SNO+ experiment

IPP townhouse meeting during 2017 CAP
Sunday, May 28th 2017
Christine Kraus
Outline

- SNO+
- Highlights last year
- Water phase data taking
- Te loading

Several SNO+ talks/posters during CAP – Tu, We
SNO+ experiment

- 780 tonnes of liquid scintillator as active volume
  - Can be loaded with double beta decay isotope
- ~9500 PMTs
- 1500 + 5300 tons ultra-pure water shielding
- 6800’ underground in SNOLAB

Organic scintillator Linear Alcyl Benzene (LAB) and PPO
Add 130Te and as loading for double beta phase
Physics goals - scintillator

- Neutrinoless Double Beta Decay
- Low Energy Solar Neutrinos
- Reactor Antineutrinos
- Geo-Neutrinos
- Supernova Neutrinos
In addition – external background analysis
Use time to circulate, clean and cool ...

Also looking at anti-neutrino analysis and
Detector is supernova life ...

5.5 m fiducial volume cut
Sun directional cut
Several month of data needed

Nucleon decay:
- Many visible channels ruled out
- SNO+ sensitive to invisible channels
  \[ n \rightarrow \nu \bar{\nu}, \quad p \rightarrow \nu \bar{\nu} \]
- \[ {^{16}}O \rightarrow {^{15}}N^* \rightarrow \gamma \]
- \[ {^{16}}O \rightarrow {^{15}}O^* \rightarrow \gamma \]
- Predicted by many standard model extensions, eg. GUT, SUSY

Understand Energy Scale with \(^{16}\text{N}\) Calibration Source

[1] I. Coulter, SNO+ Collaboration
Below 10’ – **2 leaks** - significant
[10’ to 20’ – area with 3 safety patches]
**20.7’** – most significant leak

20’ to 30’ – **1 leak**, 4 holes (safety patches)
30’ to 40’ – 3 holes (safety patches)
40’ to 56’ – **2 leaks**, 2 safety patches
Aug 2016 - workshop
Oct 2016 - UI
Nov 2016 – neck fill
Nov 28th - shifts
Feb 2017 – DCR
May 04th – water phase
Apr/May – central axis
May – assay prep
Preparation – complete work on deck (resistor replacement from PMT repairs)

November 2016 – installed 370 feed resistors

924 PMTs not usable at the end of SNO, this number is now 348

Start November 28th 2016 – exactly 10 years after last day of SNO data taking

SNO  ↓  SNO+
December 2016 to mid February

Trained 45 detector operators
Currently Taking Data (~24/7 shifts)

First neutrino candidate: 2017-02-05, upward-going, no outward-looking PMTs triggered

Electronics working well
Drive tests laser ball – April 2017 – PSUP mounted camera system

Timing

Also fibers mounted on PSUP
N16 data - preliminary

Data taken last Wednesday, less than 24 h later:

MN Hit

MC has more low NHit events

Looks quite good

Measured in SNO+ water at center.

Run 100934
2017/05/25

Entries: 87915
Mean: 33.33
RMS: 7.434
chi^2 / ndf: 89.75 / 20
Prob: 8.19e-021
Constant: 4721 ± 23.3
Mean: 32.51 ± 0.04
Sigma: 2.460 ± 0.045
40 mT LAB arriving on site – Nov 2016
SNOLAB Gateway 3A.2 Review in January 2017
recommended actions being closed out
successfully completed plant commissioning using water last year
Tellurium Purification for SNO+

Very low backgrounds are achievable in large liquid scintillator detectors

- Dominant background from solar neutrinos!
- Sensitivity scales directly with loading

Two main classes of Te intrinsic background:

- “Standard” decay chains of long-lived radioisotopes
  - Need $10^{-14}$-$10^{-15} \text{g/g}$ for $^{238}\text{U}$, $^{232}\text{Th}$, “raw” tellurium has $\sim 10^{-12} \text{g/g}$
- Some Te cosmogenics have longish half-lives and decays that overlap the $0\nu\beta\beta$ energy region (e.g. $^{60}\text{Co}$, $^{22}\text{Na}$, $^{102}\text{Rh}$, $^{110m}\text{Ag}$)

Need a purification technique that separates other metals from tellurium at the $10^4$-$10^6$ level

- Additional safety factor from underground TeA storage and purification
Te acid purification

2016 Review

Jan 2017 start of plant construction

Dec 2016 – pre-treatment area cleared

\[
\text{Te(OH)}_6 \quad \text{Insoluble} \quad \text{Te(OH)}_5\text{O}^- + \text{H}^+ \quad \text{soluble}
\]

Cobalt removal by multi-pass purification
Te acid purification plant - status

Design

Feb 2017 – steel structure

May 2017 – all trays, many vessels

May 2017
Compare: goal of 0.1 ppt U and <0.05 ppt Th in purified TeA. Other measured metals (relevant for cosmogenics) lower than Ca and Fe, <0.1 ppb goal.

**Vessels meet our purity requirements!**

Further cleaning/leaching with nitric acid after installation will provide additional safety factor.
large natural isotopic abundance 34% for $^{130}\text{Te}$

- 0.3% Te (by weight) in SNO+ is 2.34 tonnes of Te or 800 kg of $^{130}\text{Te}$ isotope
- SNO+ phase I will be 0.5% Te loading corresponding to 1,300 kg of isotope

3.8 tonnes of Te(OH)$_6$ or 2.1 tonnes Te

Corresponding to ~0.26% loading are stored UG (cooling)

“Condensation reaction” produces organometallic compound miscible in LAB.

Butanediol

Telluric Acid

“BOILING” Diolization

$+ 6 \text{H}_2\text{O}$
Scale-up path

- 8 g – principle
- 160 g – systematic study
- kg order batches
- Final plant 250 kg batch

Design – final plant

R&D program
Purification
Stability
Acrylic compatibility
Extraction
Improvements
Amine

Improve stability and light yield

~2x better light yield for New 3%Te-LS

empty viel
LS_3gl_PPO_15mgL_MSB
3%_Te_3%_PPO_3gl_PPO_15mgL_MSB
3%_Te_Diol_3.5gl_PPO_17.7mgL_MSB
0.5%_Te_Diol_3.5gl_PPO_17.7mgL_MSB
0.5%_Te_Acid(1) and Amino(1)_3.5gl_PPO_17.7mgL_MSB
3%_Te_Acid(1) and Amino(1)_3.5gl_PPO_17.7mgL_MSB

x2 improvement

-9000 D.P/Mev

3% Te-diol in LAB (prepared in Fall 2015)
Crushed 3% Te-diol in LAB after addition of ~4% O2A on 06-20-16
Collaboration Demographics

SNO+ Collaboration: Canada, US, UK, Portugal, Germany and Mexico

Alberta, Laurentian, Queen’s, SNOLAB, TRIUMF
AASU, BNL, UC Berkeley/LBNL, UC Davis, Chicago, Penn, UNC
Sussex, Oxford, QMUL, Liverpool, Lancaster
LIP Lisboa and Coimbra
TU Dresden
UNAM

Canada 43
US 37
UK 30
Portugal 5
Germany 4
Mexico 1
Additional slides ...
Fiber system

- Scattering module – 2 lasers and monitoring
- Recently completed hardware tuning – ready to go
- Located in DCR

- Timing module
- 92 fiber positions
- Test performed
- Located in DCR
New SNO+ Source Manipulator (URM)

- build by LIP (Portugal)
- delivered and unpacked at SNOLAB on 2017-02-02
Total 13.4 counts/year in ROI (Year 1)
1.3 tonnes of $^{130}$Te in LAB (at 0.5% nat-Te)

- [-0.5; +1.5] $\sigma$ around $Q_{\beta\beta}$
- 400 NHits/MeV (~4% $\Delta E$)
- Fiducial Volume: 20% total

<table>
<thead>
<tr>
<th>$T_{2/3}$ [yr]</th>
<th>$m_{0\nu\beta\beta}$ [meV]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 yr</td>
<td>$8 \times 10^{25}$</td>
</tr>
<tr>
<td>5 yrs</td>
<td>$1.96 \times 10^{26}$</td>
</tr>
</tbody>
</table>
Block Diagram

- TeA+
- UPW
- Diol
- Pre-Mixing tank
- Reactor
- Condensing system
- Vacuum system
- Waste Disposal
- Scintillator Plant
- N2
- In-line heater
- Mixer/“Aging”
- LAB