清華大學
Tsinghua University

XENON

Search for Solar ^{8}B Neutrinos and light Dark Matter with the XENON Detectors

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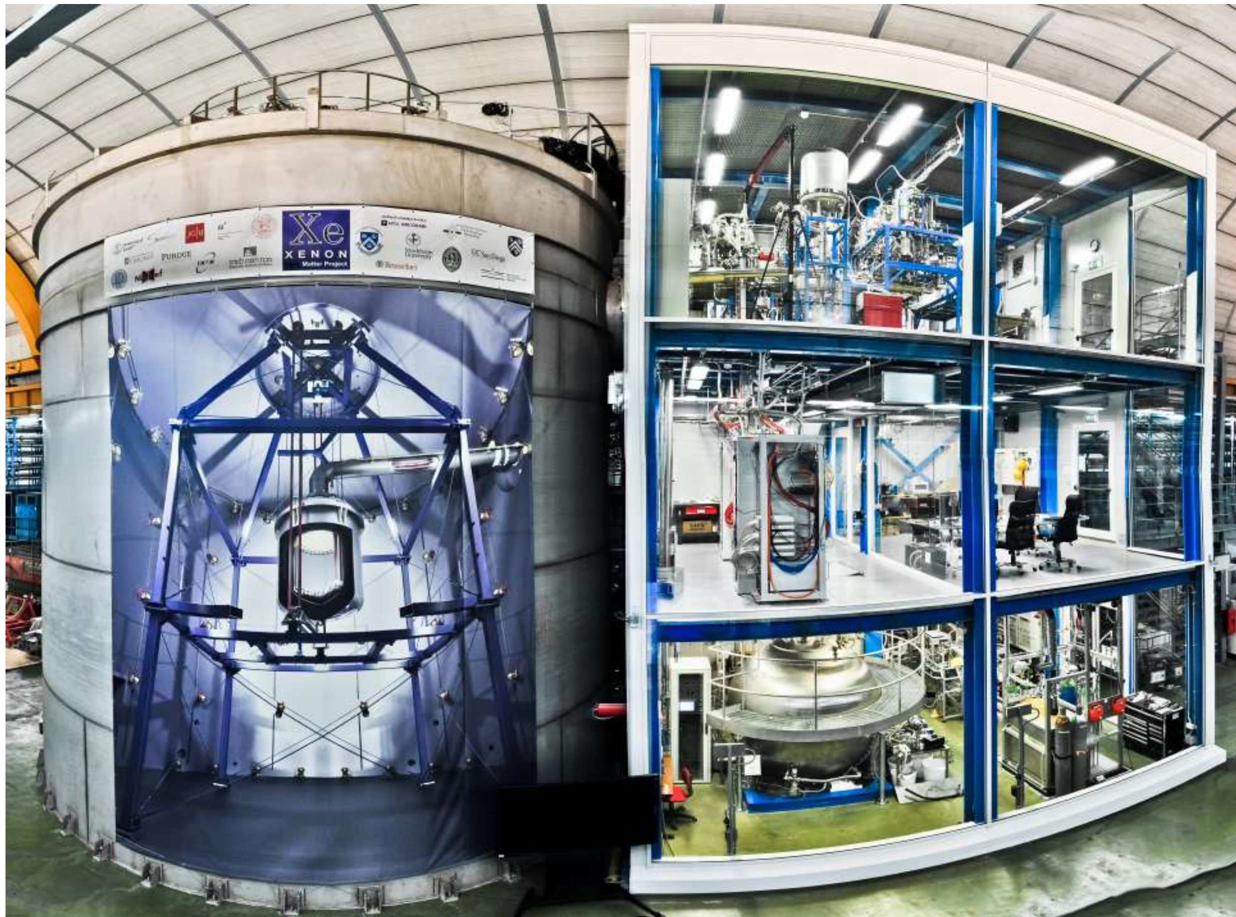
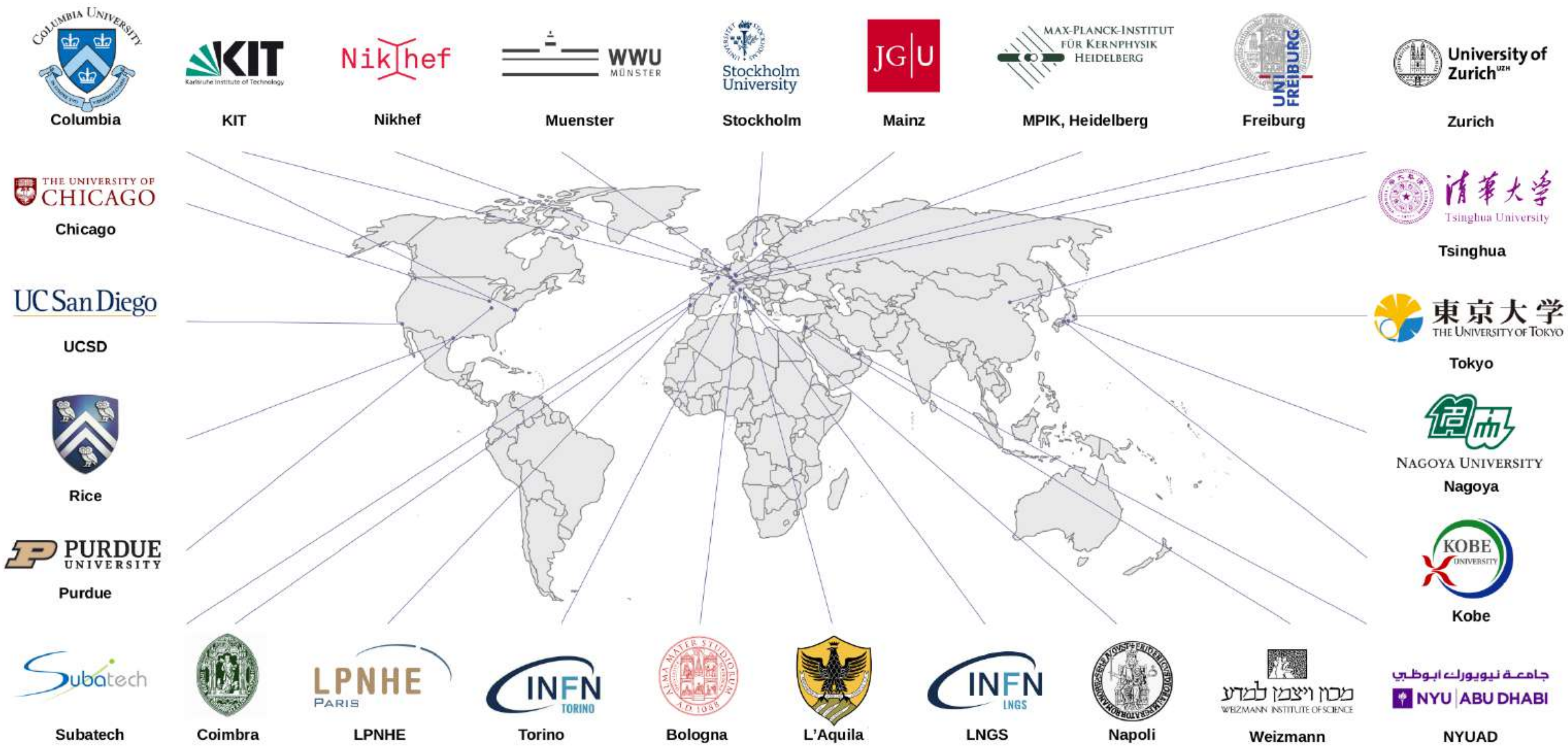
on behalf of the XENON Collaboration



UCLA Dark Matter 2023
March 29 - April 1, 2023

The XENON Collaboration



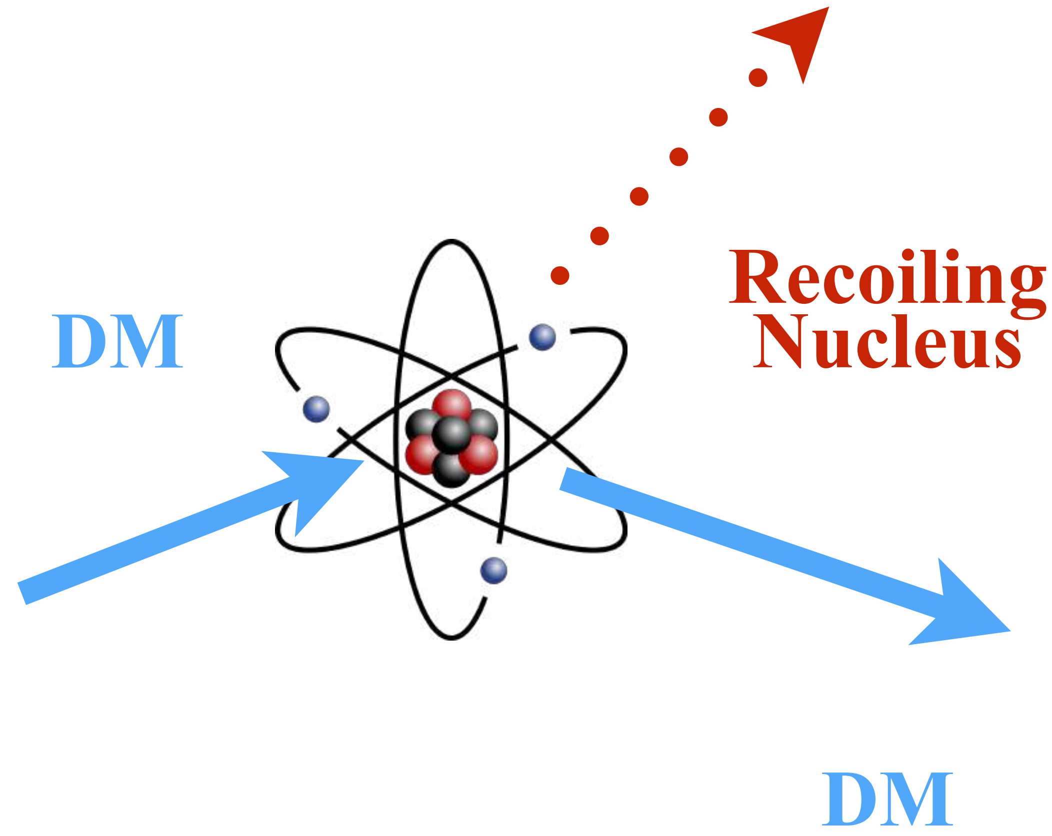
Direct Detection of Dark Matter

PHYSICAL REVIEW D VOLUME 31, NUMBER 12 15 JUNE 1985

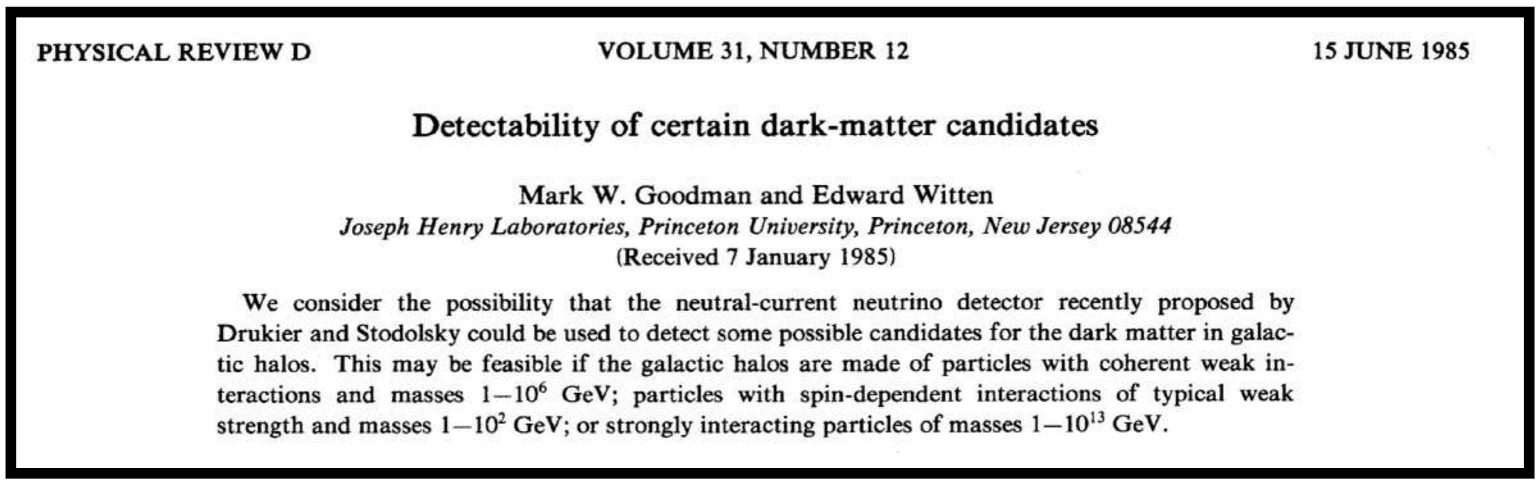
Detectability of certain dark-matter candidates

Mark W. Goodman and Edward Witten
Joseph Henry Laboratories, Princeton University, Princeton, New Jersey 08544
(Received 7 January 1985)

We consider the possibility that the neutral-current neutrino detector recently proposed by Drukier and Stodolsky could be used to detect some possible candidates for the dark matter in galactic halos. This may be feasible if the galactic halos are made of particles with coherent weak interactions and masses $1-10^6$ GeV; particles with spin-dependent interactions of typical weak strength and masses $1-10^2$ GeV; or strongly interacting particles of masses $1-10^{13}$ GeV.



“Neutrino Floor” from Solar ^{8}B neutrinos



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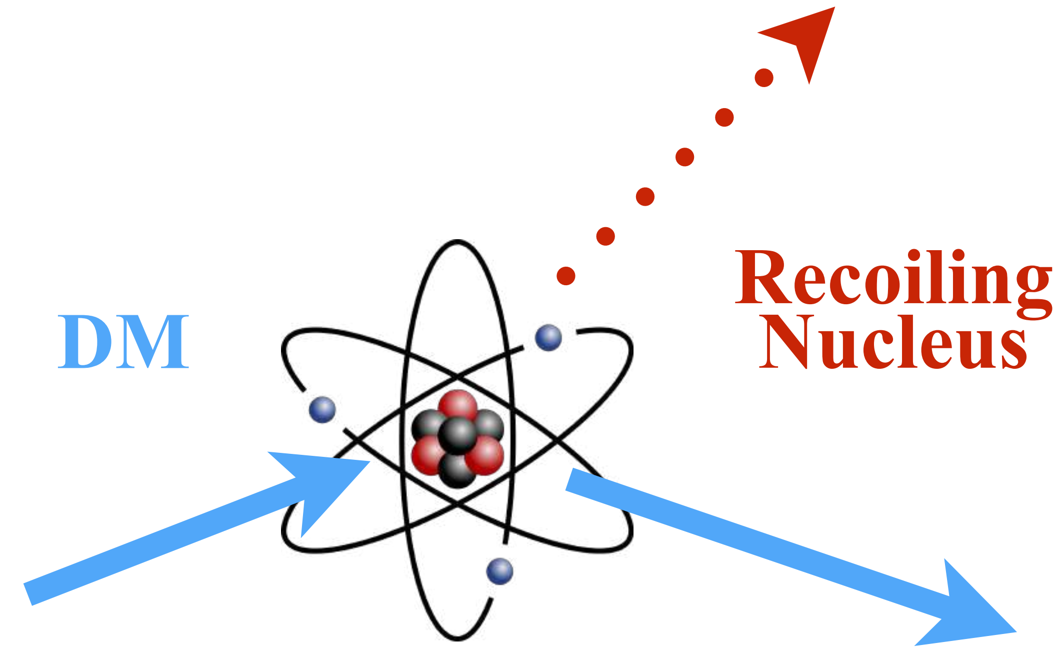
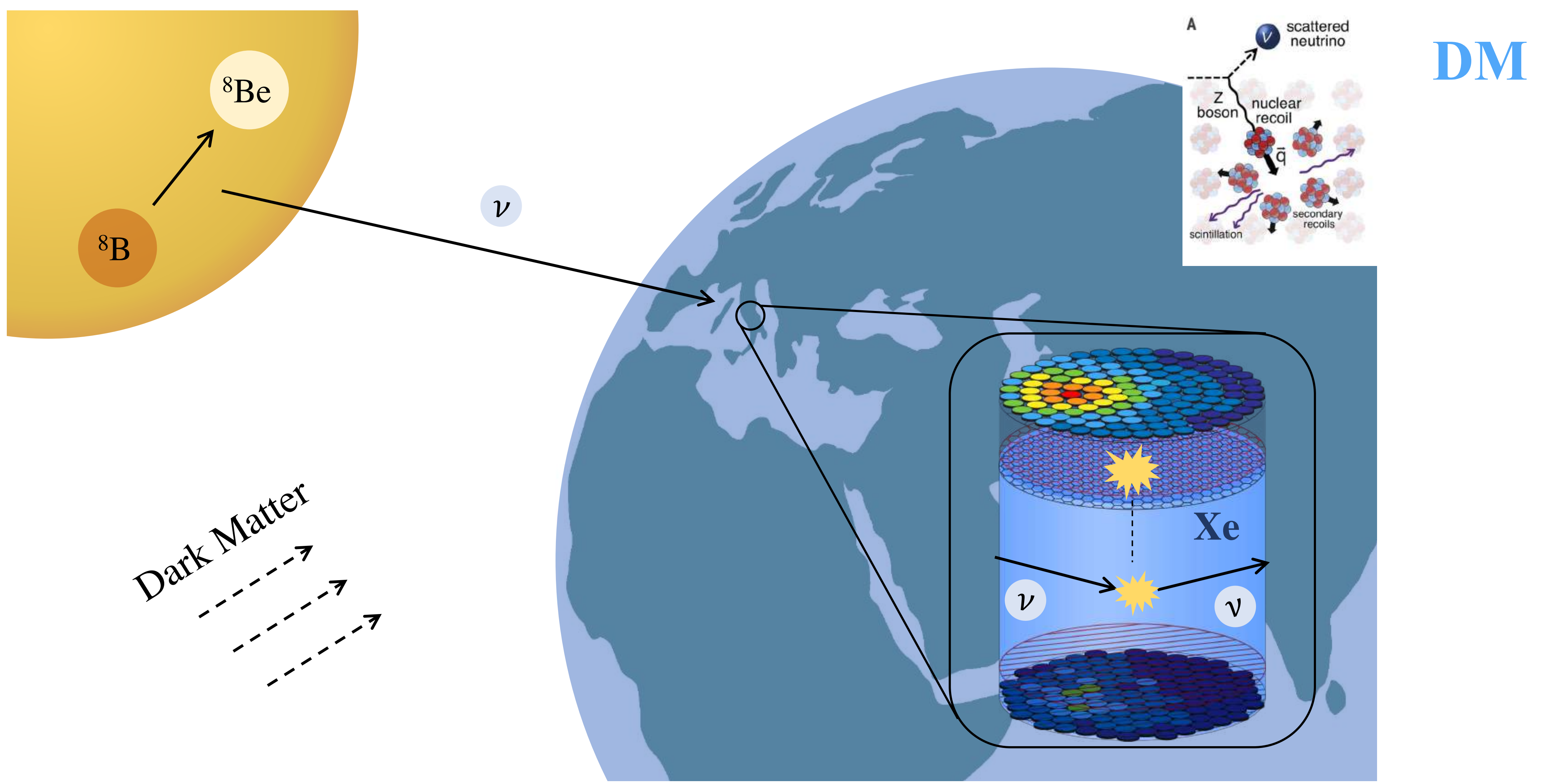




How to Reach the “Neutrino Floor”?

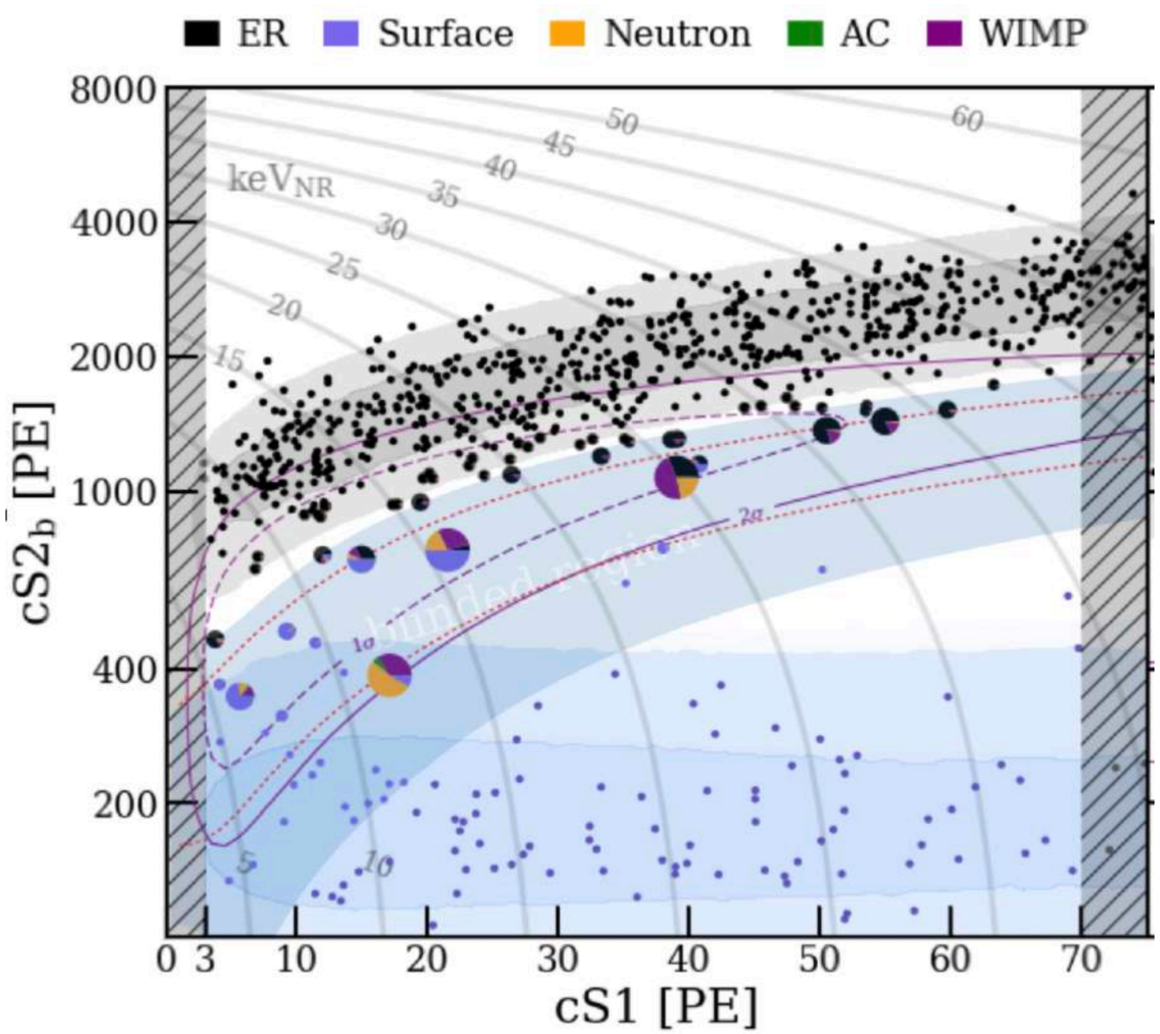
$$R = \phi(\nu) \times \sigma_\nu \times N_{Xe} \times \text{exposure}$$

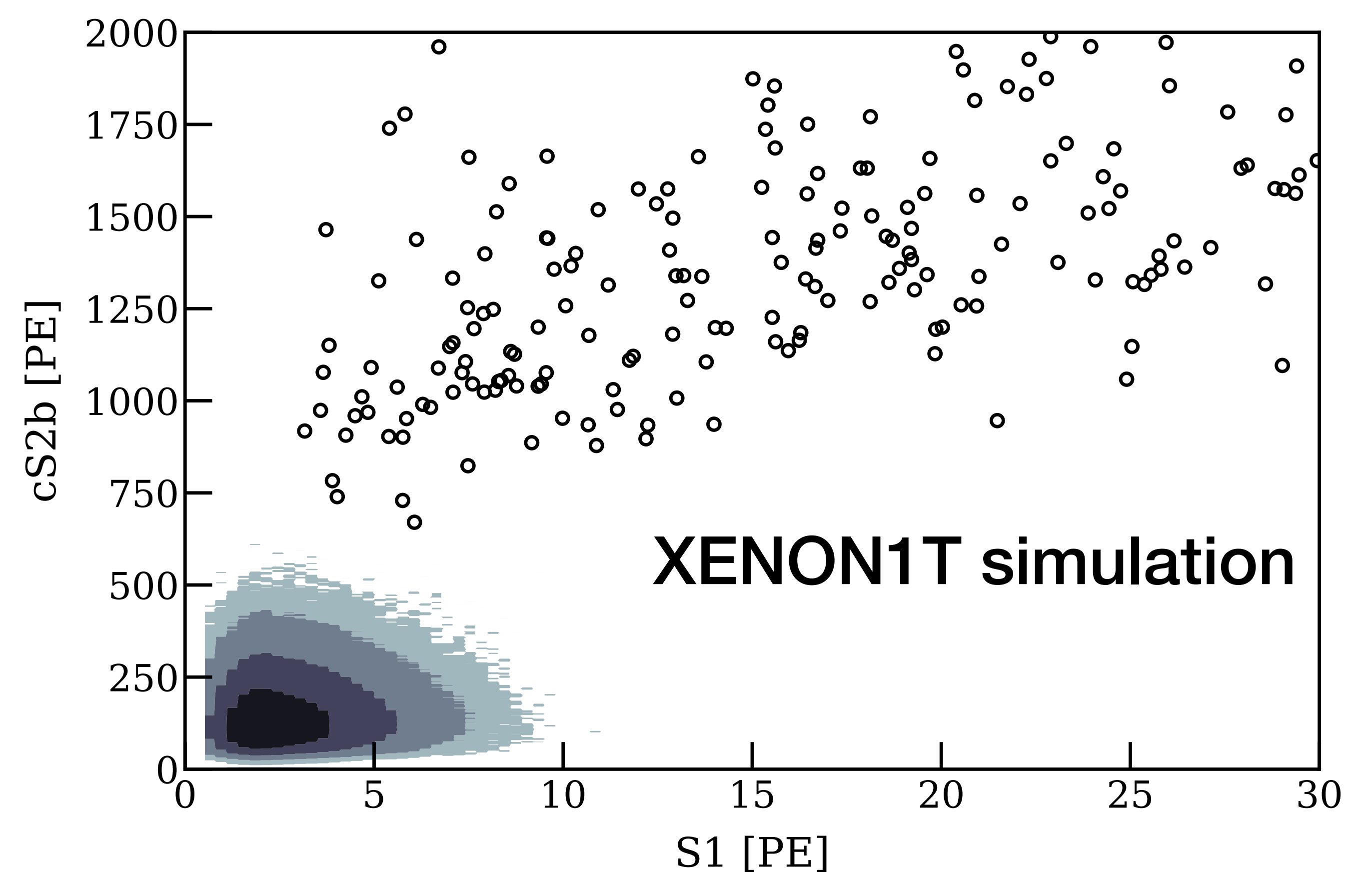
$$\simeq 600\,\text{events}/(\text{tonne} \times \text{year})$$

Without an energy threshold

XENON1T WIMP search analysis has low detection efficiency 0.01 %

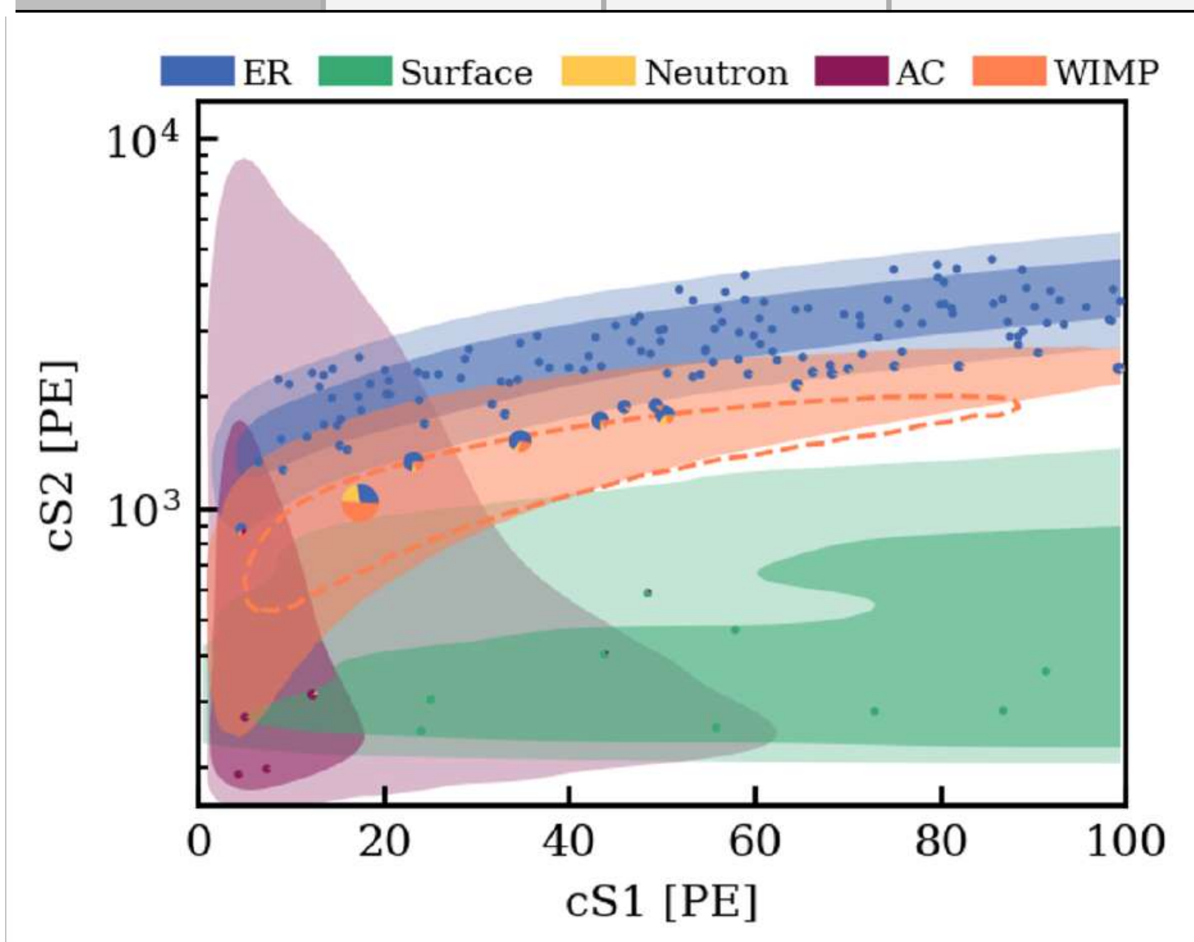
Source	1.3 t	1.3 t, NR Ref.
ER	627 ± 18	1.6 ± 0.3
Radiogenic	1.4 ± 0.7	0.8 ± 0.4
CEνNS	**0.05 ± 0.01**	0.03 ± 0.01
Accidental	**0.5 $^{+0.3}_{-0.0}$**	**0.10 $^{+0.06}_{-0.00}$**
Surface	106 ± 8	4.8 ± 0.4
Total	735 ± 20	7.4 ± 0.6
Data	**739**	**14**





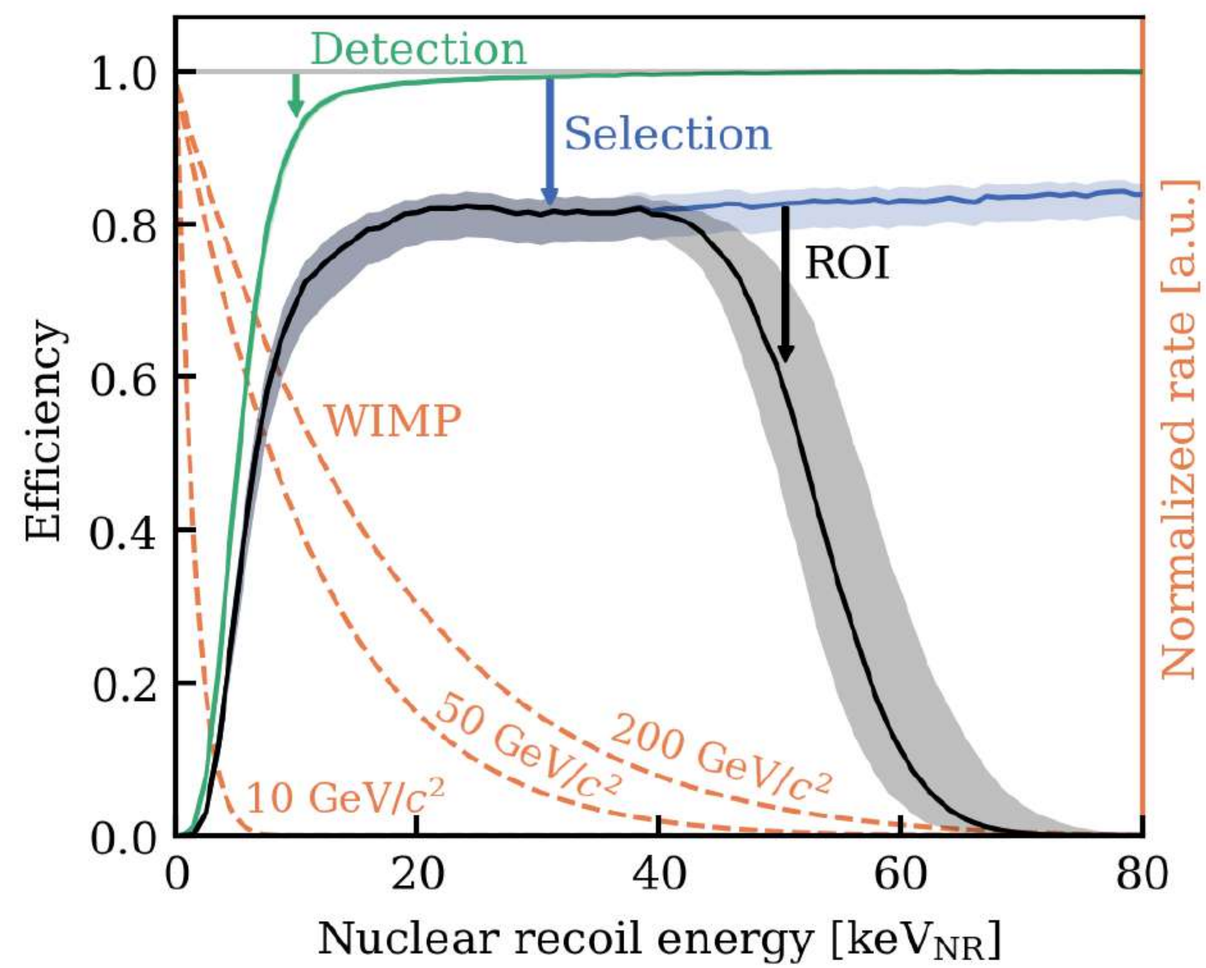
XENONnT WIMPs Search Analysis

Sources	Nominal	Best Fit	
		ROI	Signal Like
ER	134	135^{+12}_{-11}	0.81±0.07
Neutron	$1.1^{+0.6}_{-0.5}$	1.1±0.4	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}_{-4}	$0.34^{+0.01}_{-0.11}$
Total	154	152±12	$1.95^{+0.12}_{-0.16}$
Data		**152**	**3**



The same analysis threshold: 3-fold PMT coincidence for S1!

Slightly increased detection efficiency to ~0.04%, but still too low for a neutrino detection



Improved Analysis for CEvNS Search in XENON1T

$$R = \phi(\nu) \times \sigma_\nu \times N_{Xe} \times \text{exposure}$$
$$\simeq 600\,\text{events}/(\text{tonne} \times \text{year})$$

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Total	735 ± 20	7.4 ± 0.6

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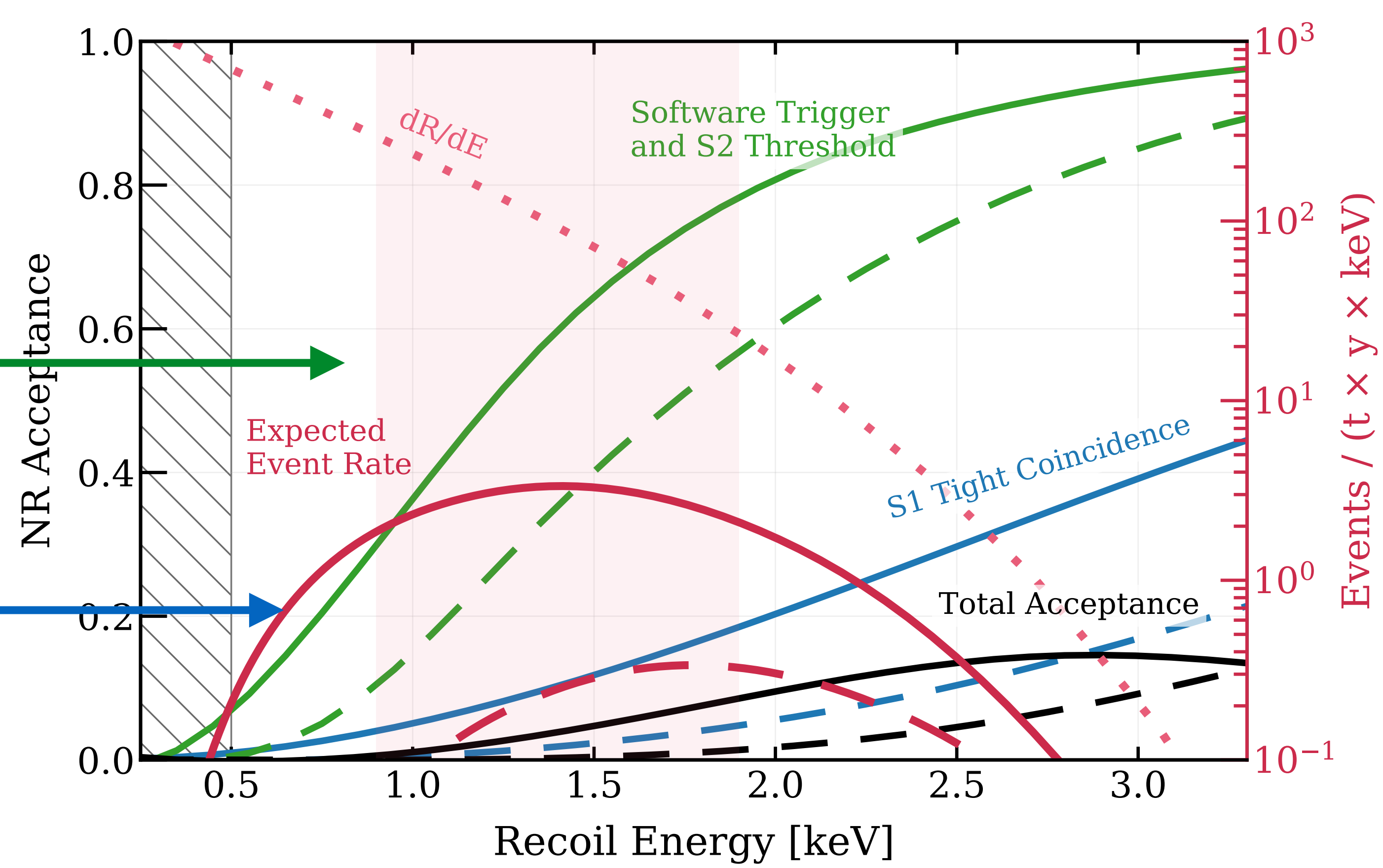
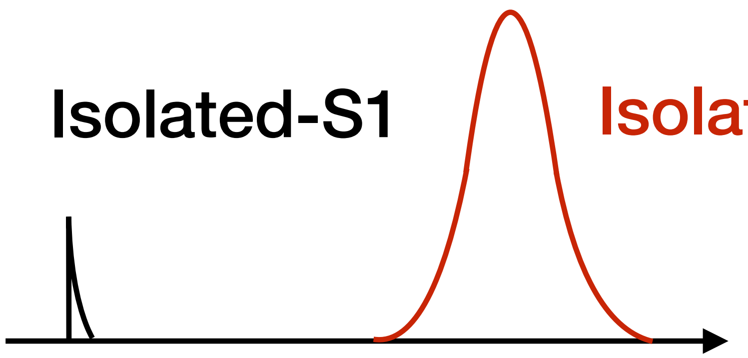
Can we increase the detection efficiency to ~1%? o(5) CEvNS

S2 threshold: S2 > ~~200~~ 120PE

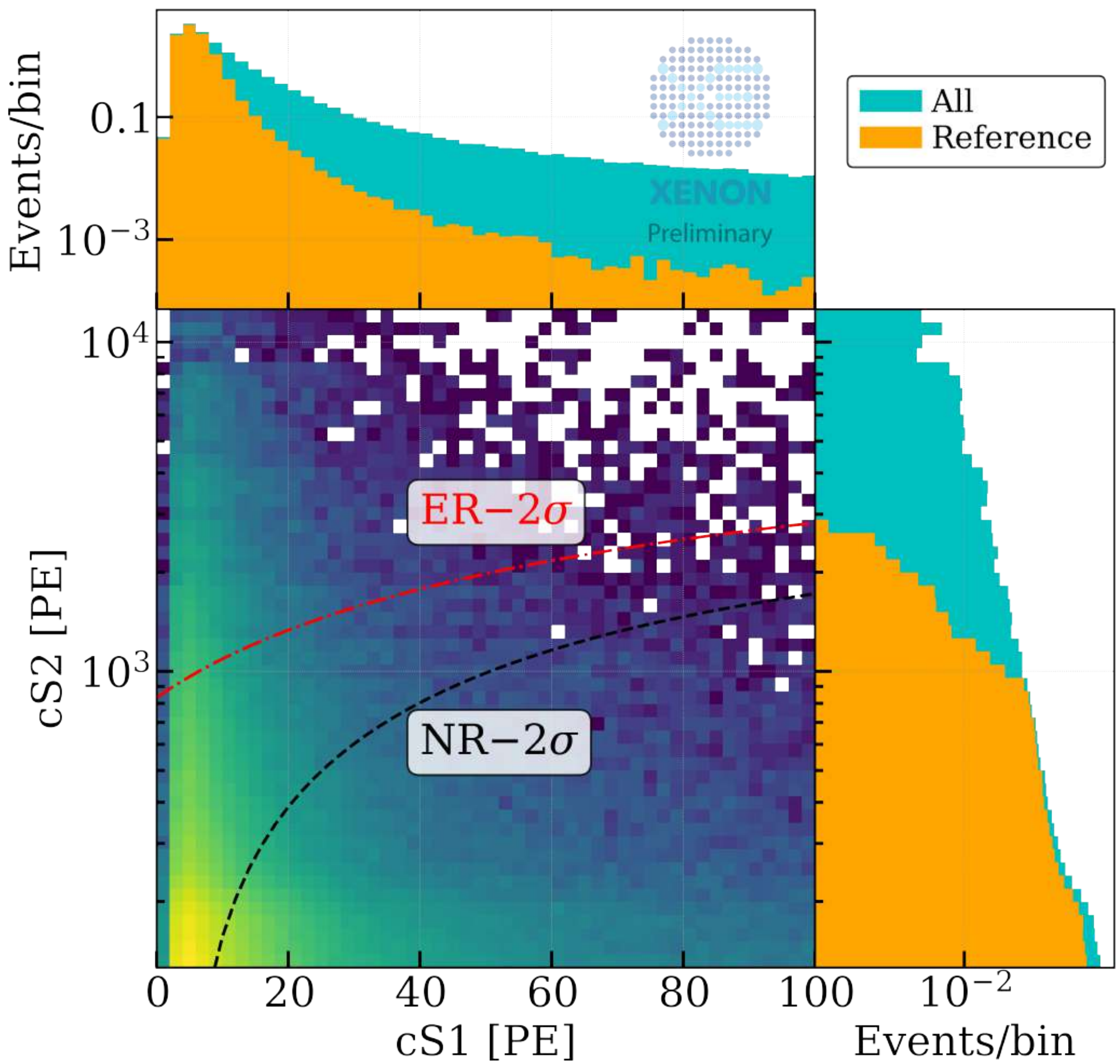
S1 threshold: ~~Three~~ Two PMTs coincidence

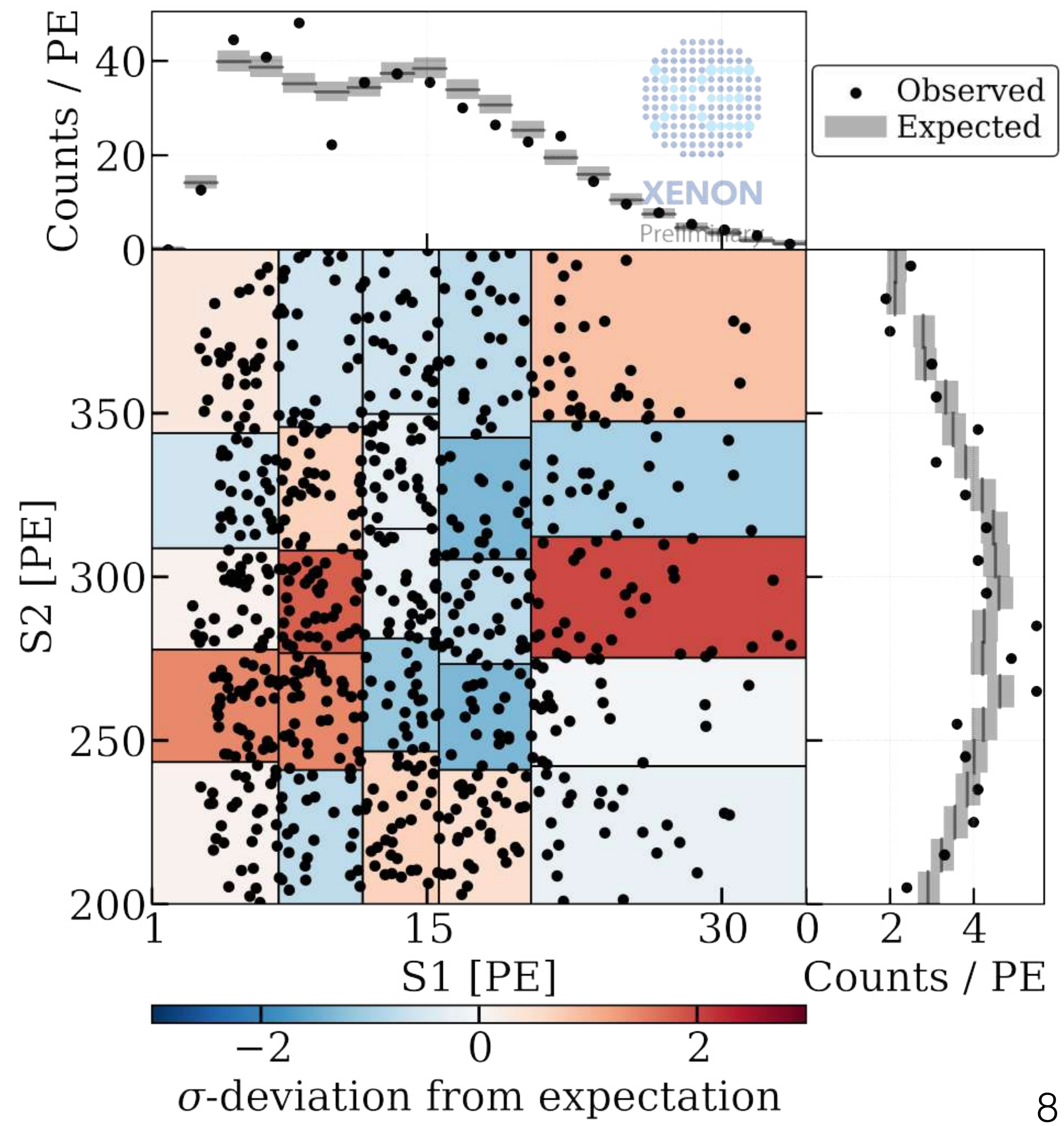


Accidental Coincidence Background

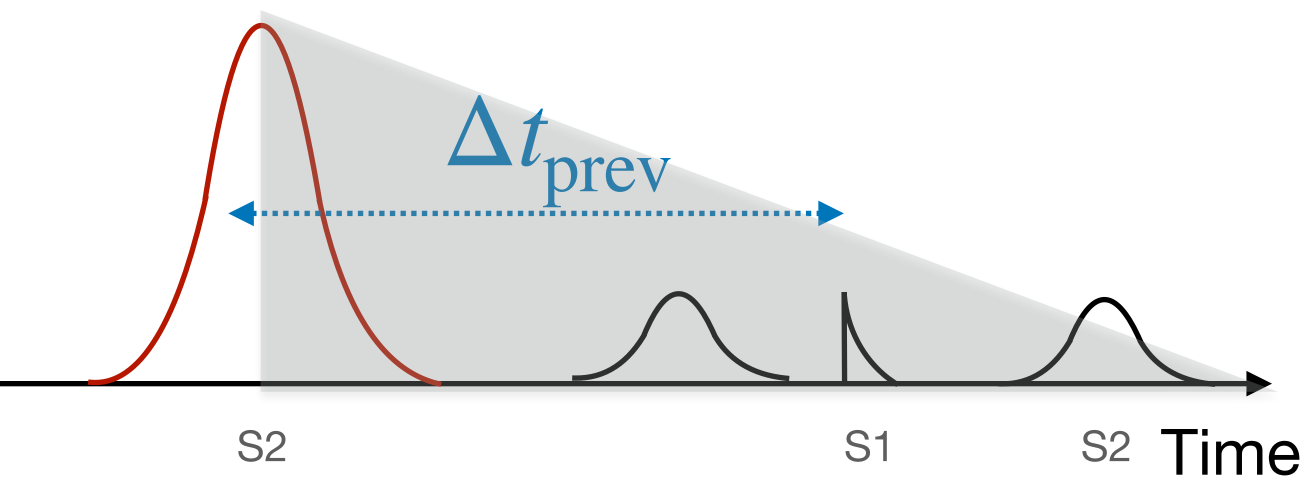


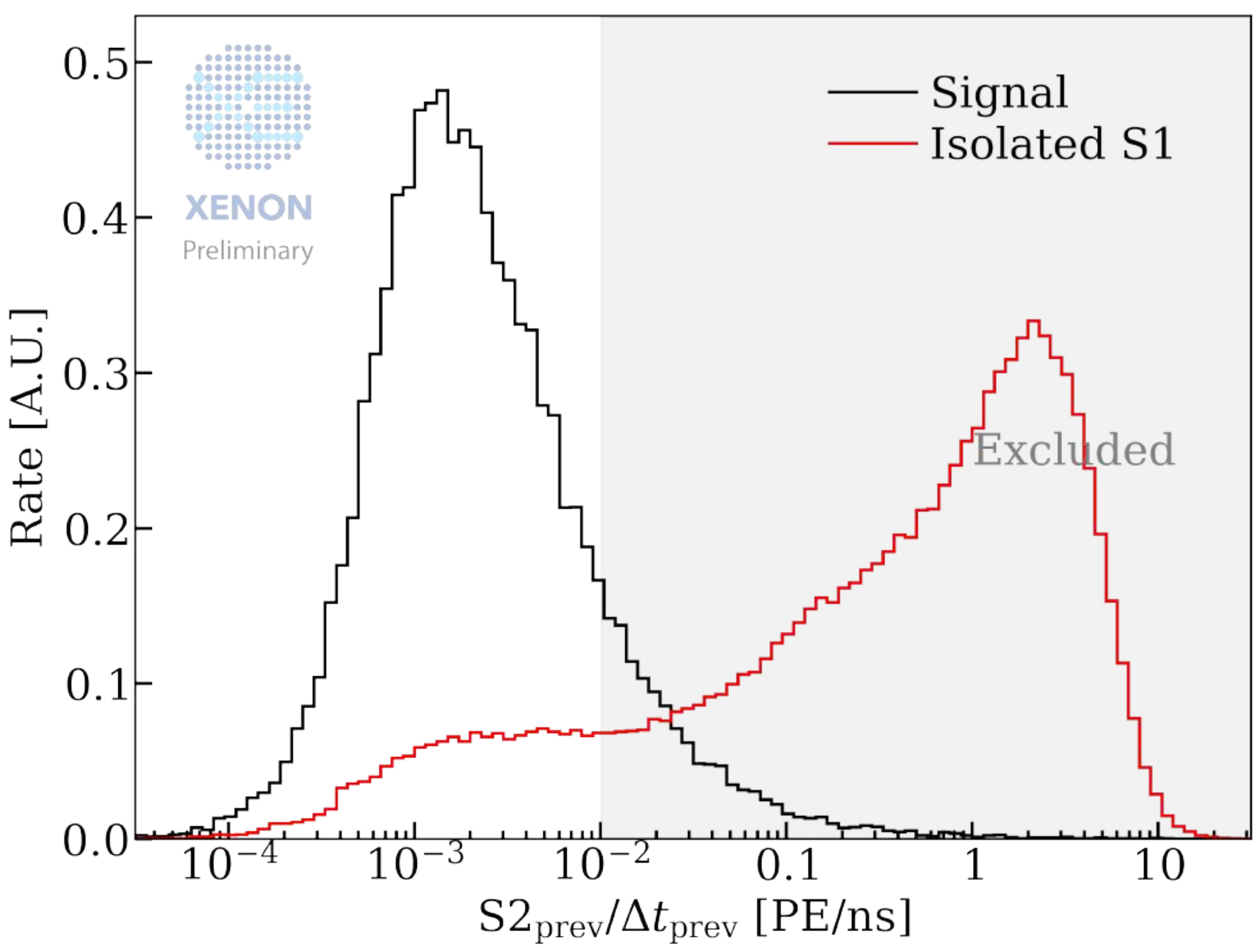
AC is seen and validated to 5% precision!

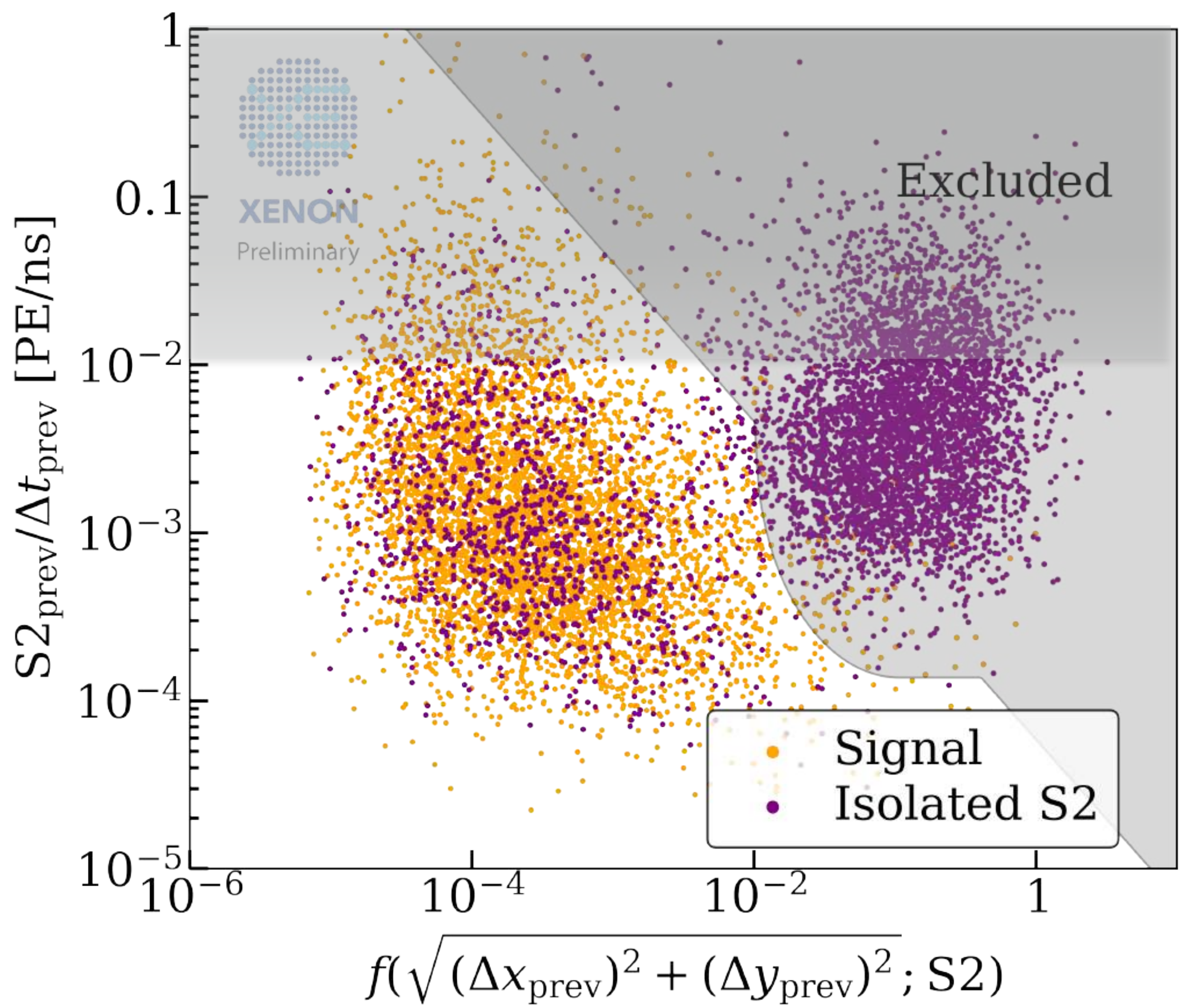




AC Suppression — Shadow Effects

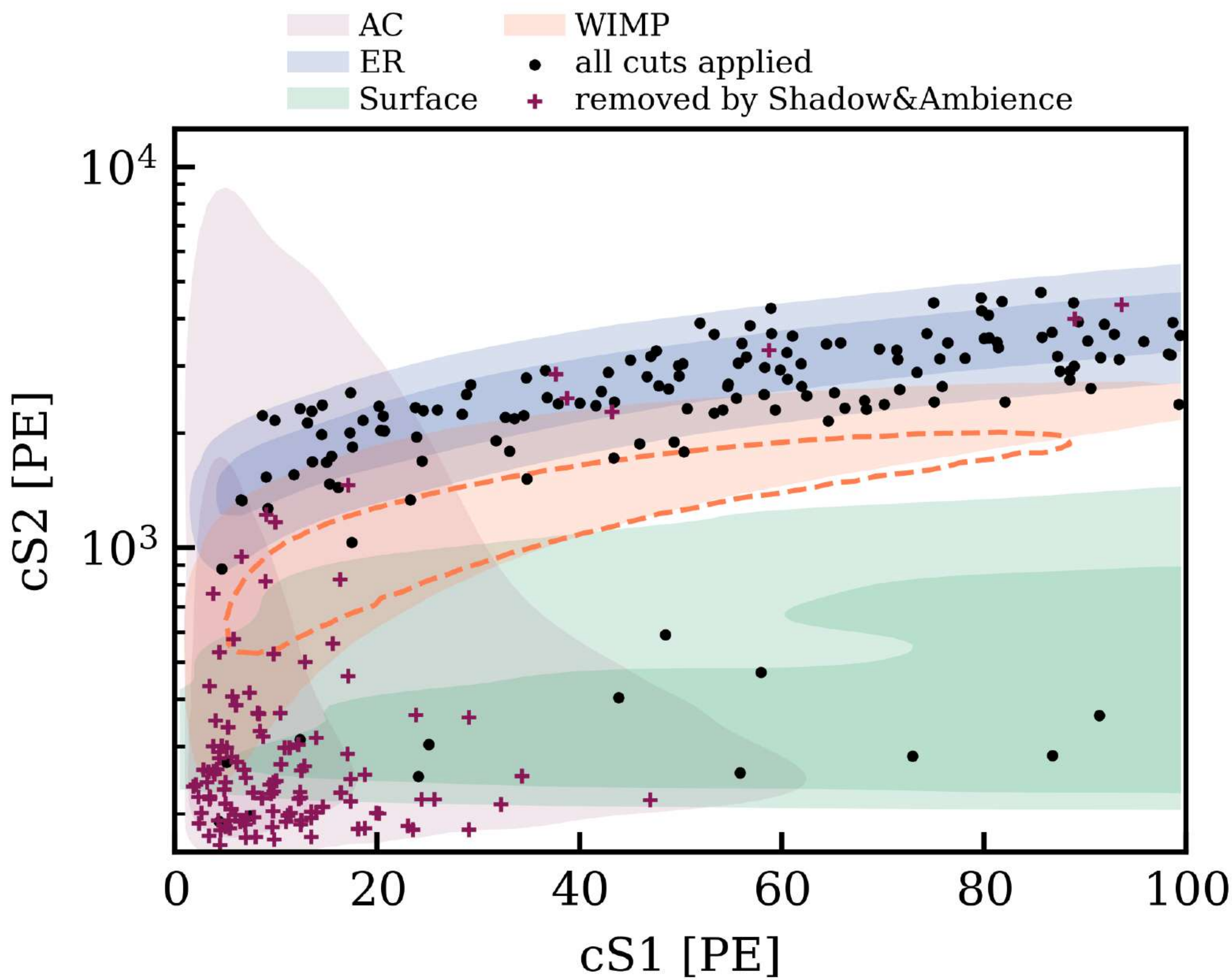




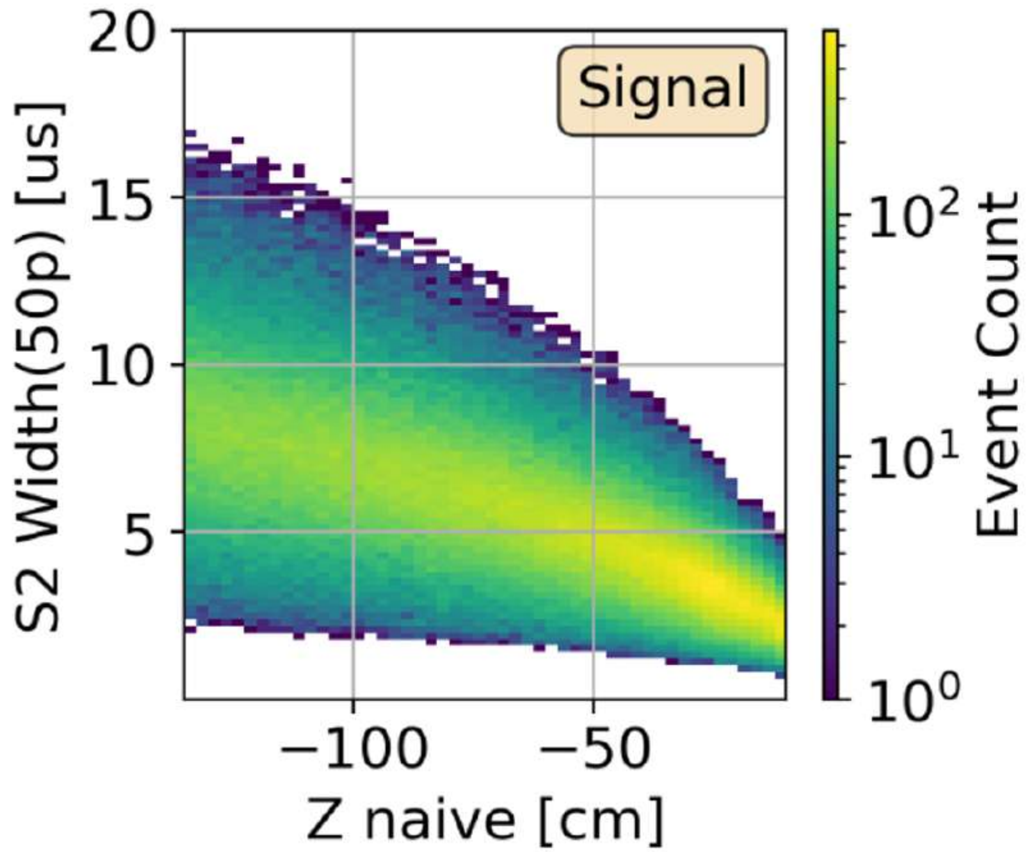


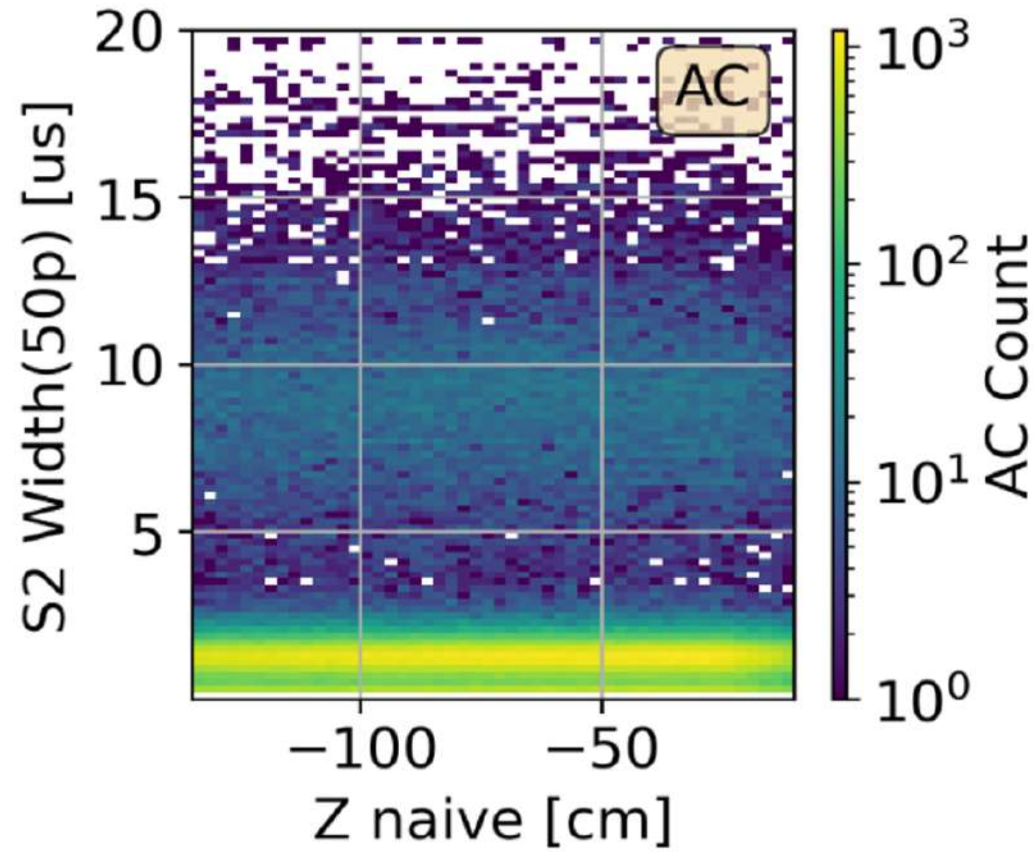
Reject exposure near high energy events

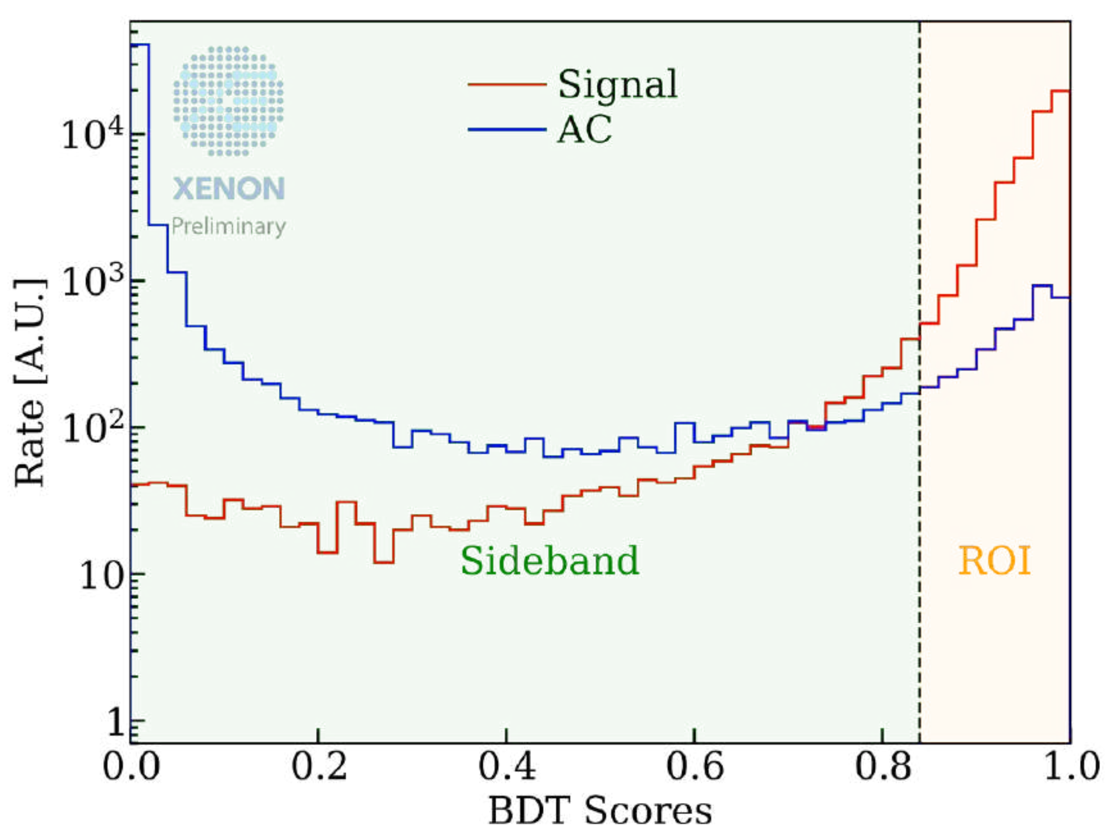
Impact of Shadow Cuts on WIMPs Search

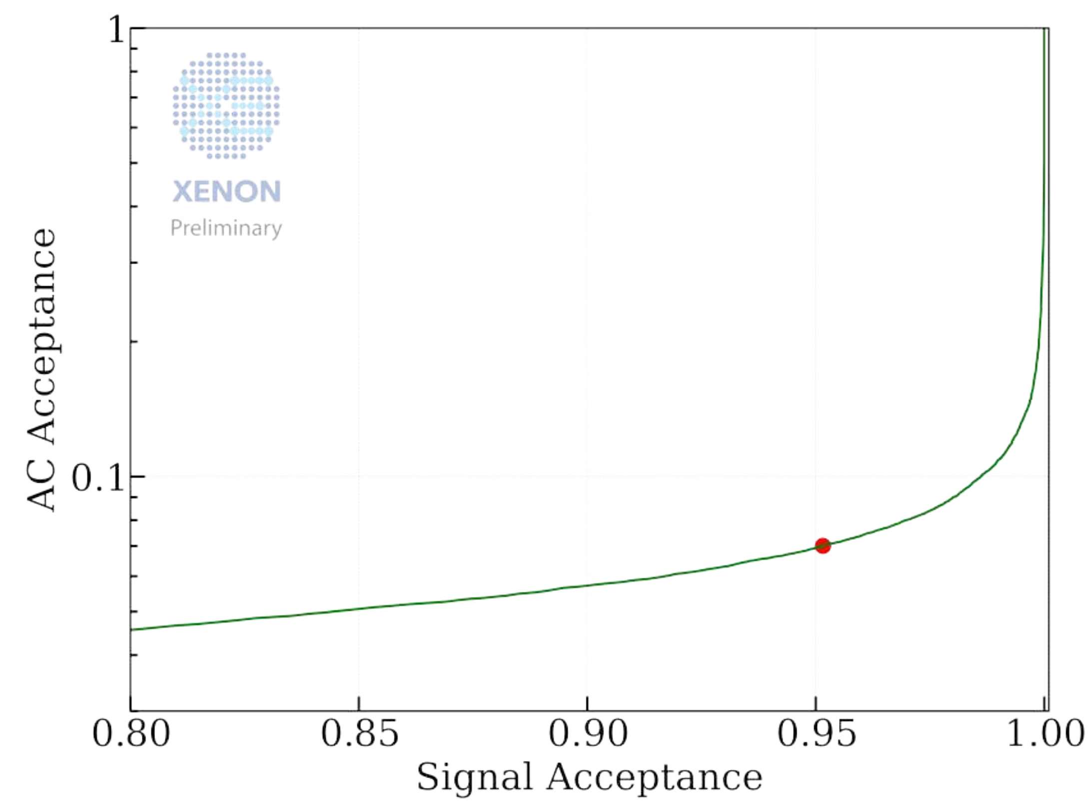


AC Suppression — S1 and S2 Correlations

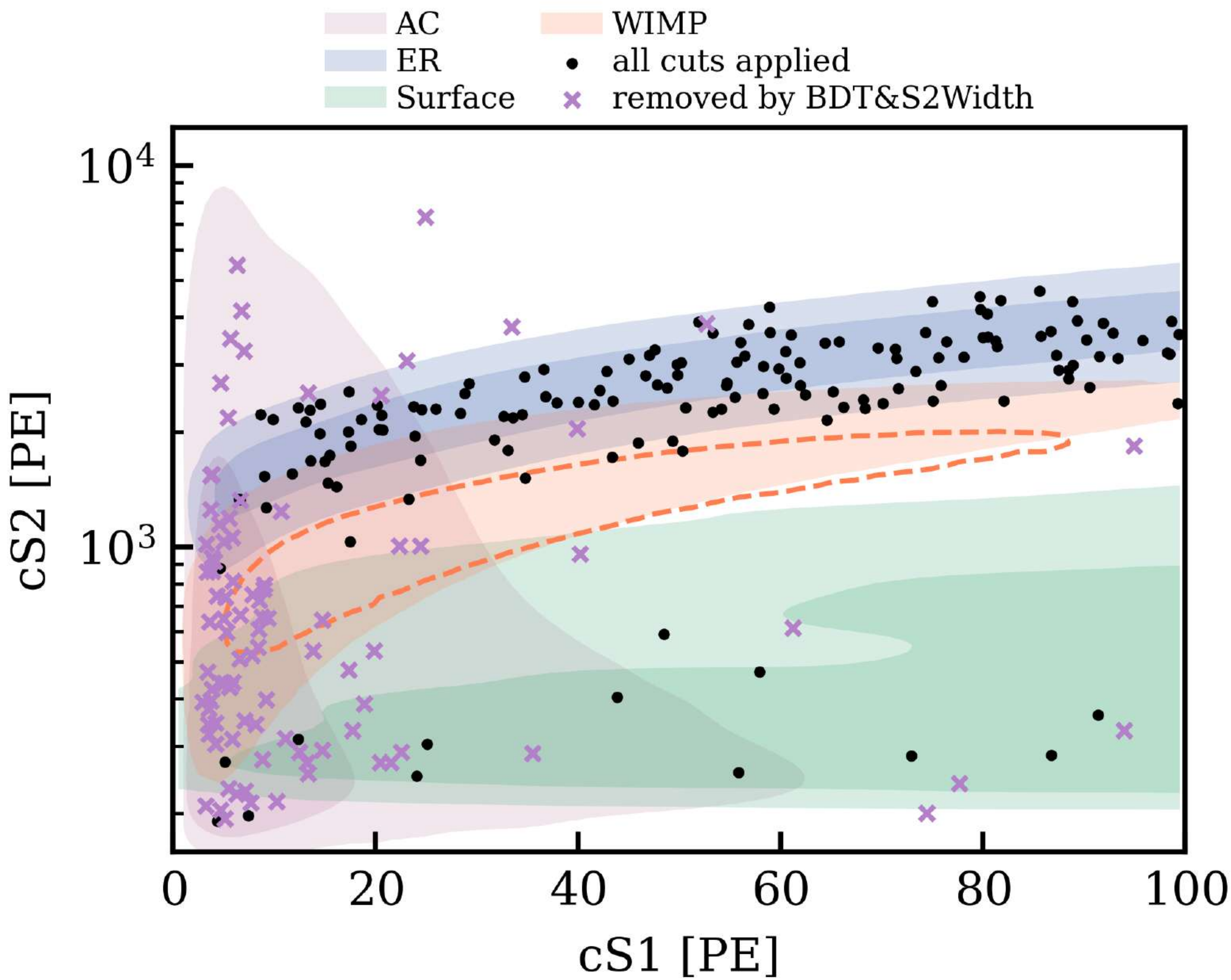








Impact of Width Cut in WIMPs Search



Search for ^{8}B CEvNS with XENON1T

Analysis ROI

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

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

Data consistent with AC background (p ~ 0.5)

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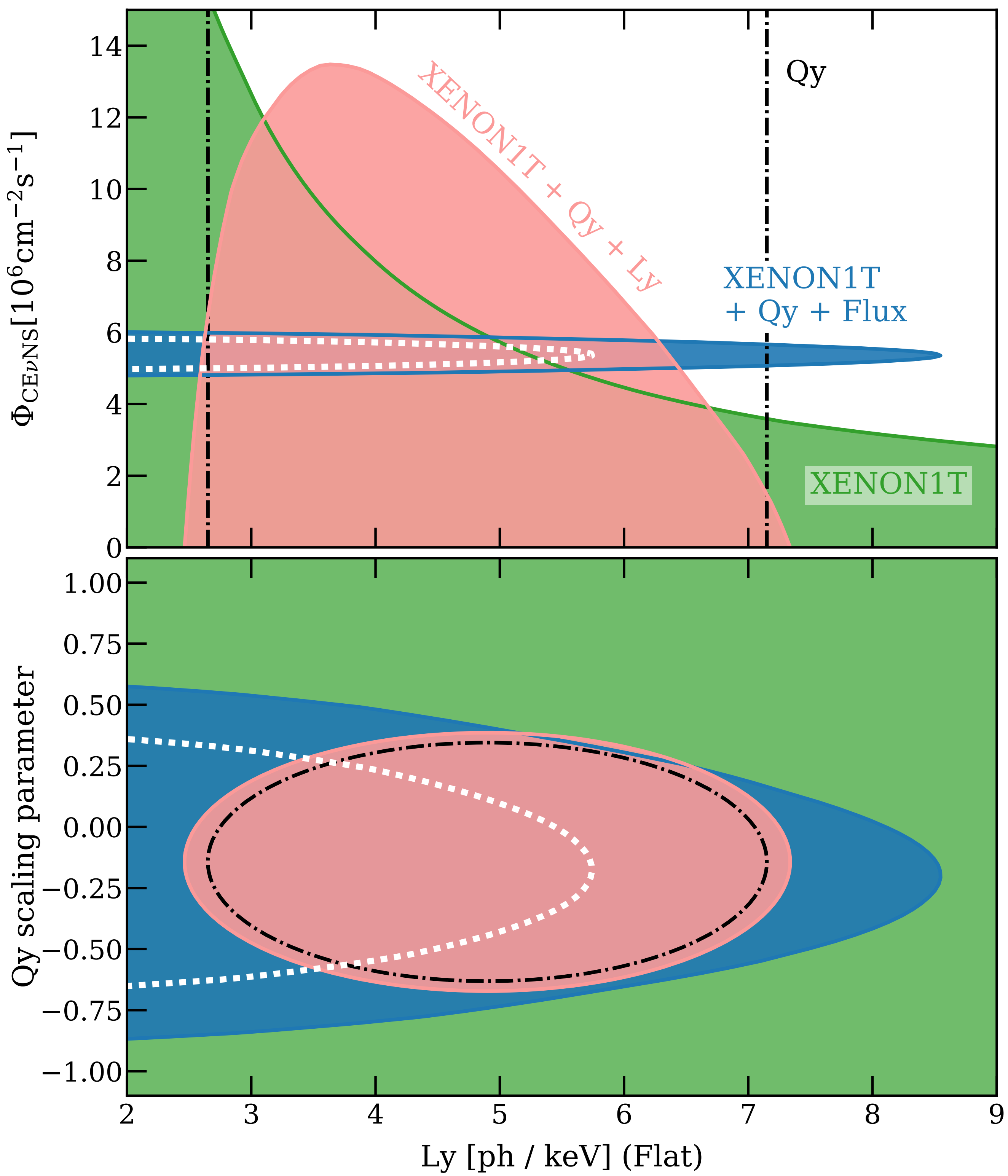
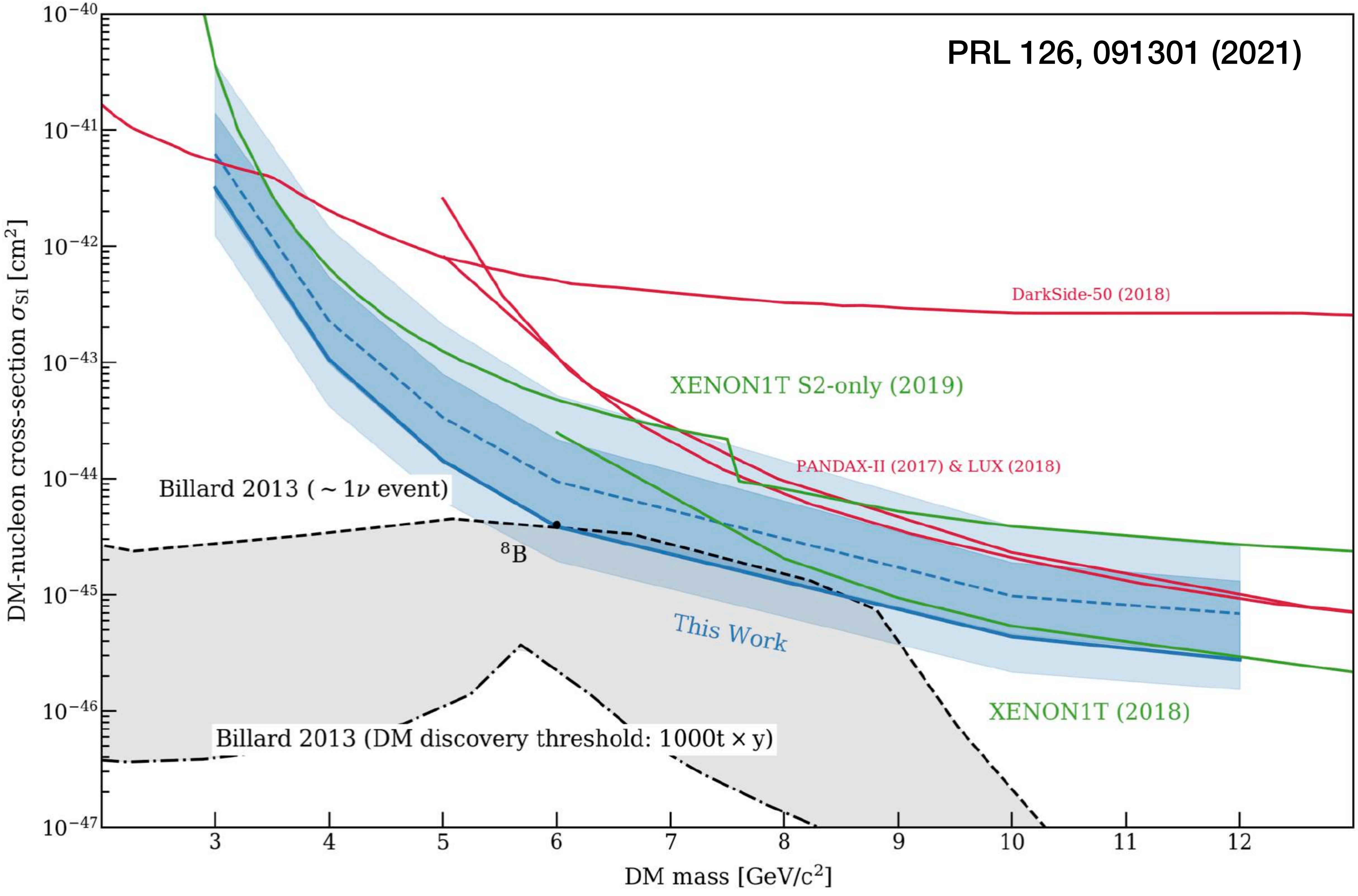


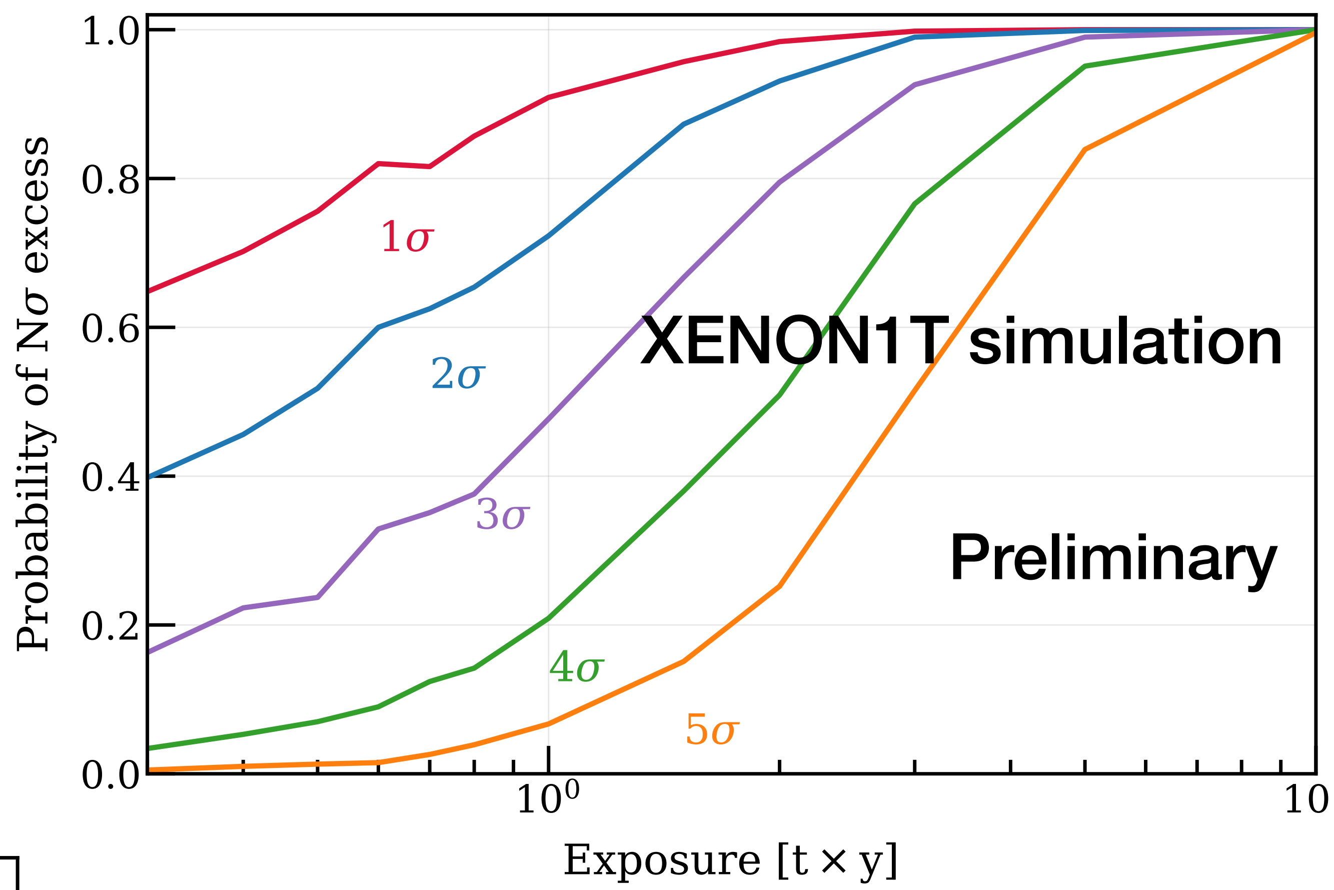
Constraints on light Dark Matter

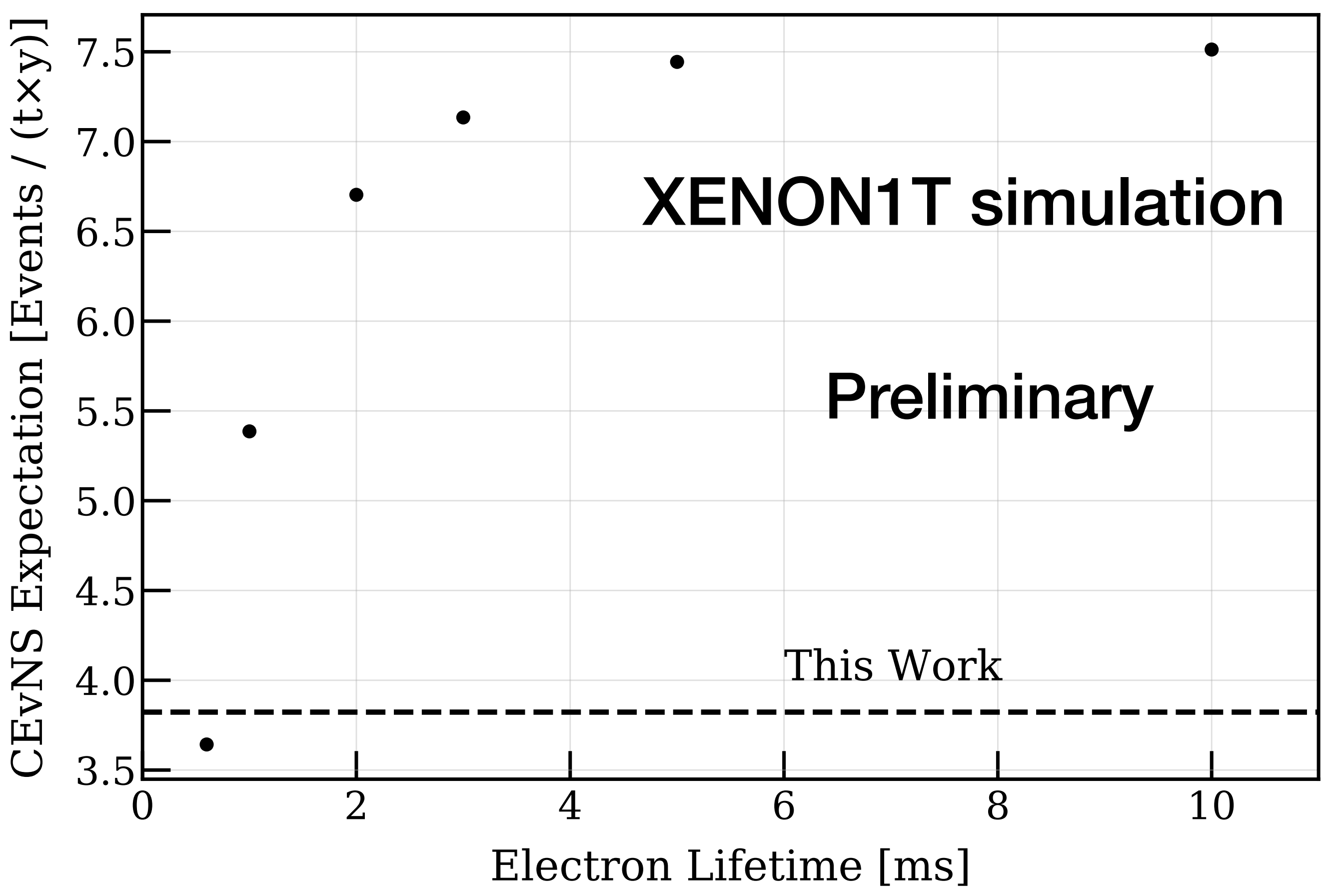


How to Find More ^{8}B CEvNS?

Discovery potential scales with exposure at the XENON1T signal to background ratio.

-> LZ, PandaX-4T, and XENONnT all have significant discovery potential!

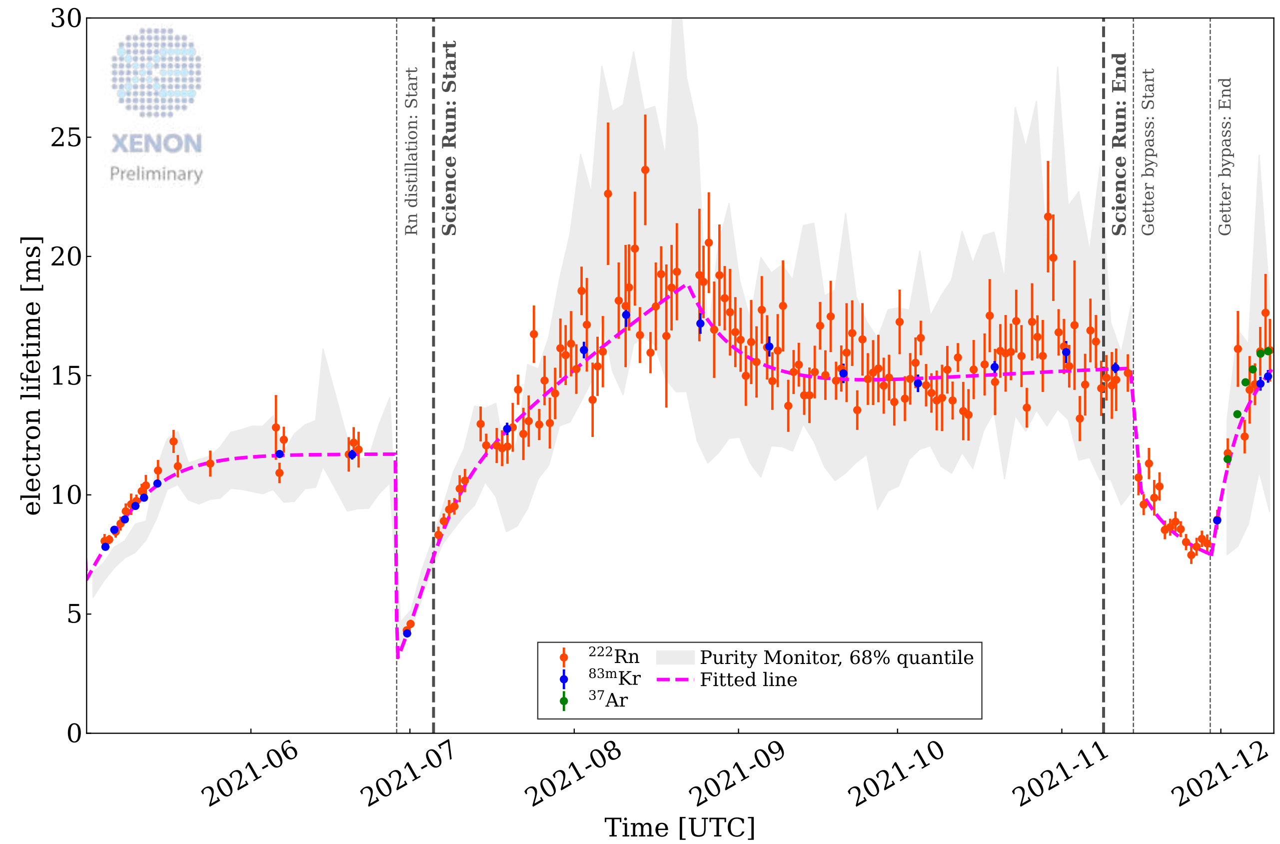




Increasing light and charge detection efficiency is critical (e.g. electron lifetime)

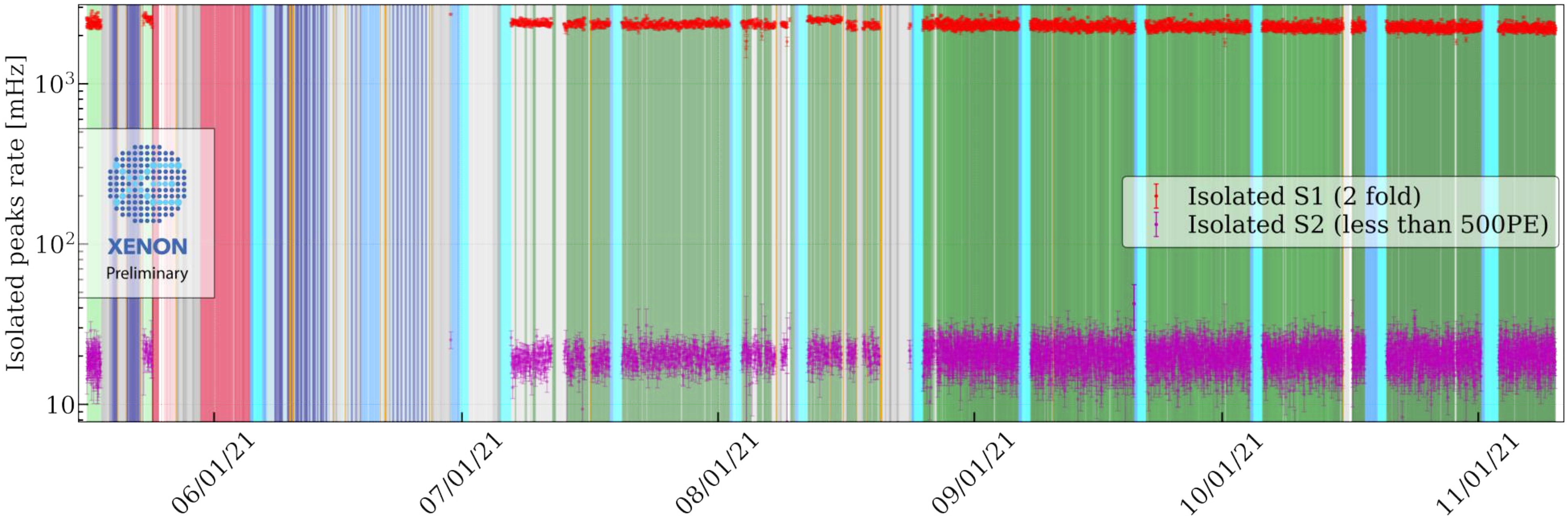
XENONnT Cryogenic Liquid Purification

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

Discovery Potential of XENONnT ^{8}B Search



Experiment	Isolated-S1	Isolated-S2	Max Drift	Relative AC
XENON1T	11.2 Hz	1.1 mHz	730 us	1
XENONnT	2.5 Hz	18.5 mHz	2200 us	~11

We expect a significant increase of AC due to the increase in Isolated-S2 rates, but…

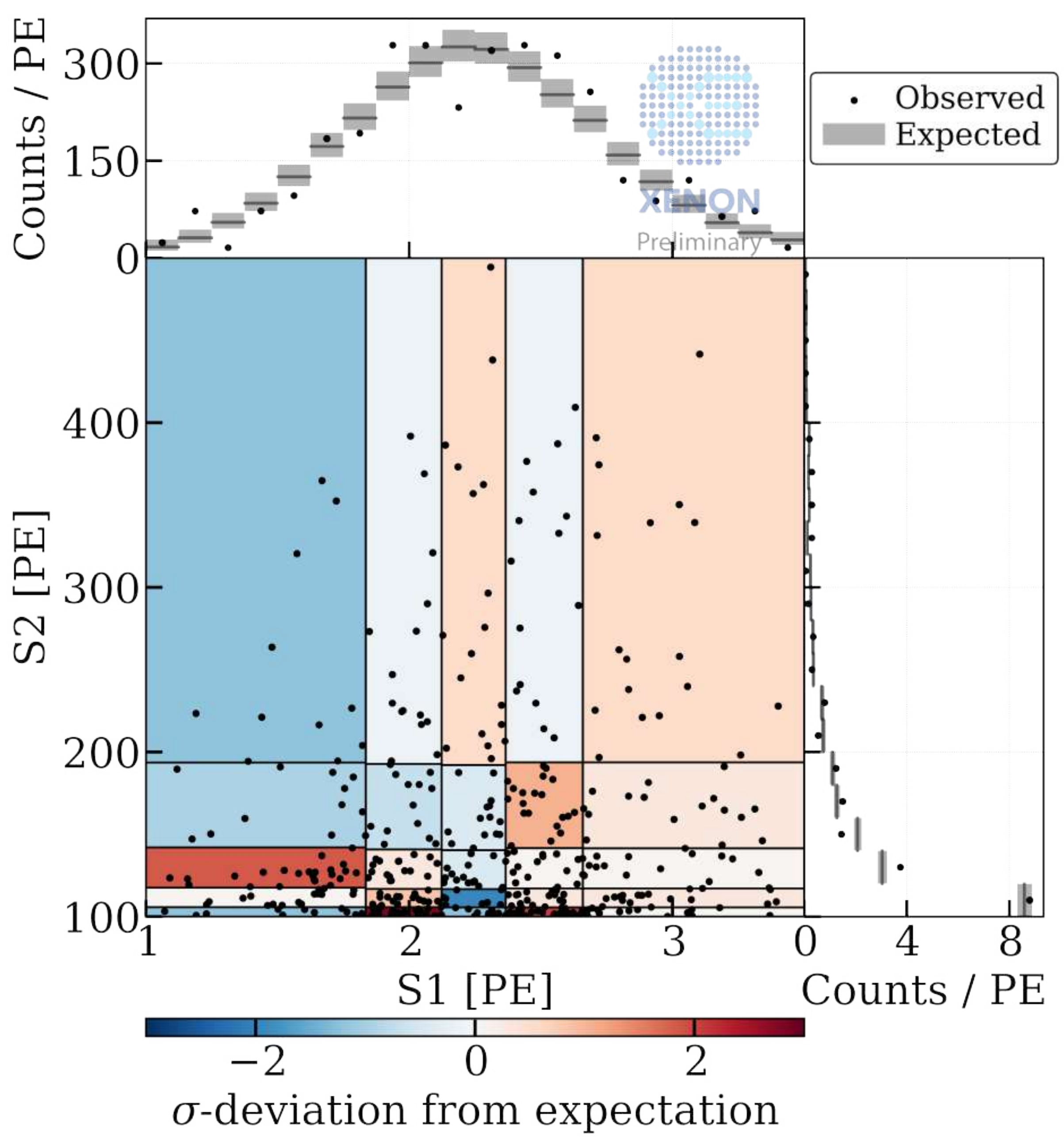
Discovery Potential of XENONnT ^{8}B Search

Further AC reduction due to S2 and S1 correlations!

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

PRELIMINARY

These numbers are very only for illustration



Significantly increase in the discovery potential of ^{8}B CEvNS due to strong suppression of AC and large exposure

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

Summary and Outlook

- Liquid Xenon detectors are sensitive to the "neutrino floor" from Solar ^{8}B neutrinos.
- XENON1T has searched for Solar ^{8}B neutrinos with 0.6 t x yr of exposure but didn't see a significant signal.
- The AC background is the dominant one in this analysis
- XENONnT will be much more sensitive to Solar ^{8}B neutrinos and have much larger exposure!

Stay tuned!

http://xenonexperiment.org

Thanks for your attention!

Uncertainties in Signal Expectation

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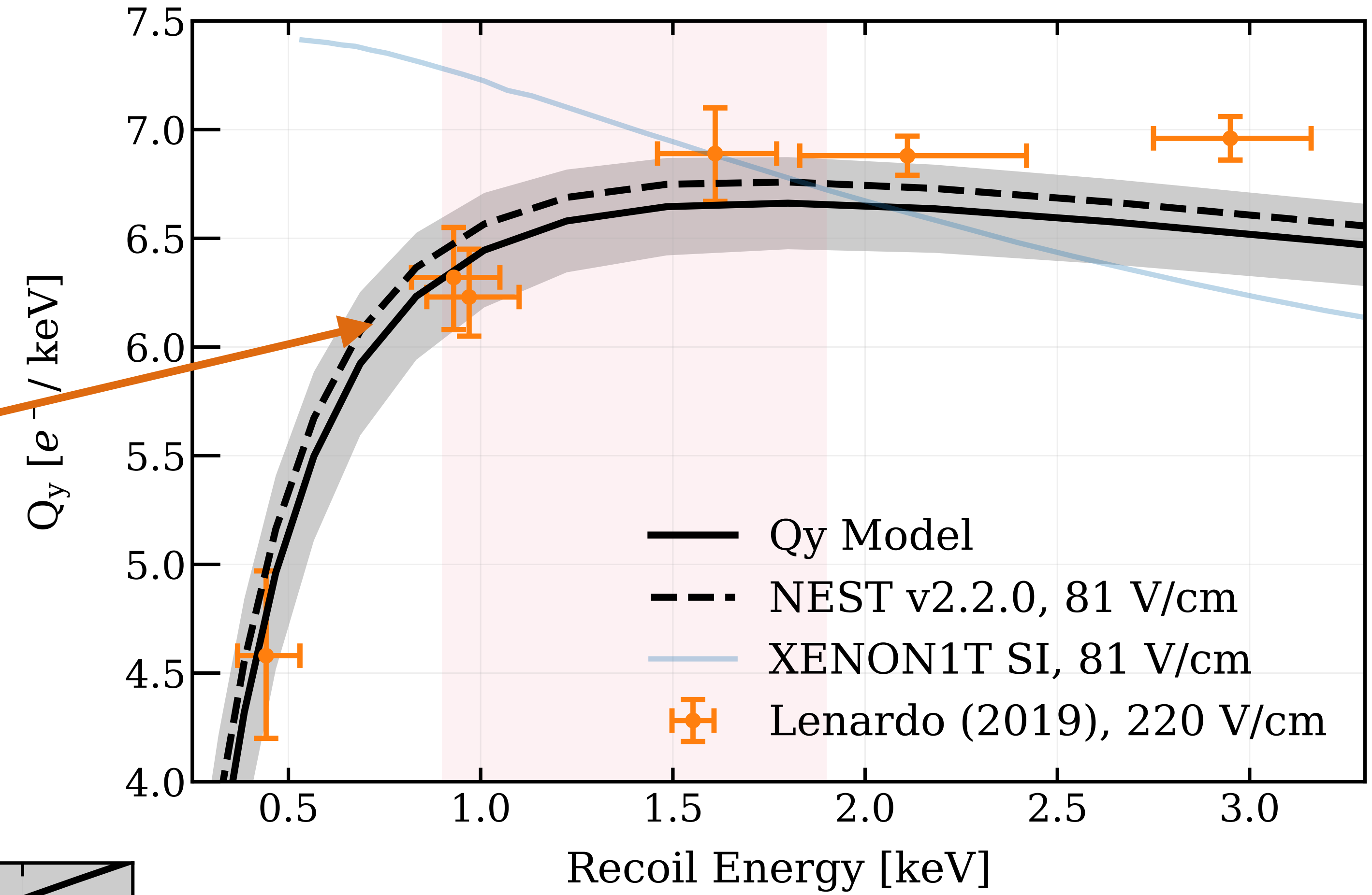
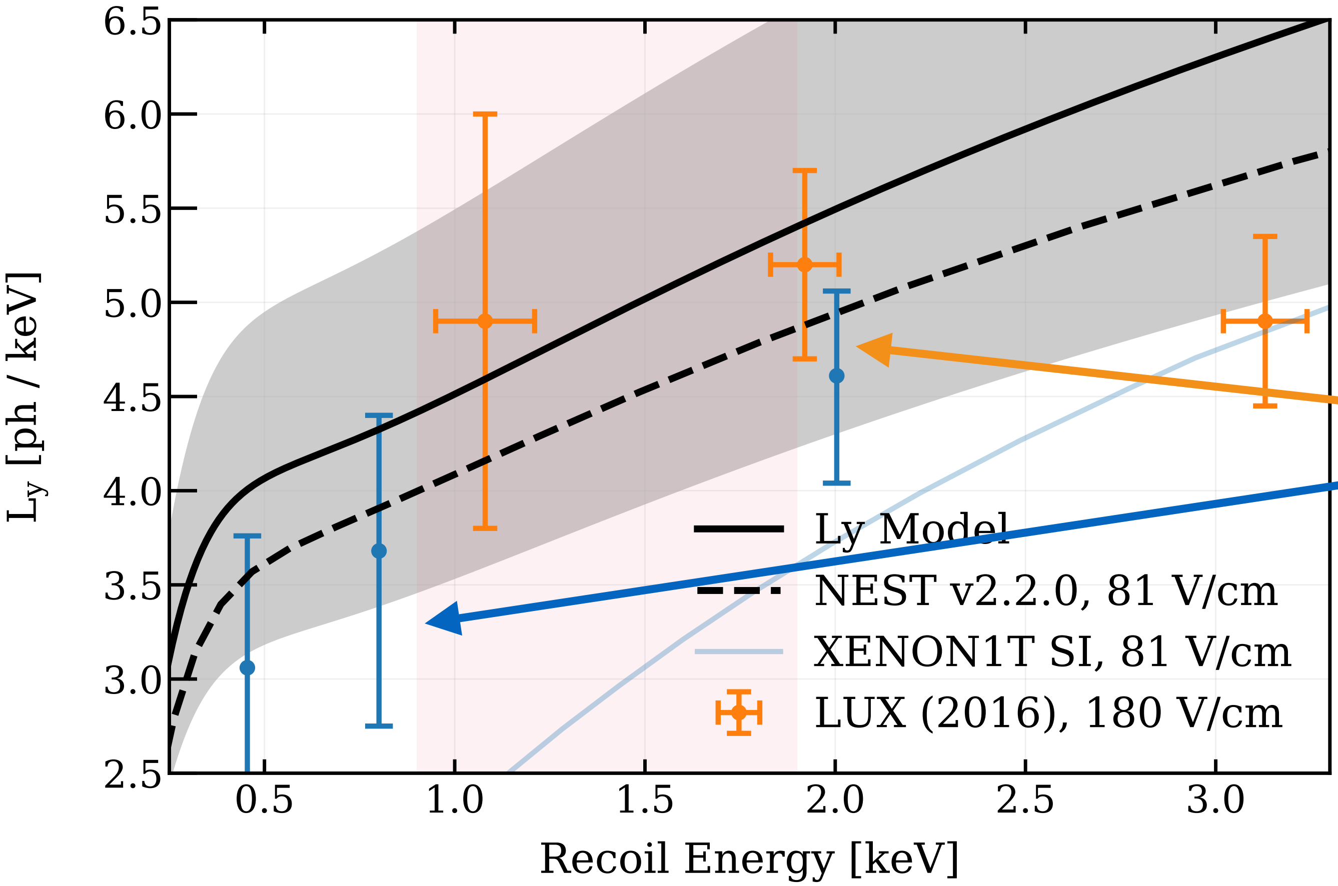


Precise measurement of ionization yields is available from LLNL group



LUX D-D calibration is the most precise measurement of scintillation yield at this energy.