First DM Search Result from the PandaX-II 500kg LXe Detector

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On Behalf of the Collaboration
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PandaX collaboration

~50 people

Started in 2009

- Shanghai Jiao Tong University (2009-)
- Peking University (2009-)
- Shandong University (2009-)
- Shanghai Institute of Applied Physics, CAS (2009-)
- University of Science & Technology of China (2015-)
- China Institute of Atomic Energy (2015-)
- Sun Yat-Sen University (2015-)
- Yalong Hydropower Company (2009-)
- University of Maryland (2009-)
- University of Zaragoza (2015-)
- Suranaree University of Technology (2015-)
China Jinping Underground Laboratory

Deepest in the world (1µ/week/m²) and Horizontal access!
PandaX experiment

PandaX = Particle and Astrophysical Xenon Experiments

Phase I:
120 kg DM
2009-2014

Phase II:
500 kg DM
2014-2017

PandaX-xT:
multi-ton DM
future

PandaX-III:
200 kg to 1 ton
$^{136}$Xe 0vDBD
future
First delivery of PandaX equipment to Jinping lab, Aug. 16, 2012
Final Results from PandaX-I

- Completed in **Oct. 2014**, with 54.0 x 80.1 kg-day exposure
- Data strongly disfavor all previously reported claims
- Competitive upper limits for low mass WIMP in xenon experiments
PandaX-II

- New inner vessel with clean SS
- New and taller TPC with brand-new electrodes
- More 3” PMTs and improved base design
- New separate skin veto region
Assembling the detector
Assembling the detector
Run history

- We had a series of engineering runs in 2015, fixing various problems as we were testing all the components of the setup.


- After a Kr distillation campaign, the detector was refilled. Physics data taking started in Mar. 2016 (Run 9)
Results from PandaX-II Run 8


- Simple counting analysis based on an expected background of 3.2(0.7) evts and 2 observed evts

- Sizable (x2) difference of using original NEST or tuned NEST to predict DM distribution due to DM acceptance, but within 1σ band

- Low mass: competitive with SuperCDMS; high mass: similar exclusion limit as XENON100 225-day
## Major upgrades in Run 9

<table>
<thead>
<tr>
<th>Items</th>
<th>Status in Run 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Krypton level</td>
<td>Reduced by x10</td>
</tr>
<tr>
<td>Exposure</td>
<td>Increased x4 (79.6 vs 19.1 day)</td>
</tr>
<tr>
<td>ER calibration</td>
<td>Now have tritium calibration</td>
</tr>
<tr>
<td>NR calibration</td>
<td>Statistics x6</td>
</tr>
<tr>
<td>Analysis</td>
<td>Improved position reconstruction</td>
</tr>
<tr>
<td>Background</td>
<td>Accidental background suppressed more than x2 using BDT</td>
</tr>
</tbody>
</table>
Configuration of fields

Field Configuration:
- TPMT
- Anode Gate
- Cathode
- Bttm Scrn
- BPMT

-650V
-30 kV
-5 kV
600mm
11mm
46mm
60mm

2016/7/22
Data sets with different fields

<table>
<thead>
<tr>
<th>Condition</th>
<th>live time (day)</th>
<th>$E_{\text{drift}}$ (V/cm)</th>
<th>$E_{\text{extract}}$ (kV/cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7.76</td>
<td>397.3</td>
<td>4.56</td>
</tr>
<tr>
<td>2</td>
<td>6.82</td>
<td>394.3</td>
<td>4.86</td>
</tr>
<tr>
<td>3</td>
<td>1.17</td>
<td>391.9</td>
<td>5.01</td>
</tr>
<tr>
<td>4</td>
<td>63.85</td>
<td>399.3</td>
<td>4.56</td>
</tr>
</tbody>
</table>

Mar. 9-Jun 30, in total 79.6 live-day of under slightly different conditions (optimization of drift and extraction fields).
Electron lifetime evolution

1st Physics Run (run 9, 79.6 days)

Commissioning Run (run 8, 19.1 days)

Krypton Distillation

A leak in the recirculation loop discovered and fixed
Typical single scatter waveform

Soft Esum Waveform run 11624, event 49, Bottom Array

S1 → S2

Top Array

Bottom Array

S1 waveform

S2 waveform
Calibration program

- Internal/external ER peaks:
  - Detector uniformity corrections
  - Light/charge collection parameters

- Low rate AmBe neutron source:
  - Simulate DM NR recoil signal

- CH$_3$T injection: tritium beta decays
  - Simulate gamma background
Gaussian fits to all ER peaks in data

Uncertainty on each data point estimated using energy nonlinearity

Linear fit in $S1/E$ vs $S2/E$ to extract PDE and EEE

$$E_{ee} = W \times \left( \frac{S1}{PDE} + \frac{S2}{EEE \times SEG} \right)$$

$W = 13.7$ eV
NR calibration

- 162.4 hours of AmBe data taken, with ~3200 low energy single scatter NR events collected
- NR median curve and NR detection efficiency determined

Data/MC comparison

ER median
NR median
95% confidence band for NR median

99.99% NR acceptance
ER calibration with CH$_3$T

- 18.0 hours of tritium data taken, with ~2800 low energy ER events collected
- 14 events leaked below NR median, (0.5 ± 0.1)%
- Consistent with Gaussian expectation, 0.55%
$^{85}\text{Kr}$

- Estimated from delayed $\beta-\gamma$ coincidence analysis
- Uniformly distributed
- Significantly reduced after distillation

**Waveform:** one $\beta$ one $\gamma$

**Graph:**
- **X-axis:** $R^2$ (mm$^2$)
- **Y-axis:** $Z$ (µs)
- Data points showing a trend
- **Legend:**
  - Commissioning run (Run8)
  - $1^{st}$ Physics run (Run 9)

**Dates:**
- 12/15
- 01/16
- 02/16
- 03/16
- 04/16
- 05/16
- 06/16

2016/7/22
Low energy background in Run 9

- Events selected with energy <10 keV
- ~2 mDRU on average (15.3 mDRU in Run 8)
- Decrease over time due to $^{127}$Xe decay
Final candidates

Gray: all
Red: below NR median
Green: below NR median and in FV

- 380 total candidates found in the FV
- 1 below NR median
- Outside FV, edge events more likely to lose electrons, leading to S2 suppression
Final candidates

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ER median

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NR median

99.99% NR acceptance
Preliminary results

Minimum upper limit for isoscalar SI elastic cross section at $2.7 \times 10^{-46} \text{ cm}^2$ @ 39.8 GeV/c$^2$, more than a factor of 2 improvement compared to the LUX 2015 results.
Summary and outlook

- 79.6 live-day of dark matter data were taken with much reduced background compared to the commissioning run (15 -> 2 mDRU)

- Extensive calibration studies with neutron and tritium

- In combination with commissioning run (19.1 day), \( \sim 3.32 \times 10^4 \) kg-day exposure in total

- Analysis will be published officially soon.
<table>
<thead>
<tr>
<th>Experiments</th>
<th>FV (kg)</th>
<th>Total exposure (kg-day)</th>
<th>Background level (mDRU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>XENON100 100 day</td>
<td>48</td>
<td>4843</td>
<td>22</td>
</tr>
<tr>
<td>XENON100 225 day</td>
<td>34</td>
<td>7650</td>
<td>5</td>
</tr>
<tr>
<td>LUX 2015</td>
<td>147</td>
<td>14000</td>
<td>3</td>
</tr>
<tr>
<td>PandaX-I</td>
<td>54</td>
<td>4325</td>
<td>23.6</td>
</tr>
<tr>
<td>PandaX-II (run8)</td>
<td>306</td>
<td>5845</td>
<td>15.3</td>
</tr>
<tr>
<td>PandaX-II (run9)</td>
<td>~300</td>
<td>~24000</td>
<td>~2</td>
</tr>
<tr>
<td>PandaX-II run8+9</td>
<td>~300</td>
<td>33200</td>
<td>2-15</td>
</tr>
</tbody>
</table>