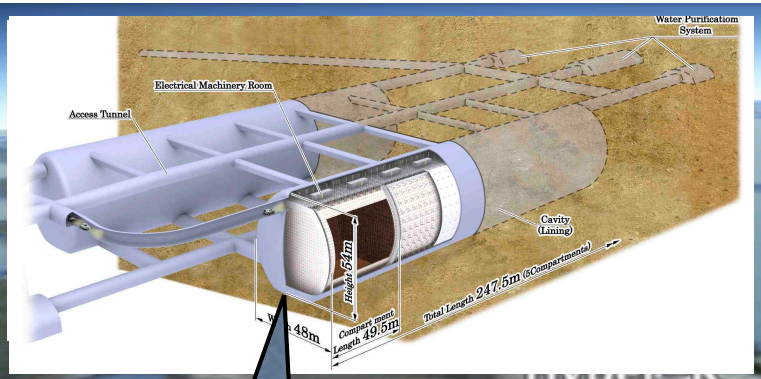
Hyper-Kamiokande project

Masato SHIOZAWA
Kamioka Observatory
January-17-2013, ICRR external review



x25 Larger ν Target

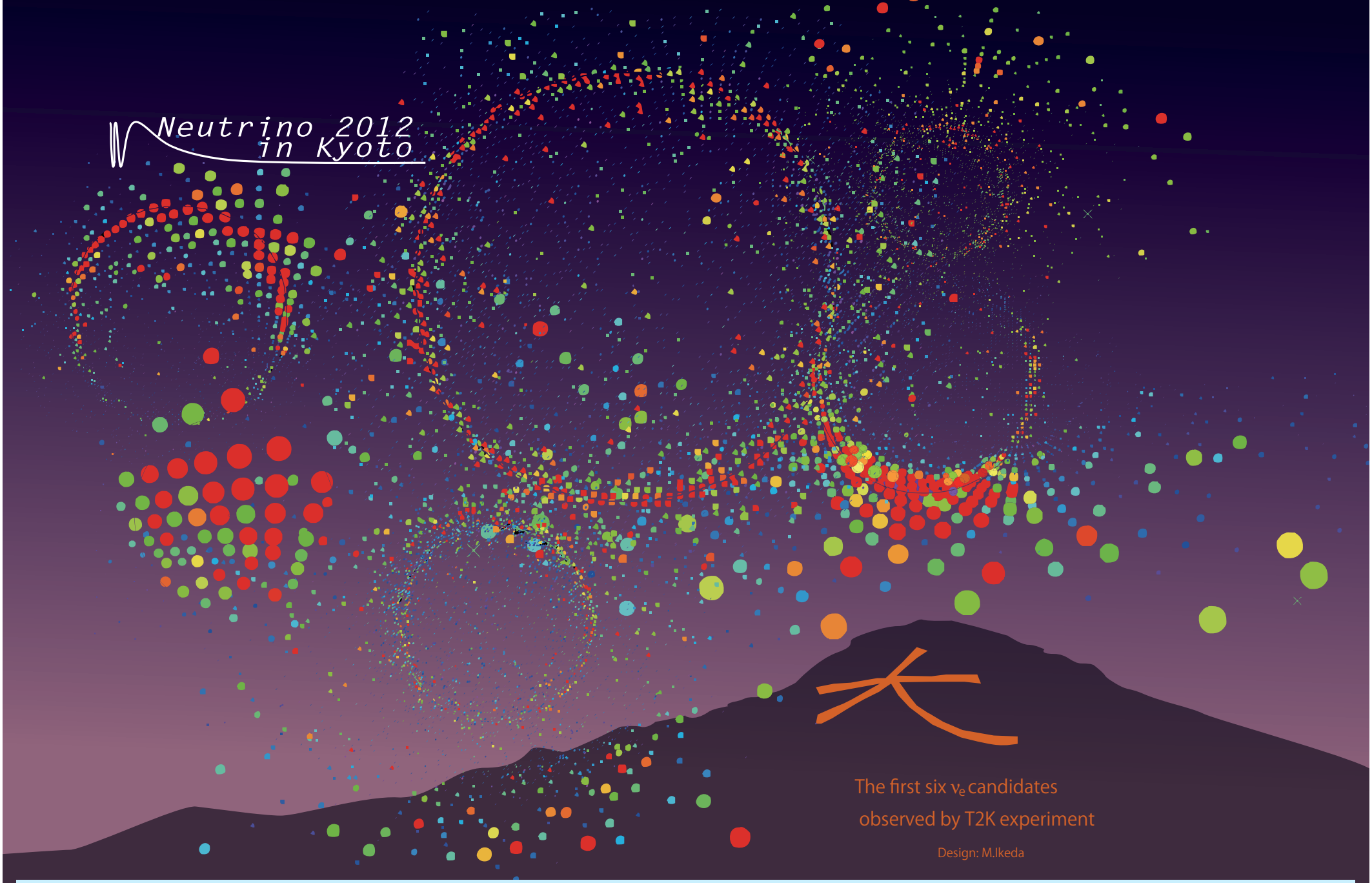
Super-K

~0.6GeV νμ
295km

Quest for CP Violation
in lepton sector
+
Proton Decay

higher intensity ν by upgraded J-PARC

JPARC



- T2K showed indication of $\nu_\mu \rightarrow \nu_e$ in PRL107,041801(2011)
- In Kyoto, presented the evidence of electron neutrino appearance

Introduction

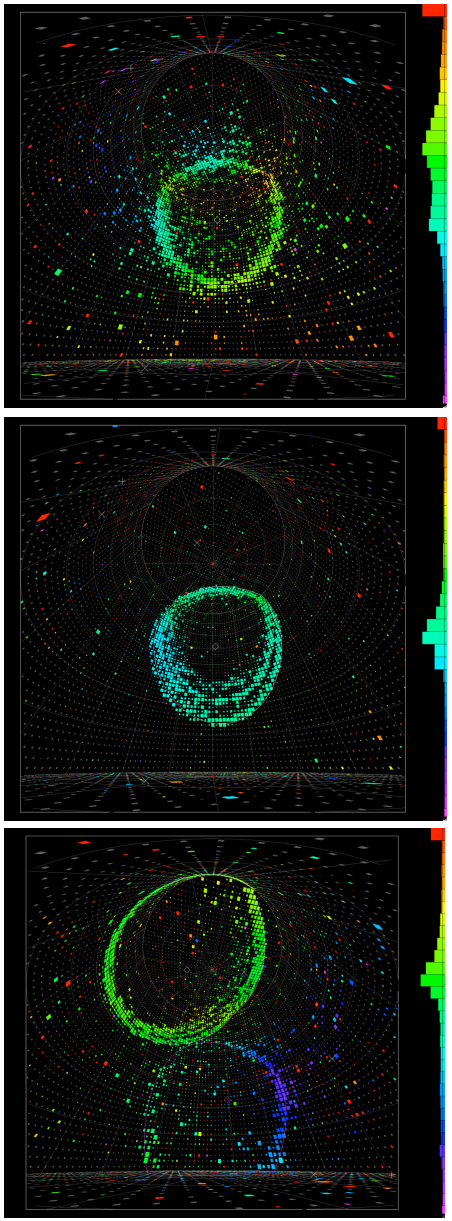
- Recent results of T2K shows evidence for $\nu_\mu \rightarrow \nu_e$ appearance
  - 11 νe candidates, p-value=0.08% (3.2σ) for zero θ_{13}
  - consistent w/ 2011 T2K result, solar+KamLAND, MINOS, Daya Bay, Reno, DoubleChooz
  - $\sin^2 2\theta_{13}=0.089\pm0.010(\text{stat.})\pm0.005(\text{syst.})$ from DayaBay

- The existence of $\nu_\mu \rightarrow \nu_e$ phenomena opens the way to perform experiments to discover leptonic CP violation.

- Good reason to do it in Japan
  - J-PARC is expected to be upgraded to ~700kW and beyond
  - well-proven & high performance detector technique w/ the successful experiences in Super-K
  - To me, it is an economical, feasible way to explore CPV by extending JPARC-SK experimental setup.

- Rich physics topics can be covered by the extension.
  - must extend nucleon decay search capability
  - high statistics atmospheric neutrino study
  - Supernova ν
  - astrophysics is also interesting topic

Water Cherenkov technique



- Good imaging capability at ~1GeV
  - accelerator ν, atmospheric ν, proton decays
- Excellent particle ID capability > 99%
- Energy resolution for e and μ ~3%
- Energy threshold ~5MeV
  - muon decay electron, nuclear de-excitation γ, Supernova ν, solar ν...
- Stable operation
  - energy scale stability ~1%
  - livetime for physics analyses > 90%

- For νe appearance in T2K
  - νe signal efficiency ~60%
  - BG ν_μ+antiν_μCC<0.1%, NCπ^0<5% (0.1<E^{rec}_ν<1.25GeV)

Well-proven technology
Excellent detector performance

Letter of Intent:

The Hyper-Kamiokande Experiment

— Detector Design and Physics Potential —

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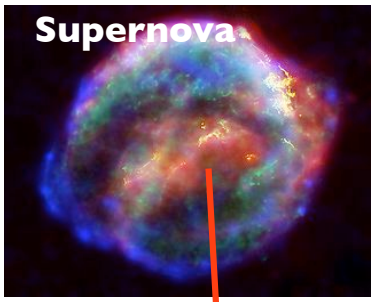
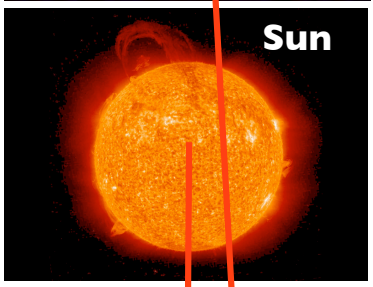
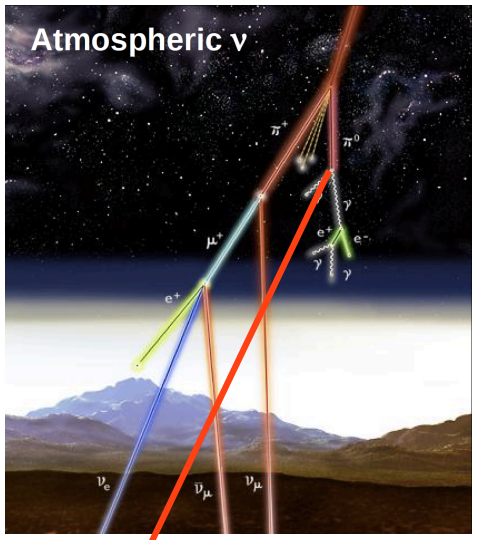
Letter of Intent, Hyper-K WG,
arXiv:1109.3262 [hep-ex]

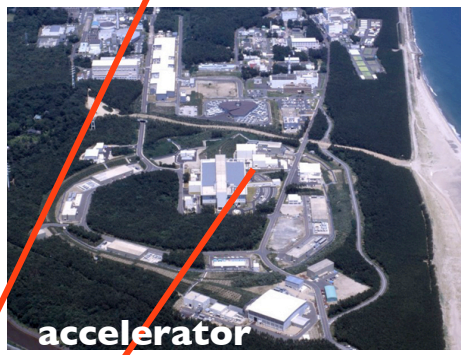
Multi-purpose detector, Hyper-K

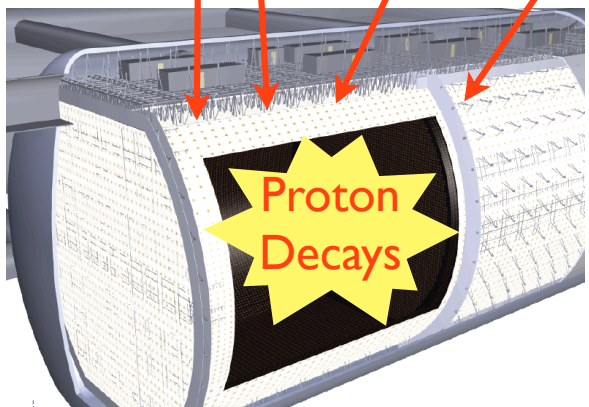
- Total (fiducial) volume is 1 (0.56) million ton
  - 25 × Super-K
- Explore full picture of neutrino oscillation parameters.
  - Discovery of leptonic CP violation (Dirac δ)
  - ν mass hierarchy determination(Δm^2_{32}>0 or <0)
  - θ_{23} octant determination (θ_{23}<π/4 or >π/4)
- Extend nucleon decay search sensitivity
  - $\tau_{proton}=10^{34}\sim10^{35}$ years
- Neutrinos from astrophysical objects
  - 200 ν's / day from Sun
    - possible time variation, ~3σ day/night asym.
  - 250,000 (50) ν's from Supernova @Galactic-center (Andromeda)
  - ~300 ν's / 10 years (>20MeV) SN relic ν
  - WIMP ν, solar flare ν, etc











First open Hyper-K meeting (Aug.23-24, 2012)

~100 participants, ~50 non-Japanese

- Review the current status of the project and discuss the strategy to realize Hyper-K
- Define the international working group and conveners
- Follow up meeting on January14 and 15, 2013

Hyper-K Working Group Organization

- oversee the HK group
- channel for contacting to the group
- involve non-Japanese in future

To be rearranged when the project is approved

Steering Committee
Nakaya (chair)
Aihara, Nakahata,
Shiozawa, Yokoyama
+ a few more

Project Leader
Shiozawa

- PL oversees the sub-WGs
- WG conveners may be composed of one Japanese plus some non-Japanese.

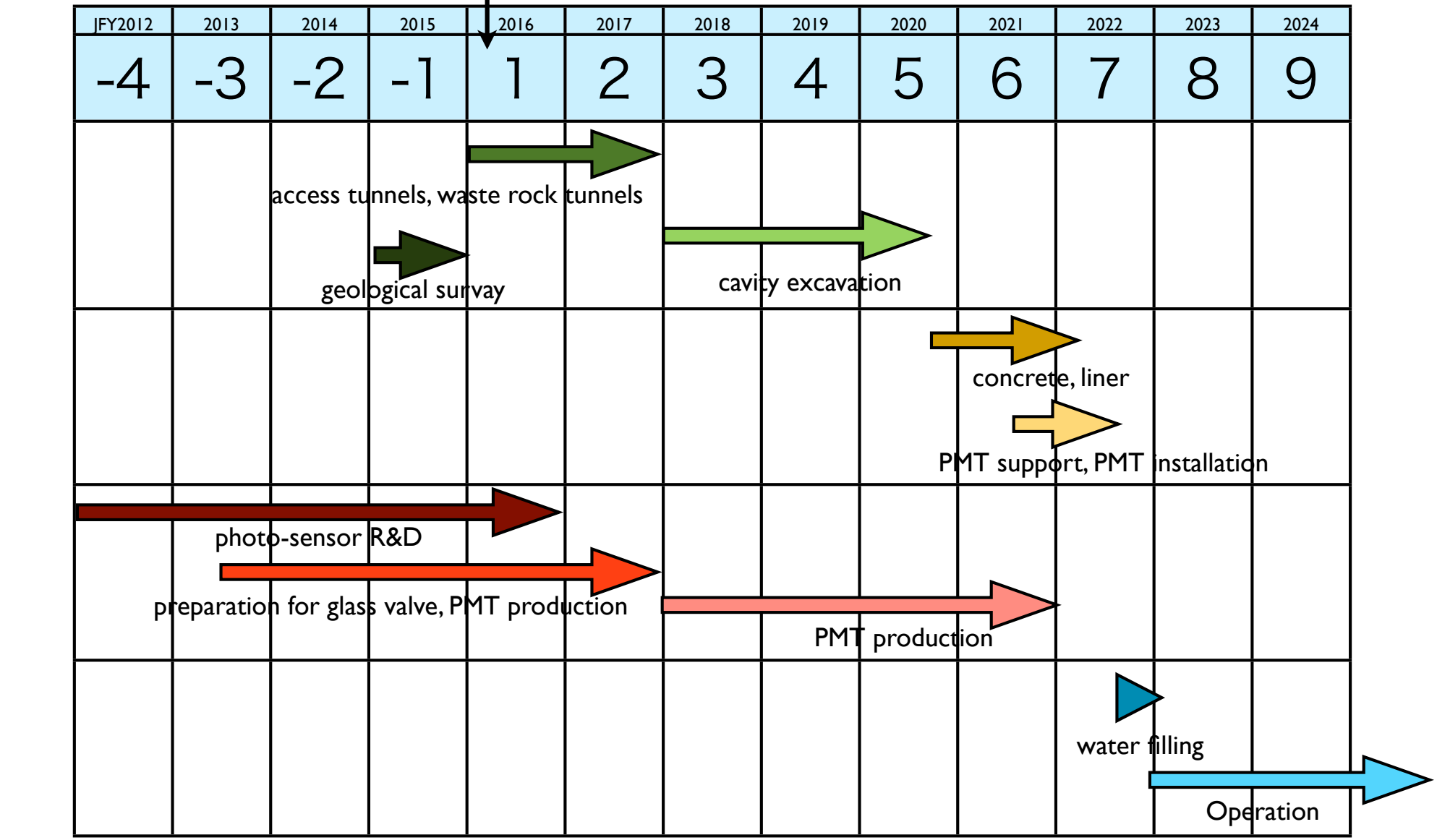
WG1	WG2	WG3	WG4	WG5	WG6	WG7	Physics WG conveners
Shiozawa	Sekiya, Vagins	Nakayama, Nishimura	Hayato	Miura	HideTanaka, HiroTanaka, Koshio, Mine, Mccauley	Convener	Yokoyama

Phys-WG1	Phys-WG2	Phys-WG3
Yokoyama	Wendell	Takeuchi

WG1: Cavity and Tank
WG2: Water
WG3: Photo-sensor
WG4: DAQ
WG5: Software
WG6: Calibration
WG7: Accelerator(&Near Detectors)

Phys-WG1: Accelerator
Phys-WG2: Atmν+Nucleon decays
Phys-WG3: Astroparticle Physics (SN, solarν, etc)

Schedule



assuming budget being approved from JPY2016

Construction cost estimation

Total	~80Billion JPY	
Excavation	30Billion JPY	
Tank	30Billion JPY	
Photo-detectors	20Billion JPY	High QE HPD

Rough estimation by pre-conceptual-design

Important events

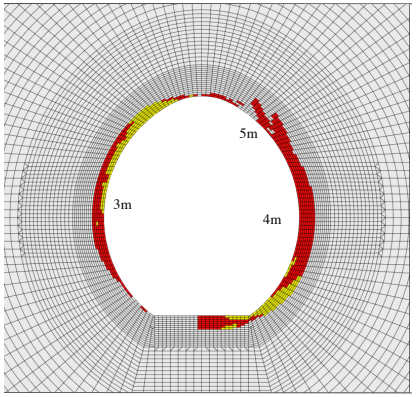
- Proposal submission to the Science Council of Japan
  - SCJ will update the Master Plan of large research project.
    - 25~30 projects will be selected by the end of 2013.
  - This will be an important inputs to the Roadmap of large research project to be released in 2015 by MEXT
  - We are submitting the project of large neutrino/nucleon decay detector.
    - Hyper-K (far detector) construction and operation cost
    - J-PARC operation w/ (~1MW or higher) and a near detector construction in the same package.
- Discussions in community
  - Japan HEP community put high priority on ILC and the large neutrino detector.
  - Had discussions in Cosmic Ray Community and expect endorsement.
  - Snowmass in US and European future strategy in EU are ongoing.

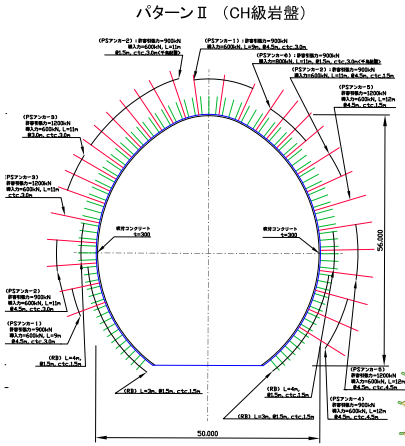
Budget Request

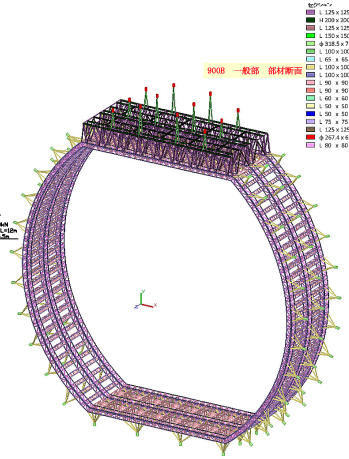
- Budget request for Hyper-K is not well defined yet until the SCJ master plan and/or the MEXT roadmap is fixed.
- Budget request for R&D is under process.
  - Submitted a proposal to Grant-in-Aid for Scientific Research on Innovative Area. ($3M/5year)
  - Construction cost for a prototypical water Cherenkov detector w/ new sensors, electronics, etc etc

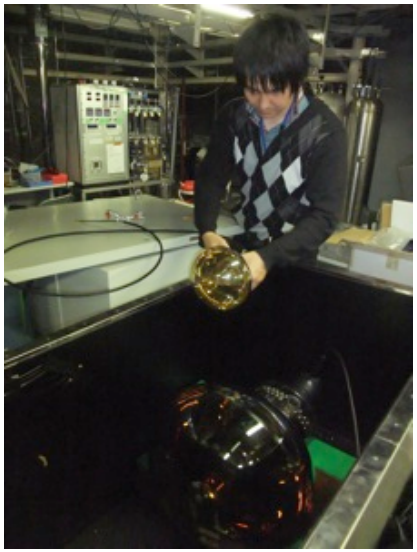
More Development works

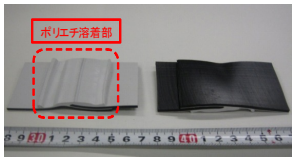
- Detector design optimization
  - tank shape, segmentation wall, tank liner, PMT support structure
- Water purification system, water flow control
- DAQ electronics (under water?)
- Calibration source deployment system
  - automated, 3D control
- Physics potential studies
  - Requirements for depth, photo-sensors, near detectors
  - Maximize physics sensitivity
- works in the international working group

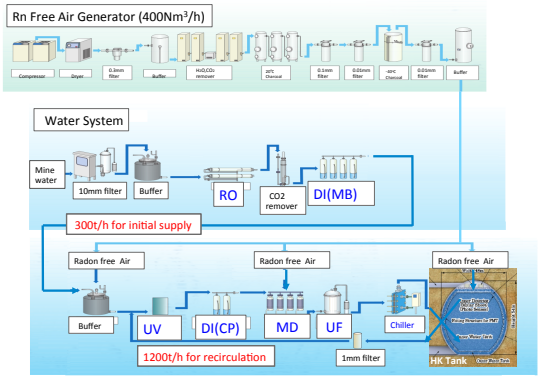


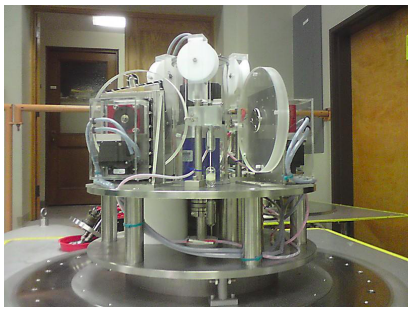


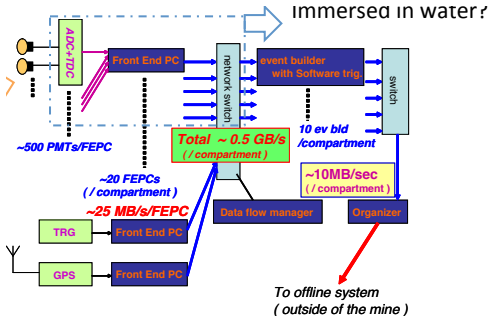




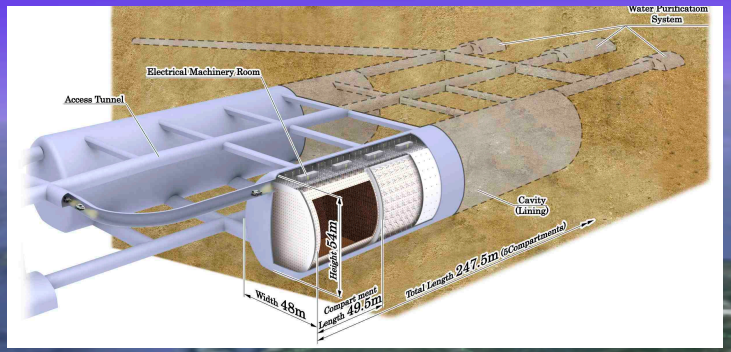








Accelerator ν



560kton (SKx25)

Hyper-K

Super-K

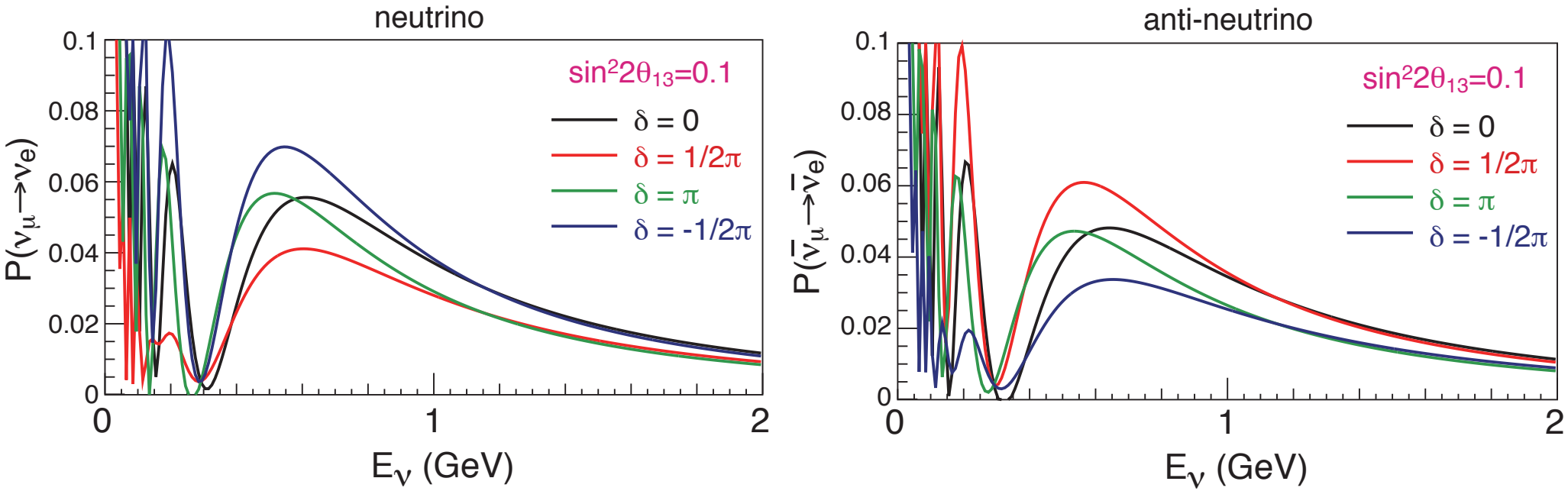
~0.6GeV νμ
295km baseline

J-PARC

750kW and beyond

$\nu_\mu \rightarrow \nu_e$ probability (L=295km)

Normal hierarchy



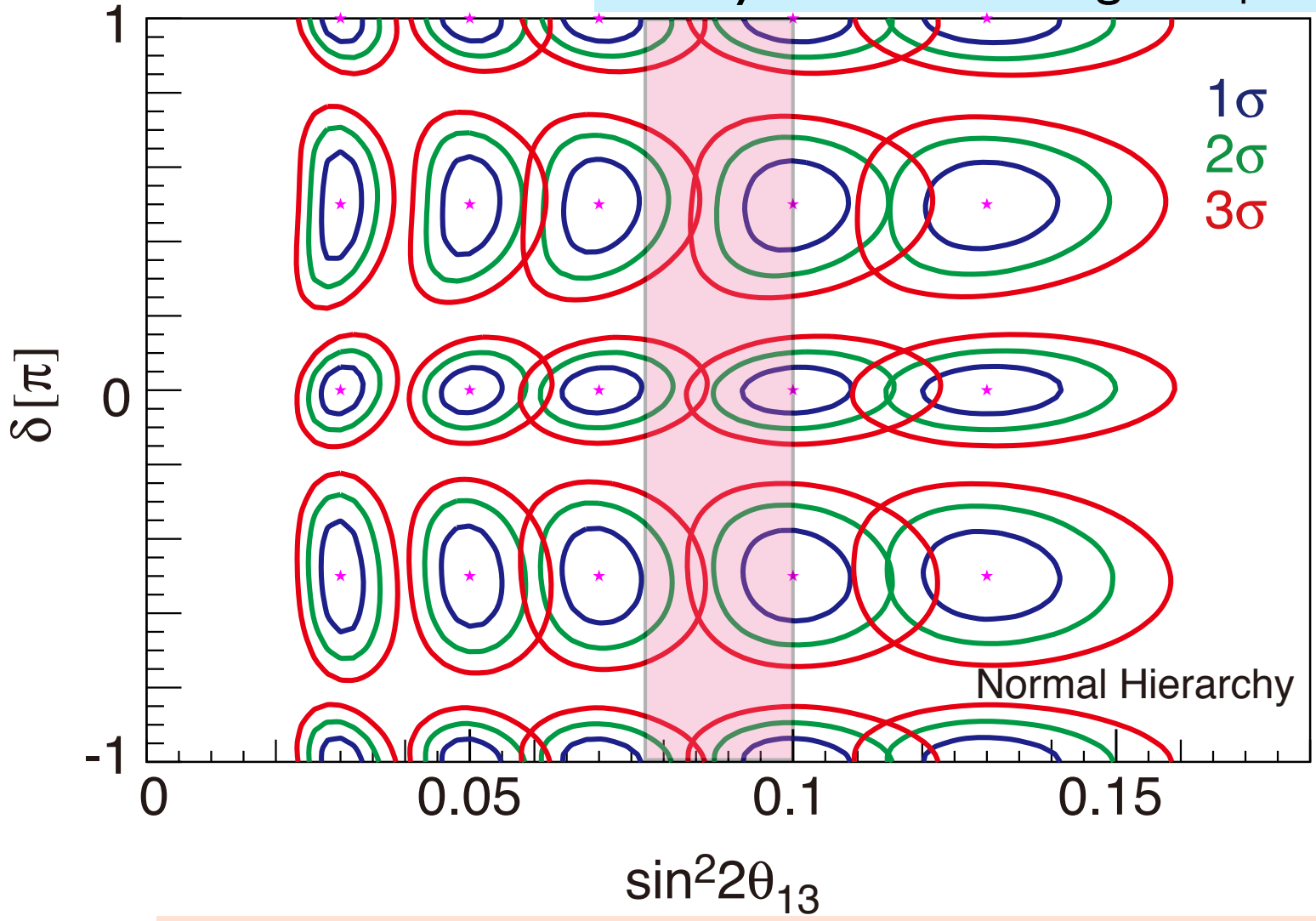
- ±25% CPδ effect at maximum
- CPV test by comparing $P(\nu_\mu \rightarrow \nu_e)$ and $P(\bar{\nu}_\mu \rightarrow \bar{\nu}_e)$
- sensitive to exotic CPV (non MNS matrix origin)

Contours

7.5MW・years

Normal mass hierarchy (known)

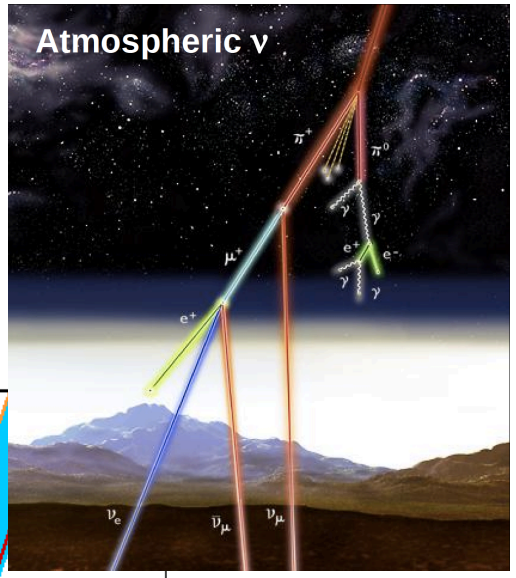
5% systematics on signal, ν_μ BG, ν_e BG, $\nu/\overline{\nu}$



DayaBay 1σCL

- Good sensitivity for CPV
- modest dependence on θ_{13} value

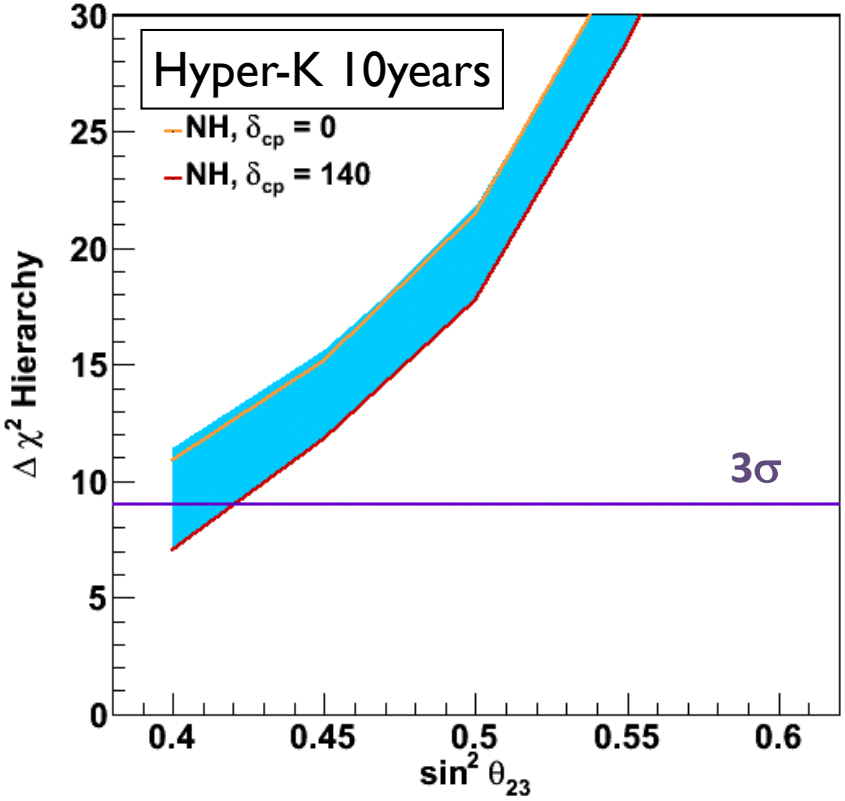
Mass hierarchy discrimination

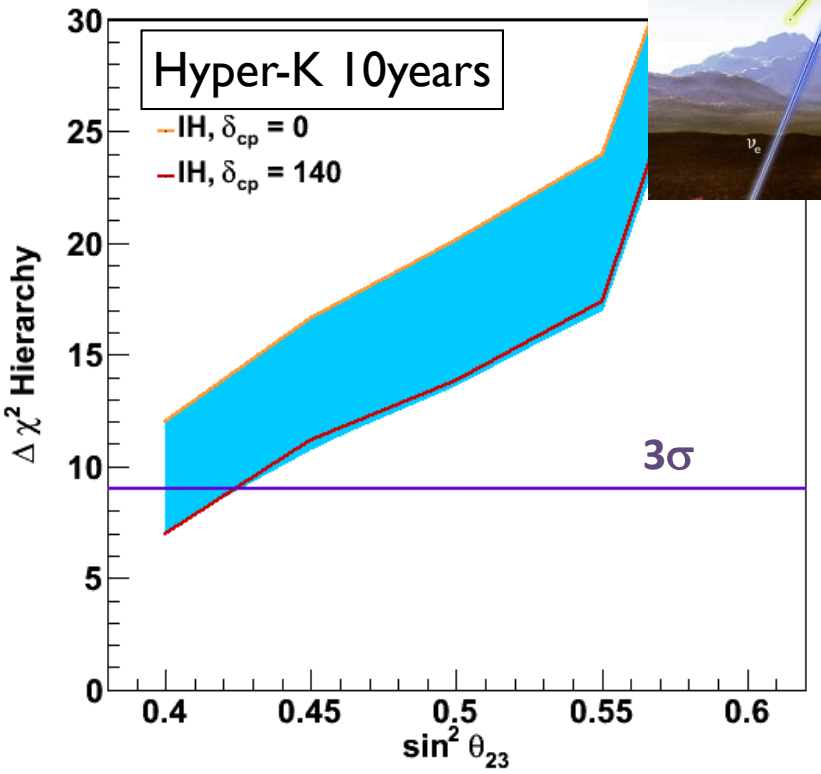


NH, unknown

θ_{13} is fixed : $\sin^2 2\theta_{13} = 0.10$

IH, Unknown



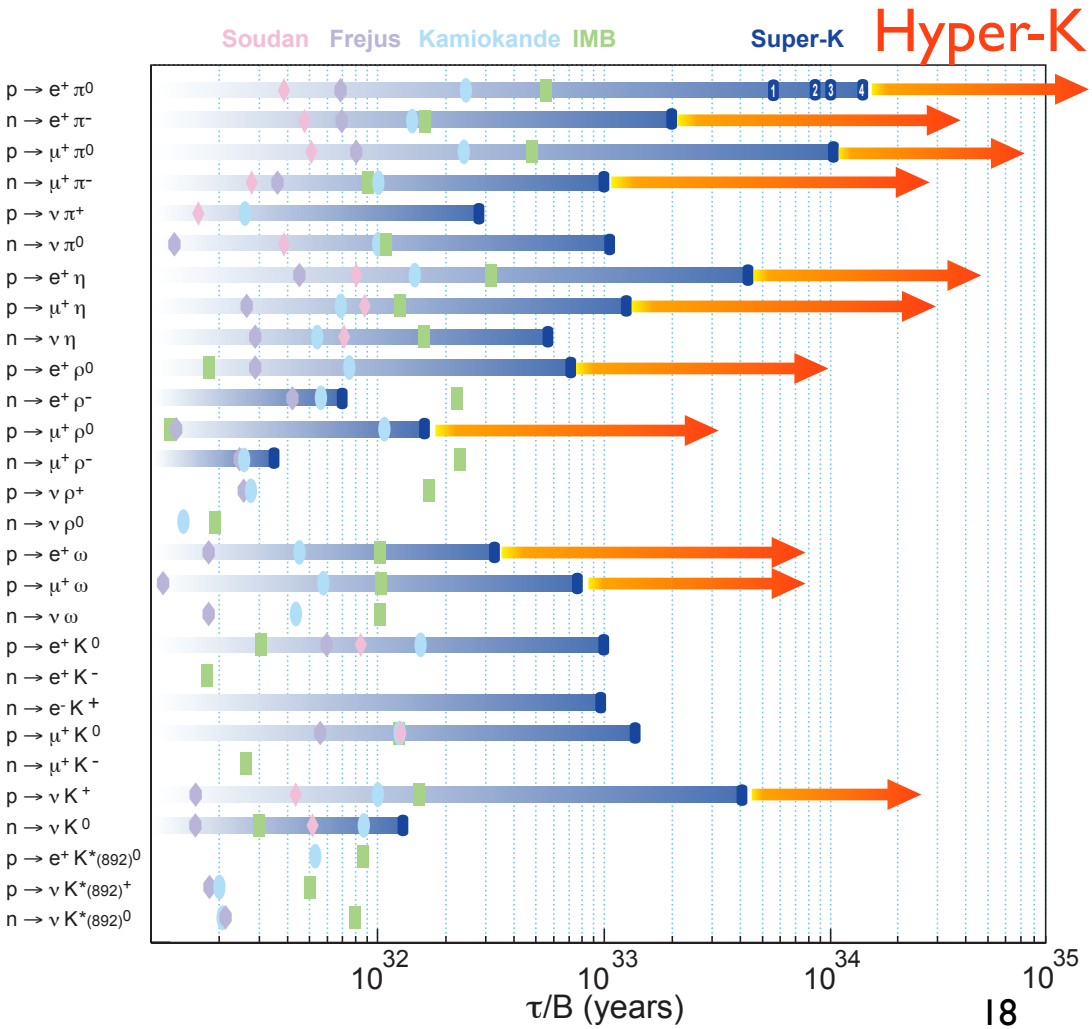


Bands correspond to δ_{CP} variation

- expect to discriminate normal from inverted hierarchy w/ 3σ significance by <~10years data.
- Higher significance and shorter time for larger θ_{23}

Search for nucleon decays

- 10 times better sensitivity than Super-K.
  - only realistic plan to go beyond 10^{35} years for $p \to e^+ + \pi^0$
- >3σ discovery is possible for lifetime beyond Super-K limits.



Hyper-K sensitivities

- $p \to e^+ + \pi^0$
  - $\tau_{proton}/Br > 1.3 \times 10^{35}$ years @90%CL
  - 5.6Mton×years (10 Hyper-K years)
- $p,n \to (e^+,\mu^+)+(\pi,\rho,\omega,\eta)$
  - $O(10^{34\sim35})$years
- *SUSY favored* $p \to \nu + K^+$
  - 2.5×10^{34} years
- K^0 modes, $\nu\pi^0$, $\nu\pi^+$ possible
- Other various decay modes.
  - (B-L) violated modes
  - radiative decays $p \to e^+\gamma$, $\mu^+\gamma$
  - neutron-antineutron振動 ($|\Delta B|=2$)
  - di-nucleon decays ($|\Delta B|=2$)
    - $pp \to XX\ldots$, $nn \to XX\ldots$

Summary

- Hyper-K covers rich fundamental physics topics.
  - discovery reach for leptonic CP violation.
    - CPV >3σ(5σ) for 74(55)% of δ
  - good chance to discriminate hierarchy and θ_{23} octant.
    - >3σ by atmospheric ν (and J-PARC ν)
  - ~10 times better sensitivity for nucleon decays.
    - >3σ: 5.7×10^{34} for $e^+\pi^0$, 1.0×10^{34} for νK^+ with 10 yrs
  - various astrophysical objects.

- Baseline design ready, design optimization going on, maximizing physics sensitivity.
- Budget request path to be defined.