

# nEXO's Search for $0\nu\beta\beta$

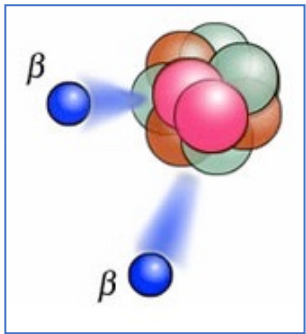
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For the nEXO Collaboration

SNOLAB Experiment Forum, July 31, 2024

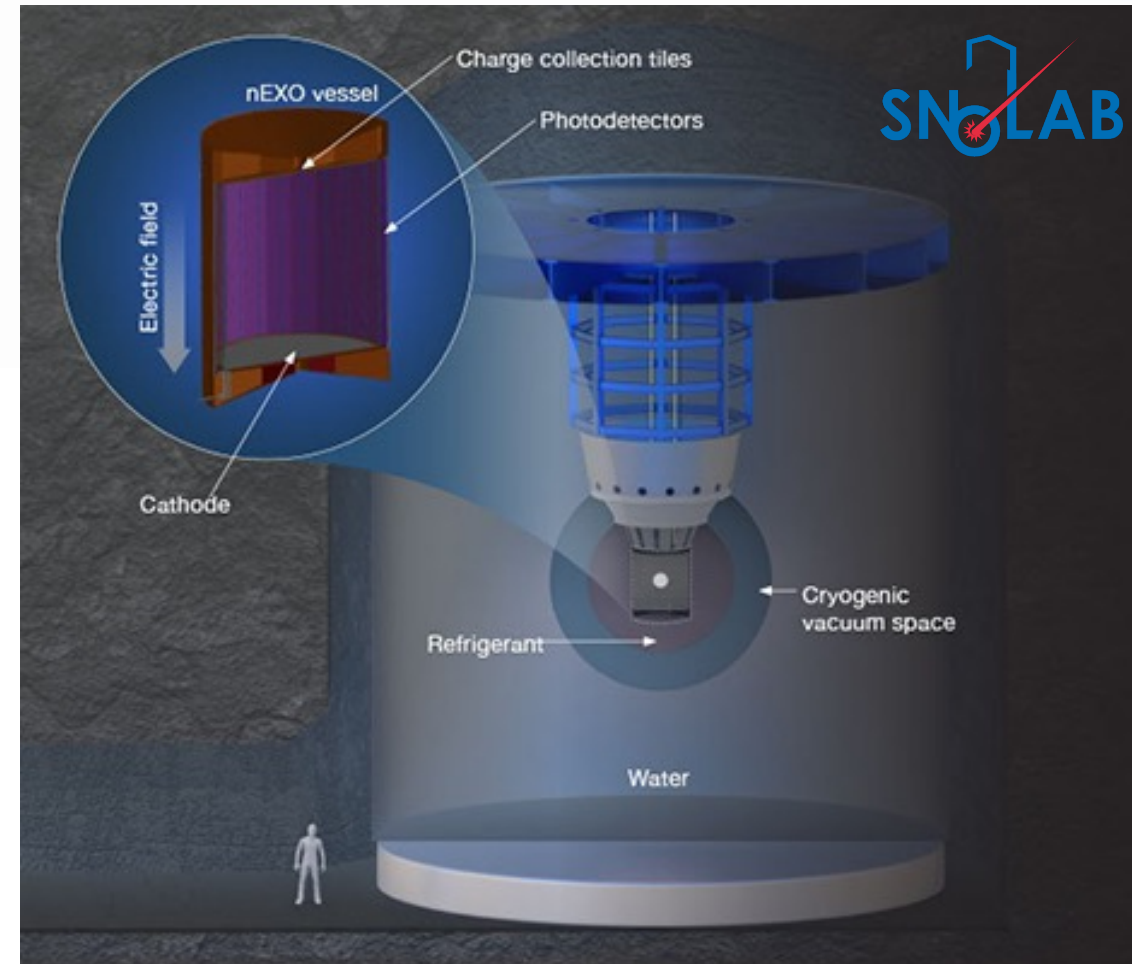
# The nEXO Search for $0\nu\beta\beta$ decay

**Goal:** observation of neutrinoless double beta decay ( $0\nu\beta\beta$ )



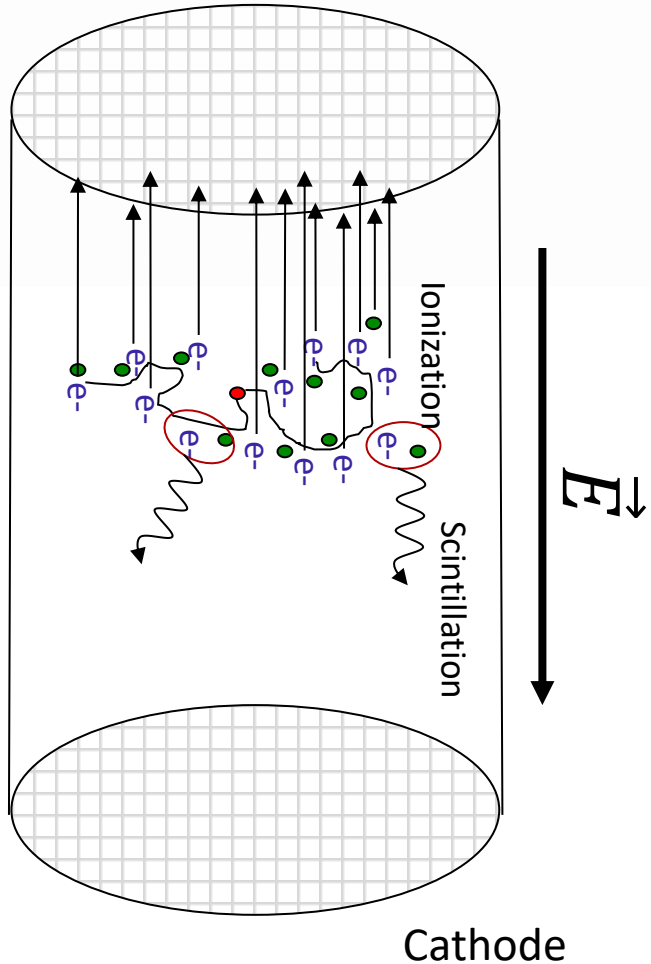
$0\nu\beta\beta$  only possible if neutrinos are special particles, so-called Majorana particles.

- **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!



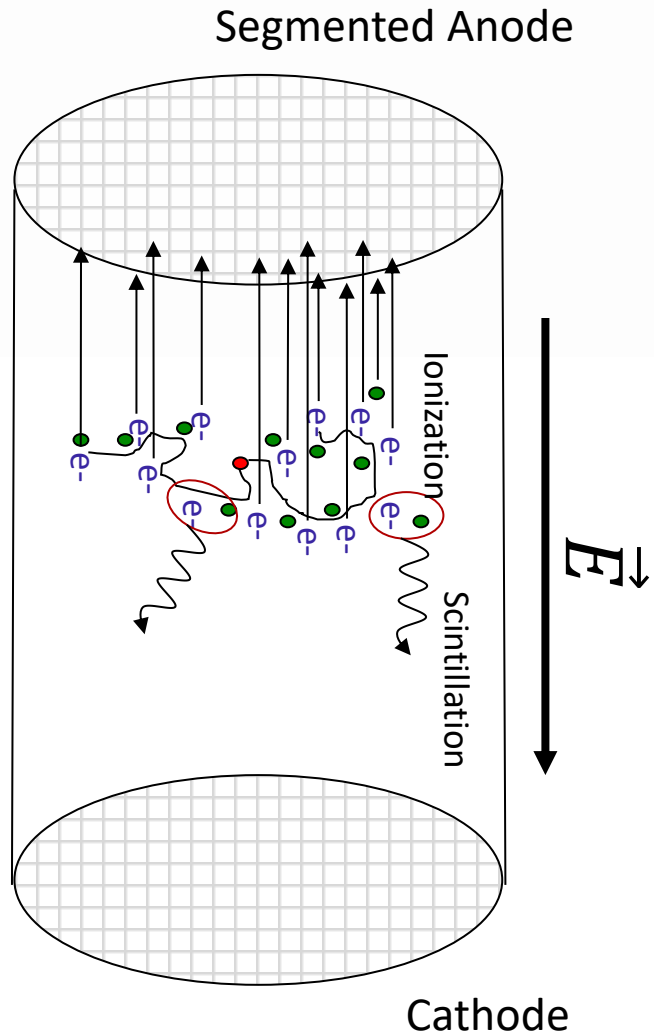
<https://nexo.llnl.gov/>

Segmented Anode



## Liquid-Xe Time Projection Chamber (TPC)

- Xe is used both as the source and detection medium.
- LXe is continuously recirculated and purified.
- No long-lived cosmogenically activated Xe isotopes
- Monolithic detector structure enables excellent background rejection capabilities.



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- Multiparameter measurement from detection of scintillation light and ionization signal:
  1. Energy from combined scintillation/ionization
  2. Topology, e.g., single-site or multi-site
  3. Position distribution from 3D event reconstruction
  4. Particle identification from scintillation/ionization ratio



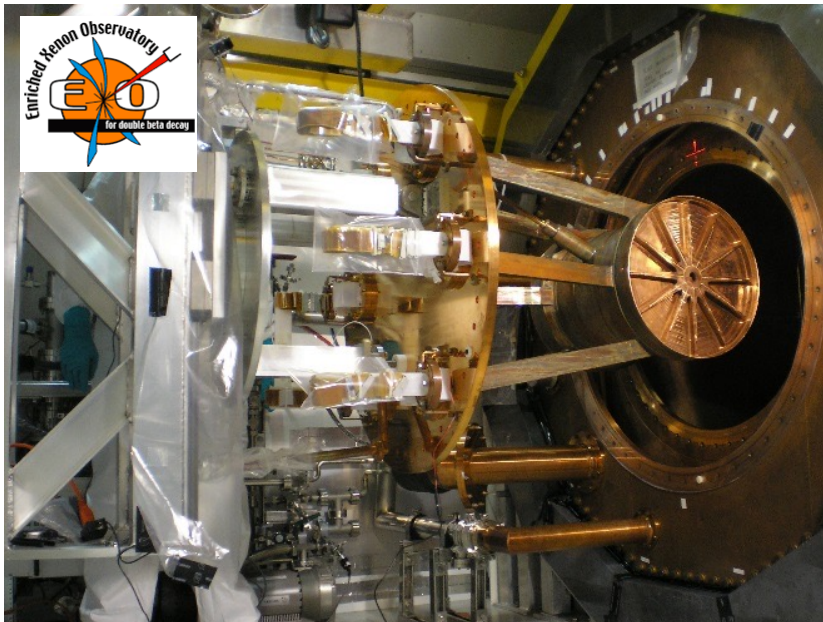
# Searching for $0\nu\beta\beta$ in $^{136}\text{Xe}$ – a phased approach

## EXO-200:

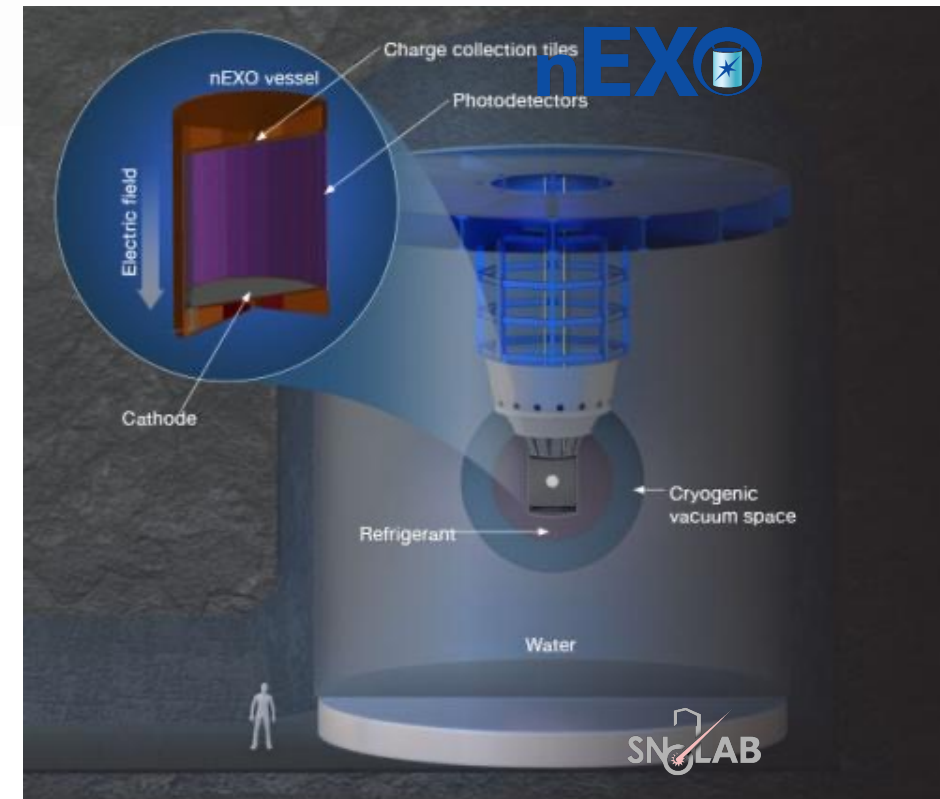
- EXO-200 first 100-kg class  $\beta\beta$  experiment
- 175kg liquid-Xe TPC with  $\sim 80\%$  Xe-136
- Located at the WIPP mine in NM, USA
- Decommissioned in Dec. 2018
- Analyze data from end-of-run calibration campaign  
→ data informs the detailed design of nEXO

## nEXO:

- 5-tonne liquid Xe TPC
- Enriched in Xe-136 at  $\sim 90\%$
- **SNOLAB cryopit preferred location by collaboration**



<https://www-project.slac.stanford.edu/exo/>



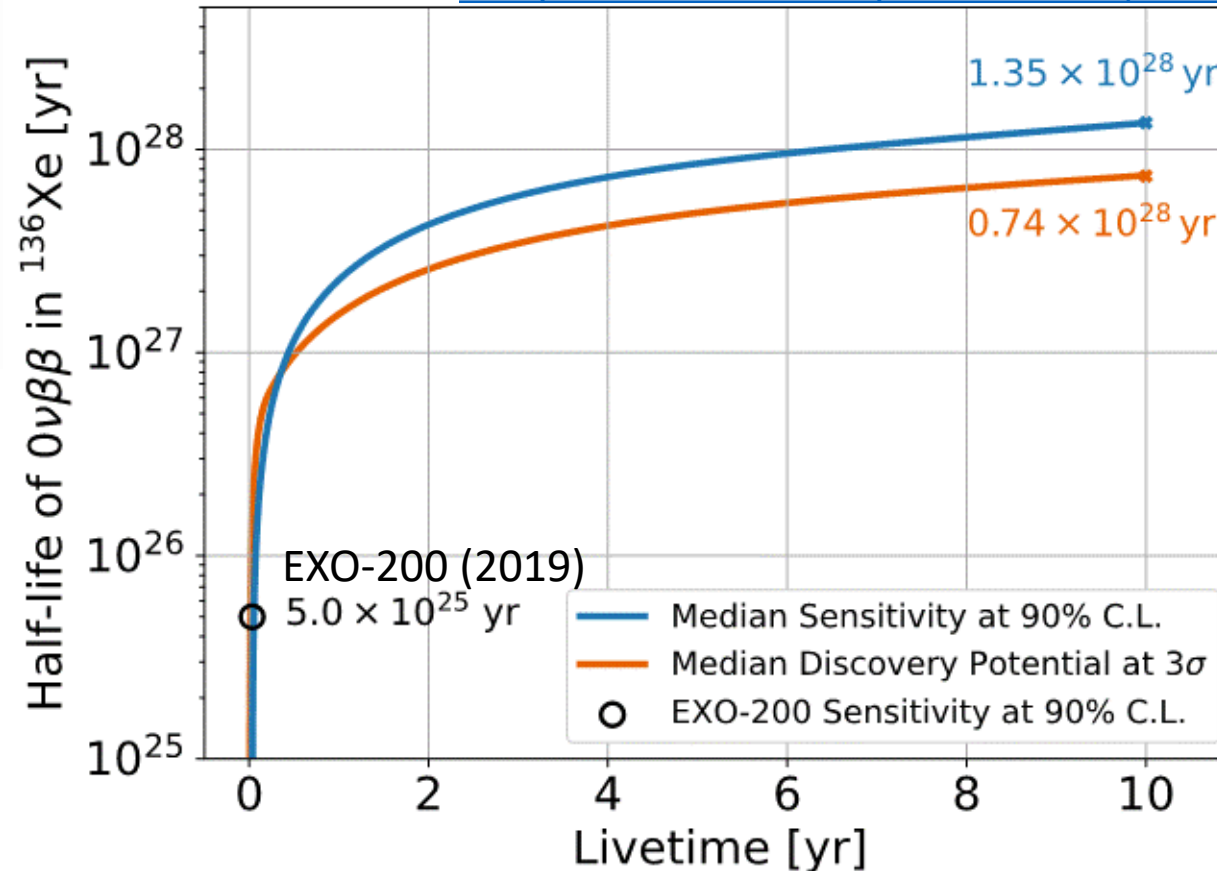
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# The nEXO collaboration



# nEXO Projected Sensitivity

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



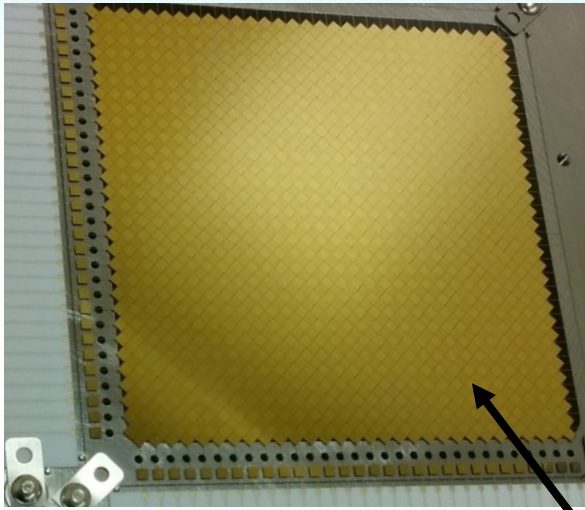
**nEXO sensitivity reaches  $10^{28}$  yr in 6.5 yr data taking**  
Projected sensitivity based on actual background level measurements!



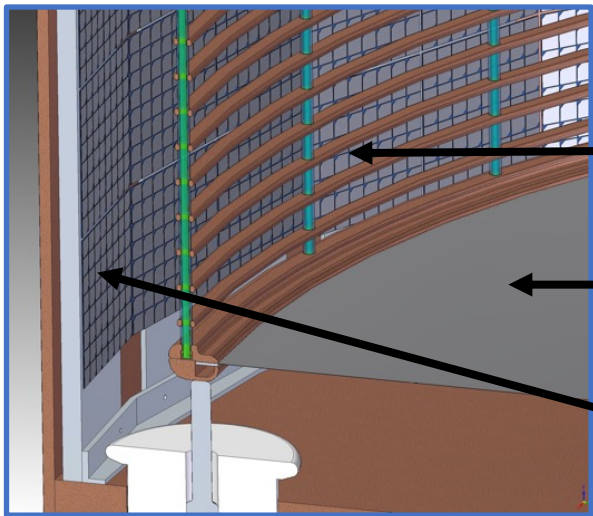
# The nEXO detector



- Next-generation neutrinoless double beta decay detector.
- 5 t liquid xenon TPC (90% enriched in Xe-136).
- SiPM for 175nm scintillation light detection,  $\sim 4.5\text{m}^2$  SiPM array in LXe.
- Tiles for charge read out in LXe.
- In-cold electronics inside TPC in liquid Xe.
- 3D event reconstruction.
- Combine charge and light readout. Goal  $\rightarrow \sigma/E < 1\%$  at Q-value.
- 1.5 ktonnes water-Cherenkov detector for muon tagging and shielding.



Picture: 10 x 10 cm<sup>2</sup> tile prototype  
JINST 13, P01006 (2018)  
Tile simulation: arXiv:1907.07512.

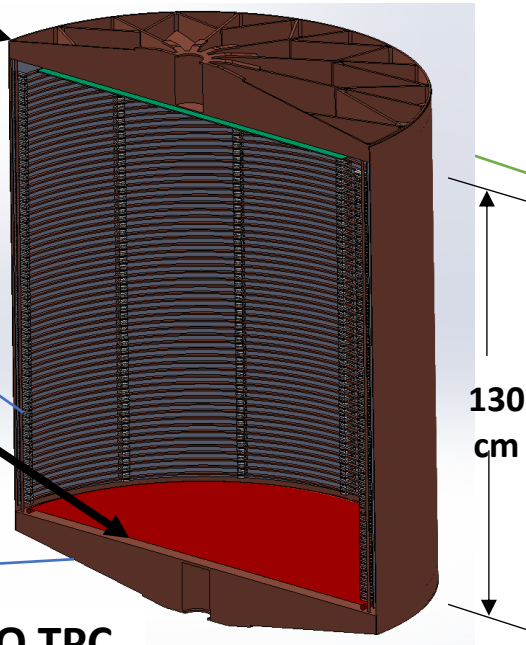


charge readout pads (anode)

Field shaping rings

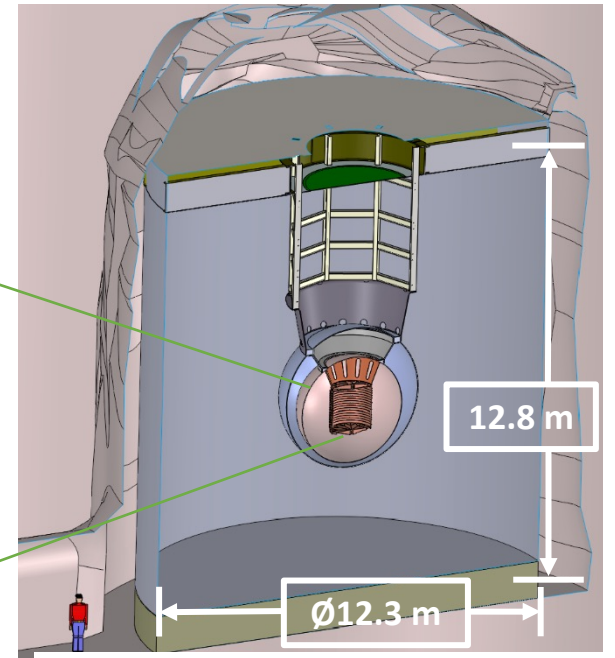
Cathode

SiPM 'staves' covering the barrel



nEXO TPC

130 cm



nEXO at the SNOLAB Cryopit

12.8 m

Ø12.3 m



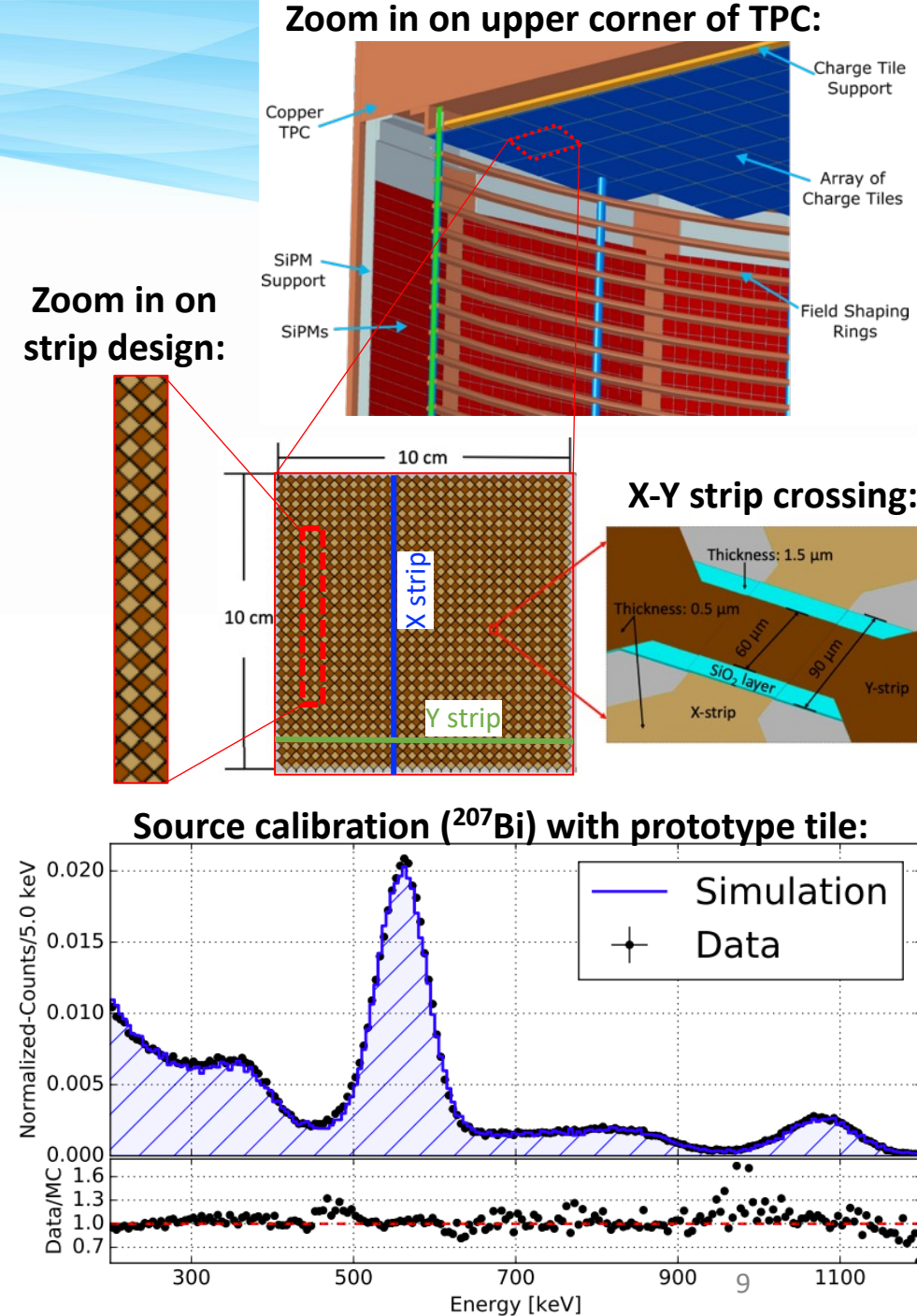
# Anode Charge Readout

- 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

Z. Li et al. (nEXO Collab) "Simulation of charge readout with segmented tiles in nEXO," JINST 14 P09020 [2019]

- Prototype tiles have been measured in LXe to validate simulation

M. Jewell et al. (nEXO Collab) "Characterization of an ionization readout tile for nEXO," JINST 13 P01006 [2018]



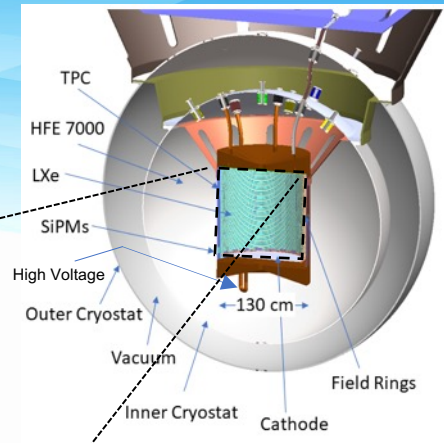
# SiPMs for photon detection

- 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 meeting requirements demonstrated through nEXO R&D
  - Prototype SiPMs from two vendors have been tested by nEXO and meet requirements (FBK and HPK)

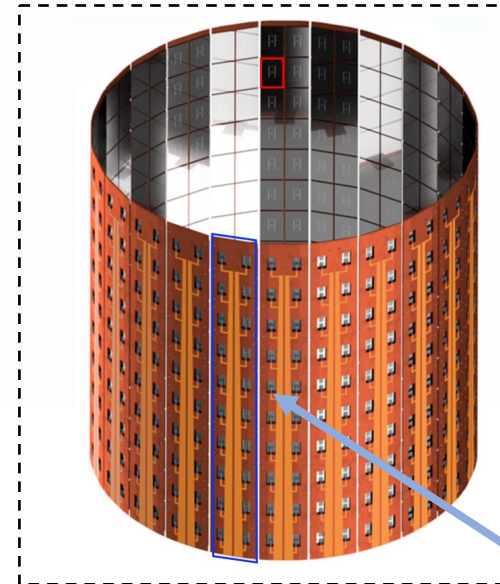
A. Jamil et al. (nEXO collab.) "VUV-sensitive Silicon Photomultipliers for Xenon Scintillation Light Detection in nEXO," *IEEE Trans. Nucl. Sci.* 65, 11 (2018)

G. Gallina et al. (nEXO collab.) "Characterization of the Hamamatsu VUV4 MPPCs for nEXO," *NIM A* 940, 371 (2019)

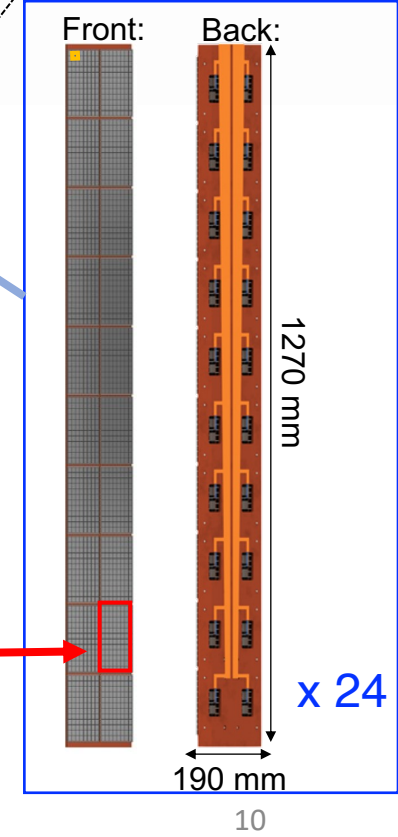
G. Gallina et al. (nEXO), "Performance of novel VUV-sensitive Silicon Photo-Multipliers for nEXO," *Eur. Phys. J. C* 82, 1125 (2022)



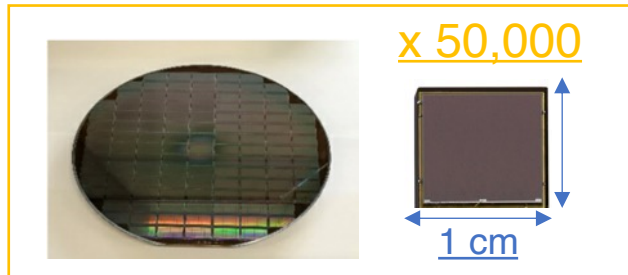
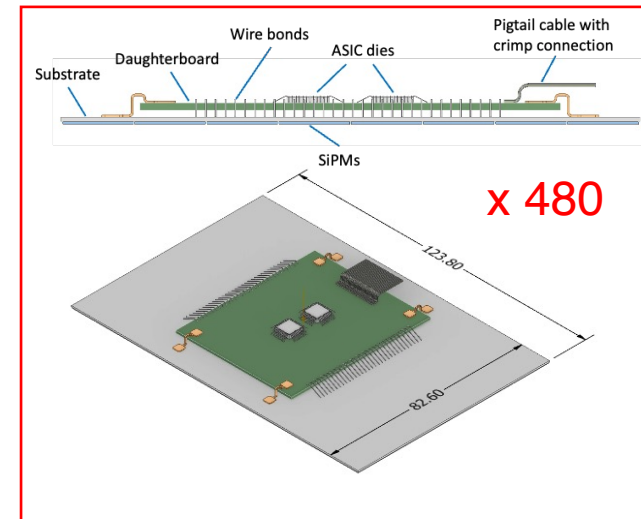
Photon detector (PD)



Stave



Tile module

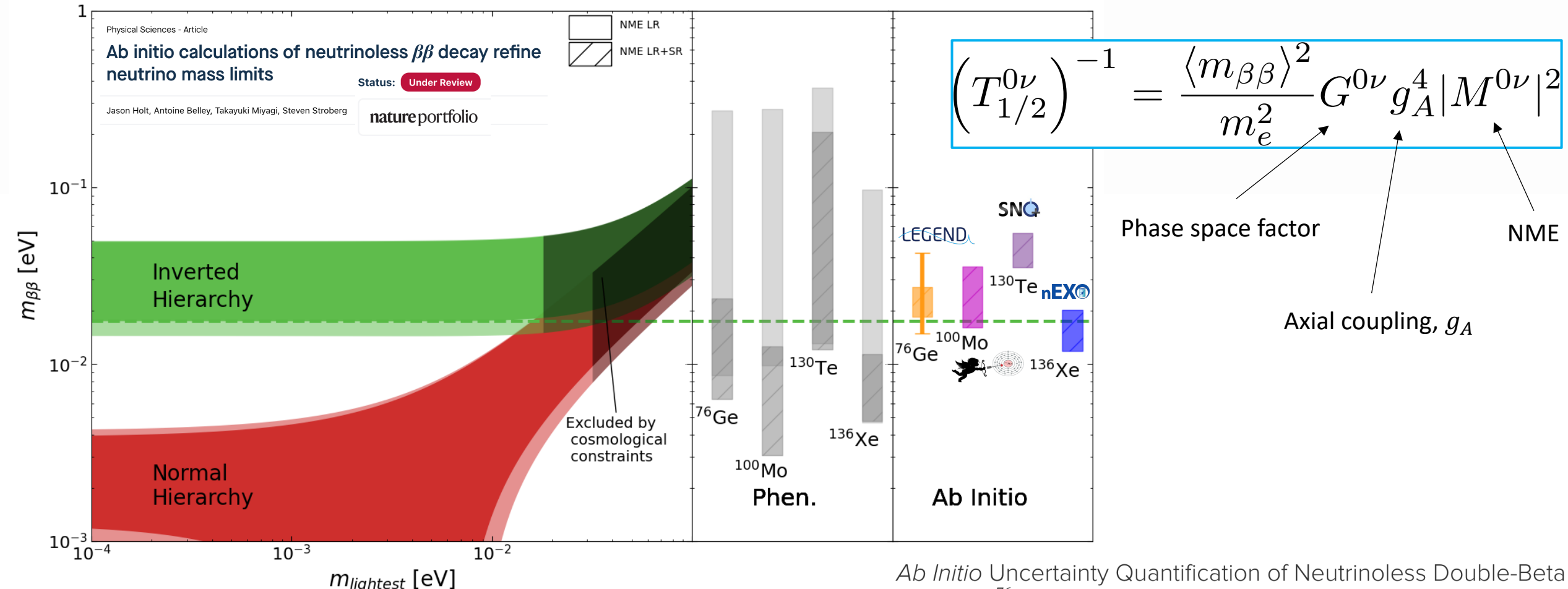


# Ab Initio Impact on Ton-Scale Searches



Converged *ab initio* NMEs for major players in global searches:  $^{76}\text{Ge}$ ,  $^{100}\text{Mo}$ ,  $^{130}\text{Te}$ ,  $^{136}\text{Xe}$

Impact for next-generation searches: sensitivities from LEGEND, SNO+, nEXO, CUPID



Ab Initio Uncertainty Quantification of Neutrinoless Double-Beta Decay in  $^{76}\text{Ge}$

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



# nEXO DEI Committee Introduction



- The nEXO DEI Committee meets monthly online to hear updates from subcommittees and brainstorm new ideas
- 15-20 active members
- Membership open to entire collaboration
- Committee Leadership
  - Two co-chairs
  - Selected by collaboration-wide elections conducted on staggered, two-year terms
- Subcommittees are led by volunteers who organize the work during the month

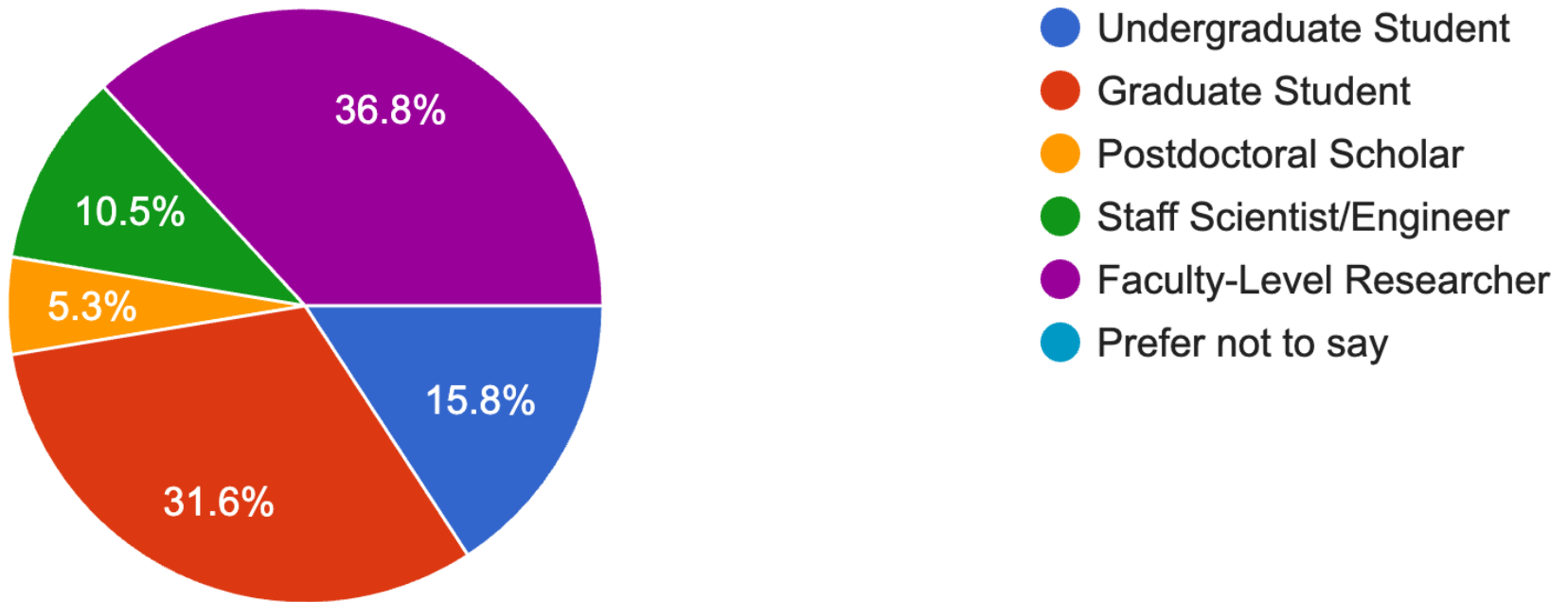
## **Initiatives of the nEXO DEI Committee**

- Information Hub
- DEI Seminar Series
- Climate Survey
- Social Media
- Showcasing Young Researchers
- Mentorship
- DEI Paper
- Publication Equity
- Junior Collaborator Board Representatives
- Student/Dependent Care Travel Grants
- Targeted job board listings
- International workshop for DEI in physics collaborations

# nEXO DEI Committee Demographics (2022)

Which of the following best describes your affiliation with the nEXO Collaboration?

19 responses



# Lunch from Summer 2023 Meeting @ McGill EXO





# Climate Survey



Everyone in nEXO (students, professors, lab scientists, managers, ...) experiences the climate of the collaboration. Surveying that climate can help to flag any themes of exclusion and institutional inaction, as well as provide specific guidance for improvement.

The AIP statistical research group has worked with the nEXO collaboration to distribute our first climate survey, results of which were obtained and presented to the collaboration in Spring 2024.

Gender		Race		Student Status		Postdoc Status		Highest Degree		Time since degree	
Man	82	White	70	Enrolled in a degree program as of January 1, 2024	25	Postdoc as of January 1, 2024	13	Doctorate	54	More than 10 years	54
Woman or Identity not listed	25	All other races & ethnicities	29	Not enrolled in a degree program as of January 1, 2024	85	Not a postdoc as of January 1, 2024	72	All others	55	Within 10 years (or still a postdoc)	52
Prefer not to respond	6	Prefer not to respond	11			Valid skip (was a student)	25				

## Information on respondents of the climate survey

# RENEW Grant



The RENEW grant is a DOE opportunity to fund DEI traineeships and initiatives, and our group was awarded the grant through PI Tim Daniels (UNCW) and co-PI Kirsten McMichael (RPI)

Received for \$83k USD over 3 years for:

- Future iteration of the Climate Survey
- Student and Dependent Care Travel Grants
- Ombudsperson Training
- Targeted Job Boards for Underrepresented Groups
- DEI Seminar Series Speaker Support
- DEI Workshop for Collaborations - Summer 2025

The US DOE RENEW grant is restricted to activities in the US. Similar opportunities would be great to have in the Canadian funding system (if you know of opportunities, please let Erica Caden or me know).

## Successes:

- Mentorship program has been running for 3 years, forming about 10 mentorship/mentee pairings per summer, with an accumulated participation of over 30 individual mentees
- Hosted 16 EDI seminars from experts outside of the collaboration and internal to the collaboration with an average attendance of 35+ researchers
- Climate survey facilitated by the AIP resulted in 127 respondents (~50% of collaboration)
- Exploring what the scope and purpose of EDI efforts in collaborations, and plans to host a workshop for other collaborations to share experiences

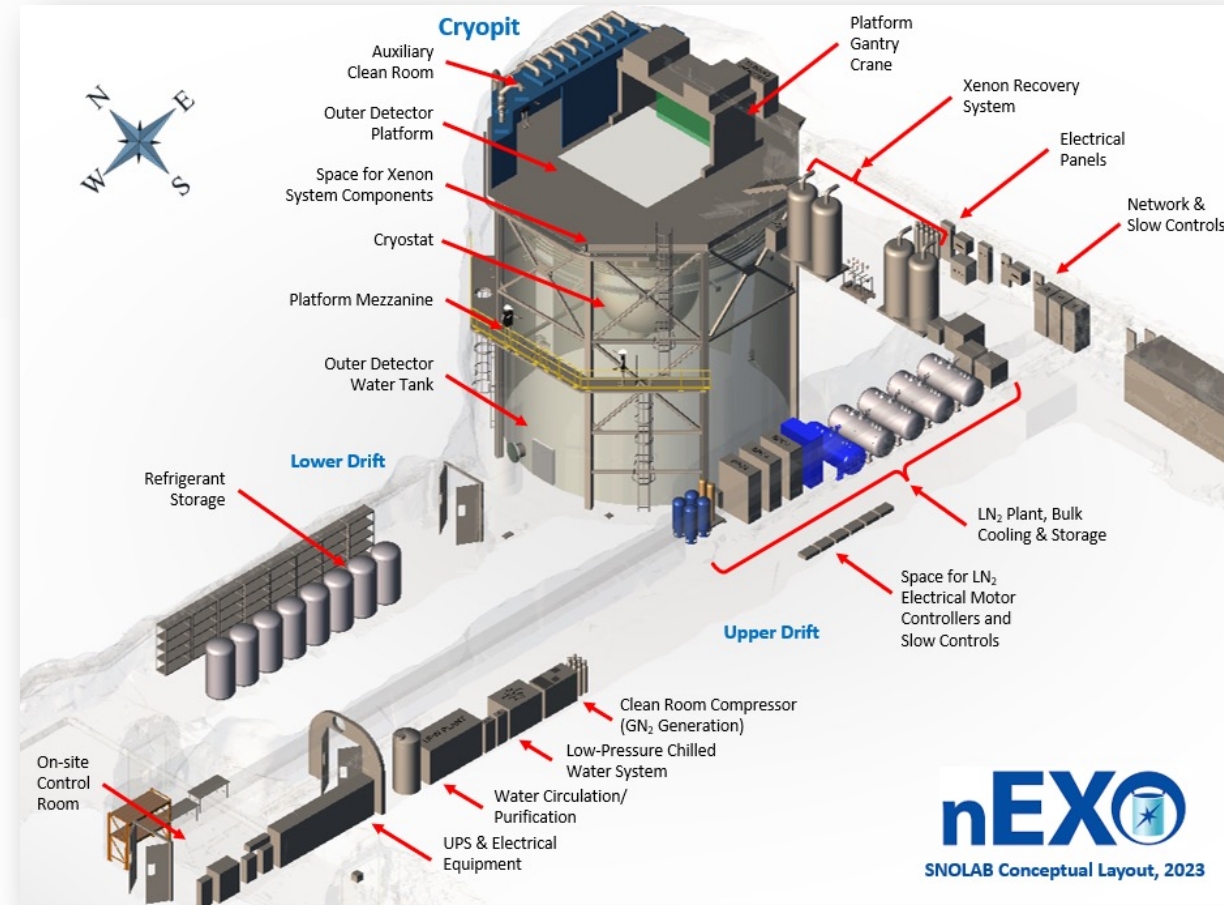
## Challenges:

- The budget for several DEI activities is not built-in, but rather comes from an independently sourced DOE RENEW award
- The nEXO climate survey took years of coordination for funding and execution
- We have more initiatives and ideas for actions than we have person-power for, as committee members balance EDI efforts with research



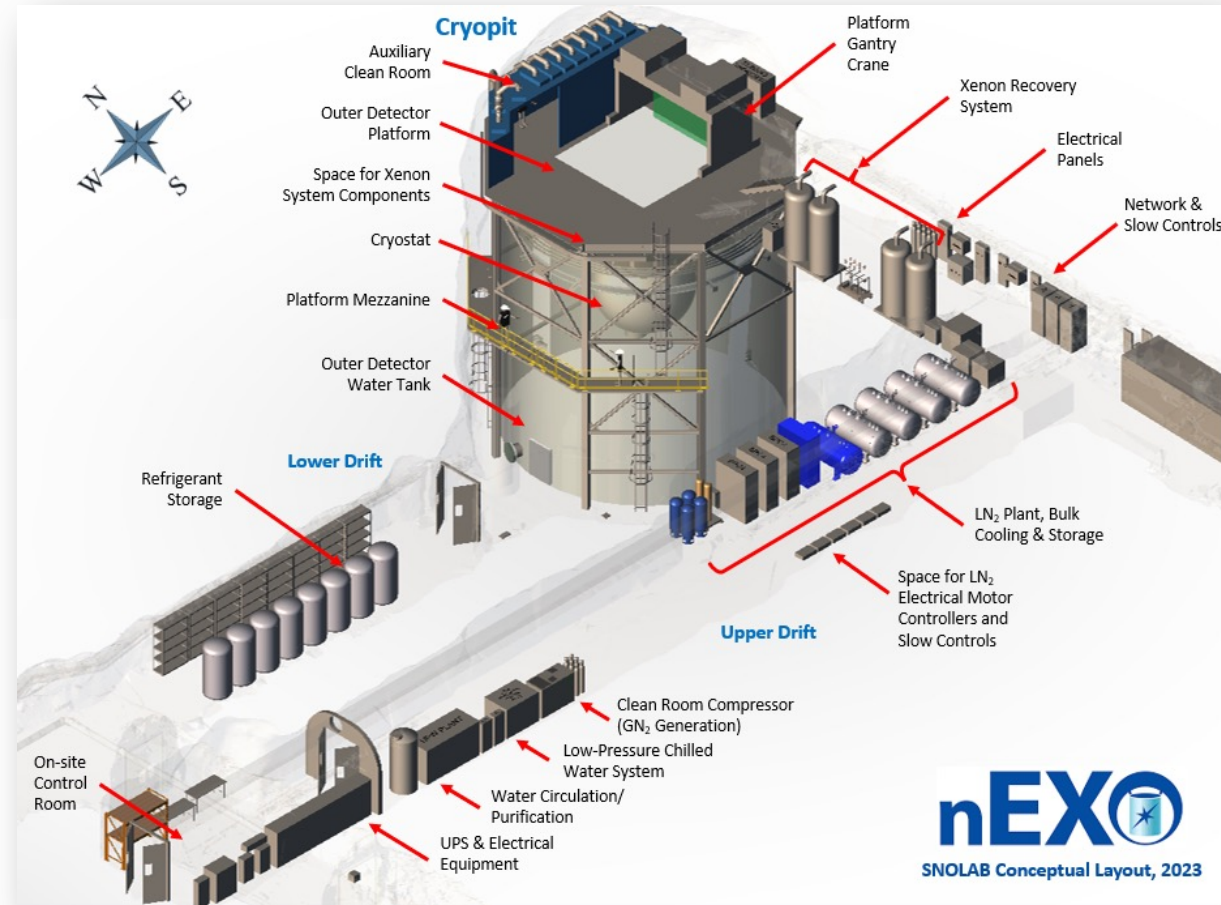
# Schedule impacts & milestones

- The nEXO design is well advanced.
- A lot of exciting R&D is ongoing.
- nEXO design is making good progress.
- Successfully completed Director's Review in July 2024.
- **Planning for Fall 2024 CD-1.**
- Canadian groups are preparing a CFI IF 2025 proposal in support of nEXO's construction at SNOLAB.
- Canadian groups are preparing a NSERC SAP project grant proposal.



# Summary

- nEXO continues taking on shape!
- Consider joining us in this exciting endeavor!







Collaboration Meeting June 2023