Hyper-K Tank

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for the Cavity and Tank WG

July 21, 2014

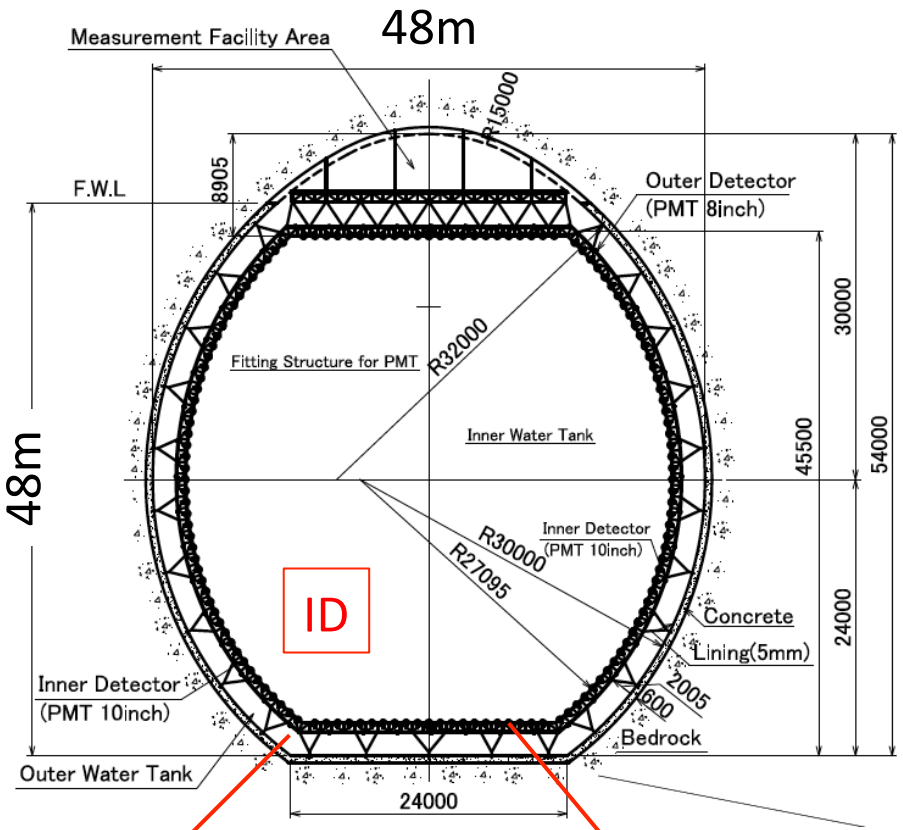
@ The 5th open Hyper-K meeting

Basic specification of Hyper-K tanks

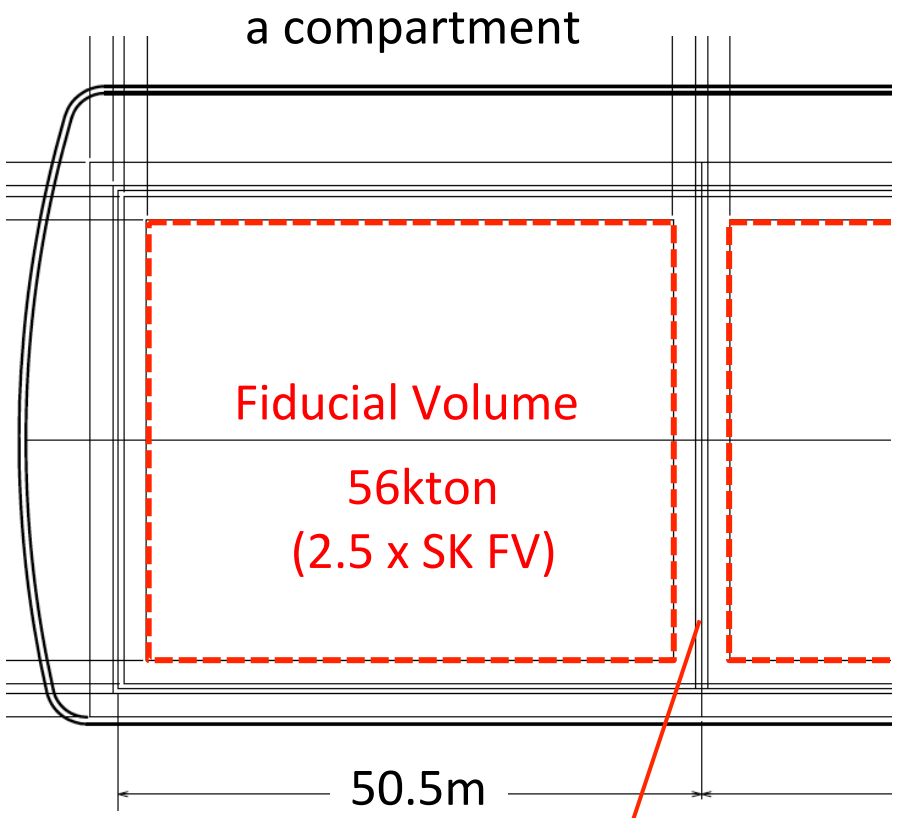
- Size and quantity : 48m(W) x 54m(H) x 250m(L) x 2(N)
- Cavern shape : Egg-shape
- Optically separated compartments : 5 x 2 = 10
- Water volume :
  - Total : 0.496 x 2 = 0.992 Mton
  - ID volume : 0.74 Mton
  - Fiducial volume : 0.056 x 10 = 0.56 Mton (25 x Super-K)
  - Depth of tank water : 48m
- Photodetectors :
  - ID : ~99,000/2tanks, 50cmϕ PMTs, 1sensor/1m^2 (~20% coverage)
  - OD : ~25,000/2tanks, 20cmϕ PMTs, 1sensor/3m^2 (~1% coverage)

Overall tank structure

Cross-Section



Side View



OD 2m thick

Dead Region 0.9m thick

Segmentation Wall

1. Lining

Possible overseas contributions

- Liner materials
- Water leak detection and draining system
-

Given basic conditions for lining design

- Physical properties of bedrock
  - → Same as those used for the Super-K designing

    Elastic modulus :

    5.1×10^7 kN/m^2 for non-damaged region

    2.0×10^7 kN/m^2 for loosened region

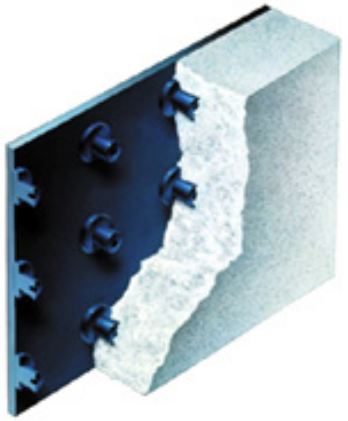
- Physical properties of concrete
  - → Taken from “Standard Specification for Concrete Structure enacted in 2012”, ISBN 978-4-8106-0613-3

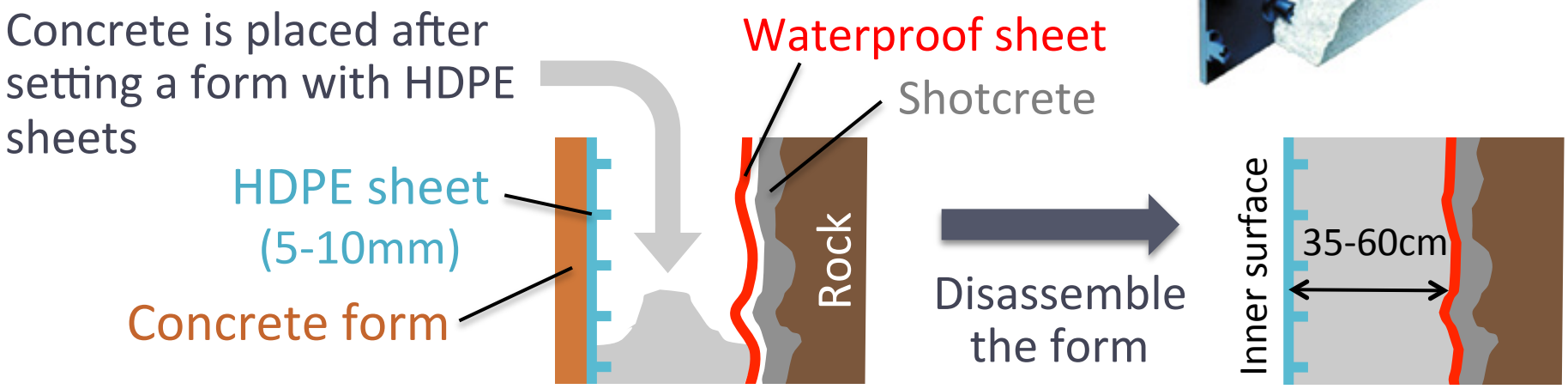
- Assuming no displacement of bedrock during/after tank construction

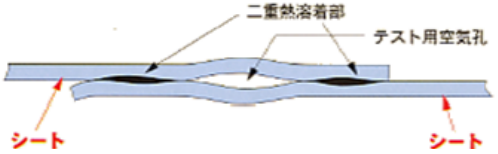
- Assuming no backwater pressure from the bedrock side
  - by controlling the surrounding water level (as we are doing for SK)

Tank lining

Tank lining consists of concrete and High Density Polyethylene (HDPE) sheet linings

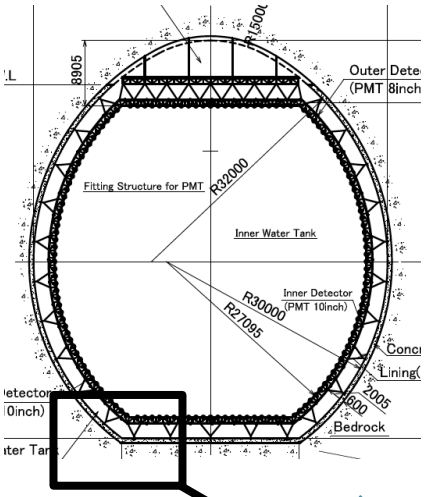






- Water permeability of HDPE sheet is very low
- Adjacent HDPE sheets are welded by heating
- Holes in a sheet (including welded part) can be found by pinhole test

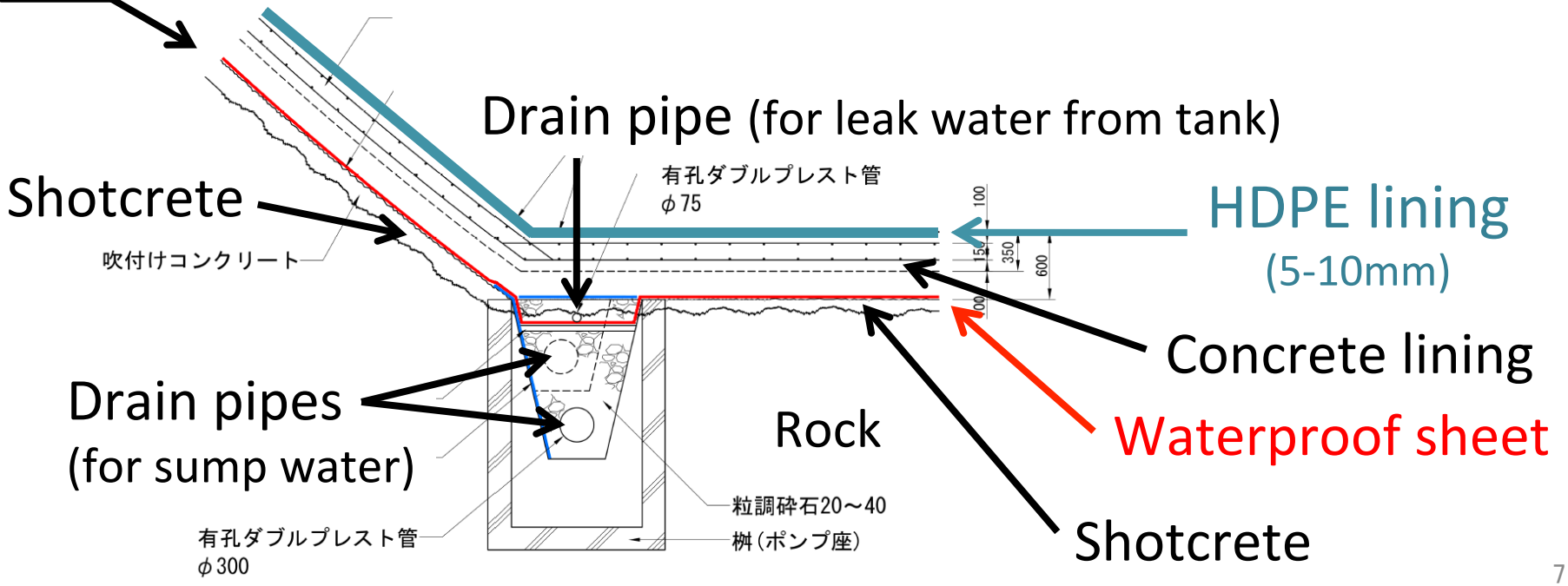
Water leak detection and draining



No water leak expected by HDPE(+concrete) lining

Additional lining with a water proof sheet just for accidental water leak

- Drain lines are separated for sump-water and tank-water



2. PD support structure, covers, sheets

Possible overseas contributions

- Support structure :
  SUS framework? Wire-hanging? Others?
- PD protective cover and assembly integration
- Black sheet (ID) and Reflective sheet (OD)
-

Given basic conditions for support design

- ID volume should be as large as possible
- OD thickness should be ≥ 2m

- Photodetectors for ID : ~99,000/2tanks, 50cmϕ
  Photodetectors for OD : ~25,000/2tanks, 20cmϕ

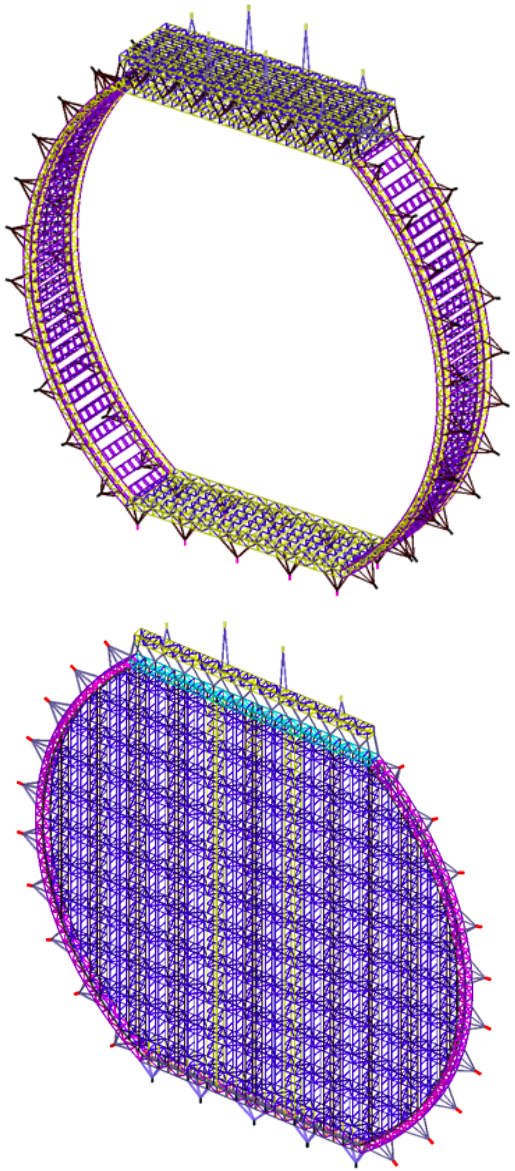
- PD mounting precision (including later displacement)
  < ±100mm

- Assuming no displacement of bedrock during/after tank construction

Photodetector support framework

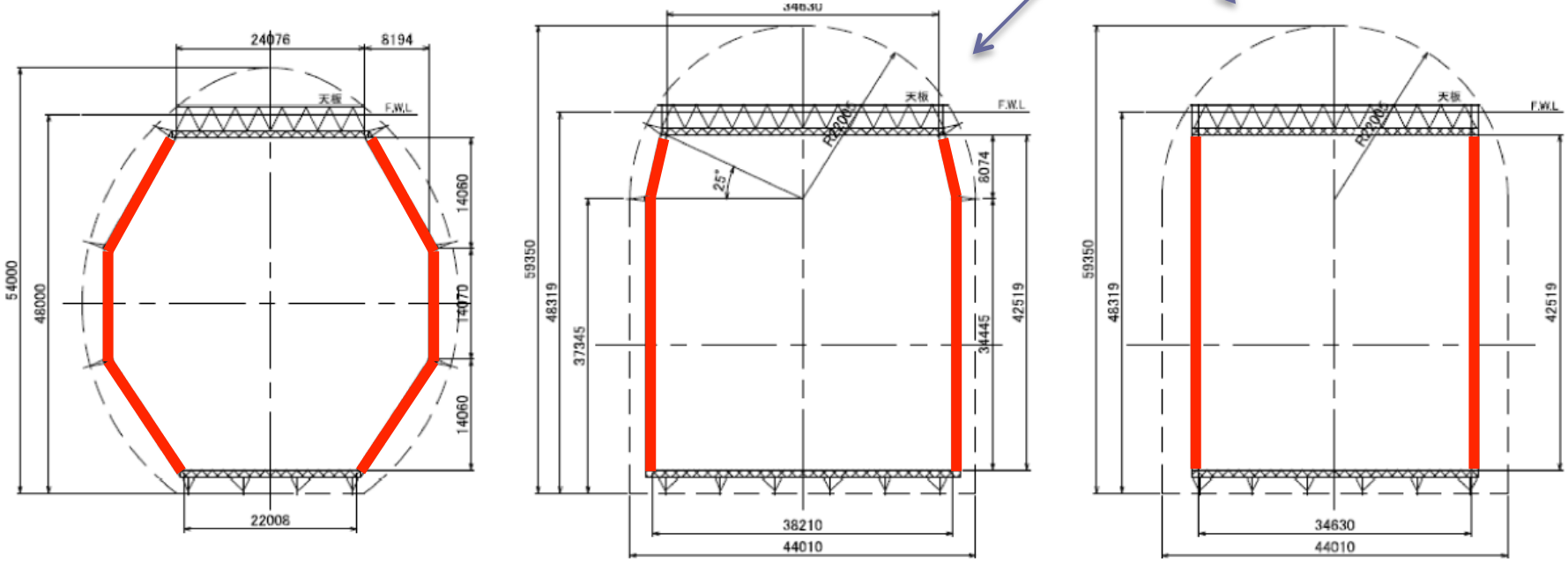
- Made of SUS304 shape steels
  - Designed to support the following load

ID PMT + case	27.8kg/PMT
OD PMT	1.7kg/PMT
PMT cable (10m)	2kg/PMT
HUB	5kg/HUB
Network cable (10m)	2kg/HUB
Load on the roof	100kg/m^2
Cables on the roof	0.15kg/m^2
Water system pipes	1.4kg/m (65A PVC)
Calibration holes	200A SUS



Wire support options

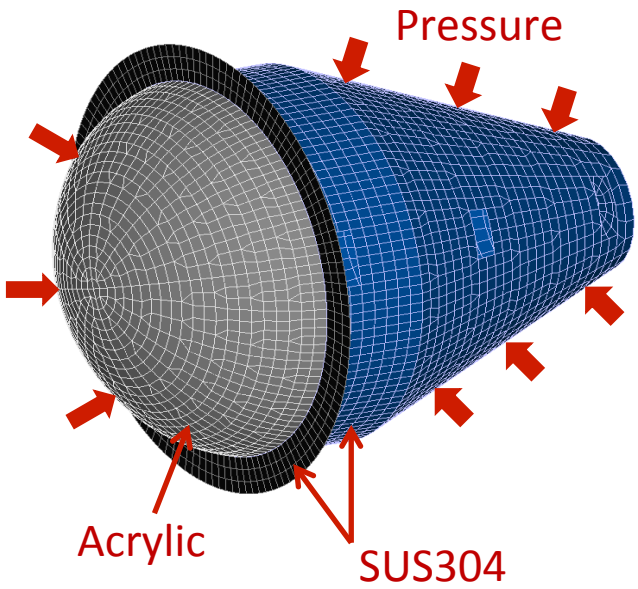
For different cavity shapes

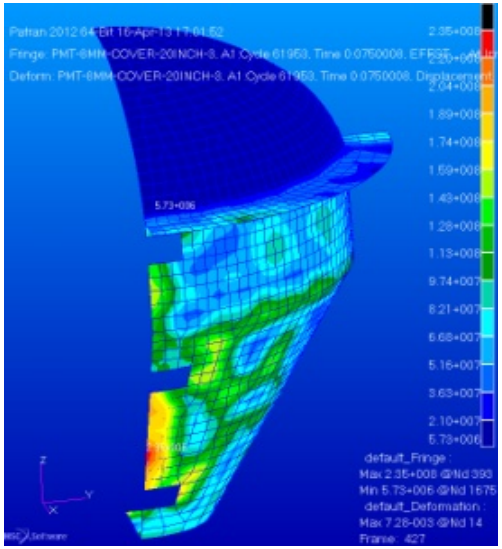


- PMT supporting by wires has also been studied
  - → Found the construction cost is comparable (even higher)
  - Wire termination requires special works and parts
  - Devices to give initial tensions and additional tensions when a wire stretches afterwards

Photodetector protective cover

- To avoid a chain-implosion of PDs due to shockwave
- Might be useful for an easier PD mounting to the frame
- If we use a passive geomagnetic shielding case for each PD, it should be implemented as a unit
- Designing work is ongoing





3. Other components

Possible overseas contributions

- Magnetic coil system
- Passive magnetic shield cases
- Plug manhole
-

Magnetic coil designing : status and plan

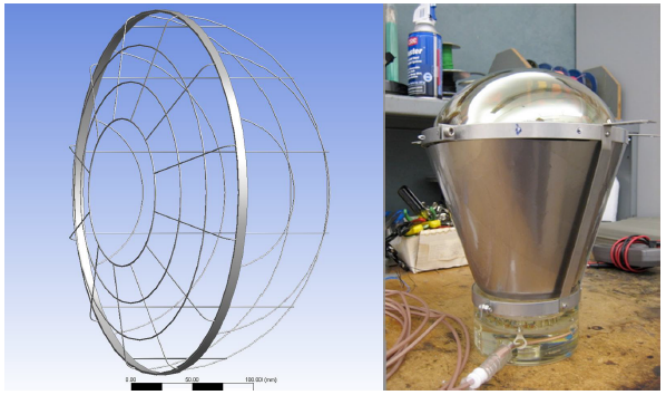
- Given basic condition for designing the coil system :
  - B < 100mG @ most of PD positions in the tank

    Based on a past R3600 measurement. May be loosen for new PDs
- Coil arrangement has been studied for an easier case
  - i.e. Geomagnetic field is perpendicular to the tank axis
  - No satisfactory result has been obtained so far (see past slides)
- Will continue the designing work
  - Better arrangement of coils
  - Coil installation method (On the wall? Inside the concrete layer?)
  - Cost estimation (current estimation includes only cost for cables)

Foreign contributions to this part are really helpful.

Designing itself could be an economic contribution.

Passive magnetic shielding



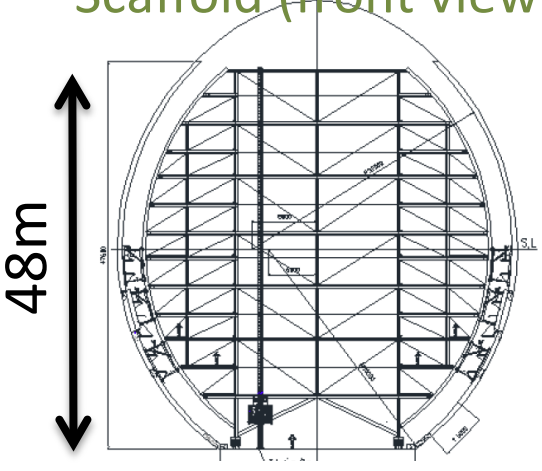
- Used in many experiments
  - Double Chooz, Daya Bay, IceCube, Kamiokande, …
- Easy to assemble with a PD case
- This option should also be studied in parallel with the coil study
- The 1st prototype is under production
  - Performance evaluation will start next month
- Many R&D works are necessary
  (material selection, shape optimization, prototype testing, cost estimation, production period, detection efficiency/acceptance check, anti-corrosion, …)
- Good for oversea contribution (designing/testing/procurement)

4. Construction procedure and cost

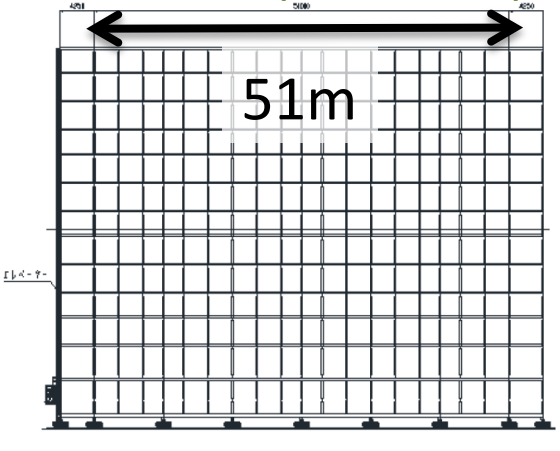
Lining and support construction

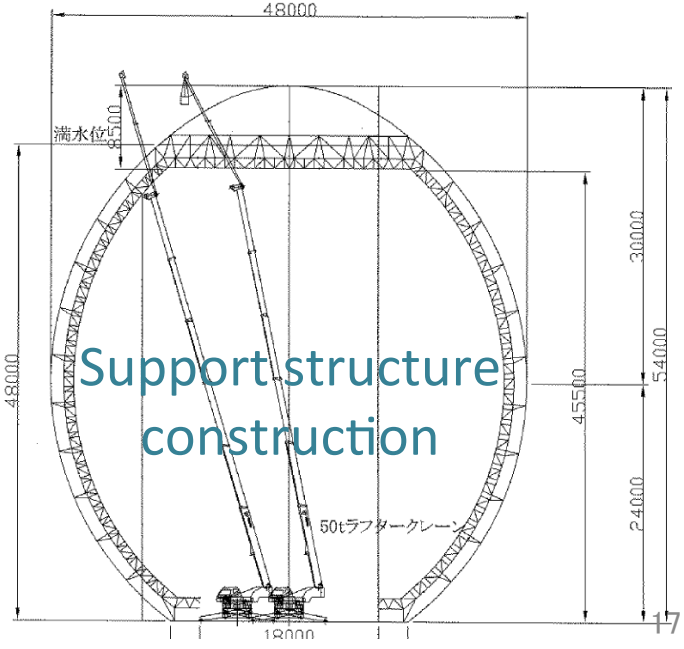
- Use a “movable” scaffold for constructing the lining
  - Size of the scaffold is about a compartment (~50m)
- When the lining finished in a compartment, slide/move the scaffold to next compartment
- Construction of support structure begins in the compartment where the lining finished
  - Using long-arm cranes

Scaffold (front view)

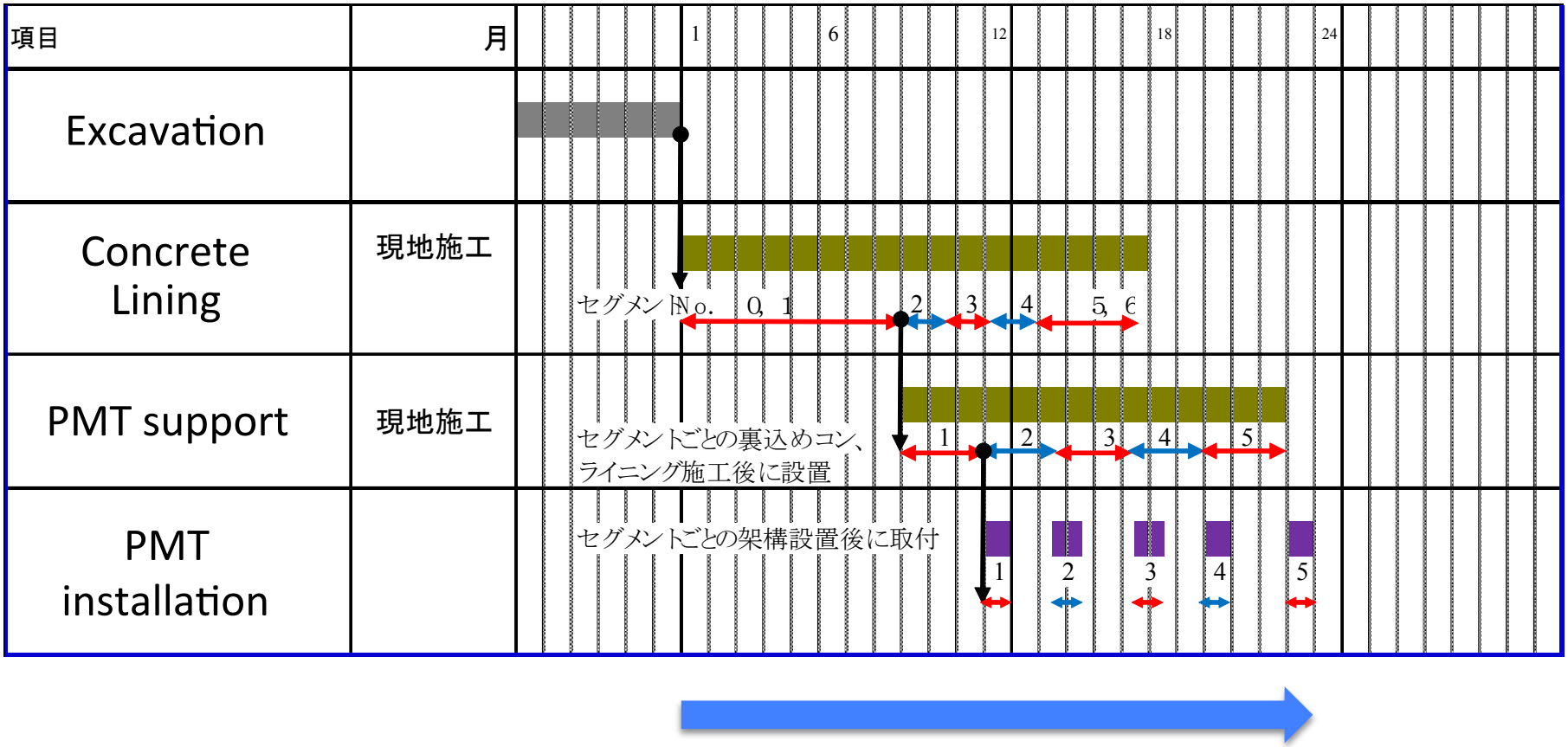


Scaffold (side view)





Tank construction schedule



~2 years for tank construction

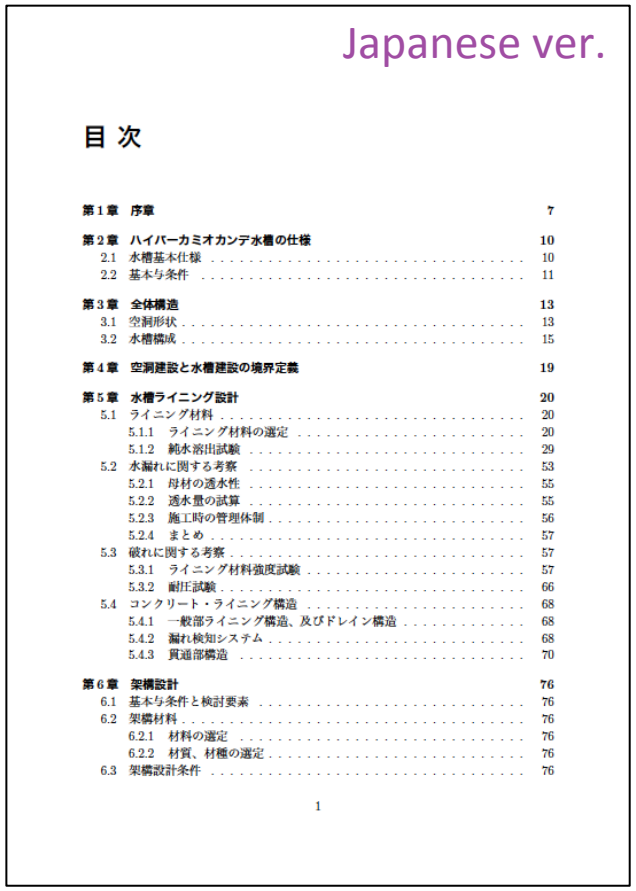
Confidential

Tank construction cost

Please ask the Cavity and Tank WG

Technical design document

Japanese ver.



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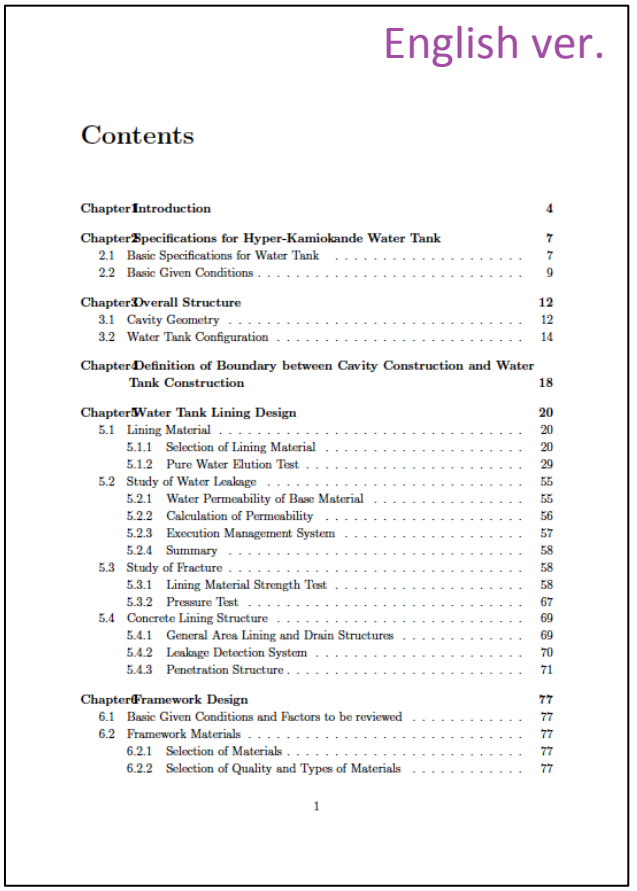
English ver.



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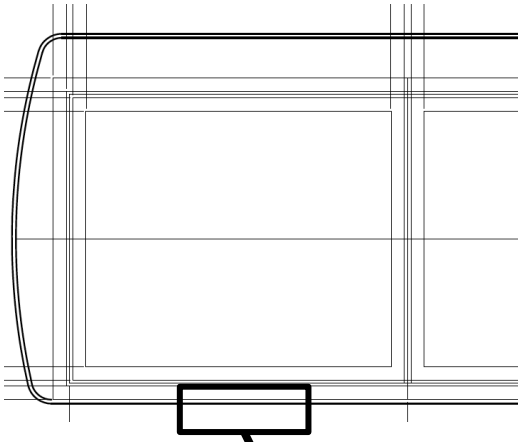
- Japanese version will be ready in this month
- English version will be ready in ~1 month

Conclusion

- Baseline design of the Hyper-K tank has mostly been established
  - Updated total cost
- Many room for foreign contributions
  - Lining, leak detection and draining system, PD cover, PD assembly integration, black sheet, reflective sheet, compensation coil, magnetic shielding case, manhole, …
  - Intellectual contributions (new ideas, review of the plan) are also valuable
- Technical document in English will be ready in ~1 month
- Further cost reduction is desirable
  - Your ideas are very welcome!

Supplement

Water leak detection and draining



- HDPE liner segmented into multiple partitions
- Each partition has own drain line, that allows to identify where the leak occurred
- Need to test the design with a prototype

Zoom

Plastic partition

OD

10m

Drain pipes
(leaked tank water)

HDPE sheet

Concrete

裏込めコンクリート

樹脂型物

Waterproof sheet

排水、回収

Drain
(tank water)

Shotcrete & Rock

岩盤

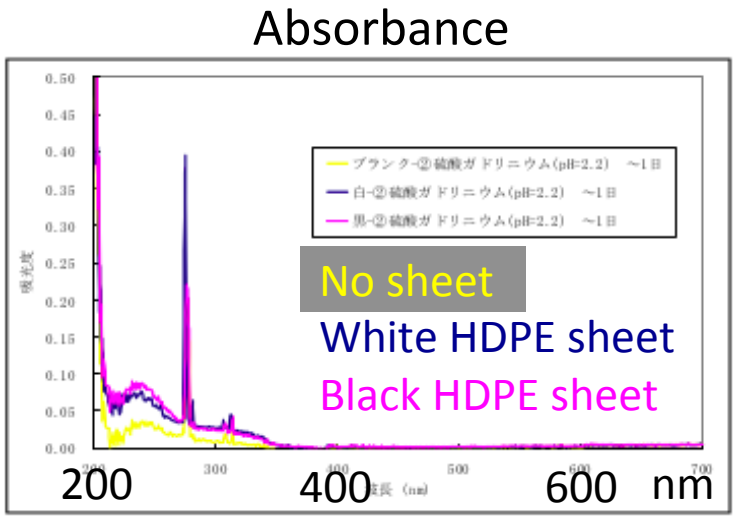
Drain
(sump water)

排水

Lining sheet testings

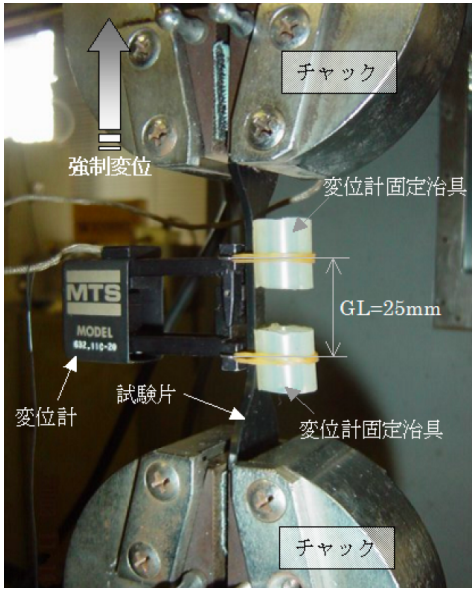
- Soak test
  - In ultra pure water &
    In 1% $Gd_2(SO_4)_3$ solution
  - Found some dissolution of organic substances, anions, and metal ions

  → Need to evaluate effect on HK



- Strength test
  - Tension test (normal part & welded part), Creep test

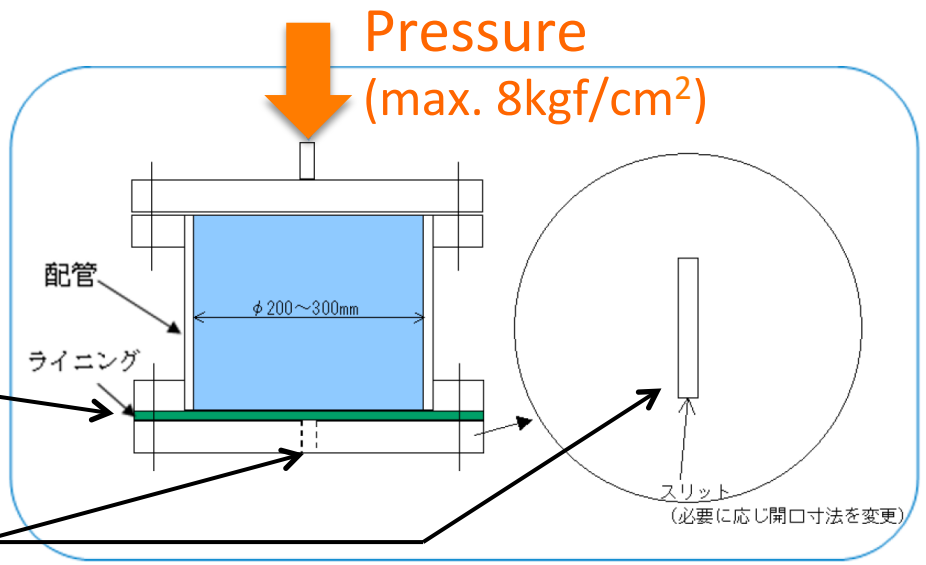
  → Candidate HDPE sheet has enough strength



Lining sheet testings

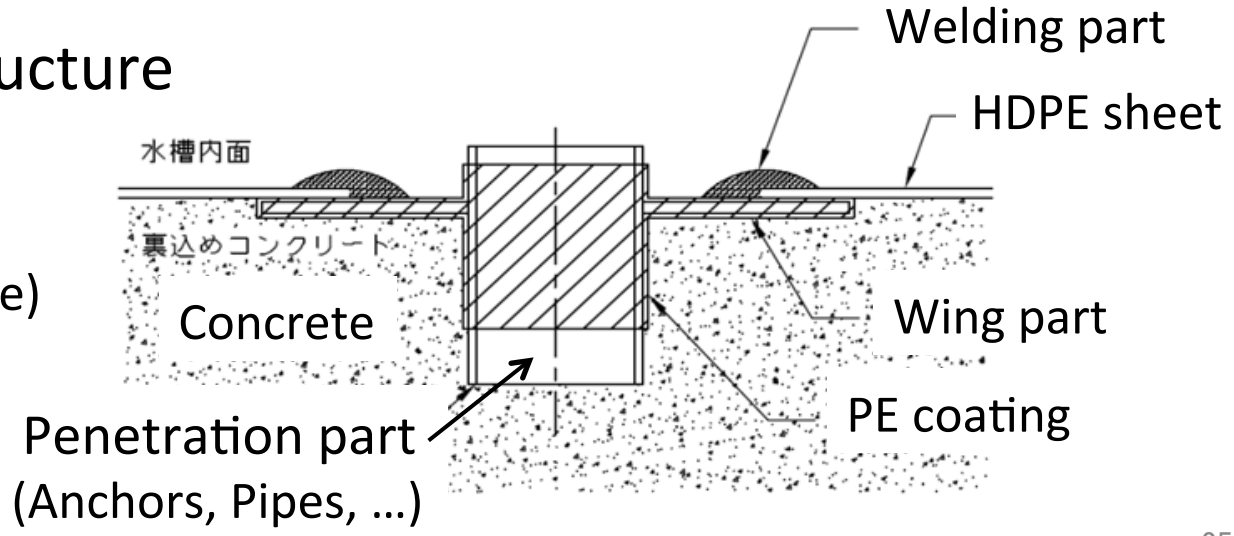
- Pressure Test

  → Sheet did not break
  No water leak found



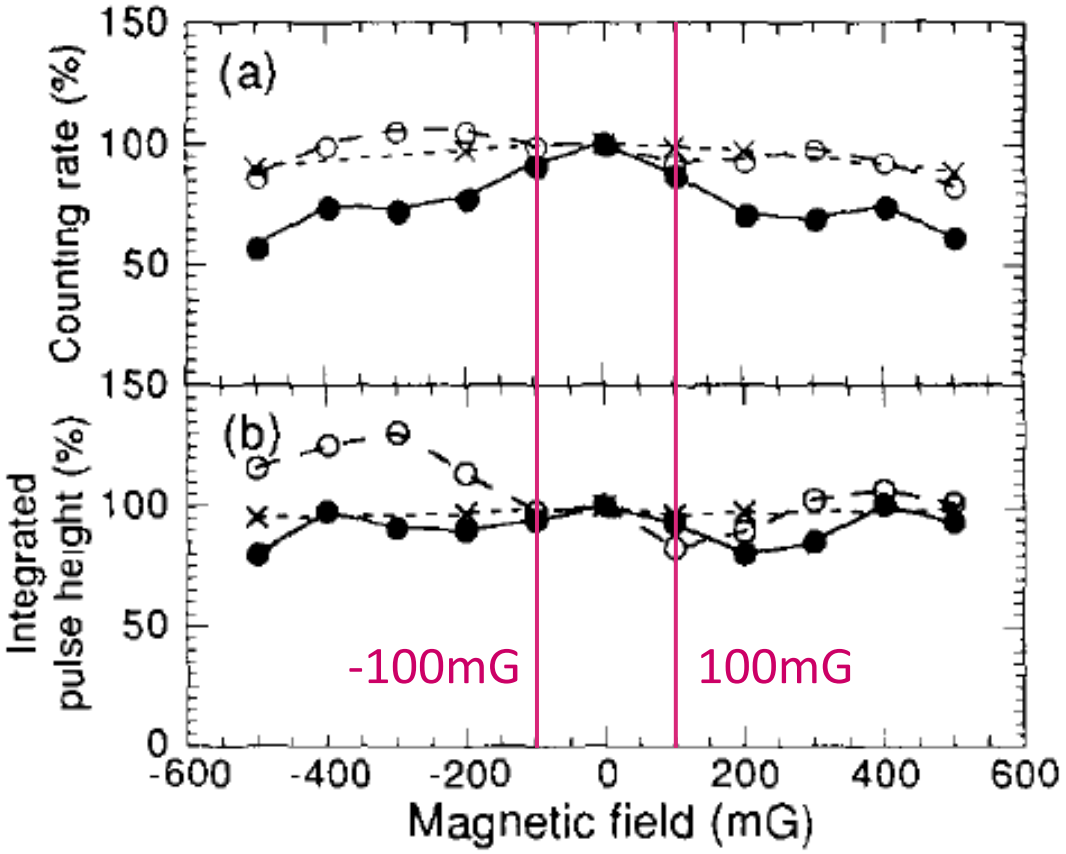
- Penetration Structure
  - Spark test and Pressure test (short/long/cycle)

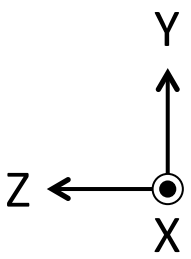
  → No leak found



PMT response in a magnetic field

20-inch PMT used in Super-K





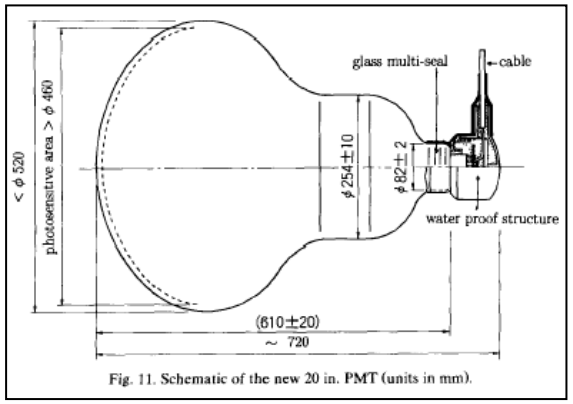


Fig. 11. Schematic of the new 20 in. PMT (units in mm).

- ● Parallel to dynode (X)
- ○ Perpendicular to dynode (Y)
- × PMT facing direction (Z)

Magnetic field perpendicular to the PMT facing direction should be < 100mG.

A. Suzuki et al., NIM A329 (1993) 299-313

Geomagnetic compensation

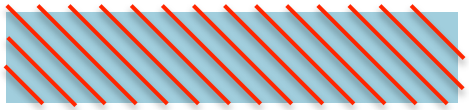
- Active compensation using coils

  Used in Super-K, but not easy in Hyper-K

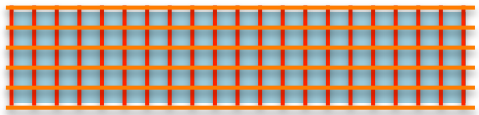
  - Long rectangular coils → Not like a Helmholtz coil
  - PMTs in the segmentation wall → Longer distance from coils
  - Detector is not ϕ-symmetric around a vertical axis
    → Basically need coils for each of (x, y, z) components

Top view

Assumed geomag. field
(Horizontal component)



→ Bad



→ OK

  - Needs very long coil cables
    → Many cable connection work

Geomagnetic compensation

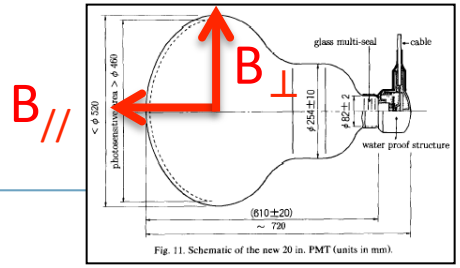


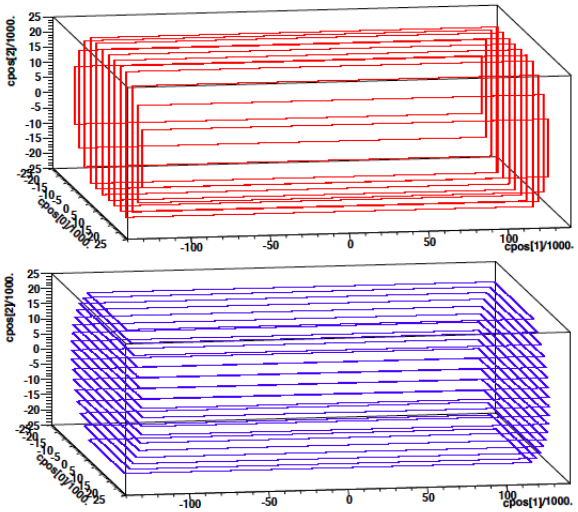
Fig. 11. Schematic of the new 20 in. PMT (units in mm).

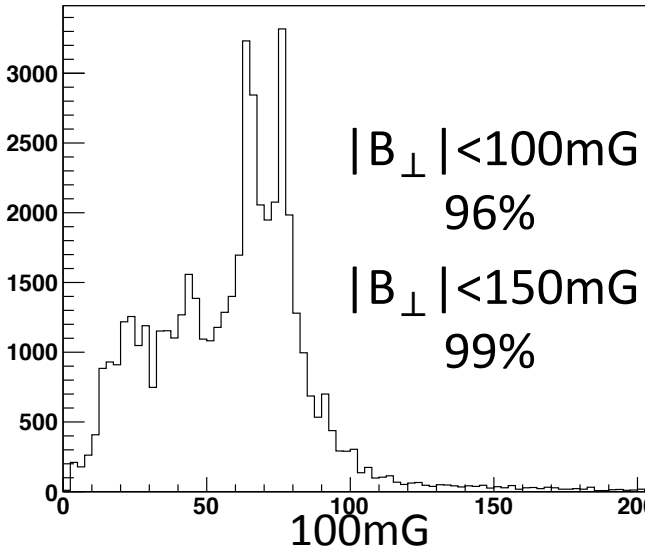
- Active compensation using coils
  - A coil arrangement study for an easier case

Residual B field ⊥ to each PMT facing direction

No component along the tank axis

(Candidate placement in the Tochibora site)





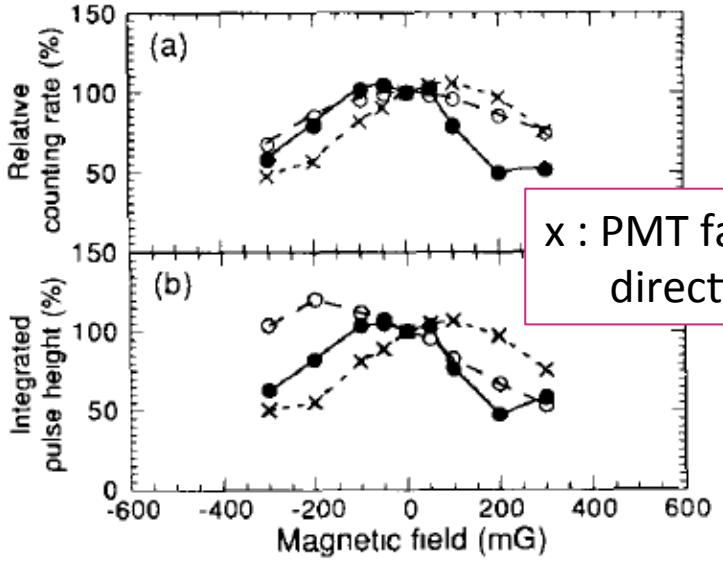
Coil configuration providing B_{total}<100mG at most of sensor positions has not yet been established (even for an easier case)

At present I don't think the active compensation is the best solution for Hyper-K

The result looks good, but …

- The fraction of sensors with 50-100mG $B_{\perp}$ is large.
  - ~30mG in Super-K
- Magnetic field parallel to the PMT facing direction also affect the PMT response
  - depending on position where a photon hits a PMT
- I have tried to find a better configuration, but am not yet successful.
  - due to the very long tank shape
  - more difficult if the tanks are not // nor ⊥ to the horizontal geomagnetic field

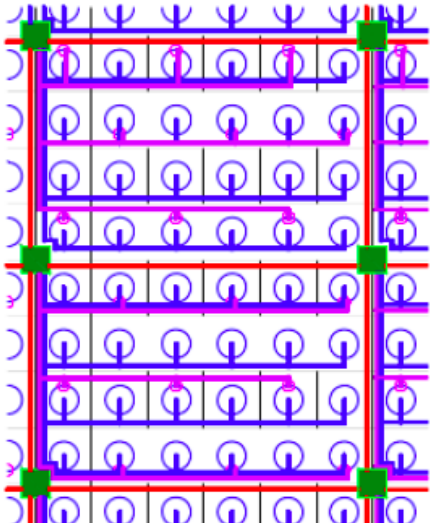
Lighting position is at 60^{o} w.r.t the PMT axis



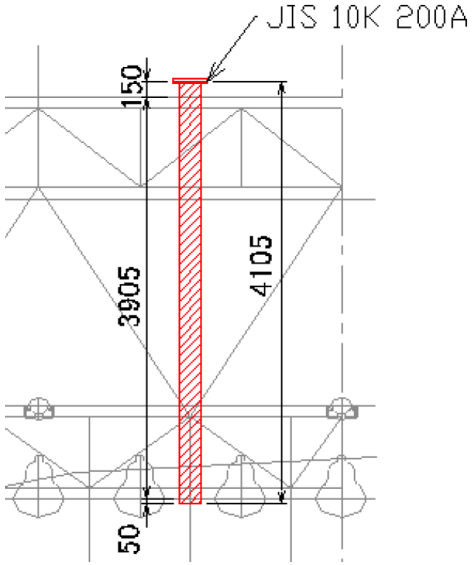
x : PMT facing direction

Other designing work

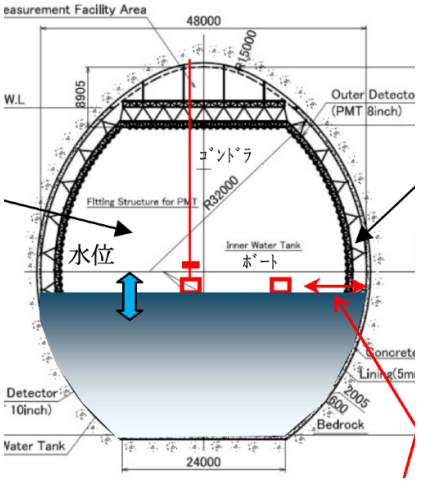
Cable & elec. layout



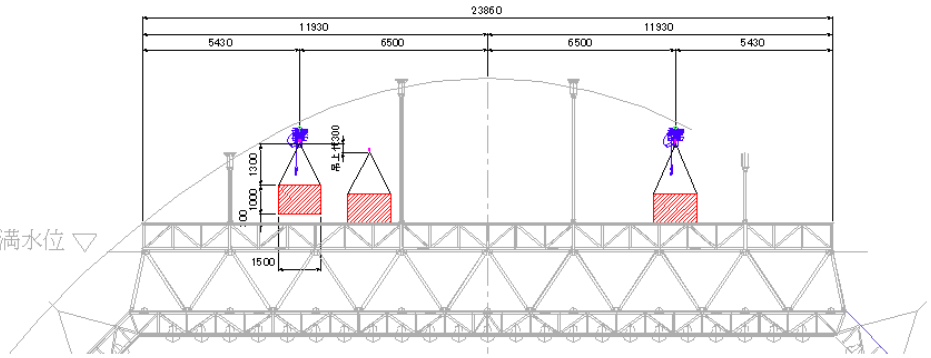
Calibration holes



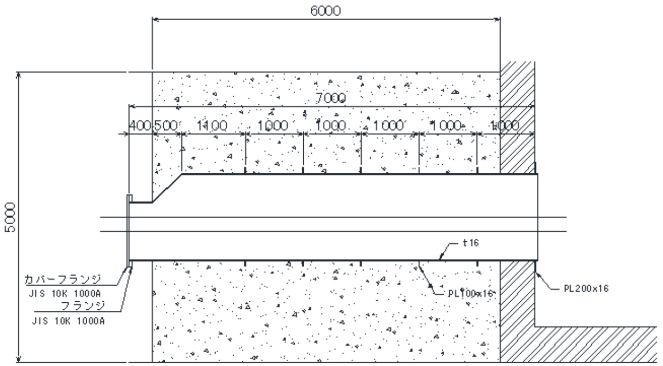
Gondola and access to PMTs for maintenance



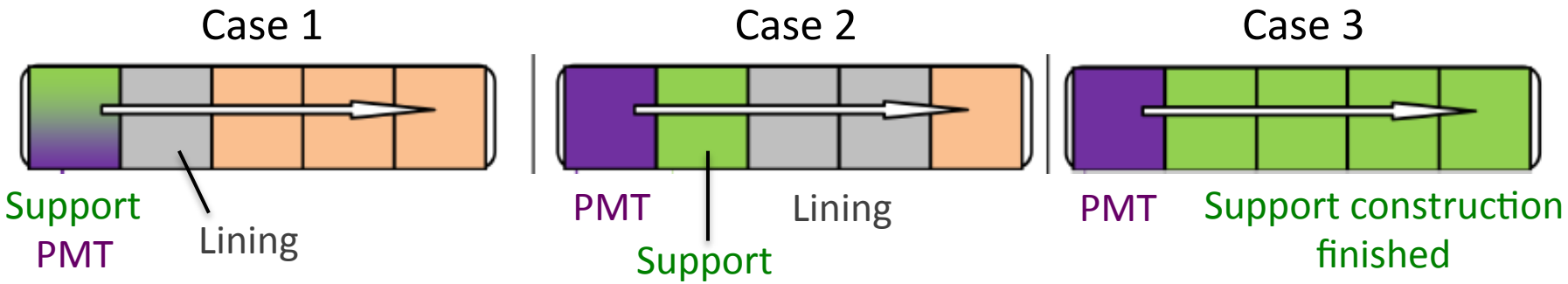
Cranes



Plug manhole



Photodetector installation procedure



- Case 1 : Construct support frame with PMTs
- Case 2 : Install PMTs in the compartment where the support construction has just finished
- Case 3 : Support construction first in the whole tank, then start PMT installation

	Case 1	Case 2	Case 3
Construction period	◎	○	△
Cost	◎	○	△
Safety	△	◎	◎
Cleanness	△	△	◎

At present, case 2 is the first choice

Need to consider antipollution measures

Remaining tasks

- Estimate influence of possible bedrock displacement or backwater pressure on the tank design
  - Modifications if needed
- Build more detailed construction procedure
  - Including tank antipollution measures
- Magnetic compensation R&D
- Further cost reduction