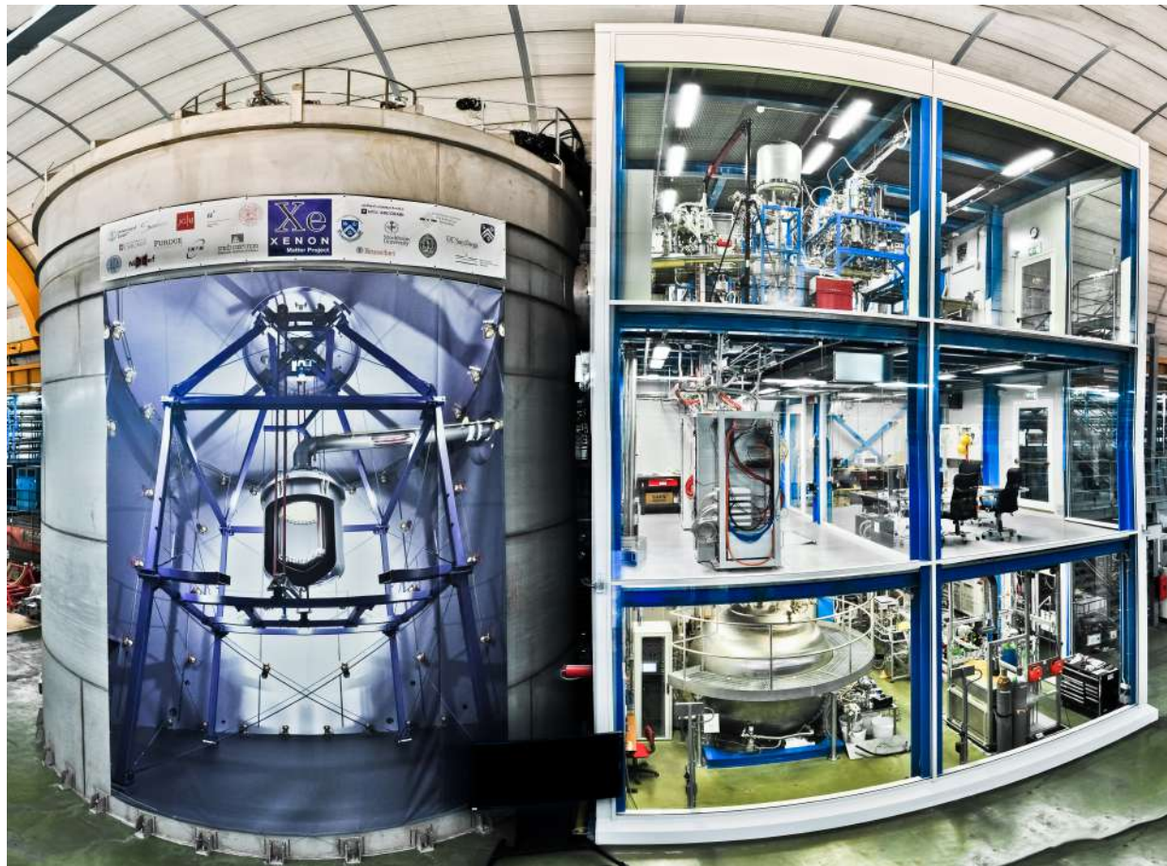
Latest Results from XENONnT

高飞　清华大学

on behalf of the XENON Collaboration

紫金山暗物质研讨会

Dec 29-31, 2023



The XENON Collaboration

Columbia · KIT · Nikhef · Muenster · Stockholm · Mainz · MPIK, Heidelberg · Freiburg · Zurich

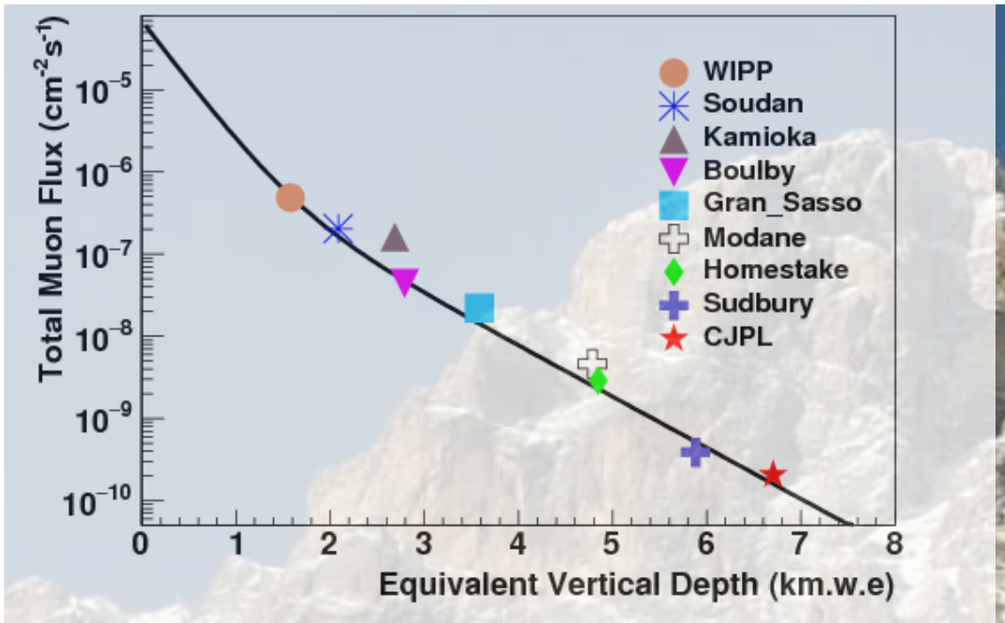
Chicago · Tsinghua · UCSD · Tokyo · Rice · Nagoya · Purdue · Kobe

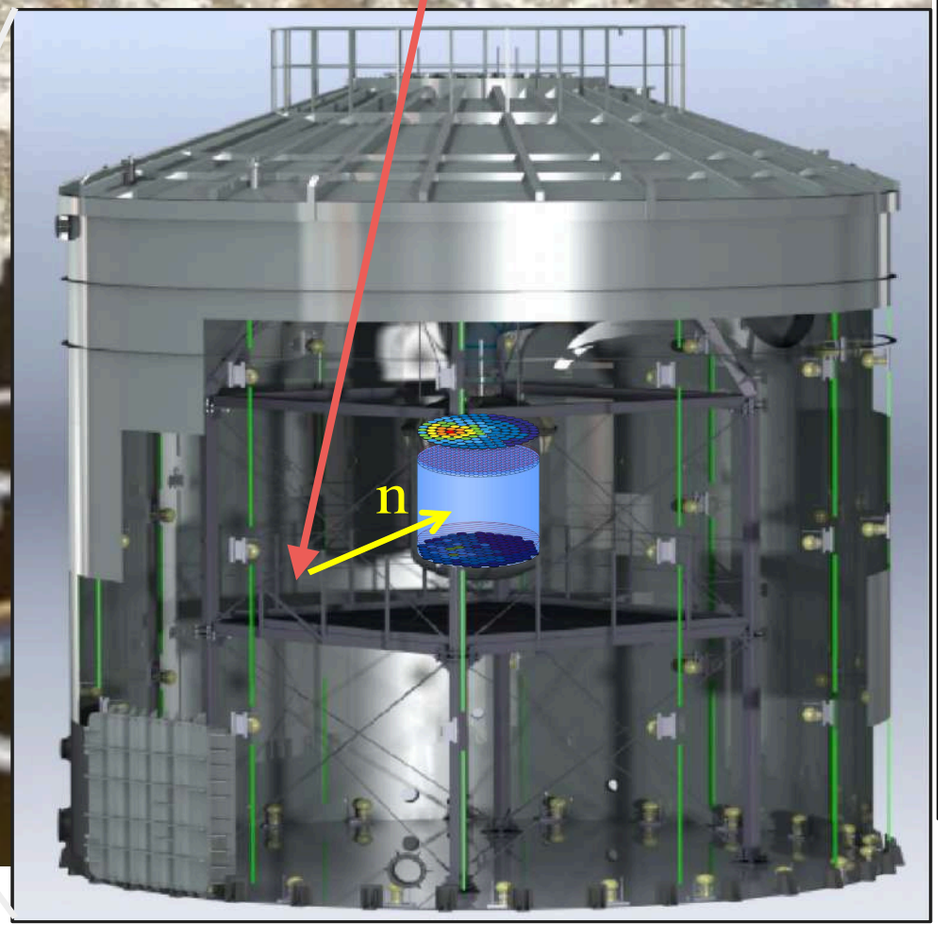
Subatech · Coimbra · LPNHE · Torino · Bologna · L'Aquila · LNGS · Napoli · Weizmann · NYUAD

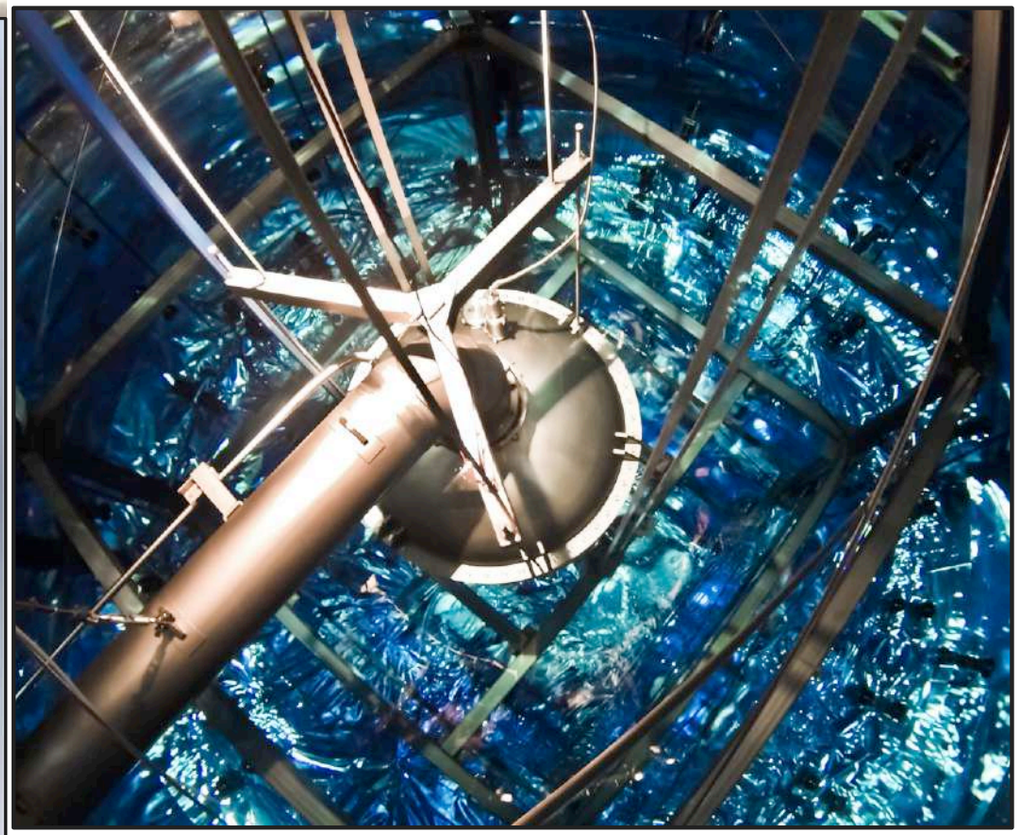
Development of XENON Program

XENON10	XENON100	XENON1T	XENONnT
			
2005-2007	2008-2016	2012-2018	2019-202x
25 kg - 15cm drift	161 kg - 30 cm drift	3.2 ton - 1 m drift	8.6 ton - 1.5 m drift
~10^{-43} cm^2	~10^{-45} cm^2	~10^{-47} cm^2	~10^{-48} cm^2

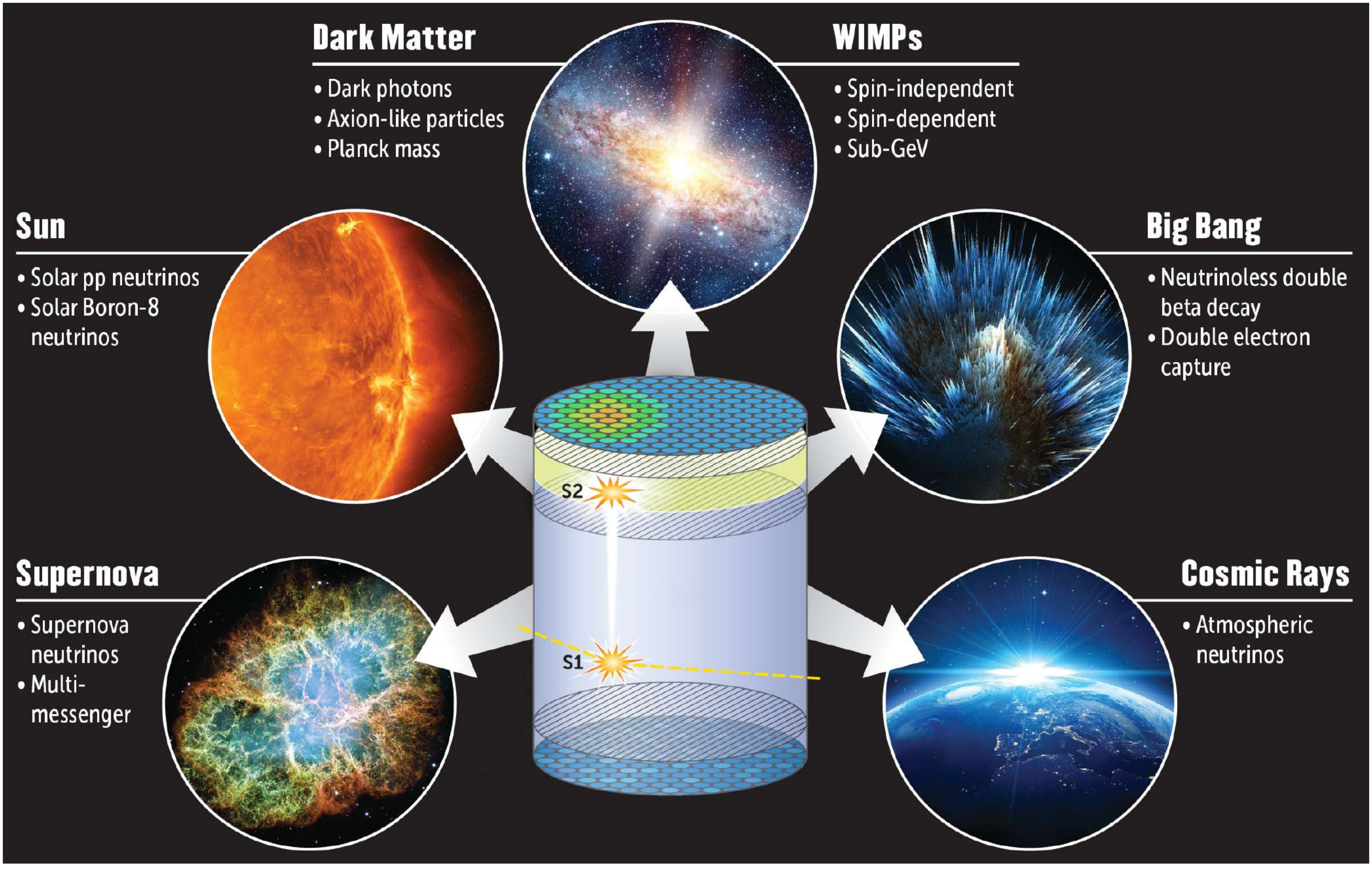
Gran Sasso: The XENON Shield







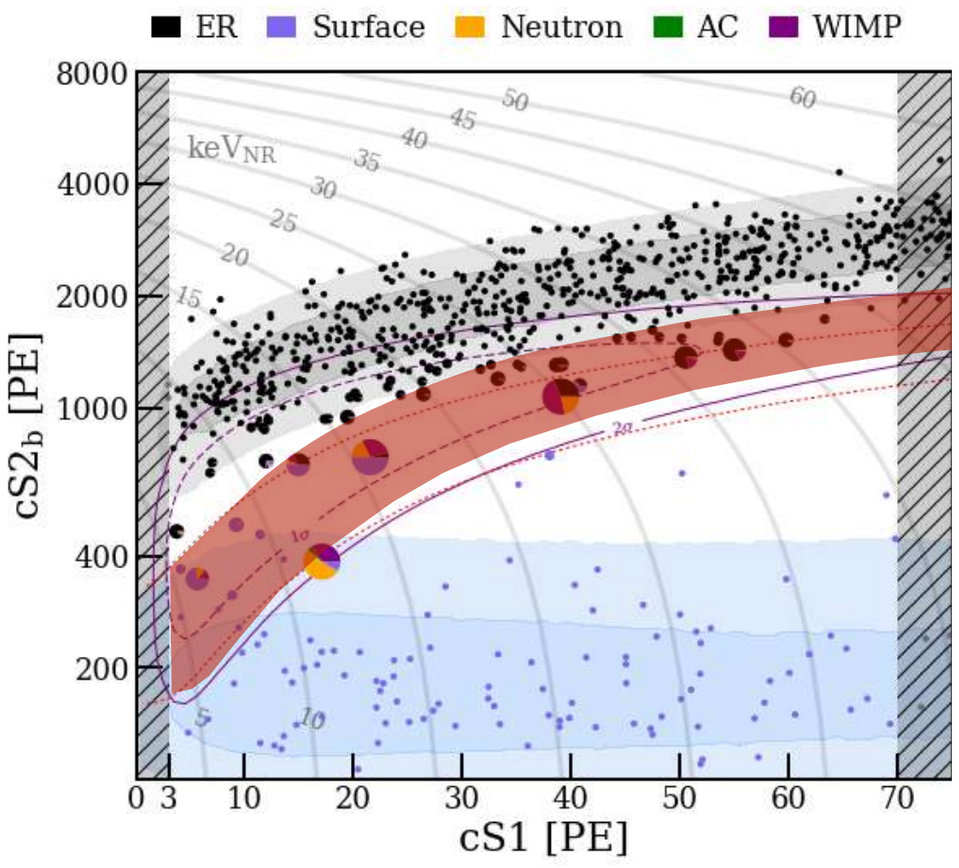
Physics with the XENON Detectors

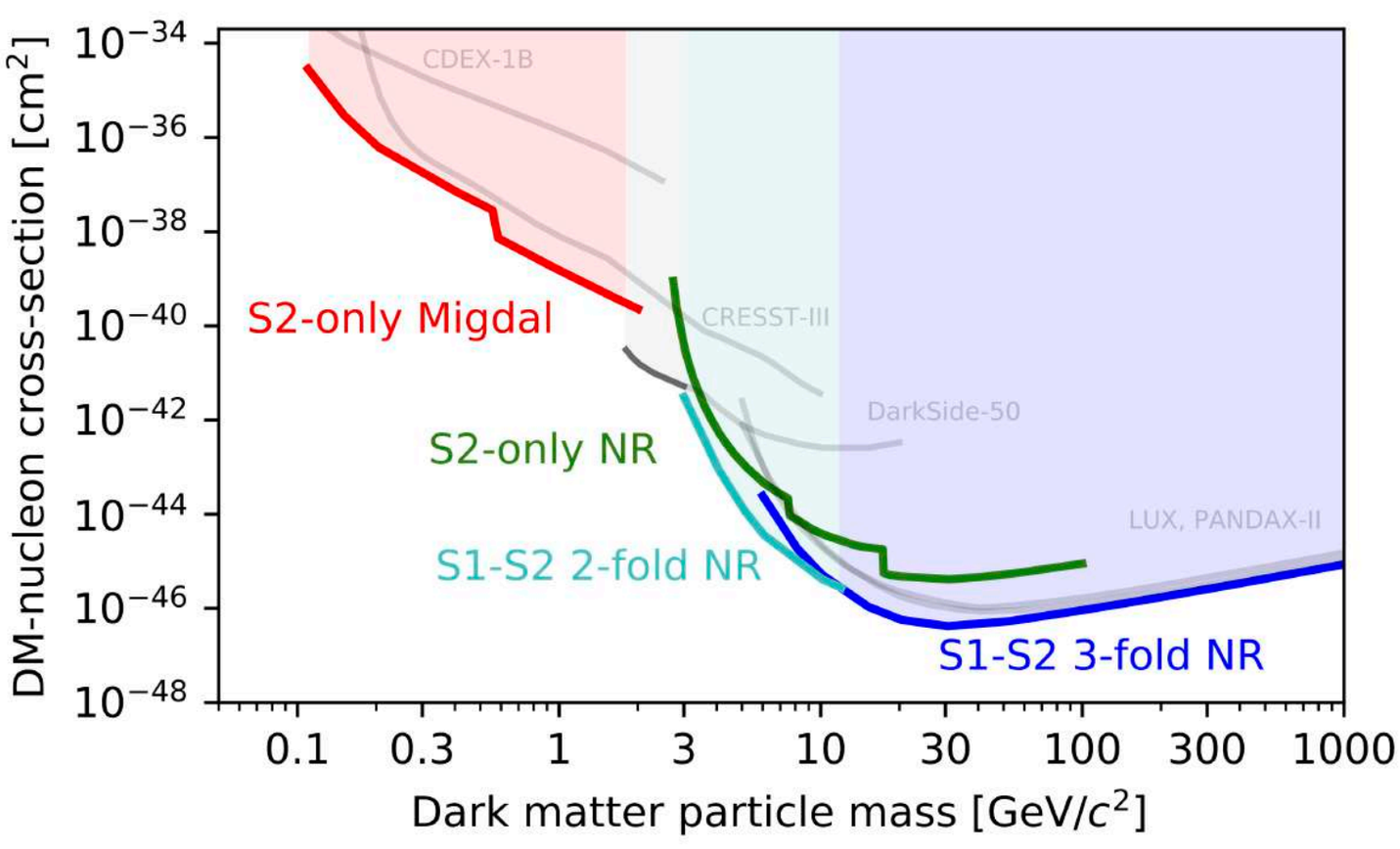


XENON1T WIMPs Search

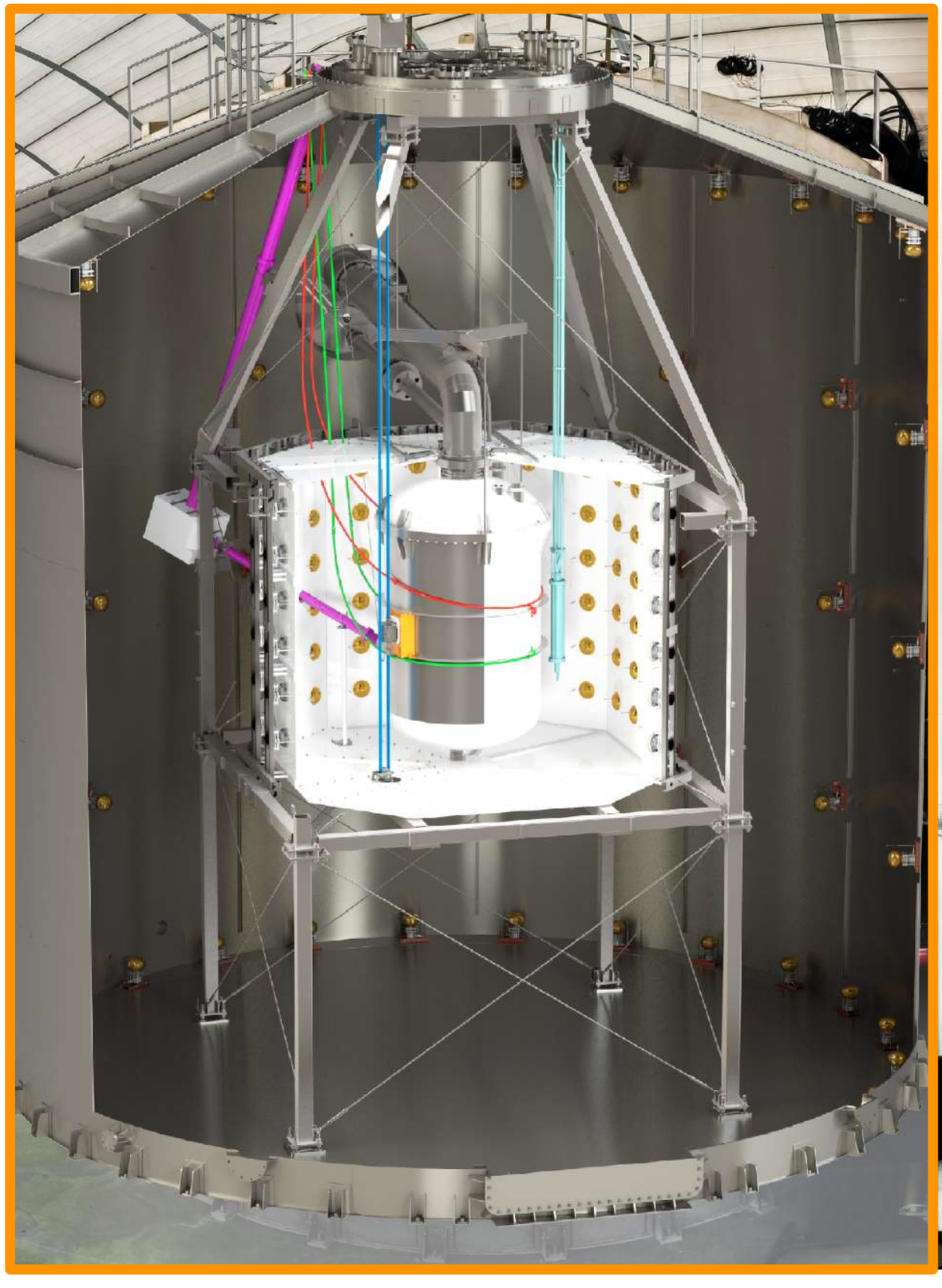
World's most sensitive WIMPs search back then

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





From XENON1T to XENONnT

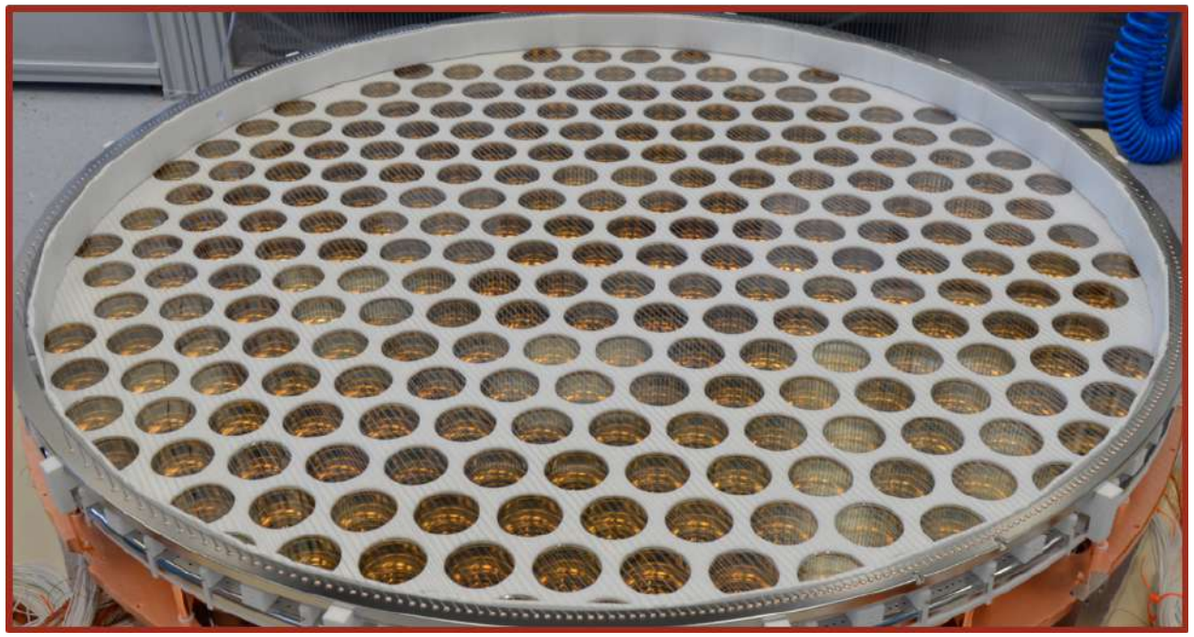


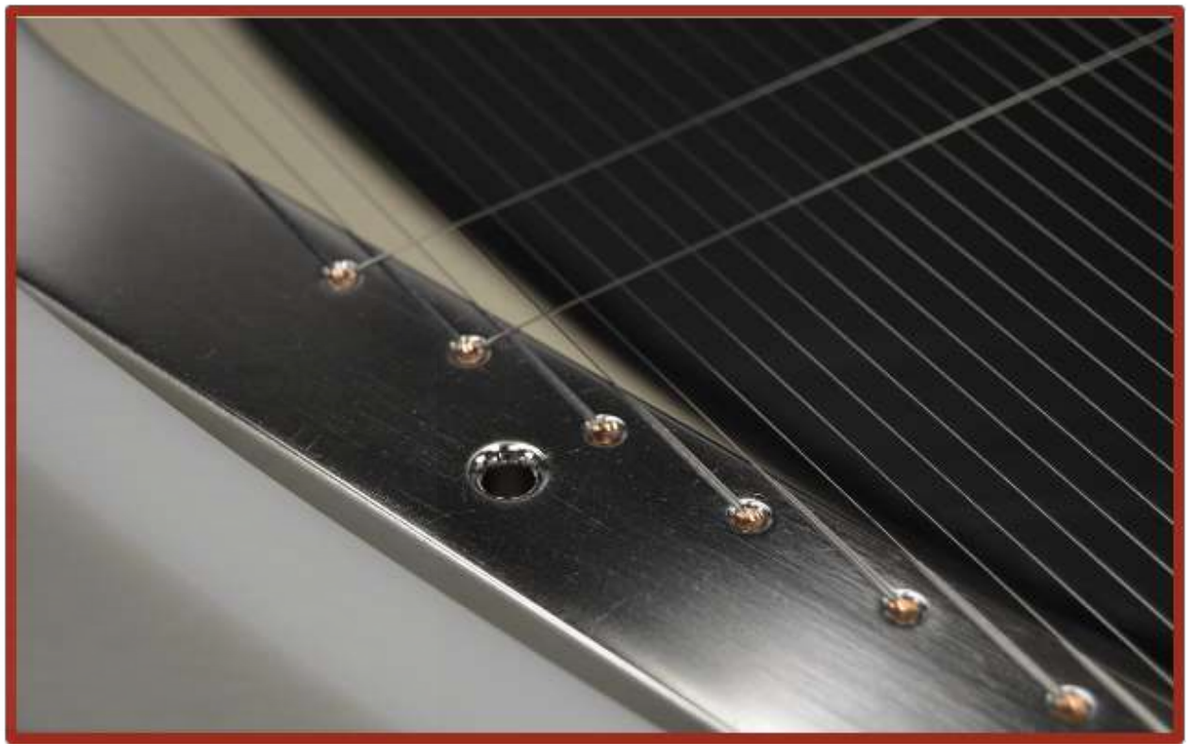
XENONnT TPC and Electrodes

+4.9 kV

+0.3 kV

-2.75 kV

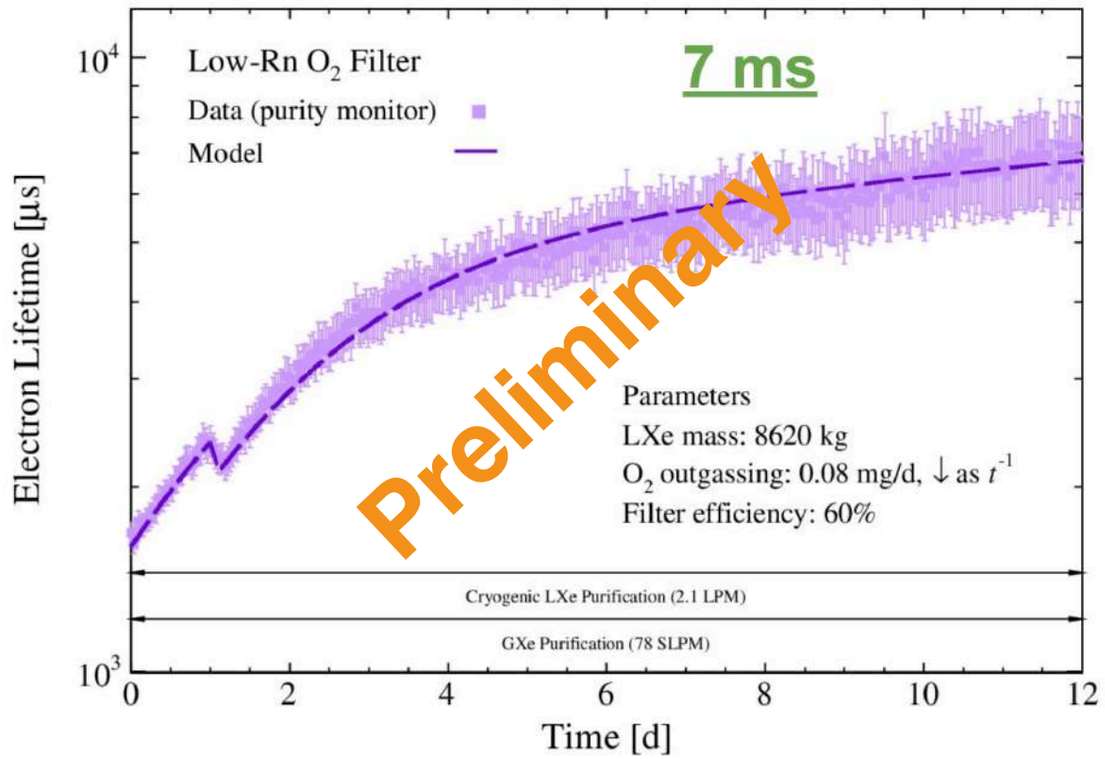


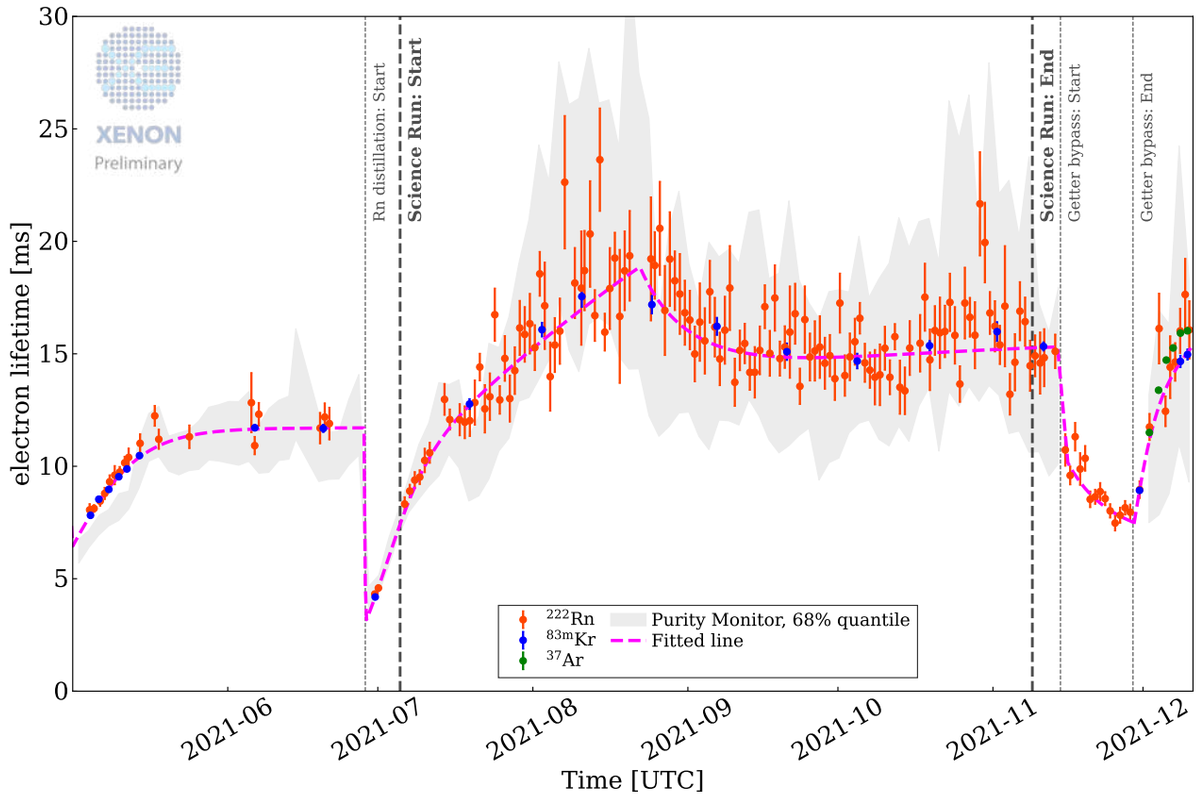


XENONnT Cryogenic Liquid Purification

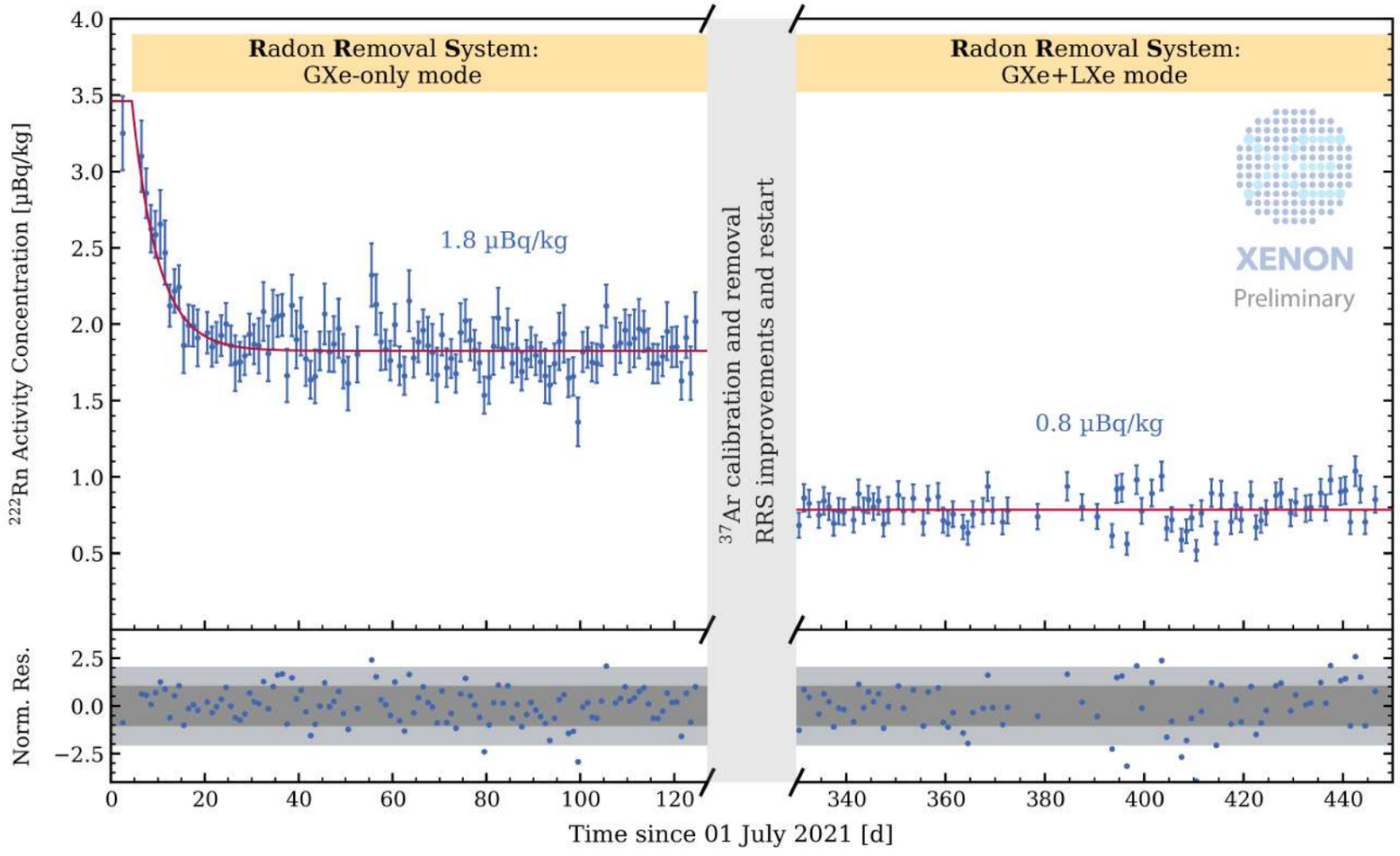
Cryostat is filled with ~8.5t of LXe

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



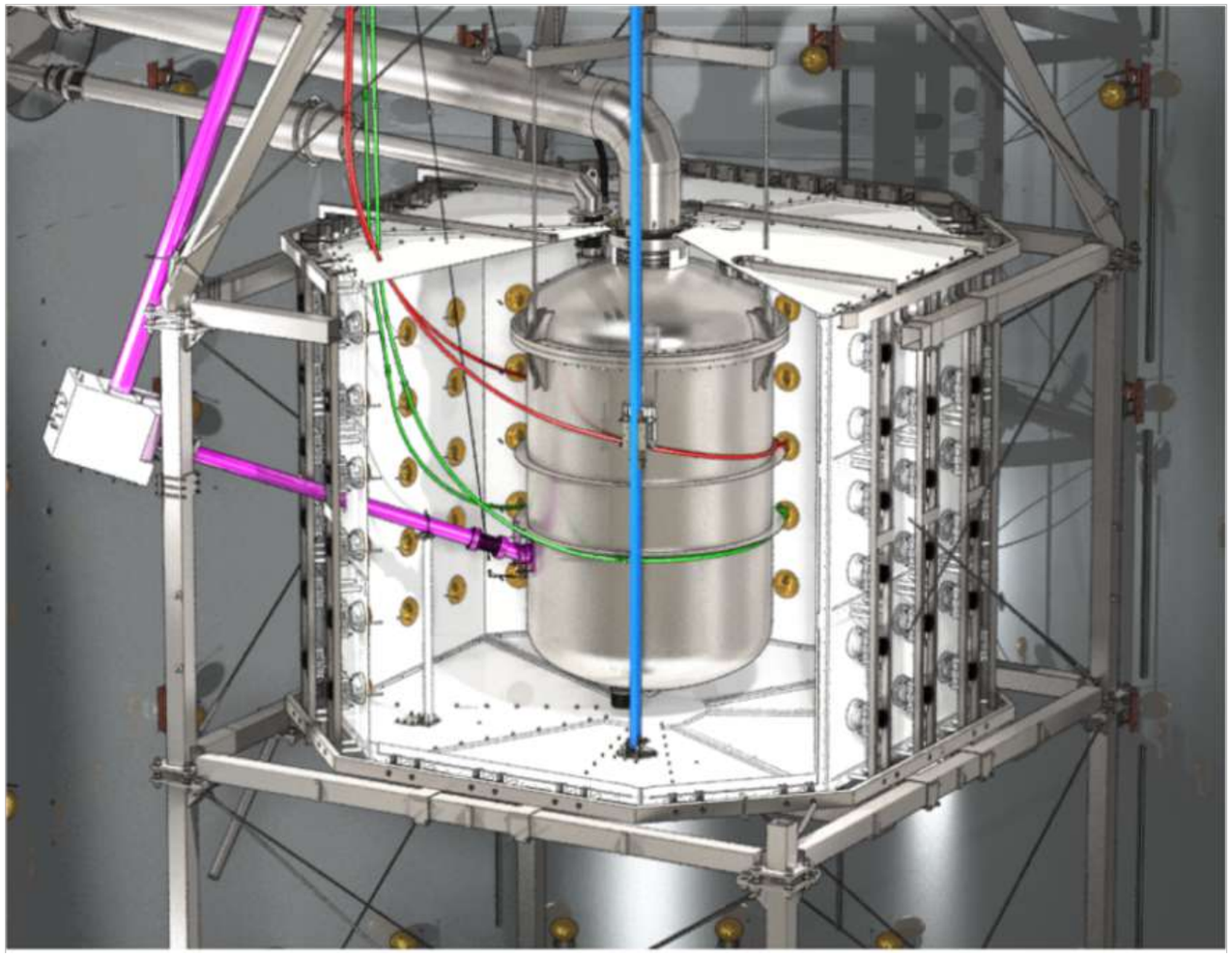


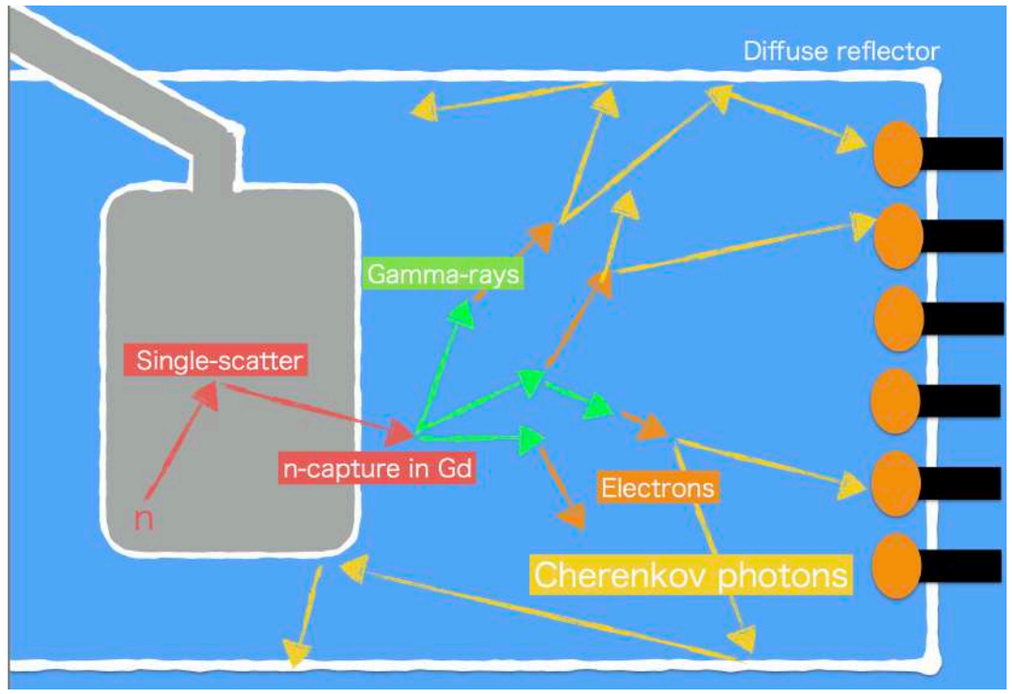
XENONnT Radon Distillation Column

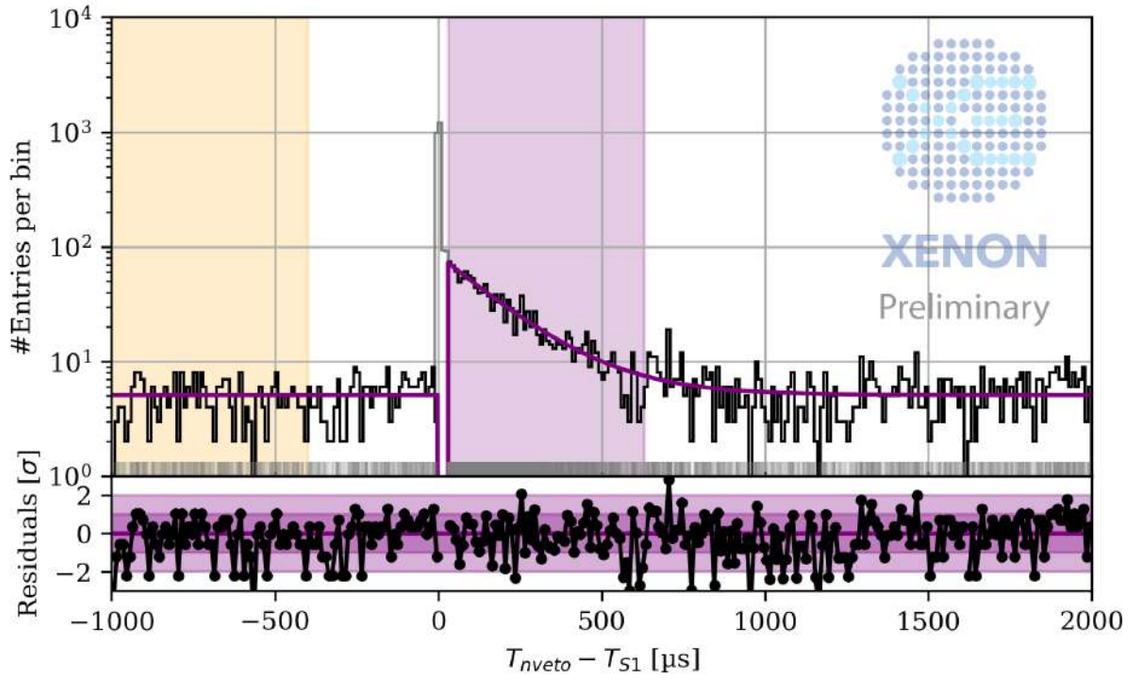


- Lowest radon level ever achieved in a LXeTPC!
  - Initial gas phase-only distillation: 1.8 µBq/kg
  - Gas + liquid phase distillation: 0.8 µBq/kg

XENONnT Neutron Veto





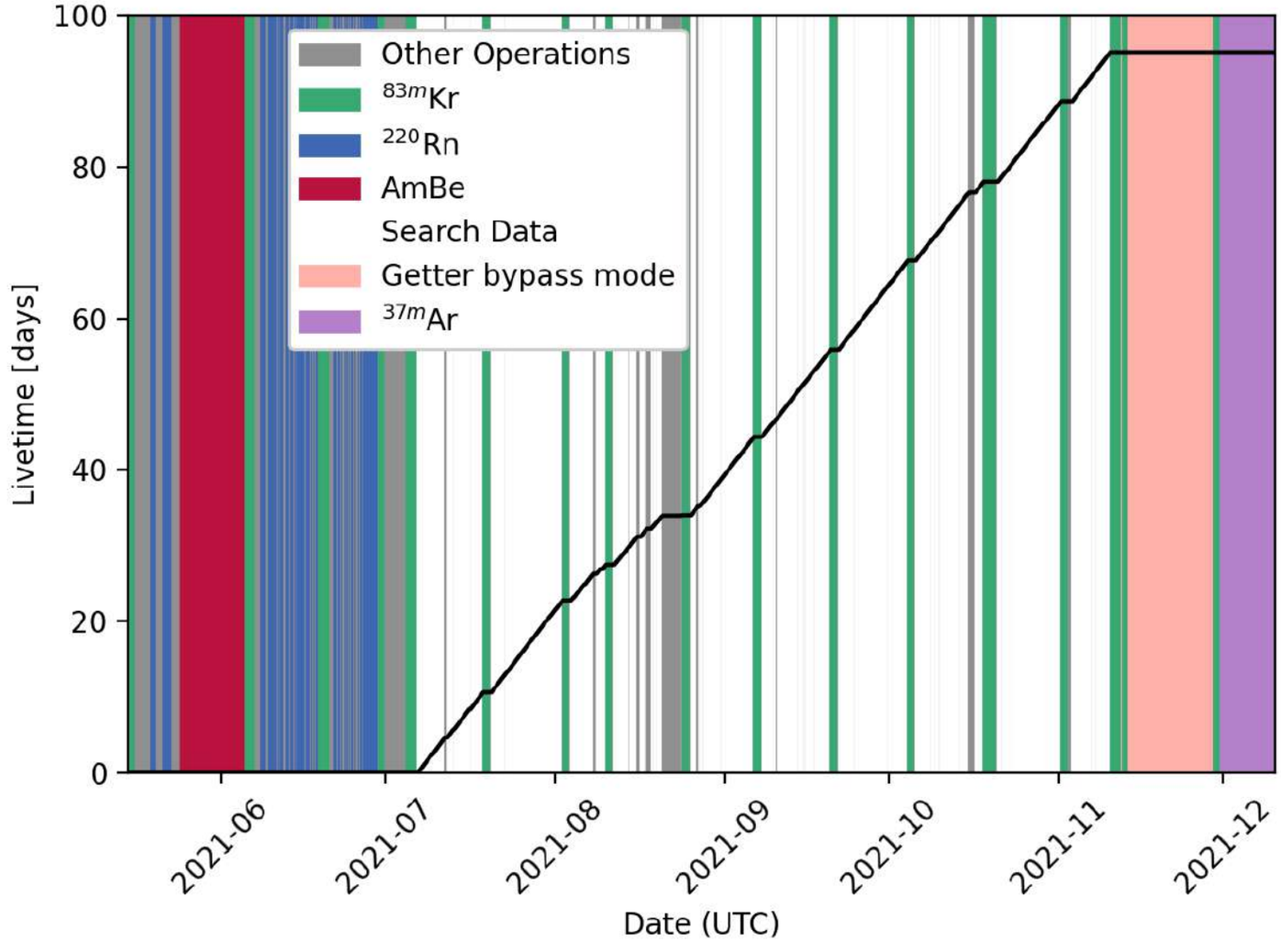


- SR0: Water only veto efficiency of 68%
- Design Goal: Gd-Water veto efficiency of >85%

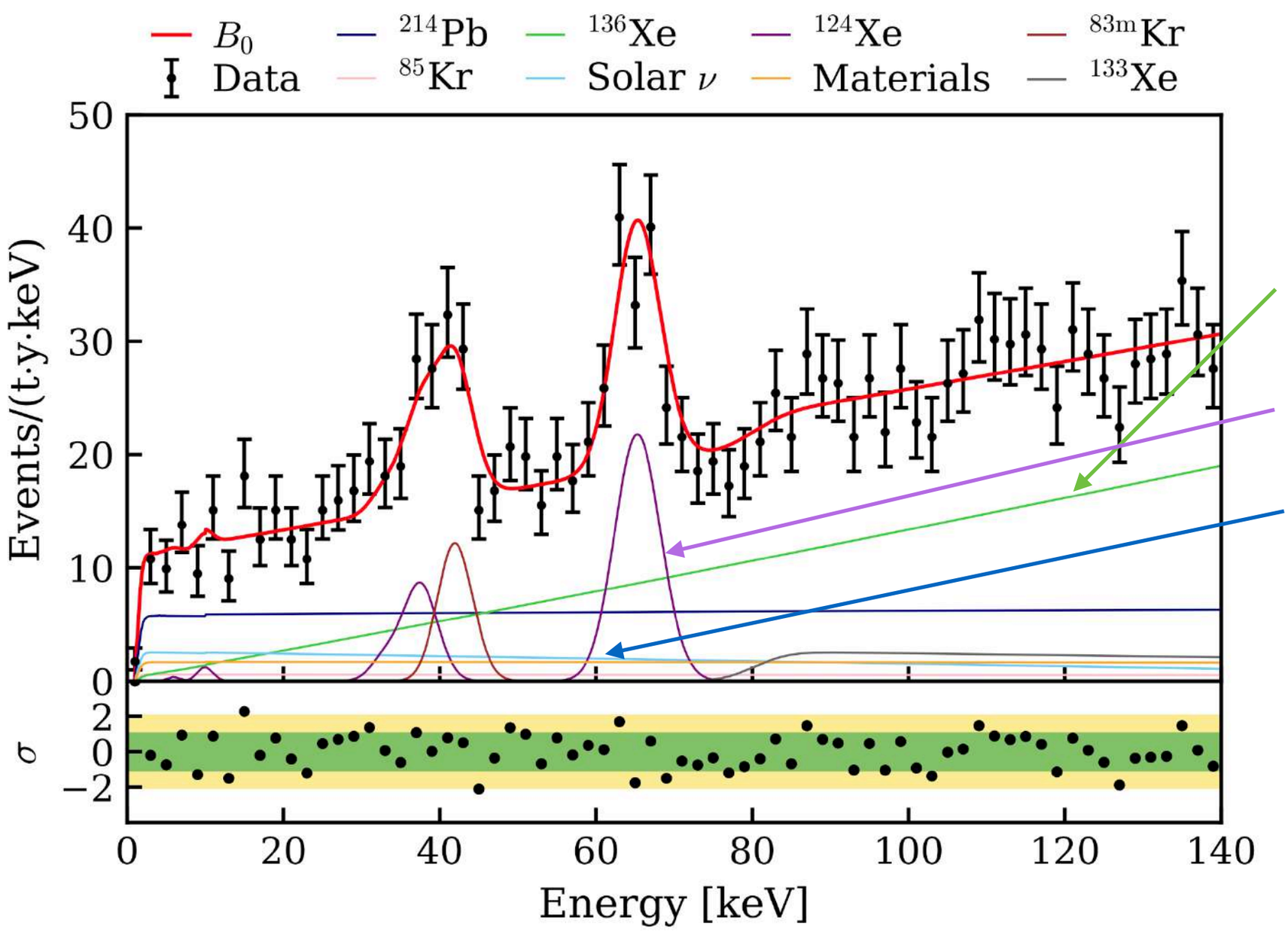
XENONnT First Data

SR0 WIMPs search data

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



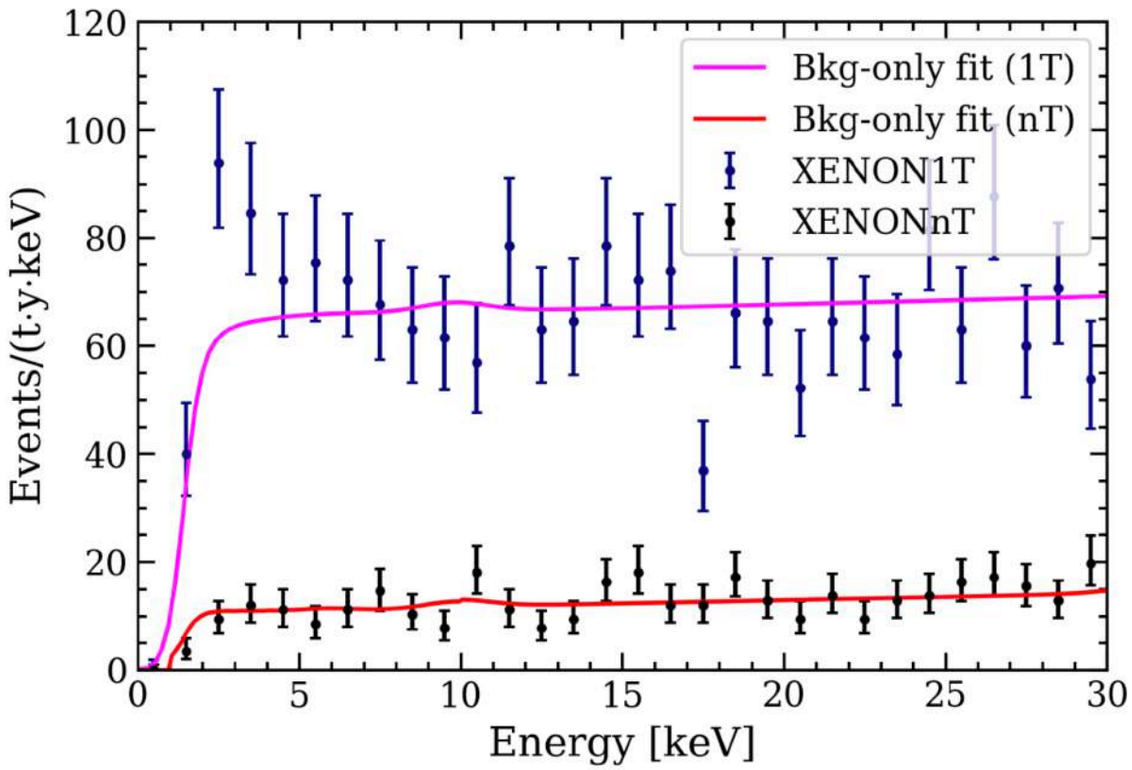
Electronic Recoil Background



Pb214	980±120
Kr85	91±58
Xe136	1523±54
Xe124	256±28
Solar pp-neutrino	298±29
Material	267±51
Xe133	163±63
Kr83m	80±16
Accidental Coincidence	0.71±0.03

ER data <20 keV is blinded before analysis is finalized

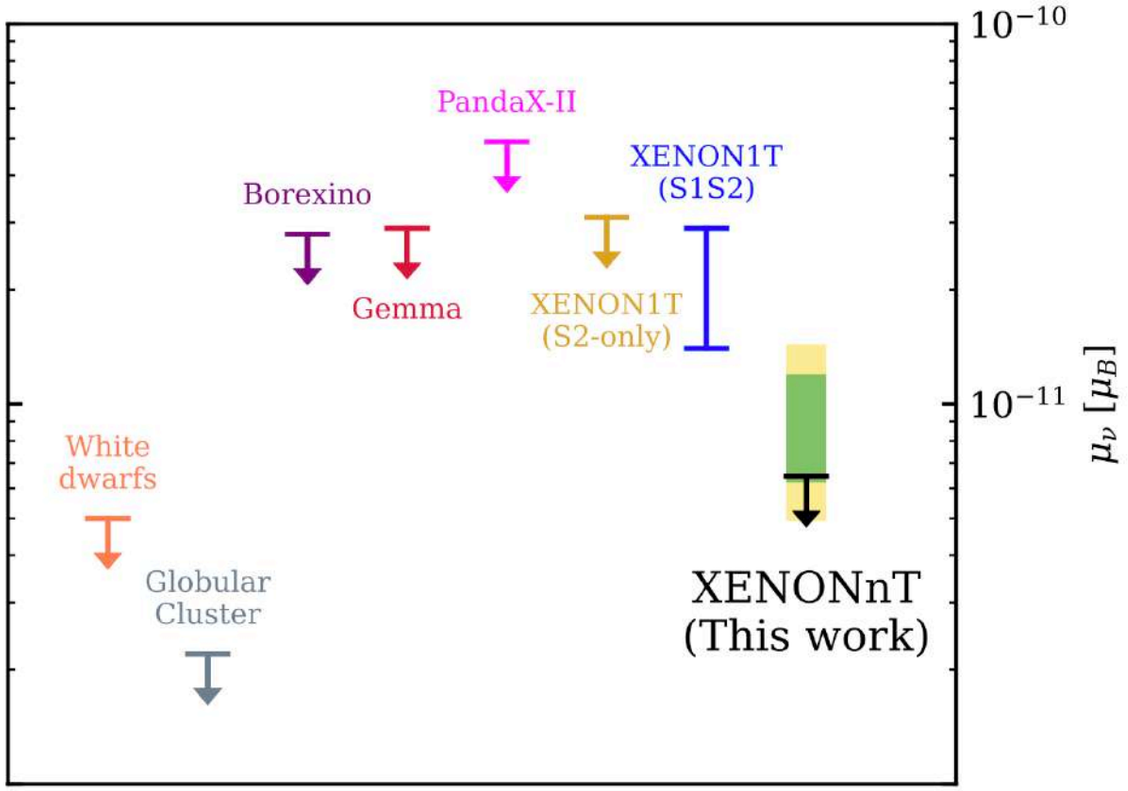
Zoomed in look below 30 keV

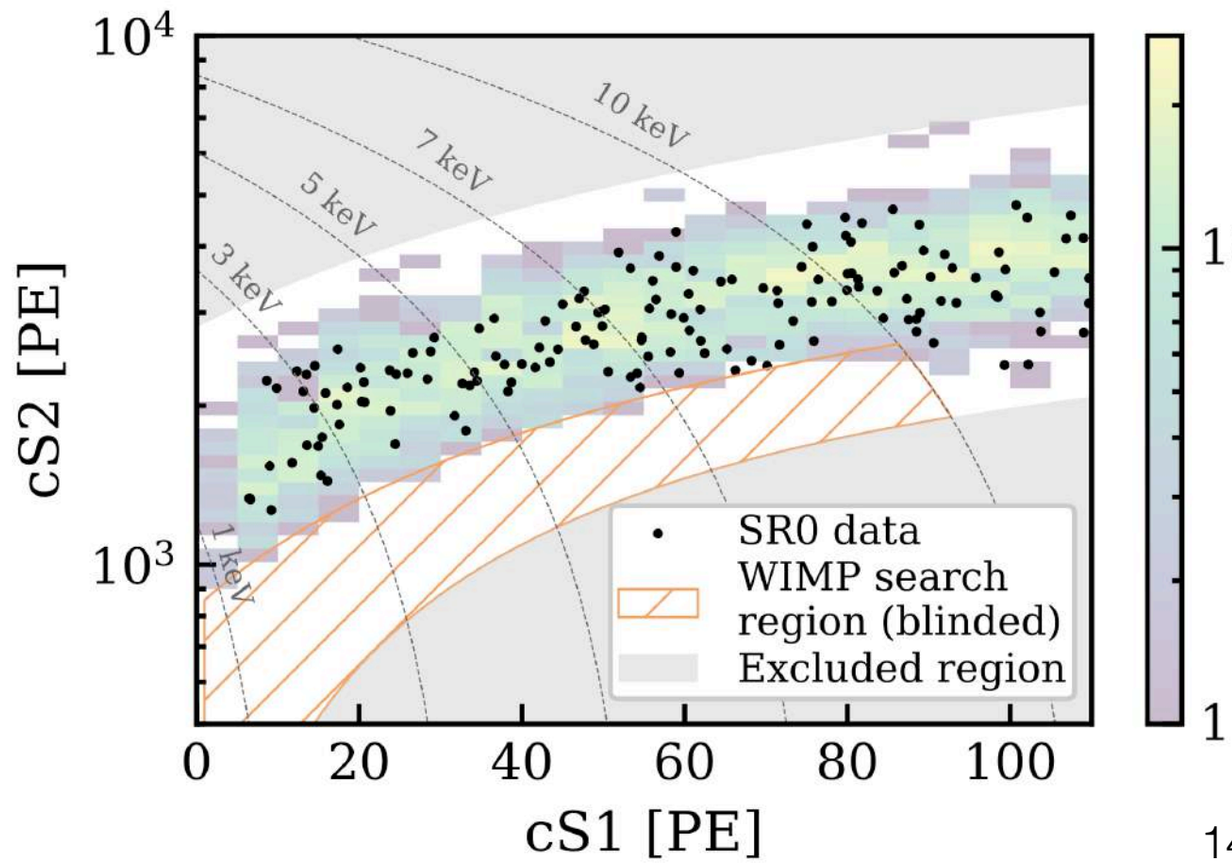


- Lowest background level is achieved:

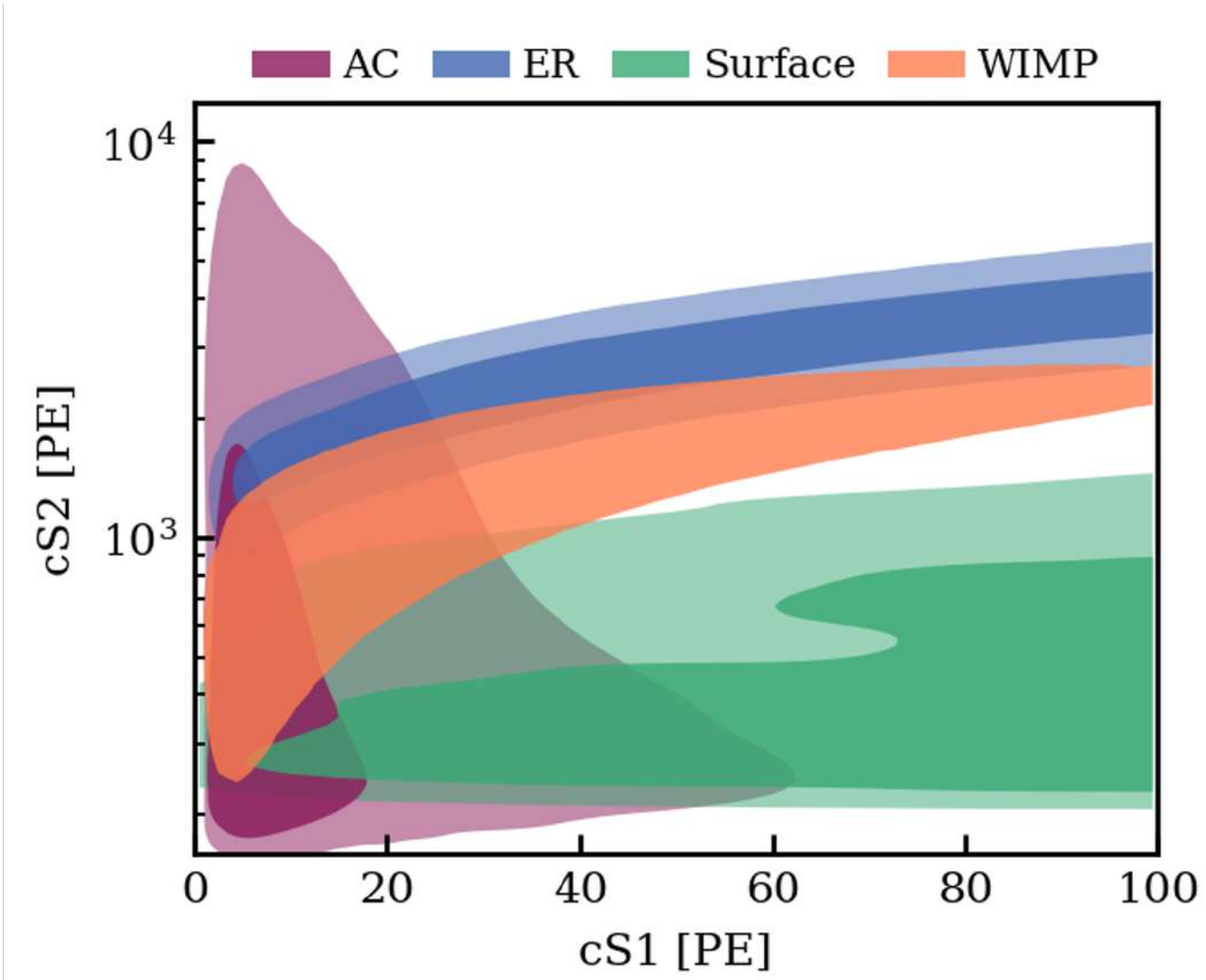
$$(16.1 \pm 1.3)\,\mathrm{events}/(\mathrm{t}\cdot\mathrm{y}\cdot\mathrm{keV})$$

- NR search data being blinded while searching for ER signals

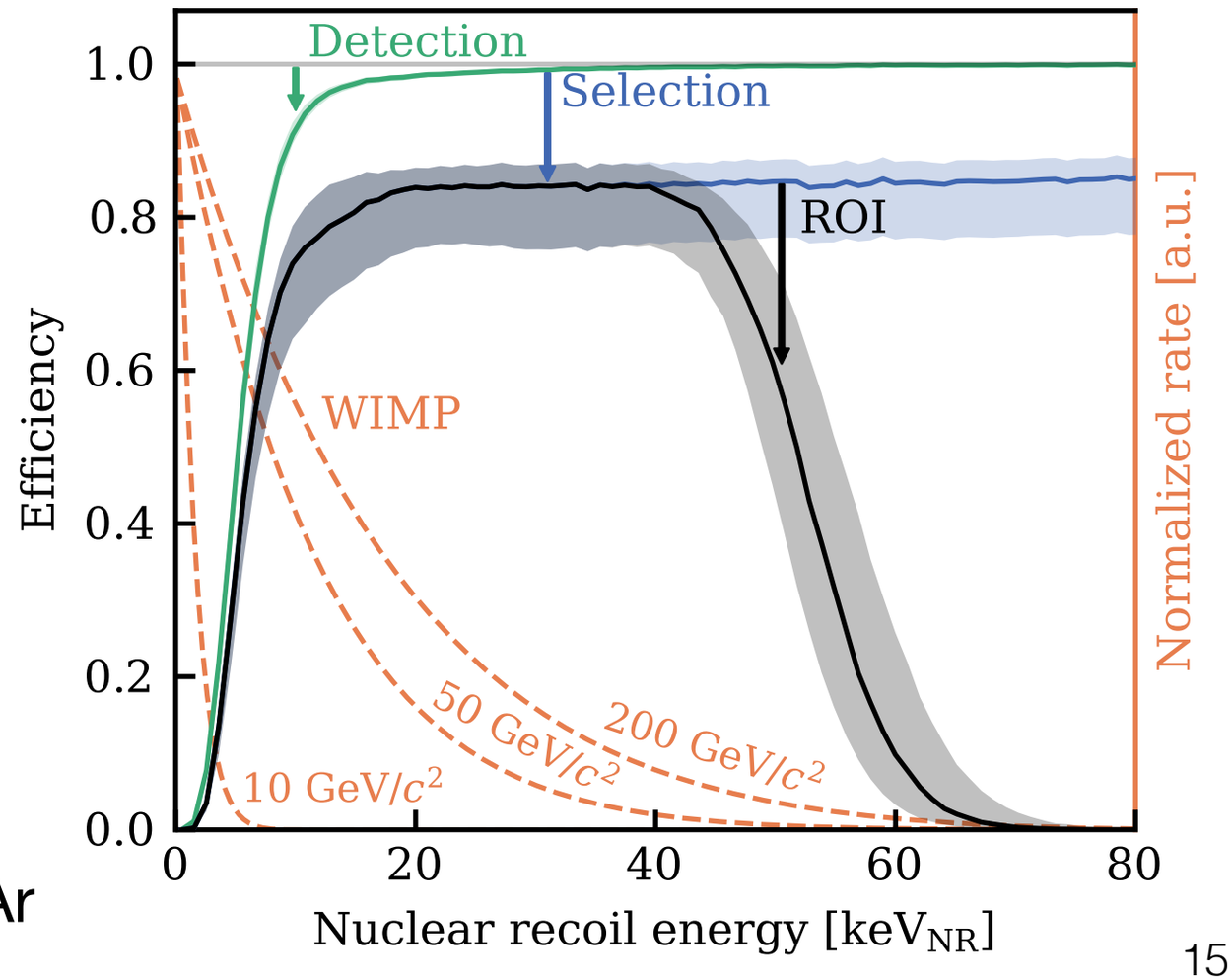




First WIMPs search



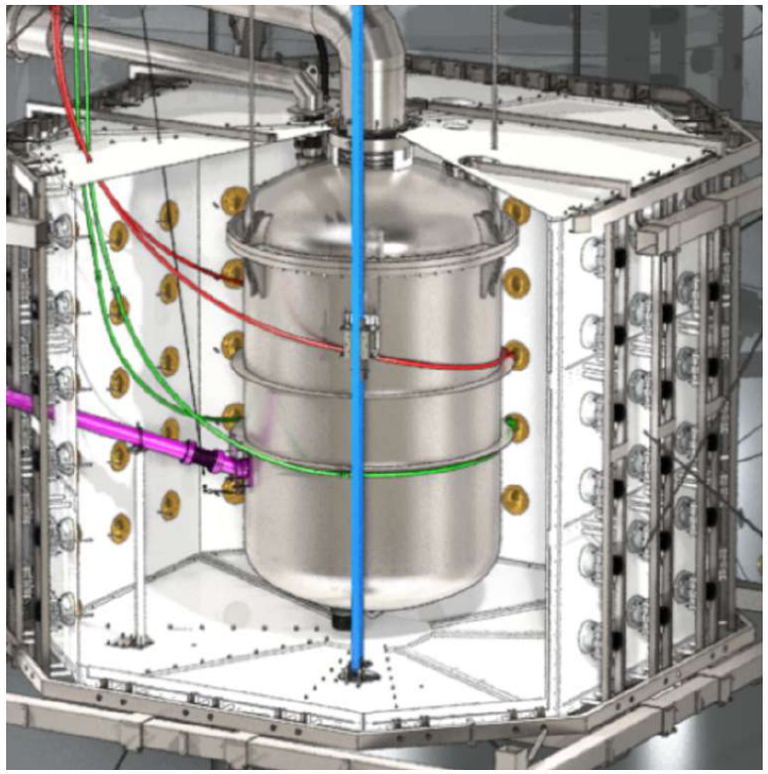
- ROI for WIMPs Search:
  - cS1 [0 pe, 100 pe]
  - cS2 [$10^{2.1}$ pe, $10^{4.1}$ pe]

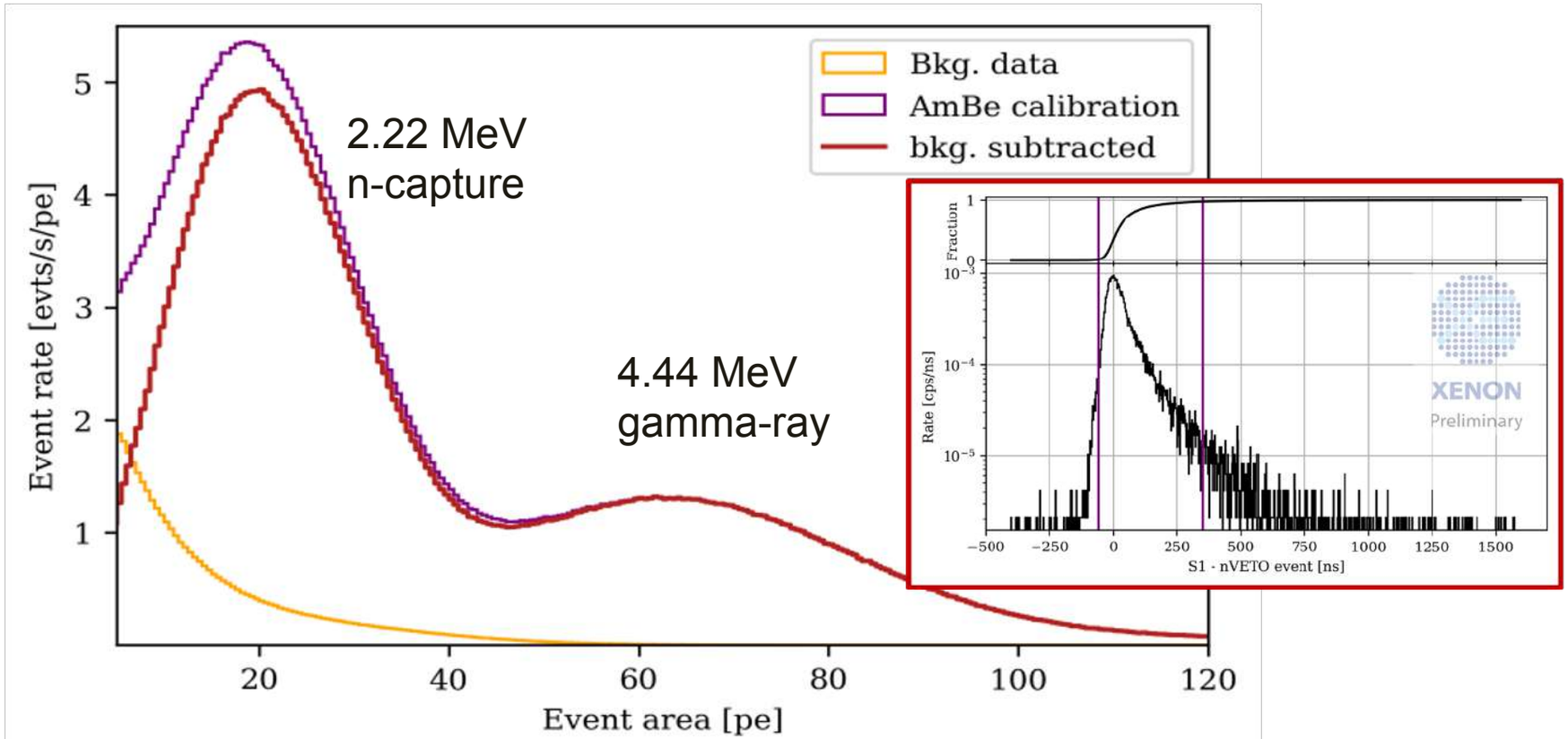


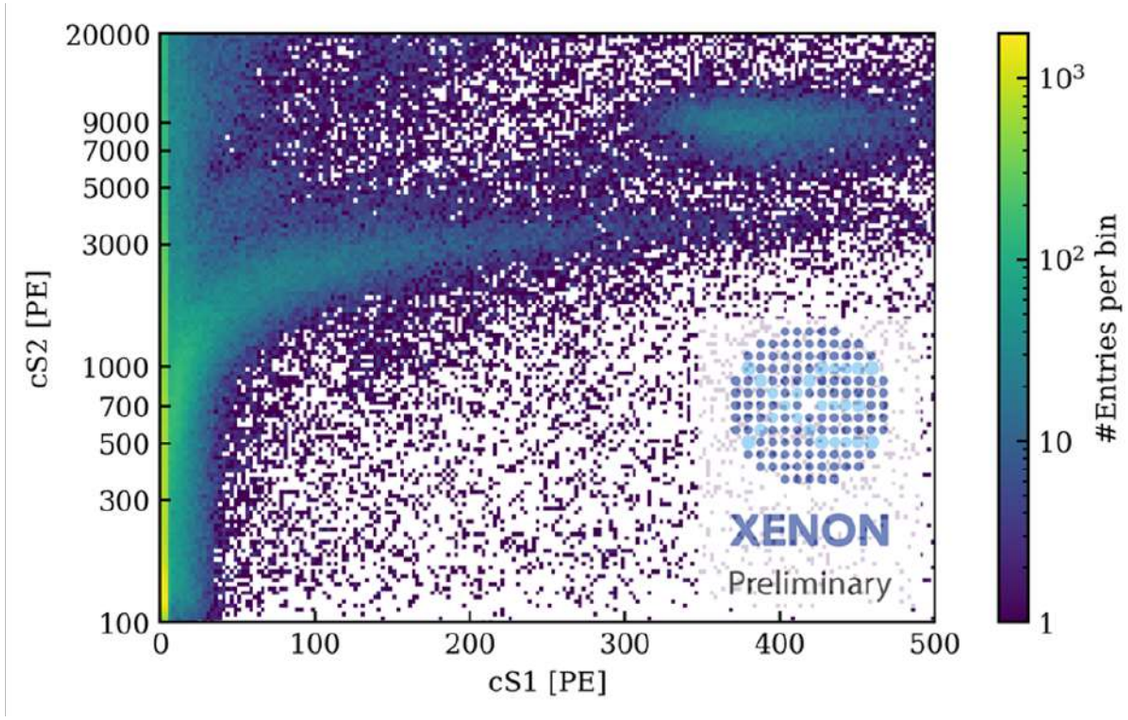
Detection efficiency:

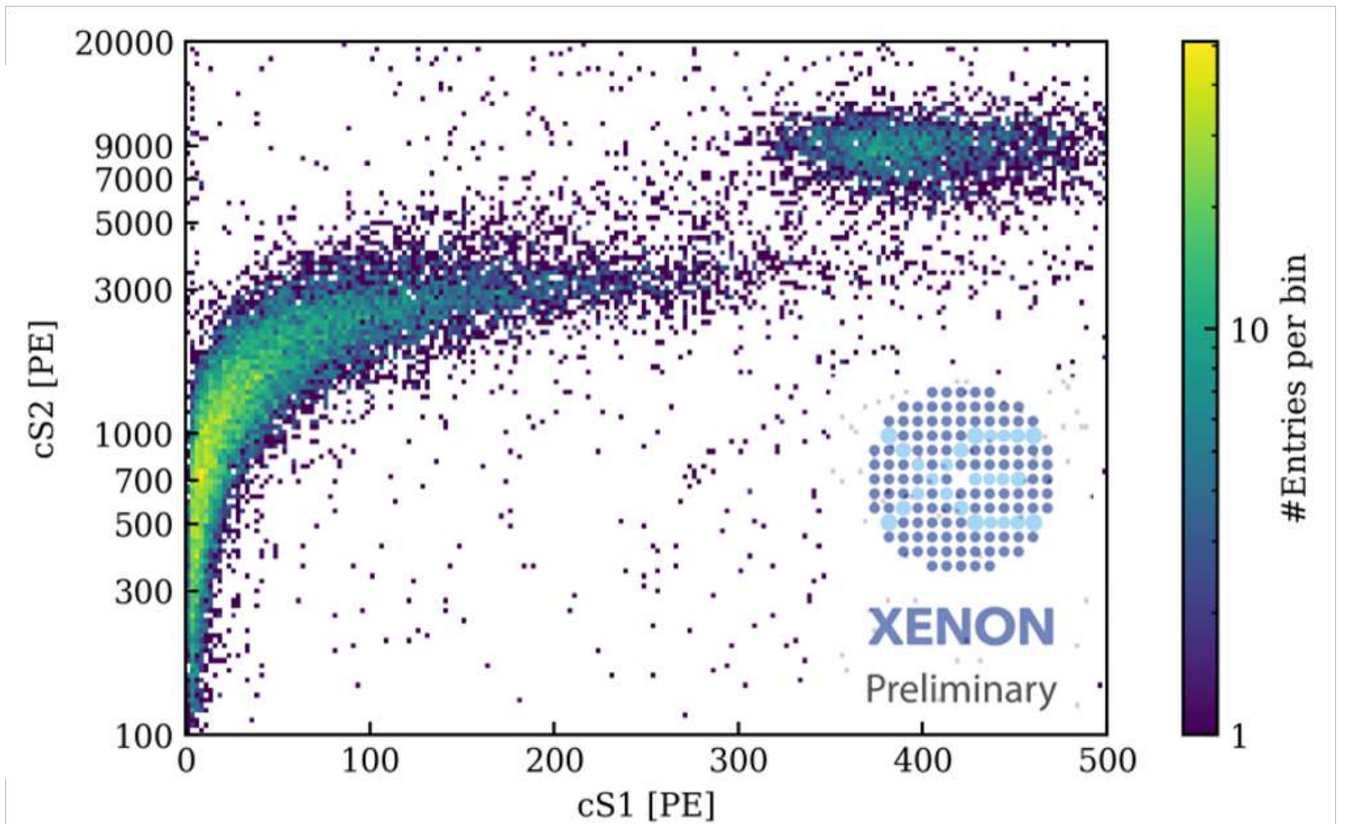
- S1 3-fold PMT coincidence
- Full waveform simulation
- Data-driven methods from ^{83m}Kr and ^{37}Ar

Nuclear Recoil Calibrations

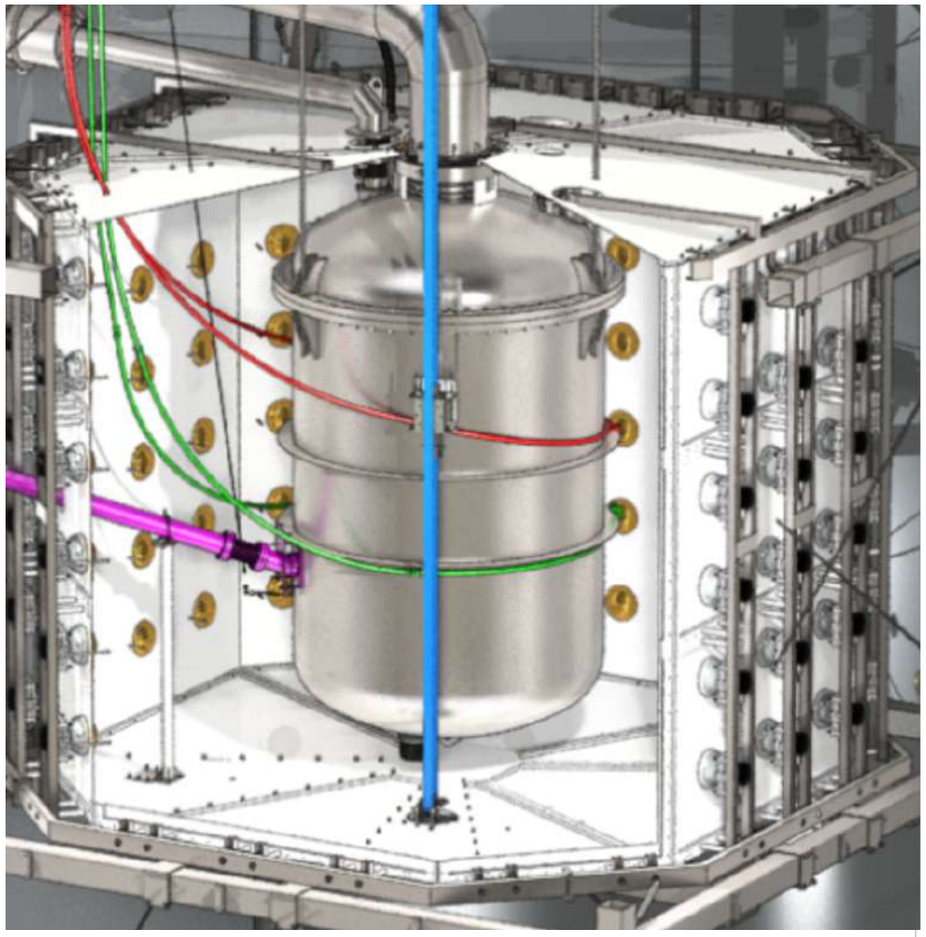




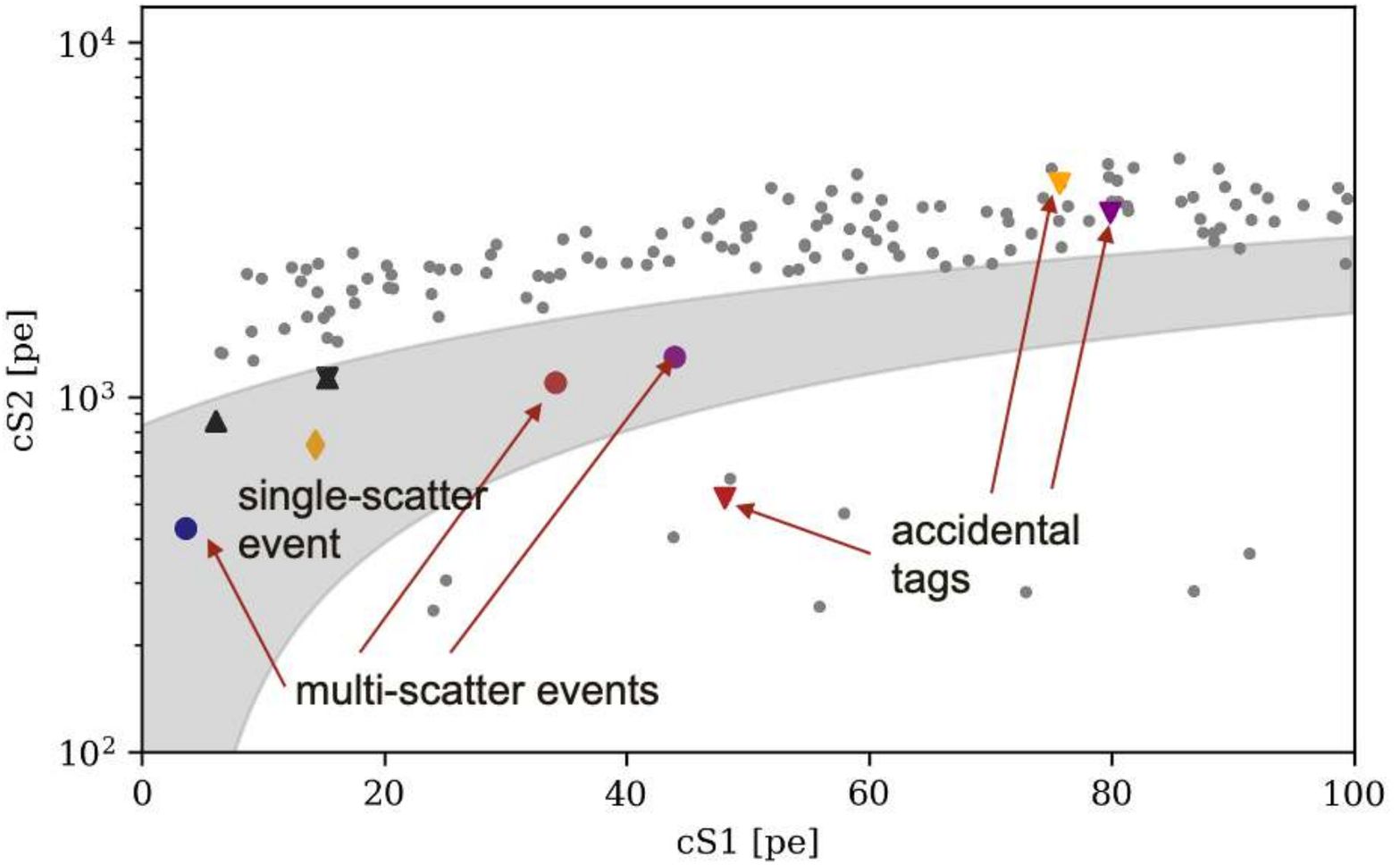




Neutron Background



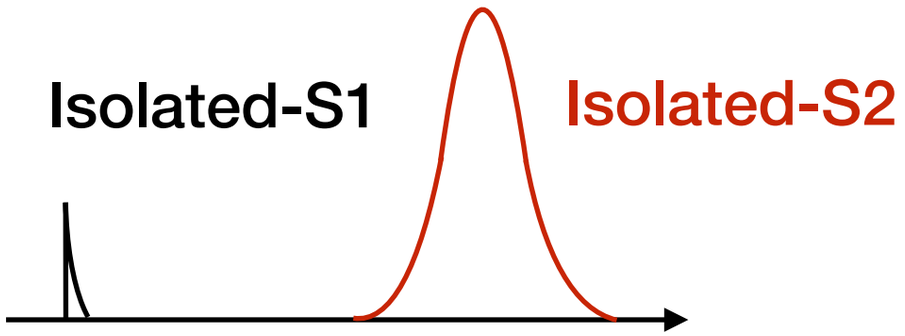
NV tagged events, and multiple scatters as data-driven neutron samples



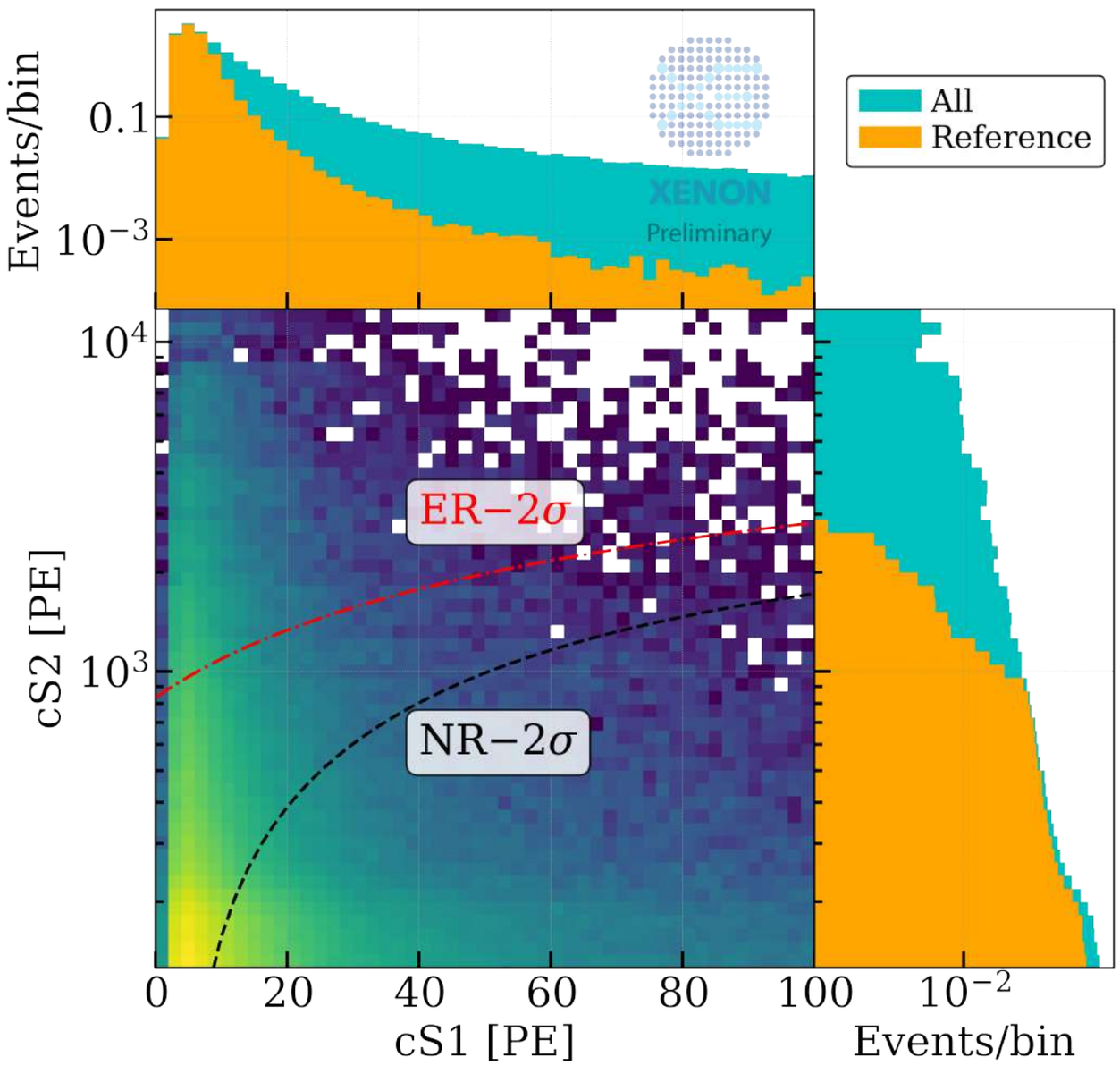
Observed neutron multiple scatter rate is x6 higher than MC predictions.

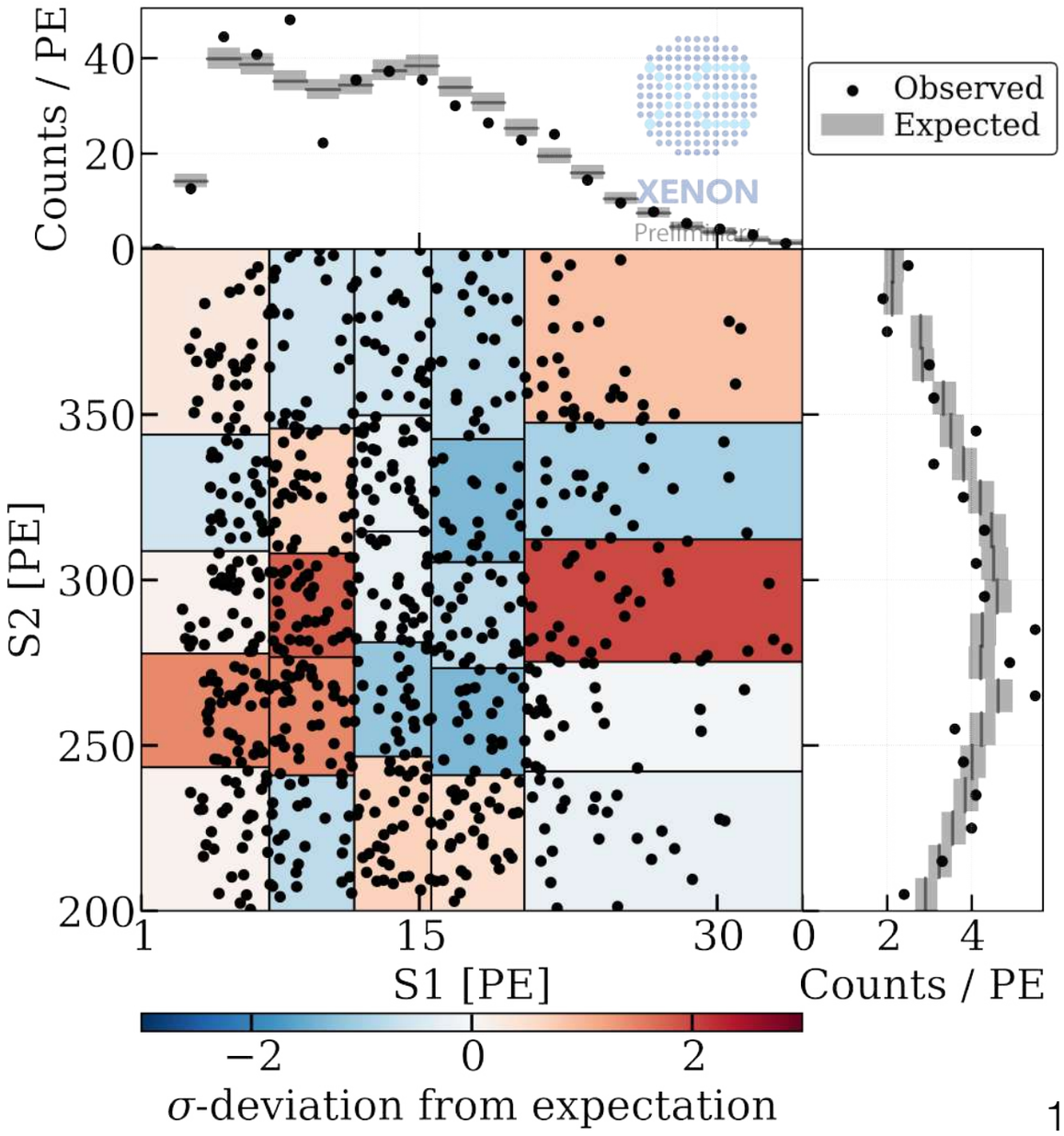
Final background prediction is performed towards the data-driven approach, without tuning fiducial volume post-unblinding

Accidental Coincidence Background



AC is seen and validated to 5% precision!



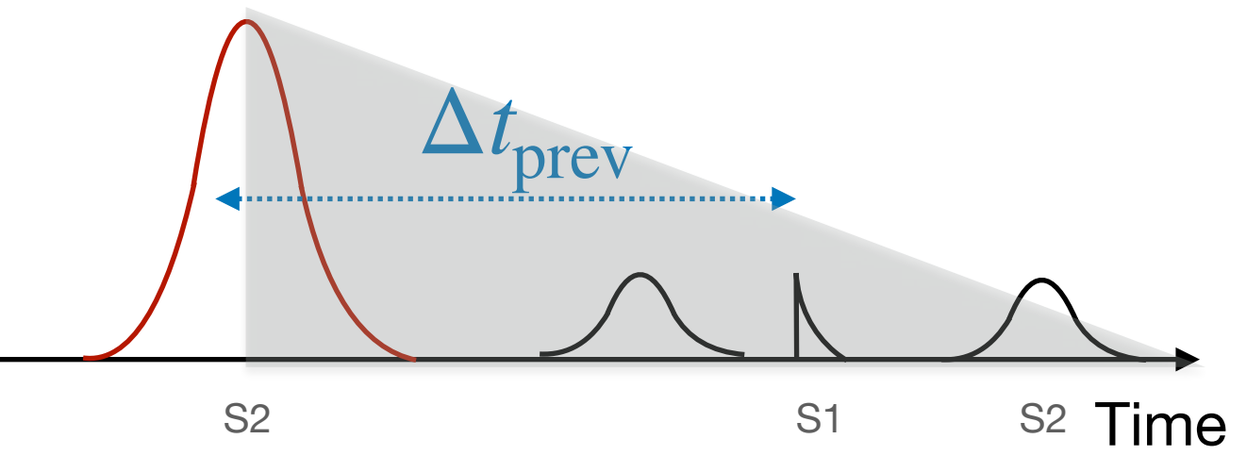


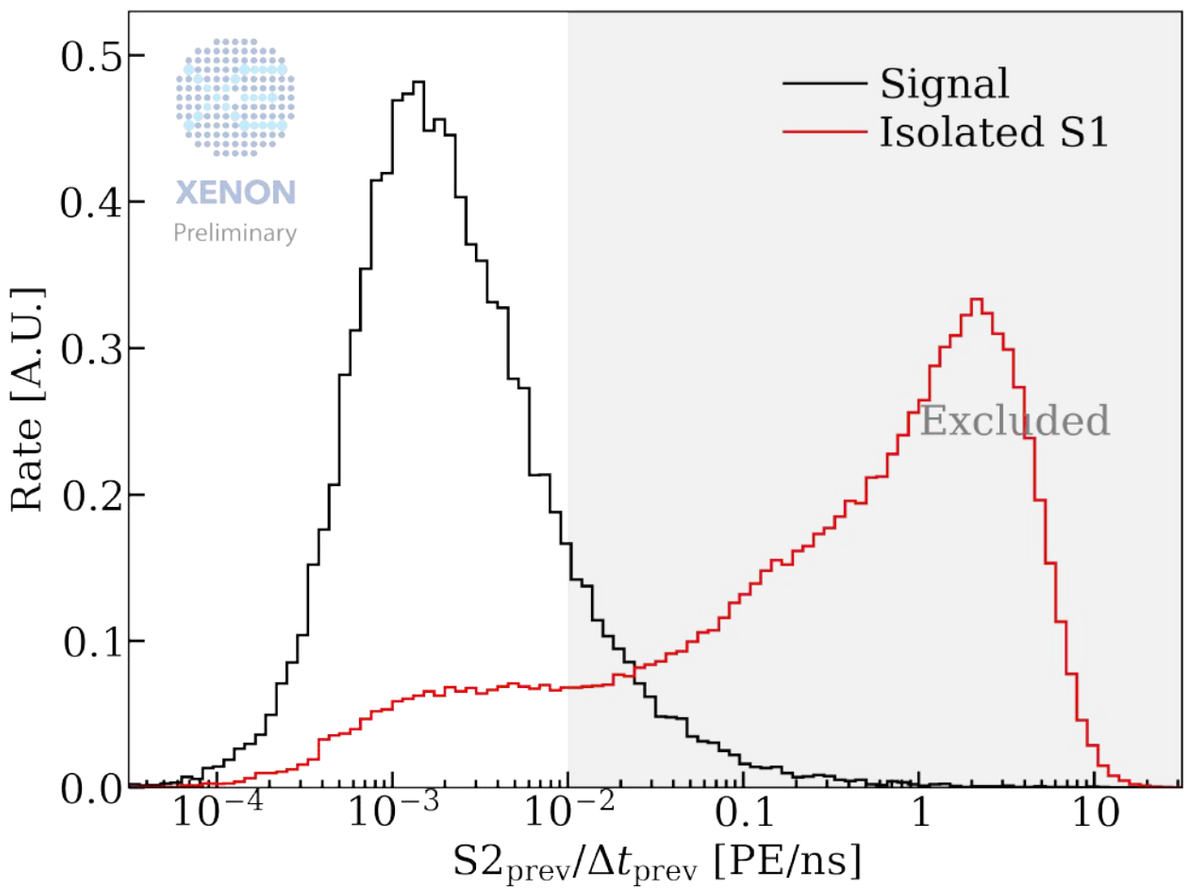
Accidental Coincidence Background

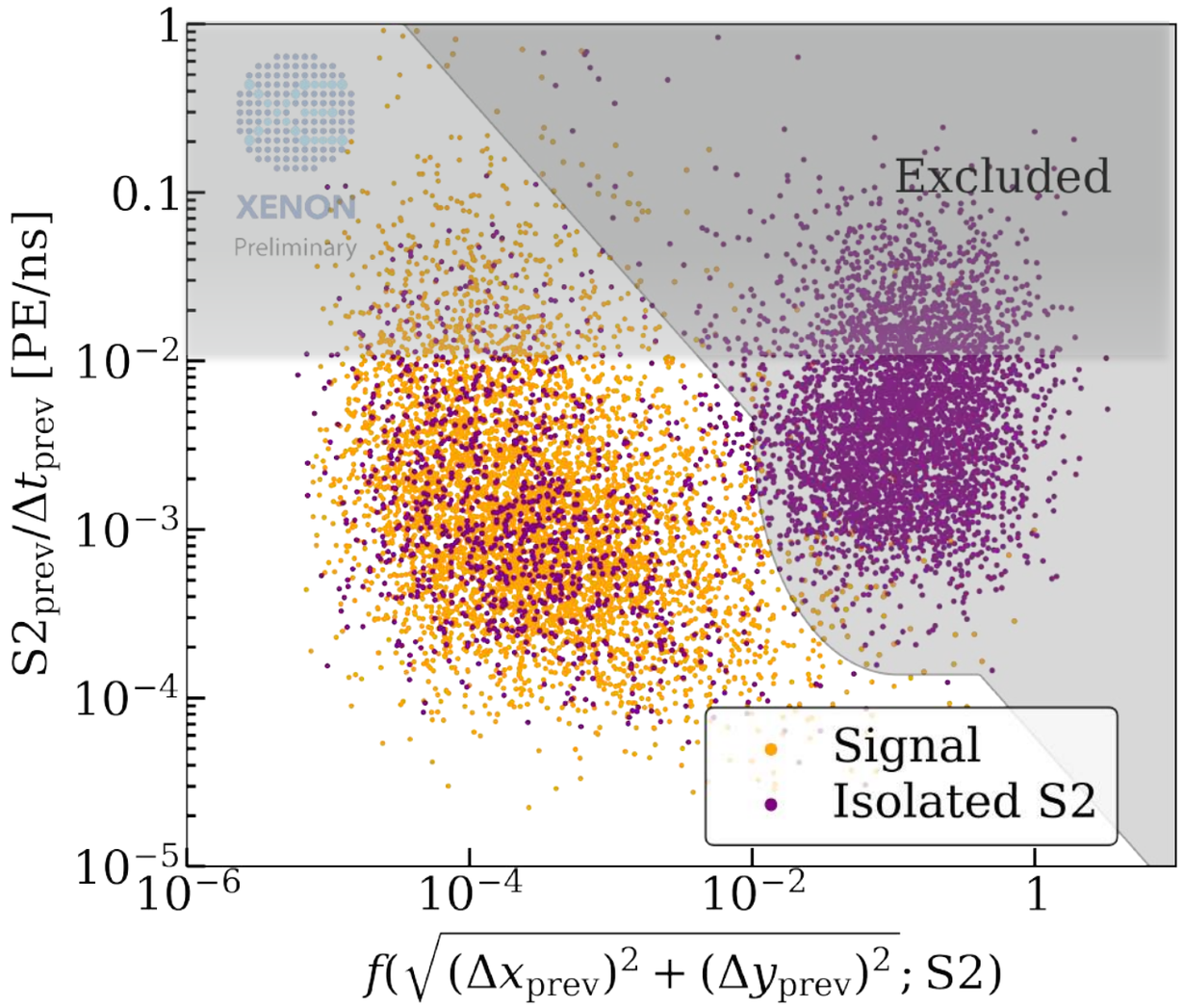
- Analyzers from Tsinghua：
- Kexin Liu（Ph. D. 2021）
- Dacheng Xu （B.S 2022, now Ph. D. @ Columbia）

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	biggest background

AC Suppression — Shadow Effects

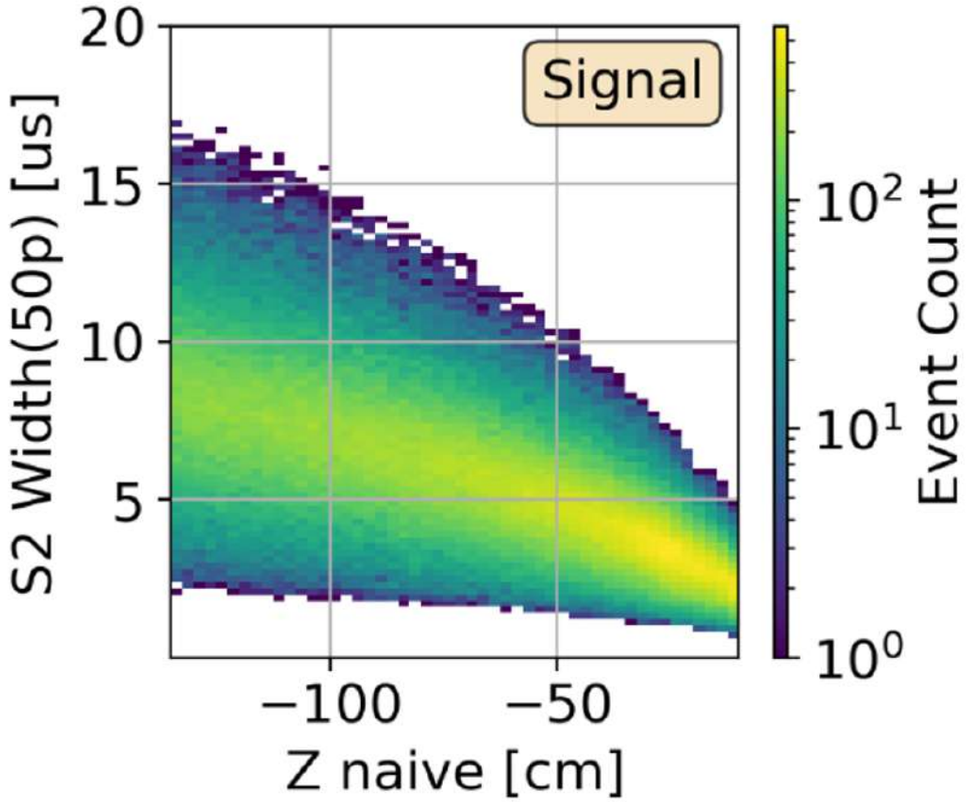


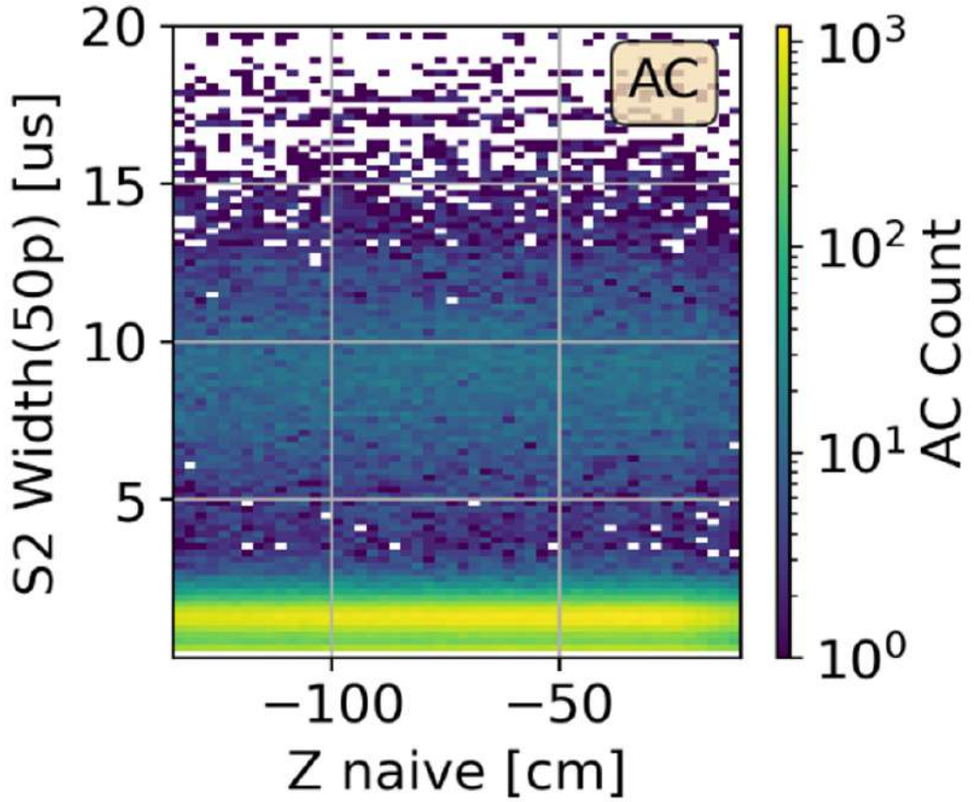


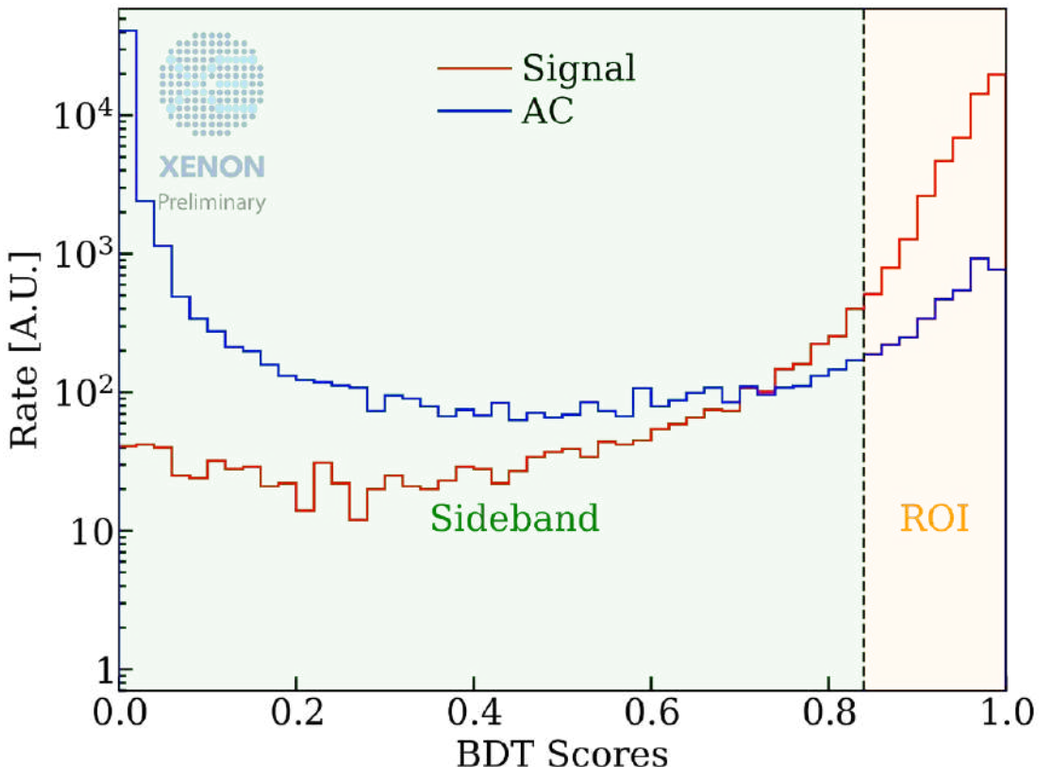


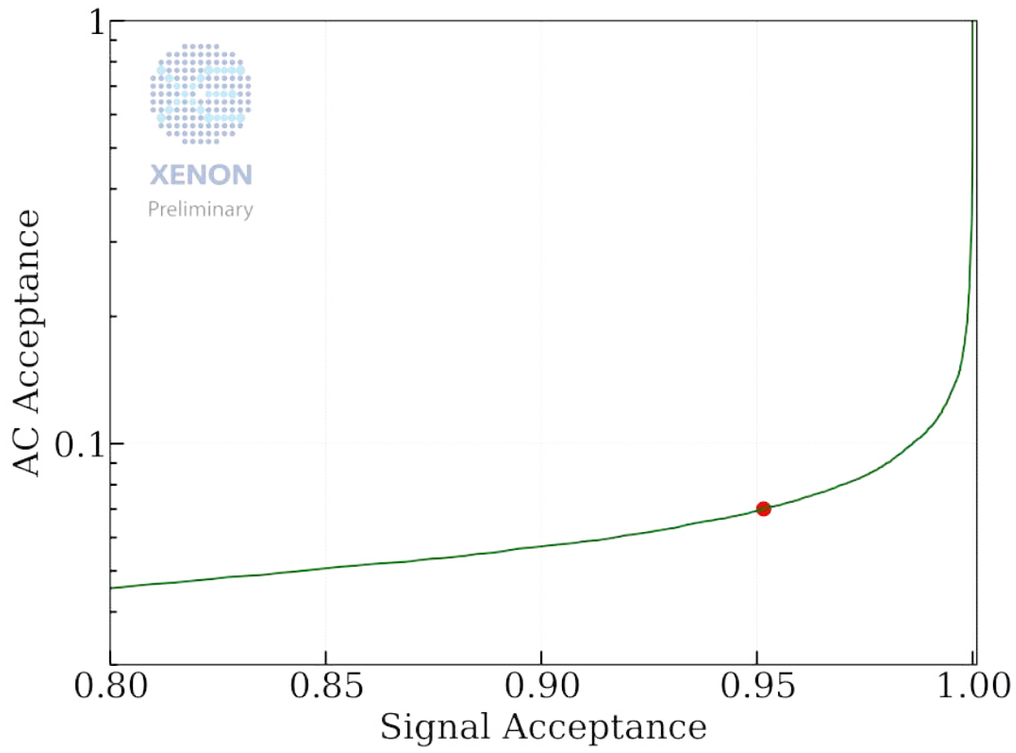
Reject exposure near high energy events

AC Suppression — S1 and S2 Correlations







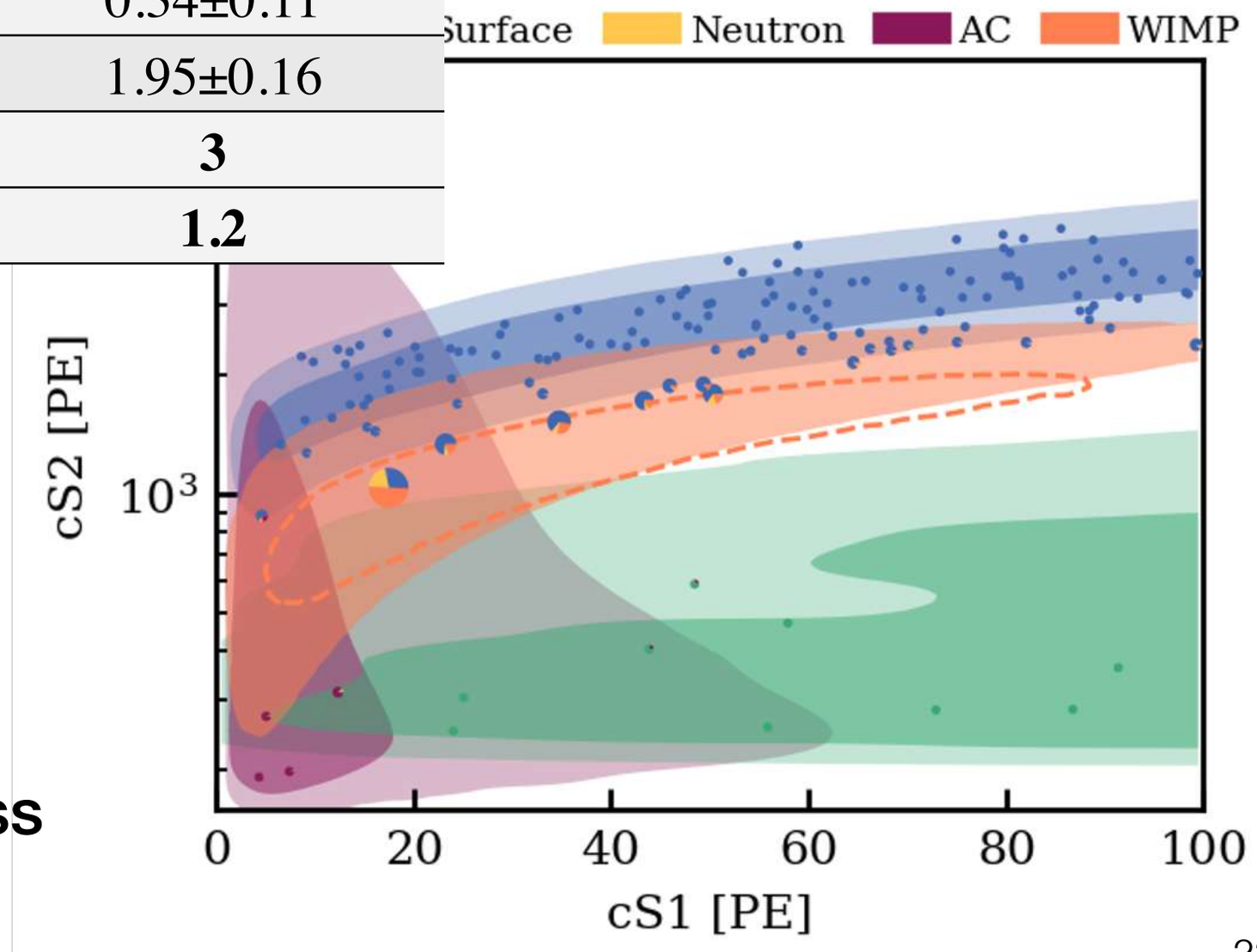


Results from Unblinding

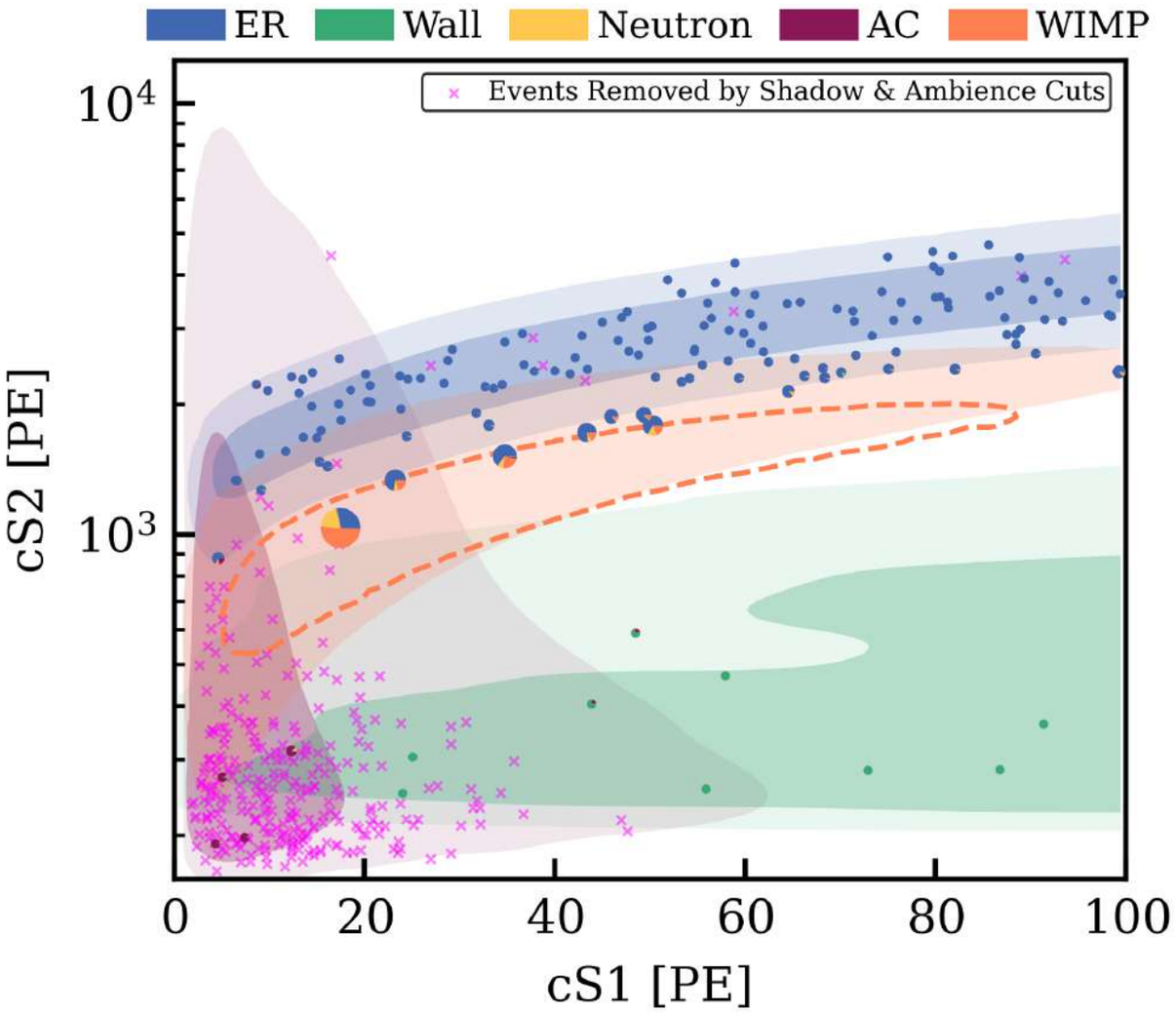
Sources	Nominal	Best Fit	
	ROI		Signal Like
ER	134	135±12	0.81±0.07
Neutron	1.1±0.6	1.1±0.6	0.42±0.20
Neutrino	0.23±0.06	0.23±0.06	0.02±0.01
AC	4.3±0.2	4.3±0.2	0.36±0.01
Surface	14±3	12	0.34±0.11
Total	154	152±12	1.95±0.16
Data		152	3
WIMPs		2.4	1.2

152 events in ROI, 16 in the blinded region

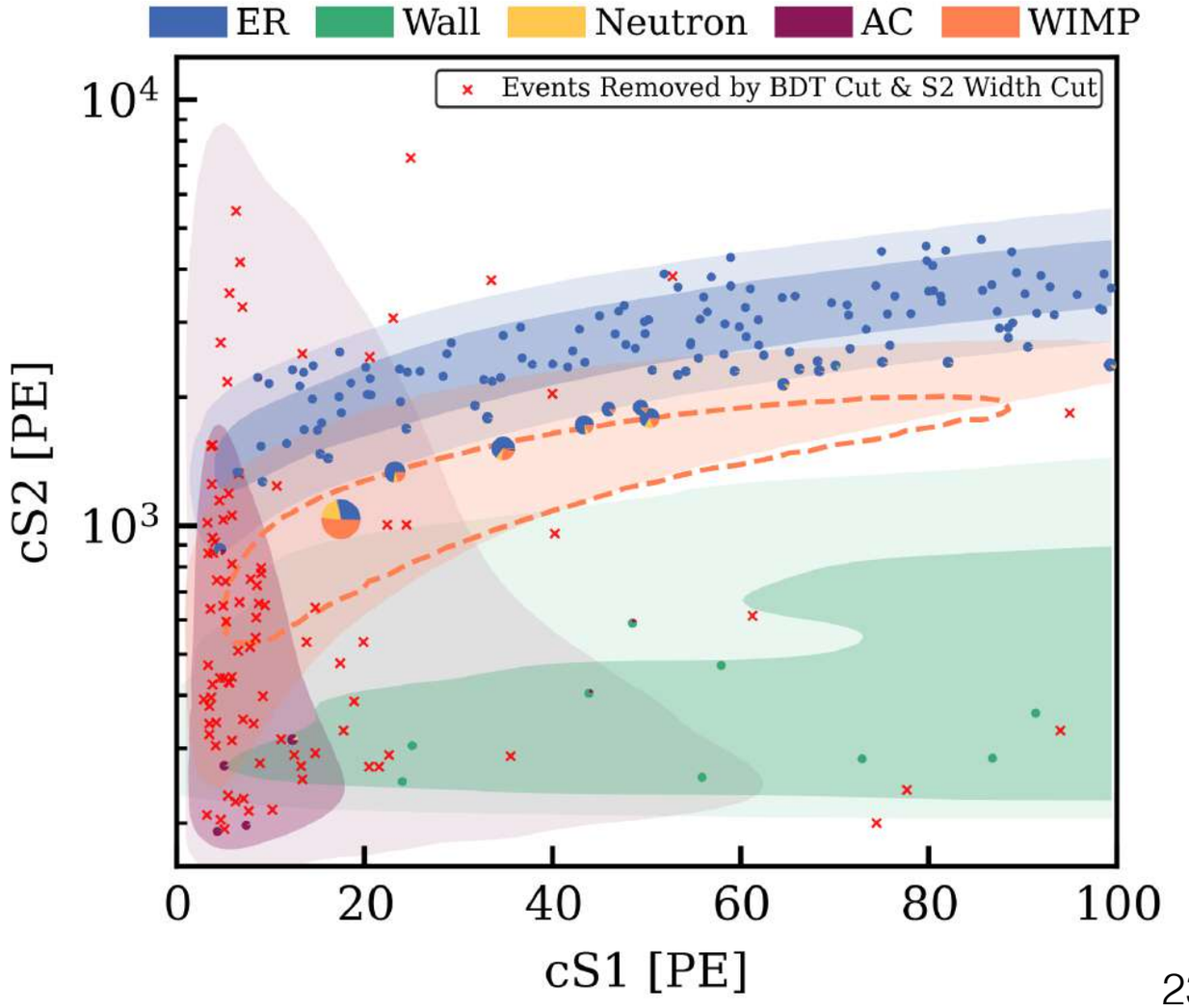
Best fit indicate no NR excess



Importance of anti-AC cuts

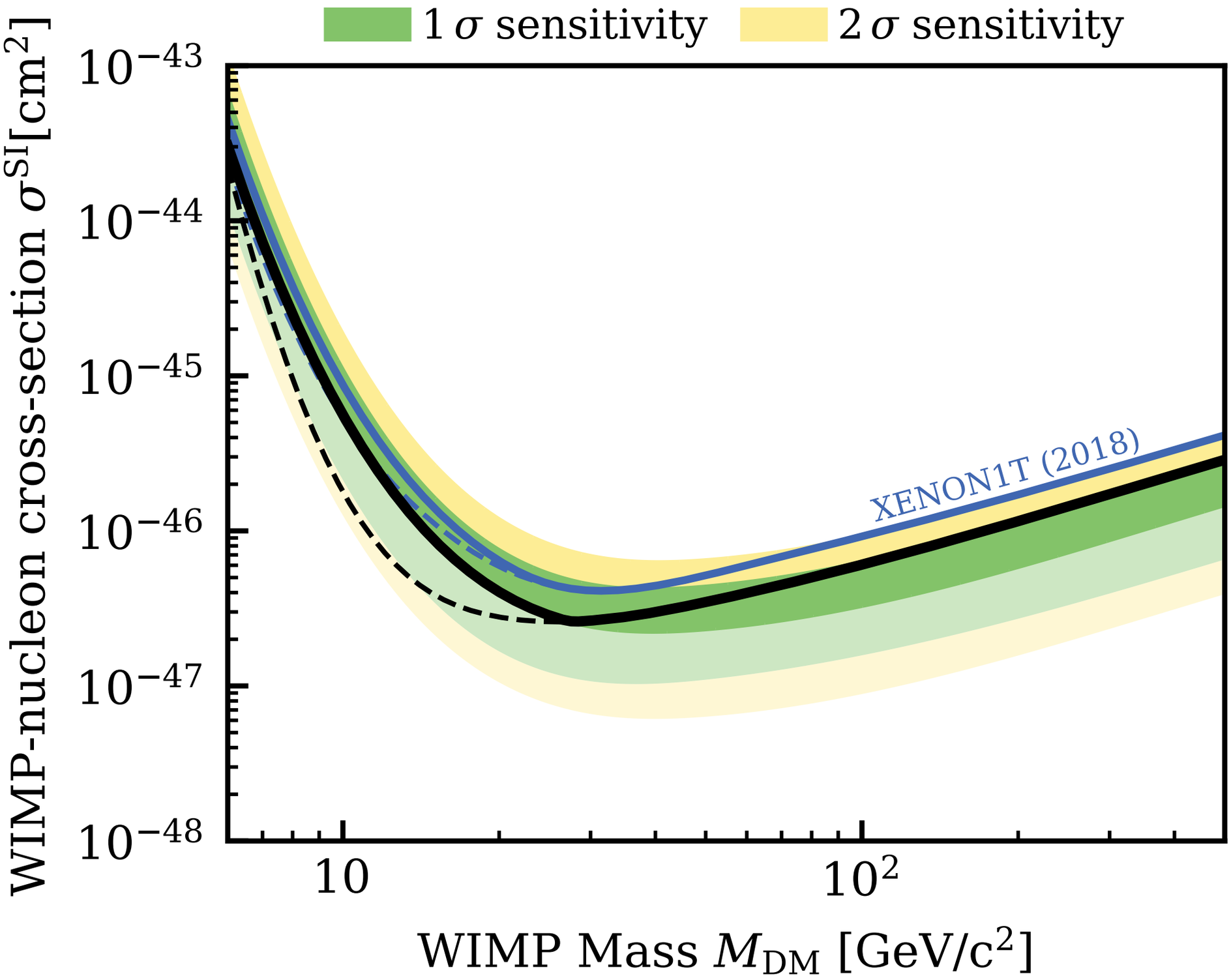


Many AC events are hiding behind the “shadow” of high energy events



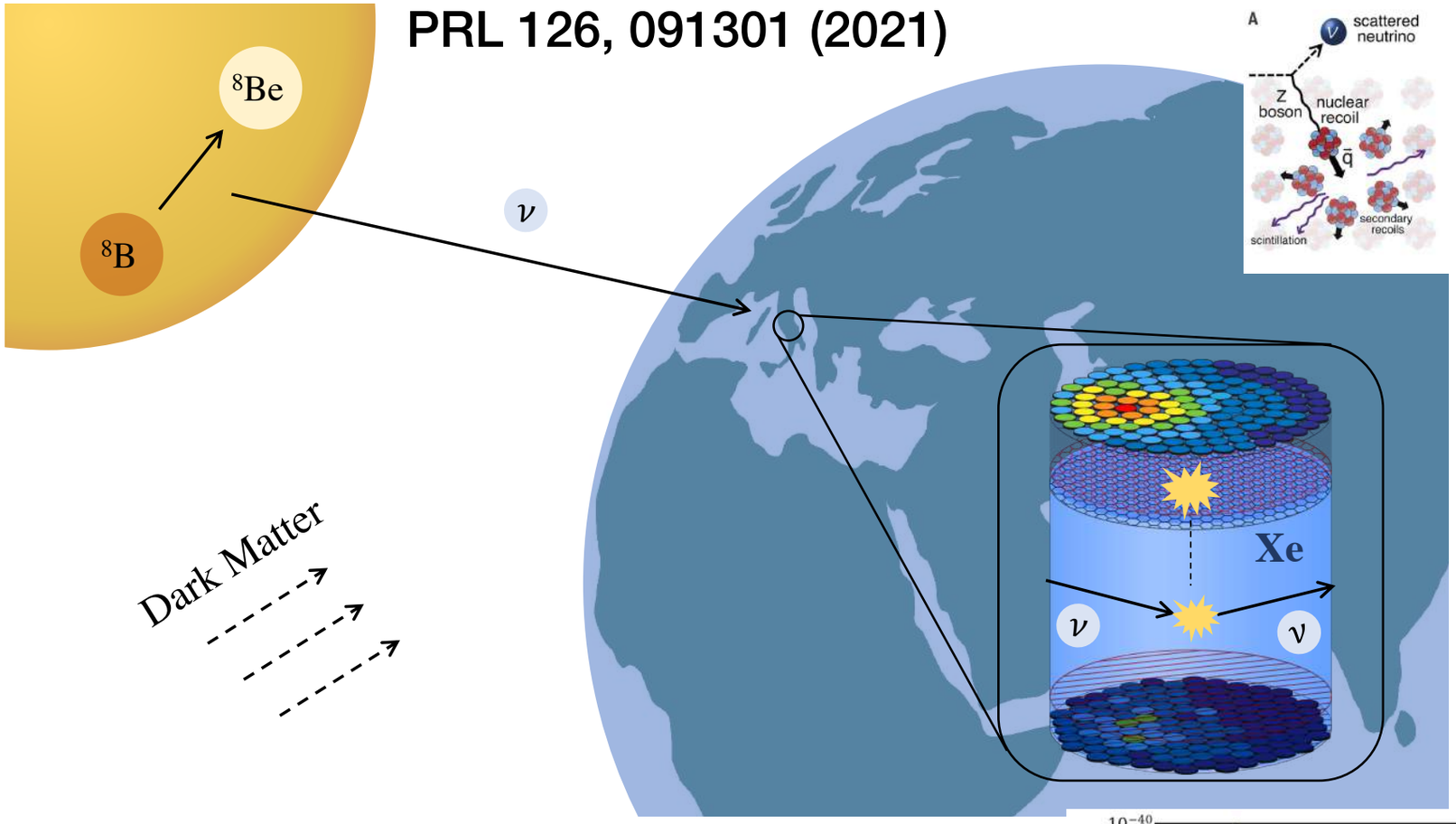
The AC background can be highly suppressed by the anti-AC BDT cut

Limits on WIMPs-nucleon Cross Sections



Discovery Potential of Solar ^{8}B Neutrinos

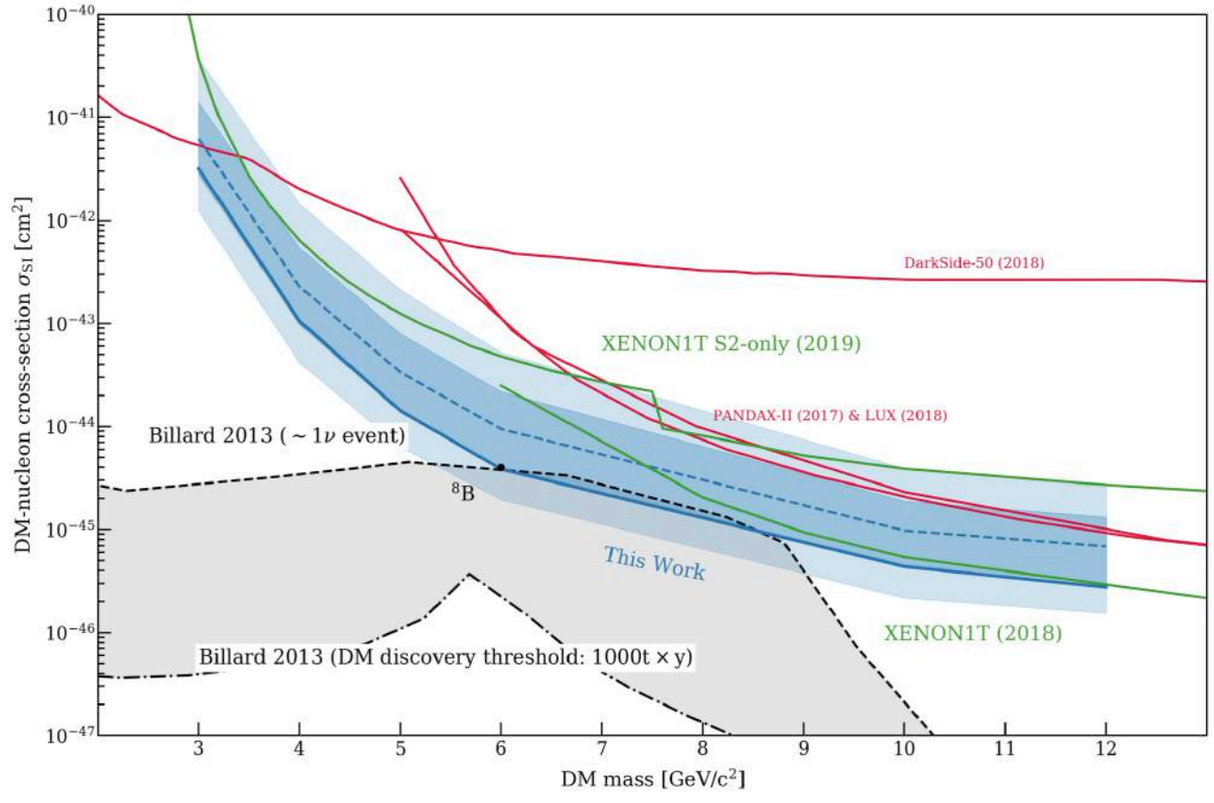
PRL 126, 091301 (2021)



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

XENON1T Search

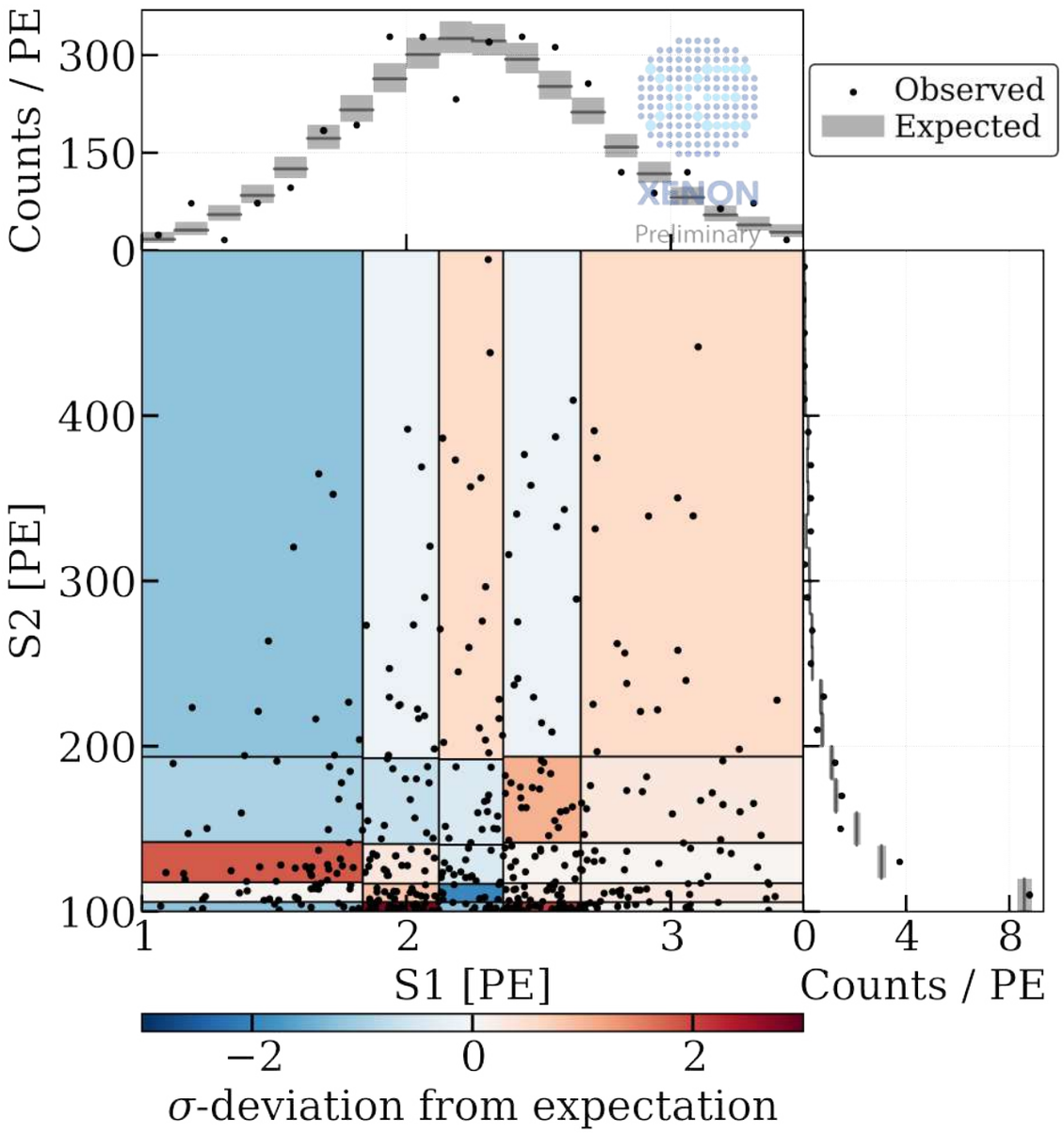
- S1: 2 or 3 hits
- S2: 120 - 500 PE
- 0.6 t-y of exposure



Discovery Potential of Solar ^{8}B Neutrinos

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

PRELIMINARY



These numbers are very only for illustration

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

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

Summary and Outlook

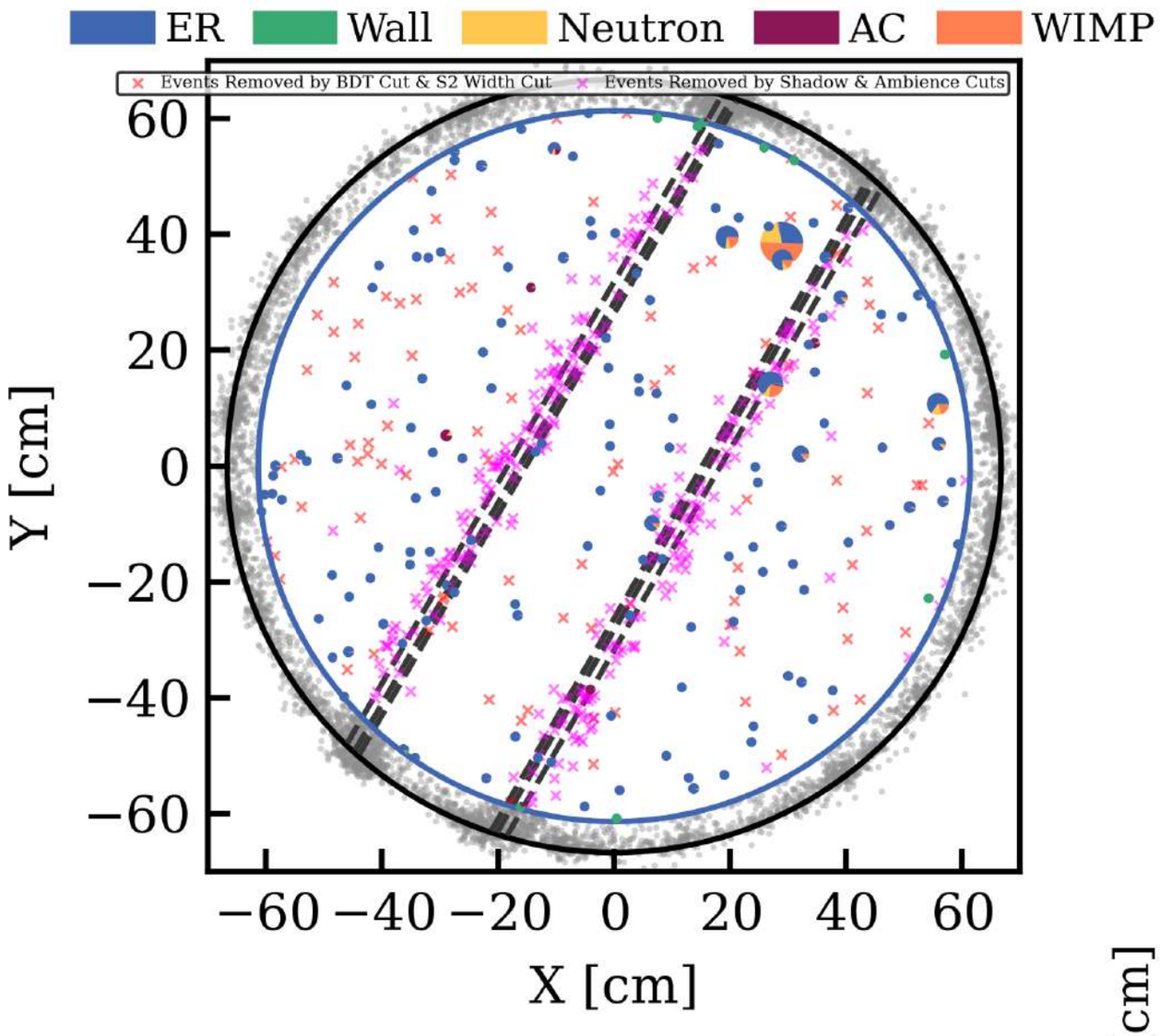
- XENONnT had finished the first WIMPs search with 1.1 ton-year exposure and the lowest electronic recoil background rate in the keV range
- No significant excess is found in the nuclear recoil search region.
- XENONnT is continuing data-taking with half of its electronic recoil background (radon dominated)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

Stay tuned!

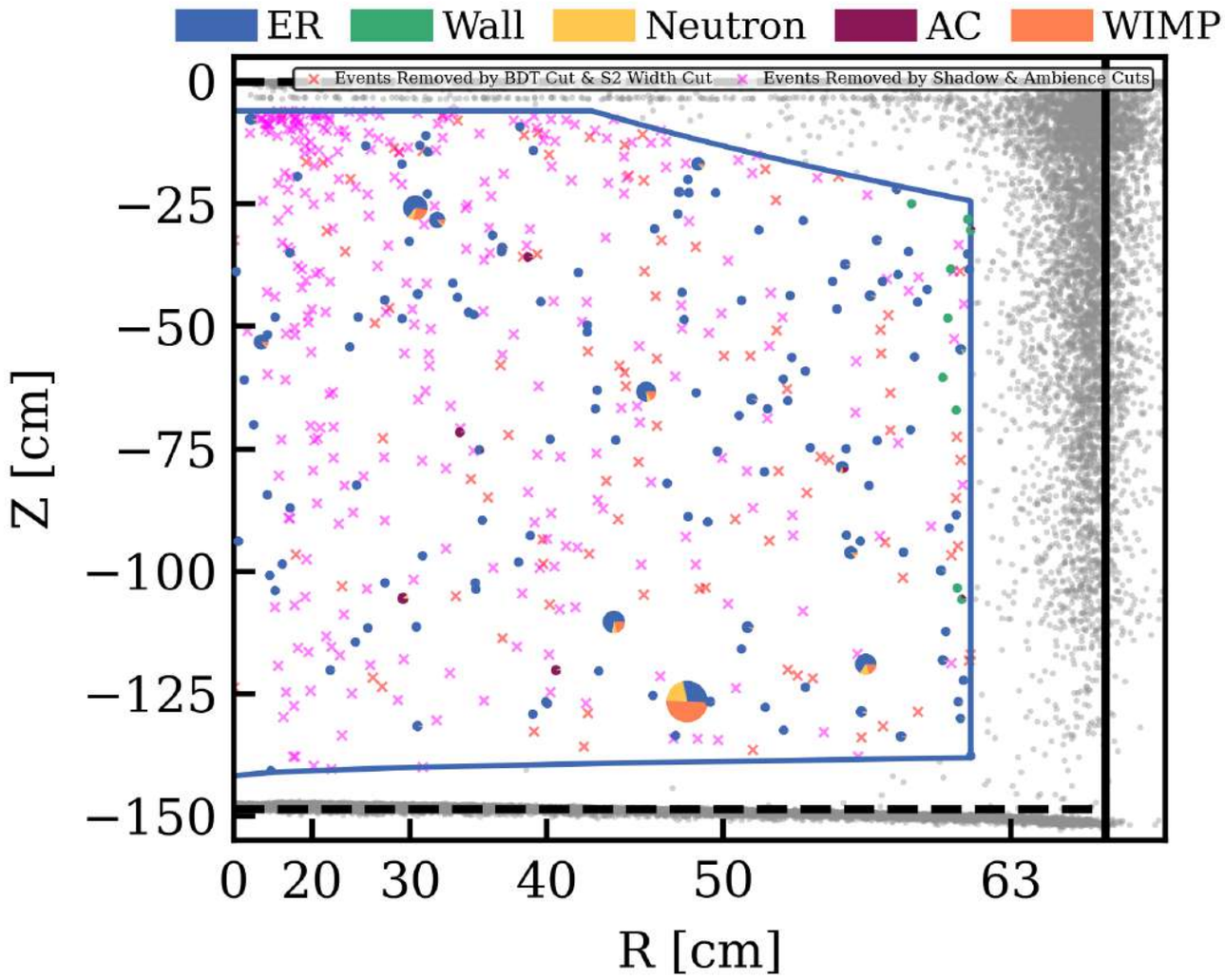
http://xenonexperiment.org

Thanks for your attention!

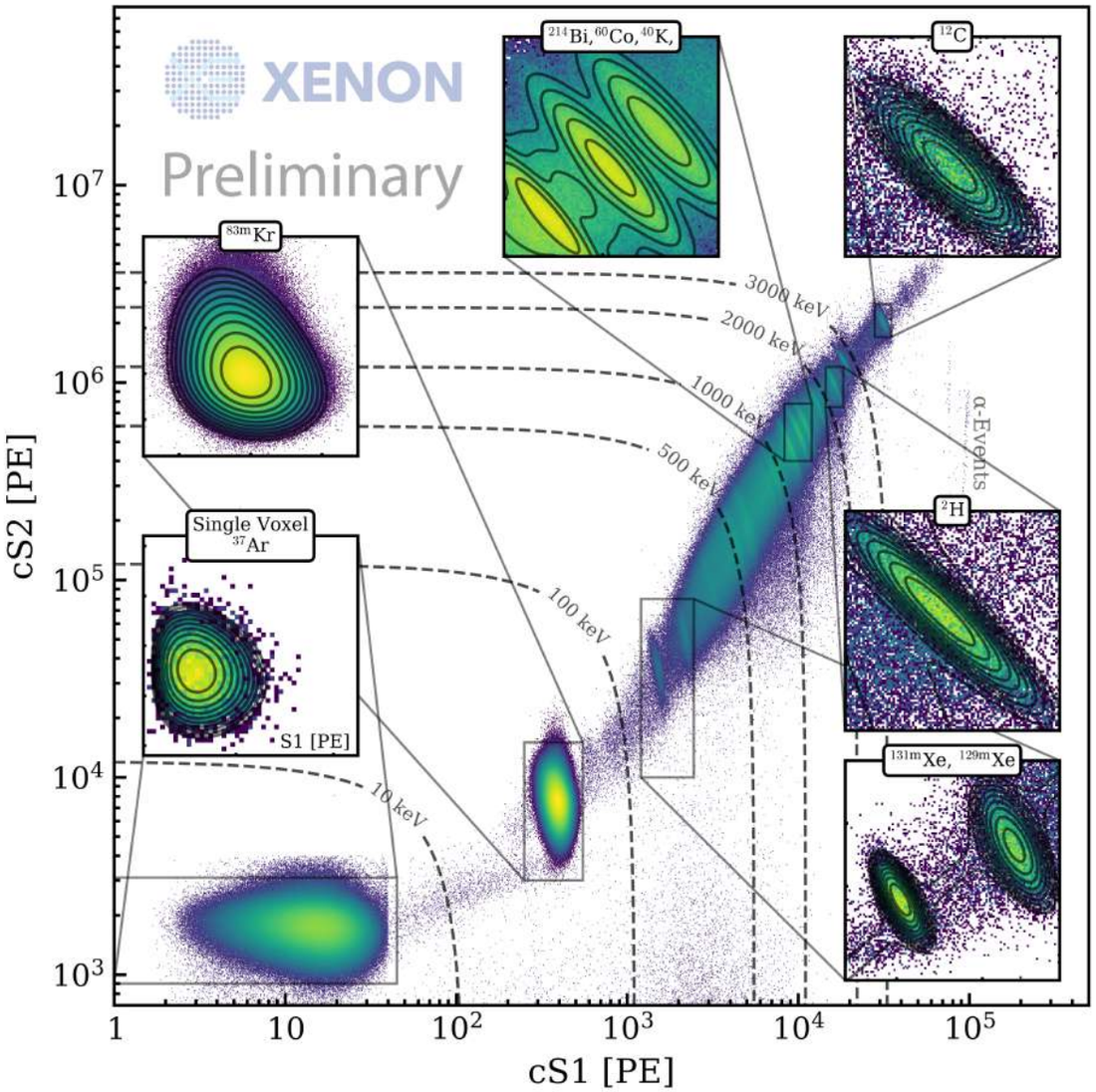
Importance of anti-AC cuts



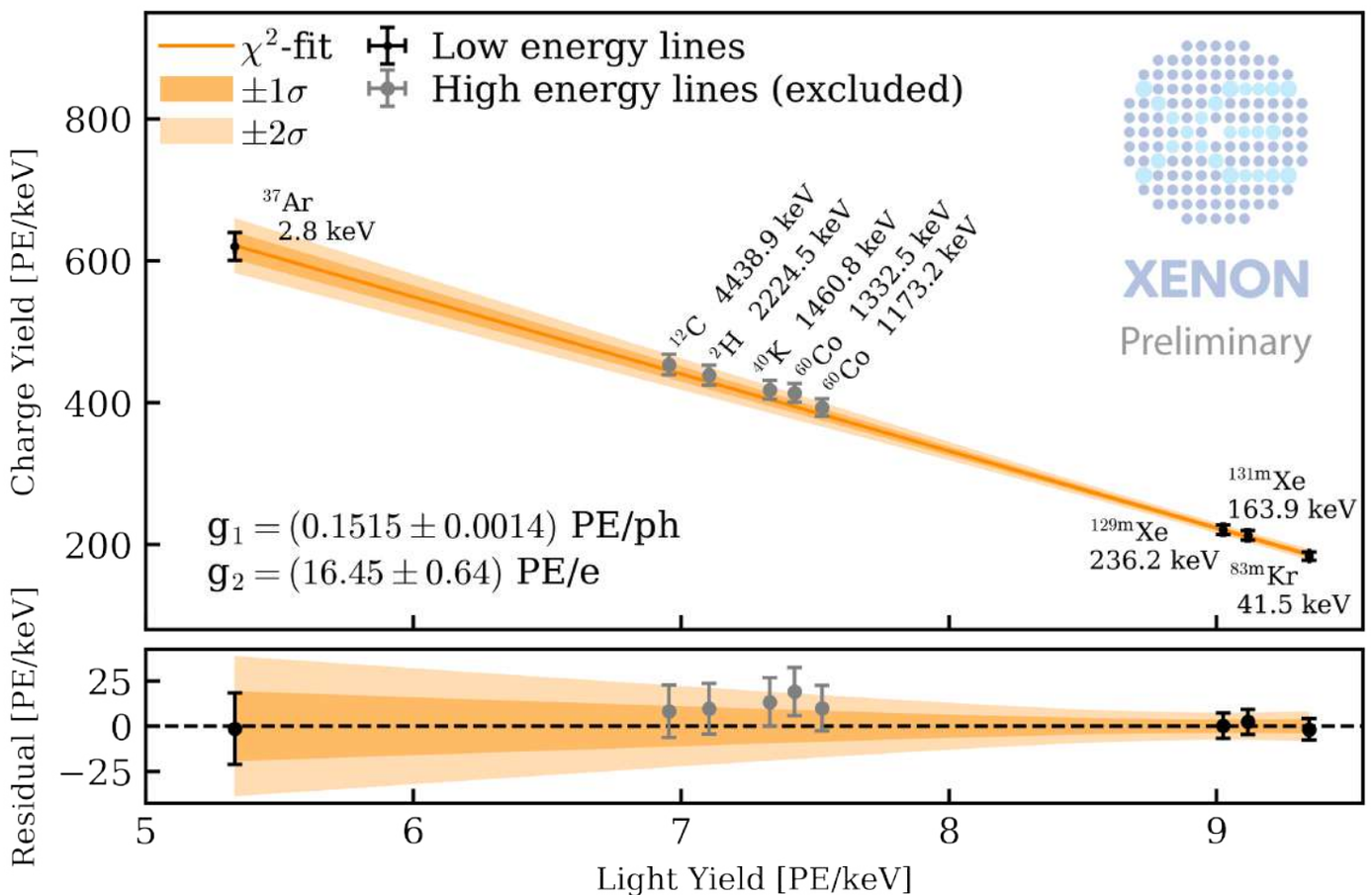
AC events are more concentrated on the supporting wires, and they are mainly suppressed by “Shadow” cuts



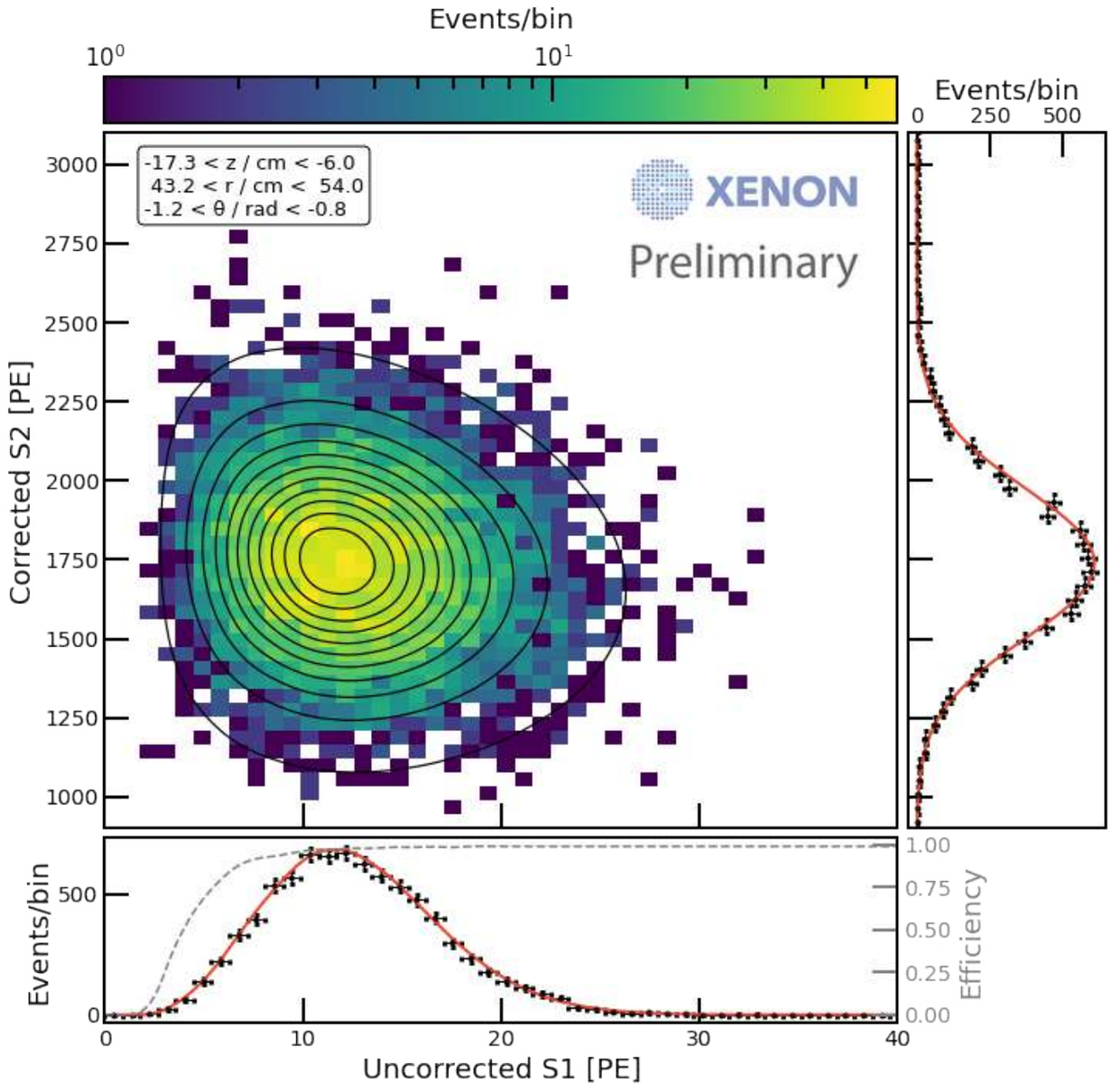
Energy Calibrations



- 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