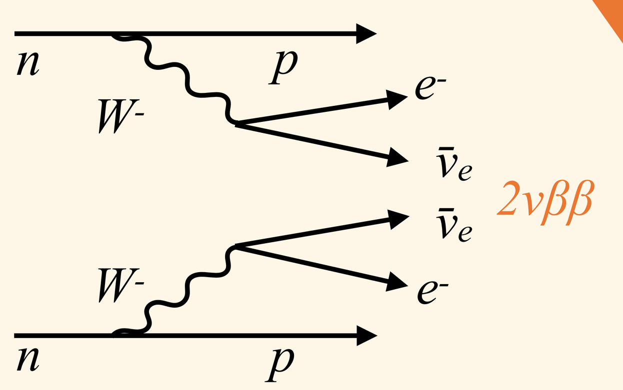
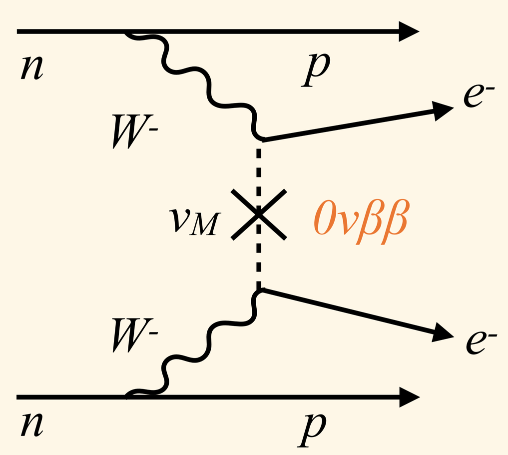
SuperNEMO double-beta decay detector progress

Cheryl Patrick, University College London, on behalf of the SuperNEMO collaboration

Double-beta decay

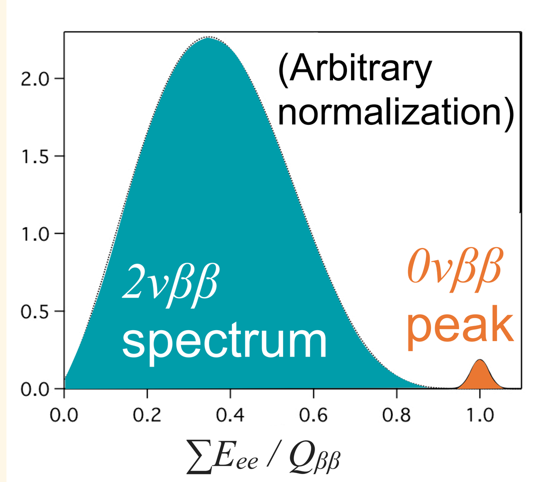
Double-beta decay ($2\nu\beta\beta$) is a **rare nuclear decay process** in even-even isotopes ($T_{1/2} \sim 10^{18}$ - 10^{20} years).



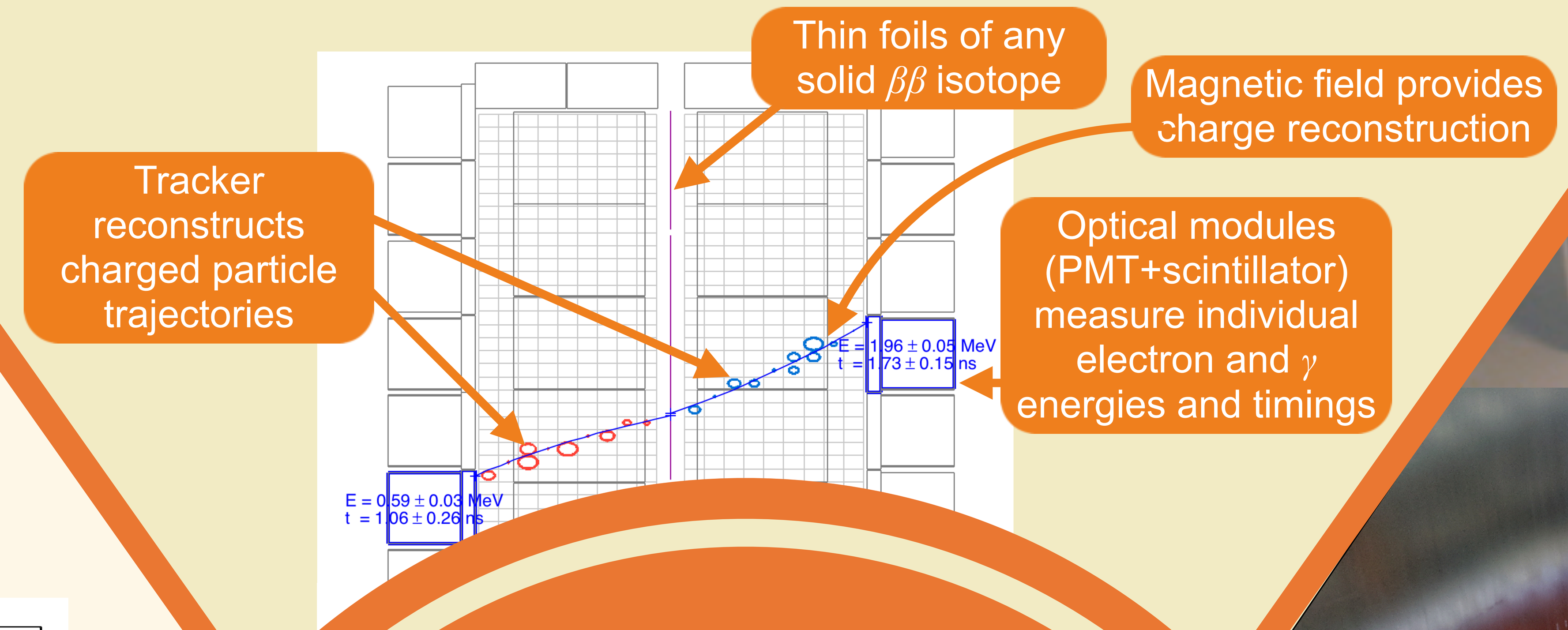


If neutrinos are **Majorana** particles, **neutrinoless double-beta decay** ($0\nu\beta\beta$) should occur in the same isotopes. Could this be related to the cosmological matter-antimatter asymmetry?

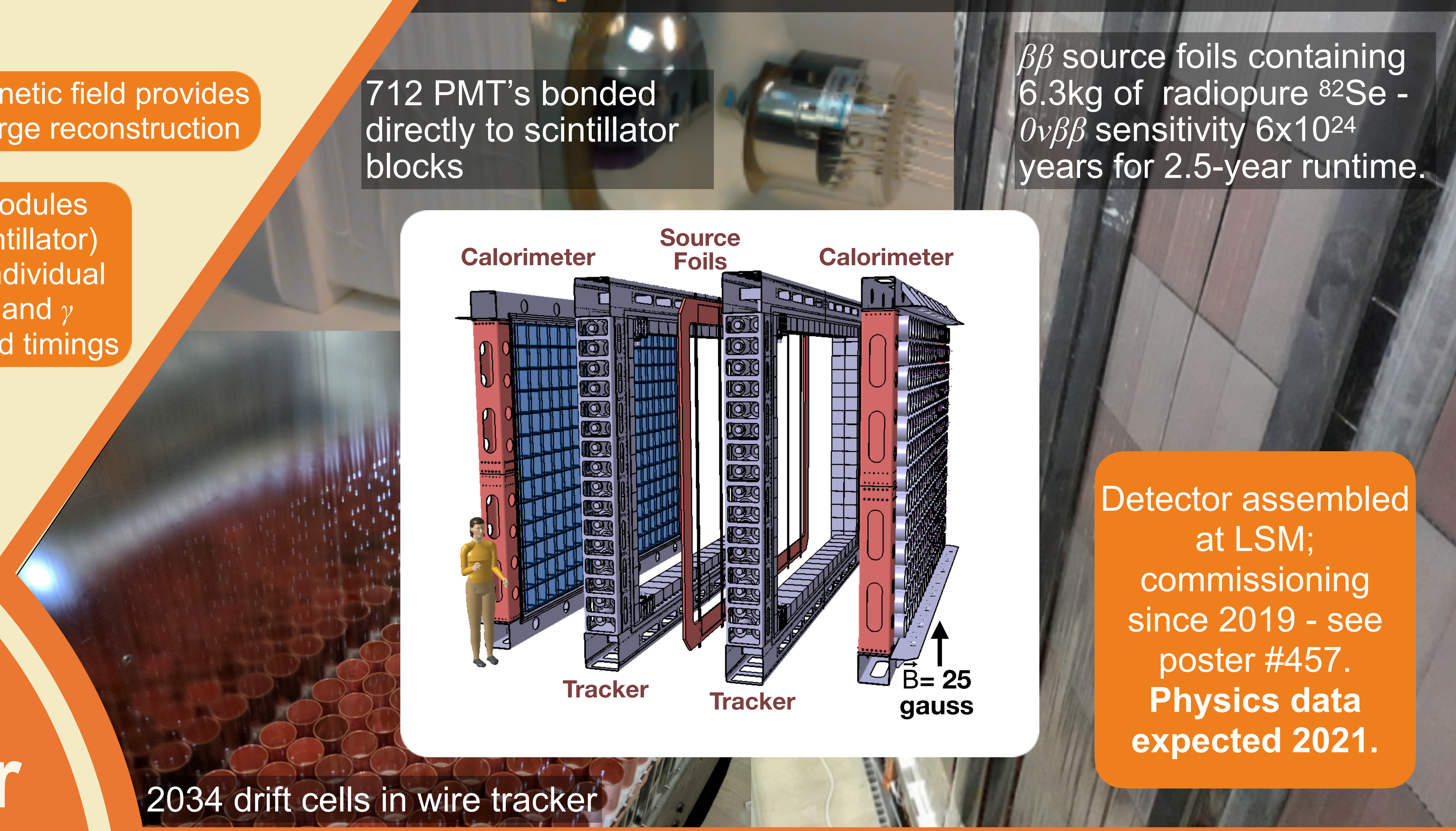
The **summed electron-energy** spectrum distinguishes $0\nu\beta\beta$ from $2\nu\beta\beta$ background. **Individual** electron energy spectra and angular separation give information about the nuclear **decay process**. Exotic $0\nu\beta\beta$ decays that produce a Majoron could also affect $2\nu\beta\beta$ spectra.



The NEMO technique used in NEMO-3 and SuperNEMO



SuperNEMO Demonstrator



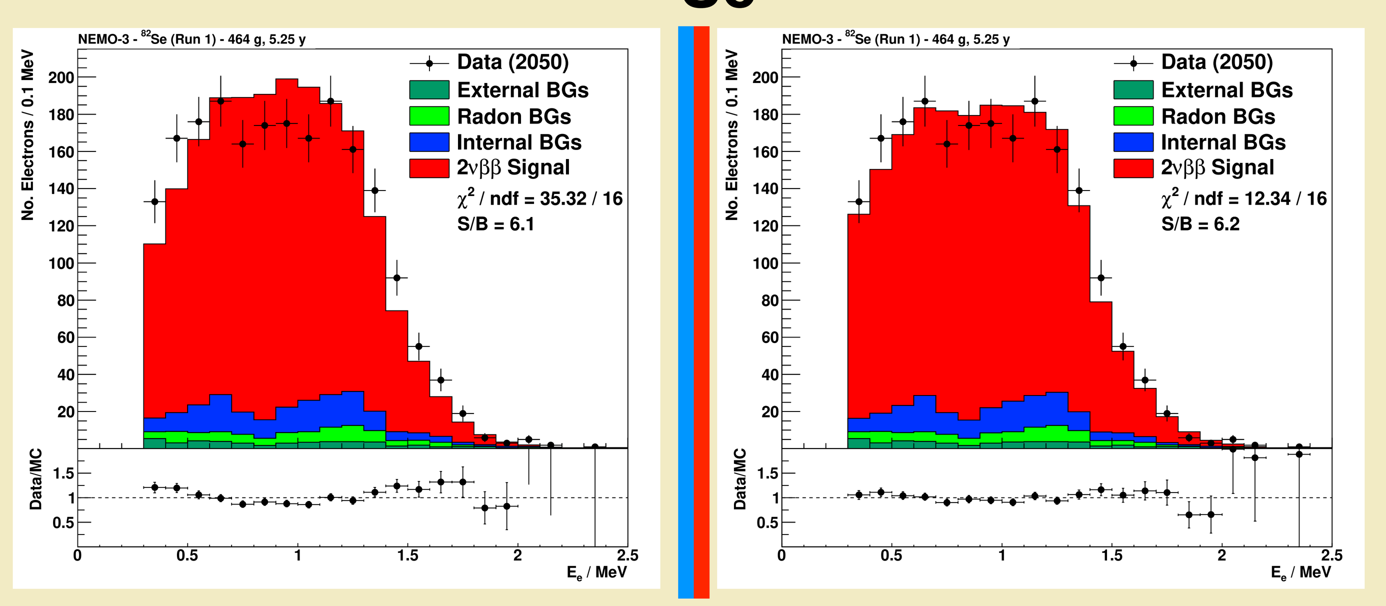
Detector assembled at LSM; commissioning since 2019 - see poster #457. **Physics data expected 2021.**

SuperNEMO's tracker-calorimeter will investigate double-beta decay mechanisms of ^{82}Se from 2021.

New NEMO-3 results show the power of the NEMO technique

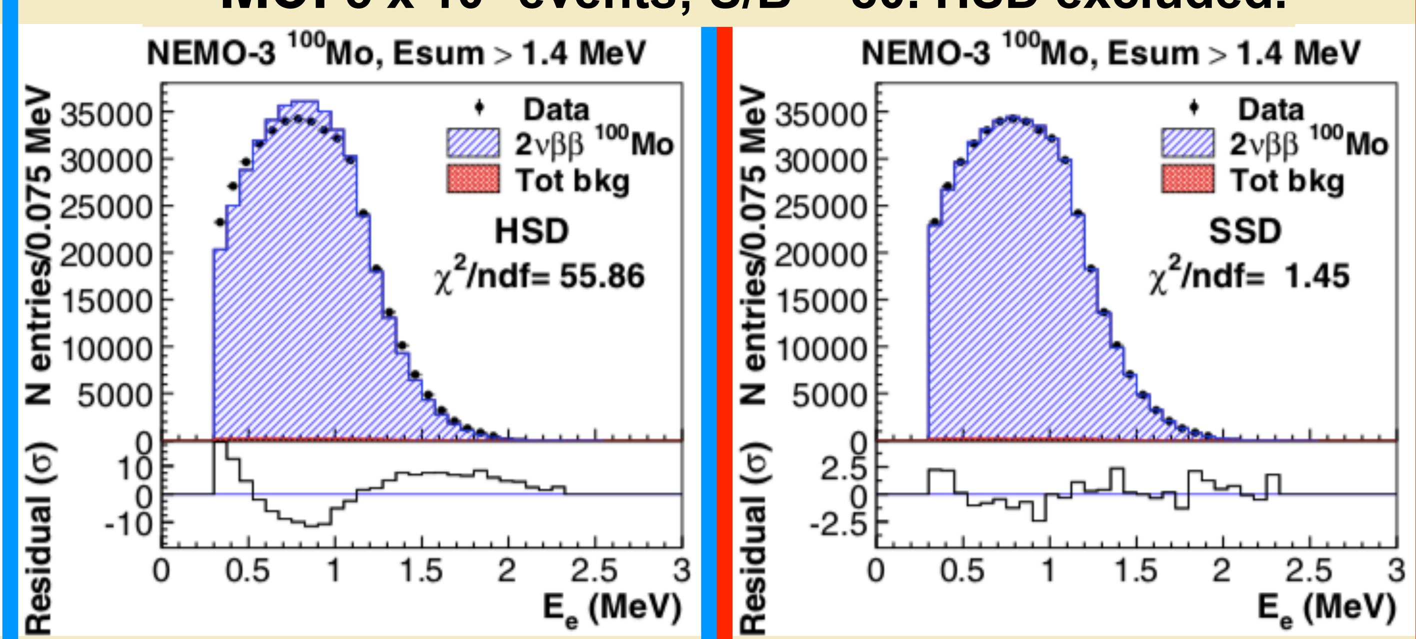
Higher-state dominated | **Single-state dominated**

^{82}Se



$T_{1/2}^{2\nu}$ = **9.39** ± 0.17 (st) ± 0.58 (sys) **x 10^{19} yr** (SSD); $T_{1/2}^{0\nu}$ > **2.5 x 10^{23} yr** (90% C.L.)

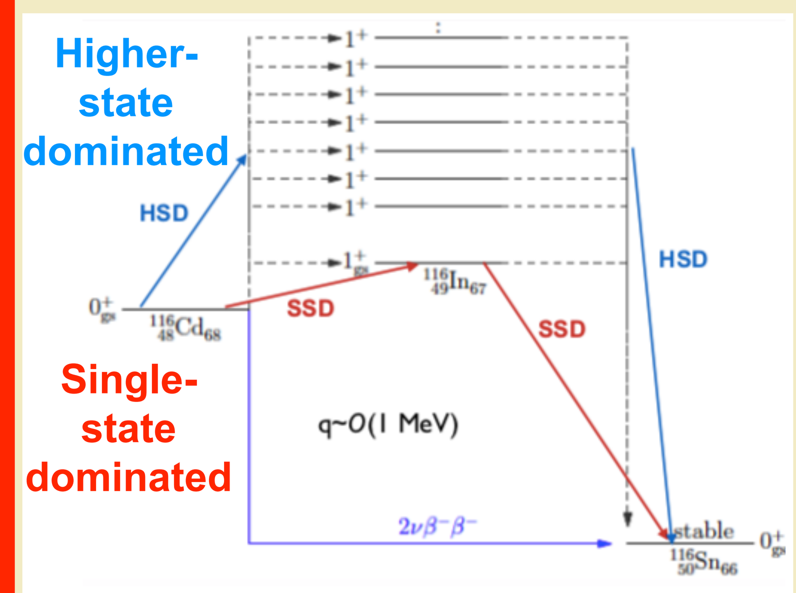
^{100}Mo: 5 x 10^5 events; S/B ~ 80. HSD excluded.



$T_{1/2}^{2\nu}$ = **6.81** ± 0.01 (stat) +0.38 / 0.40 (sys) **x 10^{18} yr** (SSD)

Using $2\nu\beta\beta$ to understand the nucleus

The shape of the individual electron energy spectrum for $2\nu\beta\beta$ **favours** a decay dominated by **transitions involving the ground state** (**SSD**) of the intermediate nucleus, rather than excited states (**HSD**), for ^{100}Mo and ^{82}Se.

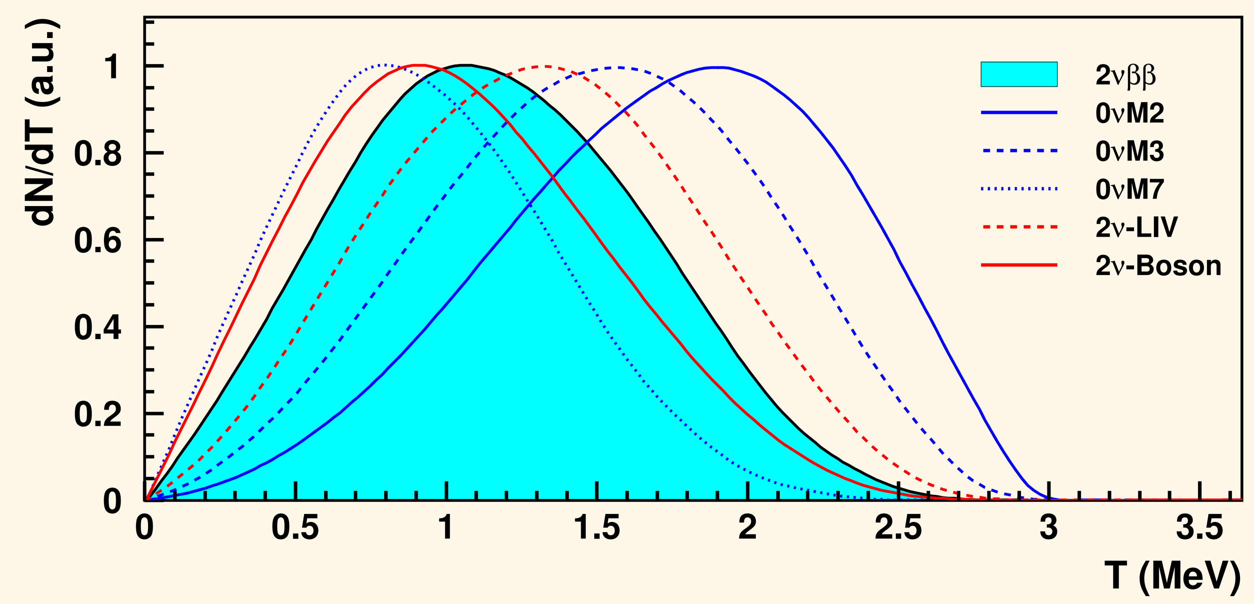


The **SuperNEMO** Demonstrator expects to achieve **5σ discrimination** between SSD and HSD in **^{82}Se.**

Future analyses will use our **topological event reconstruction** to constrain the beta decay constant g_A. Both $0\nu\beta\beta$ and $2\nu\beta\beta$ have strong ($g_A{}^4$) dependence on this parameter.

Searching for exotic phenomena with NEMO-3

NEMO-3's half-million $2\nu\beta\beta$ events for ^{100}Mo allow us to set limits on exotic $0\nu\beta\beta$ decay modes. $0\nu\beta\beta$ with Majoron emission would **distort** the 2-electron **energy spectrum** and **angular distribution**. The shift depends on the spectral index, n, with n=5 for Standard Model $2\nu\beta\beta$. (See **blue** lines on plot)



n	Mode	$\langle g_{ee}\rangle$ for ^{100}Mo
n = 3	χ^0	0.013–0.035
n = 3	$\chi^0\chi^0$	0.59–5.9
n = 7	$\chi^0\chi^0$	0.48–4.8

The lack of distortion to the spectrum allows us to calculate an upper limit on the Majoron coupling constant $\langle g_{ee}\rangle$. These limits are consistent with those for other isotopes measured at GERDA and EXO, and in the case of n=3, gives the most stringent limit.

Distortions could also be caused by BSM $2\nu\beta\beta$ mechanisms. The **red** line shows the effect of $2\nu\beta\beta$ with a **bosonic neutrino** component , corresponding to n=6. The **dashed red** line indicates the shift from **Lorentz-violating** $2\nu\beta\beta$ (n=4). NEMO-3 was able to constrain the time-like component of the Lorentz-violating operator $\mathring{a}_{of}^{(3)}$

$$-4.2 \times 10^{-7}\ \text{GeV} < \mathring{a}_{of}^{(3)} < 3.5 \times 10^{-7}\ \text{GeV (90\% C.L.)}$$

References

Detailed studies of ^{100}Mo two-neutrino double beta decay in NEMO-3 *Eur. Phys. J. C (2019) 79: 440*
Final results on ^{82}Se double beta decay to the ground state of ^{82}Kr from the NEMO-3 experiment *Eur. Phys. J. C (2018) 78: 821*
Development of methods for the preparation of radiopure 82Se sources for the SuperNEMO neutrinoless double-beta decay experiment *Radiochimica Acta, 108 (2020) 11*
Calorimeter development for the SuperNEMO double beta decay experiment *Nucl.Inst.Meth. A 868 98-108*