Overview of Hyper-Kamiokande R&D

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Mton Water Cherenkov Detector

- Concept of a Mton water Cherenkov detector dates back to 1992
  - M. Koshiba: “DOUGHNUTS”
- Concept of Hyper-Kamiokande was first presented at NNN99 @ SUNY
- A recent write-up:
What is Hyper-Kamiokande?

~1 Mton water Cherenkov detector at Kamioka
Why this design has been chosen?

- Water depth < 50 m
  (If the present 20-inch PMT or similar one will be used.)
- Linear dimensions for light path < 100 m
- Optimization of $M_{\text{FID}}/M_{\text{TOTAL}}$
- Rock stability
  - Avoid sharp edges. Spherical shape is the best.
- Our solution: Tunnel-shaped cavity
- Single Cavity or Twin Cavities?
  - Single Cavity
    - $M_{\text{FID}}/M_{\text{TOTAL}}$ is better
    - Cost is lower
    - Larger area of stable rock mass needed.
  - Twin Cavities
    - Two detectors are independent. One detector is alive when the other is calibrated or maintained.
    - Both cavities should be excavated at the same time. But staging scenario is possible for the later phase of the detector construction.
- Our solution: Twin cavities
Fiducial / Total

Fiducial volume: $39\text{m} \times 45\text{m} \times 5\text{ sections} \times 2 = 0.54\text{ Mton}$

Total Inner detector volume: $43\text{m} \times 49\text{m} \times 5\text{ sections} \times 2 = 0.72\text{ Mton}$

Total detector volume: $1\text{ Mton}$

Total number of PMTs: $200,000$ (if $2/\text{m}^2$)
## Comparison of 3 Generations of Kamioka Nucleon Decay Experiments

<table>
<thead>
<tr>
<th></th>
<th>Kamiokande</th>
<th>Super-Kamiokande</th>
<th>Hyper-Kamiokande</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass</td>
<td>3,000 t</td>
<td>50,000 t</td>
<td>1,000,000 t</td>
</tr>
<tr>
<td>Photosensitive Coverage</td>
<td>20 %</td>
<td>40 % (SK-I and -III)</td>
<td>?</td>
</tr>
<tr>
<td>Photosensitive Coverage</td>
<td>20 % (SK-II)</td>
<td></td>
<td></td>
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<tr>
<td>Observation Started</td>
<td>1983</td>
<td>1996</td>
<td>?</td>
</tr>
<tr>
<td>Cost (Oku-Yen)*</td>
<td>5</td>
<td>100</td>
<td>500? **</td>
</tr>
</tbody>
</table>

* 1 Oku-Yen ≈ 1M$

** Target cost; No realistic estimate yet
Construction Time Line

T2K-I

HK construction

HK and T2K-II experiment
What can be done with Hyper-K?

- T2K long baseline neutrino oscillation experiment:
  - 2nd phase
  - CP violation

- If the $\theta_{13}$ measurement in the 1st phase gives only an upper limit, the 2nd phase will enhance the reach

- Proton decay
  - $e^+ \pi^0 \nu_K^+$ and other modes

- Neutrino oscillation measurements with atmospheric neutrinos:
  - $\theta_{13}$, $\text{sgn}(\Delta m^2)$, sub-dominant osc., CP phase

- Measurements of low-energy neutrinos
  - Supernova neutrino ($\sim 10^5$ neutrinos for a SN at the center of the galaxy)
  - Relic supernova neutrinos
  - Solar neutrino measurements
  - Possible at the Hyper-K site (600-700 m overburden)? Under study

- Suppliers:
  - Kamioka
  - Super-K: 50 kton Water Cherenkov
  - $\nu K^+$ and other modes
  - $\sim M\text{t} \ "Hyper Kamiokande"

1st Phase:
- $\nu_\mu \rightarrow \nu_x$ disappearance
- $\nu_\mu \rightarrow \nu_e$ appearance
- NC measurement

2nd Phase:
- CPV
- proton decay

K. Nakahata's study for Mton water Cherenkov detectors in general

K. Nakahata - MM05, Aussois, April 2005
Status of Hyper-K Planning and R&D

Site studies:
Tochibora mine has been selected. Overburden 600 – 700 m
Cavity design and excavation studies: Twin cavities preferred; FEA in progress; Geological survey and boring core studies made with existing data; in situ measurement of initial rock stress yet to be done; direct exploration boring and geo-survey tunneling at the candidate site needed, etc.

Water tank and PMT support:
Conceptual design started, but progress is slow.

Spherical HPD:
5-inch prototype tested, 13-inch prototype test in progress.

Realistic cost estimation:
Yet to be done
Study trade-off between physics capabilities and photocoverage (i.e., cost): Partly done for $p \rightarrow e^+ + \pi^0$, but many more studies needed.