Updated analysis of the 2013 LUX dataset

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for the LUX collaboration
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Contents

- LUX: signal, backgrounds and first results
- Updates in the new analysis
  - Estimators of light and charge
  - Calibrated event populations and thresholds
- Search data for the reanalysis, and status.
LUX
LUX, a two-phase Xe TPC

- Energy loss to atomic electrons (also thermal motion, not measured)
- S1 (scintillation) and S2 (ionisation)
- Single detected quanta are obvious
- Event variables are light, charge and position
Near threshold: 1.5 keV electron recoil

- 95% single photoelectrons > threshold
- Trigger on S2 (775 detected photons)
- 100 ns on S1
- 1 μs on S2

95% single photoelectrons > threshold
**WIMP signal, round numbers**

- What’s kinematically accessible with Xe?
  - \( m_{\text{min}} \text{[GeV]} \approx 3 \cdot (E_{\text{min}} \text{[keV]})^{1/2} \)
- Recoil spectrum \( \sim \exp(-E/rE_0) \)
  - DM mass \( m_D \); \( v_0^2 \approx 5 \times 10^{-7} c^2 \)
  - \( r = 4 \cdot \mu_{\text{Xe}D}/(m_{\text{Xe}} + m_D) \); \( E_0 = \frac{1}{2} m_D \cdot v_0^2 \)
<table>
<thead>
<tr>
<th>Source</th>
<th>Spectrum</th>
<th>Charge-to-light ratio</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>WIMPs</td>
<td>c. exponential</td>
<td>low (NR)</td>
<td>uniform</td>
</tr>
<tr>
<td>Compton scatters from materials γs</td>
<td>c. flat</td>
<td>high (ER)</td>
<td>peripheral</td>
</tr>
<tr>
<td>internal βs from Kr-85, Rn impurities</td>
<td>c. flat</td>
<td>high (ER)</td>
<td>uniform</td>
</tr>
<tr>
<td>X-rays from Xe-127 (λ=36.4 d)</td>
<td>1, 5 keV lines</td>
<td>high (ER)</td>
<td>peripheral</td>
</tr>
<tr>
<td>decays on walls</td>
<td>c. flat</td>
<td>low, variable (NR and ER with charge loss)</td>
<td>high-radius</td>
</tr>
</tbody>
</table>
Recall: first result

- 85.3 net days
- 118 kg fiducial (r<18 cm)
- 2–30 phe $S_1_c$
- $S_{2_{raw}} > 200$ phe
- conservative 3 keV signal cutoff → 5.2 GeV $m_{min}$
- 90% UL
  - 2.4–5.3 WIMP counts
  - min. cross section $8 \times 10^{-46} \text{cm}^2$

PRL 112, 091303 (2014)

10,50,90% flat-in-E ER
10,50,90% flat-in-E NR
The reanalysis
Measuring light

Better estimators for detected photons:

- Removed a bias in baselines
- **Photon response calibrated in the VUV (2 phe from 1 photon)**
- Digital counting of photons in PMT waveforms

[Graph showing normalized counts vs. pulse area in mVns for different wavelengths (175 nm to 300 nm)]

arXiv:1506.08748
Monoenergetic sources in the mean-yields plane. Line fit and $W = 13.7$ eV give absolute quanta:

$$\langle S_{1c}[\text{phd}] \rangle = 0.12 \cdot n_{\text{phot}}, \quad \langle S_{2c}[\text{phd}] \rangle = 12 \cdot n_{\text{elec}}$$
ER calibration with tritium (0–18 keV)

2nd campaign of CH₃T calibration, Dec 2013

- 180,000 events
- Reconstruct spectrum with Doke result
- Constrain threshold, yields, fluctuations

not a fit
Calibration of decays on the wall

NR calibration with kinematically-constrained neutron scatters

See D. Huang talk Thursday

- S2 v absolute energy to 0.7 keV
- S1 yield measured to 1.2 keV via single scatters
- Lowers assumed cutoff (same conservative criterion)
- Kinematic reach now 3.3 GeV WIMP mass
Search data, reanalysed

Onwards and downwards:

- **95 days** net (previously 85 d)
- **145 kg** fiducial (118 kg)
- **1–50 phd** $S_1$, $>2$ raw photons (2–30 phe)
- **$S_2_{\text{raw}} > 165 \text{ phd}$** (200 phe)
- conservative **1.2 keV** signal cutoff $\rightarrow 3.3 \text{ GeV}$ $m_{\text{min}}$ (3.0 keV, 5.2 GeV)
- Limits on the way…
Conclusions

Since the 2013 search analysis:

- New understanding of PMT response in VUV.
- Lower analysis thresholds
- ER calibration
  - Doke plot
  - 180k tritium events 0–18 keV
- Empirical wall model: more FV
- S1 yield to 1.2 keV recoil energy with DD generator

Current status:

- Background model from new calibrations ✓
- Search dataset ✓
- DD calibration and signal models: final checks.

Also: Run 4 ongoing with higher fields, acquired livetime greater than Run 3.
Reserve
Zero-suppression threshold

![Graph showing zero-suppression threshold](image)

- $\mu_{\text{sphe}} + \sigma_{\text{sphe}}$
- $\mu_{\text{sphe}}$
- $\mu_{\text{sphe}} - \sigma_{\text{sphe}}$

- POD detect threshold
- $5\sigma$ noise

mV into digitizer vs. Time [ns]
In situ calibration of VUV photons
Tritium events below NR median $S_2|S_1$
ER charge yield
ER light yield

![Graph showing light yield vs energy for Tritium and NEST.](image)

- Tritium
- NEST
- NEST

**LUX Preliminary**
ER efficiency from tritium (Doke g1,g2)