UH-HEP Non-Accelerator
Neutrino Group

Gorham, Guillian, Hebert, Learned, Lehtinen, Link, Maricic, Matsuno, Milincic, Miocinovic, (Browder, Melnikoff, Olsen, Pakvasa, Sugawara, Rosen, Varner)

J. Learned at UH ASHRA Meeting, 8 January 2004

UH NAP Projects

Old and New

- **Past: IMB, DUMAND**
- **Super-Kamiokande (since 4/96, restarted 02)**
- **K2K (ongoing for >2 years)**
- **KamLAND (running since 3/02)**
- **Radio Detection (GLUE, ANITA, *SALSA*)**
- **New Detect. Ideas, Phenom., Astrophys**
- **Neutrinos and Arms Control (workshop 5-7 Feb '04)**
- **ASHRA**
- **Long term: Neutrino Factory, Next Gen SK**

Attempting to open a new astronomy: Optical Cherenkov Neutrino Telescope Projects

ANTARES
La-Seyne-sur-Mer

BAIKAL
Russia

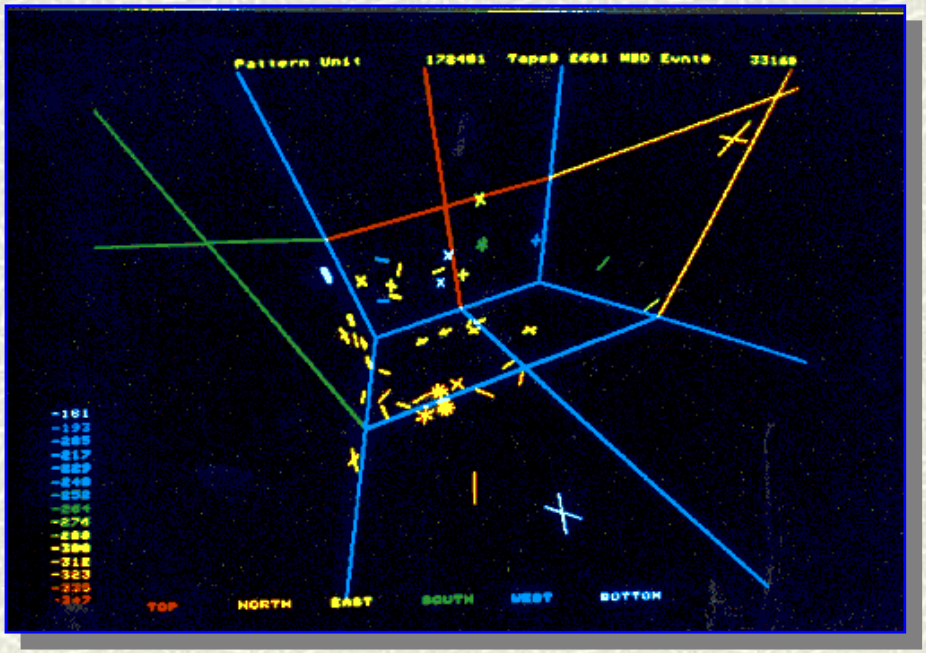
NEMO
Catania, Italy

NESTOR
Pylos, Greece

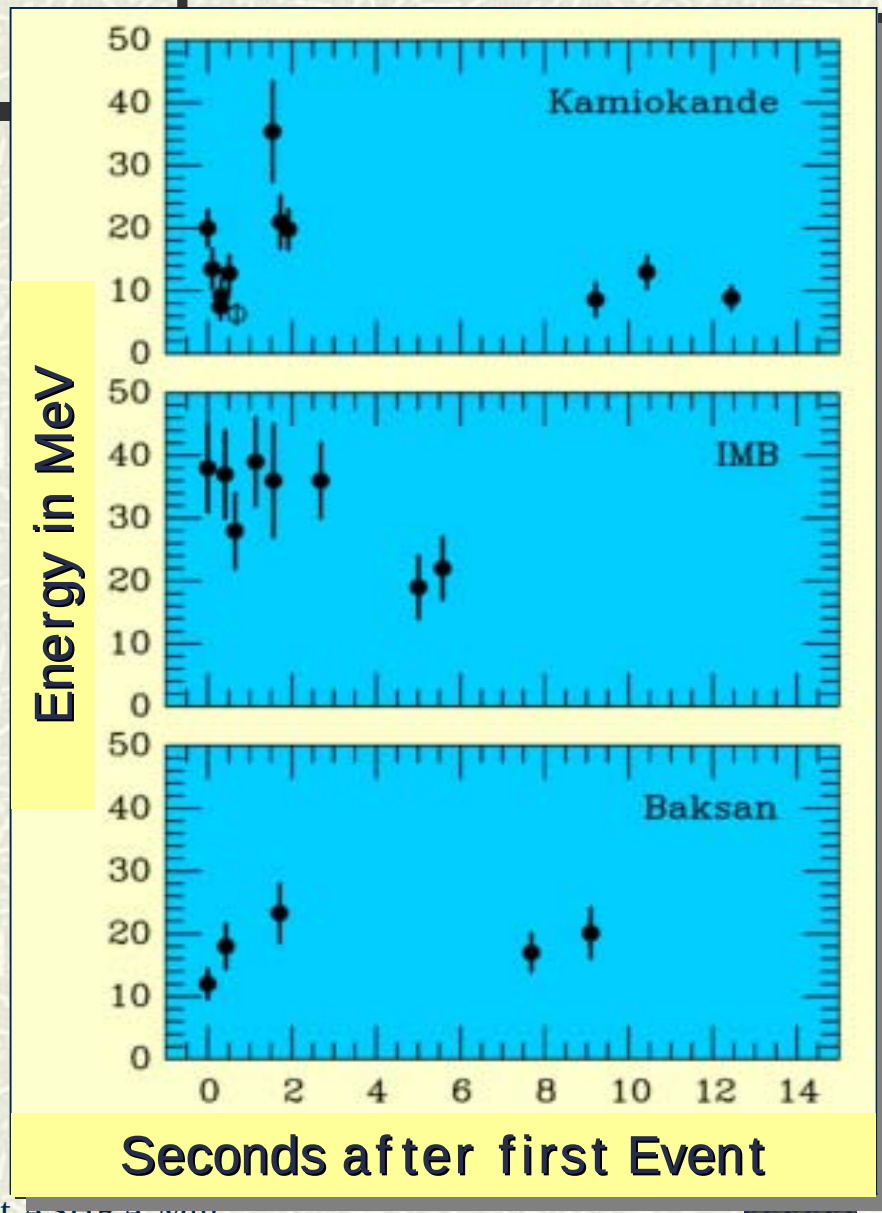
DUMAND
Hawaii
(cancelled 1995)

AMANDA, ICECUBE
South Pole, Antarctica

The beginning of Neutrino Astronomy: Neutrino Signal from Supernova 1987A



IMB event 33160, 39 MeV

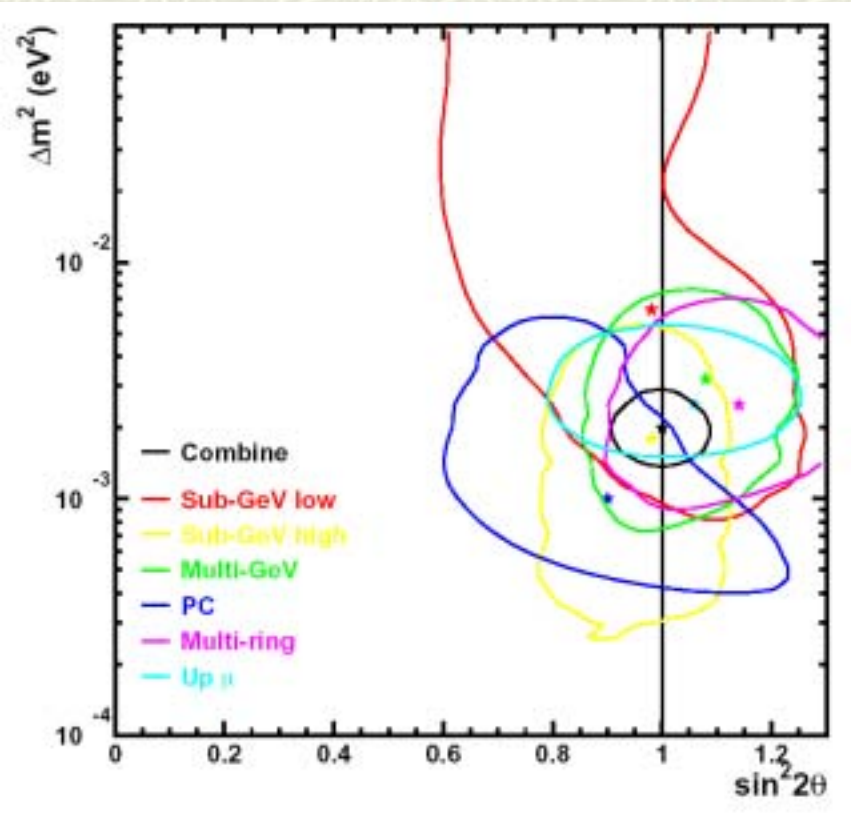


Superk-1: Busy Publishing 5 Yrs Data

- 1) solar day/night: hep-ex/0309011 [submitted Phys.Rev. D]
- 2) periodic modulation of solar nu: hep-ex/0307070
- 3) nue-bar from the Sun: hep-ex/0212067
  [Phys.Rev.Lett. 90 (2003) 171302]
- 4) relic neutrinos: hep-ex/0209028
  [Phys.Rev.Lett. 90 (2003) 061101]
- 5) gamma-ray burst nu search: astro-ph/0205304
  [Astrophys.J. 578 (2002) 317-324]
- 6) NIM paper: http://www-sk.icrr.u-tokyo.ac.jp/sk-official/
  sknimpaper_submitted.ps, accepted NIM '03
- 7) combined oscillation paper (in preparation)
- 8) upmu astro: http://www.phys.hawaii.edu/~jgl/skupmu.html (note)
- 9) WIMP paper: http://www-sk.icrr.u-tokyo.ac.jp/~upmu/wimp/index.html

SK-1Atmospheric Neutrinos

(PRL 81, 1562 (1998) #1 cited EHEP paper)



- 1496 live days, >11,000 FC atm ν's, >2,500 Up ν_μ's
- $\nu_\mu - \nu_\tau$ fits perfectly, $\Delta m^2 = 0.002$ eV^2, $\sin^2(2\theta)=1.0$
- No hint of sterile ν's
- Still ~2 σ for τ appear
- Non-standard solutions eliminated

Alternative Solutions Eliminated by SuperK Data

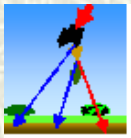
FC+PC+Upμ+multi-Ring Fit Summary

FC: 10 zenith angle×7 momentum bins
PC: 10 zenith angle bins
upStop 5 zenith angle bins — 195 Bins
upThru 10 zenith angle bins — 190 DOF
multi-Ring μ-like 10 zenith angle bins× 2 momentum bins
multi-Ring NC-like 10 zenith angle bins

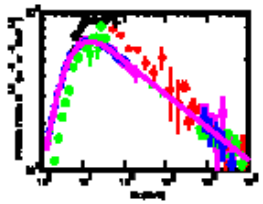
Mode	Best Fit	χ^2	$P(\chi^2)$	$\Delta\chi^2$	σ
ν_μ-ν_τ $\sin^2 2\theta \sin^2(1.27\Delta m^2 L/E)$	$\sin^2 2\theta = 1.00$ $\Delta m^2 = 2.5\times10^{-3}$ eV^2	175.0	76%	0.0	-
ν_μ-ν_e $-\sin^2 2\theta \sin^2(1.27\Delta m^2 L/E)$	$\sin^2 2\theta = 0.97$ $\Delta m^2 = 5.1\times10^{-3}$ eV^2	261.7	0.04%	86.7	9.3σ
ν_μ-ν_s $-\sin^2 2\theta \sin^2(1.27\Delta m^2 L/E)$	$\sin^2 2\theta = 0.96$ $\Delta m^2 = 2.8\times10^{-3}$ eV^2	204.9	21.8%	29.9	5.5σ
L×E $\sin^2 2\theta \sin^2(\alpha L\times E)$	$\sin^2 2\theta = 0.90$ $\alpha = 5.4\times10^{-4}$/GeV/km	261.2	0.05%	86.2	9.3σ
ν_μ Decay $\sin^4\theta + \cos^4\theta(1-e^{-\alpha L/E})$	$\cos^2\theta = 0.48$ $\alpha = 3.9\times10^{-3}$ GeV/km	269.5	0.01%	94.5	9.7σ
ν_μ Decay $(\sin^2\theta + \cos^2\theta e^{-\alpha L/2E})^2$	$\cos^2\theta = 0.33$ $\alpha = 1.3\times10^{-3}$ GeV/km	195.7	37%	20.7	4.5σ
No Oscillations	- -	427.4	0%	252.4	15.9σ

SK-1: $\Delta m^2 = 0.002\ eV^2$

Down Slightly from past



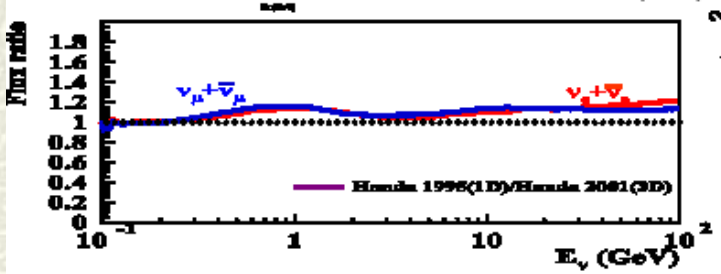
Comparison of old and new analysis results



•Neutrino flux

Honda 1995(1D)

Honda 2001(3D)

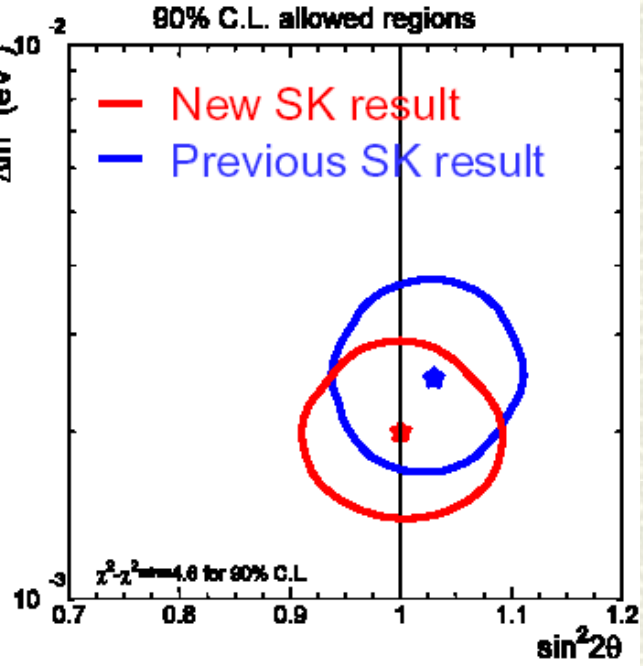


•Neutrino interaction model

several improvements:
agree better with K2K near-detector data

•Improved detector simulation

•Improved event reconstruction

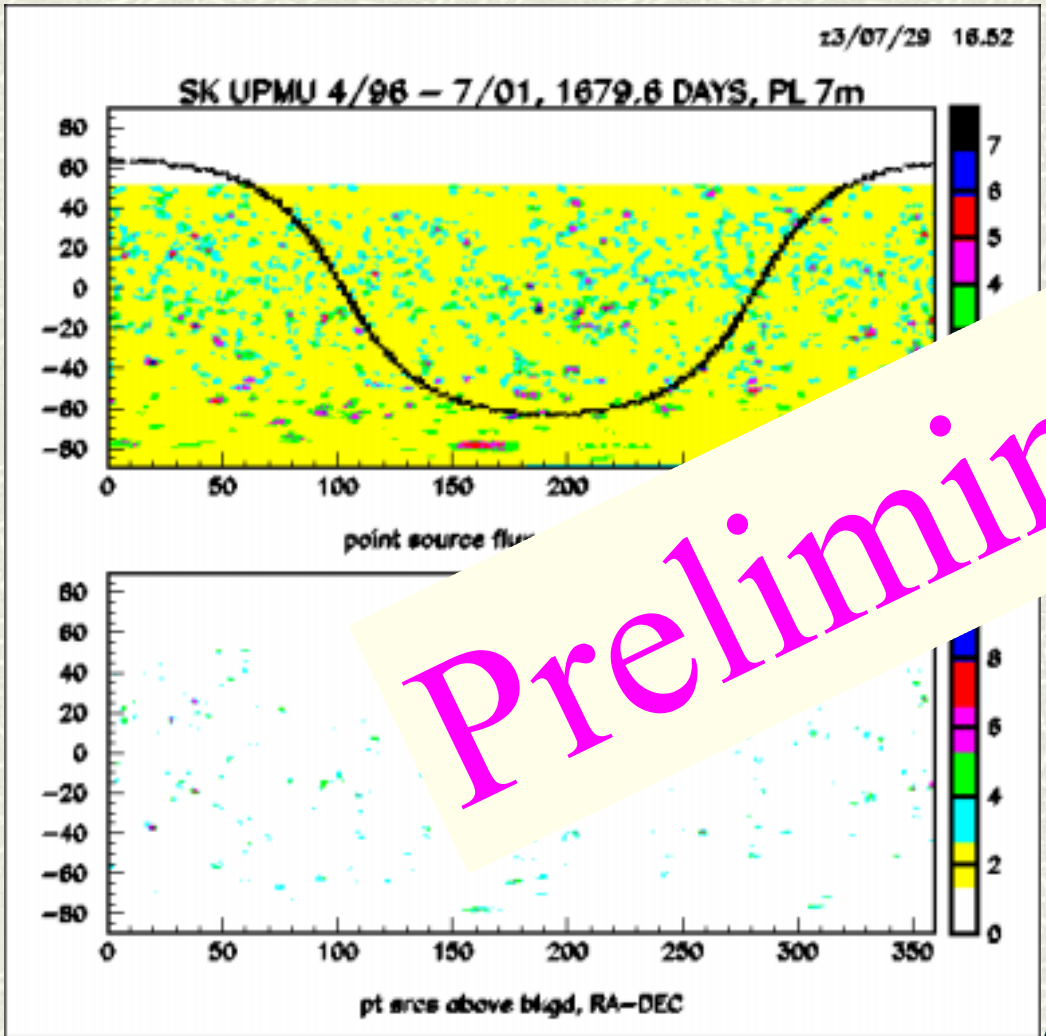


Each change contributes to the shift in the allowed Δm^2 region.

SuperK Upcoming Muon: Cosmic ν Limits

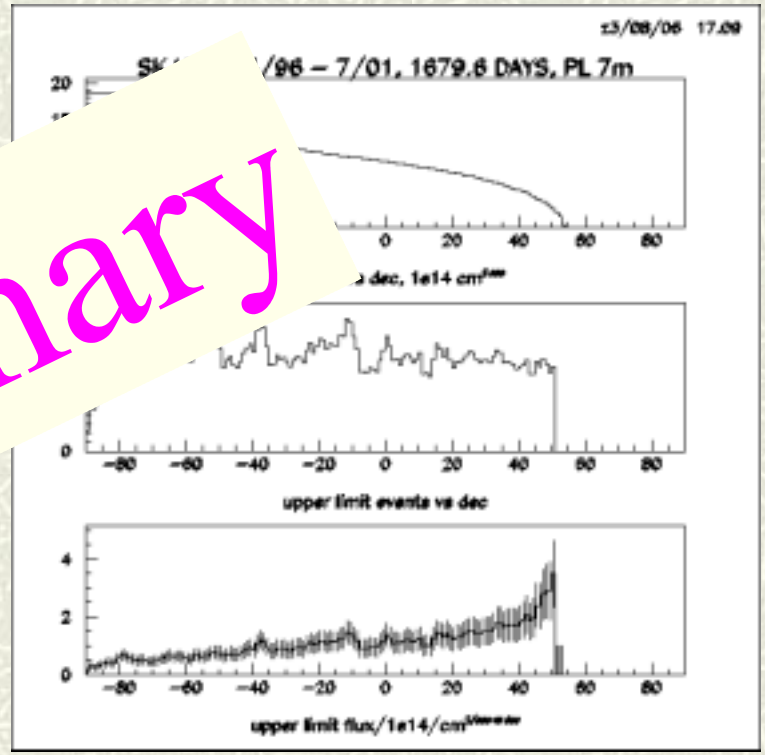
E μ>1.4 GeV; <E ν>~100 GeV

(new analysis 8/03 JGL at UH)



Astronomy paper in preparation

No Sources Found

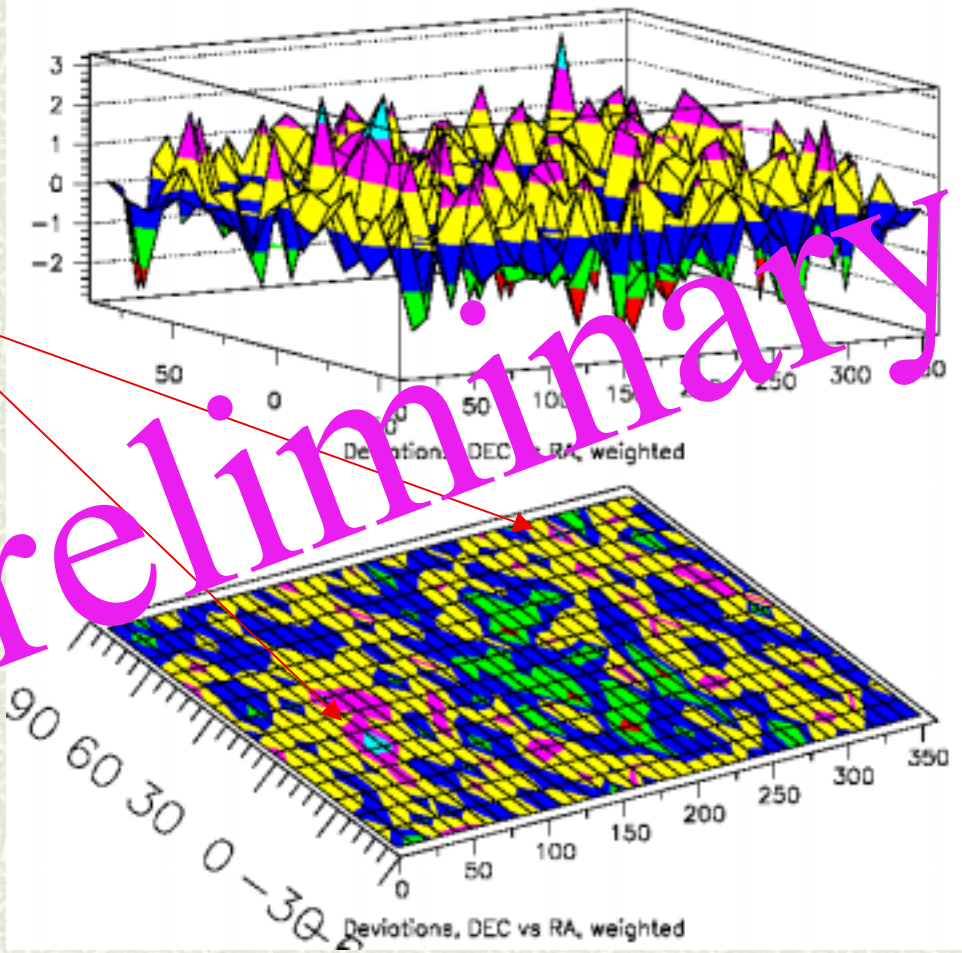


Preliminary

SK-1 Downgoing Muon Study

Gene Guillian, Jason Kerwin and J. Learned at UH

highest points



- 270 million down going cosmic ray muons analyzed
- 6 x 10^{-4} asymmetry in 10 TeV cosmic rays, not understood
- Similar to tentative results from IMB (McGrath UH thesis), MILAGRO and old Kamiokande
- Work in progress… just being presented to collaboration. Probable paper in next year.

SK-1 Solar Nu Solutions

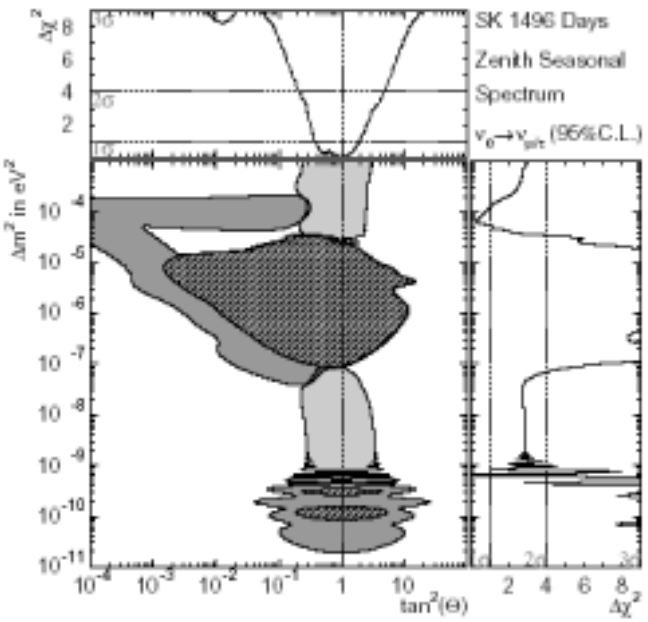


FIG. 5: Excluded (SK spectrum and time variation; dark gray) and Allowed (SK spectrum, rate, and time variation; light gray) at 95% C.L.. Overlaid are the areas excluded just by the day/night and seasonal variation (hatched regions inside thick black lines). The graphs at the top (and right) show the χ^2 difference as a function of $\tan^2\theta$ (Δm^2) alone where the Δm^2 ($\tan^2\theta$) is chosen to minimize χ^2.

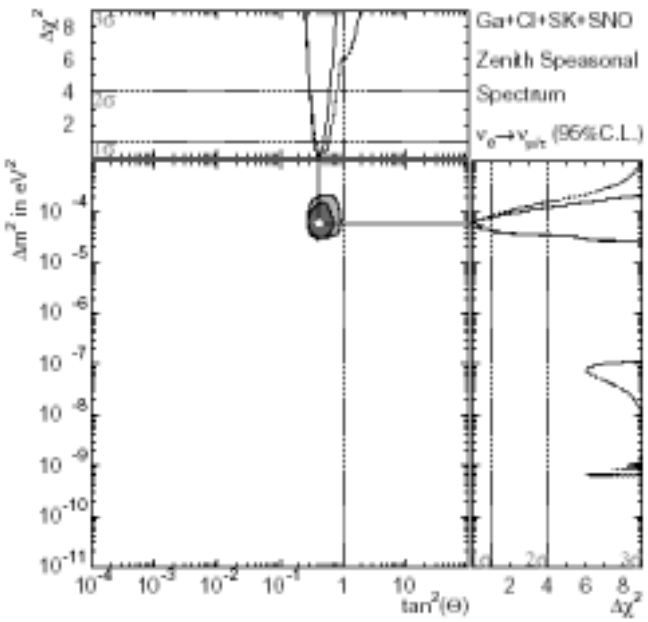
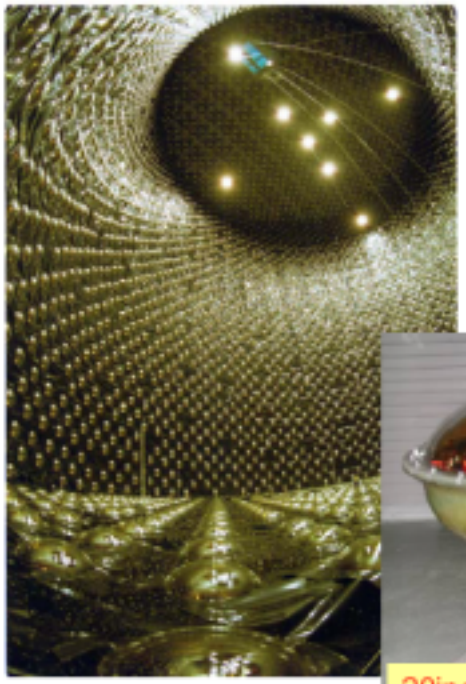


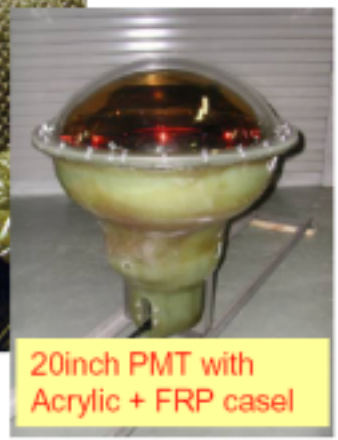
FIG. 6: Allowed area at 95% C.L from the combination of SK and SNO (gray) and all solar data (dark gray). The graphs at the top (and right) show the χ^2 difference as a function of $\tan^2\theta$ (Δm^2) only: the dashed line is the SK/SNO fit, the solid line includes all solar data. The best fit to all solar data is $\tan^2\theta = 0.42$ and $\Delta m^2 = 6.0 \times 10^{-5}\text{eV}^2$.

SuperK back on the air at half density in Inner Detector

Super Kamiokande-II

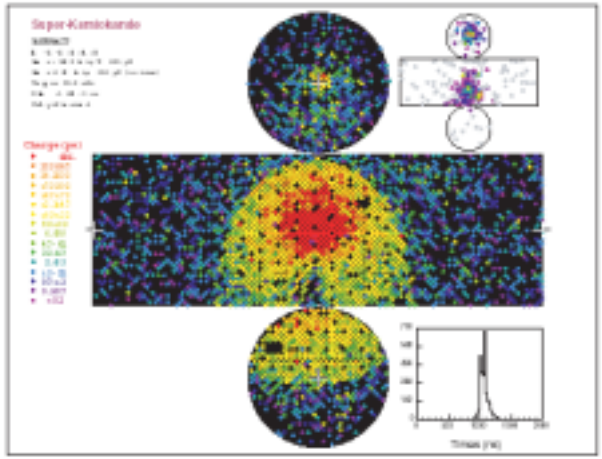


We have rebuilt the detector
and
resumed data taking in Oct. 2002.



20inch PMT with
Acrylic + FRP casel

SK-II Cosmic ray muon



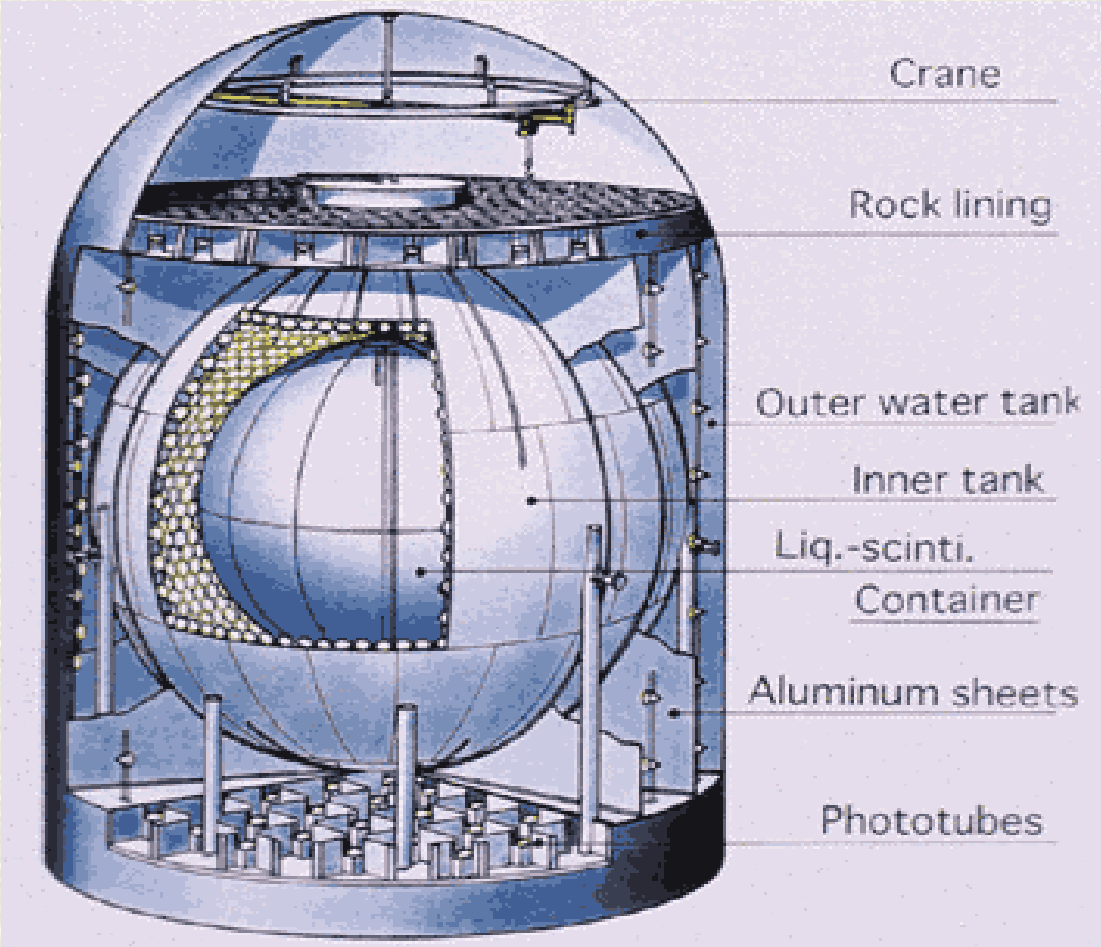
Inner detector
- ~5200 20inch PMTs

Outer detector
- 1885 8inch PMTs

KamLAND

taking data since March 2002

- **Measure ν_e's from reactors in Japan at ~200 km distance.**
- **Definitively solves solar neutrino puzzle, shows LMA-MSW correct.**
- **New data out soon (Spring 2004).**



KamLAND

First KamLAND Results 12/02

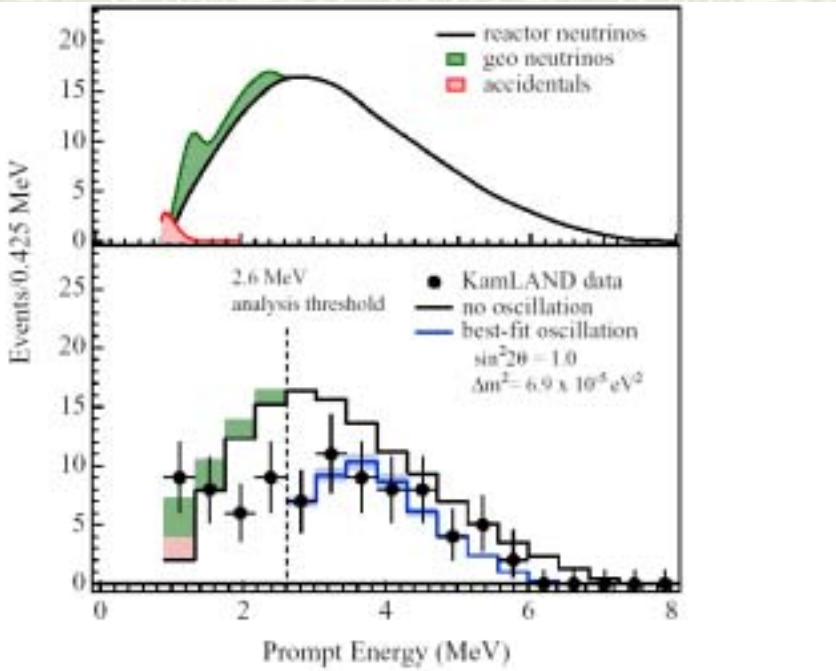


Figure 3.2: Upper panel: Expected reactor $\bar{\nu}_e$ energy spectrum along with $\bar{\nu}_{geo}$ and background. Lower panel: Energy spectrum of the observed prompt events (solid circles with error bars), along with the expected no oscillation spectrum (upper histogram, with $\bar{\nu}_{geo}$ and background shown) and best fit (lower histogram) including neutrino oscillations. The shaded band indicates the systematic error in the best-fit spectrum. The vertical dashed line corresponds to the analysis threshold at 2.6 MeV.

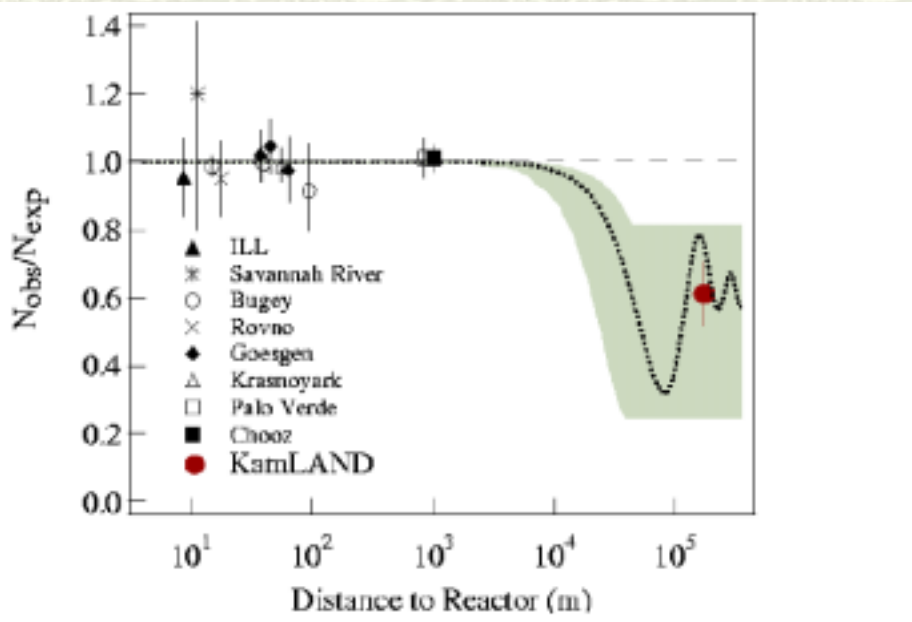


Figure 3.1: The ratio of measured to expected $\bar{\nu}_e$ flux from reactor experiments. The solid circle is the KamLAND result plotted at a flux-weighted average distance of ~180 km. The shaded region indicates the range of flux predictions corresponding to the 95% C.L. LMA region from a global analysis of the solar neutrino data. The dotted curve, $\sin^2 2\theta = 0.833$ and $\Delta m^2 = 5.5 \times 10^{-5}$ eV^2, is representative of a best-fit LMA prediction and the dashed curve is expected for no oscillations.

KamLAND Oscillations Solution Agrees with Solar Experiments

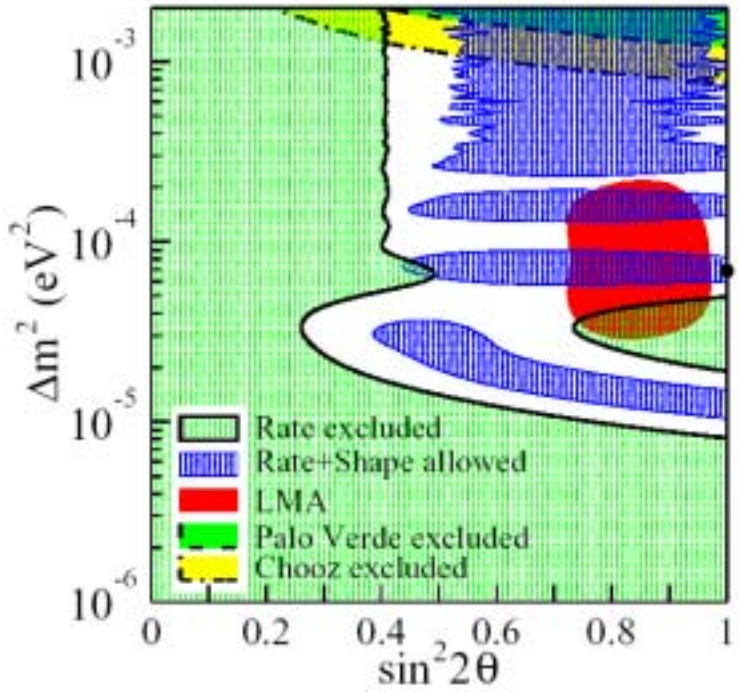


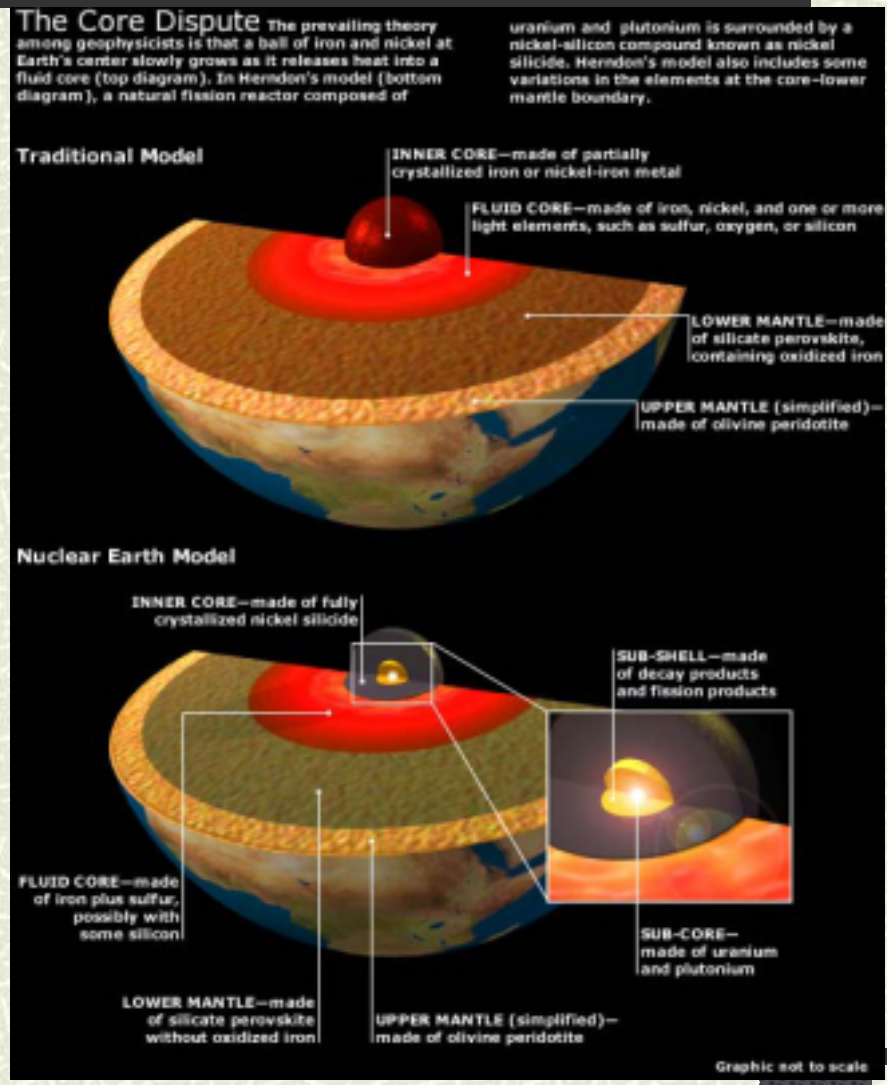
Figure 3.3: Excluded regions of neutrino oscillation parameters for the rate analysis and allowed regions for the combined rate and shape analysis from KamLAND at the 95% C.L. At the top are the 95% C.L. excluded region from CHOOZ and Palo Verde experiments, respectively. The 95% C.L. allowed region of the 'Large Mixing Angle' (LMA) solution of solar neutrino experiments is also shown. The solid circle shows the best fit to the KamLAND data in the physical region: $\sin^2 2\theta = 1.0$ and $\Delta m^2 = 6.9 \times 10^{-5}\mathrm{eV}^2$. All regions look identical under $\theta \leftrightarrow (\pi/2 - \theta)$ except for the LMA region from solar neutrino experiments.

- New analysis in progress now, paper early in 2004
- Hope to see spectral distortion and distinguish decay geo-nus
- New results on possible georeactor (Jelena Maricic, Gene Guillian and JGL at UH) (follows…)

Reactor at Earth Center?

- **Traditional Model:** content of the inner core based on **carbonaceous, oxygen rich chondrites.** As a result, U and Th do not sink, but stay in the crust and mantle.

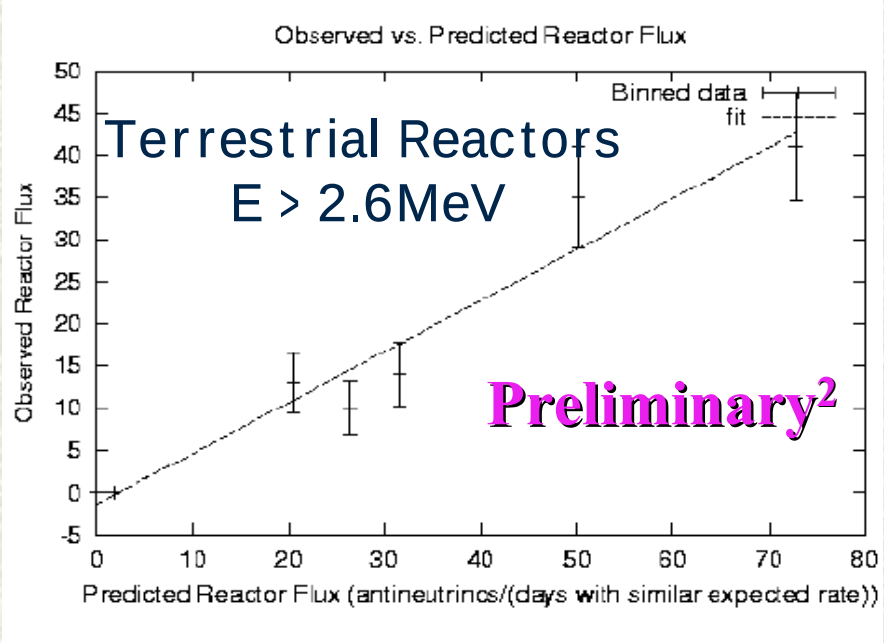
- **Nuclear Earth Model:** content of the inner core based on rare **enstatite chondrites, poor in oxygen.** U and Th can sink to the Earth's center.



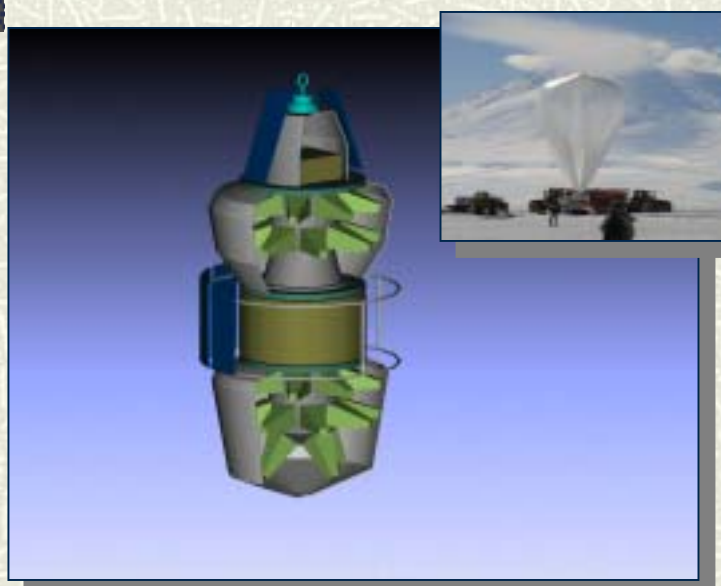
Is there a reactor at Earth's Core?

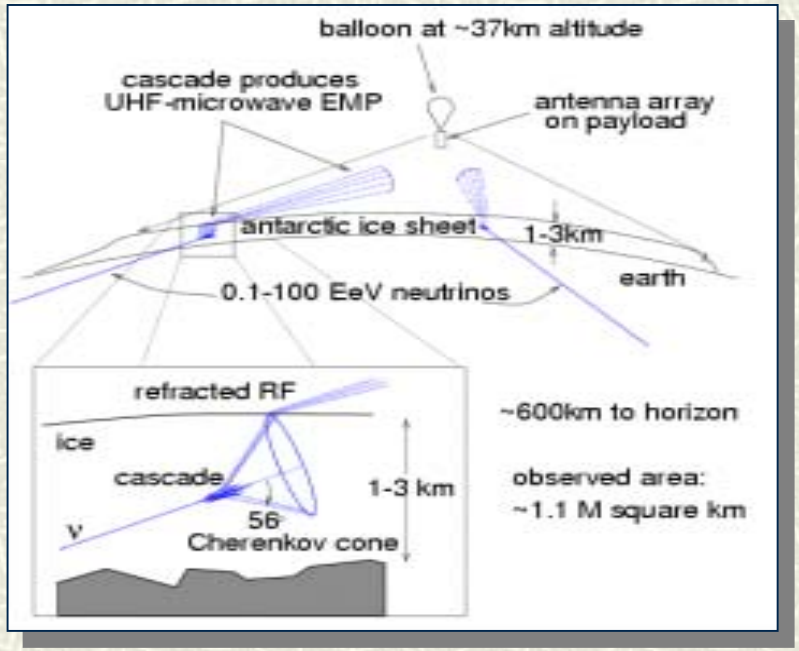
- KamLAND can detect **signature spectrum** from geo-reactor, as a **constant $\bar{\nu}_e$ flux** on the top of varying $\bar{\nu}_e$ flux from terrestrial reactors.

- **Negative y-intercept** shows that geo-reactor power is ~0.
- **Maximum Likelihood Method** is used to set **upper limit** on the power of the geo-reactor.



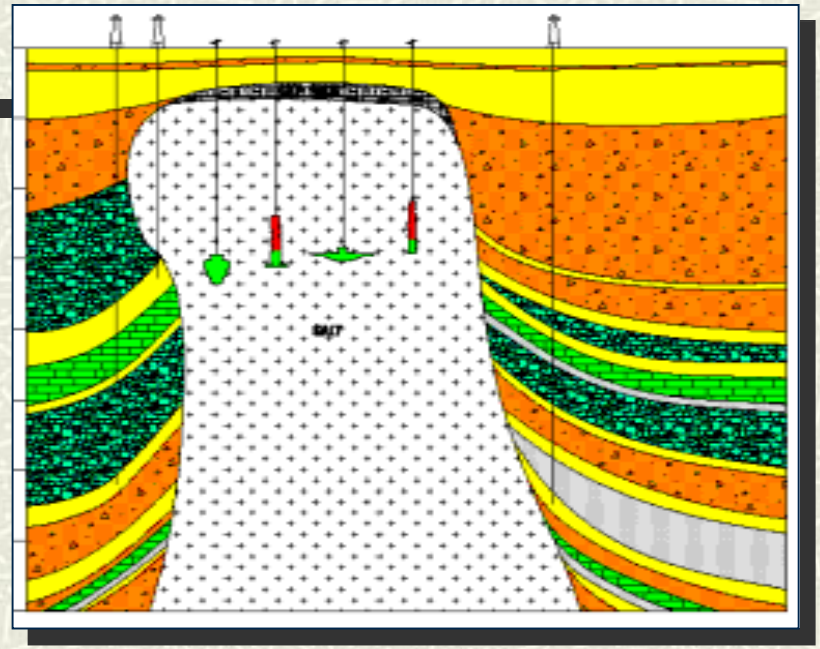
ANITA
Radio from EeV ν's in Polar Ice



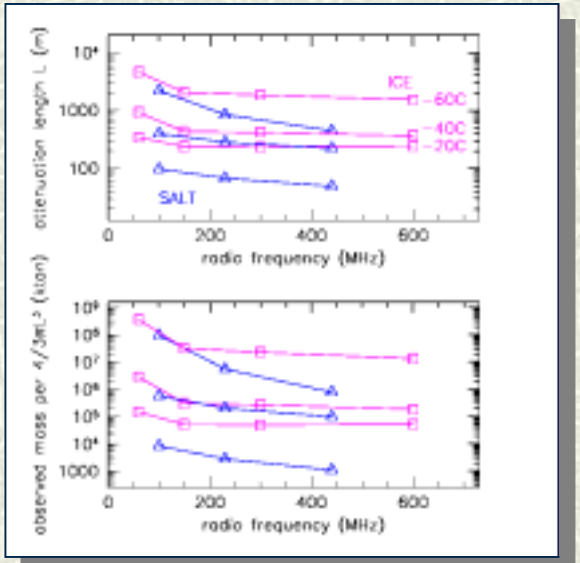


- UH, JPL, Penn. St., Bartol, UCI, UCLA, LANL, Utah, U. Wisc.
- NASA proposal accepted 11/03
- Successful test flight 1/04
- Data in 2006-7 if successful

SALSA: Potential Neutrino Detector in Natural Salt Domes

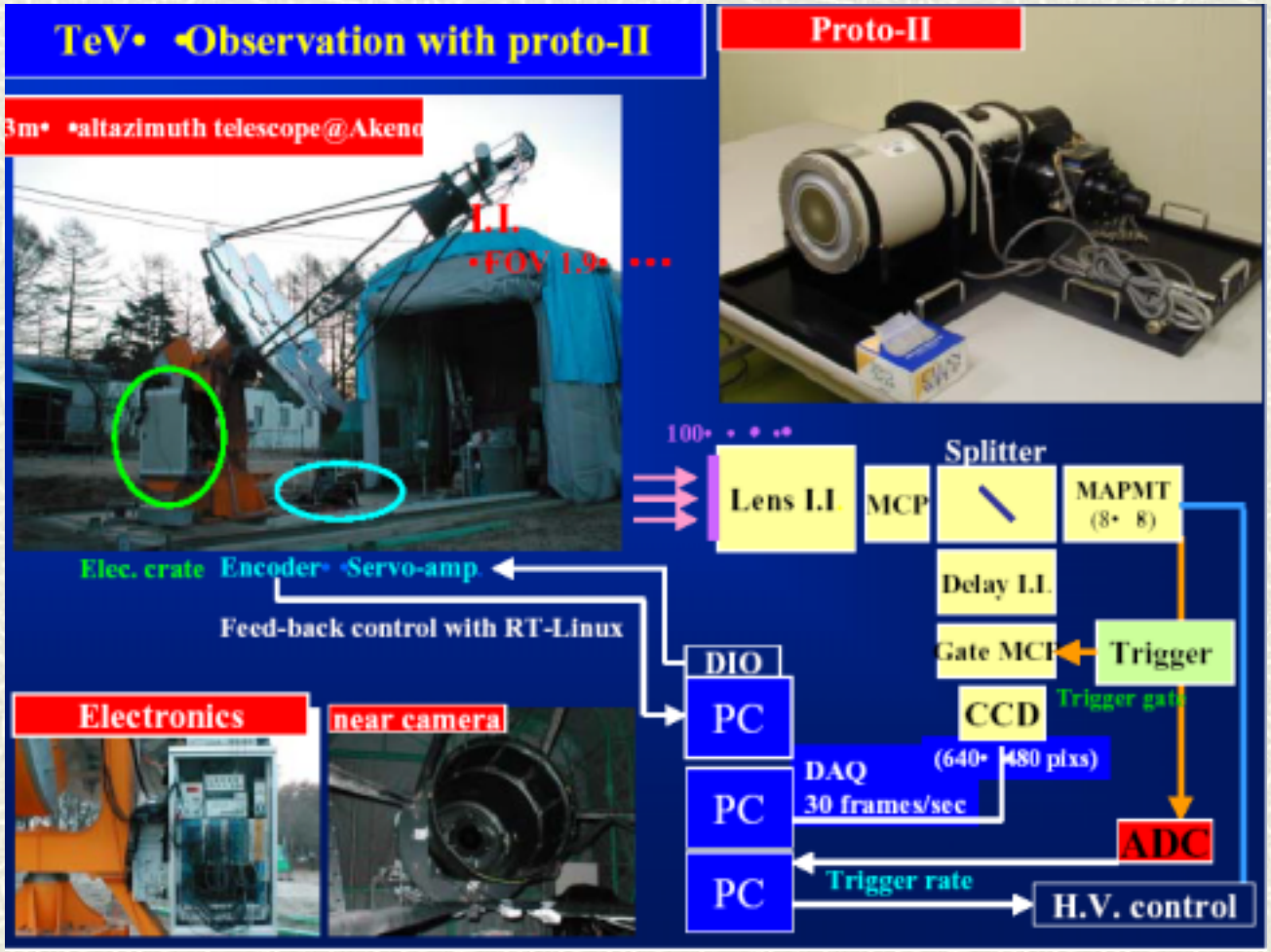


Natural salt can be extremely low radio loss: ~ as clear as very cold ice, but nearly 2.5 times as dense.



SALT curves are for (top): purest natural salt; (middle): typical good salt dome; (bottom) best salt bed halite. New measurements 2001.

ASHRA Demonstration TeV Gamma Telescope to Haleakala in 2004



Neutrinos and Arms Control

- Workshop 5-7 Feb 2004 at UH
- Major focus to discuss potential for monitoring all worlds reactors.
- Three gigaton underwater anti-neutrino detectors! (Far future).
- Plan ongoing studies, technology development.

Lots of great science, but too much to do!

- We are overwhelmed with good projects.
- Need new personnel.
- Proposing to establish a neutrino center at UH.
- The fun goes on….