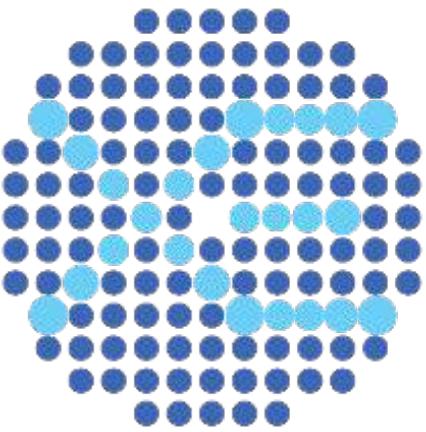




清华大学

Tsinghua University



**XENON**

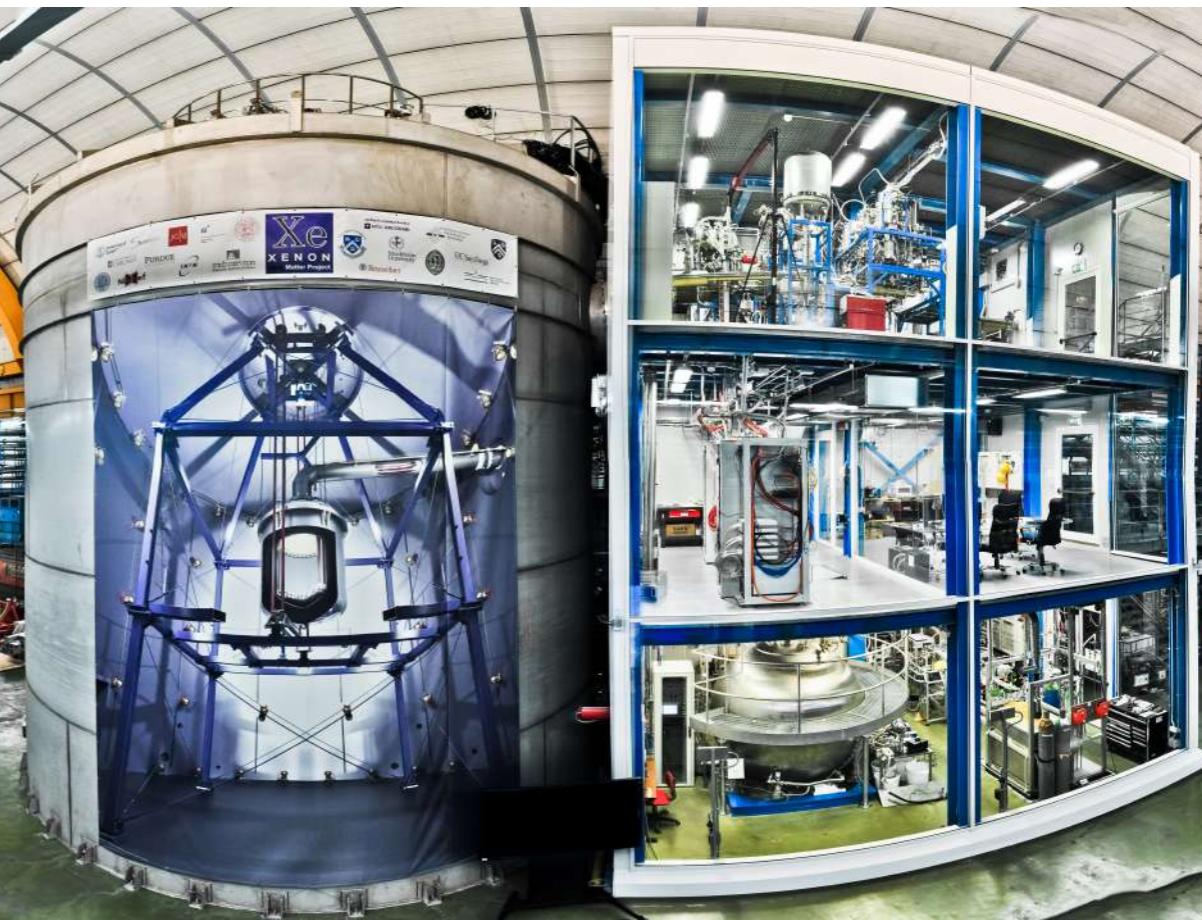
# First Dark Matter Results from XENONnT

Fei Gao  
Tsinghua University

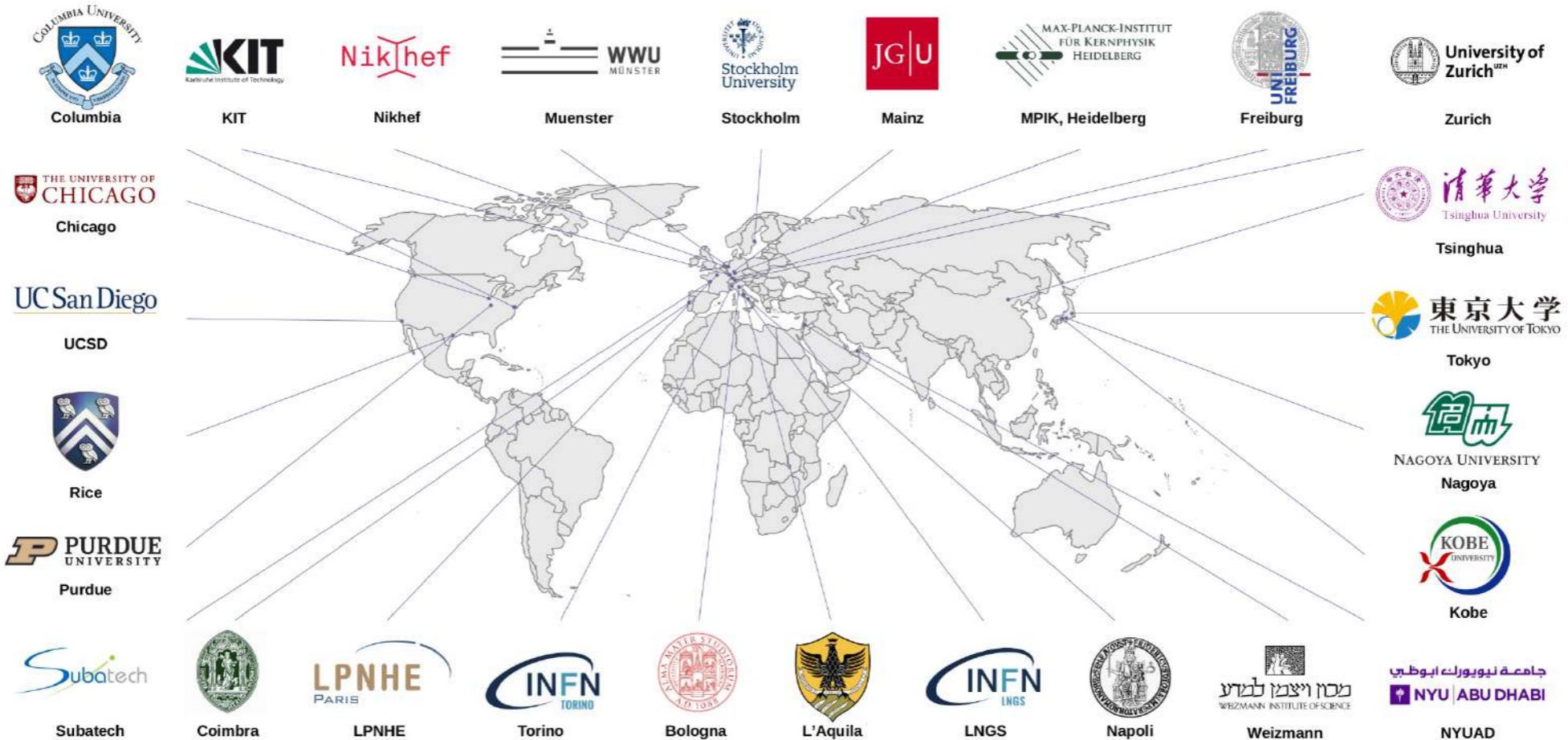
on behalf of the XENON Collaboration

第二届地下和空间粒子物理和宇宙物理  
前沿问题研讨会

May 7-12, 2023



# The XENON Collaboration



# Development of XENON Program

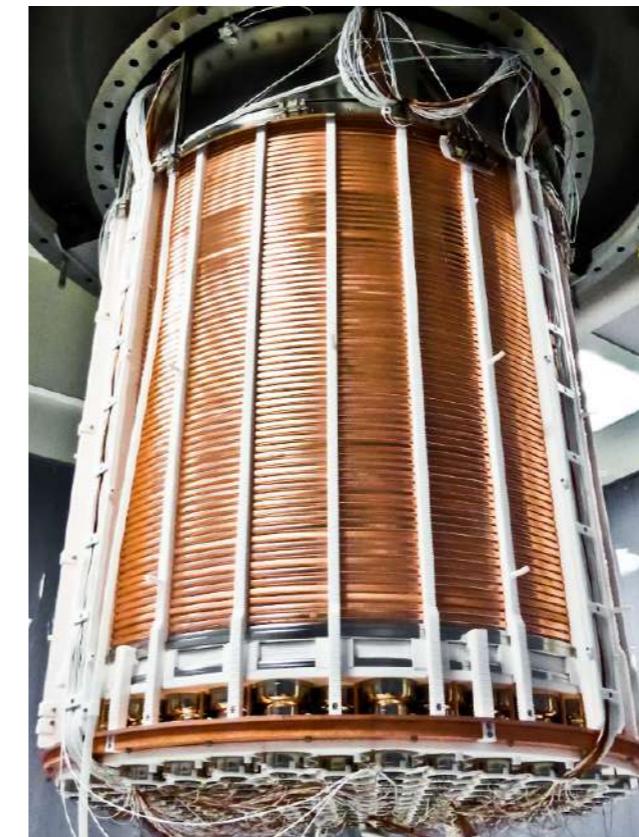
XENON10



XENON100



XENON1T



XENONnT



2005-2007

25 kg - 15cm drift

$\sim 10^{-43} \text{ cm}^2$

2008-2016

161 kg - 30 cm drift

$\sim 10^{-45} \text{ cm}^2$

2012-2018

3.2 ton - 1 m drift

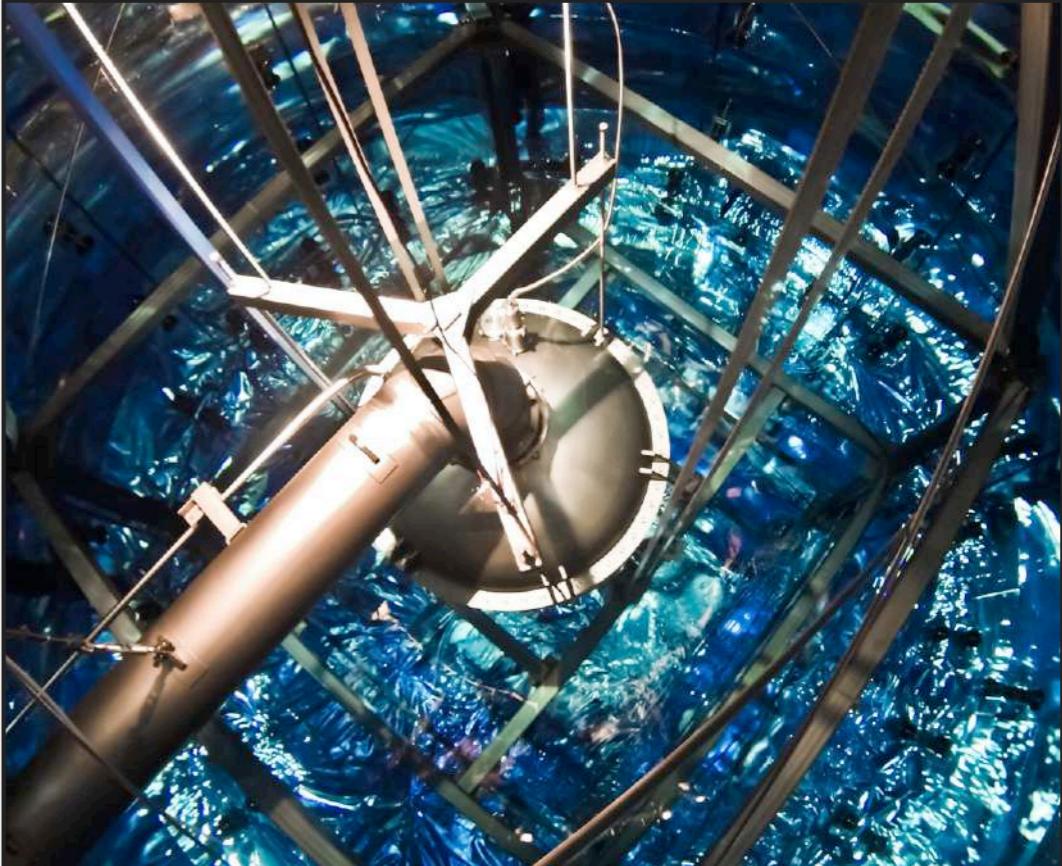
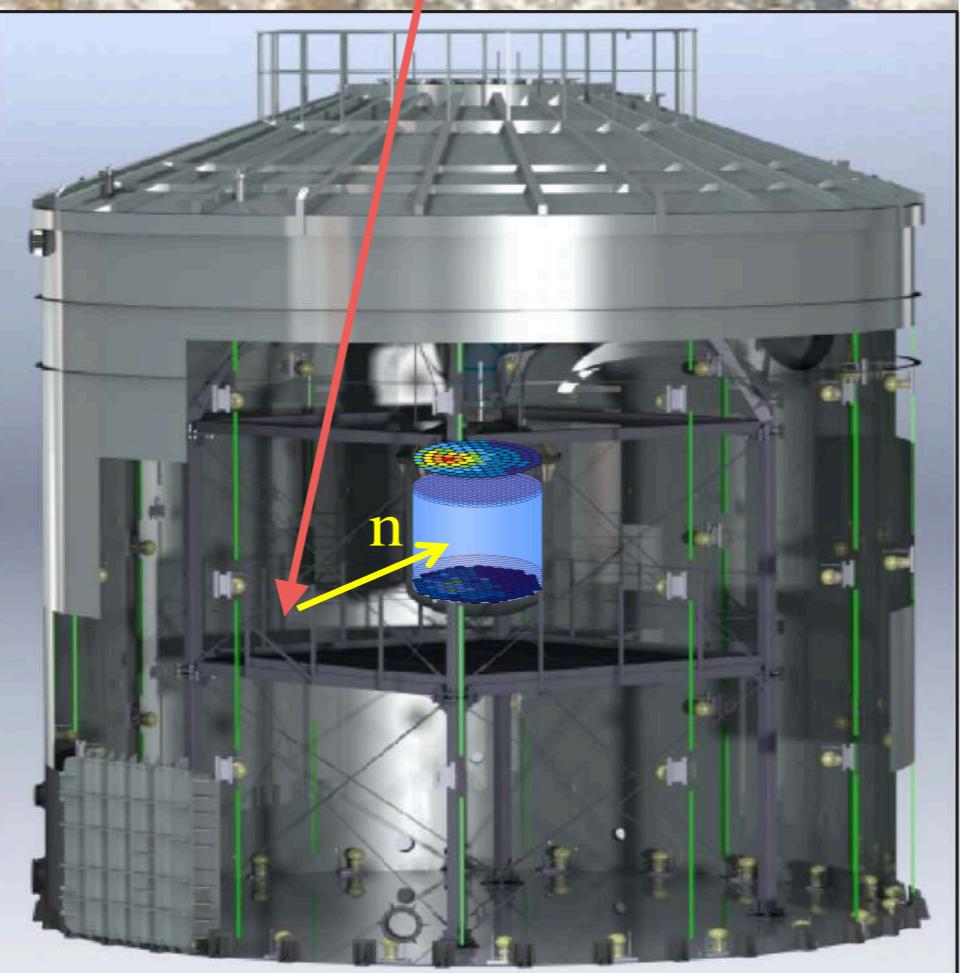
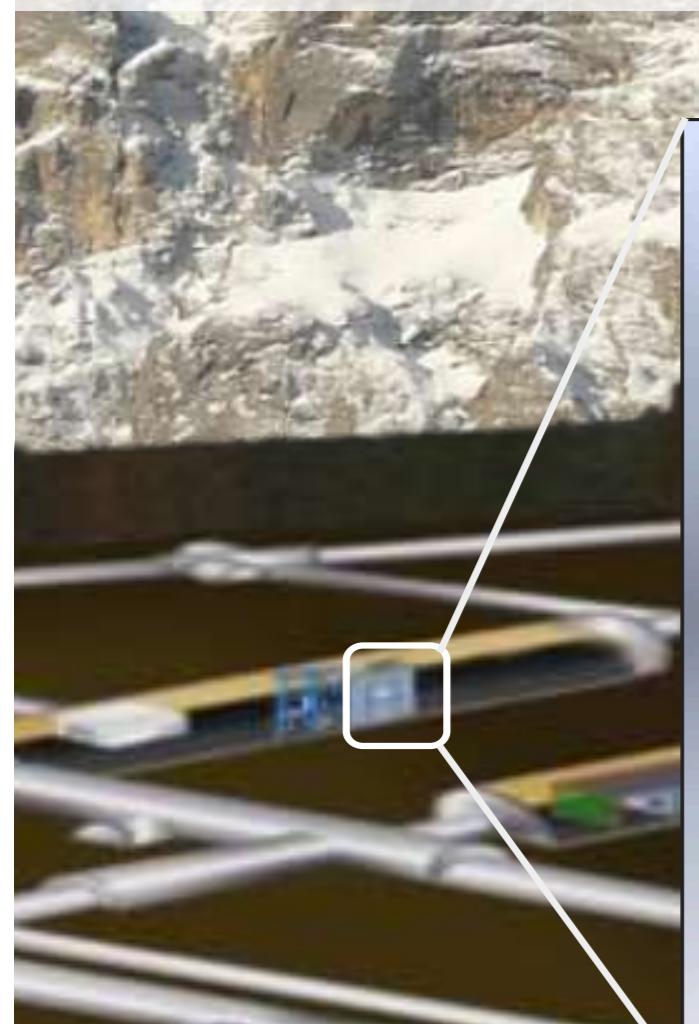
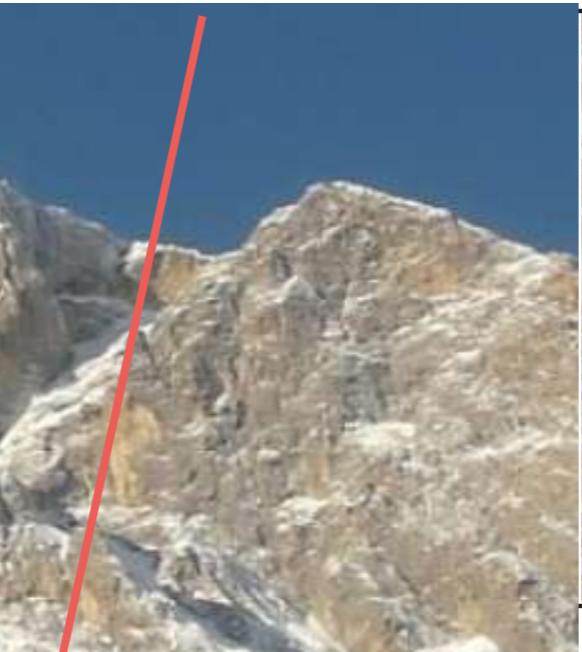
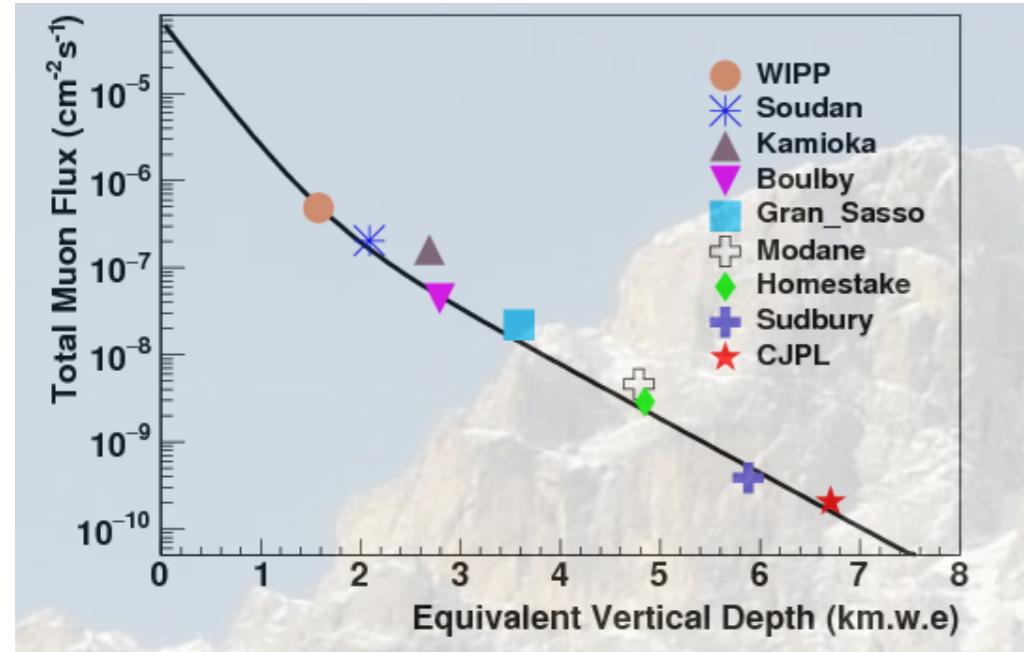
$\sim 10^{-47} \text{ cm}^2$

2019-202x

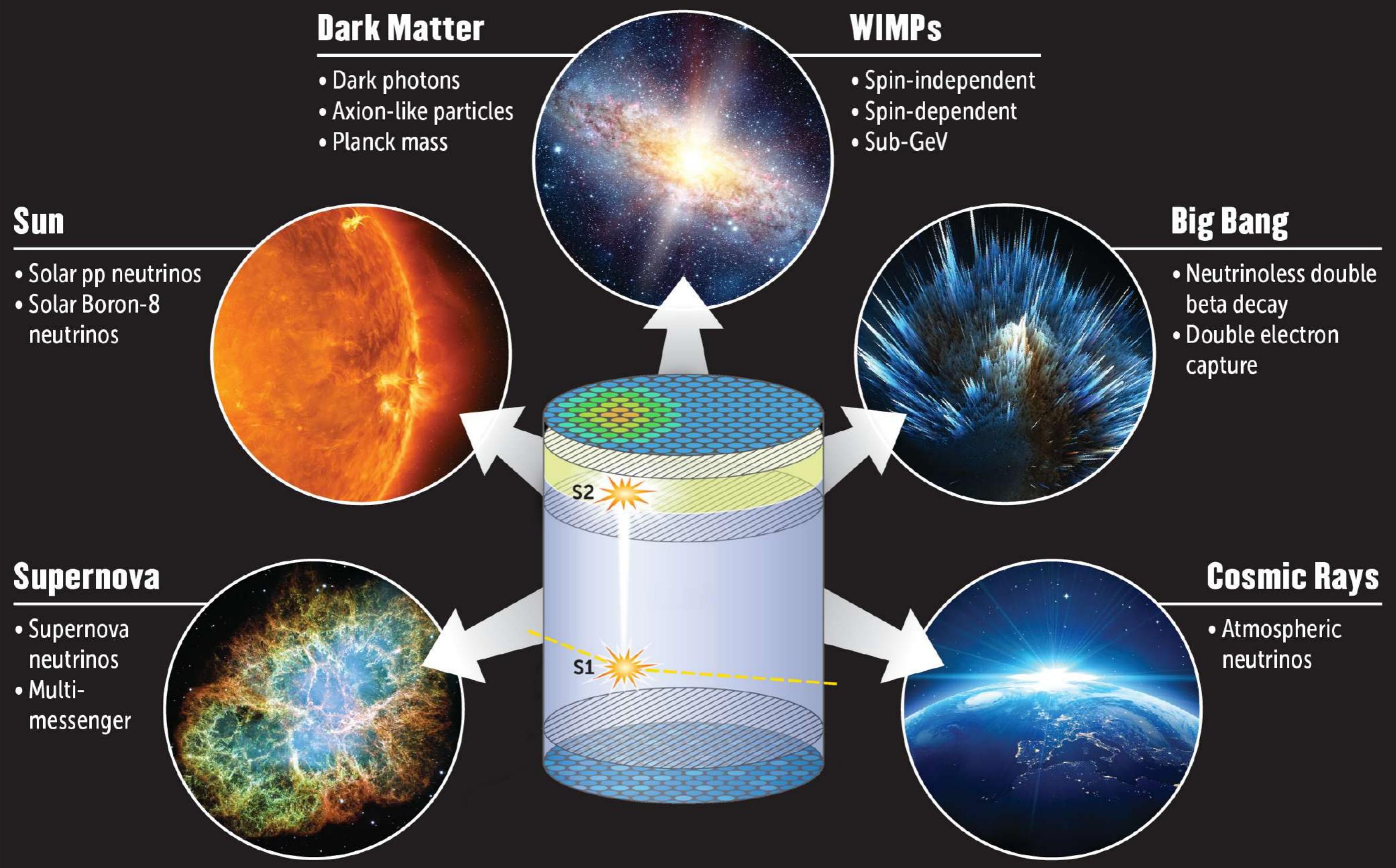
8.6 ton - 1.5 m drift

$\sim 10^{-48} \text{ cm}^2$

# Gran Sasso: The XENON Shield



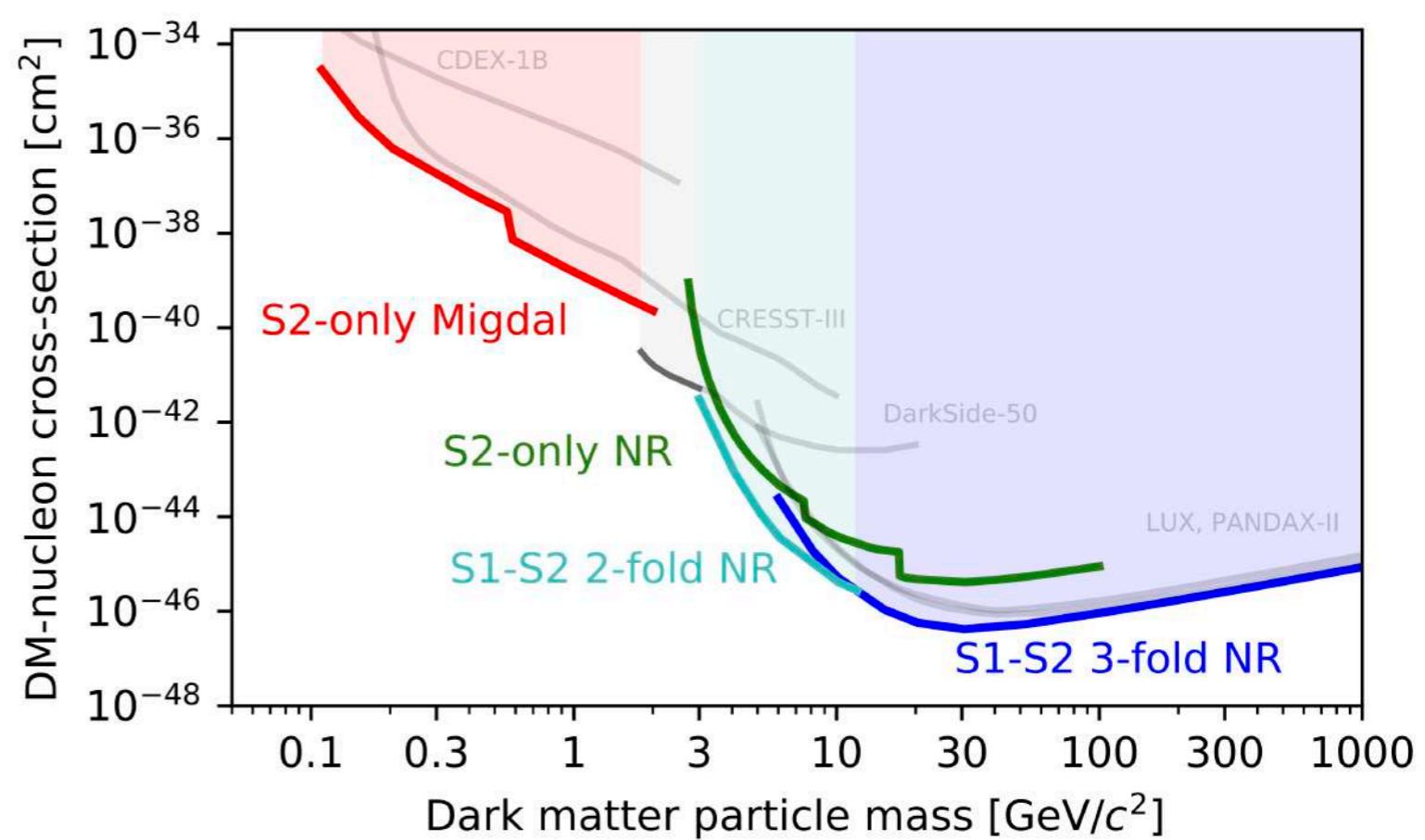
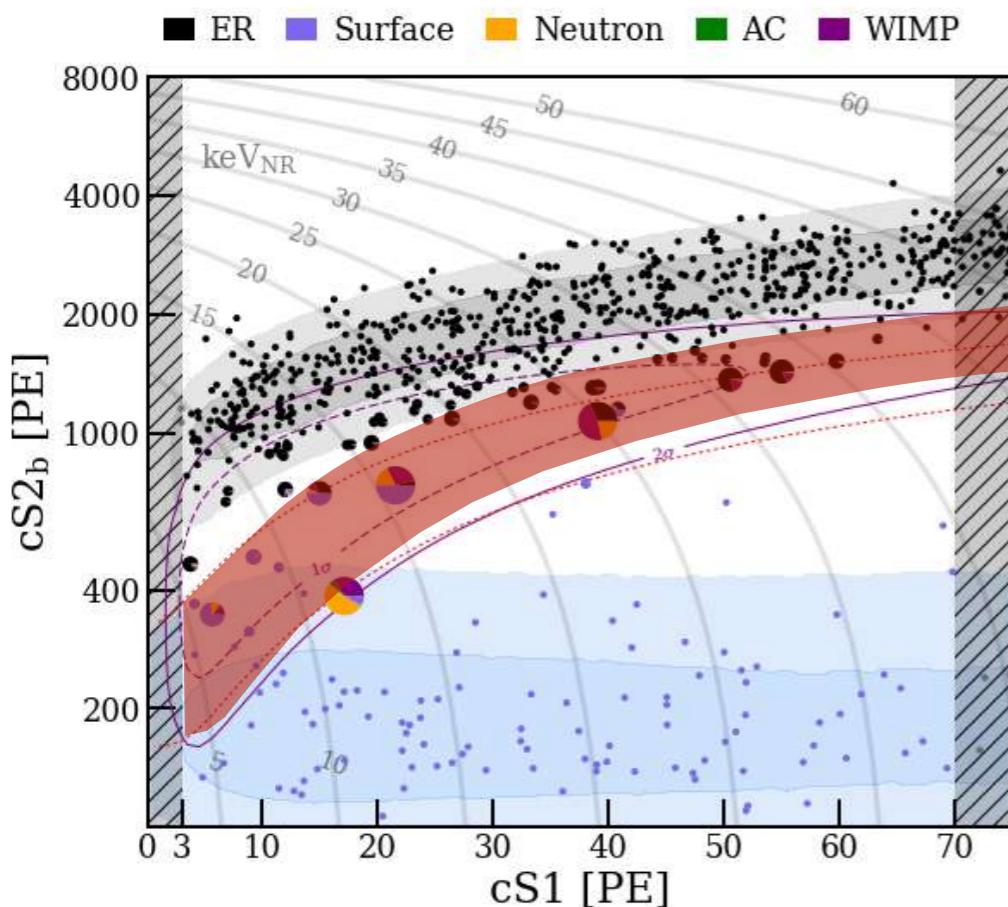
# Physics with the XENON Detectors



# XENON1T WIMPs Search

World's most sensitive WIMPs  
search back then

Source	1.3 t	0.9 t, NR Ref.
ER	$627 \pm 18$	$1.1 \pm 0.2$
Radiogenic	$1.4 \pm 0.7$	$0.4 \pm 0.2$
Accidental	$0.5^{+0.3}_{-0.0}$	$0.06^{+0.03}_{-0.00}$
Surface	$106 \pm 8$	0.02
Total	$735 \pm 20$	$1.6 \pm 0.3$
<b>200 GeV WIMP</b> $\sigma_{\text{SI}} = 4.7 \times 10^{-47} \text{ cm}^2$	3.6	1.2
Data	<b>739</b>	<b>2</b>

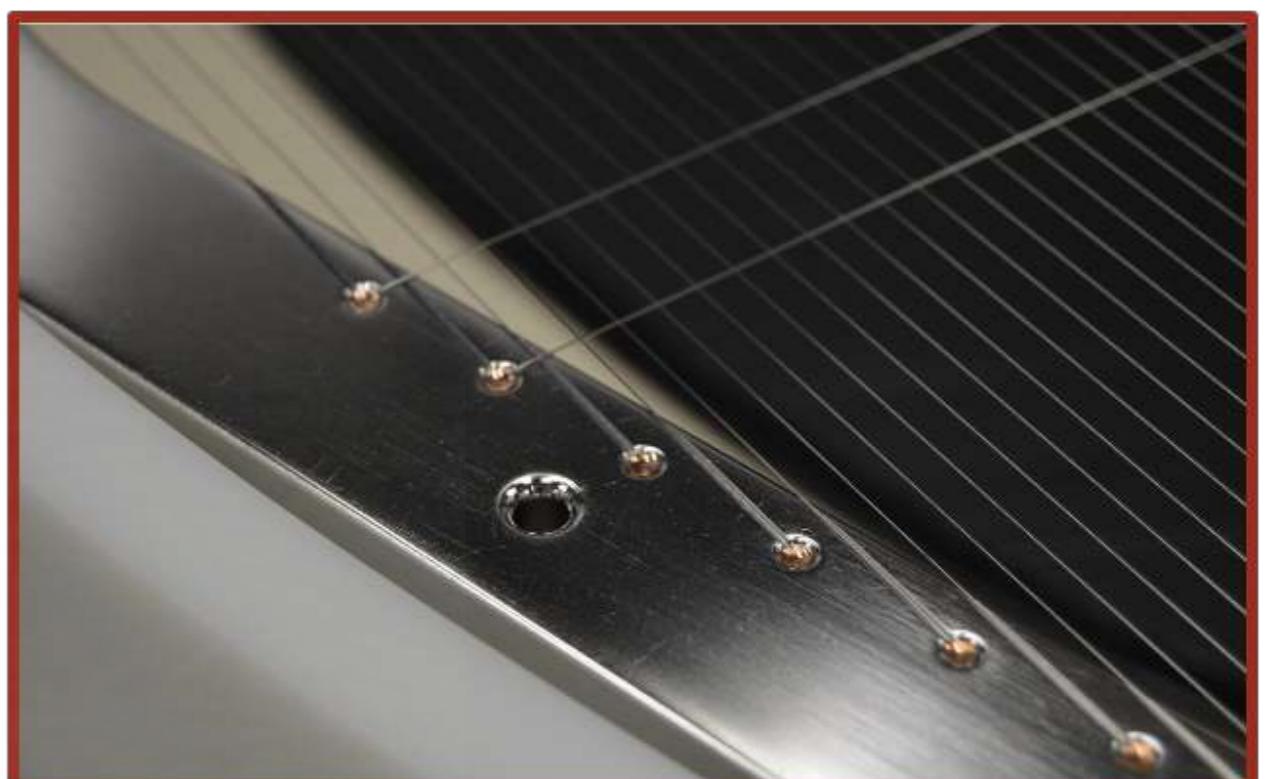
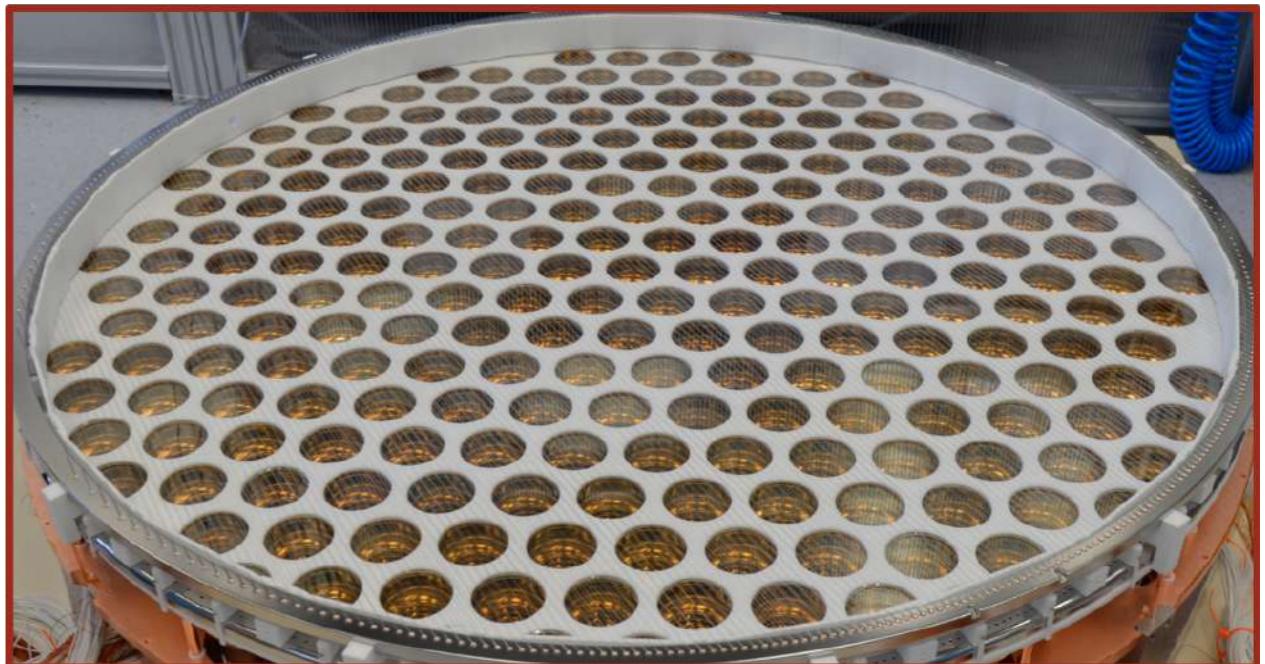


# From XENON1T to XENONnT



# XENONnT TPC and Electrodes

+4.9 kV  
+0.3 kV  
  
-2.75 kV

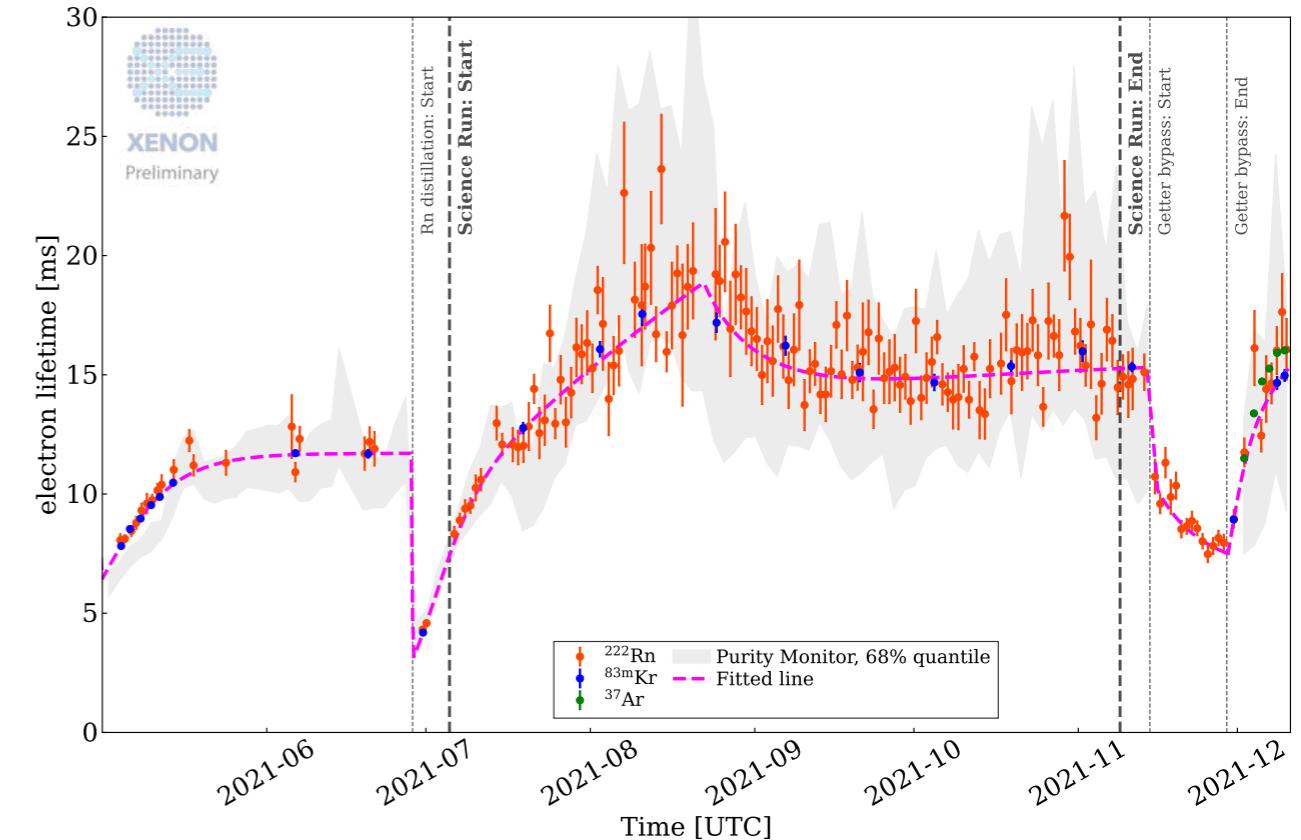
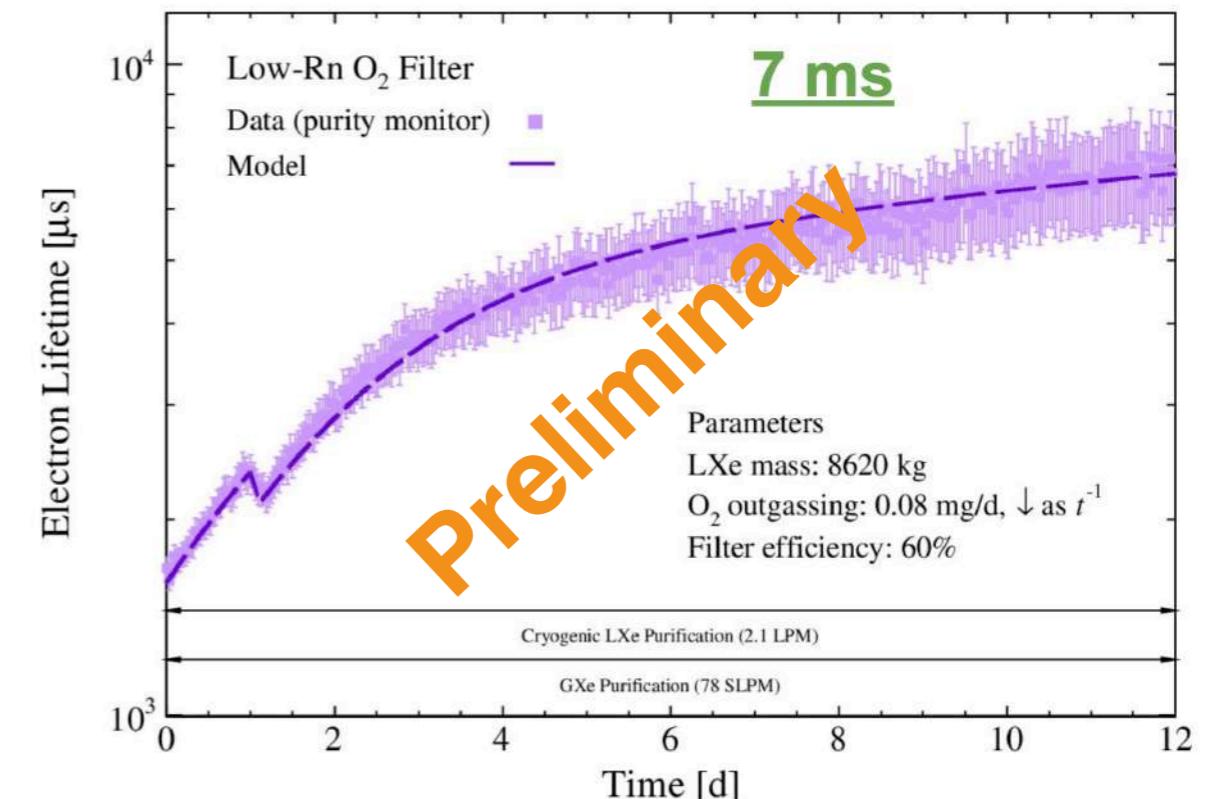


# XENONnT Cryogenic Liquid Purification

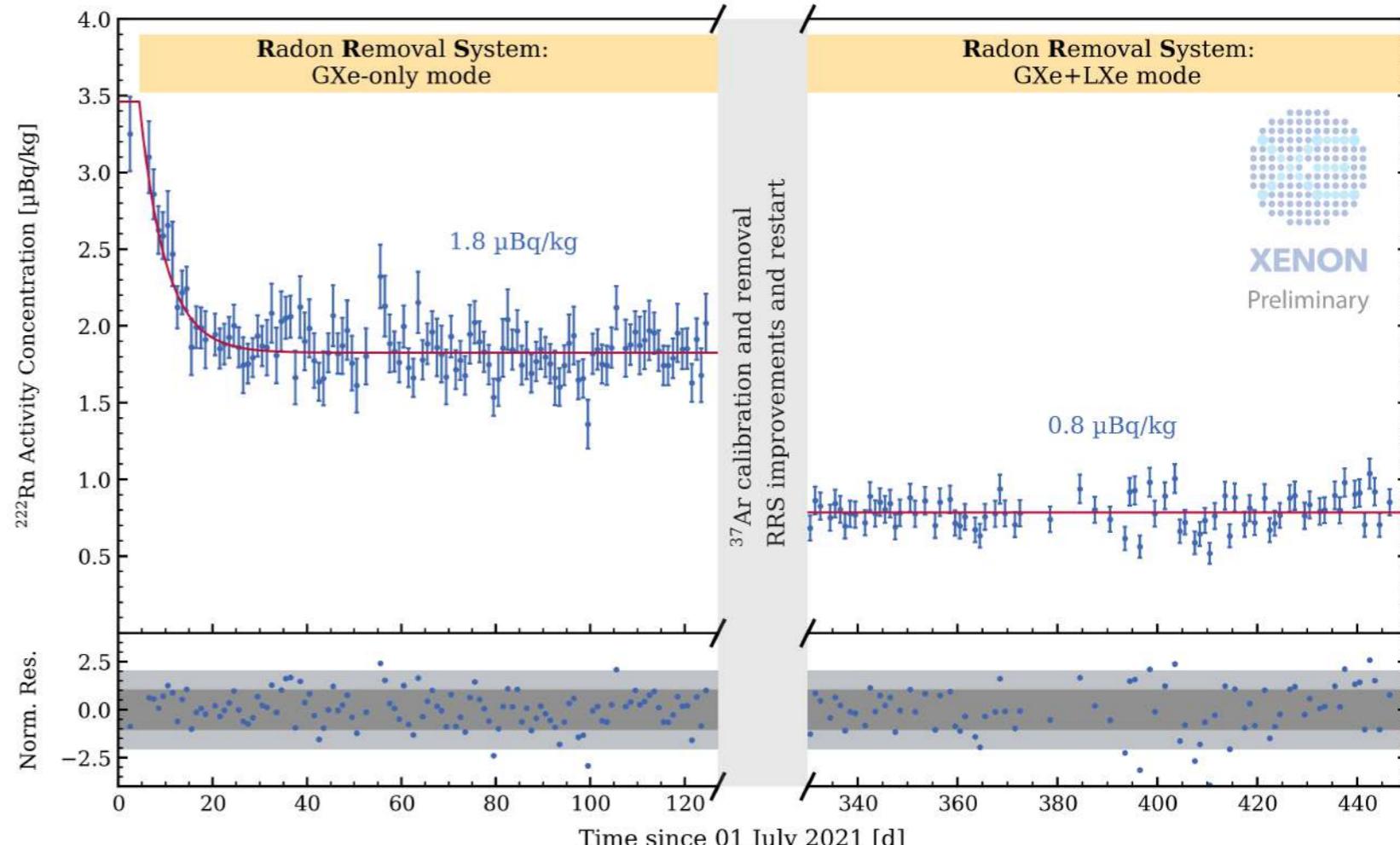
Cryostat is filled with ~8.5t of LXe



Exp	Max Drift [ms]	Electron lifetime [ms]	Cathode electron survival	Purification speed
XENON1T	0.73	0.65	30%	0.65ms in ~3 months
XENONnT	2.2	~10	>90%	5ms in ~5 days

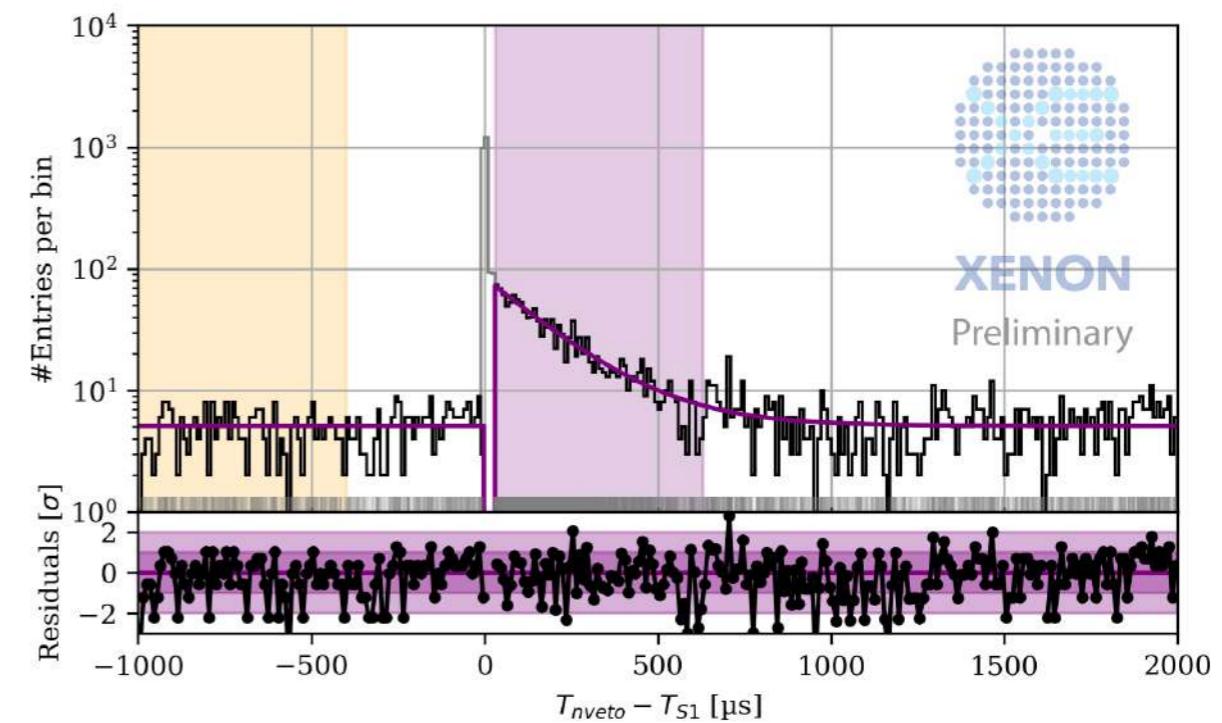
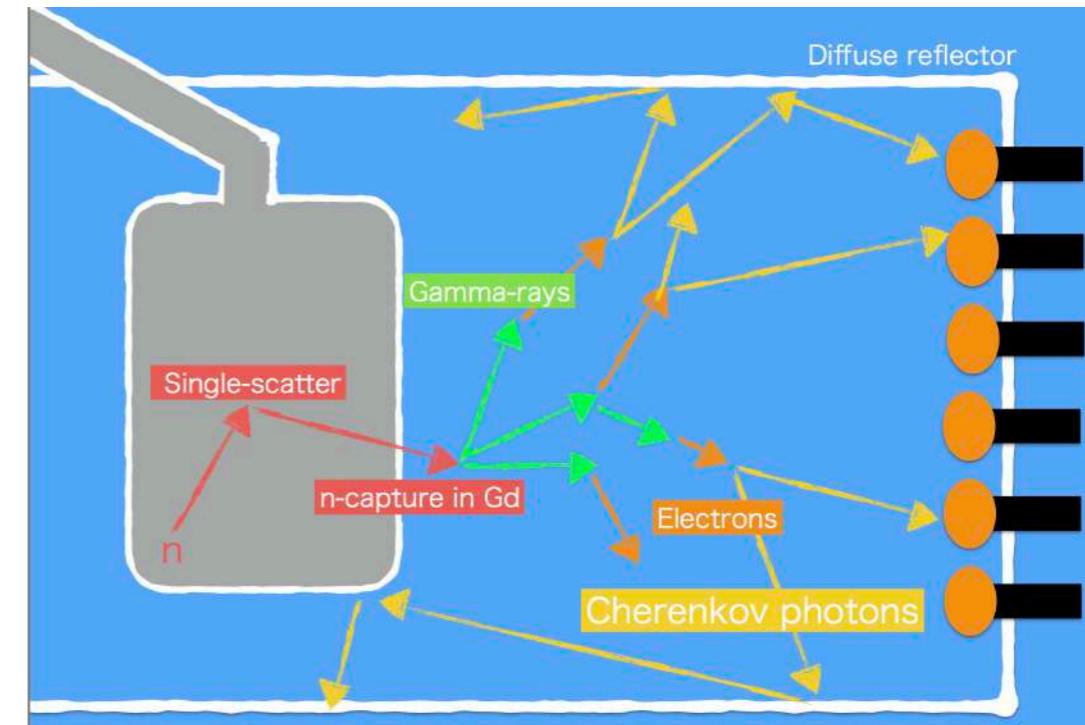
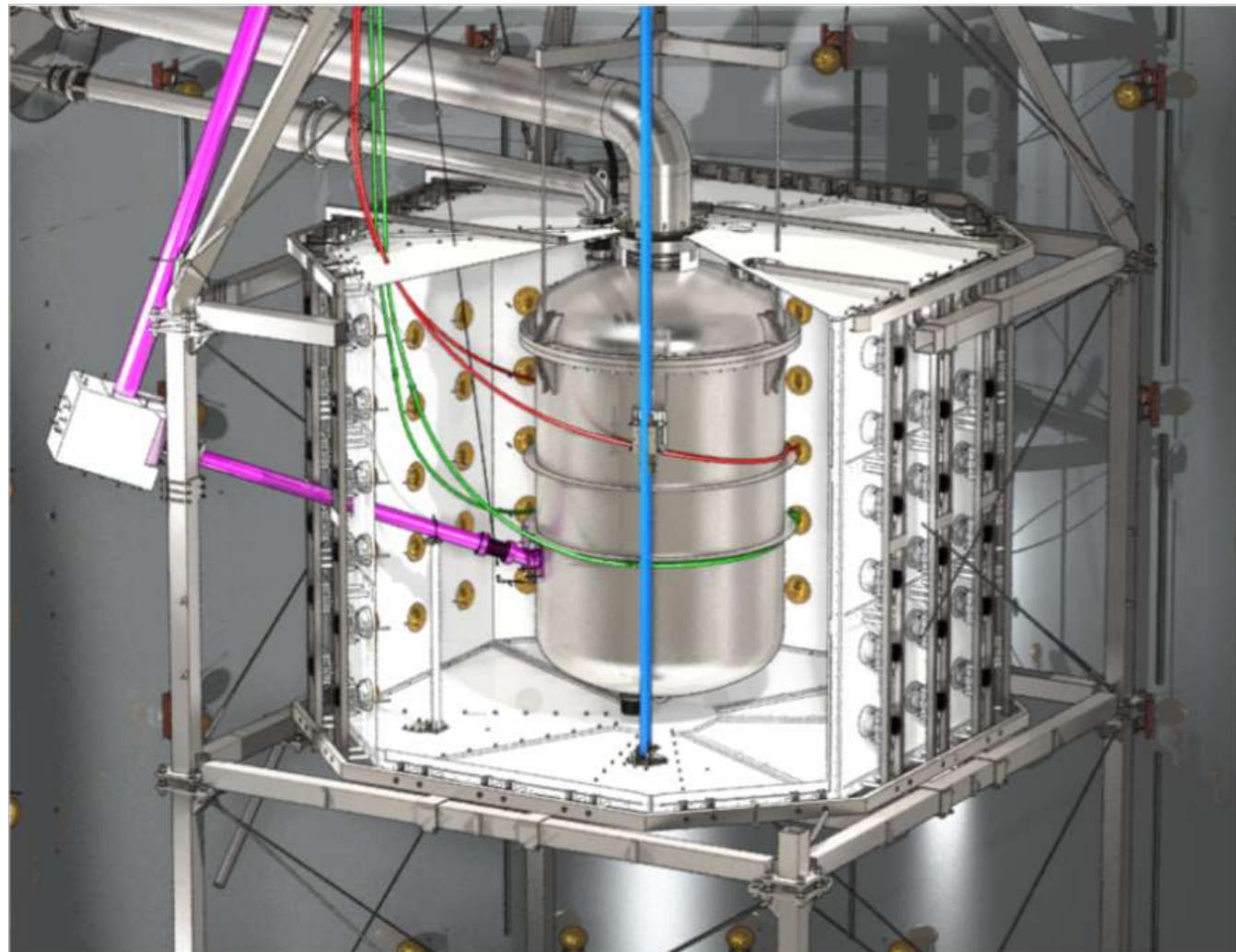


# XENONnT Radon Distillation Column



- Lowest radon level ever achieved in a LXeTPC!
  - Initial gas phase-only distillation: 1.8 µBq/kg
  - Gas + liquid phase distillation: 0.8 µBq/kg

# XENONnT Neutron Veto

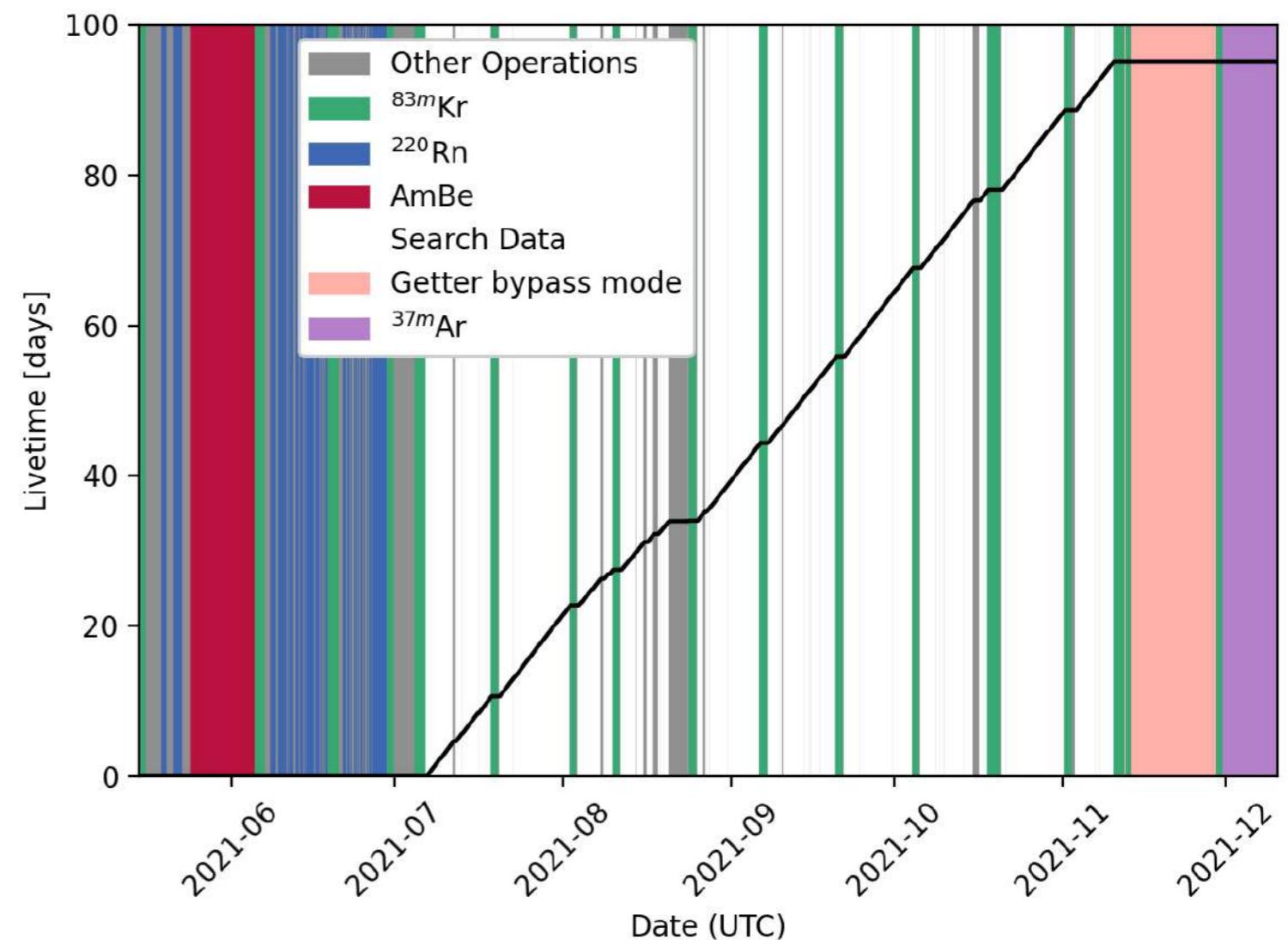


- SR0: Water only veto efficiency of 68%
- Design Goal: Gd-Water veto efficiency of >85%

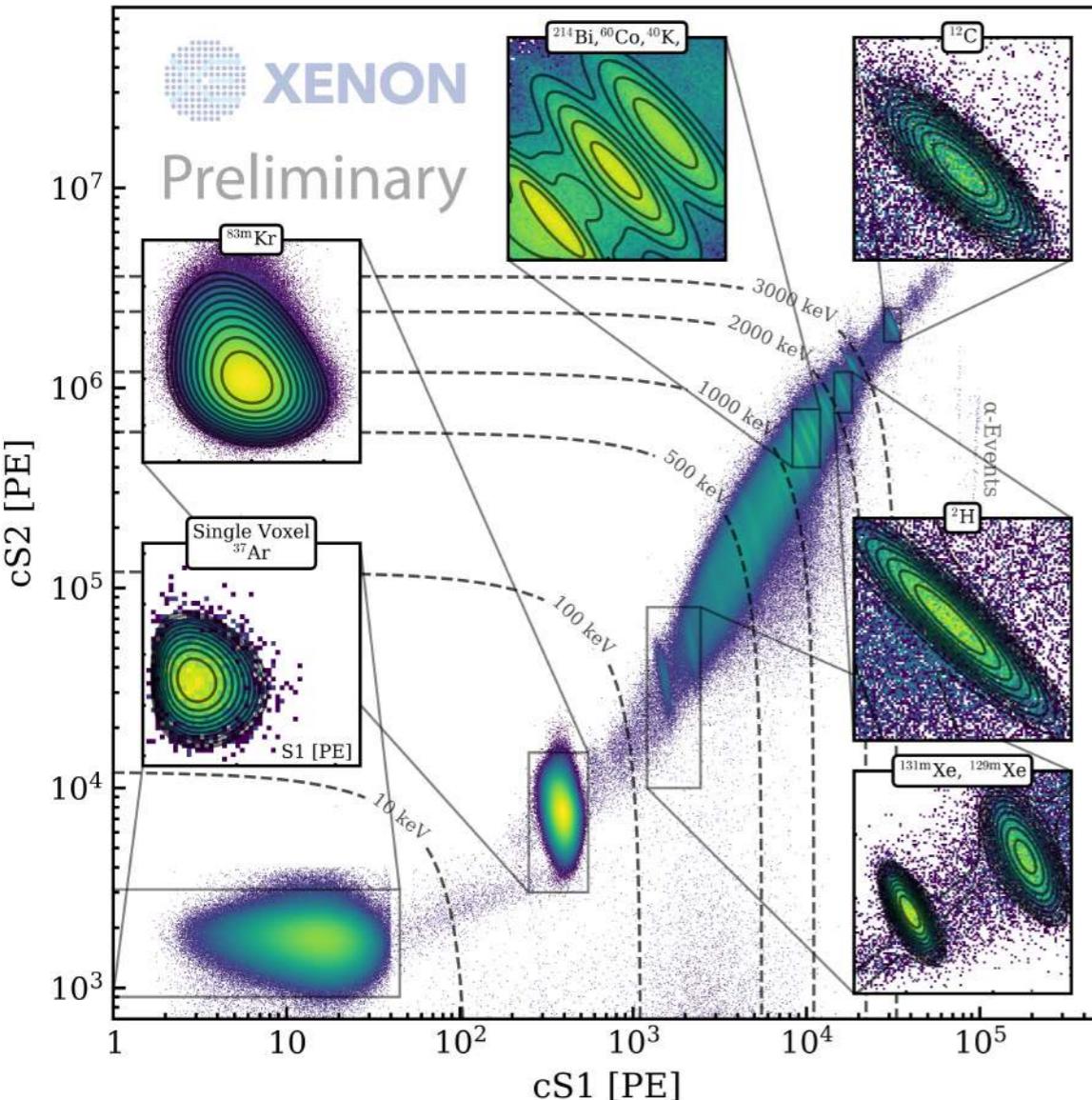
# XENONnT First Data

## SR0 WIMPs search data

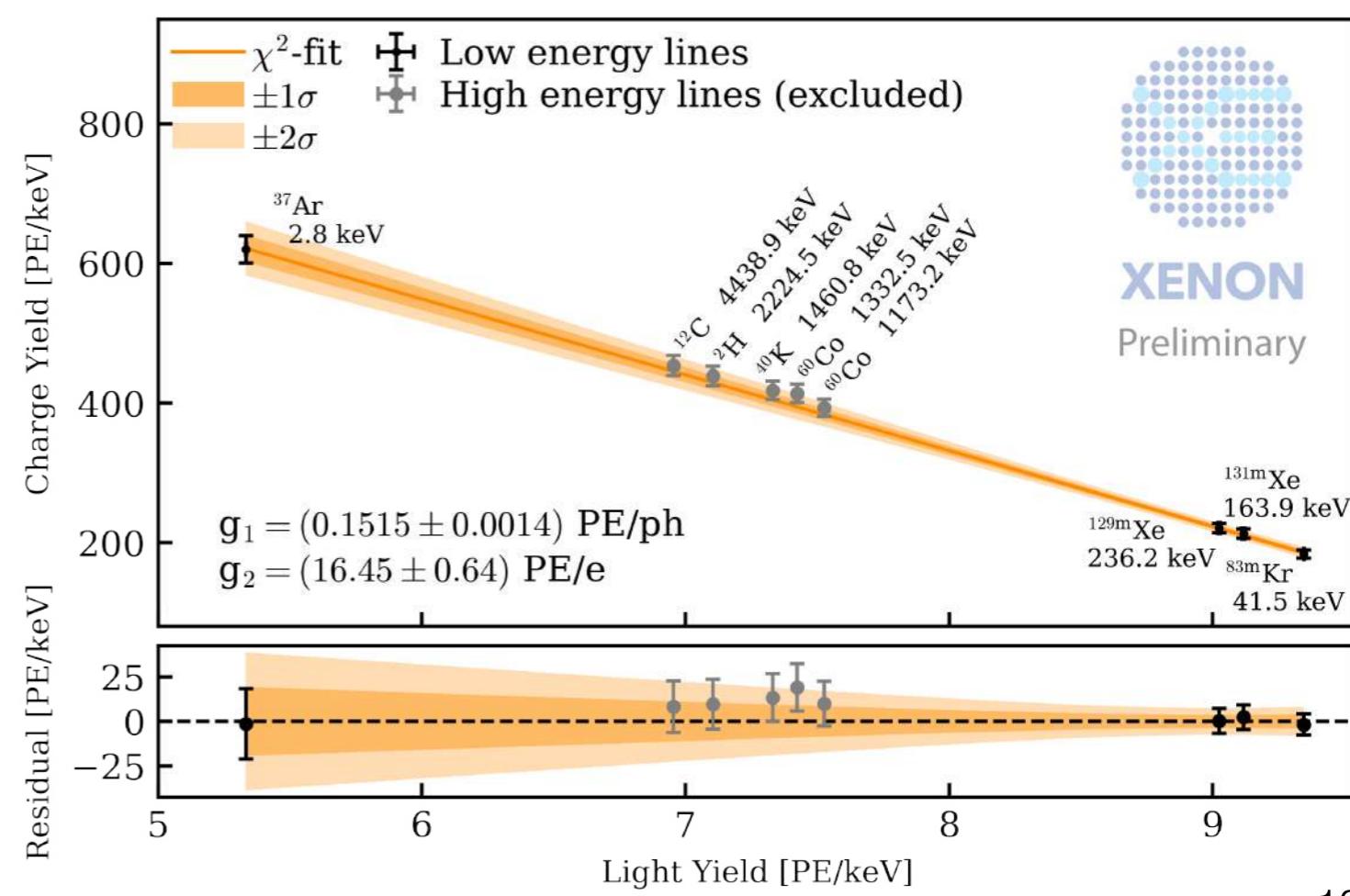
- July 6 - Nov 10, 2021
- 95.1 days live-time
- $(4.18 \pm 0.13)t$  fiducial mass
- exposure of 1.1 t-y
- blind analysis



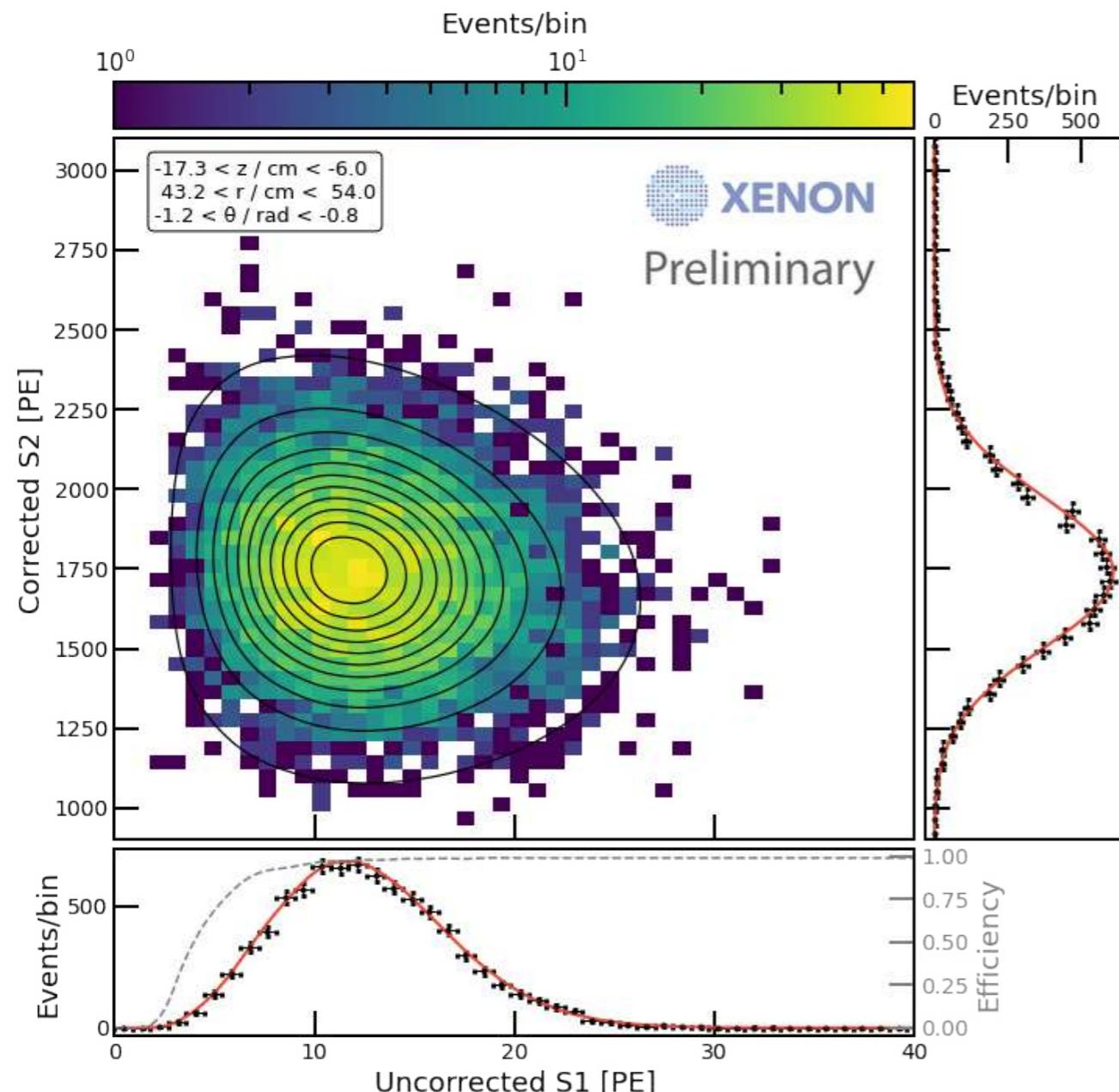
# Energy Calibrations



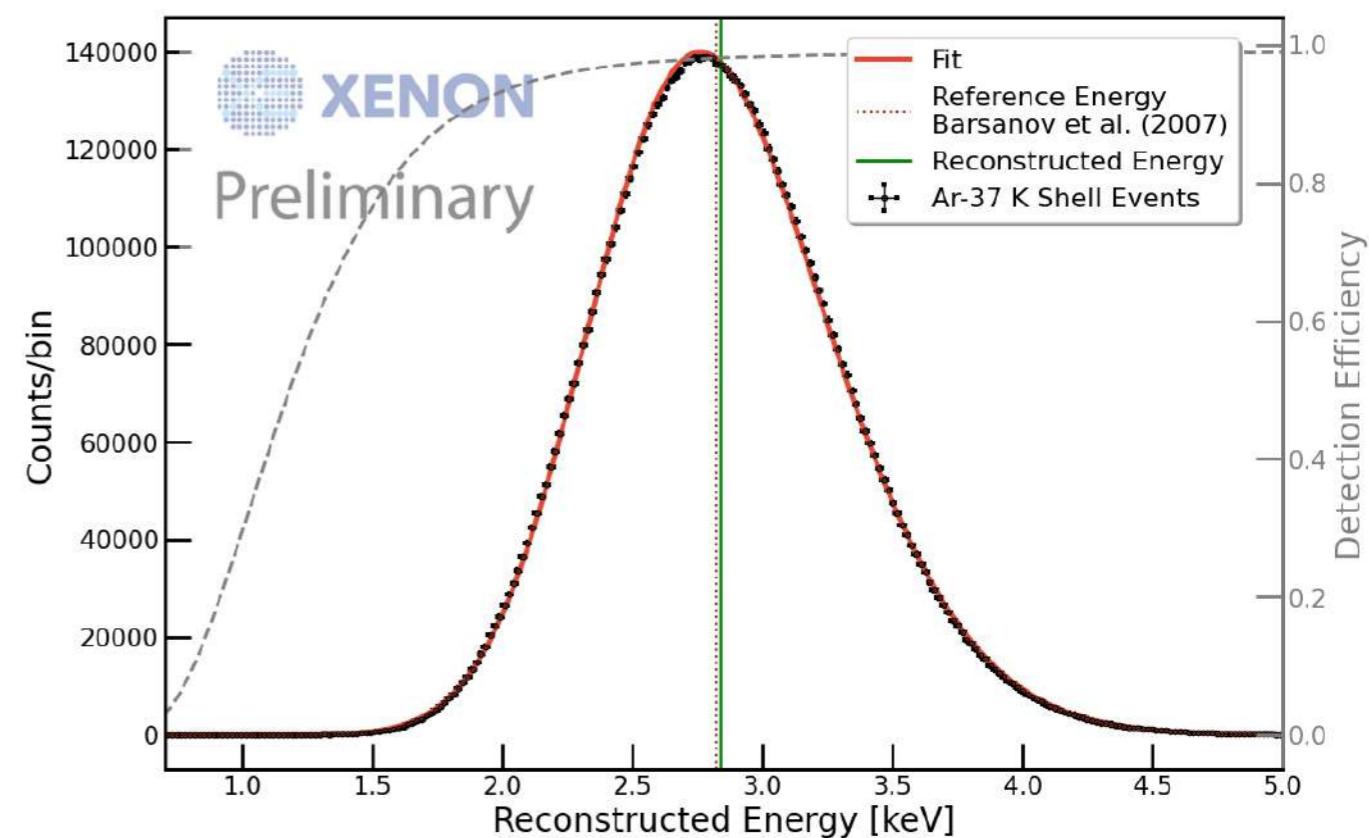
- Calibrations are done from keV to MeV
- Ar37, Kr83m, Xe131m, Xe129m are primarily used for low energy analysis



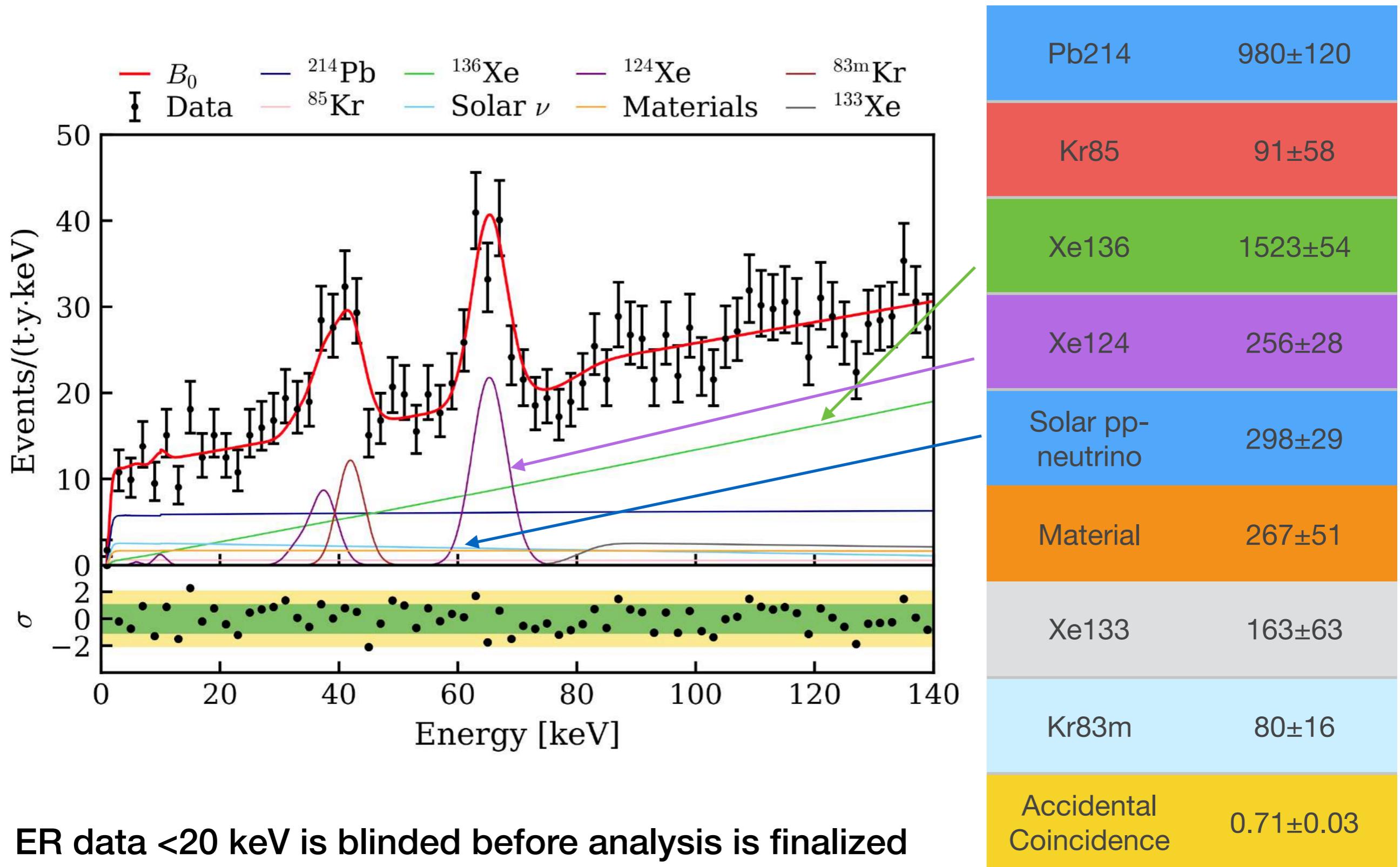
# Ar37 Calibration



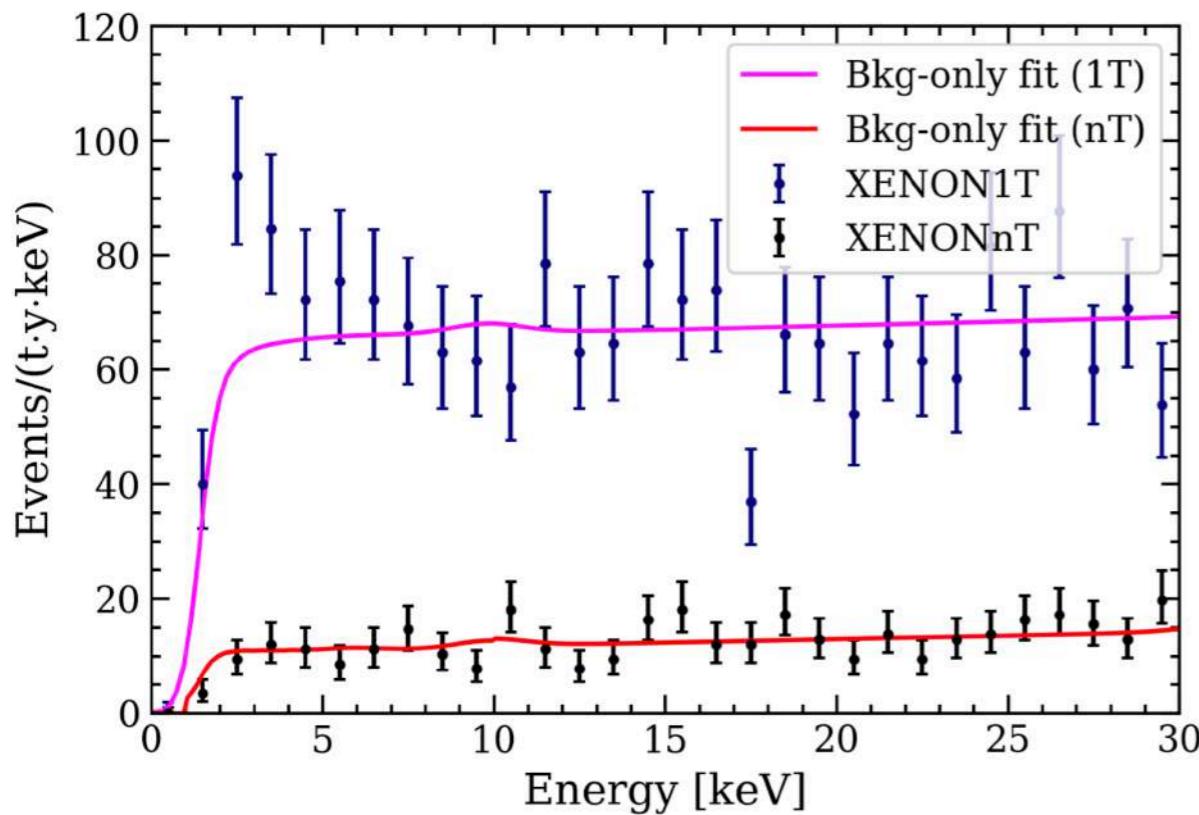
- Ar37: mono-energetic peak @ 2.8keV
- Modeled well with skewed Gaussian distribution in reconstructed energy



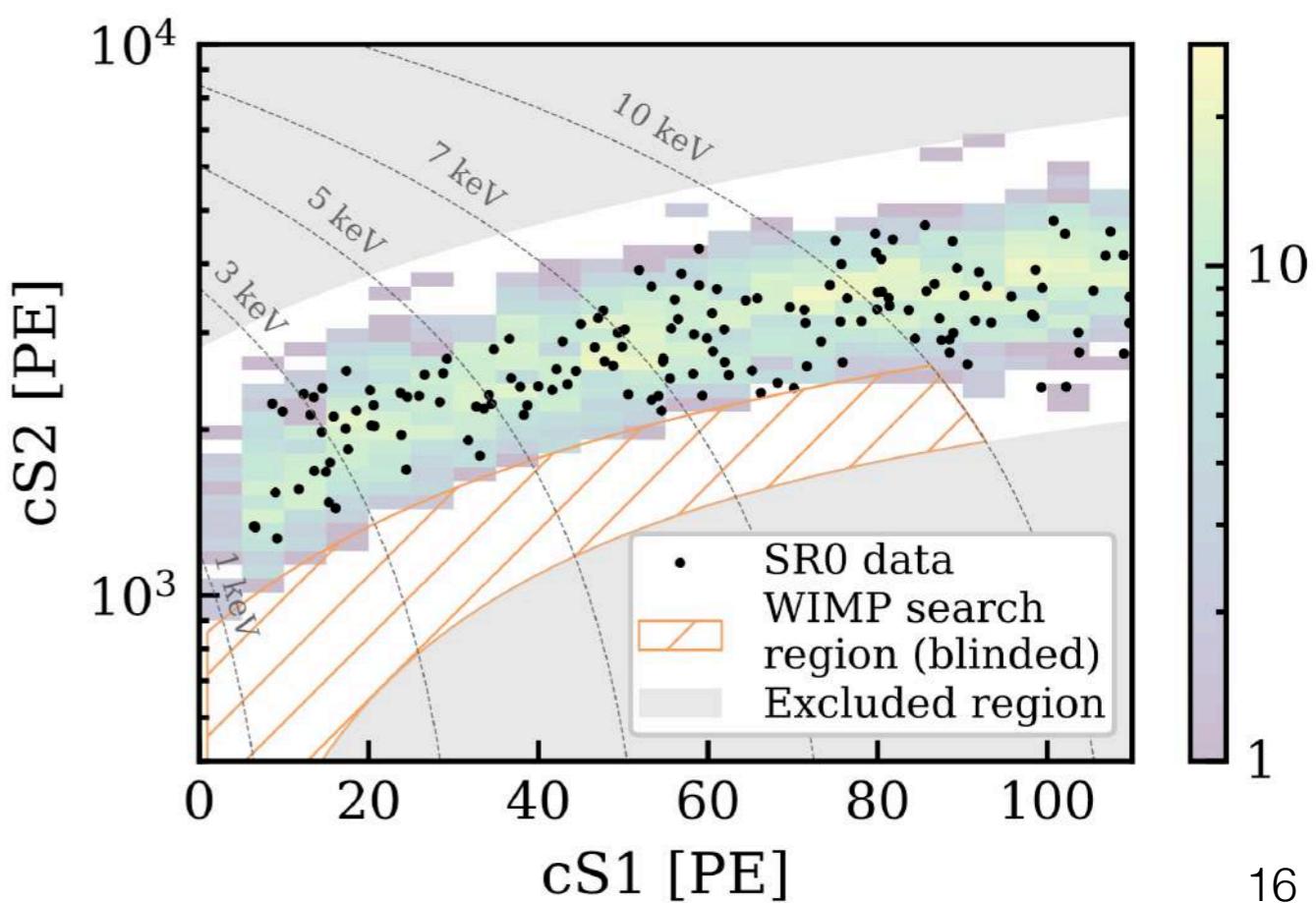
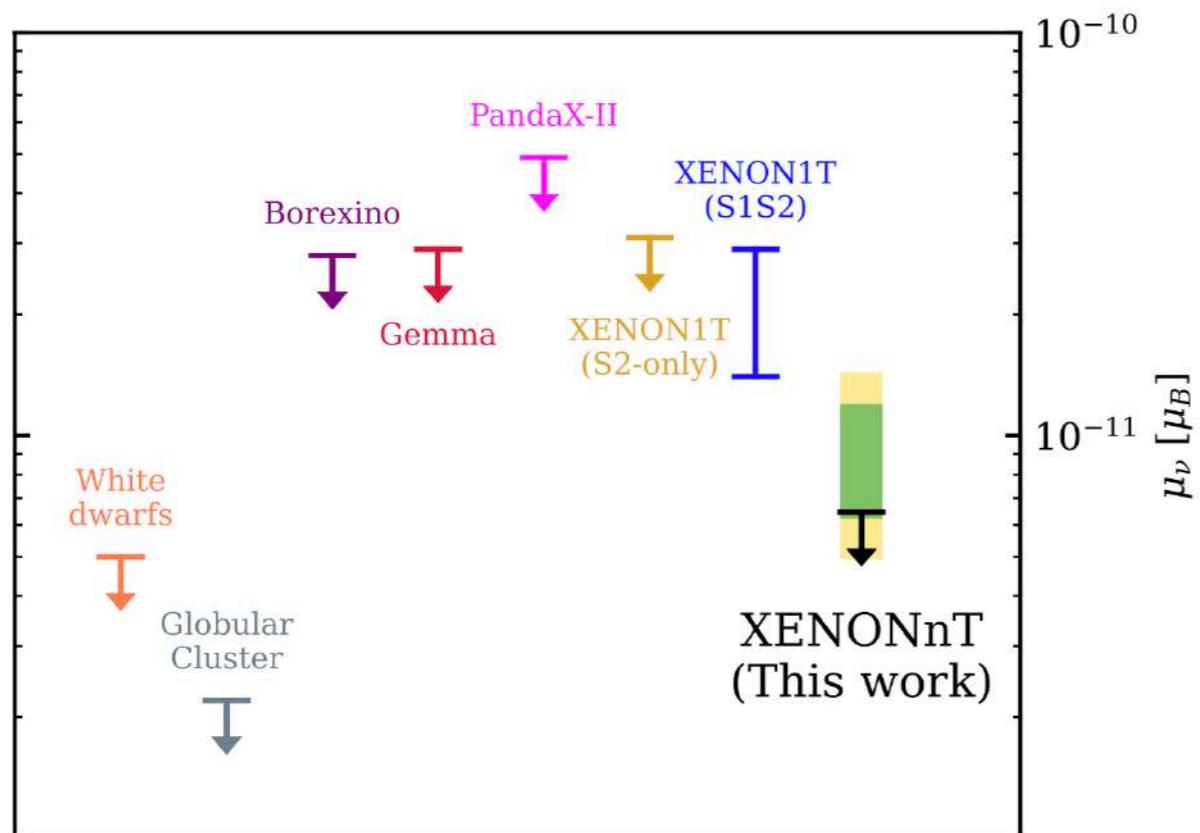
# Electronic Recoil Background



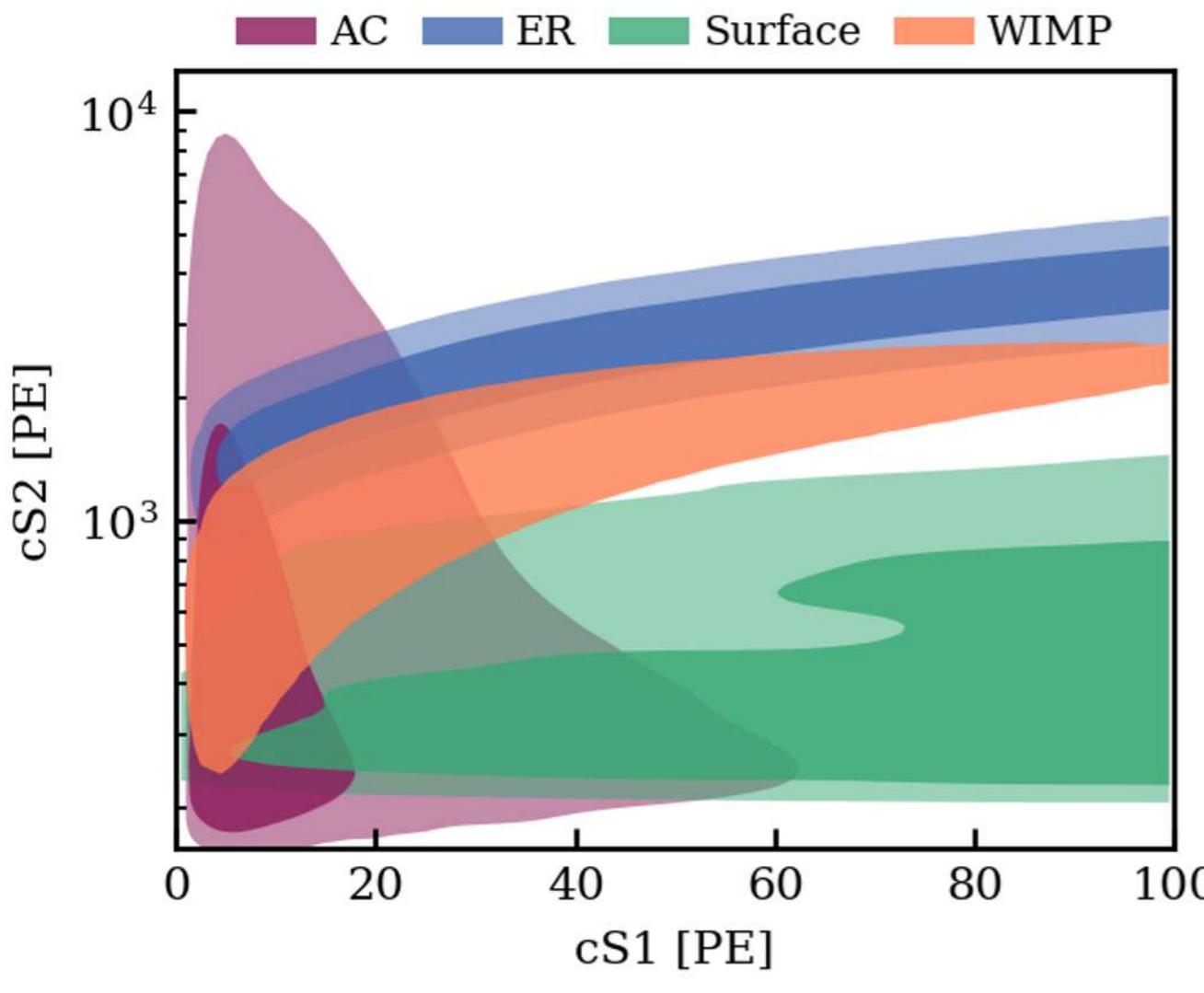
# Zoomed in look below 30 keV



- Lowest background level is achieved:  
 $(16.1 \pm 1.3)$  events/( $t \cdot y \cdot \text{keV}$ )
- NR search data being blinded while searching for ER signals



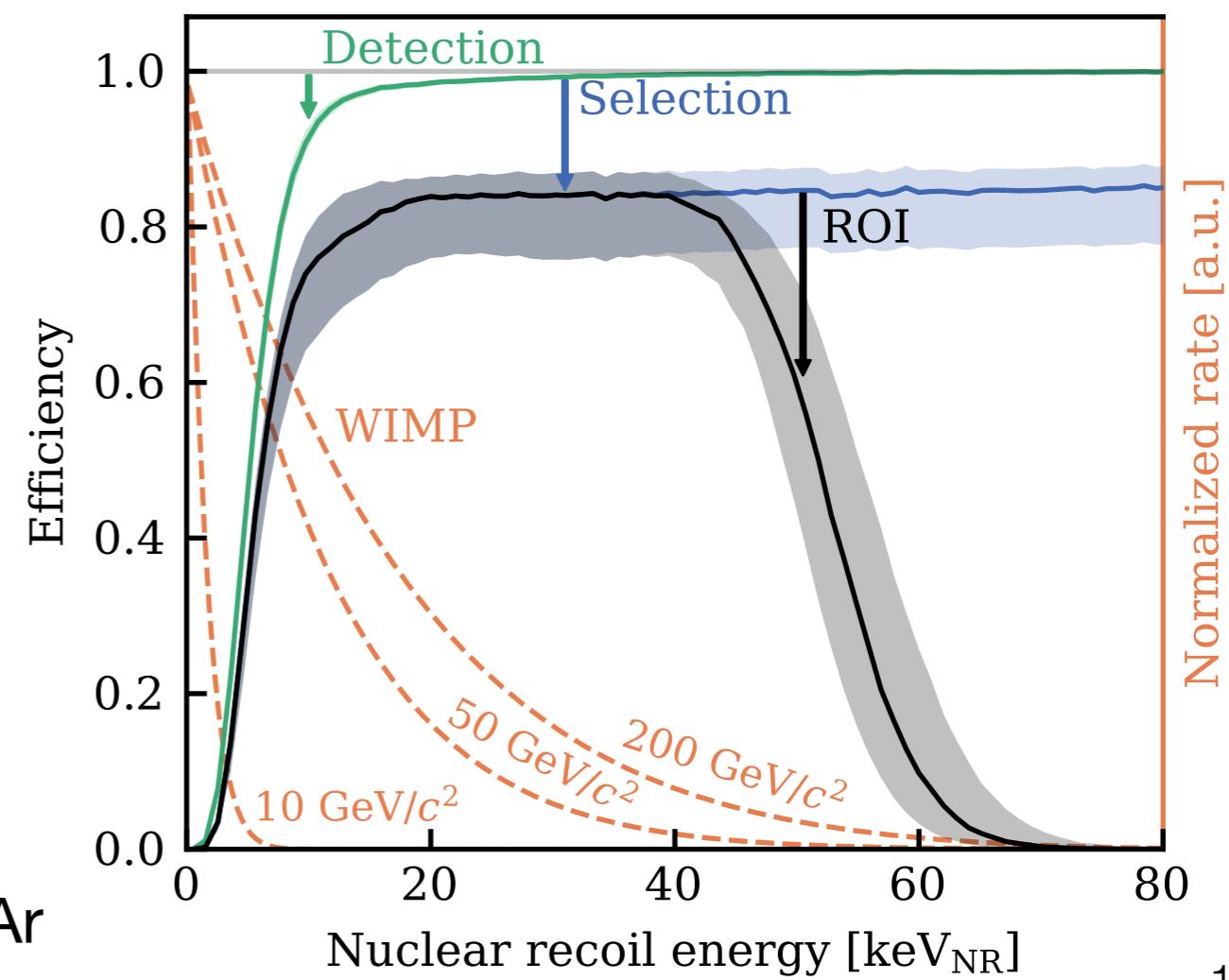
# First WIMPs search



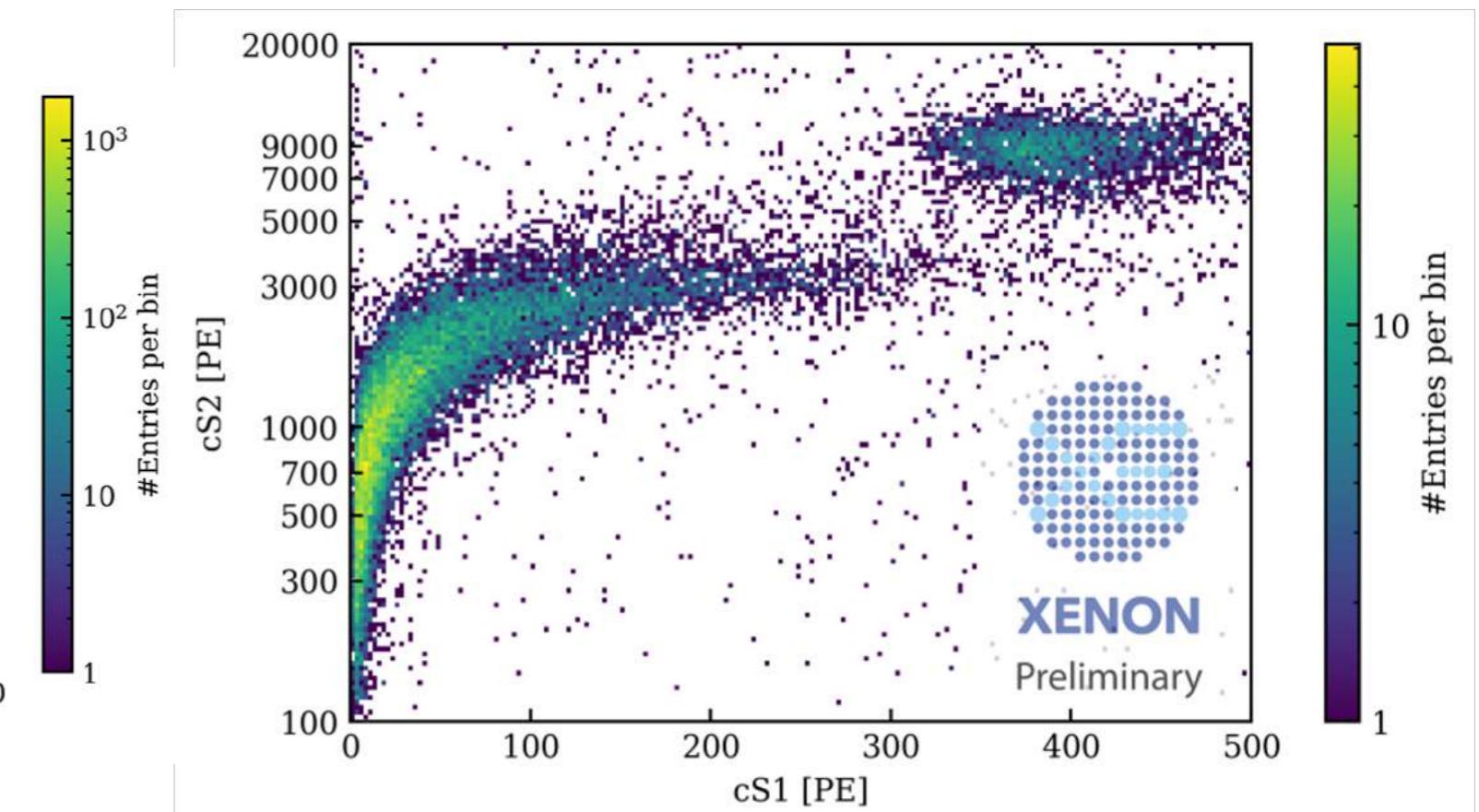
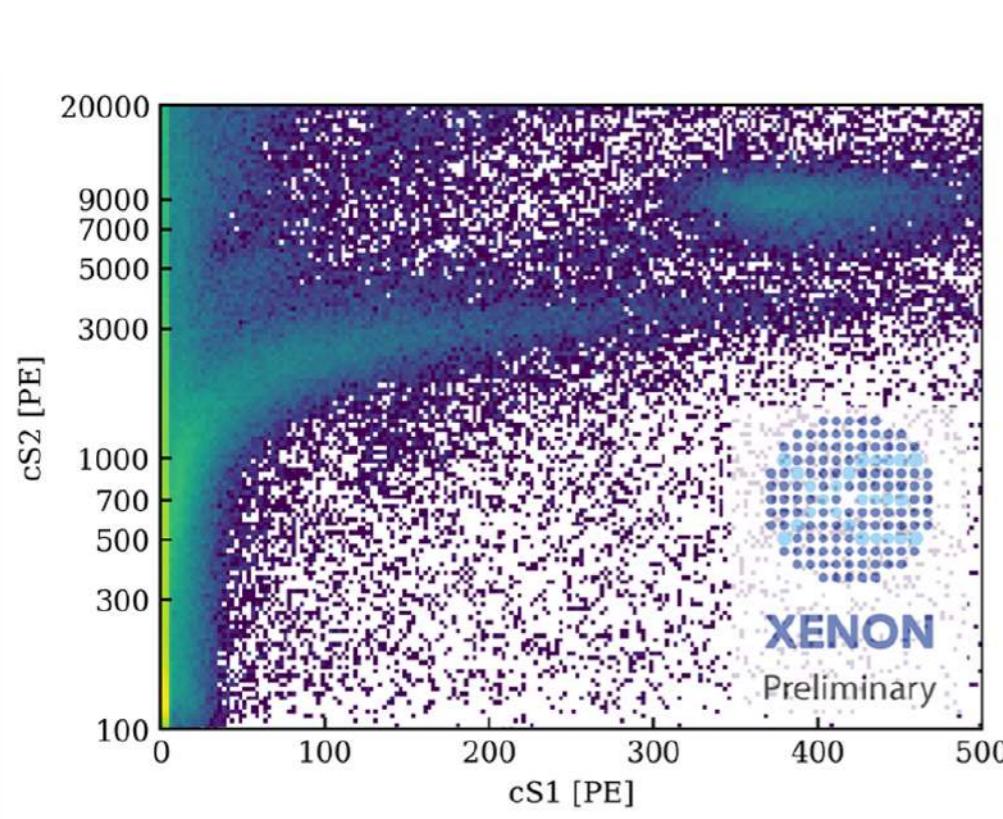
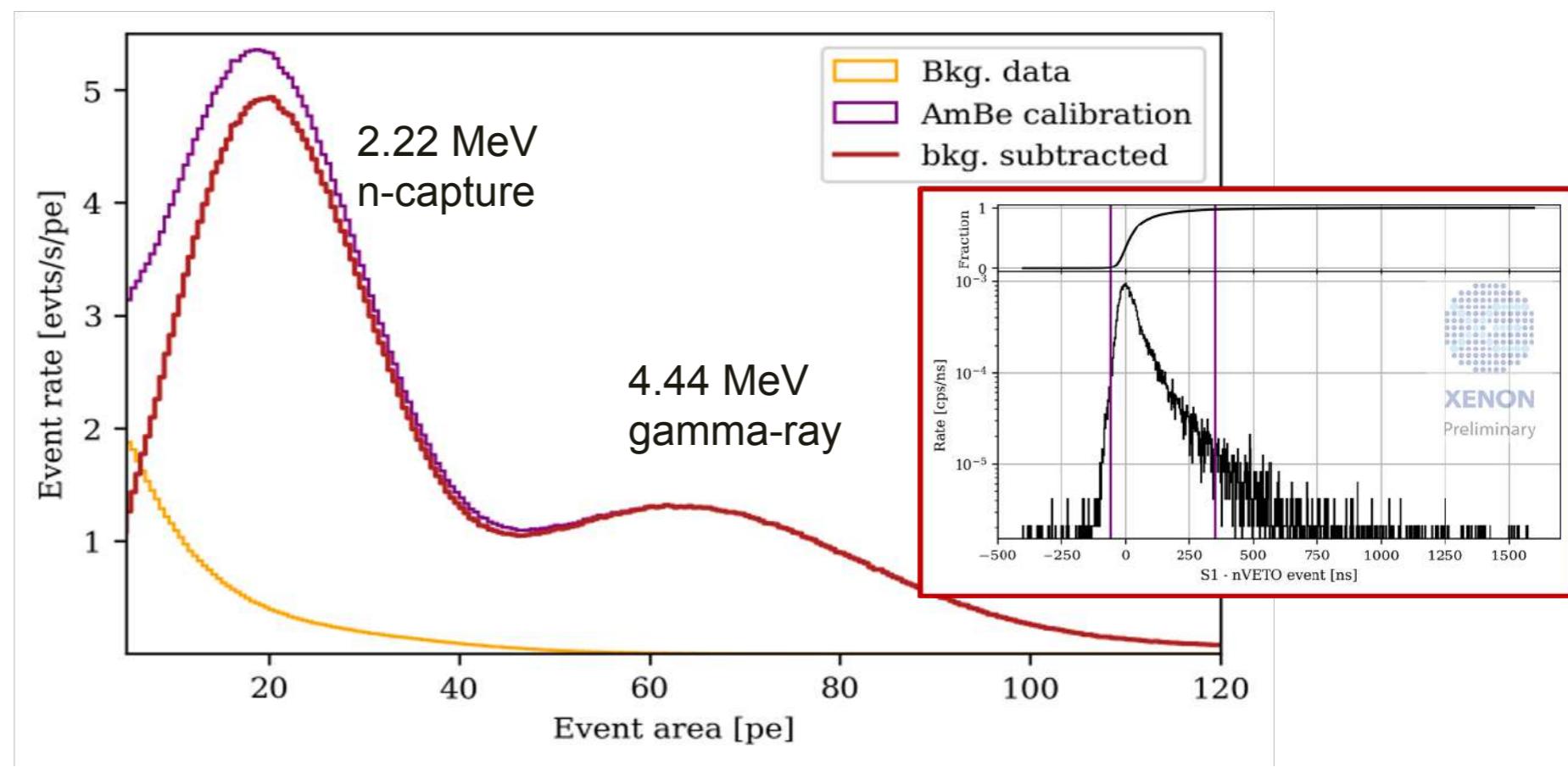
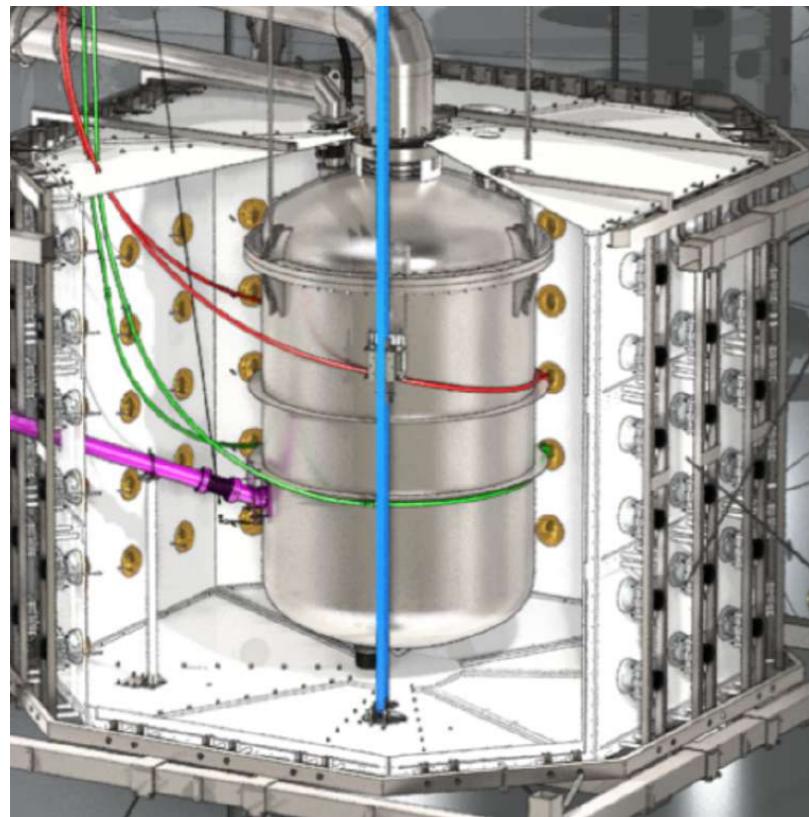
Detection efficiency:

- S1 3-fold PMT coincidence
- Full waveform simulation
- Data-driven methods from  $^{83m}\text{Kr}$  and  $^{37}\text{Ar}$

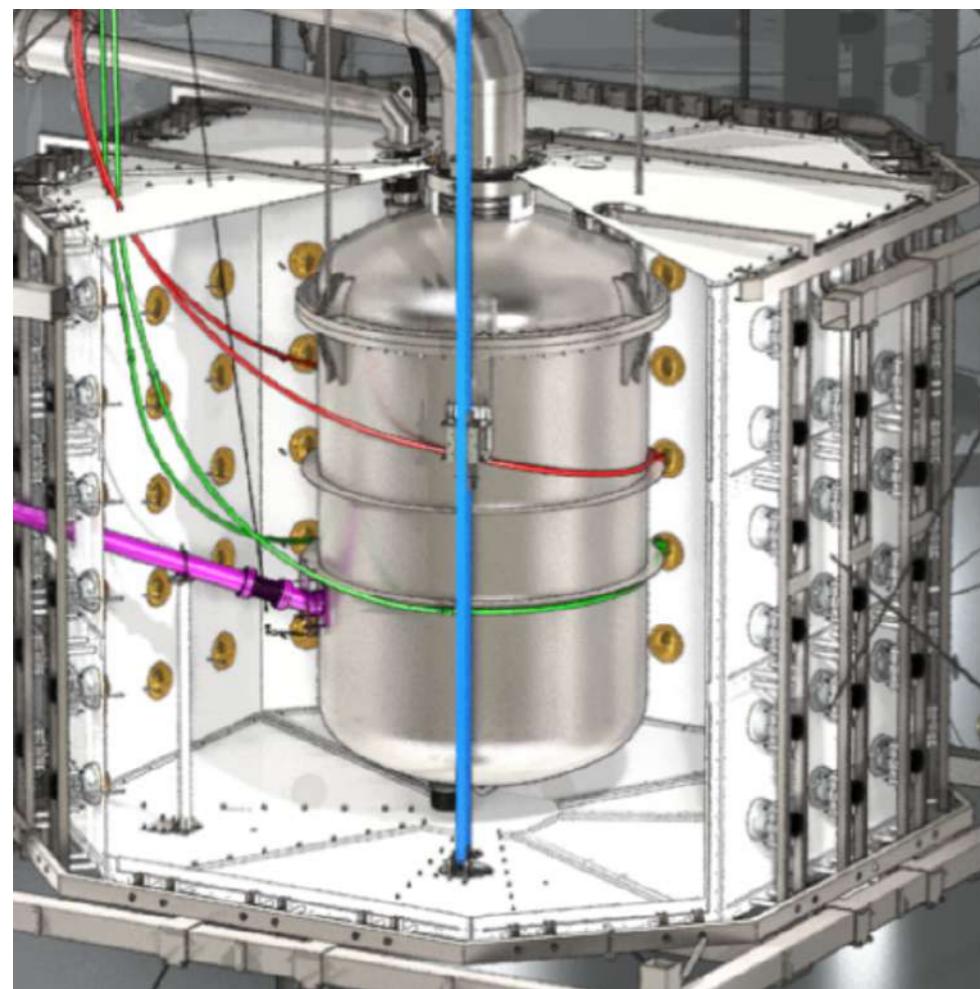
- ROI for WIMPs Search:
  - cS1 [0 pe, 100 pe]
  - cS2 [ $10^{2.1}$  pe,  $10^{4.1}$  pe]



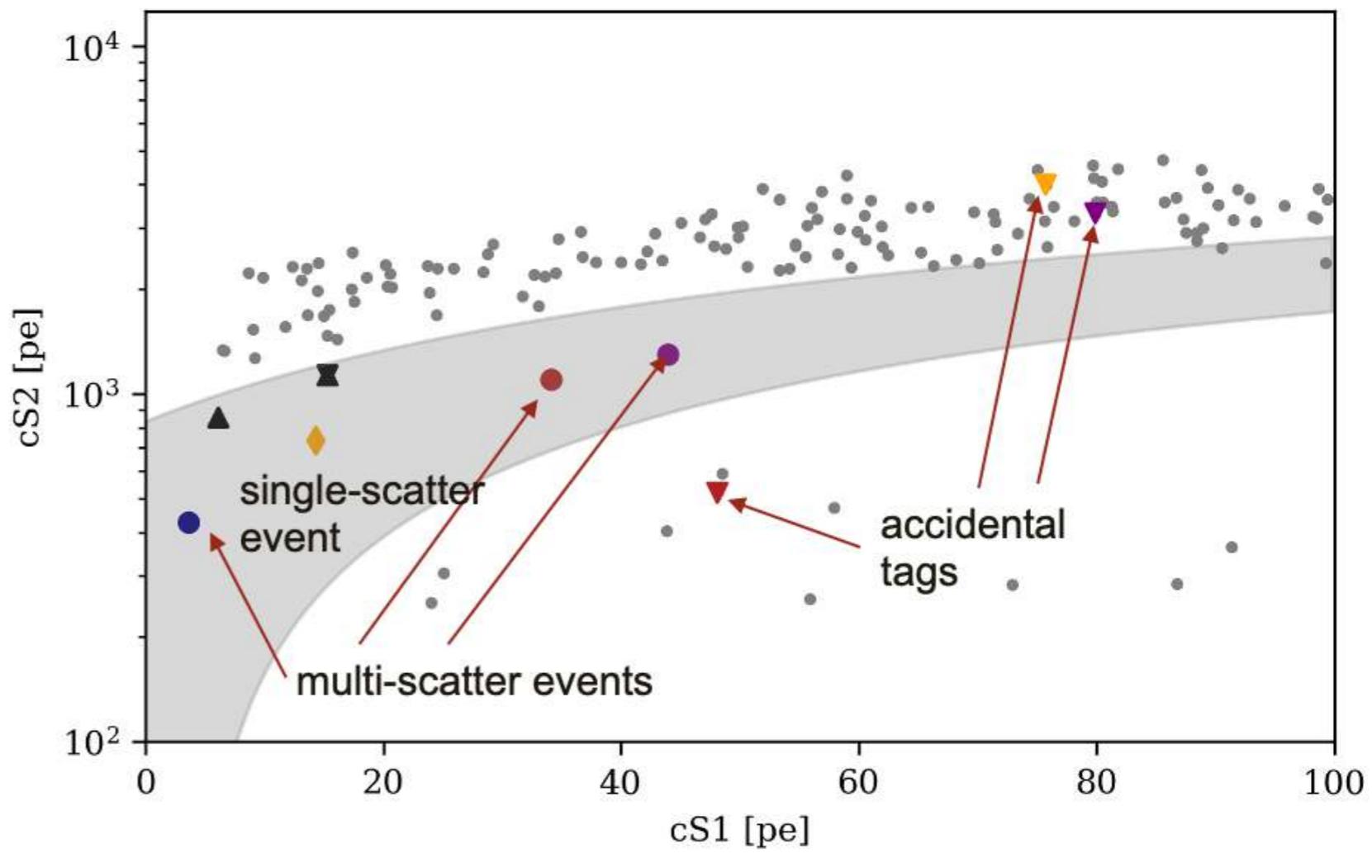
# Nuclear Recoil Calibrations



# Neutron Background



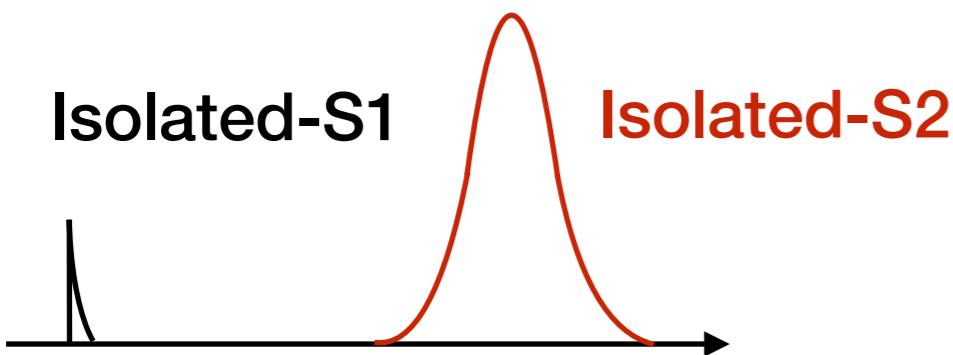
NV tagged events, and multiple scatters as data-driven neutron samples



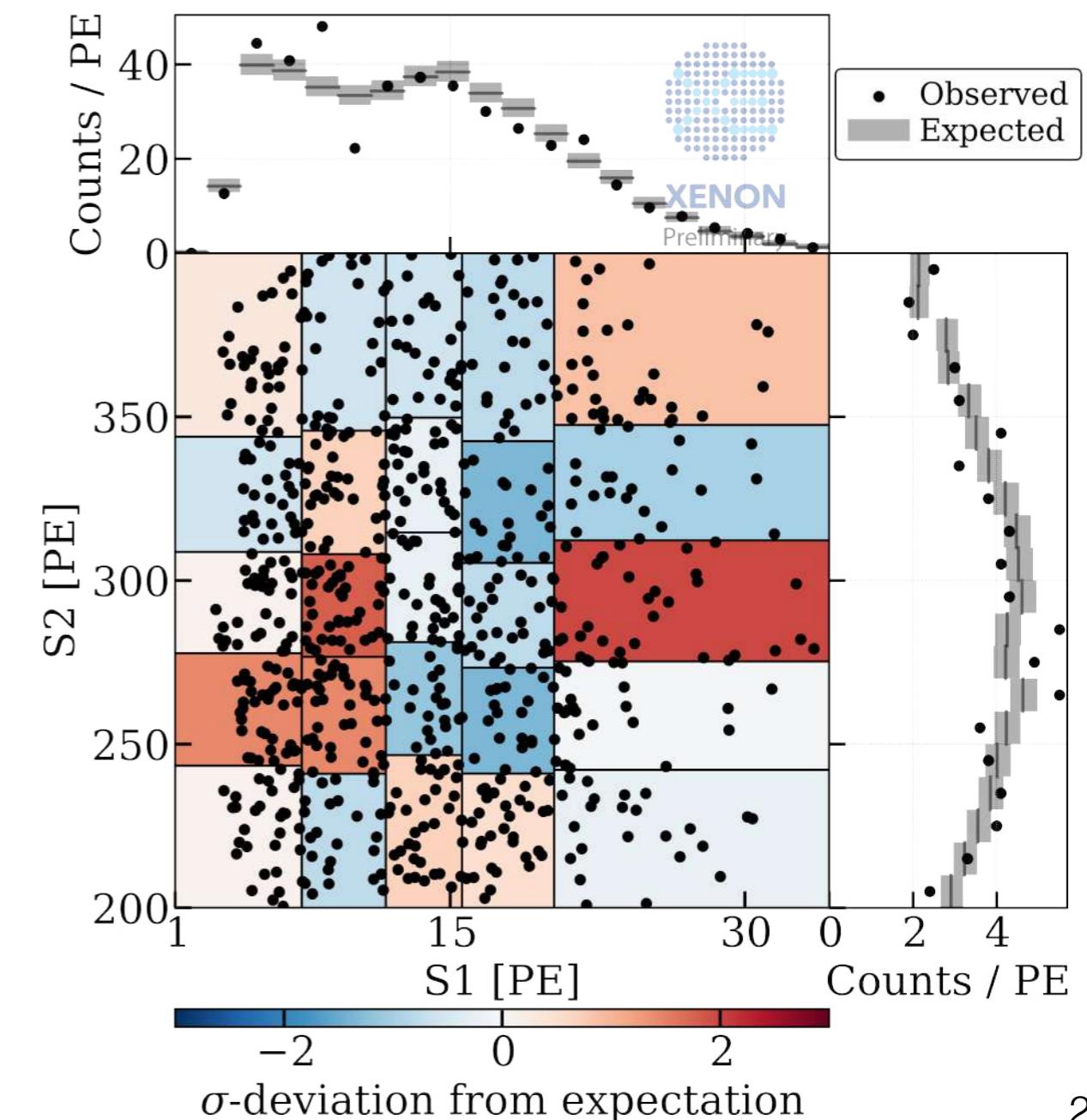
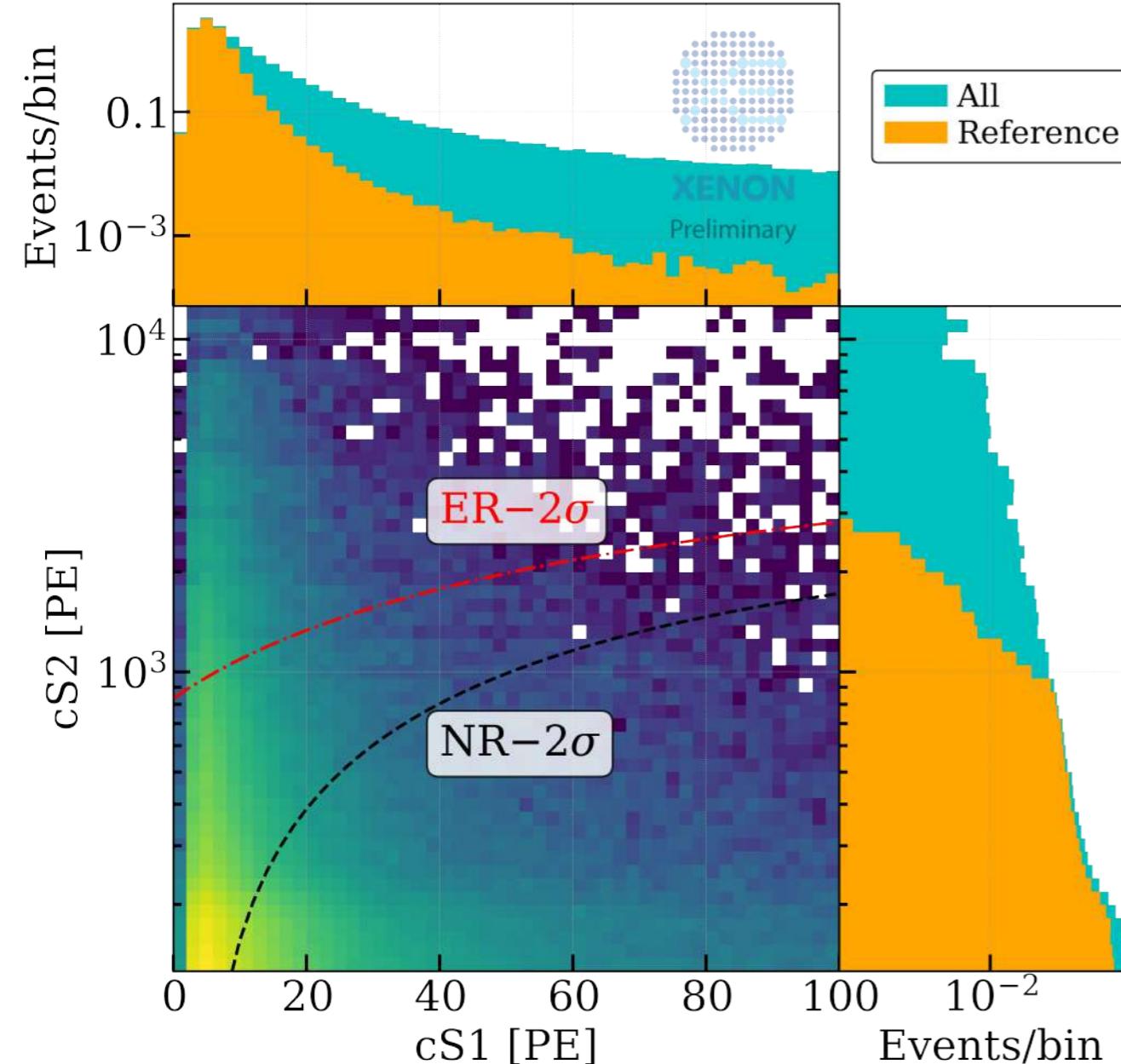
Observed neutron multiple scatter rate is x6 higher than MC predictions.

Final background prediction is performed towards the data-driven approach, without tuning fiducial volume post-unblinding

# Accidental Coincidence Background



AC is seen and validated to 5% precision!



# Accidental Coincidence Background

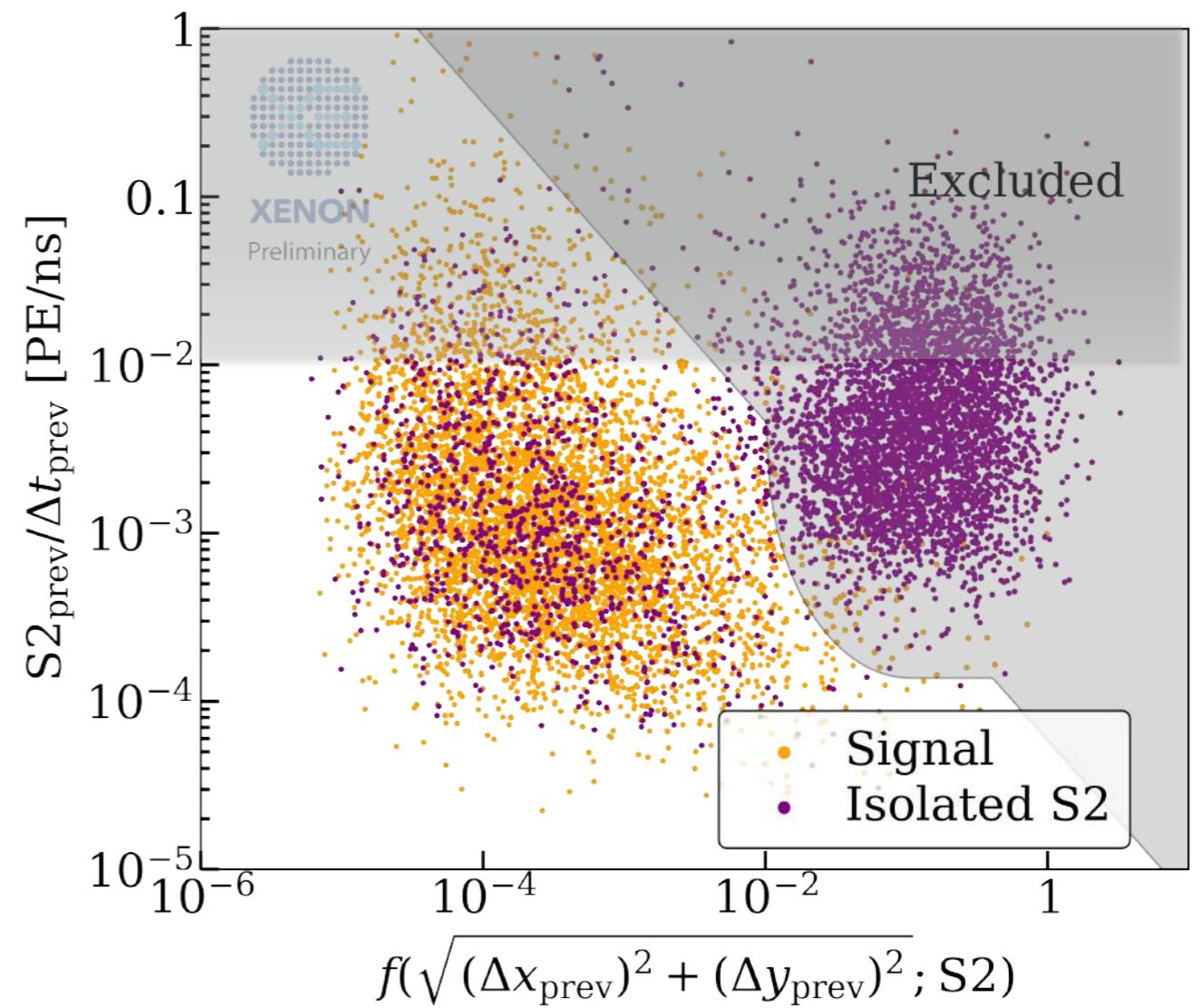
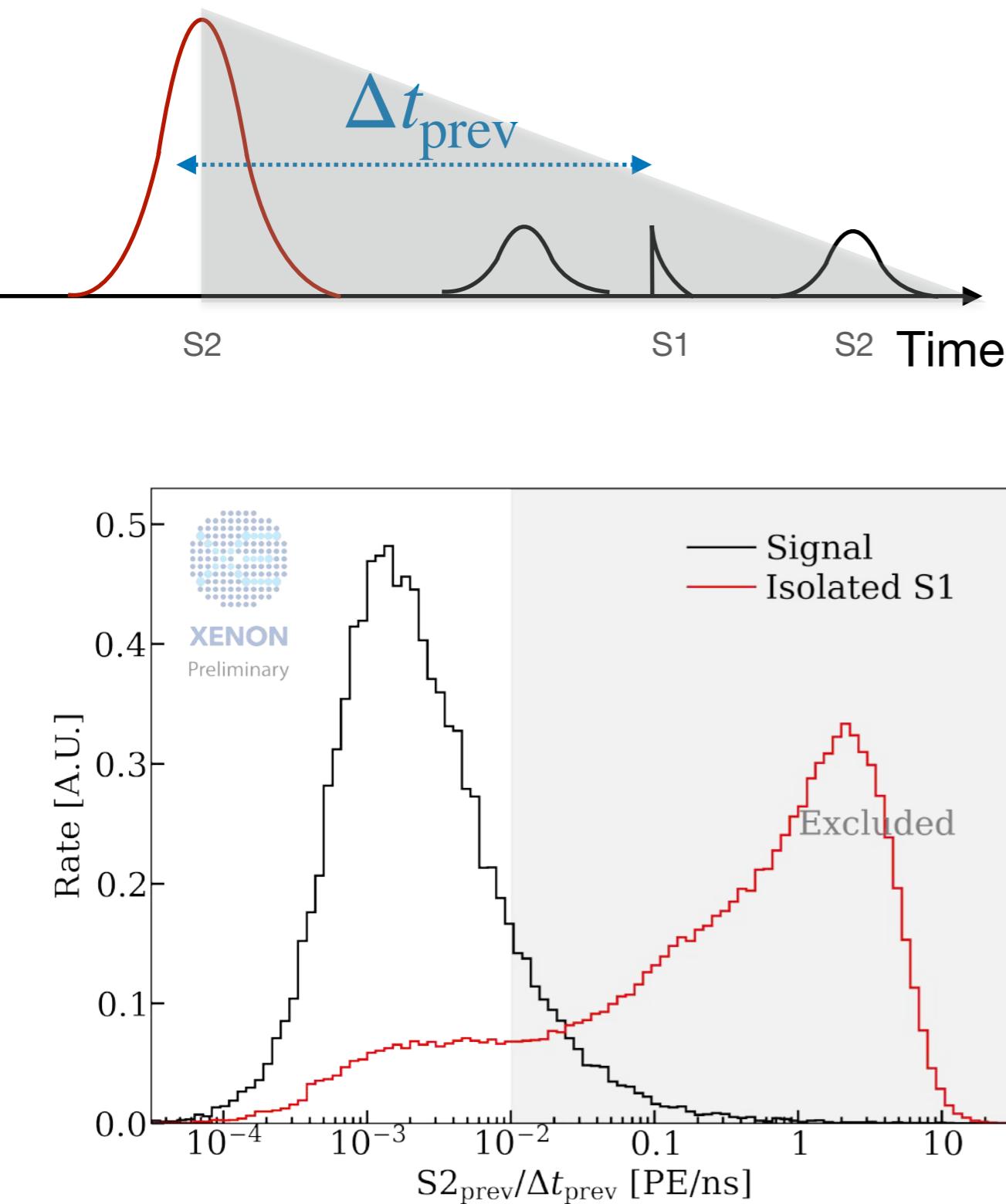


- Key Analyzers from Tsinghua:
- Kexin Liu (Ph. D. 2021)
- Dacheng Xu (B.S 2022, now Ph. D. @ Columbia)



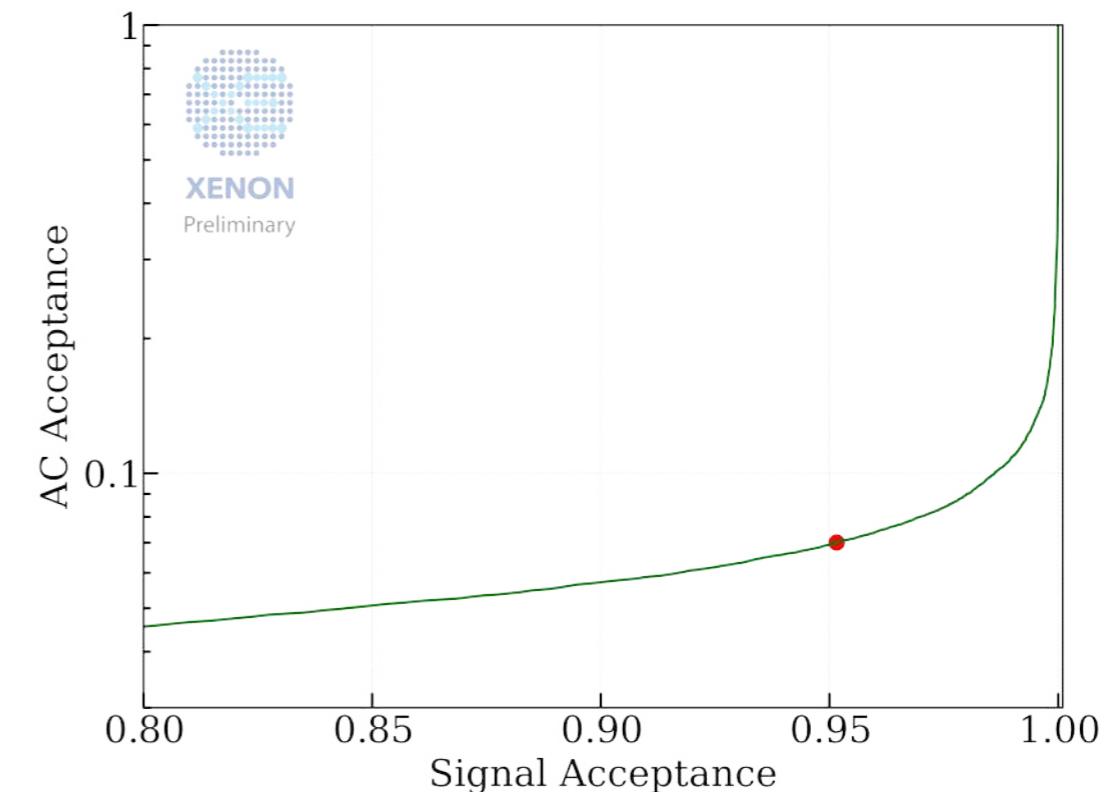
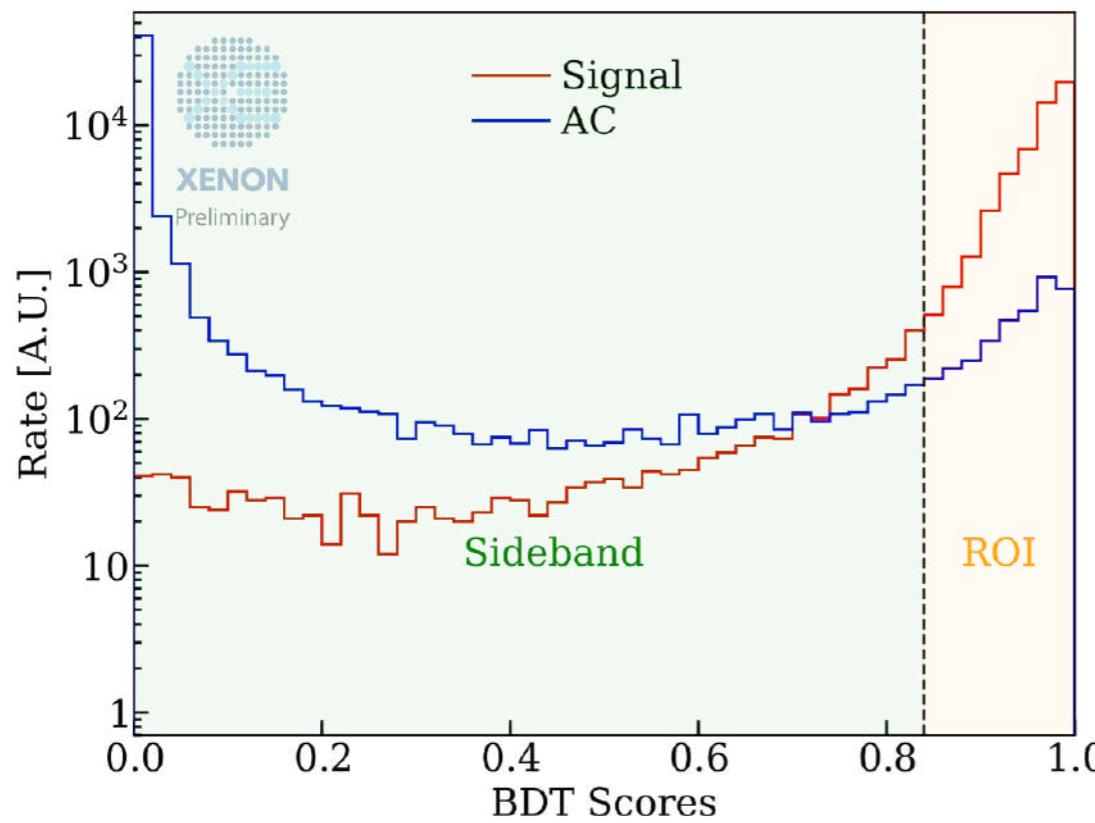
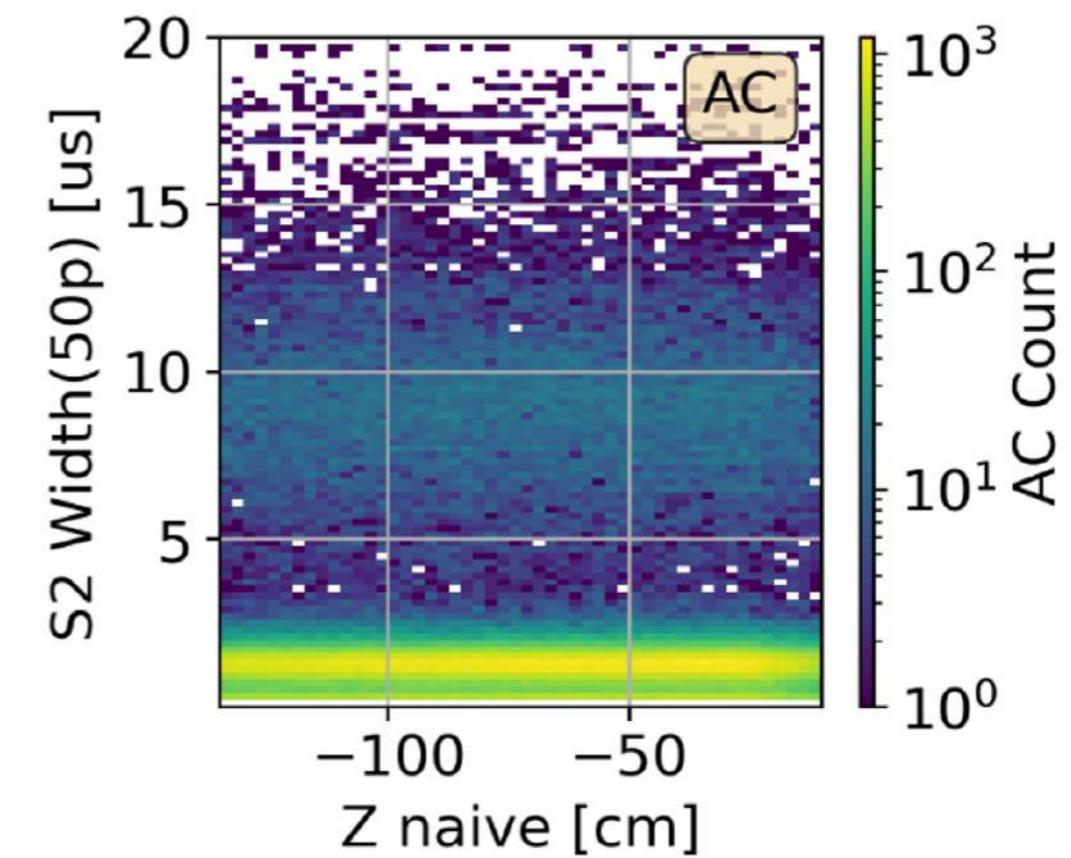
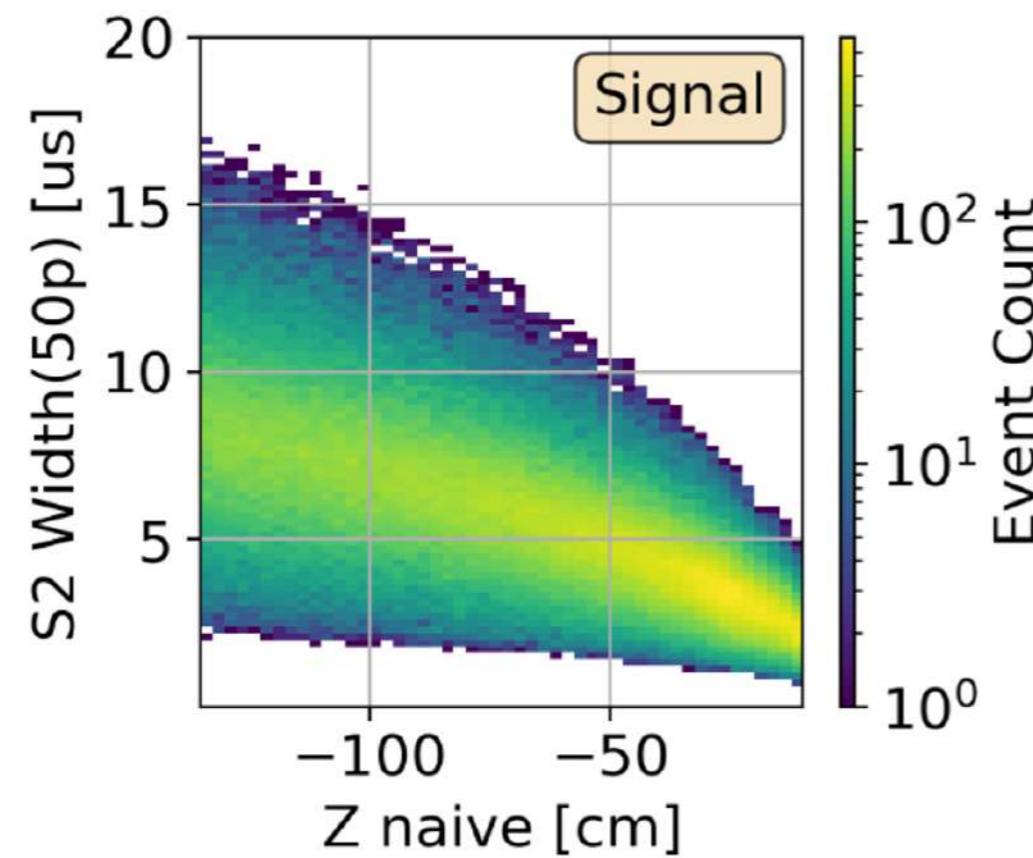
Experiment	Isolated-S1	Isolated-S2	Max Drift	AC	Importance
XENON1T	1.1 Hz	2.6 mHz	~ 650 us	0.47	negligible
XENONnT	1.9 Hz	~100 mHz	~ 2200 us	~80	bigest background

# AC Suppression – Shadow Effects



**Reject exposure near high energy events**

# AC Suppression – S1 and S2 Correlations

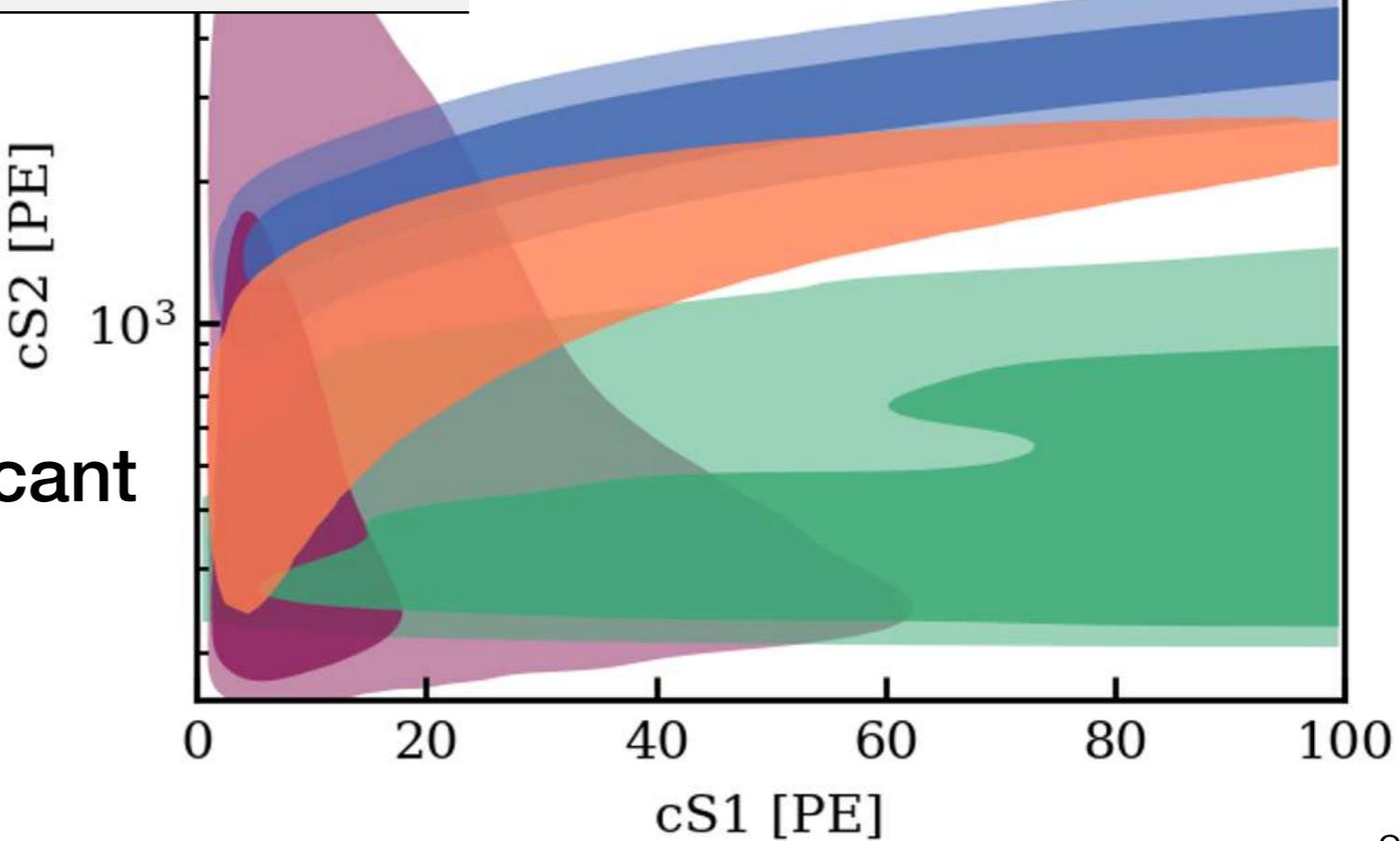


# Summary of Backgrounds

Sources	Nominal	Best Fit	
		ROI	Signal Like
ER	134	135±12	0.81±0.07
Neutron	1.1±0.6	1.1±0.6	0.42±0.20
Neutrino	0.23±0.06	0.23±0.06	0.02±0.01
AC	4.3±0.2	4.3±0.2	0.36±0.01
Surface	14±3	12	0.34±0.11
Total	154	152±12	1.95±0.16
Data			

ER Surface WIMP

AC background is still a significant contribution to WIMPs search.

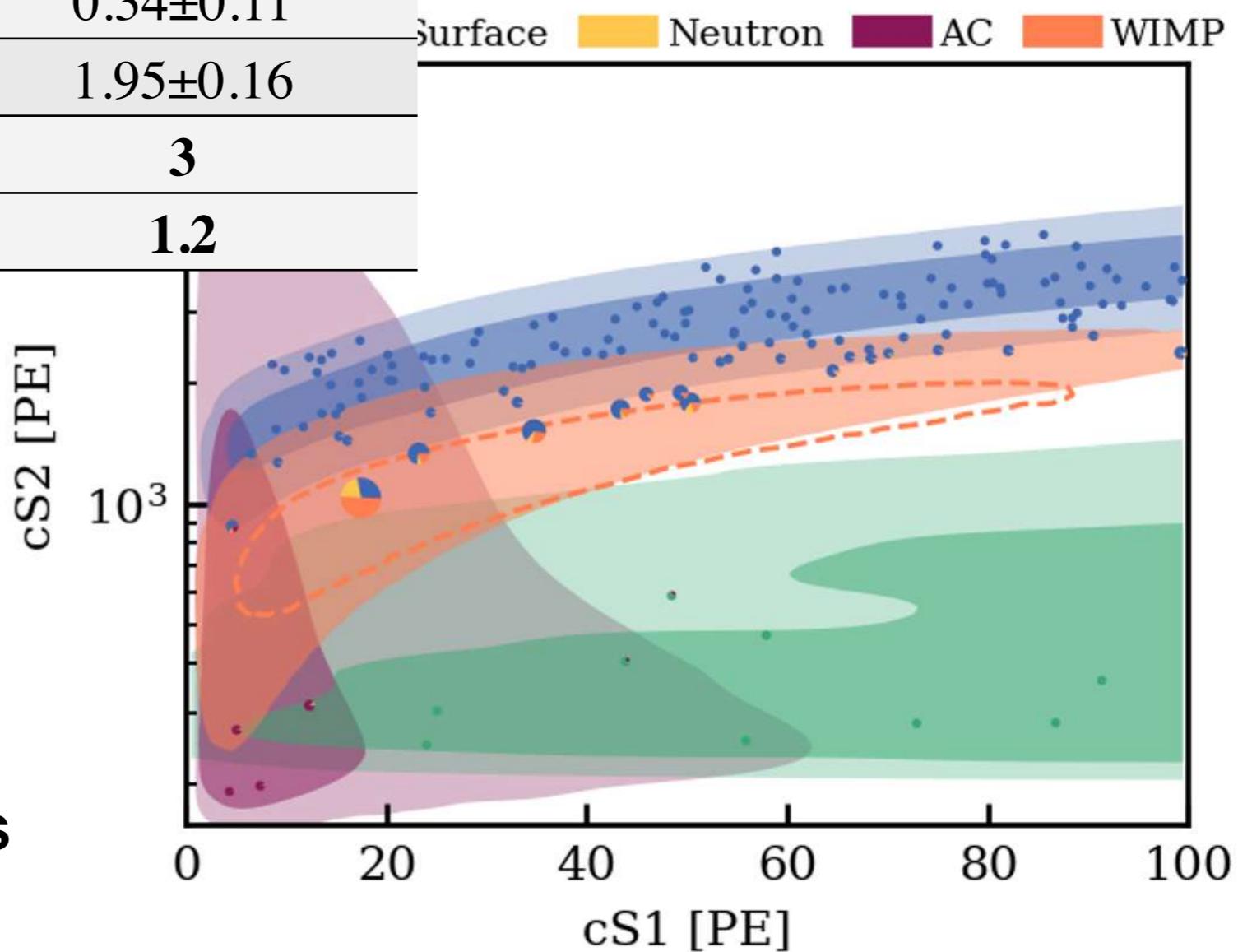


# Results from Unblinding

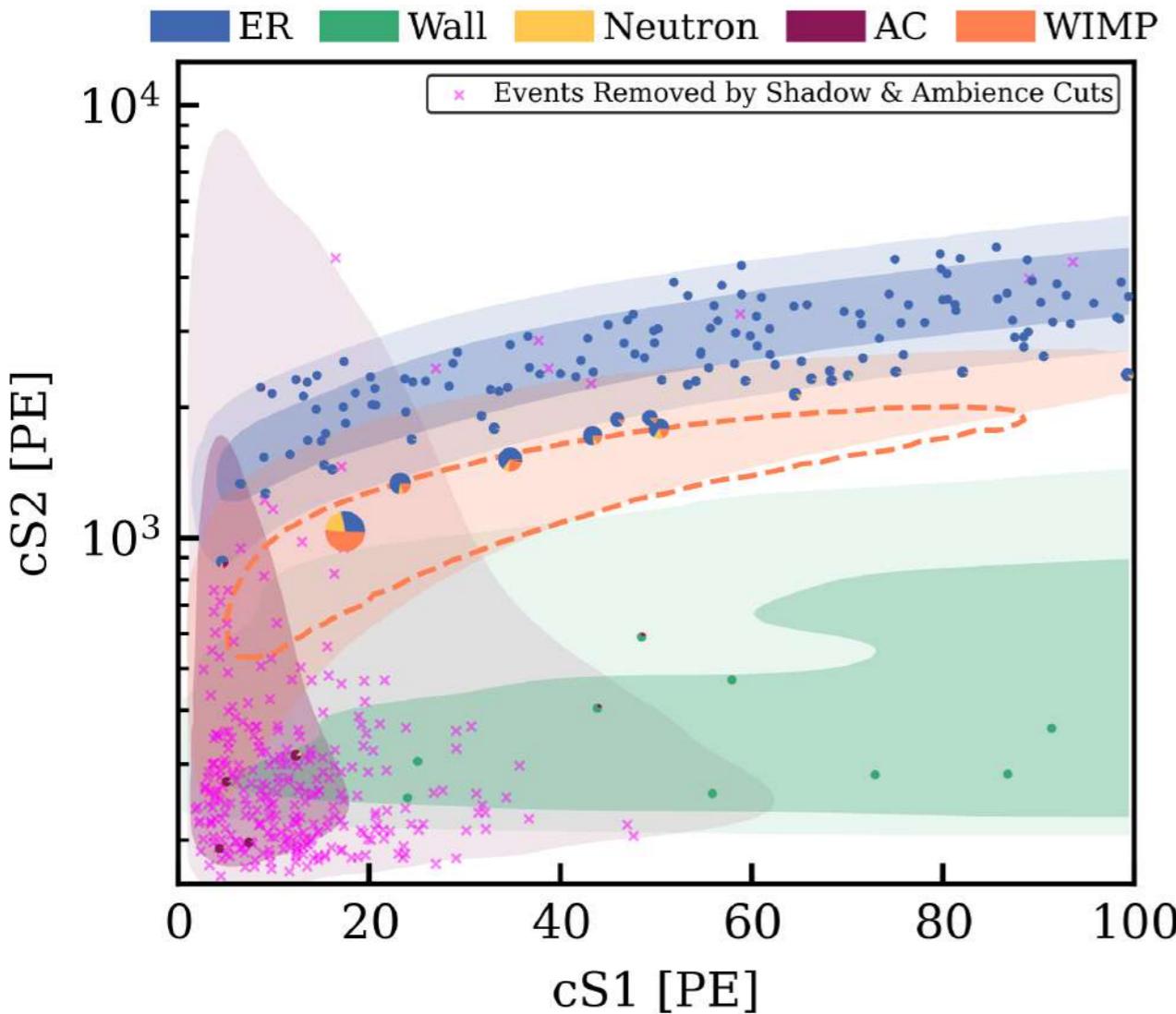
Sources	Nominal	Best Fit	
	ROI	Signal Like	
<b>ER</b>	134	$135 \pm 12$	$0.81 \pm 0.07$
<b>Neutron</b>	$1.1 \pm 0.6$	$1.1 \pm 0.6$	$0.42 \pm 0.20$
<b>Neutrino</b>	$0.23 \pm 0.06$	$0.23 \pm 0.06$	$0.02 \pm 0.01$
<b>AC</b>	$4.3 \pm 0.2$	$4.3 \pm 0.2$	$0.36 \pm 0.01$
<b>Surface</b>	$14 \pm 3$	12	$0.34 \pm 0.11$
<b>Total</b>	154	$152 \pm 12$	$1.95 \pm 0.16$
<b>Data</b>		<b>152</b>	<b>3</b>
<b>WIMPs</b>		<b>2.4</b>	<b>1.2</b>

**152 events in ROI, 16 in the blinded region**

Best fit indicate no NR excess

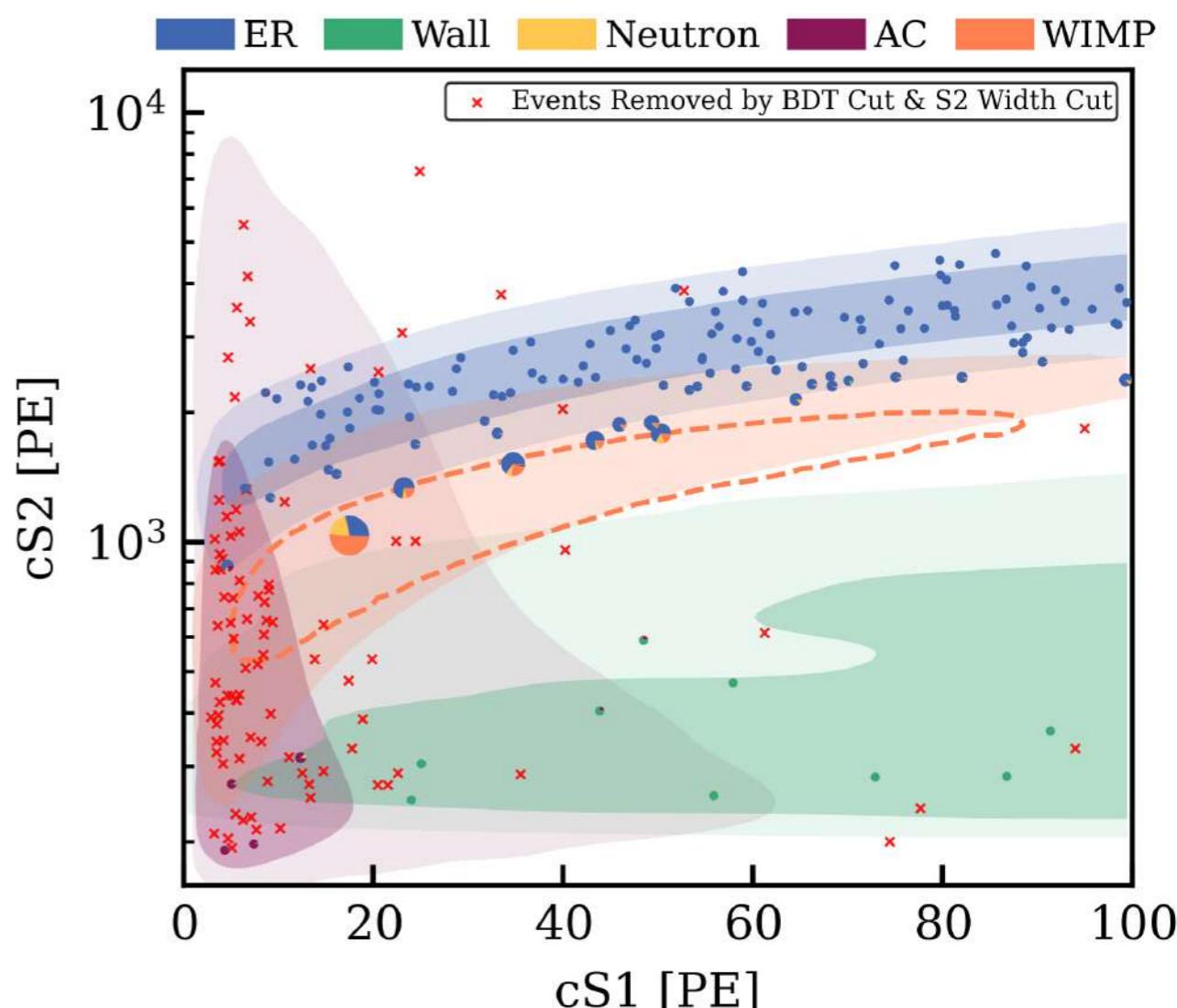


# Importance of anti-AC cuts

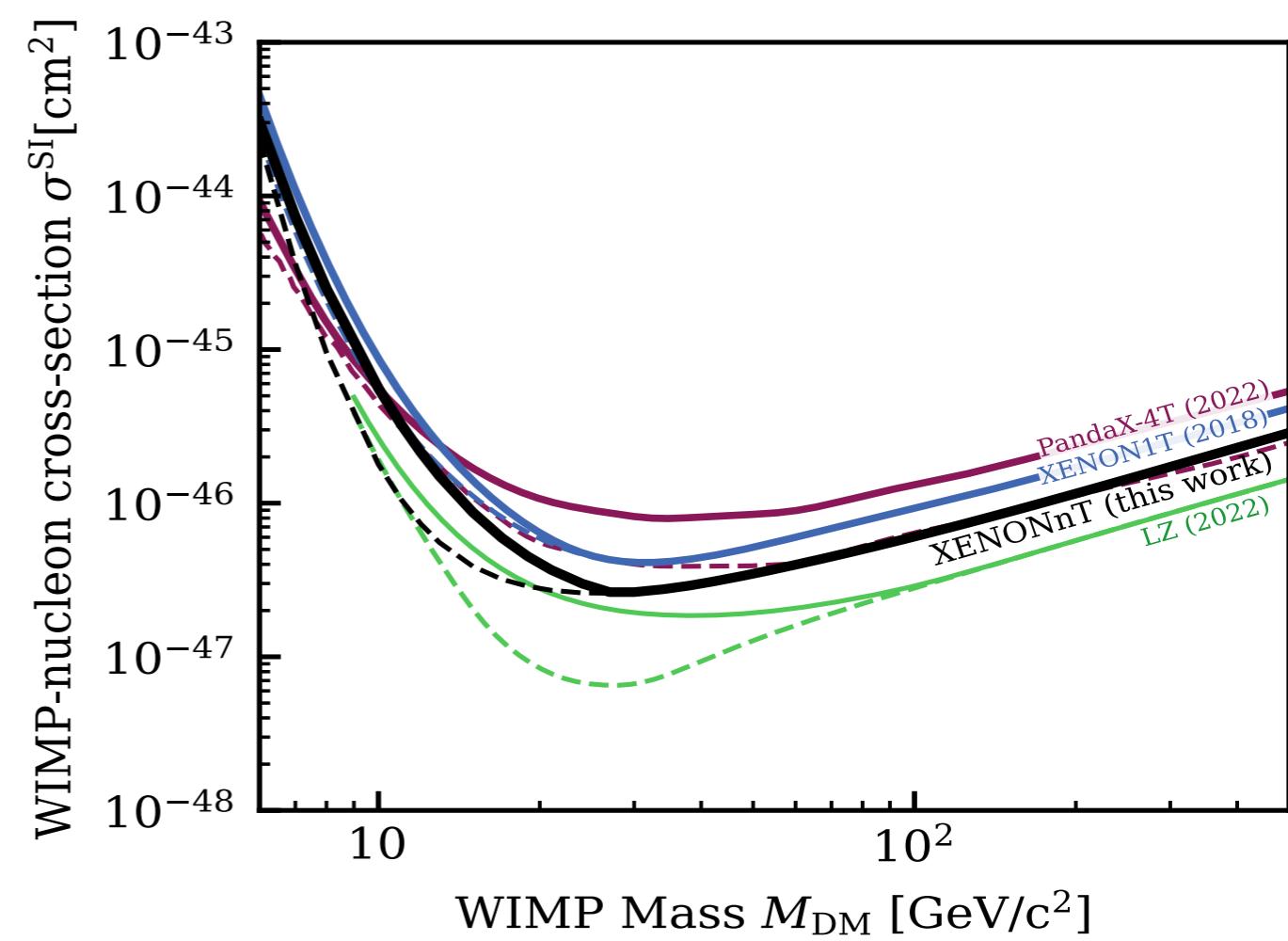
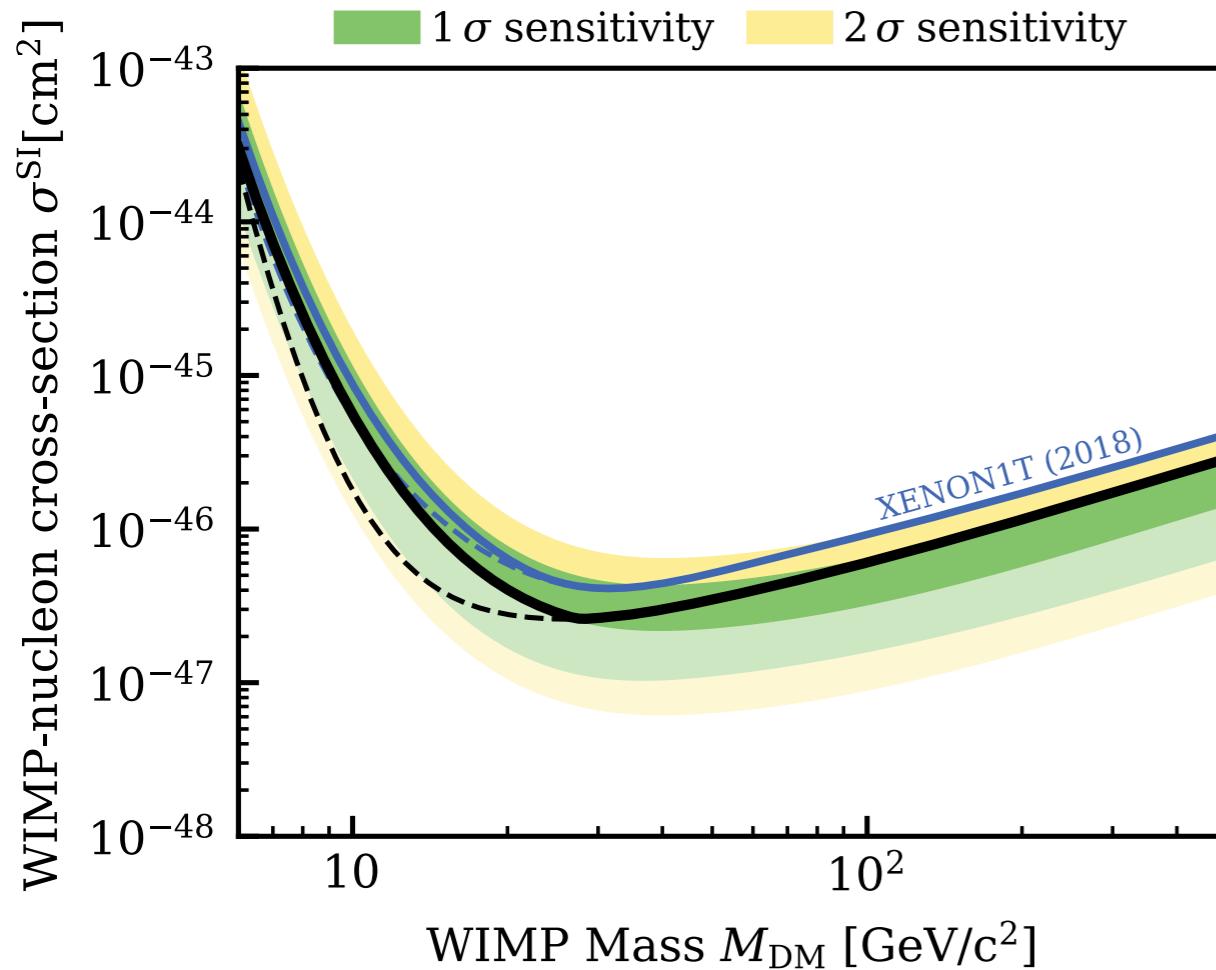


The AC background can be highly suppressed by the anti-AC BDT cut

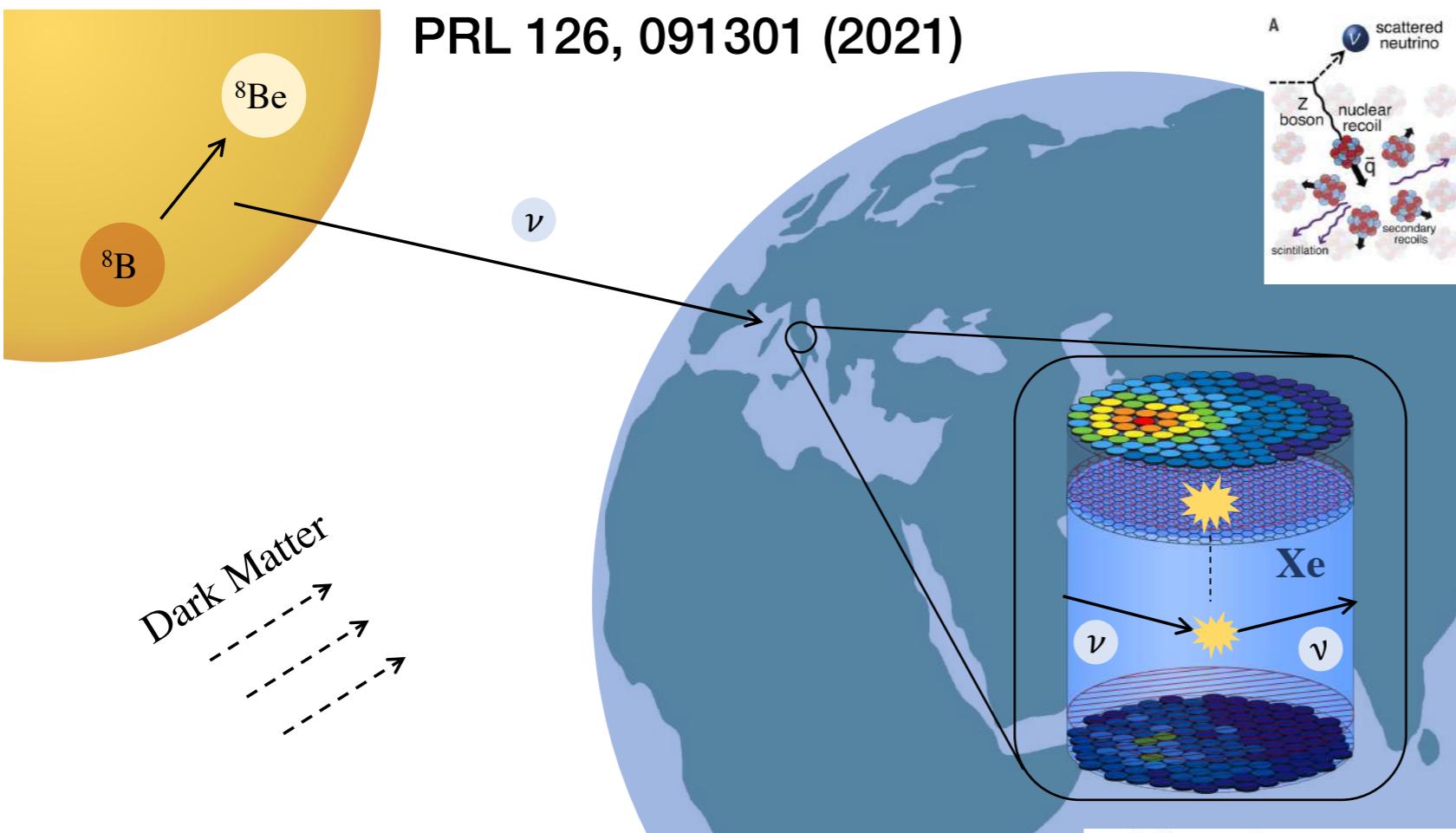
Many AC events are hiding behind the “shadow” of high energy events



# Limits on WIMPs-nucleon Cross Sections



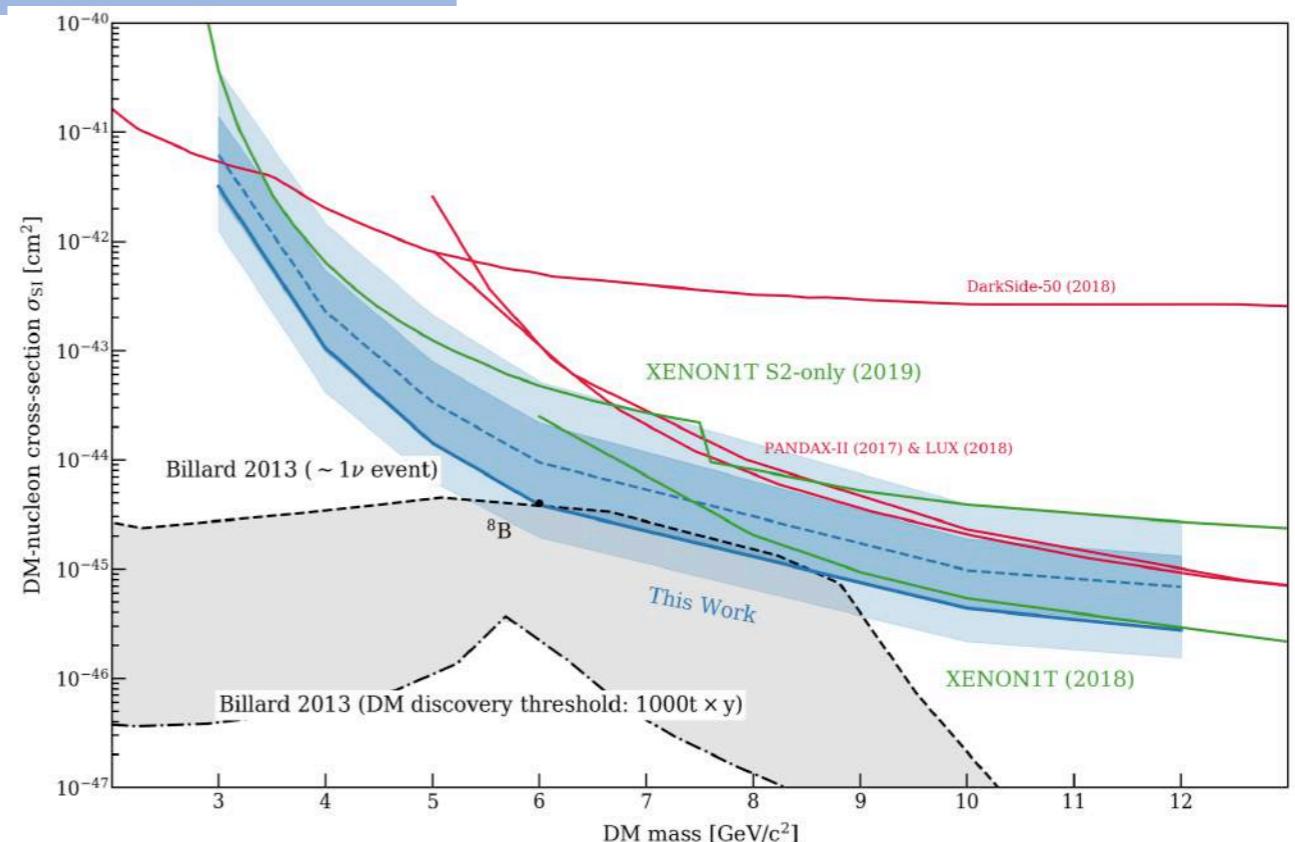
# Discovery Potential of Solar ${}^8\text{B}$ Neutrinos



Source	Expectation
CEvNS	2.11
Accidental	5.14
ER	0.21
Radiogenic	0.03
Total	7.65
Observed	6

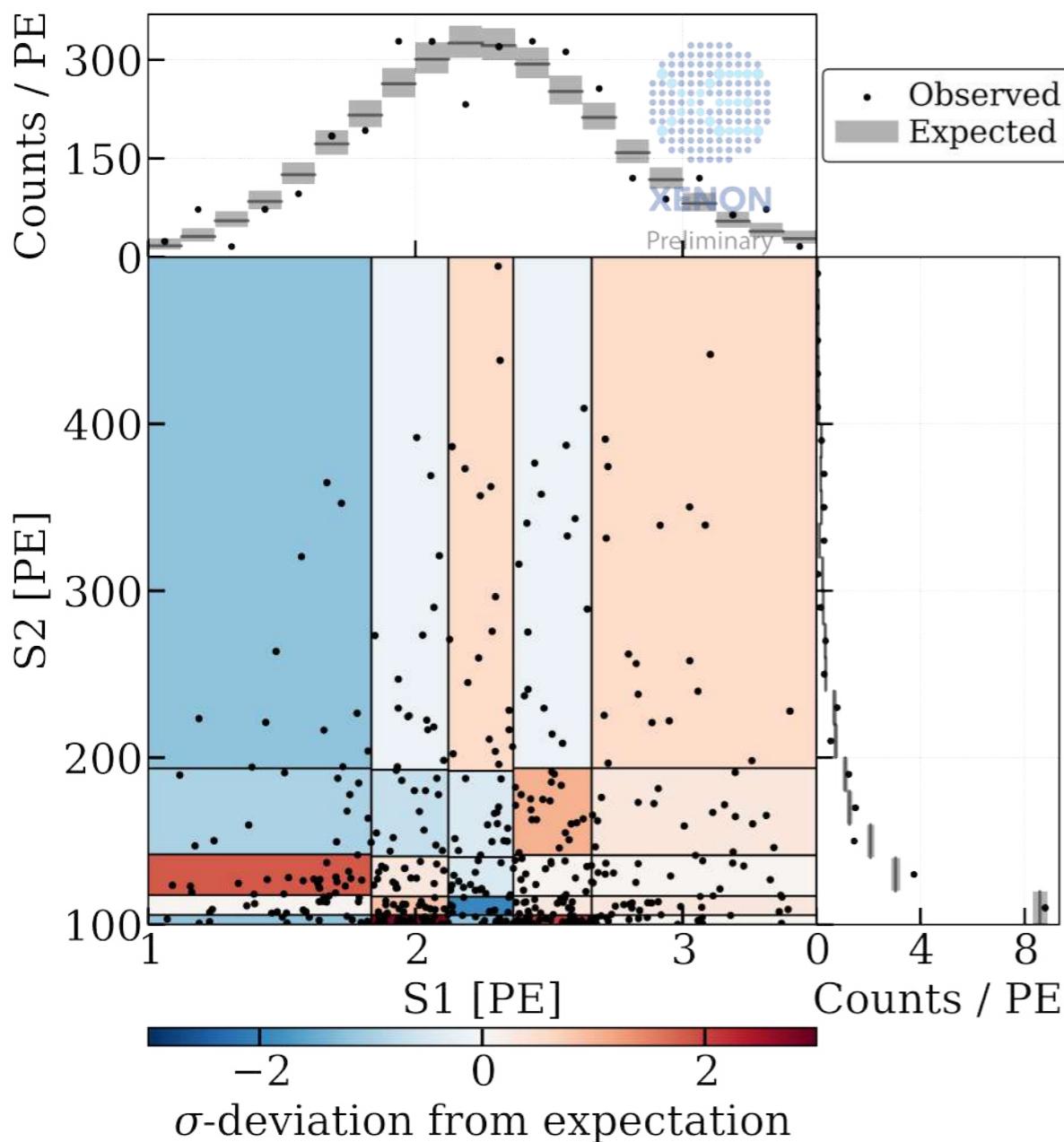
## XENON1T Search

- S1: 2 or 3 hits
- S2: 120 - 500 PE
- 0.6 t-y of exposure



# Discovery Potential of Solar ${}^8\text{B}$ Neutrinos

Exp	AC / (t x yr)	CEvNS / (t x yr)	Exposure (t x yr)
XENON1T	8.6	3.6	0.6
XENONnT	~3.2	~5	>0.6



These numbers are very only for illustration

Significantly increase in the discovery potential of  ${}^8\text{B}$  CEvNS

AC is additionally validated under the selection criteria for the CEvNS search

# Summary and Outlook

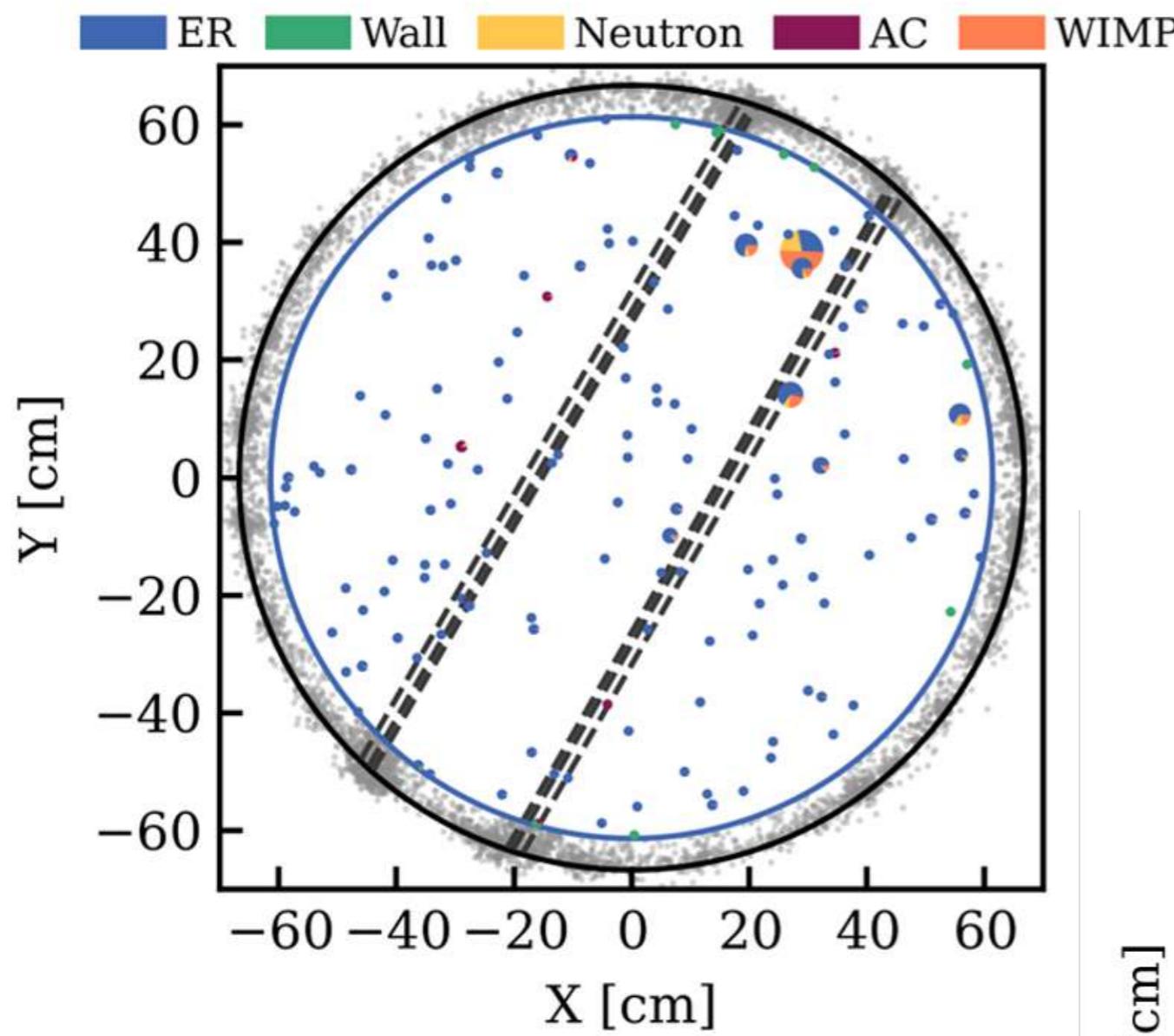
- XENONnT had finished the first WIMPs search with 1.1 ton-year exposure and the lowest electronic recoil background rate in the keV range
- No significant excess is found in the nuclear recoil search region.
- XENONnT is continuing data-taking with half of its electronic recoil background (radon dominated)
- With a lower background in SR1, XENONnT will be more sensitive to WIMPs, and also be more sensitive to Solar pp and  ${}^8\text{B}$  neutrinos

Stay tuned!

<http://xenonexperiment.org>

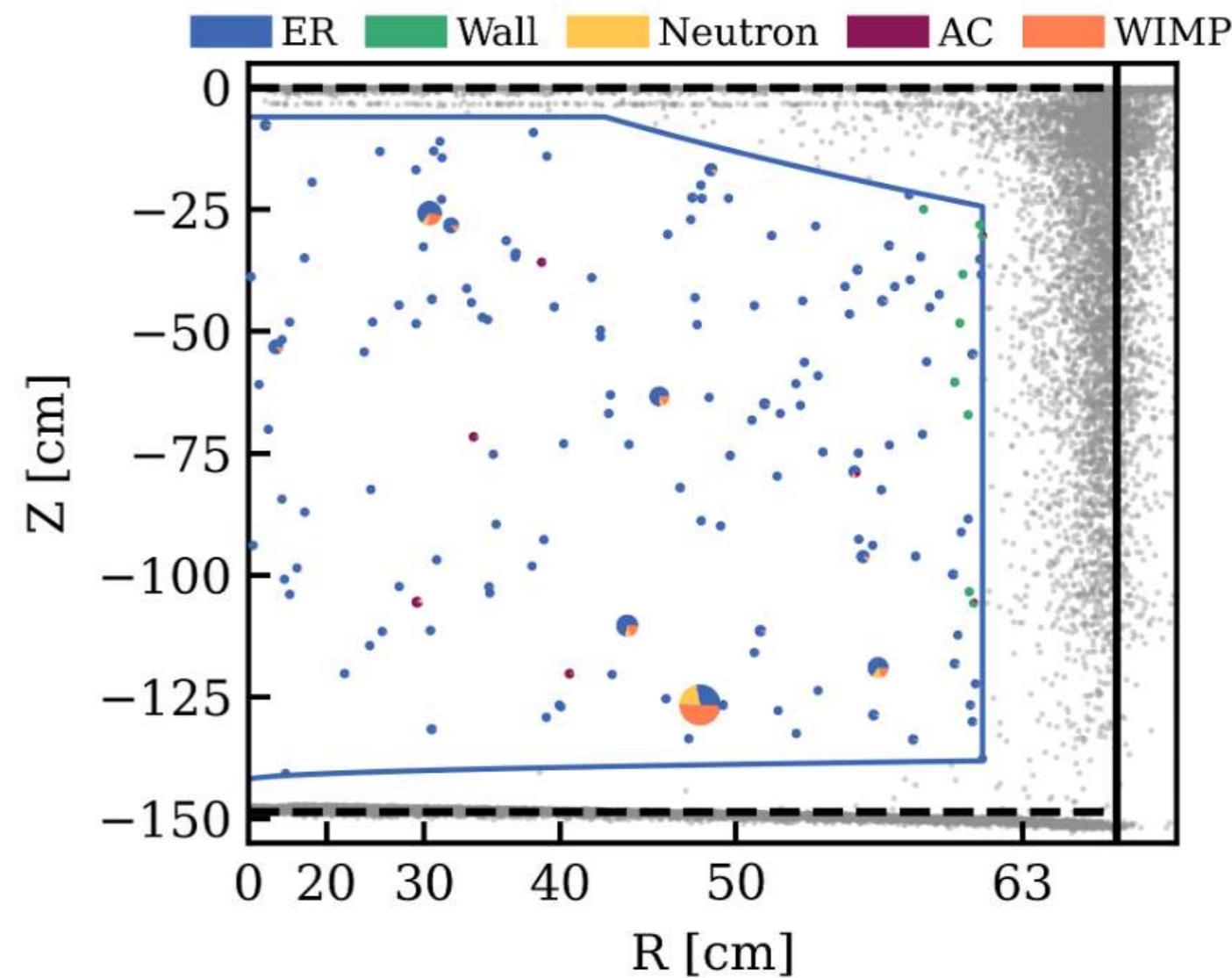
**Thanks for your attention!**

# Position Distribution of NR-like Events

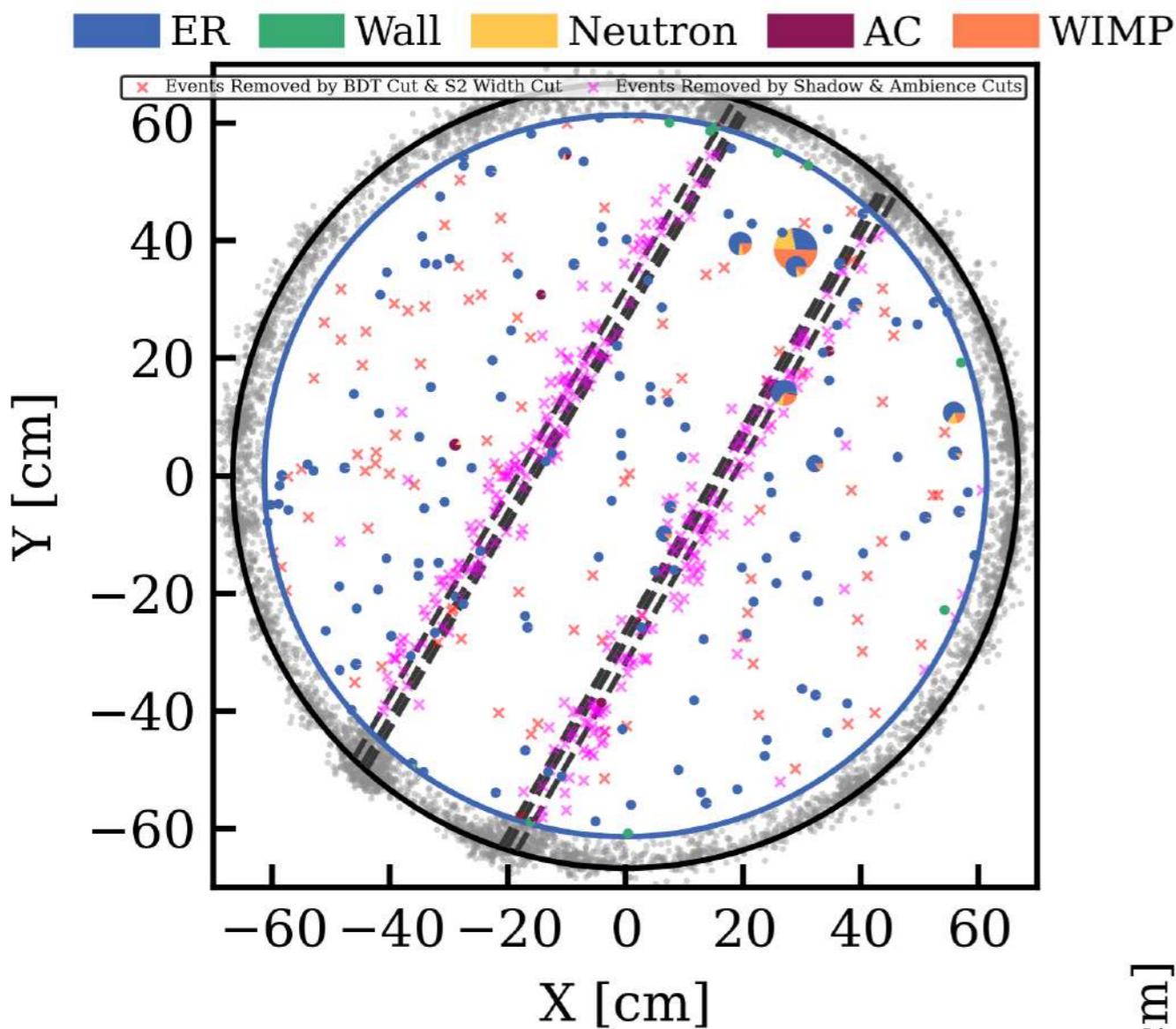


NR-like events are normally distributed across Z and R spaces

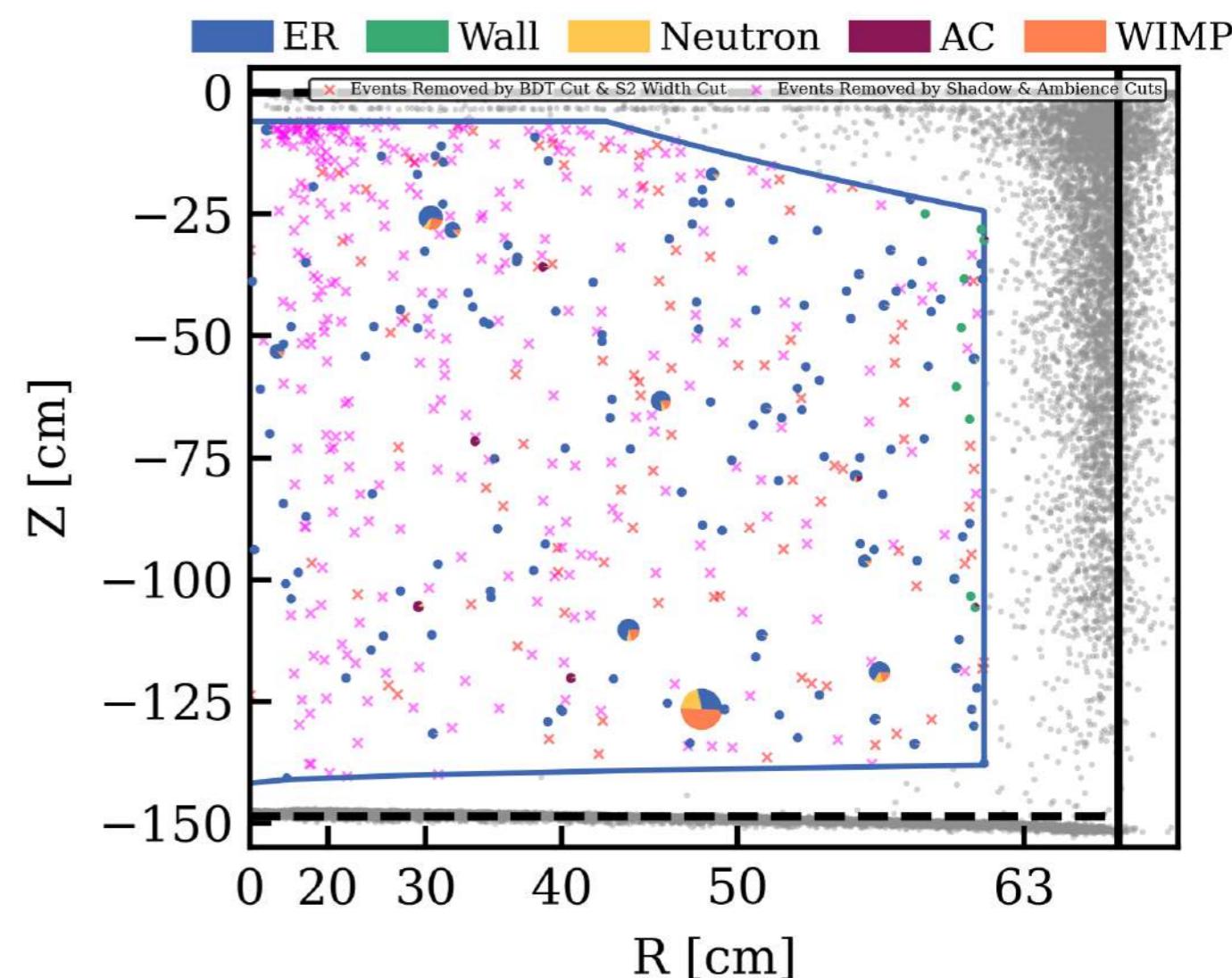
NR-like events are more concentrated in the top right corner in the X-Y plot



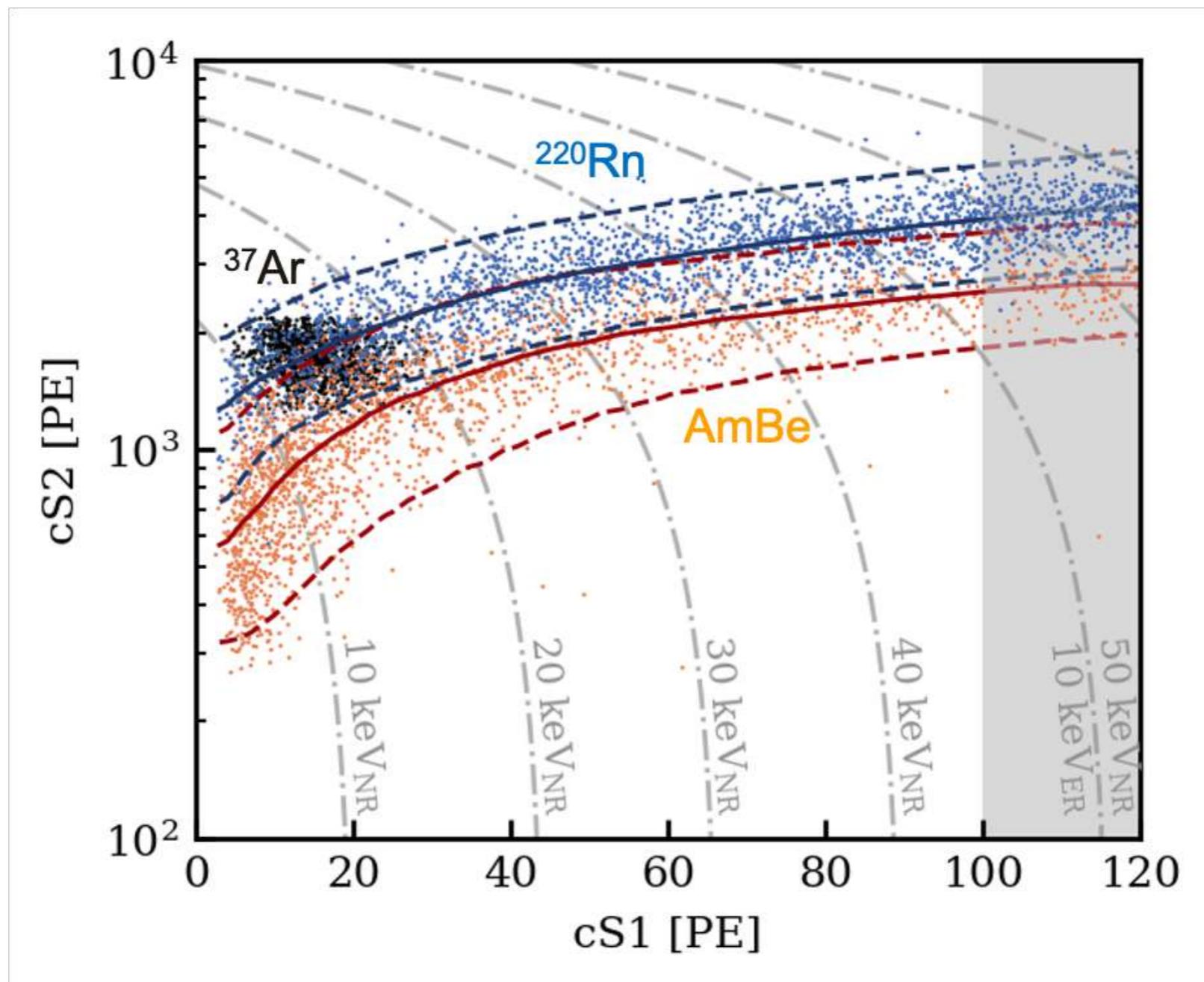
# Importance of anti-AC cuts



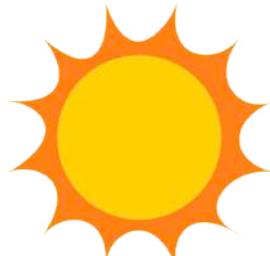
AC events are more concentrated  
on the supporting wires, and they  
are mainly suppressed by  
“Shadow” cuts



# ER and NR Events

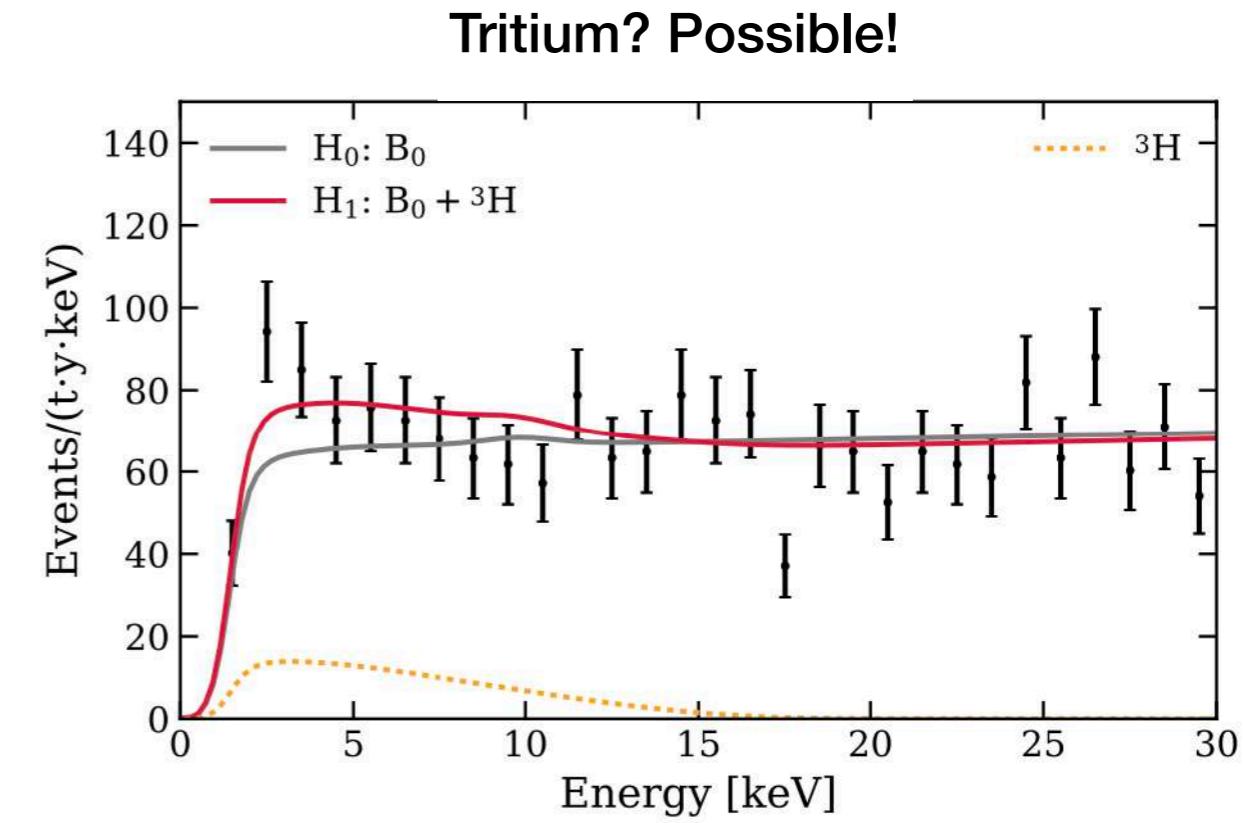
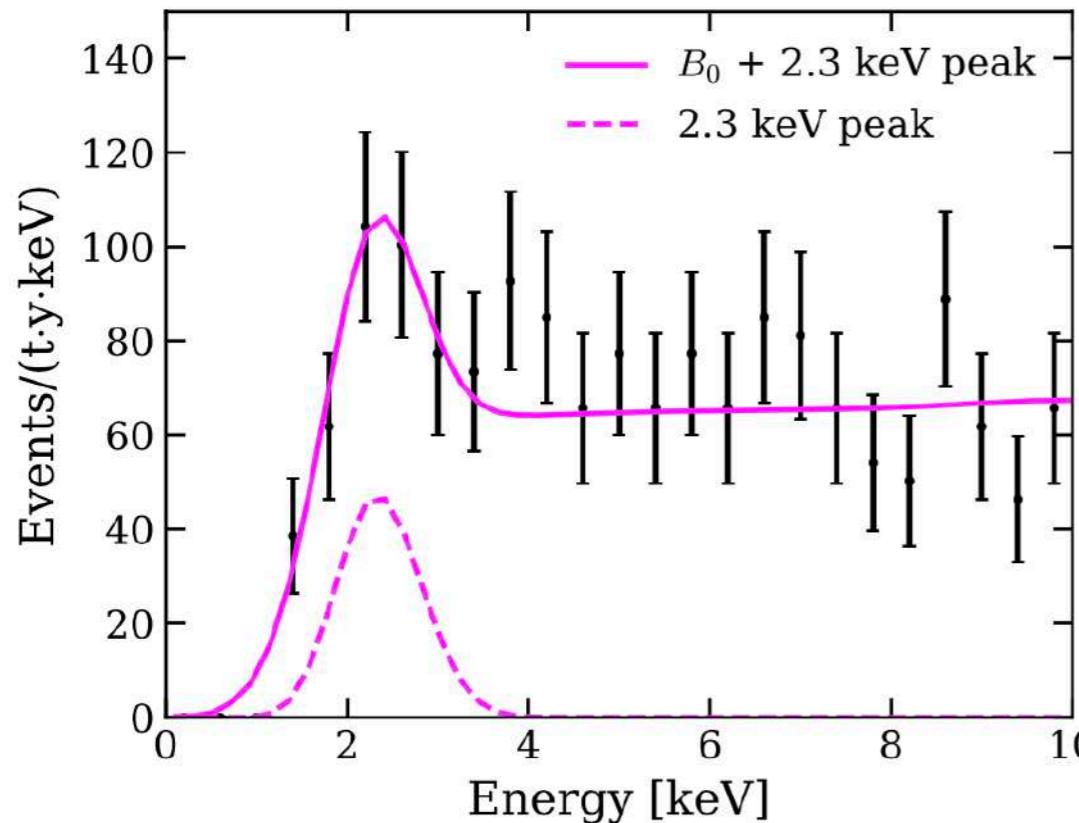
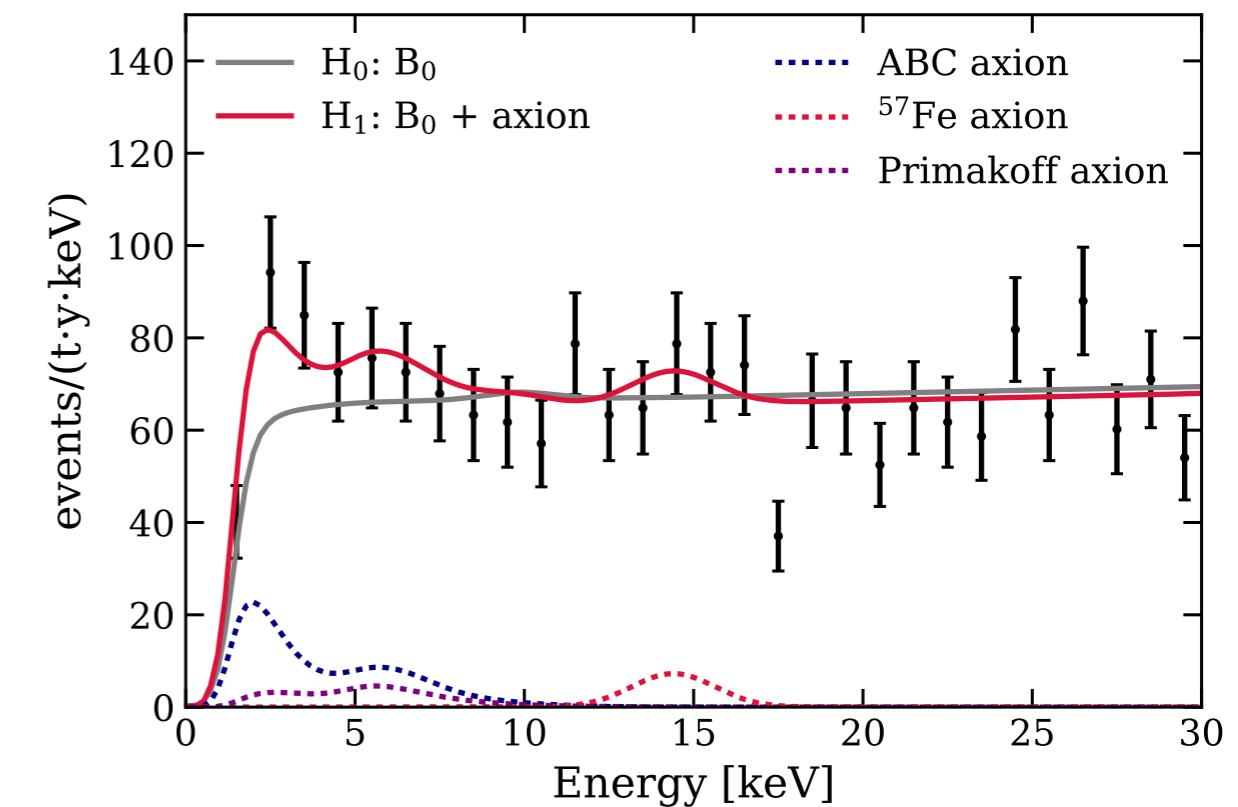
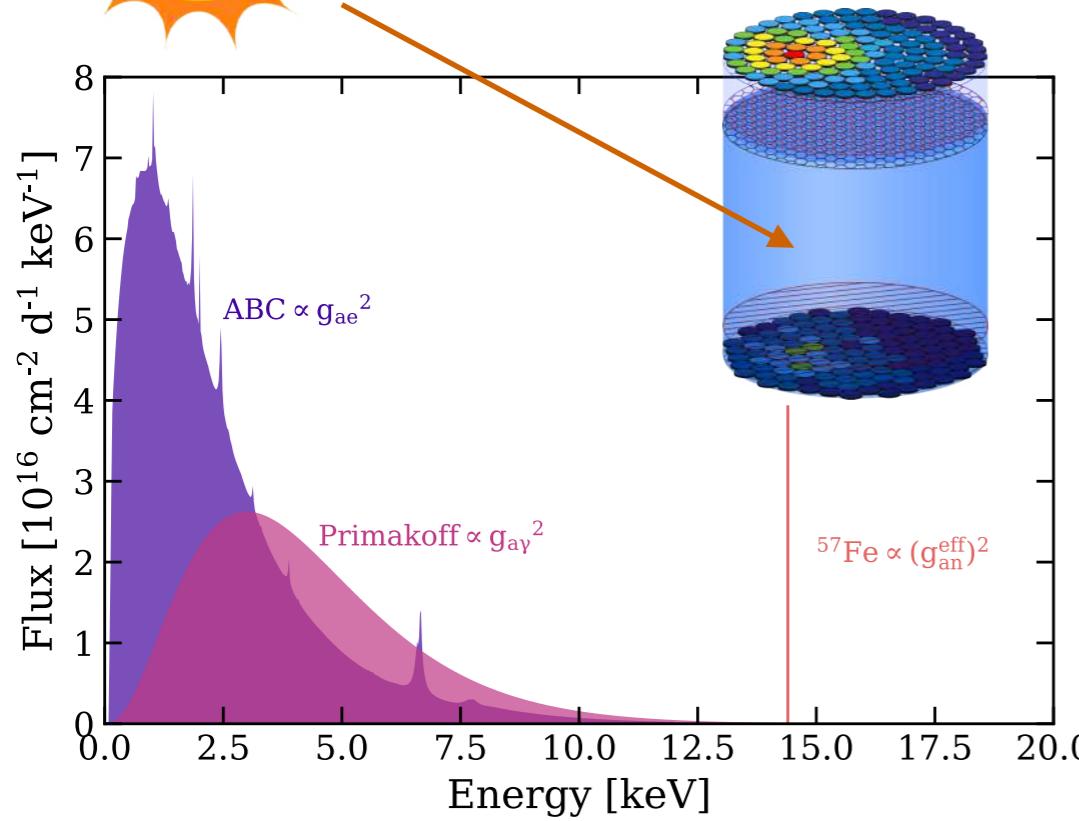


Fraction <sup>220</sup>Rn events below NR median: 1.1 %



# XENON1T Excess ER Events

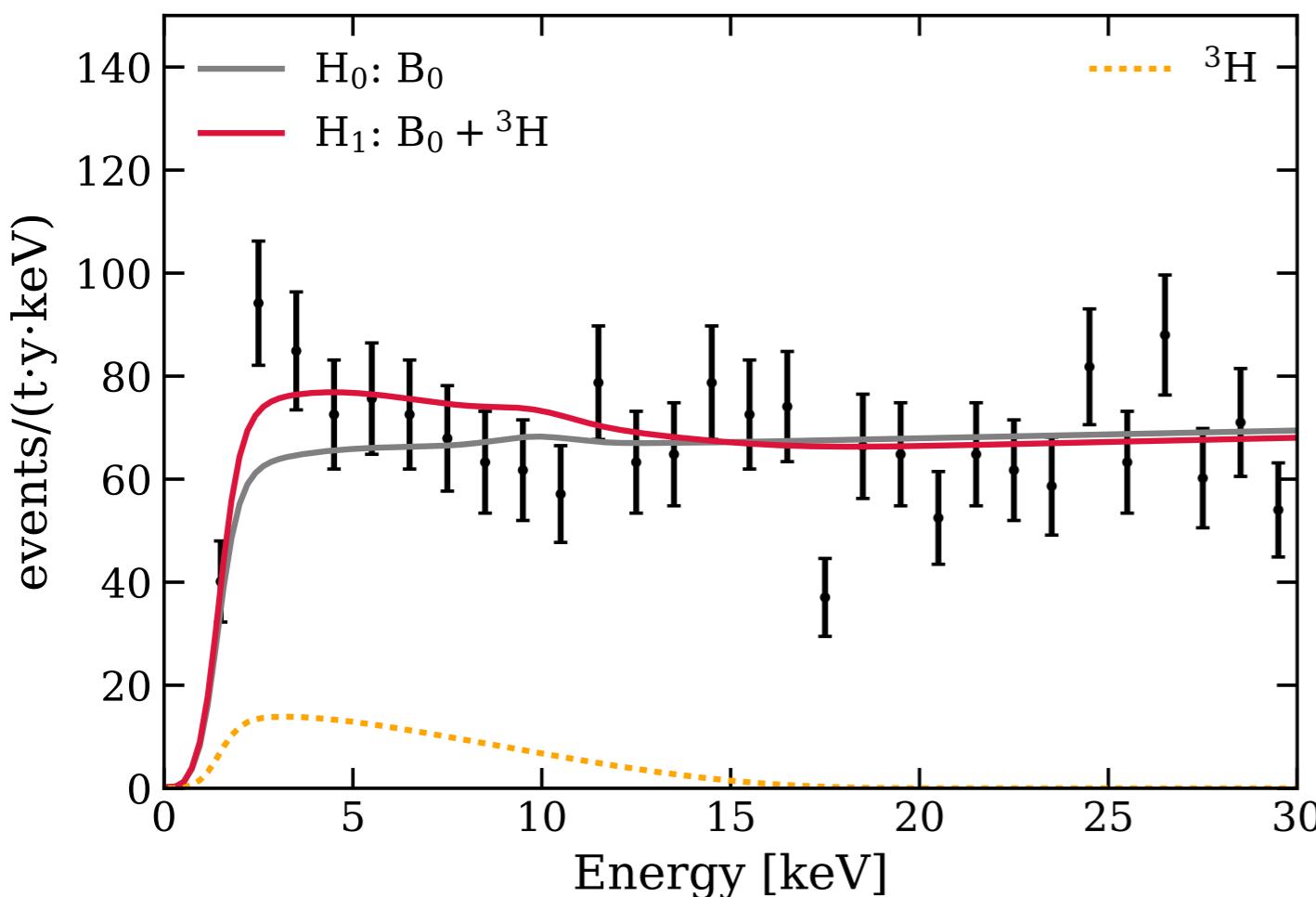
PRD 102 072004 (2020)



Tritium? Possible!

# Tritium for the XENON1T Excess?

- XENON1T Excess, interpreted as being due to tritium, is not seen by XENONnT



## Tritium Fit in XENON1T

$159 \pm 51$  events/( $t \cdot y$ )

XENONnT tritium control data

$\leq 8.2$  events/( $t \cdot y$ ), 90 C. L.

XENONnT First Data:

$\leq 14$  events/( $t \cdot y$ ), 90 C. L.