Cosmic Ray and Neutrino-induced Muons in the SNO+ Experiment

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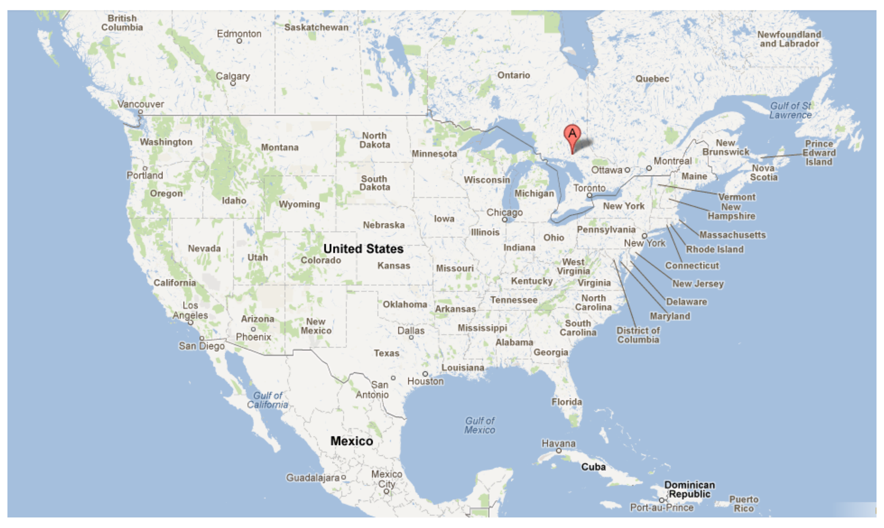
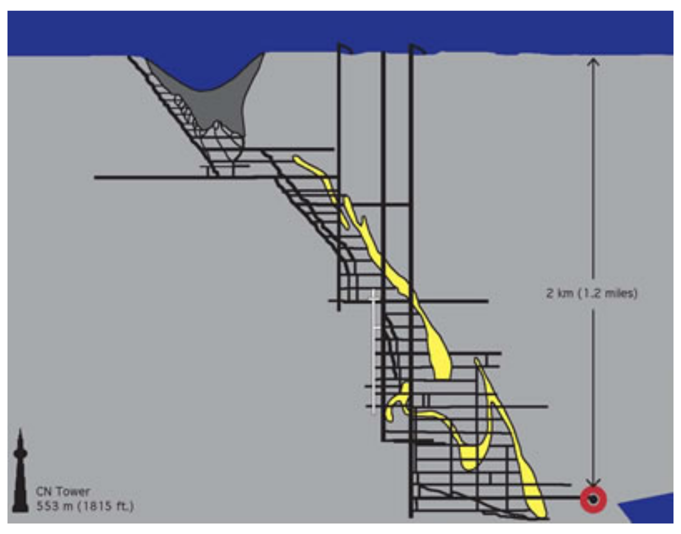
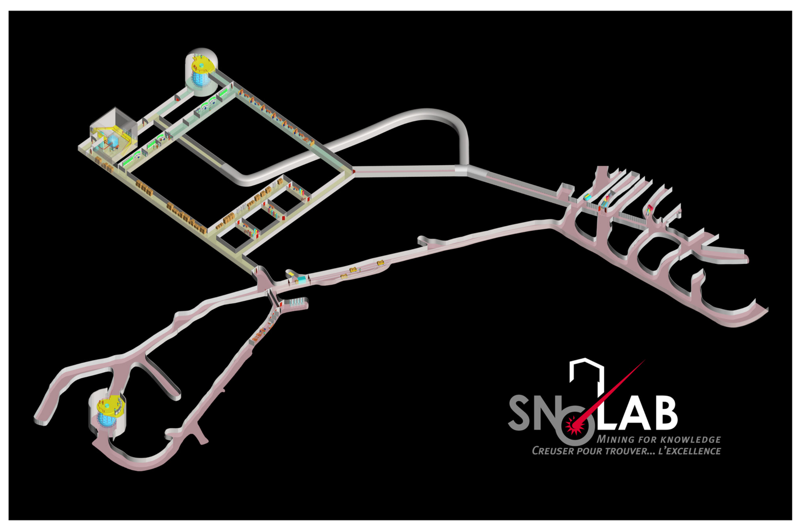
Introduction

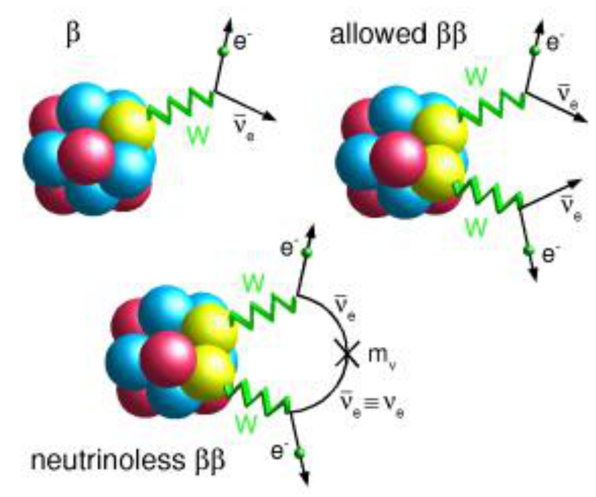


The SNO+ Experiment, the follow up of SNO (Sudbury Neutrino Observatory), is located in the Creighton mine near Sudbury, Canada.





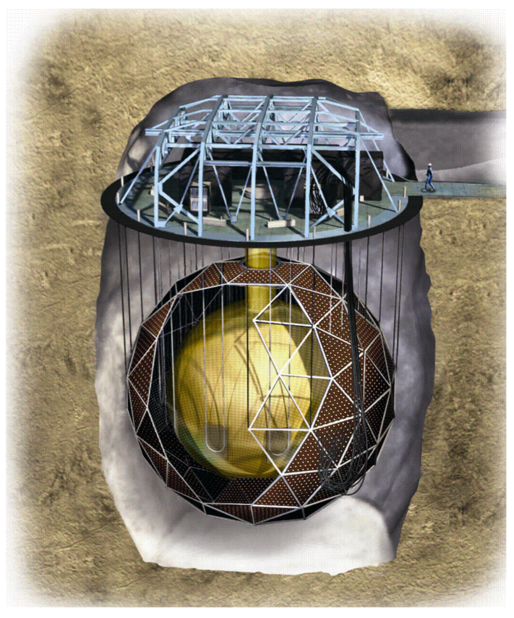
SNO+ uses the main infrastructure of SNO and is part of the SNOLab facility, which contains several neutrino and dark matter search experiments. At its depth of about 2200 m the flat overburden equals about 6000 m w.e..



The main physics goal of SNO+ is to search for the neutrinoless double beta decay in ^{150}Nd.

The SNO+ Detector

The heart of the detector is the Acrylic Vessel with a diameter of 12 m and 5 cm thick walls. It will be filled with 780t of liquid scintillator (LAB), and observed by ≈ 9.500 PMTs in a dedicated support structure (PSUP). The Photomultipliers provide a solid angle cover- age of about 54%. Light water is shielding the detector against radioactive background from the surrounding rock (1700 t between PSUP and Acrylic Vessel and 5700 t external).



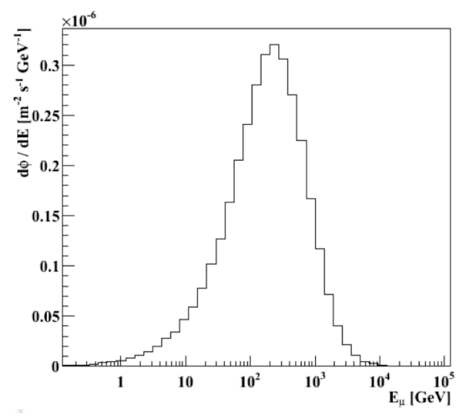
SNO+ Physics Goals

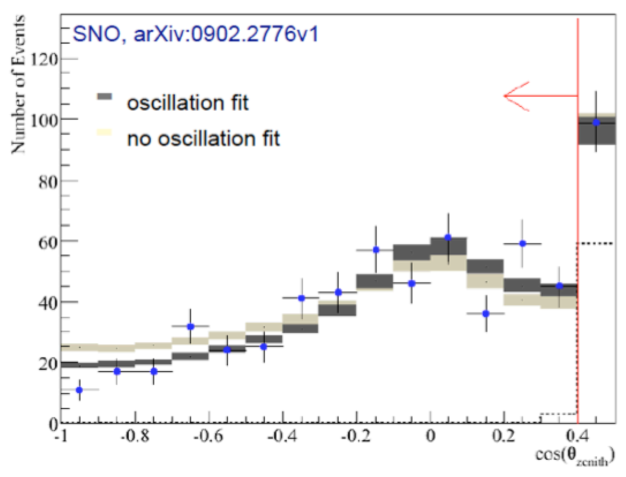
... are to search for :

- Neutrinoless ββ- Decay (^{150}Nd)
- Low Energy Solar Neutrinos (pep, CNO, ^{8}B)
- Reactor Neutrinos
- Geo Neutrinos
- Supernove Neutrinos
- **Atmospheric Neutrinos**
- Nucleon Decay

Muons in SNO+

In its 10 years of data taking, SNO thoroughly measured the atmospheric muon flux to 62.9 ± 0.2 μ/d through the fiducial volume (≈ 1μ/3d/m²). The average energy was calculated to $\langle E_\mu \rangle \approx$ 350GeV.





Due to the flat overburden, SNO also succeeded in measuring atmospheric neutrinos (neutrino-induced muons) above its horizon (i.e. $0 < \cos \Theta_{zenith} < 0.4$).

The figure above shows the zenith angle distribution of through-going neutrino-induced muons in SNO. This unique measurement of the unoscillated flux and the flux normalisation factor is not possible for other experiments situated in underground laboratories inside mountains.

To improve this measurement, and to discriminate the muon-induced background contributions, a precise muon track reconstruction in SNO+ is crucial.

μ-induced Background: High energy cosmic ray muons can contribute to the background of a liquid scintillator experiment in several ways. The most important for solar neutrino measurements is muon spallation of ^{12}C:

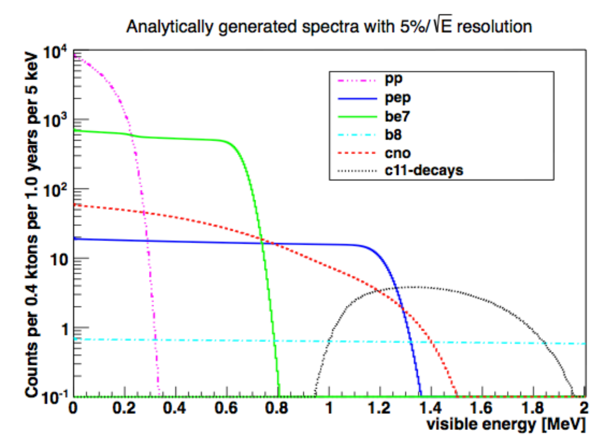
$$\mu + {}^{12}C \rightarrow \mu + {}^{11}C + n$$

which produces the β+-emitter ^{11}C (Q-value: 1.98 MeV).

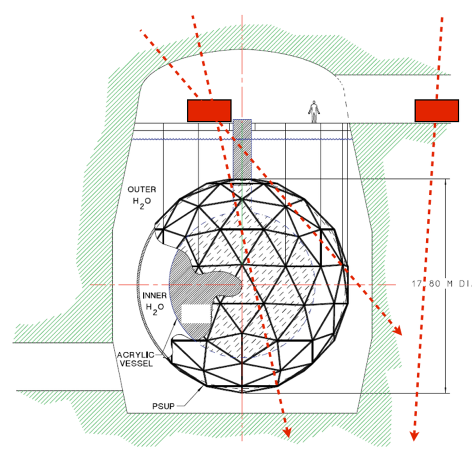
The neutron from this reaction will most likely be capture by an H-atom which de-excites by a 2.2 MeV γ-emmission, and can therefore be used as a tag. BOREXINO has shown that excluding a cylindrical **volume around the muon track** from the fiducial volume, using a sophisticated tagging technique, can significantly reduce this background.

The figure on the right below shows a simulation of the background contribution of ^{11}C to the expected solar neutrino signals in SNO+. Another cosmogenic muon background contribution are neutrons produced from high energy muons passing through the rock nearby the detector. Below, a table with measurements up to 3 km w.e. overburden and 270 GeV average muon energy:

Measurement	Depth [km.w.e]	$\langle E_\mu \rangle$ [GeV]	$\langle n \rangle [n/(\mu\, g\, cm^{-2})]$
Hertenberger	0,02	13	$(2 \pm 0,7) \times 10^{-5}$
Bezrukov	0,025	14,7	$(4,7 \pm 0,5) \times 10^{-5}$
Boehm	0,032	16,5	$(3,6 \pm 0,31) \times 10^{-5}$
Bezrukov	0,316	55	$(1,21 \pm 0,12) \times 10^{-4}$
Enikeev	0,75	120	$(2,15 \pm 0,15) \times 10^{-4}$
LVD	3,1	270	$(1,5 \pm 0,4) \times 10^{-4}$



External Trackers:



It is considered to install two different types of muon detectors above SNO+. One directly above the experiment to improve and externally calibrate the track reconstruction of through-going muons. Another station would measure muons passing close-by the detector through the rock. In coincidence with SNO+, a detection of muon-induced neutrons from rock would be possible. This would be the first measurement at this depth, with an average muon energy of $\langle E_\mu \rangle \approx$ 350 GeV.

Conclusion

- SNO performed a measurement of cosmic ray and neutrino-induced muon flux and angular distribution
- SNOLab site offers a unique opportunity to measure atmospheric neutrinos above the horizon
- Muon trackreconstruction is important to reduce muon-induced background (^{11}C)
- External muon trackers can calibrate and improve muon track reconstruction
- Deepest measurement of muon-induced neutrons in rock possible

Collaborations

- J.Plefka, T. Schuster (GK1504, QFT group, HU Berlin)
- S.Badger, V.Yundin (Niels Bohr Institut, Copenhagen)

Profit from the GK

- Financial support for travel to International Summer School
- Block Course Lectures on Neutrino Physics and Physics beyond the SM

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WWW:

- http://www.snoplus.phy.queensu.ca
- http://www.snolab.ca

DRESDEN concept

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