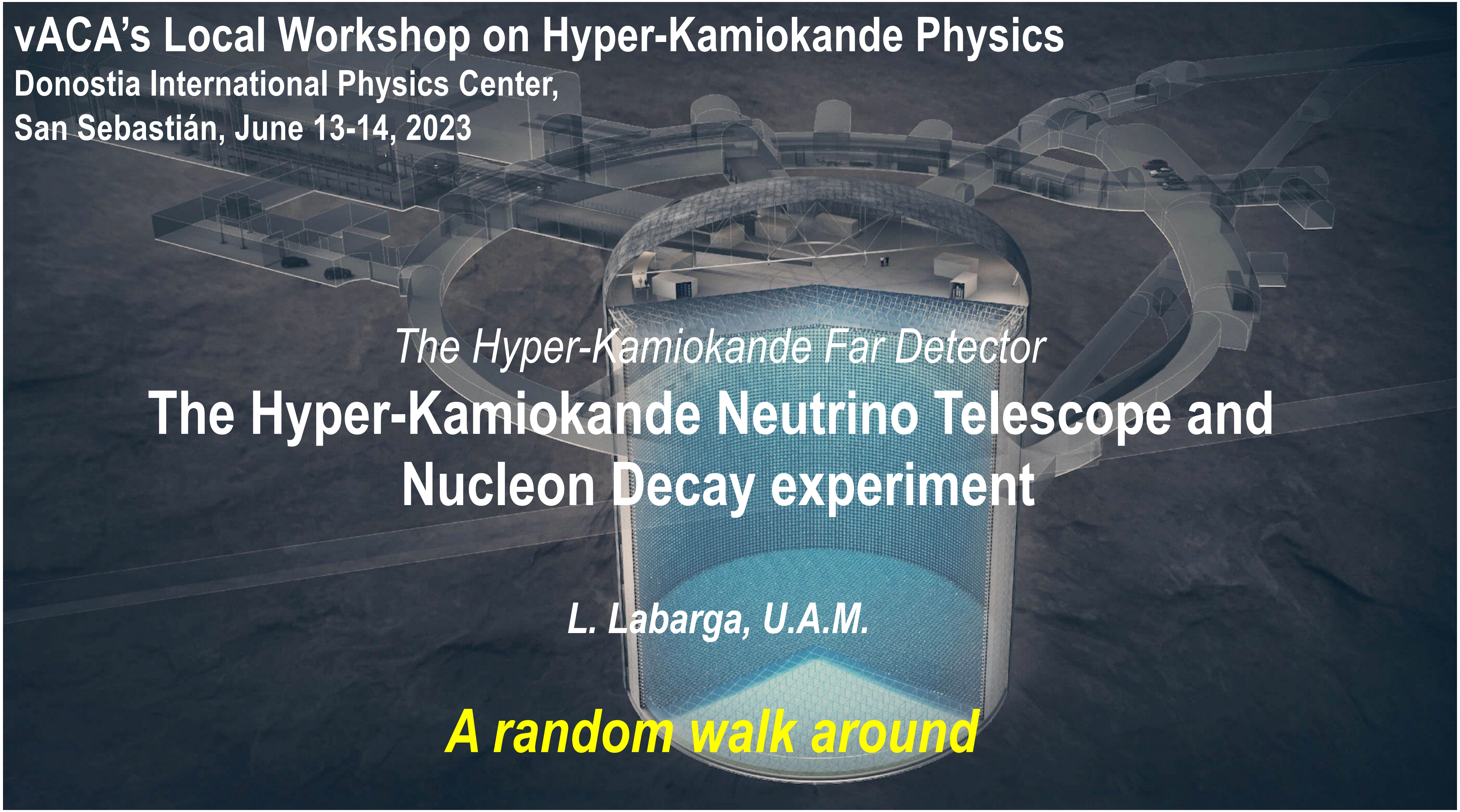


νACA's Local Workshop on Hyper-Kamiokande Physics

Donostia International Physics Center,
San Sebastián, June 13-14, 2023

The Hyper-Kamiokande Far Detector

The Hyper-Kamiokande Neutrino Telescope and Nucleon Decay experiment

L. Labarga, U.A.M.

A random walk around

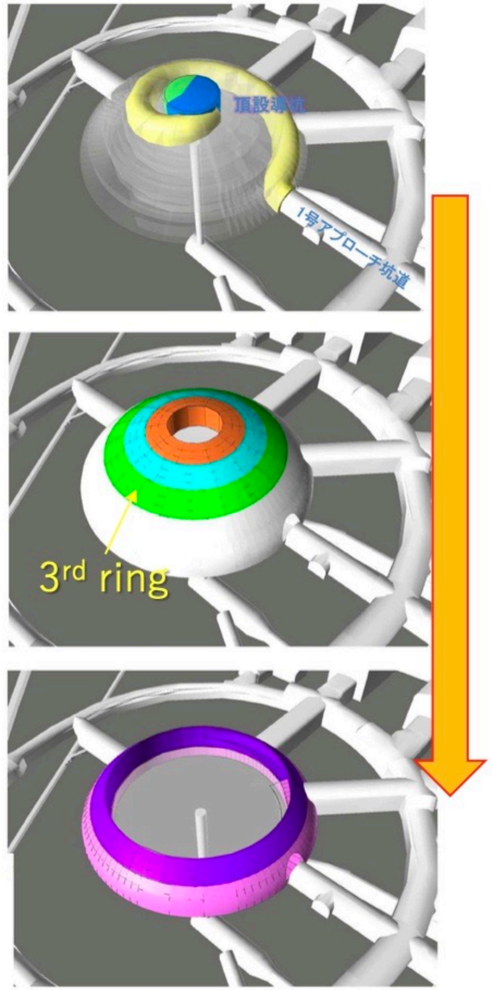
Excavation of the Main Cavern: Dome Section

Dome excavation is progressing well and has already exceeded the SK diameter.

M. Nakahata @ 7th HKFF 20230607

As of May 30, 2023

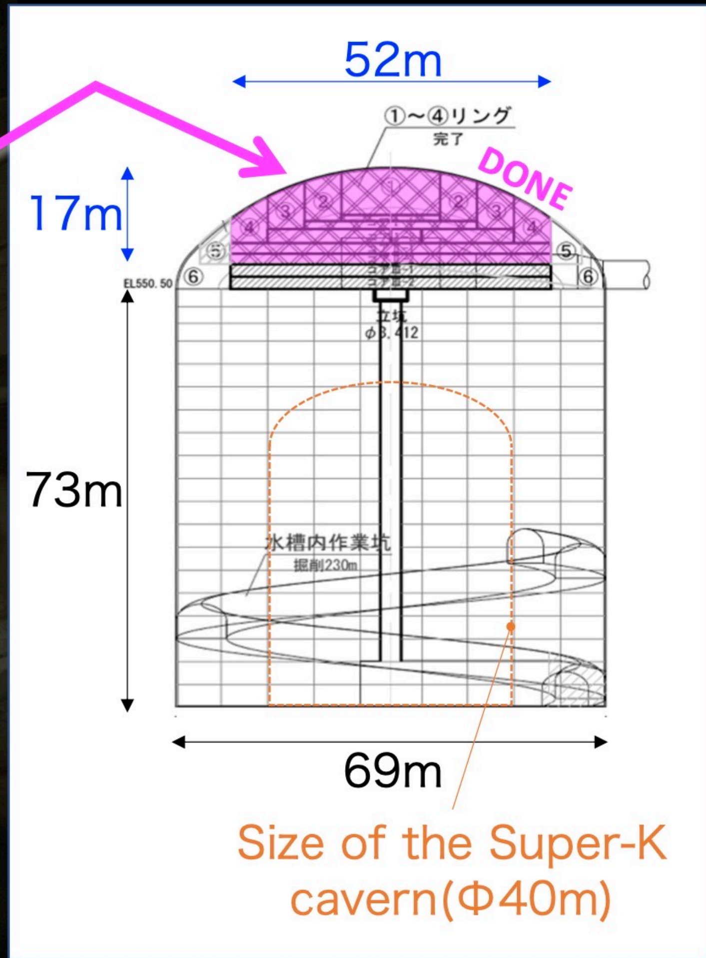
Excavation method



4th ring completed
(current status)

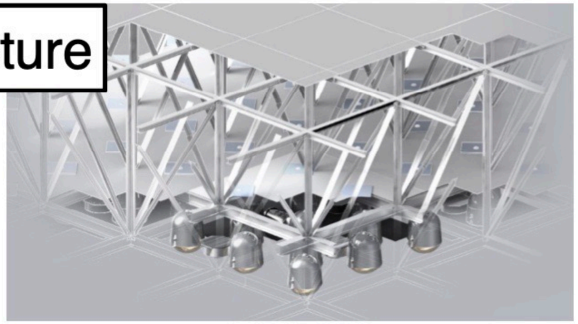
CAVERN

- Japan will complete Cavern/Tunnels/Satellite cavities in 2024.
- We are getting over the most difficult construction climax (risk of collapse).

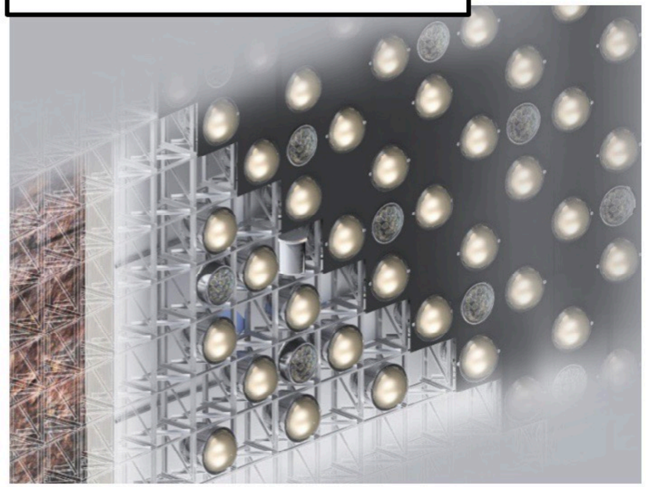


2023.5.30

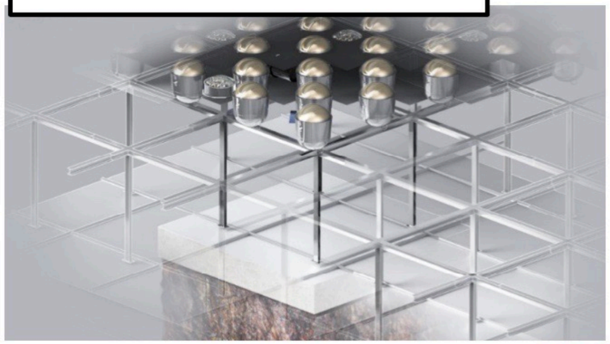
TOP structure

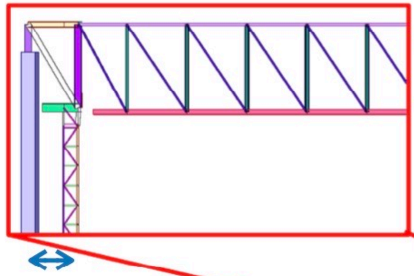


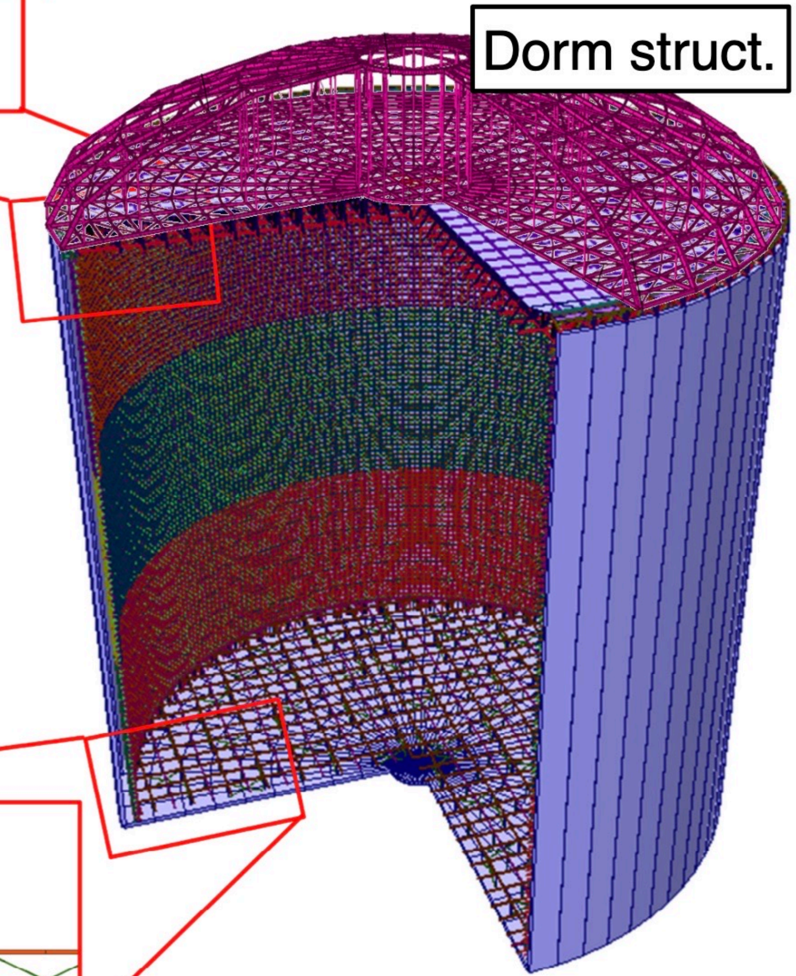
BARREL structure

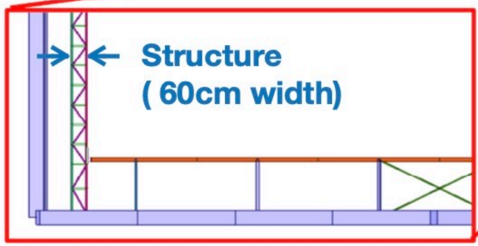


BOTTOM structure



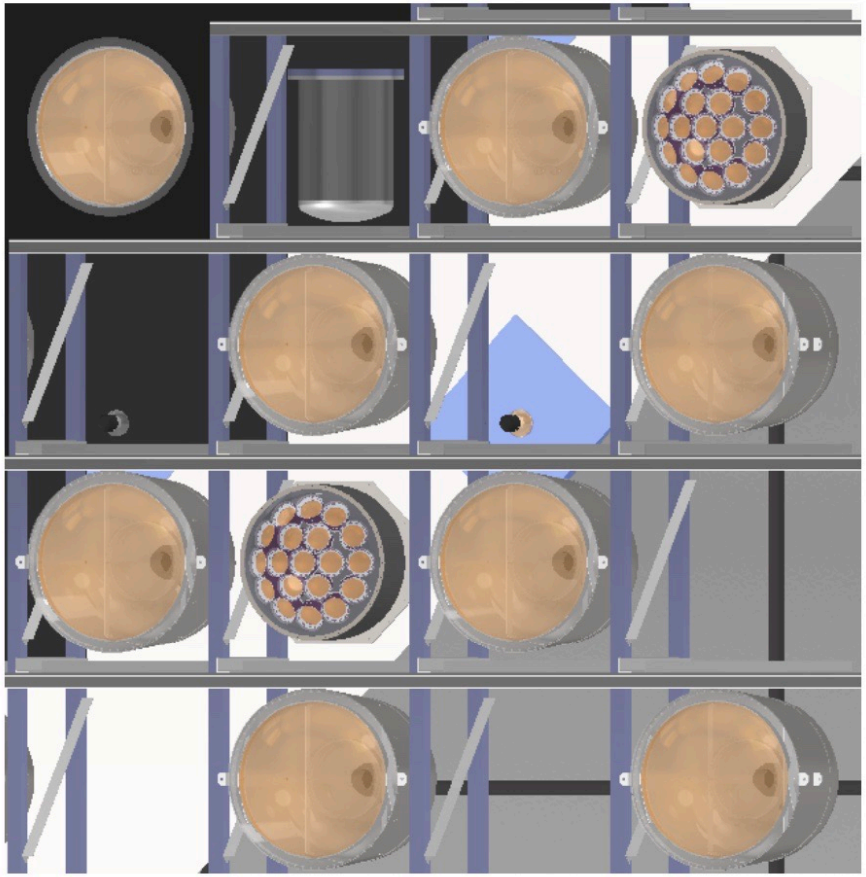




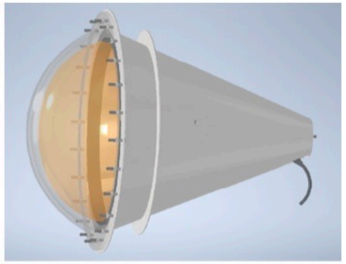


K. Okumura @ 7th HKFF 20230607

Detector Components



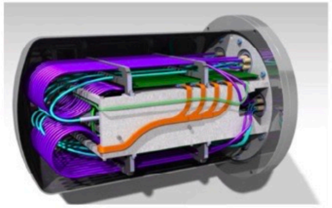
K. Okumura @ 7th HKFF 20230607



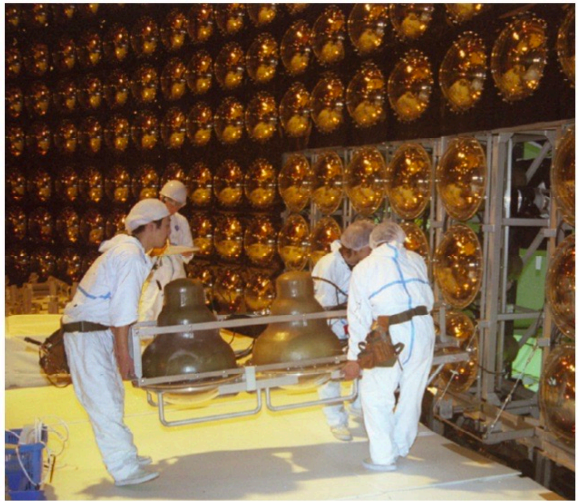
- 50cm dia. inner detector photomultiplier（IDPMT）
  - numbers ~ 20,000
  - covered with stainless cover and acrylic

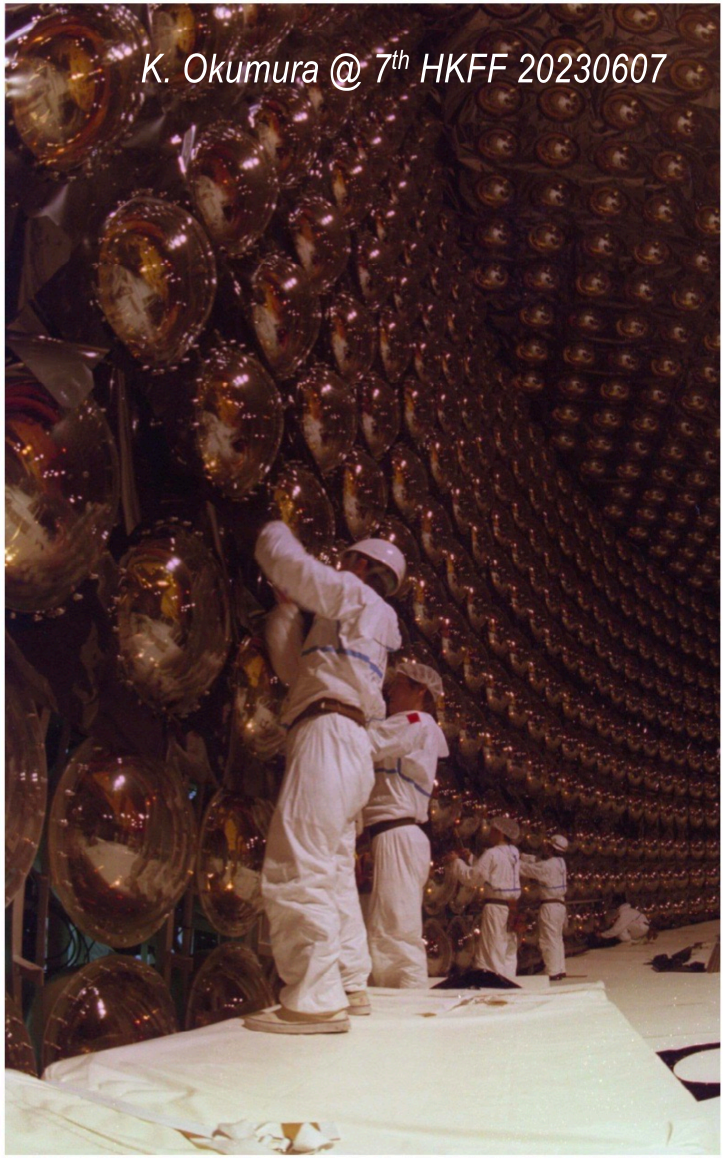
- Multi-PMT（mPMT）
  - numbers ~1000

- Outer detector photomultiplier（ODPMT）
  - numbers ~7200



- Underwater electronics
  - numbers ~1,000

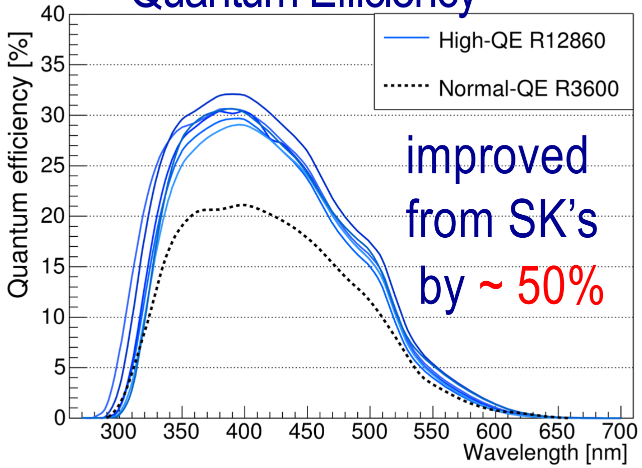



K. Okumura @ 7th HKFF 20230607

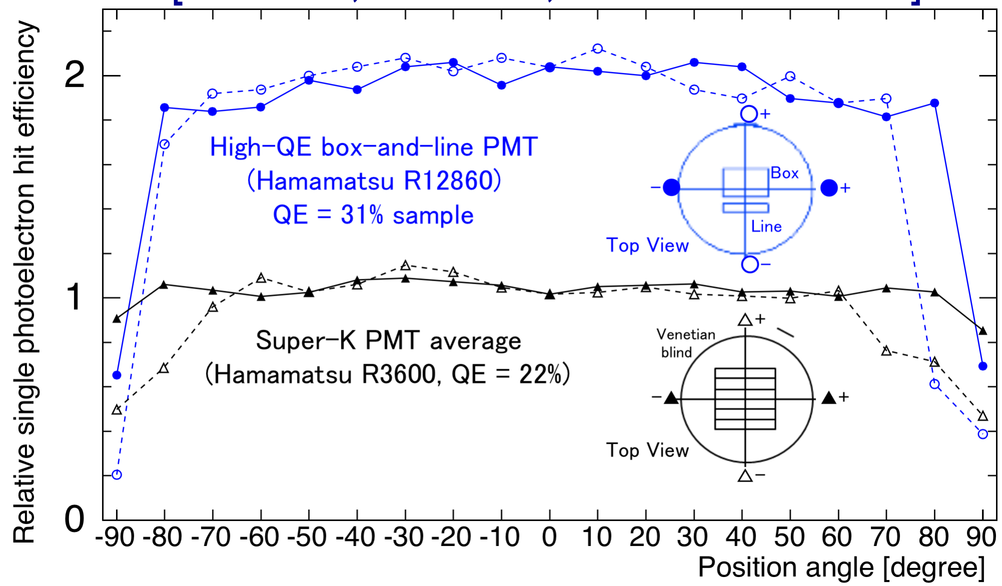

K. Okumura @ 7th HKFF 20230607

main characteristics high-QE Box&Line PMT Hamamatsu R12860 vs. SK-PMT Hamamatsu R3600

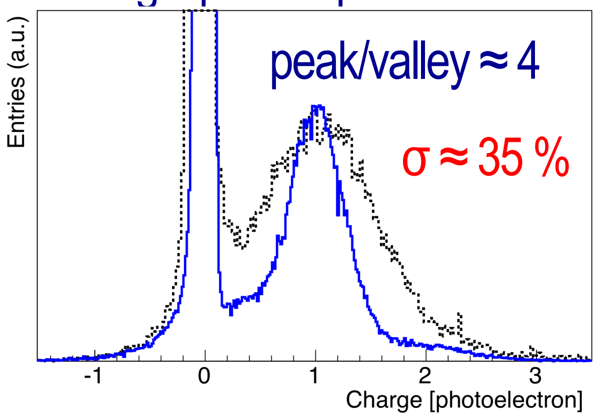
Quantum Efficiency



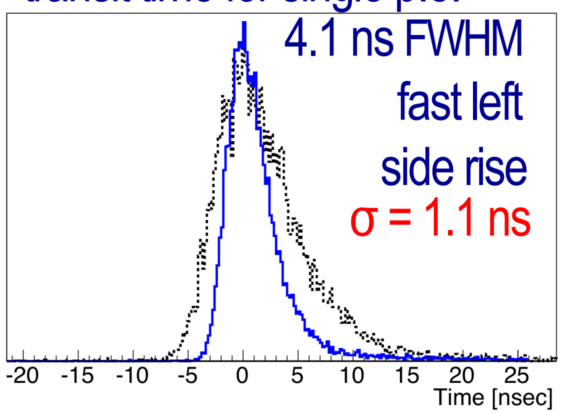
relative single photoelectron det. efficiency [Quantum, Collection, and Cut efficiencies]



single p.e. w/ pedestal



transit time for single p.e.



2 x better efficiency, timing resolution, charge resolutions →

- enhance solar ν_S ,
- signature n(p,d)γ
- p → ν K^+
- ….

Geomagnetic compensation system

(see next talk by our UO colleagues)

reduce to < 50 mG any magnetic field surrounding the PMTs for them to work)

Orden 0: a la SK *HK Design Report; arXiv:1805.04163v1*

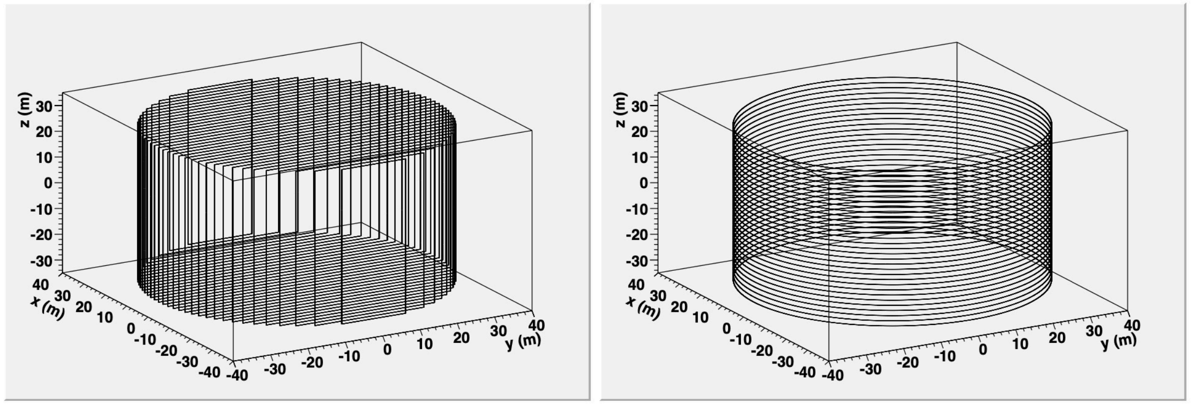
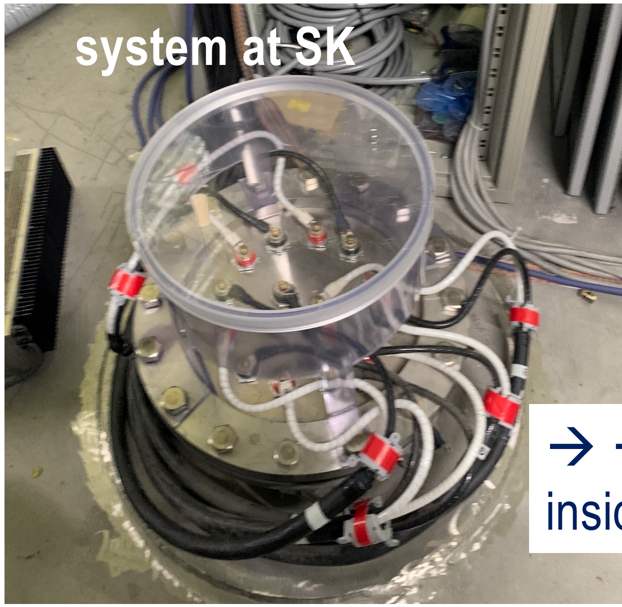


FIG. 48. Location of vertical rectangular coils (left) and horizontal circular coils (right).



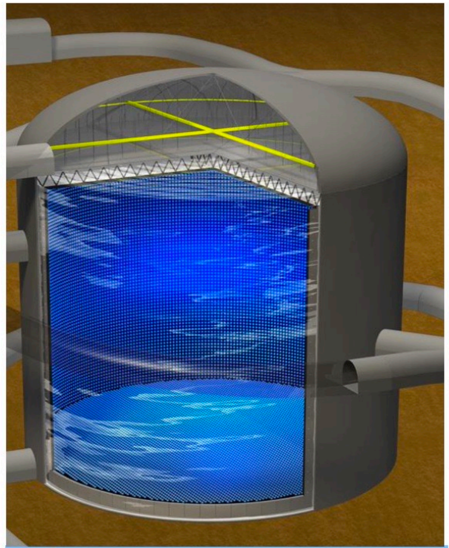
→ → to the coils inside the SK tank

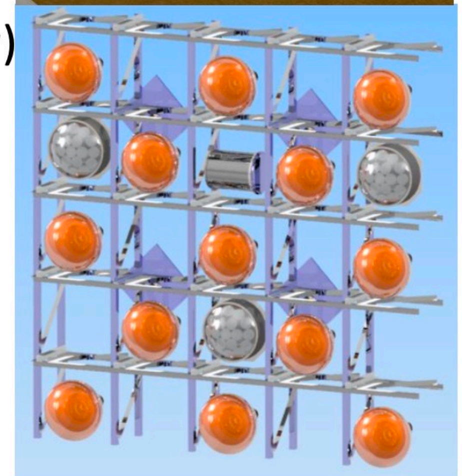
Electronics

Electronics for the Hyper-Kamiokande far detector

Hyper-Kamiokande

~ Water Cherenkov detector





Necessary functions

- Measure charge from photo sensors
- Measure arrival timing of photons

What we need?

- Self triggering signal digitizer
- Accurate timing synchronization system
- GNSS (accurate absolute time stamp for accelerator ν)
- Stable HV power supplies for photo sensors
- System and environment monitors

Continuous operation

24hrs/7days/365 days for > 10 years

- ***Stable and reliable electronics*** without failure

Detector size is so large (70m x 70m).

Install the front-end electronics modules in the water.

Y. Hayato @ 7th HKFF 20230607

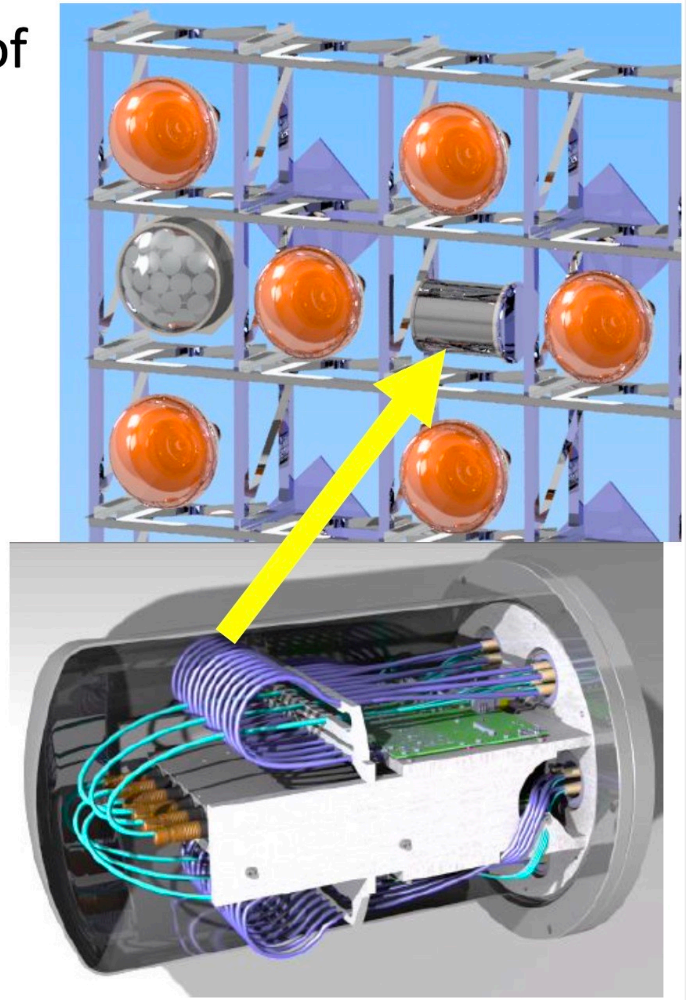
Electronics

Y. Hayato @ 7th HKFF
20230607

Hyper-Kamiokande underwater electronics

Underwater electronics module consists of

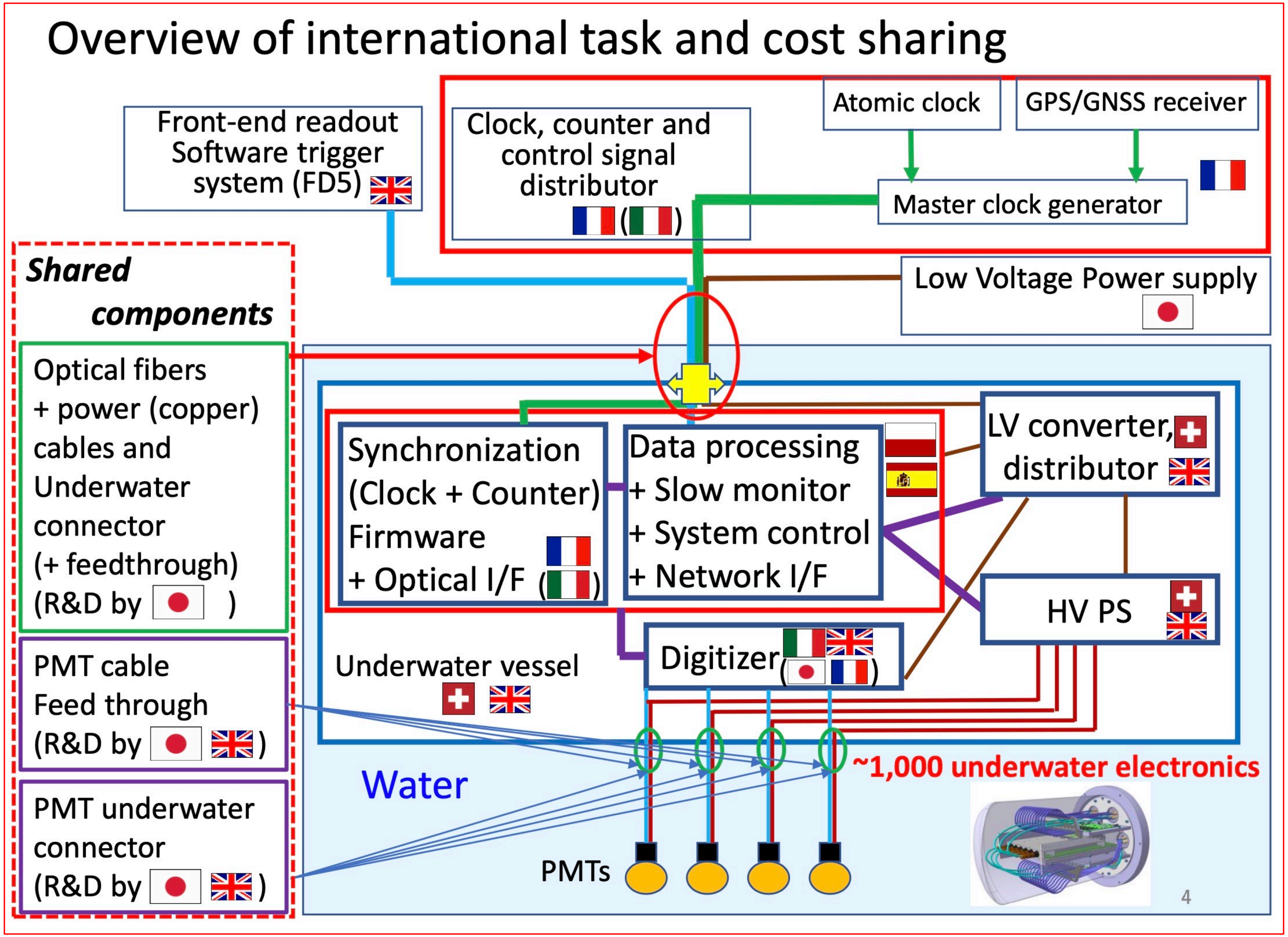
- Water pressure tolerant vessel
- Digitizers
- Data processing board
  with synchronization system
- High voltage power supply
- Low voltage DC/DC converted
- Communication fiber & power cables
  with feedthrough
- PMT cable & feedthrough



Each underwater electronics module
is connected to the DAQ system
on the tank roof
with special underwater fibers and cables.

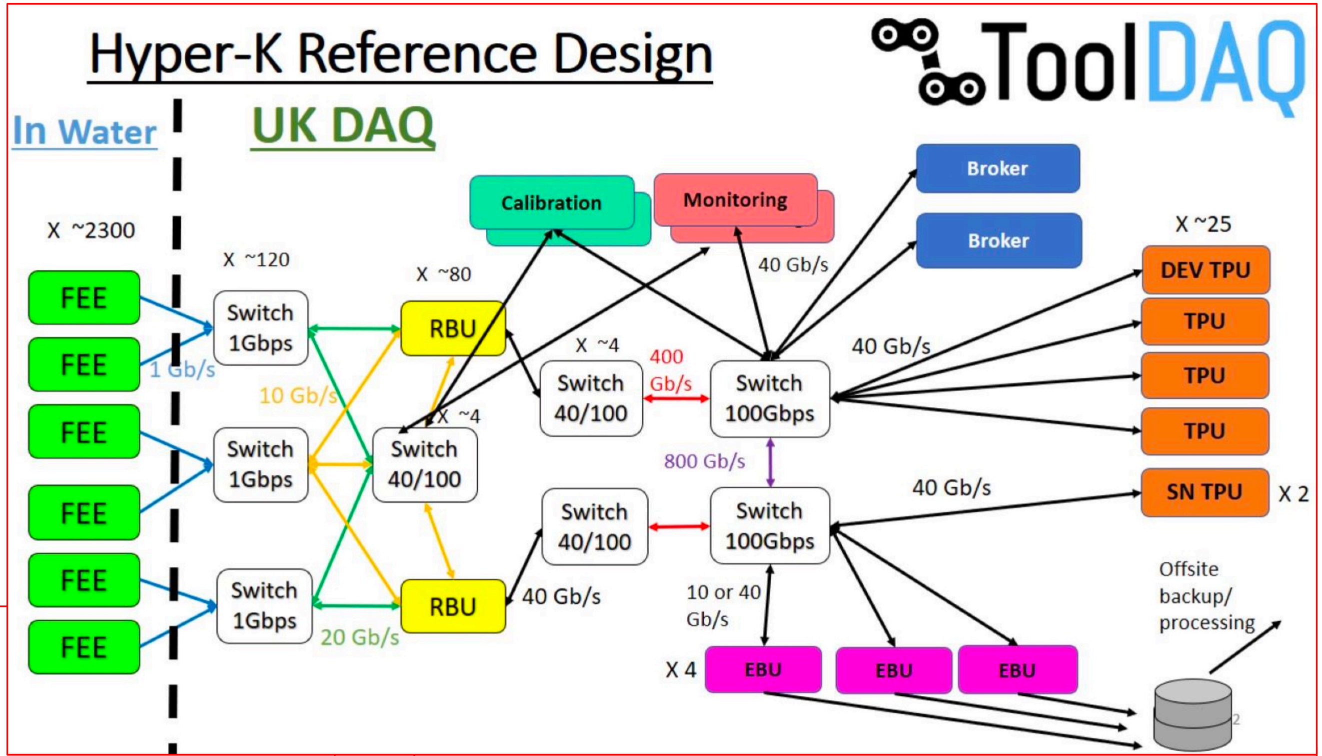
Electronics

Y. Hayato @ 7th HKFF 20230607



DAQ

B. Richards @ HK CM 202303



RBU: Readout Buffer Units

TPU: Trigger Processor Units

SN TPU: Super Nova Processor Units

EBU: Event Builder Unit

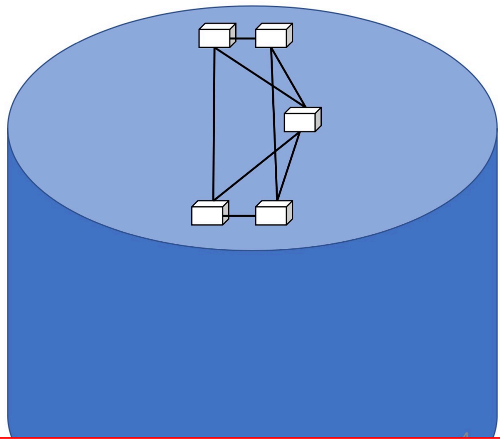
DAQ Location

Current Plan is to have 5 electronics huts on top of the tank

- 4 x huts where PMTs are connected housing RBUs
- 1 x central hut with TPUs, EBUs and brokers
- Interconnecting cables between each hut

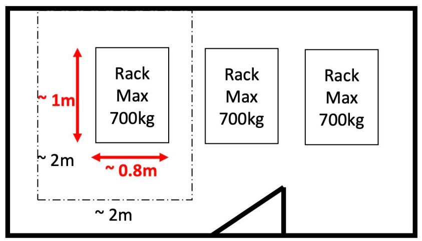
Construction to take place in parallel to barrel construction

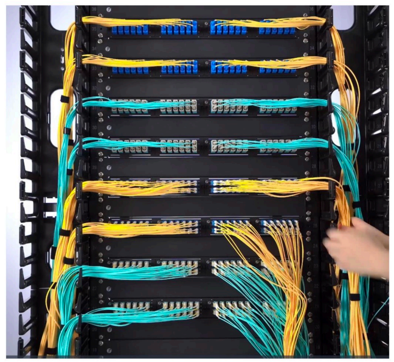
With PMT and Inter rack cabling delayed till after tank finished to avoid damage to the fibre interconnects.



Rack Floor Space

- ~8-12 m^2 needed per hut for ~2/3 racks



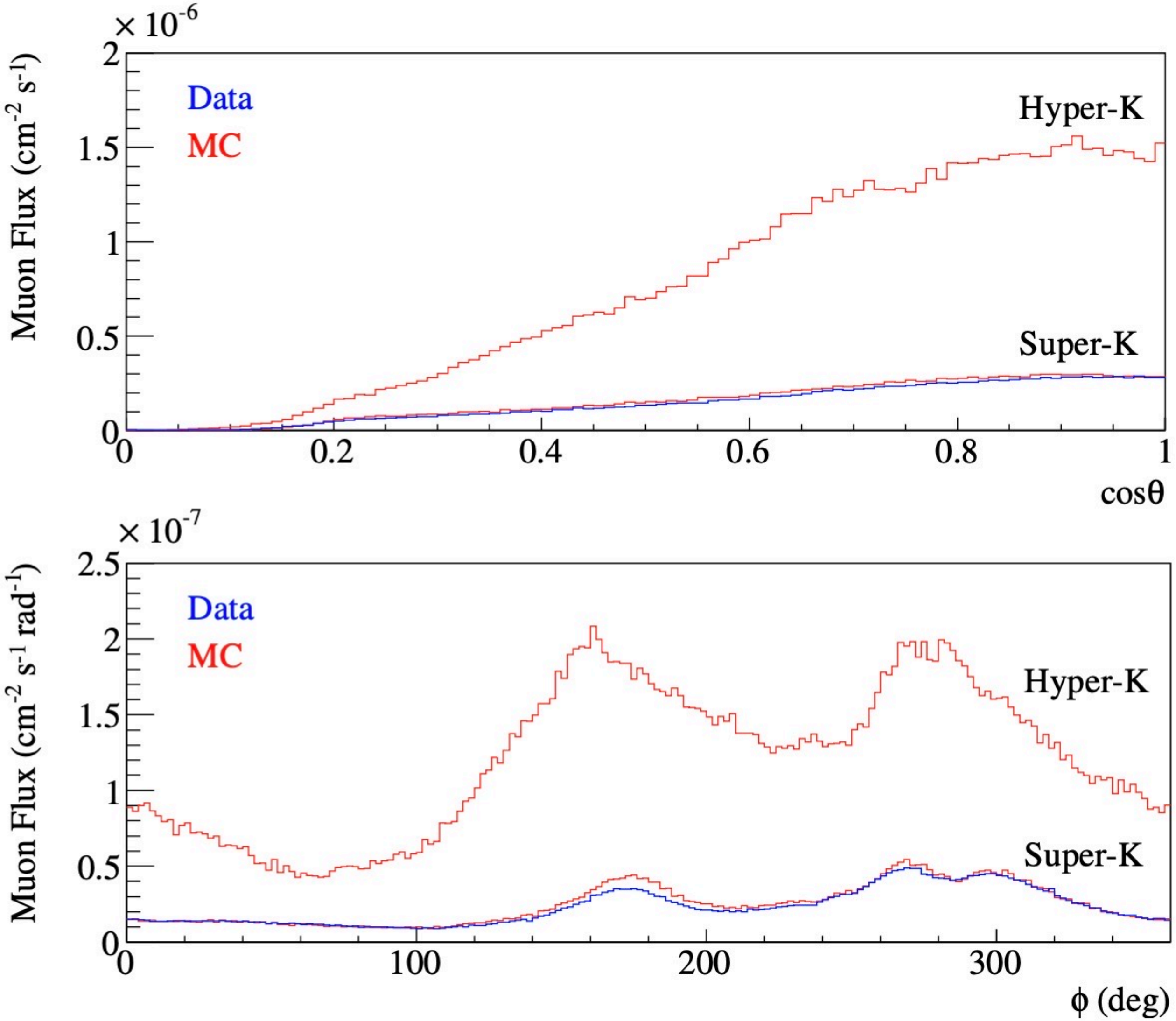


Cosmic muon flux is not negligible in HK

TABLE XXIX. Calculated muon flux (J_μ) and average energy ($\overline{E}_\mu$) in Hyper-K and Super-K for 2.70 g/cm^3 specific gravity Ikeno-yama rock based on the simulation method [165]. The basing point in Hyper-K is illustrated in Fig. 120.

Detector site	Vertical depth (m)	J_μ (10^{-7} cm^{-2}s^{-1})	$\overline{E}_\mu$ (GeV)
Hyper-K (basing point)	600	7.55	203
Super-K	1,000	1.54	258

Cosmic muon flux is not negligible in HK



Muon flux as a function of zenith angle θ (upper) and azimuth angle $\boldsymbol{\varphi}$ (lower) for Super-K and Hyper-K at the basing point. The east corresponds to the azimuth angle of zero degree. The blue lines show the data for Super-K, and the red lines show the MC predictions for Super-K and Hyper-K based on the MUSIC simulation. The absolute flux and the shape of the Super-K data, which are determined by slant depths for each angle, are well reproduced by MC.

Cosmic muon flux is not negligible in HK

TABLE XXX. Estimation of isotope production yields for Hyper-K and Super-K by muon spallation with FLUKA. The ratio of the production yields for Hyper-K compared with Super-K are also listed. The ratio of the production rates are calculated by multiplying the isotope yield ratio by the muon flux ratio of 4.9 ± 1.0, evaluated by the MUSIC simulation.

Isotope	Isotope yield by FLUKA (μ/m)		Ratio of isotope yield	Ratio of production rate
	Hyper-K	Super-K	(Hyper-K / Super-K)	(Hyper-K / Super-K)
^{12}B	8.05×10^{-5}	9.93×10^{-5}	0.811 ± 0.078	3.98 ± 0.88
^{12}N	8.70×10^{-6}	1.11×10^{-5}	0.785 ± 0.075	3.84 ± 0.85
^{9}Li	1.23×10^{-5}	1.68×10^{-5}	0.732 ± 0.070	3.59 ± 0.80
^{8}Li	8.67×10^{-5}	1.08×10^{-4}	0.805 ± 0.077	3.95 ± 0.87
^{15}C	5.12×10^{-6}	6.68×10^{-6}	0.768 ± 0.073	3.76 ± 0.83
^{16}N	2.74×10^{-4}	3.41×10^{-4}	0.804 ± 0.077	3.94 ± 0.87
^{11}Be	5.32×10^{-6}	7.76×10^{-6}	0.685 ± 0.065	3.36 ± 0.74

It makes low energy **ν** physics much more difficult