PANDA X
PARTICLE AND ASTROPHYSICAL XENON TPC

北京航空航天大學
BEIHANG UNIVERSITY

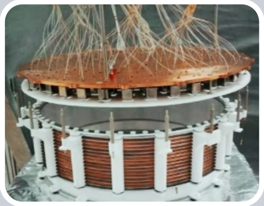
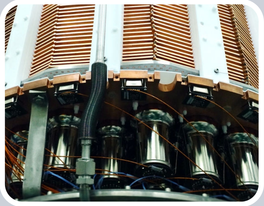
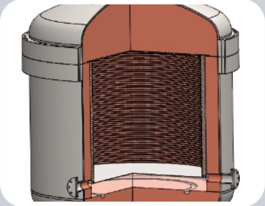
New Results from PandaX-4T

周小朋 (Beihang University)

On behalf of PandaX Collaboration

International Conference on Neutrinos and Dark Matter (NuDM-2022)

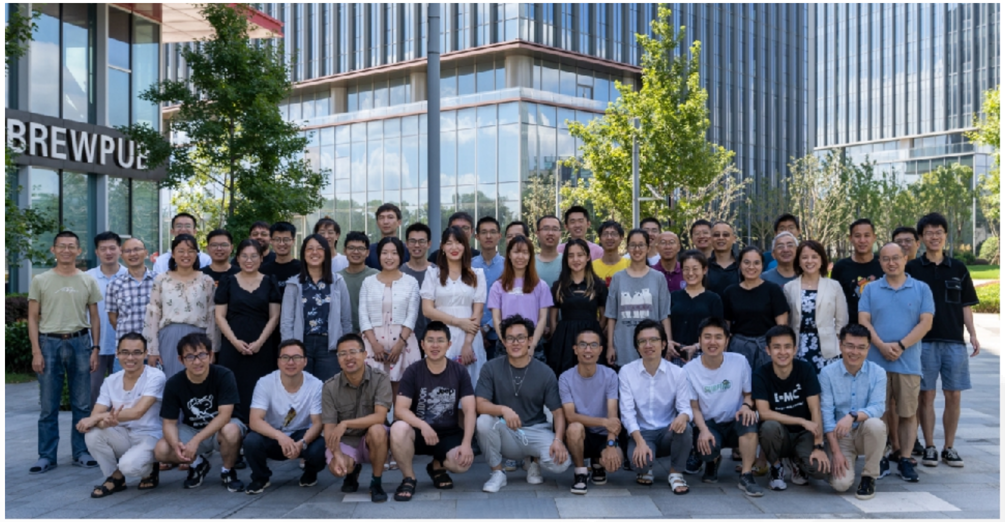
PandaX experiment

			
PandaX-I 120kg LXe DM 2009-2014	PandaX-II 580 kg LXe DM 2015-2019	PandaX-4T 4 ton LXe DM 2019.8-	PandaX-III 200kg-1T gas Xe-136 $0\nu2\beta$ Near future

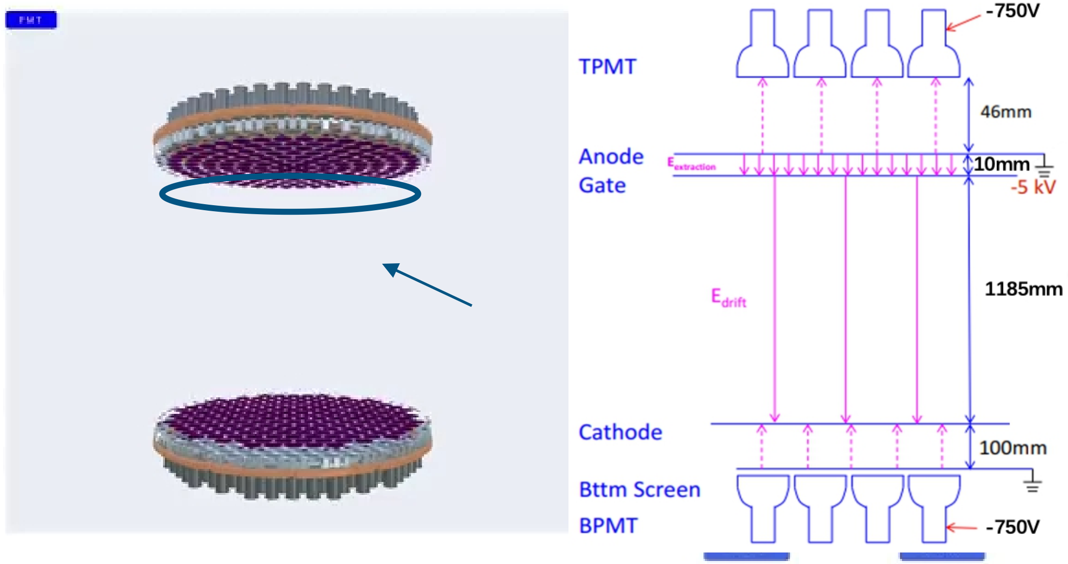
PandaX

- Series of xenon based rare-event detection experiments
- Formed in 2009
- >50 collaborators
- China JinPing Underground Laboratory

PANDA X
PARTICLE AND ASTROPHYSICAL XENON TPC



Dual-phase xenon Time Projection Chamber(TPC)

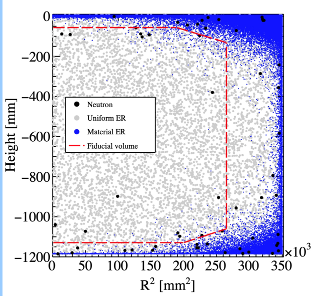


ZEPLIN，XENON，LUX，LZ，PandaX…

XENON

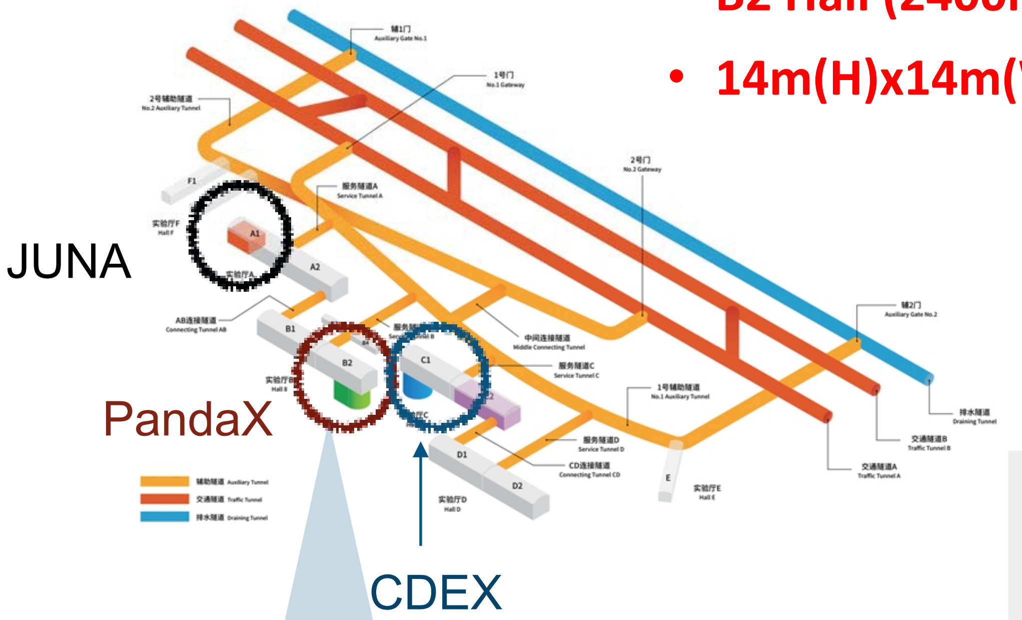
Advantages :

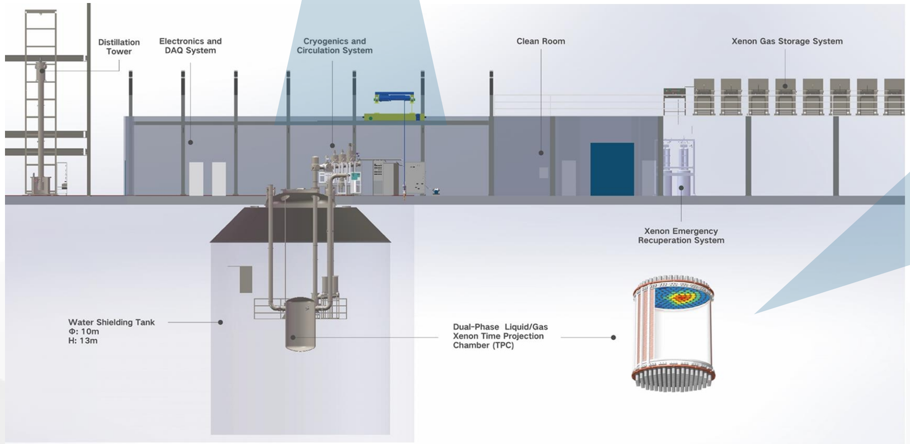
- ✓ Xenon has no long-lived radioactive isotopes (except ^{136}Xe)
- ✓ Large A: large cross section & self-shielding
- ✓ Discrimination power
  WIMPs， ν， n → Nuclear Recoil (NR)
  γ， β → Enectronic Recoil(ER)
- ✓ 3D fiducialization
- ✓ Scalability
- ✓ Good resolution



PandaX-4T

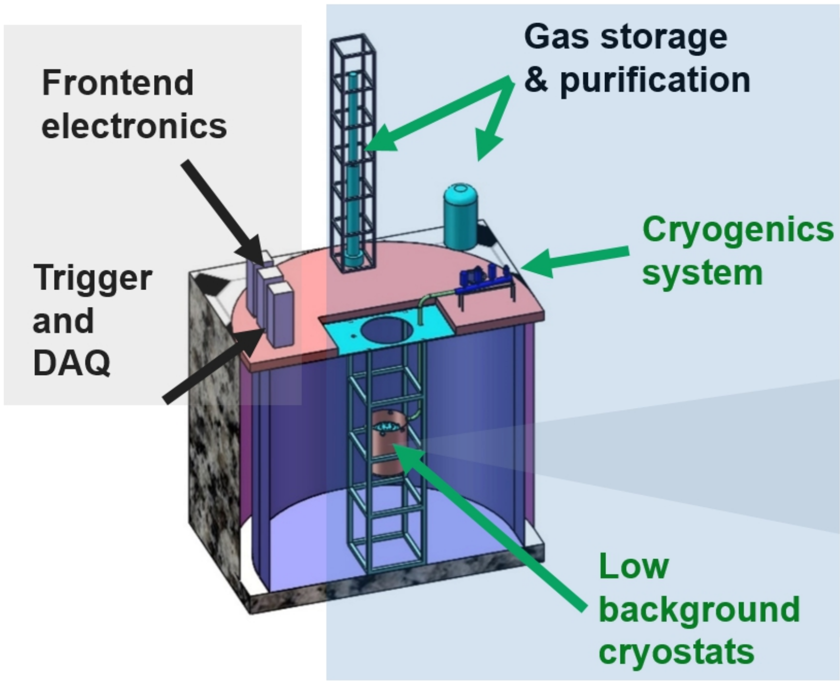
- B2 Hall (2400m rock burden)
- 14m(H)x14m(W)x65m(L)

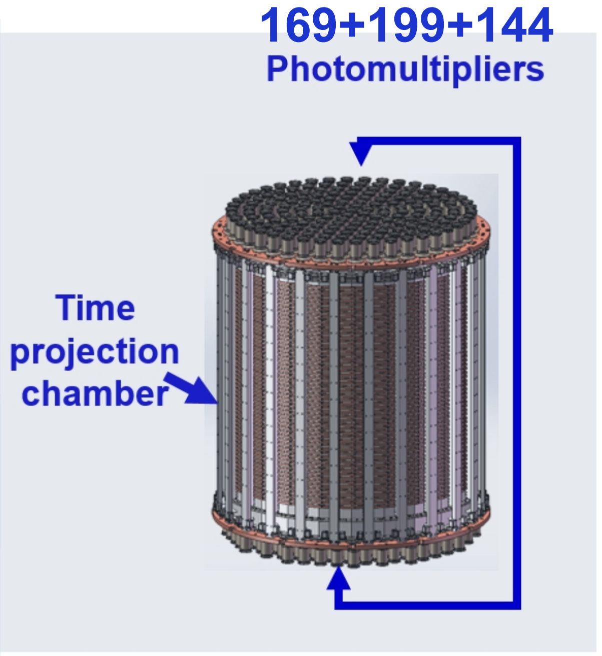




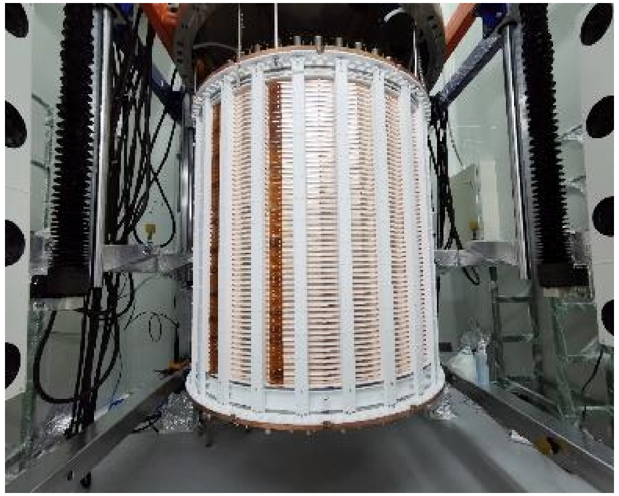
- Pure water passive shelding
- 1000m3

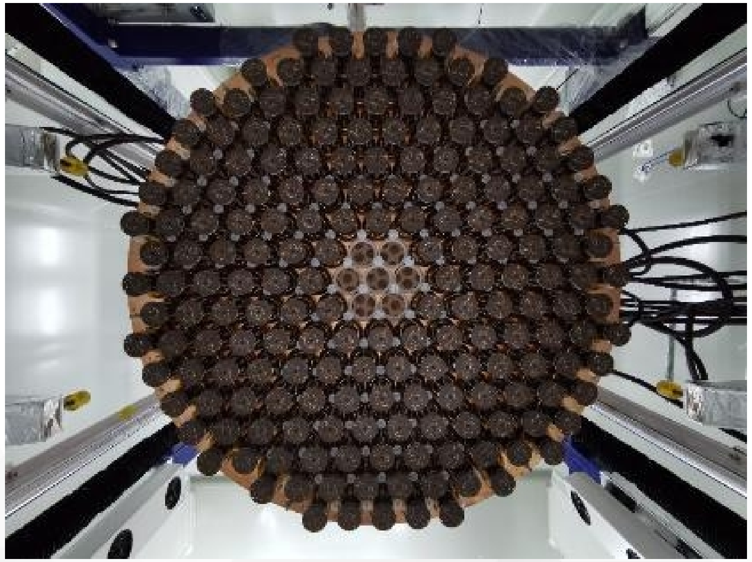
- PandaX-4T self-shelding
- (4-ton in sensitive region)





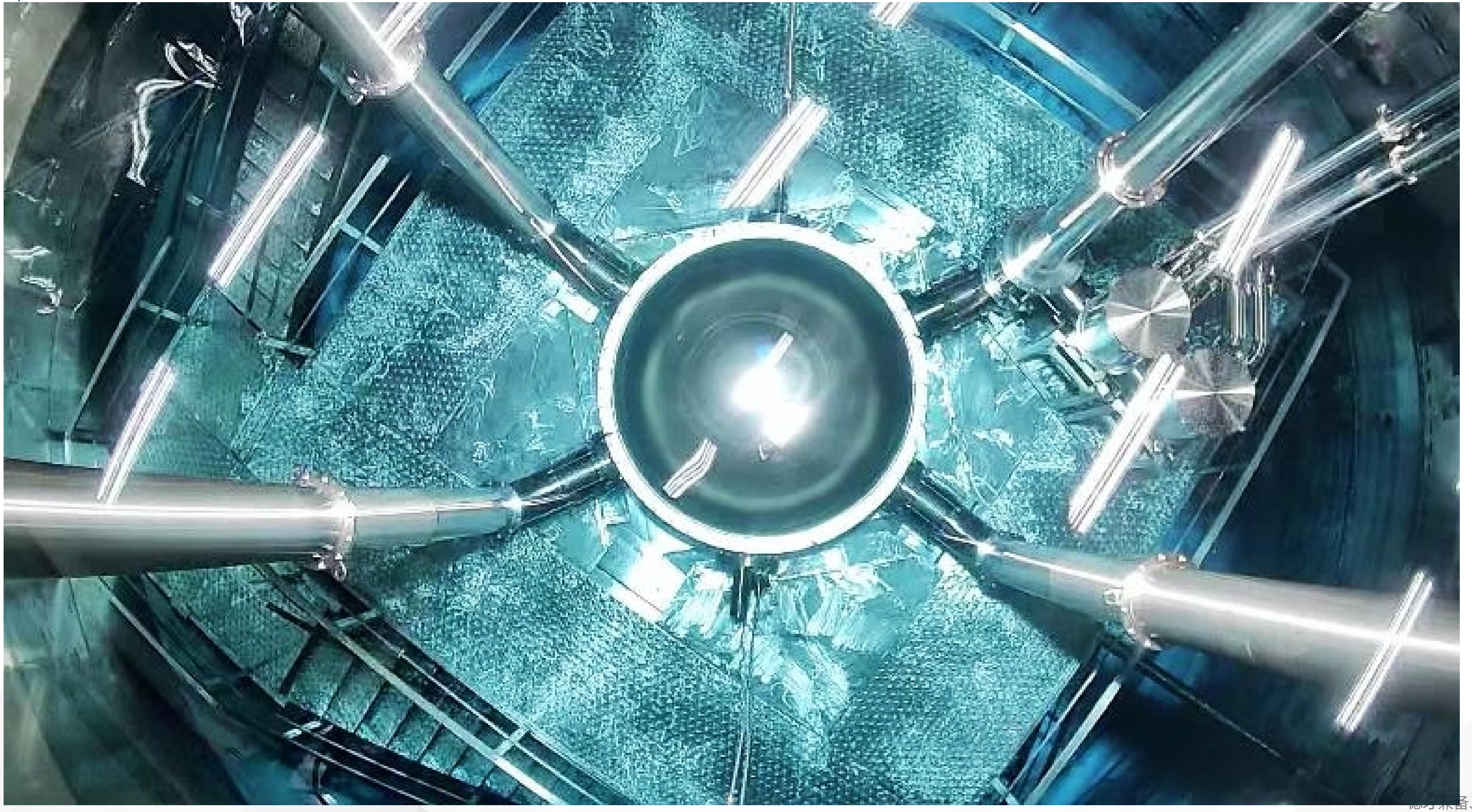
PandaX-4T



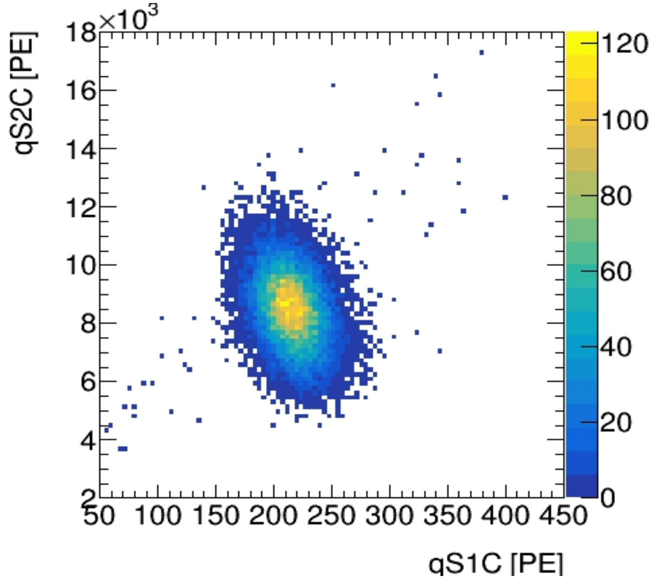


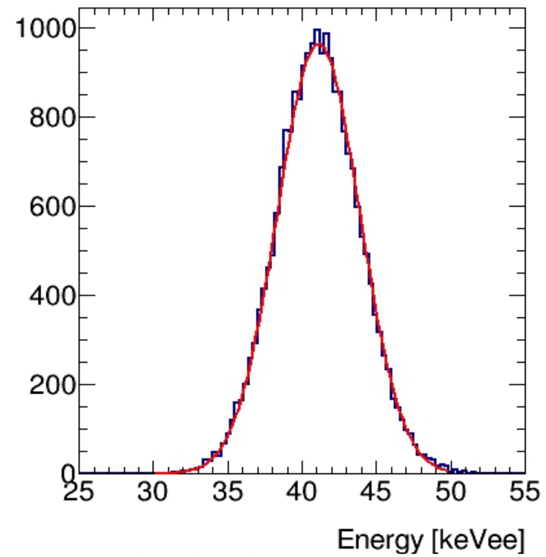
PandaX-4T

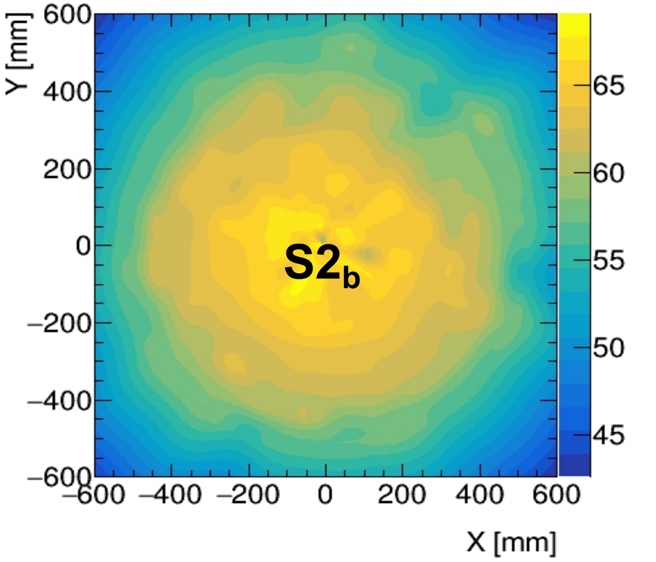
PandaX-4T

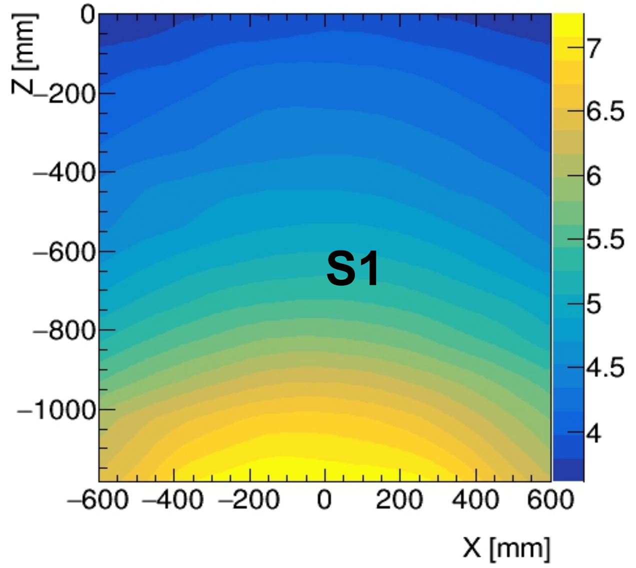


Horizontal Uniformity Correction with ^{83m}Kr (41.5 keV)



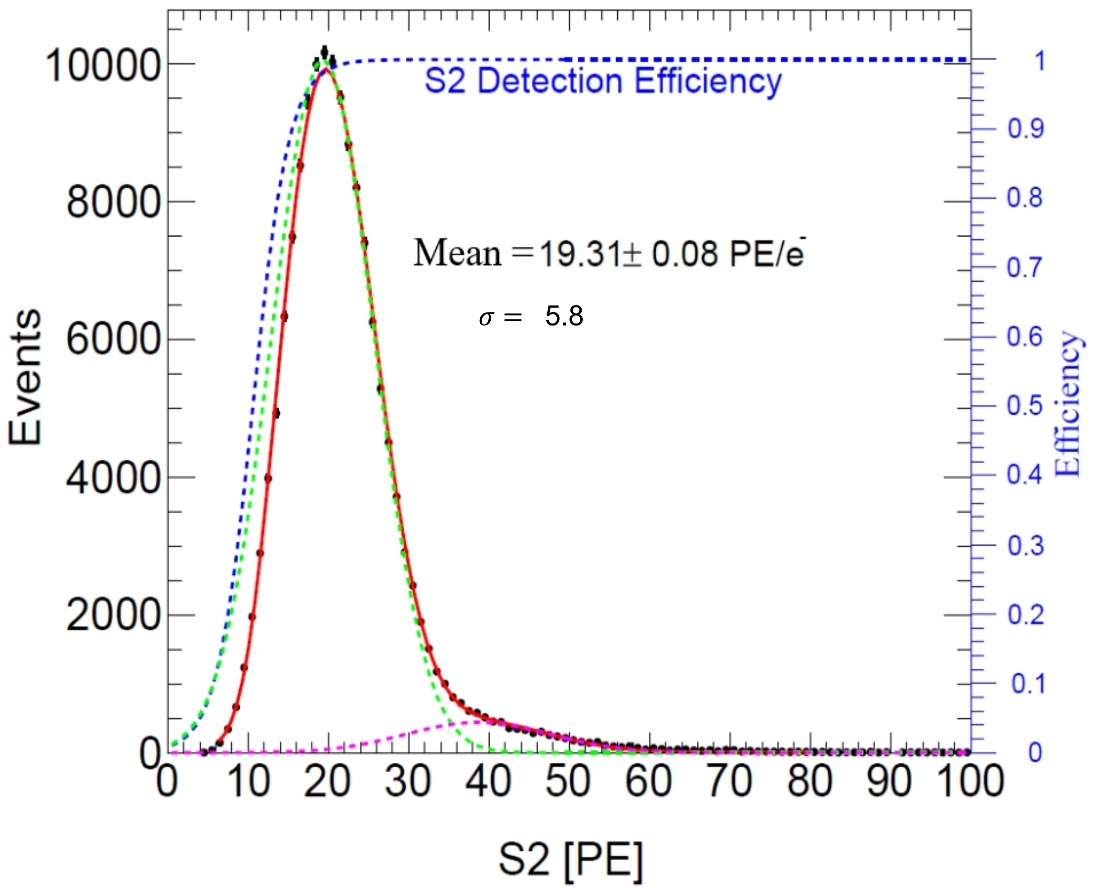


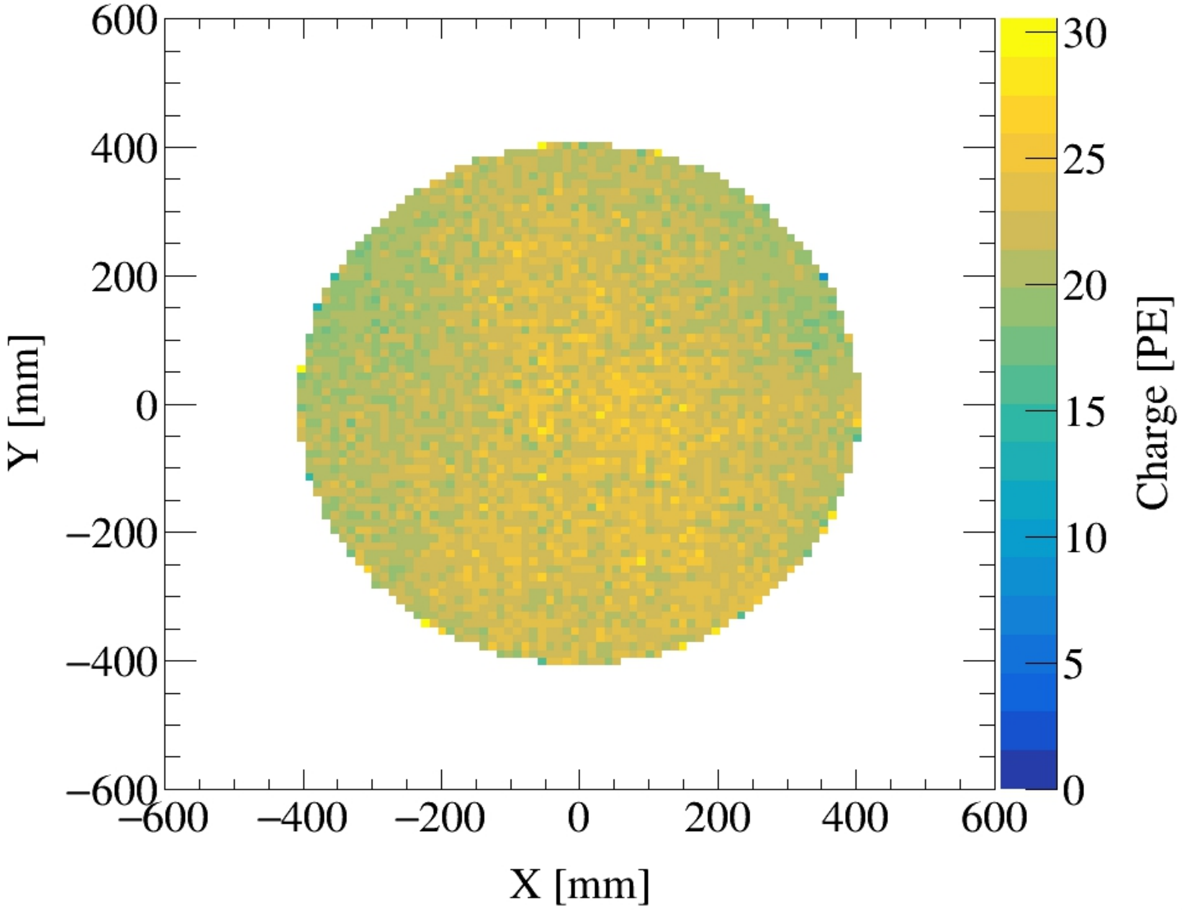




- ❑ Energy resolution @ 41.5 keV: **6.8%**
- ❑ $S2_b$ RMS in FV: **15%**
- ❑ S1 RMS in FV: **19%**

SEG & Uniformity

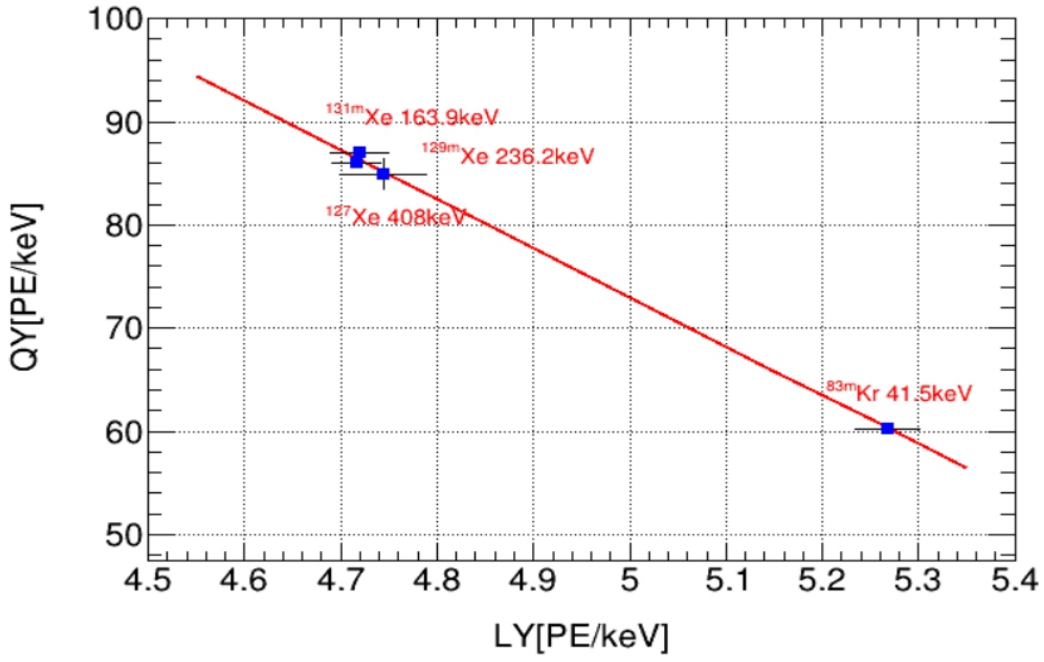


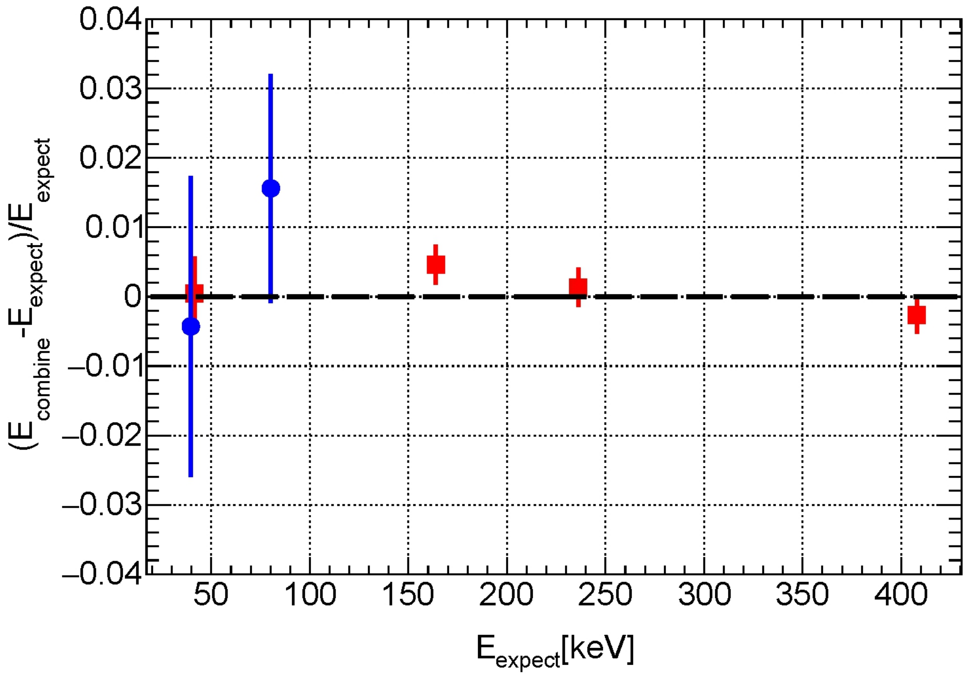


SEG: single electron gain： 19.31±0.08 PE/e

RMS variation 7.6%

Energy Reconstruction

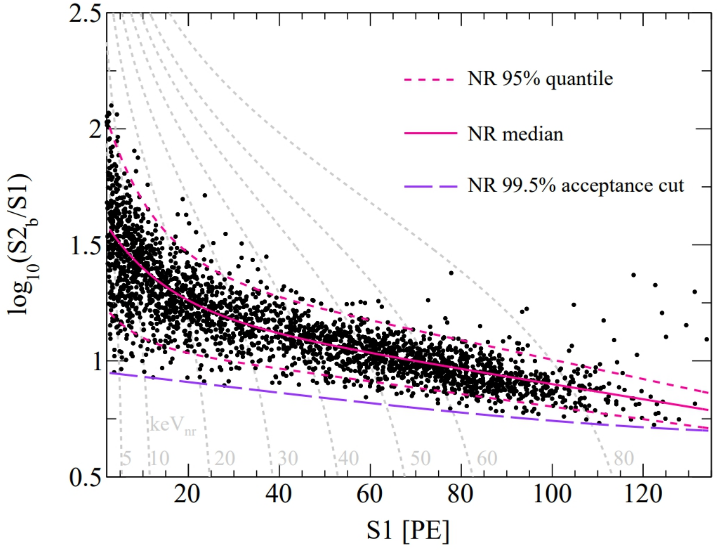


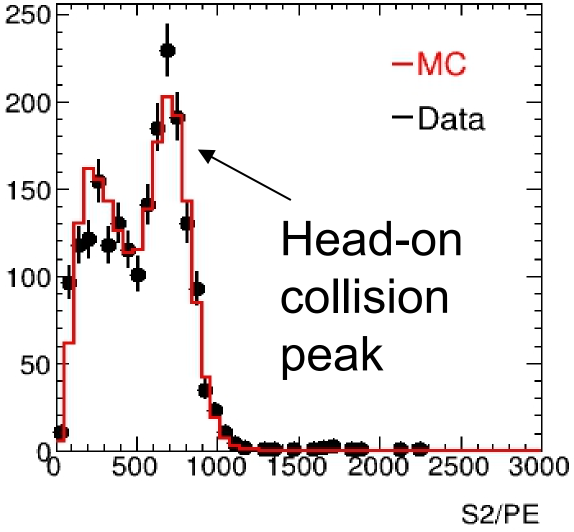


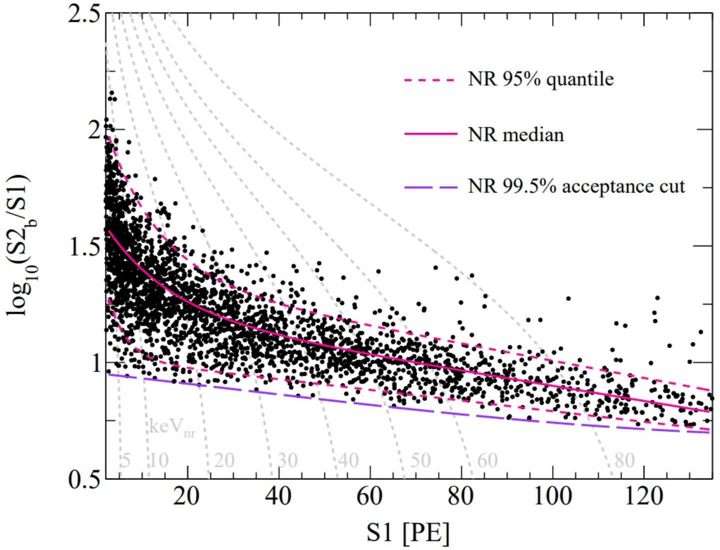
$$E = 13.7\ \text{eV} \times \left(\frac{\text{S1}}{\text{PDE}} + \frac{\text{S2}_\text{b}}{\text{EEE} \times \text{SEG}_\text{b}}\right)$$

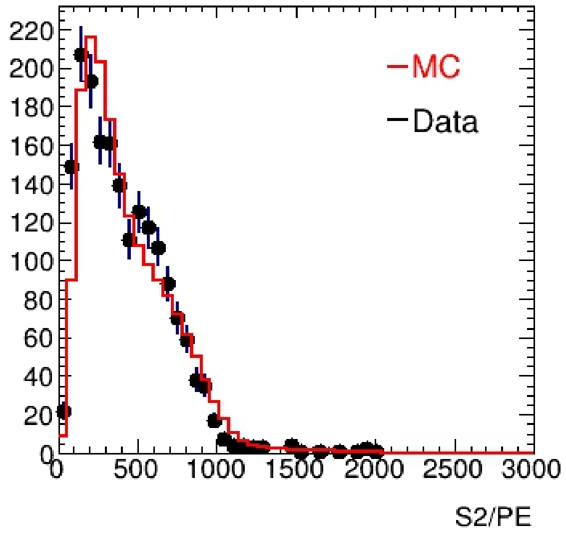
# Set	PDE [%]	EEE [%]	SEG_b [PE/e-]
1-2	9.0±0.2	90.2±5.4	3.8±0.1
3-5	9.0±0.2	92.6±5.4	4.6±0.1

Nuclear recoil (NR) Calibration



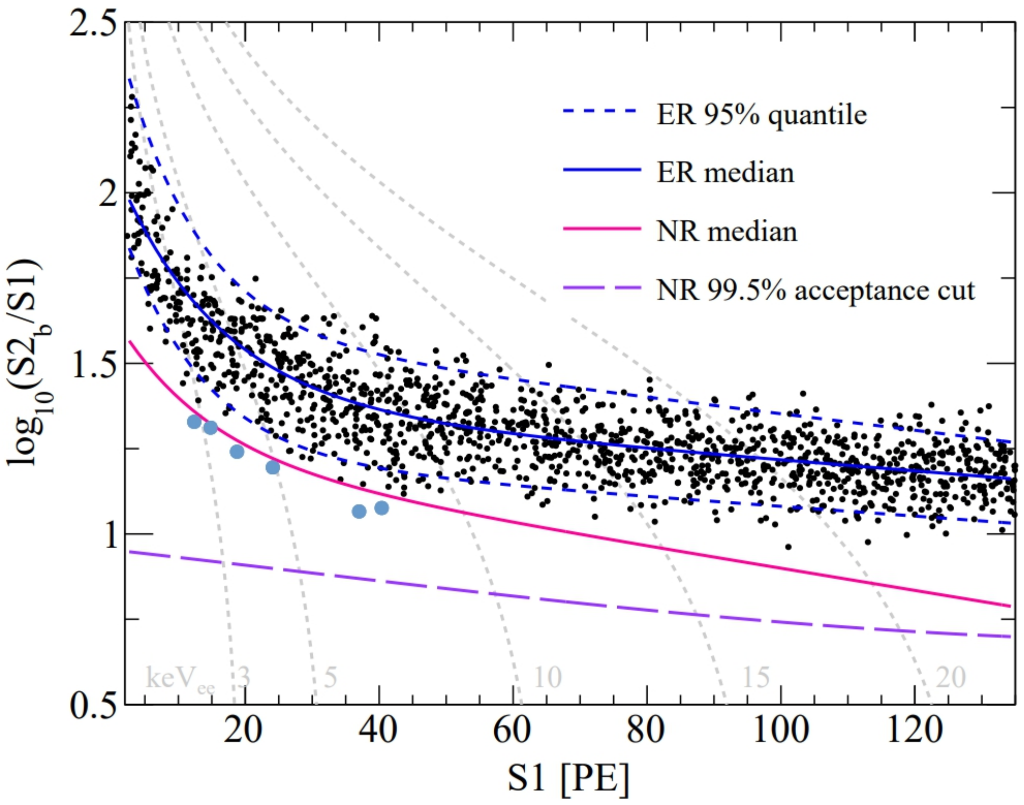


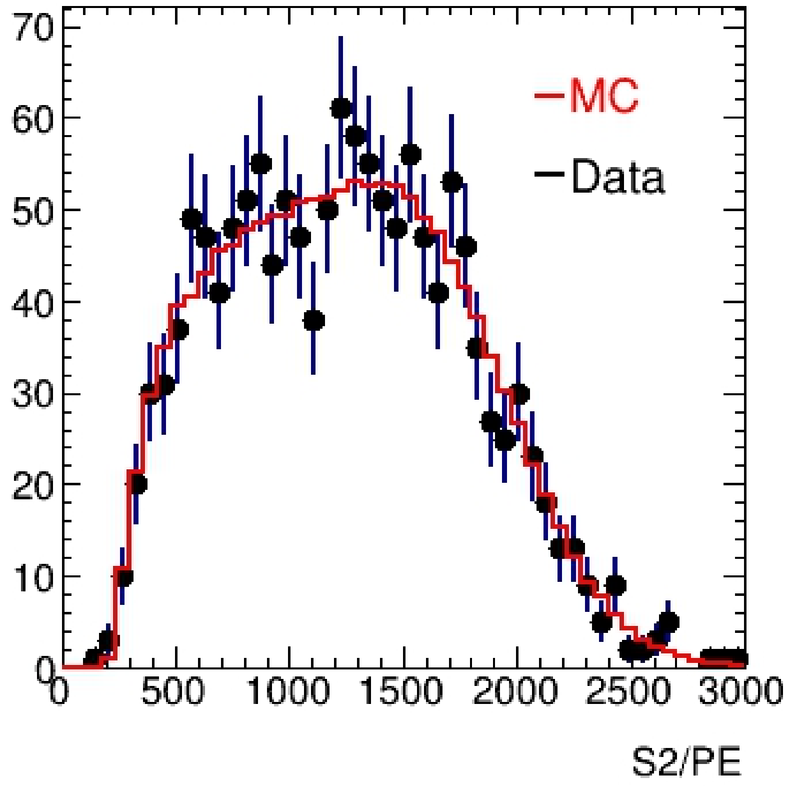




- **DD (first used in PandaX) and AmBe data are used to tune the light yield, charge yield, as well as fluctuations in signal model**

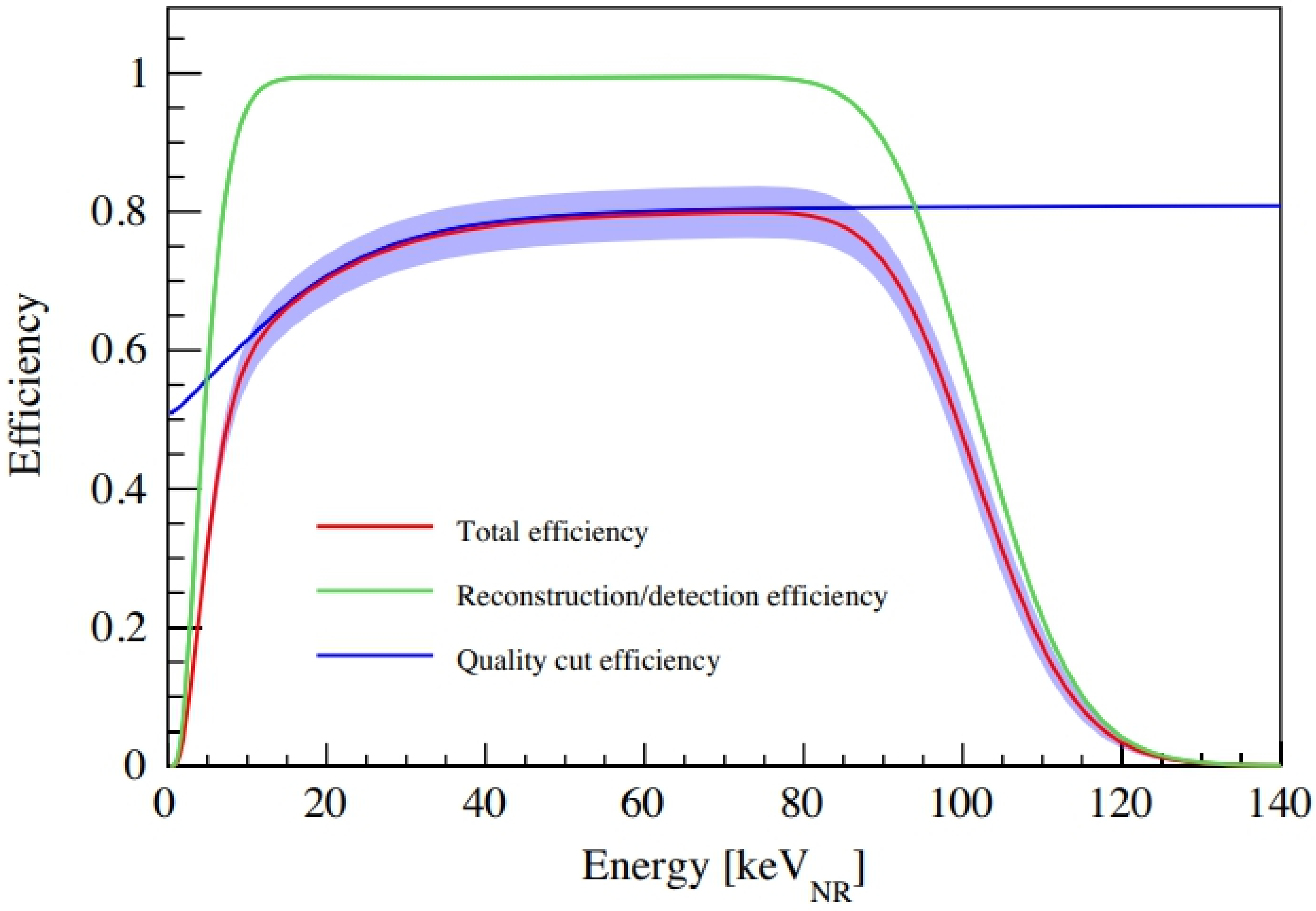
Electronic recoil (ER) Calibration

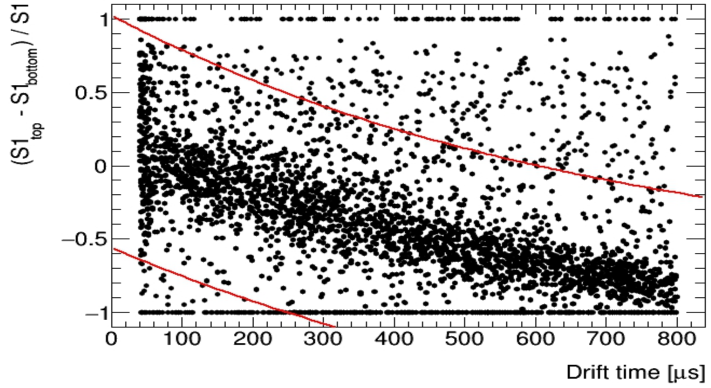


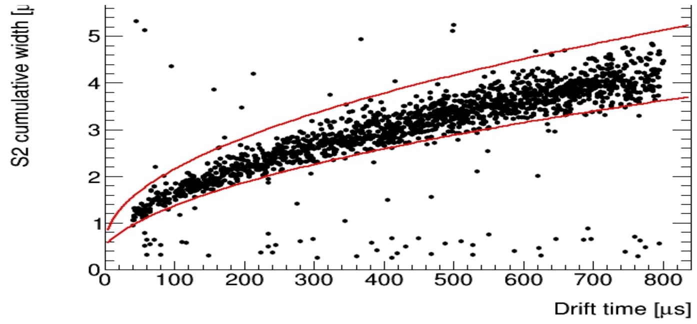


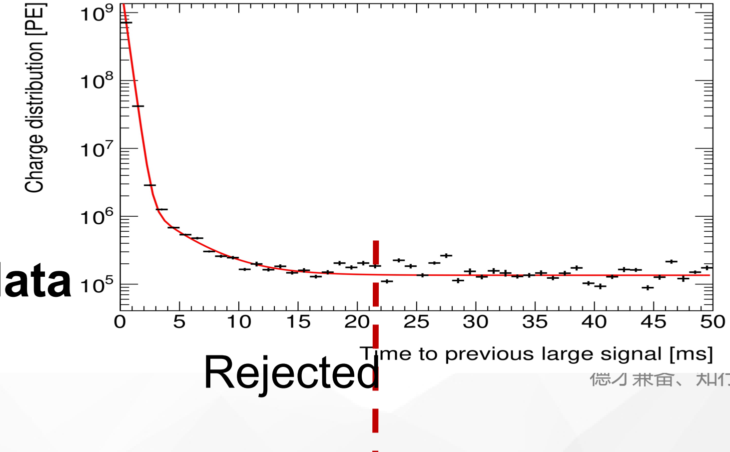
- ❑ **Measured leak ratio (below NR median) = 6/1393 = 0.43%±0.18%**
- ❑ **Data and ER model agree well**

Efficiency from Calibration



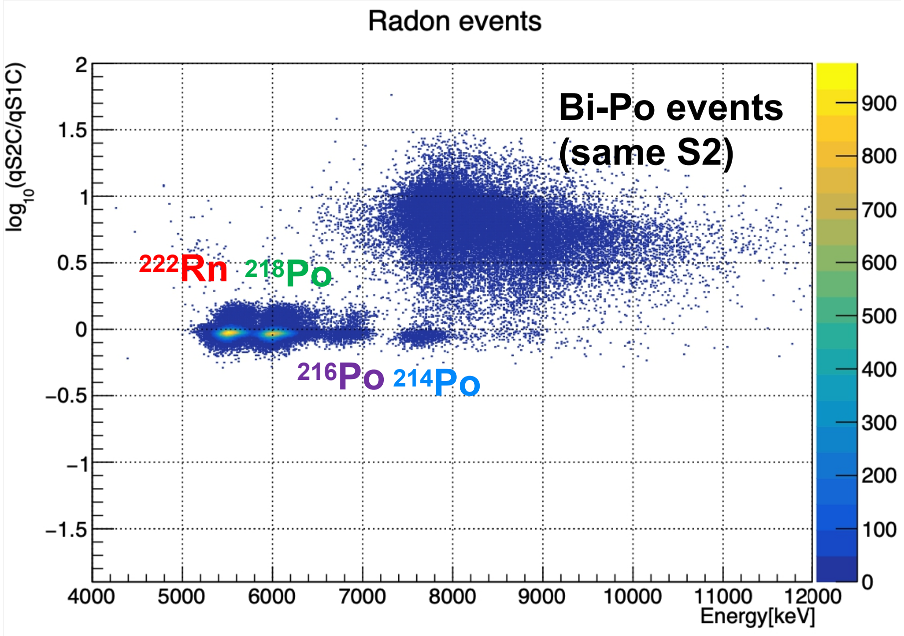


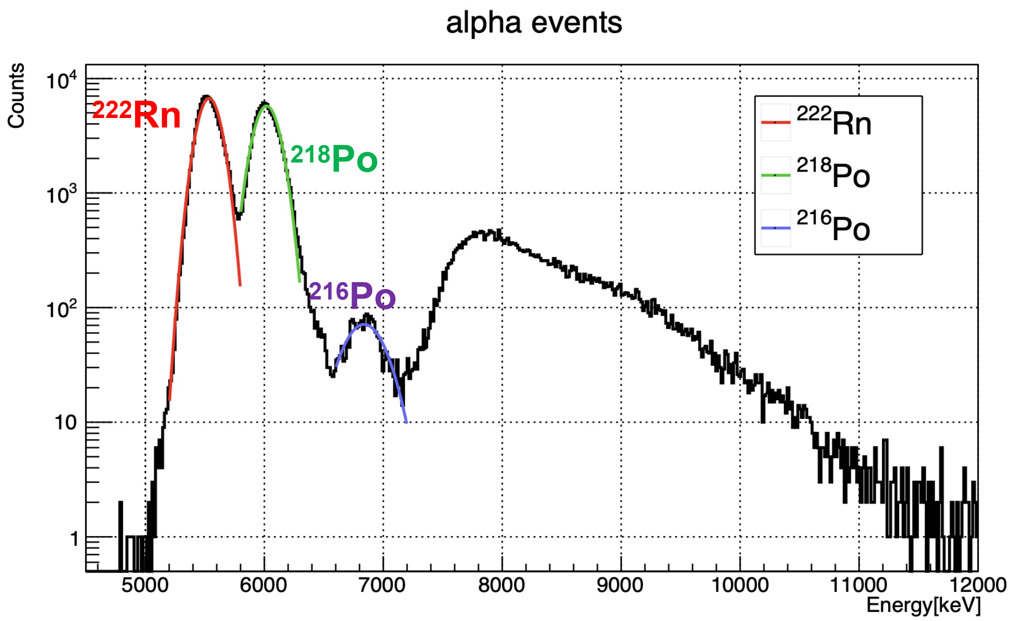




- ❑ **Consistent S1 and S2 efficiencies obtained from calibration data**
- ❑ **Plateaued efficiency at 40 keV$_{nr}$ ~78%.**

Rn Background

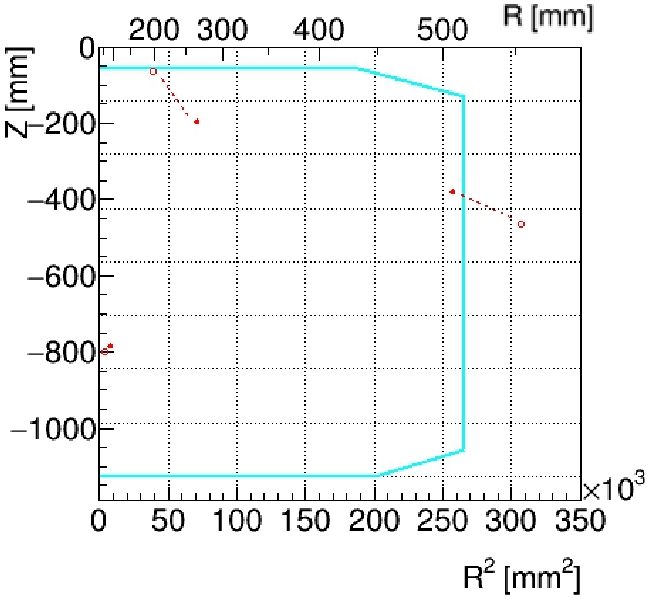


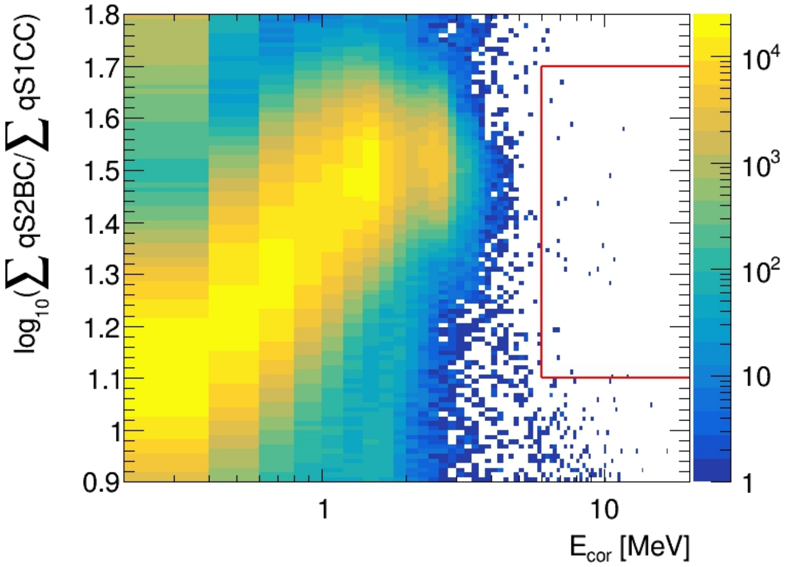


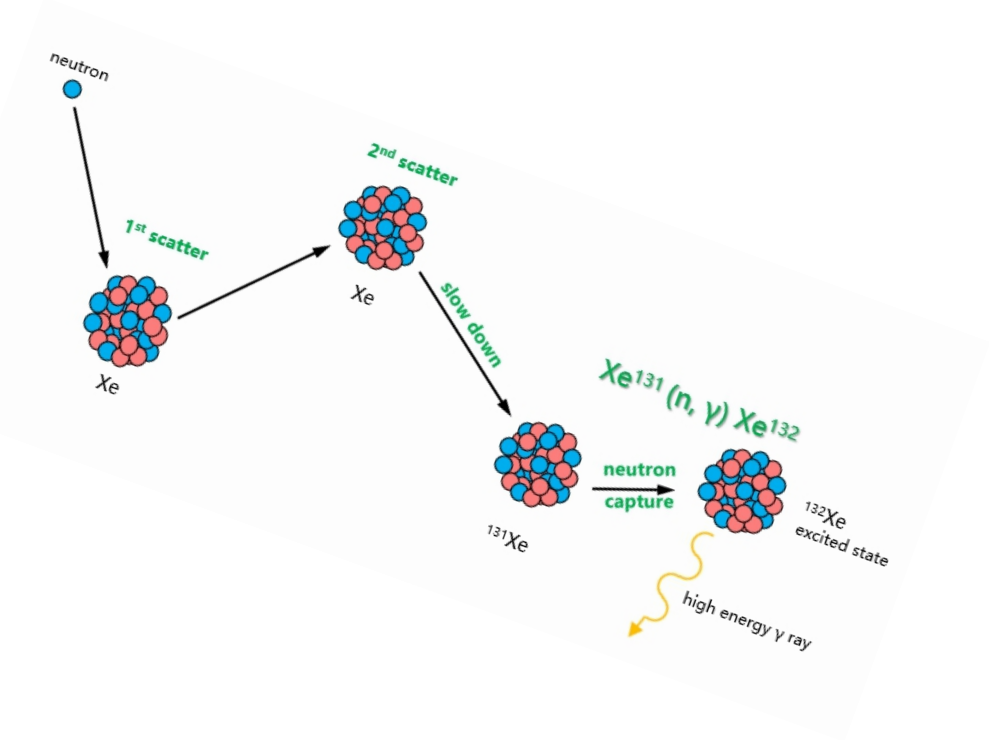
Rn background	Estimation method	Activity [μBq/kg]
^{222}Rn	^{222}Rn alpha	4.8 (0.1)
	^{218}Po alpha	4.5 (0.1)
	^{214}Bi-^{214}Po coincidence	0.87 (0.01)
^{220}Rn	^{220}Rn-^{216}Po coincidence	0.07 (0.01)

Improved 6 times from PandaX-II!

Neutron background

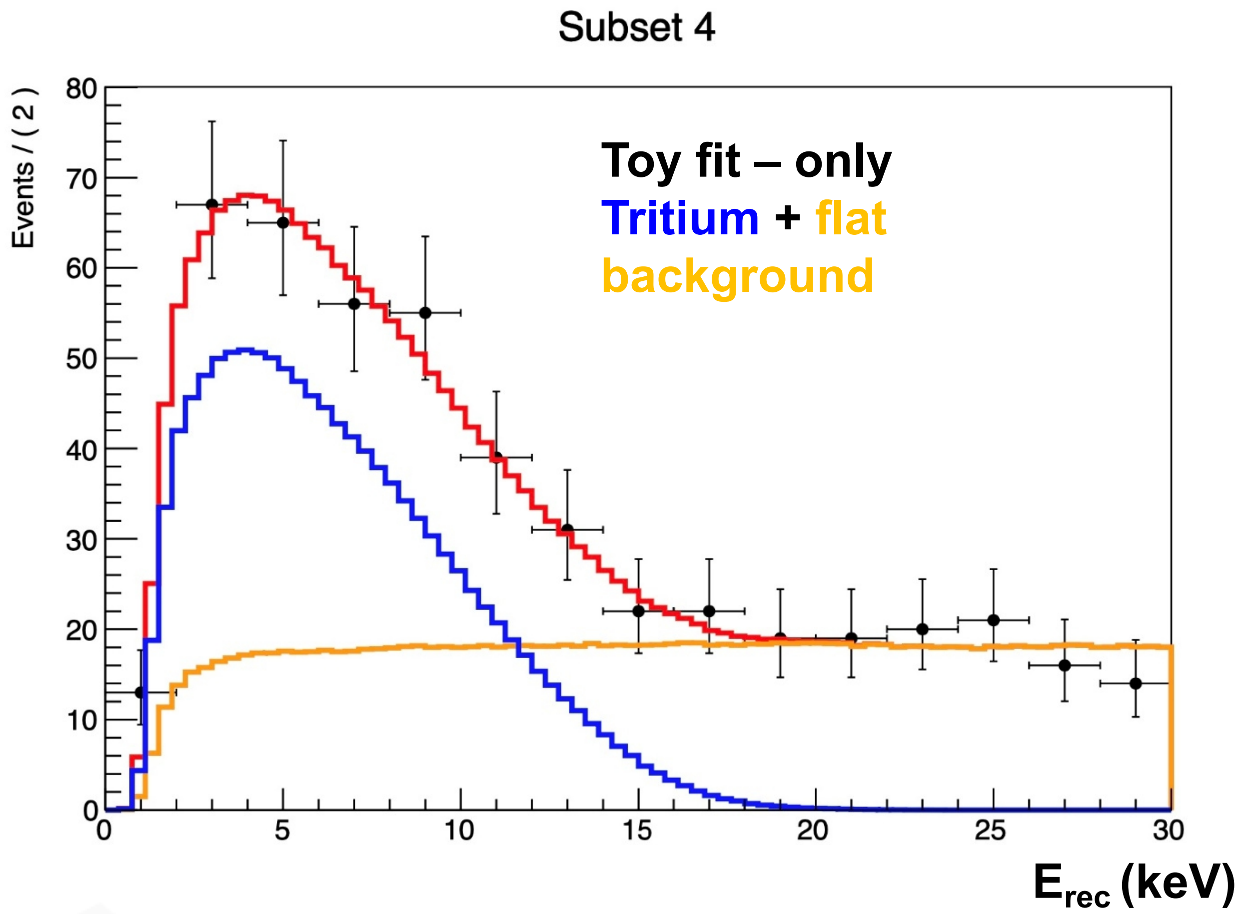






- ❑ **Tags: multi-scatter and captures**
- ❑ **Both processes benchmarked by neutron source calibration**
- ❑ **Neutron background: 1.2 ± 0.6 events, including 30% "neutron-X" events (Energy deposition in the below-cathode region)**

Tritium

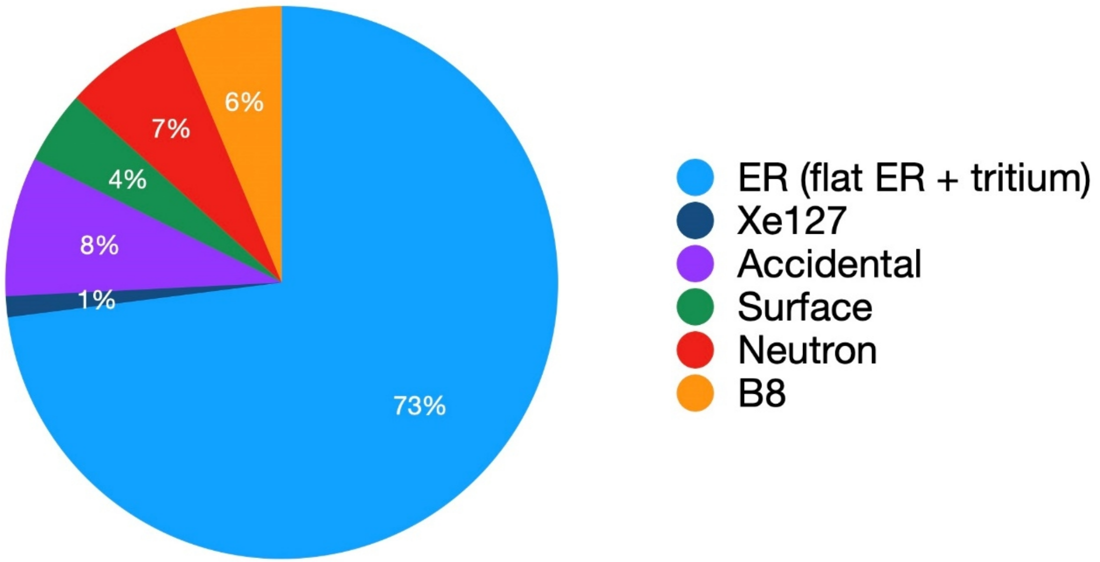


- ❑ Tritium spectrum identified in the data
- ❑ Likely originated from a tritium calibration at the end of PandaX-II
- ❑ Level floating in the final dark matter fit: ~ $5(0.3)\times10^{-24}$ (mol/mol)
- ❑ further removal surgery on the way

Background Composition Summary

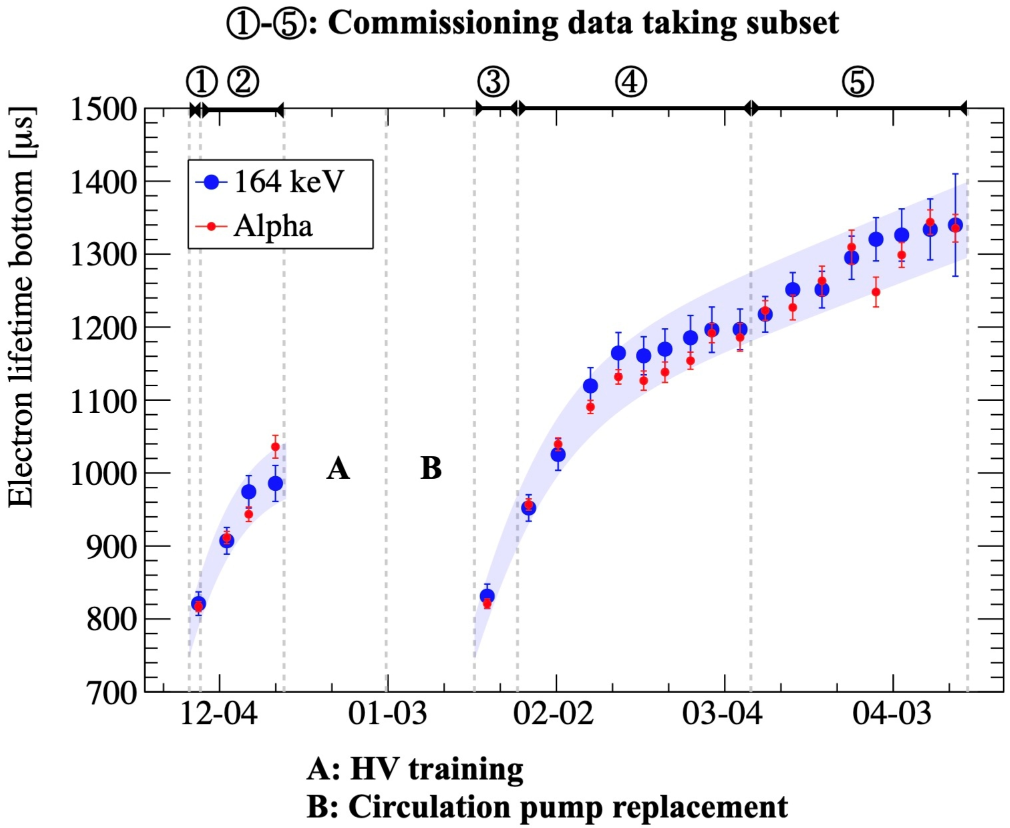
Component	Nominal (evts)
^{3}T (from fit to data)	532 (32)
Flat ER* (18-30keV side band)	492 (31)
Rn	347 (190)
Kr	53 (34)
Material	40 (5)
Xe127	8 (1)
Neutron	0.9 (0.5)
Neutron-X	0.2 (0.1)
Surface	0.5 (0.1)
Accidental	2.4 (0.5)
B8	0.6 (0.3)
Sum	1037 (45)

Expected below-NR-median events: 9.8 (0.6) evts



- ❑ **Flat ER (Rn+Kr+Material) is determined from side band in DM data**
- ❑ **Background per unit target is improved from PandaX-II by 4 times (<10 keV)**

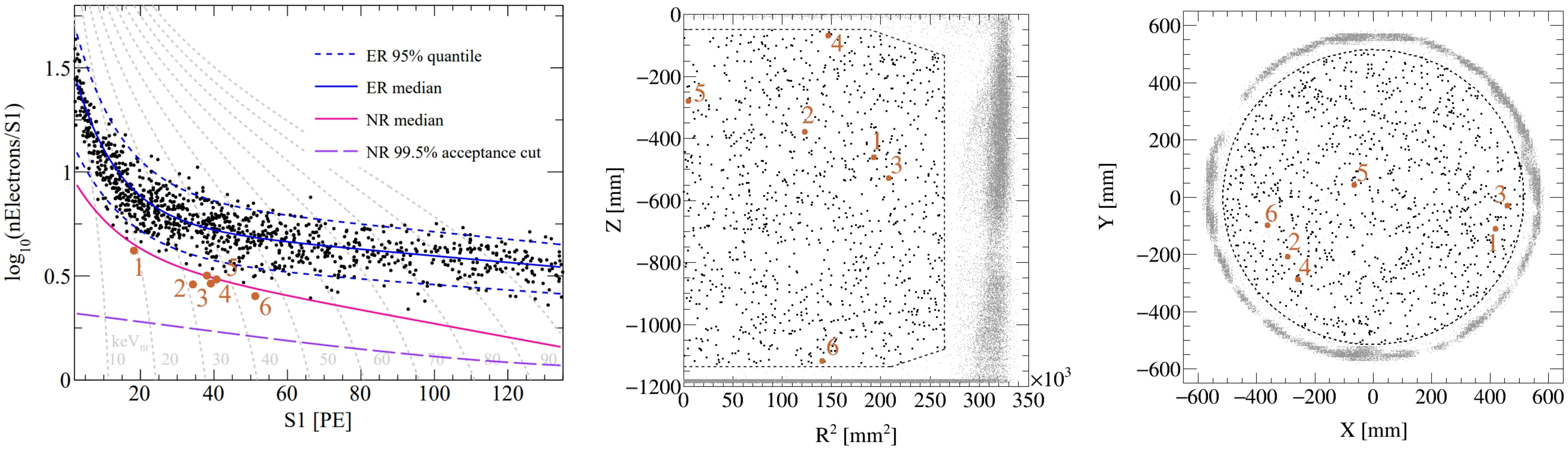
Data Taking History – 5 Subsets



Set	1	2	3	4	5
Duration (day)	1.95	13.25	5.53	35.58	36.51
$\langle \tau_e \rangle$ (μs)	800.4	939.2	833.6	1121.5	1288.2
dt_{max} (μs)	800	810	817	841	841
$V_{cathode}$ (−kV)	20	18.6	18	16	16
V_{gate} (−kV)	4.9	4.9	5	5	5
PDE (%)	9.0±0.2		9.0±0.2		
EEE (%)	90.2±5.4		92.6±5.4		
SEG_b (PE/e)	3.8±0.1		4.6±0.1		

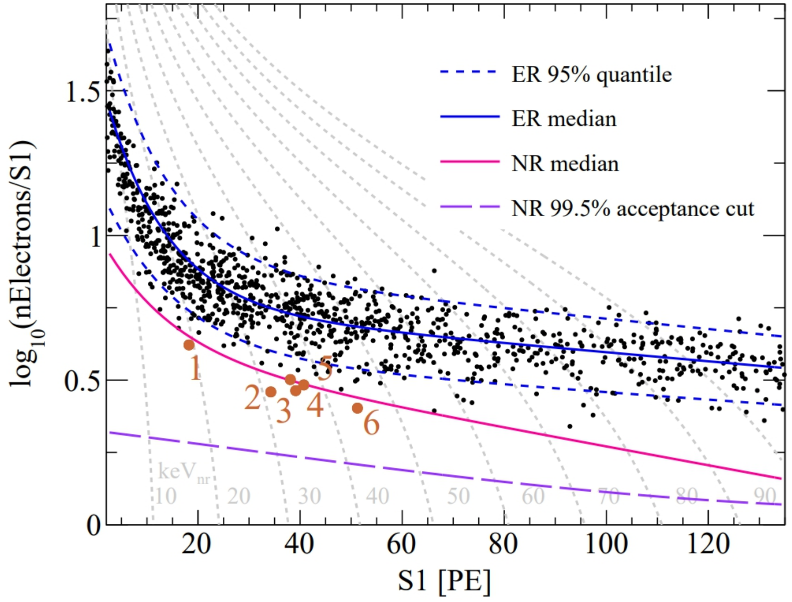
- Electron lifetime: *in situ* S2 vertical uniformity calibration
- Stable data running period: 95.0 calendar days

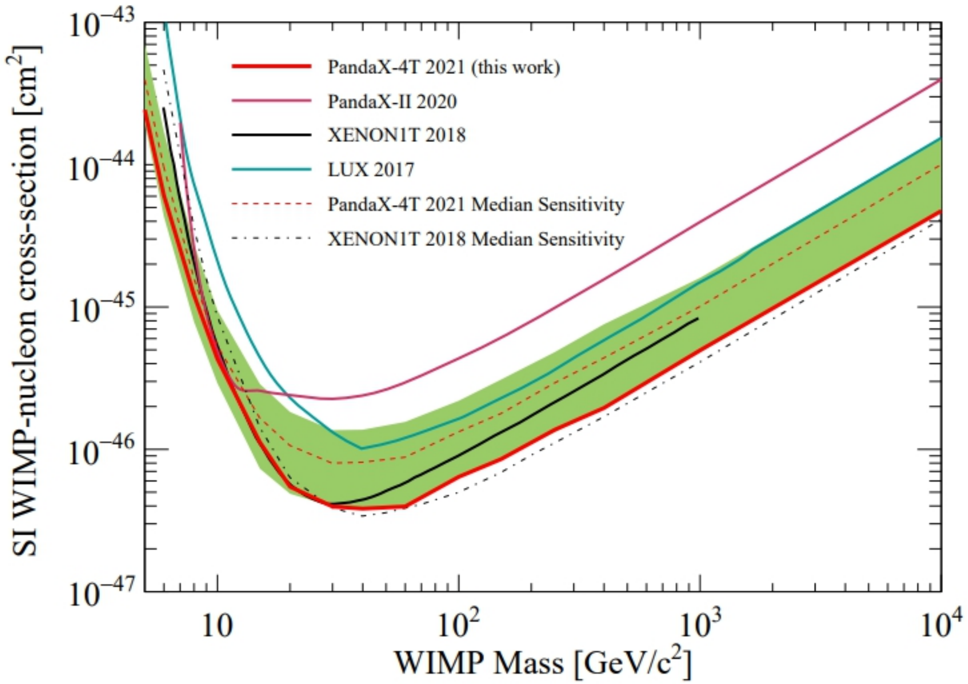
DM Candidates & Position Distribution

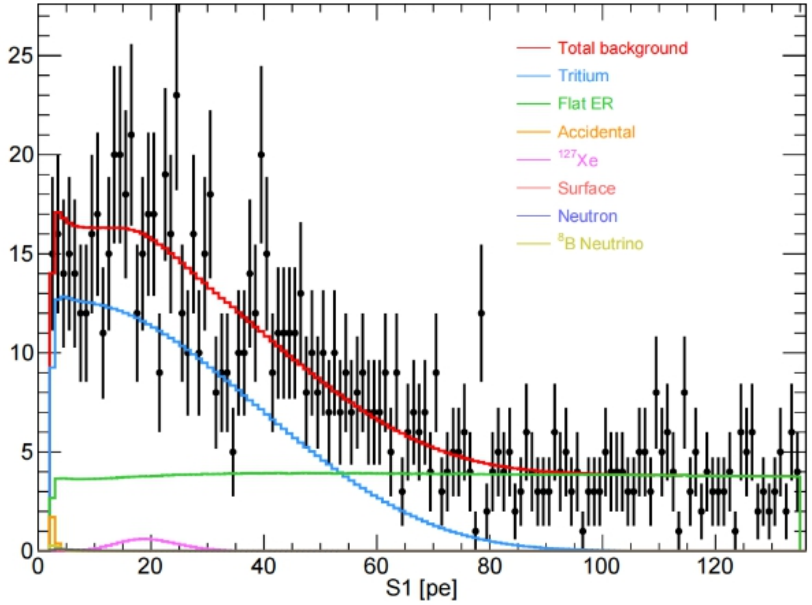


- S1 = (2, 135) PE, $S2_{raw}$ > 80 PE, S2 < 20000
- In FV, 1058 candidates, 6 below NR median line
- Events uniformly distributed in the FV, expected if dominated by tritium and radon.

PandaX-4T's first result on WIMPs search



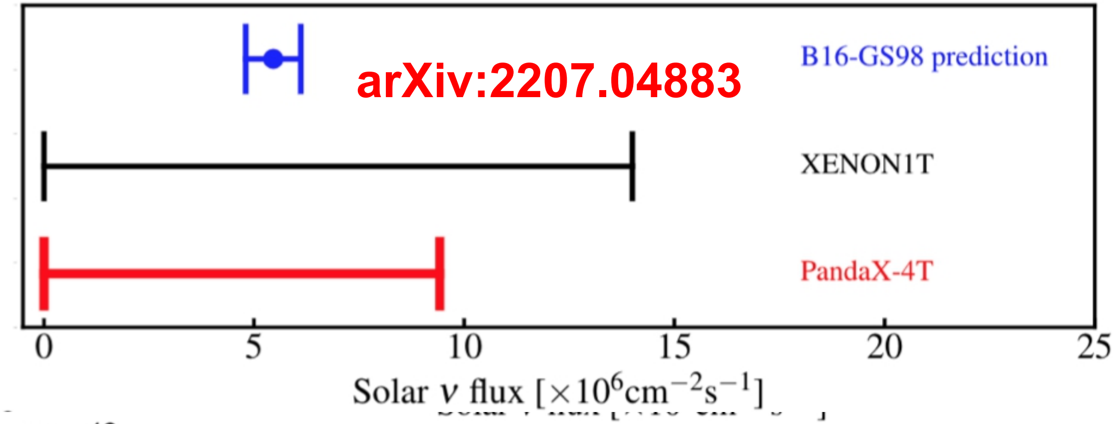


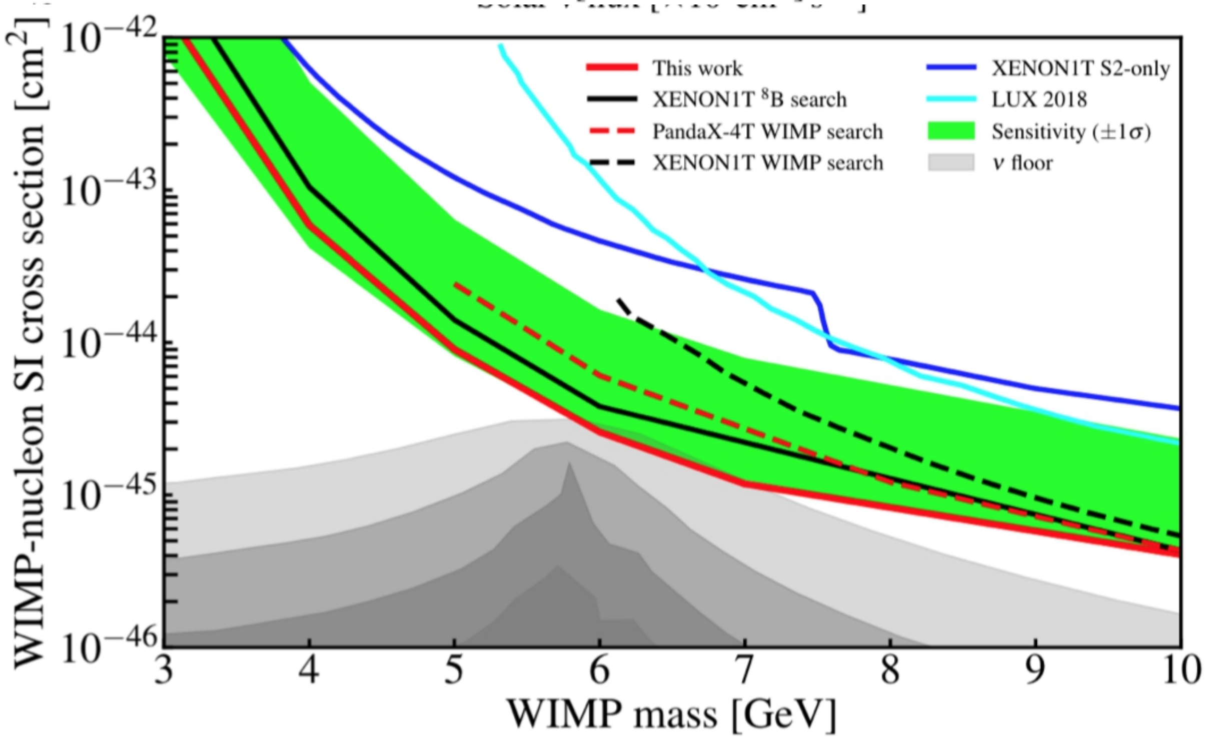


- ❑ Exposure: 0.63 tonne·year
- ❑ Sensitivity improved from PandaX-II final analysis by **2.9** times (30 GeV/c^2)
- ❑ Approaching the "low E" neutrino floor

PandaX-4T's first result on B8 neutrino detection

- ❑ Exposure: 0.48 tonne·year
- ❑further optimized data selection
- ❑lower energy threshold [1.33 to 0.95 keV] v.s. acc
- ❑ better senstivity on (3-10 GeV/c²) WIMP
- ❑ real touch the "low E" neutrino floor

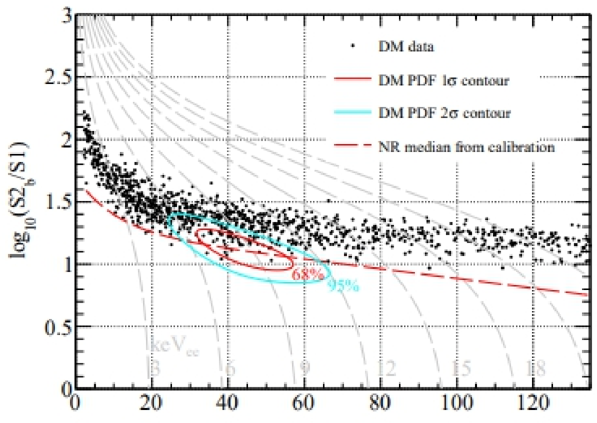


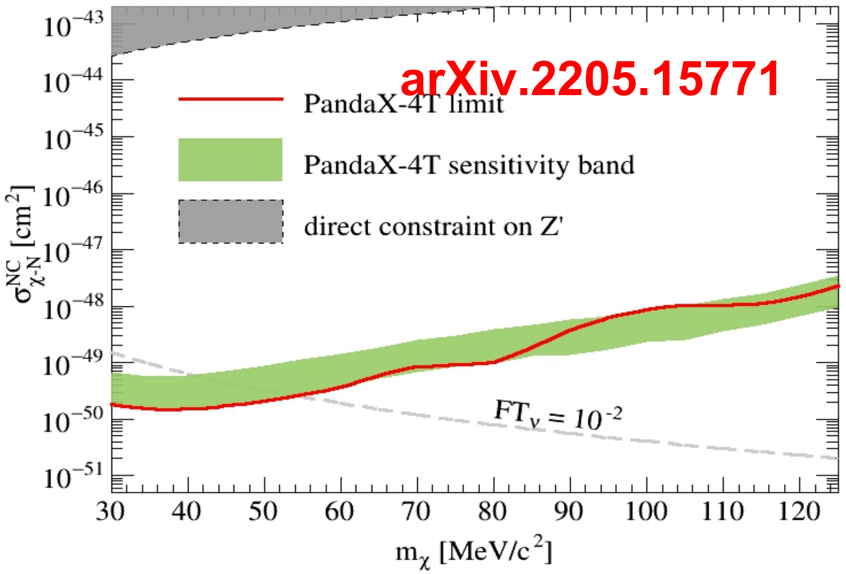


PandaX-4T's results on new DM models search

- First searches on Fermionic Absorption Dark Matter

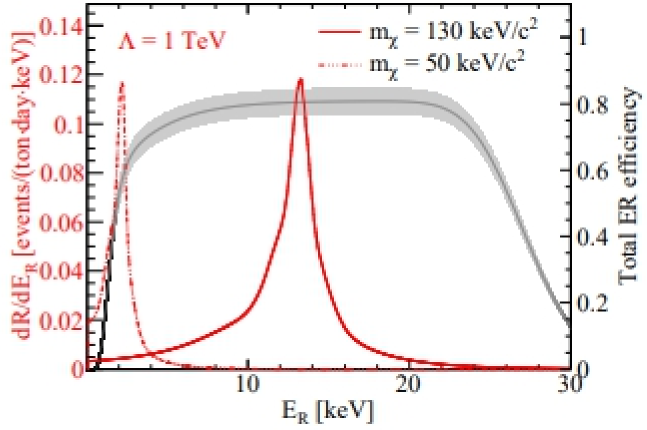
NR

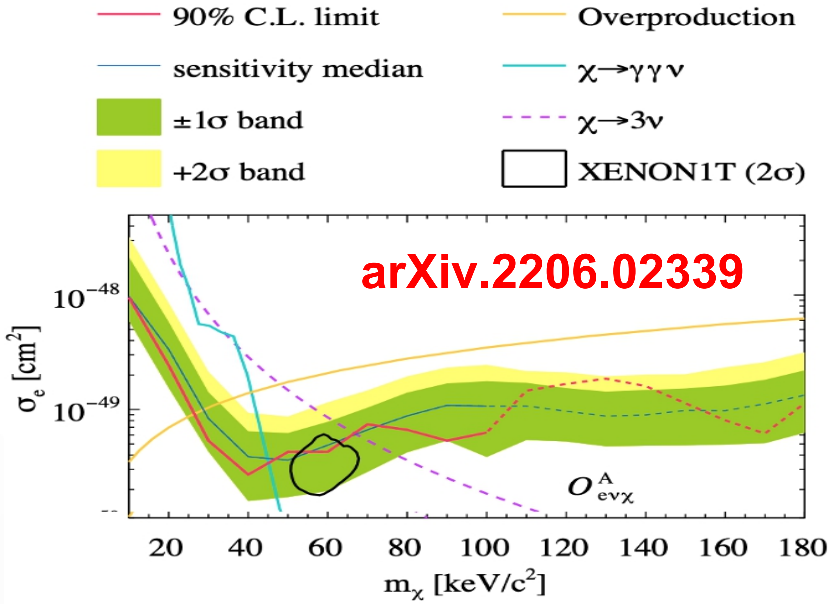




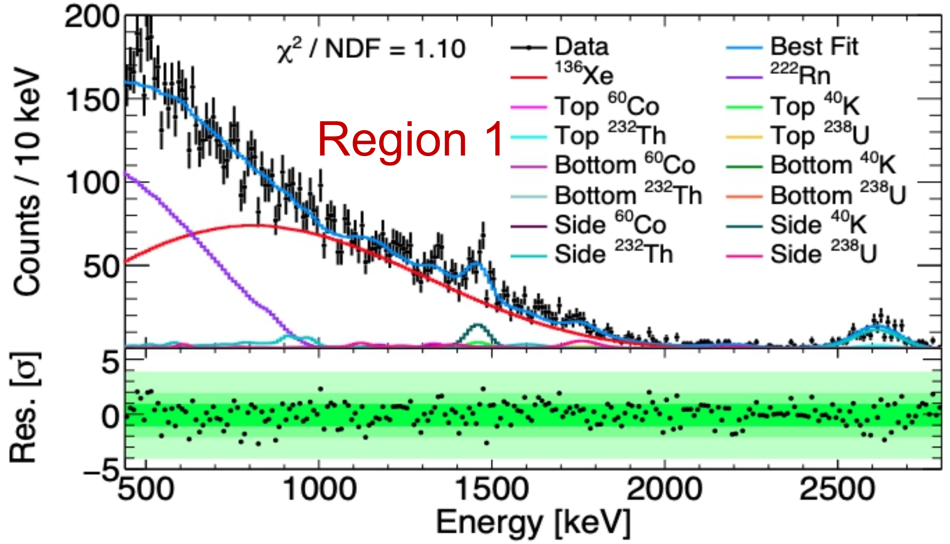
ER

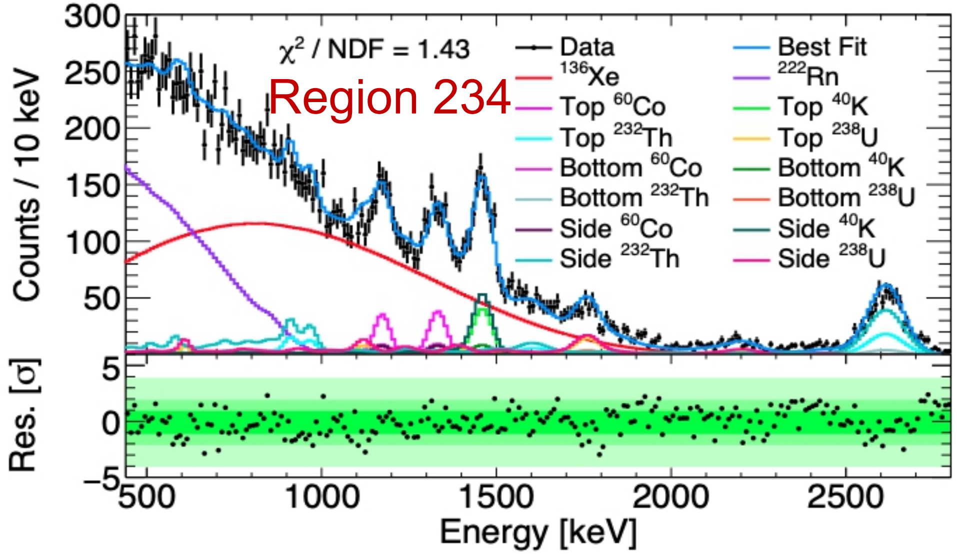
$\chi e \rightarrow e\nu$



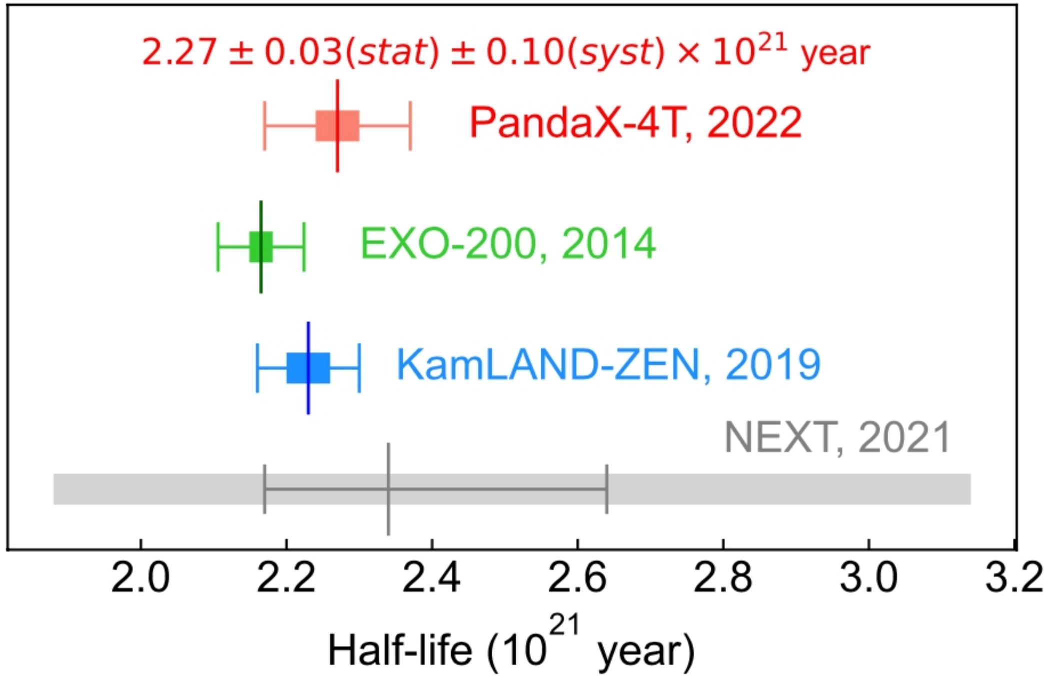


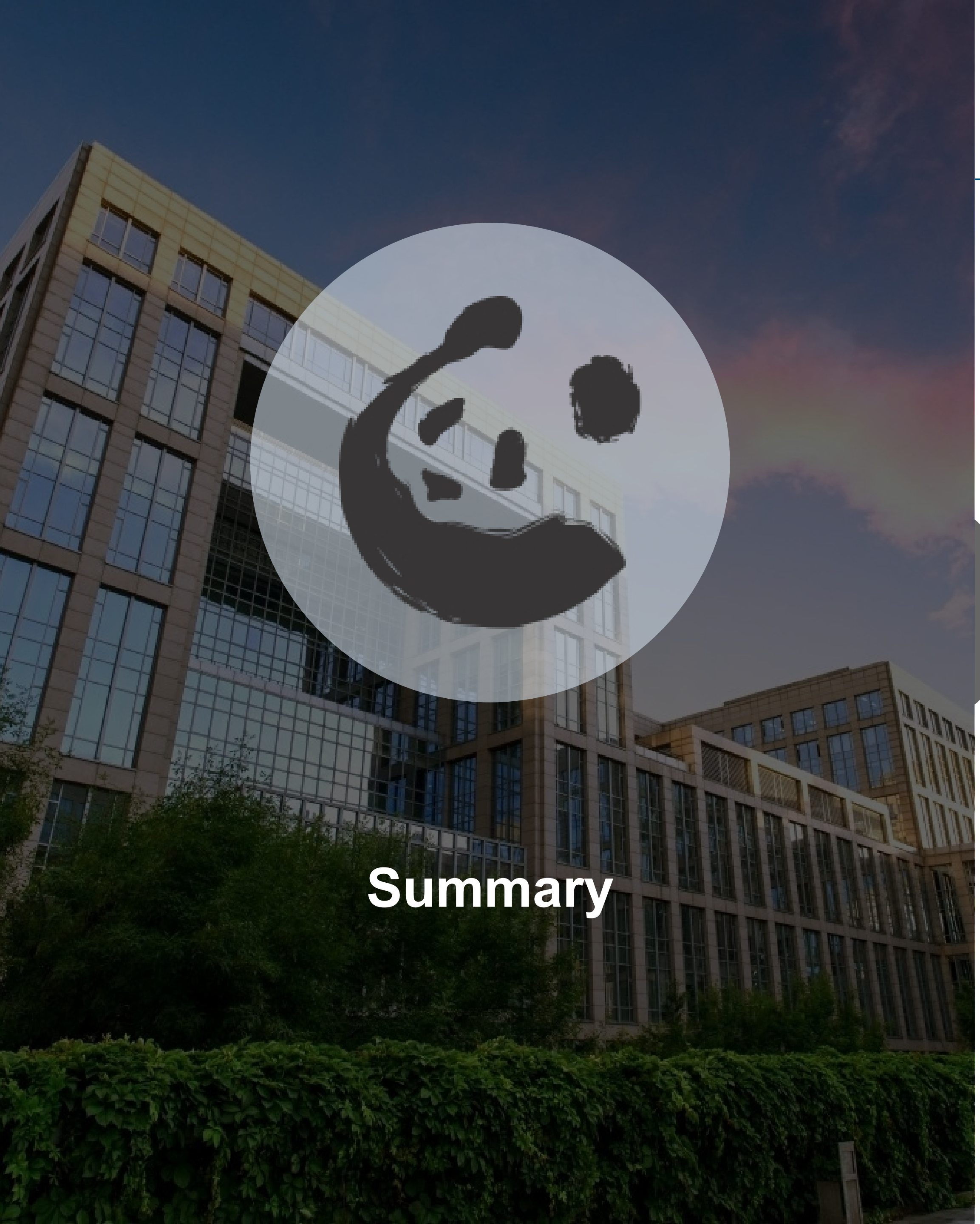
PandaX-4T's results on measurement of ^{136}Xe lifetime





- ❑ First lifetime result of ^{136}Xe from a neutral xenon detector
- ❑ Better measurement on <1000keV

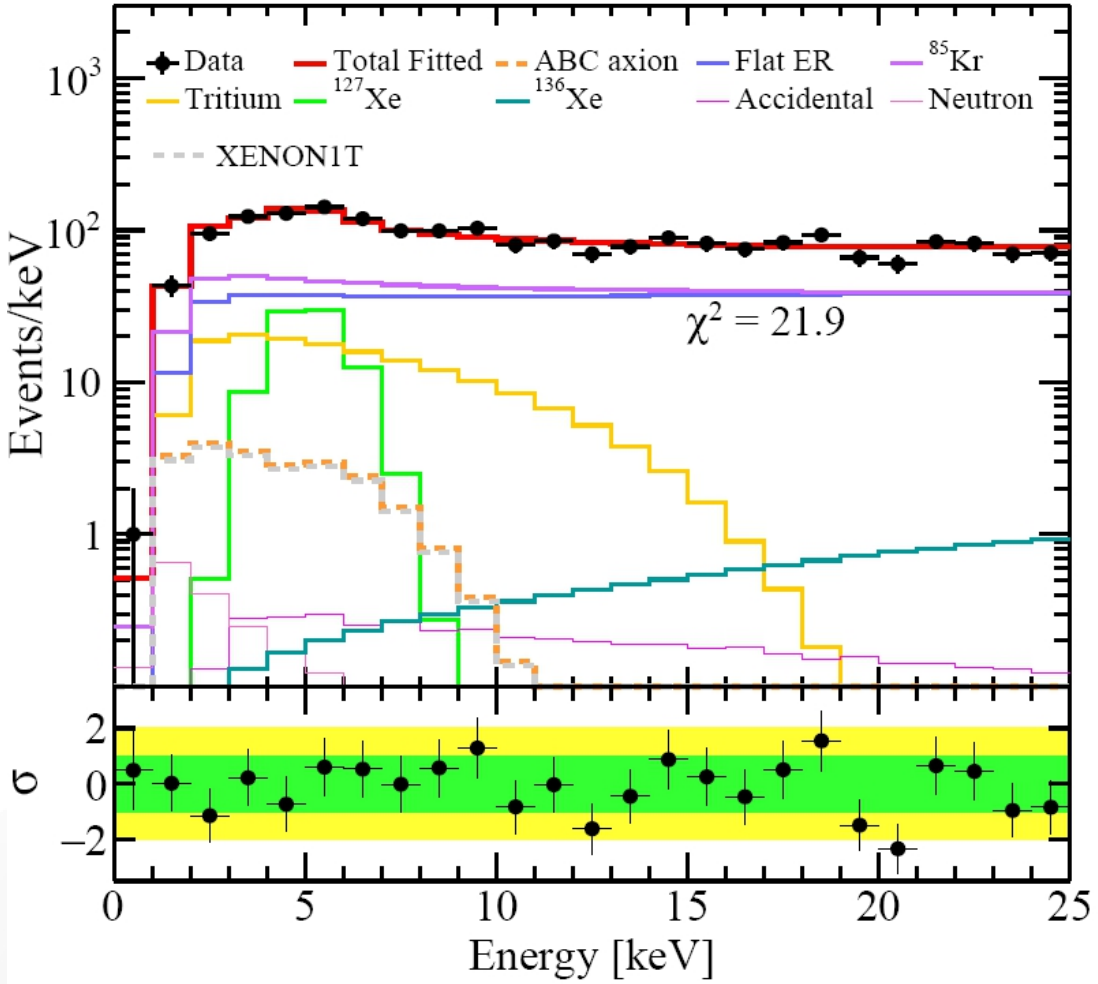


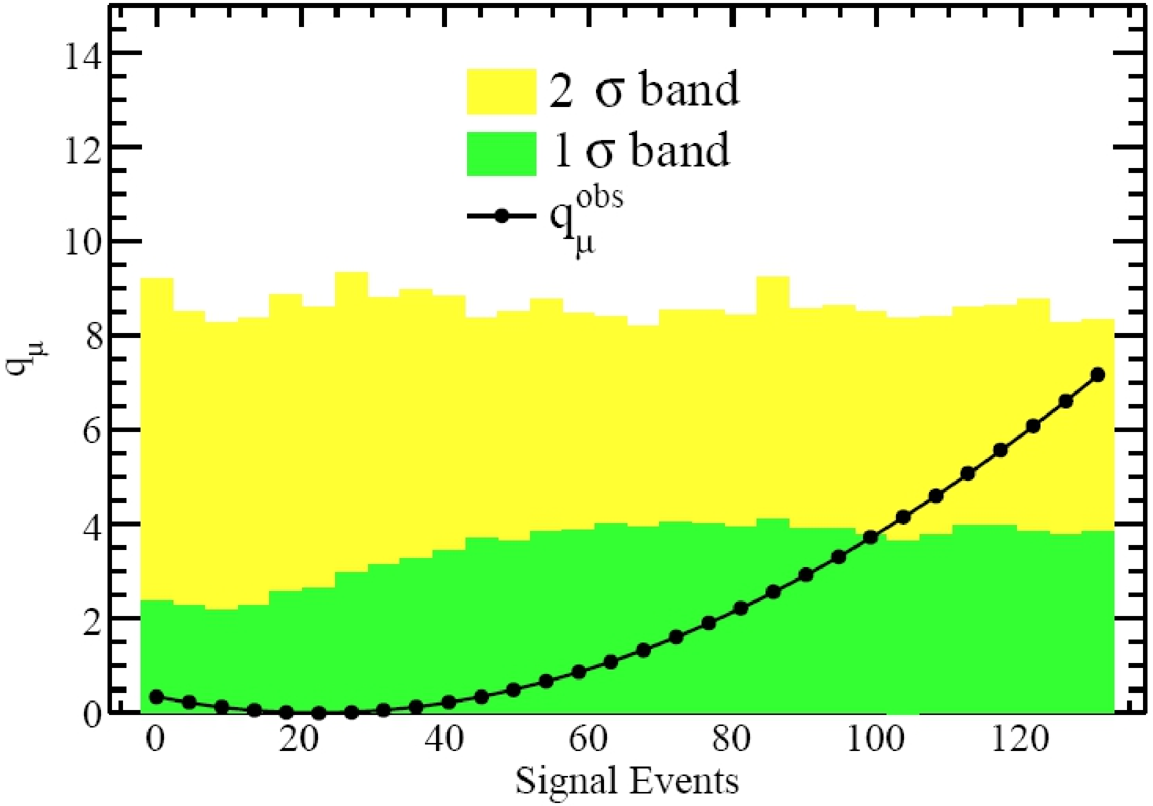


Summary

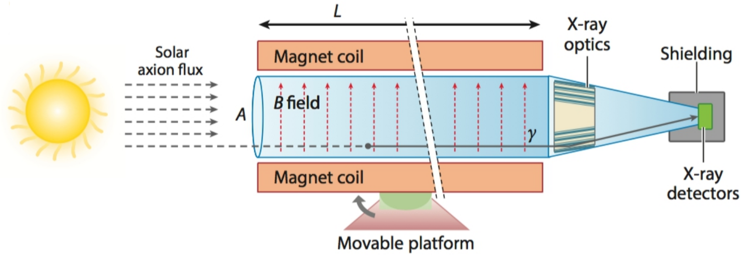
- ❑ PandaX-4T has completed its commissioning run and the data has been analyzed.
- ❑ Lower level event selection cuts and detection efficiencies are determined by NR & ER calibrations.
- ❑ Expected background contributions are estimated respectively.
- ❑ Applying WIMP-nucleon SI elastic scattering model, in 0.63 tonne·year exposure data, no dark matter candidates are identified above expected background.
- ❑ Other physical models be explored with the data of PandaX-4T commissioning run.

THANK YOU

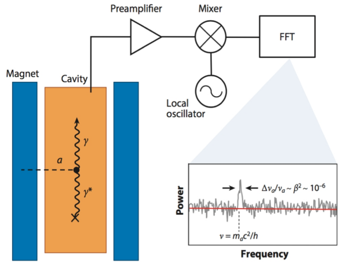


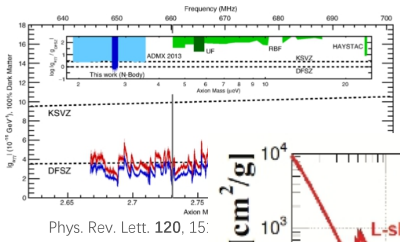


0.4 sigma significance



CAST,IAXO

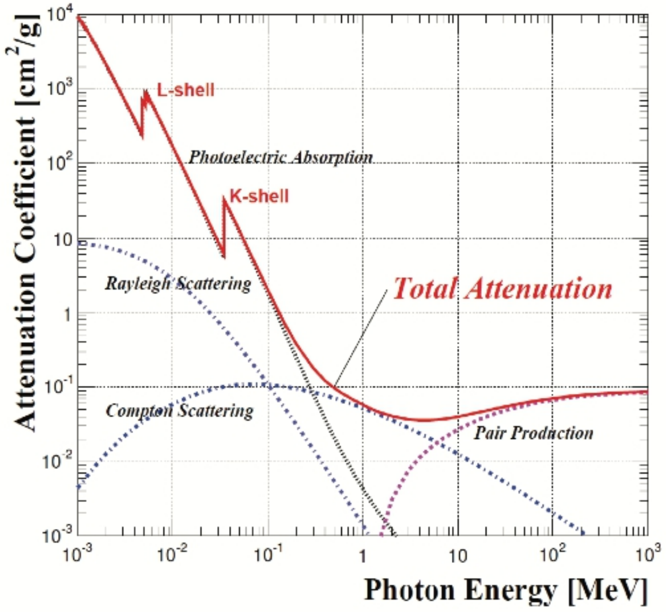




ADMX, ADMX

Detect the axion couplings photon or electron

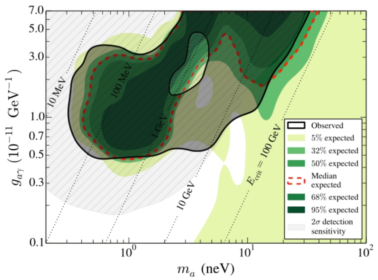
Axio-electric effect



Matched Fabry–Pérot cavities

ALPS

Fermi_LAT



Direct

Indirect

Generate

Direct the astrophysics anomaly caused by axion couplings

Generate axion with LASER in strong B field

$$\sigma_{Ae}(E_A) = \sigma_{pe}(E_A)\frac{g_{Ae}^2}{\beta}\frac{3E_A^2}{16\pi\alpha m_e^2}\left(1-\frac{\beta^{2/3}}{3}\right)$$

Like WIMPs, no strong positive result yet

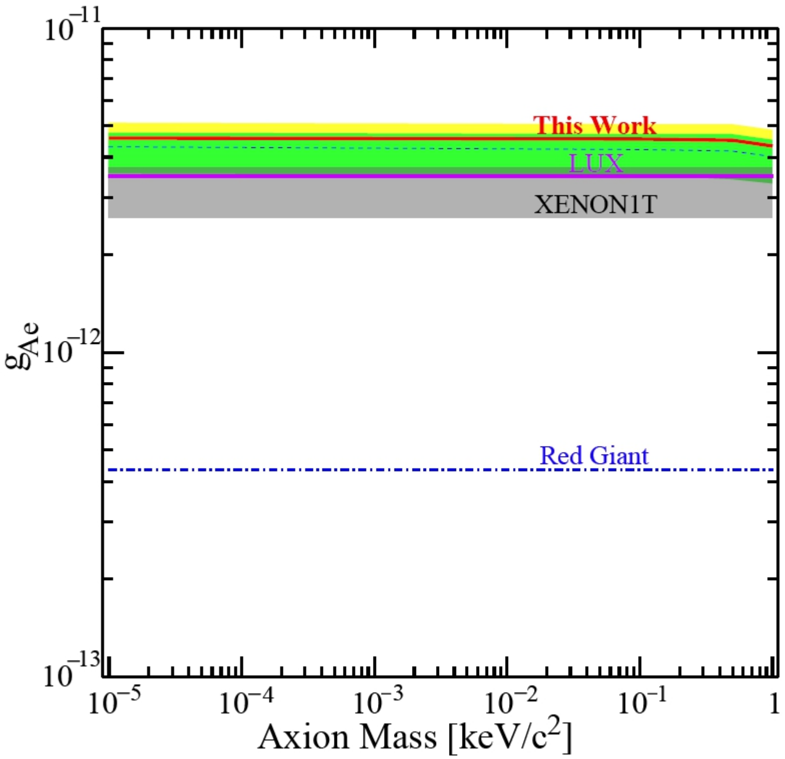
More and more experiments carried out

Axion Sources:

Sun, the biggest photon source around us

DM halo, assuming DM particle is axion-like particles

Axion Fitting results



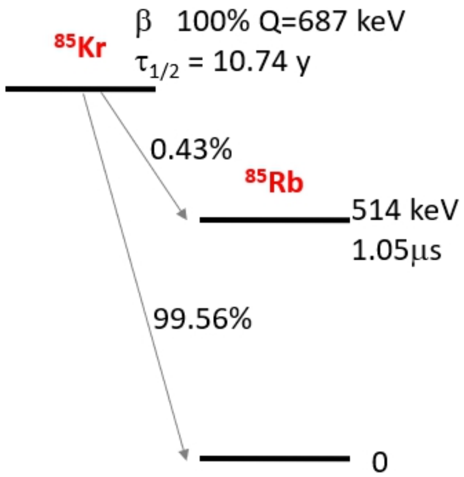
♀∈→∇. ϒ∈®ℵ. ✍∪§§. 2021, ♎⌢↓. 38 Ψℵℵ†∪ (1): 011301

Independent test on XEONN1T's excess with same detection technology but different background

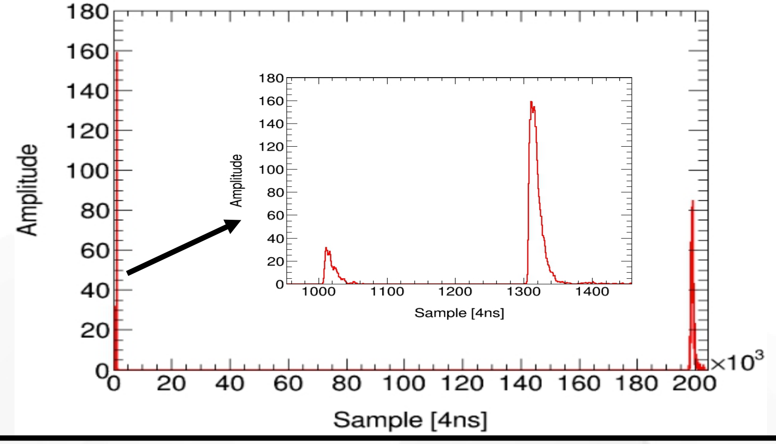
Axion-electron coupling g_{Ae} **< 4.6 × 10⁻¹²** for an axion mass less than 0.1 keV/c^2

The observed excess from XENON1T **is within our experimental constraints**.

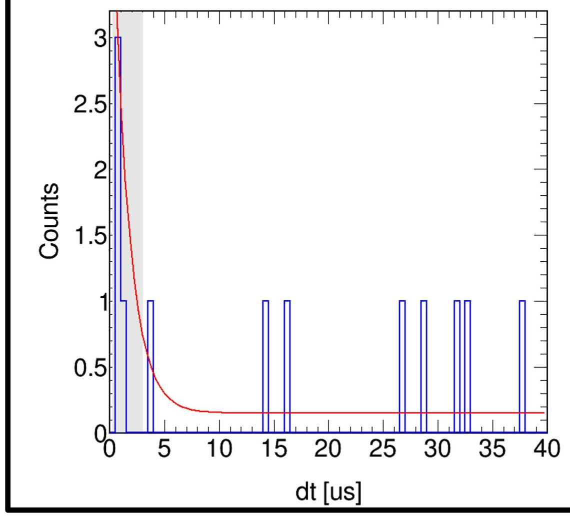
Kr Background



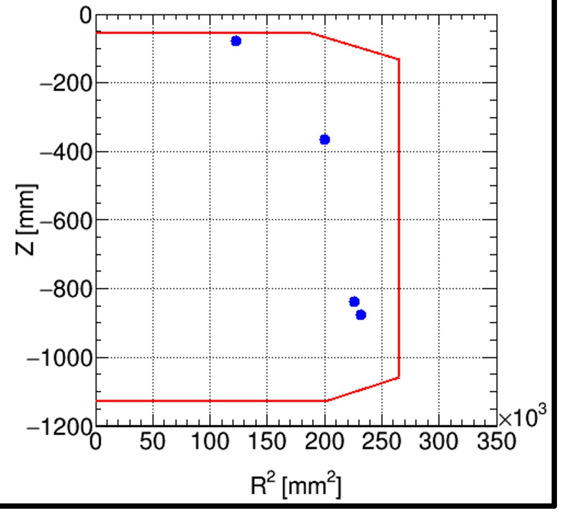
Waveform of ^{85}Kr's β-γ coincidence



Time separation between β-γ

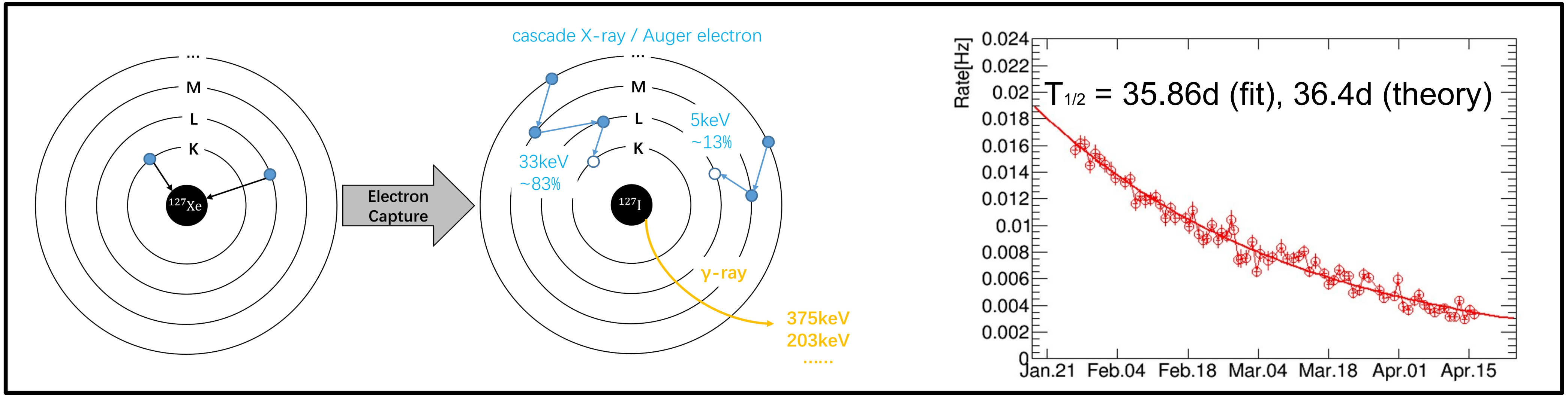


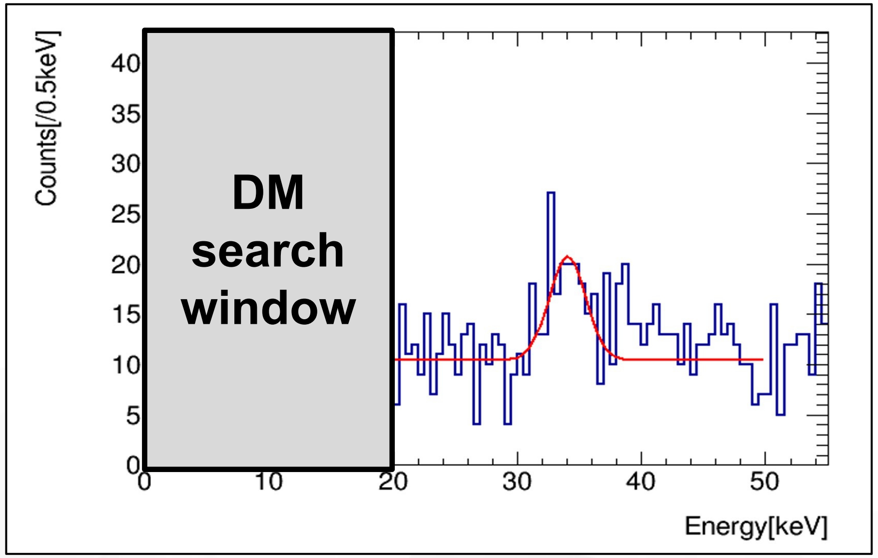
Vertex distribution of β-γ candidates



- **Kr/Xe = 0.33(0.21) ppt (mol/mol), improved 20 times from PandaX-II !**
- **Expected background: 53 ± 34 events**

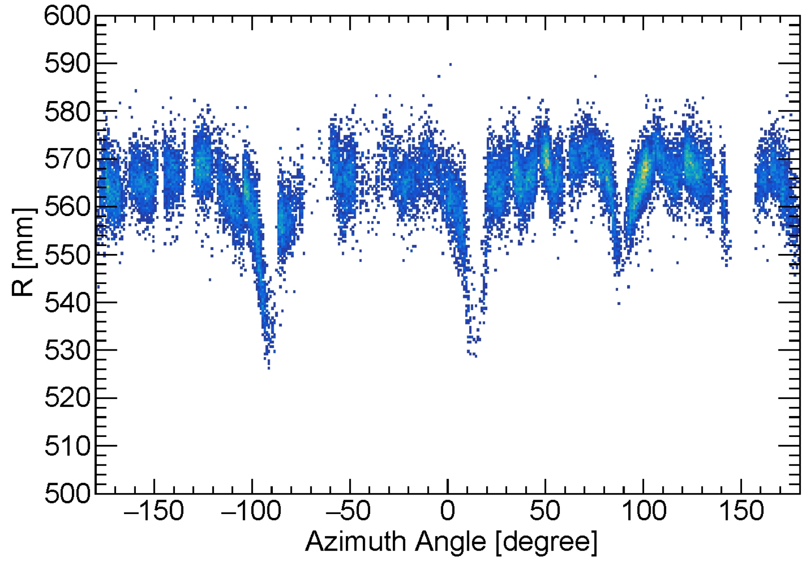
^{127}Xe (Cosmogenically Activated)

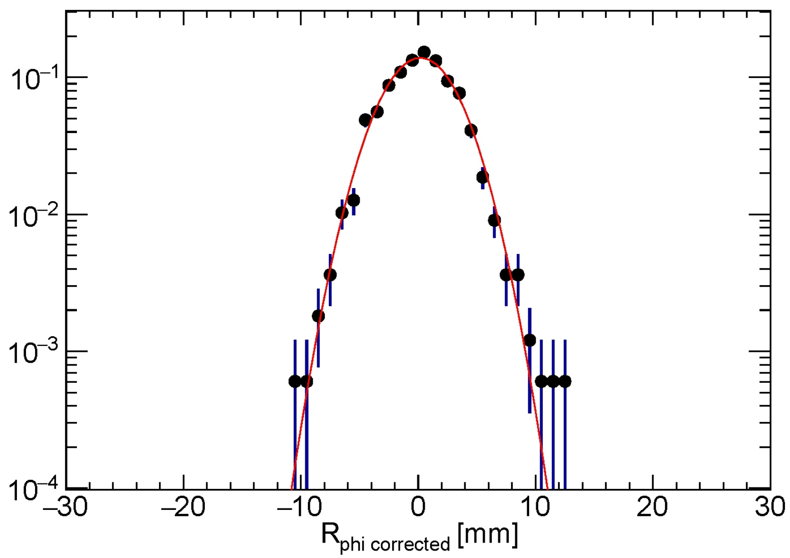


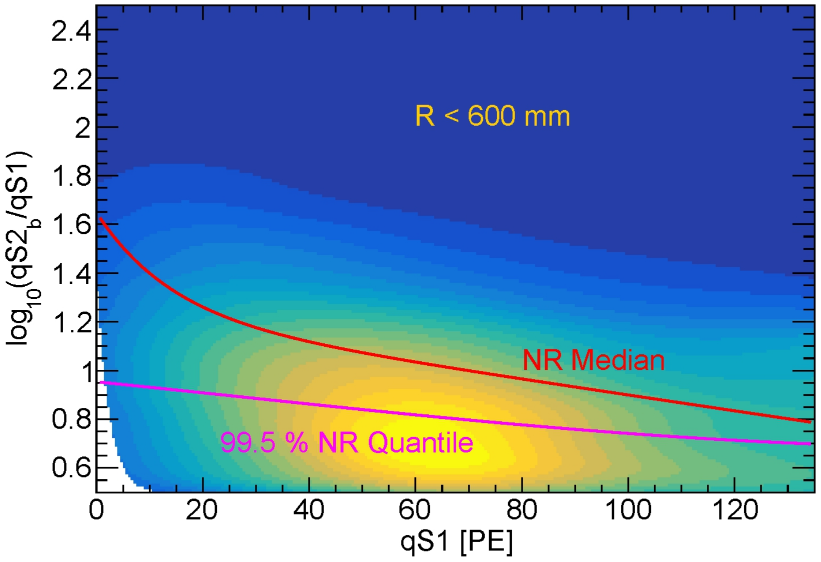


- **Expected background (5 keV): 8 ± 1 events**

Surface Background (Rn Progenies)

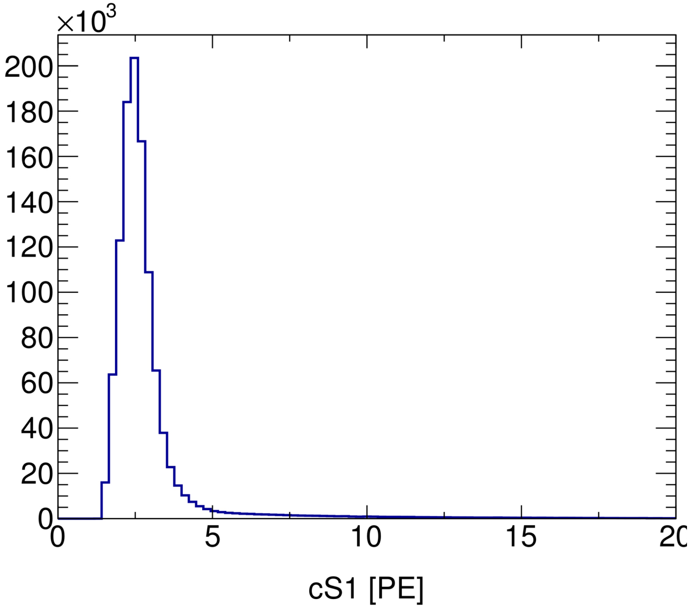


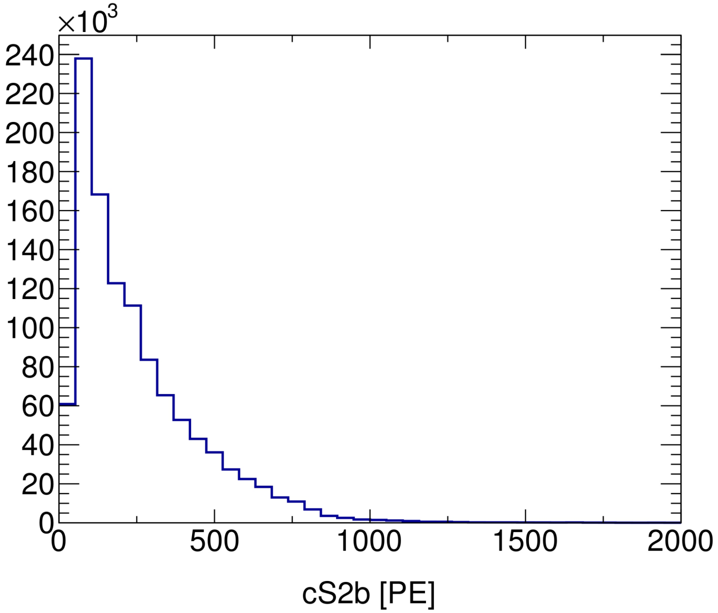


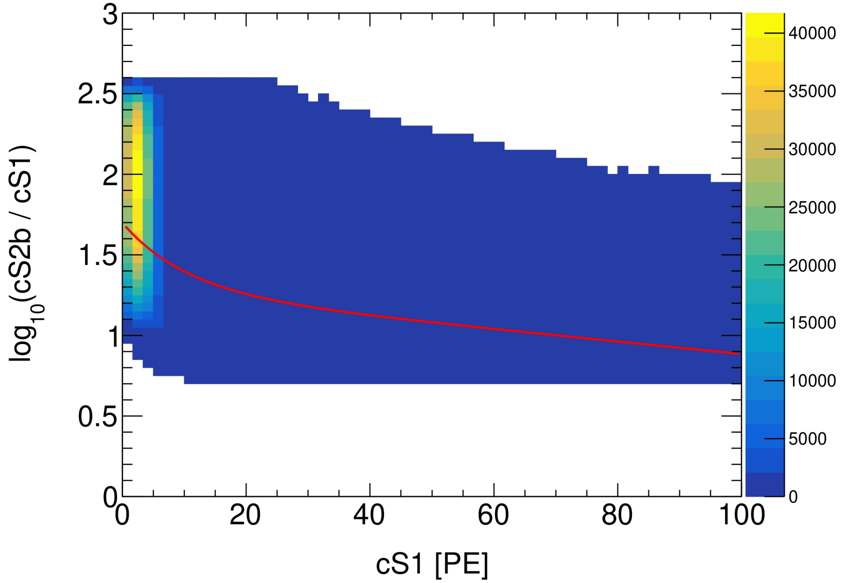


- **Surface events with larger qS2 (better reconstruction) are more suppressed by radial cut.**
- **Expected background: 0.5 ± 0.1 events**

Accidental coincidence of isolated S1 & S2







- **Isolated S1 rate: 9.5 Hz; Temporal variation: 10.5%**
- **Isolated S2 rate: 4.5×10^{-3} Hz; Temporal variation: 12.7%**
- **Expected accidental background: 2.4 ± 0.5 events**

2vdb

- Very preliminary HE spectrum reconstructed from S1 signal only without single-site cut
- Select the most central volume of ~0.5 ton of xenon
- 2vββ spectrum (half-life 2.165E21 yr) becomes prominent