The SNO+ Double beta decay Experiment

Carsten B. Krauss, University of Alberta for the SNO+ Collaboration
THIS TALK

- SNO+ = SNO + Liquid Scintillator

- SNO+ Collaboration

- Physics

- Progress & Status

- Outlook, Summary
SNO EXPERIMENT

- SNO used heavy water to be able to measure all flavours of solar $^8$B neutrinos
- Data was taken between 1999 and 2006 in three different phases, differing by the neutron detection method
- Current Focus: lower threshold analysis and combination of three phases
- Solved the solar neutrino Problem: Solar neutrino Flux understood, Neutrinos Oscillate in the sun
- see Josh Klein’s talk on Saturday
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Linear Alkylbenzene

- Linear Alkylbenzene is an intermediate product in the production of detergent.
- It is also a scintillator with a good light yield, mass produced (therefore cheap) and relatively safe.
- Large scale production facility in Canada.

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**Large scale production facility in Canada**
Government of Canada Invests in SNOLAB
June 18, 2009

Sudbury (Ontario) - Staff and Scientists at SNOLAB are thrilled with the funding announcement coming from the Canadian Foundation for Innovation today. The funding will provide the capital resources to build DEAP-3600 Experiment and the SNO+ Experiment as they continue their search for the elusive missing mass in the universe called ‘dark matter’ and continued studies of the properties of neutrinos.

"The successful award of these CFI funds to the projects is really great news. These experiments will deliver world class research on a variety of cutting-edge physics questions, which will keep Canada at the forefront of the underground physics field." said Director-elect Dr. Nigel Smith. “SNOLAB is delighted to be able to host these wonderful experiments in the underground laboratories."

Dark Matter is thought to make up about 25% of all the mass in the universe while the ordinary matter that we are made of only comprises about 5% (the remaining 70% of the universe is so called "Dark Energy"). Dark Matter is fundamental to the structure and evolution of galaxies, including our own; while it appears to have almost no interactions with ordinary matter, it does interact with gravity and that gravitational interaction shapes and holds together galaxies and even clusters of galaxies. Nobody knows exactly what the Dark Matter particles are, and there are many experiments around the world searching for it; this funding will ensure SNOLAB is at the leading edge of the effort to solve this fundamental problem in physics.
The Collaboration

University of Alberta:
A. Bialek, P. Gorel, A. Hallin, M. Hedayatipoor, C. Krauss

Brookhaven National Laboratory:
R. Hahn, M. Yeh, Y. Williamson

Dresden University of Technology:
K. Zuber

Idaho National Laboratory:
J. Baker

Idaho State University:
J. Heise, K. Keeter, E. Tatar, C. Taylor

Laurentian University:
O. Chkvoretz, E.D. Hallman, S. Korte, M. Schumaker, C. Virtue

University of Leeds:
S. Bradbury, J. Rose

LIP Lisbon:
S. Andringa, N. Barros, J. Maneira

University of North Carolina at Chapel Hill:
M. Howe, J. Wikerson

Oxford University:
S. Biller, P. Jones, N. Jelley, A. Reichold, J. Wilson-Hawke

University of Pennsylvania:
E. Beier, R. Bonventre, W.J. Heintzelman, J. Klein, G. Orebi-Gann, J. Secrest, T. Sokhair

Queen's University:
M. Boulay, M. Chen*, X. Dai, E. Guillian, P.J. Harvey, C. Kraus, X. Liu, A. McDonald, H. O'Keeffe, E. O'Sullivan, P. Skensved, A. Wright

SNOLAB:
B. Cleveland, F. Duncan, R. Ford, E.V. Jauregui, C.J. Jillings, I. Lawson

University of Sussex:
E. Falk-Harris, S. Fernandes, J. Hartnell, S. Peeters

University of Washington:
J. Kaspar, J. Nance, N. Tolich, H. Wan Chan Tseung
Experiment @ SNOLAB

![Graph showing neutron flux vs depth for different sites: WIPP, Soudan, Kamioka, Boulby, Gran Sasso, Sudbury. The data is from mei, Hime Phys Rev D 2006.]

Courtesy of National Geographic
Physics of SNO+

- Neutrinoless Double Beta Decay
- Supernova Neutrinos
- Solar Neutrinos
- Geo-Neutrinos
- Reactor Neutrino Oscillation
PHYSICS OF SNO+

- **Neutrinoless Double Beta Decay**
  - Skipped
- **Supernova Neutrinos**
  - Skipped
- **Solar Neutrinos**
  - Skipped
- **Geo-Neutrinos**
  - Skipped
- **Reactor Neutrino Oscillation**
  - Skipped
**Double Beta Decay**

- **Only a very small fraction of isotopes for which an ordinary beta decay is energetically forbidden undergo double beta decay $\beta\beta^{2\nu}$.**

- **If the neutrino is a Majorana particle, a neutrinoless double beta decay could occur $\beta\beta^0\nu$.**

- **$^{150}\text{Nd}$ is the $\beta\beta$ decaying isotope with the largest phase space factor and therefore potentially one of the highest decay rates.**

**Nd has a high Q value of 3.37 MeV**

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DOUBLE BETA DECAY

ONLY A VERY SMALL FRACTION OF ISOTOPES FOR WHICH AN ORDINARY BETA DECAY IS ENERGY FORBIDDEN undergo Double beta decay $\beta\beta$. If the neutrino is a Majorana particle, a neutrinoless double beta decay could occur $\beta\beta^0\nu$. Nd has a high $Q$ value of 3.37 MeV, making it the isotope with the largest phase space factor and therefore potentially one of the highest decay rates. Nd is the $\beta\beta$ decaying isotope with the largest $Q$ value and therefore potentially one of the highest decay rates.
**Nd Loaded Liquid Scintillator - $0\nu\beta\beta$ decay**

- Add Nd to scintillator liquid to get a homogeneous mixture between detection medium and emitter.

- With natural Nd a maximal loading of 0.1% Nd is possible. ($^{150}\text{Nd}$ abundance: 5.6%, mass ~48kg before fiducial cuts)

- In a scintillator experiment the $0\nu\beta\beta$ “line” becomes a “bump” at the high end of the $2\nu\beta\beta$ spectrum.
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**SNO+ expects to be able to reach a sensitivity for the neutrino mass below 100 meV with 2 years of running**
Natural Nd detection Limit

Expectation for sensitivity of the SNO+ experiment to reach within a given live time

Enriched option now not part of baseline experiment, options are being explored
**Effect of Backgrounds**

- $^{208}$Tl and $^{214}$Bi are the only backgrounds in the energy range of the $2\beta^0\nu$ signal.

- $^{208}$Tl can be vetoed by preceding $^{212}$Bi alpha and coincidence of $^{212}$Bi/$^{212}$Po.

- Effect of backgrounds on sensitivity is well understood.

- Full data analysis chain is now being refined and ported to post SNO software package.

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Friday, July 3, 2009
Main changes to SNO system

- Hold down of acrylic vessel is a major construction task that needs to be performed under clean room conditions.

- New hold down net will add several hundred kilos of material close to the active mass.

- LAB will need to be loaded with Nd and purified during operation - will need purification and distillation system.

- New calibration systems will be needed.
Technical Challenges

- Now buoyant acrylic vessel needs to be tied to the floor of the cavity
- All wet surfaces have to be made compatible with LAB based scintillator
- Data acquisition will have to updated to be able to handle higher event rates and light yield
CHALLENGES

The buoyant acrylic vessel needs to be tied to the floor of the cavity. All wet surfaces have to be made compatible with LAB-based scintillator.

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Technical challenges include:

- Mixture, board in bag (after) - note color change
- Brush off residual dark matter
- Mixture, board in bag (before) - put in ultrasonic cleaner - 10 min

Friday, July 3, 2009
WHAT HAS HAPPENED?

- Have dismantled the heavy water systems from the SNO era

- Preparing the installation of new Scintillator purification plant

- Designing new seal for Acrylic vessel

- Planning installation and anchoring of 120t of buoyant force in cavity floor in clean room environment

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What happened?

- Dismantling of heavy water systems from the SNO era
- Preparation for installation of new scintillator purification plant
- Designing new seal for acrylic vessel
- Planning installation and anchoring of 120t of buoyant force in cavity floor in clean room environment

Friday, July 3, 2009
have dismantled the heavy water systems from the SNO era
Preparing the installation of new Scintillator purification plant
Designing new seal for Acrylic vessel
Planning installation and anchoring of 120t of buoyant force in cavity floor in clean room environment
Preparations for the installation of a new Scintillator purification plant include designing a new seal for an acrylic vessel, planning the installation and anchoring of 120t of buoyant force in the cavity floor in a clean room environment.

What has happened?

- The top face elevations of the new gate valves reflect the current elevations on the existing glove box.

Diagram details:
- 6" Gate valve
- 8" Gate valve
- 10" Gate valve
- 6X CF Flanges 2"
- 4X 10" CF FlANGES FOR 8" PMT'S
- 4X Take up reel box
- 4X Encoder pulley box
- 3X Rotatable hoist rings for the upper section are located on this flange & do not need to be removed.

The viewport shown is 3.88 inches in diameter without the light cover installed.

Approximate weight of the UI assembly is 4000 lbs.

Section A-A:
- Finished Floor EL.

Detail B:
- Scale 1:4
- 36X 1/4-20 X 1.00 LG. STUDS

Detail C:
- Scale 1:4
- 4X 1/2-13 X 3.00 LG. STUDS

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Canadian National Laboratory for Particle and Nuclear Physics
TRIUMF
Vancouver, British Columbia
Canada V6T 2A3
4004 Wesbrook Mall
Canada's National Laboratory for Particle and Nuclear Physics
TRIUMF
Vancouver, British Columbia
Canada V6T 2A3
4004 Wesbrook Mall

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6" Gate valve
8" Gate valve
10" Gate valve

4X Take up reel box
4X Encoder pulley box
3X Rotatable hoist rings for the upper section are located on this flange & do not need to be removed.

3.88 inch viewport shown without light cover installed.

APPROXIMATE WEIGHT OF UI ASSEMBLY 4000 LBS

54.00
1.20
24.69
29.22
66.85
41.28
45.03
30.78
49.03
54.63
75.00
61.73
59.10

3X 150LB Flange
4X 10" CF FLANGES FOR 8" PMT'S
4X Encoder pulley box
 Rope motor boxes are rotated from the center line 10 typ.
Qualification of LAB Scintillator

Did a micro SNO+ experiment with an acrylic container filled with LAB scintillator in a light water filled SNO experiment

Allows to determine quenching, light yield, backgrounds and to exercise data taking and analysis abilities

Light yield measured (450 hits/MeV Nd loaded), Alphas and betas can be distinguished based on timing, quenching factor ~8.3 (at 7.8MeV)
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Summary

- **SNO+ will use the SNO experiment for a new multi-purpose neutrino experiment based at SNOLAB**

- **SNO+ has a rich physics program with great potential in almost all aspects of neutrino physics**

- **Initial focus will be neutrinoless double beta decay with $^{150}$Nd**

- **Most of the experiment has already been built!**

- **“Minor upgrades” will commence as soon as funding starts flowing**