SNO+ STATUS

CHRISTINE KRAUS FOR THE SNO+ COLLABORATION

LAURENTIAN UNIVERSITY

CAP 2016 OTTAWA, JUNE 13TH 2016
OUTLINE

• SNO+ INTRODUCTION
• SNO+ DOUBLE BETA DECAY PHASE
• ACCOMPLISHMENTS LAST YEAR
• OUTLOOK
• SUMMARY
SNO+ is located at SNOLAB, 300 km from Sudbury, Ontario, Canada. It is located in the Creighton mine and uses the existing SNO cavity. SNO+ is 2 km or 6000 m.w.e. away.
SNO DETECTOR (INHERITED)

- Sunset in Sudbury

**Sudbury Neutrino Observatory**

- **DCR = Deck Clean Room**
- **12 m acrylic vessel**
- **1000 tonnes D2O**
- **1700 t H2O (inner)**
- **18 m PSUP**
- **5300 t H2O (outer)**
- **~9500 PMTs**
- **54% coverage**
- **780 tonnes liquid org. scintillator**
- **Hold-down ropenet**
LIQUID SCINTILLATOR

- DETECTOR TO BE FILLED WITH 780 TONNES OF ORGANIC LIQUID SCINTILLATOR (LS)
- MORE LIGHT YIELD THAN ČERENKOV, AROUND 400 P.E./MEV, ENABLING LOWER ENERGY THRESHOLD
- LINEAR ALKYL BENZENE (LAB)
  - HIGH LIGHT YIELD
  - LONG ATTENUATION LENGTH
  - SAFE: HIGH FLASH POINT AND LOW TOXICITY
  - MORE AFFORDABLE THAN OTHER SCINTILLATORS
- ADD WAVELENGTH SHIFTER
  - INITIAL PLAN: 2G/L PPO FLUOR
SNO+ BROAD PHYSICS PROGRAM

• NEUTRINOLESS DOUBLE BETA DECAY
  – SCINTILLATOR LOADED WITH $^{130}\text{Te}$
  (0.5% LOADING ~ 1300 KG OF $^{130}\text{Te}$)

• GEO- AND REACTOR NEUTRINOS

• SUPERNOVA NEUTRINOS

• SOLAR NEUTRINOS (PEP, CNO, LOW $^{8}\text{B}$)

• NUCLEON DECAY (WATER PHASE 2016)

Multi-purpose detector

• Review paper released this year
  (S. Andringa, E. Arushanova, S. Asahi, et al., “Current Status and Future Prospects of the
TOWARDS TE LOADED DETECTOR

• NOW – WATERFILL – EXPECT COMPLETED BY END OF SUMMER

• EXTERNAL BACKGROUND AND INVISIBLE NUCLEON DECAY MEASUREMENT WITH WATER FILLED DETECTOR

• INTERNAL BACKGROUND WITH PURE SCINTILLATOR FILLED DETECTOR (2017)

• TE LOADING IN 2017 – DOUBLE BETA PHASE STARTS LATE 2017/EARLY 2018

Scintillator Cocktail:
LAB + PPO
Telluric Acid (TeA)
1,2 butanediol
Ultrapure water (during synthesis)
SNO+ WITH TE LOADED SCINTILLATOR

- 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:
  - DECAY CHAINS OF LONG-LIVED RADIOISOTOPES
    - NEED $10^{-14}$-$10^{-15}$ G/G $^{238}$U, $^{232}$TH, “RAW” TELLURIUM HAS $\sim10^{-12}$ G/G
  - SOME TE COSMOGENICS HAVE LONGISH HALF-LIVES AND DECAYS THAT OVERLAP THE 0VBB ENERGY REGION (E.G. $^{60}$CO, $^{22}$NA, $^{102}$RH, $^{110}$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
Estimated spectrum after 5 years of running

Background budget – 13.4 counts per year

ROI, fiducial volume cut at 3.5 m radius, background coincidence rejection, modest light yield 200 NHIT per MeV

$T_{\frac{1}{2}} > 1.96e26 \text{ yr (90\% CL)}$

$m_{\beta\beta} < 36-90 \text{ meV}$
**PH SELECTIVE TELLURIC ACID RE-CRYSTALLIZATION**

- Telluric acid obeys the following equilibrium:

  \[ \text{Te(OH)}_6^{2-} \leftrightarrow \text{Te(OH)}_5\text{O}^- + \text{H}^+ \]

  - Insoluble
  - Soluble

- PH determines the equilibrium state

- Purification basics:
  1. Dissolve telluric acid in water and filter it
     - Removes water insoluble impurities
  2. Add nitric acid to force the telluric acid to recrystallize/precipitate, pump away the liquid, rinse
     - Removes acid soluble impurities

- By "tuning" the process PH's, this can be quite specific to telluric acid – most other chemicals are removed with high efficiency

# Measured Single Pass Purification Factors

<table>
<thead>
<tr>
<th>Element</th>
<th>Reduction Factors From Spike Tests</th>
<th>Non-spiked, before purification (ppb)</th>
<th>Non-spiked, after purification (ppb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sn</td>
<td>&gt;1.67×10^2</td>
<td>20</td>
<td>&lt;20</td>
</tr>
<tr>
<td>Zr</td>
<td>&gt;2.78×10^2</td>
<td>70</td>
<td>&lt;10</td>
</tr>
<tr>
<td>Ti</td>
<td></td>
<td>40</td>
<td>&lt;10</td>
</tr>
<tr>
<td>Co</td>
<td>(1.62±0.34)×10^3</td>
<td>&lt;10</td>
<td>&lt;10</td>
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<tr>
<td>Mn</td>
<td></td>
<td>150</td>
<td>&lt;5</td>
</tr>
<tr>
<td>Fe</td>
<td></td>
<td>40</td>
<td>&lt;30</td>
</tr>
<tr>
<td>Ag</td>
<td>&gt;2.78×10^2</td>
<td>&lt;10</td>
<td>&lt;10</td>
</tr>
<tr>
<td>Y</td>
<td>&gt;2.78×10^2</td>
<td>&lt;10</td>
<td>&lt;10</td>
</tr>
<tr>
<td>Sc</td>
<td>&gt;1.65×10^2</td>
<td>&lt;10</td>
<td>&lt;10</td>
</tr>
<tr>
<td>Sb</td>
<td>&gt;2.43×10^2</td>
<td>20</td>
<td>&lt;20</td>
</tr>
<tr>
<td>Th</td>
<td>(3.90±0.19)×10^2</td>
<td>&lt;0.02</td>
<td>&lt;0.02</td>
</tr>
<tr>
<td>Ra</td>
<td>(3.97±0.20)×10^2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ba</td>
<td></td>
<td>1400</td>
<td>&lt;5</td>
</tr>
<tr>
<td>Pb</td>
<td>(2.99±0.22)×10^2</td>
<td>440</td>
<td>&lt;3</td>
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<tr>
<td>Bi</td>
<td>(3.48±0.81)×10^2</td>
<td>300</td>
<td>&lt;10</td>
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<tr>
<td>U</td>
<td>(3.90±0.19)×10^2</td>
<td>&lt;0.02</td>
<td>&lt;0.02</td>
</tr>
</tbody>
</table>

Two-pass purification (with a thermal recrystallization step to remove nitric acid) is expected to meet our purity goals.
PLANT LAYOUT – LOWER LEVEL
TELLURIUM LOADING – NEW APPROACH

• LATE 2014:
  • NEED A “NEW” METHOD OF SUSPENDING TELLURIUM IN THE LIQUID SCINTILLATOR THAT IS CLEAN, STABLE, AND GIVES GOOD OPTICS
  • SET TARGET OF DEFINING LOADING METHOD BY END 2015
• JANUARY 2016: TELLURIUM-BUTANEDIOL TECHNIQUE SELECTED

“Condensation reaction” produces organometallic compound miscible in LAB.
PILOT PLANT AT LAURENTIAN

Setup past week – Queen’s and LU team

Successfully produced a 150g batch
ACCOMPLISHMENTS LAST YEAR

- DETECTOR – DAQ DEVELOPMENT AND TESTING  
  ERICA CADEN  (TUESDAY MORNING)

- SCINTILLATOR PLANT – WATER COMMISSIONING  
  RICHARD FORD  (TUESDAY MORNING)

- ASSAY SYSTEMS DEVELOPMENT  
  JANET RUMLESKIE (THIS SESSION)

- CALIBRATION – GAS BOARD FOR UI  
  ZACK BARNARD (POSTER)

- COMPLETE TEST OF HOLD-DOWN ROPE SYSTEM TO FULL LOAD

- LOCATE AND FIX CAVITY LEAKS

- INSTALL CALIBRATION HARDWARE COMPONENTS (UI, SLIDING FLOOR, ETC.)
11.2 million events total for timing calibration
See: Commissioning SNO+ detector by Erica Caden (Detector Manager) – Tuesday T1-5
SCINTILLATOR PLANT

He leak checking
And cleaning/passivation
Completed

1 mille of pipes

See: A Scintillator Purification Plant and Fluid Handling System for SNO+ by Richard Ford – Tuesday T1-5
ROPENET FULL LOAD TEST (FTB)
APRIL 25TH TO MAY 13TH 2016

• RAISE CAVITY WATER LEVEL FROM 36 TO 40 FEET, WHILE AV WATER LEVEL STAYS CONSTANT
• RAISE IN 5 STEPS TO FULL LOAD OF 284 000 LBS
• ROPE NET BEHAVES AS EXPECTED – SUCCESSFUL TEST
FIBER INSTALLATION

- UPPER PSUP COMPLETE
- LEVEL BELOW EQUATOR COMPLETE
  - > 2/3 COMPLETE
  - COMPLETED LAYER BELOW EQUATOR
  - REMAINING LAYERS ABOVE EQUATOR (2)

Upper PSUP
From a boat
NEXT STEPS – FIBER INSTALLATION

Bundle 6: done, from top of PSUP (October 2014)

Bundle 3: done, from boat (November 2014)

Bundles 1, 2: done, from cavity floor (March 2012)

Outstanding levels: Summer 2016
PMT REPAIRS

• DEVELOPED AT QUEEN’S (BELOW EQUATOR) --- 220 PMTS DONE
• ACTIVE FACILITY AT LAURENTIAN (UPPER PSUP) --- 150 PMTS DONE
• PHILOSOPHY: DO WHAT WE CAN WITHOUT HOLDING UP WATER FILL
• 480 PMTS REMAINING DURING BOATING (WORKING ON 50 NOW)

Resources:

Boating team
2 people repair team for 1 week per batch (10)

Testing high efficiency PMTs
PMT REPAIRS

- Take “advantage” of the leak
- Resumed PMT repairs
- ~400 PMT's swapped so far.
CAVITY LINER INSPECTIONS

Located and fixed several leaks in the cavity liner
Well developed methods and monitoring
CLOSING AV

Lowe half – installed 2014

Upper half at Triumf

Upper half at SNOLAB

Upper half shipped UG
Ready to install
SNO+ DATA TAKING

- COMPLETE WATERFILL AND DETECTOR COMMISSIONING THIS SUMMER
- WATER FILLED DATA – FALL 2016
- SCINTILLATOR PLANT LAB COMMISSIONING – FALL 2016
- SCINTILLATOR FILL AND PURE SCINTILLATOR DATA IN 2017
- TE PURIFICATION AND LOADING PROCESS – FALL 2017
- TE FILLED SCINTILLATOR DATA LATE 2017/EARLY 2018