Overview of Super-Kamiokande experiment

M. Ikeda for ICRR (young?) SK members
2020.11.13 ICRR Young Researchers’ Workshop
Contents

• Introductions
• Supernova Relic Neutrinos
• R&Ds for SK-Gd
• First Gd to SK
• SK-tour
The Super-Kamiokande Collaboration

Kamioka Observatory, ICRR, Univ. of Tokyo, Japan
RCCN, ICRR, Univ. of Tokyo, Japan
University Autonoma Madrid, Spain
BC Institute of Technology, Canada
Boston University, USA
University of California, Irvine, USA
California State University, USA
Chonnam National University, Korea
Duke University, USA
Fukuoka Institute of Technology, Japan
Gifu University, Japan
GIST, Korea
University of Hawaii, USA
Imperial College London, UK
INFN Bari, Italy
INFN Napoli, Italy
INFN Roma, Italy
Kavli IPMU, The Univ. of Tokyo, Japan
Keio University, Japan
KEK, Japan
King's College London, UK
Kobe University, Japan
Kyoto University, Japan
University of Liverpool, UK
LLR, Ecole polytechnique, France
Miyagi University of Education, Japan
ISEE, Nagoya University, Japan
NCBJ, Poland
Okayama University, Japan
University of Oxford, UK
Queen Mary University of London, UK
Rutherford Appleton Laboratory, UK
Shizuoka University of Welfare, Japan
Sungkyunkwan University, Korea
Stony Brook University, USA
Tokai University, Japan
The University of Tokyo, Japan
Tokyo Institute of Technology, Japan
Tokyo University of Science, Japan
University of Toronto, Canada
TRIUMF, Canada
Tsinghua University, Korea
University of Warsaw, Poland
Warwick University, UK
The University of Winnipeg, Canada
Yokohama National University, Japan

~190 collaborators from 49 institutes in 10 countries
Super-Kamiokande

Kamioka mine

~1km
(2700 mwe)
~2km
~3km

50000 tons of Water Cherenkov detector

Physics target

- Solar neutrinos
- Supernova neutrinos
- Atmospheric/Accelerator neutrinos
- Nucleon decay

~ MeV

~ GeV
History of Super-Kamiokande

- 1996 Start observation
- 1998 Discovery of the neutrino oscillation by atmospheric neutrino observation
- 2001 Discovery of the solar neutrino oscillation (together with SNO result)
- 2011 Discovery of electron neutrino appearance (T2K)
- 2015 Nobel prize
- 2016 Breakthrough prize
- 2020 Constraint on neutrino CP phase (T2K)
History of Super-Kamiokande

1996
SK-I
Photo coverage 40%

2002
SK-II
20%

2006
SK-III
40%

2008
SK-IV
40%

2018
2019
2020
SK-V
SK-Gd
40%
40%

13 ton of Gd$_2$(SO$_4$)$_3$ · 8H$_2$O

First Gd loading to SK in last summer!
SK-Gd project
Dissolving Gd to enhance detection capability of neutrons from $\nu$ interactions

**Physics targets:**
(1) Discovery of Supernova relic neutrino (SRN)
(2) Galactic supernovae (pointing accuracy, and Si-burning $\nu$)
(3) Reduction of BG for proton decay, solar $\nu$, or reactor $\nu$
(4) Neutrino/anti-neutrino discrimination

**Final goal**
$\sim$50% n-capture on Gd

**Initial loading (this year)**

Supernova Relic Neutrino (SRN)  
Discovery of neutrinos from past supernovae!

Theoretical flux prediction: 0.3~1.5 /cm²/s (17.3MeV threshold)
Supernova Relic Neutrino (SRN)

Discovery of neutrinos from past supernovae!

3σ discovery is within our reach in 10 year observation

Expected sensitivity of SK-Gd

σ: 10 years with SK-Gd

- total bkgd
- HBD 6 MeV
- HBD 4 MeV
- SN 1987a

3σ discovery is within our reach in 10 year observation
Prototype of SK-Gd: EGADS
Evaluating Gadolinium’s Action on Detector Systems

- 200 m³ tank with 240 PMTs
- 15 m³ tank to dissolve Gd
- Gd water circulation system (purify water with Gd)

Transparency measurement (UDEAL)
Main results from EGADS

• Gd water quality
  • Transparency: same as SK water
  • Scattering and absorption:
    No problem for all physics analyses

• Delayed coincidence technique
  • Confirmed by Am/Be source.
  • Capture efficiency, delayed signal timing and spectrum are as expected.

Ask Guillaume san for more detail
R&D of ultra-pure Gd powder

- Radio impurities in Gd power could introduce additional backgrounds to solar and supernova neutrinos
- Stringent requirement for RI imposed
- Developed methods to evaluate low concentration RI
  - Screened at multiple sites
    - ICP-MS: Kamioka
    - HPGe: Canfranc, Boulby and Kamioka
    - Worked with production companies and achieved the required purity

Radioactive impurities for Gd$_2$(SO$_4$)$_3$ powder [mBq/kg]

<table>
<thead>
<tr>
<th>Chain</th>
<th>Isotope</th>
<th>SK-Gd requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>For solar</td>
</tr>
<tr>
<td>$^{238}\text{U}$</td>
<td>$^{238}\text{U}$</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>$^{226}\text{Ra}$</td>
<td>$&lt; 0.5$</td>
</tr>
<tr>
<td>$^{232}\text{Th}$</td>
<td>$^{228}\text{Ra}$</td>
<td>$&lt; 0.05$</td>
</tr>
<tr>
<td></td>
<td>$^{228}\text{Th}$</td>
<td>$&lt; 0.05$</td>
</tr>
<tr>
<td>$^{235}\text{U}$</td>
<td>$^{235}\text{U}$</td>
<td>$&lt; 30$</td>
</tr>
<tr>
<td></td>
<td>$^{227}\text{Ac}/^{227}\text{Th}$</td>
<td>$&lt; 30$</td>
</tr>
</tbody>
</table>

Radioactive impurities

For solar
- $^{238}\text{U} < 400$ ppt
- $^{226}\text{Ra} < 0.5$
- $^{232}\text{Th} < 0.05$
- $^{235}\text{U} < 30$
- $^{227}\text{Ac}/^{227}\text{Th} < 30$

For DSNB
- $^{238}\text{U} < 5$
- $^{226}\text{Ra}$
- $^{232}\text{Th}$

U contamination (ICP-MS)  Th contamination (ICP-MS)

Requirement:
- $^{238}\text{U} < 400$ ppt
- $^{232}\text{Th} < 13$ ppt
First Gd loading to SK

- 13 ton of Gd$_2$(SO$_4$)$_3$ - 8H$_2$O, (5 ton of Gd) was loaded at Lab-G from 7/14 to 8/17

Ask Nakamura san for more detail
Gd concentration in SK tank

Suck pure water from top, dissolve Gd, and supply cold Gd water from the bottom of SK.

Gd concentration during loading

Uniform concentration since the beginning of Sep.

Gd concentration after loading
Go To SK tour!
Summary

- SK is running for more than 20 years.
  - Keep releasing new results.
- Now, it’s time to change!
  First loading of Gd was done in last summer.
- Enjoy more physics with SK-Gd.