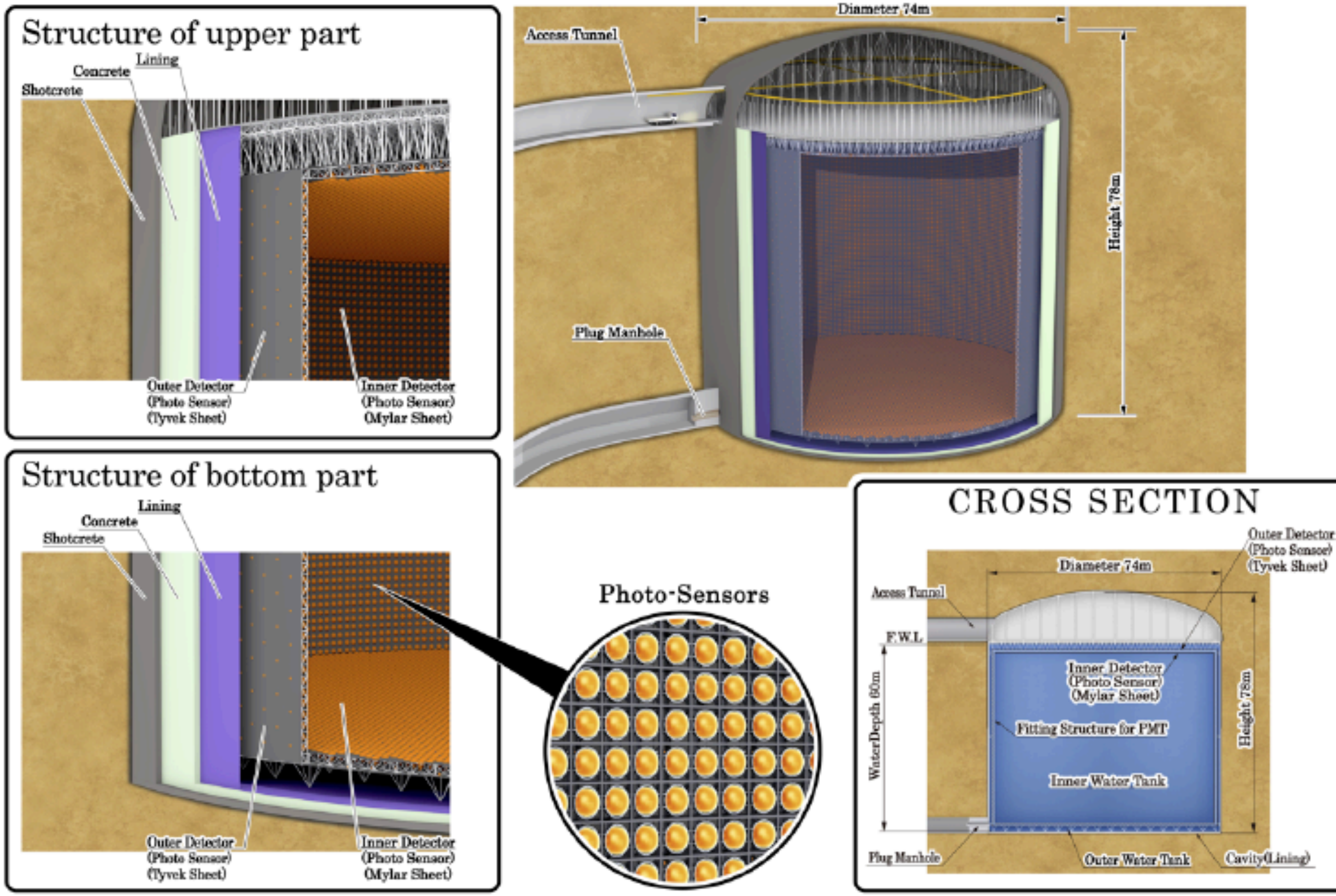


Hyper-Kamiokande detector

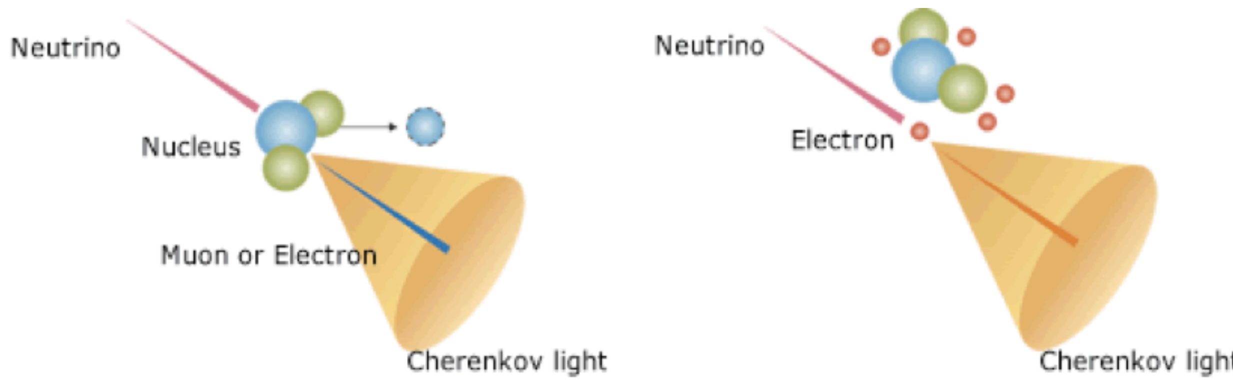


Two 74m (D) x 60m (H) tanks
Total (fiducial) volume of two tanks: 516 kT (374 kT).
We are prioritizing the quick realization of the first tank, with a second tank to follow. Unless indicated, all plots in this talk show sensitivity with one tank.

Hyper-Kamiokande detector



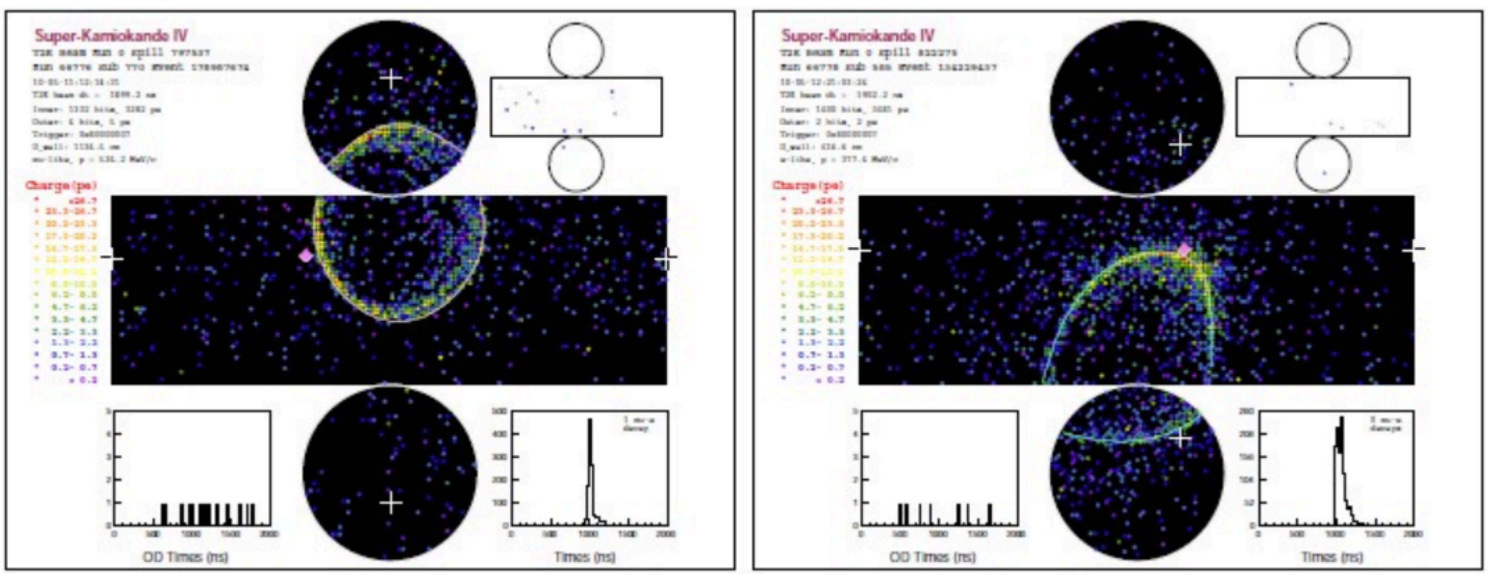
Water Cherenkov technology



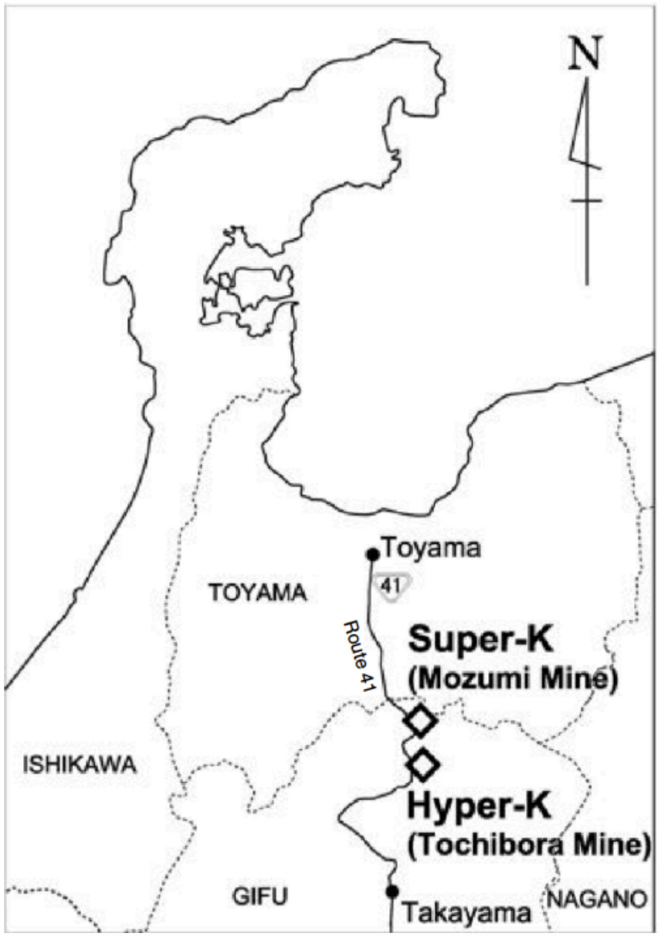
The generated charged particle emits the Cherenkov light.

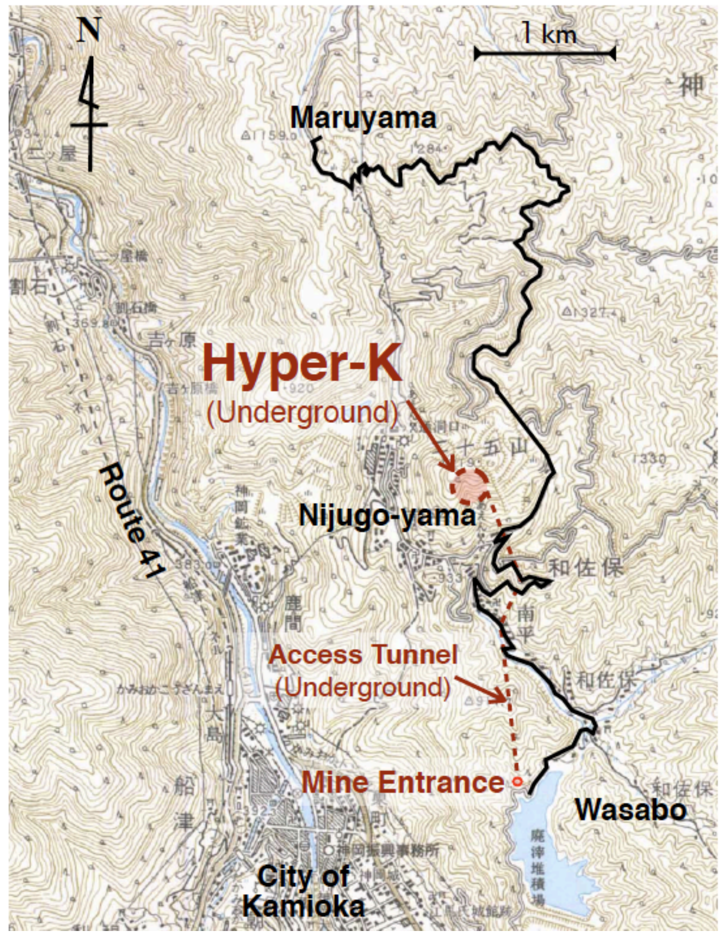
Muon: sharp ring

Electron: fuzzy ring



Hyper-Kamiokande site



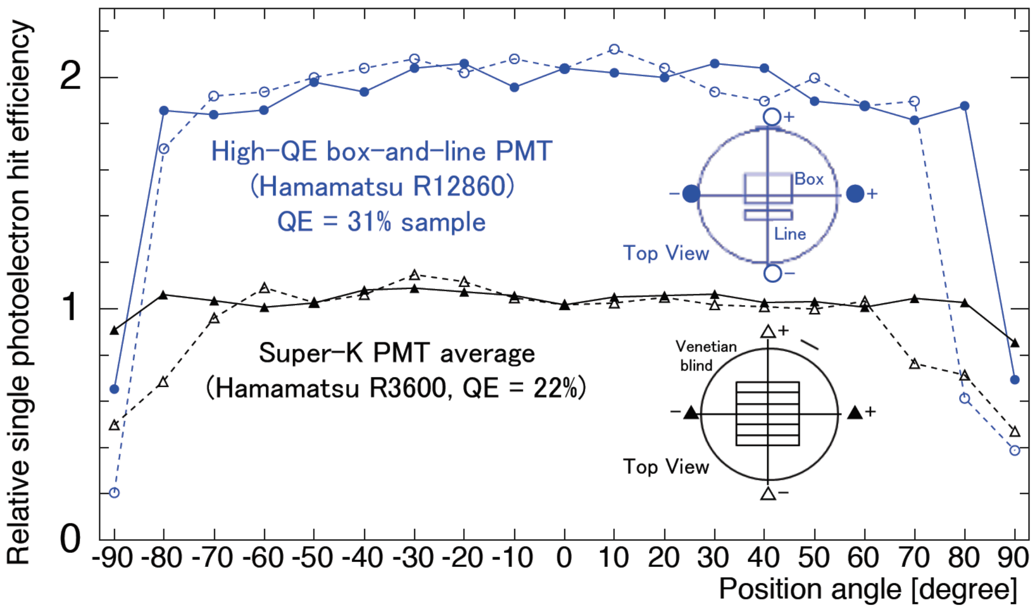


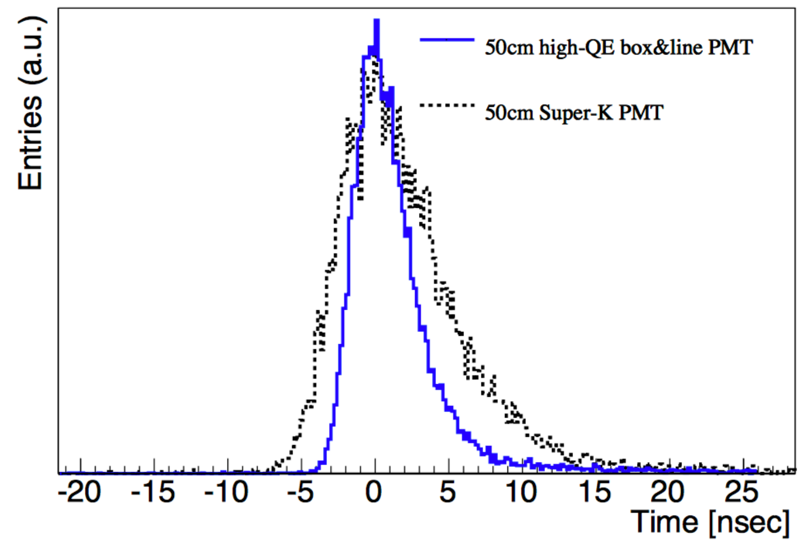
Detector will be located at the Tochibora Mine site

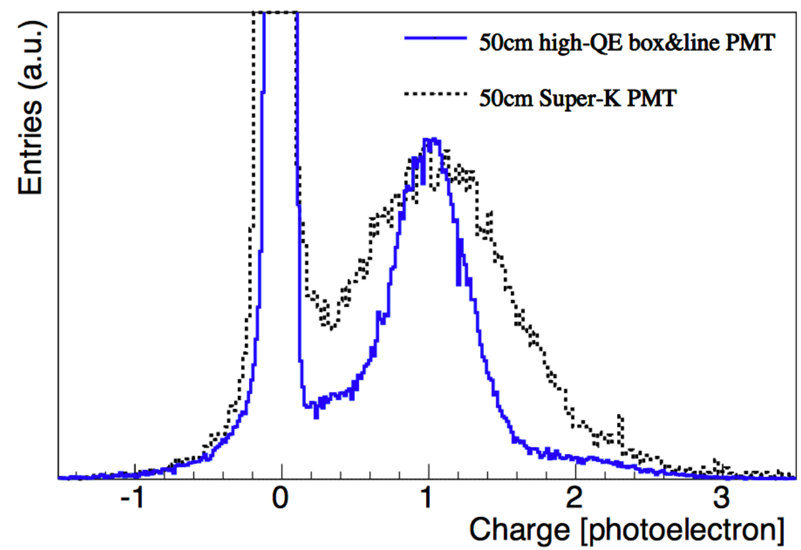
8 km south of SK

Overburden of 1,750 mwe

HK phototubes





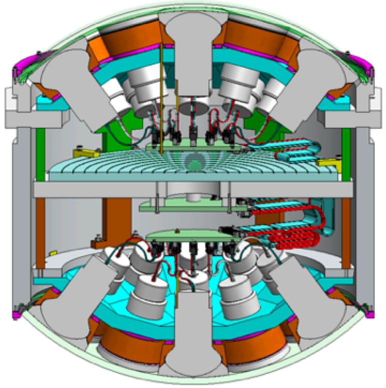


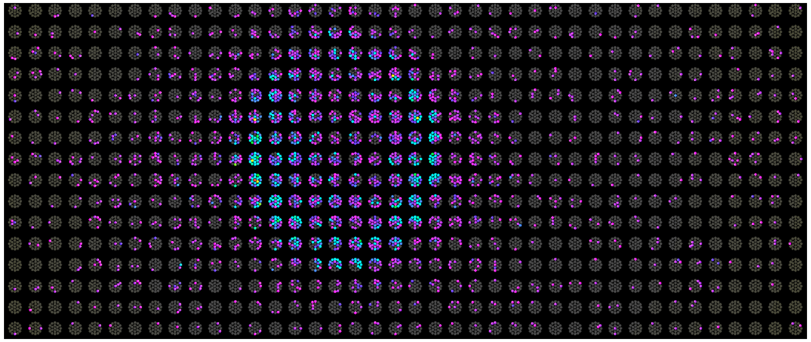
HK baseline design: box and line (SK uses venetian blind)
Twice the detection efficiency, better timing and charge resolution

HK phototube development

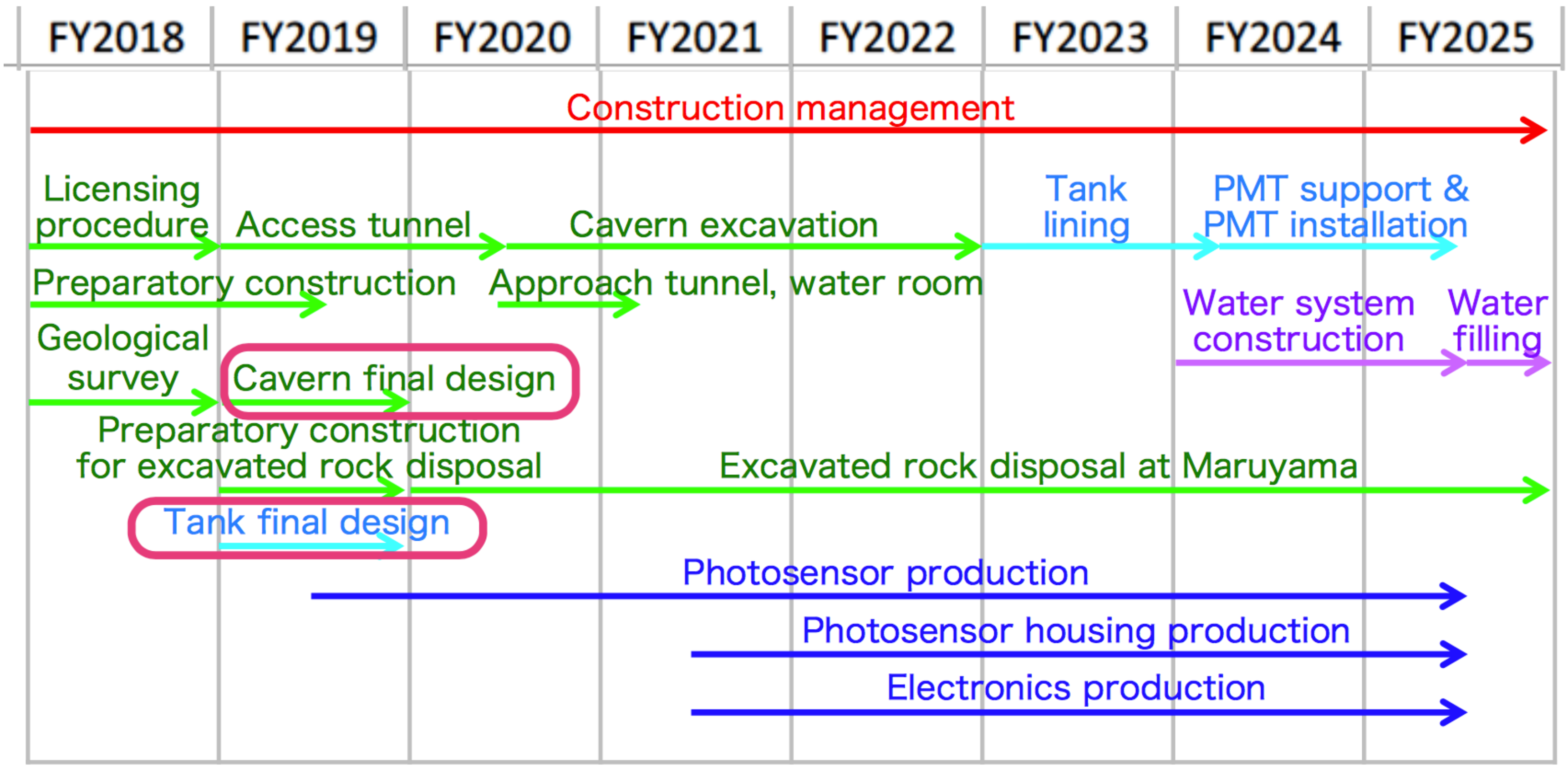
Covers to protect against pressure are being developed

Multi-PMT option (adapted from KM3NeT design) being explored



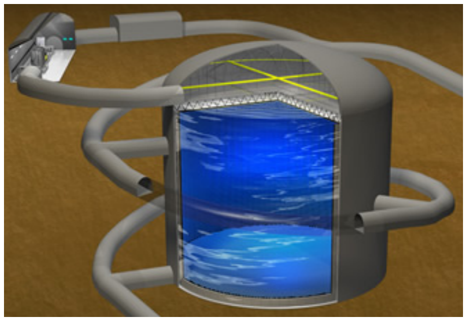


HK construction timeline



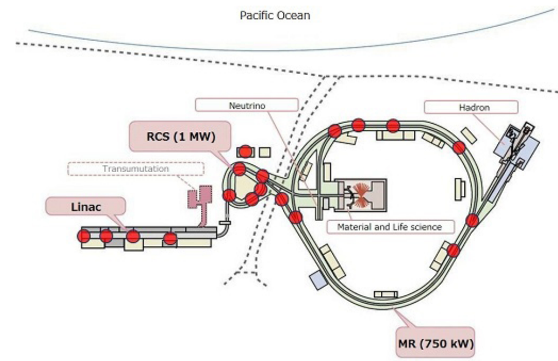
Data taking expected in 2026

T2HK

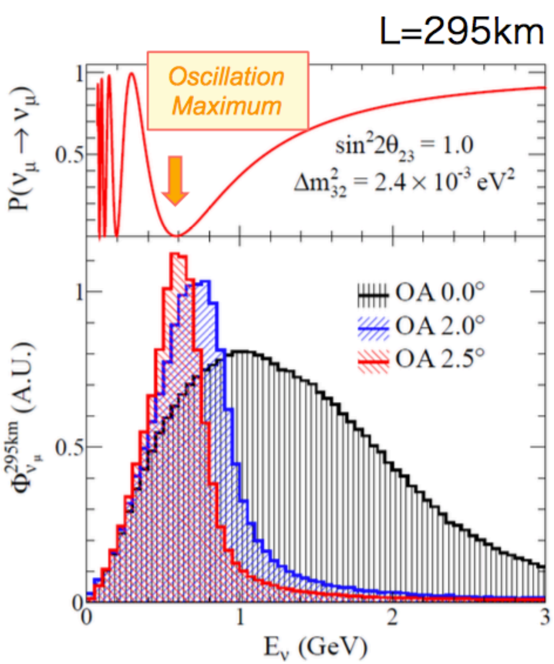


Hyper-K detector (Kamioka)

295 km



J-PARC neutrino Beam (Tokai)

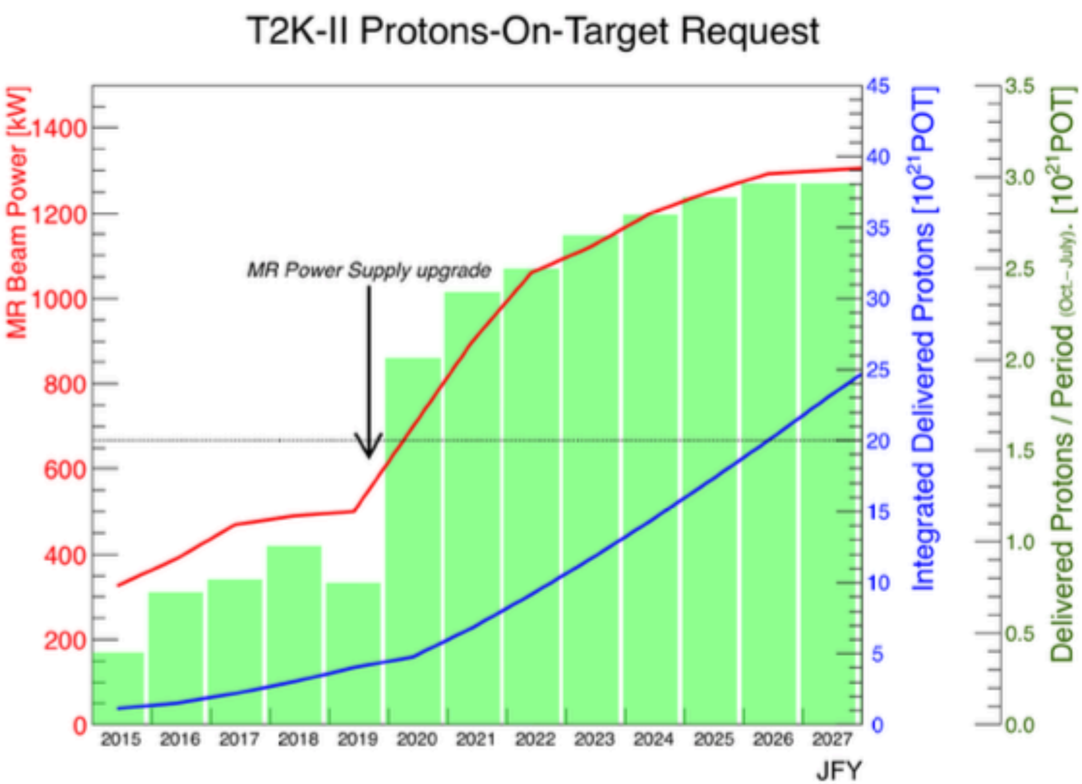


Building off the successful T2K program, Hyper-K also plans to measure neutrinos from the J-PARC neutrino beam

J-PARC beam – Planned upgrade

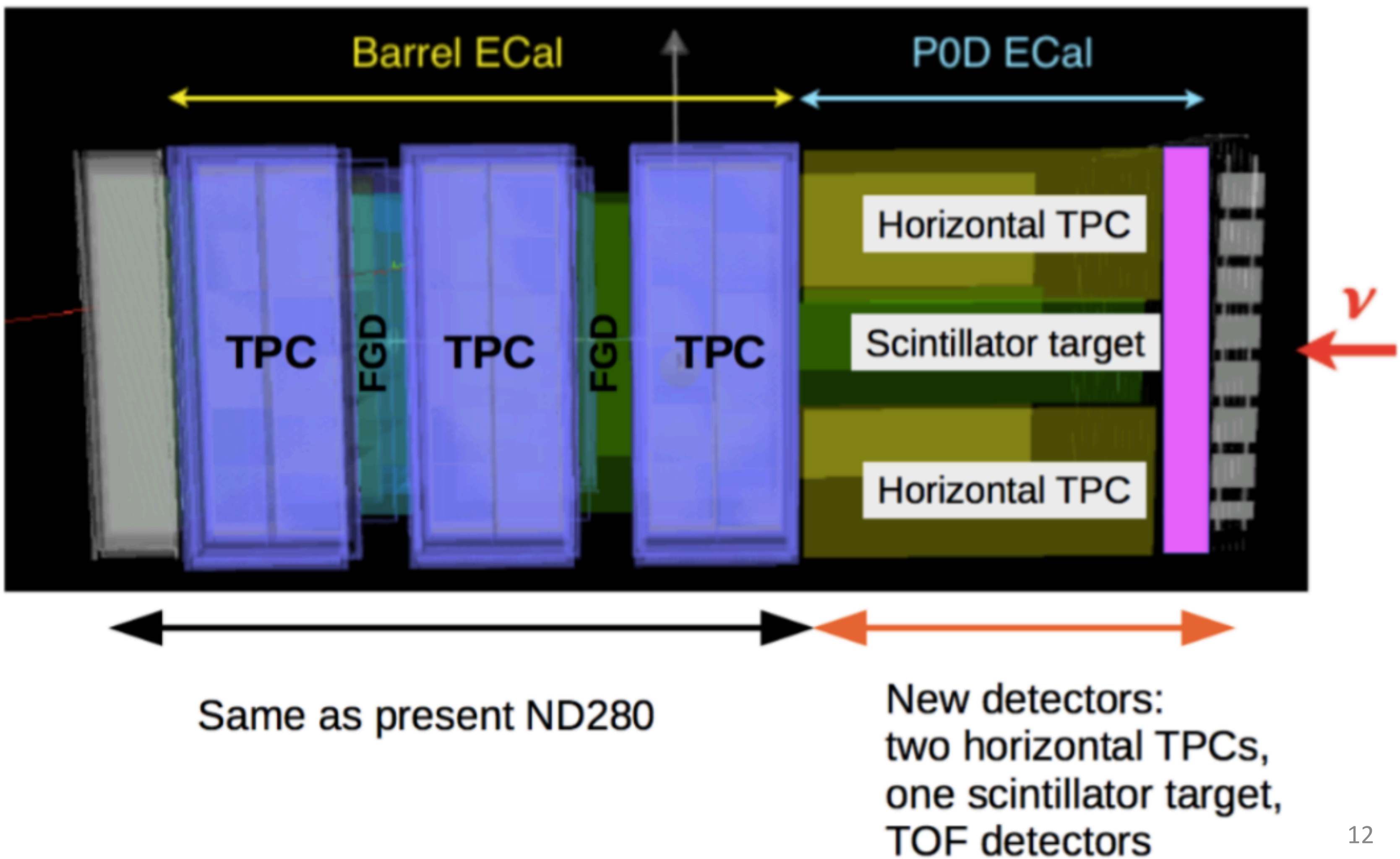
Plans to upgrade main ring would increase J-PARC beam power to ~1.3MW

Upgrades will mean 3x more beam power by 2026 (in time for Hyper-K)



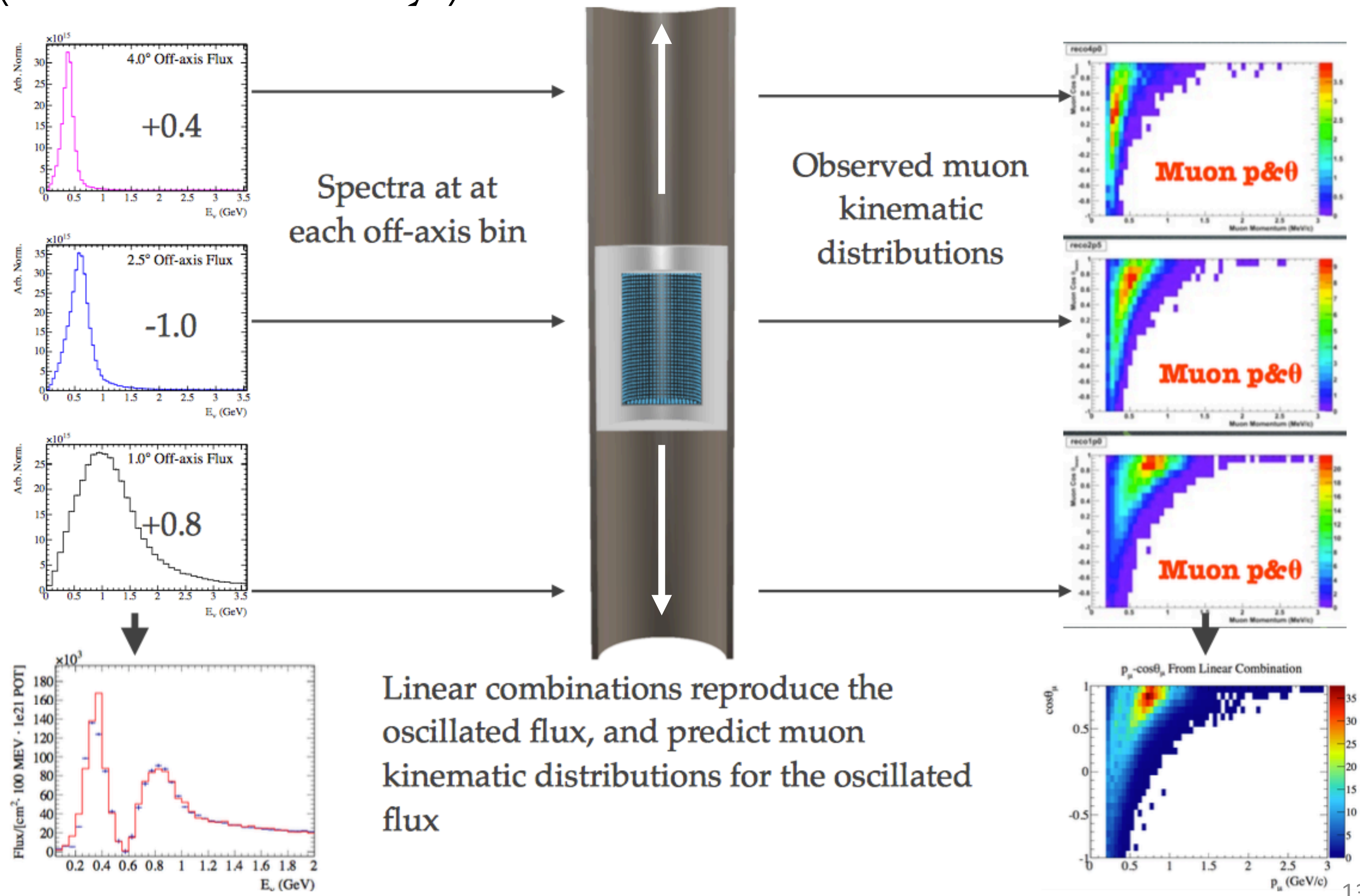
See Mathieu Lamoureaux's talk tomorrow in the WG1+WG2 session at 11:30

Near Detector – Planned upgrade

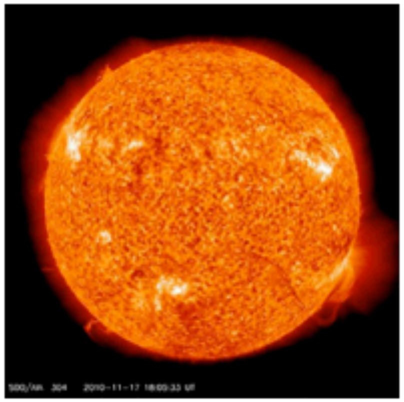


See Cris Vilea's talk tomorrow in the WG1+WG2 session at 11:30

1 kton E61 Intermediate Detector (1 km away)



Hyper-Kamiokande Physics Goals

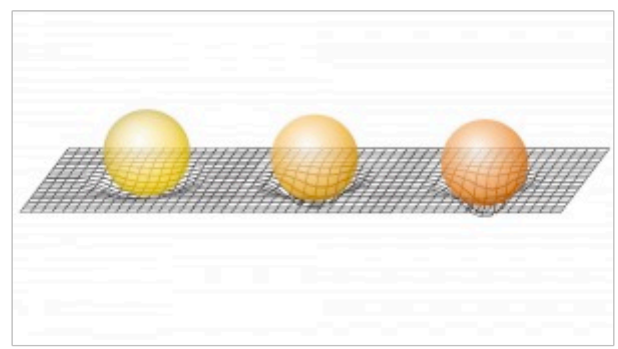


Solar neutrinos

CP violation

Astrophysical neutrinos

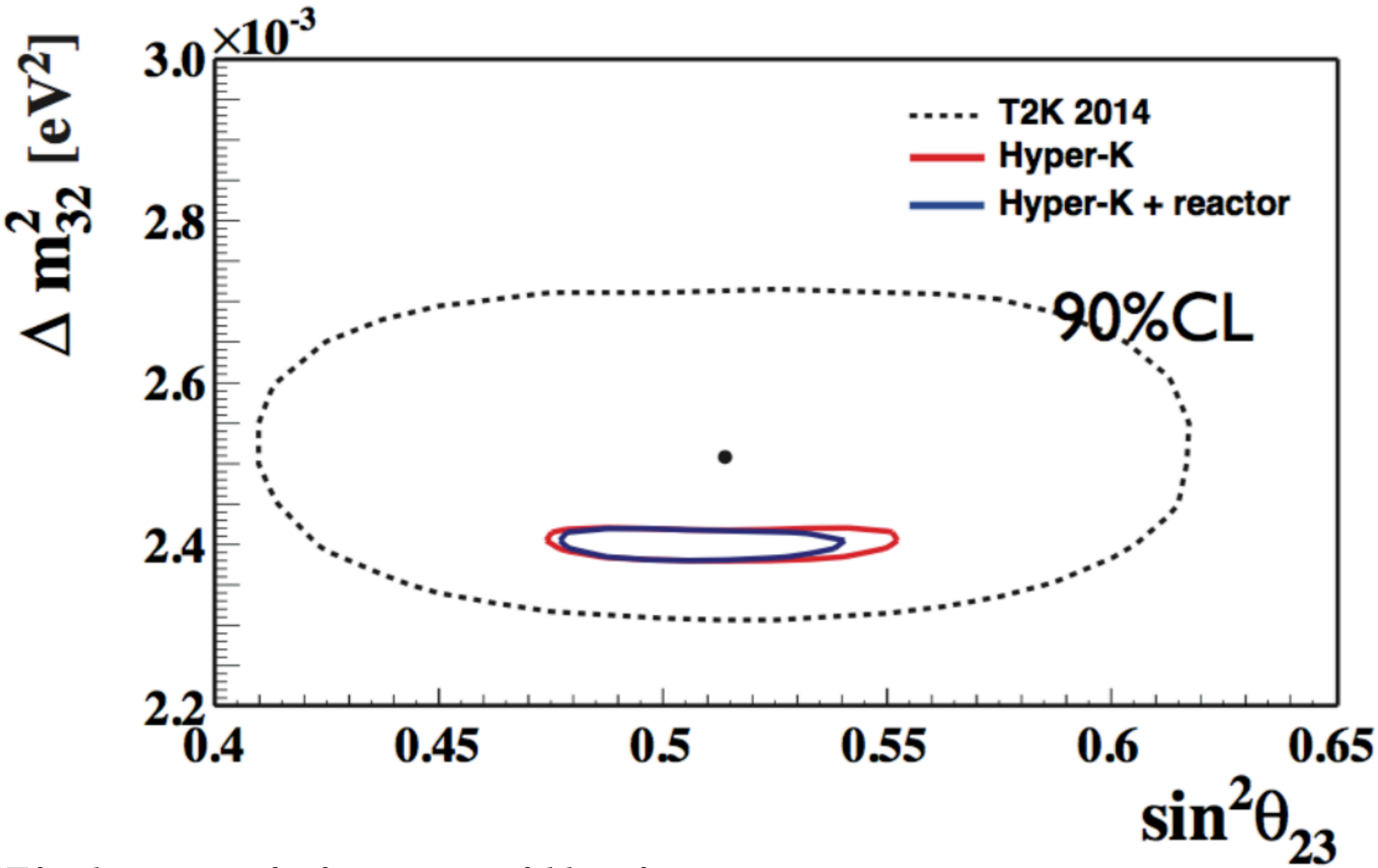
Proton decay



Mass hierarchy

See Christophe Bronner's talk today in the WG1 session at 14:48

Neutrino oscillation parameters



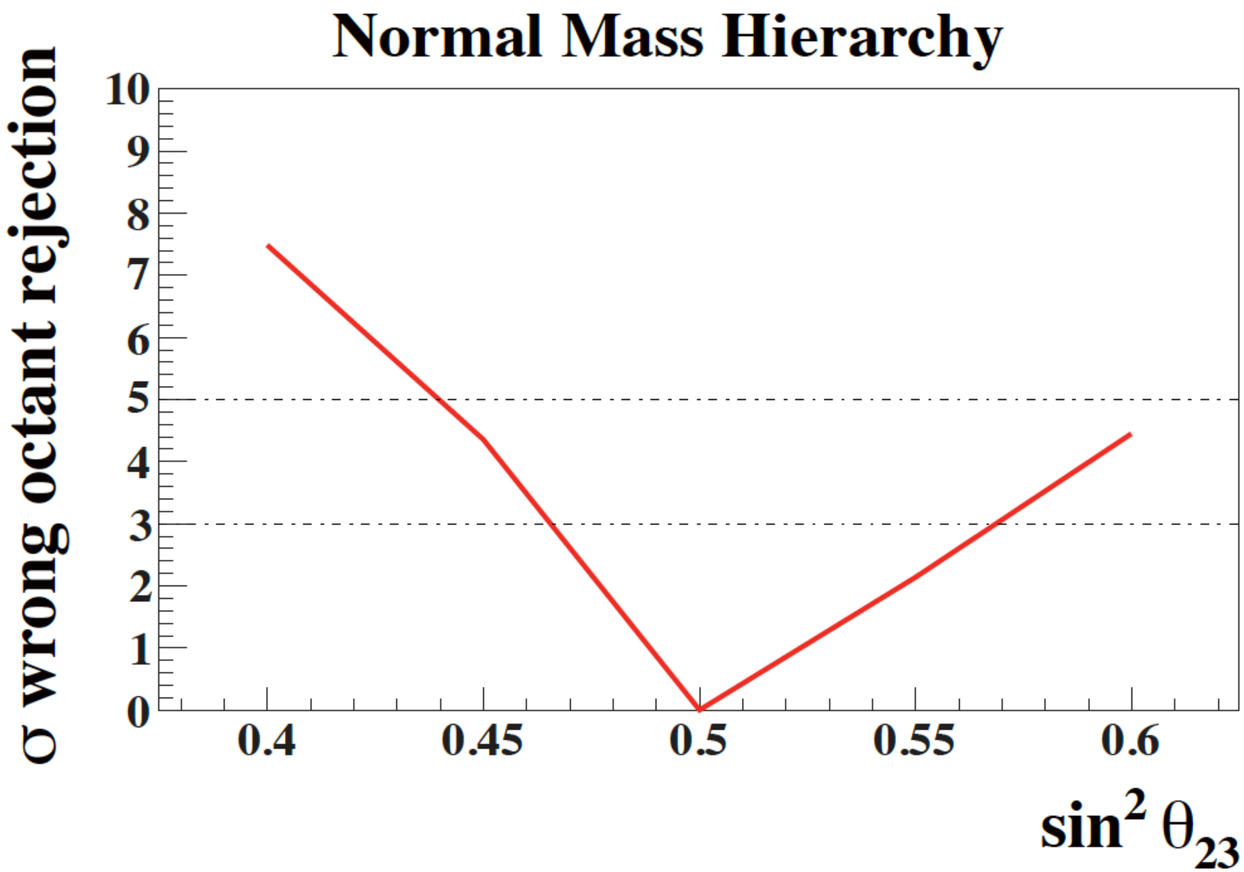
High precision oscillation parameter measurement:

$\delta(\sin^2\theta_{23}) \sim 0.006$ (for $\sin^2\theta_{23}=0.45$)

$\delta(\sin^2\theta_{23}) \sim 0.015$ (for $\sin^2\theta_{23}=0.50$)

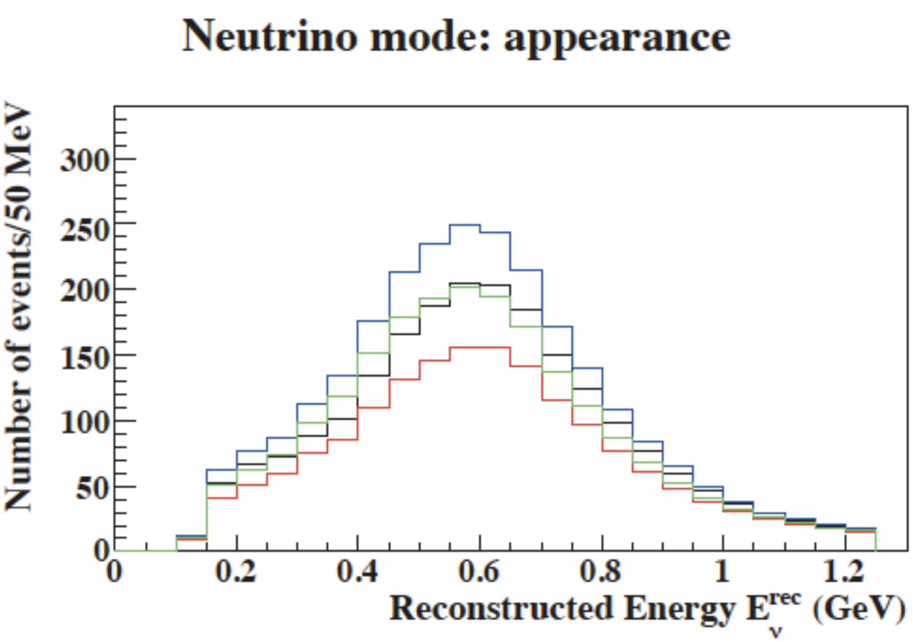
$\delta(\Delta m^2_{32}) \sim 1.4\times10^{-5}\mathrm{eV}^2$

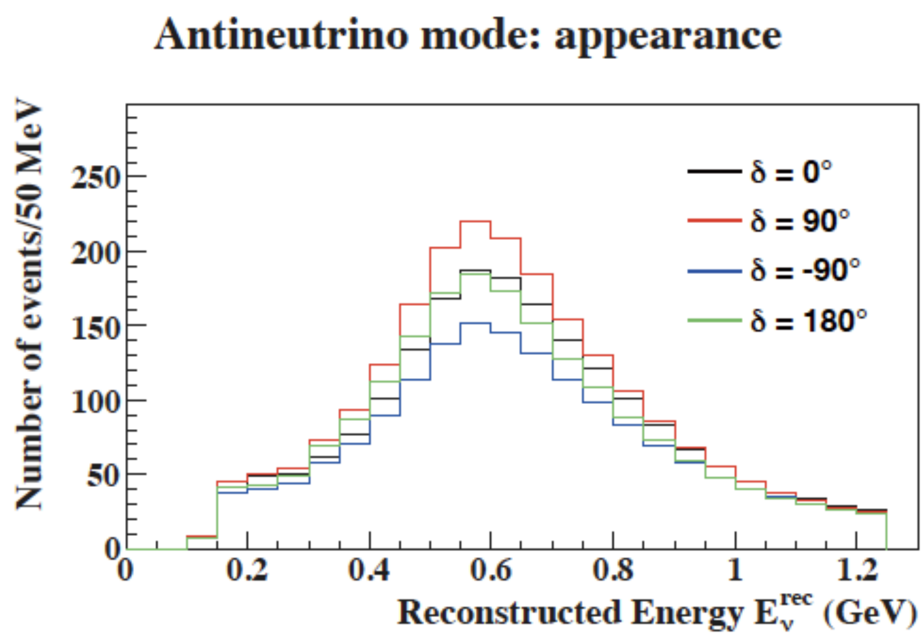
Octant determination: Using accelerator neutrinos



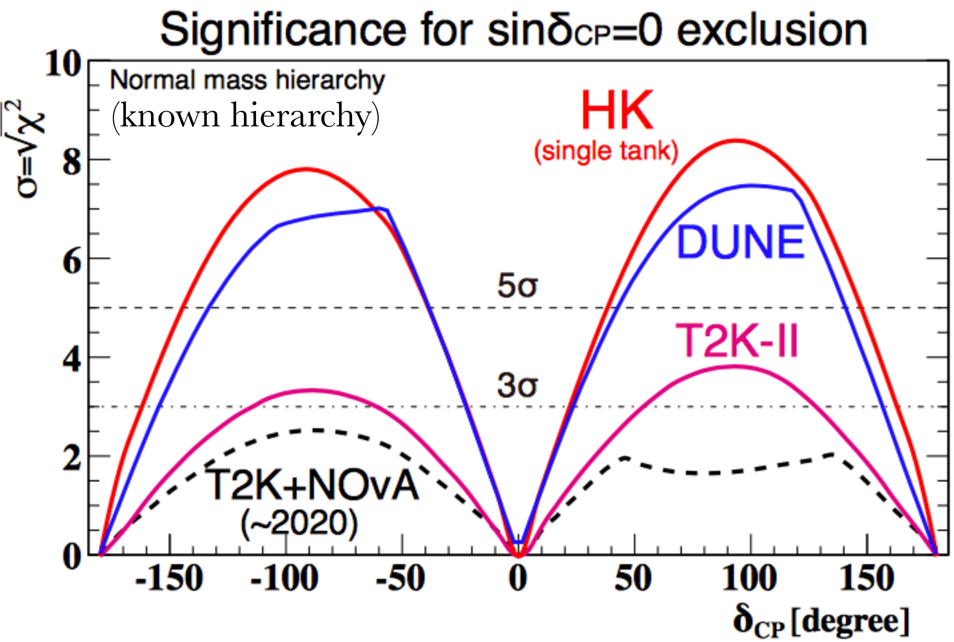
CP violation measurement

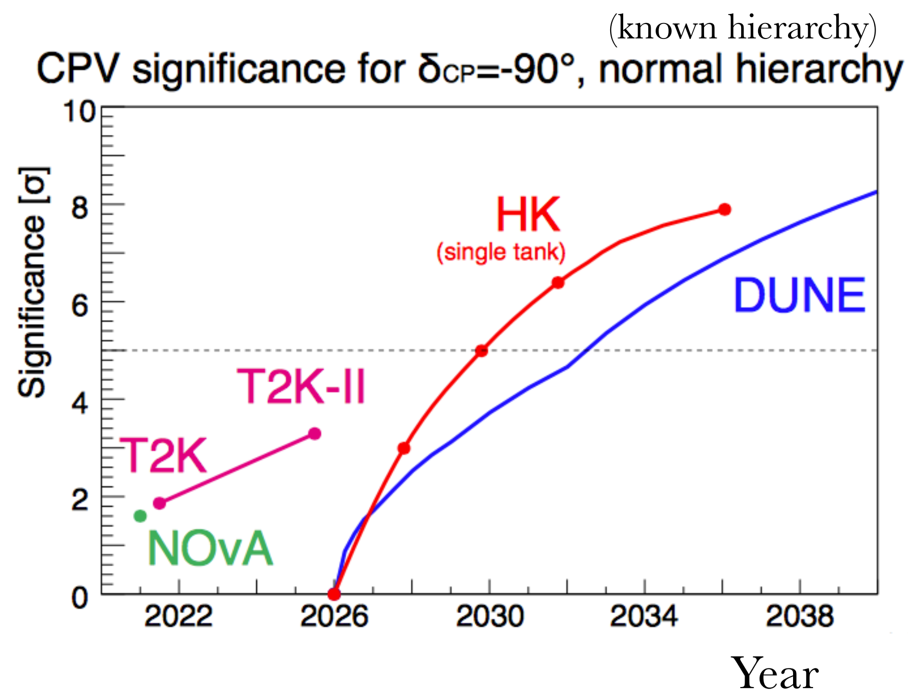
Looking for differences in the oscillation behaviour between neutrinos and anti-neutrinos





CP violation measurement: Using accelerator neutrinos

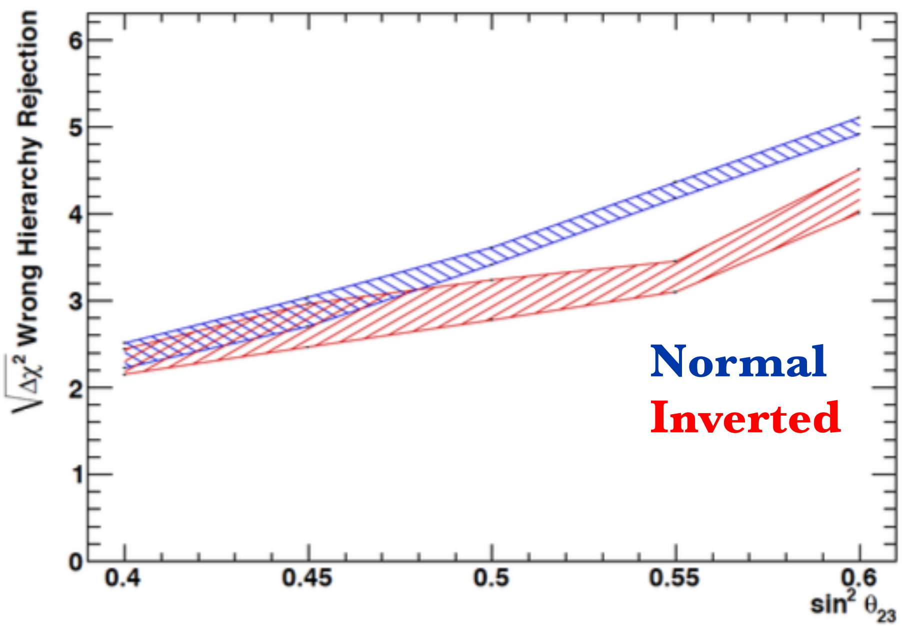




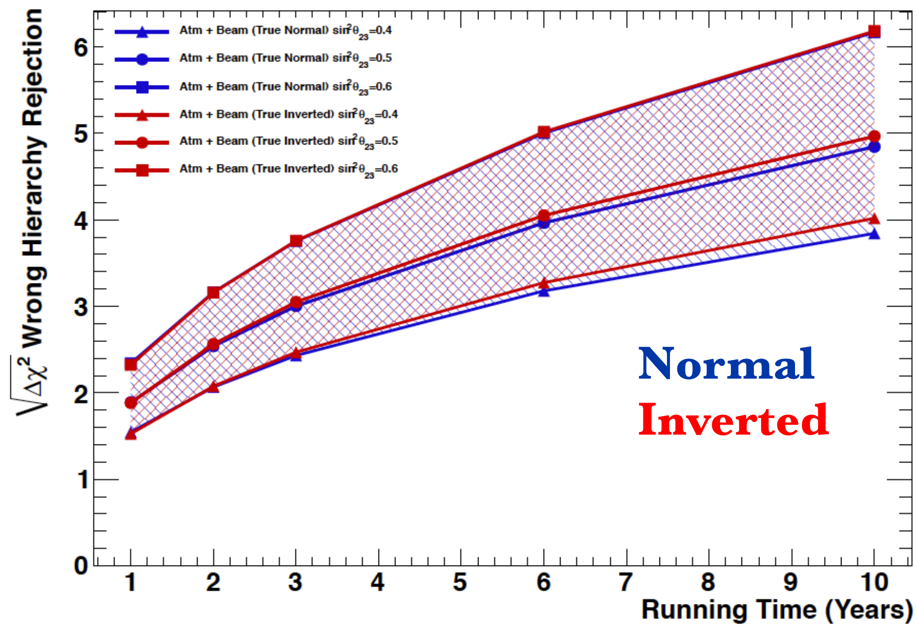
After 10 years of running, HK will be able to measure ~50% of the δ_{CP} space to better than 5σ

Mass hierarchy

10 years of running, atmospheric-only



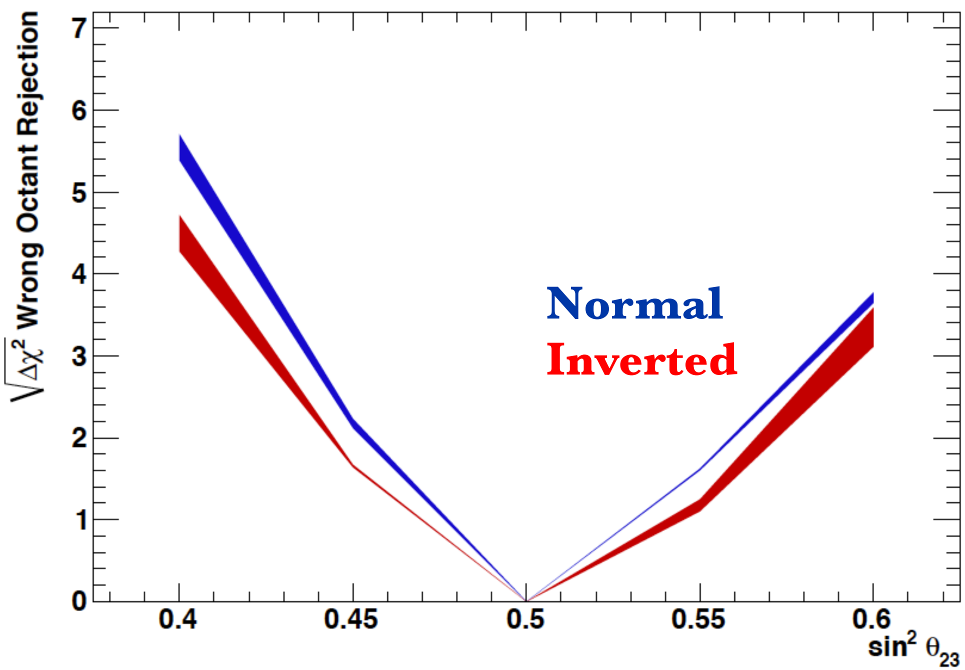
Combined accelerator+atmospheric



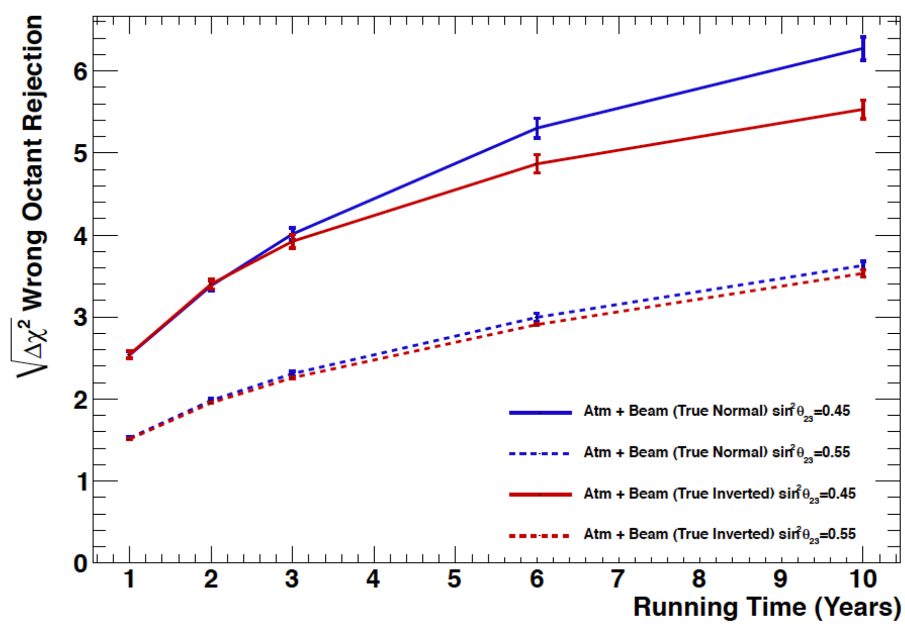
Depending on θ_{23}, mass hierarchy can be determined with $\sqrt{\Delta\chi^2}$ between 4 and 6

Octant determination: Adding atmospheric neutrinos

10 years of running, atmospheric-only

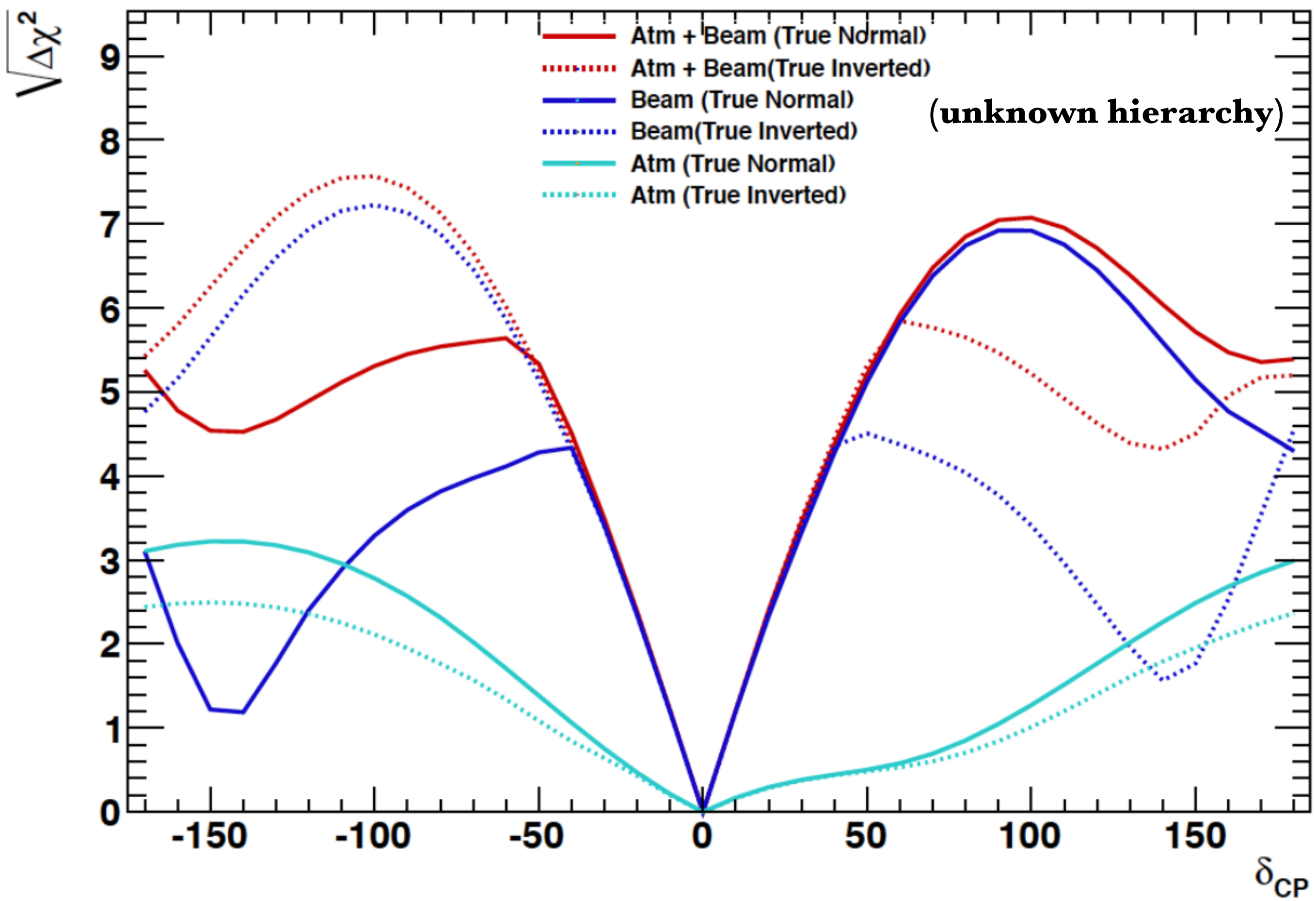


Combined atmospheric+accelerator



For $\sin^2\theta_{23}$=0.45: beam alone ~4σ, atmospheric alone ~2σ, beam+atmospheric ~5-6 σ

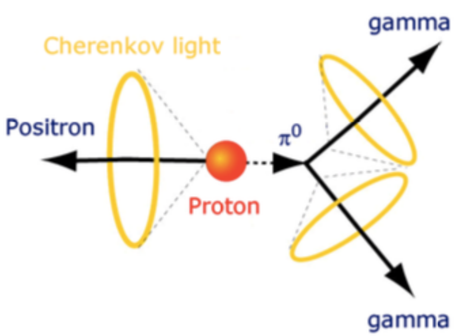
CP violation measurement: Resolving parameter degeneracies by adding atmospheric neutrinos



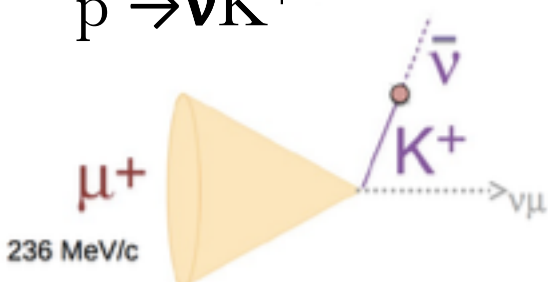
Nucleon decay

Flagship nucleon decay modes:

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



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

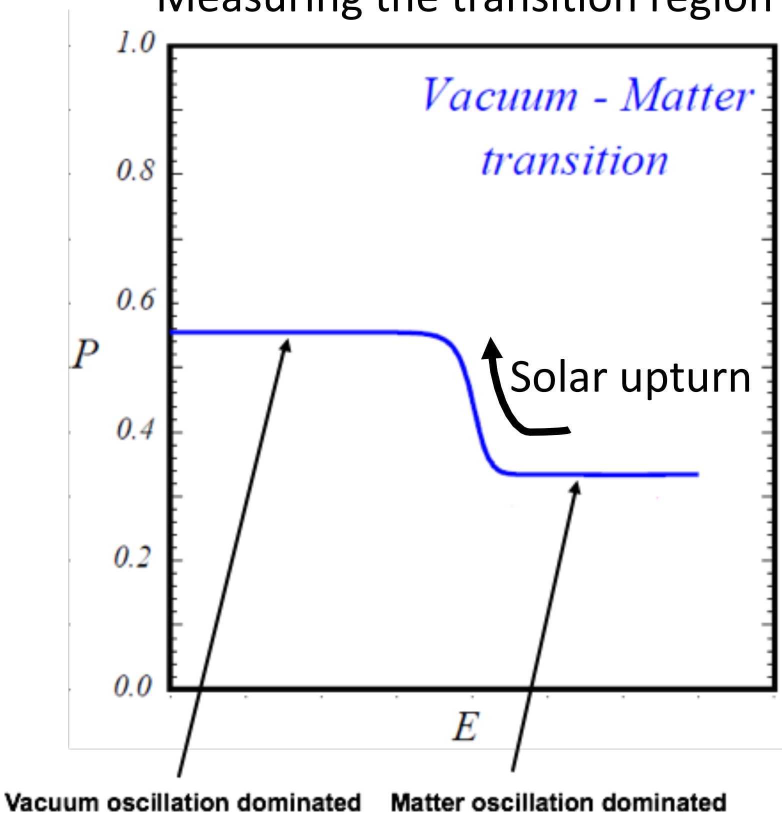


Mode	Sensitivity (90% CL) [years]	Current limit [years]
$p \rightarrow e^+\pi^0$	7.8×10^{34}	1.6×10^{34}
$p \rightarrow \overline{\nu} K^+$	3.2×10^{34}	0.7×10^{34}
$p \rightarrow \mu^+\pi^0$	7.7×10^{34}	0.77×10^{34}
$p \rightarrow e^+\eta^0$	4.3×10^{34}	1.0×10^{34}
$p \rightarrow \mu^+\eta^0$	4.9×10^{34}	0.47×10^{34}
$p \rightarrow e^+\rho^0$	0.63×10^{34}	0.07×10^{34}
$p \rightarrow \mu^+\rho^0$	0.22×10^{34}	0.06×10^{34}
$p \rightarrow e^+\omega^0$	0.86×10^{34}	0.16×10^{34}
$p \rightarrow \mu^+\omega^0$	1.3×10^{34}	0.28×10^{34}
$n \rightarrow e^+\pi^-$	2.0×10^{34}	0.53×10^{34}
$n \rightarrow \mu^+\pi^-$	1.8×10^{34}	0.35×10^{34}

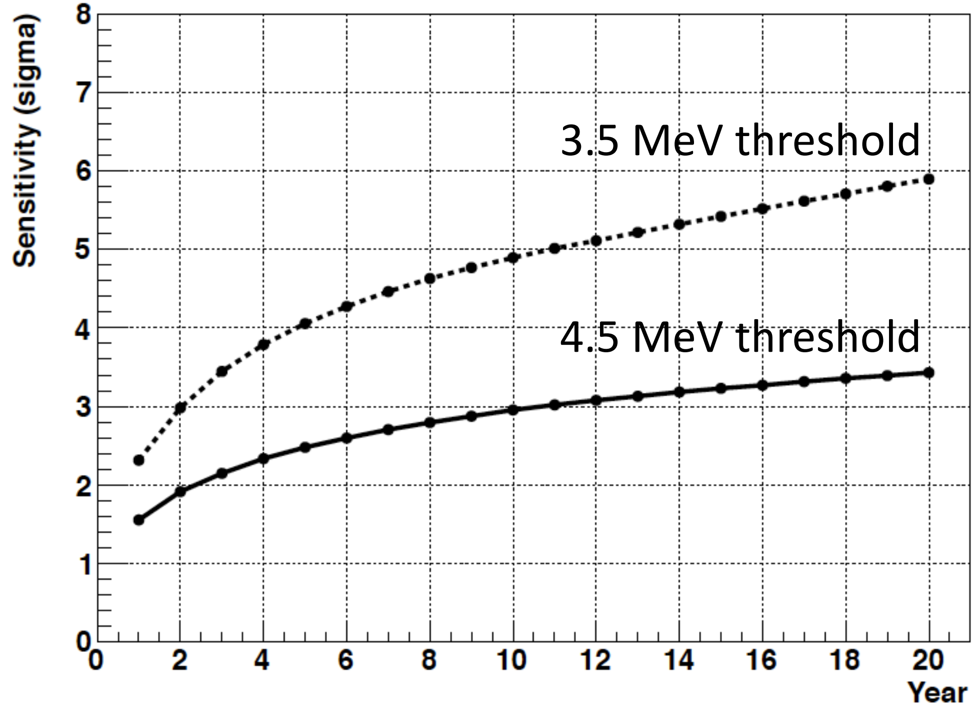
Limits will be improved across all nucleon decay channels, some by an order of magnitude.

Solar neutrinos

Measuring the transition region



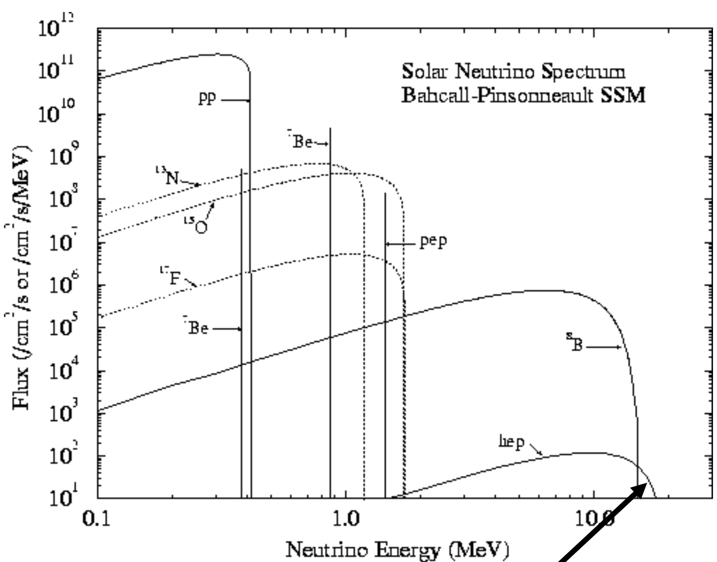
Solar upturn sensitivity

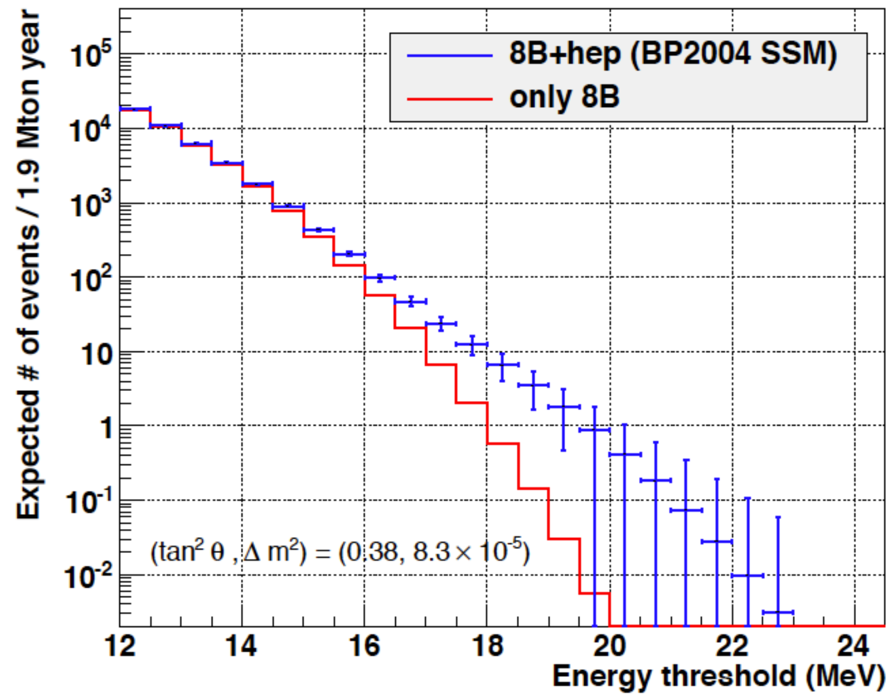


Hyper-K can measure the solar upturn to ~5σ (3σ) after 10 years with 3.5 MeV (4.5 MeV) threshold

Solar neutrinos

Measuring the hep neutrino





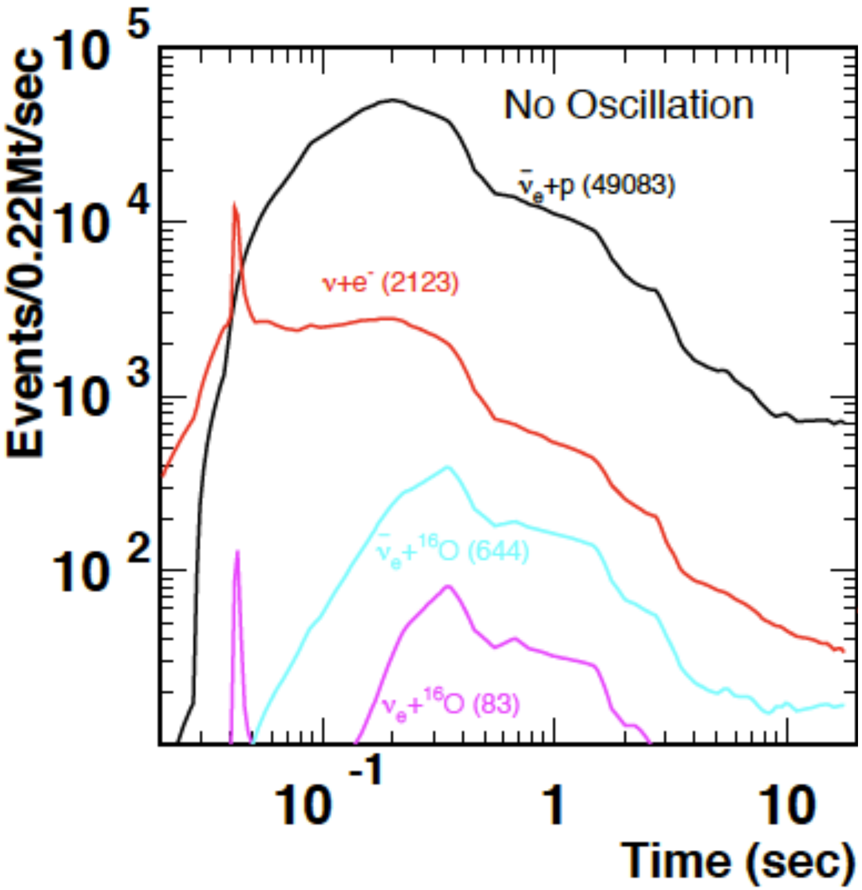
Small energy region above ^{8}B neutrinos

Good energy resolution and high statistics means Hyper-K will have sensitivity to hep solar neutrinos

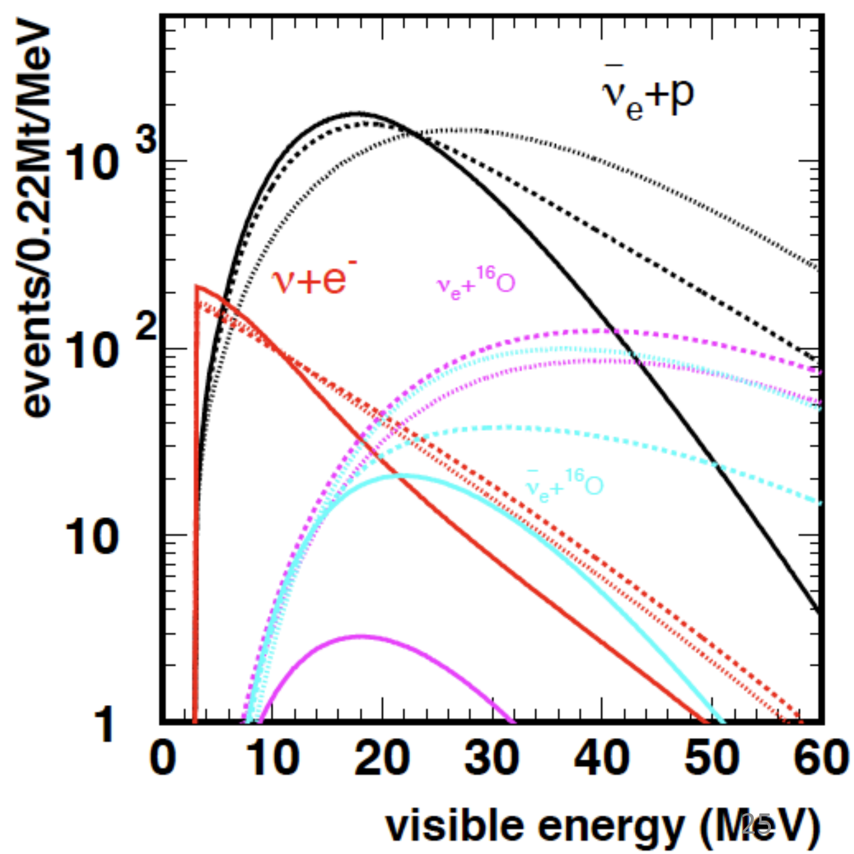
Supernova neutrinos

What would a galactic (10kpc) supernova look like in Hyper-K?

Timing information

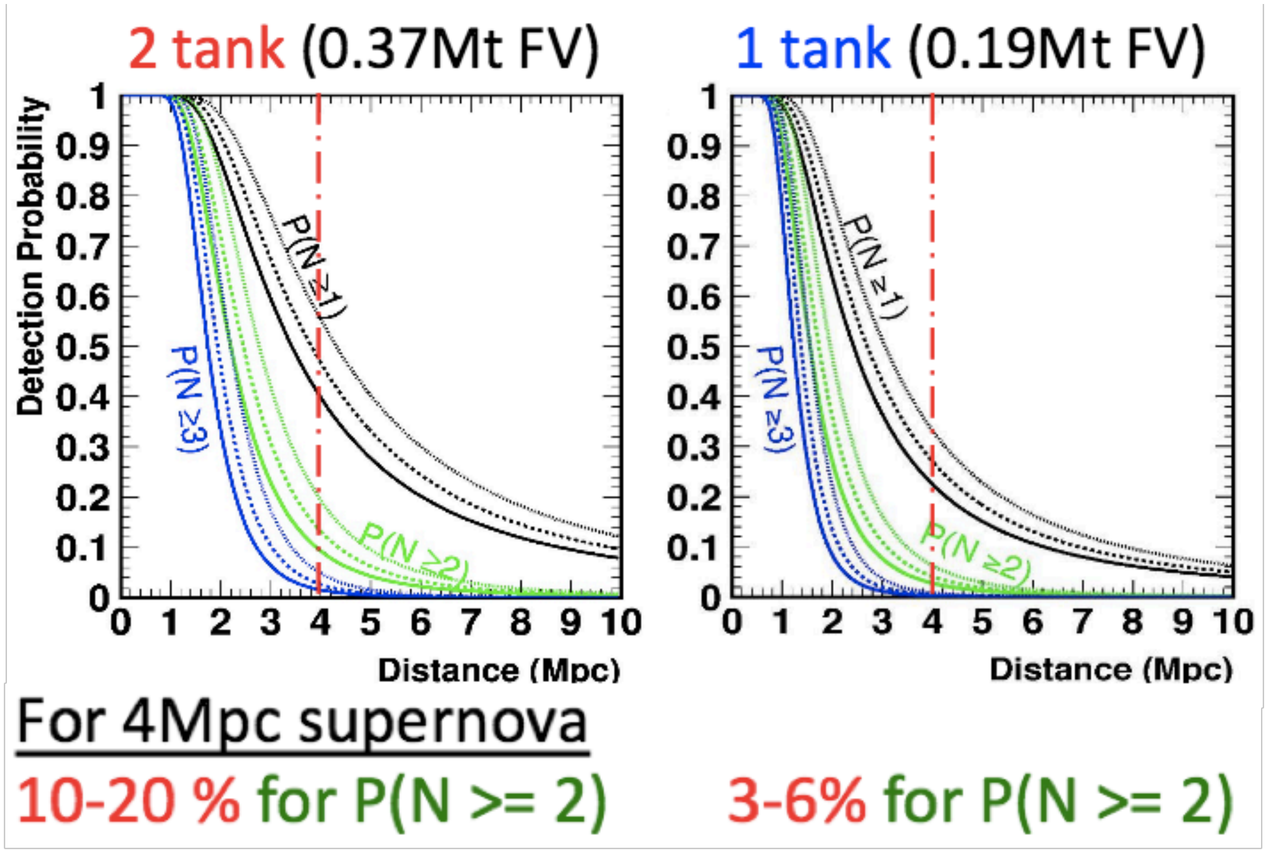


Energy information



Supernova neutrinos

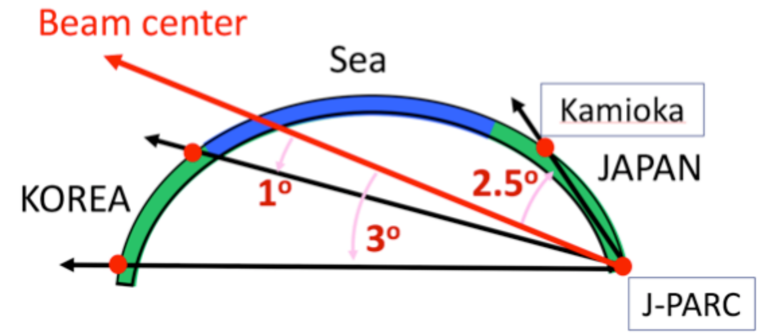
Seeing distant supernovae with Hyper-K



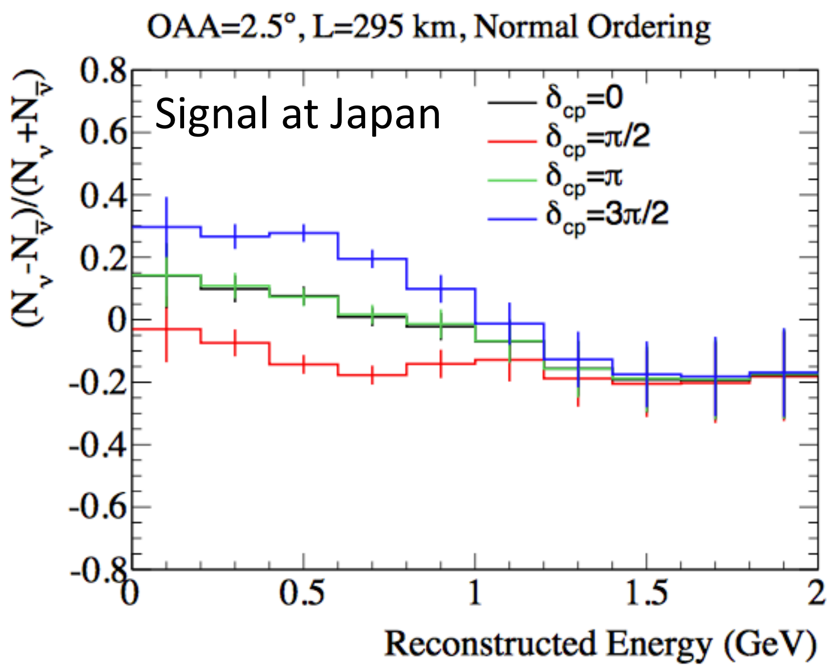
Livermore, 10 MeV threshold, expectation range from oscillation effects

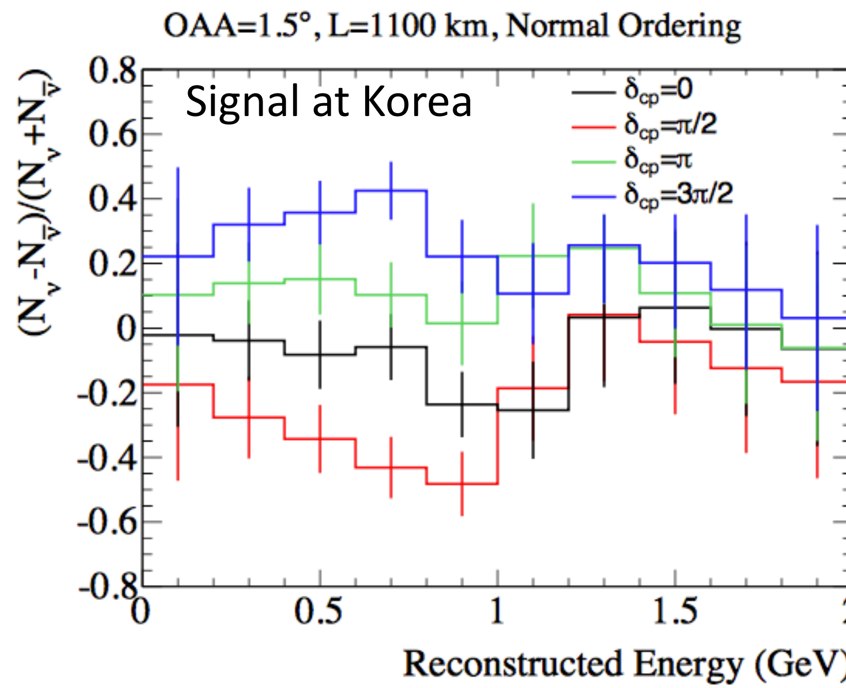
See arXiv:1611.06118 [hep-ex]

HK-K



Exploring option of putting second HK tank in Korea



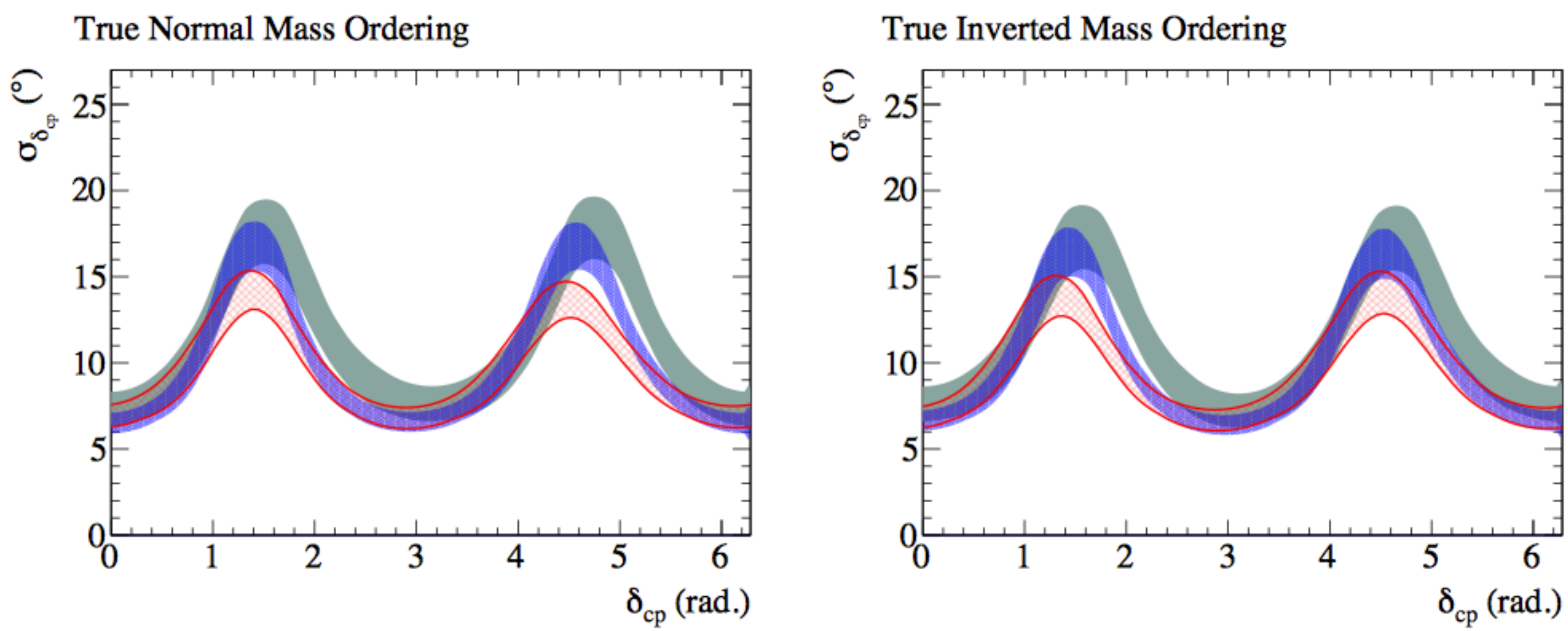


Putting the second detector at the second oscillation maximum means our signal has a different shape →makes us less sensitive to systematic errors

T2HKK

Two detectors in Japan

Second detector in Korea, two colours for two different candidate sites



The second detector in Korea allows us to better measure the CP-phase, compared with both detectors in Japan

HK Status

- In summer 2017, HK was listed as a top project on the Ministry of Education, Culture, Sports, Science and Technology (MEXT) roadmap with the highest possible rating of (a,a)
- A budget request to the Japanese funding agency has been submitted
- Many opportunities for new collaborators to make an impact - please join us!

Summary

- Hyper-K will be a world-leading water Cherenkov experiment
- Good prospects for detecting CP-violation, oscillation parameters, and mass hierarchy with accelerator and atmospheric neutrinos
- Non-accelerator physics goals include nucleon decay and astrophysical neutrinos
- Placing the second HK tank in Korea could enhance our sensitivity to our physics goals, including CP-violation.