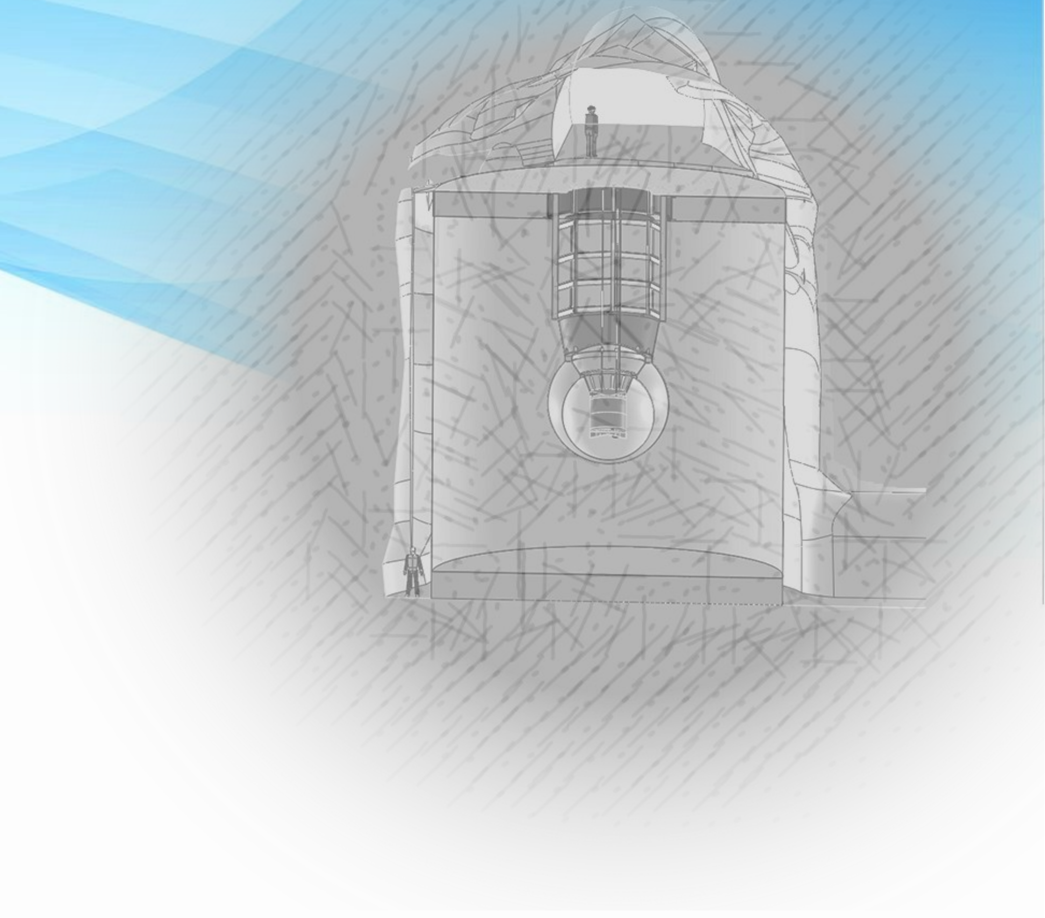
nEXO Technical Update



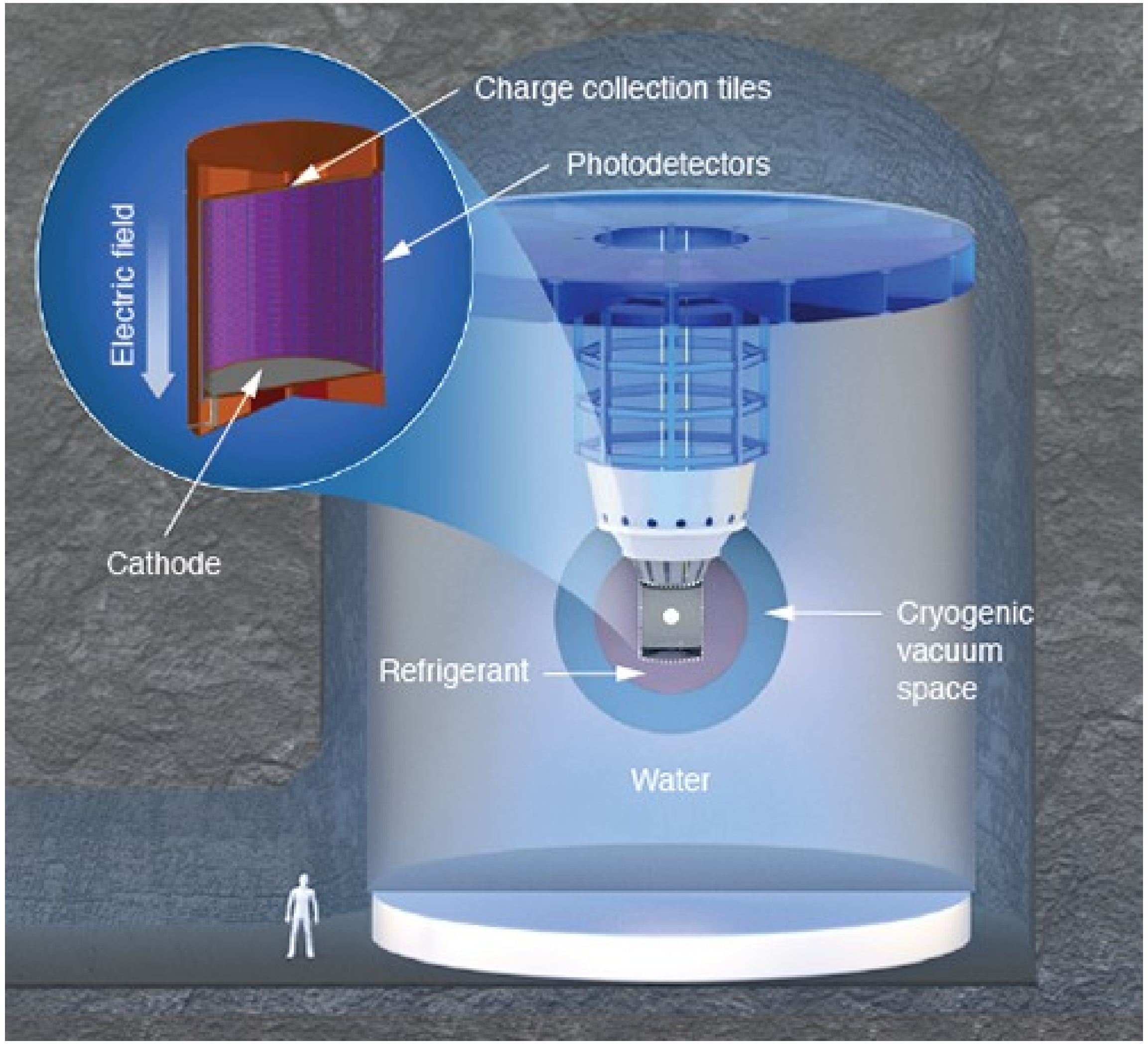
Mike Heffner – nEXO Project Director

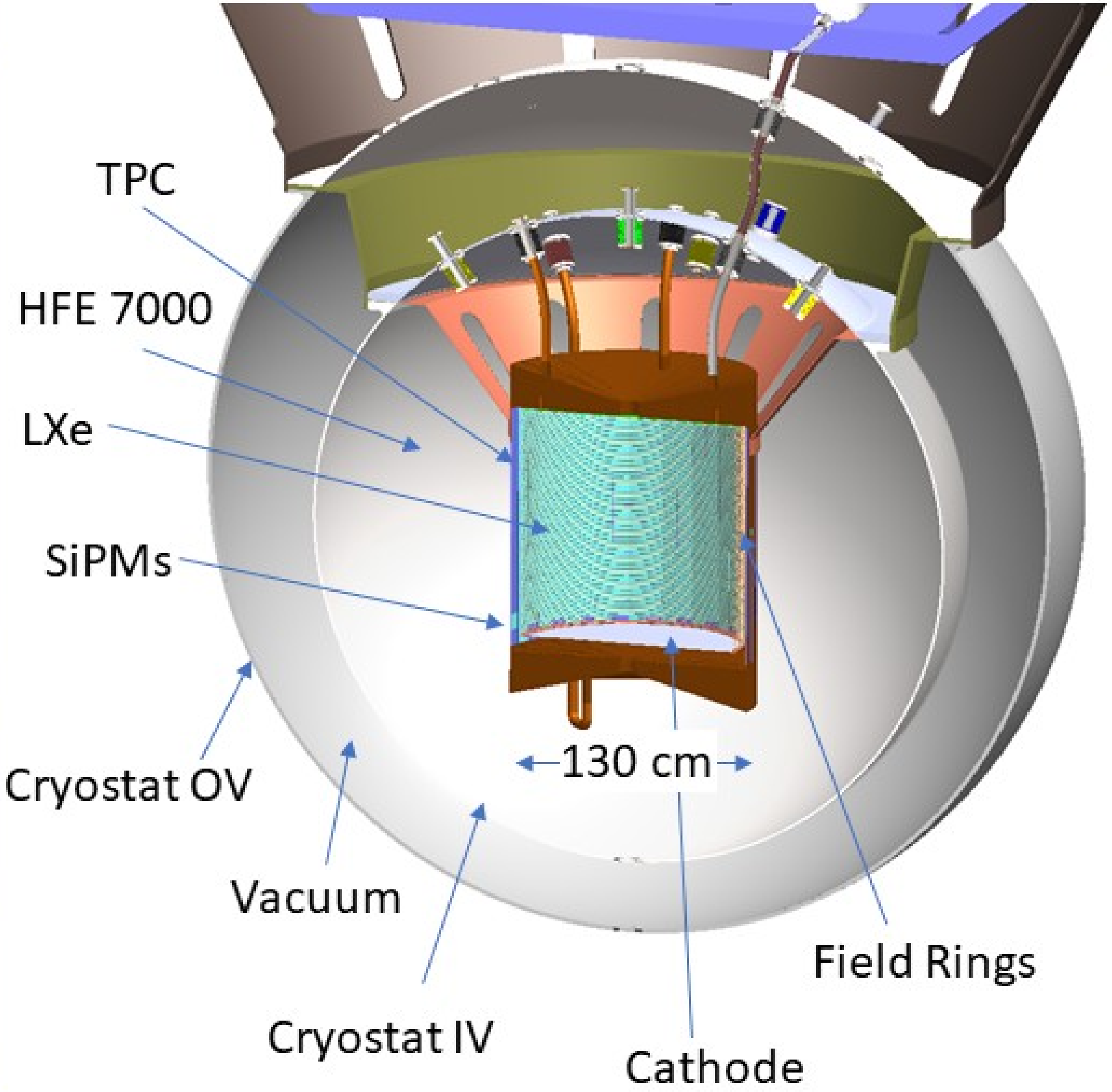
Nuclear and Particle Physics Deputy Group Leader

Lawrence Livermore National Laboratory

16th November 2021

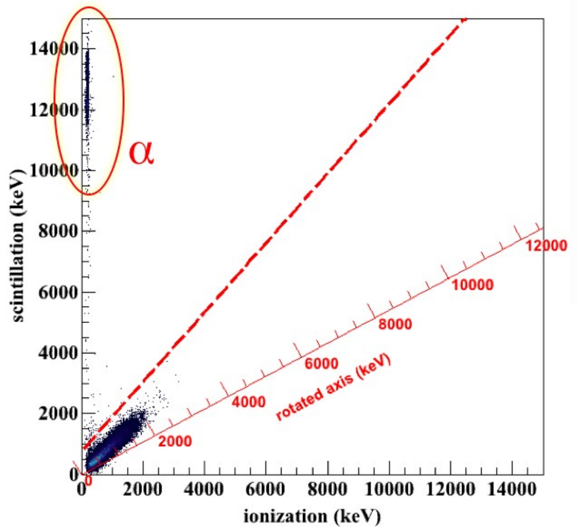
nEXO is a Liquid Xenon TPC with Shielding



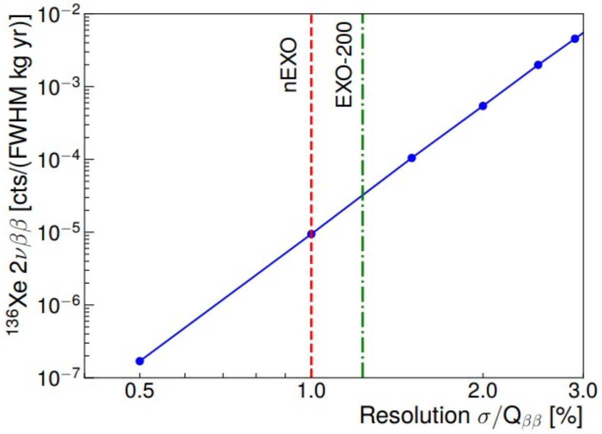


The nEXO TPC Measures Scintillation and a "3D Image" of the Ionization.

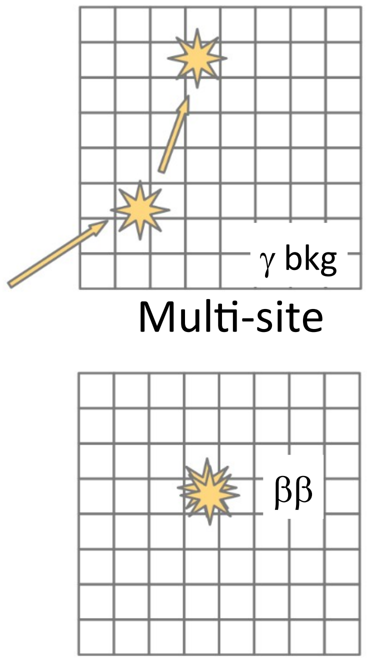
Particle Identification



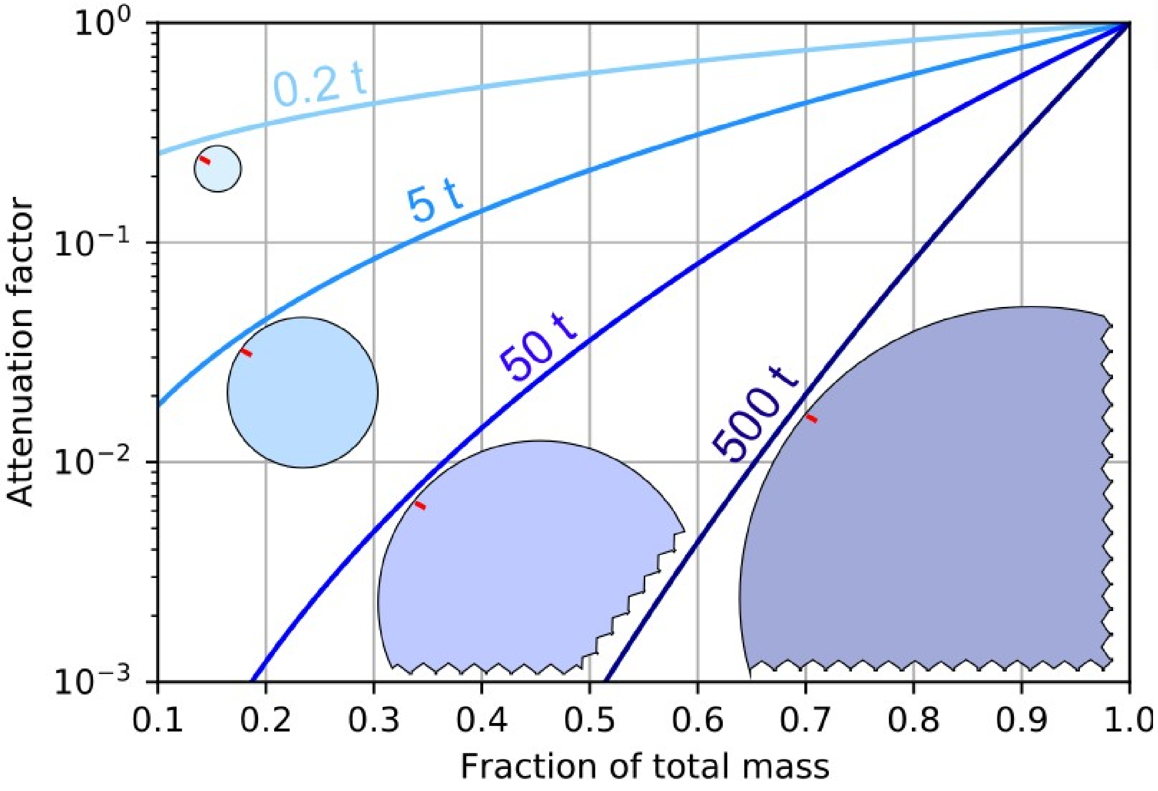
Sufficient Energy Res.



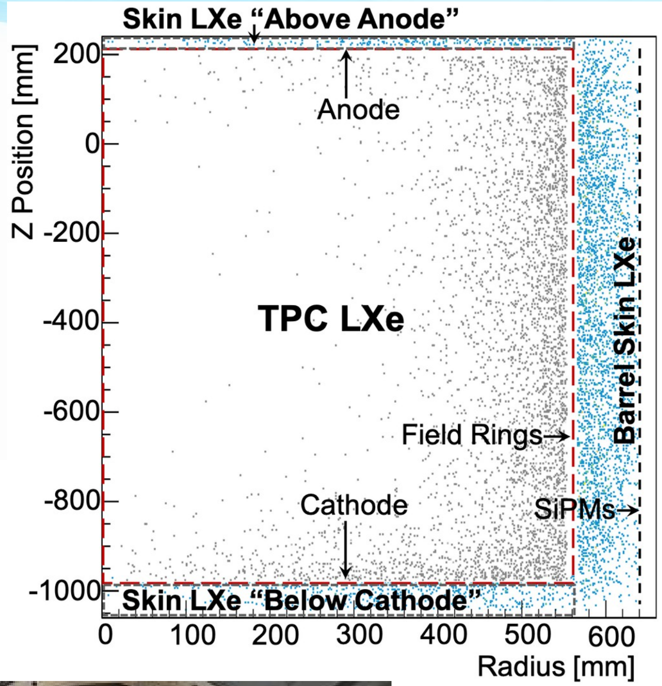
Topology



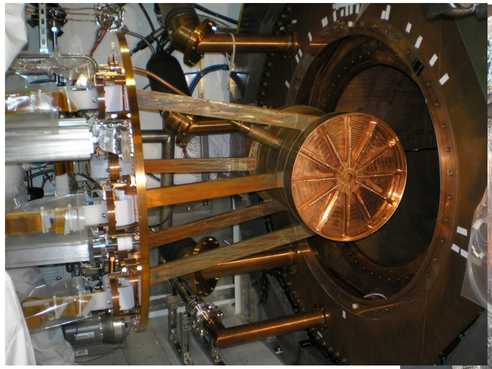
Favorable background scaling with mass (with no improvement in specific radioactivity of construction materials)

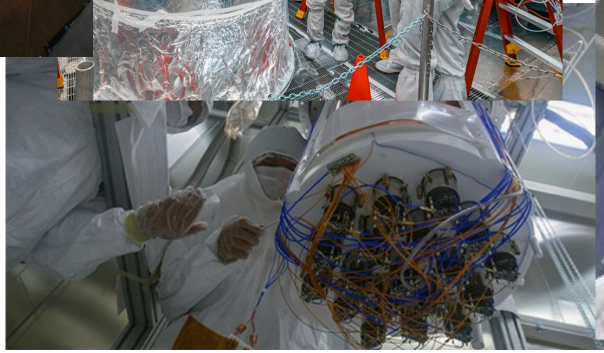


A few Advantages of a Xe136 TPC



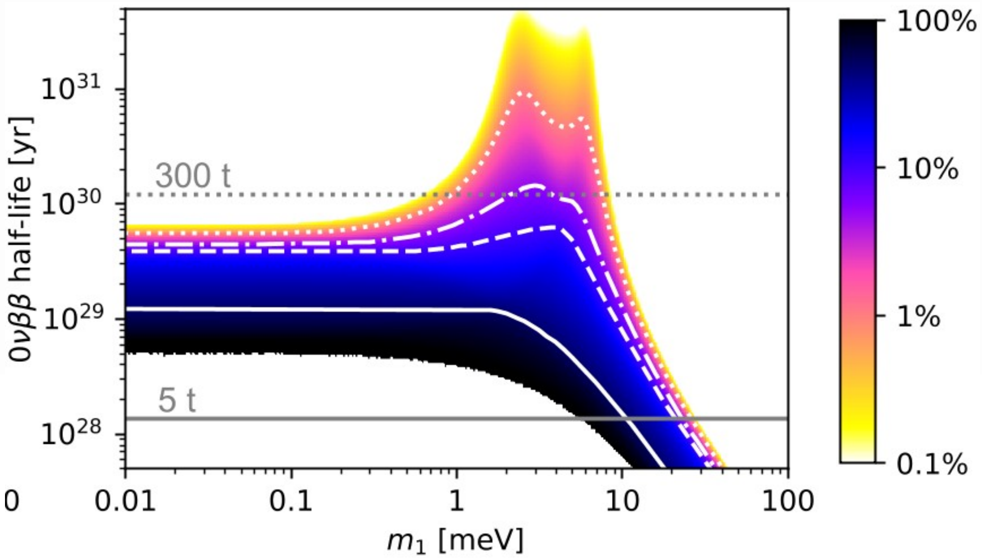
- Favorable Background Scaling with Mass
  - Signal and Background spatial distributions are different
  - Much larger detectors are possible
- ^{136}Xe can be swapped out for depleted or natural
  - A null experiment will conclusively verify a discovery
- Large Underground Noble Liquid TPCs are becoming routine
  - EXO-200
  - LUX
  - LZ
  - Xenon1T
  - DUNE (Ar)
  - Darkside (Ar)

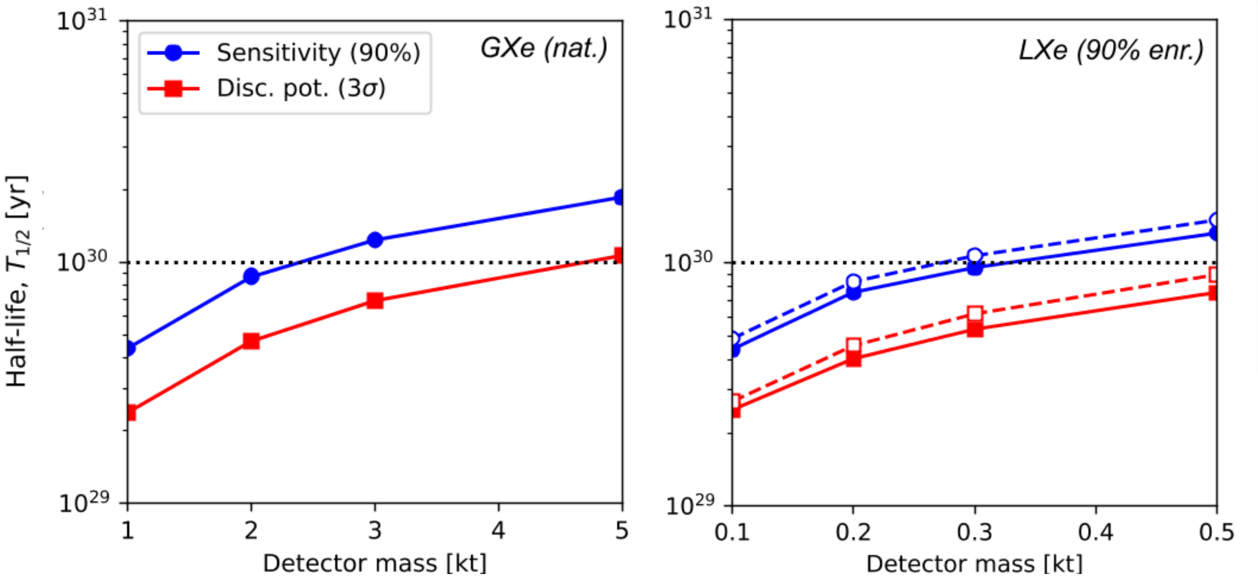


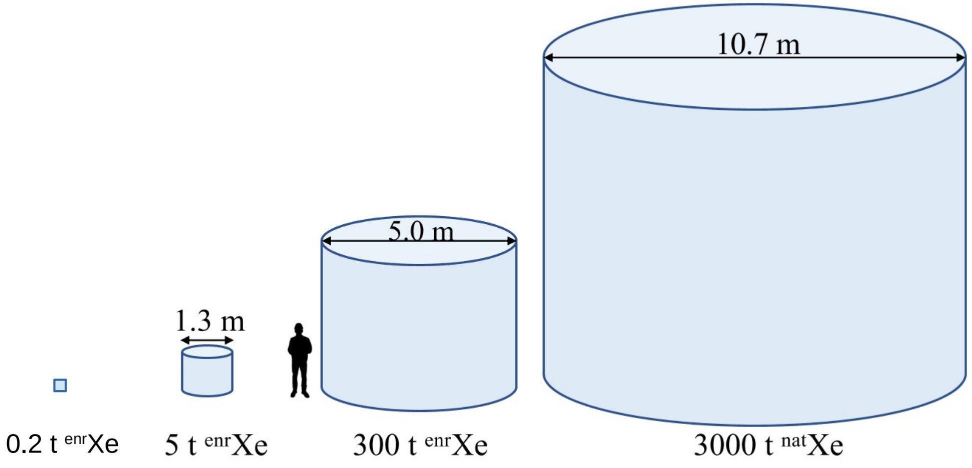


kTonne 0νββ detector? Yes, it is possible with xenon.

nEXO is an important step towards a ktonne detector







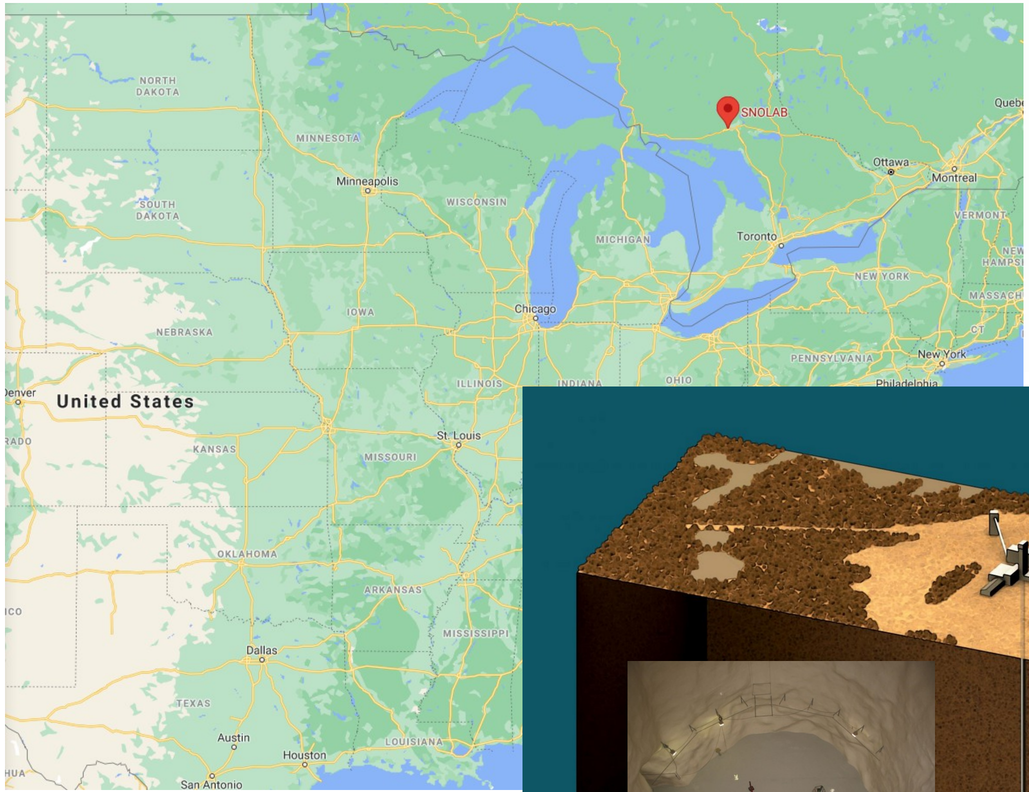
Plausible R&D path exists to obtain kTonns of xenon

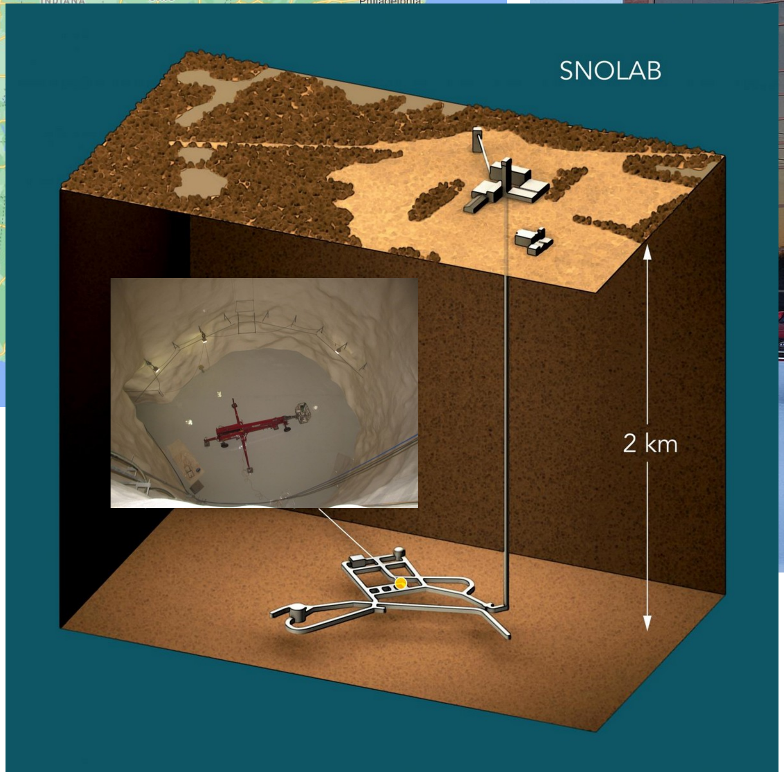
Kilotonne-scale xenon detectors for neutrinoless double beta decay and other new physics searches

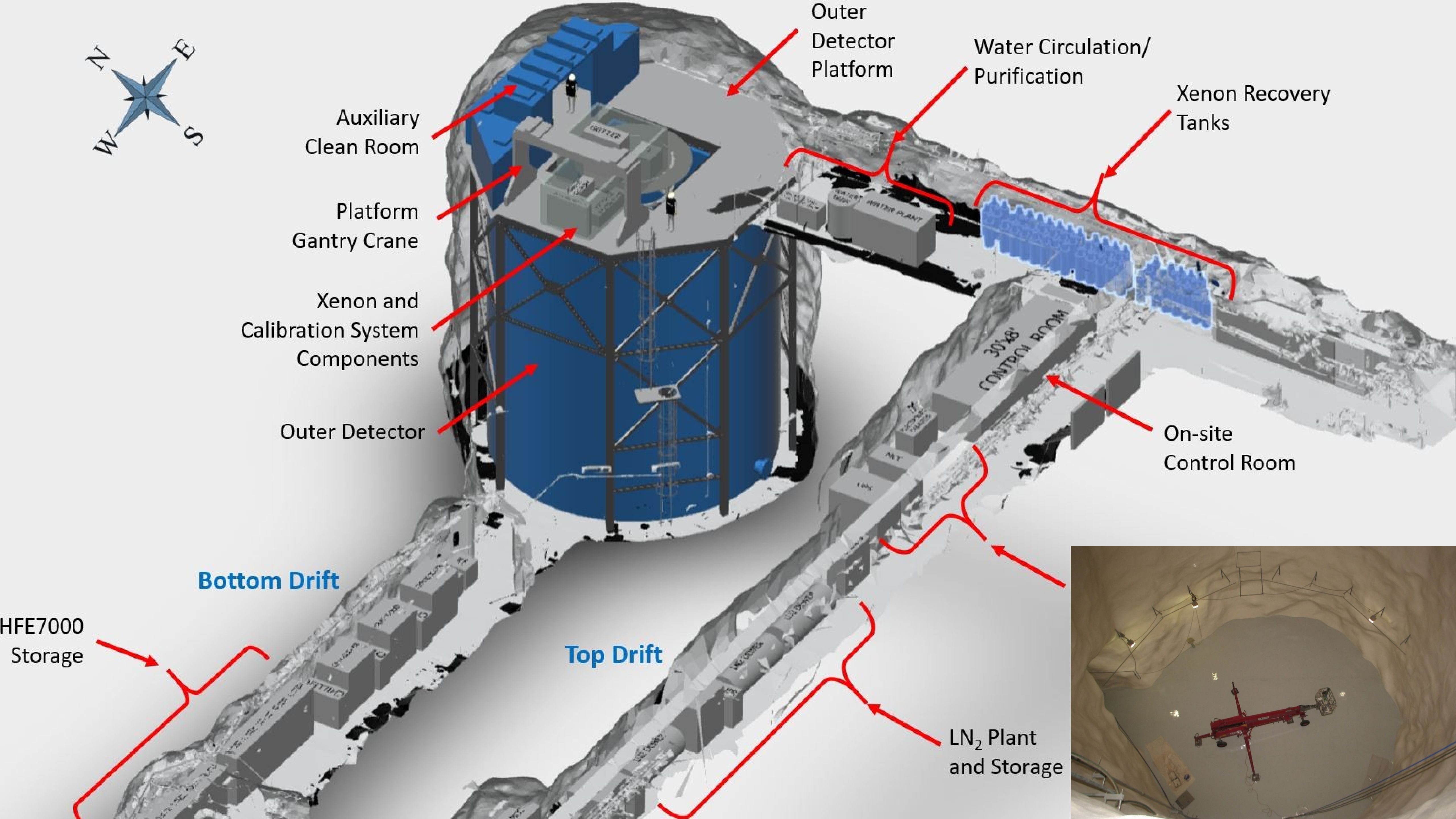
A. Avasthi,[1] T.W. Bowyer,[2] C. Bray,[3] T. Brunner,[4,5] N. Catarineu,[6] E. Church,[2] R. Guenette,[7] S.J. Haselschwardt,[8] J.C. Hayes,[2] M. Heffner,[6,*] S.A. Hertel,[9] P.H. Humble,[2] A. Jamil,[10] S. Kim,[6] R.F. Lang,[11] K.G. Leach,[3] B.G. Lenardo,[12] W.H. Lippincott,[13] A. Marino,[3] D.N. McKinsey,[14,8] E.H. Miller,[15,16] D.C. Moore,[10,†] B. Mong,[15] B. Monreal,[1] M.E. Monzani,[15,16] I. Olcina,[8,14] J.L. Orrell,[2] S. Pang,[6] A. Pocar,[17] P.C. Rowson,[15] R. Saldanha,[2] S. Sangiorgio,[6] C. Stanford,[7] and A. Visser[6]

Avasthi et al., arXiv: 2110.01537 (2021)

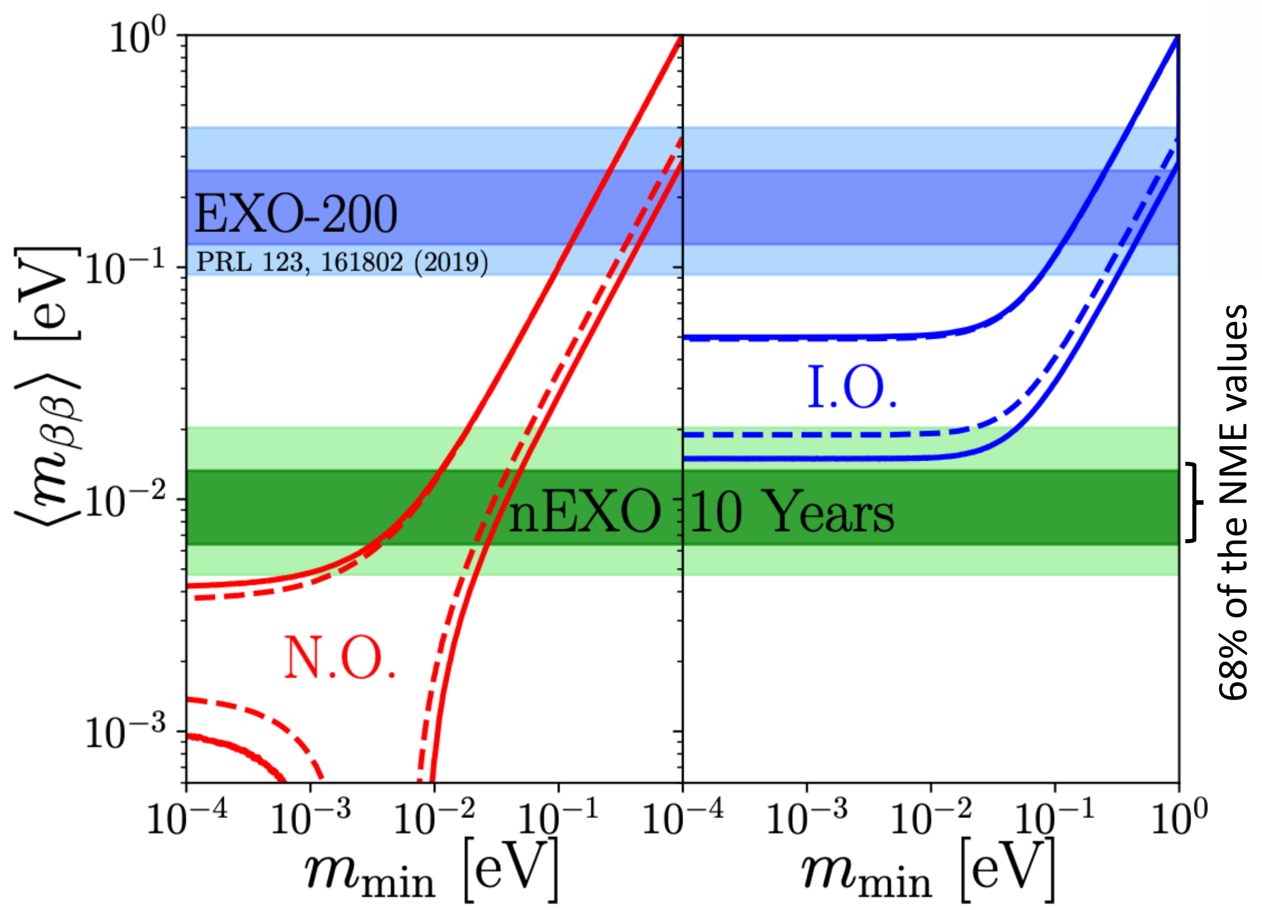
SNOLAB is the best location for nEXO

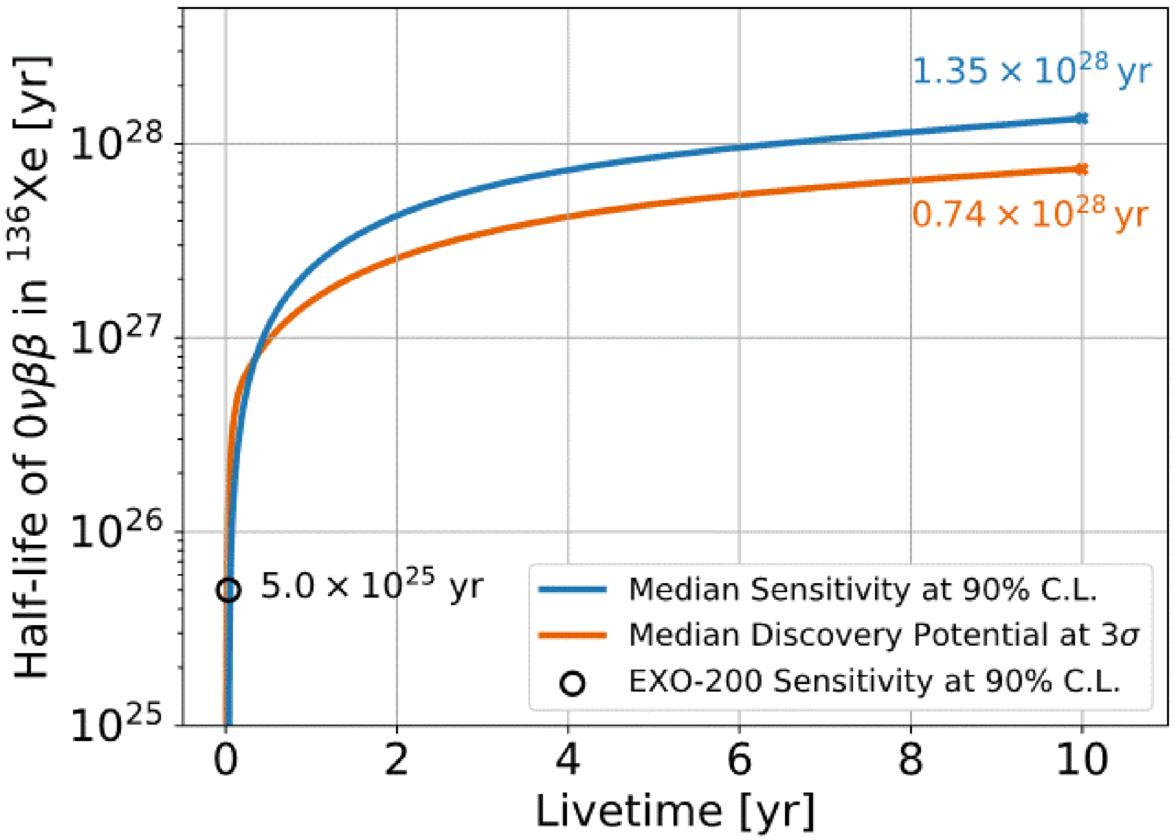




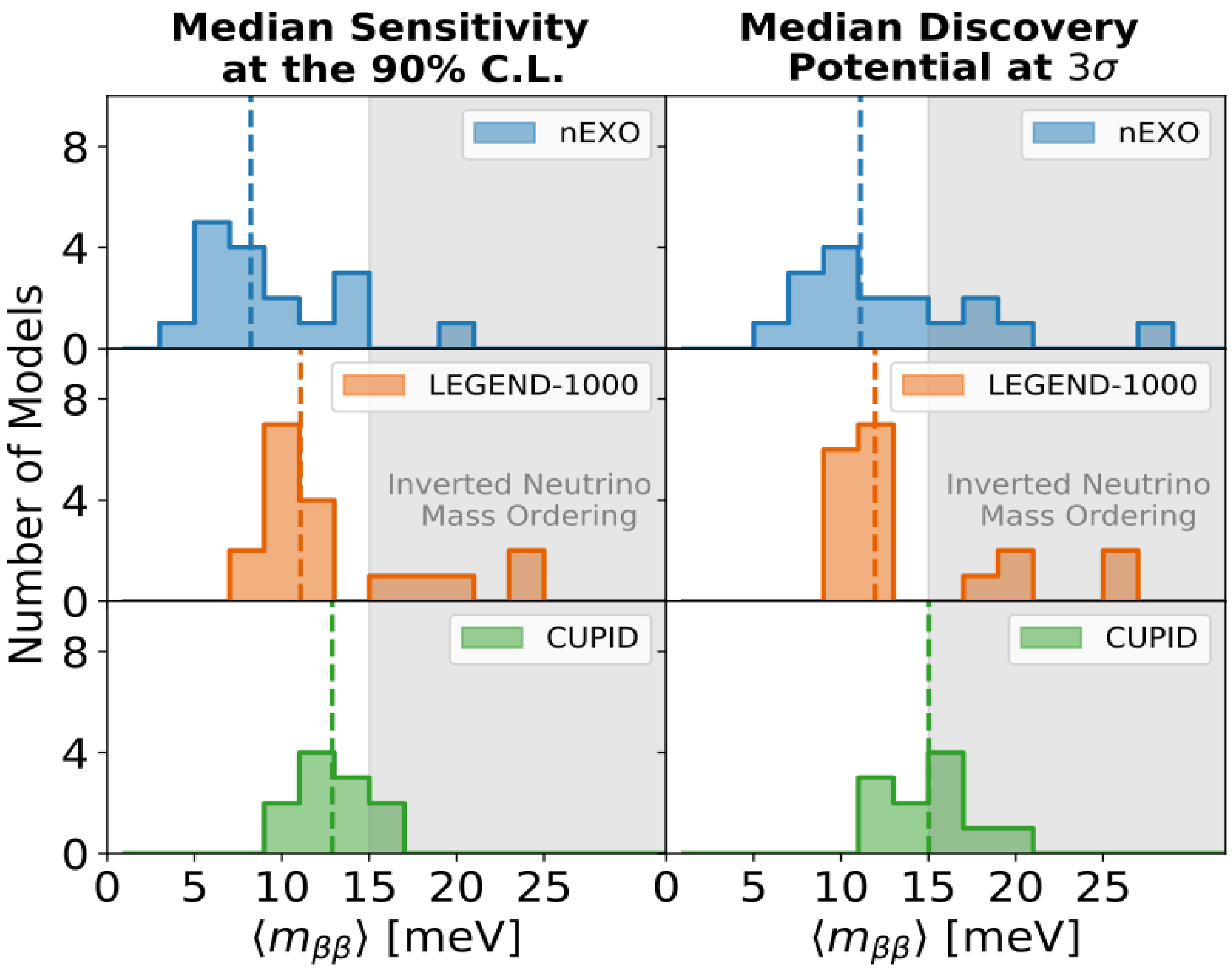

N
E
S
W
Outer Detector Platform
Water Circulation/ Purification
Xenon Recovery Tanks
Auxiliary Clean Room
Platform Gantry Crane
Xenon and Calibration System Components
Outer Detector
On-site Control Room
Bottom Drift
HFE7000 Storage
Top Drift
LN$_2$ Plant and Storage
30'x8' CONTROL ROOM
WATER PLANT

nEXO Sensitivity. https://arxiv.org/abs/2106.16243 (Jun2021)



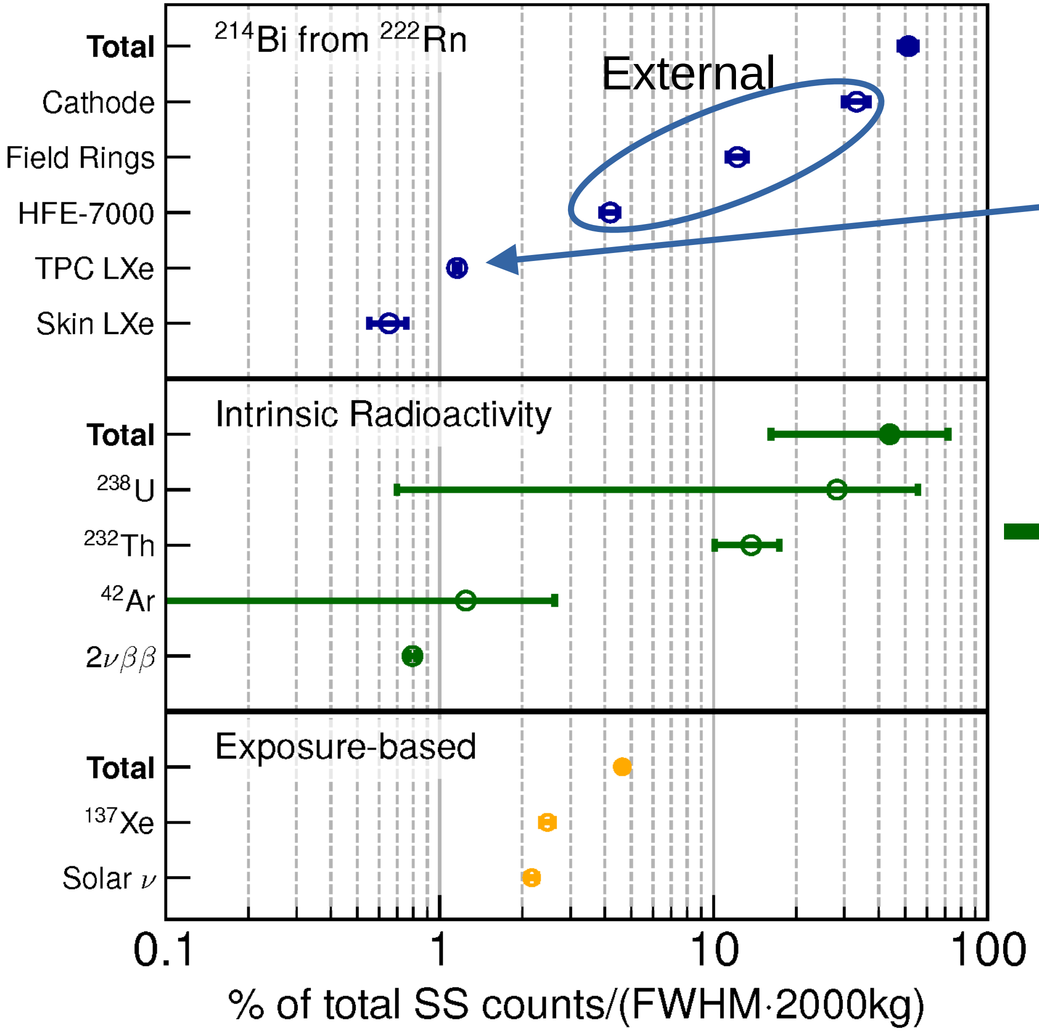


Experiment Comparison

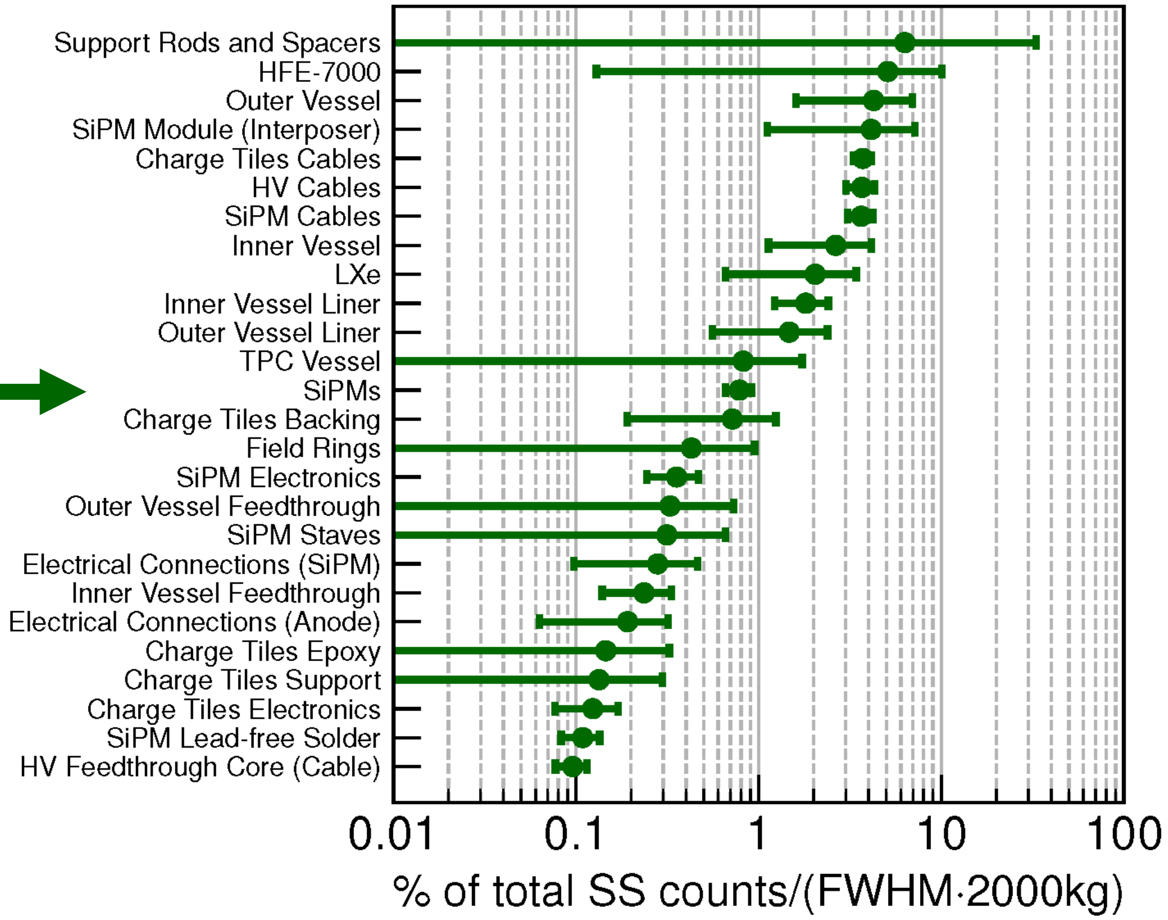


Deeper Physics Reach

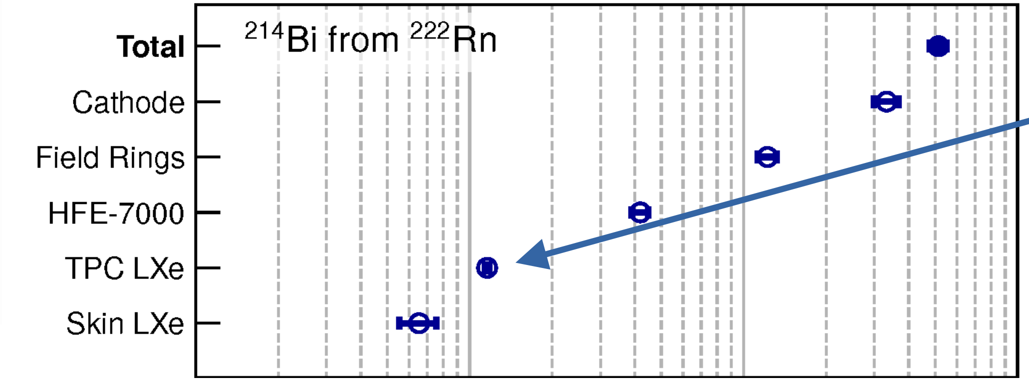
nEXO Backgrounds are Well Understood



^{222}Rn/^{214}Bi homogeneously distributed in xenon



Radon daughter of interest (^{214}Bi) mostly ends up on cathode. In xenon ^{214}Bi decay is highly suppressed.

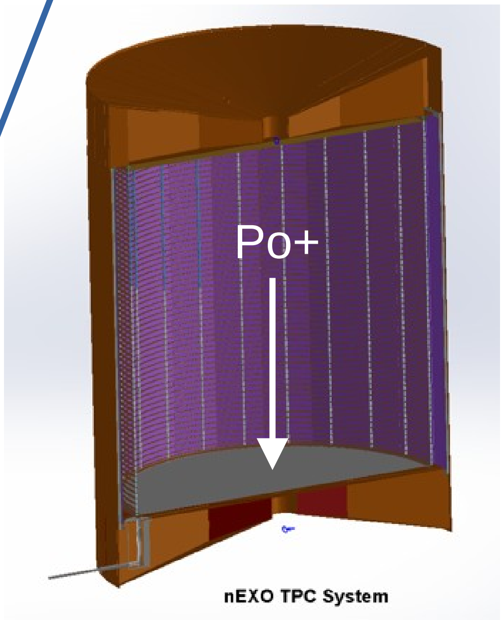


^{222}Rn/^{214}Bi homogeneously distributed in xenon

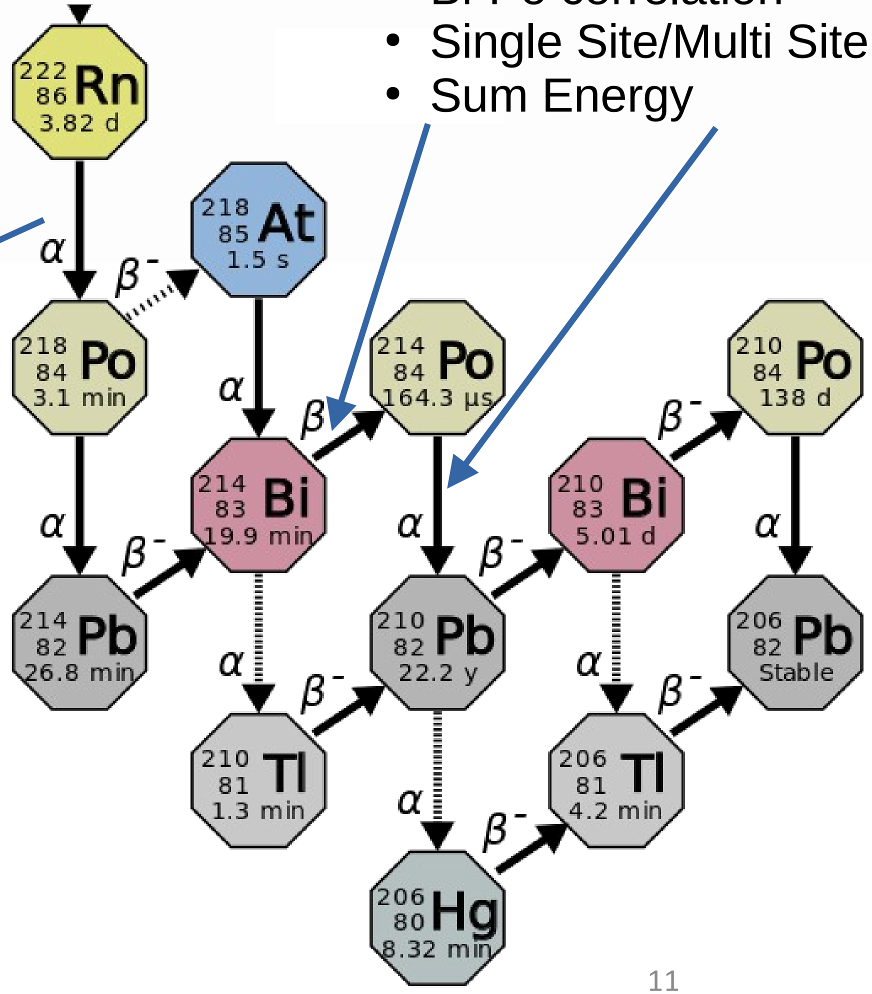
Decay Location ℓ	f_ℓ	$\varepsilon_{\alpha,\ell}$	$N_{\mathrm{Rn},\ell}$
Cathode top surface	0.617	0.5	185.41
Field rings surfaces	0.184	0.49	56.32
Cathode bottom surface	0.044	0.01	26.37
Skin LXe above anode	0.012	0.01	7.04
Skin LXe under cathode	0.003	0.01	1.65
TPC LXe bulk	0.128	0.999	0.21
Skin LXe barrel	0.012	0.98	0.16

Table 6. List of ^{214}Bi decay locations ℓ with the corresponding decay fractions f_ℓ, α tagging efficiency $\varepsilon_{\alpha,\ell}$, and number of background-contributing atoms $N_{\mathrm{Rn},\ell}$ present in steady-state in the LXe.

Nuclear decay cause atomic ionization



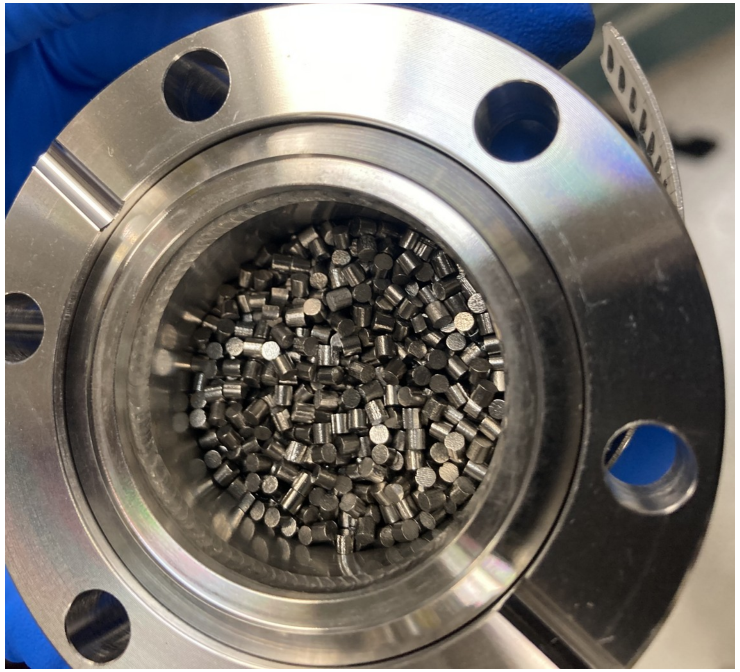
- Bi-Po correlation
- Single Site/Multi Site
- Sum Energy



R&D to Further Reduce Radon Background Component

Emanation testing of
EXO-200 gas system

Improved Getter

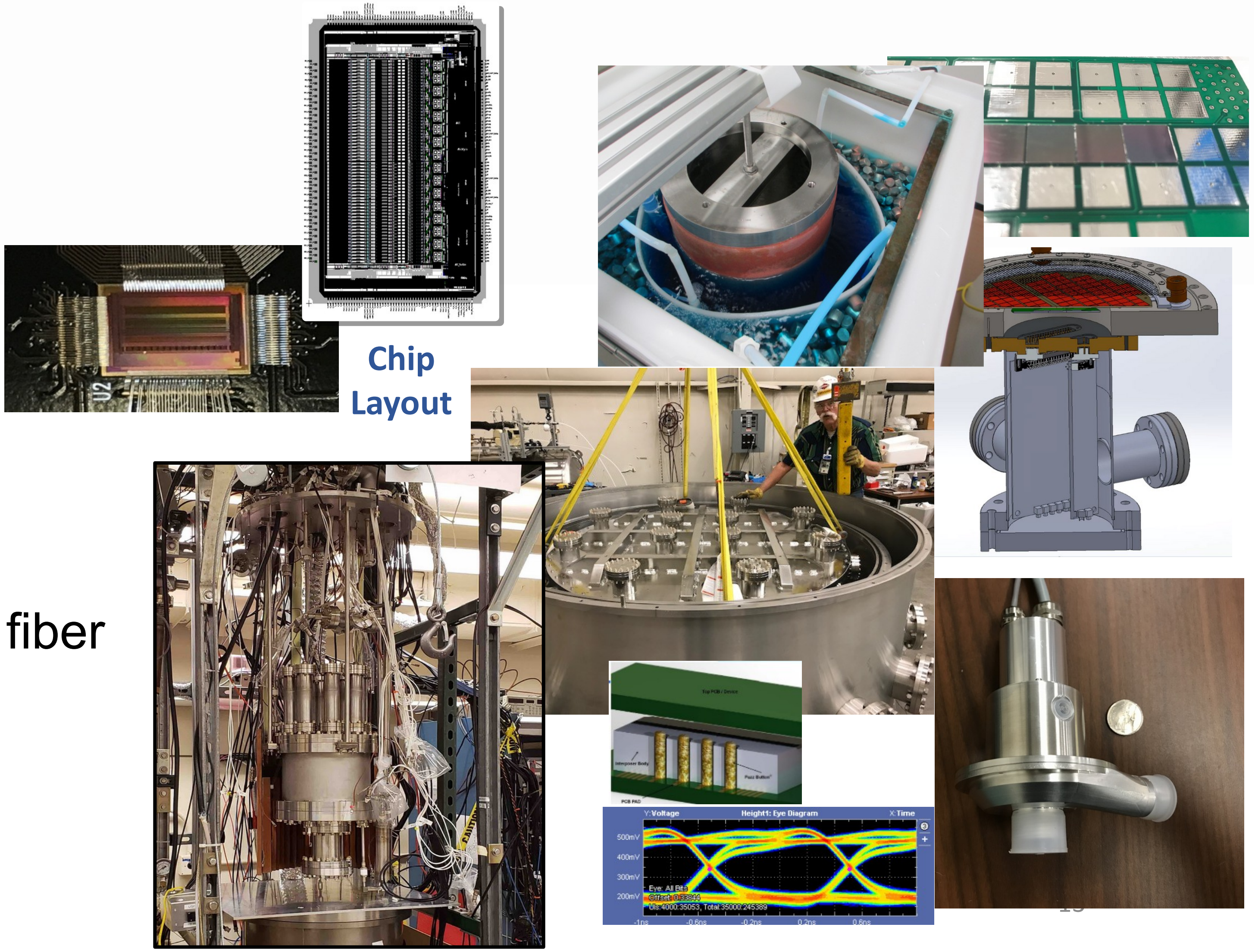


Distillation removal
LDRD

R&D Continues to Refine the nEXO Concept

Some areas of R&D include:

- Readout electronics
- SiPM development
- Radioassy
- TPC prototyping
- High Voltage
- Materials EF copper, nickel, carbon fiber
- Radon mitigation and daughter attachment



Chip Layout

nEXO

Laurentian University / Université Laurentienne
Carleton University
McGill
Université de Sherbrooke
UMass Amherst
Yale University
Brookhaven National Laboratory
WWU Münster
Rensselaer
The University of British Columbia
TRIUMF
Pacific Northwest National Laboratory
Skyline College
Lawrence Livermore National Laboratory
SLAC National Accelerator Laboratory
Stanford University
Caltech
UC San Diego
Colorado School of Mines
Colorado State University
The University of Alabama 1831
Oak Ridge National Laboratory
University of Kentucky
University of the Western Cape
University of North Carolina Wilmington
Drexel University
FAU Friedrich-Alexander Universität Erlangen-Nürnberg
ИТЭФ
Technical University of Munich TUM
ibs Institute for Basic Science
IHEP
IMECAS
u^b Universität Bern
Subatech

9 Countries, 33 institutions, ~200 collaborators

Project Management Roles are Well Defined

nEXO

Office of Nuclear Physics
Federal Program Manager:
Ivan Graff

LLNL Field Office
Manager: Peter Rodrik
Federal Project Director: TBD

Laboratory Management
LLNL Laboratory Director:
K. Budil
Deputy Director, Science and Technology:
P. Falcone
Associate Director, Physical and Life Science:
G. Fox
Deputy Associate Director for S&T, PLS:
S. Letant

DOE Partner Laboratory Council

nEXO Management Advisory Committee

PLI PROJECT LEADERSHIP INSTITUTE

Experienced Leaders
In DOE O413.3B Projects

nEXO Project Office
Project Director: M. Heffner (LLNL)
Project Manager: V. Riot (LLNL)
Deputy Project Manager: L. Thompson (LLNL)
Deputy Project Manager: B. Wahl (BNL)

nEXO Executive Council

Spokesperson
G. Gratta (Stanford)

nEXO Scientific Collaboration

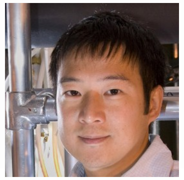
Project Functional Support
Risk Manager: TBD
Safety Coordinator: C. Hint (LLNL) - Acting
QA Manager: TBD
PMCS Lead: P. D'Ambrogi (LLNL)
Finance Lead: TBD
Procurement Support lead: Yvonne Garcia (LLNL)
Configuration Management Lead: TBD

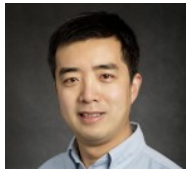
System Integration and Commissioning
System Engineer: W. Hunt (LLNL)
Chief Mech. Engineer: A. House (LLNL) - Acting
Chief Electrical Engineer: L. Fabris (ORNL)
Radioactivity Manager: TBD
Commissioning Manager: M. Nordby (SLAC)
Commissioning Scientist: TBD

Charge Readout | Photon Readout | TPC | Photon Detector

BROOKHAVEN NATIONAL LABORATORY
Lawrence Livermore National Laboratory
OAK RIDGE National Laboratory
Pacific Northwest NATIONAL LABORATORY
SLAC NATIONAL ACCELERATOR LABORATORY

Project Management Roles Well Staffed


Configuration Management Lead: TBD

Commissioning Scientist: TBD

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: TBD	**Radioactive Background Control (SLAC)** Subsystem Scientist: A. Piepke (UA) Subsystem Manager: TBD	**TPC Support Systems (LLNL)** Subsystem Scientist: A. Pocar (Umass) Subsystem Manager: A. House (LLNL)	**Xenon (LLNL)** Subsystem Scientist: G. Gratta (Stanford) Subsystem Manager: TBD
	Facility (SNOLAB) Subsystem Scientist: E. Caden Subsystem Manager: D. Hawkins	**Outer Detector (SNOLAB)** Subsystem Scientist: T. Brunner Subsystem Manager: D. Hawkins	

- Laboratory Leadershi
- Advisory Committees
- Engineering Leadersh
- Project Leadership
- WBS Tasks
- WBS Tasks—Canada
- DOE







Summary

Long Range Plan for Nuclear Physics

RECOMMENDATION II:
We recommend the timely development and deployment of a **U.S.-led ton-scale** neutrinoless double beta decay experiment

- Ton-scale ☑
- U.S. Led ☑

Page 67 (LRP):

- $m_{\beta\beta} < 15$meV ☑
- $T_{1/2} > 10^{27}$-10^{28} yr ☑

- Project has key staff in place and ready to go
- Established technology used many times underground
  - The "prototype" was completed >7 years ago
- Scaling is favorable for background reduction
  - Background distribution is different than signal
  - Much larger detectors are possible
- Radon mitigation is understood and the relevant radon background components **do not** have a signal like spatial distribution.
- Swapping xenon provides a robust discovery verification