Hyper-Kamiokande

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for Hyper-Kamiokande proto-collaboration

TAUP2017 at Sudbury, July 26, 2017

Hyper-K talks at TAUP2017

- "Hyper-Kamiokande"
  - Hide-Kazu TANAKA (this talk)

- "The 2nd Hyper-Kamiokande detector in Korea"
  - Seon-Hee Seo (next talk)

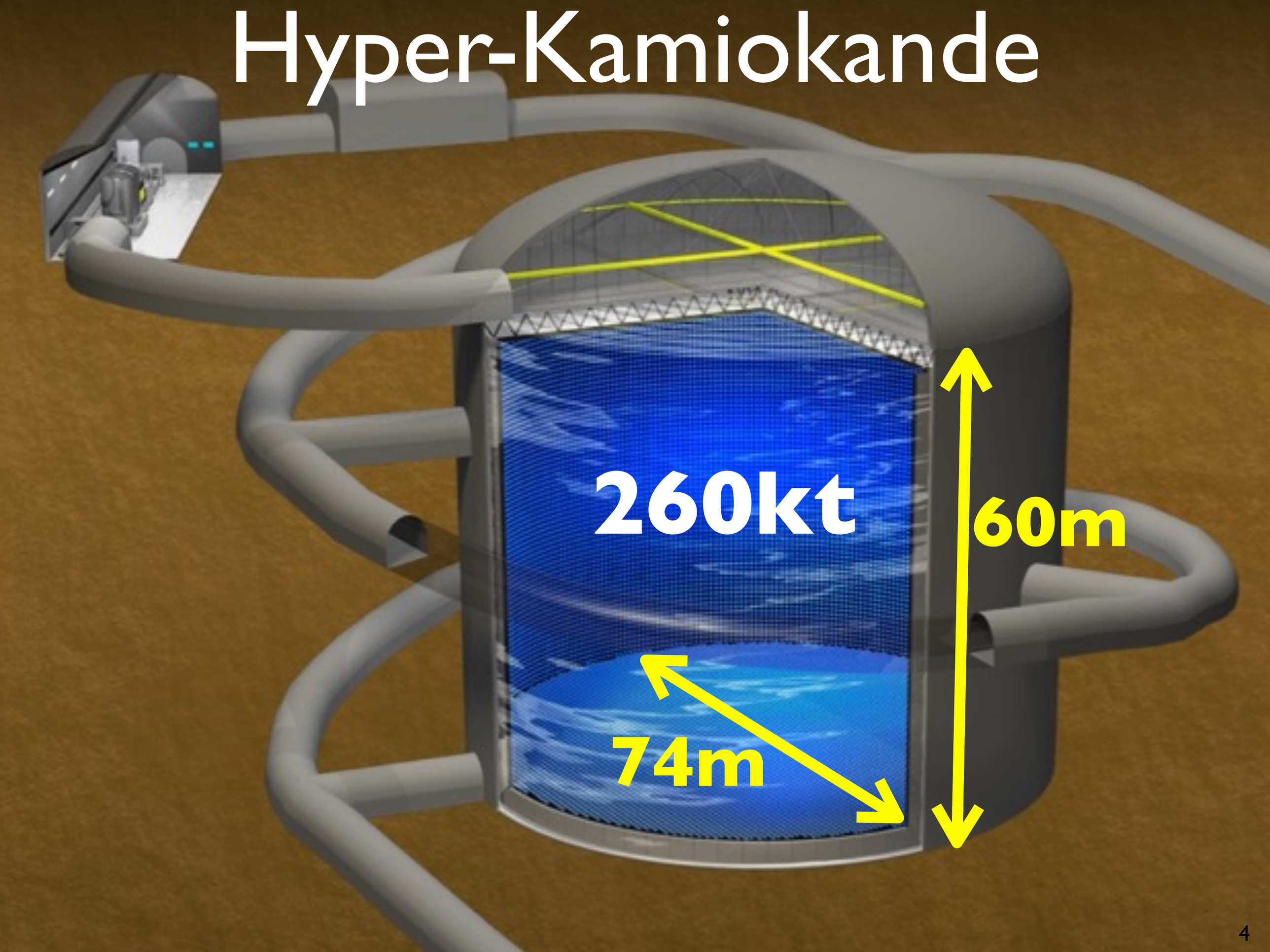
- "The Hyper-K near detector program"
  - Jeanne Wilson (after the next talk)

- "Astroparticle physics in Hyper-Kamiokande"
  - Takatomi YANO (next session)

Hyper-K proto-collaboration

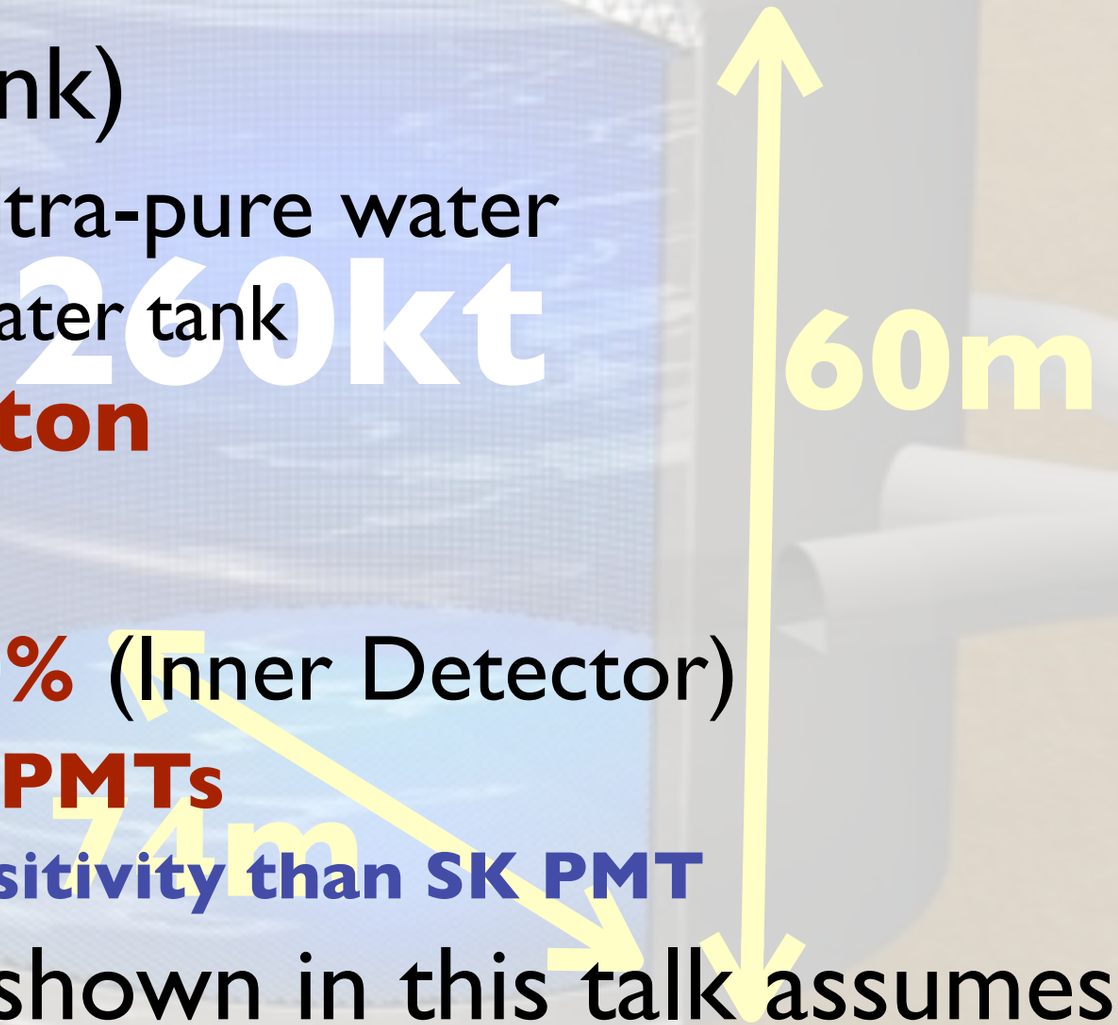
- ~300 collaborators
- 75 institutions from 15 countries
  - as of April 2017
- ~70% of collaborators from oversea countries

Hyper-Kamiokande



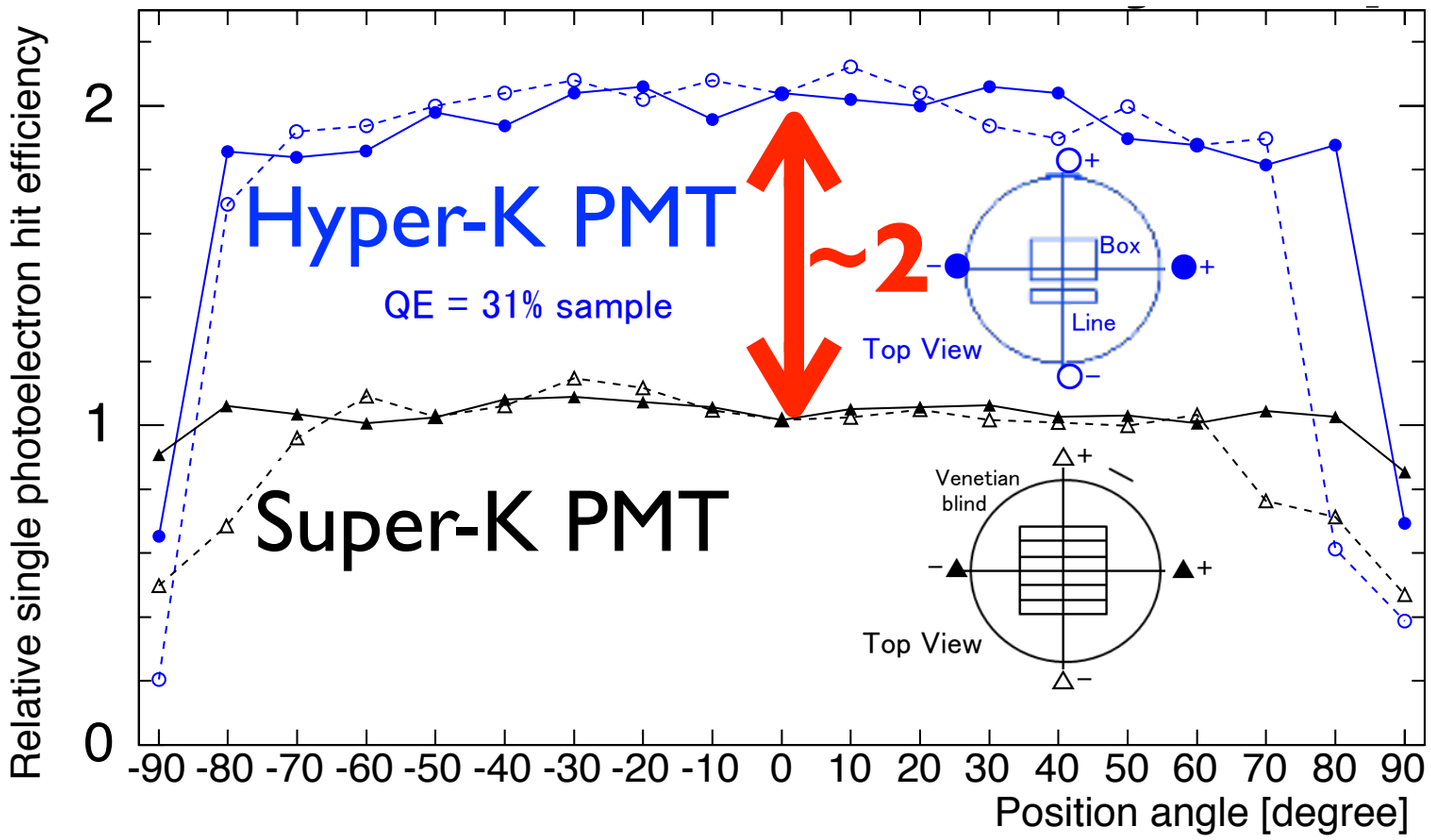
Hyper-Kamiokande

- **Next generation water Cherenkov detector**
  - Construct two detectors in stage
  - Realize the first detector as soon as possible
    - See Sunny's talk (next talk) for option of second detector in Korea
- The first detector (1 tank)
  - Filled with 260kton of ultra-pure water
    - 60m tall x 74 diameter water tank
  - **Fiducial mass: 190kton**
    - **~10 x Super-K**
  - **Photo-coverage: 40%** (Inner Detector)
    - 40,000 of **new 50cmϕ PMTs**
      - **x2 higher photon sensitivity than SK PMT**
- All physics sensitivities shown in this talk assumes 1 tank



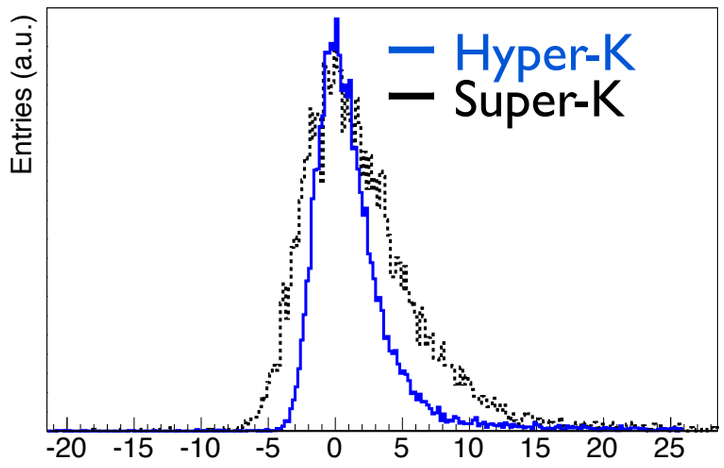
New 50cmϕ PMT for Hyper-K

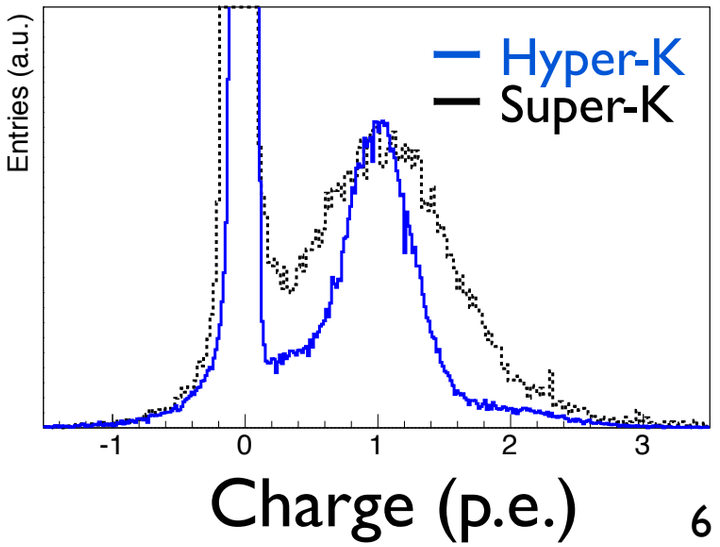
Photo-detection efficiency (1p.e.)



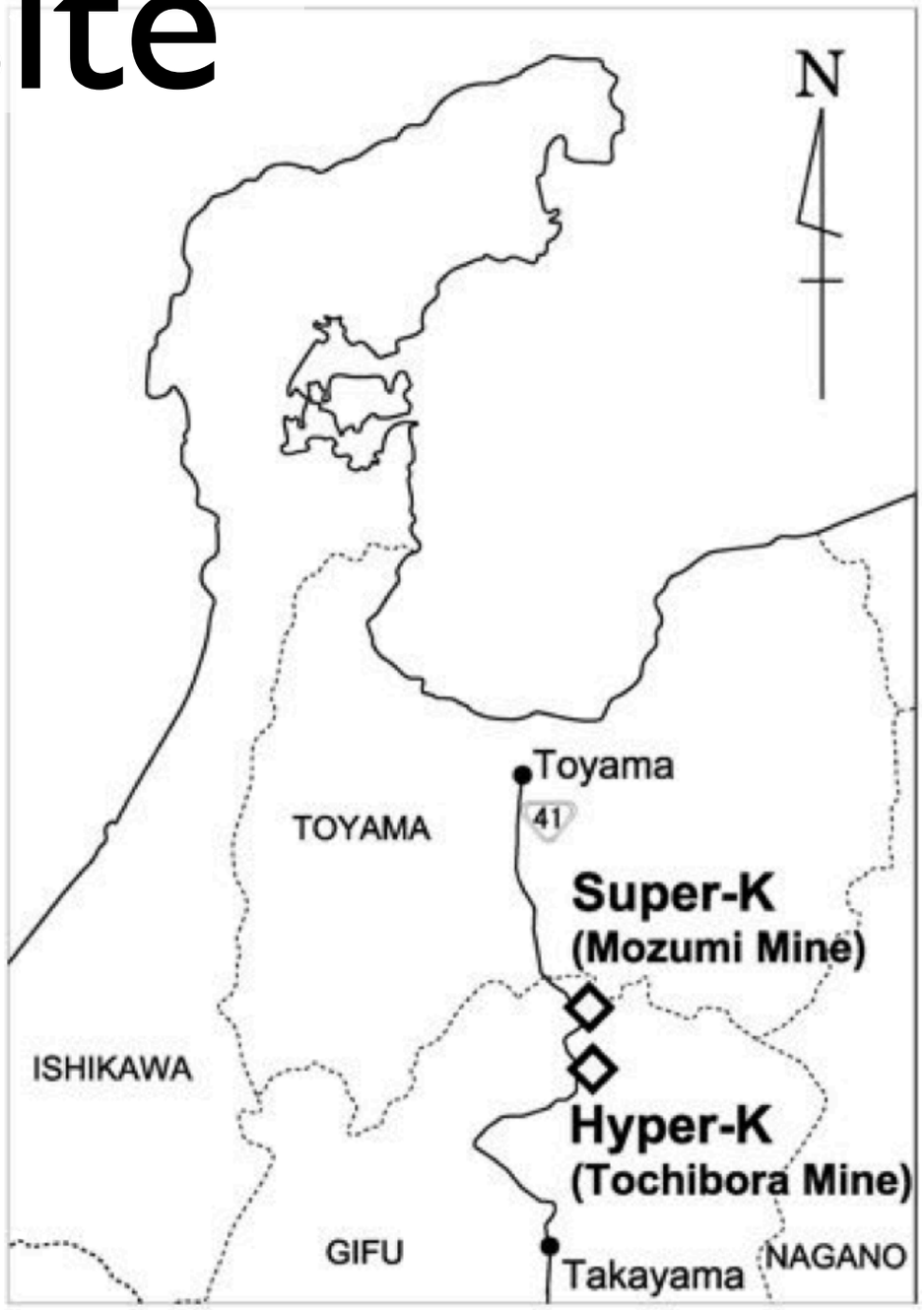
- Twice better photo-detection efficiency than SK PMTs
- Timing resolution (TTS): 1.1ns
  - cf. SK PMT: 2.1ns
- Higher pressure tolerance: >80m

Box & line dynode PMT





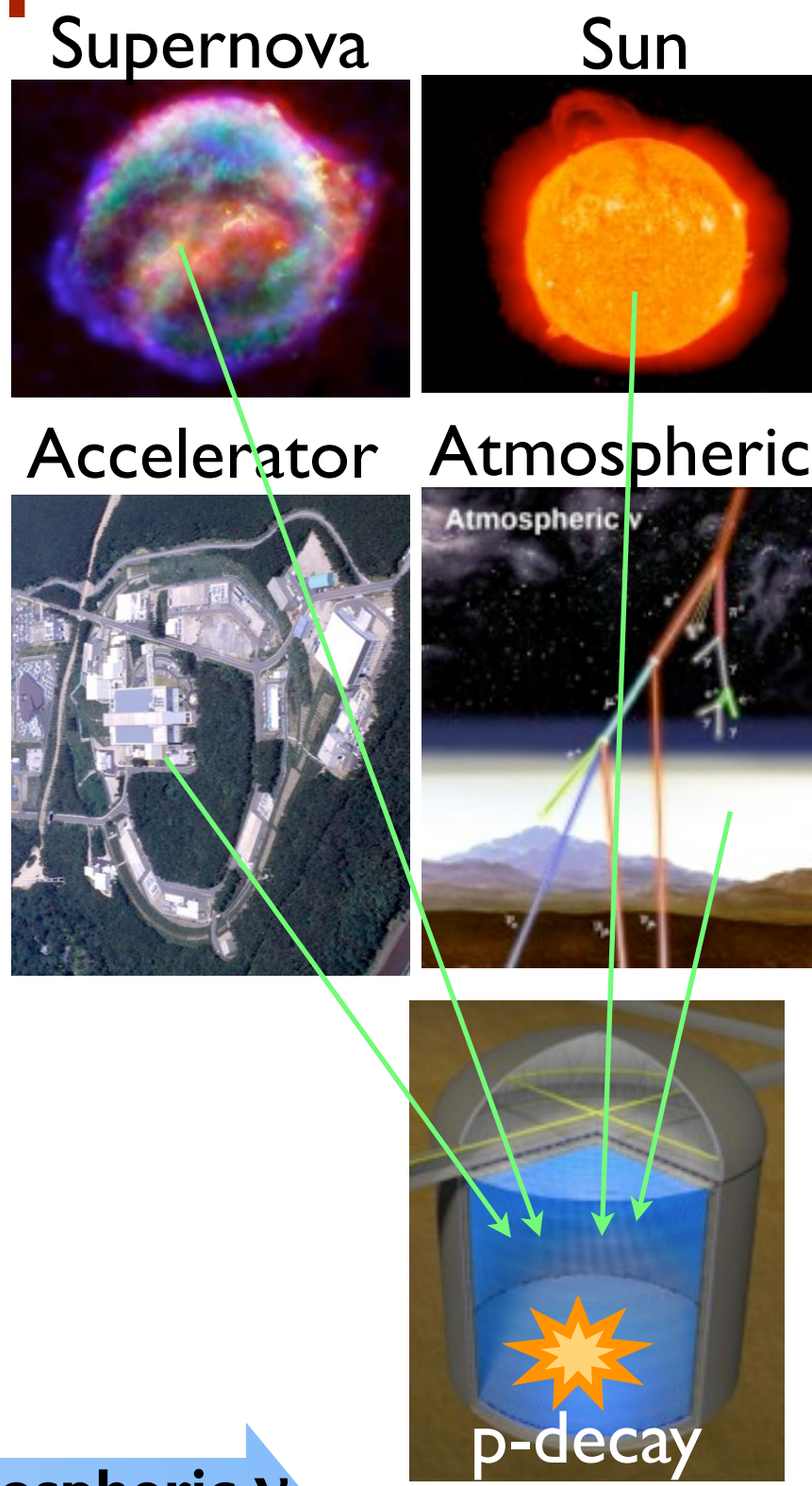
Detector site

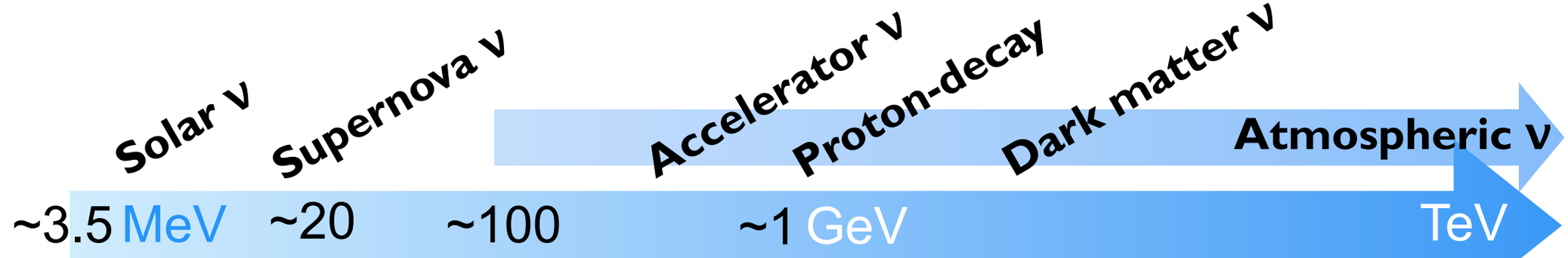


- The candidate site locates under Mt. Nijugo-yama
  - ~8km south from Super-K
  - Identical baseline (295km) and off-axis angle (2.5deg) to T2K
- Overburden ~650m (~1755 m.w.e.)

Hyper-K: multi-purpose detector

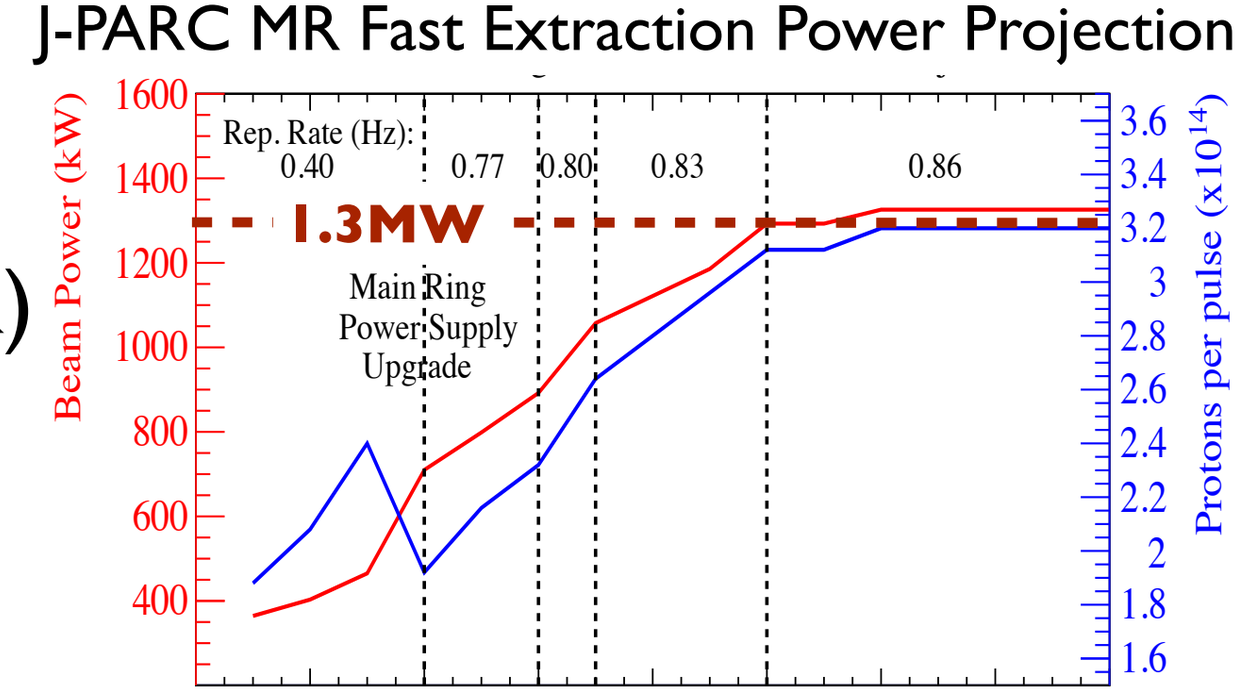
- **Comprehensive study of ν oscillation**
  - CPV: 76% of δ space w/ 3σ, <22° precision
  - MH determination for all δ with J-PARC/Atm ν
  - θ_{23} octant determination at $|\theta_{23}-45°|>2°$
  - <1% precision of Δm^2_{32}
  - Test standard ν oscillation scenario w/ acc/atm ν
- **Proton decay 3σ discovery potential**
  - 1×10^{35} years for $p\rightarrow e^+\pi^0$
  - 3×10^{34} years for $p\rightarrow \nu K^+$
- **Astrophysical neutrino**
  - Solar ν: test standard matter effect (MSW) model
  - Supernova ν, supernova relic-ν
  - Dark matter neutrinos from Sun, Galaxy, Earth

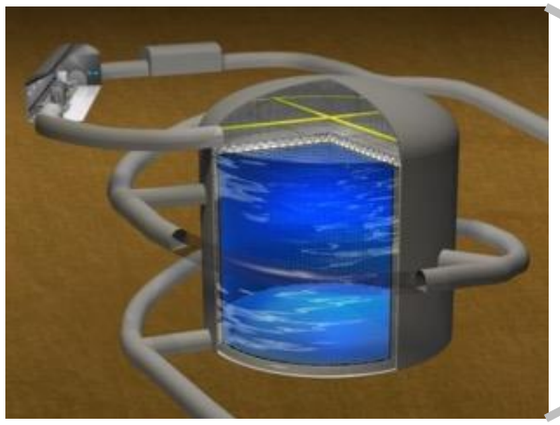




Accelerator based neutrinos

- High quality & high intensity neutrino beam
- 2.5 deg. off-axis narrow band neutrino beam (identical to T2K)
- Beam power: 1.3MW (before Hyper-K starts)
  - KEK Project Implementation Plan: top priority on 'J-PARC upgrade for Hyper-K'





Hyper-K

J-PARC

Accelerator Complex

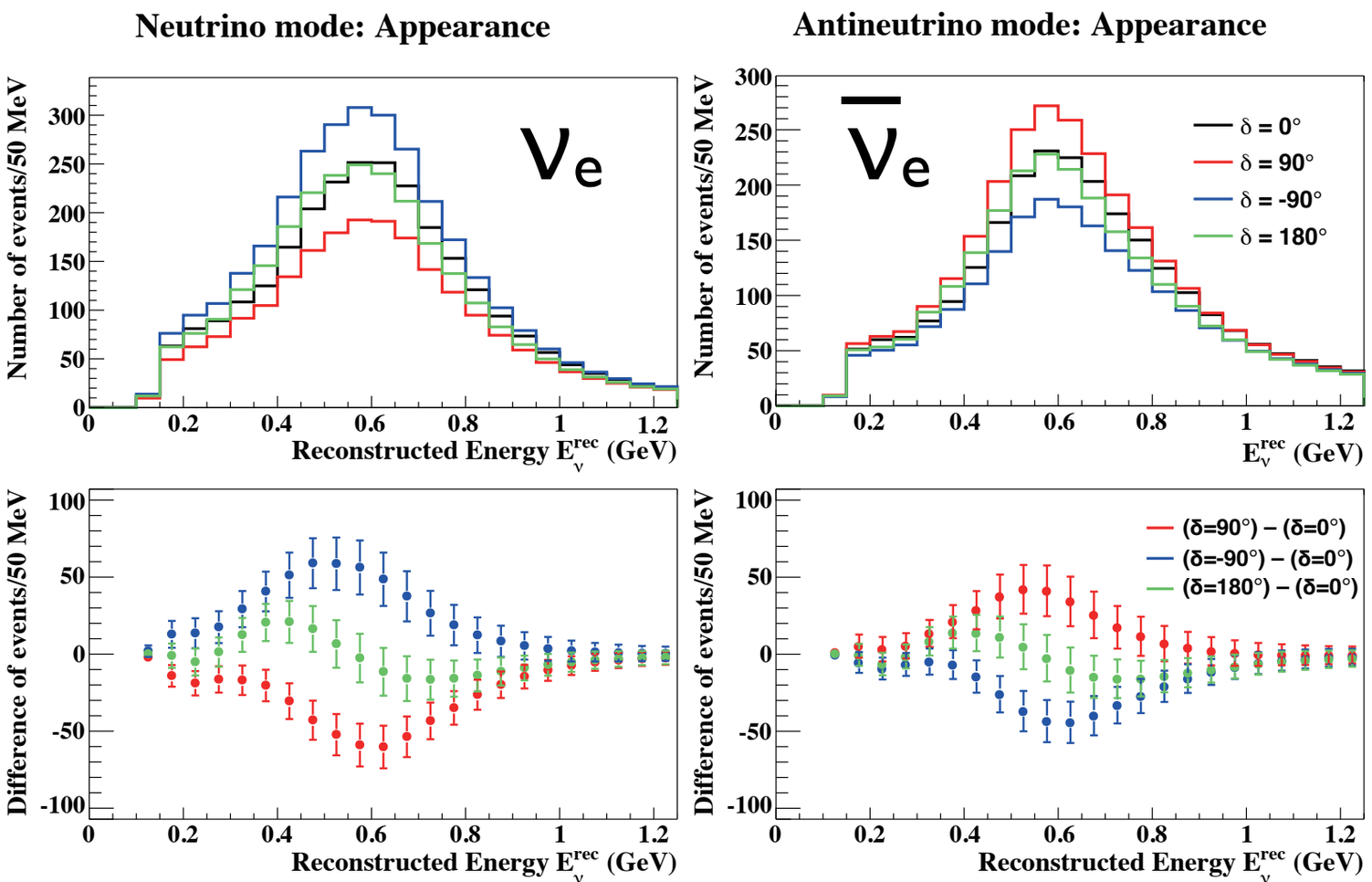
Expected events in Hyper-K for CPV

Expected # of events in $\nu_e/\bar{\nu}_e$ appearance

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

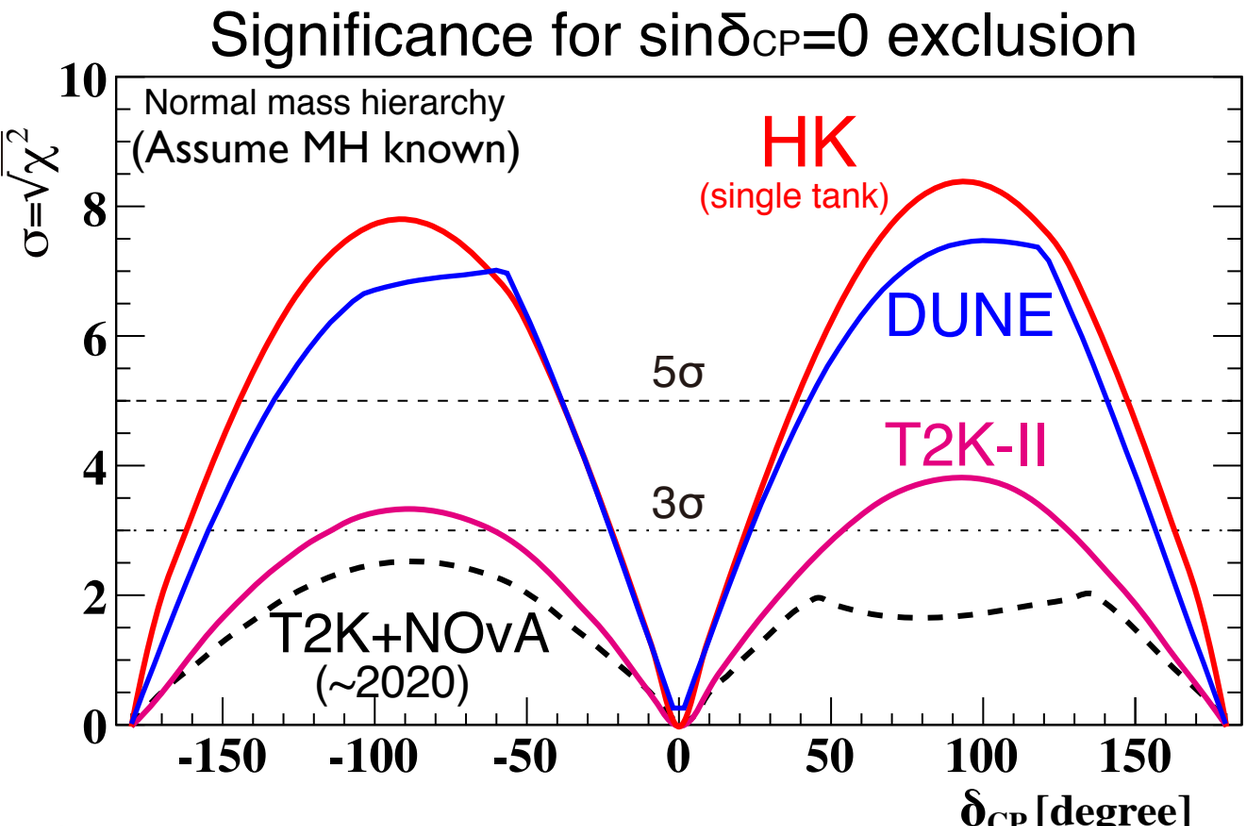
for $\delta_{CP} = 0$	Signal $\nu_\mu \rightarrow \nu_e$ CC	Wrong sign appearance	$\nu_\mu / \bar{\nu}_\mu$ CC	Beam $\nu_e / \bar{\nu}_e$ contamination	NC
ν beam	1,643	15	7	259	134
$\bar{\nu}$ beam	1,183	206	4	317	196

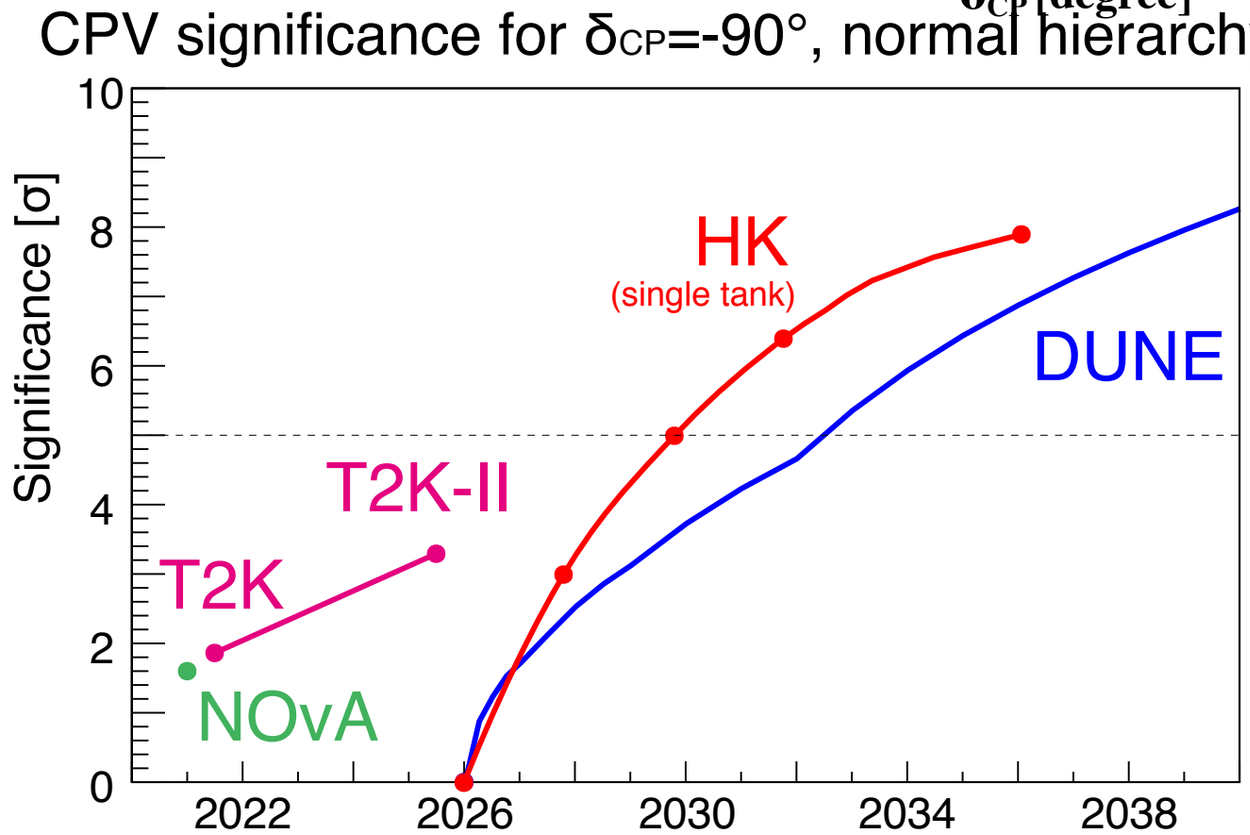
Reconstructed E_ν spectra



$\sin^2 2\theta_{13}=0.1$
Normal Hierarchy

Expected sensitivity for CPV



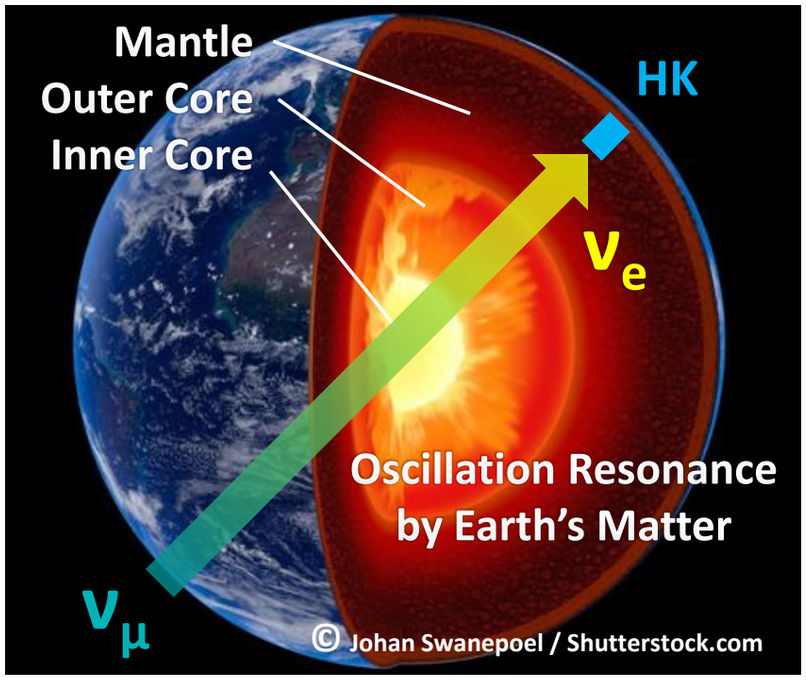


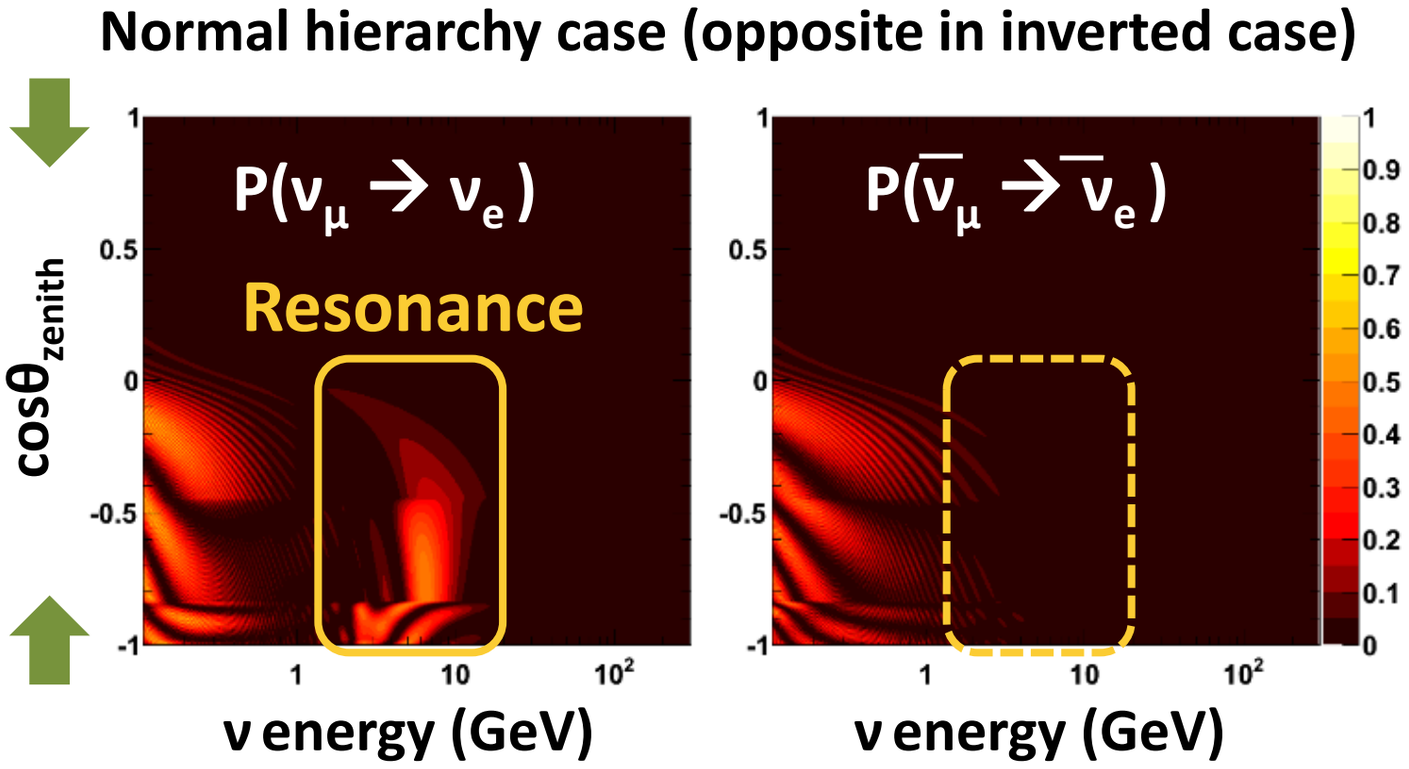
- $\sin\delta_{CP}=0$ exclusion:
  - ~8σ significance if $\delta_{CP}=\pm90°$
  - ~6σ significance if $\delta_{CP}=\pm45°$
- Observe CPV for 76% (58%) of δ_{CP} space w/ 3σ (5σ) significance
- δ_{CP} resolution:
  - 22° at $\delta_{CP}=\pm90°$
  - 7° at $\delta_{CP}=0°$ / 180°

Assume 3~4% systematic error
cf. 5~6% in T2K (2017)
[See Jeanne Wilson's talk]

Mass Hierarchy determination in Hyper-K

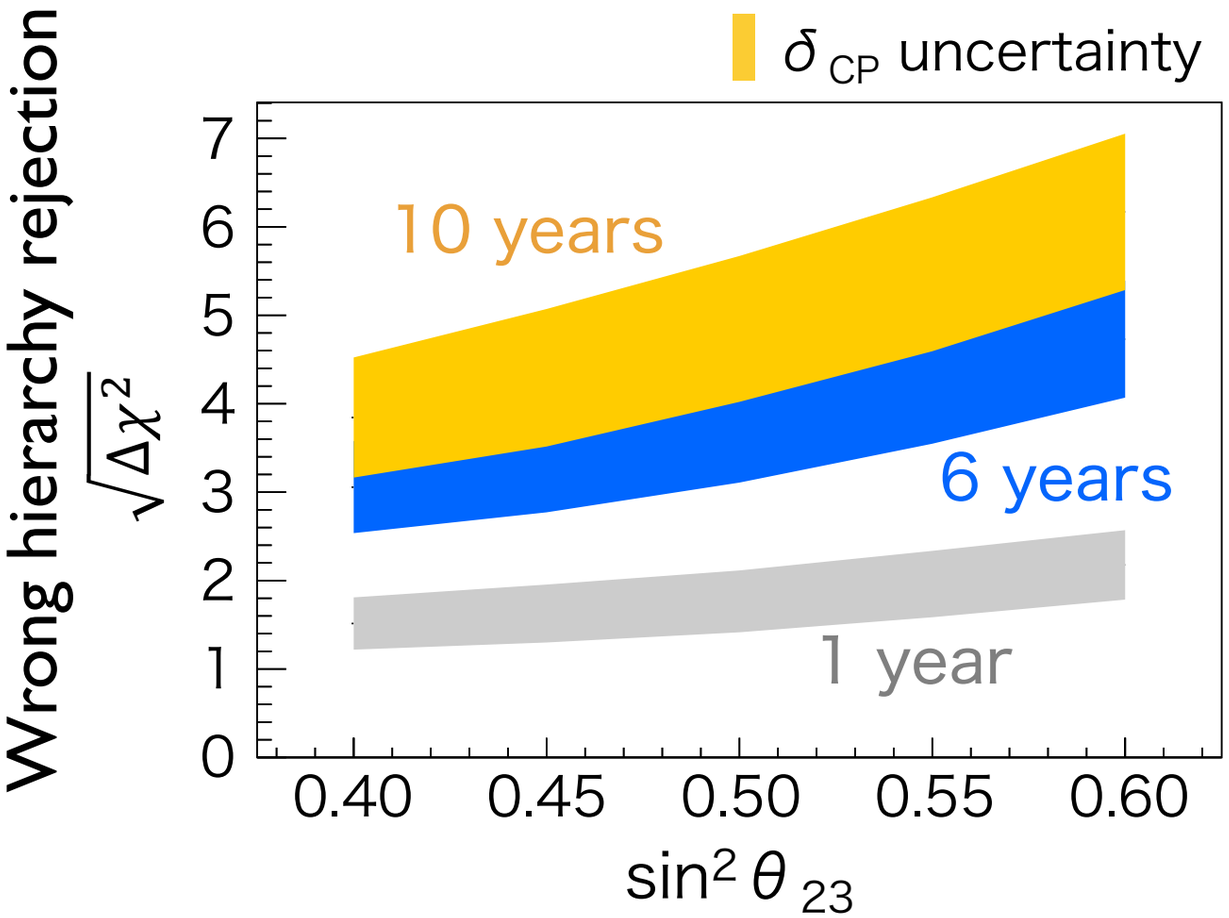
- Earth matter effect in upward-going multi-GeV ν_e sensitive to mass hierarchy
  - Earth matter effect 'resonance' appears in ν_e app. for NH, in $\bar{\nu}_e$ app. in IH
- Combination of atmospheric ν and beam ν to determine mass hierarchy





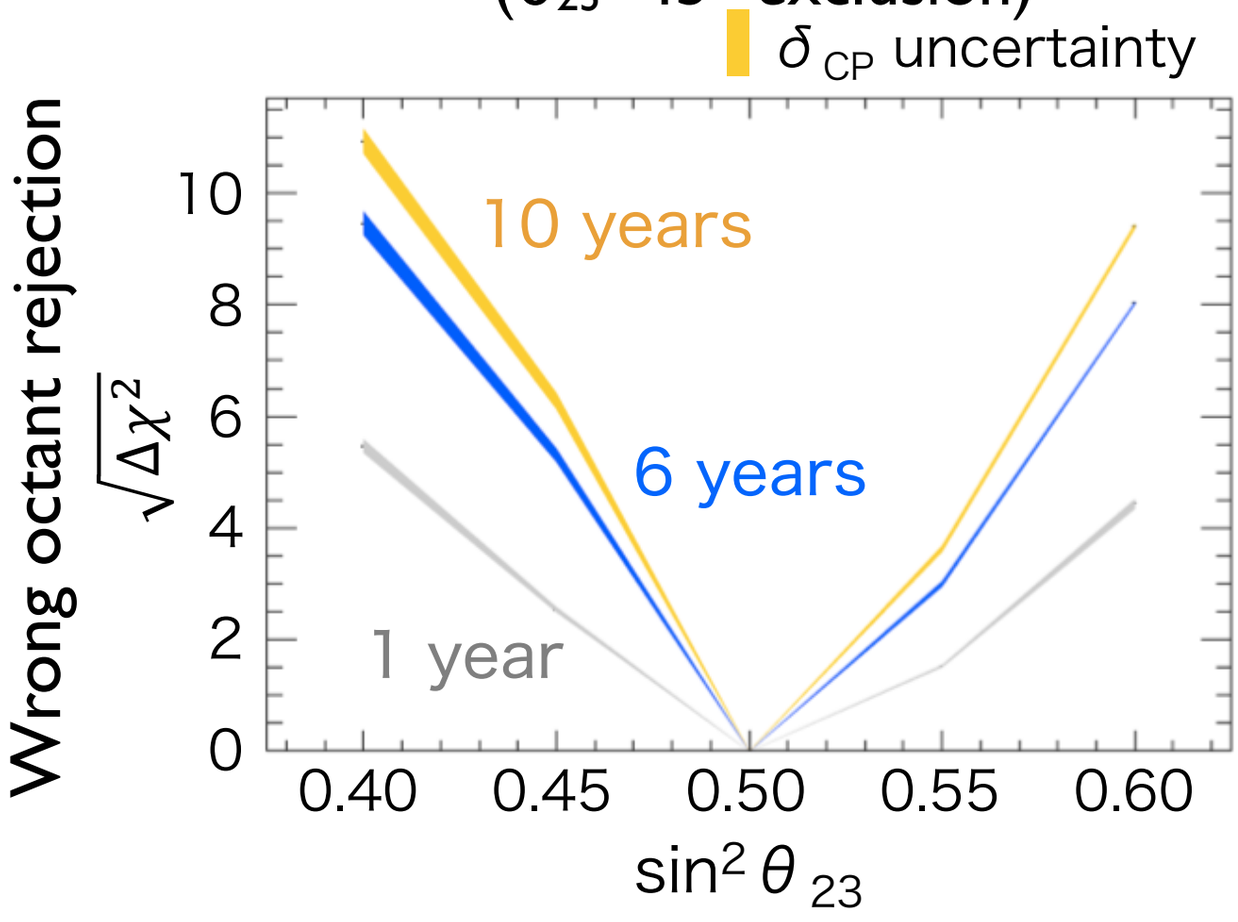
Mass Hierarchy sensitivity in Hyper-K

Mass Hierarchy



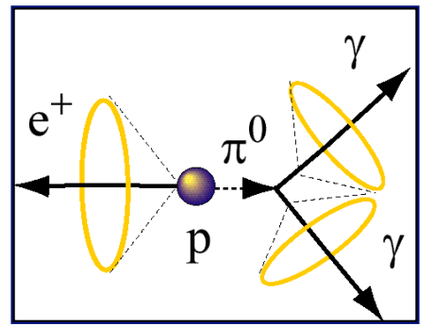
θ_{23} octant

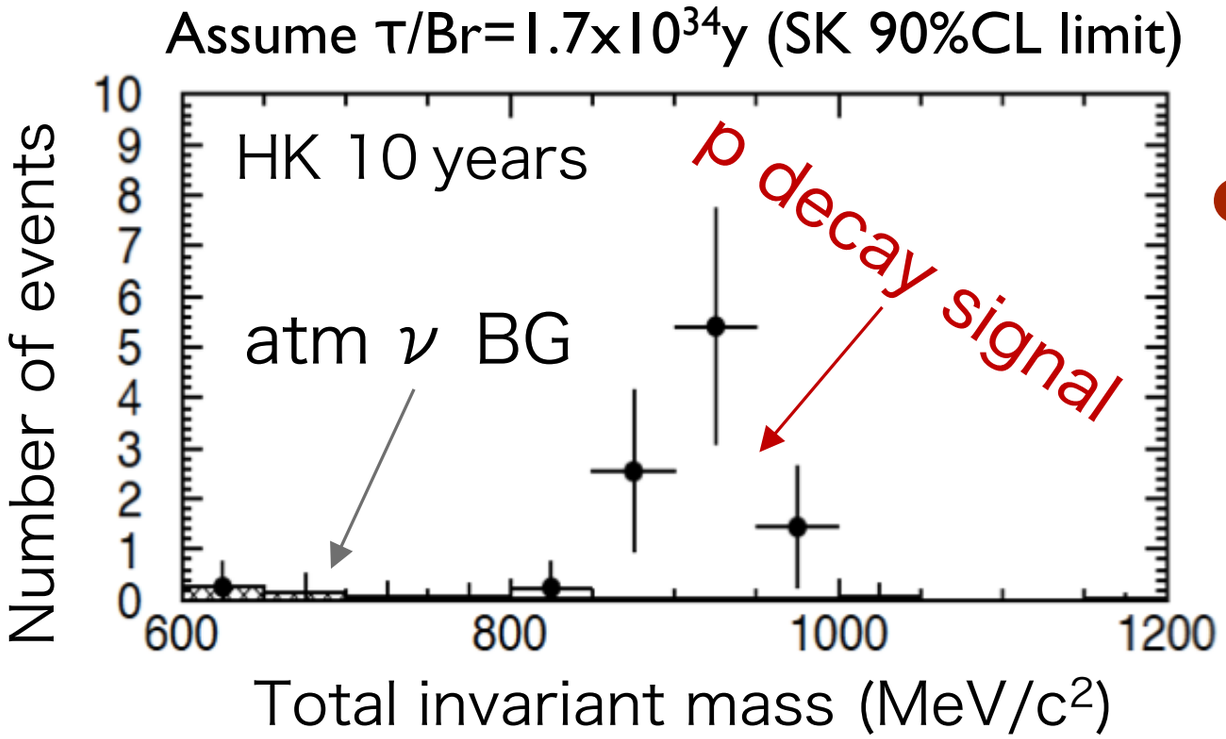
(θ_{23}=45° exclusion)



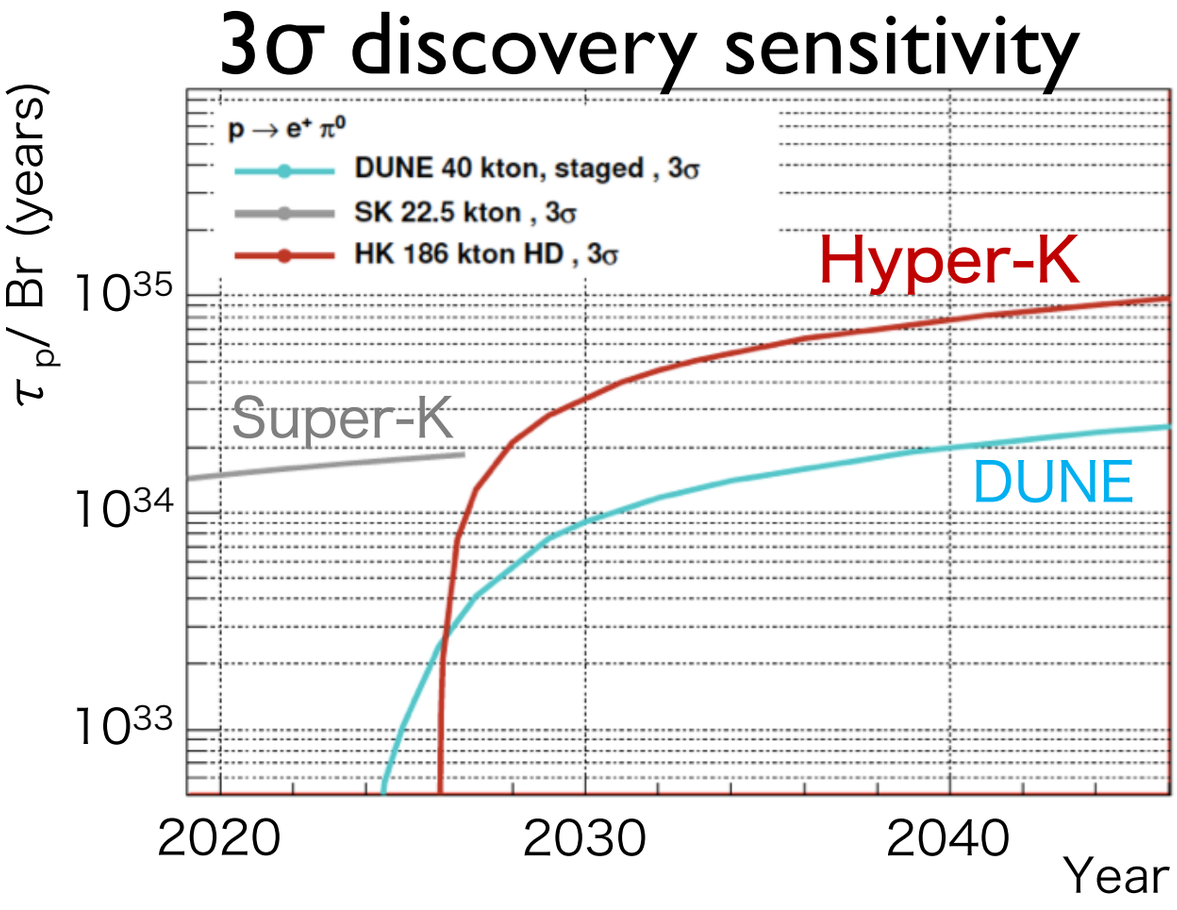
- Mass hierarchy and θ_{23} octant can be determined ($\geq 3\sigma$) within several years for the nearly entire parameter space

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



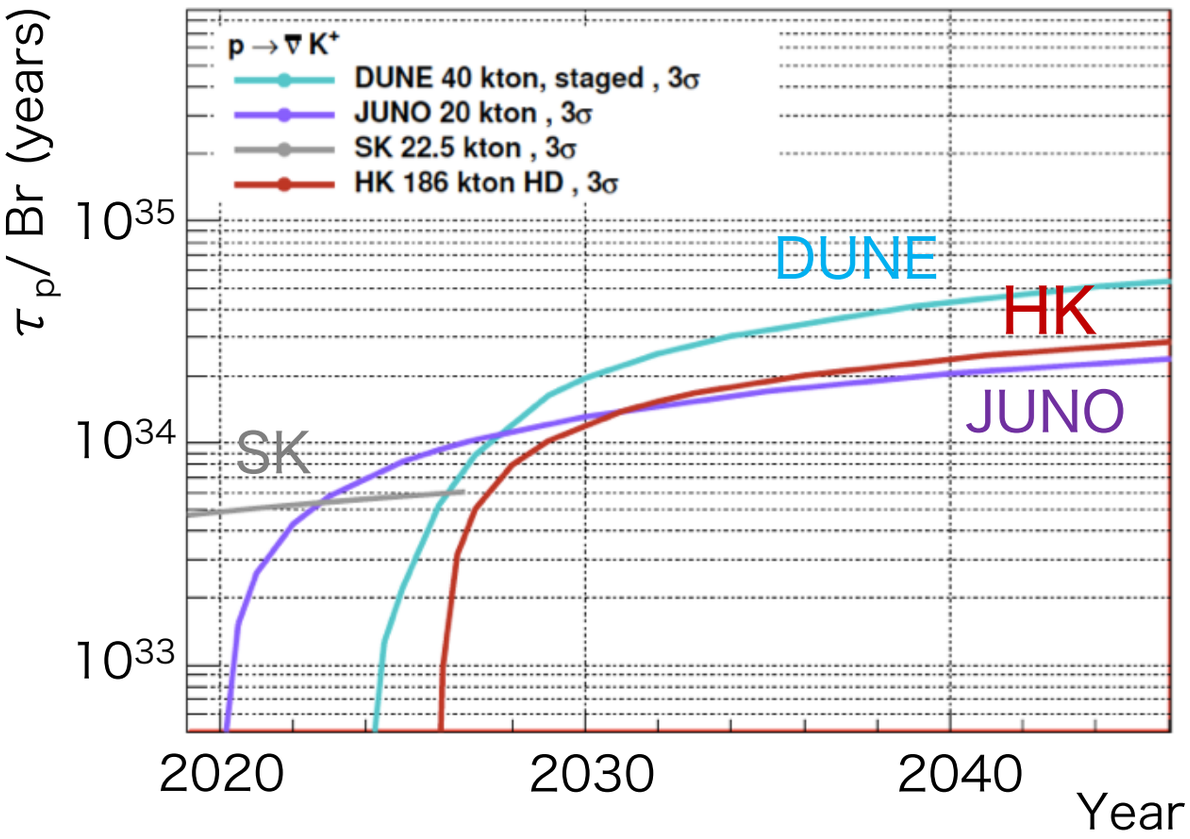


- "Background free" meas. of proton decay
  - 0.06 Bkg events / Mt·year
  - Bkg atm-ν events are largely reduced by 'neutron-tag': eff.~70% with new PMT
    - $n+p \rightarrow d+\gamma$ (2.2MeV)

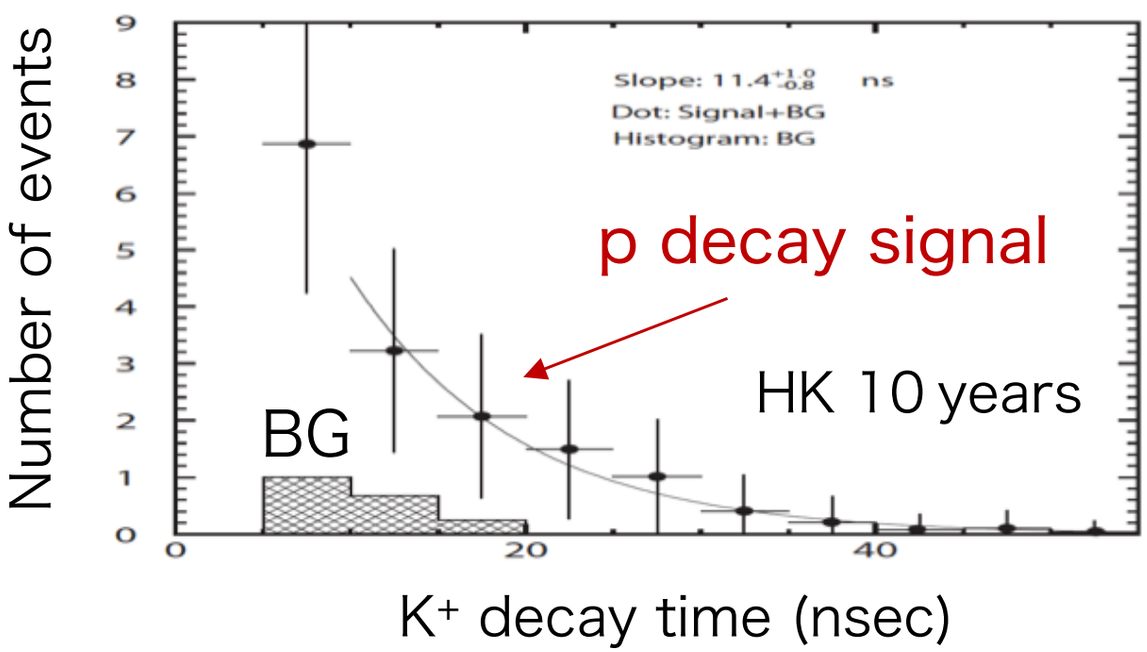


- Great discovery potential
- 3σ discovery sensitivity reaches $\tau_p/Br=10^{35}$ years

$p \to \bar{\nu} K^+$ search in Hyper-K



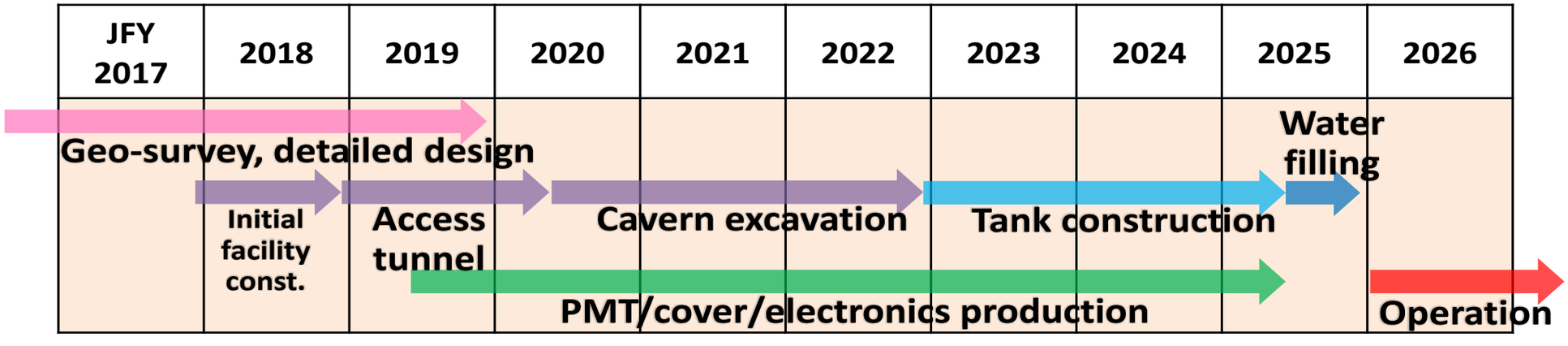
Assume τ/Br=6.6x10³³y (SK 90%CL limit)



- Identify K^+ by its decaying products
- $K^+ \to \mu^+ \nu$ (Br: 64%)
  - 236MeV/c μ^+
  - de-excitation γ from $^{15}O^*$ (6MeV γ)
- $K^+ \to \pi^+ \pi^0$ (Br: 21%)
  - 205MeV/c π^0 & π^+ back-to-back
- New PMT improves signal and background efficiencies
- Other decay modes, $l+\omega$, ρ, η, x10 improved than SK

Project status in Japan

- 'Hyper-K Design Report' released
  - KEK preprint 2016-21, ICRR-Report-701-2016-1
- Strong commitment from host institutes: ICRR, U. Tokyo and KEK (MoU for Hyper-K)
- Strong support from Japanese communities
  - Cosmic-ray (CRC) and high-energy (JAHEP)
- Science Council of Japan selected Hyper-K as one of the top priority large-scale projects in 'Master Plan 2017'
- MEXT (funding agency) will soon release 'Roadmap 2017'
  - Hyper-K is selected in the preliminary version of the Roadmap released on July 18, 2017
- Budget request being submitted, aiming to begin the construction in JFY 2018 & begin operation in JFY 2026



Summary

- **Wide Physics topics, many discovery potentials**
  - ν CPV: 76% of δ space w/ 3σ, δ resolution <20°
  - Proton decay discovery sensitivity reaches 10^{35} years
  - SN burst, SN relic ν, indirect WIMP search, etc (See Yano-san's talk)
  - Physics sensitivity enhanced with new photosensor
- **Project is boosted toward an early realization**
  - International proto-collaboration formed
  - Hyper-K Design Report released
  - Strong support from Japanese communities and host institutes
  - Selected in 'Master Plan' of Science Council of Japan
  - Listed in 'Roadmap 2017 (preliminary)' of MEXT
  - Budget request being submitted to begin the construction in JFY 2018 & begin the operation in JFY 2026
- **Open for new collaborators**

Back-up

Predictions & experiments for p-decay