+ Other Results!

Light Dark Matter Results from the LZ Experiment

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July 28, 2026

- on behalf of the LZ Collaboration

The LZ Collaboration

- 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
- 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

@lzdarkmatter

LZ (LUX-ZEPLIN) Collaboration, 38 institutions

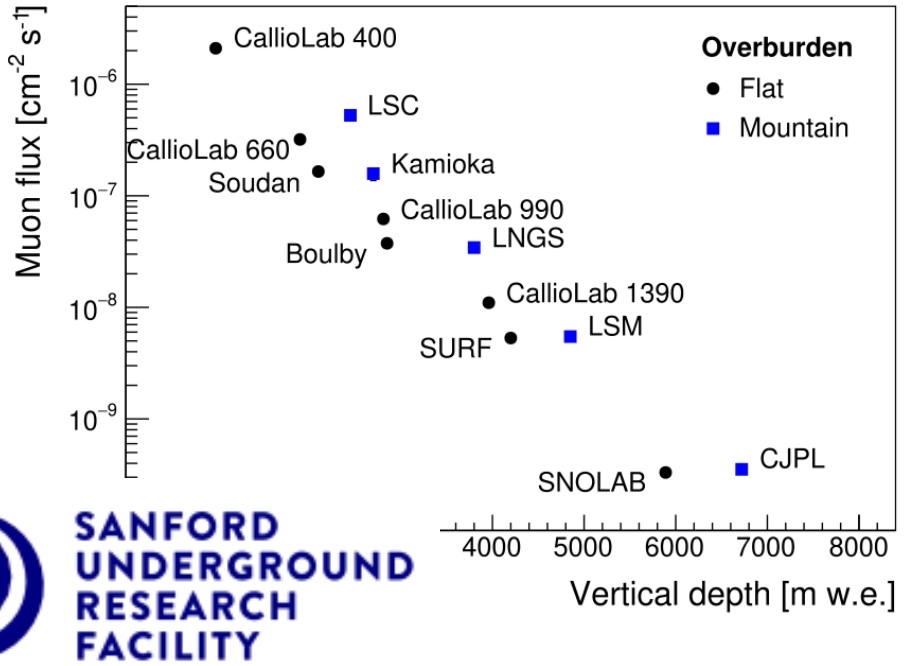
250 scientists, engineers, and technical staff

https://lz.lbl.gov/

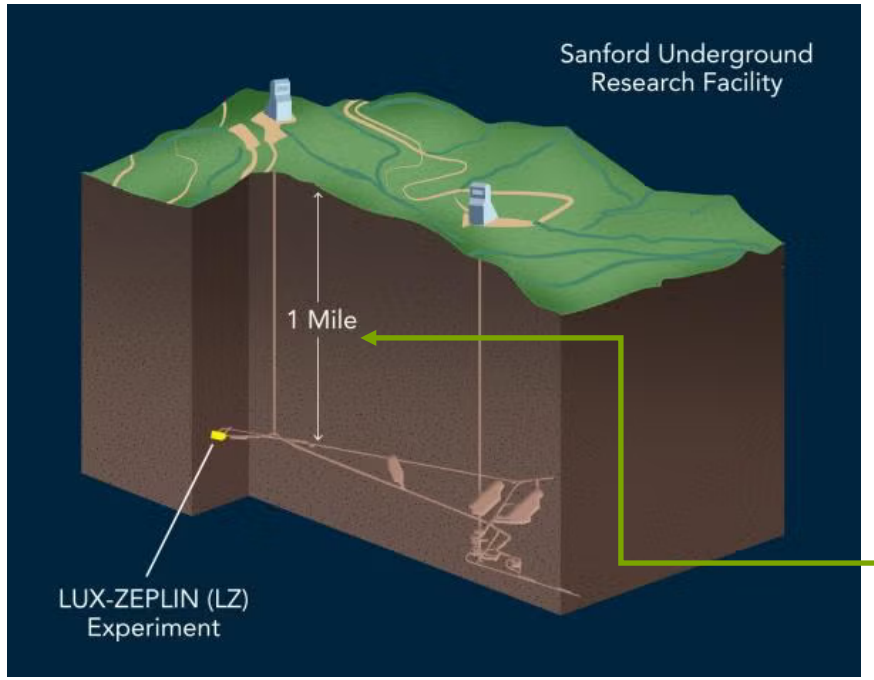
Thanks to our sponsors and participating institutions!

Going Underground

https://sanfordlab.org/

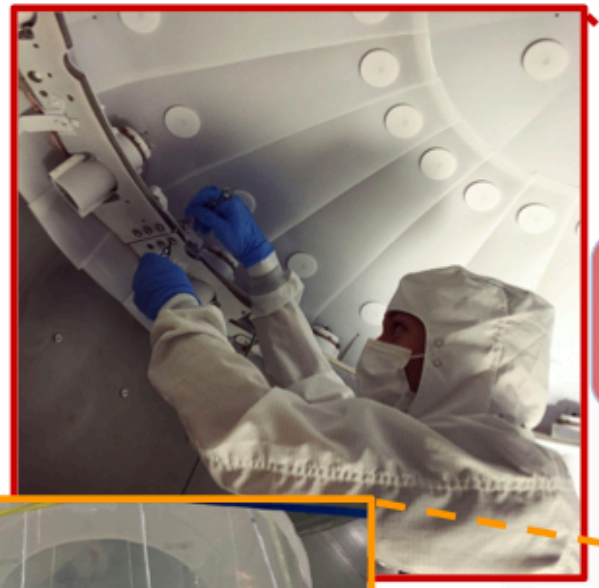


SANFORD UNDERGROUND RESEARCH FACILITY



4300 mwe rock overburden to shield from cosmic rays

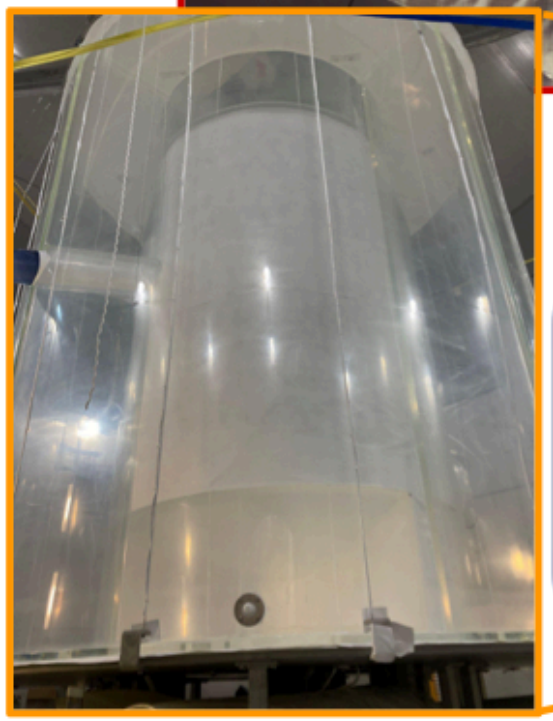
LZ Detector Overview



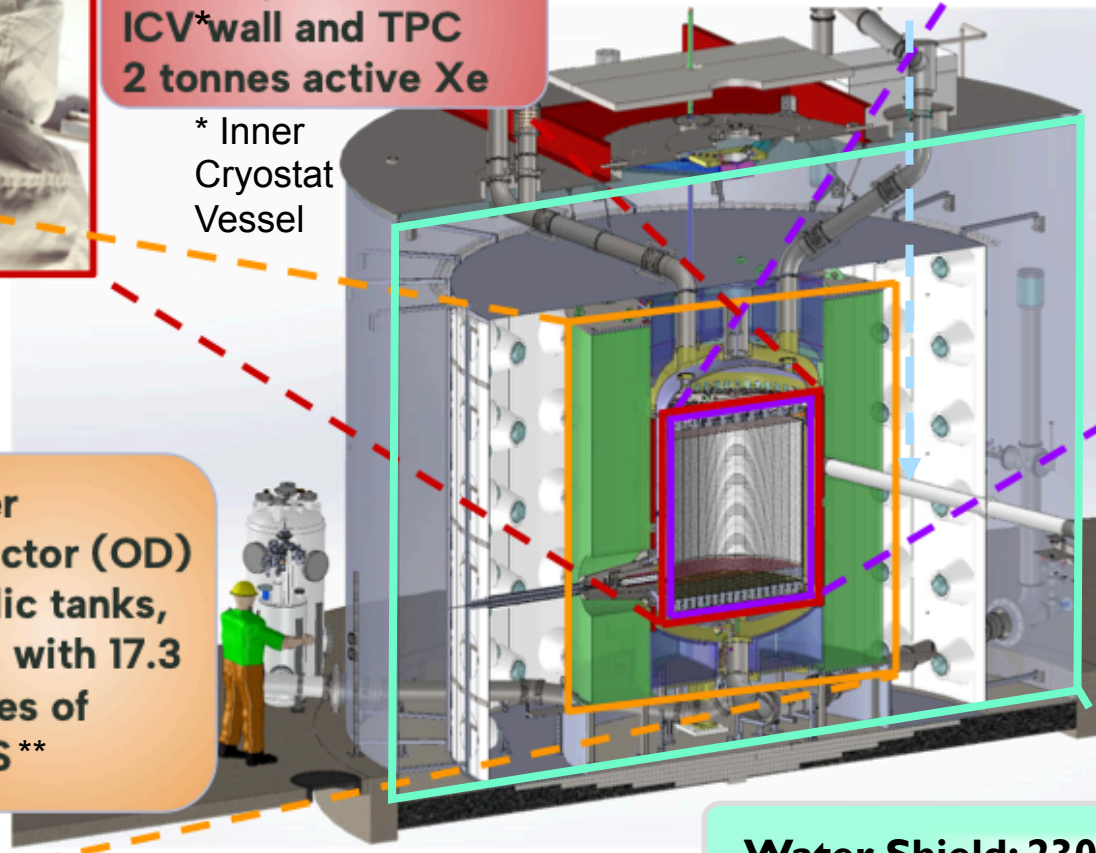
Nitrogen-purged evacuated water conduit for neutron calibrations

Skin region between ICV*wall and TPC 2 tonnes active Xe

* Inner Cryostat Vessel



Outer Detector (OD) acrylic tanks, filled with 17.3 tonnes of GdLS **

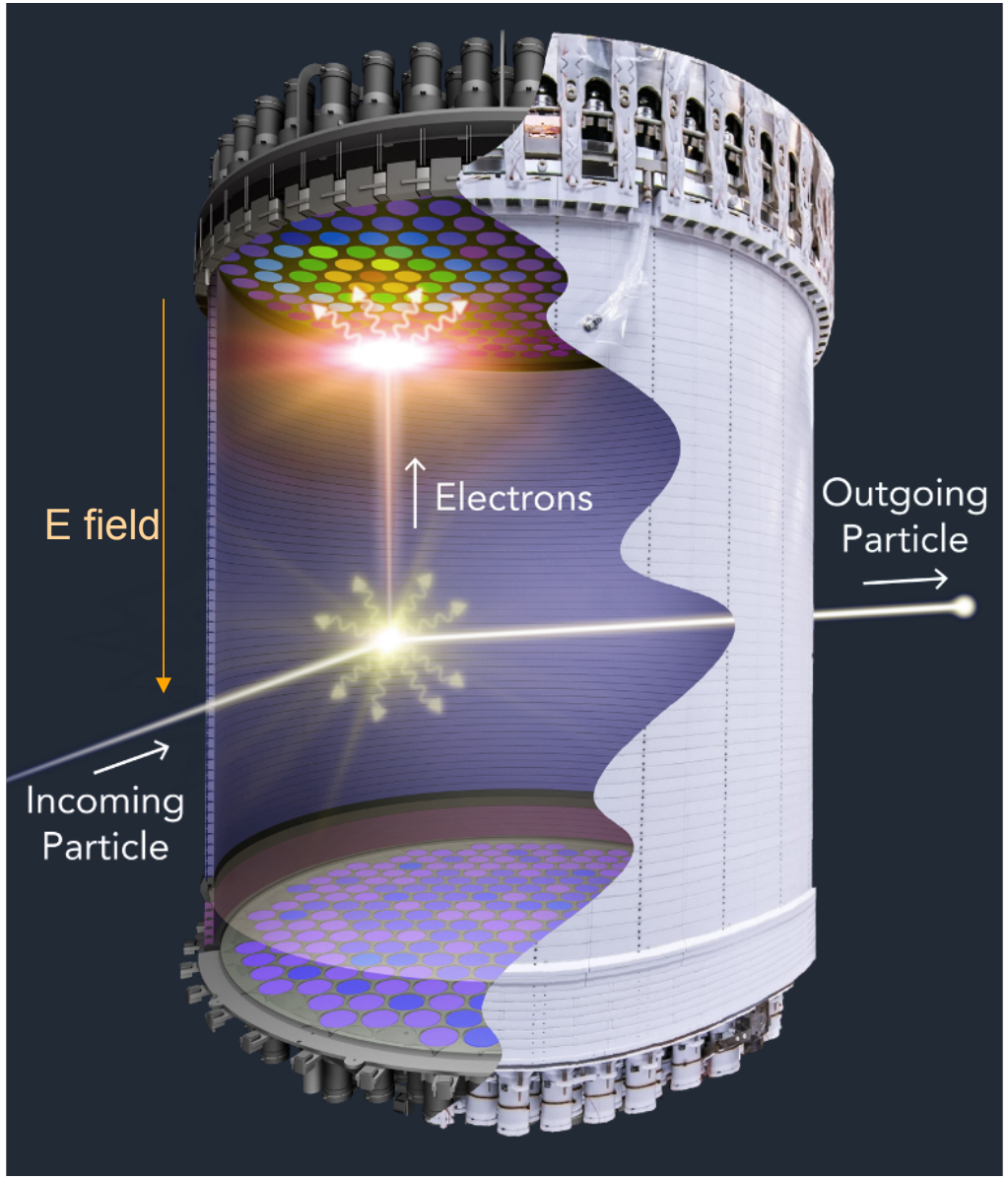


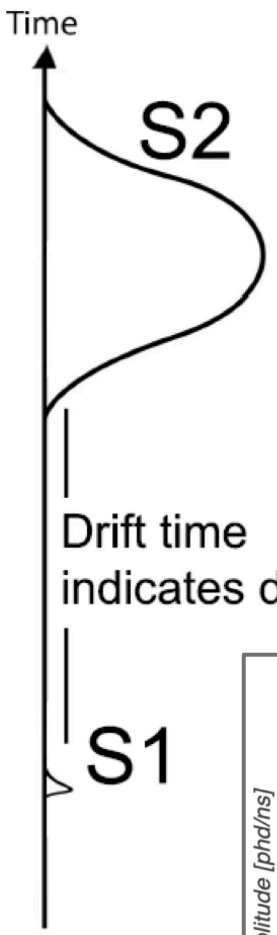
Dual-phase Time Projection Chamber (TPC) 7 tonnes active Xe

Water Shield: 230 tonnes DI water

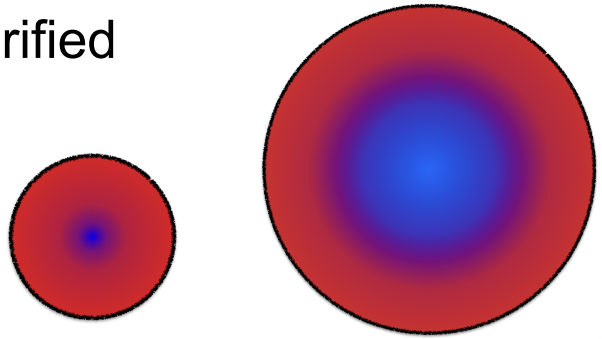
** Gadolinium-loaded Liquid Scintillator

Dual Phase Time Projection Chamber

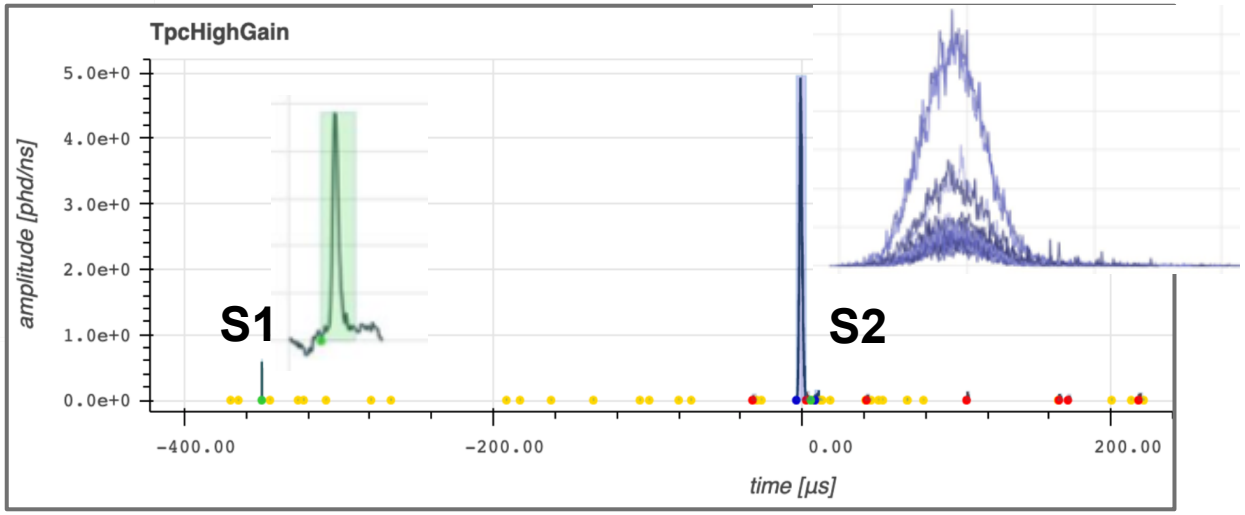




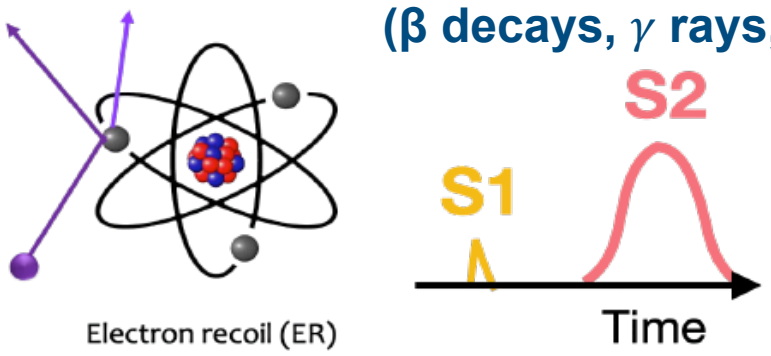
- Excellent 3D imaging capability
  - Z position from S1 - S2 timing
  - XY positions from S2 light pattern
- Xenon is easily purified
- Xenon is dense!
- Self-shielding
- Fiducial Volume



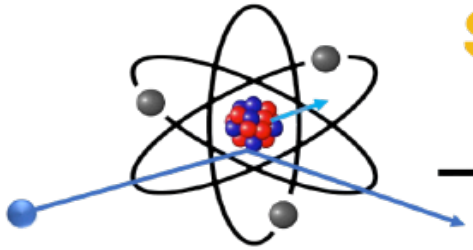
Background rate

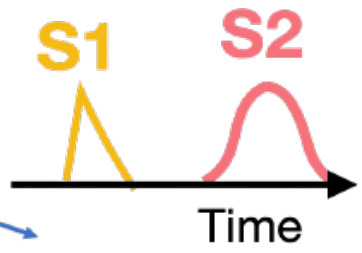


Xenon Time Projection Chamber

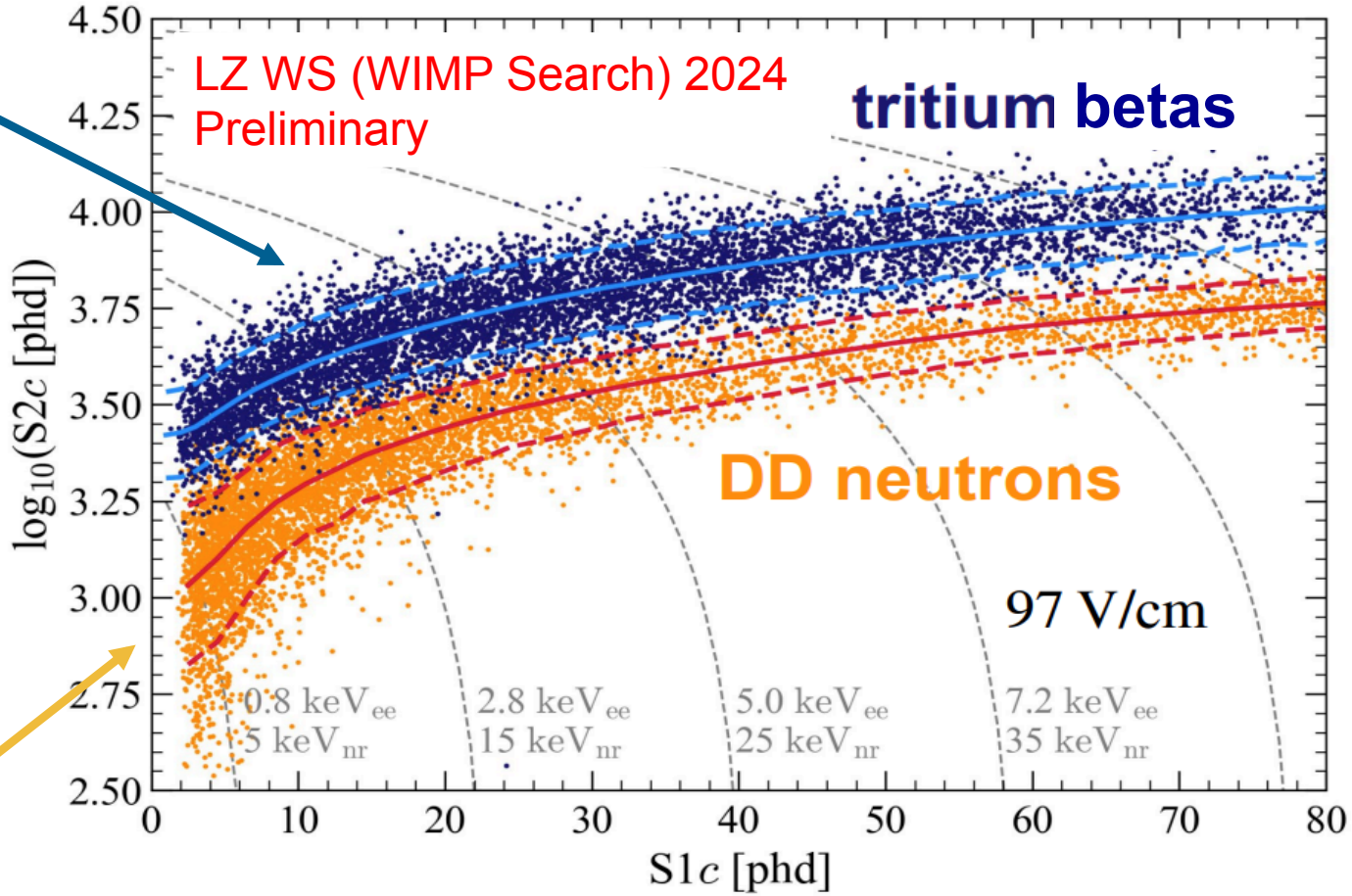


(β decays, γ rays, ν-e$^-$)





(WIMPs, CEνNS, neutrons)



- Charge (S2) vs Light (S1) gives signal vs background discrimination
- CH_3T : tritiated methane injection, spatially homogeneous β source
- DD: deuterium-deuterium neutron generator gives ~monoenergetic 2.45 MeV neutrons

Timeline

PRL 131, (2023) 4, 041002

PRL 135, (2025) 011802

Commissioning begins

WS2022 results (60 live days)

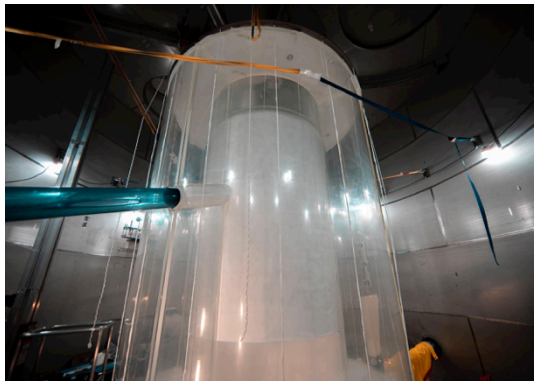
WS2024 results (60 + 220 live days)

Run to end of 2027 = about 2x data

2021 2022 2023 2024 2025 2026

First WIMP search starts (WS2022)

WS2024 starts

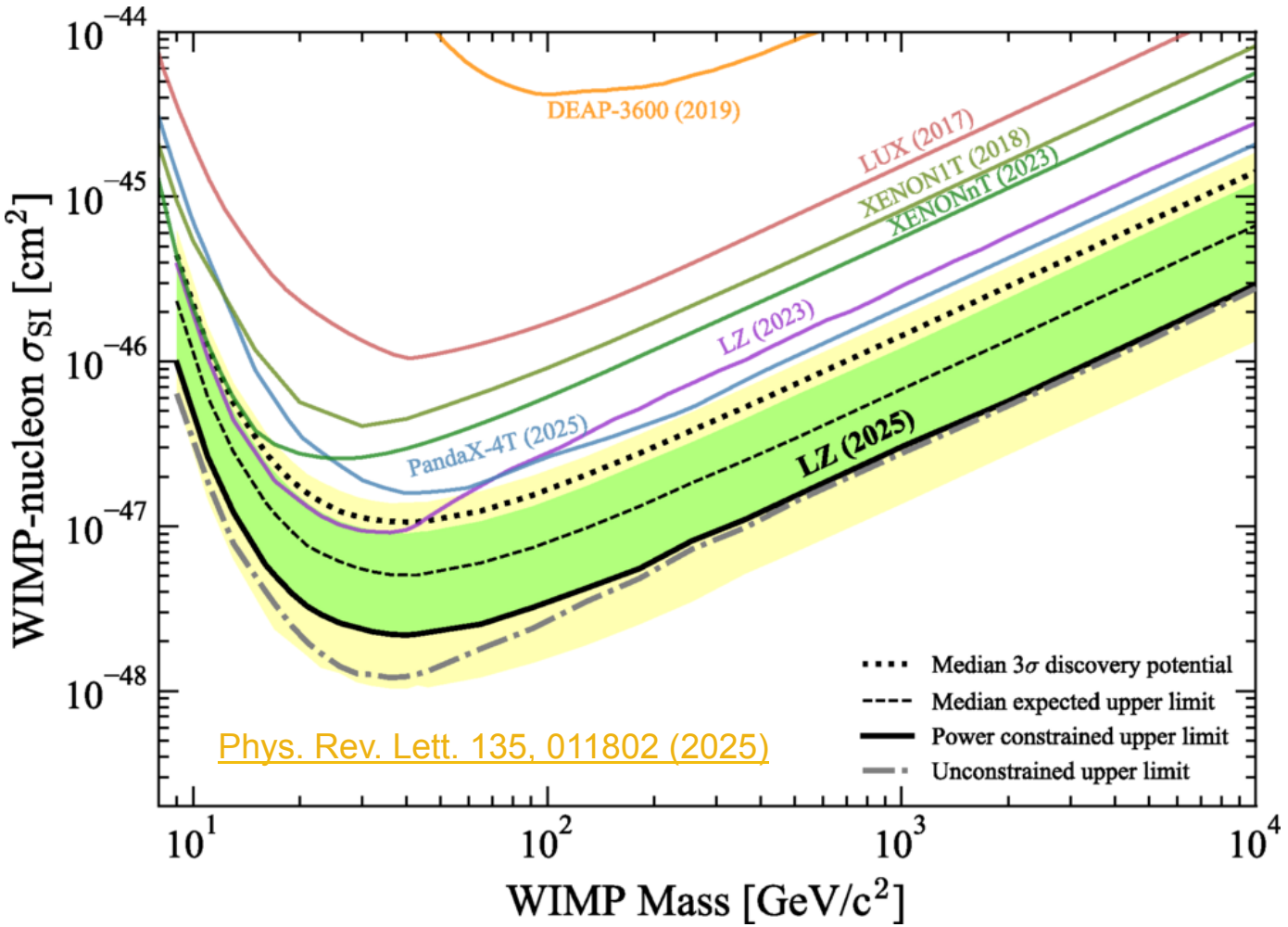


WS2025 results (417 live days)

https://arxiv.org/abs/2512.08065

Periodic calibration throughout

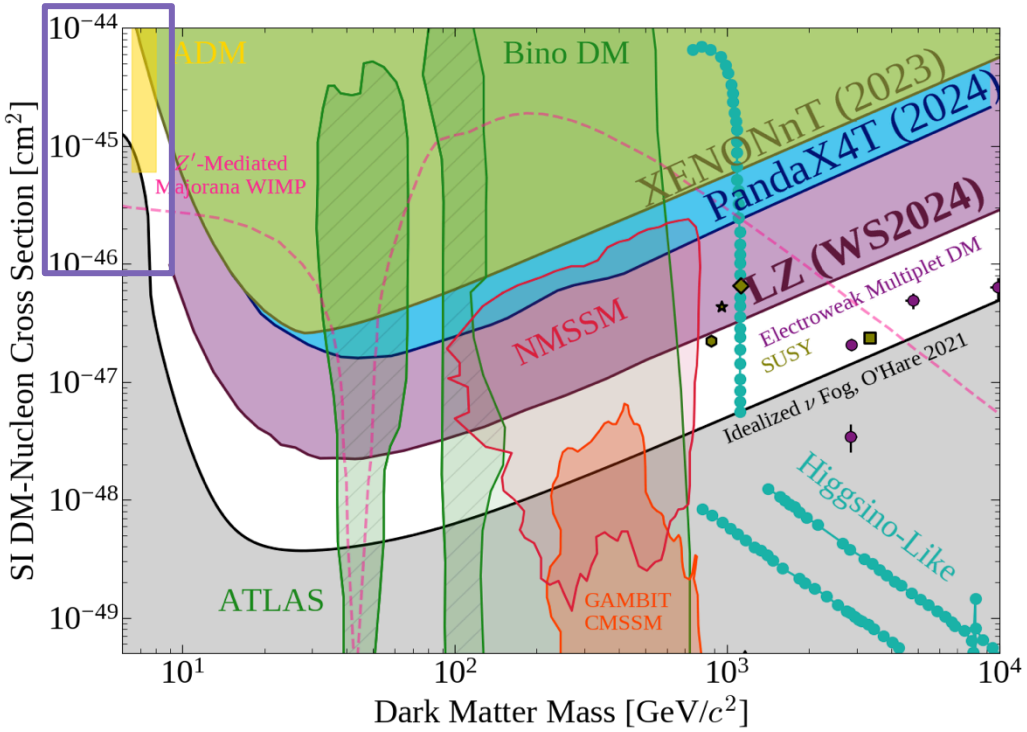
LZ Spin-Independent Results WS2024



- No evidence of WIMPs at any mass
- 280 live-days: 4.2 tonne-years
- Minimum exclusion on SI WIMP-nucleon cross section
  - 2.2 x 10^{-48} cm^2 at 40 GeV / c^2
- Under-fluctuation from combining with 2022 result
- Observed limit is power-constrained (DM convention)
  European Physical Journal C 81, 907 (2021)

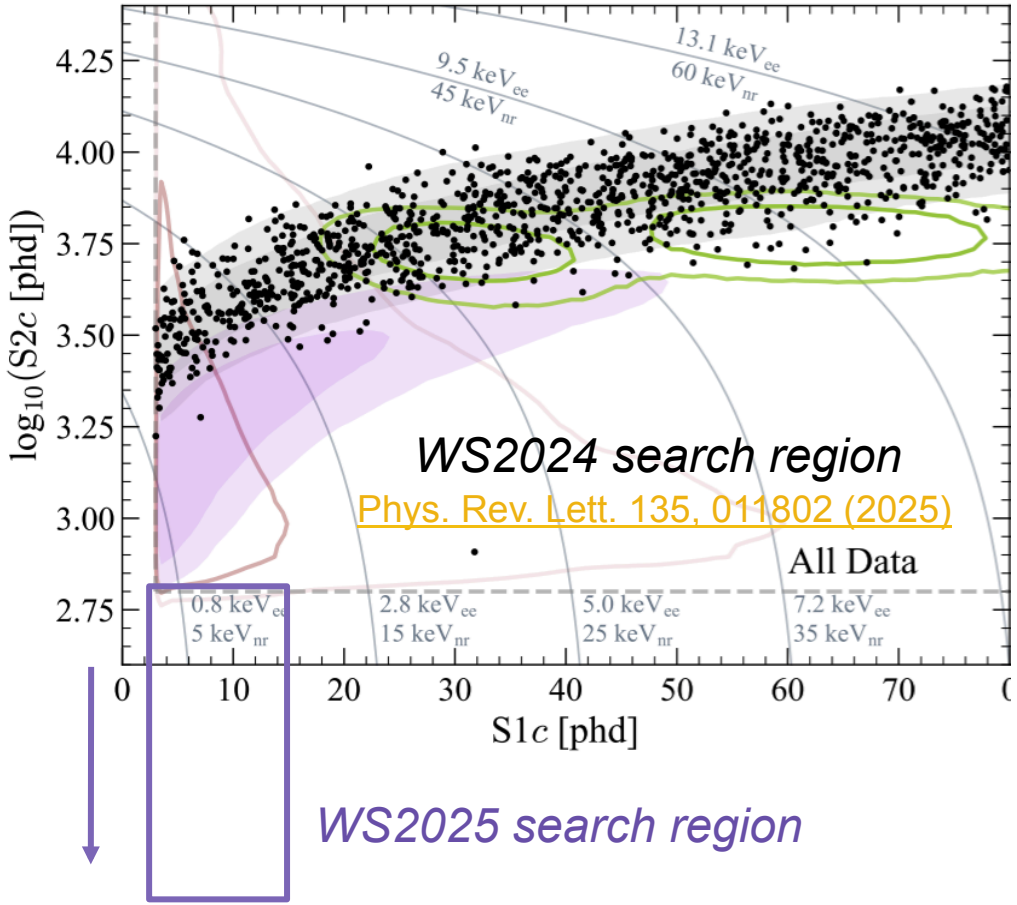
More from LZ: EFT (Effective Field Theory) operator-based searches, covariant EFT, WIMP-pion scattering, axions & ER searches, ultra-heavy DM, millicharged, cosmic ray boosted DM

New: WS2025, Going to <9 GeV / c²



- First LZ search for < 9 GeV DM NR
- Lighter candidates produce lower-*E* signals with handful of photons + electrons → Unique set of challenges
- Narrowing down where dark matter might be:

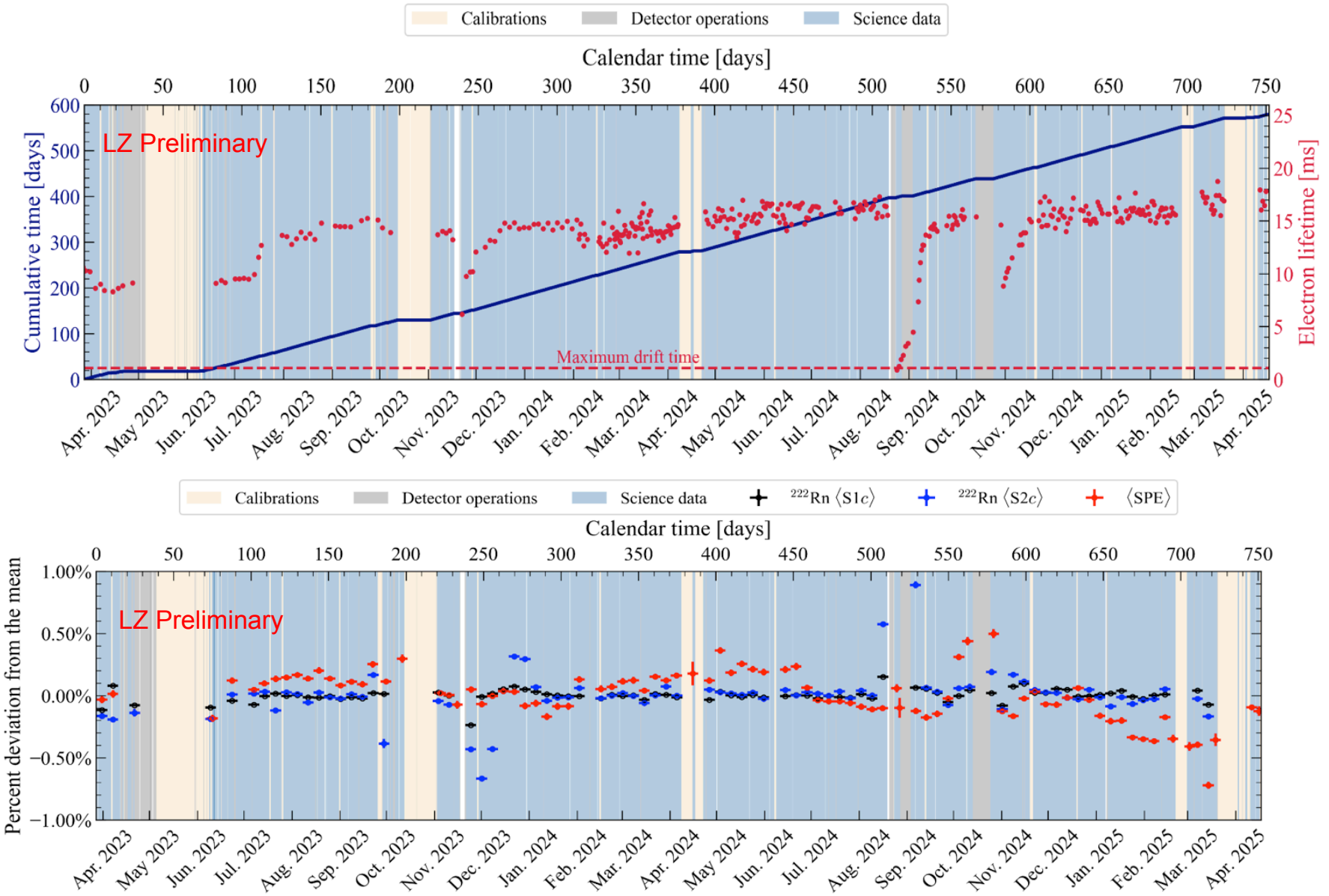
→ leave no stone unturned



- Well motivated: no actual cosmological bound at the GeV scale, BSM frameworks like asymmetric dark matter, astrophysical hints
- Neutrino fog is much higher at lower energies → CEνNS from ^{8}B solar neutrinos

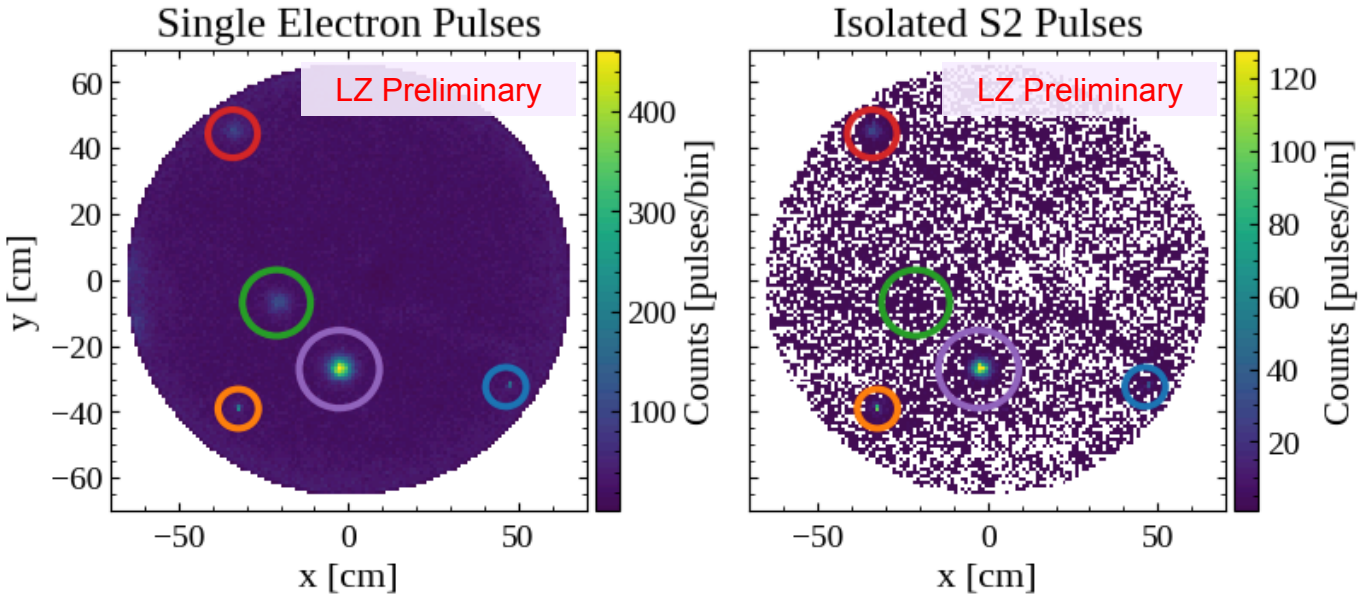
LZ Search Dataset

- Data taken from April 2023-May 2025
- 5.7 tonne-year exposure
- Drift field 97 V/cm
- Extraction field 3.4 kV/cm
- Dedicated AmBe and DD neutron calibrations
- Data calibrated for uniformity in S1 and S2 response in time and space



Cuts and Analysis in a Nutshell

- Look for single scatters (~1-6 keVnr recoil energy)
- >= 3-fold S1 (signals in >= 3 PMTs)
- S1c ∈ [2,15] photons detected (phd)
- S2 ∈ [3.5,14.5] e- (44.5 phd/e-)

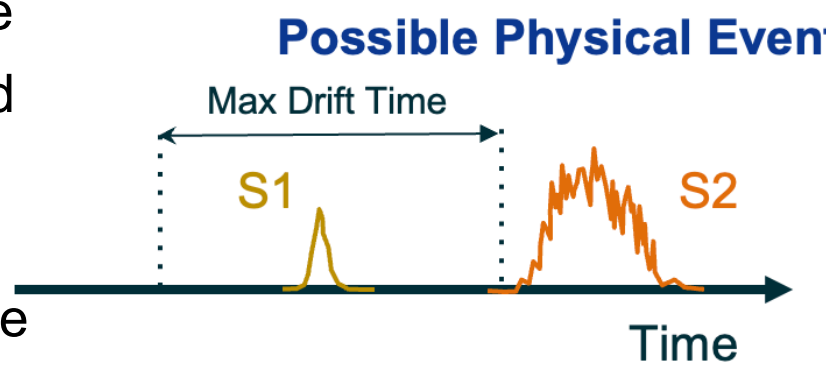


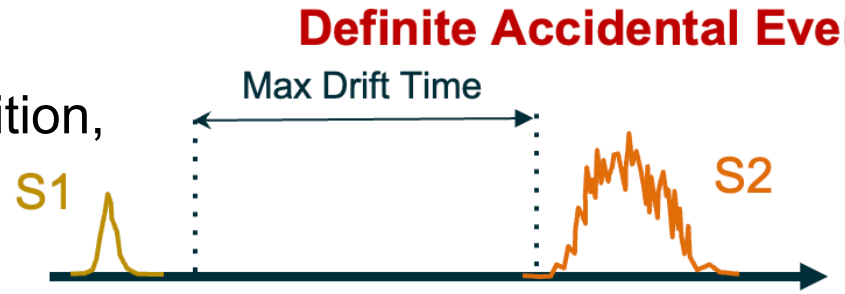
Intense period of electrode electron emission

- Data quality cuts:
  - time-based exclusions (*i.e.* PMT high voltage trip, muon crossing detector), hold-offs after large energy depositions, operational issues
- Fiducial volume cut = 5.09 ± 0.15 tonnes
  - reject external backgrounds and detector edge effects
- S1 and S2 based cuts:
  - target accidental coincidence backgrounds
- External veto cuts:
  - target neutrons which produce coincident signals in the OD/Skin
- Final exposure: 5.7 ± 0.2 tonne-years

Backgrounds

- Electronic recoil (ER) backgrounds (betas, gammas) are negligible
- Neutron backgrounds are < 1 event (tagged w/ Outer Detector and Skin)
- Accidental coincidence events: isolated S1s & S2s can pile-up to fake a scatter, where the S1 and S2 do not originate from the same energy deposition
- Sources: PMT dark counts, charge loss near the TPC walls degrades S2, large photon/electron rates after big energy deposition, Rn-chain decays in grid wires (https://arxiv.org/abs/2602.21177)



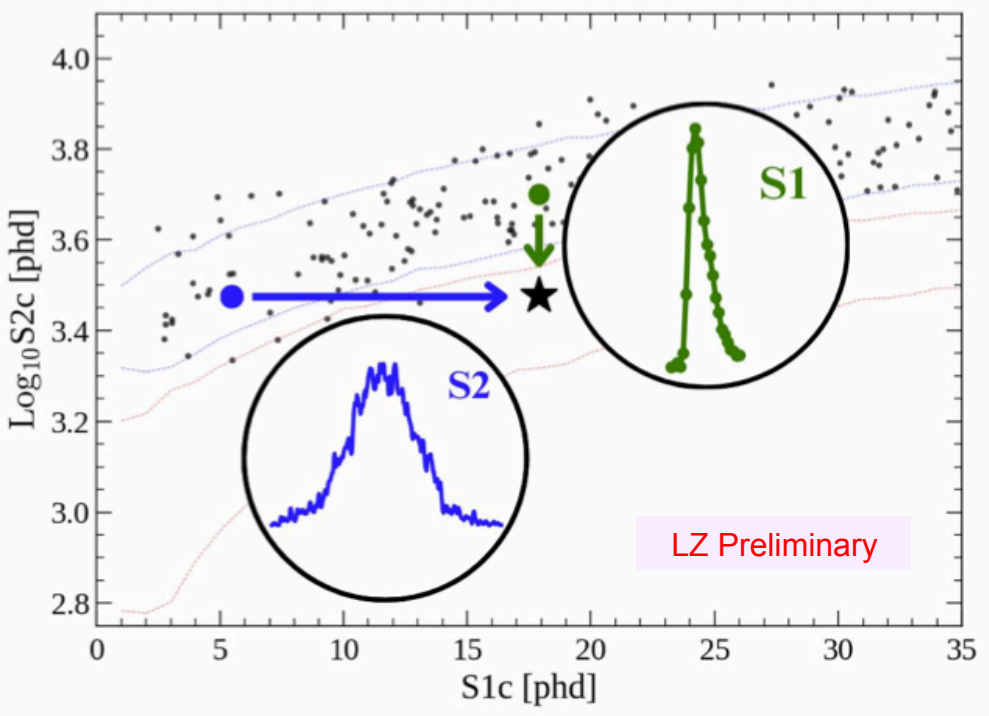


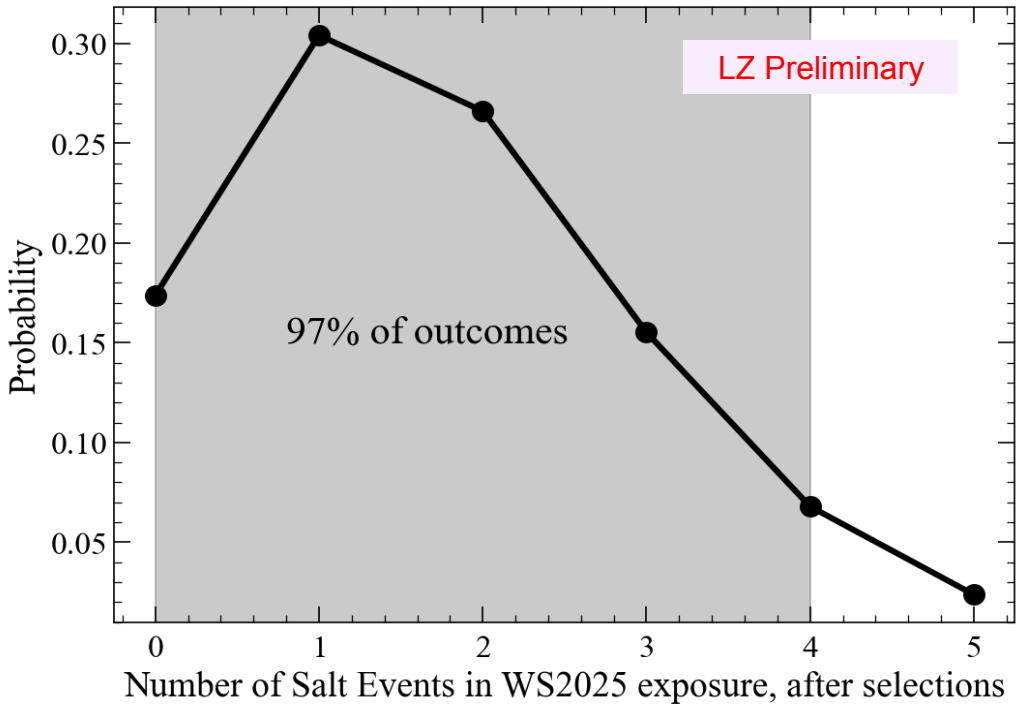
Max drift time = time for electron to drift from cathode to liquid surface (~1 ms)

Accidental model: randomly pairing isolated S1s and S2s, then validating and normalizing the model using clearly nonphysical S1-S2 pairs

Prediction: 6.6 ± 0.3 events in the full exposure

Bias Mitigation

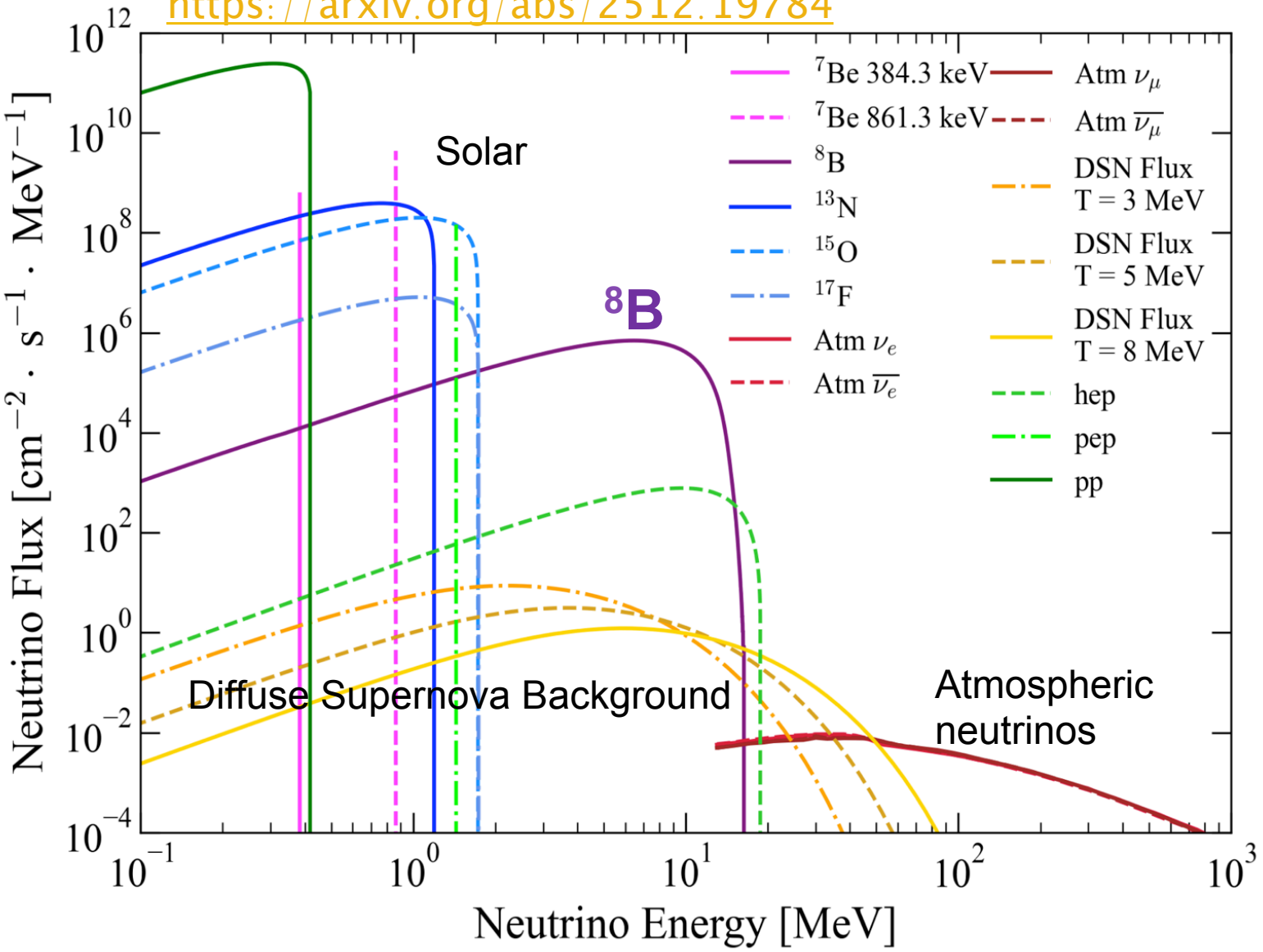




- Use of sideband datasets for all data selection and background measurements
- Salting: artificial signal randomly injected into the data stream both for ^{8}B and WIMP searches
  - Salt is created from calibration data (CH_3T, ^{220}Rn, AmLi)
  - Salt rate chosen to match Poisson uncertainty on expected rates
  - Salt events are unknown to analyzers, only revealed after all final decisions and analysis cuts are made

Neutrino Signals

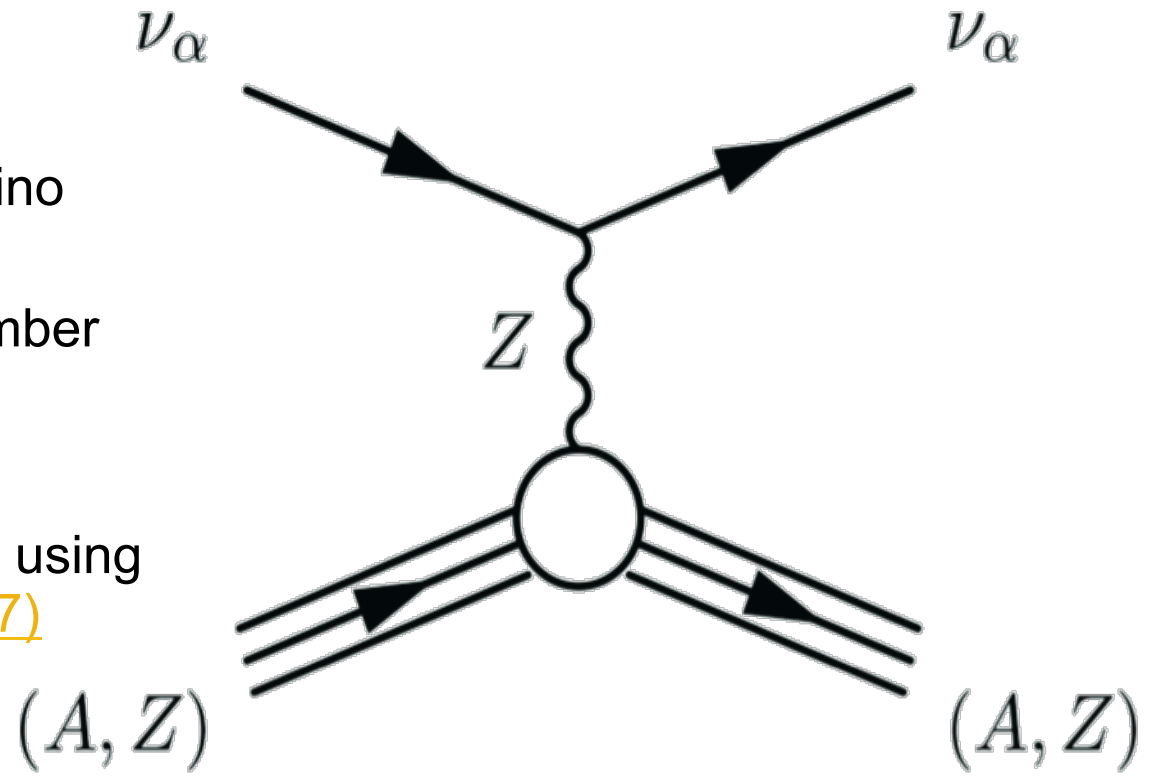
https://arxiv.org/abs/2512.19784



- Neutrinos are not new and have been widely detected
- Solar ^{8}B coherent scattering from Xe
  - $^{8}B \rightarrow {}^{8}Be^{*} + e^{+} + \nu_e$
  - enhanced rate means a modest 5 tonne fiducial target can record events
- Neutrinos are high energy so the Xe recoils are high enough energy to be seen with keV threshold

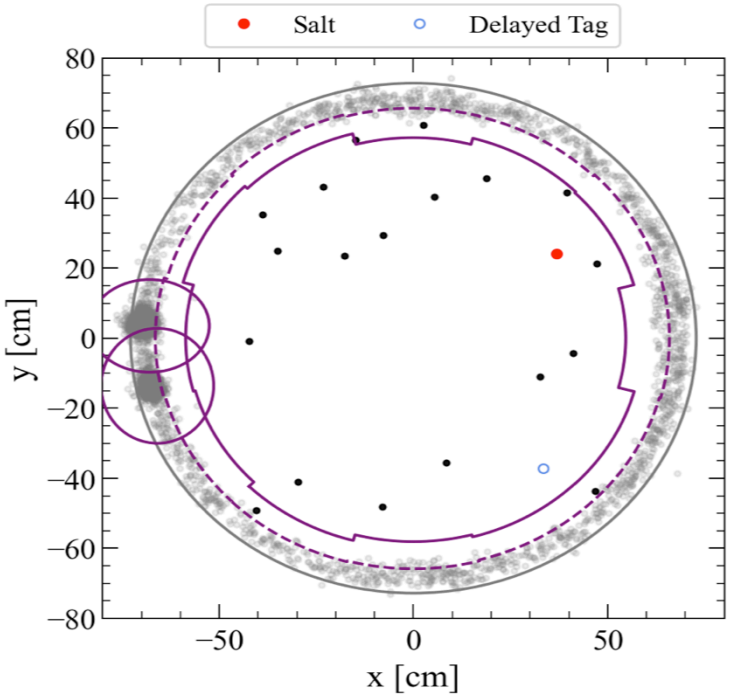
CEνNS

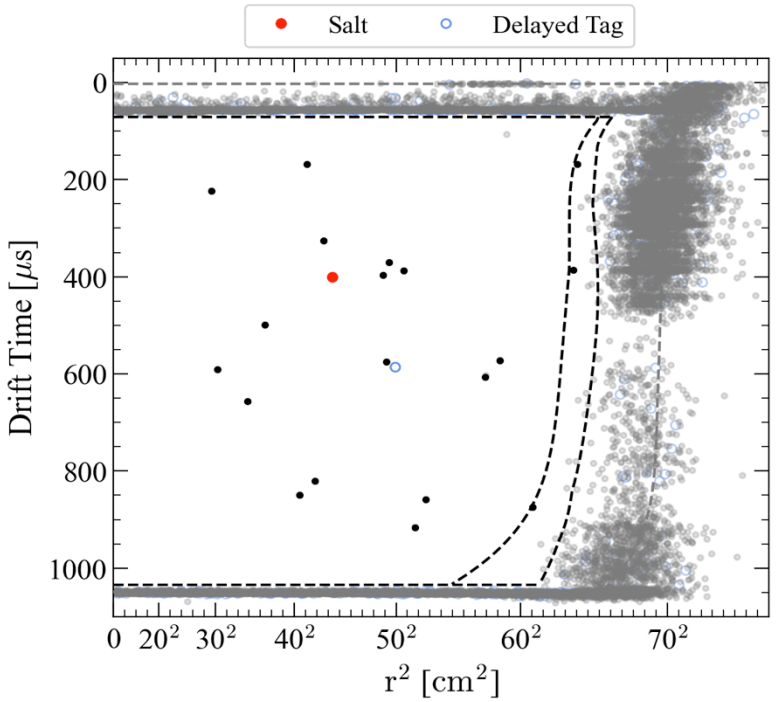
- Coherent Elastic Neutrino-Nucleus Scattering
- Well predicted neutral current SM process where neutrino scatters off of the whole nucleus
- Cross section is enhanced and scales with neutron number squared
- Entire nucleus recoils
- First measured by the COHERENT experiment in 2017 using the Spallation Neutron Source Science 357, 6356 (2017)

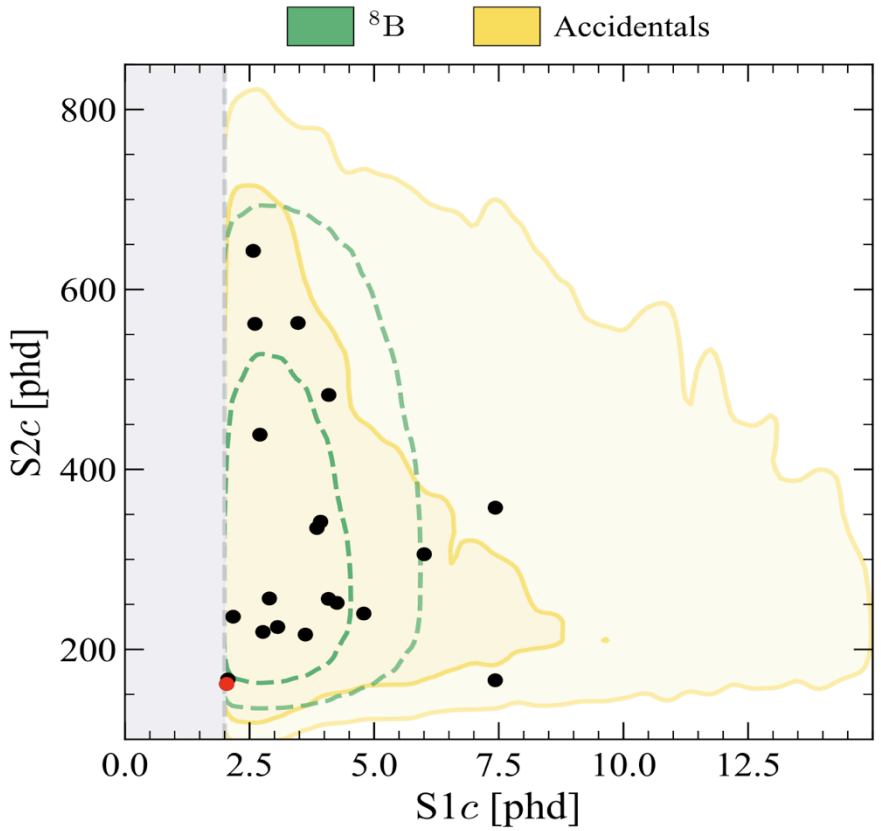


- Additional measurements with reactor neutrinos, anti-neutrinos by Dresden-II PRL 129, 211802 (2022), CONUS+ Nature 643, 1229-1233 (2025)
- First indications (< 3σ) of CEνNS with solar neutrinos from PandaX-4T PRL 133, 191001 (2024), XENONnT PRL 133, 191002 (2024)

The Final Dataset







- 20 events in dataset after all selections
- 1 is salt (red) 0-4 expected
- 19 events for science search
- Sideband dataset of “neutron-rich” data: passing all selections except delayed veto

doi.org/10.1103/jvqf-njpj

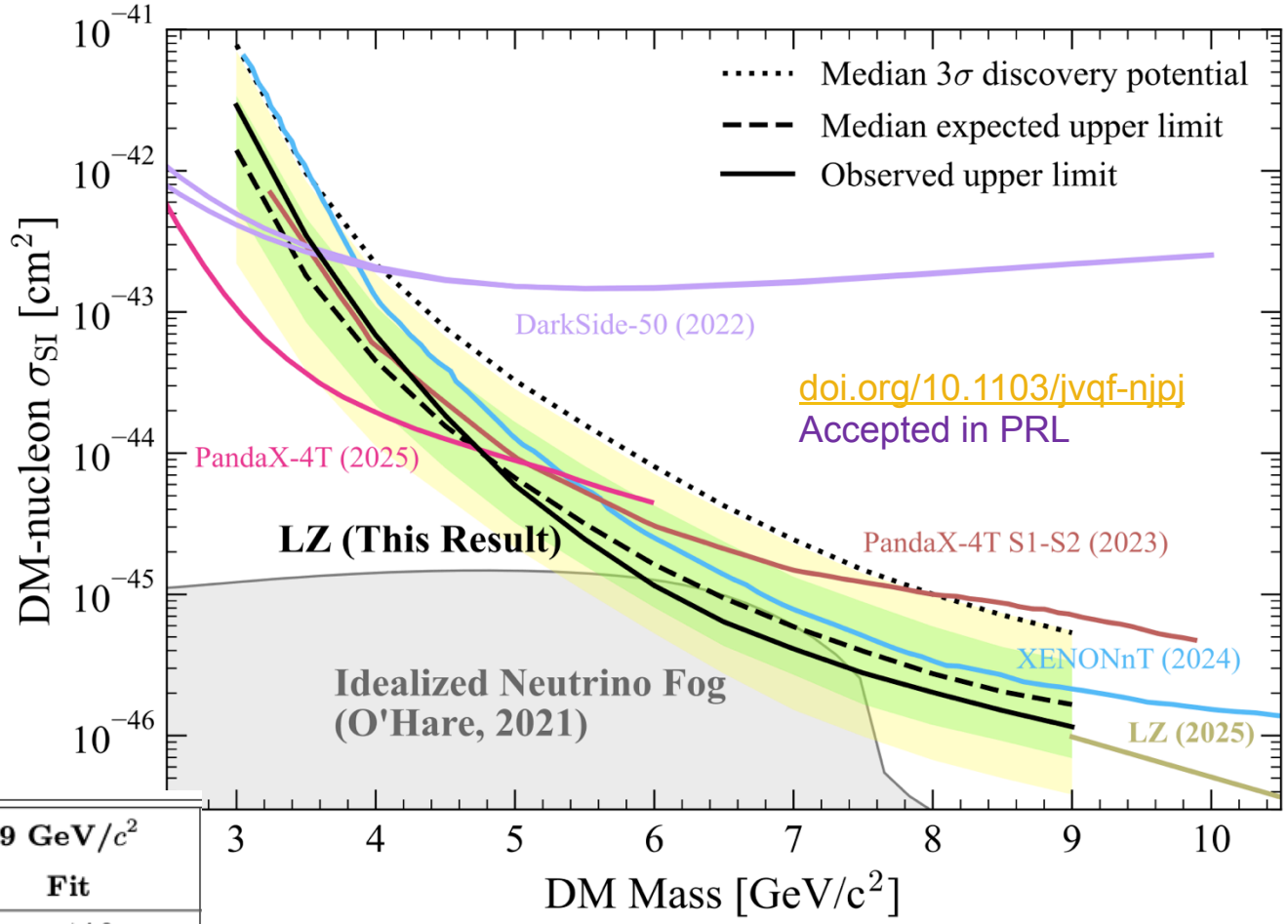
- 1 event → in-situ constraint for neutrons
- Neutron expectation in main dataset:

$0.04^{+0.25}_{-0.04}$ events

- ^{8}B CEνNS gives detector signal spectrum similar to 5.5 GeV DM

WIMP Search 2025 (LENR)

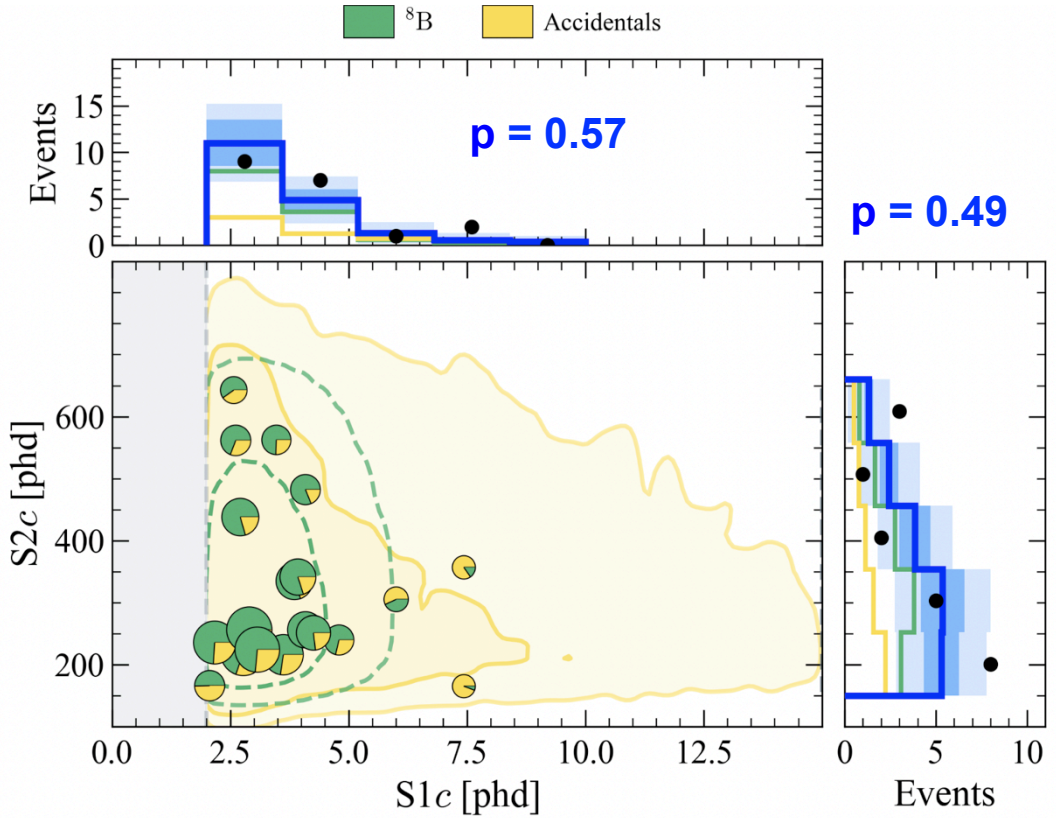
- Limit setting for Spin Independent (SI) DM-nucleon interaction strength using two-sided test statistic based on PLR (Profile Likelihood Ratio)
- Assumes SM CEνNS cross-section and ^{8}B flux as measured by SNO
- Backgrounds: ^{8}B CEνNS, accidentals, neutrons
- No statistically significant excess from any potential WIMP measured for SI-interacting WIMPs between 3 - 9 GeV / c^2



Components	Expectation	Background-Only Fit	3 GeV/c^2 Fit	9 GeV/c^2 Fit
SI DM	-	-	$0.4^{+5.4}_{-0.4}$	$0.0^{+4.0}_{-0.0}$
^{8}B CEνNS	$20.6^{+8.9}_{-6.8}$	$15.0^{+2.9}_{-2.5}$	$14.7^{+3.0}_{-2.8}$	$15.0^{+2.9}_{-2.5}$
Accidental coinc.	6.6 ± 0.3	6.5 ± 0.3	6.5 ± 0.3	6.5 ± 0.3
Detector neutrons	$0.04^{+0.25}_{-0.04}$	$0.1^{+0.2}_{-0.1}$	$0.1^{+0.2}_{-0.1}$	$0.1^{+0.2}_{-0.1}$
Total	$27.2^{+10.1}_{-7.3}$	$21.6^{+4.7}_{-3.8}$	$21.7^{+6.2}_{-2.8}$	$21.6^{+5.0}_{-2.5}$

- World-leading limits at >5 GeV/c^2
- Reaching into neutrino fog shoulder

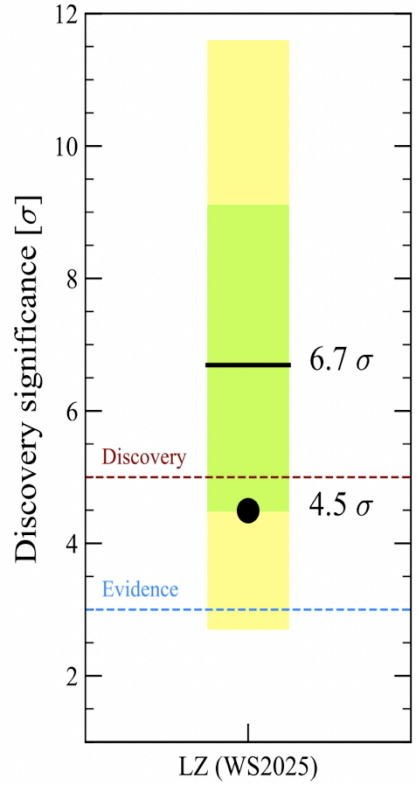
Evidence of ^{8}B

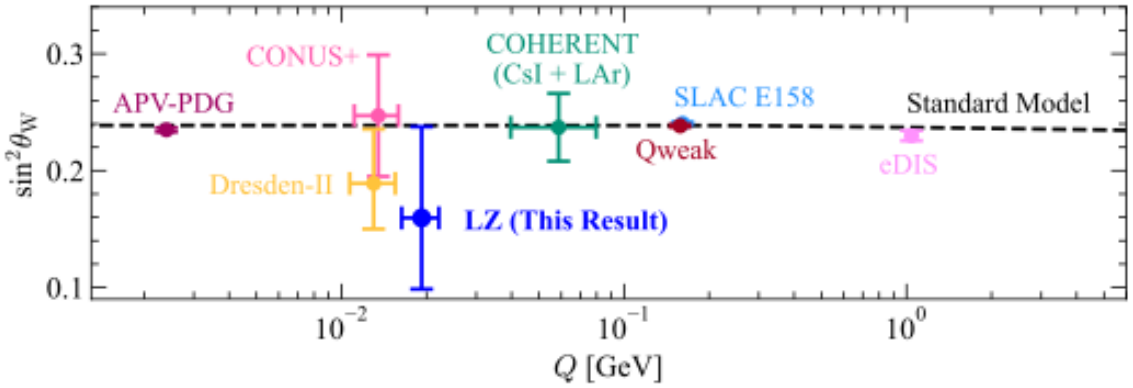


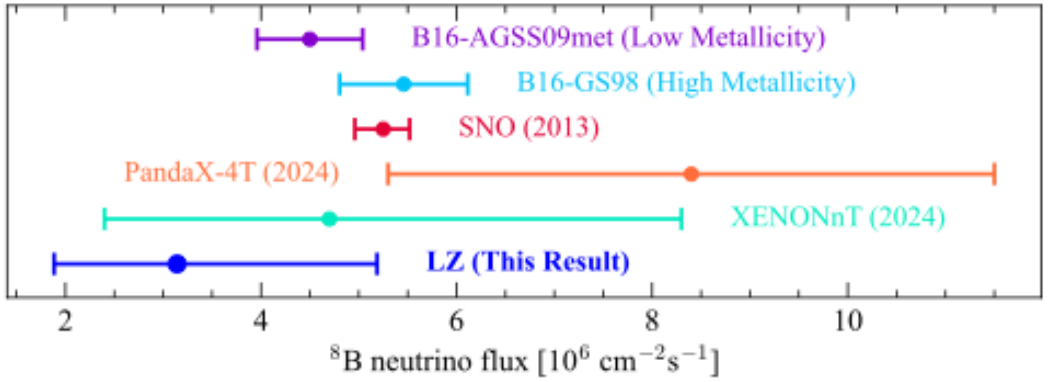
Components	Expectation	Fit Results
^{8}B CEνNS	-	$12.3^{+7.0}_{-5.4}$
Accidental coincidences	6.6 ± 0.3	6.6 ± 0.3
Detector neutrons	$0.04^{+0.25}_{-0.04}$	$0.1^{+0.2}_{-0.1}$
Total	6.6 ± 0.3	$18.9^{+7.0}_{-5.5}$

- Assume zero WIMP events
- Background-only model rejected with 4.5σ significance (expected: 6.7σ)
- Demonstration of LZ's ability to detect a low-energy signal!!

https://arxiv.org/abs/2512.08065







Summary

- LZ is the largest liquid xenon TPC in the world
- LZ has set world-leading limits on WIMPs above 5 GeV / c^2
- 4.5σ detection significance => evidence of ^{8}B CEνNS interactions in liquid Xenon
- LZ continues to take data and improve sensitivity: toward 1,000 live-day objective
- Challenging S2-only (ionization channel) analysis underway

Thank you!!!