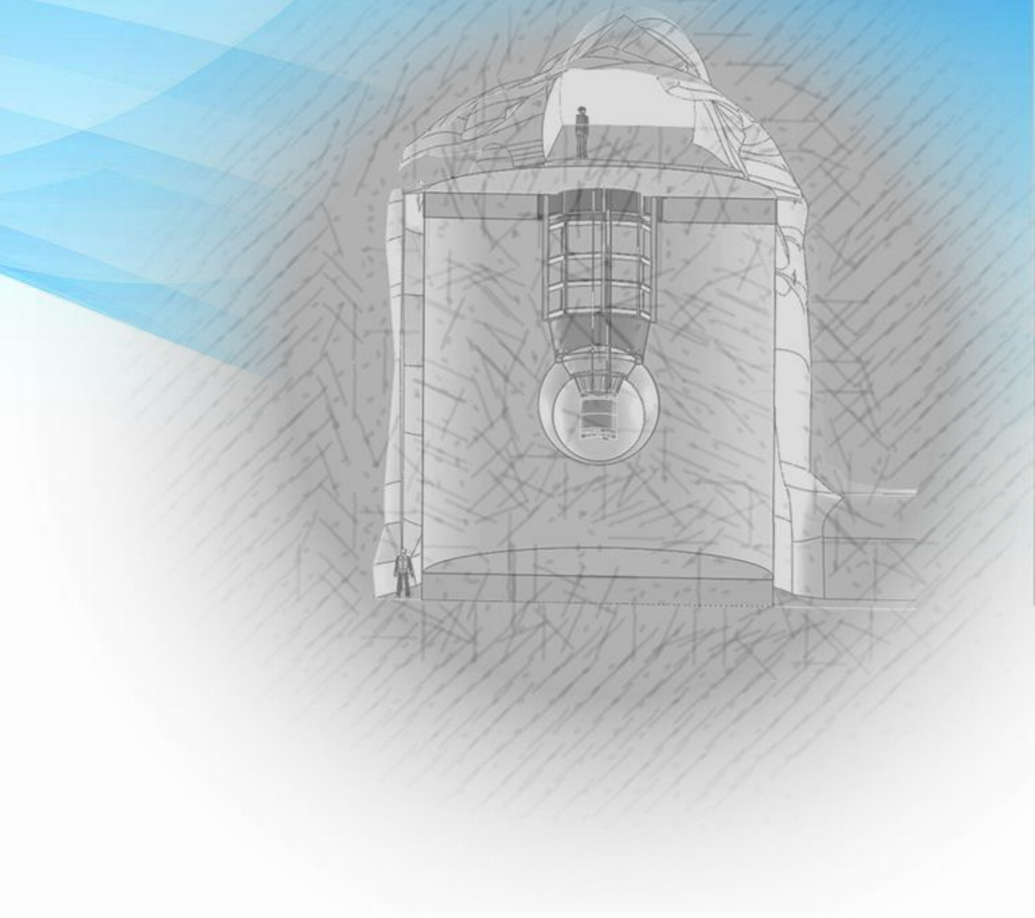
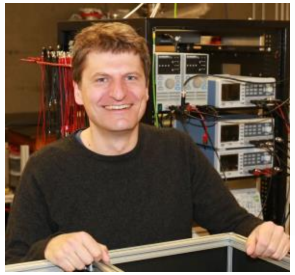


# The nEXO Search for 0νββ

Thomas Brunner (thomas.brunner@mcgill.ca)
nEXO Canada Spokesperson
For the nEXO Collaboration

0νββ International Summit at SNOLAB, April 27, 2023

# nEXO Delegation at this Summit



**Dr. Thomas Brunner**
McGill University
Canada
CFI co-lead

**Dr. Beatrice Franke**
TRIUMF
Canada
CFI co-lead

**Dr. Giorgio Gratta**
Stanford University
USA
Spokesperson

**Dr. Mike Heffner**
Lawrence Livermore National Laboratory
USA
Project Director

**Dr. Julien Masbou**
SUBATECH
France
LXe detector expert

**Dr. Yifang Wang**
Director, Institute of High Energy Physics of the Chinese Academy of Sciences (IHEP)
China (unexpectedly unable to travel)

Please approach us with any questions you may have concerning our experiment.

# nEXO Subsystems

**Charge Readout Electronics (SLAC)**
Subsystem Scientist:
L. Yang (UCSD)
Subsystem Manager:
A. Dragone (SLAC)

**Photon Readout Electronics (BNL)**
Subsystem Scientist:
M. Chiu (BNL)
Subsystem Manager:
L. DeMino (BNL)

**TPC (PNNL)**
Subsystem Scientist:
J. Orrell (PNNL)
Subsystem Manager:
A. Gorham (PNNL)

**Photon Detector (BNL)**
Subsystem Scientist:
D. Moore (Yale)
Subsystem Manager:
M. Worcester (BNL)

**Computing, Control and Software (LLNL)**
Subsystem Scientist:
S. Sangiorgio (LLNL)
Subsystem Manager:
F. Nekogar (LLNL)

**Radioactive Background Control (SLAC)**
Subsystem Scientist:
A. Piepke (UA)
Subsystem Manager:
D. Seiner (PNNL)

**TPC Support Systems (LLNL)**
Subsystem Scientist:
A. Pocar (UMass)
Subsystem Manager:
A. House (LLNL)

**Xenon (LLNL)**
Subsystem Scientist:
G. Gratta (Stanford)
System Manager:
TBD

**Facility (SNOLAB)**
Subsystem Scientist:
E. Caden
Subsystem Manager:
D. Hawkins

**Outer Detector (SNOLAB)**
Subsystem Scientist:
T. Brunner
Subsystem Manager:
D. Hawkins

# nEXO Subsystems and Canadian Contributions

nEXO

WBS with Canadian Contributions

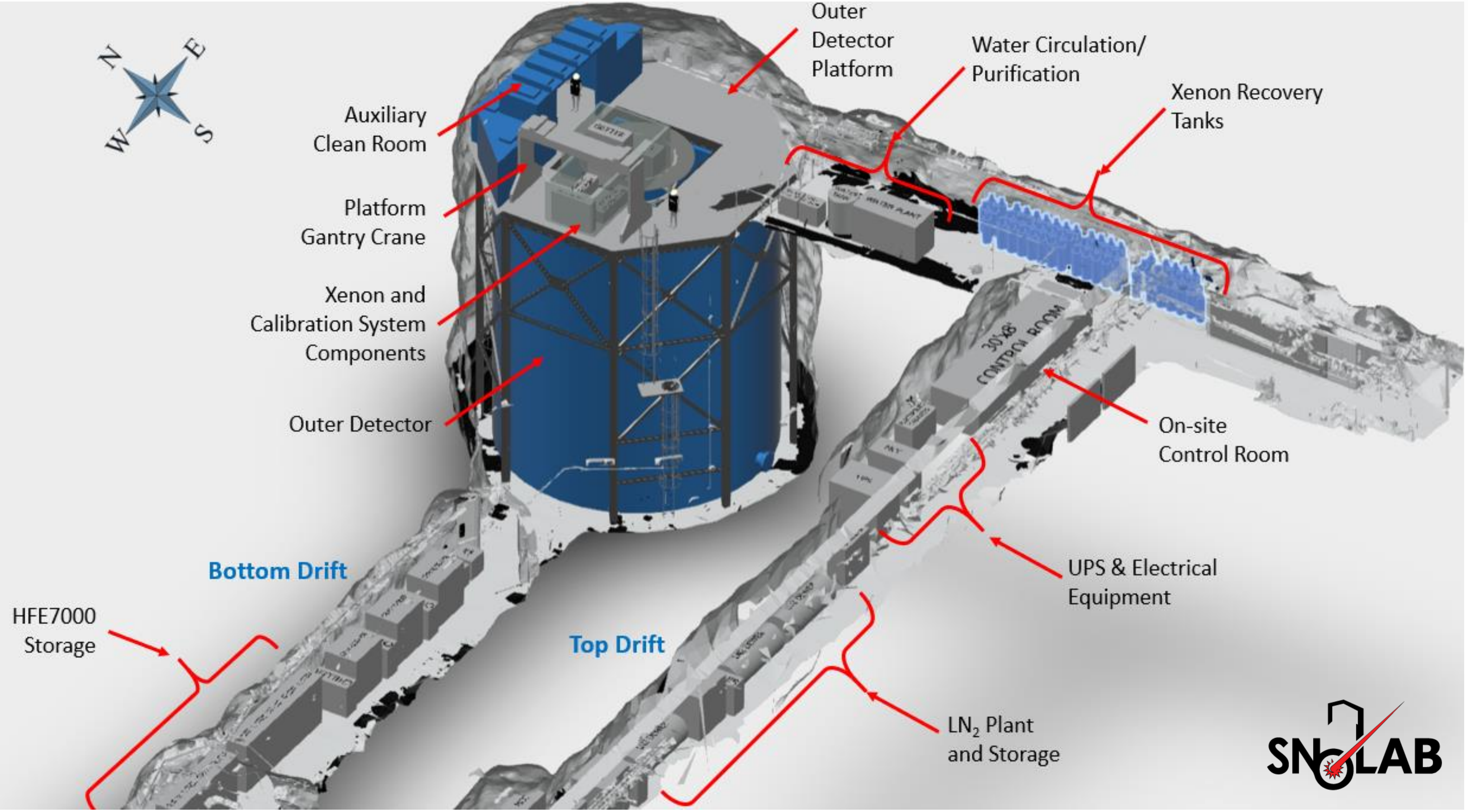
WBS with Canadian Leadership

| | | | |
|---|---|---|---|
| **Charge Readout Electronics (SLAC)**<br>Subsystem Scientist:<br>L. Yang (UCSD)<br>Subsystem Manager:<br>A. Dragone (SLAC) | **Photon Readout Electronics (BNL)**<br>Subsystem Scientist:<br>M. Chiu (BNL)<br>Subsystem Manager:<br>L. DeMino (BNL) | **TPC (PNNL)**<br>Subsystem Scientist:<br>J. Orrell (PNNL)<br>Subsystem Manager:<br>A. Gorham (PNNL) | **Photon Detector (BNL)**<br>Subsystem Scientist:<br>D. Moore (Yale)<br>Subsystem Manager:<br>M. Worcester (BNL) |
| **Computing, Control and Software (LLNL)**<br>Subsystem Scientist:<br>S. Sangiorgio (LLNL)<br>Subsystem Manager:<br>F. Nekogar (LLNL) | **Radioactive Background Control (SLAC)**<br>Subsystem Scientist:<br>A. Piepke (UA)<br>Subsystem Manager:<br>D. Seiner (PNNL) | **TPC Support Systems (LLNL)**<br>Subsystem Scientist:<br>A. Pocar (UMass)<br>Subsystem Manager:<br>A. House (LLNL) | **Xenon (LLNL)**<br>Subsystem Scientist:<br>G. Gratta (Stanford)<br>System Manager:<br>TBD |
| | **Facility (SNOLAB)**<br>Subsystem Scientist:<br>E. Caden<br>Subsystem Manager:<br>D. Hawkins | **Outer Detector (SNOLAB)**<br>Subsystem Scientist:<br>T. Brunner<br>Subsystem Manager:<br>D. Hawkins | |

- **Two subsystems are Canada-led.**
- Canadian groups are contributing to 5 other subsystems.
- **Significant engineering and project management support from SNOLAB**

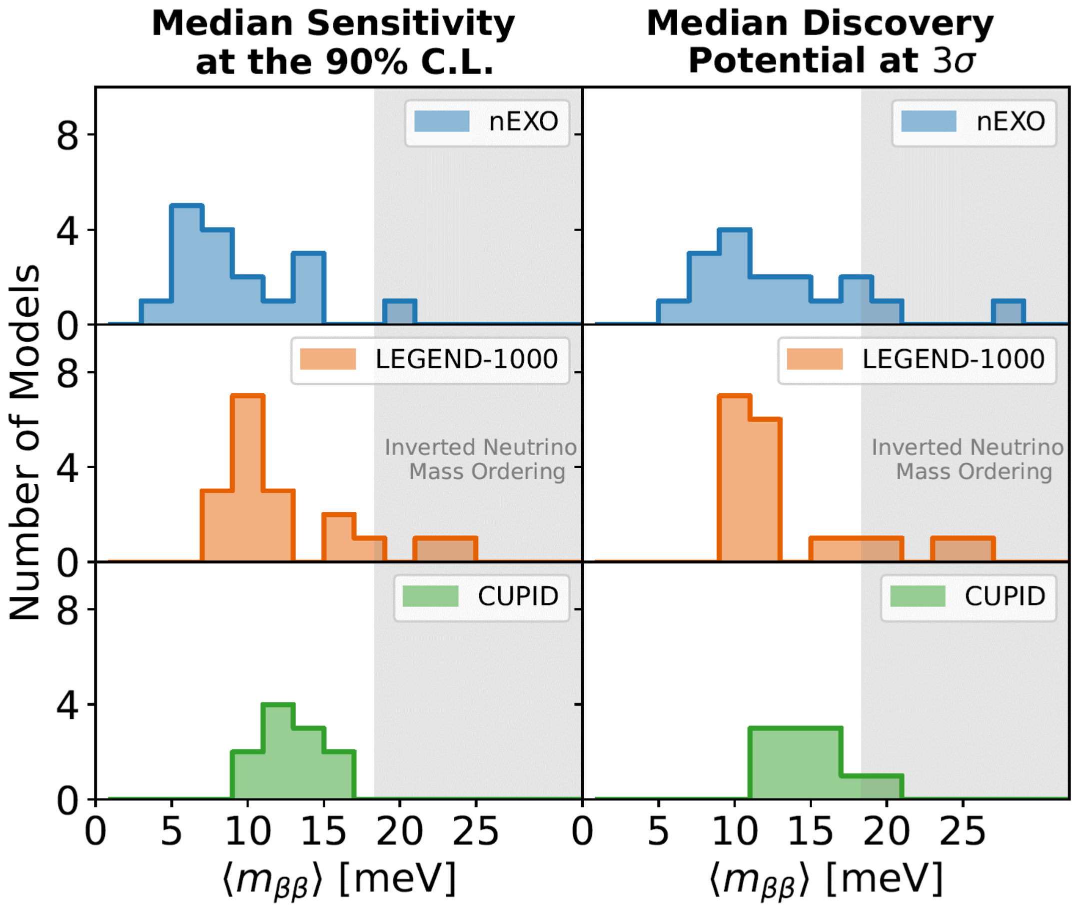
# Very substantial engineering done by SNOLAB nEXO

*Note that the Outer Detector Tank is on a critical path (infrastructure requested in CFI IF 2023), because it is also used as a clean room for constructing the cryostat and assembly of the inner detector components.*



# Comparison with other experiments






Deeper Physics Reach

Effective Majorana mass $\langle m_{\beta\beta} \rangle$ is an effective, albeit imperfect, metric to compare physics reach between isotopes and experiments.

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

Phase space factor — Axial coupling, $g_A = 1.27$ — NME

| | $m_{\beta\beta}$ [meV], (*median* NME*) | |
|---|---|---|
| | *90% excl. sens.* | $3\sigma$ discov. potential |
| nEXO | 8.2 | 11.1 |
| LEGEND | 10.4 | 11.5 |
| CUPID | 12.9 | 15.0 |

*$T_{1/2}$ values used [x$10^{28}$ yr]:
- nEXO: 1.35 (90% sens.), 0.74 ($3\sigma$ discov.) [1]
- LEGEND: 1.6 (90% sens.), 1.3 ($3\sigma$ discov.) [2]
- CUPID: 0.15 (90% sens.), 0.11 ($3\sigma$ discov.) [3]

[1] nEXO collaboration, J. Phys. G: Nucl. Part. Phys. 49 015104 (2022), arXiv:2106.16243
[2] LEGEND pCDR, arXiv: 2107.11462
[3] CUPID pCDR, arXiv:1907.09376

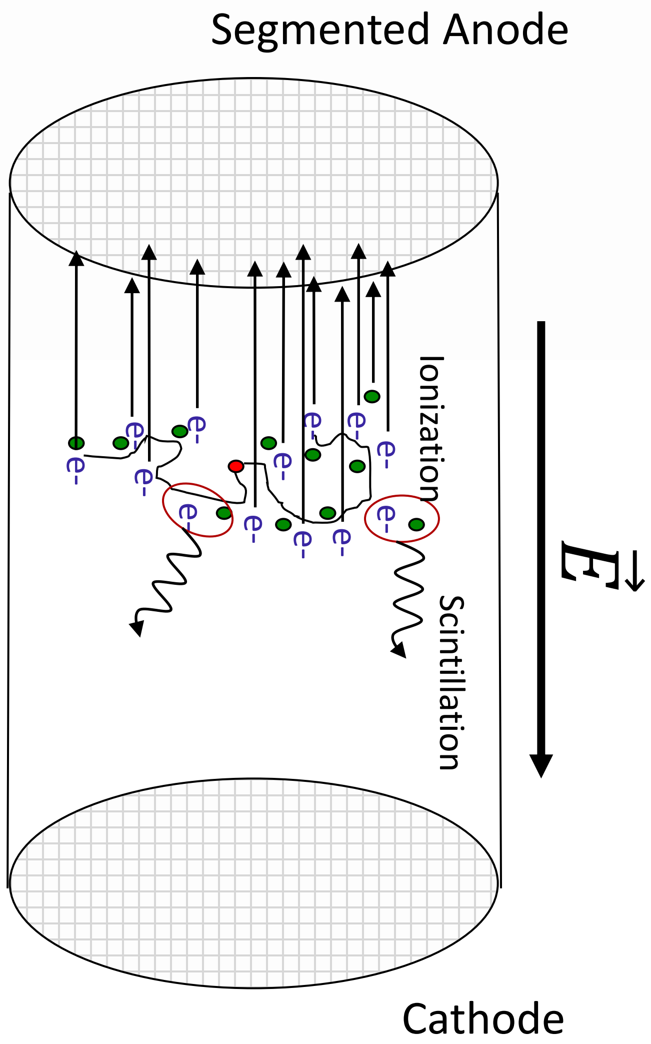
# nEXO Construction Budget

- Bottom-up project budget with more than 13,000 entries.
- Assumption that nEXO is located at SNOLAB Cryopit.
- Assume CD-1 in US DOE FY24 (early CY2024).
- Assume data taking start in 2031.
- Total cost estimate for nEXO of order US$441M (without contingency).

| Source | Amount |
|---|---|
| US DOE Project | US$311M (US$431M with contingency) |
| Canada | US$58M-US$77M (MSI + IF + NSERC) |
| US grants and base funding | US$49M |
| China | US$4M |
| **Additional opportunities being evaluated** | |
| Europe | Under discussion |
| China | Possible contribution of enriched xenon |

# nEXO's 0νββ search with a liquid Xe TPC

nEXO




## Liquid-Xe Time Projection Chamber (TPC)

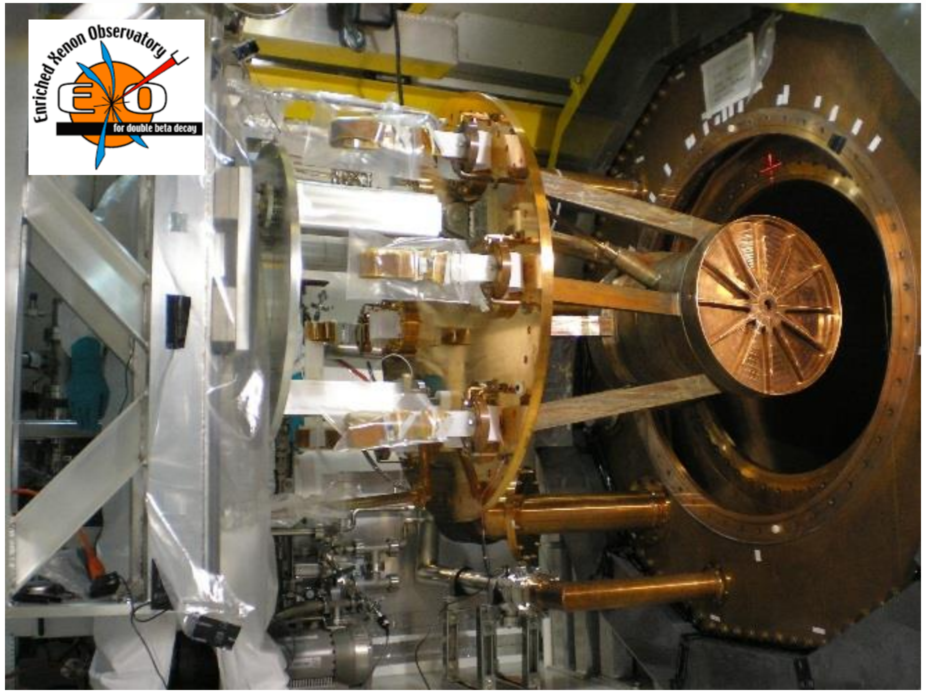
- Xe is used both as the source and detection medium.
- LXe is continuously recirculated and purified.
- LXe TPCs are well understood. As a fully homogeneous detector, it precisely measures backgrounds in situ.

  → **No internal materials (other than Xe), making nEXO uniquely robust against unknown backgrounds**
- Multiparameter measurement from scintillation light and ionization signal:
  1. Energy from combined scintillation/ionization
  2. Topology, e.g., single-site or multi-site event
  3. Position distribution from 3D event reconstruction
  4. Particle identification from scintillation/ionization ratio

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

**EXO-200 at WIPP** (Decommissioned in Dec. 2018):

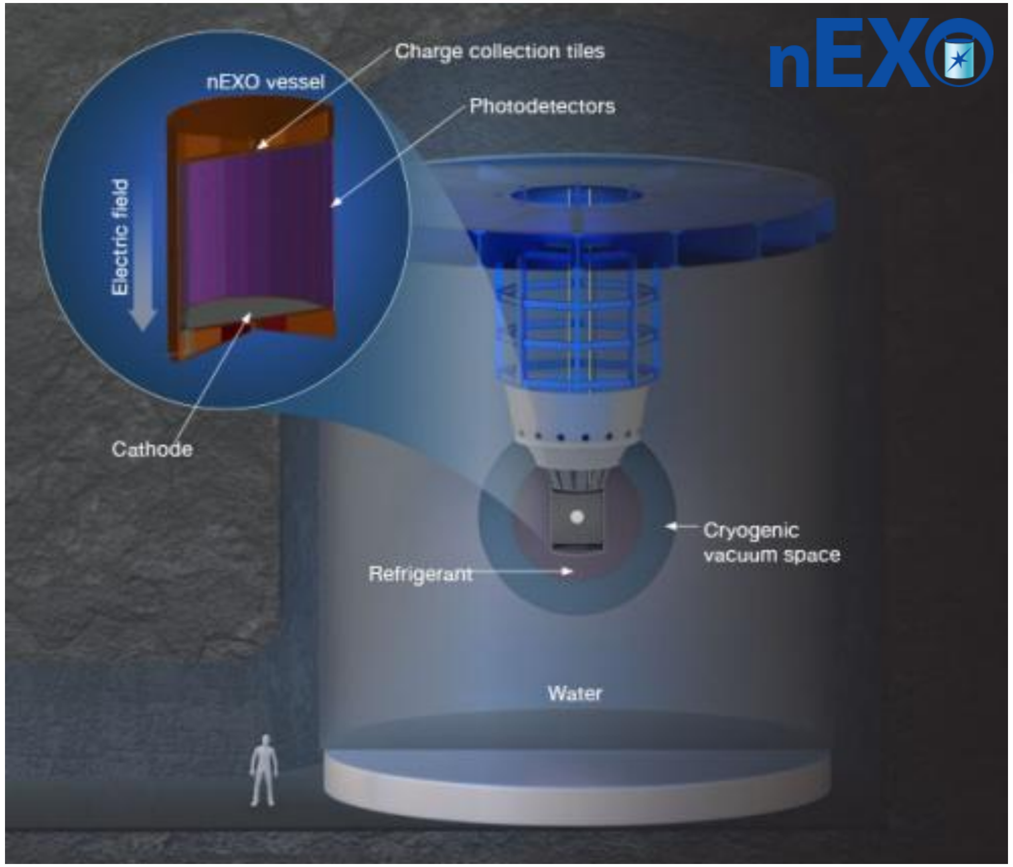
- EXO-200 first 100-kg class ββ experiment
- 175 kg liquid-Xe TPC with ~80% Xe-136
- Discovered 2νββ in Xe-136
- **Demonstrated excellent background identification through multiplicity and location of event in TPC**
  **→ this is essential for nEXO design**




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

**nEXO:**

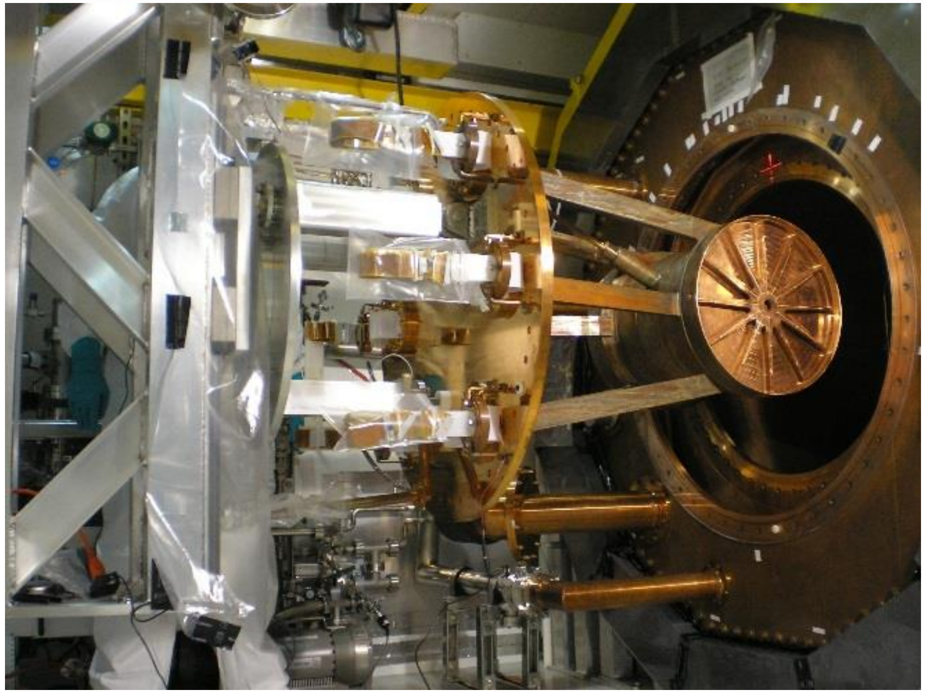
- 5-tonne liquid Xe TPC
- Enriched in Xe-136 at ~90%
- SNOLAB cryopit preferred location by collaboration




https://nexo.llnl.gov/

# EXO-200 0νββ results

- First 100 kg-class experiment to take data.
- Excellent background, very well predicted by the massive material characterization program (and the simulation) → ***This is essential for nEXO design.***
- More papers on non-ββ decay physics.



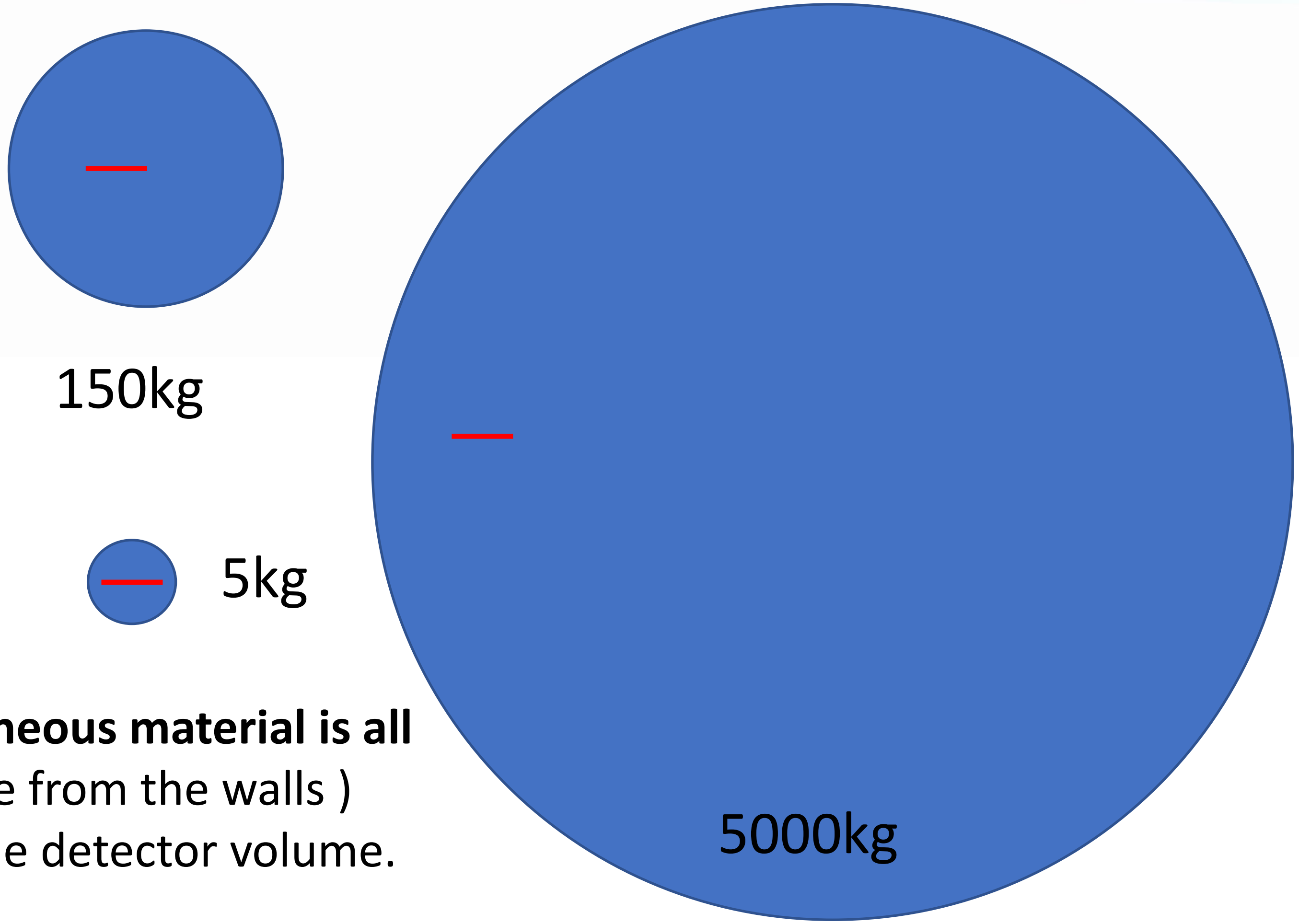
*2012: Phys.Rev.Lett. 109 (2012) 032505*
*2014: Nature 510 (2014) 229-234*
*2018: Phys. Rev. Lett. 120, 072701 (2018)*
*2019: Phys. Rev. Lett. 123 (2019) 161802*

**Final result**
**Phase I+II: 234.1 kg yr of $^{136}Xe$ exposure**
**Limit: $T_{1/2}^{0\nu\beta\beta}$ > $3.5\times10^{25}$ yr (90% CL)**
**$\langle m_{\beta\beta} \rangle$ < (93 -286) meV**
**Sensitivity: $5.0\times10^{25}$ yr**

# The power of a monolithic detector

| LXe mass (kg) | Diameter or length (cm) |
|---|---|
| 5000 | 130 |
| 150 | 40 |
| 5 | 13 |

2.5 MeV $\gamma$-ray
attenuation length in LXe
8.5cm = —

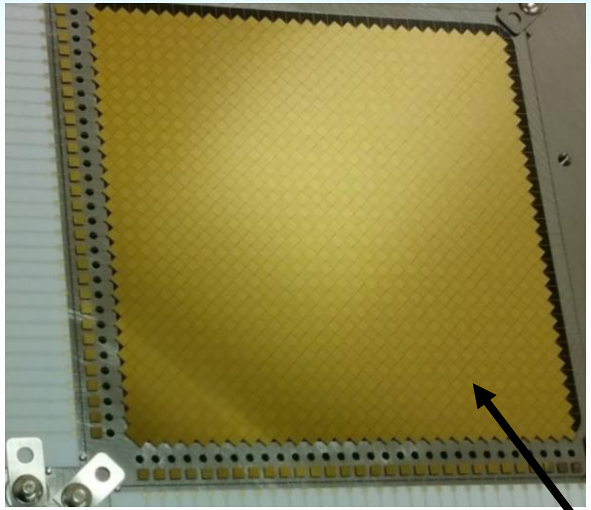



- **Monolithic/Homogeneous is key because extraneous material is all external** (Gamma backgrounds typically originate from the walls )
  → photons Compton scatter on their way into the detector volume.

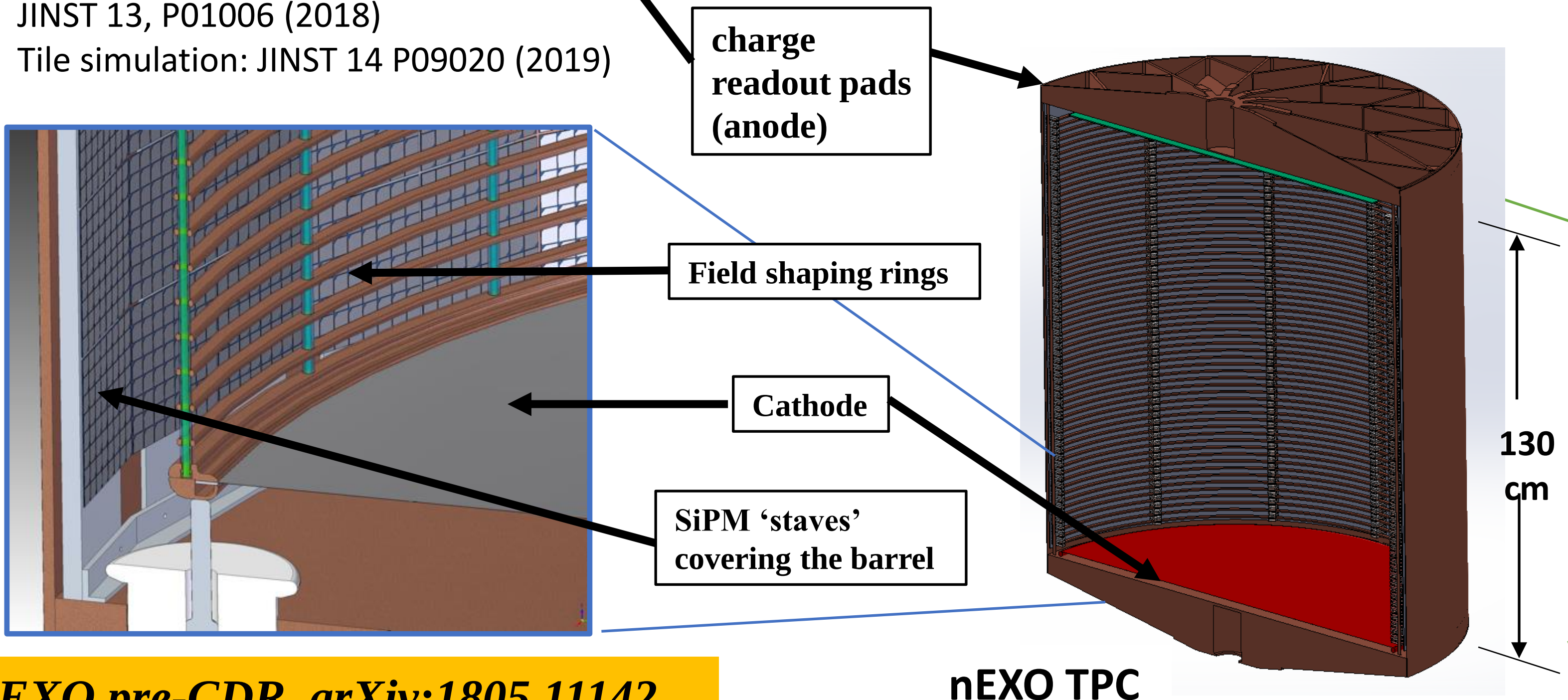
**Among the projects selected and funded by DOE for tonne-scale, nEXO is the only Monolithic/Homogeneous detector**

# The nEXO detector

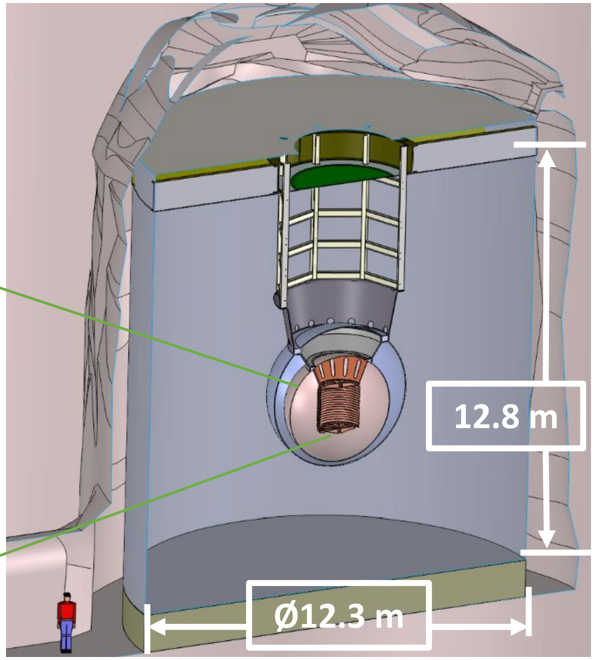
- 5 t liquid xenon TPC similar to EXO-200 (~30x the volume).
- SiPM for 175nm scintillation light detection, ~4.5m$^2$ SiPM array in LXe.
- Tiles for charge read out in LXe.
- Cold electronics inside TPC in liquid Xe.
- 3D event reconstruction.
- Combine charge and light readout. Goal → σ/E of <1% at Q-value.
- 1.5 ktonnes water-Cherenkov detector for muon tagging and shielding.



Picture: 10 x 10 cm$^2$ tile prototype
JINST 13, P01006 (2018)
Tile simulation: JINST 14 P09020 (2019)




nEXO TPC




nEXO at the SNOLAB Cryopit

***nEXO pre-CDR, arXiv:1805.11142***

# Anode Charge Readout

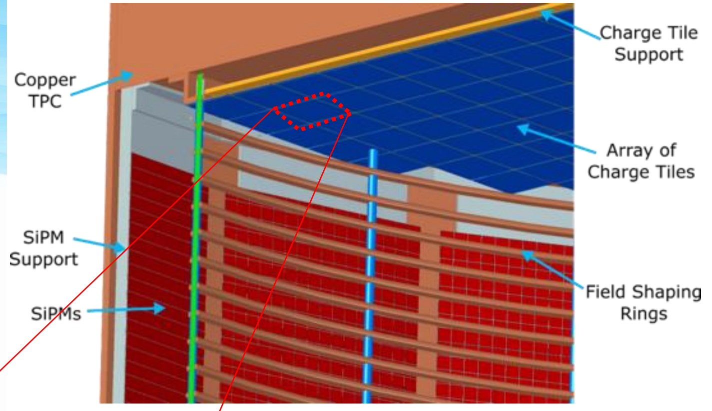
- Charge collection on tiled anode plane
- Full simulation of charge collection in nEXO used to optimize design
  - Crossed strips with no shielding grid
  - Channel pitch: 6mm
  - Tile size: 10 cm x 10 cm

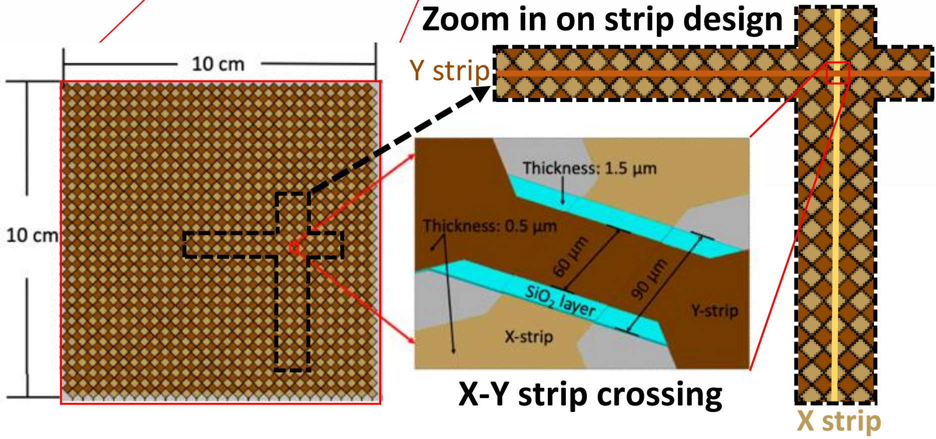
*Z. Li et al. (nEXO Collab) "Simulation of charge readout with segmented tiles in nEXO," JINST 14 P09020 (2019)*

- Prototype tiles have been measured in LXe to validate simulation

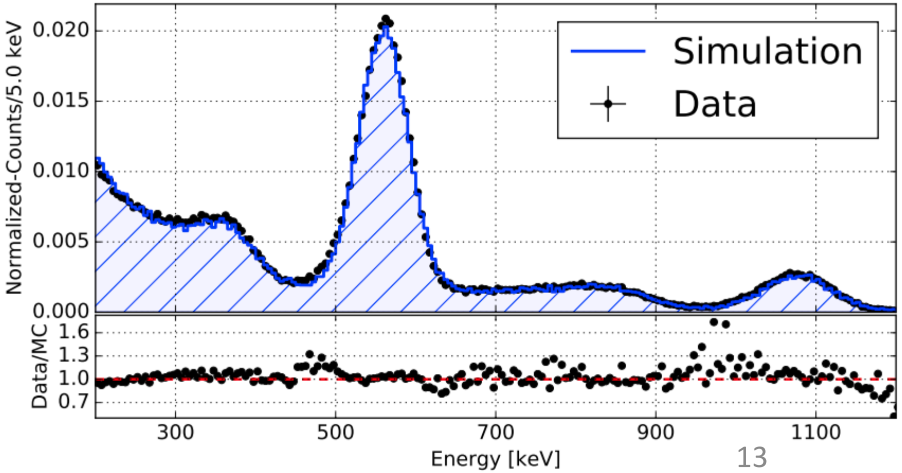
*M. Jewell et al. (nEXO Collab) "Characterization of an ionization readout tile for nEXO," JINST 13 P01006 (2018)*

**Zoom in on upper corner of TPC:**



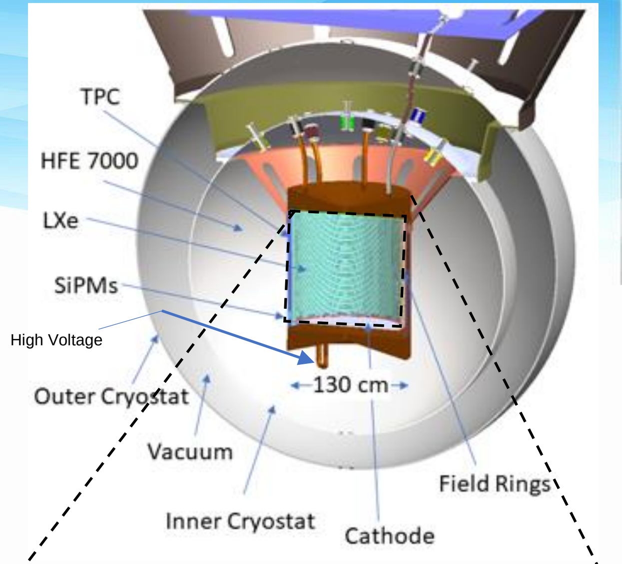




**Source calibration ($^{207}$Bi) with prototype tile:**

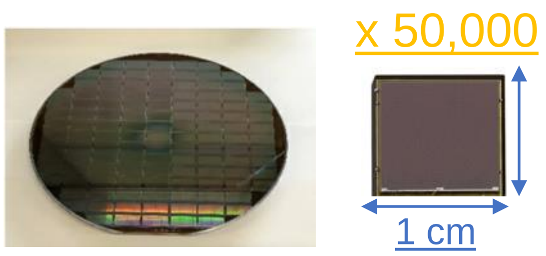


# SiPMs for photon detection

- 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, demonstrated through R&D.



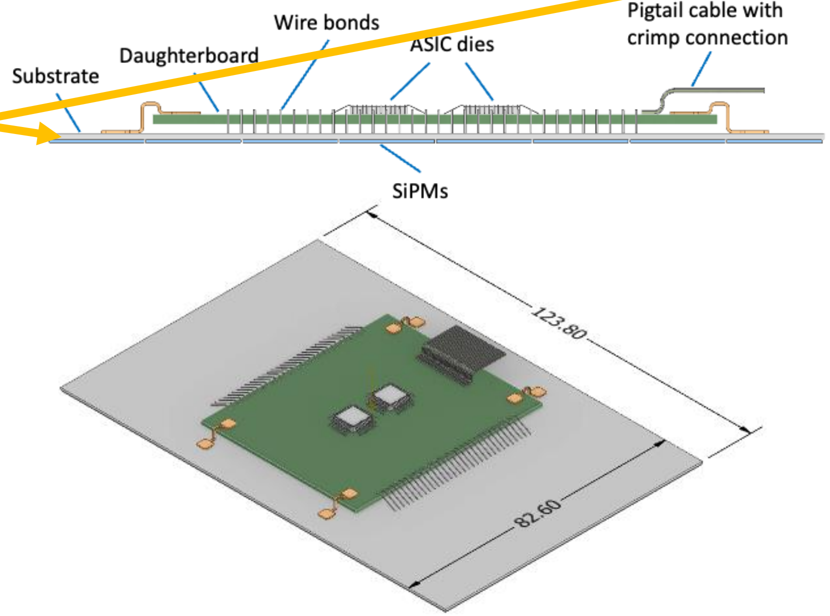

***SiPM Devices***



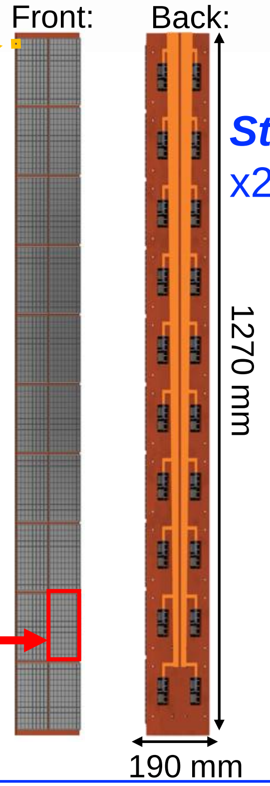

*A. Jamil et al. (nEXO collab.) "VUV-sensitive Silicon Photomultipliers for Xenon Scintillation Light Detection in nEXO," IEEE Trans. Nucl. Sci. 65, 11 (2018)*

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

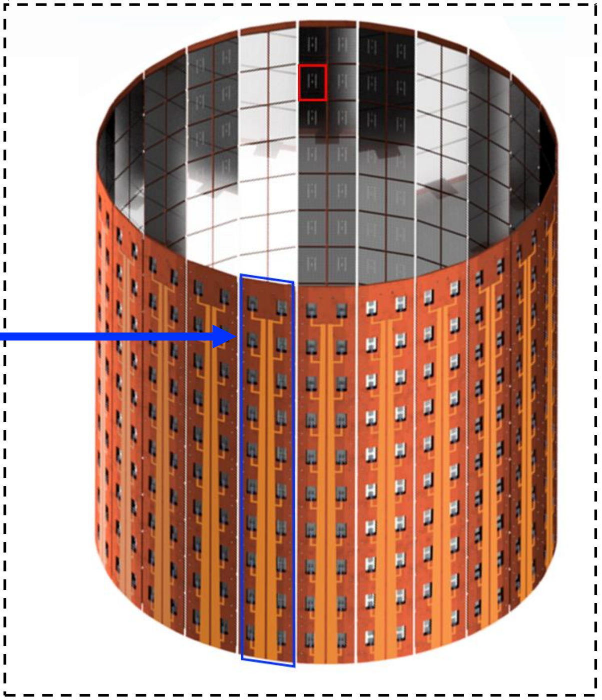
*G. Gallina et al. (nEXO), "Performance of novel VUV-sensitive Silicon Photo-Multipliers for nEXO," Eur. Phys. J. C 82, 1125 (2022)*




***Tile module*** x 480




***Stave*** x24



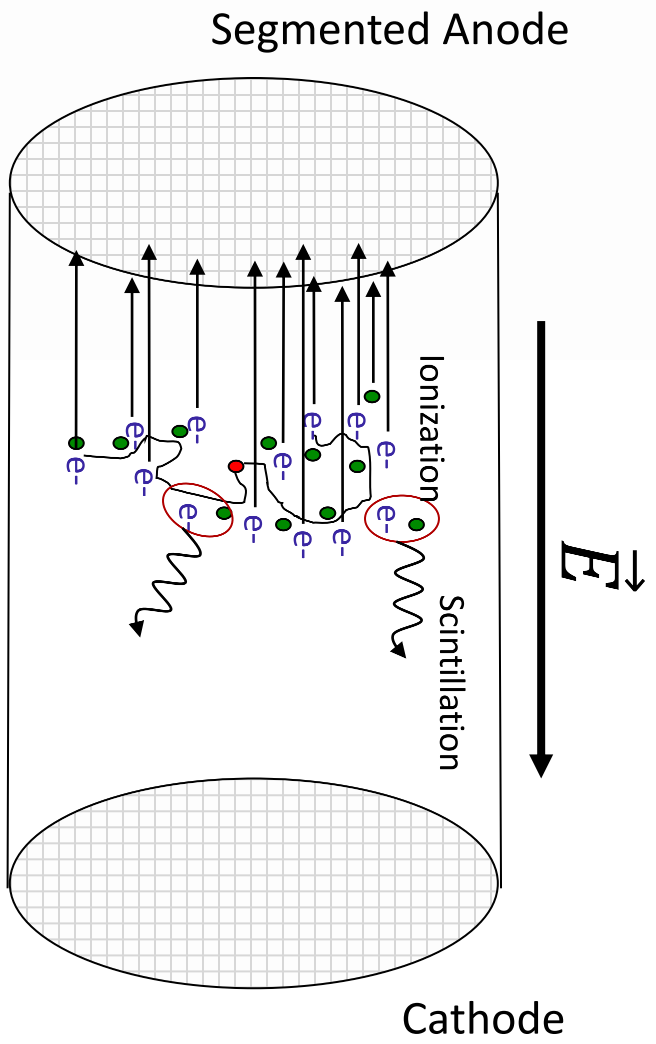
***Photon detector (PD)***

# nEXO publications

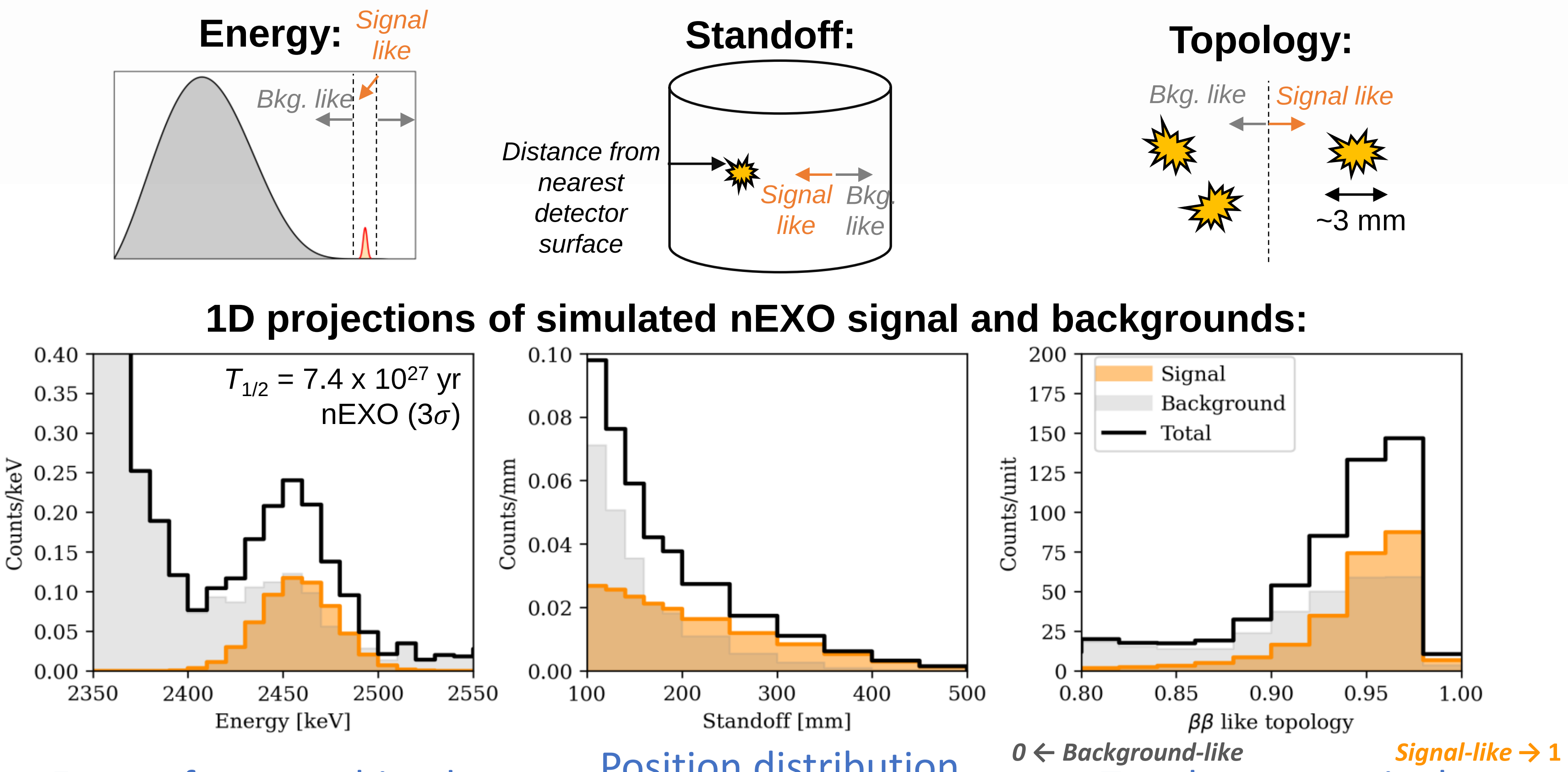
- The nEXO collaboration is pursuing a targeted, successful research program.
- **Most of the studies were led by graduate students and postdocs.**

- **An integrated online radioassay data storage and analytics tool for nEXO,** R.H.M. Tsang, et al., submitted to NIM A, arXiv:2304.06180 (2023)
- **Performance of novel VUV-sensitive Silicon Photo-Multipliers for nEXO,** G. Gallina, et al., Eur. Phys. J. C 82, 1125 (2022)
- **Development of a $^{127}$Xe calibration source for nEXO,** B. G. Lenardo, et al., JINST, 17, 07, P07028 (2022)
- **nEXO: neutrinoless double beta decay search beyond $10^{28}$ year half-life sensitivity,** G. Adhikari et al., J. Phys. G: Nucl. Part. Phys. 49 015104 (2022)
- **Reflectivity of VUV-sensitive silicon photomultipliers in liquid Xenon,** M. Wagenpfeil, et al., JINST 16 P08002 (2021),
- **SNEWS 2.0: A Next-Generation SuperNova Early Warning System for Multi-messenger Astronomy,** SNEWS 2 collaboration, New J. Phys. 23 031201 (2021)
- **Event Reconstruction in a Liquid Xenon Time Projection Chamber with an Optically-Open Field Cage,** T. Stiegler, et al, NIMA 1000, 165239 (2021)
- **Reflectance of Silicon Photomultipliers at Vacuum Ultraviolet Wavelengths,** P. Lv, et al, IEEE Trans. Nucl. Sci. 67, 2501 (2020)
- **Reflectivity and PDE of VUV4 Hamamatsu SiPMs in liquid xenon,** P. Nakarim, et al., JINST 15, P01019 (2020)
- **Measurements of electron transport in liquid and gas Xenon using a laser-driven photocathode,** O. Njoya, et al., NIM A 972, 163965 (2020)
- **Characterization of the Hamamatsu VUV4 MPPCs for nEXO**, G. Gallina, et al., NIMA 940, 371 (2019)
- **Simulation of charge readout with segmented tiles in nEXO,** Z. Li, et al., JINST 14, P09020 (2019)
- **Imaging individual Ba atoms in solid xenon for barium tagging in nEXO,** C. Chambers, et al., Nature 569, 203 (2019)
- **Study of Silicon Photomultiplier Performance in External Electric Fields,** X.L. Sun, et al., JINST 13, T09006 (2018)
- **VUV-sensitive Silicon Photomultipliers for Xenon Scintillation Light Detection in nEXO,** IEEE Transactions on Nuclear Science 1 (2018)
- **nEXO Pre-Conceptual Design Report,** arXiv:1805.11142v2
- **Characterization of an Ionization Readout Tile for nEXO,** M. Jewell, et al., JINST 13, P01006 (2018)
- **Sensitivity and Discovery Potential of nEXO to Neutrinoless Double Beta Decay,** J.B. Albert, et al., Physical Review C 97, 065503 (2018)

# nEXO Signal and Background




**nEXO measures multiple parameters for each event to be able to robustly identify a 0νββ signal**

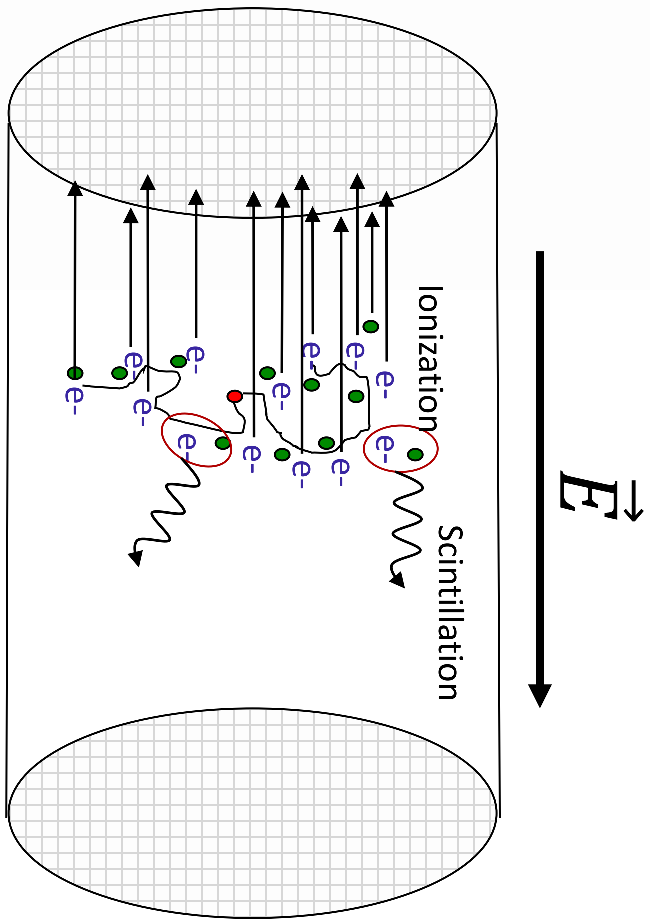



Energy from combined scintillation/ionization

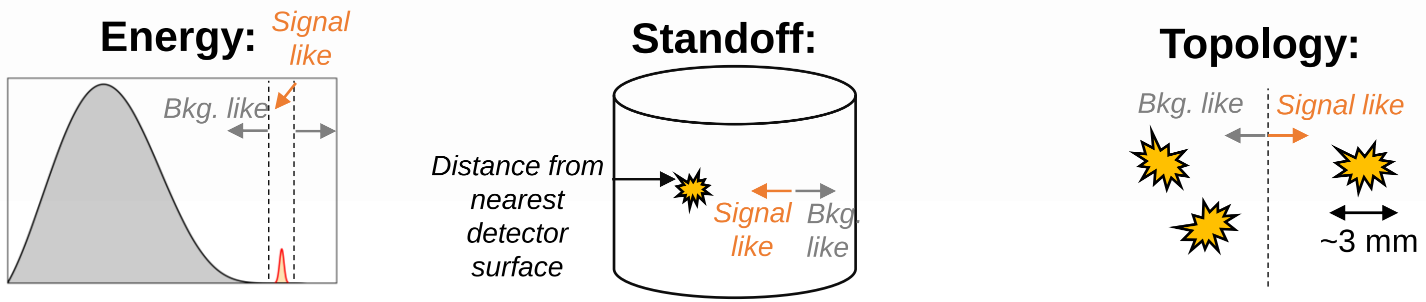
Position distribution from 3D event reconstruction

Topology, e.g., single-site or multi-site

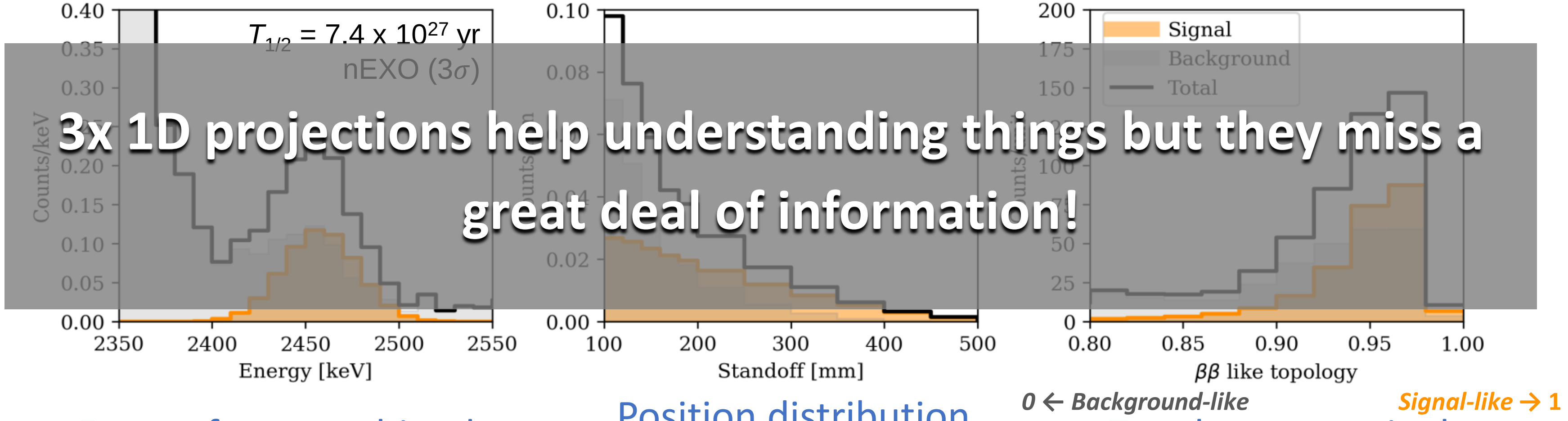
# nEXO Signal and Background




**nEXO measures multiple parameters for each event to be able to robustly identify a 0νββ signal**




**1D projections of simulated nEXO signal and backgrounds:**




Energy from combined scintillation/ionization

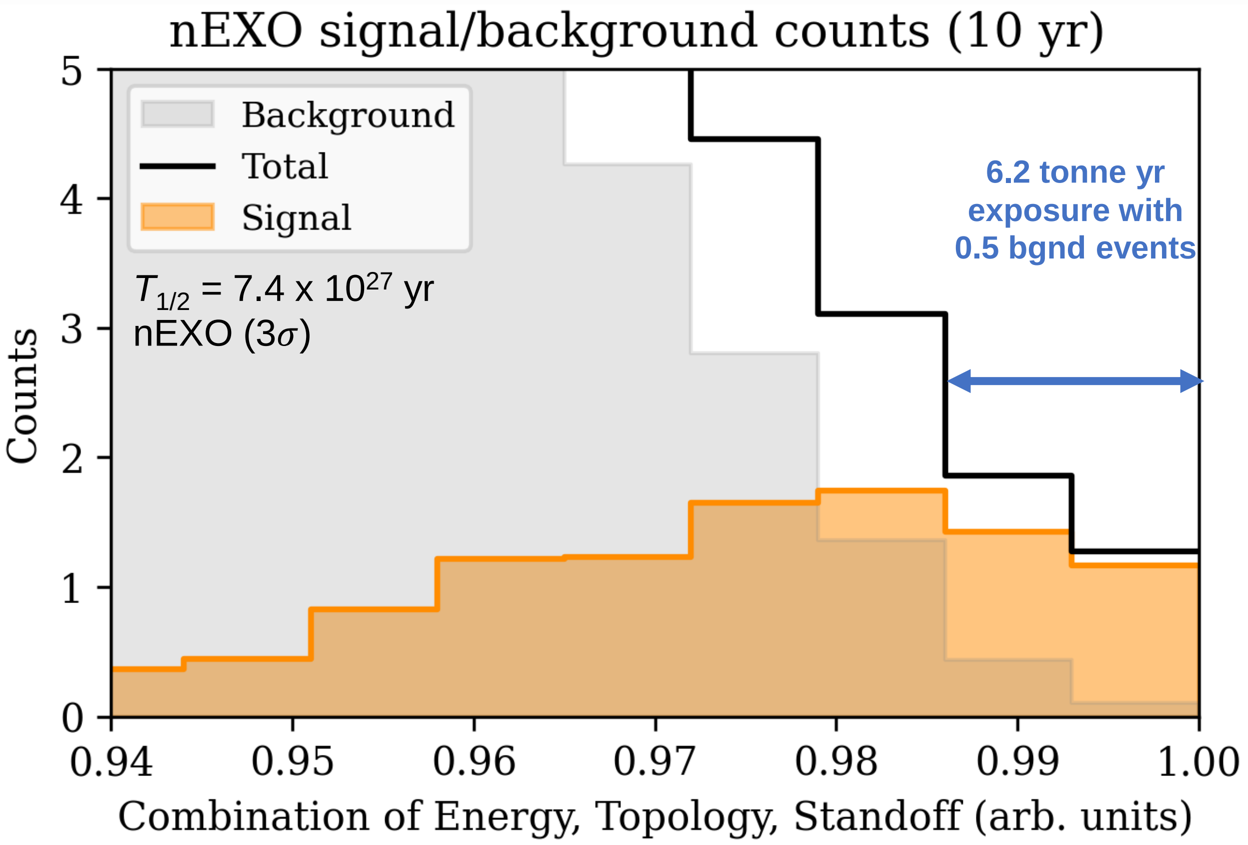
Position distribution from 3D event reconstruction

Topology, e.g., single-site or multi-site

# nEXO Signal and Background

- Likelihood fit allows optimal weighting between signal and background combining energy, topology, and standoff over full 3D parameter space
- For clarity, we arrange the 3D bins into 1D, ordered by signal-to-background ratio.

Combine energy, topology, and standoff (preserving correlations)

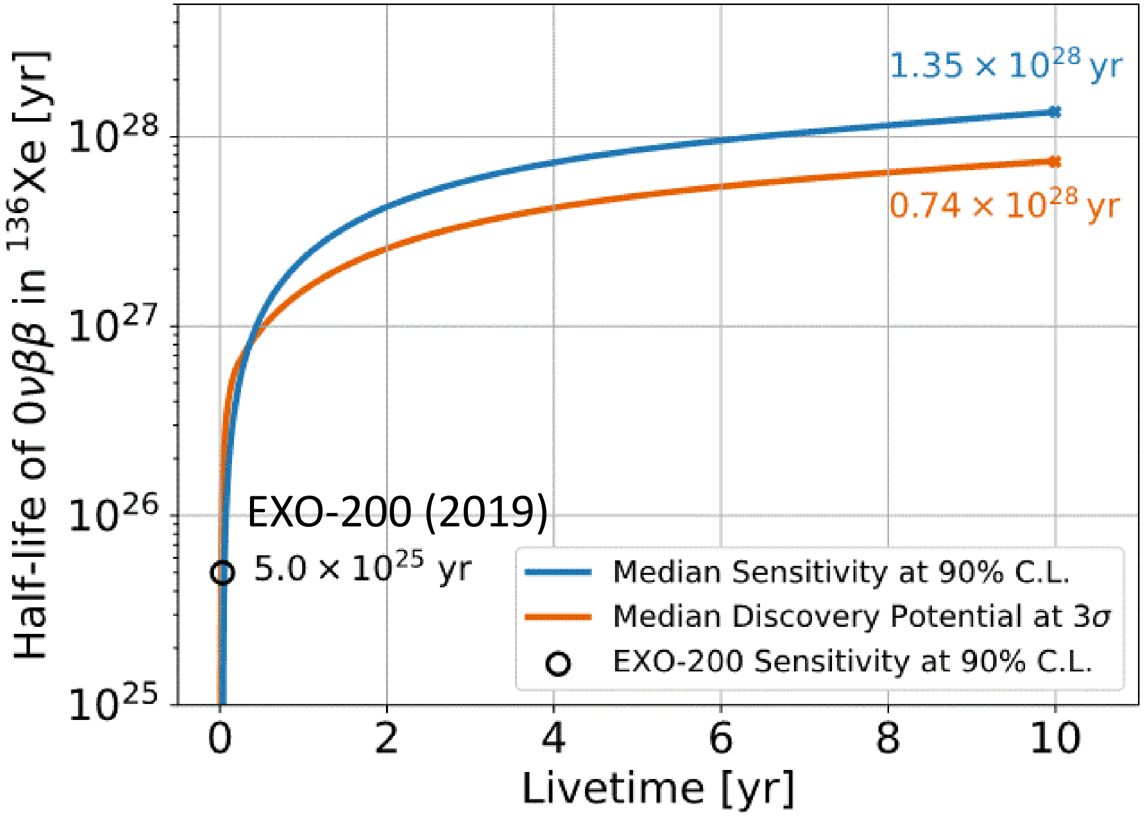



***0 ← Background-like*** ***Signal-like → 1***

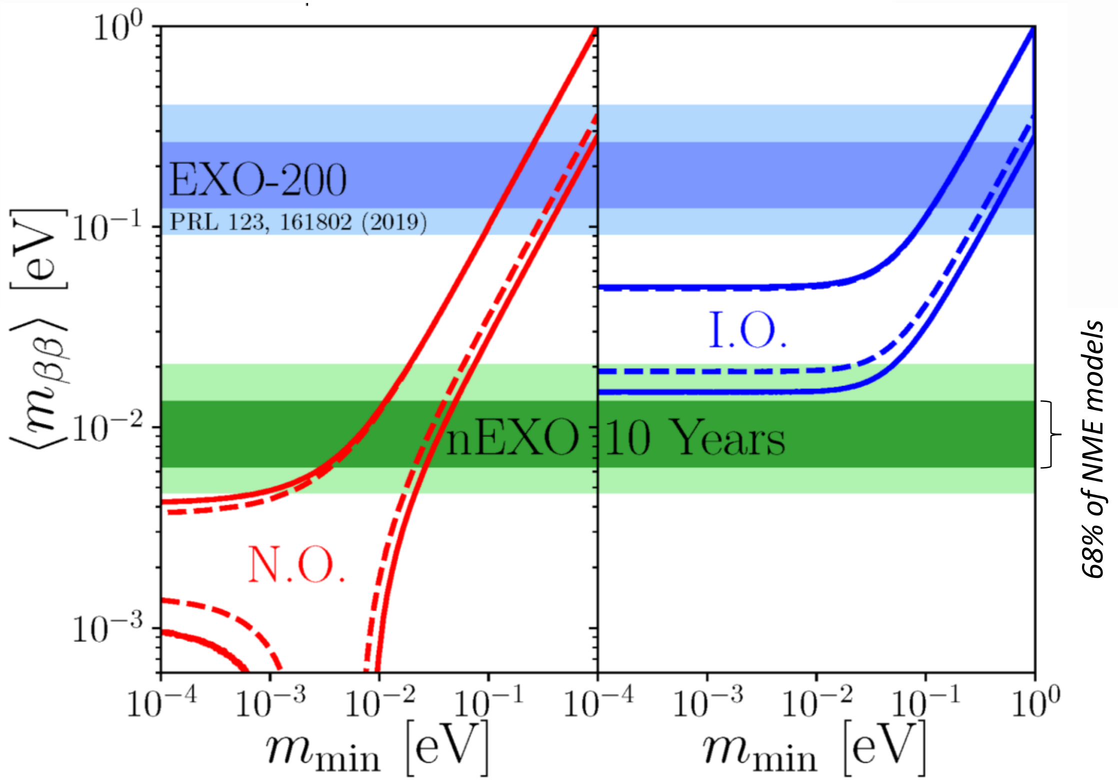
→ **nEXO is a "background-free" experiment**

# nEXO Projected Sensitivity

J. Phys. G: Nucl. Part. Phys. 49, 015104 (2022), arXiv:2106.16243




**Allowed parameter space and nEXO exclusion sensitivity (90% CL):**




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

Projected sensitivity based on background levels measured in samples of all detector materials!

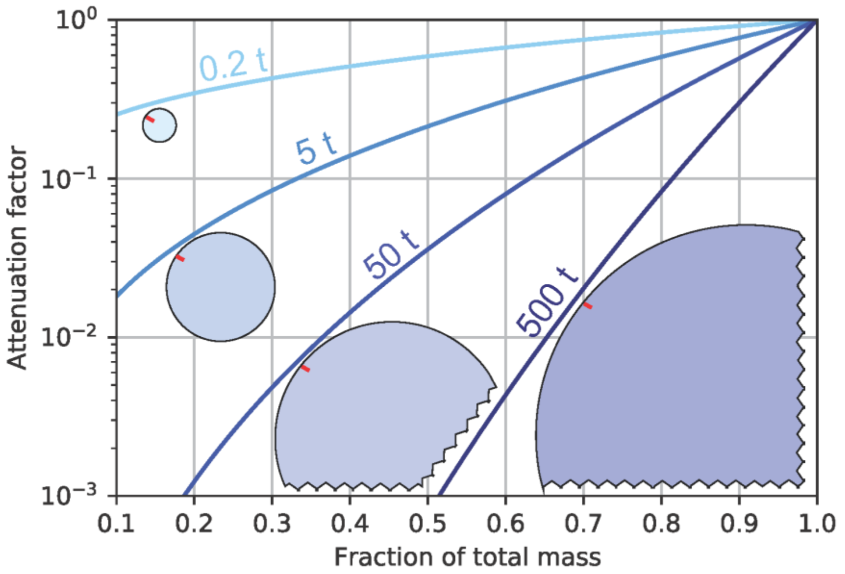
# Other Unique Features of nEXO:

- LXe reduces risk, as the purification system can be upgraded if unexpected backgrounds are discovered.
- **If nEXO discovers 0νββ decay:**
  - nEXO can make a discovery by itself, by repeating the experiment with non-enriched (natural or depleted) xenon to confirm that a signal goes away.
  - The enriched xenon is NOT “frozen” in a particular detector. Should 0νββ decay be discovered by nEXO, the xenon could be re-used in a different experimental configuration to investigate the underlying physics.

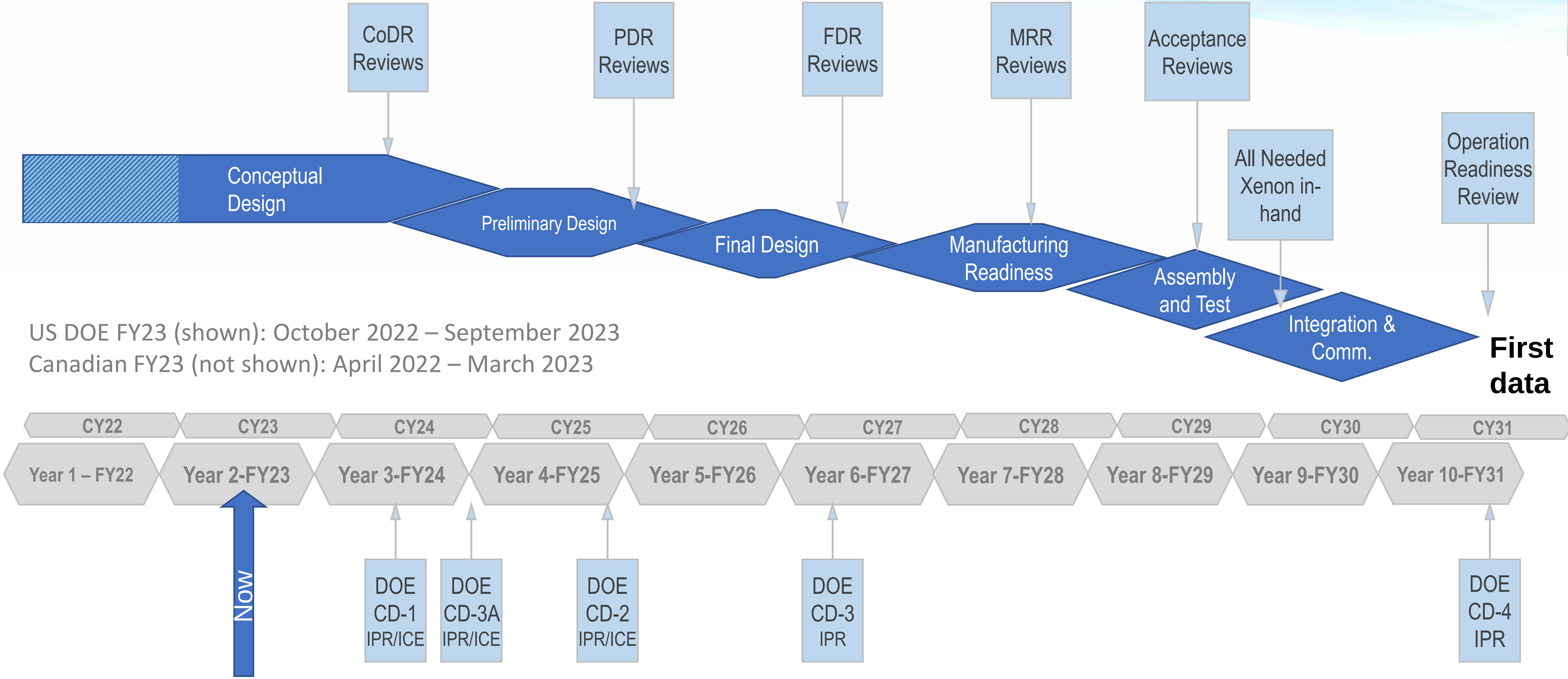
***→ This is particularly important at the tonne scale, given the cost of the material.***

- **If nEXO does not discover 0νββ decay:** The advantages of the homogeneous detector keep improving with size. Should 0νββ decay not be discovered by nEXO, larger detectors using the same technology are possible (A. Avasthi et al, Phys. Rev. D 104, 112007 (2021))

***→ The technology needs to be developed with an eye to the future.***



# nEXO high-level schedule




US DOE FY23 (shown): October 2022 – September 2023
Canadian FY23 (not shown): April 2022 – March 2023

# nNEXO Project near term funding: DOE FY24 Estimates

nEXO

| WBS | Sub-system | Review Location | Date (CoDRs) |
|---|---|---|---|
| 1.05 | Time Projection Chamber support systems | 1.05 | 7/24-7/28/2023 |
| 1.10 | Outer Detector | SNOLAB | 8/21-8/25/2023 |
| 1.11 | Facilities | SNOLAB | 8/21-8/25/2023 |
| 1.06.01 | Charge Readout Electronics | SLAC | 9/11-9/15/2023 |
| 1.06.02 | Photon Readout Electronics | BNL | 9/18-9/22/2023 |
| 1.04 | Photon Detector | BNL | 9/18-9/22/2023 |
| 1.08 | Computing, Controls and Software | LLNL | 11/13-11/17/2023 |
| 1.03 | Time Projection Chamber | PNNL | 12/11-12/15/2023 |
| 1.07 | Radioactive Background Control | PNNL | Q1/Q2 FY24 |
| 1.09 | Xenon | LLNL | Q1/Q2 FY24 |
| 1.02 | System Integration and commissioning | SLAC | Q1/Q2 FY24 |
| | CD-1 Director's Review | LLNL | February 2024 |
| | **CD-1 Independent Project Review** | LLNL | Target: March 2024 |

CoDR: Project organized external design review

Estimate complete with DOE FY23 funding in hand

Estimate $3.8M of DOE FY24 dollars

**FY24 Funding (US DOE only)**

- Technically Limited $42M ($57M with contingency).
- Of the FY24 dollars, $3.8M is required to complete CD1 (CoDRs shown above + all CD1 deliverables shown on previous slide).
- **$6.0M** in FY24 (constant funding+ inflation) required to avoid reversing ramp up.

# nEXO Project Cost Profile

| DOE FY | FY22 | FY23 | FY24 | FY25 | FY26 | FY27 | FY28 | FY29 | FY30 | FY31 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| US DOE Project [US$k] | 500 | 5,000 | 42,000 | 47,800 | 59,100 | 57,000 | 50,800 | 26,700 | 11,400 | 10,700 | **311,000** |
| CFI Innovation Fund [US$k] | | 300 | 11,000 | 7,000 | 7,000 | 9,000 | 6,000 | 6,000 | 800 | 800 | **47,900** |

Notes:

- US DOE Project
  - 40% contingency is NOT included.
  - **Updated with inflation for 2-year shift from Portfolio Review** and suggested escalation model.
- Canada CFI Innovation Fund
  - CFI IF construction components listed only – R&D specific infrastructure excluded from table.
  - Assuming multiple CFI IF awards (2023, 2025, 2027, …)
- Funding Status
  - $5.5M of DOE funding in hand.
  - CFI IF 2020 in hand: CAN$2M towards nEXO construction, CAN$9.2M for nEXO R&D infrastructure.

# Analysis of Alternatives (AoA)

nEXO

In preparation for the next steps, DOE is proceeding with a formal Analysis of Alternatives.

**This includes an analysis of the cost and performance at various sites.**

***For the cost, the analysis is done "differentially" from the case we analyzed with the most detail (Cryopit).***

| Site | Cost to DOE (M$) | Total Cost (M$) |
|---|---|---|
| SNOLAB primary | 311 | 441 |
| LNGS primary* | 301** | 462 |

* Account for some re-design work

** **Assumes contributions from Europe that are not as solid as CFI contributions from SNOLAB and Canada.** Does not take credit for a possible larger Italian contribution.

***While the cost at LNGS and SNOLAB is comparable, due to cosmogenic activation of $^{136}Xe \rightarrow {}^{137}Xe$ the physics reach is better at SNOLAB.***

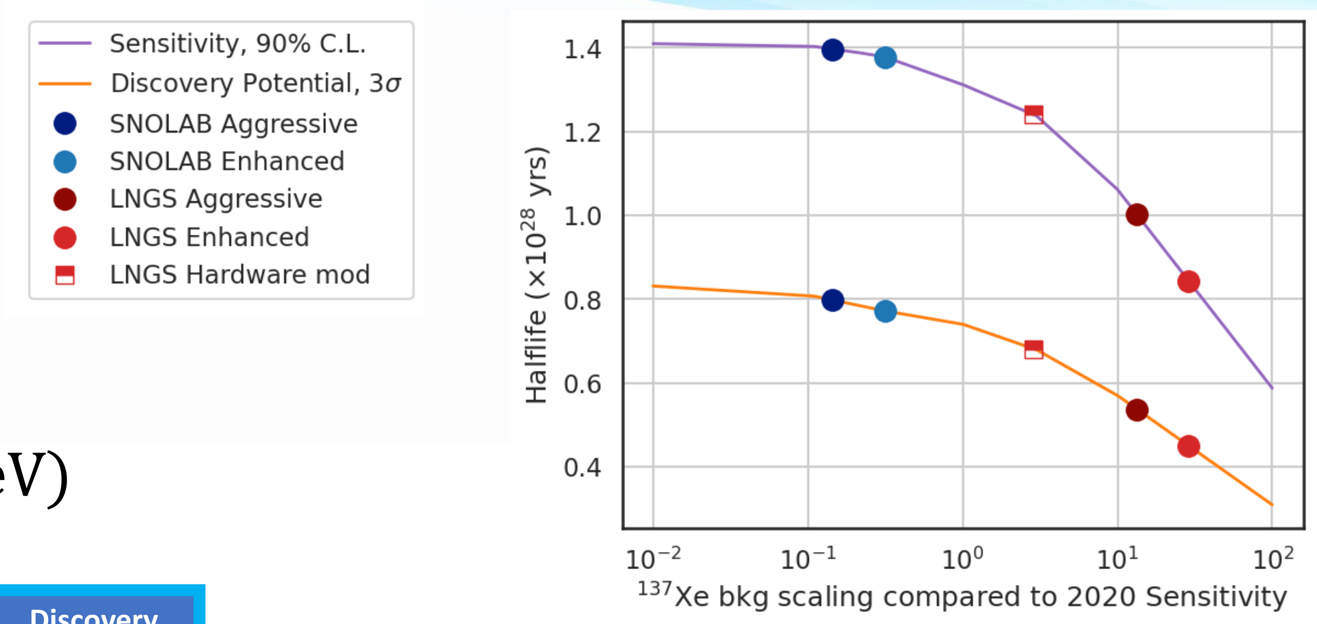
# For the two more plausible cases: LNGS and SNOLAB

nEXO

$$\mu + A \rightarrow n + X$$

$$n + {}^{136}\mathrm{Xe} \rightarrow {}^{137}\mathrm{Xe} + \gamma(4.\,\mathrm{MeV})$$

$${}^{137}\mathrm{Xe} \xrightarrow{3.82\mathrm{min}} {}^{137}Cs + \beta + \gamma(\mathrm{Q}_\beta = 4.2\mathrm{MeV})$$




| | Site | $^{137}$Xe Total Background Fraction [%] | Deadtime [days] (% of 10 yrs) | 90% CL $0\nu\beta\beta$ Sensitivity [$10^{28}$ y] | Discovery Potential, 3σ [$10^{28}$ y] |
|---|---|---|---|---|---|
| Enhanced | ***SNOLAB*** | ***1.1%*** | ***1.6 (0.04%)*** | ***1.38*** | ***0.77*** |
| | LNGS | 45% | 148 (4%) | 0.84 | 0.45 |
| Aggressive | SNOLAB | 0.7% | 1.9 (0.05%) | 1.39 | 0.80 |
| | LNGS | 28% | 178 (5%) | 0.99 | 0.53 |
| Hardware Modification | SNOLAB | - | - | - | - |
| | LNGS | 7.8% | 15 (0.4%) | 1.24 | 0.68 |

**HIGH LEVEL ASSUMPTIONS**

- **Enhanced** – Neutron capture tag eff = 80% (nominal γ threshold)
- **Aggressive** – Neutron capture tag eff = 93% (lower γ threshold) details of dead-time reduction algorithm to be finalized
- **Hardware Modification** - Add neutron capture dopant to HFE volume

# The international nEXO collaboration

nEXO


Canadian contingent within nEXO

- 14 PIs members of nEXO
- ~45 undergraduate and graduate students and postdocs
- Canadian groups constitute ~25% of the collaboration, contribute to 5 subsystems, and lead 2 subsystems.
- Significant engineering and project management support from SNOLAB

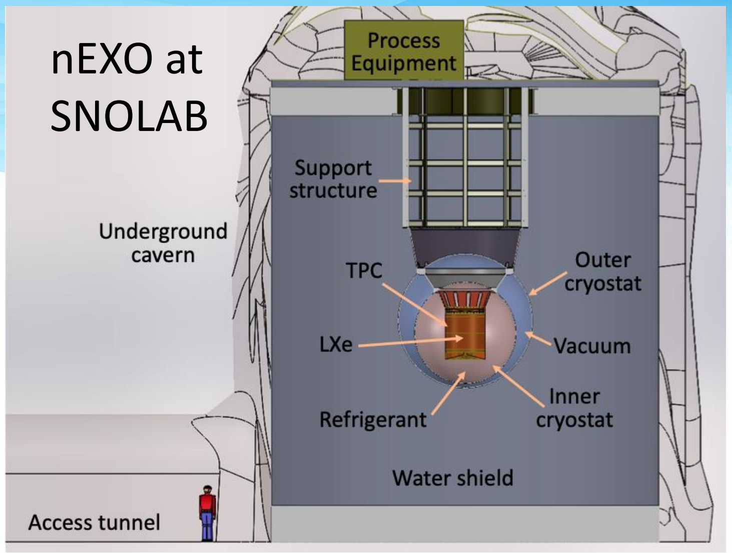
List of collaborators available at https://nexo.llnl.gov/

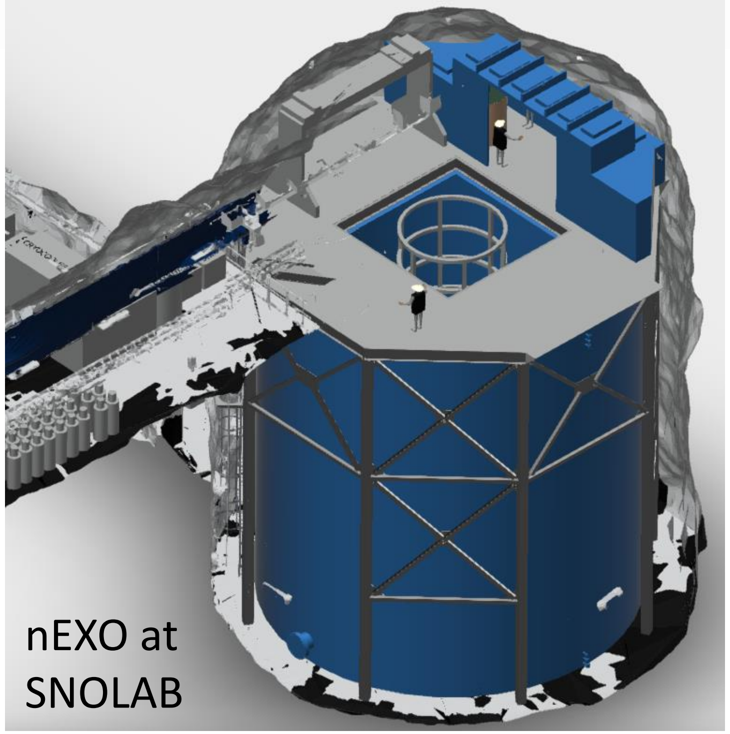
**~200 scientists, 34 institutions in 9 countries on 4 continents**


nEXO
Collaboration Meeting December 2022
We are looking forward to welcome the collaboration in Montreal for the summer 2023 collaboration meeting!

# Summary

- **nEXO is a discovery focussed 0νββ experiment.**
- nEXO's multi parameter signal extraction enables a "background-free" 0νββ search that is particularly robust against unknown backgrounds.
- nEXO is being designed to reach a sensitivity beyond ~$10^{28}$ years and will probe the entire inverted ordering parameter space.
- **SNOLAB is the location preferred by nEXO.**
- **nEXO design at SNOLAB Cryopit is well advanced.**
- We hope to engage with international funding agencies to refine our funding strategy.



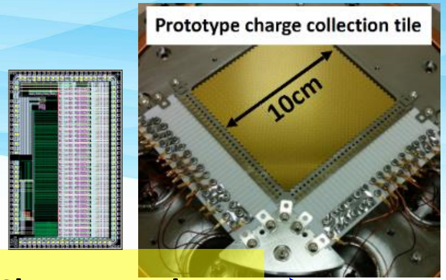
# IHEP Beijing Status and Interests

Yifang Wang

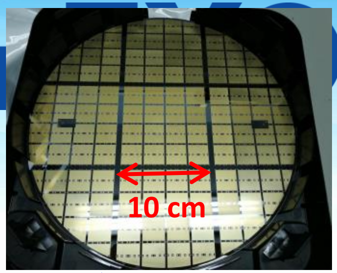
- Management Roles in EXO-200/nEXO
  - **Physics coordinator: Liangjian Wen (2015-2016), Gaosong Li (2017-2022)**
  - **1.04.02 L3** (Photon Detector - photon detector specification) : **Guofu Cao**
  - **1.03.04 L3** (TPC - Charge Detection & Anode) : **Liangjian Wen**
- Major activities in nEXO R&D：

**Planned Hardware contribution from IHEP, not including manpower & overhead**

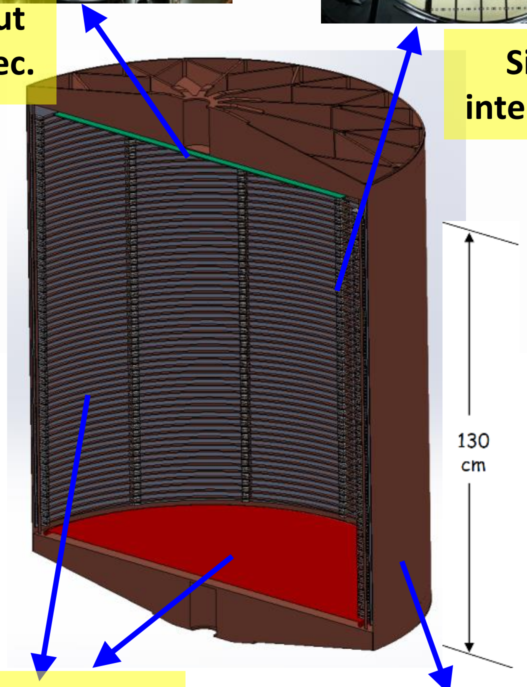
| L2 systems | WBS tasks | M&S Budget |
|---|---|---|
| TPC System | **Anode charge tiles (full size ~1.3 m$^2$)** | \$ 2.5 M |
| Photon Detector | **Si-interposer (full size ~ 5 m$^2$)** for SiPM readout | \$ 3.5 M |
| | **($Al+MgF_2$) coating** on cathode & shaping rings to reflect VUV photons | \$ 1 M |
| Electronics (charge readout) | **Analog multiplexing ASIC (cold) + under-water FADC electronics based on JUNO experience** | \$ 1 M |
| Radioactivity Control | Radio-assay via **ICP-MS** at IHEP | \$ 0.3 M |
| Veto system | **~500 water-proof 8-in. PMTs** (R5912) and readout electronics from Daya Bay | (in-kind, ~ \$ 1 M equivalent) |



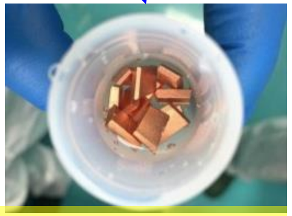

Charge readout tiles & ASIC elec.




SiPM interposer




($Al + MgF_2$) plating



Radioassay by ICP-MS

- **Pursue a domestic solution for Xe-136 enrichment (up to about ~ 1 ton $^{enr}Xe$)**

# IHEP Beijing Status and Interests

- We have been a main player of EXO-200 and will continue with nEXO, motivated by physics.
- We worked a lot on nEXO R&D and will contribute to electronics, detector, physics, etc.
- We have been working with the industry to explore the possibility to provide 1t enriched Xe. Technologically it is feasible but initial investment for equipment has not yet been started, due to uncertainties of nEXO (slow progress in DOE did not help in China).
- We plan to start exploring the funding possibilities for Xe enrichment and related equipment investment.