The LZ Dark Matter Detector

Maria Elena Monzani on behalf of the LZ Collaboration

SUSY 2015, August 25
LZ collaboration:

- currently 30 institutions
- USA, UK, Portugal, Russia
- about 185 physicists and engineers
- collaboration is rapidly expanding
Moore’s Law of Direct Detection

- Ge, NaI no discrimination
- Ge, w/discrim.
- LXe, w/discrim.

90% CL SI Cross Section Upper Limit

$[\text{cm}^2 \text{ per nucleon, } M_{\text{WIMP}}=50 \text{ GeV/c}^2]$
Moore’s Law of Direct Detection

- Ge, NaI no discrimination
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- LUX
- XENON 1T

90% CL SI Cross Section Upper Limit

- [cm² per nucleon, M_{WIMP}=50 GeV/c²]

- Crystals
- Cryogenic
- Liquid xenon
- Liquid argon
- LUX 2013
- LUX 2015
- XENON1T
- LZ

LZ: 2×10^{-48} cm²
Go big or go home!

Liquid detectors: “easy” scaling

- Scale up ~50x in Target Mass
- Gain ~400x in Sensitivity

LZ
Total Xe mass – 10 T
Active Mass – 7 T
Fiducial Mass – 5.6 T

LUX
The Xenon TPC Detector

Section view of TPC

- 247 PMT
- Upper PMT Array
- Weir structure
- TPC field cage
- HV umbilical and connection to cathode

Electroluminescence region and gas phase

- Anode
- Liquid surface
- Gate
- Skin PMT
- 180 Skin PMT
- Cathode grid
- Reverse field region
- Skin PMT
- Lower PMT array
Selected Experimental Challenges

• Backgrounds, backgrounds, backgrounds:
  – External (PMT, Cryostat, etc.): select materials carefully
  – Internal (Kr + Rn): Kr removal by charcoal chromatography
  – Cosmogenic (muons etc.): experiment deep underground
  – Cosmogenic (neutrinos): ER/NR selections, will graze floor
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  – Self-shielding necessary (Xe100-LUX: fiducial fraction ~1/2)

• ER and NR Calibrations:
  – Self-shielding complicates matter: source injections (LUX)

• High-voltage requirements:
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How to maximize the WIMP target mass?

- Two-component outer detector:
  - 0.75 m thick Gd-loaded scintillator
  - instrumented Xenon “skin”
  - tag neutrons and gammas

\{ \textit{in-situ} monitoring of residual backgrounds!!! \}
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\{ in-situ monitoring of residual backgrounds!!! \}

- Xe-TPC Only
- Xe-TPC + “skin”
- TPC + skin + Gd-scint.

Fiducial Mass: 3.3 T
Fiducial Mass: 4.2 T
Fiducial Mass: 5.6 T
### Backgrounds, backgrounds, backgrounds

Expected backgrounds for 5.6 T fiducial - 1,000 days

<table>
<thead>
<tr>
<th>WIMP background events</th>
<th>ER</th>
<th>NR</th>
</tr>
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<tr>
<td>(99.5% ER discrimination, 50% NR acceptance)</td>
<td>1.96</td>
<td>0.41</td>
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<td>Total ER+NR background events</td>
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<th>Event Type</th>
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<tr>
<td>Total events</td>
<td>391.5</td>
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<th>Source</th>
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<tr>
<td>Dispersed radionuclides (Rn, Kr, Ar)</td>
<td>54.8</td>
<td>-</td>
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<td>$^{136}\text{Xe} , 2\nu\beta\beta$</td>
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<tr>
<th>Item</th>
<th>Mass kg</th>
<th>U mBq/kg</th>
<th>Th mBq/kg</th>
<th>$^{60}$Co mBq/kg</th>
<th>$^{40}$K mBq/kg</th>
<th>n/yr</th>
<th>ER cts</th>
<th>NR cts</th>
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<tr>
<td>R11410 PMTs</td>
<td>93.7</td>
<td>2.7</td>
<td>2.0</td>
<td>3.9</td>
<td>62.1</td>
<td>373</td>
<td>1.24</td>
<td>0.20</td>
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<td>R11410 bases</td>
<td>2.7</td>
<td>74.6</td>
<td>29.1</td>
<td>3.6</td>
<td>109.2</td>
<td>77</td>
<td>0.17</td>
<td>0.03</td>
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<tr>
<td>Cryostat vessels</td>
<td>2,140</td>
<td>0.09</td>
<td>0.23</td>
<td>$\approx$0</td>
<td>0.54</td>
<td>213</td>
<td>0.86</td>
<td>0.02</td>
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<tr>
<td>OD PMTs</td>
<td>122</td>
<td>1,507</td>
<td>1,065</td>
<td>$\approx$0</td>
<td>3,900</td>
<td>20,850</td>
<td>0.08</td>
<td>0.02</td>
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<td>Other components</td>
<td>-</td>
<td>-</td>
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<td>602</td>
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Xenon detector prototyping

• Extensive program of prototype development underway

• Three general approaches:
  
  – Testing in liquid argon, primarily of HV elements, at Yale and soon at LBNL
  
  – Design choice and validation in small (few kg) LXe test chambers in many locations: LLNL, Yale/UC Berkeley, LBNL, U Michigan, UC Davis, Imperial College, MEPhi
  
  – System test platform at SLAC, Phase I about 100 kg of LXe, TPC prototype testing to begin in a few weeks
SLAC Noble Liquid Test Platform

- High voltage validation
- Purification (Kr removal)
- Fundamental properties
- Integrated system test
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Phase-1 detector (currently in fabrication)

Realistic test of LZ field configuration
Expected Sensitivity Reach of LZ

2 × 10^{-48} \text{ cm}^2

ν-N coherent scattering

1 event

ν-N coherent, 3σ significance

1000 Tonne-years
Conclusions

- LZ detector selected for G2 phase:
  - DOE CD-1/3a approval in April 2015
  - April 2016: CD-2/3b review expected
  - June 2017: surface assembly at SURF
  - July 2018: underground installation

- Extensive prototyping program underway
- LZ benefits from excellent LUX calibrations and understanding of backgrounds

- LZ science run to start in 2019:
  - Spin-Indep. sensitivity: $2 \times 10^{-48} \text{ cm}^2$
  - 3 years run, 5.6 tons fiducial volume
  - sensitivity limited by neutrino-induced backgrounds