Status of Hyper-Kamiokande Detector R&D

Masashi Yokoyama (U. Tokyo)
for Hyper-Kamiokande Working Group

Hyper-Kamiokande WG:
(ICRR/U.Tokyo/IPMU/Kyoto/Kobe/Nagoya)

TIPP11, 9-14 June 2011, Chicago
Contents

• Baseline design of Hyper-Kamiokande
• Physics capability
• Status of ongoing R&D
• Prospects
Three generations of Water Cherenkov Detector at Kamioka

Kamiokande (1983-1996)  
Super-Kamiokande (1996-)  
Hyper-Kamiokande (201x-)

3kton  
50kton  
1Mton=1000kton

x17  
x20
Large Water Cherenkov Detector

- High efficiency, 4π coverage
- Excellent performance for <~1 GeV
- Nucleon decays, sub-GeV neutrino beam
- e/μ separation: >99%
- E threshold ~5 MeV

Well established technology with >30 years experience.

(More on Super-K: Talk by Dr. Y. Obayashi, Sat. 8:30-)

Masashi Yokoyama (Tokyo)
Hyper-Kamimokande

(Baseline design)

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)
20 inch PMT x 102,000
Timeline for Hyper-K

Site study, design, R&D

Construction (5yrs assumed)

Operation
Hyper-Kamikande project:
covering a wide range of particle physics/astrophysics

- Search for nucleon decay
- Long baseline neutrino experiment
- Atmospheric neutrino
- Solar neutrino
- Supernova neutrino
- WIMP, GRB,
Nucleon decay: Exploring quark/lepton unification

Direct evidence of GUT!

$\tau/B(p \rightarrow e^+ + \pi^0) > 10^{34}$ years!

$p \rightarrow e^+ + \pi^0$ (Super-K MC)
Proton decay search with Hyper-K

For 10 years of HK data,

\[ \tau/B(p \to e^+ + \pi^0) : > 1.3 \times 10^{35} \text{ years} \]

\[ \tau/B(p \to K^+ + \nu) : > 2.4 \times 10^{34} \text{ years} \]
Long baseline experiment

Quest for $CP$ violation in lepton sector
Effect of CP asymmetry

\[
\nu_{e} \text{ interaction candidates} \quad \bar{\nu} \text{ 3.5 years} \quad (\sin^2 2\theta_{13} = 0.1)
\]

\[
\nu_{\mu} \rightarrow \nu_{e} \quad \sin \delta \neq 0 \rightarrow \text{CP violation!}
\]

Full simulation with latest J-PARC / Super-K (20% cov.) MC

Basic selection established for T2K
Total 5 years running

$\sin^2 2\theta_{13}$

5% syst. error for signal, $\nu_{\mu}BG$, $\nu_{e}BG$, $\nu/\bar{\nu}$ assumed
Sensitivity to CP violation ($\sin\delta \neq 0$)

$\sin^2 2\theta_{13} \sim 10^{-2}$ for $5\sigma$, $\sim 3 \times 10^{-3}$ for $3\sigma$

Hyper-K (540kt FV)
1.5yrs $\nu + 3.5$yrs $\bar{\nu}$
1.66MW

Normal hierarchy
Sensitivity vs. exposure

For \( \sin^2 2\theta_{13} > 0.03, 0.01 \), 58(62)\% of \( \delta \) covered with 3(8)MWyrs
Atmospheric neutrinos

- Wide range of
  - energy
  - travel length
  - flavor
- For free
- High stat. sample with HK will provide more info on ν parameters

Complimentary to accelerator experiment

Exploring full picture of ν mass and mixing
Other topics

- Precise meas. of solar neutrino
- Short time variation (~4hrs) neutrino solar physics
- Supernova neutrinos
  - For SN @10kpc, ~240k evts
    - Energy+time meas.
      → discriminate models
- Relic neutrino (w/ Gd?)
- WIMP, GRB, solar flare, ....

SN2011dh (7Mpc) may be still a bit far.
R&D list for Hyper-K

- Feasibility of large cavern
  - Geological survey
  - Stress analysis
  - Excavation procedure
- Design of tank
- Water purification system
- Photosensor
- Readout and DAQ
- Realistic construction procedure
Candidate site and geological survey

Mozumi Mine ~10km

Tochibora Mine

Super-K

Hyper-K

Entrance

~horizontal access tunnel

Hyper-Kamiokande

Kamioka Smelting Plant

1750m.w.e (648m overburden)
Effect to low-E physics under study

~horizontal access tunnel
R&D for cavern design

3D analysis with measured rock stress

Excavation procedure (very preliminary)

Preliminary estimate: 2 years under optimization
Disposal of excavated waste rock

- excavate inclined straight tunnel
- transportation by belt conveyers
Designing tank

Optical separation

Preliminary

5 compartments for each tank
Photosensor

- Baseline: 20inch PMT (same as SK)
- Proved to work!
- Single photon capability, low dark rate, timing resolution
- One of cost drivers
- R&D ongoing/starting
- Size/number optimization
- New sensor (high QE PMT, HPD, gas PMT? ...)
- Pressure tolerance, avoiding chain implosion

Dr. T. Abe: Fri. 16:50-
Dr. H. Sekiya: Sat. 11:00-
**DAQ/Electronics**

- Requirements basically the same as SK
- Can be realized with current technology
- Conceptual design exists
- Handling of cables, attenuation of signal, ...
- Front-end electronics inside water under consideration

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*SK-IV electronics*
Summary and prospects

- Hyper-Kamiokande, a megaton water Cherenkov detector, will provide excellent opportunities for a wide range of science.
- Feasibility studies close to completion.
- Optimization study and R&D for real construction are ongoing.
- Preparing a report summarizing baseline design and physics potential. Will be released soon.
Timeline for Hyper-K

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Construction (5 yrs assumed)

Operation