New Results from the XENON1T Dark Matter Experiment

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On behalf of the XENON collaboration

SPS Meeting, EPFL Lausanne
28th - 31st August 2018
XENON Collaboration

- 170 scientists
- 25 institutions
- 11 countries

Search for WIMP dark matter candidate

Located at LNGS, Italy, under 3600 m.w.e
The XENON1T Experiment

• Dual-phase xenon time projection chamber:
  • Detected both light and charge signals
  • 3D position reconstruction
  • ER-NR identification
• 2 t of xenon instrumented out of 3.2 t
• Light detected by two arrays of 3” PMTs
• More info in A. Brown previous talk

XENON journey

<table>
<thead>
<tr>
<th>XENON10</th>
<th>XENON100</th>
<th>XENON1T</th>
<th>XENONnT</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 kg - 15cm drift</td>
<td>161 kg - 30 cm drift</td>
<td>3.2 ton - 1 m drift</td>
<td>8 ton - 1.5 m drift</td>
</tr>
<tr>
<td>$\sim 10^{-43} \text{ cm}^2$</td>
<td>$\sim 10^{-45} \text{ cm}^2$</td>
<td>$\sim 10^{-47} \text{ cm}^2$</td>
<td>$\sim 10^{-48} \text{ cm}^2$</td>
</tr>
</tbody>
</table>
Science Data

- Over one year of stable data taking:
  - 278 DM days
  - 140 Calibration days
- Electron lifetime > 600 μs
Energy Calibration

- Mono-energetic lines from calibration and material contaminations
- Linear detector response
- Excellent expectations from data-MC matching
ER and NR Calibration

- ER from internal $^{220}$Rn (17 days)

- NR from external AmBe (30 days) and D-D neutron generator (1.5 days)

- Combined ER and NR fit with models taking into account xenon physics

- 99.7% ER rejection in the NR region [median,-2σ]
ER and NR Calibration

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- 99.7% ER rejection in the NR region [median,$-2\sigma$]
ER Background

- Initially $^{85}\text{Kr}$ dominated $\rightarrow$ distillation campaign $\rightarrow$ from 1 ppb to 0.66 ppt
- SR1 $^{222}\text{Rn}$ dominated from material emanation: $\sim10 \, \mu\text{Bq/kg}$
- Lowest ER background in DM detector: $(82^{+5}_{-3} \text{(syst)} \pm 3_{\text{(stat)}})$ events/(t\cdot yr\cdot keV_{ee})

<table>
<thead>
<tr>
<th>Source</th>
<th>Fraction [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{222}\text{Rn}$</td>
<td>85.4</td>
</tr>
<tr>
<td>$^{85}\text{Kr}$</td>
<td>4.3</td>
</tr>
<tr>
<td>Solar $\nu$</td>
<td>4.9</td>
</tr>
<tr>
<td>Materials</td>
<td>4.1</td>
</tr>
<tr>
<td>$^{136}\text{Xe}$</td>
<td>1.4</td>
</tr>
</tbody>
</table>

NR background

- Radiogenic neutrons: from (α,n) reactions in detector materials
- Coherent elastic ν-nucleus scattering: $^8\text{B}$ from the sun
- Cosmogenic neutrons: induced by muons interactions
- MC prediction based on measured material contaminations
- 9 neutron multiple scatters identified in the ROI

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<td>Radiogenic n</td>
<td>96.5</td>
</tr>
<tr>
<td>CEνNS</td>
<td>2.0</td>
</tr>
<tr>
<td>Cosmogenic n</td>
<td>&lt; 2.0</td>
</tr>
</tbody>
</table>

Source Fraction [%]

Radiogenic n 96.5
CEνNS 2.0
Cosmogenic n < 2.0
Other Backgrounds

- **Accidental coincidence:**
  - from lone S1s and S2s paired together
  - Model validated on $^{220}$Rn data

- **Surface background:**
  - $^{210}$Pb and $^{210}$Po from PTFE
  - Smaller S2 signal $\rightarrow$ leak into the ROI
  - Model based on $^{210}$Po surface control sample
WIMP Analysis

- Blinded (against bias on cuts and model) and salted analysis (against bias on post-unblinding tuning)

- ROI in 3-70 PE S1:
  - [1.4-10.6 keV$_{ee}$]
  - [4.9-40.9 keV$_{nr}$]

- 1 ton $\times$ year exposure in 1.3 t fiducial volume to maximise sensitivity

- Detection efficiency dominated by 3-fold coincidence requirement

- Selection efficiency from control or MC data samples
Unblinding–Desalinating

- Events pie-charts of the best fit-model in (S1, S2, R, Z) parameters space
- Signal model for 200 GeV/c$^2$ WIMP
Unblinding–Desalinating

- Events pie-charts of the best fit-model in (S1, S2, R, Z) parameters space

- Signal model for 200 GeV/c² WIMP
Results

- Sensitivity 7 times better than previous experiments (Sensitivity normalised on median compared with LUX and PandaX-II experiments)

- Profile likelihood with background only and background+WIMP hypothesis

- No significant excess > 3σ

- Over-fluctuation of background worsened the exclusion limit

- Best 90% CL exclusion limit on SI WIMP interaction above 6 GeV/c²

- Minimum $\sigma_{SI} \approx 4.1 \times 10^{-47}$ cm² at 30 GeV/c²

arXiv:1805.12562 accepted to PRL
**XENONnT at UZH**

**PMTs testing**
- Each PMT tested for leaks in LXe

**Read-out**
- Cables, connectors and PMT bases selected to give best performances

**Light calibration**
- LEDs ans optical fibers for PMTs calibration system
Outlook

• Multi-ton dual-phase TPC stable data for more than a year
• Lowest background level for TPC DM experiments
• Sensitivity 7 times better than other experiments for masses > 6 GeV/c^2
• World leading upper limit on SI WIMP-nucleon interaction

**XENONnT**

• 8 tonne LXe (6 target)
• Reduce background by factor 10
• Use XENON1T subsystems
• Commissioning 2019
Thank you for your attention
Backup slides
Why Xenon

• High mass number $A=131$ \( \rightarrow \sigma \propto A^2 \)

• Non long-lived radioisotope: background to ppt level

• High stopping power: self-shielding

• Scalable to large mass
Stability plots

[Graphs showing stability plots for different calibration sources (220Rn, AmBe, NR).]

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How events look like

Event 3930 from 170927_1844
Recorded at 2017/09/27, 18:57:30 UTC, 477360128 ns

S1 at 382.5 us
Amplitude (pe/bin)
Time (us)

S2 at 1004.2 us
Amplitude (pe/bin)
Time (us)

S1 bottom
y (cm)
x (cm)

S2 top
y (cm)
x (cm)

S1
S2

PMT channel
Time (us)

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Corrections

- Plot 1: Depicts the relative S2 light yield as a function of $x_{\text{rec}}$ and $y_{\text{rec}}$.
- Plot 2: Shows the reconstructed interaction position with a TPC boundary indicated.

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ER and NR models

220Rn

AmBe

NG
Improving Purification

**Diagram 1:**
- **XENON preliminary**
- **Installation of $^{222}$Rn reduced recirculation pump**

**Diagram 2:**
- **Electron Lifetime [μs]**
- **Jan 2018**
- **Feb 2018**
- **Mar 2018**
- **Apr 2018**
- **May 2018**
- **Jun 2018**
- **Jul 2018**

- **Date**
- **~48 SLPM**
- **End Science Run 1**
- **Power Outage**
- **~70 SLPM**
- **Par. upgrade 1 OD pipes**
- **~80 SLPM**
- **Par. upgrade: mag. pump installation**

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