Hyper-Kamiokande Project

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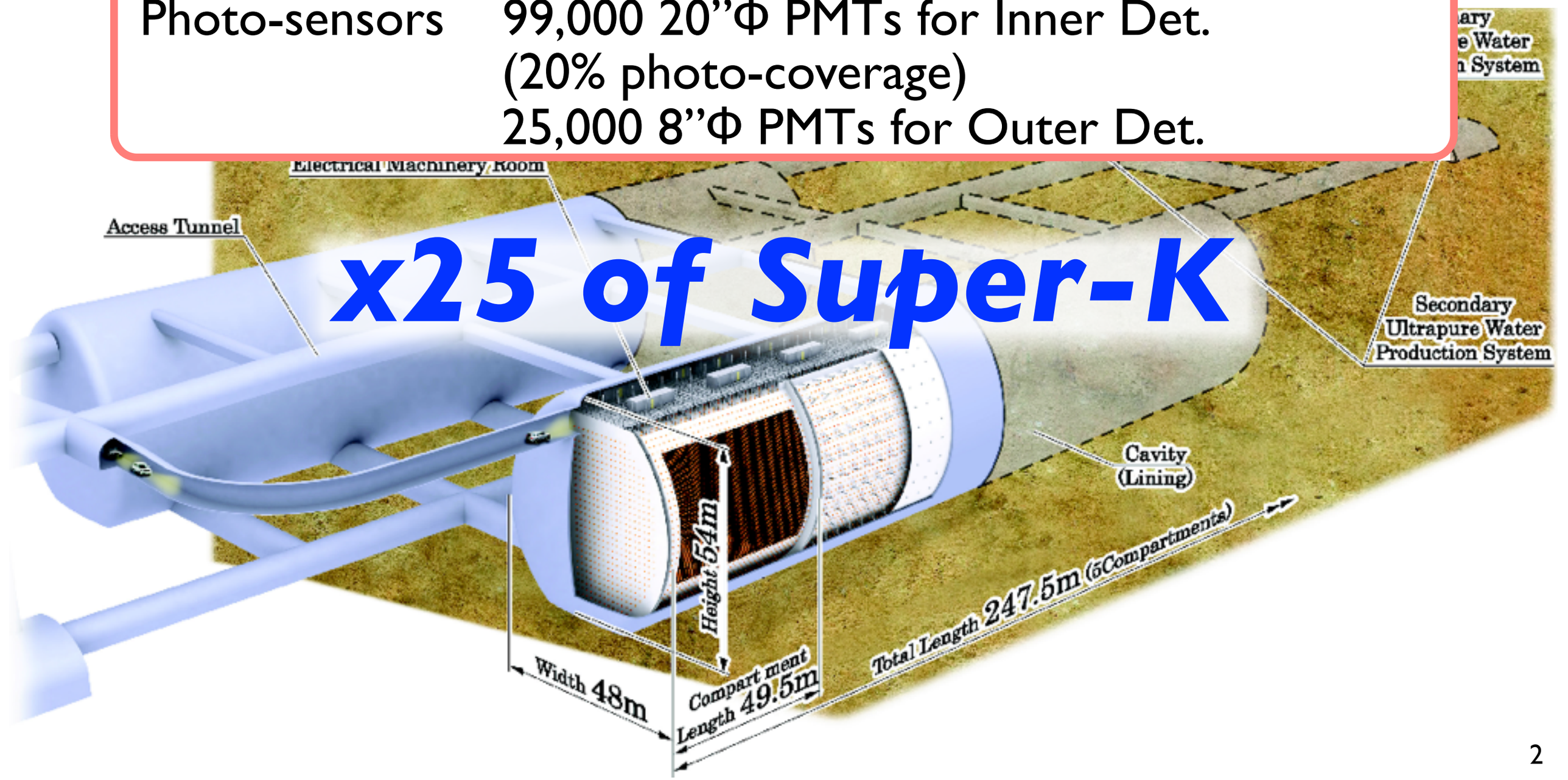
for Hyper-K Working Group

EPS-HEP, July 19, 2013

Hyper-Kamiokande

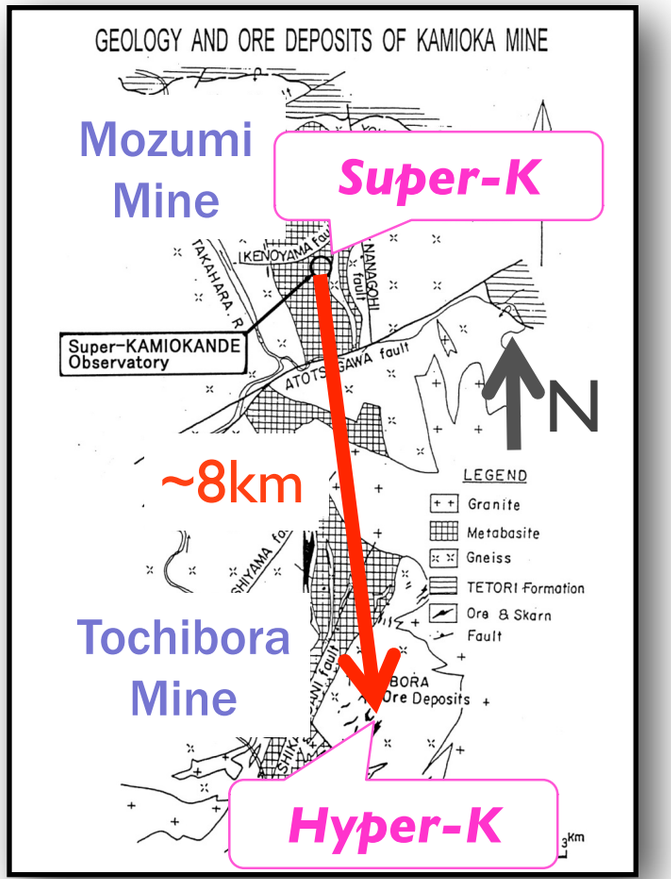
Total Volume	0.99 Megaton
Inner Volume	0.74 Mton
Fiducial Volume	0.56 Mton (0.056 Mton × 10 compartments)
Outer Volume	0.2 Megaton
Photo-sensors	99,000 20”Φ PMTs for Inner Det. (20% photo-coverage) 25,000 8”Φ PMTs for Outer Det.

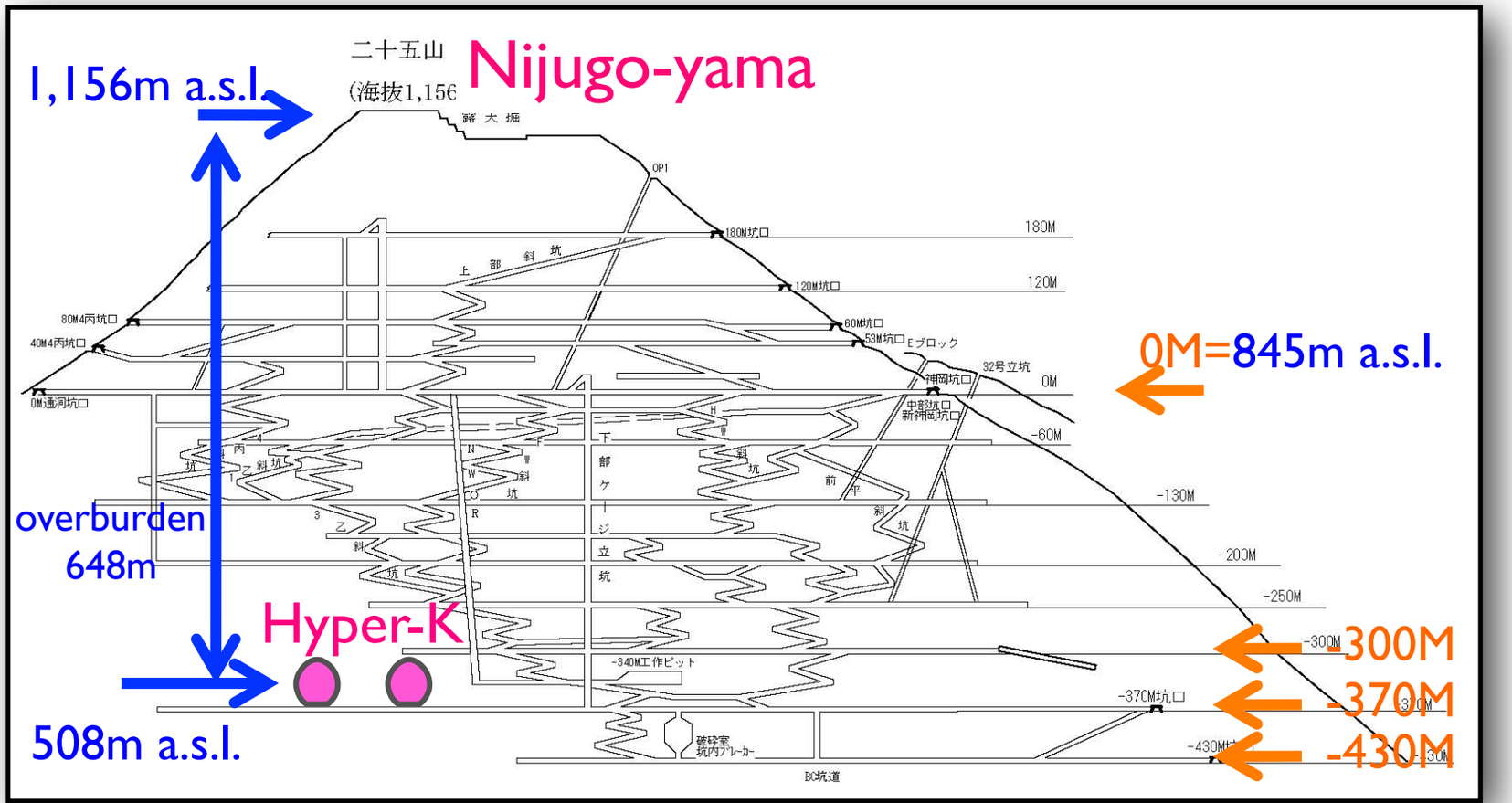


x25 of Super-K

Candidate Site

- The candidate site locates under “Nijugo-yama” (Mt. 25)
  - ~8km south from Super-K
  - Identical baseline and off-axis angle to T2K (295km, 2.5 deg)
- Overburden ~650m (~1755 m.w.e.)





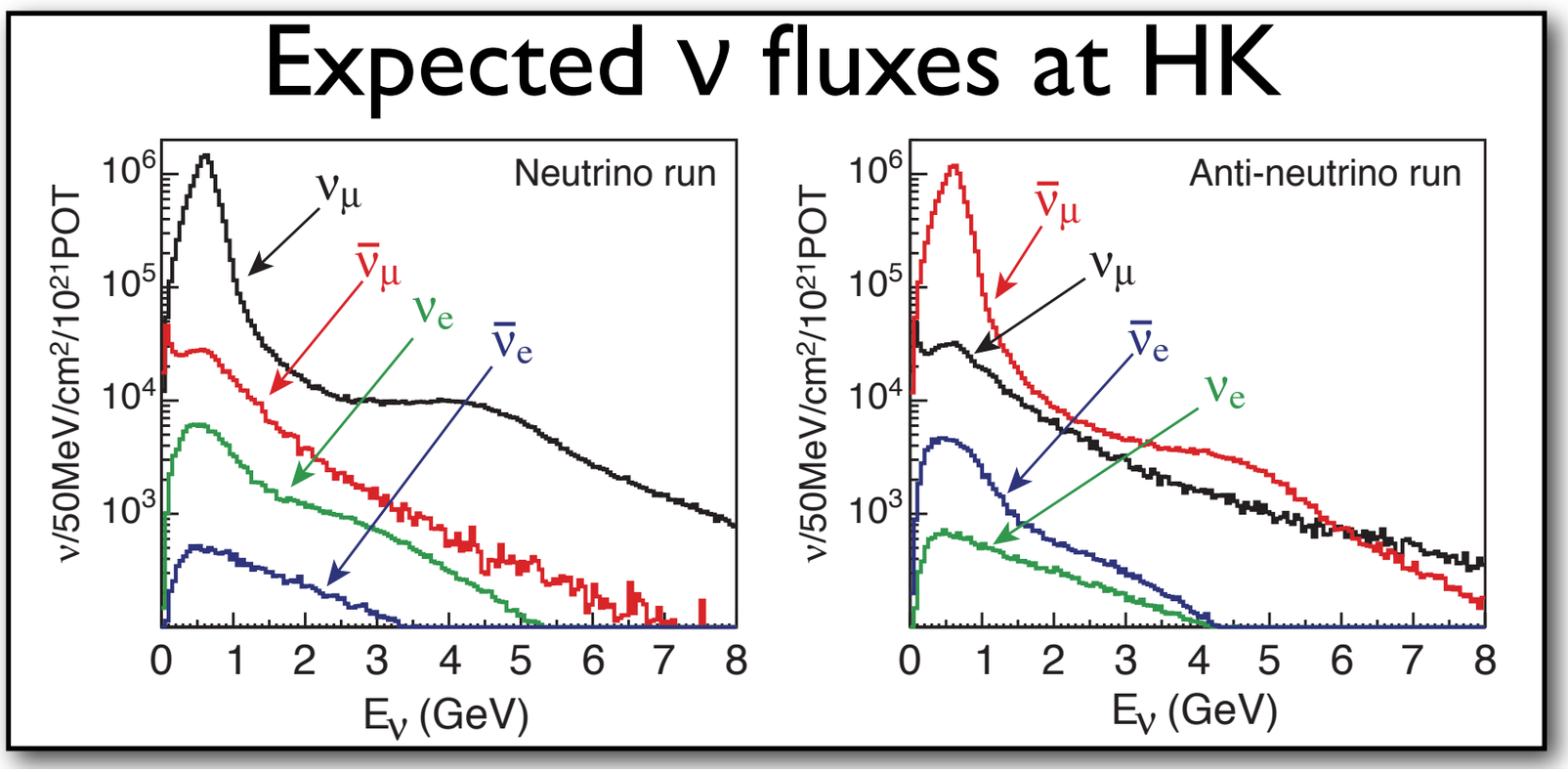
Physics Topics at Hyper-K

Letter of Intent, Hyper-K WG, arXiv:1109.3262

- Hyper-K explores full picture of neutrino oscillation with beam-ν from J-PARC and Atmospheric-ν
  - Discovery reach for neutrino CPV >3σ (5σ) for 74% (55%) of δ region
  - Good chance to discriminate mass hierarchy and θ_{23} octant with >3σ
- ~10 time better sensitivity for nucleon decay
  - $p \rightarrow e^+ \pi^0$: 5.7×10^{34} years lifetime with >3σ for 10 years
- Astrophysical neutrinos
  - 200k ν's from Supernova at Galactic center (10kpc) → time variation & energy meas. with high statistics
  - 200 ν's / day from Solar → ~3σ day/night asymmetry

J-PARC to Hyper-K

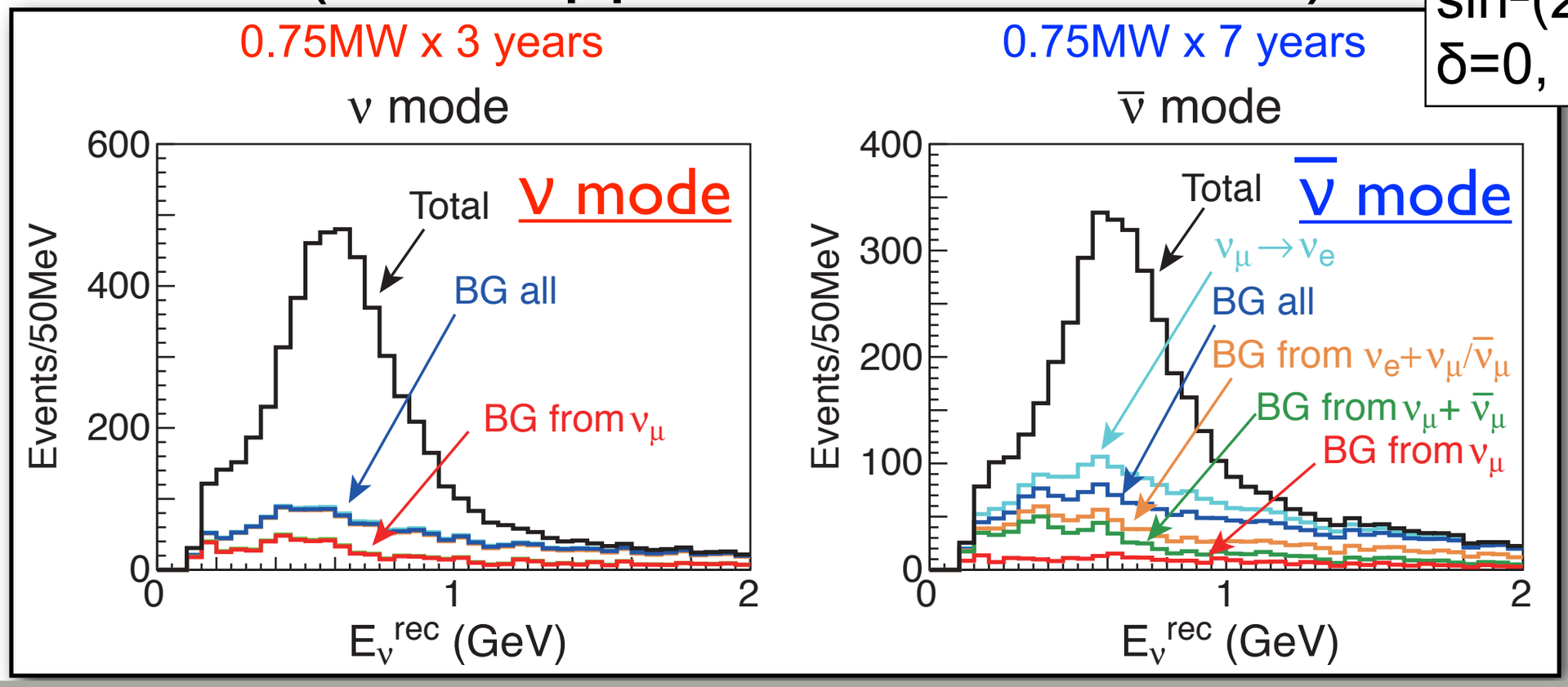
- Relatively short baseline (295km, same as T2K)
  - Less matter effect: good for CP measurement
  - Complementary to other experiments with longer baseline (>1000km)
- 2.5 deg. Off-Axis beam (same as T2K)
- Low energy (~0.6GeV) and narrow band beam
  - Peak around oscillation maximum
- Good match for Water Cherenkov detector



νe CC candidates

Reconstructed ν energy distributions (after applied selection cuts)

$\sin^2(2\theta_{13})=0.1$, $\delta=0$, normal MH

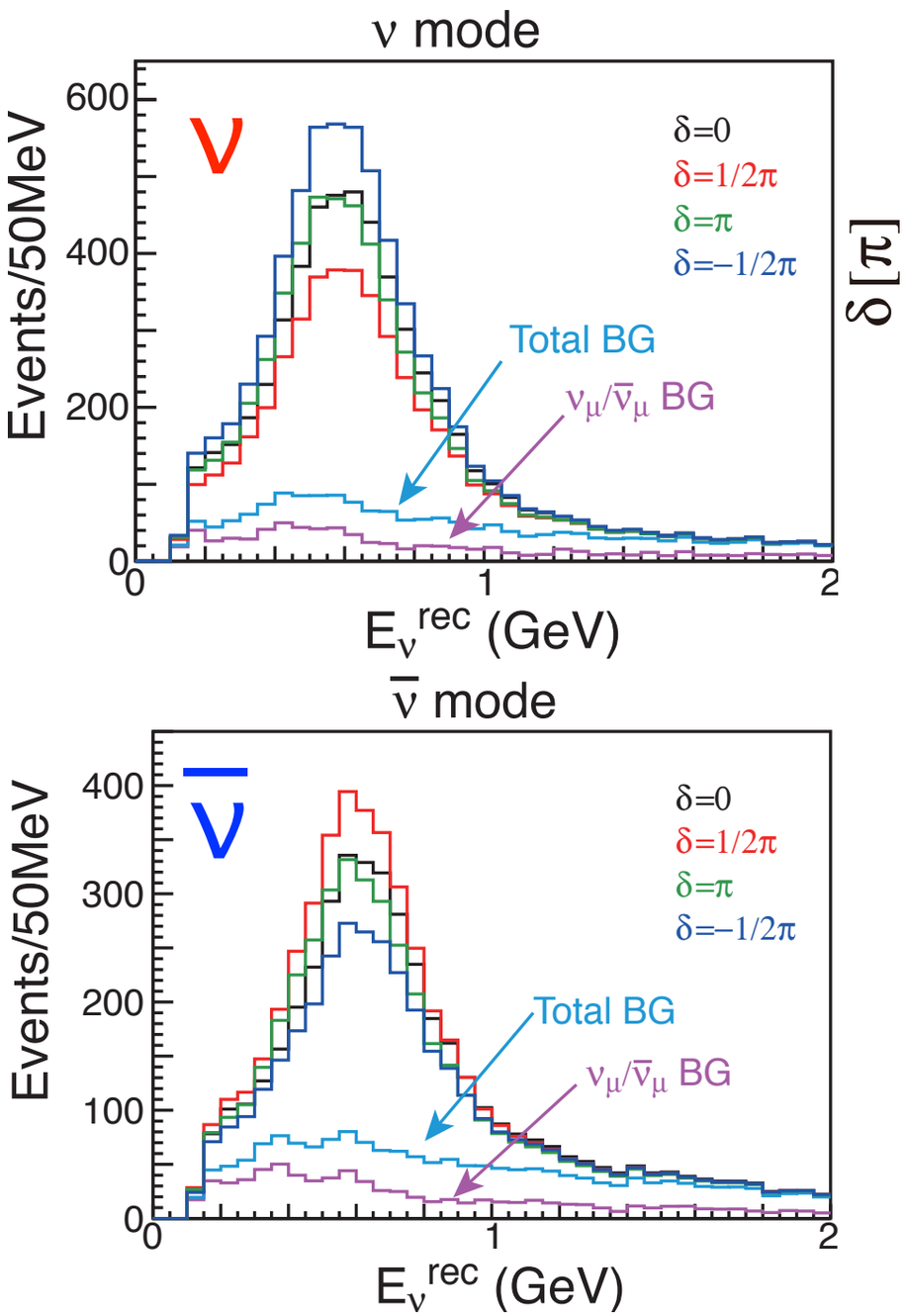


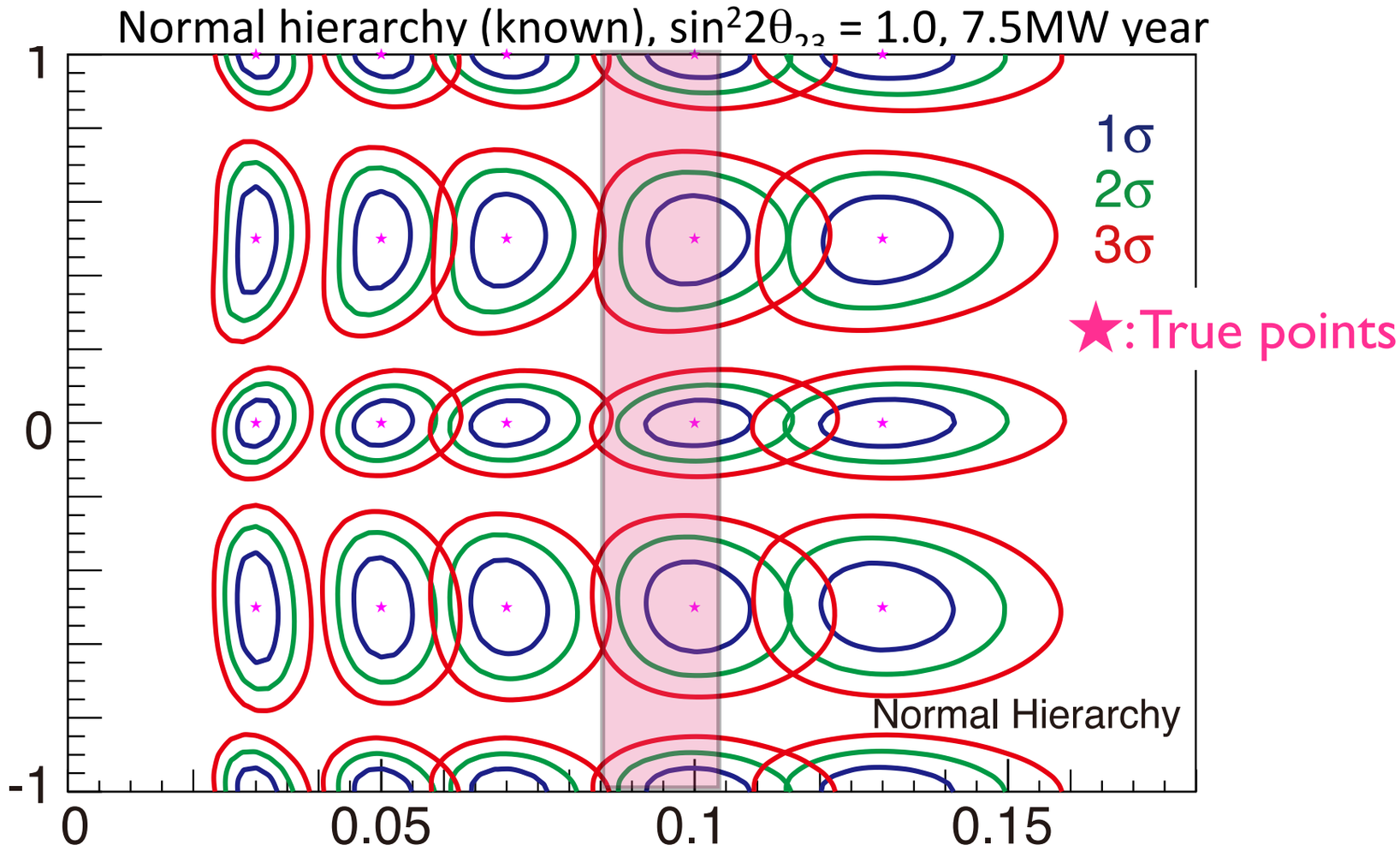
	Signal (νμ→νe CC)	Wrong-sign appearance	Beam νμ/$\bar{\nu}$μ CC	Beam νe/$\bar{\nu}$e CC	NC
ν-mode (0.75kW x 3yrs)	3,560	46	35	880	649
$\bar{\nu}$-mode (0.75kW x 7yrs)	1,959	380	23	878	678

- 2000~3600 signal events in each ν and $\bar{\nu}$ beam
- Major background: beam νe/$\bar{\nu}$e and NC-π^0

Expected sensitivity to CP asymmetry

Rec E_ν dists.
for various δ values





Reactor θ13 exps.(1σ)

Assume 5% syst. errors on signal,
beam νμ Bkg, beam νe Bkg, and ν/ν̄

δ precision (1σ error size)
< 20° at δ=90°
< 10° at δ=0°

Mass hierarchy determination with atmospheric ν

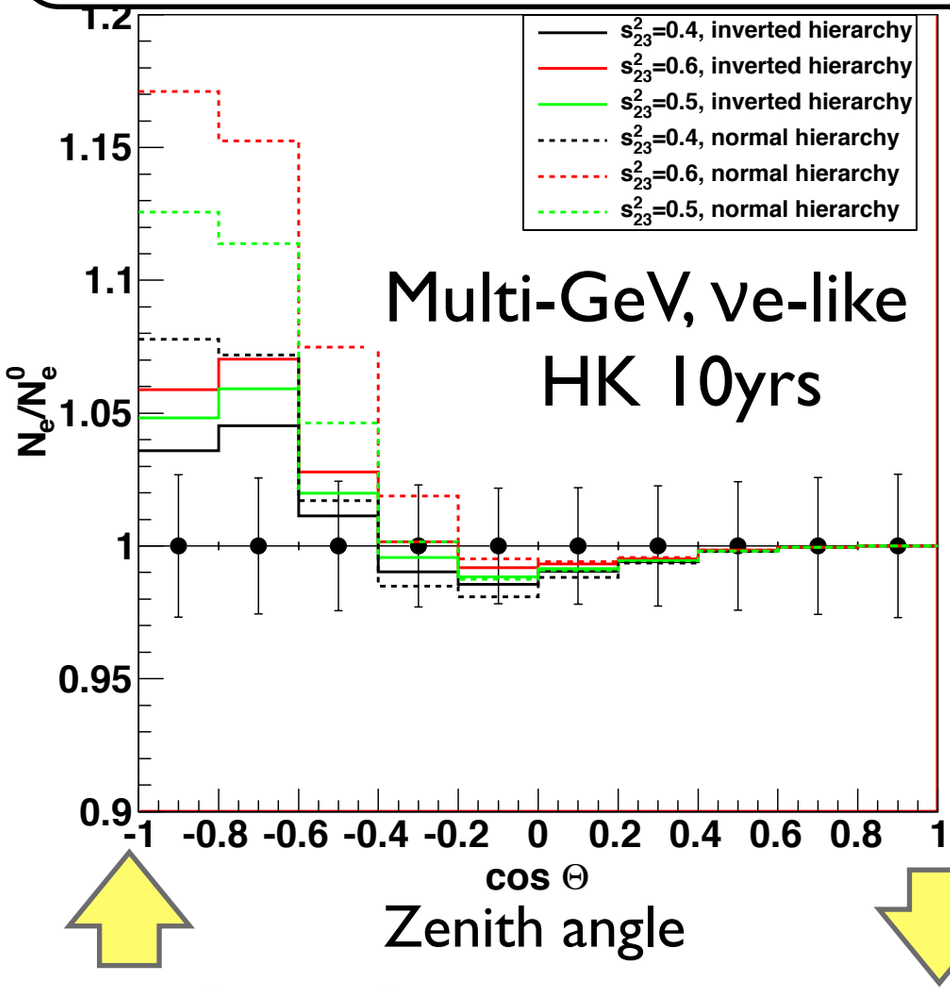
e-like event rate (in zenith angle)

ratio to no-oscillation

$\sin^2\theta_{23}$=0.4 ——— inverted hierarchy

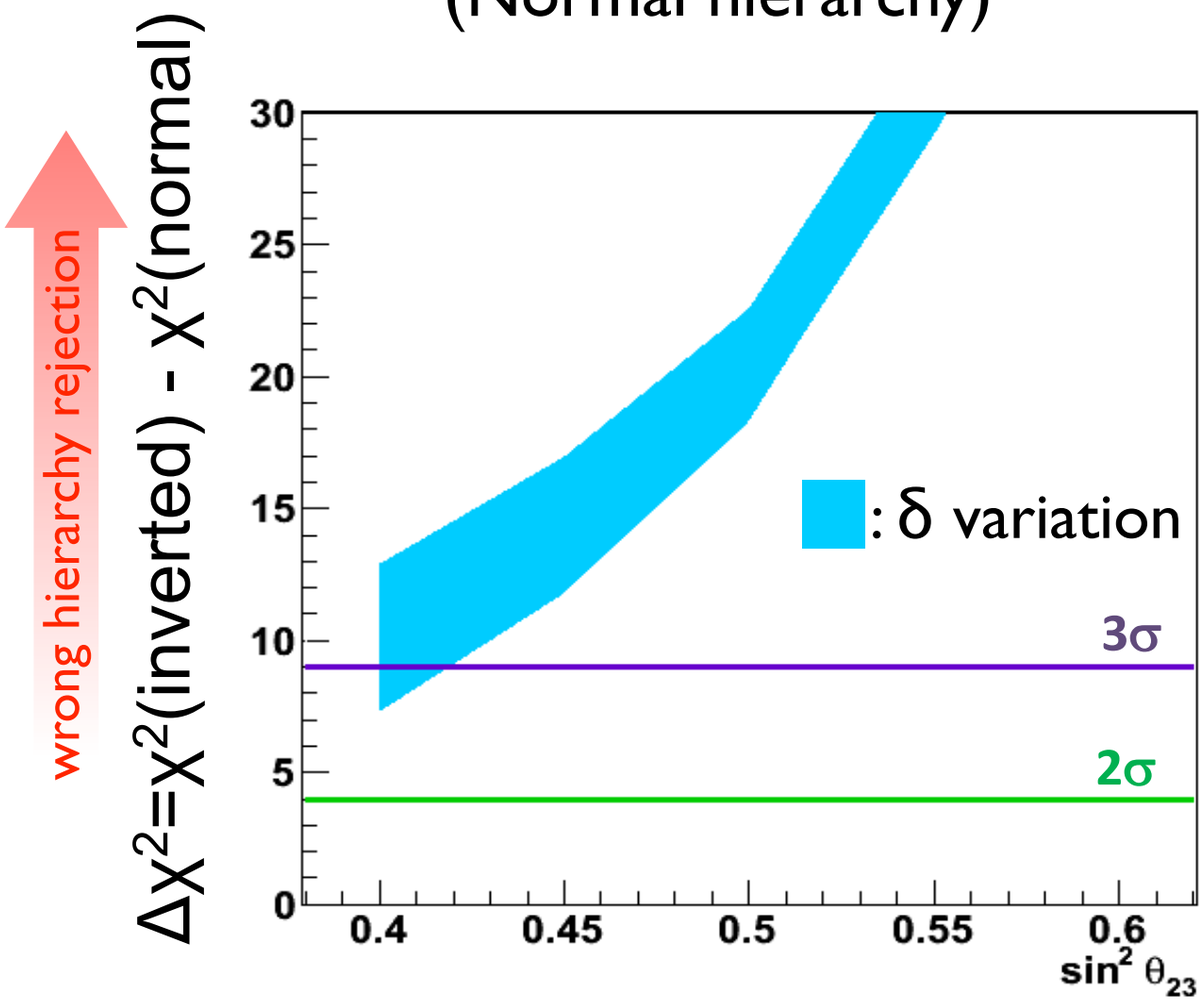
$\sin^2\theta_{23}$=0.5

$\sin^2\theta_{23}$=0.6 - - - - - normal hierarchy



Expected significance MH

(Normal hierarchy)

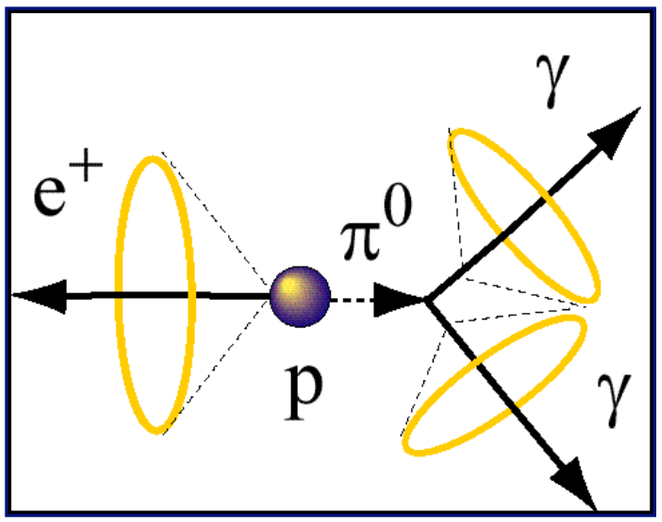


3σ determination with <10 years exposure

(sensitivity depends on θ_{23} and δ)

Nucleon decay search

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



$e^+\pi^0$ selection

Invariant mass of p
Momentum balance

- 2 or 3 e-like rings
- No decay-e
- $85 < M_{\pi^0} < 185$ MeV/c^2 (3ring)
- $800 < M_p < 1050$ MeV/c^2
- $p_{tot} < 250$MeV/c

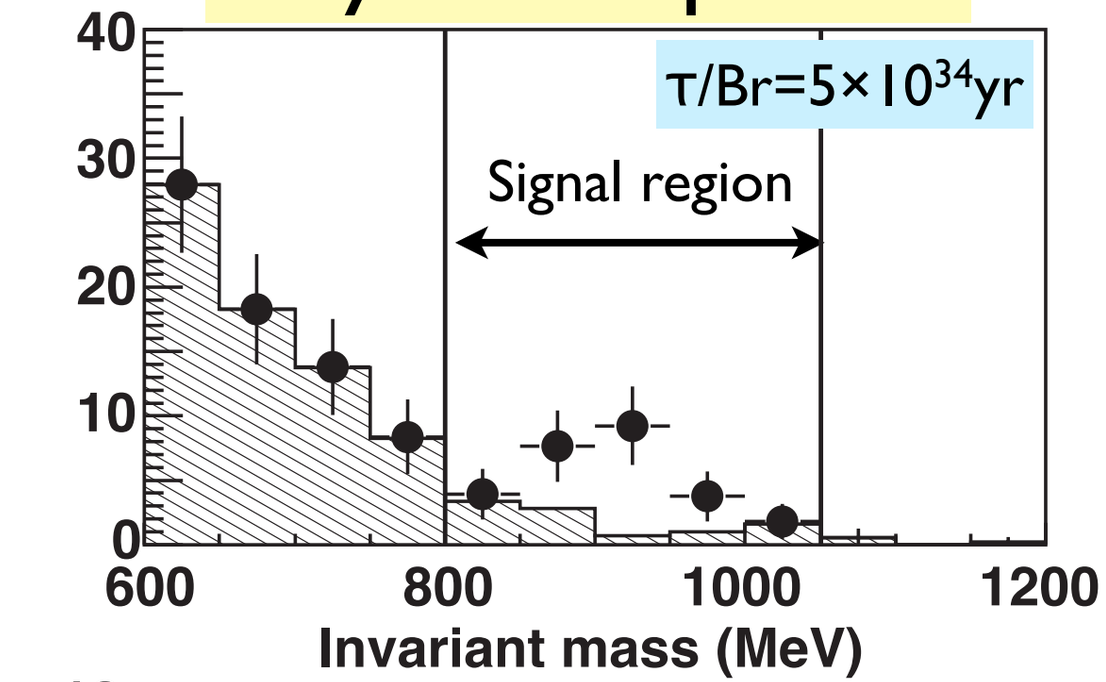
Efficiency 45%
(87% for free proton)

(Inefficiency due to π^0 interaction in nucleus)

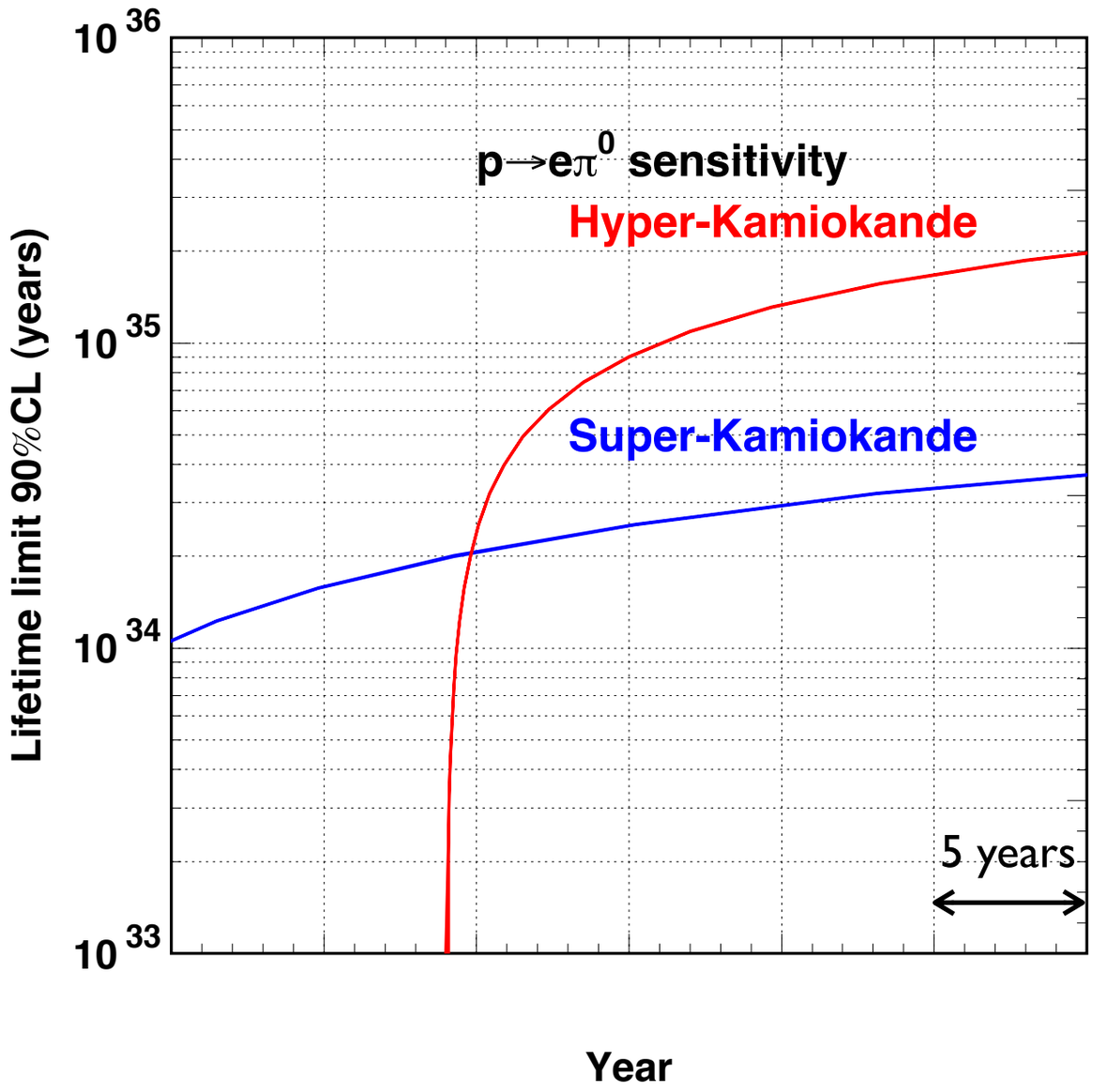
2/10 free protons in H_2O

Hyper-K $p \rightarrow e^+\pi^0$ sensitivity

10 years exposure



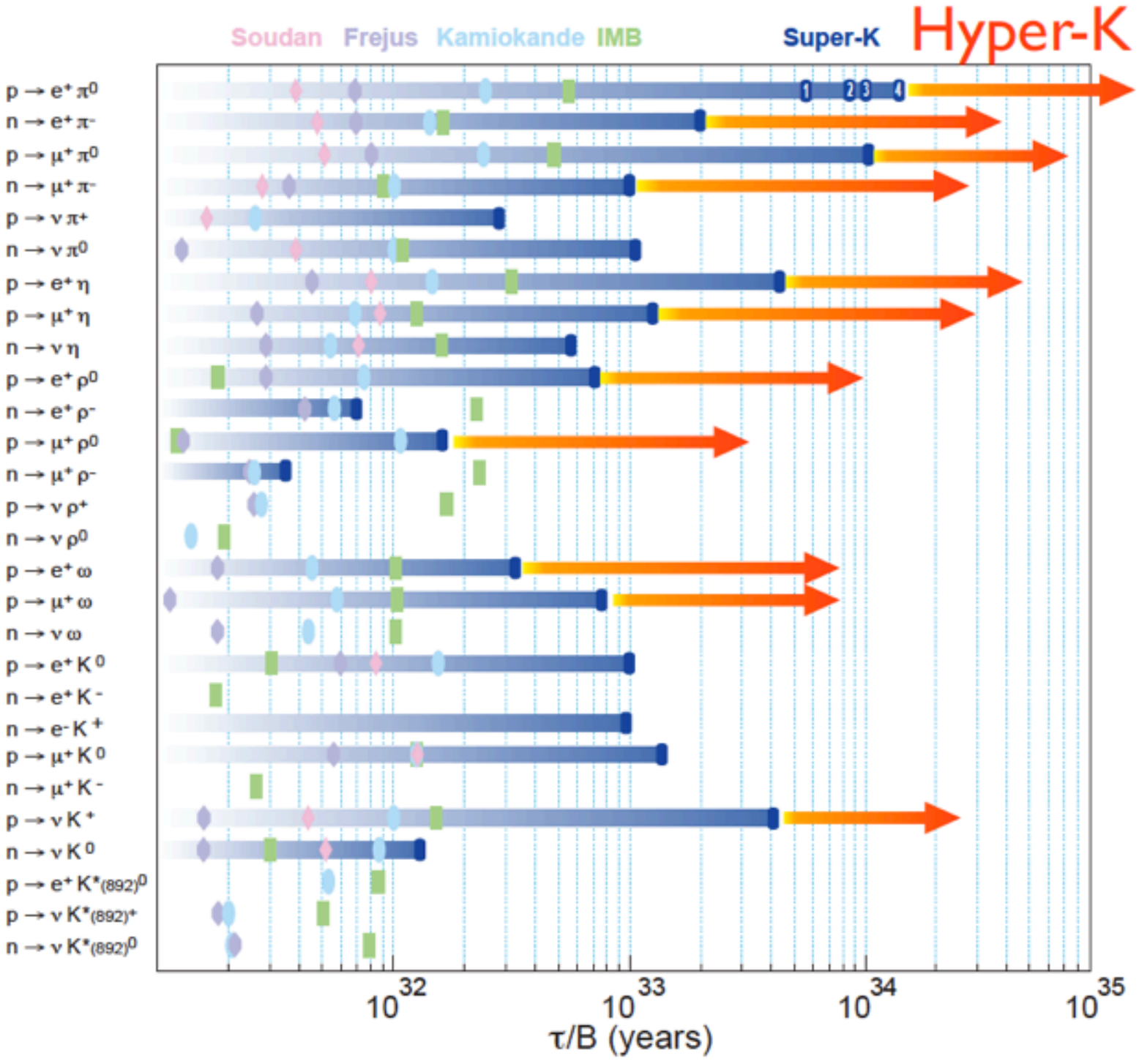
Assume 44% uncertainties on background (same as SK)



Will surpass SK limit in ~1 year.

90% limit with 10 years: 1.3×10^{35}yrs

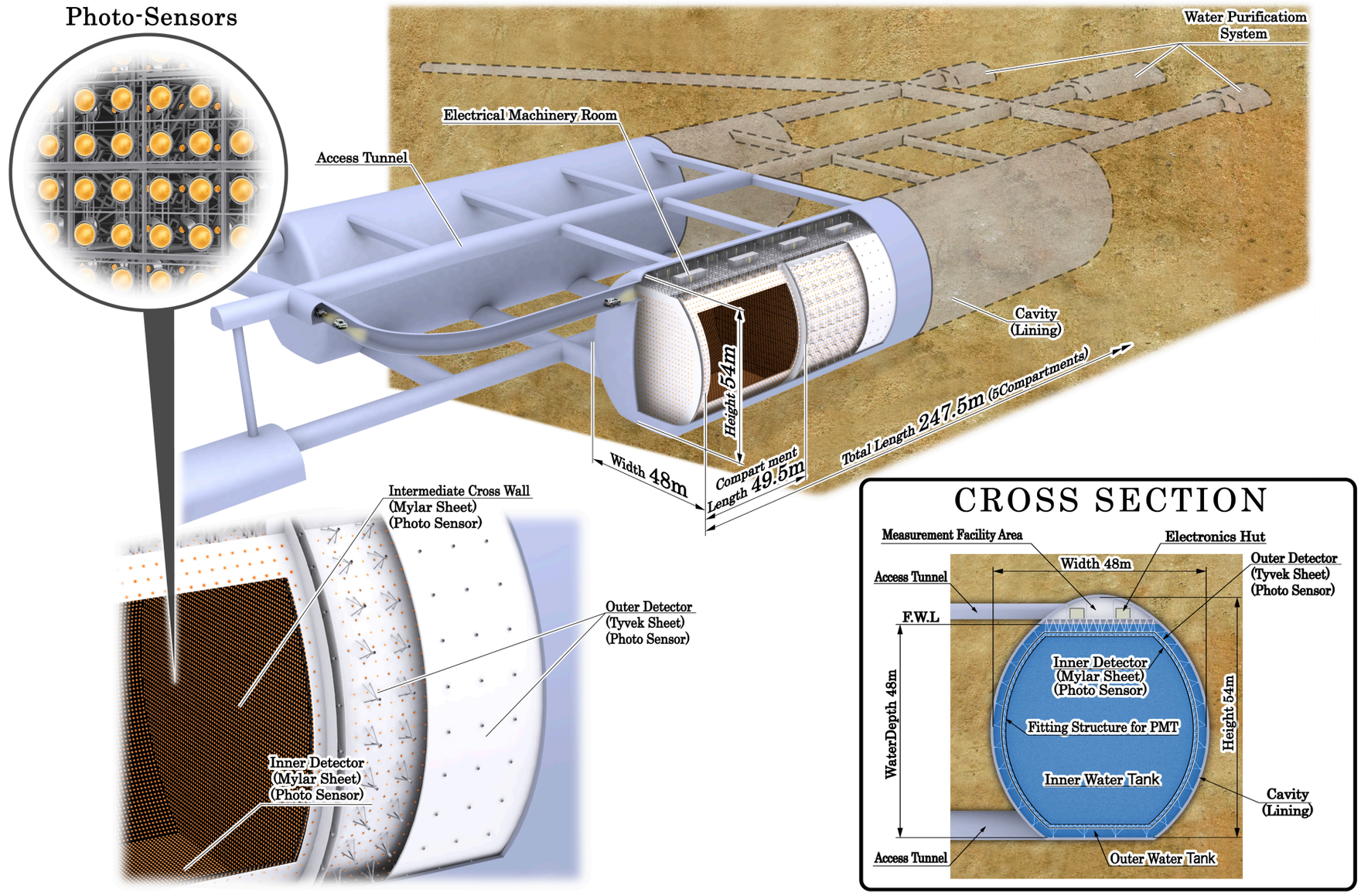
Search for nucleon decays



~10 times higher sensitivity than current SK limits w/ HK 10 yrs operation

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

Schematic View of the Hyper-Kamiokande



CROSS SECTION

Project Status

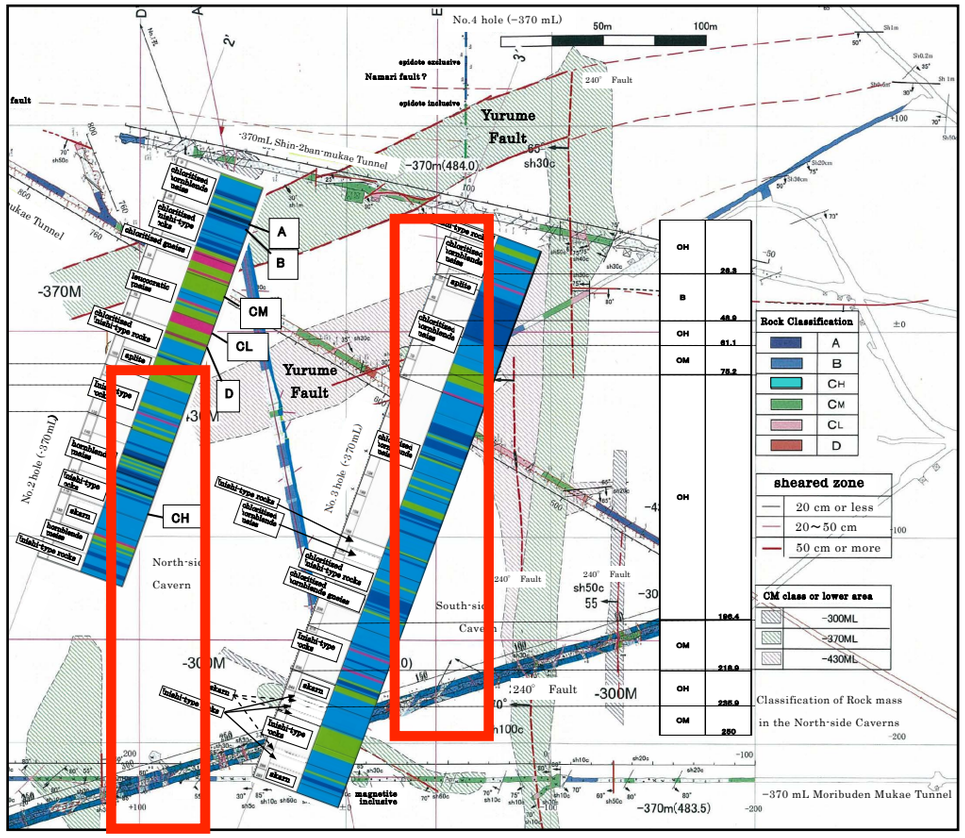
International Hyper-K Meetings

- Hyper-K is opened to the international community
- Three Hyper-K Open meetings held so far
  - Aug. 2012, Jan. 2013, and Jul. 2013
  - ~100 participants in each meeting (~50% from abroad)
- Formed International Working Groups

Next meeting: Jan. 27-28, 2014 at Kavli IPMU, Kashiwa, JAPAN

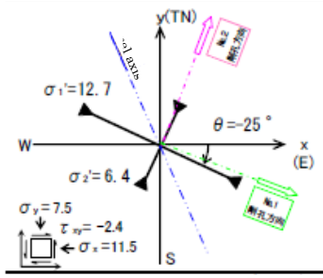
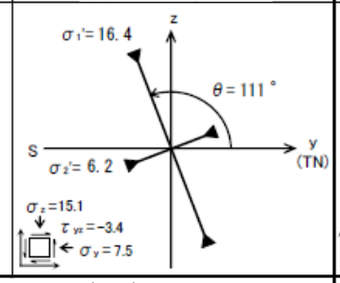
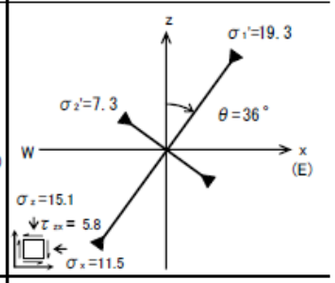
Geological survey & Cavern stability

Rock mass characterization

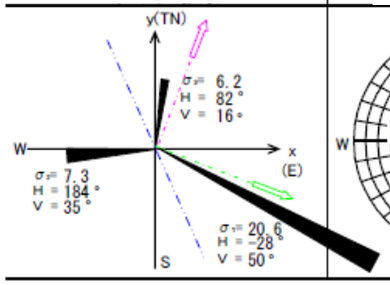
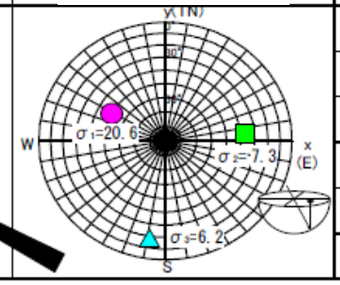


Initial stress (in-situ meas.)

In-plane principal stress (MPa)

Horizontal plane (x-y plane)	North-south section (y-z plane)	East-west section (z-x plane)
		

3D principal stress (MPa)

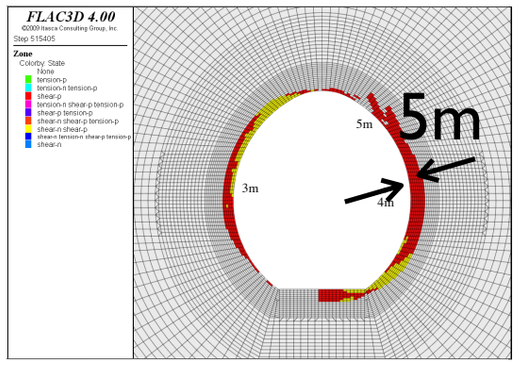
Horizontal plane projection	Schmidt Net: Lower Hemisphere Projection
	

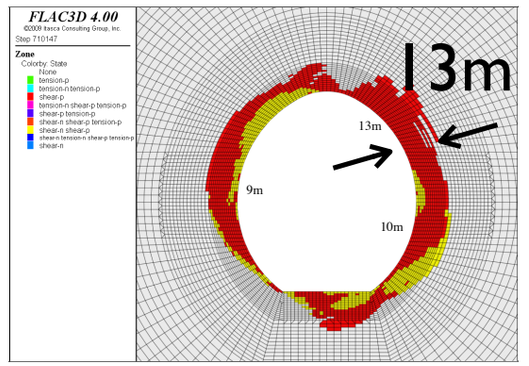
Six Stress Components (MPa)

σ_x	11.5
σ_y	7.5
σ_z	15.1
τ_{xy}	−2.4
τ_{yz}	−3.4
τ_{zx}	5.8

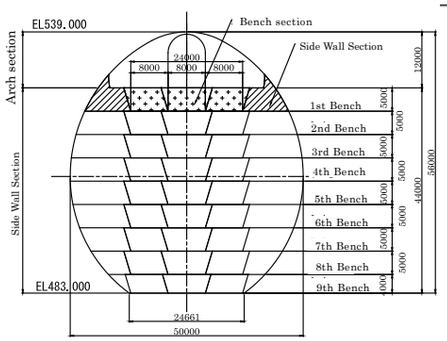
- Detailed geological surveys at the candidates site vicinity
- Cavern stability and its supporting method has been studied
- Confirmed that the HK cavern can be constructed with the existing techniques

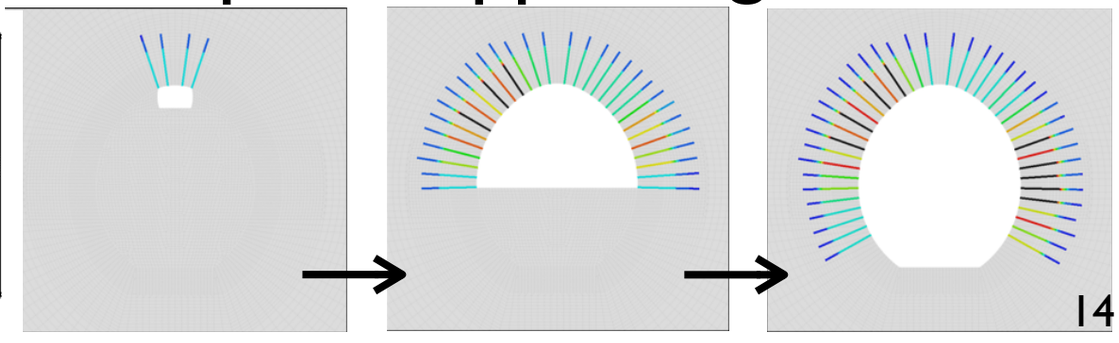
Cavern stability



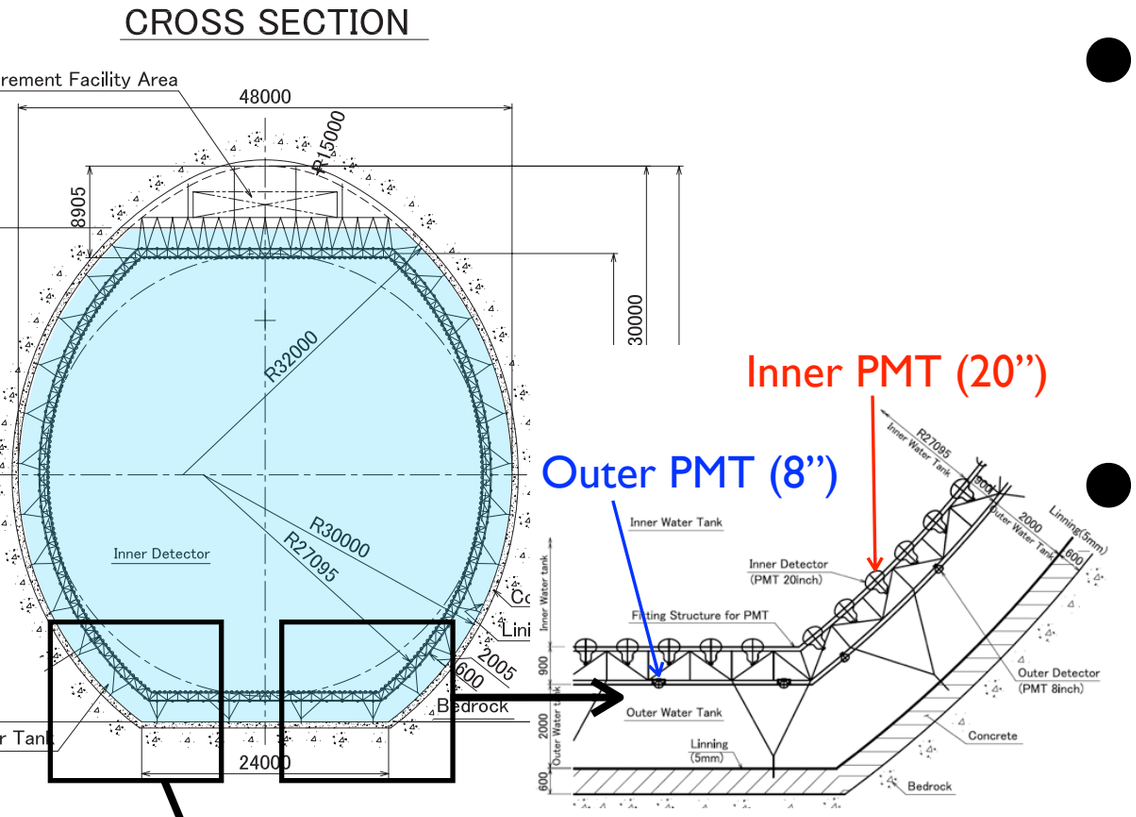


Excavation steps & supporting method



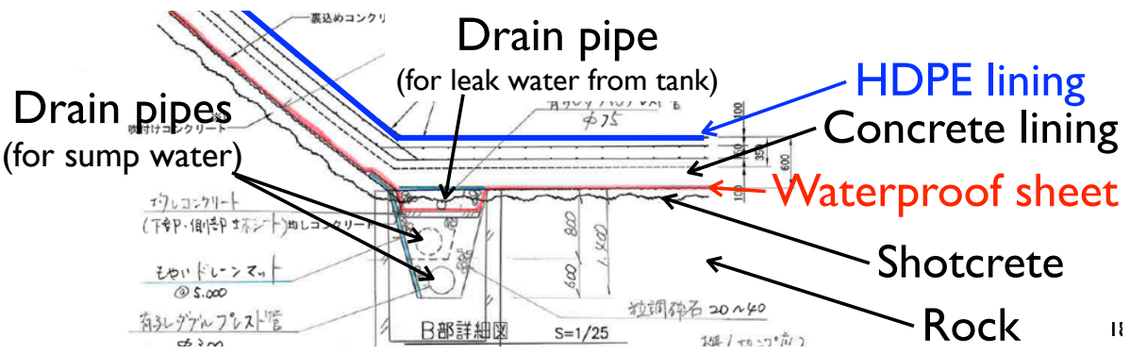


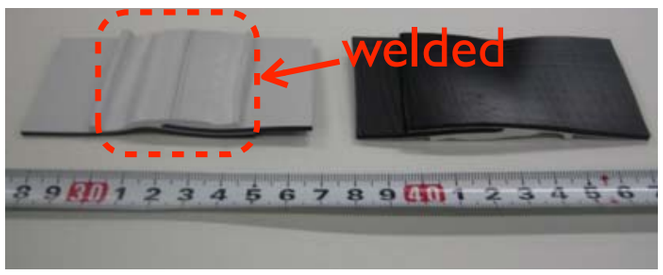
Tank and photo-sensor support



- Baseline designs of the water containment system and photo-sensor support are ready
- Build a prototype detector (1kt)
- Funding request approved

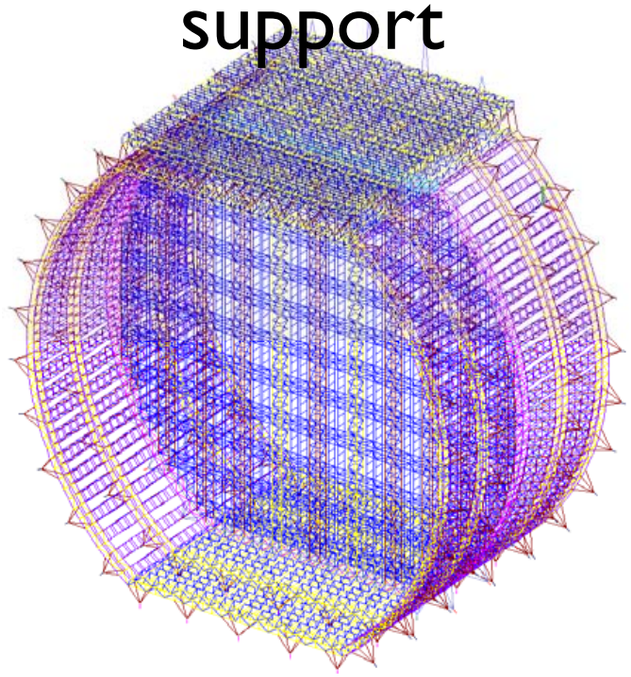
Lining & drain system



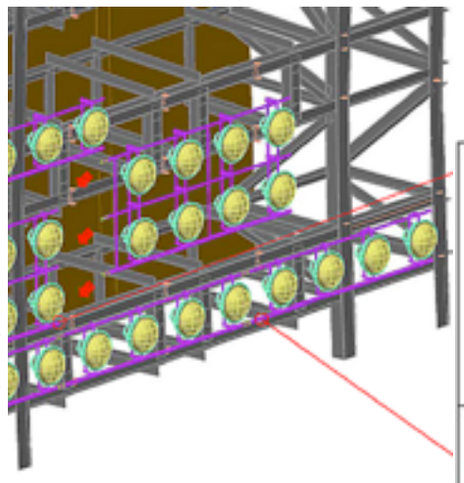


Polyethylene sheet

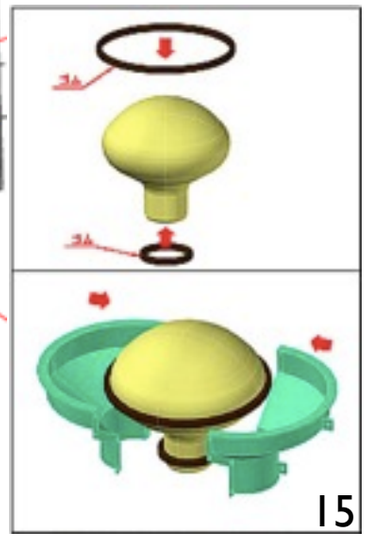
Photo-sensor support



Mounting Photo-sensor



Housing

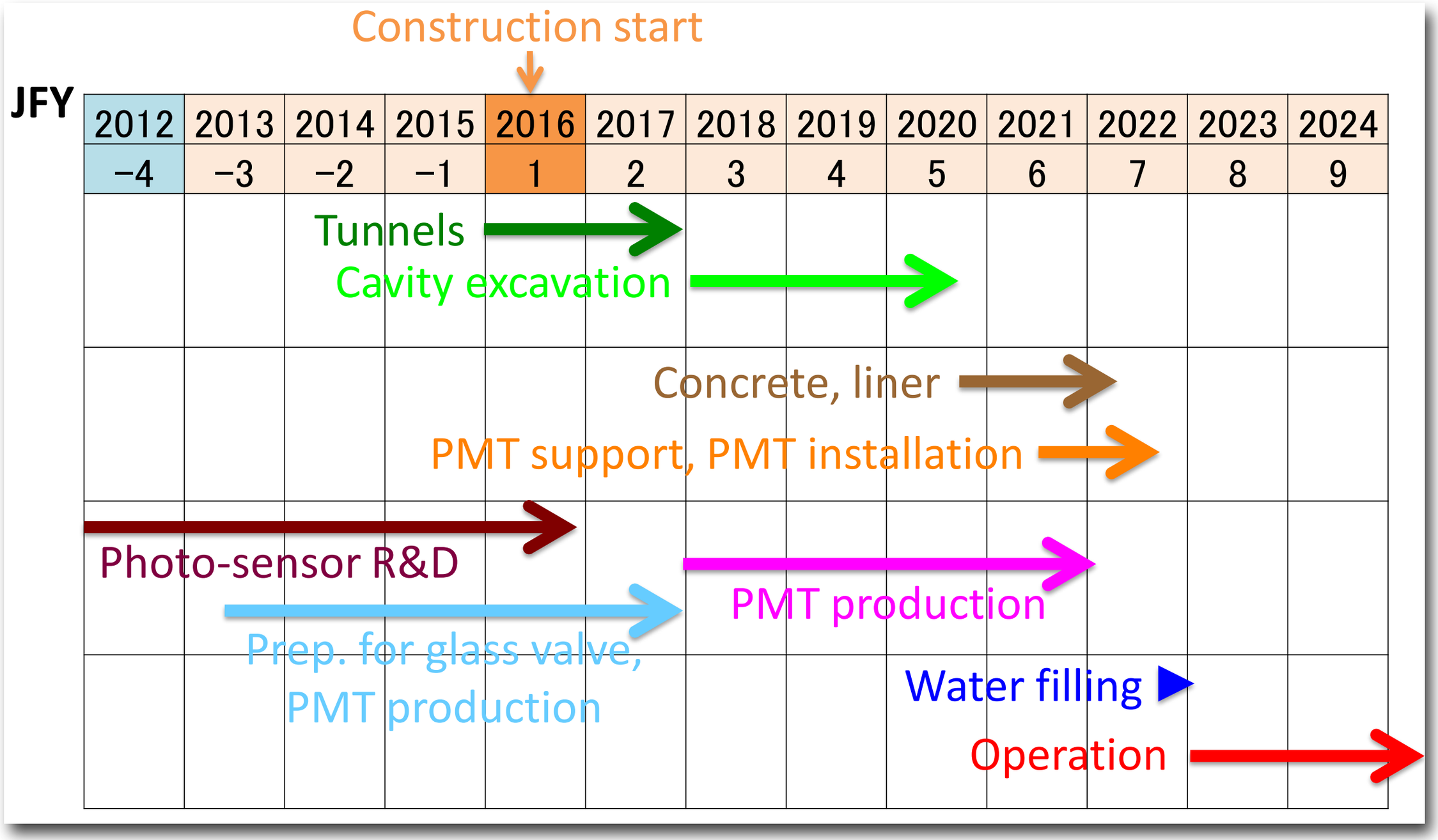


Summary

- Hyper-K covers wide range of physics
  - Neutrino oscillation with beam-ν & atmospheric-ν
  - Search for nucleon decays
  - Astrophysical neutrinos, etc
- Detector baseline design ready
  - Cavern, tank, and photo-sensor support
  - Design optimization & R&D/prototyping projects
    - Several R&Ds are progressing in international working groups: photo-sensors, water system, calibration system, etc.
    - Build 1kton prototype detector to prove the design: Funding request approved.
- Join us and build the detector!

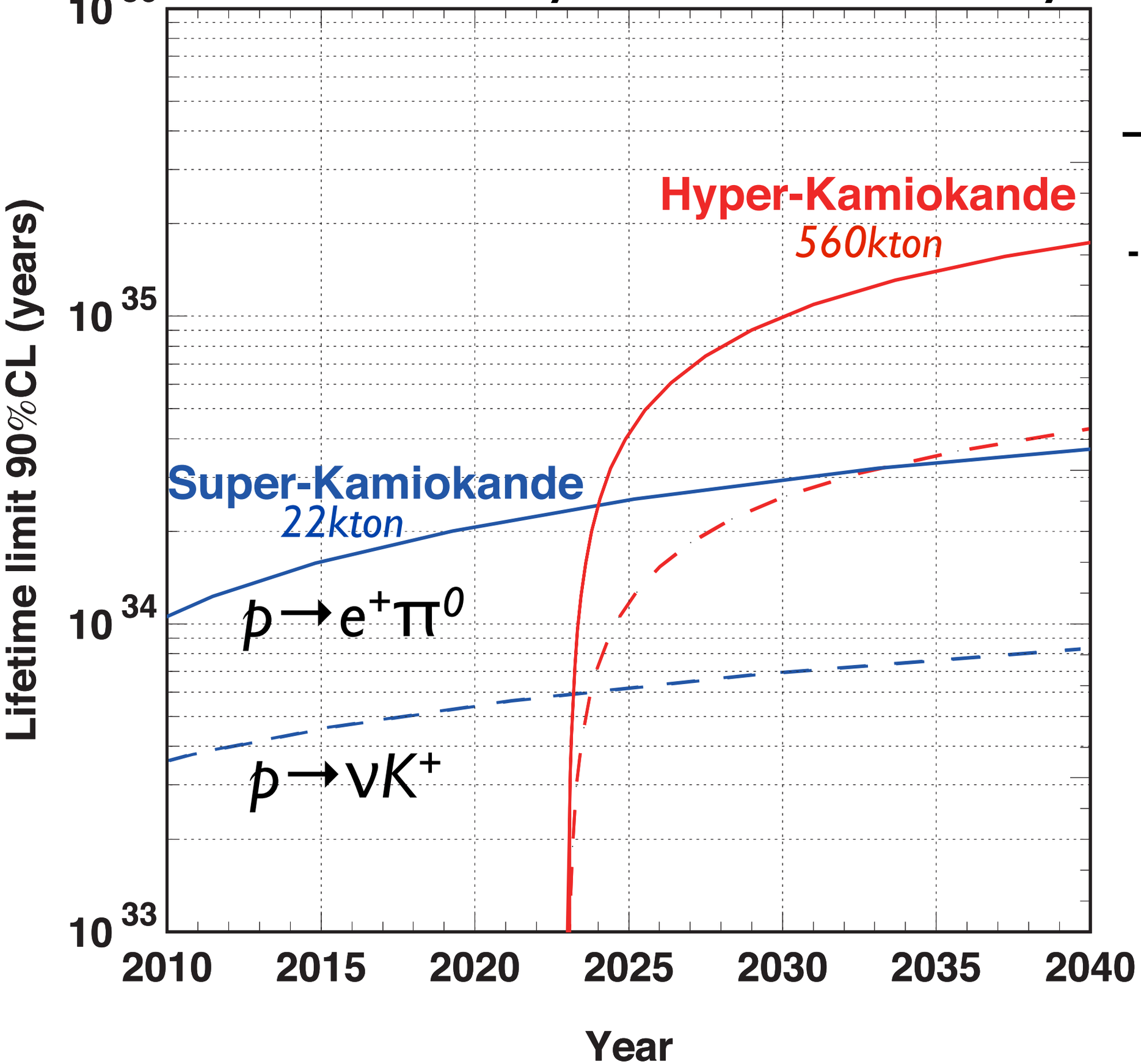
Supplements

Project Schedule



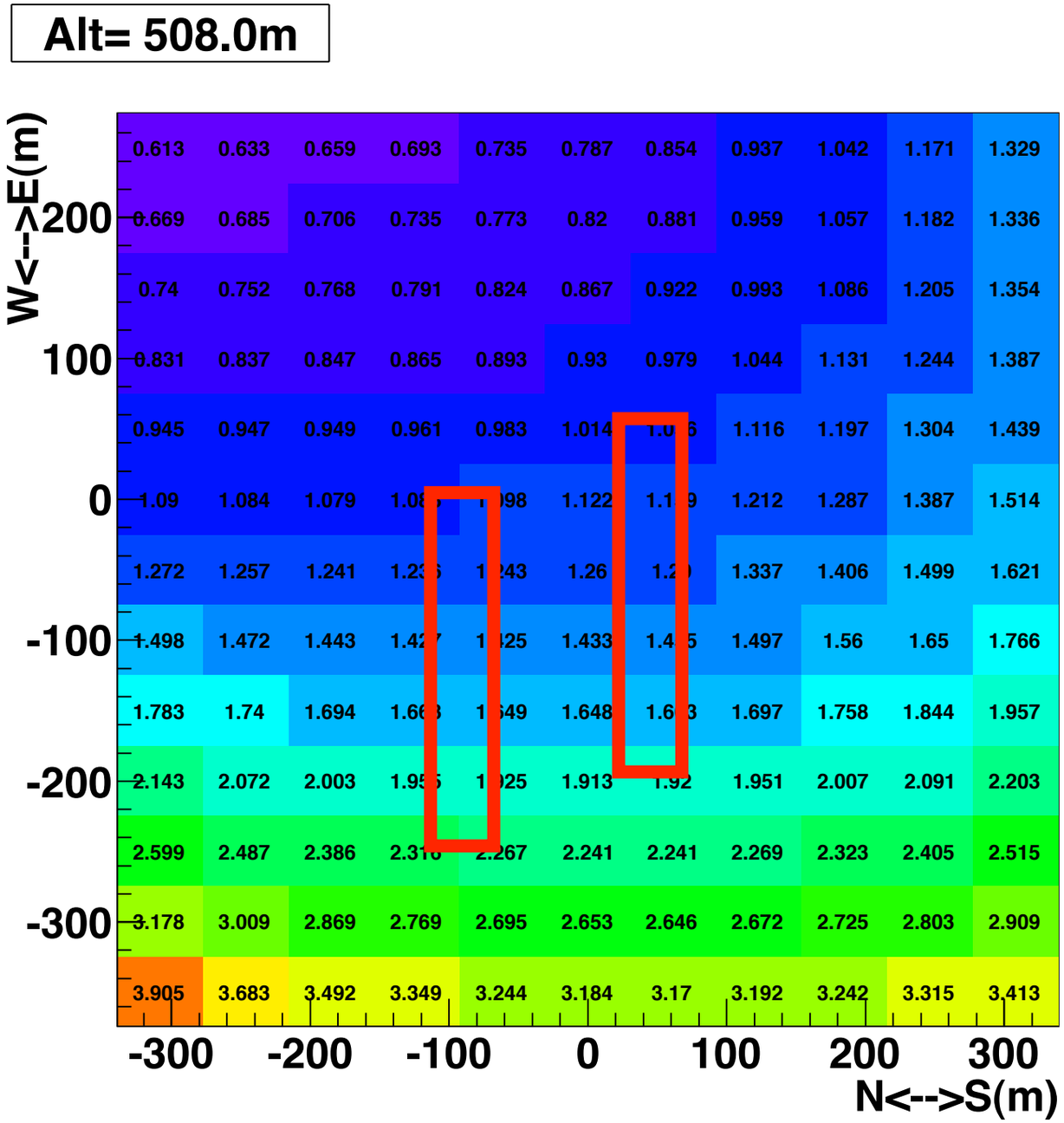
- Cavern construction: ~5 years
- Tank construction and photo-sensor installation: ~2 years

Nucleon Decay 90% CL sensitivity



Muon rate at candidate site

Muon rates at HK tank floor level in (cm^{-2} sec^{-1})



- Estimated cosmic-ray muon rate
  - HK candidate site (1755m.w.e.): 1.0~2.3 x 10^{-6} /cm^2/sec
    - cf. SK location (2700m.w.e): ~0.14 x 10^{-6} /cm^2/sec

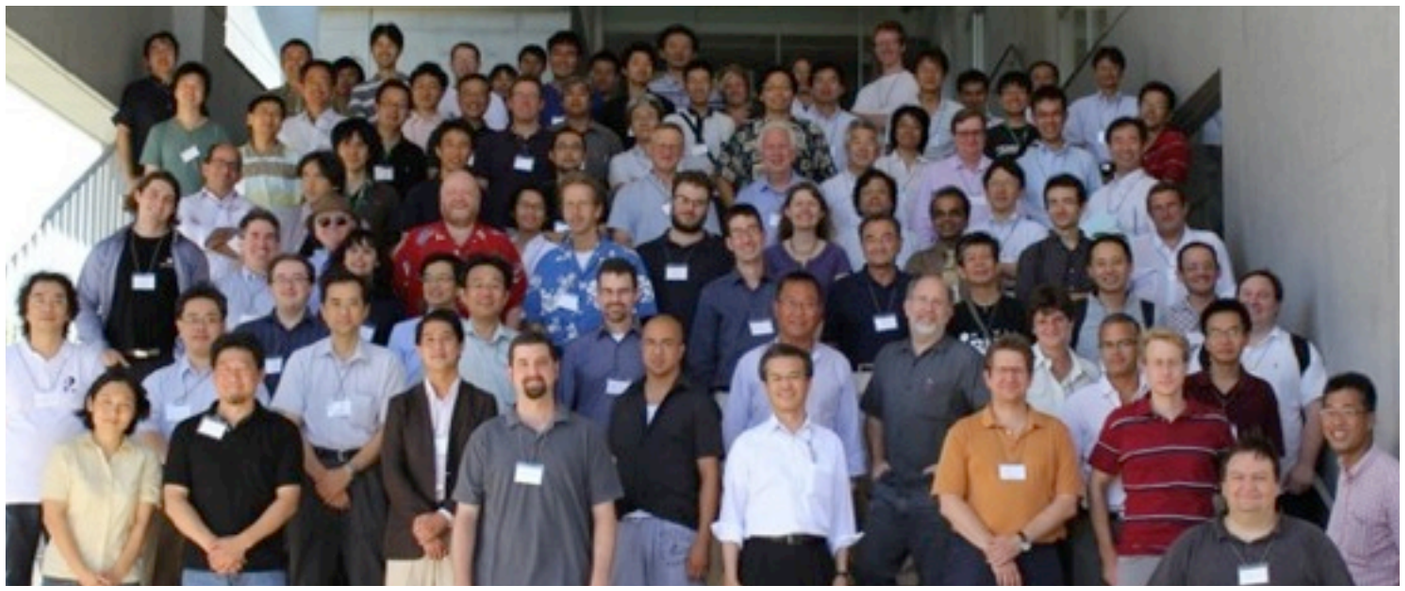
T2K systematic errors and toward HK

Error on # of events	w/o ND constrain	w/ ND constrain
Flux and ν cross section	24.4%	5.7%
Other ν xsec (constrained by other exps)	7.4%	
Final State Int. & secondary int	2.4%	
SK detector	3.1%	
Total	25.9%	10.3%

- HK sensitivity studies assumed 5% syst. errors on each item
- Flux, cross section, and detector uncertainties almost achieved HK goal
- On-going x-sec meas. in T2K ND provide further improvements

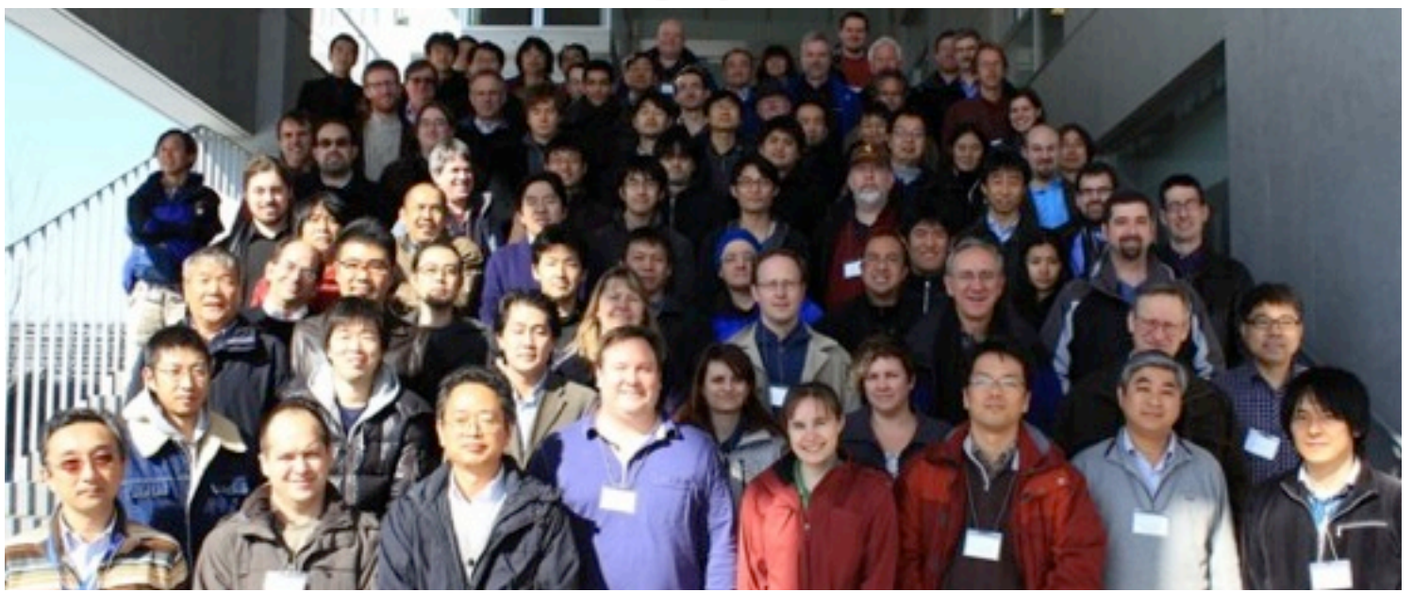
International Hyper-K Meetings

First meeting: Aug. 23-24, 2012



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

Second meeting: Jan. 14-15, 2013



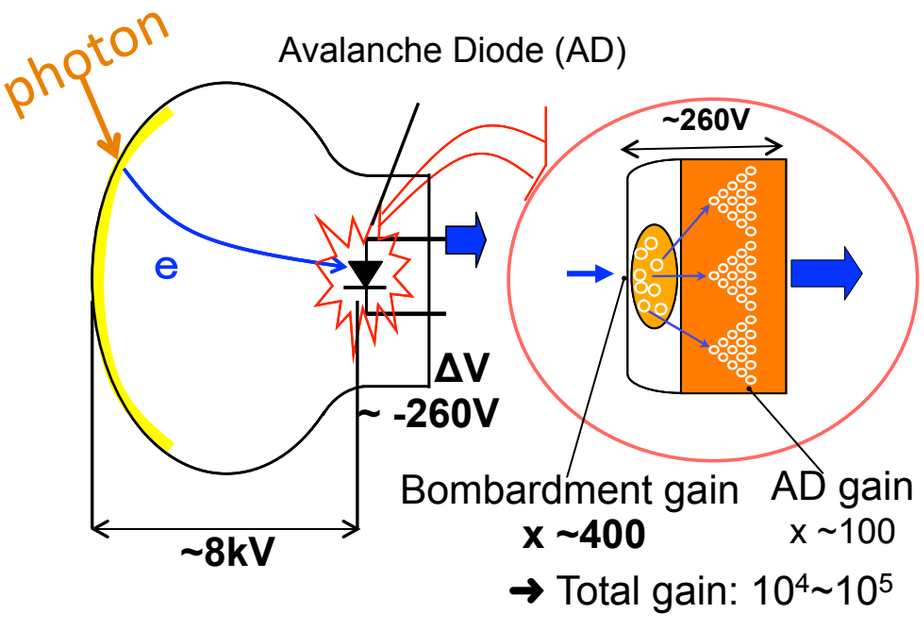
http://indico.ipmu.jp/indico/conferenceTimeTable.py?confId=10

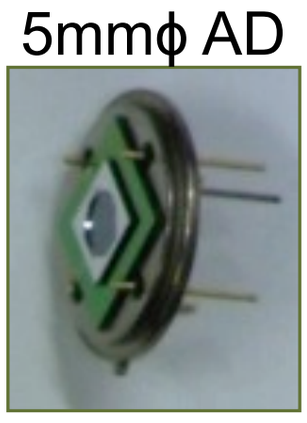
- Hyper-K is opened to the international community
- Three Hyper-K Open meetings
  - ~100 participants (~50% from abroad)
- Formed International Working Group
- Current members are from: Japan, Canada, Spain, Switzerland, Russia, U.K., and U.S.

3rd meeting: June 21-22, 2013 ➜ http://indico.ipmu.jp/indico/conferenceDisplay.py?confId=23

Hybrid Photo-detector

- Hybrid Photo-detector (HPD) is a new type of photo-sensor with an avalanche diode, replacing metal dynode.
- HPD expected to have better performances than standard PMTs:
  - Timing resolution: shorter e-multiplication process
  - Collection efficiency: higher operating voltage (~10kV)
  - Lower cost: mechanically simple

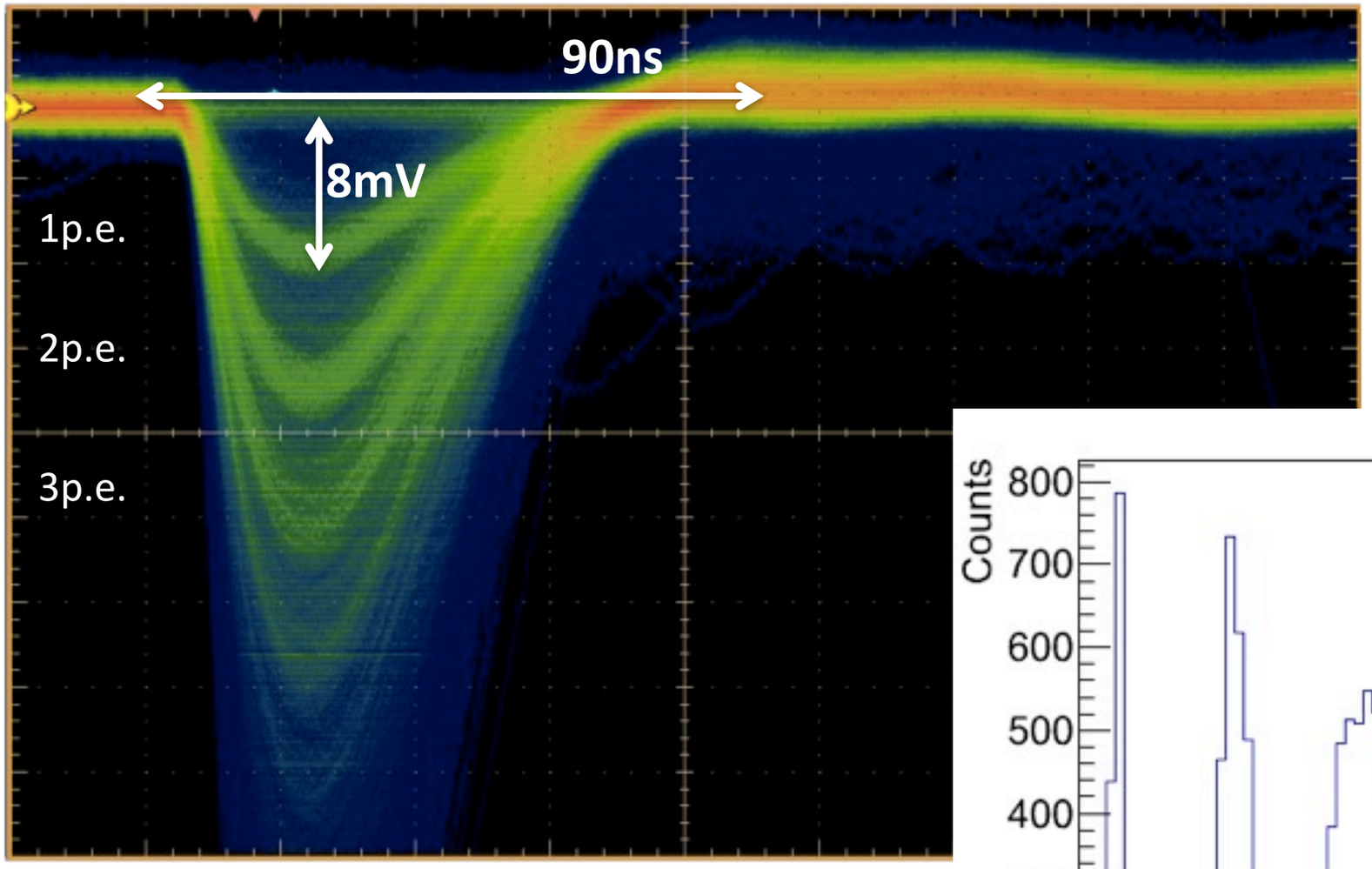




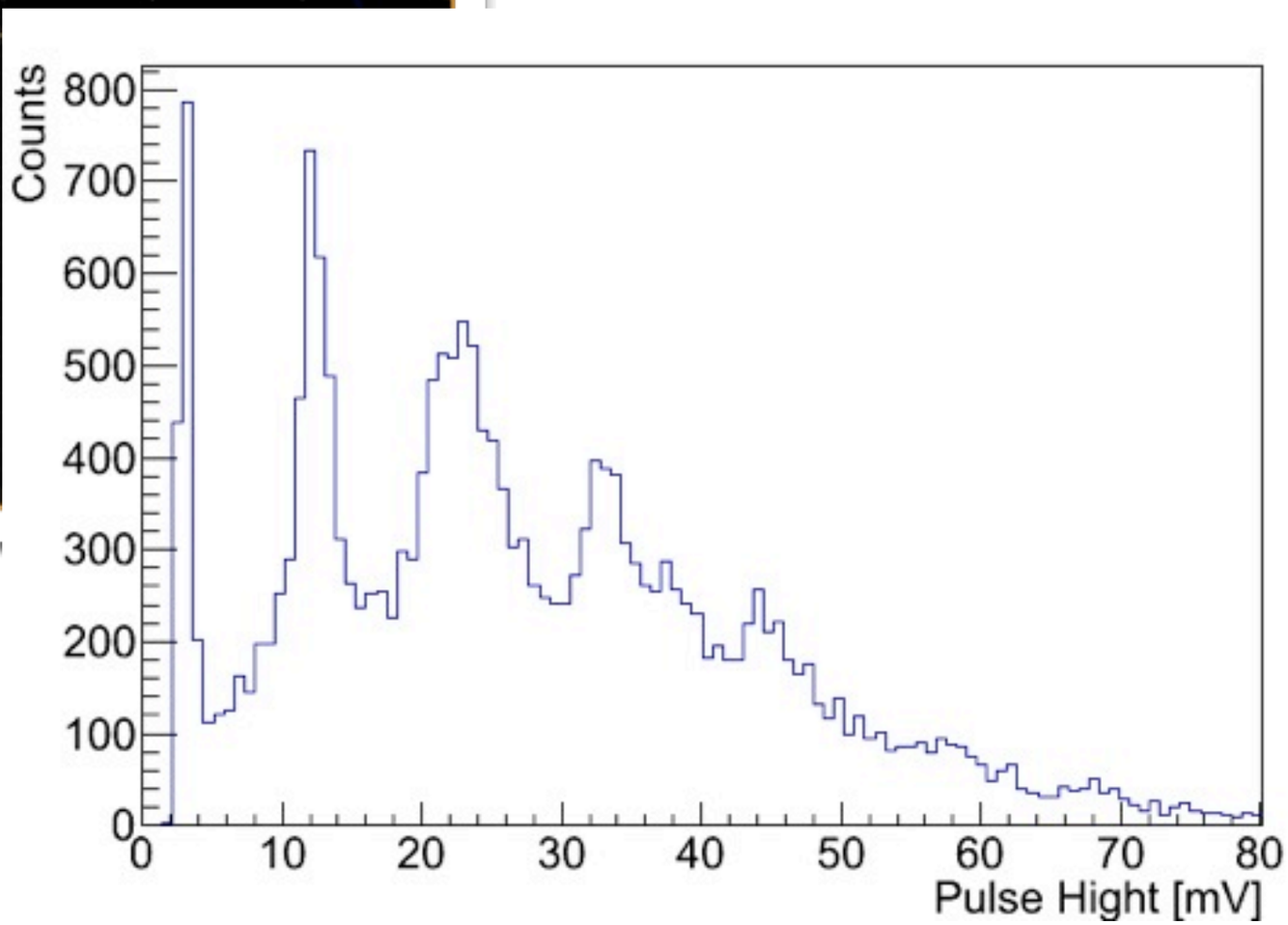
	8"HPD	20"HPD	20"PMT
HV	~8kV	~8kV	~2kV
Gain	10^4-10^5	10^4-10^5	~10^7
TTS(ns)	0.6	1.1(*)	2.2
C.E.	~97%	~95%(*)	~70%
AD dia.	5mm	20mm	-

(*) expectation from field calculation. preliminary value

Signal from HPD



8 inch HPD prototype



Photon counting capability

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/conferenceDisplay.py?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 (re-)submitted a proposal 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.

Budget request

- Budget request for Hyper-K is not well defined yet until the SCJ master plan and/or the MEXT roadmap will be fixed.
- We submitted the proposal to the Science Council of Japan in March 2013.
  - Hyper-K (far detector) construction and operation cost.
  - J-PARC operation w/ ~1MW and a near detector construction in the same package.
  - About 200 projects will be pre-selected. 25~30 projects will be selected as important large projects → **"SCJ Mater plan of large scale research projects"**
  - This results will be important inputs to **"Roadmap of large scale research projects" to be released by MEXT in 2015.**
- Submitted a proposal of R&D (photo-sensor etc) to Grant-in-Aid ($2.3M/5year).