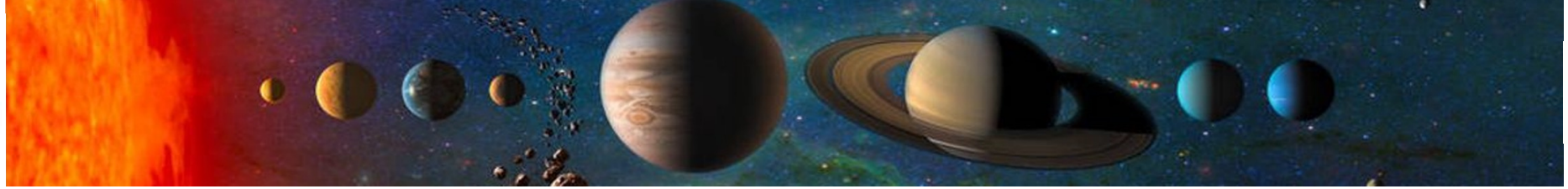

Accidental pileup and low-S2 background in PandaX-4T

Speaker：Qing Lin

(On behalf of PandaX collaboration)

University of Science and Technology of China

@ Nagoya Workshop, 2024.02.15

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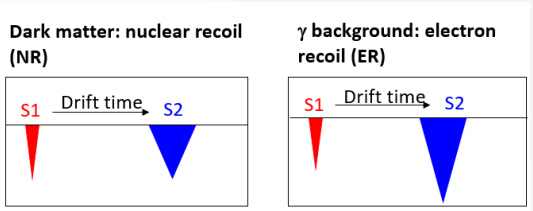
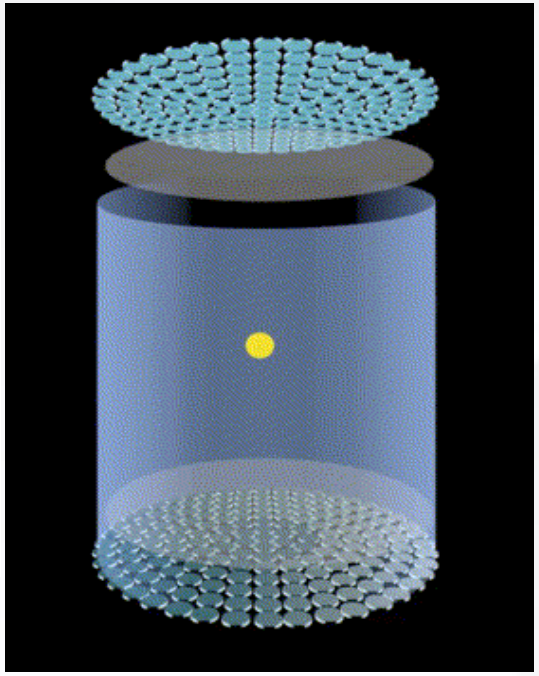
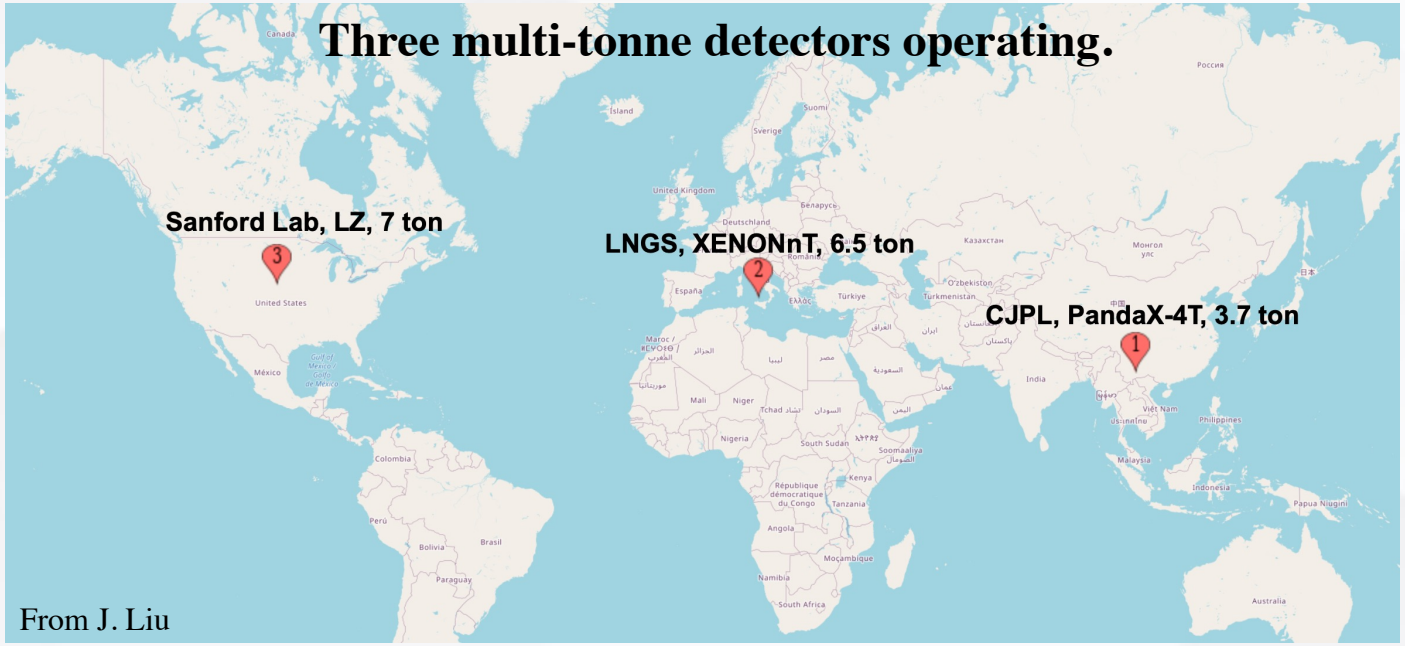
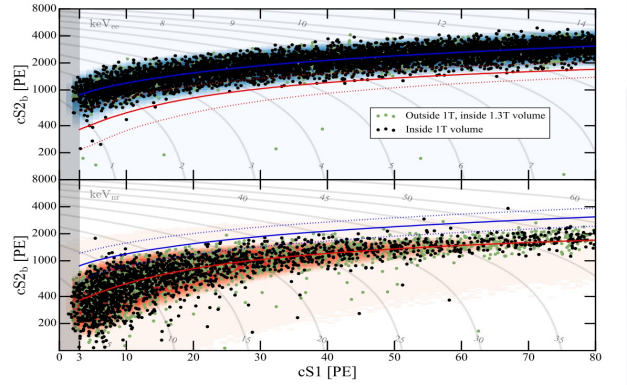
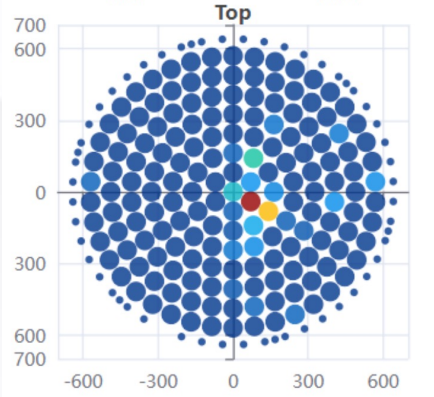
Dual phase xenon TPC





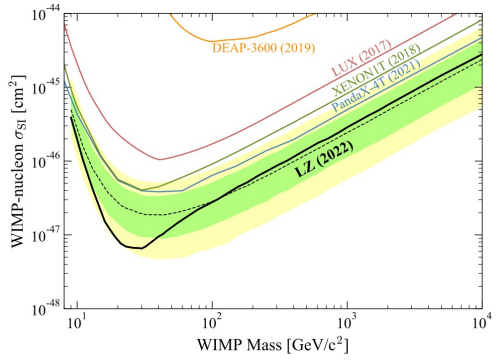






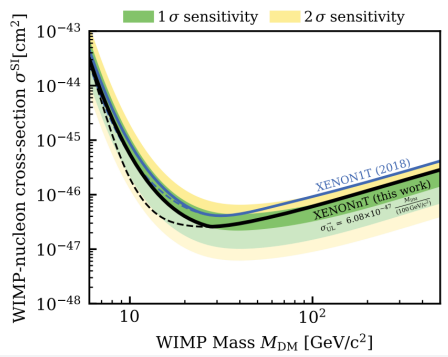
LZ

PRL 131, 041002 (2023)



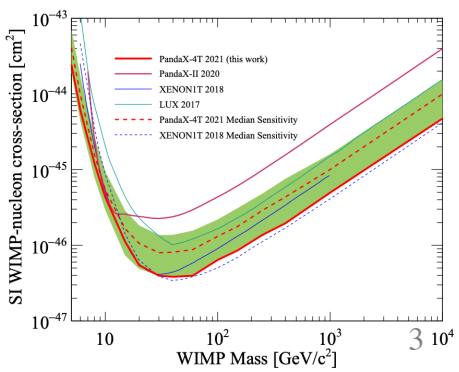
XENONnT

PRL 131, 041003 (2023)



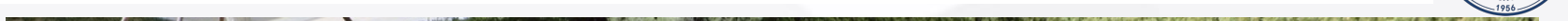
PandaX-4T

PRL 127, 261802 (2021)



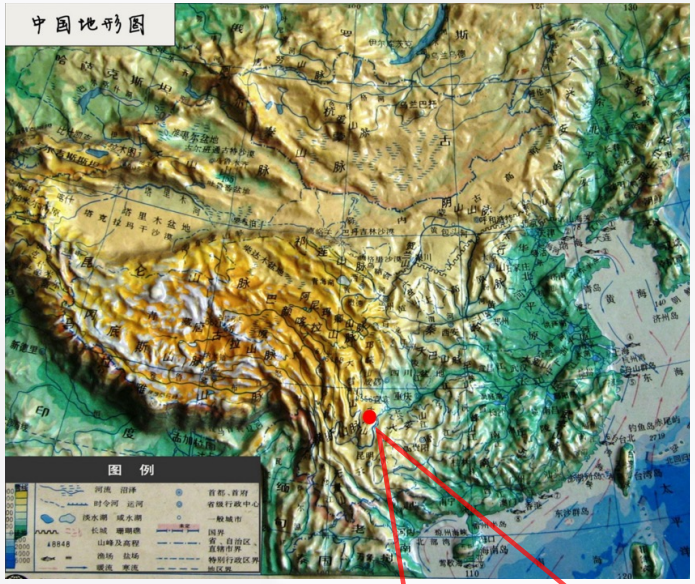
PandaX collaboration

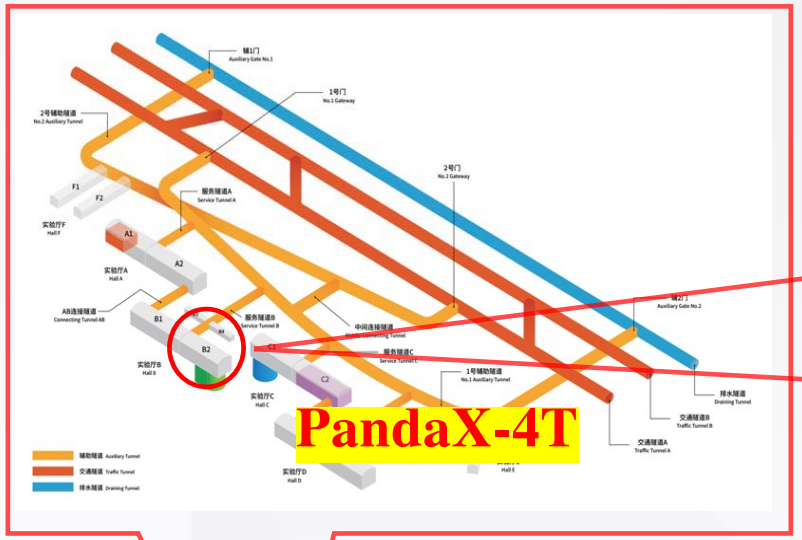
- PandaX: **particle and astrophysical xenon detector**
  - dark matter, Majorana neutrino, astrophysical neutrino

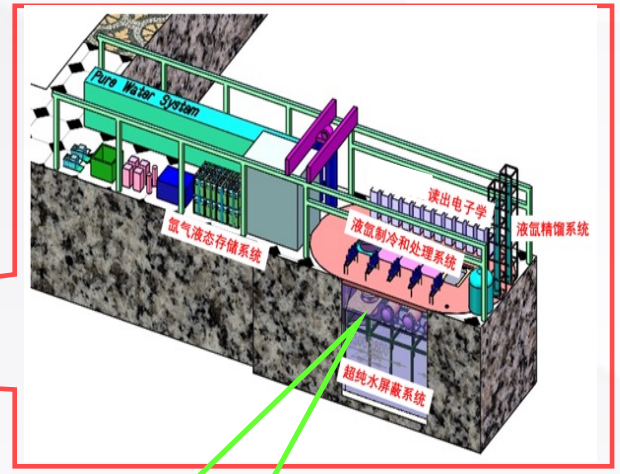


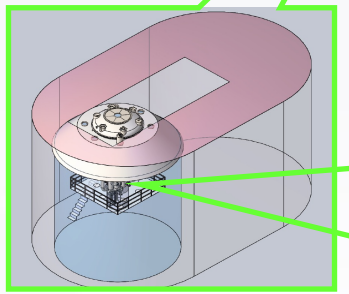
54
Xe
Xenon
131.29

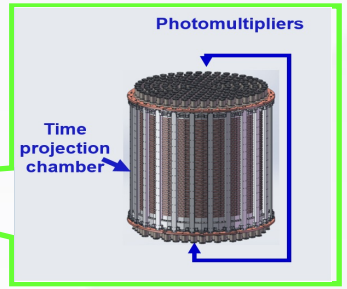
PandaX @ CJPL

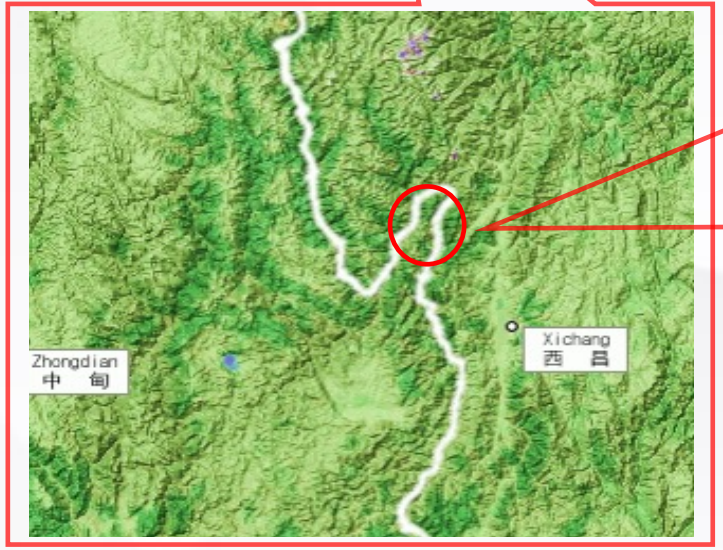

中国地形图
图 例

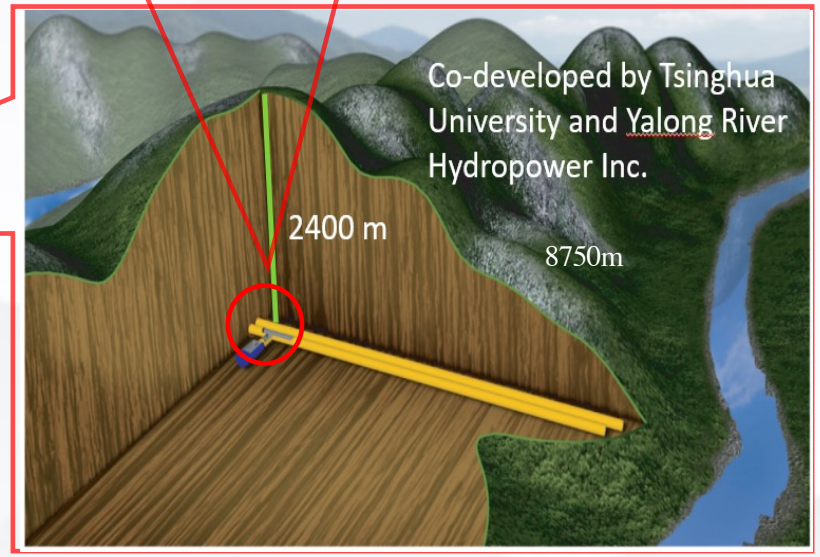

PandaX-4T

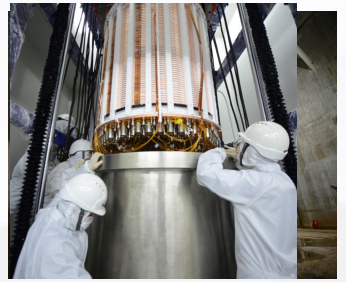

Pure Water System
氙气液态存储系统
液氙制冷和处理系统
超纯水屏蔽系统
液氙精馏系统

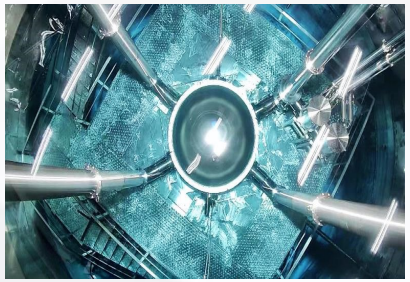



Photomultipliers
Time projection chamber

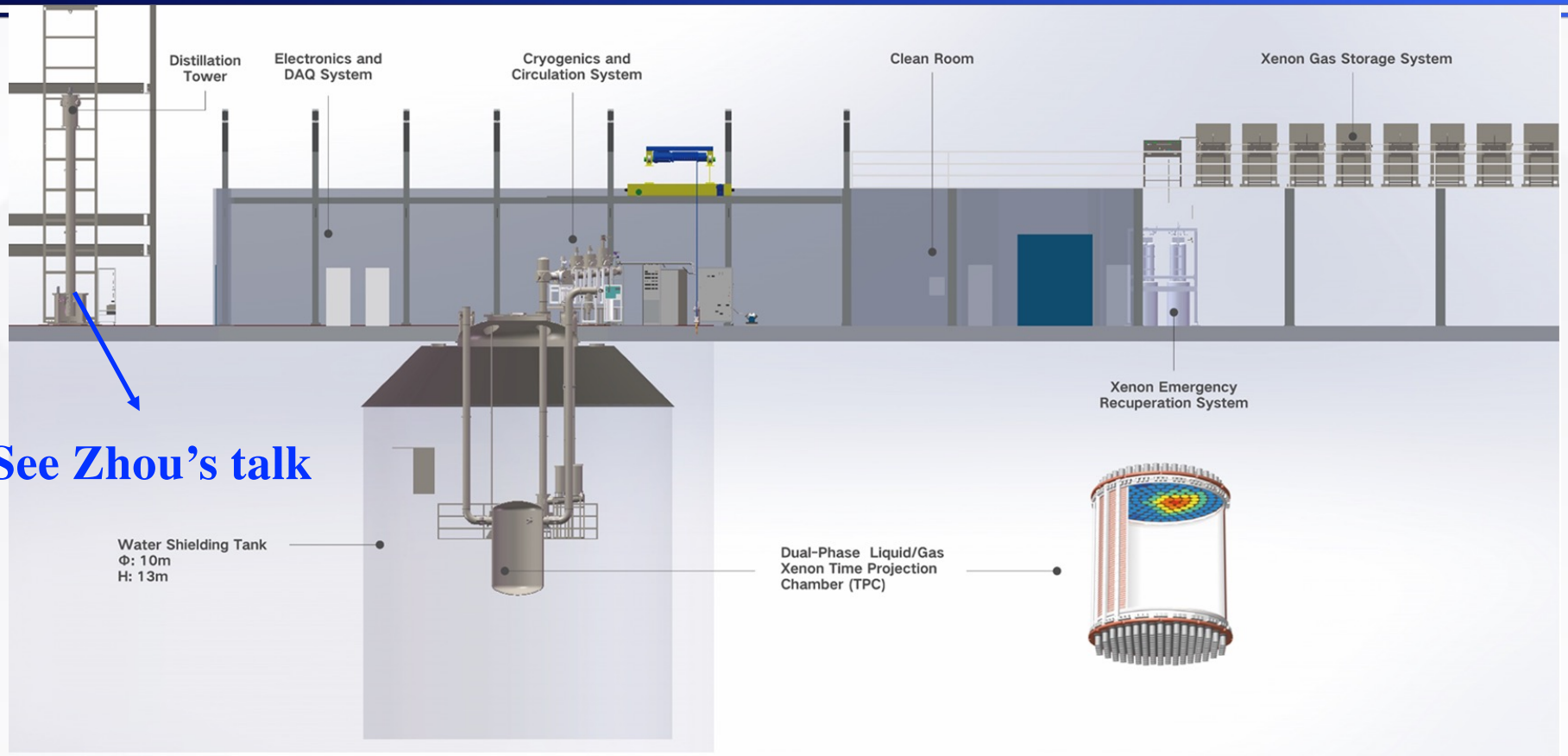

Zhongdian
中 甸
Xichang
西 昌


Co-developed by Tsinghua University and Yalong River Hydropower Inc.
2400 m
8750m

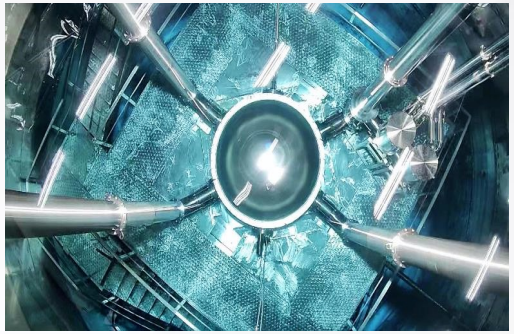




PandaX-4T systems



See Zhou's talk



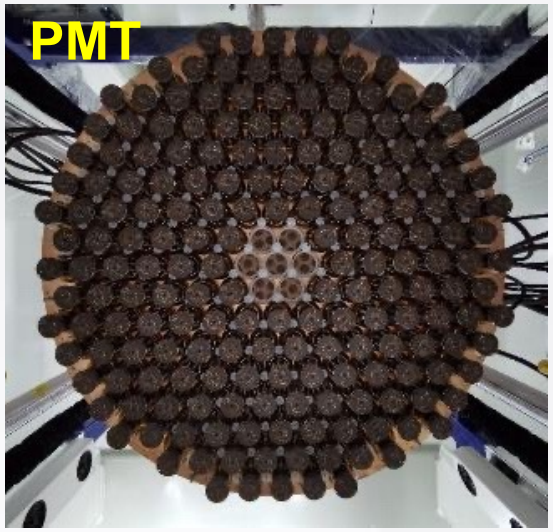
- ❑ Ultrapure water shield: 13 m (H) x 10 m (D) ~ 900 m^3
- ❑ TPC: 1.2 m (H) x 1.2 m (D)
- ❑ 3-in PMTs: 169 top/199 bottom

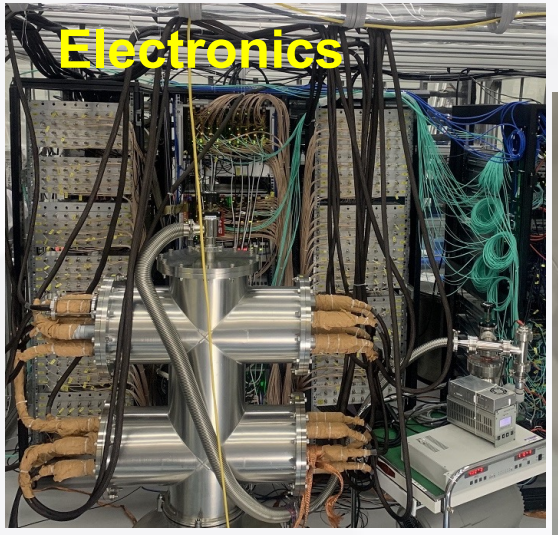
See Lingyin's talk

- Sensitive volume: 3.7-tonne LXe

Some Pic

Some Pic of the subsystems





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02 First data from PandaX-4T

03 Accidental pileup & Single electron

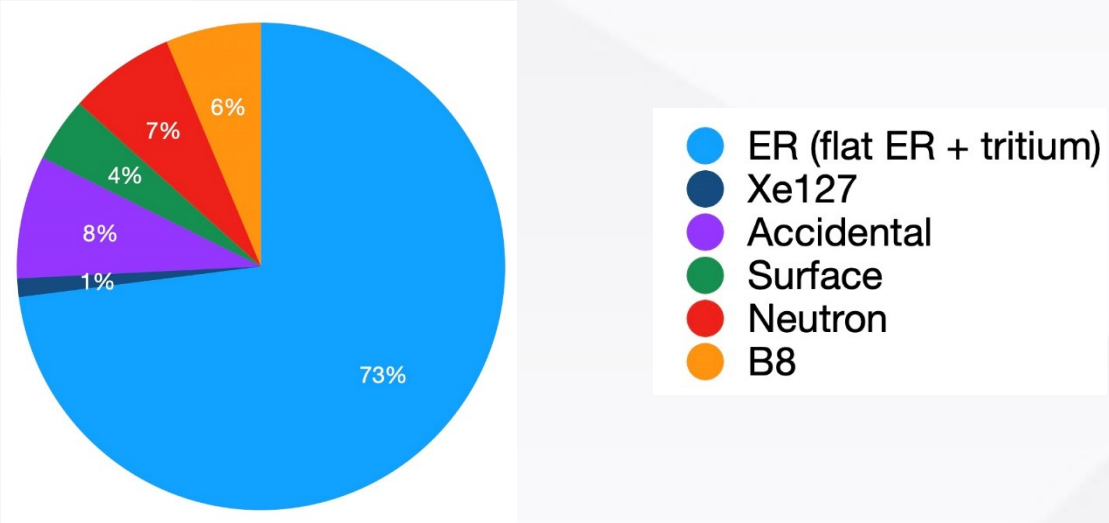
Timeline of PandaX-4T

- Apr. 2, 2018, permission from CJPL management to start construction in B2 hall
- Aug. 19, 2019, infrastructure completed, detector installation in CJPL-II started
- Mar 6, 2020, offline distillation of xenon completed
- May 28, 2020, installation completed
- Nov. 28, 2020 – Apr. 16, 2021, commissioning run (**Run0**)
- **2021 Summer:** Tritium removal
- **2021/11 – 2022/05: physics run (Run1)**
  - 164 days: ~ 1 tonne-year
- **2022/09** - 2023/12: hall construction
  - xenon recuperation
  - detector upgraded
- **2023.11 – now: Resuming**

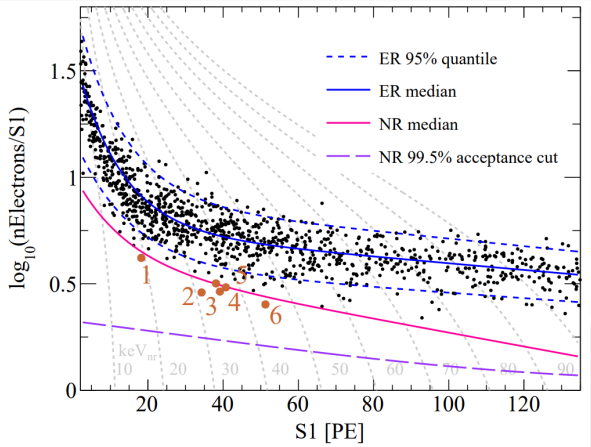
Background table

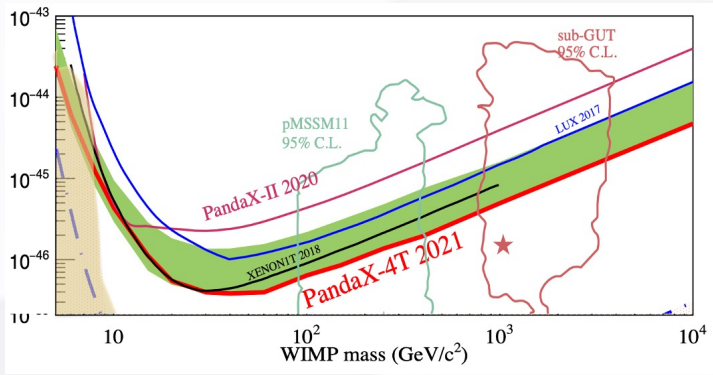
Component	Nominal (evts)
^{3}T (from fit to data)	532 (32)
Flat ER* (18-30keV side band)	492 (31)
Rn	347 (190)
Kr	53 (34)
Material	40 (5)
Xe136	31(6)
Solar pp neutrino	37(8)
Xe127	8 (1)
Neutron	0.9 (0.5)
Neutron-X	0.2 (0.1)
Surface	0.5 (0.1)
Accidental	2.4 (0.5)
B8	0.6 (0.3)
Sum	1037 (45)

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



Dominant bkg component: CH3T





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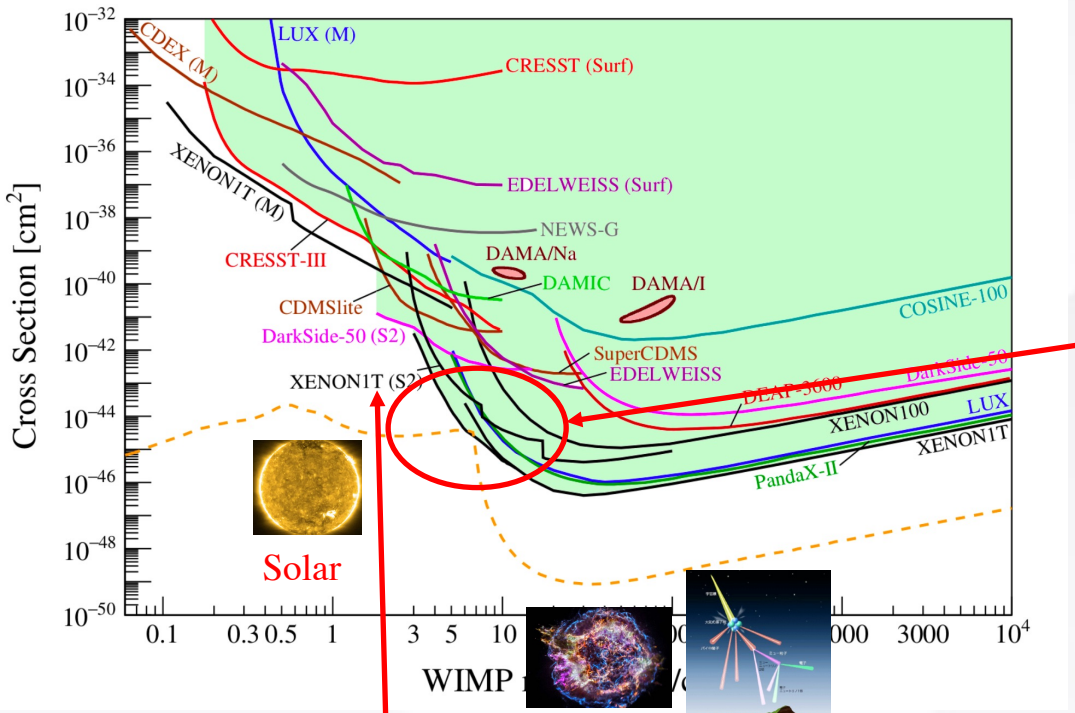
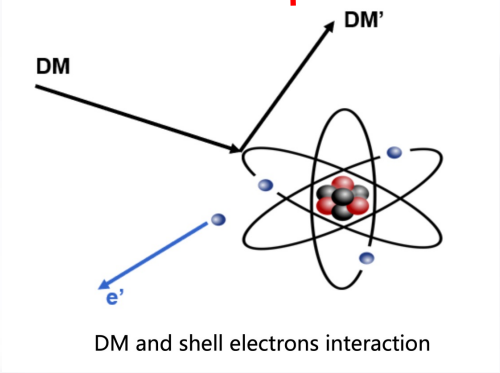
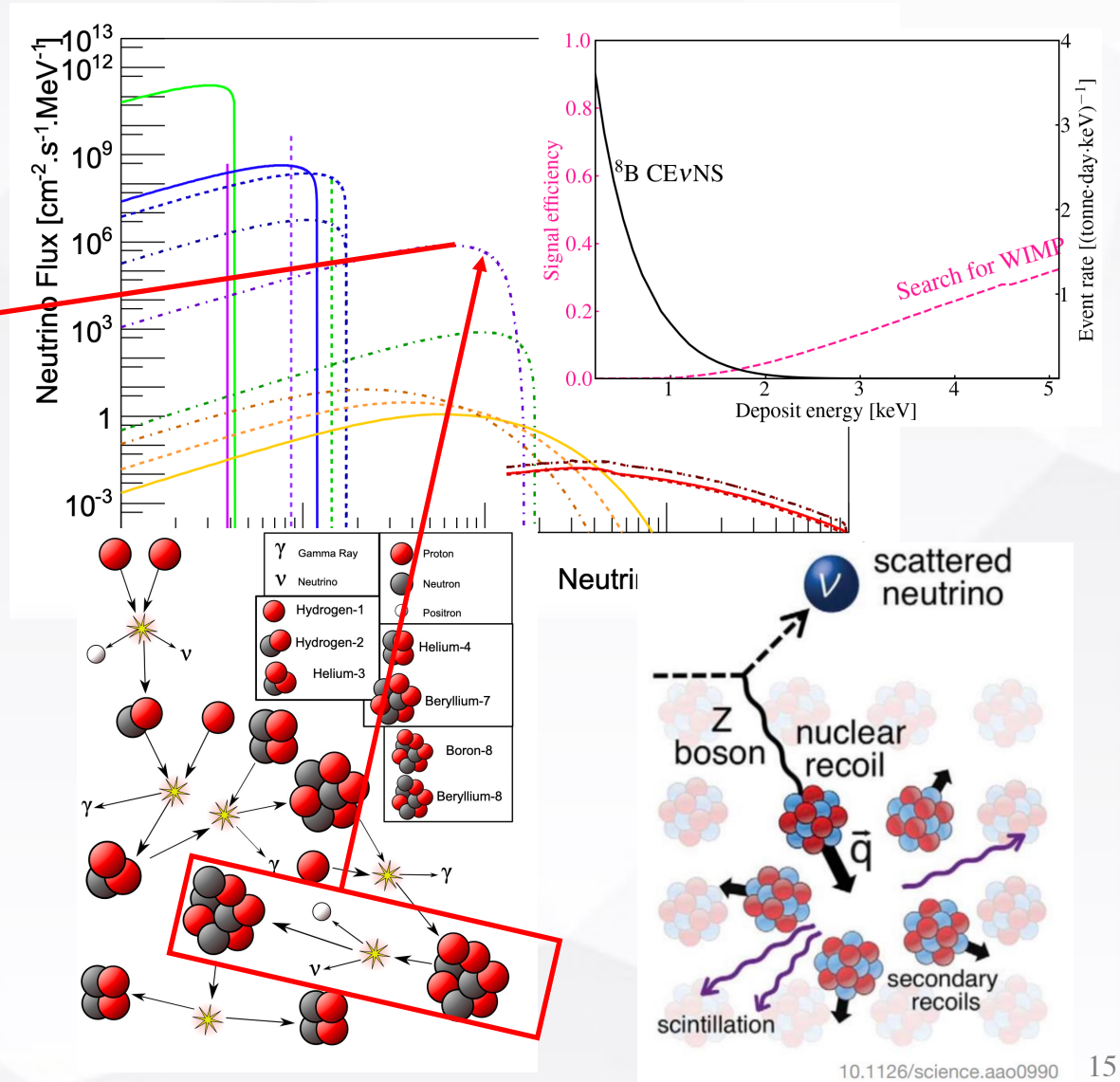
Low-energy searches



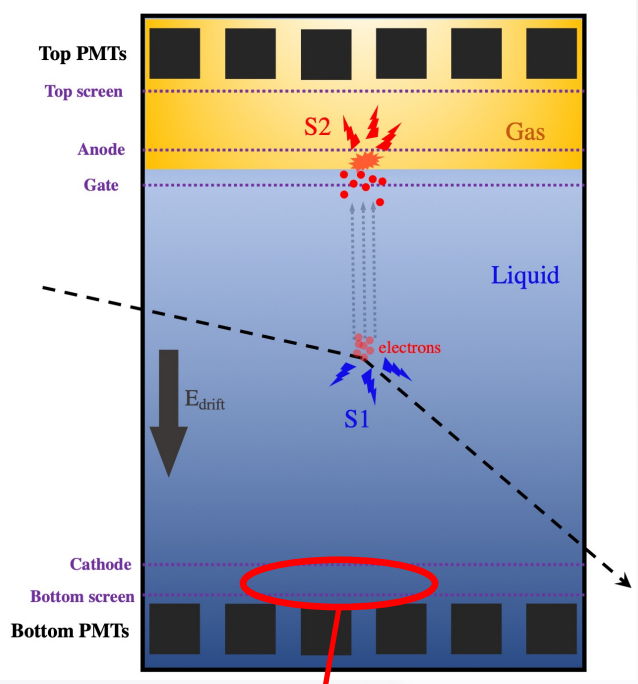


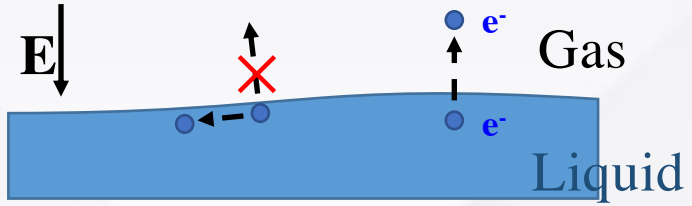
DM and shell electrons interaction

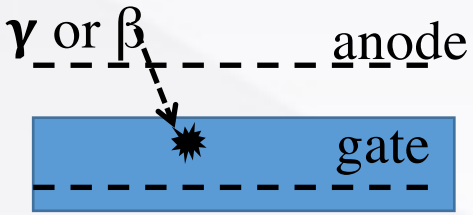


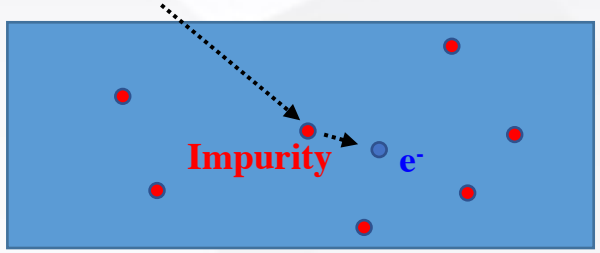
10.1126/science.aao0990

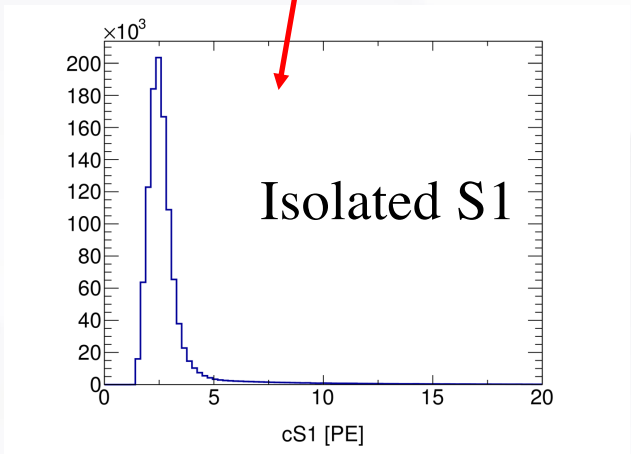
Challenges：Emerged bkg with lowered threshold

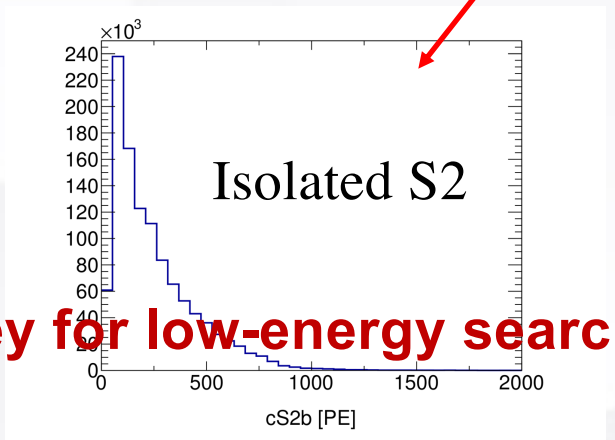




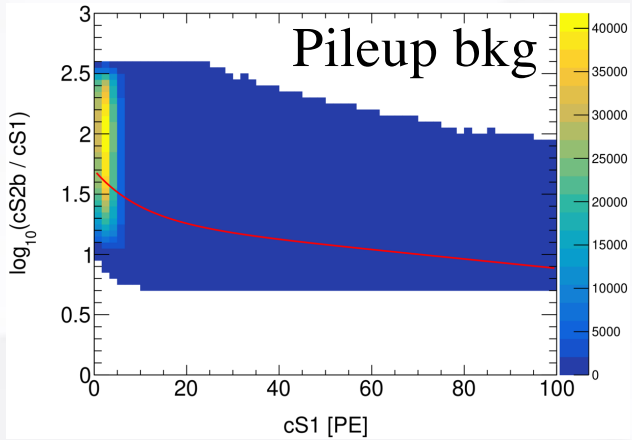




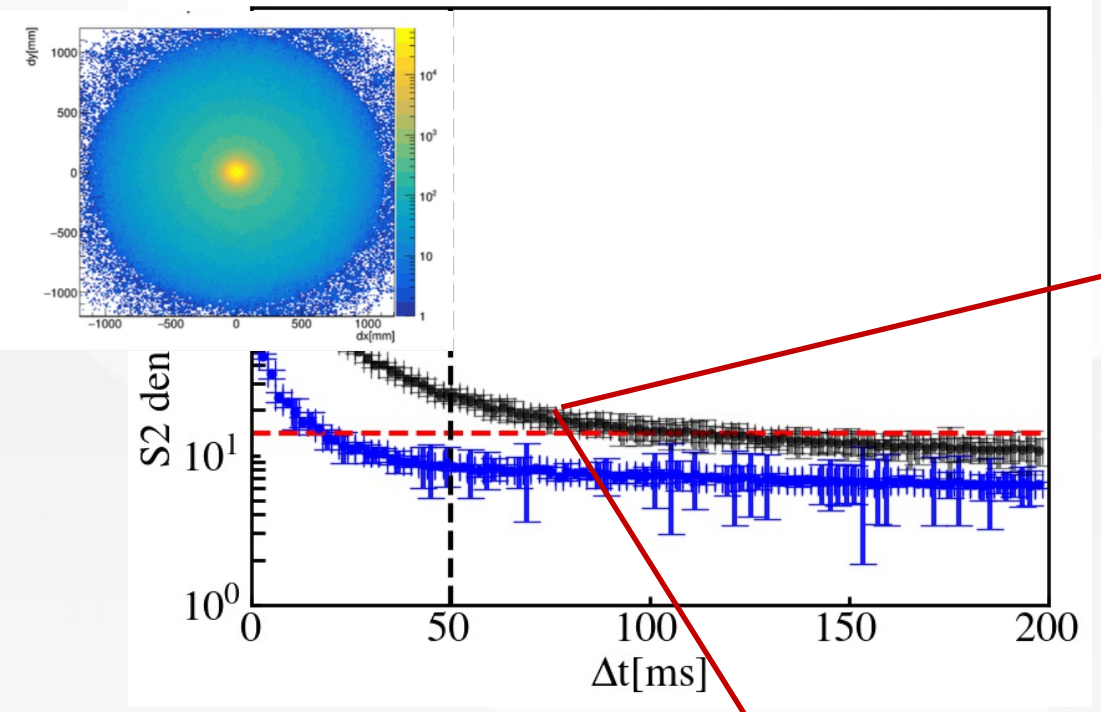




Key for low-energy searches!

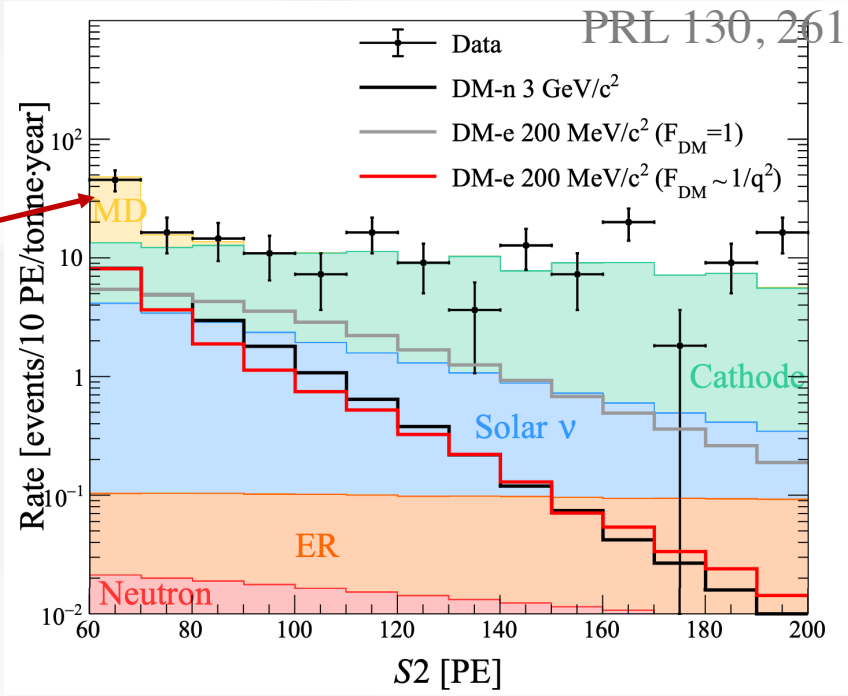


Delayed electrons



PRL 130, 021802 (2023)

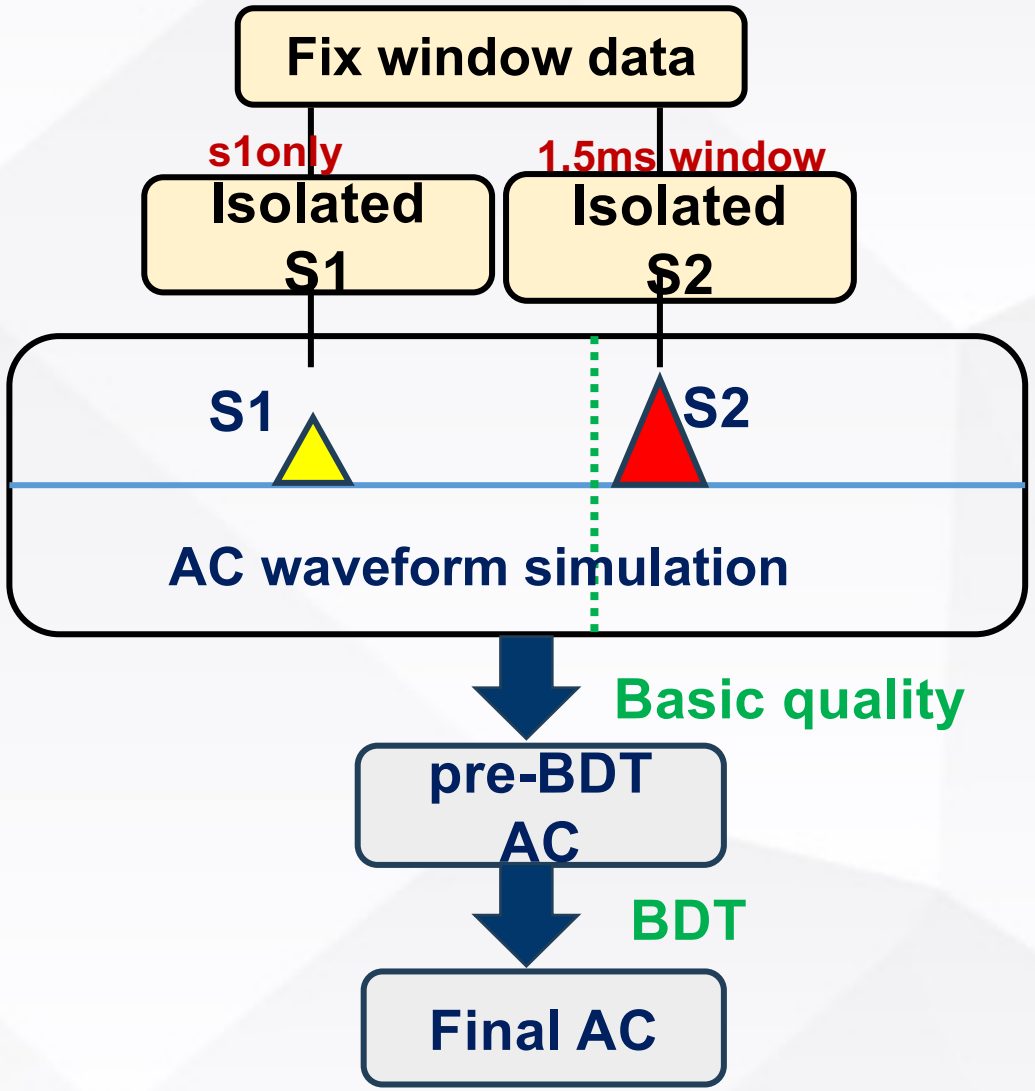
PRL 130, 261001 (2023)

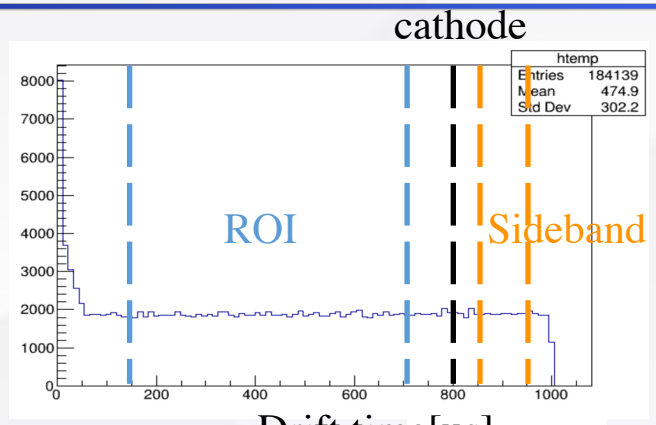


N_{hit}	$S2$ range [PE]	BDT	ER	NR	Surf	AC	Total BKG	^{8}B	**Obs**
2	65-230	pre	0.04	0.10	0.14	62.43	62.71	2.32	**59**
		post	0.02	0.04	0.03	1.41	1.50	1.42	**1**
3	65-190	pre	0.01	0.05	0.08	0.79	0.93	0.42	**2**
		post	0.00	0.02	0.03	0.02	0.07	0.29	**0**

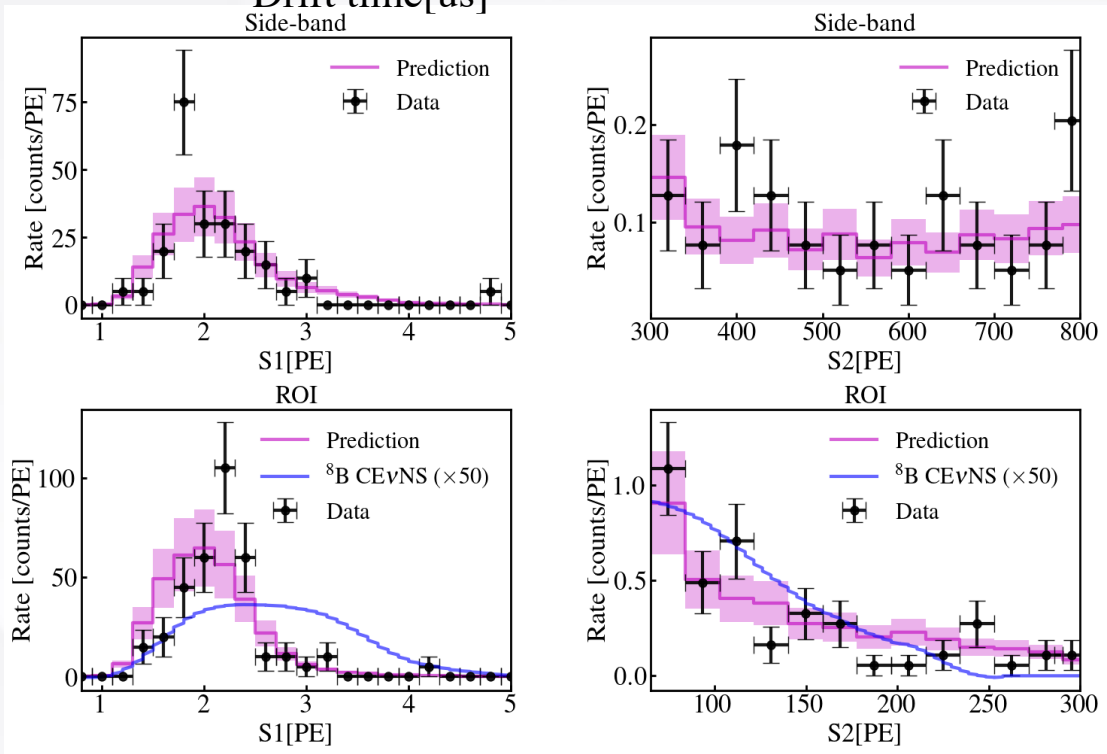
- Delayed electrons play critical roles in the search of B8 (paired S1-S2) and light dark matter (S2-only);
- G3 detectors may also see more contributions from AC;

Model of Accidental pileup (Especially B8 analysis)



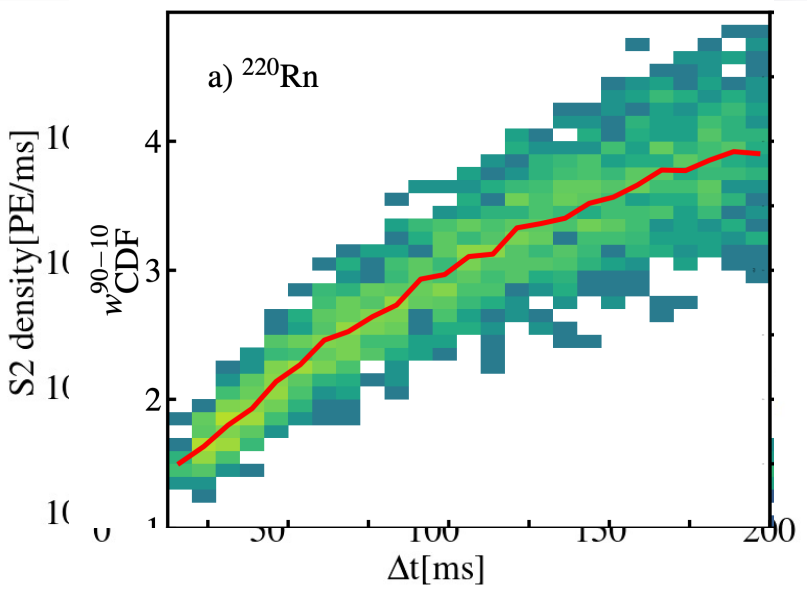


- Pileup dominates!
- Model matches greatly with the sideband data!



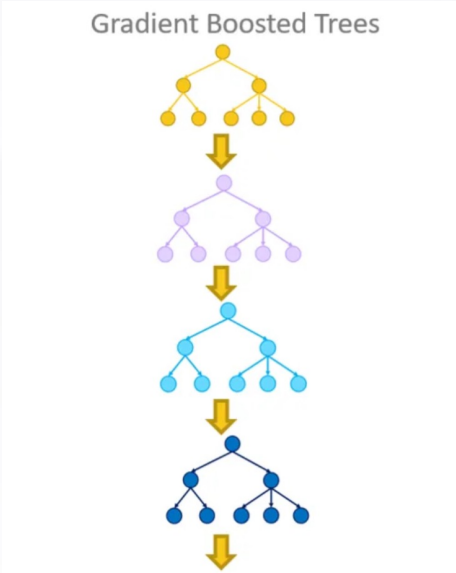
Suppression of AC

Key cut optimization

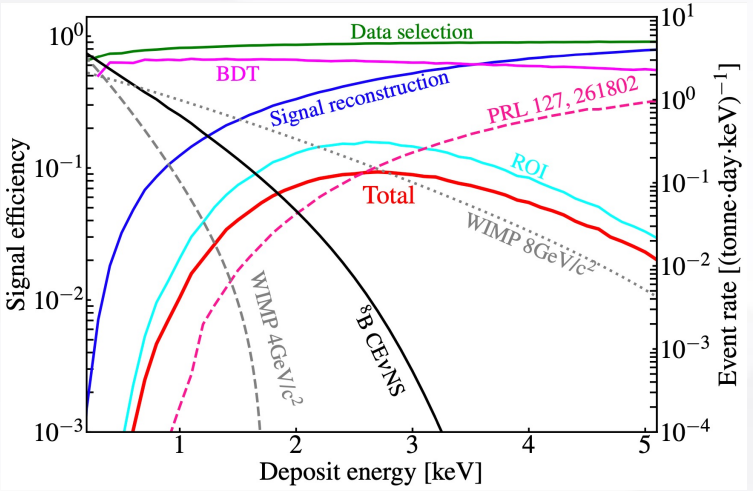


- We observe detector "activated" after large S2s.
- Livetime and volume after a large S2 is cut to reduce AC background!

Boosted Decision Tree (BDT)

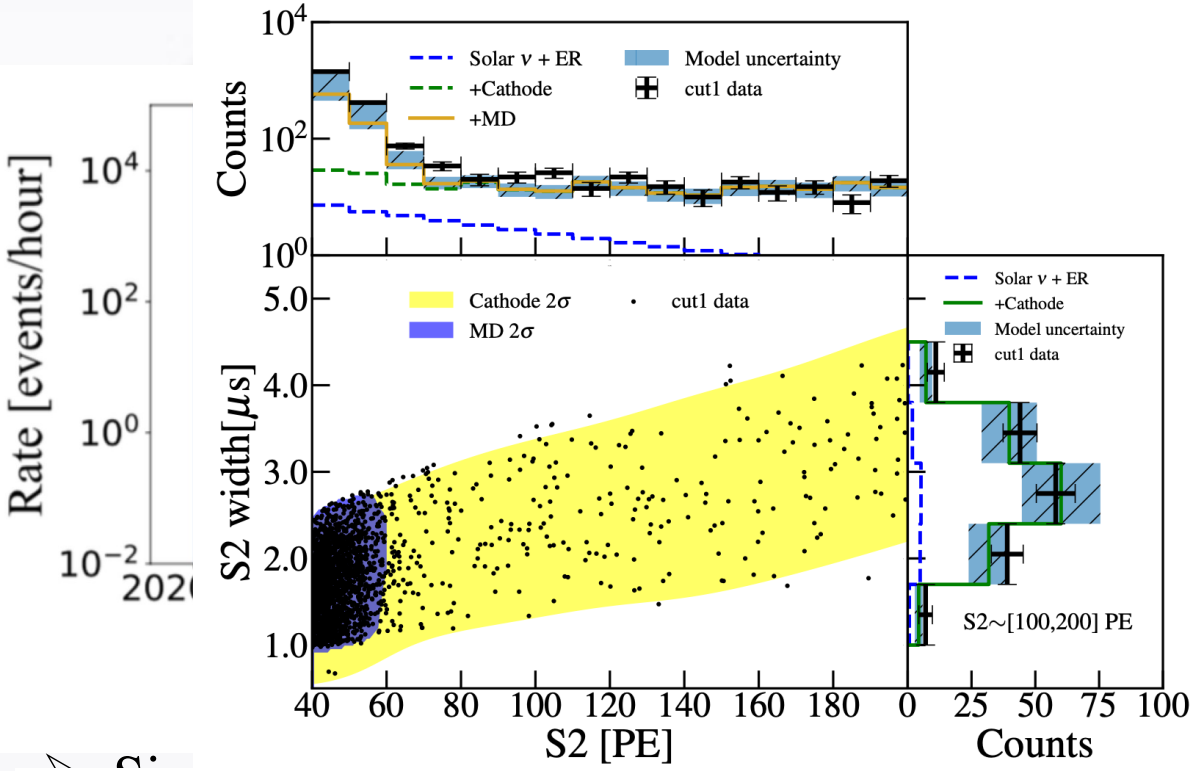


- S1 & S2 width
- Spurious charges beside S1&S2
- S2 pulse shape
- Difference of reconstructed positions;
- Goodness-of-fit between data and sim;
- Top-bottom asymmetry

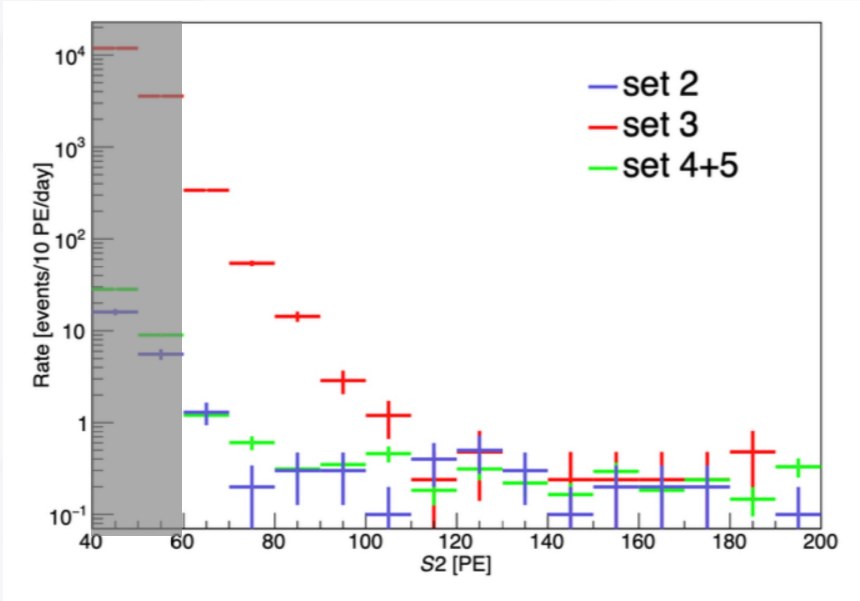


CEvNS rate increases from **~1.6** to **~7.7** per year in 2.7 tonne fiducial volume

Model of low-S2(MD) background



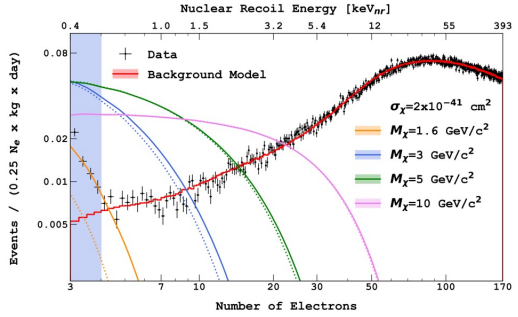
- Samples with loosened cuts are used a control samples;
- Asymmetrical uncertainty is assigned for the difference of control region w.r.t nominal;

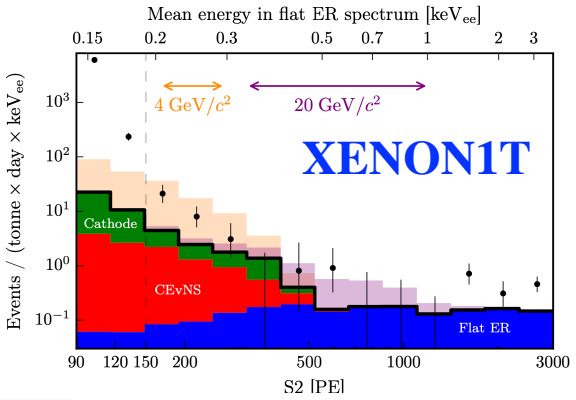


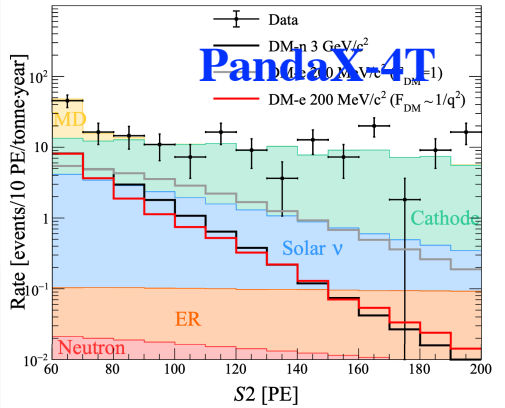
- S2 of 40-60 PE is taken as a side-band region;
- The S2 spectrum of set 3 is taken as the MD shape;
- Difference of set4-5 minus set3 taken as nominal rate;

MD really MD?

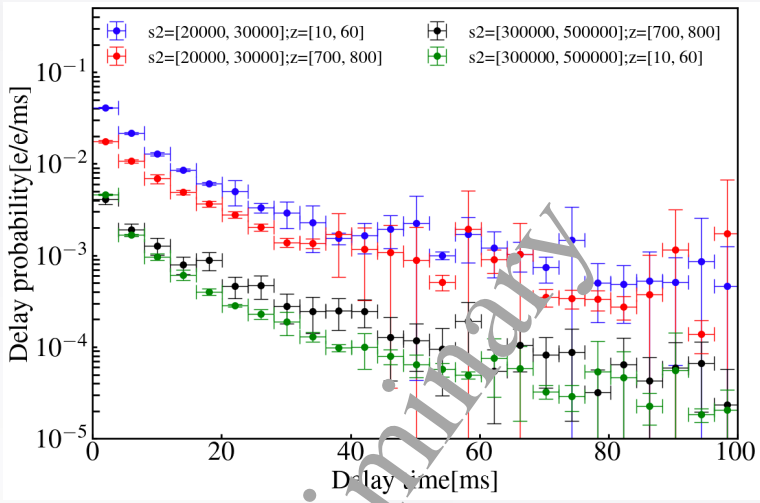
DarkSide-50

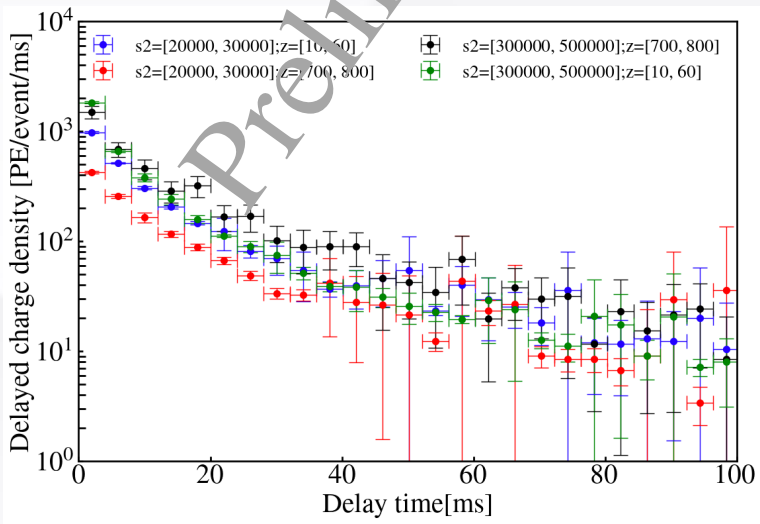




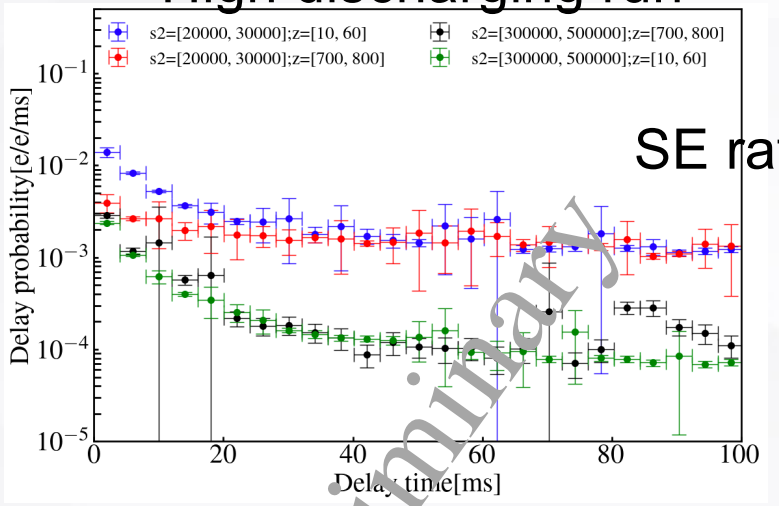


DM run

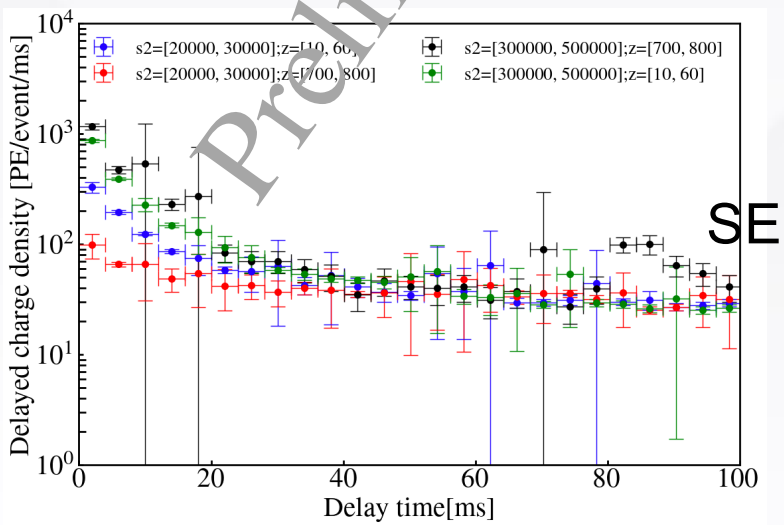




High discharging run



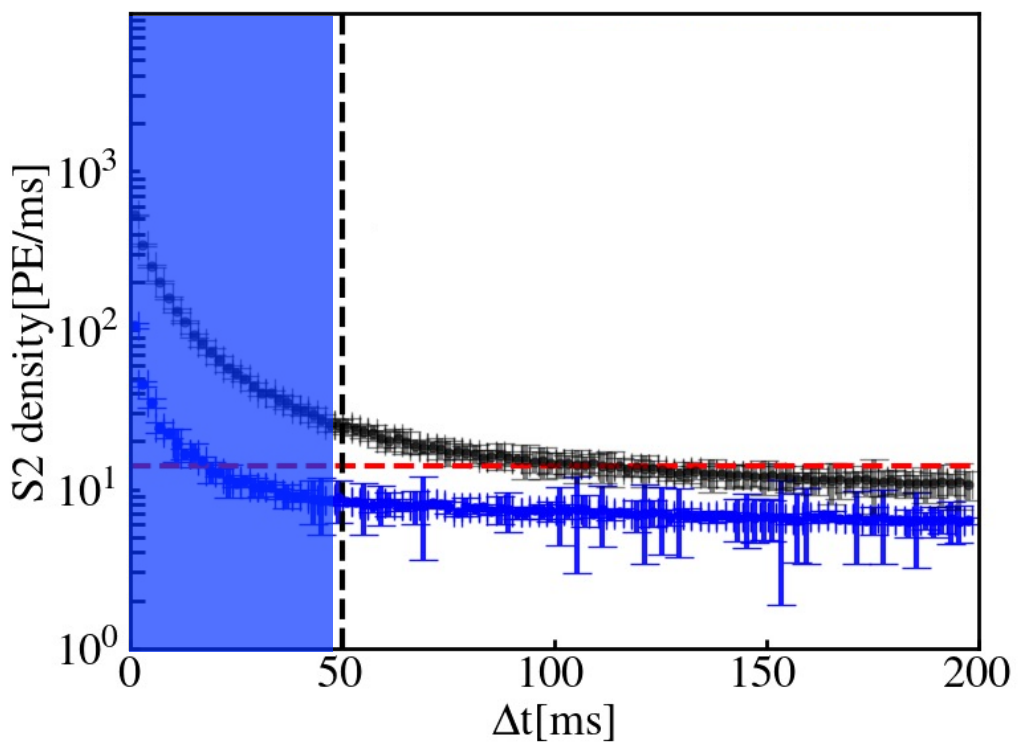
SE rate/pre-S2

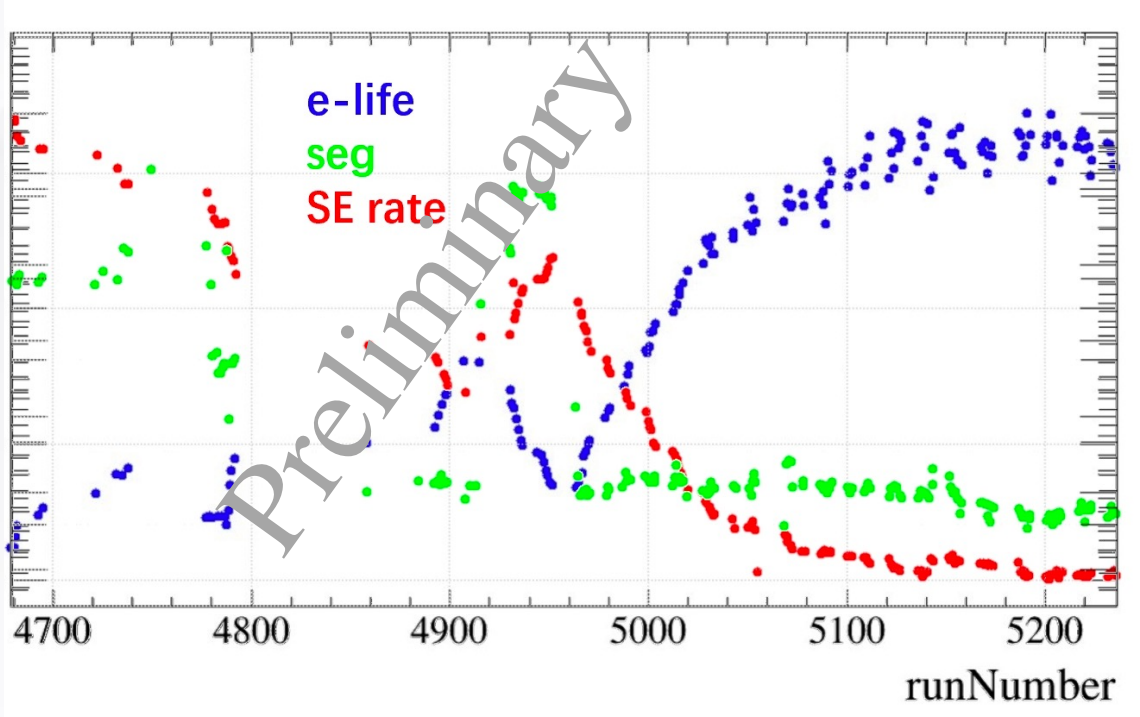


SE rate

It seems the delayed electrons correlated more with event rate than S2 size and Z!

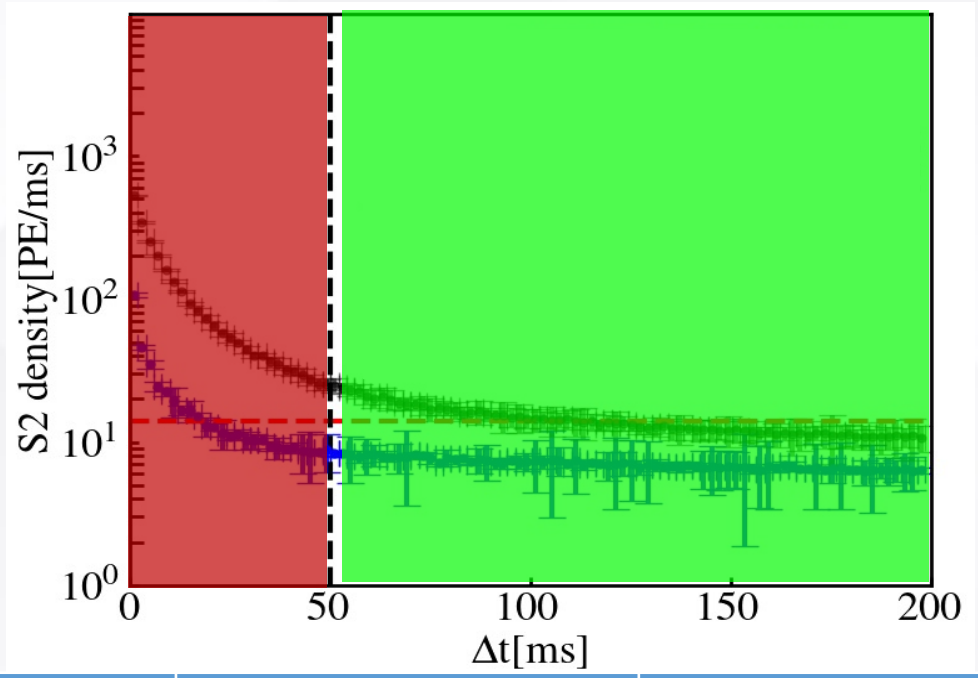
Correlation test



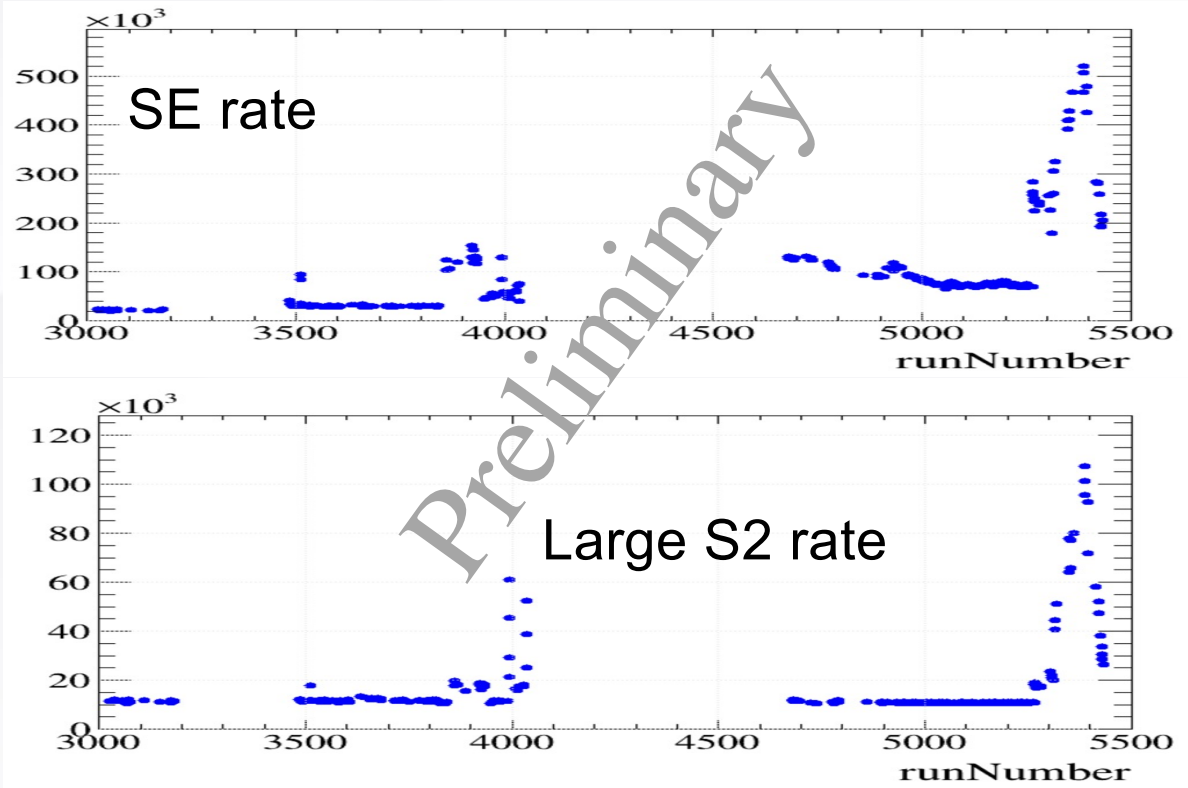


- SEs close to large S2 are strongly correlated with the electron lifetime;

Correlation test



coeff	W deadtime		WO deadtime	
	W calib.	Bkg data	W calib.	Bkg data
S2 rate	**0.84**	0.49	**0.91**	0.55
E-life	0.13	**-0.98**	0.03	**-0.99**
Mean S2	0.27	**0.82**	0.18	**0.82**



- Could be due to SE-primary S2 ambiguity, quantitative analysis ongoing;
- Correlation coefficient also indicates the silent rate correlates more with event rate;
- Ripple model?

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Things need to be done

- Spectral shape analysis: multiple-e due to single-e pileup?

  Influence of photoionization.

- More fine correlation test:
  - Not run-by-run average variables;
  - Correlation with distinct S2 ranges;
- Quantification of the SE pileup with larger S2 rates;