Overview and Status of the EXO-200 experiment

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On behalf of the EXO Collaboration

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Outline

- EXO Concept
  - Double Beta Decay
  - Xenon
- EXO-200 Prototype
  - Time Projection Chamber
  - Vessel and Cryostat
  - WIPP Site
- Status
  - Time Projection Chamber
  - At WIPP
Concept: Double Beta Decay

- Occurs in $^{48}$Ca, $^{76}$Ge, $^{82}$Se, $^{130}$Te, $^{136}$Xe (theorized), ...

- Neutrinoless mode
  - Lepton number not conserved
  - $\nu = \bar{\nu}$
  - $m_\nu \neq 0$

- Rate tells majorana mass:
  
  \[
  \langle m_\nu \rangle^2 \propto \left( T_{1/2}^{0\nu \beta \beta} \right)^{-1}
  \]
  
  \[
  \langle m_\nu \rangle = \sum_{i=1}^{3} \left| U_{e,i} \right|^2 m_i \epsilon_i \quad \pm 1 \text{ if CP conserved}
  \]

  neutrino mixing matrix

Feynman diagrams

Double beta decay spectrum for 5% energy resolution

Concept: Xenon

Advantages:
- High Q (2.48 MeV)
- Easily enriched (gas centrifuge)
- Reusable
- No long-lived, cosmically activated isotopes
- Can be used as its own detector
- Tag barium daughter nucleus to minimize backgrounds
- Purify in situ

Disadvantages:
- Comparatively poor energy resolution (~1%) vs. solid state (~0.1%)
EXO-200: Sketch

- Prototype using 200 kg of xenon enriched in isotope 136
- Time projection chamber using liquid xenon
  - Detect ionization and scintillation due in order to improve energy resolution with anticorrelation
- Expected energy resolution
  \[ \sim 1.6 \% @ Q_{\beta\beta}^{1} \]
- No barium tagging

<table>
<thead>
<tr>
<th>Case</th>
<th>Mass (ton)</th>
<th>Eff. (%)</th>
<th>Run Time (yr)</th>
<th>$\sigma_{E}/E$ @ 2.5MeV (%)</th>
<th>Radioactive Background (events)</th>
<th>$T_{1/2}^{\nu}$ (yr, 90%CL)</th>
<th>Majorana mass (meV) QRPA (NSM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prototype</td>
<td>0.2</td>
<td>70</td>
<td>2</td>
<td>1.6*</td>
<td>40</td>
<td>$6.4 \times 10^{25}$</td>
<td>$133^{2} (186)^{3}$</td>
</tr>
</tbody>
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EXO-200: Time Projection Chamber

- Monolithic: liquid xenon is both detector and medium
- Wire grid gives 2D location for event
- Solid state Avalanche PhotoDiodes (APDs) detect scintillation light, allowing 3D reconstruction
- Connects to outside world through thin (~ 50 μm) flex cables
- Copper, phosphor bronze, acrylic, teflon construction
EXO-200: Vessel and Cryostat

- Cryostat and vessel constructed of ultra pure copper
- Inner cryostat filled with HFE-7000
  - Refrigerant and shielding
- Real-time control system keeps xenon pressure inside vessel within 15 torr of HFE pressure
  - Thin walls minimize radioactivity
- Long arms support vessel and connect TPC to readout electronics

View of cryostat and vessel in clean room

Extensive care to measure and minimize radioactivity for all materials used

EXO-200: WIPP

- The Waste Isolation Pilot Plant is a DoE facility located near Carlsbad, NM.
- Mission is to safely and permanently dispose of US nuclear waste.
- Salt mine.
- Also holds our experiment at the opposite end from waste.
- 2000 mwe protects from cosmic rays.

Status: TPC 1

Half chamber with field rings, cathode, teflon reflectors installed. Wire grid and APD plane (no APDs) at bottom.
Status: TPC 2

Cables being potted into their flanges. A very delicate operation.
Status: TPC 3

Inserting the APDs
Status: TPC 4

TPC wired and inserted into vessel.
Status: TPC 5

- TPC undergoing final electrical testing prior to transport to WIPP
- Probably will reach WIPP in June or July

The TPC team pose after finally getting it assembled
Status: WIPP 1

Clean rooms, gas tent, and dewar container (for HFE), viewed facing north

Clean rooms and HVAC system, viewed facing south
Status: WIPP 2

Xenon plumbing

Cryostat with temporary door
Currently tweaking systems and preparing for chamber arrival

Veto panel installation “soon”

Technical run with natural xenon in late summer or fall 2009

Begin data taking before end of 2009