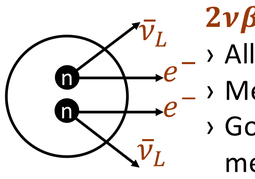
Searching for exotic modes of $2\nu\beta\beta$ with the SuperNEMO Experiment

supernemo collaboration

Basics of $\beta\beta$ decays

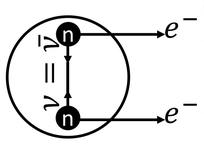
Two-neutrino double-beta decay



$2\nu\beta\beta$

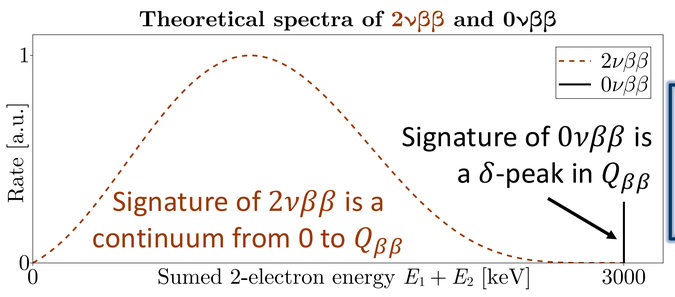
› Allowed in SM
› Measured for 11 isotopes
› Goal now precision measurements

Neutrinoless double-beta decay



$0\nu\beta\beta$

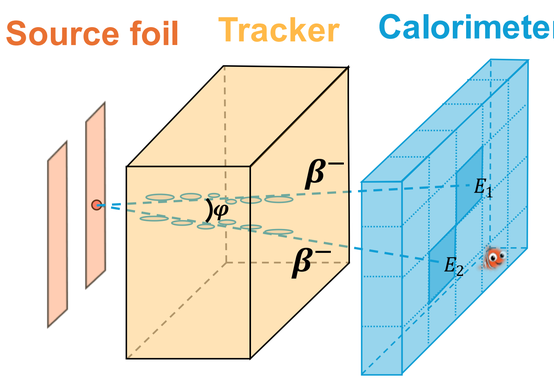
› If discovered → Beyond SM physics
› Main goal of double beta experiments
› Majorana nature of neutrino



Most double beta experiments can measure **only** the sum of the two electrons' energies → **best signature for $0\nu\beta\beta$**

SuperNEMO: Full $\beta\beta$ topology detection

Measurement principle



› **Full kinematics of decay**
  › Individual **electron energies** (E_1, E_2)
  › **Angle between electrons** (φ)
  › Time of Flight

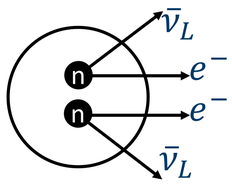
› **Source foil:**
  › ^{82}Se (6.11 kg)
  › $Q_{\beta\beta}$ = 3 MeV
› **Tracker:**
  › 2034 drift cells
  › **See poster #871!**
› **Calorimeter:**
  › 712 plastic scintillators
  › 8" and 5" PMTs

Status

› Source foil ✓
› Tracker ✓
› Calorimeter ✓
› Shielding ⌛
› Data: Sep'24 – '27
› **See talk #331!**

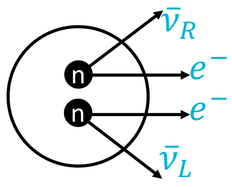

Current status

Exotic modes: theory and where to look



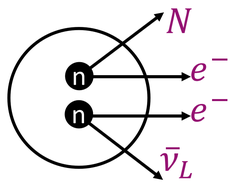
Improved description of $2\nu\beta\beta$ spectrum shape
› Precise shape analysis can constrain g_A[1]
› Shape parameters: ξ_{31}, ξ_{51}

Where to look:
› **Single-electron energy spectrum**



Decay with right-handed neutrino
› **$\nu_R\nu_L\beta\beta$**
› Constrains on the RH neutrino interactions $(V + A)$[2]

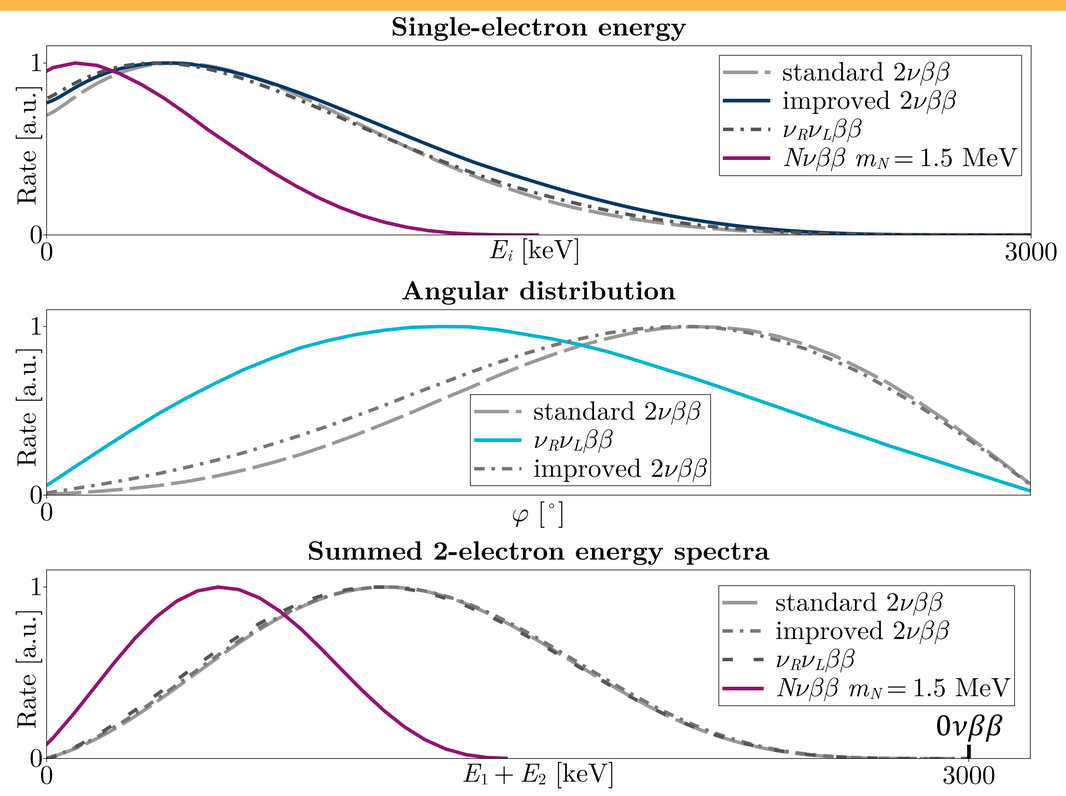
Where to look:
› **Angular distribution**



Decay with sterile neutrino
› **$N\nu\beta\beta$**
› Shape depends on m_N[3]

Where to look:
› **Single-electron energy and Summed energy spectra**

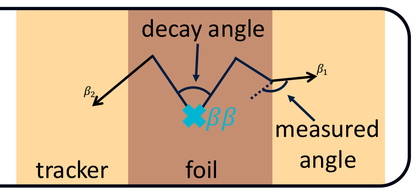
Exotic modes: what they look like



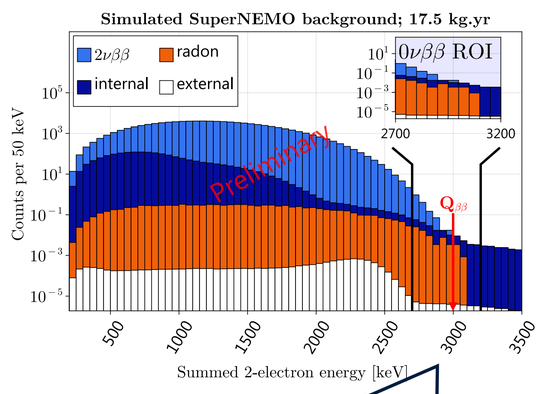
The analysis: from prediction to simulation of what can be achieved

SuperNEMO has access to **unique observables**. Thanks to the tracker-calorimeter approach, analysis can be tailored to look for each decay mode's most **significant trait!**

As electrons traverse through the bulk of source foil their direction changes:
the **decay** angle ≠ the **measured** angle
Paper summarizing these effects in preparation

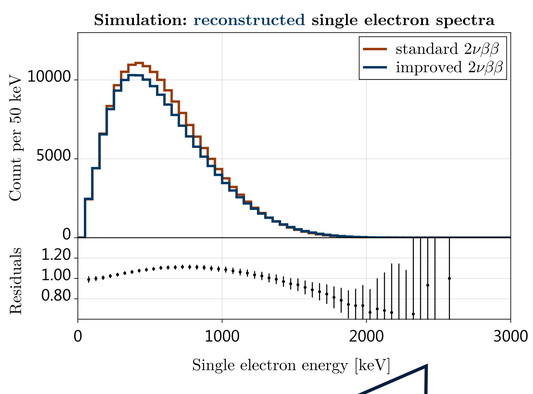


Observable 1
Summed 2-electron energy



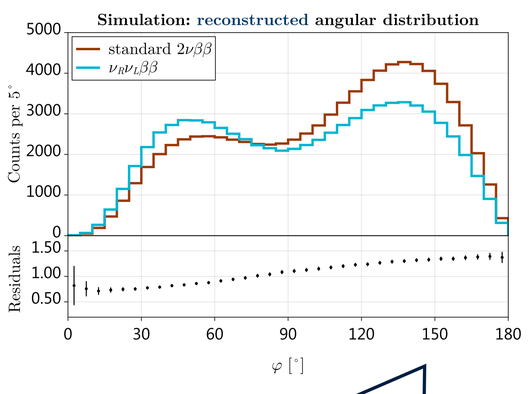
Thanks to the combination of tracking and calorimetry SNEMO expects very low background in a wide ROI, ideal for **$0\nu\beta\beta$** search.
The expected background rate in ROI is:
$< 10^{-4}$ events per keV.kg.yr

Observable 2
Single-electron energy



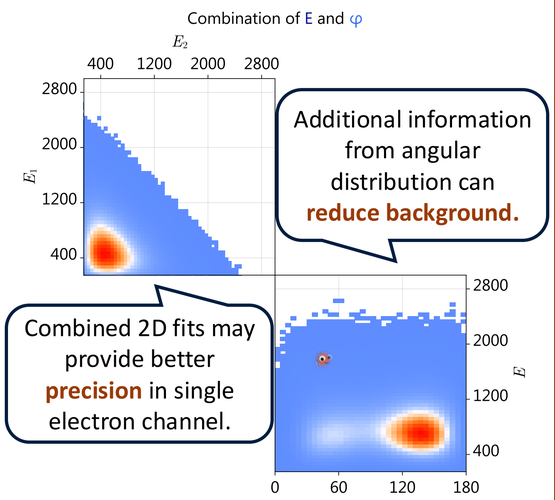
Access to single-electron energy spectra allows SuperNEMO to **study the shape of $2\nu\beta\beta$ with high precision** and to see the subtle changes predicted from advanced theoretical calculations in the **improved $2\nu\beta\beta$**.

Observable 3
Angle between electrons



Contribution of **$\nu_R\nu_L\beta\beta$** can best be studied via the so called **forward-backward asymmetry: The ratio of events with $\varphi > 90°$ and $\varphi < 90°$.**

Multivariate
Combining E and φ?



Additional information from angular distribution can **reduce background.**

Combined 2D fits may provide better **precision** in single electron channel.

The **potential advantage** of the multivariate analysis is yet to be uncovered. **Stay tuned!**

Poster mini-game!
Can you find all 5 NEMOs?

References:
[1] - Nițescu, O.; Dvornický, R.; Stoica, S.; Šimkovic, F.; Universe 2021, 7(5), 147
[2] - Deppisch, F. F.; Graf, L.; Šimkovic, F.; Phys. Rev. Lett. 125, 171801
[3] - Bolton, P. D. ; Deppisch, F. F.; Graf, L.; Šimkovic, F.; Phys. Rev. D 103, 055019

Acknowledgments:
Input data for theoretical descriptions of various spectra presented were provided by L. Gráf and R. Dvornický.
This contribution was supported with the grant No. 24-10180S.

Maros Petro on behalf of the SuperNEMO collaboration

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ICHEP 2024
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