Overview of PandaX experiment

Yong Yang (SJTU), On behalf of PandaX collaboration

TeVPA, 2026/8/31

Tendo, Japan

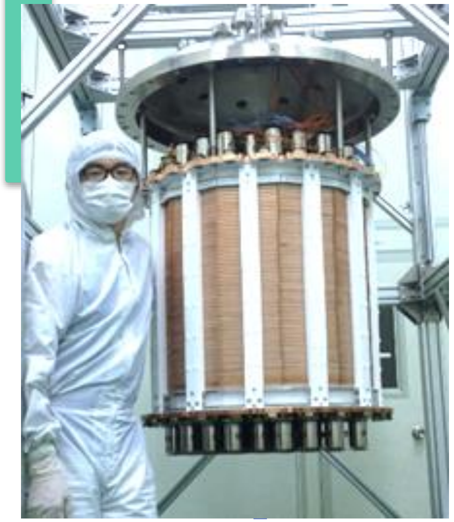
Particle and Astrophysical Xenon observatory

PANDA X

PandaX initiated

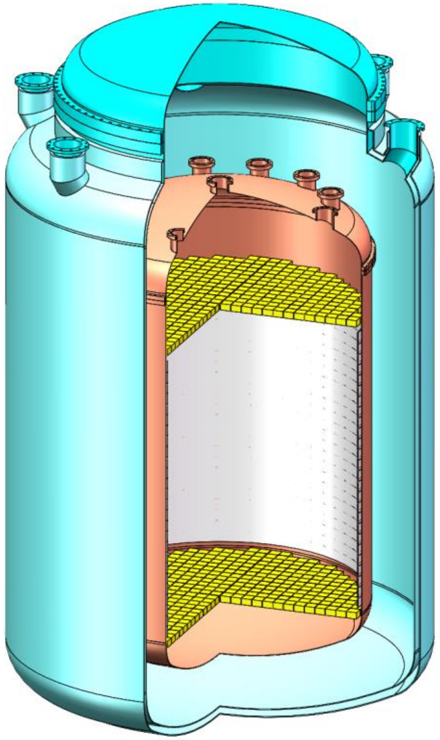
PandaX-I
120 kg LXe

PandaX-II
580 kg LXe



PandaX-4T
3.7 tonne

PandaX-xT



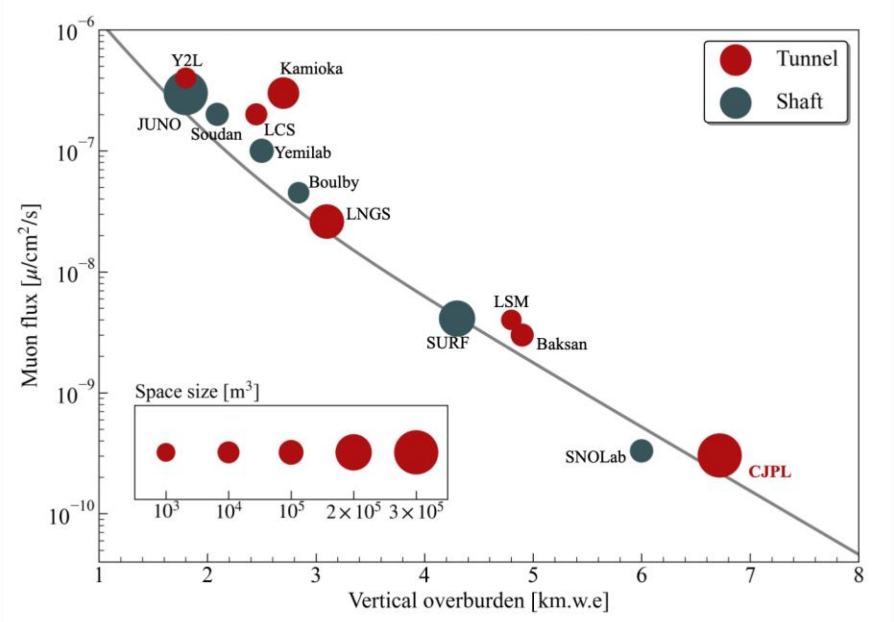
2009 | 2010-2014 | 2015-2019 | 2020-2026 | 2027-

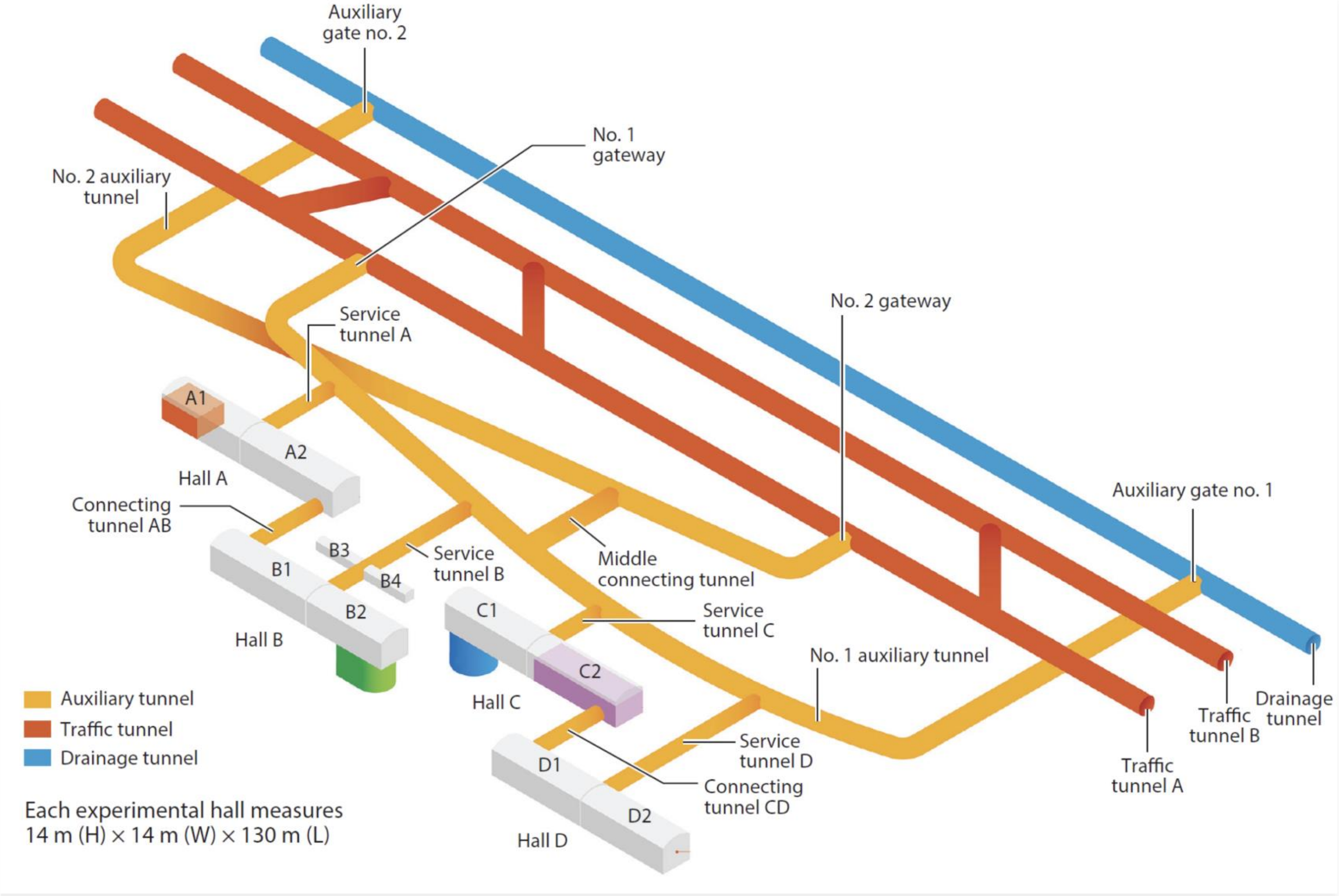
SINAP CNNC 雅砻江水电

North Korea
Beijing
北京
Dalian
大连市
Pyongyang
평양
Japan
Tokyo
東京
Jiuquan
酒泉市
Yinchuan
银川市
HEBEI
Tianjin
天津
Osaka
大阪
GANSU
Jinan
济南市
South Korea
Xining
西宁市
NINGXIA
SHANXI
SHANDONG
Yellow Sea
Fukuoka
福岡
QINGHAI
Lanzhou
兰州市
SHAANXI
Xi'An
西安市
China
HENAN
JIANGSU
Shanghai
上海
East China Sea
Chengdu
成都市
HUBEI
Wuhan
武汉市
ANHUI
Hangzhou
杭州市
SICHUAN
ZHEJIANG
China Jinping
Underground Laboratory
GUIZHOU
HUNAN
JIANGXI
FUJIAN
Kunming
昆明市
YUNNAN
GUANGXI
GUANGDONG
Hong Kong
香港
Myanmar
(Burma)
Hanoi
2430m
8750m

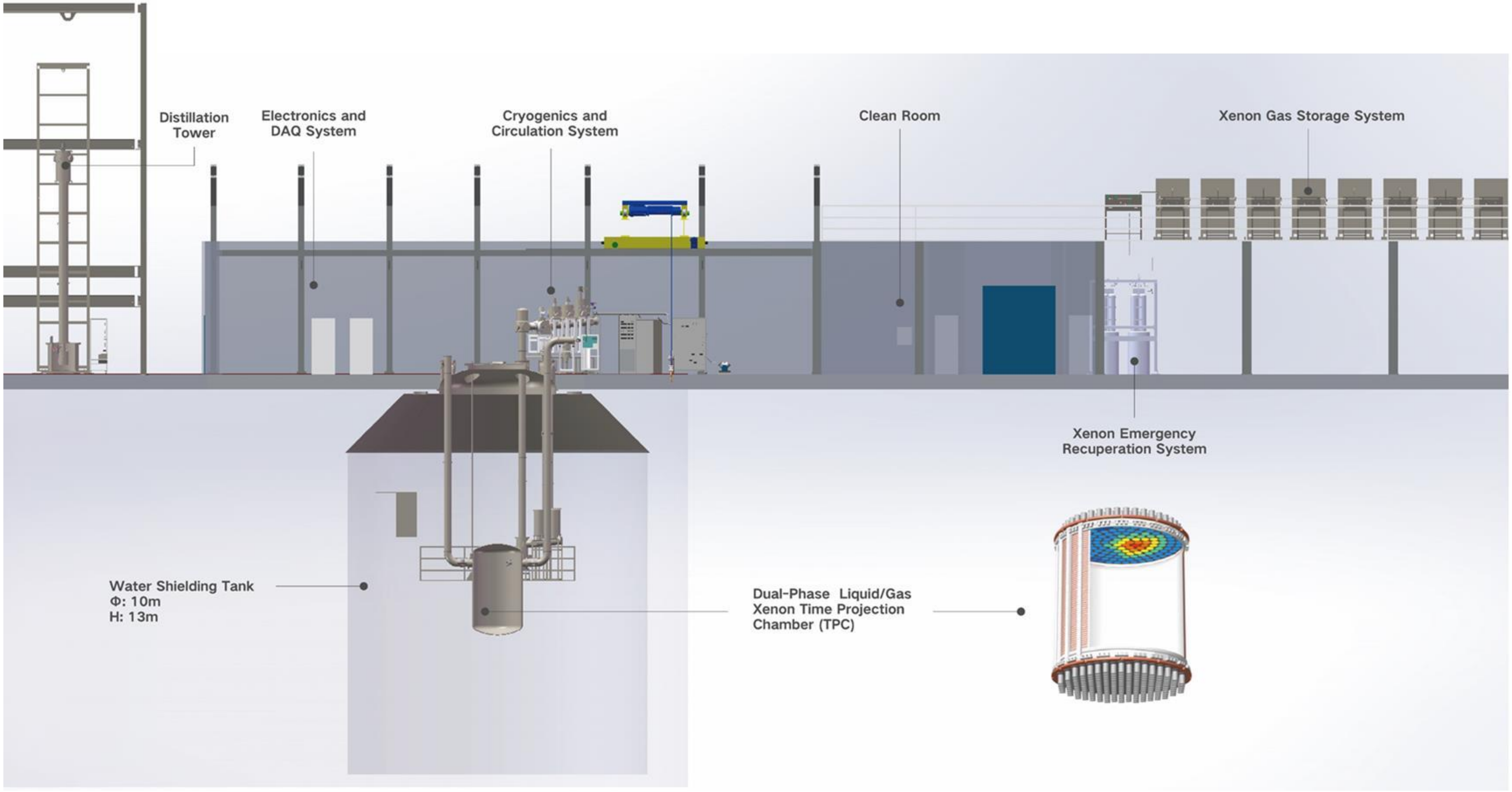
CJPL-II: deepest and largest underground lab

- 2400 m rock overburden
- UG volume: 330,000 m^3
- μ-flux: ~96 $m^{-2}yr^{-1}$



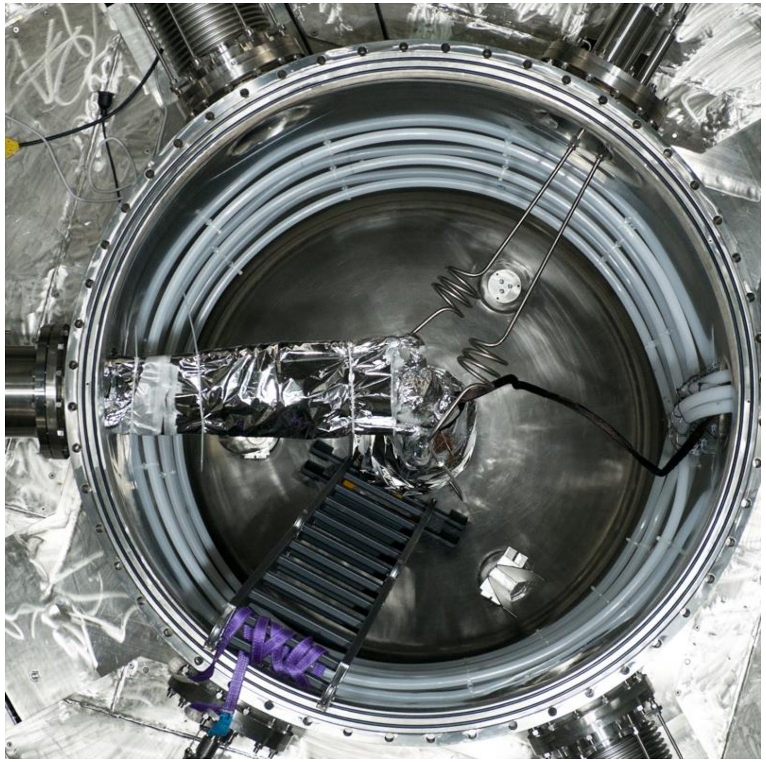


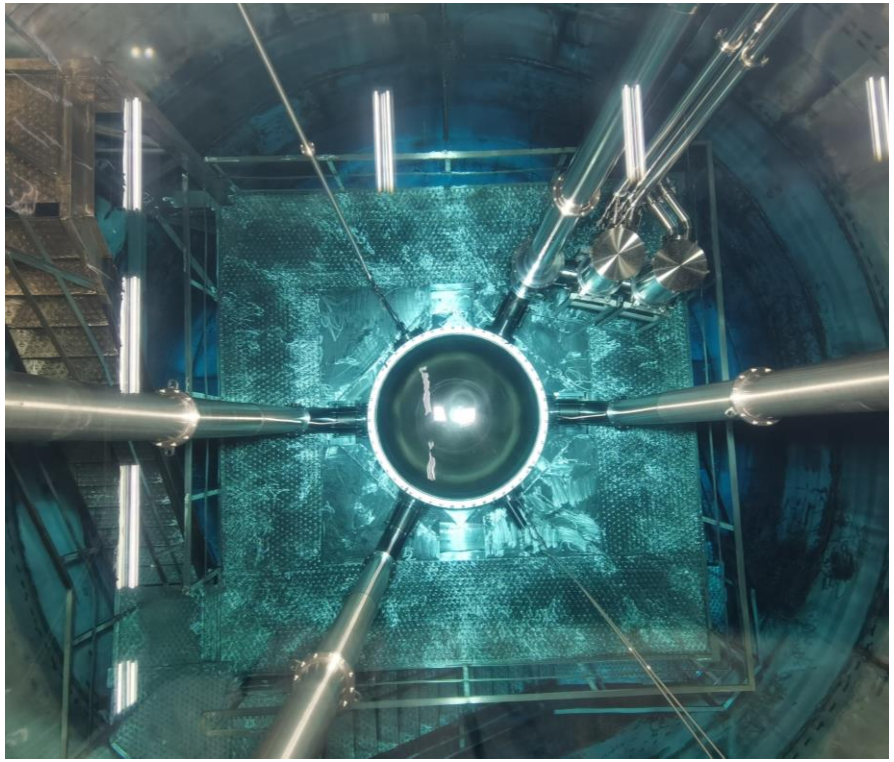
PandaX-4T @ Hall B2 of CJPL-II



PandaX-4T: A multi-ton dual-phase xenon TPC

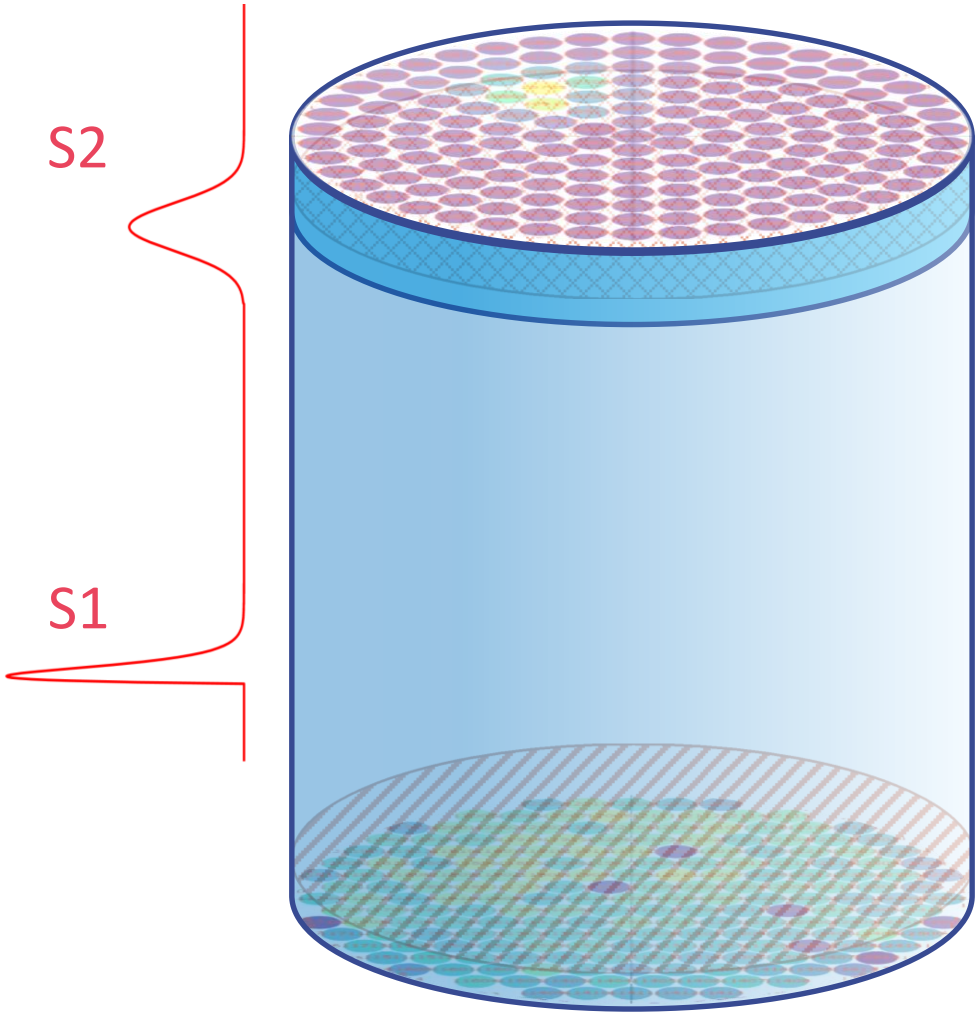
- 1.2 m (D) ×1.2 m (H); Sensitive volume: 3.7-ton LXe; 3-inch PMTs: 169 top / 199 bottom
- Ultrapure water shielding: 4 m in all directions



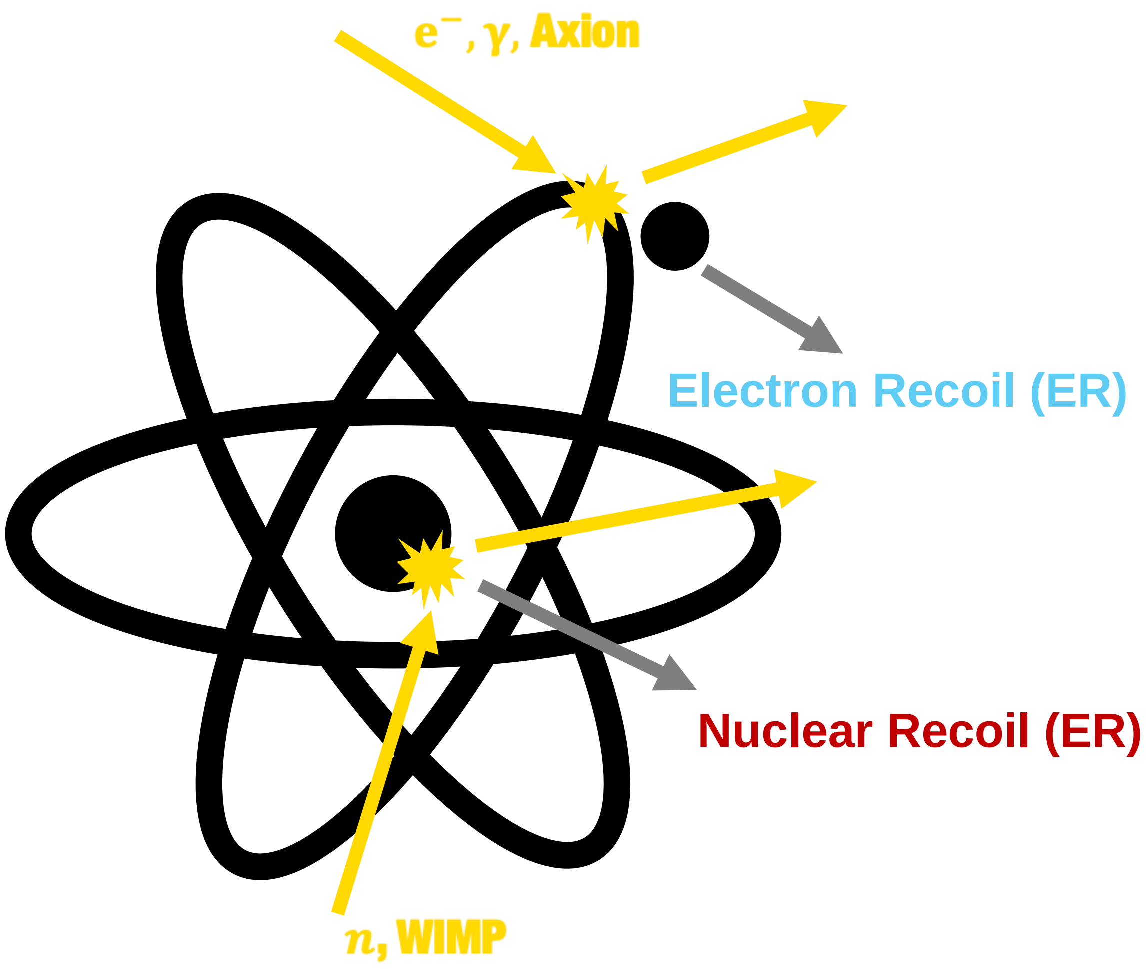


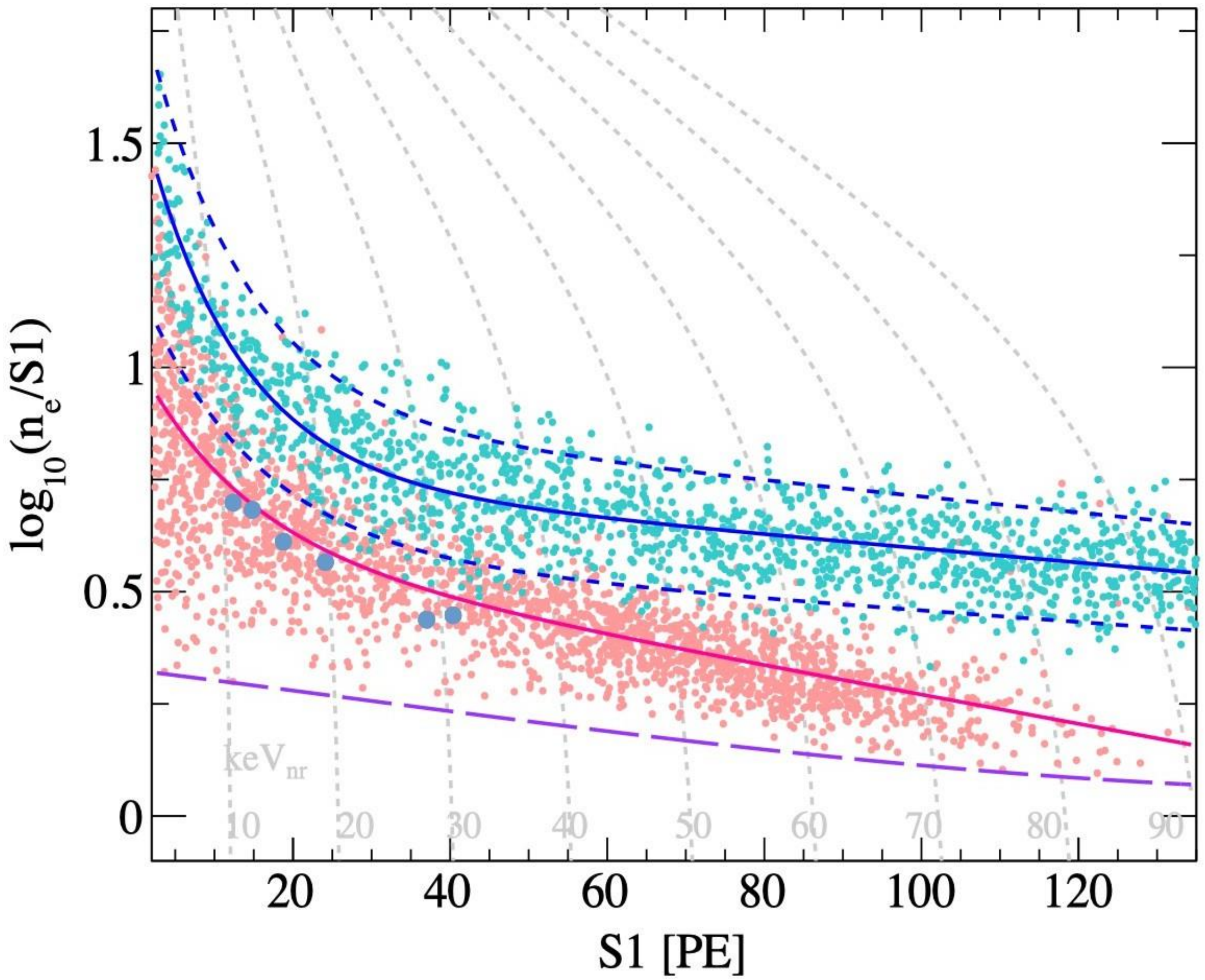
Dual-phase Xenon Time Projection Chamber

- Prompt scintillation signal (S1) followed by drift electron signal (S2)
- Measures the 3D position, energy, and time
- Large monolithic target: high signal efficiency and effective self-shielding
- LXe TPC as a Total-Absorption 5D Calorimeter



ER (electron recoil) and NR (nuclear recoil)

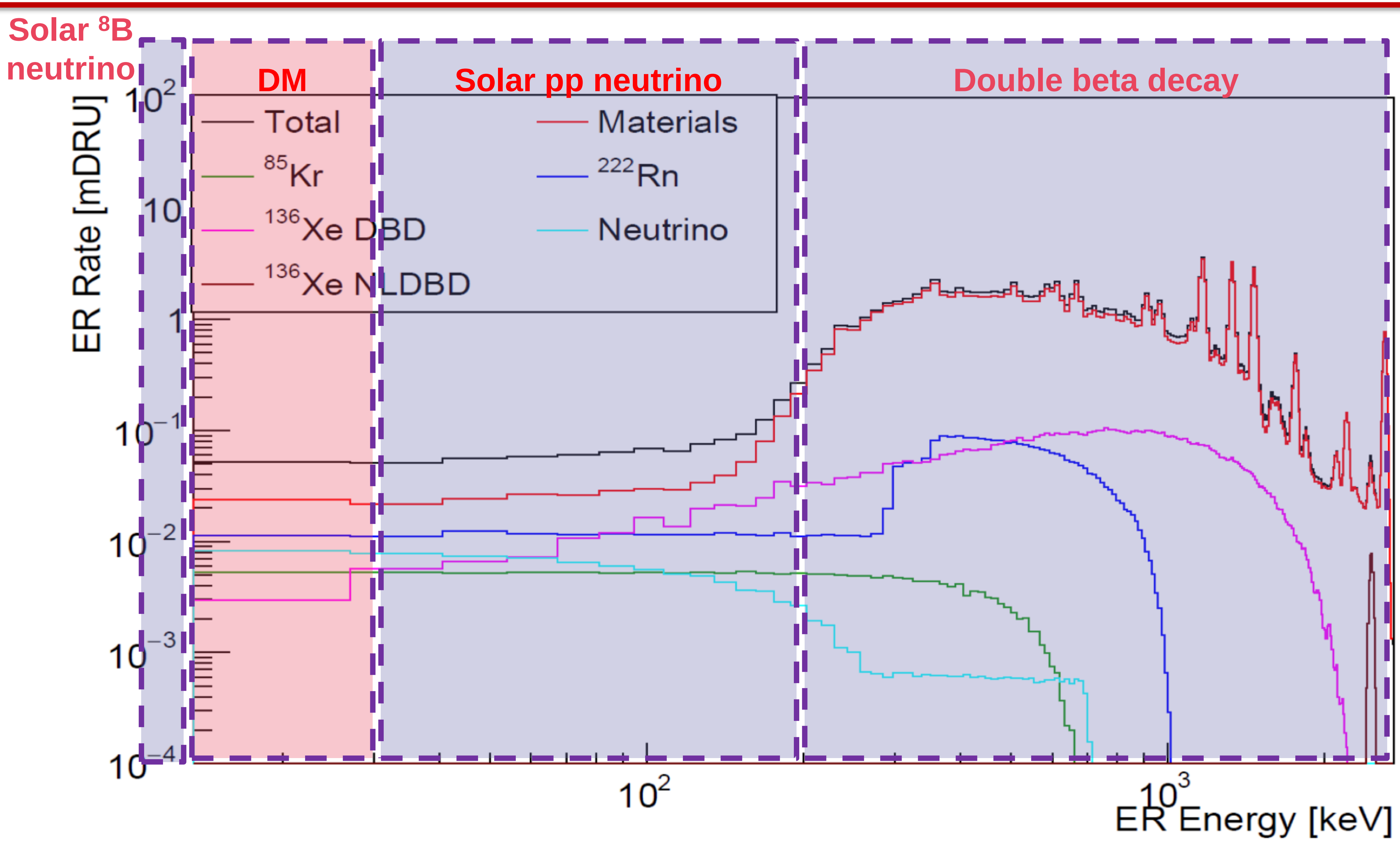




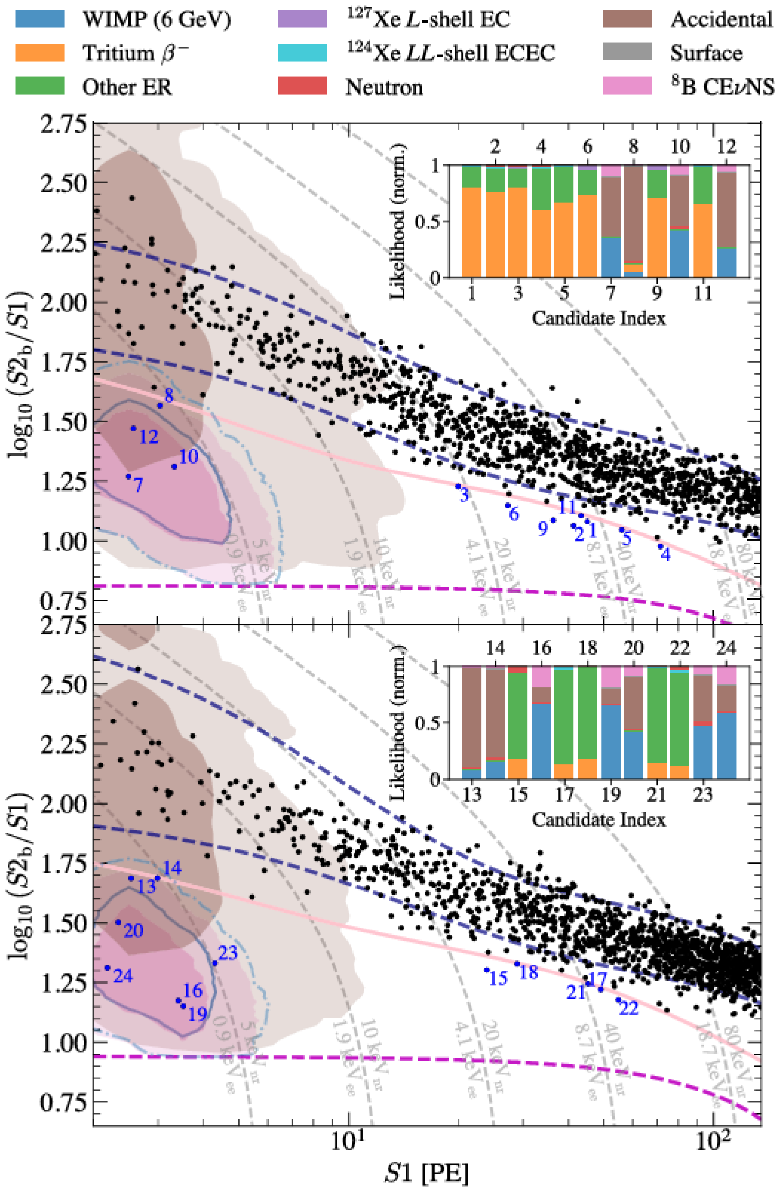
PandaX-4T Timeline

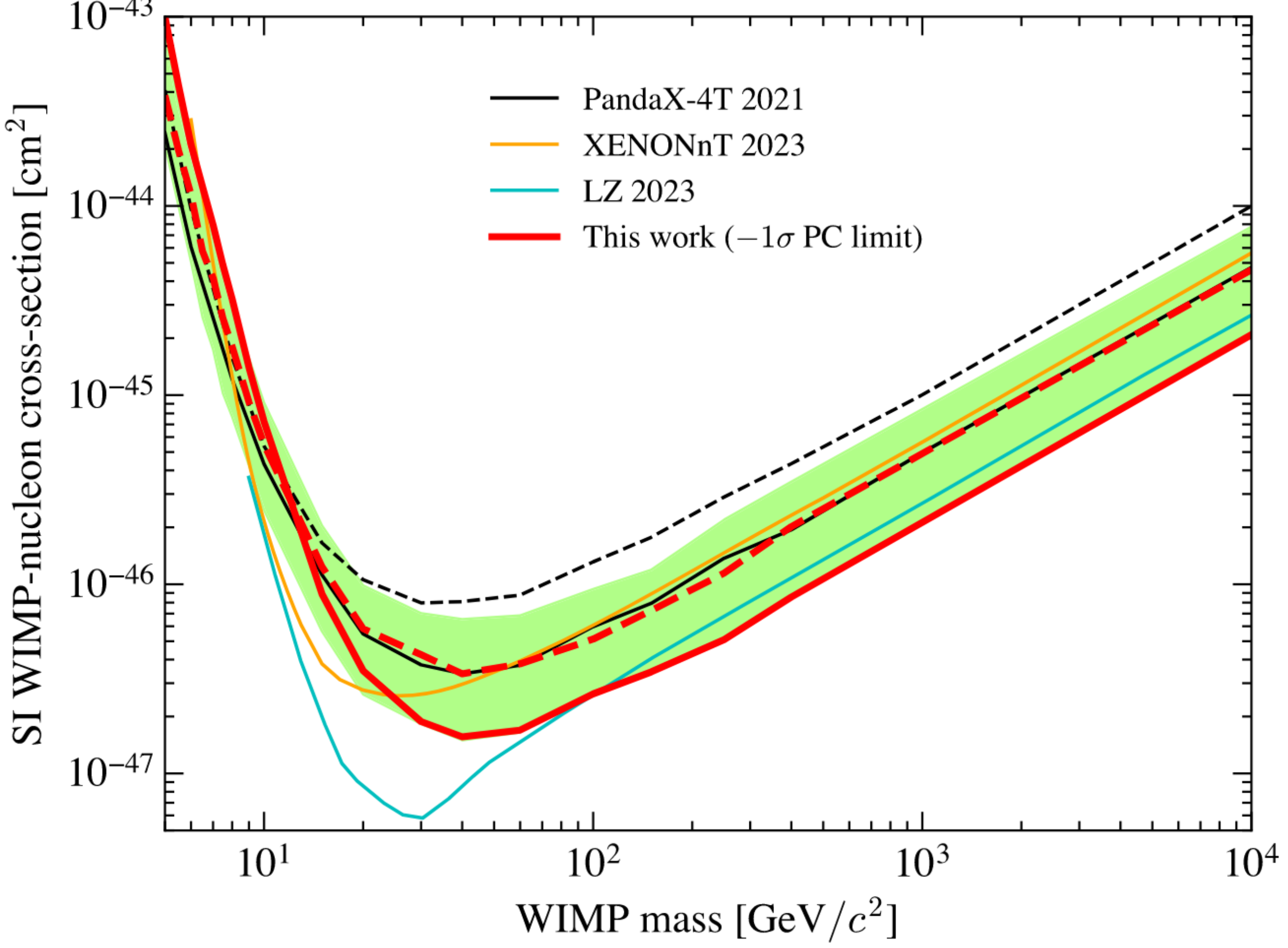
Time	Activity
2020/11-2021/04	commissioning (Run0) 95 days
2021/07-2021/10	tritium removal xenon distillation, gas flushing, etc.
2021/11-2022/05	physics run (Run1) 164 days
2022/09-2023/12	CJPL B2 hall renovation xenon recuperation, detector upgrade
2024/01-2026/04	resuming operation (Run2)
2026/4/15	Shut down

PandaX-4T: fully exploring physics opportunities



5GeV-10TeV WIMP (S1+S2 paired data)

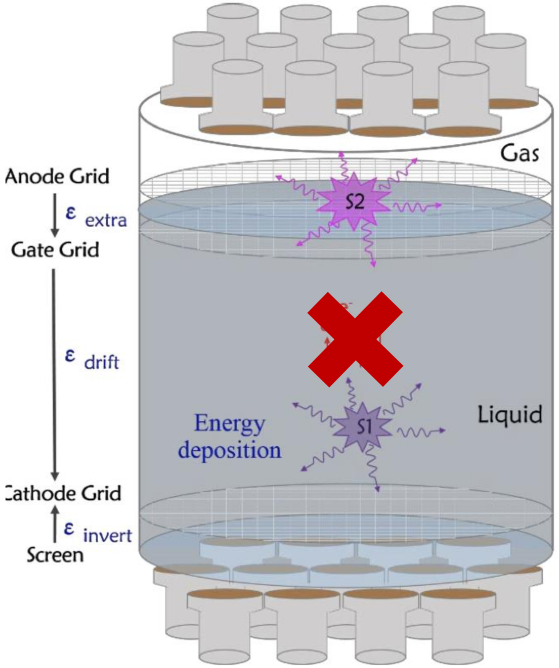


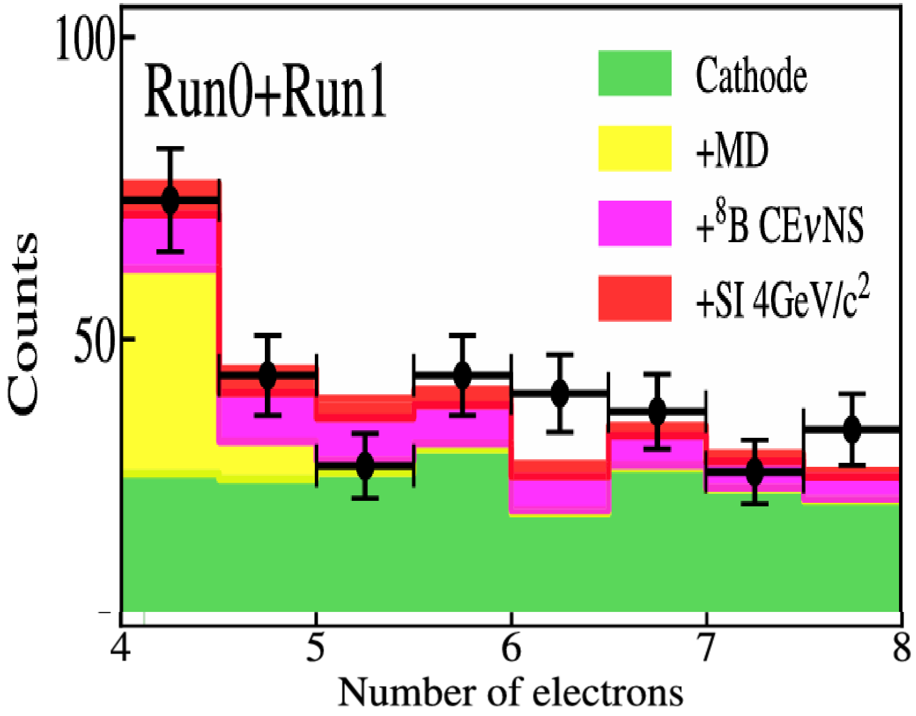


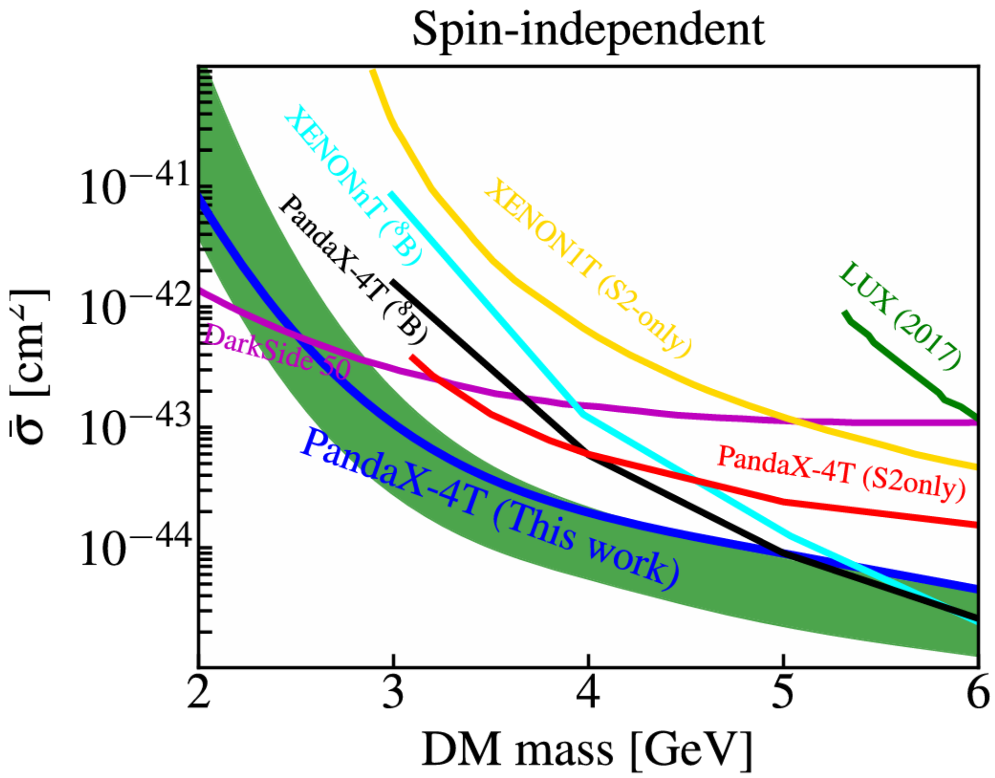
Phys. Rev. Lett. 134, 011805 (2025)

~GeV DM (S2-only data): More in next talk

- Minimal Nuclear Recoil Energy: 3 keV for S1+S2 → 0.3 keV for S2-only
- Most stringent limits on SI DM-nucleon interaction for 2.5-5GeV DM



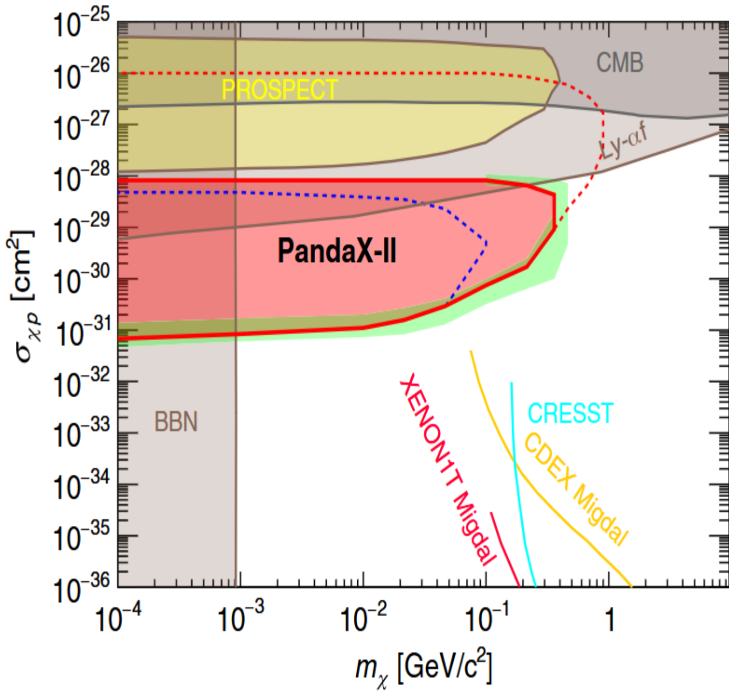




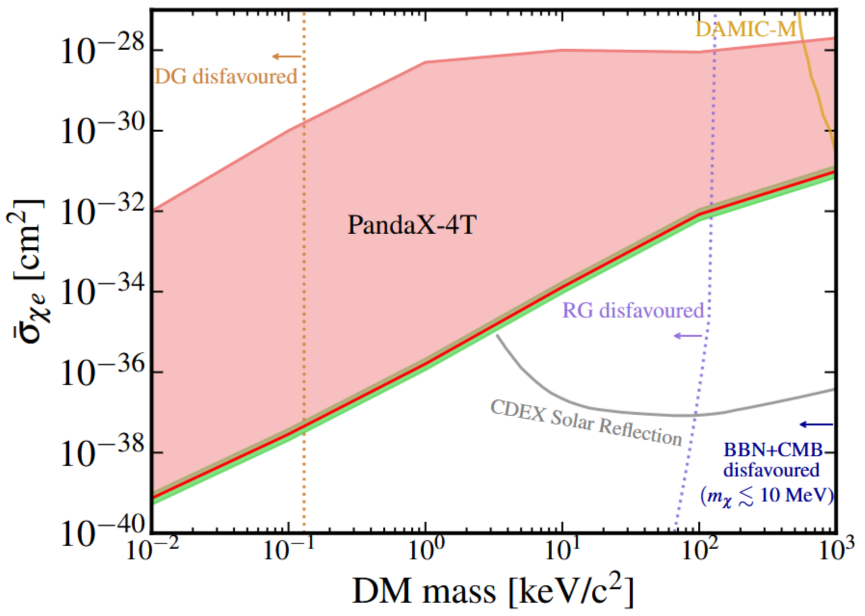
PRL 130, 261001 (2023), PRL 135, 211001 (2025)

Sub GeV and Sub MeV DM (boosted)

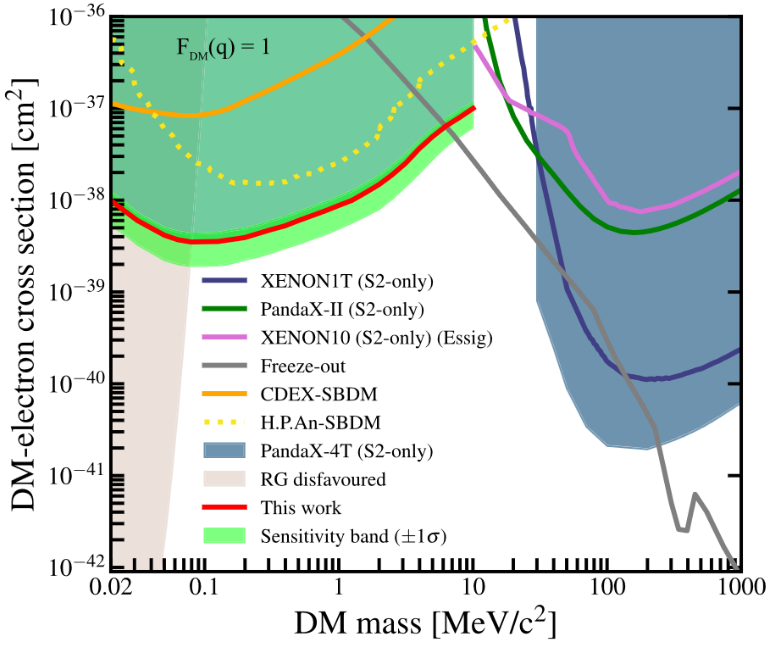
Cosmic-ray proton boosted
PRL. 128, 171801 (2022)



Cosmic-ray electron boosted
PRL 133, 101805 (2024)



Solar electron boosted
PRL 134, 161003 (2025)



Best constraints: 1 MeV - 0.3 GeV

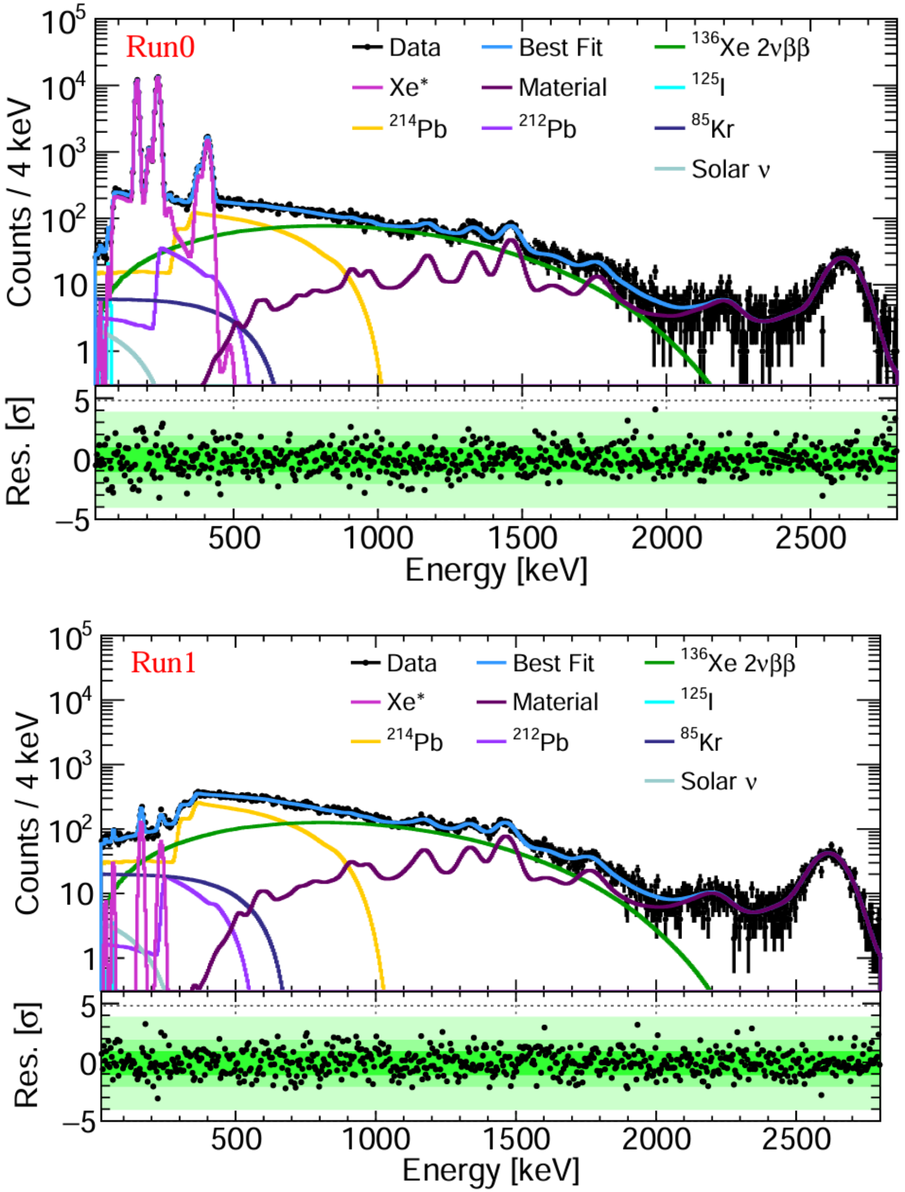
10 eV - 3 keV

0.02 MeV - 10 MeV

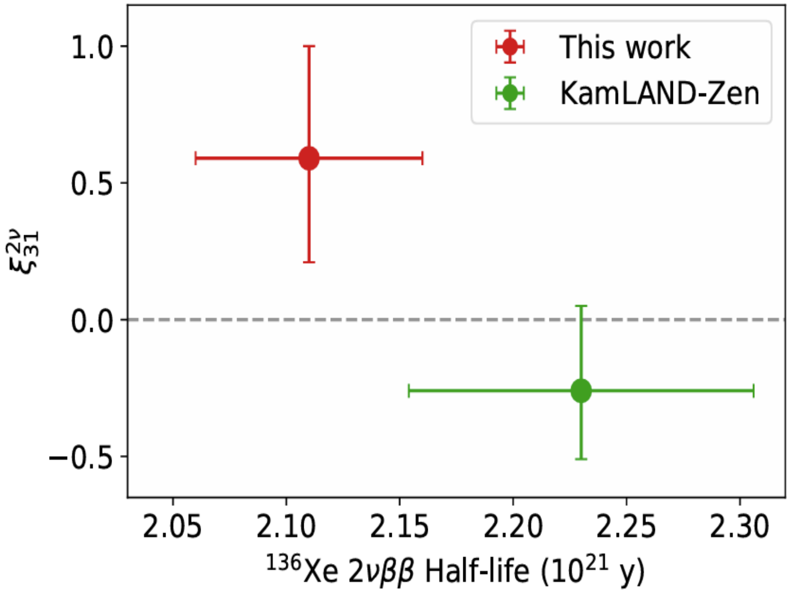
Broad non-standard-WIMP DM searches

Topics/Motivation	Publication
Effective electromagnetic interactions between DM and xenon nuclei	Limits on the luminance of dark matter from xenon recoil data, Nature 618, 47–50 (2023)
Dark mediator	Search for Dark-Matter–Nucleon Interactions with a Dark Mediator in PandaX-4T, PRL 131, 191002 (2023)
Dark matter from cascading decays of η meson	Search for Light Dark Matter from the Atmosphere in PandaX-4T, PRL 131, 041001 (2023)
Solar axions, ALP, dark photons, and light fermionic dark matter	Exploring New Physics with PandaX-4T Low Energy Electronic Recoil Data, PRL 134, 041001 (2025)
MeV ALP and Dark photon	Search for MeV-Scale Axionlike Particles and Dark Photons with PandaX-4T, PRL 134, 071004 (2025)
Lepton-portal dark matter	Search for lepton portal dark matter in the PandaX-4T experiment, PLB 864, 139389 (2025)

Measuring ^{136}Xe 2νββ half-life



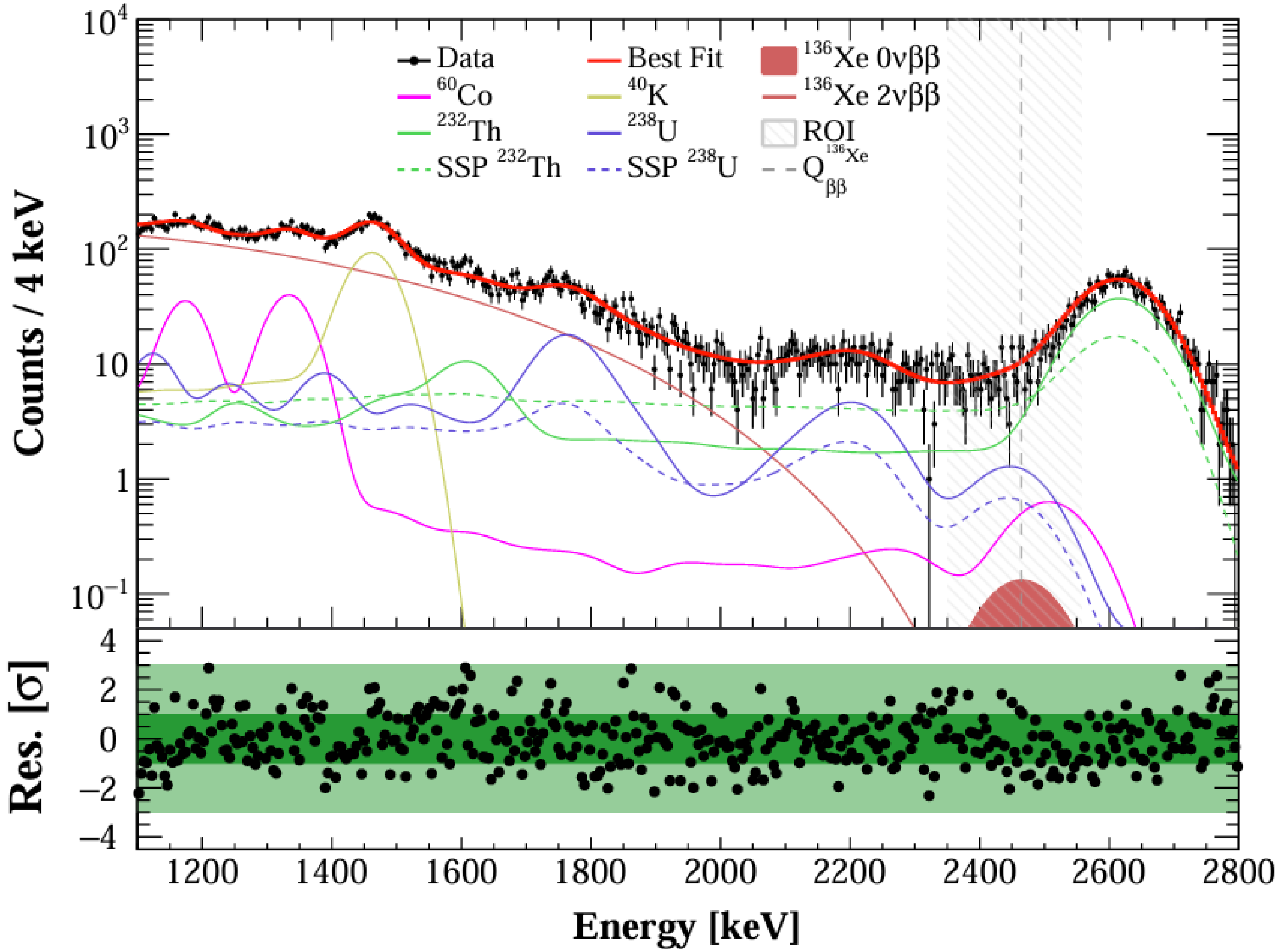
Phys. Rev. Lett. 136, 162501 (2026)



- 39 kg-yr of ^{136}Xe exposure from Run0+Run1
- Most accurate (2.3%) half-life thanks to nearly complete spectrum fit
- Constrains higher-order matrix elements contribution $\xi_{31}^{2\nu}$ and Majoron emissions

$$(T_{1/2}^{2\nu})^{-1} = (g_A^{\mathrm{eff}})^4 |M_{\mathrm{GT}}^{2\nu}|^2 (G_0^{2\nu} + \xi_{31}^{2\nu} G_2^{2\nu})$$

Searching for ^{136}Xe 0νββ decays



Science Bulletin 70, 11 (2025)

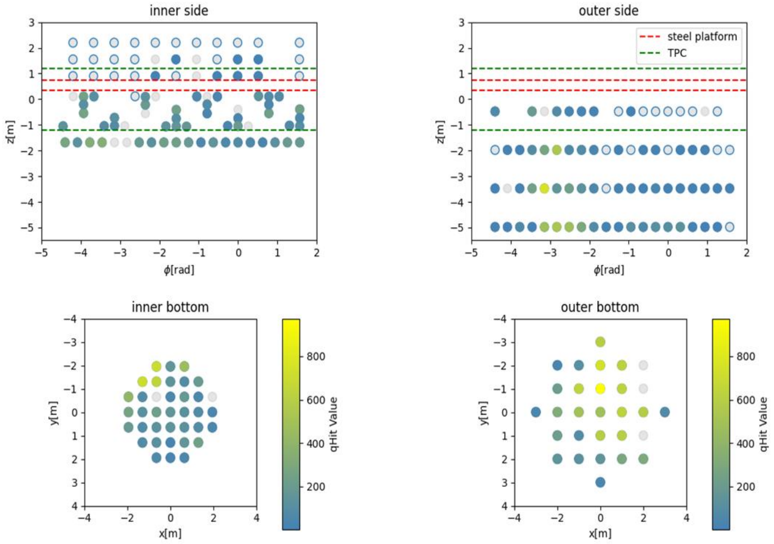
- 44.6 kg-yr of ^{136}Xe exposure from Run0+Run1
- Obtained $T_{1/2} > 2.1 \times 10^{24}$year 90% CL
- The most stringent constraint from a natural xenon detector to date.

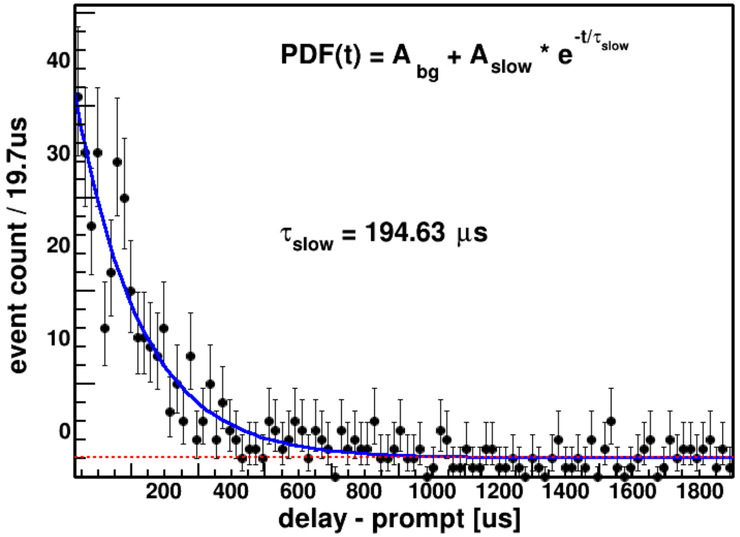
PandaX-4T Run2: new Water Cherenkov Veto

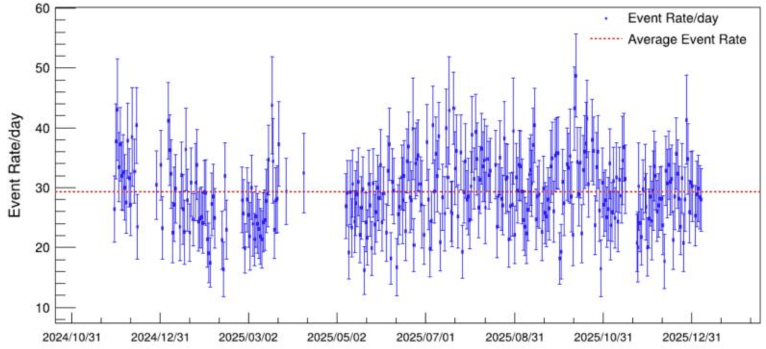
- Two layers of 8-inch MCP PMTs from NNVT in 900 m^3 water shielding
- Inner layer: 2 m radius, outer layer: 5 m radius
- Data taking: from July 2024 to April 2026

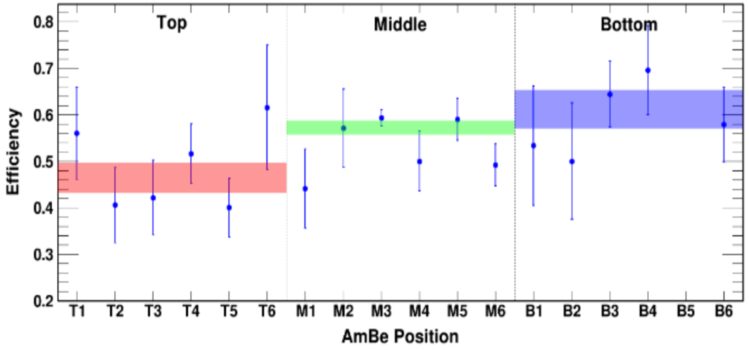


Tagging Muons and Neutrons



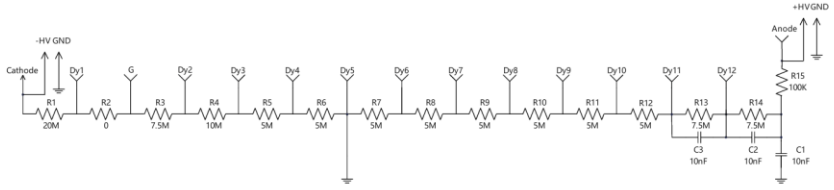




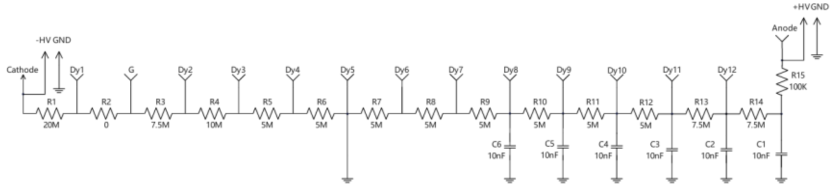


- 30 muons per day
  - 83.2 ± 2.7 (stat) / m^2 / year (preliminary)
  - largest muon detector at CJPL
- Calibrating neutron veto efficiency with AmBe source
  - 500 μs time window: 53.9%
  - 800 μs time window: 57.4%

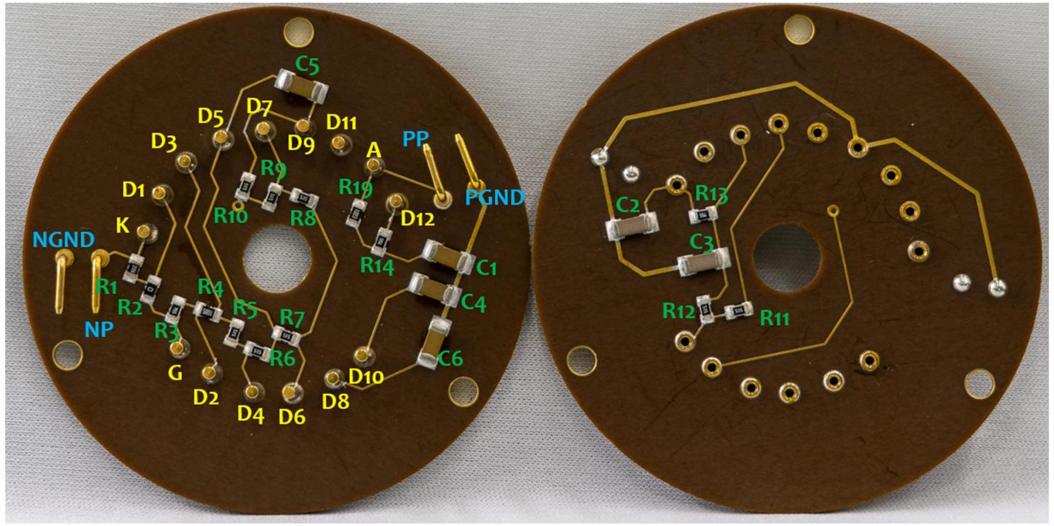
PandaX-4T Run2 : new PMT HV divider base



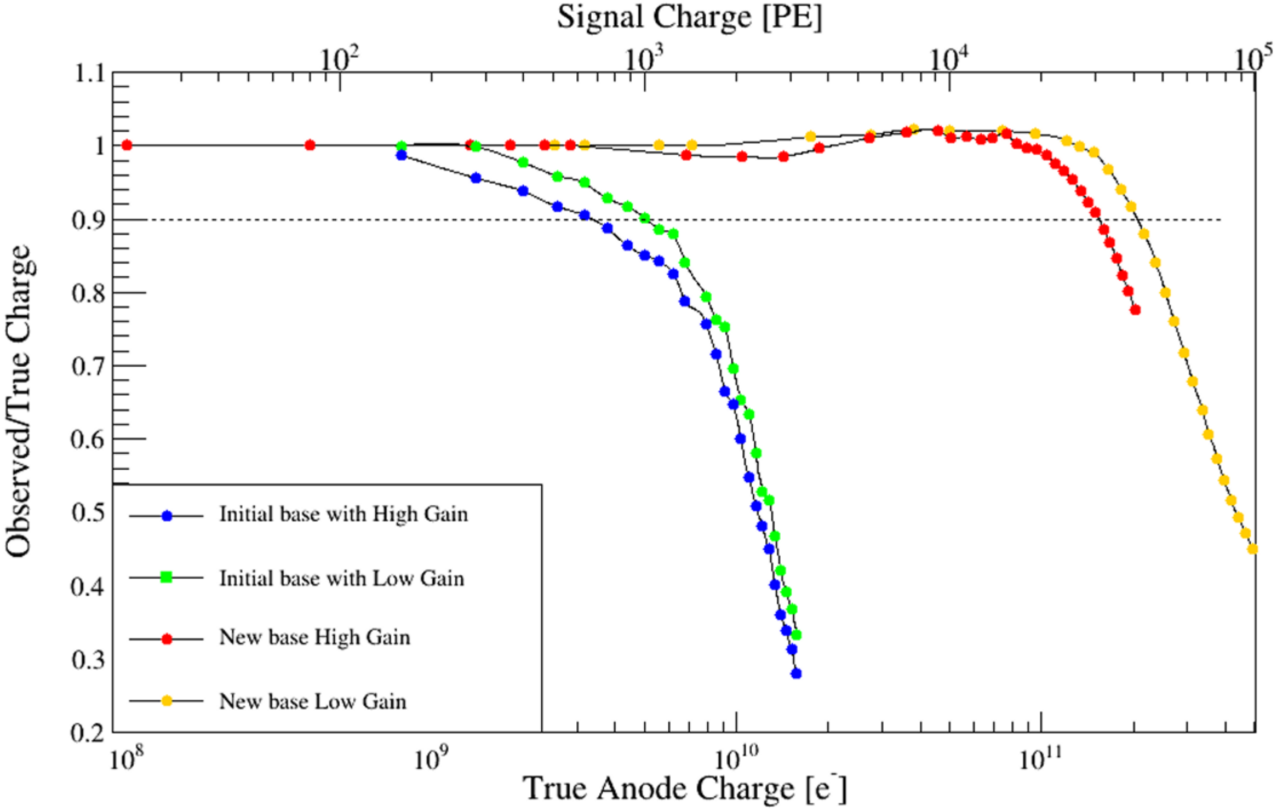
(a) The original PMT base with three capacitors



(b) The improved PMT base with six capacitors



JINST **19** P05021 (2024)



- New decoupling capacitor configuration
- linearity range of 1k PE improved by 40x

PandaX-4T Run2: new Digitizer and Trigger

14-bit 250MS/s Digitizer

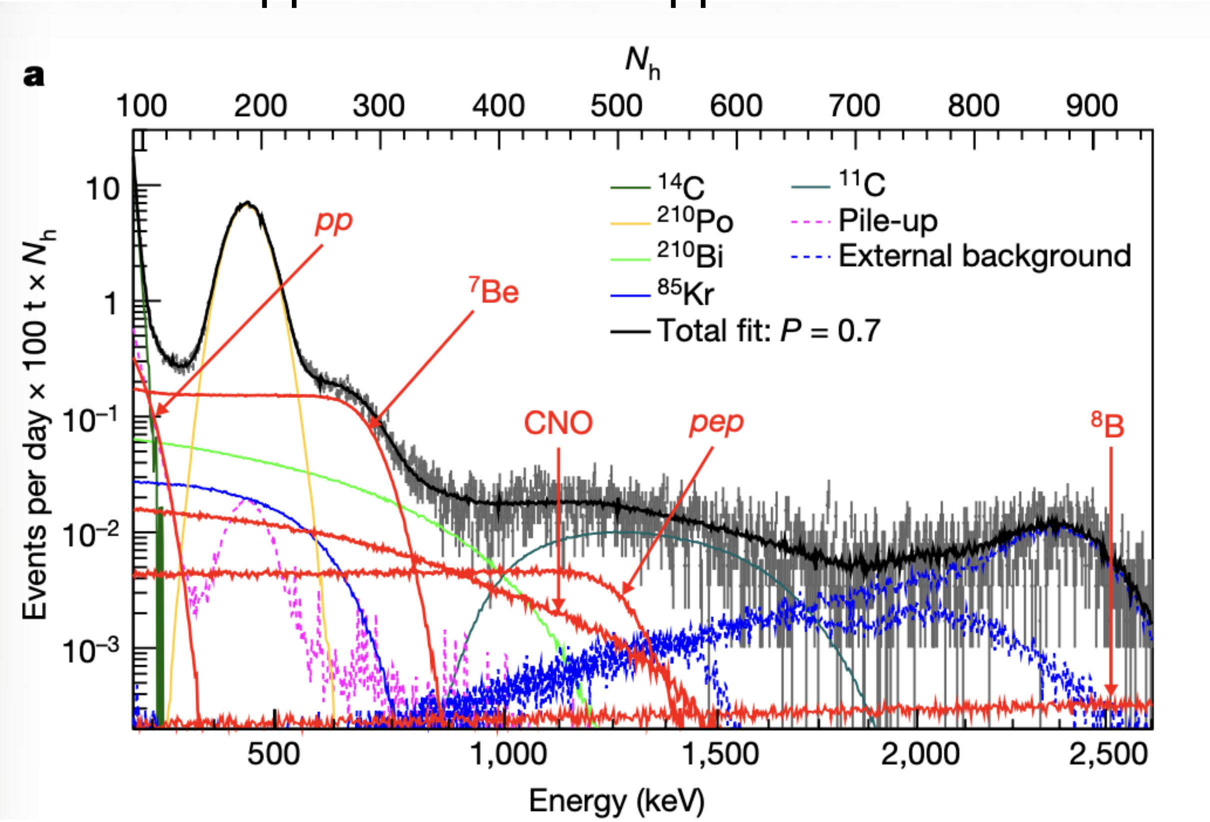
14-bit 500MS/s Digitizer

JINST 16 T12015 (2021)

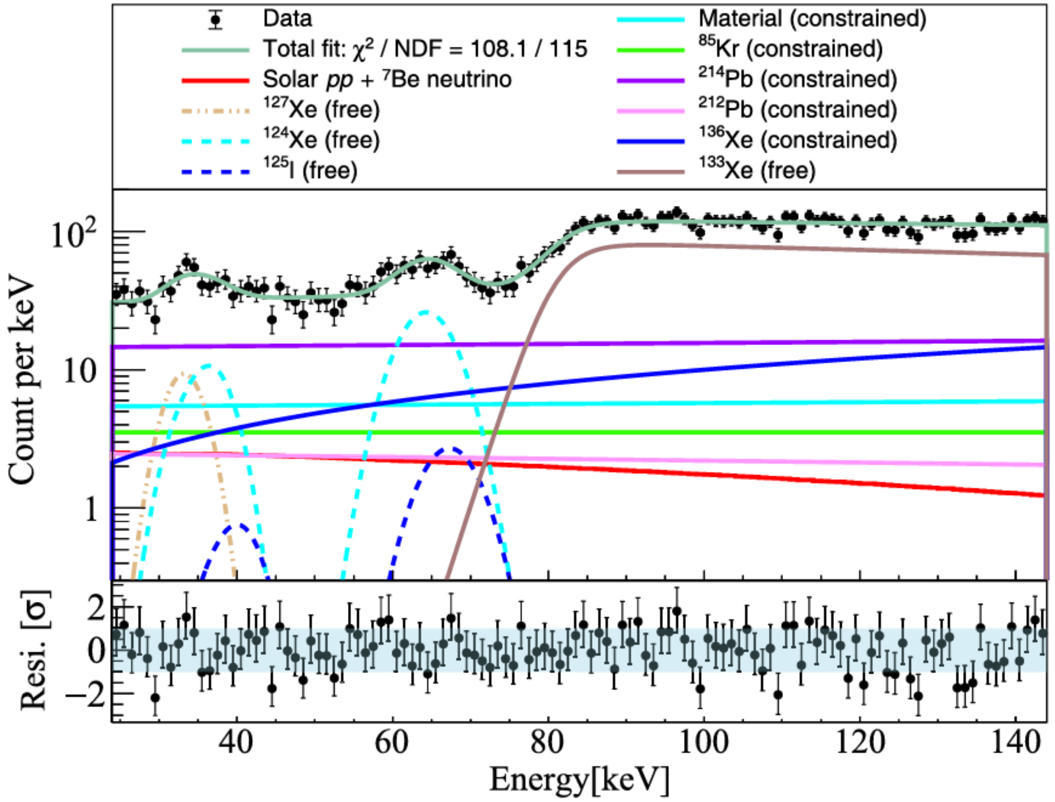
Experiment	Sampling rate (MS/s)	Clock	Trigger modes
PandaX-I&II (2012-2019)	100	Daisy chained	Global trigger
PandaX-4T (2019-2022)	250	Distributed	Triggerless (Channel-by-channel SelfTrigger)
PandaX-4T (2022-2026)	500	Distributed	Triggerless, Global Trigger

Solar pp neutrino scattering on electrons

- Leading result from Borexino with a recoil energy of >165 keV
- The first measurement in recoil energy from 24 to 144 keV with PandaX-4T Run0 data
    - pp neutrino flux upper limit : 23.3×10^{10} /cm²/s @ 90 CL



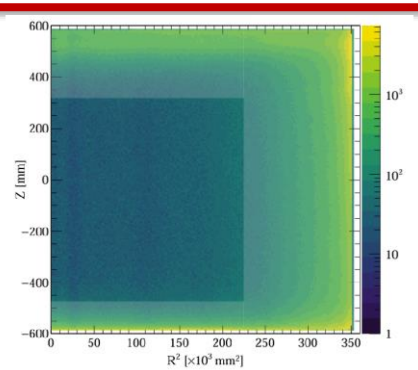
Borexino, Nature 562, 505 (2018)

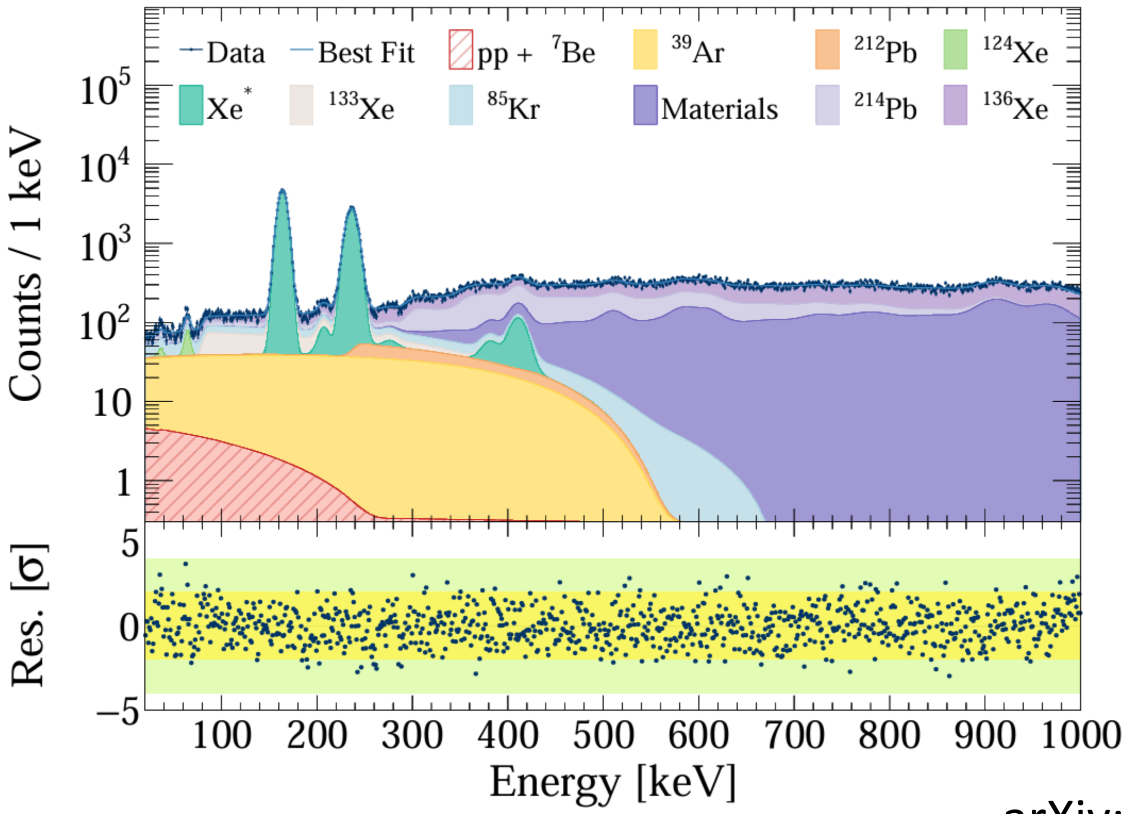


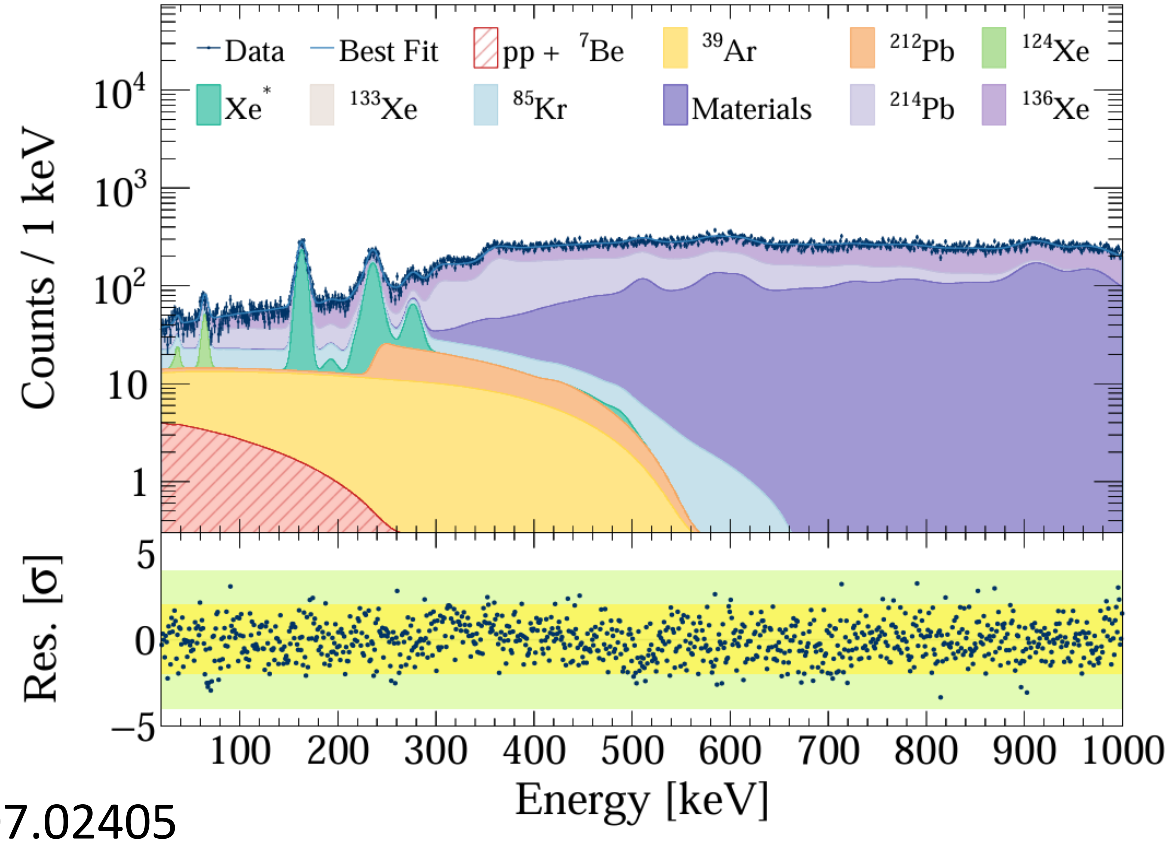
CPC 48 091001 (2024)

First Run2 data release for pp neutrino

- Final unblinding after ROI/FV(1.6T) optimization and validation checks
- Simultaneous fit of the High Ar and Low Ar spectra in Run 2



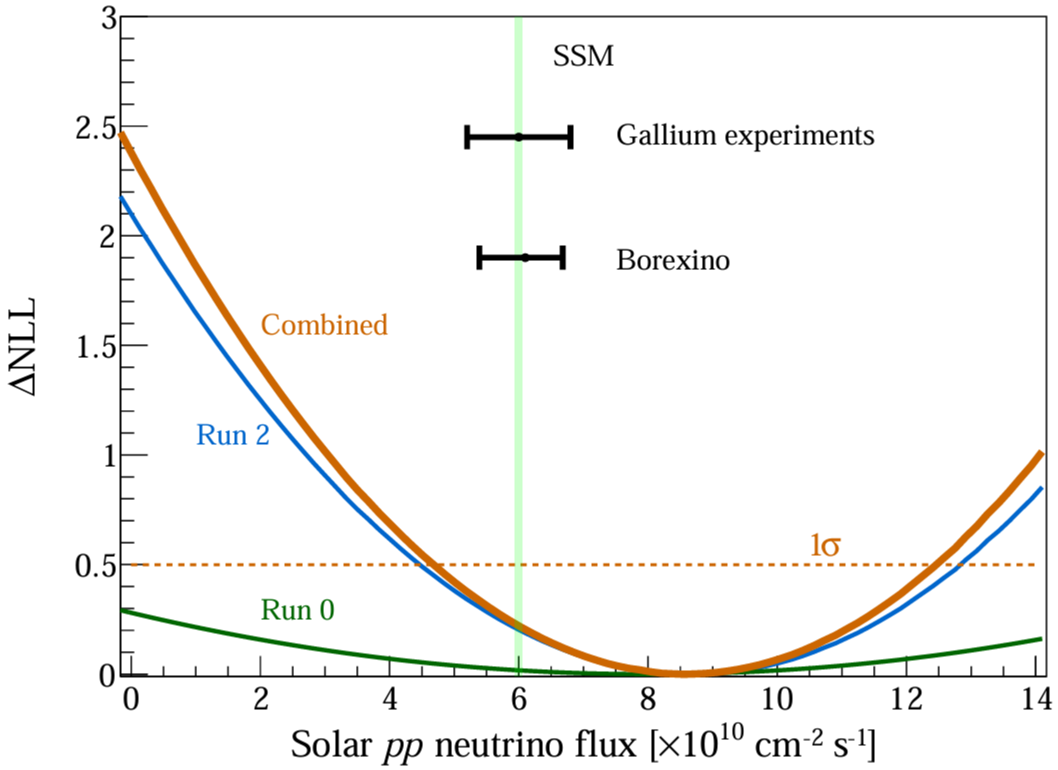


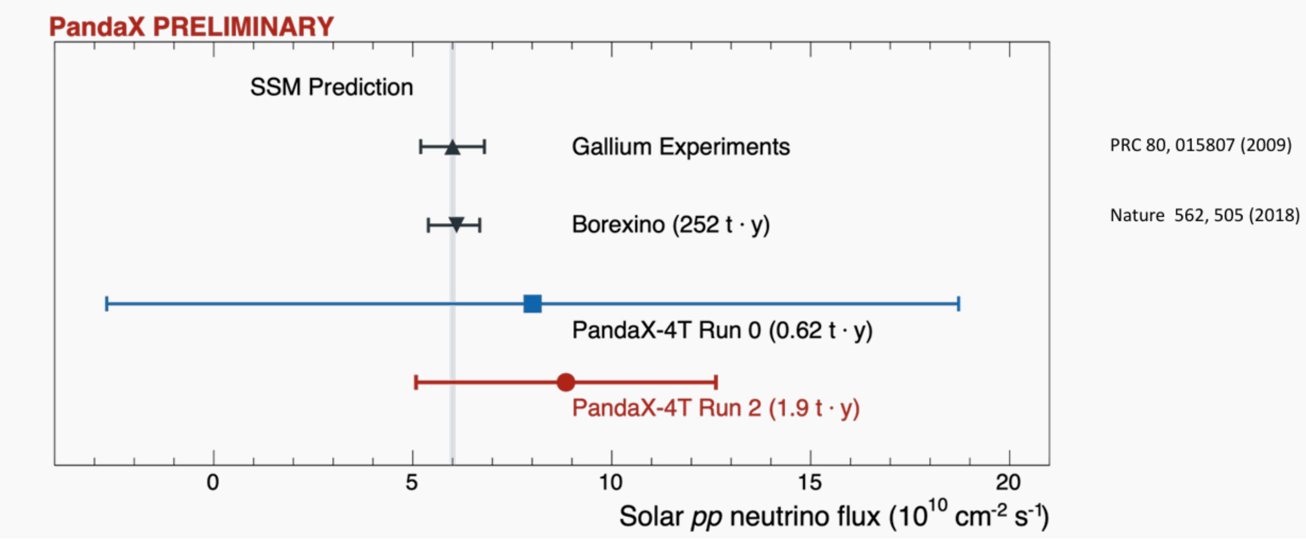


arXiv:2607.02405

Preliminary Results

- Measured pp neutrino flux: $8.5 \pm 3.5 \times 10^{10}$ /cm²/s
- First indication(2.2σ) of a non-zero flux at electronic-recoil energies below 165 keV

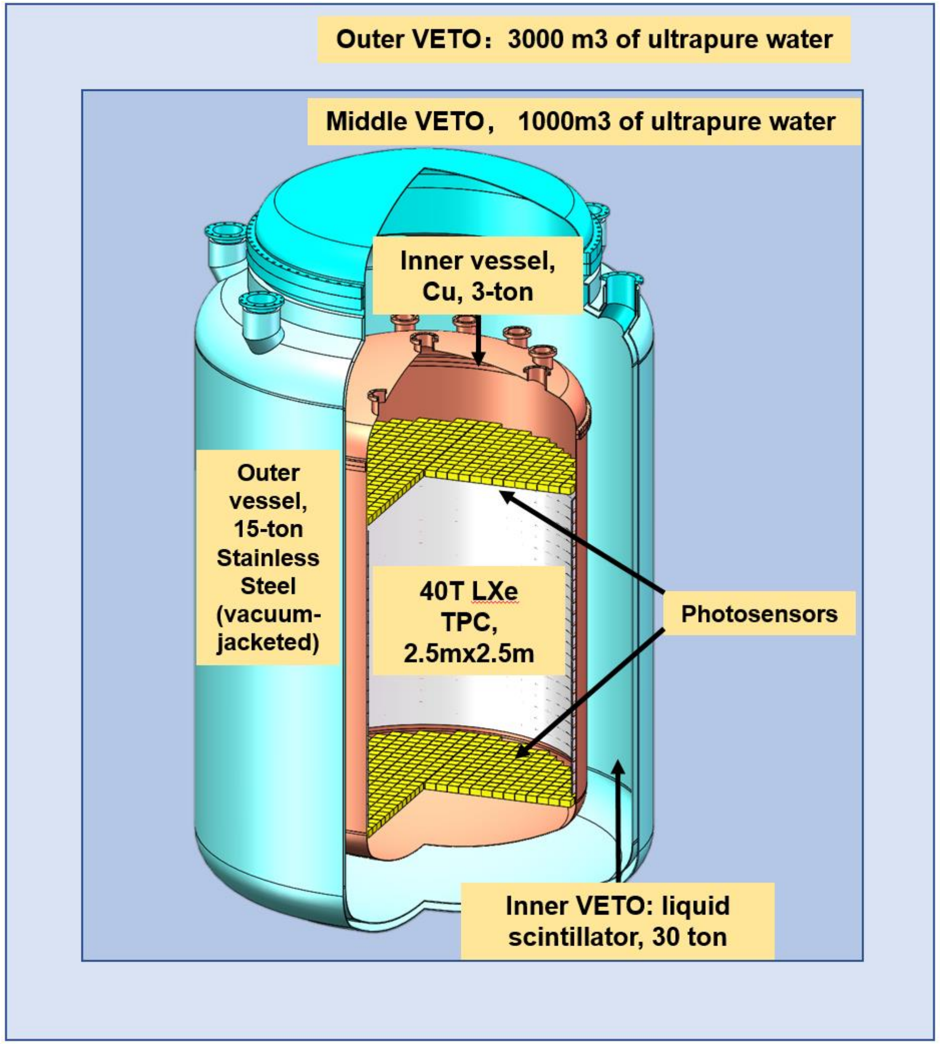




arXiv:2607.02405

Future: PandaX-xT

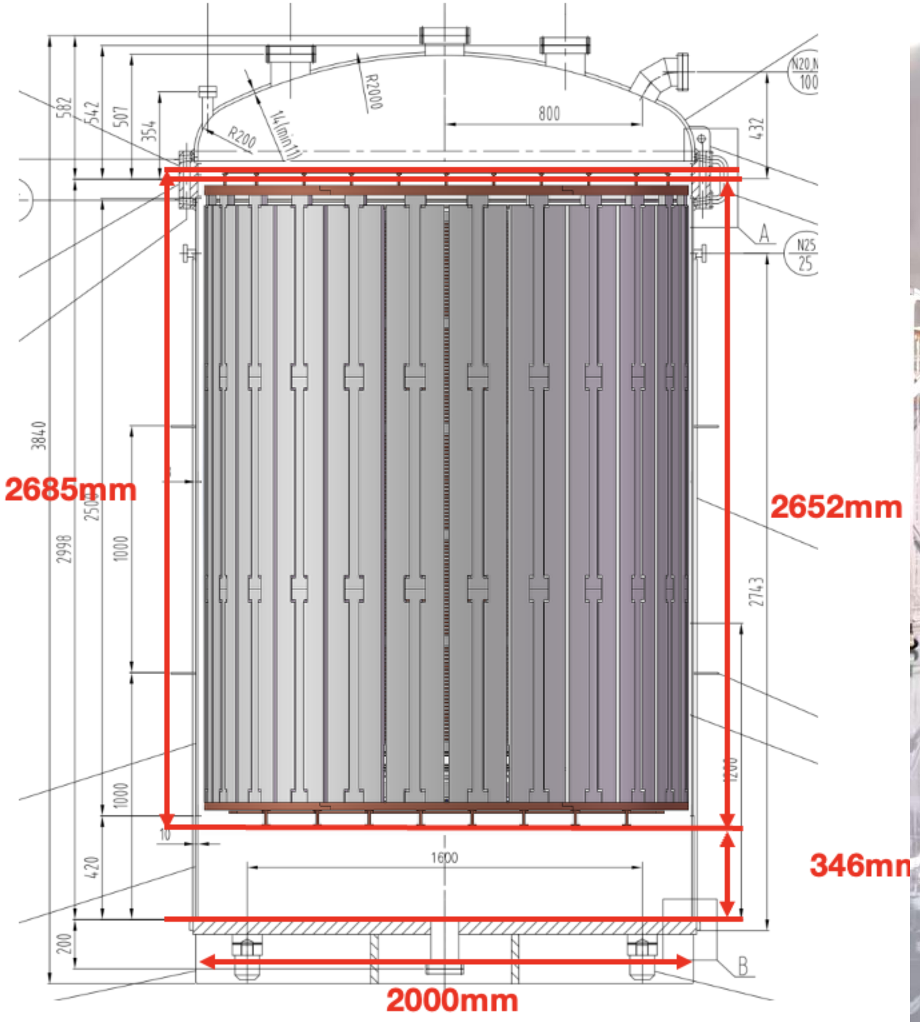
- A deep underground multi-ten-tonne liquid xenon observatory



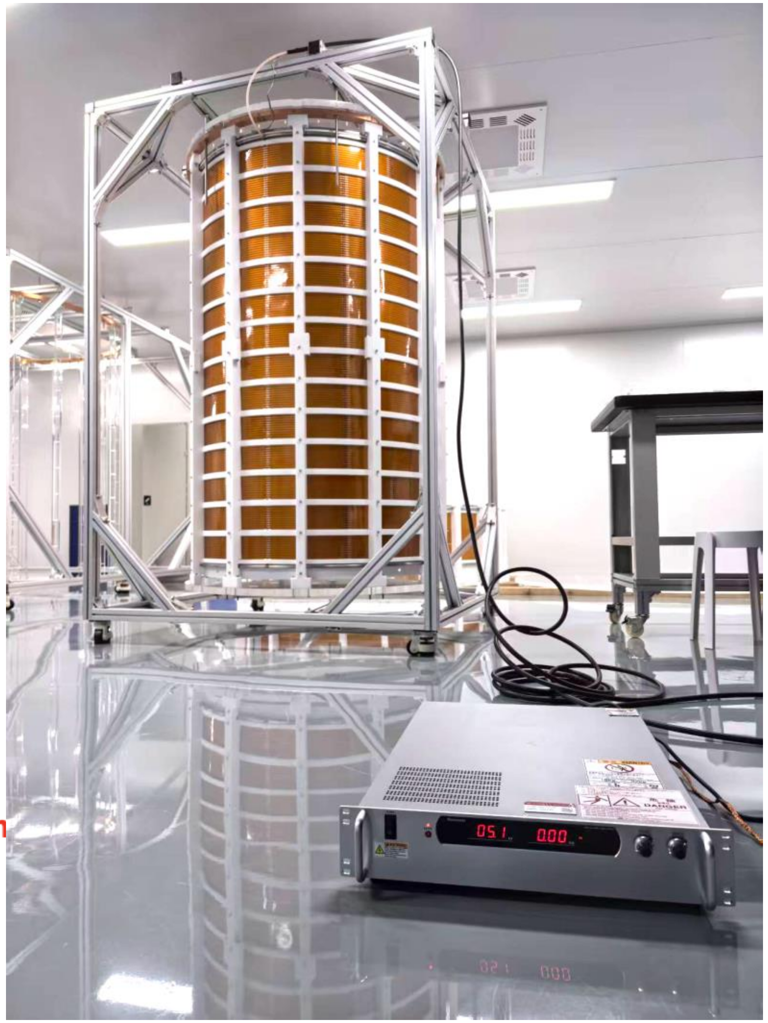
- Eventually, 47-ton xenon, including 40-ton sensitive volume
  - TPC 2.5 meters in diameter and height
  - Cold LS veto right outside Cu cryostat
  - Staged and upgradable
  - Dual-phase or single-phase options
- First stage： PandaX-20T

Sci. China Phys. Mech. Astron. 68, 221011 (2025)

PandaX-20T TPC in preparation



PCB shaping ring (Flexible, insulating and easy to scale up)

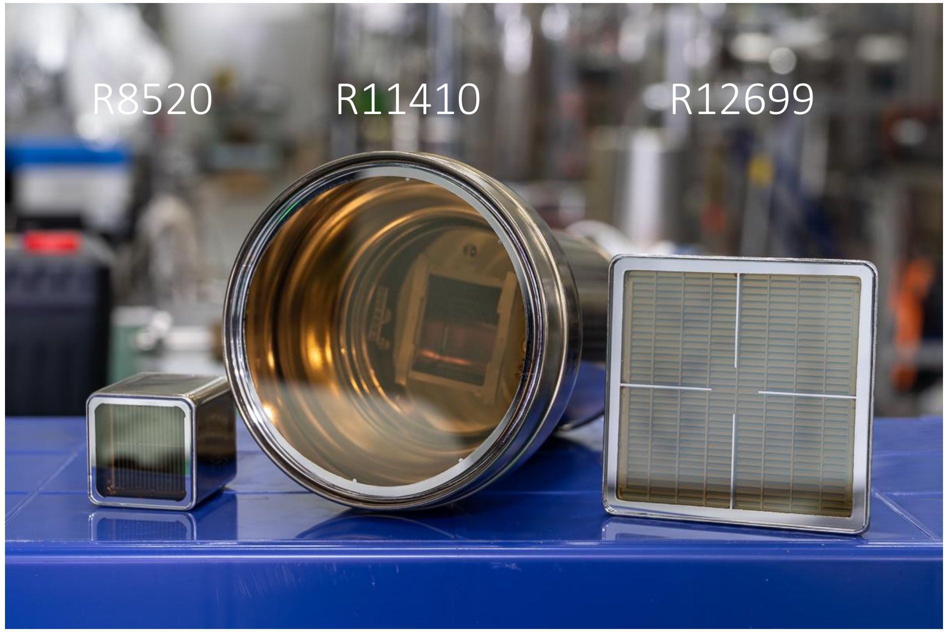


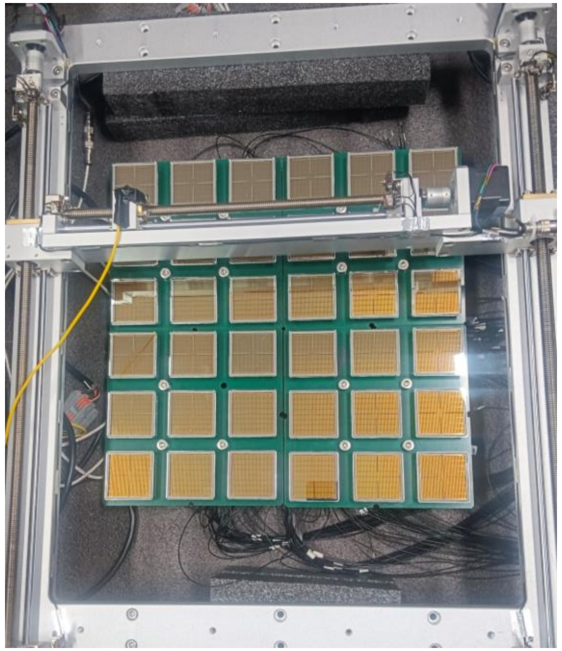
2m-diameter Wire grid

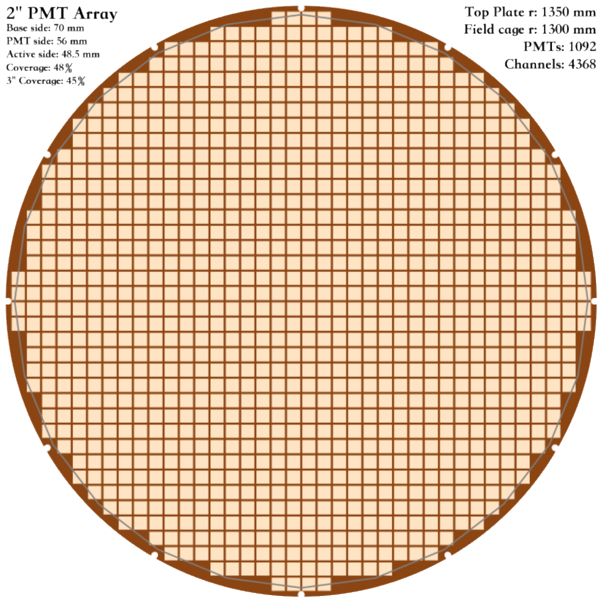
New 2-inch multi-anode R12699 PMTs

- Higher granularity while maintaining low dark noise: best of both large PMT and SiPM
  - Improved position reconstruction for better event topology
  - 2” array has an effectively wider dynamic range for DM and DBD simultaneously

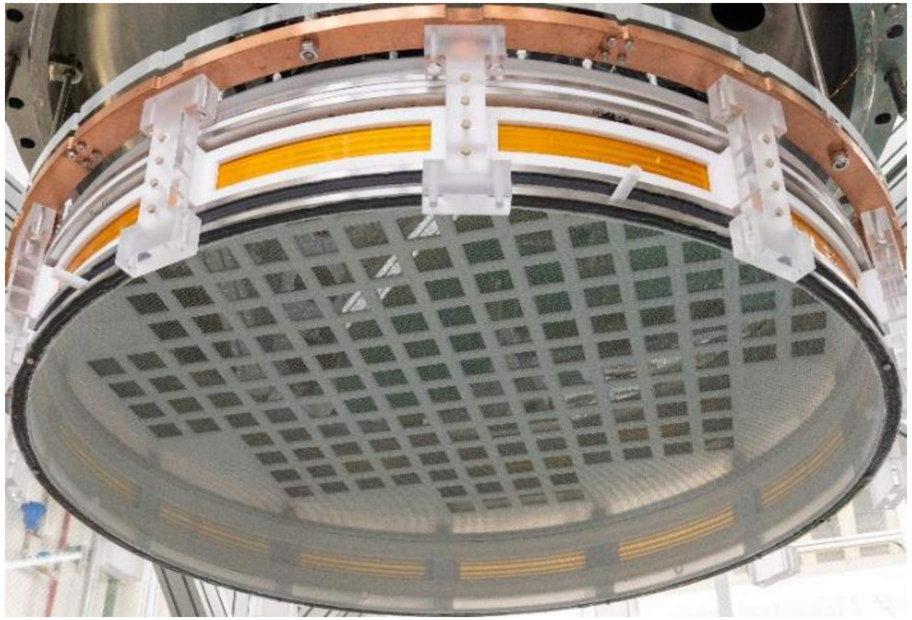
- Collaboration between PandaX and Hamamatsu for a low-radioactivity version of R12699, NIMA 1073 (2025) 170290

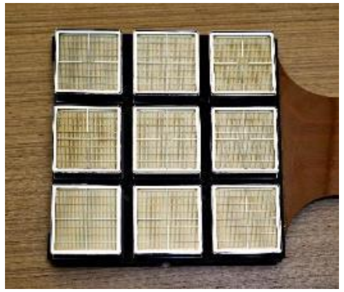


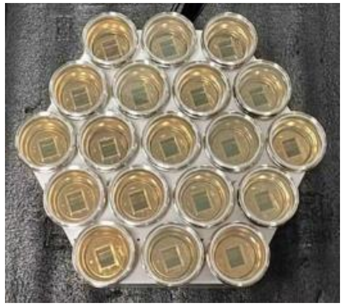




PandaX-20T PMT arrays

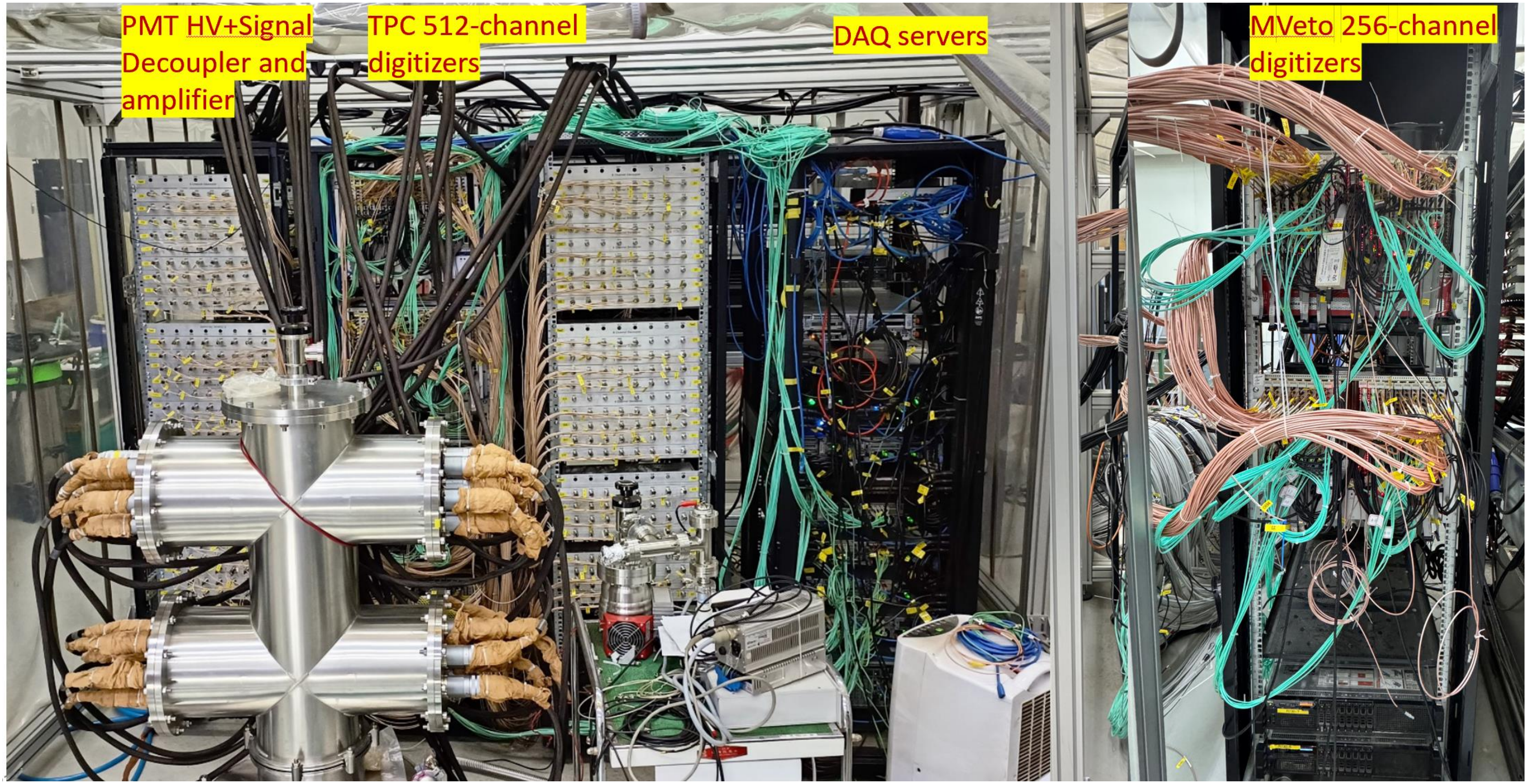


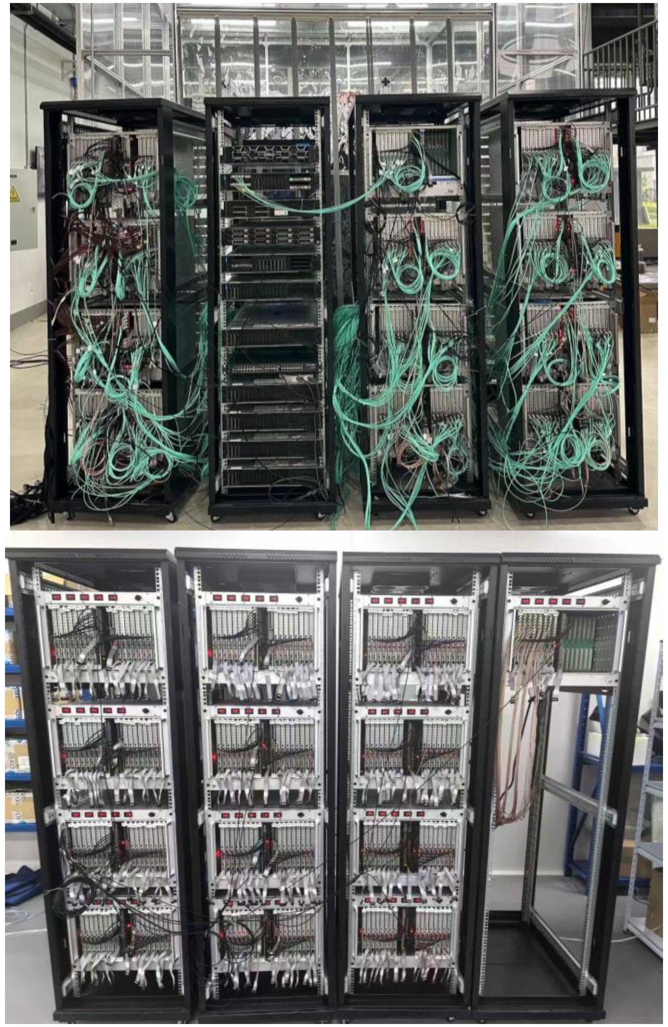




- Top PMT arrays:
  - 616 2inch multi-anode PMTs (R12699)
  - Low-radioactivity version to be delivered in 2026
  - Flexible-Rigid PCB (FRP) boards for integrated HV/signal readout lines with base
- Bottom PMT arrays
  - 433 3inch PMTs (PandaX-II and PandaX-4T)
  - Flexible PCB bases

PMT waveform digitization and readout

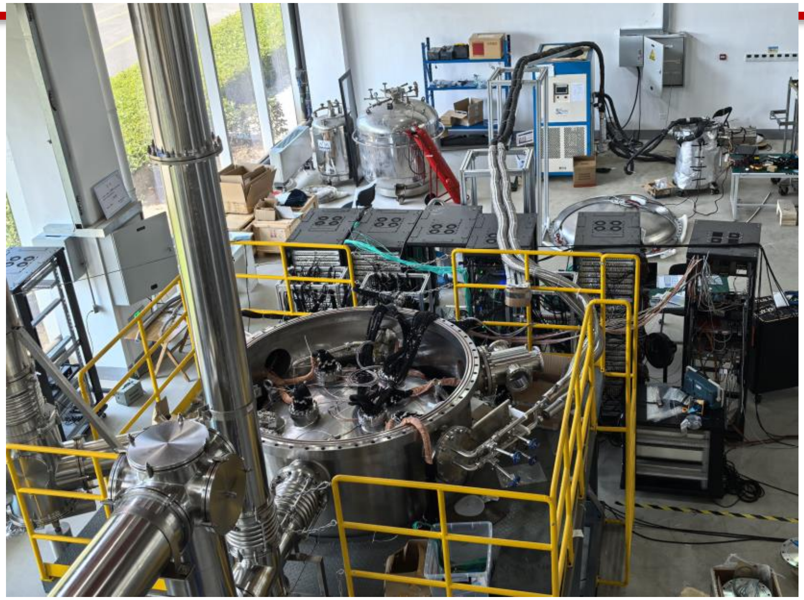


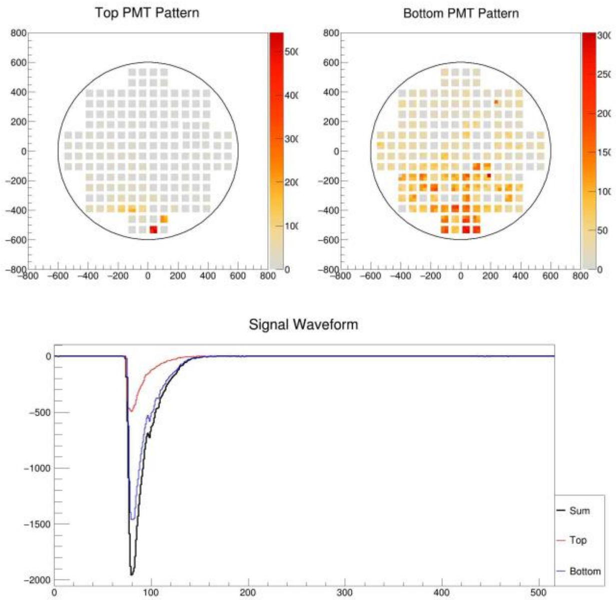


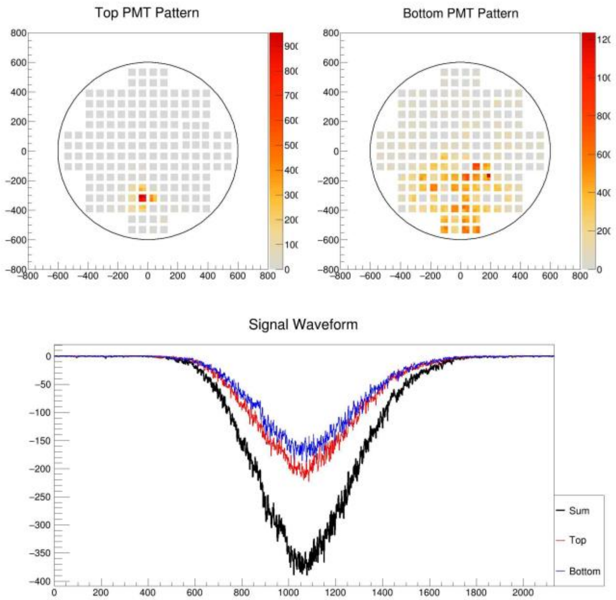
768 custom-design 500MS/s digitizer channels in CJPL

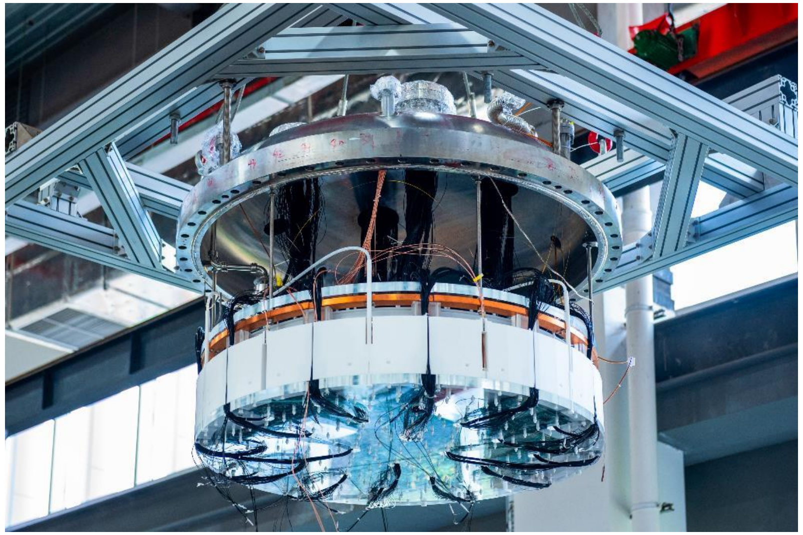
3000 channels in TDLI

Prototype Test at TDLI



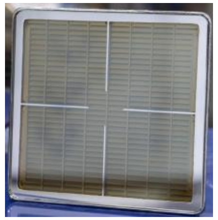






Full-chain readout

- Current: HV/signal feedthrough, signal amplification & digitization with warm electronics



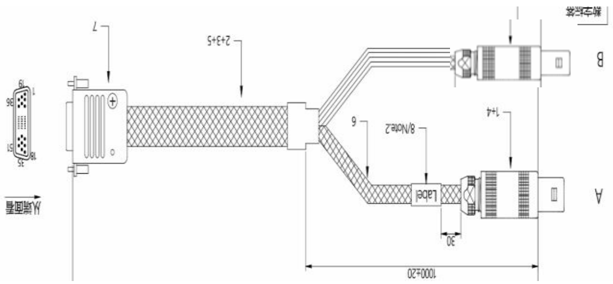
PMT

70-110 cm

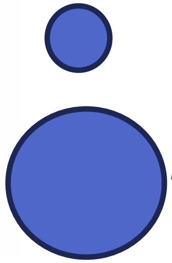
Base & FRP

feedthrough

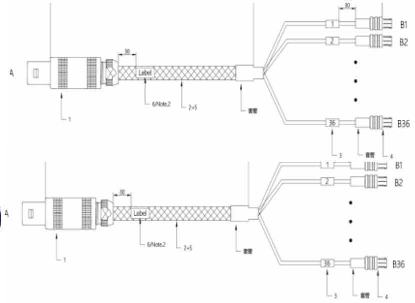
IF



IOC



OF



OC

IF = Inner feedthrough
IOC = Inner-outer cable
OF= Outer feedthrough
OC=Outer cable

Cable length: 12-14 m

High Voltage

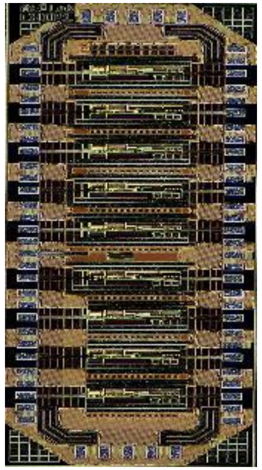
Pre-Amplifiers

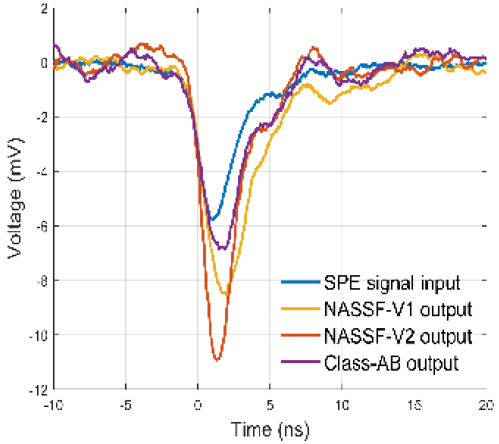
Digitizers

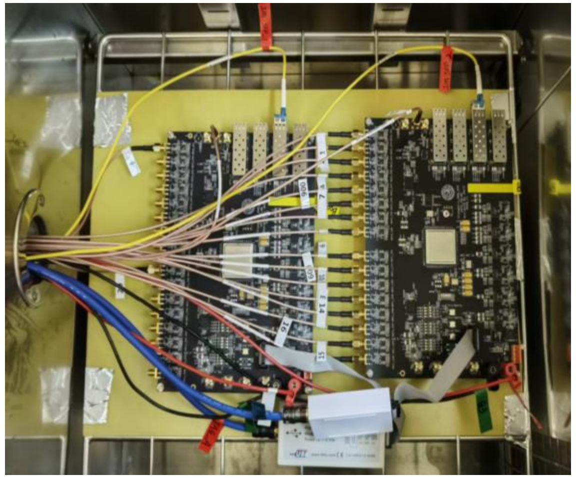
DAQ server

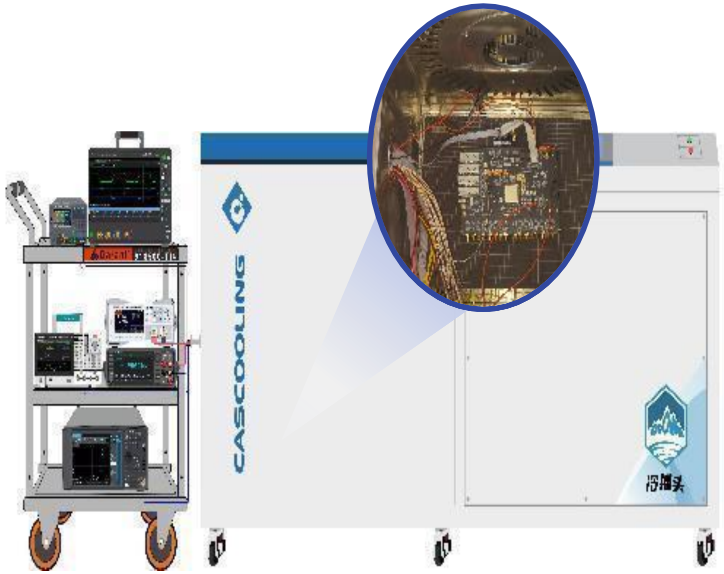
- Large number of feedthroughs, and coaxial cables (radioactivity and outgassing)
- signal cross talks or attenuation/distortion

Cold electronics R&D







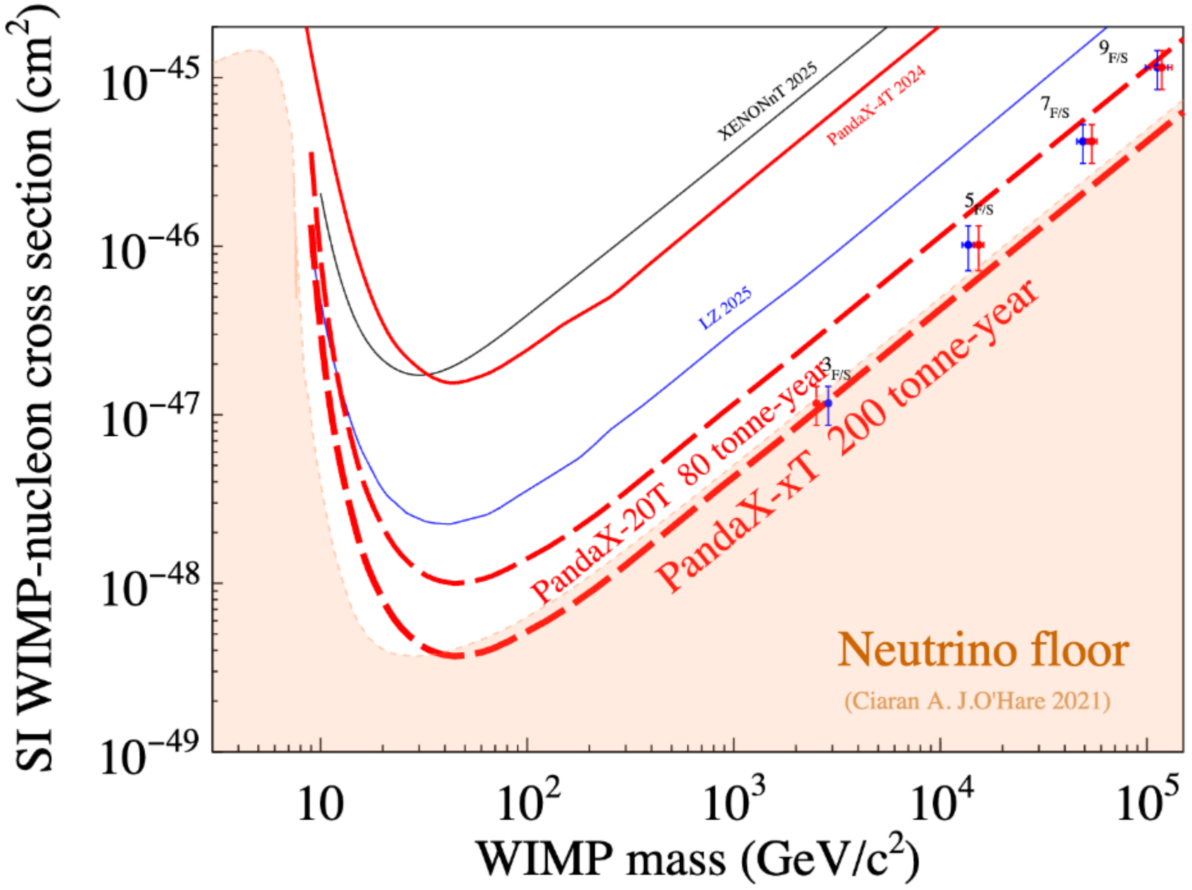


- High-speed low-power cryogenic pre-amp ASIC
  - Gain: x2; Bandwidth: >200MHz
  - Channels: x9
  - Power consumption: ~10mW/ch
  - Taped out, under packaging
- Verified at −100 ℃ environment

- 16-ch 125MS/s 14-bit ADC system
  - All components were pre-verified at low temperature
  - Power consumption: ~500mW/ch (probably optimized to ~300mW/ch)
- Verified at a −100 ℃ environment for 1216 hours.
- Low-background optimization is ongoing.

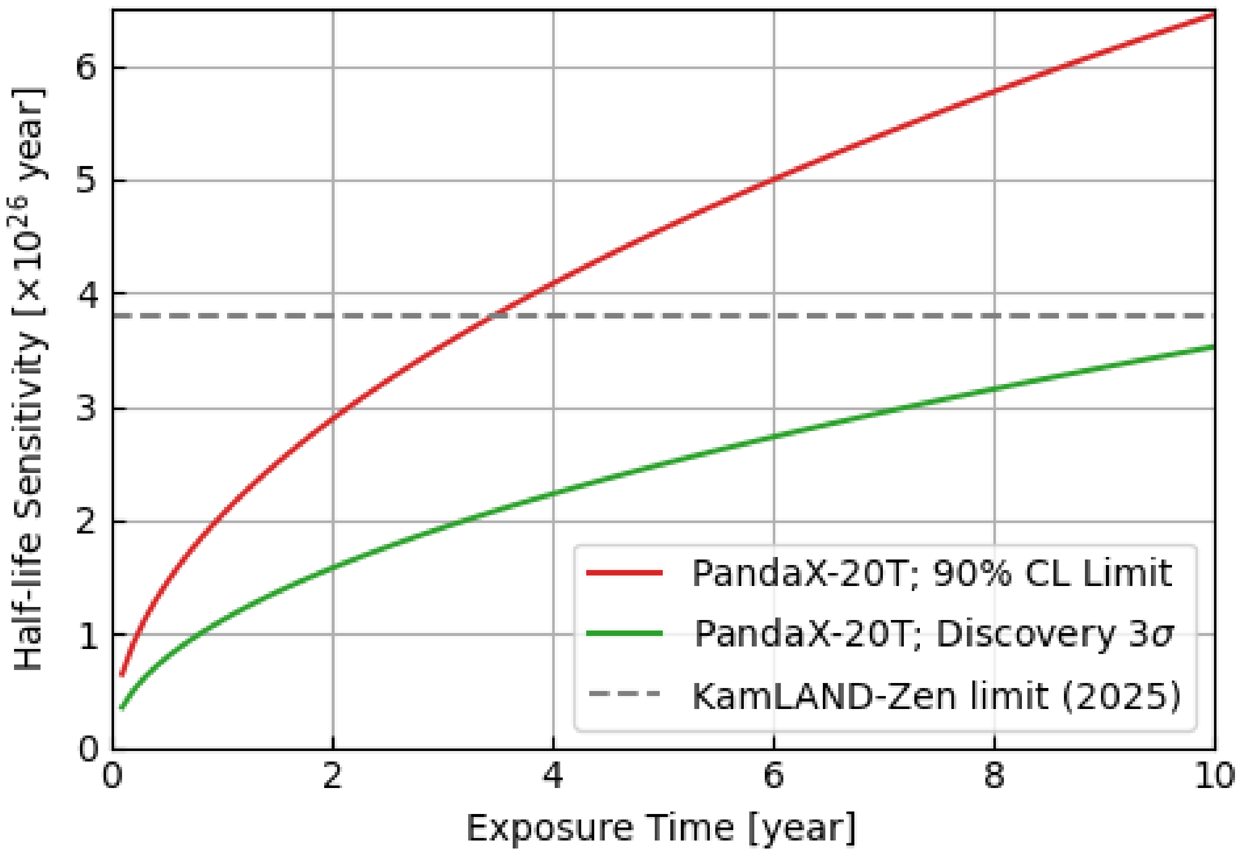
PandaX-20T:Baseline scientific potential

Dark matter



FV 13 ton, ROI 1-10 keVee, 99.7% ER rejection

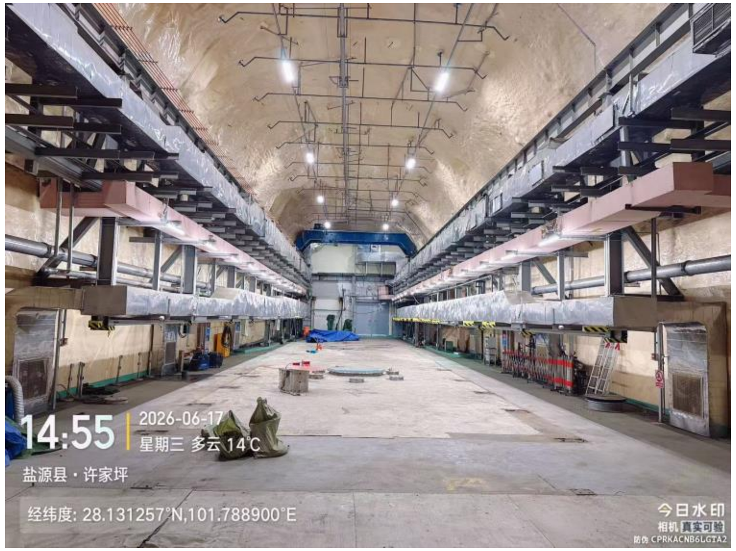
$0\nu\beta\beta$

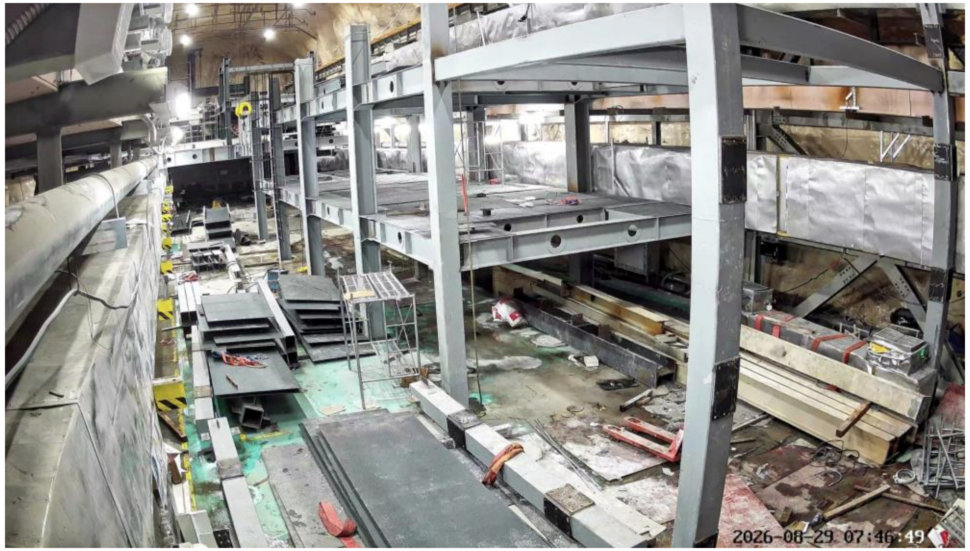


FV 2.4 ton natural, 1% resolution

PandaX-20T schedule

- 2026.4-6: PandaX-4T decommissioning
- 2026.6-12: PandaX-20T infrastructure construction
- 2027.1-6: Installation
- 2027.7-12: Commissioning
- 2028.1: Physics operation





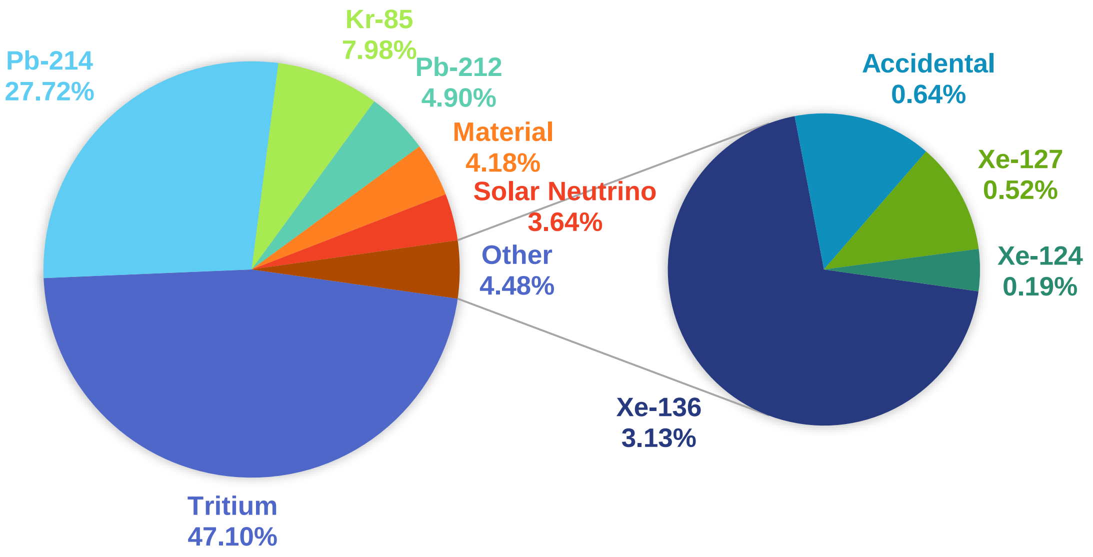
PandaX-xT open meetings, challenges

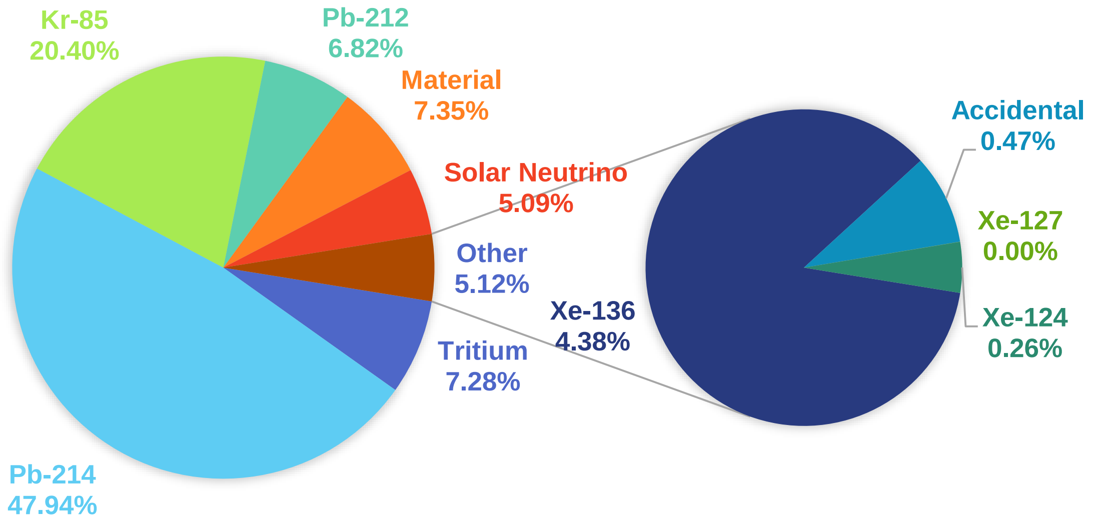
Item	Need	Best now	Challenge level
Low bkg cryostat	Thin-Walled Cu	Low background SS	***
Photosensor array	10 m^2, high QE, low noises, fast	3 m^2, R11410 3” PMT	*
Readout electronics	Cold and low background	Custom digitizers 500 MS/s	***
Energy res. @ 2.5 MeV	1%	1.9%	**
^{85}Kr background	0.1 ppt	0.3 ppt	***
^{222}Rn background	0.5 uBq/kg	4 uBq/kg	***
Cryogenics & recirculation	500 slpm	150 slpm	**

- PandaX will be continuously upgraded, with developing technologies tested in full-size experiment, Collaboration is highly welcome!

Thank you !

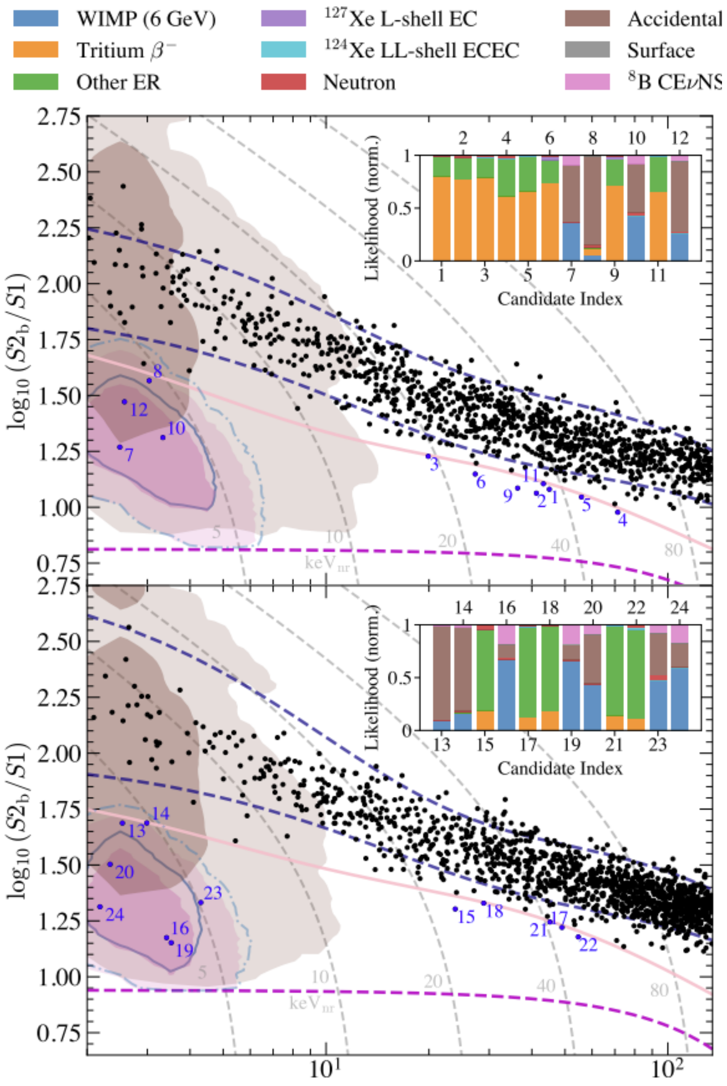
Backgrounds in low energy region for DM





- Energy Region of Interest: S1 > 2 Photoelectrons (PE), E_{rec} < 30 keV, and ER 99.5% acceptance;
- Background Composition: Tritium, ^{214}Pb, ^{85}Kr dominate the background level
  - Run0: 0.20 events/day/ton/keV,   Run1: 0.14 events/day/ton/keV

Run0+1: 0.54+1 ton-yr, blinded WIMP search



	Run0	Run1	Total	Below NR median
^{214}Pb	281 ± 13	675 ± 35	956 ± 38	$3.6^{+0.9}_{-0.7}$
^{212}Pb	49 ± 13	97 ± 25	146 ± 30	$0.6^{+0.2}_{-0.2}$
^{85}Kr	80 ± 40	289 ± 88	369 ± 96	$1.4^{+0.5}_{-0.5}$
Material ER	42 ± 5	105 ± 11	147 ± 12	$0.6^{+0.2}_{-0.1}$
EνES	38 ± 4	74 ± 7	111 ± 8	$0.4^{+0.1}_{-0.1}$
^{136}Xe	28 ± 1	59 ± 3	87 ± 3	$0.2^{+0.1}_{-0.1}$
Other ER (data)	504 ± 16	1226 ± 28	1730 ± 32	$6.4^{+1.7}_{-1.2}$
CH$_3$T	556 ± 33	114 ± 33	670 ± 47	$5.2^{+1.2}_{-1.1}$
^{127}Xe	7.7 ± 0.4	0.0 ± 0.0	7.7 ± 0.4	$0.10^{+0.02}_{-0.02}$
^{124}Xe	2.3 ± 0.6	4.1 ± 1.1	6.3 ± 1.7	$0.03^{+0.01}_{-0.01}$
Neutron	0.6 ± 0.3	1.1 ± 0.6	1.7 ± 0.9	$1.0^{+0.5}_{-0.5}$
^{8}B CEνNS	0.3 ± 0.1	0.7 ± 0.2	1.0 ± 0.3	$1.0^{+0.3}_{-0.3}$
Surface	0.09 ± 0.06	0.17 ± 0.11	0.26 ± 0.12	$0.26^{+0.12}_{-0.12}$
Accidental	11 ± 3	13 ± 4	24 ± 5	$6.4^{+1.4}_{-1.4}$
Sum	1082 ± 37	1356 ± 43	2439 ± 43	$20.5^{+2.5}_{-2.2}$
Observed	1117	1373	2490	24