Solid xenon bolometers

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Liquid xenon detectors

Energy → Ionization → Scintillation

Heat (not detected) → (recombination)
Double beta decay

\[ \left[ T_{1/2}^{0\nu} \right]^{-1} = G^{0\nu} \ast \left| M^{0\nu} \right|^2 \ast \left< m_{\beta\beta} \right>^2 \]

\( G^{0\nu} \) is a phase space factor \( \propto Q^5 \)
\( M^{0\nu} \) is the nuclear matrix element

0\( \nu \beta \beta \) can only occur for nonzero Majorana neutrino mass term!

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\[ 2\nu\beta\beta \text{ spectrum (normalized to 1)} \]

\[ 0\nu\beta\beta \text{ peak (normalized to } 10^{-6} \) \]

\[ 0\nu\beta\beta \text{ peak (normalized to } 10^{-2} \) \]
EXO-200
Liquid Xe Time Projection Chamber

~110 kg active mass Xe enriched to 80% in $^{136}$Xe, ultralow background construction
Readout plane is made up of LAAPDs (scintillation) + crossed wire grid (ionization)
Achieve electron lifetime in liquid xenon $\tau_e > 2$ ms
Began operating with enriched Xe at the Waste Isolation Pilot Plant (WIPP) in May 2011
Anticorrelation has been modeled empirically but is not understood from first principles.

[M. Szydagis et al., *Journal of Instrumentation* 6, 10002 (2011).]
$T_{1/2}^{0
u \beta \beta} > 1.1 \times 10^{25} \text{ yr}$

$\langle m_{\beta \beta} \rangle < 190 - 450 \text{ meV (90\% C.L.)}$

[Nature 510, 229 (2014)]

The energy resolution is $\sigma/E = 1.53\%$ at 2458 keV.
Solid Xe bolometers(+)

The heat signal may provide an important piece of the puzzle for understanding anticorrelation in Xe.
Bolometers+

CRESST and LUCIFER combine a bolometric technique with scintillation light. CDMS and Edelweiss combine bolometers with ionization.
Step 1: Grow solid Xe

Step 2: Make it a bolometer
Step 3: Read out light and charge
Summary

• The liquid xenon technique is a powerful tool in the search for rare events, including neutrinoless double beta decay and dark matter.

• These detectors rely on anticorrelation between scintillation and ionization, which is not well understood. Solid xenon bolometers would provide a missing piece to the puzzle.

• The Drexel group is working to overcome the technical challenges to building solid xenon bolometers (and more!).