Hyper-K Tank

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for the Cavity and Tank WG

January 27, 2014

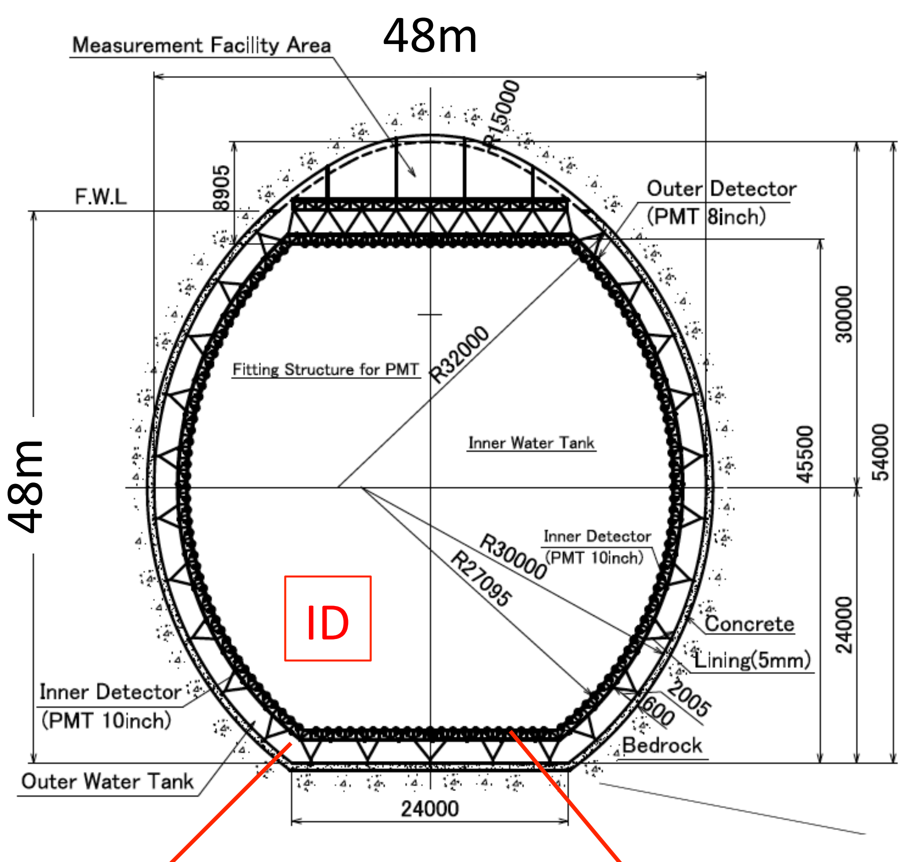
@ The 4th open Hyper-K meeting

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

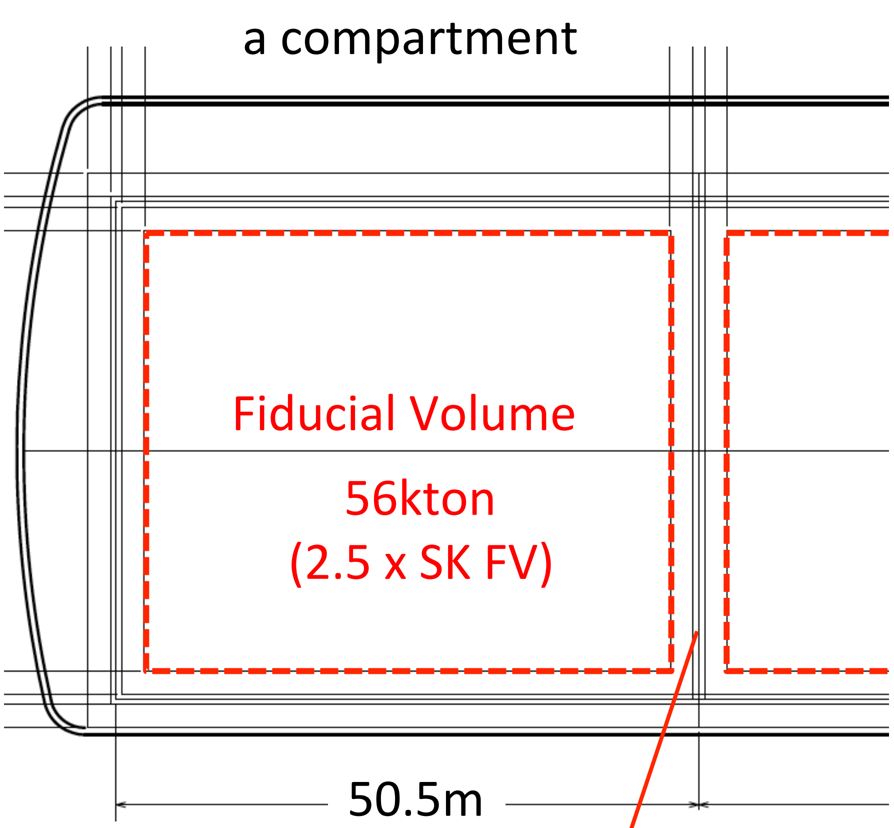
Cross-Section



OD 2m thick

Dead Region 0.9m thick

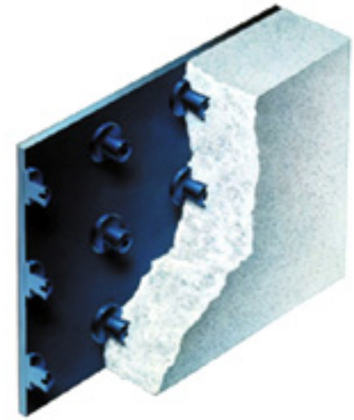
Side View

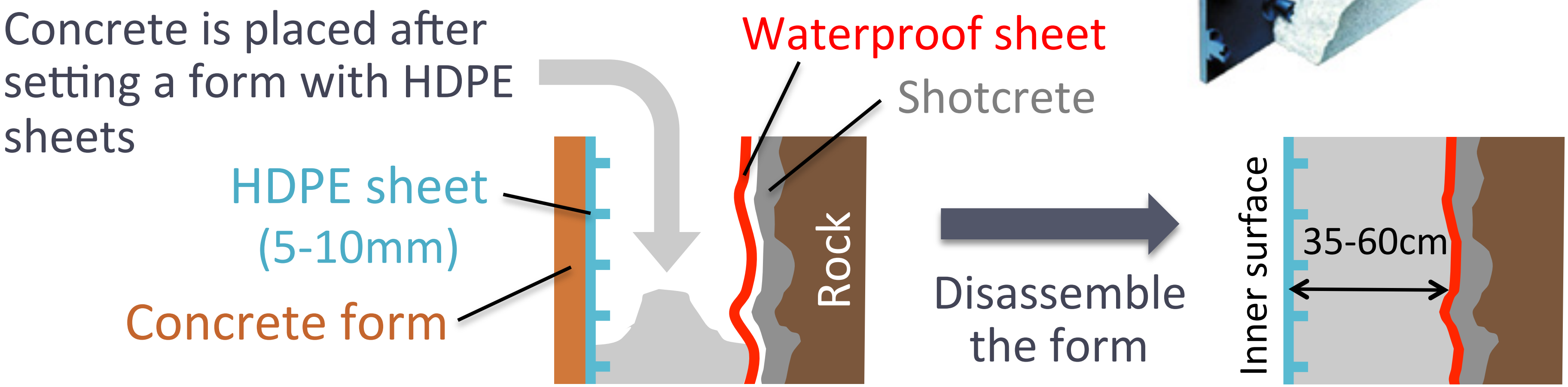


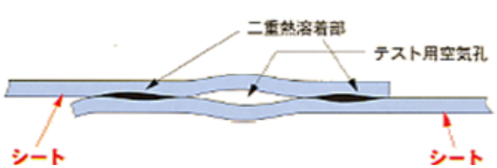
Segmentation Wall

Tank Lining

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

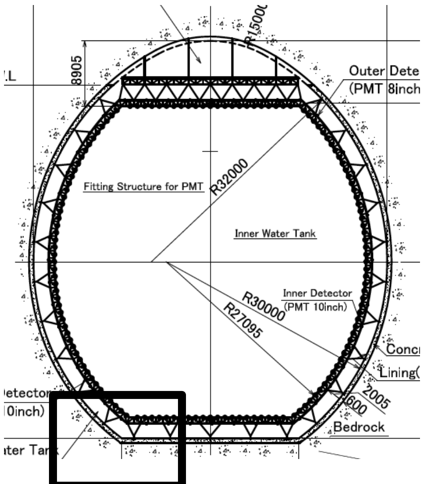






- Water permeability of HDPE sheet is very low
- Adjacent HDPE sheets are welded by heating
- Holes in a sheet (including welded part) can be found by pinhole test

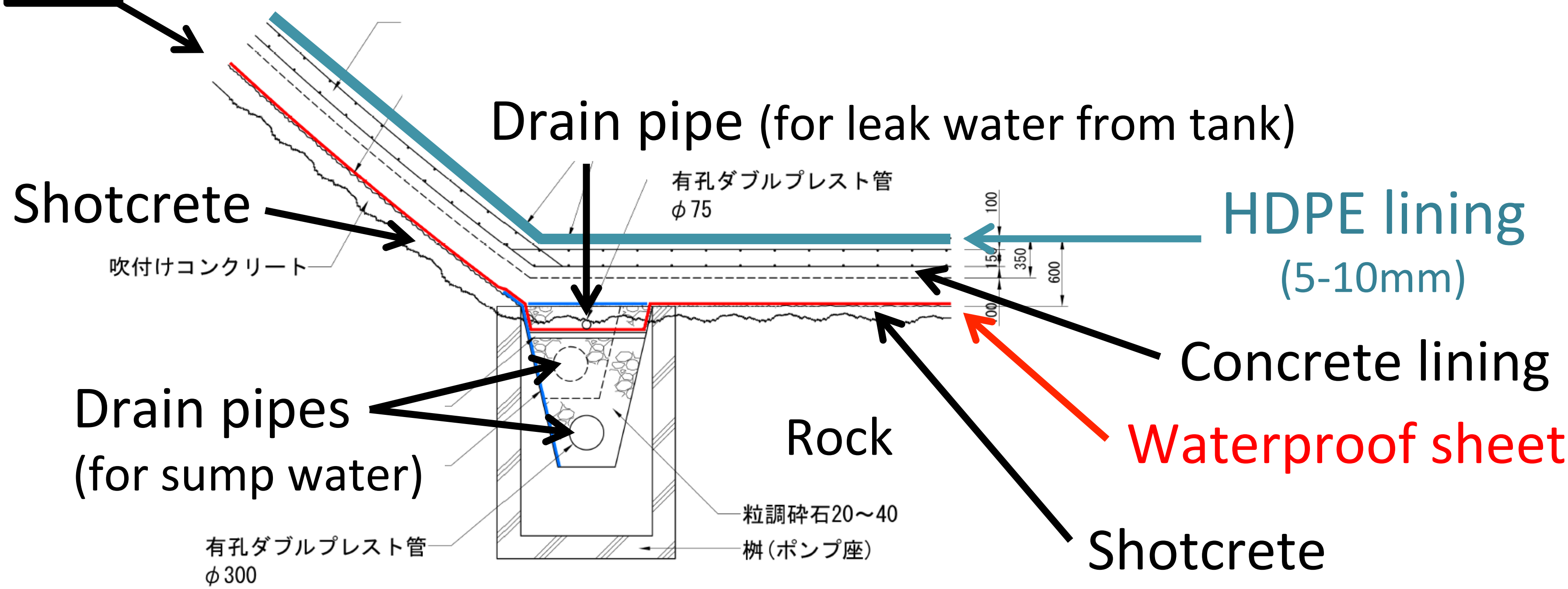
Water Leak Detection and Draining



No water leak expected by HDPE(+concrete) lining

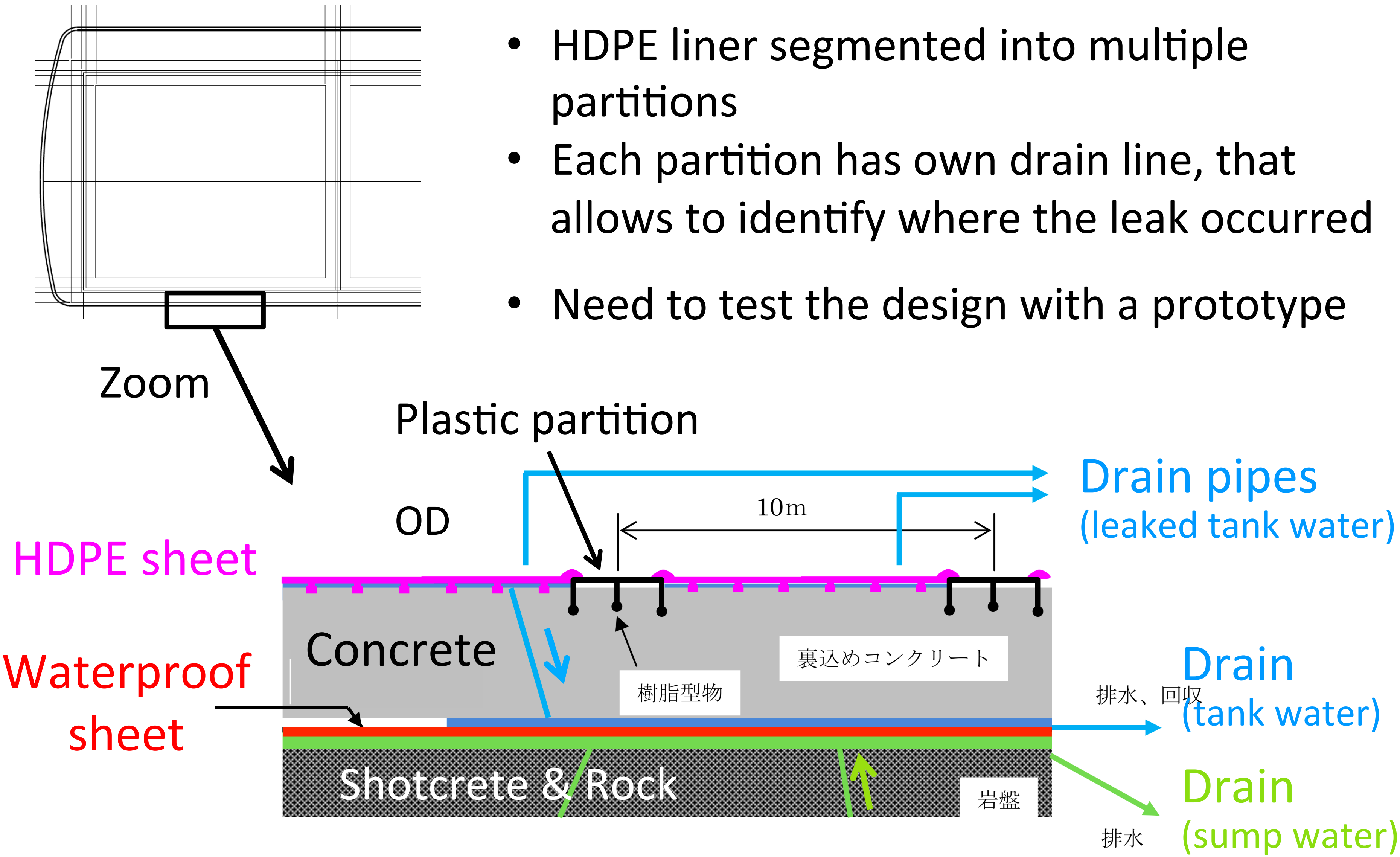
Additional lining with a water proof sheet just for accidental water leak

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



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

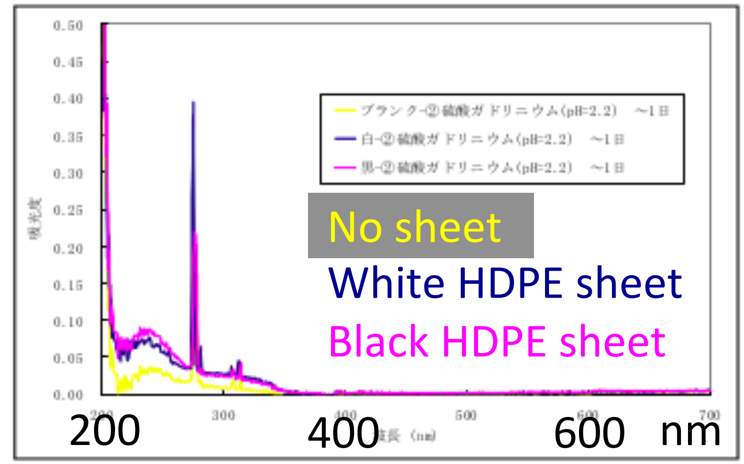


Lining Sheet Testings

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

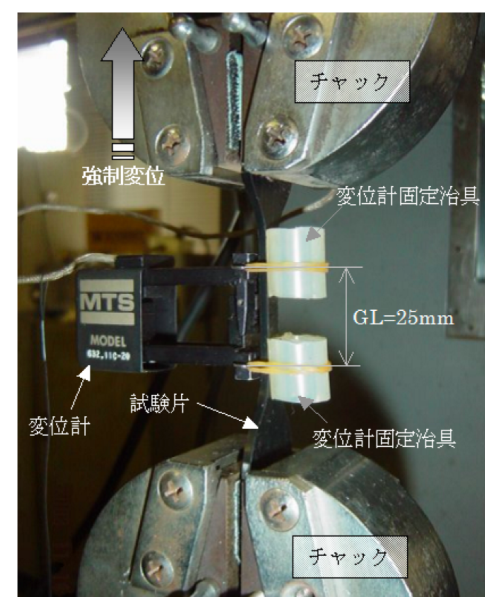
  → Need to evaluate effect on HK

Absorbance



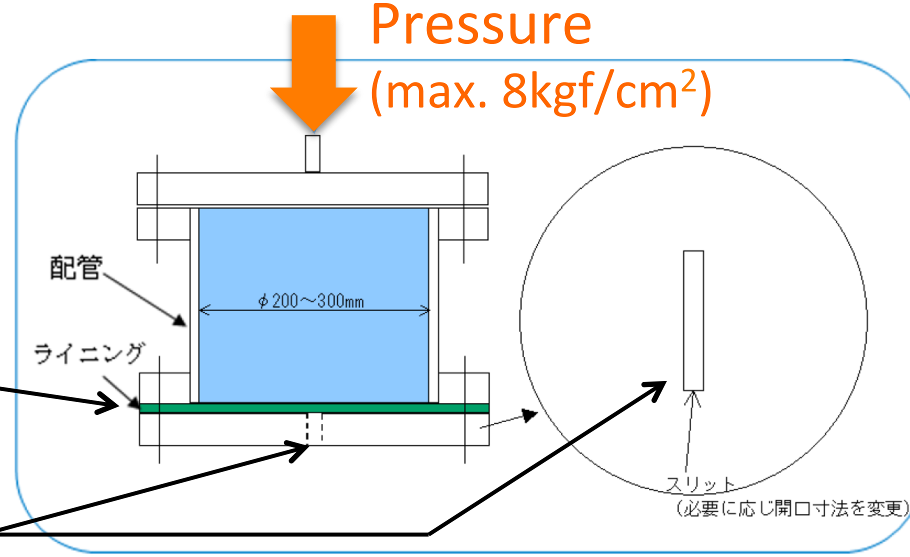
- Strength test
  - Tension test (normal part & welded part), Creep test

  → Candidate HDPE sheet has enough strength

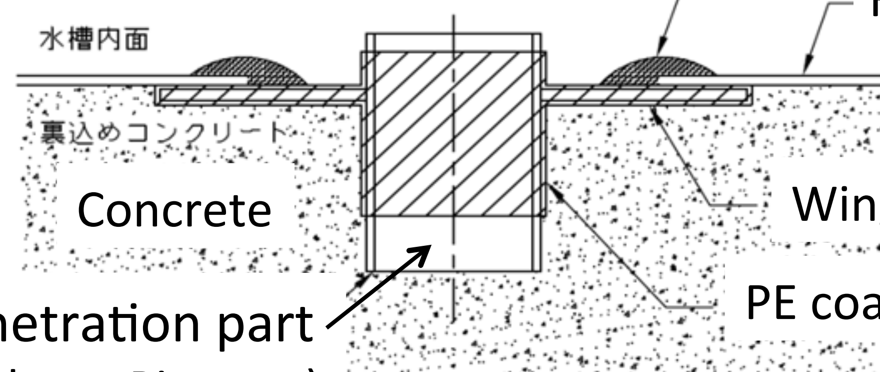


Lining Sheet Testings

- Pressure Test
  - → Sheet did not break
    No water leak found



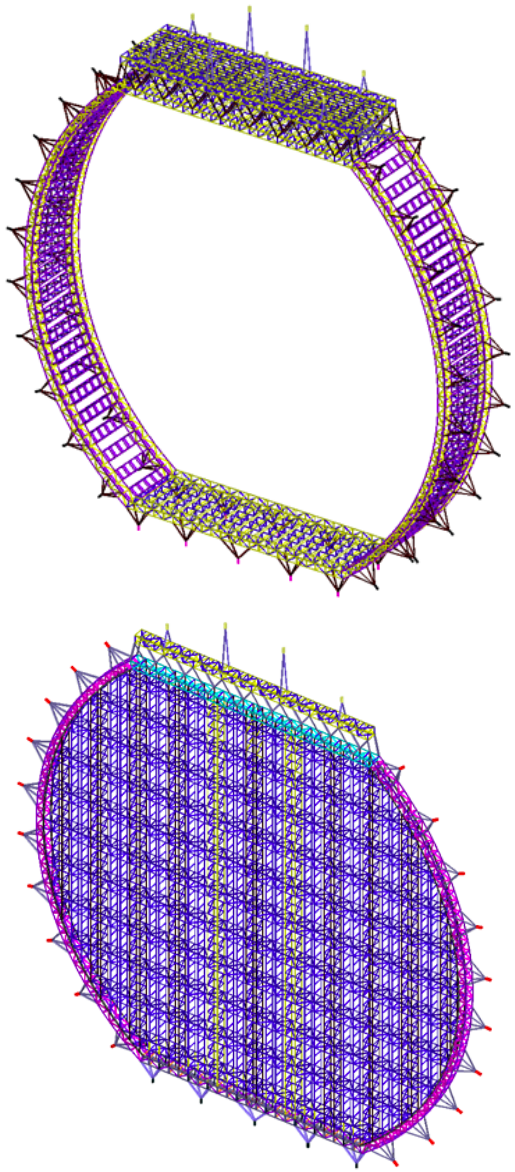
- Penetration Structure
  - Spark test and Pressure test (short/long/cycle)
  - → No leak found



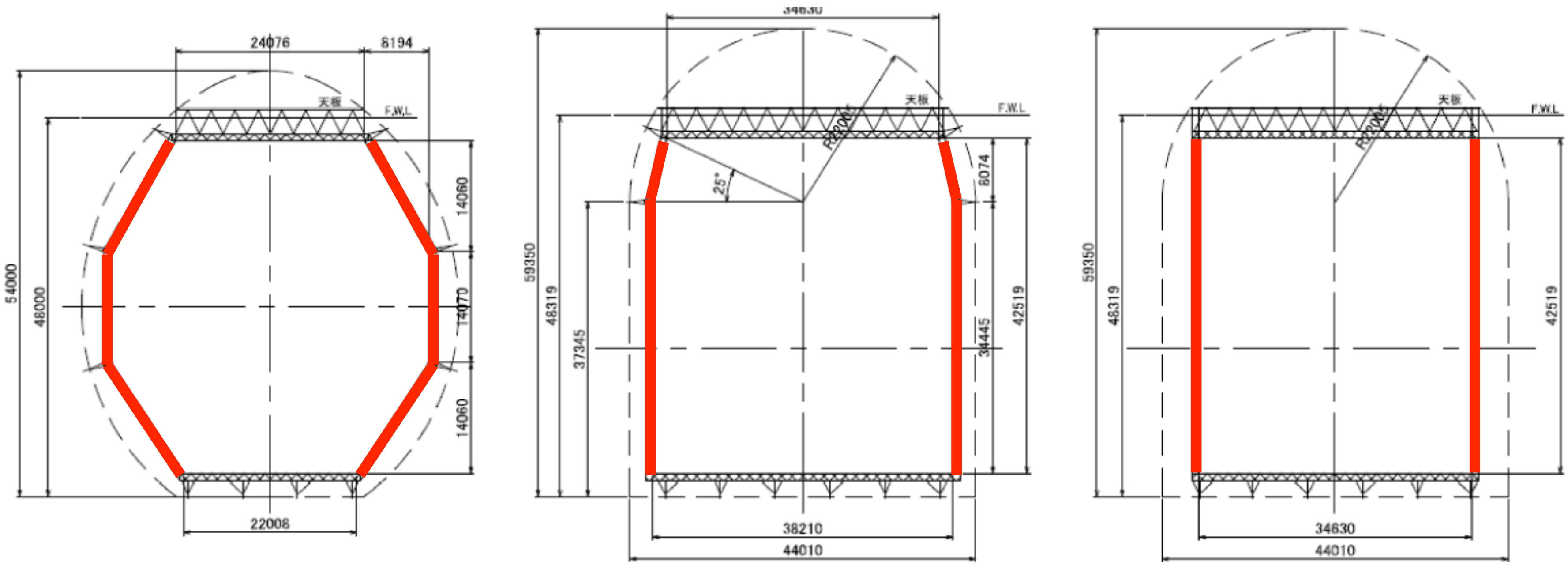
Photodetector Support Structure

- 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



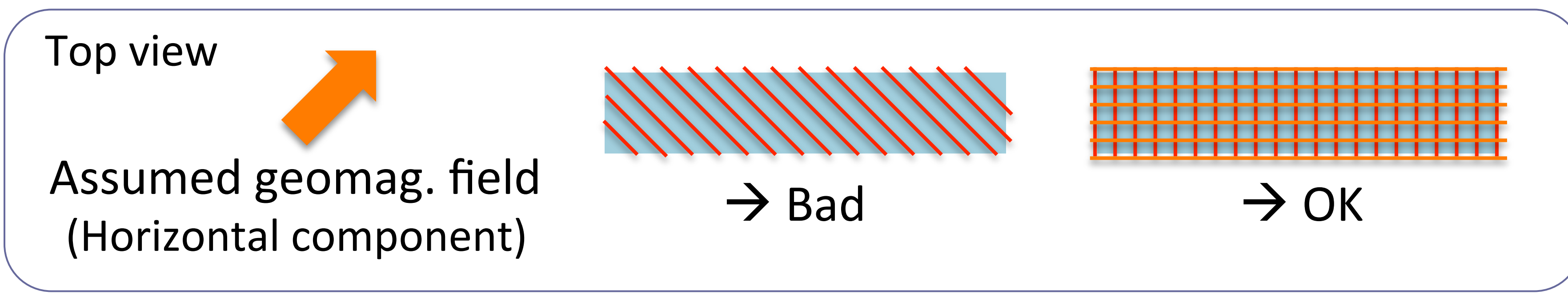
- PMT supporting by wires has also been studied
  → Found the construction cost is comparable (even higher)
  - Wire termination requires special works and parts
  - Devices to give initial tensions and additional tensions when a wire stretches afterwards

Geomagnetic Compensation

- Active compensation using coils

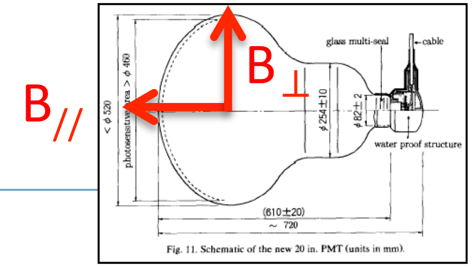
  Used in Super-K, but not easy in Hyper-K

  - 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



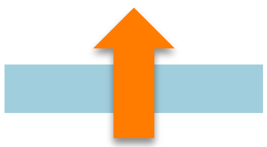
  - Needs very long coil cables
    → Many cable connection work

Geomagnetic Compensation



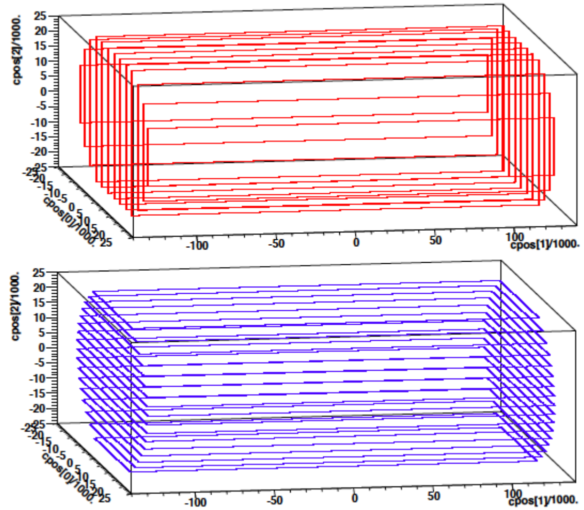
Residual B field ⊥ to each PMT facing direction

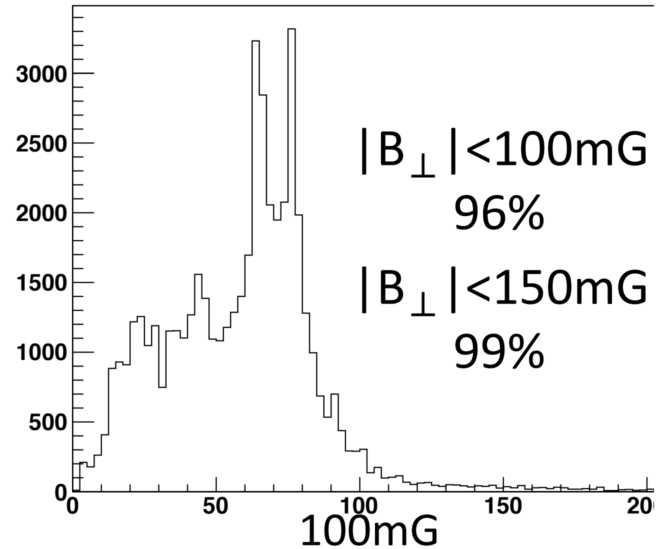
- Active compensation using coils
  - A coil arrangement study for an easier case



No component along the tank axis

(Candidate placement in the Tochibora site)





$|B_\perp|$<100mG 96%

$|B_\perp|$<150mG 99%

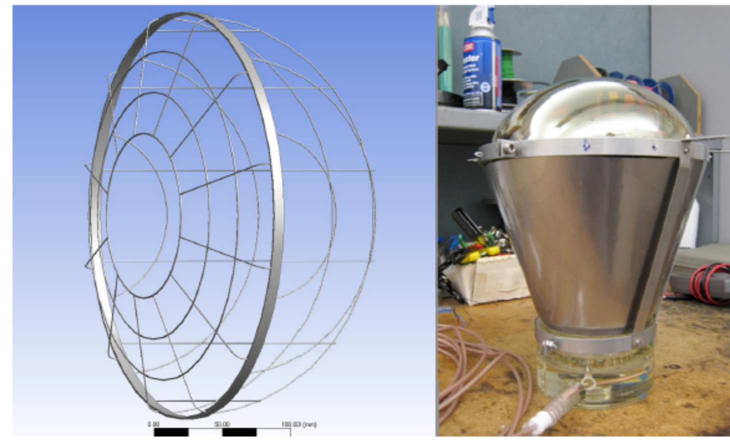
Coil configuration providing B_{total}<100mG at most of sensor positions has not yet been established (even for an easier case)

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

Geomagnetic Compensation

- Passive Magnetic Shielding
  - Used in many experiment

    Double Chooz, Daya Bay, IceCube, Kamiokande, …
  - Easy to assemble with PMT case

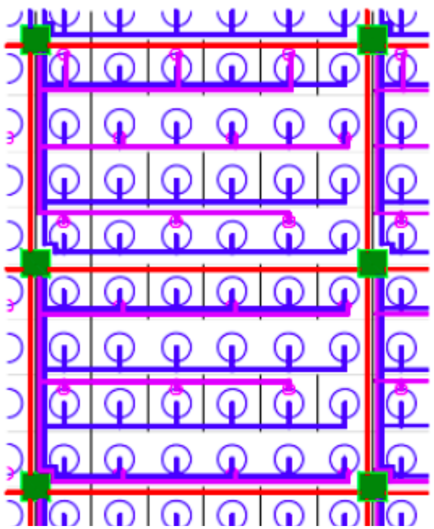


Many R&D works are necessary
(shielding estimation, prototype testing, cost estimation, production period, detection efficiency/acceptance check, anti-corrosion, …)

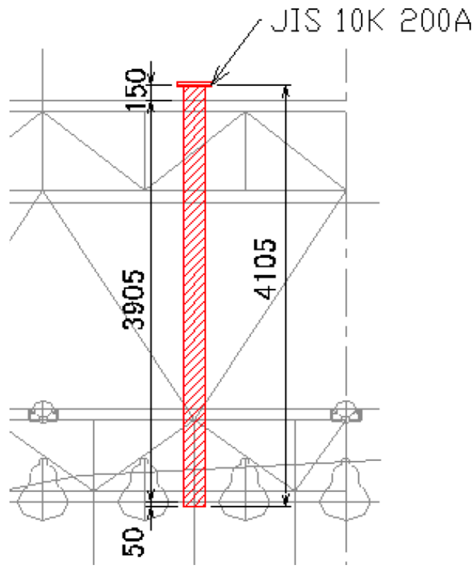
- Contribution to the magnetic compensation R&D is really helpful
  - May be good for overseas contribution

Other Designing Work

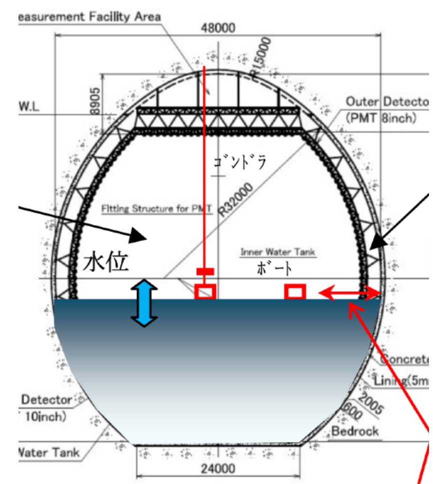
Cable & elec. layout



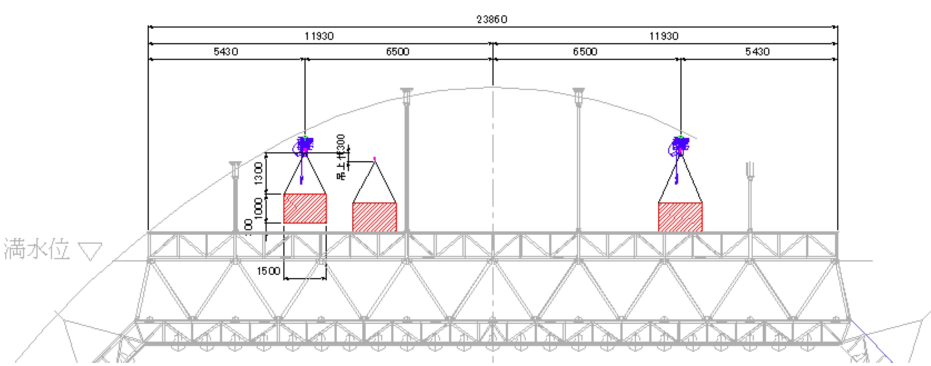
Calibration holes



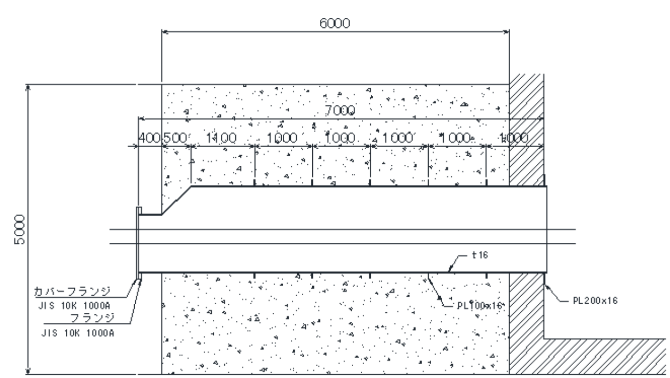
Gondola and access to PMTs for maintenance



Cranes



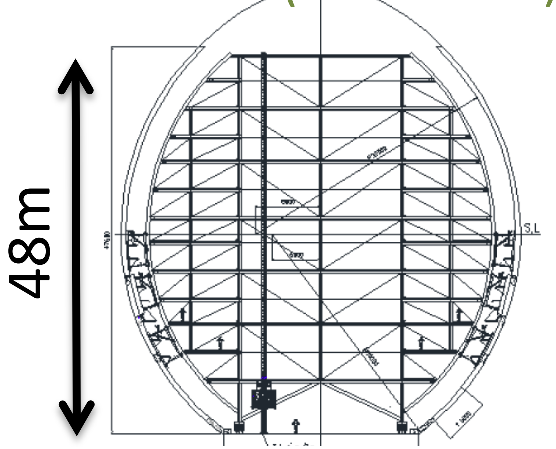
Plug manhole



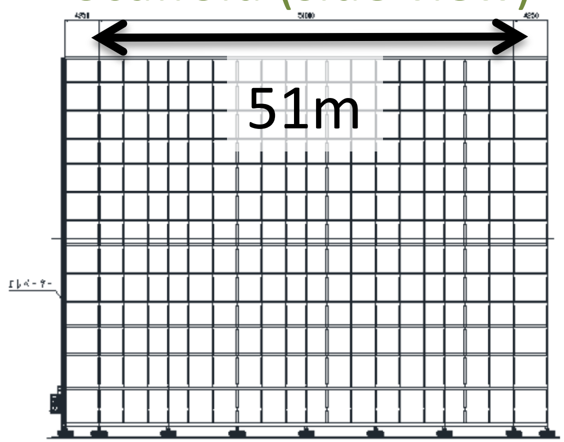
Lining and Support Construction

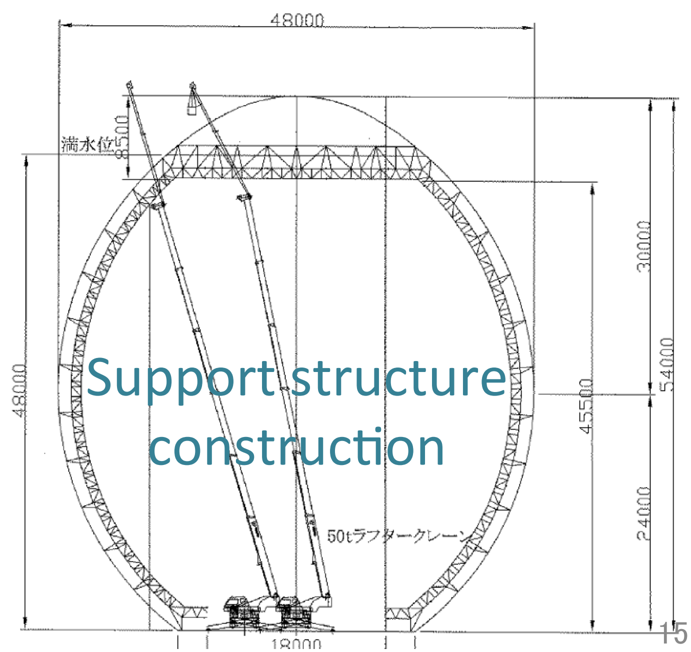
- Use a “movable” scaffold for constructing the lining
  - Size of the scaffold is about a compartment (~50m)
- When the lining finished in a compartment, slide/move the scaffold to next compartment
- Construction of support structure begins in the compartment where the lining finished
  - Using long-arm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

Scaffold (front view)

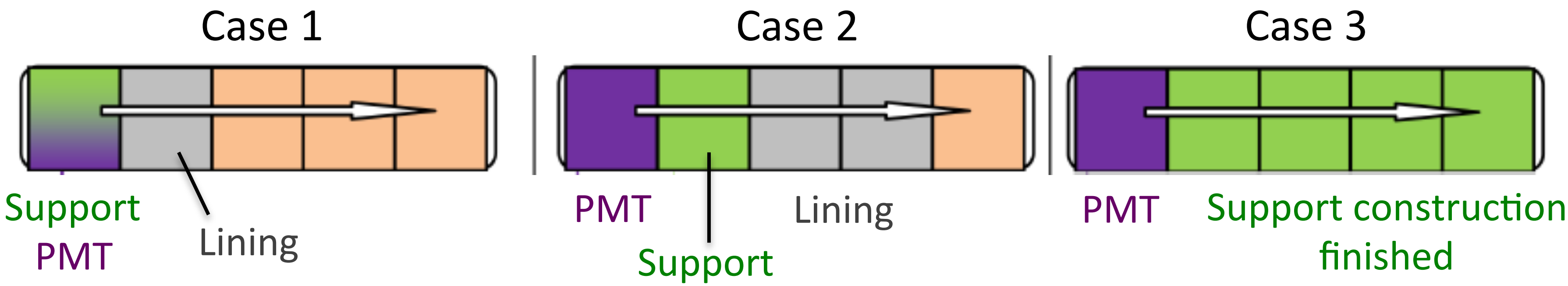


Scaffold (side view)





Photodetector Installation Procedure



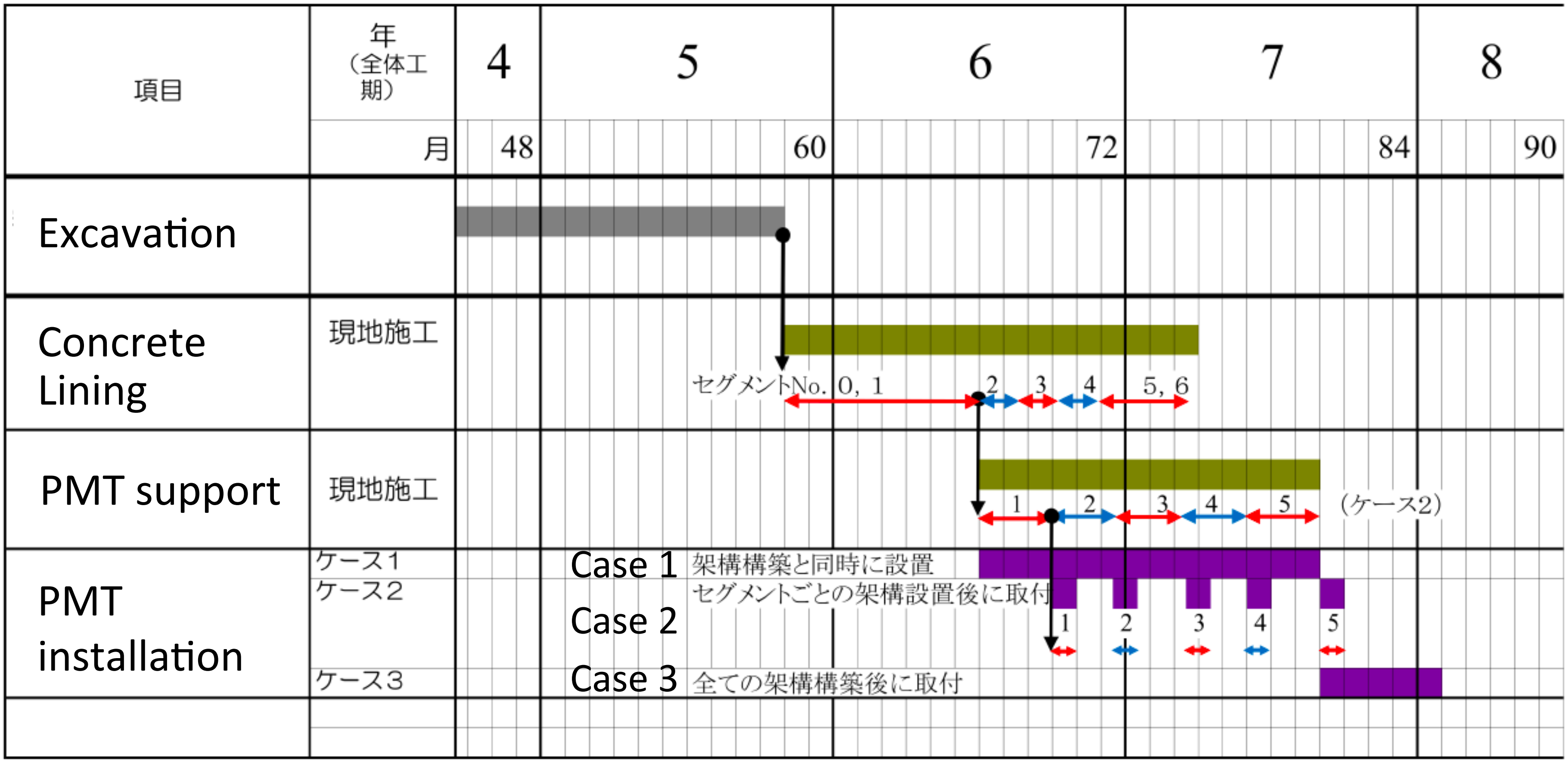
- Case 1 : Construct support frame with PMTs
- Case 2 : Install PMTs in the compartment where the support construction has just finished
- Case 3 : Support construction first in the whole tank, then start PMT installation

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

At present, case 2 is the first choice

Need to consider antipollution measures

Tank Construction Schedule



~2 years for tank construction

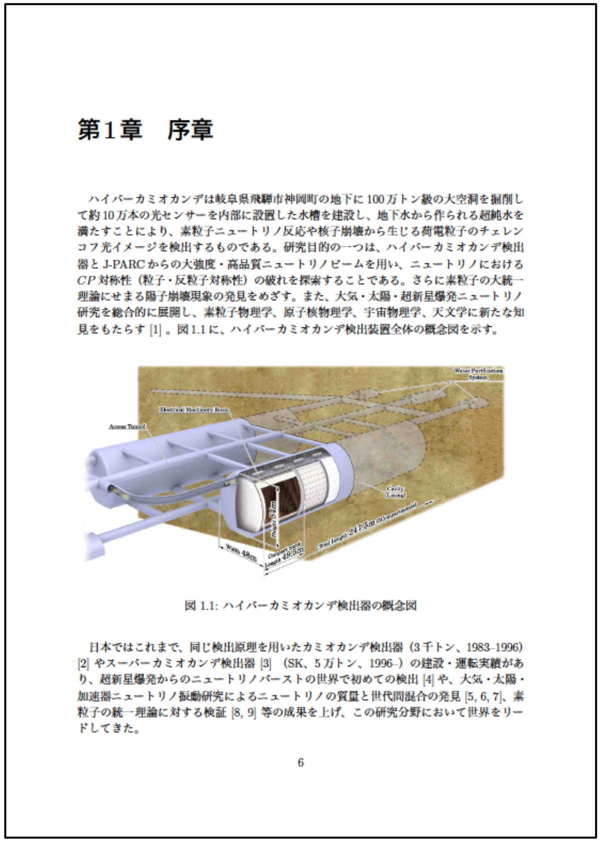
Confidential

Tank Construction Cost

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

Technical Design Document



第1章　序章

ハイパーカミオカンデは岐阜県飛騨市神岡町の地下に 100 万トン級の大空洞を掘削して約 10 万本の光センサーを内部に設置した水槽を建設し、地下水から作られる超純水を満たすことにより、素粒子ニュートリノ反応や核子崩壊から生じる荷電粒子のチェレンコフ光イメージを検出するものである。研究目的の一つは、ハイパーカミオカンデ検出器と J-PARC からの大強度・高品質ニュートリノビームを用い、ニュートリノにおける CP 対称性（粒子・反粒子対称性）の破れを探索することである。さらに素粒子の大統一理論にせまる陽子崩壊現象の発見をめざす。また、大気・太陽・超新星爆発ニュートリノ研究を総合的に展開し、素粒子物理学、原子核物理学、宇宙物理学、天文学に新たな知見をもたらす [1] 。図 1.1 に、ハイパーカミオカンデ検出装置全体の概念図を示す。

図 1.1: ハイパーカミオカンデ検出器の概念図

日本ではこれまで、同じ検出原理を用いたカミオカンデ検出器（3 千トン、1983–1996）[2] やスーパーカミオカンデ検出器 [3] （SK、5 万トン、1996–）の建設・運転実績があり、超新星爆発からのニュートリノバーストの世界で初めての検出 [4] や、大気・太陽・加速器ニュートリノ振動研究によるニュートリノの質量と世代間混合の発見 [5, 6, 7]、素粒子の統一理論に対する検証 [8, 9] 等の成果を上げ、この研究分野において世界をリードしてきた。

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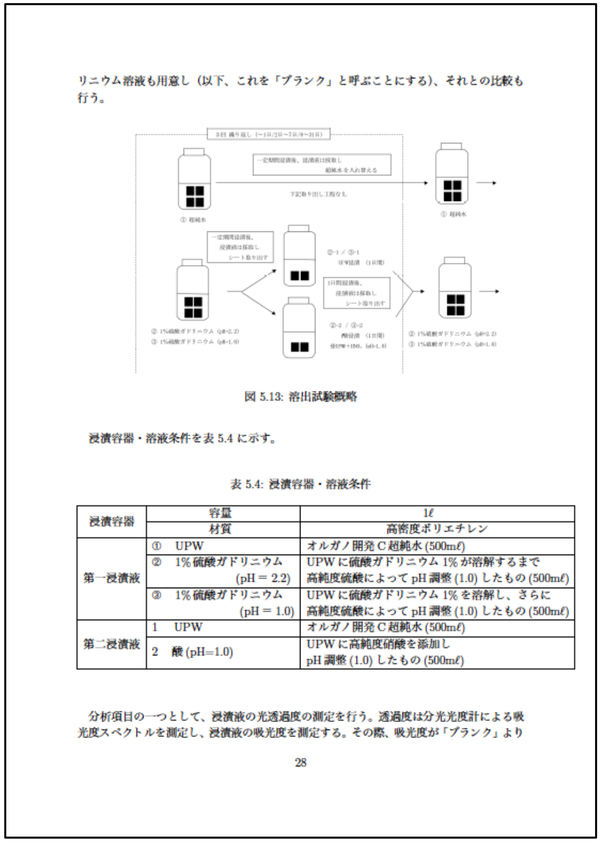

リニウム溶液も用意し（以下、これを「ブランク」と呼ぶことにする）、それとの比較も行う。

図 5.13: 溶出試験概略

浸漬容器・溶液条件を表 5.4 に示す。

表 5.4: 浸漬容器・溶液条件

浸漬容器	容量	1ℓ
	材質	高密度ポリエチレン
第一浸漬液	①　UPW	オルガノ開発 C 超純水 (500mℓ)
	②　1% 硫酸ガドリニウム (pH = 2.2)	UPW に硫酸ガドリニウム 1% が溶解するまで 高純度硫酸によって pH 調整 (1.0) したもの (500mℓ)
	③　1% 硫酸ガドリニウム (pH = 1.0)	UPW に硫酸ガドリニウム 1% を溶解し、さらに 高純度硫酸によって pH 調整 (1.0) したもの (500mℓ)
第二浸漬液	1　UPW	オルガノ開発 C 超純水 (500mℓ)
	2　酸 (pH=1.0)	UPW に高純度硝酸を添加し pH 調整 (1.0) したもの (500mℓ)

分析項目の一つとして、浸漬液の光透過度の測定を行う。透過度は分光光度計による吸光度スペクトルを測定し、浸漬液の吸光度を測定する。その際、吸光度が「ブランク」より

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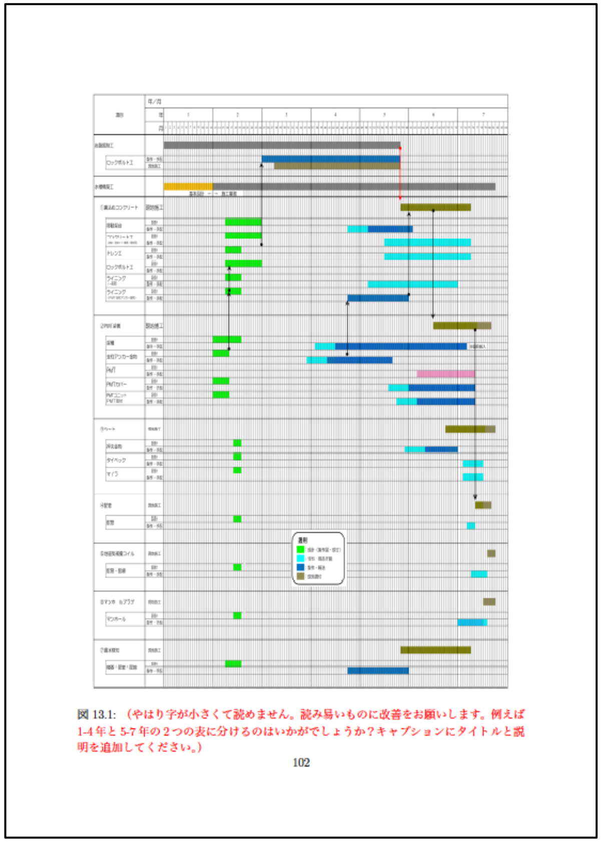

図 13.1: （やはり字が小さくて読めません。読み易いものに改善をお願いします。例えば 1-4 年と 5-7 年の 2 つの表に分けるのはいかがでしょうか？キャプションにタイトルと説明を追加してください。）

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- Document in Japanese is almost ready
  - Will be completed in early-February
- English version will be available by the end of March

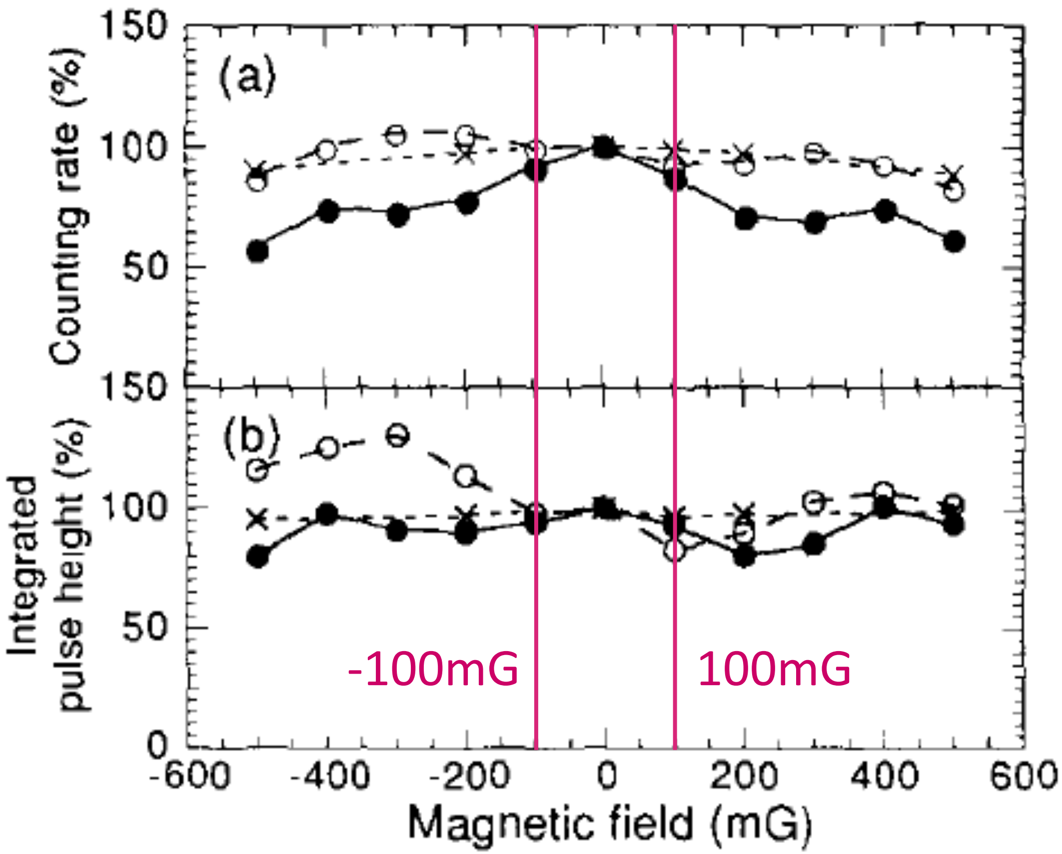
Summary

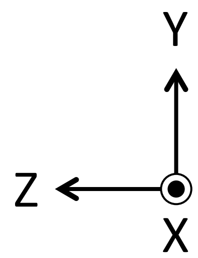
- Baseline design of the Hyper-K tank has mostly been established
  - Construction period and cost estimated
- Magnetic compensation method has to be established
- Technical document in English will be ready in March
- Need further (drastic) cost reduction
  - Your ideas are very welcome

Supplement

PMT response in a magnetic field

20-inch PMT used in Super-K





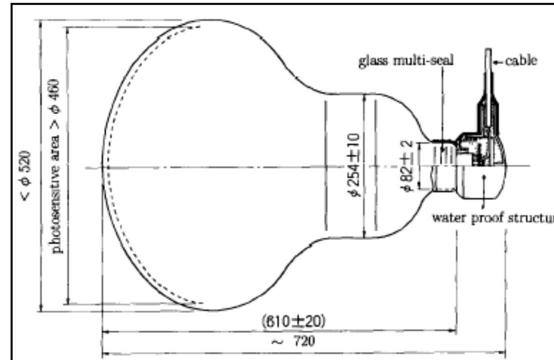


Fig. 11. Schematic of the new 20 in. PMT (units in mm).

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

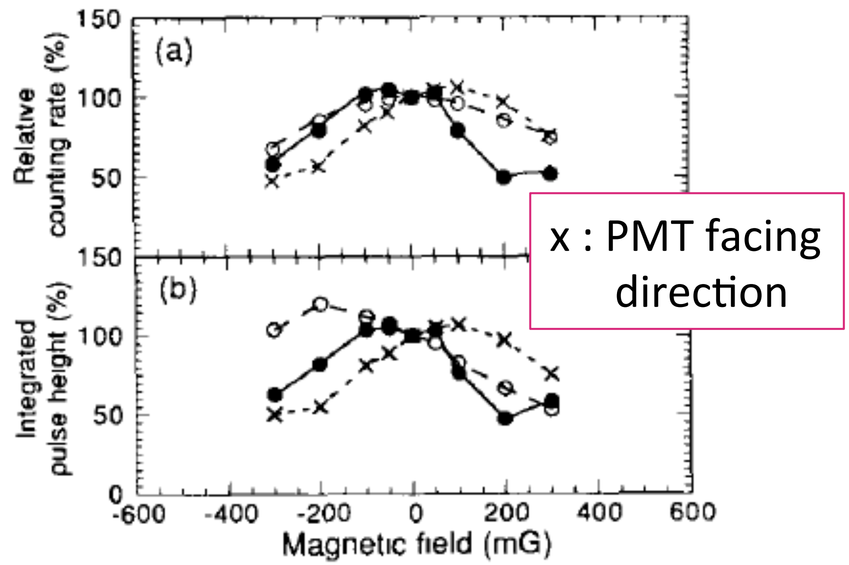
Magnetic field perpendicular to the PMT facing direction should be < 100mG.

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

The result looks good, but …

- The fraction of sensors with 50-100mG $B_{\perp}$ is large.
  - ~30mG in Super-K

Lighting position is at
60° w.r.t the PMT axis



- 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