STATUS OF THE SNO+ EXPERIMENT

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Outline

- The SNO+ detector
- Science goals
SNO (SNO+) detector

- Located in the Vale Inco Ltd. Creighton Mine near Sudbury, Canada
  - 1 kton D$_2$O held in 12 m diameter acrylic vessel, to be replaced with Nd doped liquid scintillator
  - 18 m diameter support structure holds 9500 PMTs (~60% photocathode coverage)
  - 1.7 kton inner shielding H$_2$O
  - 5.3 ktons outer shielding H$_2$O

Depth: 2092 m (~6010 m.w.e.)
Liquid scintillator

- We will use linear alkylbenzene (LAB) with PPO
  - safe: high flash point, low toxicity
  - low cost!

- List of things studied in bench top measurements
  - acrylic compatibility
  - light yield ~12,000 photons/MeV
  - attenuation length
  - comparison of scattering length
  - LAB-PPO energy transfer efficiency
  - scintillation lifetime
  - alpha/beta pulse shape discrimination
  - quenching and Birks constant
  - metal-loading
Scintillator “bucket” test

- Last year we deployed a “bucket” of scintillator in the SNO detector filled with water
  - measured alpha quenching and Birks constant
  - confirmed scintillator light yield
  - tested position reconstruction (bucket deployed at different $z$-positions)
  - compared scintillator timing to benchtop
  - tested PSD for alpha-beta discrimination
Bucket deployment: Birks constant

Runs 70771 - 70779

phototube hits

number of counts

$\times 10^3$

phototube hits

Birks’ law (kB=73.2 microns/MeV)

Data

Energy (Mev)
Hold down net

- $D_2O$ is denser than $H_2O$, liquid scintillator is less dense, therefore instead of supporting the acrylic vessel from the top, we will have to hold it down.
- SNO+ will use Tensylon rope basket to hold AV down.
- Tensylon has low $U$, $Th$, $K$.
- Finite element buckling calculations showed
  - extreme case with empty AV surrounded by water outside: does not buckle
  - normal operating conditions maximum equivalent stress in vessel was 538.5 psi and is less than “crazing limit”
Science goals

- Search for neutrinoless double-beta-decay.
- Neutrino physics:
  - Solar neutrinos
  - Geo antineutrinos
  - Reactor antineutrinos
  - Supernova neutrinos
Neutrinoless double-beta-decay

- This is the best probe we have to determine if the neutrino and antineutrino are the same particle, a “Majorana” particle.
- A positive result would demonstrate lepton number violation.
Double-beta-decay in SNO+

50% fiducial volume
75% livetime

- Add 1000 kg Nd (56 kg of $^{150}\text{Nd}$) to liquid scintillator.
- “Economical” way to build a detector with a large amount of isotope.
- Ultra-low background (phototubes stand off from the scintillator, self-shielding of fiducial volume).
- Possibility to purify in-situ to further reduce backgrounds.

* H.V. Klapdor-Kleingrothaus and I.V. Krivosheina
56 kg of $^{150}$Nd and $\langle m_\nu \rangle = 100$ meV

6.4% FWHM at Q-value
3 years livetime
Solar neutrinos: pep

- Tests transition from vacuum to matter oscillations.
- Gives essentially the same information as the pp neutrinos, thus measures total solar neutrino flux.

Solar metallicity

In 2005 a new measurement of solar metallicity resulted in a lower value than previous measurements.

This new lower metallicity broke the previous excellent agreement between solar model calculations and helioseismology.

arXiv:0909.2668
## Solar neutrinos: CNO

### Solar model assumptions:
- Initial core metallicity fixed to today’s surface abundance
- Sun is homogeneously mixed, no substantial mass loss or accretion

- Haxton proposed metal depletion during planet formation causing different solar core and surface metallicity.
- CNO neutrinos can measure the metallicity of the core.

<table>
<thead>
<tr>
<th>Source</th>
<th>Old metalicity</th>
<th>New metalicity</th>
<th>Diff.</th>
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<td>pp</td>
<td>5.97</td>
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<td>pep</td>
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<tr>
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<td>$^{13}$N</td>
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<tr>
<td>$^{15}$O</td>
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<tr>
<td>$^{17}$F</td>
<td>5.82</td>
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</table>

BPS08 solar model:
Peña-Garay and Serenelli
arXiv:0811.2424
pep and CNO neutrinos in SNO+

- Main background from cosmogenic production of $^{11}$C, which has a 20 min half-life.
- 6000 mwe depth reduces muon flux
  - ~700 times lower than Kamioka
  - ~100 times lower than Gran Sasso
- Depths reduces $^{11}$C background in two ways:
  - Reduced $^{11}$C production
  - Vetoing after muons easier

- SNO+ could extract CNO with ±6% uncertainty in three years

figure from KamLAND
Reactor antineutrinos in SNO+

- Reactor energy spectrum allows for measurement of neutrino oscillations parameters $\Delta m^2$ and $\theta_{12}$.
- Average baseline $\sim 4$ times that of KamLAND and neutrino flux is $\sim 1/5$ that of KamLAND.
- Despite lower flux observation of multiple oscillation peaks allows for approximately equal sensitivity to $\Delta m^2$ as KamLAND.

Eugene Guillian
arXiv:0809.1649
Geo antineutrinos

- The estimated radiogenic heat produced is 19 TW is inconsistent with total heat flow from Earth and/or models of mantle convection.
- Geoneutrinos allow us to measure the radiogenic heat production.
- Geoneutrinos have been observed at KamLAND, but the statistics were limited by the high background from reactor antineutrinos.
- SNO+ has 1/5 the reactor background.
- The two measurements would be somewhat complementary due to the different nature of the crust surrounding SNO+ and KamLAND.
We have funding for the major upgrades necessary. Hopefully, SNO+ will start operation in 2011. We will operate for a short period without Nd added to the scintillator in order to understand our detector. This will not be long enough for a precise solar physics result. We will then add Nd and begin the double-beta-decay phase. We can do antineutrino physics during this phase but not solar neutrino physics. We could return to solar a phase after we have completed the double-beta-decay phase. SNO+ should be able to contribute to a broad range of physics.
Supernovae detection

- Observe ~200 neutrinos from a supernova via proton scattering.
- This process would be the only model independent method capable of determining the total energy and $\nu_x$ temperature.

Total energy $2 \times 10^{53}$ ergs at 10 kpc.