Status of the Gadolinium project for Super-Kamiokande

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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!

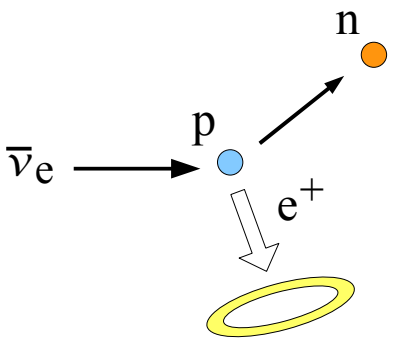
- Contribution to the discovery of atmospheric neutrino oscillations

Super-Kamiokande at present

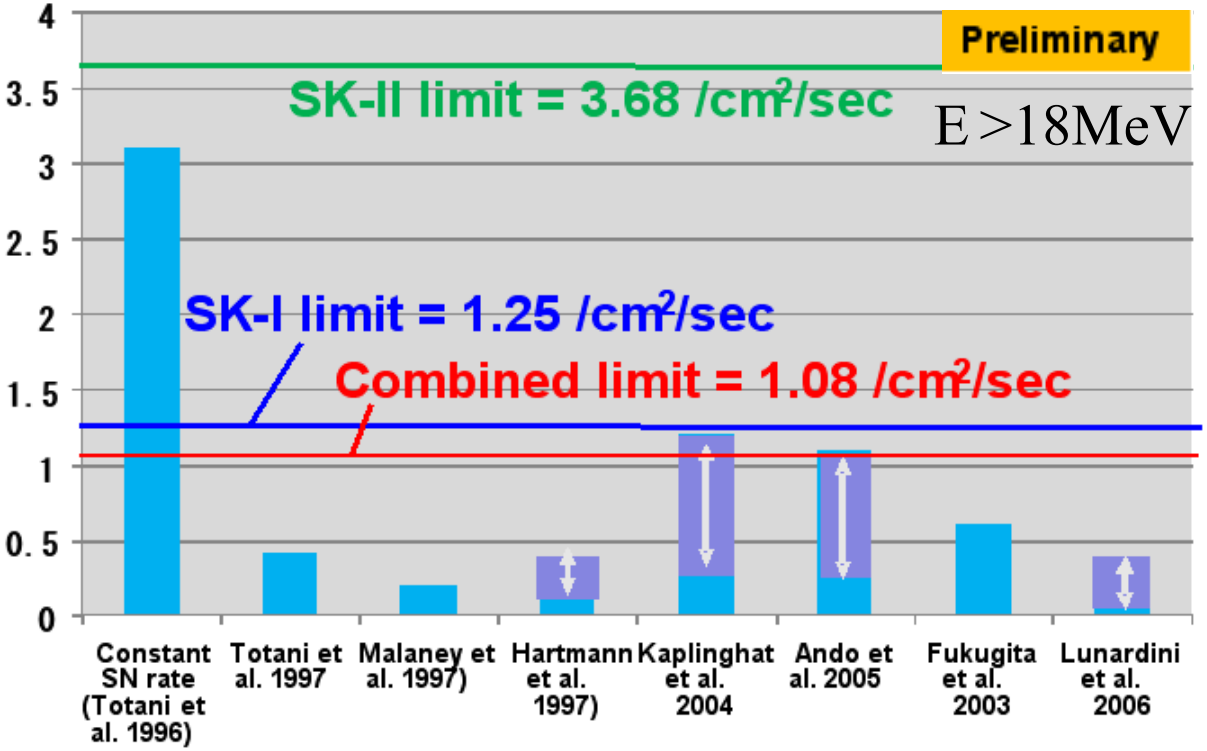
At present, Super-Kamiokande...

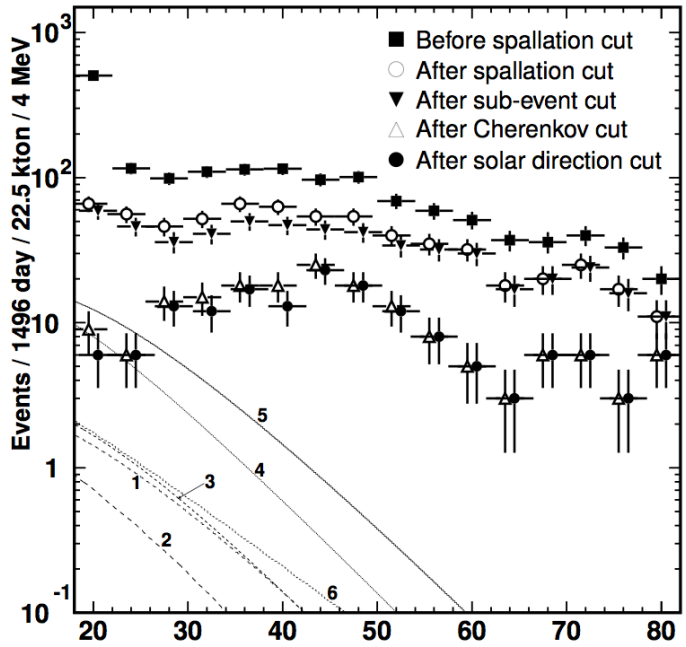
- has the best proton lifetime limit
- T2K long baseline neutrino oscillation experiment
- has a very precise measurement of θ_{12} and θ_{23}
- has the best Diffuse Supernova Neutrino Background [DSNB] limit

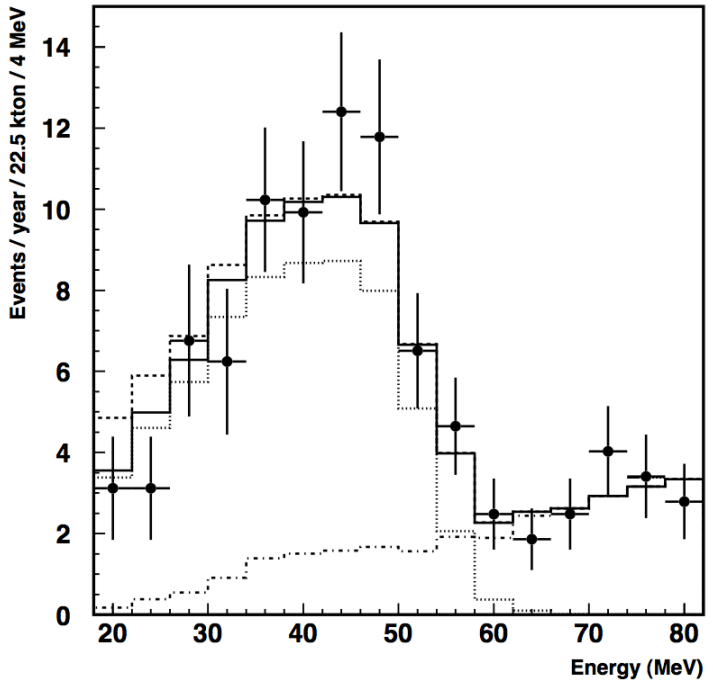
Super-Kamiokande at present



M.Malek et al., Phys.Rev.Lett.90 061101 (2003)







Here, the backgrounds dominate and thus restrict the measurement

Super-Kamiokande in the future?

Since some years now, there has been the idea of adding Gd into the SK water

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Antineutrino Spectroscopy with Large Water Čerenkov Detectors

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We propose modifying large water Čerenkov detectors by the addition of 0.2% gadolinium trichloride, which is highly soluble, newly inexpensive, and transparent in solution. Since Gd has an enormous cross section for radiative neutron capture, with $\sum E_\gamma = 8$ MeV, this would make neutrons visible for the first time in such detectors, allowing antineutrino tagging by the coincidence detection reaction $\bar{\nu}_e + p \rightarrow e^+ + n$ (similarly for $\bar{\nu}_\mu$). Taking Super-Kamiokande as a working example, dramatic consequences for reactor neutrino measurements, first observation of the diffuse supernova neutrino background, galactic supernova detection, and other topics are discussed.

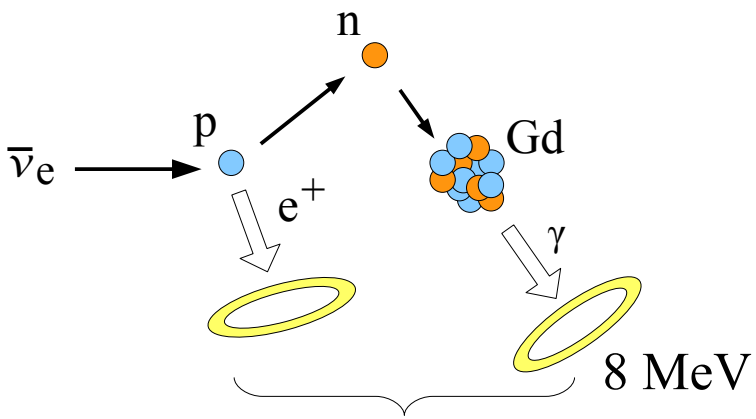
DOI: 10.1103/PhysRevLett.93.171101 PACS numbers: 95.55.Vj, 29.40.Ka

Gadzooks!

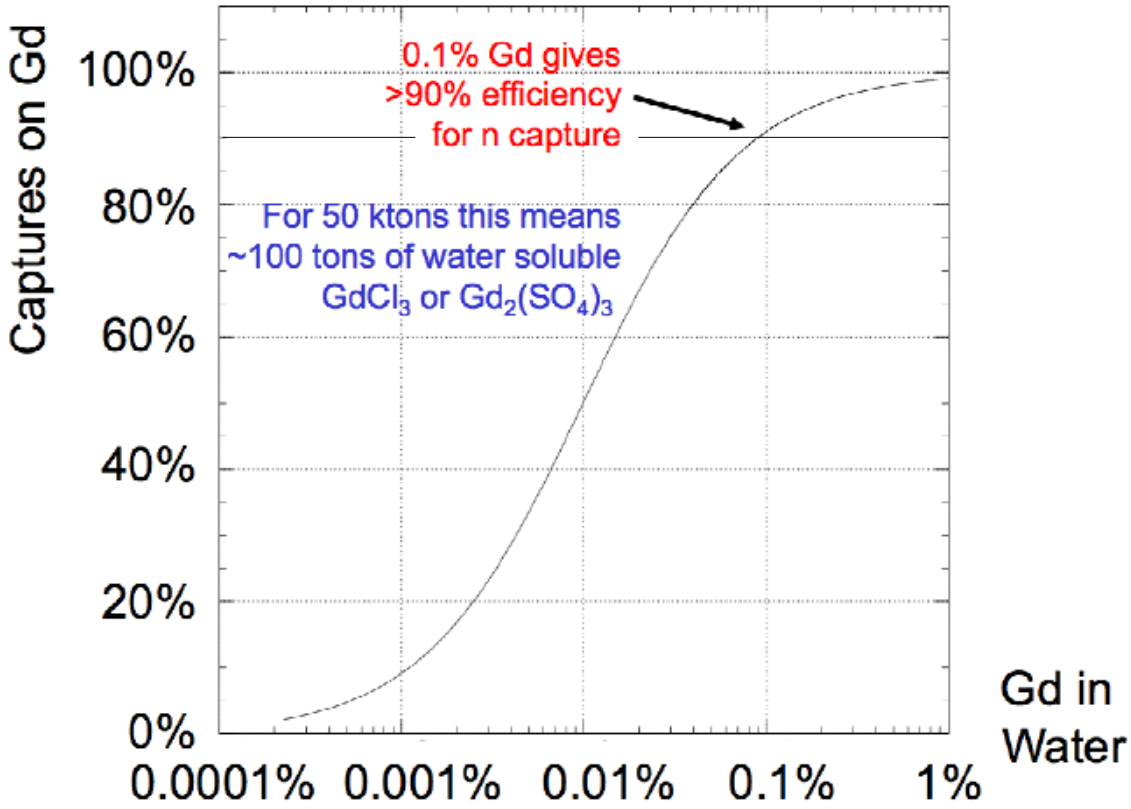
See also Mark's talk at NOW in 2006

Super-Kamiokande in the future?

Gadolinium is known to be an excellent neutron capture nucleus. With it, we can reduce backgrounds by demanding a delayed coincidence



ΔT~30μs
Vertices within 50cm



-soluble

-cheap

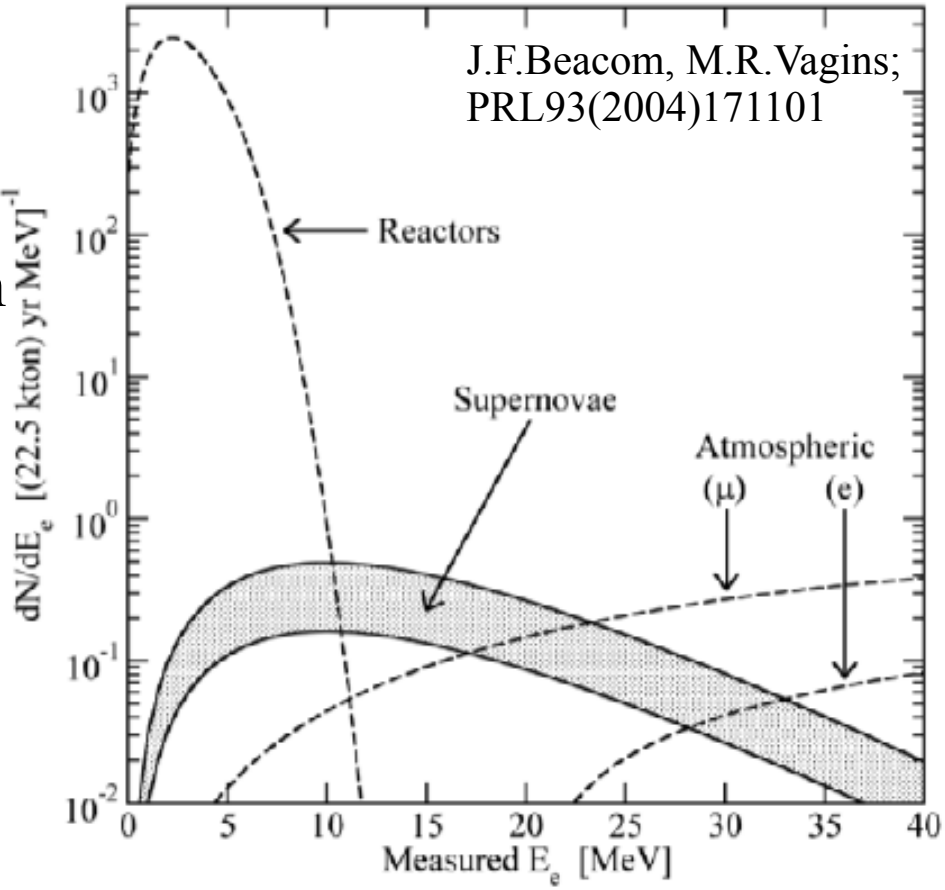
-easy to handle and store

Super-Kamiokande in the future?

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)



Super-Kamiokande in the future?

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 νs

(free) proton decay background reduction

New solar antineutrino flux limit

New long-baseline flux normalization for T2K

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Super-Kamiokande in the future?

Because all of these possibilities are so attractive, the SK collaboration has embarked on a multi-year $\mathcal{R}\&\mathcal{D}$ 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 (**E**valuating **G**adolinium's **A**ction on **D**etector **S**ystems).

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 Ĉherenkov 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?

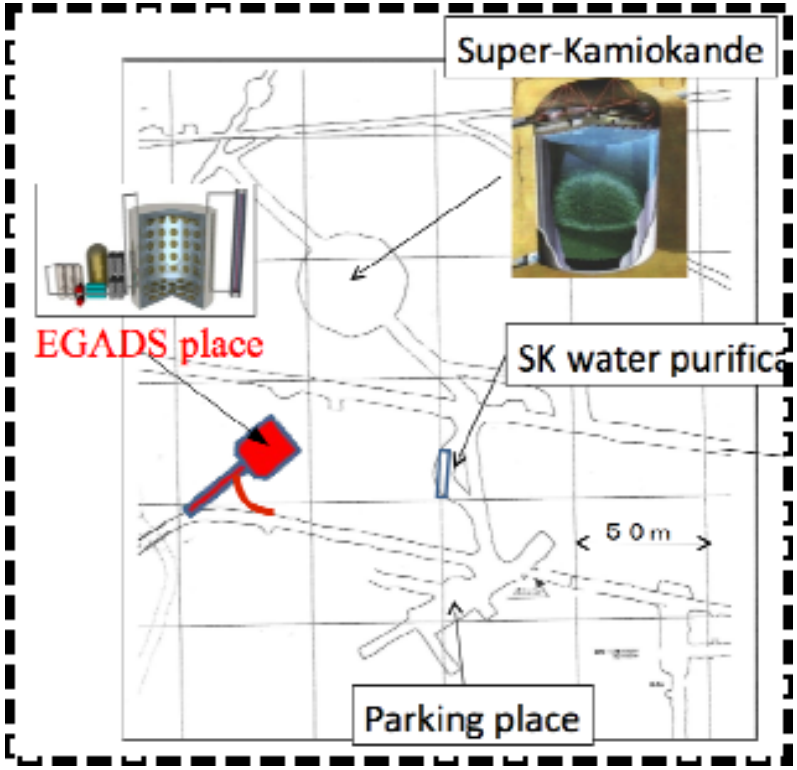
Material Effects: the addition of the Gd solution must not corrode SK materials

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

The EGADS Project

We want to recreate the conditions in SK here, perform any needed system improvements for Gd, and finally verify that it works.



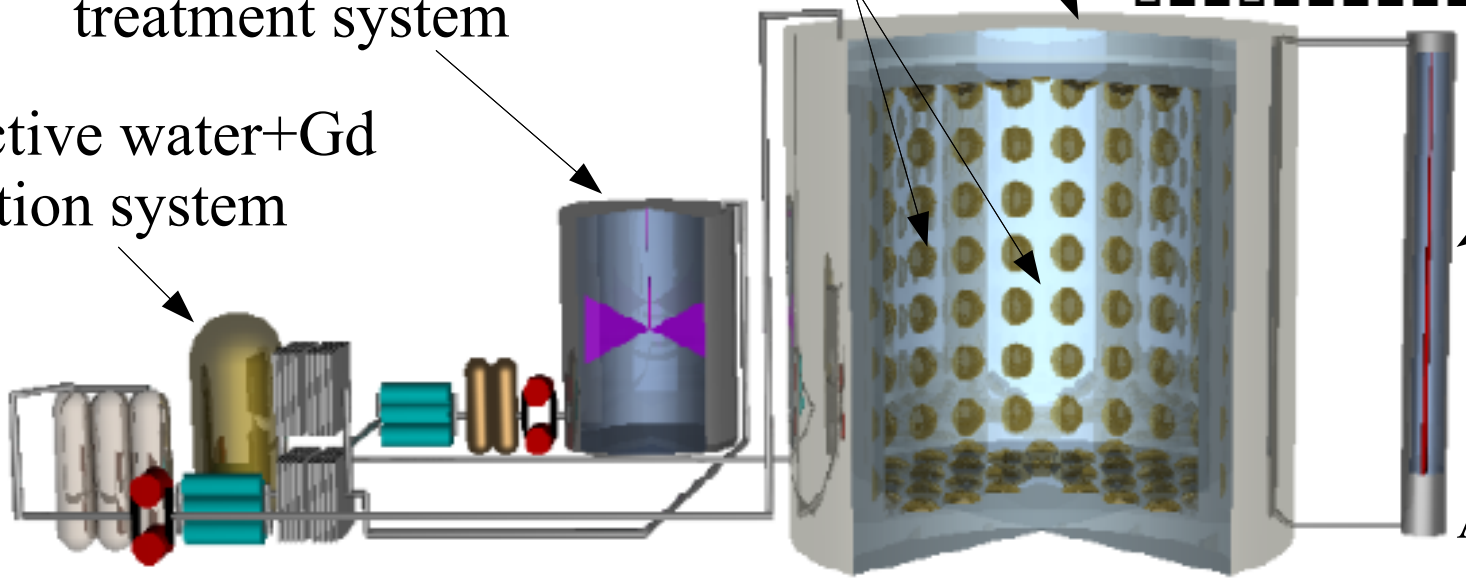
200 ton water tank
(d=6.5m, h=6.5 m)

Water+Gd pre-treatment system

240 50cm-PMTs

Selective water+Gd filtration system

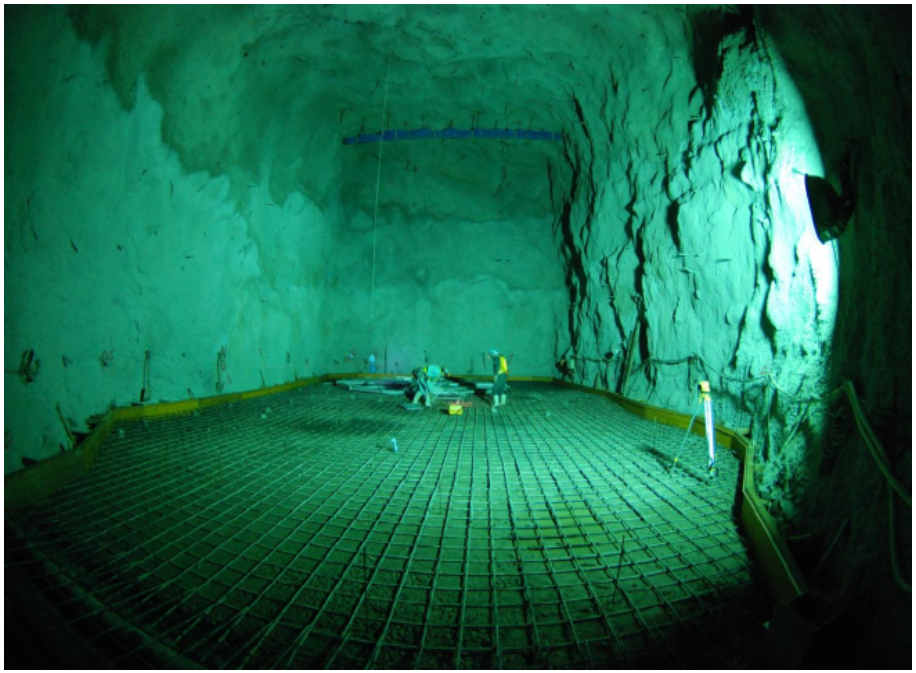
Transparency measurement device



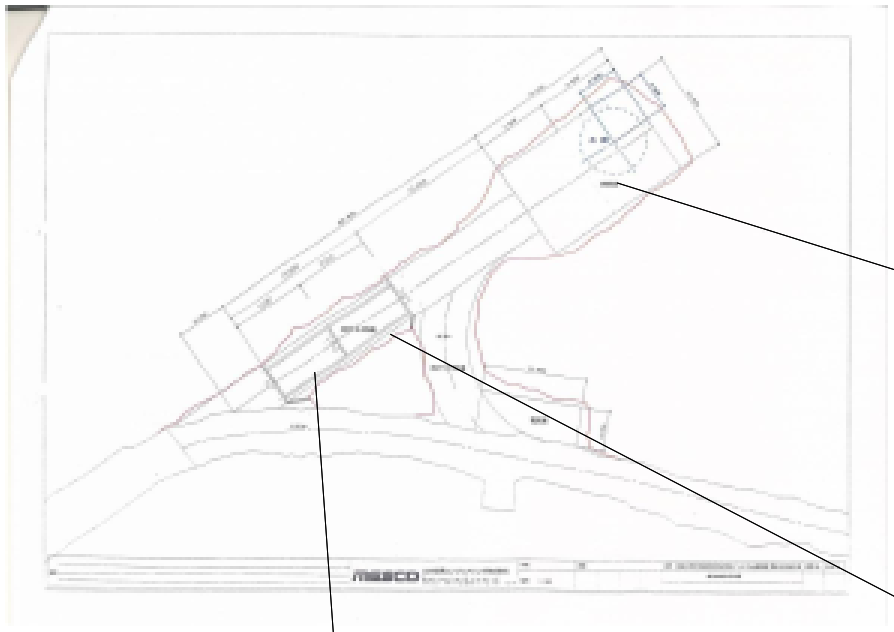
A.Kibayashi

The EGADS Project

Excavation started in September 2009

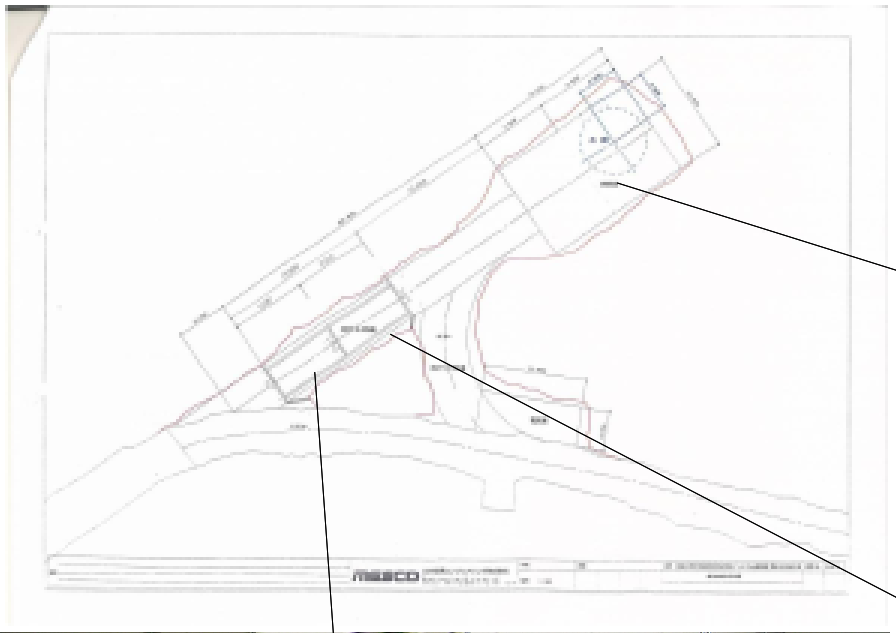


The EGADS Project



M.Nakahata

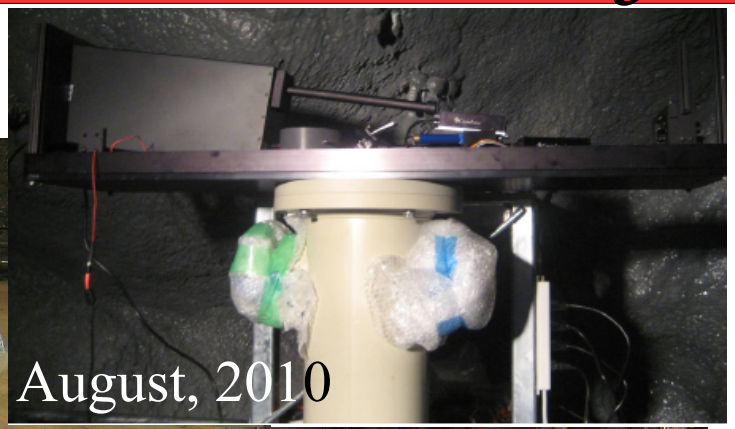
The EGADS Project

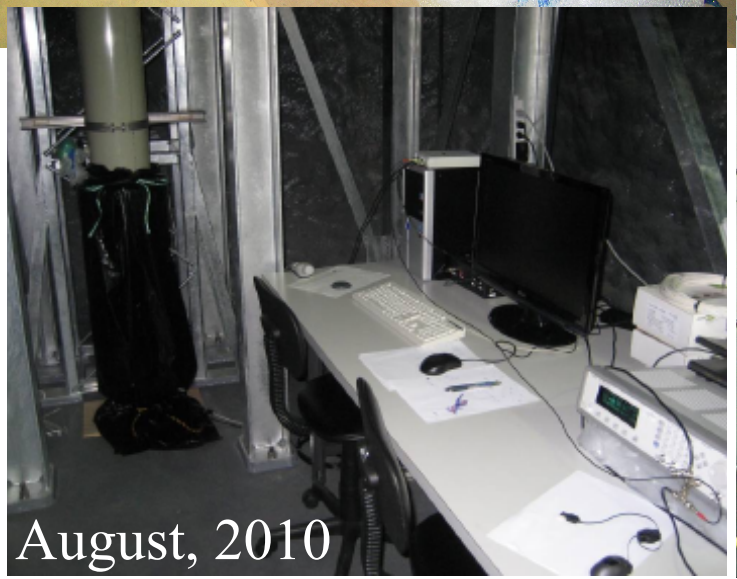


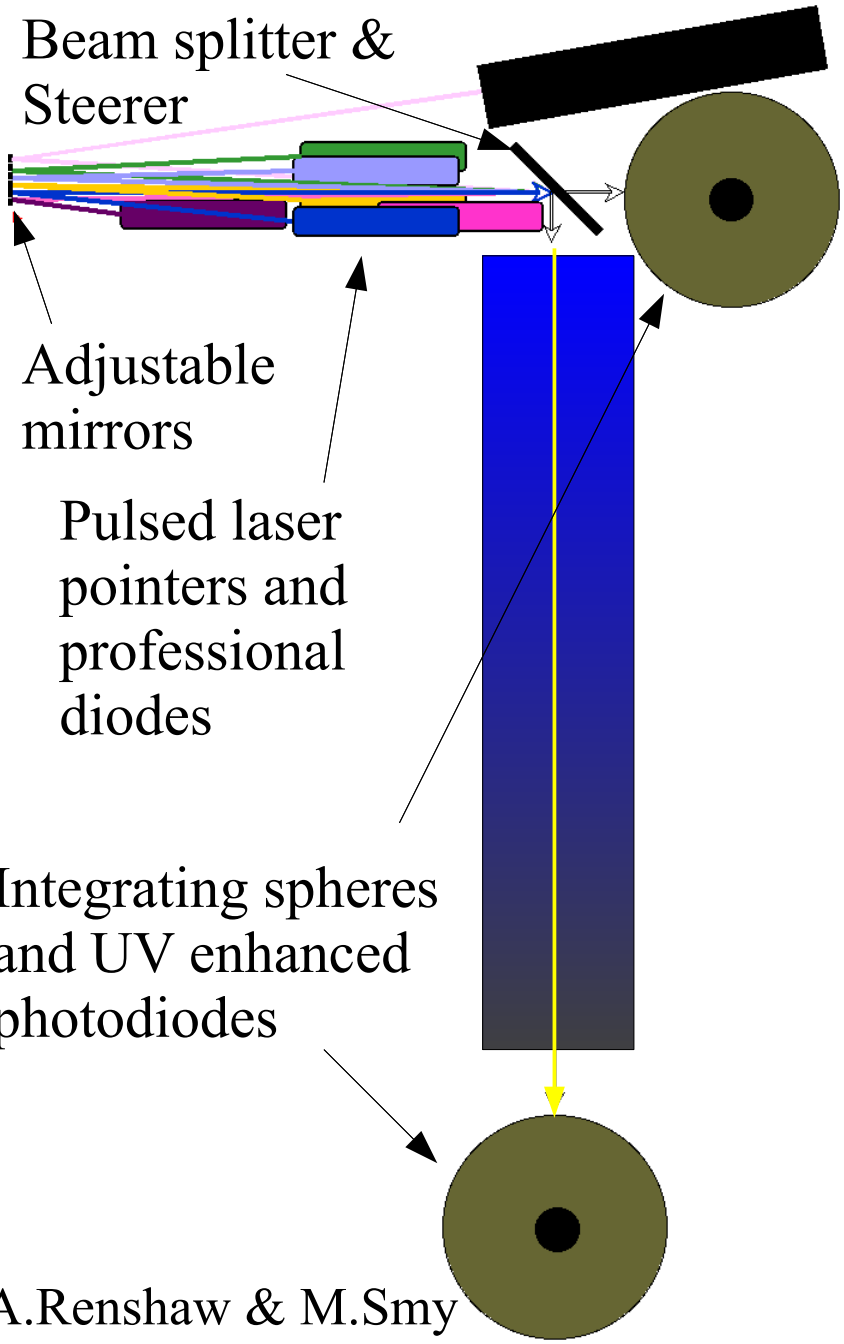
The EGADS Project

M.Nakahata

The EGADS Project: UDEAL



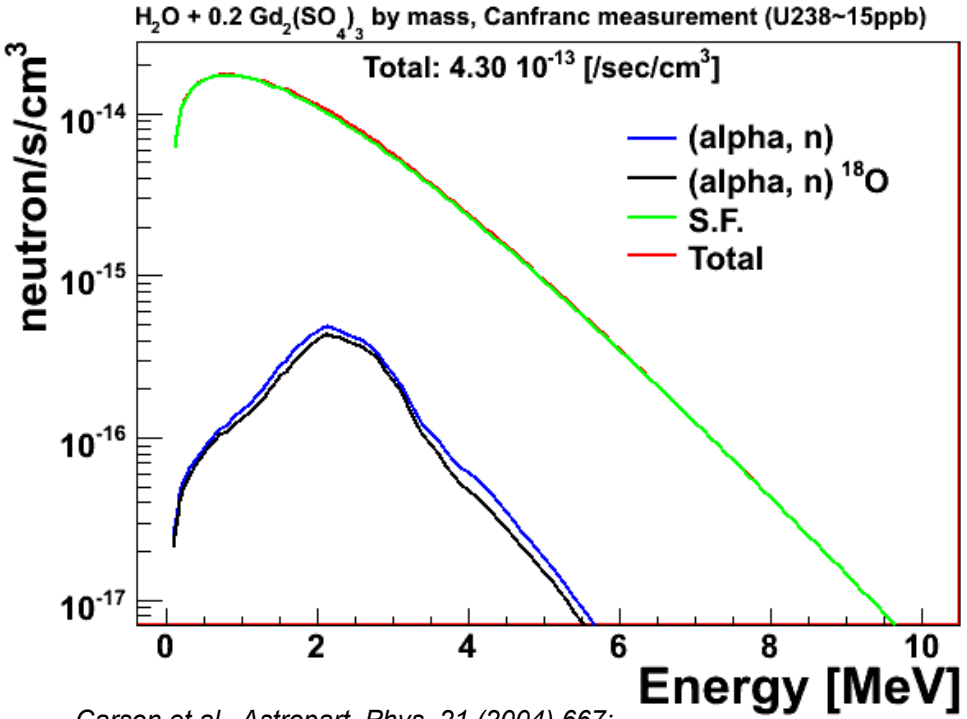




The EGADS Project: neutron Bckgrd

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 ~15 and 1 ppb (the U chains being, by far, the most important neutron sources)



Carson et al., Astropart. Phys. 21 (2004) 667;
Lemrani et al., NIMA 560 (2006) 454;
W.B. Wilson et al., SOURCES-4A, Technical Report LA-13639-MS, Los Alamos (1999)

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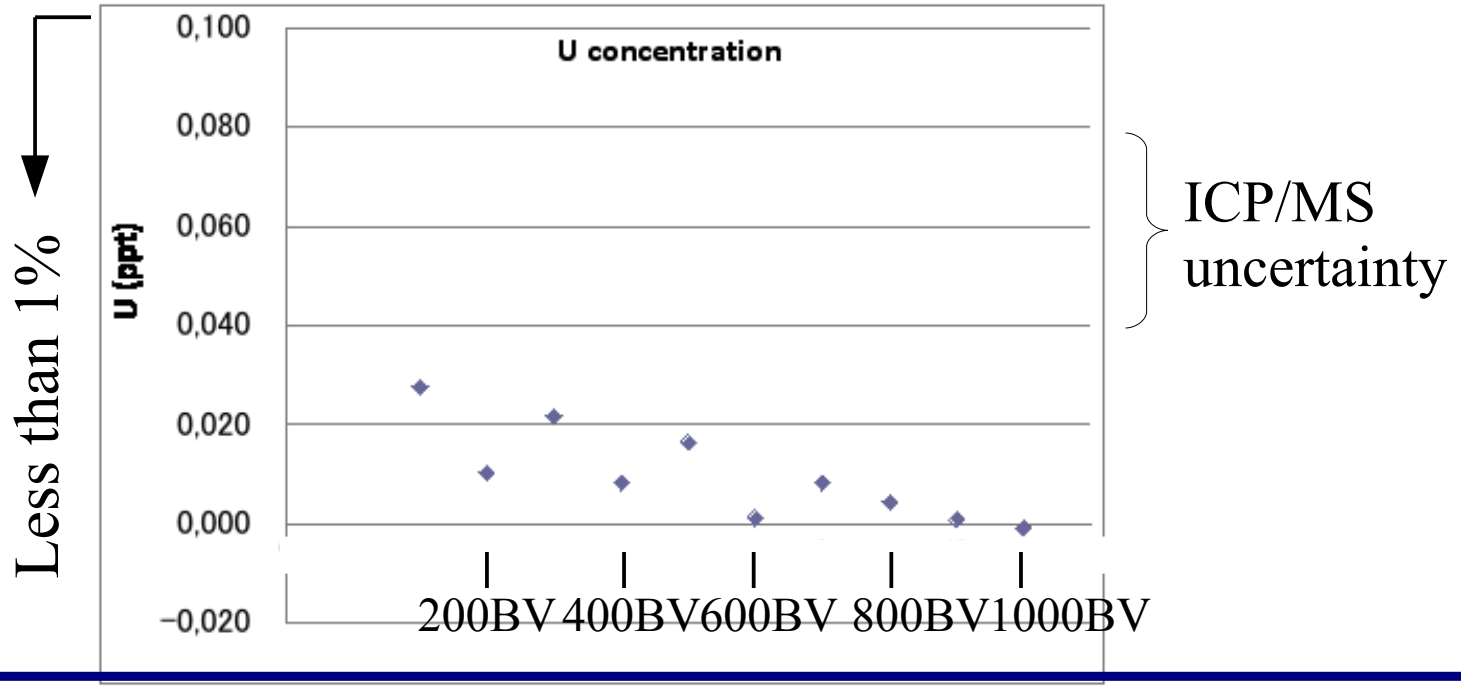
<u>Input:</u> water with 10 ppt of U



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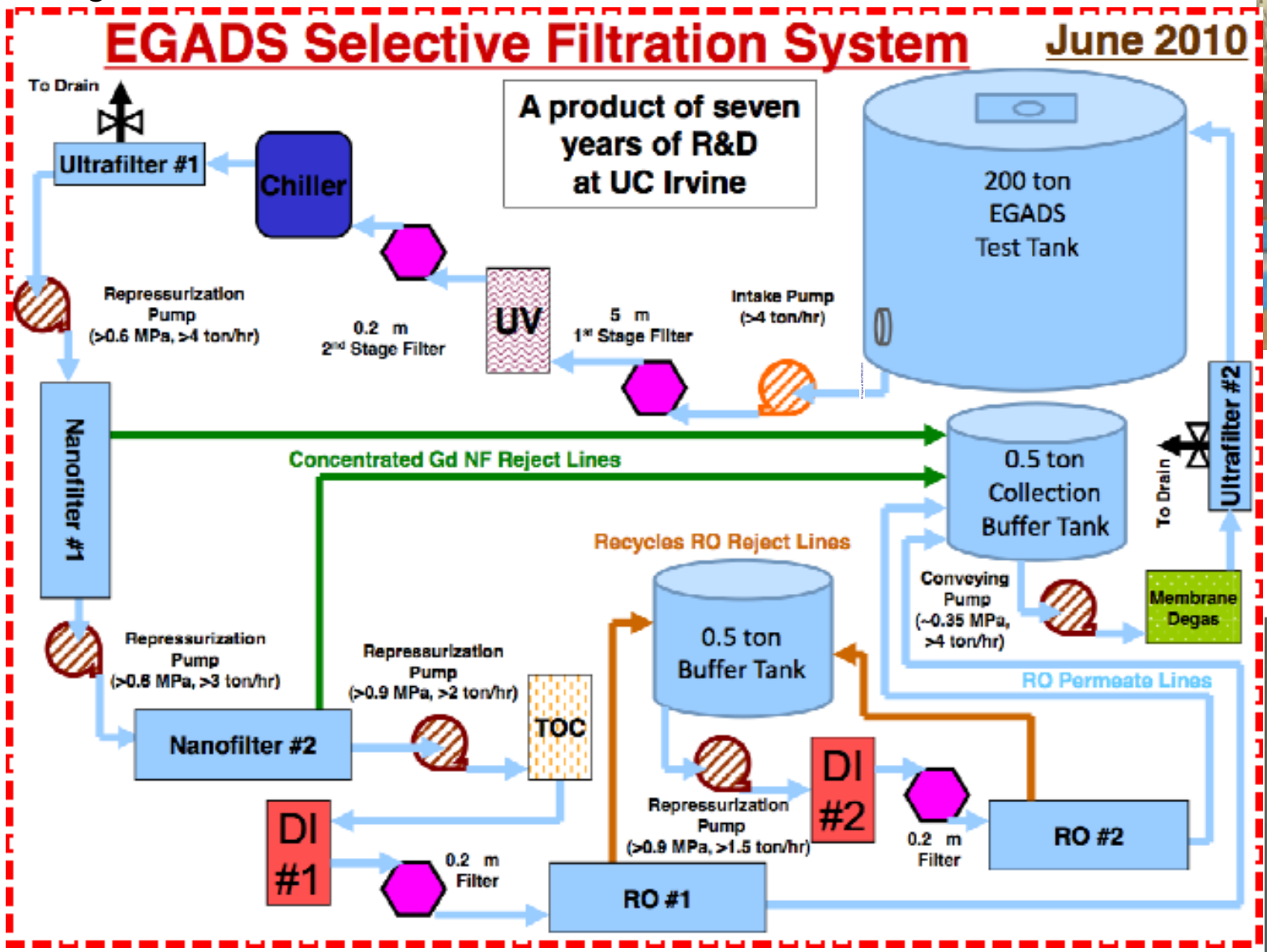
Taking into account the SK capabilities to reduce Ra, we conservatively estimate the number of neutrons to be ~600/day in the SK ID (~1800/day w/o any pre-treatment). This number is comparable to the solar event rate (~400 events/day, 4.5MeV threshold) but more studies are ongoing.

The EGADS Project: filtration

M.Vagins at NEUTRINO 2010



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!!