The Turn-on of EXO-200

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On behalf of the EXO Collaboration

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Enriched Xenon Observatory

- EXO (Enriched Xenon Observatory) is a series of experiments to look for the neutrinoless double beta decay of xenon 136

  - Only occurs if neutrino is a Majorana particle
  - Half life goes like $\left(T_{1/2}^{0\beta\beta}\right)^{-1} \propto \left\langle m_{\nu}\right\rangle^2$ (and $\nu$ mass is small!)

  $$\left\langle m_{\nu}\right\rangle = \sum_{i=1}^{3} \left| U_{e,i} \right|^2 m_i \epsilon_i$$

  - Violates lepton number conservation

- EXO-200 is a TPC utilizing 200 kg liquid xenon installed at the WIPP site (~1600 mwe) near Carlsbad, NM
EXO-200 TPC

- Xenon serves as both source and detector
- Energy deposited in xenon creates:
  - Charge: drifted to wires
  - Light: collected by LAAPDs
  - (The two signals can be combined)
Engineering Run

- Engineering Run ~Dec 2010
- Natural xenon
- TPC fully operational, but not in low background mode:
  - No front Pb wall
  - No Rn free enclosure
  - No Rn trap
  - Muon veto not running
- Test:
  - Electronics
  - Emergency Procedures
  - Stability
  - etc.
An Event in EXO-200

- Charge signal is picked up on crossed wires (shown above)
  - V wires (induction) see it before U wires (collection)
- Light signal is shown at right. This event occurs in TPC 2, and so most light is there, but some is collected in TPC 1
- Light signal precedes charge signal
A 2-site Event in EXO-200

- Gamma rays can Compton scatter in the TPC, creating multiple site events
- All scintillation light arrives simultaneously, indicating multiple-site event and not coincident single-site events
- For this event, both sites were in TPC 1
Particle ID and $^{214}\text{Bi}$-$^{214}\text{Po}$ Decays

- Alpha particles have large dE/dX. The large energy deposition means more ions recombine, producing more scintillation light than betas do.
- Beta decays produce more ionization signal than alphas.
- $^{214}\text{Bi}$ β-decay is followed by a $^{214}\text{Po}$ α-decay, $\tau = 237$ μs. This has a topology that can be identified in the detector and likely occurs in a single trigger frame.
More $^{214}$Bi-$^{214}$Po Decays

- Ionization/scintillation ratios allow clear discrimination between $\alpha$ and $\beta$ events
- A simple check of engineering run data finds 15 Bi-Po events
  - Efficiency still under study, but seems rate is consistent with what is expected with no Rn trap on system
  - 6 near cathode, the remainder in bulk
  - Mean lifetime consistent with $^{237}\mu$s

![Graph](image)
Muons in the TPC

- Muons leave ionization trail in the xenon

- This muon traverses the cathode, leaving ionization in both TPC halves

- We can identify these trails and get a rate that agrees with expectations at our depth
\textbf{85}Kr in the TPC

- The low energy spectrum is consistent with \textsuperscript{85}Kr contamination in the natural xenon used for the engineering run
- Plot shows simulated spectrum scaled to match data in 450 – 687 keV region
  - 450 keV chosen to be well above trigger
  - Q = 687 keV

- Rate consistent with \( \sim 10^{-11} \) abundance of \textsuperscript{85}Kr/Kr based on mass spectrometer\(^\dagger\) analysis of xenon

\( \chi^2/\text{n.d.f.} = 46.2/39 \)

\(^\dagger\)A.Dobi et al., arXiv:1103.2714v1
Q value for $^{85}\text{Kr}$

- At higher energies, other backgrounds start to contaminate spectrum
- Fit a line to Kurie plot between 450 and 635 keV to obtain Q value consistent with 687 keV
- Energy scale verified with $^{60}\text{Co}$ source data

\[ Q = (668 \pm 22^{\text{stat}} \pm 18^{\text{sys}}) \text{ keV} \]

\[ \chi^2/\text{n.d.f.} = 26.5/29 \]

PRELIMINARY
For calibration, various sources can be placed in positions near the TPC

- e.g. $^{60}$Co just outside the cathode along +x axis
Compton telescope of $^{60}$Co

- Using Compton telescope technique, we can verify location of source
  - (Also for finding radioactive hot spots)

- Detector measures energy and location
  \[
  \phi = \arccos \left[ 1 - m_e c^2 \left( \frac{1}{E_y - E_1} - \frac{1}{E_1} \right) \right]
  \]

- This gives a cone from each site, add up to produce plot on right
Conclusions and Status

- Detector operates well!
- We are beginning to understand detector
- We have techniques to understand backgrounds and calibrate detector once we begin taking physics data

Current status:
- Paused to get into low background mode (front Pb wall, Rn enclosure, muon veto)
- Filled with xenon again
- Physics data taking ~now
The EXO Collaboration

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## Backup Slide 1: Sensitivity

<table>
<thead>
<tr>
<th>Case</th>
<th>Mass (ton)</th>
<th>Eff. (%)</th>
<th>Run Time (yr)</th>
<th>$\sigma_E/E @ 2.5$MeV (%)</th>
<th>Radioactive Background (events)</th>
<th>$T_{1/2}^{0v}$ (yr, 90%CL)</th>
<th>Majorana mass (eV) QRPA</th>
<th>NSM</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXO-200</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>0.133†</td>
<td>0.186*</td>
</tr>
</tbody>
</table>

* Caurier, *et. al.*, arXiv:0709.2137v1
Backup Slide 2: Double Beta Spectrum

Backup Slide 3: $^{85}$Kr

Beta decay of $^{85}$Kr is unique first forbidden
Backup Slide 4: Cryostat

HFE7000 cooling/shielding fluid
Backup Slide 5: TPC Internals
Backup Slide 6: Pictures

WIPP Site