Finding the neutrino mass from 0νββ decay

- For 2νββ the half-life of the decay is unrelated to the neutrino mass.
- For 0νββ the half-life of the decay is related to the Majorana mass of the neutrino.

$T_{1/2} > \frac{\ln(2) \cdot N_{TH} \cdot \sigma_{B}}{n \cdot \sqrt{B \cdot t \cdot m \cdot 4 \cdot \sigma_{B}}}$

For EXO-200: $N_{TH} = 2.6 \times 10^{14}$

- $t = 1.3 \text{ yr}$
- $m = 1.6$ for 90% CL
- $B = 1.7$ cts/(yr eV)
- $m = 0.1$ t
- $\sigma_{B} = 37$ keV

To achieve the sensitivity needed (reduce backgrounds):
1. Natural radioactivity
2. Man-made radioactivity
3. Cosmic radioactivity

Impact can be minimized by appropriate materials selection.

Backgrounds
- EXO-200 has one of the lowest backgrounds in our field
- The nEXO Majorana neutrino mass sensitivity (above) is based mainly on materials measurements performed for EXO-200. We know a "low background" solution exists for these choices.
- Deviate from EXO-200 materials whenever needed to accommodate the larger detector size (cryostat), un-availability of EXO-200 components (APDs), or address technical imperfections (large amounts of internal Teflon).

The nEXO materials R&D programme currently focuses on these issues.

Philosophy
- To reduce the risk of finding an unacceptably high background nEXO will adopt the same general strategy as in EXO-200.
- There will be no component allowed into the detector for which we don’t have a quantitative background impact estimate.
- The low energy radioactivity such as $^{39}$Ar and $^{137}$Cs will be traced as well to maintain the capability to measure 2νββ decay with a signal to background ratio similar to that of EXO-200. This is a convenient two electron data set that can serve as an in situ calibration tool.

How to minimise the background
1. Use the Monte Carlo model to determine a hit efficiency for each technical component.
2. Define a percent allowance for major and minor components. This, together with the component mass, defines the tolerable radioactivity content of a component (we specify these in ppb of K and ppt of Th/U).
3. Choose an analysis tool adequate for the material and the desired sensitivity, perform a measurement, and arrive at a yes/no decision.
4. Work with the manufacturer to improve the material properties, find an alternative vendor, or change the design amount.

Neutrinoless double beta decay (0νββ)
- Double beta decay is a second order weak interaction where two neutrons turn into two protons
- Only observable for nuclei where beta decay is energetically forbidden or highly suppressed
- Two-Neutrino double beta decay (2νββ) is allowed in the Standard Model and has been found for a handful of isotopes
- There are two neutrons in the final state
- Neutrinoless double beta decay (0νββ) is only allowed
- Neutrinos are massive Majorana particles
- And lepton number is not conserved (A=2)

Radio assay for nEXO

David Austy for the nEXO Collaboration

Neutrinoless double beta decay (0νββ)

| Decay | Q-value | Rate
|-------|---------|------------------|
| 0νββ  | 2.26 MeV | 1.826 ± 0.0003 \(1\) \(2\)

Neutrinoless double beta decay (0νββ)

What methods were used for EXO-200
1. gdfit: A 50 ppm Th/U per sensitivity, fast turn around (~1 week per sample). Interpretation of data requires chain equilibrium assumption
2. TD: Neutrinoless double beta decay, fast turn around (~1 week per sample). Excellent on-exhibit assumptions, suited for background with good sensitivity, small sample size order 1 g.
3. NAK: K (¹³⁷) Na (¹²⁴) Ti/¹⁴⁴ to look for sensitivity, slow turn around (~1 month per three to four samples). Requires equilibrium assumption, suited for non-metals or those metals with low neutron capture cross section of about half half lives.

Finding the neutrino mass from 0νββ decay

What methods were used for nEXO
- Direct Ge detector based counting, above and underground Th/U.
- IDPM at SNS (Summit) and LANSCE.
- Survey (future Duke) Th/U.
- gdfit: Neutrinoless double beta decay, fast turn around (~1 week per sample).

Relative loads for different methods:

- EXO: 49%
- GDO: 11%
- NA: 10%
- UG: 9%
- Other: 4%

Neutrinoless double beta decay (0νββ)

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