PandaX Liquid Xe TPC for Dark Matter Direct Detection at CJPL

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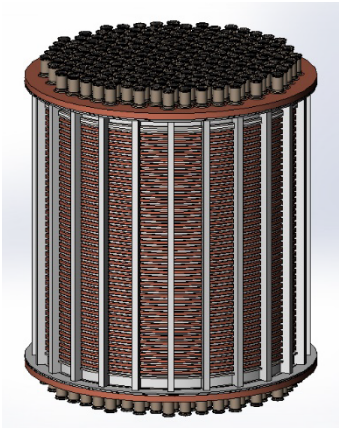
Shanghai Jiao Tong University, April 26, 2019

PandaX: Particle and Astrophysical Xenon TPC

PandaX-I: 120kg LXe
(2009 – 2014)

PandaX-II: 500kg LXe
(2014 – 2018)

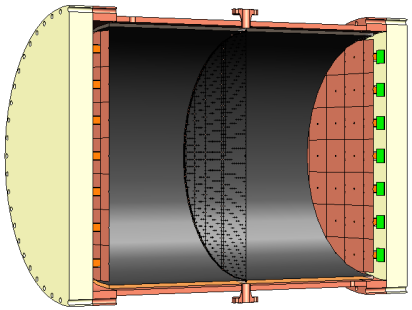


PandaX-xT LXe
(Future)

Dark matter WIMP searches

Exploring the invisible Universe from deep underground

- Physics beyond the Standard Model.
- Interconnects particle physics, nuclear physics, cosmology, and astrophysics.



PandaX-III:
200kg - 1 ton HPXe (Future)

0νββ searches

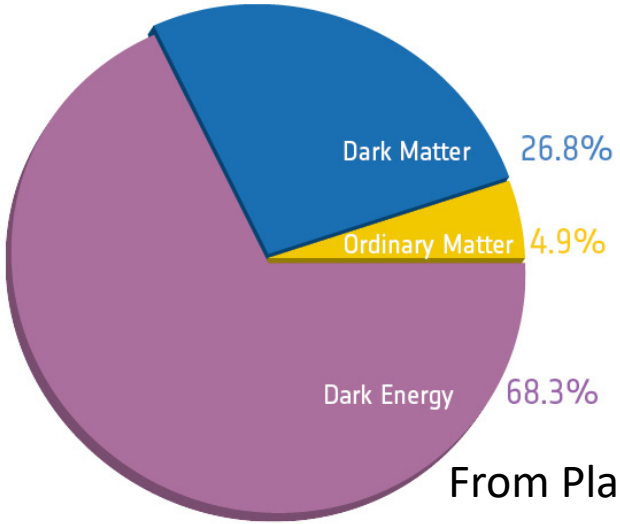
PandaX Collaboration

PANDA X
PARTICLE AND ASTROPHYSICAL XENON TPC

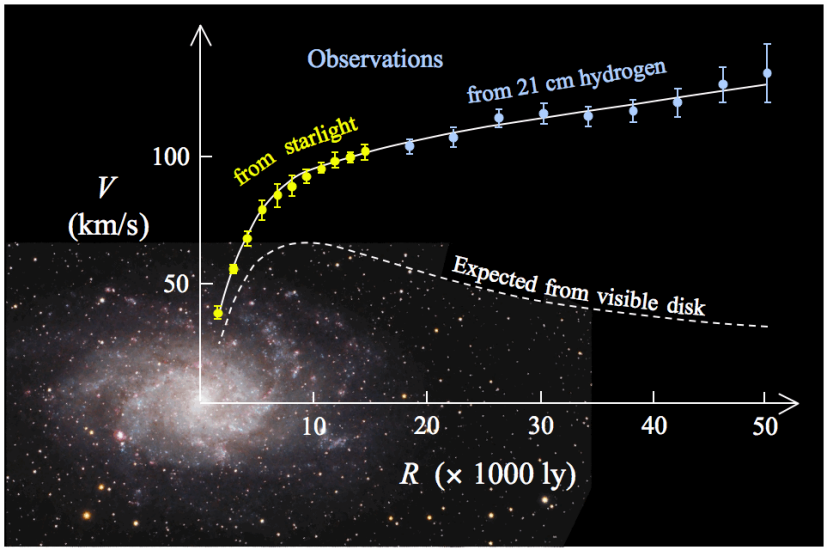
- Shanghai Jiao Tong University
- Peking University
- Shandong University
- Nankai University
- Shanghai Institute of Applied Physics
- Yalong Hydropower Company
- University of Science & Technology of China
- China Institute of Atomic Energy
- Sun Yat-Sen University
- Central China Normal University
- University of Maryland
- Lawrence Berkeley National Lab
- CEA Saclay
- University of Zaragoza
- Suranaree University of Technology

PANDA X

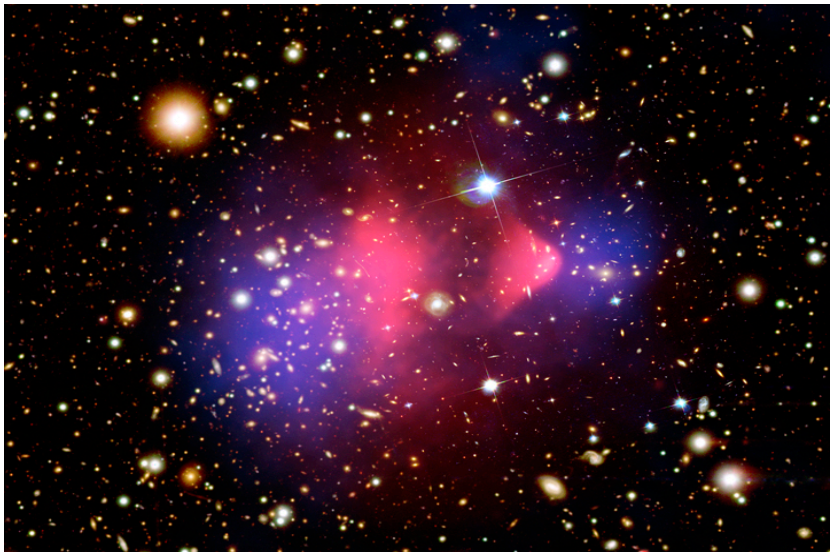
Dark Matter



From Planck

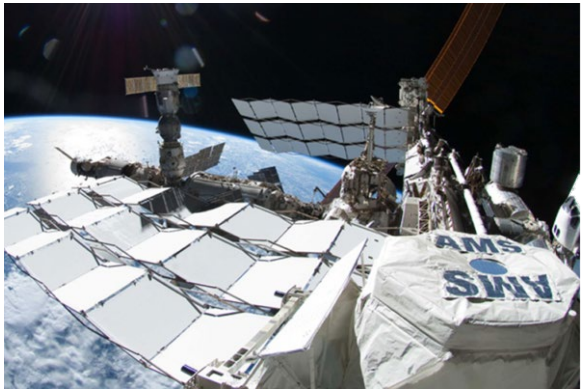


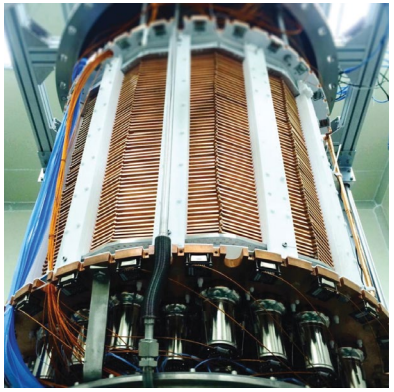
- Existence of dark matter is firmly established
- Particle nature of dark matter?
  - WIMP?

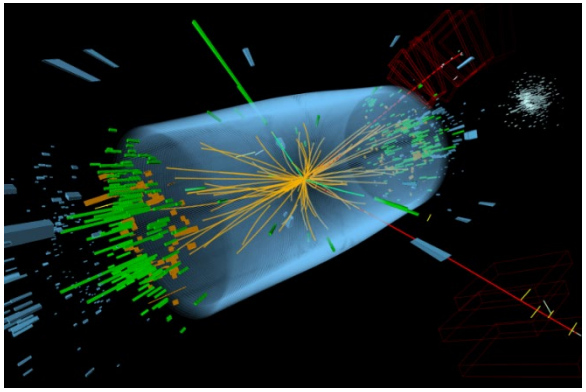


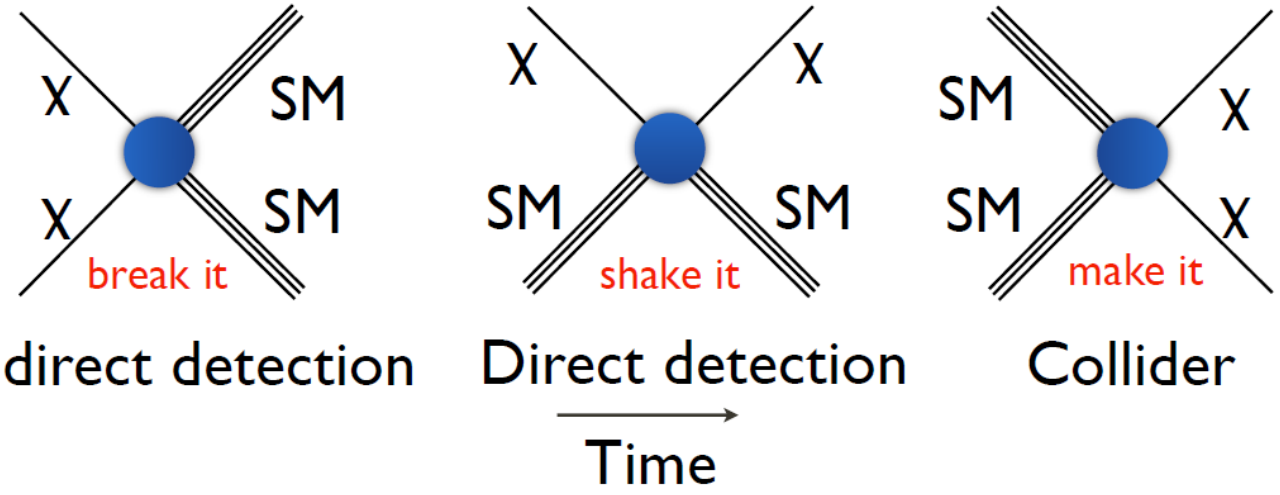
X-ray image (pink) superimposed over a visible light image (galaxies), with matter distribution calculated from gravitational lensing (blue).

WIMP searches









Tracy Slatyer

Direct detection: DM: velocity ~1/1500 c, mass ~100 GeV, KE ~ 20 keV
Nuclear recoil (NR): recoiling energy ~10 keV

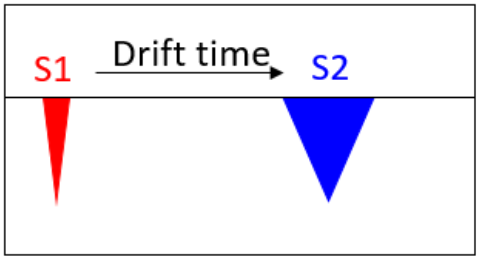
Dual phase Xe TPC for dark matter

PANDA X
PARTICLE AND ASTROPHYSICAL XENON TPC

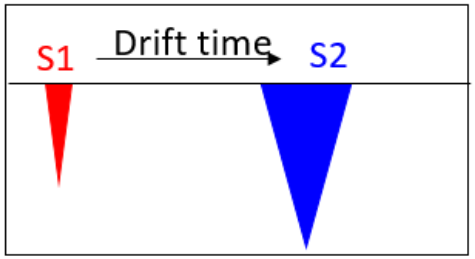
PandaX WIMP direct detection

- **PandaX-I**: 2009-2014
- **PandaX-II**: 2014-2018
  - 60 cm x 60 cm dual-phase xenon TPC
  - 580 kg LXe in sensitive volume
- Dual-phase xenon detectors:
  - Large monolithic target
  - 3D reconstruction and fiducialization
  - Good ER/NR rejection
  - Calorimeter capable of seeing a couple of photons/electrons

Dark matter: nuclear recoil (NR)



γ background: electron recoil (ER)



$$(S2/S1)_{NR} << (S2/S1)_{ER}$$

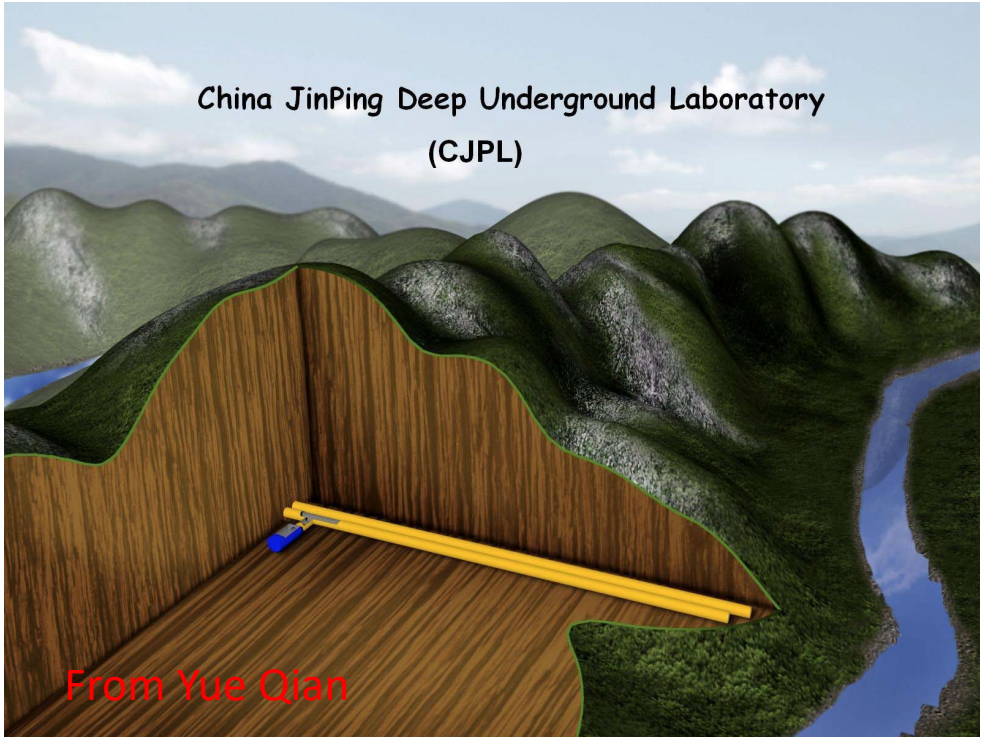
Phase I: 120 kg

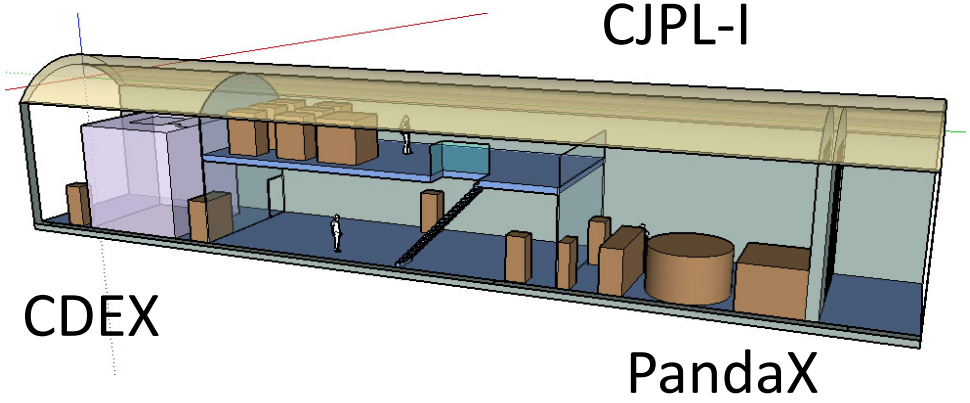
2009-2014

Phase II: 580 kg

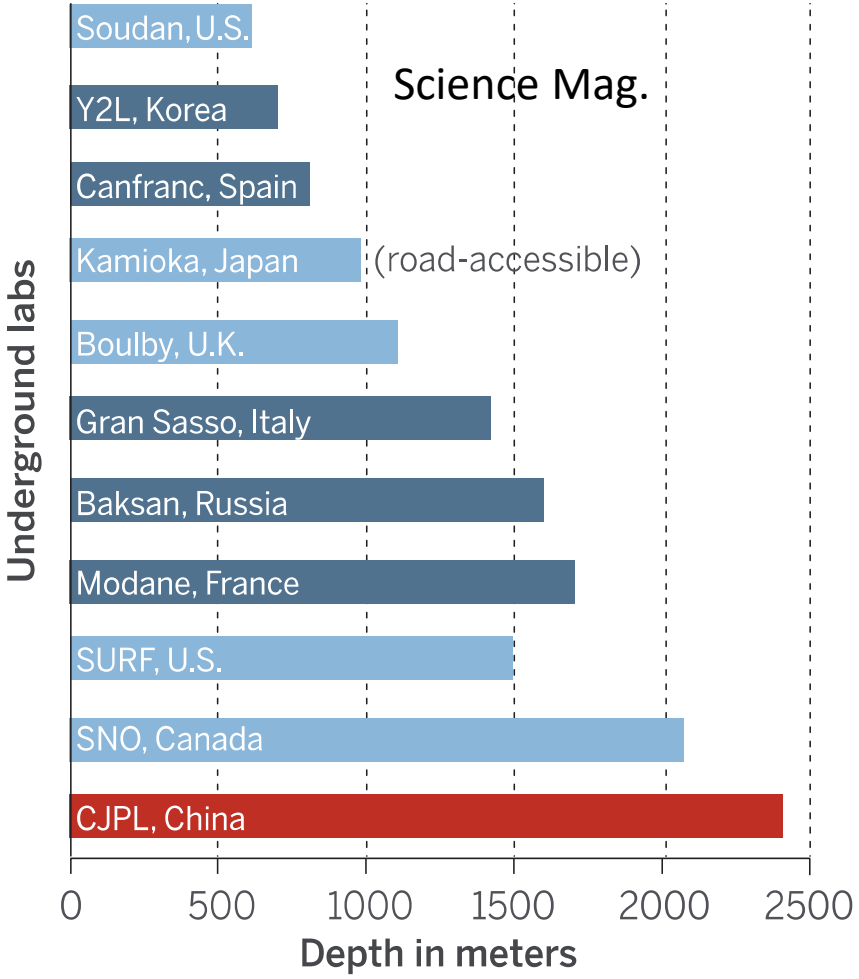
2014-2018

CJPL: – Deepest underground lab in the world



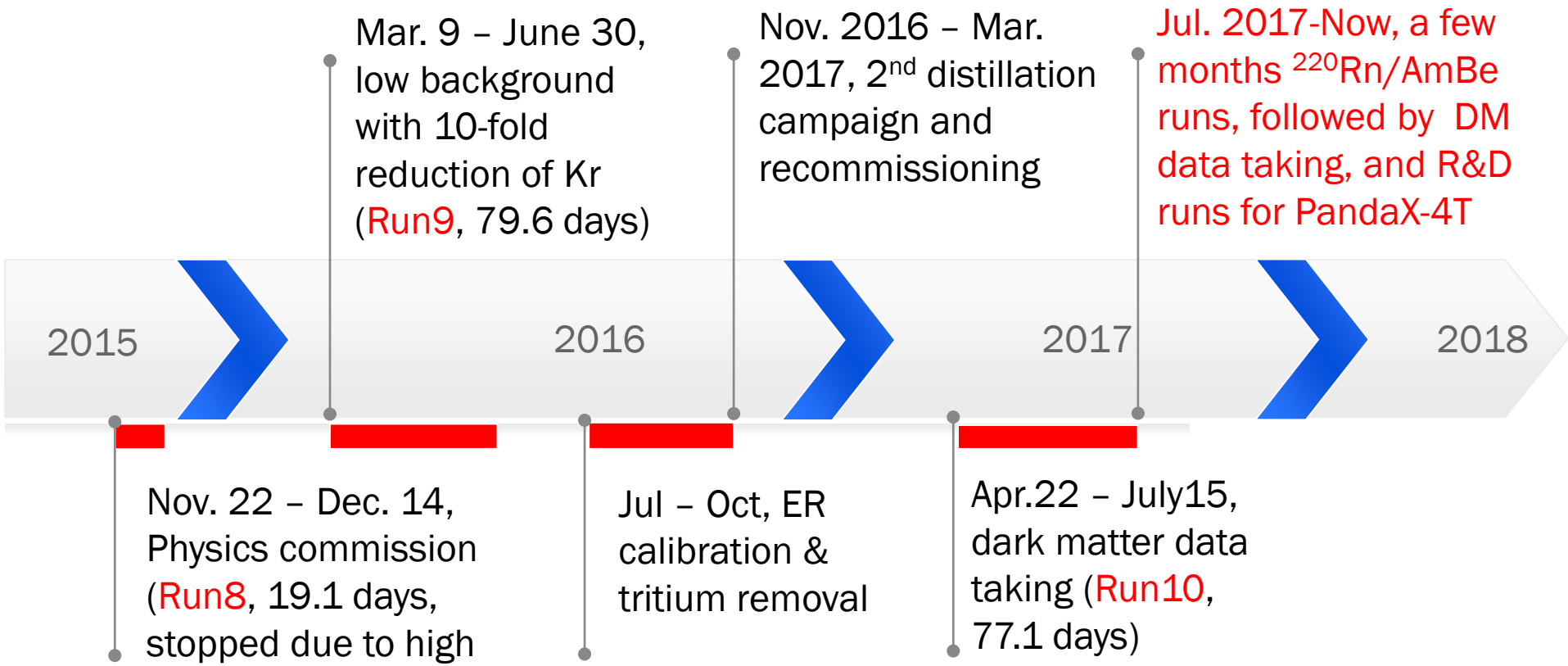


Labs are built in mines (light blue) and tunnels (dark blue and red).

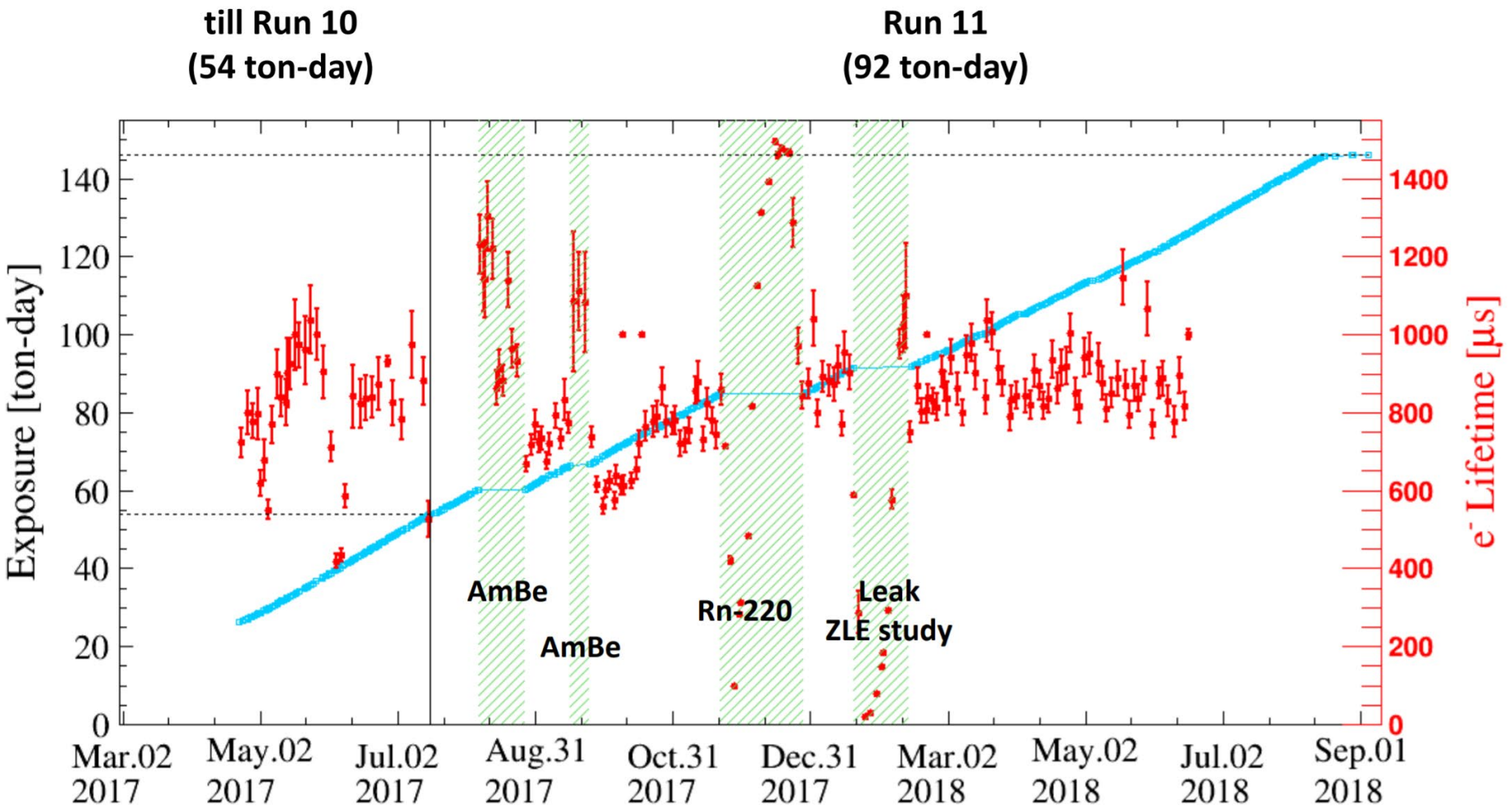


PandaX-II Run Status

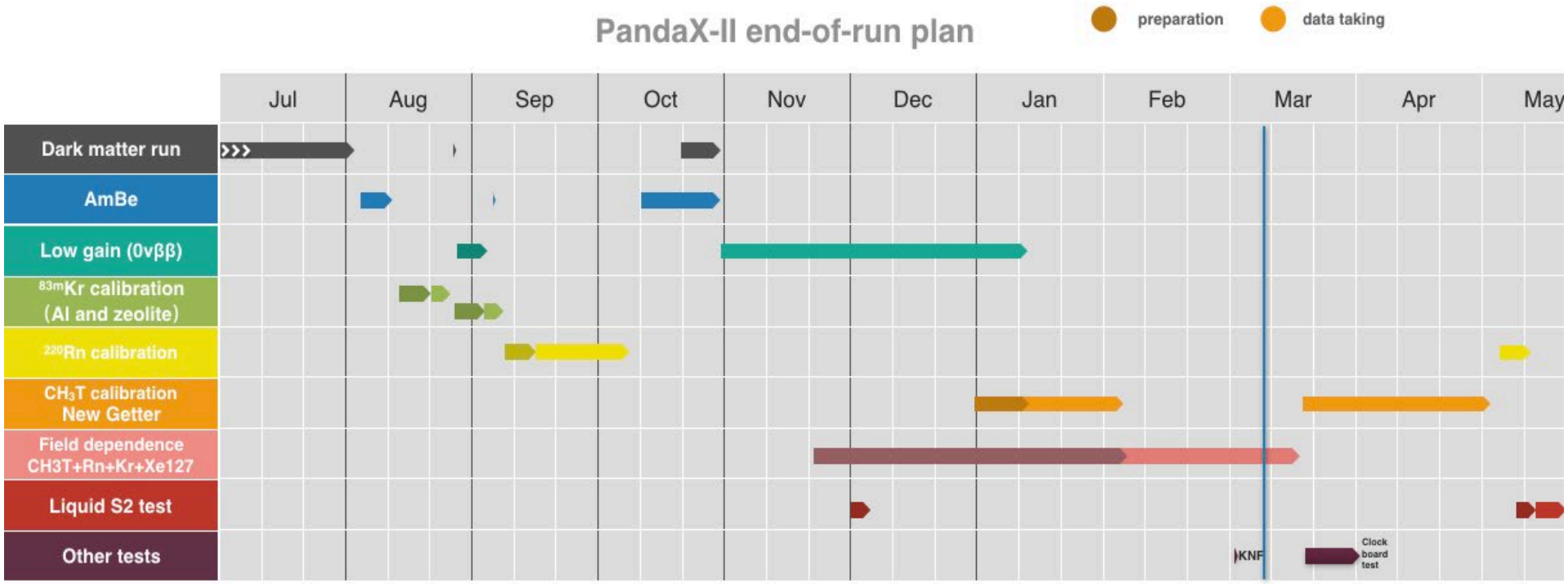
- Run9 =79.6 days, exposure: 26.2 ton-day
- Run10 = 77.1 days, exposure: 27.9 ton-day
- Run11 ~ 254 days, exposure ~ 92 ton-day



Run 11 details

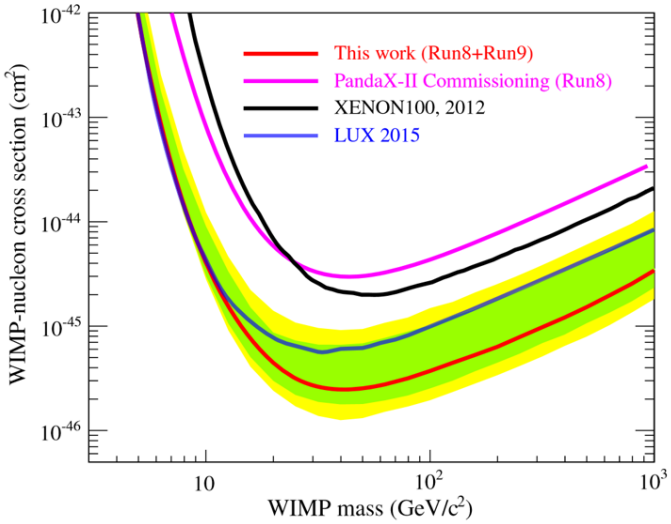


R&D runs since August 2018



Highlights of PandaX-II Results

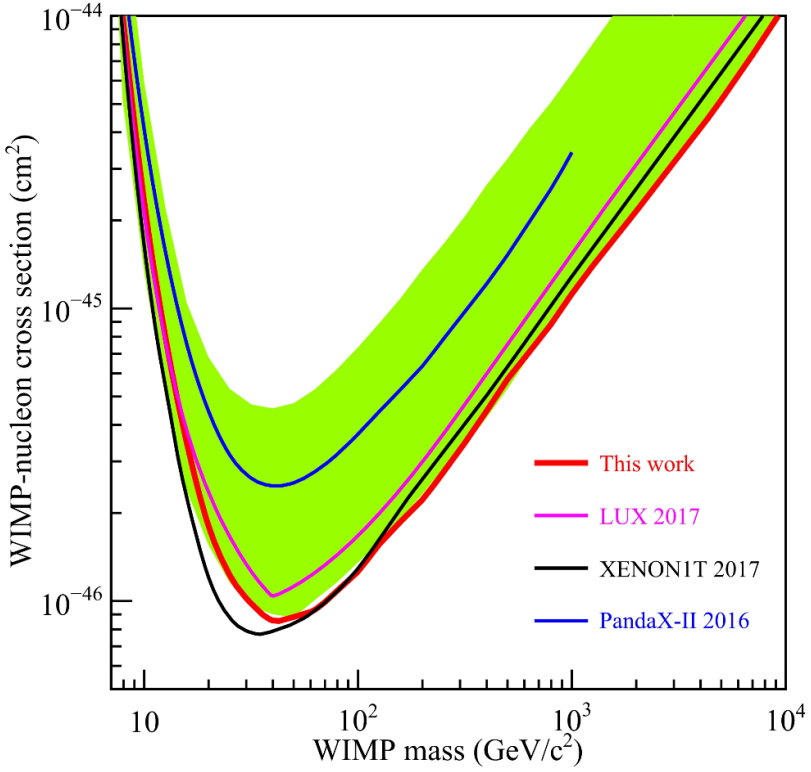
- 33 ton-day: spin independent search, **PRL 117, 121303 (2016)**

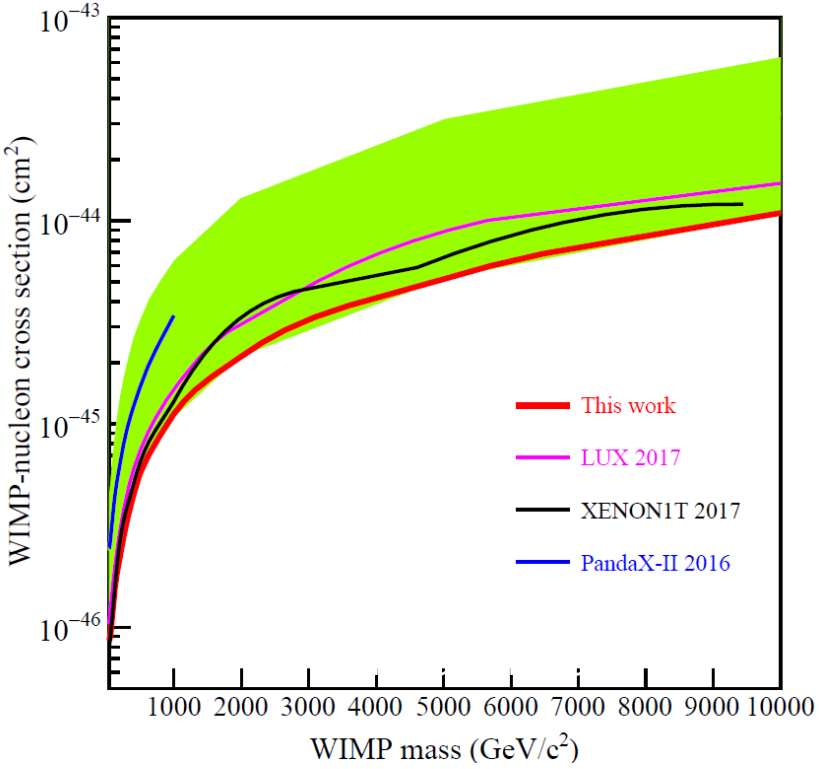


- 33 ton-day: spin dependent search, **PRL 118, 071301 (2017)**
- 27 ton-day: inelastic scattering search, **PRD 96, 102007 (2017)**
- 27 ton-day: Axion and ALP search, **PRL 119, 181806 (2017)**
- 54 ton-day: spin independent search, **PRL 119, 181302 (2017)**
- 54 ton-day: light mediator search, **PRL 121, 021304 (2018)**
- 54 ton-day: general EFT and spin-dependent search, **PLB 792, 193(2019)**

WIMP-nucleon SI result update

PRL 119, 181302 (2017)





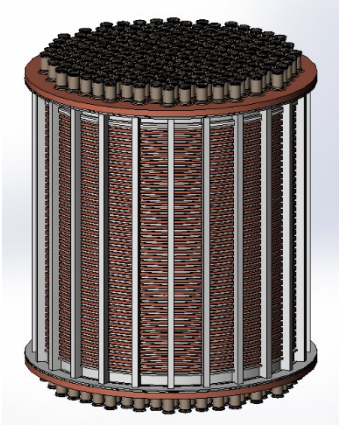
- Improved from PandaX-II 2016 limit about 2.5 times for >30GeV/c^2
- Lowest exclusion at 8.6×10^{-47}cm^2 at 40GeV/c^2
- Most stringent limit for WIMP-nucleon cross section for mass >100GeV/c^2 when published

Next PandaX LXe TPC

PandaX-I: 120kg LXe
(2009 – 2014)

PandaX-II: 500kg LXe
(2014 – 2018)

CJPL-I

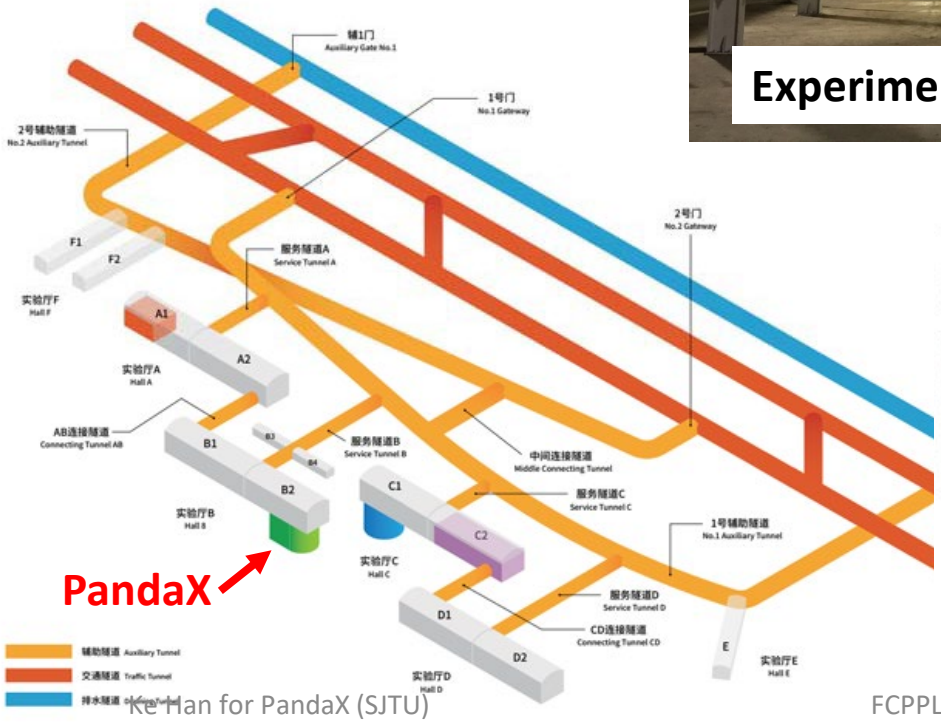


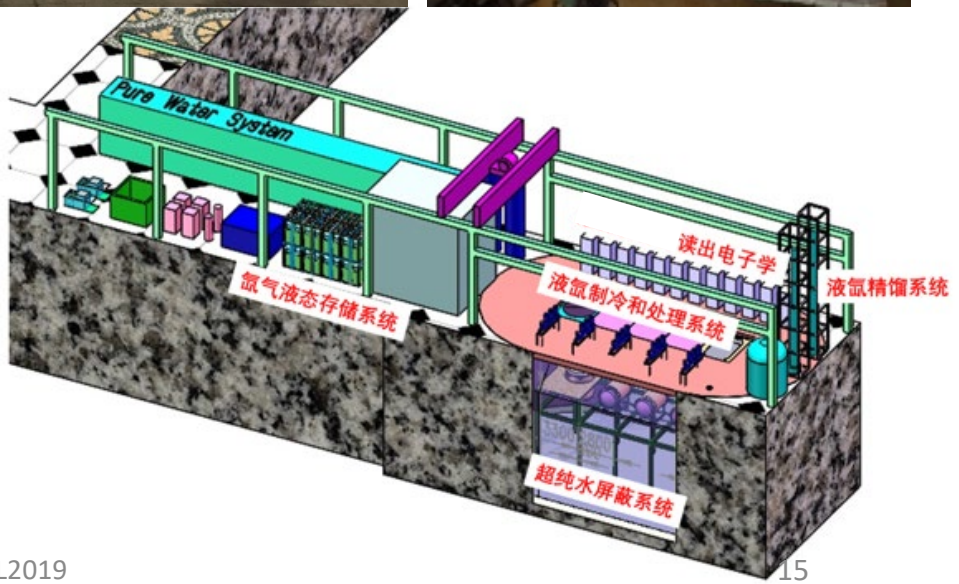
PandaX-xT LXe
(Future)

CJPL-II

New Experiment Hall at CJPL-II

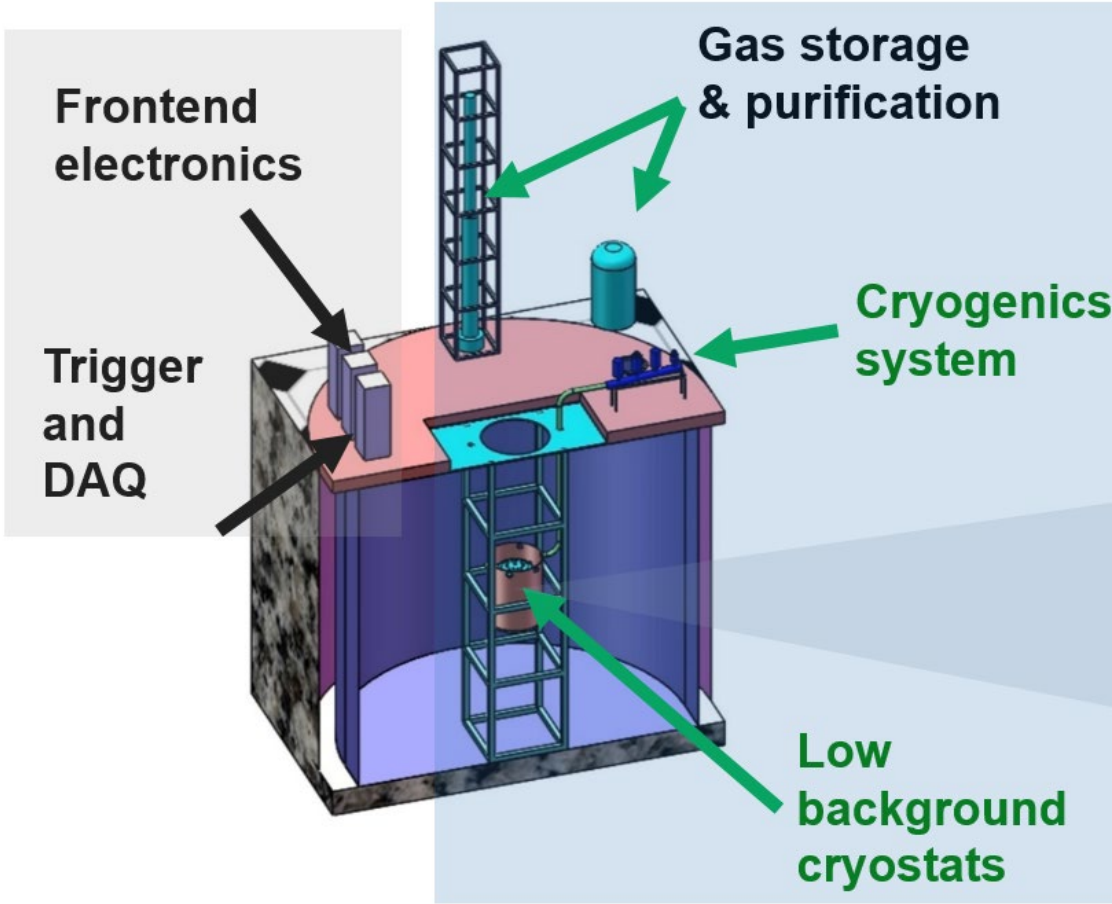
- B2 Hall
- 14m(H)x14m(W)x65m(L)
- Water Shielding
  - 5000 Ton pure water
  - U/Th <10^{-14} g/g





DM direct direction next step: PandaX-xT

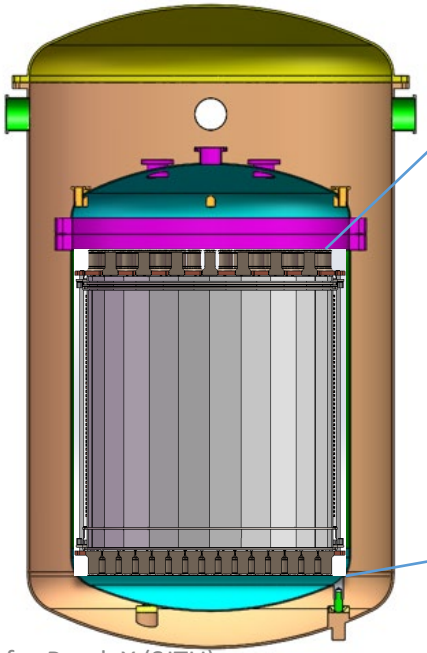
- Larger TPC with more detector mass
- Ultra-pure water shielding
  - 5 m of water shielding in all directions
- Online xenon purification

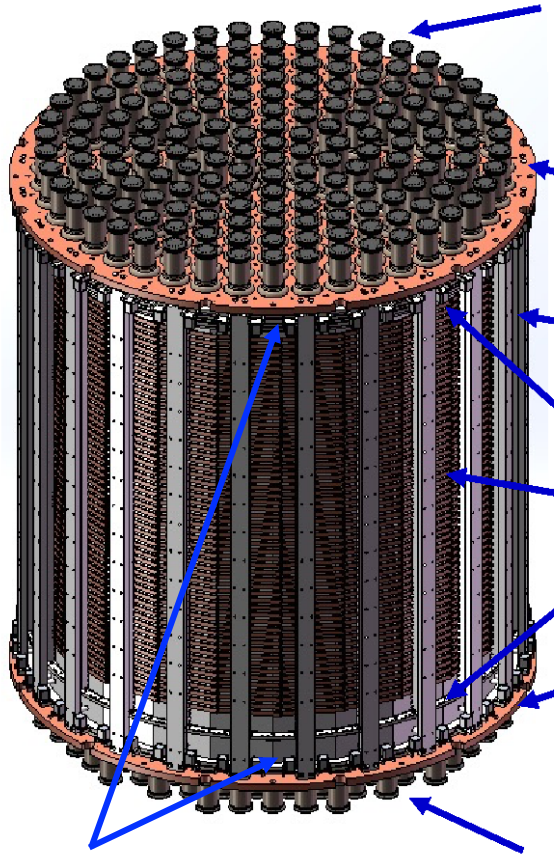


- Intermediate stage:
  - **PandaX-4T** (4-ton target) with SI sensitivity ~10^{-47} cm^2

PandaX-4T Large Scale TPC

- Drift region: Φ~1.2m, H~1.2m
  - Xenon in sensitive region ~ 4 ton, drift field 400 V/cm
- Design goal:
  - High signal collection efficiency
  - Uniform *E* field in a large volume
  - Veto facility

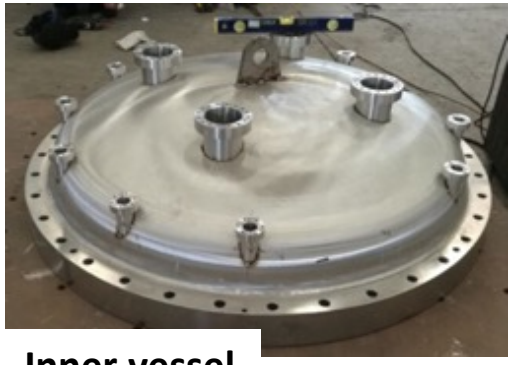




Veto System

Current Status and Schedule

- R&D work-in-progress
- 2019-2020: assembly and commissioning

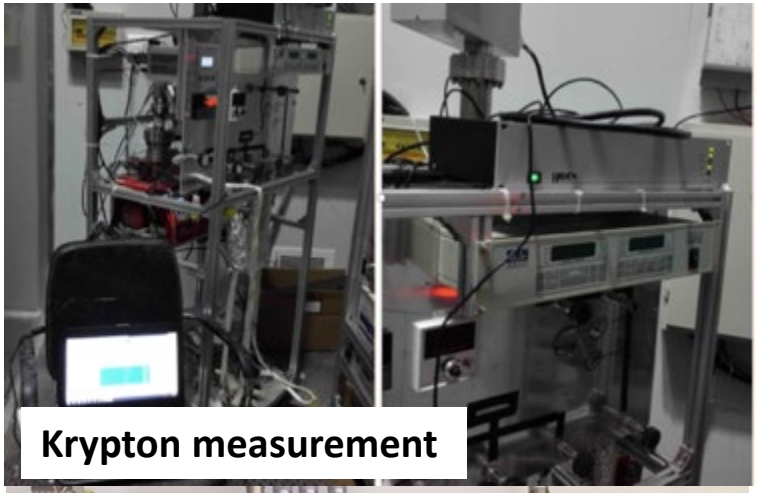


Inner vessel

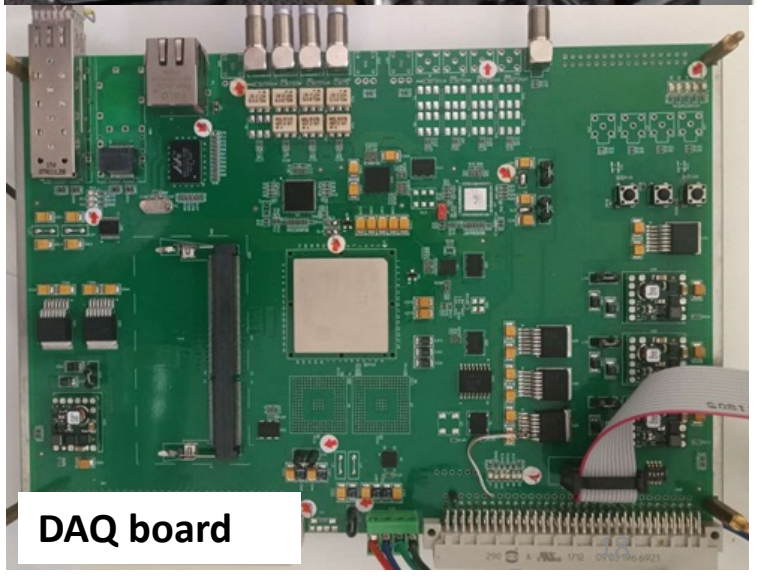
Cooling bus

TPC prototype

PMT test



Krypton measurement



DAQ board

PandaX-4T Sensitivity study

- Simulated ER and NR events
  - Detector materials
  - Radioactivity in xenon: ^{85}Kr, ^{222}Rn, ^{136}Xe
  - Neutrino
- Background in signal region
  - Total ER background: 0.05 mDRU
  - Total NR background: 1 event/year
- With two-year exposure, SI DM-nucleon sensitivity: 10^{-47}cm^2
  - About x10 improvement w.r.t. PandaX-II

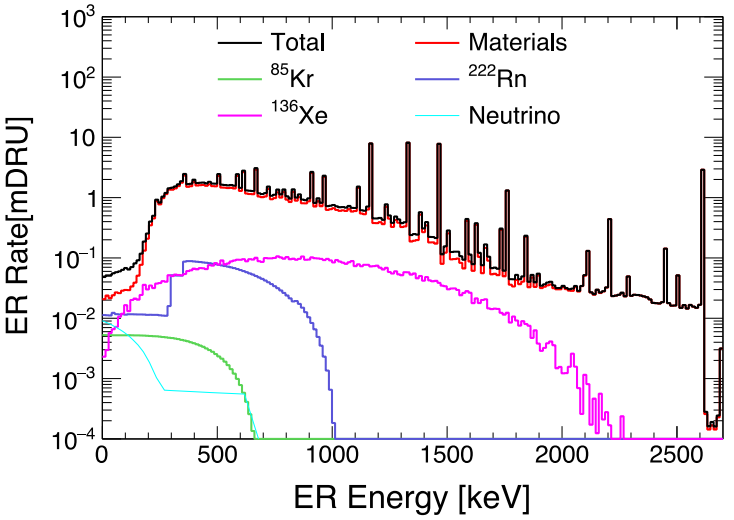
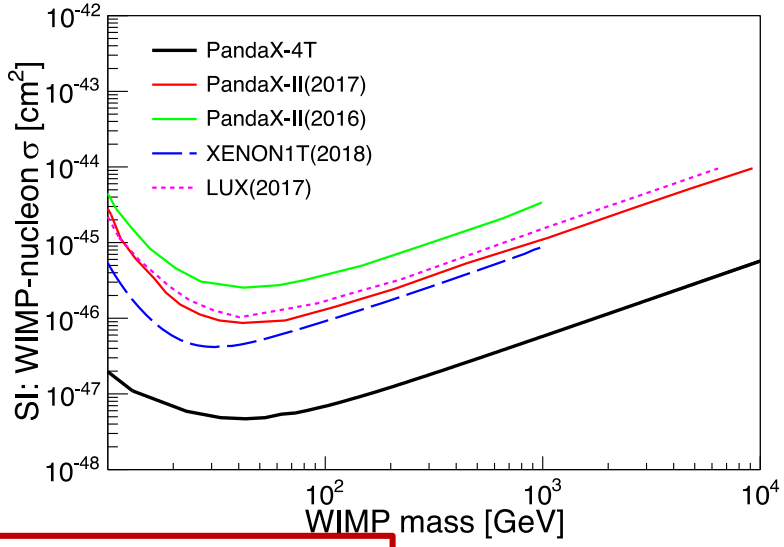


Table 4 Final background budget within the WIMP search window.

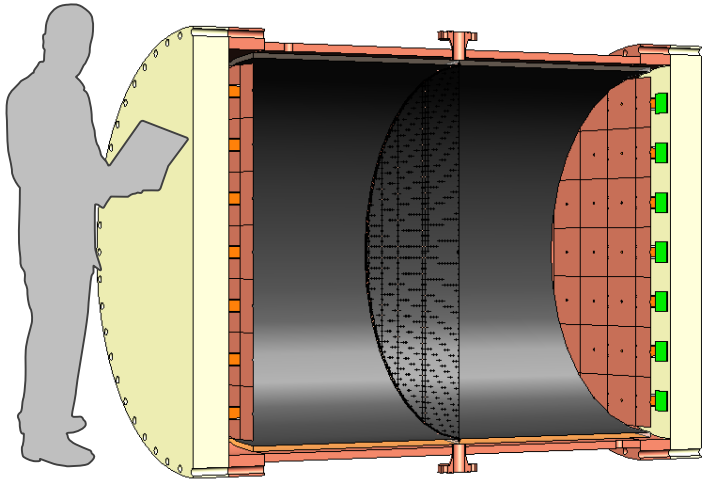
Sources	ER in mDRU	NR in mDRU
Materials	0.0210±0.0042	$2.0 \pm 0.3 \cdot 10^{-4}$
^{222}Rn	0.0114±0.0012	-
^{85}Kr	0.0053±0.0011	-
^{136}Xe	0.0023±0.0003	-
Neutrino	0.0090±0.0002	$0.8 \pm 0.4 \cdot 10^{-4}$
Sum	0.049 ±0.005	$2.8 \pm 0.5 \cdot 10^{-4}$
2-year yield (evts)	1001.6± 102.2	5.7±1.0
after selection (evts)	2.5±0.3	2.3±0.4



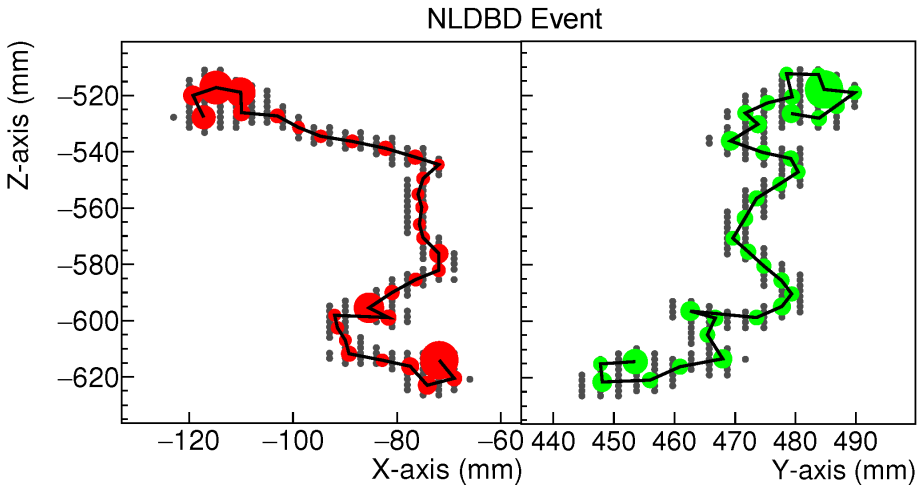
Sci. China-Phys. Mech. Astron. 62 3 (2019)

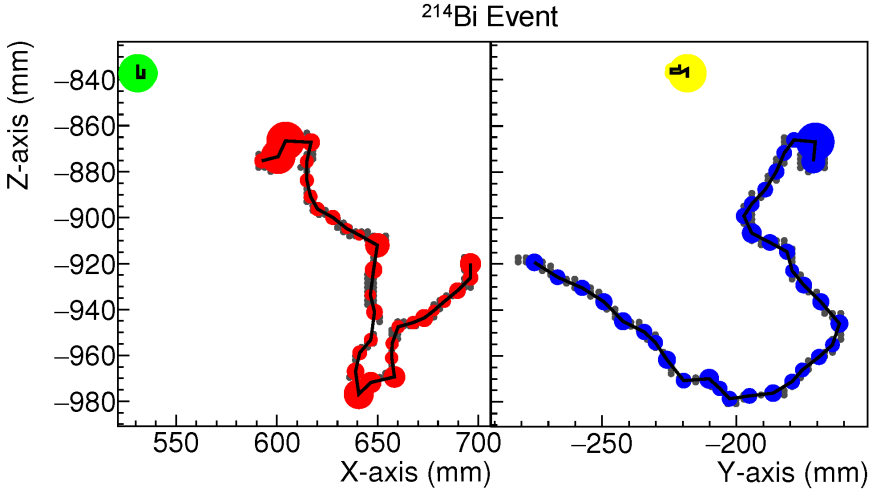
PandaX-III: high pressure gas TPC for 0νββ of ^{136}Xe

- TPC: 200 kg scale, symmetric, double-ended charge readout, with 10 bar of ^{136}Xe
- Main features: good energy resolution and background suppression with tracking



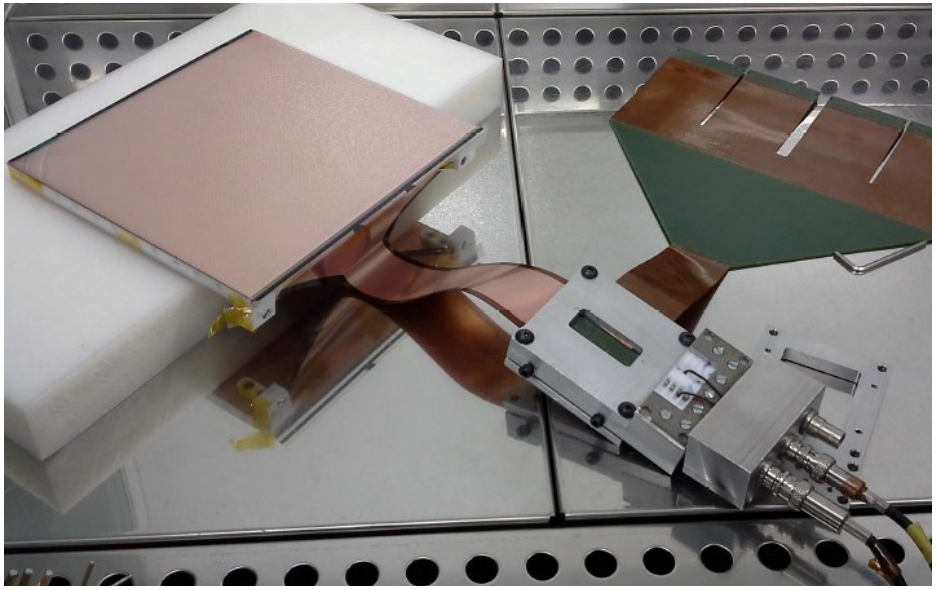
arXiv:1610.08883

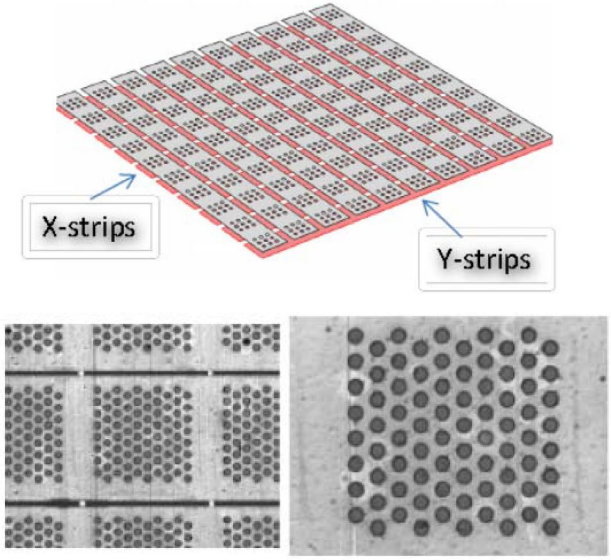




PandaX-III Micromegas work at Saclay

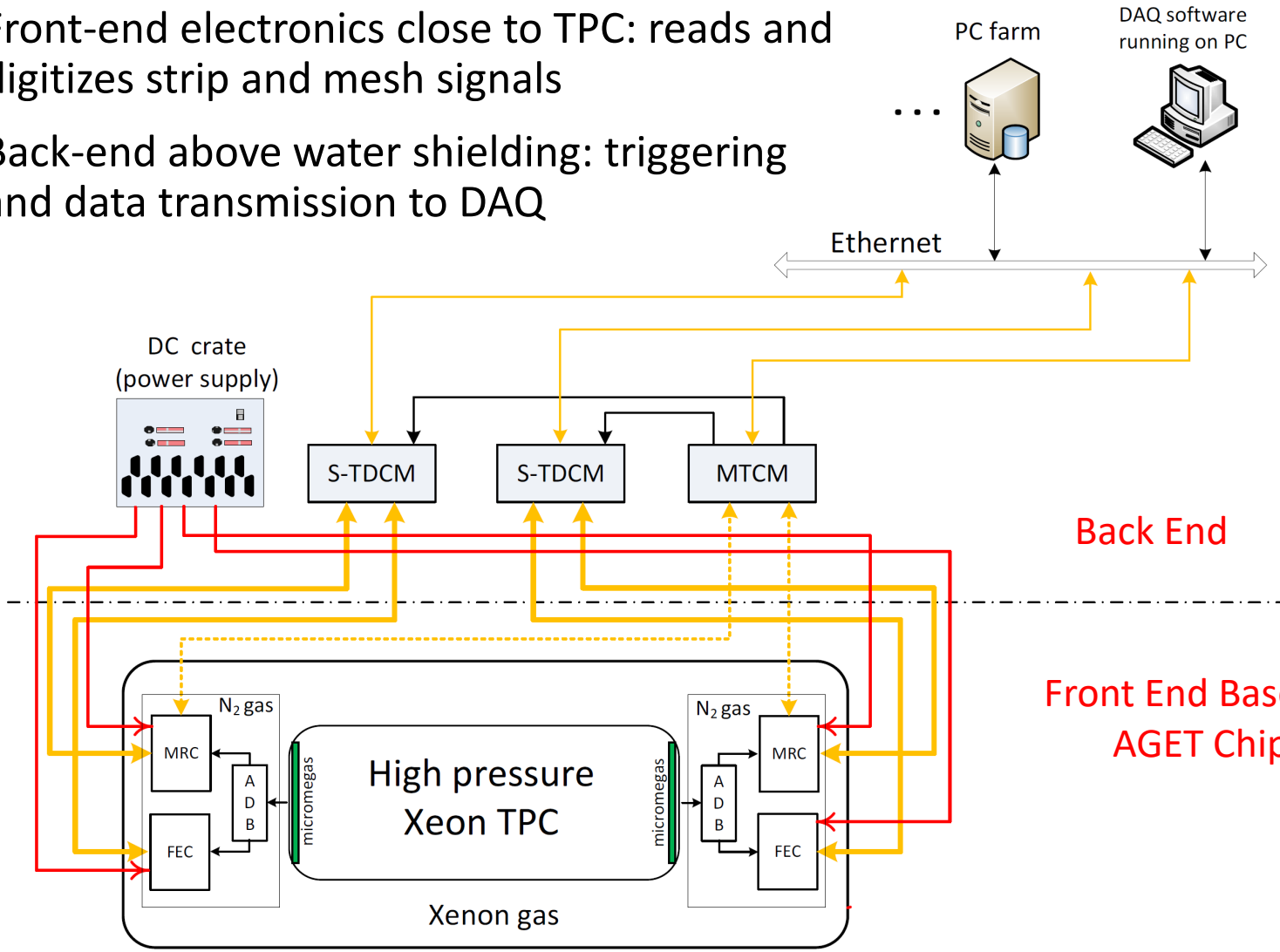
- Microbulk Micromegas characterization
- Bulk Micromegas production
- Long term: segmented mesh for true X and Y strips





Electronics work at Saclay

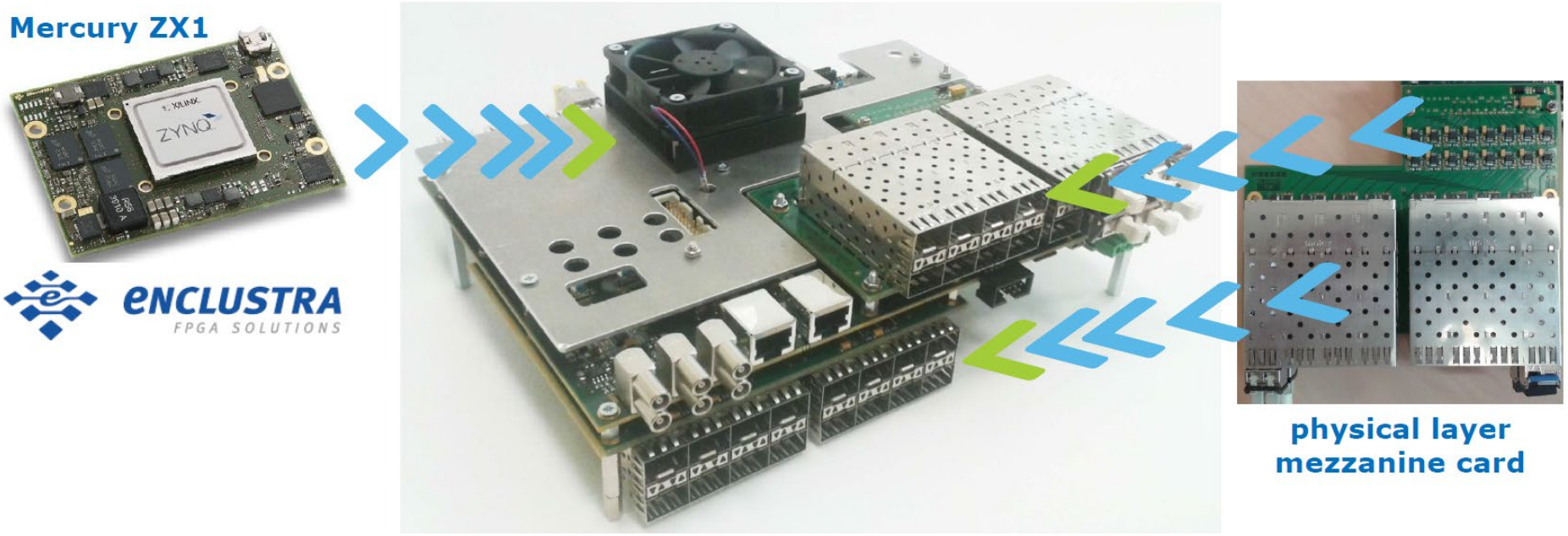
- Front-end electronics close to TPC: reads and digitizes strip and mesh signals
- Back-end above water shielding: triggering and data transmission to DAQ



Back end and DAQ

- The Trigger and Data Concentrator Module – TDCM
  - Designed by Saclay for PandaX-III and T2K-II
  - A custom-made 6U form factor carrier board, a commercial FPGA module, and up to two physical layer mezzanine cards
  - Controls up to 32 FECs
- DAQ software based on MIDAS are under development.

Denis Calvet, arXiv:1806.07618



Conclusions and outlook

- PandaX-II with 580kg xenon has reached the world frontier of dark matter direct detection.
- PandaX-4T reaches an expected sensitivity to SI interaction of 10^{-47} cm^2 with 2 year live time.
  - Assembly and commissioning: 2019-2020
- PandaX-III aims to build multiple 200-kg scale high pressure xenon TPC for NLDBD search at CJPL.
- Close collaboration between China and France (Saclay).
- First 200 kg module: 2020