nEXO Technical Update

Mike Heffner – nEXO Project Director
Nuclear and Particle Physics Deputy Group Leader
Lawrence Livermore National Laboratory
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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 $0\nu\beta\beta$ 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

Avasthi et al., arXiv: 2110.01537 (2021)
SNOLAB is the best location for nEXO
Experiment Comparison

Median Sensitivity at the 90% C.L.

- nEXO
- LEGEND-1000
- CUPID

Median Discovery Potential at 3σ

- nEXO
- LEGEND-1000
- CUPID

Deeper Physics Reach
nEXO Backgrounds are Well Understood

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

- External
- Intrinsic Radioactivity
- Exposure-based

- Total
- $^{214}\text{Bi}$ from $^{222}\text{Rn}$
- $^{222}\text{Rn}$
- $^{238}\text{U}$
- $^{232}\text{Th}$
- $^{40}\text{Ar}$
- $2\nu\beta\beta$
- $^{137}\text{Xe}$
- Solar $\nu$

% of total SS counts/(FWHM-2000$\text{kg}$)

- Support Rods and Spacers
- HFE-7000
- Outer Vessel
- SiPM Module (Interposer)
- Charge Tiles Cables
- HV Cables
- SiPM Cables
- Inner Vessel
- LXe
- Inner Vessel Liner
- Outer Vessel Liner
- TPC Vessel
- SiPMs
- Charge Tiles Backing
- Field Rings
- SiPM Electronics
- Outer Vessel Feedthrough
- SiPM Staves
- Electrical Connections (SiPM)
- Inner Vessel Feedthrough
- Electrical Connections (Anode)
- Charge Tiles Epoxy
- Charge Tiles Support
- Charge Tiles Electronics
- SiPM Lead-free Solder
- HV Feedthrough Core (Cable)

% of total SS counts/(FWHM-2000$\text{kg}$)
Radon daughter of interest (\(^{214}\text{Bi}\)) mostly ends up on cathode. In xenon \(^{214}\text{Bi}\) decay is highly suppressed.

**Table 6.** List of \(^{214}\text{Bi}\) decay locations \(\ell\) with the corresponding decay fractions \(f_\ell\), \(\alpha\) tagging efficiency \(\varepsilon_{\alpha,\ell}\), and number of background-contributing atoms \(N_{\text{Rn,} \ell}\) present in steady-state in the LXe.
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
9 Countries, 33 institutions, ~200 collaborators
Project Management Roles are Well Defined

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

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)

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

Experienced Leaders
In DOE O413.3B Projects
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 (Unmass)
- 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
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):
- $m_{\beta\beta} < 15\text{meV}$ ✓
- $T_{1/2} > 10^{27}-10^{28} \text{yr}$ ✓

- 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