The Hyper-Kamiokande Project

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On behalf of the Hyper-Kamiokande Proto-Collaboration

NNN 2018, Vancouver

The Hyper-Kamiokande Proto-Collaboration

15 countries, 76 institutes, ~300 people

Hyper-Kamiokande

Some Excellent News…

HYPER-KAMIOKANDE EXPERIMENT TO BEGIN CONSTRUCTION IN APRIL 2020

Posted on SEPTEMBER 19, 2018 5:01 PM by ADMIN

Last week at the 7th Hyper-Kamiokande proto-collaboration meeting, a statement was issued by the University of Tokyo recognizing the significant scientific discoveries which the planned Hyper-Kamiokande experiment would enable.

It states that, based on these exciting prospects, the University of Tokyo will ensure that construction of the experiment will begin in 2020. Hyper-Kamiokande now moves from planning to a real experiment.

The Hyper-Kamiokande proto-collaboration welcomes this exciting endorsement of the project and the boost it will give to increasing even further the international contributions and participation in the experiment. Introducing the statement, Professor Takaaki Kajita, Director of the Institute for Cosmic Ray Research at the University of Tokyo and 2015 Nobel Laureate in Physics, pointed out that the Japanese funding agency MEXT has included seed funding for Hyper-Kamiokande in its JFY 2019 budget request. He illustrated with many examples that it is standard in Japan for large projects to begin with a year of seed funding, and said that in any case the University of Tokyo commitment meant that Hyper-Kamiokande construction will begin in April 2020.

The Hyper-Kamiokande Proto-Collaboration will now work to finalize designs, and is very open to more international partners to join in this far-reaching new experiment.

Some Excellent News…

Naturally, this made us all very happy at the September Proto-Collaboration meeting!

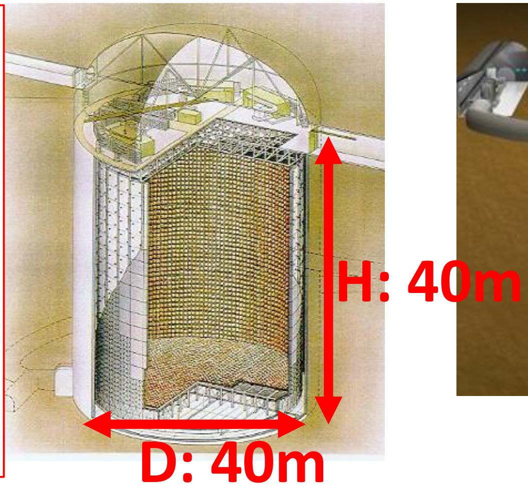
Hyper-Kamiokande

Hyper-Kamiokande Detector

- Next generation Water Cherenkov detector, building from expertise and knowledge from Kamiokande and Super-Kamiokande

	Super-K	Hyper-K (1st Tank)
Site	Mozumi	Tochibora
ID PMTs	11,129	40,000
Photo-coverage	40%	40% (x2 1PE efficiency)
Mass (Fiducial Mass)	50kton (22.5kton)	260kton (187kton)

- Increase in fiducial mass ~x10
- Improved photo-detection capabilities gives x2 sensitivity of PMTs
  → x2 effective photocoverage
- Keeping low background and energy threshold



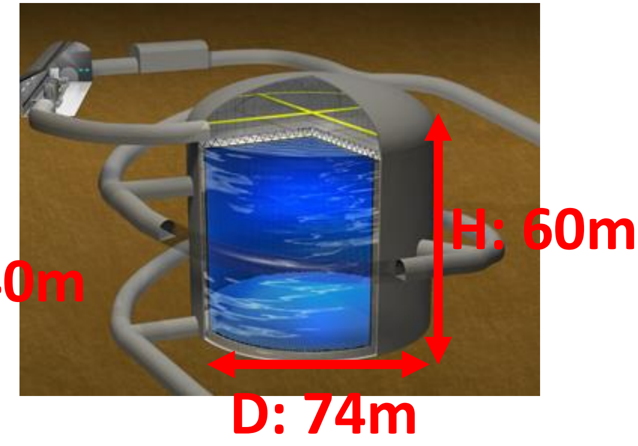
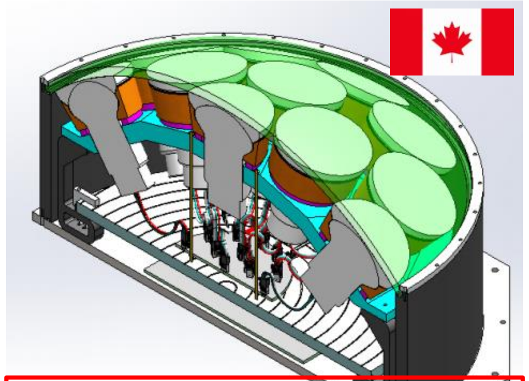


Photo-Sensor R&D

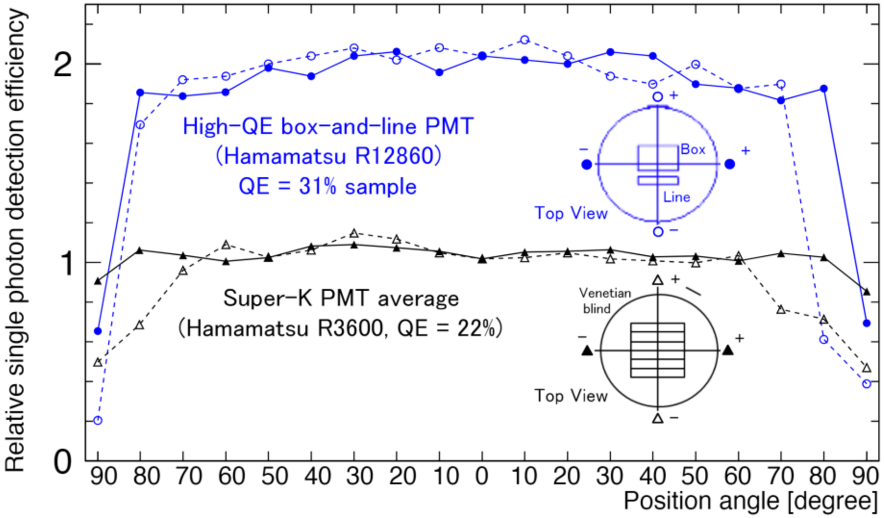
- New Hamamatsu box-and-line PMTs with high QE will be used in HK for half the coverage:
  - x2 single photon detection efficiency relative to SK PMTs
  - Improved charge and timing resolutions

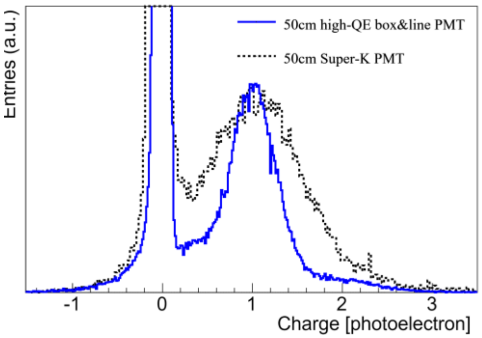
- Considering other international contributions for remainder of PMTs, eg Canadian mPMT

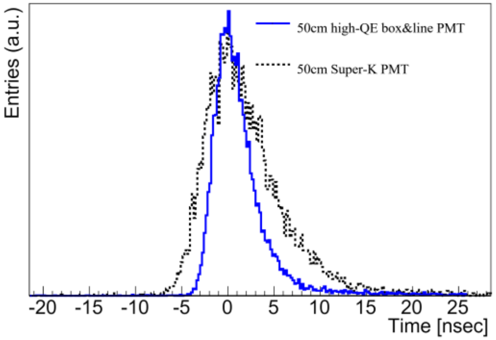
See talk by J. Kameda



See talk by T. Lindner







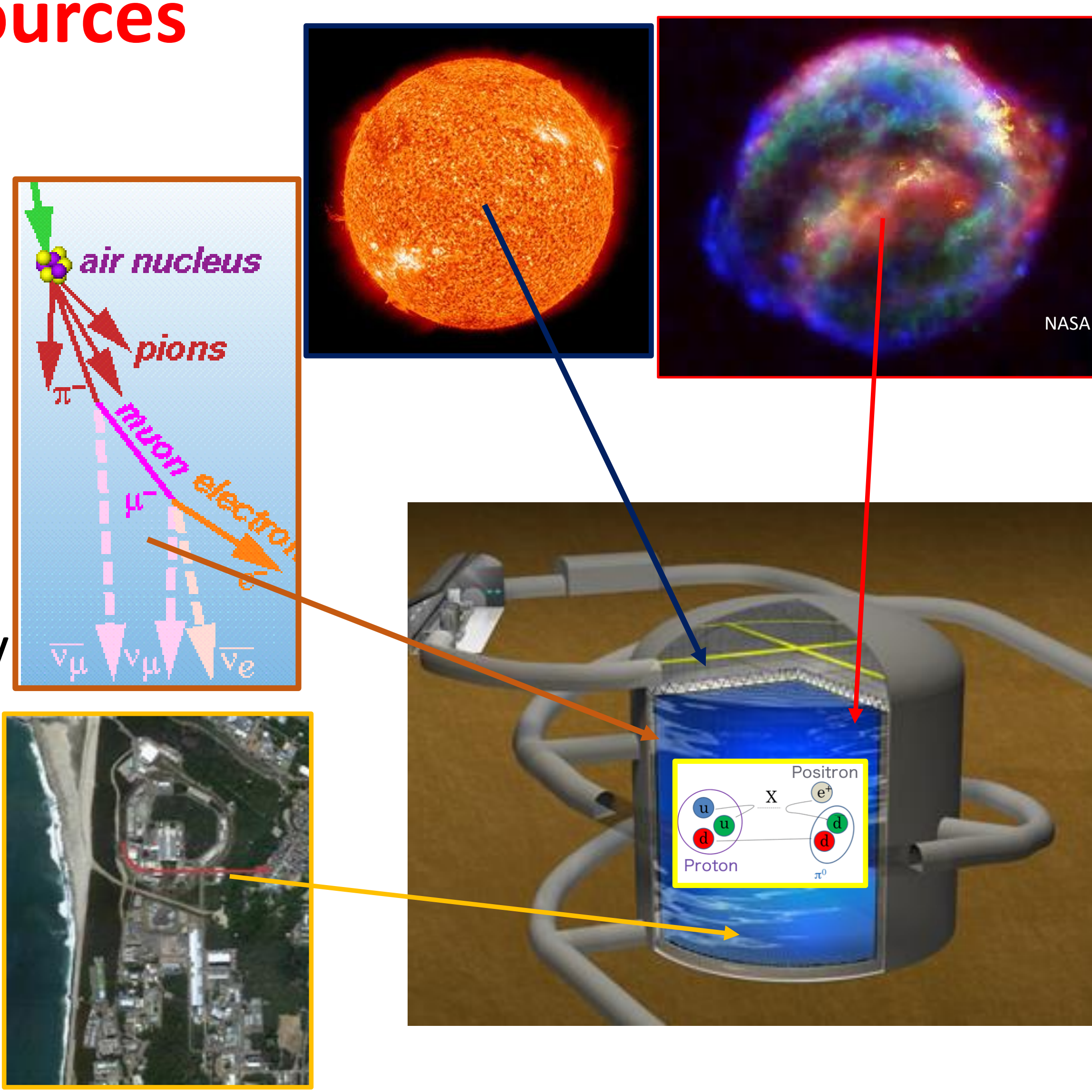
Hyper-Kamiokande

Many Physics Goals

Sensitive to many sources of neutrinos

- Search for CP violation, measurement of δ_{CP}
- Precision oscillation parameter measurements
- θ_{23} octant
- Mass ordering
- Solar day/night asymmetry
- Supernova detection
- Supernova Relic Neutrinos

- Search for proton decay



Long Baseline Beam Neutrinos

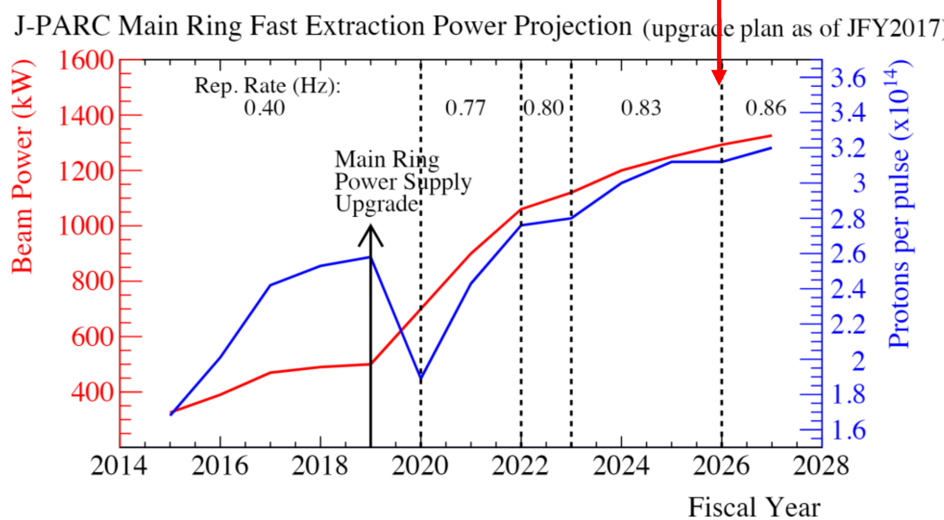
Hyper-K site is just 8km from current Super-K site

- **L = 295km**, the same as for Super-K
- Beam has same 2.5° off-axis angle, same narrow band energy peak as Super-K at **E = 600MeV**

Long Baseline Beam Neutrinos

- Increase in beam power: 485kW → 1.3MW in time for HK
- Reduced systematics thanks to
  - ND280 upgrade (see talk by E. Noah Messomo)
  - Addition of an Intermediate Water Cherenkov Detector (see talk by J. Walker)

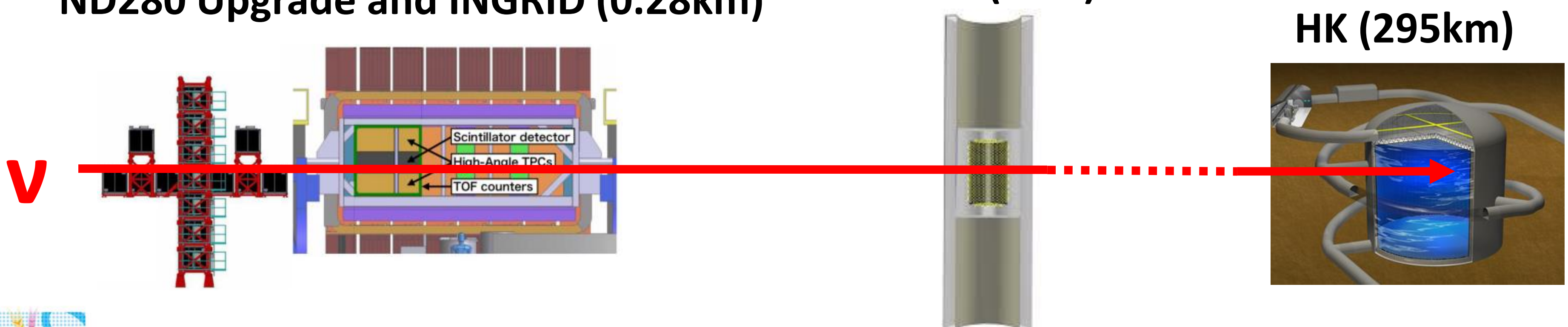
1.3MW for HK



ND280 Upgrade and INGRID (0.28km)

IWCD (1km)

HK (295km)

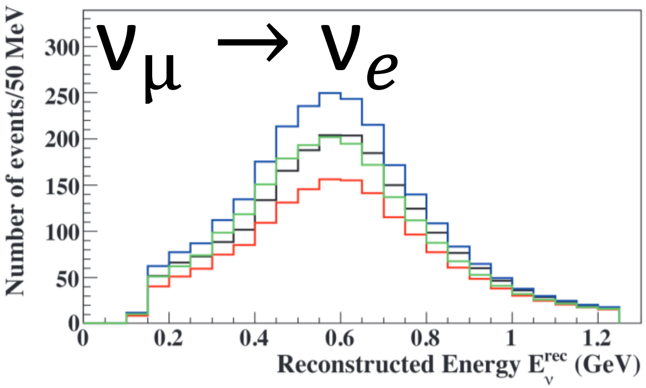


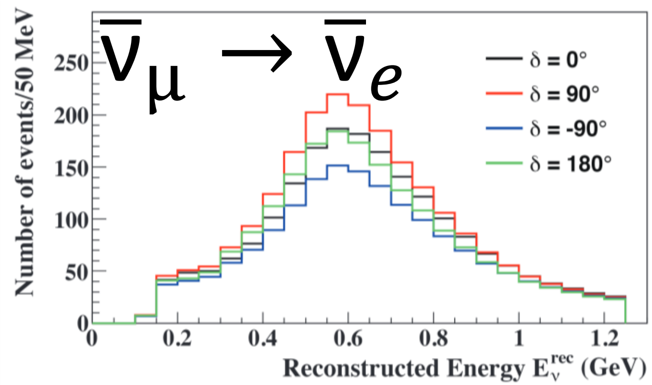
Expected Events

Assuming Normal Hierarchy and $\sin^2 2\theta_{13} = 0.1$
10 years running ($1.3\text{MW} \times 10^8\text{s}$), $\nu : \bar{\nu} = 1:3$

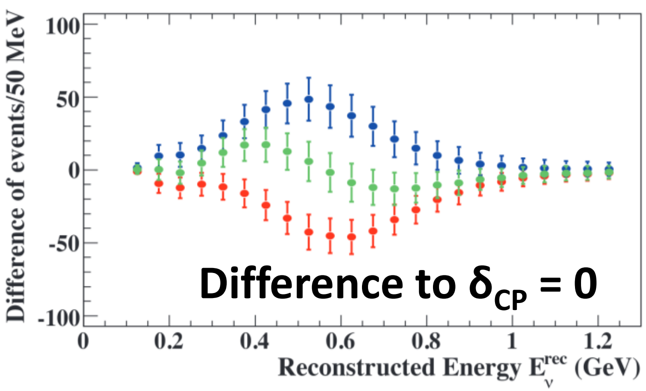
		signal		BG						Total
		$\nu_\mu \to \nu_e$	$\bar{\nu}_\mu \to \bar{\nu}_e$	ν_μ CC	$\bar{\nu}_\mu$ CC	ν_e CC	$\bar{\nu}_e$ CC	NC	BG Total	
ν mode	Events	1643	15	7	0	248	11	134	400	2058
	Eff.(%)	63.6	47.3	0.1	0.0	24.5	12.6	1.4	1.6	—
$\bar{\nu}$ mode	Events	206	1183	2	2	101	216	196	517	1906
	Eff. (%)	45.0	70.8	0.03	0.02	13.5	30.8	1.6	1.6	—

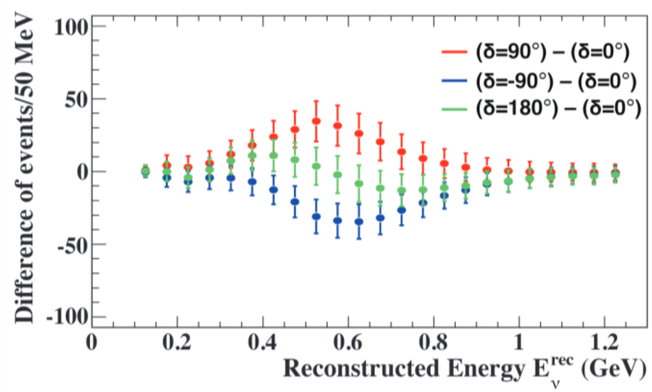
Realistic BG estimates based on T2K – see talk by L. Kormos for latest results





Effect of δ_{CP} clearly seen in energy spectra

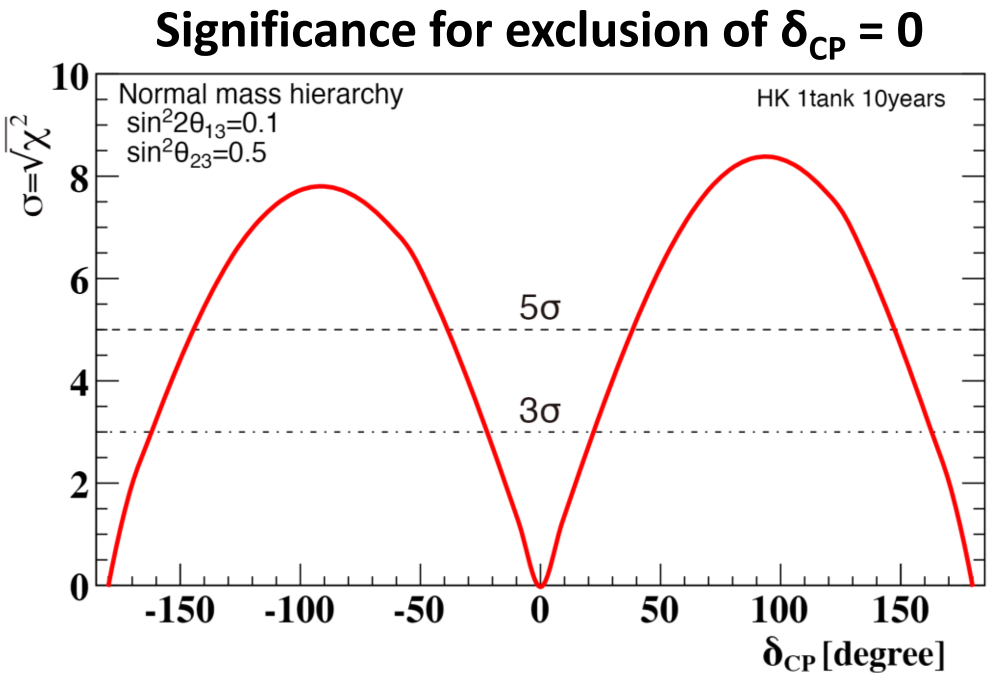


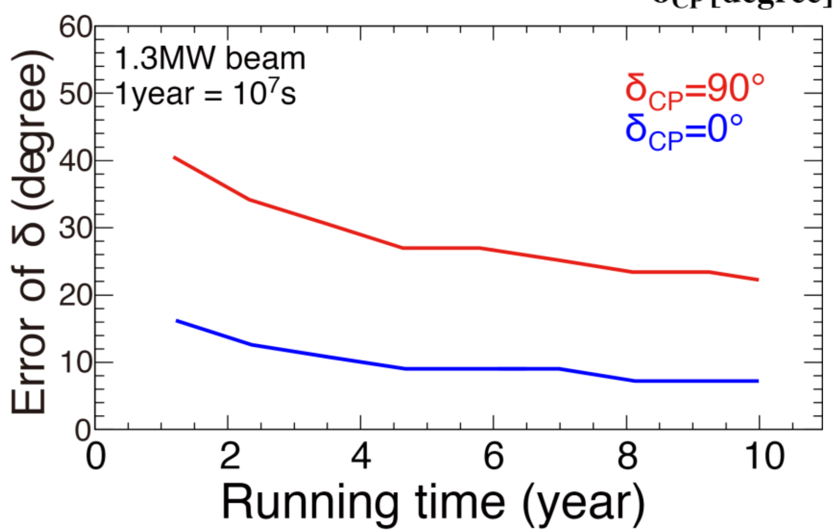


See talk by T. Yoshida for details of systematics!

Hyper-Kamiokande

Sensitivity To δ_{CP}





Expected significance for exclusion of CP conservation, 10 years running (1.3MW x 10^8s), $\nu : \bar{\nu} = 1:3$

5σ observation of CP Violation for 58% of δ_{CP} parameter space

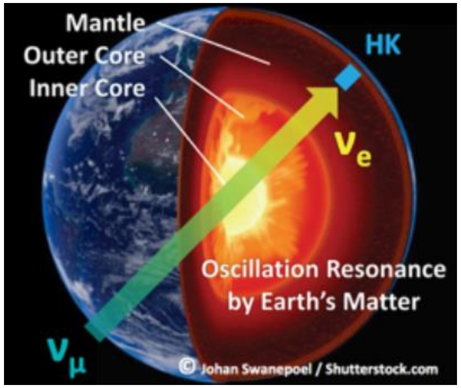
Precision of δ_{CP} measurement:

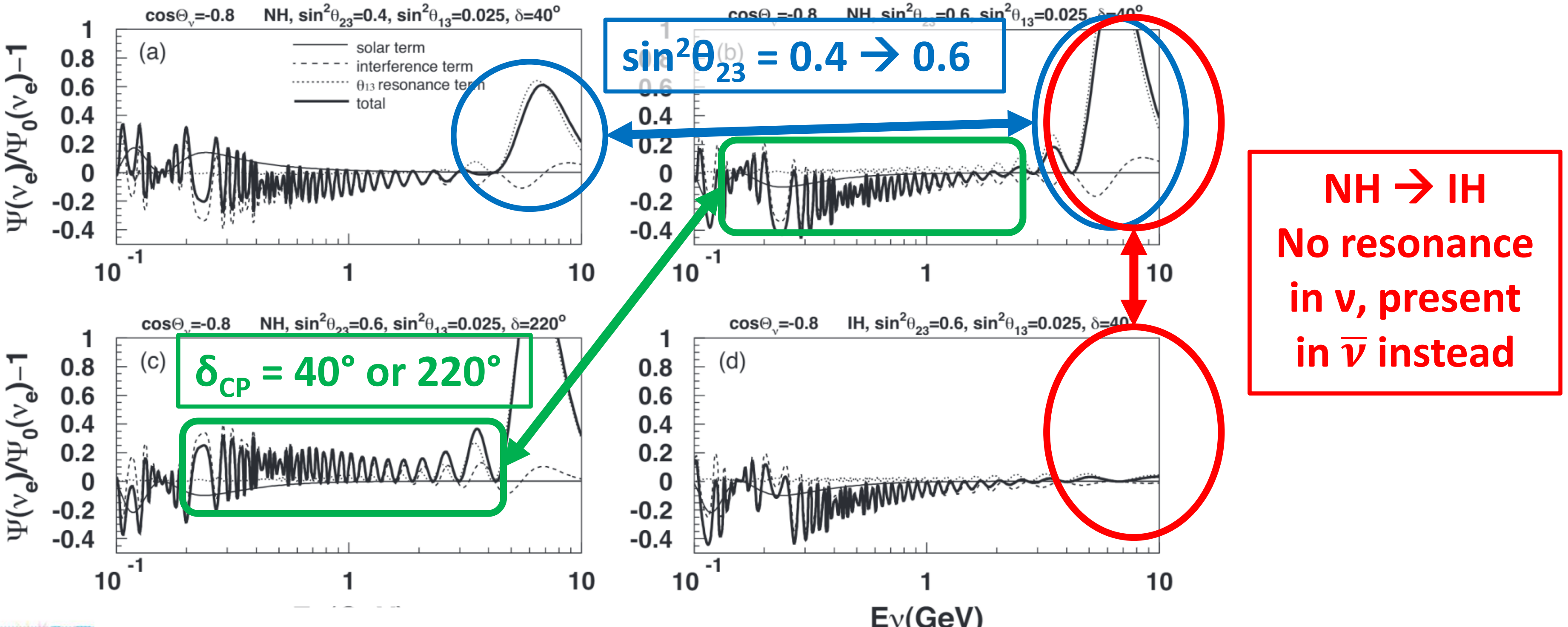
~**22°** for δ_{CP} = **±90°**
~**7°** for δ_{CP} = **0°**

Hyper-Kamiokande

Atmospheric Neutrinos

- Earth Matter Effect modifies energy spectrum of atmospheric neutrino oscillations as they pass through core
- Sensitive to **mass hierarchy**, δ_{CP}, and θ_{23} **octant**



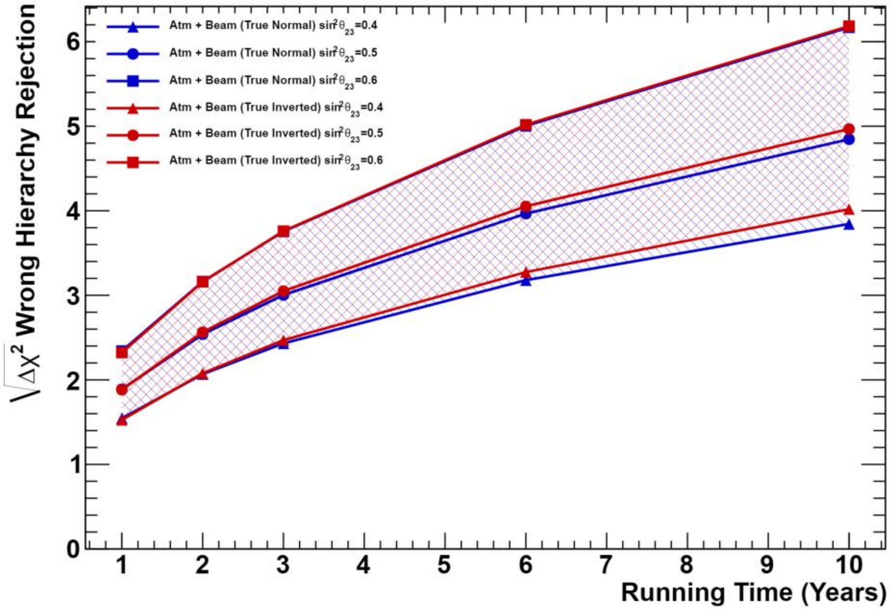


Hyper-Kamiokande

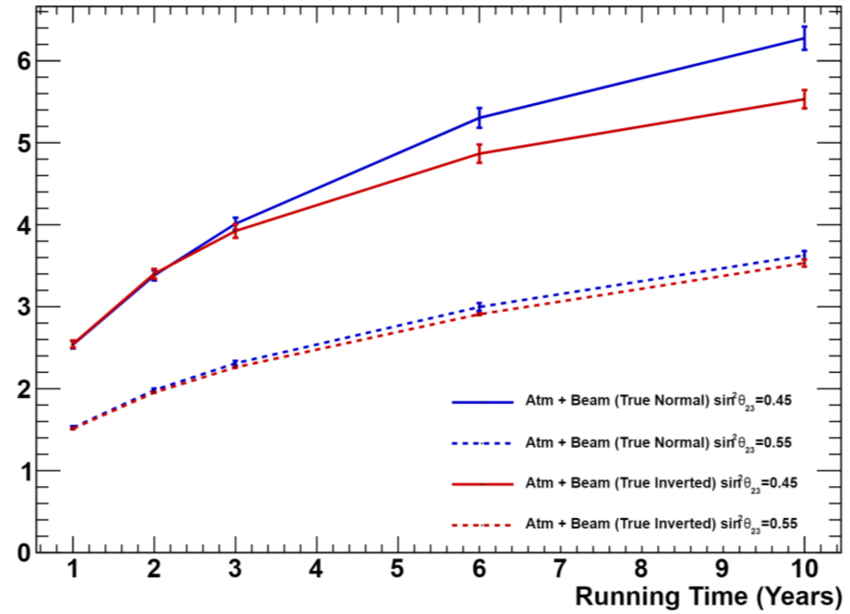
Hierarchy and Octant Sensitivities

- Combining 1 HK tank beam and atmospheric samples for joint analysis

Wrong Hierarchy Rejection



Wrong Octant Rejection



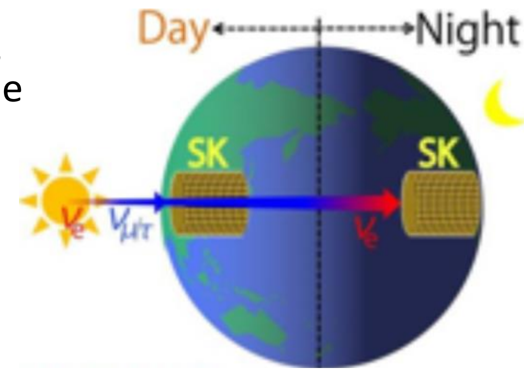
Mass hierarchy determination at 3σ for all possible values of θ_{23}

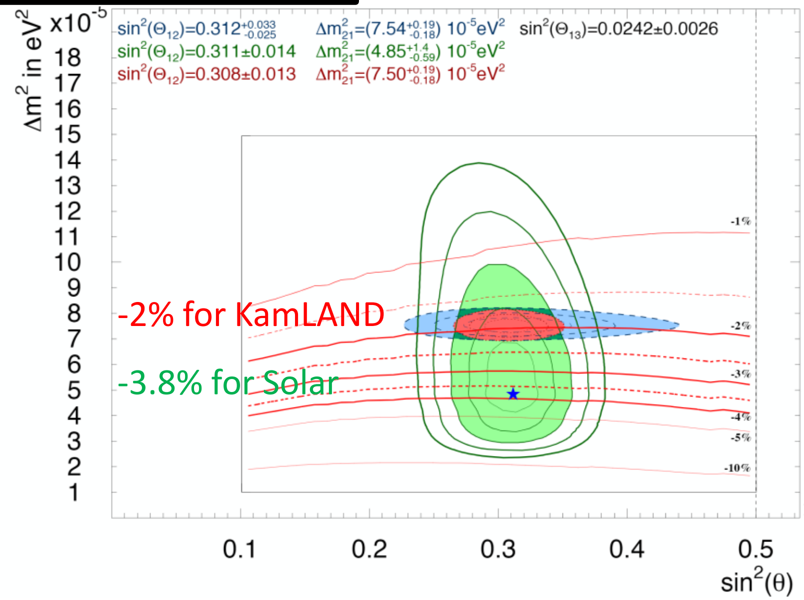
Octant determination at 3σ for $|\theta_{23} - 45°| \geq 2.3$

Hyper-Kamiokande

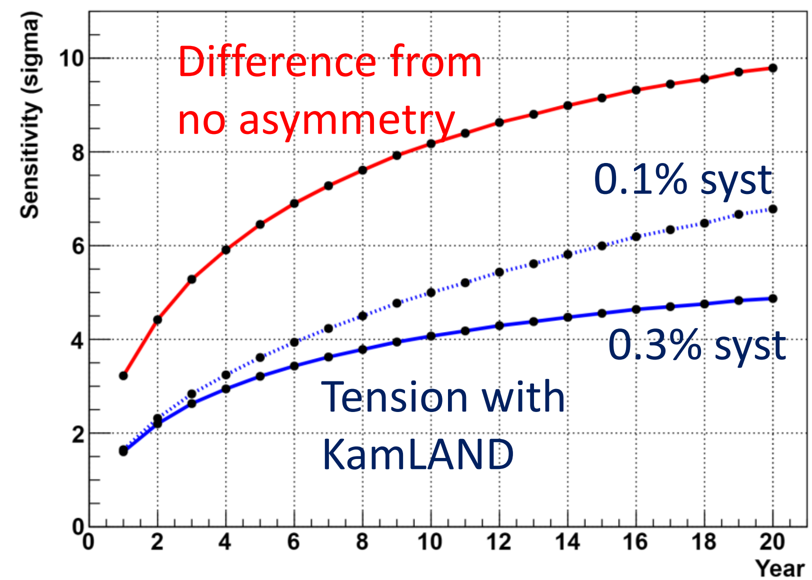
Solar Neutrinos: Day-Night Asymmetry

Regeneration of ν_e due to Earth matter effect





- Higher flux at night when solar neutrinos must pass through Earth to reach HK
- Sensitive to Δm^2_{21}



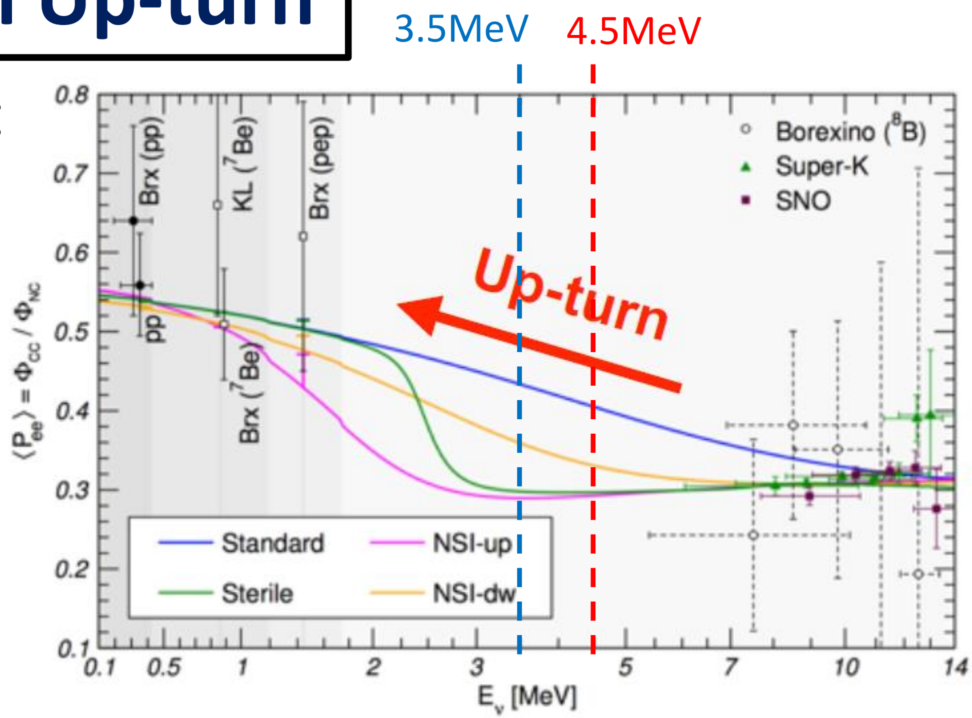
Probe of minor tension with KamLAND reactor results

- Can be determined at >4σ if effect is real

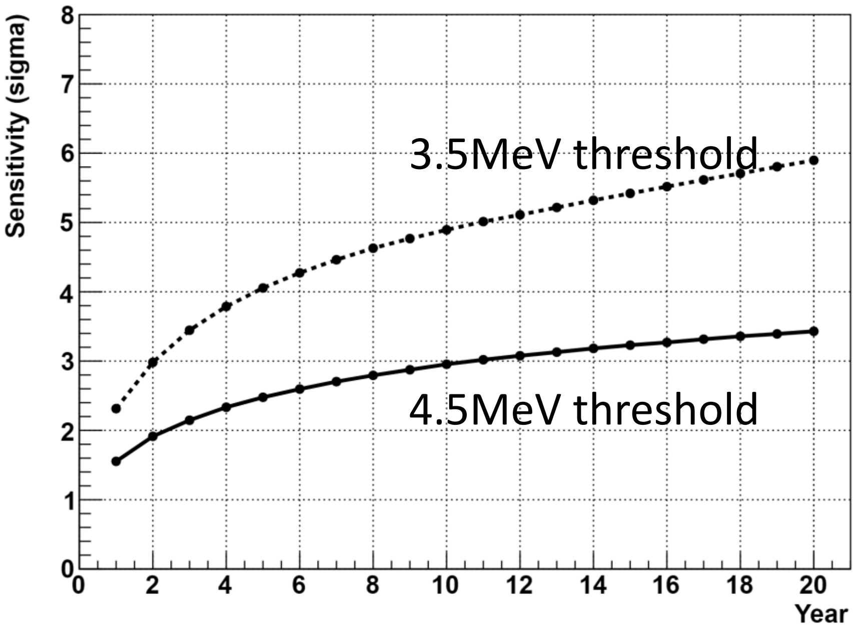
Hyper-Kamiokande

Solar Neutrinos: Spectrum Up-turn

- Up-turn in survival probability at low energies due to MSW effect
- Spectrum depends on details of MSW effect – probe for Non-Standard Interactions (NSI)



M. Maltoni et al., Phys. Eur. Phys. J. A52, 87 (2016)



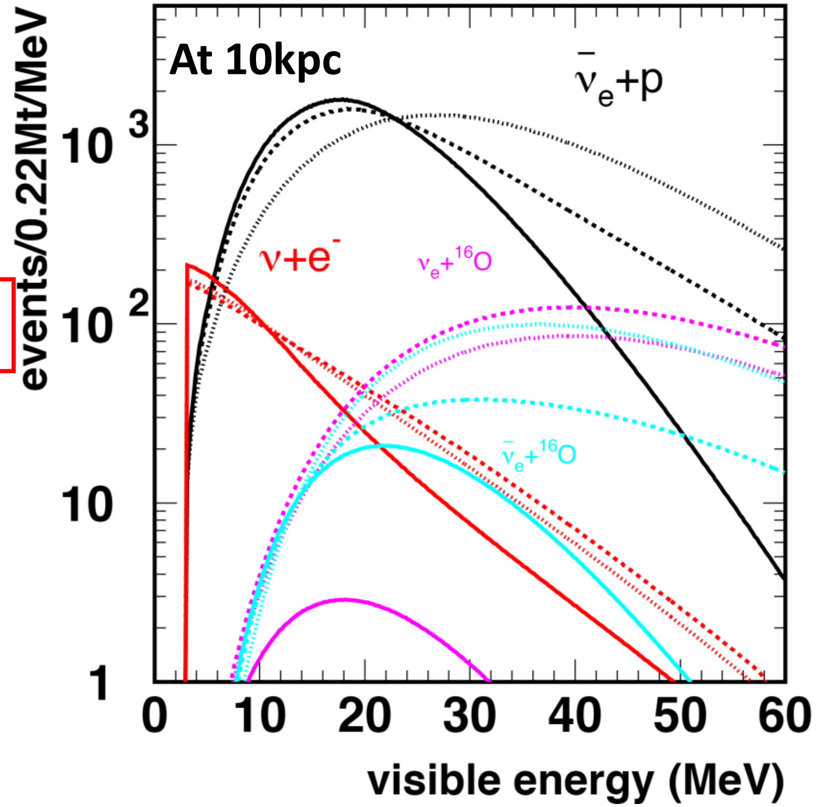
- Requires similar low energy performance to SK

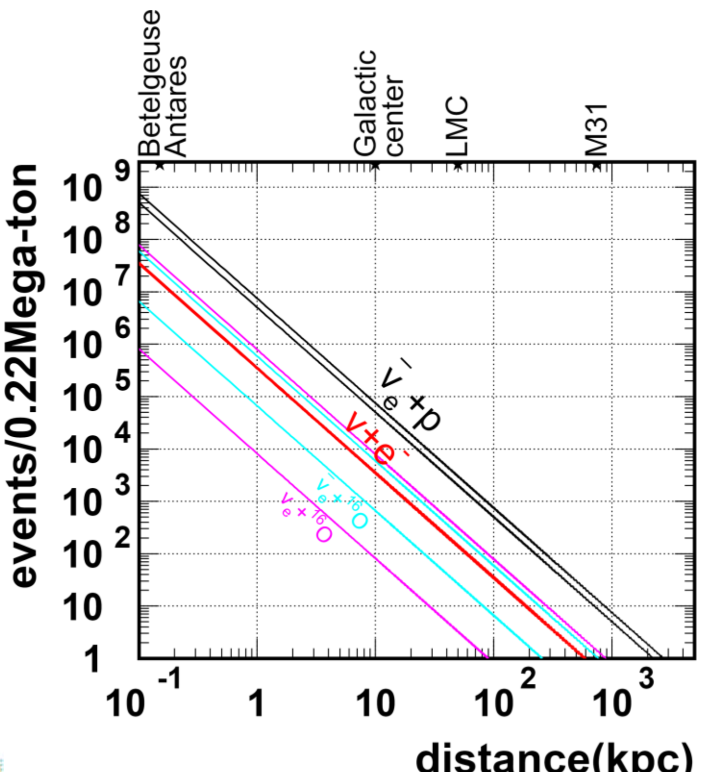
Potential for 3σ measurement of spectrum up-turn

Supernova Neutrinos

HK will collect many events in the case of a galactic supernova

- Primary reaction: $\bar{\nu}_e + p \rightarrow e^+ + n$
- Core collapse supernova physics, oscillation physics, early warning, etc



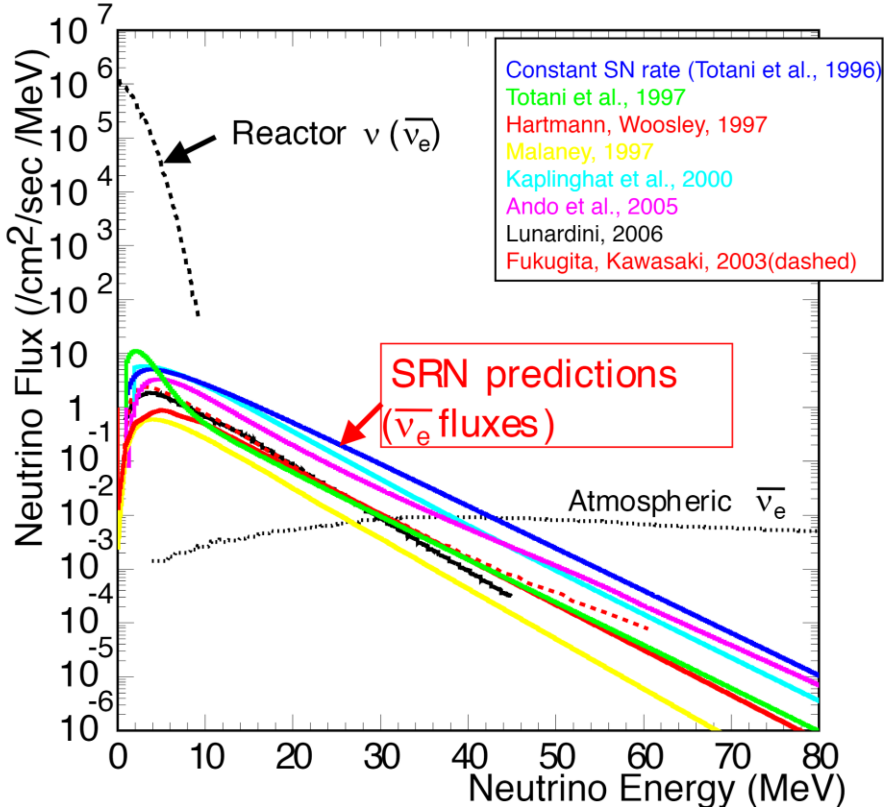


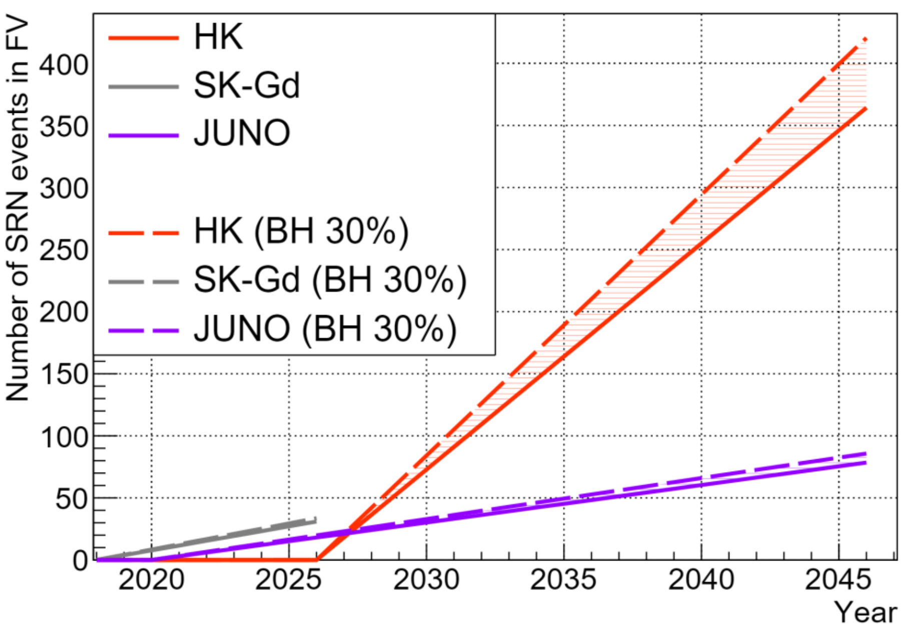
Predicted number of events:
At 10kpc (Galactic Centre) = 50k – 80k
LMC (location of SN1987a) = 2k – 3k
M31 (extended range of HK!) = ~10

Hyper-Kamiokande

Supernova Relic Neutrinos

- SK-Gd will detect SRN thanks to improved neutron capture efficiency of Gd (see talk by M.Smy)
- HK will collect enough events to measure the spectrum



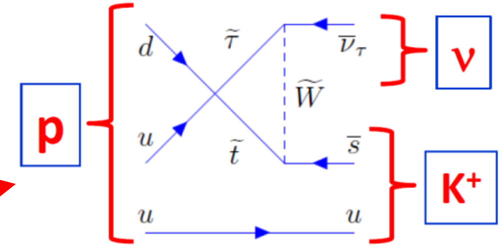


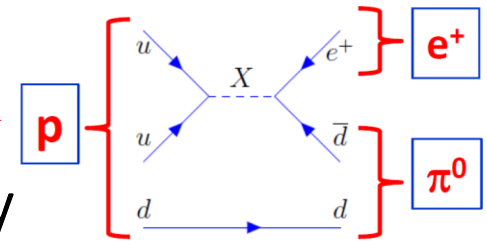
- Star formation history, heavy elements
- Black hole formation

Proton Decay

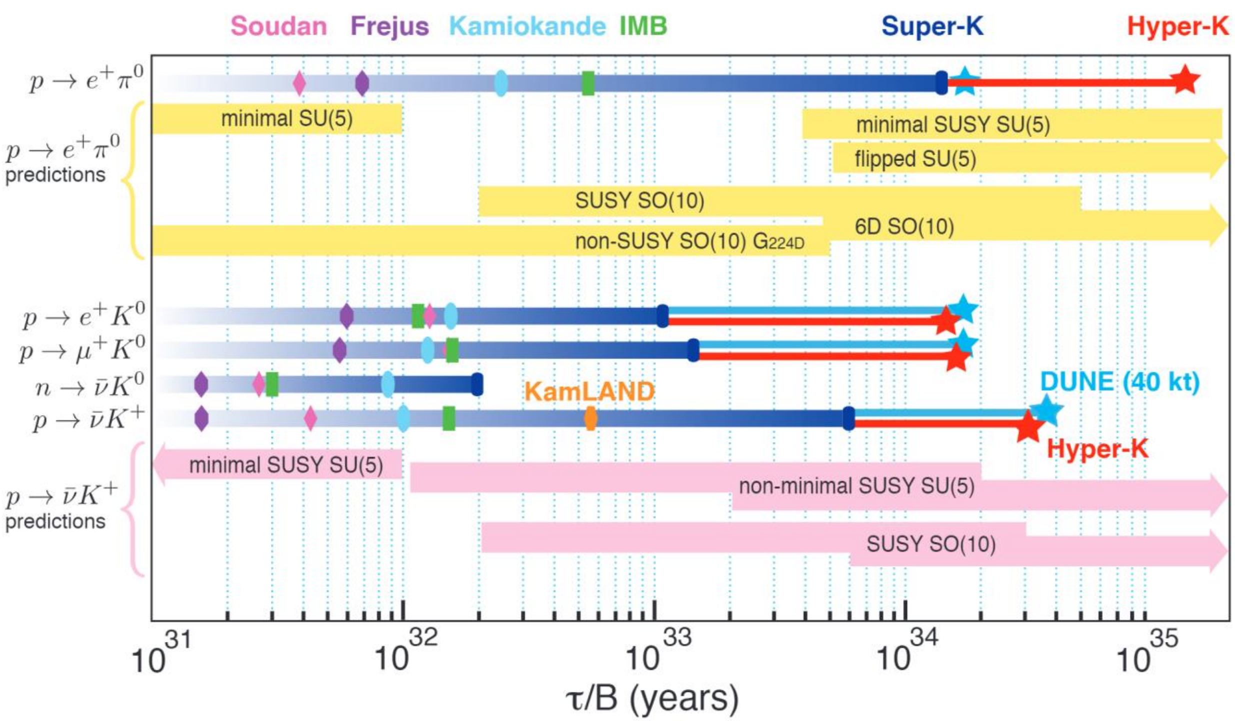
Fundamental prediction of GUT theories:

- Supersymmetric GUT theories
- X boson mediated GUT theories





HK will extend search to 10^{35} years, covering many more theoretical models than present



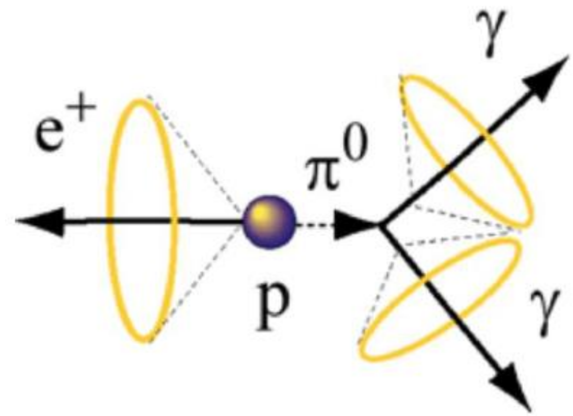
See talk by S. Mine for current limits set by Super-K

Hyper-Kamiokande

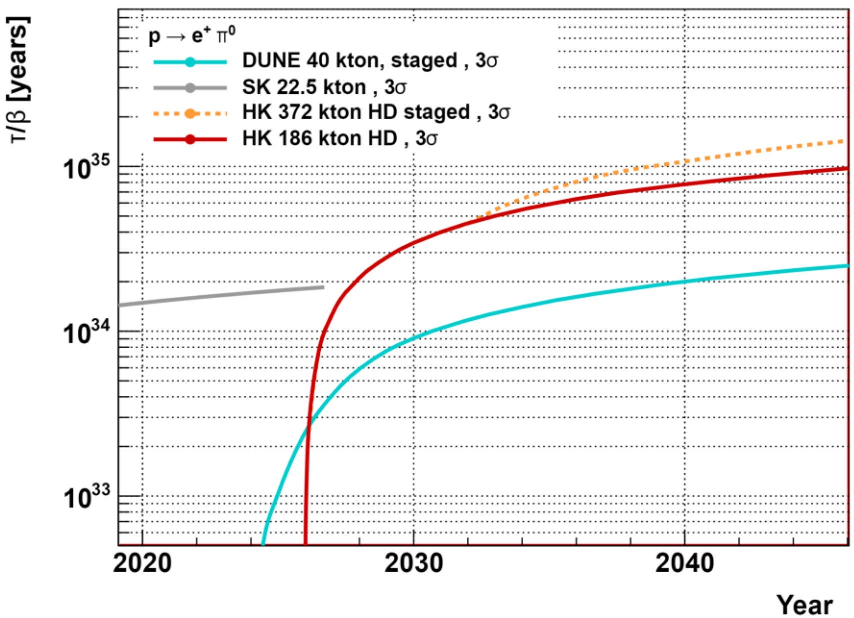
Proton Decay: $p \rightarrow e^{+}\pi^{0}$

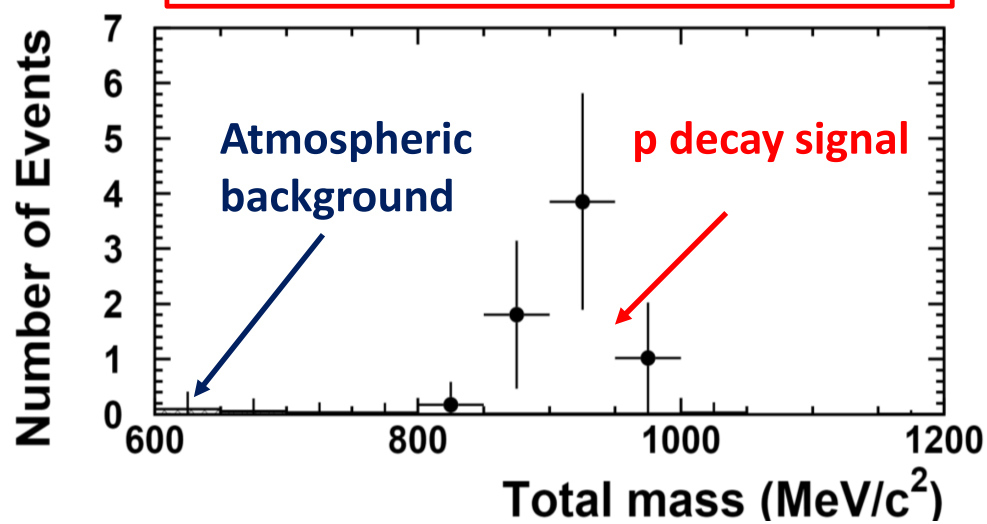
'Golden Mode' for WC detectors

- Practically background-free (0.06 events/Mt-year)
- Atmospheric neutrino background greatly reduced by neutron tagging



3σ discovery sensitivity: **τ/BR = 10^{35} years** for 20 year operation





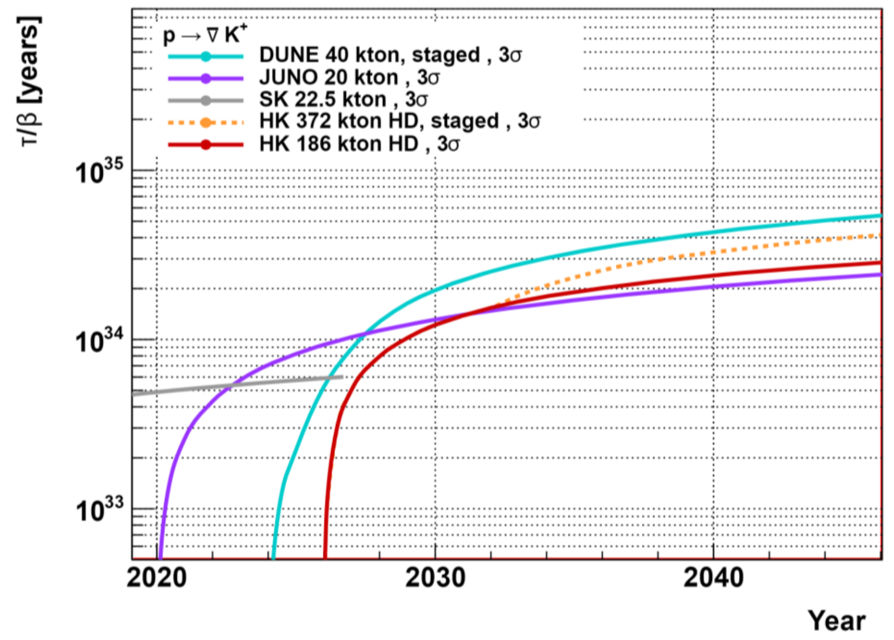
Hyper-Kamiokande

Proton Decay: $p \to \bar{\nu} K^+$

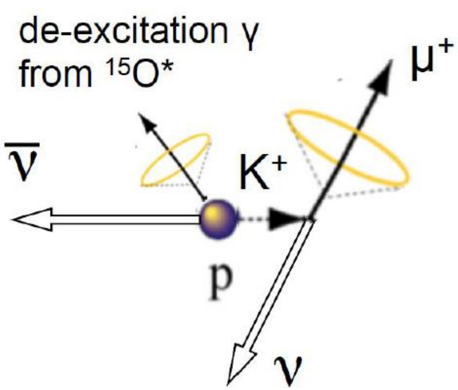
Identify K^+ by decay products:

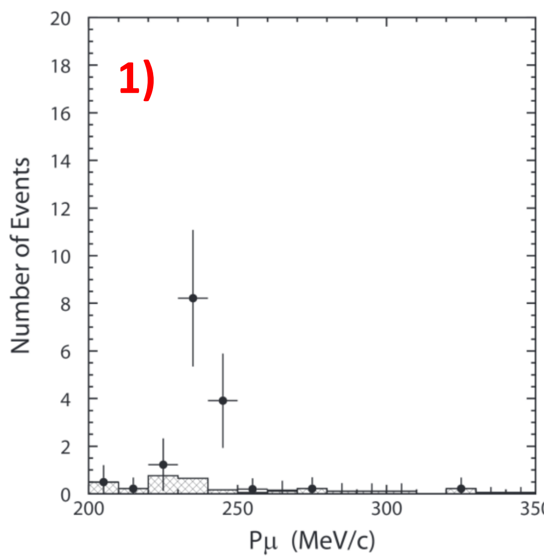
1) $K^+ \to \mu^+\nu$ (64%) - 236MeV/c
muon + decay e, prompt γ from $^{15}O^*$ de-excitation

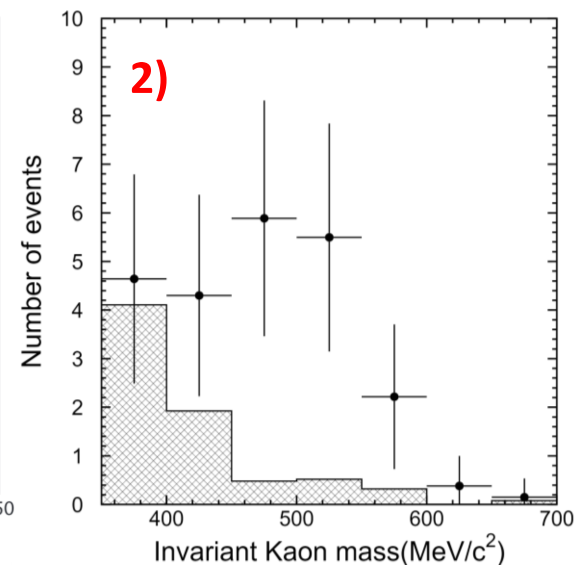
2) $K^+ \to \pi^+\pi^0$ (21%) – 205MeV/c
π^+ and π^0 back to back



3σ discovery sensitivity:
τ/BR = 3 x 10^{34} years
for 20 year operation

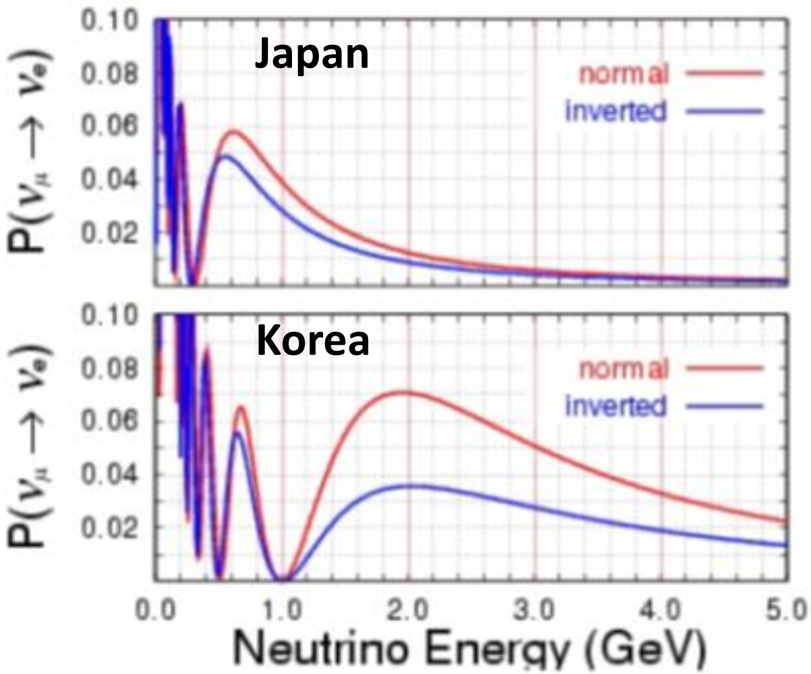






Hyper-Kamiokande

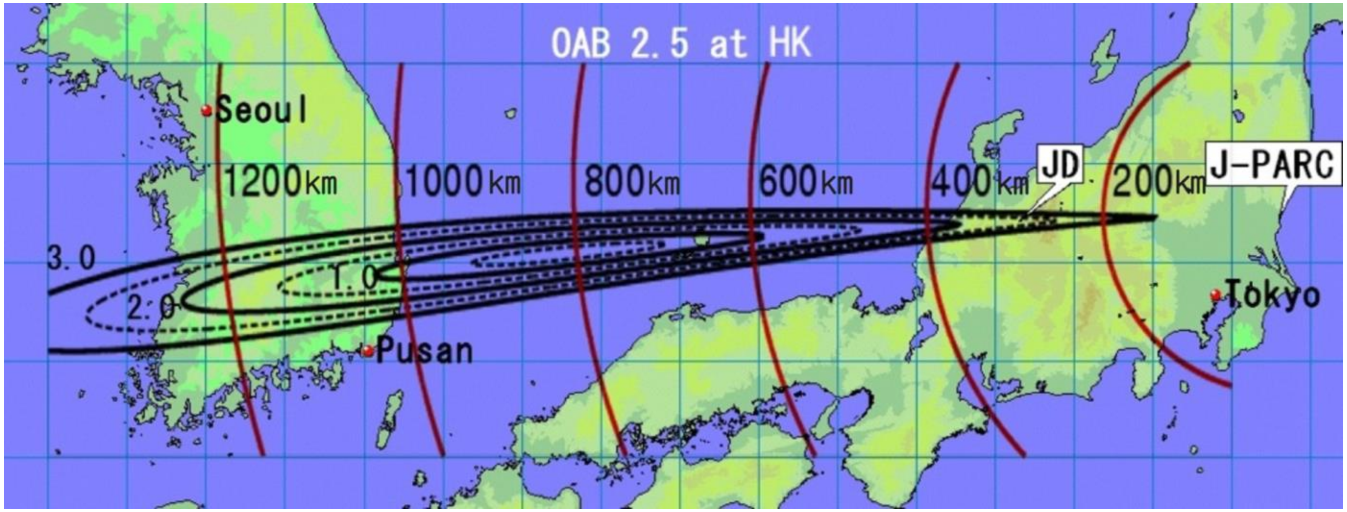
Second Tank in Korea



Plan to add a second, identical, HK tank in future – likely in South Korea

Benefits of locating in Korea:

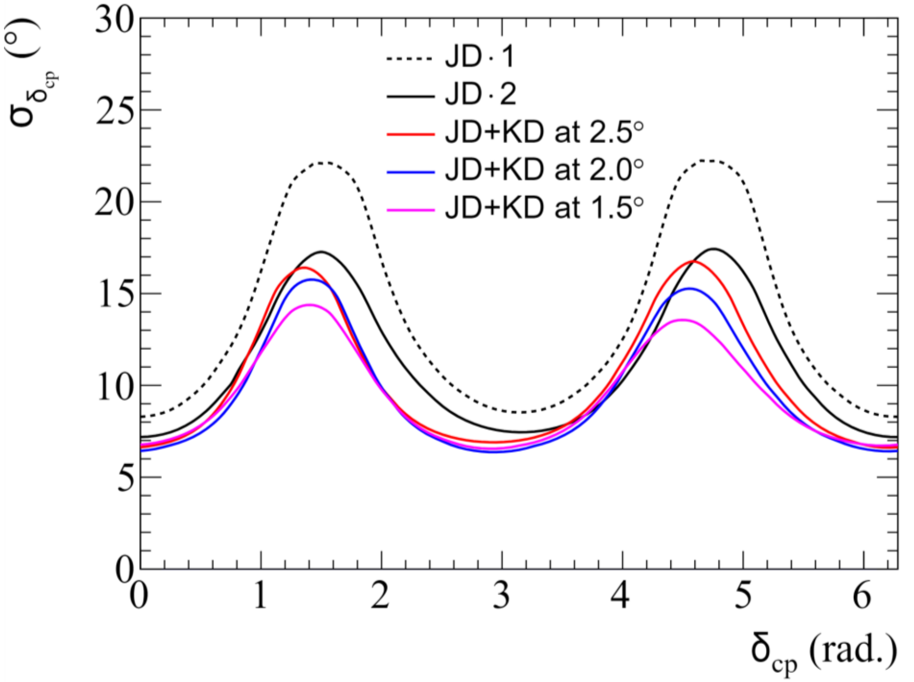
- Access to second oscillation maximum – measure parameters in a different way
- **Improved sensitivities for all HK physics studies**

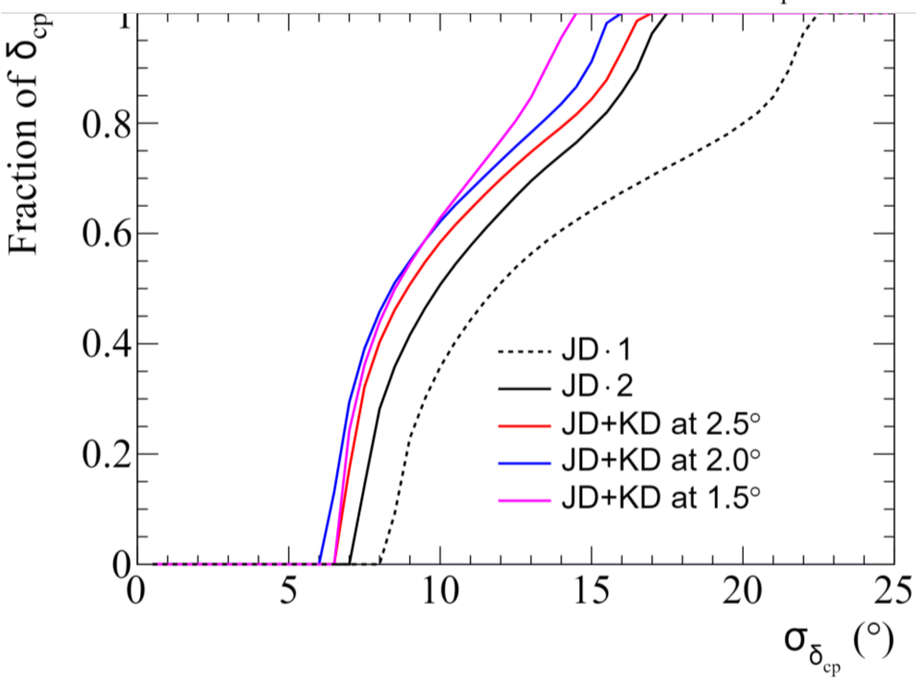


Second Tank in Korea

For 10 years running (1.3MW x 10^8s), $\nu : \bar{\nu} = 1:3$

- Locating second detector in Korea gives improved sensitivity compared to 2x Japanese detectors
- Uncertainty on δ_{CP} up to 3° smaller with second tank in Korea compared with Japan
- Increase sensitivity to hierarchy due to increased matter effects



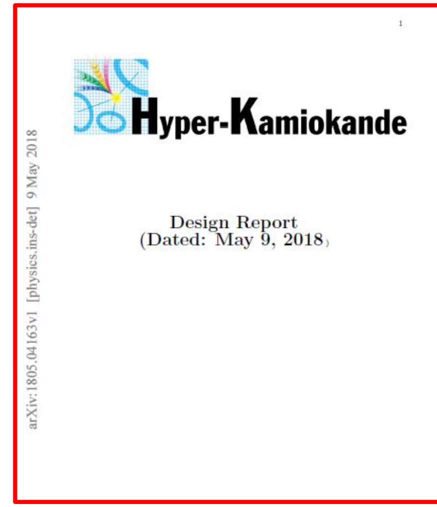


Hyper-Kamiokande

Further Material

- Hyper-Kamiokande Website:
  www.hyperk.org

- Hyper-Kamiokande Design Report:
  K. Abe et al (Hyper-Kamiokande Collaboration)
  arXiv:1805.0416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Hyper-Kamiokande

Design Report
(Dated: May 9, 2018)

arXiv:1805.04163v1 [physics.ins-det] 9 May 2018

- Physics Potentials with the Second Hyper-Kamiokande Detector in Korea:
  K. Abe et al (Hyper-Kamiokande Collaboration)
  PTEP 2018(2018) 6, 063C01


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Volume 2018, Issue 6
June 2018

Physics potentials with the second Hyper-Kamiokande detector in Korea

The Hyper-Kamiokande Proto-Collaboration, K Abe, Ke Abe, S H Ahn, H Aihara, A Aimi, R Akutsu, C Andreopoulos, I Anghel, L H V Anthony, ... Show more

Author Notes

Progress of Theoretical and Experimental Physics, Volume 2018, Issue 6, 1 June 2018, 063C01, https://doi.org/10.1093/ptep/pty044

Published: 20 June 2018 **Article history** ▾

- Technical Report coming soon!

Summary

- HK will cover a broad range of physics topics, and will make many leading measurements in fields of neutrino oscillations, proton decay, astroparticle physics research

- Funding for first Hyper-Kamiokande tank is secured:
  - **Excavation** will begin in **2020**
  - **Operation** will begin in **~2027**

- Lots of exciting years ahead for the collaboration
  - **A great time to get involved!**