The Next Generation Neutrinoless Double-Beta Decay Experiment nEXO

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Outline

• Motivation
• nEXO Concept Design
• The R&D Status
• Summary
Search for $0\nu\beta\beta$ decay

- Neutrinos are Majorana Particles
- Demonstration of Lepton number violation

Current half-life limit:
- $>1.9 \times 10^{25}$ yr (90% CL) EXO200
- $>1.07 \times 10^{26}$ yr (90% CL) KamLAND-Zen

Basics requirement:
Low background, Large mass,
Good energy resolution, Good background rejection
Tone scale LXe TPC

**Advantage of Xe:**
- **Easy to enrich:** can be enriched to 80% relatively easily (better than growing crystals)
- **Easy to build Tone scale detector:**
  - Liquid, high density 3g/cm³
- **Low background ¹³⁶Xe:**
  - Can be purified continuously, no long-life radioactive isotopes,
  - Background rejection potentially by Ba²⁺ tagging

**Advantage of TPC:**
- **3D event reconstruction:**
  - Self shielding, SS selection and MS rejection
- **Energy resolution:** using scintillation and charge anti-correlation

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**Candidate nuclei with Q>2 MeV**

<table>
<thead>
<tr>
<th>Candidate</th>
<th>Q (MeV)</th>
<th>Abund. (%)</th>
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</thead>
<tbody>
<tr>
<td>⁴⁰Ca→⁴⁰Ti</td>
<td>4.271</td>
<td>0.187</td>
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<tr>
<td>⁷⁶Ge→⁷⁶Se</td>
<td>2.040</td>
<td>7.8</td>
</tr>
<tr>
<td>⁸²Se→⁸²Kr</td>
<td>2.995</td>
<td>9.2</td>
</tr>
<tr>
<td>⁹⁶Zr→⁹⁶Mo</td>
<td>3.350</td>
<td>2.8</td>
</tr>
<tr>
<td>¹⁰⁰Mo→¹⁰⁰Ru</td>
<td>3.034</td>
<td>9.6</td>
</tr>
<tr>
<td>¹¹⁰Pd→¹¹⁰Cd</td>
<td>2.013</td>
<td>11.8</td>
</tr>
<tr>
<td>¹¹⁶Cd→¹¹⁶Sn</td>
<td>2.802</td>
<td>7.5</td>
</tr>
<tr>
<td>¹²⁴Sn→¹²⁴Te</td>
<td>2.228</td>
<td>5.64</td>
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<tr>
<td>¹³⁰Te→¹³⁰Xe</td>
<td>2.533</td>
<td>34.5</td>
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<tr>
<td>¹³⁶Xe→¹³⁶Ba</td>
<td>2.479</td>
<td>8.9</td>
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<tr>
<td>¹⁵⁰Nd→¹⁵⁰Sm</td>
<td>3.367</td>
<td>5.6</td>
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</table>

**Tone scale is Critical for background rejection**
Next Generation: nEXO

EXO-200: 200kg liquid-Xe TPC

Detector concept design:
• 5 t liquid xenon TPC
• Possible location in SNOLab CryoPit (6010 mwe)
• SiPM for light detection
• Tiles for charge read out
• 3D event reconstruction
• Expected Energy Resolution of 1% at Q-value

nEXO: 5-ton liquid Xe TPC with Ba tagging option (SNO lab cryopit)
Charge tiles

- 10 x 10 cm² Prototype Tile
- Metallized strips on fused silica substrate
- 60 orthogonal channels (30 x 30)
- 3 mm strip pitch
- Strip intersections isolated with SiO₂ layer
- Currently testing in LXe with a $^{207}$Bi source

energy spectrum from an internal $^{207}$Bi source ionization only
Charge readout

Series readout Low number of connections

LAr read out for nEXO
SiPM

- Large area, order of 4 m²
- 24 ladder staves
- 30 tiles per stave, 84 mm x 84 mm tiles

VUV sensitive SiPMs
- Hamamatsu produces devices with QE = ~12% @ 175nm
- FBK “RGB” devices reach 15% QE with 7.7x7.7 mm².

- Analog readout of SiPMs
- 3D SiPM readout
Cooling options

Total cold heat from RT to 165K: $7.25 \times 10^9$ J
32T HFE, 5T Xenon, cryostat

• Thermosiphons with LN2 for the HFE
• Circulating cold HFE with pumps
• Thermosiphon directly on Xenon
• Hybrid solution
Background vs signal

nEXO, 5 yr data, $0\nu\beta\beta @ T_{1/2} = 6.6 \times 10^{27}$ yr, projected backgrounds from subsets of the total volume
Sensitivity

- a half life sensitivity of $> 5 \times 10^{27}$ years
- cover the inverted neutrino mass hierarchy with 5 years of data
Summary

• nEXO is the next Generation 0νββ experiment
  5 tonne enriched LXe, 3D homogenous TPC, charge and light signal channels
• nEXO will allow for the full probing of the inverted mass hierarchy
• Lots of R&D work are underway
The nEXO Collaboration

Thank you