PandaX-4T Dark Matter Detector

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On behalf of PandaX Collaboration

Outline

- Dark Matter direct detection
- PandaX program in China
- PandaX-4T detector R&D
- Summary

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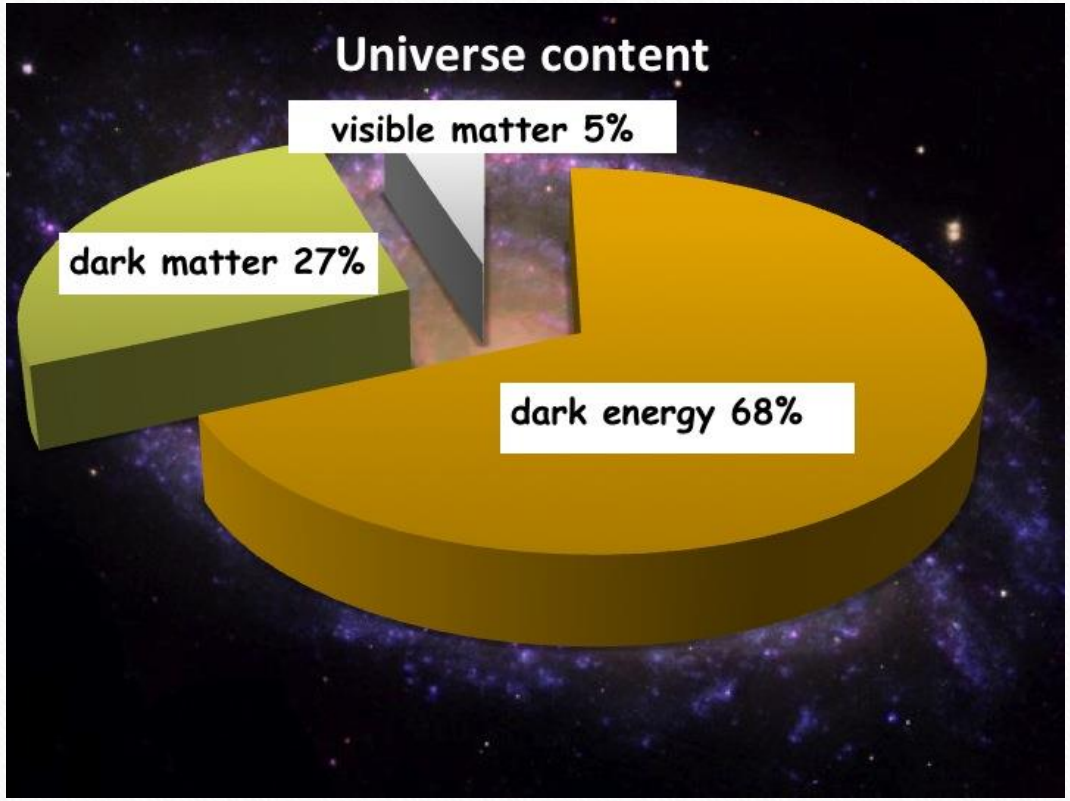
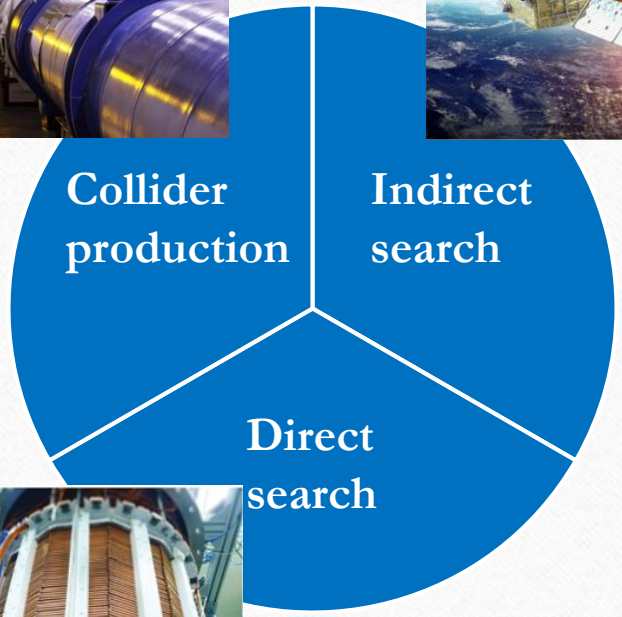
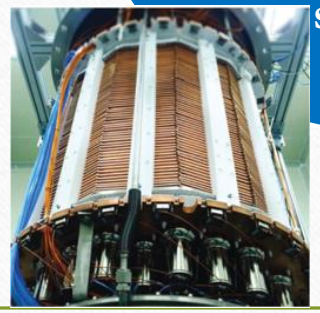
Detect Dark Matter in universe







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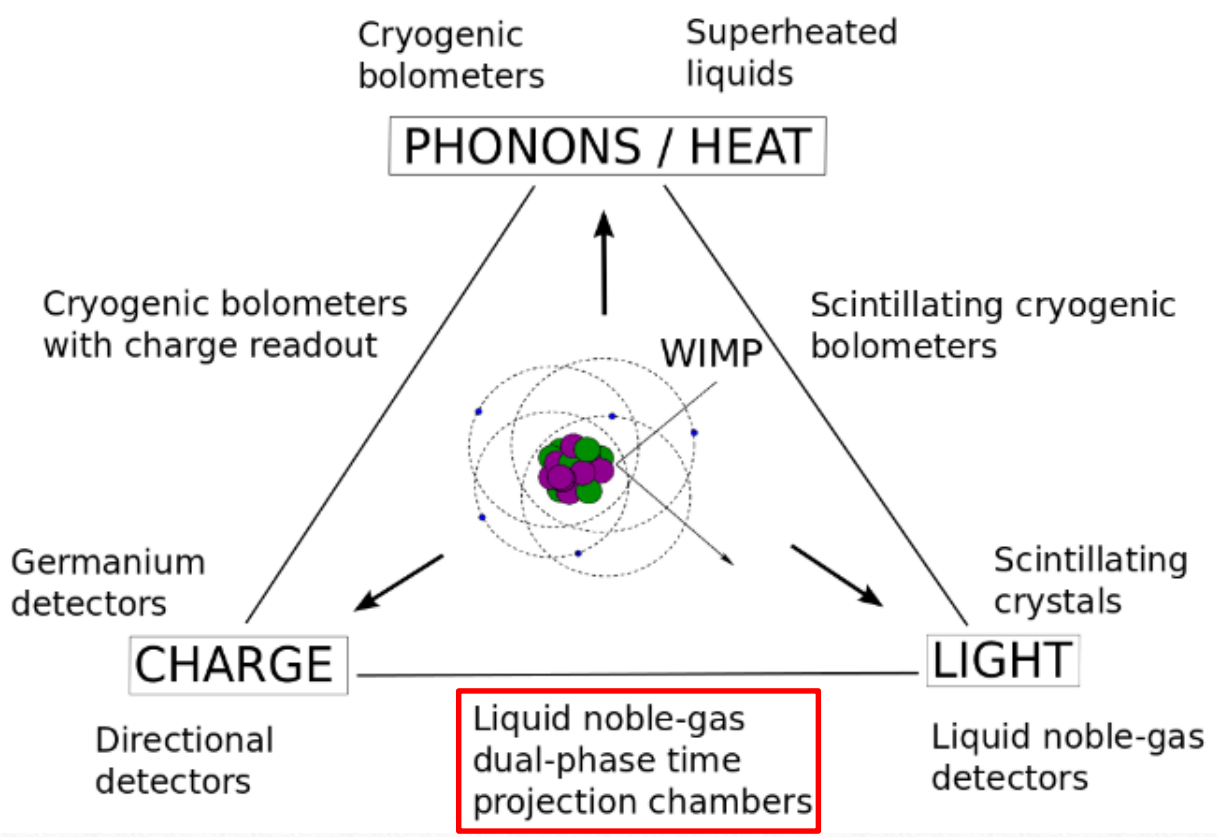
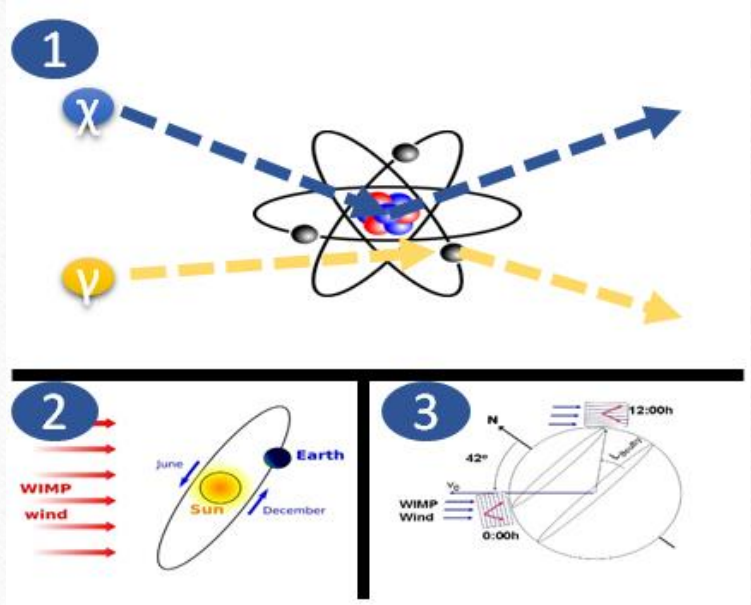
Direct detection technologies





1. Nuclear recoils (γ/e⁻ electron recoils)
2. Annual modulation (3% variation)
3. Diurnal directional modulation

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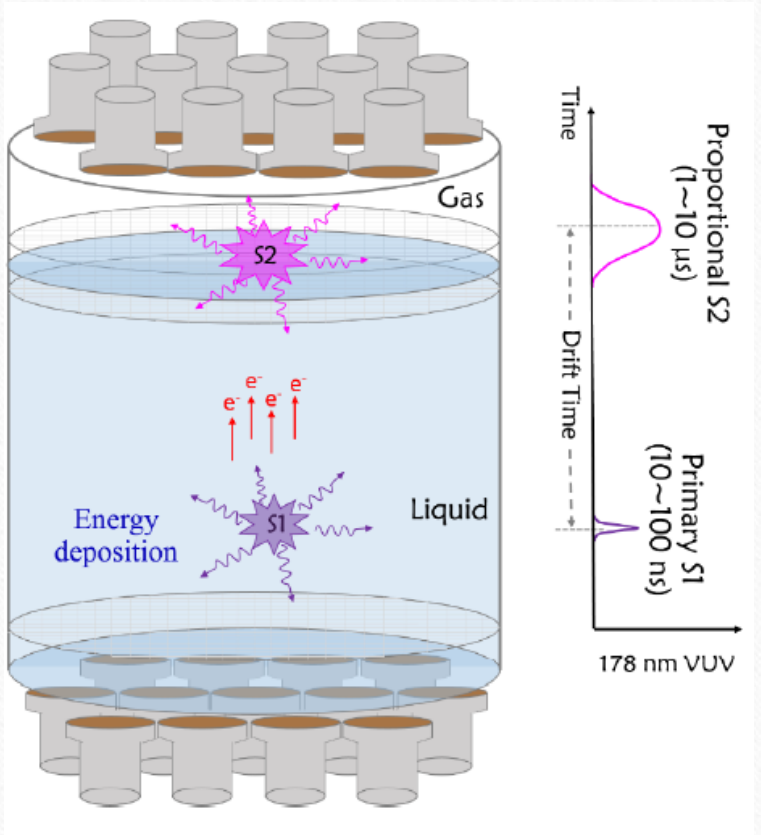
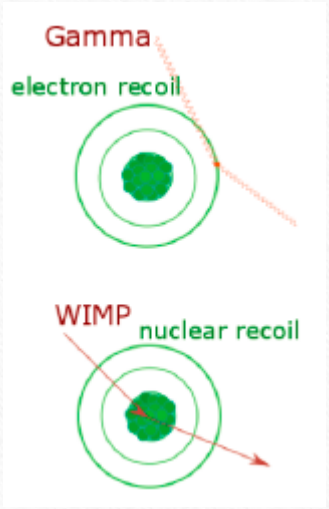
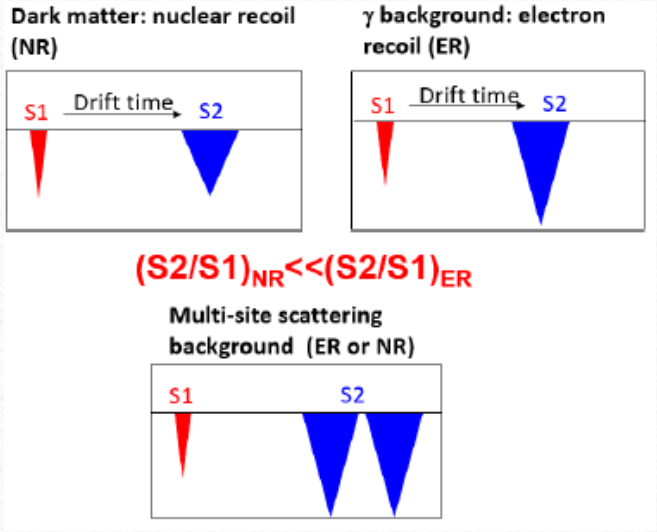
Dual-phase Xenon TPC







Advantages:

1. Excellent self-shielding of liquid Xenon;
2. 3D positon reconstruction and fiducialization;
3. Good nuclear/electron recoil discrimination with S2/S1 ratio.

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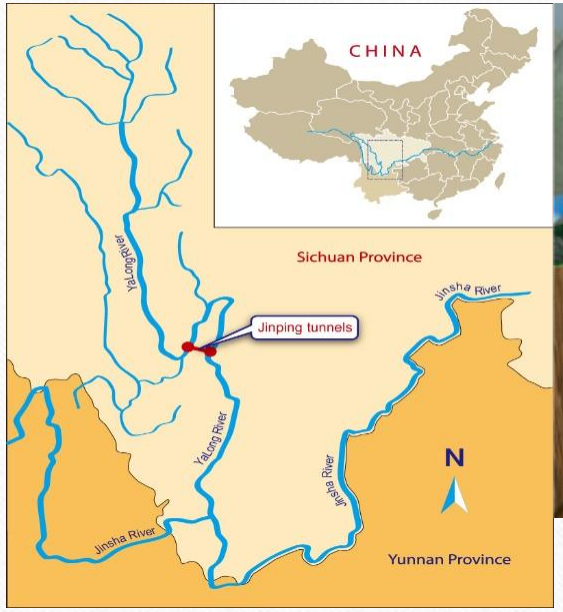
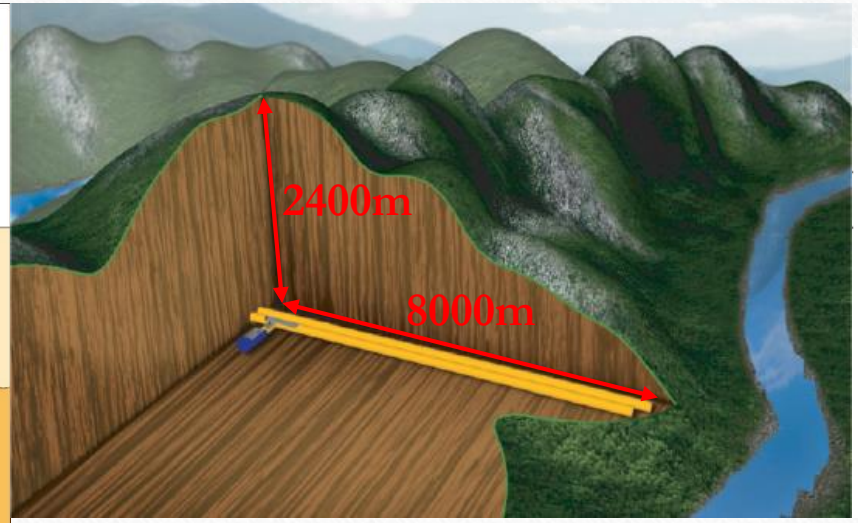
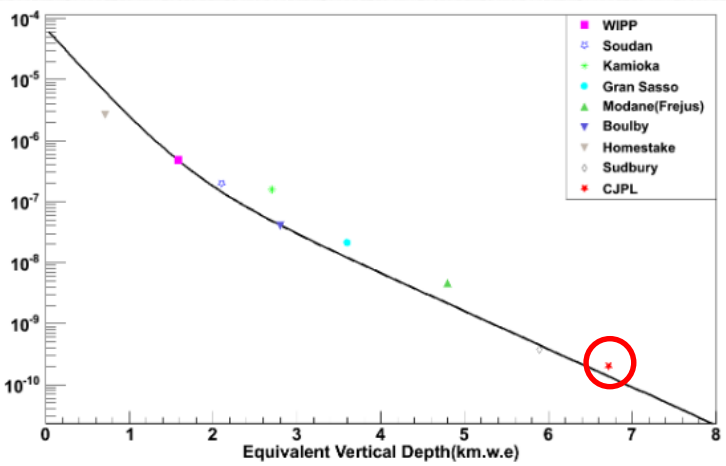
PandaX program

- PandaX: **P**article **and** **A**strophysical **X**enon Experiments (started from 2009)
- Location: **C**hina **J**in-**P**ing underground **L**ab (CJPL)





arXiv:1305.0899



- 2400m rock, Muon flux: 1μ/week/m^2
- Horizontal access

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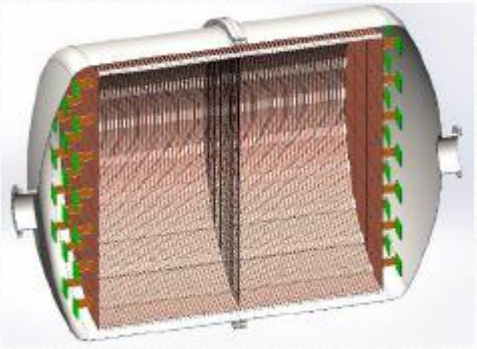
PandaX program

- Finished: PandaX-I, 2009-2014, 120kg, Dark Matter search
- Running: PandaX-II, 2014-2017, 580kg, Dark Matter search
- R&D: PandaX-4T(Dark Matter search), PandaX-III(0νββ, Shaobo's talk)

PandaX-I

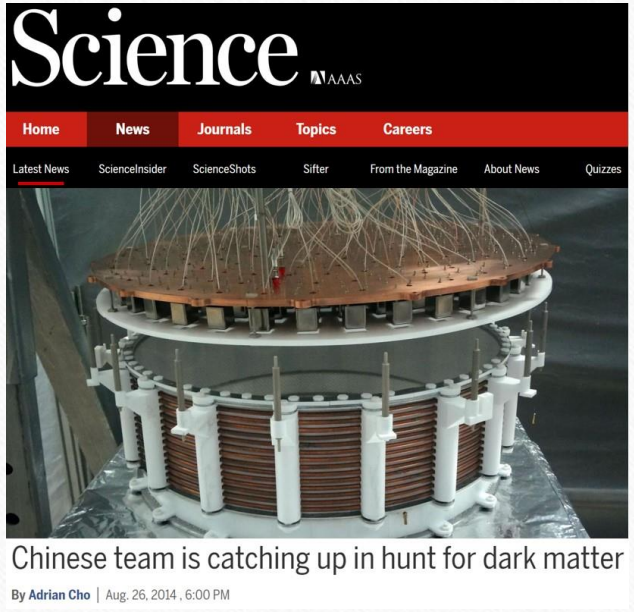
PandaX-II

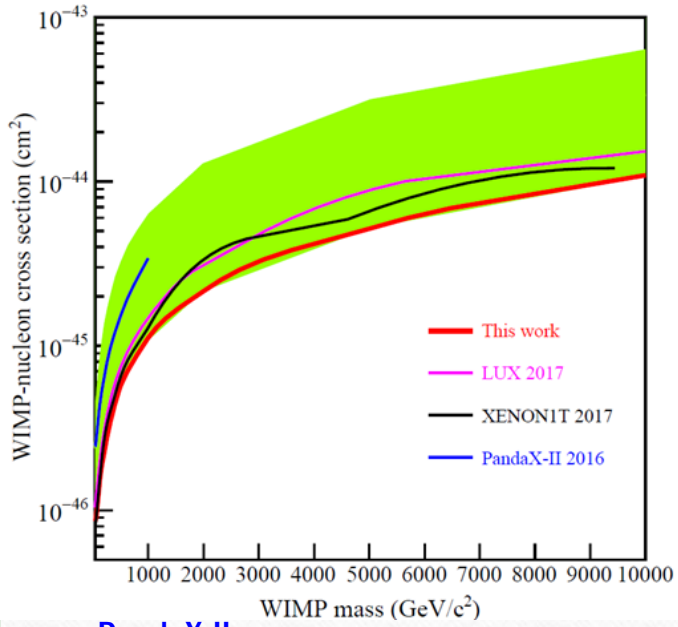
PandaX-4T



PandaX-III

DM search by PandaX





PandaX-I:

- Completed after 54.0×80.1 kg-day exposure
- Data strongly disfavor all previously reported claims

PandaX-II:

- Results from 54-Ton-Day Exposure published in 2017
- Most stringent limit for WIMP-nucleon cross section for mass >100GeV

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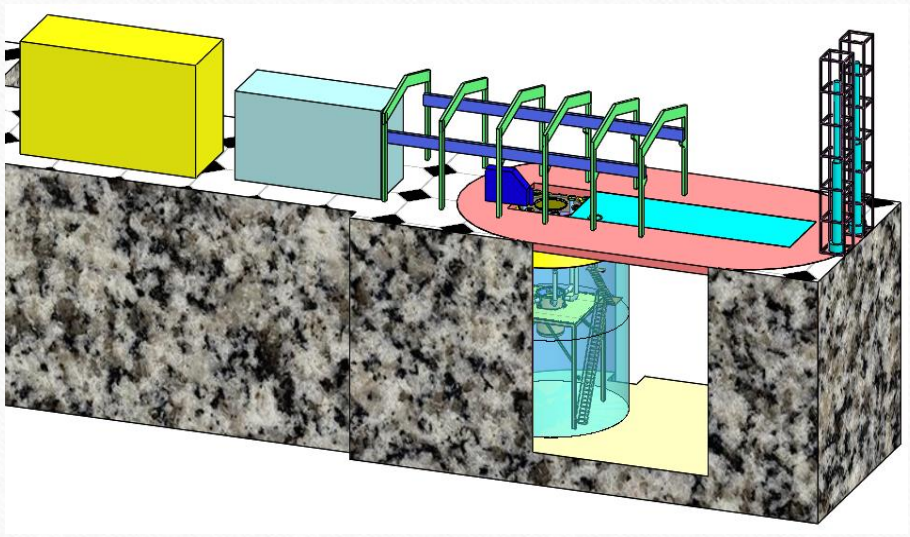
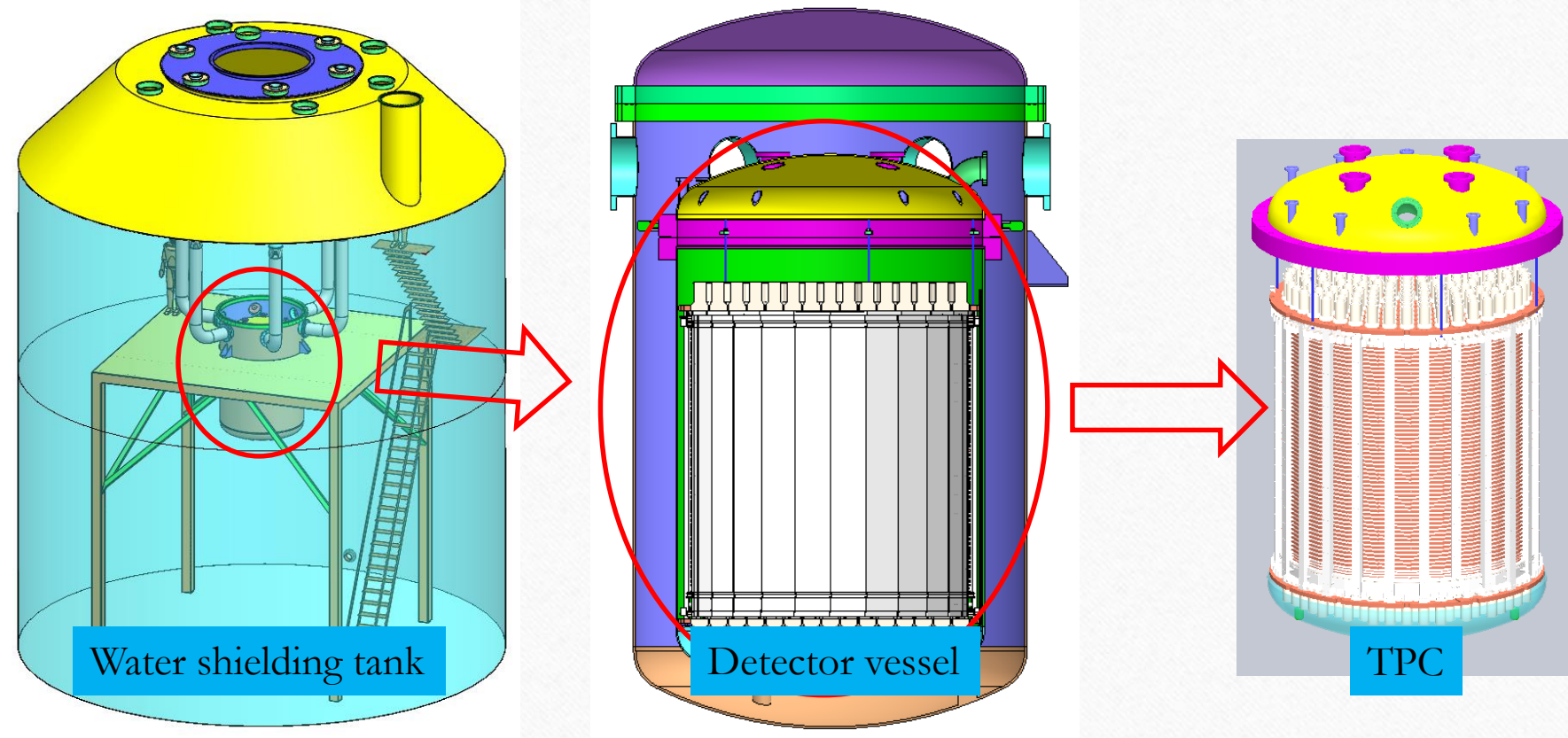
PandaX-4T DM search experiment

- A **4-ton** Xenon experiment is planed, to push the DM Spin-independent sensitivity down to ~10^{-47} cm^2
- Onsite assembling and commissioning: 2019-2020



PandaX-4T detector

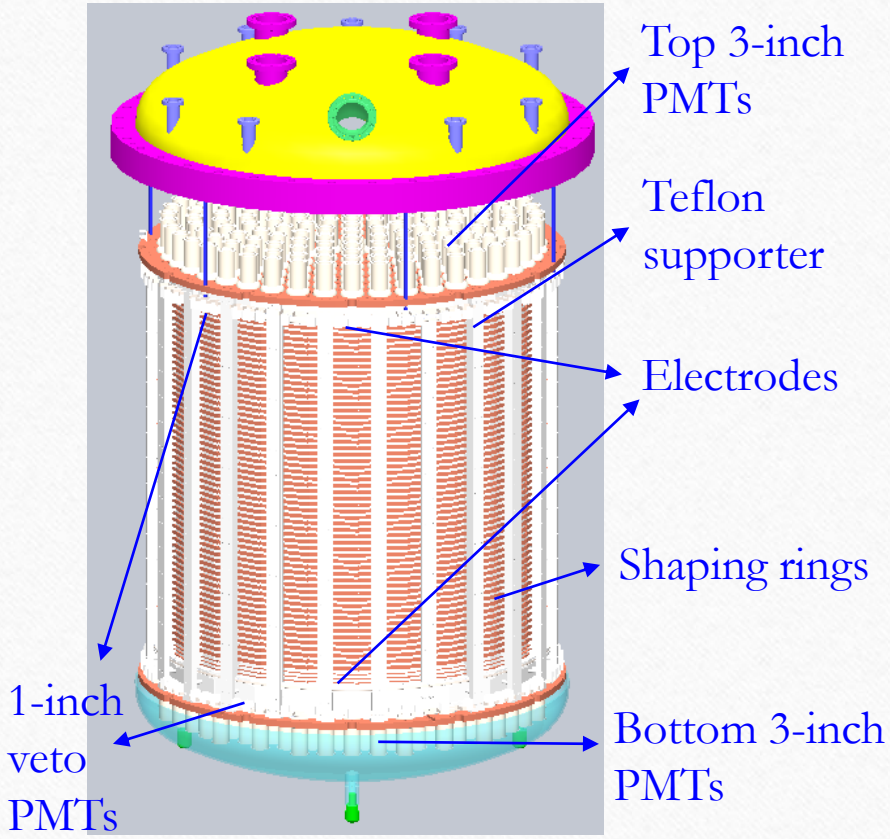


Large scale TPC

- Characteristics:
  - Sensitive region:

    ~4-ton Xenon
  - Drift region:

    Φ~1.2m, H~1.2m
- Challenges:
  - 1.2m-scale large and uniform electric field
  - High signal efficiency and low background
  - Large amount of Xe handling



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TPC-electric field

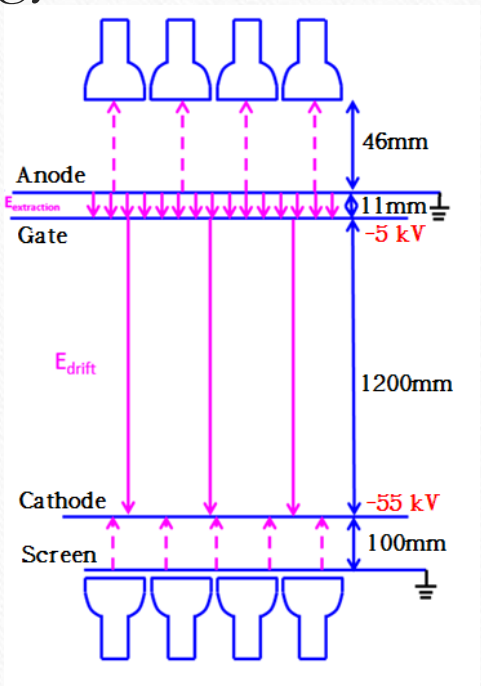
- Strong and uniform electric field in a large volume

  -for better ER/NR discrimination, position and energy resolution

- Based on experience from PandaX-I&II

Drift Field (V/cm)	Design	Actual run
LUX	400	180
XENON1T	400	120
PandaX-II	400	400

- Four electrodes: anode, gate, cathode and screen
- Shaping rings for uniformity



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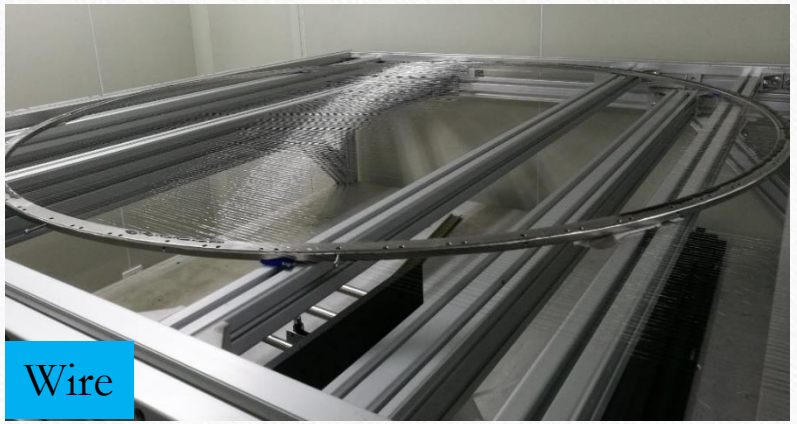
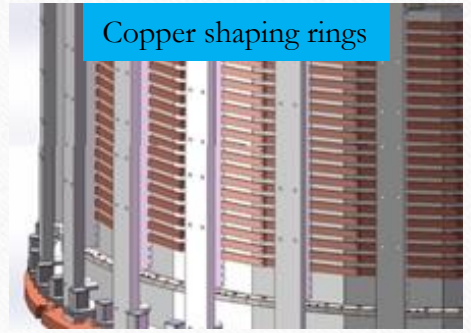
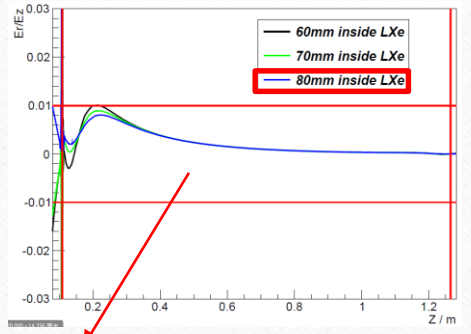
TPC-electrodes and shaping rings

- Electrodes: Φ1.2m mesh and wire
- High light transparency (>85%)
- Small deformation ~1mm


Mesh


Wire


Copper shaping rings



- Electric field is shaped by shaping rings (deformation inside FV< 1%)

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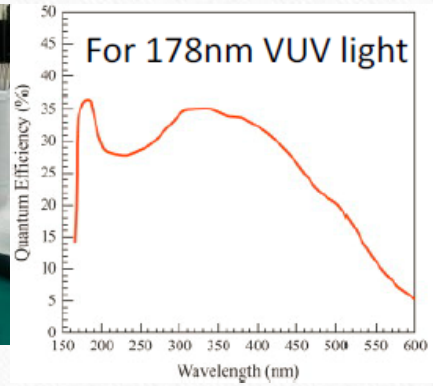
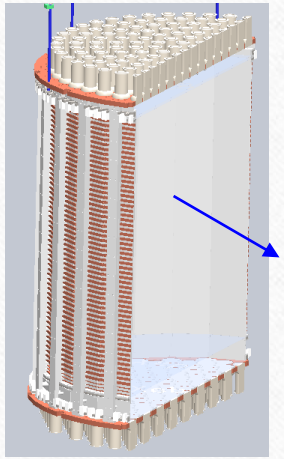
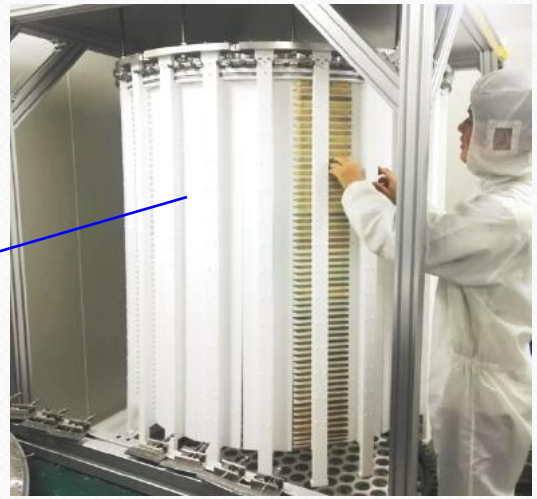
TPC-photon collection

- PMTs for signals: 3-inch Hamamatsu R11410
  - 169 pieces in circular array@top
  - 199 pieces in hexagonal array@bottom
- PTFEs with high reflectivity (>98%@178nm)





PTFE reflectors



Copper plates holding PMT arrays are also covered by PTFEs

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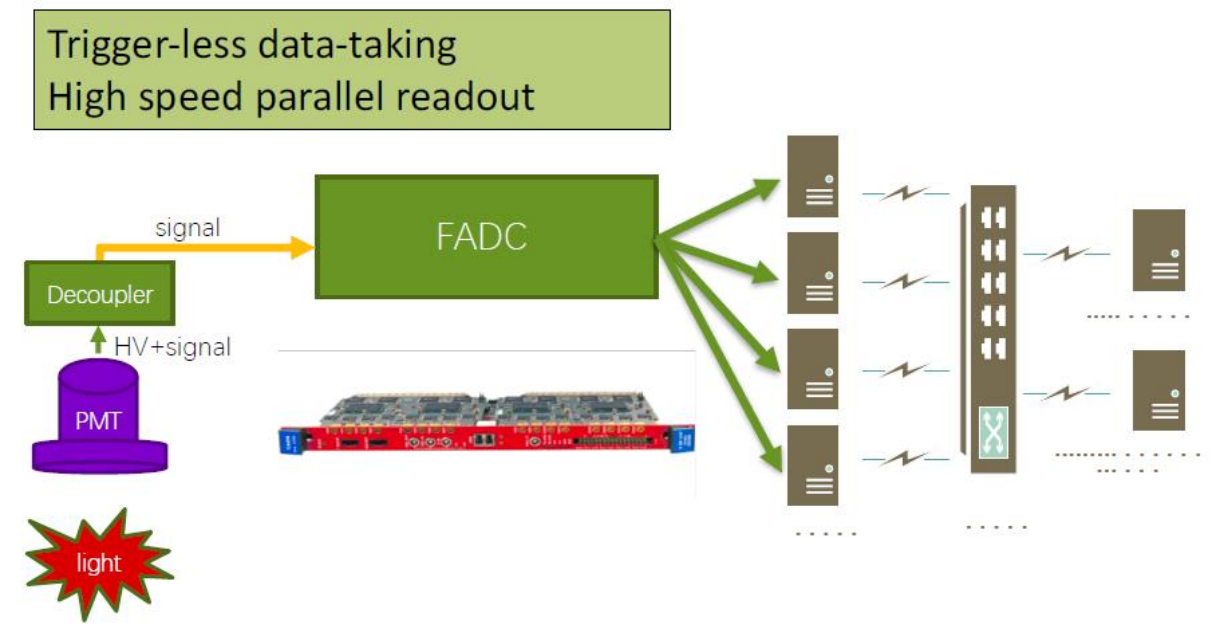
Electronics and DAQ

- 512 channels (including 3” PMT and 1” veto PMT)
- Calibration run 2GB/s, physics run 0.4GB/s



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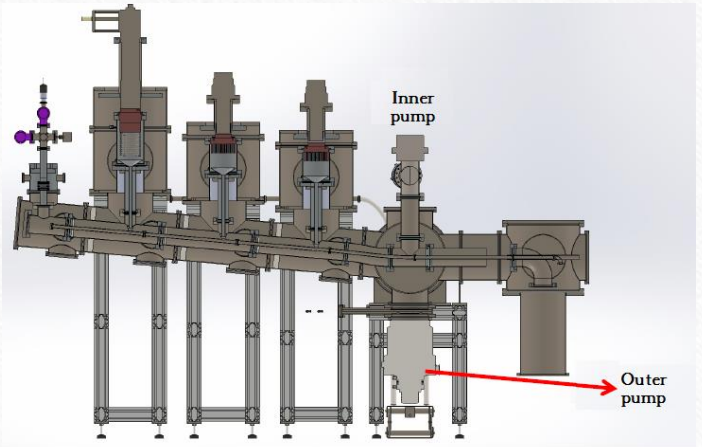
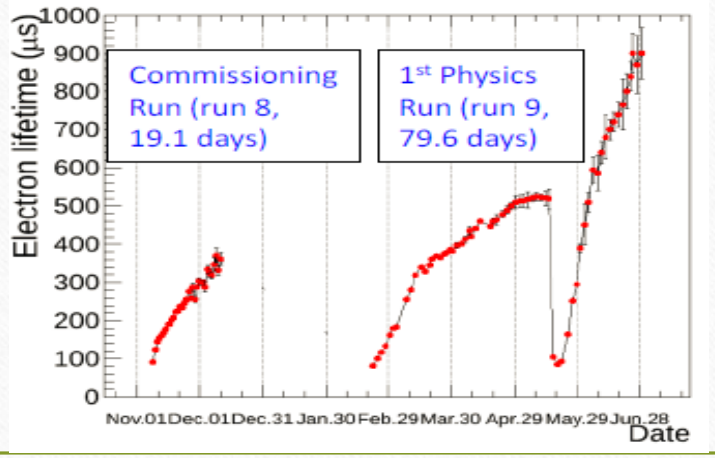
Xenon Storage, Cooling and Purification

- Storage: 6 ton xenon
  - 6 sets 4x4 (50kg, 40L)
  - Filling speed: 600-1000kg/day
- Cooling bus:
  - PandaX-II: one cold head (180W)
  - PandaX-4T: three cold heads (620W)
- Online purification
  - Remove impurities (O2, H_2O)
  - Maintain a high electron life time





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Background Control

- Current background level at PandaX-II: 0.8 mDRU

- For PandaX-4T, proposed background level:
  - Materials: 0.01 mDRU
  - ^{nat}Kr: 0.1 ppt
  - ^{222}Rn: 1 μBq/kg
  - **Total ER background: 0.04 mDRU**
  - **Total NR background: 0.5 event/ton/year**

Ultra-low radioactivity measurement device

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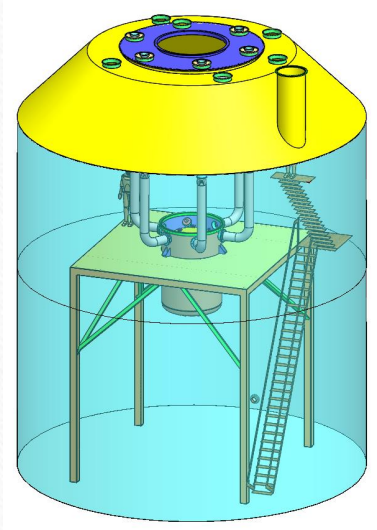
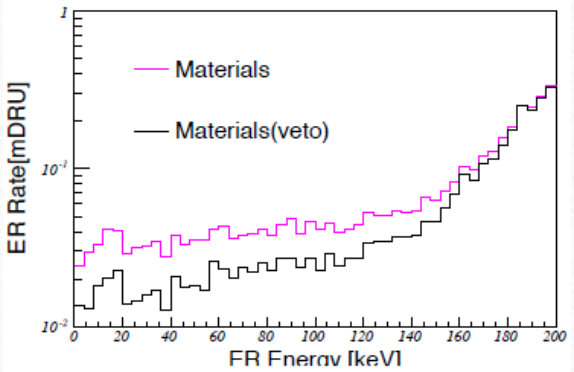
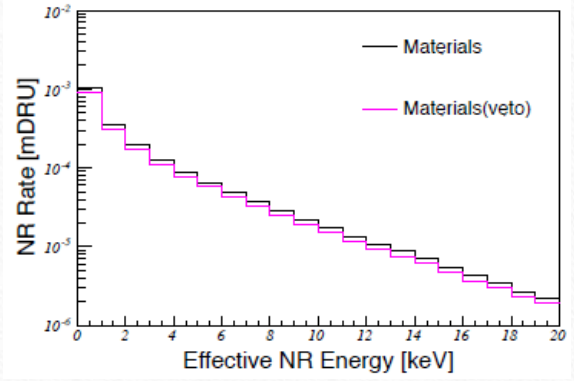
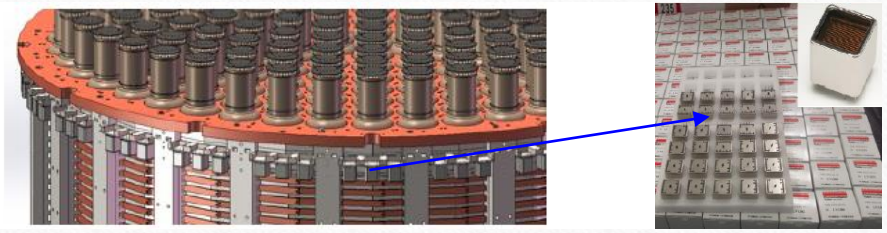
Background Control

- 5m pure water shielding
- Low radioactive materials
  - Obtaining the lowest 60Co in SS
- Veto PMTs outside TPC
  - Assume 60 keV_{ee} veto threshold
  - Suppress 60% ER bkg, 15% NR bkg









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^{85}Kr and ^{222}Rn Control

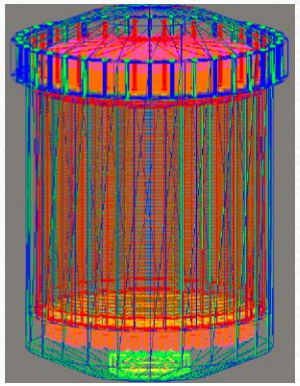
- ^{85}Kr level control

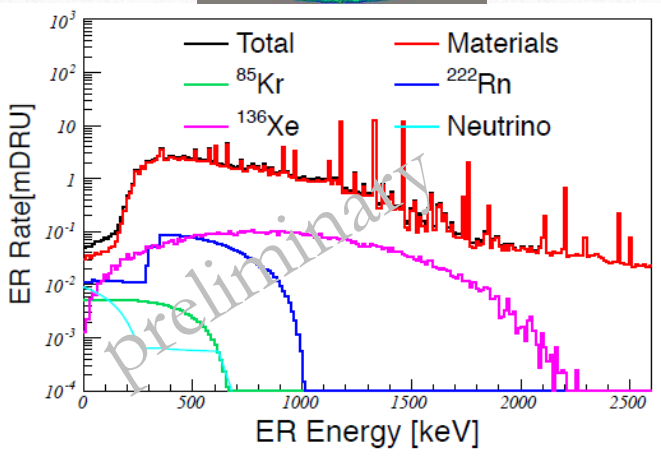
PandaX-II	Run 8	Run 9	Run 10
Kr level	437 ± 13 ppt	44.5 ± 6.2 ppt	6.6 ± 2.2 ppt

  - Distillation tower at CJPL -> ^{nat}Kr below 0.1ppt
  - ^{nat}Kr measurement system -> 0.1-0.01ppt sensitivity

- ^{222}Rn level control
  - Current PandaX-II level: 8.6μBq/kg (primarily from plumbing)
  - Rn filtration/distillation plan in consideration
  - Use Rn emanation measurement chamber to screen components
  - The goal is to reach 1μBq/kg

Background Simulation



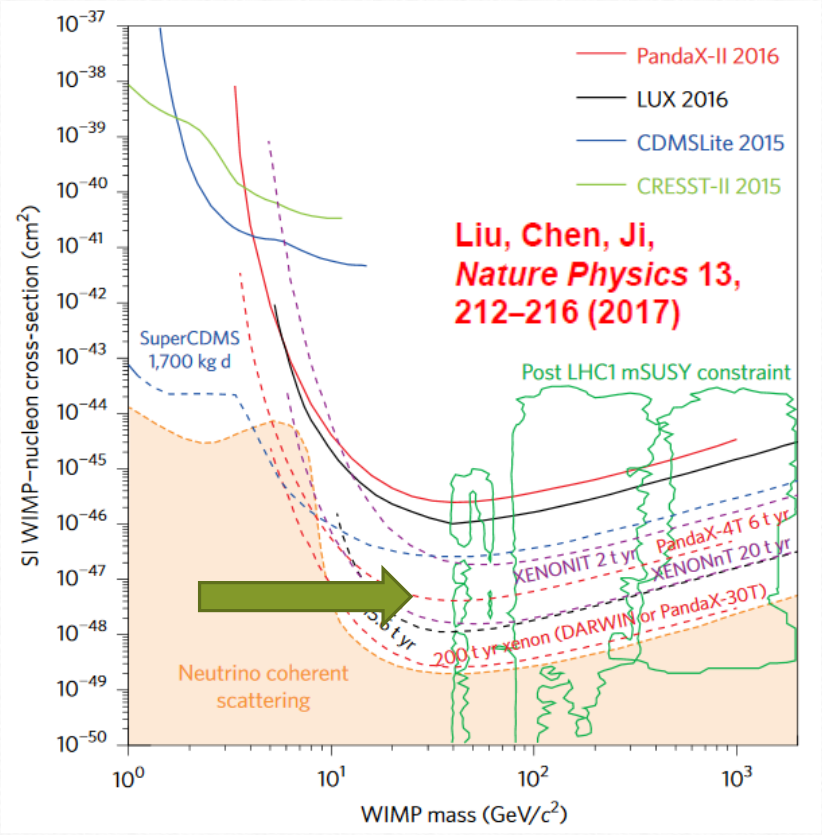


Assuming ^{nat}Kr ~ 0.1 ppt, ^{222}Rn ~1 μBq/kg

Dark Matter Background with Veto		
Source	ER in mDRU	NR in mDRU
Materials	0.0118±0.0021	0.00006± 0.00006
^{222}Rn	0.0114±0.0012	-
^{85}Kr	0.0053±0.0011	-
^{136}Xe	0.0023±0.0003	-
Neutrino	0.0090±0.0002	0.00008± 0.00004
Sum	0.040 ±0.003	0.00014± 0.00007
2-year yield	832.2± 62.4	2.9±1.5
after selection	2.1±0.2	1.2±0.6

Expected Sensitivity

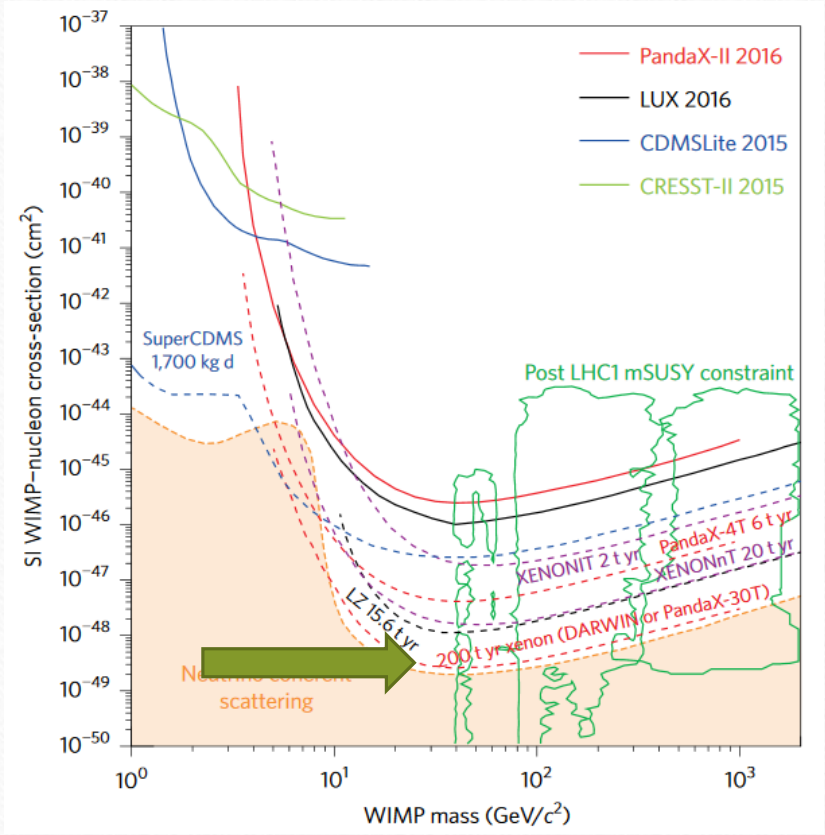
- With exposure reaching 6 ton-year
- DM SI sensitivity could reach ~10^{-47}cm^2



Outlook-PandaX-30T

- To reach the neutrino floor with

  200 ton-year exposure
- Diameter 2.4m
- Height 2.4m
- Sensitive volume: 30 ton



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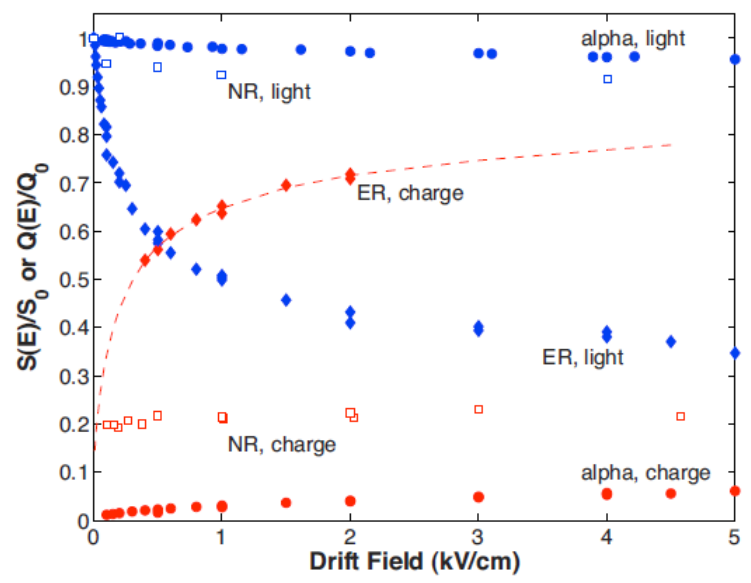
Summary

- PandaX-II has reached the world frontier of dark matter direct detection.
- PandaX-4T, a 4-ton Xenon detector, is under construction based on the successful experience of previous PandaX experiments.
- The sensitivity to SI DM could reach ~10^{-47}cm^2 with 6ton-year exposure.
- Future PandaX-30T is in proposal.

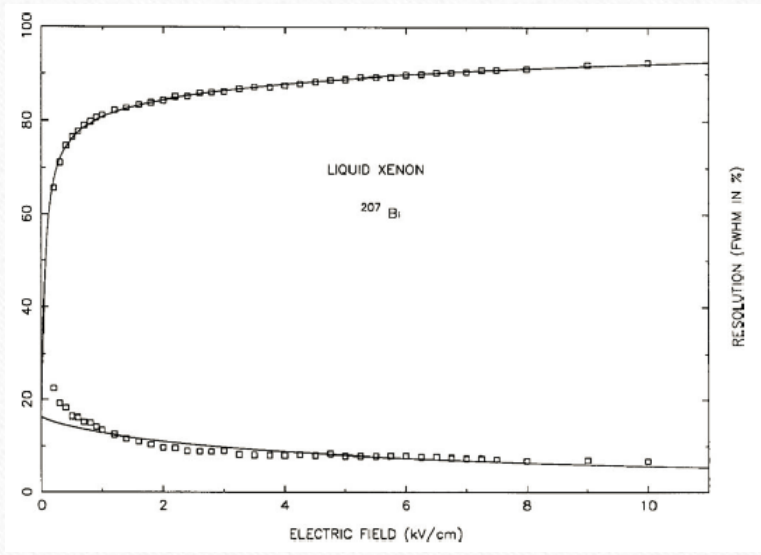
Thank you!

backups

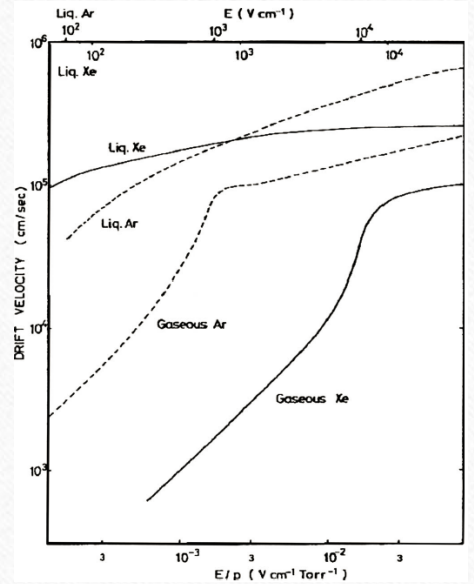
Backup-effect of drift field



Field dependence of scintillation and ionization yield in LXe for 122 keV electron recoils (Ers), 56.5 keV$_r$ nuclear recoils (NRs) and 5.5 MeV alphas, relativeto the yield with no drift field (*Aprile et al., 2006*).



Energy resolution and collected charge for 570 keV gamma rays in LXe as a function of electric field (*Aprile, Mukherjee, and Suzuki, 1991a*).



Electron drift velocity in gaseous and liquid xenon and argon, as a function of reduced electric field (Pack *et al.*,, 1962; Miller *et al.*,, 1968; Yoshino *et al.*,, 1976).

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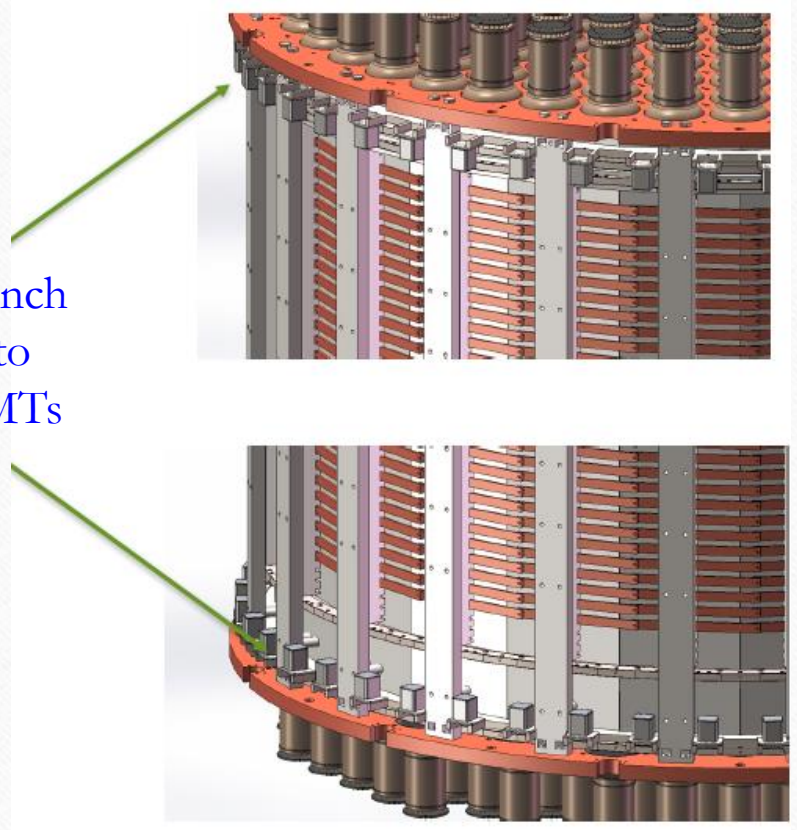
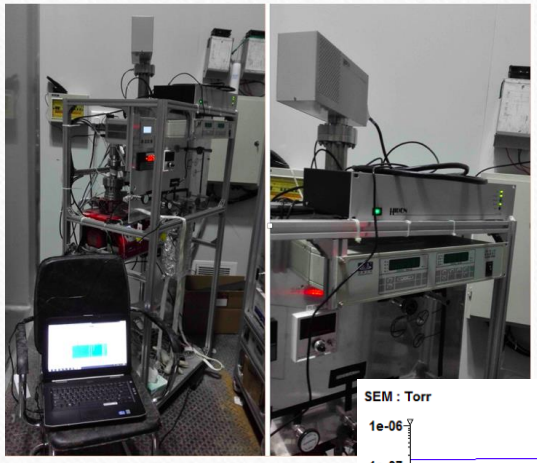
Veto volume

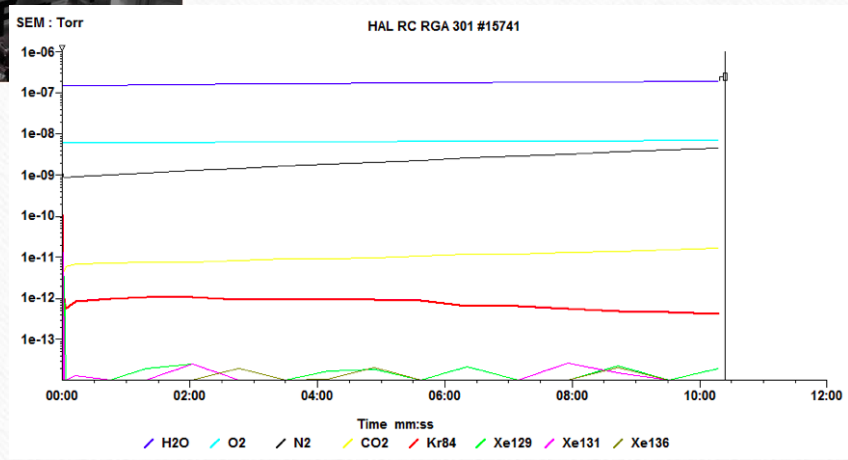
- Xenon in skin area: 0.5 ton
- Suppress gamma background
  - Compton scatter in skin area
  - 50% veto efficiency
- 1-inch R8520 PMTs
  - 72 top and 72 bottom



Xenon purity measurement

1. **目标**
   - 测量氙中杂质气体至**<0.1PPT**
2. **主要技术措施**
   - 低温**冷阱法**
   - 高性能RGA（Hiden）
     - 灵敏度比SRS的RGA提高200倍
3. **目前状态**
   - 系统净化。
   - Hiden-RGA调试中





PANDA X

上海交通大學 SHANGHAI JIAO TONG UNIVERSITY

Background level in PandaX-II

Item	Run 9 (mDRU)	Run 10 (mDRU)
^{85}Kr	1.19 ± 0.20	0.20 ± 0.07
^{127}Xe	0.42 ± 0.10	0.021 ± 0.005
^{3}H	0	0.27 ± 0.08
^{222}Rn	0.13 ± 0.07	0.12 ± 0.06
^{220}Rn	0.01 ± 0.01	0.02 ± 0.01
ER (material)	0.20 ± 0.10	0.20 ± 0.10
Solar ν	0.01	0.01
^{136}Xe	0.0022	0.0022
Total	1.96 ± 0.25	0.79 ± 0.16