Neutrinoless double beta decay with SNO+

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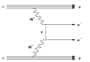
Double beta decay physics

Discovery of neutrinoless double beta decay (0νββ) will answer:

- If neutrinos are **Majorana or Dirac**
- What the **scale of the neutrino mass** is
- If neutrino masses follow **inverted or normal hierarchy**

$$(A,Z) \rightarrow (A,Z+2) + 2e^-$$



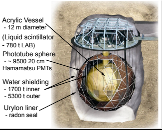
This process violates lepton number conservation and the rate is given by:

$$(T^{0\nu}_{1/2})^{-1} = G^{0\nu} g_A^4 |M^{0\nu}|^2 |\frac{\langle m_\nu \rangle}{m_e}|^2$$

Where $T_{1/2}$ is the half-life, G is the phase space factor, g_A is the Axial-Vector coupling constant of the weak interaction, <m> is the effective neutrino mass.

The SNO+ detector

SNO+ is situated at **6800 feet** underground at **SNOLAB**, Sudbury, Ontario. The **primary goal** of the experiment is to **search for 0νββ** with Te-loaded liquid scintillator.



Other physics goals:

- Low energy solar neutrinos
- Reactor/geo anti-neutrinos
- Supernova neutrinos

SNO+ Te-loaded liquid scintillator

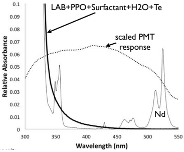
Liquid scintillator approach:

- **Economical** way to build a detector with a large amount of 0νββ isotope
- **Low background environment** can be achieved (purification, self-shielding and β-α rejection techniques)

At its initial phase, SNO+ plans to run with 0.3% natural Te (~ **790 kg** of ^{130}Te).

The advantage of ^{130}Te is:

- **High natural abundance** (34%)
- **Low two neutrino double beta decay half-life** (factor of 100 lower than ^{150}Nd, the previous isotope of choice)
- **No natural absorption peaks**



The **Te-loaded cocktail:**

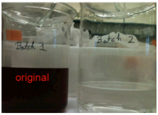
- LAB + wavelength shifters
- H2O
- A surfactant
- Natural Te

Backgrounds

^{8}B solar neutrino and **2νββ**

Internal radioactivity and **cosmogenics:** reduced by

- Purification: **multi-stage distillation** of the **liquid scintillator**, **re-crystallization** of the **telluric acid** using **nitric acid** and removing surface impurities with **ethanol**, **QuadraSil scavengers** to purify the surfactant
- In-situ analysis: All ^{214}Bi-^{214}Po (^{238}U) and ^{212}Bi-^{212}Po (^{232}Th**)** events that are in two separate trigger windows can be tagged and removed. The rest of the events (**pile-up**) are removed via **likelihood ratio** and **PMT time residuals**

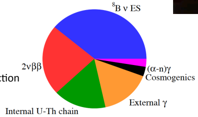


^{60}Co was removed by factor of >10^4 after two passes

External γs and **radon:**

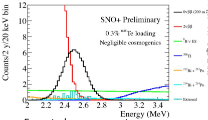
- Removing background events by **fiducialization**
- **PMT time residuals** can be used to **reduce AV ^{208}Tl**
- Reducing radon ingress with a new sealed **cover gas system**

α-n: Neutrons produced by ^{210}Po and ^{214}Po/^{212}Po α interaction with ^{13}C can interact with protons and give 2.2 MeV γs.



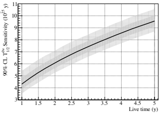
Optimized region of interest 22.2 expected background events/year

Sensitivity with 0.3% Te loading



Expected energy spectrum

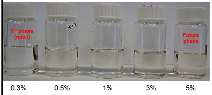
- 200 hits/MeV light yield
- Factor of 50 reduction of BiPo pile-up events
- <m_ν>=200 meV[1][2]
- 3.5 m fiducial volume cut



Half-life sensitivity @90%CL

[1] J. Barea et al. Phys. Rev. C 87, 014315 (2013)
[2] J. Kotila, F. Iachello. Phys. Rev.C 85, 034316 (2012)

SNO+ future



Increasing sensitivity by

- Higher loading
- Increasing light yield: **improving loading techniques** and using **higher QE PMTs**
- Using a **low background bag** to reduce external background