Status of the Gadolinium project for Super-Kamiokande

Lluís Martí Magro.
NOW 2010 Conca Specchiulla, Italy.
5th of September, 2010.
Super-Kamiokande in the past

The Super-Kamiokande collaboration had many successes in the past:

- Contribution to the discovery of solar neutrino oscillations
  
  See Ikeda's talk on Monday!

- Contribution to the discovery of atmospheric neutrino oscillations
At present, Super-Kamiokande...

- has the best proton lifetime limit
- T2K long baseline neutrino oscillation experiment
- has a very precise measurement of $\theta_{12}$ and $\theta_{23}$
- has the best Diffuse Supernova Neutrino Background [DSNB] limit
Here, the backgrounds dominate and thus restrict the measurement.
Since some years now, there has been the idea of adding Gd into the SK water
Gadolinium is known to be an excellent neutron capture nucleus. With it, we can reduce backgrounds by demanding a delayed coincidence.

\[ \bar{\nu}_e \rightarrow p \rightarrow n \rightarrow Gd \rightarrow e^+ + \gamma \]

\( \Delta T \sim 30 \mu s \)

Vertices within 50 cm

-soluble

-cheap

-easy to handle and store

For 50 ktons this means

~100 tons of water soluble

GdCl₃ or Gd₂(SO₄)₃

0.1% Gd gives >90% efficiency for n capture
By converting SK into an electron anti-neutrino detector we will be able to achieve two major goals:

- Diffuse Supernova Neutrino Background measurement (~5 events/yr)
- Precision measurement of neutrinos from Japan's nuclear reactors (~5000 events/yr)

Anything else to offer? Apart from the two mentioned new signals, this technique opens up for new possibilities:

- Nearby SN burst early warning
- Full deconvolution of a galactic SN $\nu$s
- (free) proton decay background reduction
- New solar antineutrino flux limit
- New long-baseline flux normalization for T2K
Because all of these possibilities are so attractive, the SK collaboration has embarked on a multi-year R&D project.

In June 2009, this project was funded with $400,000,000¥ (3.5 Million €)

A 200 ton tank facility is now under construction: EGADS (Evaluating Gadolinium's Action on Detector Systems).

It will have its own water filtration system, PMTs, DAQ, etc and will show us if we can use the Gd principle with SK.

**Goal:** study the effect of Gd on all the materials and the neutron background
The EGADS Project

**Water Transparency:** as a water Čerenkov detector the water transparency must be large and with no time degradation.

**Water Purification system:** the new purification system should remove all ions except Gd

**How to Add/Remove Gd:** how uniformly can Gd be dissolved? How efficient/economically can we remove Gd?

**Material Effects:** the addition of the Gd solution must not corrode SK materials

**Neutron Background:** since neutron background is going to be seen, how will this affect the trigger rates and the current analyses?

- No Gd should leak to the environment and therefore the SK tank has to be repaired
We want to recreate the conditions in SK here, perform any needed system improvements for Gd, and finally verify that it works.

200 ton water tank (d=6.5m, h=6.5 m)

Water+Gd pretreatment system

240 50cm-PMTs

Selective water+Gd filtration system

Transparency measurement device

A. Kibayashi
The EGADS Project

Excavation started in September 2009

Gadolinium Project for SK

Messengers of the Universe
The EGADS Project

M. Nakahata
The EGADS Project

Gadolinium Project for SK  Messengers of the Universe
The EGADS Project

February 27, 2010

April 16, 2010

April 28, 2010

June 8, 2010
The EGADS Project: UDEAL

- Adjustable mirrors
- Pulsed laser pointers and professional diodes
- Beam splitter & Steerer
- Integrating spheres and UV enhanced photodiodes

July 7th, 2010

August, 2010

A. Renshaw & M. Smy

August, 2010
While at SK the amount of neutrons is very low, adding a Gd solution to the water has to be done with care.

Studying samples of Gd$_2$(SO$_4$)$_3$ and without any pre-treatment we have seen that the U and Th concentrations are $\sim$15 and 1 ppb (the U chains being, by far, the most important neutron sources)

![Graph showing neutron flux vs. energy]  

$H_2O + 0.2 \text{ Gd}_2(\text{SO}_4)_3$ by mass, Canfranc measurement (U238$\sim$15ppb)

- $4.30 \times 10^{-13}$ [/sec/cm$^3$]

- (alpha, n)
- (alpha, n)$^{18}$O
- S.F.
- Total

Lemrani et al., NIMA 560 (2006) 454;  
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We have been doing studies with resins and we have found the U concentration can be reduced to less than 1%.

**Input:** water with 10 ppt of U

**Less than 1%**

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**ICP/MS uncertainty**

Gadolinium Project for SK  
Messengers of the Universe
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Taking into account the SK capabilities to reduce Ra, we conservatively estimate the number of neutrons to be ~600/day in the SK ID (~1800/day w/o any pre-treatment). This number is comparable to the solar event rate (~400 events/day, 4.5MeV threshold) but more studies are ongoing.
Three weeks ago, 500 Kg of Gd$_2$(SO$_4$)$_3$ arrived already!
Summary

The idea of adding a Gd solution and proposed in Gadzooks! opens up new possibilities that are very appealing.

Before implementing it at SK we need to evaluate its action on the detector.

A multi-year R&D program is ongoing and last year got funding for it: the EGADS project.

The EGADS project's goal is to probe that the idea works and as you have seen the project is moving forward!
Thank you for your attention!!