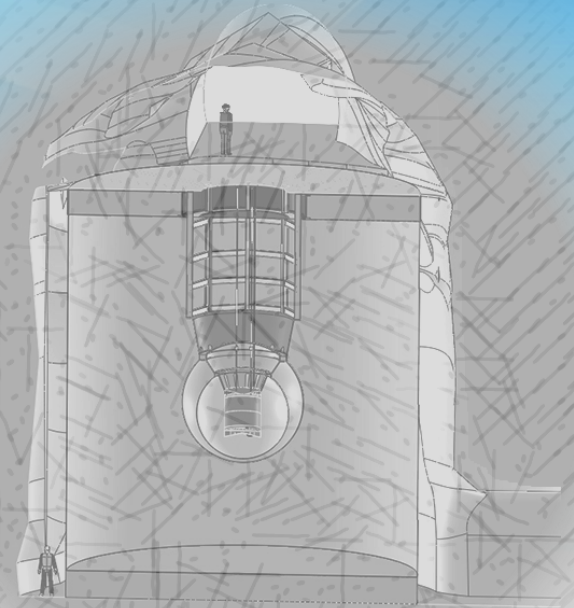


nEXO's Search for 0νββ

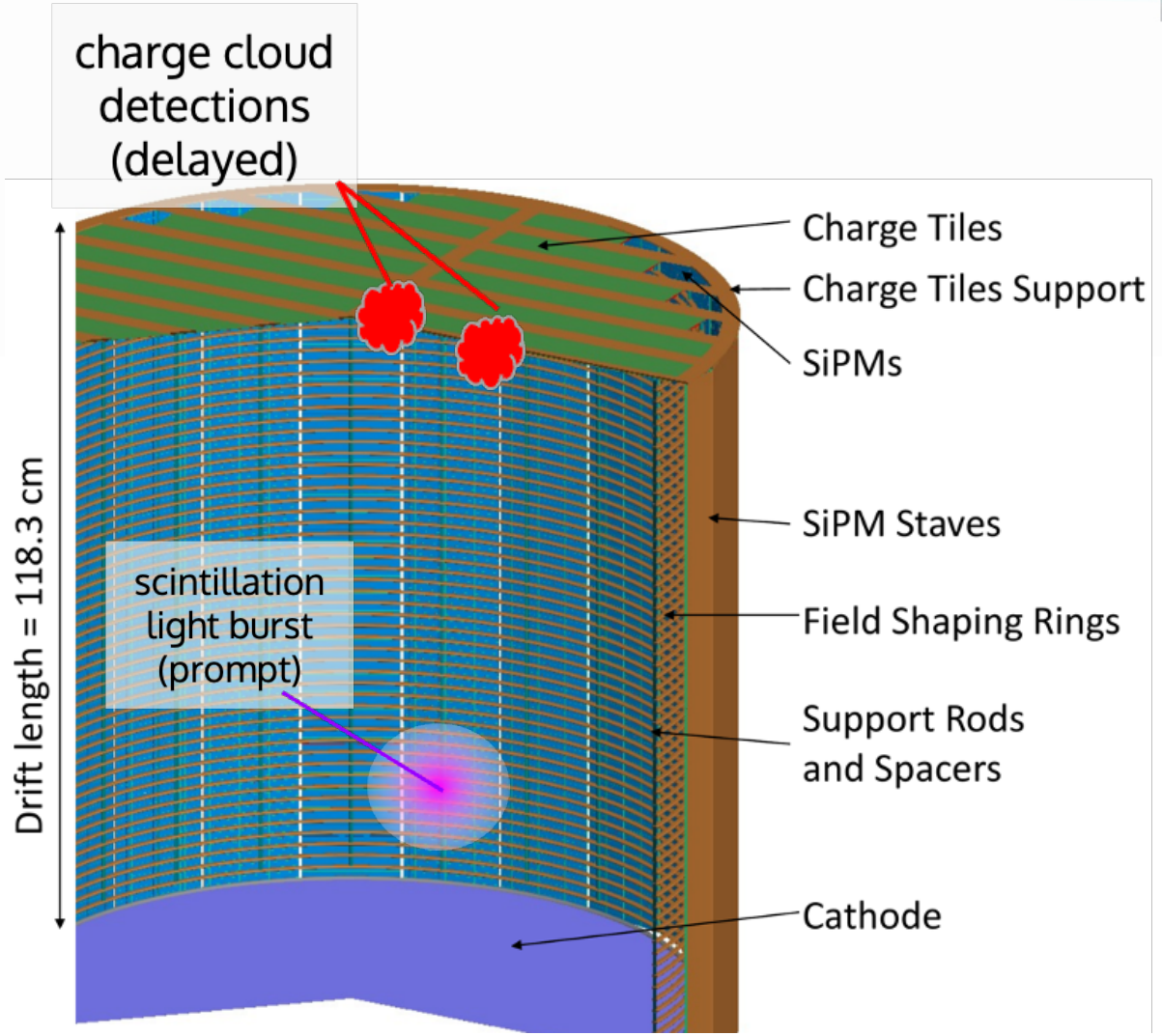
Erica Caden, she/her

Deputy Spokesperson, nEXO Canada

SNOLAB Experiment Forum, 4 February 2025

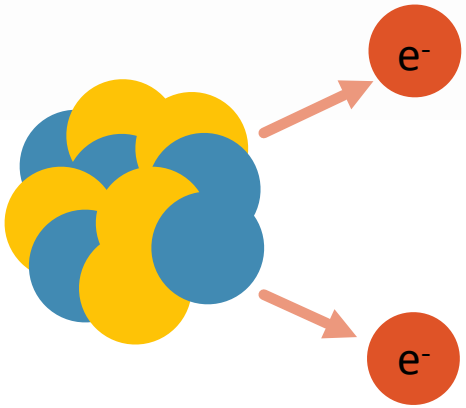
Experimental Overview: Liquid Xenon Time Projection Chamber

- Energy deposits in the LXe liberate electrons, ionize the surrounding liquid
- Excited dimers of Xe_2 release ~175 nm scintillation light
- Ionization clouds drift to segmented anode in applied E-field
- Combination of light + charge readout gives us:
  - Improved energy resolution <1% at $Q_{\beta\beta}$
  - Improved spatial positioning (event localization)
  - Discrimination between α, β, and γ events



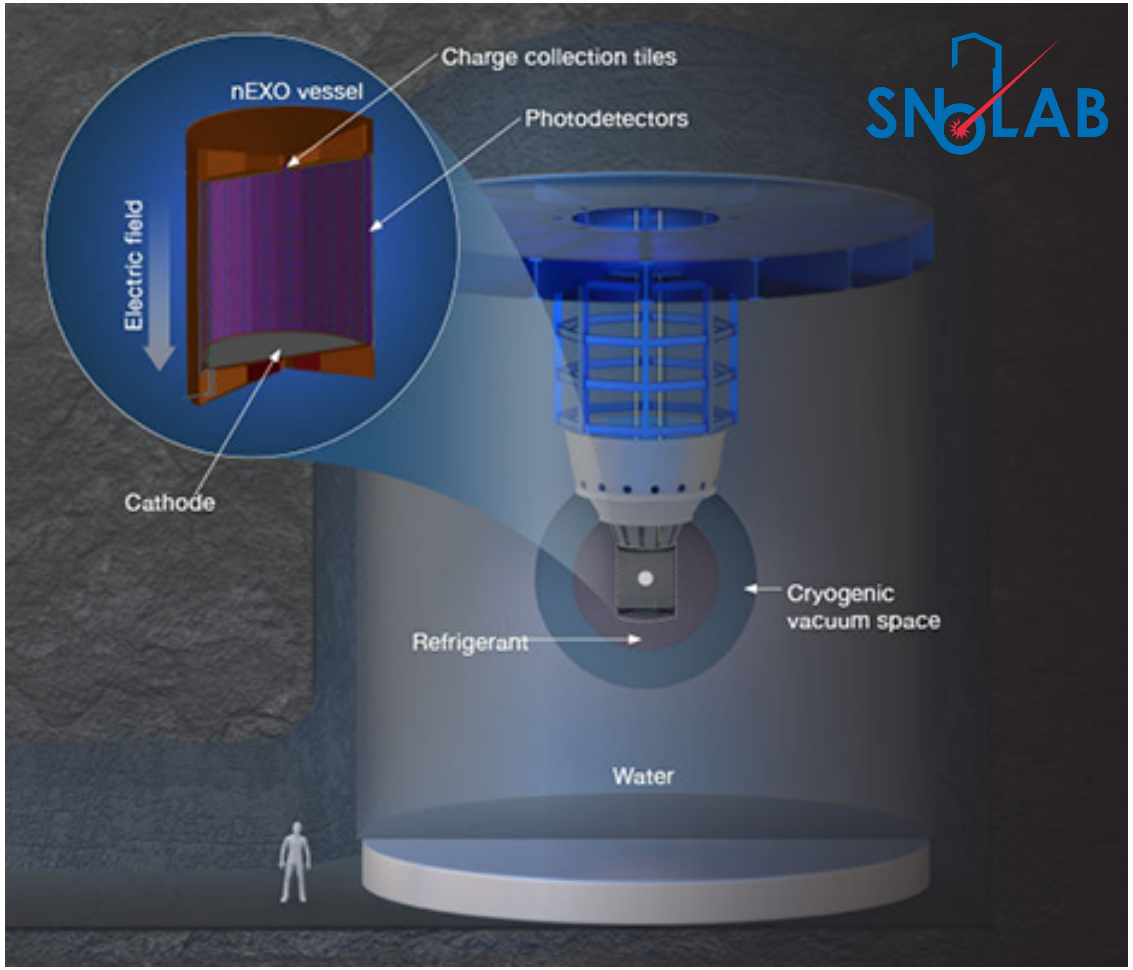
The nEXO Search for 0νββ decay

- Goal: observation of neutrinoless double beta decay (0νββ)



0νββ only possible if neutrinos are Majorana particles.

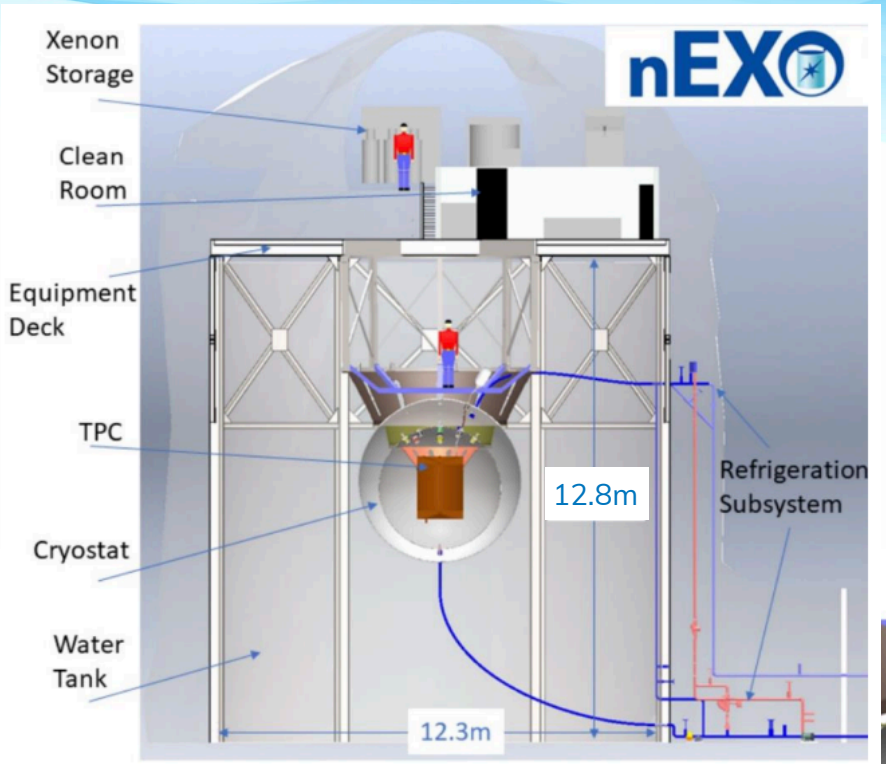
- **Observation would violate lepton number in weak decays**
- Observation would prove existence of a process in which matter is produced without equal amounts of anti-matter!

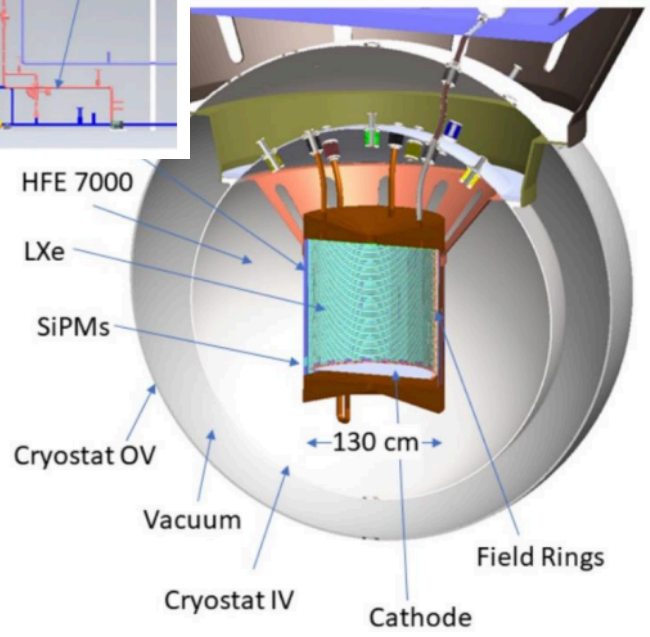


https://nexo.llnl.gov/

The nEXO Experiment

- TPC with 5000 kg of 90% enriched ^{136}Xe
- Xe is used both as the source and detection medium.
- LXe is continuously recirculated and purified, No long-lived cosmogenically activated Xe isotopes
  - $Q_{\beta\beta}$=2457 keV





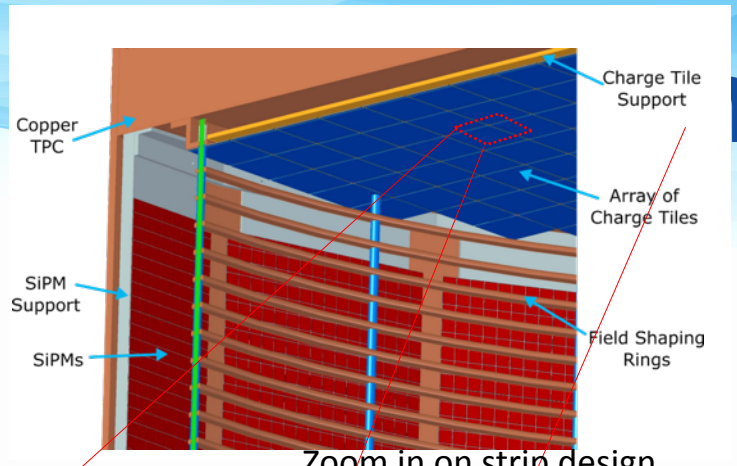
- 1.5 kT UPW in instrumented Outer Detector to veto muons
- Monolithic design means self-shielding from external backgrounds
- Multi-parameter measurement from detection of scintillation light and ionization signal

Anode Charge Readout

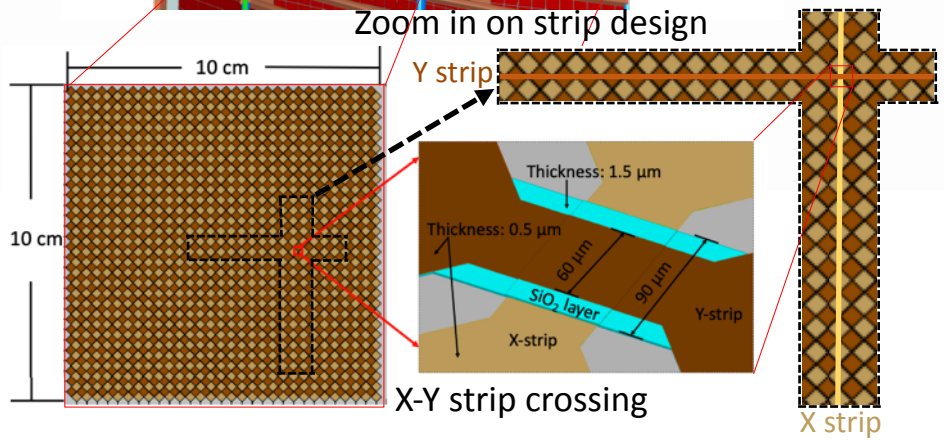
- Charge collection on tiled anode plane
- Full simulation of charge collection in nEXO used to optimize design
  - Crossed strips with no shielding grid
  - Channel pitch: 6mm
  - Tile size: 10 cm x 10 cm
- Prototype tiles have been measured in LXe to validate simulation

[JINST 14 P09020 (2019)]
[JINST 13 P01006 (2018)]

Zoom in on upper corner of TPC:

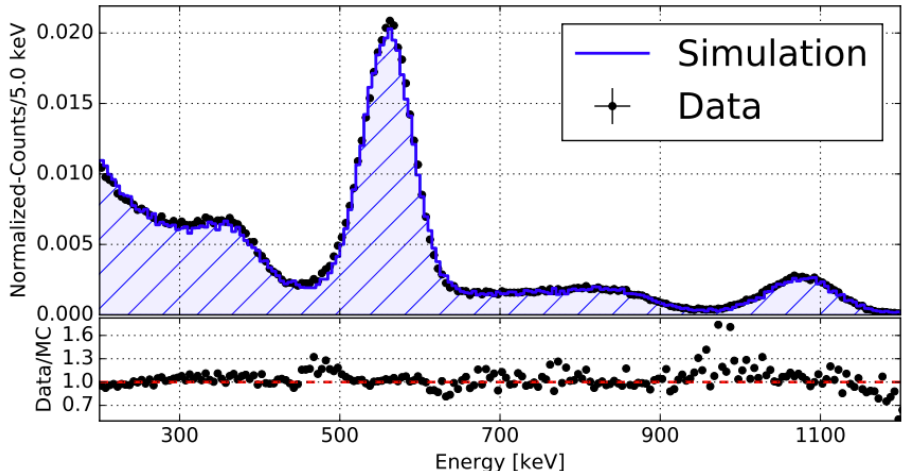


Zoom in on strip design



X-Y strip crossing

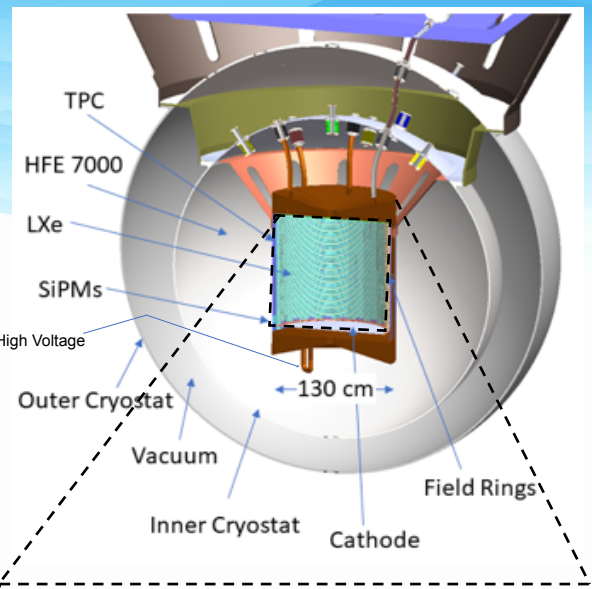
Source calibration (^{207}Bi) with prototype tile:



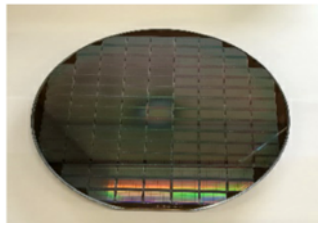
5

SiPMs for photon detection

- Advantages of SiPMs for photon detection
  - Low intrinsic radioactive backgrounds.
  - Improved energy resolution (SiPMs high gain).
  - Lower bias required for SiPMs (~50 V versus ~1.5 kV).
  - Devices from 2 vendors meeting requirements

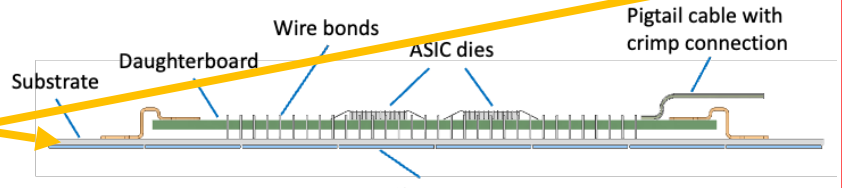


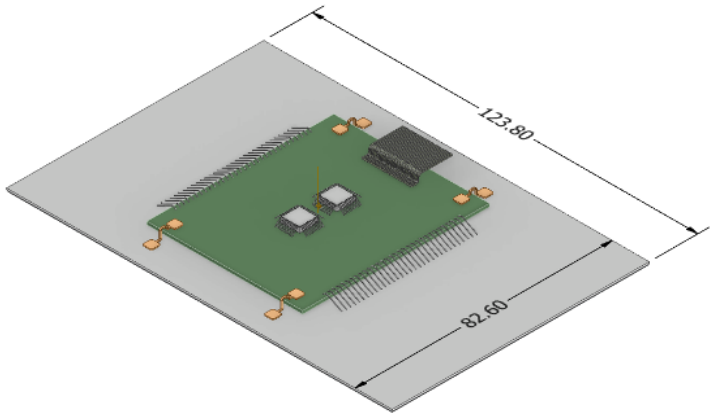
SiPM Devices



x 50,000

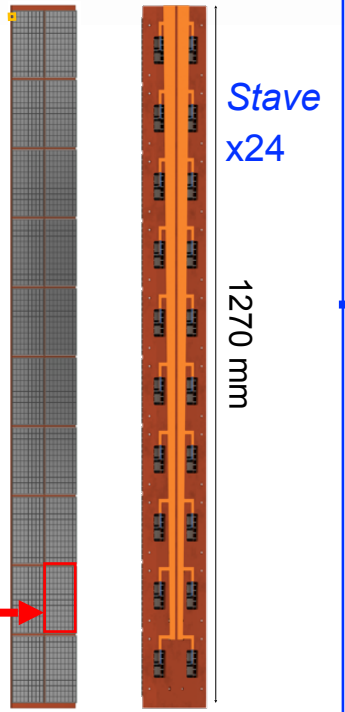
1 cm

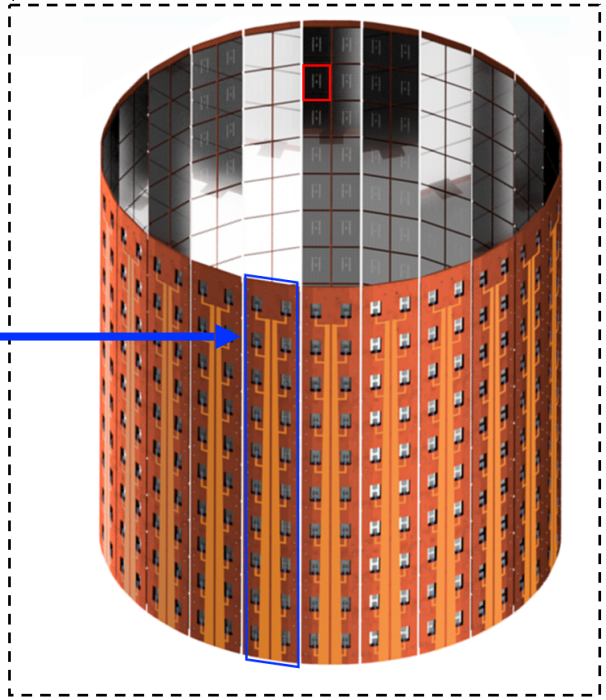




Tile module

x 480

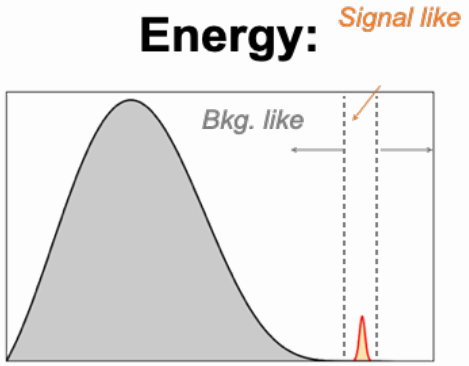


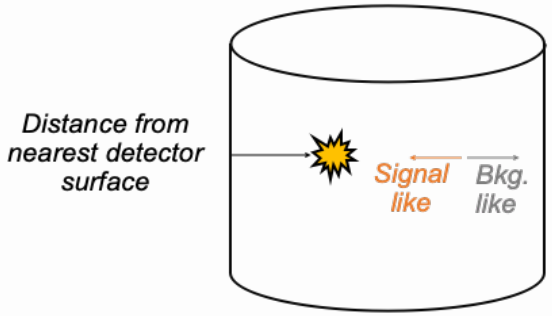


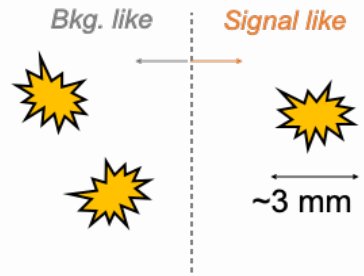
Photon detector (PD)

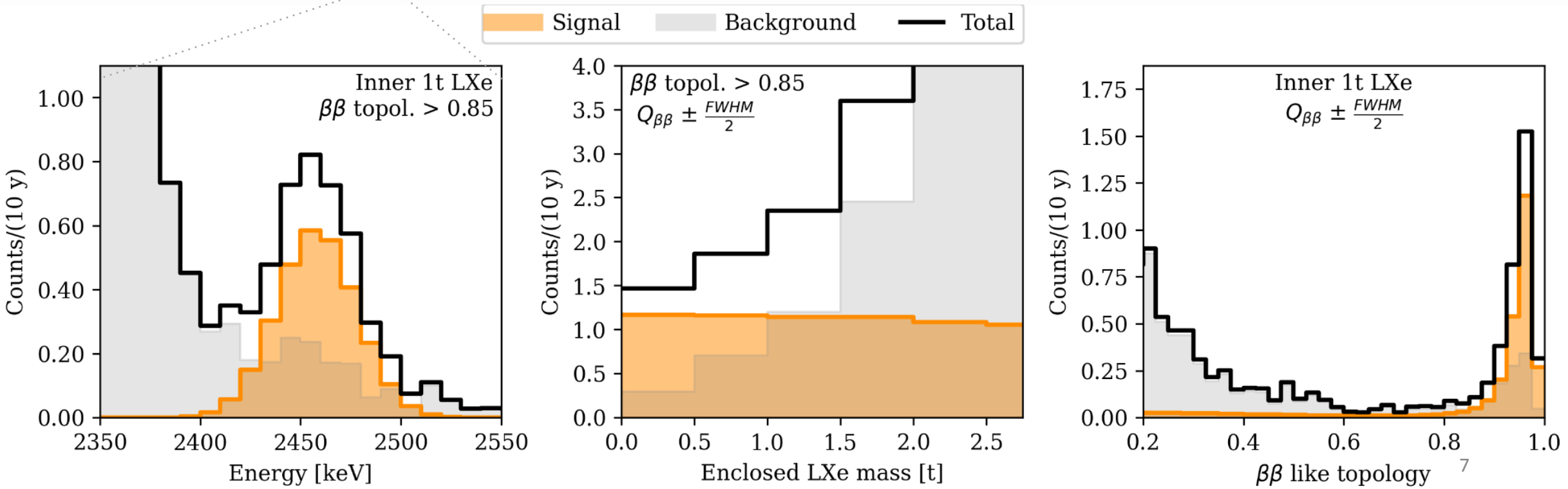
[NIM A 940, 371 (2019)]
[IEEE Trans. Nucl. Sci. 65, 11 (2018)]
[Eur. Phys. J. C 82, 1125 (2022)]

Multiparameter Analysis





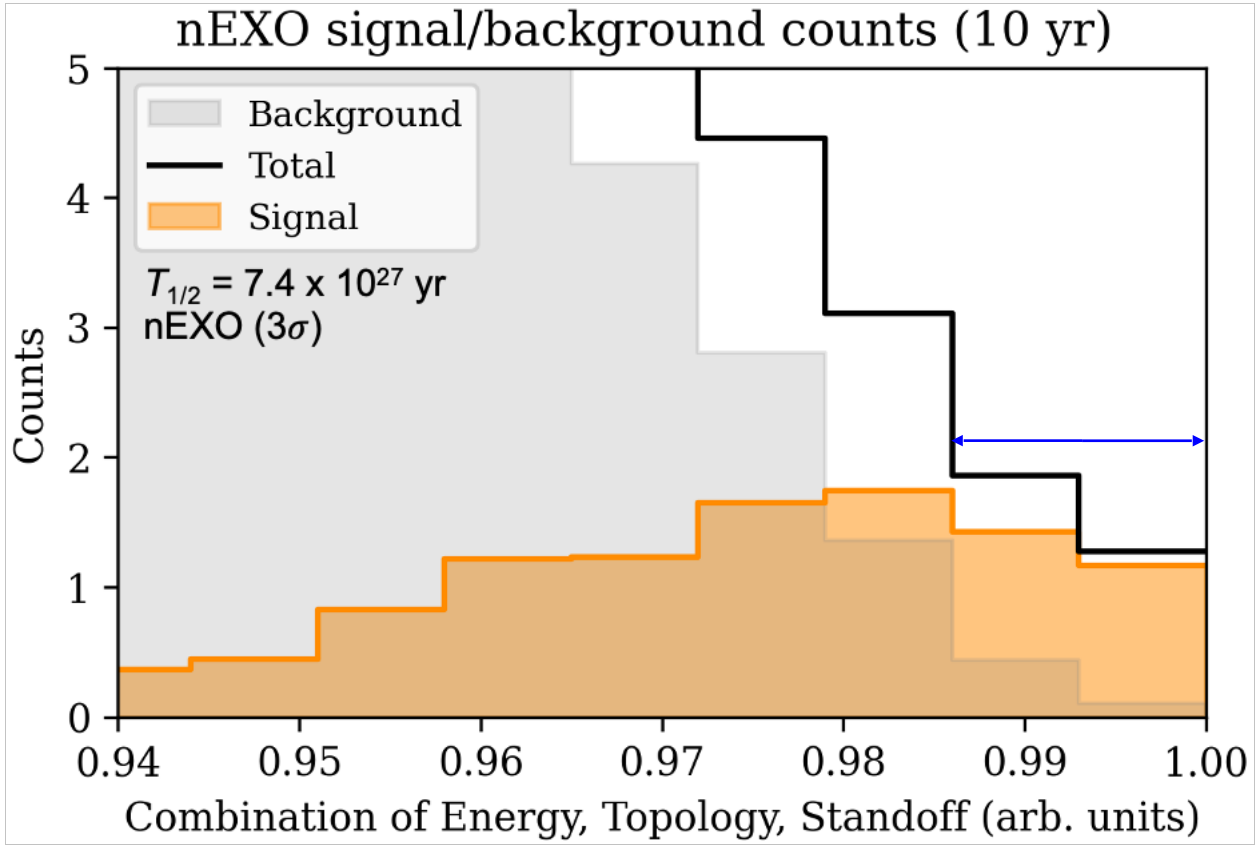




Multiparameter Analysis

- Arranging the 3D bins into 1D, ordered by signal-to-background ratio, helps visualize the signal and background separation in nEXO

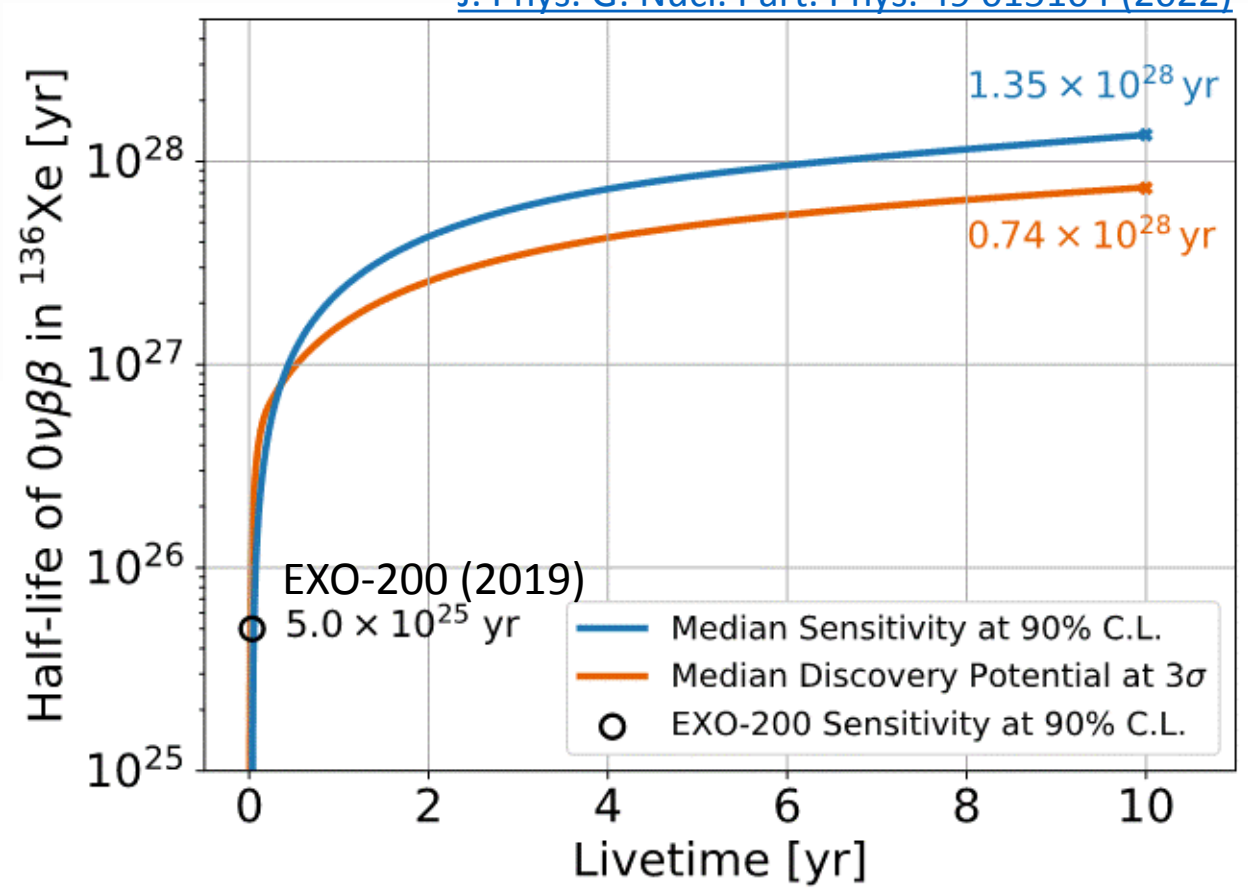
Combine energy, topology, & standoff (preserving correlations)



nEXO is a "background-free" experiment

nEXO Projected Sensitivity

J. Phys. G: Nucl. Part. Phys. 49 015104 (2022)



nEXO sensitivity reaches 10^{28} yr in 6.5 yr data taking

Projected sensitivity based on actual background level measurements!

Ab Initio Impact on Ton-Scale Searches

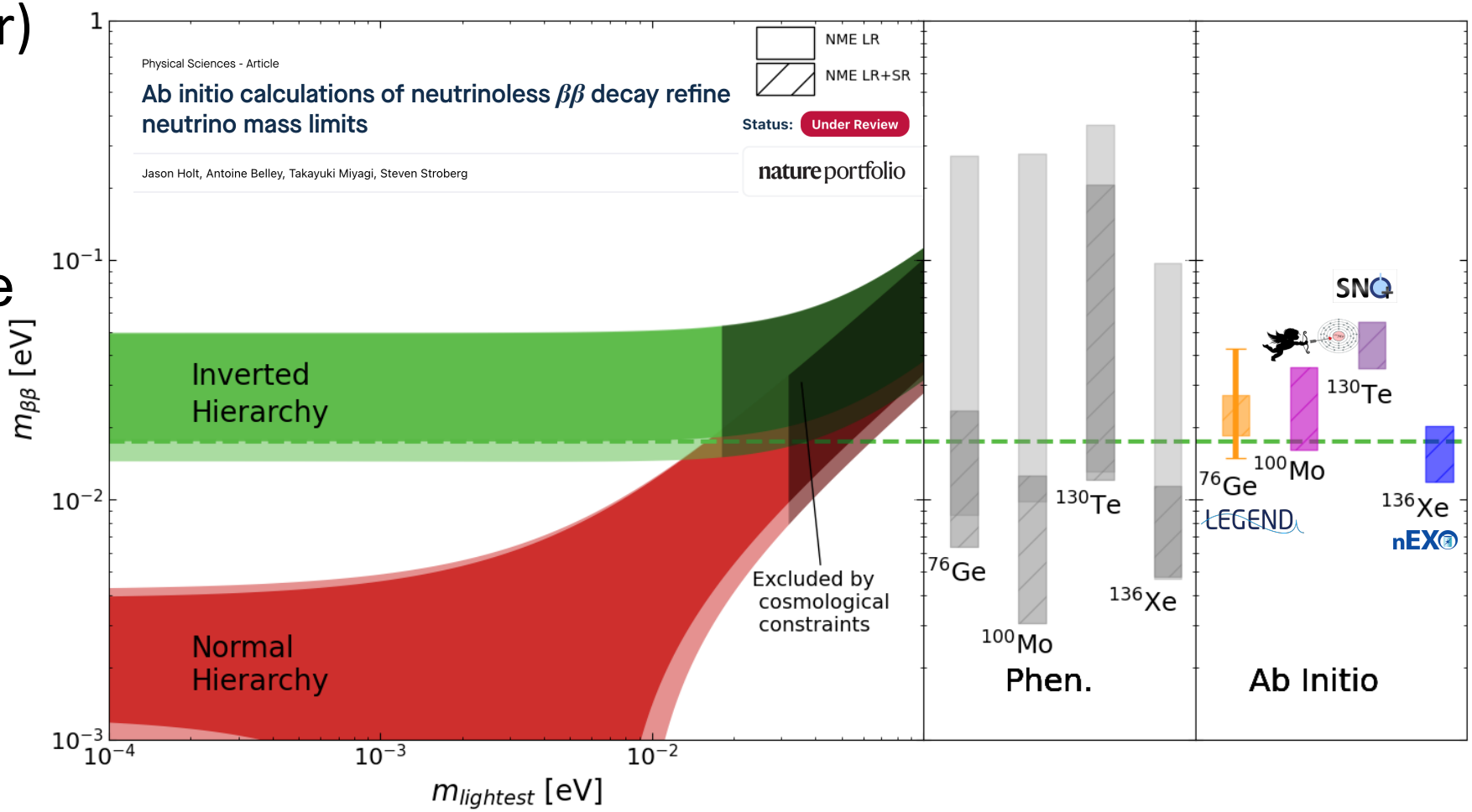
- J. Holt (nEXO collaborator) *et al.* converged *ab initio* NMEs for major players in global searches: ^{76}Ge, ^{100}Mo, ^{130}Te, ^{136}Xe

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

Phase space factor

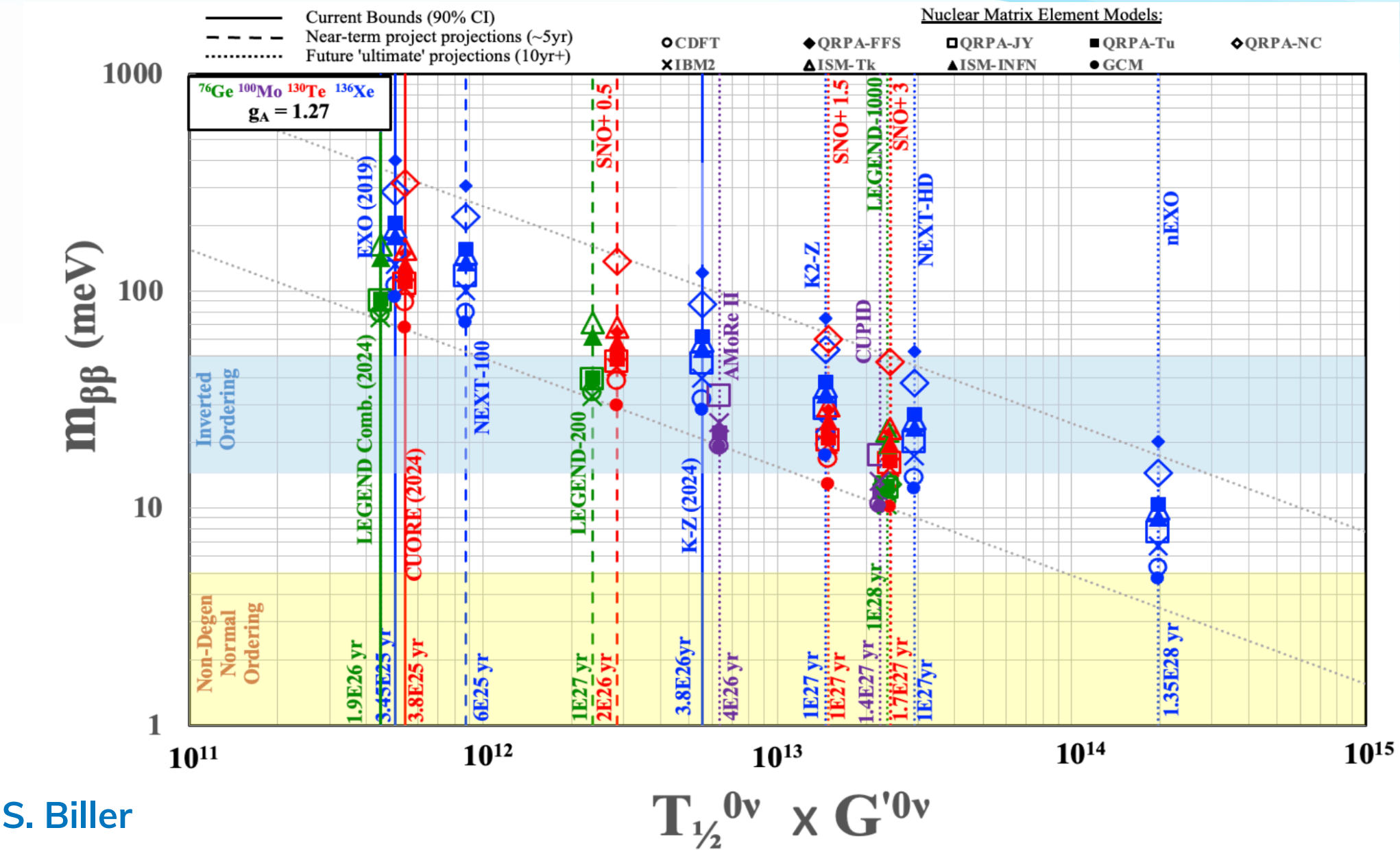
Axial coupling, g_A

NME



Uncertainty reduced ***over one order of magnitude***!

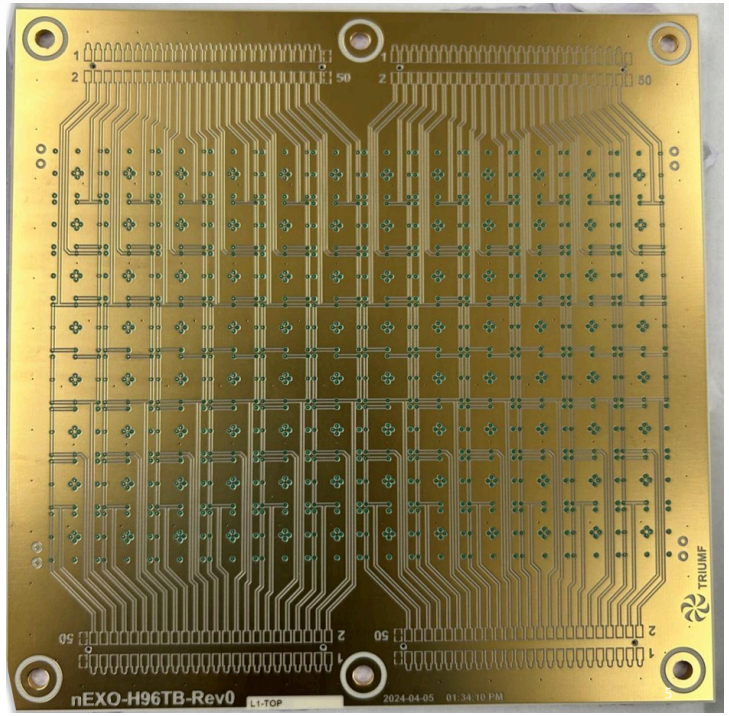
Global Sensitivities Projected



Plot by S. Biller

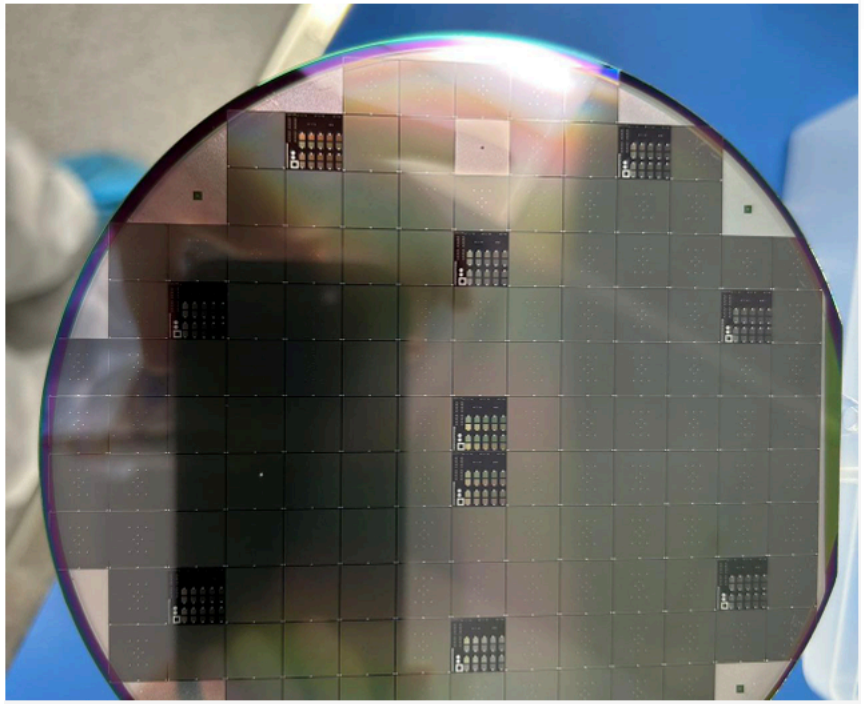
New science developments!

- A SiPM prototype tile is being fabricated on a quartz wafer and another tile with on the order of 100 SiPMs is in preparation for measurements of SiPM assembly yield.
  - SiPM tiles and initial tests are foreseen for the first half of 2025.



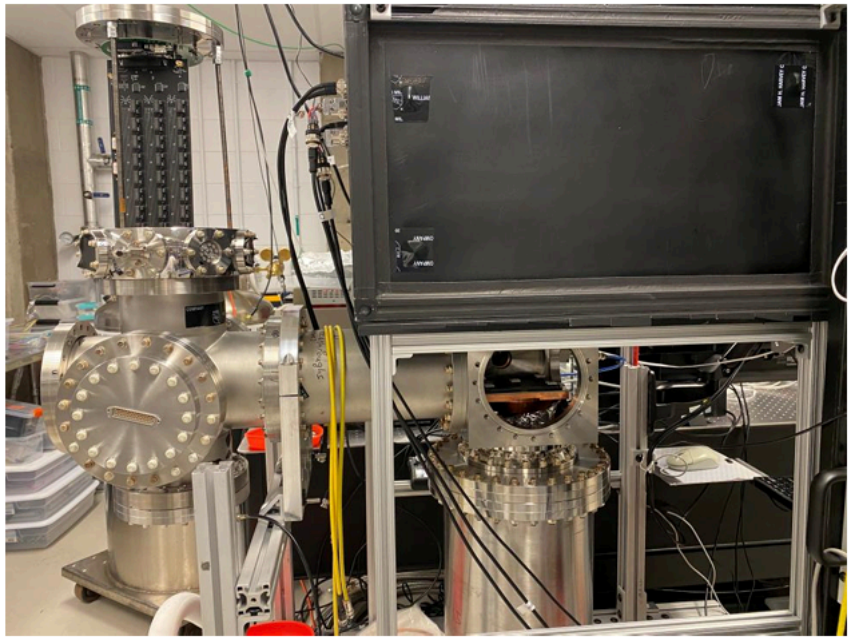
<- nEXO Test Tile

FBK SiPM ->



New science developments!

- The Canadian groups are making good progress on developing infrastructure supported through IF2020 (released in 2023).
- The construction of a clean room at TRIUMF is advancing,
- Renovations of a new lab at McGill University were completed
  - A chamber to test full size staves is being assembled with a first pump down anticipated in March 2025.
- The Rn-emanation lab space at University of Windsor is being set up.



preparation for tile characterization with 96 SiPMs

Collaboration EDI: Mentorship Mixer

Collaboration EDI: Invited Lectures

The China Initiative:
Its Impact on Academics of Chinese Ethnicity

Xiaoxing Xi

Temple University

Speaker's Travel Funding provided by nEXO's DOE RENEW Grant

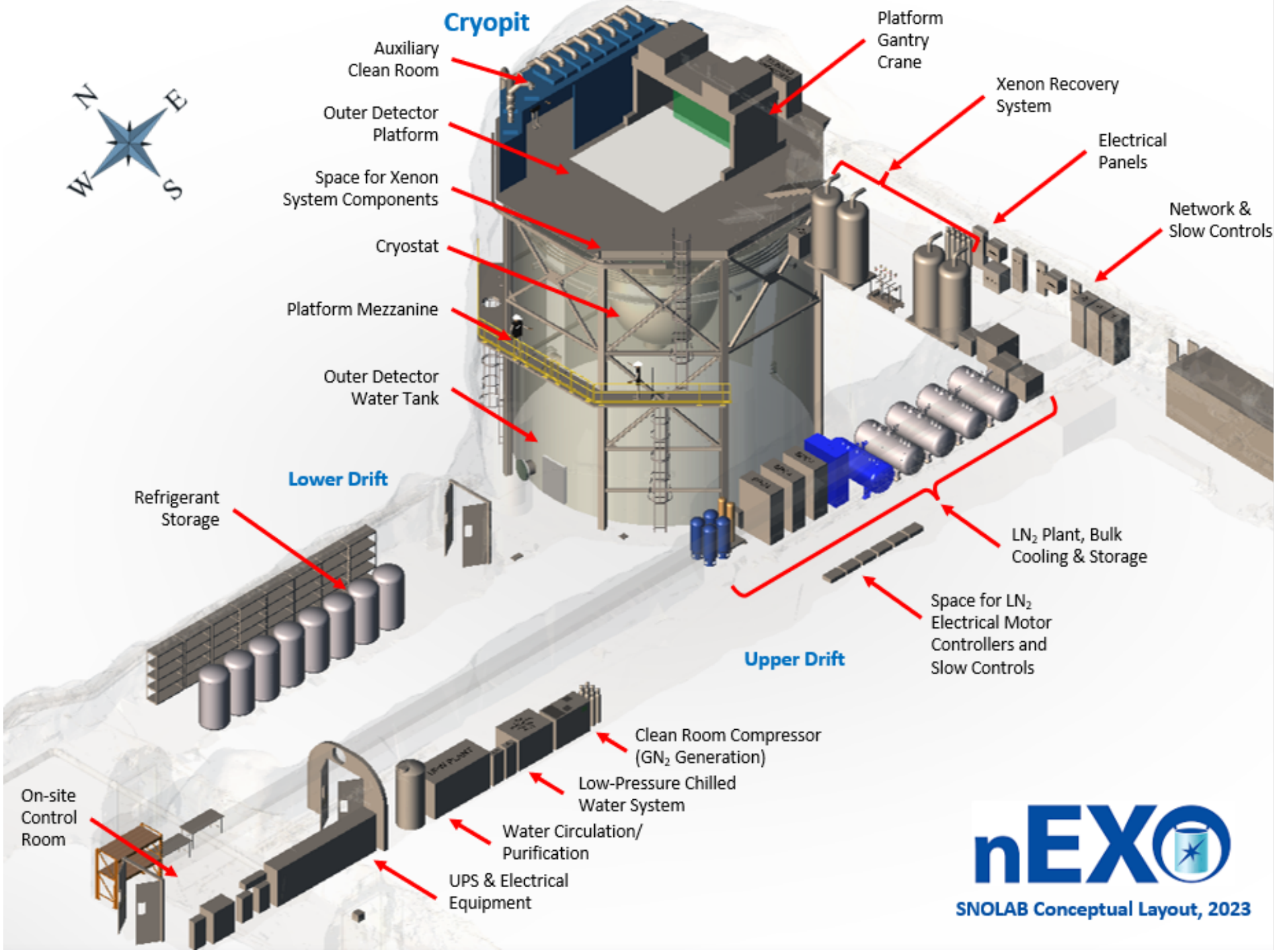
The nEXO collaboration

>200 scientists, 42 institutions in 10 countries on 4 continents

Jan. 2025 Collaboration Meeting

Experiment Status

- The nEXO design is well advanced, with more exciting R&D ongoing.
- All Subsystems completed internal CoDRs.
- nEXO successfully completed Director's Review in July 2024, recommended to go forward with CD-1 review.
- Canadian groups prepared a NSERC SAP project grant proposal, presenting at LPD in February.


Cryopit
Auxiliary Clean Room
Outer Detector Platform
Space for Xenon System Components
Cryostat
Platform Mezzanine
Outer Detector Water Tank
Platform Gantry Crane
Xenon Recovery System
Electrical Panels
Network & Slow Controls
Lower Drift
Refrigerant Storage
LN2 Plant, Bulk Cooling & Storage
Space for LN2 Electrical Motor Controllers and Slow Controls
Upper Drift
Clean Room Compressor (GN2 Generation)
Low-Pressure Chilled Water System
Water Circulation/ Purification
UPS & Electrical Equipment
On-site Control Room
nEXO
SNOLAB Conceptual Layout, 2023

Update on situation in the US

- DOE announced on December 19-20, 2024, to advance LEGEND-1000 to CD-1 and continue nEXO and CUPID as R&D projects. DOE also stated its continuing interest in developing an international 0νββ program.
  - The letter specifically states that this decision was driven by financial limitations and not by scientific merit.
- While this decision from DOE threatens nEXO's construction schedule, **it offers opportunity for Canada to take over leadership of nEXO and realize this international flagship experiment at SNOLAB!**

Future Opportunities

- nEXO switched to co-spokespersonship with **Thomas Brunner** and **Giorgio Gratta** elected as **co-spokespersons.**
- We are actively working to grow the Canadian and International scope of the collaboration!
- The schedule and budget are being reworked for Canadian costing methods, removing DOE overhead.
- There are new opportunities to contribute to this experiment with the US DOE dropping leadership.
- We need engaged scientists willing to take on leadership for detector components where DOE national labs had to withdraw.

Consider joining us in this exciting endeavour!

Milestones

- The next international summit on 0νββ decay searches is scheduled for the end of May 2025 in Heidelberg, Germany.
- SNOLAB, ISED, NSERC, and CFI have been invited as Canadian representatives, along with members of the collaborations LEGEND, nEXO, and CUPID, and DOE and European funding agencies.
- **We will present our plan to advance nEXO as a Canadian flagship experiment during this summit. Join us!**