Developments in Asia

(Only cover experiments based in Asia)

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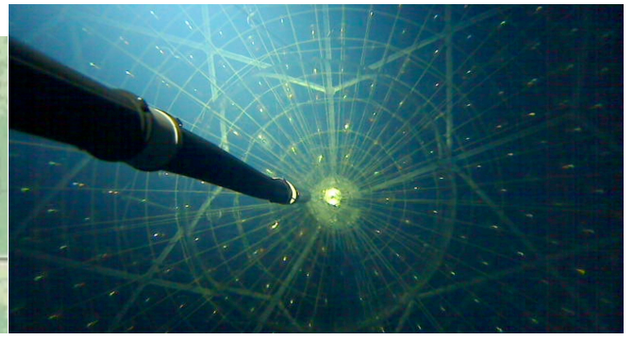
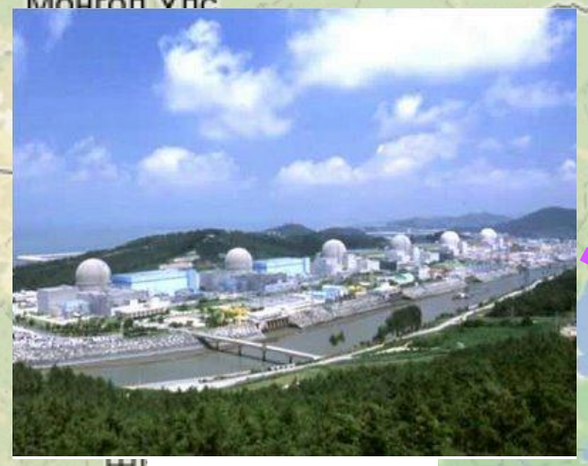
SCHOOL OF SCIENCE
THE UNIVERSITY OF TOKYO

Intensity Frontier
Neutrino subgroup meeting
Mar. 6-7 2013, SLAC

Exciting ν results from Asia-based experiments



KamLAND(-Zen)



RENO

Daya Bay

Super-Kamiokande

T2K

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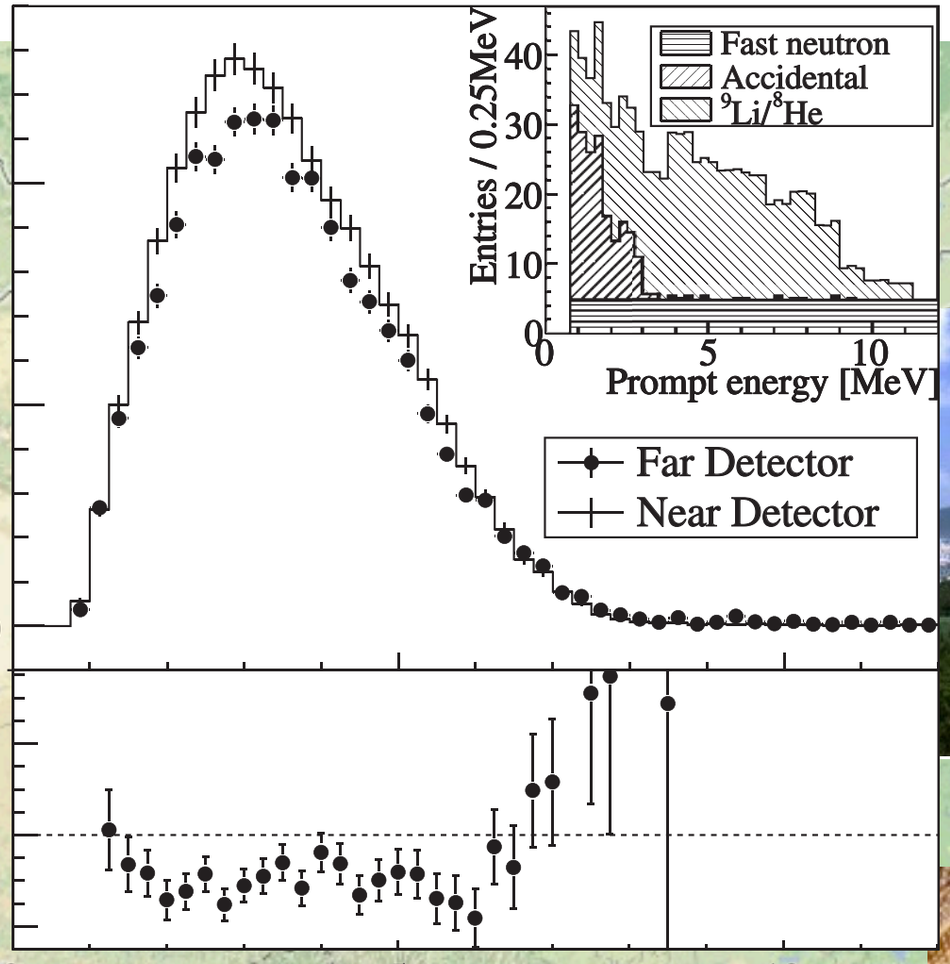

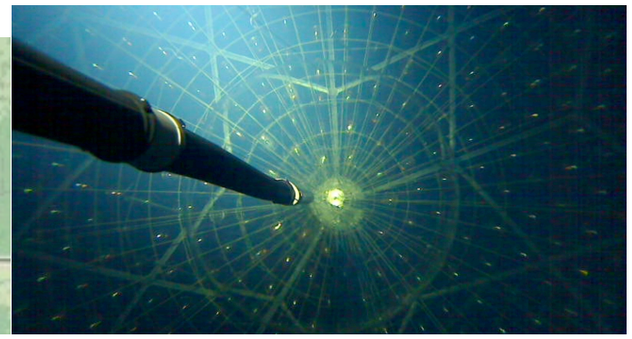

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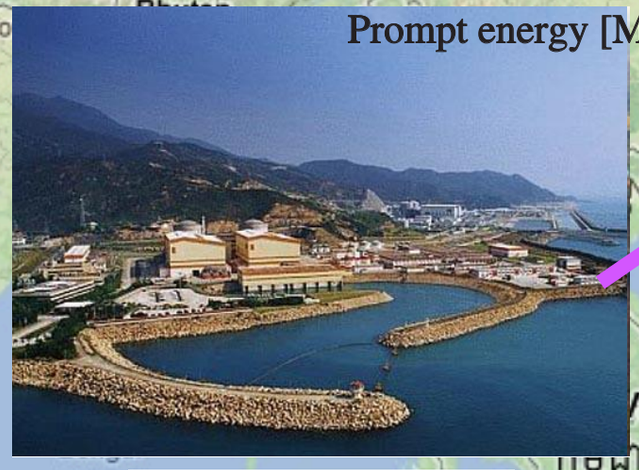

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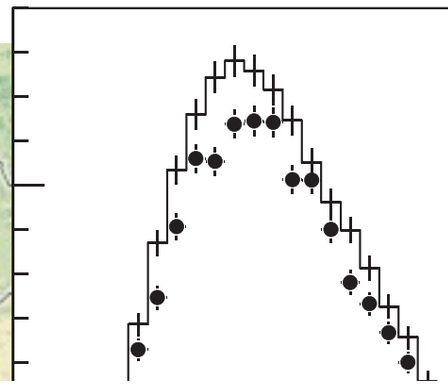

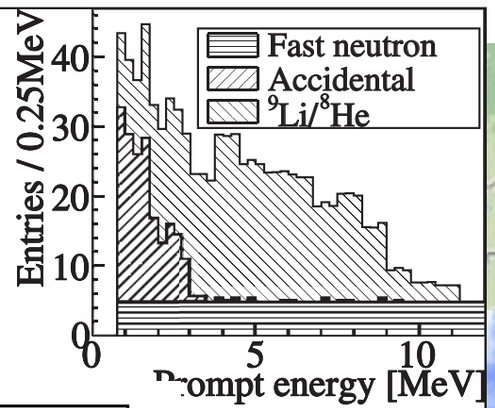

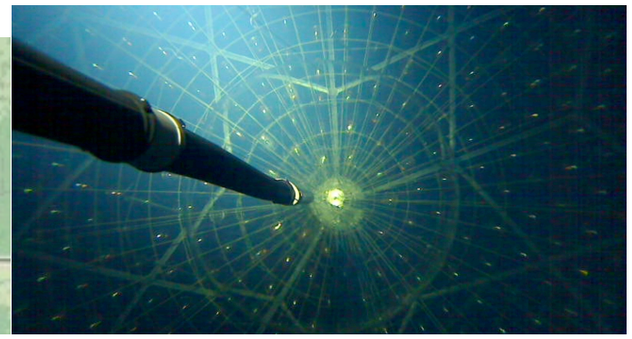

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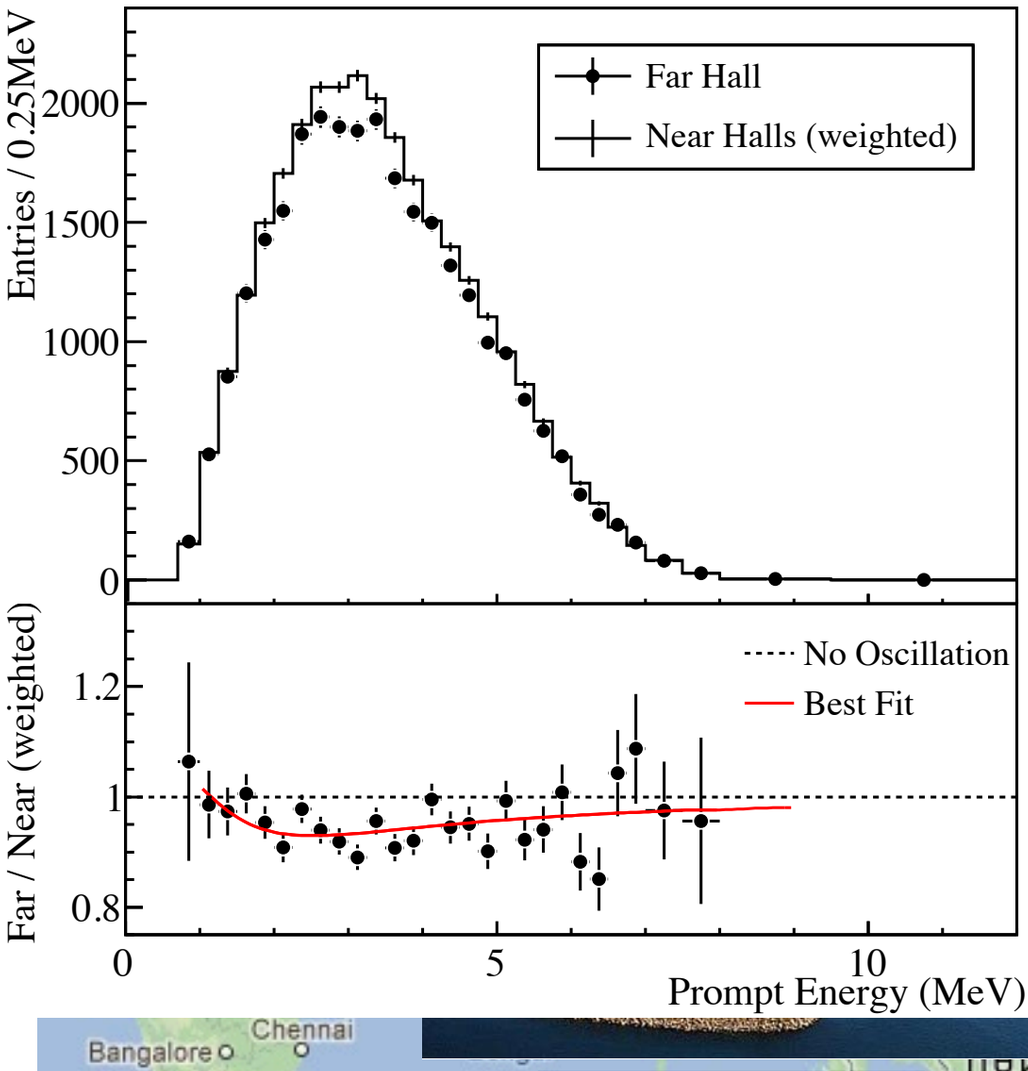

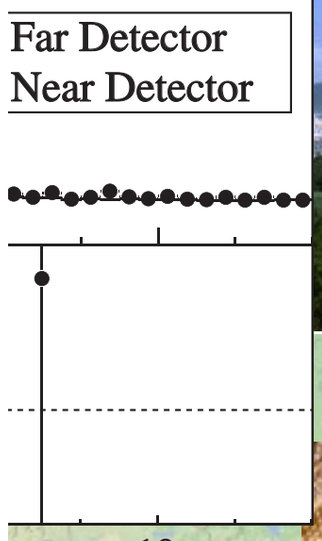

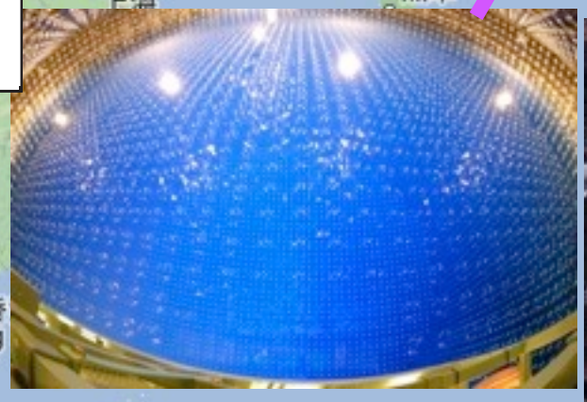

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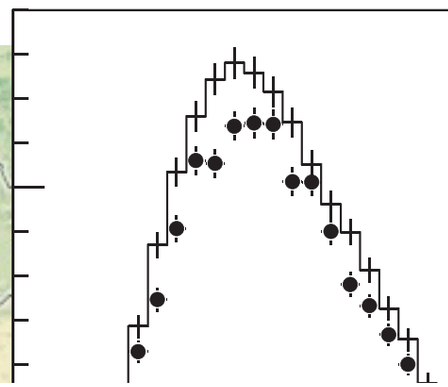

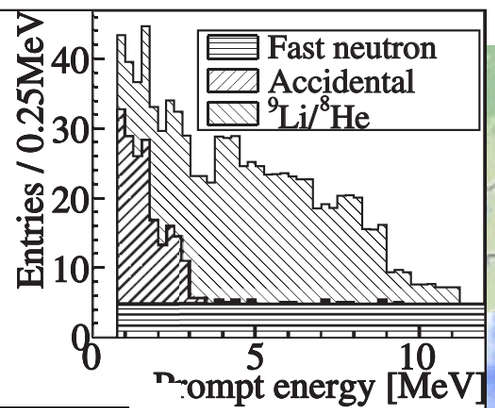

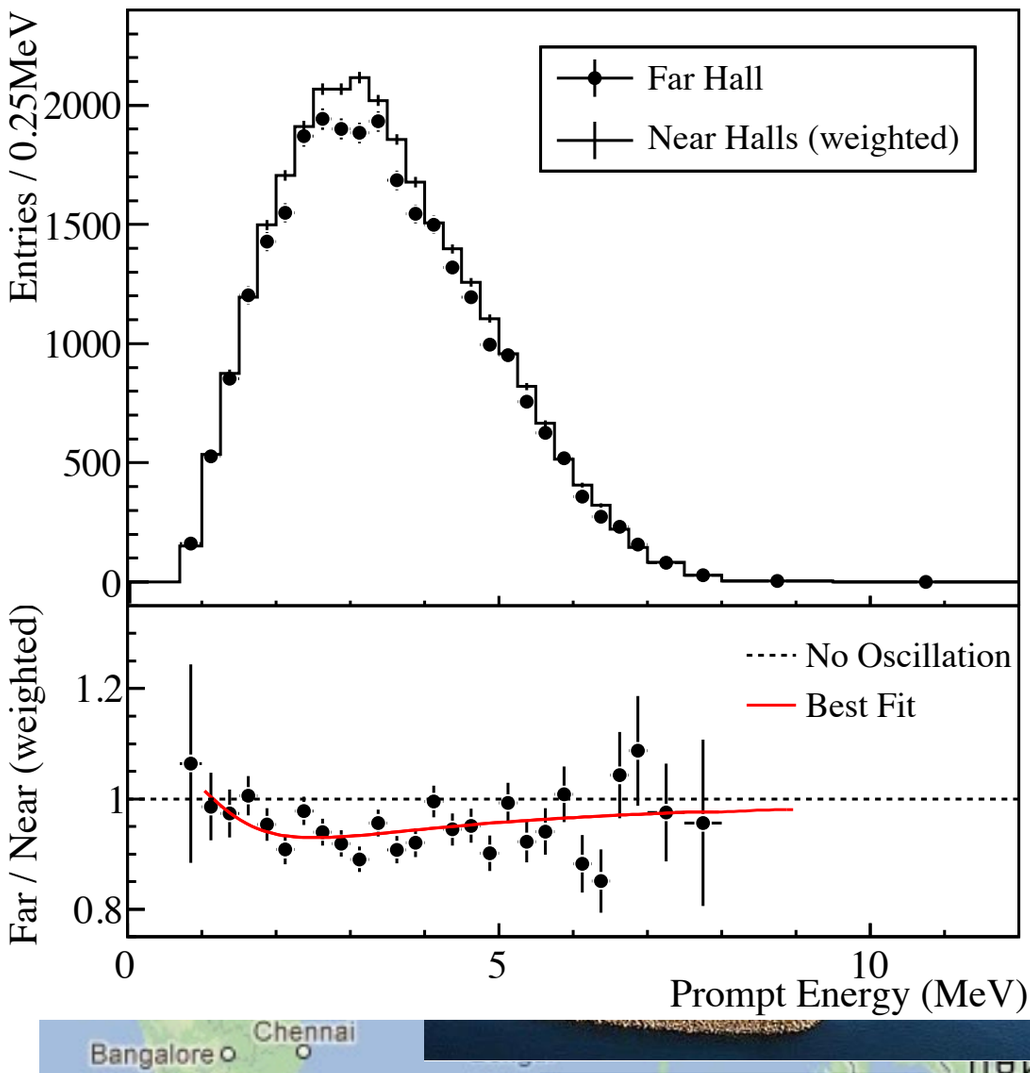

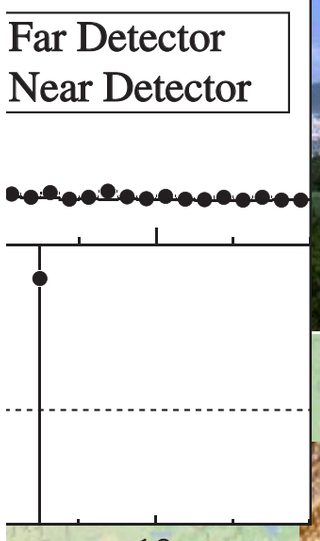

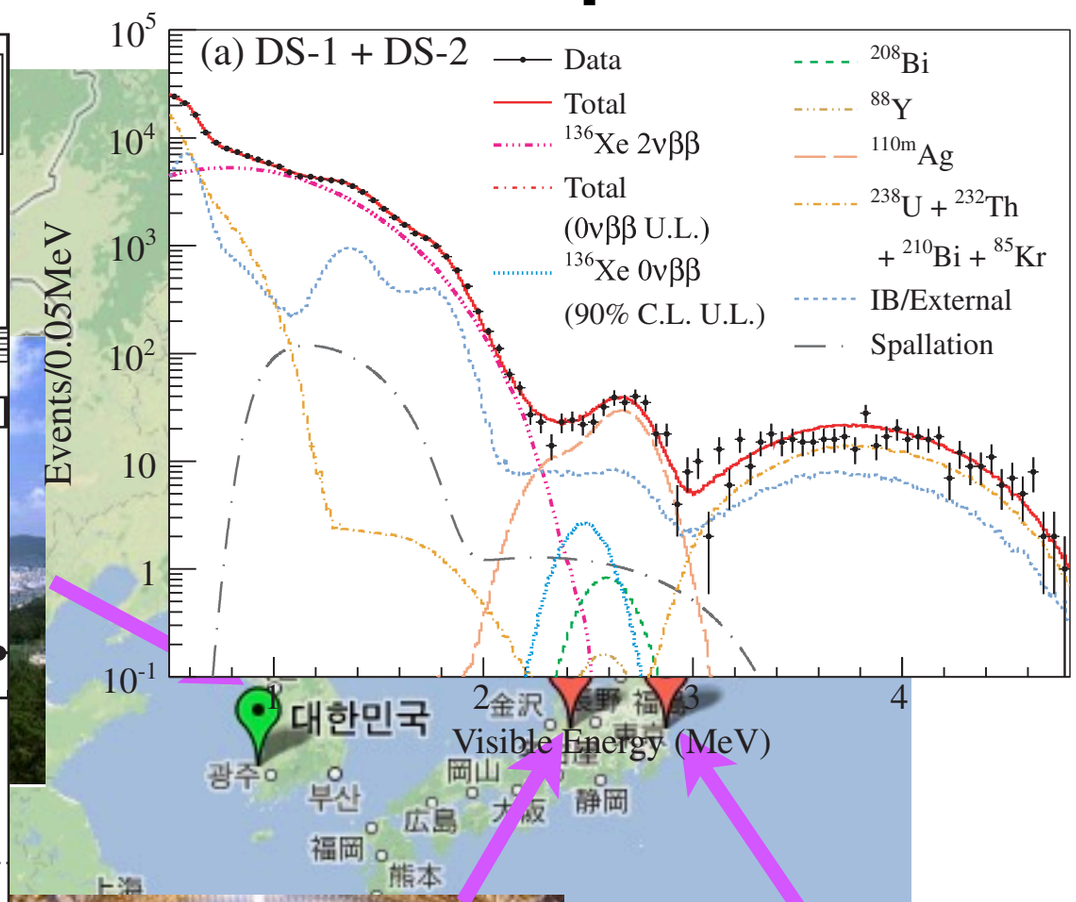

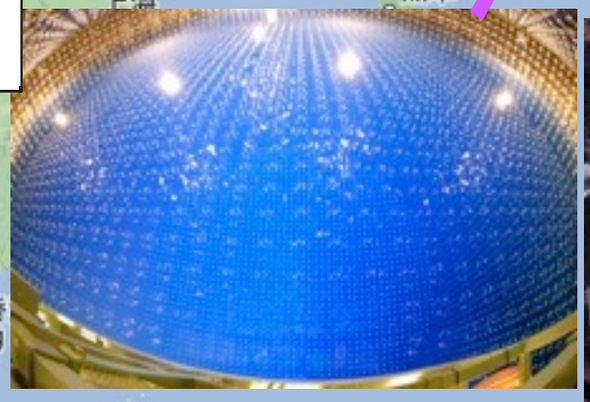

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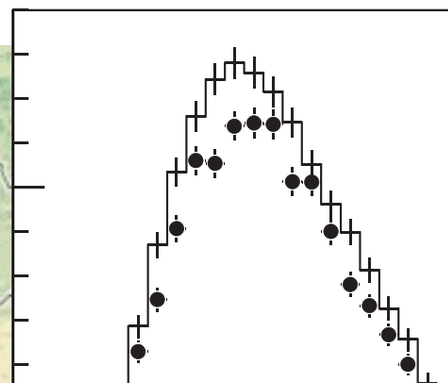

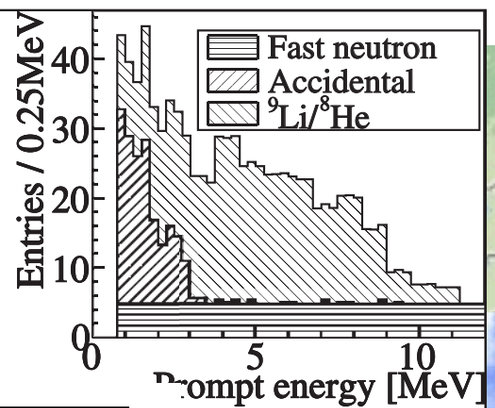

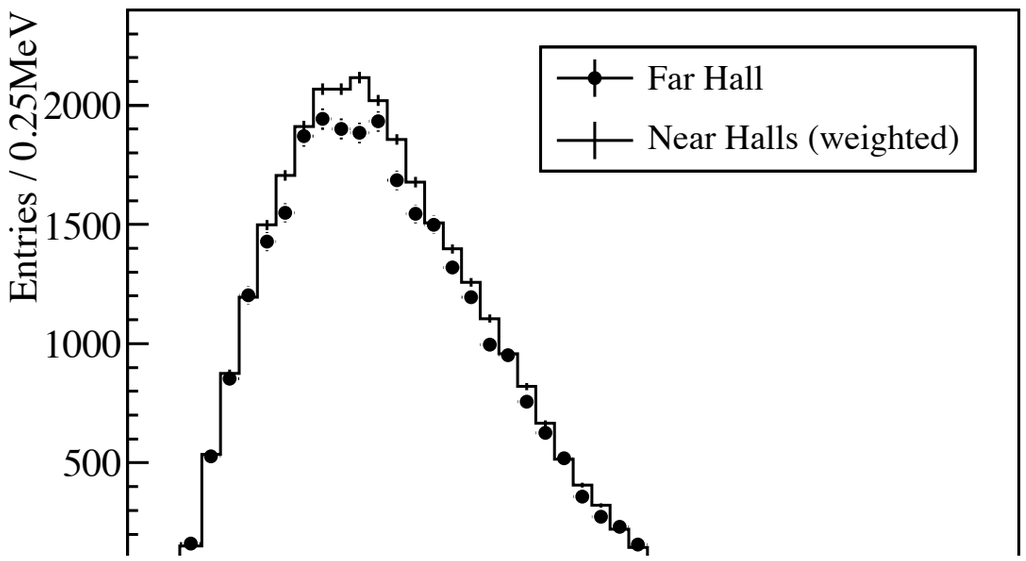

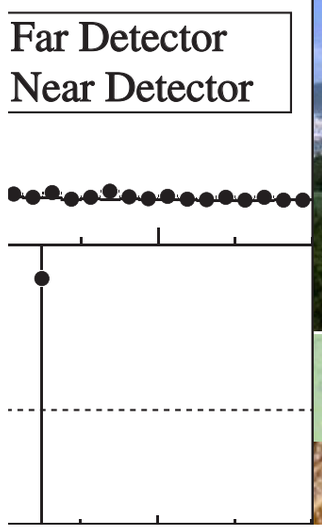

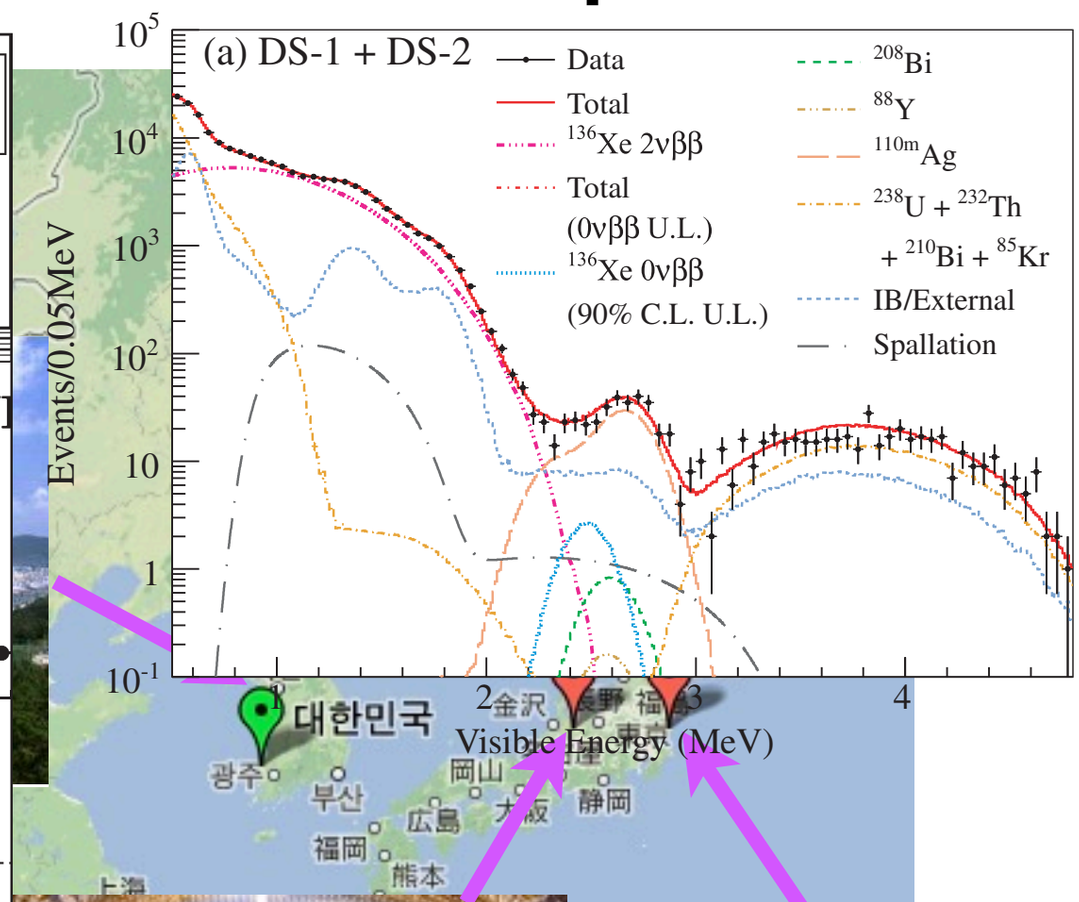

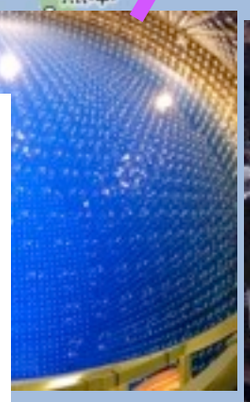

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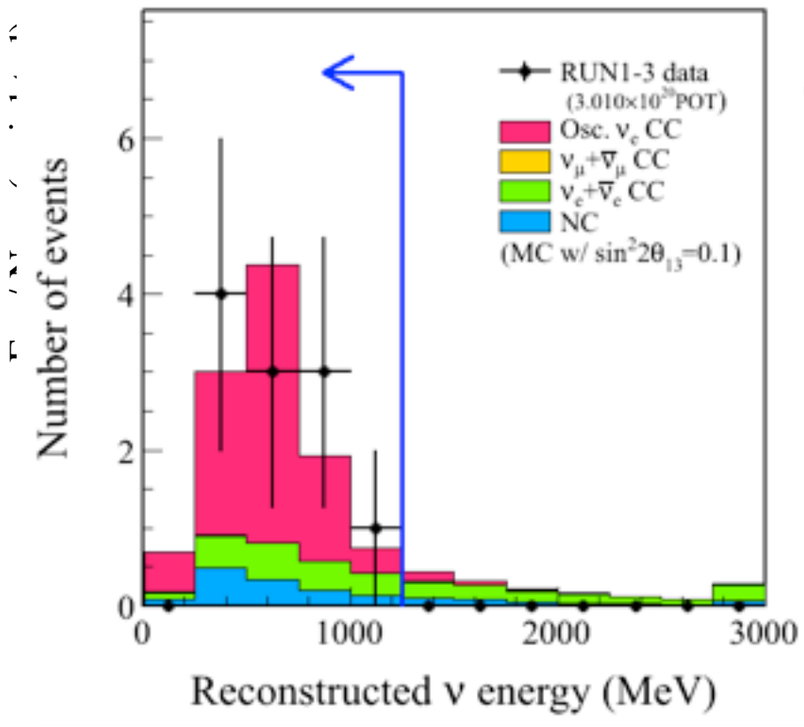

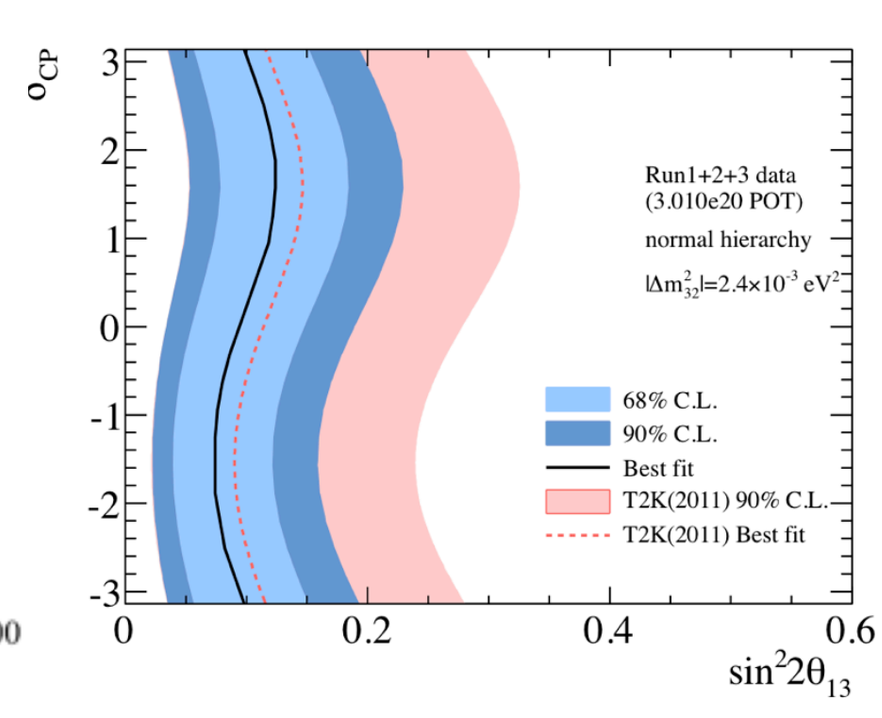

T2K

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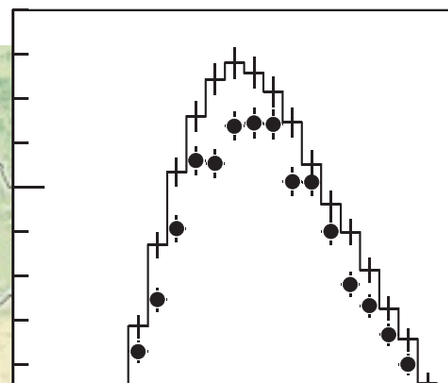

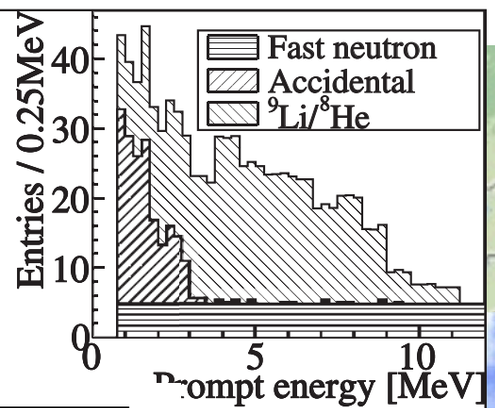

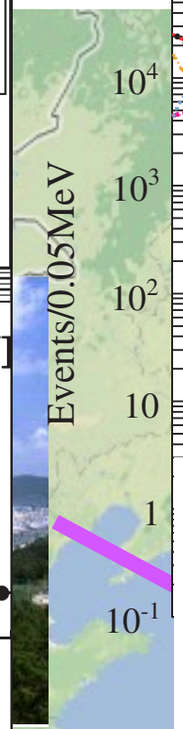

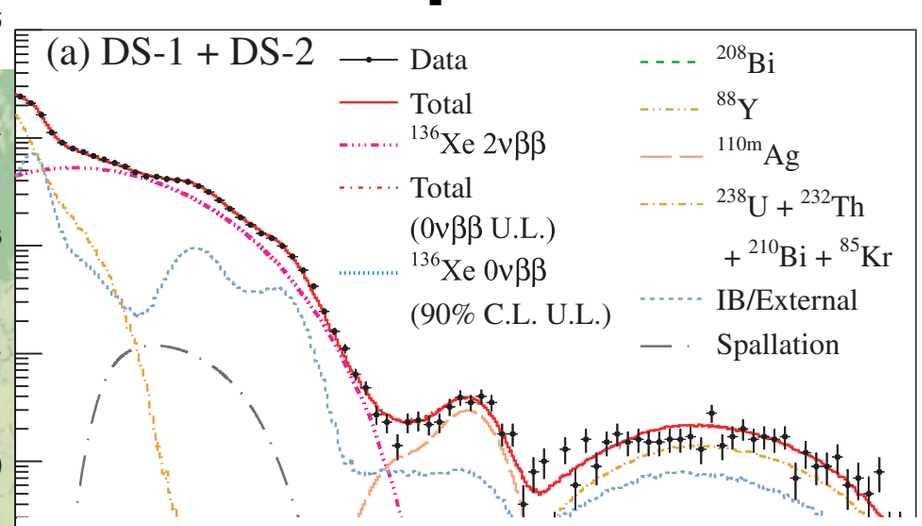

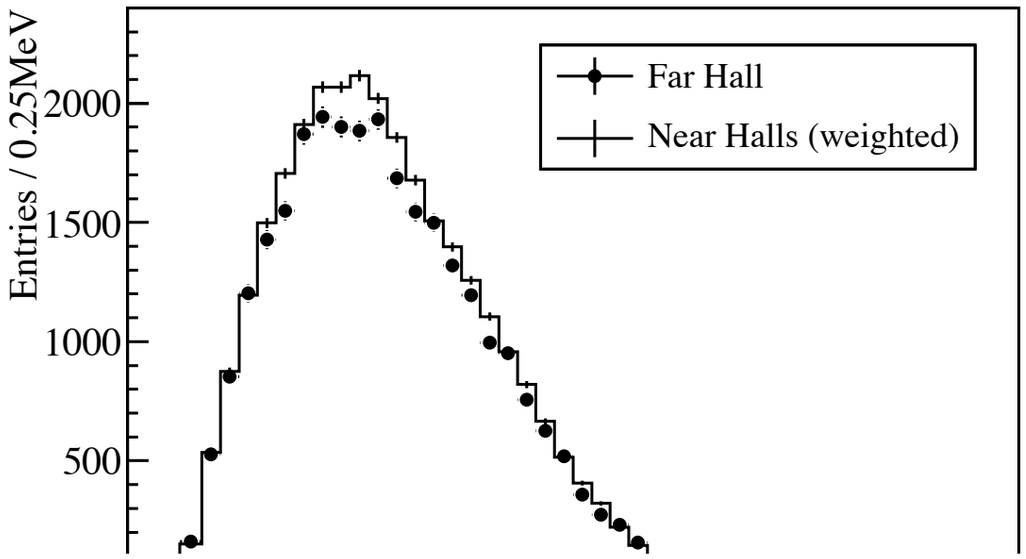

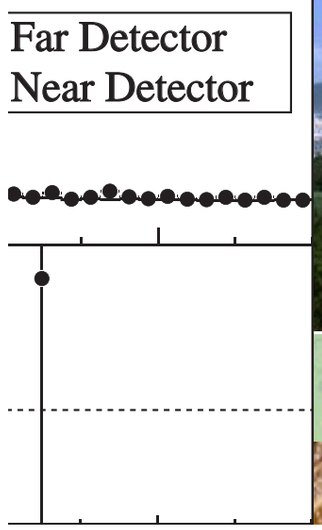

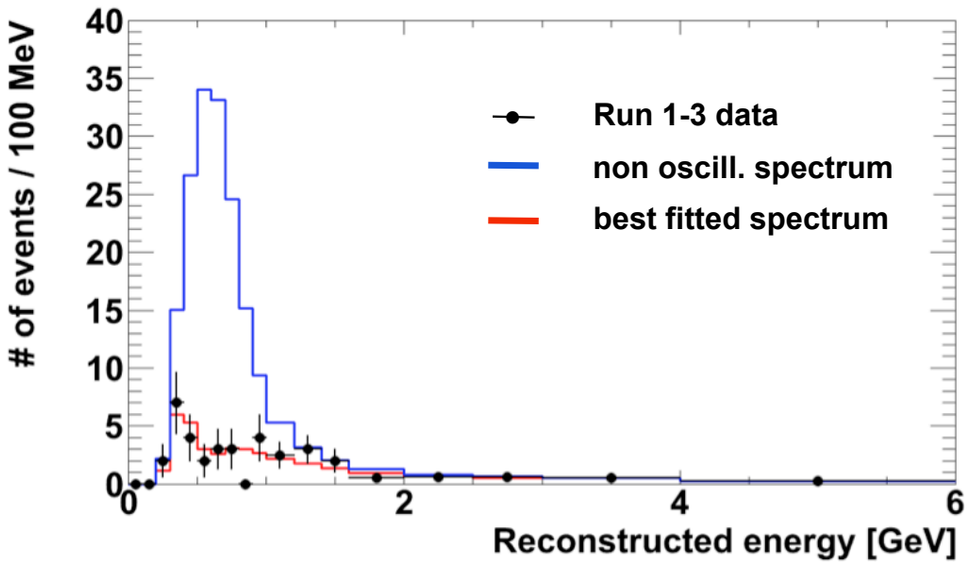

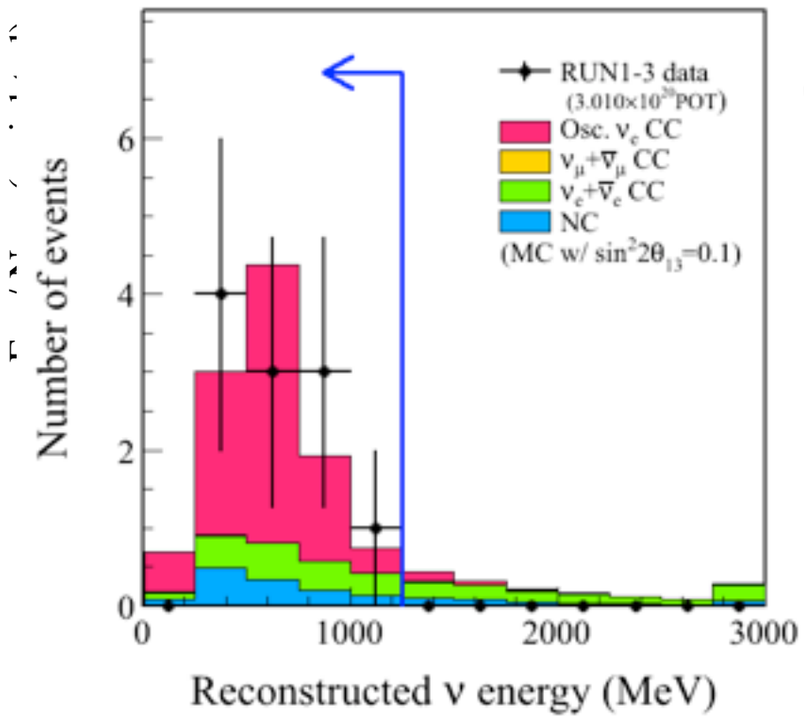

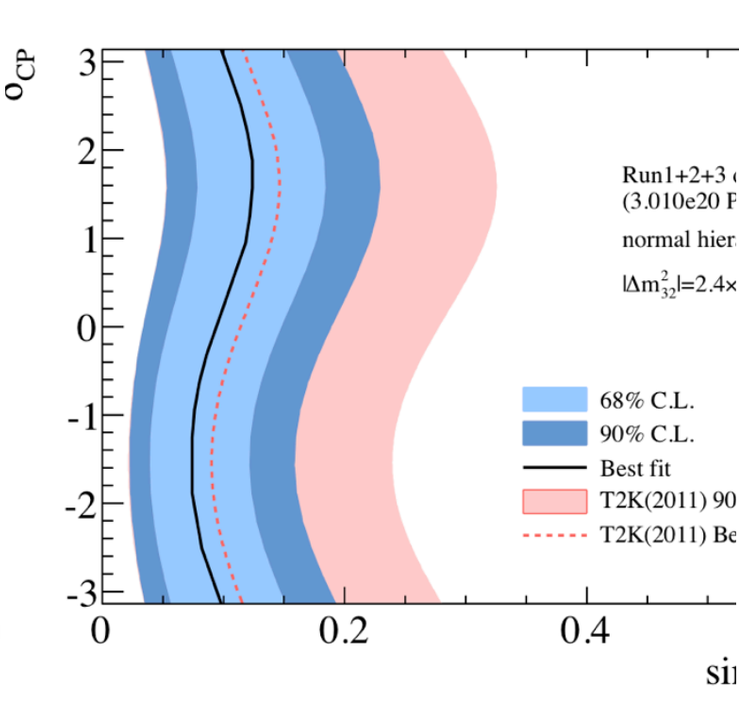

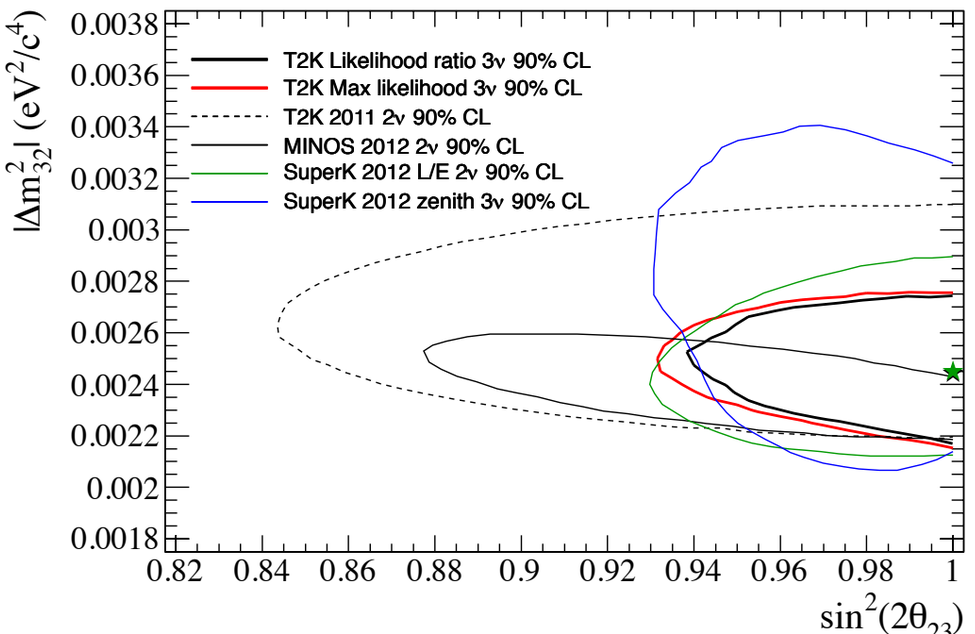

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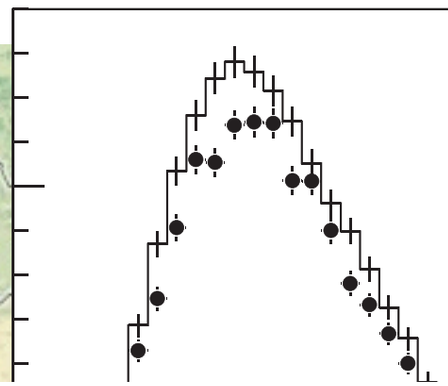
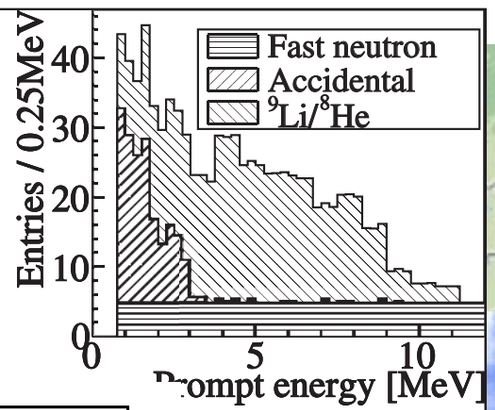
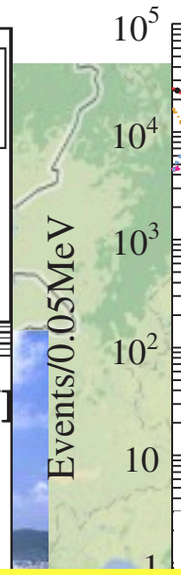
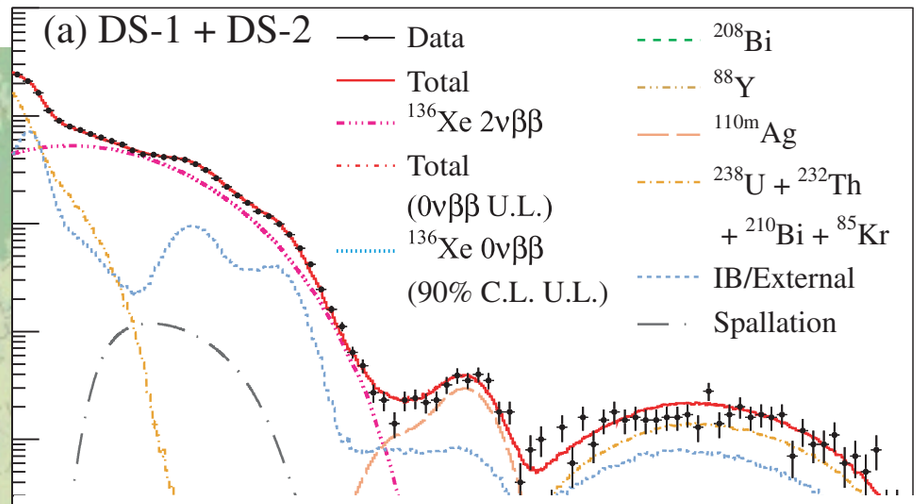
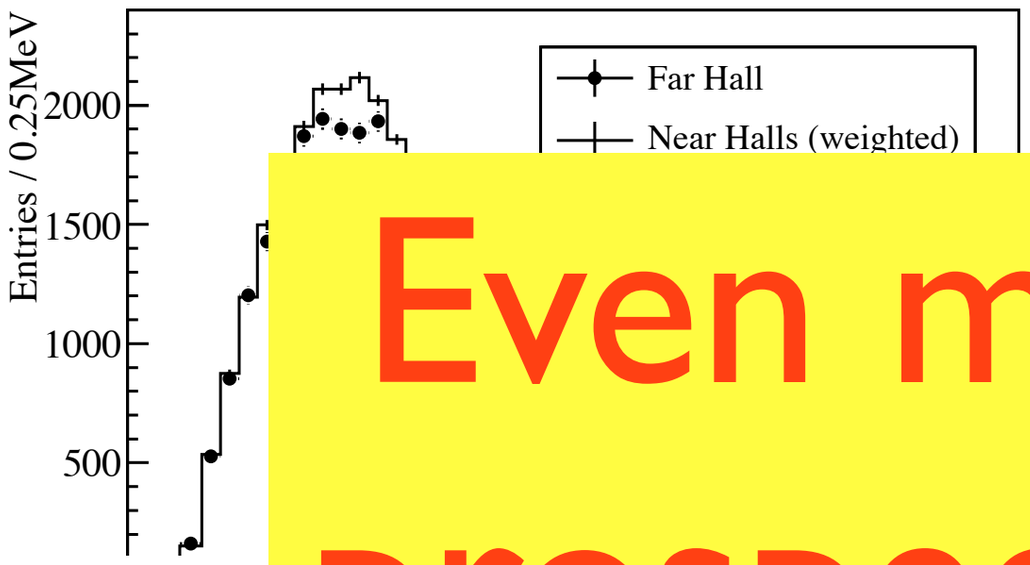


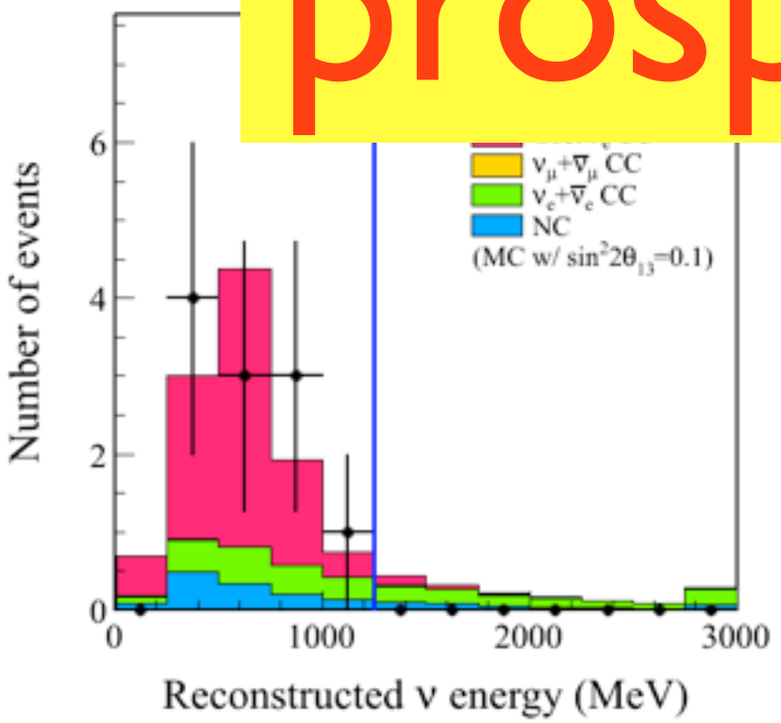


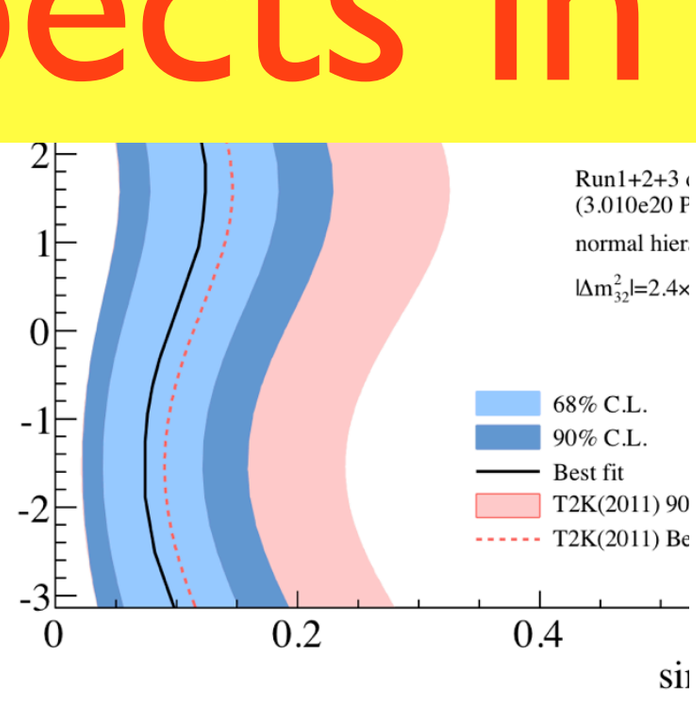


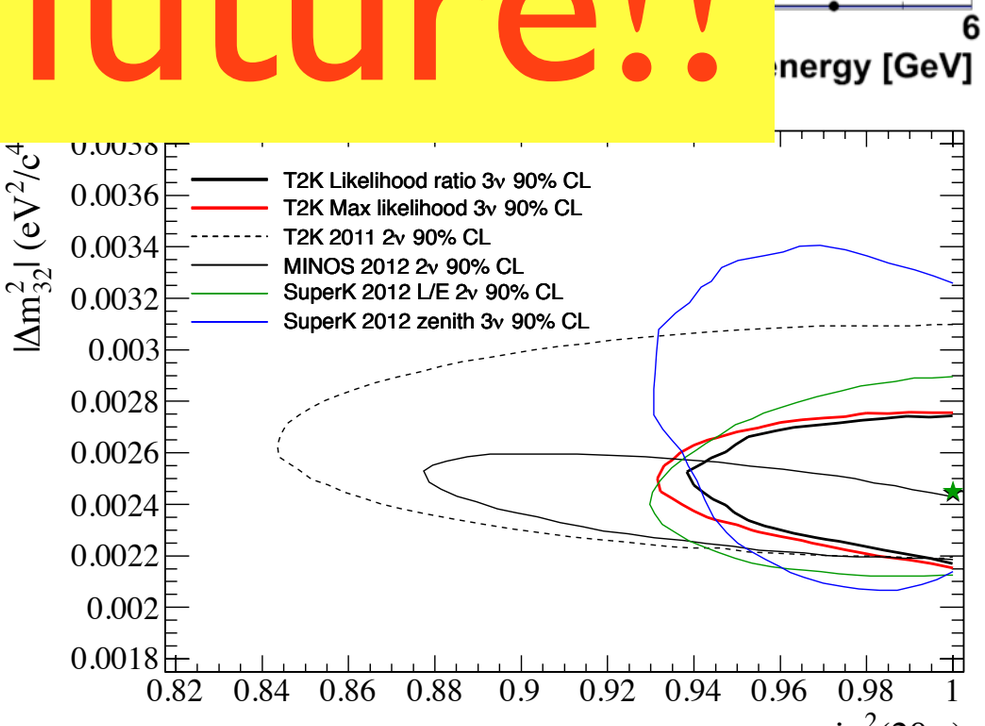




Even more exciting prospects in future!!



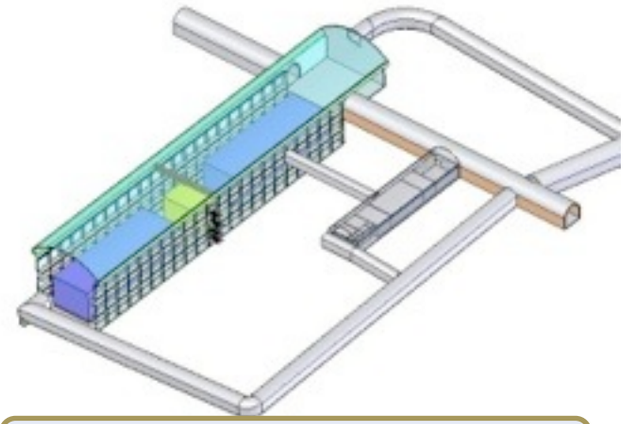





India
Information from Naba Mondal
Монгол Улс
Улан-Батор
Ulaanbaatar
Бишкек
Bishkek
Алматы
Almaty
Кыргызстан
北京
북한
Sea of Japan
日本
서울
대한민국
札幌
青森
秋田
盛岡
新潟
仙台
金沢
長野
福島
東京
名古屋
광주
부산
岡山
大阪
静岡
広島
福岡
熊本
鹿児島
上海
East China Sea
那覇
Lahore
New Delhi
Jaipur
Lucknow
नेपाल
Bhutan
India
Kolkata
Mumbai
Pune
Hyderabad
Chennai
Bay of Bengal
Sri Lanka
Laccadive Sea
Myanmar (Burma)
Yangon
Hà Nội
Lao
ประเทศไทย
กรุงเทพมหานคร
Việt Nam
ភ្នំពេញ
Phnom Penh
thành phố Hồ Chí Minh
Andaman Sea
Malaysia
South China Sea
Hong Kong
澳門
Luzon
Manila
Catanduanes Island
Pilipinas
Panay
Palawan
Negros
Leyte Island
Sulu Sea
Mindanao
Basilan Island
Celebes

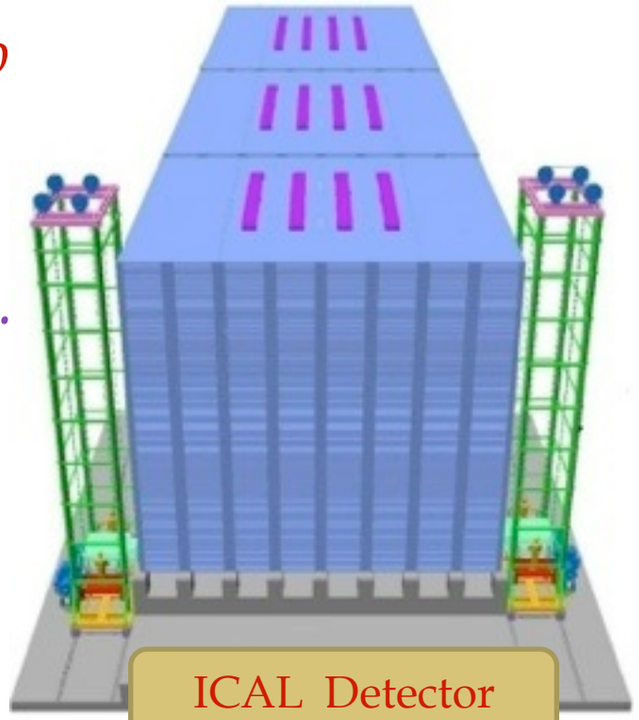
India-based Neutrino Observatory (INO)

- *An underground laboratory with ~1.2 km all-round rock cover accessed through a 1.9 km long tunnel. A large and several smaller caverns to facilitate many experimental programmes*
- ***Frontline neutrino issues e.g., mass parameters and other properties, will be explored in a manner complementary to ongoing efforts worldwide.***
- ***The detector will be a magnetised iron calorimeter (ICAL) with magnetised iron plates interleaved with RPC detectors. Total weight will be 50 kton.***



INO Underground Lab (conceptual)

- *ICAL detector, with its charge identification ability, will be able to address questions about the neutrino mixing parameter space specially the issue of* ***neutrino mass hierarchy.***
- *Will support several experiments in Physics, Biology, Geology etc. when operational. Neutrino-less Double Beta Decay and Dark Matter Search experiments foreseen in the immediate future.*
- *Welcome international participation.*



ICAL Detector (conceptual)

Current status

- Full size RPCs (2m X 2m) are now being fabricated not only in the lab but also by the Industry. Ready for large scale production. Construction of an Engineering module will start soon.
- Development & fabrication of various electronic modules for the INO-ICAL detector are advancing well.
- Two prototype detectors- one at TIFR and the 2nd one at VECC are running.
- Detailed Project Reports (DPR) for site infrastructure as well as for the magnet structure are ready.
- Obtained forest as well as environmental clearances for the INO project. Civil construction will start soon.
- TN govt. has handed over 66 acres of land to DAE for the construction of INO facilities at site. Additional 33 acres of land acquired at Madurai for the INO centre.
- INO graduate training program with strong emphasis on hands on training for detector development is running for the last three years.
- INO-ICAL will have an important role specially due to the large value of θ_{13} announced recently.

Prototype ICAL at VECC

2mX2m RPC Test Stand at TIFR

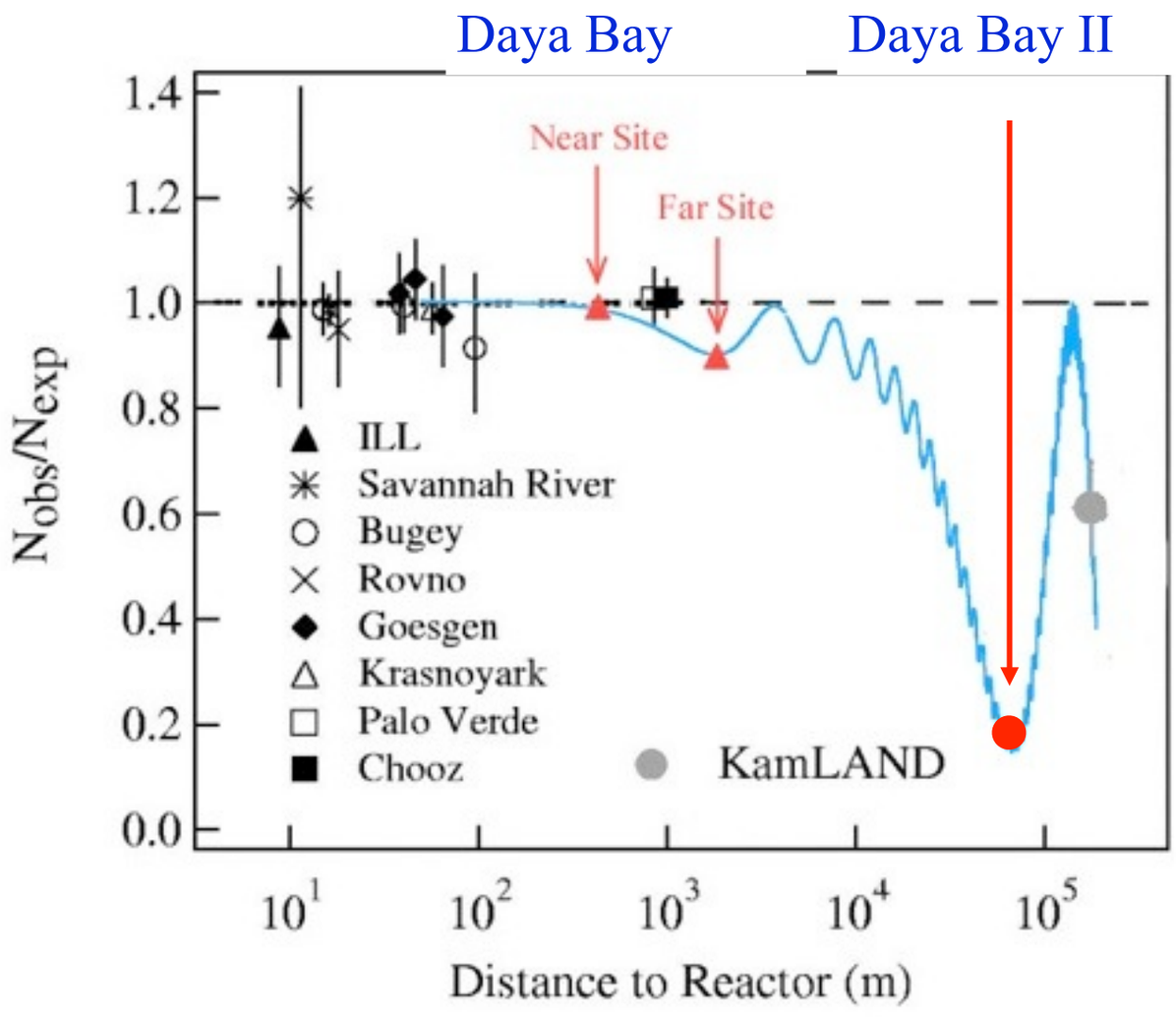
China

Information from Jun Cao

Daya Bay-II Experiment

DYB-II has been approved in China in Feb. 2013

Equivalent to CD1 of US DOE

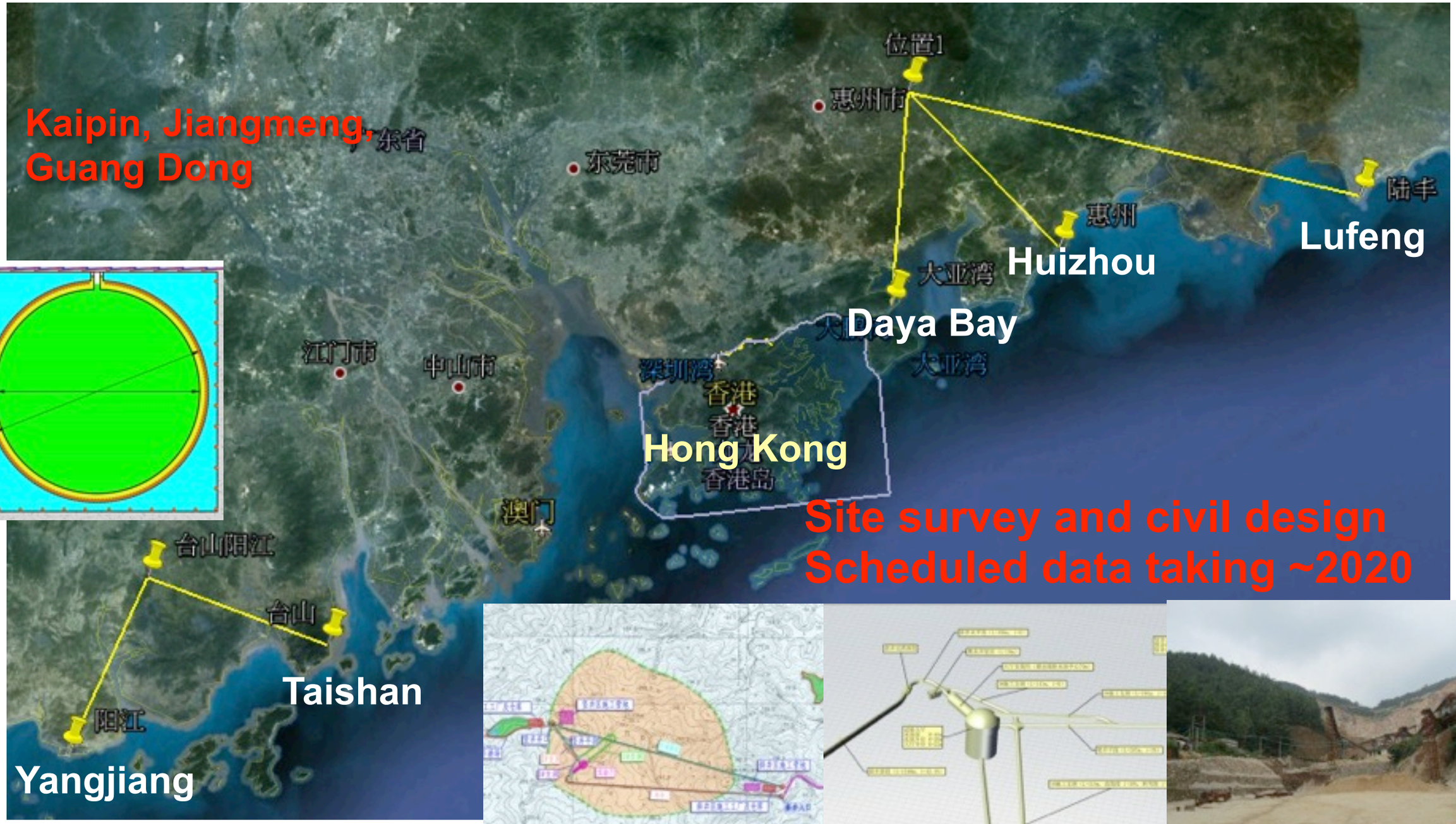


- 20 kton LS detector
- 3%/$\sqrt{E}$ resolution
- Rich physics
  - ⇨ Mass hierarchy
  - ⇨ Precision measurement of 4 oscillation parameters to <1%
  - ⇨ Supernovae neutrino
  - ⇨ Geoneutrino
  - ⇨ Sterile neutrino
  - ⇨ Atmospheric neutrinos
  - ⇨ Exotic searches

Talk by Y.F. Wang at ICFA seminar 2008...NuFact 2012; by J. Cao at Nutel 2009...NPB 2012 (ShenZhen);
Paper by L. Zhan, Y.F. Wang, J. Cao, L.J. Wen, PRD78:111103,2008; PRD79:073007,2009

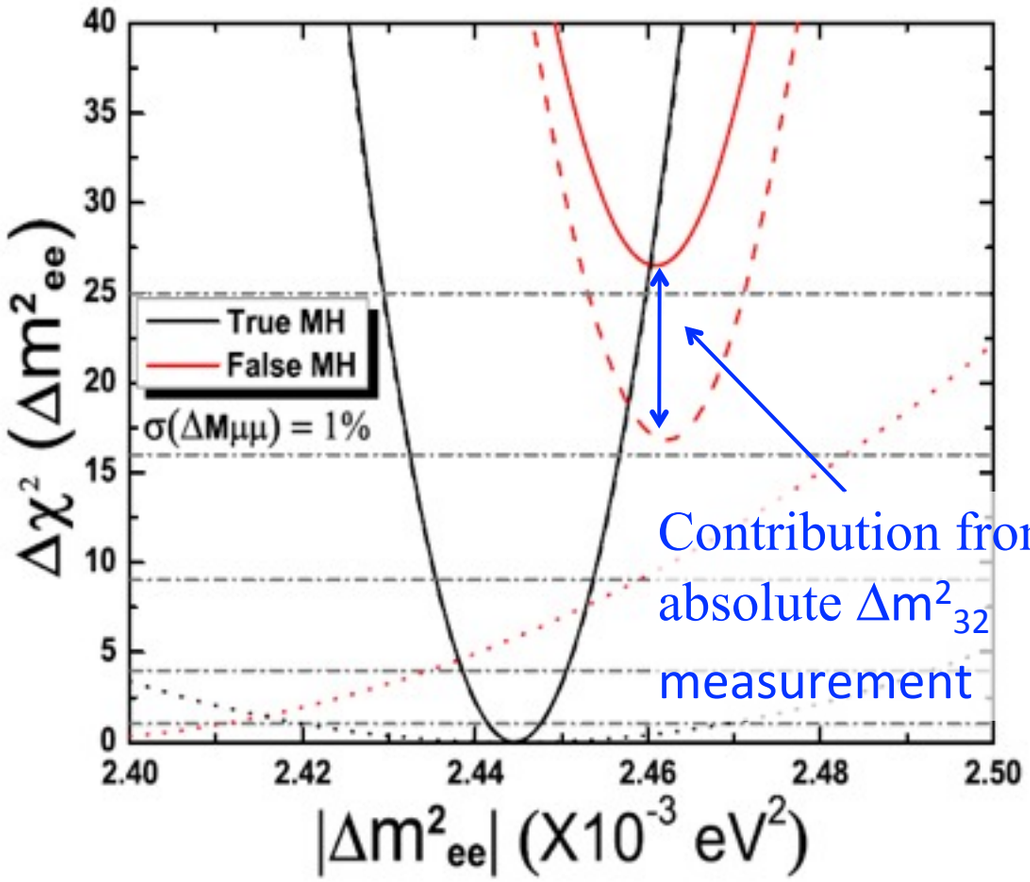
The reactors and possible sites

	Daya Bay	Huizhou	Lufeng	Yangjiang	Taishan
Status	Operational	Planned	Planned	Under construction	Under construction
Power	17.4 GW	17.4 GW	17.4 GW	17.4 GW	18.4 GW



Projected Sensitivity

Taking into account Δm^2_{32} from T2K and Nova in the future：



	Current	DYB II
Δm^2_{12}	3%	0.6%
Δm^2_{23}	5%	0.6%
$\sin^2\theta_{12}$	6%	0.7%
$\sin^2\theta_{23}$	20%	N/A
$\sin^2\theta_{13}$	14%➔ 4%	~ 15%

If Δm^2_{32} at 1% precision， mass hierarchy could be determined to ~5σ in 6 years. (core distribution and energy non-linearity may degrade it a little.

Will be more precise than CKM matrix elements !

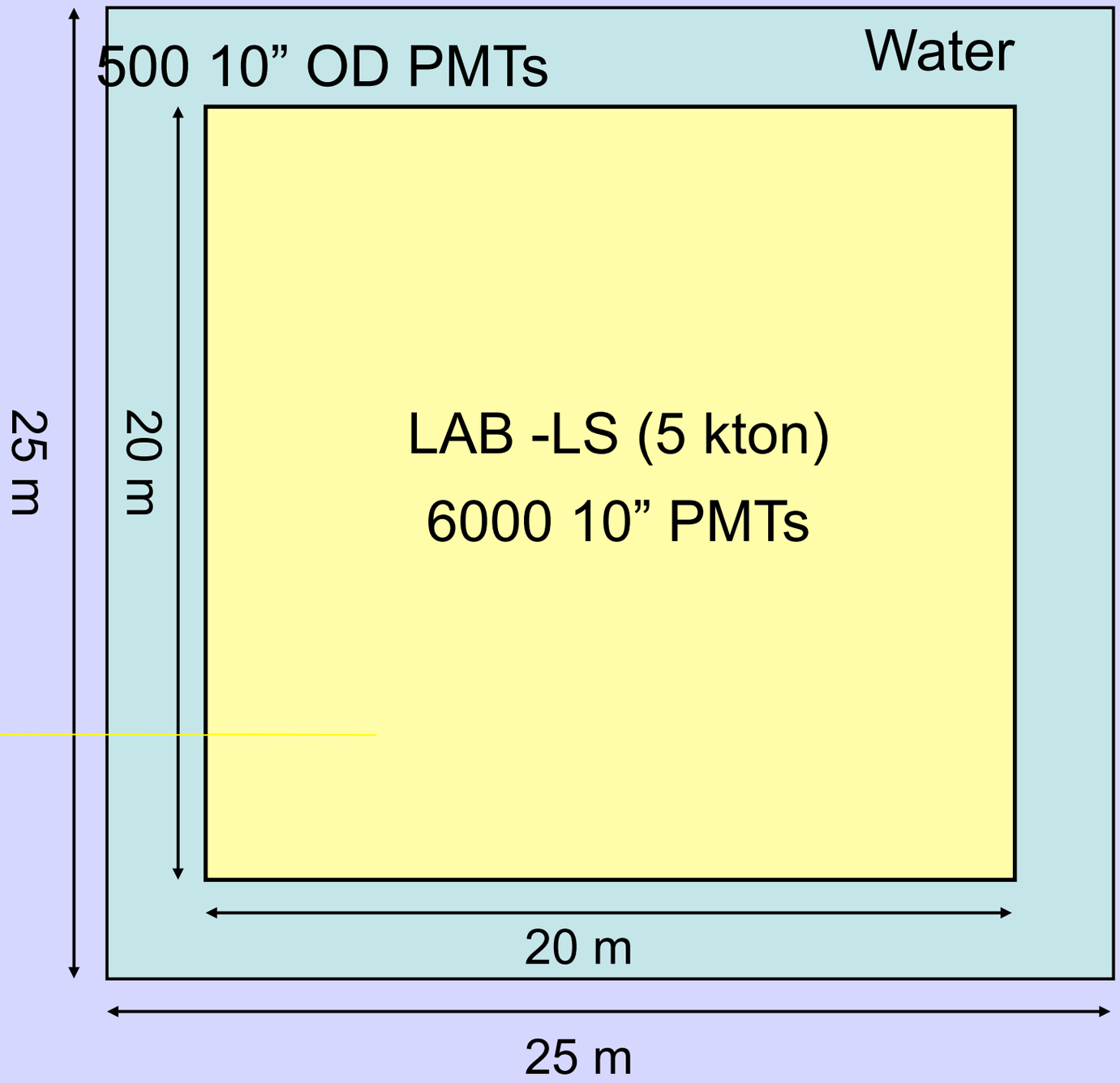
Probing the unitarity of UPMNS to ~1% level

Korea

Information from Soo-Bong Kim

RENO-50 (2018~)

- **Large θ_{12} neutrino oscillation effects at 50 km + 5kton liquid scintillator detector**
- **RENO can be used as near detectors. → Precise (~0.3%) reactor neutrino fluxes**
- **Dedicated to YG → negligible contribution from other nuclear power plants.**



- **Possible sites :**
  - Mt. Byungpoong (822 m, 43.9 km)
  - Mt. Choowol (729 m, 51.9 km)

International WS on RENO-50 in June
http://home.kias.re.kr/MKG/h/reno50/

Physics with RENO-50

- Precise measurement of θ_{12} and Δm^2_{21}

$$\frac{\delta \sin^2\theta_{12}}{\sin^2\theta_{12}} \sim 1.0\%(1\sigma) \text{ in a year} \quad (\leftarrow 5.4\%)$$

$$\frac{\delta \Delta m^2_{21}}{\Delta m^2_{21}} \sim 1.0\%(1\sigma) \text{ in 2~3 years} \quad (\leftarrow 2.6\%)$$

- Determination of mass hierarchy (sign of Δm^2_{31} or Δm^2_{32})

  - Challenging : good (2~3%) energy resolution & large (> 30 kton) detector
  - Add a 1000 ton detector at ~10 km (L : 300 m + 1.4 km + 10 km + 50 km)

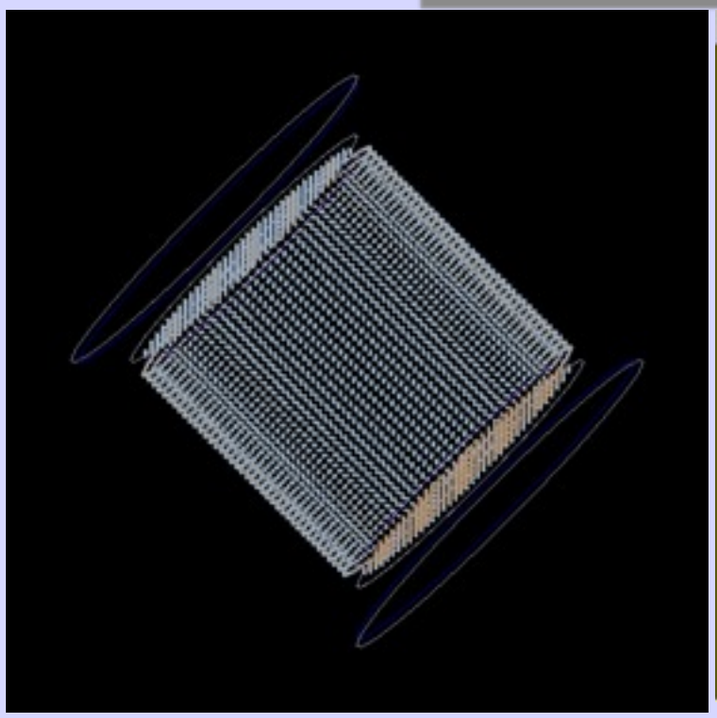
- Neutrino burst from a galactic supernova : ~1500 events @8 kpc
- Geo-neutrinos : ~ 300 geo-neutrinos for 5 years
- Solar neutrinos : with ultra low radioacitivity like Borexino
- Reactor physics : non-proliferation
- Detection of J-PARC beam (4MW) : ~100 events/year
- Search for neutrinoless double beta decay

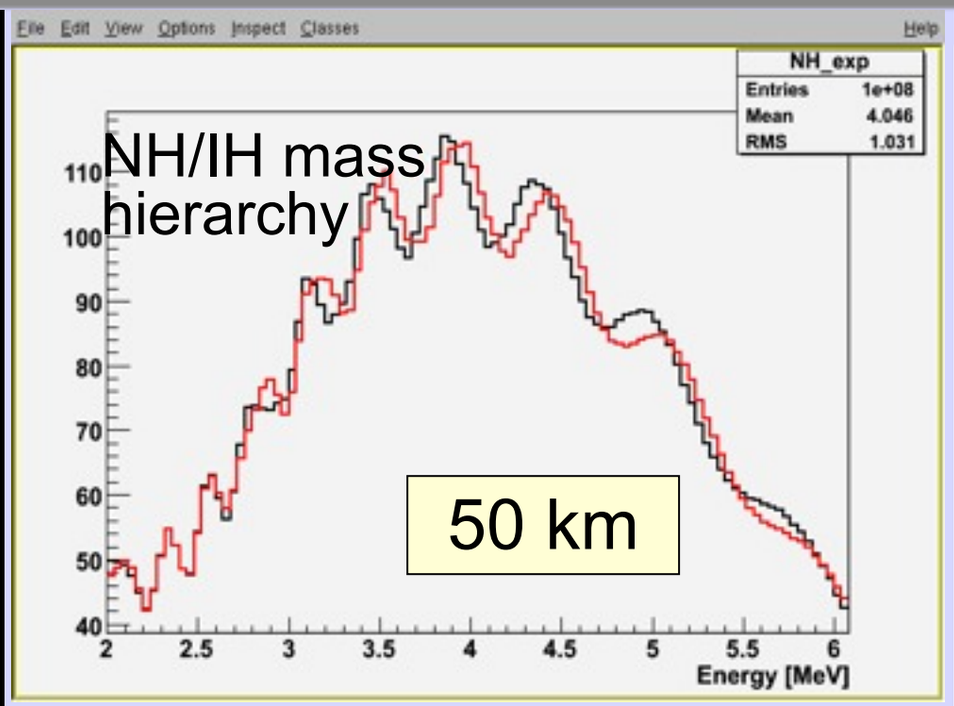
RENO-50 vs. KamLAND

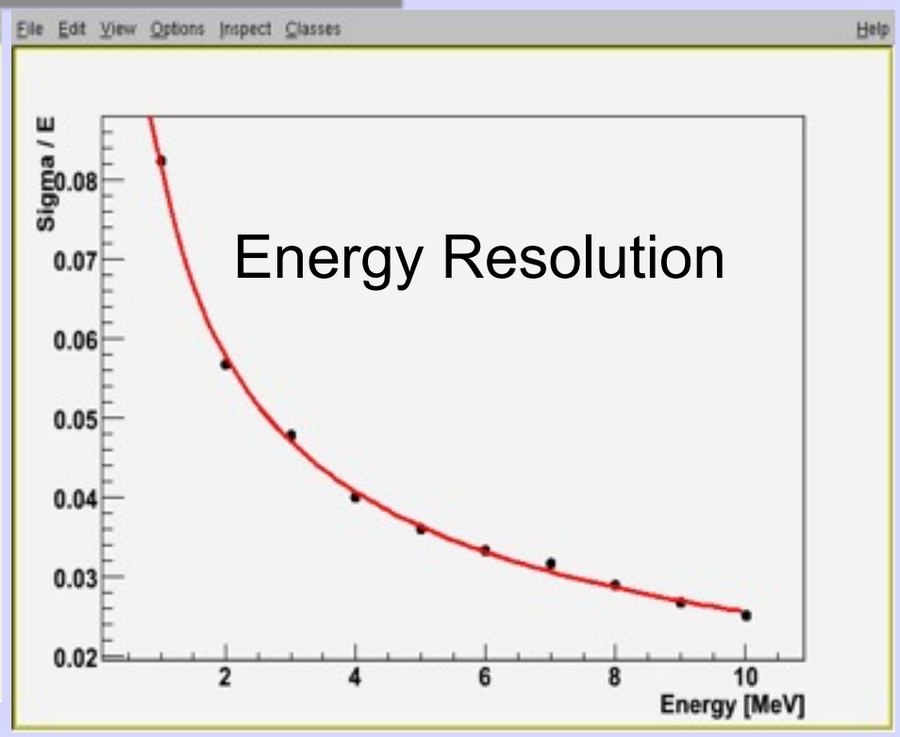
	Oscillation Reduction	Reactor Neutrino Flux	Detector Size	Syst. Error on ν Flux	Error on $\sin^2\theta_{12}$
RENO-50 (50 km)	80%	$13\times6\times\varphi_0$ [6 reactors]	5 kton	~ 0.3%	~1%
KamLAND (180 km)	40%	$53\times\varphi_0$ [53 reactors]	1 kton	3%	5.4%
Figure of Merit	×2	×1.5	×5	×10	

$(50\ \text{km} / 180\ \text{km})^2 \approx 13$

MC Simulation for RENO-50

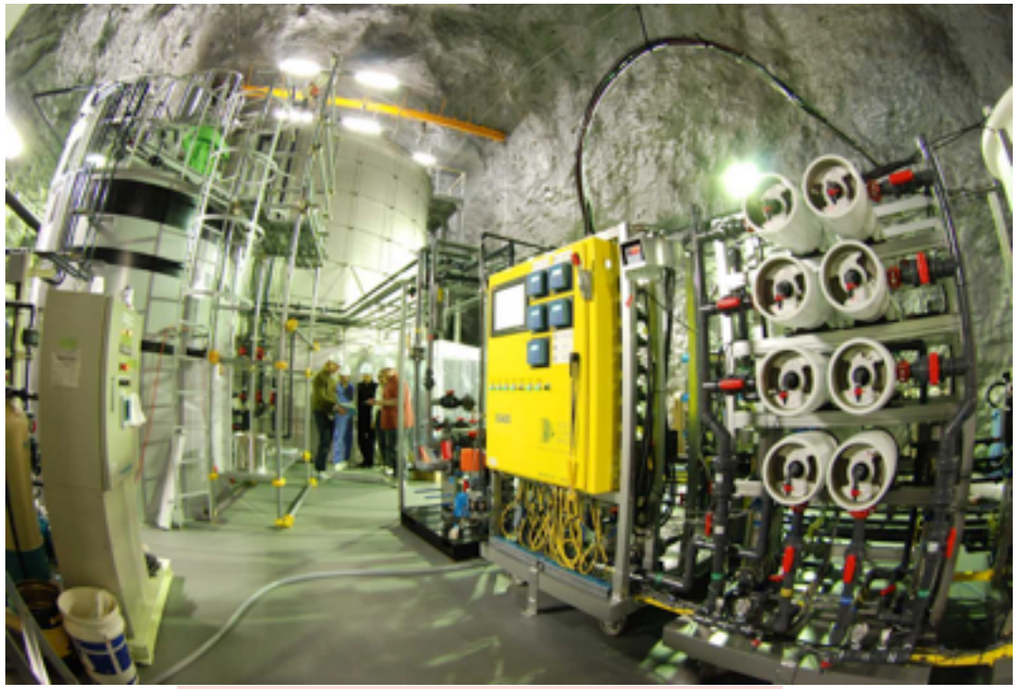




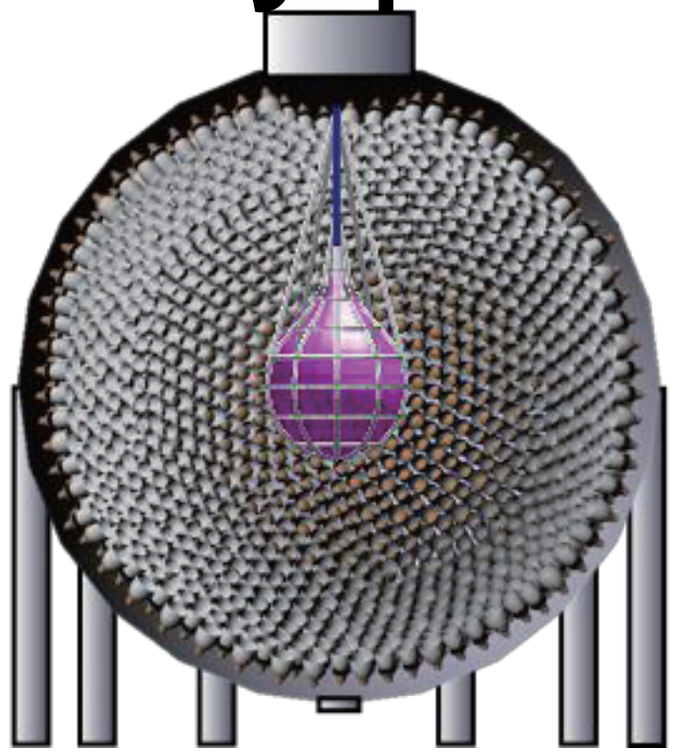



Улан-Батор
Ulaanbaatar
Монгол Улс
Бишкек
Bishkek
Алматы
Almaty
Кыргызстан
北京
북한
서울
대한민국
광주
부산
札幌
青森
秋田
盛岡
日本
新潟
仙台
金沢
長野
福島
東京
名古屋
静岡
熊本
鹿児島
East China Sea
那覇
Sea of Japan
Japan
Lahore
New Delhi
Jaipur
Lucknow
नेपाल
Bhutan
বাংলাদেশ
India
Kolkata
Myanmar (Burma)
Hà Nội
Lao
Yangon
ประเทศไทย
กรุงเทพมหานคร
Việt Nam
កម្ពុជា
ភ្នំពេញ
Phnom Penh
thành phố Hồ Chí Minh
Mumbai
Pune
Hyderabad
Chennai
Bangalore
Bay of Bengal
Andaman Sea
Sri Lanka
Laccadive Sea
Malaysia
South China Sea
台灣
香港
Hong Kong
澳門
Luzon
Manila
Catanduanes Island
Pilipinas
Panay
Palawan
Negros
Leyte Island
Sulu Sea
Mindanao
Basilan Island
Celebes

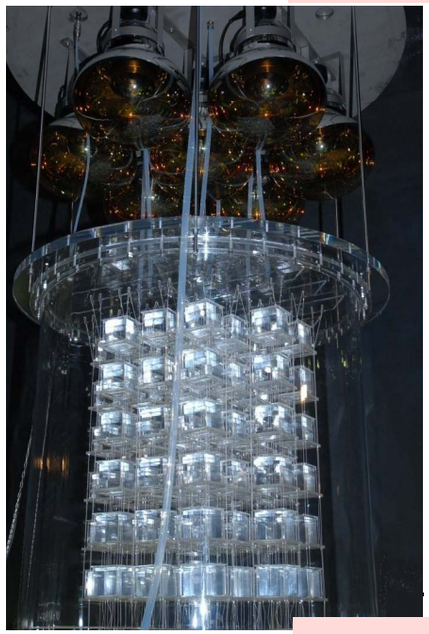
Future projects in Japan



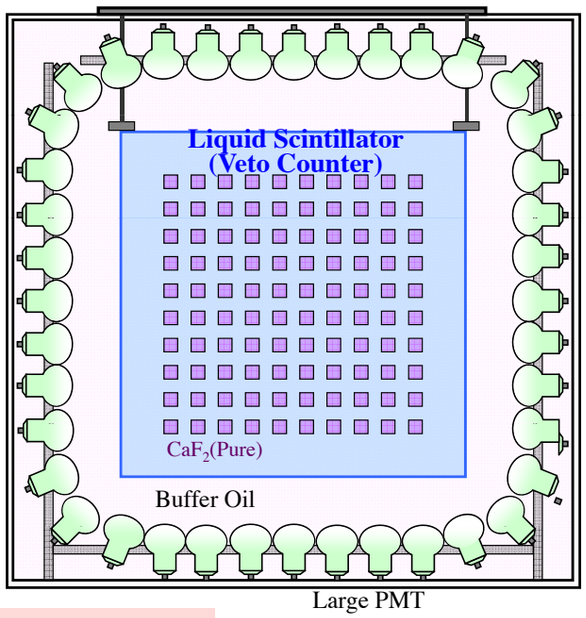
GADZOOKS!

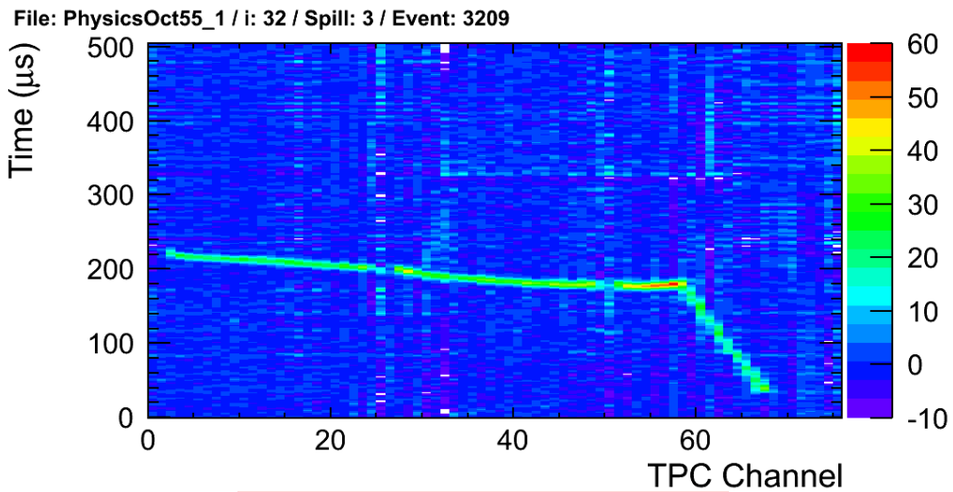


KamLAND2(-Zen)



CANDLES



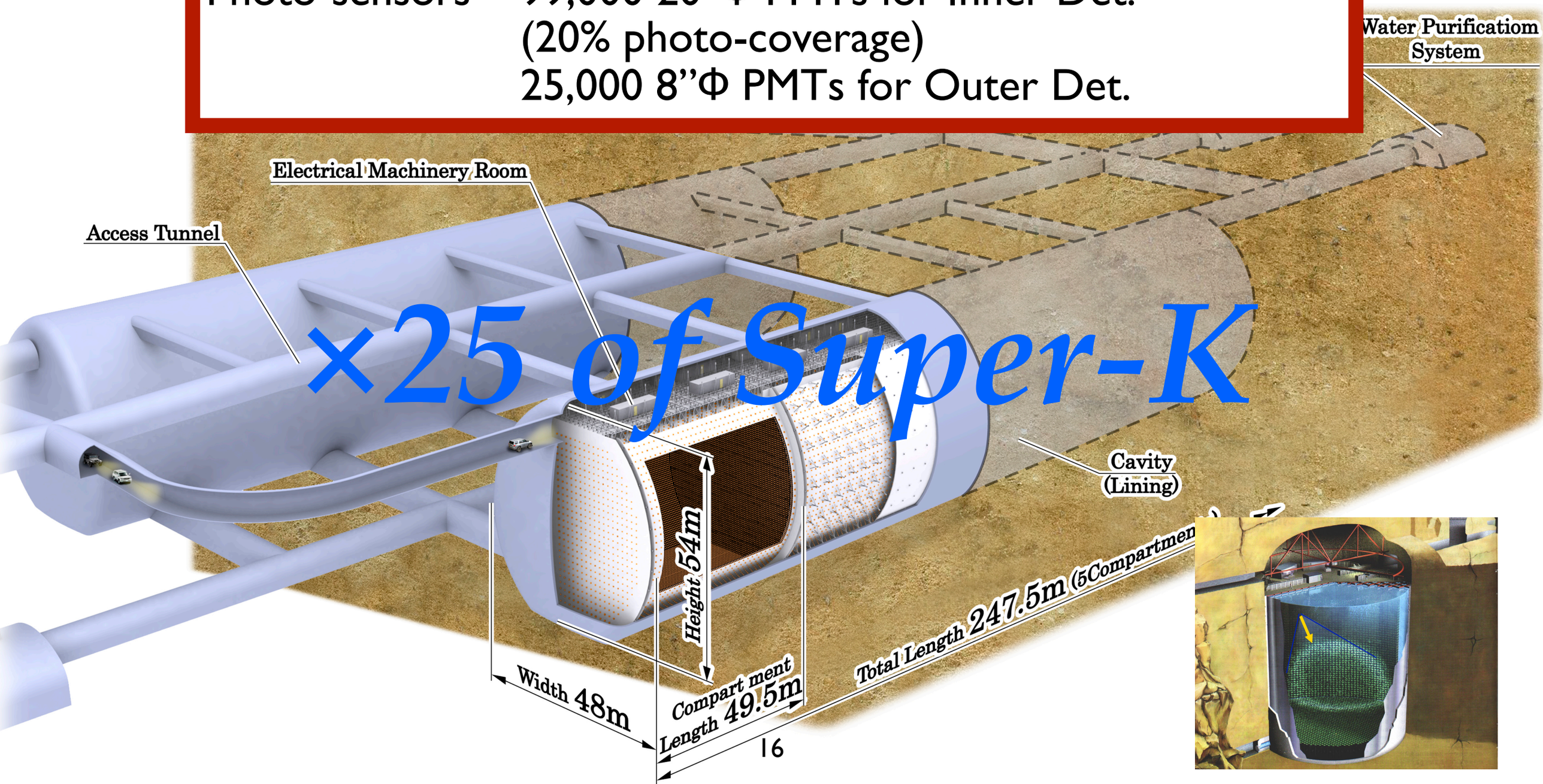


LAr-TPC R&D

+ Continued running of Super-K, T2K(incl. anti-ν run), ..

Hyper-Kamiokande

Total Volume	0.99 Megaton
Inner Volume	0.74 Mton
Fiducial Volume	0.56 Mton (0.056 Mton × 10 compartments)
Outer Volume	0.2 Megaton
Photo-sensors	99,000 20”Φ PMTs for Inner Det. (20% photo-coverage) 25,000 8”Φ PMTs for Outer Det.



Letter of Intent:

The Hyper-Kamiokande Experiment

— Detector Design and Physics Potential —

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A. K. Ichikawa,[4] M. Ikeda,[4] K. Inoue,[8,14] H. Ishino,[7] Y. Itow,[6] T. Kajita,[13,14] J. Kameda,[12,14]
Y. Kishimoto,[12,14] M. Koga,[8,14] Y. Koshio,[12,14] K. P. Lee,[13] A. Minamino,[4] M. Miura,[12,14]
S. Moriyama,[12,14] M. Nakahata,[12,14] K. Nakamura,[2,14] T. Nakaya,[4,14] S. Nakayama,[12,14]
K. Nishijima,[9] Y. Nishimura,[12] Y. Obayashi,[12,14] K. Okumura,[13] M. Sakuda,[7] H. Sekiya,[12,14]
M. Shiozawa,[12,14,*] A. T. Suzuki,[3] Y. Suzuki,[12,14] A. Takeda,[12,14] Y. Takeuchi,[3,14]
H. K. M. Tanaka,[11] S. Tasaka,[1] T. Tomura,[12] M. R. Vagins,[14] J. Wang,[10] and M. Yokoyama[10,14]

(Hyper-Kamiokande working group)

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[2] *High Energy Accelerator Research Organization (KEK), Tsukuba, Ibaraki, Japan*

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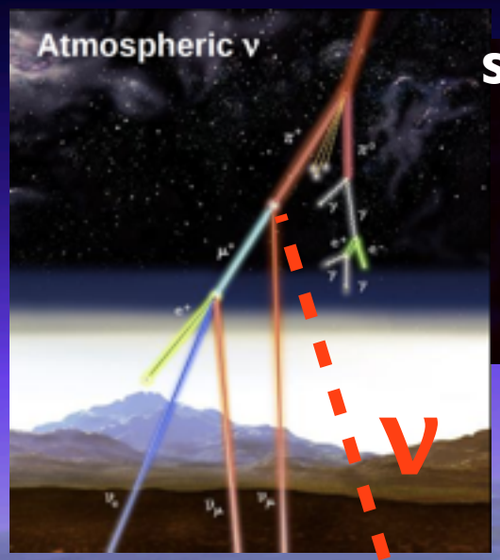
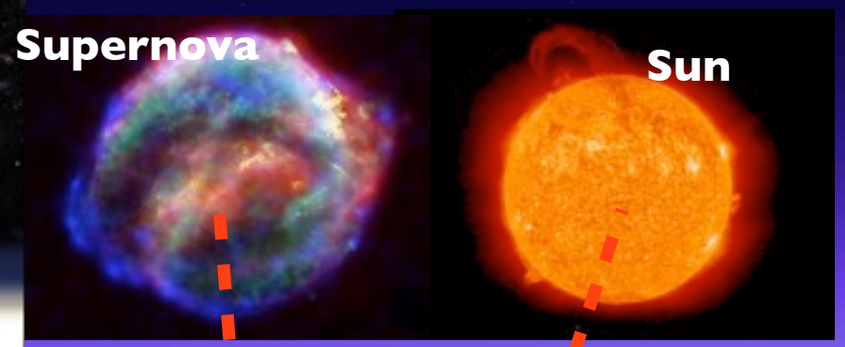
[4] *Kyoto University, Department of Physics, Kyoto, Kyoto 606-8502, Japan*

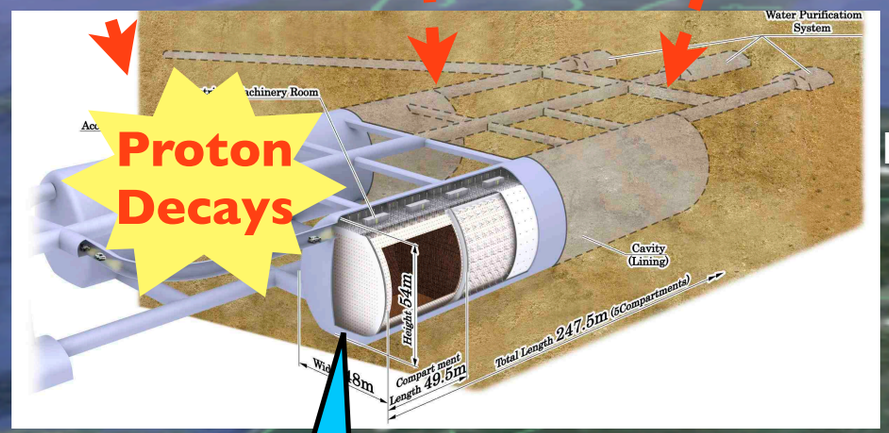
[5] *Miyagi University of Education, Department of Physics, Sendai, Miyagi 980-0845, Japan*

Multi-purpose detector Hyper-Kamiokande





ν ν ν



Hyper-K

Super-K

ν

J-PARC

x25 Larger ν Target
& Proton Decay Source

higher intensity ν by upgraded J-PARC

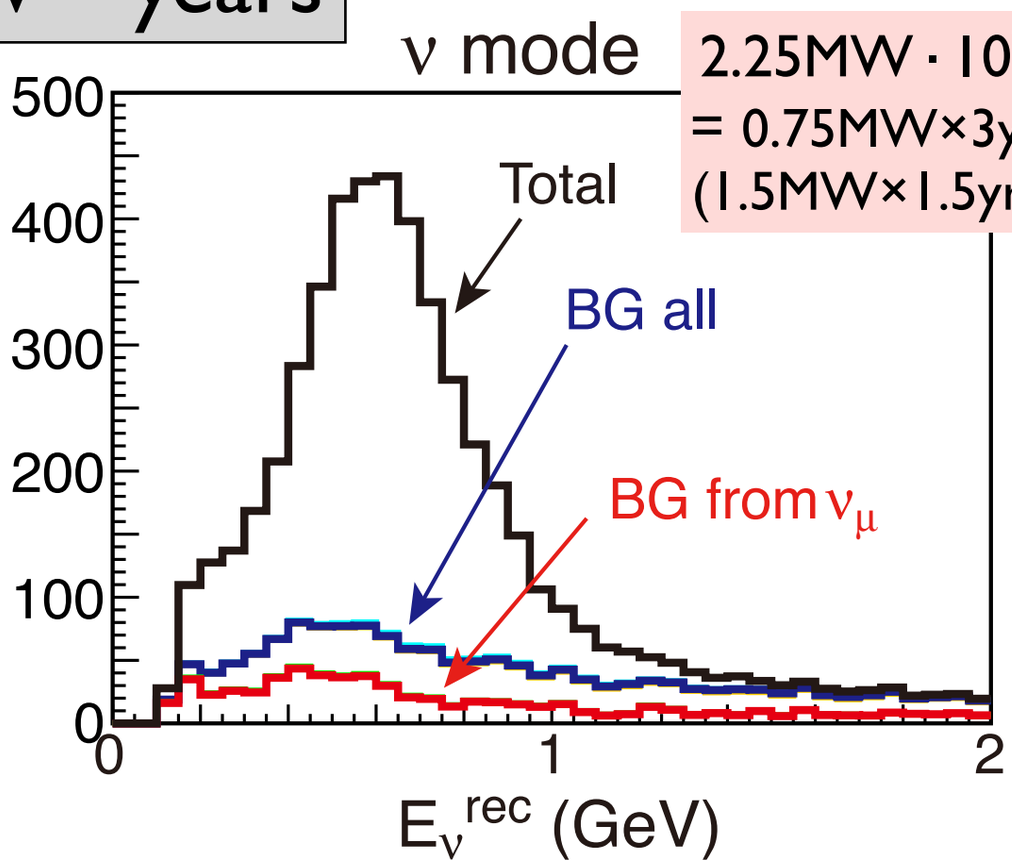
x2 (year or power)

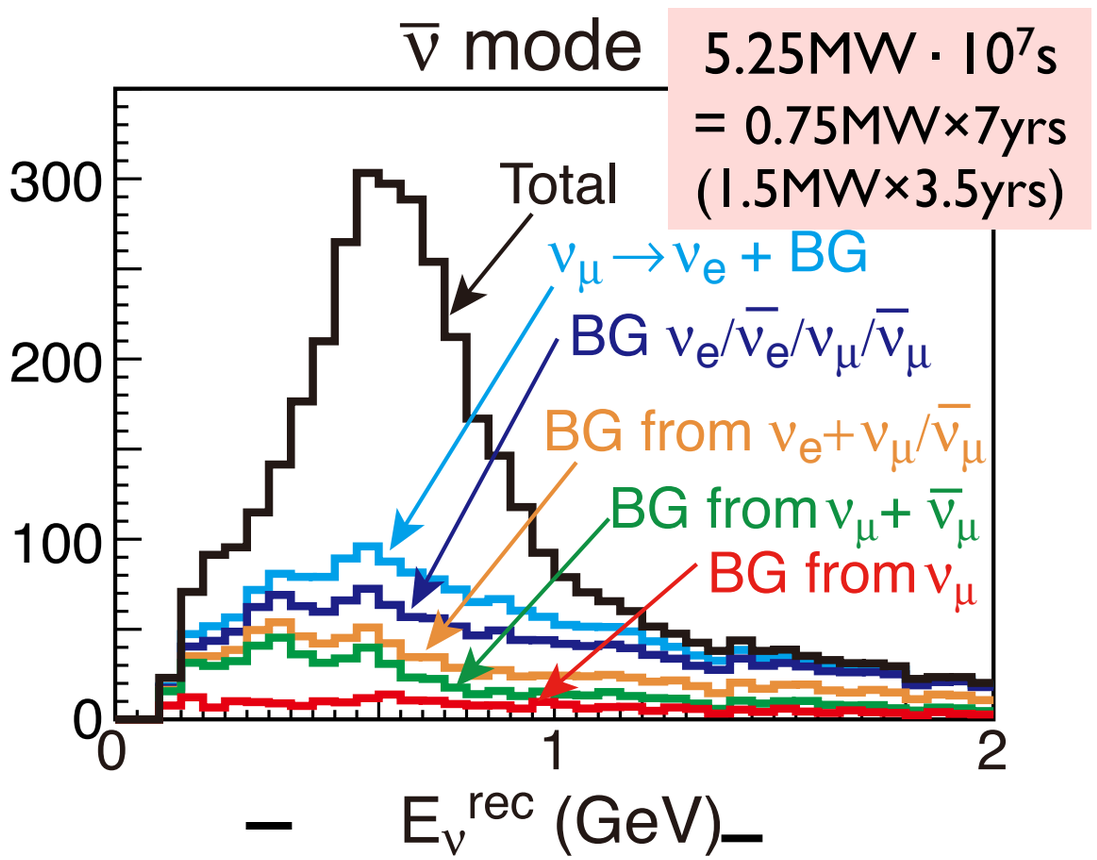
x50 of T2K for νCP

J-PARC to Hyper-K LBL experiment: ν_e candidate reconstructed energy distributions

7.5MW · years

$\sin^2 2\theta_{13}$=0.1,δ=0, normal MH





	Signal ($\nu_\mu \to \nu_e$ CC)	Wrong sign appearance	ν_μ/ν_μ CC	beam ν_e/ν_e contamination	NC
ν (2.25MW · 10^7s)	3,560	46	35	880	649
ν̄ (5.25MW · 10^7s)	1,959	380	23	878	678

2000-4000 signal events for each of ν and ν̄

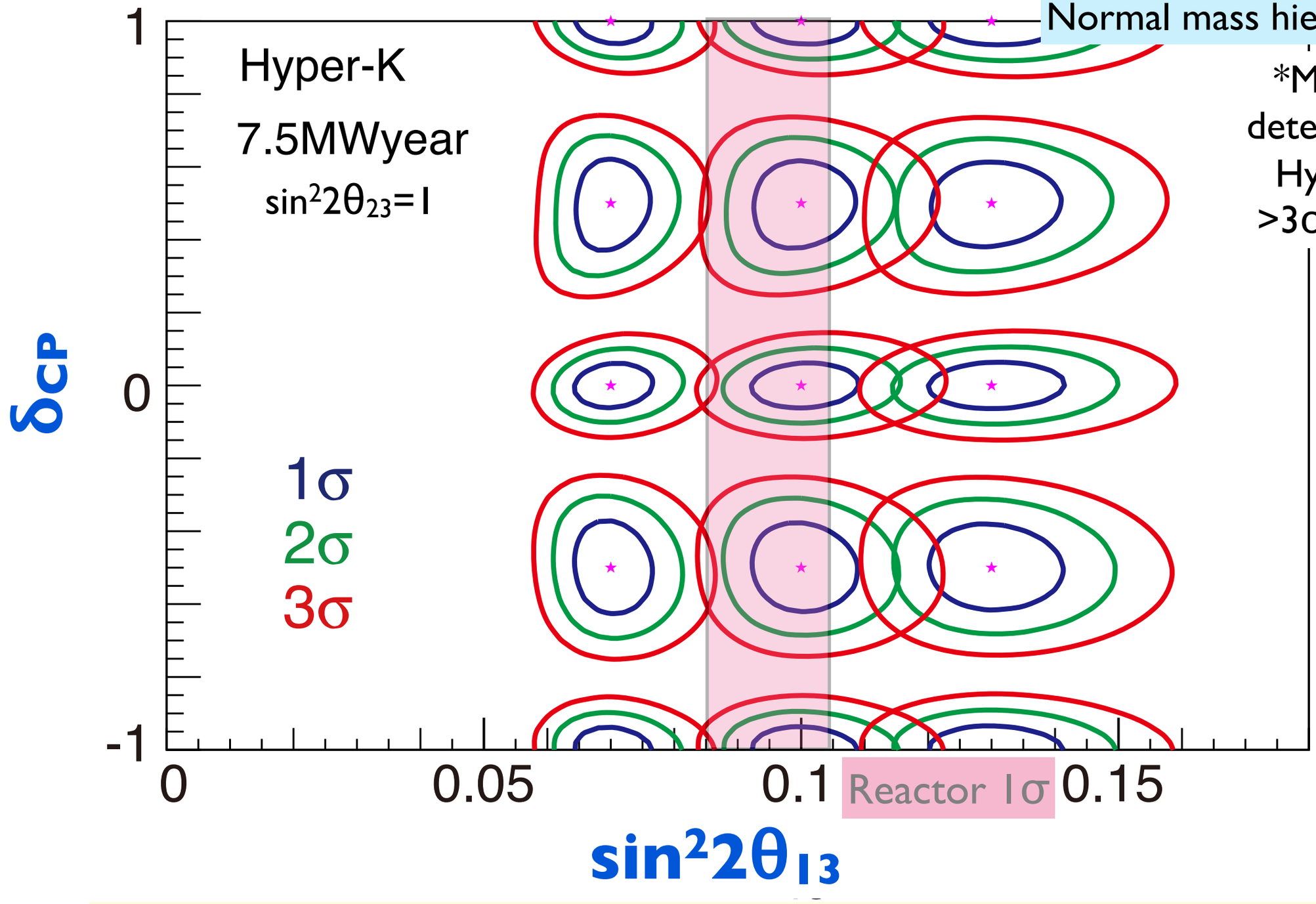
acc. ν

Expected sensitivity to CP asymmetry

7.5MW・years

5% systematics on signal, ν_μ BG, ν_e BG, $\nu/\bar{\nu}$

Normal mass hierarchy (known*)



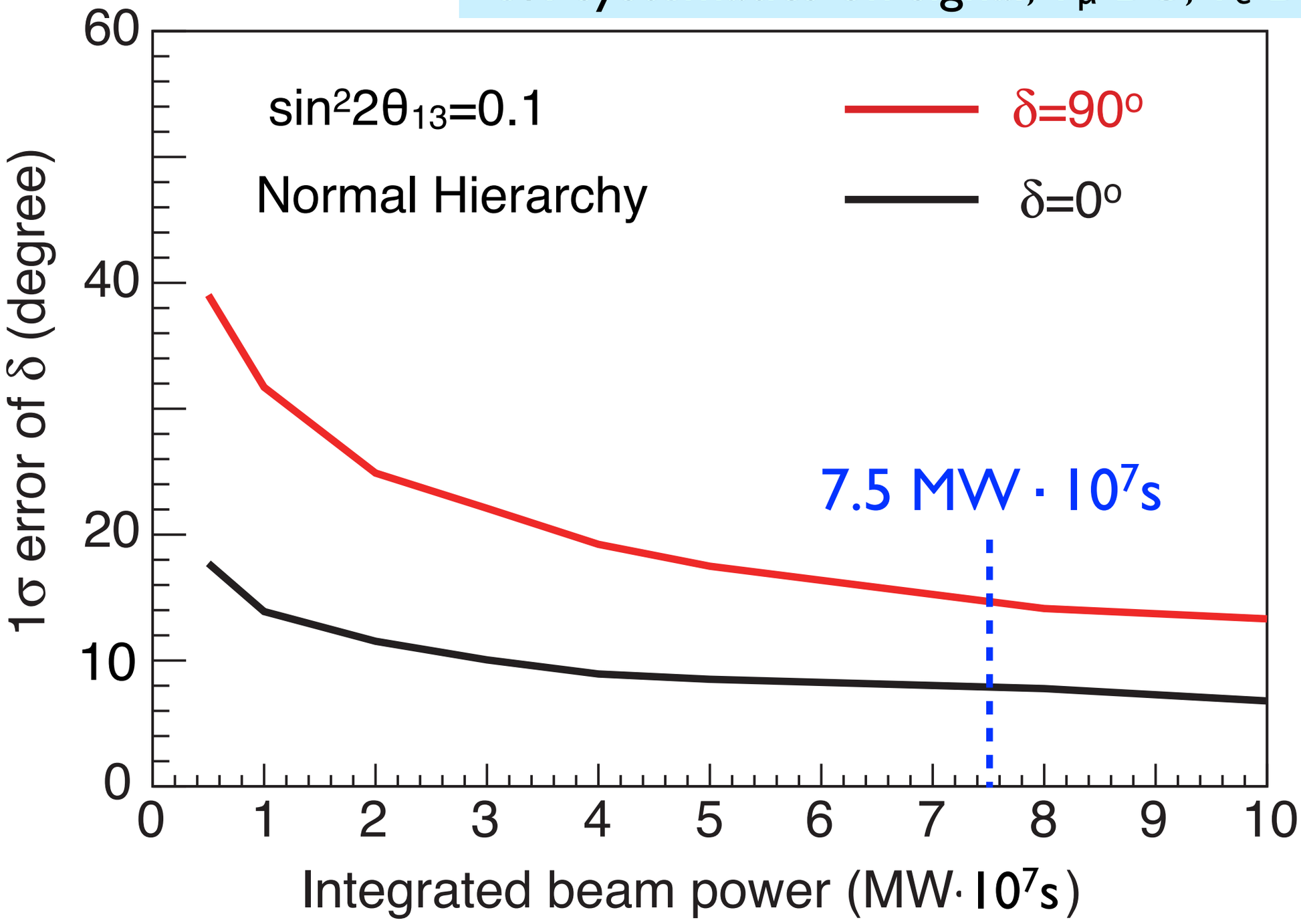
*Mass hierarchy determination with Hyper-K atm. ν: >3σ in 5-10 years

Good sensitivity for currently allowed values

Expected uncertainty of δ (1σ)

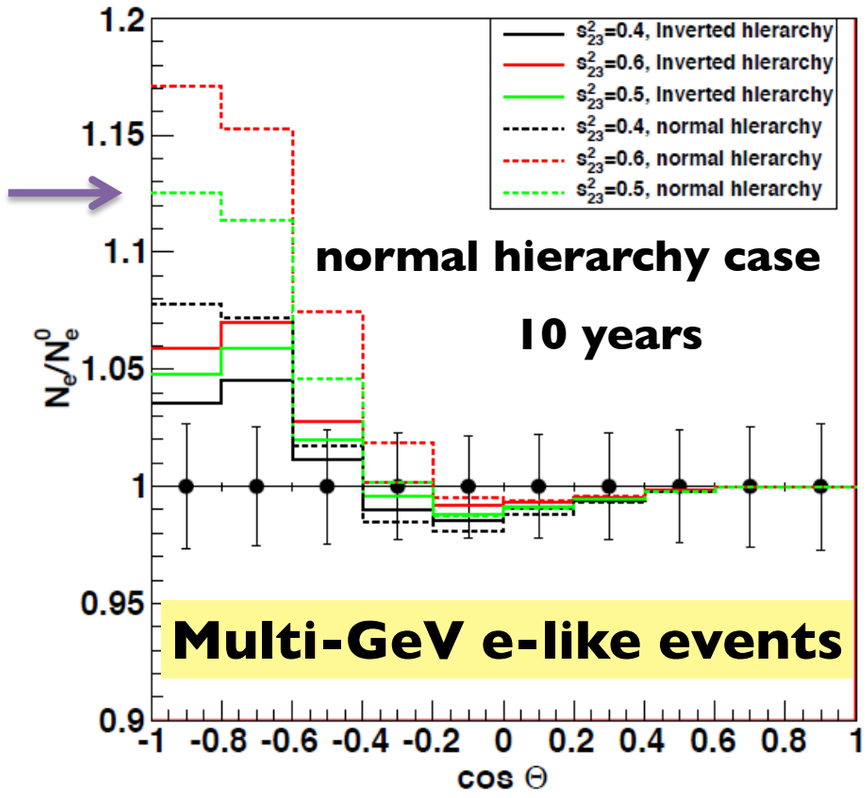
acc. ν

5% systematics on signal, ν_μ BG, ν_e BG, $\nu/\overline{\nu}$

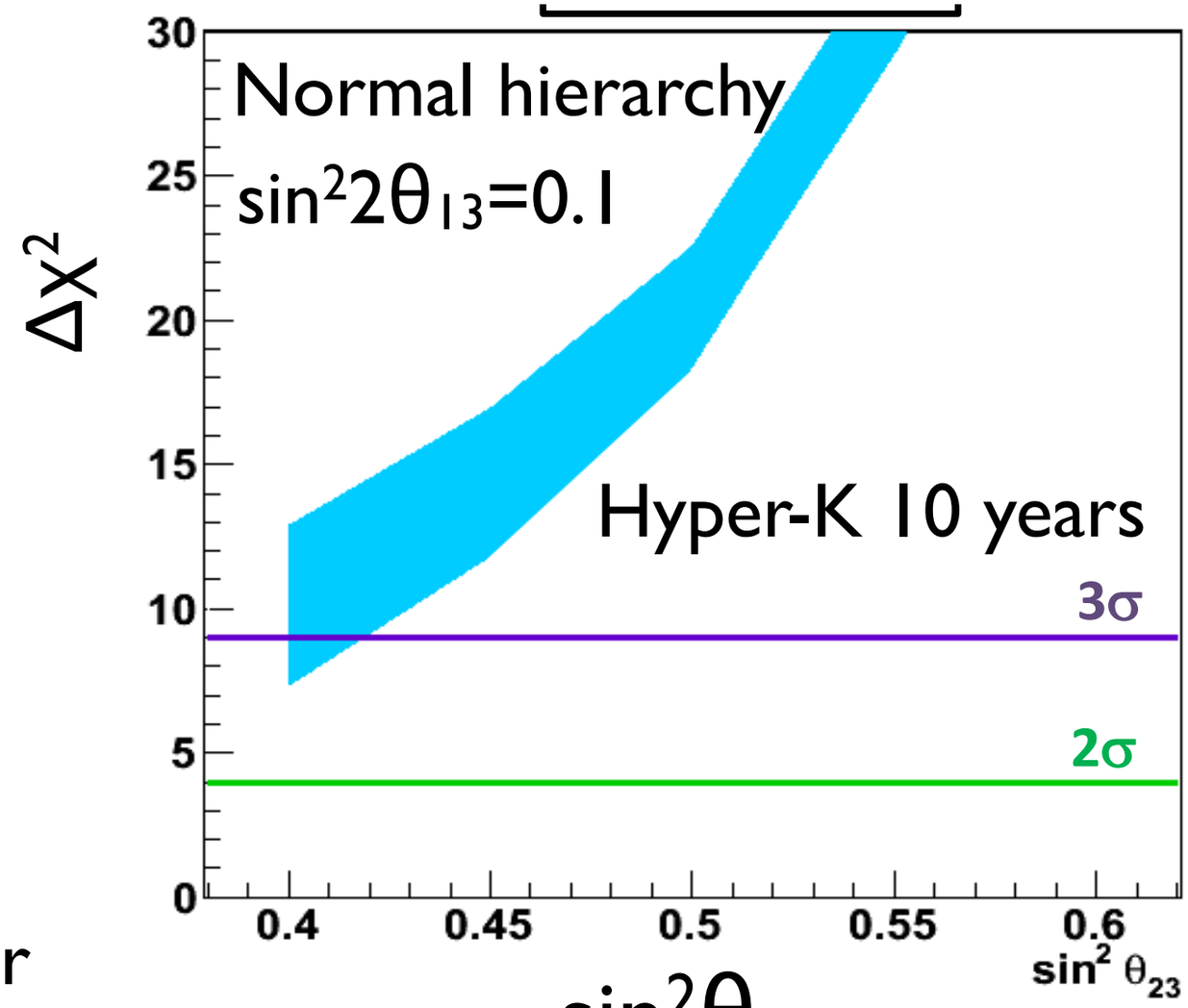


<20° (δ=90°), <10° (δ=0°)

Mass hierarchy determination with atmospheric neutrinos



MSW effect in Earth's core
→ resonance effect on either
ν or anti-ν



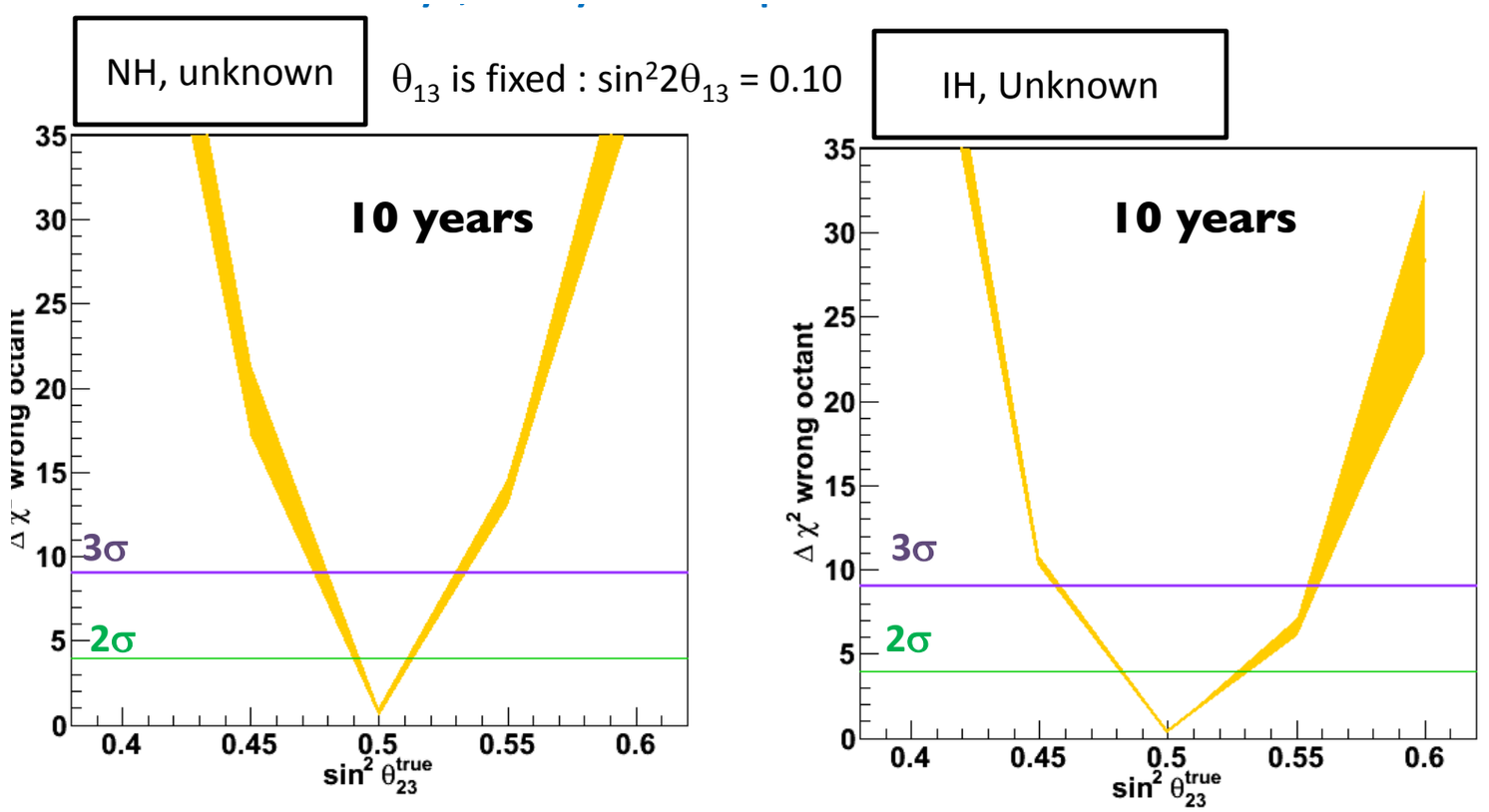
$\sin^2\theta_{23}$

3σ determination with <10 year observation
(better sensitivity depending on the value of θ_{23})

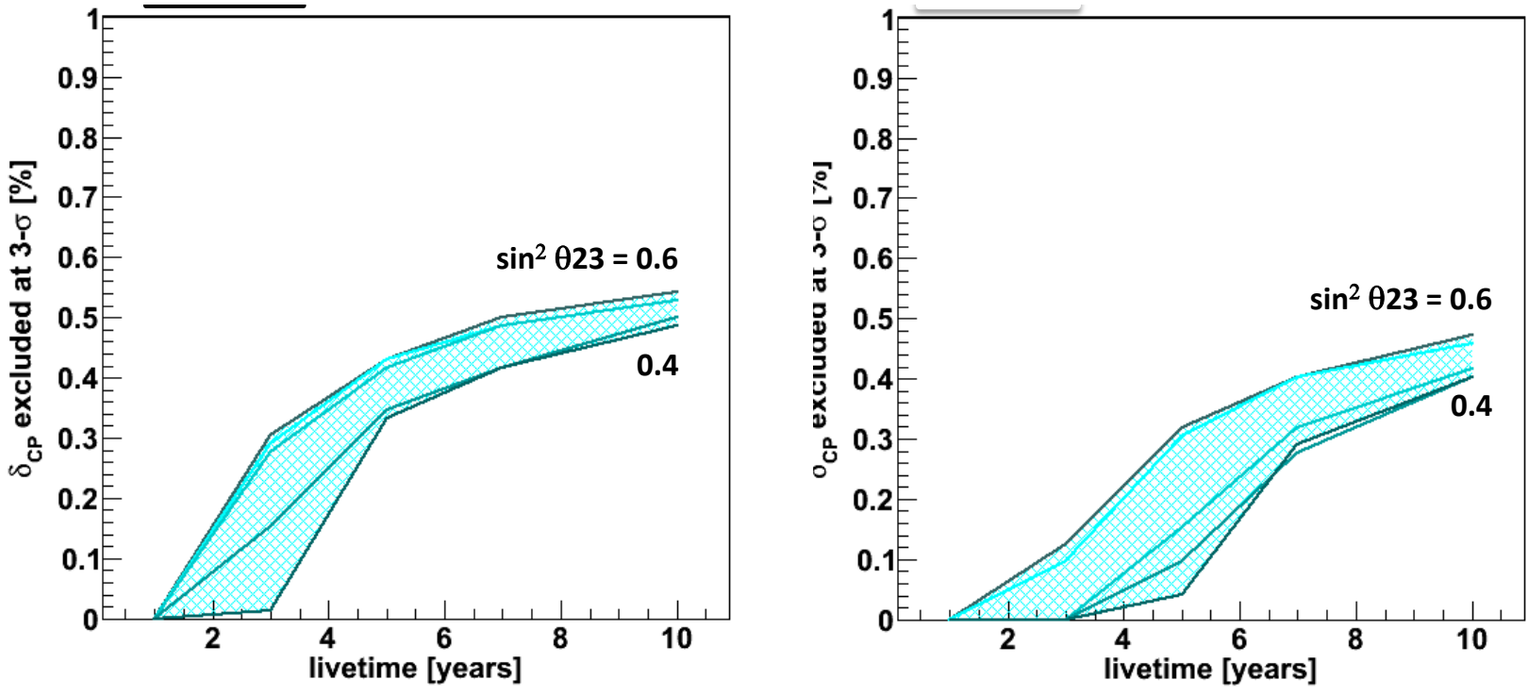
atm ν: θ_{23} octant and CPV

θ_{23} octant sensitivity

(band depends on δ)

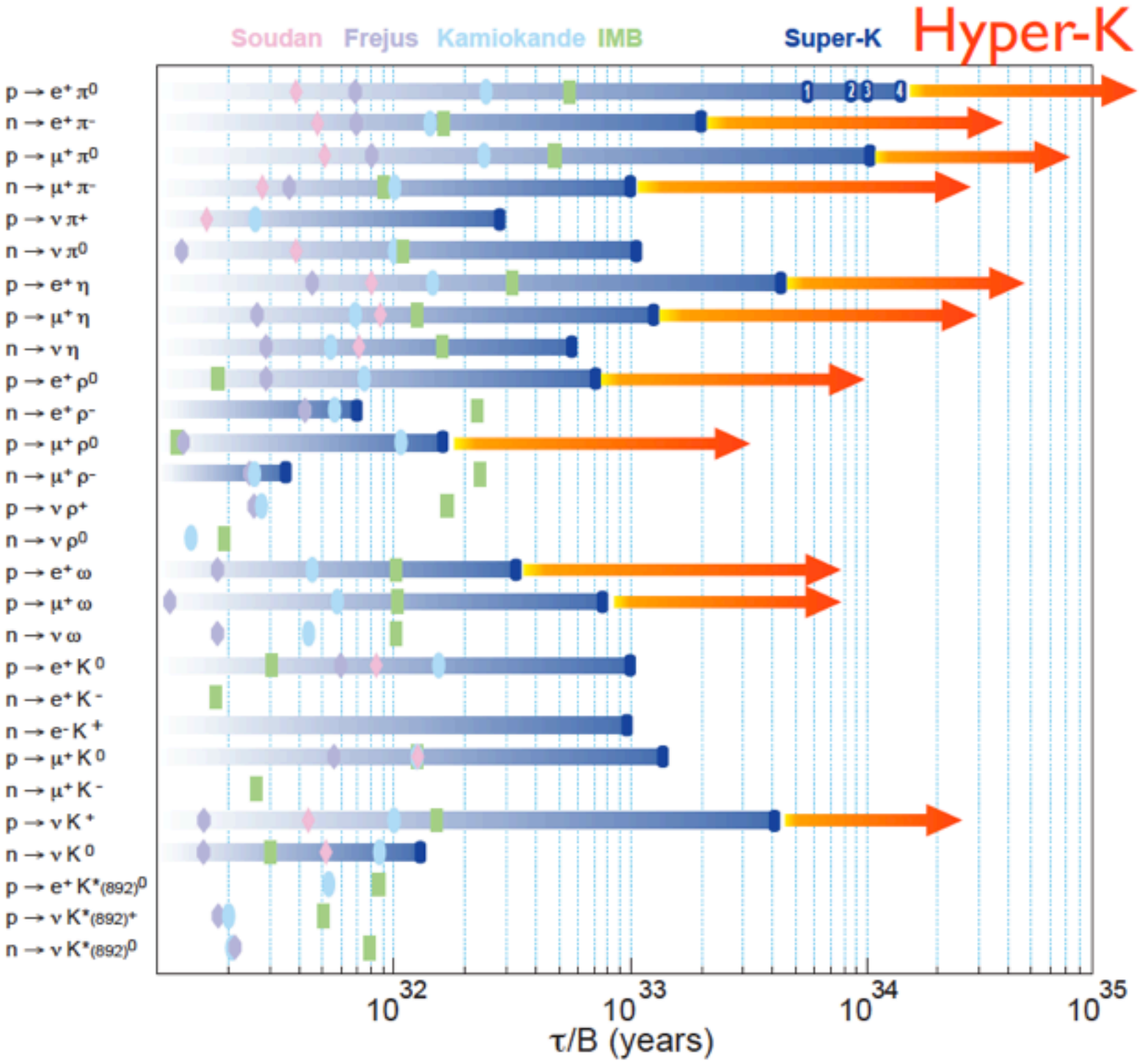


Fraction of δ_{CP} excluded (3 σ)



Complementary measurements to accelerator ν

Search for nucleon decays



~10 times sensitivity than current Super-K limits

- $p \to e^+\pi^0$:
  - 1.3×10^{35}yrs (90%CL)
  - 5.7×10^{34}yrs (3σ)
- $p \to \nu K^+$:
  - 2.5×10^{34}yrs (90%CL)
  - 1.0×10^{34}yrs (3σ)

(10 years)

Neutrino astrophysics

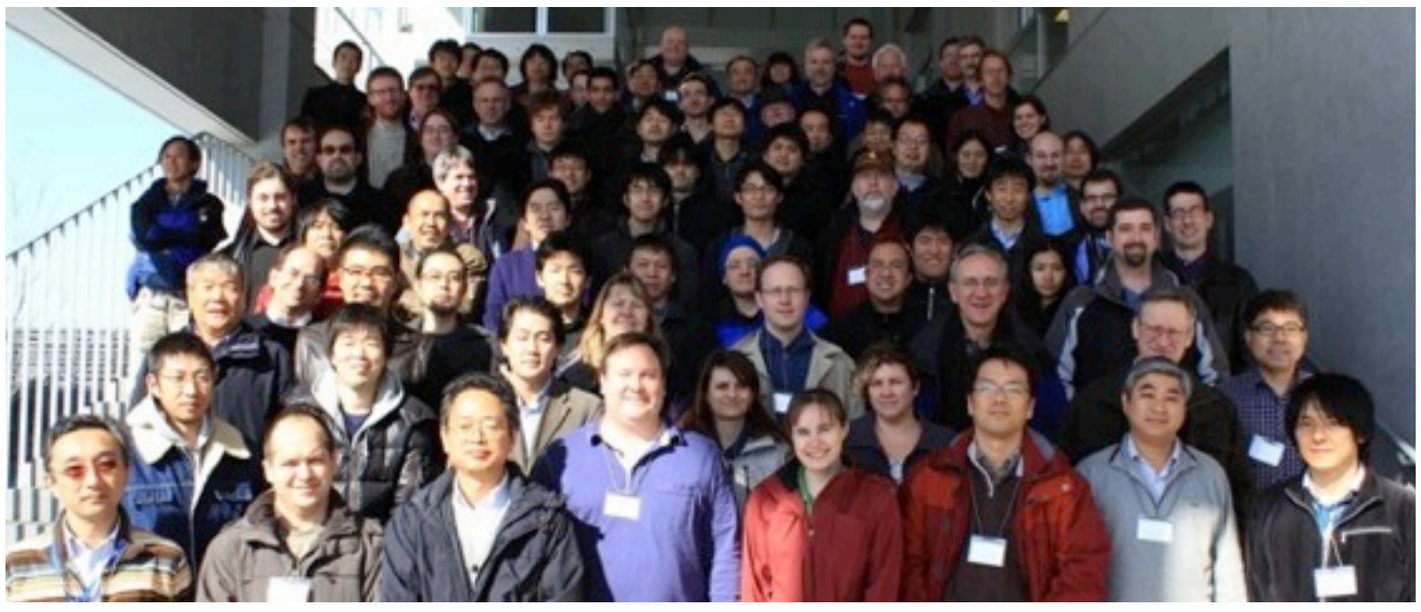
- **Supernova burst neutrino**
  - ~250k events (Garactic center) /
    ~25 events (Andromeda)
  - Reveal the detailed mechanism of supernova explosions with very large statistics sample
- **Supernova relic neutrino**
  - Study the history of heavy element synthesis in the universe
- Precision measurements of solar neutrino
- Indirect WIMP Search

International Hyper-K meetings

First meeting: Aug. 23-24, 2012

http://indico.ipmu.jp/indico/conferenceTimeTable.py?confId=7

Second meeting: Jan. 14-15, 2013



http://indico.ipmu.jp/indico/conferenceTimeTable.py?confId=10

Hyper-K is completely open to the international community

~100 participants for each of two meetings (~half from abroad)

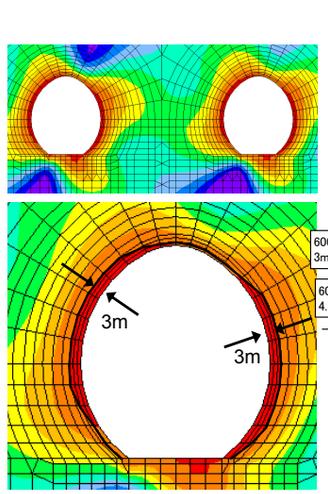
International working group was formed

Current members from Japan, Canada, Spain, Switzerland, Russia, UK, and US

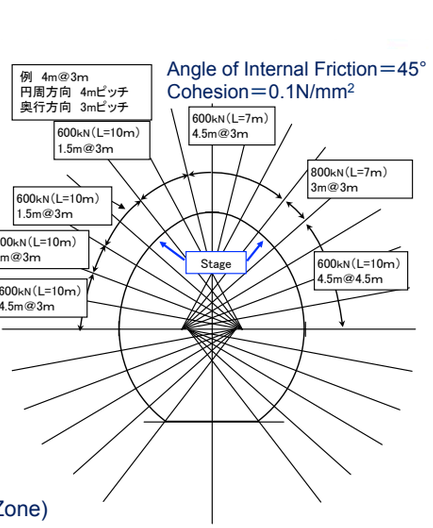
Next meeting: Jun. 21-22

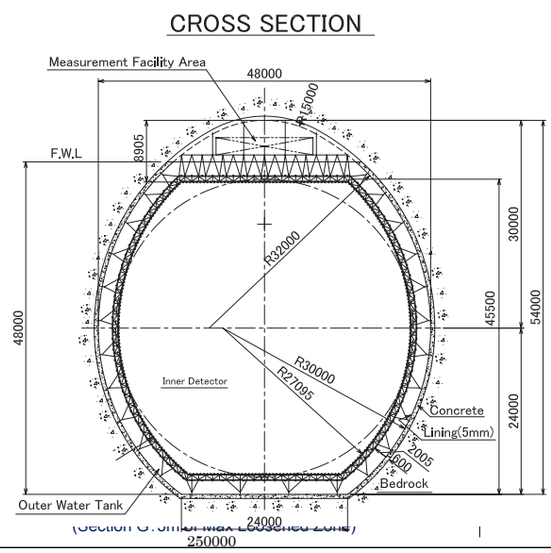
Detector design

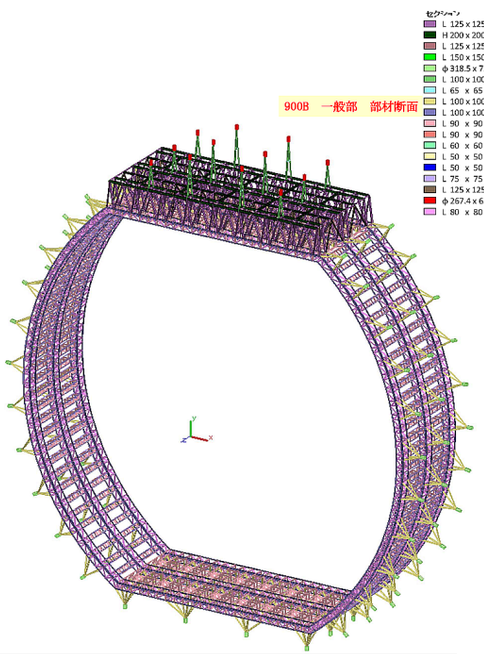
- Cavity design based on the in situ measurement of rock quality and stress
  - Feasible design established
- Optimization of cavity shape, segmentation walls, sensor support etc. ongoing

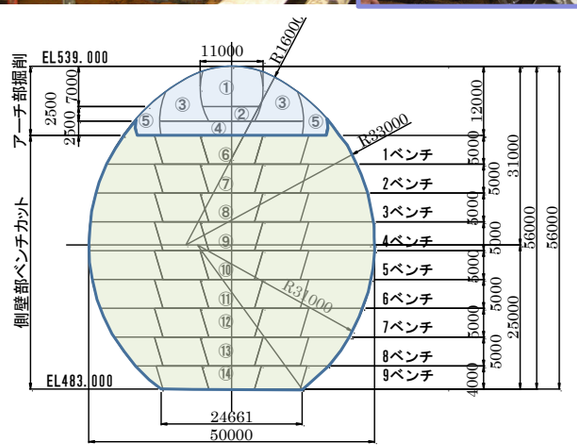


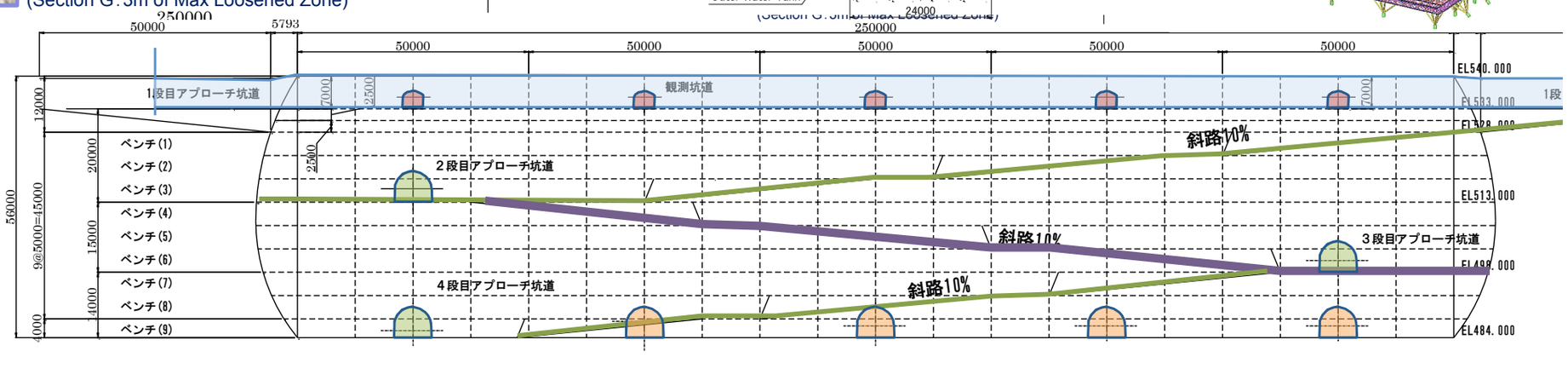
(Section G：3m of Max Loosened Zone)





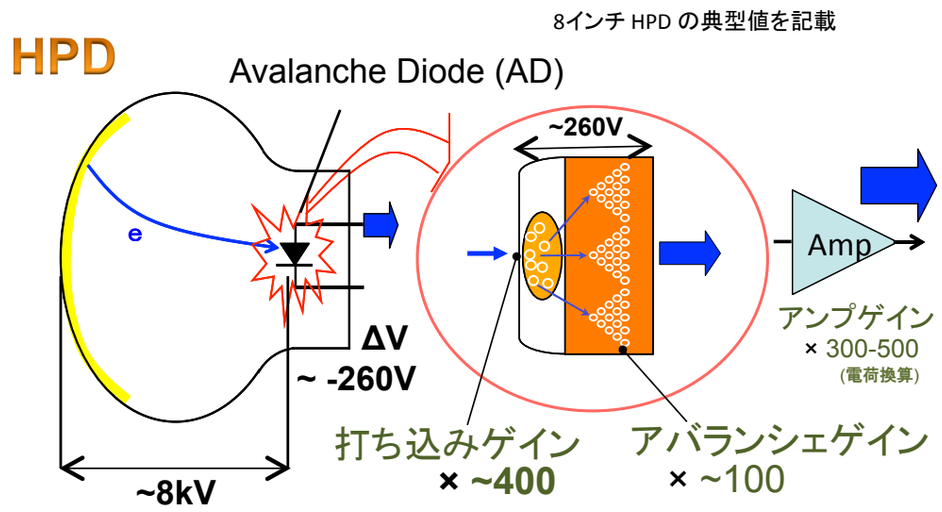


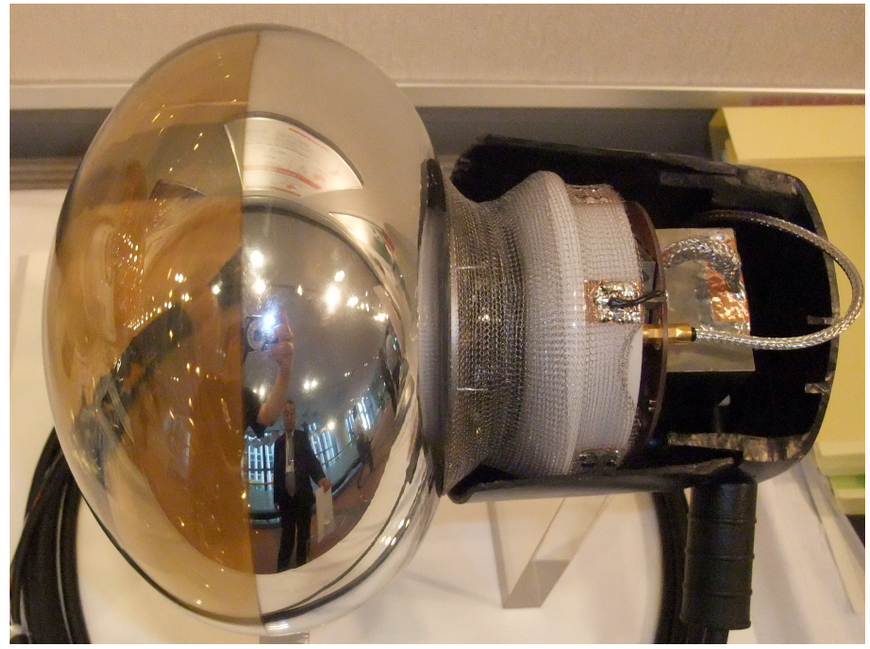




R&D of photo sensor

- Hybrid Photodetecotr (HPD)
  - Photo cathode + avalanche diode
  - Goal: higher performance, less expensive than PMT
  - 8-in prototype test in water (200-ton water tank @ Kamioka)
  - 20-in prototype available soon
- 20-in PMT with improved dynode
- Higher QE 20” photocathode under development
- Finish R&D and be ready for mass production in a few years



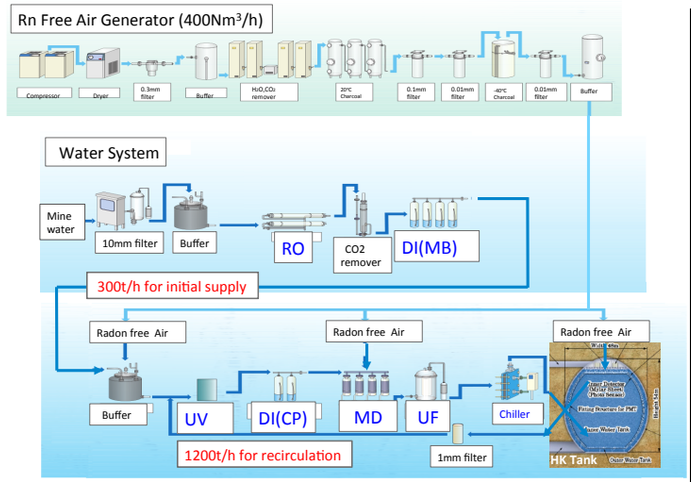


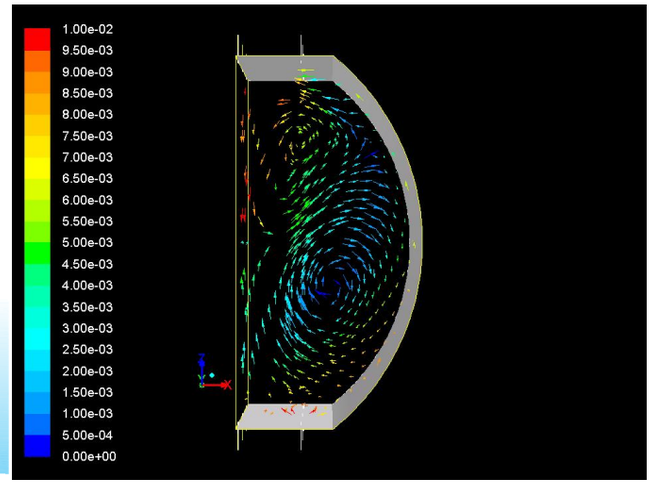
8-inch HPD prototype

Other R&D topics

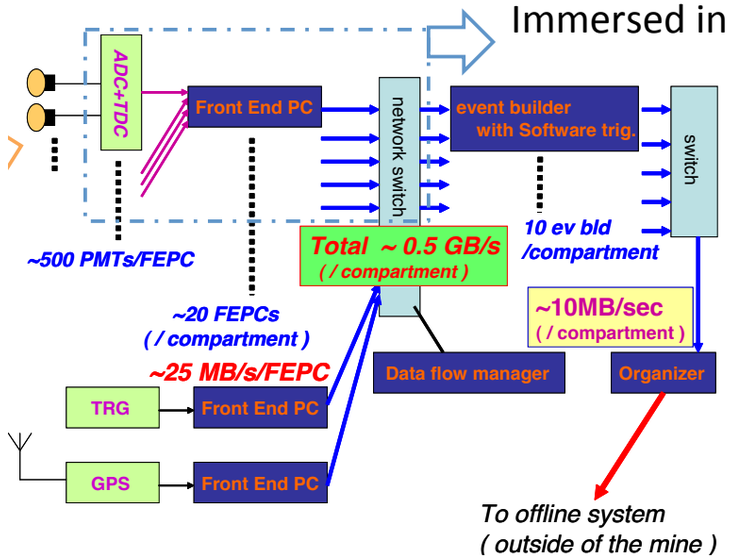
- Water system
- Readout electronics
- Calibration system
- Software development
- Physics potential
- Design of near detector(s)
- ...

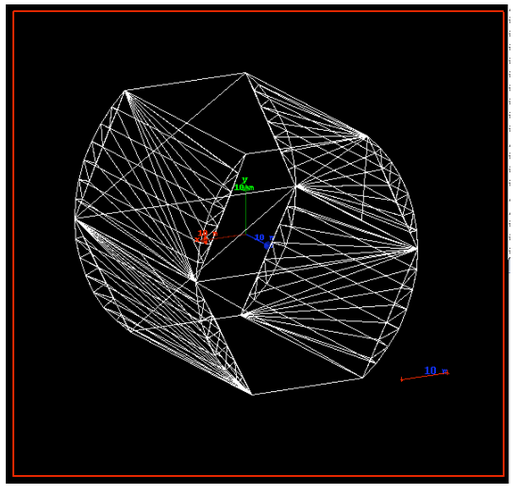
- Progress within international working group
(Japan, Canada, Spain, Switzerland, Russia, UK, US)

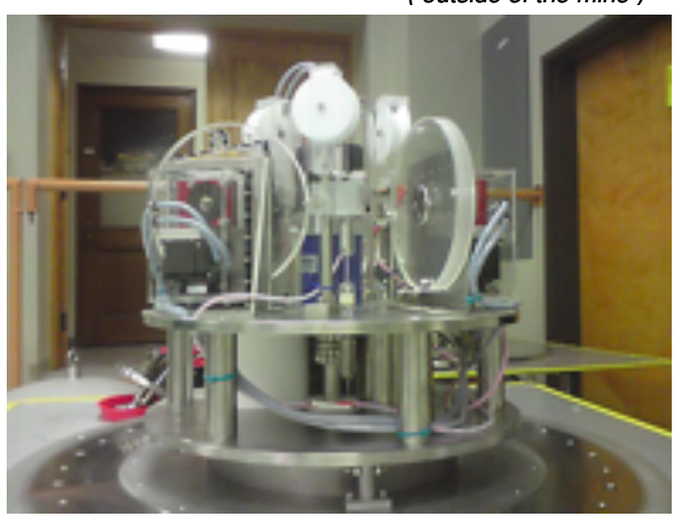


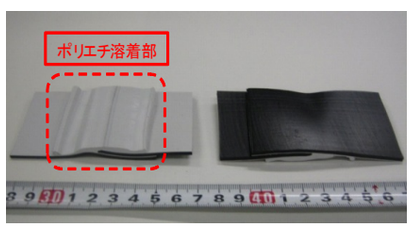


Immersed in water?





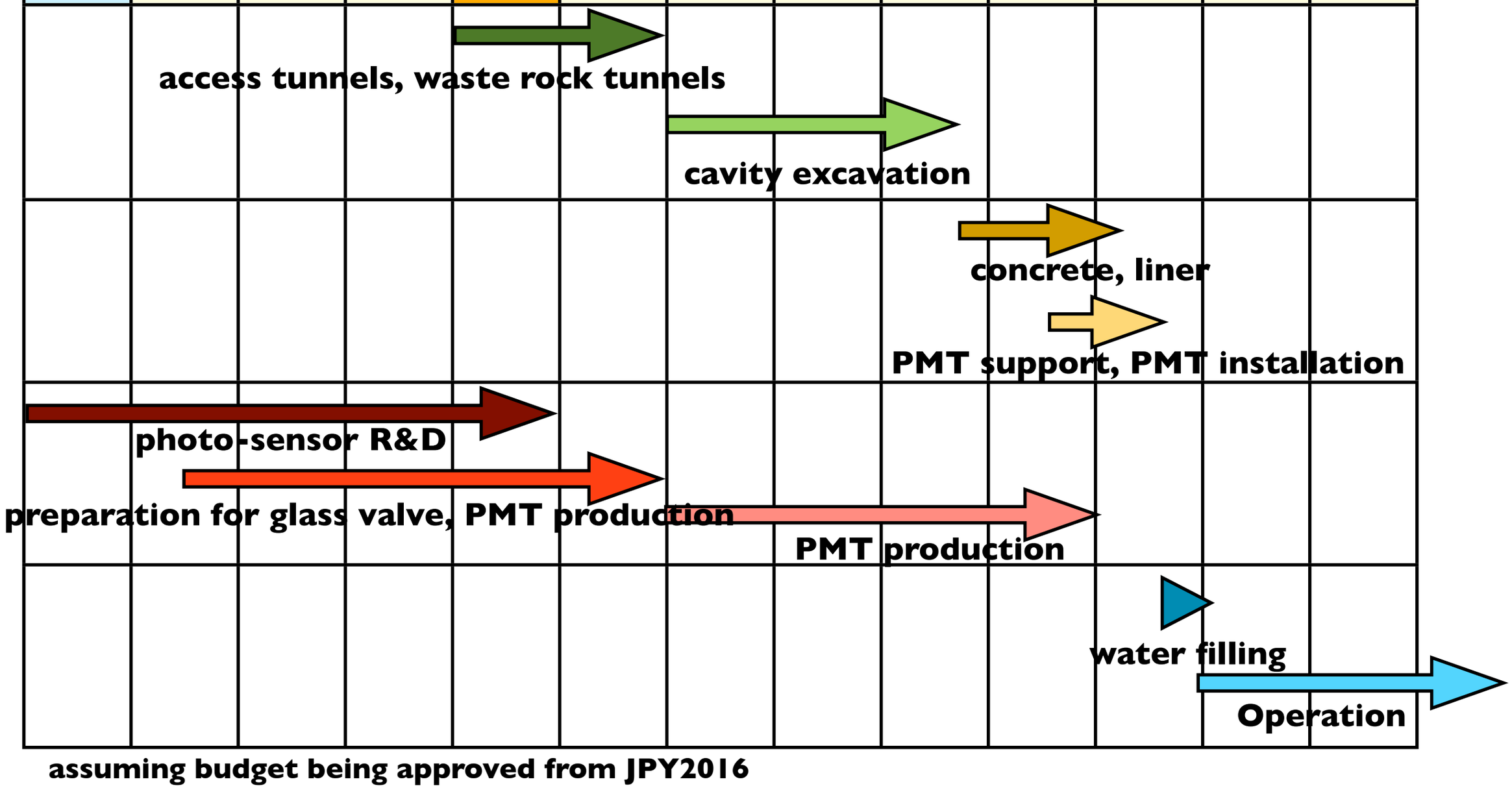




Target Schedule

Construction start

JFY2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
-4	-3	-2	-1	1	2	3	4	5	6	7	8	9



assuming budget being approved from JPY2016

- Data taking and science program duration: >15 years

Hyper-K in Japanese future strategy discussions

- Recommendation by HEP future projects committee (Feb.2012) http://www.jahep.org/office/doc/201202_hecsubc_report.pdf
  - Two large-scale projects recommended
    - ILC
    - Large neutrino/nucleon decay detector (Hyper-K/LAr)
- Final draft of KEK roadmap (Jan. 2013) includes Hyper-K http://kds.kek.jp/getFile.py/access?sessionId=1&resId=0&materialId=0&confId=11728
- Cosmic ray physics community endorses Hyper-K as a next large-scale project
- ICRR future plan under discussion

Planning process in Japan

- In 2013-14, Science Council of Japan is going to update the *Master Plan* for large scale projects (for all fields of science).
  - Large neutrino/nucleon decay detector (Hyper-K/LAr) was listed on the previous versions of the *Master Plan* (2010/2011).
  - We are going to (re-)submit proposal this month with Hyper-K as *the* project.
  - 25-30 projects will be selected as priority.
- The *Master Plan* is expected to be an important input to the Japanese government.

Summary

- Exciting results in past one year from Asia
- Even more exciting prospects with future plans in each country
  - INO, Daya Bay II, RENO
  - Hyper-Kamiokande and many projects in Japan

NNN13 workshop

Nov. 11–13, 2013

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