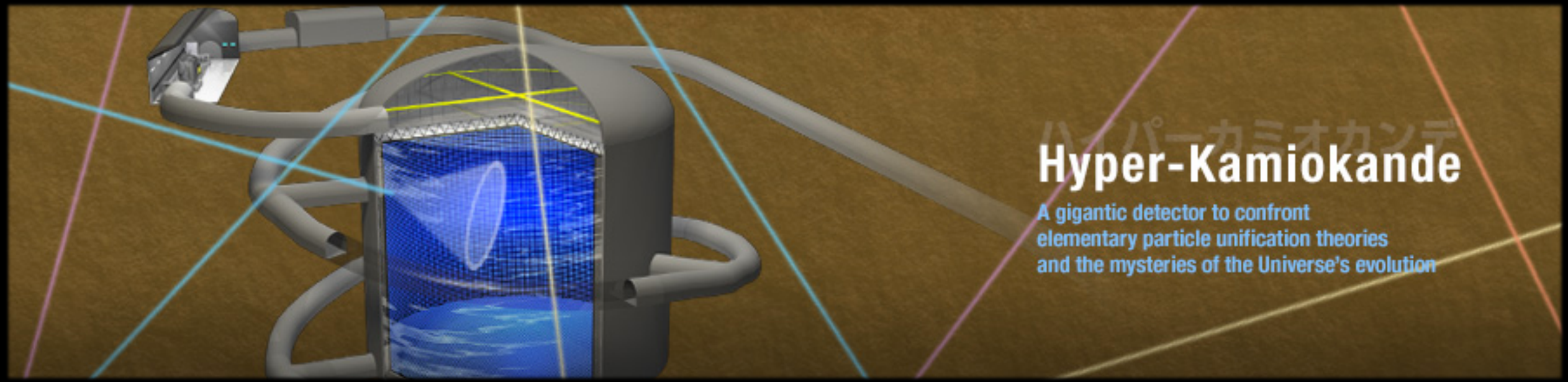
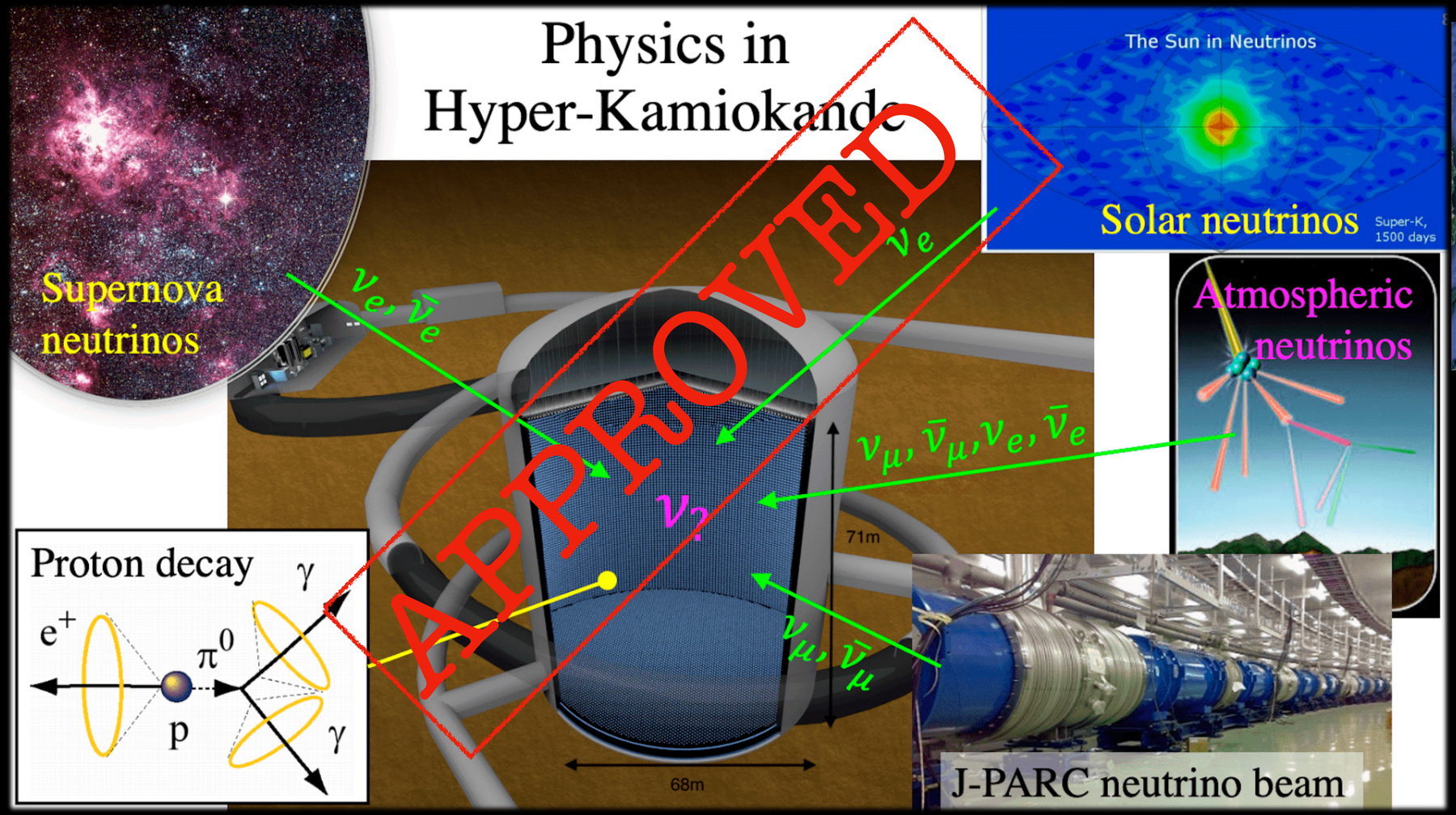


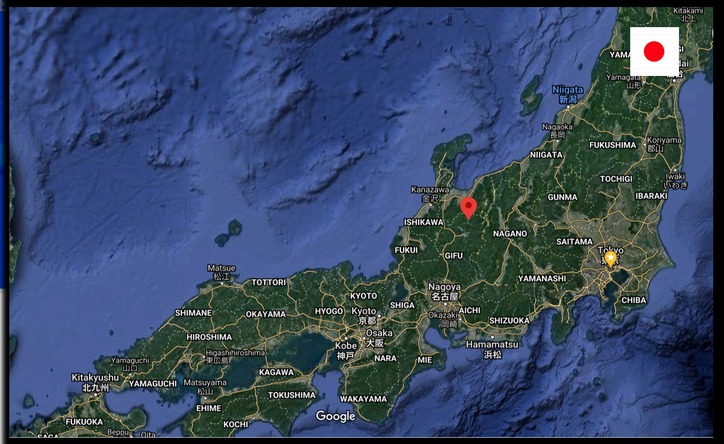
Hyper-Kamiokande Construction

Francesca Di Lodovico, Gabriella Catanesi for the Hyper-Kamiokande Collaboration

XIX International Workshop on Neutrino Telescopes
25 February 2021

The Hyper-Kamiokande Experiment



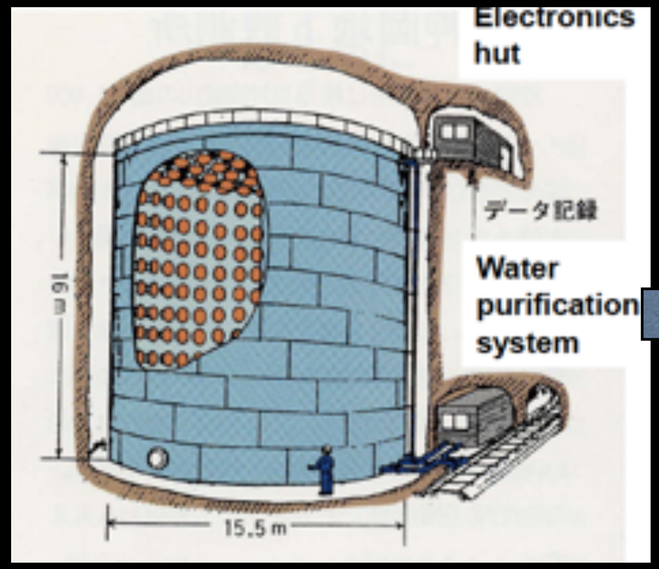


- Multi-purpose experiment
  - Beam physics
  - Astrophysical observatory
  - Rare (e.g.proton) decays

Kamioka"NDE"

Nucleon Decay Experiment
Neutrino Detection Experiment

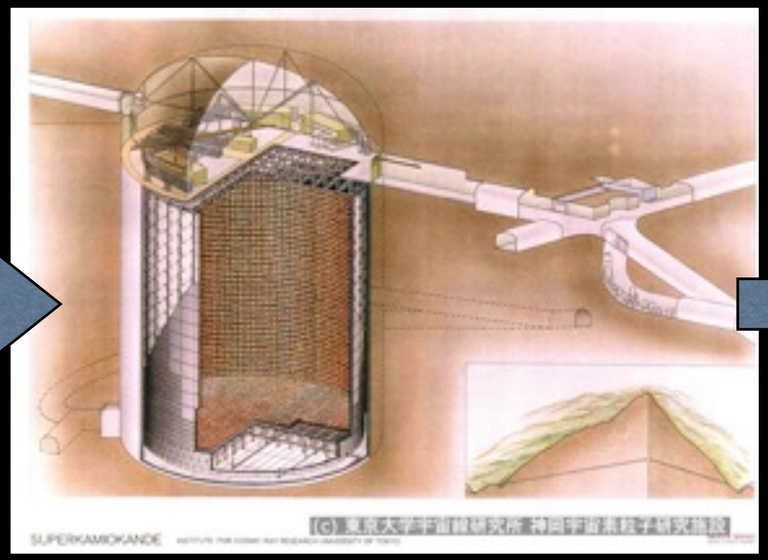
Kamiokande
(1983-1996)



3kton
20% coverage
with 50cm PMT

20x

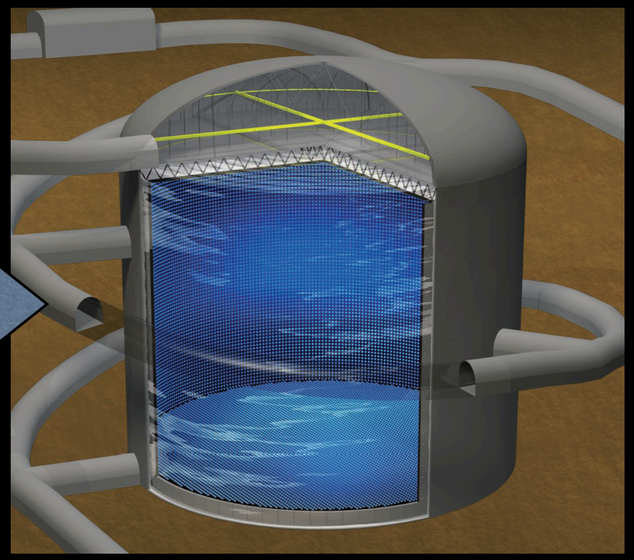
Super-Kamiokande
(1996-)



50k(22.5k)ton
40% coverage
with 50cm PMT

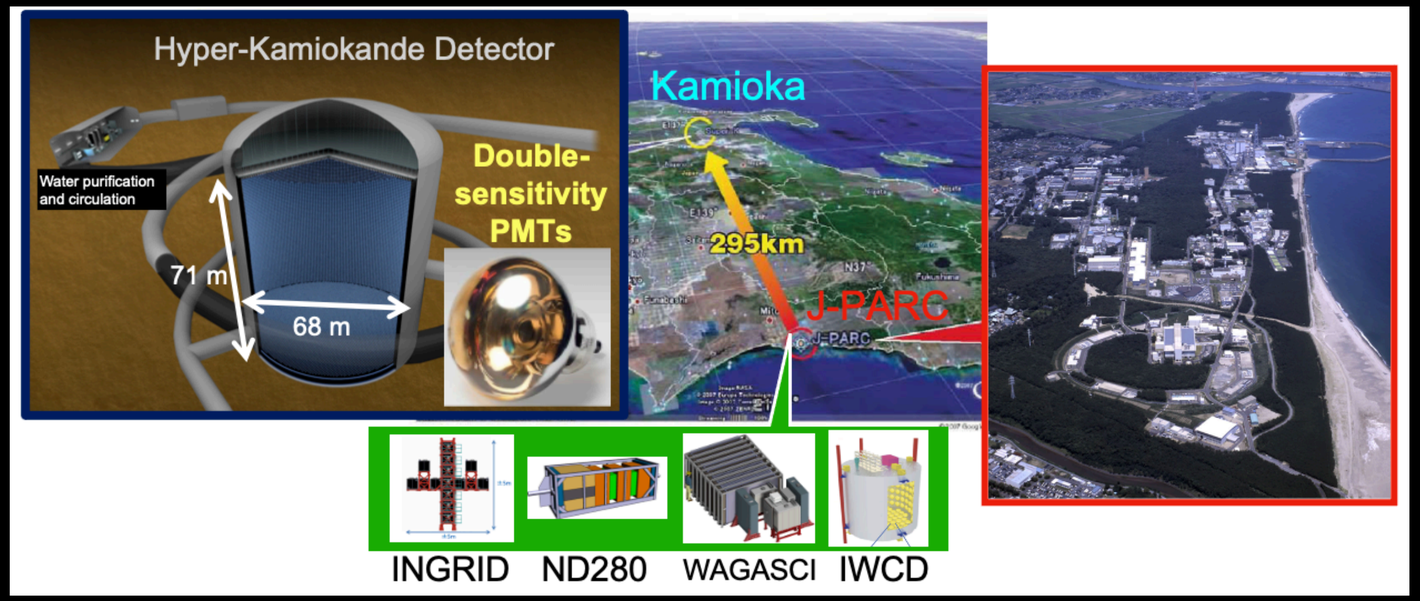
8.4x

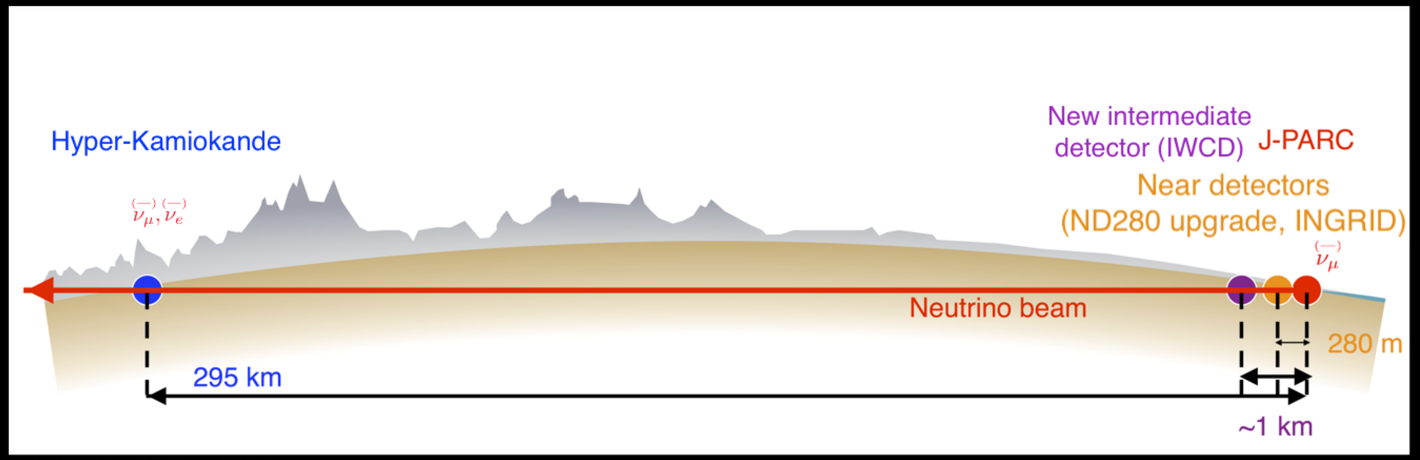
Hyper-Kamiokande
(~2027-)



260k(188k)ton
40% coverage w/ high-QE
50cm PMTs

Hyper-Kamiokande Experiment

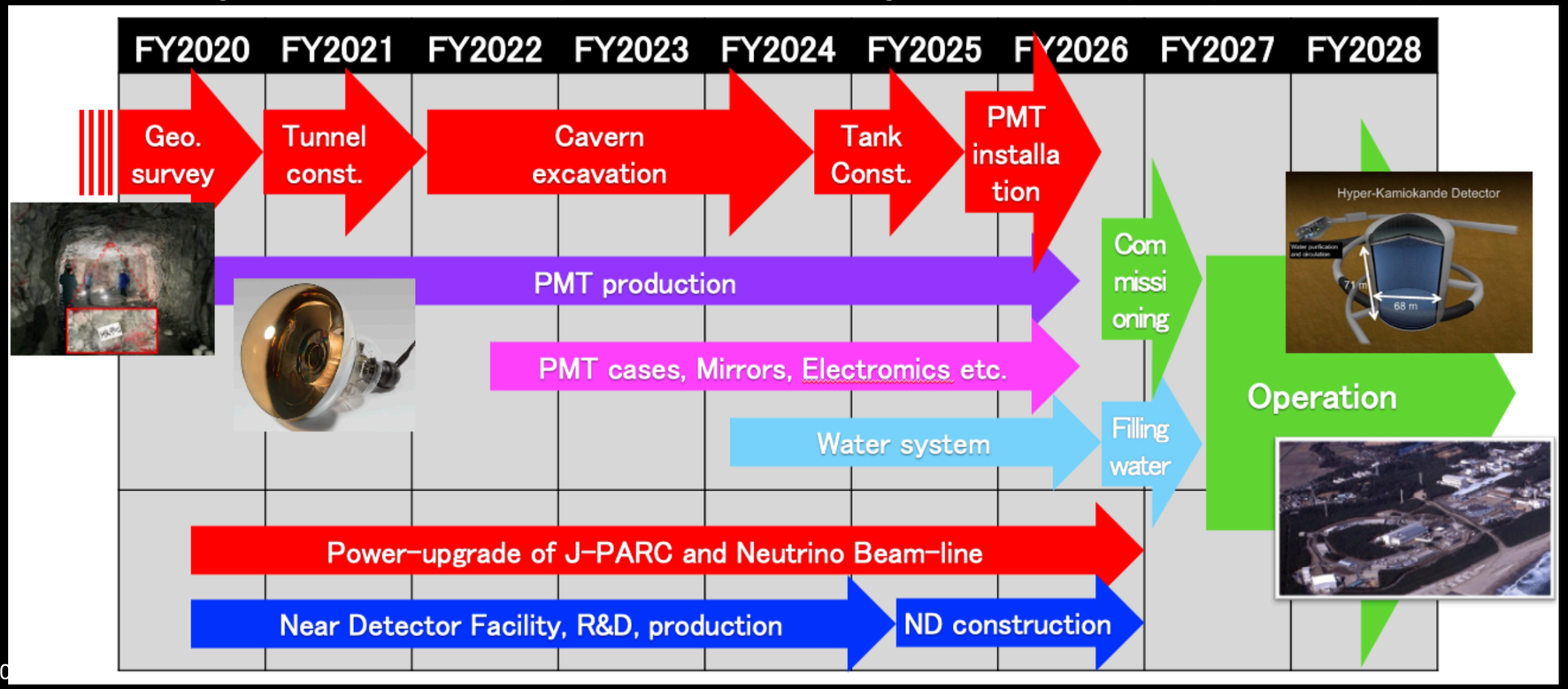




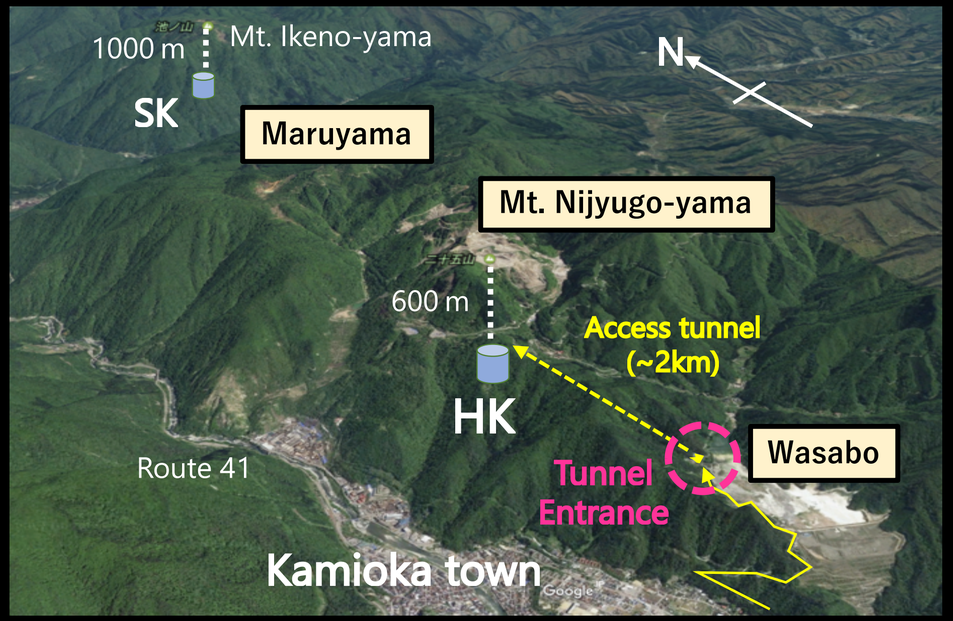
- Hyper-K detector with **8.4 times larger fiducial mass** (190 kiloton) than Super-K with **double-sensitivity PMTs**
- J-PARC neutrino beam will be upgraded from 0.5 to 1.3MW (**x2.5** higher than current T2K beam power)
- New (IWCD) and upgraded (@280m) near detectors to control systematic error.

Hyper-K Schedule

- 7 years construction from year 2020; 5 years excavation + subsequent 2 years detector construction. Data taking from 2027.
- We will start water filling and detector commissioning in Dec.-2026.
- The participating countries need to be ready to start installation of their components by Dec.-2025 (We have ~5 years for preparation).

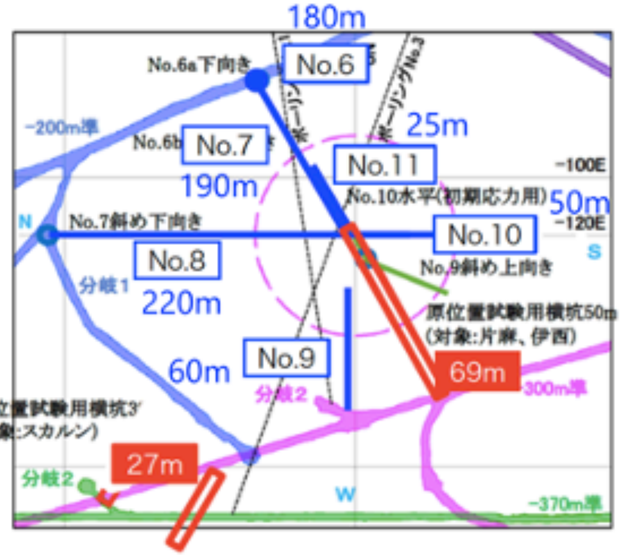


Entrance Yard Construction



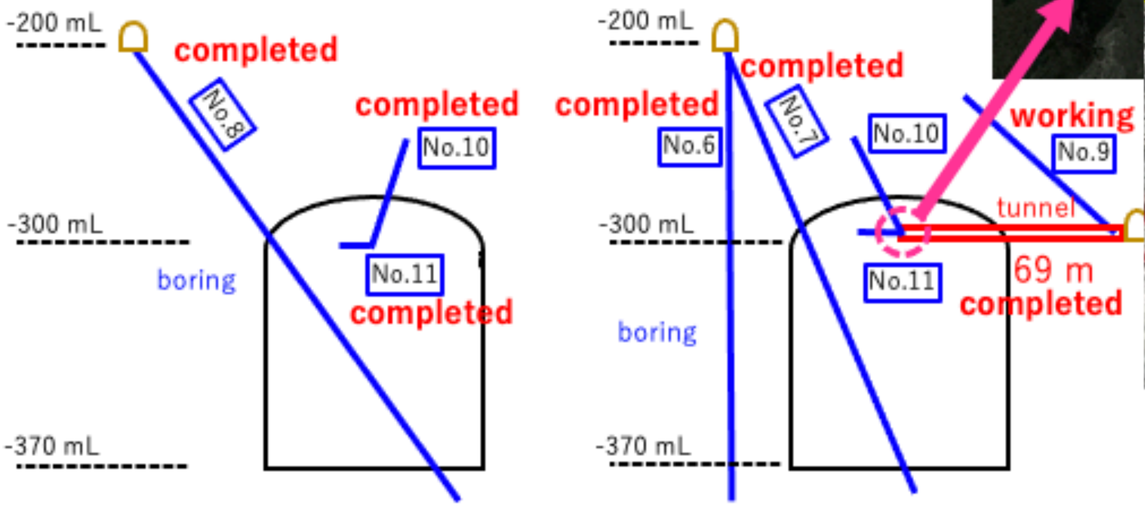
- Construction of entrance yard in Wasabo is completed.
- Construction of the waste water treatment facility at the entrance yard.

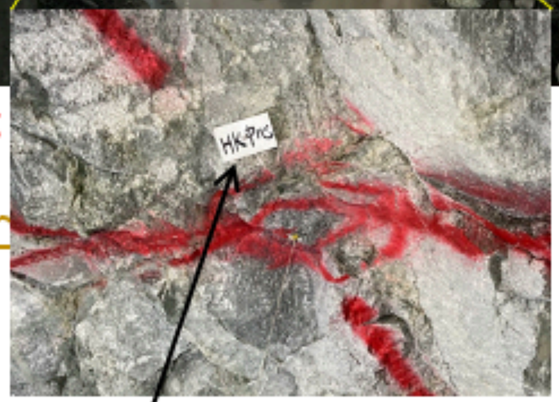
Geological Survey



Survey tunnel

Near the center of the (future) HK dome

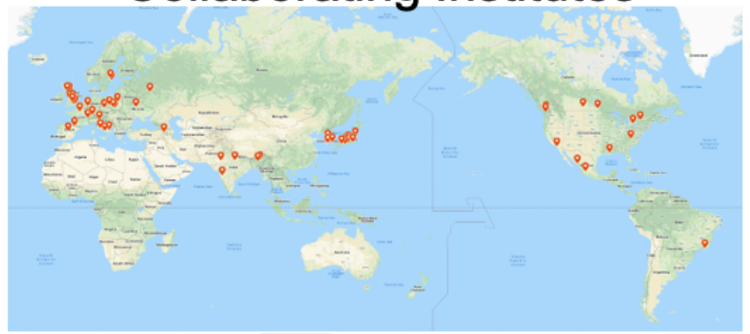




"HK center"

Hyper-K Collaboration

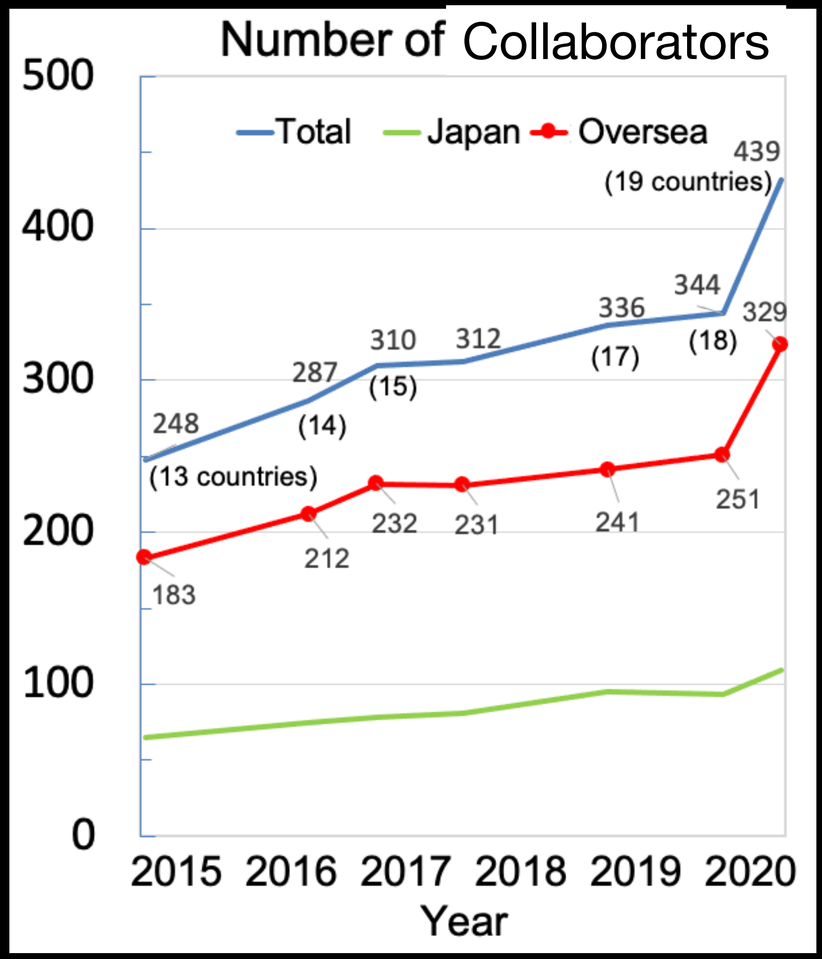
Collaborating Institutes



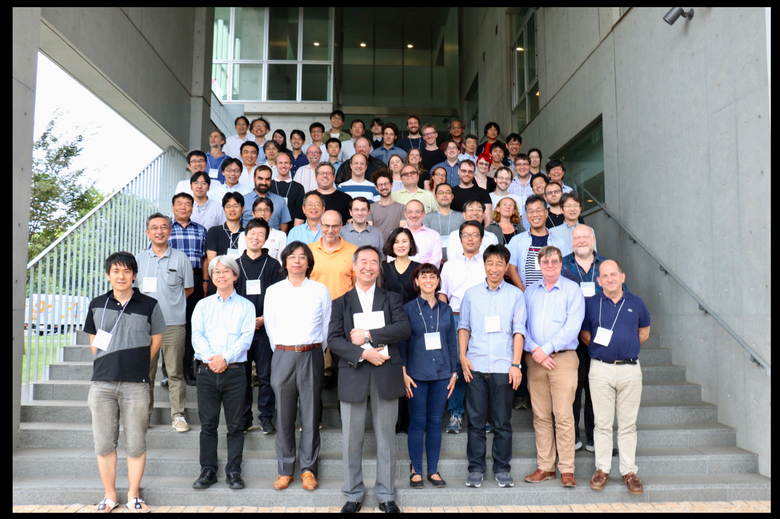
Europe	249 members
Armenia	3
Czech	3
France	24
Germany	1
Italy	53
Poland	37
Russia	21
Spain	26
Sweden	5
Switzerland	5
Ukraine	3
UK	68

Asia	138 members
India	10
Korea	18
Japan	110

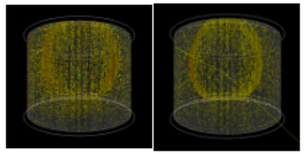
Americas	52 members
Brazil	3
Canada	28
Mexico	12
USA	9



19 countries, 93 institutes, ~440 people as of November 2020, growing

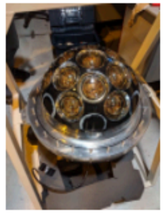


Hyper-K Experiment (Far Detector)



Neutrino interactions

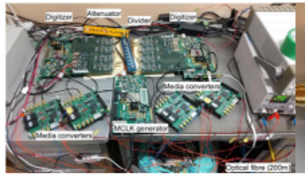
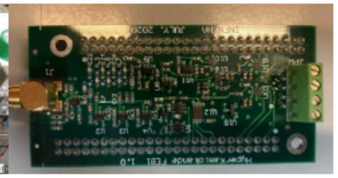
Water system:
1st stage system
2nd stage system for 155 + 155 m^3/hour




Photosensors

Photosensors:
PMT
Cover
Light Collection
Coils…

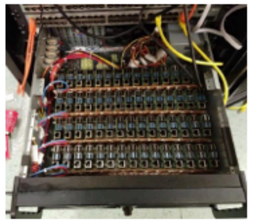
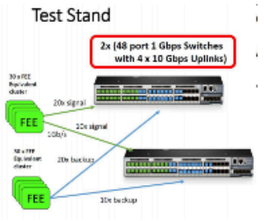
Half of ID PMTs

Electronics

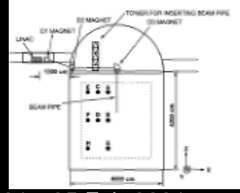
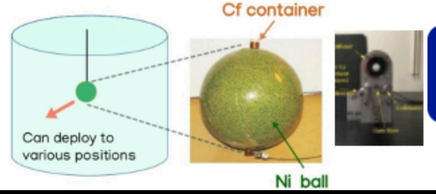
Electronics:
Digitizer
Boards
High Voltage Supply
Network
Waterproof'd box, connectors, cabling…

Part of ID Electronics

Data Acquisition and triggering

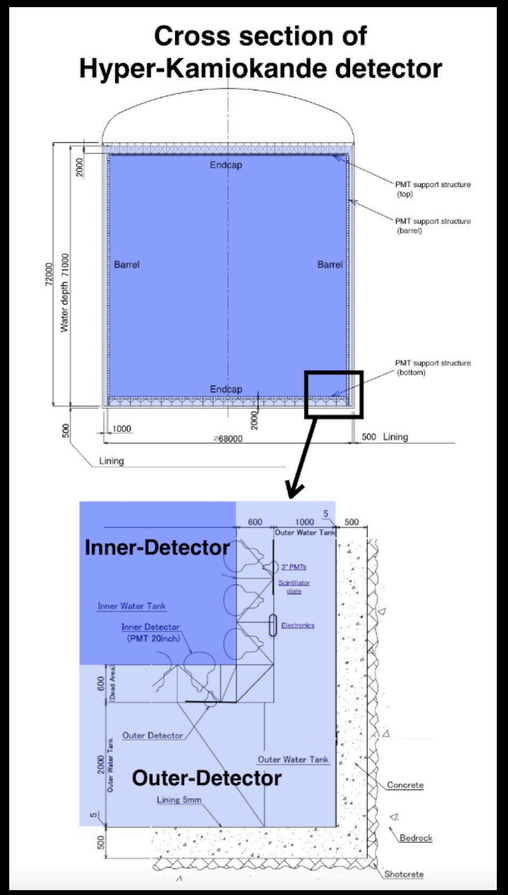
DAQ & Triggering:
Readout
Event builder
Software Triggers

Calibration

Calibration:
Electron LINAC
Deployment system
Other RI sources, light sources et

Two components:
- Inner Detector (ID)
- Outer Detector (OD)



Hyper-K Detector Construction has Started

PMTs for the Inner Detector

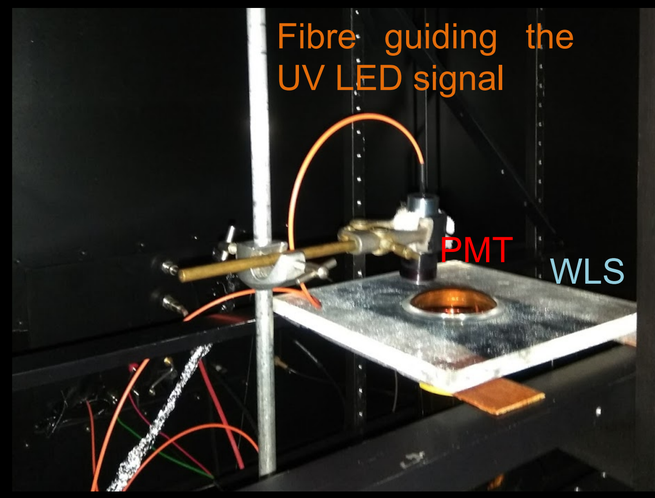
	Super-K	Hyper-K
Number of PMTs	11,129 50cm PMTs	20,000 50cm PMTs (JPN) (+ additional PDs (Oversea))
Photo-sensitive Coverage	40 %	20 %
Single photon efficiency /PMT	~12%	~24%
Dark Rate /PMT	~4 kHz (Typical)	4 kHz (Average)
Timing resolution of 1 photon	~3 nsec	~1.5 nsec

2020/12 First six PMTs delivered to Kamioka

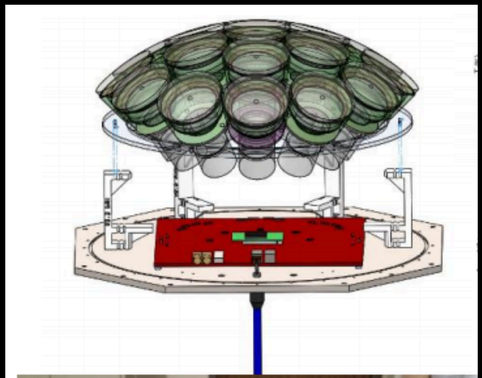
- Production has started on time for the 50cm PMTs with Box&Line dynode.
- 300 PMTs by March, 20,000 PMTs in total by 2026 according to the Japanese budget profile.

Photodetection System

- 3 x 4 PMT frame mockup in Kashiwa from Jan/2020 to test installation
- Ongoing work on covers for 20” PMTs. Further R&D on material test, fabrication method, installation method, full validation under water pressure etc.
- Full validation test in early 2021 for covers. Production starts in 2022.
- Outer Detector: 3” PMTs, WLS plate, Tyvek



mPMTs



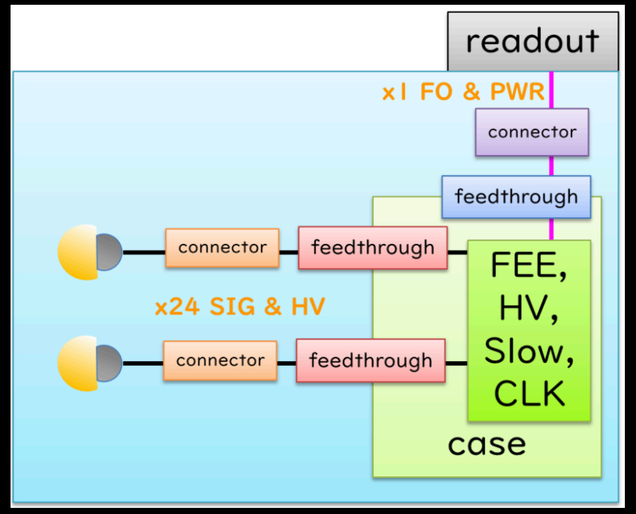
Prototype at TRIUMF

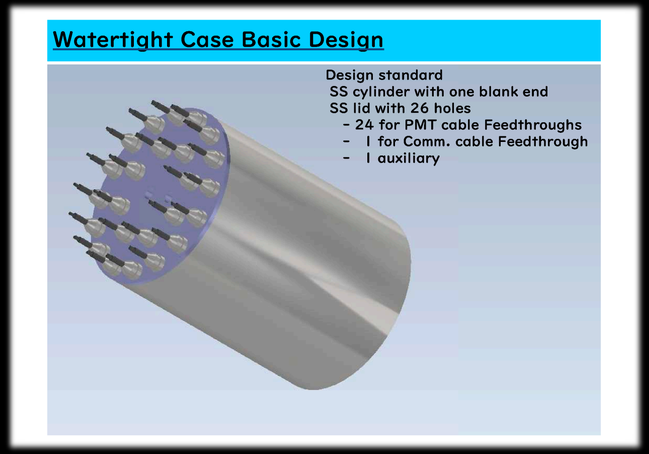
HK FD mPMT Electronics at INFN

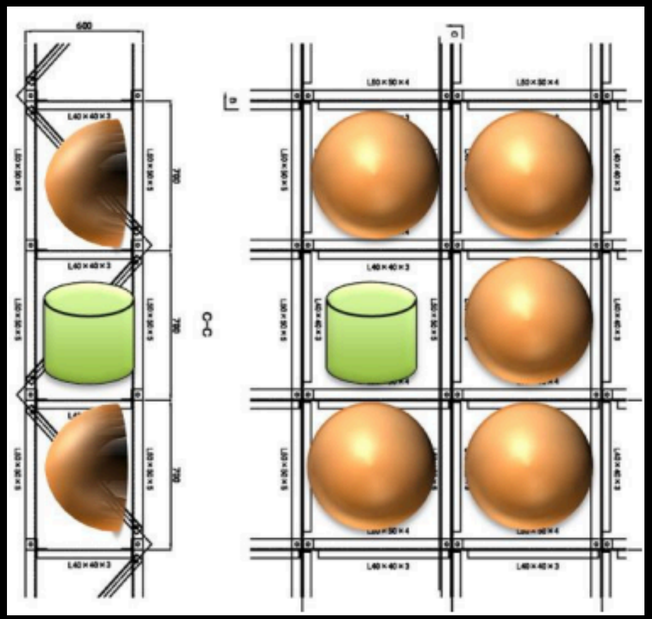
- mPMT is a vessel which houses and protects an array of 19 3” PMTs:
- improves the granularity and timing;
- additional intrinsic directional information.
- Far detector “hybrid” photocoverage: 20” PMTs and mPMTs.
- IWCD will be instrumented only with mPMTs.
- Different constraints on far detector and IWCD mPMTs.

Electronics

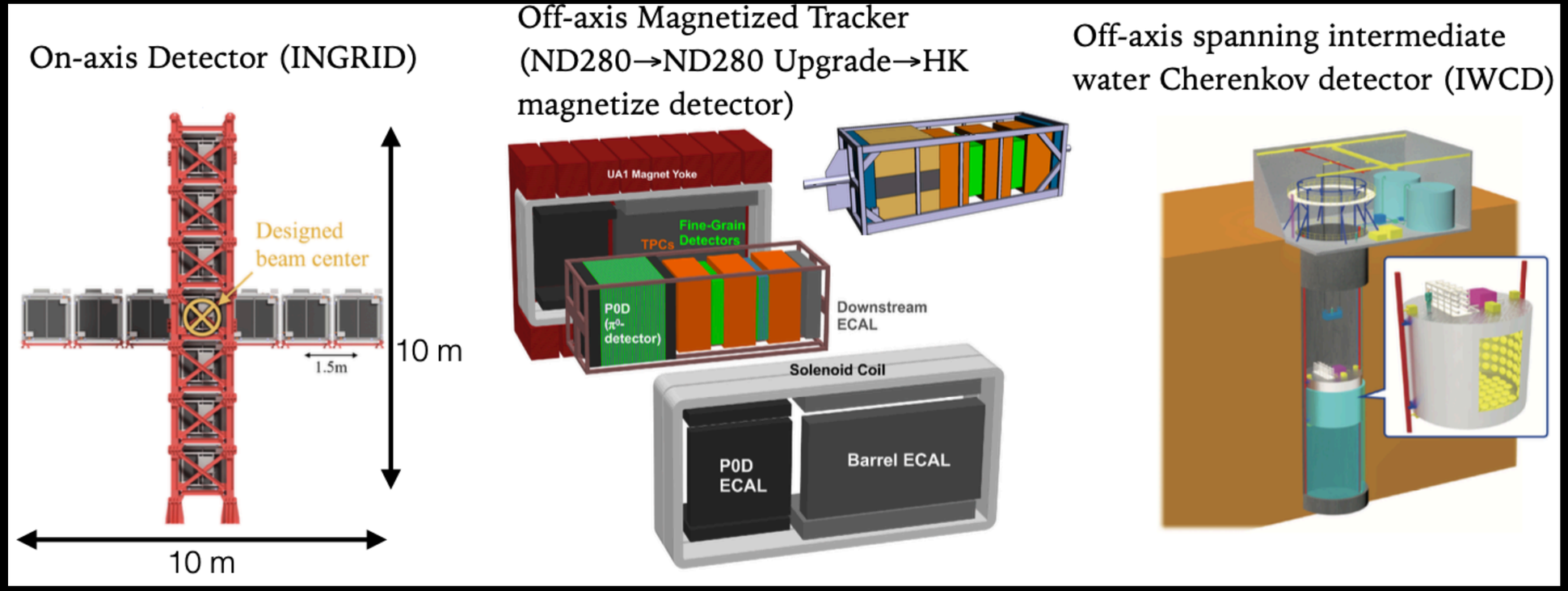
- Critical components which define the HK detector performance and its systematics. There are many technical challenges as
  - Mechanical design of a box for water tightness
  - High performance, long life digitizers, high voltage PS, comunication system, timing synchronization system, and so on.







Near Detector Suite

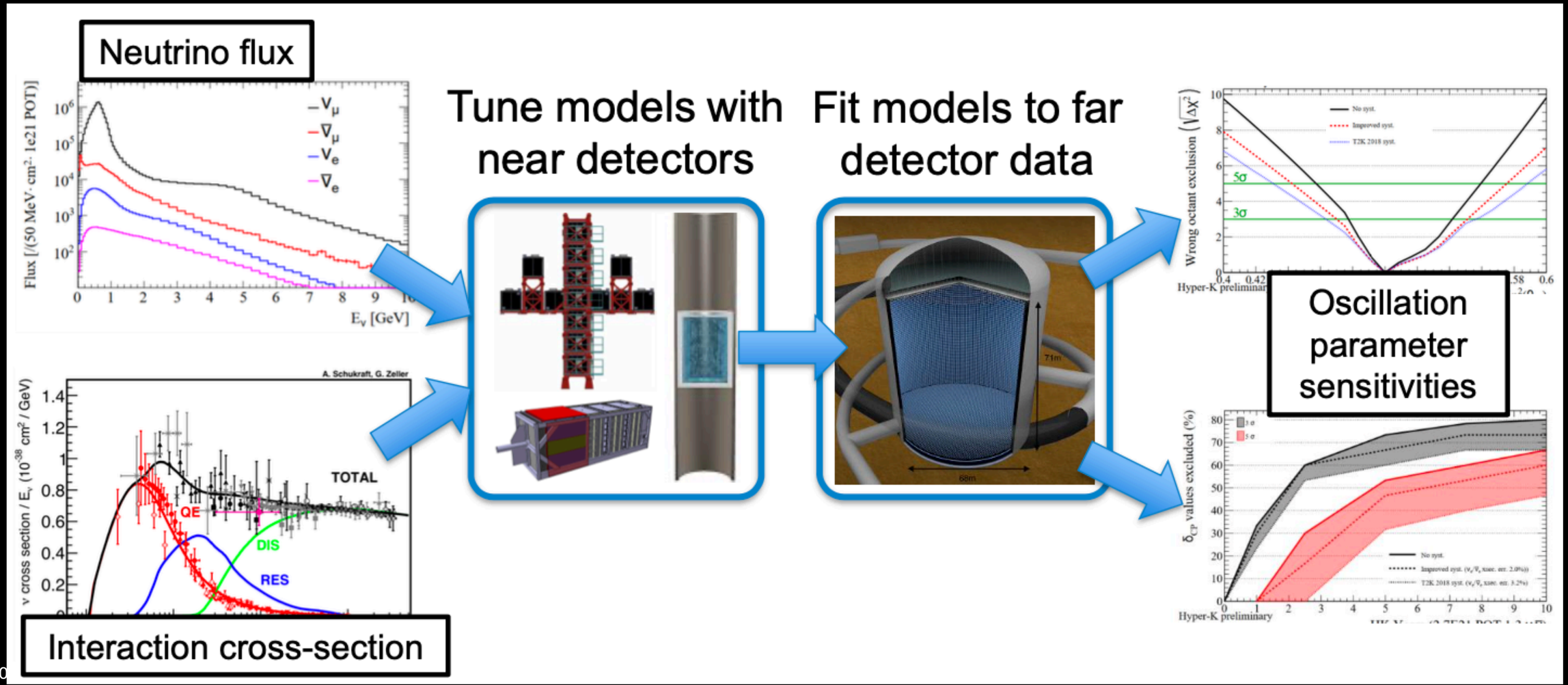


- On-axis detector: measure beam direction, monitor event rate.
- Off-axis magnetized tracker: charge separation (wrong-sign background), recoil system
- Off-axis spanning water Cherenkov detector: intrinsic backgrounds, electron.

(anti)neutrino cross-sections, neutrino energy vs. observables, H_2O target.

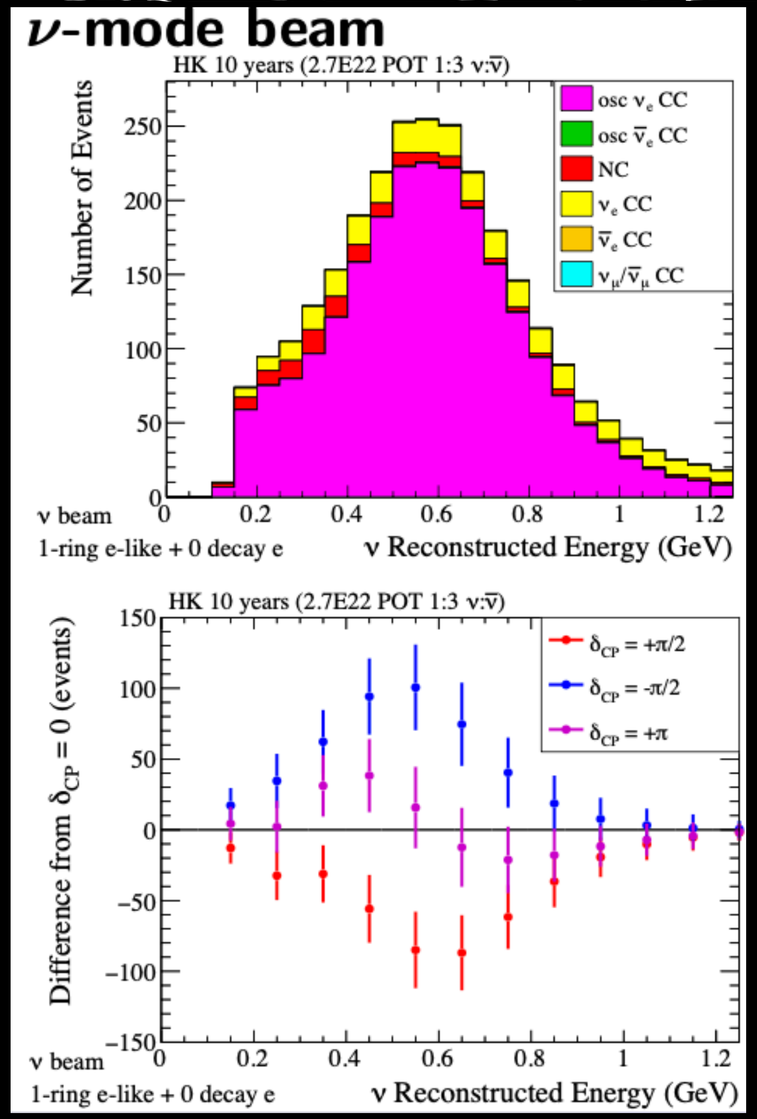
Hyper-K Beam Oscillation Analysis

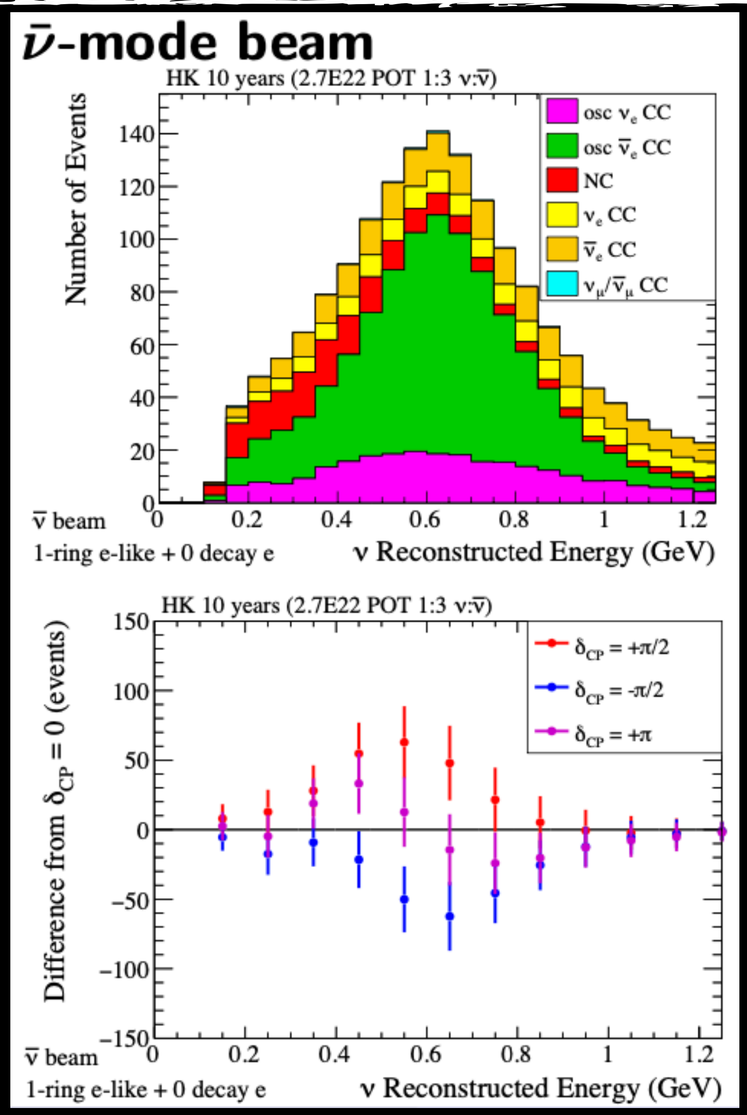
- Based on T2K oscillation method.



Talk by T. Dealtry

Hyper-K Beam Oscillation Analysis



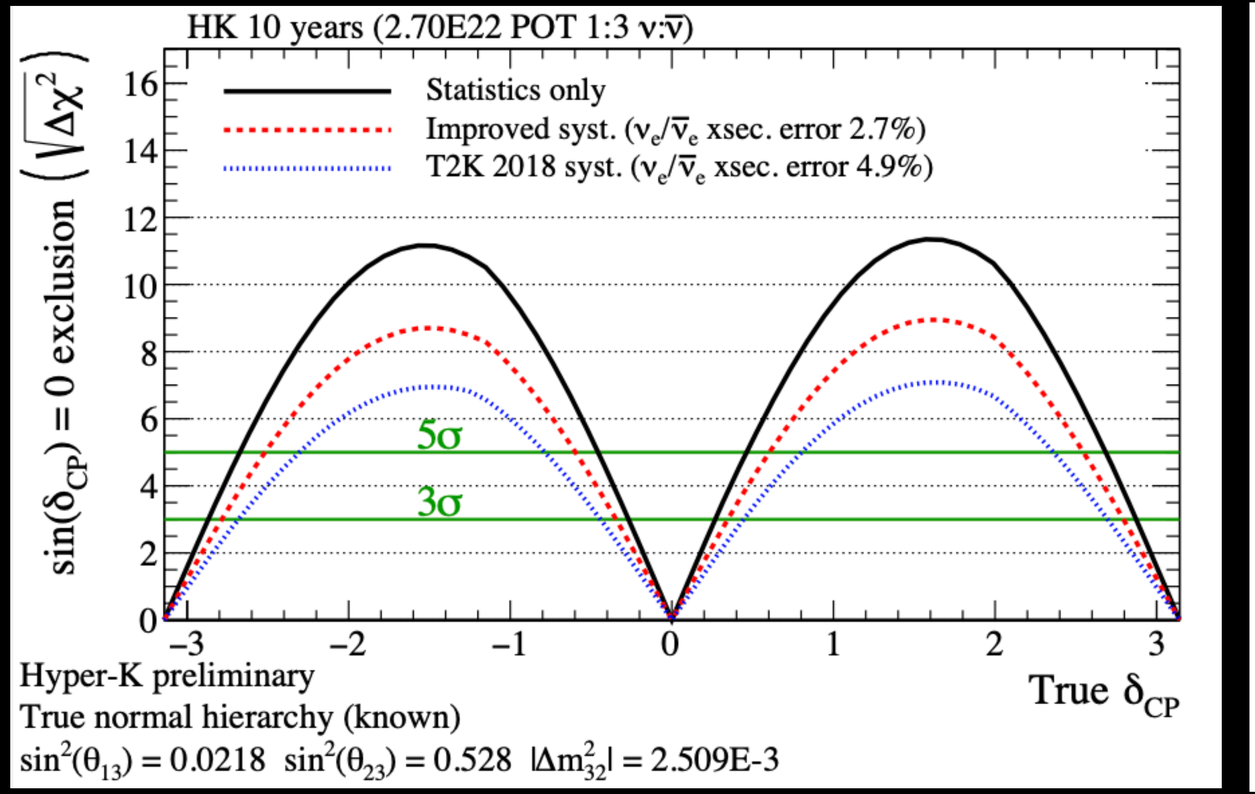


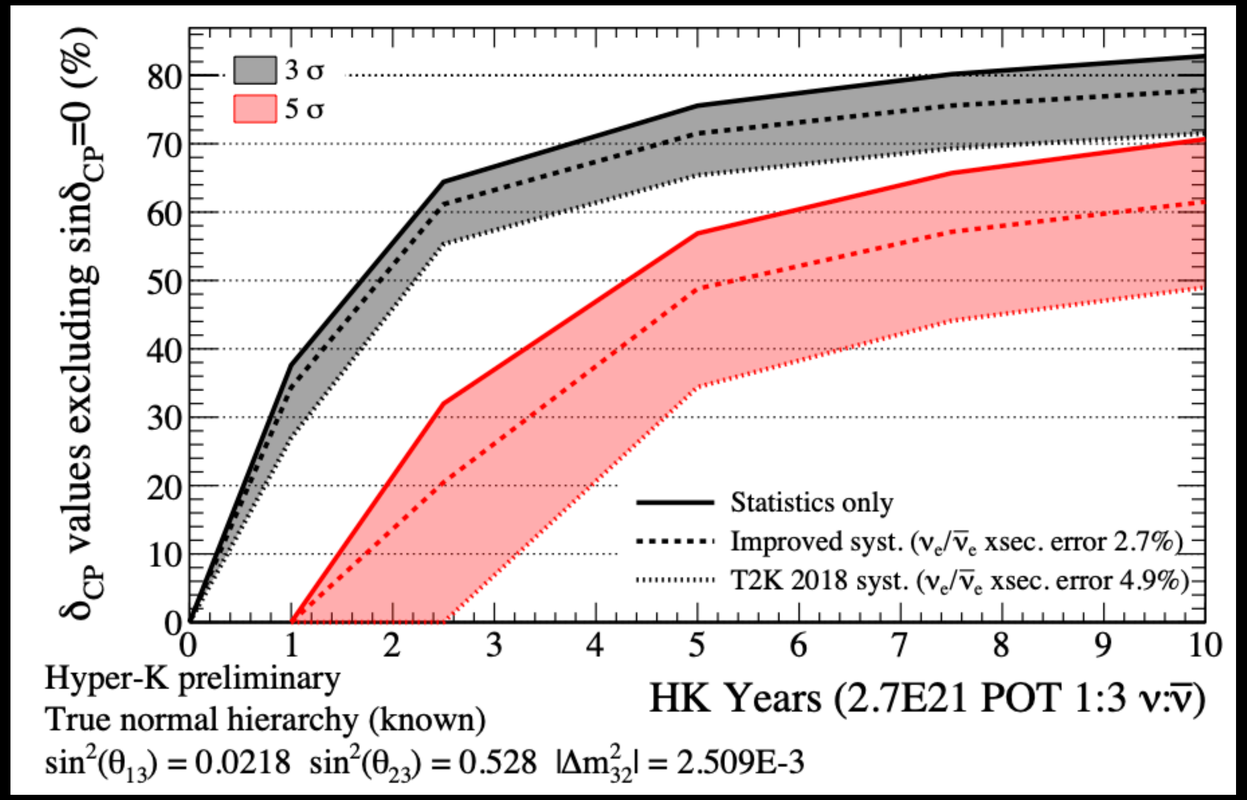
10 years (2.7E22 POT), $\nu : \bar{\nu} = 1 : 3$

- Use Super-K MC, scaled to HK volume and exposure
- Expect approx:
  - 2300 ν_e events
  - 1900 $\bar{\nu}_e$ events
  - Assuming $\sin(\delta_{CP}) = 0$
- Difference between neutrino and antineutrino rates gives δ_{CP}

$\sin \delta_{CP} \neq 0$ *Sensitivity*

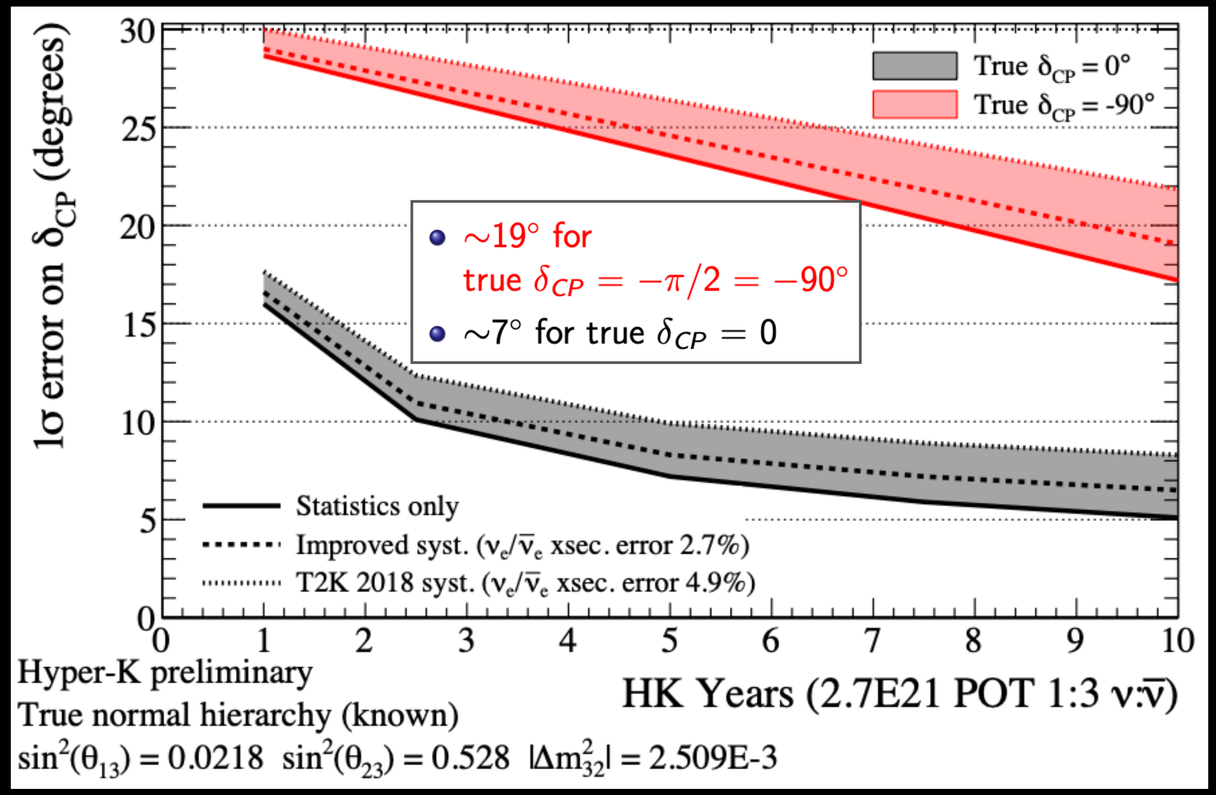
- Ability to exclude CP conservation versus true value of δ_{CP}

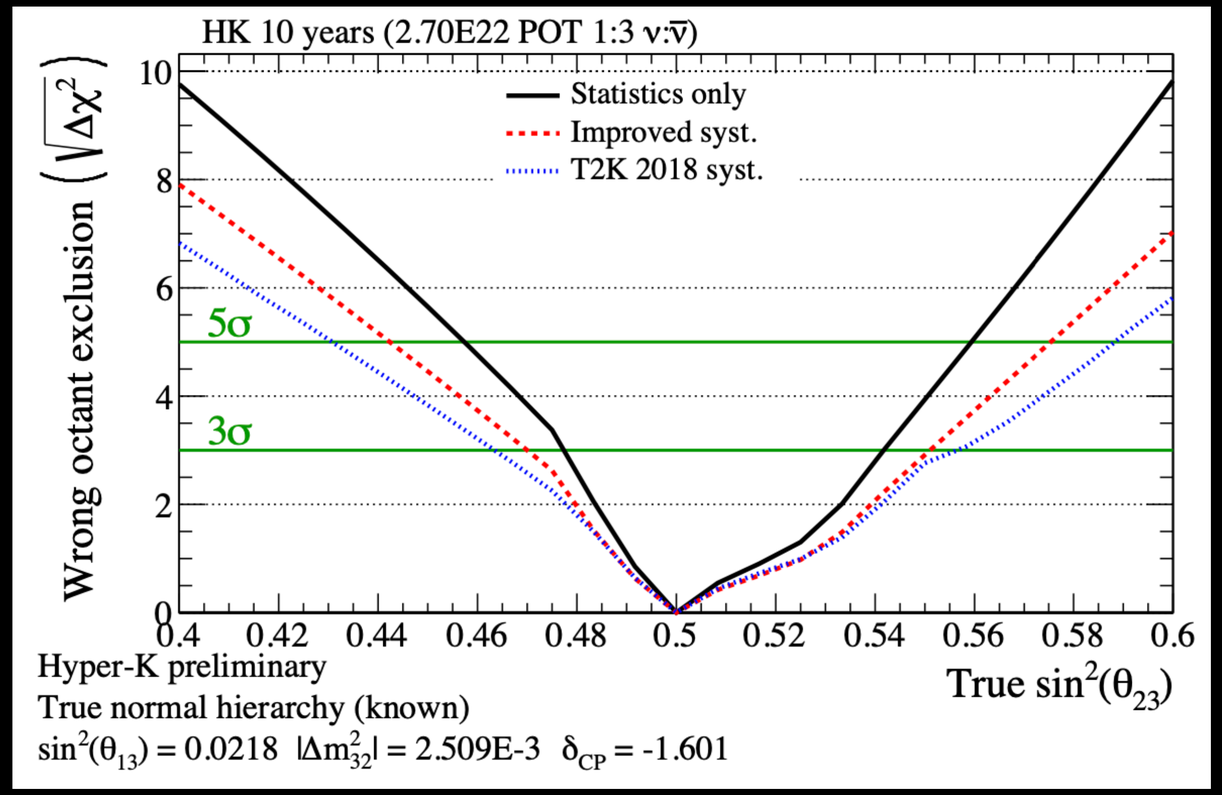




Resolution on δ_{CP} and measurement of $\sin^2\theta_{23}$

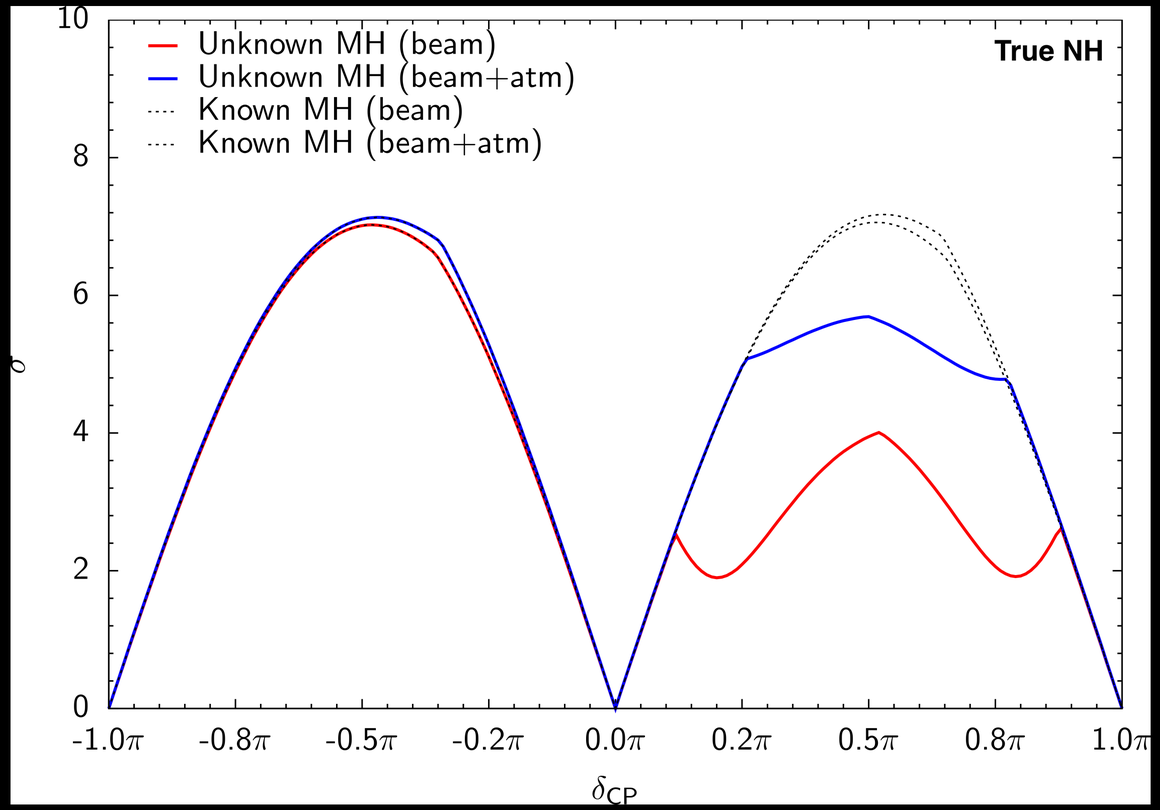
- How accurately can we measure the value of δ_{CP}?
- For a true value of $\sin^2\theta_{23}$, how much can we exclude the wrong octant? ($\sin^2\theta_{23}$ < or > 0.5)





Adding Atmospherics

- Atmospheric neutrinos have longer baseline and higher energies ⇒ sensitivity to neutrino mass ordering
- If MO unknown, beam analysis less sensitive for some values of δ_{CP}.
- Joint atmospheric and beam analysis increases sensitivity above 5σ
- Can exclude incorrect mass ordering at $\mathbf{4-6\sigma}$ significance (depending on value of $\sin^2\theta_{23}$)

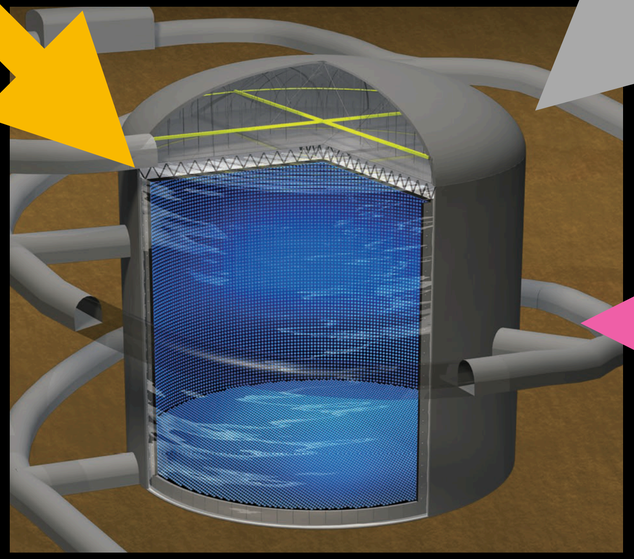


- Ability to exclude CP conservation versus true value of δ_{CP}

Astrophysics Neutrinos at Hyper-K

Solar Neutrinos
- Burning processes, modelling of the Sun
- Property of neutrino

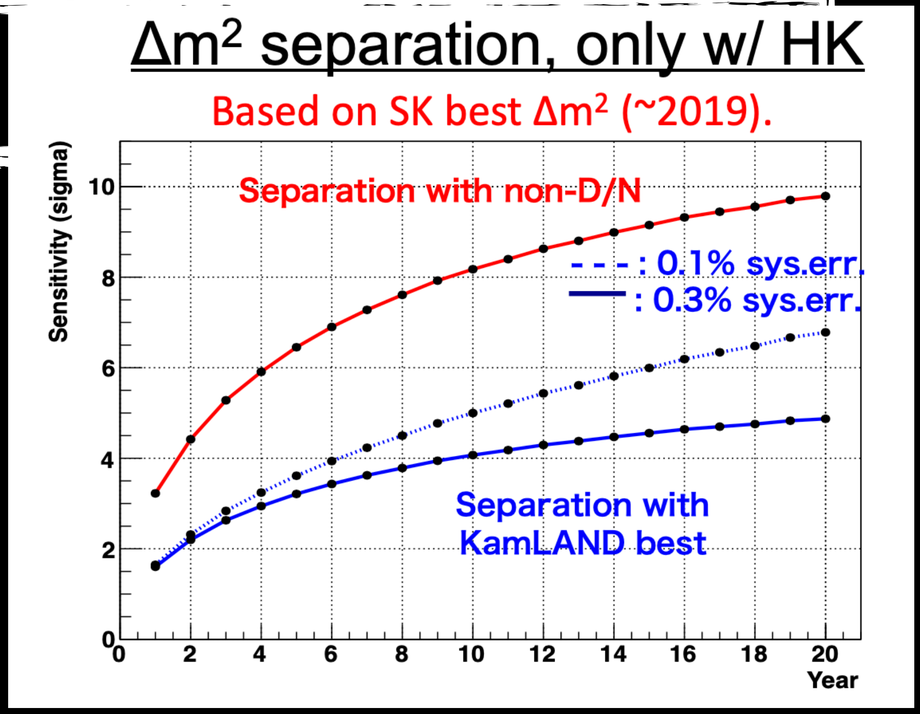
Supernova Neutrinos
- SN explosion mechanism
- SN monitor
- Nucleosynthesis

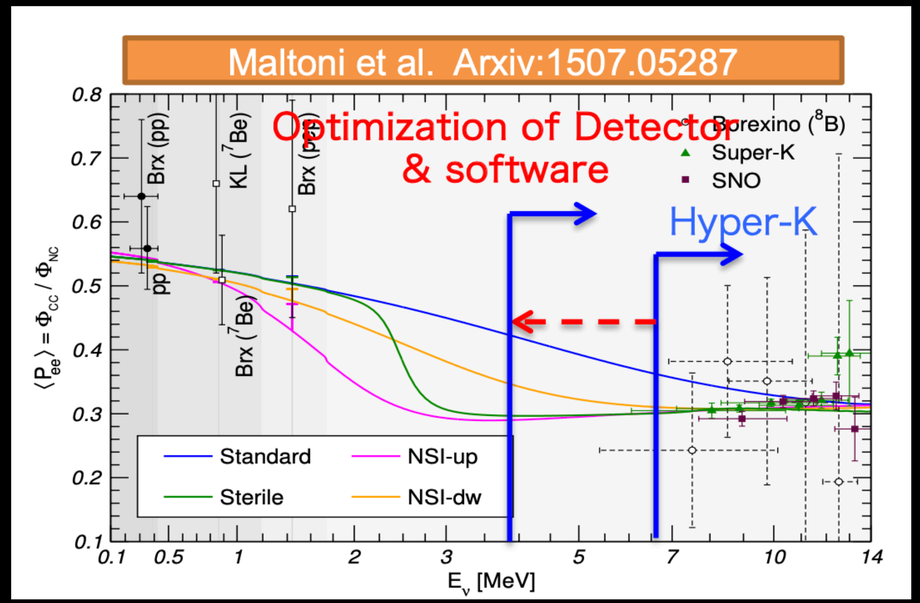


Supernova Relic Neutrinos
- SN mechanism
- Star formation history
- Extraordinary SNe

Solar Neutrinos

- Large statistics: 130 ν ev./day/tank, E_{vis}>4.5MeV
- Highlights of solar ν measurements in particle physics and astrophysics:
  - Precision measurement Δm^2_{21}
    - Day/Night asymmetry
  - Solar ν spectrum up-turn
  - Discovery of Hep neutrino
  - Variation of solar ν flux





Solar Neutrinos

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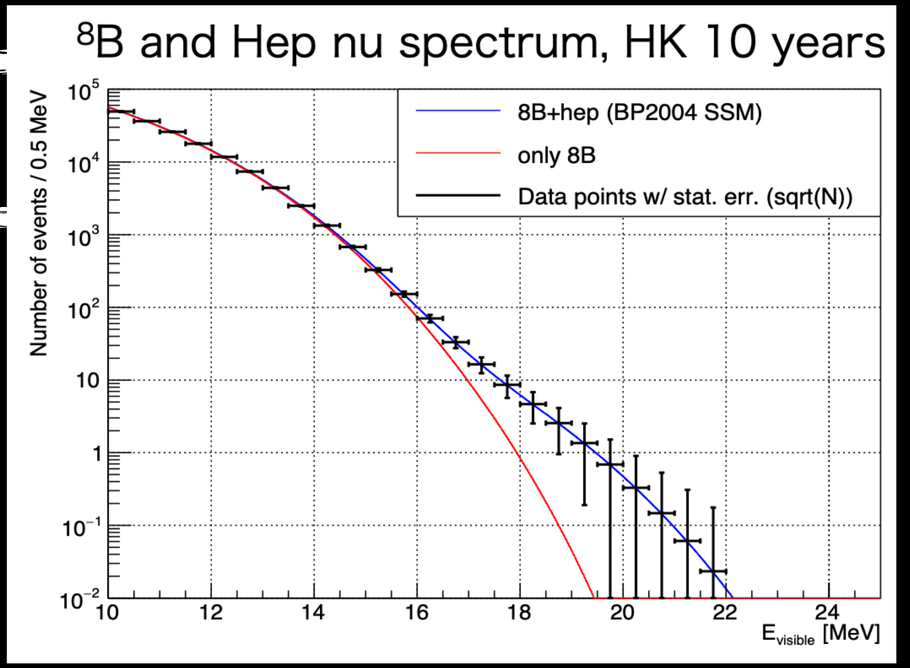
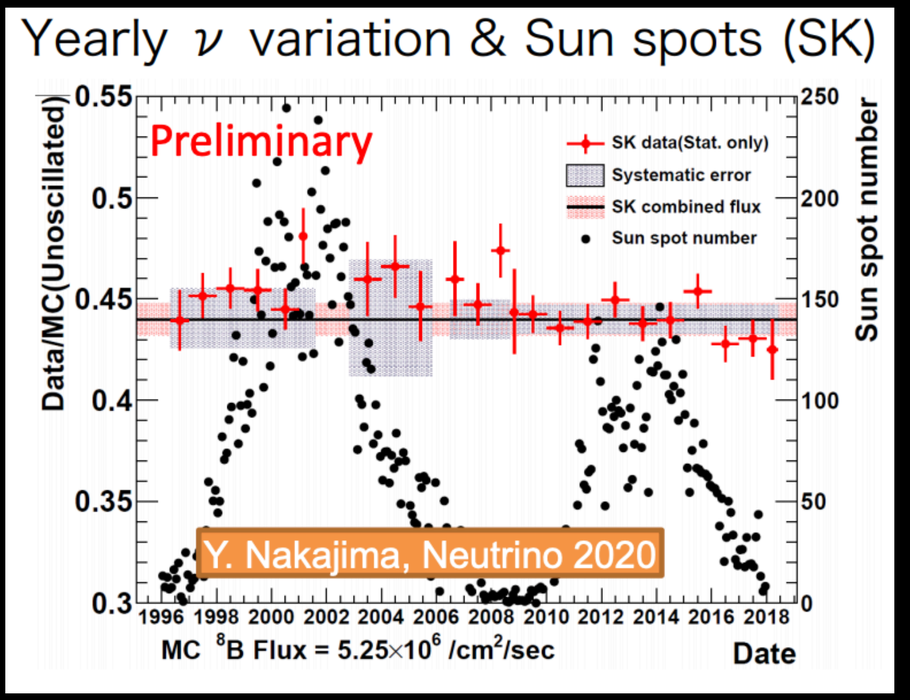
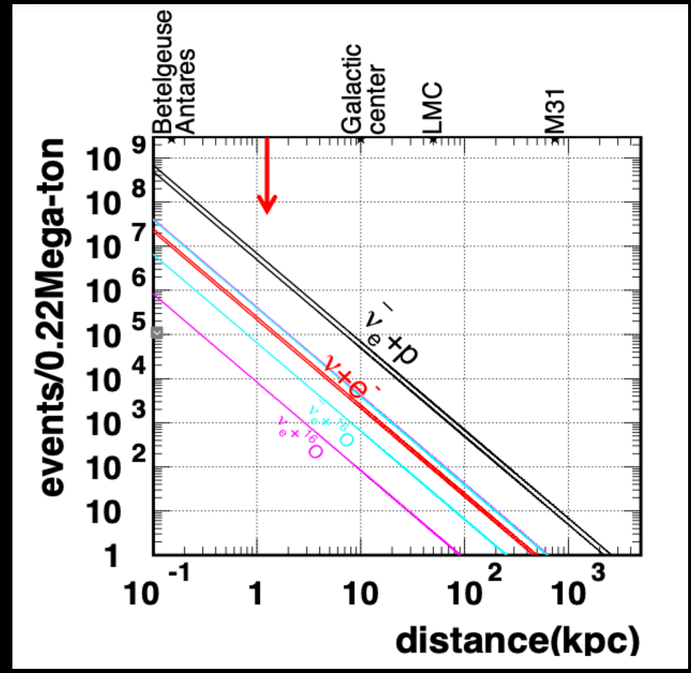




Talk by J. Migenda

Supernova Neutrinos

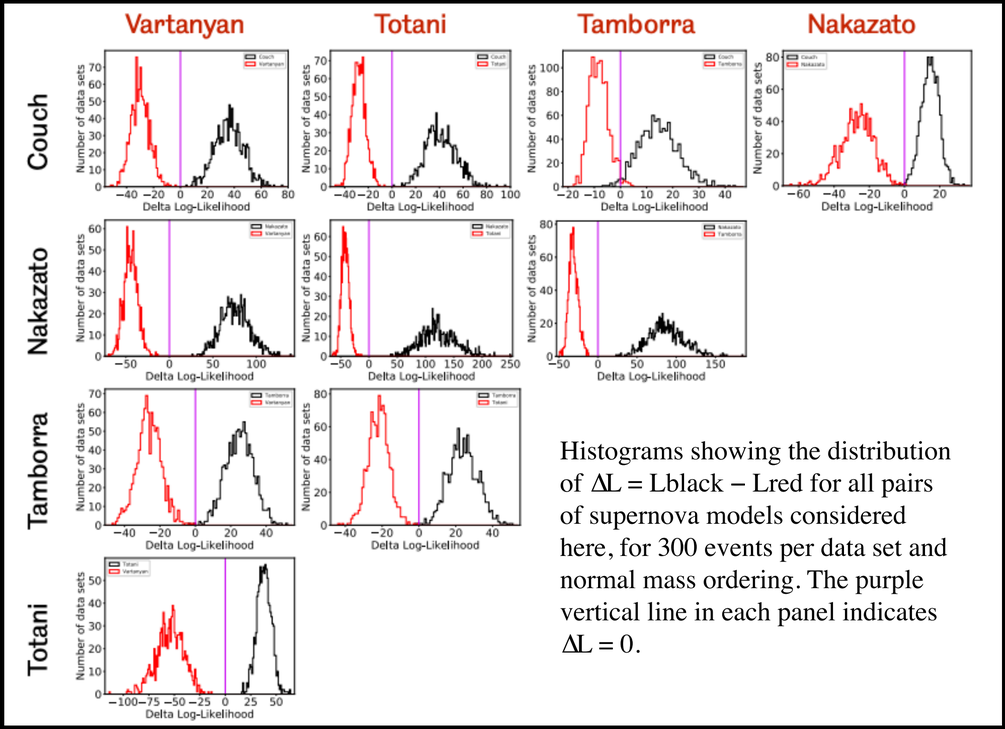
- Supernova neutrino observation:
  - 54-90k events for SN at 10 kpc (most sensitive to $\bar{\nu}_e$)
  - Precise Neutrino Time profile
  - Precise spectrum measurement
  - Investigation of the SN mechanism (SASI/ Rotation/Convection)



- Models by different groups, using various approximations
→ telling models apart can help understand the explosion mechanism

Supernova Neutrinos

- Supernova Model Discrimination with Hyper-Kamiokande
- e-Print: 2101.05269 [astro-ph.IM]



Histograms showing the distribution of $\Delta L = L_{black} - L_{red}$ for all pairs of supernova models considered here, for 300 events per data set and normal mass ordering. The purple vertical line in each panel indicates $\Delta L = 0$.

Accuracy with which the true model can be identified, for 300 events per data set

Normal mass ordering.

True Model \ Reconstructed Model (Normal)	Couch	Nakazato	Tamborra	Totani	Vartanyan
Couch	**98.2**	0.2	1.6	0.0	0.0
Nakazato	0.1	**99.9**	0.0	0.0	0.0
Tamborra	1.6	0.0	**98.0**	0.2	0.2
Totani	0.0	0.0	0.0	**100.0**	0.0
Vartanyan	0.0	0.0	0.0	0.0	**100.0**

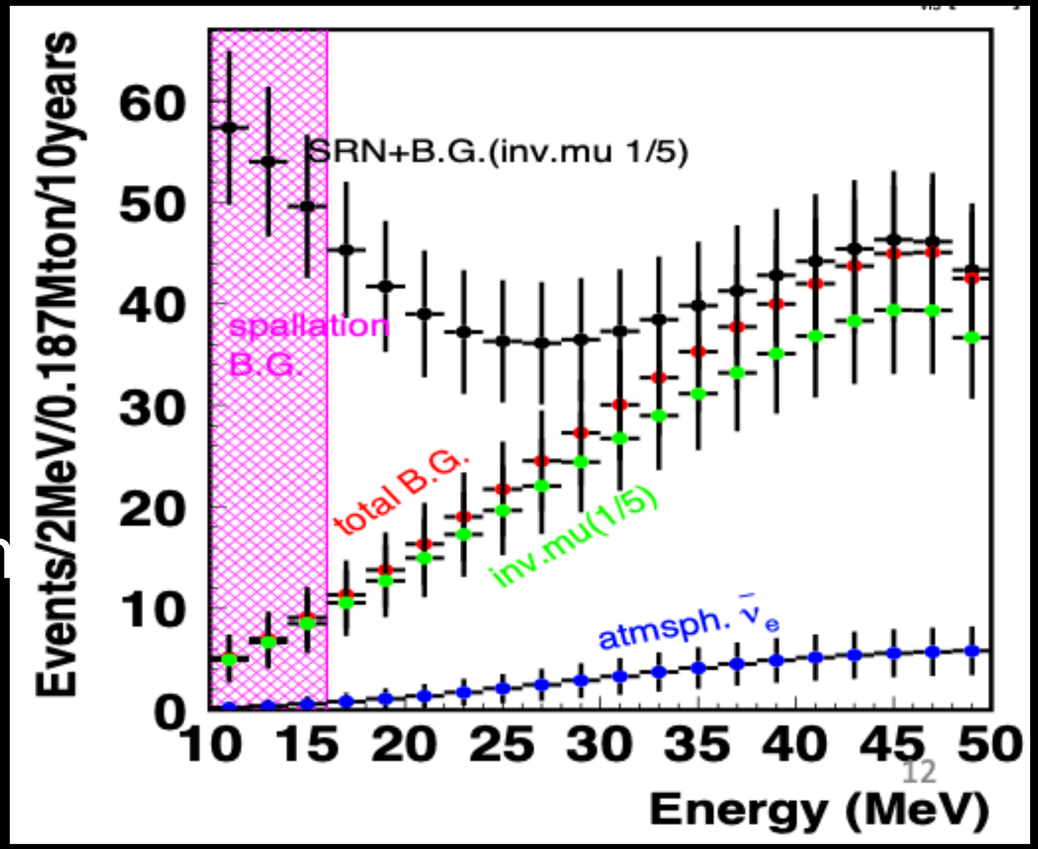
Inverted mass ordering.

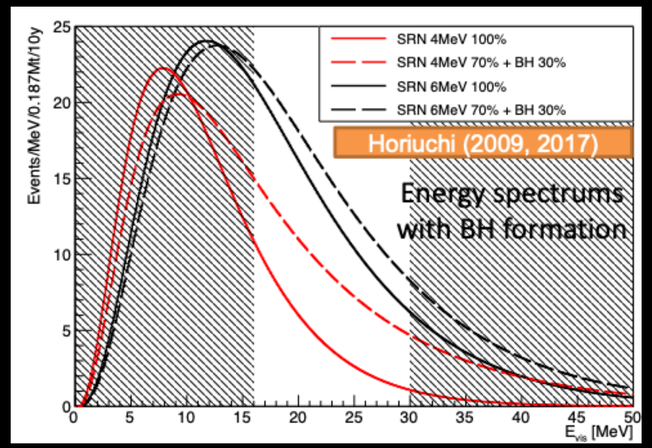
True Model \ Reconstructed Model (Inverted)	Couch	Nakazato	Tamborra	Totani	Vartanyan
Couch	**99.9**	0.1	0.0	0.0	0.0
Nakazato	0.0	**100.0**	0.0	0.0	0.0
Tamborra	0.0	0.0	**97.4**	0.1	2.5
Totani	0.0	0.0	0.0	**100.0**	0.0
Vartanyan	0.0	0.0	0.8	0.0	**99.2**

- With 300 events, corresponding to SN at 60-100 kpc, >97% identification is realized.

Supernova Relic Neutrinos

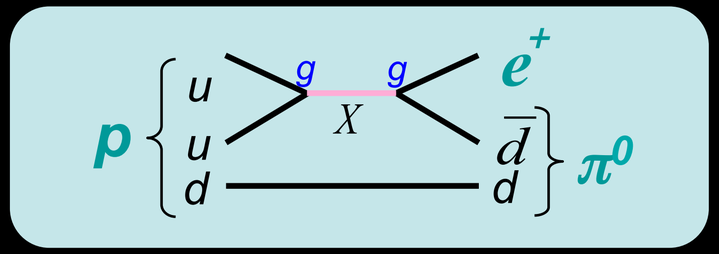
- Supernova Relic Neutrino (SRN)
- Diffused neutrinos coming from all past supernovae.
- Not discovered but promising extra-galactic ν.
- SRN can be observed by HK in 10y with ~70±17 events. It is > 4σ for SRN signal.



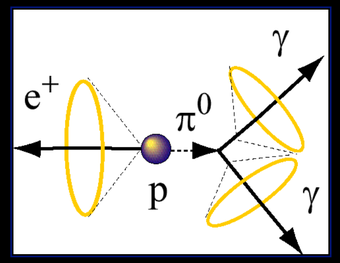


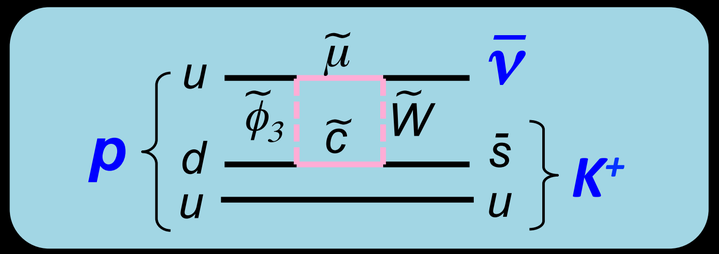
Proton Decay Searches

- Two major modes predicted by many models

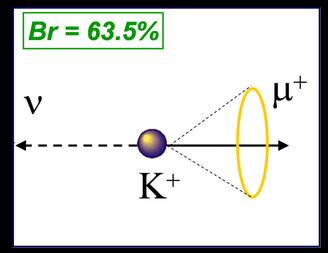


p→e⁺π⁰

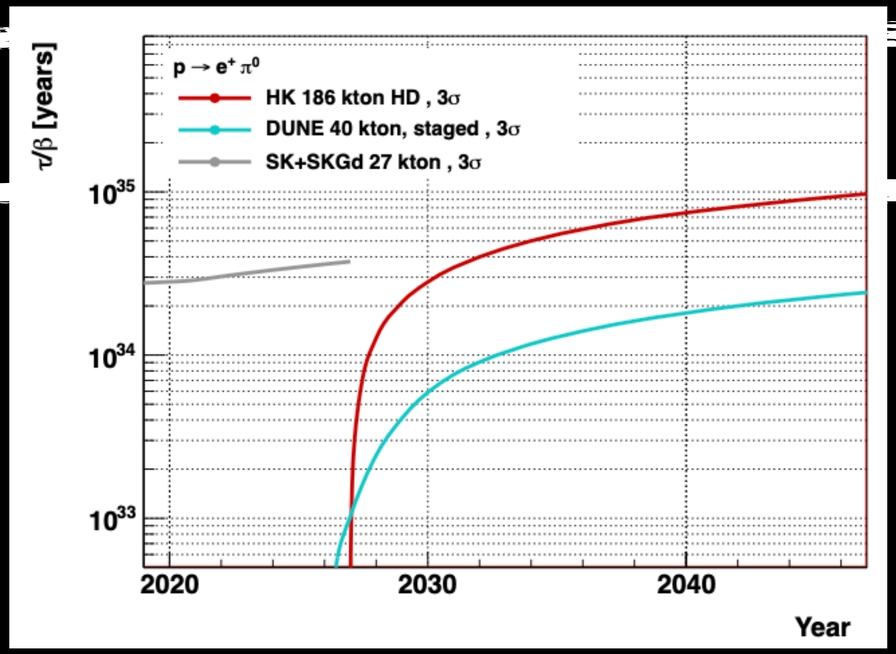


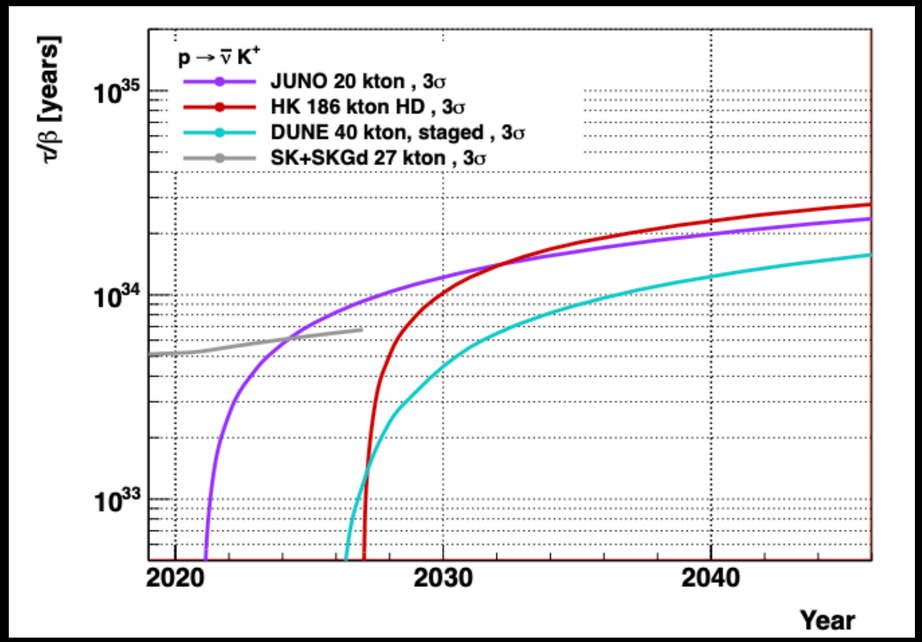


p→ν̄K⁺



- Hyper-K is able to pursue these and other final states with the highest precision.





Conclusion

- A groundbreaking experiment is being built in Japan.
- It will address major open questions in science!
- It will start to take data in 2027!!

Backup Slides

- Additional slides for perusal

New Research Building in Kamioka

New research building at Kamioka

- It is now being constructed. It will be completed by next summer.
- It has 4 floors and 3,050 m^2 total floor area.

Dormitory rooms.

Many physicists and engineers will come to Kamioka during the HK construction. They can use this research building.

Dinning rooms.

Many visiting researcher's Rooms in 2nd and 3rd floors.

Lab. Rooms to construct detector components.

Big hall to accommodate about 150 people on the 1st floor.

Image of new research building