Status and Plans

Wolfgang Lorenzon
University of Michigan
(on behalf of the PandaX Collaboration)
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Direct Dark Matter Detection: The Path Forward

Decrease detection threshold and improve sensitivity for low-mass DM detection

At the Brink of Discovery!
- Generation 2 experiments likely to produce a positive detection.
- PandaX will expand sensitivity in both directions: low mass and low cross-section.
- PandaX heritage from pioneering experiments: XENON100, ZEPLIN...

Enlarge effective mass of detector, explore theoretical models.
The PandaX Experiment
(Particle AND Astrophysical Xenon TPC)

- A dual-phase xenon Dark Matter direct detection experiment
- Located at China Jinping underground Lab (CJPL) (covered with 2,400 m of marble)
- Probing WIMP-nucleon cross section
- A staged approach to reach ton-scale target mass
  - Stage-1a: Time Projection Chamber (TPC) design optimized for low mass dark matter: 25 kg (fid)
  - Stage-1b: increase the fiducial mass to 300 kg (~LUX)
  - Stage-2: increase the fiducial mass to 1 ton: optimized for high mass dark matter

Jan 2013
(Stage-1a installation)
The PandaX Collaboration

Shanghai Jiao Tong University
Shanghai Institute of Applied Physics
Shandong University
Peking University
Yalong River Hydropower Development Company

University of Michigan
University of Maryland
Stage-1a Design and Goals

• Design:
  – TPC diameter/length: 60/15.4 cm
  – Target Xe mass: 125 kg
  – Expected fiducial mass: 25 kg
  – Top PMT: 143 R8520
  – Bottom PMT: 37 R11410

Goals:
  – Demonstrate high field operation for high ER background rejection
  – Demonstrate efficient Xe purification and low Kr-contamination
  – Low energy threshold for light WIMPs
Key to Low Threshold - Light Yield

a 5 keV NR only produces about 20 scintillation photons

Every photon is precious!

- Disk-like structure: increase PMT coverage
- Highly reflective Teflon walls
- Hexagonal Teflon reflectors for the bottom PMTs to avoid dead space
- Highly transparent wire planes
- Efficient purification to minimize photon absorption by impurity molecules, e.g. $\text{H}_2\text{O}$

Assumptions:
- Absorption length: 5 m
- Teflon reflectivity: 90%
- Scattering length: 40 cm

Goal: achieve a 5 keVr NR threshold, equivalent to a light yield of 4-5 pe/keVee (with field)
Stage-1a: Current Status

- Passive shield, cryogenics, and Kr removal system were designed for ton-scale experiment from the beginning.
- Passive shield and cryogenic system are installed at CJPL.
- Kr removal system started operation at SJTU.
Stage-1a: Current Status - II

- Started commissioning at CJPL
  - currently 440 kg LXe in vessel
- Operation in 2013
- Planned exposure: 25-kg x 60-days
- Expected bkg (dominated by ERs from vessel and PMTs): 0.3 (after 99.9% rejection based on S2/S1)
- Expected threshold/NR acceptance: 1.5 keVee/35%
- Expected sensitivity (SI): $1 \times 10^{-43}$ cm$^2$ at 10 GeV with 1,500 kg-day exposure
The PandaX Experiment at CJPL

- Deepest lab in operation: 7,200 mwe (66 μ/m²/yr) → μ veto shield unnecessary
- Radiopure “marble” mountain → water shield not needed
- Middle of 18 km tunnel → easy access by road
- Cavern floor and walls coated with Rn blocking paint
- Scalable design → room to grow
Tunnels at JinPing Mountain

- Four water tunnels: length of 16.67 km
  - two of diameter of 12.4 m: TBM
  - two of diameter of 13m: drilling and blasting,
- Two traffic tunnels: 5.5×5.7m, 6×6.25m, length of 17.5km
- One drain tunnel with diameter of 7.2m, length of 17.5km
  (only used during construction, and could be used for super big volume experiment!)
- maximum Overburden 2525m
JinPing Mountain

Yalong river

steep mountains
CJPL: A low Background Facility

low muon flux

radio-pure rock

<table>
<thead>
<tr>
<th>facility</th>
<th>depth [mwe]</th>
<th>$\mu$ flux [events/m²/yr]</th>
<th>rock</th>
<th>$^{238}$U [Bq/kg]</th>
<th>$^{232}$Th [Bq/kg]</th>
<th>$^{40}$K [Bq/kg]</th>
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<tbody>
<tr>
<td>Jinping (PandaX)</td>
<td>7,200</td>
<td>66</td>
<td>marble</td>
<td>1.8 ± 0.2</td>
<td>&lt; 0.27</td>
<td>&lt; 1.1</td>
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<tr>
<td>Homestake (LUX)</td>
<td>4,500</td>
<td>950</td>
<td>rhyolite</td>
<td>100</td>
<td>45</td>
<td>900</td>
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<tr>
<td>Grand Sasso – Hall B (XENON)</td>
<td>3,500</td>
<td>8,030</td>
<td>dolomite</td>
<td>5.2</td>
<td>0.25</td>
<td>4.9</td>
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</tbody>
</table>
The Next Step: Stage-1b

Stage-1a: 25 kg (fid)

- same detector vessel and PMT arrays
- only increase TPC height (and add more Xe)
- NO change to shield, outer vessel, cryogenics, purification and general infrastructure → quick to implement

Stage-1b: 500 kg (fid)

- Goal:
  - Construction: 2013
  - Commission/Operation: 2014
  - Sensitivity reach: $4 \times 10^{-46}$ cm$^2$ at 100 GeV with 54,000 kg-day exposure
Stage-2: Design and Plans

- **Design:**
  - TPC diameter/length: 100/100 cm
  - Target Xe mass: 2.4 ton
  - Exp. Fiducial mass: 1.4 ton
  - Top PMTs: 151 R8520 or R11410
  - Bottom PMTs: 151 R11410

- **Plan:**
  - Start construction in 2014 (depends on funding)
  - Commission/operation: 2015-2017
  - Sensitivity reach: $3 \times 10^{-47}$ cm$^2$ at 100 GeV with a 600,000 kg-day exposure
PandaX expected sensitivity

**PandaX Stage 1a:**
- light yield: 4-5 pe/keV$_{ee}$
- S1 energy range: 3-30 pe
- exposure: 25 kg x 60 days
- NR acceptance: 0.35
- estimated bkg events: 0.3

**PandaX Stage 1b:**
- light yield: 2.5 pe/keV$_{ee}$
- S1 energy range: 3-30 pe
- exposure: 300 kg x 180 days
- NR acceptance: 0.35
- estimated bkg events: 0.5

**PandaX Stage 2:**
- light yield: 2.5 pe/keV$_{ee}$
- S1 energy range: 3-30 pe
- exposure: 1000 kg x 1000 days
- NR acceptance: 0.35
- estimated bkg events: 1.2
Current Layout of CJPL

- Main hall: 6.5*6.5*40m
- Total Volume: ~4000m³
Rapid Development at CJPL

Nov 2009

PandaX

May 2011
(under renovation)

Oct 2011
(after renovation)

Jan 2013
(stage-1a installation)
CJPL-I: plans shown in 2010 for future development (shape & location flexible)
CJPL-II: finalizing plans to build 8 caves each 12m (W) x 12m (H) x 60m (L)
- start excavation in late 2013
- operational by end of 2015

Owner of lab (YRHDC) is supporting underground science
- much larger experiments possible in the future
- multi-ton DM experiment
- 0νββ with only slightly modified detector (enrich Xe)
Michigan Team

Exp. Faculty
- Gregory Tarlé
- Wolfgang Lorenzon
- Tim Chupp
- Dave Gerdes

Research Scientists
- Michael Schubnell
- Richard Raymond

Graduate Students
- Zach Jackson
- Max Hawley
- Mykola Murskyj

Postdoc
- Kirill Pushkin

Undergraduate Students
- Tom Schwarz

Professional Staff
- Curtis Weaverdyck
- Jon Ameel

Theorists
- Kathryn Zurek
- Aaron Pierce
- Gordy Kane
- Katy Freese

Scientists Under Graduate Students
- Wolfgang Lorenzon
- Gregory Tarlé
- Tom Schwarz
Conclusions

• XENON 100 has demonstrated the power of LXe for DM searches
• Jinping Lab provides an excellent environment to carry on DM searches
• PandaX (stage-1a) will target light DM starting in mid-2013
• R&D underway for ton-scale PandaX
• Pending successful completion of stage-1, infrastructure in-place to proceed rapidly towards stage-2 (greater sensitivity)