

Search for dark matter interactions in a high nuclear-recoil energy window with LUX-ZEPLIN

arXiv:2609.02823 (2026)

Kelsey C Oliver-Mallory

On behalf of the LZ collaboration

Imperial College London

13 Nov 2026

DISCRETE 2026

LUX-ZEPLIN (LZ) collaboration



@lzdarkmatter

https://lz.lbl.gov/

39 institutions
~250 scientists, engineers, and technical staff

- Black Hills State University
- Brookhaven National Laboratory
- Brown University
- Center for Underground Physics
- Edinburgh University
- Fermi National Accelerator Lab.
- Imperial College London
- King's College London
- Lawrence Berkeley National Lab.
- Lawrence Livermore National Lab.
- LIP Coimbra
- Northwestern University
- Pennsylvania State University
- Purdue University
- Royal Holloway University of London
- SLAC National Accelerator Lab.
- South Dakota School of Mines & Tech
- South Dakota Science & Technology Authority
- STFC Rutherford Appleton Lab.
- Texas A&M University
- University of Albany, SUNY
- University of Alabama
- University of Bristol
- University College London
- University of California Berkeley
- University of California Davis
- University of California Los Angeles
- University of California Santa Barbara
- University of Liverpool
- University of Maryland
- University of Massachusetts, Amherst
- University of Michigan
- University of Oxford
- University of Rochester
- University of Sheffield
- University of Sydney
- University of Texas at Austin
- University of Wisconsin, Madison
- University of Zürich

US Europe Asia Oceania

Thanks to our sponsors and participating institutions!

Science and Technology Facilities Council

Swiss National Science Foundation

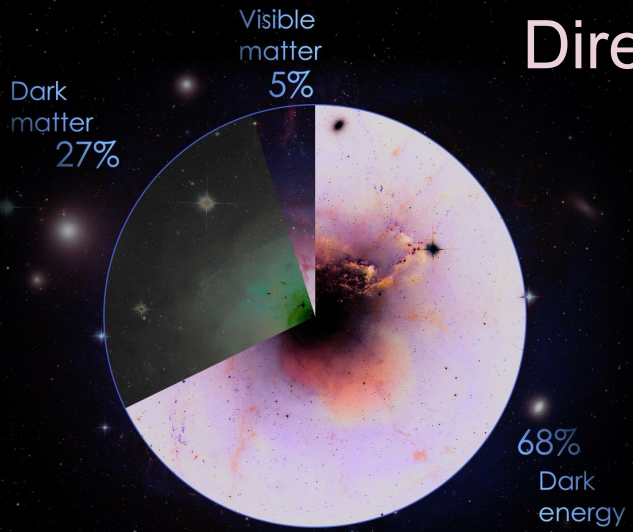
Fundação para a Ciência e a Tecnologia

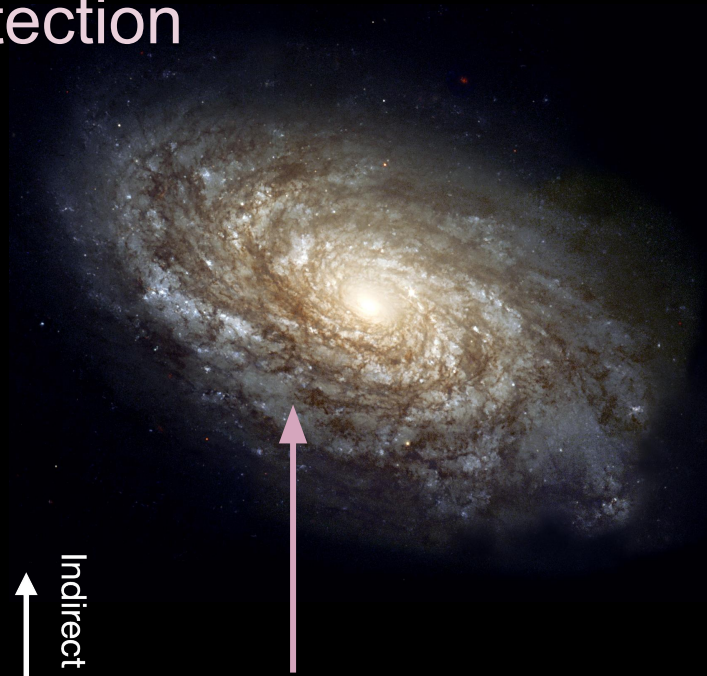
SANFORD UNDERGROUND RESEARCH FACILITY

Institute for Basic Science

ARC CENTRE OF EXCELLENCE FOR DARK MATTER PARTICLE PHYSICS

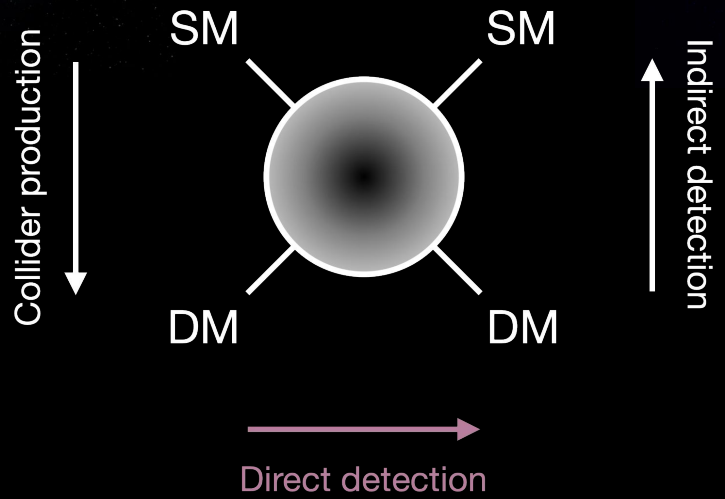
Direct dark matter detection



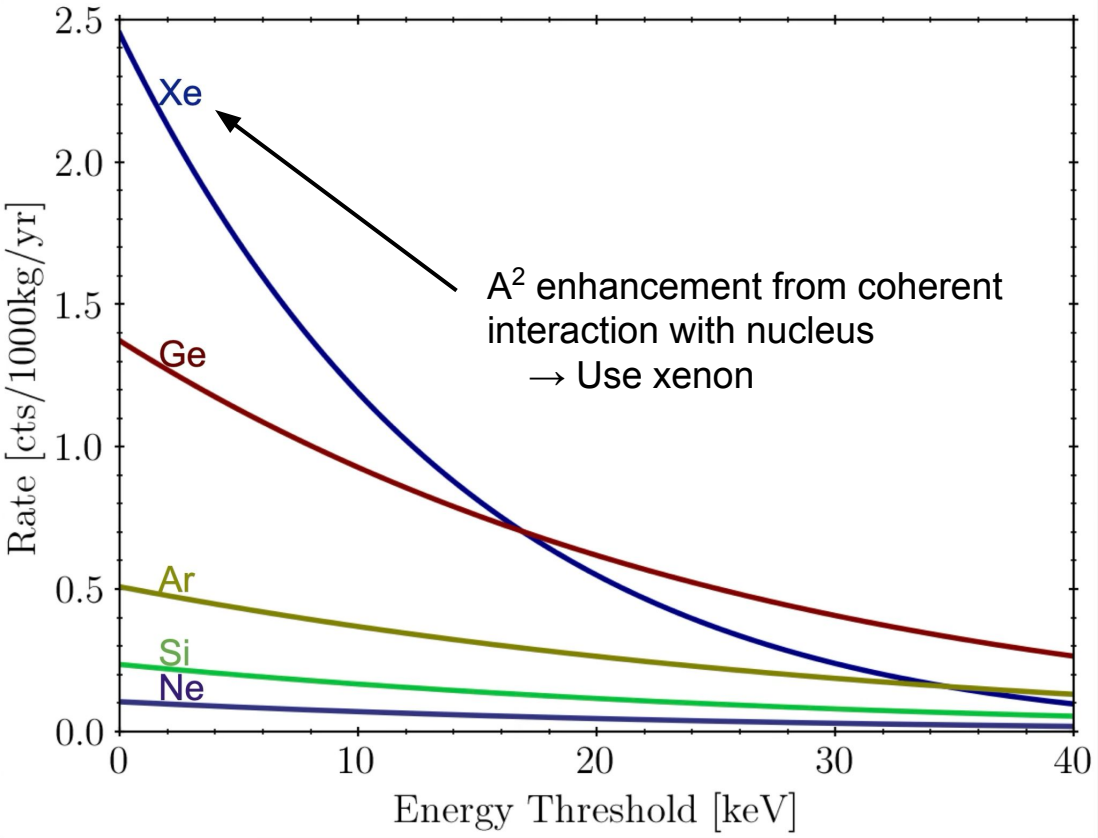


We are here

Estimate the local dark matter density (~0.3 GeV/cm3) and average velocity (~ 220 km/s)



Xenon: the ultimate WIMP target



WIMP dark matter – cosmologically well motivated through freeze out

Coherent elastic nuclear scattering rate
~ σ_{SI} A^2 F_{SI}^2

Low-energy nuclear recoils of a ~few-tens of keV

Looking for a few events per year per tonne of material!

→ Large detector
→ Low background rate
→ Low threshold

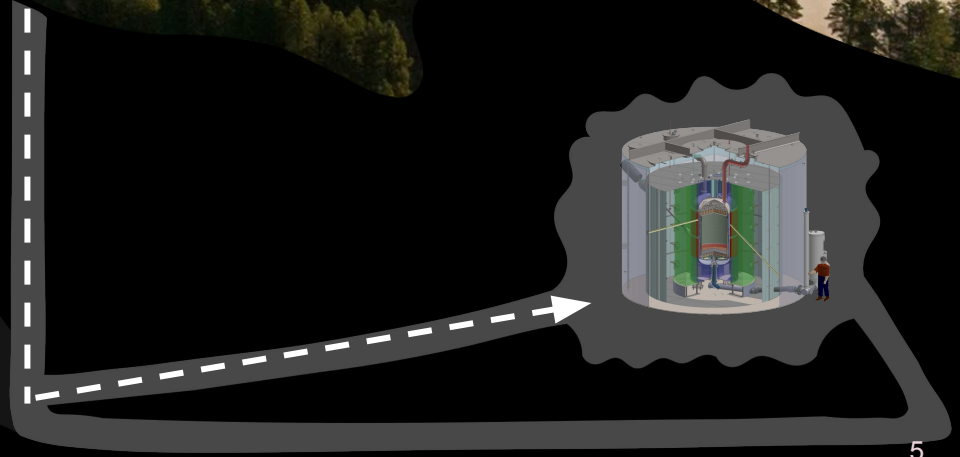
Sanford Underground Research Facility

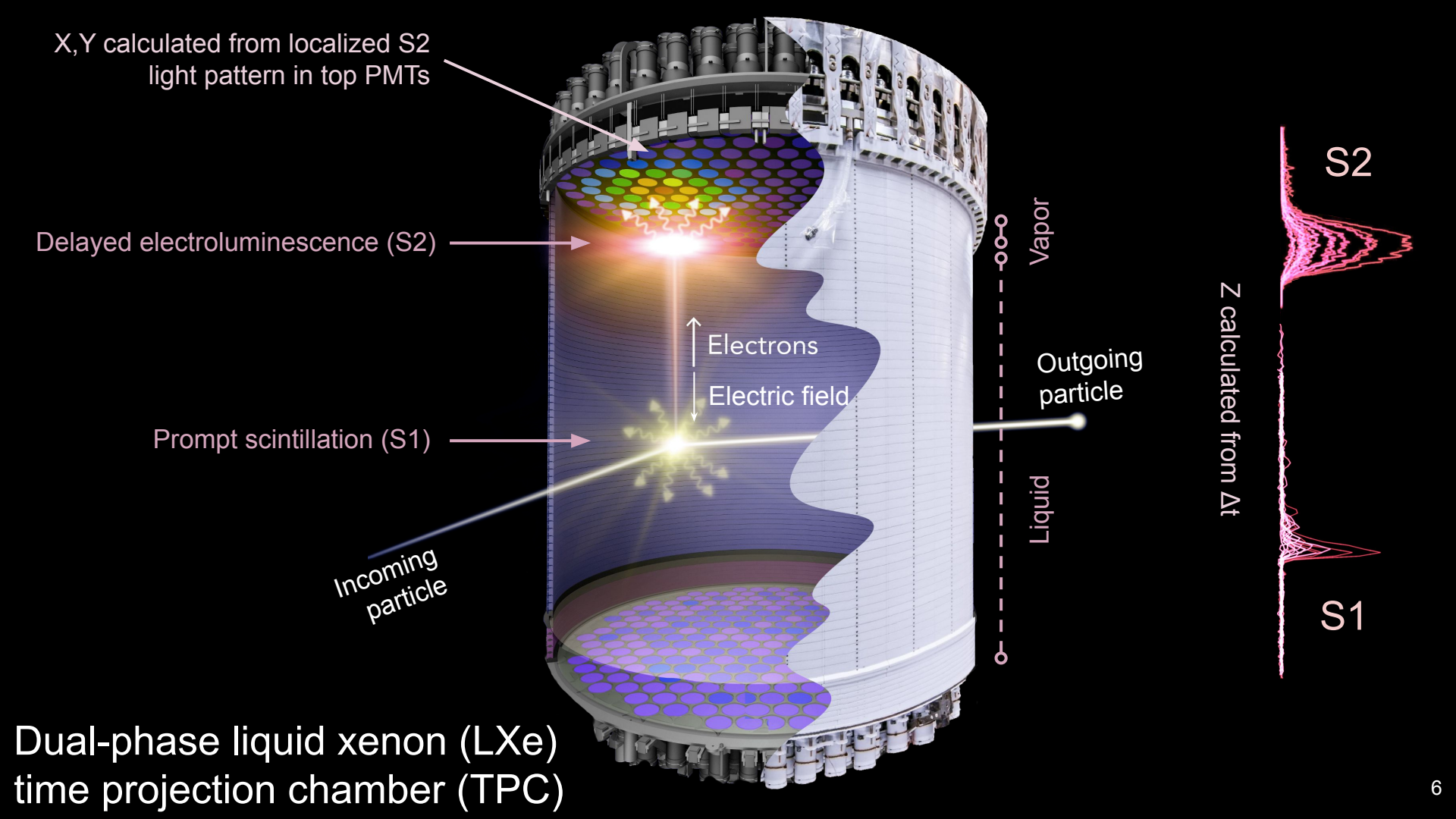
In South Dakota

Located at former Homestake Mine

4850 ft underground (4300 m.w.e)

Reduce muon rate $O(10^{-6})$

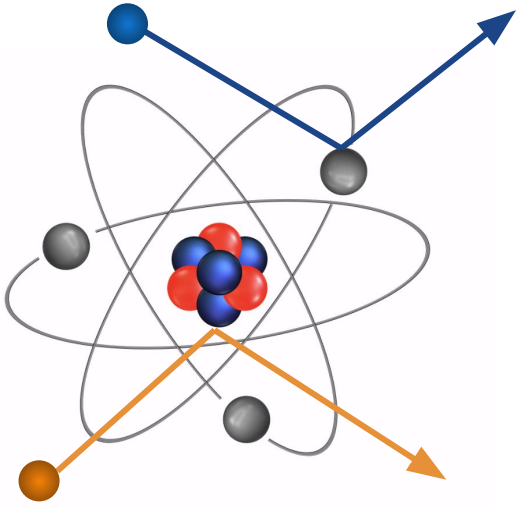


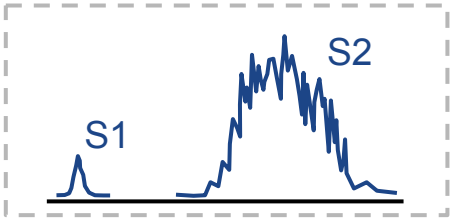


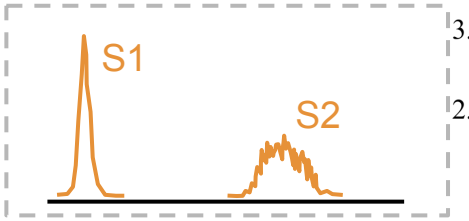
Dual-phase liquid xenon (LXe) time projection chamber (TPC)

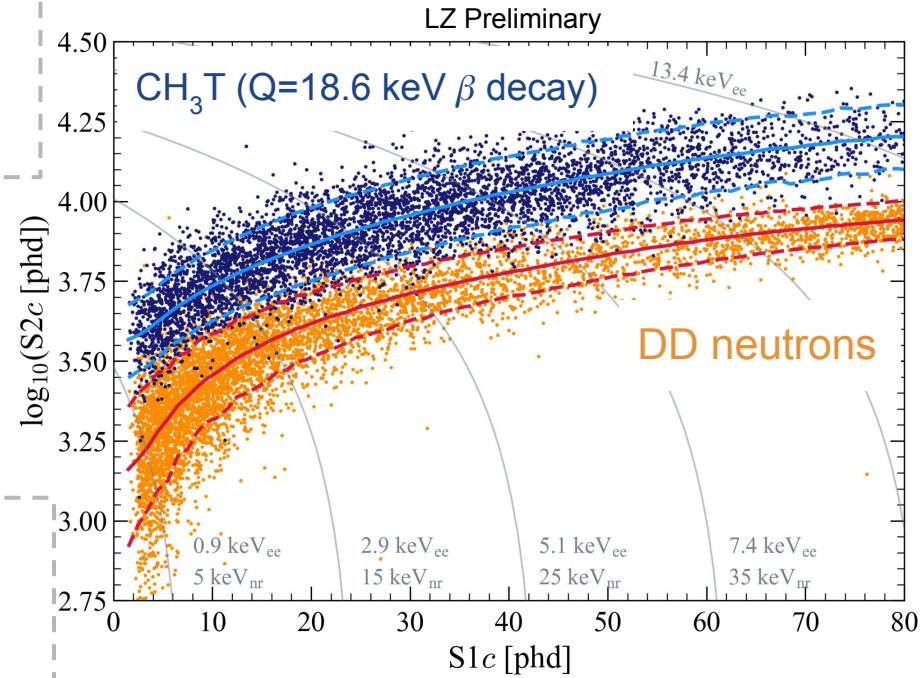
Electron/nuclear recoil discrimination

Electron recoil (ER):
γ/β backgrounds &
ν-electron scattering









Nuclear recoils (NR): dark matter, coherent-elastic neutrino-nucleus scattering (CEvNS), & neutron backgrounds

LZ detector

LXe-TPC to detect dark matter (1.5x1.5 meters, 7 tonnes)

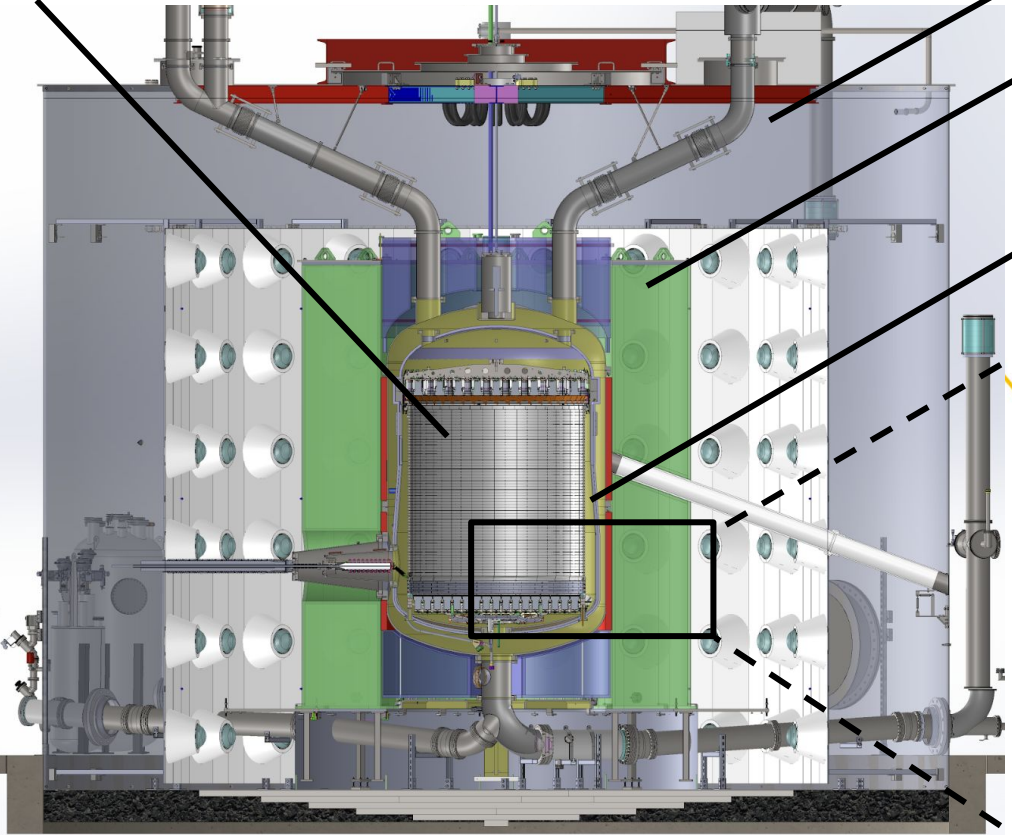
High-purity water as passive shielding

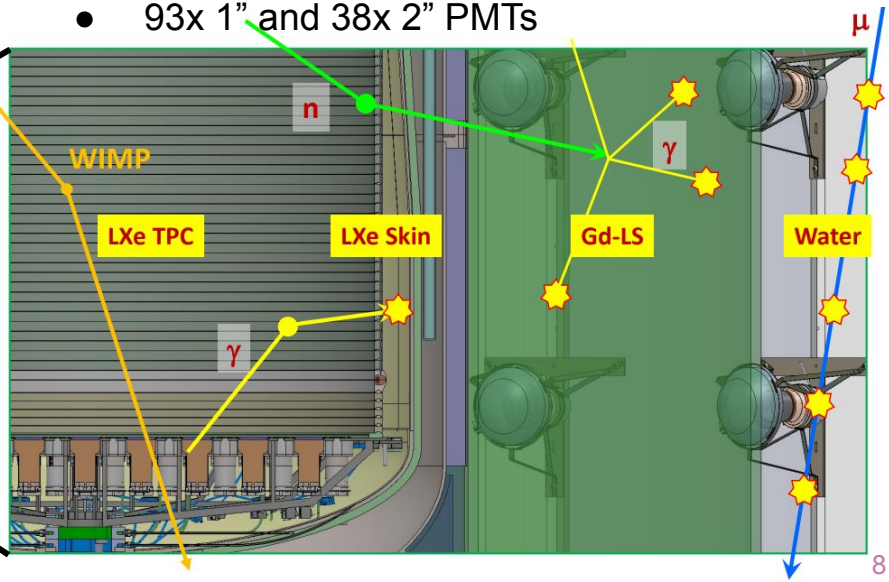
Outer detector (OD) to veto neutrons

- 17 tonne gadolinium loaded liquid scintillator
- 120x 8” photomultiplier tubes (PMTs)

Skin detector to veto gamma rays

- 2 tonne liquid xenon
- 93x 1” and 38x 2” PMTs





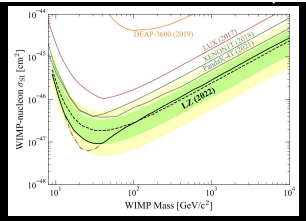
LZ collaboration, Nuc. Inst. Meth. A, **953**, 163047 (2020)

Timeline of LZ science



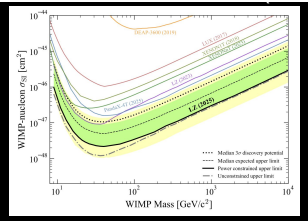
Commissioning begins

Phys. Rev. Lett. **131**, 041002 (2023)



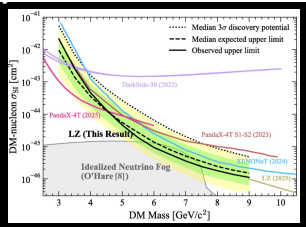
First WIMP search result (WS2022)
60 livedays

Phys. Rev. Lett. **135**, 011802 (2025)



Second WIMP search result (WS2024)
60+ 220 = 280 livedays

Phys. Rev. Lett. 137, 091806 (2026))



Light DM & solar ^{8}B CEvNS (WS2025)
220 + 197 = 417 livedays

arXiv:2609.02823 (2026)

Higher energy (EFT2024)
220 livedays

2021 2022 2023 2024 2025 2026 2027

60 livedays

220 livedays

197 livedays

Continued data collection

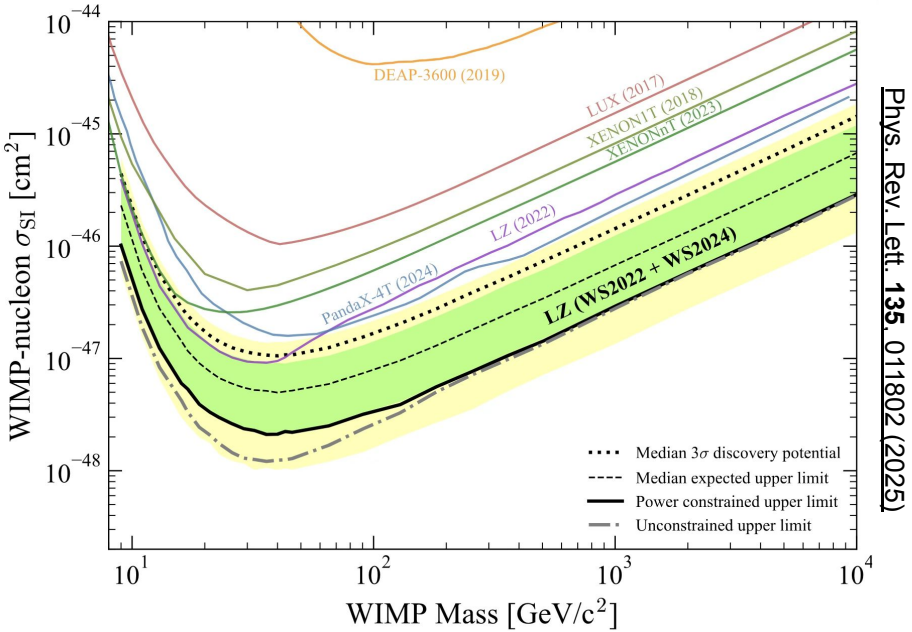
Going to higher energies

World leading exclusion limits!

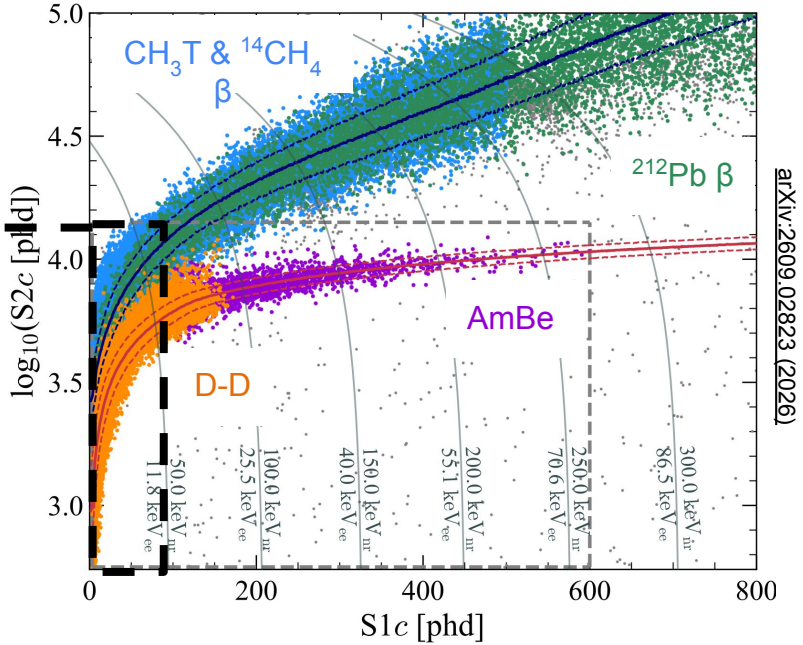
Coherent elastic dark matter–nucleus scattering (<55 keV_{nr})

Search region motivated by vanishing nuclear form factor at high recoil energies

Now exploring higher recoil energies (<270 keV_{nr})



Phys. Rev. Lett. **135**, 011802 (2025)



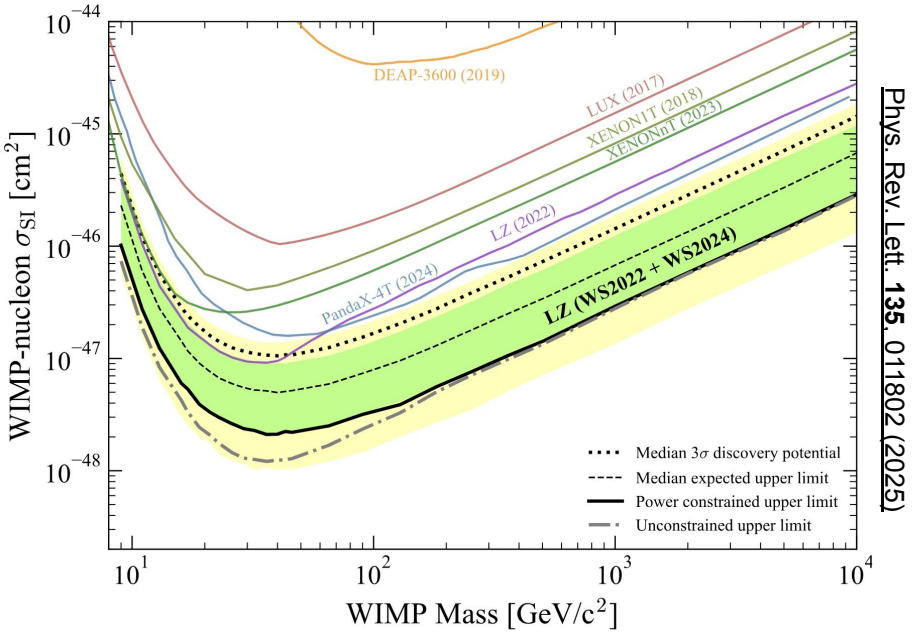
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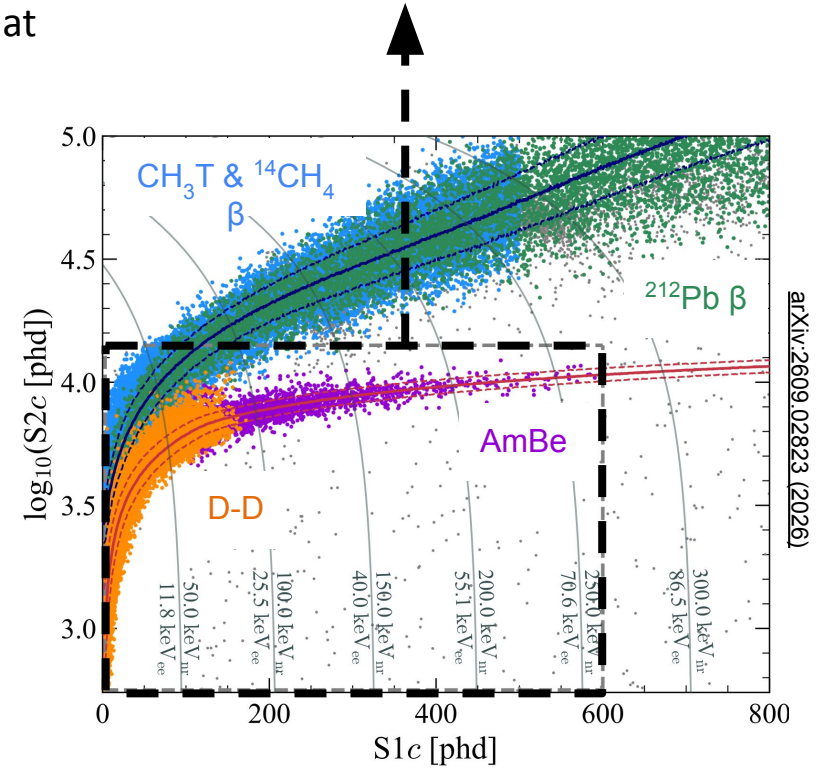
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Phys. Rev. Lett. **135**, 011802 (2025)

Now exploring higher recoil energy window (<270 keV_{nr})



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Interactions at higher energies

Dark matter scattering interactions with:

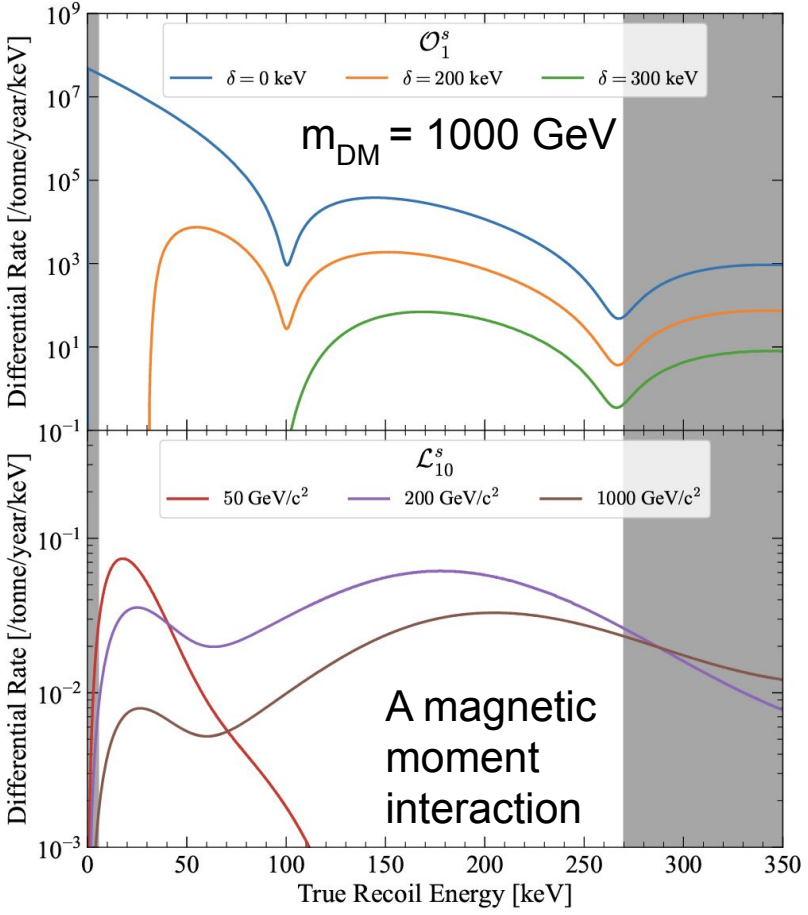
- Momentum-dependent coupling
- Nearly degenerate mass states, separated by δ (i.e. inelastic scattering)

$$v_{min} = \frac{1}{\sqrt{2E_R m_N}}\left(\frac{E_R m_N}{\mu} + \delta\right)$$

We perform a search for:

1. Non-relativistic effective field theory (EFT) $\mathcal{L}_1 - \mathcal{L}_{20}$
2. Inelastic SI($\mathcal{O}_1$) + inelastic SD($\mathcal{O}_4$)

Total of 616 models



arXiv:2609.02823 (2026)

Backgrounds

Electron recoils

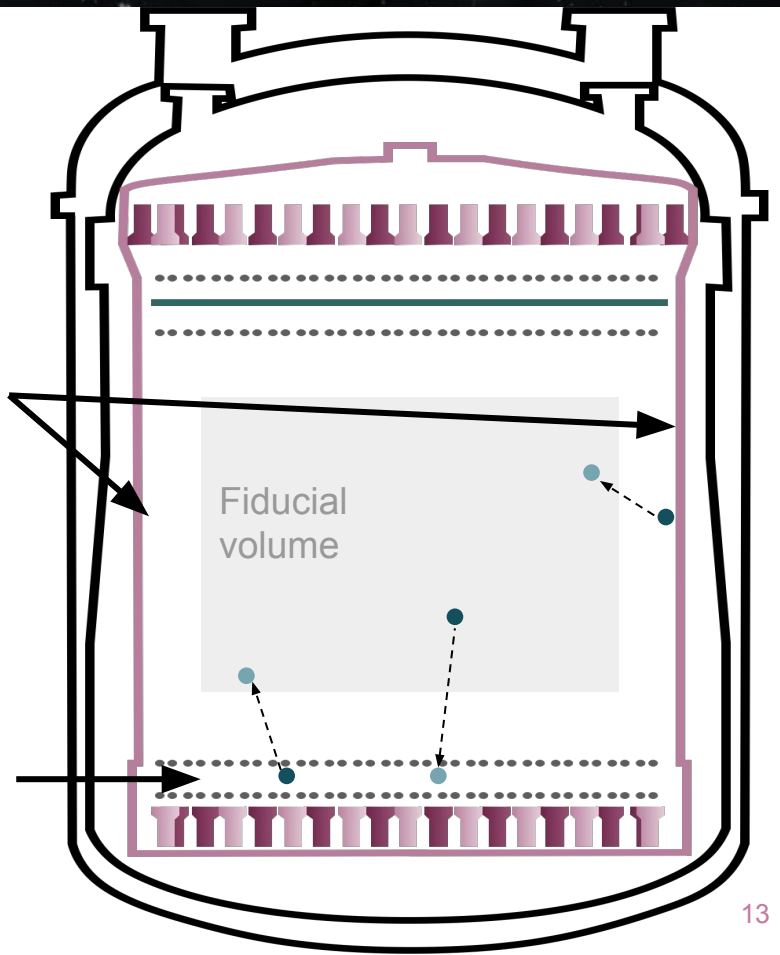
- Primarily ^{214}Pb β decays in the liquid xenon
- Suppressed by strong ER/NR discrimination at high energies

Nuclear recoils

1. Astrophysical neutrinos
2. Neutrons

NR-like events from detector effects

3. Multiple-scintillation single-ionisation (MSSI) events
   - γ rays from detector components
   - ^{214}Pb β decay + IT with γ-ray emission (352, 839, ... keV)
4. Accidental coincidences of lone S1s & S2s



Backgrounds

S1s & S2s from elevated photon & electron rates following previous interactions

Electron recoils

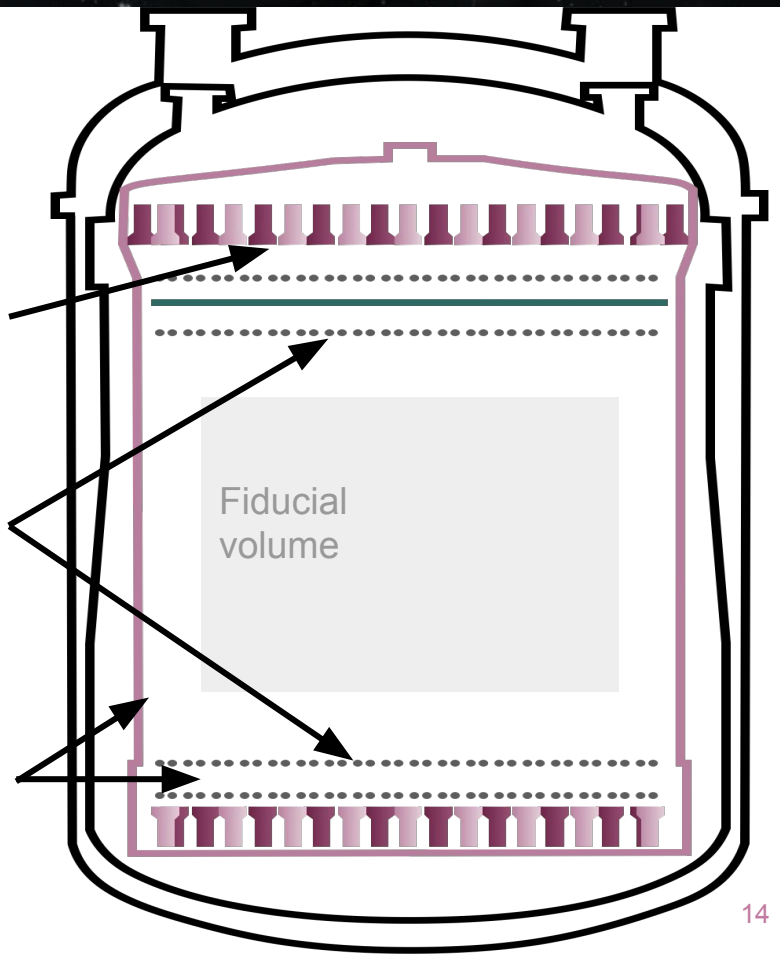
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Data quality

Data quality cuts

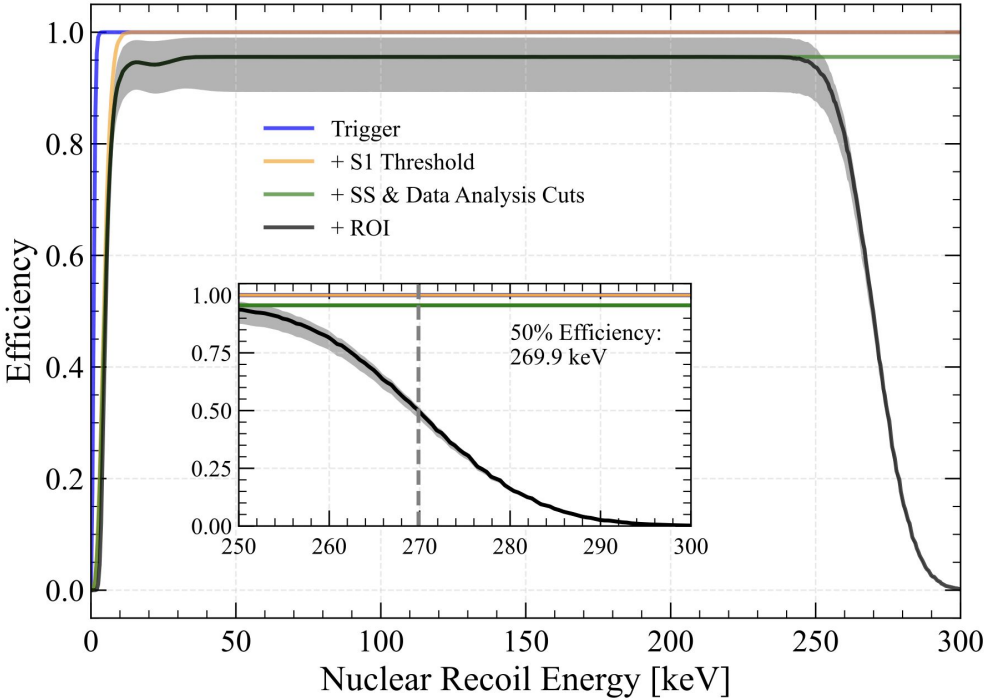
- Remove unphysical S1 & S2 waveforms
- Signal acceptance calculated from AmBe calibration data

Time exclusions

- Periods of high event rate
- Periods of detector instability

Region of interest

- Box in S1-S2 space surrounding the nuclear recoil band



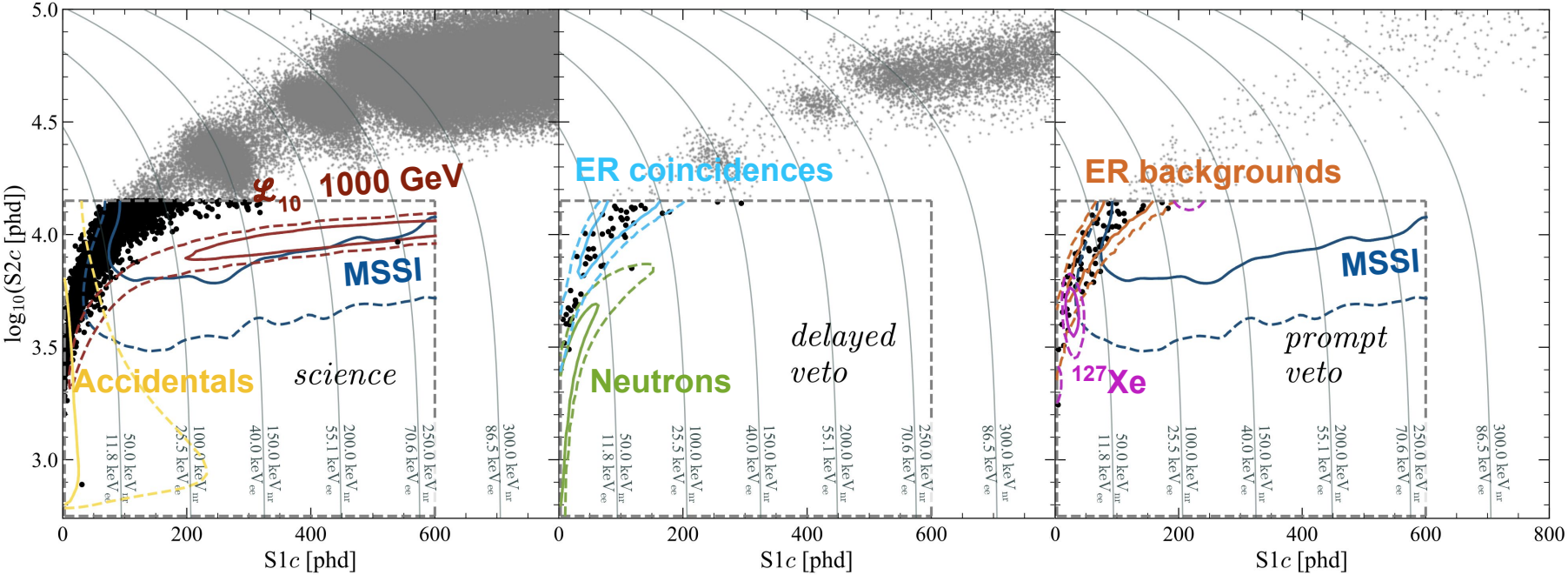
arXiv:2609.02823 (2026)

Data

No veto signal

Delayed veto

Prompt veto

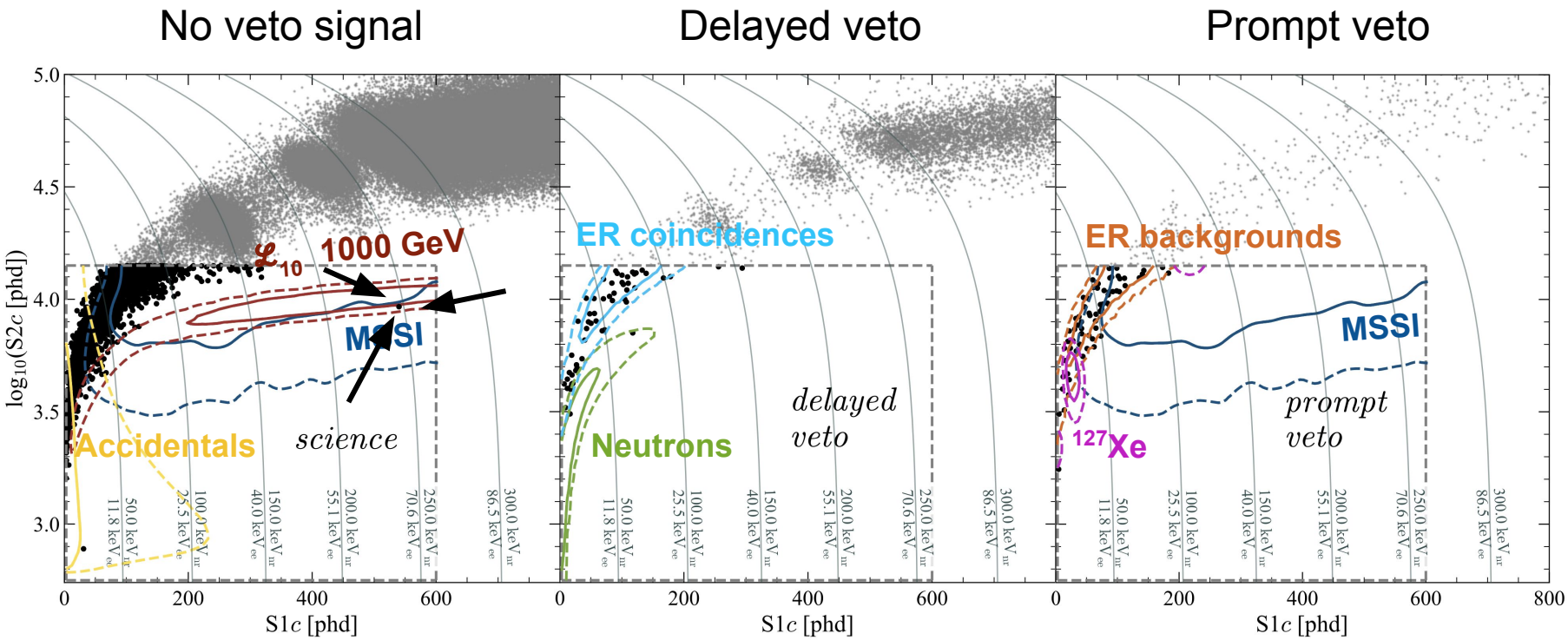


arXiv:2609.02823 (2026)

Skin signal > 300 keV or OD signal > 200 keV within 600 μs of S1

Skin signal > 2.5 phd or OD signal > 4.5 phd within ±0.25 or ±0.3 μs of S1, respectively

Data



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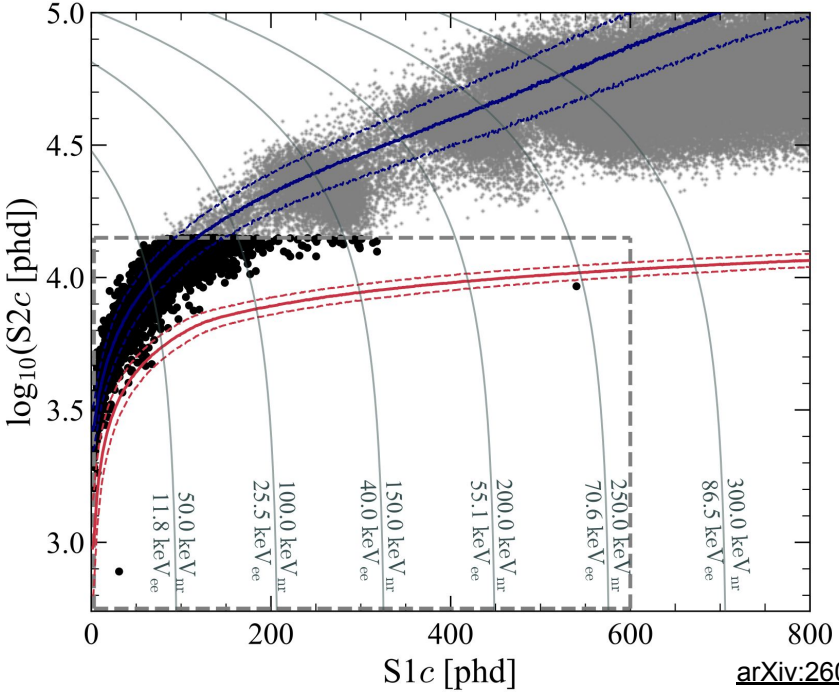
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A single event - LZ230616

Occurred on 16 June 2023

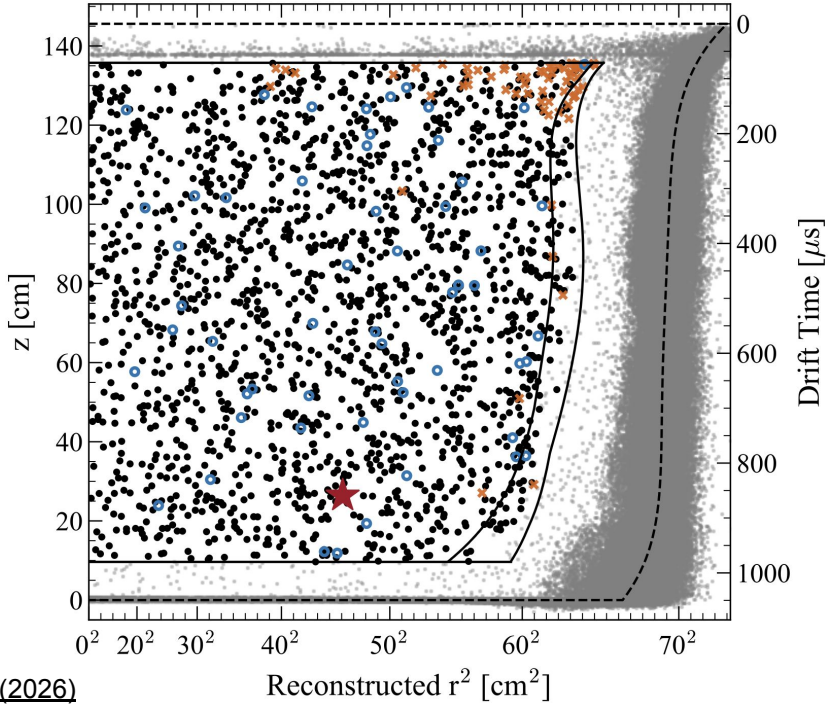
Compatible with 248 ± 23 ± 23 keV elastic nuclear recoil

1.6σ from centre of NR band



26.4 cm from cathode

26.9 cm from wall



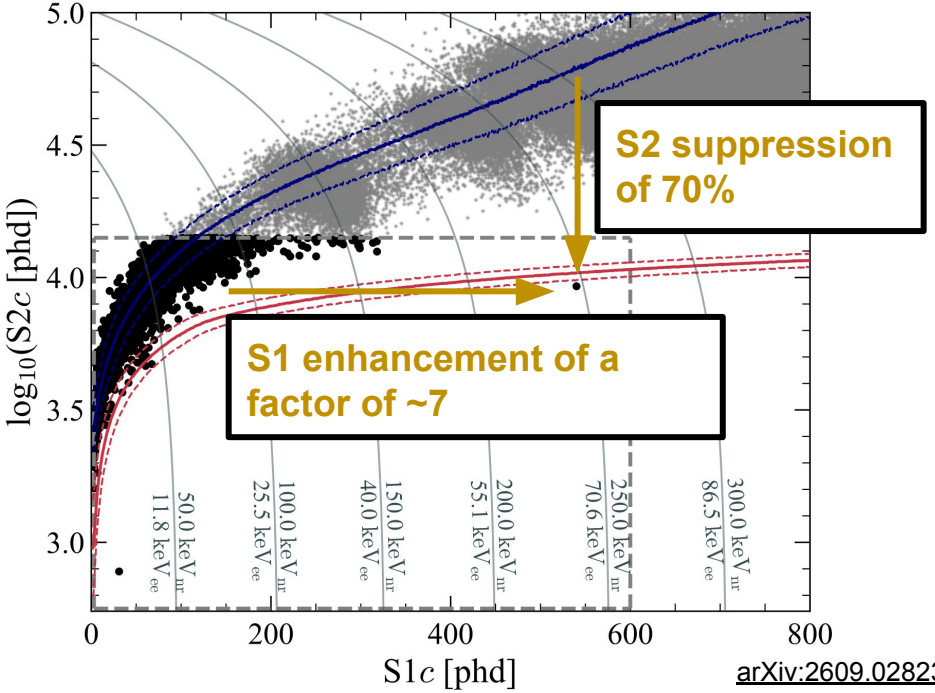
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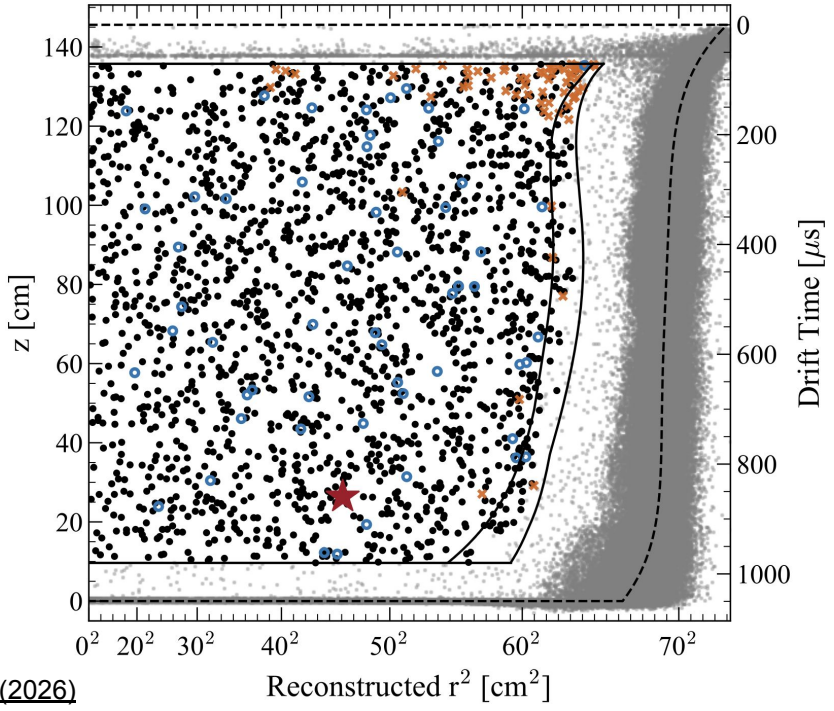
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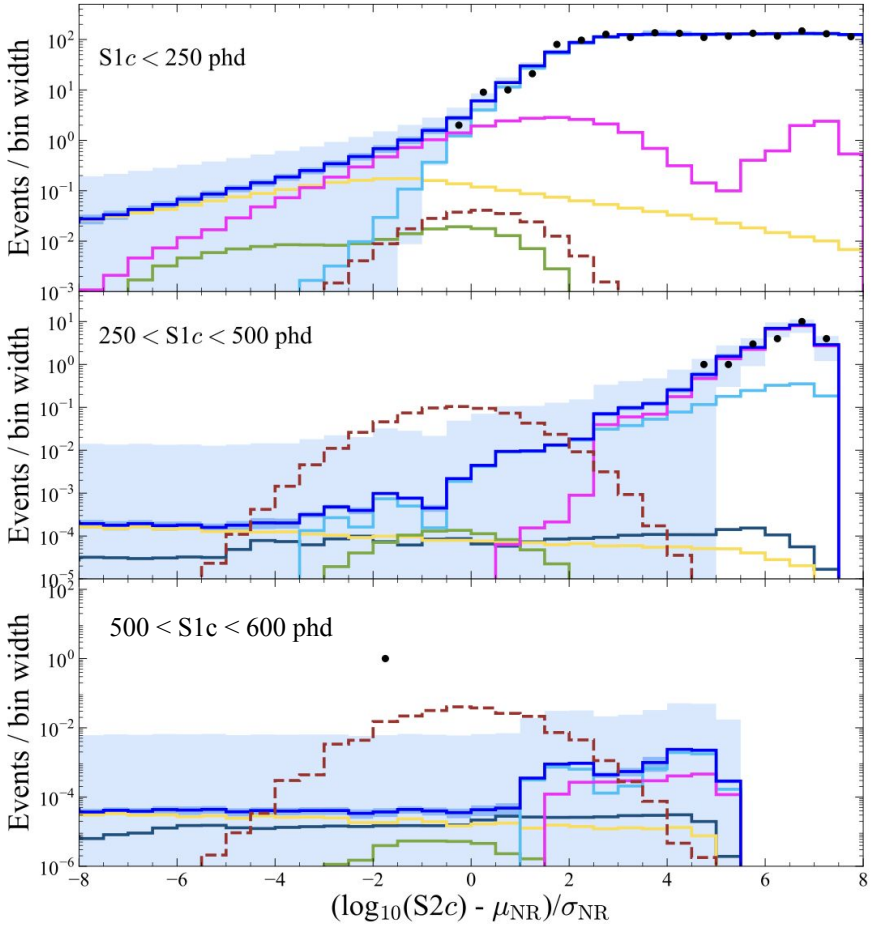


arXiv:2609.02823 (2026)

Comparison with background model

Projections of background model along NR band mean

Integrated background count in 500 < S1c < 600 region is 0.0106 ± 0.0008 sys

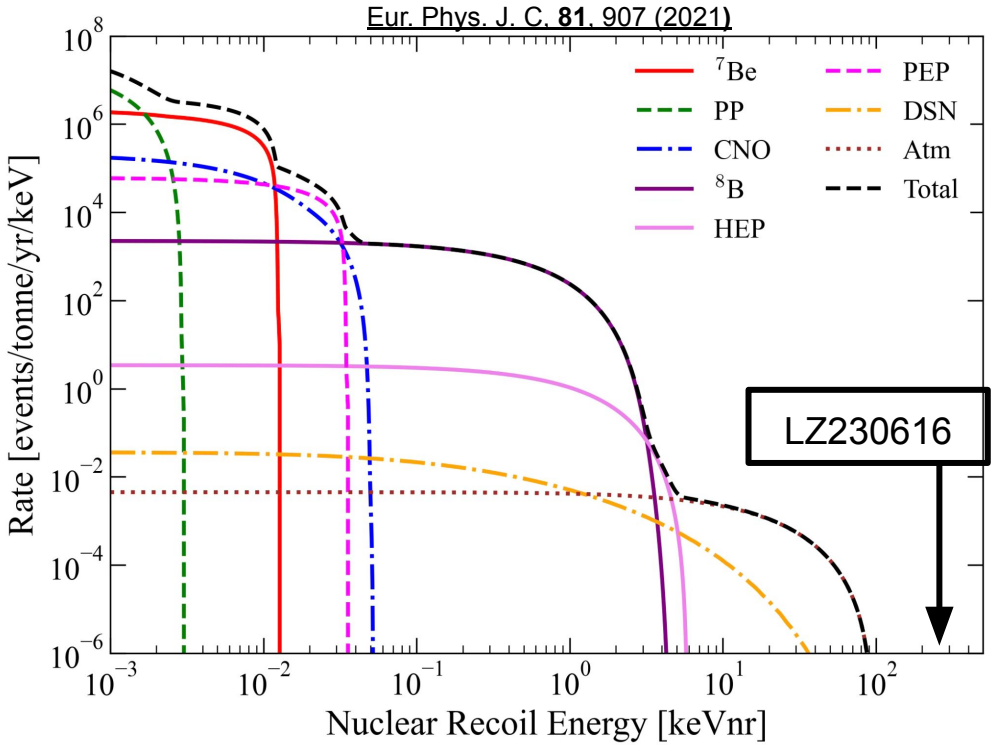


arXiv:2609.02823 (2026)

Potential background origins

1. Astrophysical neutrinos
2. Neutrons
3. Multiple-scintillation single-ionisation (MSSI) events events
4. Accidental coincidences of lone S1s & S2s

Event in very low probability region



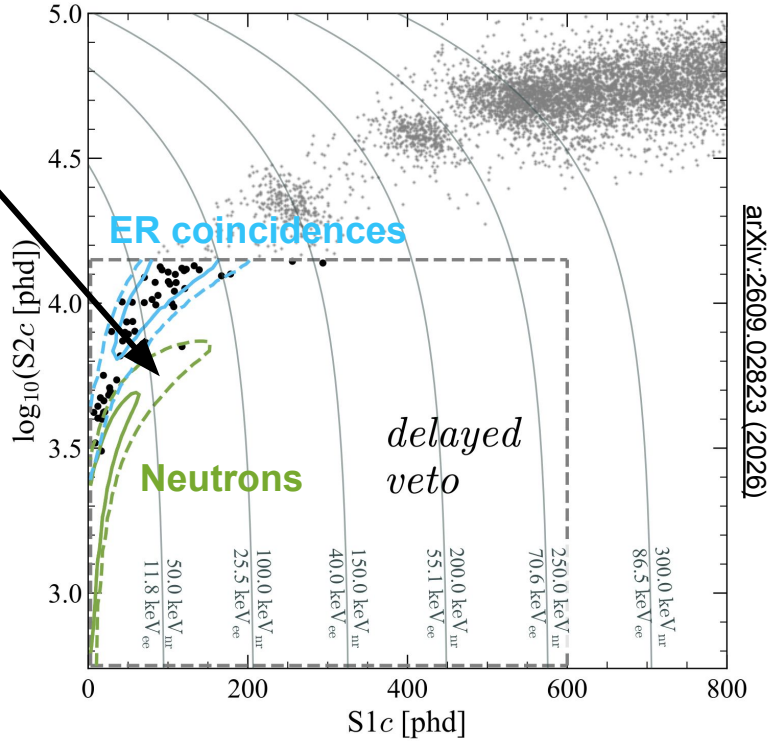
Potential background origins

1. Astrophysical neutrinos
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92% tagging efficiency

Highly unlikely to see untagged neutron given only one tagged neutron

Delayed veto



arXiv:2609.02823 (2026)

Potential background origins

1. Astrophysi

2. Neutrons

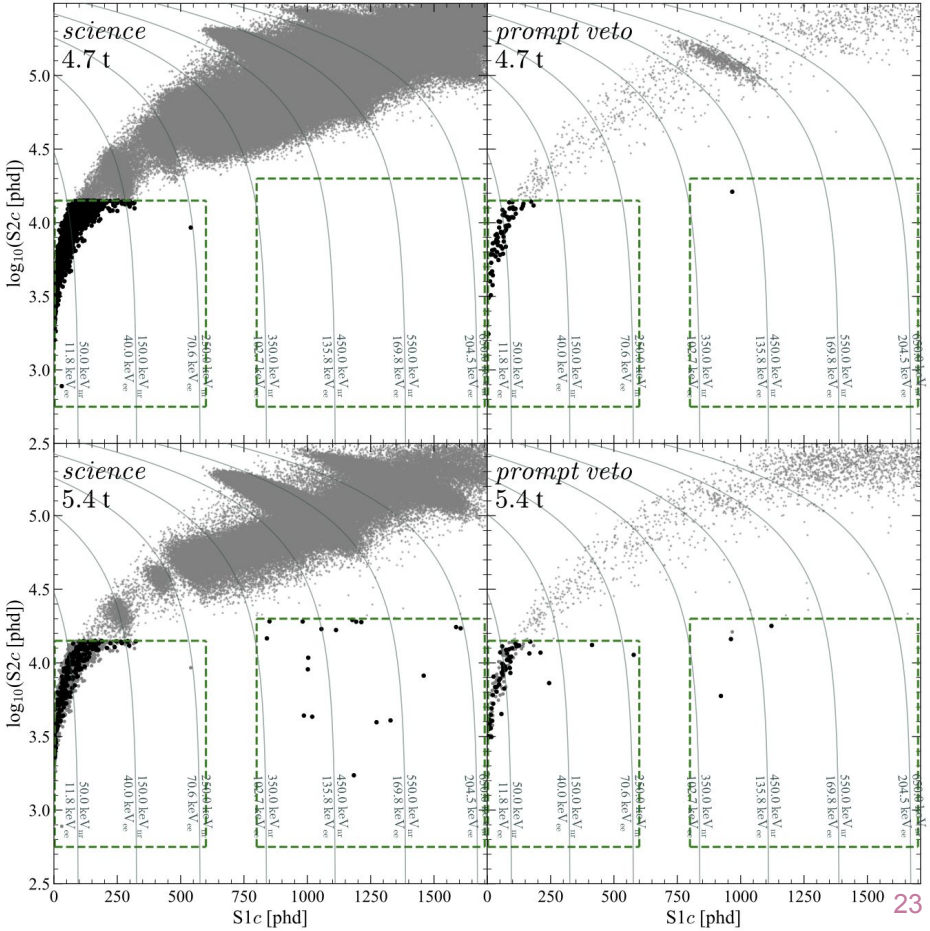
Rate derived from simulation

Validated data at high-energies and outside fiducial volume

Predict 0.0049 ± 0.0049 events in science dataset

3. Multiple-scintillation single-ionisation (MSSI) events

4. Accidental coincidences of lone S1s & S2s



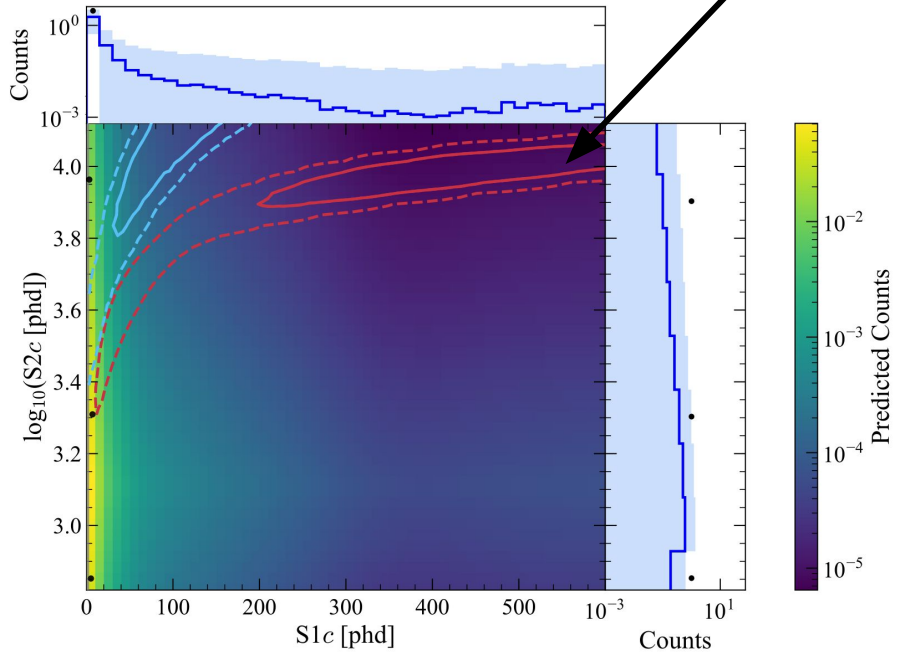
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Empirical model developed from unphysical drift time events

Expect 2.7 ± 0.6 events in entire model space

Event in very low probability region

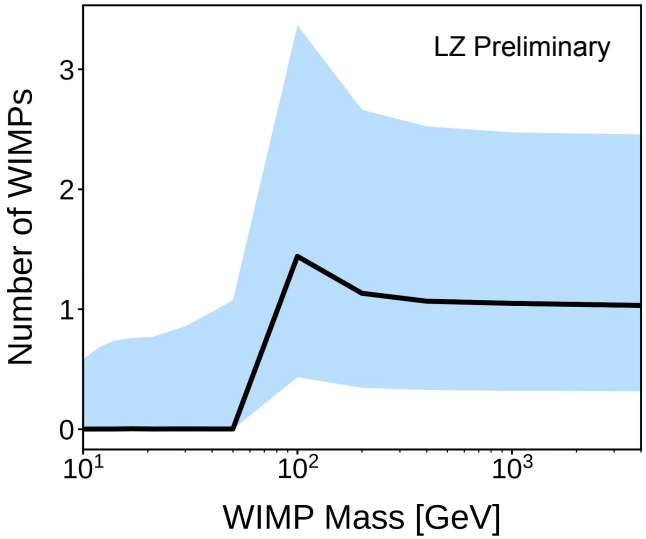


$\mathcal{L}^{S}_{10}$ fit result

Science, delayed veto, and prompt veto datasets are fit simultaneously

Best fit number of WIMPs for $\mathcal{L}^{S}_{10}$ is 1 for masses > 100 GeV

Similar trend for all signal models



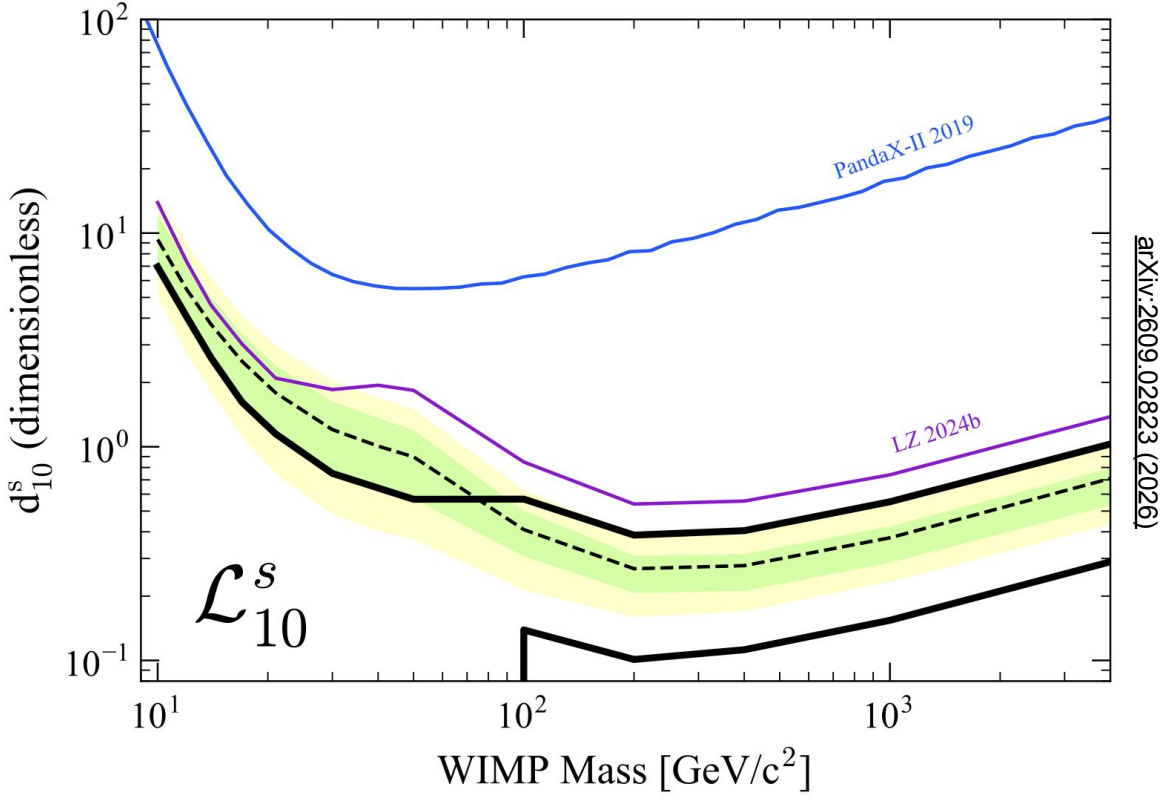
Source	Expected Events	Fit Result
Internal β decays	1341 ± 160	1340 ± 43
ν ER	140.6 ± 8.4	140.3 ± 8.4
^{136}Xe	110.0 ± 16.5	114.2 ± 16.1
CH_3T & ^{14}C	55.3 ± 3.1	55.2 ± 3.1
^{124}Xe	21.0 ± 6.3	22.6 ± 5.0
^{83m}Kr	17.1 ± 5.1	$17.0^{+3.5}_{-3.3}$
^{125}I	8.9 ± 2.7	9.8 ± 2.3
Detector ERs	8.5 ± 3.4	$9.4^{+1.7}_{-1.6}$
Accidental coincs.	2.7 ± 0.6	2.6 ± 0.6
^{127}Xe + ^{125}Xe	1.5 ± 0.3	1.2 ± 0.3
Atmospheric ν	$(1.1 \pm 0.2) \times 10^{-1}$	$(1.1 \pm 0.2) \times 10^{-1}$
^{8}B+*hep* ν	$(5.7 \pm 0.6) \times 10^{-2}$	$(5.7 \pm 0.6) \times 10^{-2}$
MSSI	$(4.9 \pm 4.9) \times 10^{-3}$	$(4.6^{+4.8}_{-4.6}) \times 10^{-3}$
Detector NRs	–	$[0, 0.118]$
$\mathcal{L}^{s}_{10}$ (1000 GeV/c^2)	–	$1.0^{+1.4}_{-0.7}$
Total counts	–	1713 ± 39
Observed counts	–	1710

Limit

90% upper and lower CL intervals on all models probed

- $\mathcal{L}_1 - \mathcal{L}_{20}$
- Inelastic SI($\mathcal{O}_1$) + inelastic SD($\mathcal{O}_4$) up to δ = 350keV
- Isoscalar, isovector basis

Full results to be provided in future data release



Significance + look elsewhere effect

616 models tested

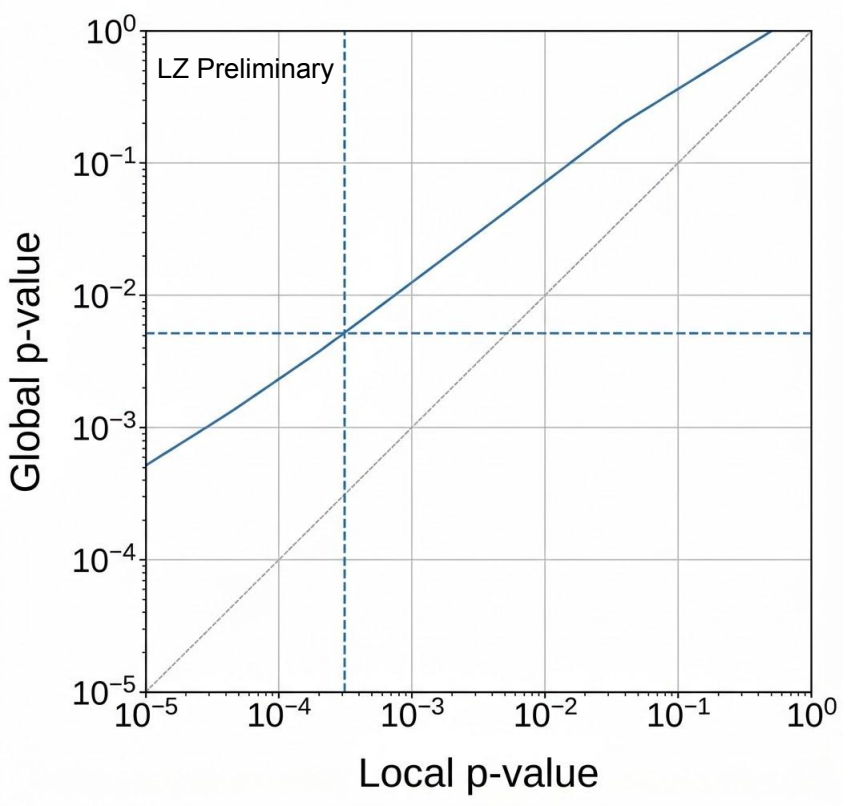
How often would the background produce an excess at least this significant anywhere among the hypotheses we tested?

3.4σ highest local significance

2.6σ sigma global significance

Multiple models have >3σ local significance

Local significance for all models will be provided in the data release



Going forward

New LZ search result in high nuclear-recoil energy window up to 270 keV_{nr}

Total exposure 2.8 tonne-years

LZ has more data already

- Will collect data until at least 2028 (~4x the current dataset)
- Undergoing review for extension to ~2030s (~8x the current dataset)
- Publication schedule TBD

Thank you for listening!

Limit on inelastic scattering

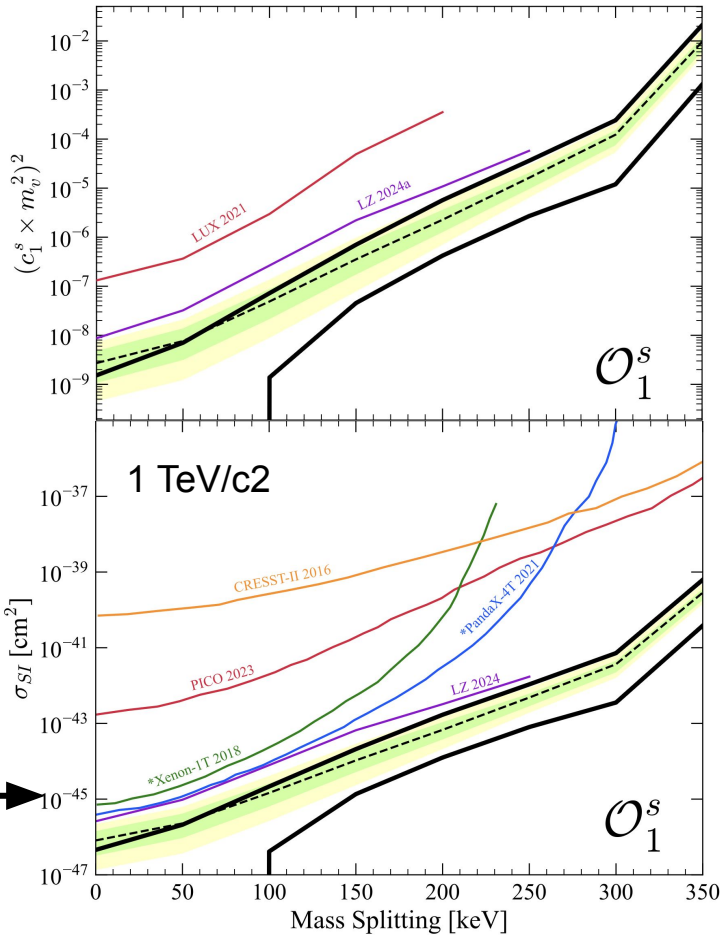
90% upper and lower CL intervals on all models probed

- $\mathscr{L}_1 - \mathscr{L}_{20}$
- Inelastic SI($\mathscr{O}_1$) + inelastic SD($\mathscr{O}_4$)
- Isoscalar, isovector basis

Full results to be provided in future data release

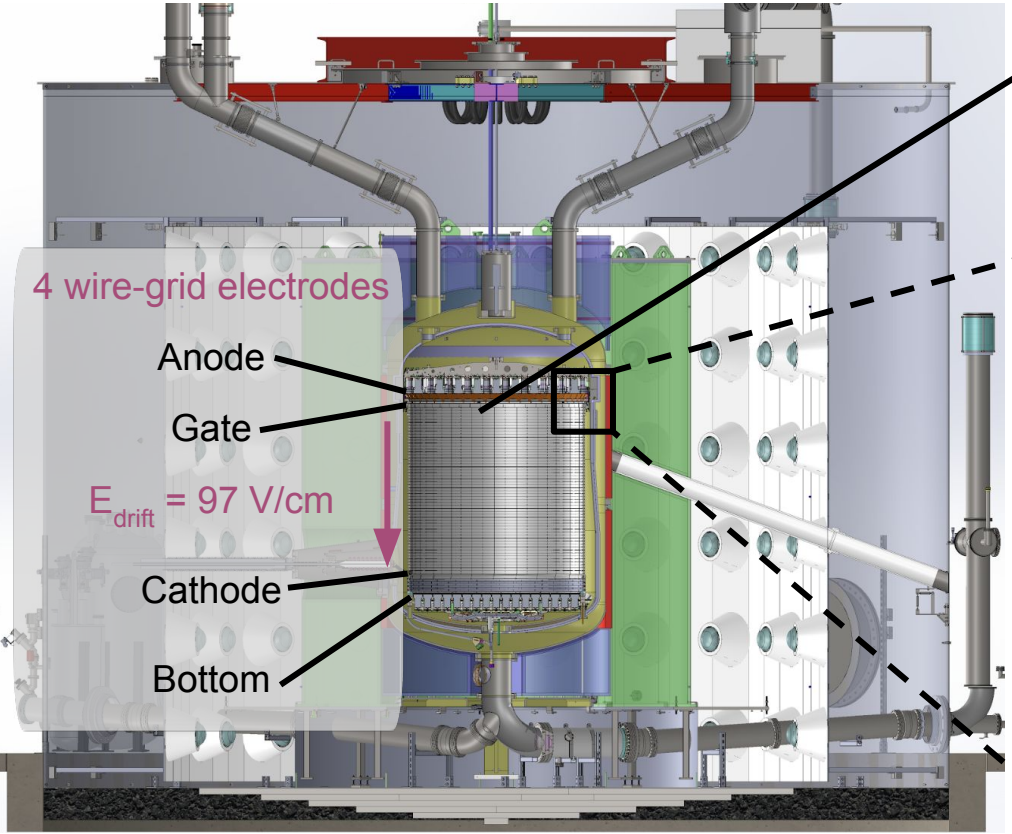
Recast as cross sections

$$(c_1^s \times m_v^2)^2 = \sigma_{SI}^N \frac{\pi \cdot m_v^4}{(\frac{(\hbar c)}{\mathrm{GeV}})^2 \mu_N^2}$$



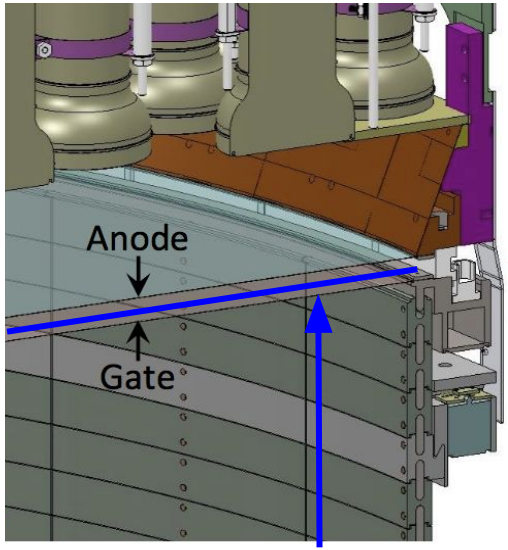
arXiv:2609.02823 (2026)

LZ dark matter detector



LXe TPC

- 1.5 m dia x 1.5 m height
- 7 tonnes liquid xenon
- PTFE everywhere to reflect light
- 494 3” PMTs



$E_{ext, liquid}$ = 3.4 kV/cm

Extraction efficiency = 72.5%

LZ collaboration, Nuc. Inst. Meth. A, **953**, 163047 (2020)