PANDA X
PARTICLE AND ASTROPHYSICAL XENON TPC

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Solar axion and anomalous μ_ν searches with the full PandaX-II exposure

arXiv:2008.06485 [hep-ex]

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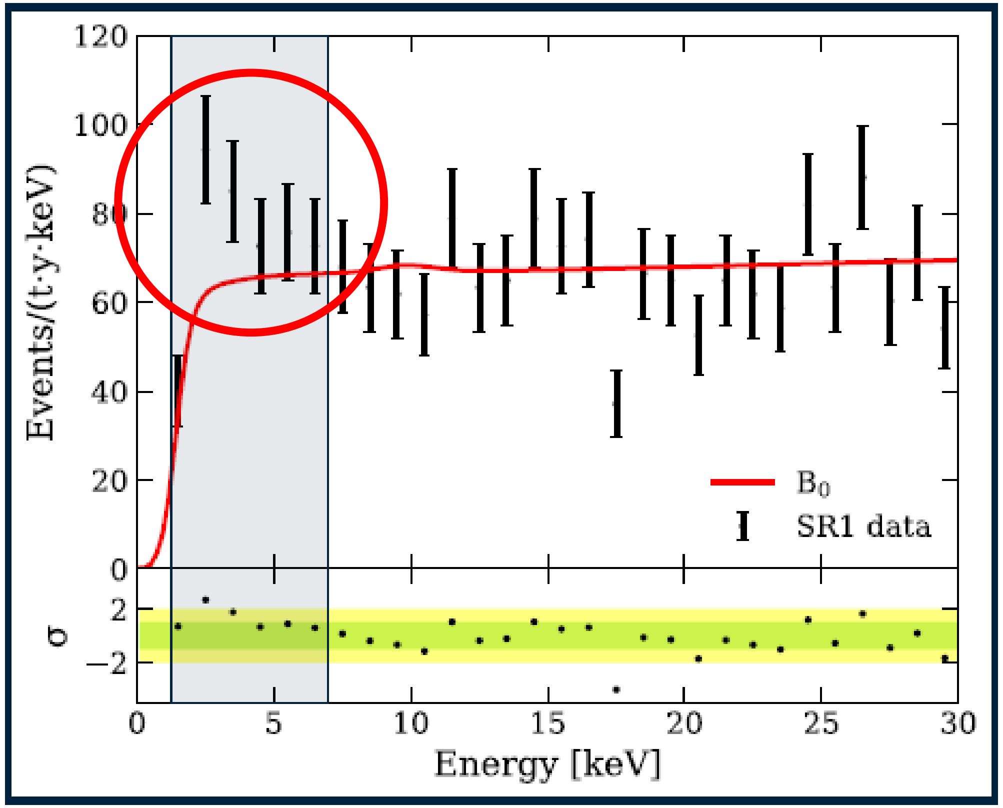
On behalf of PandaX Collaboration

TDLI & INPAC Joint Particle Physics Seminar Series, 2020.8.20

Xenon1T's new results on Electron Recoil arXiv: 2006.09721



A excess was reported in low energy ER spectrum using 0.65 ton year exposure!

Axion

Strong CP problem → PQ symmetry → A new boson → KSVZ DFSZ

Strong CP conserve

V.S.

quantum chromodynamics

QCD was predict to break CP-symmetry

nEDM measurement say "no violation"

A plausible solution for strong CP problem (1977,Peccei & Quinn)

Introducing a new U(1) symmetry

Phys. Rev. Lett. 1977-06: 1440 – 1443.

Axion (1978, Wilczek & Weinberg)

U(1) broken to generate a new Nambu – Goldstone bosons named after a laundry detergent (Wilczek,2004 Nobel Lecture)

Phys. Rev. Lett. 1978-01: 223 – 226.
Phys. Rev. Lett. 1978-01: 279 – 282.

Invisible axion DM candidate

PQWW axion excluded in reactor and beam-dump experiments

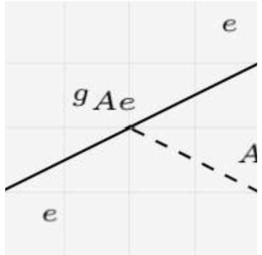
Physical Review D, **1978**, 18(5): 1607.

new models and detection methods proposed

Phys. Rev. Lett. 1979-07: 103 – 107.
Nuclear Physics B, **1980**, 166(3): 493 – 506.
Physics Letters B, **1981**, 104(3): 199 – 202.
Sov.J.Nucl.Phys. **1980**, 31: 260.

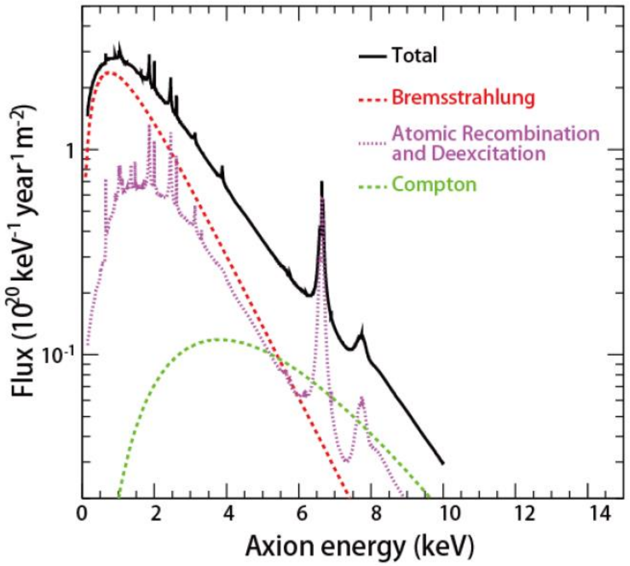
Solar axion

Production



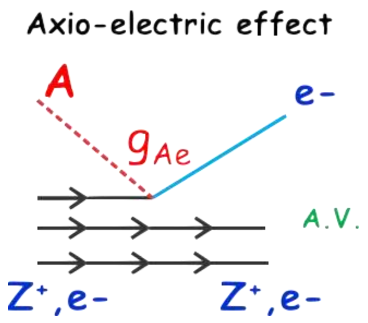
ABC axion

Atomic recombination and deexcitation
Bremsstrahlung
Compton



Assuming $g_{Ae}= 10^{-13}$

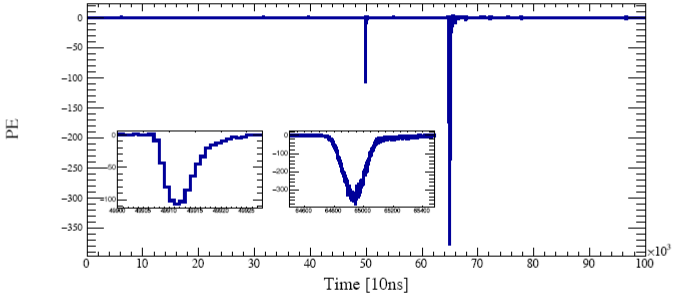
Detection

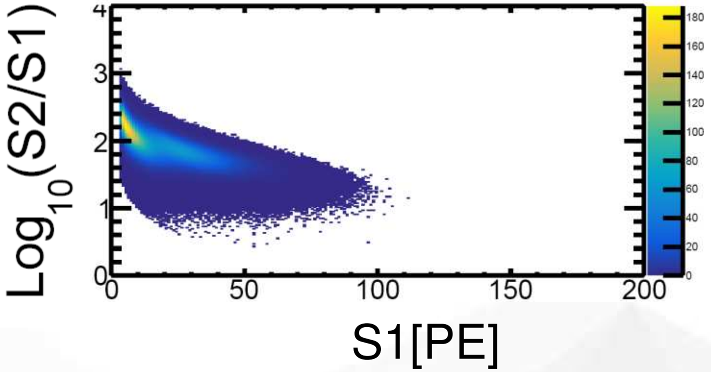


$$\sigma_{Ae}(E_A) = \sigma_{pe}(E_A)\frac{g_{Ae}^2}{\beta}\frac{3E_A^2}{16\pi\alpha m_e^2}\left(1-\frac{\beta^{2/3}}{3}\right)$$

Signal

Typical ER signal in PandaX-II



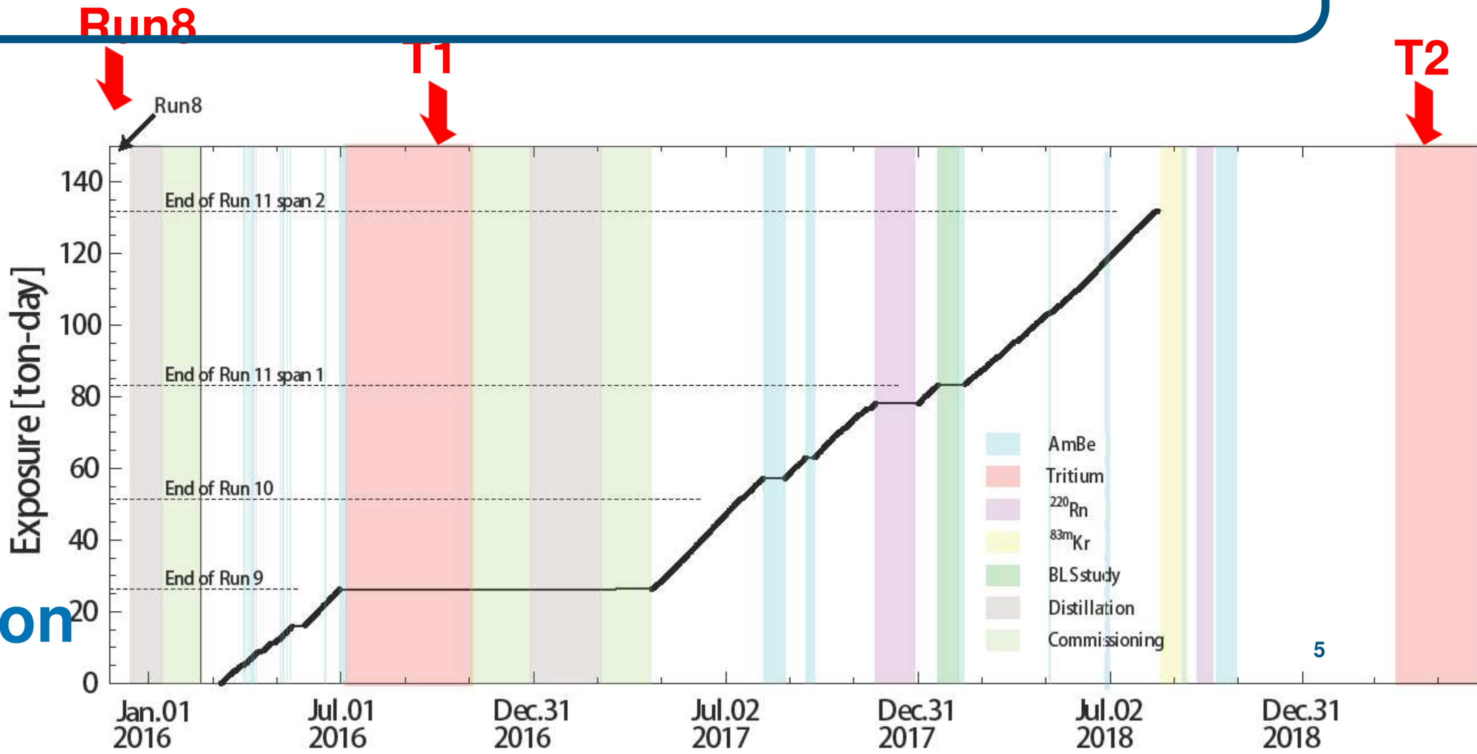


PandaX-II Data Sets

2015.11 start with commissioning Run8

2019.06 "End-of-Run" completed

- **Run 9: 79.6 days (published)**
- **Run 10: 77.1 days (published)**
- **Run 11, span 1: 96.4 days**
- **Run 11, span 2: 147.9 days**



Full data analysis

(same with WIMP search)

- **New position reconstruction**
- **New detector response model**
- **Improved background evaluation**

PandaX-II Data selection

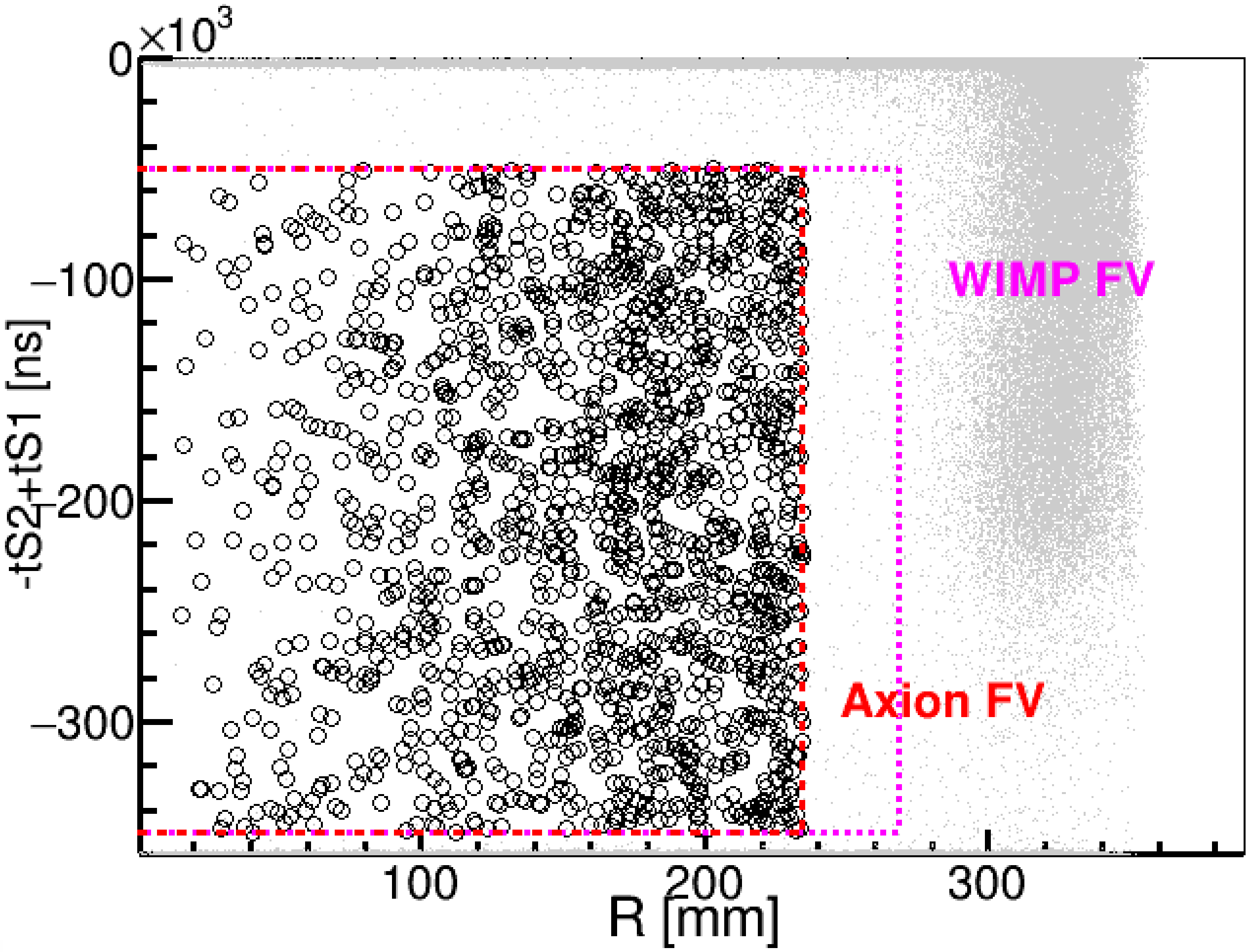
Axion signal in xenon detector:

low energy ER events

- Expand the energy window to **25 keV**
- Reduce the FV to **250 kg** to avoid the affect of Surface events

Dominant background:

- ^{127}Xe: decay away in Run 11
- **Tritium**: appearing since Run 10
- Flat ER: ^{222}**Rn**, materials
- ^{85}**Kr**



100.7 ton-day exposure
2121 events selected

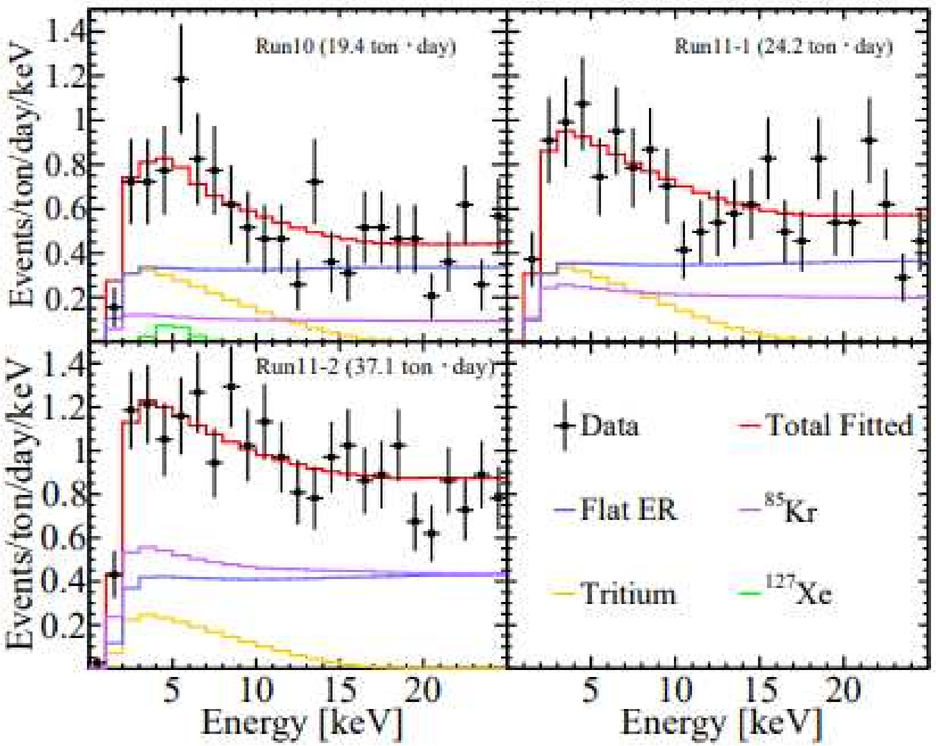
Tritium

Degenerate significantly with axion signal

- Introduced by CH_3T calibration
- Unbinned likelihood fit on Run 10, 11-1, 11-2 independently
- Consistent with a constant rate

Total fitted 0.037±0.013 μBq/kg

floating in the fit

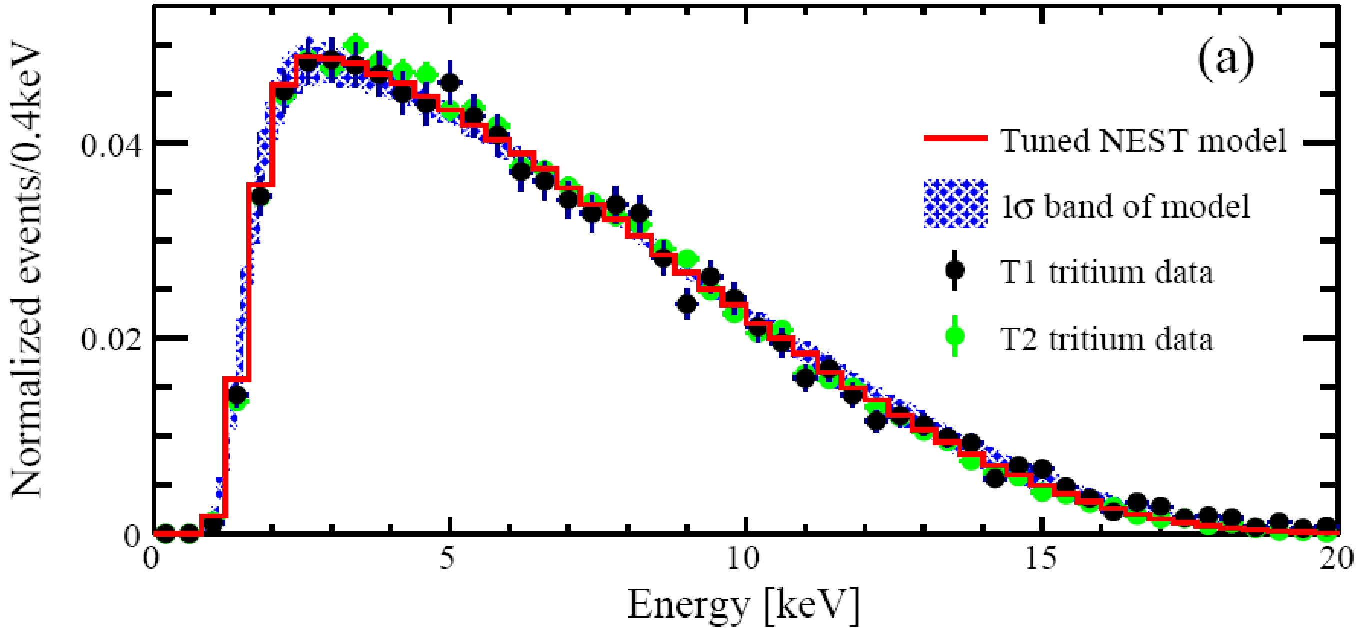


Run	Tritium level
10	0.040±0.012 μBq/kg
11-1	0.043±0.013 μBq/kg
11-2	0.032±0.018 μBq/kg

Tritium

Degenerate significantly with axion

- The shape of tritium well understood (small shape systematic error)

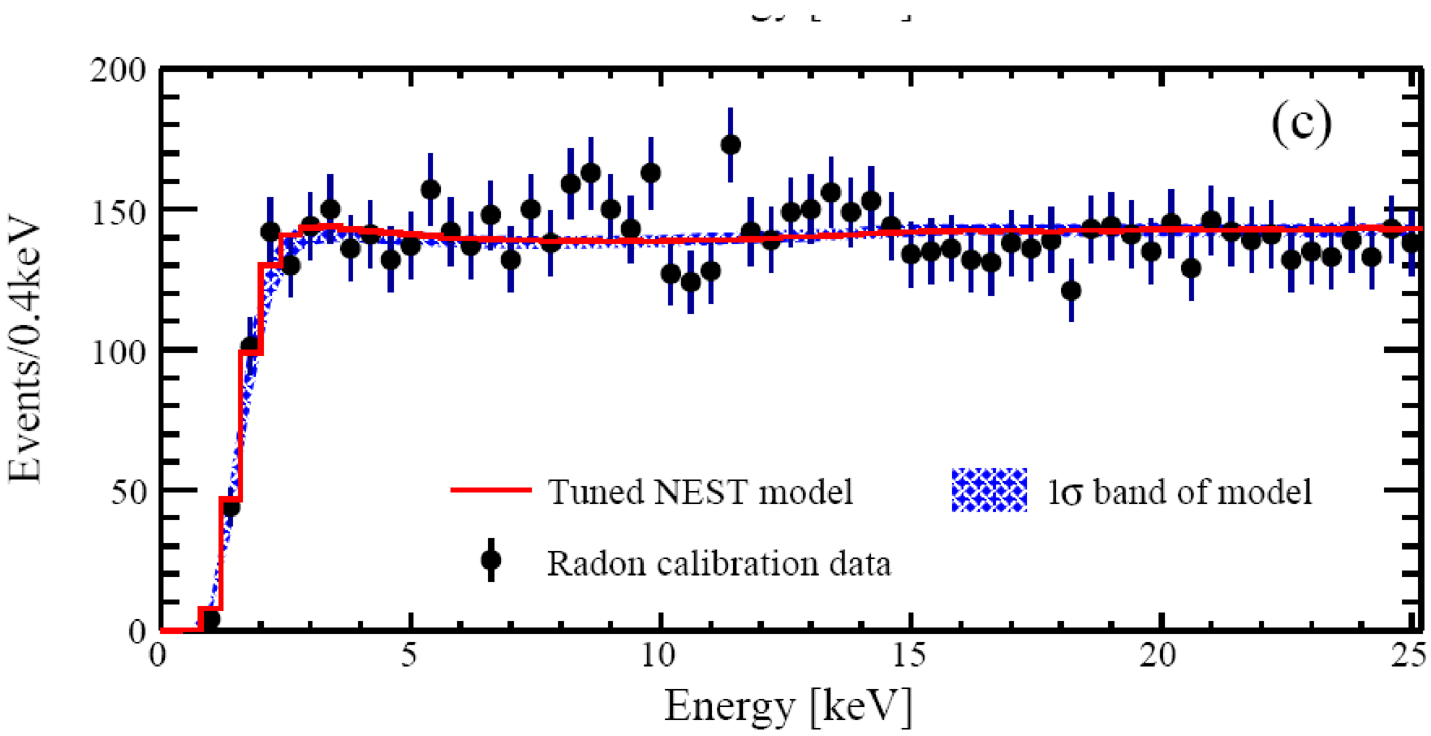


Reconstruction considering BLS correction
Fitting good！！

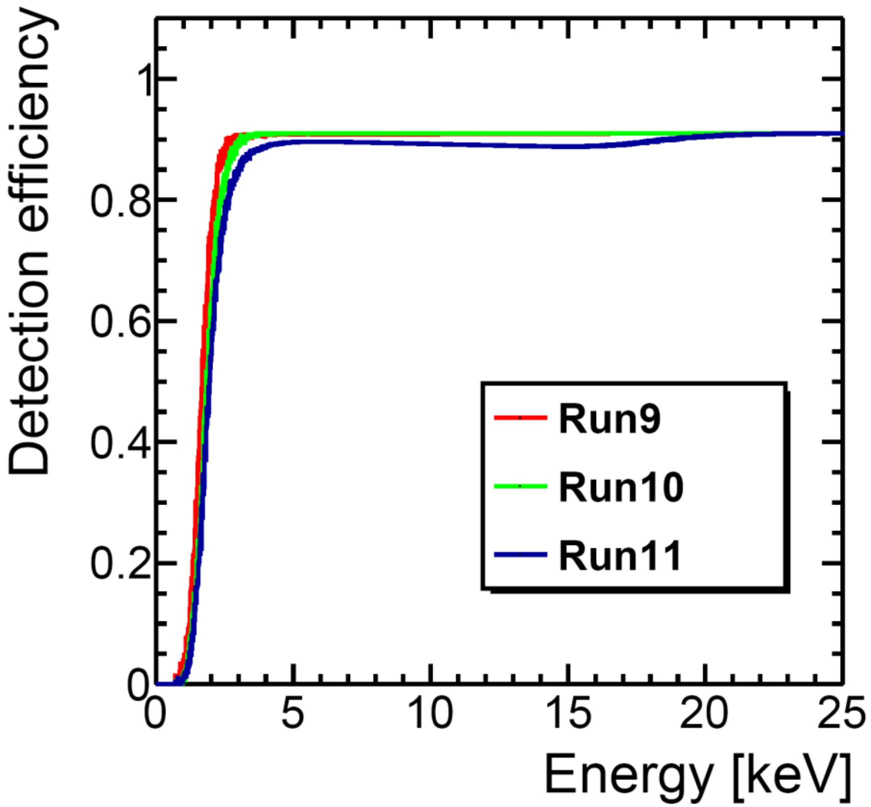
floating in the fit

^{222}Rn

^{220}Rn calibration shows "flat"



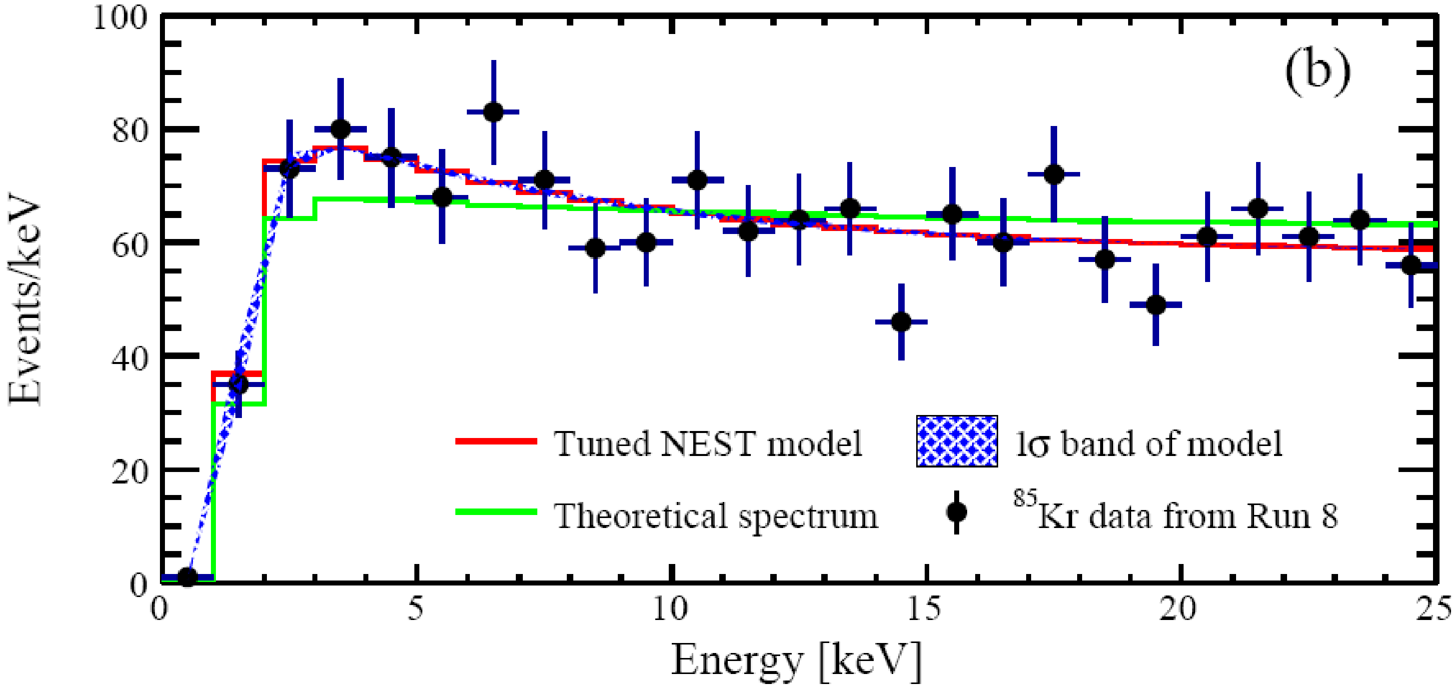
ER detection efficiency



arXiv:2006.09311

Run8 LE data was dominated (98%, 15mDRU) by ^{85}Kr

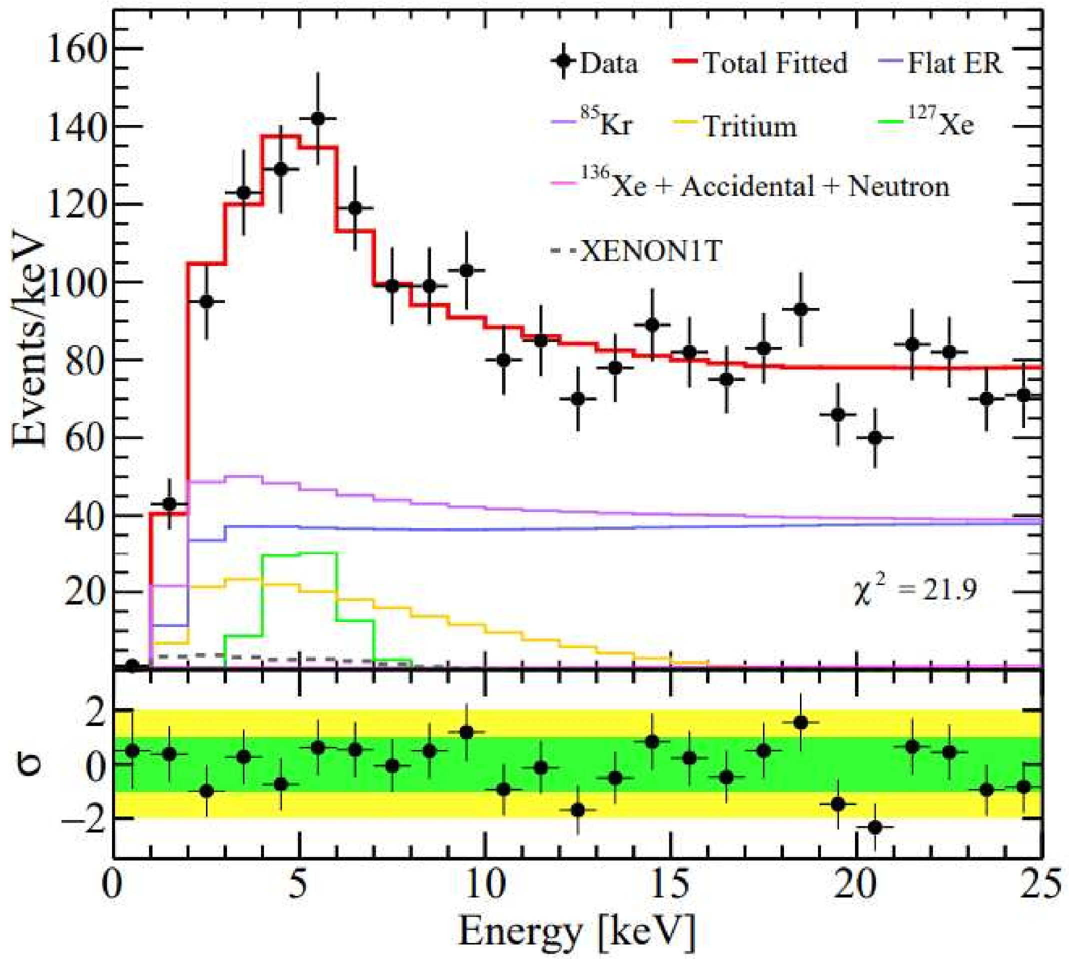
- **Direct measurement of ^{85}Kr @ low energy region**
- **Data driven model (Expo+flat)**
- **fed into fitting analysis**
- **Theoretic spec difference as systematic**



nuclear structure effects involved arXiv:2007.13686
exchange effect calculated using the extended formalism for first-forbidden unique transitions

1mDRU = 1 E-3 /keV/kg/day

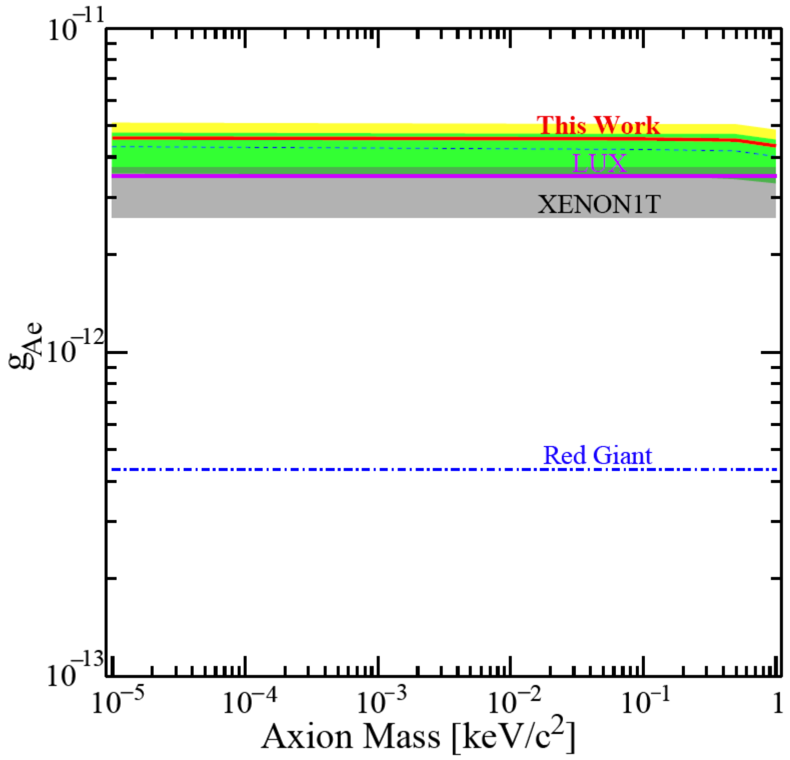
Axion Fitting results



BKG only fitting results

Events	Run 9	Run 10	Run 11-1	Run 11-2
^{127}Xe	80.7	3.7	0.0	0.0
tritium	0	45.9	55.6	85.3
^{85}Kr	388.0	38.8	122.5	440.7
flat ER	173.0	167.7	205.6	315.4
accidental	1.6	0.9	0.8	1.3
neutron	0.6	0.4	0.5	0.8
^{136}Xe	2.3	2.2	2.7	4.1
Total	646.3 ± 32.7	259.5 ± 19.8	387.7 ± 28.8	847.5 ± 48.4
Data	646	249	387	839

Axion Fitting results

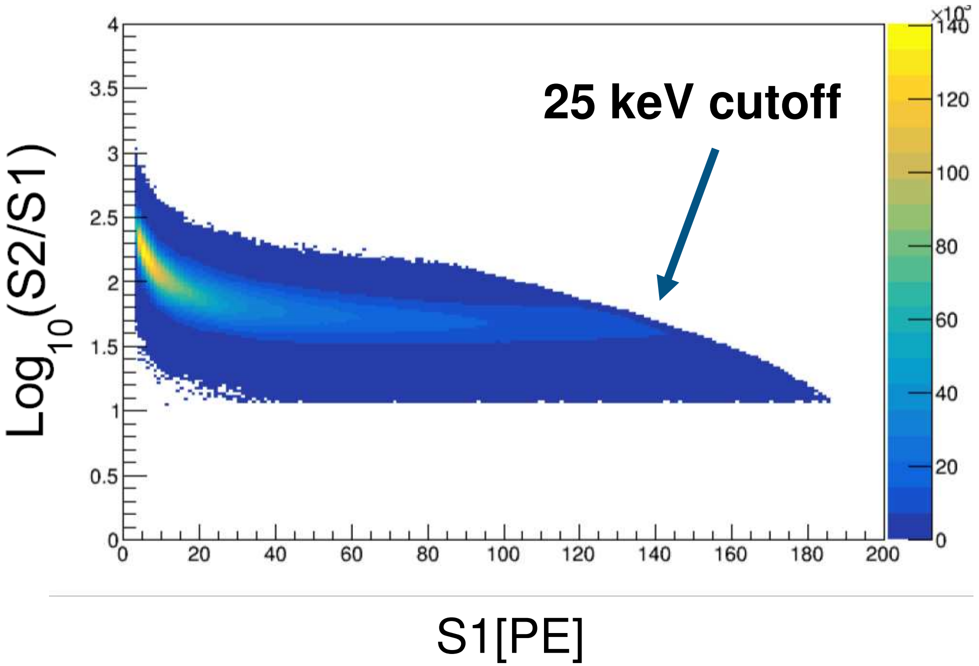


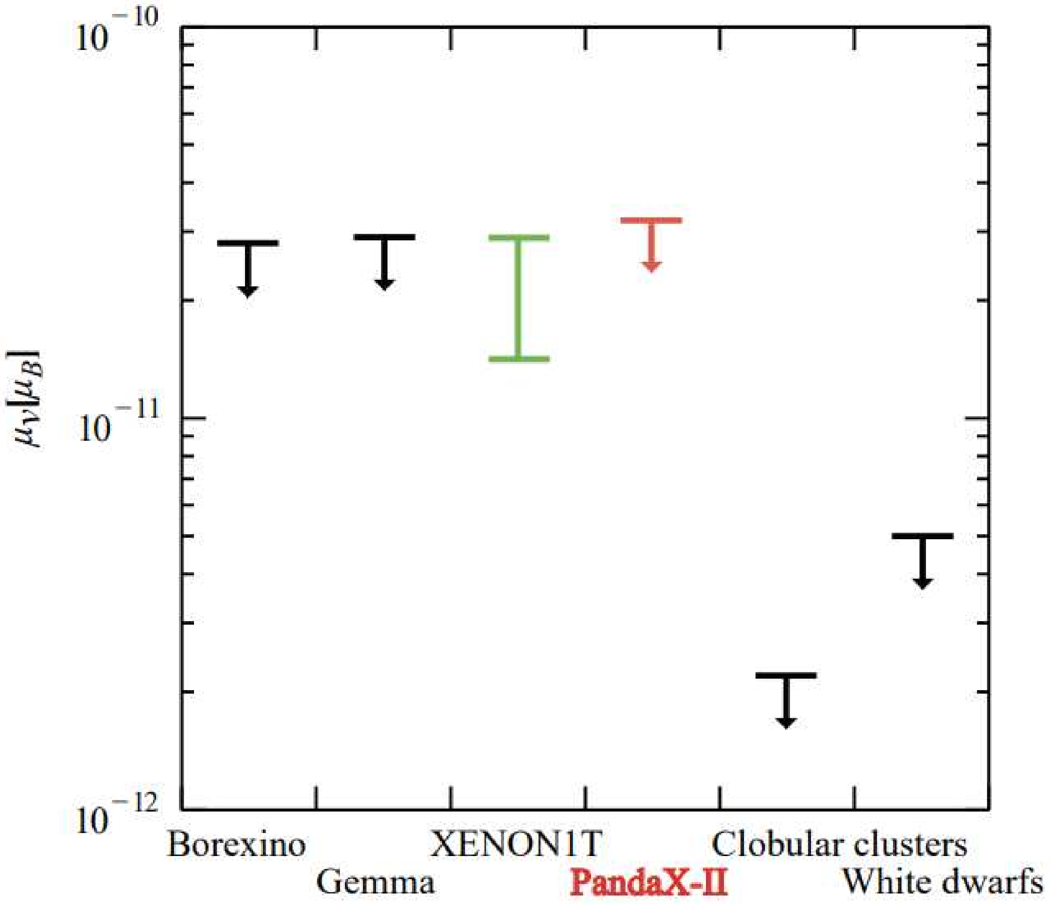
Independent test on XEONN1T's excess with same detection technology but different background

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**.

μ_ν Fitting results



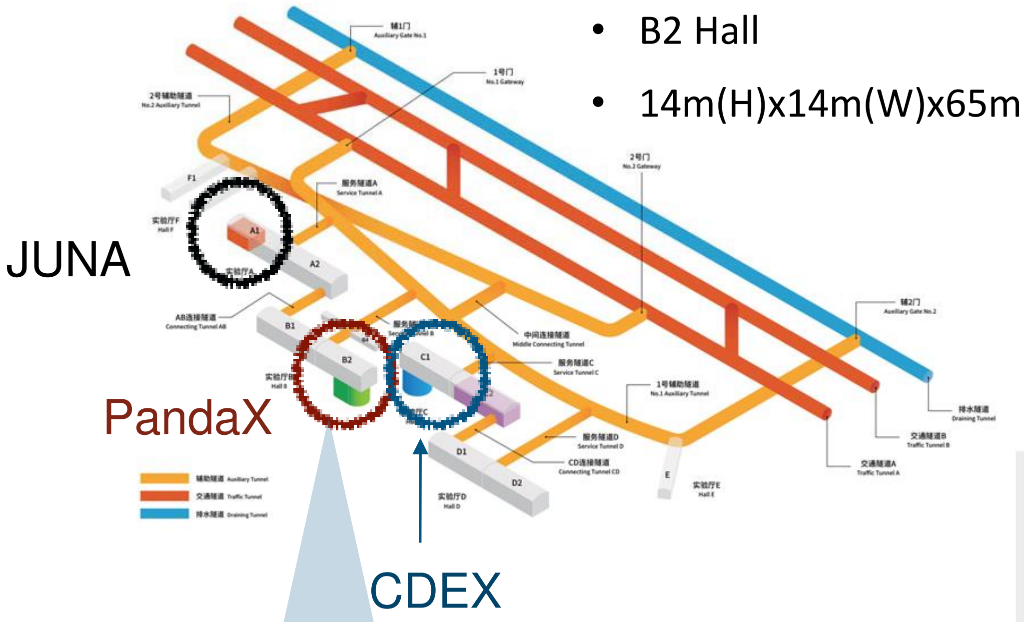


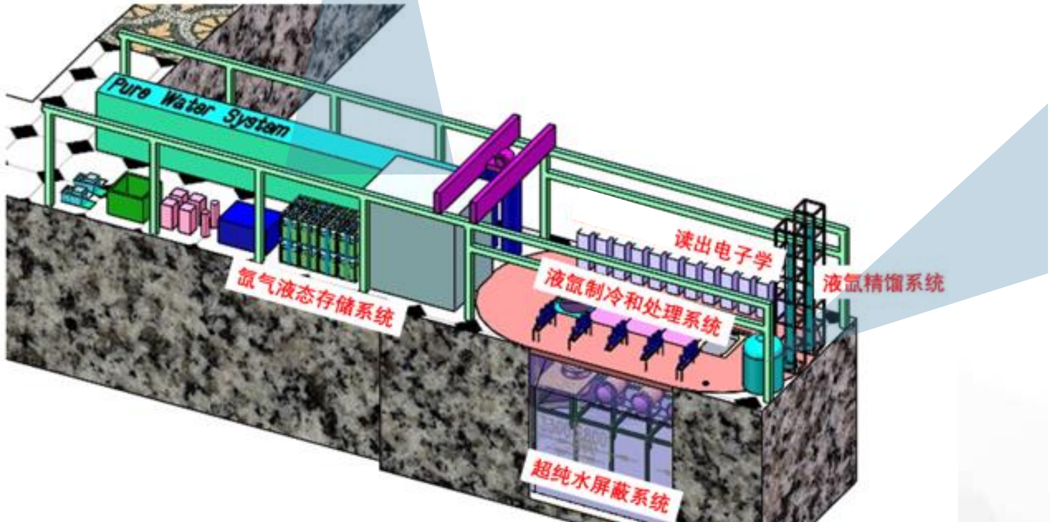
$\mu_\nu < 3.2 \times 10^{-11} \mu_B$

PandaX-4T

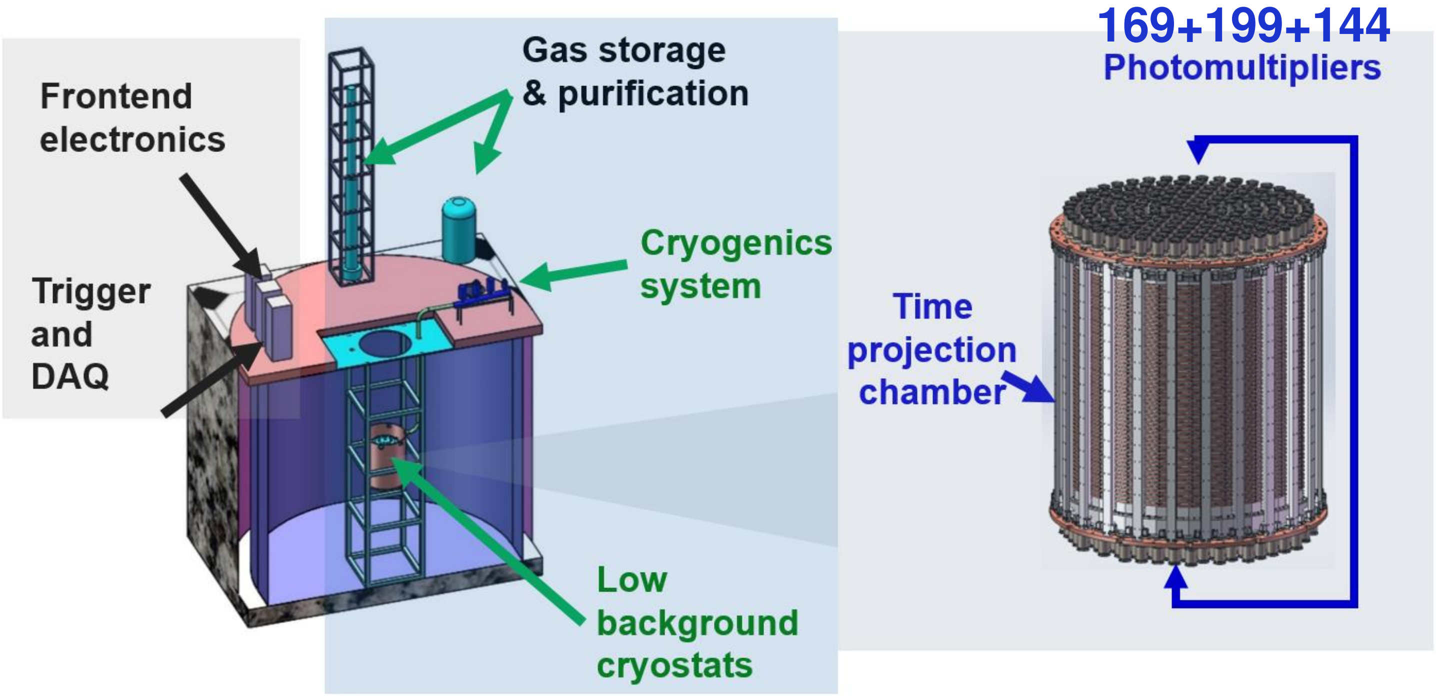
编辑母版文本样式

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



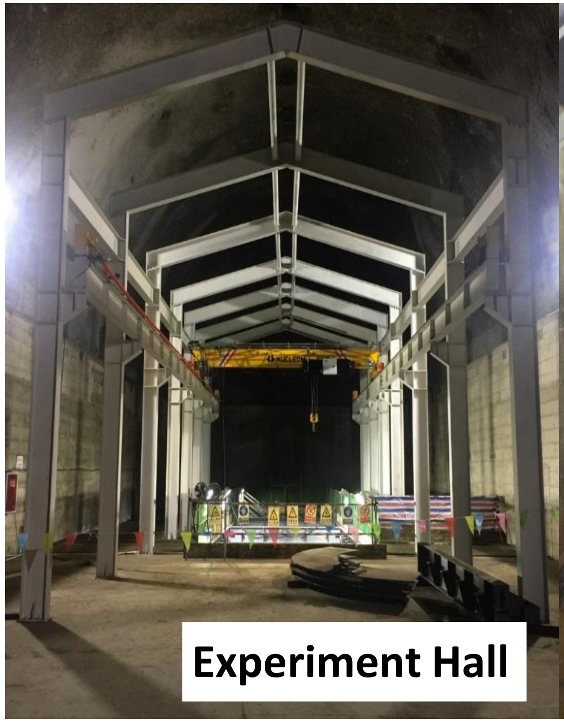


- **PandaX-4T** (4-ton in sensitive region)

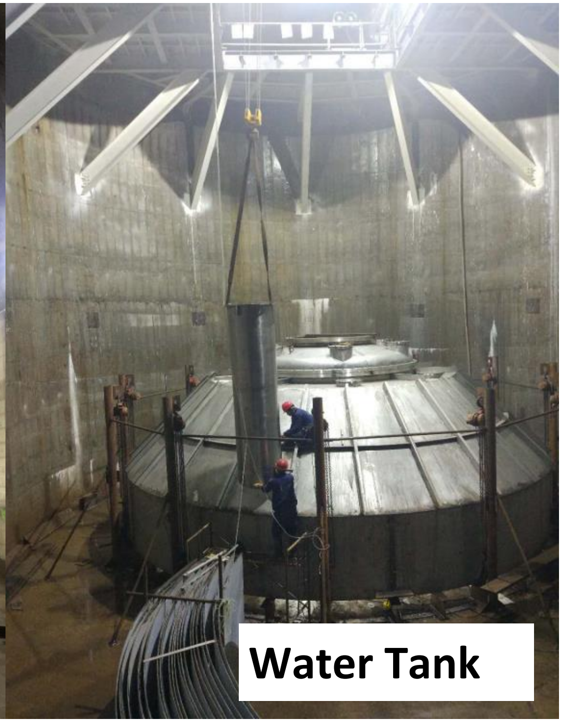


PandaX-4T's house

编辑母版文本样式



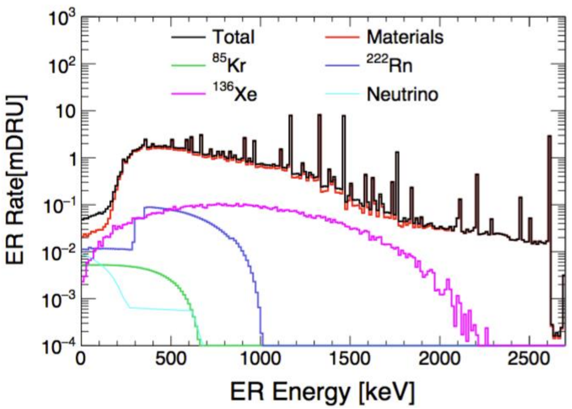
Experiment Hall

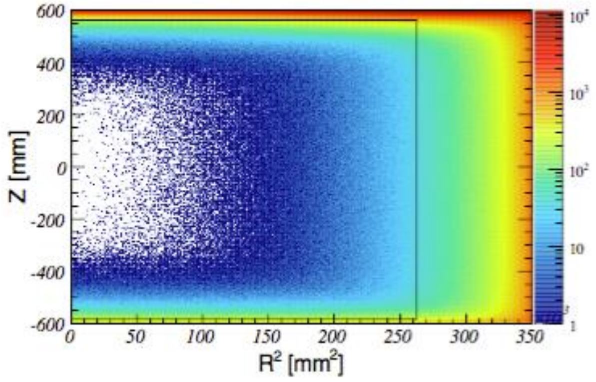


Water Tank

编辑母版文本样式 PandaX-4T Simulation

Sci. China PMA 62 (2019) no.3, 31011

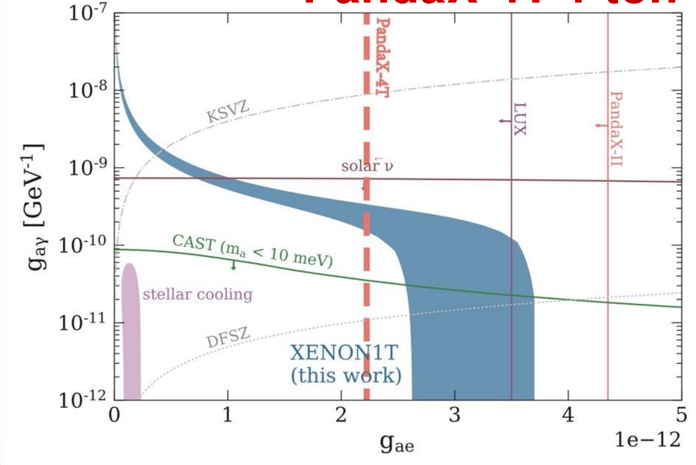




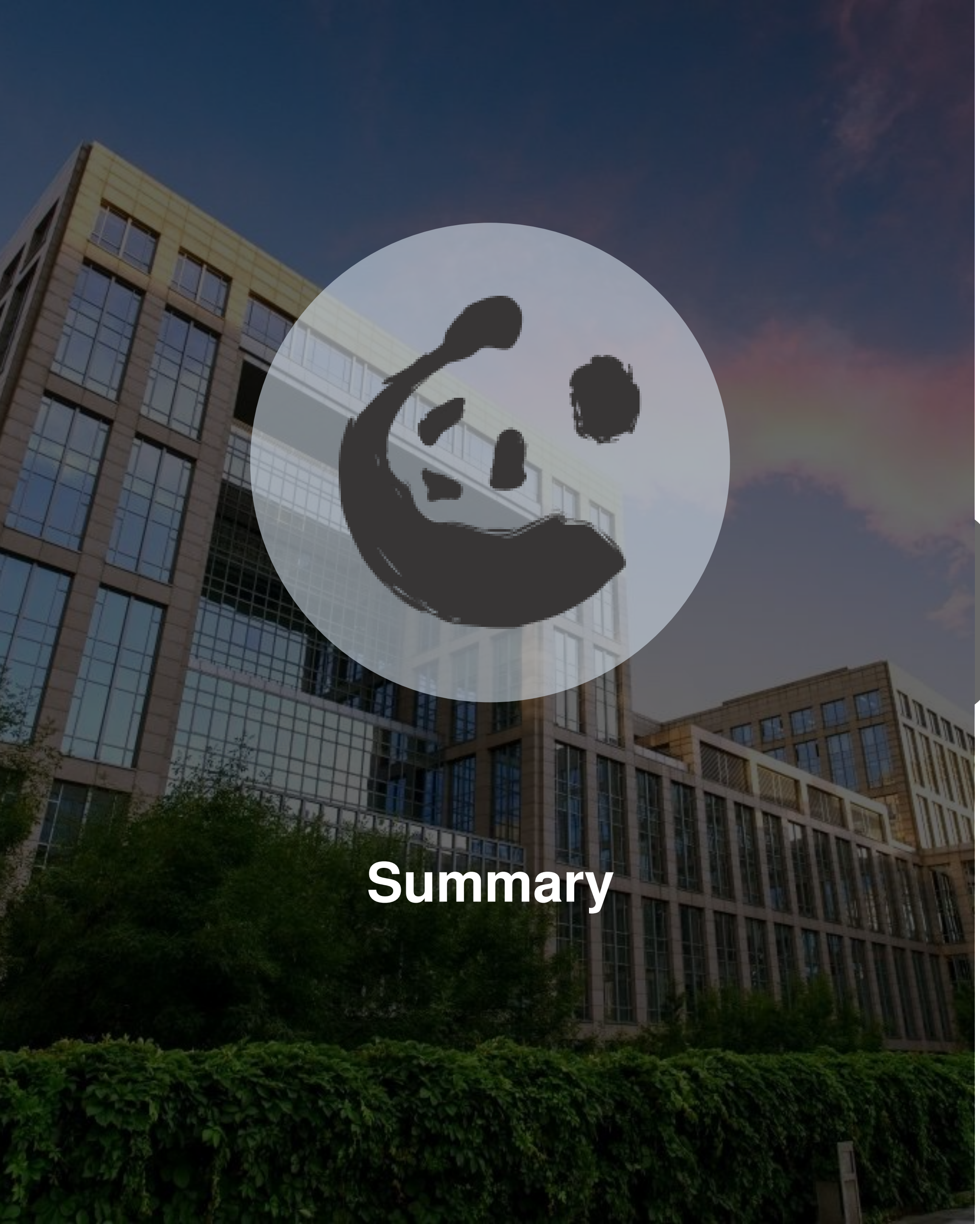
ER background in PandaX-4T

Summary of ER and NR backgrounds		
Source	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

PandaX-4T 1 ton-year



- **Onsite detector assembly started: Aug. 2019**
- **Commissioning of PandaX-4T: end of 2020**
- **first physics data from PandaX-4T in 2021**



Summary

01 PandaX-II shutdown in 2019.06, with 100.7 ton days data for axion analysis

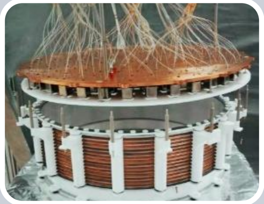
02 Four major backgrounds at low energy region were studied with robust data driven estimate and modeling.

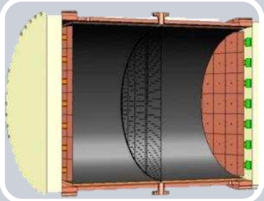
03 Independent test of ABC axion and neutrino with enhanced magnetic moment hypotheses carried out.
XENON1T's excess is within our experimental constraints.

04 PandaX-4T is on progress, and will test the excess together with upcoming XENON-nT and LZ

THANK YOU

PandaX experiment



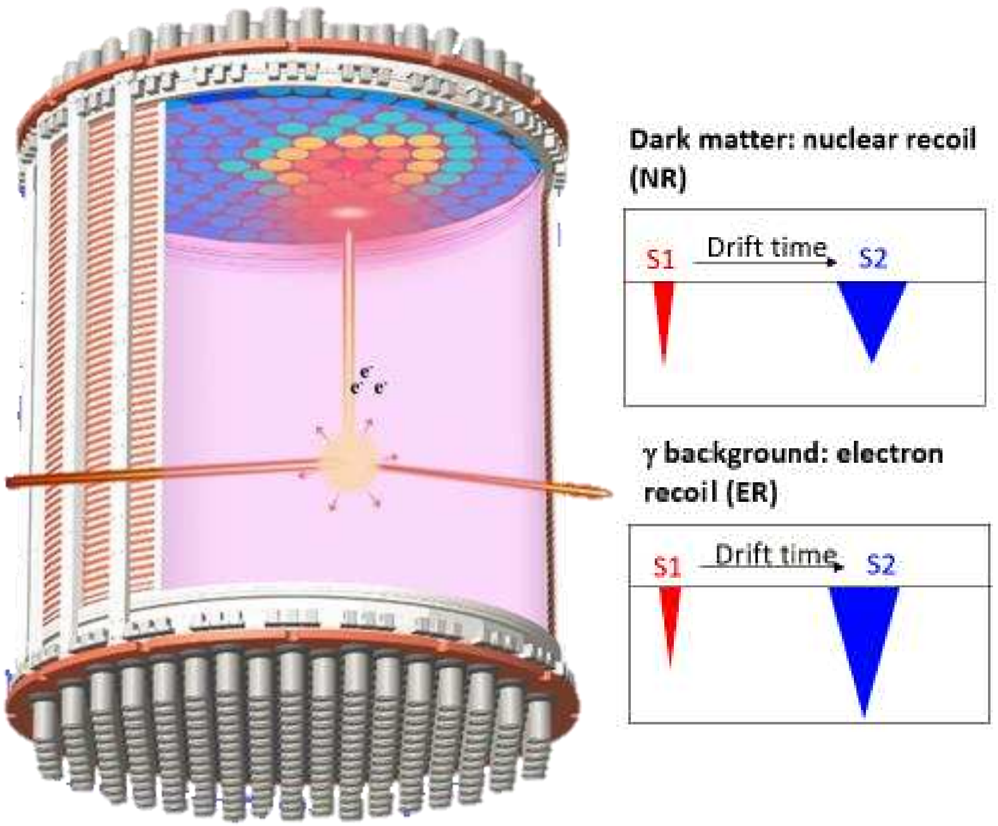


PandaX-I	PandaX-II	PandaX-xT	PandaX-III
120kg LXe	580 kg LXe	X ton LXe	200kg-1T gas Xe-136
DM	DM	DM	0ν2β
2009-2014	2015-2019	Near future	future

PandaX

- Series of xenon based rare-event detection experiments
- Formed in 2009
- ~50 collaborators

Dual-phase xenon Time Projection Chamber(TPC)

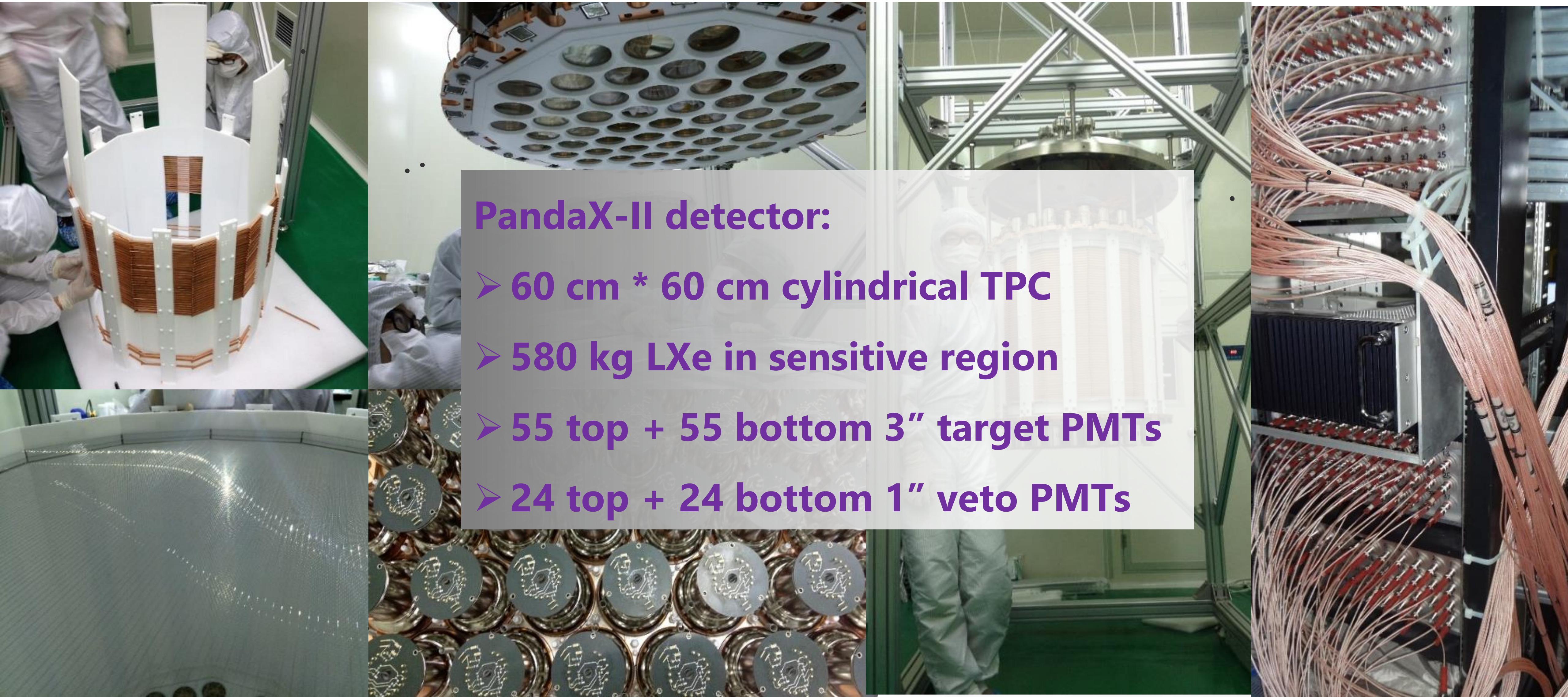


ZEPLIN, XENON, LUX, LZ, PandaX…

Advantages :

- ✓ Xenon has no long-lived radioactive isotopes (except ^{136}Xe)
- ✓ Large A: large cross section & self-shielding
- ✓ Excellent discrimination between nuclear and electron recoils and 3D fiducialization
- ✓ Scalability
- ✓ 9% ^{136}Xe for $0\nu 2\beta$

PandaX-II detector



PandaX-II detector:

- 60 cm * 60 cm cylindrical TPC
- 580 kg LXe in sensitive region
- 55 top + 55 bottom 3” target PMTs
- 24 top + 24 bottom 1” veto PMTs

Some published results of PandaX-II

Dark matter models	Exposure (Ton-day)	Publications
WIMP-nucleon Spin-Independent	33	PRL 117, 121303 (2016)
WIMP-nucleon Spin-dependent	33	PRL 118, 071301 (2017)
Inelastic scattering	27	PRD 96, 102007 (2017)
Axion and ALP	27	PRL 119, 181806 (2017)
WIMP-nucleon SI	**54**	**PRL 119, 181302 (2017)**
light mediator，self-interacting DM (*)	**54**	**PRL 121, 021304 (2018)**
EFT models and SD (*)	**54**	**PLB 792, 193–198 (2019)**
$0\nu2\beta$ decay search	**8.1 (^{136}Xe)**	**CPC 43, 113001 (2019)**

(*) collaborating with theorists: Hai-bo Yu (UCI) and Wick C. Haxton (UCB&LBNL)

Three experiments with similar dual-phase Xe TPC technology, LUX, XENON1T, and PandaX-II, pushed limits down further and further for WIMP direct detections