Background programme for PandaX-20T

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Outline

- PandaX introduction
- Screening programme
  - HPGe
  - ICPMS
  - Radon emanation measurement system
  - Kr/Ar assay system
  - Surface screening method (radon daughters and dust)
- Background control
- Summary

PandaX pathway

- Dark matter/neutrinoless double beta decay searching, solar neutrino measurement and etc
- Dual-phase xenon time projection chamber (TPC) technique
- Increasing sensitive target volume, lowering radioactive background

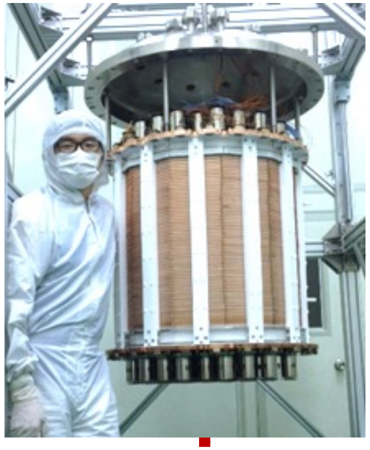
PandaX initiated

2009

PandaX-I
120 kg

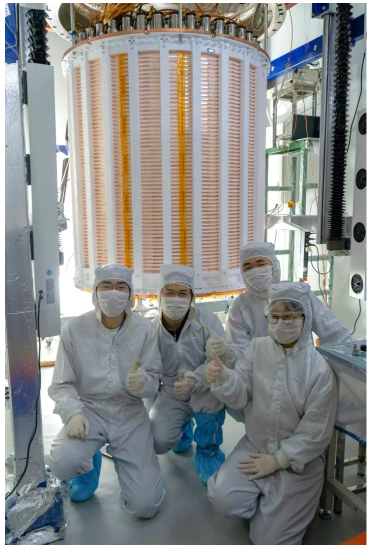
2010-2014

PandaX-II
580 kg



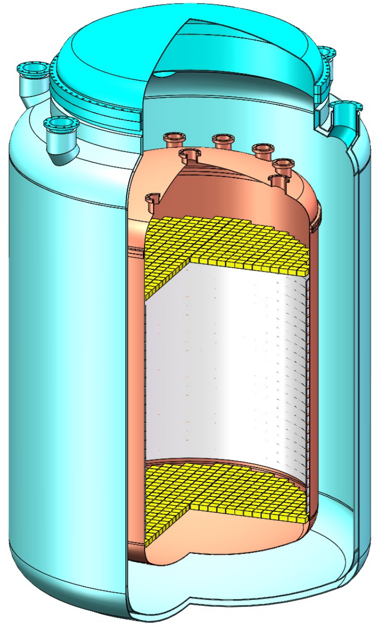
2015-2019

PandaX-4T
3.7 tonne



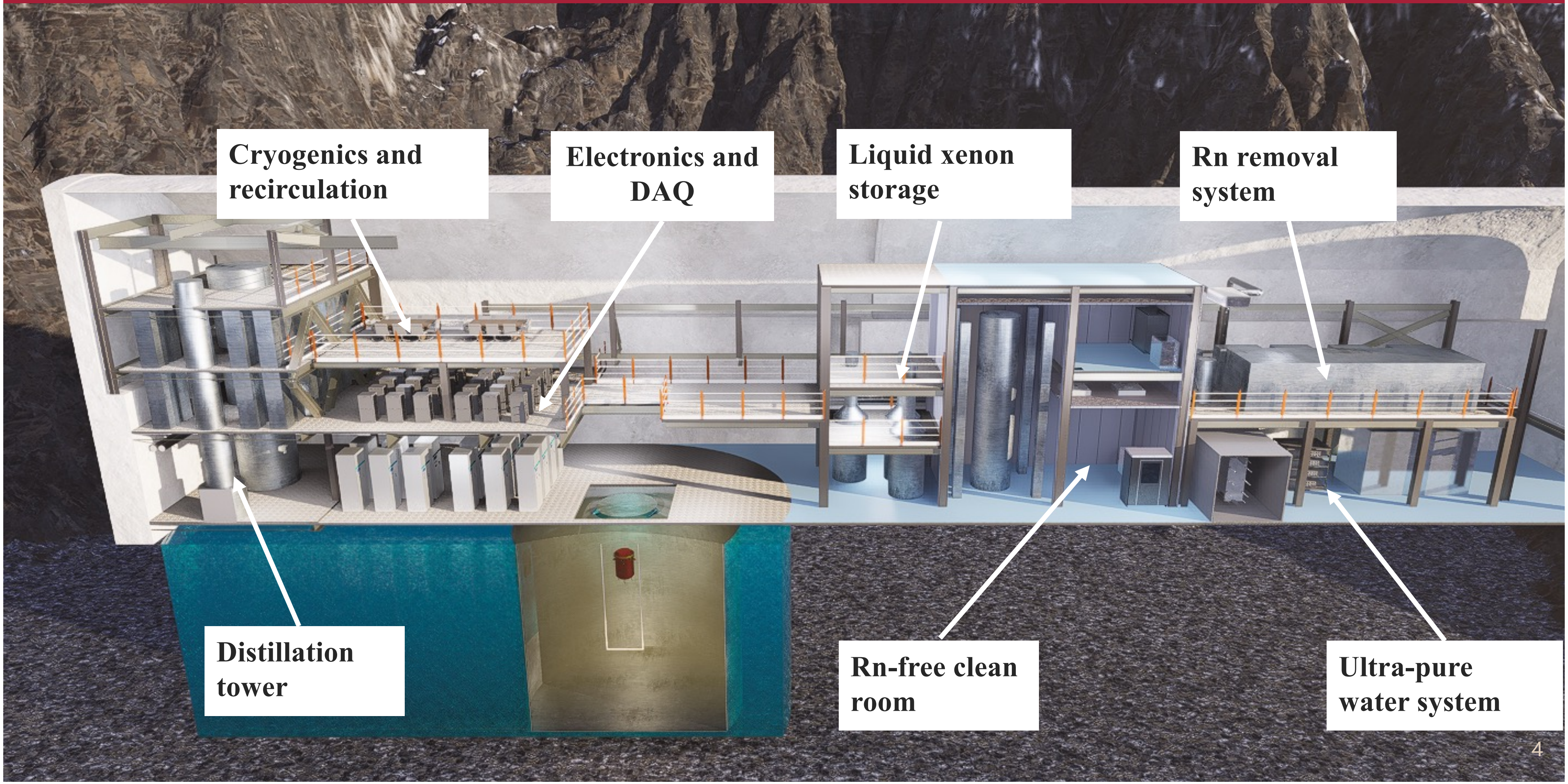
2020-2026

PandaX-xT
20 tonne -> 47 tonne



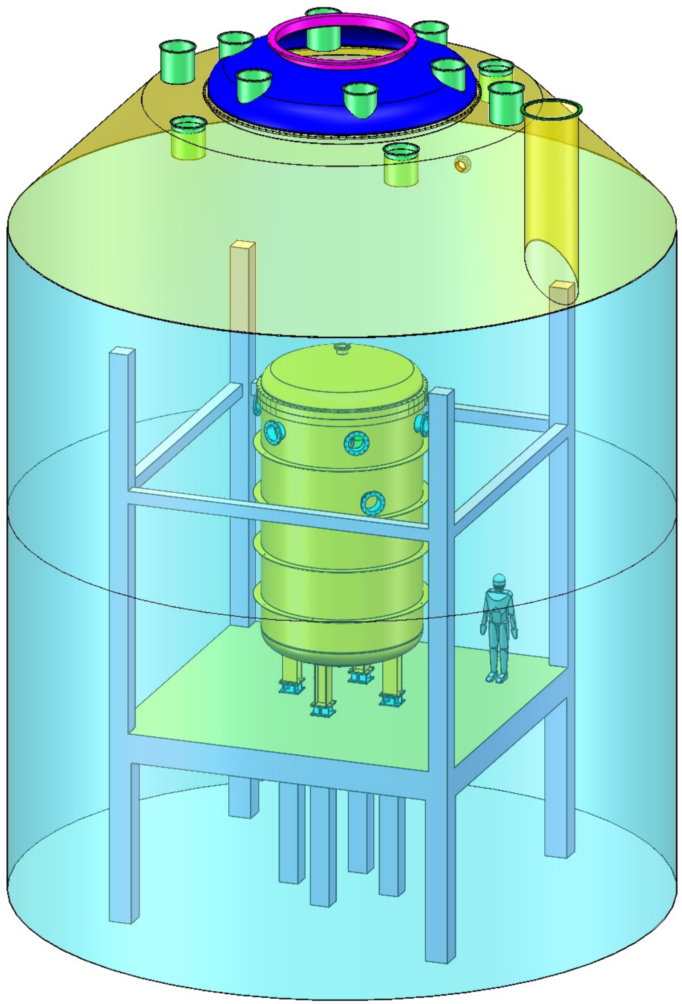
2027-

Layout of infrastructure renovation at CJPL



PandaX-20T overall design

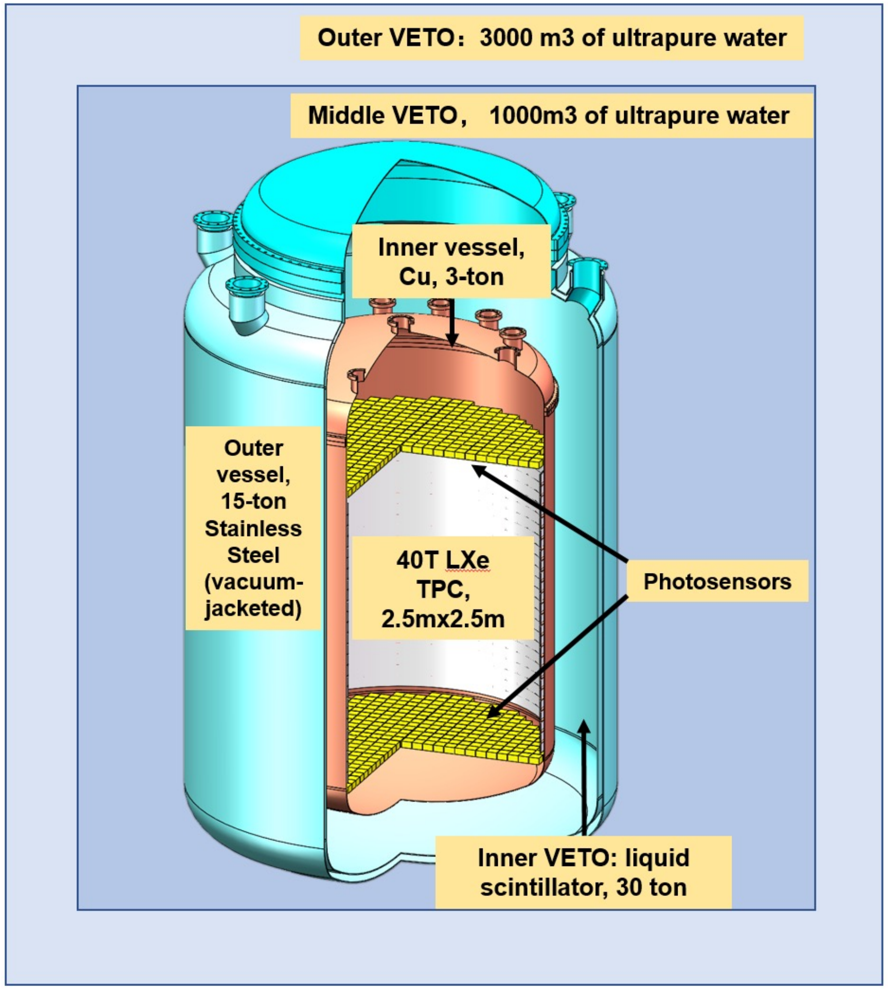
- Dual-phase TPC
- 2-inch PMT on top and 3-inch PMT on bottom
- Titanium cryostat
- Room-temperature liquid scintillator veto outside titanium cryostat
- Ultrapure water veto and shielding
- Cryogenics, LXe storage, krypton & radon distillation tower, etc. for the final-stage 47-tonne detector



PandaX-xT conceptual design

- Staged plan, eventually 47-tonne Xe with 40-tonne sensitive volume
  - TPC: 2.5 m in diameter and height
  - Cold LS veto right outside Cu vessel
  - Ultrapure water as veto and shielding
  - Dual-phase or single-phase options
- First stage PandaX-20T “fully” funded

*arXiv:2402.03596, **SCPMA** 68, 221011 (2025)*



Backgrounds across the energy range

Analysis region	Backgrounds to control	Main handles
Sub-keV ER / few-electron S2	Cathode activity, delayed electrons, Accidental S1–S2 pairs	Electrode cleanliness and S2 width Timing and control samples
1–10 keV_{ee} WIMP search	^{214}Pb, ^{85}Kr, tritium, Material gamma rays, neutrons, neutrinos	Radon / krypton removal, material selection, eletron recoil(ER)/neutron recoil(NR) discrimination, FV and veto
10–150 keV_{ee} Solar neutrinos	^{214}Pb / ^{212}Pb, ^{85}Kr, ^{39}Ar, ^{136}Xe $2\nu\beta\beta$ and ^{124}Xe	Independent activity constraints Spectral fit and time evolution
2433–2483 keV_{ee} ^{136}Xe $0\nu\beta\beta$	Material gamma rays, ^{214}Bi, $2\nu\beta\beta$ tail	Radiopurity, Single scattering(SS)/multiple scattering(MS), FV, Bi–Po tags Energy resolution near $Q_{\beta\beta}$

Background screening facility for PandaX-20T

HPGe gamma spectroscopy

- Three HPGe detectors are installed in the Jinping Underground Laboratory for measuring the intrinsic gamma radioactivity of materials and detector components.

Gamma spectroscopy

Germanium detector	JP1	JP2	JP3
Crystal diameter (mm)	94	71	83.9
Crystal height (mm)	104	30	31.5
Relative detection efficiency	175%	35%	51%
FHWM@1332 keV (keV)	2.7	2.5	2.0
FHWM@662 keV (keV)	2.5	2.3	1.4
60-2700 keV Integral (counts/kgGe/day)	594	1349	1352
MDA(mBq/kg) for U-238(late)	**~2.8**	**~4.4**	**~2.8**

Sensitivity

ICP-MS screening of U and Th

- Two ICPMS devices @ PKU and SJTU to measure U-238/Th-232 concentration
- Class 100 cleanroom with various pre-treatment methods
- **Sensitivity: ~sub-ppt level**

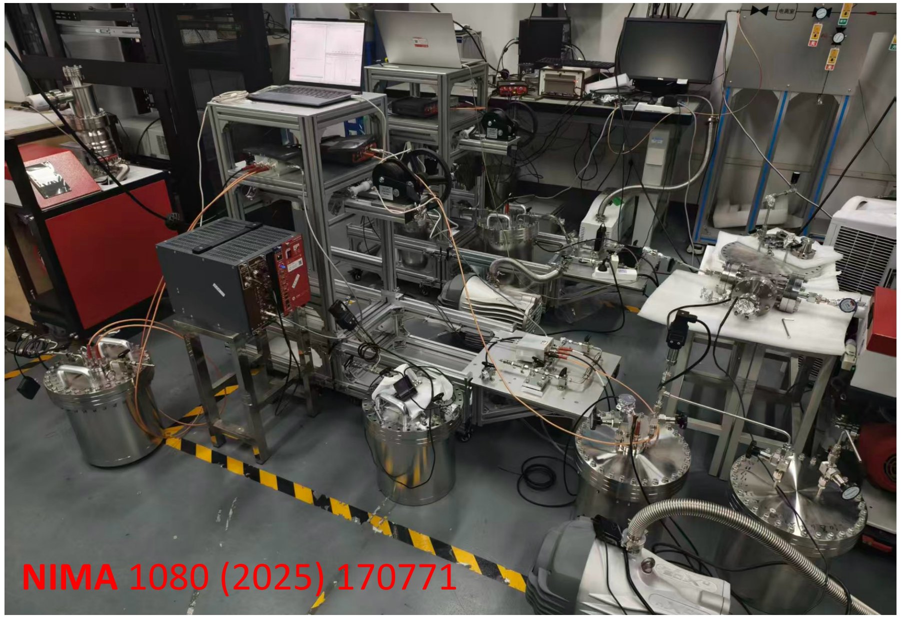
Agilent 7900@PKU

Cleanroom @SJTU

Resin exchange method

Radon emanation system

- 5 radon detectors: electrostatic collection method to measure radon emanation rate



The best blank is 0.03 mBq

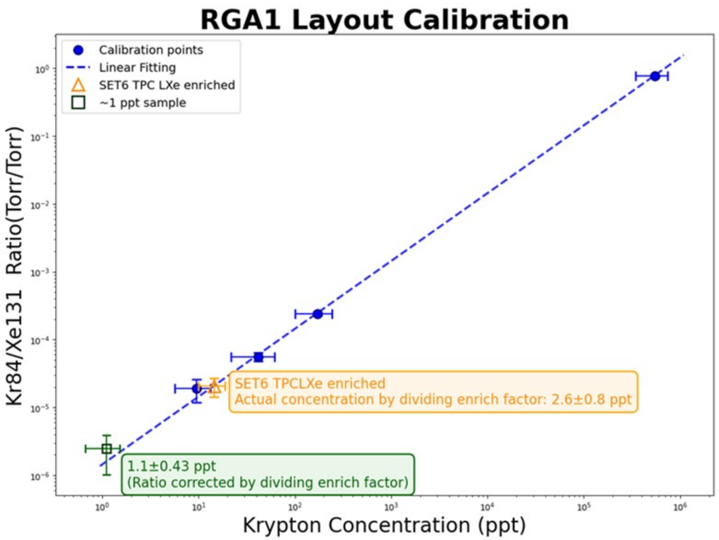
Cold trap system

Suitable to measure large volume containers (cryostat, distillation tower and etc), boost sensitivity by a factor of ~30

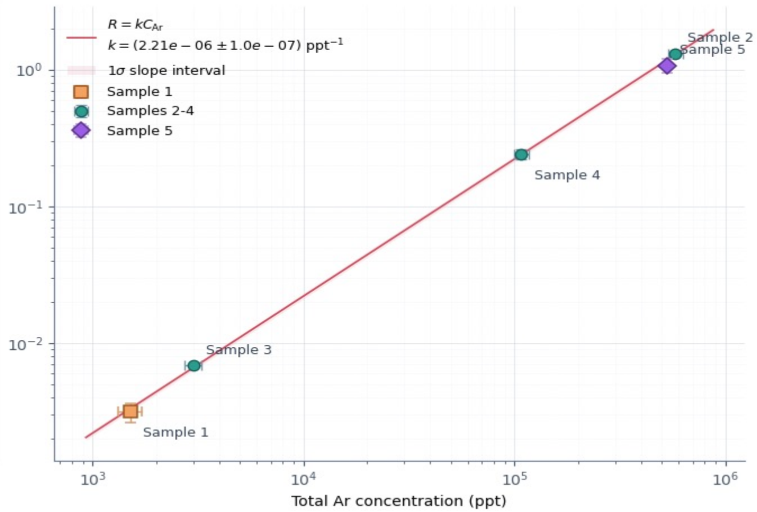
Krypton and Argon Assay

- Cold-trap/cold head enrichment and RGA at CJPL-II and SJTU.
- Kr/Xe and Ar/Xe ratios are measured to estimate the concentration
- About 1 ppt sensitivity for krypton

System setup



Krypton calibration

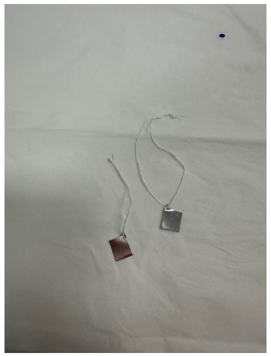


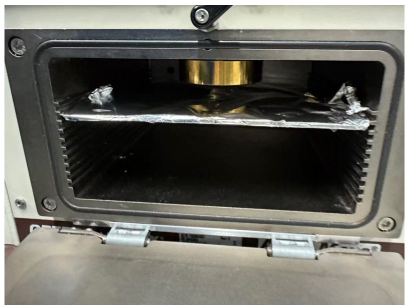
Argon calibration

Surface radon daughter contamination

- **Motivation:** measure surface Po-210 background from the cathode/mesh/grid
- **Method:** Po-210 extraction with silver plates

Mesh soaked in nominal 26% HNO_3 for ~24 h, then heated near 80 °C → Concentrate the HNO_3 leachate Add 0.6 M HCl directly → Silver plate deposition and alpha counting



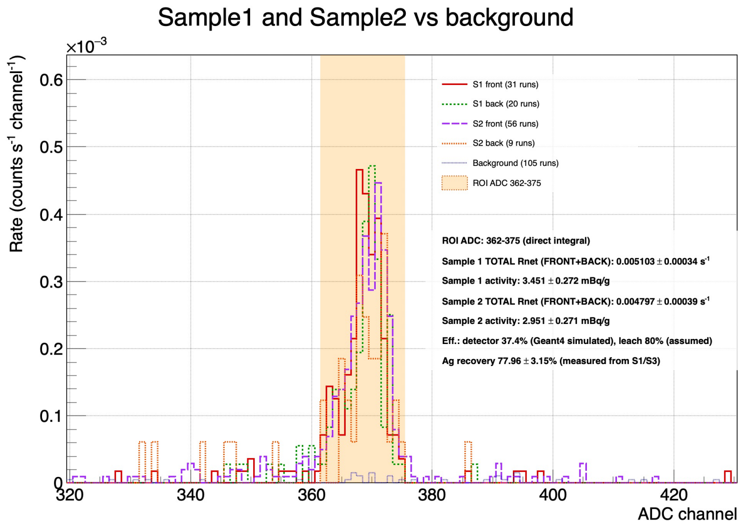


Sensitivity: 0.5 uBq/cm^2

Activity

$$a = \frac{R_{\text{net}}}{m\, \epsilon_{\text{det}}\, \epsilon_{\text{leach}}\, \epsilon_{\text{Ag}}}.$$

- Detector / geometry 38%
- HNO_3 leaching 40%
- Ag deposition 78%



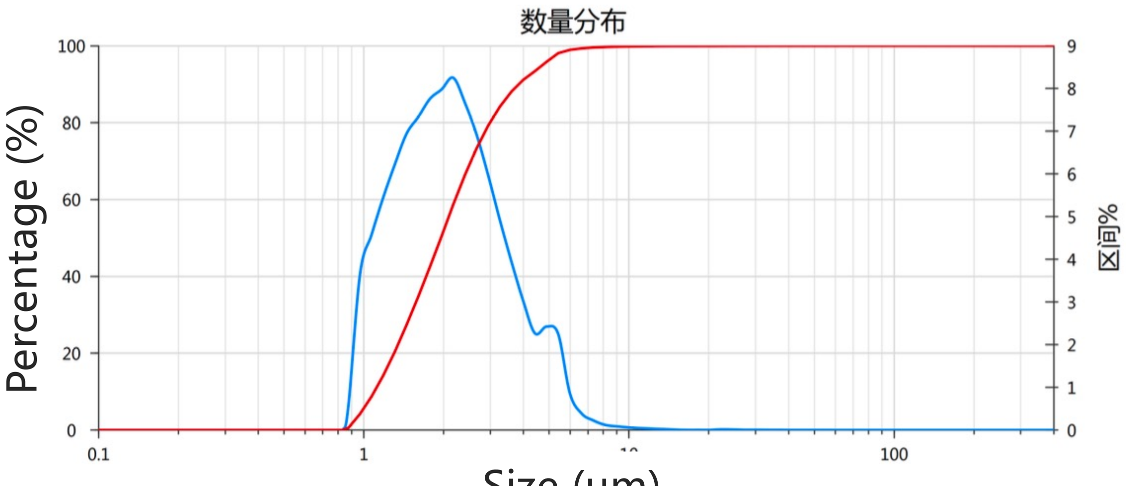
Surface dust contamination

- Radioactivity of surface dust contribution is evaluated by counting the particulate size distribution

$$A = N \times \frac{\pi}{6} d^3 \times \rho_{rock} \times \left[C_U \times 12.35 + C_{Th} \times 4.06 \right]$$

JUNO reference

- U -238： 9.6×12.35 ≈ 118.69.6×12.35≈118.6 Bq/kg
- Th -232： 26.6×4.06 ≈ 108.026.6×4.06≈108.0 Bq/kg



Particulate size distribution

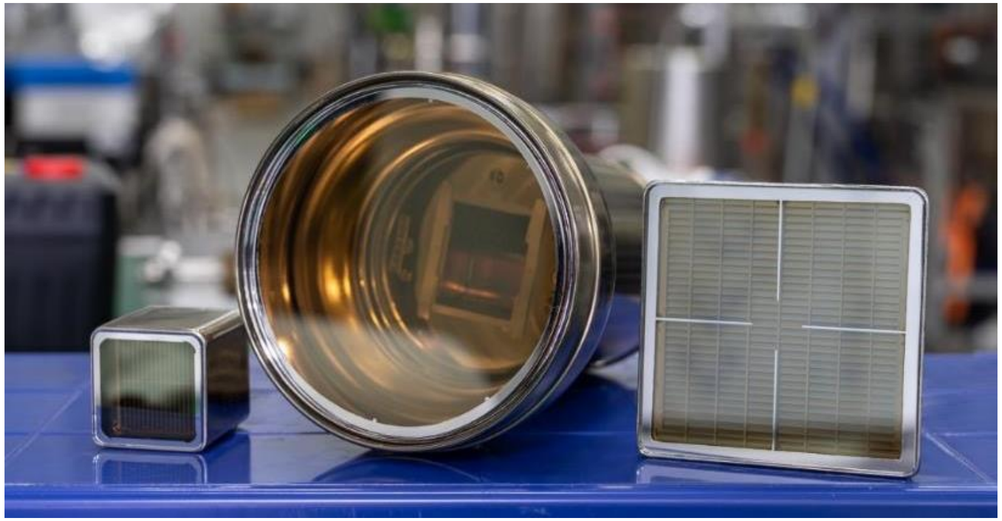
Particulate counter

Background control for PandaX-20T

Low-background PMTs

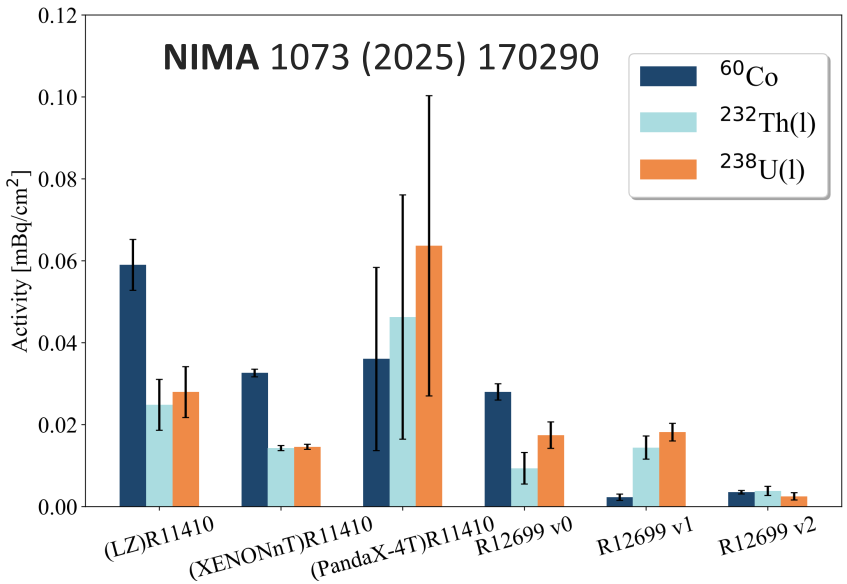
A Novel PMT - PandaX team & Hamamatsu Photonics K.K corporation

- Low background
- Compact, high granularity, 4 individual channels
- Quick transit time and rise time



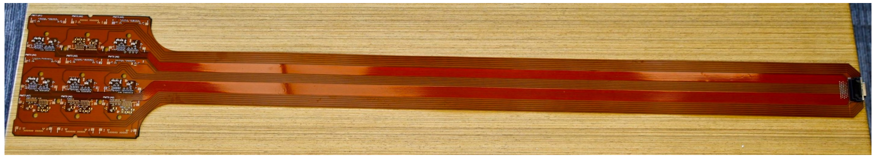
Three generations of PMTs used in the LXe experiment

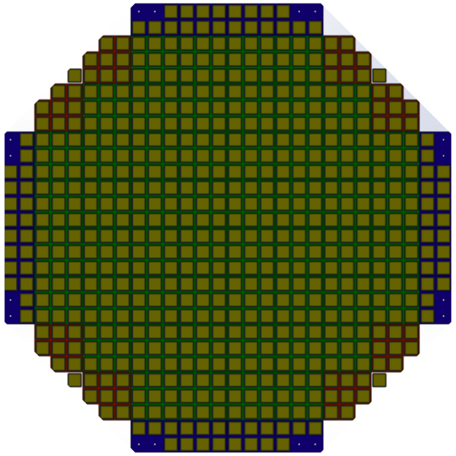
Radioactivity comparison

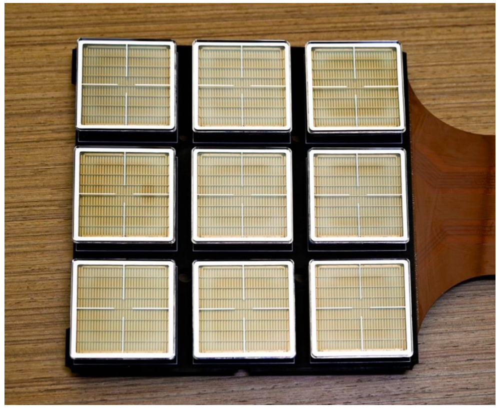


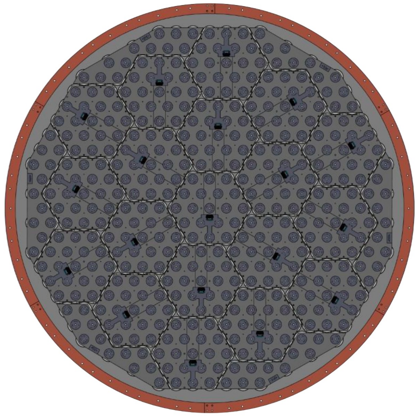
Low-background PMTs and readout materials

- Top PMT array:
  - 616 2-inch multi-anode PMTs (R12699)
  - Co-development with Hamamatsu for low-radioactivity version
  - Mainly 3×3 PMT tiles
  - Flexible-Rigid PCB (FRP) boards for integrated HV/signal readout lines with base
- Bottom PMT array:
  - 433 3-inch PMTs (R11410)
  - Mainly 19 PMT tiles
  - Flexible PCB bases









Bases, flexible boards, MicroD connectors, cables and feedthroughs also require assay.

Cryostat material and chain disequilibrium

- Lower cryostat radioactivity is a priority for the MeV programme

PandaX-20T titanium vessel

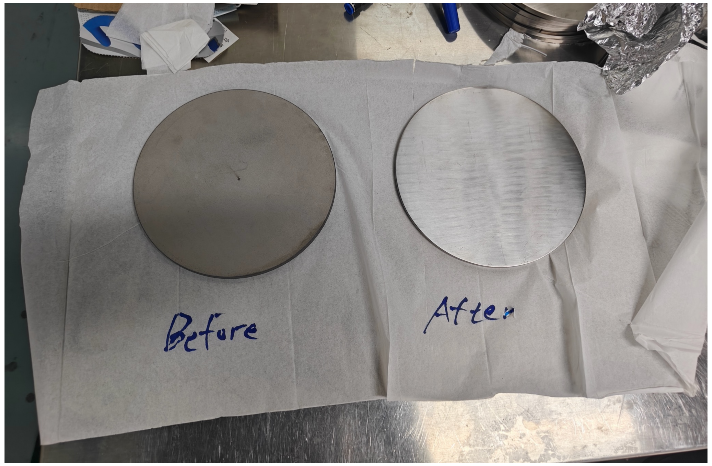
- Inner vessel: 2 m diameter, 3 m height.
- 8 mm barrel thickness.
- Measure both U early and U late.

unit: mBq/kg	K-40	Th-232 (early)	Th-232 (late)	U-238 (early)	U-238 (late)
Stainless steel	<2.32	1.81±0.51	1.12±0.42 <1.81	4.74±4.44 <12.02	1.38±0.36
Titanium	0.00±0.79 <1.30	0.08±0.23 <0.45	0.78±0.20	14.70±2.86	0.27±0.17
Copper	-	0.040±0.009	-	0.091±0.008	-

Inner vessel production

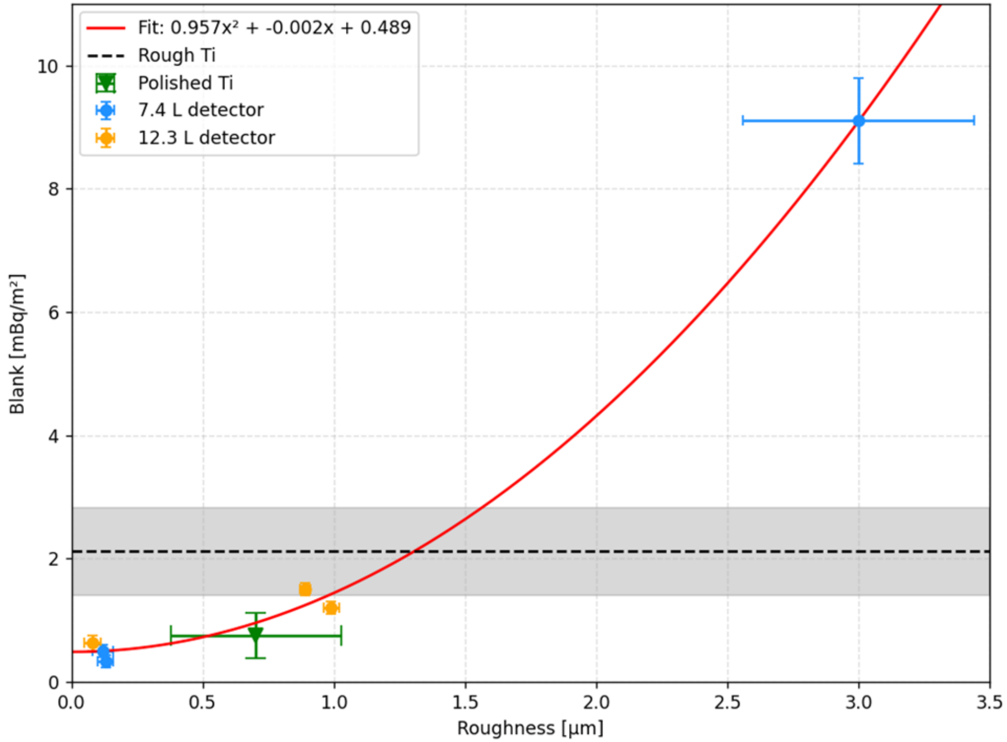
Ti surface treatment for radon control

- Ti sample polish: roughness = 0.7μm
  - 2.08±0.70 mBq/m² → 0.77±0.38 mBq/m²
- Coating W-Th electrode sample (Rn-220 emanation)
  - Copper: thickness = 9.6 μm, 80% reduction
  - Gold: thickness = 0.3 μm, 69% reduction



Ti sample before/after polish

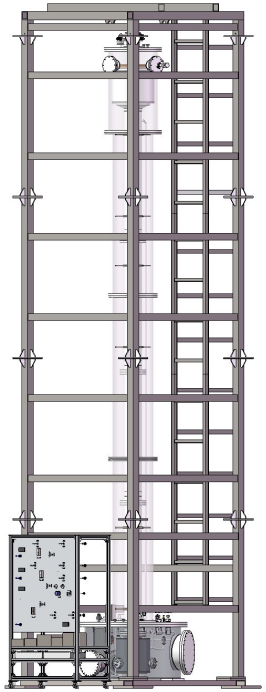
NIMA 1080 (2025) 170771



Radon vs roughness of Ti and SS

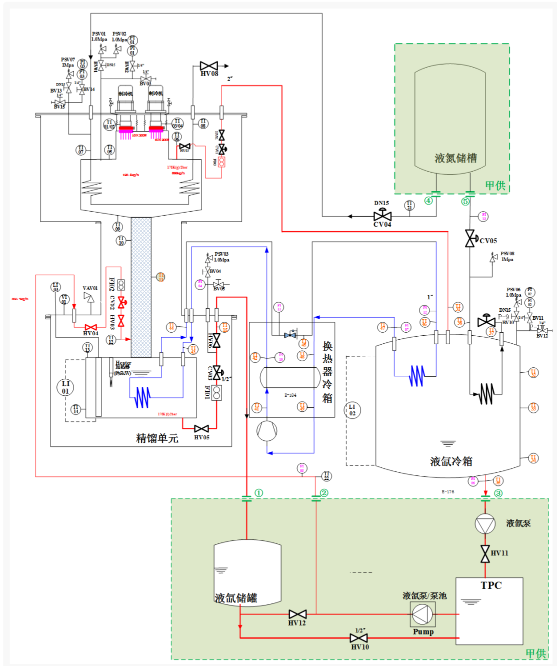
Krypton & radon distillation tower

Krypton distillation tower



- Kr distillation tower: 30 kg/hour
- **Target Kr concentration in Xe: 0.1 ppt**

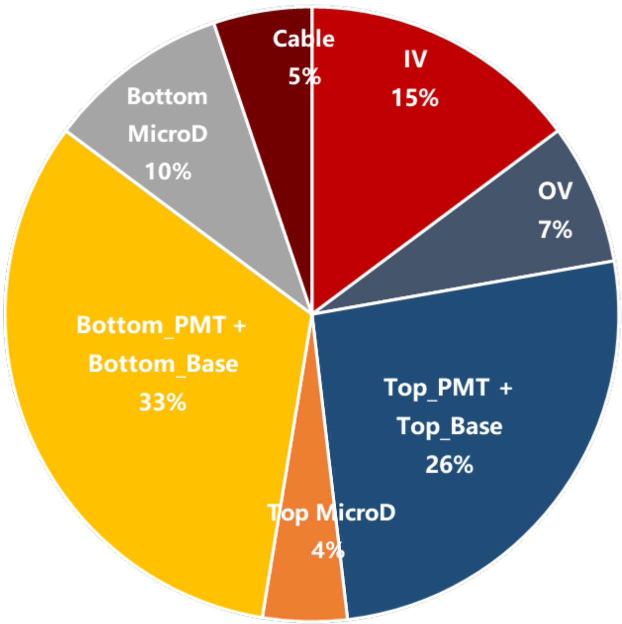
Radon distillation tower



- Rn distillation tower: 850 kg/hour
- High-power cooling recovery system under R&D, aiming 20 kW cooling power for 850 kg/h xenon flow rate
- **Target Rn level: 0.5 μBq/kg**

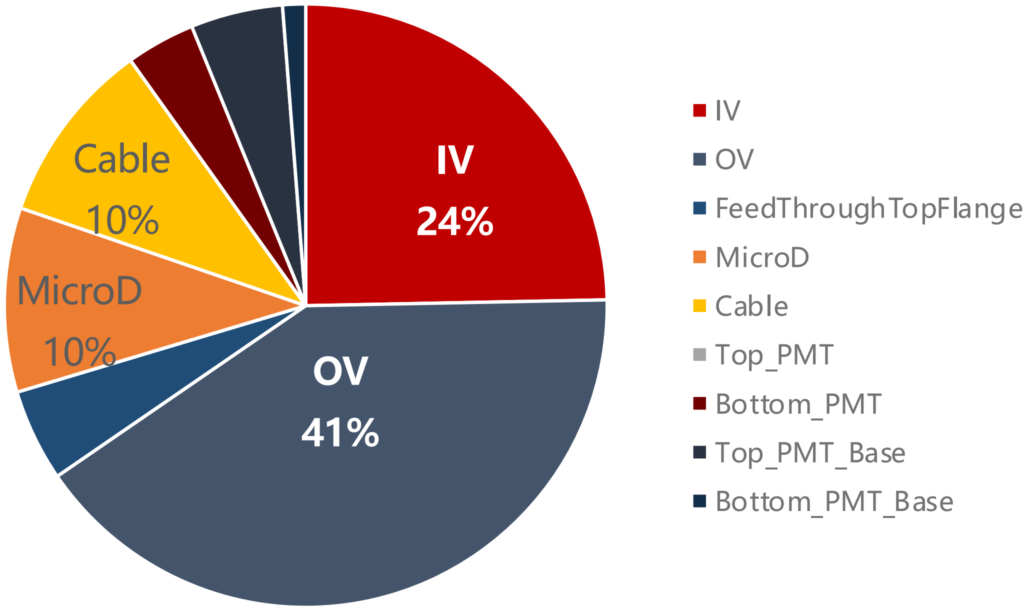
Material Background Budget

FV: 13.3 ton



Dark Matter
1-10 keV

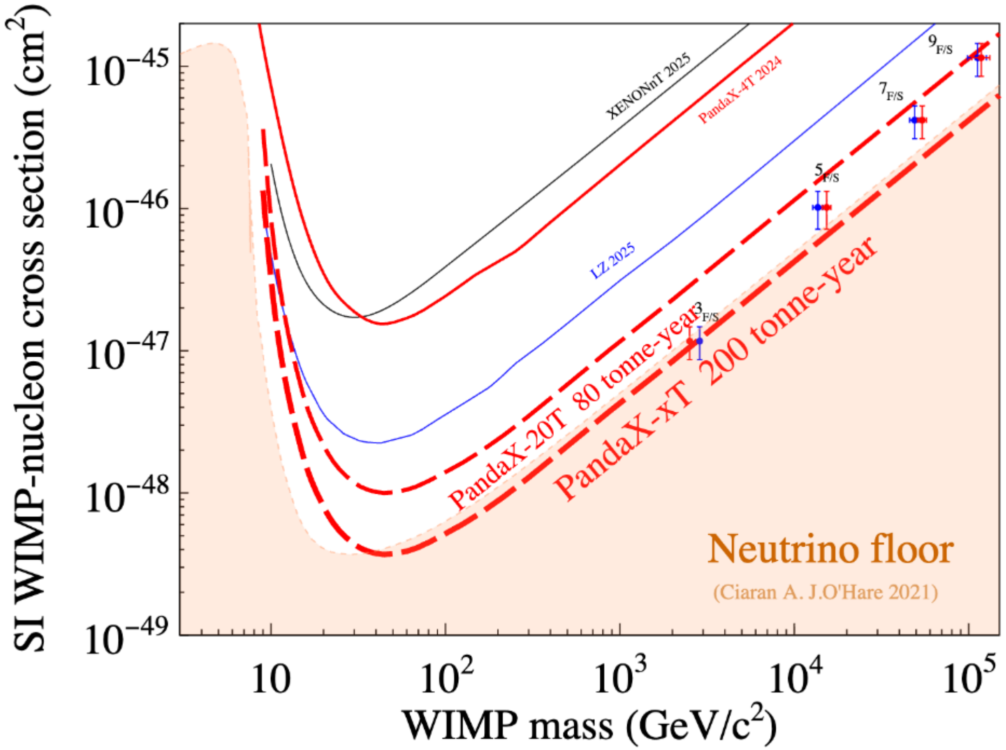
FV: 2.41 ton



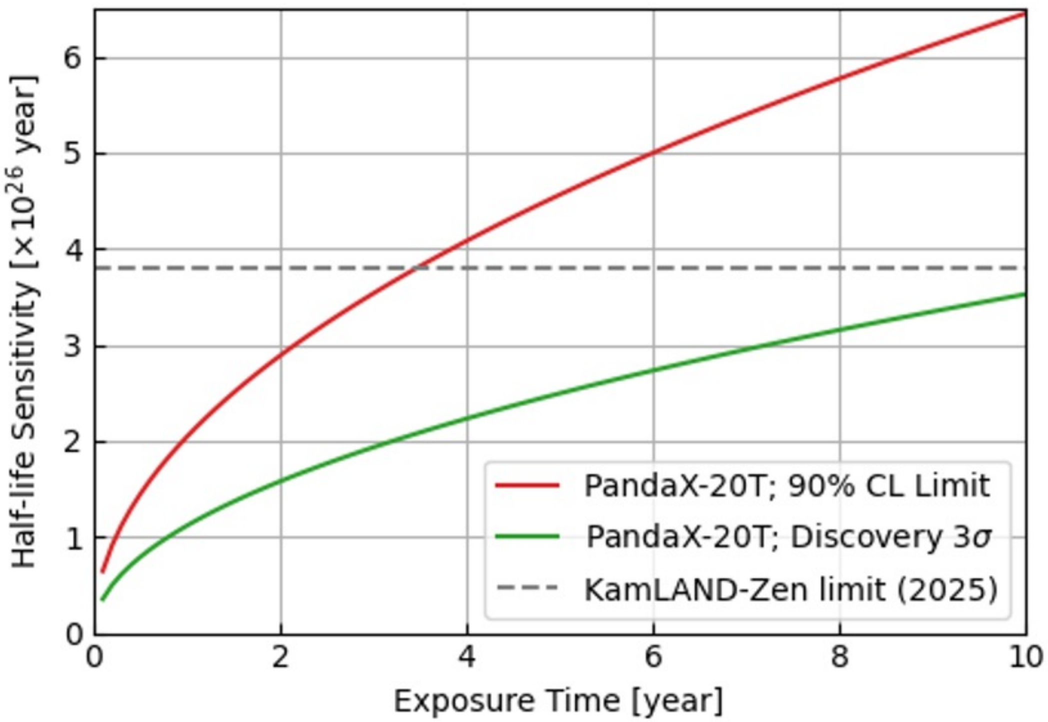
Neutrinoless double beta decay
2433-2483 keV

Sensitivity projection

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



FV 2.4 tonne natural Xe, 1% resolution @Q-value



Schedule

- 2026.4-6: PandaX-4T decommissioning
- 2026.6-12: PandaX-20T infrastructure construction
- 2027.1-6: PandaX-20T installation
- 2027.7-12: PandaX-20T commissioning
- 2028.1: PandaX-20T physics operation

Summary

Staged detector programme

- PandaX-20T uses a 17 t sensitive target. Shared infrastructure supports the later PandaX-xT upgrade.

Energy-dependent background control

- Sub-keV: cathode activity and delayed electrons.
- keV: dissolved beta emitters and ER leakage, and control NR background
- MeV: material gamma rays, Bi–Po tagging and energy resolution.

PandaX open meetings

The 1st open meeting at Shanghai (Apr. 10-11, 2025)	The 2nd open meeting at Huangshan (Apr. 10-12, 2026)	The 3rd open meeting at Qingdao (Oct. 16-18, 2026)

https://indico-tdli.sjtu.edu.cn/event/5143/

PandaX will be continuously upgraded, with developing technologies tested in full-size detector.

Collaboration is highly welcome!

Thanks

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