Status of the PandaX Experiment at China Jinping Underground Lab

Xiangdong Ji
Shanghai Jiao Tong U. and UMD
On Behalf of the Collaboration
PandaX collaboration

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 (2015-)
- China Institute of Atomic Energy (2015-)
- Sun Yat-Sen University (2015-)
- Yalong Hydropower (2009-)
- University of Maryland (2009-)
- University of Michigan (2011-2015)

~40 people
Deepest in the world (1μ/week/m²) and Horizontal access!
See Qian Yue’s talk
PandaX experiment

PandaX = Particle and Astrophysical Xenon Experiments

Phase I: 120 kg DM
2009-2014

Phase II: 500 kg DM
2014-2017

Phase III: 200 kg to 1 ton $^{136}$Xe 0vDBD
2016-

Phase IV: 20 ton DM
2019-
First batch of PandaX equipment were moved to Jinping lab on Aug. 16, 2012
Final Results from PandaX-I

- Completed Oct. 2014, with 54.0 x 80.1 kg-day full exposure
- Data strongly disfavors all previously reported claims from other experiments
- Competitive upper limits for low mass WIMP
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
- New overflow chamber
Assembling the detector
Configuration of fields

Field Configuration:

TPMT

Anode

Gate

Cathode

Bttm Scrn

BPMPT

-650V

-600mm

-30 kV

-5 kV

46mm

11mm

-650V

60mm

600mm
Run history

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

• A physics commissioning run: Nov. 22 – Dec. 14 (19.1 live-day x 306 kg FV)
  not everything in perfect conditions:
    no gamma calibration (-) * large Kr contamination (-)
  = some physics result (+)
Typical single-scatter waveform
Calibrating the detector responses

• Detector uniformity correction

• Light/charge collection parameters in energy reconstruction

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

• Compare the low energy NR response between neutron calibration data and MC (NEST-based + measured parameters)
Activated xenon peaks

“Workhorse” in uniformity correction

- Electron lifetime kept improving during the data taking (average 324 μs)
- Energy resolution <6% (1σ) achieved for 164 keV γ rays
- Energy bias <3%
Identifying smallest S2 in the data

Varying selection method and fits to study systematics

\( \Rightarrow 22.1 \pm 0.7 \) PE/e,
PDE and EEE

Fractional sys. uncert. estimated by comparison with NEST ER model: 5.6% (PDE), 7.1% (EEE)
NR calibration

Fit to data median
Median of untuned NEST1.0 MC
Median of tuned NEST1.0 MC

99.99% NR acceptance (NEST)

- Geant4 energy spectrum
- NEST 1.0 photons/electrons
- PDE/EEE/SEG from calibration
- Double PE emission from R11410 from Faham et al. (JINST 10, P09010)
- Electron lifetime correction

Tuned NEST 1.0:
$N_{ex}/N_i$ ratio scaled up by 1.5
Kryton background

- Significant uniformly distributed ER background observed in the data
- $(\beta, \gamma)$ analysis confirmed that it is due to $^{85}$Kr, $\text{Kr}/\text{Xe} = (437 \pm 70)$ ppt
- Due to an accidental air leak in the previous recuperation

Distribution of $\beta$ vertices
ER background summary

- Shape in reasonable agreement with MC
- Low energy agreement also within 17%

<table>
<thead>
<tr>
<th>Item</th>
<th>Background (mDRU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>15.33</td>
</tr>
<tr>
<td>$^{85}$Kr</td>
<td>15.04</td>
</tr>
<tr>
<td>$^{222}$Rn</td>
<td>0.075</td>
</tr>
<tr>
<td>$^{220}$Rn</td>
<td>0.021</td>
</tr>
<tr>
<td>$^{129m}$Xe, $^{131m}$Xe, $^{133}$Xe</td>
<td>$\sim$0</td>
</tr>
<tr>
<td>PMT arrays &amp; bases</td>
<td>0.097</td>
</tr>
<tr>
<td>PTFE wall</td>
<td>0.021</td>
</tr>
<tr>
<td>Inner vessel</td>
<td>0.045</td>
</tr>
<tr>
<td>Others IV components</td>
<td>0.026</td>
</tr>
<tr>
<td>Cu outer vessel</td>
<td>0.016</td>
</tr>
</tbody>
</table>
ER background leakage

- Simple DM acceptance cut: below NR median
- Insufficient statistics of low energy ER calibration data in the FV
- Assume ER nature in DM search data above the 33% NR acceptance
- Use Gaussian fit to predict the tail below NR median
- Consistent leakage obtained using full data distribution

Gaussian ER leakage

0.4%±0.2%
Total expected background

- Accidental background statistically determined from data using isolated S2 and S1 from the data
- Neutron background dominated by the $(\alpha, n)$ from PTFE reflector
- Background systematics dominated by the ER leakage fraction $(0.4\% \pm 0.2\%)$ and Kr rate (17%) uncertainty

<table>
<thead>
<tr>
<th></th>
<th>ER</th>
<th>Accidental</th>
<th>Neutron</th>
<th>Total Expected</th>
<th>Total observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>611</td>
<td>5.9</td>
<td>0.13</td>
<td>617±104</td>
<td>728</td>
</tr>
<tr>
<td>Below</td>
<td>2.5</td>
<td>0.7</td>
<td>0.06</td>
<td>3.2±0.71</td>
<td>2</td>
</tr>
<tr>
<td>NR median</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Final selection cuts

- Horizontal cut determined by reconstruction quality (removing the last ring of PMT)
- Vertical cut determined by choosing the flat region in non-DM-window for both data and MC (excess at cathode likely due to Rn daughters accumulation)
- S1 cut: [3, 45] PE by optimizing the median sensitivity using expected background only
Final candidates

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

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

<table>
<thead>
<tr>
<th>Cut</th>
<th>#Events</th>
<th>Rate (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All triggers</td>
<td>4779083</td>
<td>2.89</td>
</tr>
<tr>
<td>Single S2 cut</td>
<td>1833756</td>
<td>1.11</td>
</tr>
<tr>
<td>Quality cut</td>
<td>1262906</td>
<td>0.76</td>
</tr>
<tr>
<td>Skin veto cut</td>
<td>1081044</td>
<td>0.65</td>
</tr>
<tr>
<td>S1 range</td>
<td>45883</td>
<td>$2.77 \times 10^{-2}$</td>
</tr>
<tr>
<td>S2 range</td>
<td>29755</td>
<td>$1.80 \times 10^{-2}$</td>
</tr>
<tr>
<td>Fiducial volume</td>
<td>728</td>
<td>$4.40 \times 10^{-4}$</td>
</tr>
</tbody>
</table>
Final candidates

Two events below NR median appear consistent with Gaussian background leakage.
Exclusion limits

- 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.
A preprint will be submitted to arXiv this weekend and it will appear on Tuesday.
PandaX new home: CJPL-II

8 experimental Halls, 65m long each.
PandaX experiment

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Half-ton scale PandaX-II has tuned up all key components of the experiments.

Commissioning run with 19.1 live-day x 306 kg exposure observed no DM candidate with an exclusion limit similar to 225 day XENON100 results.

After a maintenance to distill Kr, PandaX-II will resume physics data taking in the spring.

Stay tuned!