TECHNISCHE UNIVERSITÄT DRESDEN

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The SNO+ experiment: current status and future perspectives

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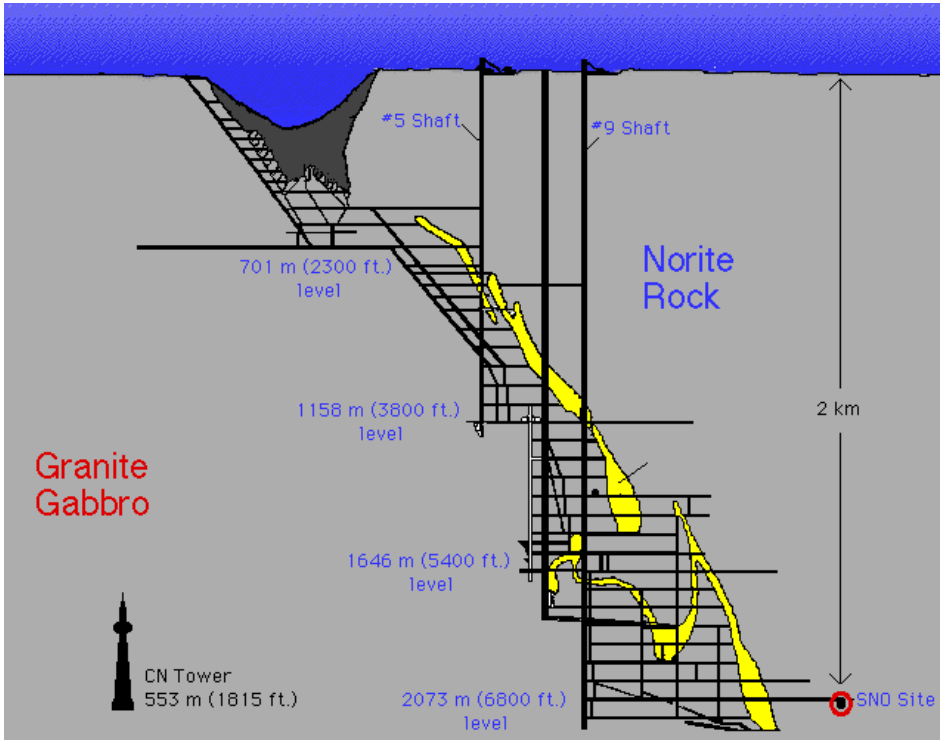
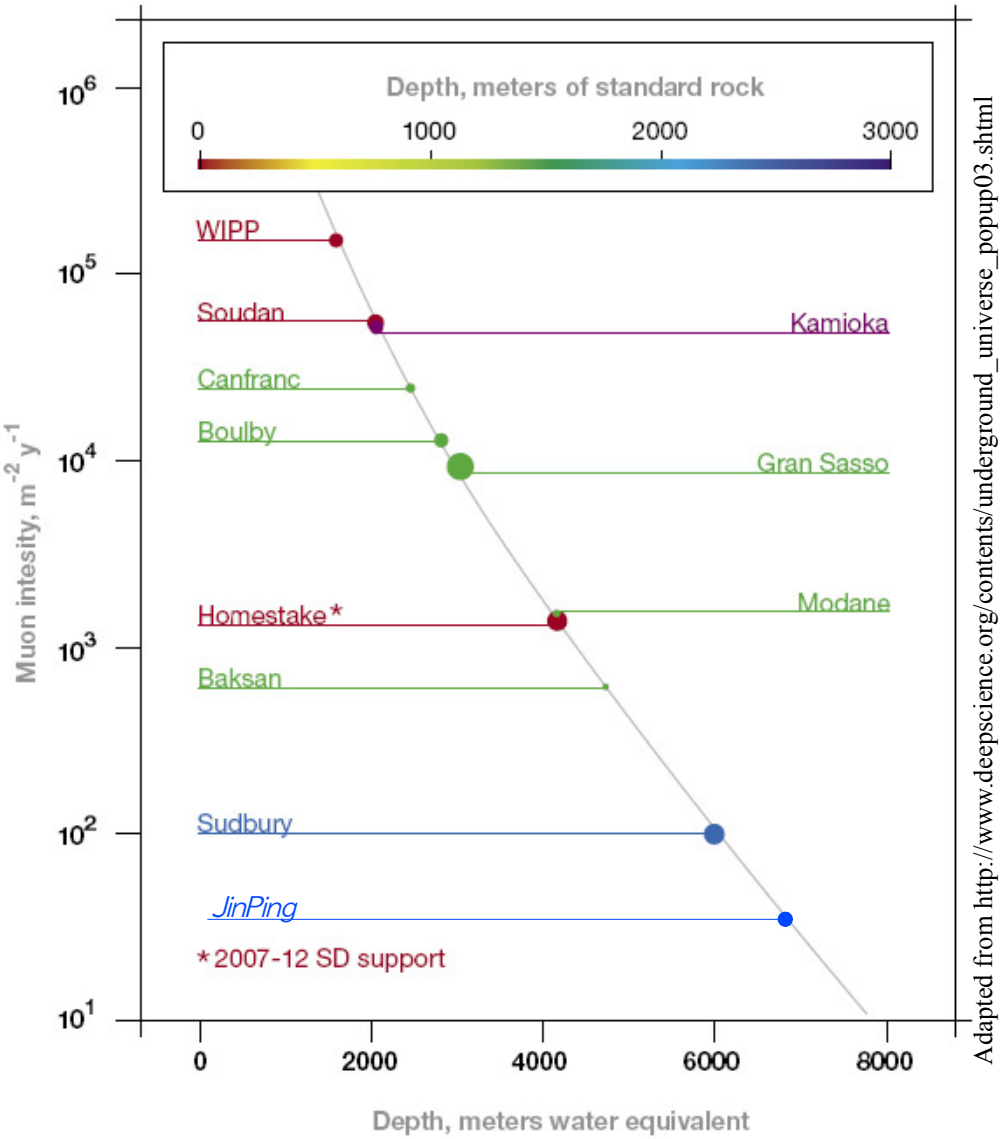
LOCATION

Depth of 5890±94 m.w.e.

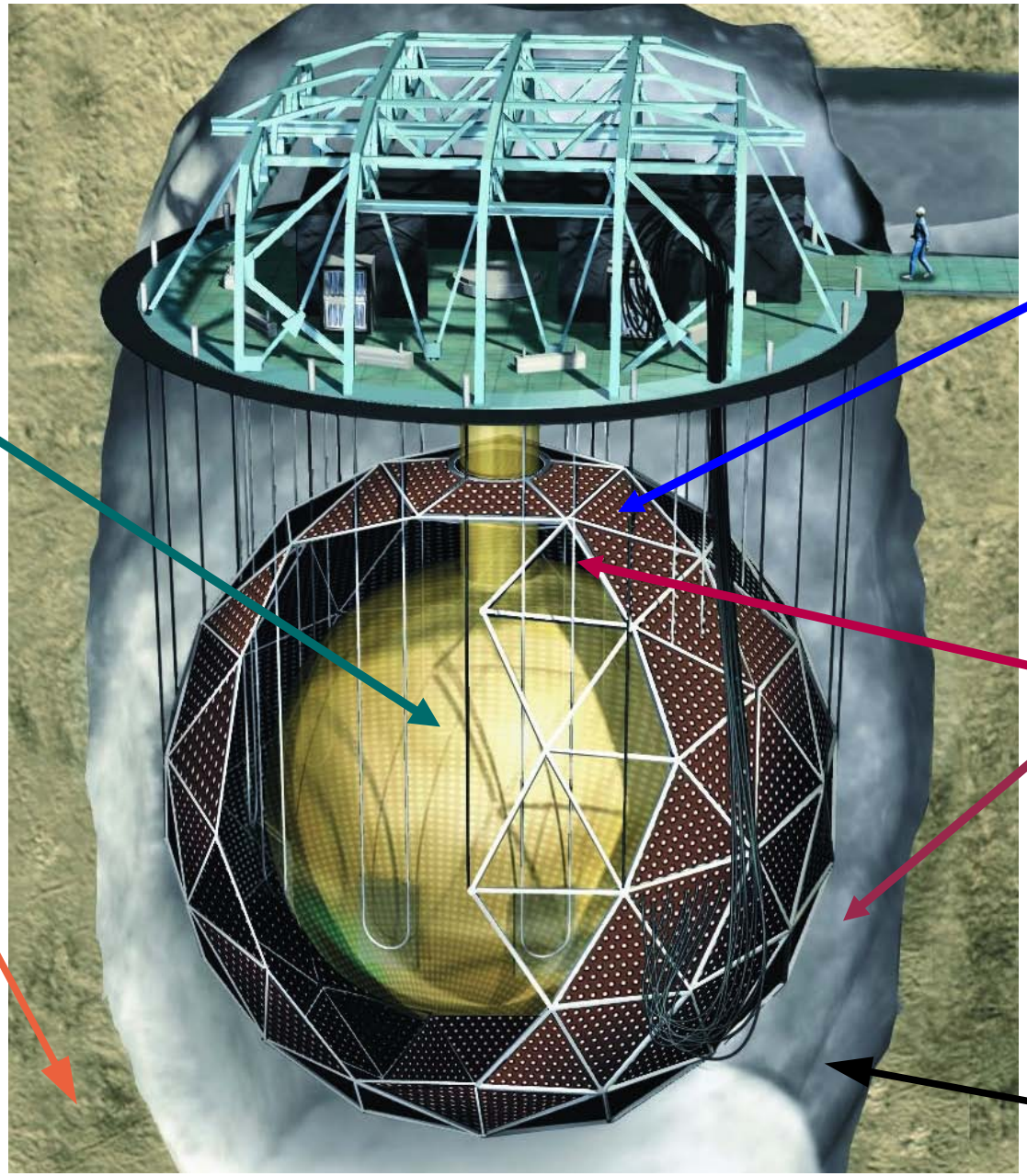
Muon flux = 62.9±0.2 muons/day through a 830 cm radius circular fiducial area

Class-2000 clean room lab





Detector



Acrylic Vessel
R_{AV} = 6 m
t = 5.5 cm
780 t LAB-PPO

Norite Rock

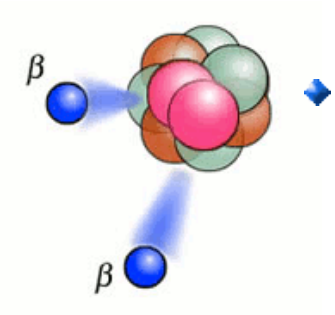
PSUP
PMT Support Structure
~9500 PMT
54% Coverage

Light water (H_2O)
Shielding

- 1700t internal
- 5300t external

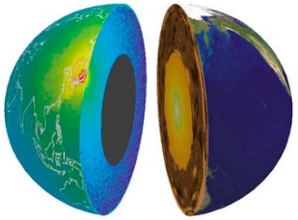
Urylon Liner/Radon Seal

Physics Program



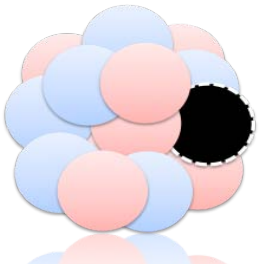
- Neutrinoless double beta decay of ^{130}Te

- Reactor antineutrinos



- Geo-neutrinos

- Supernova neutrinos and antineutrinos



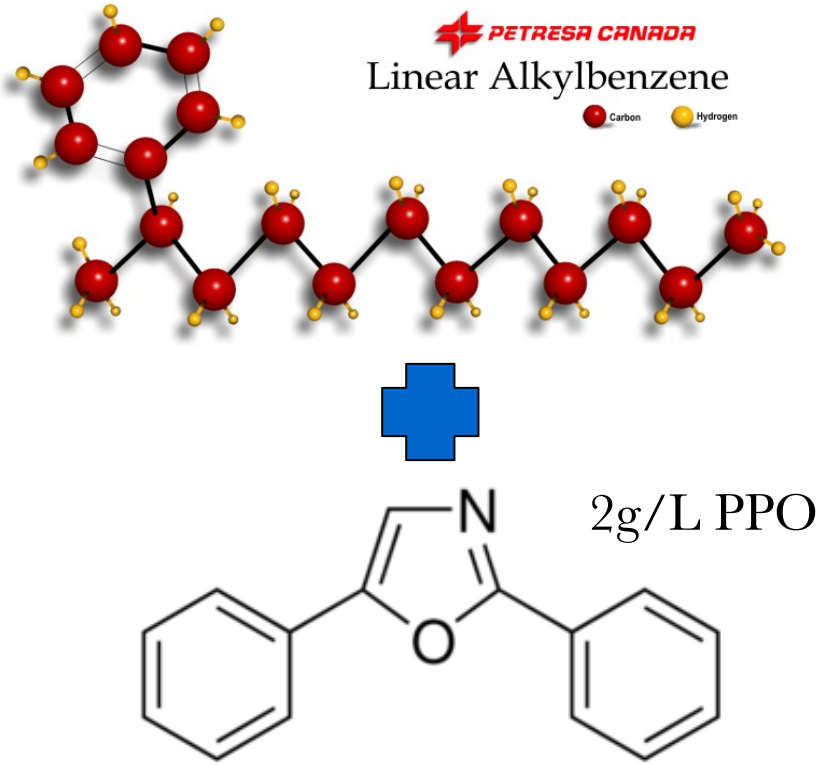
- Invisible nucleon decay and ALPs

- Solar Neutrinos (pep, CNO, low energy ^{8}B)

LIQUID SCINTILLATOR

Linear alkylbenzene (LAB) + 2g/L fluor 2,5-diphenyloxazole (PPO)

- Chemical compatibility with acrylic
- High light yield (~10,000 optical photons/MeV)
- High purity available
- Low scattering
- Good optical transparency
- Fast decay (different for betas and alphas)
- Environmentally safe
- Low solubility in water



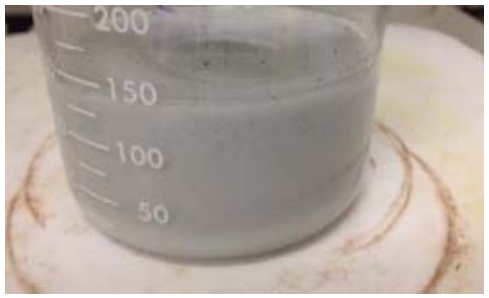
LAB–PPO WITH Te

Use ^{130}Te :

- ☺ High natural abundance (34.08%)
  Q-value = 2526.97±0.23 keV
- ☺ $T^{2\nu\beta\beta}_{1/2} = 7\text{x}10^{20}$ yr, one of the longest of all $2\upsilon\beta\beta$ isotopes
- ☺ No inherent optical absorption lines ⇨ possible to load secondary wavelength shifters to better match PMT QE

0.3% ^{nat}Te loading
=
~ 800 kg ^{130}Te

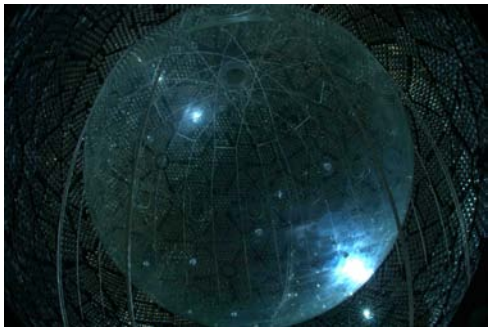
Successfully loaded in LAB: 0.3% ^{nat}Te loading demonstrated to be stable and clear for over 2 yrs

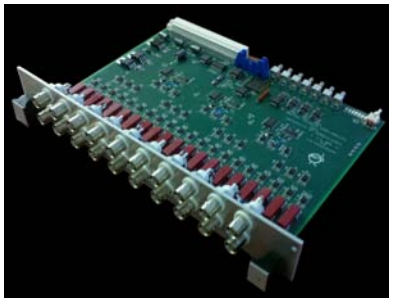


LAB+surfactant+H_2O+^{nat}Te
+wavelength shifter

UPGRADES/1

- New hold-down rope system on the top of the AV anchored to the cavity floor.
  High purity Tensylon
- New hold-up rope system material (Tensylon)





- DAQ and trigger system upgraded to cope with the high light yield of scintillator
- ~ 500 defective PMT bases have been repaired
  Expected ~9500 working PMT at the start of data taking
- New calibration system
  Optical sources (LED and lasers coupled to fibers)
  Radioactive sources (gamma, alpha, neutron, beta)
- New cover gas system to limit Rn ingress into the detector

Purification plant for LAB and Te ⇒ installation ongoing

LAB-PPO

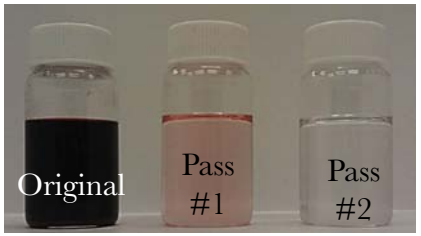
- Multi-stage distillation (remove metal + optical clarity)
- Pre-purification of PPO concentrated solution
- Steam/N_2 stripping (remove gases)
- *In-situ* re-purification + *ex-situ* water assays
  - Full volume in 4 days
  - Water-LAB extraction column
  - Metal scavengers (remove metals)
  - Microfiltration for removal of suspended fines.

TELLURIUM

Purification system for tellurium to remove U/Th + cosmogenics

On surface (2x)
- Factor 10^4-10^5

Underground
- Factor ~100
- 70% of Te in solution
- 30% recovered on surface



10kg pilot-scale plant
Final design ~200 kg

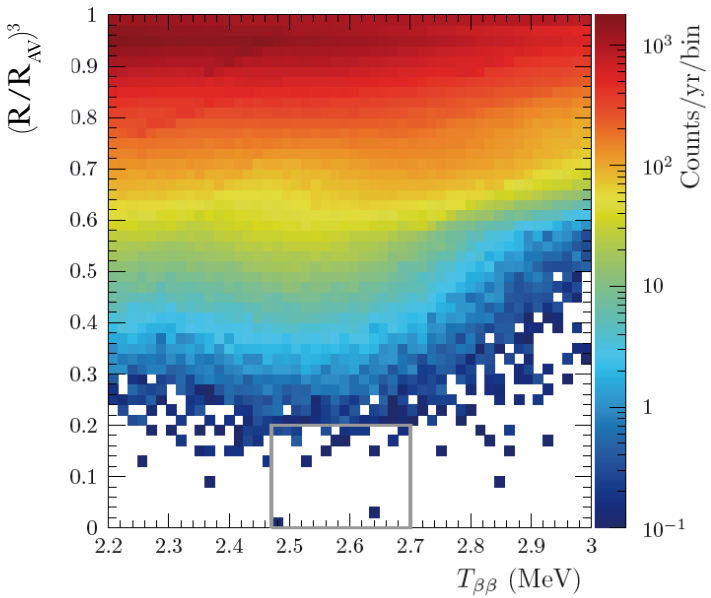
0νBB WITH SNO+

Key Advantages:

- Fiducialization to remove external backgrounds
- Measure internal/external backgrounds before/after Te deployment
- High purity + Tagging techniques + PID to remove internal backgrounds
- Easy to increase loading and affordable scaling
- Possibility to change to another isotope
- Remove and re-purity Te if high levels of backgrounds are found

External betas/gammas:

- PMTs, Hold-down and hold-up rope systems, AV + dust, Shielding water
- *Mitigation = fiducial volume cut at 3.5 m (20%)*
  PMT time distribution ⇒ /2

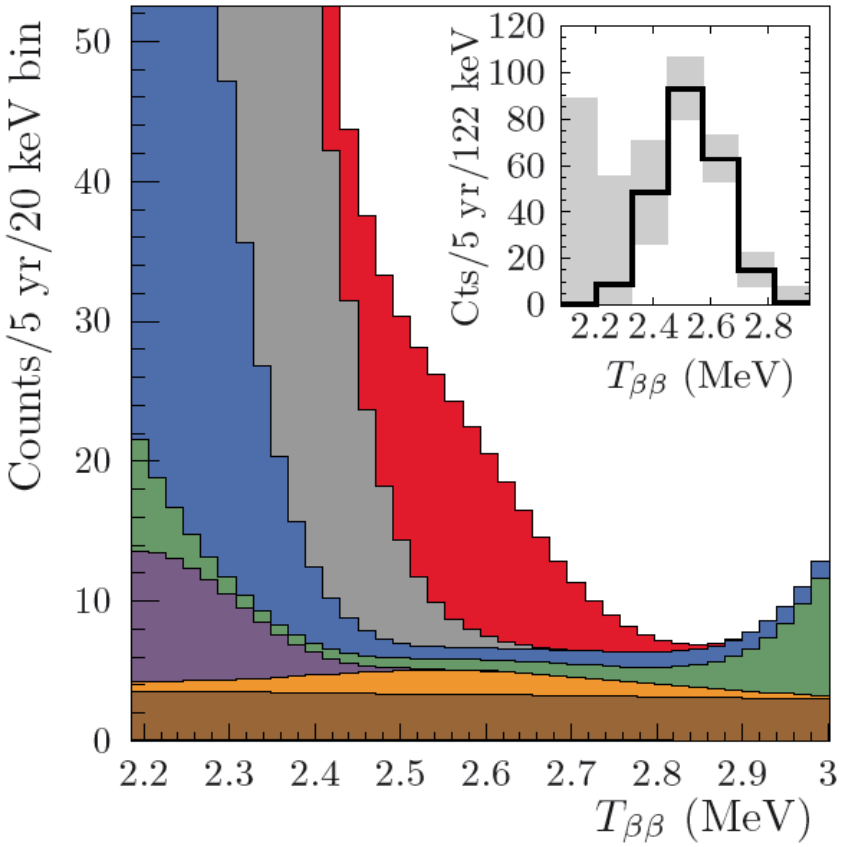


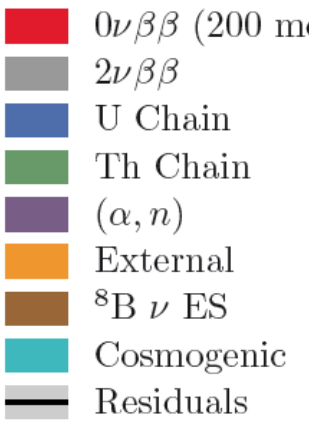
Internal U/Th chain:

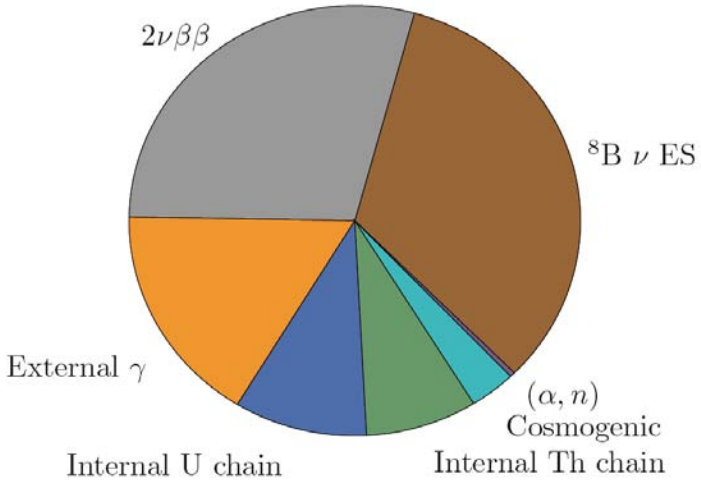
- ^{238}U chain: target level ~ 2.5x10^{-15} g_U/g_{TeLS}
  - ^{214}Bi, ^{210}Tl, ^{210}Bi, ^{210}Po
- ^{232}Th chain: target level ~ 3x10^{-16} g_{Th}/g_{TeLS}
  - ^{212}Bi, ^{208}Tl
- *Mitigation =*
  - *beta-alpha delayed coincidence tagging*
    ^{214}Bi → ^{214}Po → ^{210}Pb
    ^{212}Bi → ^{212}Po → ^{208}Pb
    ~ 100% reduction in ROI and FV
  - *PMT time distribution*
    ^{214}Bi+^{214}Po pile-up
    ^{212}Bi+^{212}Po pile-up
    ~ 98% reduction in ROI and FV

DBD Spectrum

Asymmetric ROI: -0.5σ – 1.5σ







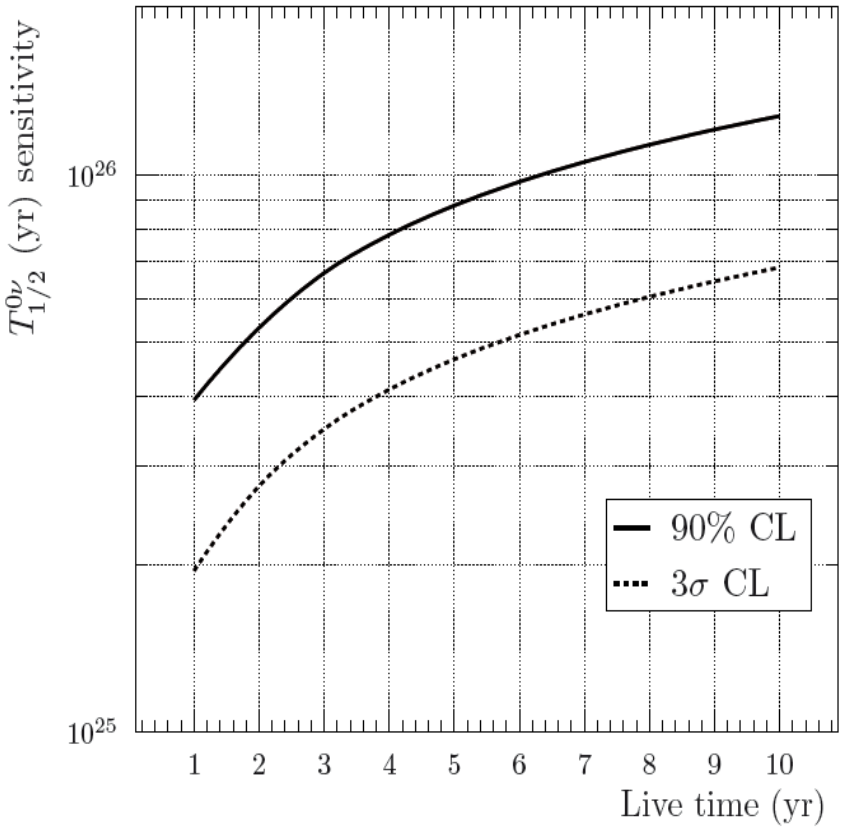
~22 events/yr

- 3.5 m (20%) fiducial volume cut
- 200 hits/MeV
- 5 years
- > 99.99% efficient ^{214}Bi tag
- > 98% efficient internal ^{212}Bi tag

- Negligible cosmogenic isotopes
- $m_{0\nu2b}$=200 meV **

**J. Barea et al. Phys. Rev. C87 (2013) 014315
J. Kotila, F.Iachello. Phys. Rev. C 85 (2012) 034316

Sensitivity



90% C.L.

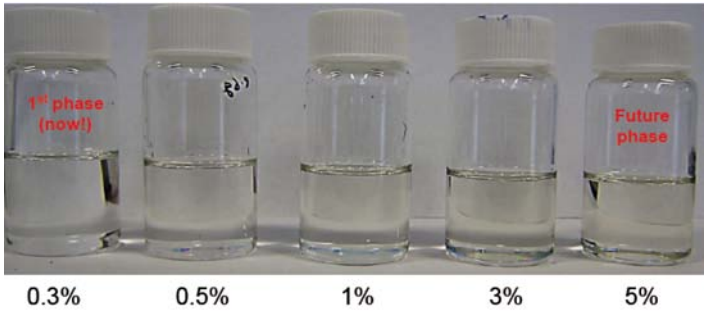
- 1 Year: $T^{0\nu\beta\beta}_{1/2} = 3.9\text{x}10^{25}$ y
- 5 Years $T^{0\nu\beta\beta}_{1/2} = 9.4\text{x}10^{25}$ y

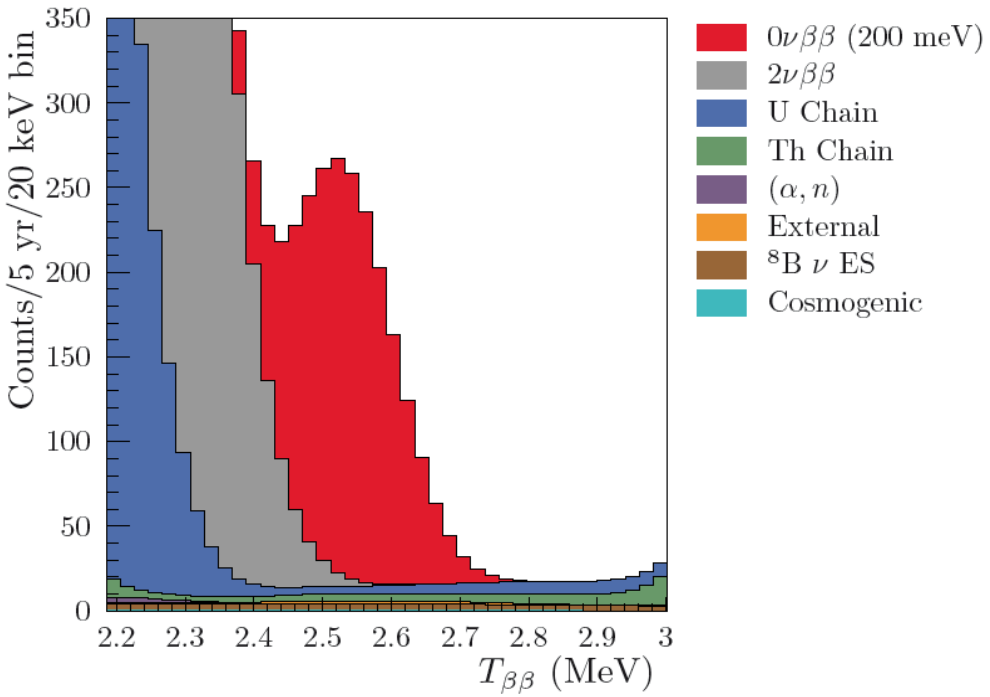
  $m_{\beta\beta} = 55 - 133$ meV $(G^{0\nu} = 3.69\text{x}10^{-14}\,y^{-1})$

Higher Loading

Increasing sensitivity by

- Higher loading
- Increasing light yield by:
  - Higher QE PMTs
  - Improved concentrators
- Using a low background bag to reduce external background





3% ^{nat}Te loading
=
~ 8 tonnes ^{130}Te

450 nHits/MeV
3% energy resolution at $Q_{\beta\beta}$

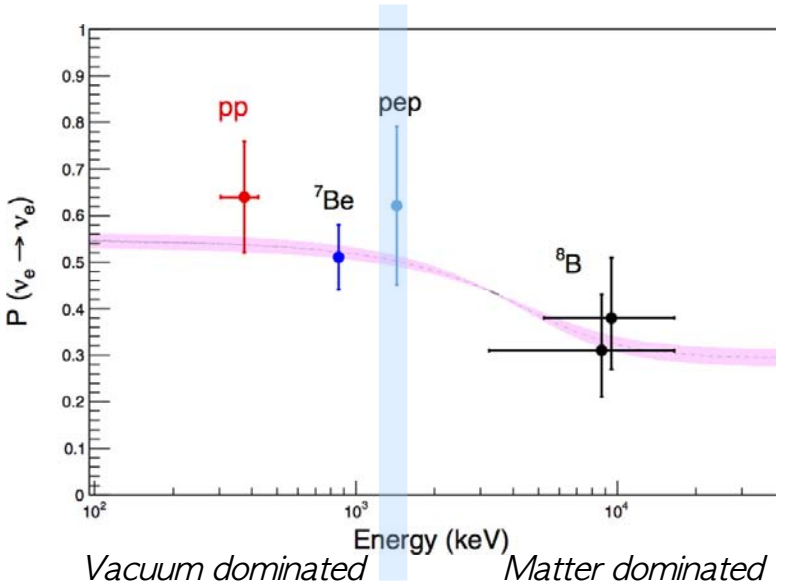
$T^{0\nu\beta\beta}_{1/2} > 7x10^{26}$ yr. (5 years data taking)

Solar Neutrinos

- Precision measurement of pep solar neutrino and low energy ^{8}B neutrinos
  ⇨ Probe the interactions of neutrinos with matter to search for new physics

Pep component is favorable due to:
- single energy (1.44 MeV)
- very well predicted flux (1.2 % uncertainty)

^{8}B neutrinos are favorable due to:
- the production region closer to solar interior (new physics effects enhanced)



Borexino Coll. Nature, 512, 383–386 (2014)

- CNO neutrinos: depends linearly on the core metallicity
  ⇨ Constrain metallicity of the solar interior and resolve the metallicity problem

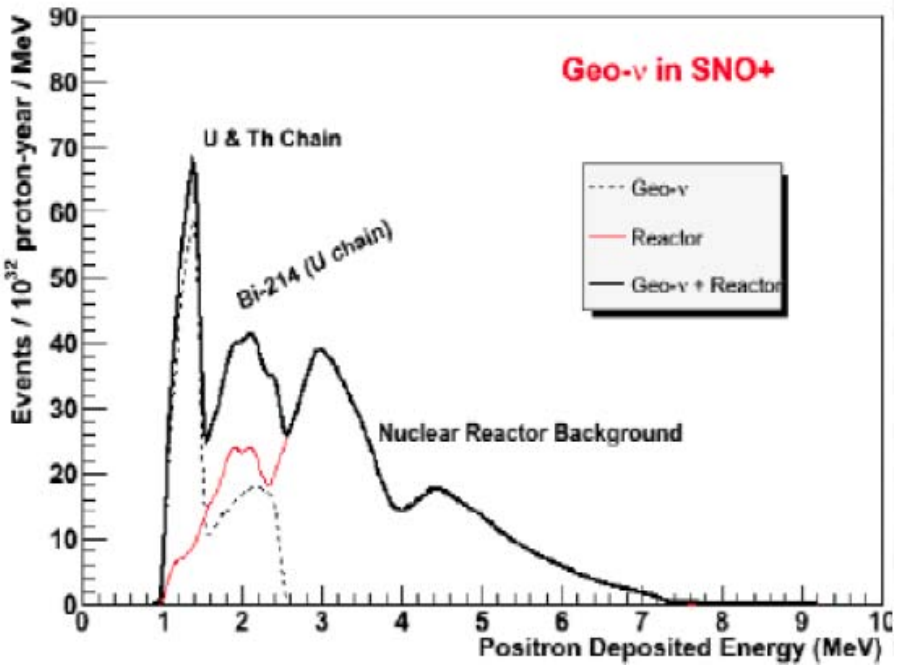
- pp neutrinos depend on the ^{14}C and ^{85}Kr levels in pure scintillator

ANTI-NEUTRINOS

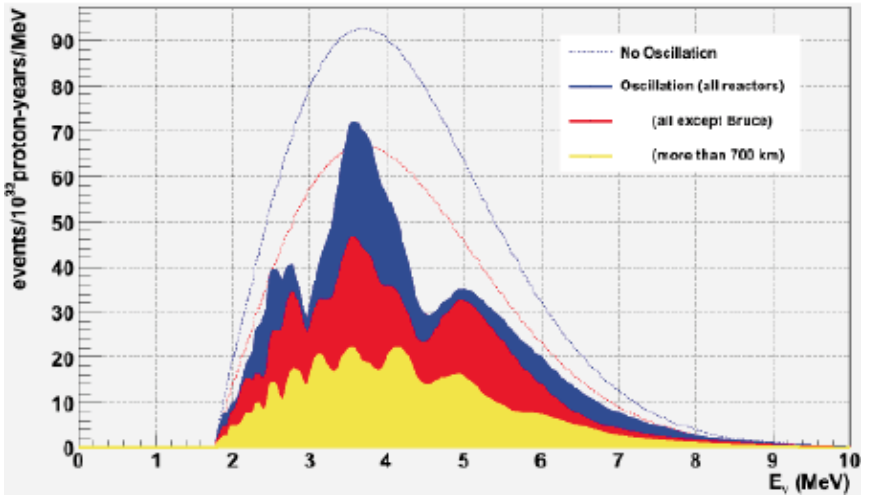
- SNO+ detection via Inverse Beta Decay

$$\bar{\nu}_e + p \rightarrow e^+ + n$$

- Geo-neutrinos from mantle+crust
  - U and Th chain
  - Measurement complementary to Borexino and KamLAND
  - Investigate heat production from the Earth



- Reactor antineutrinos
  - 3 main sources: 1 reactor at 240 km (40%), 2 reactors at 350 km (20%), other reactors in USA at larger distances (40%)
  - Clear oscillation pattern from sources 1 and 2
  - Better constrain Δm^2_{12} osc. parameter



Time Scale

- 2015: water fill and water commissioning
  - Exotics physics: invisible nucleon decay and ALPs
  - Supernova neutrinos
  - Analysis of backgrounds
- 2016: start liquid scintillator fill
  - Reactor- and geo- antineutrinos
  - Supernova neutrinos
  - Low energy solar neutrinos
  - Analysis of backgrounds
- 2016-2017: 0.3% Te loading
  - Neutrinoless double-beta decay
  - Reactor- and geo- antineutrinos
  - Supernova neutrinos

THANK YOU FOR YOU ATTENTION

SNOLAB
TRIUMF
University of Alberta
Queens University
Laurentian University

Armstrong State University
Brookhaven National Lab
University of California Berkeley
University of Chicago
University of Pennsylvania
University of Washington
UC Davis

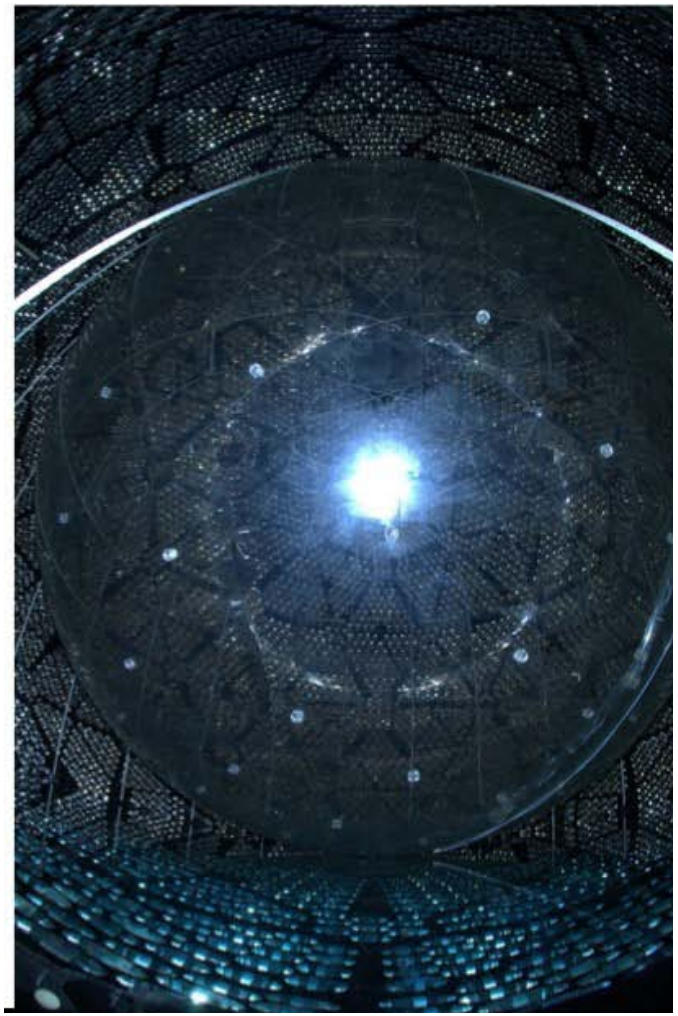
Oxford University
Queen Mary,
University Of London
University of Liverpool
University of Sussex
University of Lancaster

TU Dresden

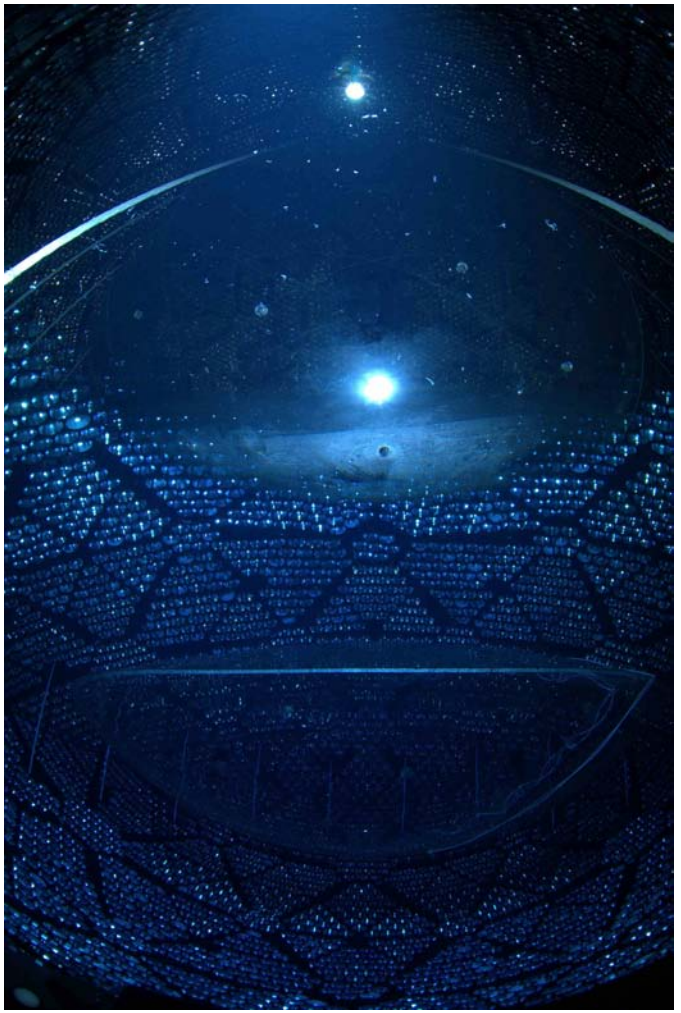
UNAM

LIP Coimbra
LIP Lisboa

Camera above water



Camera and light underwater



Camera underwater, light above water