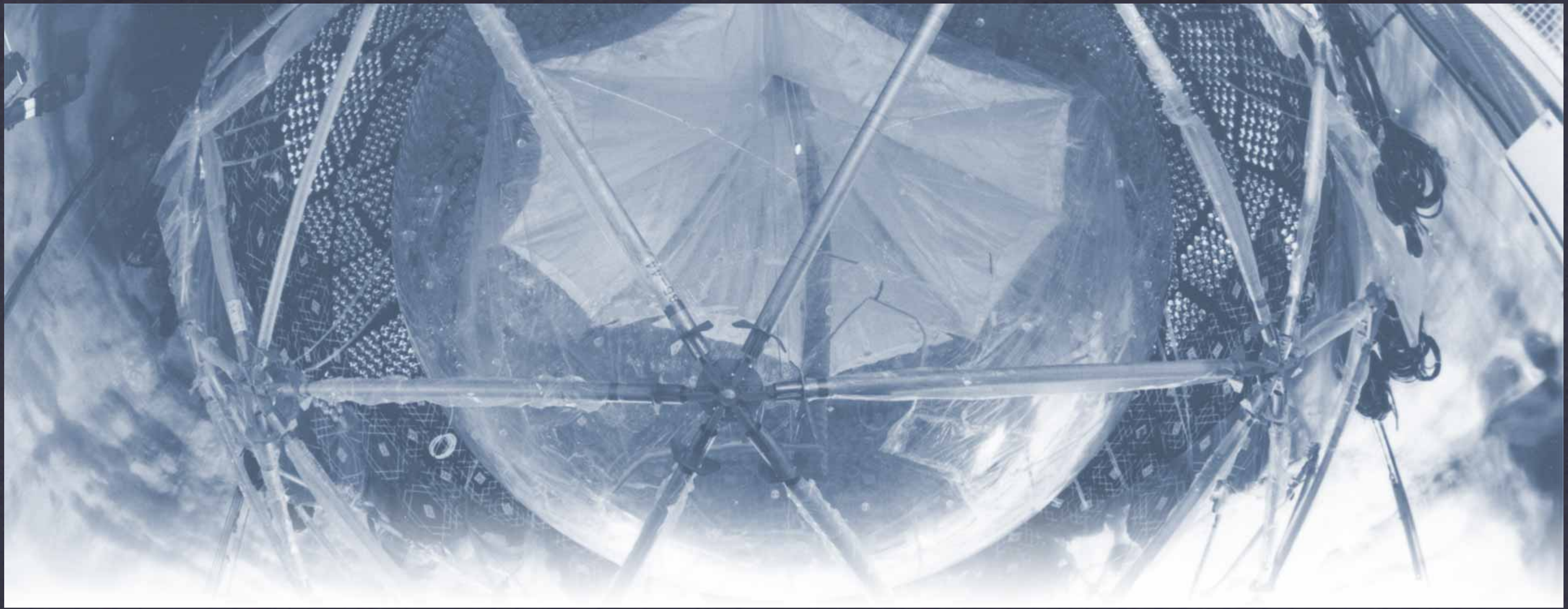


# The SNO+ experiment: status and overview


## Simon JM Peeters

on behalf of the SNO+ collaboration

University of Sussex
Physics & Astronomy

# SNO+ collaboration

**University of Alberta**

A. Baliek, P. Gorel, A. Hallin, M. Hedayatipoor, C. Krauss, Z. Petriw, L. Sibley, K. Sing, J. Sokoup.

**Amstrong Atlantic State University**

J. Secrest

**Black Hills State University**

K. Keeters

**Brookhaven National Laboratory**

W. Beriguette, S. Hans, L. Hl, R. Rosero, M. Yeh, Y. Williamson

**University of California, Berkeley / LBNL**

F. Descamps, K. Kamdin, K. Haghighi, G. Orebi Gann, O. Wasalski

**Dresden University of Technology**

N. Barros, V. Lozza, B. von Krosigk, F. Krger, P. Schrock, K. Zuber

**Laurentian University**

D. Chauhan, E.D. Hallman, C. Kraus, T. Shantz, C. Virtue

**University of Leeds**

S. Bradbury, J. Rose

**LIP Lisbon and Coimbra**

S. Andringa, J. Carvalho, L. Gurriana, A. Maio, J. Maneira.

**University of Liverpool**

N. McCauley

**Univeristiy of North Carolina at Chapel Hill**

M.Howe, J. Wilkerson

**Oxford University**

S. Biller, I. Coulter, N. Jelley, K. Majumdar, A. Reichold, M. Schwendener

**University of Pennsylvania**

E. Beier, R. Bonventre, W.J. Heintzelman, S. Grullon, J. Klein, P. Keener, A. Mastbaum, T. Shokair, R. Van Berg

**Queen Mary, University of London**

A. Back, F. Di Lodovico, P. Jones, J. Wilson

**Queen's University**

S. Asahi, M. Boulay, M. Chen, K. Clark, N. Fatemi-Ghomi, P.J. Harvey, C. Hearns, A. McDonald, A. Noble, T. Sonley, E. O'Sullivan, P. Skensved, I. Takashi

**SNOLAB**

C. Beaudoin, G. Bellehumeur, O. Chkvorets, B. Cleveland, F. Duncan, R. Ford, N. Gagnon, C. Jillings, S. Korte, I. Lawson, T. O'Malley, M. Schumaker, E. Vazquaz-Jauregui

**University of Sheffield**

J. McMillan

**University of Sussex**

E. Falk, J. Hartnell, G. Lefeuvre, M. Mottram, S. Peeters, J. Sinclair, J. Waterfield, R. White

**TRIUMF**

R. Helmer

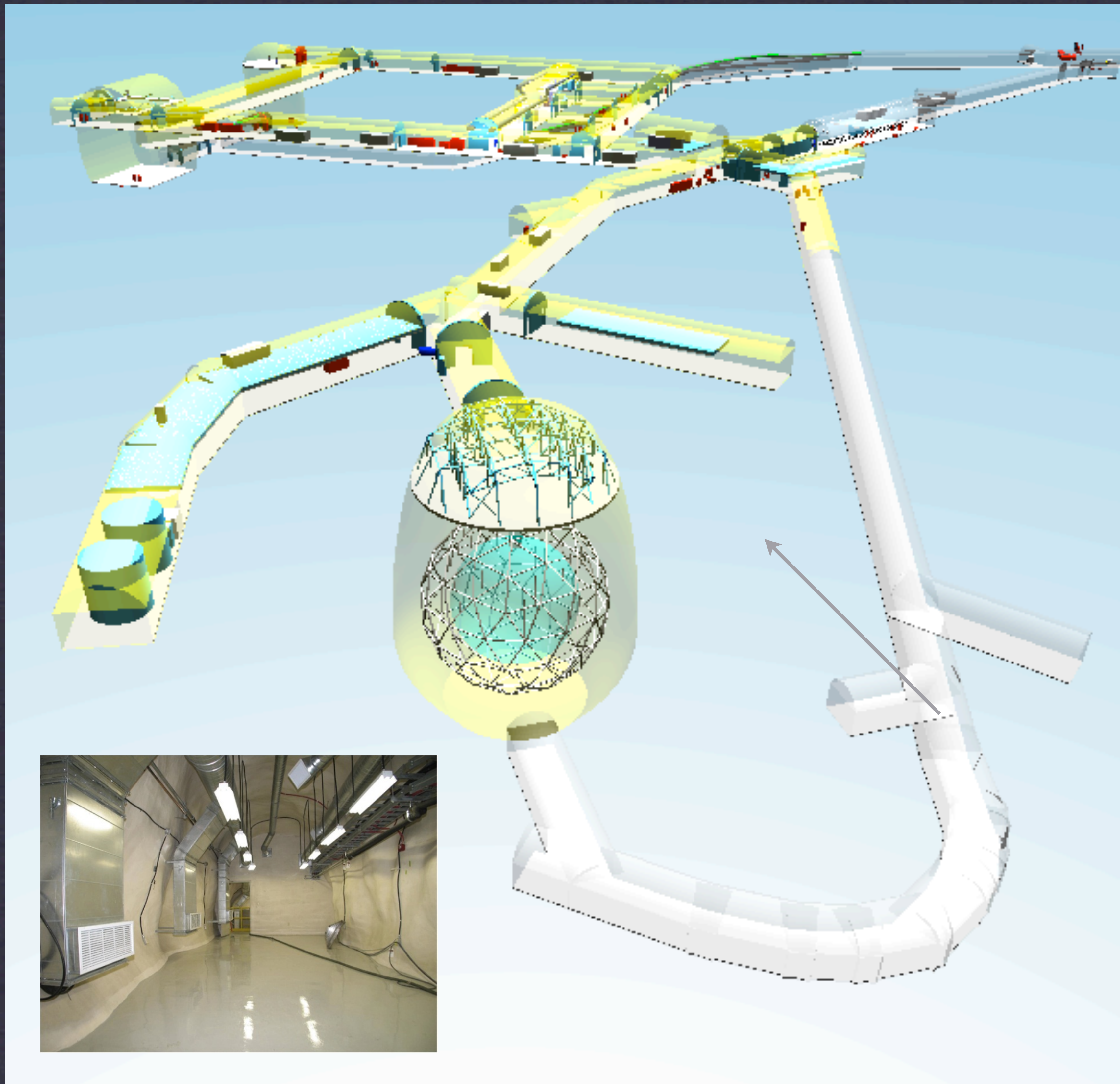
**University of Washington**

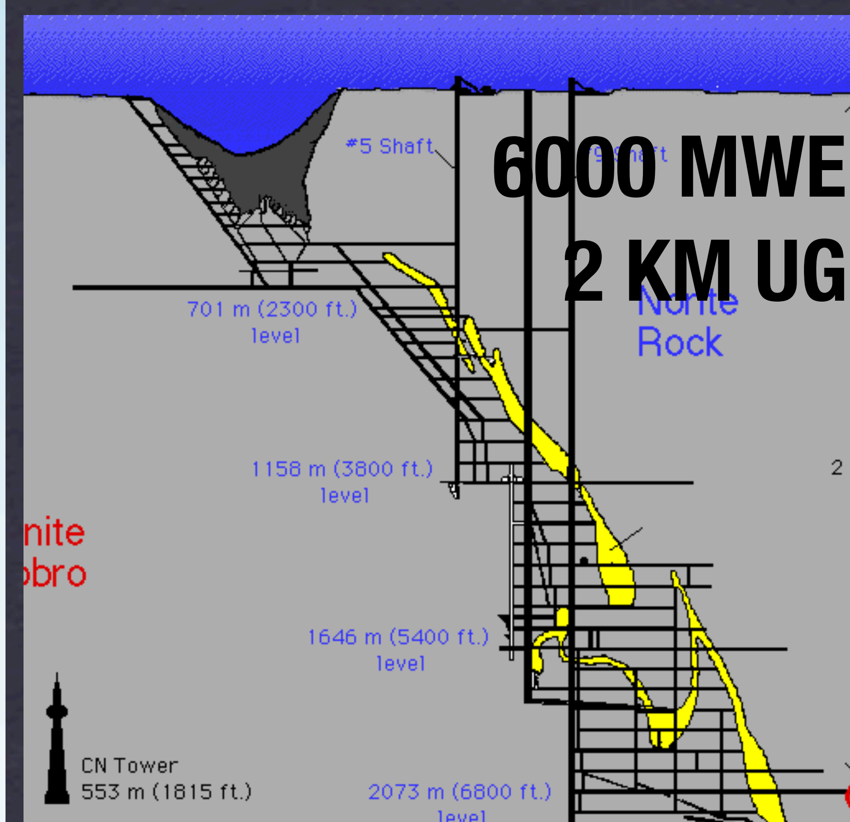
S. Enomoto, J. Kaspar, J. Nance, D. Scislowski, N. Tolich, H. Wan Chan Tseung

# Content

- The SNO+ experiment @ SNOLAB
- The SNO+ physics programme
  - *Double beta decay with $^{150}$Nd*
  - Supernova neutrinos
  - Low energy solar neutrinos
  - Geo-neutrinos
  - Reactor neutrinos oscillation
  - Nucleon decay
- Status and outlook

# The SNO+ experiment at SNOLAB



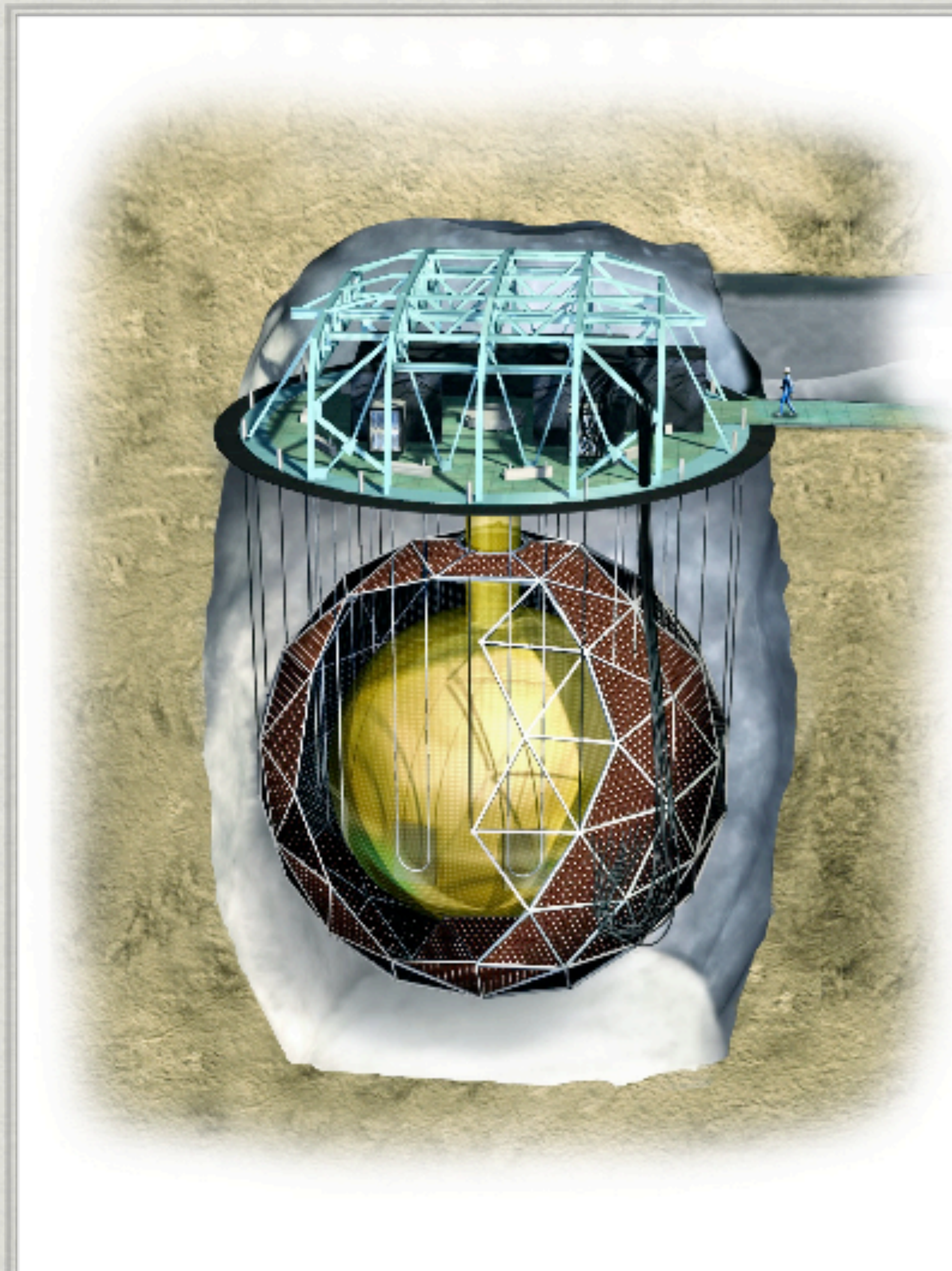




# SNOLAB

## DEEPEST AND CLEANEST LARGE-SPACE INTERNATIONAL FACILITY IN THE WORLD

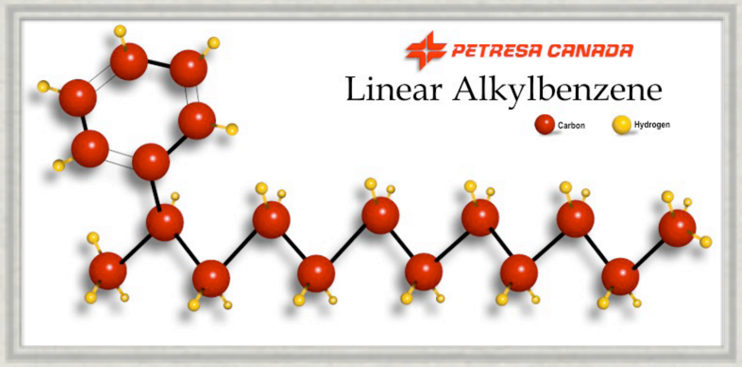
# The SNO+ experiment

- 780 tonne liquid scintillator (LAB + PPO)
- Surrounded by 9000 PMTs
- Nd-loaded at 0.1-0.3% (780-2240 kg of natural Nd)
- Water shield: 1700 + 5700 tons UPW
- Urylon liner
- New rope system to hold down the 12 m diameter acrylic vessel

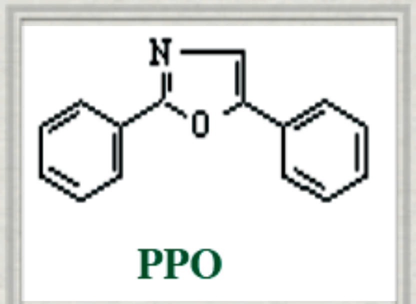


# Linear Alkyl Benzene (LAB)

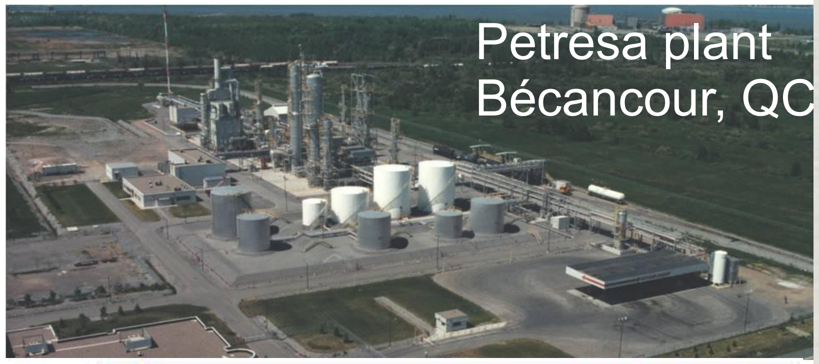
- Solvent: Linear Alkylbenzene (LAB)

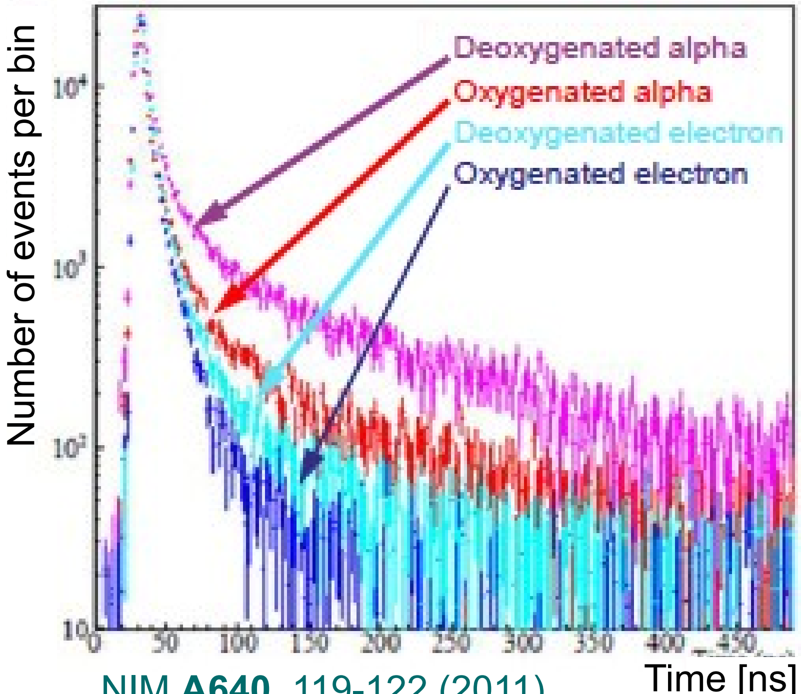



- Chemically compatible with acrylic, high purity achievable
- Low toxicity, high flash point (130° C)
- Environmentally safe
- Readily available – used in the production of detergents
- Fluor: 2,5-Diphenyloxazol (PPO)

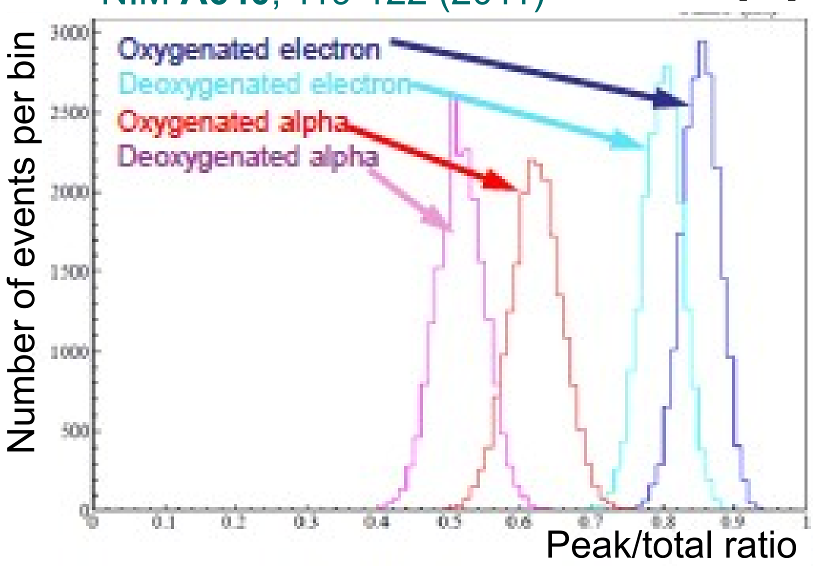



- Concentration of 2 g/L at the optimum between light yield and self-absorption. High light yield (~10,000 p.e./MeV)




NIM **A640**, 119-122 (2011)

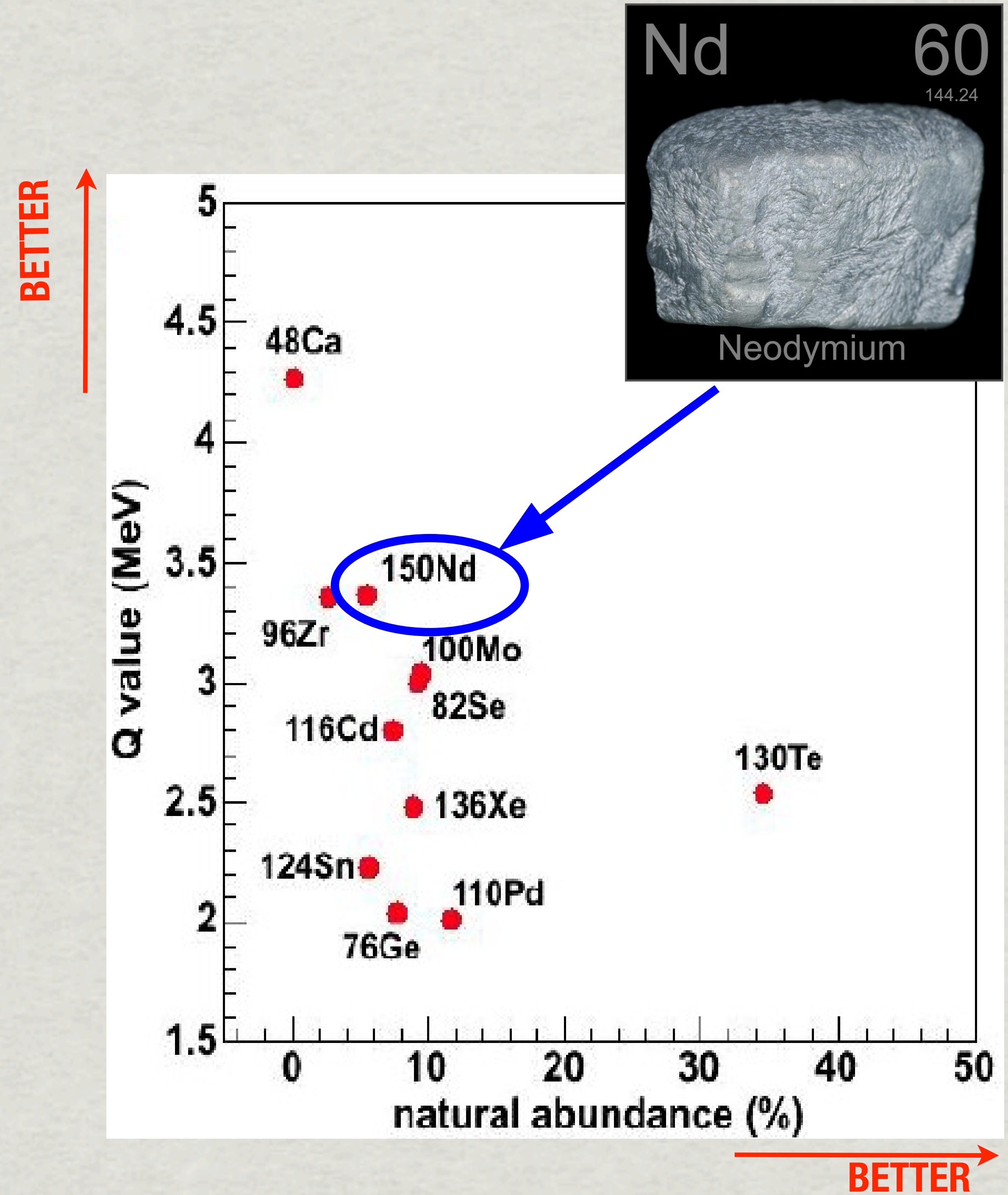


# The SNO+ physics goals

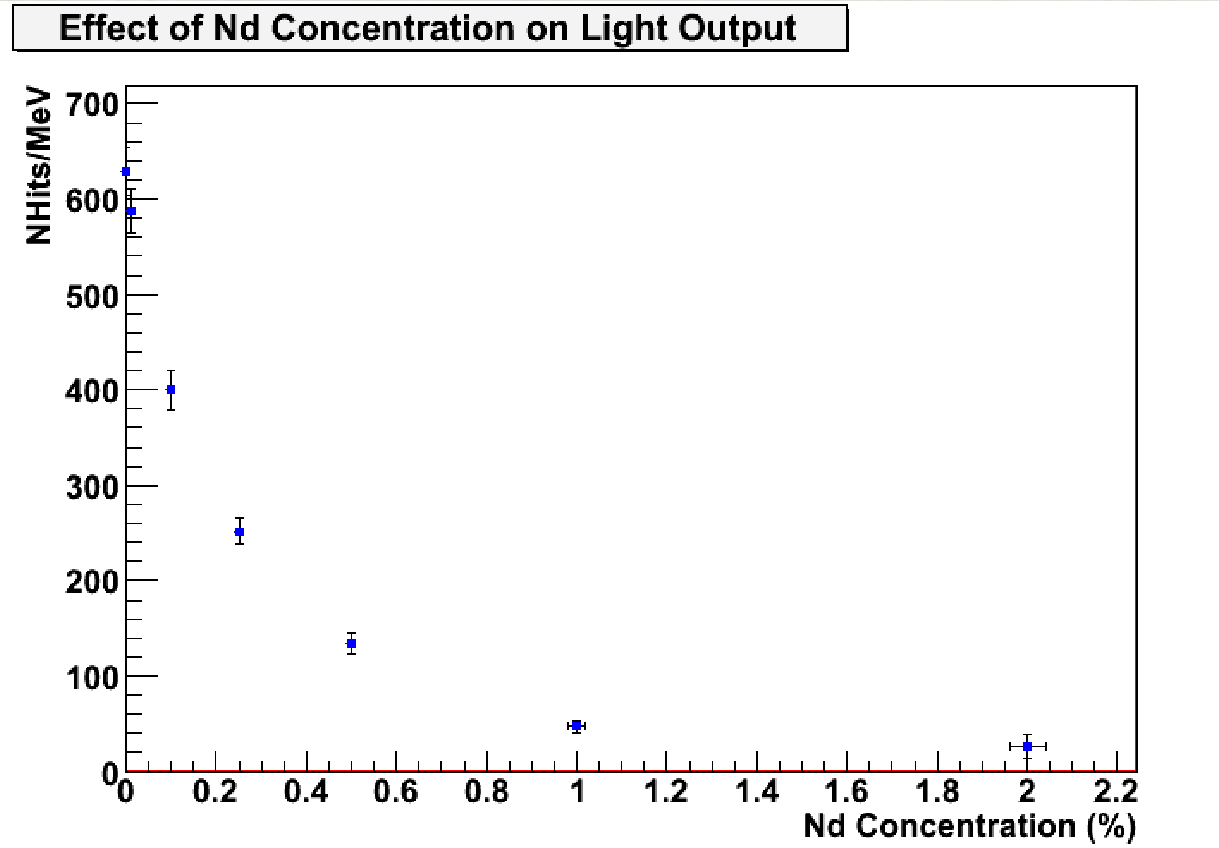
# $0\nu\beta\beta$ decay with $^{150}Nd$

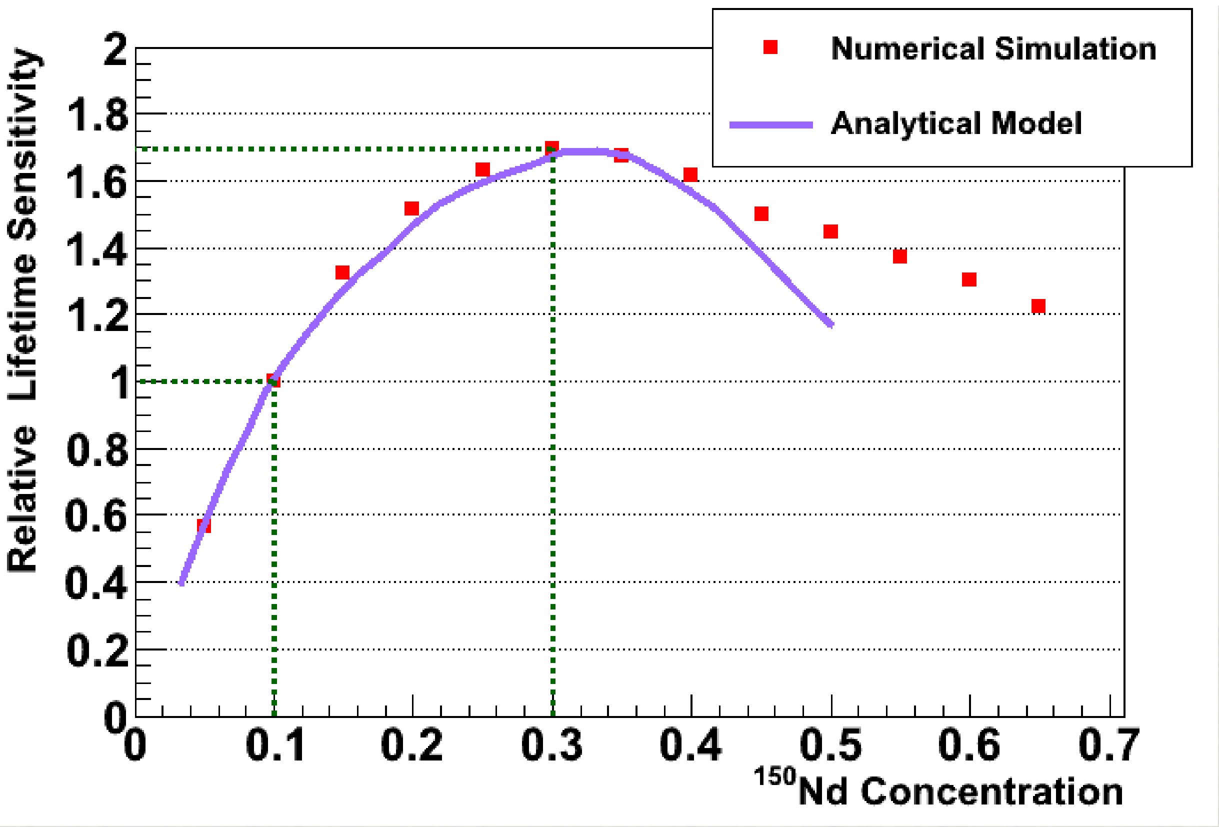
**Isotope of choice: $^{150}Nd$**

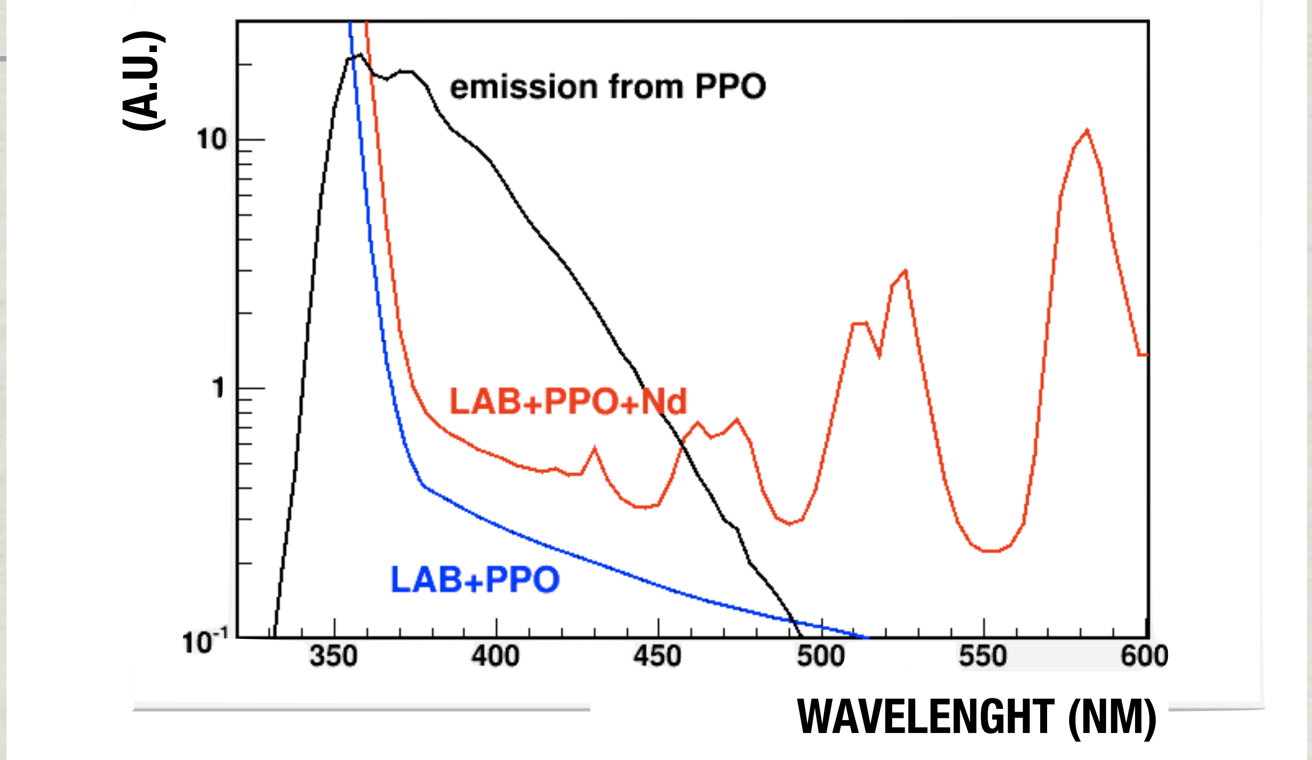
- Largest phase space of all $0\nu\beta\beta$ isotopes
- High 3.3 MeV end-point
- 5.6% abundance
- Relatively cheap
- Demonstrated to be in solution in LAB for over 3 years at high concentrations



# $^{150}$Neodymium



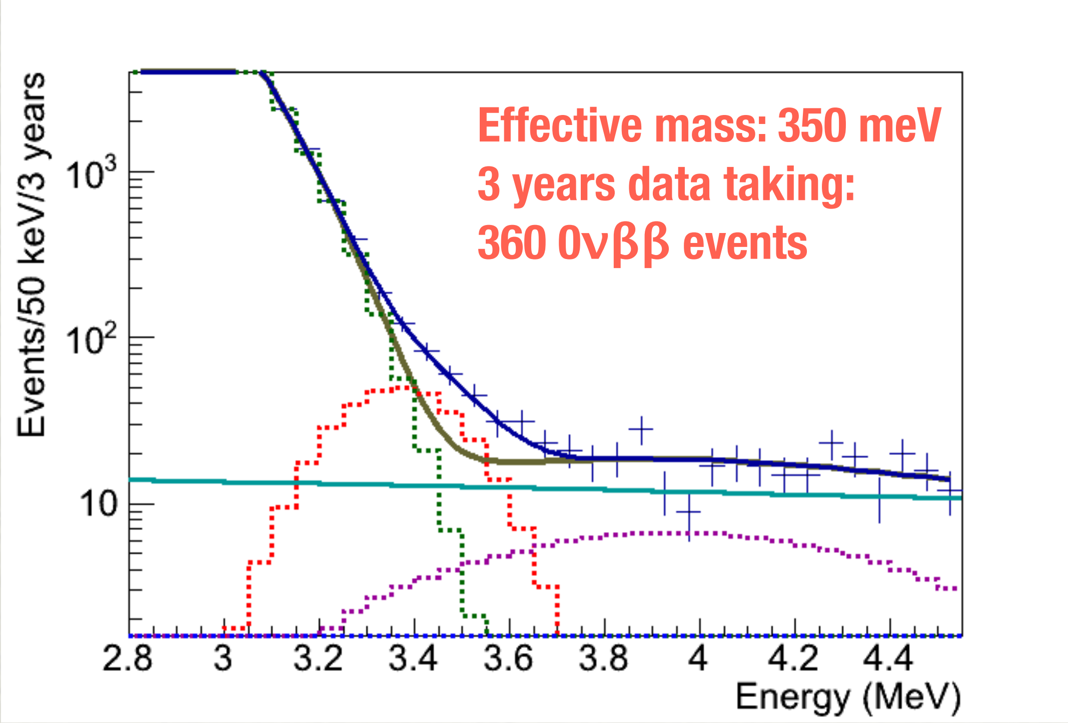

**Expect optimal loading @ 0.3% (131 kg)**

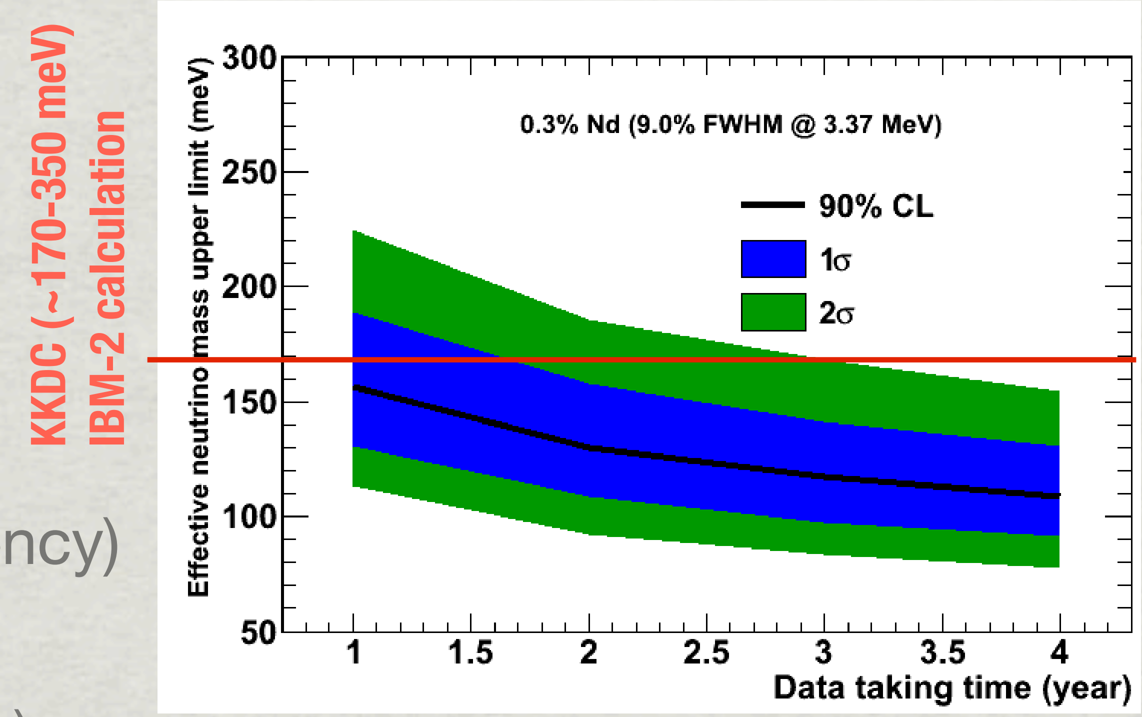
Run initially @ 0.1%(44 kg)

- 0.1% loading:
  400 p.e./MeV
  (6.4% FWHM resolution @ 3.37 MeV)
- 0.3% loading:
  200 p.e./MeV
  (9.0% FWHM resolution @3.37 MeV)

# 0νββ sensitivity

- 0.3% loading of $^{150}$Nd
- Nuclear matrix element: IBM-2
  (Barea & Iachello, Phys. Rev. C 79 (2009))
  (matrix element 2.5, phase space factor 2.69 x $10^{-13}$)
- Fiducial volume: 50%
- 80% livetime
- Main backgrounds:
  - Solar $^{8}$B
  - $^{150}$Nd 2νββ
  - $^{214}$Bi
    (tagged and removed 99.98% efficiency)
  - $^{208}$Tl
    (tagged and removed 90% efficiency)



# Supernova neutrinos

## POSSIBLE REACTIONS IN SNO+ FOR A 3 · $10^{53}$ ERG SN @ 10 KPC

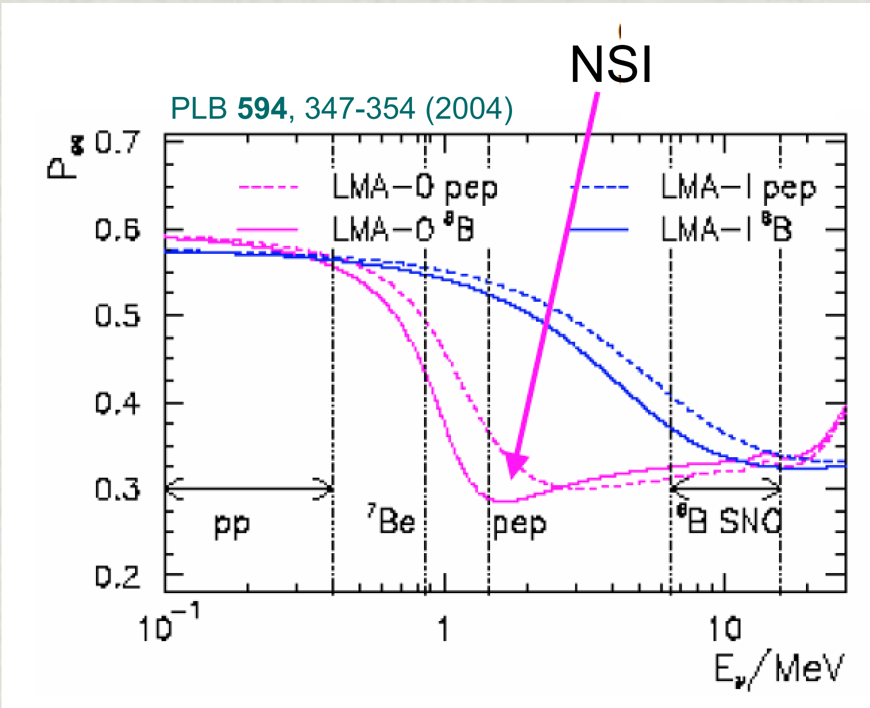
| Anti-neutrino reaction | Exp nr of events |
|---|---|
| $\nu_e + e^- \longrightarrow \nu_e + e^-$ | 8 |
| $\nu_e + e^- \longrightarrow \nu_e + e^-$ | 3 |
| $\nu_{\mu,\tau} + e^- \longrightarrow \nu_{\mu,\tau} + e^-$ | 4 |
| $\nu_{\mu,\tau} + e^- \longrightarrow \nu_{\mu,\tau} + e^-$ | 2 |
| $\nu_e + p \longrightarrow n + e^+$ | 263 |
| $\nu_e + {}^{12}C \longrightarrow {}^{12}N + e^-$ | 27 |
| $\nu_e + {}^{12}C \longrightarrow {}^{12}B + e^+$ | 7 |
| $\nu_x + {}^{12}C \longrightarrow {}^{12}C^*(15.11\,MeV) + \nu_x$ | 58 |
| $\nu_x + p \longrightarrow \nu_x + P$ | 273 |

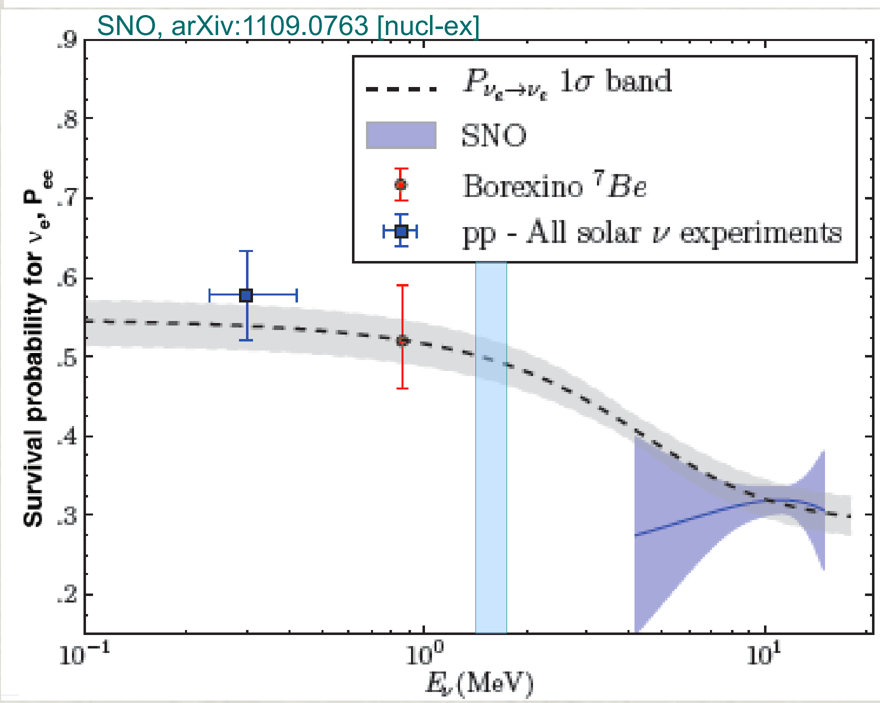
A careful design of calibration hardware and operational procedures should allow a semi-automated response in the long run.

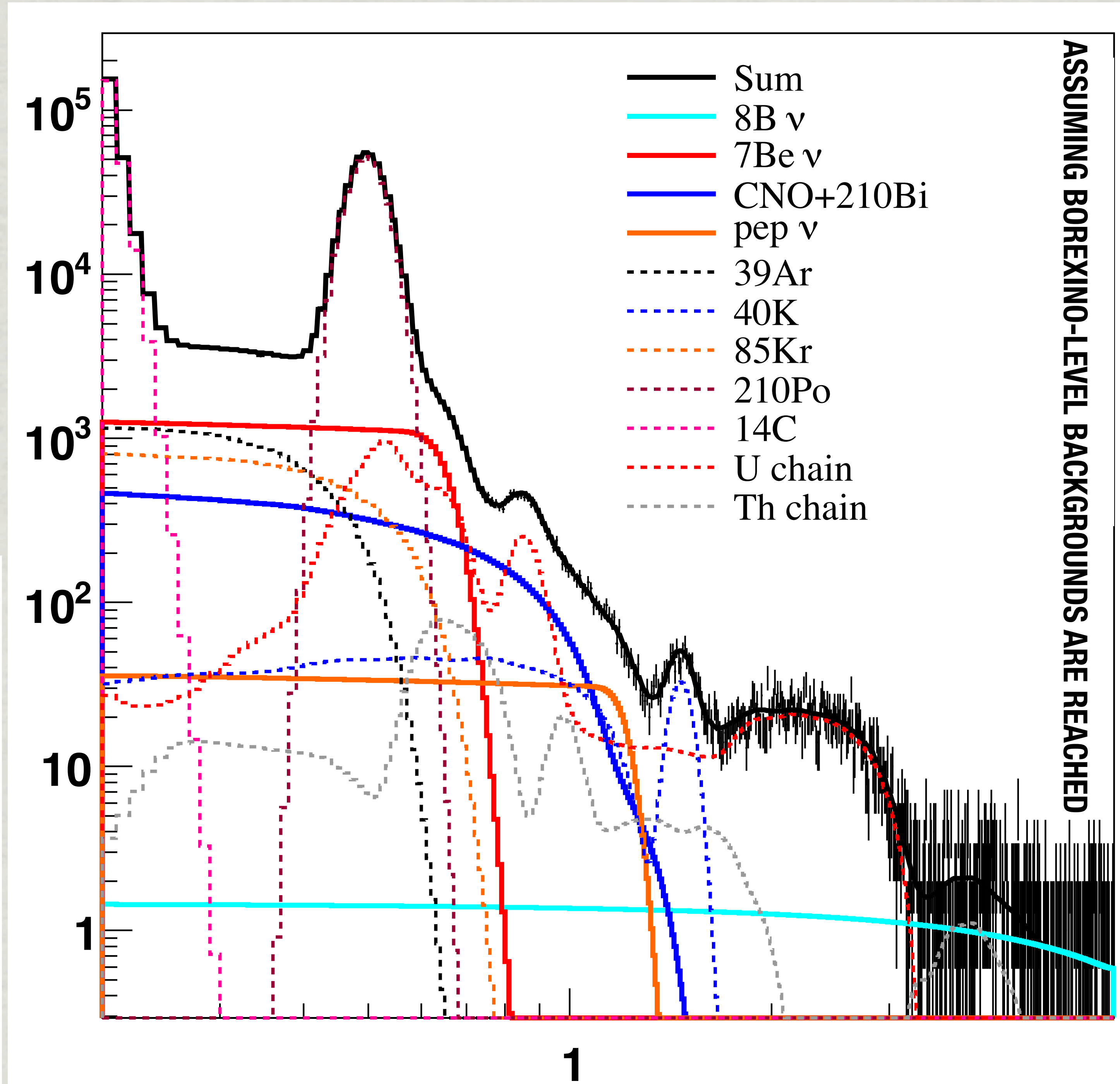
SNO+ electronics will be upgraded and therefore able to handle very high data rates.
(Special SN calibration source is being developed to test the DAQ)

# Solar neutrinos

**1 YR DATA**
**50% FIDUCIAL VOLUME**



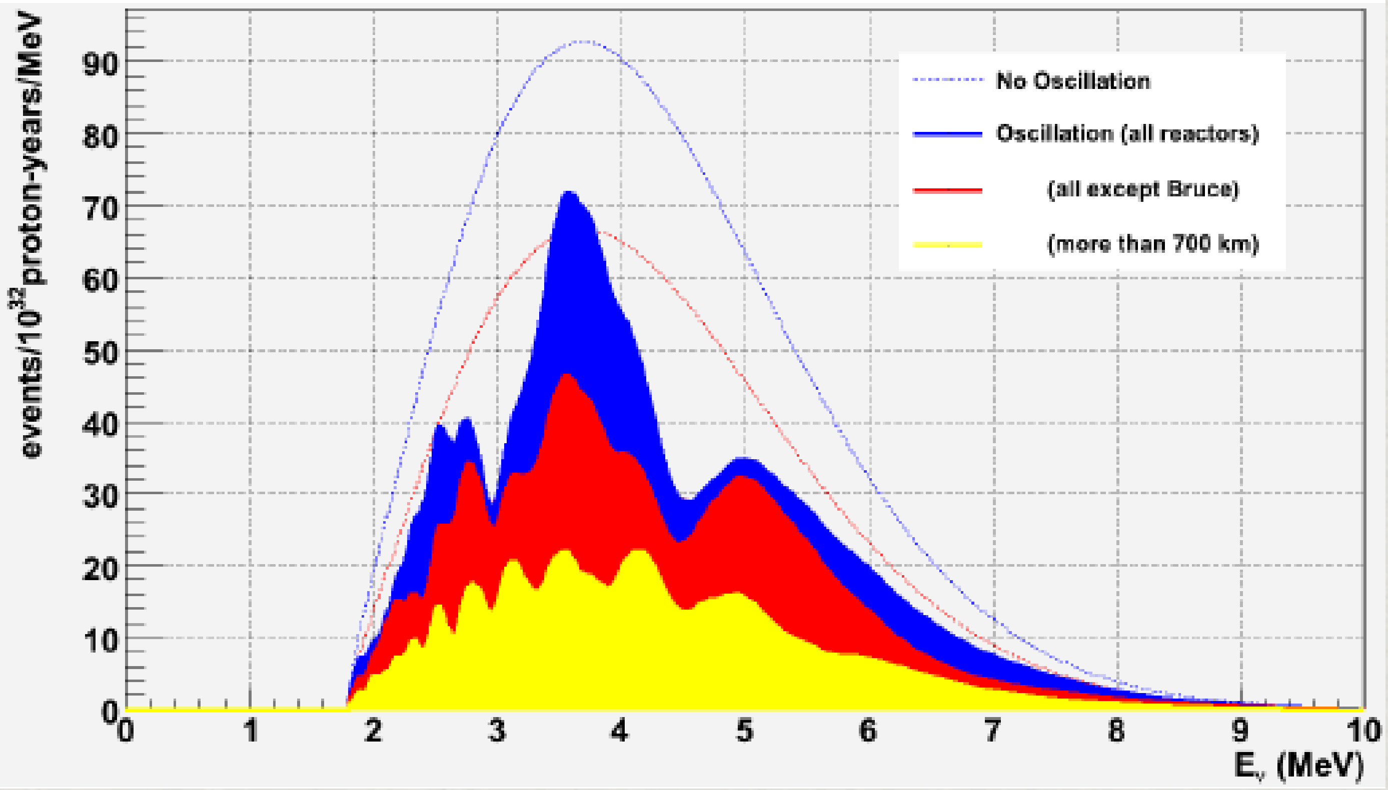

SNOLAB is very deep: very low muon flux, and thus insignificant $^{11}C$ background

- Precise measurement of pep flux
- CNO neutrinos

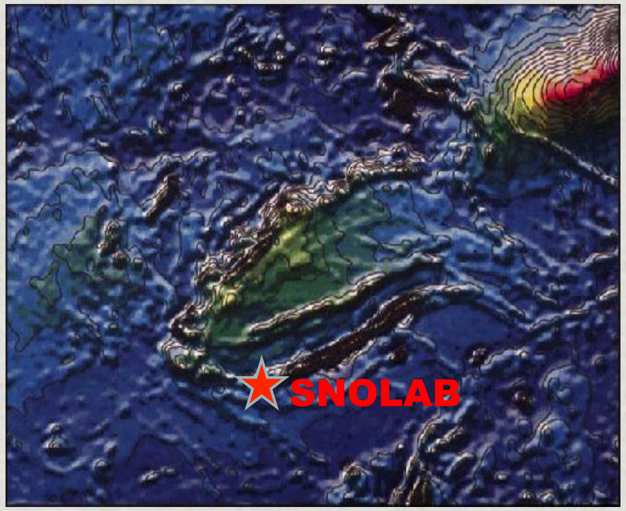
# Other physics with SNO+

## REACTOR NEUTRINOS

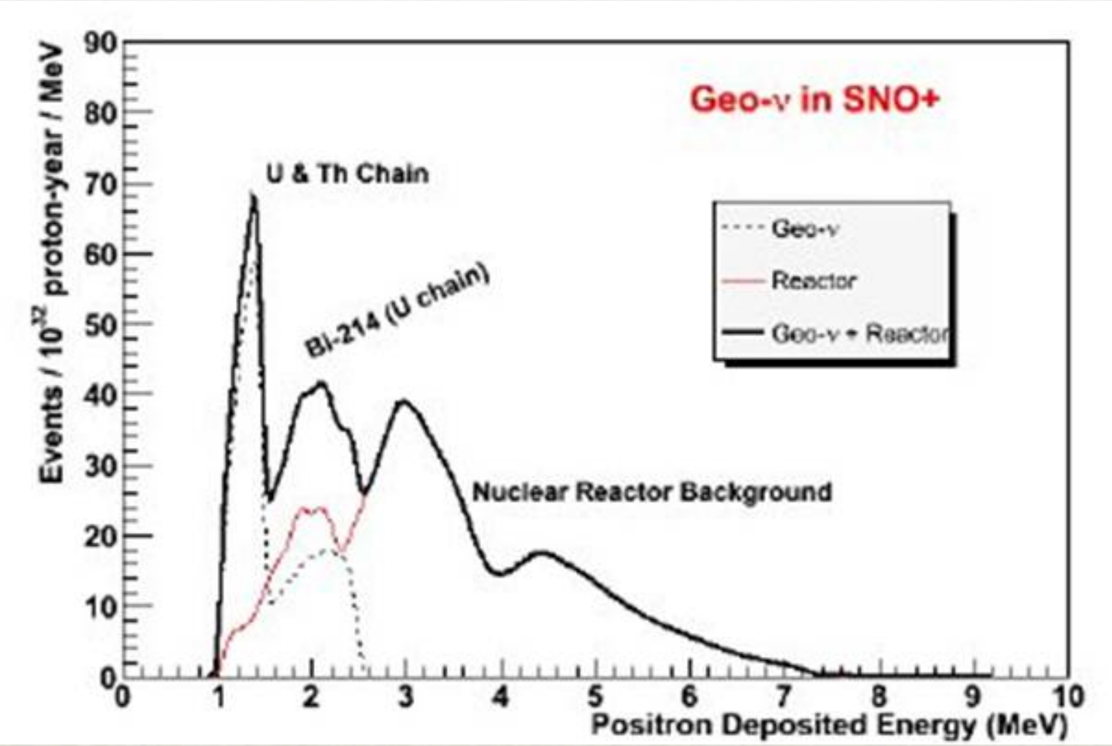
SNO+ is situated 240 km from one 6.3 GW station (as of 2012) and 340 km from two ~ 3.3 GW stations.
Expect about 90 events/year (oscillated).




## GEO NEUTRINOS

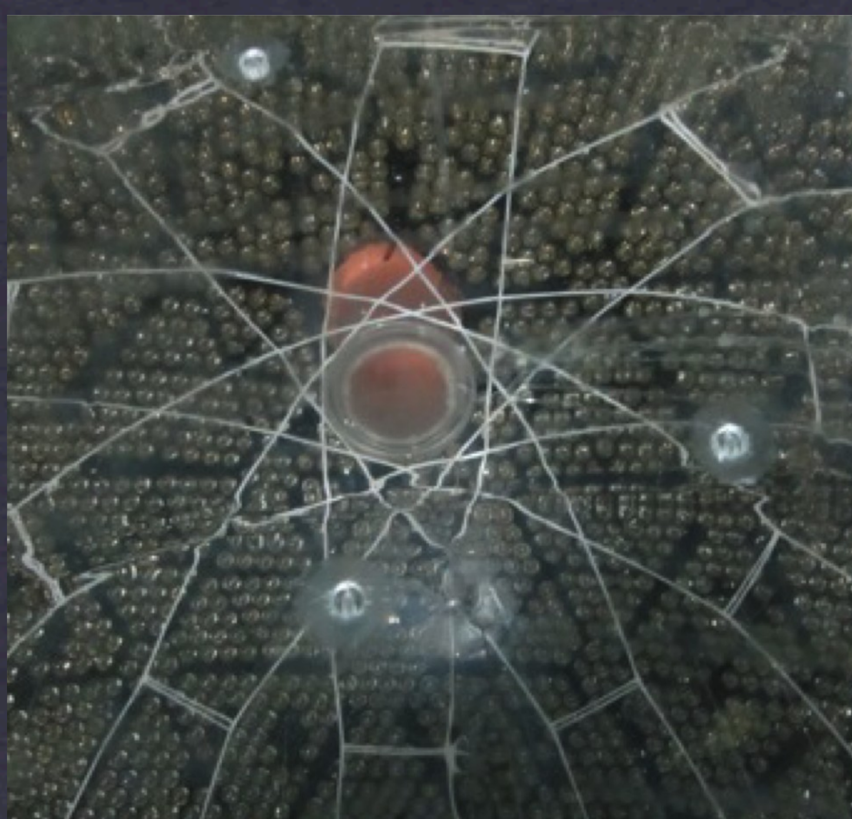
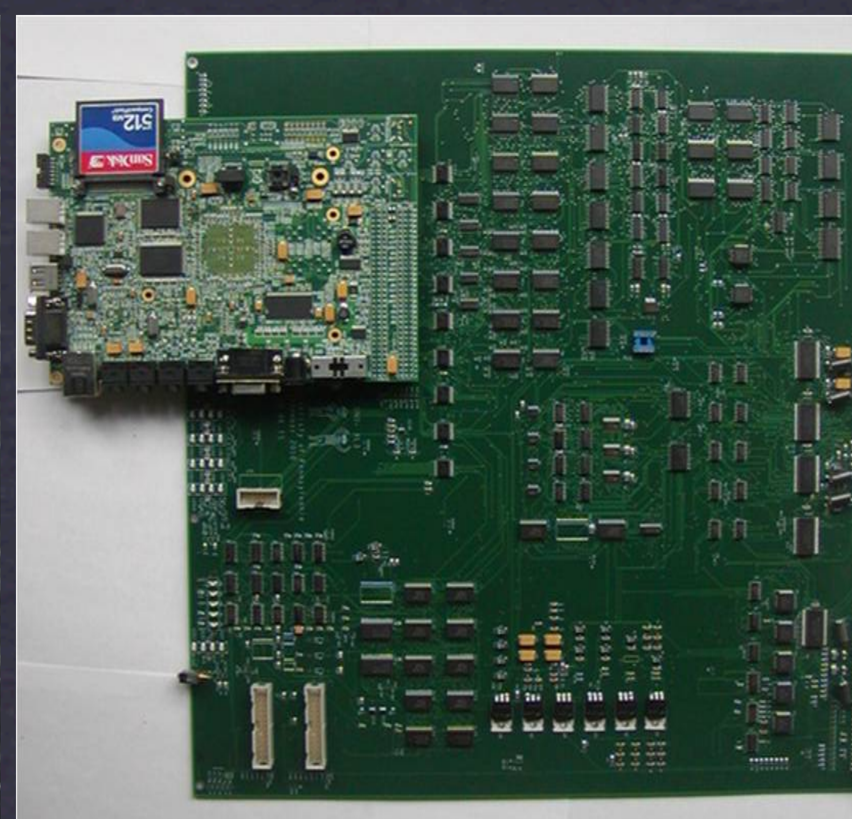
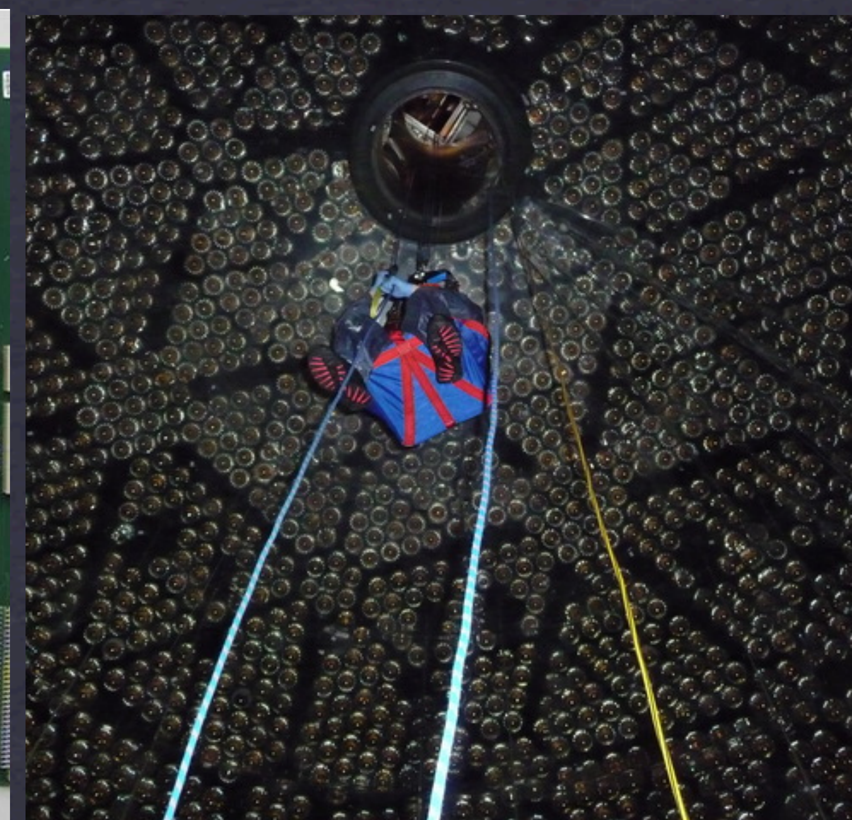



- geo-neutrinos
  in Sudbury from:
  mantle
  old, thick continental crust
- local region is being studied in great detail
- reactor/geo-neutrino ratio: 0.9 (4.4 for KamLAND)



# Status & outlook



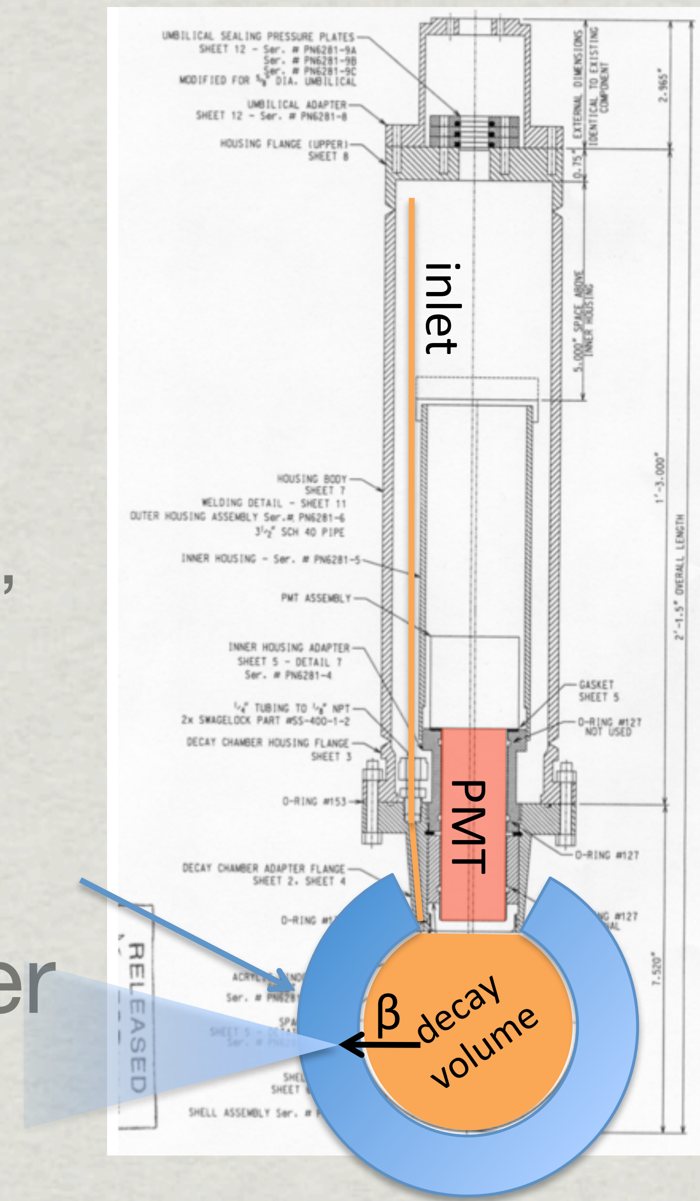
# SOME HIGHLIGHTS OF THE REFURBISHMENT OF SNO

# Calibration programme

- Comprehensive programme with sparse deployment of source to minimalise the risk of $^{222}Rn$ contamination
- *Development of a large number of calibration sources:*
  AmBe (n, γ), $^{16}N$ (γ), $^{24}Na$ (γ), *$^{48}Sc$ (γ)*, $^{57,60}Co$ (γ), $^{65}Zn$ (γ), $^{90}Y$ (β)
  - *Development of several optical sources:*
    internal laserbal, *external* LED/laser injection system with 92 injection points distributed over the PMT support system, Cherenkov source

## CHERENKOV SOURCE

*$^{8}Li$ source + radiator*

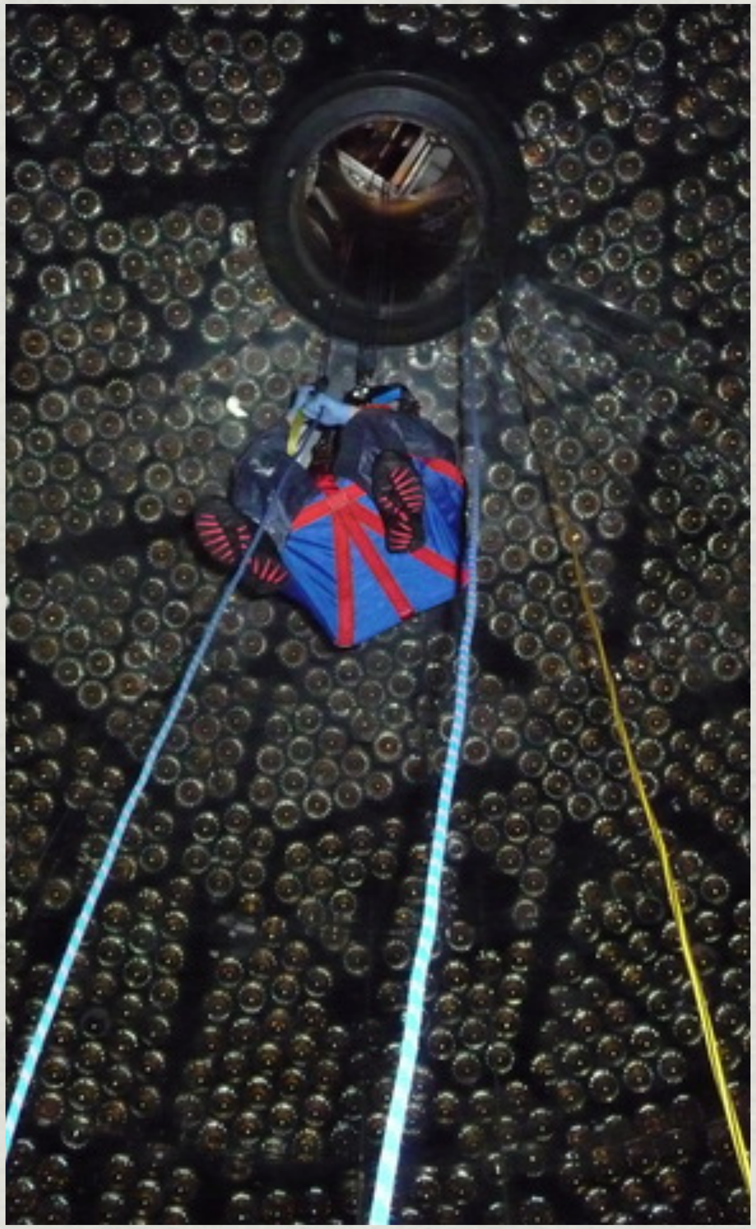



$^{8}Li$: β, 10 MeV endpoint

SNO+

# Timeline

- **2012**
  - Finish work in cavity
  - Process system construction
- **2013**
  - Water phase
  - Scintillator filling
- **2014**
  - Nd-loading
  - Double Beta Decay phase



# Conclusions

- SNO+ is a multi-purpose neutrino detector: rich physics programme
- Double beta decay measurement with $^{150}$Nd
- Sensitivity to the effective neutrino mass down to 100 meV at 90% C.L. after running for 3 years
- Data taking will start in 2013

# Backup slides

# Solar neutrino physics

- **SNO+ has prioritised $0\nu\beta\beta$.**
- Radon daughters have accumulated on the surface of the AV over the last few years in a significant way. If these leach into the scintillator, the purification system has the capability to remove them.
- However, depending on the actual leach rate, that removal might be inefficient and the $^{210}$Bi levels in the scintillator too high for a pep/CNO solar neutrino measurement without further mitigation.
- Mitigation could include enhancing online scintillator purification, draining the detector and sanding the AV surface to remove radon daughters, or deploying a bag.
- *Double beta decay and low-energy 8B solar neutrino measurements are not affected by these backgrounds.*