

Recent Results and Progress of PandaX-4T Experiment

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University of Science and Technology of China

iDM @ L'Aquila, 2024.07.08

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PandaX-4T DM search experiment

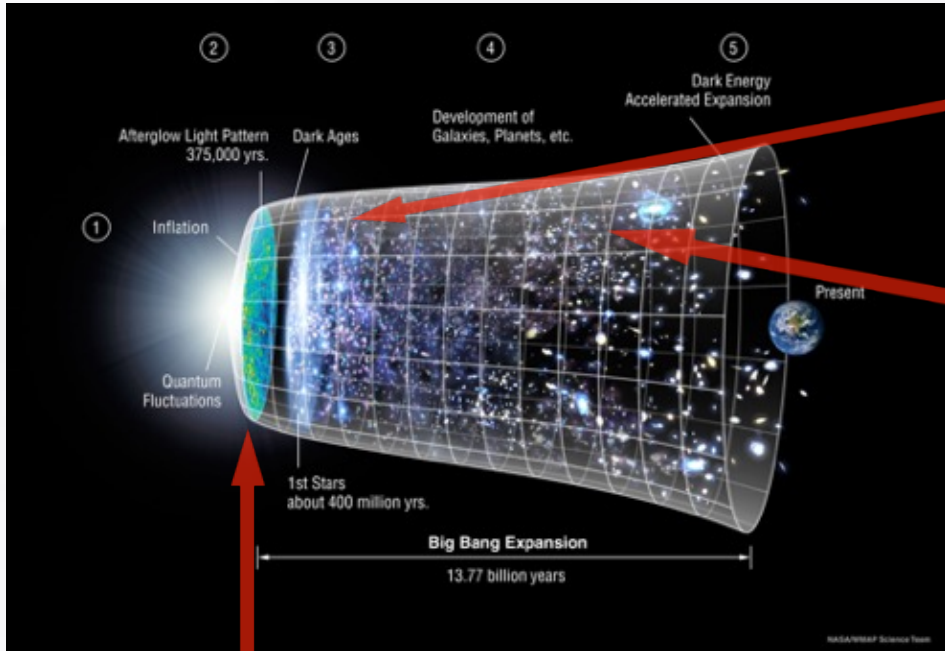
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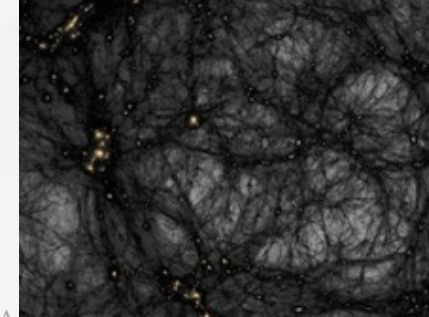
Status of B8 CE ν NS search

Dark Matter and its Gravitational Evidence



Primordial Universe

Large Structure



Courtesy of NASA

Credit: <https://youtu.be/sI23cwbbNqs>

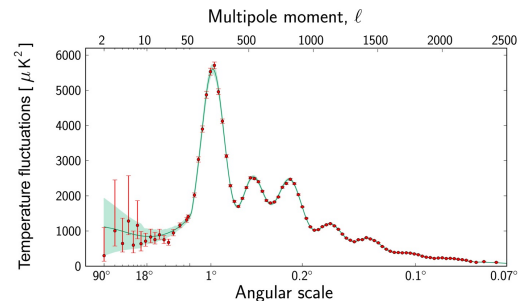
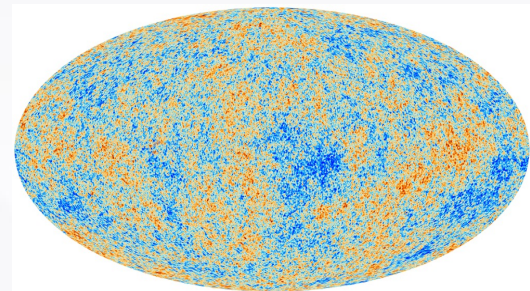
Small Structure



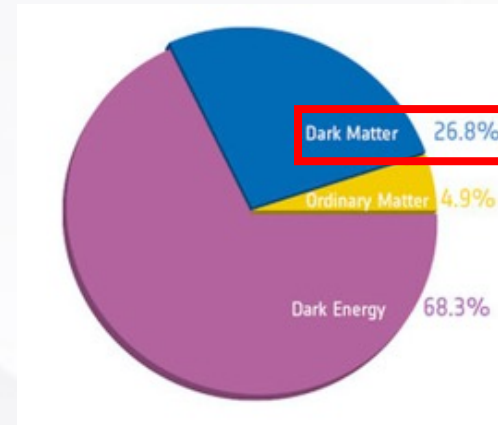
Bullet cluster collision



Galaxy rotation curve

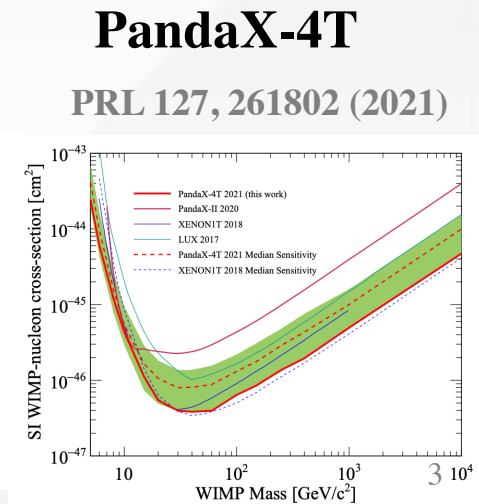
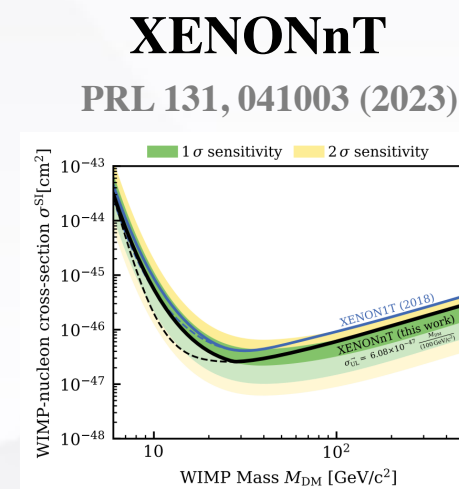
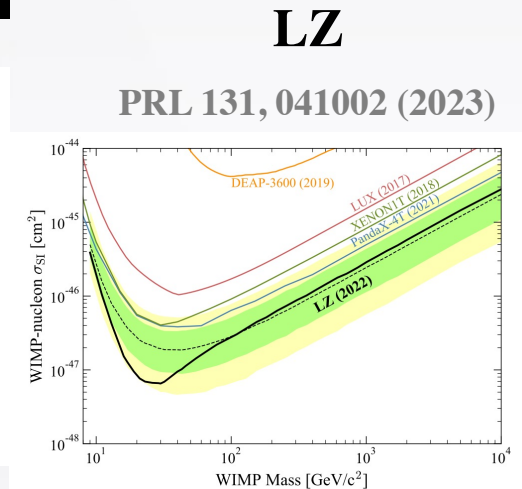
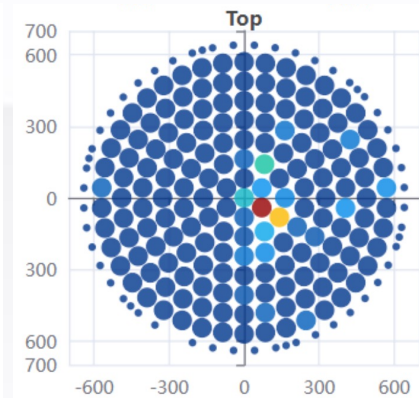
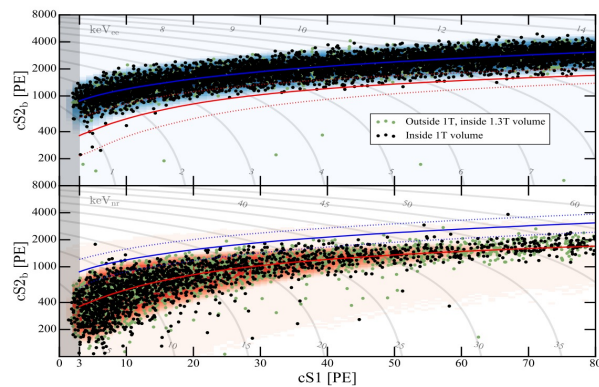
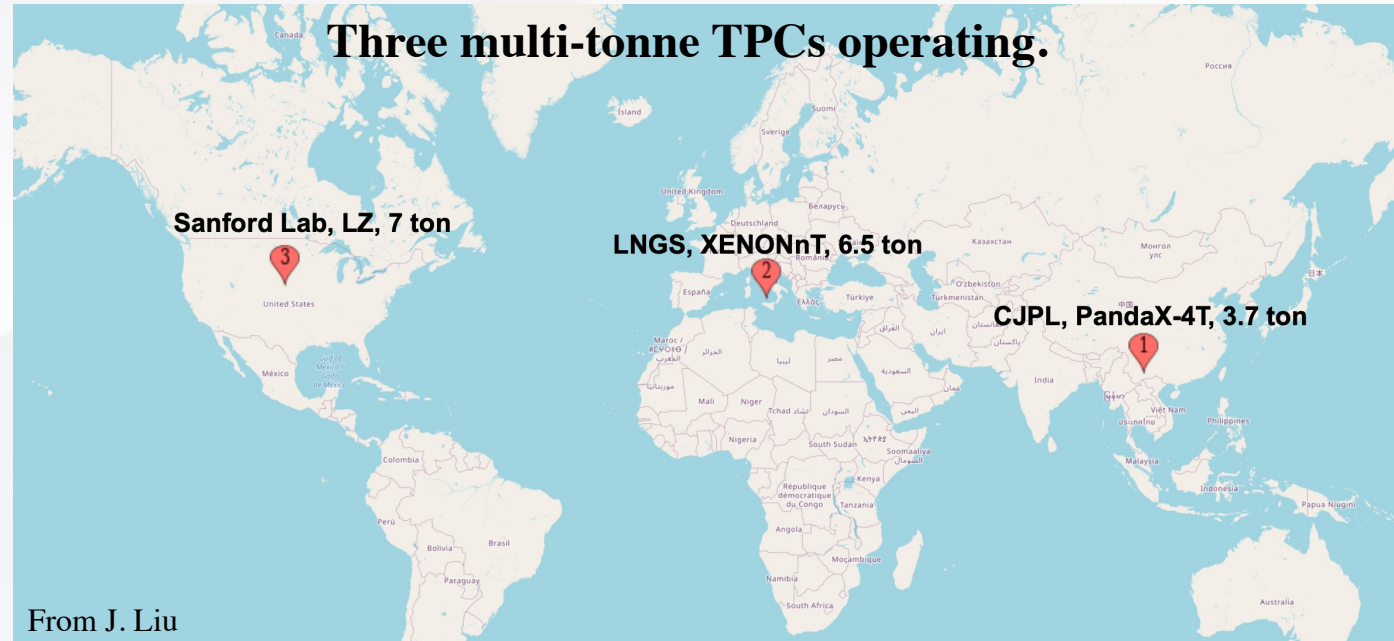
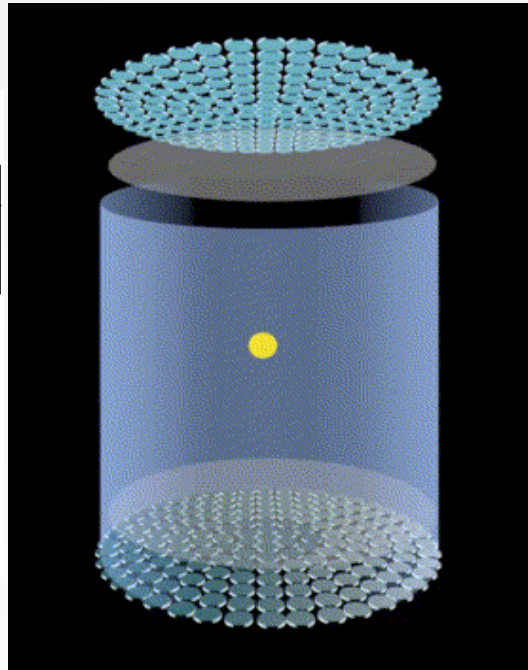
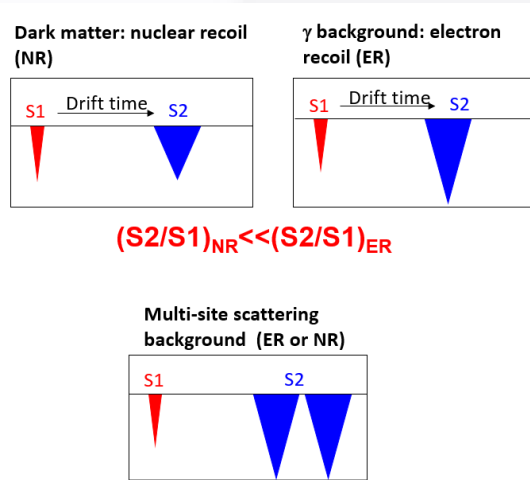


Courtesy of PLANCK



Gravitational evidences suggest **dark matter** is the **dominant form of matter** in Universe!

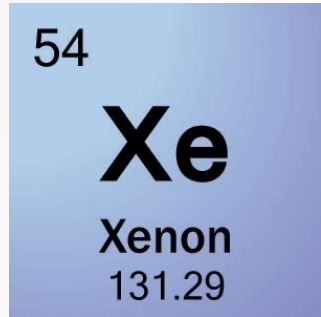
Dual phase xenon TPC



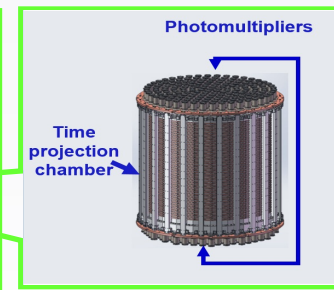
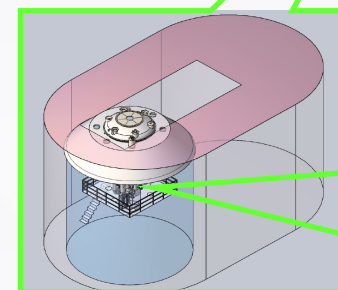
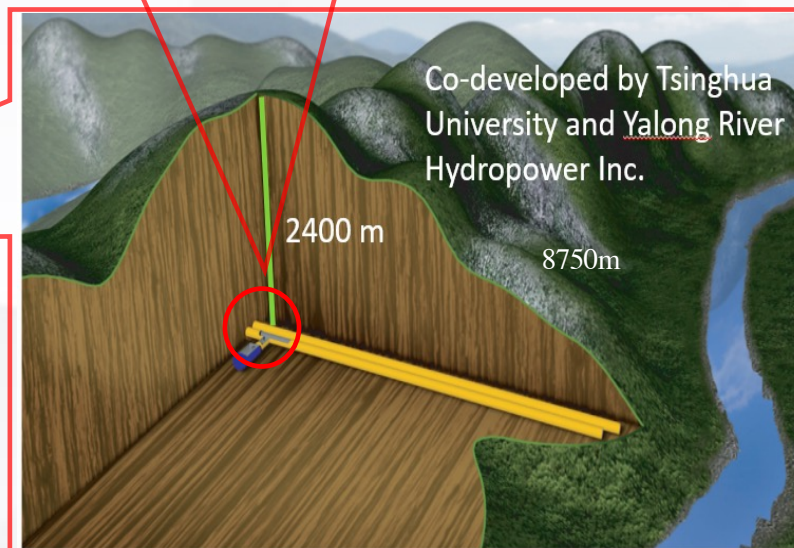
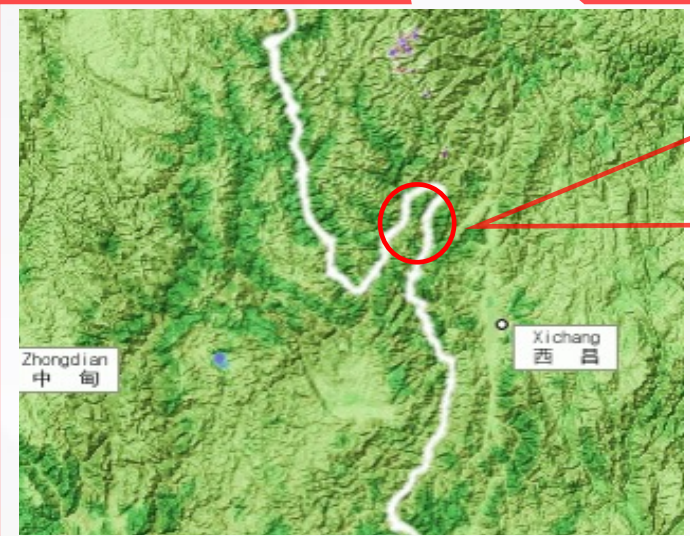
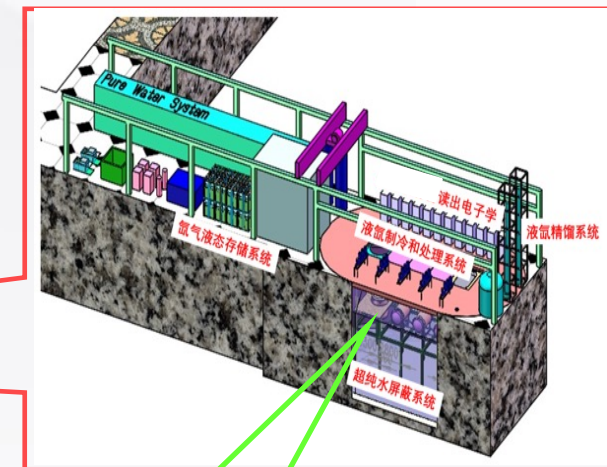
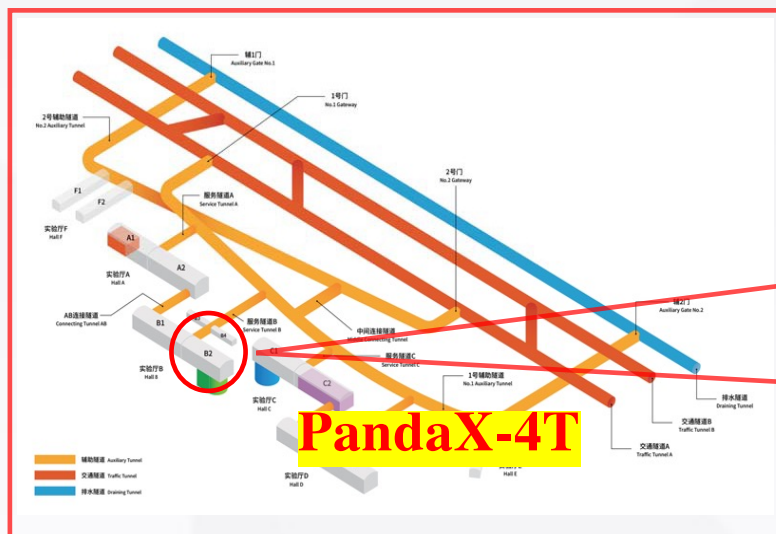
PandaX collaboration



- PandaX: **p**article **and** **a**strophysical **x**enon detector
 - dark matter, Majorana neutrino, astrophysical neutrino



PandaX @ CJPL-II



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Timeline of PandaX-4T Experiment



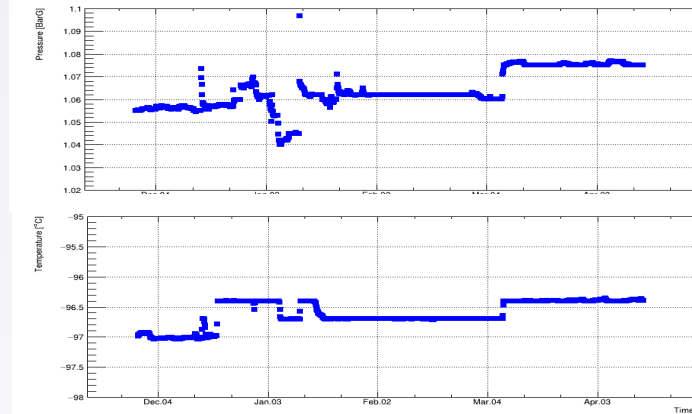
2020/11 – 2021/04	Commissioning (Run 0) 95 days
2021/07 – 2021/10	Tritium removal xenon distillation, gas flushing, etc
2021/11 – 2022/05	Physics run (Run 1) 164 days
2022/09 – 2023/12	CJPL B2 hall renovation xenon recuperation, detector upgrade
Current Status	Resuming physics data-taking



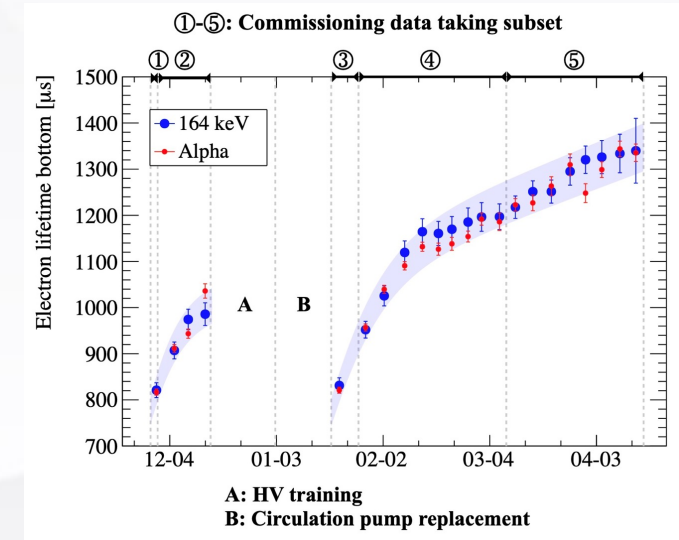
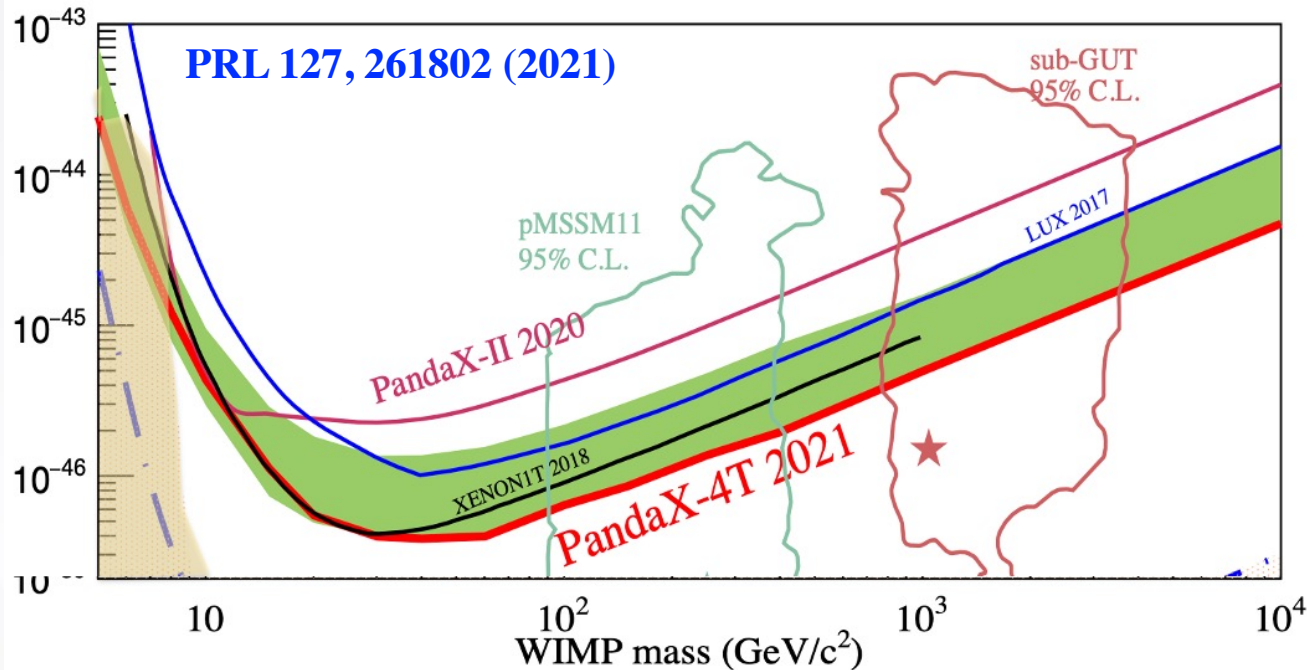
First WIMP Search Results



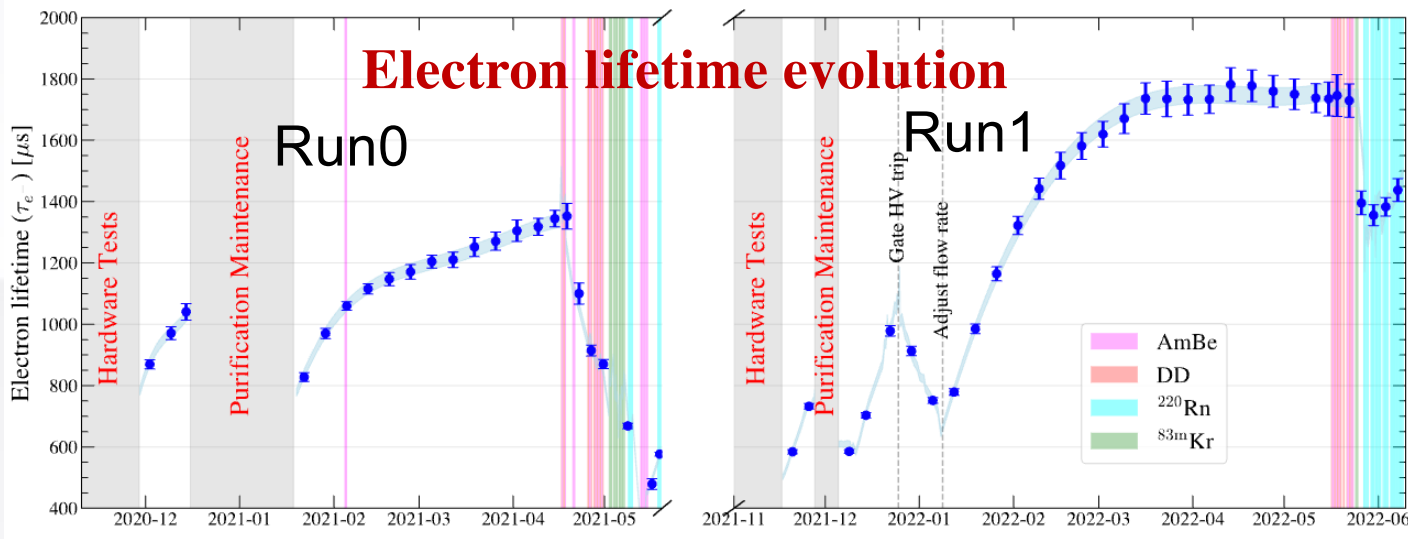
- ❑ Electron lifetime: *in situ* S2 vertical uniformity calibration
- ❑ Stable data running period: 95.0 calendar days (86 days after selection)
- ❑ Sensitive Volume: 3.7 tonne;
- ❑ Total exposure: 0.63 tonne-year;
- ❑ Limits on SI WIMP-nucleon cross section reach $3.8 \times 10^{-47} \text{cm}^2$



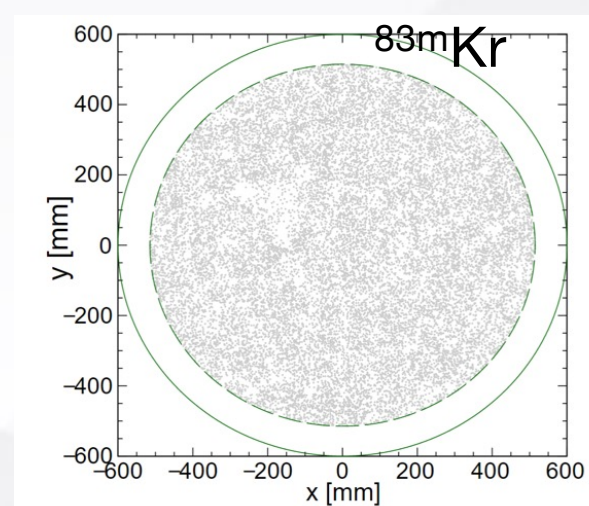
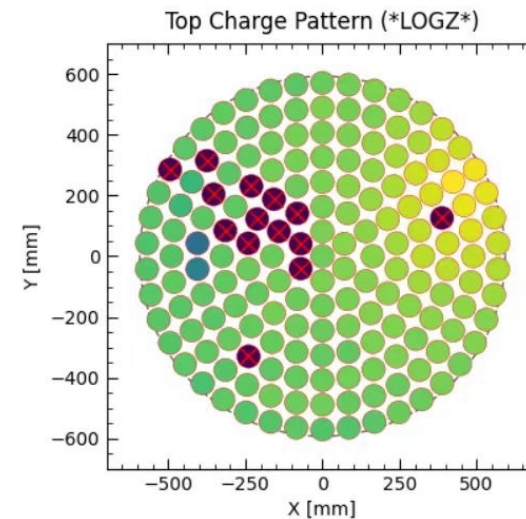
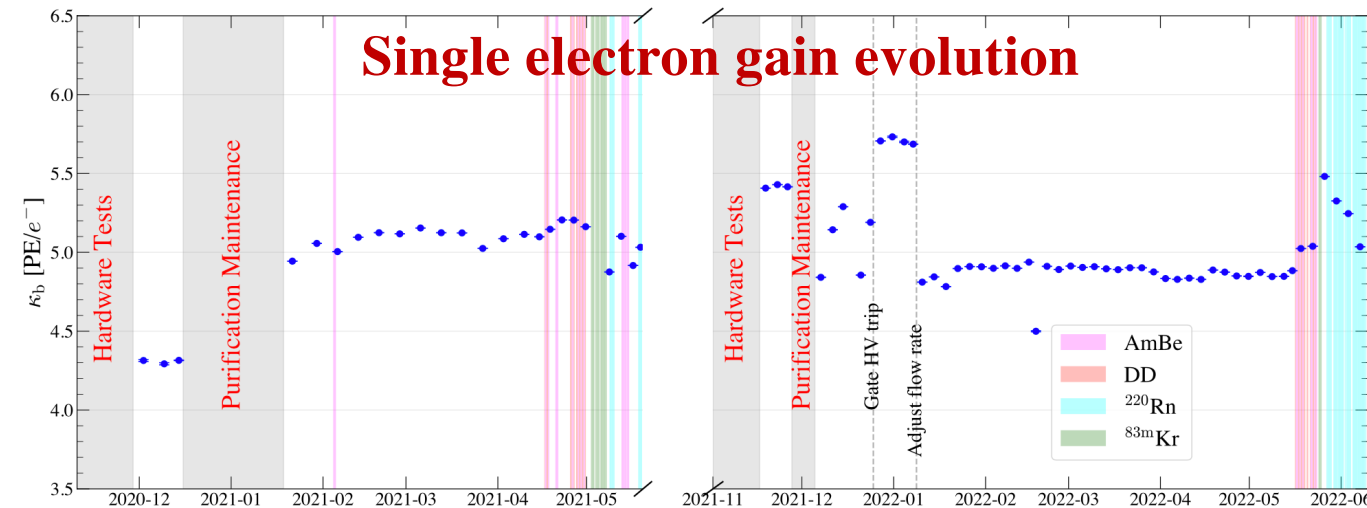
	Set1	Set2	Set3	Set4	Set5
Gate(kV)	-4.9	-5	-5	-5	-5
Cathode (kV)	-20	-18.6	-18	-16	-16



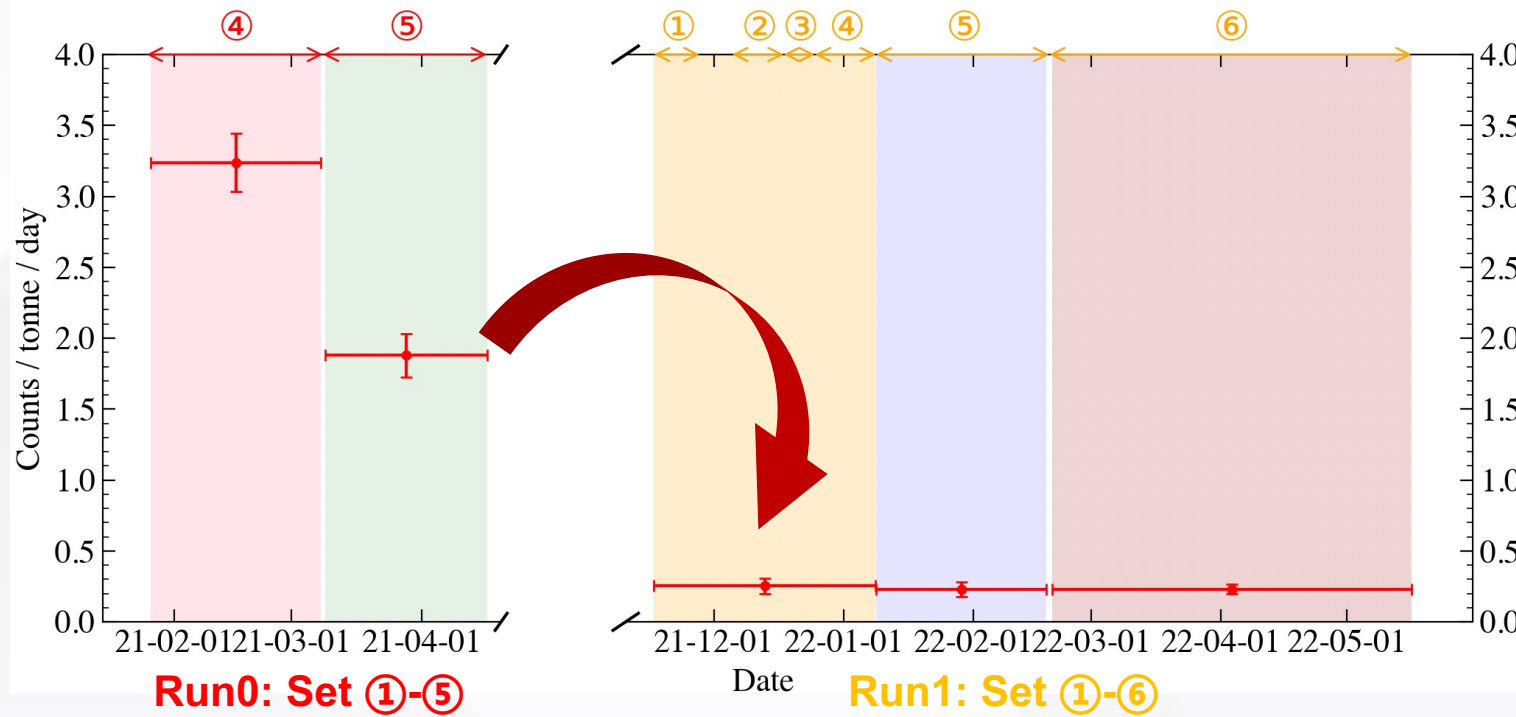
Data taking condition in Run1



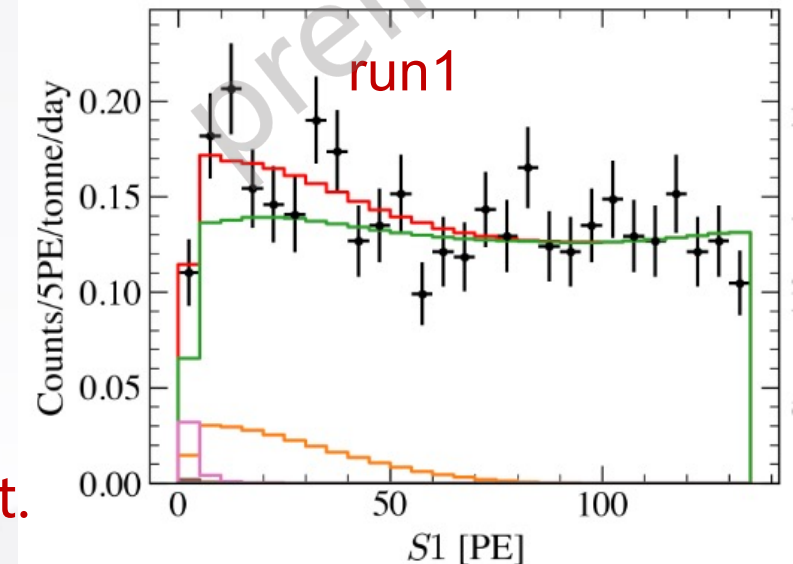
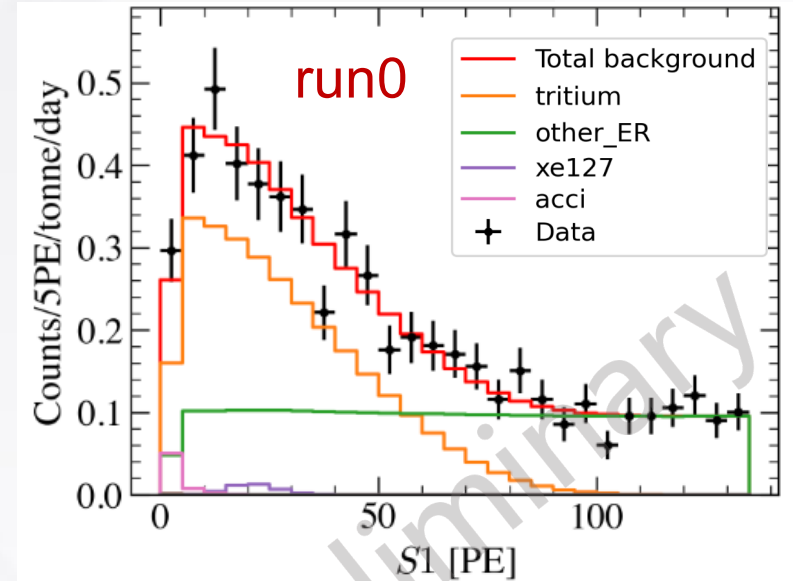
- Gate -6kV, Cathode -16kV
- E-lifetime monitoring through alpha events
 - maximum reaches 1800 us
- Failure of liquid level controlling; Dividing into 6 subsets accordingly
- Additional 10 top PMTs turned off;
- Near off-PMT region: dedicated selection cuts
 - Loosened Top/Bottom ratio, and pos. rec. quality requirement;
- Reconstruction refined (summarized in arXiv2403.04239)



Tritium Background



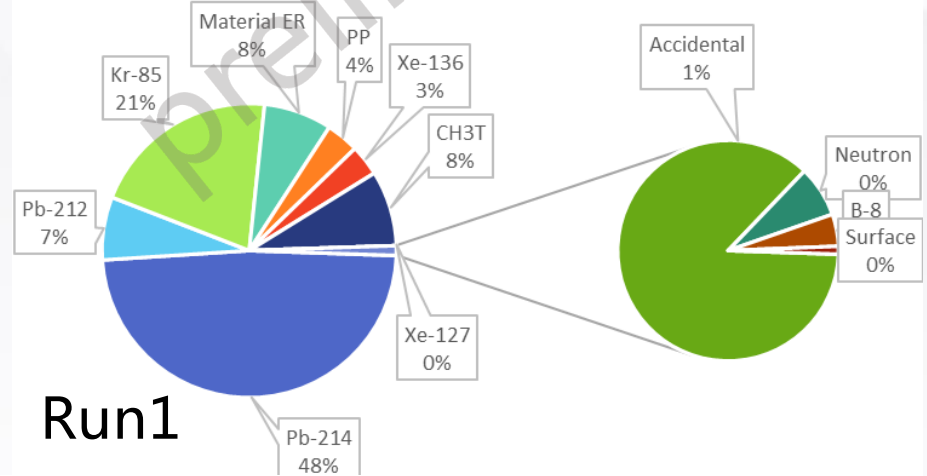
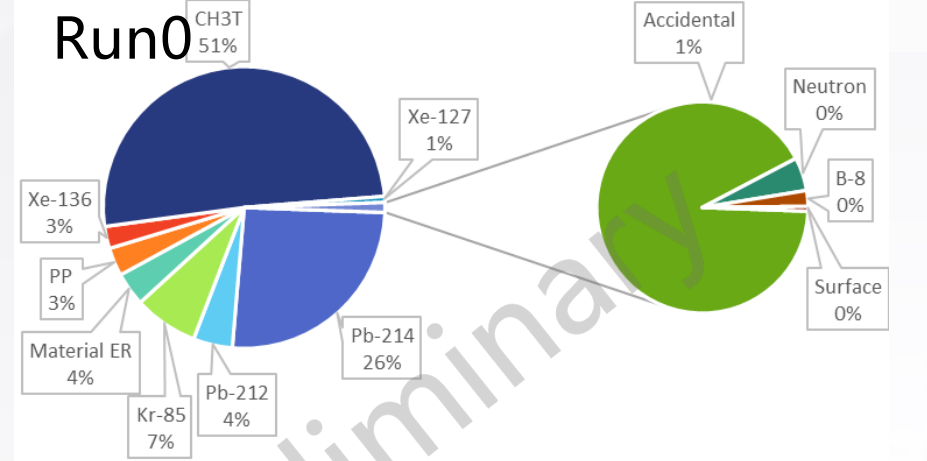
Dataset	Run0 Set4	Run0 Set5	Run1 Set1-4	Run1 Set5	Run1 Set6
Rate [tonne/day]	3.24 ± 0.20	1.88 ± 0.15	0.25 ± 0.05	0.23 ± 0.05	0.23 ± 0.03



CH3T rates significantly decreased, estimated from S1 fit.

Background composition

	Run0	Run1	Total	Below NR median	Best fit
^{214}Pb	281 ± 13	675 ± 35	956 ± 38	$3.6^{+0.9}_{-0.7}$	-
^{212}Pb	49 ± 13	97 ± 25	146 ± 30	$0.6^{+0.2}_{-0.2}$	-
^{85}Kr	80 ± 40	289 ± 88	369 ± 96	$1.4^{+0.5}_{-0.5}$	-
Material ER	42 ± 5	105 ± 11	147 ± 12	$0.6^{+0.2}_{-0.1}$	-
Solar ν	37.5 ± 3.8	73.7 ± 7.4	111.2 ± 8.3	$0.42^{+0.10}_{-0.08}$	-
^{136}Xe	27.8 ± 1.4	59.3 ± 3.1	87.0 ± 3.4	$0.16^{+0.05}_{-0.03}$	-
Other ER (data)	504 ± 16	1226 ± 28	1730 ± 32	$6.4^{+1.7}_{-1.2}$	1767 ± 39
CH ₃ T	556 ± 33	114 ± 33	670 ± 47	$5.2^{+1.2}_{-1.1}$	677 ± 47
^{127}Xe	7.65 ± 0.77	0.02 ± 0.00	7.67 ± 0.77	$0.10^{+0.02}_{-0.02}$	7.69 ± 0.17
^{124}Xe	2.26 ± 0.61	4.05 ± 1.09	6.31 ± 1.70	$0.03^{+0.01}_{-0.01}$	6.25 ± 1.68
Neutron	0.63 ± 0.18	1.10 ± 0.24	1.73 ± 0.30	$1.04^{+0.13}_{-0.13}$	1.75 ± 0.28
$^8\text{B CE}\nu\text{NS}$	0.31 ± 0.03	0.69 ± 0.07	0.99 ± 0.08	$0.98^{+0.30}_{-0.30}$	1.10 ± 0.33
Surface	0.09 ± 0.06	0.17 ± 0.11	0.26 ± 0.12	$0.26^{+0.12}_{-0.12}$	0.25 ± 0.11
Accidental	11.3 ± 3.4	12.7 ± 3.8	24.0 ± 5.1	$6.42^{+1.36}_{-1.36}$	25.7 ± 5.2
Sum	1079 ± 37	1355 ± 43	2434 ± 43	$20.5^{+2.5}_{-2.2}$	2487 ± 56
Observed	1117	1373	2490	24	-

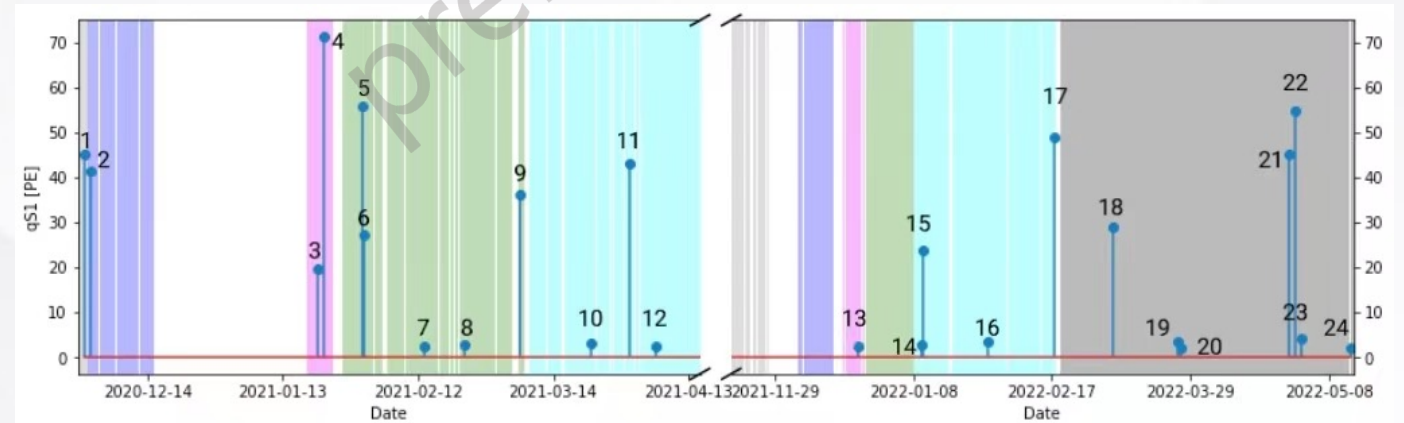
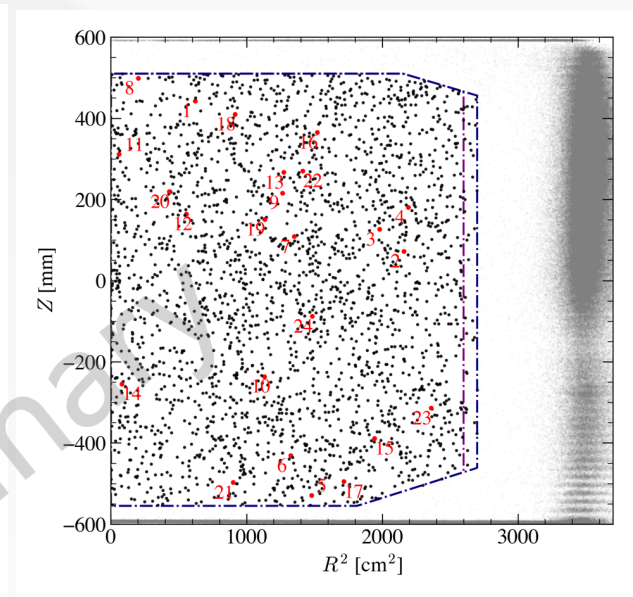
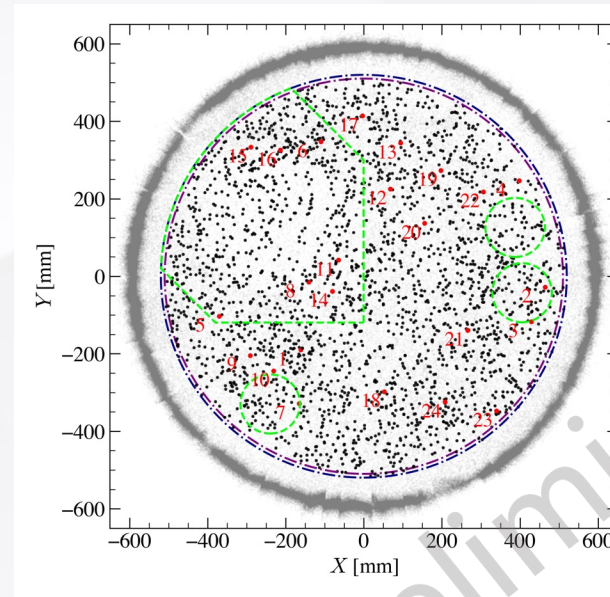
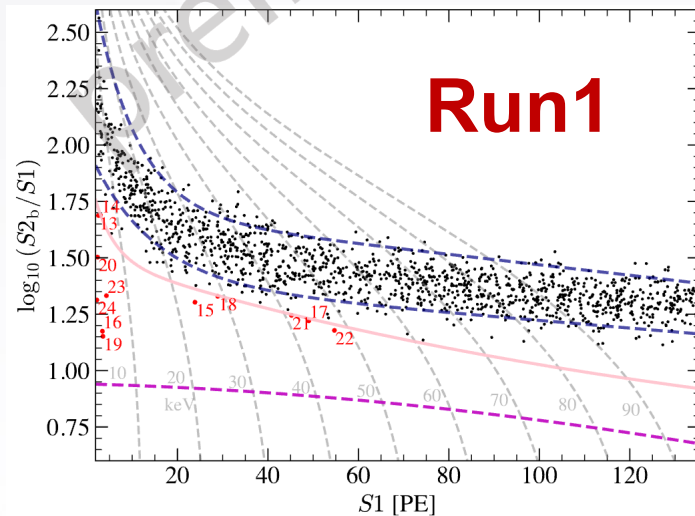
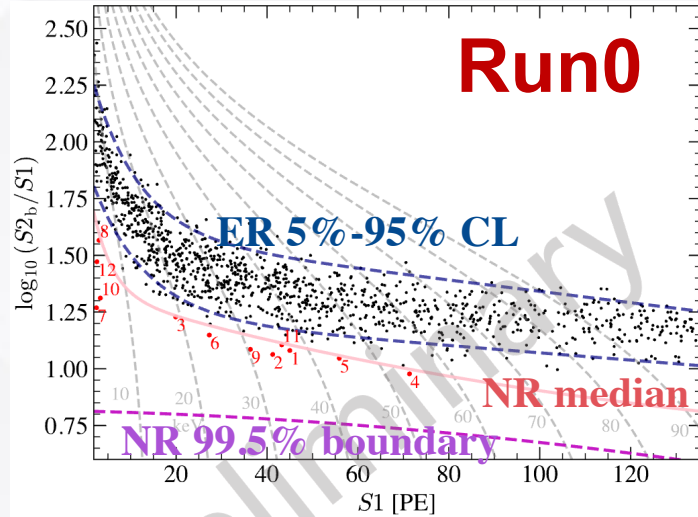


- CH3T dominate in Run0;
- After tritium removal, Pb214 and Kr85 are the dominant bkg components in Run1;



Unblinded Data

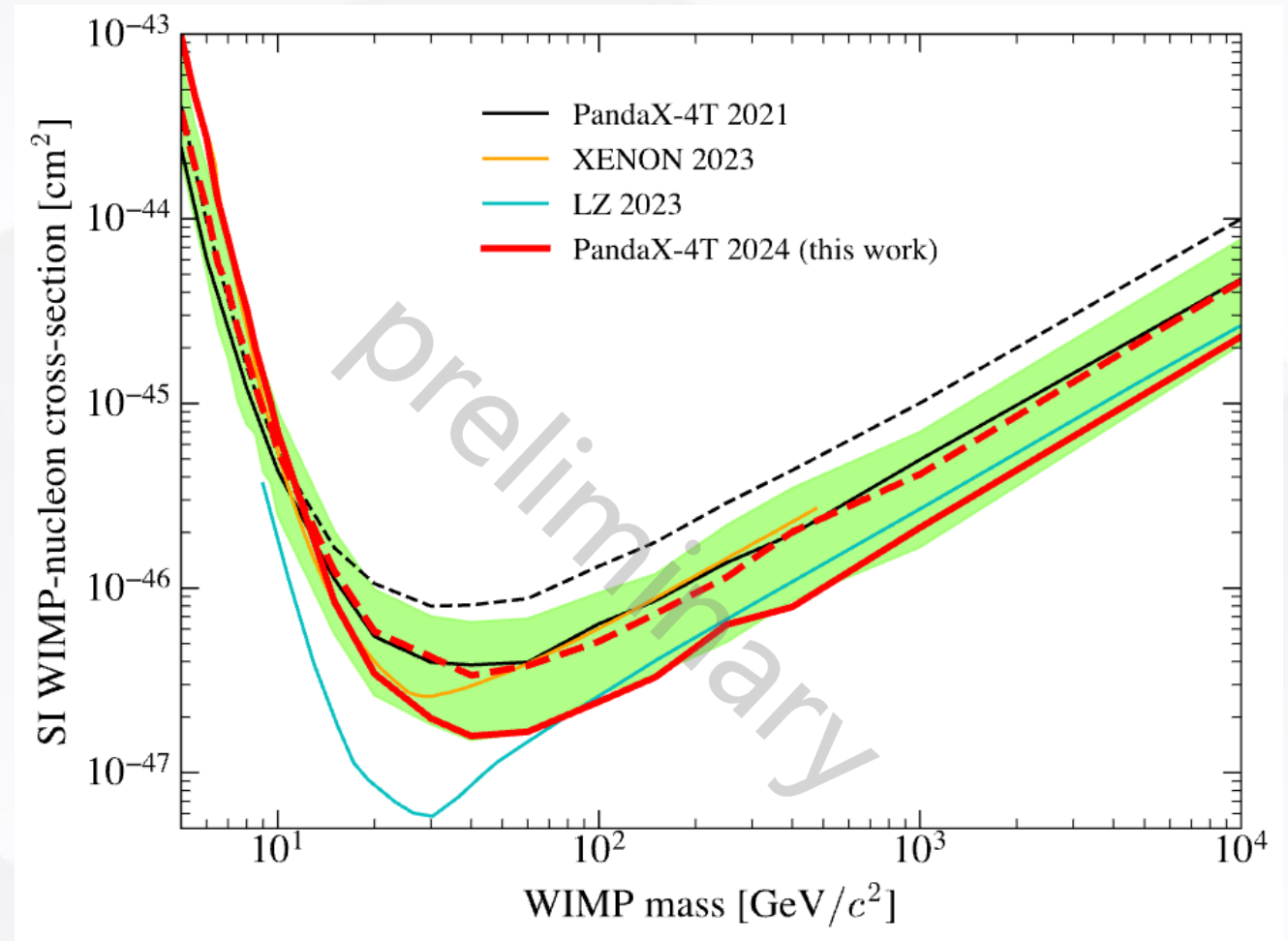
- 24 (12+12) in Ref. region while expecting 20;
- Spatially and Timely uniformly distributed;



Constraint to WIMP



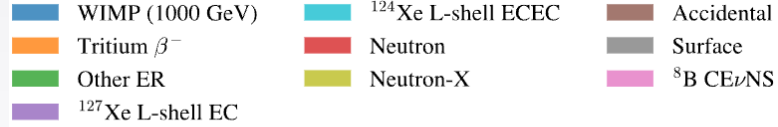
- Blind analysis using Run0+1, total exposure = **1.54** tonne-year;
- No significant excess;
- 1σ upward fluctuation with $<8\text{GeV}$;
- Downward fluctuation in high-mass region;
- Best constraint $> 100\text{GeV}$;
- **$1.6e-47 \text{ cm}^2 @ 40\text{GeV}$.**



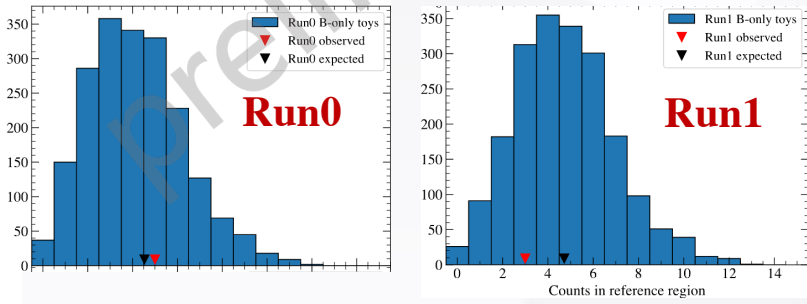
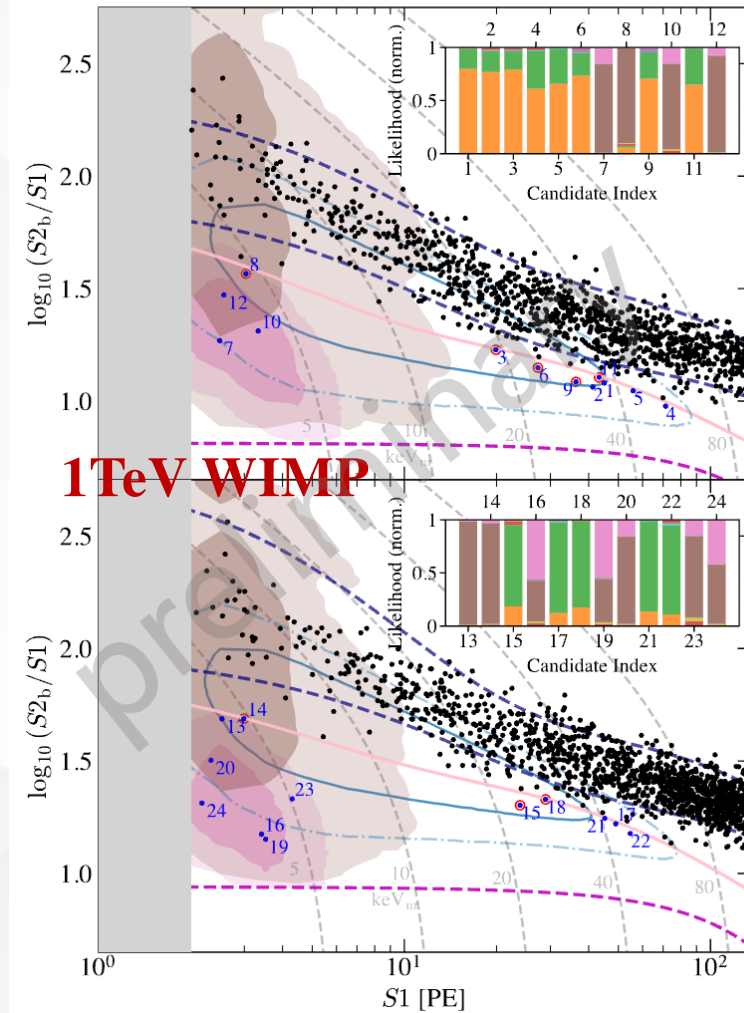
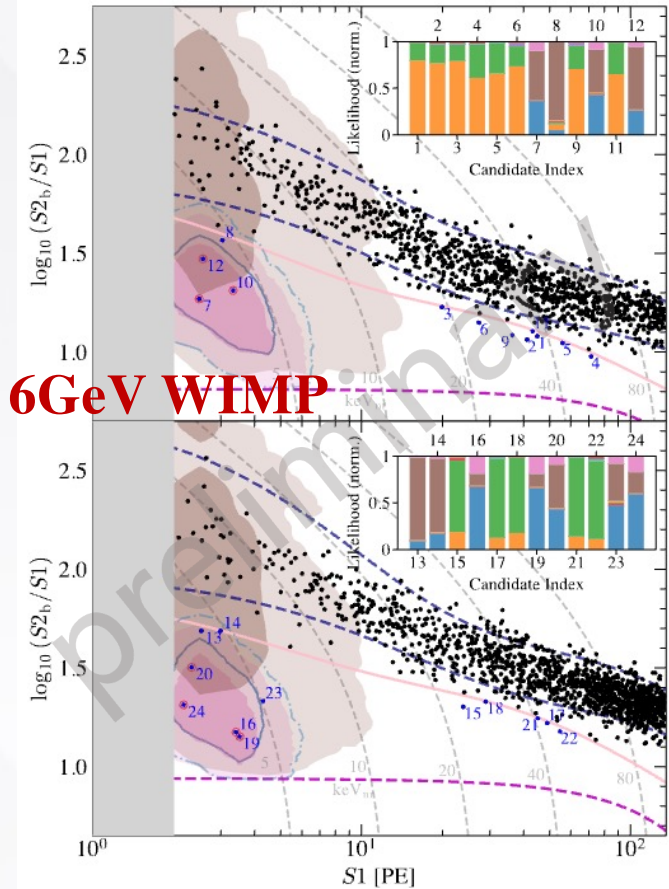
More close look at Ref. region



$S1 < 5P_E$		AC	B8	Bkg	Obs
	Run0	2.2±0.4	0.28±0.02	2.7±0.4	4
	Run1	2.8±0.5	0.65±0.04	3.6±0.5	7



Below NR median	Inside 1000 GeV/c ² WIMP 1 σ contour		
	Expected	Observed	Toy Median
Run0	4.531	5	4.163
Run1	4.716	3	4.741



- In 1 σ & ref. region of 1 TeV WIMP, Run0 and Run1 see upward and downward, respectively;
- Run1 dominates the limit, the downward tendency is about 1 σ , consistent with limit vs. sensitivity;

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PandaX-4T DM search experiment

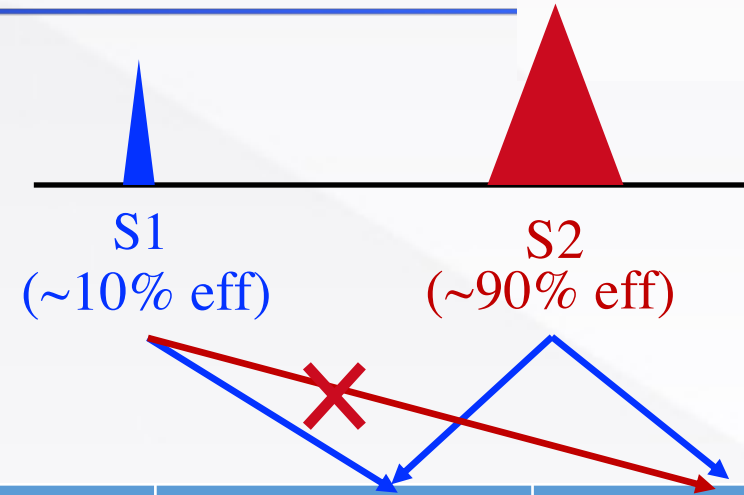
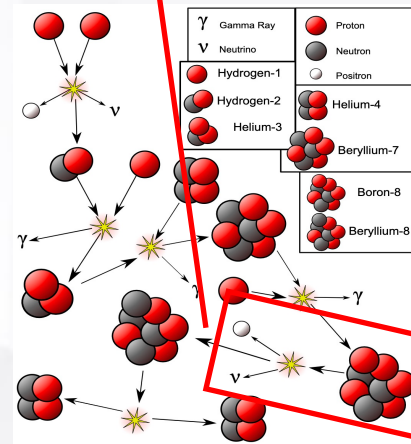
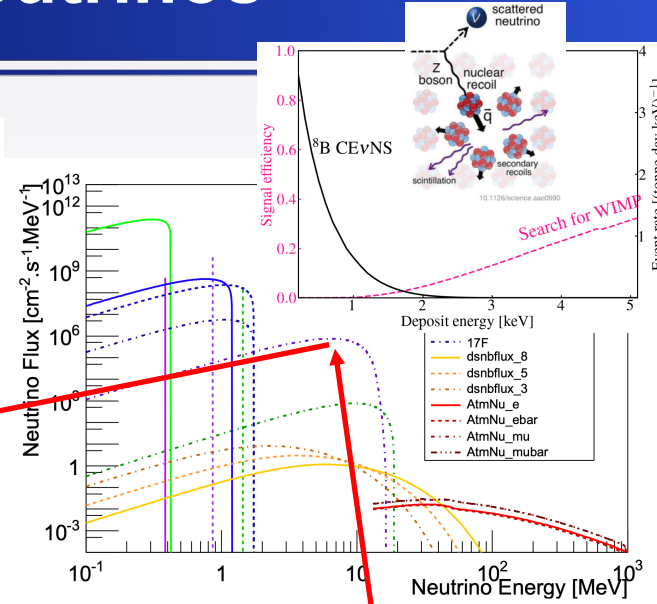
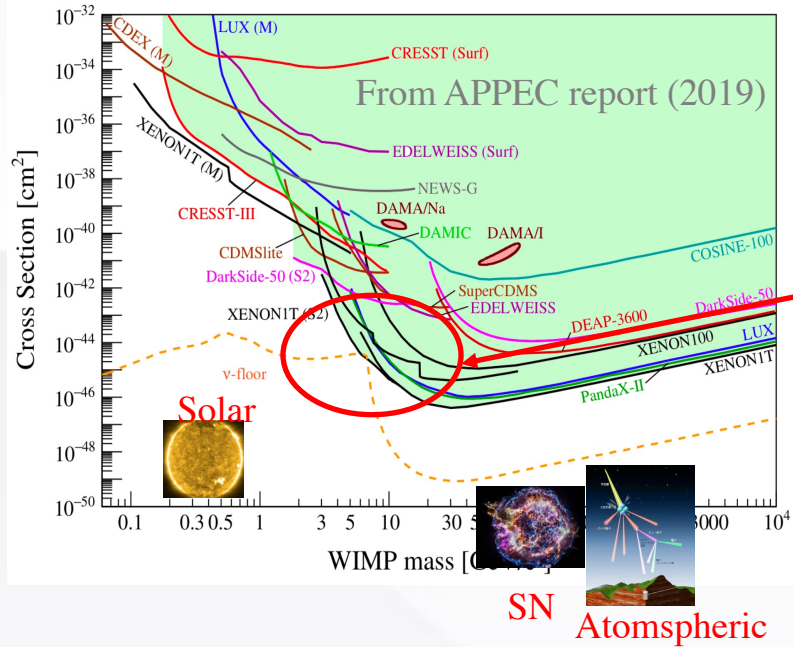
02

Status of WIMP searches

03

Status of B8 CEvNS search

Search for solar neutrinos



	Paired	S2only
ROI	2or3 hit, 60<S2<300PE	4-8 e-
Energy range	~0.8-1.8 keVnr	~0.4-1.2keVnr
B8 CEvNS Rate	Low	High
Bkg rate	Low	High
Effective Exposure	1.25 tonne-year	1.04 tonne-year

- PandaX-4T searches for solar B8 CEvNS with lowered threshold;
- Large amount of **background** emerged with lowered threshold;
- Two data regions used: **Paired and S2-only**;

AC background in Paired data and unblinded results



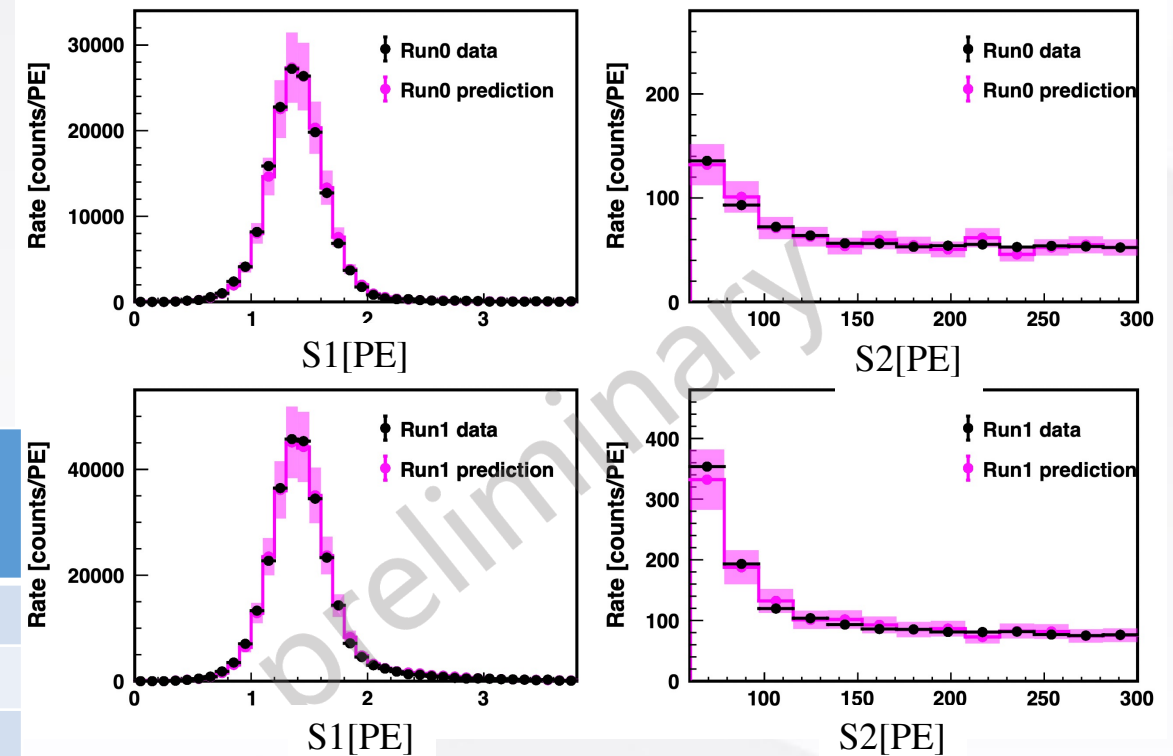
- Randomly pair isolated S1 and S2 waveforms as AC sample waveforms;
- Off-window, 10% open data (OD), and 1-hit sideband for AC validation;
- Off-window events are those with drift time larger than maximum allowed by the TPC height;
- Cut-and-count BDT selection with more variables given in BDT;

		Run0		Run1	
		WO BDT	W. BDT	WO BDT	W. BDT
Off-window	Model	209±25	1.2±0.4	485±43	0
	Data	209	1	495	2
OD	Model	26±6	0.12±0.04	34±7	0.06±0.02
	Data	18	0	29	0
1-hit side-band	Model	17095±2564	14±4	27567±4135	15±5
	Data	17374	9	29359	17

Unblinded data

	Other (surface, ER, etc)	AC	Total bkg	B8 CEvNS	Obs.
2-hit Run0	0.08±0.01	1.08±0.28	1.16±0.28	1.17±0.39	1
3-hit Run0	0.09±0.01	0.07±0.02	0.16±0.02	0.29±0.10	0
2-hit Run1	0.07±0.01	1.15±0.35	1.23±0.35	2.21±0.68	2
3-hit Run1	0.06±0.02	0.24±0.08	0.30±0.08	0.53±0.19	0

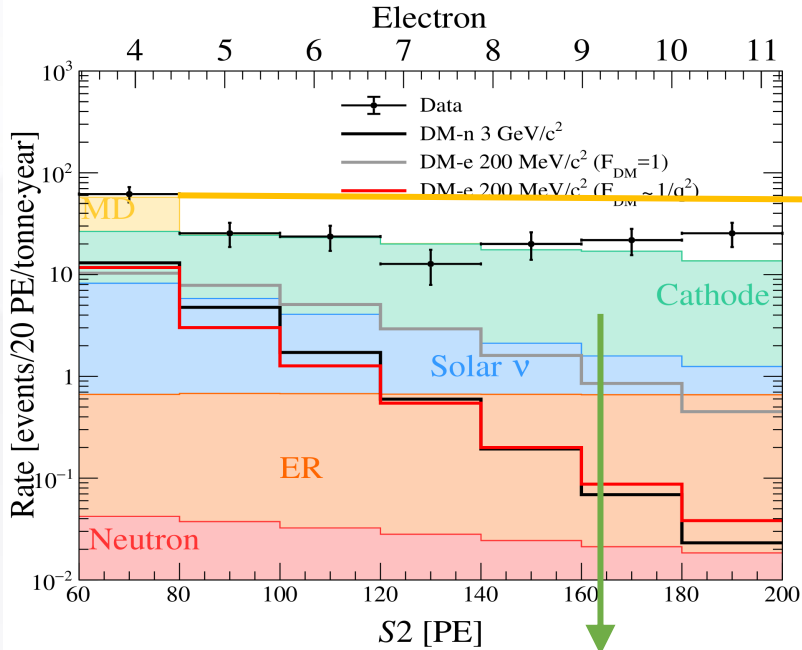
1-hit sideband



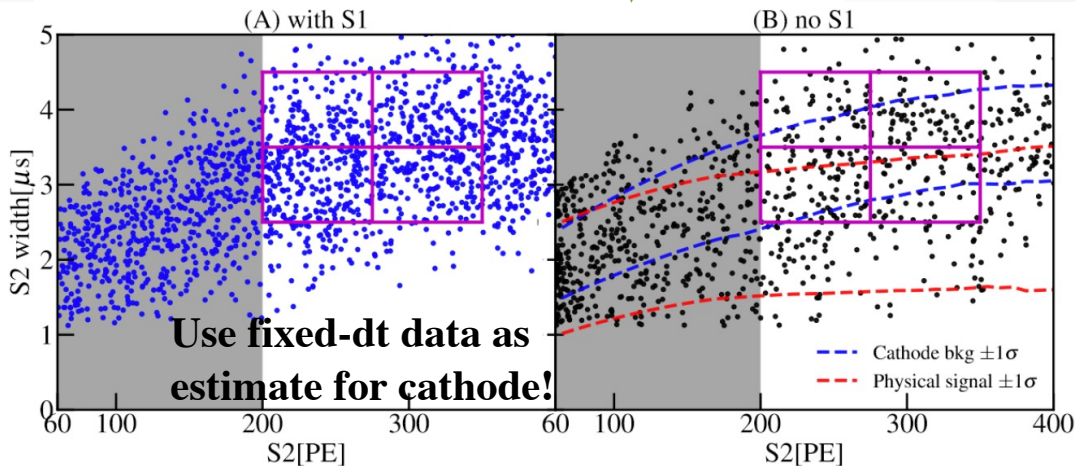
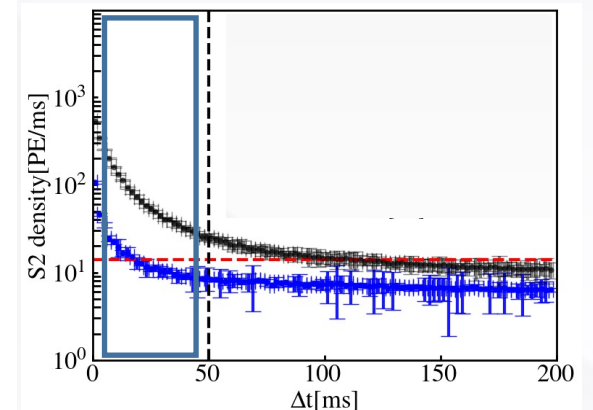
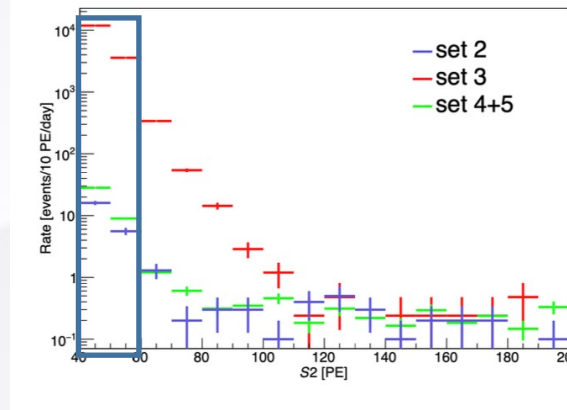
Cathode & “MD” background in S2-only



Run0 as example (PRL 130, 261001)



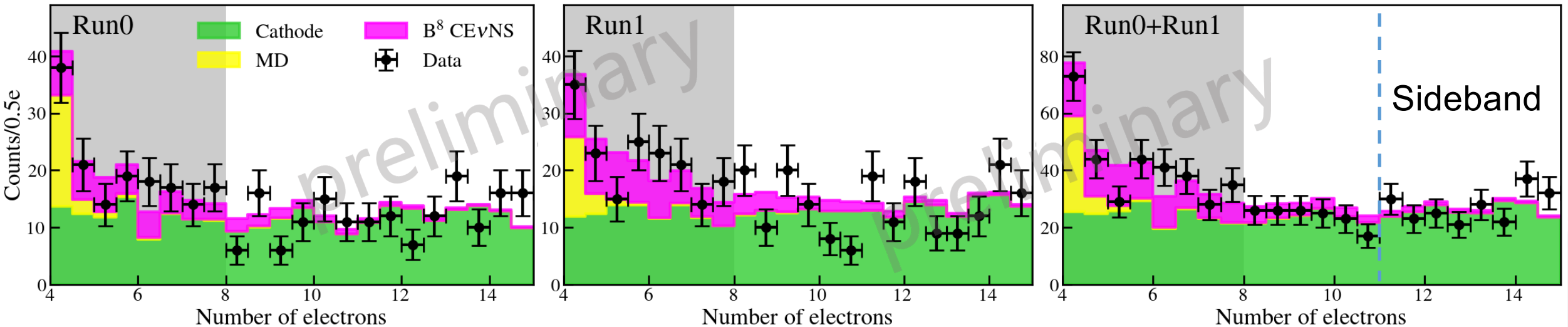
Use events with small S2 and timely close to previous large S2 as sideband



- Cathode spectral shape is estimated using cathode sample with S1, rate estimated using sideband;
- MD spectral shape is estimated using events timely close to large S2;
- MD rate is estimated using small-S2 sideband;

More details in Shuaijie Li's talk on Wednesday

Unblind the S2-only data



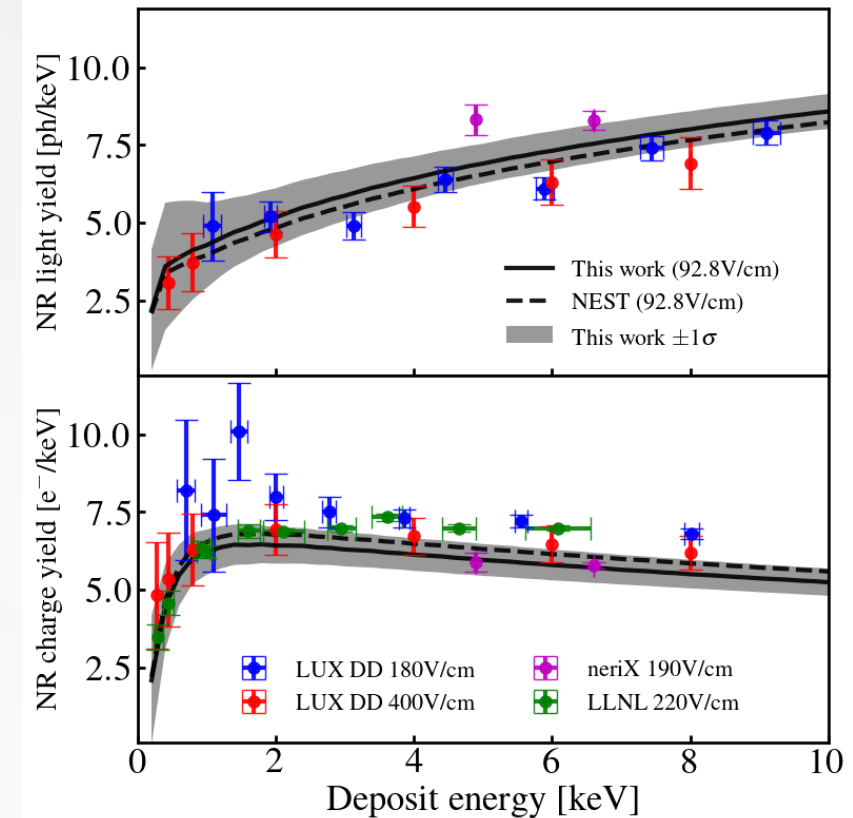
- Run0+1 seem to see an excess in S2-only data, but a downward fluctuation in paired data!
- S2only fit shows a best-fit B8 rate larger than expectation: $\mu_{B8} = 1.8 \pm 0.8$;
- S2only background-only hypothesis $p\text{-value} = 0.003$;

Systematic Uncertainties

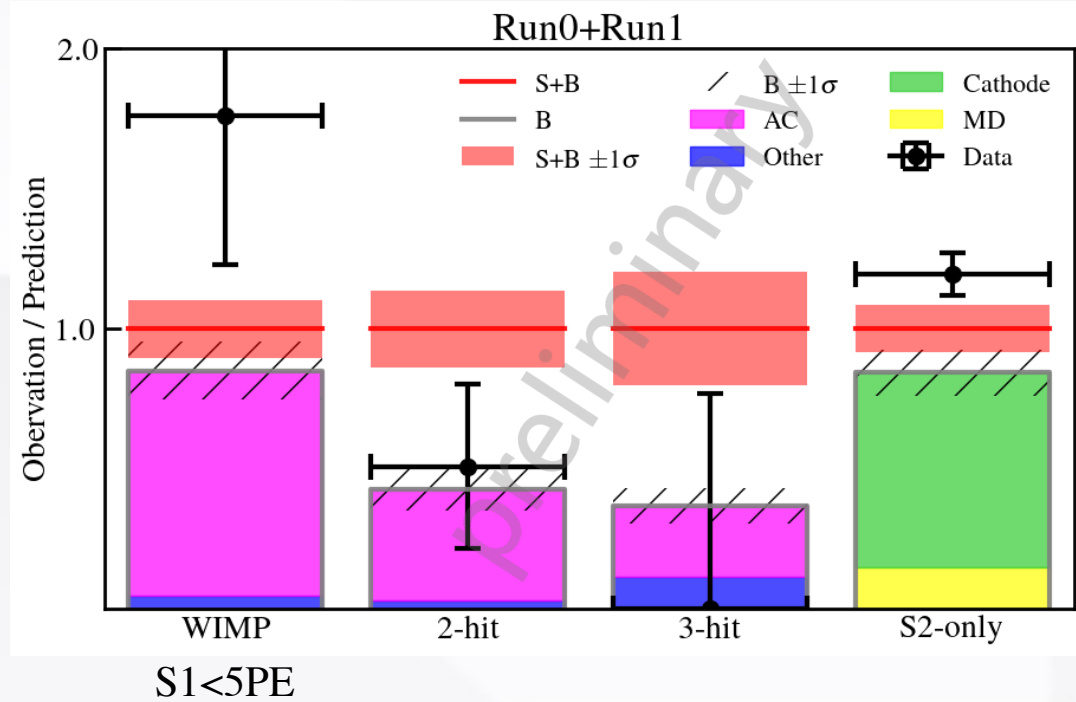


Nuisance parameters	Stdev./Nominal						Estimated by
	Paired				US2		
	Run0	Run1	Run0	Run1	Run0	Run1	
Selection	0.10	0.10	0.11	0.17	-	-	WS vs. DS
BDT to ^8B CE ν NS	0.17	0.11	-	-	-	-	WS vs. DS
Light/charge production	0.24	0.37	0.28	0.44	0.17	0.16	Average in ROI based on NEST
AC model	0.15	0.15	-	-	-	-	WS vs. control samples
BDT to AC	0.14	0.23	-	-	-	-	WS vs. control samples
Cathode model	-	-	-	-	0.24	0.20	Varying side-band selection
MD model	-	-	-	-	0.13	0.16	Varying side-band selection

- Uncertainties of selection, BDT, AC model, and LY/CY are included in paired data;
- Uncertainties of selection, cathode, MD, and LY/CY are included in S2only data;
- Uncertainties are given by MC vs real data, and varied control selection;



Searching for B8 combining S2-only and paired data



	Background-only p-value	Best-fit / Theoretical prediction
S2-only	0.003	1.8+/-0.8
Paired & S2only combined	0.105	0.8+/-0.7

- 1D fitting on S2 spectra for S2-only;
- Signal uncertainty is assumed to be anti-correlated between paired and S2only data;
- **2D fitting on S2 vs width space is ongoing!**

- Preliminary results of blind WIMP analysis on the Run0 and Run1 combined data;
- Upward fluctuation in $<8\text{GeV}$; Best constraint for $>100\text{GeV}$;
- Preliminary results of B8 CEvNS search using Run0+1 and S1-S2 paired/S2-only combined analysis;
- S2-only sees slight sign of B8 signal; Energy vs width fitting is ongoing!
- Next stage of PandaX (PandaX-20T) is expected to be online in 2027!

Thank You for your attention !