SNO+ Status Report

Alex Wright,
Queen's University
for the SNO+ Collaboration

Introduction to SNO+

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

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

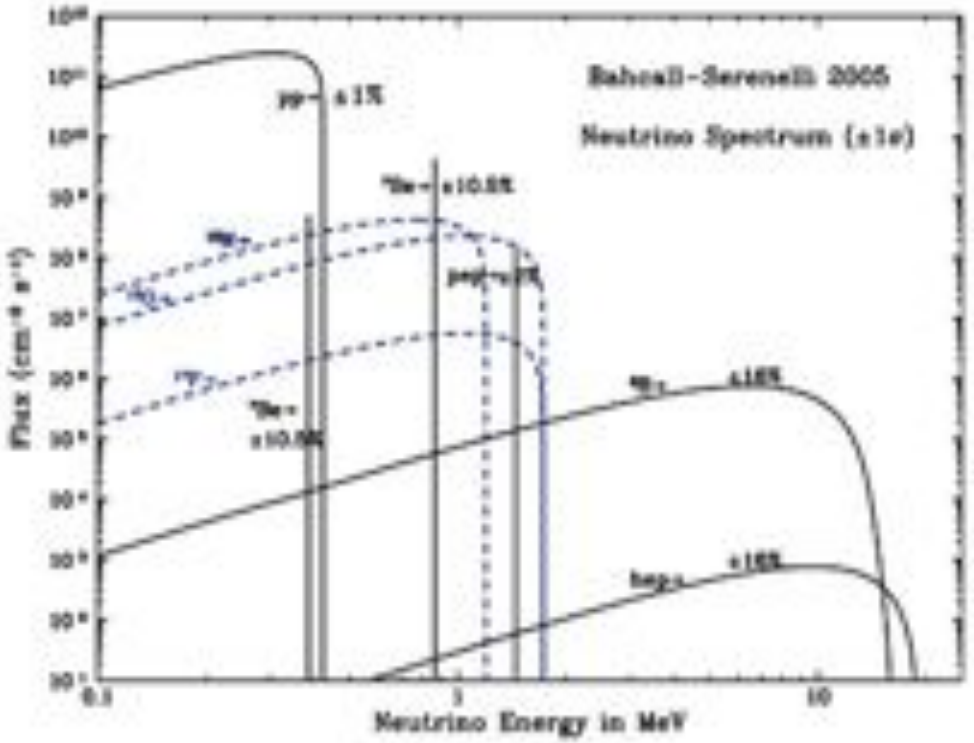
$${}^{2}H + p \rightarrow {}^{3}He + \gamma$$

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

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

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

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



CNO Cycle

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

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

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

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

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%

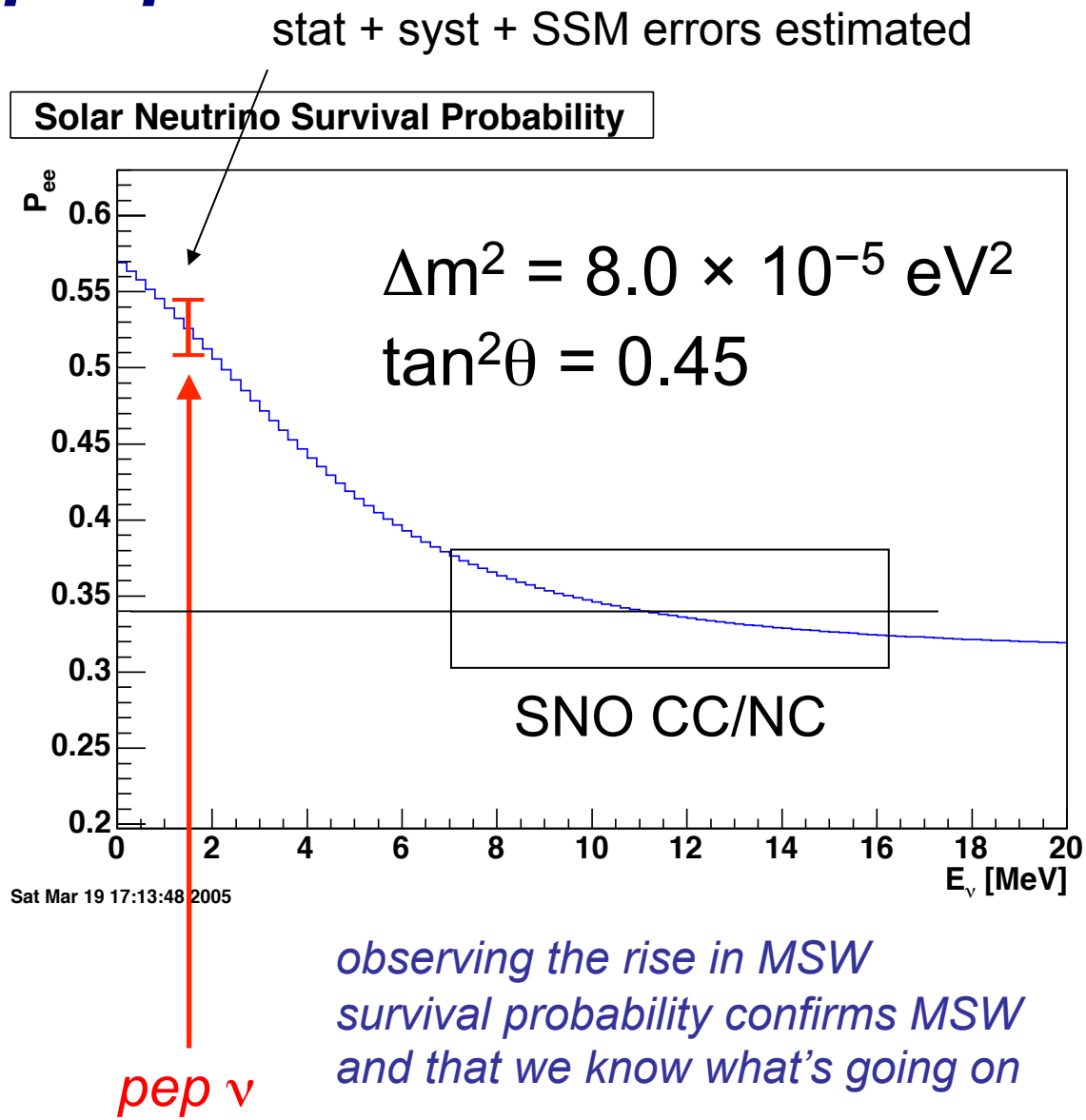
High statistics + known source

→ precision test

improves precision on θ_{12}

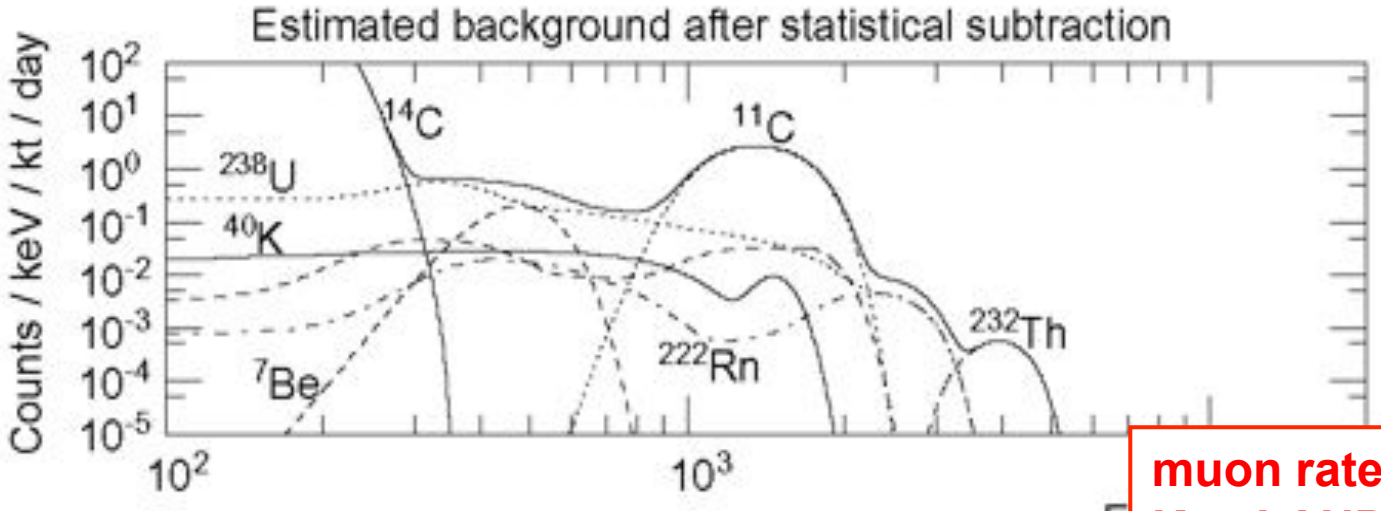
sensitive to new physics:

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



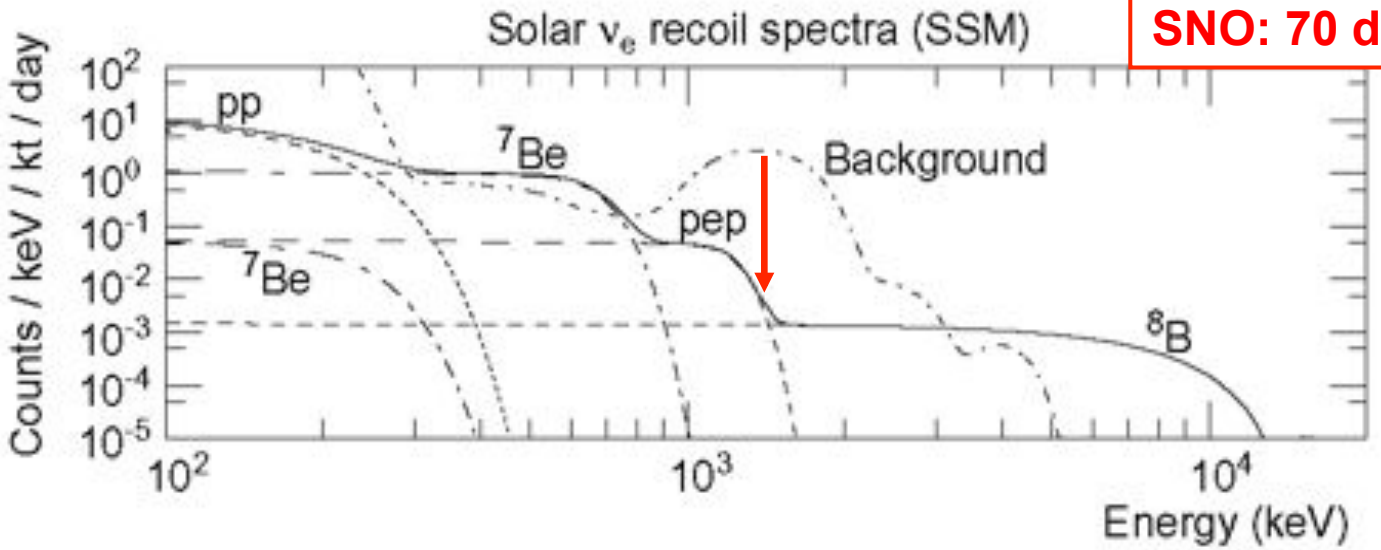
observing the rise in MSW survival probability confirms MSW and that we know what's going on

^{11}C Cosmogenic Background



these plots from the KamLAND proposal

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



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”

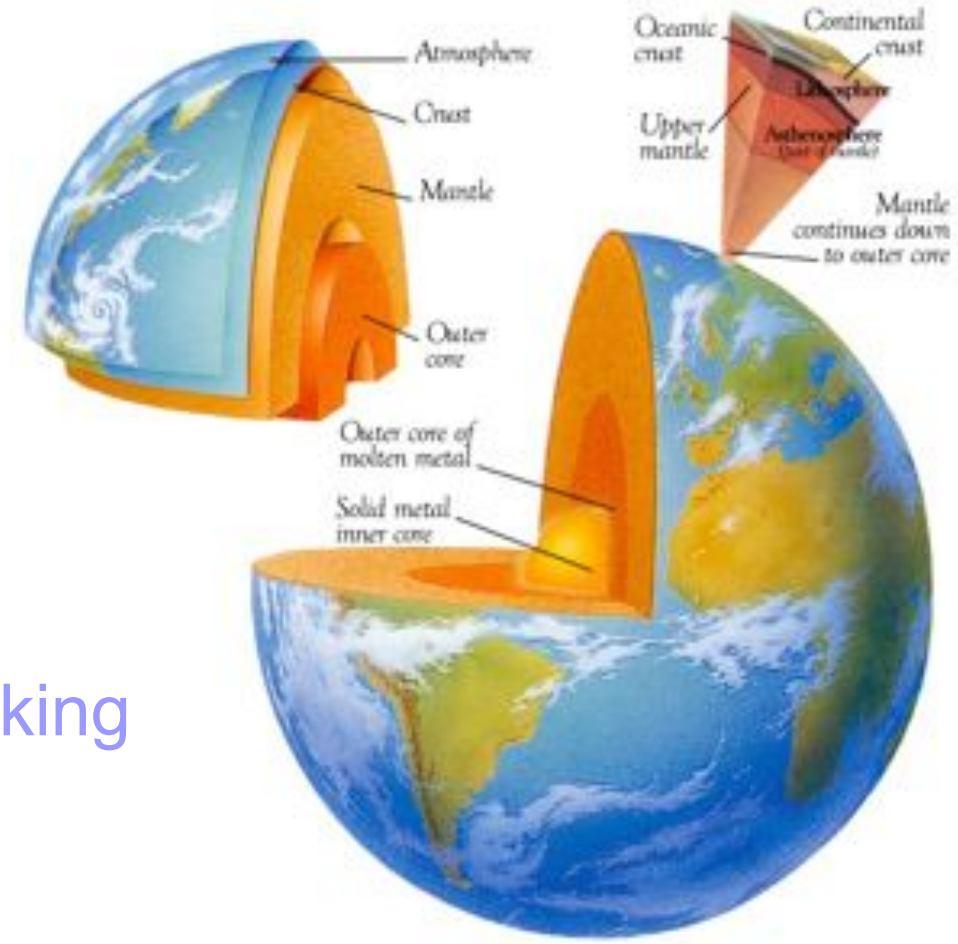
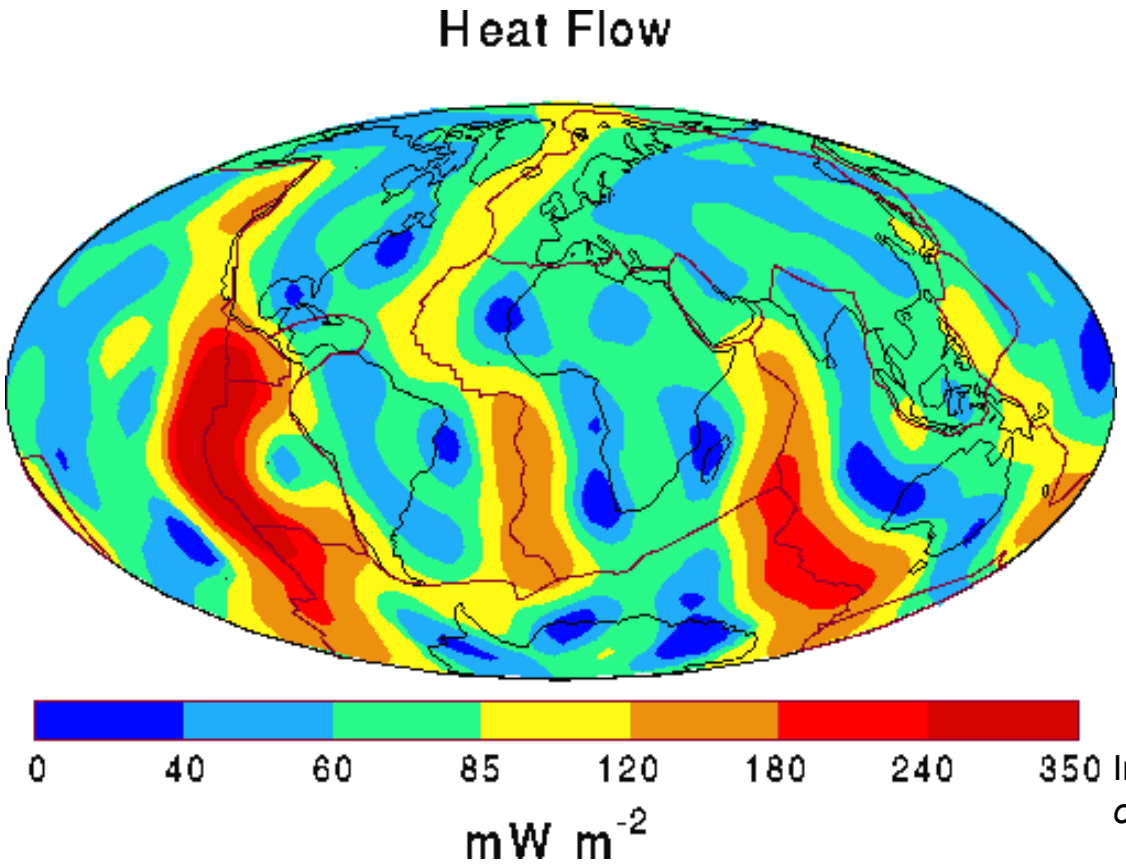


Image by: Colin Rose, Dorling Kindersley

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!



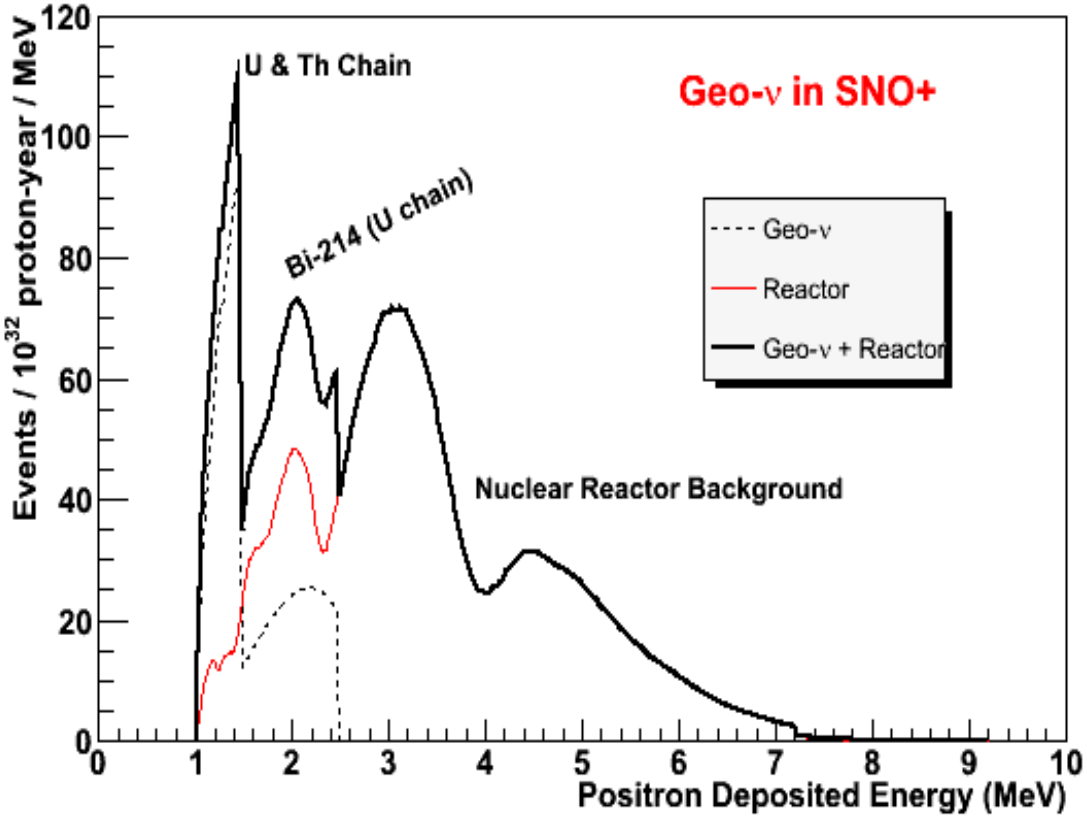
measuring the geo-neutrinos will help us understand radiogenic heat production in the Earth, and hence the Earth's thermal history

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

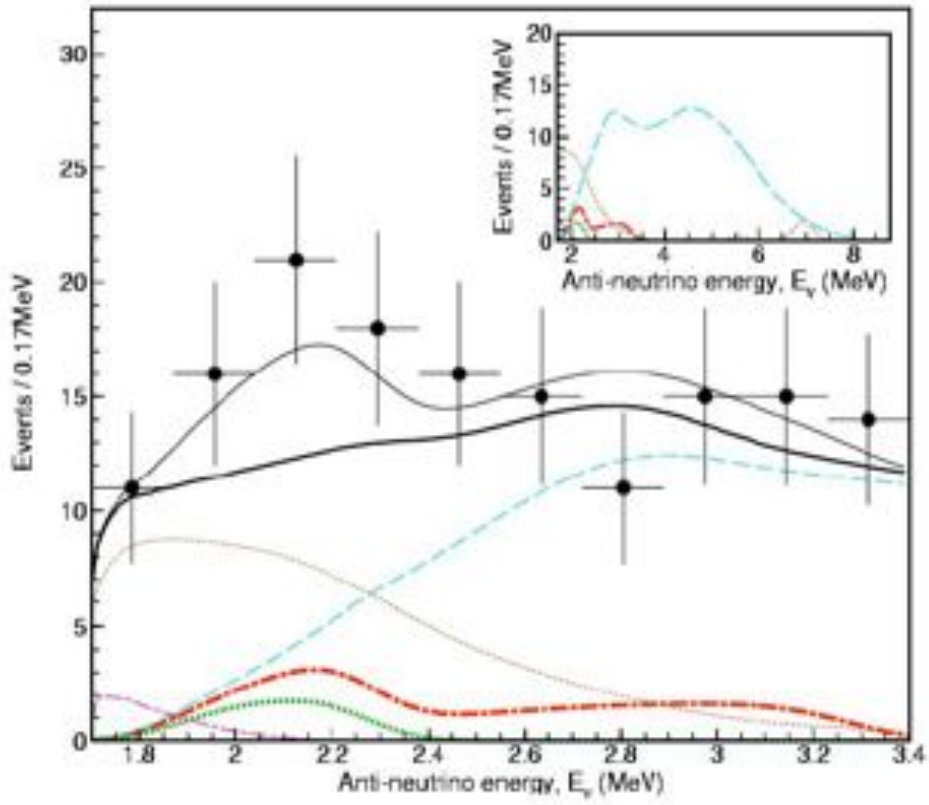
Geo-Neutrino Signal

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

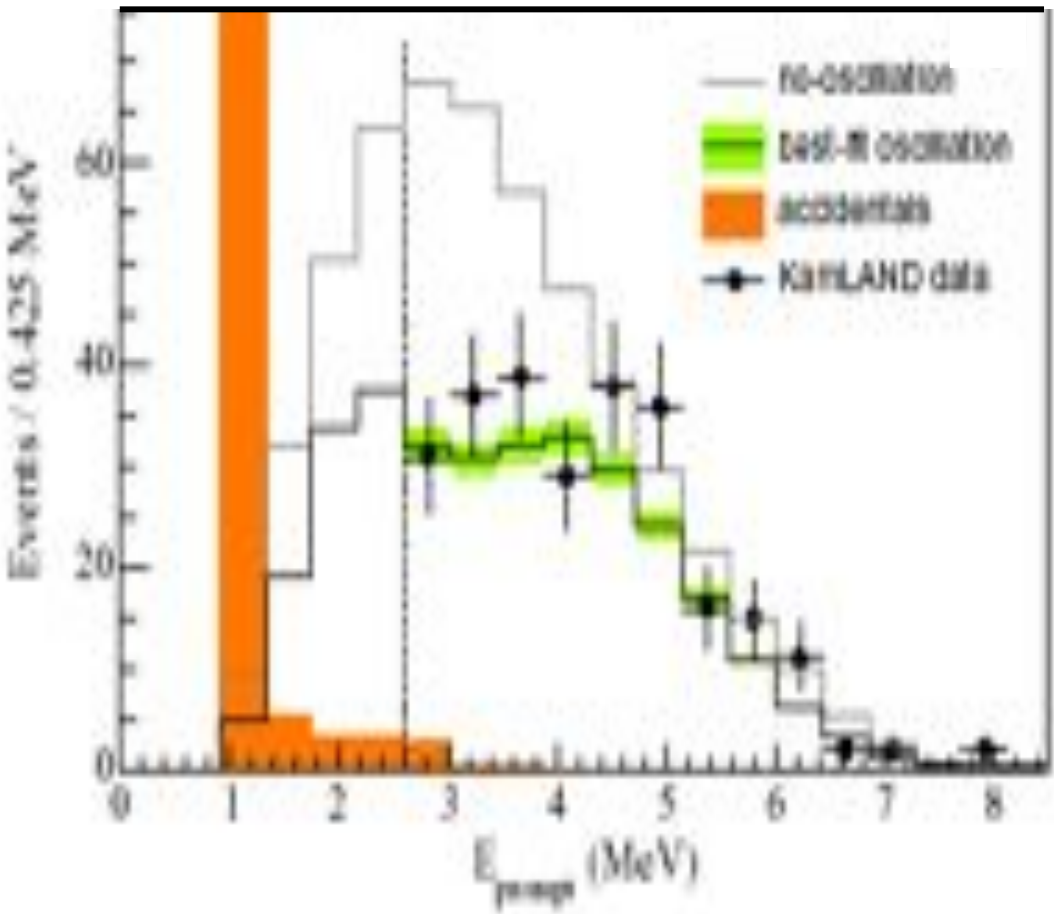
Reactor Antineutrinos

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

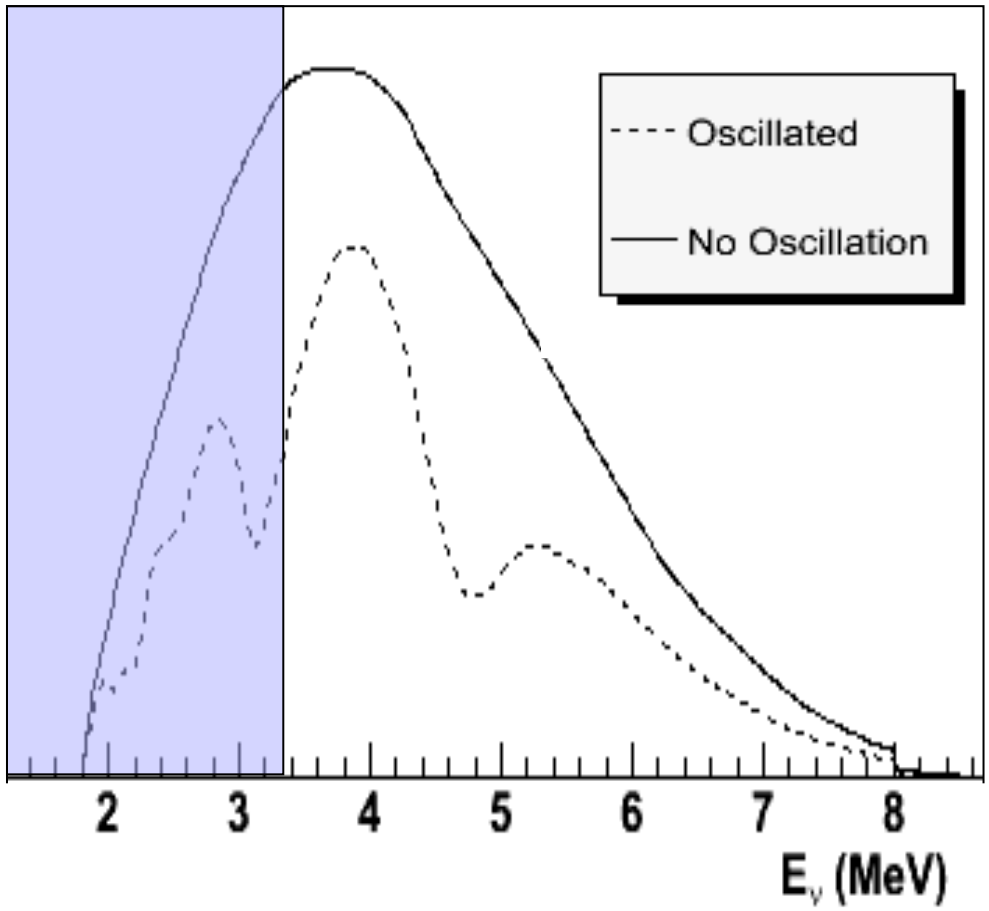
Source	Baseline (km)	SNO+ Rate (/10^{32} protons/yr)
Bruce	240	33
Pickering + Darlington	340	25
Other	>500	60

Oscillated Reactor Spectra

KamLAND



SNO+



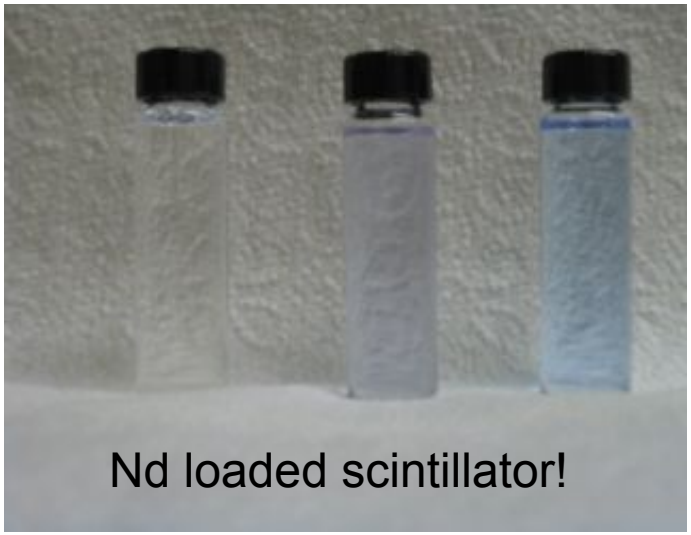
T. Araki *et al.*, hep-ex/0406035 (2004)

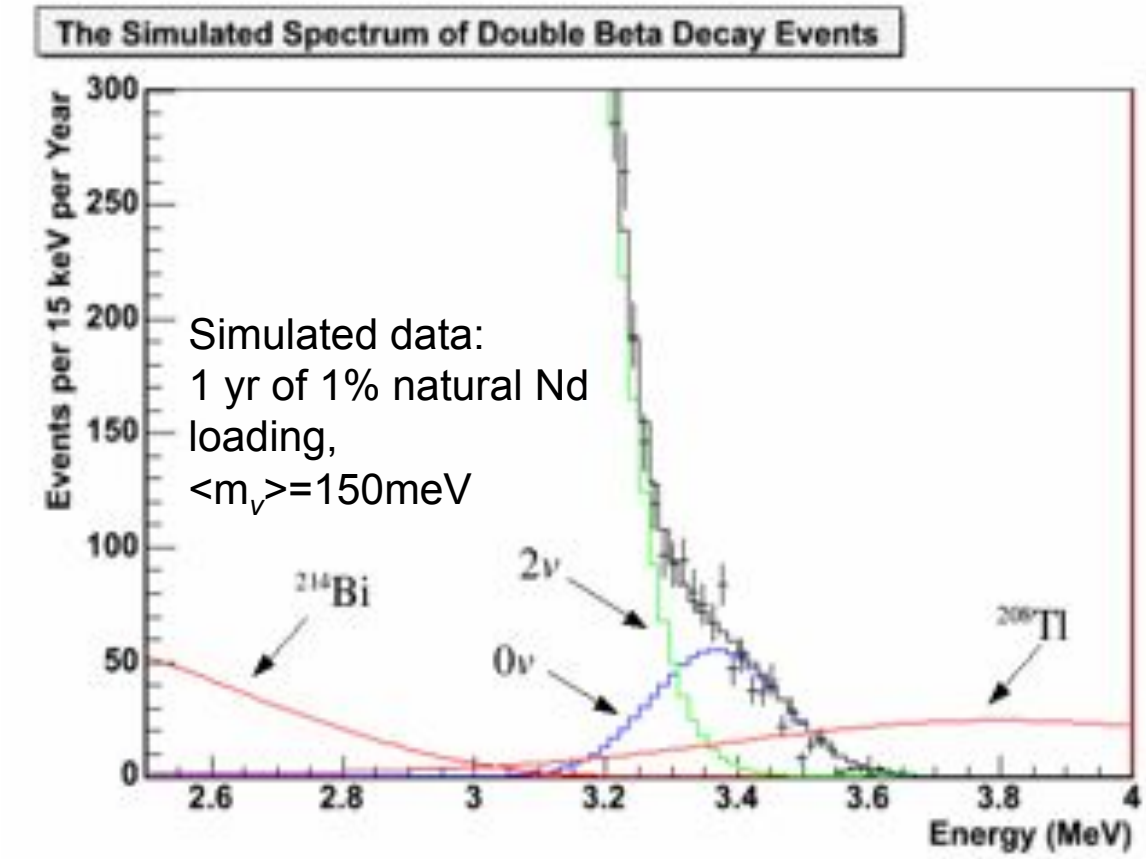
Supernova Neutrinos

- 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)

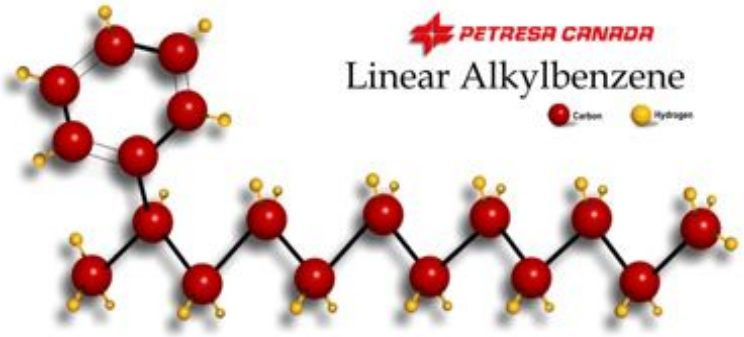




← *high statistics helps compensate for the poor energy resolution of liquid scintillator*

Alex Wright, CAP 2006

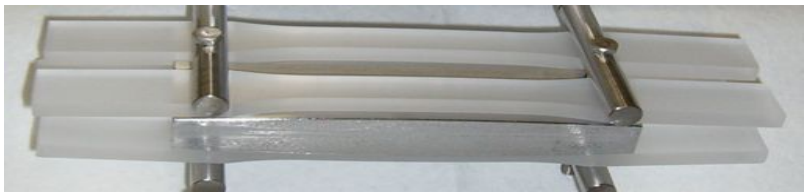
Liquid Scintillator Selected



- 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 ρ = 0.86 g/cm^3

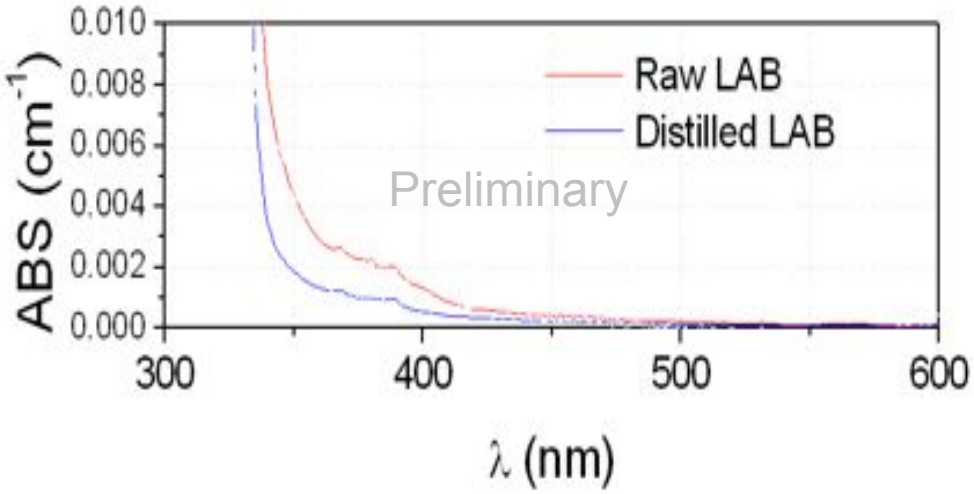
Acrylic Compatibility

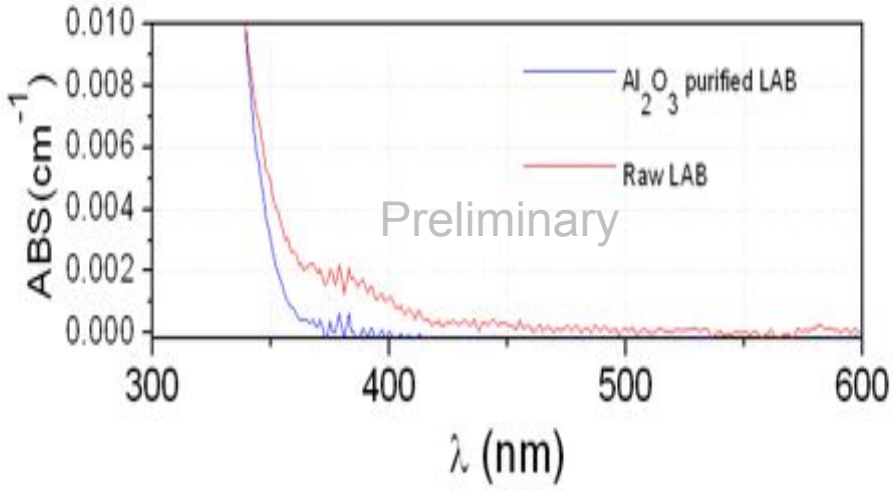
- optical tests
  - look for changes in the LAB/acrylic optical properties after exposure
  - heat accelerated tests underway
- acrylic “dog-bone” tests
  - test for changes in the acrylic bulk modulus and breaking strength
  - no change seen in unstressed acrylic after 5 month’s LAB exposure
  - tests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



LAB Purification Tests

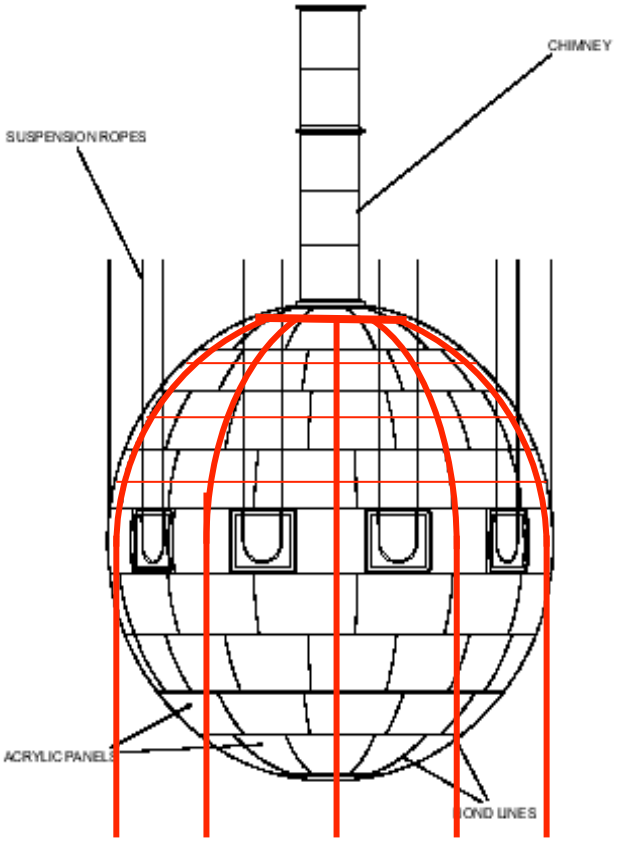
- vacuum distillation
  - single pass Pb reduction by factor >650
  - increased transmission length
- column purification
  - alumina shows high Pb K_d (~4500)
  - increased transmission length





Acrylic Vessel Hold-down

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



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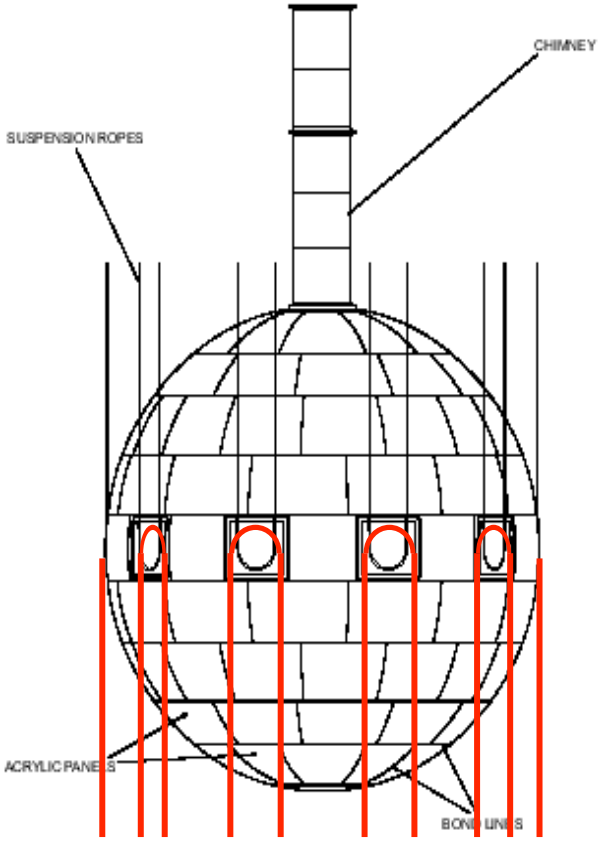

Moving Forward

- 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

M. Chen, M. Boulay, X. Dai, K. Graham, E. Guillian, A. Hallin, P. Harvey, C. Hearns, C. Kraus, C. Lan, A. McDonald, V. Novikov, S. Quirk, P. Skensved, A. Wright

Laurentian

D. Hallman, C. Virtue

Trent

J. Jury

SNOLAB

B. Cleveland, F. Duncan, R. Ford, I. Lawson

Brookhaven National Lab

D. Hahn, M. Yeh

University of Texas

J. Klein

LIP Lisbon

J. Maneira

University of Sussex

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