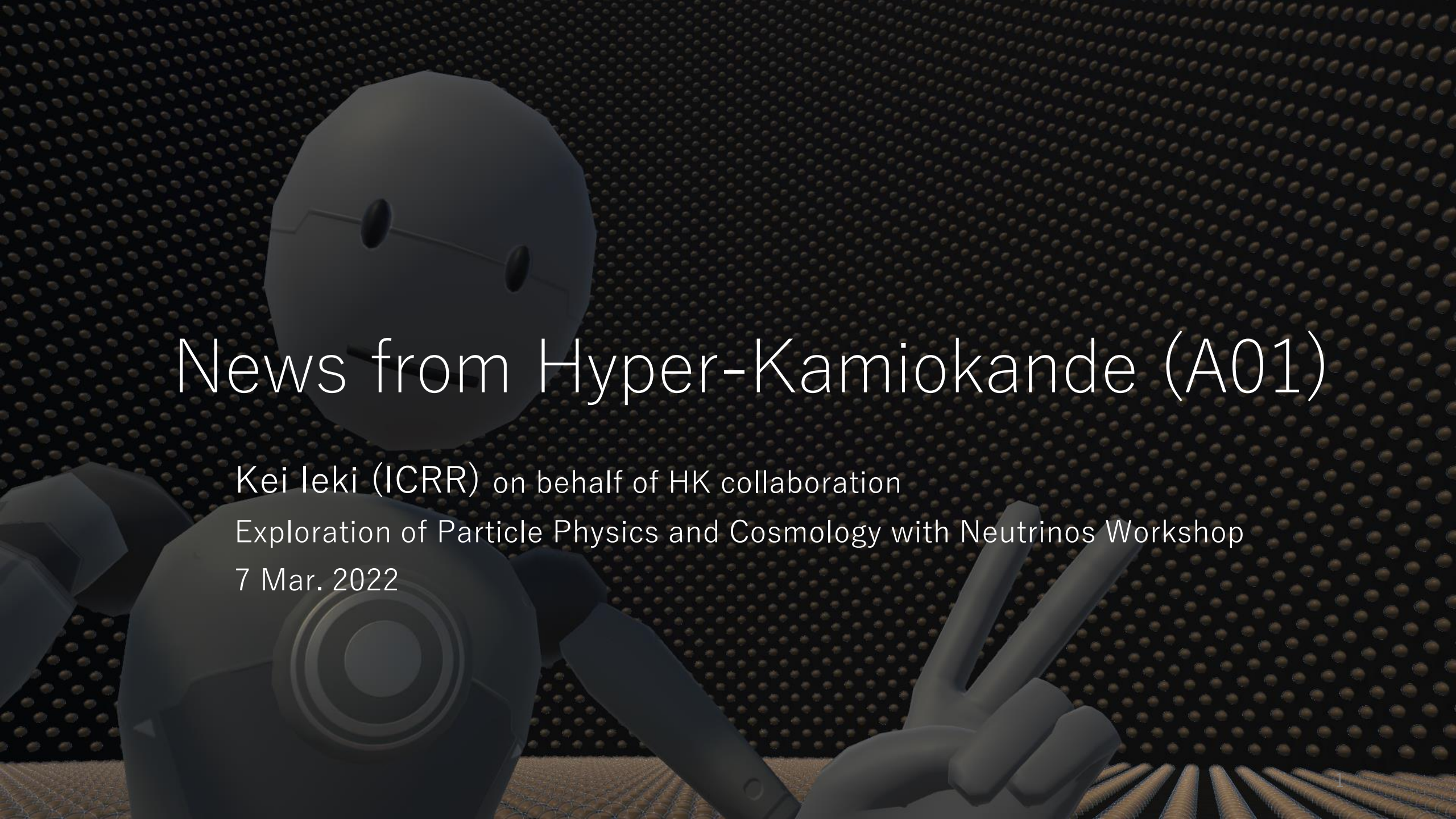


News from Hyper-Kamiokande (A01)

Kei Ieki (ICRR) on behalf of HK collaboration

Exploration of Particle Physics and Cosmology with Neutrinos Workshop

7 Mar. 2022

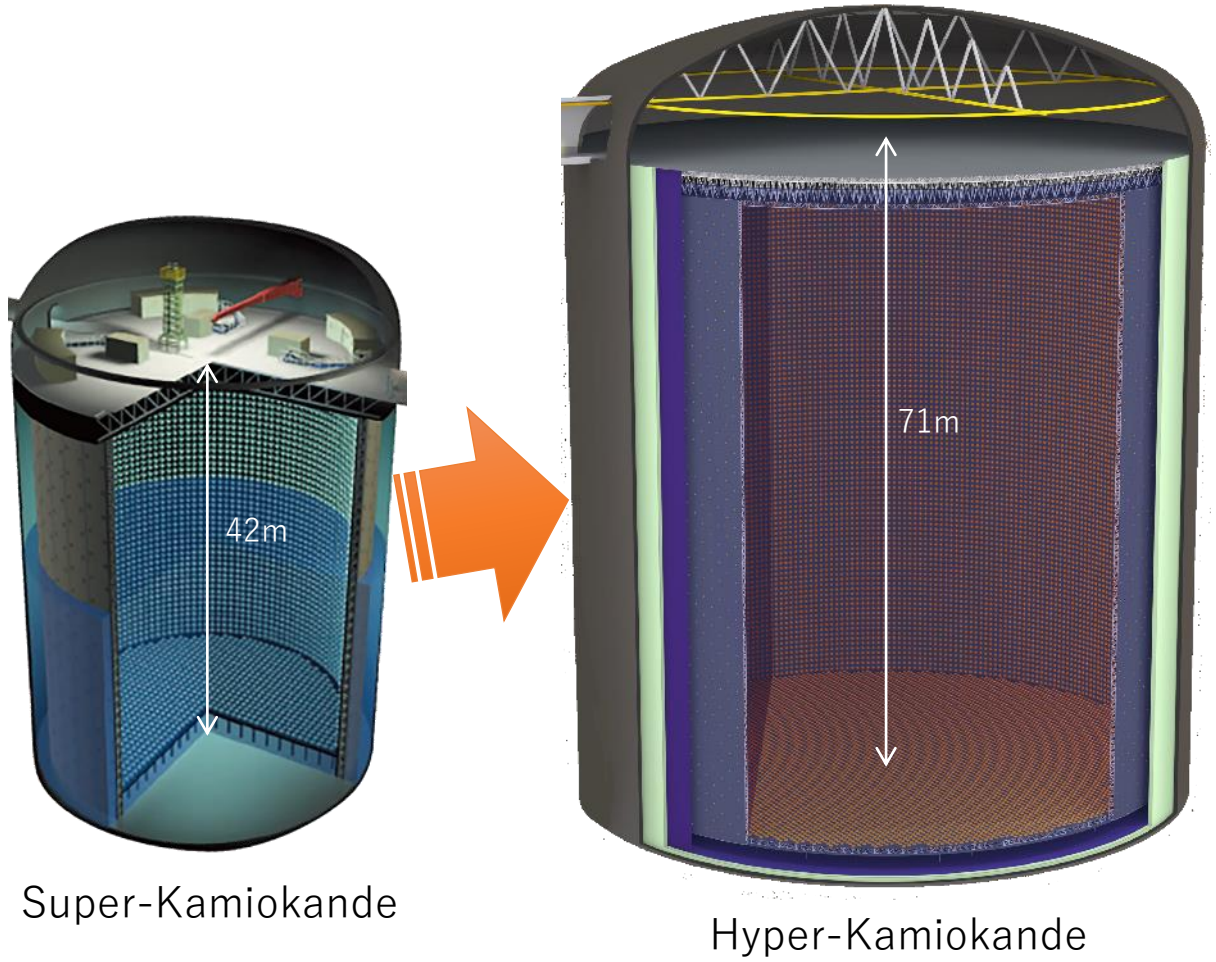
Topics

- Introduction
  - Hyper-Kamiokande project
  - Physics
- Recent status
  - Tunnel excavation
  - PMT production
  - **R&D of electronics**

Introduction

Hyper-Kamiokande

- Upgrade of SK
  - Pure water Cherenkov detector
  - 8.4 times larger fiducial volume
- Rich physics program
  - Neutrino oscillation
    - Beam ν, atmospheric ν, solar ν
  - Nucleon decay search
  - Supernova neutrino
- Construction started in 2020, operation from 2027~

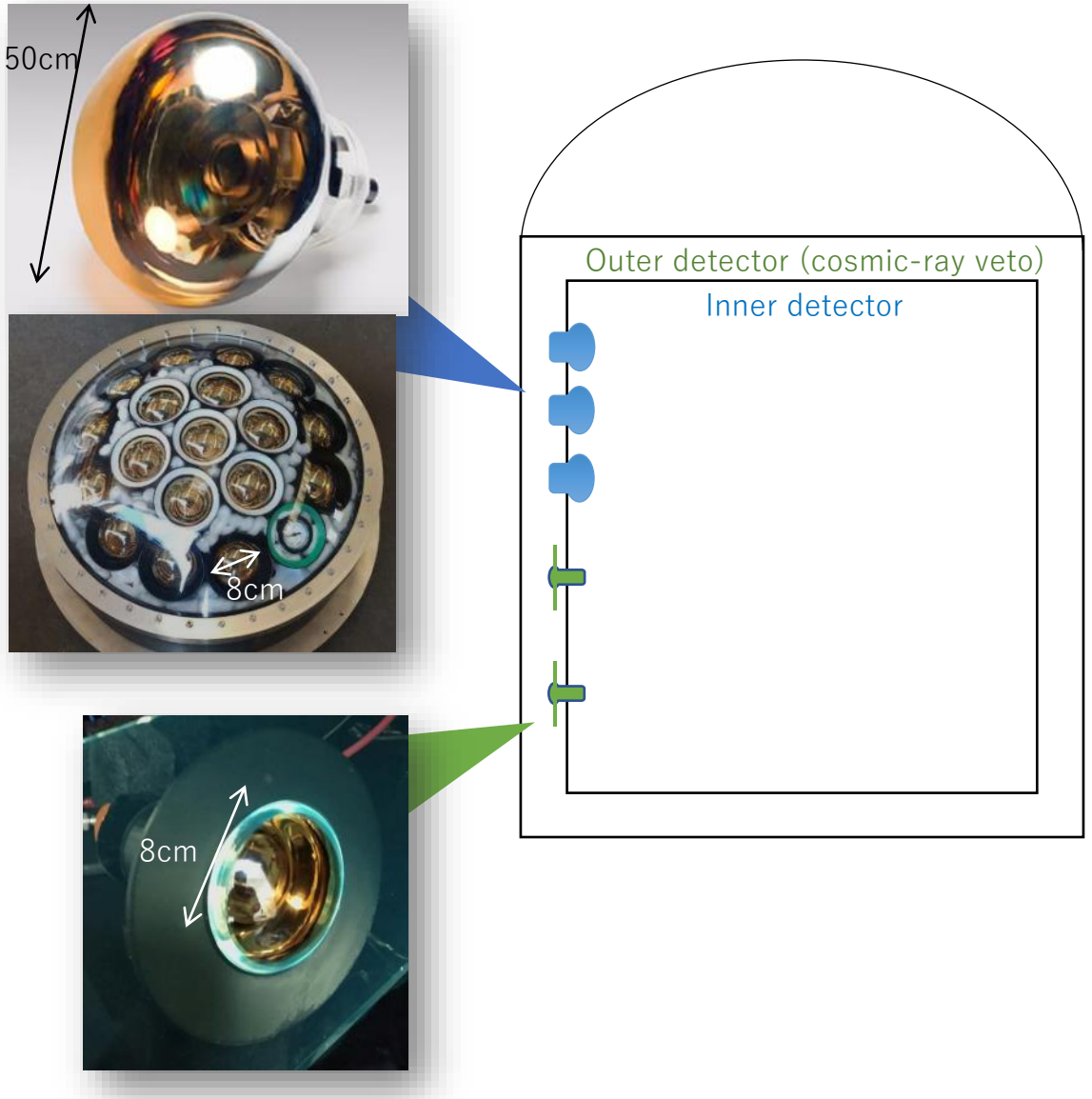


Super-Kamiokande

Hyper-Kamiokande

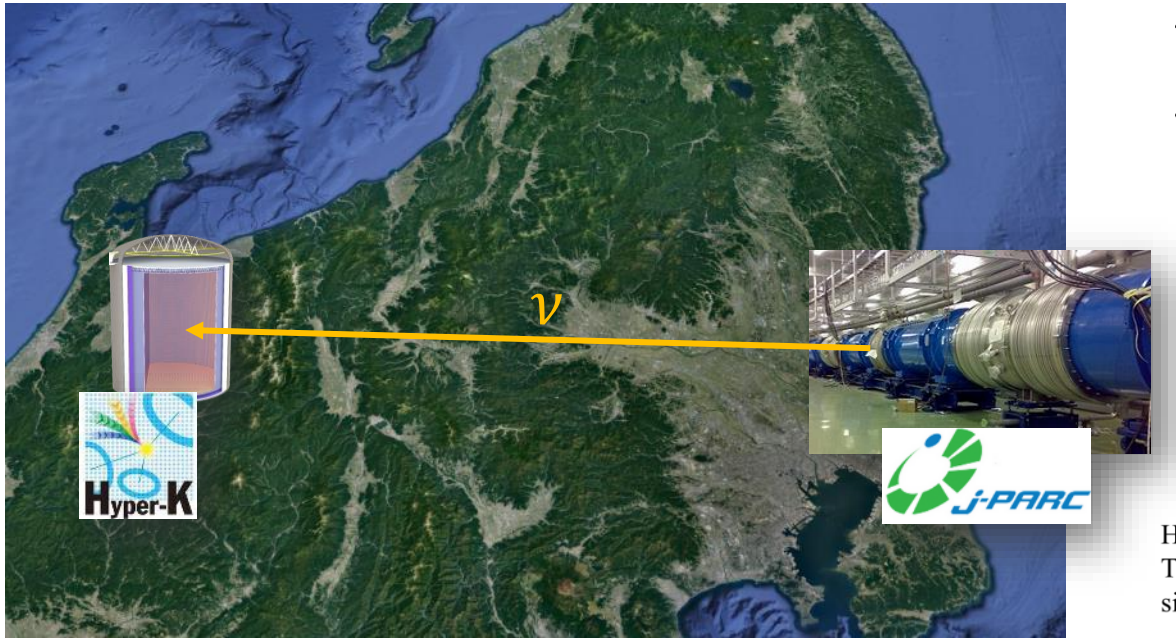
Detector

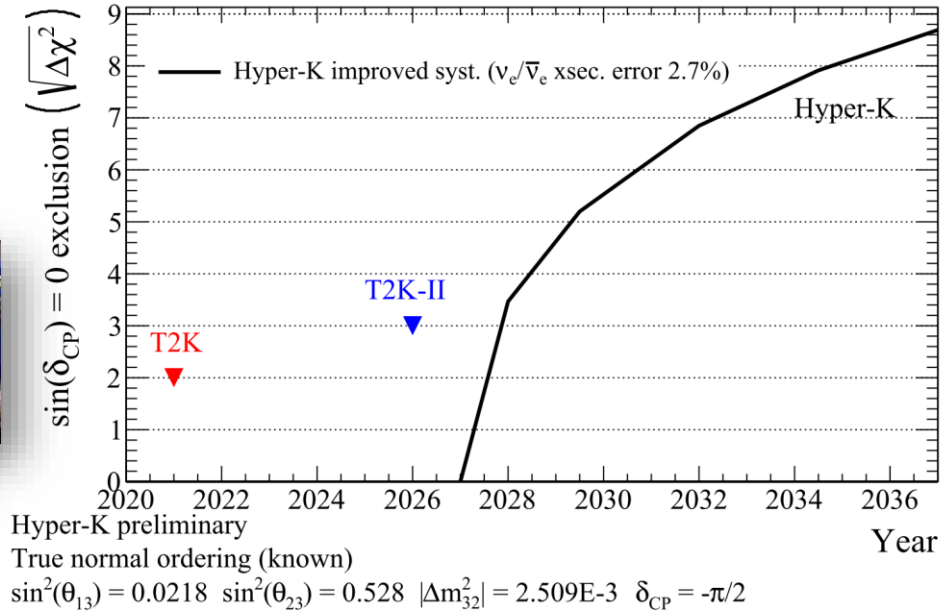
- 260 kton pure water
  (190 kton fiducial volume)
  - Inner and outer detector
- ~20000 50 cm PMTs in the inner tank
  - Box-line dynode
  - **x2 detection efficiency,**
    x2 timing resolution
    x2 pressure tolerance
- ~1300 multi-PMTs in the inner tank
  - 8cm PMT x19
  - Directional information, better granularity
- ~7500 8cm PMT + WLS plate in the outer tank
- **Under-water electronics**
  → Some details in this talk



Physics: neutrino oscillation (1)

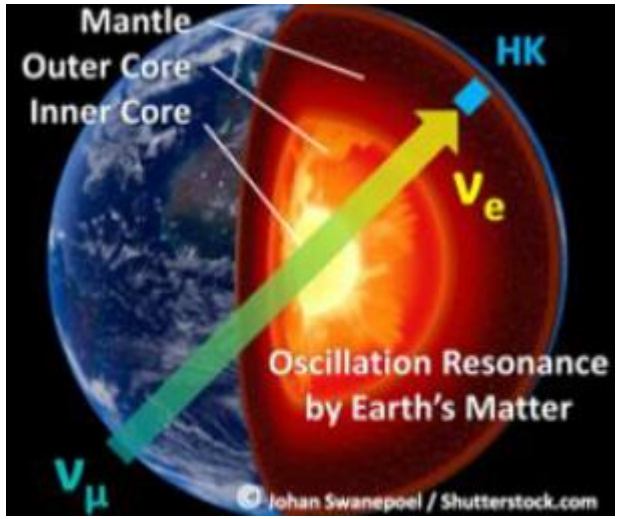
- Non-zero $\boldsymbol{\delta_{CP}}$ **discovery** with J-PARC ν beam
  - $\nu_\mu \rightarrow \nu_e$ and $\overline{\nu_\mu} \rightarrow \overline{\nu_e}$ probability depends on δ_{CP}
  - In T2K, we already see a hint of CP violation ($\sin\delta_{CP} \neq 0$)
  - Beam power will be upgraded: 0.5→1.3 MW
  - Exclude (5σ) non-CPV in 60% of parameter region
  - From “discovery” to “measurement”

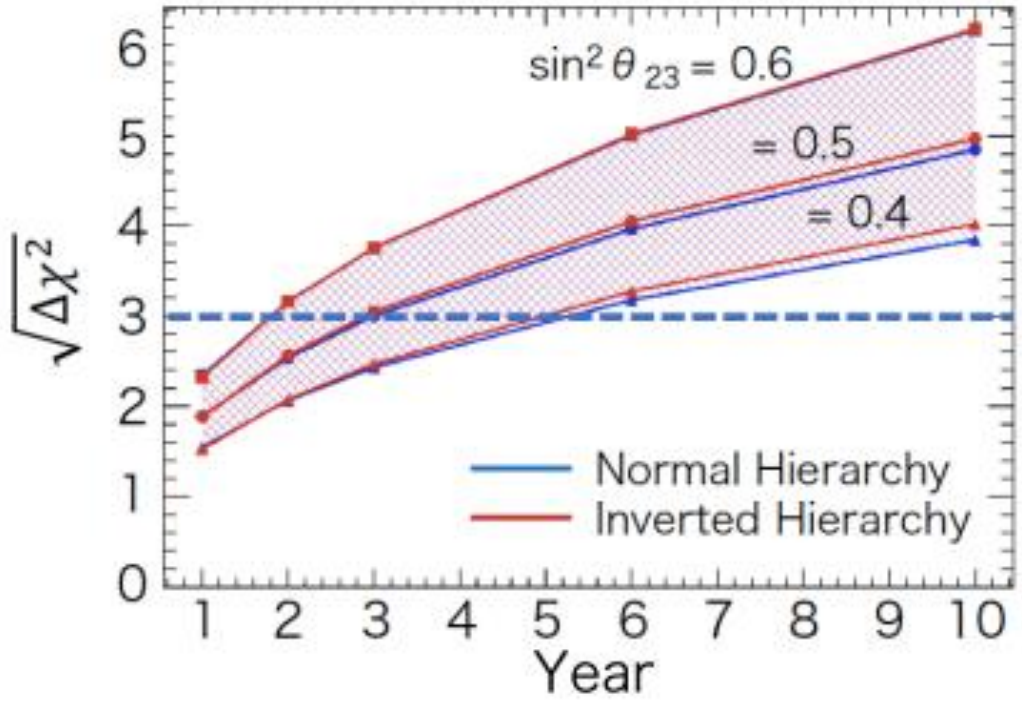




Physics: neutrino oscillation (2)

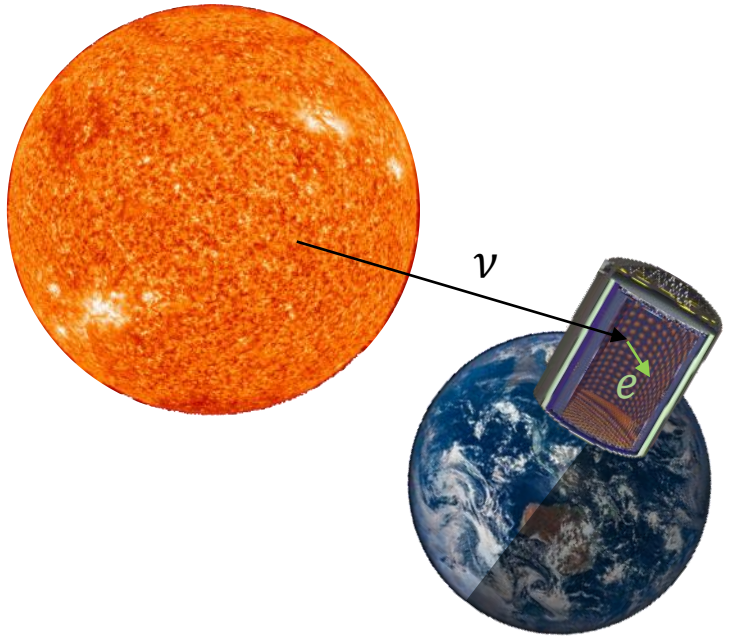
- **Determination of mass hierarchy** in atmospheric neutrino measurement
  - $\nu_\mu \to \nu_e, \overline{\nu_\mu} \to \overline{\nu_e}$ probability differs in normal/inverted hierarchy due to matter effect in the earth core.
- $>3\sigma$ determination of mass hierarchy in all values of $\sin^2\theta_{23}$

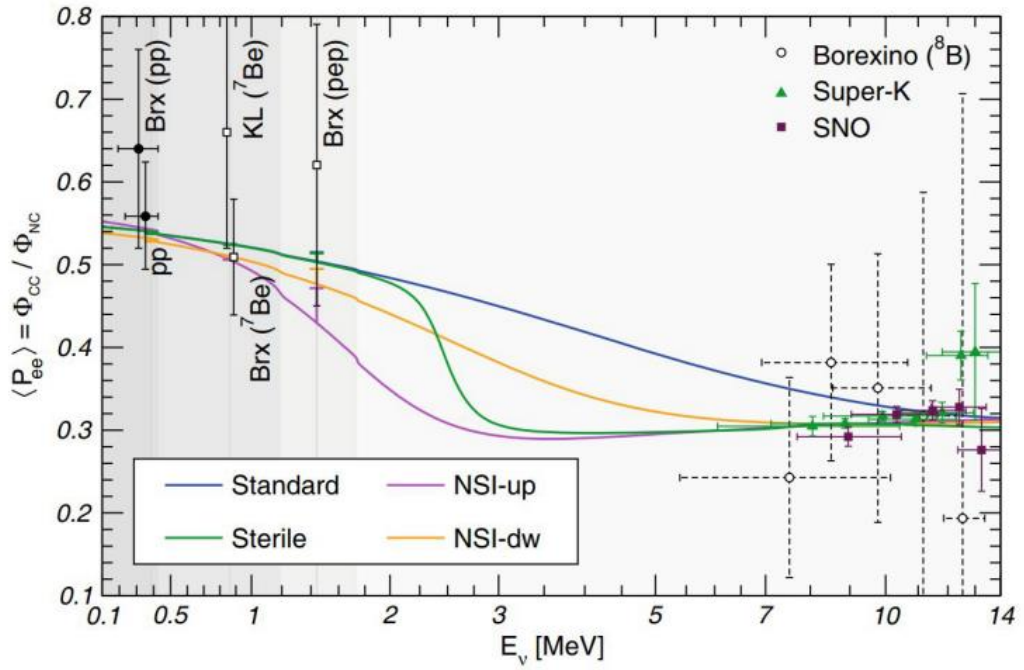




Physics: neutrino oscillation (3)

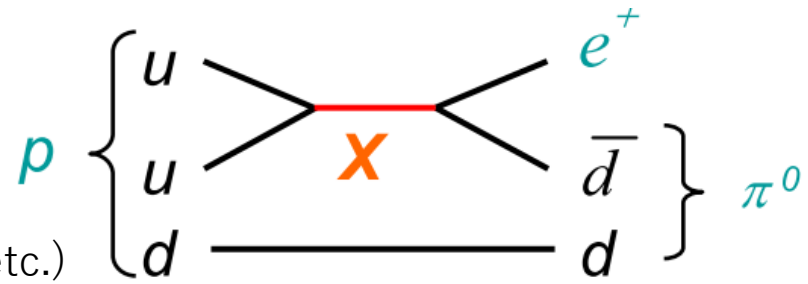
- Solar neutrino flux is affected by the matter effect in the sun.
  - Energy spectrum “upturn” should exist at ~4 MeV
  - Non-standard interaction (NSI) models can be tested.

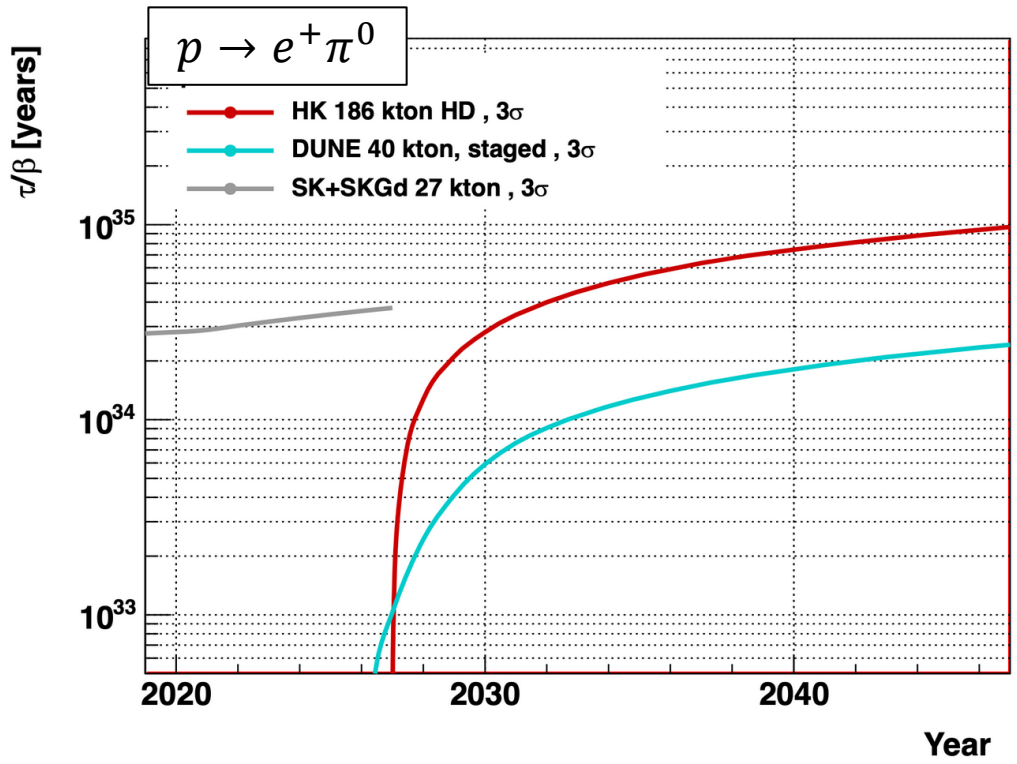


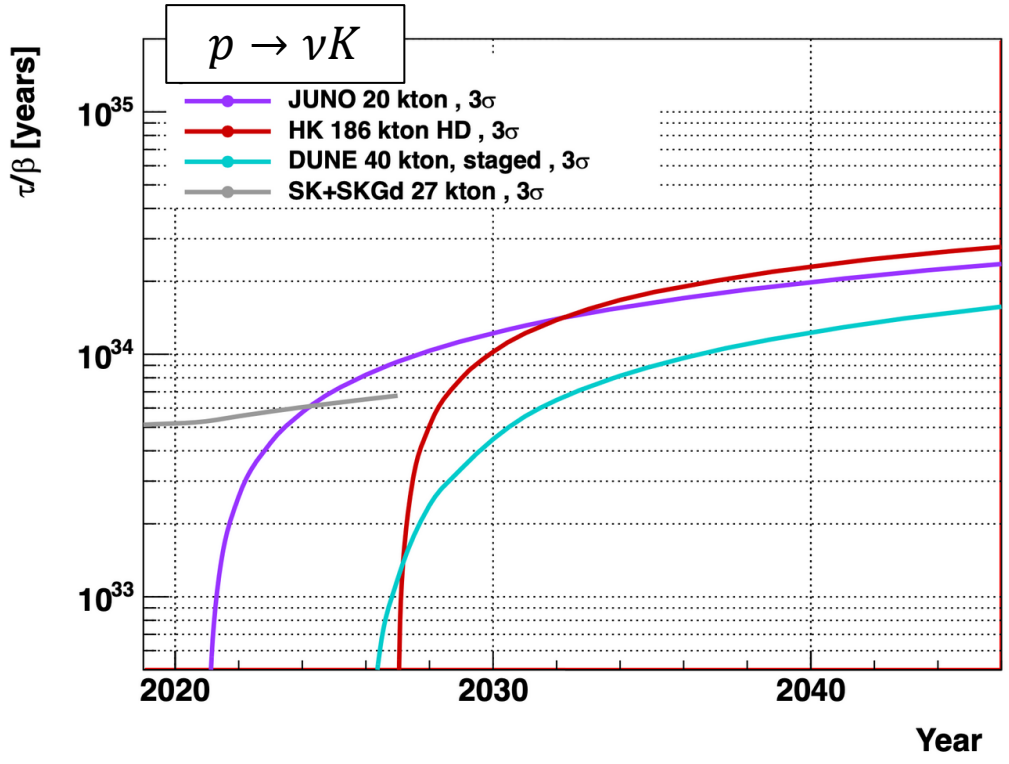


Physics: nucleon decay

- Probe of new physics: GUT, SUSY-GUT
- World-leading sensitivity in two golden channels
  - Sub-dominant modes and others (di-nucleon decay etc.) are also interesting.

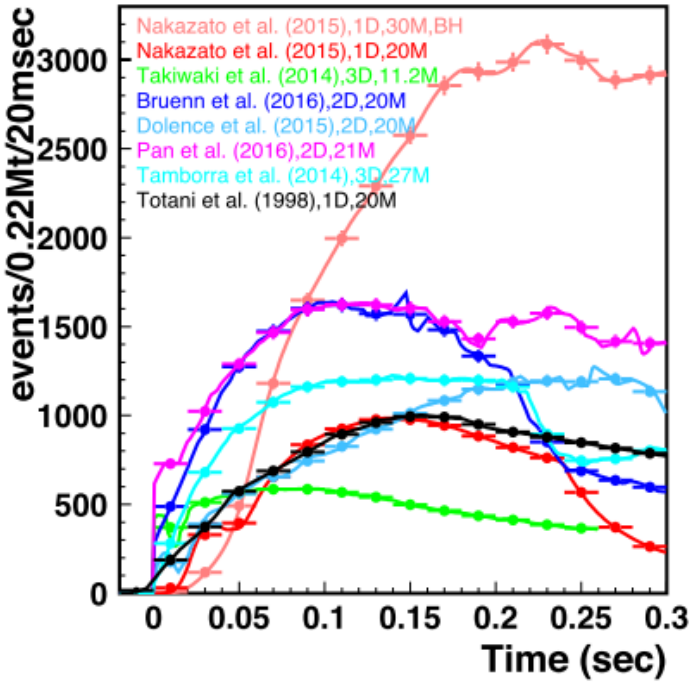




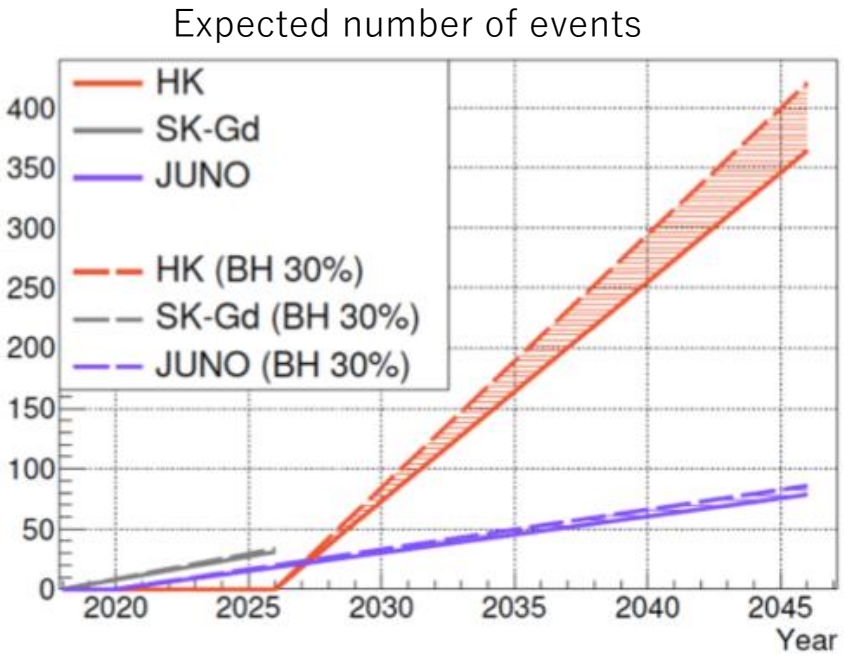


Physics: supernova

- Supernova Neutrino
  - Distinguish explosion models from rate, energy variation in time
  - 5-90000 events expected at ~10kpc (SN in this galaxy)

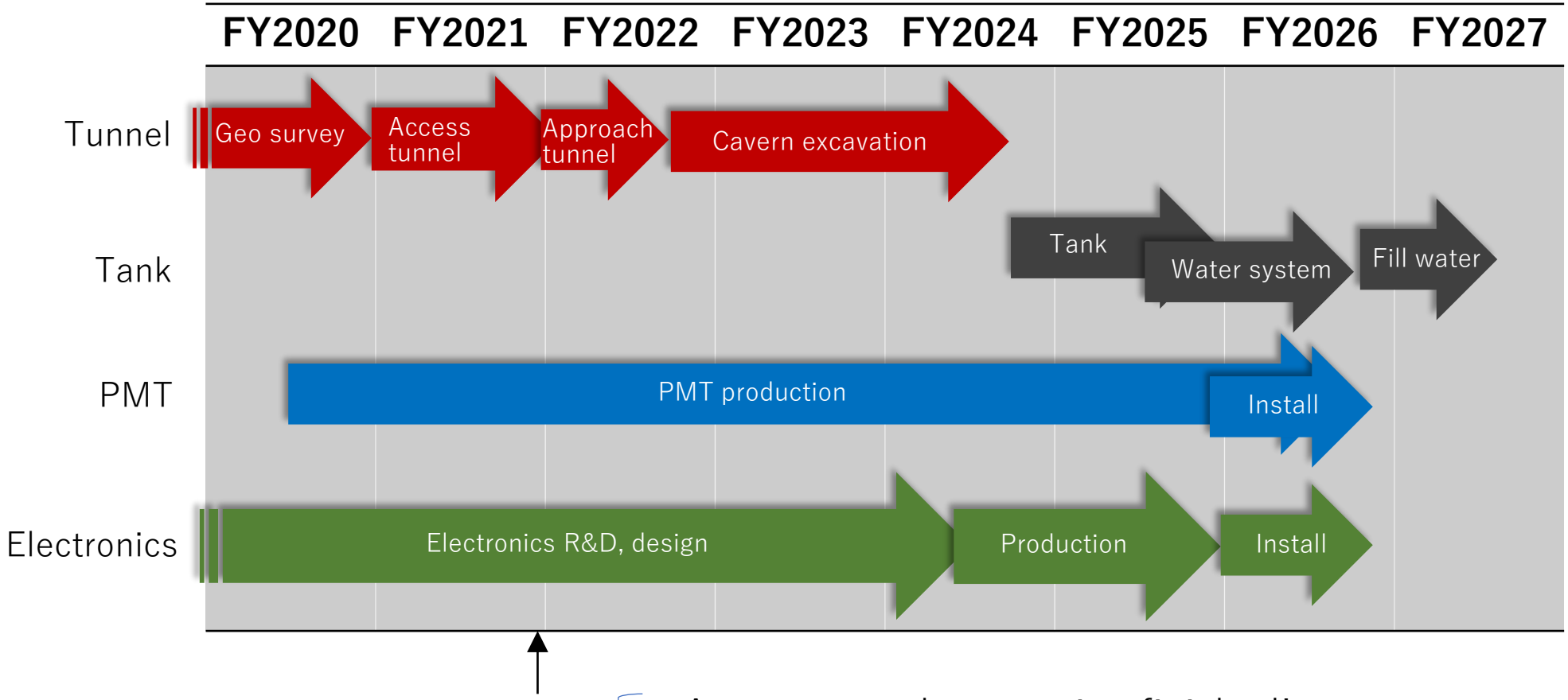


- Supernova **Relic** Neutrino
  - Detect neutrinos from past supernova → star formation history
  - Aiming at first observation in SK(Gd), spectrum measurement in HK



Latest news

Schedule and highlights



- Access tunnel excavation finished!
- PMT production is in progress on schedule
- Electronics R&D is ongoing

Tunnel excavation

ハイ パー カミ オカ ンデ
祝 アクセス坑道掘削完了
L= 187 3.4 88m

Excavation of the access tunnel completed!
Next: approach tunnel, tank cavity

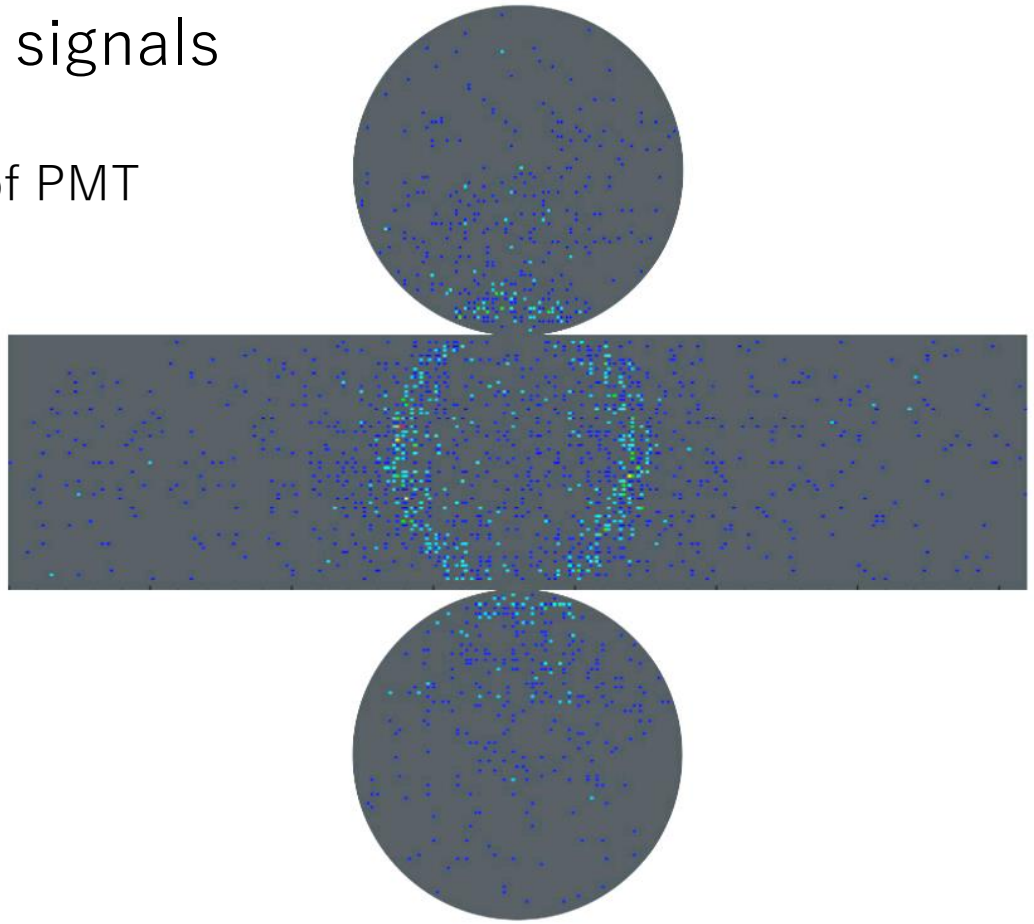
PMT production

- ~3000 PMTs (out of 20000) have been delivered so far without delay.
- Currently, we check 10% of the delivered PMTs
  - Signal check & visual inspection of the glass and sealing

Electronics R&D

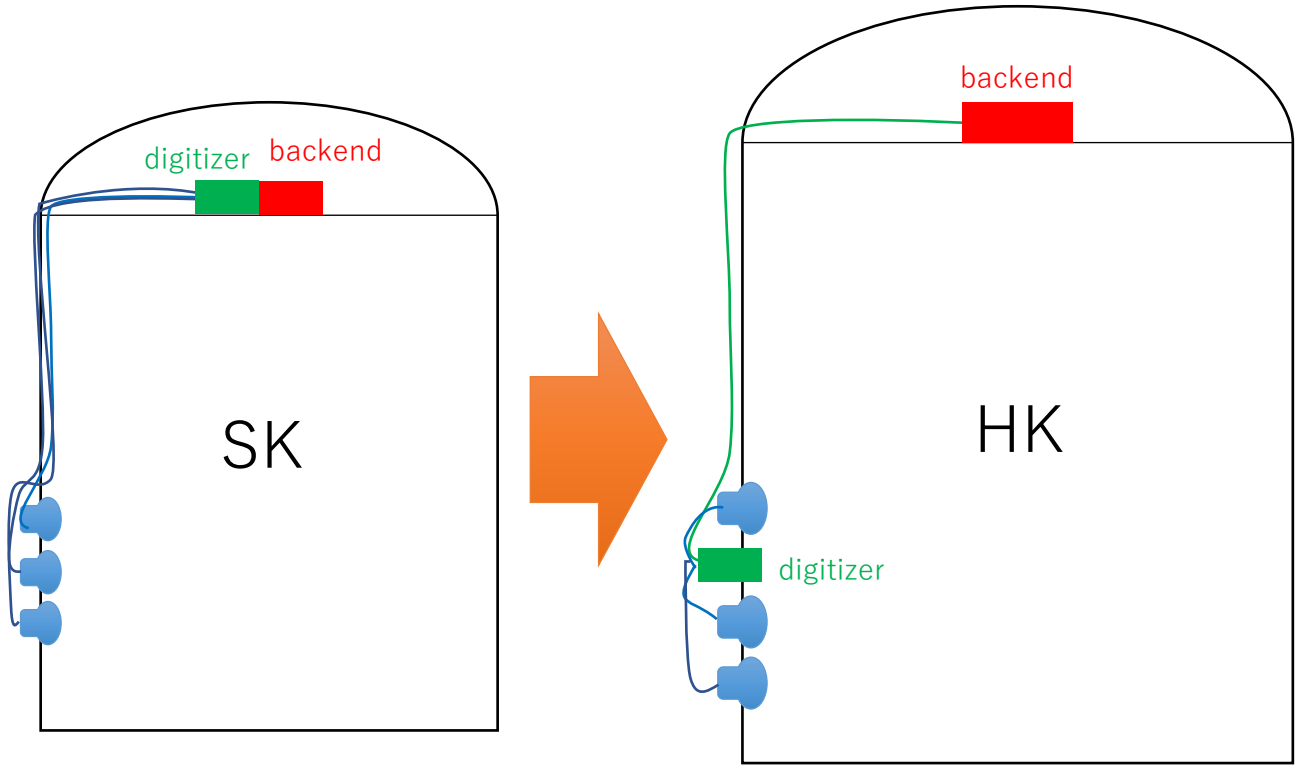
Requirements for the electronics

- Record charge and time of the PMT signals
  - Self trigger
  - Resolution must be much better than that of PMT
- Special needs
  - Wide energy range (MeV to 10 GeV~)
    → Low noise (<1/6 p.e. threshold),
    good linearity (<1% up to 1250 p.e.)
  - Under-water (new in HK)
    → Low power, long lifetime
  - High rate in case of nearby supernova
    → Dead time < 1us
    Also important for Michel-electron



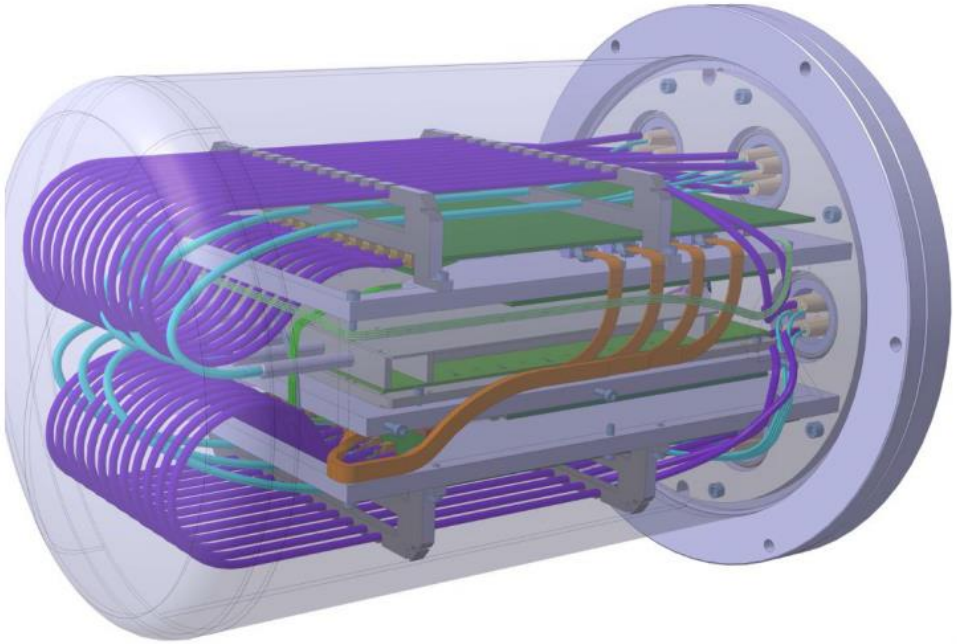
System overview

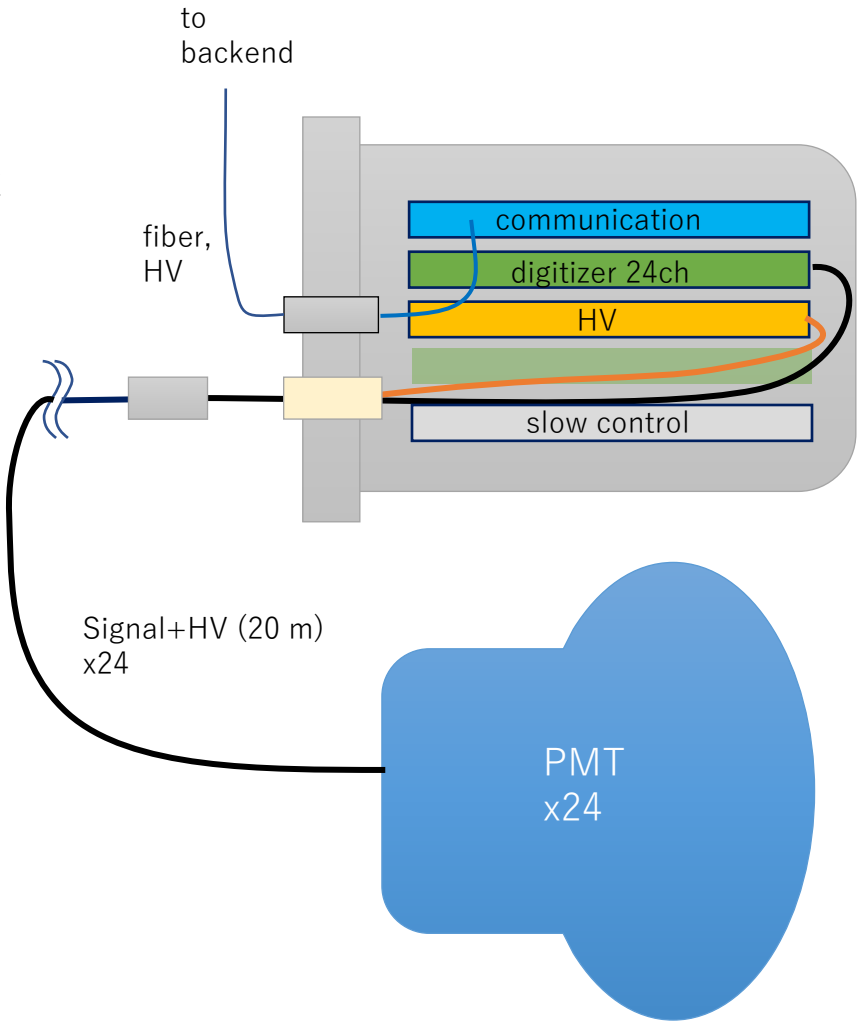
- In HK, we decided to have digitizer in water
  - ☺ Less cable
    → Reduce cost
  - ☺ Less signal degradation
  - ☹ Maintenance difficult
- Backend DAQ manages data from digitizer
  - It also distributes clock signal for synchronization



Under-water electronics

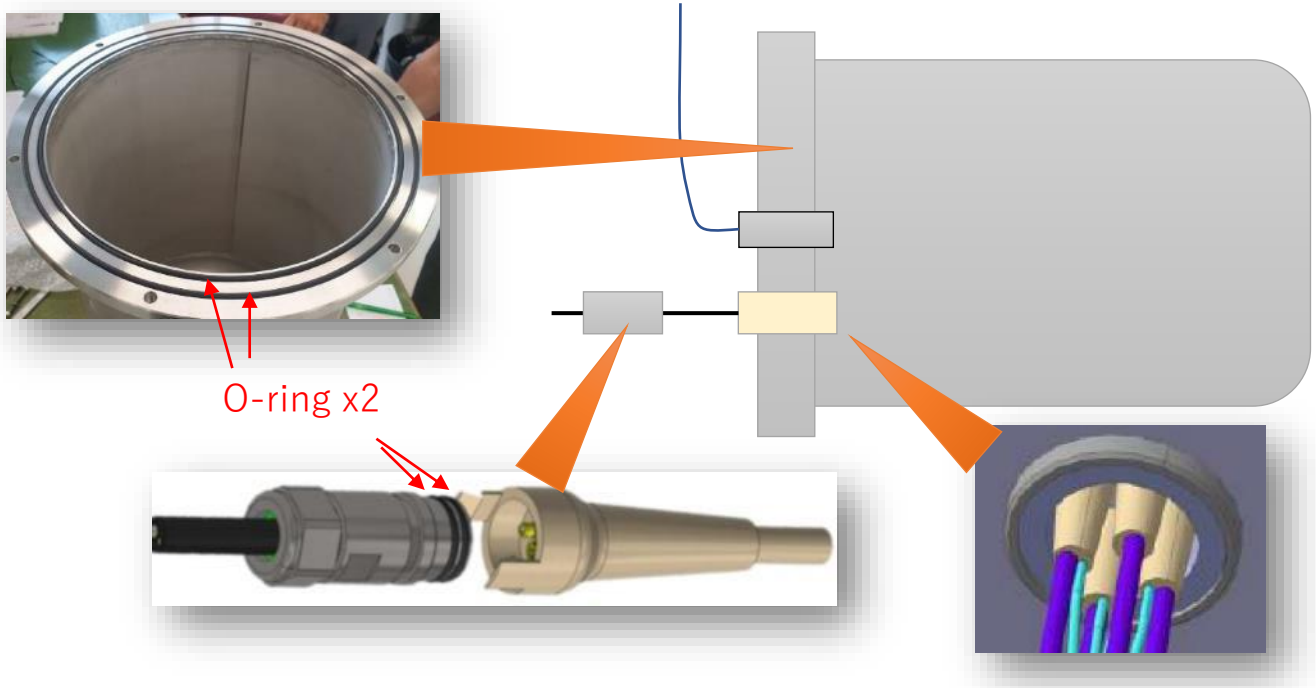
- Water-tight vessel per 24 PMTs
  - Light (~30kg) and small (ϕ30cm) for installation work
  - 1MPa water pressure tolerant
- Electronics boards will be contained in the vessel
  - Digitizer, HV, communication, slow control



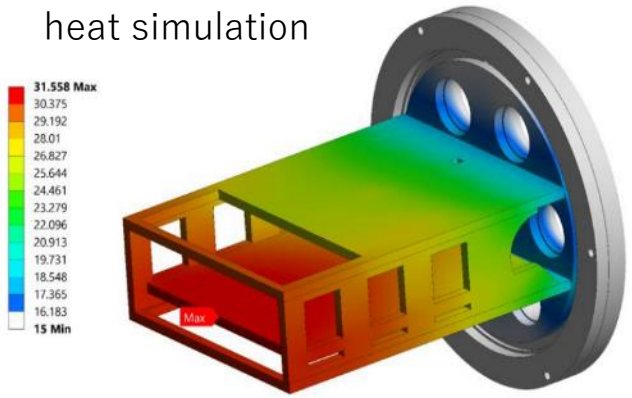


Vessel and cable connections

- Multiple sealing (O-ring etc.) at each connection
- Prototype R&D is ongoing.
  - 1MPa pressure test (prototype without feedthrough)
    → No leak, strength OK
  - Heat dissipation to outside water through metal support
    → Board temp. is <~30deg. in simulation.
    To be tested with dummy boards



heat simulation

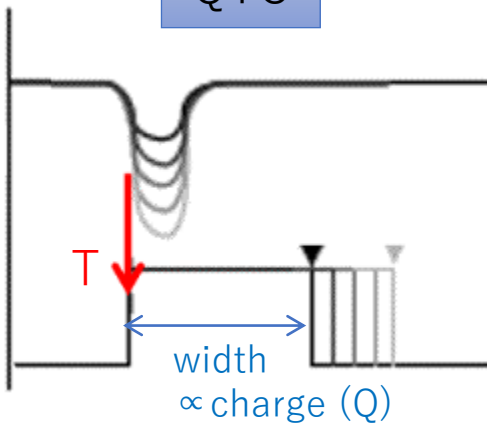


Digitizer candidates

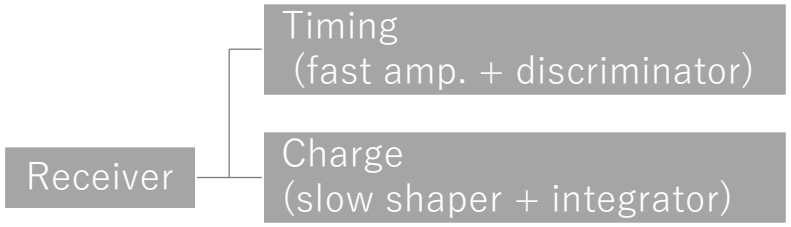
Three candidates → need to select one

- QTC
  - ASIC to convert T,Q to timing pulse width edge and width
  - Long-term operation experience in SK
- Discrete
  - No special ASIC, use amp, shaper, discriminator and integrator
  - Parameter optimization is relatively easy
- HKROC
  - New ASIC to sample waveform and calculate T,Q
  - Minimal deadtime

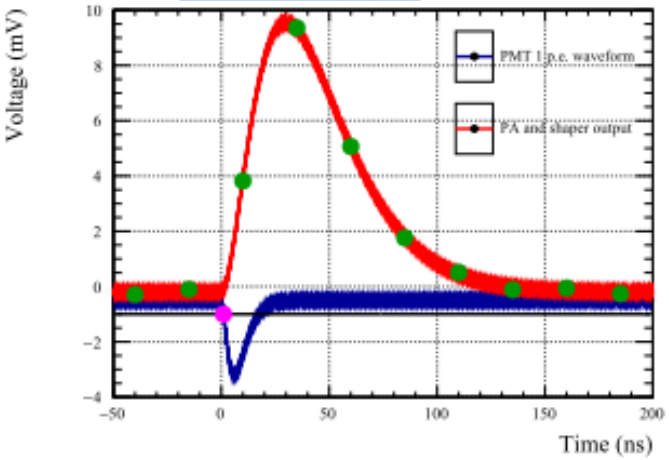
QTC



Discrete



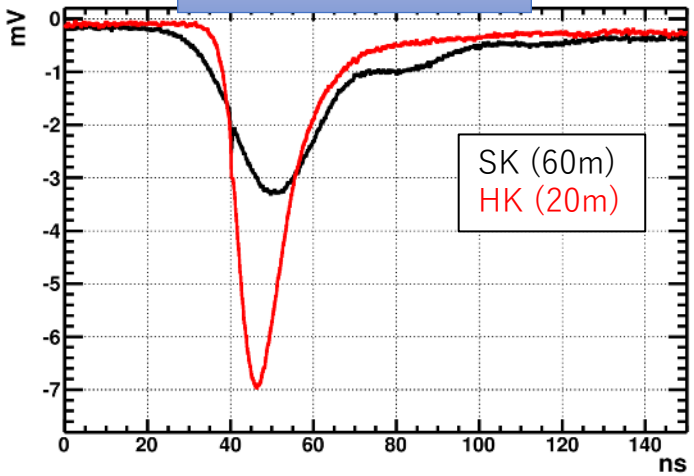
HKROC



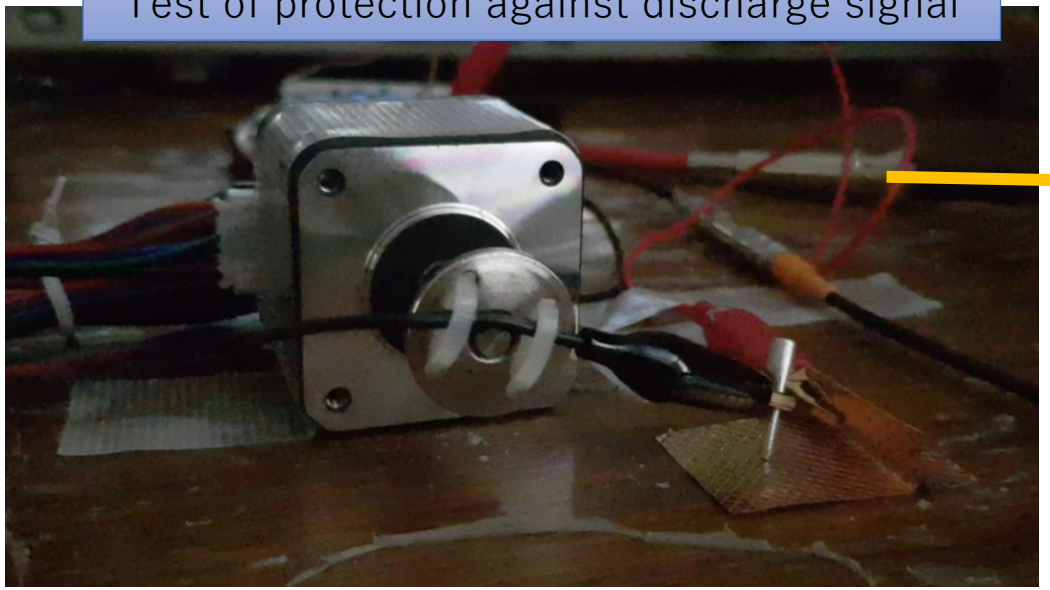
QTC R&D

- QTC chip itself does not change, but the analog frontend is tuned for the HK PMT waveform
  - Protection against ESD signal (TVS diode)
  - Slow shaper + buffer amp.
- R&D is ongoing
  - Test with HV discharge signal (~1kV) → OK

PMT waveform



Test of protection against discharge signal

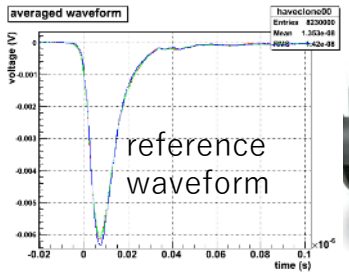


analog frontend test board

TVS diode

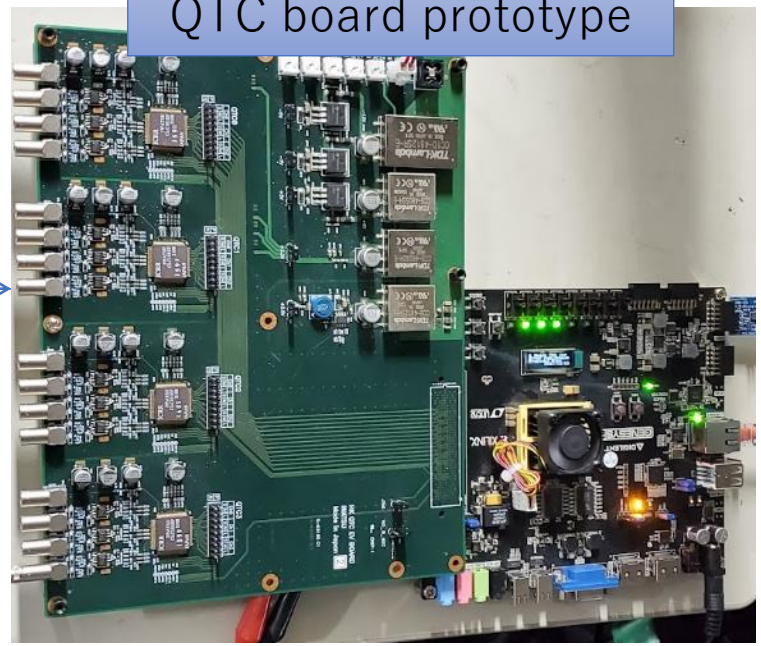
Evaluation for design decision

- Each digitizer group needs to evaluate the boards in a common method
  - Measure noise, resolutions, linearity etc.
  - FIT (Failure In Time), resource availability estimation



arbitrary function
generator or PMT

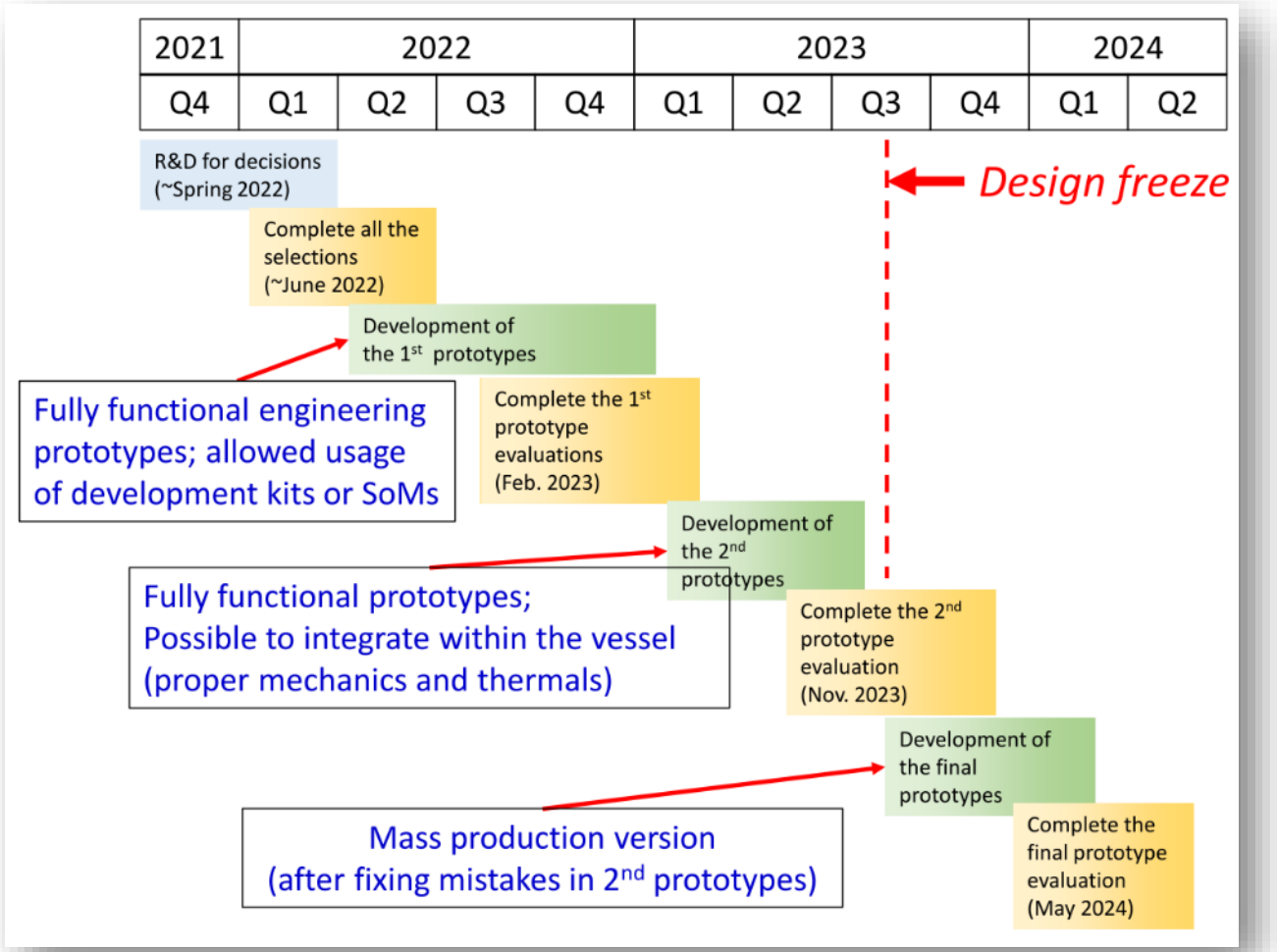
QTC board prototype



Electronics R&D schedule

- We will finalize the digitizer design this year.
  - HV, timing and other boards are also being developed.
- Three times iterations of the tests is planned for the digitizer
  - Including tests in water with water-tight vessel
- To be followed by mass production which in FY2024.

Hayato-san's slide



Summary

- Rich physics program in HK
  - Neutrino oscillation, nucleon decay, supernova etc.
- Construction is on schedule towards the start of the operation in 2027.
  - Access tunnel excavation finished!
  - ~3000 PMTs arrived
- Electronics R&D is ongoing
  - Under-water system is challenging.
  - Three candidate digitizers are being evaluated.