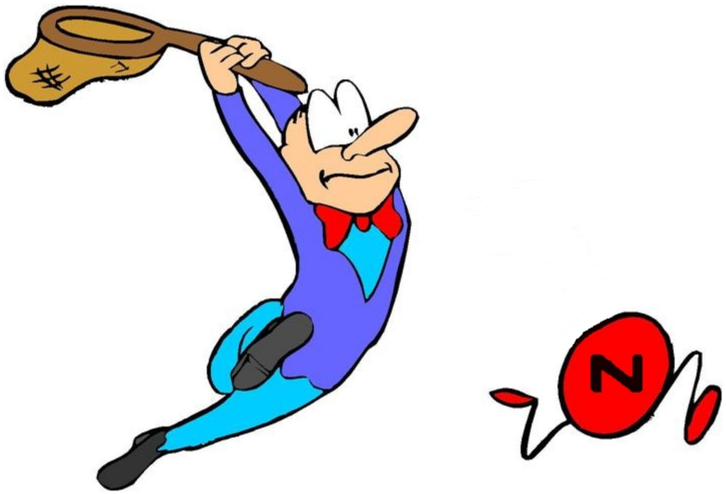
# GADZOOKS!
# Megaton Scale Neutron Detection




Mark Vagins
University of California, Irvine

NNN05 - Aussios
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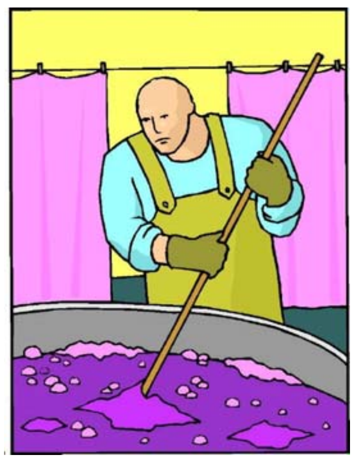
How can we identify neutrons produced by the inverse beta process (from supernovae, reactors, etc.) in really big water Cherenkov detectors?

$$\bar{\nu}_e + p \longrightarrow e^+ + n$$

Beyond the kiloton scale, you can forget about using liquid scintillator, $^3$He counters, or heavy water!

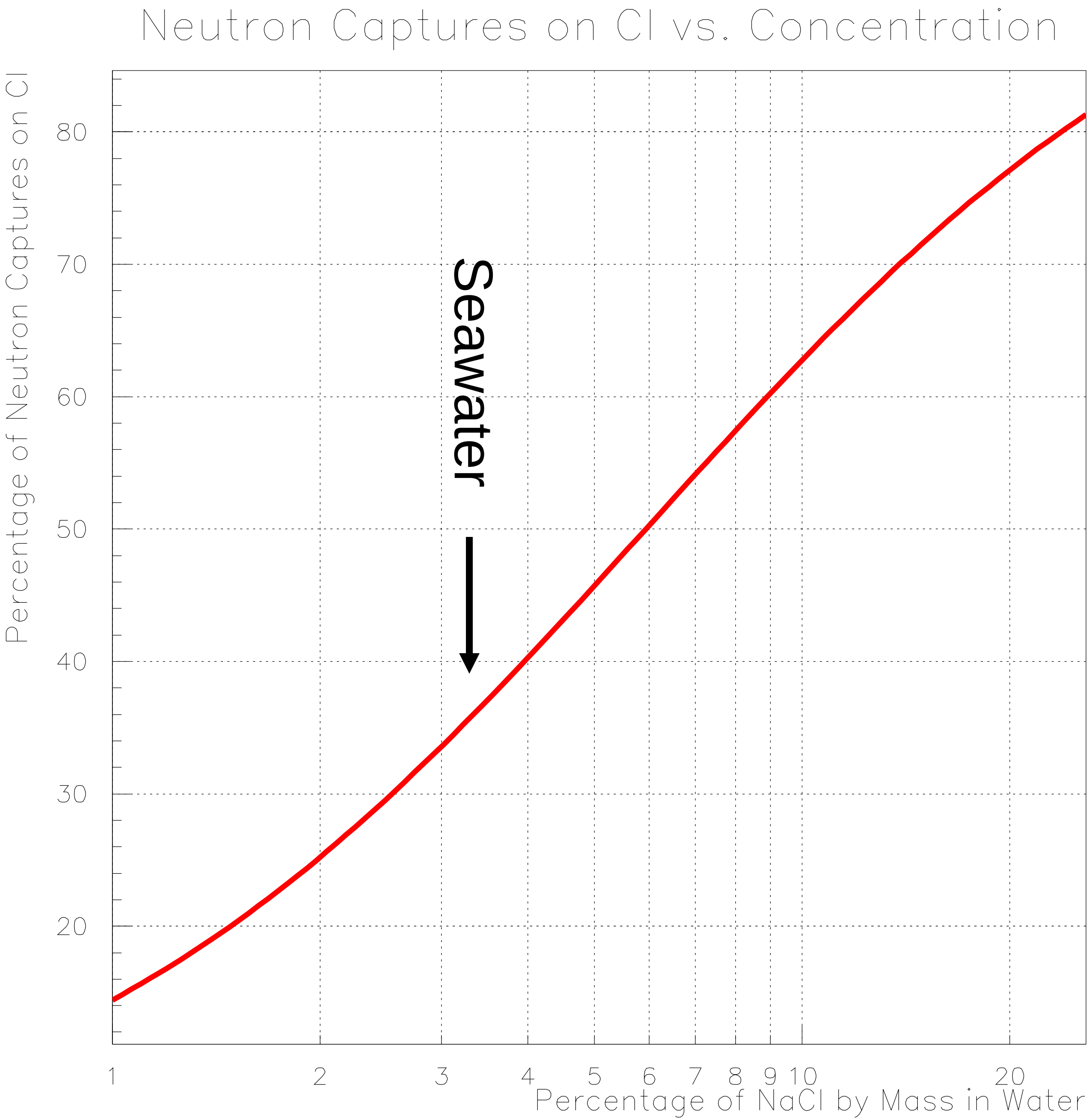
Without a doubt, at the megaton scale the only way to go is a solute mixed into the light water...



# One thing's for sure: plain old NaCl isn't going to work!

To get 50% neutron capture on Cl
(the other 50% will be on the hydrogen
in the water and essentially invisible)
you'll need to use 6% NaCl by mass:

→ *60 <u>kilotons</u> of salt for a megaton detector!* ←



Neutron Captures on Cl vs. Concentration
Percentage of Neutron Captures on Cl
80
70
60
50
40
30
20
Seawater
1
2
3
4
5
6
7
8
9
10
20
Percentage of NaCl by Mass in Water

As many of you know, for the last three years John Beacom and I have been working on this issue with an eye towards enhancing the (soon to be) existing Super-Kamiokande-III detector.

We finally got our first GADZOOKS! (Gadolinium Antineutrino Detector Zealously Outperforming Old Kamiokande, Super!) paper written up as hep-ph/0309300 and sent it off to *Physical Review Letters.*

After a long wait due largely to one of the *world's slowest referees,*

our paper was finally published in *Physical Review Letters* as

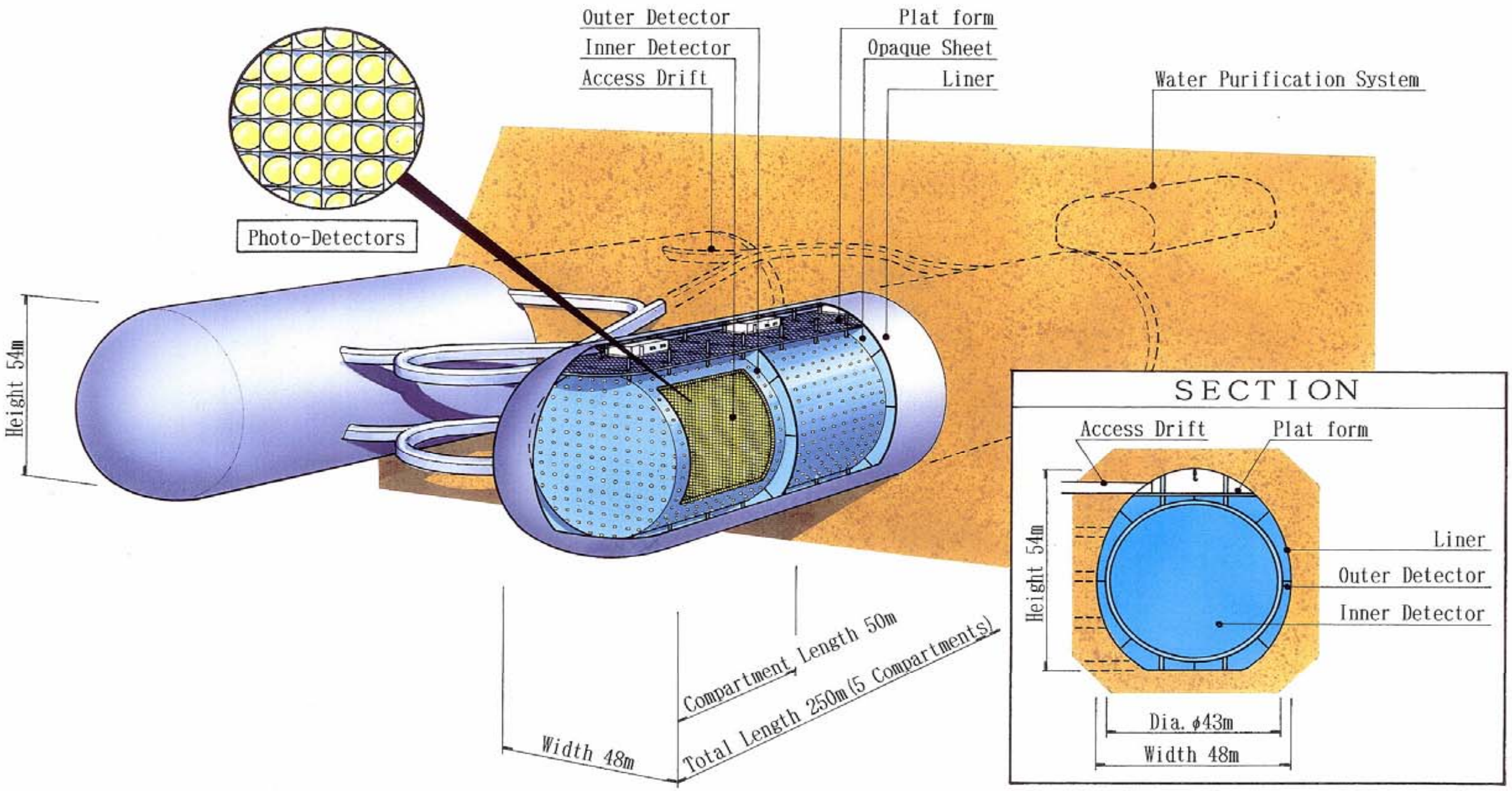
*Phys. Rev. Lett.*, **93**:171101, 2004

# We decided to use the best neutron capture nucleus known – gadolinium.

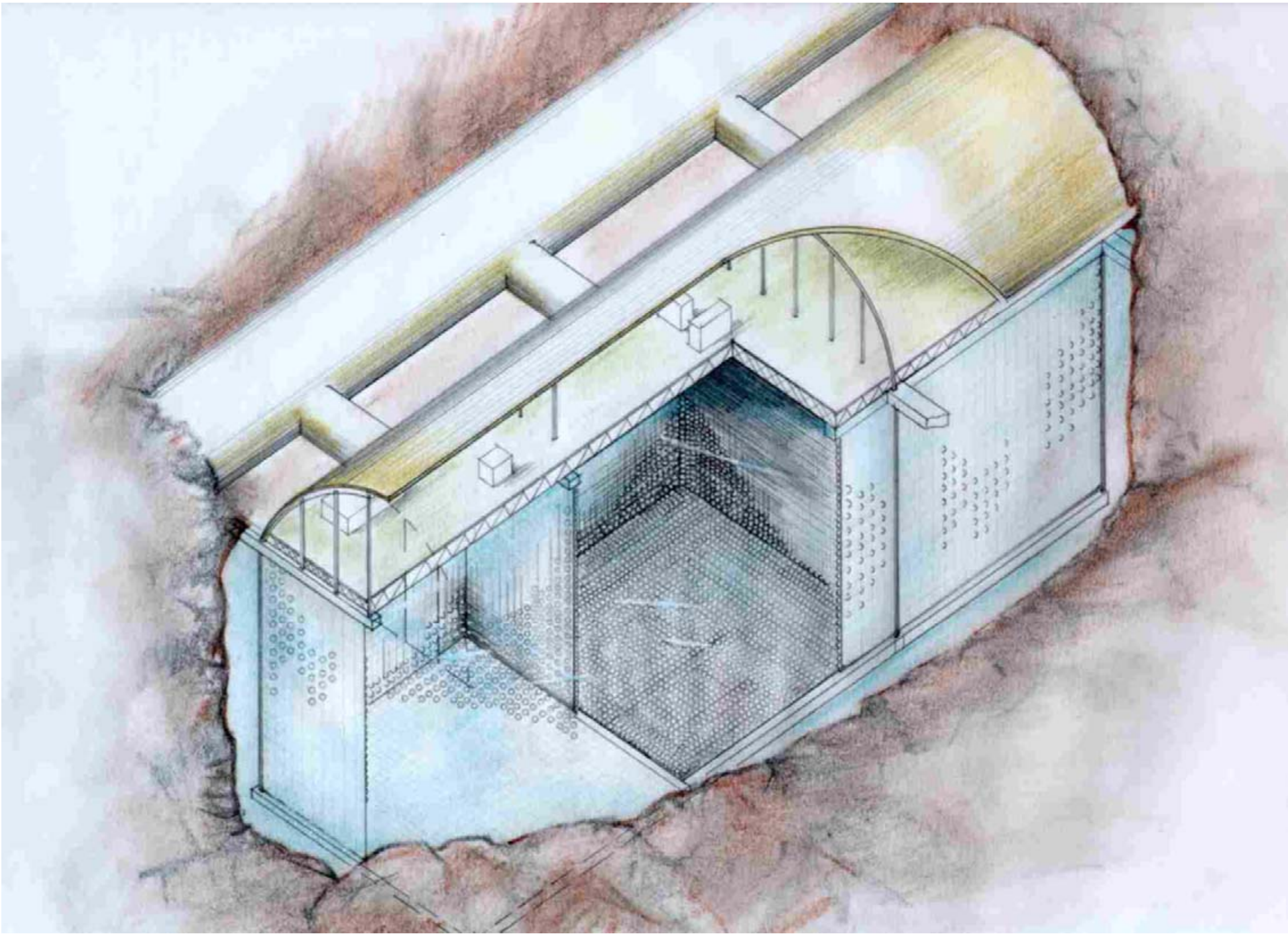

- $GdCl_3$ , unlike metallic Gd, is highly water soluble
- Neutron capture on Gd emits a 8.0 MeV $\gamma$ cascade
- 100 tons of $GdCl_3$ in SK-III (0.2% by mass) would yield >90% neutron captures on Gd
- Plus, it's not even toxic!

This positron/neutron capture coincidence technique is readily scalable to megaton class detectors at ~1% of their total construction cost, with one important caveat:


In order to be both big and sensitive, ~40% photocathode coverage is required in at least part of the detector.

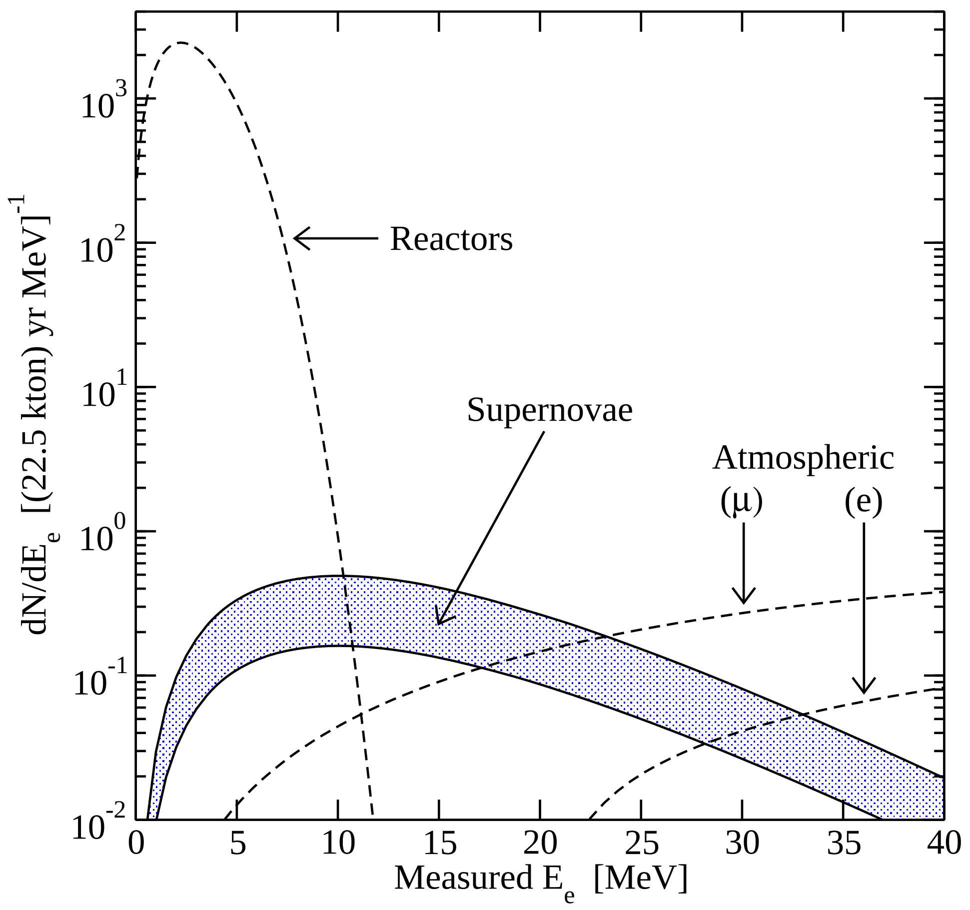



Hyper-Kamiokande: 540 kton fiducial volume, complete 40% coverage (same as SK-I/III) assumed



UNO: 440 kton fiducial volume,
central section (1/3) has 40% PMT coverage

# From our GADZOOKS! paper, here's what the coincident signals in SK or HK with $GdCl_3$ will look like (energy resolution is applied):




HK will collect >100 clean DSNB (relic) events per year!

[See Ando, Beacom, and Yuksel, astro-ph/0503321, for SN signals from nearby galaxies.]

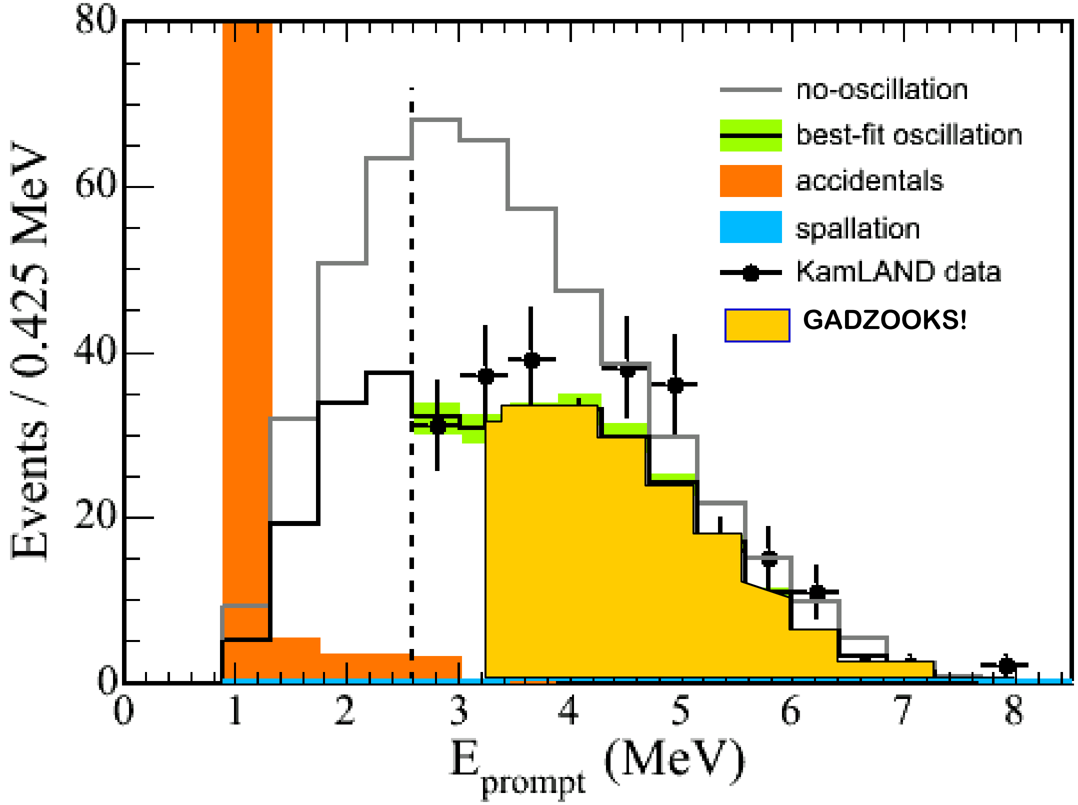
# If we can do relics, we can do a great job with a galactic supernova:

- The copious inverse betas get individually tagged and can be subtracted away from
- the directional elastic scatter events, doubling the SN pointing accuracy.
- The $^{16}O$ NC events no longer sit on a large background and are hence individually identifiable, as are
- the backwards-peaked $^{16}O$ CC events.

*~300,000 SN events in Hyper-K at 10 kpc!*

# Another big advantage of collecting $\bar{\nu}_e$'s…

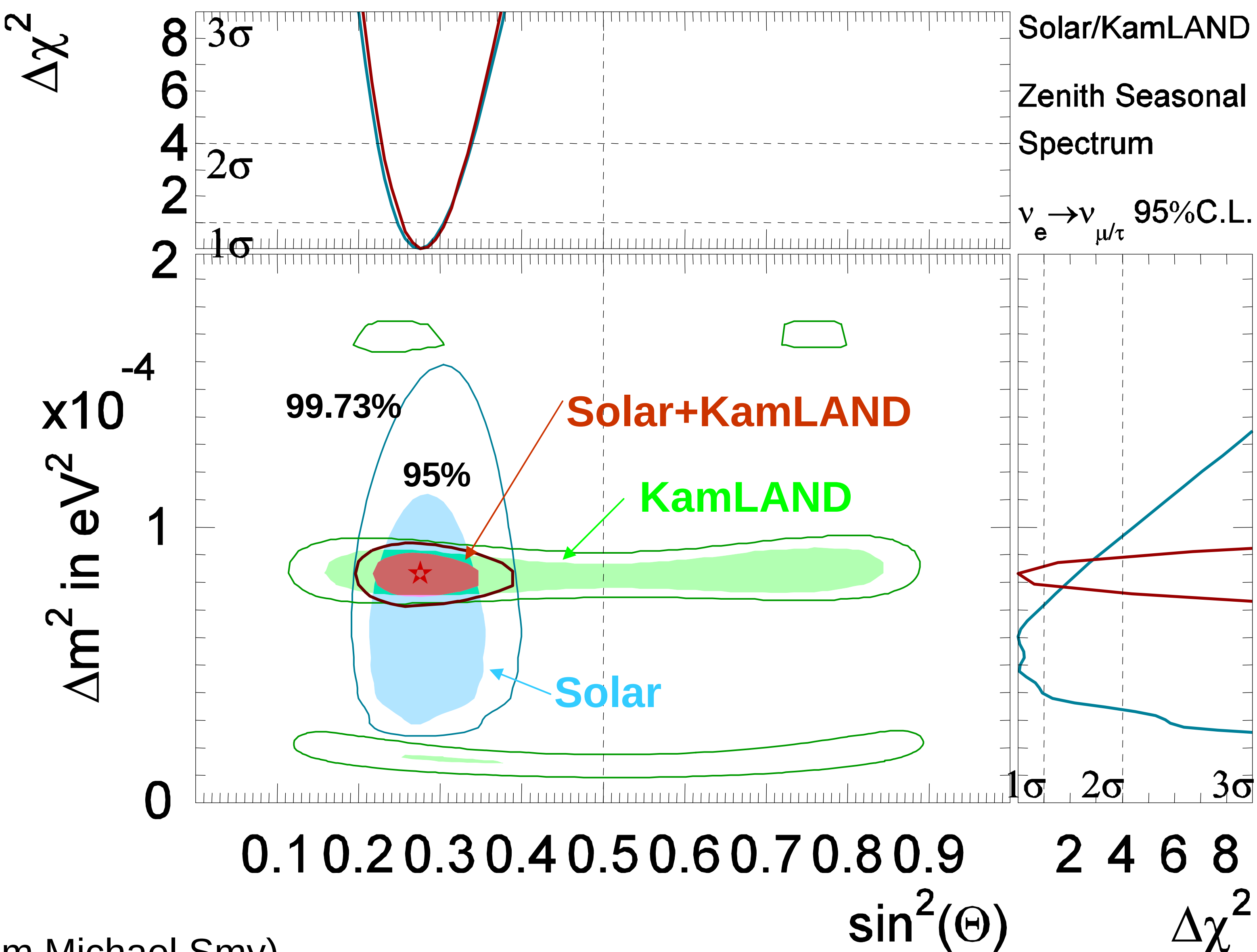
KamLAND's first 22 months of data




GADZOOKS! will collect this much reactor neutrino data in *two weeks.*

*Hyper-K with $GdCl_3$ will collect six KamLAND years of data in one day!*

# Oscillation parameters from solar neutrino and KamLAND experiments

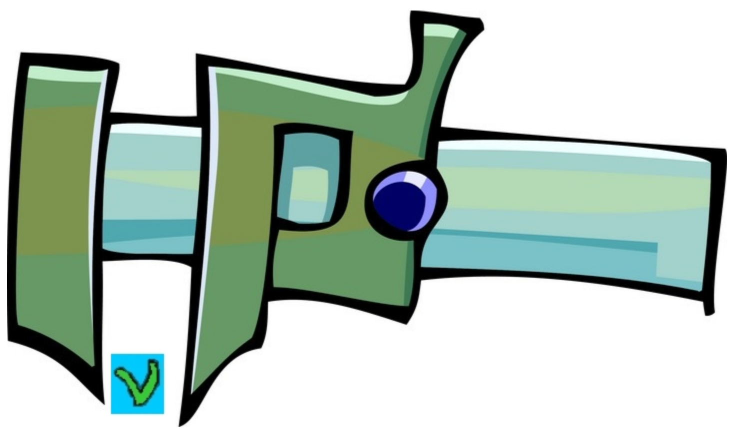



(From Michael Smy)

Following the method of

Choubey and Petcov, *Phys. Lett.* **B594**:333-346, 2004:

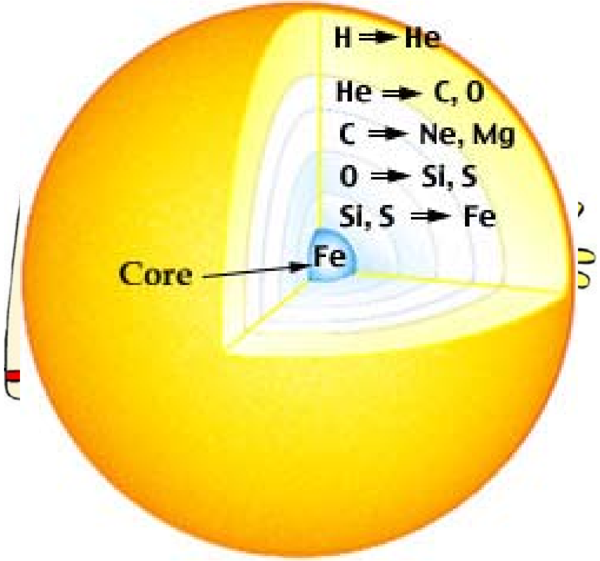
We can reduce the current combined 99% C.L. spread on the value of $\Delta m^2_{12}$ from ~10% to <1% with *just three months* of Hyper-K with $GdCl_3$ data.



Welcome to the world of

precision neutrino measurements!

Also very nice: late-stage Si burning in large, relatively close stars could provide a two day early warning of a core collapse supernova <u>if and only if</u> efficient, large scale neutron detection is possible.



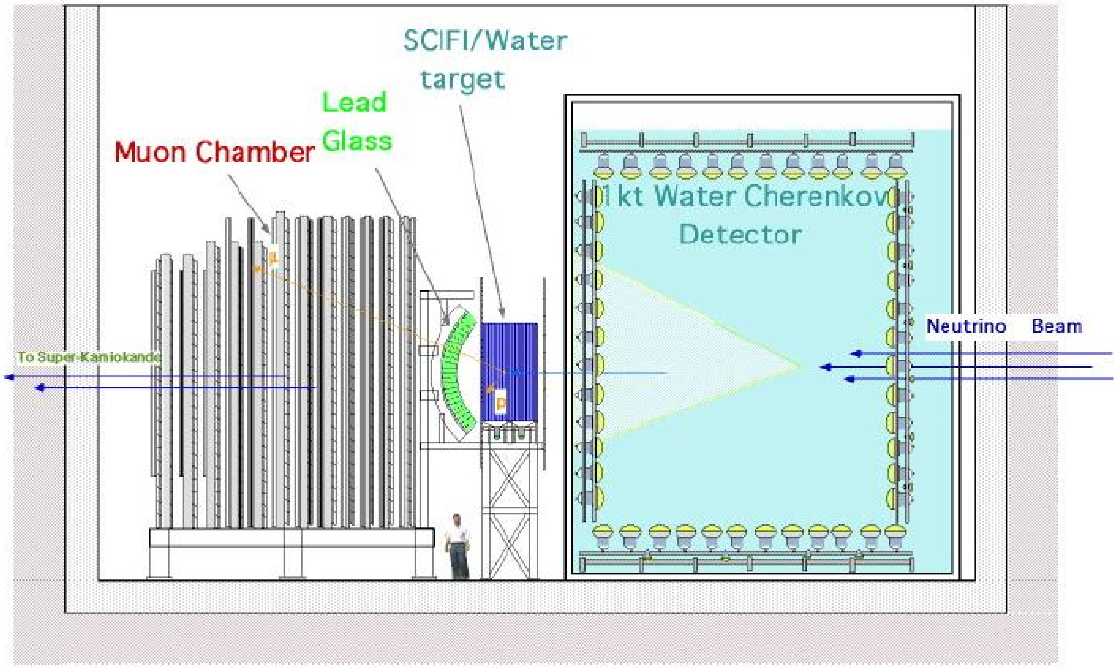

In HK or UNO with $GdCl_3$ this would mean a dramatic increase in the low energy singles rate, effective out to about 5 kiloparsecs (halfway to the galactic center).

[See Odrzywodek, Misiaszek, and Kutschera, *Astropart. Phys.* **21**:303-313, 2004]

The theorists *do* seem to be excited… but can the water + gadolinium trick be made to work experimentally?

I've now been doing small-scale (bench) testing for over one year with special Advanced Detector Program funding from the U.S. Department of Energy:

# This summer I'll employ some excellent large-scale hardware to find out if the $GdCl_3$ technique will work:




<u>K2K's 1 kiloton tank will be used for "real world" studies of</u>

- Gd Water Filtering – UCI built and maintains this water system
- Gd Light Attenuation – using real 20" PMTs
- Gd Materials Effects – many similar detector elements as in SK/HK/UNO

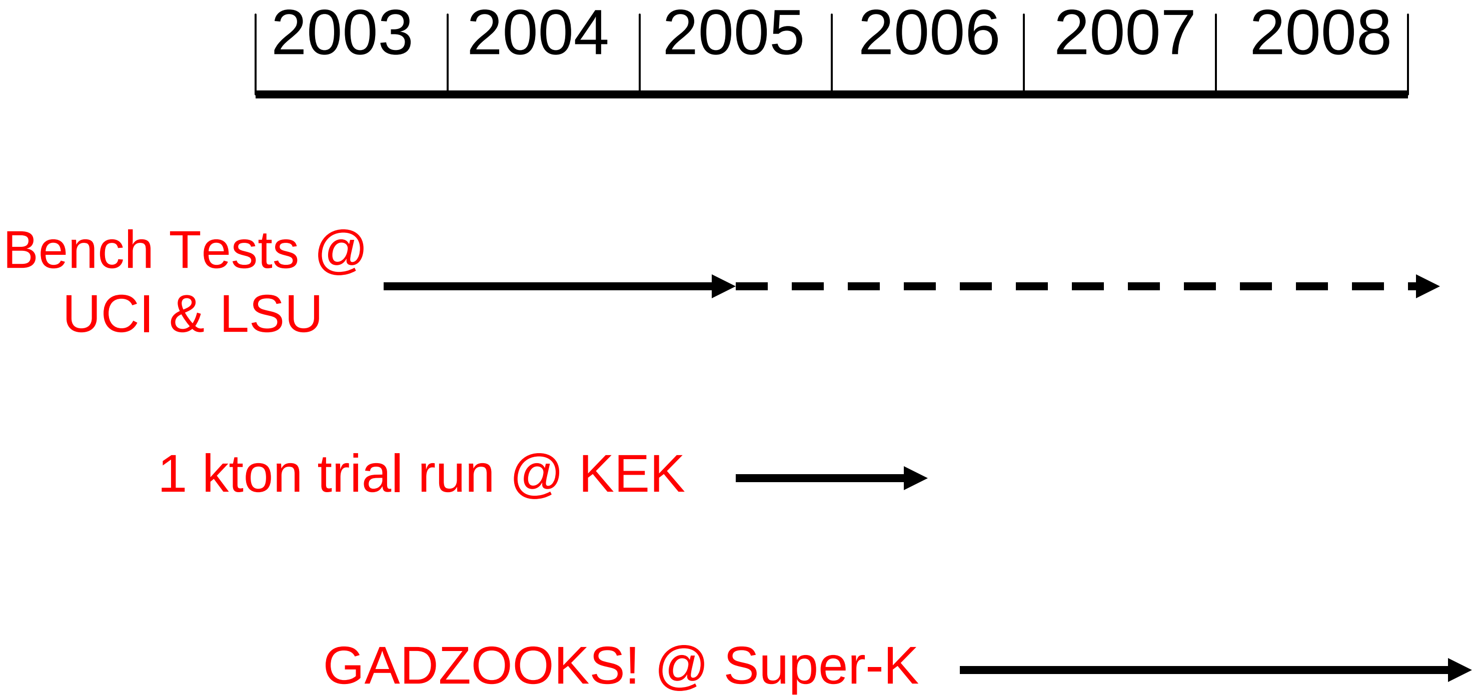
We are already gearing up for this effort…

I have an official quote from my Chinese connection on 4,000 kg of $GdCl_3$ (enough for two 1 kton fills at 0.2% concentration):


4,000 kg @ $3.08/kg → $12,320

*Amazingly, this price <u>includes</u> shipping to the Japanese port of our choice!*

# Okay, how about a $GdCl_3$ timeline?



That's it for now…
time for me to get back to seeing if this beautiful dream can be made a reality!