Hyper-Kamiokande Design

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Introduction

~1 Megaton Water Cherenkov Detector is feasible given conditions:

- enough underground space (~300m)$^2$
- with excellent rock quality, no faults
- uniform rock stress, with $P_{\text{horizontal}}/P_{\text{vertical}} < 1$
- enough construction money and time
Hyper-K construction cost
(old, crude estimation, to be revised soon)

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Unit</th>
<th>Cost/Unit</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excavation</td>
<td>1.3Mm³</td>
<td></td>
<td>@$200</td>
<td>260M$</td>
</tr>
<tr>
<td>Liner</td>
<td>40,000m²</td>
<td></td>
<td>@$400</td>
<td>16M$</td>
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<td>PMT support structure</td>
<td>Super-Kx10</td>
<td></td>
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<td>40M$</td>
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<tr>
<td>PMT+cover+cable</td>
<td>100,000(20inch,20%)</td>
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<td>@$3,500</td>
<td>350M$</td>
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<tr>
<td>Electronics</td>
<td>100,000</td>
<td></td>
<td>@$300</td>
<td>30M$</td>
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<tr>
<td>Outer Detector</td>
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<td></td>
</tr>
<tr>
<td>Others</td>
<td></td>
<td></td>
<td></td>
<td>10M$</td>
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<tr>
<td>Others</td>
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<td></td>
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<td>20M$</td>
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<tr>
<td>Total</td>
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<td>726M$</td>
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- the excavation cost $200/m³ is for usual laboratories
  ↔ ↔ excavation method&speed are different for Hyper-K
- cost of access tunnel and waste rock disposal have to be taken into account

→ need realistic design to estimate realistic cost/period
<table>
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<td>2</td>
<td>3</td>
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</table>

**Hyper-K timetable**

- **Site study, design, R&D**
- **Pilot Survey**
- **Construction (assuming 5yrs)**
- **Operation**
On-going study

• *global geological survey* is being performed now
  → accumulating data of actual rock properties, rock distribution, and initial rock stress

• to decide detector layout, access tunnels, rock disposal, choice of liner material,…

• realistic design → realistic estimation of construction cost and period

→ *Status Report Today.*
Super-K
50kton total
22kton fiducial

Hyper-K
1Mton total volume, twin cavity
~0.6Mton fiducial volume
Inner (D43m x L250m) x 2
Outer Detector >2m
Photo coverage 20% (1/2 x SK) or less?
1. The cavern with egg-shape optimized for stability
   - avoiding sharp edges

2. PMT support structure (inner detector surface)
   circle (black) \( \rightarrow \) barrel shape (red)
   - Expecting easier construction and 10% larger fiducial volume

- circle: \( 1,450m^2 \)
- barrel-shape: \( 1,590m^2 \)
Detector Volume

Fiducial volume: \(1,300m^2 \times 45m \times 5 \text{ compartments} \times 2 = 0.59 \text{ Mton}\)

Total Inner detector volume: \(1,590m^2 \times 49m \times 5 \times 2 = 0.78 \text{ Mton}\)

Total detector volume: 1 Mton

Total number of PMTs: 100,000 (if 1/m^2)
Candidate detector site

- Mozumi Mine
- Tochibora Mine
- Super-K
- Hyper-K
- Mine Entrance
- Candidate site
Candidate site

Overburden: 681 m

- Hyper-K

1,156 m a.s.l.

0 M = 845 m a.s.l.

-300 M

-370 M

-430 M
geological survey
Global Site Study

1,156m a.s.l.

overburden
681m

475m a.s.l.

Hyper-K

Study site

0M=845m a.s.l.

-300M
-370M
-430M
Overview of survey

"Namari fault"

"240°-me fault"

"jigokutani fault"

"Anko fault"
Overview of survey

- 4 borehole coring @-300M,-370M
- Tunnel survey in the three levels
- in-situ stress measurements (two points)
- rock properties
Survey at higher level (-300m)

- Joint Survey in the tunnel and the borehole were Performed
- Borehole Loading Tests were also Performed to Estimate the Mechanical Properties of In-situ Rock mass.

The site is dominated by class-B (blue).
(class B: very sound intact mass in excellent condition)
Gneiss & Migmatite.
On-going Survey in middle (-370M) and lower (-430M) level
Borehole No.3 (-370M)

- No thick break (good!)
- ~50% B, ~50% C_H
- accumulate more data till Mar. 2011
  → cavity analysis with realistic conditions
Disposal of excavated waste rock

- excavate inclined straight tunnel
- transportation by belt conveyers

Maruyama (collapsed mountain)

Hyper-K

Tochibora (Hyper-K)
enough space for $\sim 1.3 \text{Mm}^3$ waste rock
Excavation Procedure
(very preliminary)

Preliminary estimation:
2 years excavation
(by 2 cars, 2 cavity in parallel)
Cavity Analysis

Studies by Hyon and Yamatomi
The widths of four FLAC3D models are $517 \sim 592$ m and the numbers of elements employed are $245,788 \sim 286,012$.

The FLAC3D models are finished to have curved surfaces at the both ends of the caverns to reduce the stress concentration effects.
## Input Parameters for FLAC3D Analyses

### Table: Cavern Spec and Engineering Properties of Rock.

<table>
<thead>
<tr>
<th>Analyzed Cavern</th>
<th>Type and Length</th>
<th>2075.6 m²</th>
<th>Modified Egg Shaped</th>
<th>Slanted and Pressed Ellipsoid</th>
<th>9 m</th>
<th>25m, 50m, 75m, 100m</th>
<th>600 m</th>
<th>2700 Kg/m³</th>
<th>10.0 GPa</th>
<th>0.25</th>
<th>Mohr-Coulomb’s Condition</th>
<th>60°</th>
<th>4.90 MPa</th>
<th>B</th>
</tr>
</thead>
</table>

**Fig. Cross-sectional view of the Hyper-KAMIOKANDE.**
Orientation of the Twin Cavity

Measured Principal stress orientation
(Lower hemisphere projection)

<table>
<thead>
<tr>
<th></th>
<th>$\sigma_x$</th>
<th>11.53</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\sigma_y$</td>
<td>7.51</td>
</tr>
<tr>
<td></td>
<td>$\sigma_z$</td>
<td>15.09</td>
</tr>
<tr>
<td>$\tau_{xy}$</td>
<td>-2.40</td>
<td></td>
</tr>
<tr>
<td>$\tau_{yz}$</td>
<td>-3.37</td>
<td></td>
</tr>
<tr>
<td>$\tau_{zx}$</td>
<td>5.75</td>
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</tbody>
</table>

* $\theta$ is the azimuth of the cavern direction measured positive clockwise from north.

projection onto horizontal plane

* $\theta$ is the azimuth of the cavern direction measured positive clockwise from north.
RESULT ($\theta = 30^\circ$, perpendicular to the rock stress)

Width of Pillar : 25m

Width of Pillar : 50m

Width of Pillar : 75m

Width of Pillar : 100m

Factor of safety

1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2.0
RESULT ($\theta = 120^\circ$, parallel to the rock stress)

- Width of Pillar : 25m
- Width of Pillar : 50m
- Width of Pillar : 75m
- Width of Pillar : 100m

Factor of safety

THE UNIVERSITY OF TOKYO, DEP. OF SYSTEMS INNOVATION
YAMATOMI & MURAKAMI LAB.
Optimum Orientation of the Twin Cavern

Fig. Differences in safety width of the pillar and input stresses on vertical cross section caused by changes of the cavern direction.

A series of 3D stress analyses by FLAC3D were carried out and, theoretically, it is found that the most optimum orientation($\theta=120.37^\circ$) of the longitudinal axis of the cavern coincides with the normal of the plane where in-plane shear stresses vanish.

Further study soon by using the accumulated data
Other subject of improvements/optimizations/confirmation

• Tank liner polyethylene is first candidate, under study

• PMT support structure under design, optimization of cost and period

• PMT choice of sensor type (conventional PMT, high QE PMT, Hybrid PD), size, density, avoid chain reaction of implosion

• DAQ Super-K like system (trigger-less) in water, under conceptual design

• water system & supplied water under design

Talks by Miura, Yokoyama, and Sekiya
Tank Construction
(water sealing and support structure)

Preliminary estimation:
2 years construction period
Summary

• Extensive Feasibility Study is going on
  • Global geological survey for rock/fault distributions, rock properties
  • Analysis for twin cavity
  • Preliminary results look encouraging.
• Optimization/Confirmation is necessary for other components
  • water sealing, PMT support structure, PMTs, DAQ, water, purification system
• to make a realistic design, construction cost and period estimation soon.