

Hyper-K detector (cavern, tank, water, ...)

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For

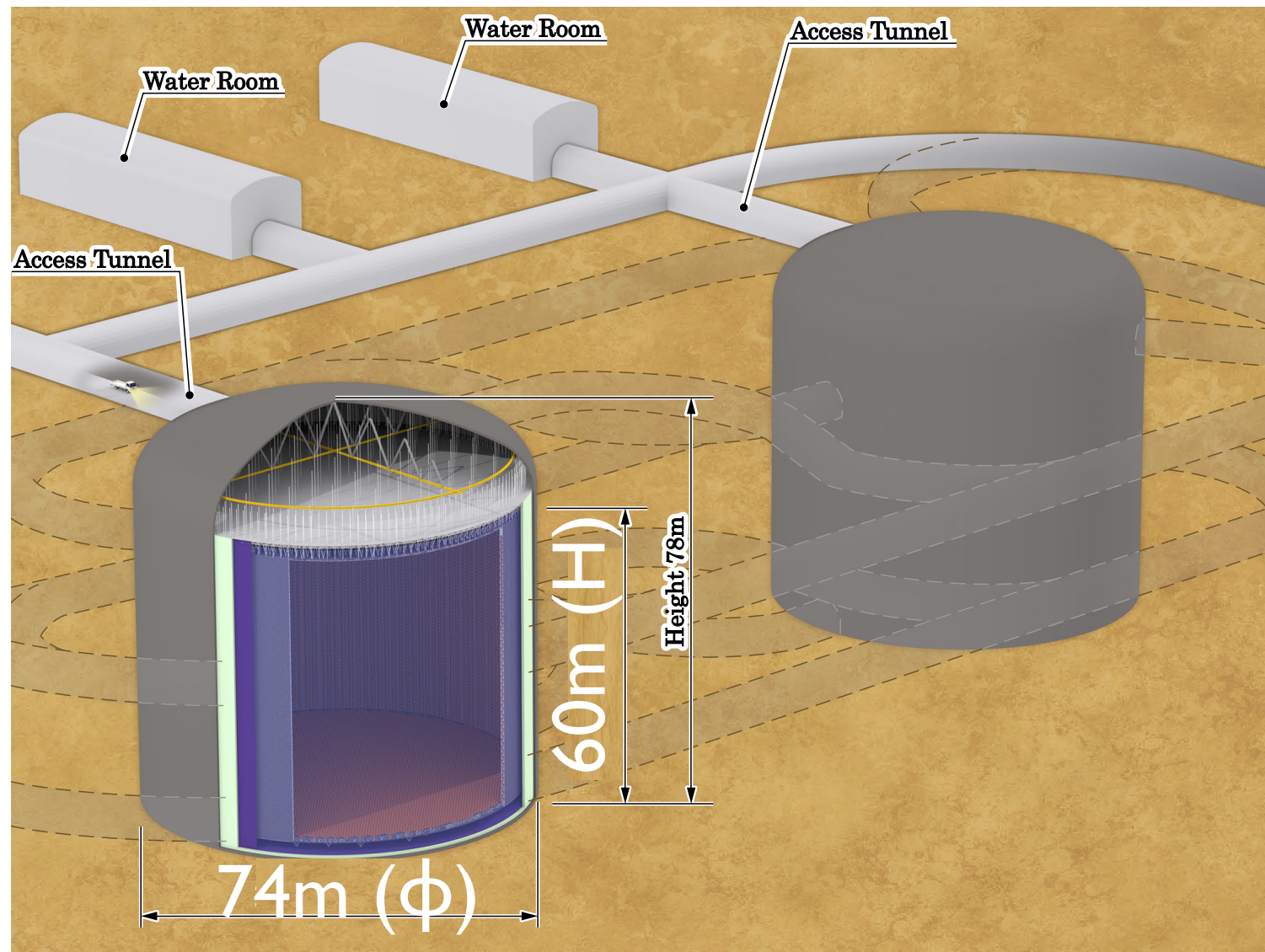
Cavern and Tank WG, Water WG, Photo-sensor WG

Hyper-K Open Meeting, July 10, 2016

Outline

- Hyper-K detector overview
- Detector design
- Hyper-K detector construction timeline
- Summary

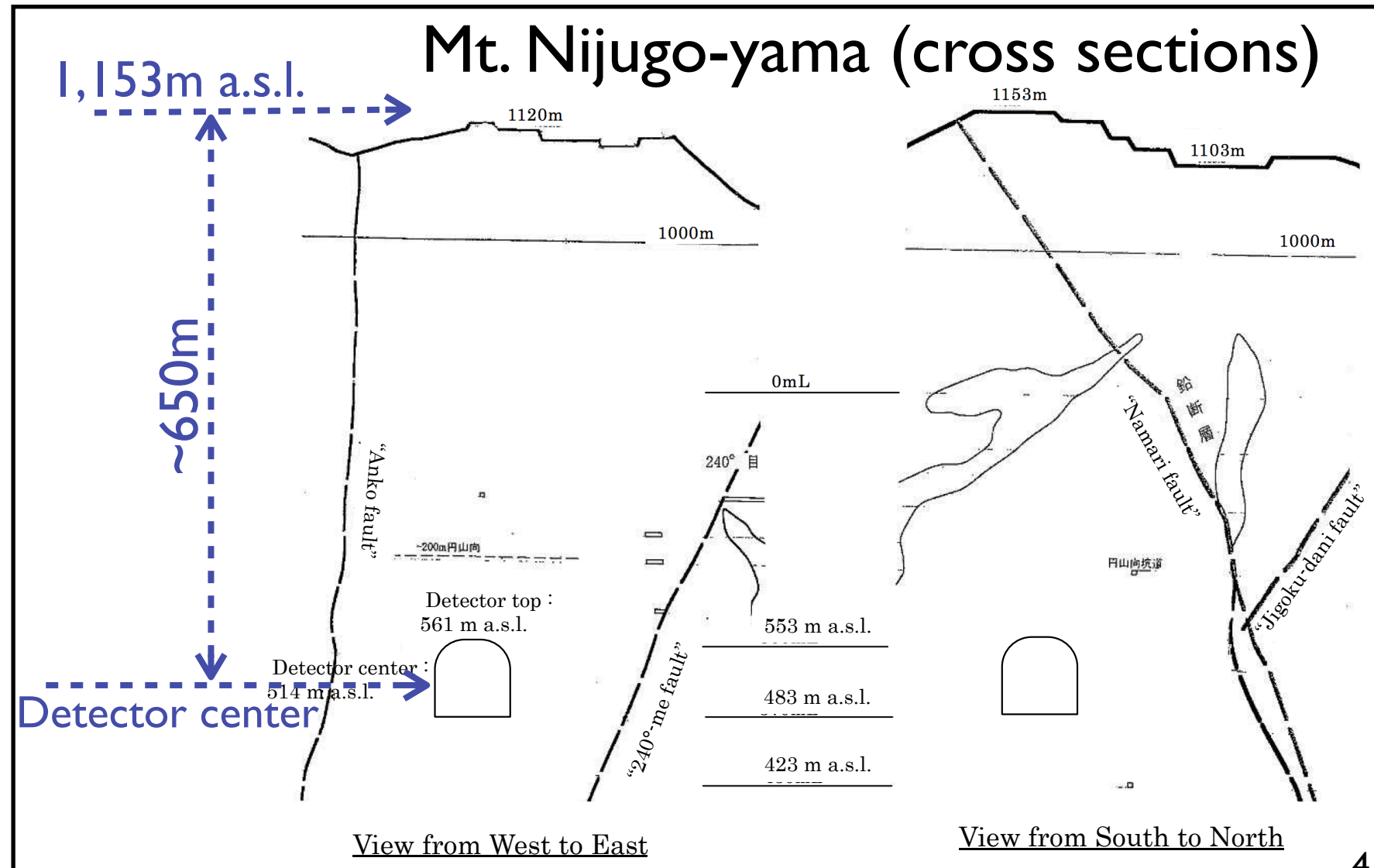
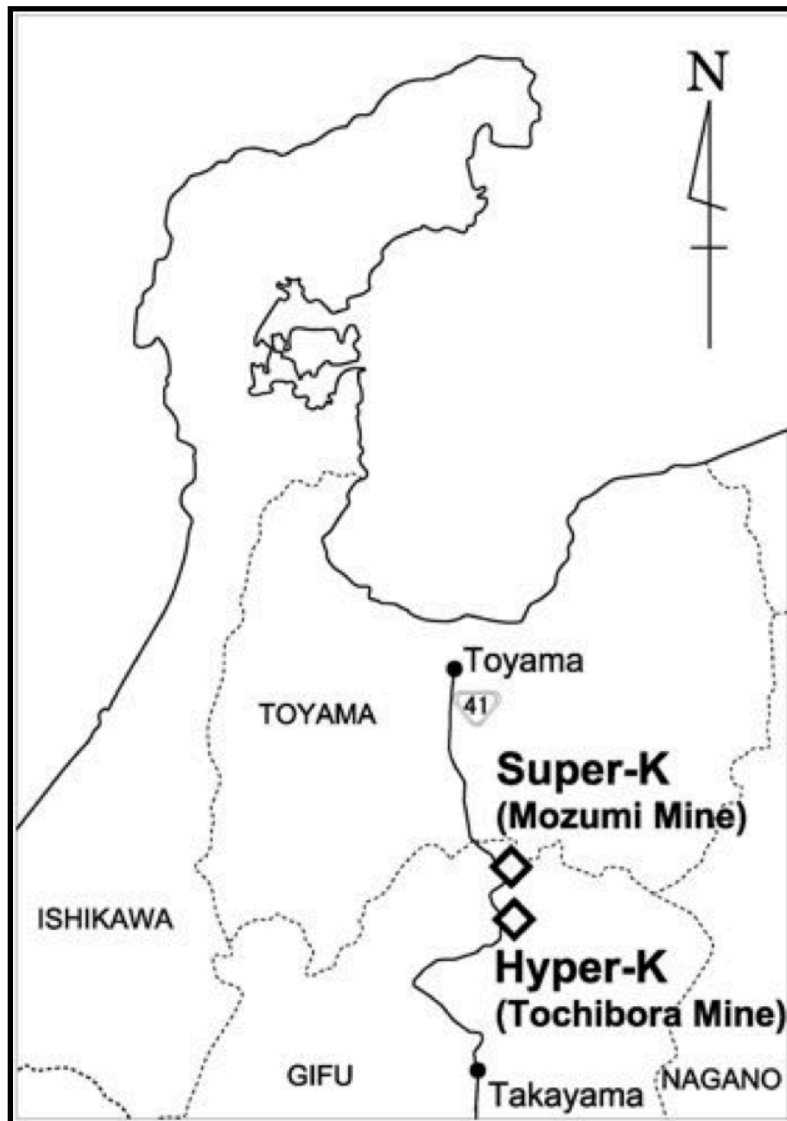
Hyper-K detector overview



- Two cylindrical-shape detectors in stages
 - 74m diameter, 60m water-depth
- Fiducial volume: 0.37Mton
 - ~20 times larger FV than Super-K
- 40% photo-coverage (inner-detector: 80k PMTs)

Detector location

- 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.)



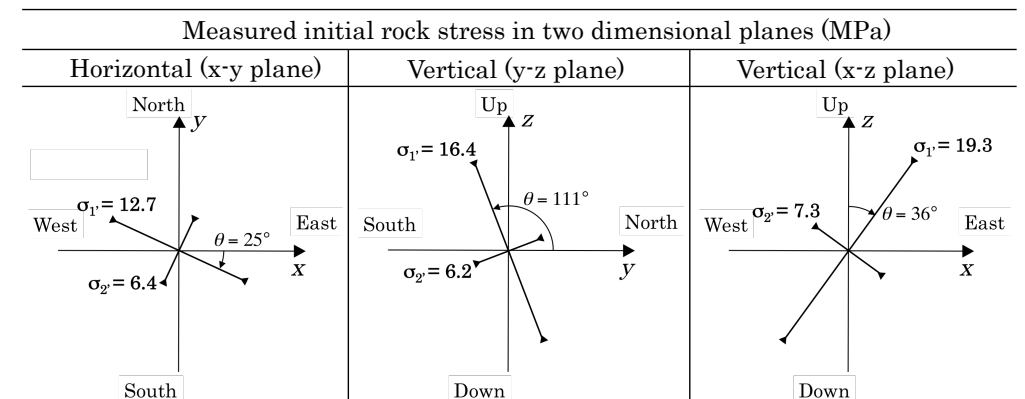
Cavern Excavation

Geological condition

Rock cores



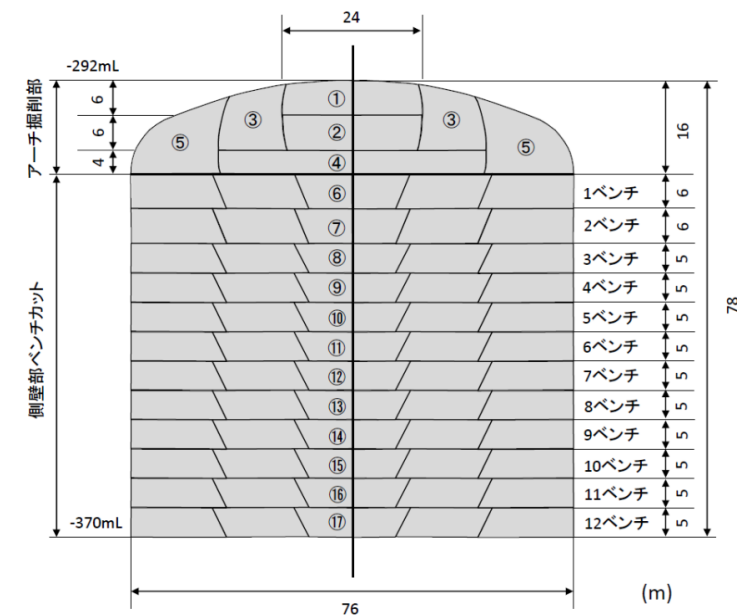
Initial rock stress



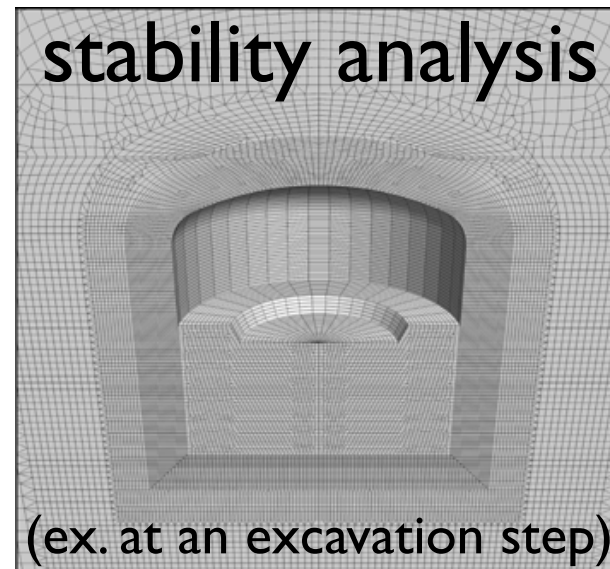
- Detailed geological surveys at the candidates site vicinity
- Rock core sampling, initial stress of bedrock, etc
- Confirmed the bedrock condition suitable for a large cavern construction
- Examine the cavern stability based on the geological survey results

Cavern stability analysis

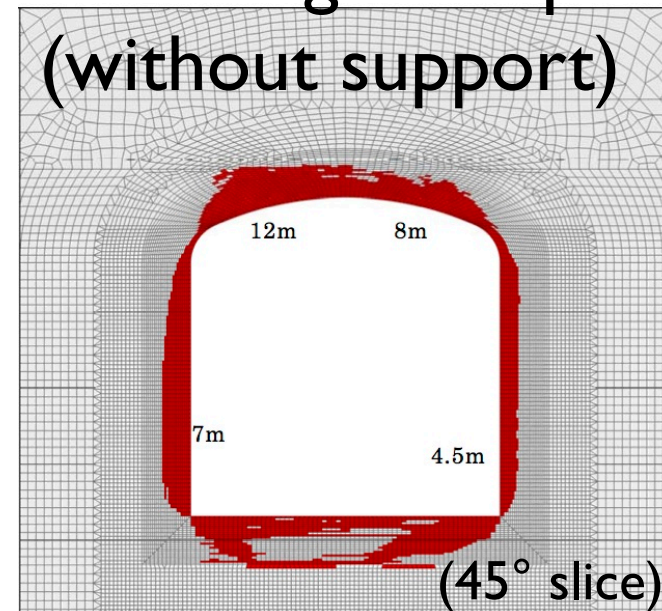
Excavation steps



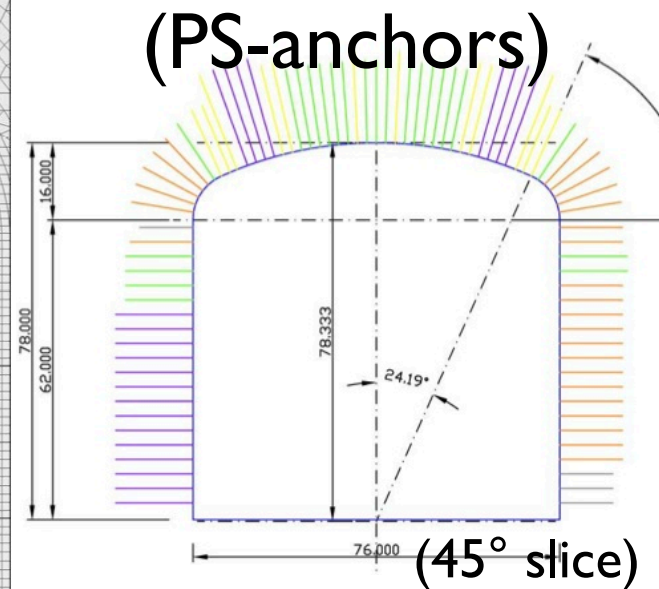
3D model for stability analysis



Plastic region depth (without support)



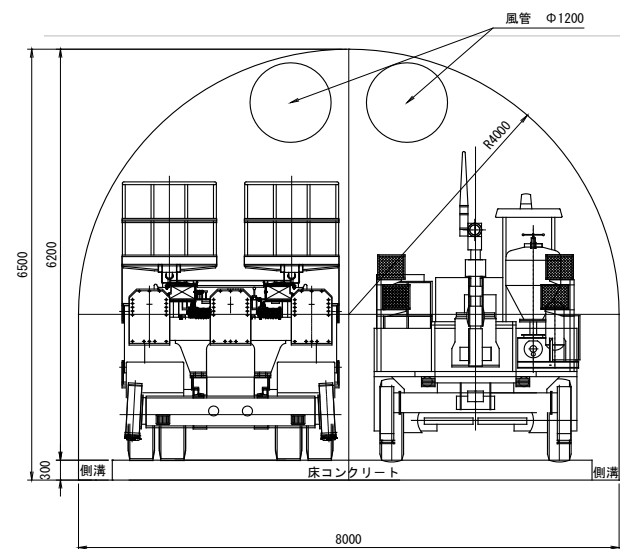
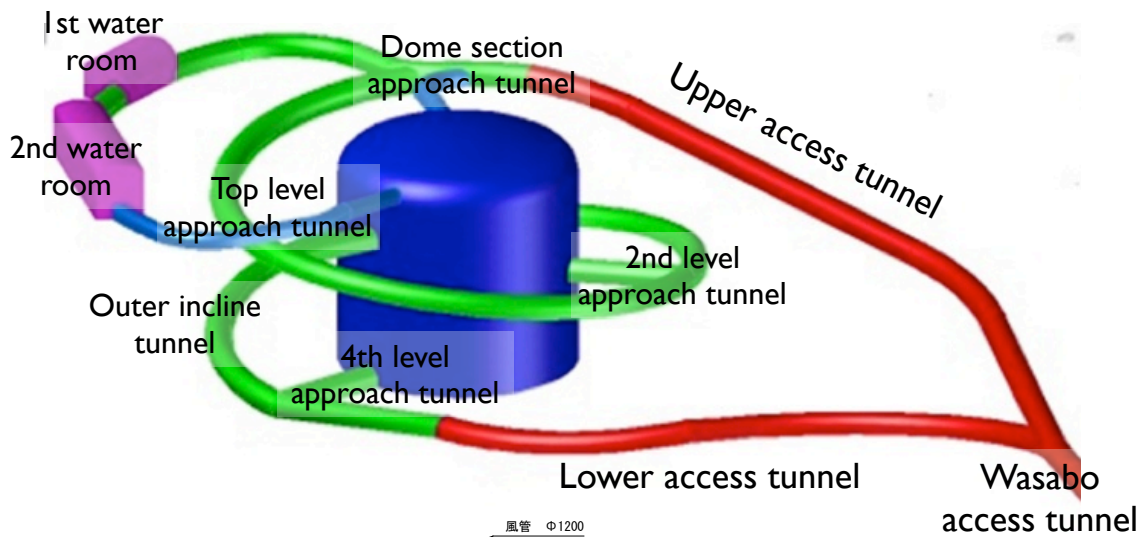
Cavern support (PS-anchors)



- Cavern stability analyses based on geol. survey results
- 3D finite element analysis adopting Hoek-Brown model
 - Adopt a model to treat the elastic and inelastic behaviors of rock
- Excavation steps taken into account in stability analysis
- Evaluate plastic region depth and design cavern support
- Confirmed the Hyper-K cavern can be constructed with the existing technologies

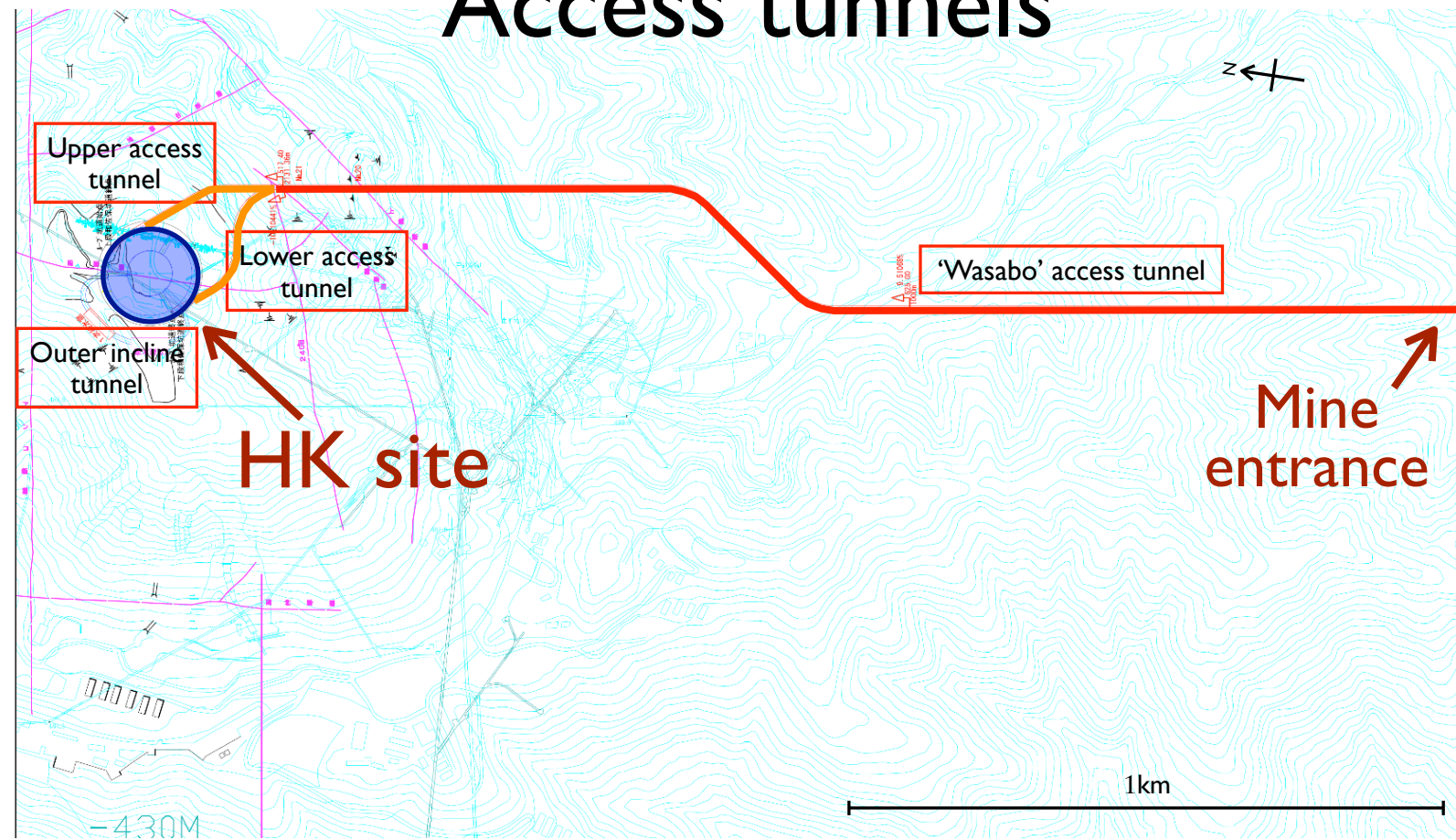
Tunnels

Approach tunnels



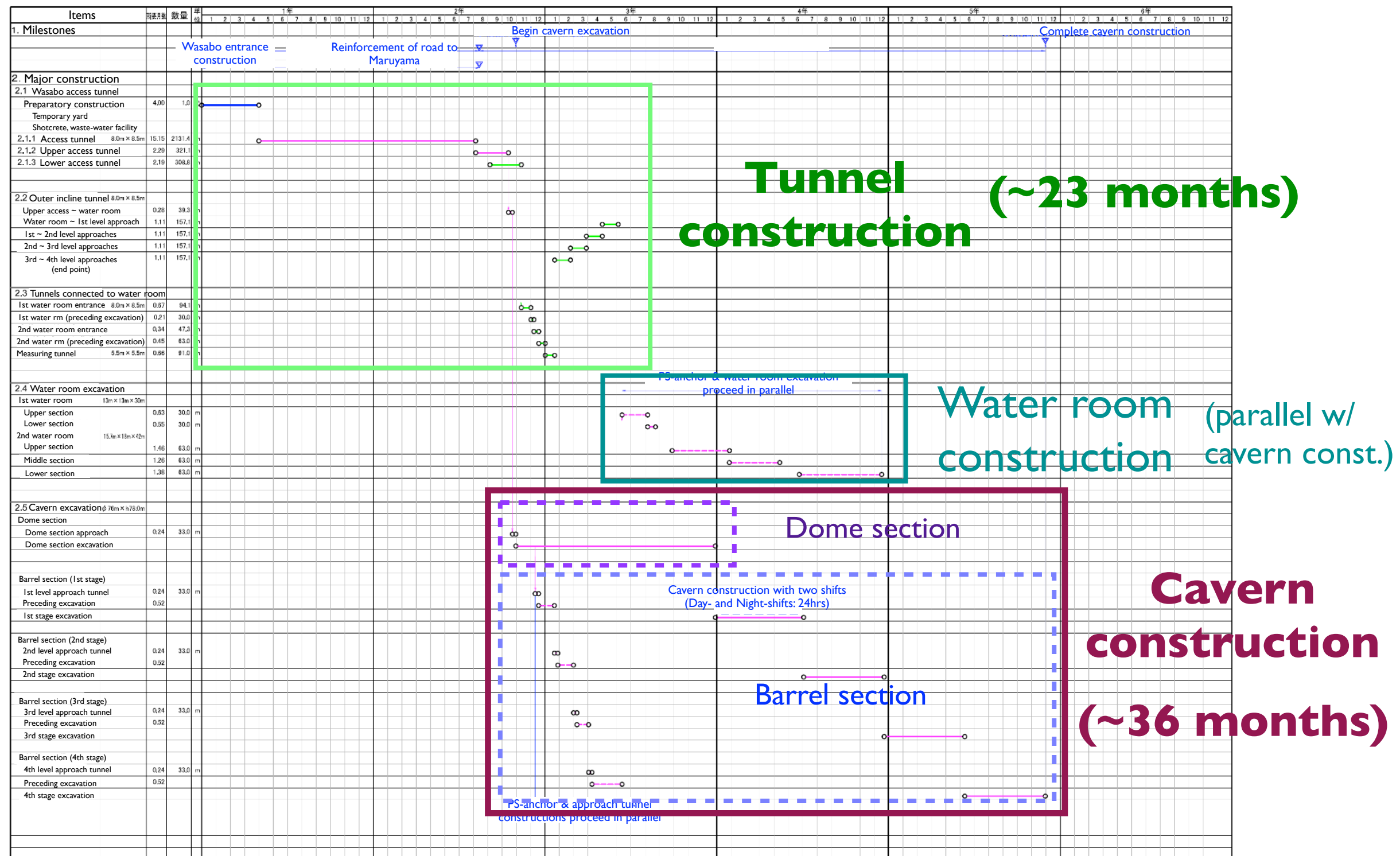
Tunnel cross section

Access tunnels



- Cavern construction begins with tunnels construction
 - Access tunnels, outer incline tunnels, approach tunnels
- Design & layout of the tunnels established
 - Include the cavities for water purification system

Cavern excavation timeline

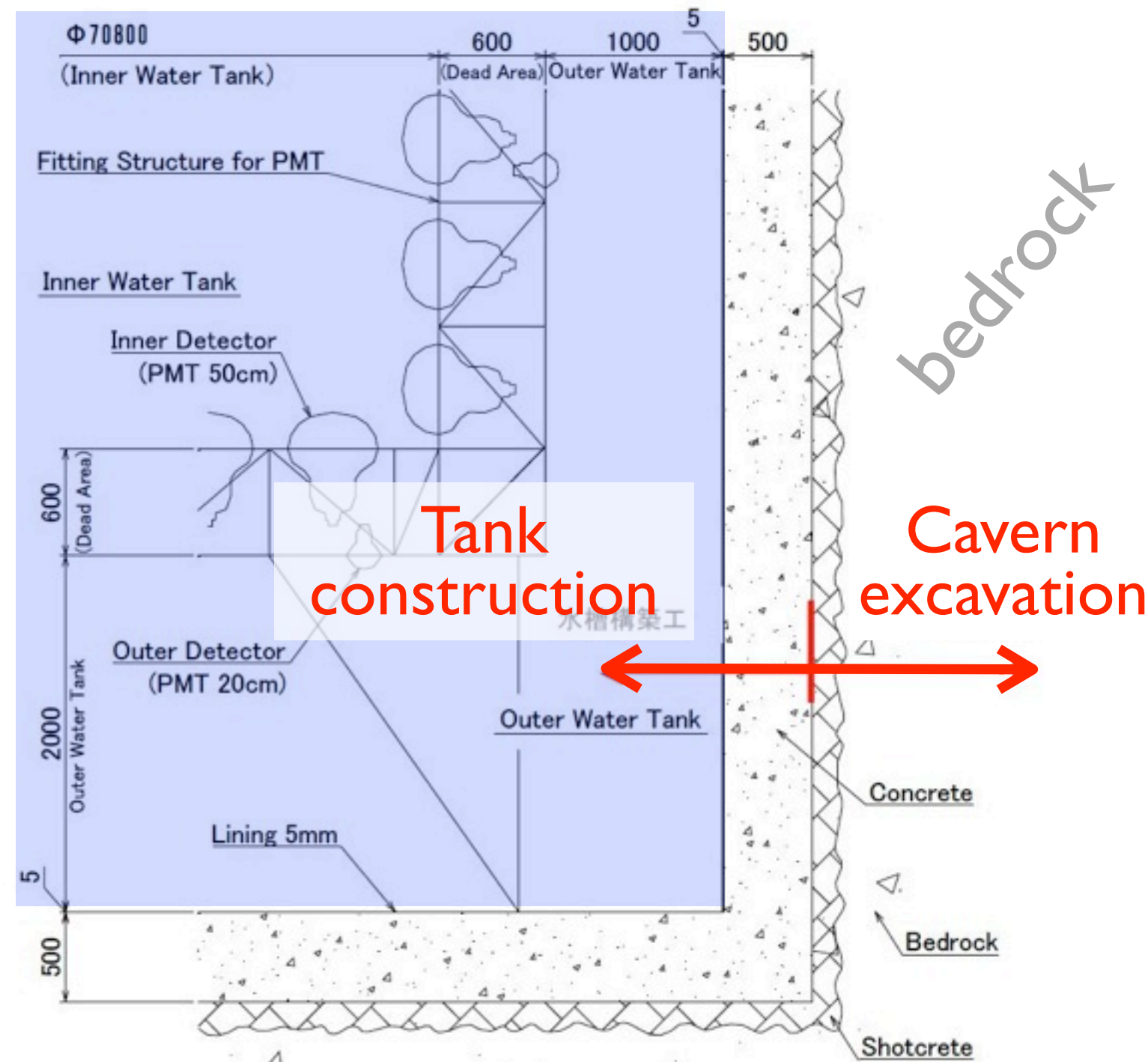
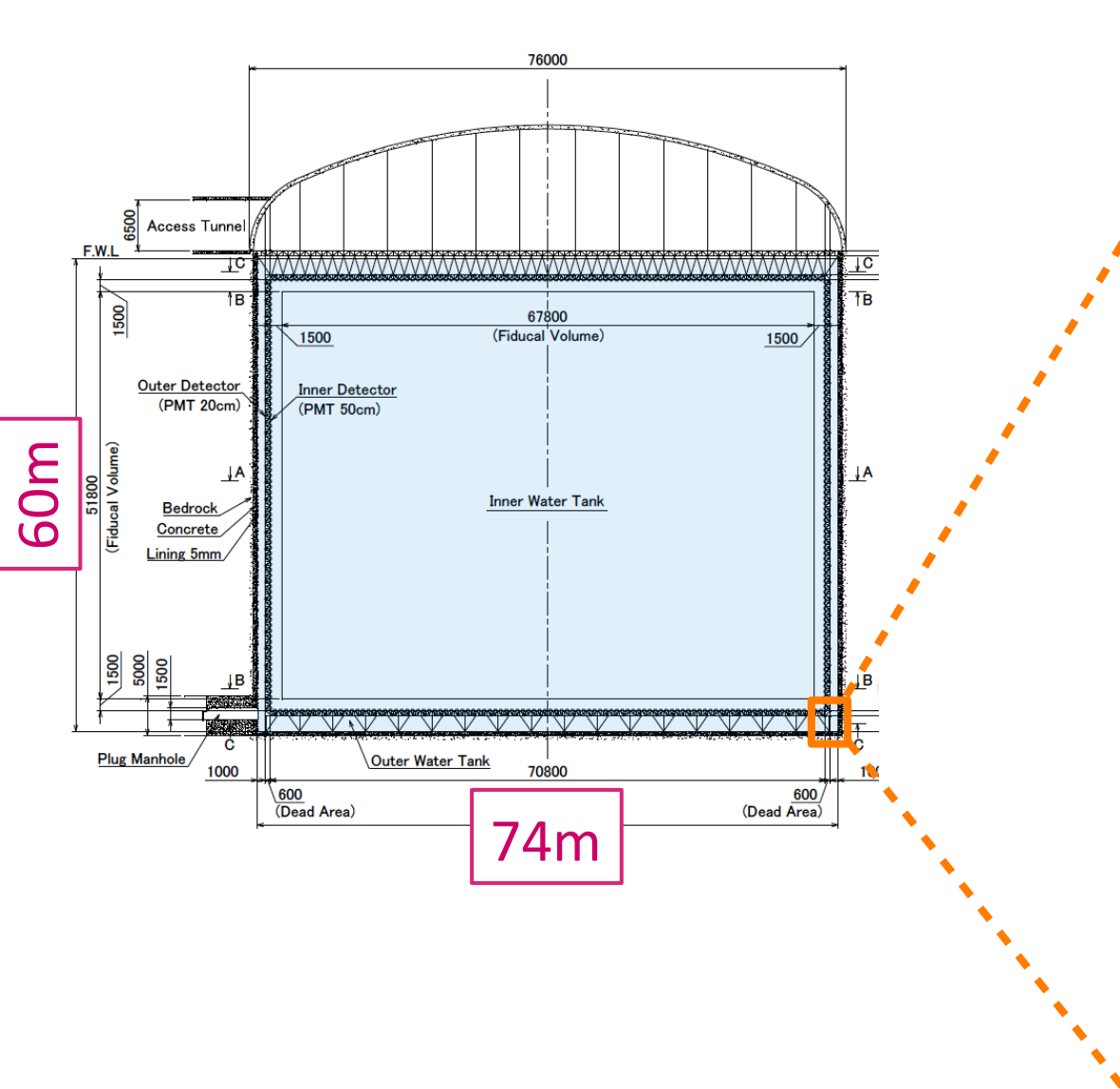


- Tunnel construction: ~2 years
 - Cavern construction: ~3 years
- ~5 years in total**

Tank Construction

Water containment system, photosensor support

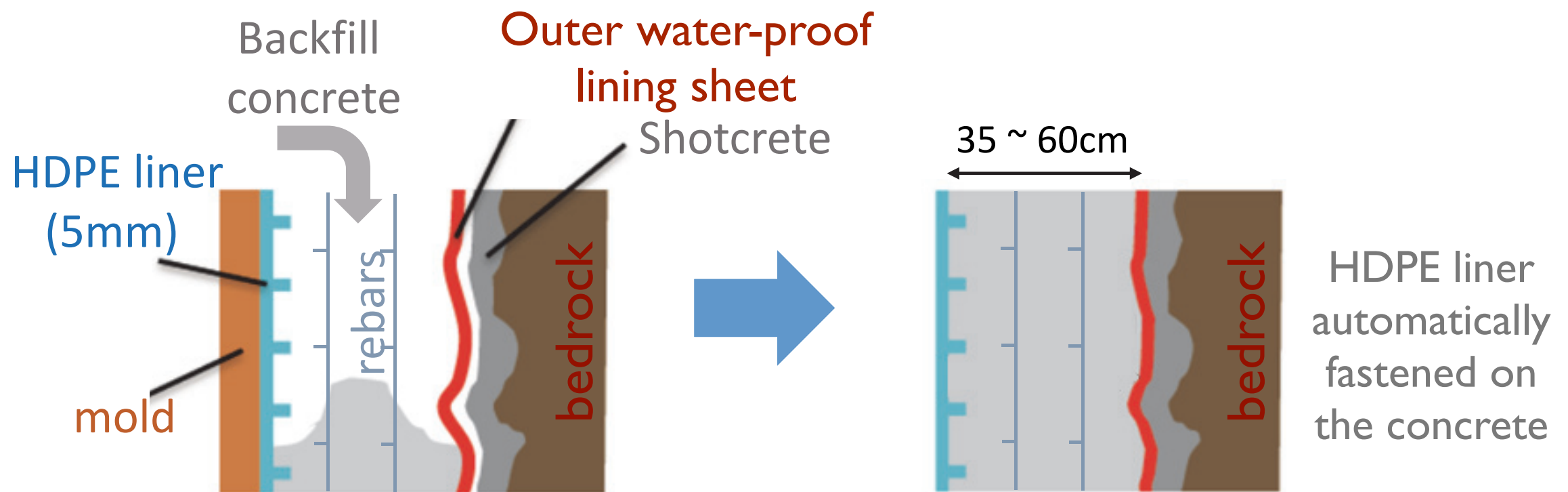
Hyper-K “Tank”



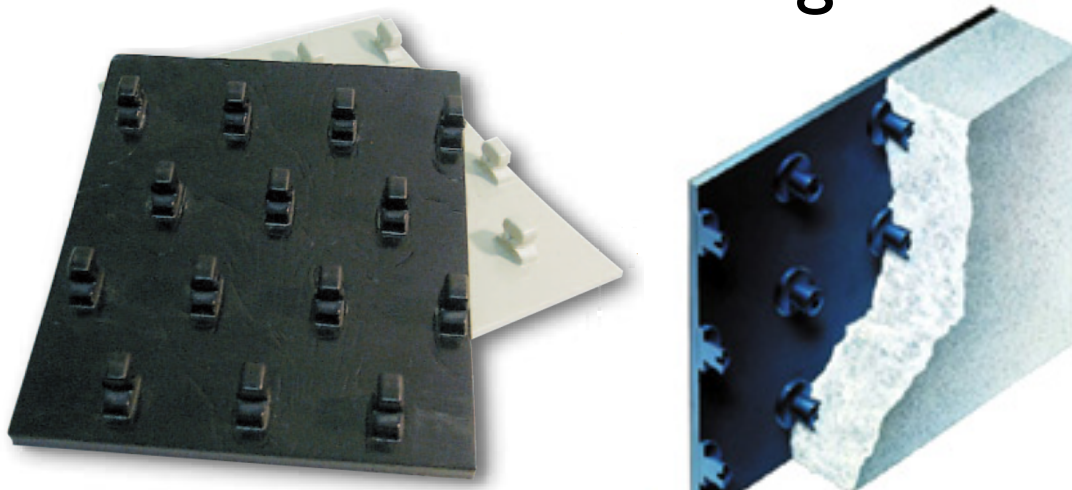
- “Tank” construction:
 - Water containment system
 - Hold the ultra-pure water for the water Č detector
 - PMT support structure

Water containment system

- Water containment system consists of three layers of lining system:
- Outer water-proof sheet, Concrete lining, High Density Polyethylene (HDPE) lining



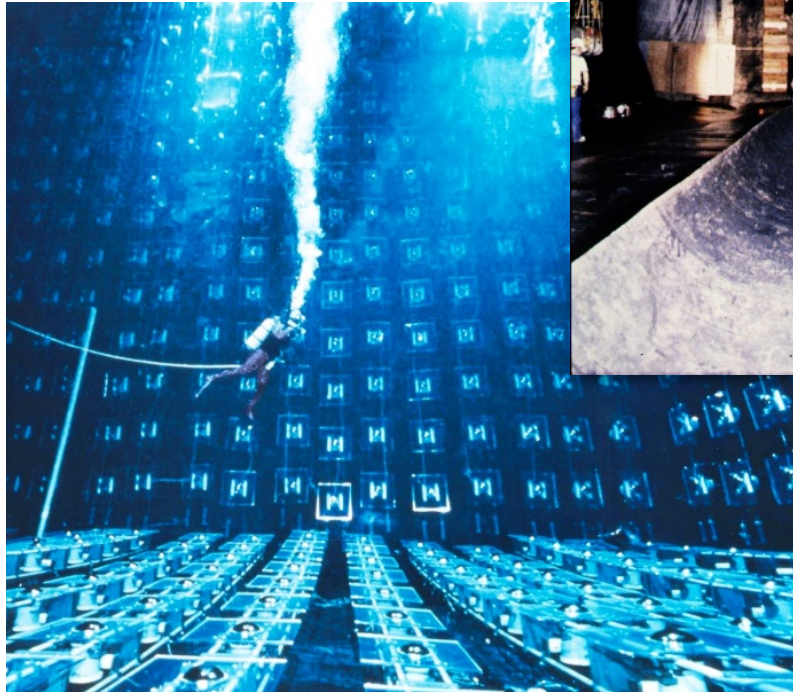
Studded HPDE lining sheet



Three layers of liners are constructed simultaneously
→ Minimize the const. time

HDPE lining

- HDPE lining system is a widely used and established lining technique for water containment systems
- HDPE sheet has been tested within Hyper-K WG
 - Material compatibility with ultra-pure water, strength testing (tension, creep, pressure)



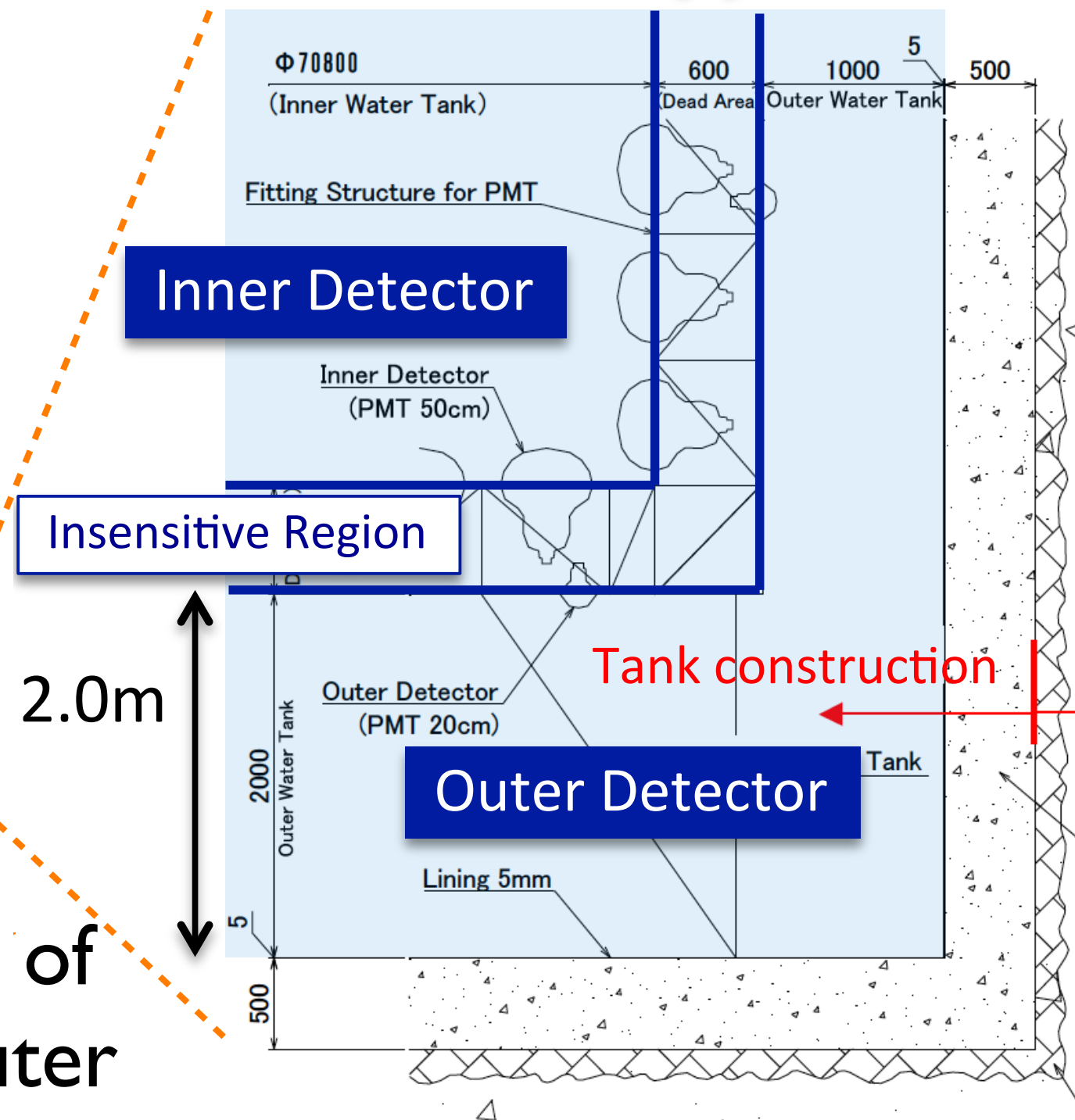
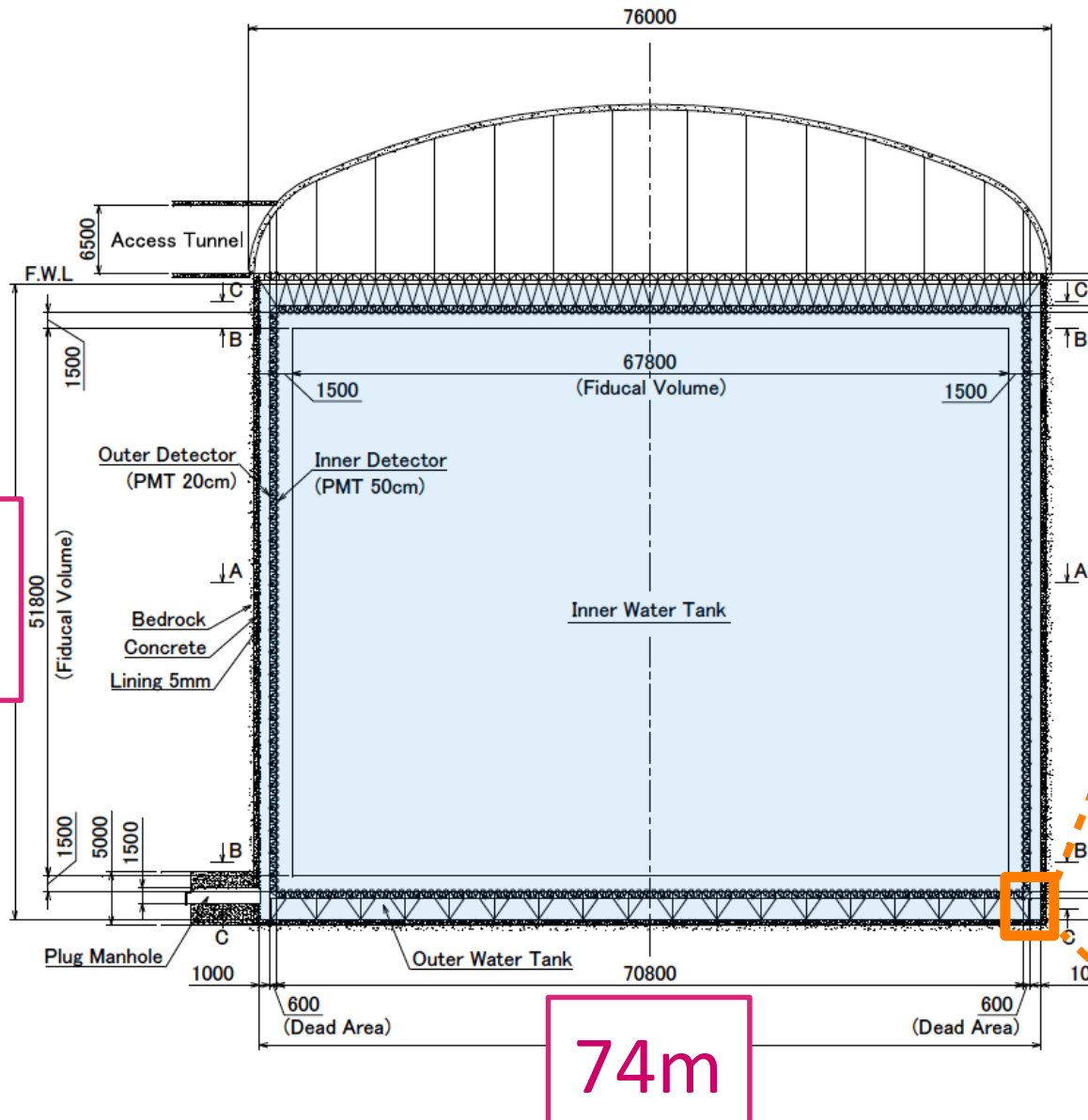
IMB water Cherenkov detector



Industrial waste processing trench



Waste-water treatment facility
(~30m water depth)



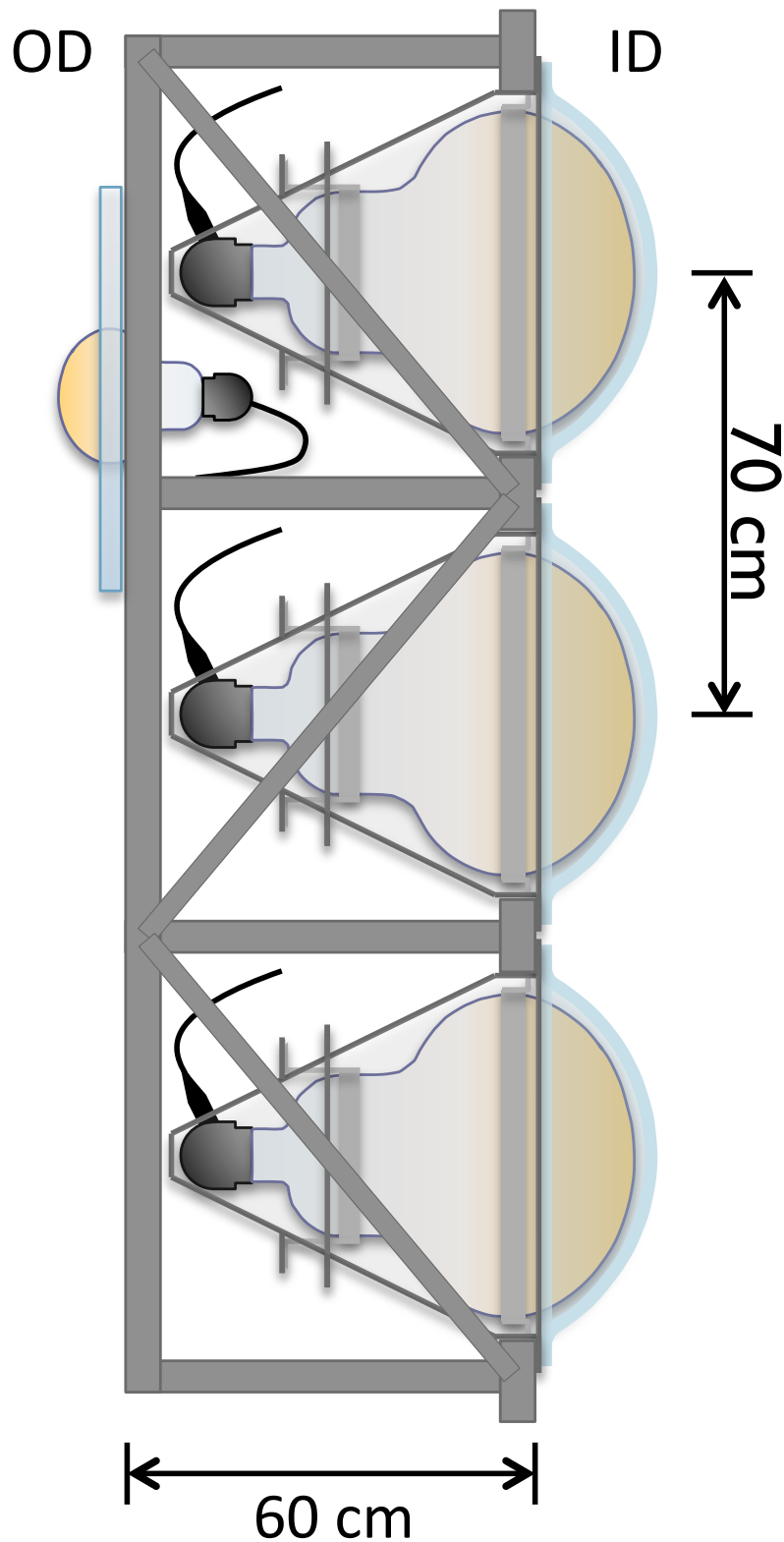
- Hyper-K detector consists of inner detector (ID) and outer detector (OD)
 - and 'insensitive region' in between
 - ID & OD are optically separated

1 ID-PMT/0.5m² (40% coverage)

→ ~40,000 ID-PMTs/tank

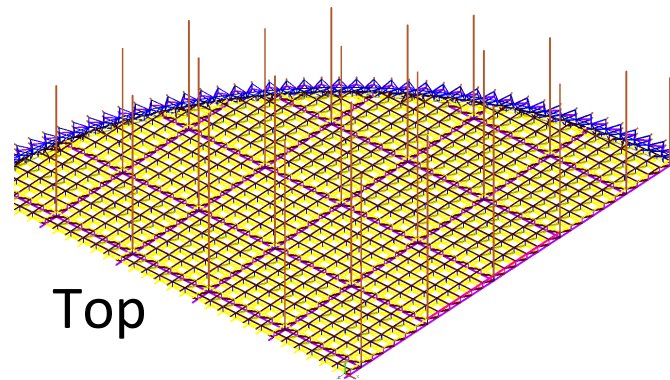
~6,700 OD-PMTs/tank

PMT support structure



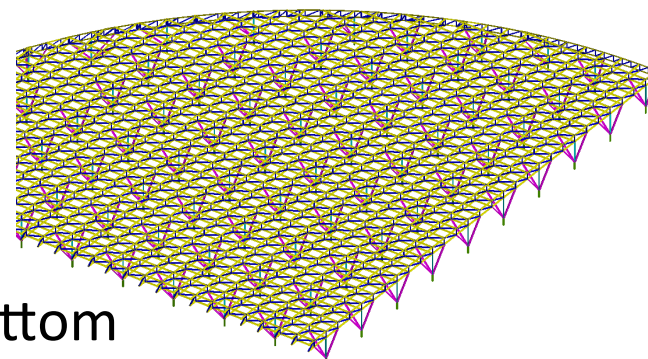
- PMT support structure adopts a truss structure made of SUS members (angles)
- Seismic response analysis confirmed earth quake do not make damage to the detector
- even if no water in the tank

- Top/Barrel → Hung from the ceiling
- Bottom → Set on the ground

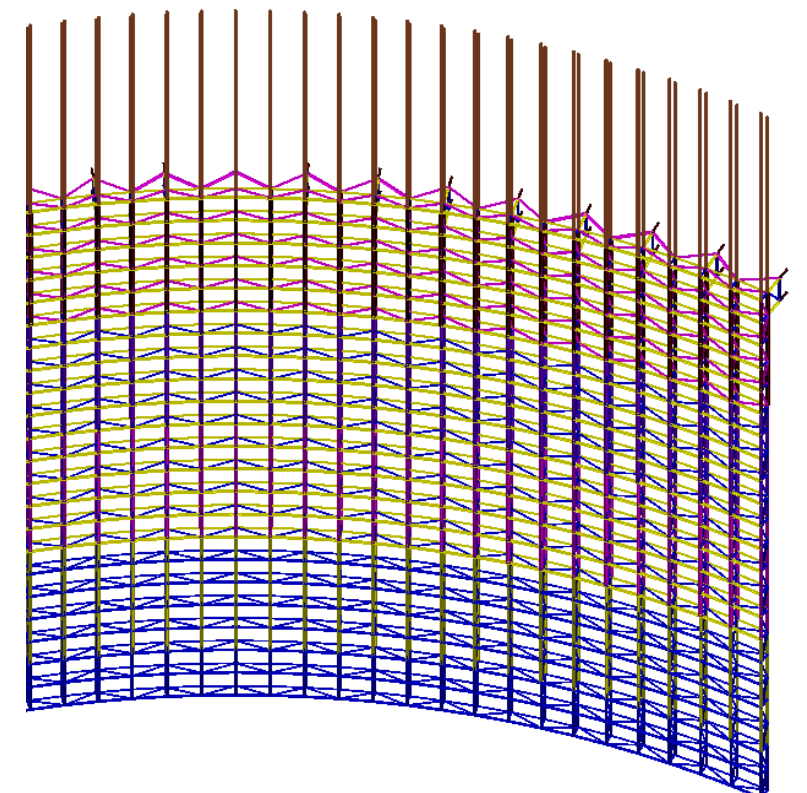


Top

Barrel



Bottom



Tank construction timeline

Lining
construction

20 months

+

PMT support
construction
PMT installation

13 months

Total : 33 months

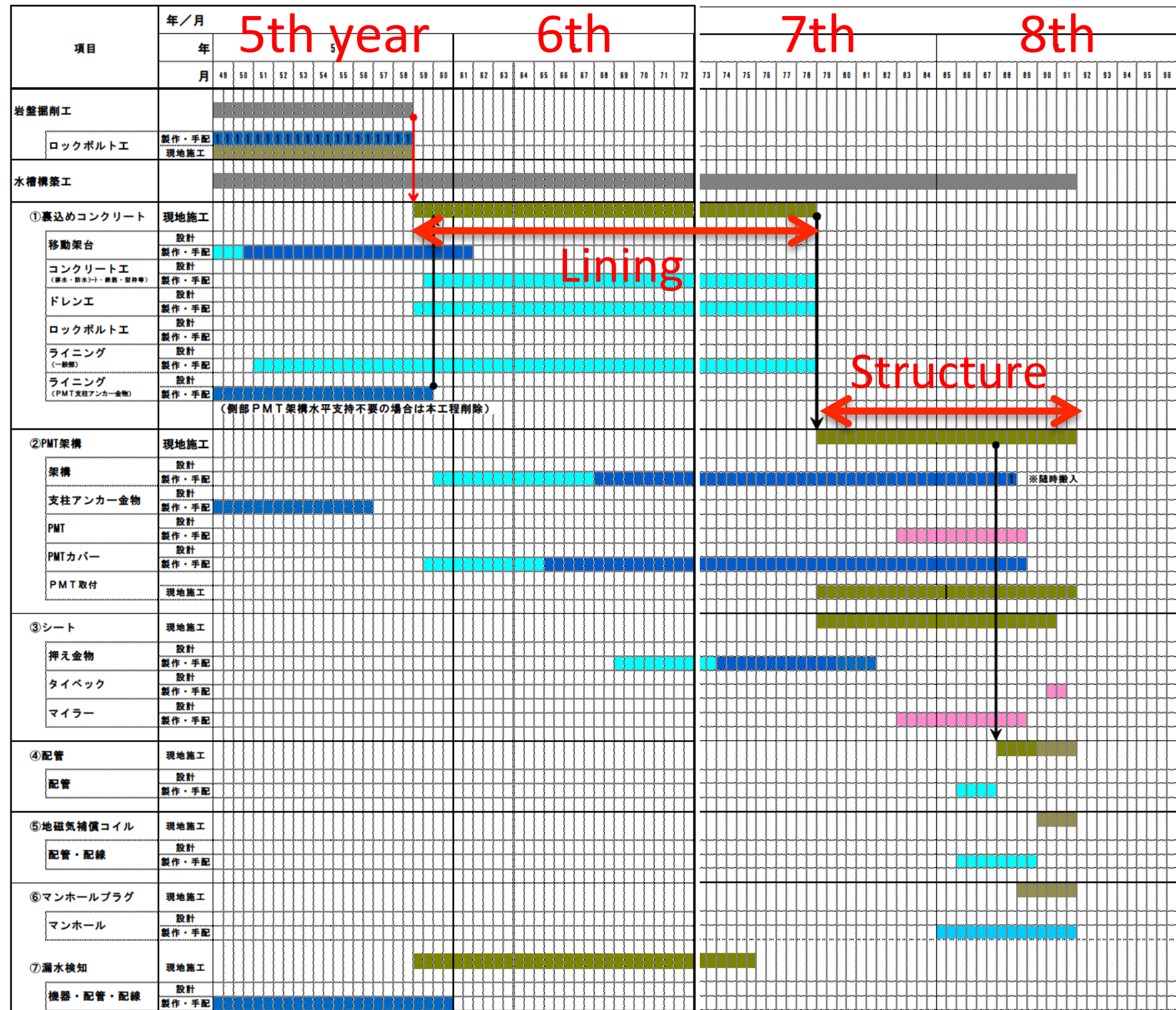
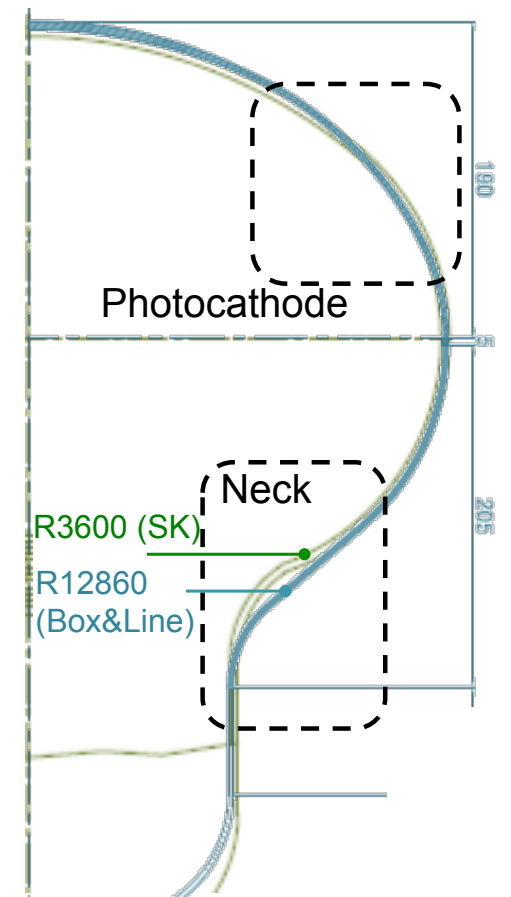


Photo-sensor (I)

- New 50cm ϕ PMT for Hyper-K has a mechanical improvements
- Gives a higher pressure tolerance than Super-K PMTs
 - HK water depth: 60m (cf. 40m in SK)
- Confirmed no damage in new PMTs under 1.25 MPa (125m water depth)
- PMT housing has also been developed to prevent PMT chain implosion
- Confirmed the PMT housing prevents chain reaction at 80m under water
- New PMT works with baseline design

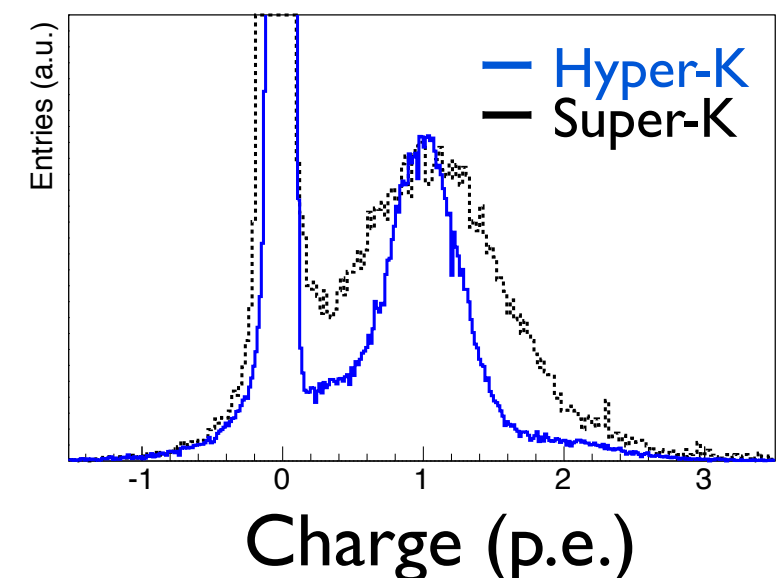
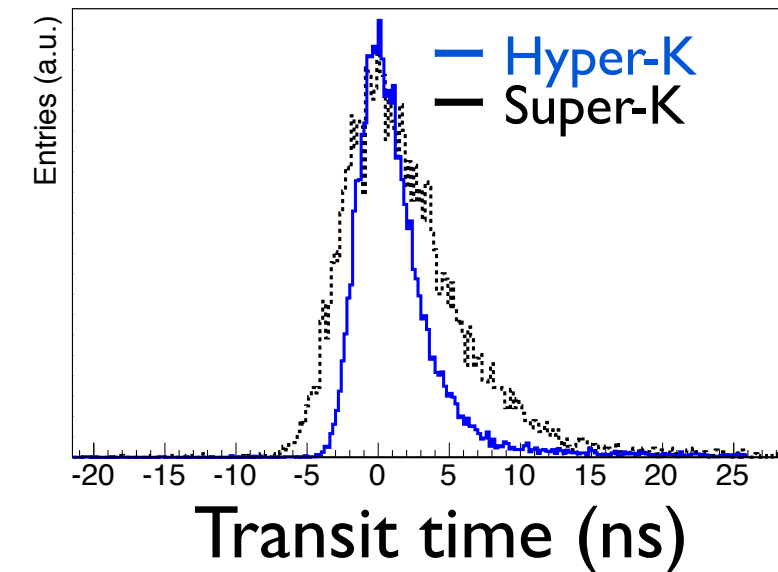
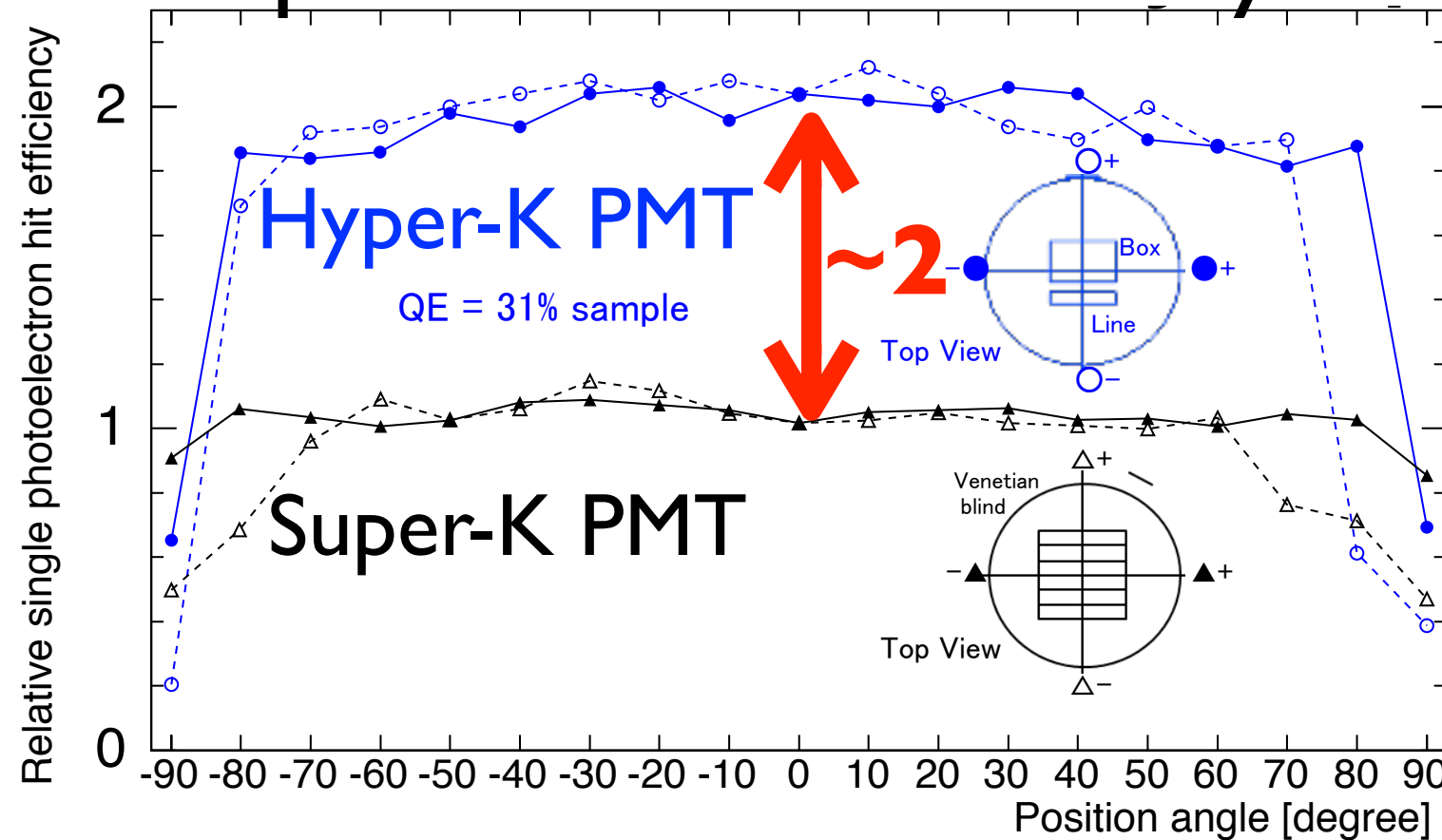


PMT housing



Photo-sensor (2)

1 p.e. detection efficiency

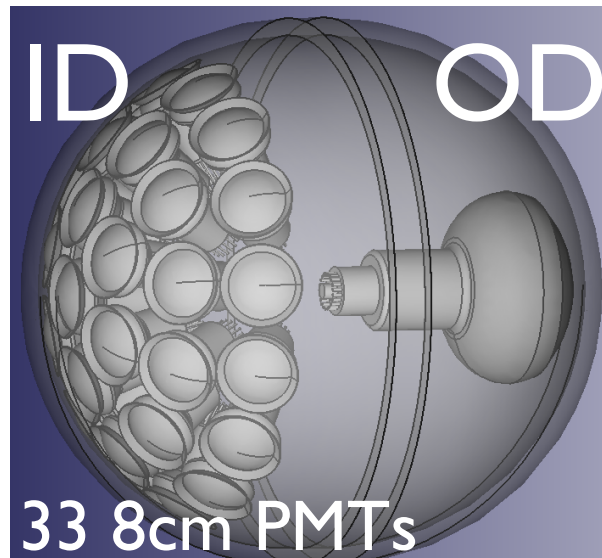
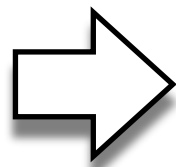


- New 50cm ϕ PMT for Hyper-K has twice better photo-detection efficiency than Super-K PMT
- Also better timing and charge resolution
- Implemented in Hyper-K detector simulation for the sensitivity studies

Photo-sensor (3)

- Number of photo-sensor R&D on-going in world-wide for further improvement:
 - 50cm ϕ Hybrid Photo-detector (HPD)
 - 20-30cm ϕ photo-sensors for OD / ID
 - Multi-PMT
 - Being developed based on KM3NeT optical module
 - MoU with KM3NeT to exchange knowledge on Multi-PMT technology
 - See *Nishimura-san's talk (tomorrow)*
- ## Multi-PMT

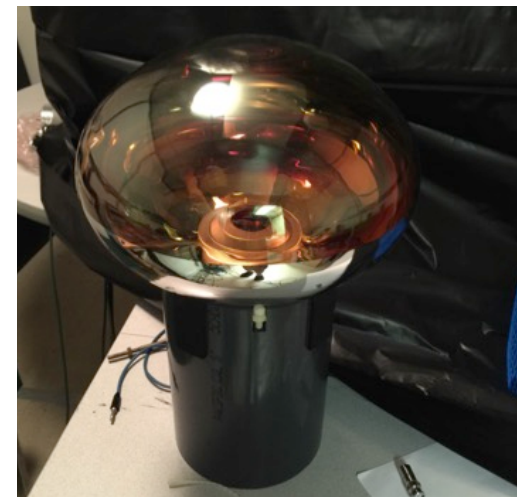
KM3NeT
optical module



HPD



28cm (8") PMT



8cm (3") PMT



Water System

Source water survey

- Source water for HK sampled at the candidate site
- Quality of HK source water is almost same as in SK
- Hyper-K water purification system designed based on the Super-K system

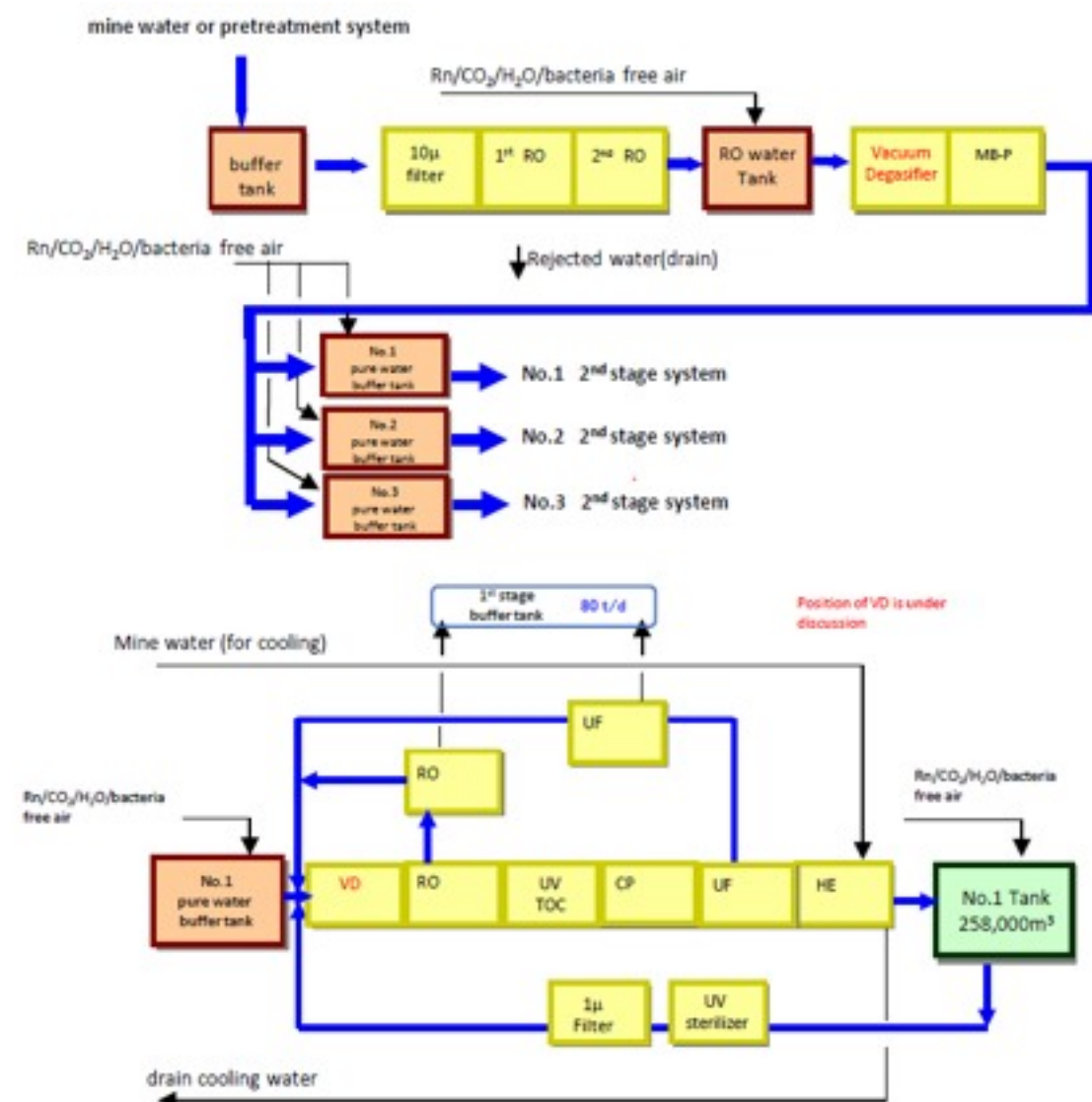
Source water quality

		Tochibora spring water as of 1 Mar. 2011	Mozumi spring water as of 16 Mar. 2011
Temperature(Typical)	°C	11	12
pH (25°C)		7.8	7.8
Conductivity	μS/cm	170	221
Turbidity	degree(Kaolin)	< 1	< 1
Acid consumption (pH 4.8)	mg CaCO ₃ /L	40.0	75.8
TOC	mg/L	< 1	< 1
Phosphate	mg/L	< 0.1	< 0.1
Nitrate	mg/L	1.0	1.6
Sulfate	mg/L	36.4	30.2
Fluoride	mg/L	0.3	0.4
Chloride	mg/L	1.6	1.8
Sodium	mg/L	4.9	6.2
Potassium	mg/L	0.5	0.5
Calcium	mg/L	25.2	32.0
Magnesium	mg/L	1.5	2.9
Ammonium	mg/L	< 0.1	< 0.1
Ionic silicon dioxide	mg/L	17.1	11.8
Iron	mg/L	< 0.01	< 0.01
Copper	mg/L	< 0.01	< 0.01
Zinc	mg/L	0.09	< 0.01
Lead	mg/L	< 0.1	< 0.1
Aluminum	mg/L	< 0.01	< 0.01
Boron	mg/L	< 0.01	0.2
Strontium	mg/L	0.18	0.52
Barium	mg/L	< 0.01	0.03

possible source water for HK

SK source water

Schematic diagram of water purification system

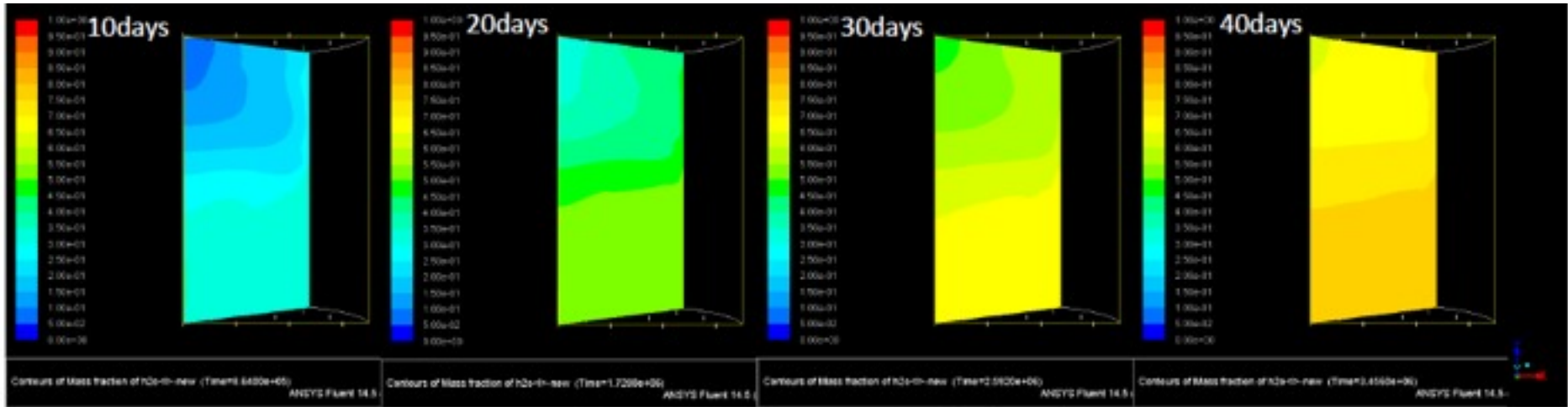


Water flow design by simulation

Water flow in the tank directly affects the water quality and the physics results. When cold water is supplied from the bottom of the tank, convection in the tank is suppressed and the flow becomes laminar (water replacement goes effectively).

Tank shape	Baseline C shape
ID flow rate	273.7 m ³ /h
Inlets/outlets	65A×37/65A×37
Supply water temperature	13.0 °C
Top level rock temperature	16.7 °C
Bottom level rock temperature	17.7 °C
Heat flux from the PMT/electronics/coil	3.2W/m ²

TABLE XIII. Input parameters for the water flow simulations.
FIG. 51. Water replacement efficiencies



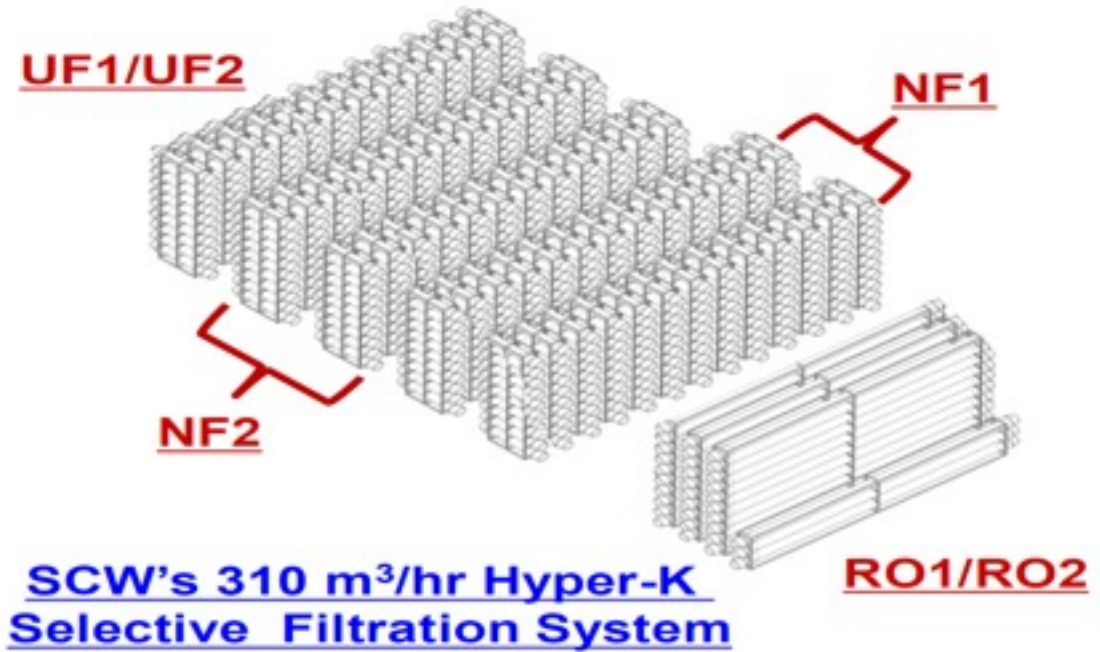
(a) Supply to the bottom and drain from the top

This behavior was already confirmed in Super-K tank and seems to be identical to cylindrical tanks; thus the water flow in HK should be controlled like SK.

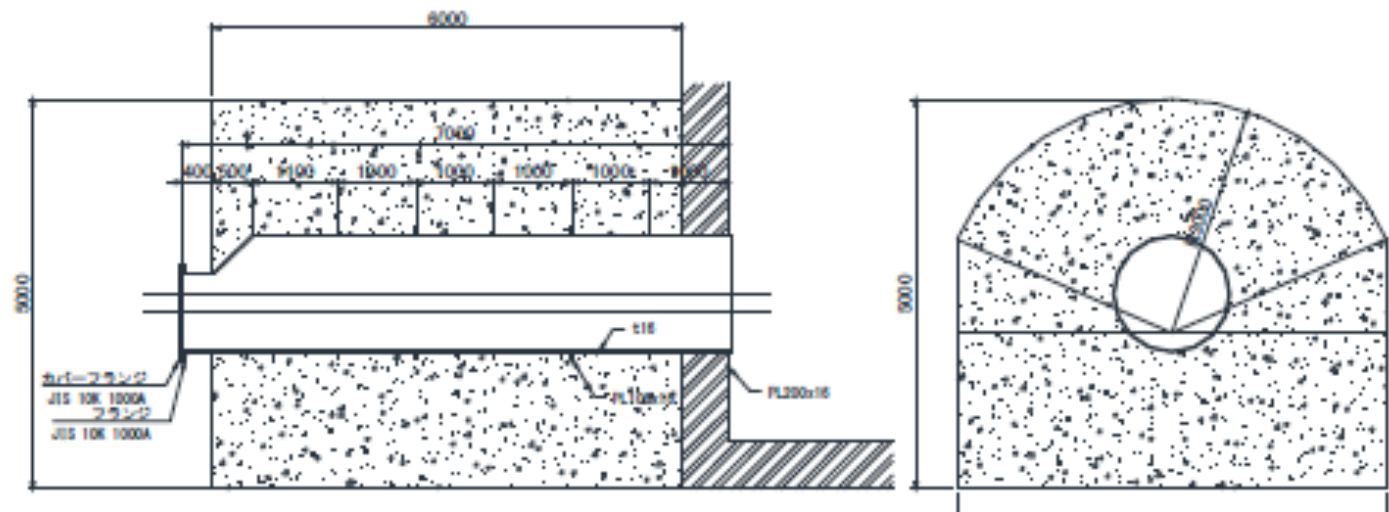
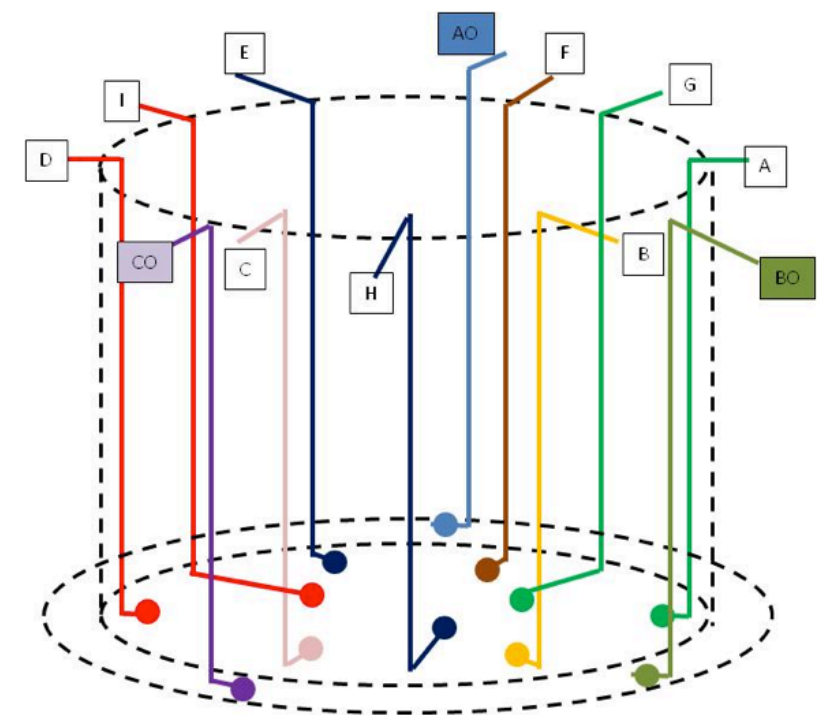
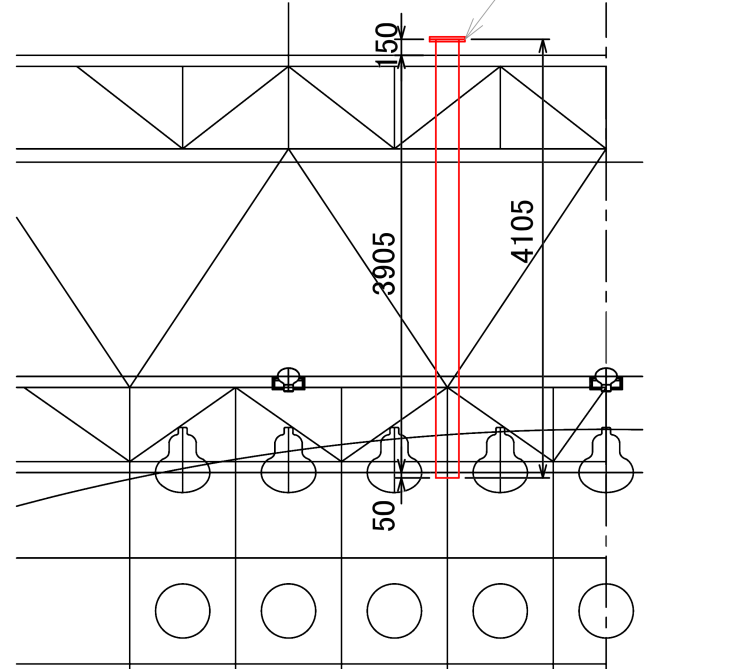
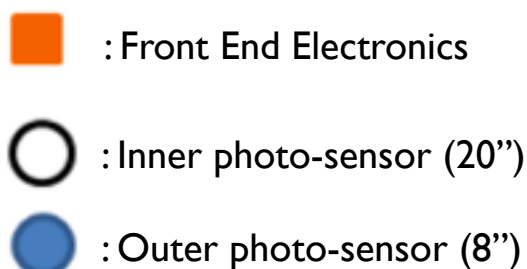
Gd-Option

Now that gadolinium loading of Super-Kamiokande has been formally approved by the SK Collaboration, this new technology and the many physics advantages of the efficient neutron tagging it provides will be well established in Super-K long before HK turns on.

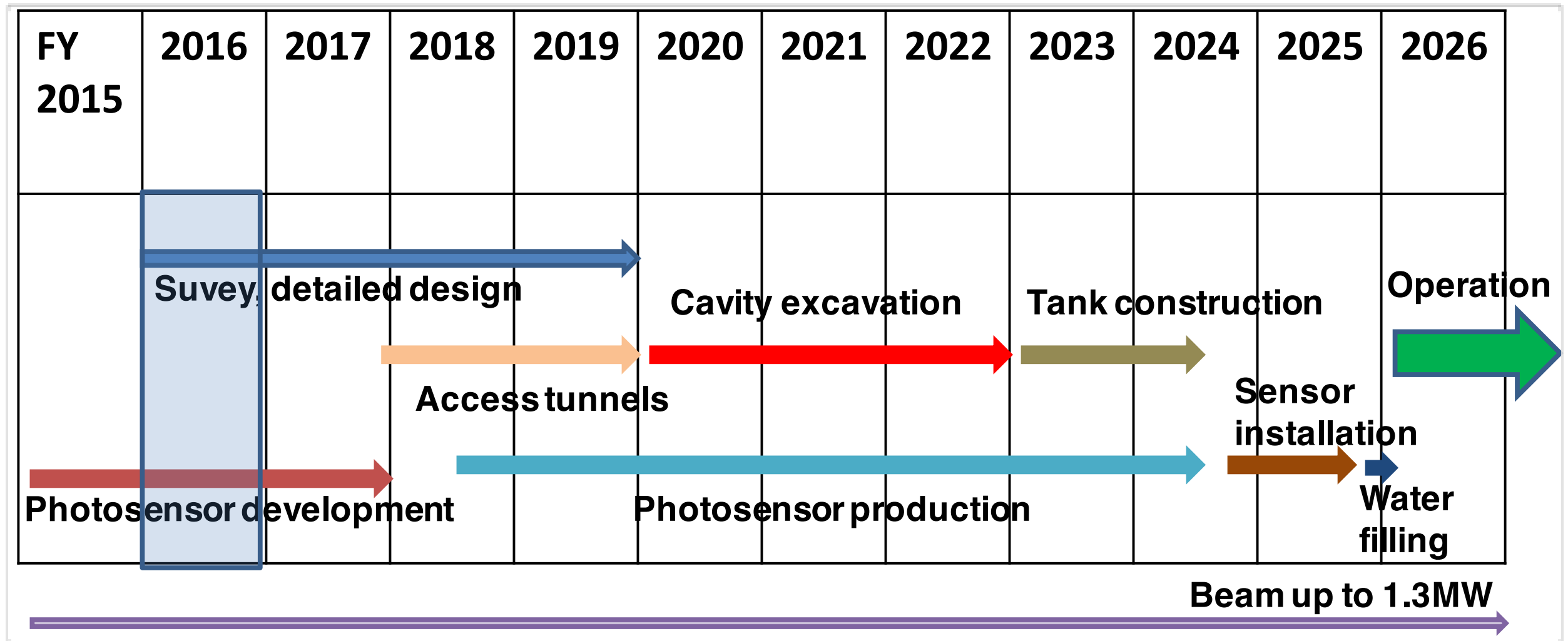
South Coast Water’s detailed design of the new Gd water system for Super-K serves as the starting point for an equivalent system for Hyper-K schematically shown here.



- All HK detector components has been designed
 - Front-end electronics, cables, layout of water pipes, calibration holes, crane, ... etc.



Hyper-K construction timeline



- The 1st detector construction in 2018~2025
 - Now: Further detailed geological survey and photosensor development on-going
 - Cavern excavation: ~5 years
 - Tank (liner, photosensors) construction: ~3 years
 - Water filling: 0.5 years

Summary (I)

- Hyper-K baseline design has been established
 - Cavern excavation, water containment system, PMT support structure, and several other detector components
- Several intensive R&D projects on-going in world-wide to further improve/optimize the detector design
 - photo-sensors, electronics, DAQ, calibration, near detector, analysis software, ... etc
 - See following talks for further details
- And...

Summary (2)

- Still many things need to be done for *final* detector design and to improve/optimize the detector design:
- Cavern and tank
 - Material-testing of liner, improve PMT support design, support structure for multi-PMT
- Photo-sensor
 - PMT housing, multi-PMT, photo-detection system for outer-detector
- Electronics, DAQ, calibration, analysis software, Physics sensitivity studies, Near Detector,, etc
- New contributions to the projects highly welcome!
 - If you have any questions and/or are interested in, please contact WVG conveners or project leaders

Contact people

