Moriond EW 2023

First WIMP Search Results from XENONnT

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for the XENON Collaboration

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27 institutions
and 167 collaboration members

https://xenonexperiment.org

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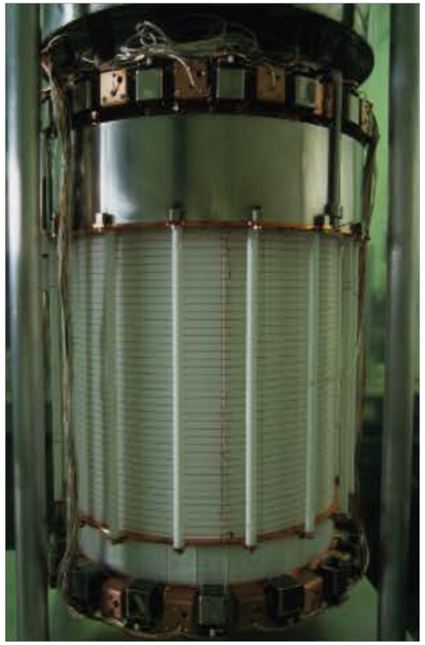
XENON Phases @ LNGS

	XENON10	XENON100	XENON1T	XENONnT
	2005-2007	2008-2016	2012-2019	2020-2026
LXe target mass	14 kg	62 kg	2000 kg	5900 kg
	~10^{-43} cm^2	~10^{-45} cm^2	4×10^{-47} cm^2	1.8×10^{-48} cm^2 [20 t-yr exposure]
ER BG rate	2M evts/(keV×t×yr)	1800 evts/(keV×t×yr)	82 evts/(keV×t×yr)	16 evts/(keV×t×yr)

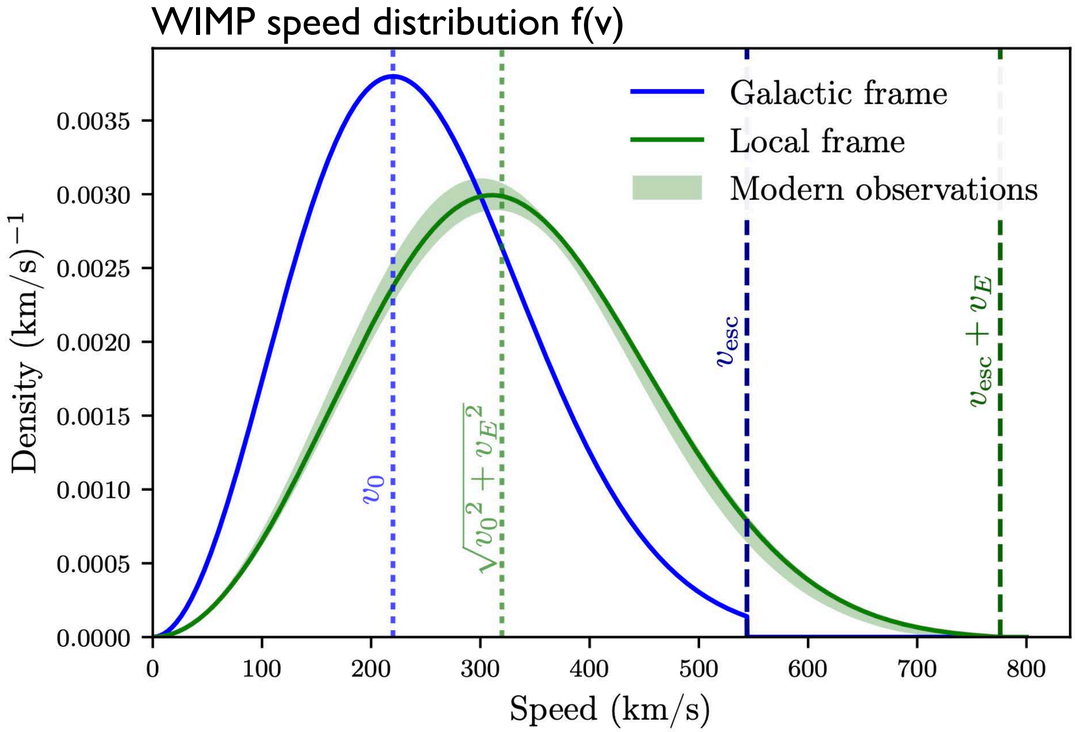
Sensitive to SI and SD WIMP Searches

We aim to measure:

$$\frac{dR}{dE_R} = \frac{\rho}{m_\chi} \frac{1}{m_N} \int_{v_{min}}^{v_{esc}} dv\, f(v) v \frac{d\sigma}{dE_R}(v)$$

with

$$\frac{d\sigma}{dE_R} = \frac{1}{E_{max}} \left(\sigma_{SI} F_{SI}^2 + \sigma_{SD} F_{SD}^2\right)$$



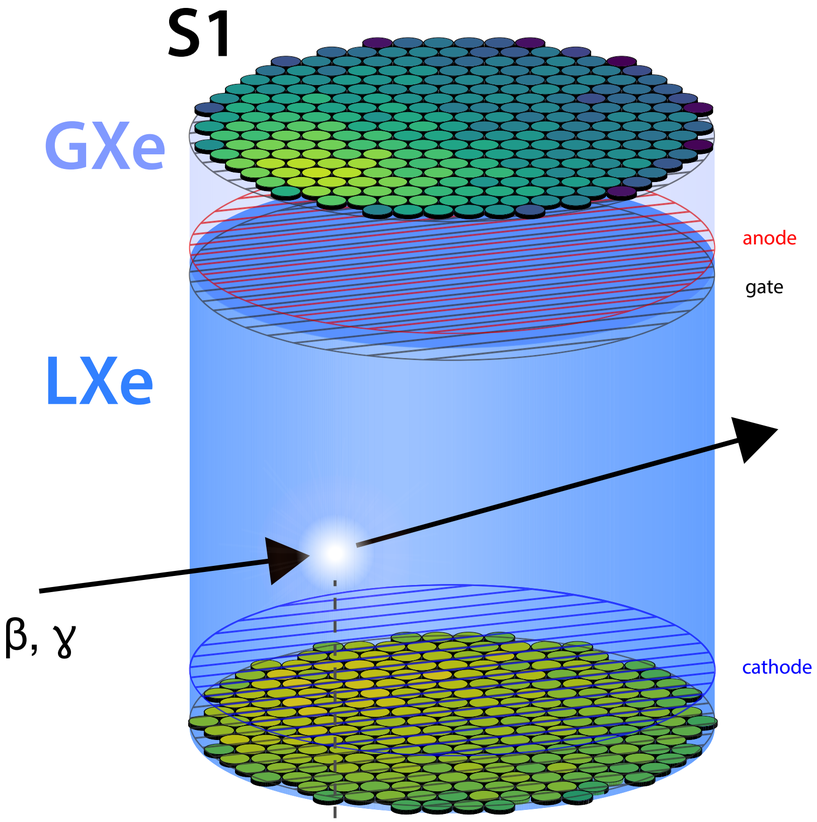
Spin-independent
scales like A^2

Spin-dependent
needs nuclei with non-zero spin

^{129}Xe (spin-1/2) , 26.4% n.a.

^{131}Xe (spin-3/2), 21.2% n.a.

Detection Principle



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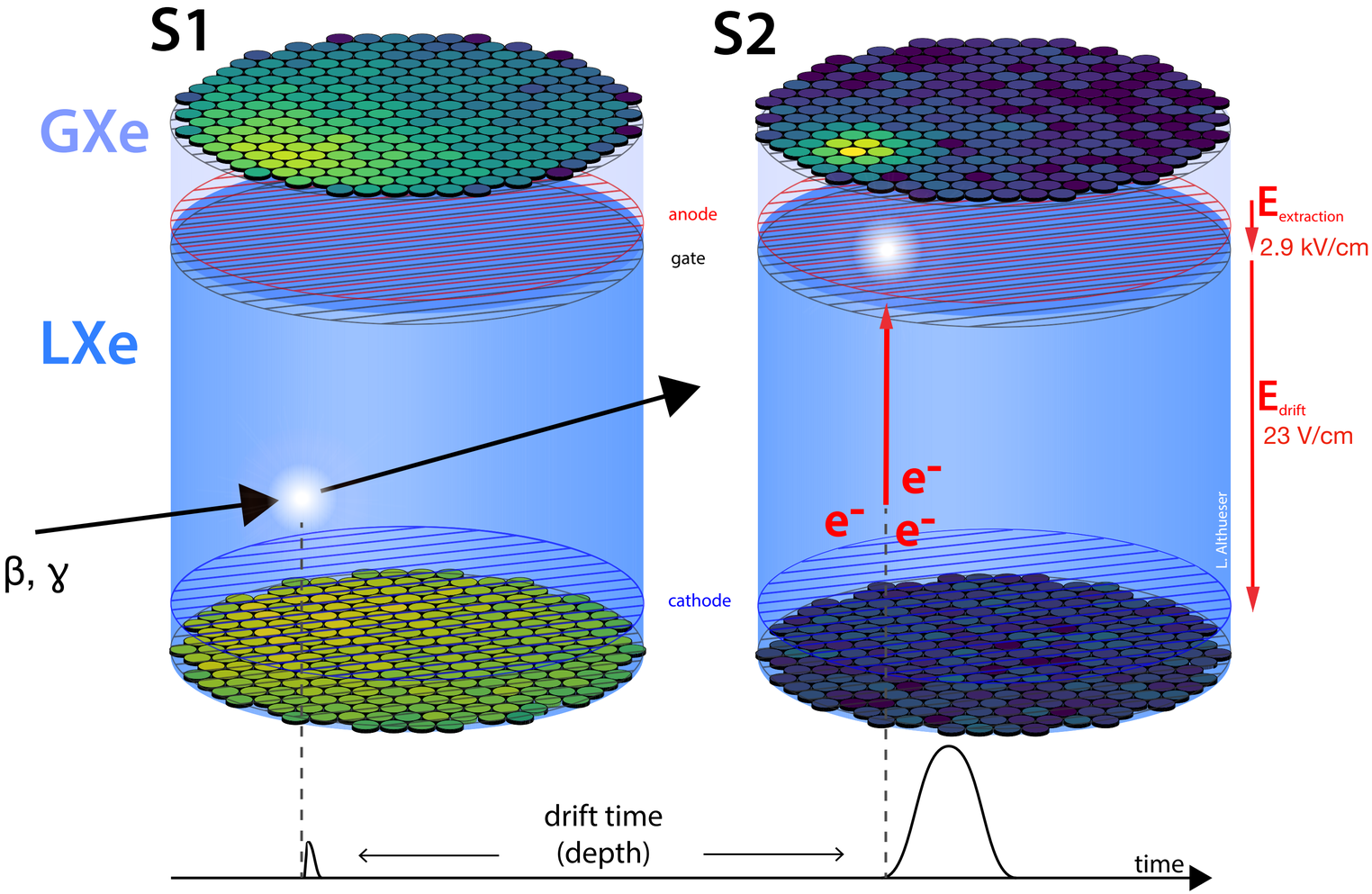

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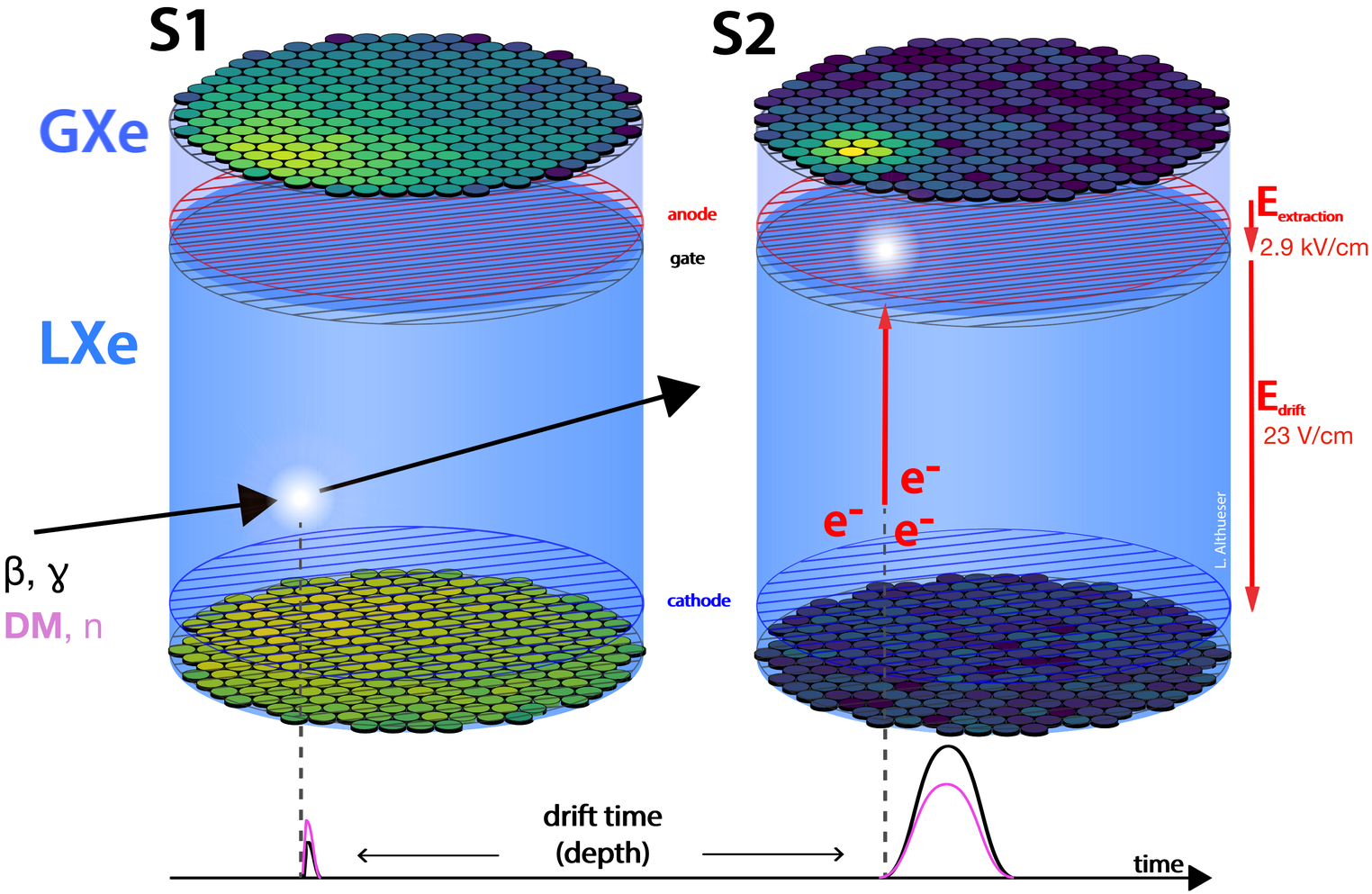
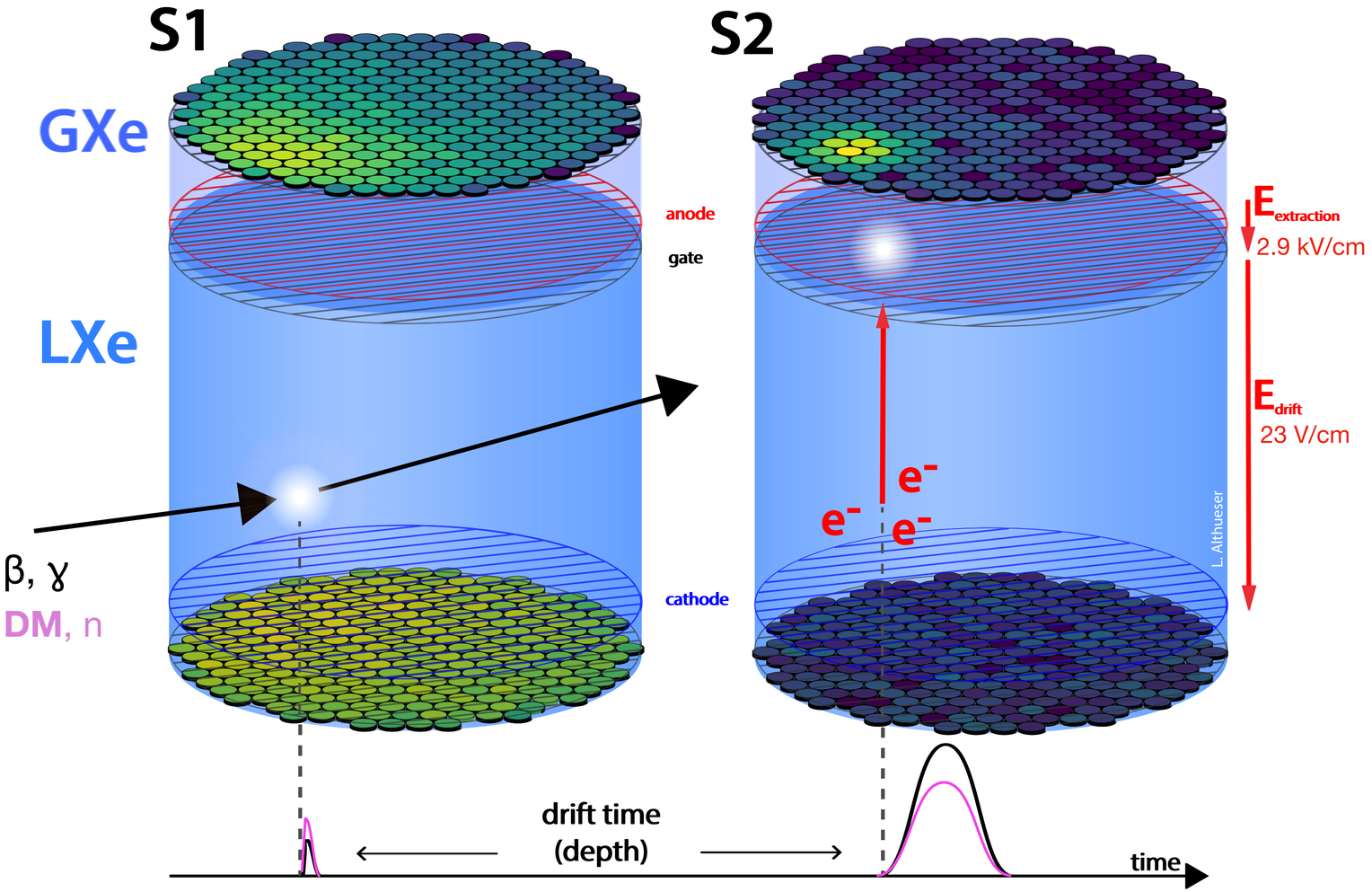


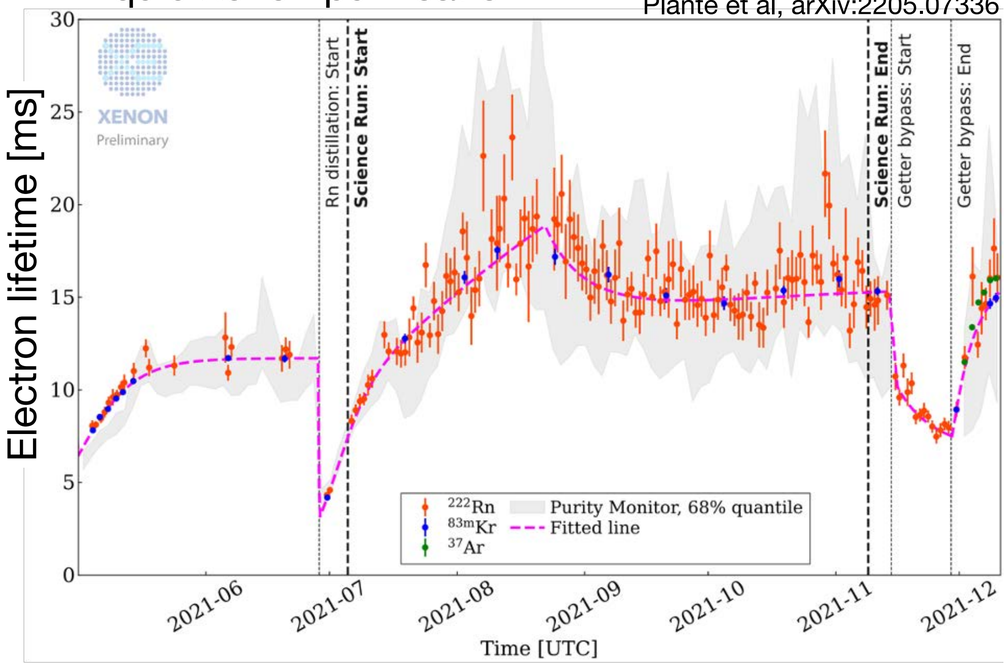
ER / NR recoil discrimination: $\frac{S2}{S1}_{NR} < \frac{S2}{S1}_{ER}$

Detection Principle



Liquid xenon purification

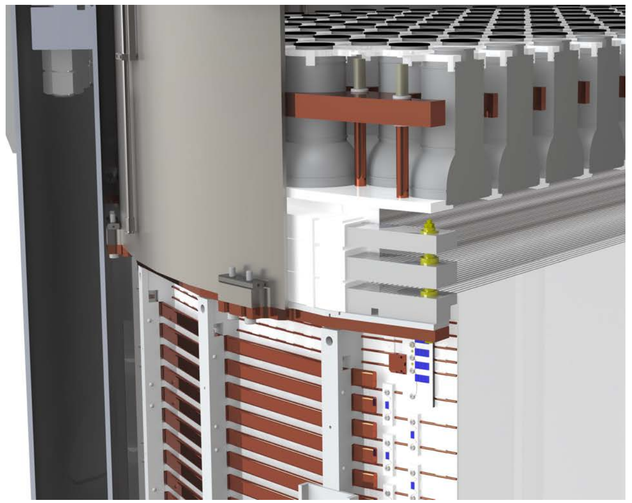
Plante et al, arXiv:2205.07336

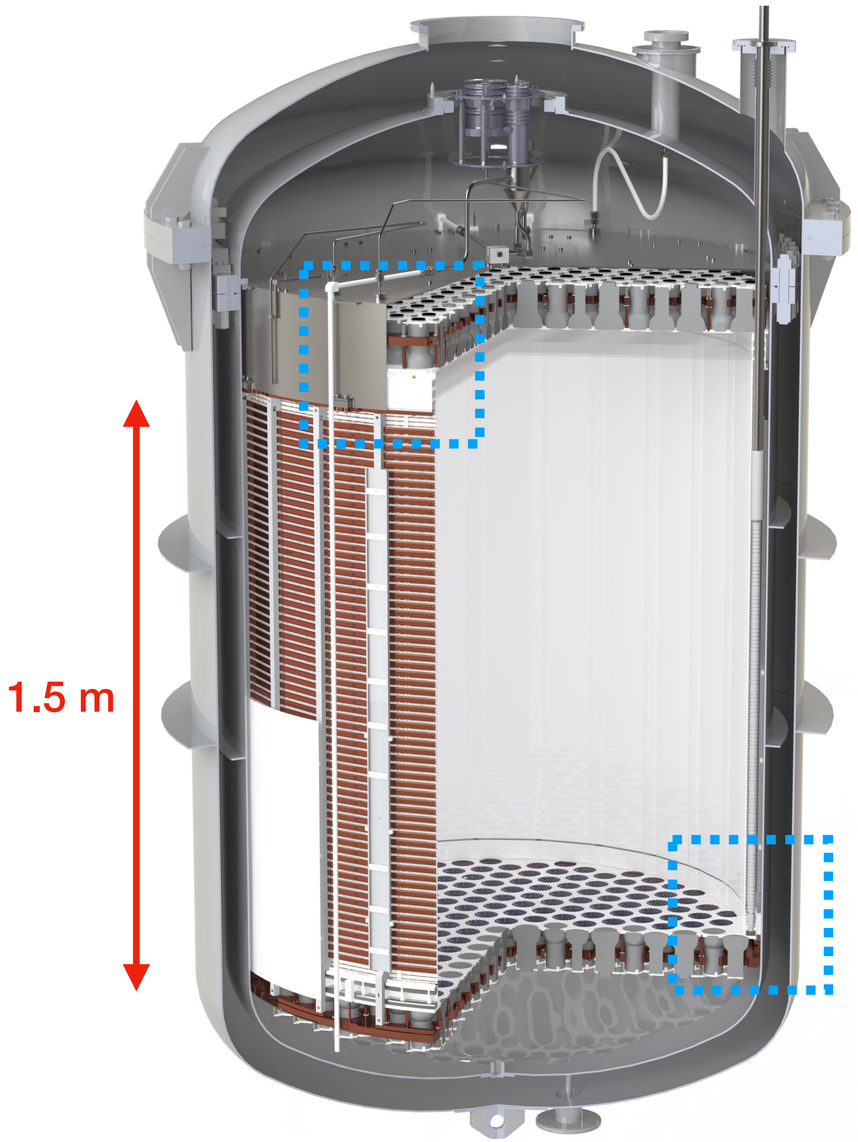


	Drift time [ms]	Electron lifetime [ms]
XENON1T	0.67	0.65
XENONnT	2.2	~15

ER / NR recoil discrimination: $\frac{S2}{S1}_{NR} < \frac{S2}{S1}_{ER}$

XENONnT Time Projection Chamber

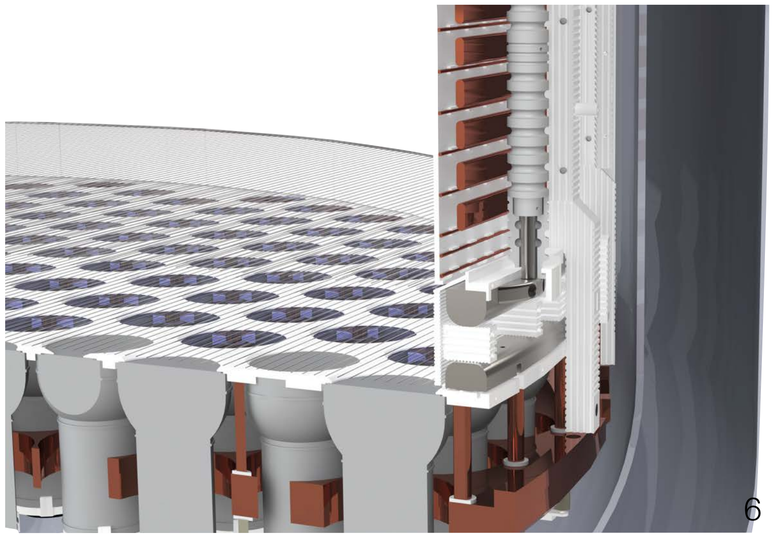




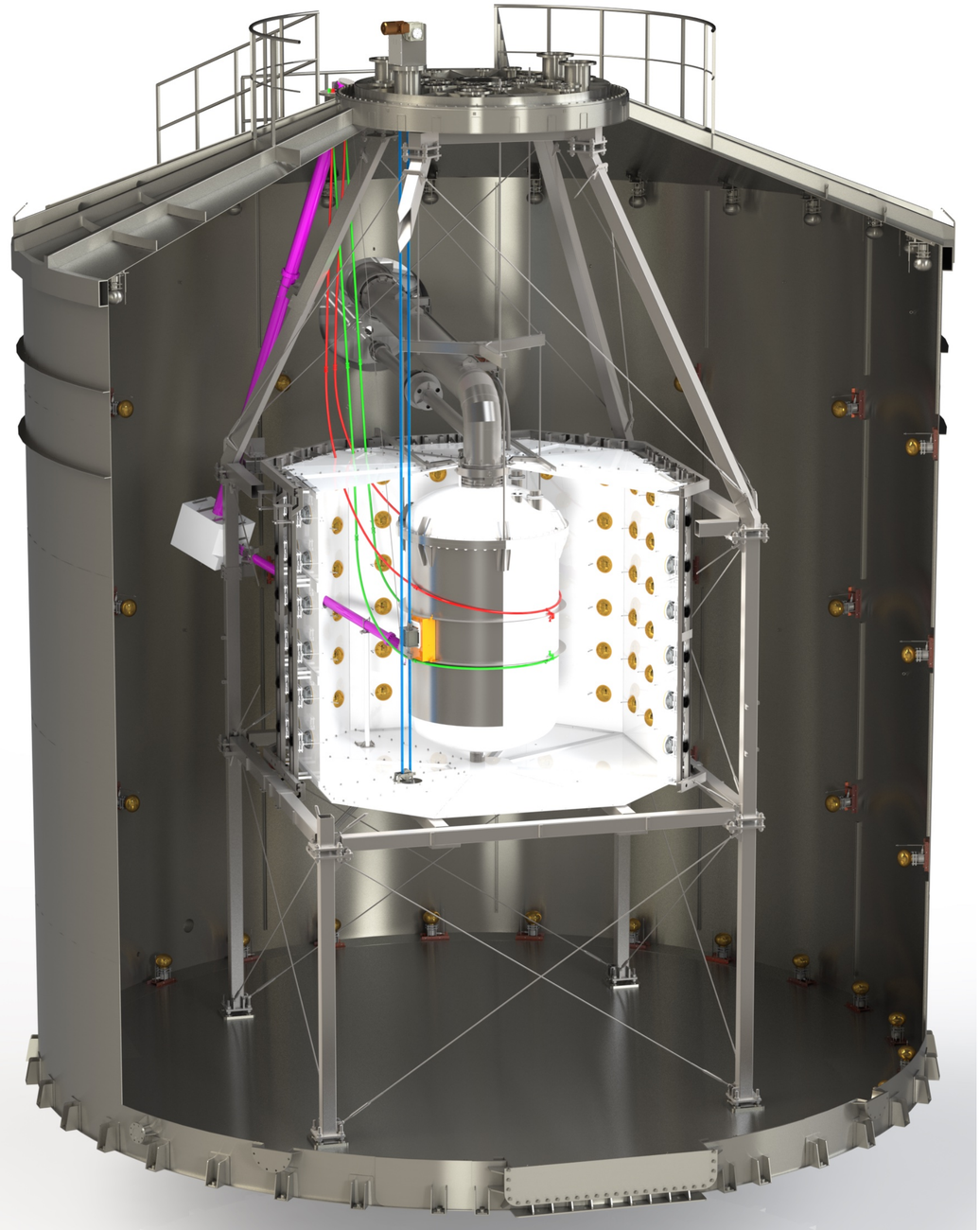
- 8.5 t of LXe total, 5.9 t in target
- 494 3-inch Hamamatsu R11410-3 PMTs
- 3 electrodes for drift and extraction fields
- 2 additional electrodes for PMT shielding

Calibration of detector response and efficiency:

- Internal sources: ^{37}Ar, ^{83m}Kr, ^{129m}Xe, ^{131m}Xe, ^{220}Rn
- External sources: AmBe, Th



XENON1T → XENONnT Improvements



- Reused much of the XENON1T infrastructure
- Larger TPC: 2 t → 5.9 t LXe
- Improved cleanliness and radiopurity XENON, arXiv:2112.05629
- Liquid xenon purification system Plante et al, arXiv:2205.07336
- Radon distillation system Murra et al, arXiv:2205.11492
- Water Cherenkov neutron-veto
- New calibration systems and techniques
- Triggerless DAQ XENON, arXiv:2212.11032

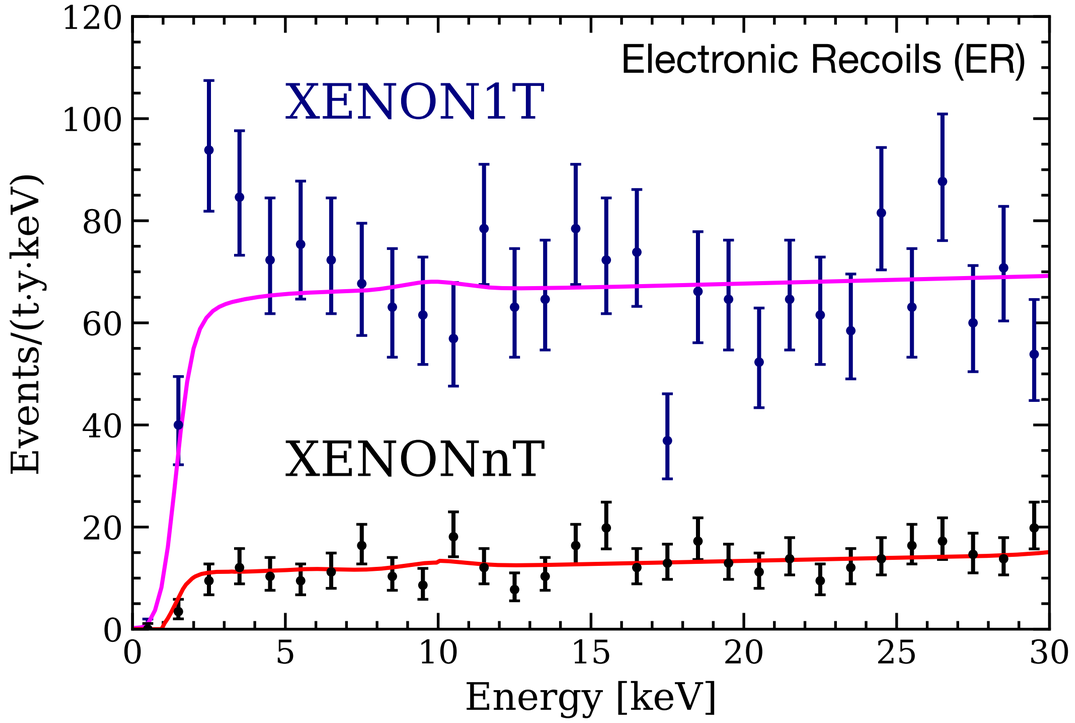
Background Mitigation

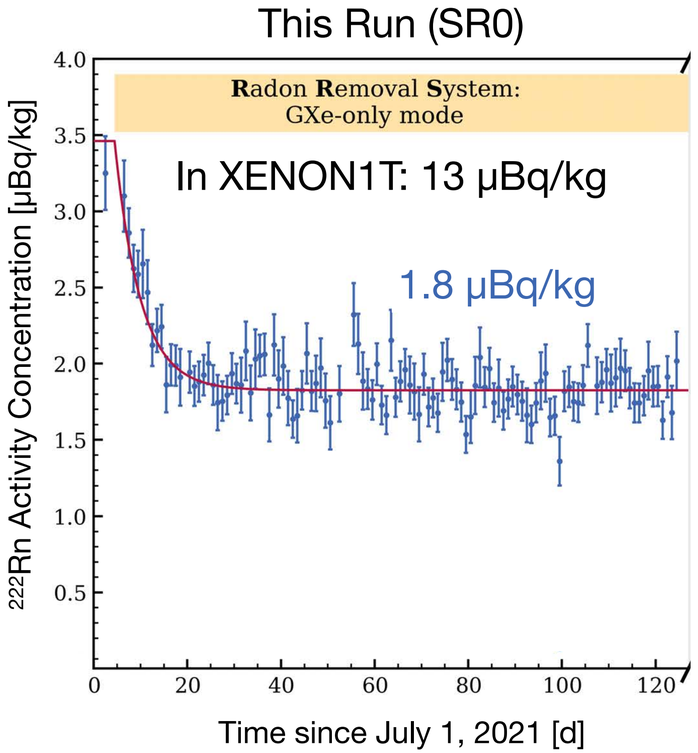
Murra et al, arXiv:2205.11492
XENON, arXiv:2112.05629

Background from intrinsic radioactive isotopes:

- ^{214}Pb (^{222}Rn daughter)
- ^{85}Kr

Careful screening, material selection and
Continuous Radon Removal through distillation





(15.8 ± 1.3) events / (keV × t × yr)

Background ~5x smaller than in XENON1T

XENON, PRL 120, 161805 (2022)

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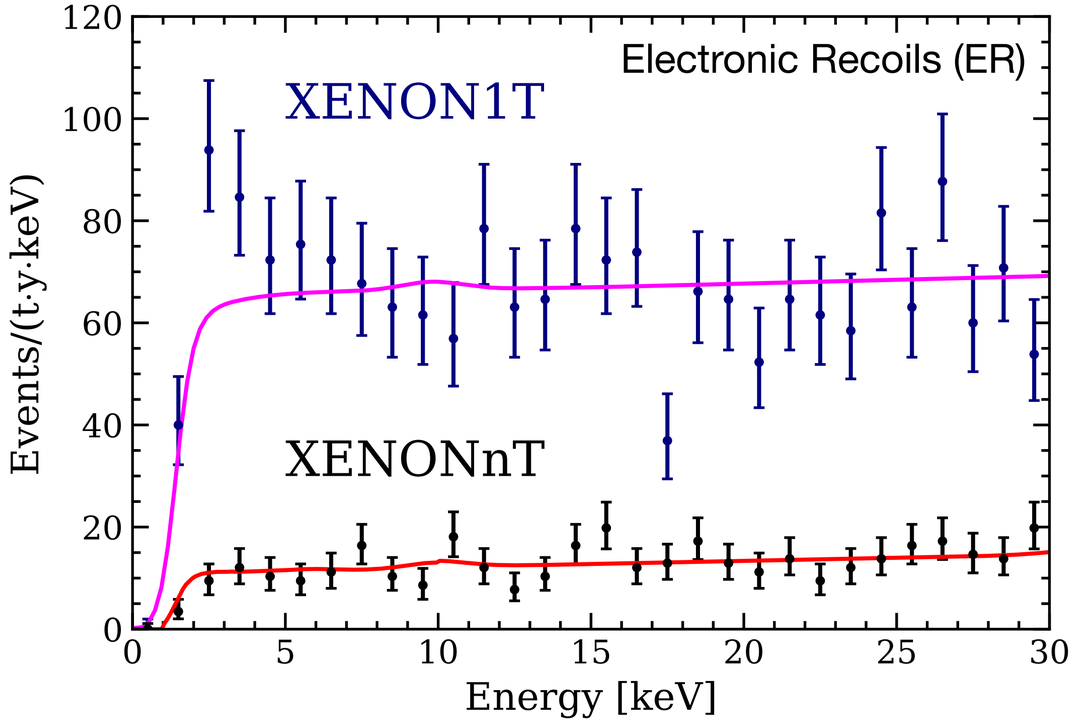

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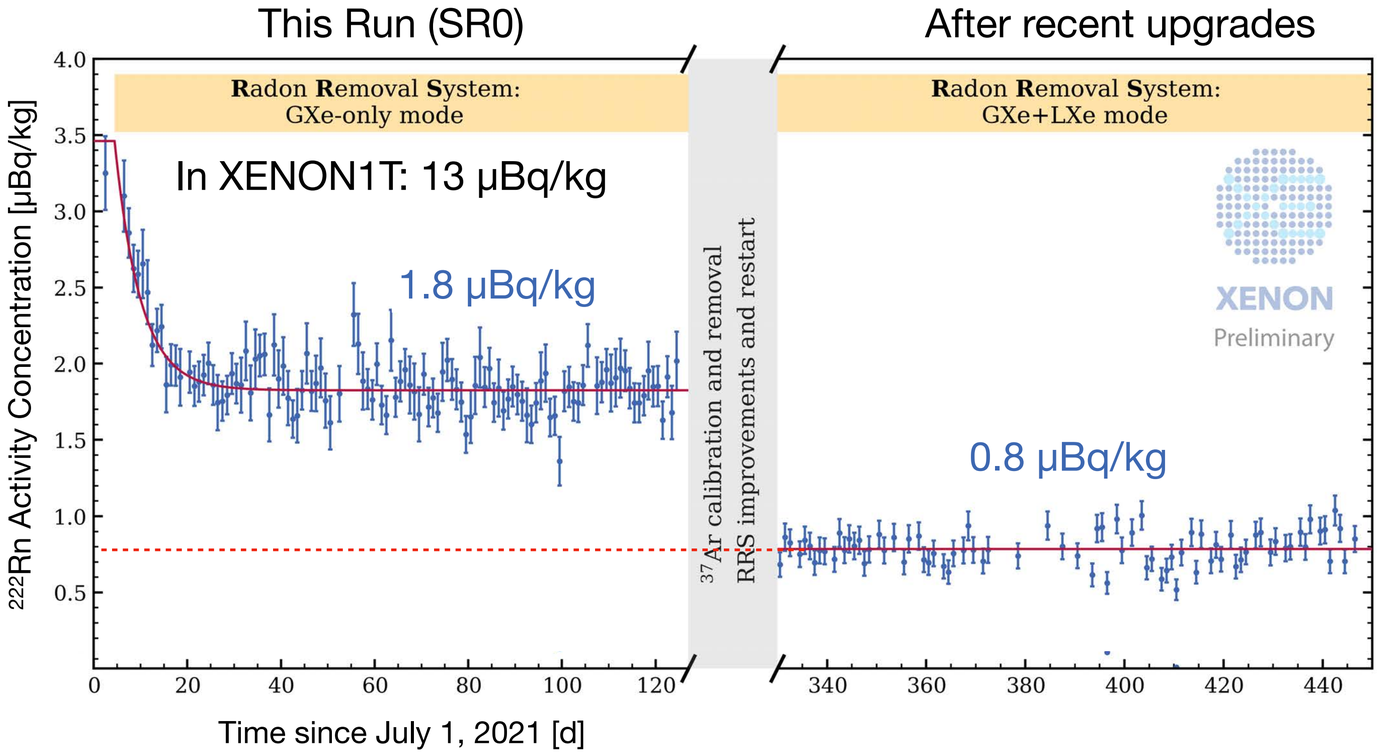

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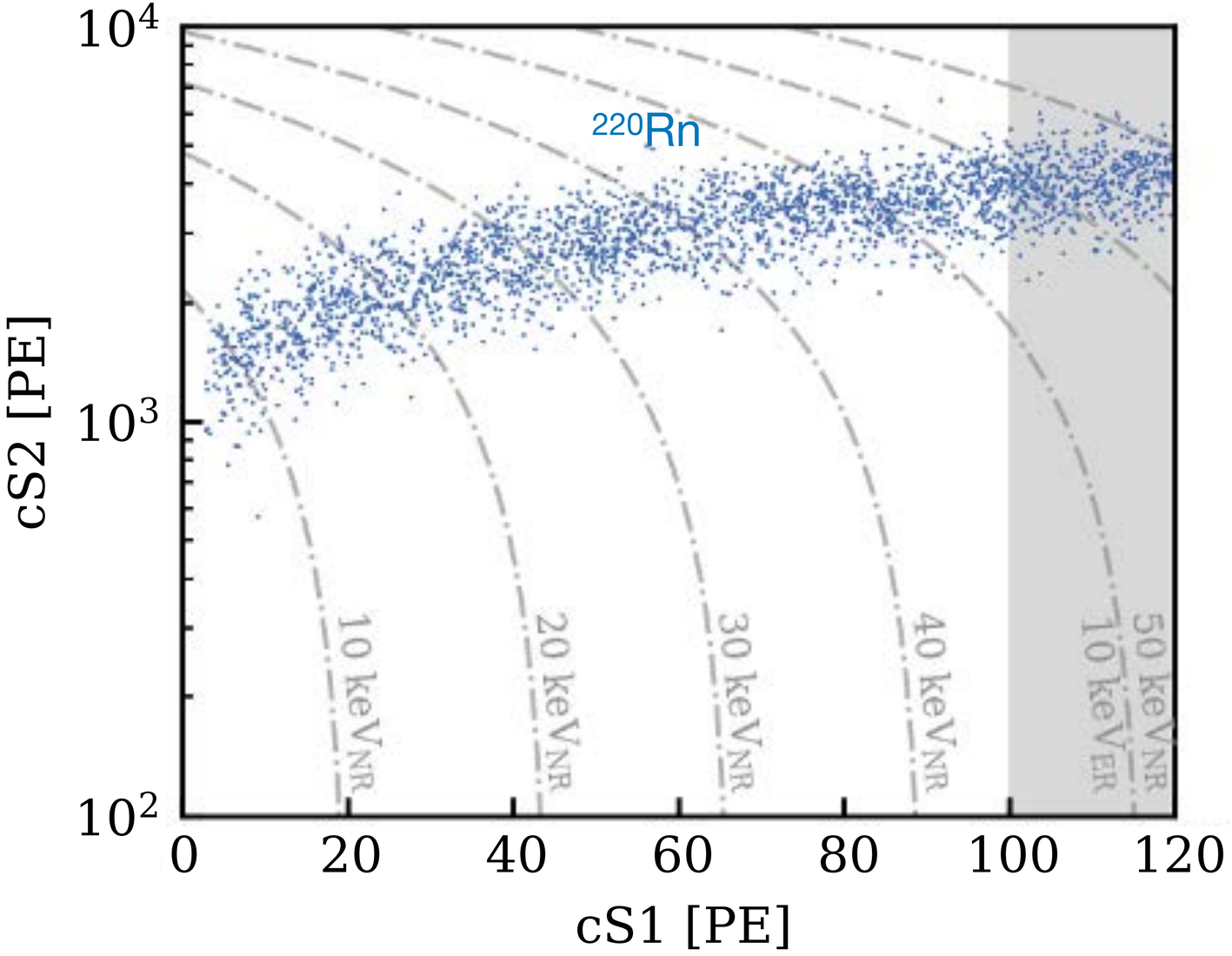
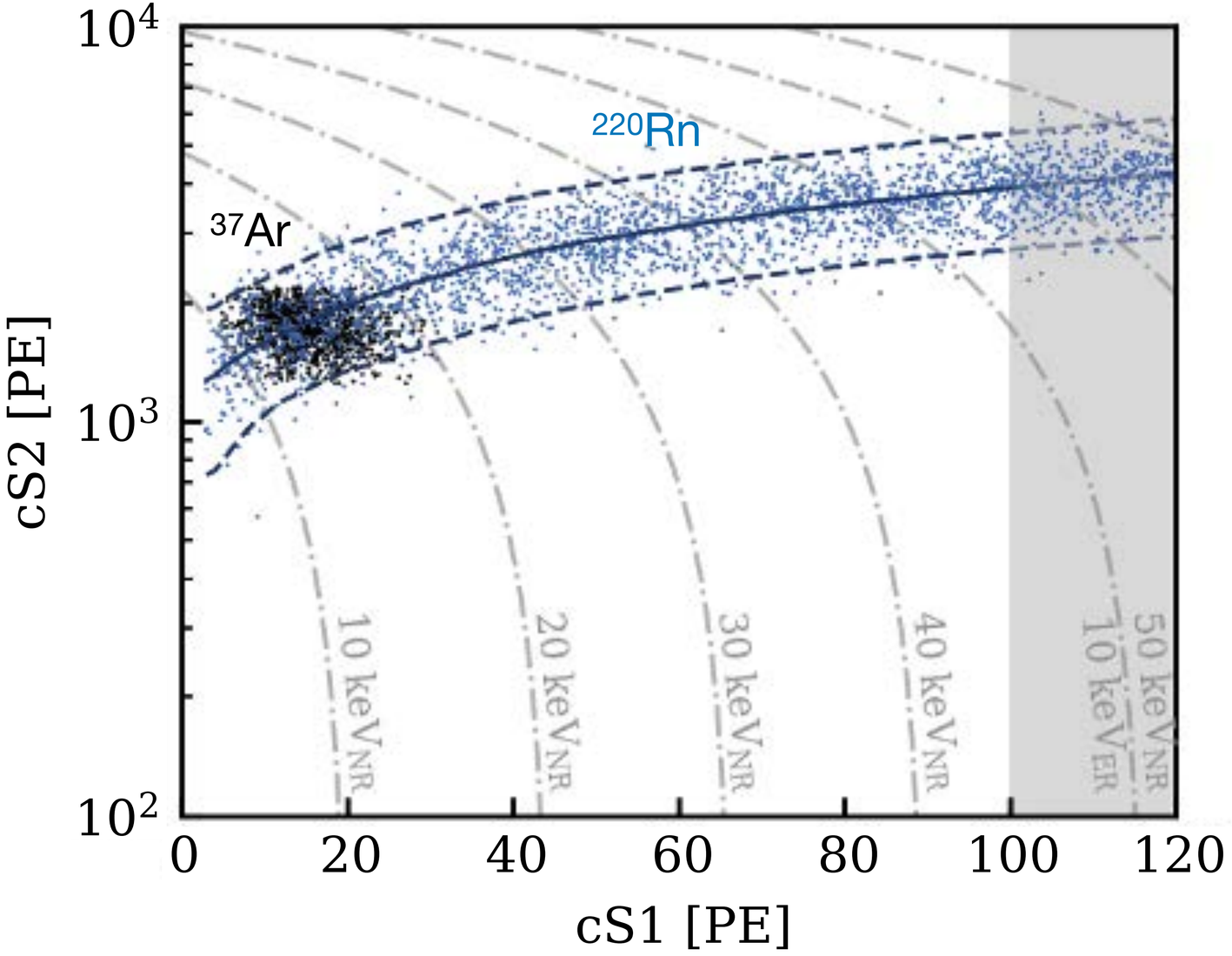
Calibration of ER / NR Response



- **Calibration of ER** response using ^{220}Rn
  - Gives approximately flat energy spectrum
  - Used to validate cut acceptance
- Detector performance at low energy with ^{37}Ar
  - Mono-energetic line at 2.8 keV
  - High statistics
  - Removed via distillation column ($T_{1/2}$ = 35 d)
- **Calibration of NR** response with AmBe
- ER model based on combined fit
- Uncertainties propagated via Principal Component Analysis

Calibration of ER / NR Response



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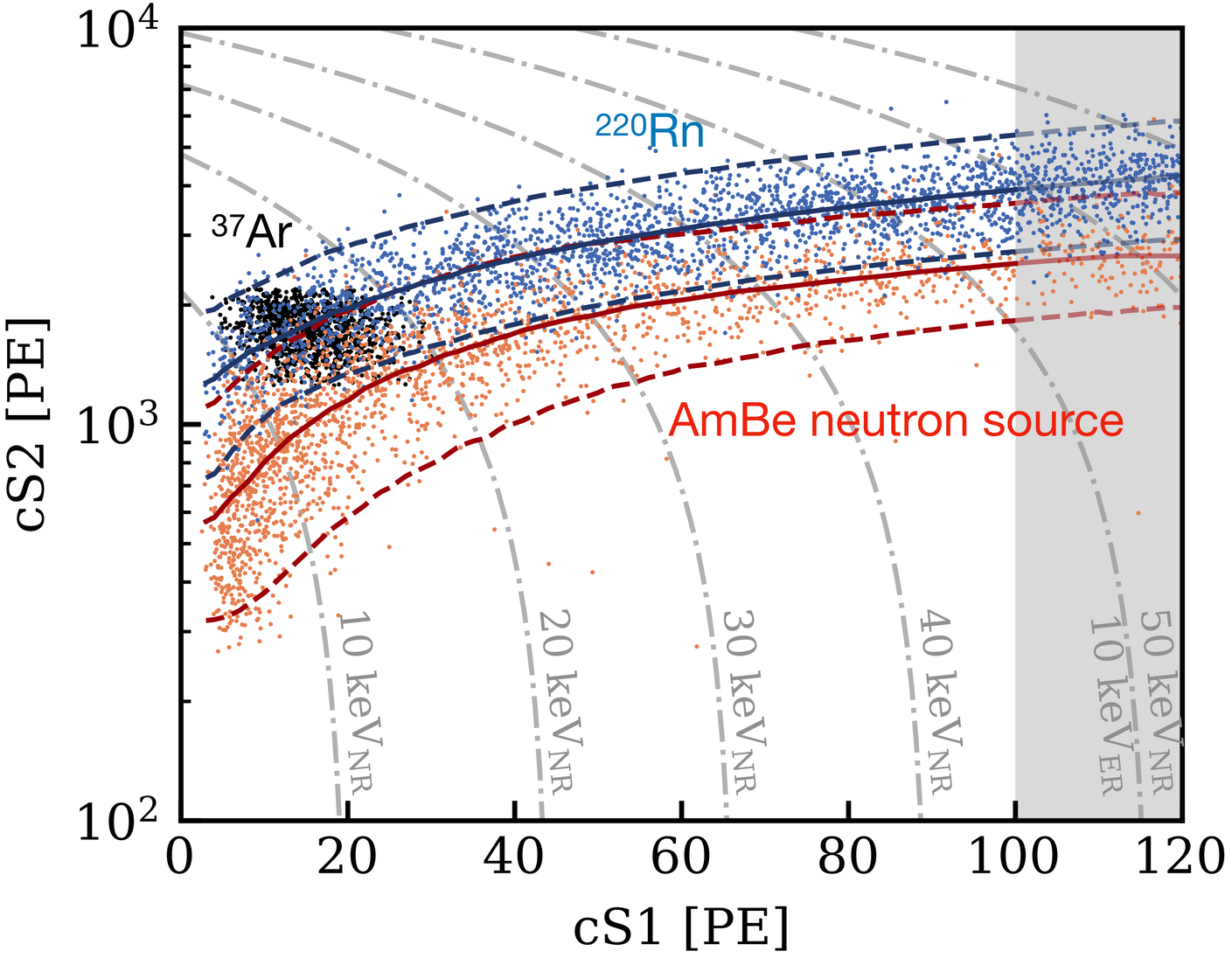

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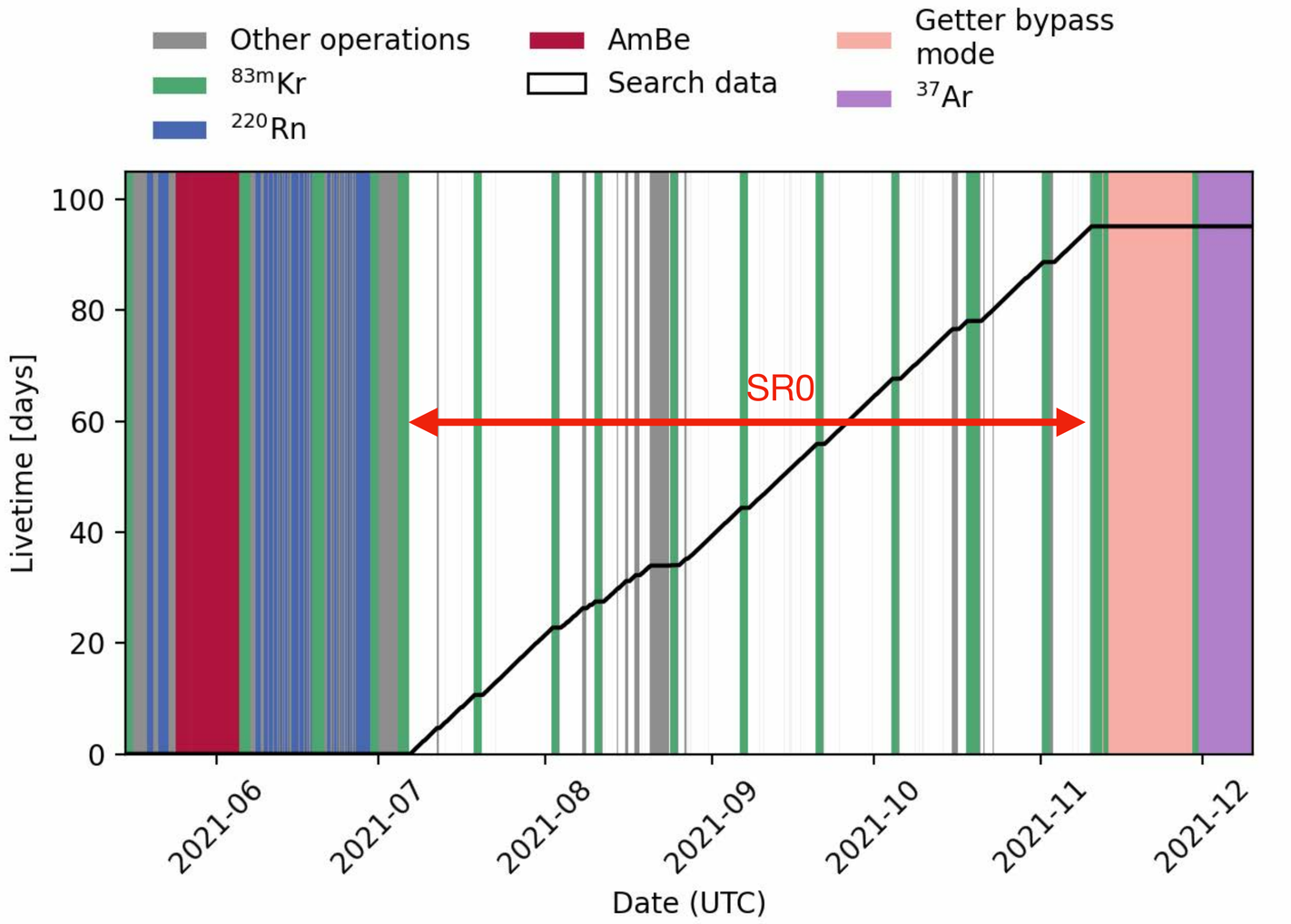
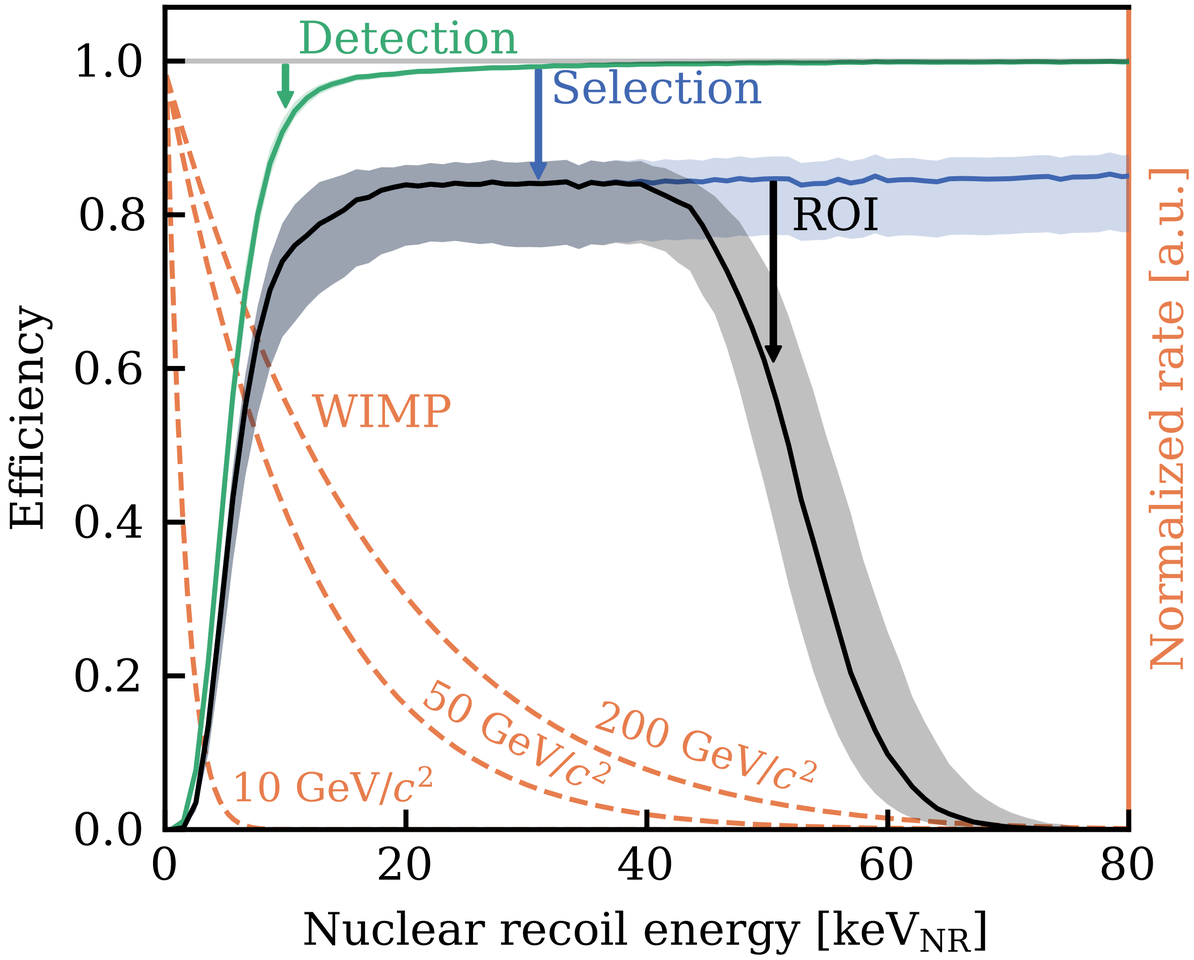
Data Set: Science Run 0



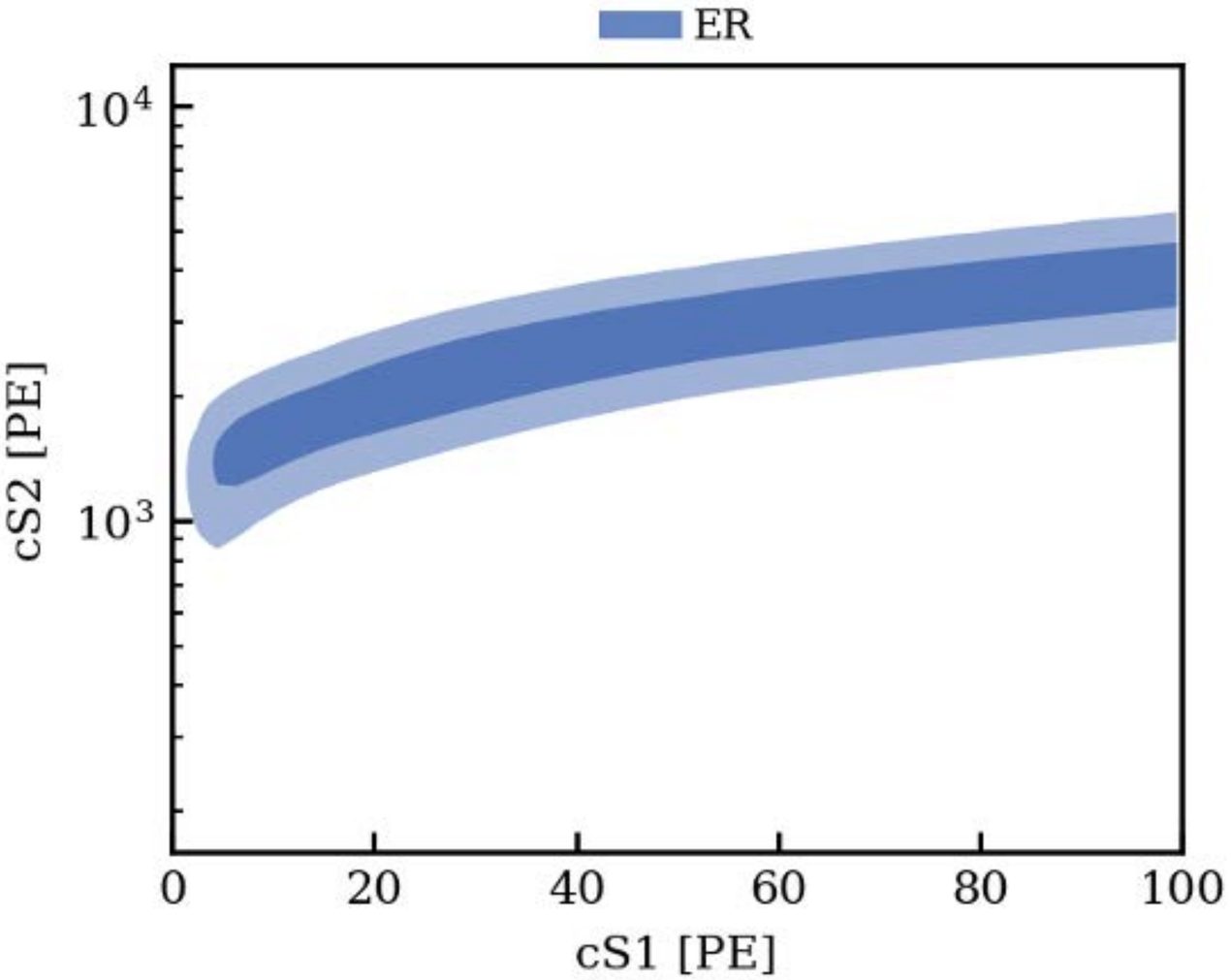
- SR0 Nuclear Recoil Search Data
- July 6 to Nov 10, 2021 (97.1 days)
- 95.1 days lifetime corrected
- (4.18 ± 0.13) tonne Fiducial Volume
- Exposure: 1.1 tonne-year
- Blind analysis

Efficiency



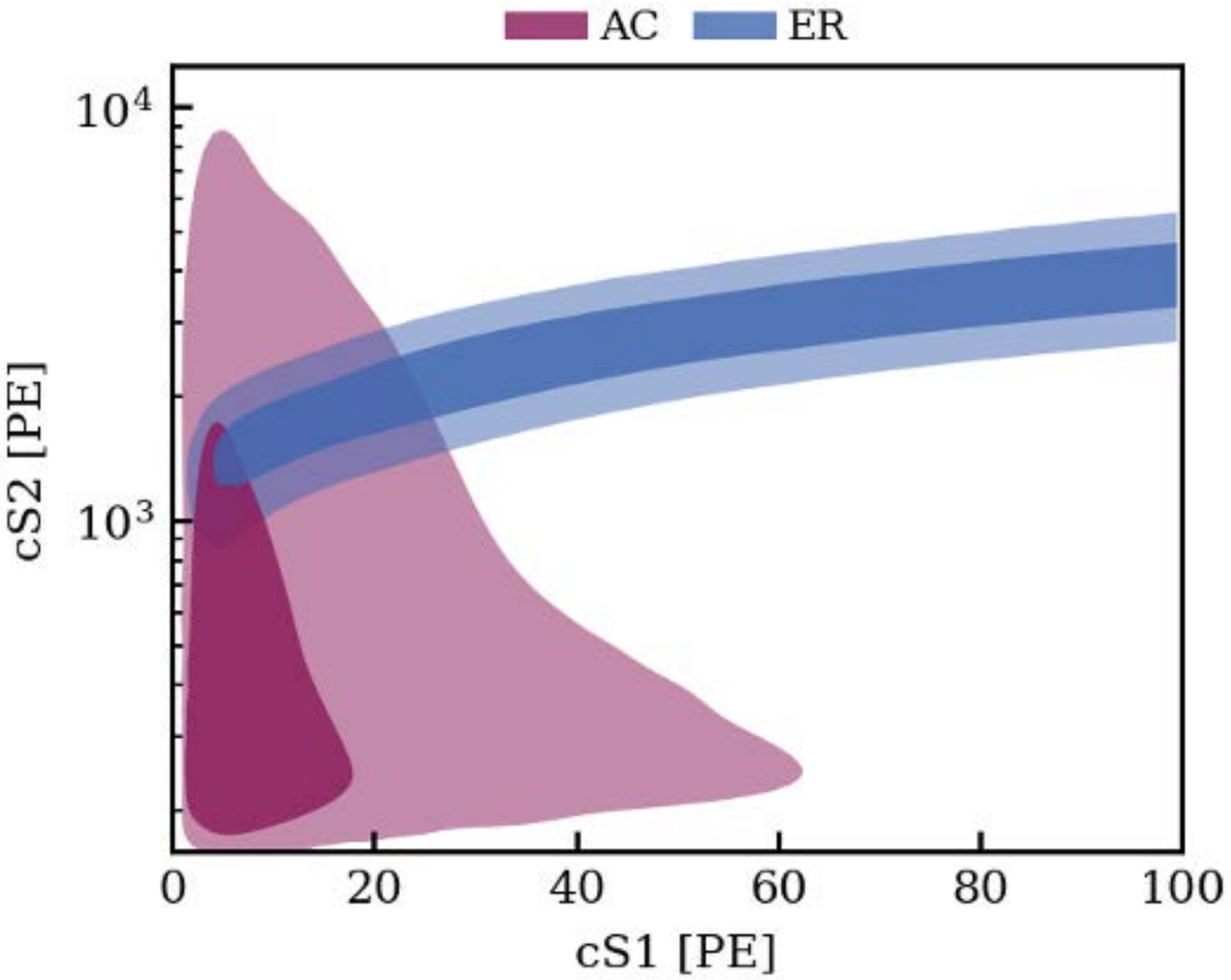
- Detection efficiency:
  - Threshold driven by 3-fold PMT coincidence for S1
  - Full waveform simulation
  - Data-driven methods from ^{83m}Kr and ^{37}Ar
- Data quality selection evaluated with calibration data
- ROI defined to fully contain WIMP spectra
  - cS1 [0 pe, 100 pe]
  - cS2 [$10^{2.1}$ pe, $10^{4.1}$ pe]
- Total acceptance > 10% for [3 keV$_{NR}$, 60 keV$_{NR}$]

Backgrounds



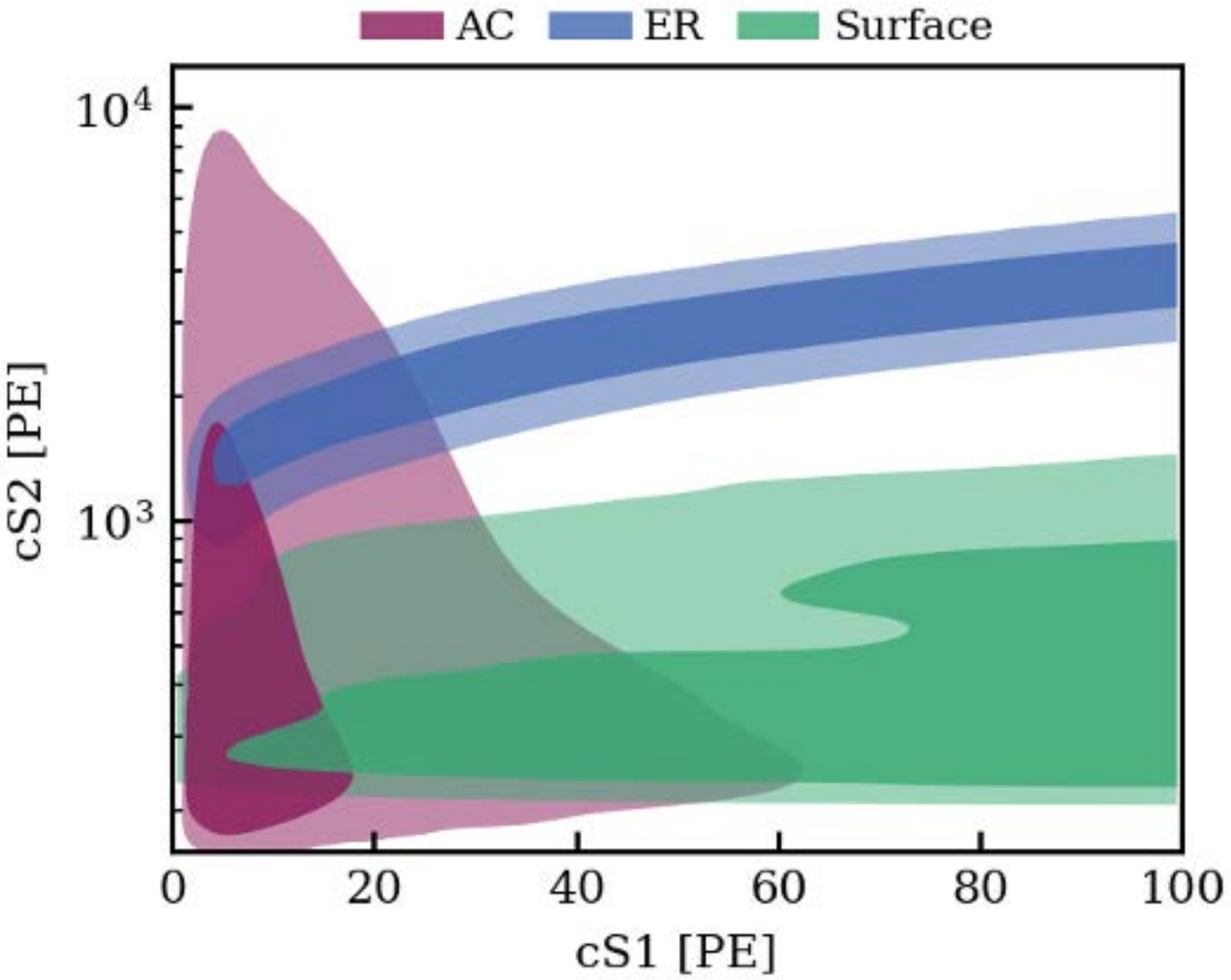
- Electronic Recoil (ER): Dominated by beta decay of ^{214}Pb from ^{222}Rn

Backgrounds



- Electronic Recoil (ER): Dominated by beta decay of ^{214}Pb from ^{222}Rn
- Accidental Coincidences (AC): random pairing of small S1 and S2 signals

Backgrounds



- Electronic Recoil (ER): Dominated by beta decay of ^{214}Pb from ^{222}Rn
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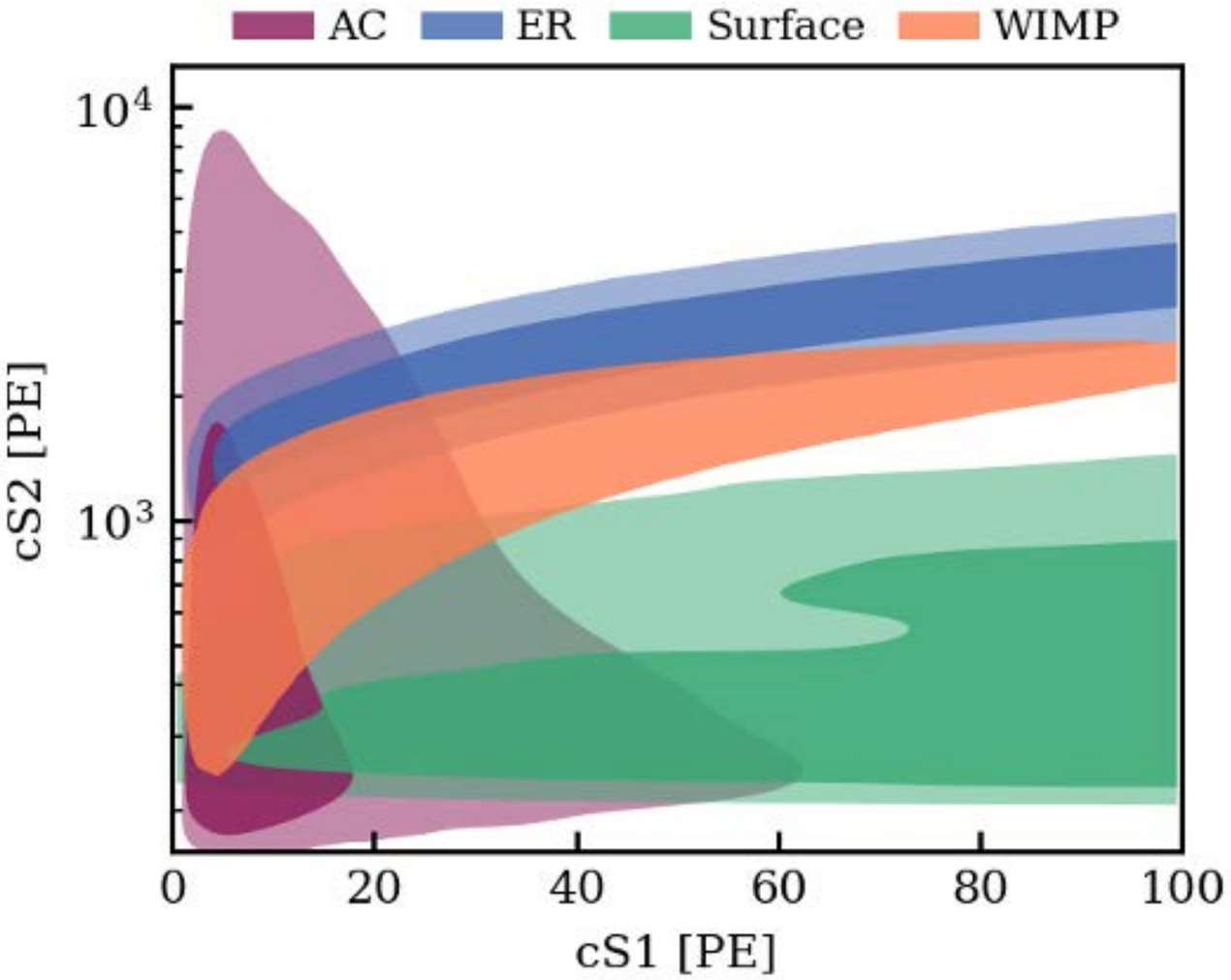
- Surface/Wall: ^{210}Pb plate-out on the PTFE wall of the TPC → ^{210}Po α-decays

Backgrounds



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- Accidental Coincidences (AC): random pairing of small S1 and S2 signals
- Surface/Wall: ^{210}Pb plate-out on the PTFE wall of the TPC → ^{210}Po α-decays
- Nuclear Recoil backgrounds:
  - CEvNS
  - Neutrons

WIMP Results

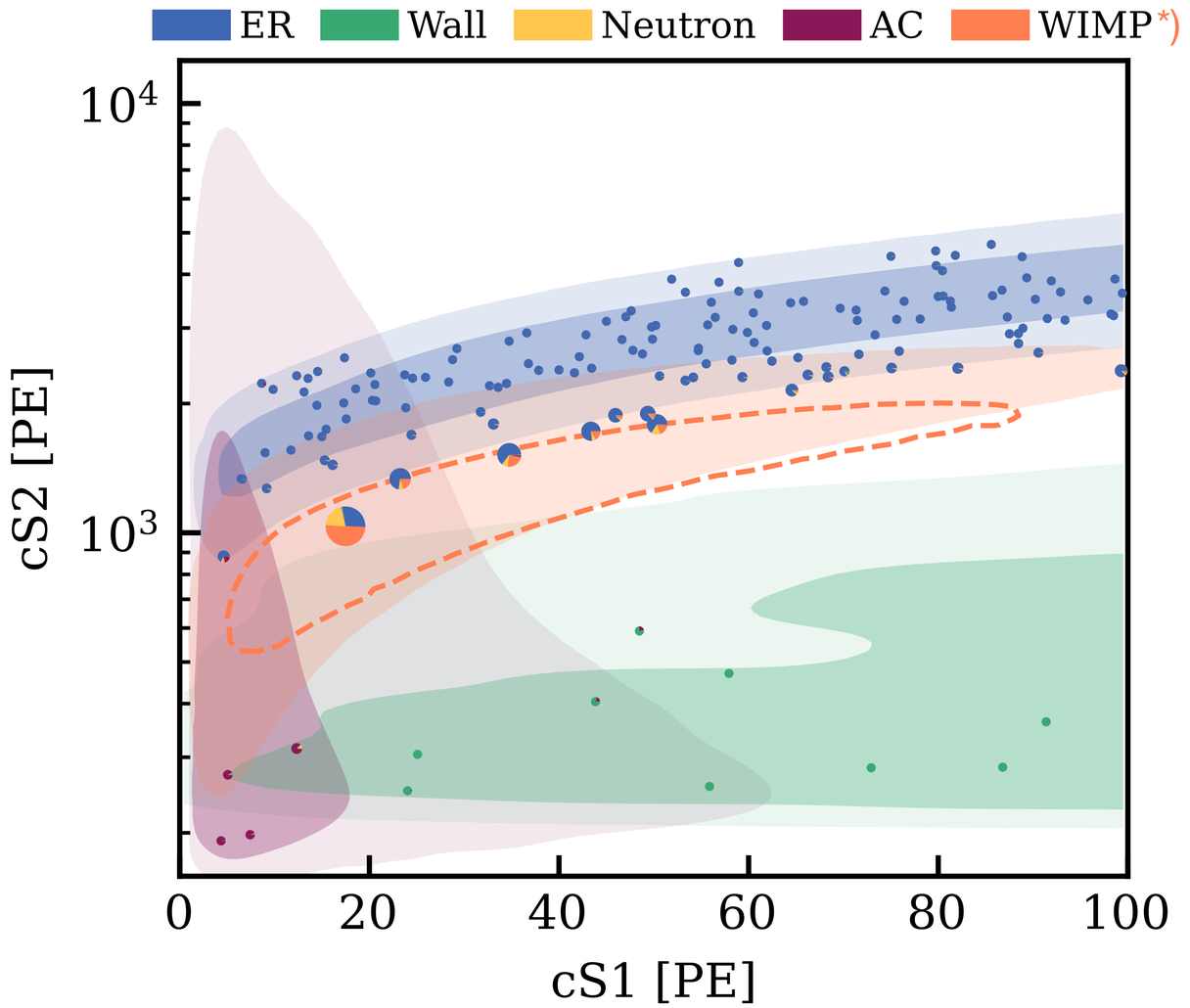
	Expectation
ER	134
Neutrons	$1.1^{+0.6}_{-0.5}$
CEvNS	0.23 ± 0.06
AC	4.3 ± 0.2
Wall	14 ± 3
Total	154
WIMP	
Observed	

WIMP Results

	Expectation	Best Fit	
	ROI		Signal-like
ER	134	135^{+12}_{-11}	0.81 ± 0.07
Neutrons	$1.1^{+0.6}_{-0.5}$	1.1 ± 0.2	0.42 ± 0.10
CEvNS	0.23 ± 0.06	0.23 ± 0.06	0.022 ± 0.011
AC	4.3 ± 0.2	4.32 ± 0.15	0.363 ± 0.013
Wall	14 ± 3	12^{+0}_{-4}	$0.34^{+0.01}_{-0.11}$
Total	154	152 ± 12	$1.95^{+0.12}_{-0.16}$
WIMP		2.4 *)	1.2 *)
Observed		152	3

152 events in ROI, 16 in blinded region

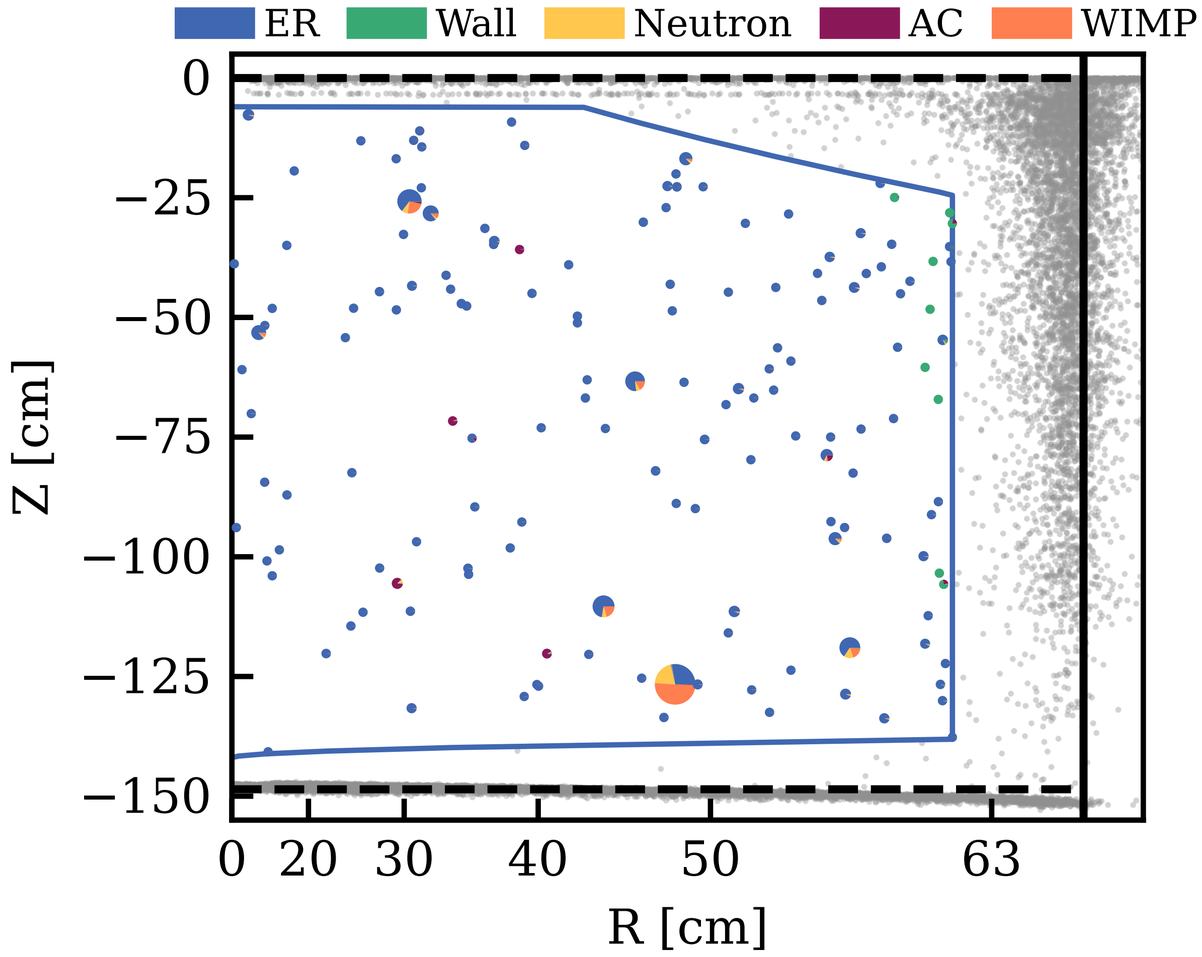
Best fit indicates no significant excess

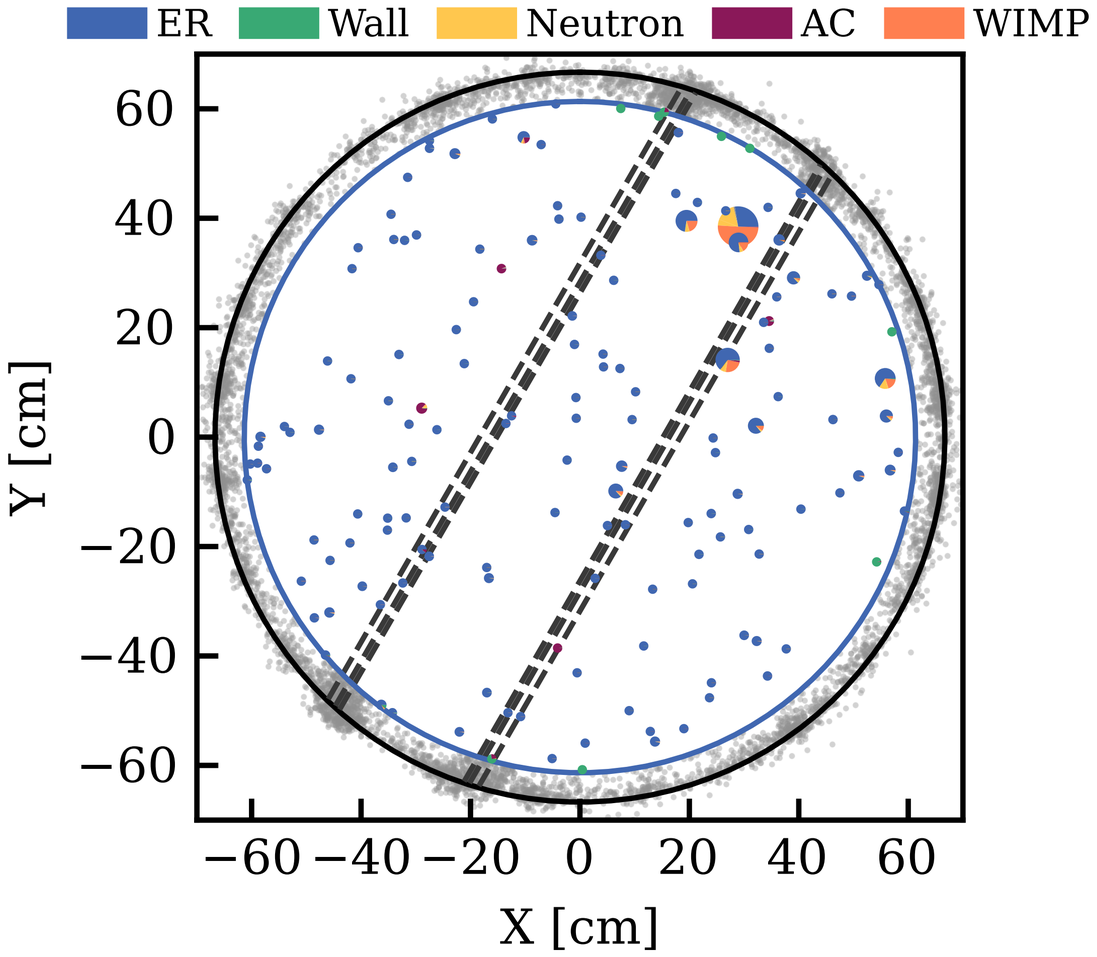


*) Assuming a 200 GeV WIMP and a best-fit $\sigma = 2.5 \times 10^{-47}$ cm^2

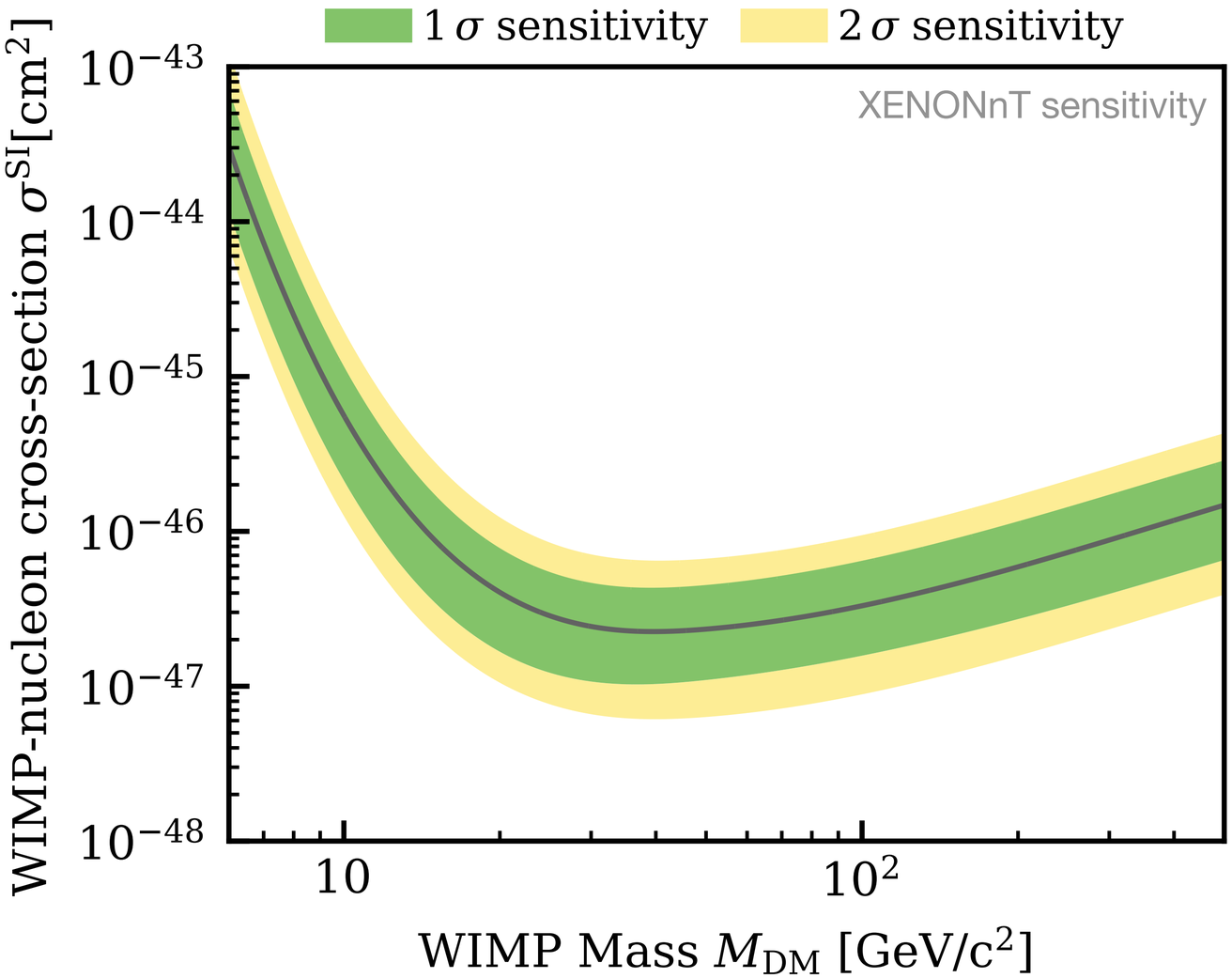
WIMP Results

- XY asymmetry in unblinded data
- Not observed in corrections, quality selection or calibration data





WIMP Spin-Independent Results



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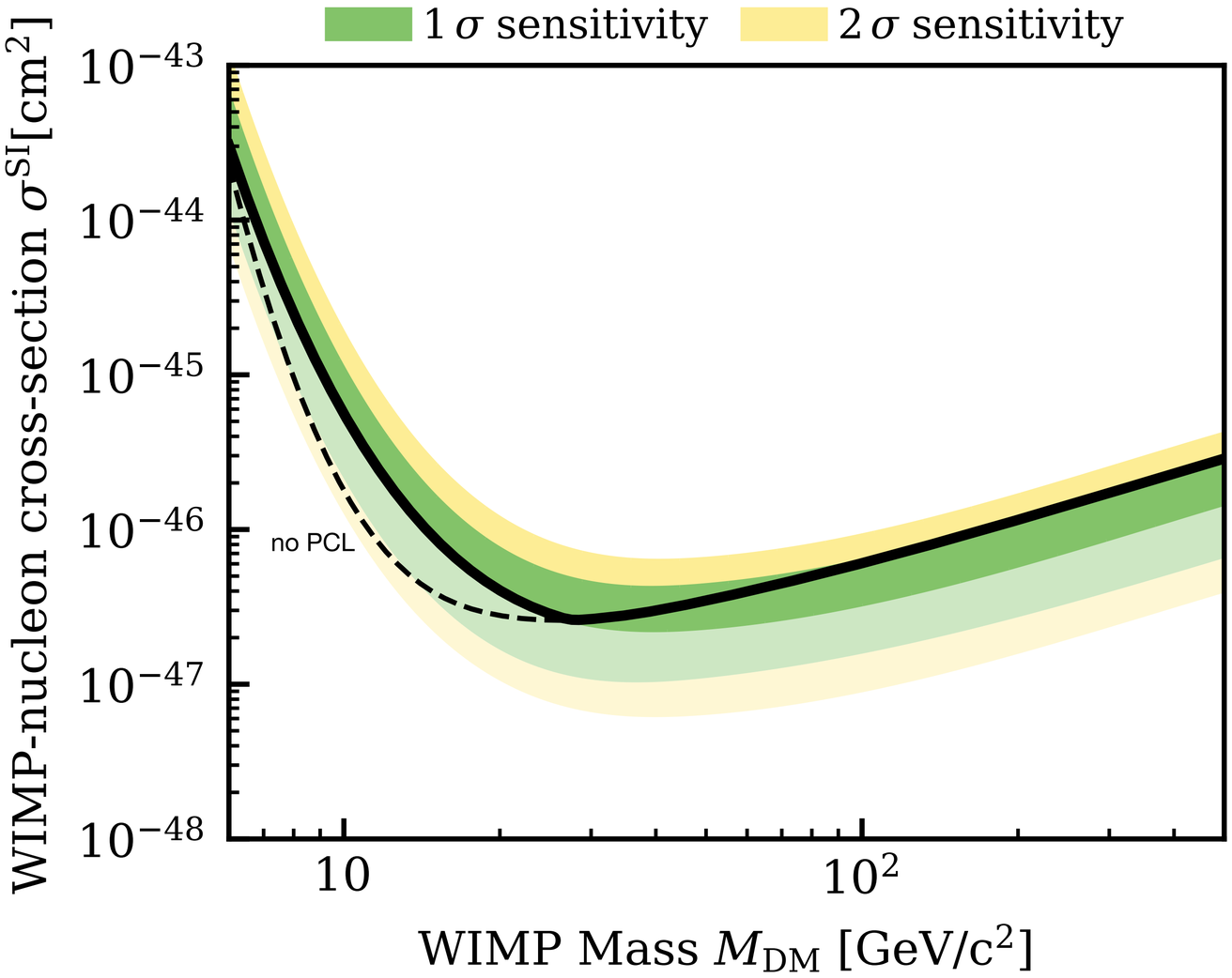

XENONnT 90% C.L. Power-Constrained Limit*

*) arXiv:1105.3166, arXiv:2105.00599 with 50% [median] rejection power

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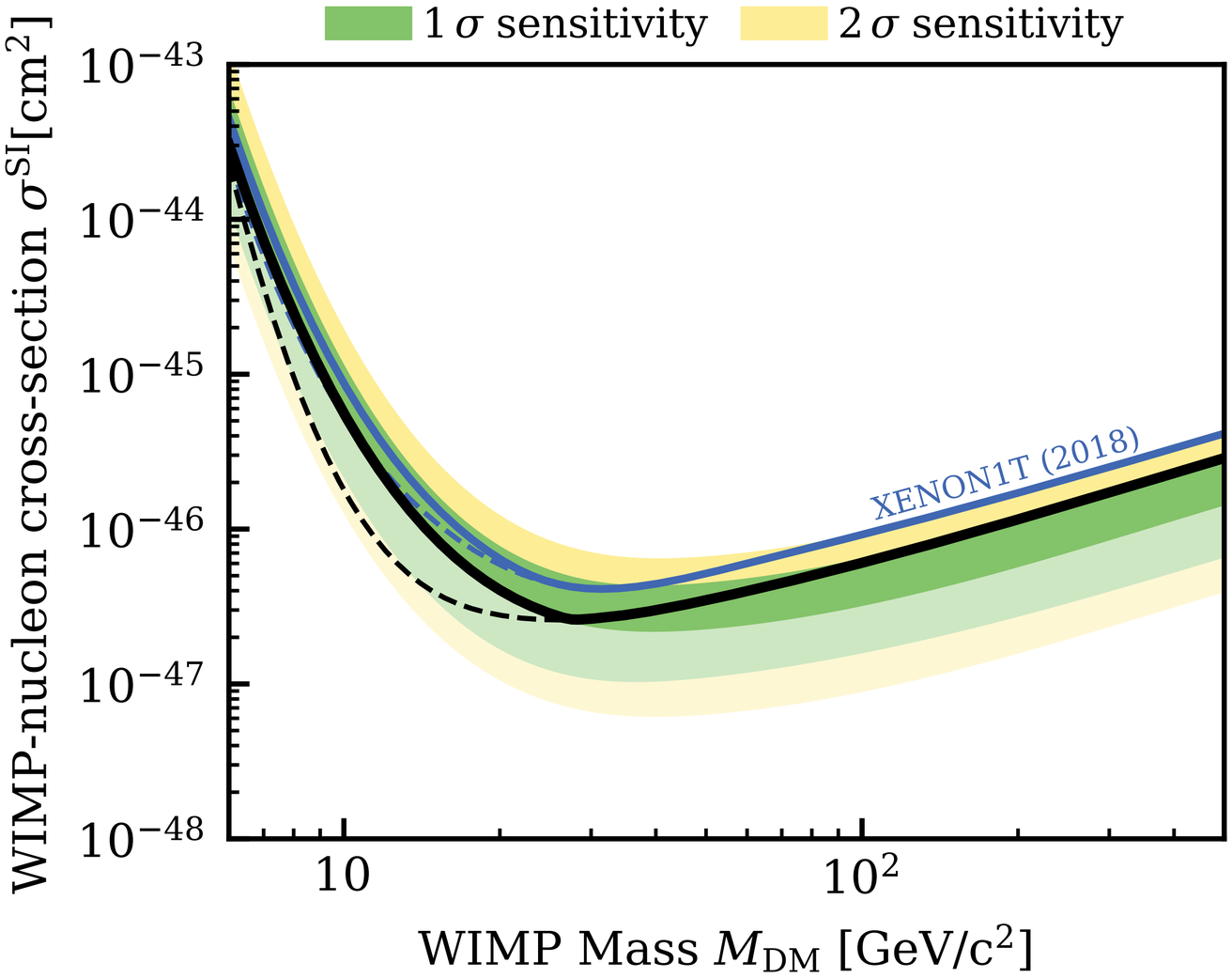

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XENON, PRL 121, 111302 (2018)

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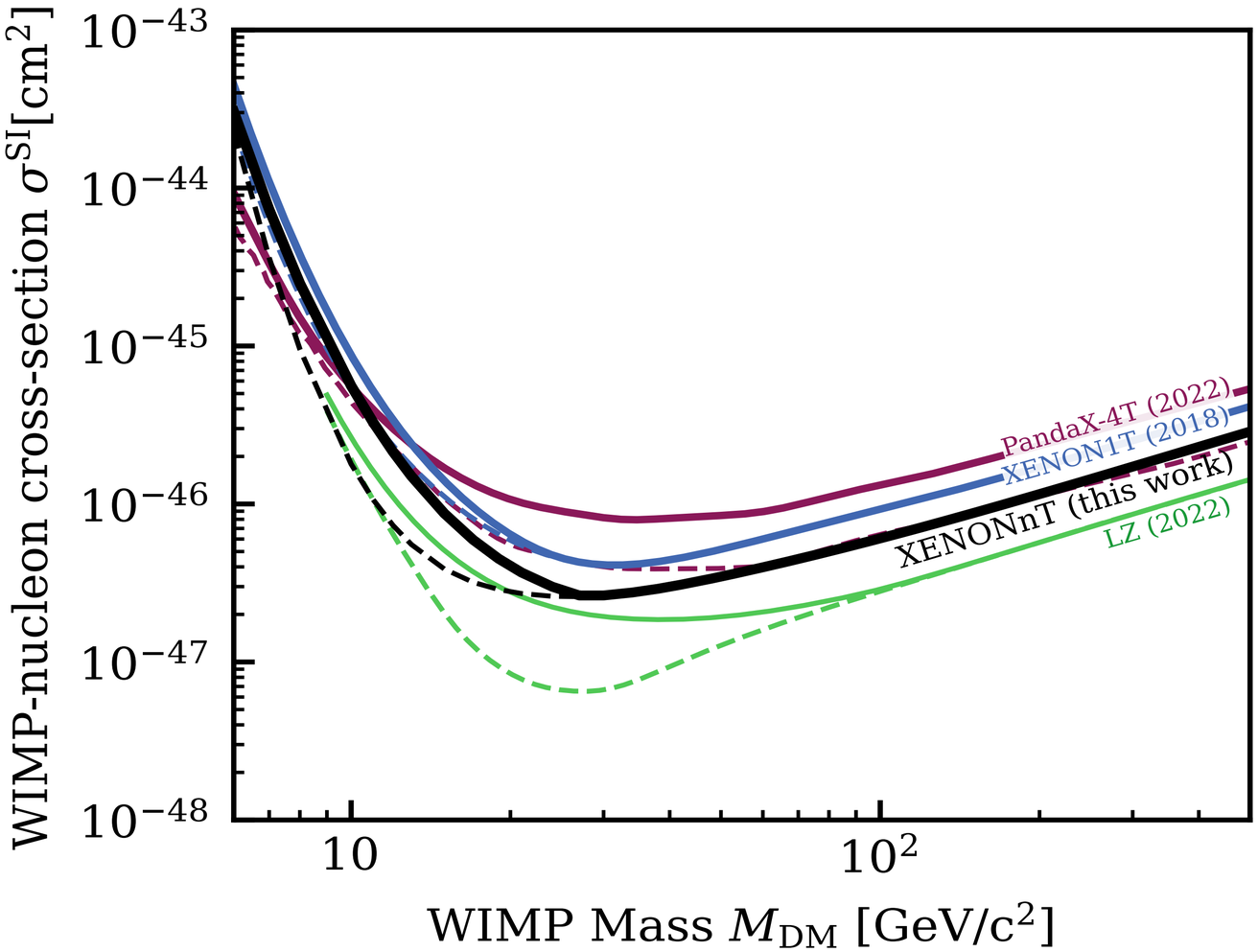
WIMP Spin-Independent Results

Same conservative power-constraint applied to results of other recent LXe experiments

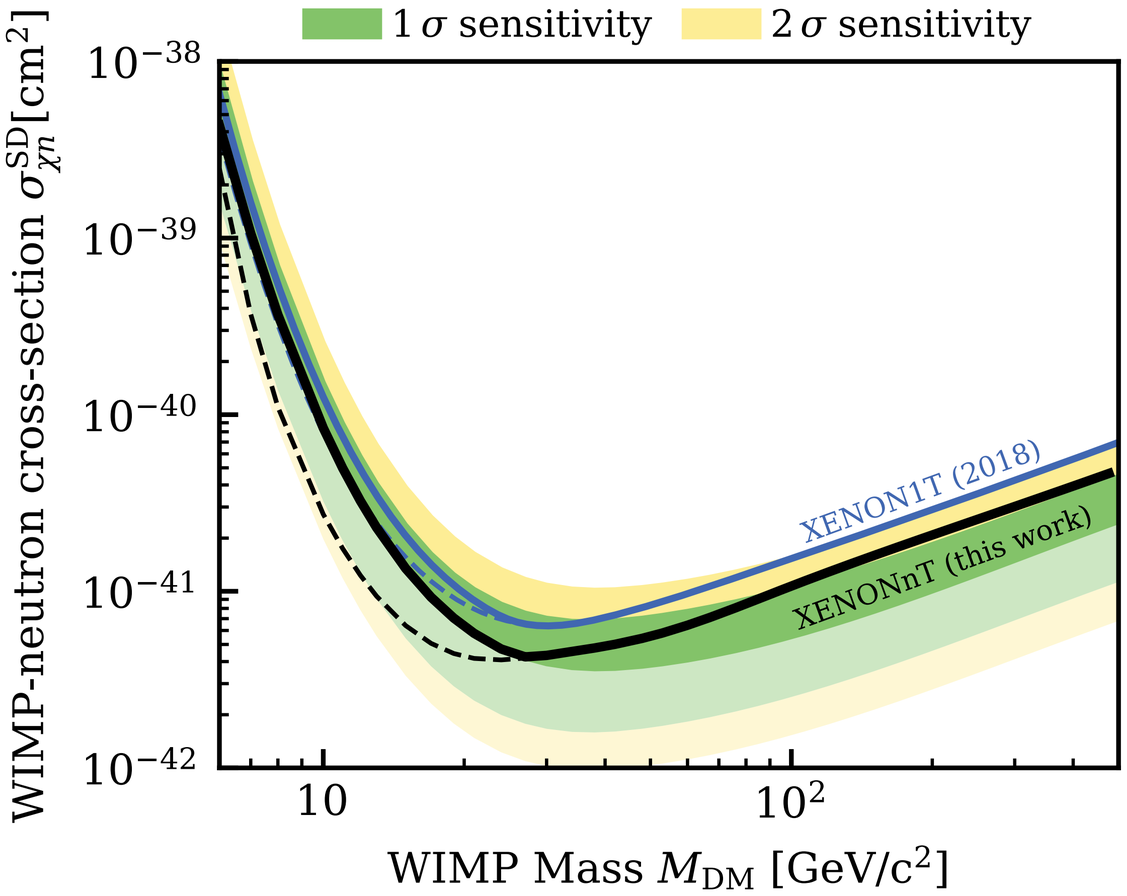


PandaX-4T, PRL 127, 261802 (2021)
XENON, PRL 121, 111302 (2018)
LZ, arXiv:2207.03764

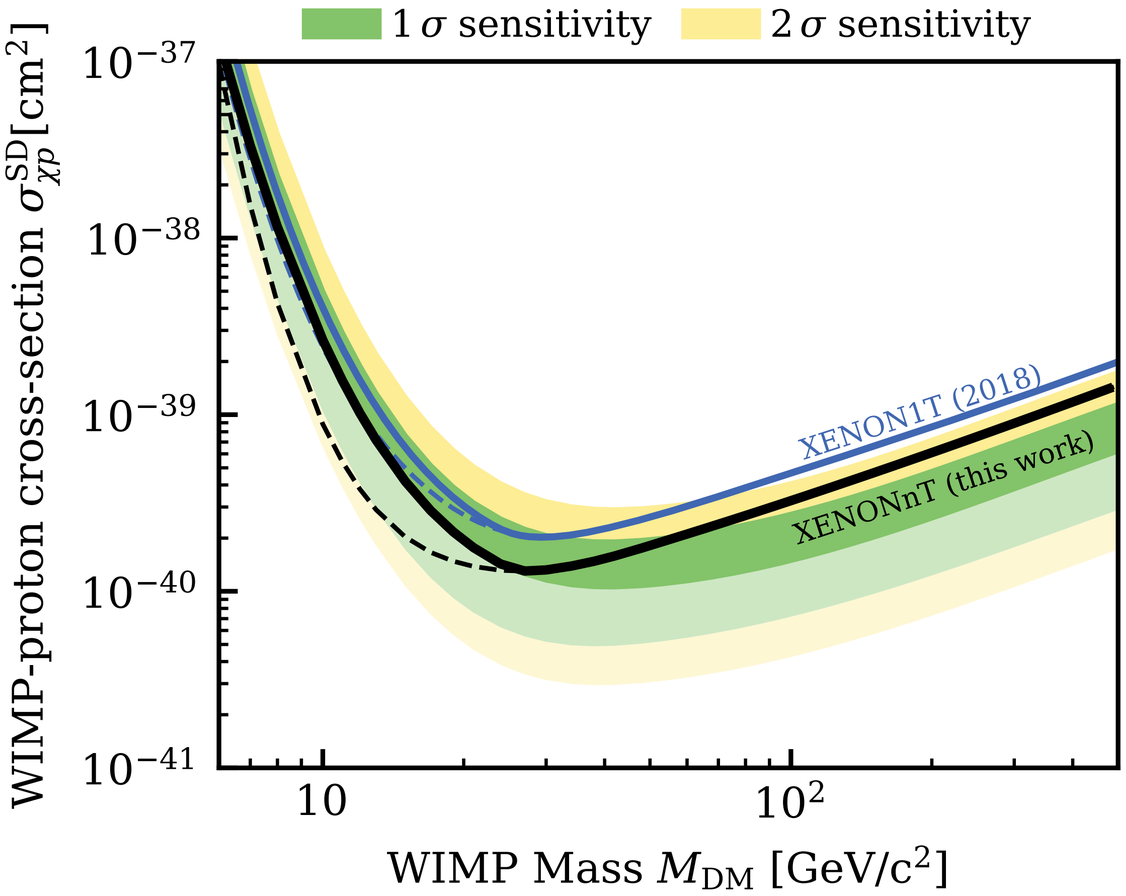
WIMP Spin-Dependent Results

Reinterpreting results as a purely spin-dependent coupling to ^{129}Xe and ^{131}Xe

WIMP - neutron coupling



WIMP - proton coupling



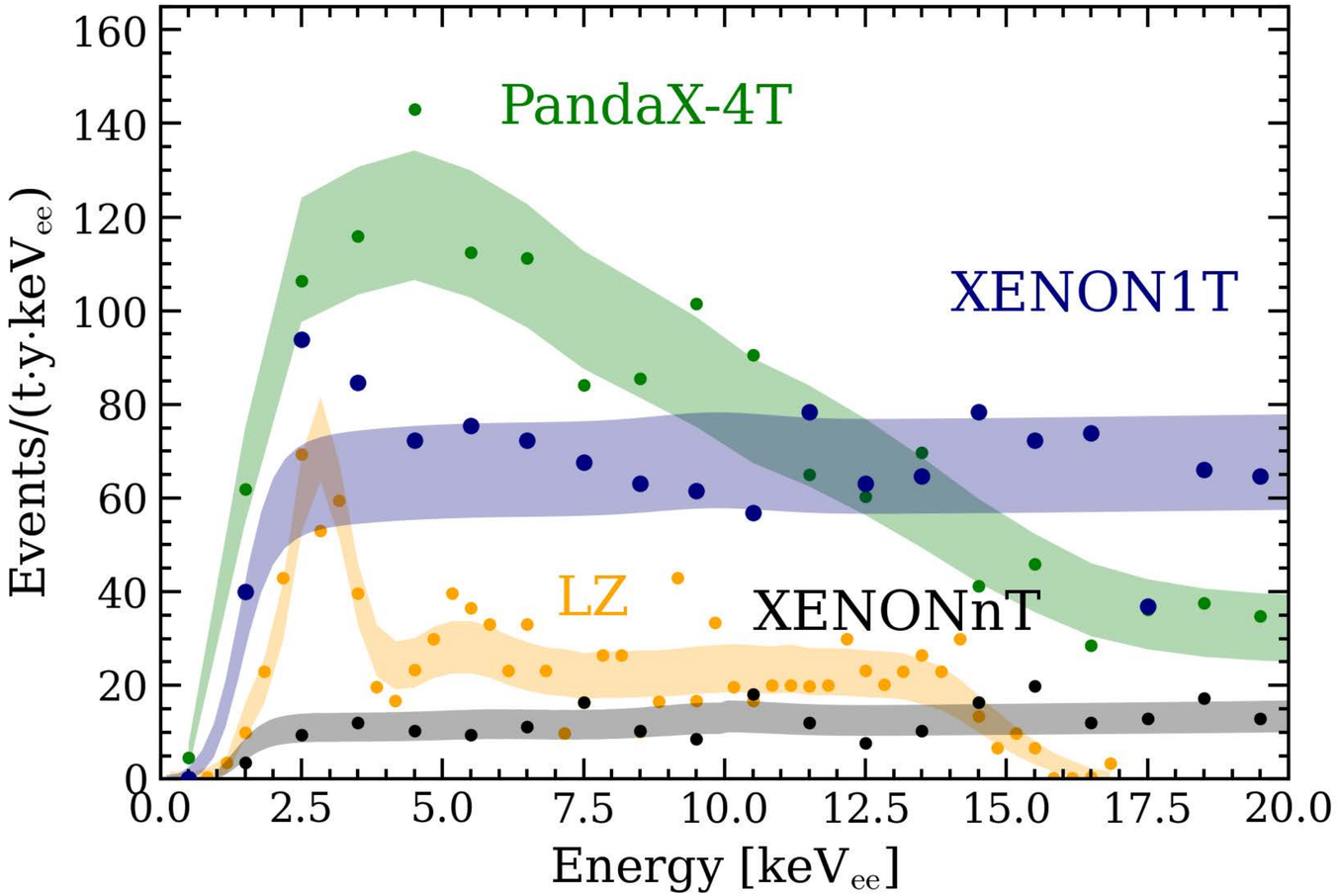
Conclusions

- Results from a blinded Dark Matter search with 1.1 tonne-year exposure
- Unprecedented low ER background rate of (15.8 ± 1.3) events / (keV × t × yr)
  - Further reduction with GXe + LXe radon distillation
- Spin-independent limit of 2.6×10^{-47} cm^2 (90% C.L.) at 28 GeV/c^2
- Data taking ongoing with improved ER background
- Neutron veto will be loaded with Gd-sulfate octahydrate to increase neutron detection efficiency

Paper to appear on arXiv and available at

https://xenonexperiment.org

ER Background Comparison



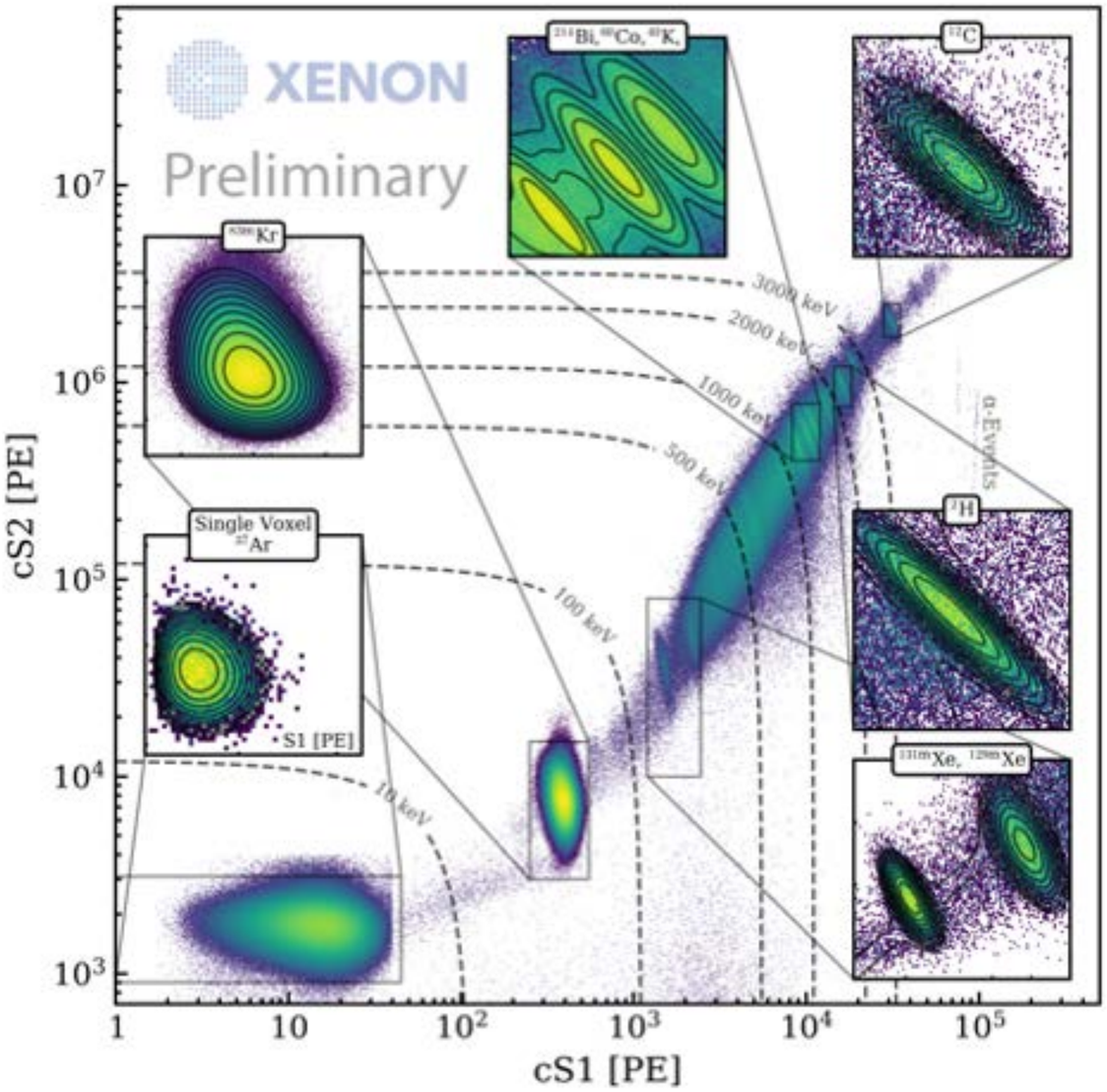
PandaX-4T PRL 129, 161804 (2022)

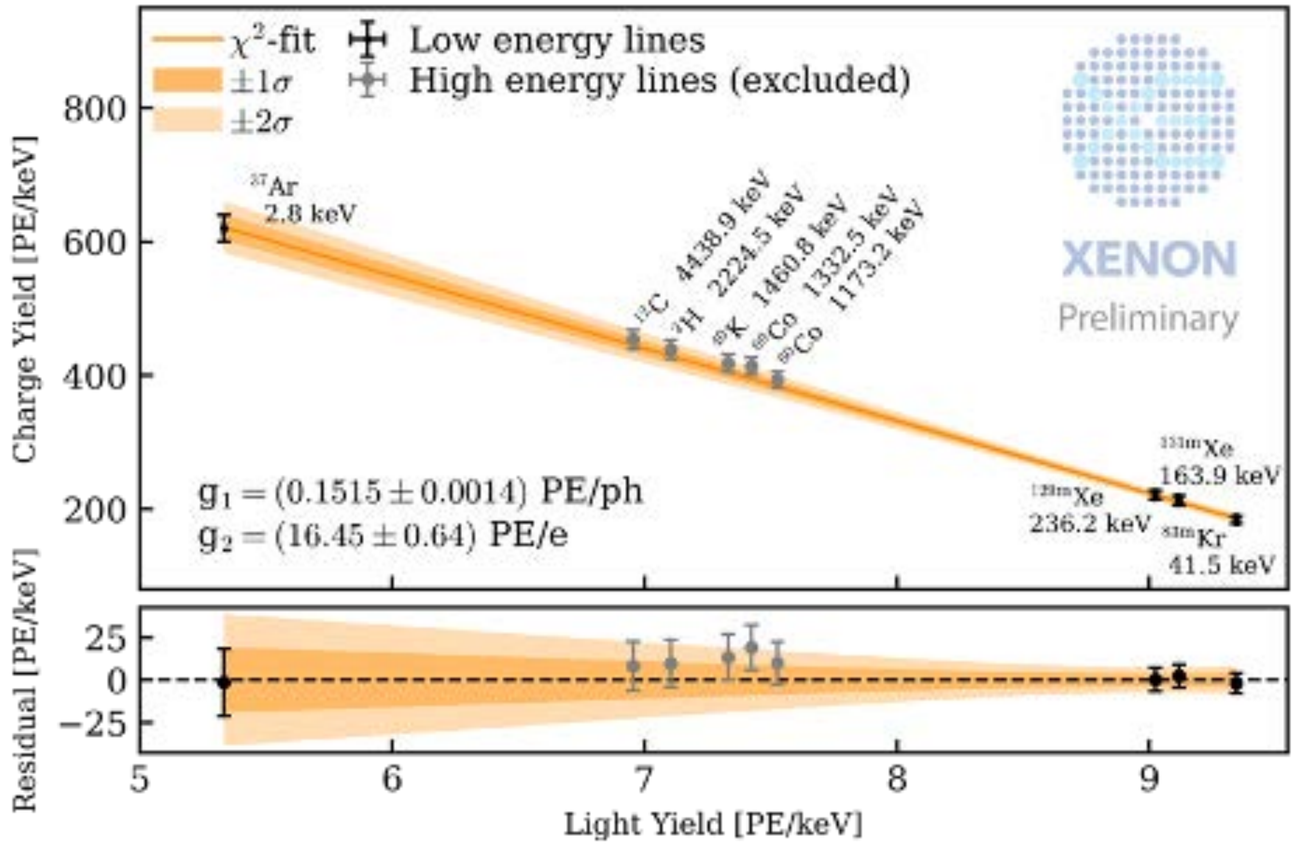
XENON1T PRD 102, 072004 (2020)

LZ arXiv:2207.03764

XENONnT PRL 129, 161805 (2022)

Energy scale in XENONnT





- Photon and electron gain g1/g2 used as prior in the LXe response model
- Energy scale important to make WIMP spectrum in S1-S2 space