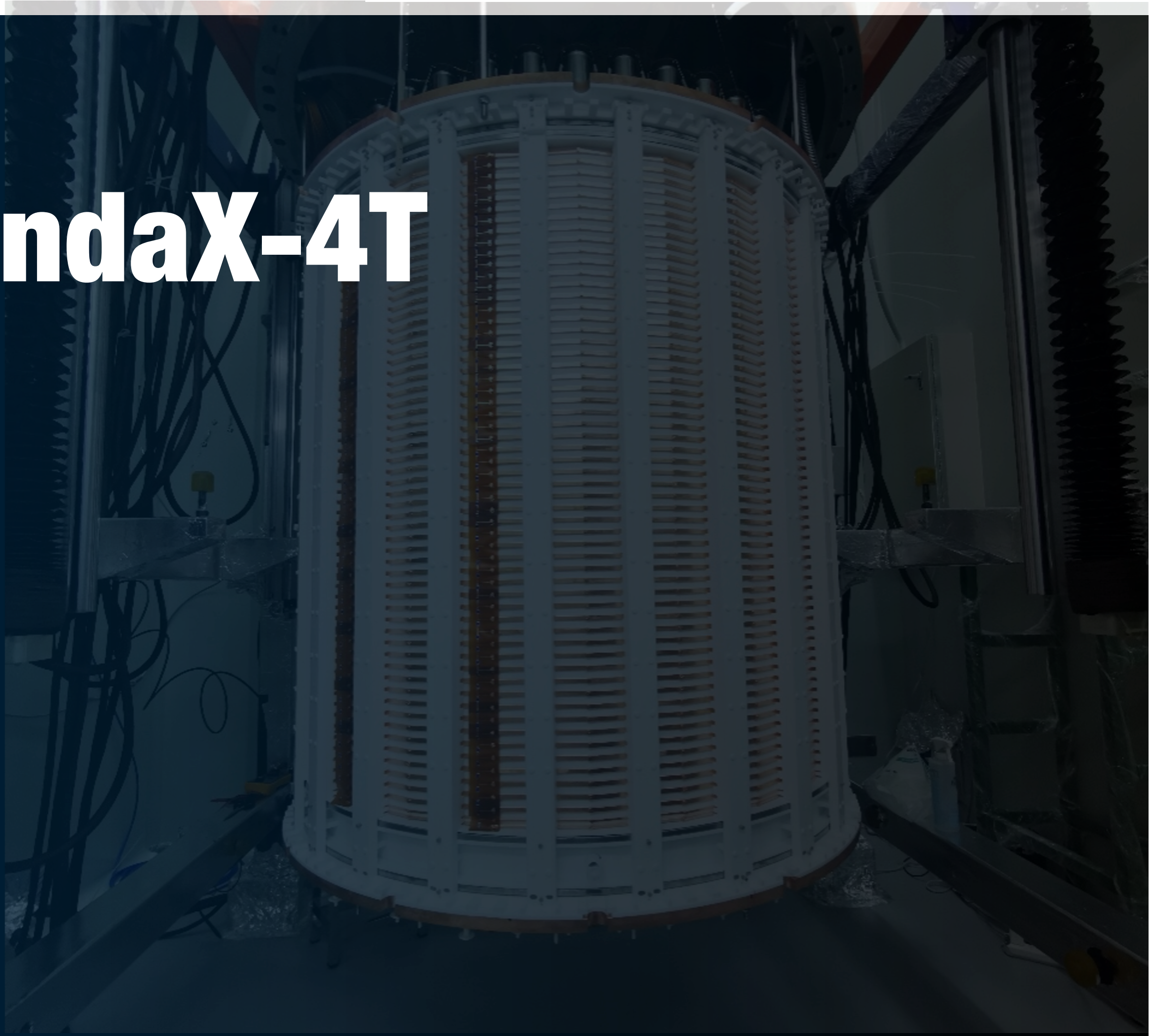
PANDA X
PARTICLE AND ASTROPHYSICAL XENON TPC

北京航空航天大學
BEIHANG UNIVERSITY

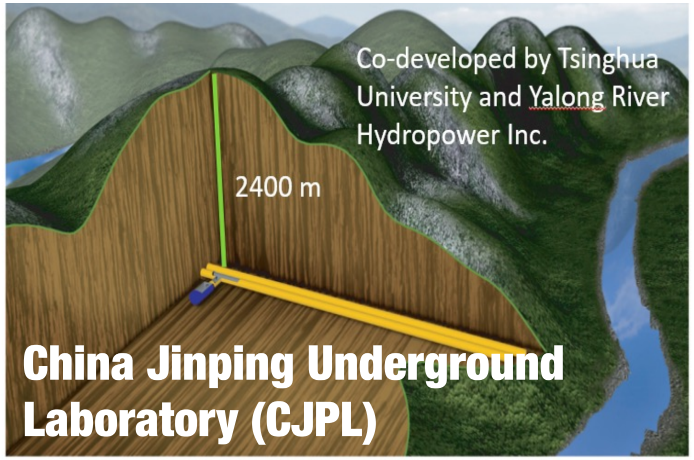
Recent Progress from PandaX-4T



Xiaopeng Zhou, On behalf of PandaX

iDM 2026 @ Spain

PandaX: Particle and Astrophysical Xenon Experiments



- 16 institutions, ~100 collaborators
- CJPL: Deepest (2400 m rock, 6800 m.w.e);

PANDA X
PARTICLE AND ASTROPHYSICAL XENON TPC

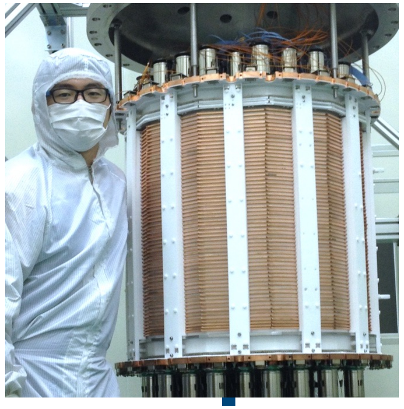
PandaX start

2009.3

PandaX-I 120kg

2010 - 2014

PandaX-II 580kg

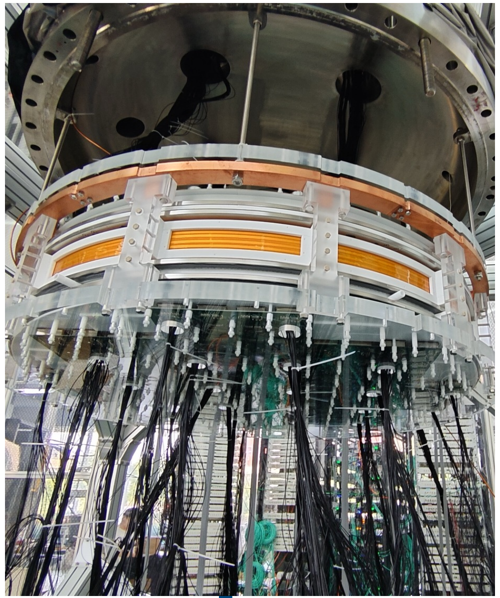


2015 - 2019

PandaX-4T(3.7 ton)

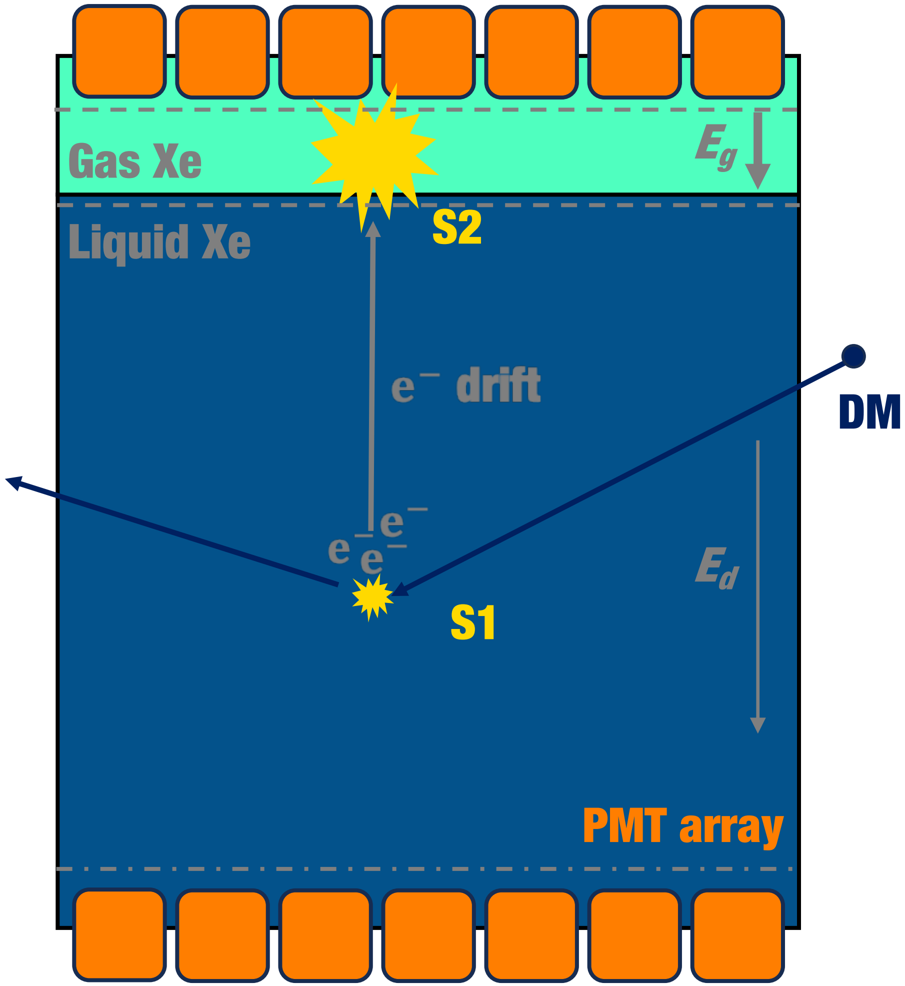
2020 - 2026

PandaX-xT(20 ton)
Xiang's talk



~ 2027

Dual-Phase Xenon Time Projection Chamber



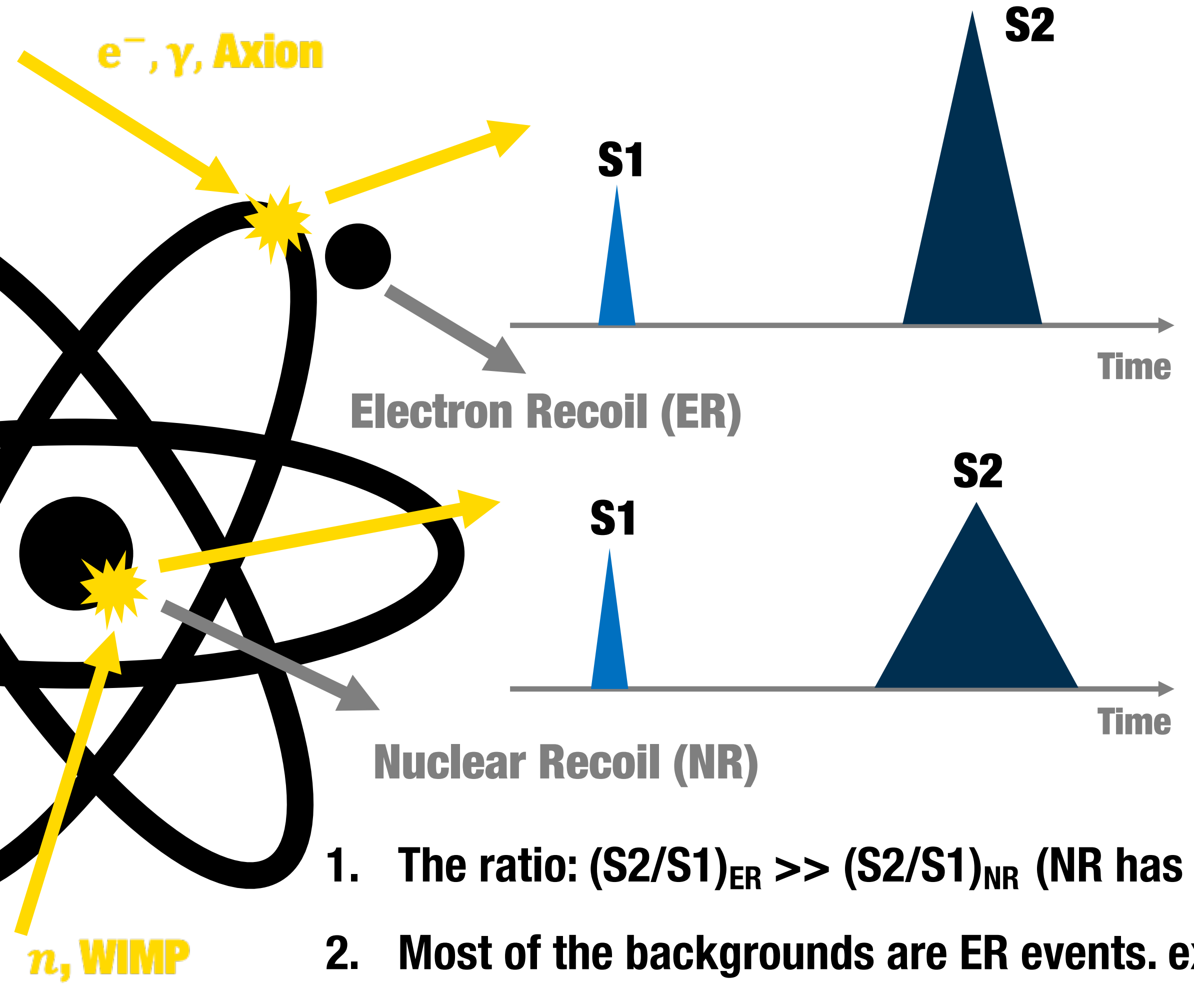
Liquid Xenon Properties

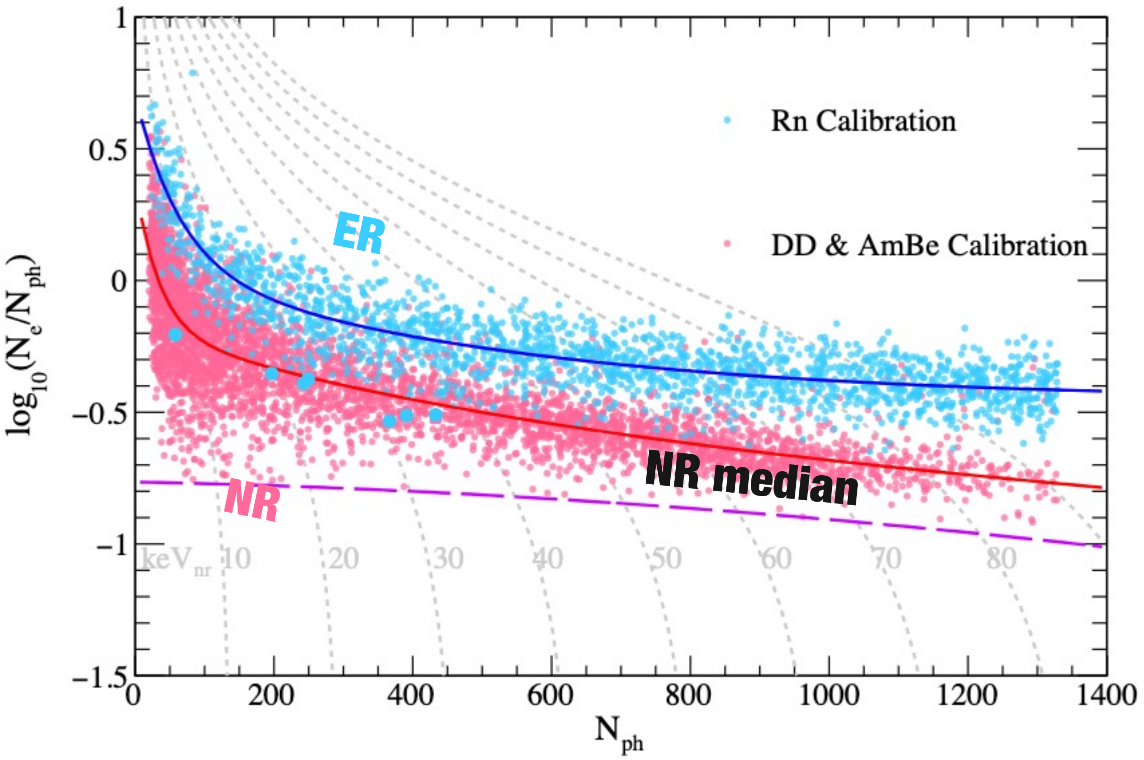
- ❑ Large atomic number Z = 54; High mass number ⟨A⟩ = 131.3
- ❑ High density @ 177K, $\langle \rho \rangle = 2.86\ g/cm^3$
- ❑ No long-lived radioisotopes in WIMP ROI
- ❑ Efficient UV scintillator (178 nm)

Liquid Xenon As DM Detection Medium

- ❑ Maximized interaction cross section for WIMP ($\propto A^2$)
- ❑ High stopping power and self-shielding
- ❑ Ultra-low intrinsic background
- ❑ Scintillation and Ionization Combined: Discrimination of nuclear recoil and electron recoil; 3D position reconstruction
- ❑ Scalable – further sensitivity improvement

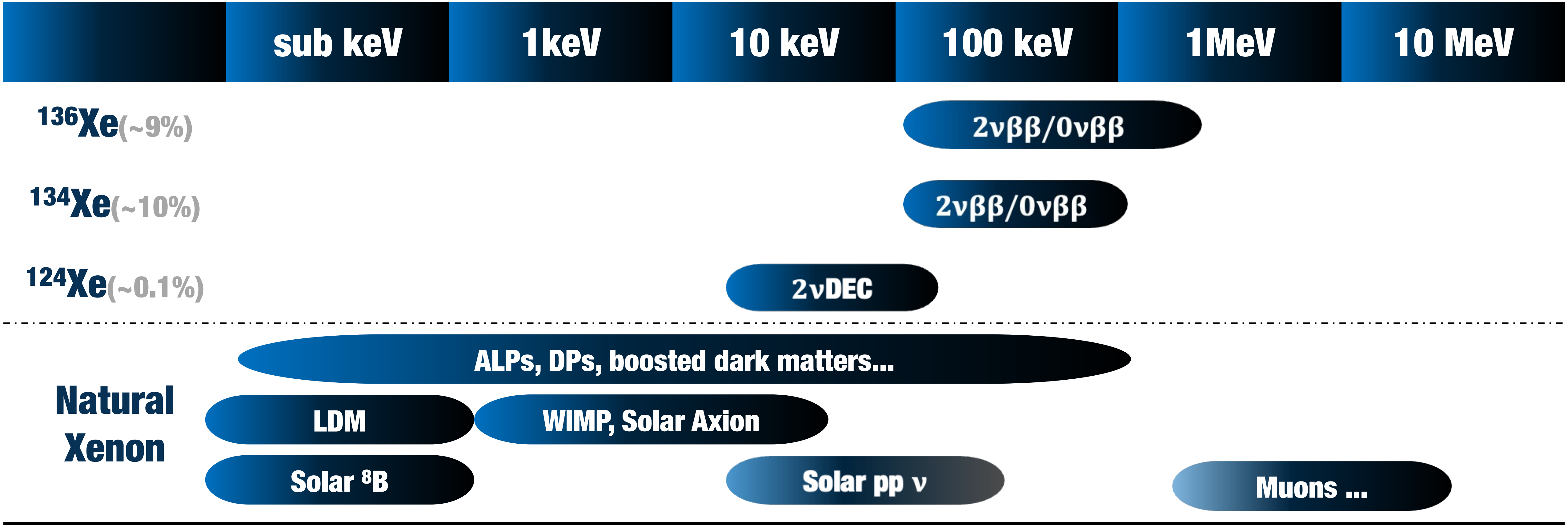
Nuclear Recoil V.S. Electron Recoil





1. The ratio: $(S2/S1)_{ER} >> (S2/S1)_{NR}$ (NR has lower ionization rate but higher charge density);
2. Most of the backgrounds are ER events. exploring the ER region also holds promise for discovering new physics.
3. ER and NR response are calibrated separately: ^{220}Rn (ER), DD + AmBe (NR);

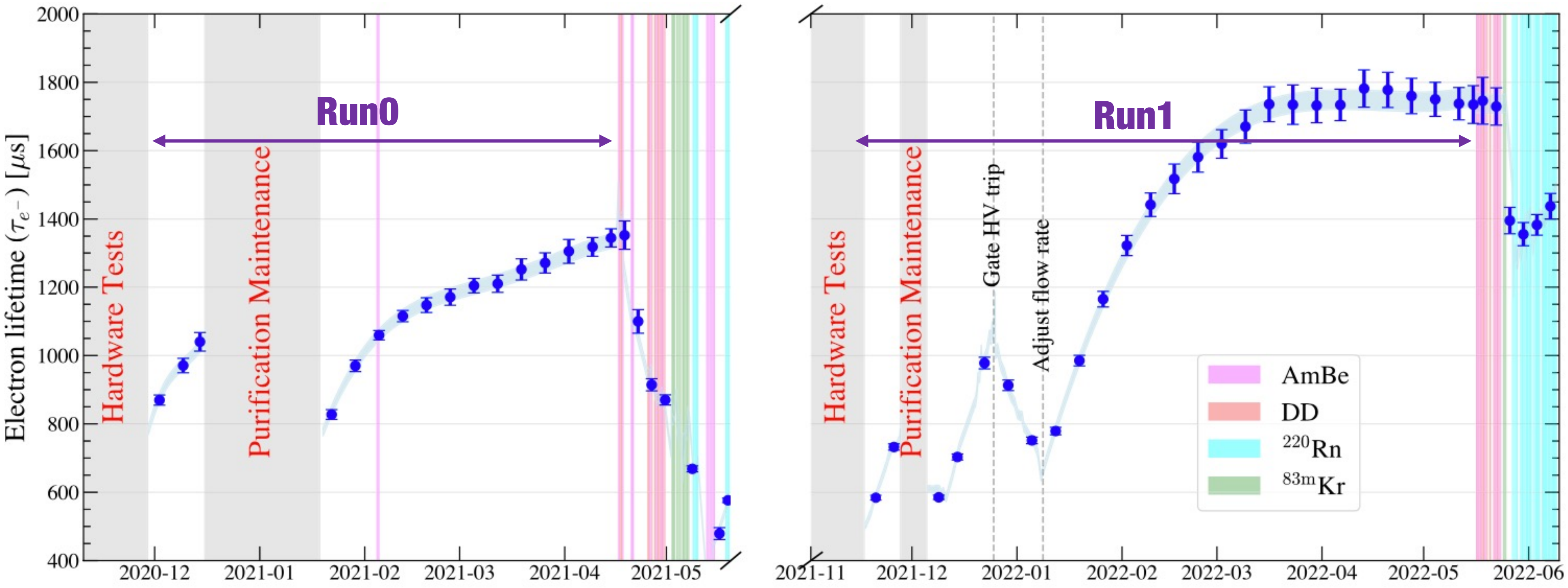
Rich Physics with Recoil Data



Timeline of PandaX-4T Experiment

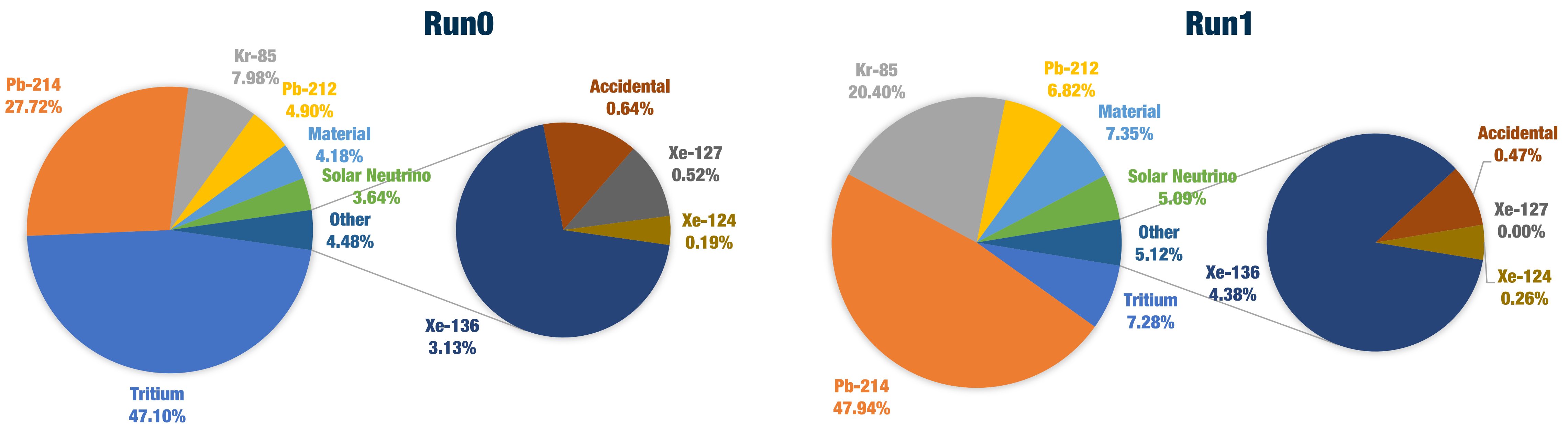
Time	Activity
2020/11-2021/04	commissioning (Run0) 95 days
2021/07-2021/10	tritium removal xenon distillation, gas flushing, etc.
2021/11-2022/05	physics run (Run1) 164 days
2022/09-2023/12	CJPL B2 hall renovation xenon recuperation, detector upgrade (Yuehuan's talk)
2024/01-2024/07	resuming operation
Current status	Shut down on April 17, 2026 (Run2)

Data-taking of PandaX-4T



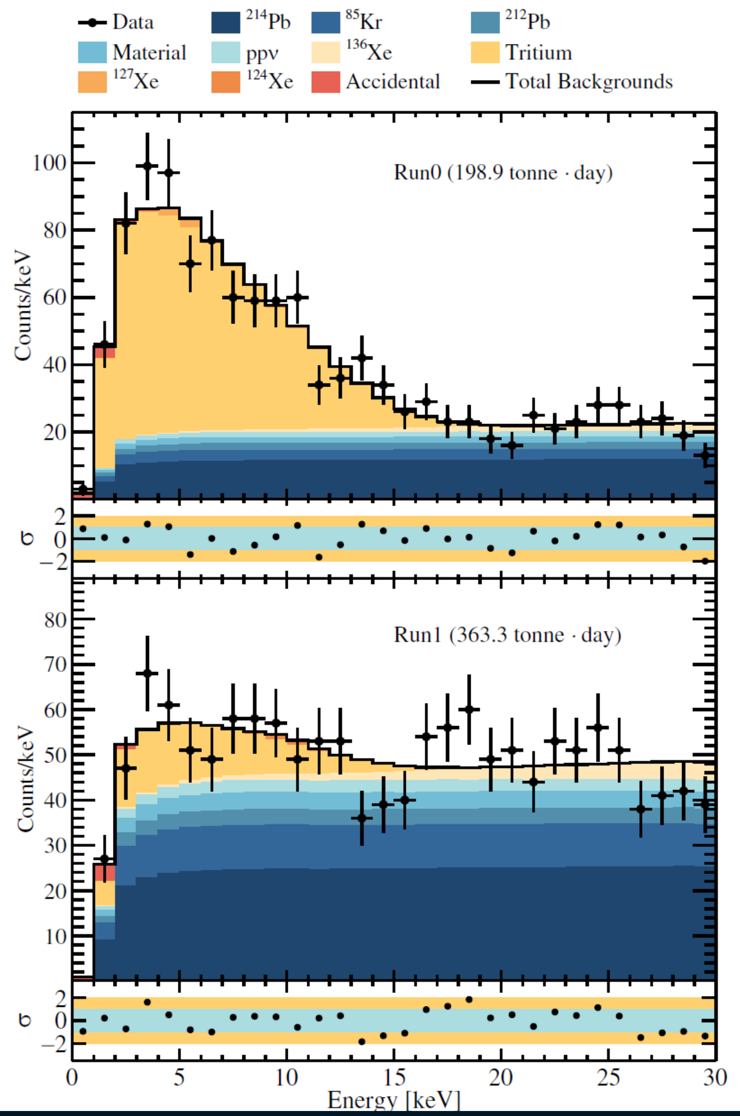
1. PandaX-4T has finished two physics runs: Run0 and Run1, a total exposure of 1.54 ton×year after removed low-quality data;
2. Run0 results published @ 2021; Run0 + Run1 combined blind-analysis published @ 2025.

Background Model for keV region



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

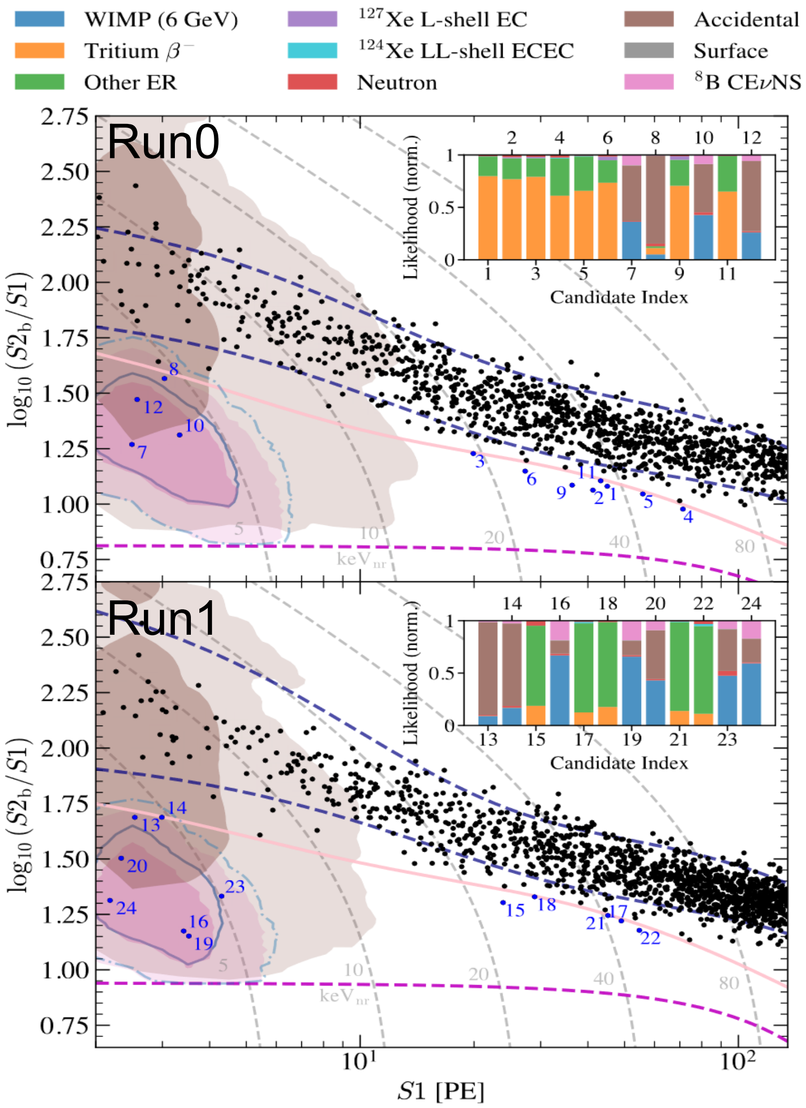
Best-fit of keV Background Model



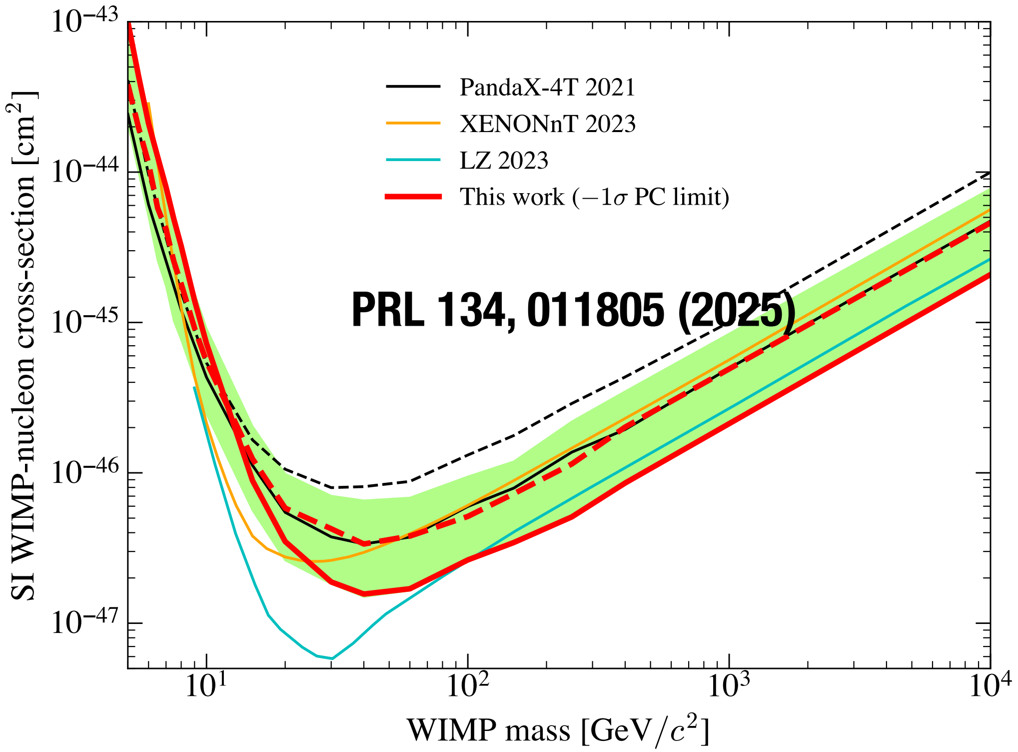
	Run0		Run1	
Run	Expected	Fitted	Expected	Fitted
Tritium	···	578.6 ± 32.5	···	118.4 ± 31.1
^{214}Pb	327.2 ± 18.8	328.0 ± 17.1	724.0 ± 61.5	700.3 ± 45.3
^{212}Pb	57.8 ± 14.7	57.3 ± 14.1	103.3 ± 26.9	96.5 ± 23.8
^{85}Kr	94.2 ± 47.3	87.3 ± 31.2	308.1 ± 95.2	272.2 ± 58.9
Material	49.4 ± 3.3	49.5 ± 3.1	111.7 ± 9.9	105.9 ± 7.8
^{136}Xe	36.9 ± 2.5	36.9 ± 2.4	66.2 ± 5.9	62.3 ± 4.6
^{127}Xe	6.1 ± 0.3	6.1 ± 0.3	0.0 ± 0.0	0.0 ± 0.0
^{124}Xe	2.3 ± 0.6	2.3 ± 0.6	4.0 ± 1.1	3.9 ± 1.1
Solar ν	43.0 ± 4.6	42.9 ± 4.5	76.8 ± 9.4	72.6 ± 8.1
Accidental	7.6 ± 2.4	7.8 ± 2.1	7.1 ± 2.3	7.0 ± 1.9
Total	···	1196.6 ± 32.6	···	1439.2 ± 36.2
Observed	1197		1431	

- **A combined fit of Run0 and Run1 in 1D energy space;**
- **Tritium is set to free in fit;**
- **No excess found: consistent with background model (p-value = 0.16).**

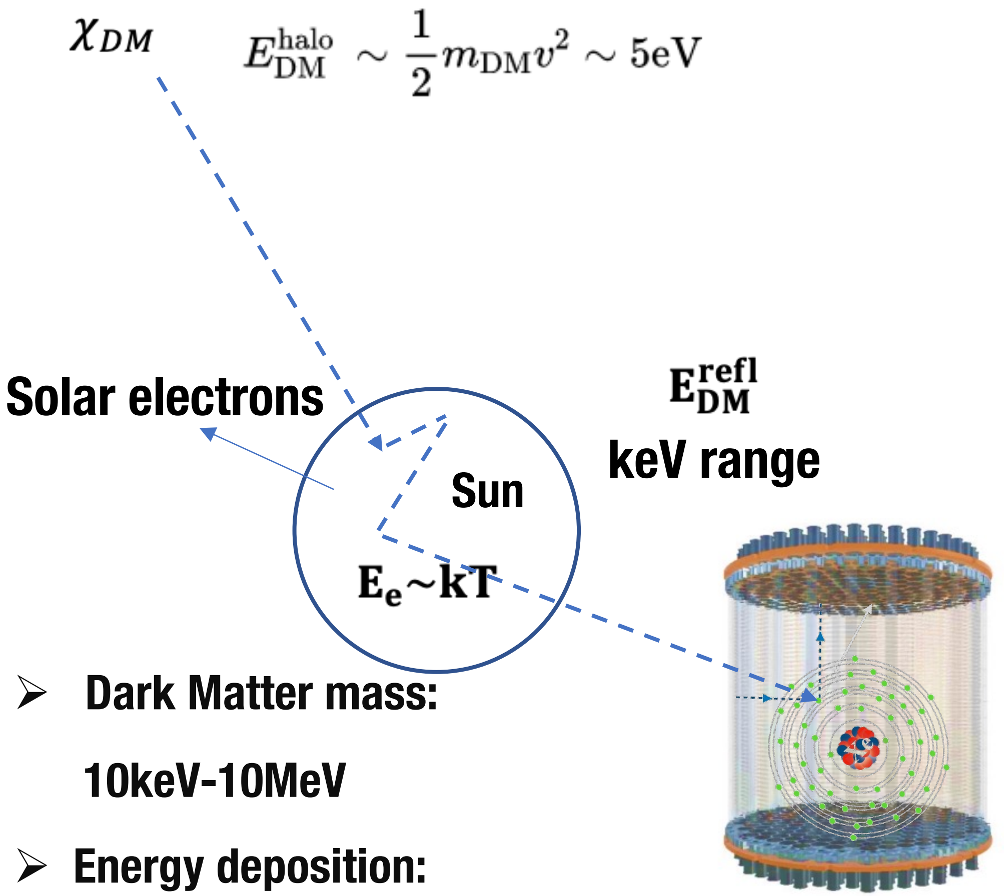
WIMP (S1-S2 paired)



- 1 sigma upward fluctuation with <8 GeV, while downward fluctuation in high-mass region;
- Exclusion reaches 1.6e-47 cm2 @ 40GeV;

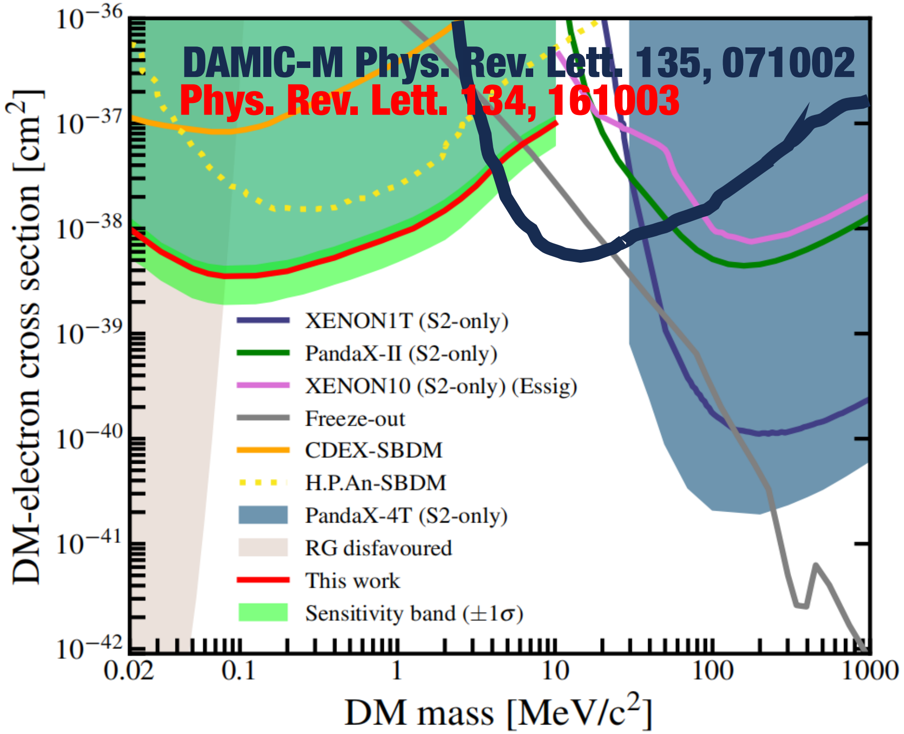


Solar Boosted Light Dark Matter (S1-S2 paired)

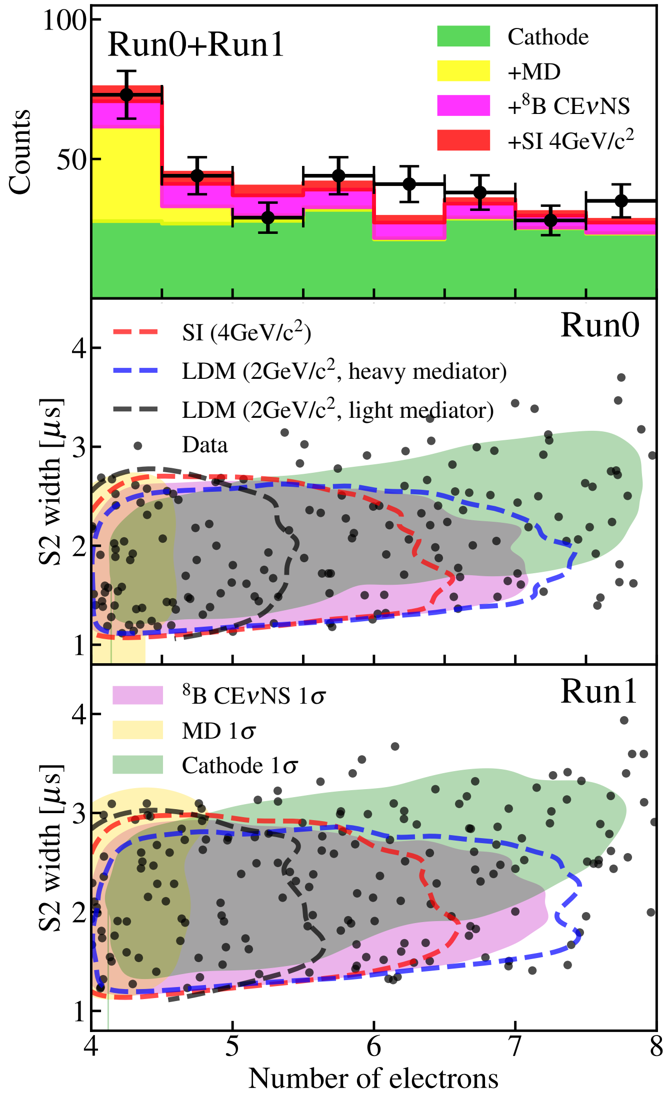


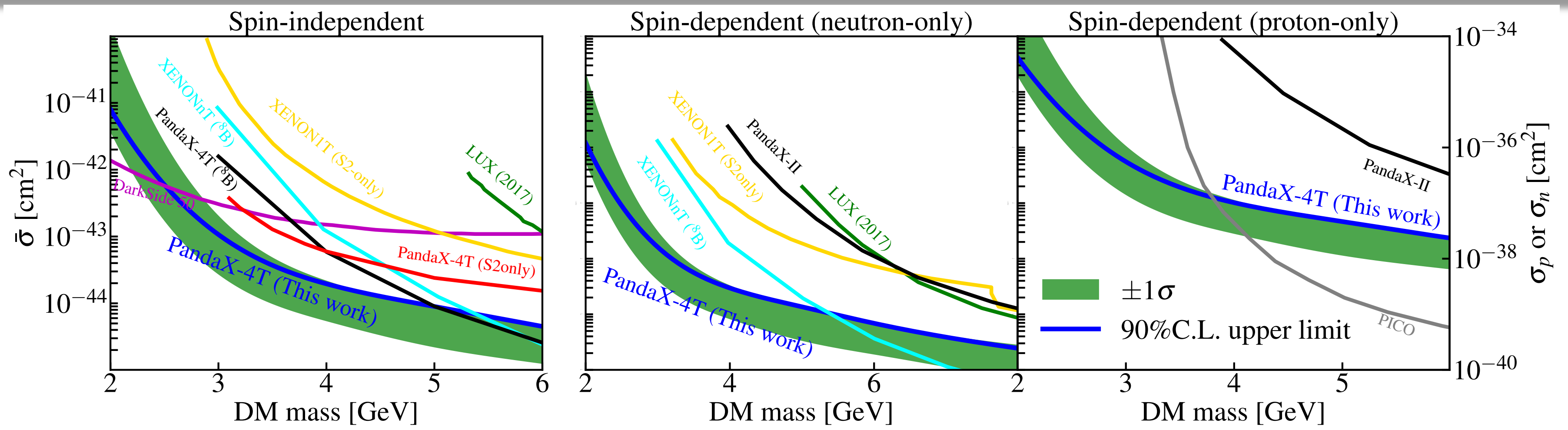
- Dark Matter mass: 10keV-10MeV
- Energy deposition: 10 to ~10^3eV

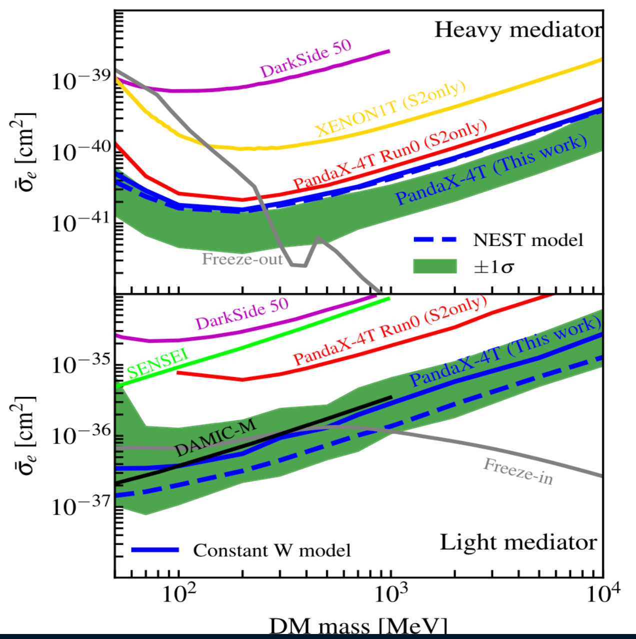
- most stringent cross-section for mass ranging from 0.02 to 10 MeV/c^2
- Combined with DAMIC-M new result, almost all the parameter space below 200 MeV for Freeze-out model was ruled out.



Light Dark Matter (mainly Unpaired S2)

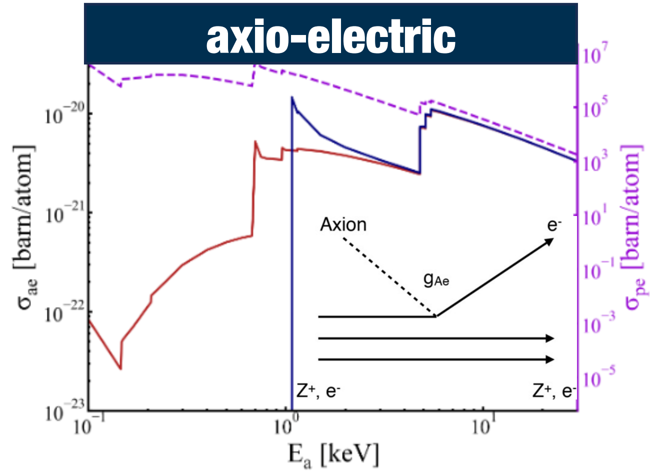


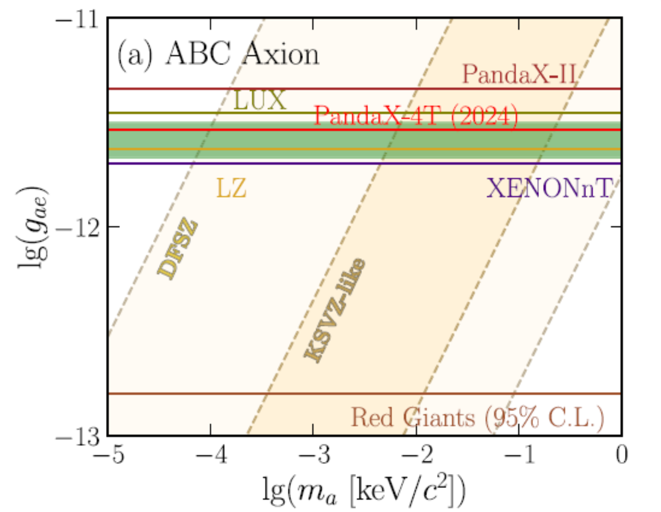


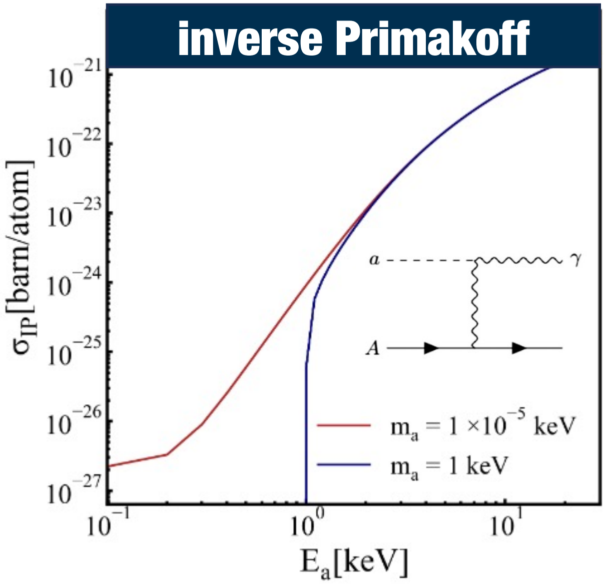


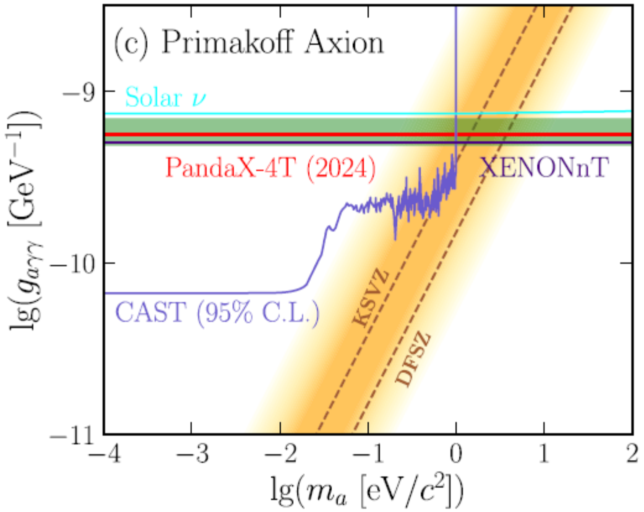
Achievement	Result
Exposure	259 days, up to 1.20 tonne·year
Threshold	0.33 keV (NR), 0.04 keV (ER)
Technique	Ultra-low-threshold S2-only analysis
SI WIMP	best limits for 2.5–5 GeV
SD WIMP	best neutron/proton limits below ~5 GeV
DM–e (light)	Up to 9.3× improvement

Solar Axions (S1-S2 paired)









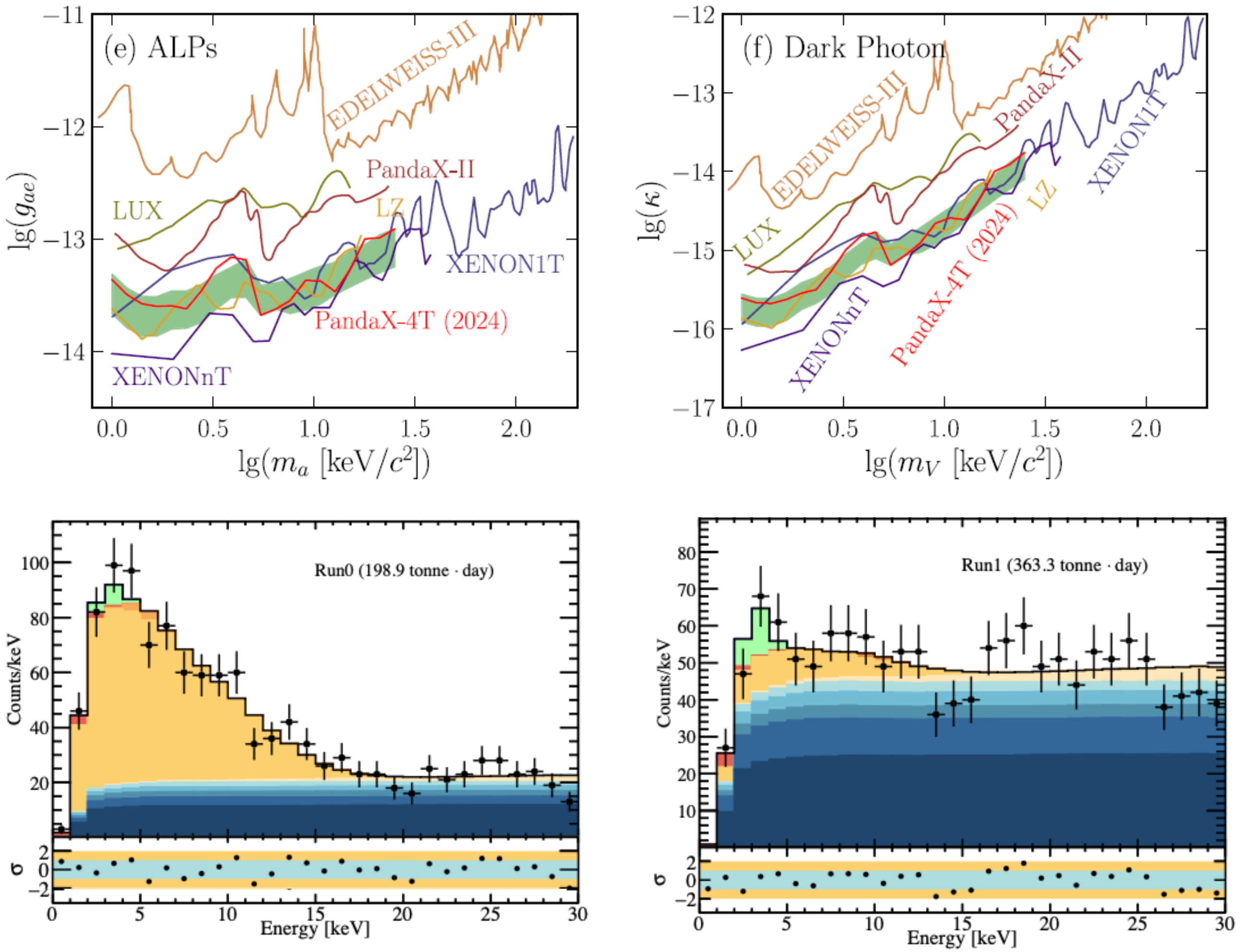
1. Solar axion can have O(keV) energy deposition in liquid xenon;
2. Two detection channels for solar axion: axio-electric effect and inverse Primakoff effect;
3. Indpendent fit of different couplings in energy space: g_{ae} , $g_{a\gamma\gamma}$.

$$\frac{dR_{ABC}}{dE_r} = \frac{N_A}{A}\left(\frac{d\Phi_A}{dE_a}(E_r) + \frac{d\Phi_B}{dE_a}(E_r) + \frac{d\Phi_C}{dE_a}(E_r)\right) \times \sigma_{ae}(E_r).$$

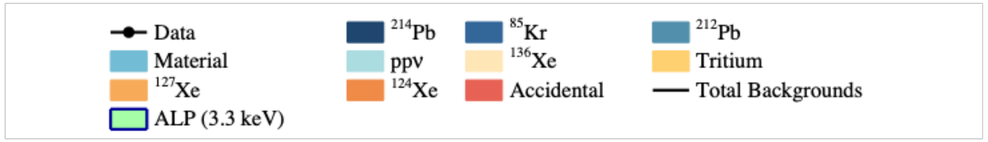
$$\frac{dR}{dE_r} = \frac{N_A}{A} \times \frac{d\Phi_P}{dEa}(E_r) \times \sigma_{IP}(E_r)$$

Phys. Rev. Lett. 134, 041001

Axion like particles (S1-S2 paired)

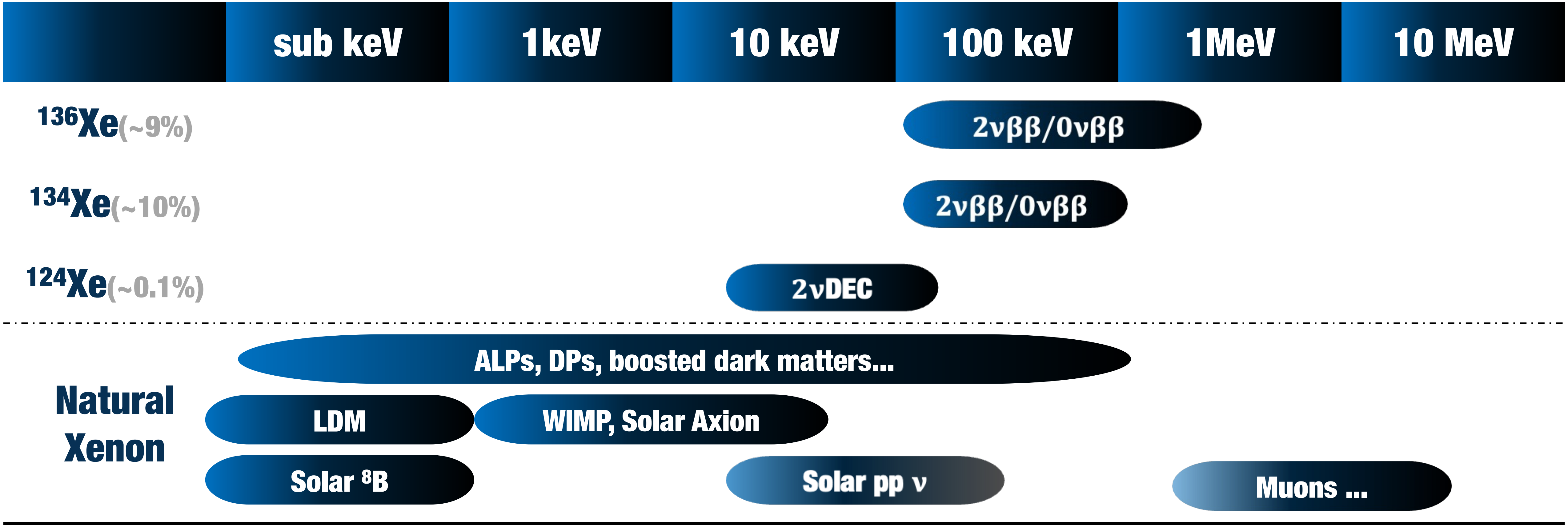


1. **Light Dark matter searching: Mono-energetic signals scan.**
   - **Axionlike Particles (ALPs) and Dark Photons (DPs)**
   - **Fermionic Dark Matter – ν conversion**

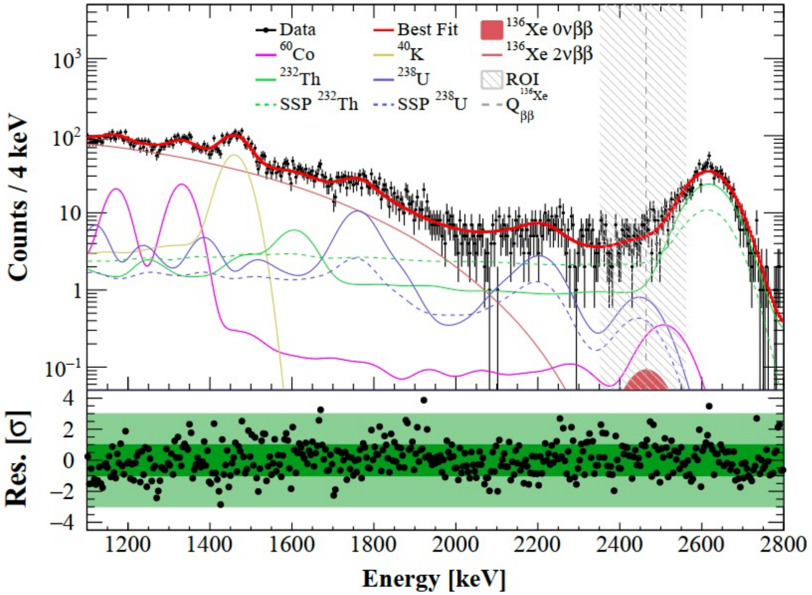


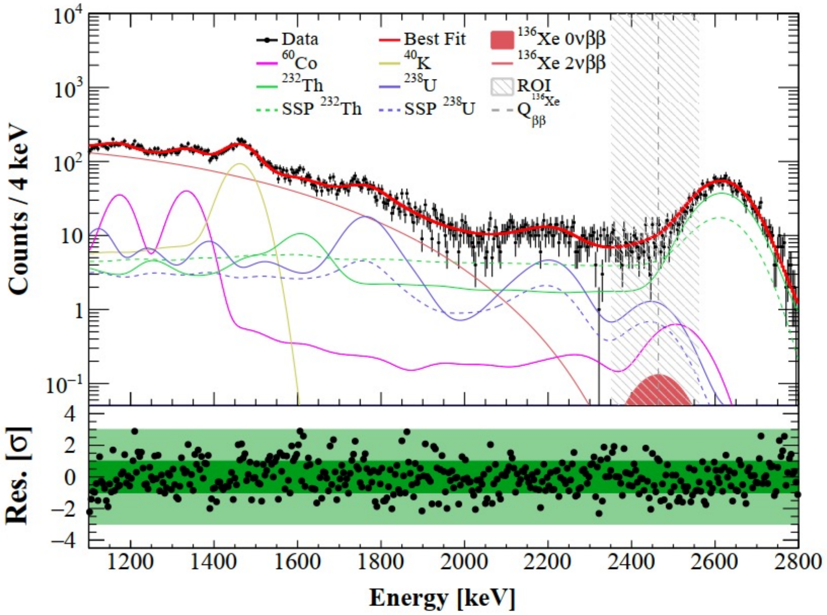
Phys. Rev. Lett. 134, 041001

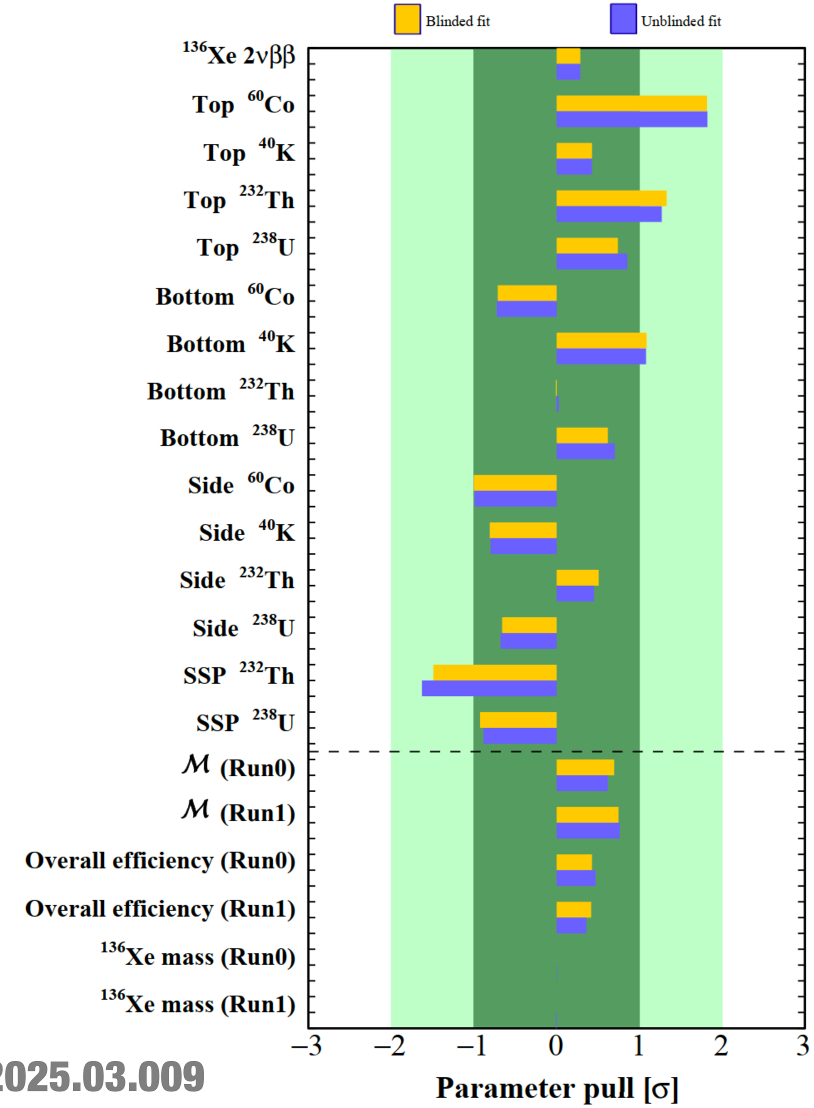
Rich Physics with Recoil Data



Neutrinoless Double Beta Decay of Xe-136







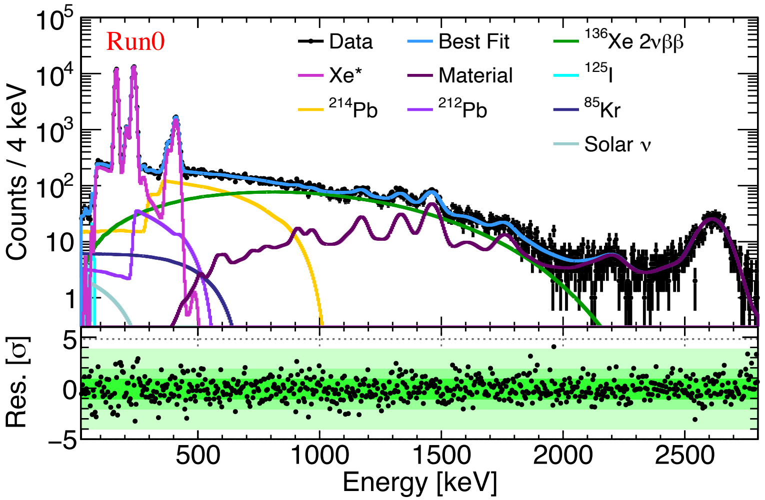
- ^{136}Xe $0\nu\beta\beta$ event rate is fitted to be 14±55 $\mathrm{t^{-1}yr^{-1}}$, the upper limit of 111 $\mathrm{t^{-1}yr^{-1}}$ at 90% C.L. is derived

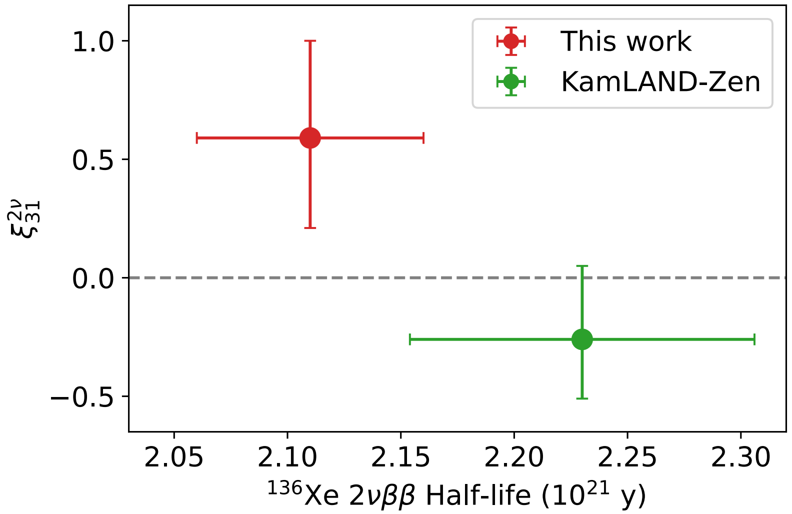
$$T_{1/2}^{0\nu\beta\beta} > 2.1\times 10^{24}\ \text{yr at 90\% C.L.}$$

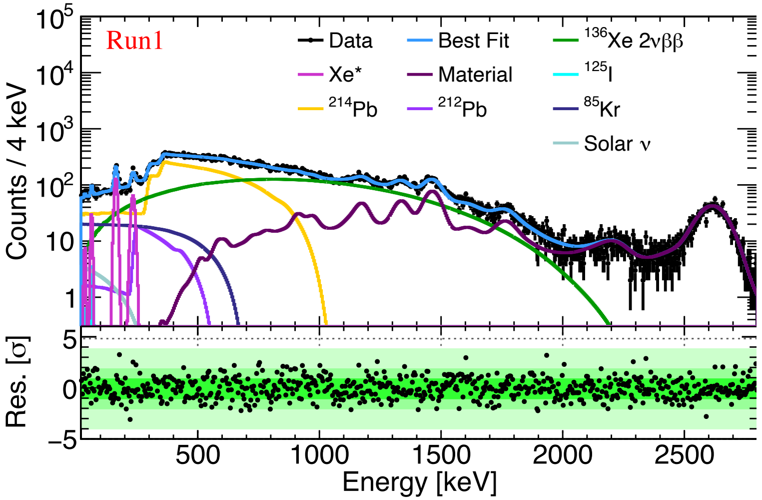
- Improvement to our previous PandaX-II results by an order of magnitude

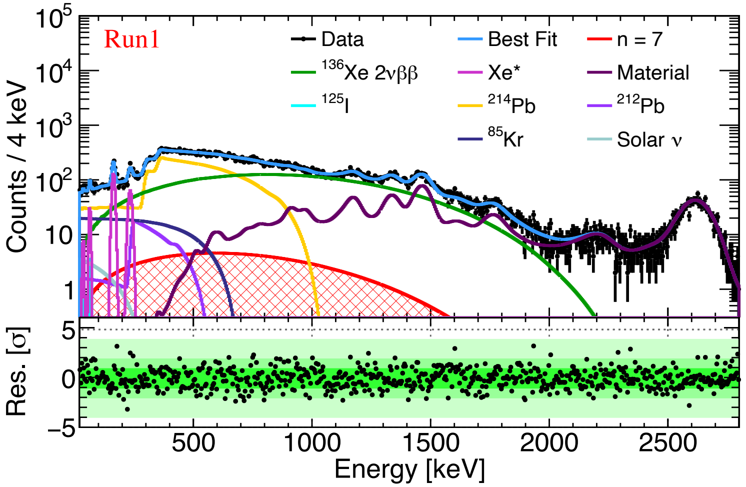
Science Bulletin, 2025.03.009

Double Beta Decay of Xe-136









Transforms PandaX-4T from a dark-matter detector into a precision double-beta-decay observatory, delivering the most accurate ^{136}Xe half-life measurement

$T_{1/2}^{2\nu}=(2.14\pm0.05)\ 10^{21}$ yr

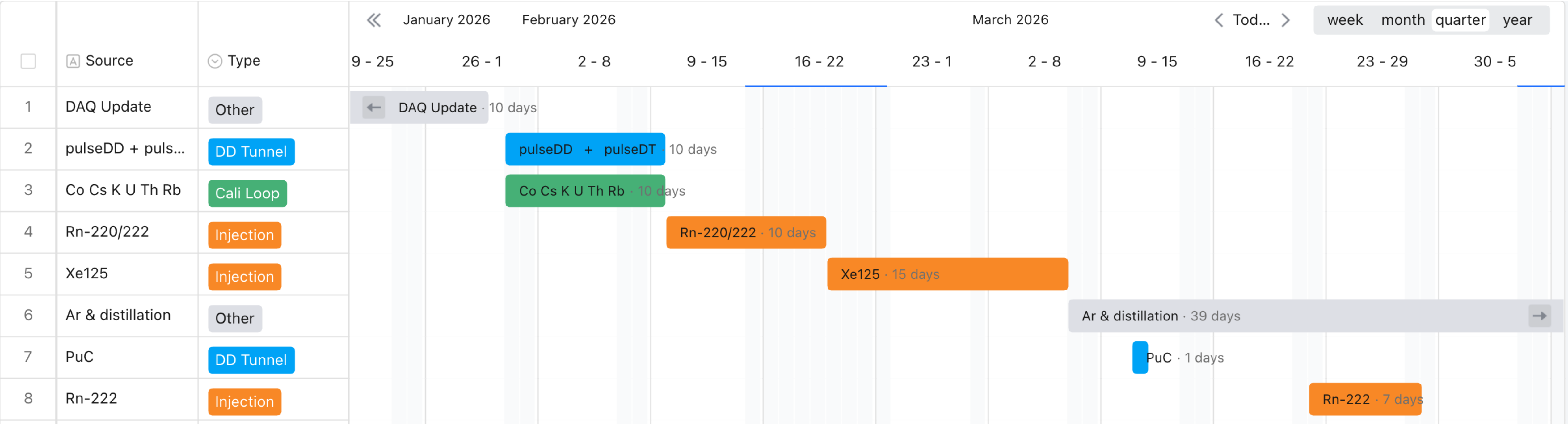
Direct probe of subleading nuclear matrix elements

Important for reducing uncertainties in future $0\nu\beta\beta$ interpretations

Strongest constraint on this Majoron-emission scenario

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

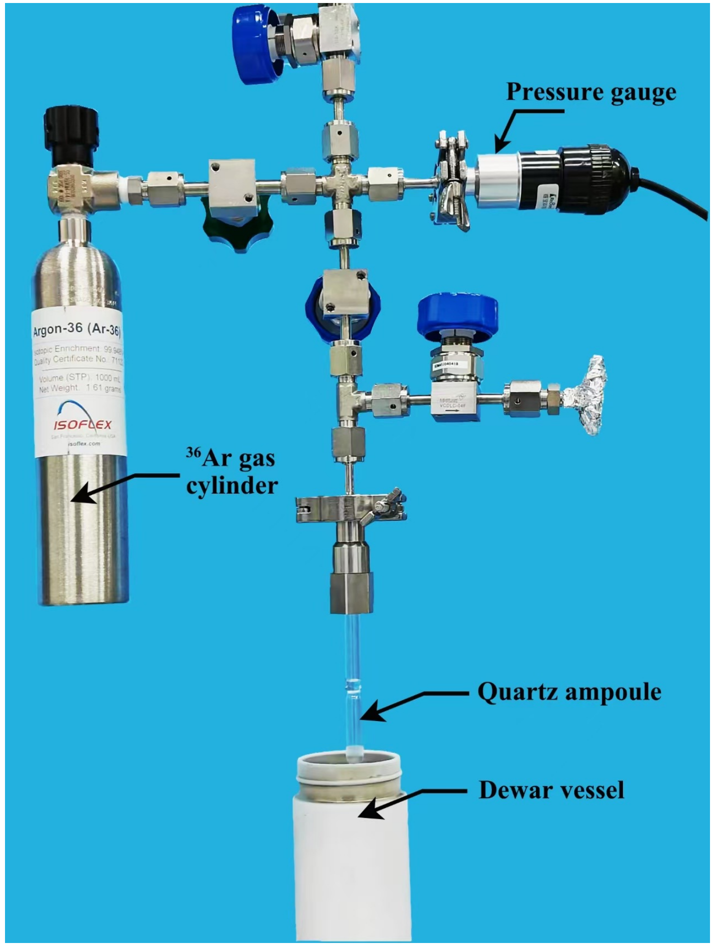
Calibration on END of RUN



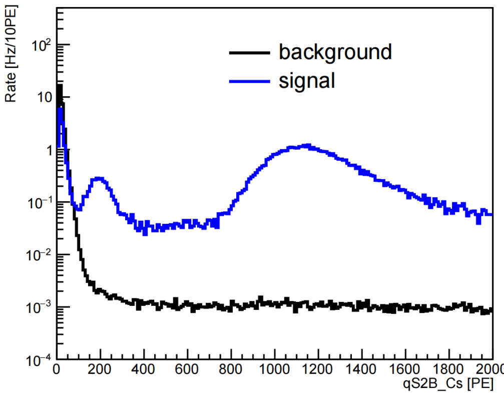
During the End of Run phase, we explored a wide range of calibration techniques. In addition to carrying out an extensive program of conventional calibrations, we developed and tested several novel calibration methods. These new approaches have provided invaluable experience and technical insights for the upcoming 20-ton detector, laying a solid foundation for its calibration strategy and future operation.

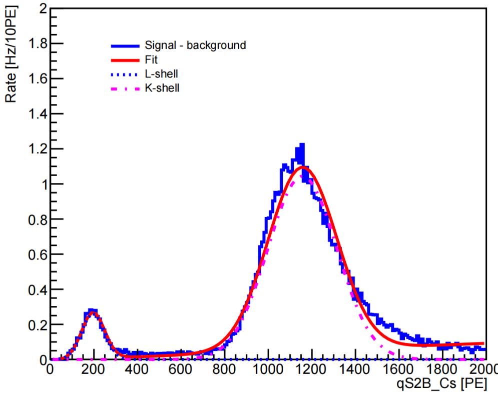
Calibration on END of RUN

Ar-37 calibration

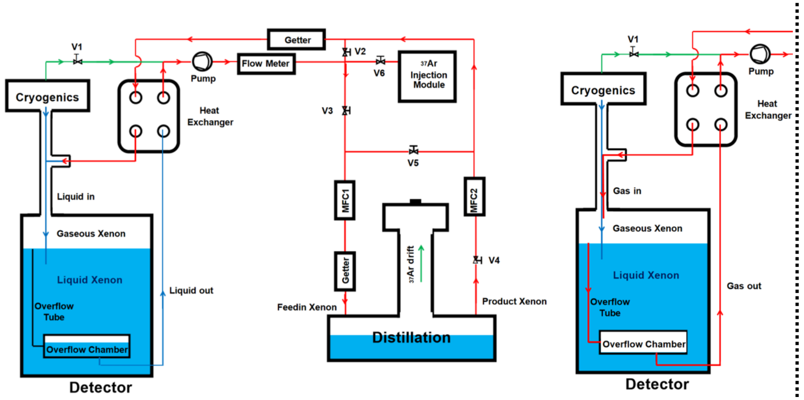


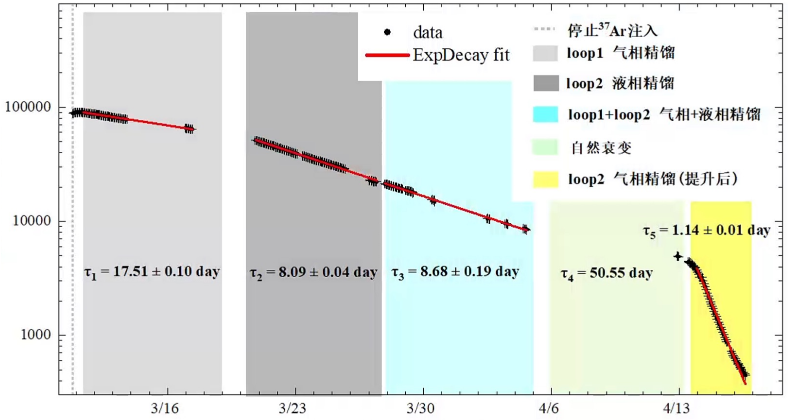
n irradiation





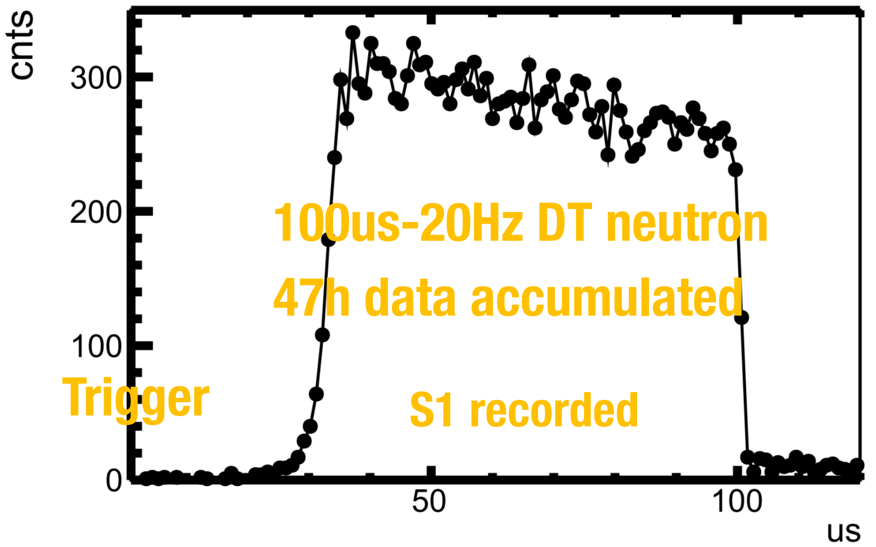
K:2.82keV(90%)、 L:0.27keV(9%)

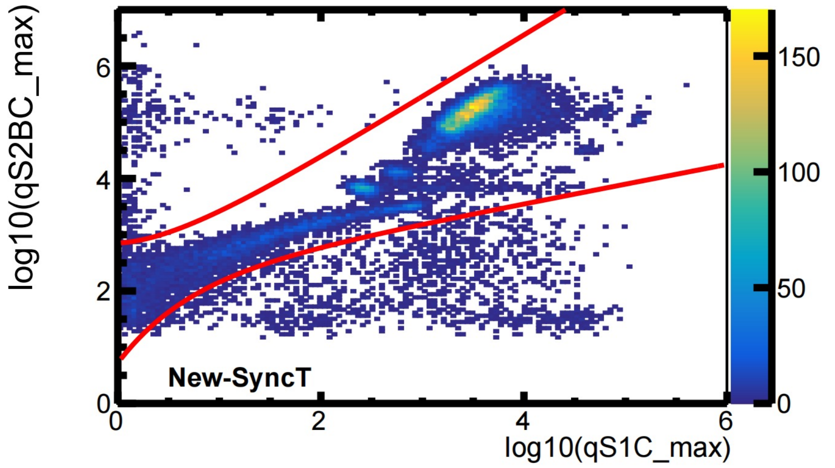




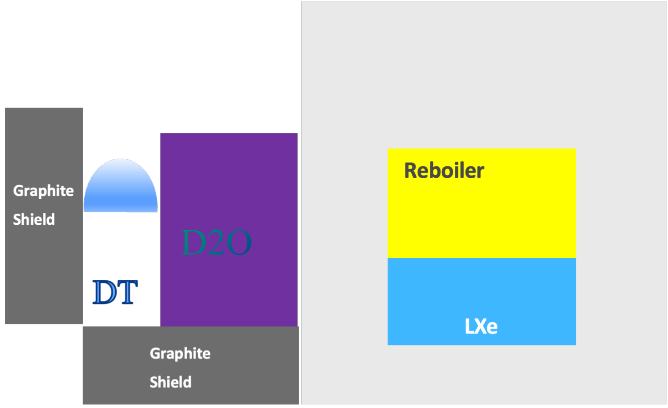
Calibration on END of RUN

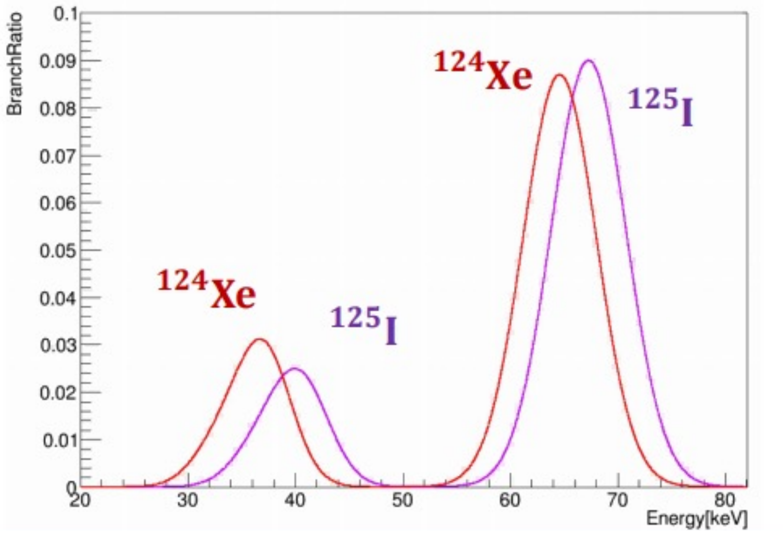
Pulsed DD/DT neutron

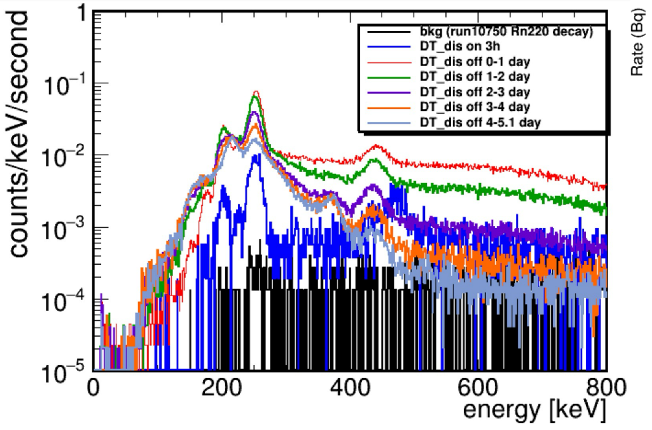


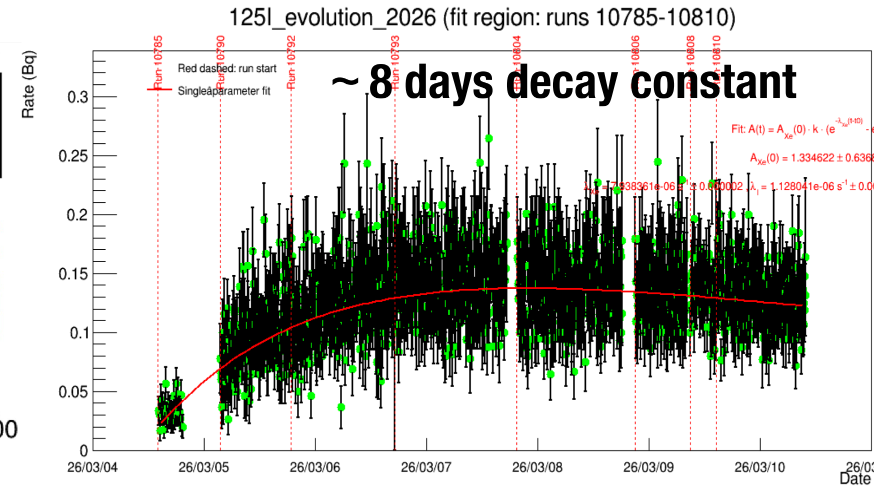


Online neutron activation









Conclusions

- PandaX-4T has now completed its full physics program.
- We collected approximately 700 live days of dark matter search data.
- During the end-of-run campaign, we devoted significant effort to testing a number of new calibration techniques.
- Further details on the Run 2 veto upgrades, as well as R&D activities for the 20-ton detector, will be presented in the following two talks by Xiang and Yuehuan.

Thanks