SNO+ Status Report

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for the SNO+ Collaboration

Introduction to SNO+

- one kilotonne liquid scintillator neutrino experiment
- located at SNOLAB
- built using SNO hardware/infrastructure
- separate from SNO

SNOLAB
MINING FOR KNOWLEDGE
CREUSER POUR TROUVER...

SNO

Outline

- SNO+ physics overview
  - solar neutrinos
  - geo-neutrinos
  - reactor neutrino oscillation confirmation
  - supernova neutrinos
  - double beta decay
- technical progress
- future plans

Low Energy Solar Neutrinos

- refine our understanding of neutrinos from the Sun

  pep, CNO, ^{7}Be

p-p Solar Fusion Chain

$p + p \rightarrow {}^2H + e^+ + \nu_e$ $p + e^- + p \rightarrow {}^2H + \nu_e$

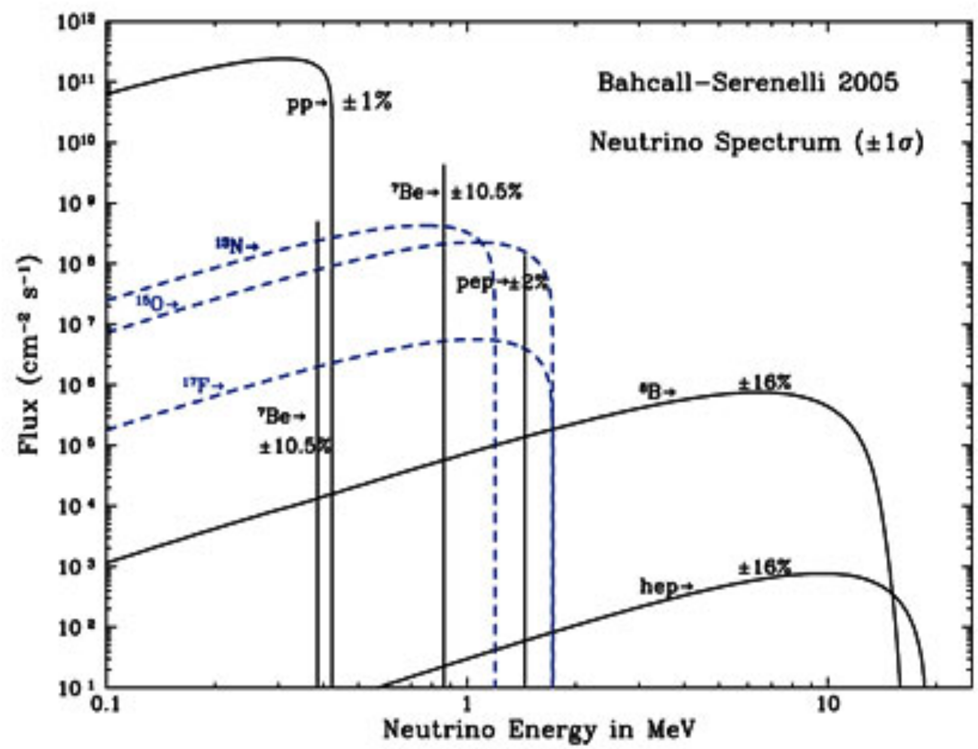
$^2H + p \rightarrow {}^3He + \gamma$

$^3He + {}^3He \rightarrow {}^4He + 2\,p$ $^3He + p \rightarrow {}^4He + e^+ + \nu_e$

$^3He + {}^4He \rightarrow {}^7Be + \gamma$

$^7Be + e^- \rightarrow {}^7Li + \gamma + \nu_e$ $^7Be + p \rightarrow {}^8B + \gamma$

$^7Li + p \rightarrow \alpha + \alpha$ $^8B \rightarrow 2\,\alpha + e^+ + \nu_e$



CNO Cycle

$^{12}C + p \rightarrow {}^{13}N + \gamma$ $^{13}N \rightarrow {}^{13}C + e^+ + \nu_e$

$^{13}C + p \rightarrow {}^{14}N + \gamma$

$^{14}N + p \rightarrow {}^{15}O + \gamma$ $^{15}O \rightarrow {}^{15}N + e^+ + \nu_e$

$^{15}N + p \rightarrow {}^{12}C + \alpha$

SNO+ could measure the CNO contribution to solar energy generation

Physics from *pep* Neutrinos

Event rate:

  3600 events/yr/kton

SSM pep flux:

  uncertainty ±1.5%

High statistics + known source

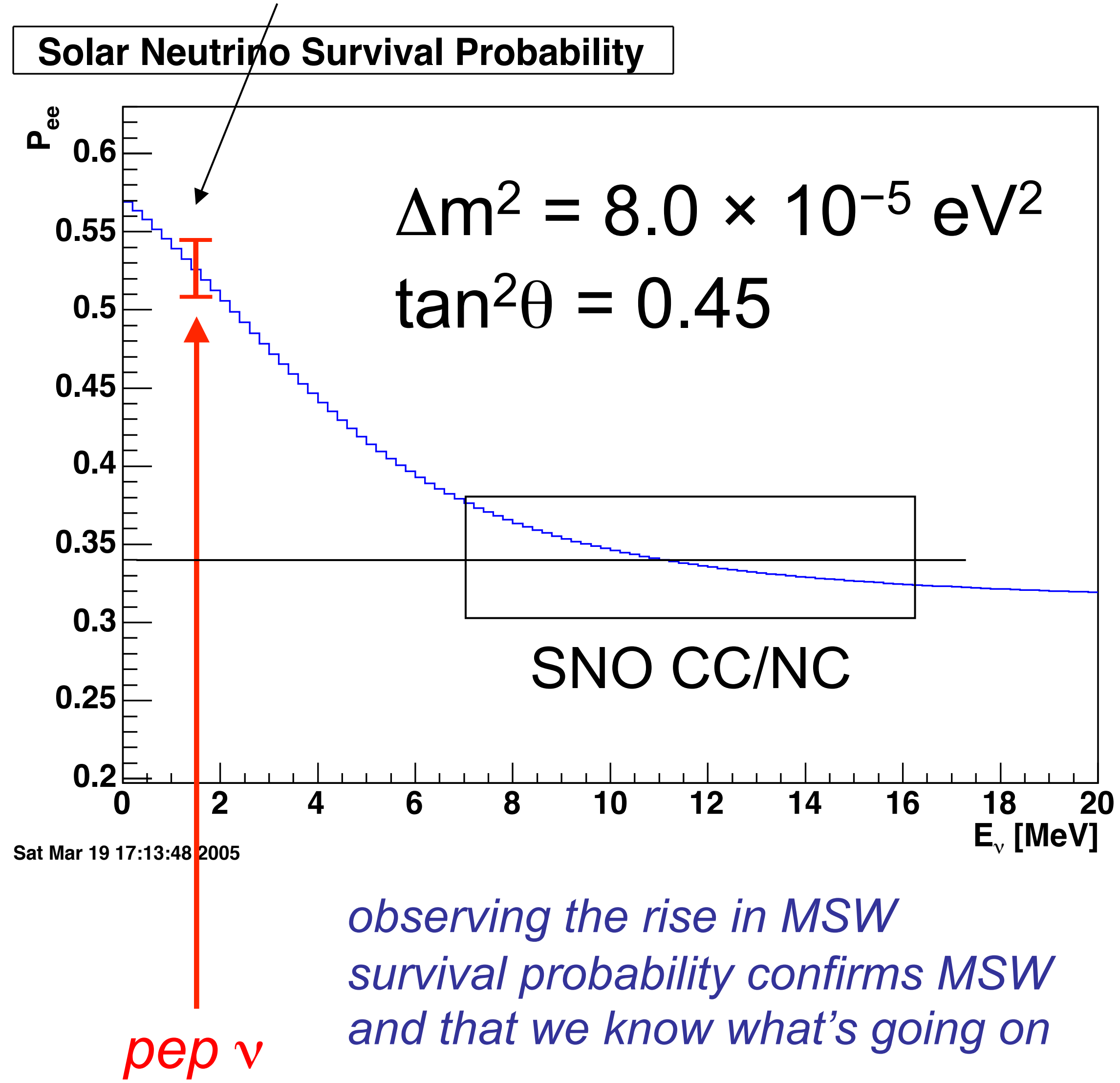
  → precision test

improves precision on θ_{12}

sensitive to new physics:

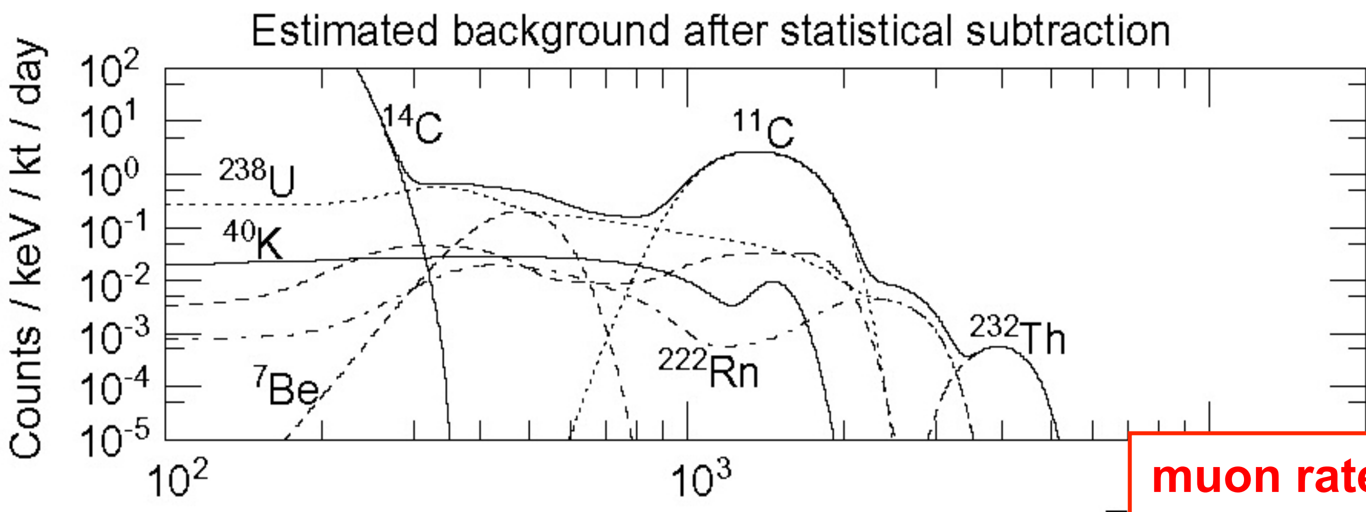
- non-standard interactions
- solar density perturbations
- mass-varying neutrinos
- CPT violation
- large θ_{13}
- sterile neutrino admixture

stat + syst + SSM errors estimated



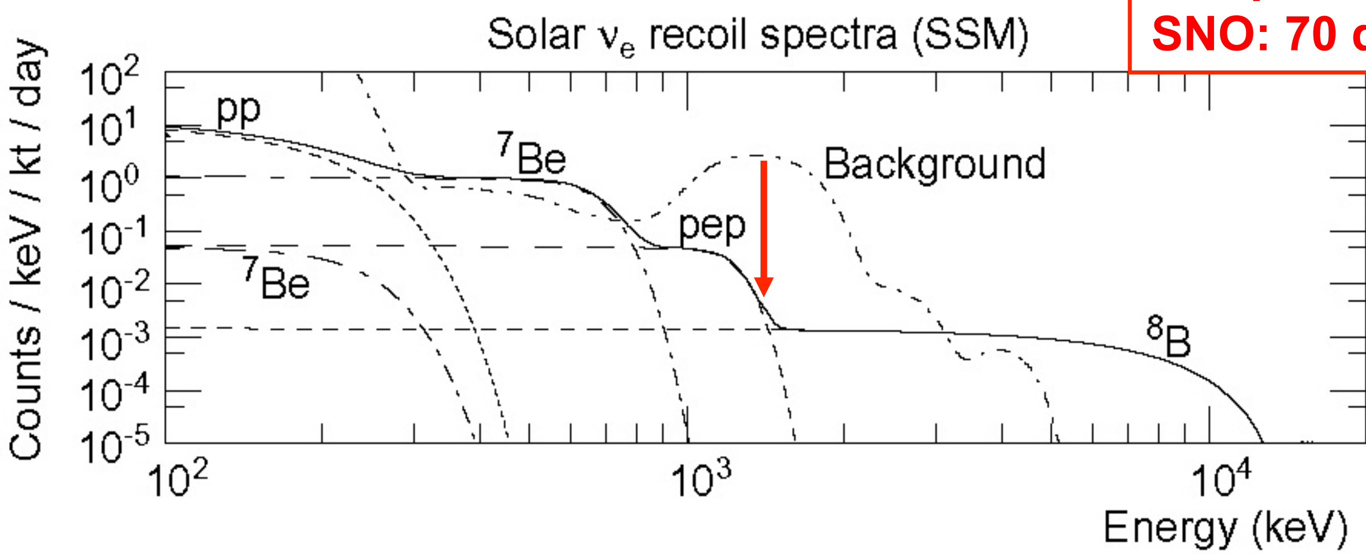
observing the rise in MSW survival probability confirms MSW and that we know what's going on

^{11}C Cosmogenic Background



muon rate in KamLAND: 26,000 d^{-1} compared with SNO: 70 d^{-1}

these plots from the KamLAND proposal



SNOLAB is the only deep site that exists where the *pep* solar neutrinos could be measured *with precision*

Geo-Neutrinos

- can we detect the antineutrinos produced by natural radioactivity in the Earth?

radioactive decay of heavy elements (uranium, thorium) produces antineutrinos

$$\bar{\nu}_e$$

assay the entire Earth by looking at its "neutrino glow"

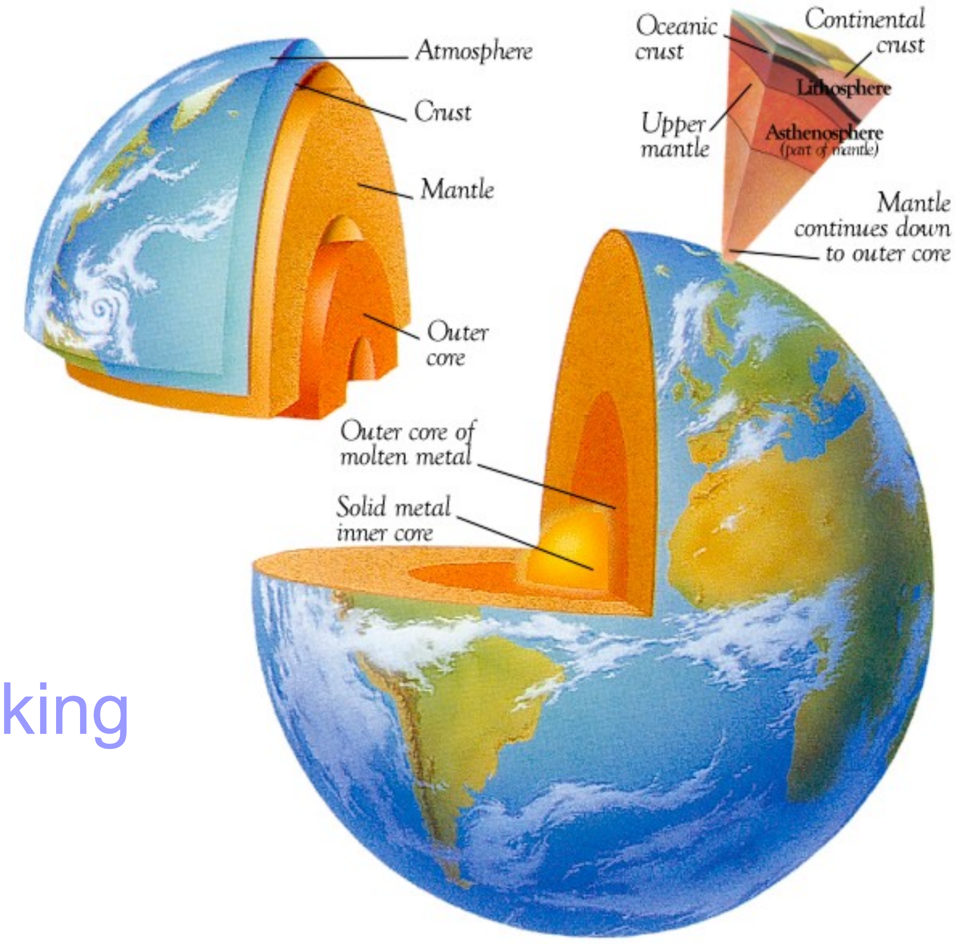
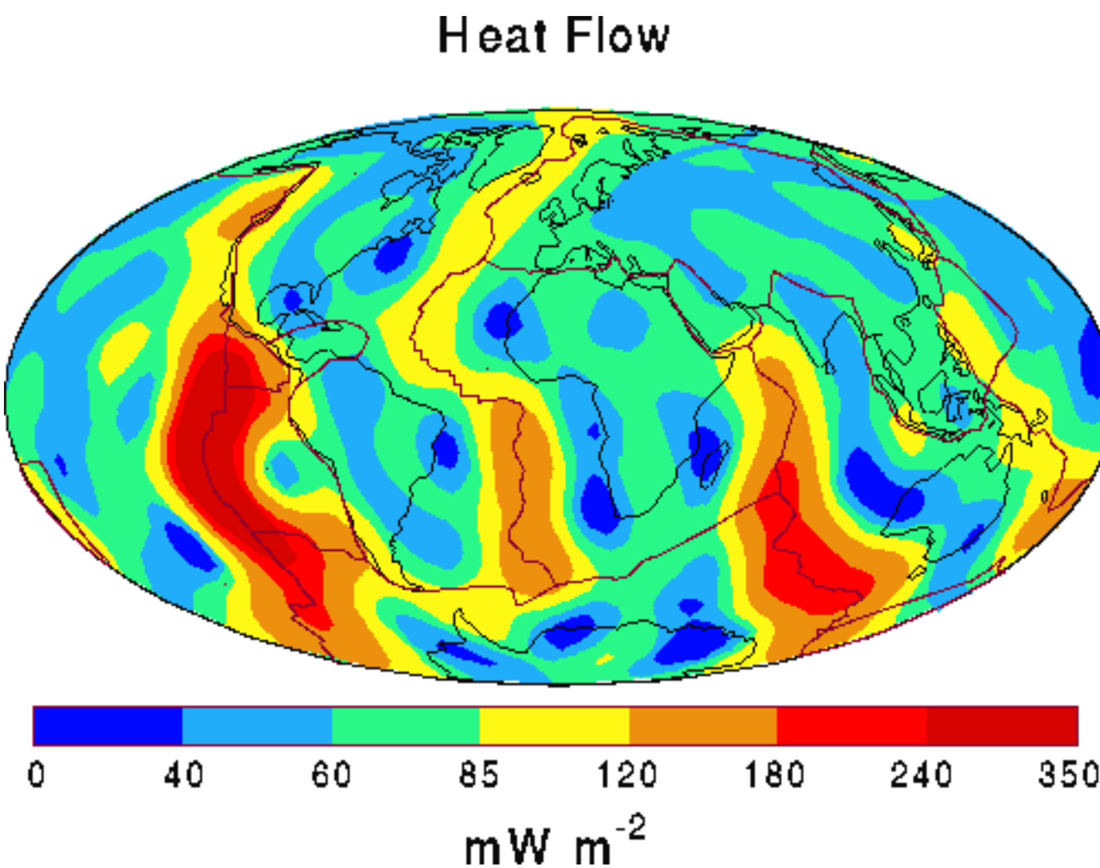


Image by: Colin Rose, Dorling Kindersley

Earth's Heat Flow

- models of Earth's heat sources suggest that radioactivity contributes 40-100% towards Earth's total heat flow

the radiogenic portion is not that well known!



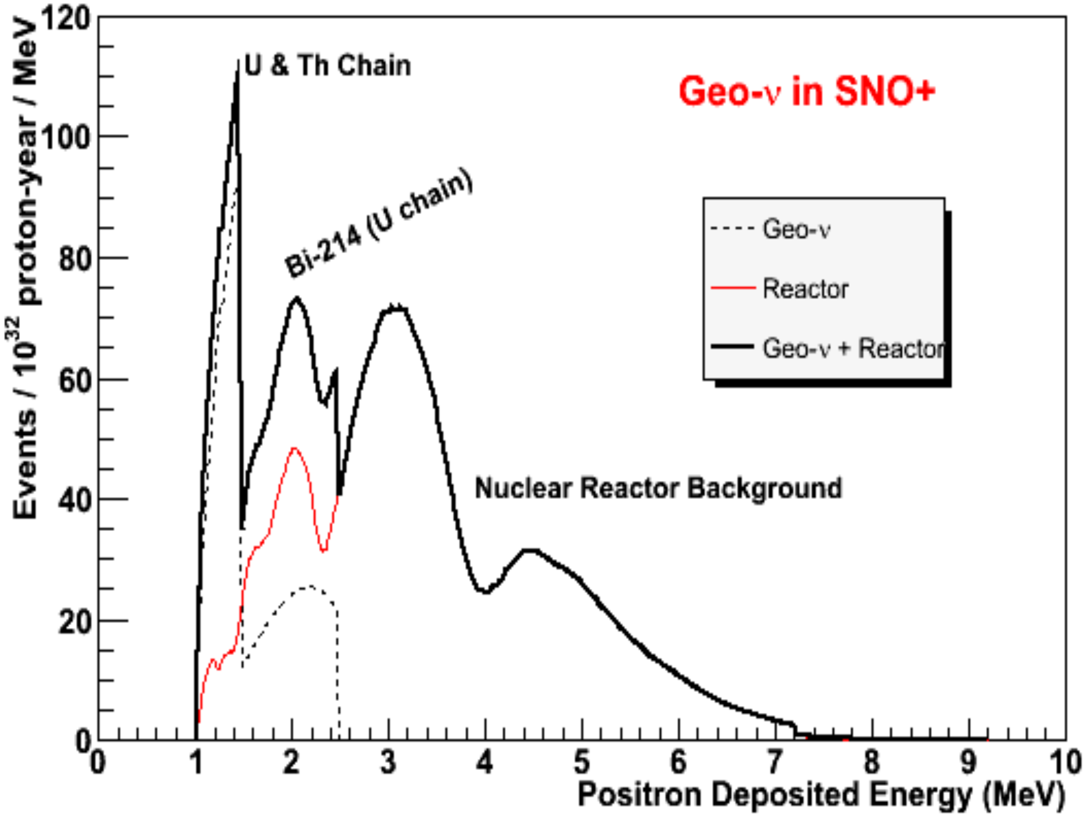
measuring the geo-neutrinos will help us understand radiogenic heat production in the Earth, and hence the Earth's thermal history

Image from H.N. Pollack, S.J. Hurter and J.R. Johnson, *Reviews of Geophysics* **31**(3), 267-280, 1993

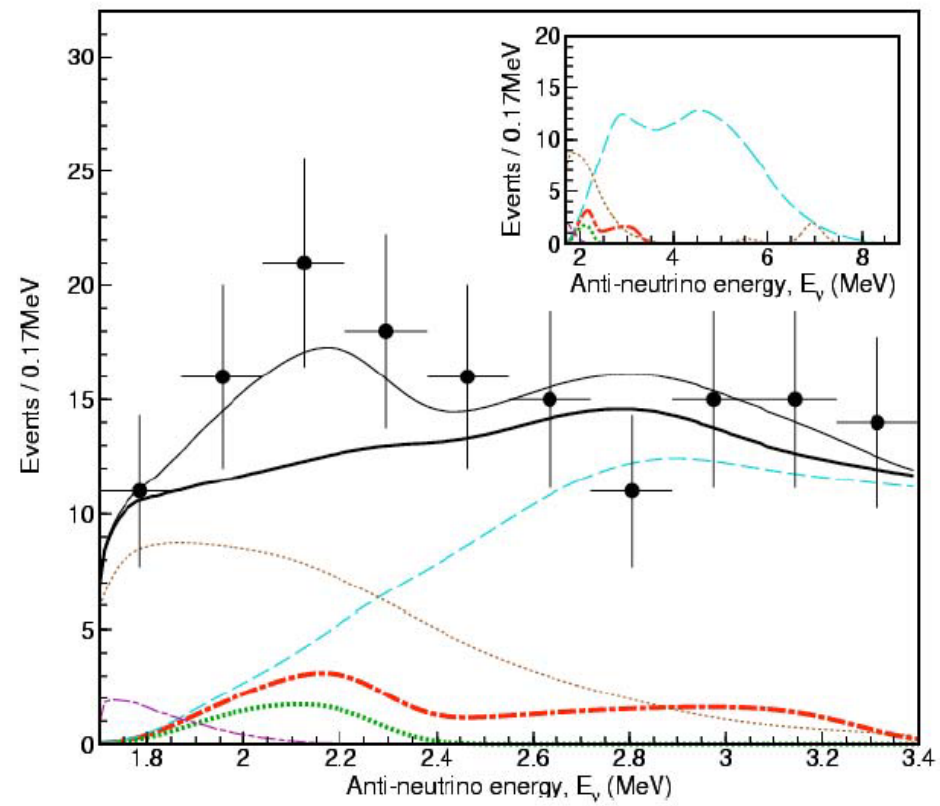
Geo-Neutrino Signal

antineutrino events ($\bar{\nu}_e + p \rightarrow e^+ + n$):

- KamLAND: 33 events per year (1000 tons CH_2) / 142 events reactor
- SNO+: 44 events per year (1000 tons CH_2) / 38 events reactor



SNO+ geo-neutrinos and reactor background



KamLAND geo-neutrino detection…July 28, 2005 in Nature

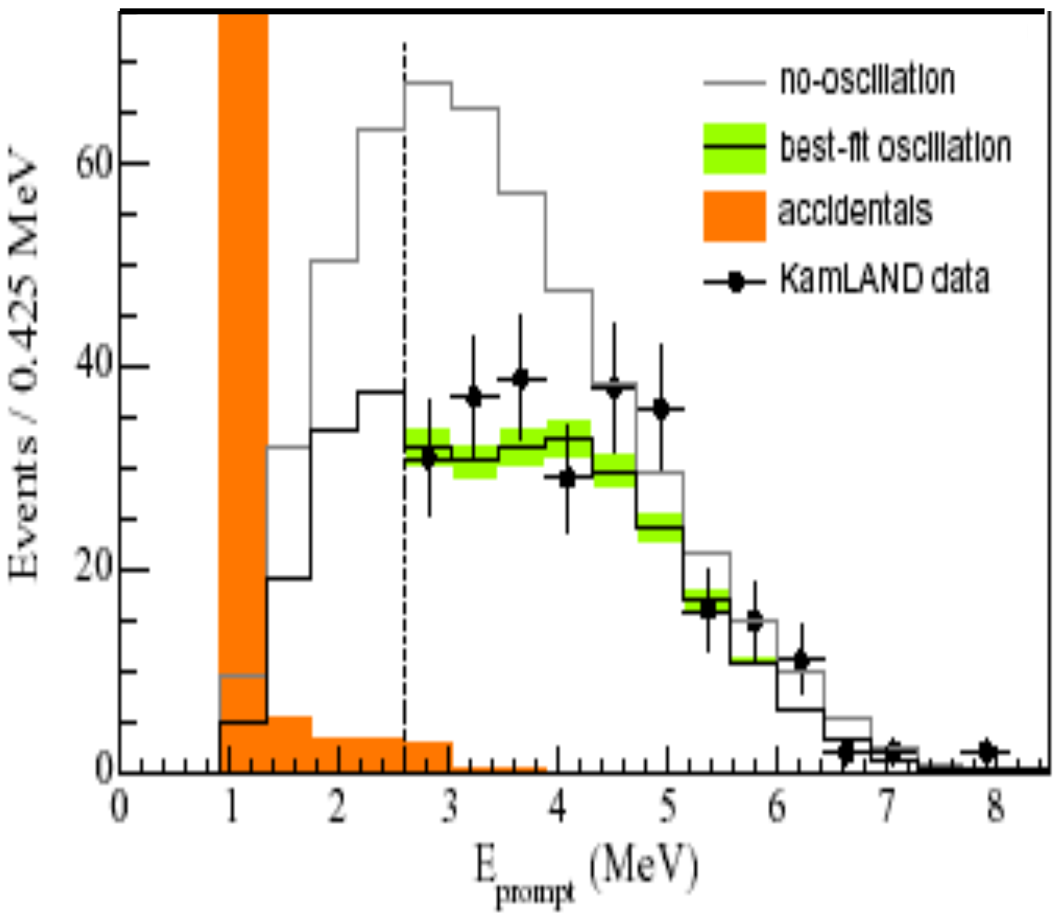
Reactor Antineutrinos

- SNO+ can confirm reactor neutrino oscillations
- an interesting test:
  - move KamLAND's spectral distortion to higher energies by going to a slightly longer baseline

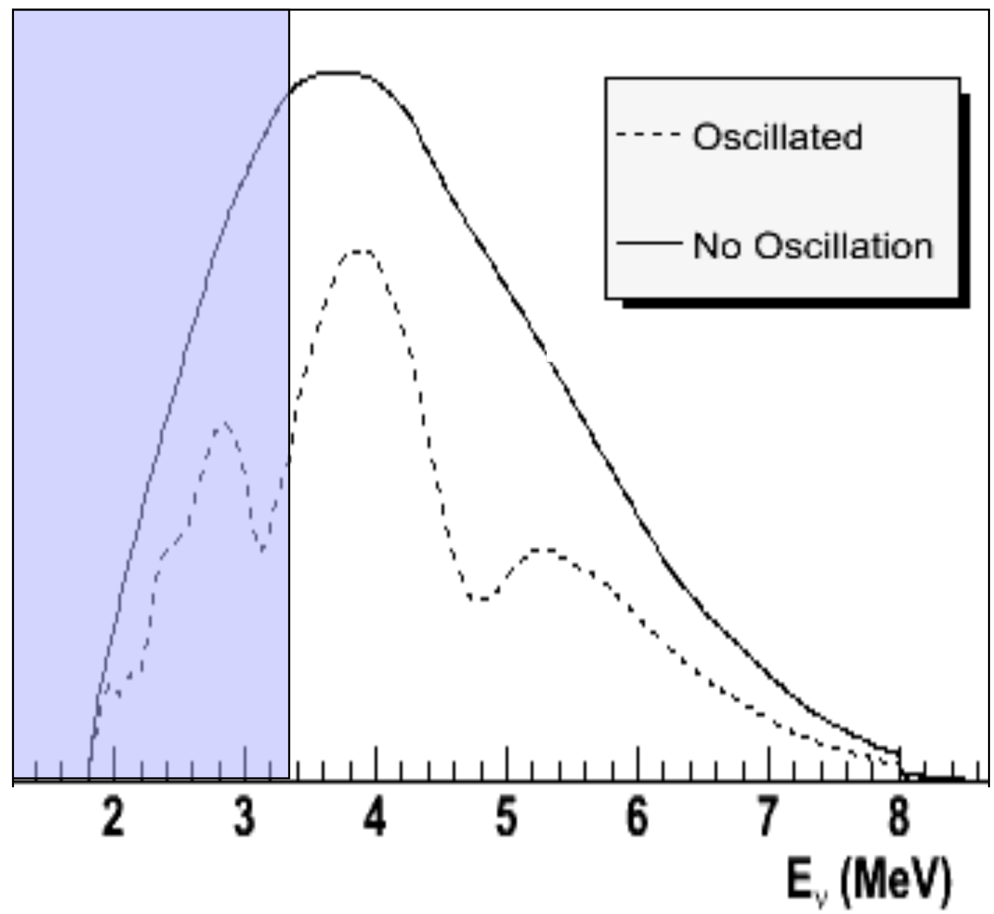
Source	Baseline (km)	SNO+ Rate (/10^{32} protons/yr)
Bruce	240	33
Pickering + Darlington	340	25
Other	>500	60

Oscillated Reactor Spectra

KamLAND



SNO+



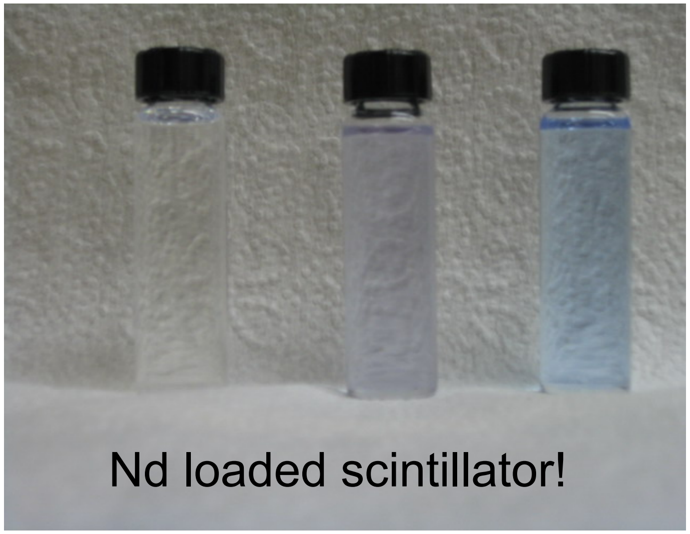
T. Araki *et al.*, hep-ex/0406035 (2004)

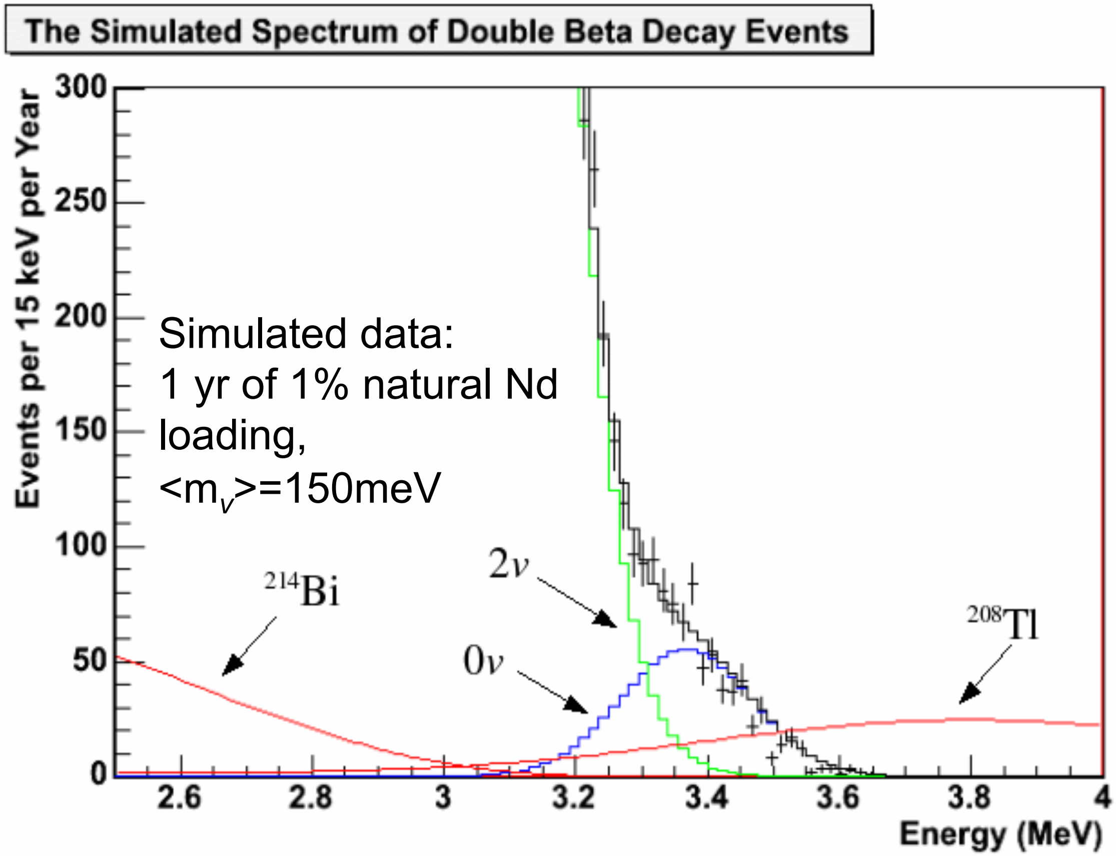
Supernova Neutrinos

- 1 kton organic liquid scintillator would **maintain** excellent supernova neutrino capability
  - $\bar{\nu}_e$ + p (CC) [large rate]
  - $\bar{\nu}_e$ + ^{12}C (CC)
  - ν_e + ^{12}C (CC)
  - ν_x NC excitation of ^{12}C (NC)
  - ν_x + e elastic scattering (NC/CC)
  - $\bar{\nu}_x$ + e elastic scattering (NC)

Double Beta Decay: SNO++

- add ββ isotopes to liquid scintillator
  - dissolved Xe gas (2%)
  - organometallic chemical loading (Nd, Se, Te)
  - dispersion of nanoparticles (Nd_2O_3, TeO_2)

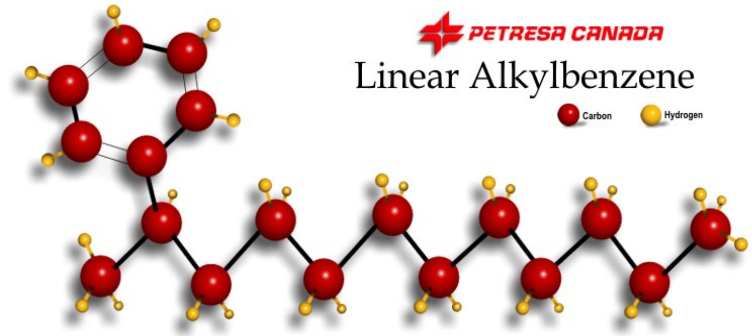




Alex Wright, CAP 2006

← *high statistics helps compensate for the poor energy resolution of liquid scintillator*

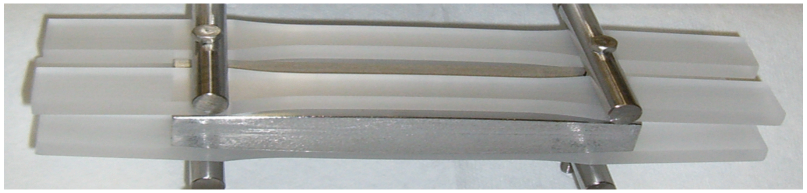
Liquid Scintillator Selected



- linear alkylbenzene
  - compatible with acrylic
  - high light yield
  - pure (light attenuation length >10 m at 420 nm)
  - smallest scattering of all scintillating solvents investigated
  - low cost
  - high flash point
  - low toxicity
  - density $\rho = 0.86\ g/cm^3$

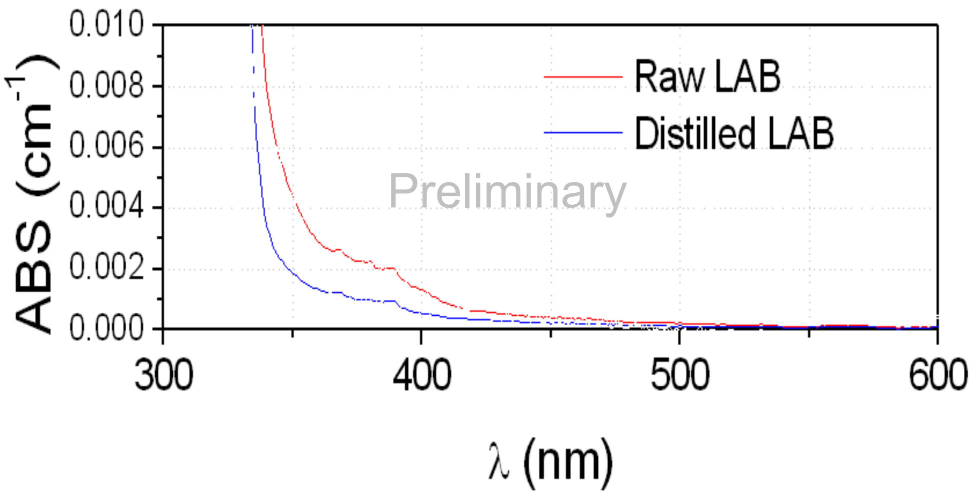
Acrylic Compatibility

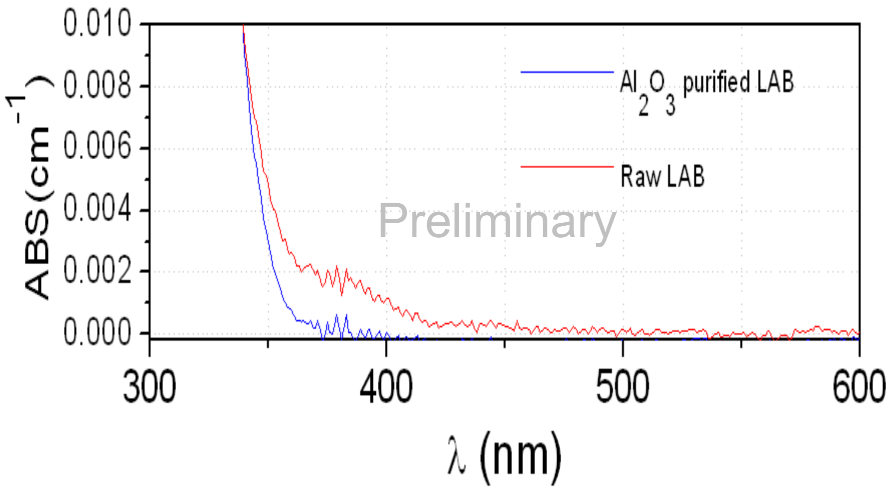
- optical tests
  - look for changes in the LAB/acrylic optical properties after exposure
  - heat accelerated tests underway
- acrylic "dog-bone" tests
  - test for changes in the acrylic bulk modulus and breaking strength
  - no change seen in unstressed acrylic after 5 month's LAB exposure
  - tests with stressed SNO acrylic underway



LAB Purification Tests

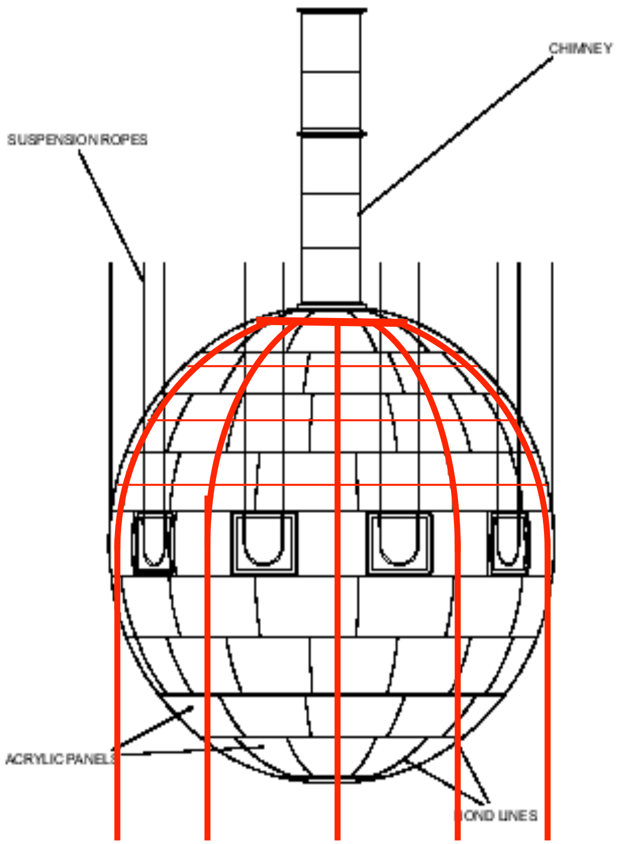
- vacuum distillation
  - single pass Pb reduction by factor >650
  - increased transmission length
- column purification
  - alumina shows high Pb K_d (~4500)
  - increased transmission length

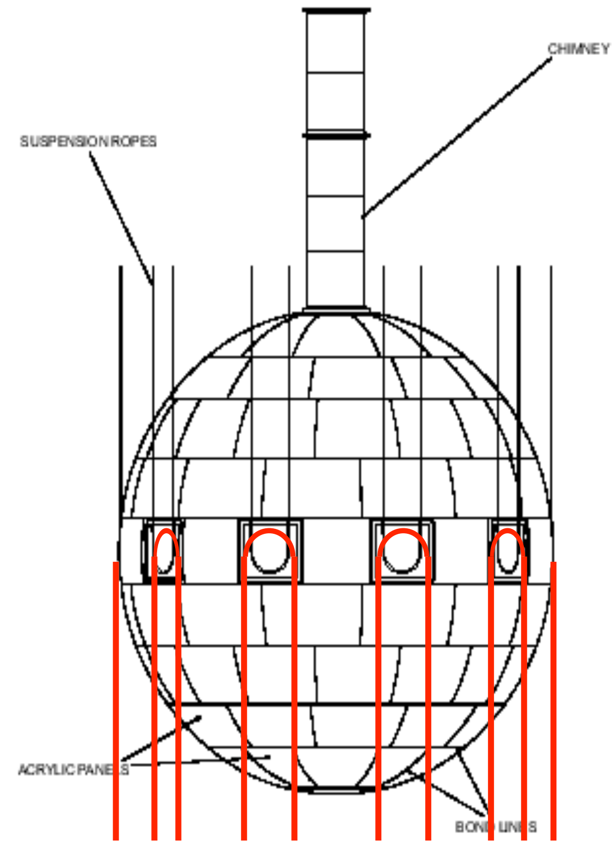




Acrylic Vessel Hold-down

- engineering study validated preliminary designs (rope net and reverse rope grooves)
- full design/installation plan being developed





Moving Forward

- SNO+ has demonstrated "proof of principle"
  - liquid scintillator identified
  - preliminary design to hold down the acrylic vessel
- finalize plans for the conversion
  - process engineering
  - AV mechanics
  - electronics/DAQ
- precisely estimate SNO+ physics potential
- prelim TDR by Fall 2006
- proposals to some agencies by Fall 2006

SNO+ Collaboration

Queen's

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K. Zuber

only a subset of the SNO collaboration will continue with SNO+

- potential collaborators from outside SNO (Italy, Germany, USA) have indicated some interest