Progress and Future Plan of PandaX

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State key Laboratory of Dark Matter Physics

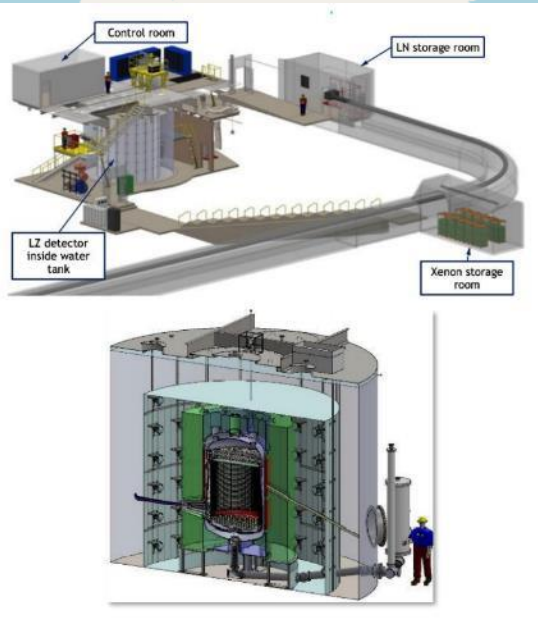
Tsung-Dao Lee Institute and School of Physics and Astronomy

Shanghai Jiao Tong University

Particle and Astrophysical Xenon observatory

Natural xenon detectors in operation

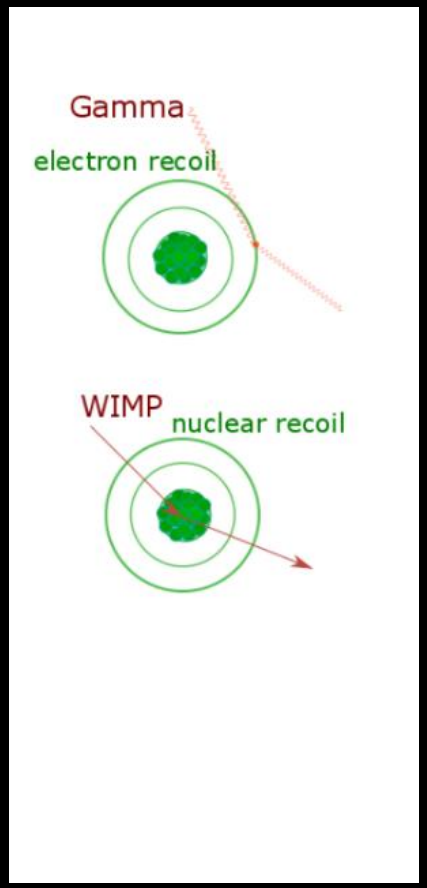
LZ

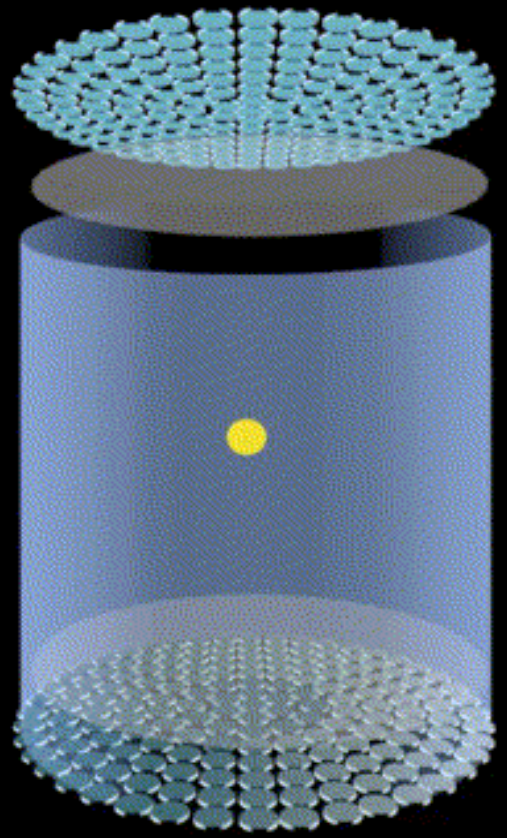


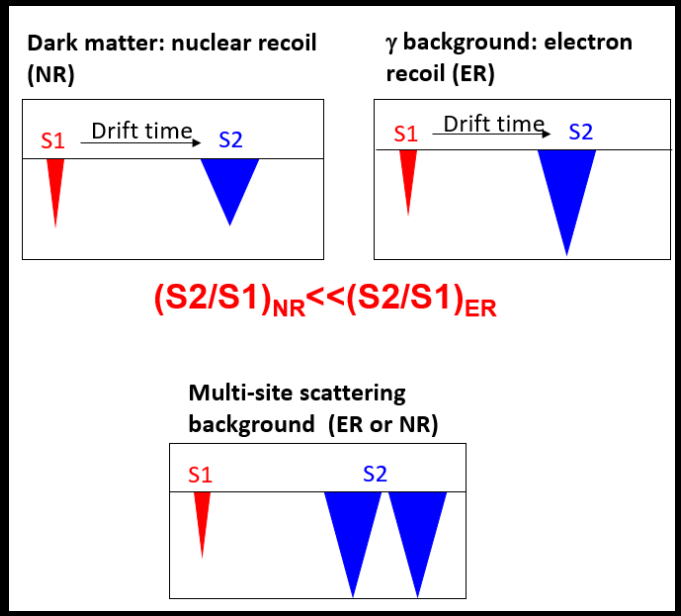
XENON

PandaX

Dual-phase xenon time projection chamber (TPC)



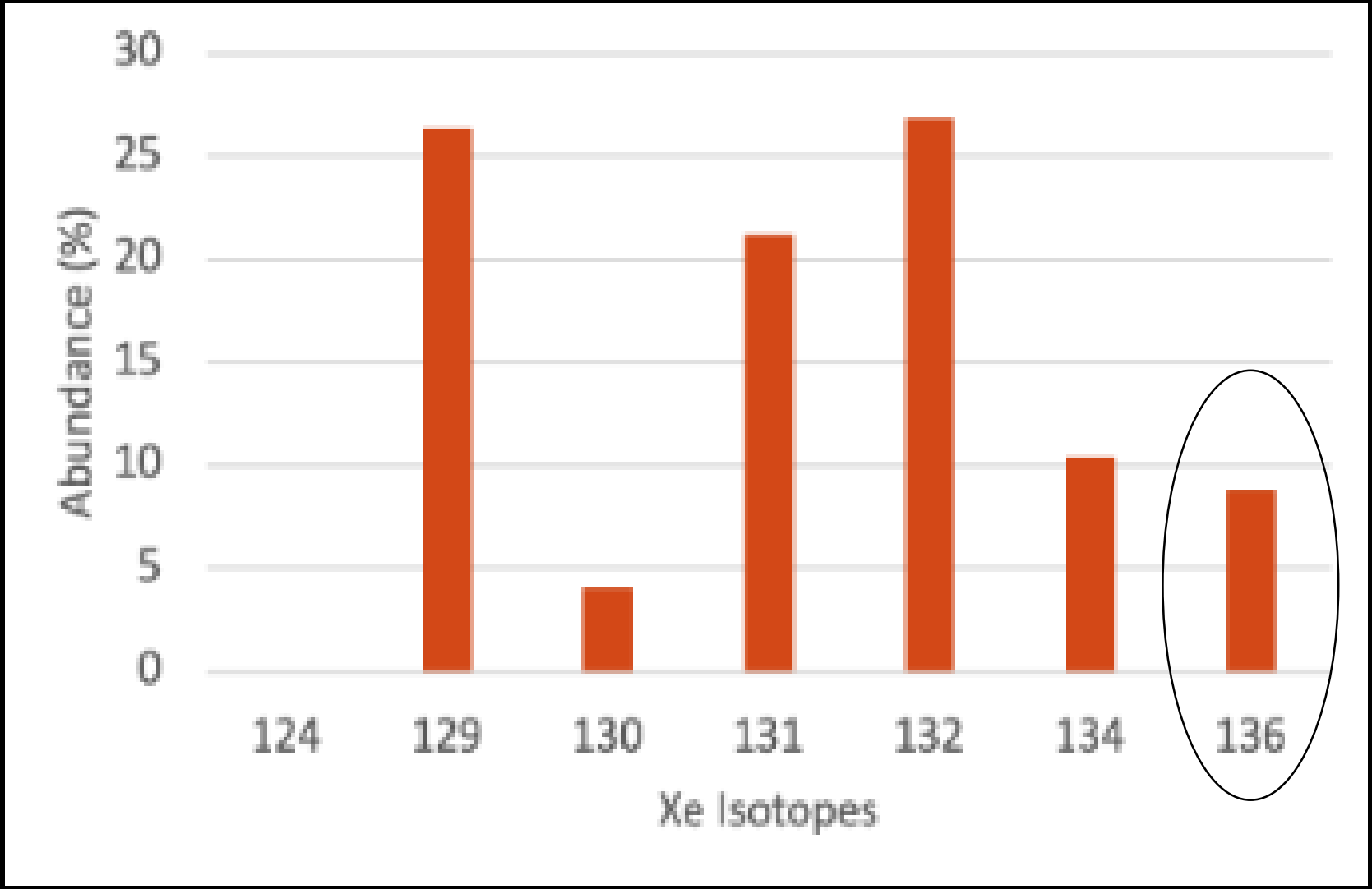




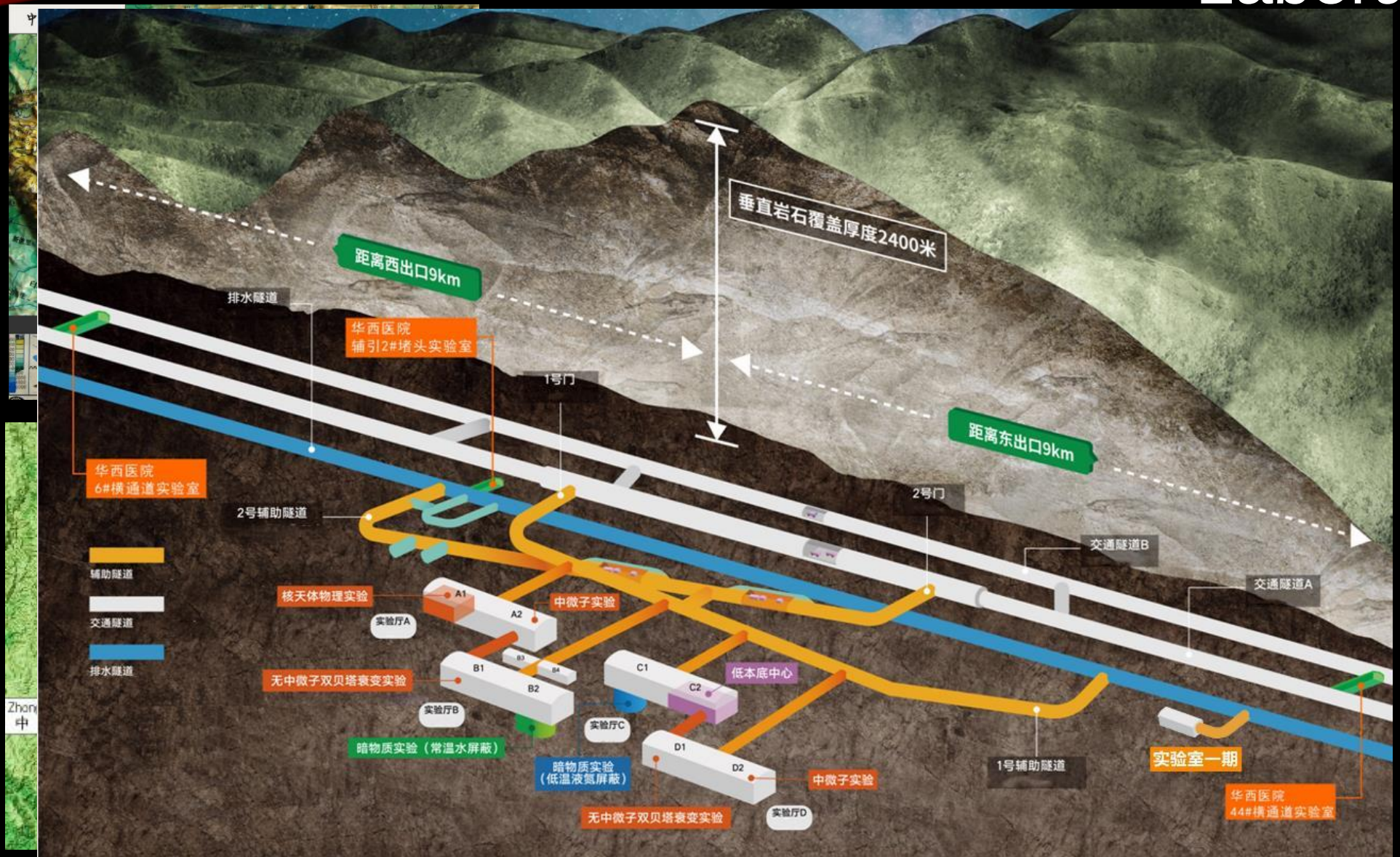
Detector capability:

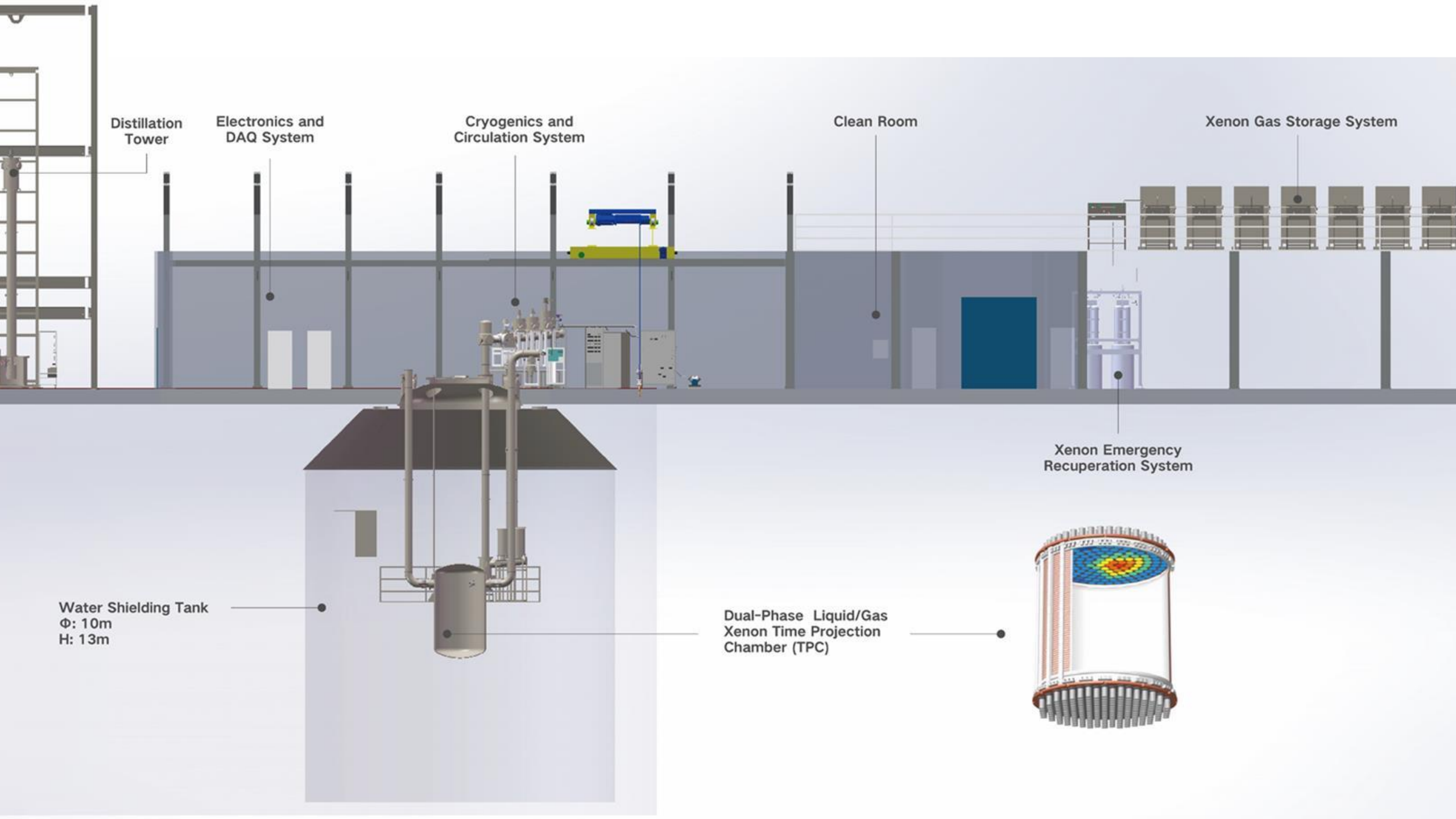
- 3D reconstruction and fiducialization
- Good ER/NR rejection
- Calorimeter capable of seeing a couple of photons/electrons

Natural abundance



China Jinping underground Laboratory



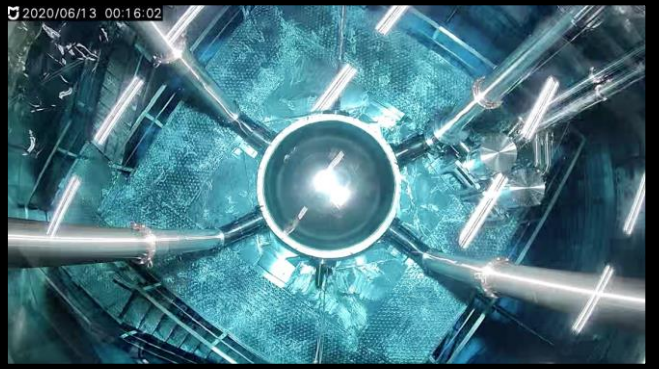

Distillation Tower
Electronics and DAQ System
Cryogenics and Circulation System
Clean Room
Xenon Gas Storage System
Xenon Emergency Recuperation System
Water Shielding Tank
Φ: 10m
H: 13m
Dual-Phase Liquid/Gas Xenon Time Projection Chamber (TPC)

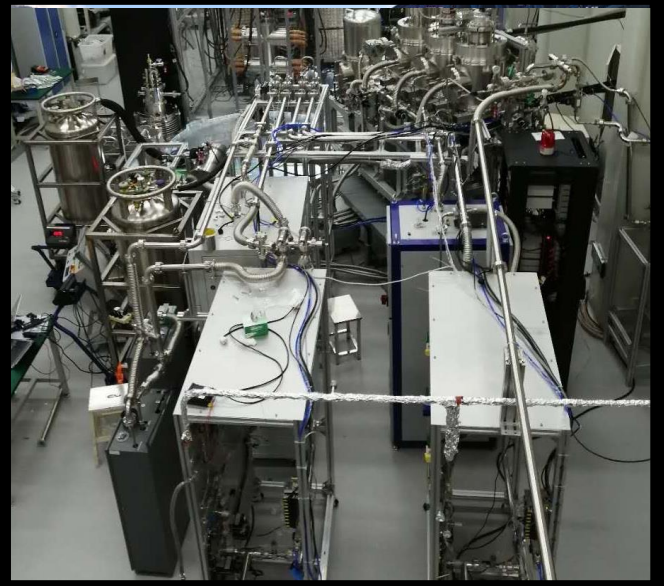
2018.4 water tank construction

2019.8 PandaX-4T instllation

2020.5 liquid xenon filling

2020/6-2020/11 integration tests



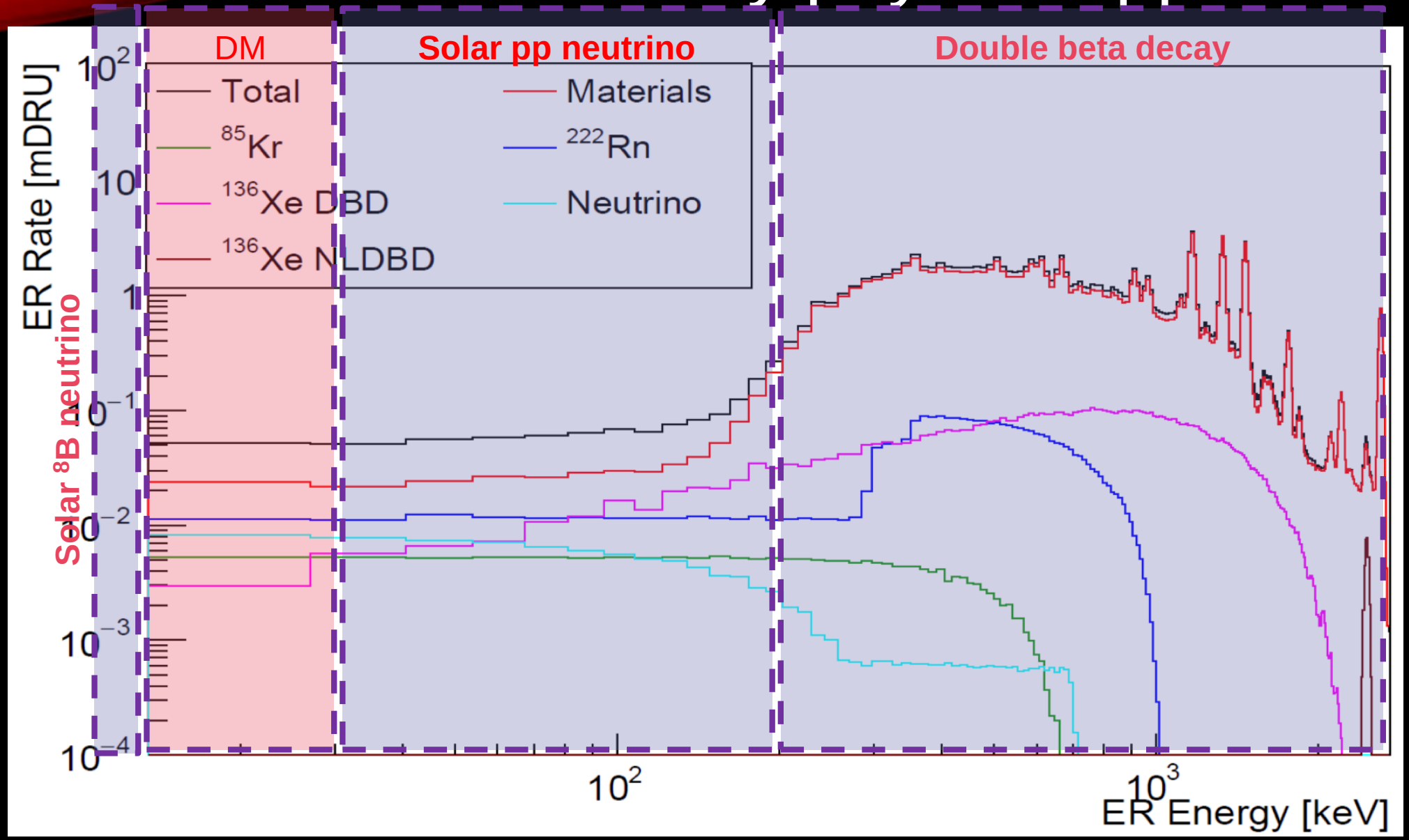



上海交通大学PandaX暗物质与中微子实验平台

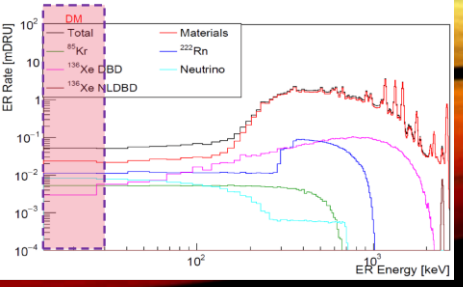
Data taking interleaved with surgeries and lab construction

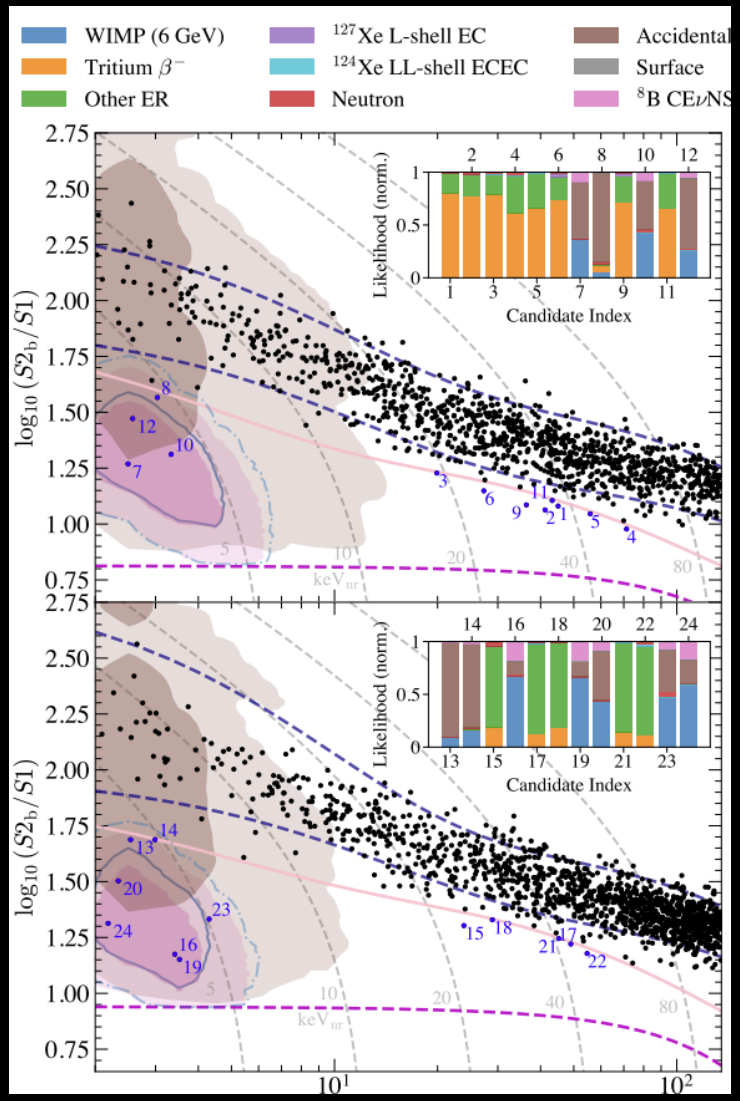
Time	Activity
2020/11-2021/04	commissioning (Run0) 95 days
2021/07-2021/10	tritium removal xenon distillation, gas flushing, etc.
2021/11-2022/05	physics run (Run1) 164 days
2022/09-2023/12	CJPL B2 hall renovation xenon recuperation, detector upgrade
2024/01-2024/07	resuming operation
Current status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

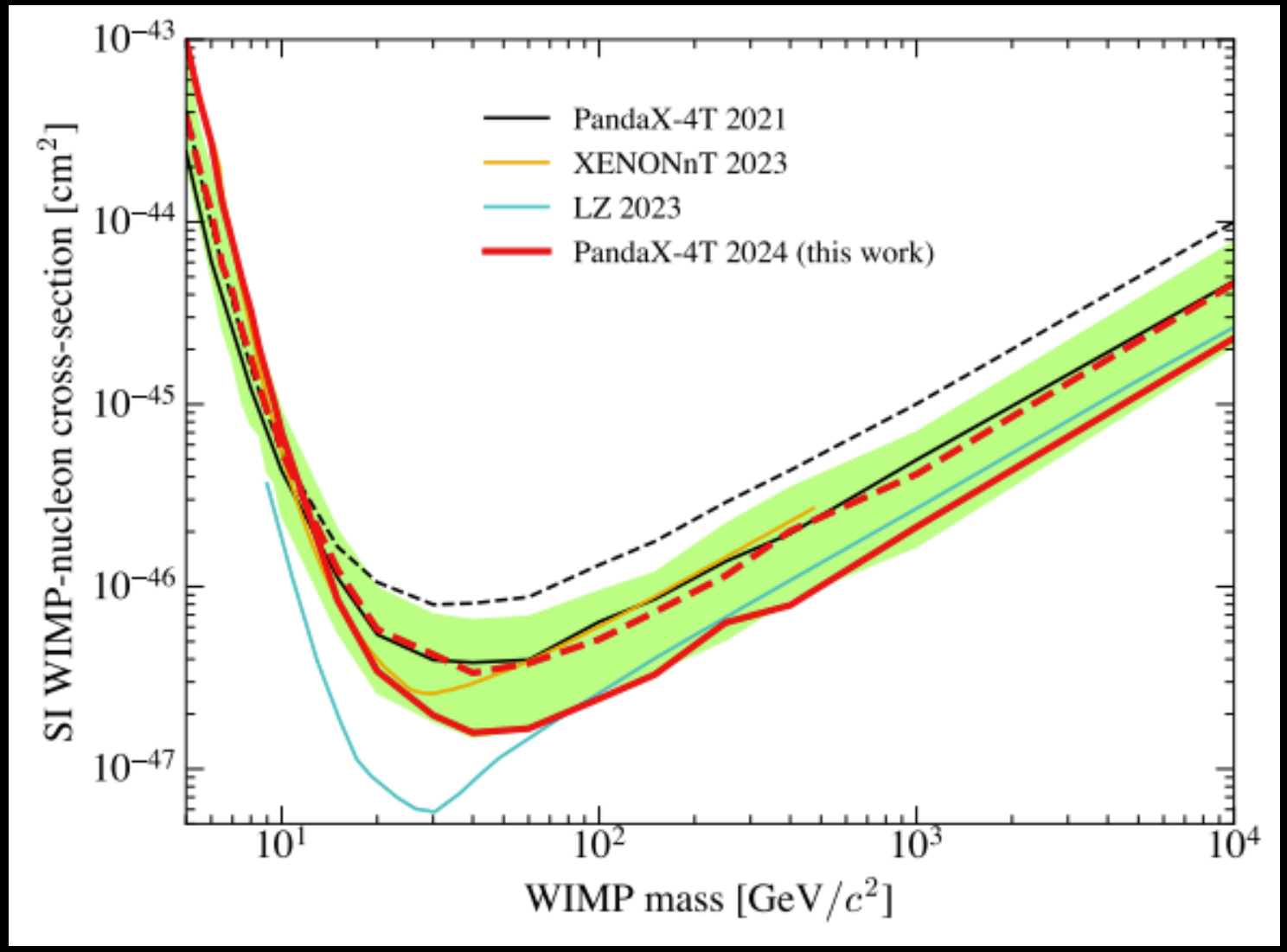
Many physics opportunties



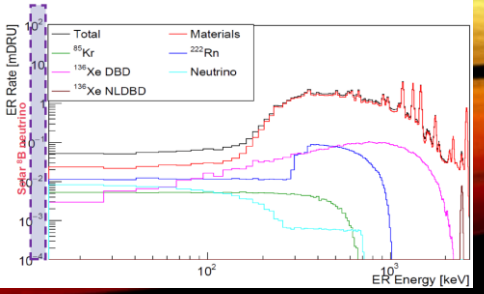
1.5 tonne*year, blinded analysis, Run0+1

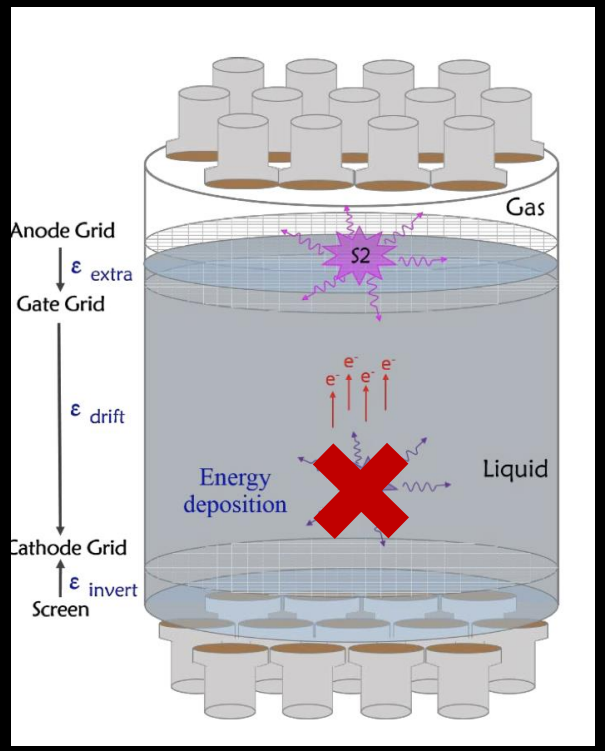


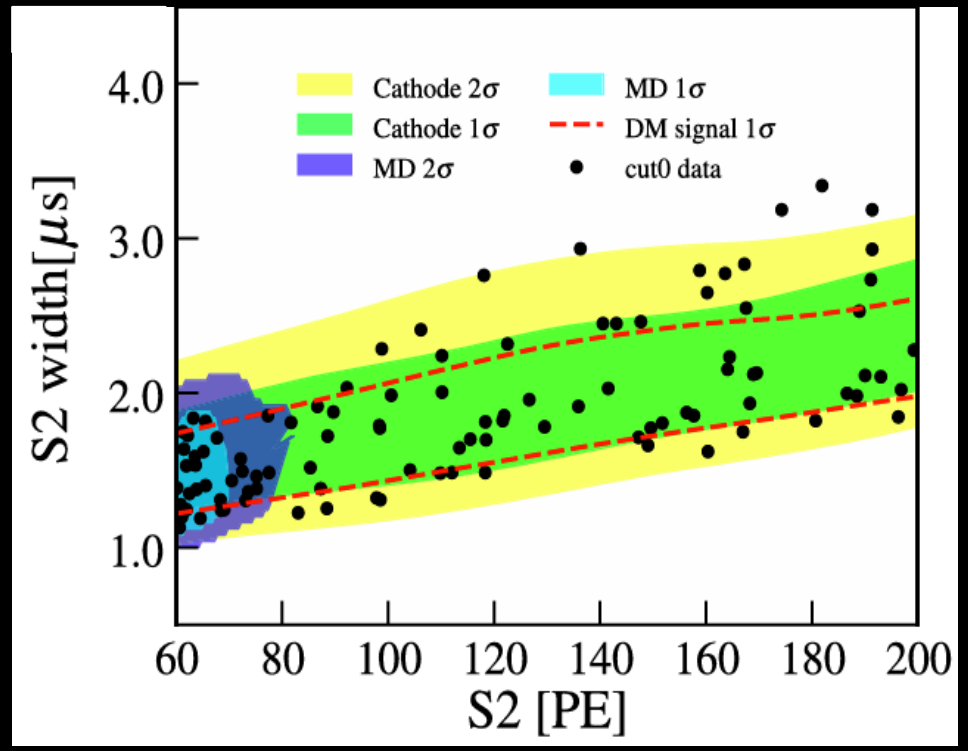


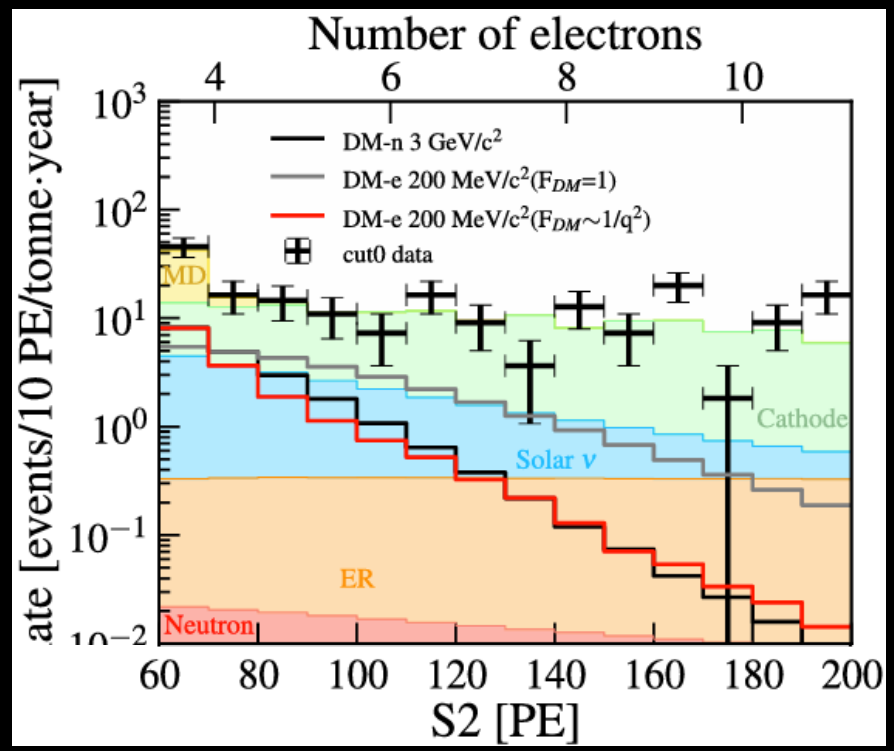


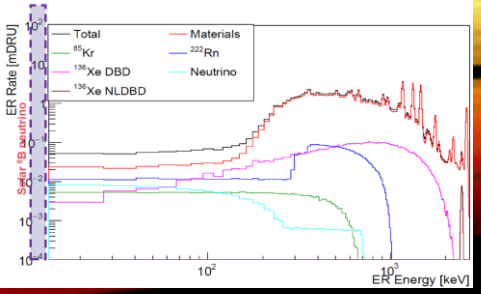
S2-only approach





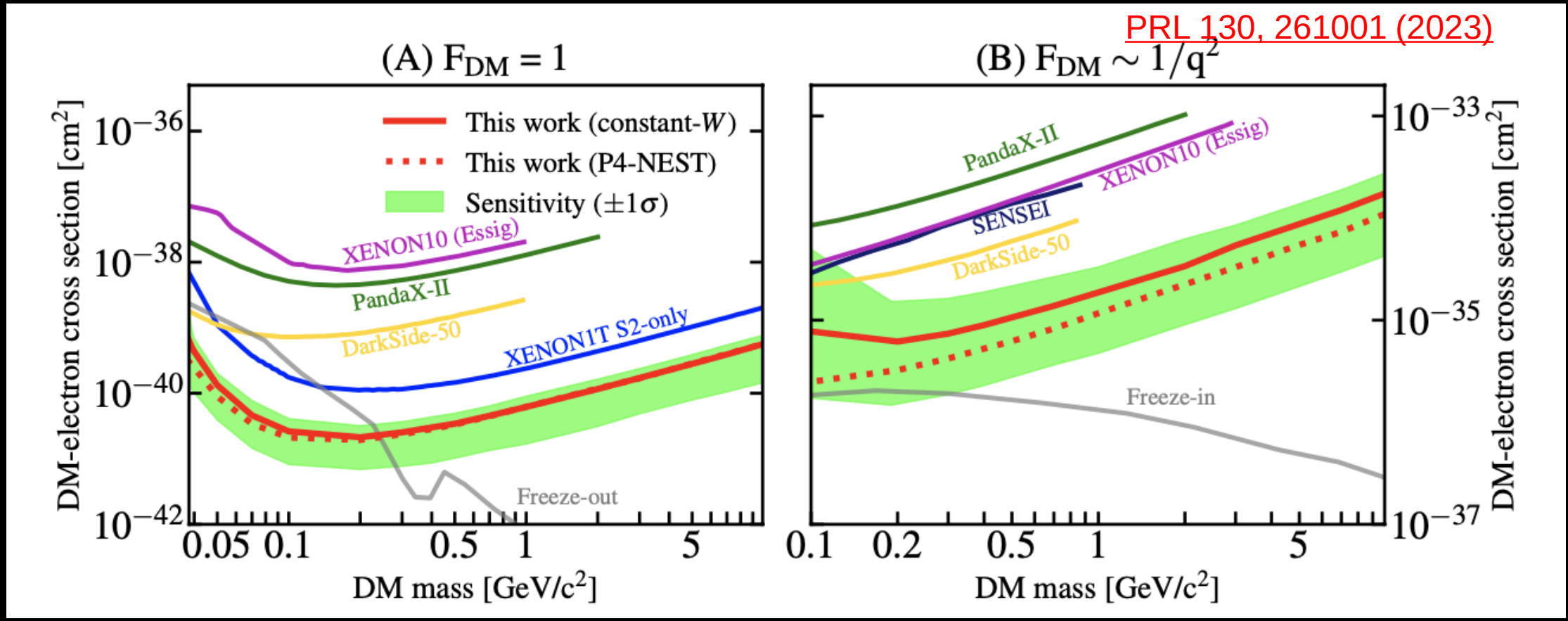


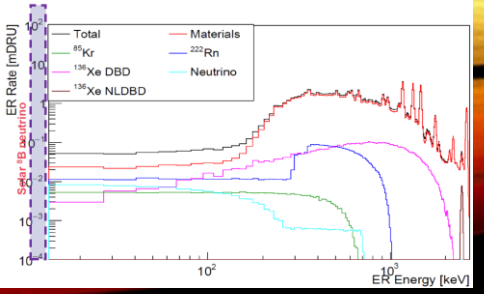




Tight limits on DM-e scattering with S2-only analysis

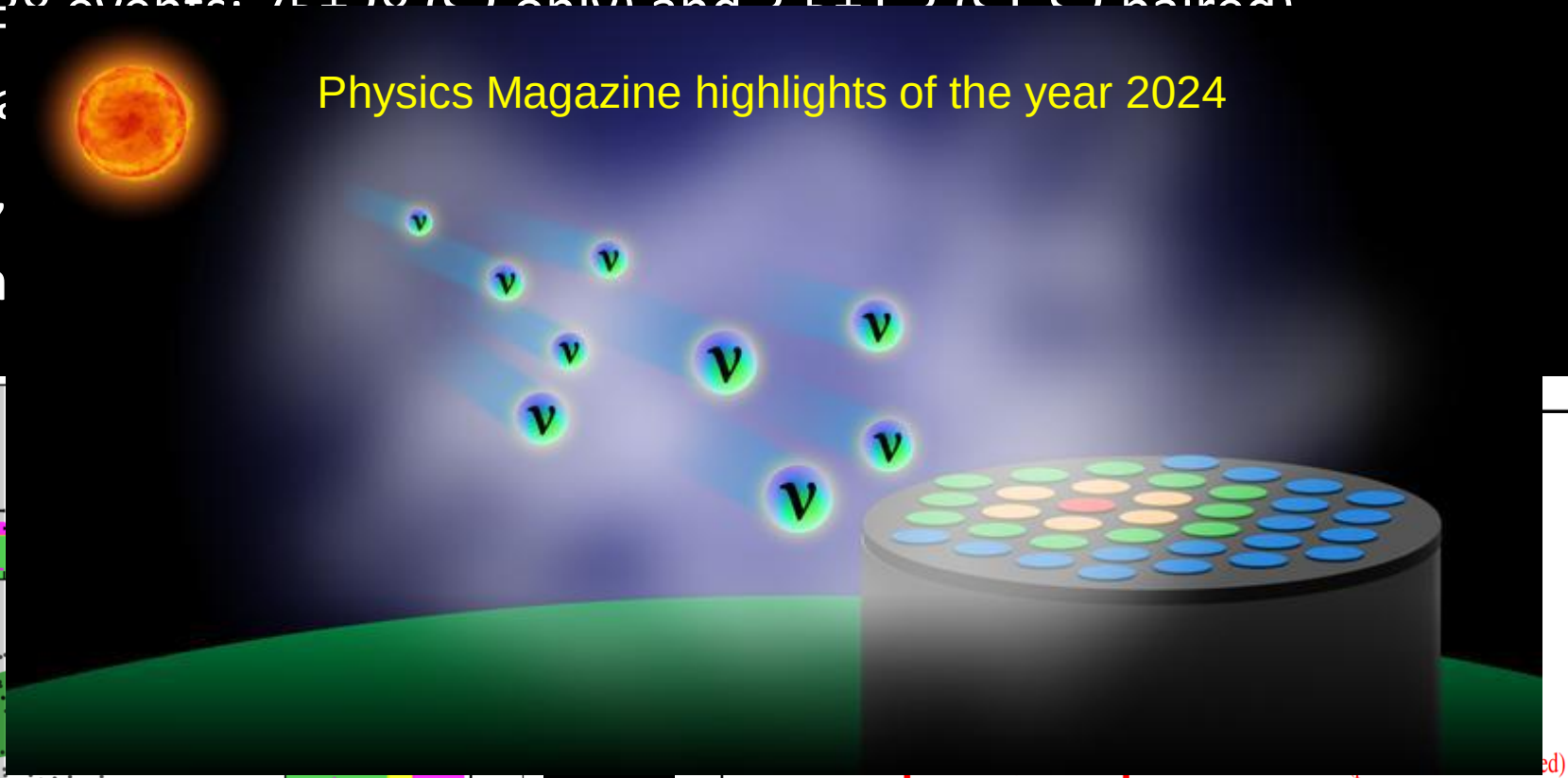
PRL 130, 261001 (2023)

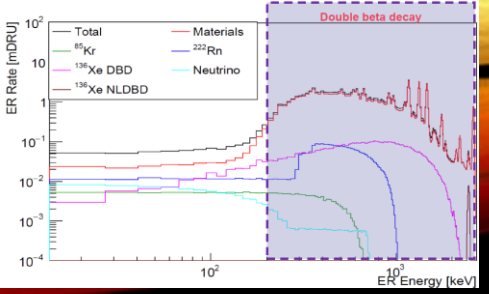




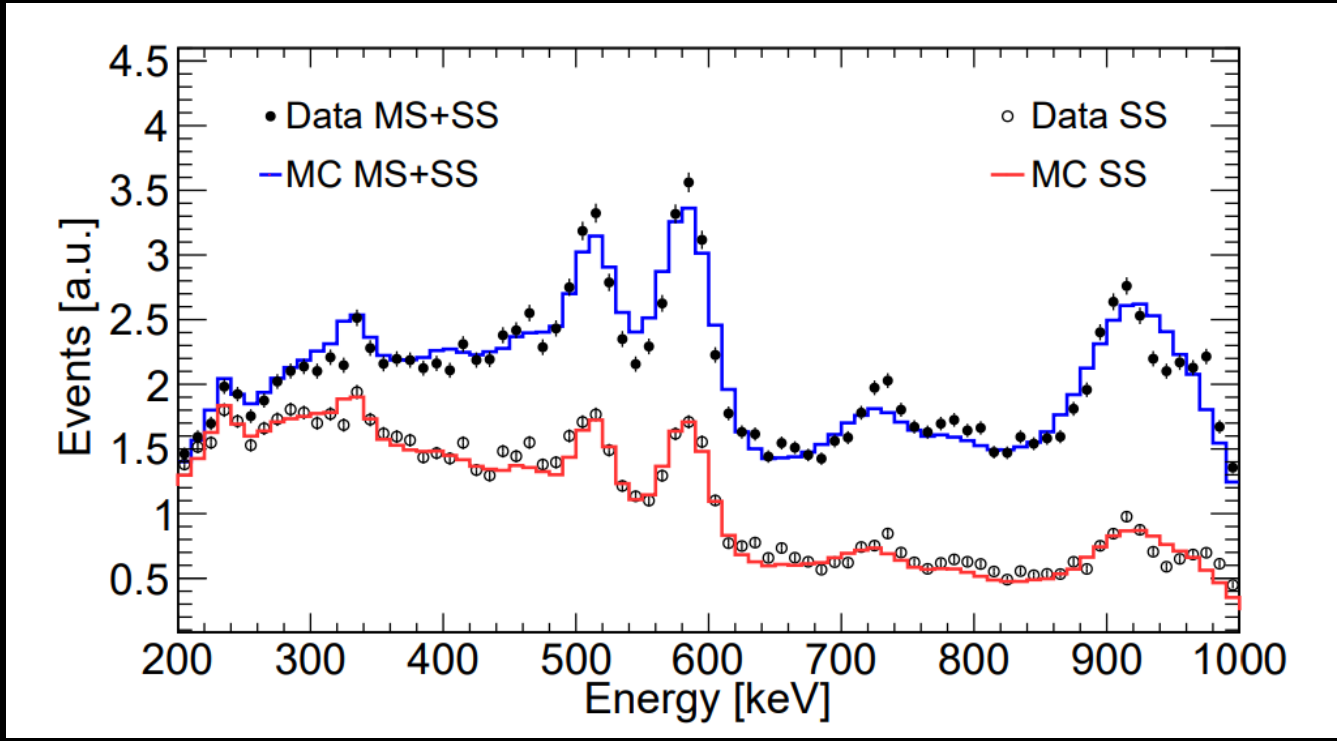
B8 neutrino CEvNS

- Greatly benefit from S2-only data (~ton×year)
- Best-fit B8 events: 75±28 (S2-only) and 2.5±1.2 (S1-S2 paired)
- Reject ba
- PRL 133,
- XENONn

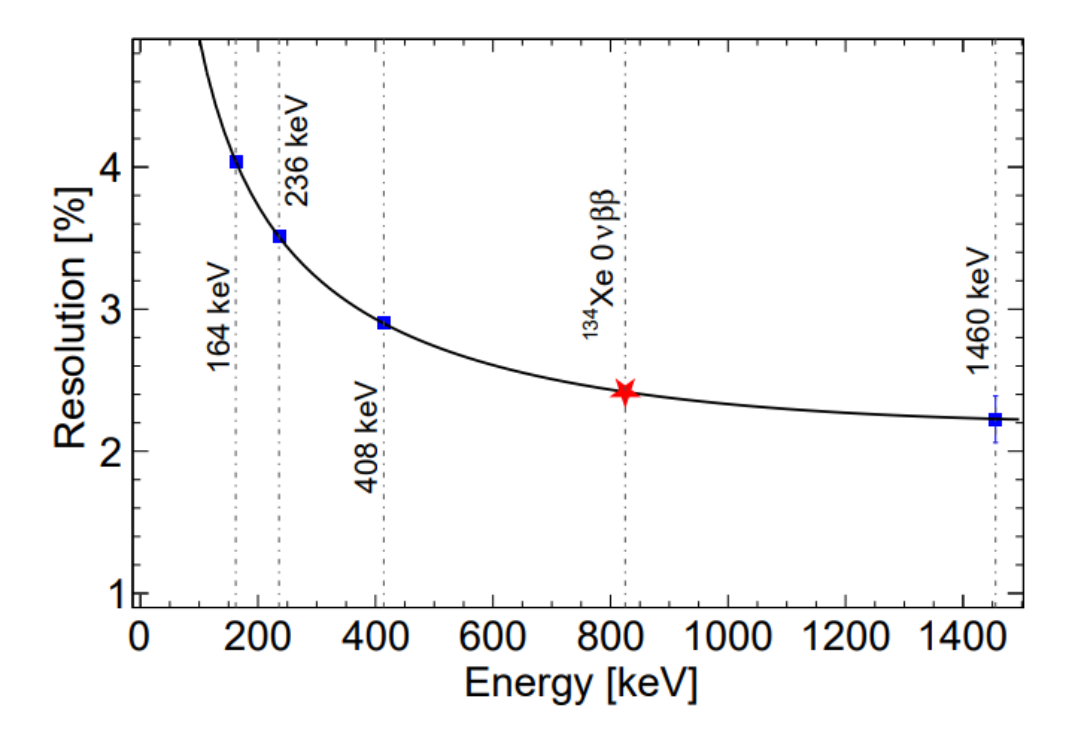




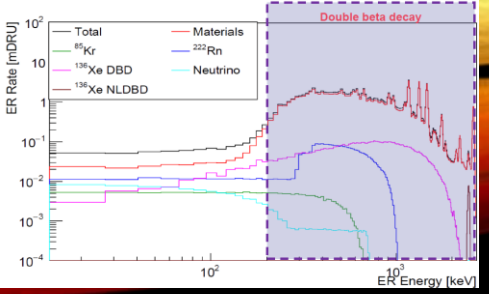
Calibrating PandaX at MeV



Th232 gamma calibration data

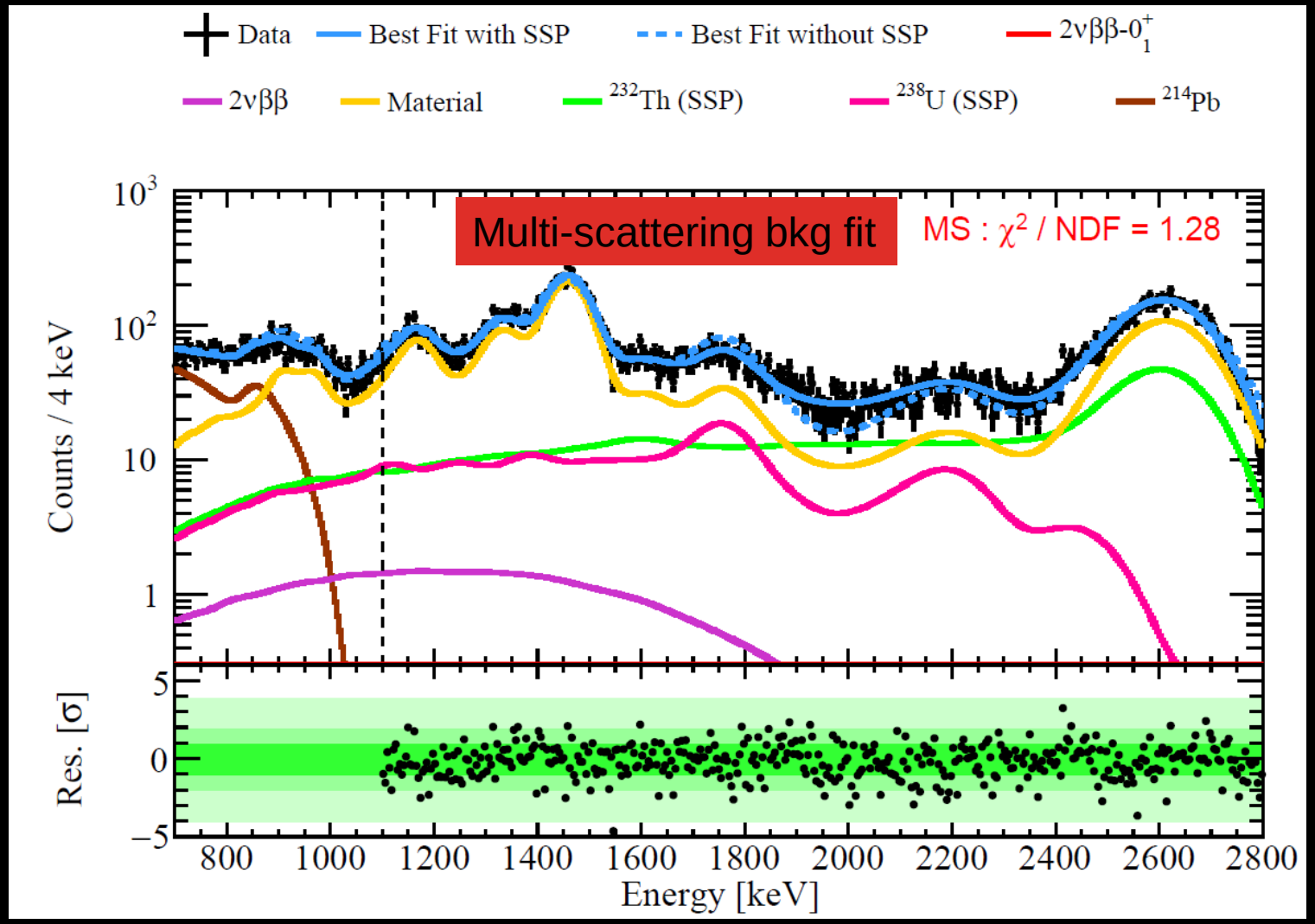


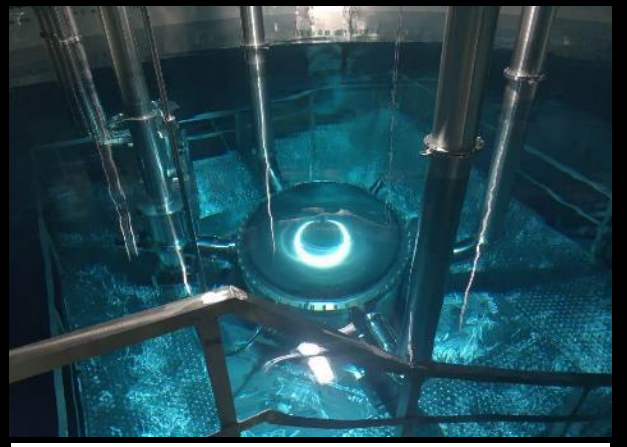
Internal gamma peaks

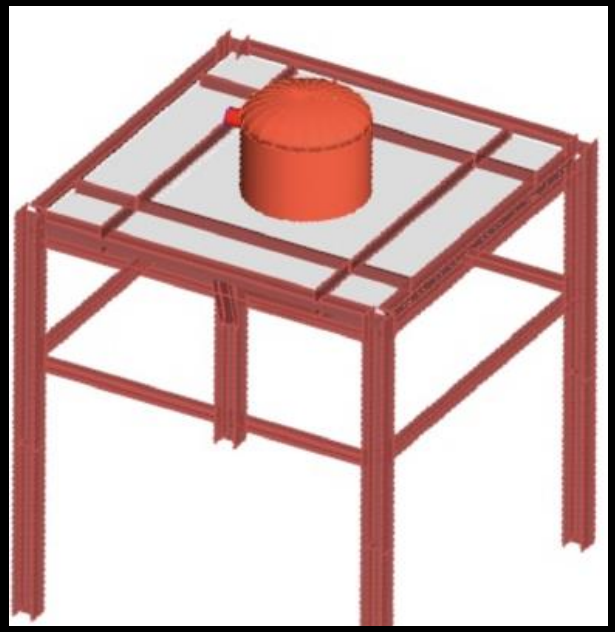


Understanding background at MeV

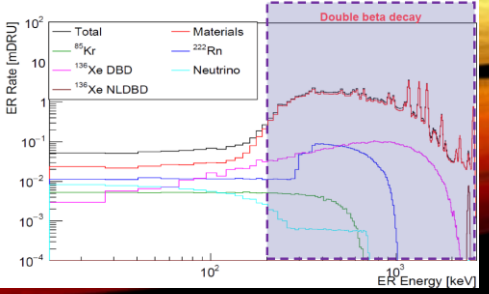
JHEP 05 (2025) 089, arXiv:2502.03017

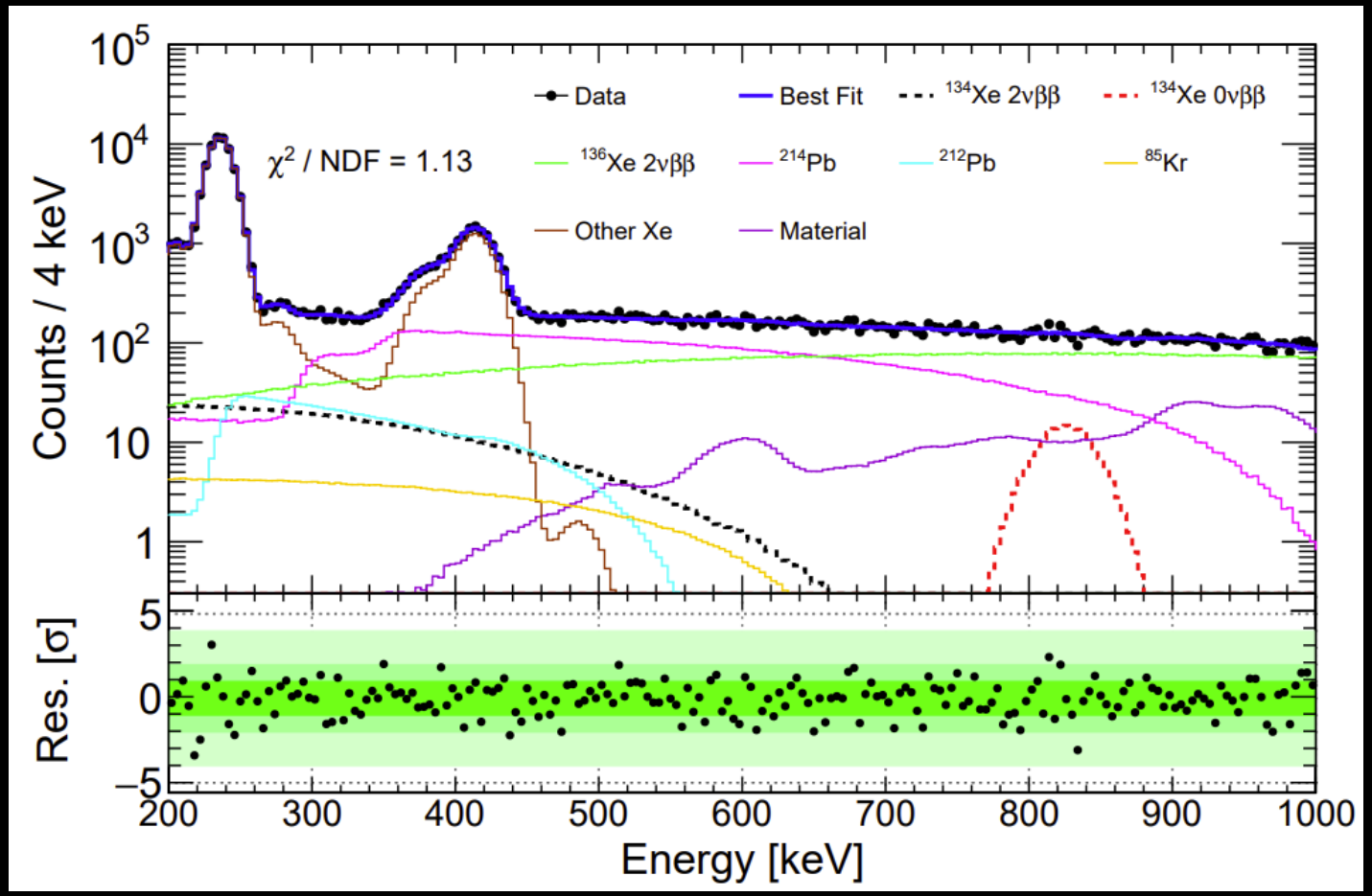


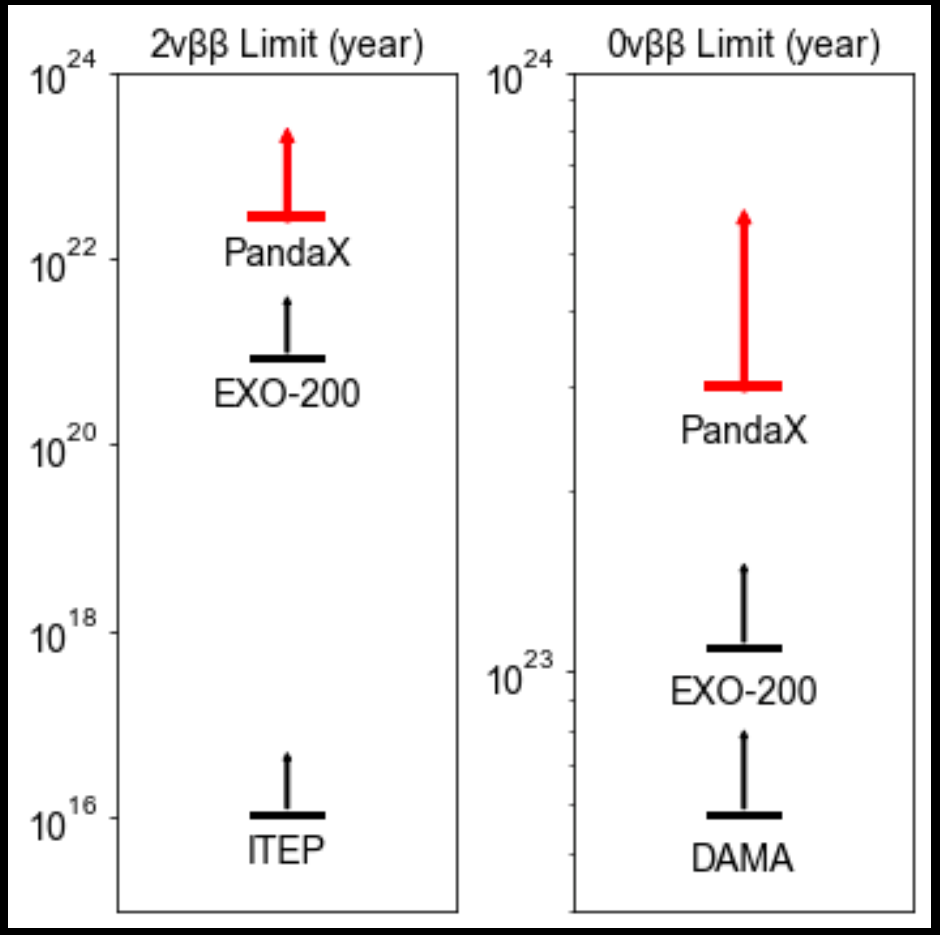




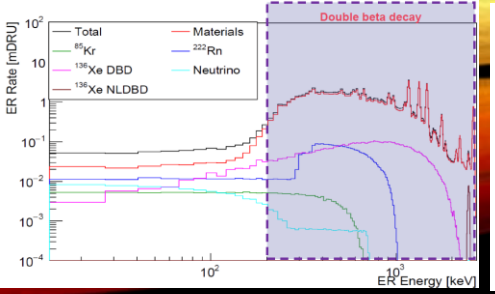
^{134}Xe: a unique blessing

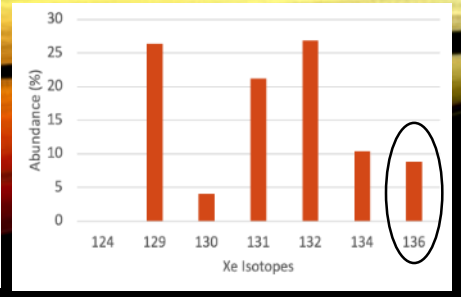




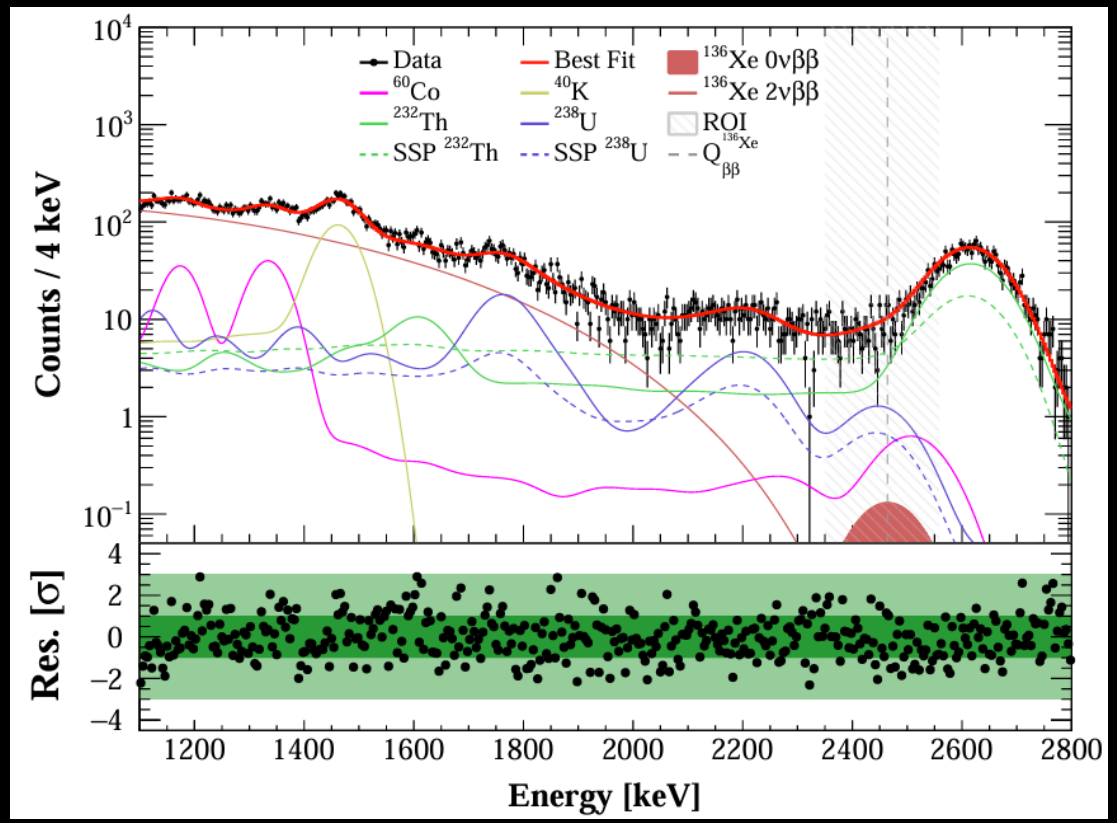


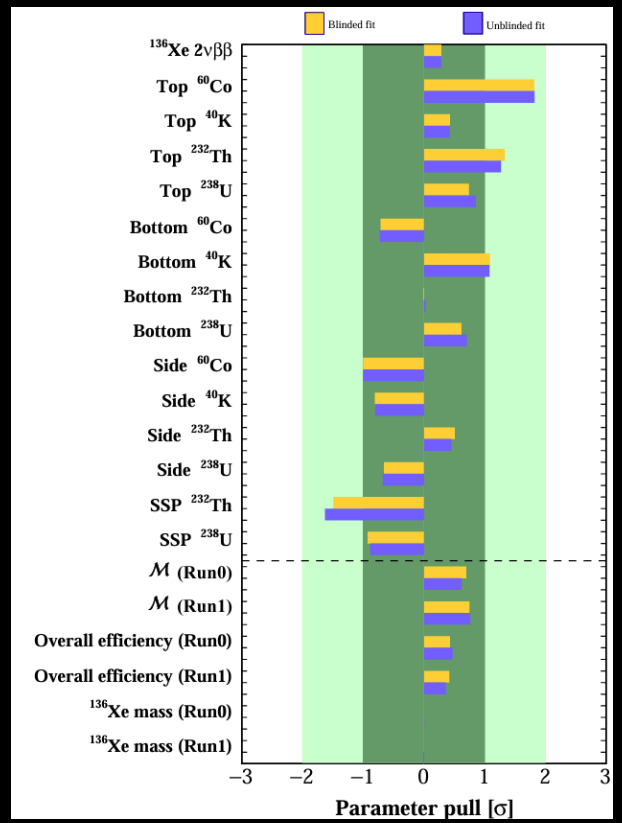
PRL 132, 152502 (2024)





Search for Xe136 0vDBD

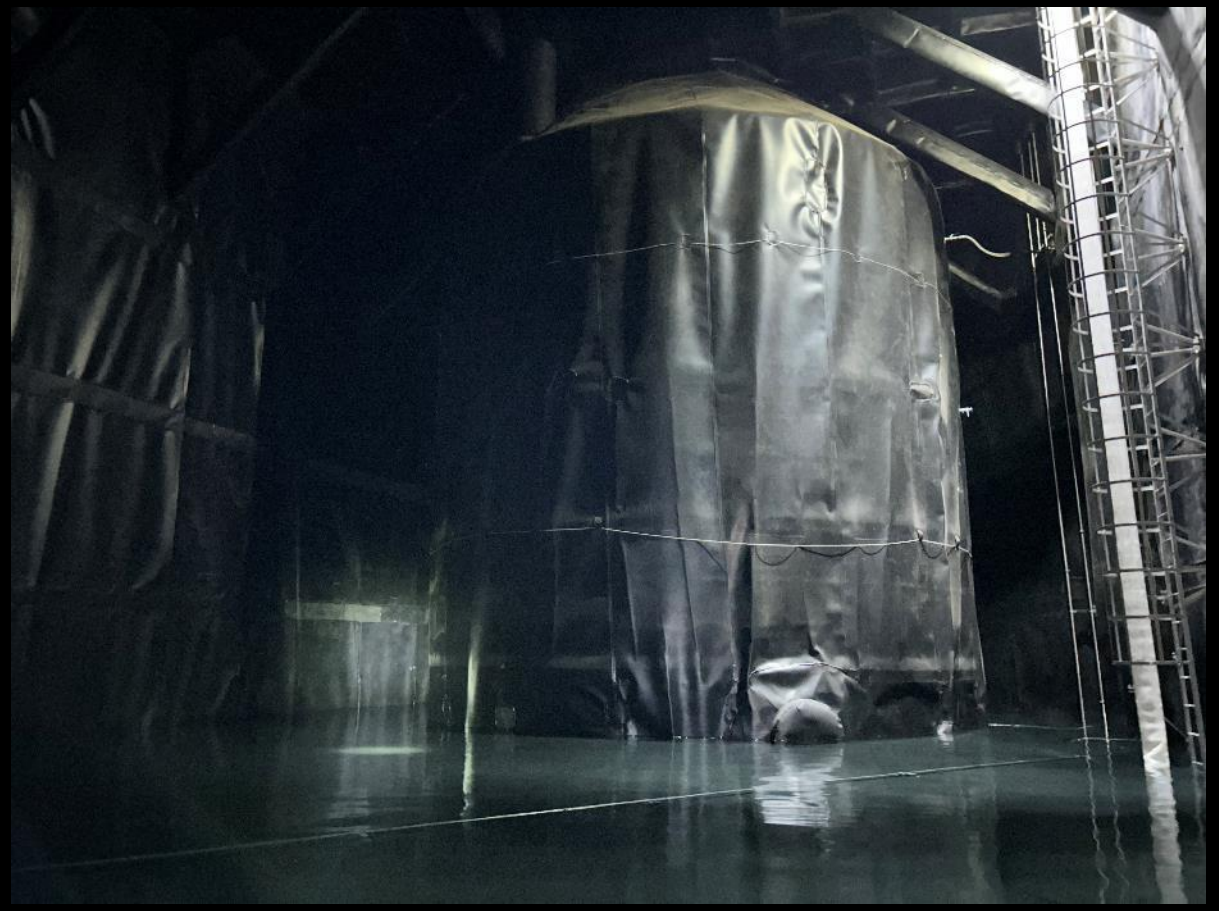




Science Bulletin Vol. 70,11 (2025)
arXiv:2412.13979

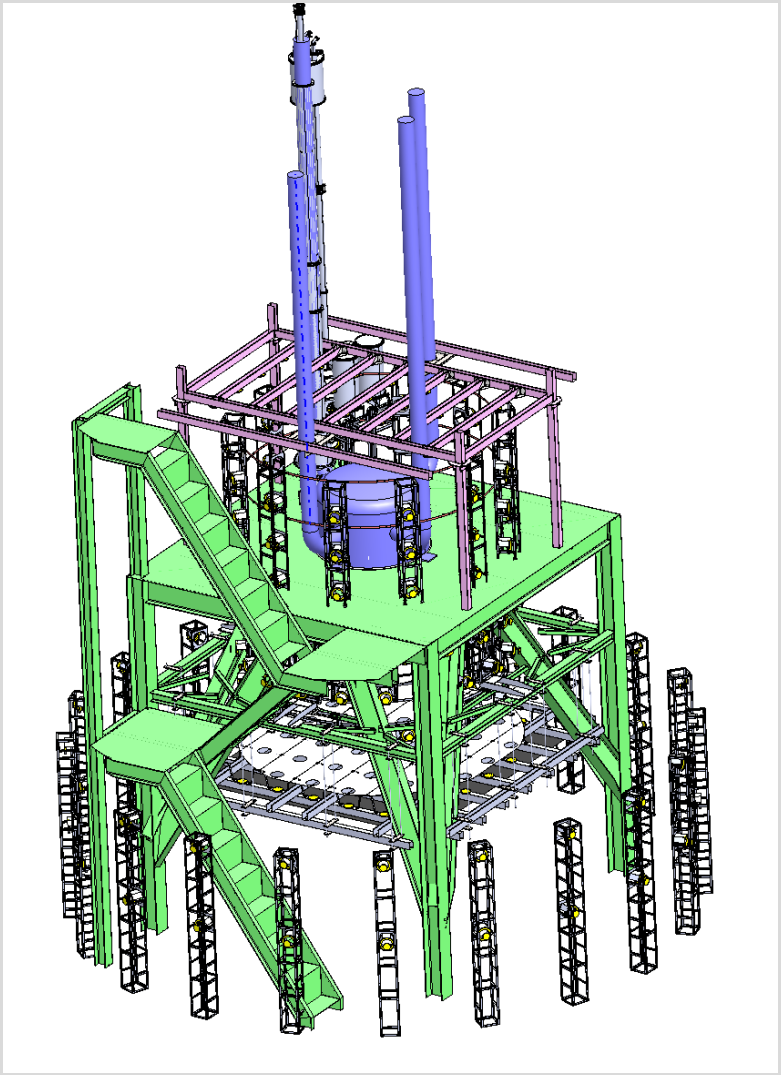
Lifetime
$> 2.1 \times 10^{24}$year
90% CL
$m_{\beta\beta}$<0.6-1.4 eV

2024: Shiny again!



Newly implemented water veto detector

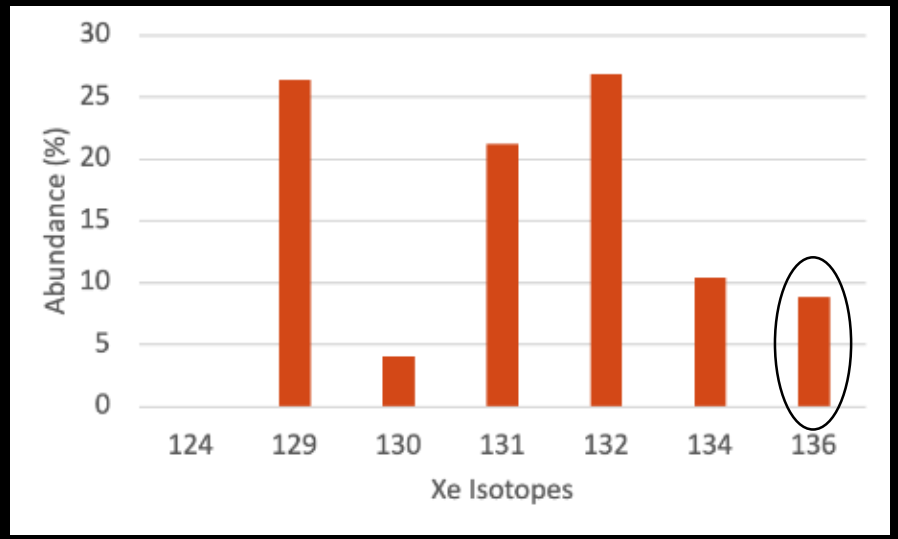
- installed 270 8-inch PMTs in late 2023
- inner layer: 2 m radius, about 1 m to the outer surface of the LXe cryostat
- outer layer: 5 m radius
- Seeing muons, seeing neutrons !



PandaX-xT

$$Sensitivity \propto \sqrt{\frac{B}{Mt}}$$

B = bkg rate in ROI per unit target mass



A multi-ten ton liquid xenon project at CJPL-II

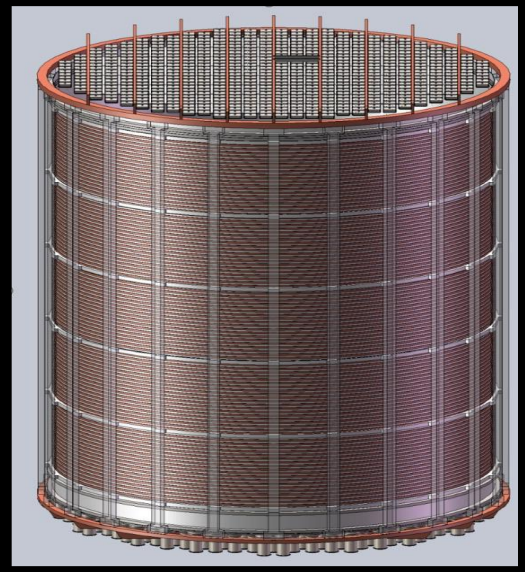
1. Searching for DM-nucleon interactions to neutrino floor, a decisive test on WIMP paradigm
2. A sensitive test on Majorana nature of neutrinos using the 0vDBD of ^{136}Xe, covering inverted neutrino MO parameter space
3. Detecting low-energy neutrinos from the Sun and other astrophysical and terrestrial origins, and exploring other ultra-rare signals.

Next Generation Xe

PandaX-xT: step-wise strategy to a 40-ton-scale LXe observatory at CJPL

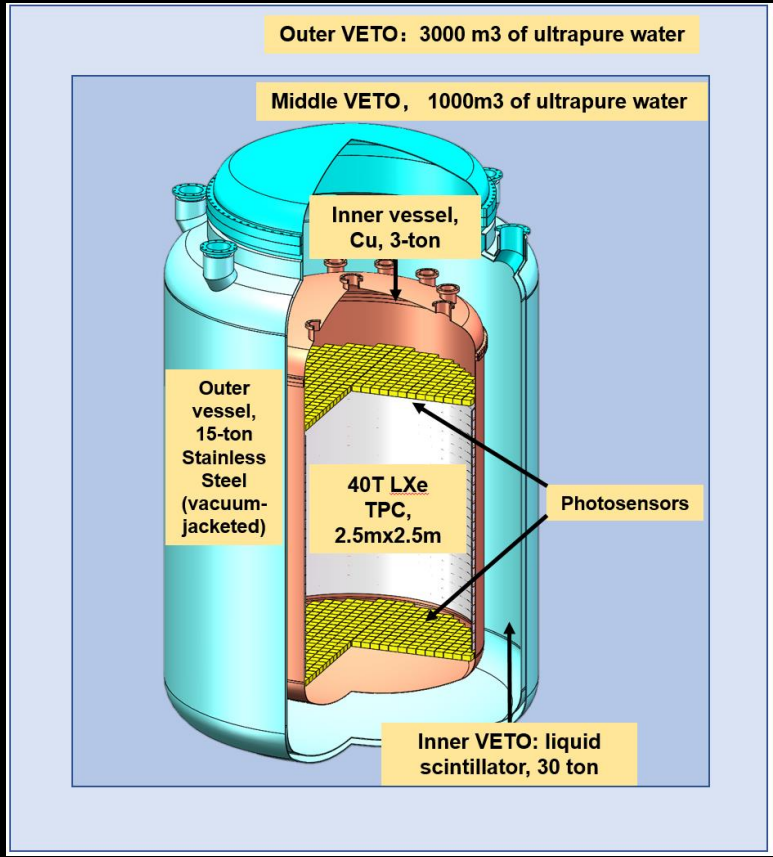
PandaX-4T

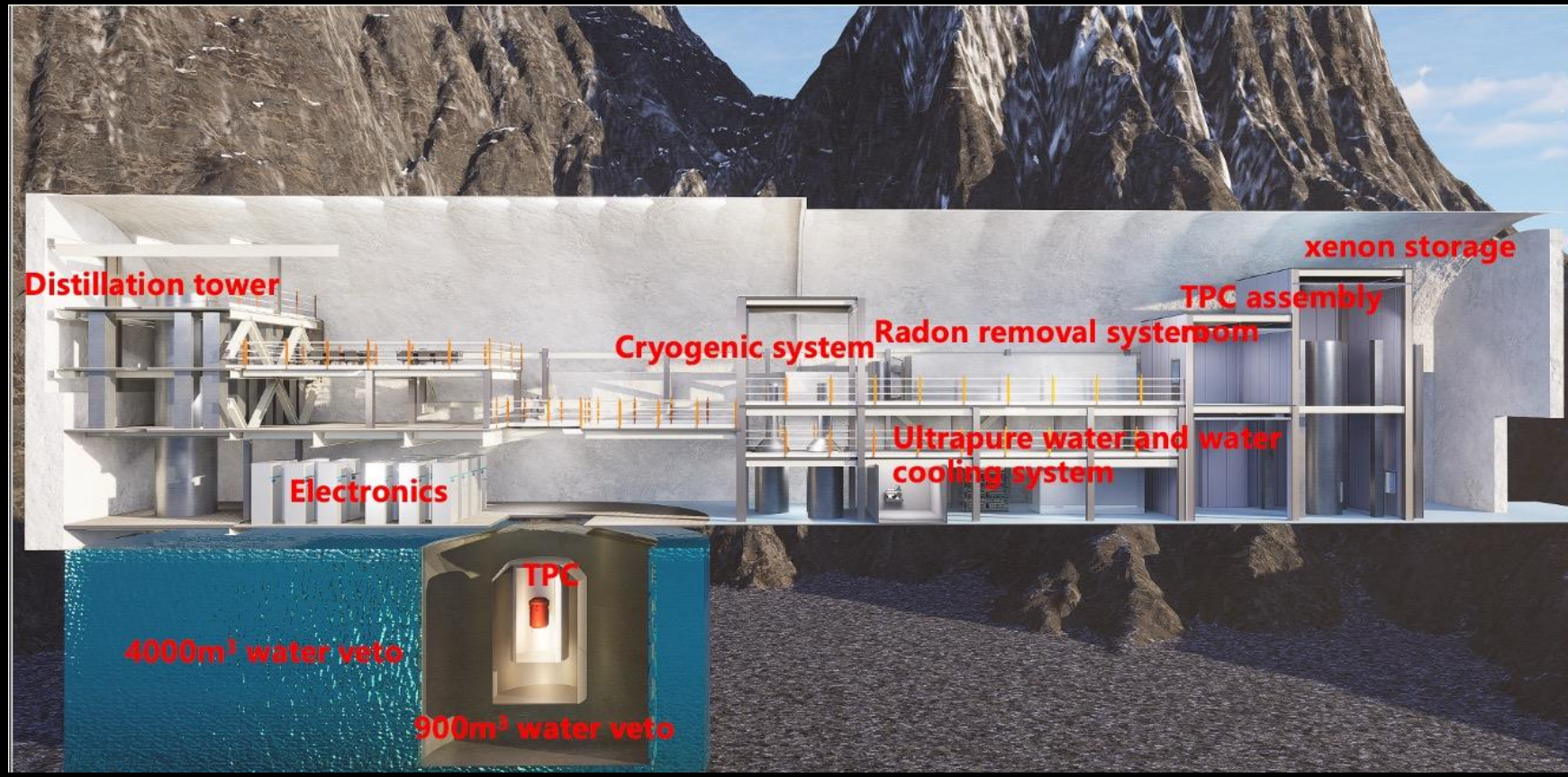
PandaX-20T (2027, mostly funded)



PandaX-40T

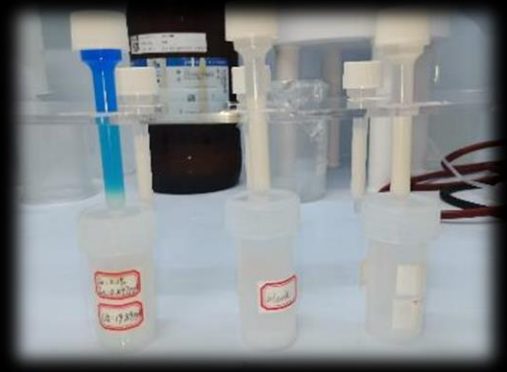
PandaX-20/40T @ CJPL



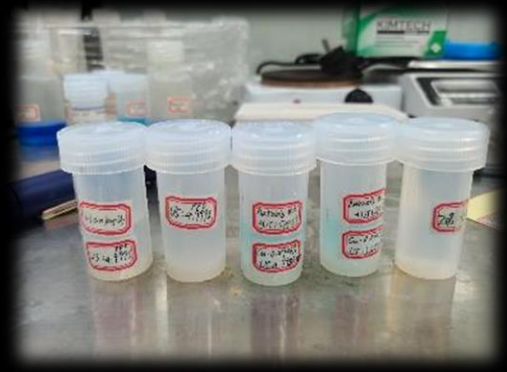


Ultrapure copper measurement

- Two batches of Aurubis NOSV copper from Germany manufacture were sampled and screened
- Preparation methods:
  - UTEVA/TEVA resin exchange
  - Directly dilute dissolved solution
- Measurement devices：
  - PerkinElmerNexION5000 and Agilent7900 ICPMS



Resin exchange



Dilute dissolved solutions

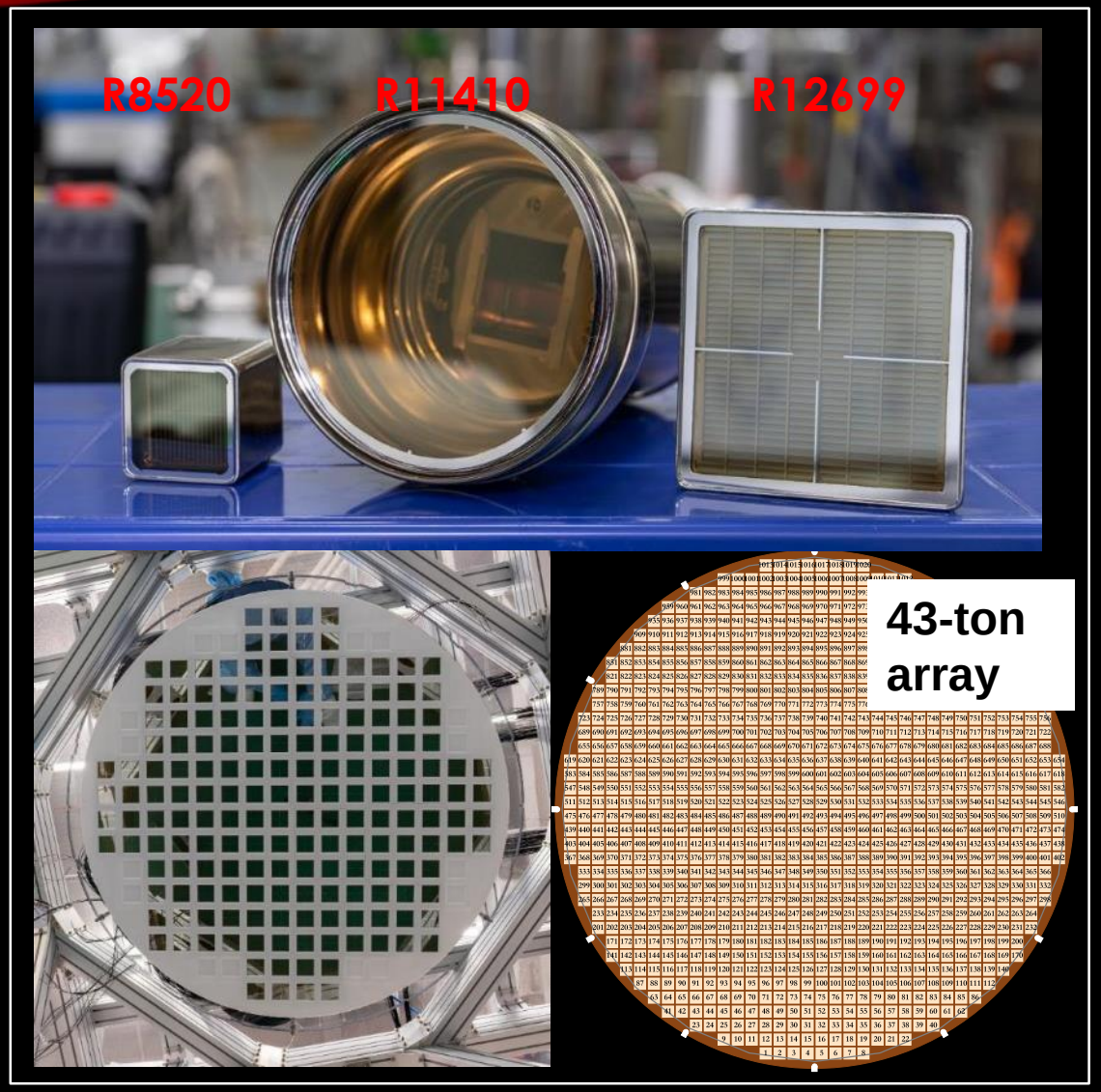
Aurubis id	Preparation method	Measured Devices	Time	Th-232(ppt)	U-238(ppt)
#1-no.14	Dilution	SJTU ICPMS1	2025.6.12	2.18±5.97	26.08±14.77
#1-no.15	Dilution	PKU ICPMS	2025.6.23	4.6±0.6	4.4±0.3
#1-no.16	Resin exchange	SJTU ICPMS2	2025.7.21	<1	1.14±0.01
#1-no.17	Dilution	SJTU ICPMS1	2025.7.27	22.4±49.9	5.5±5.1
#1-no.18	Resin exchange	SJTU ICPMS1	2025.9.29	<0.74	<2.28
#2-no.6	Dilution	PKU ICPMS	2025.6.23	6.0±0.5	5.1±0.5
#2-no.7	Resin exchange	SJTU ICPMS2	2025.7.21	<1	1.55±0.33

1.2 ton of copper shipped from Hamburg to Shanghai

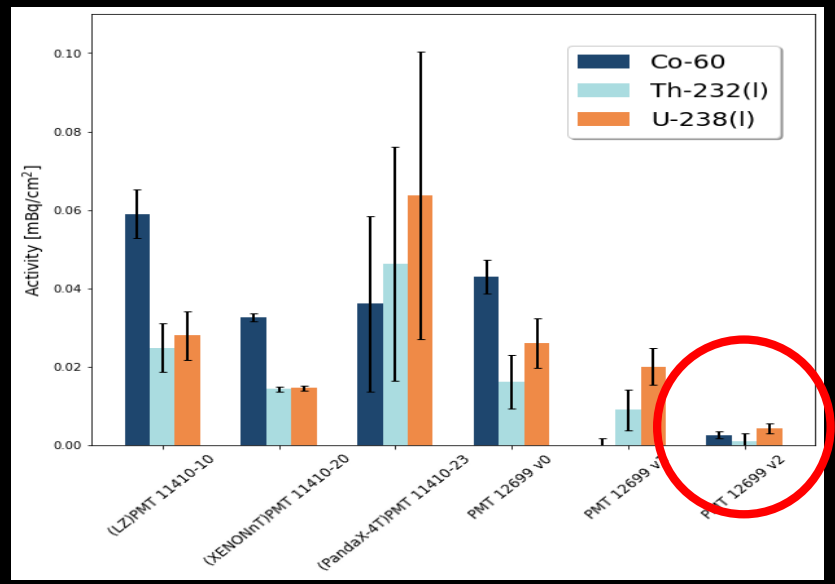
TPC development

- Field cage: Kapton film with copper embedded
- Supporting structure: low radioactivity PMMA (developed in JUNO) or PTFE
- 400 kg prototype TPC under construction @TDLI
- 2.6 m electrodes built and tested

New photosensors



- 10 m^2 top/bottom coverage
- Hamamatsu R12699 (2”x2”), iterated two versions (v1/v2)
- Dark noise <10 Hz/channel，QE @178 nm > 30%
- arXiv:2412.10830, NIMA



Liquid xenon storage and handling

Each storage tank: 6-m^3 (maximum 18 ton) of LXe
Cryogenic pump: filling/emptying detector @ 1.5 ton/hour.

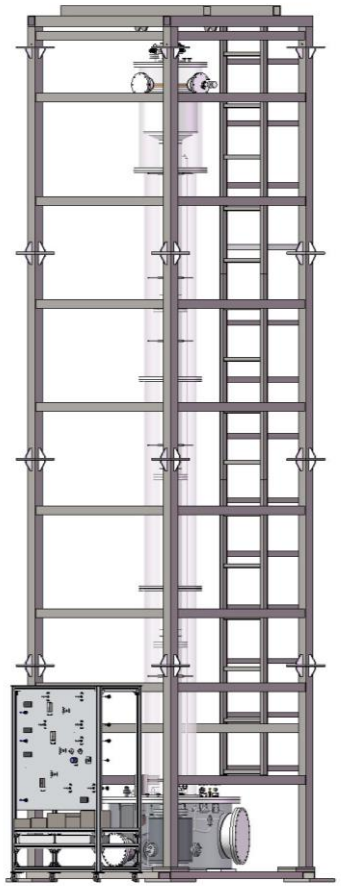
Cryogenics and recirculation

- Flexible with redundancy
- Cooling Power:

  ≥ 1500W@178K (GM cooler) + others
- Online purification speed:

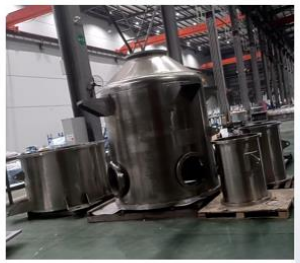
3.5-ton/day for gas, 8-ton/day for liquid

Distillation towers



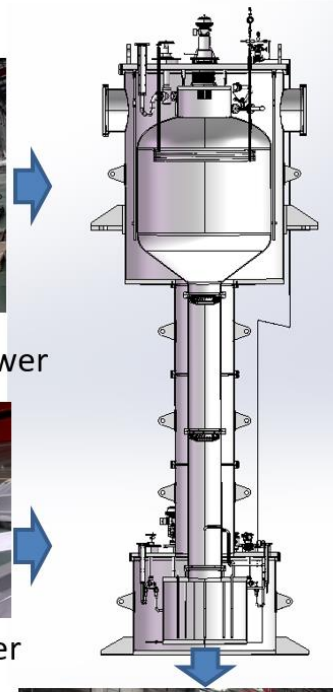
Kr distillation tower : 30 kg/hour.

Target Kr concentration in Xe: 0.01 ppt



Outer vacuum tower

Outer vacuum chamber



condenser

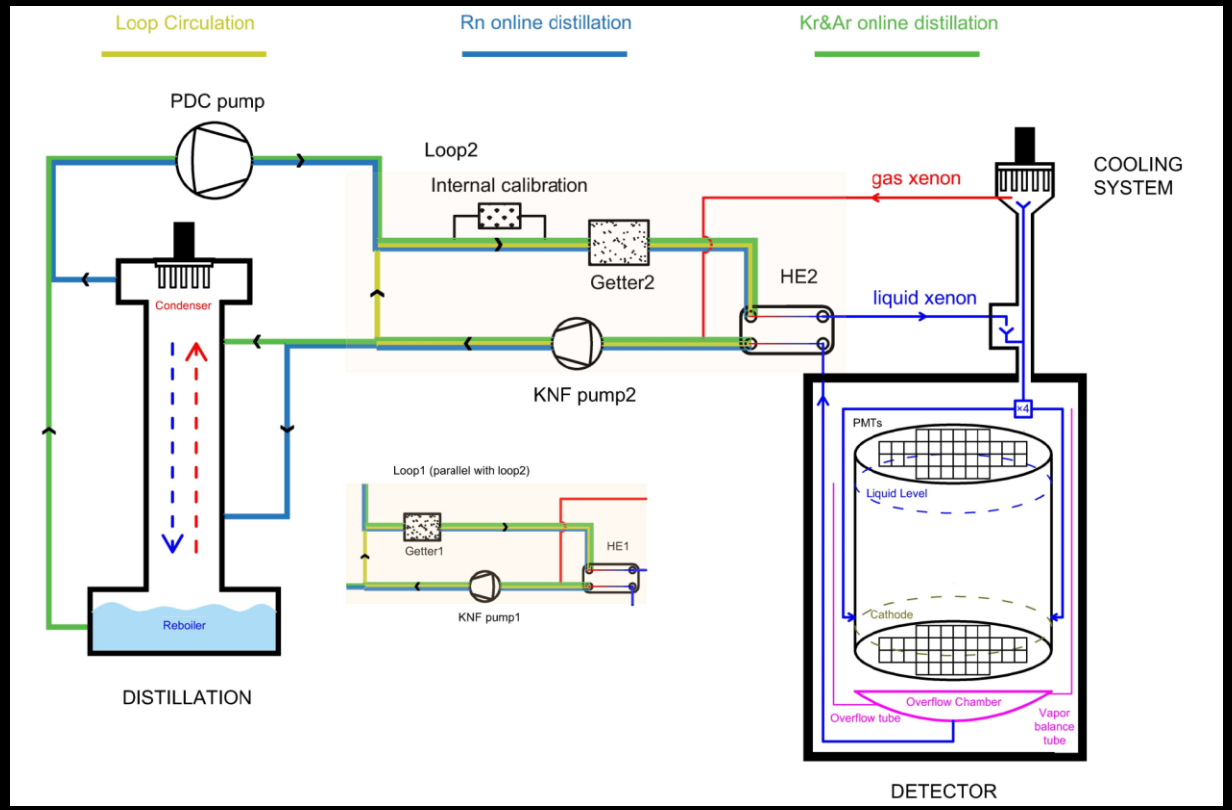
reboiler

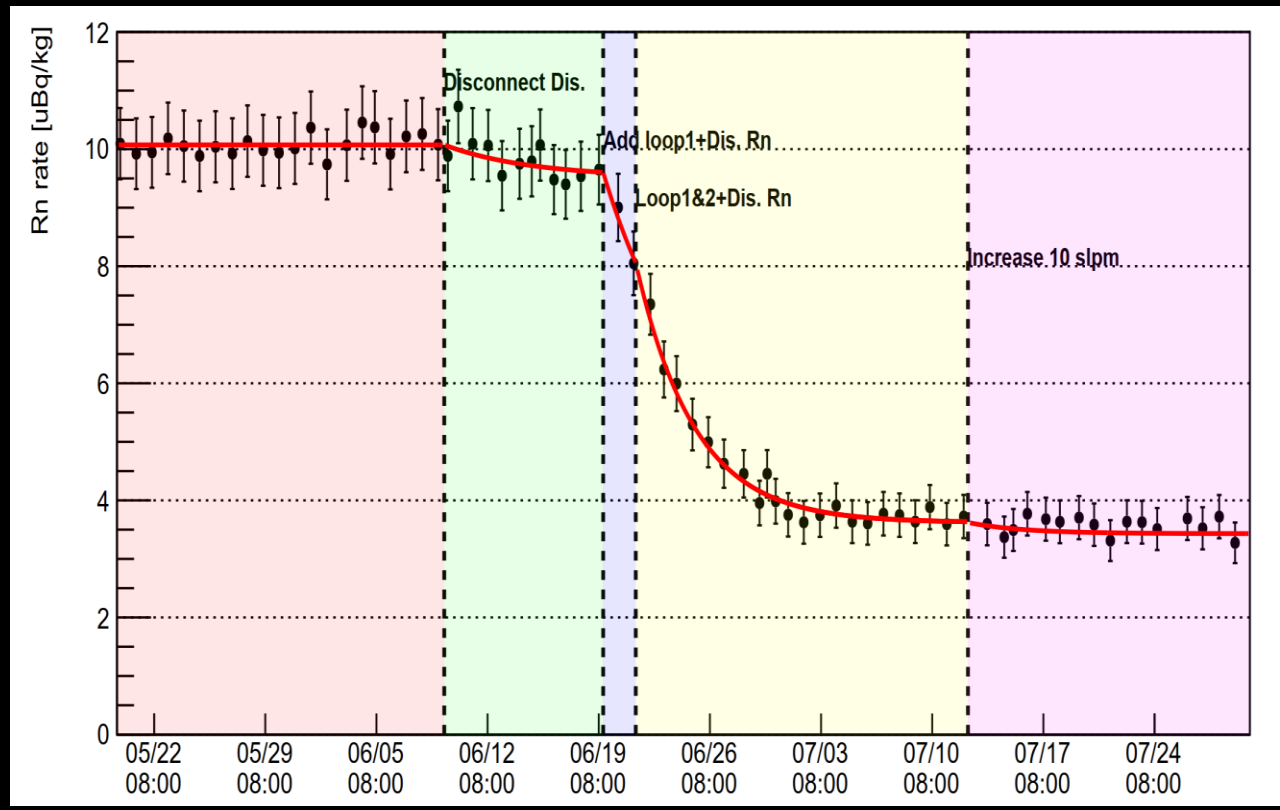
Inner tower

Rn distillation tower : 850 kg/hour.

Target: 0.5 μBq/kg

Rn online suppression studies with PandaX-4T

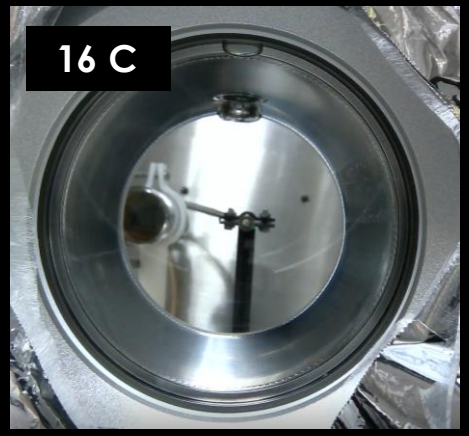


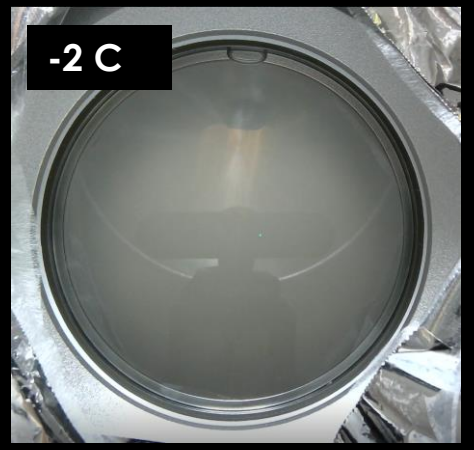


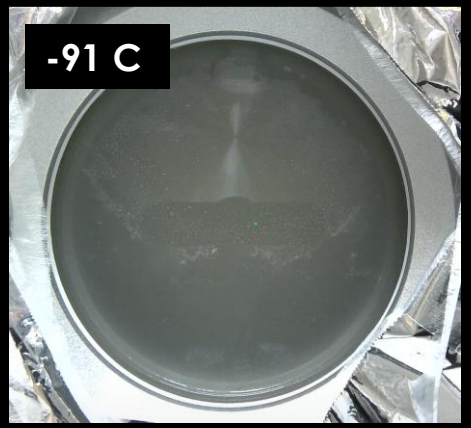
With online distillation, Rn222 level reached 3.6 uBq/kg

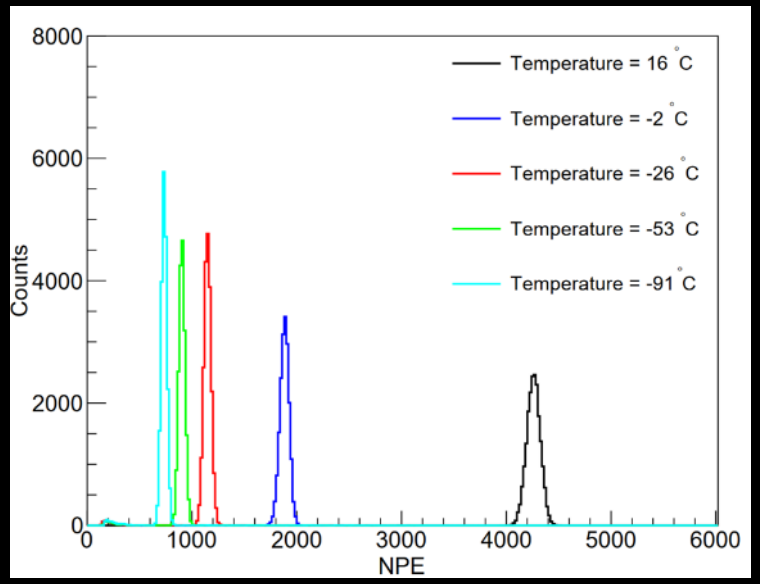
Inner Veto R&D

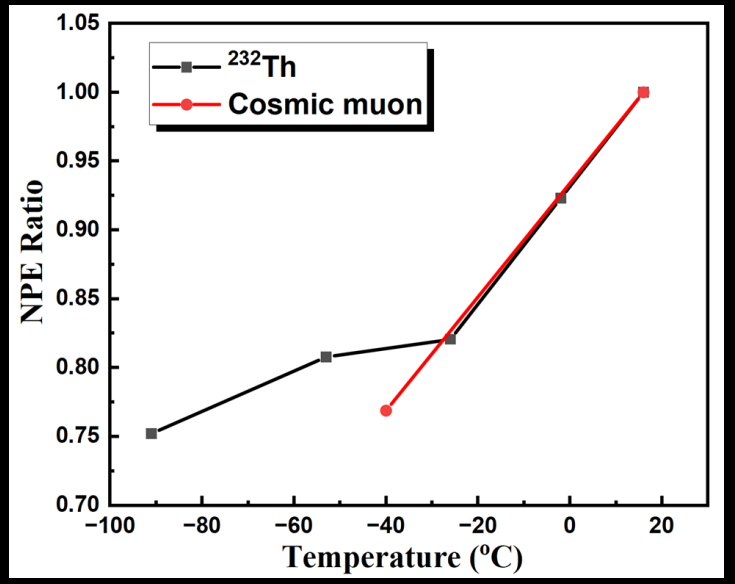
- LAB-based liquid scintillator becomes semi-transparent and viscous at liquid xenon temperature (about -100 ℃)
  - pressure balance: like refrigerant fluid (HFE-7000) used in EXO, make thinner liquid xenon container
  - veto: use wavelength shifting fibers for light detection, as in LiquidO









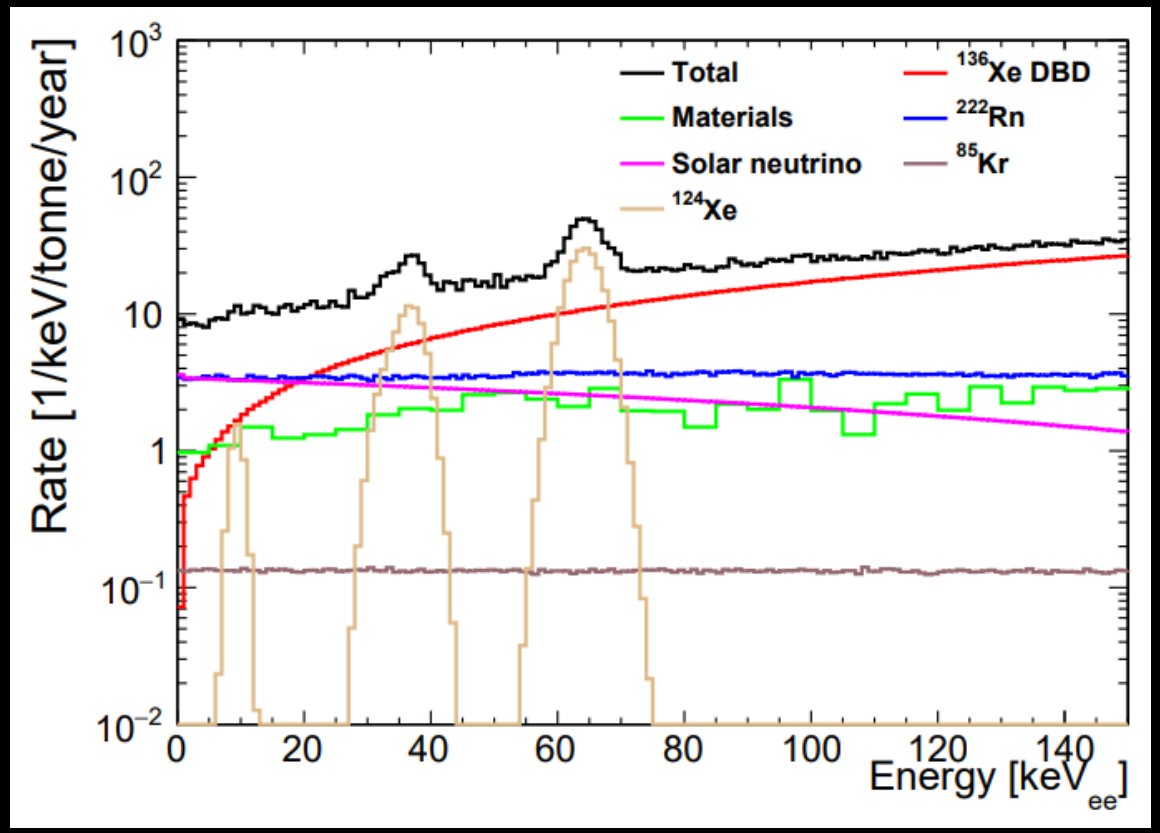


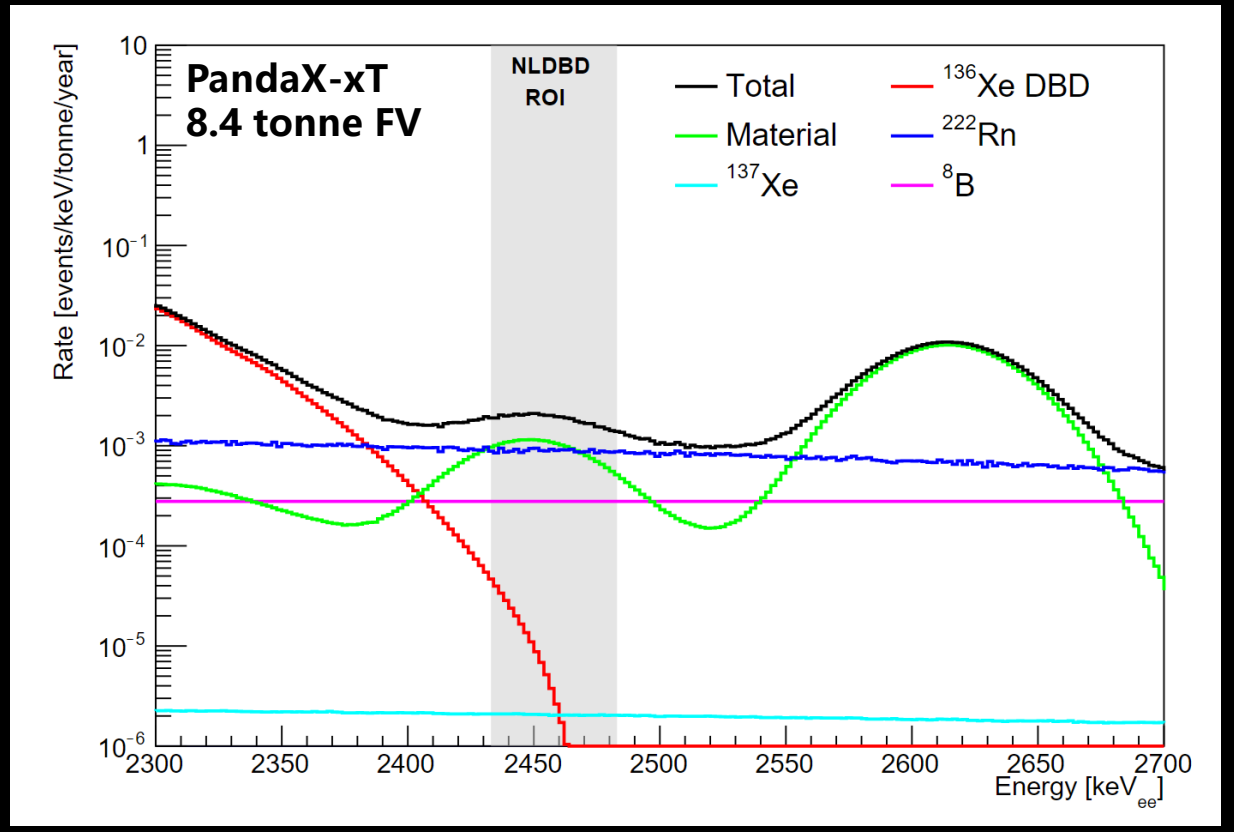
Transporting Xenon to CJPL

“Baseline” background

Component		Background assumption
1	Photosensors	U/Th/K = 0.02/0.01/1.5 mBq/cm^2 Hamamatsu R12699 prototype
2	Inner vessel	U/Th/K 5 ppt (g/g)
3	Kr	0.01 ppt (mol/mol)
4	Rn222	0.5 uBq/kg

Today's signal, tomorrow's background



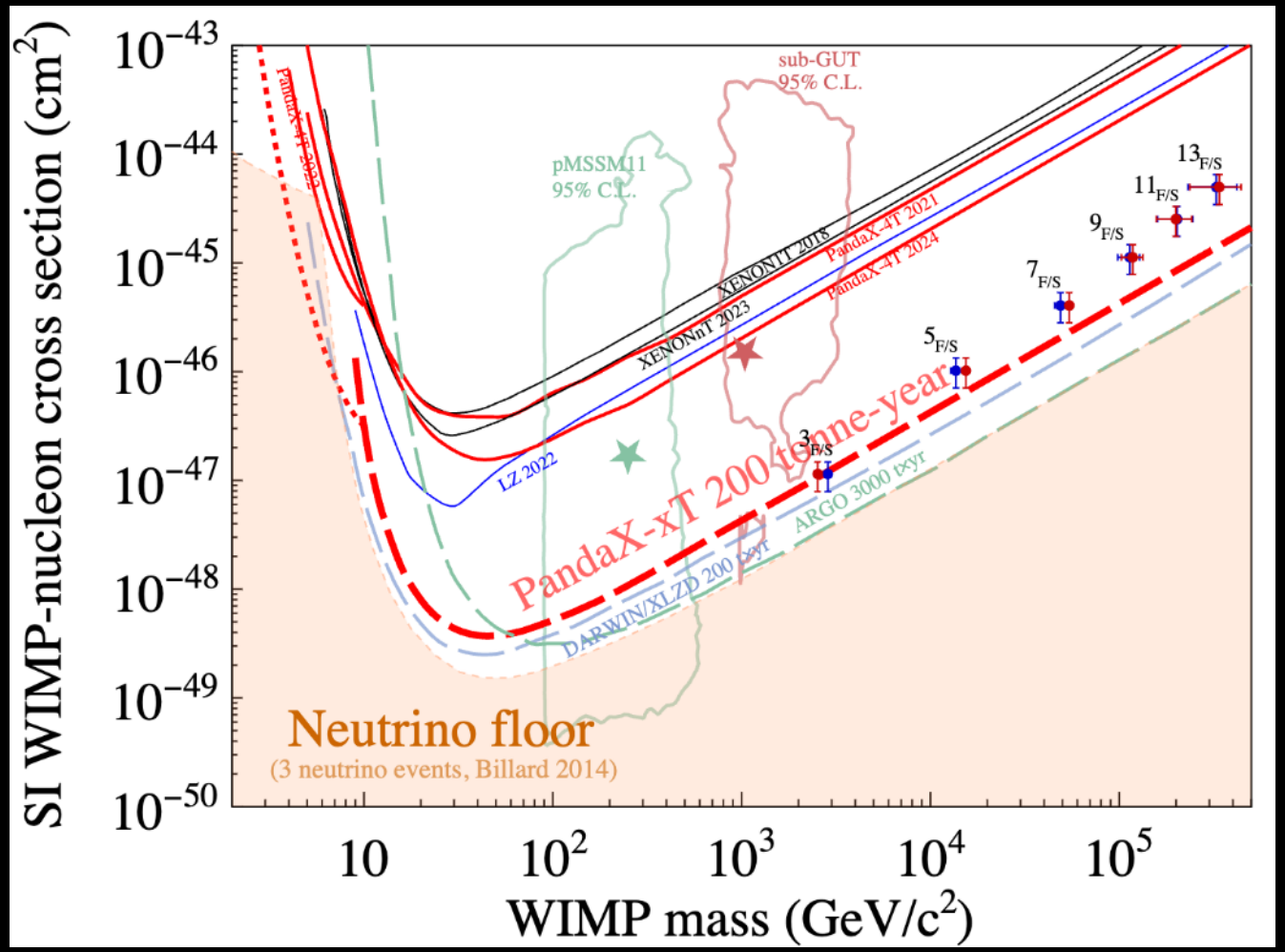


Low energy: dominated by ^{222}Rn, pp neutrino, ^{136}Xe （34.2 ton FV)

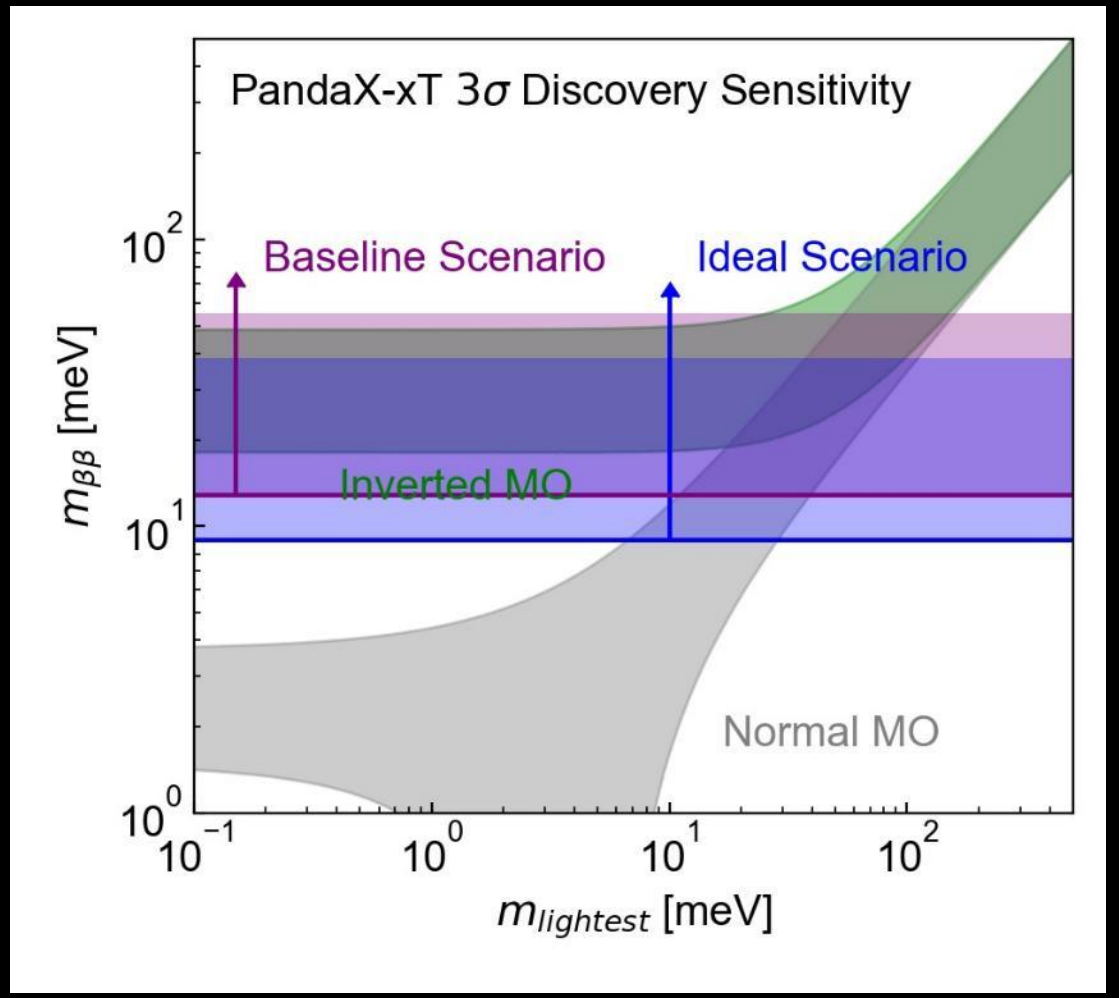
High energy: dominated by ^{222}Rn, ^{8}B neutrino, and ^{238}U in material (8.4 ton FV)

Physics reach

Dark matter sensitivity

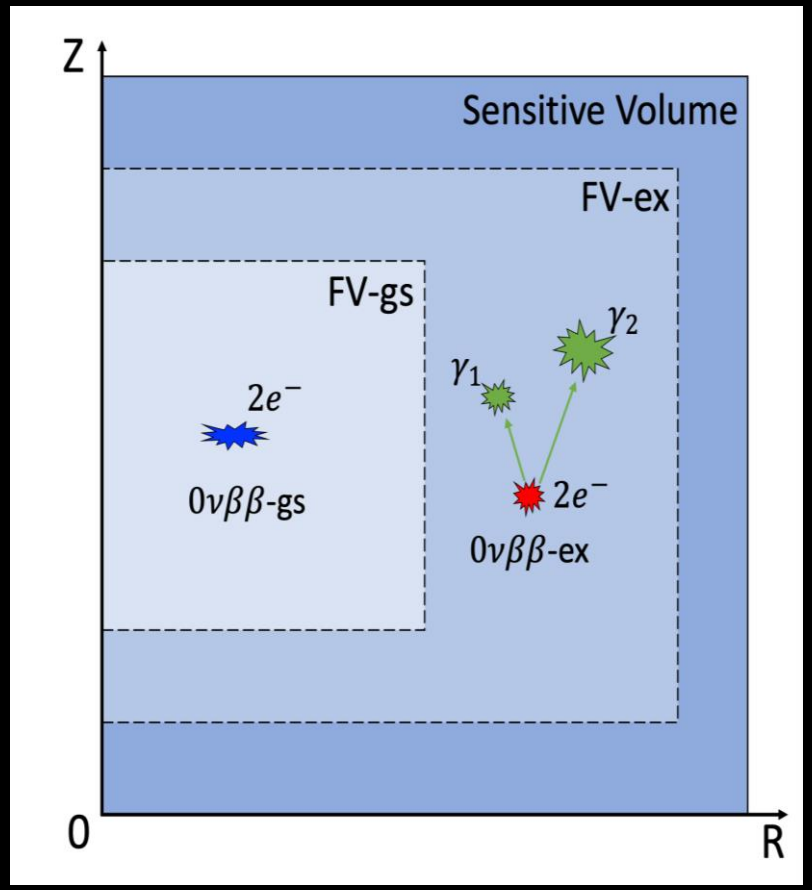


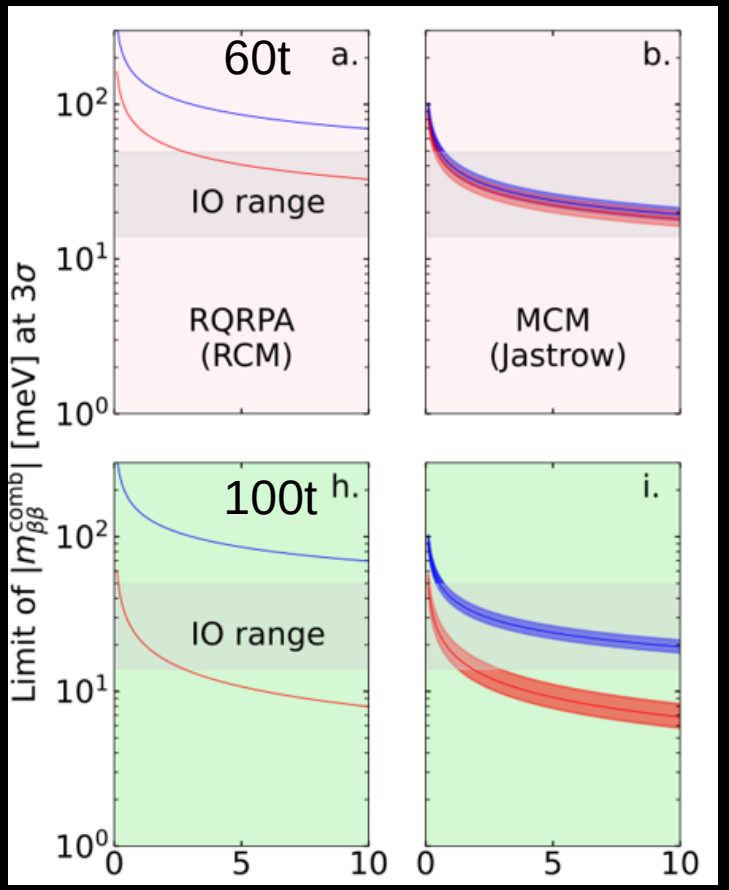
Majorana sensitivity



Unique advantage of natural xenon detector

- Large Liquid Xe TPC offers a unique detector response to search for 0νββ-ex of ^{136}Xe
  - Larger FV
  - Lower background rate
- Combining 0νββ-gs and 0νββ-ex improves the sensitivity to $m_{\beta\beta}$
- Depends on how lucky we are with the NME
- The bigger FV => the more favorable the combined approach with natural xenon



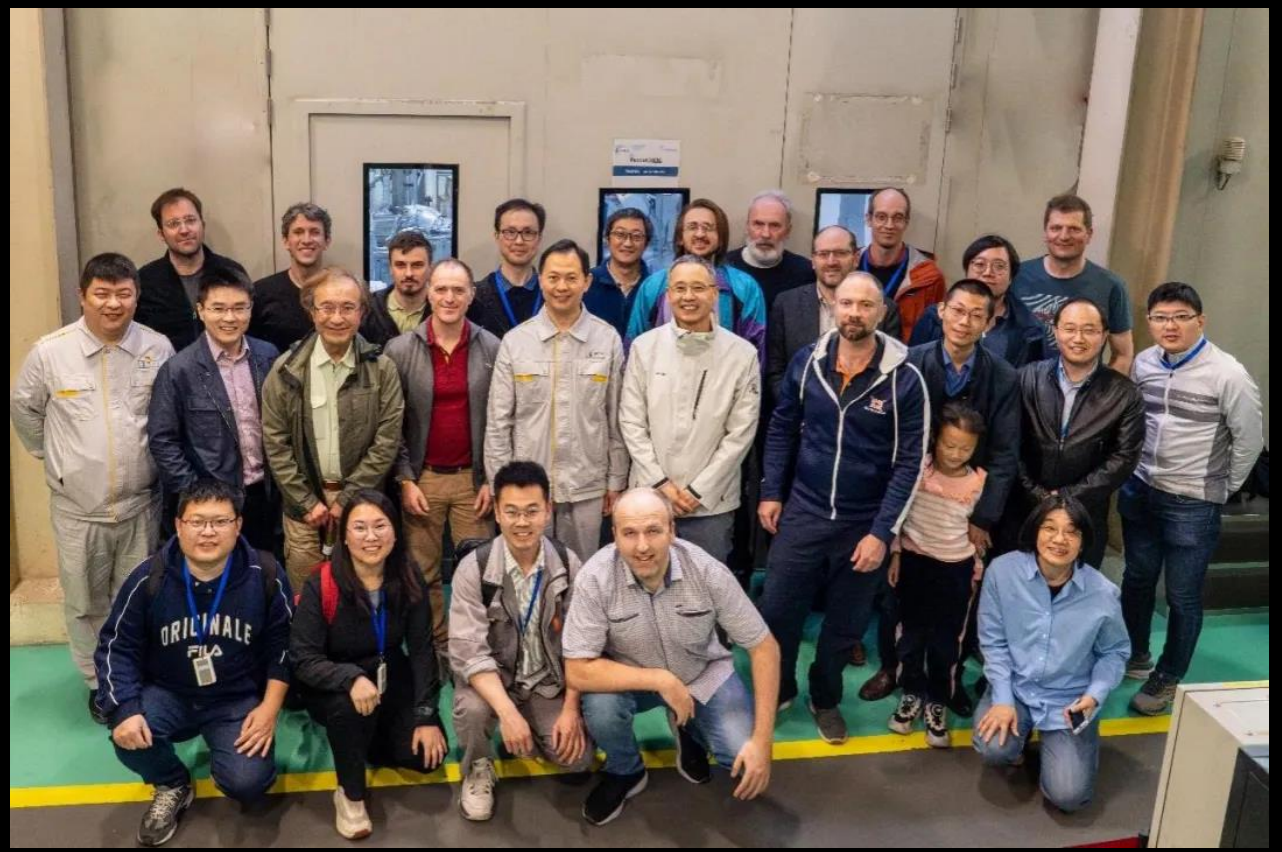


arXiv:2508.17413, Ding, Han, Wang, Yao

Complementarity with XLZD

- Friendly competition good for the science
- Data taking in parallel => increase the world data for global analysis
- Different experimental sites/detector design features/background $\Rightarrow$ Cross checks
- Learn from each other's lessons and technological breakthrough
- Joint force in a general way

PandaX-xT first open meeting (Apr. 7-11, 2025)



- A few groups in Russian, Japan, and UK would like to participate in the development.
- Some NSFC-CJPL international cooperation “incubator” funding

Summary

- PandaX-4T has developed a very rich physics program in DM and Neutrinos(!)
  - Technically: developing more and more sensitive detectors
  - Physics-wise: stronger connections with theorists
- A pragmatic approach with a stage-wise upgrade to PandaX-xT aiming for VERY exciting physics
  - Next stage: PandaX-20T
- Highly welcome collaborators!
- Hiring postdoc and students!