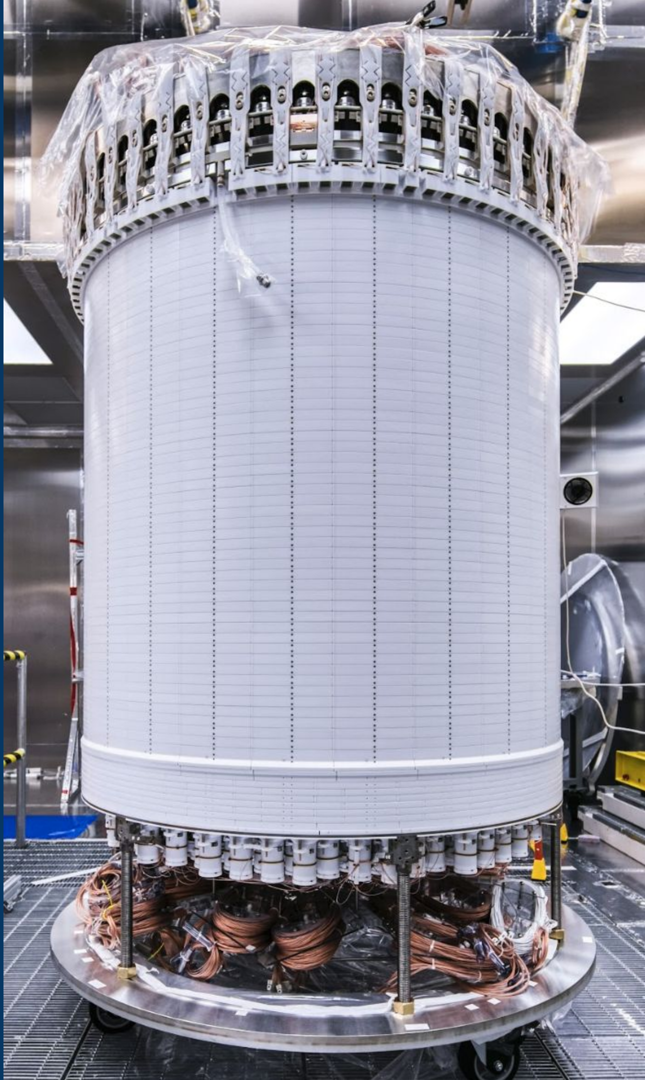
Searches for Solar Neutrinos and Light Dark Matter with the LUX-ZEPLIN Experiment

Daniel Kodroff | TeVPA | Aug. 31, 2026

On behalf of the LZ Collaboration

BERKELEY LAB



LZ (LUX-ZEPLIN) Collaboration

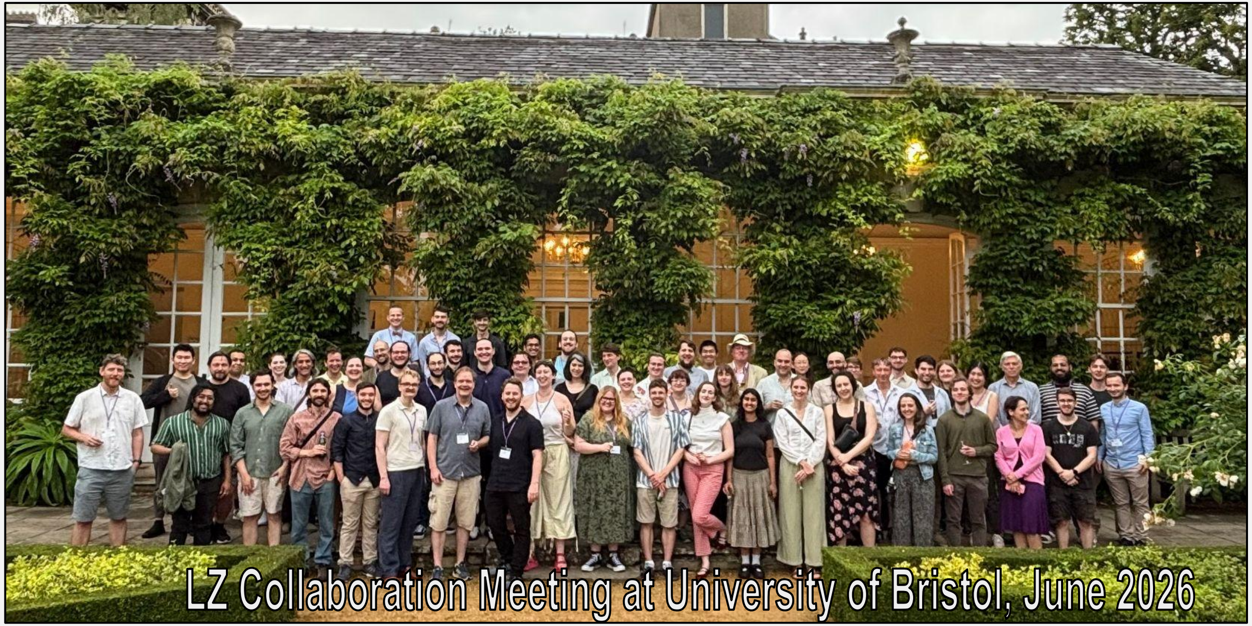
39 Institutions
250 scientists, engineers, and technical staff

@lzdarkmatter
https://lz.lbl.gov/

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

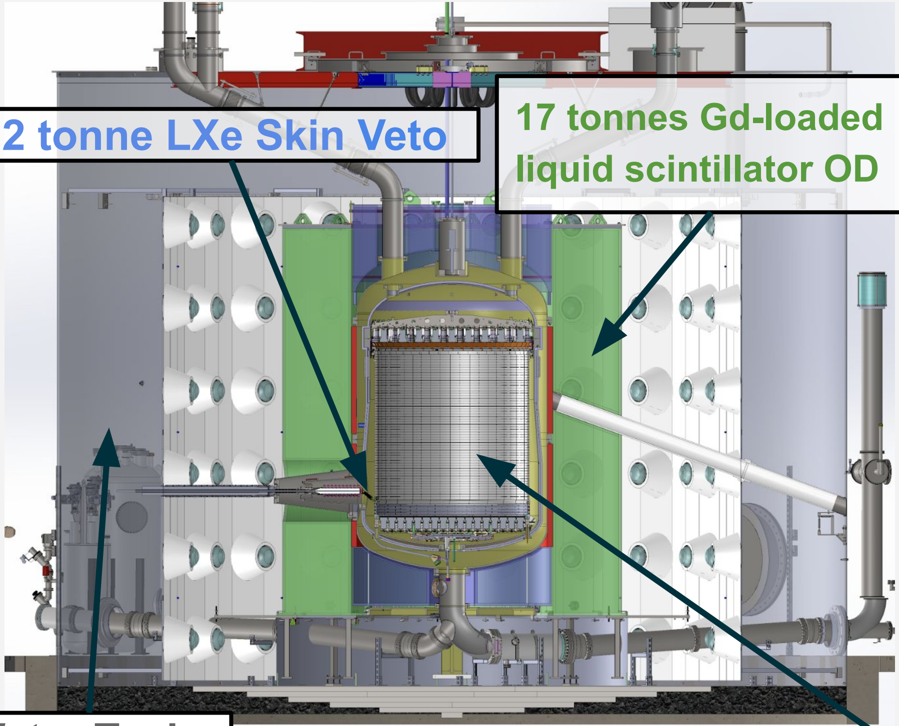


Science and Technology Facilities Council
Fundação para a Ciência e a Tecnologia
Sanford Underground Research Facility
Swiss National Science Foundation
Institute for Basic Science

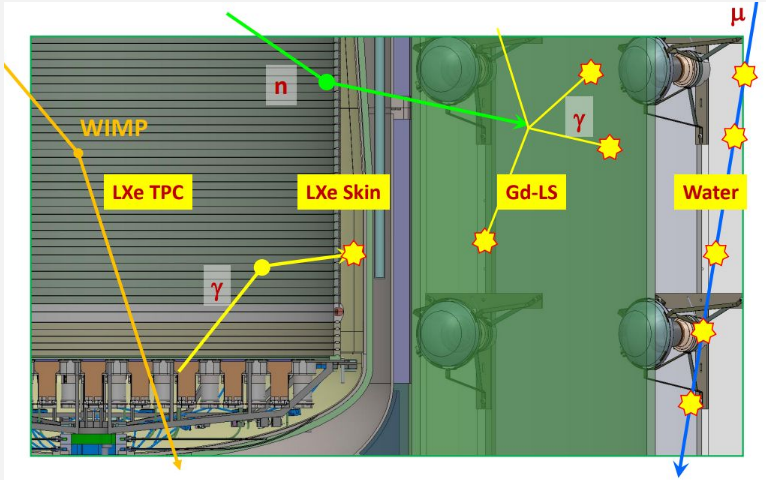
Thanks to our Sponsors and Participating Institutions!

The LUX-ZEPLIN (LZ) Detector

LZ Detector Design: NIM A, 953 163047 (2020)



Located in the Davis Campus on the 4850' level of Sanford Underground Research Facility (SURF)

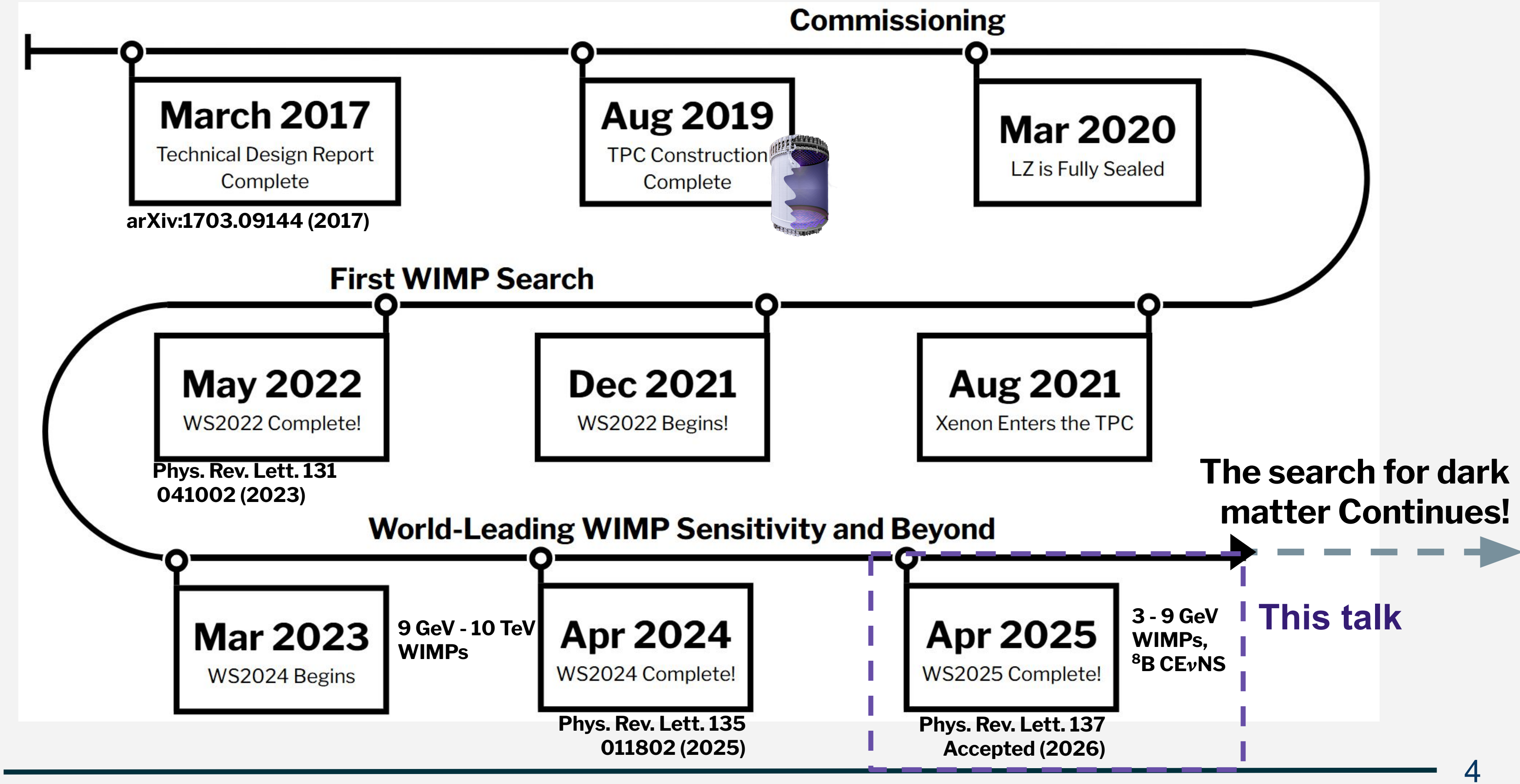


Xe Skin & Outer Detector (OD)

characterize and reject γ + neutron backgrounds!

<u>92 ± 4 % detector neutron veto efficiency</u>

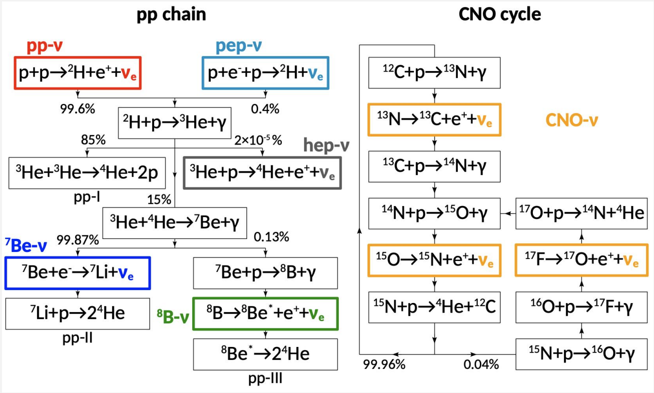
LZ so far…

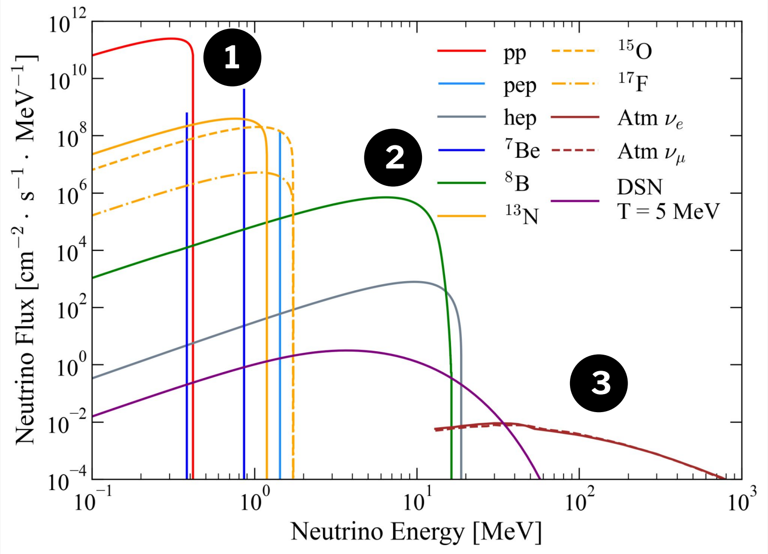

Commissioning
March 2017
Technical Design Report Complete
arXiv:1703.09144 (2017)
Aug 2019
TPC Construction Complete
Mar 2020
LZ is Fully Sealed
First WIMP Search
May 2022
WS2022 Complete!
Phys. Rev. Lett. 131 041002 (2023)
Dec 2021
WS2022 Begins!
Aug 2021
Xenon Enters the TPC
The search for dark matter Continues!
World-Leading WIMP Sensitivity and Beyond
Mar 2023
WS2024 Begins
9 GeV - 10 TeV WIMPs
Apr 2024
WS2024 Complete!
Phys. Rev. Lett. 135 011802 (2025)
Apr 2025
WS2025 Complete!
3 - 9 GeV WIMPs, ^{8}B CEνNS
This talk
Phys. Rev. Lett. 137 Accepted (2026)

Neutrino signals in LZ

1. **Electron recoils from solar neutrinos**
   → background in >10 GeV DM searches
   a. Mostly pp-chain neutrinos with contributions from ^{7}Be and CNO chain
2. **CEνNS from ^{8}B solar neutrinos**
   → this analysis
   a. Lower energy neutrinos produce CEνNS below xenon threshold
3. **CEνNS from diffuse supernova and atmospheric neutrinos**
   a. Higher energy, but much lower flux
   → need more exposure for statistically significant measurement

Nature 562 (2018) 7728, 505-510

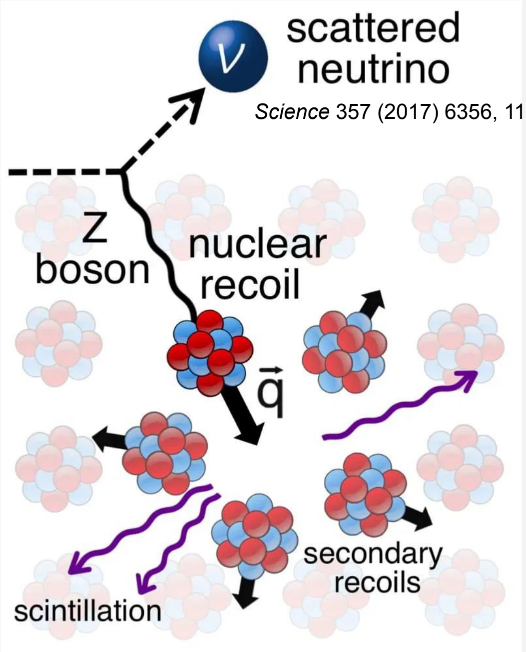




Coherent Elastic Neutrino-Nucleus Scattering

Well-predicted neutral current Standard Model process proposed in the 1970s where neutrino “sees” whole nucleus

- First measured by the COHERENT experiment in 2017 using CsI detectors the Spallation Neutron source
  - *Science 357, 6356 (2017)*
  - *Phys. Rev. Lett. 126, 012002 (2021)* - Ar
  - *Phys. Rev. Lett. 129, 081801 (2022)* - CsI
  - *Phys. Rev. Lett. 134 231801 (2025)* - Ge
- Seen in other reactor-based experiments
  - Dresden-II *PRL 129, 211802 (2022) - Ge*
  - CONUS+ *Nature 643, 1229-1233 (2025) - Ge*
- Liquid xenon TPCs for dark matter
  - PandaX-4T *PRL 133, 191001 (2024)* — < 3σ
  - XENONnT *PRL 133, 191002 (2024)* — < 3σ
  - ***LZ PRL 137, 091806 (2026) — 4.5σ***
  - XENONnT *PRL 137, 091807* — 3.3σ



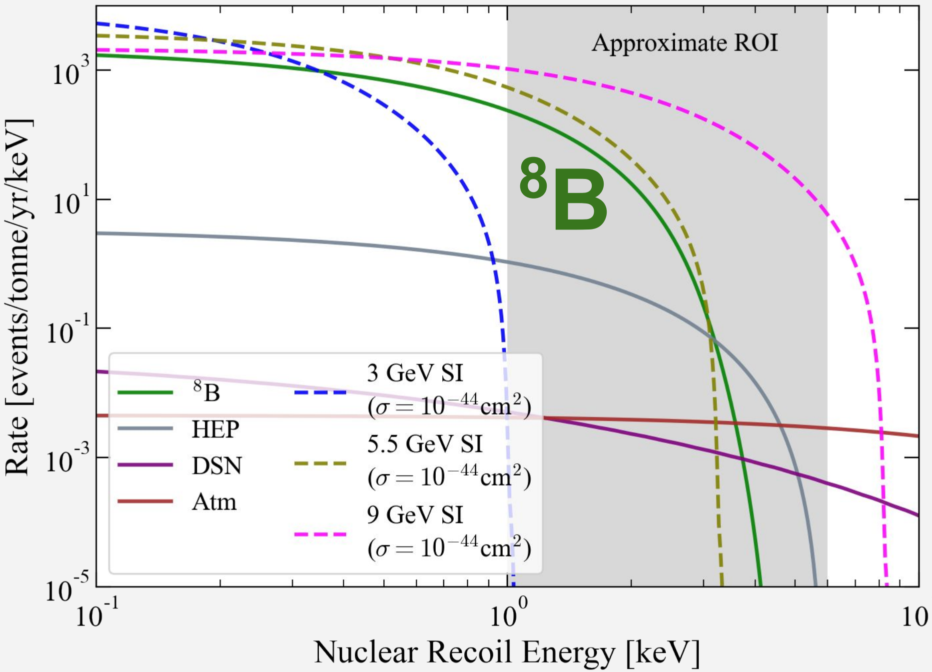
Science 357 (2017) 6356, 1123-1126

$$\frac{d\sigma(E_\nu, E_r)}{dE_r} = \frac{G_f^2}{4\pi} Q_w^2 m_N \left(1 - \frac{m_N E_r}{2E_\nu^2}\right) F^2(E_r)$$

$$Q_w = N - (1 - 4\sin^2\theta_w)Z$$

The neutrino fog

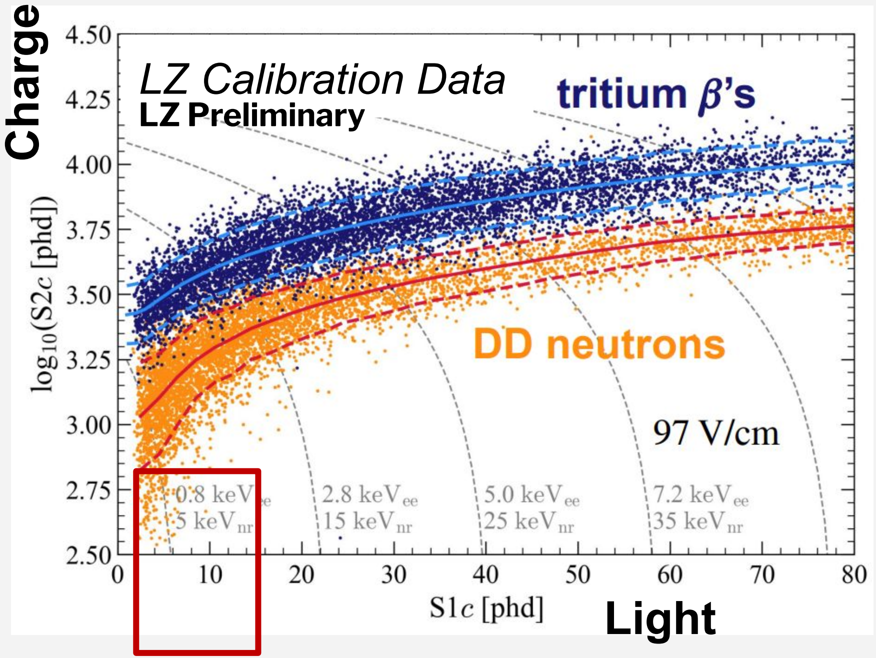
- Expect significant number of ^{8}B solar neutrino CEνNS interactions in low energy regime [1,6] keVnr
- ^{8}B CEνNS spectrum is similar to spin independent elastic recoil of 5.5 GeV DM candidate
  → ***low-energy "neutrino fog"***



Search for CEνNS interactions from ^{8}B solar neutrinos and light (< 9 GeV) dark matter in 5.7 tonne-year exposure

What are the backgrounds?

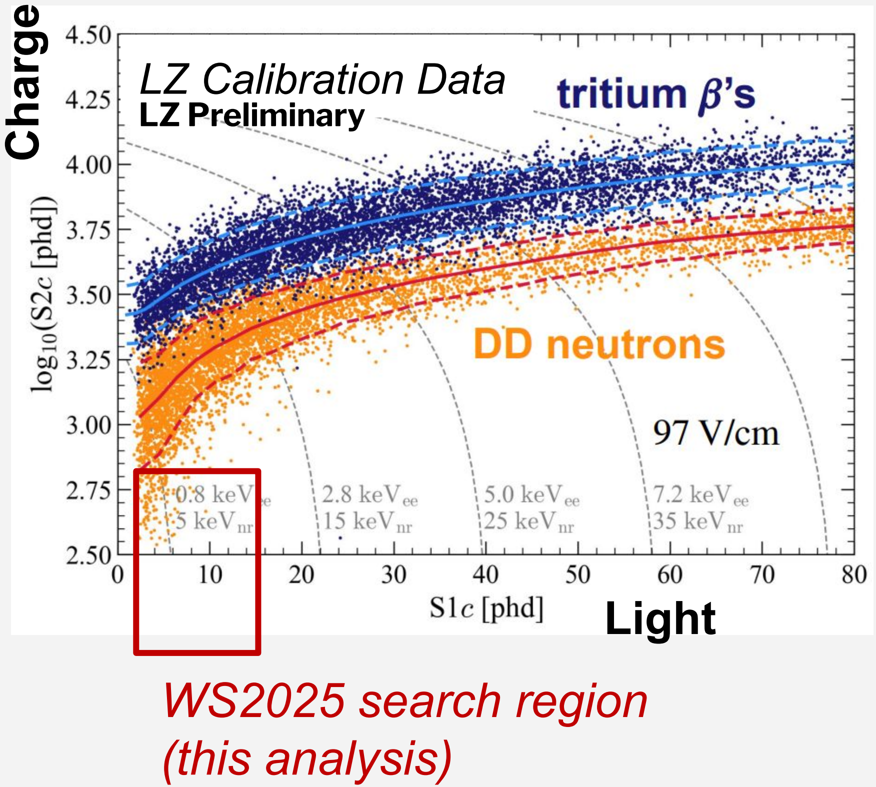
- Electron recoil (ER) backgrounds (betas, gammas) are **negligible**



WS2025 search region (this analysis)

What are the backgrounds?

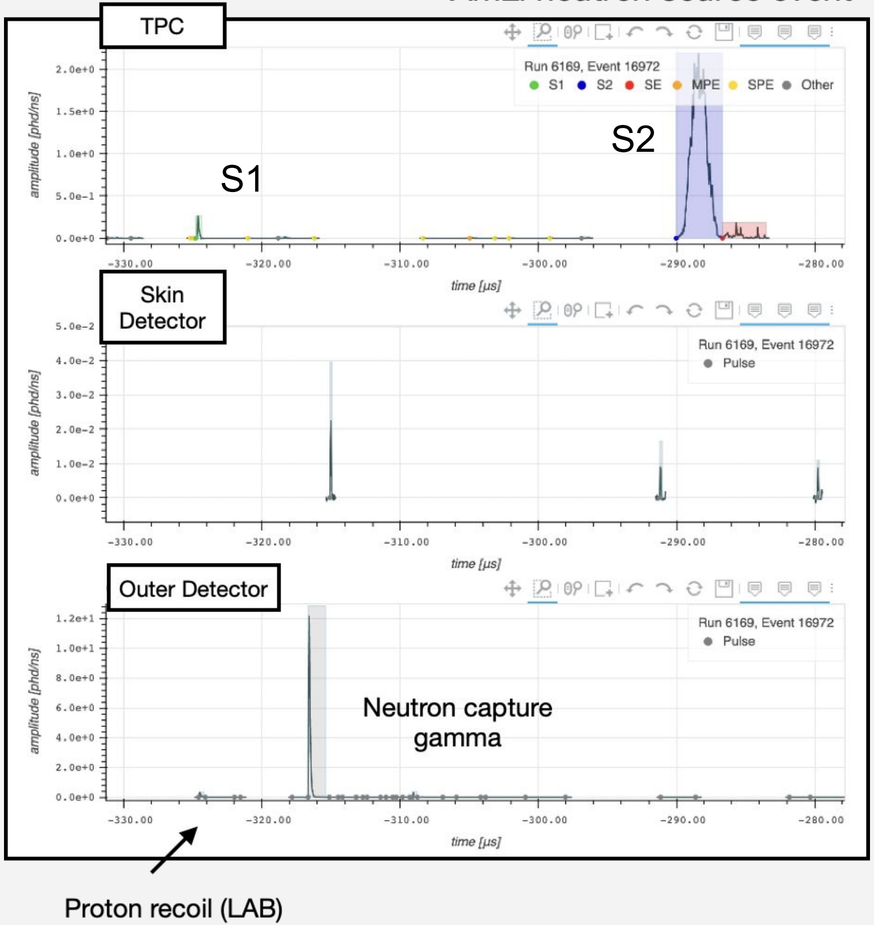
- Electron recoil (ER) backgrounds (betas, gammas) are **negligible**
- Neutron backgrounds are **< 1 event** (tag with Outer Detector and LXe Skin)



OD and Skin vetoes

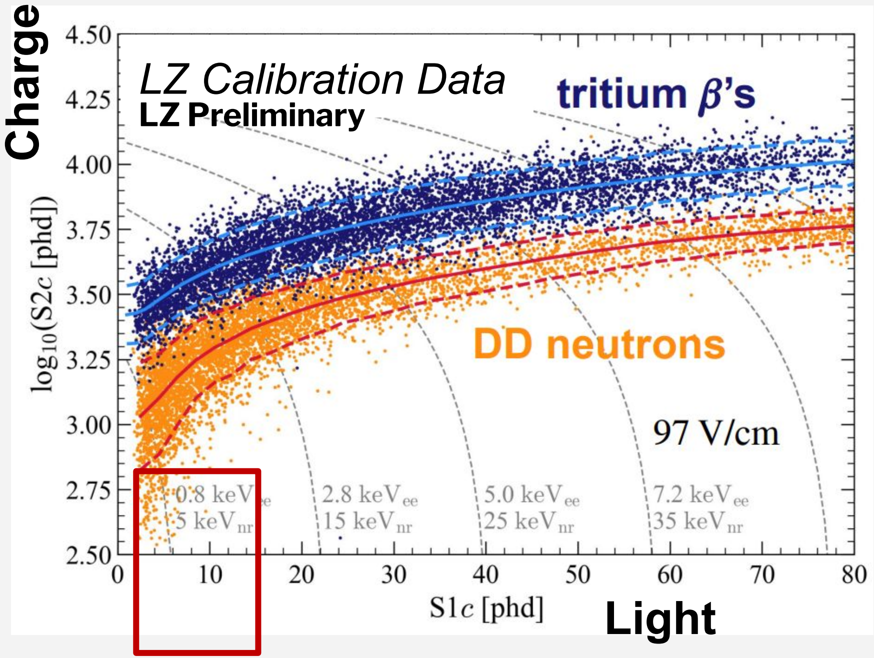
- Active vetoes to reject radiogenic neutrons with **prompt and delayed coincidences**
  - Assessed with AmLi and AmBe
- Delayed-only neutron veto efficiency: **87 ± 2 %**
- Total neutron veto efficiency: **92 ± 4 %**
- Data driven neutron rate constraint using sideband of events failing vetoes
  - **< 1 event in 5.7 tonne-yr exposure**

AmLi neutron source event



What are the backgrounds?

- Electron recoil (ER) backgrounds (betas, gammas) are **negligible**
- Neutron backgrounds are **< 1 event** (tag with Outer Detector and LXe Skin)
- **Dominated by accidental coincidence events**

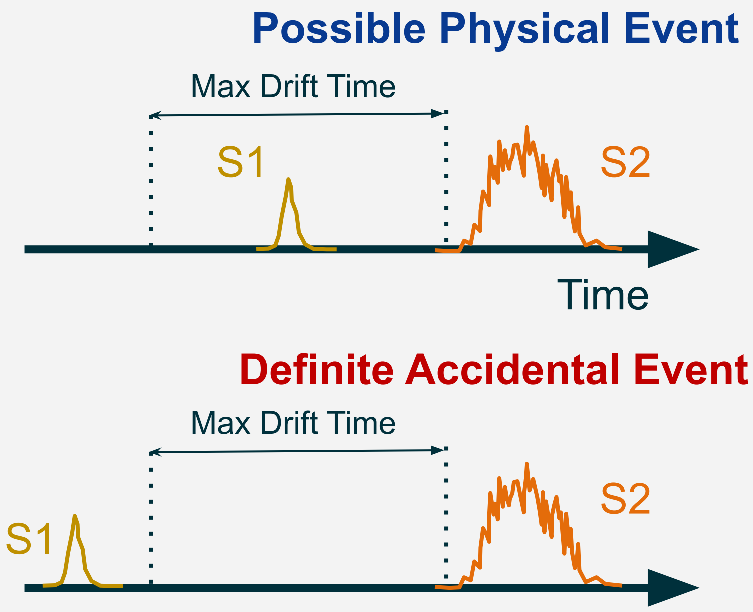


WS2025 search region (this analysis)

Accidental Coincidences

- **Spurious S1s and S2s can pile-up to mimic a genuine signal-like single scatter**
- Targeted removal of these events based on S1 and S2 pulse topologies
- Data driven accidental model built by environment-matched pairing of isolated S1s and S2s pulses
- Rate+shape validated on multiple datasets

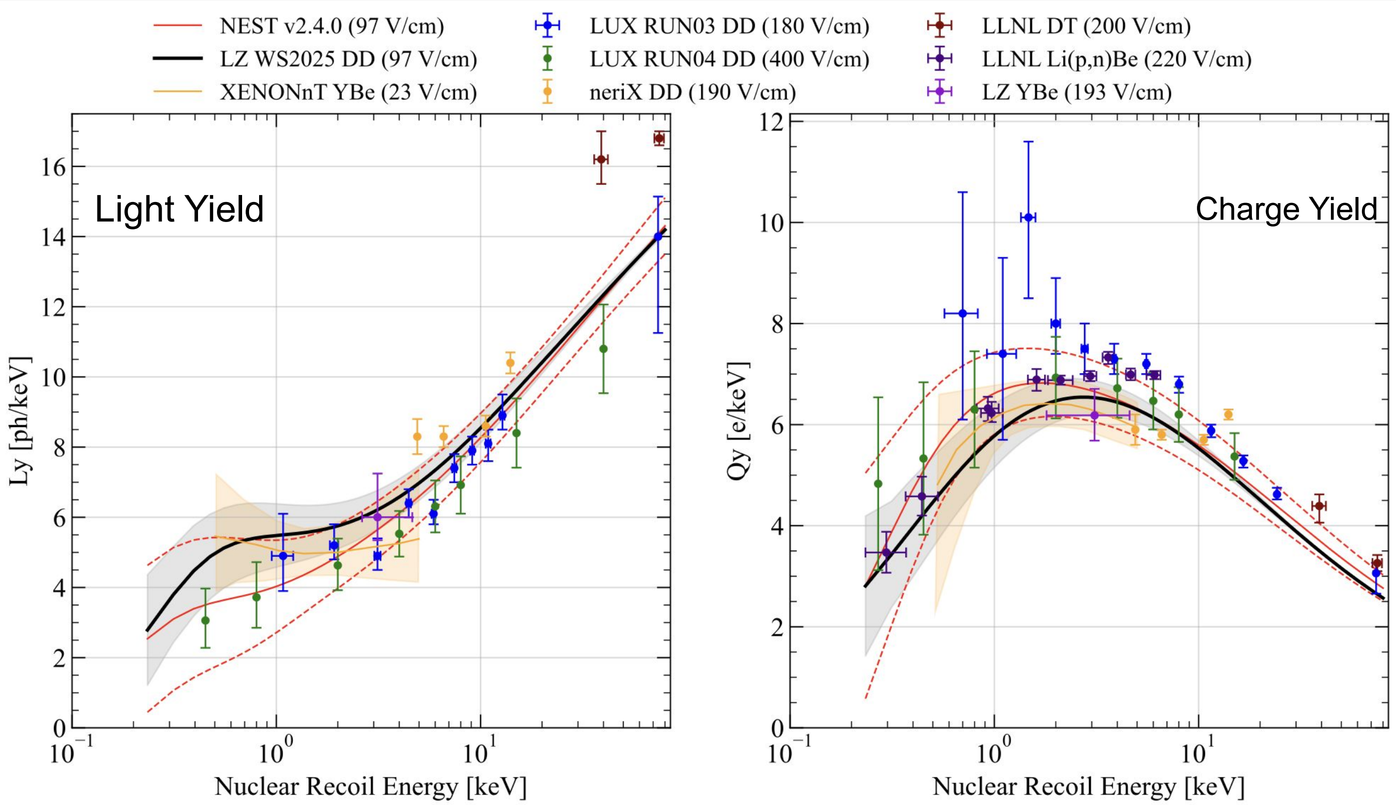
6.6 ± 0.3 events in full exposure (5.7 tonne-years)



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

Calibrated nuclear recoil response

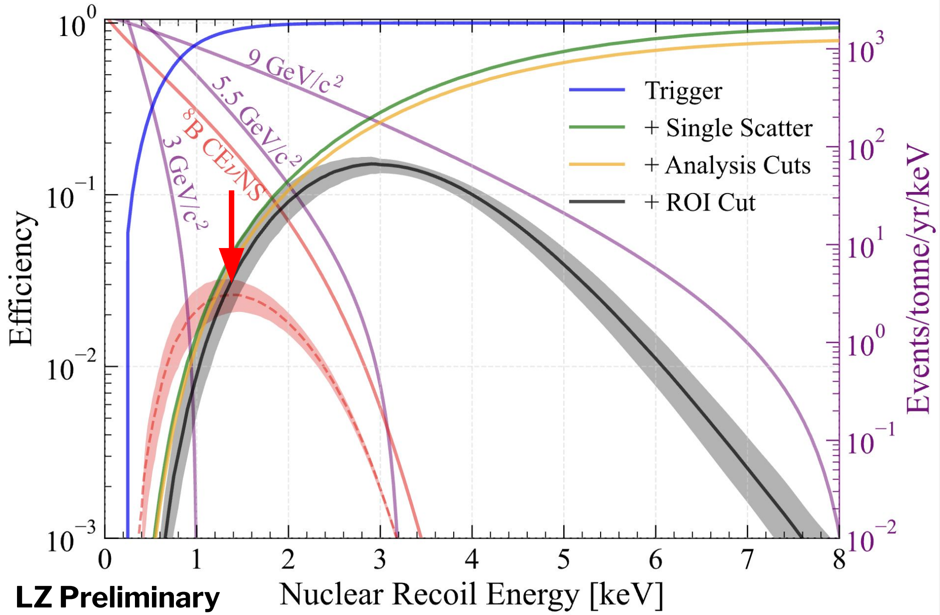
LZ Phys. Rev. Lett. 137, 091806



Detection efficiency & uncertainty

- Detect ~ 0.4% of ^{8}B CEνNS events after all selections and efficiencies
    - Predict $20.6^{+8.9}_{-6.8}$ events
      5.7 tonne-yr exposure
- Total systematic on detector response:
    - Light/charge yields
    - Photon fluctuations
    - Reconstruction and selections
- Systematic on rate folded into statistical analysis

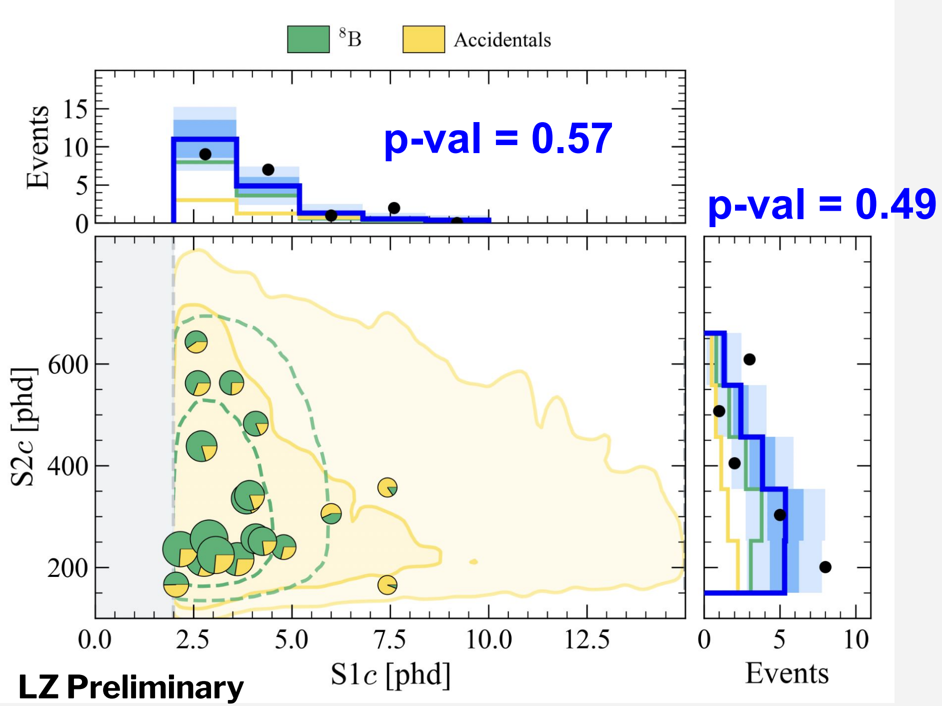
LZ Phys. Rev. Lett. 137, 091806



Searching for ^{8}B CEνNS

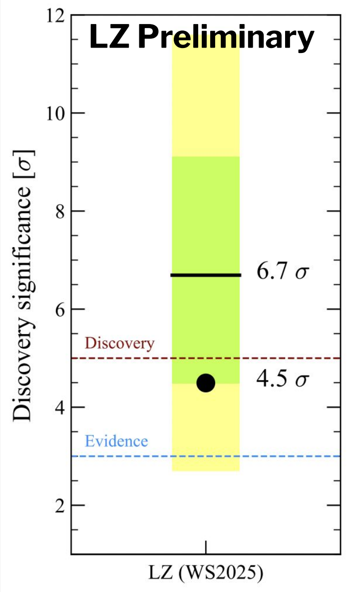
- Search for ^{8}B CEνNS events, ***assuming zero DM events***
- ^{8}B CEνNS rate is **unconstrained**, floating freely in fits

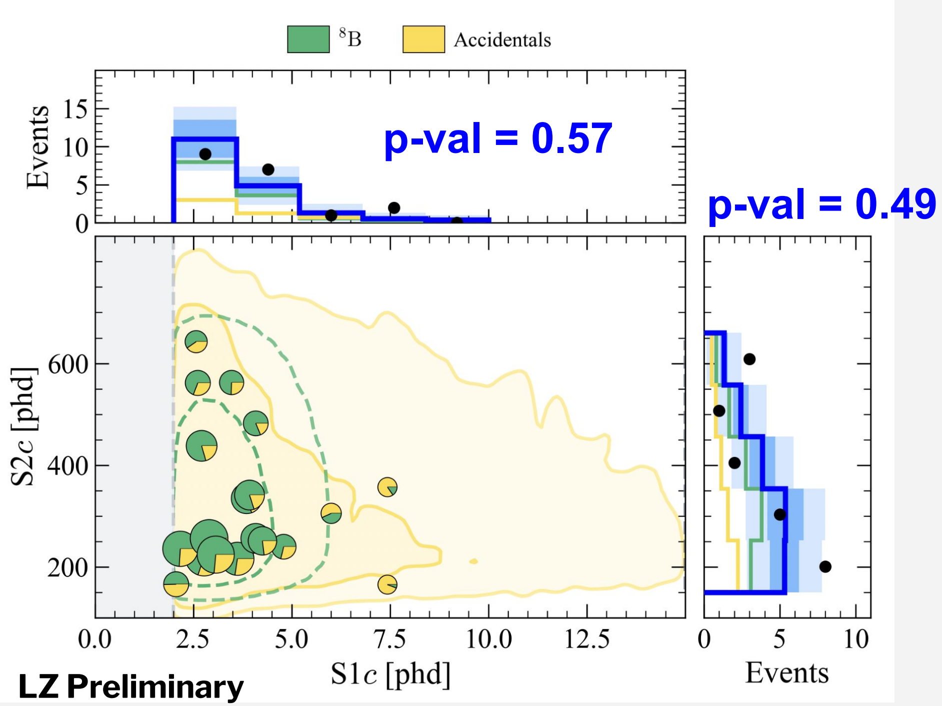
Components	Expectation	^{8}B CEνNS Unconstrained Fit
SI DM	-	-
^{8}B CEνNS	$20.6^{+8.9}_{-6.8}$	$12.3^{+7.0}_{-5.4}$
Accidental coinc.	6.6 ± 0.3	6.6 ± 0.3
Detector neutrons	$0.04^{+0.25}_{-0.04}$	$0.1^{+0.2}_{-0.1}$
Total	$27.2^{+10.1}_{-7.3}$	$18.9^{+7.0}_{-5.5}$



Evidence for ^{8}B CEνNS

- Background-only model rejected with **4.5σ significance**
- **Demonstration of LZ's ability to detect a low-energy signal!**





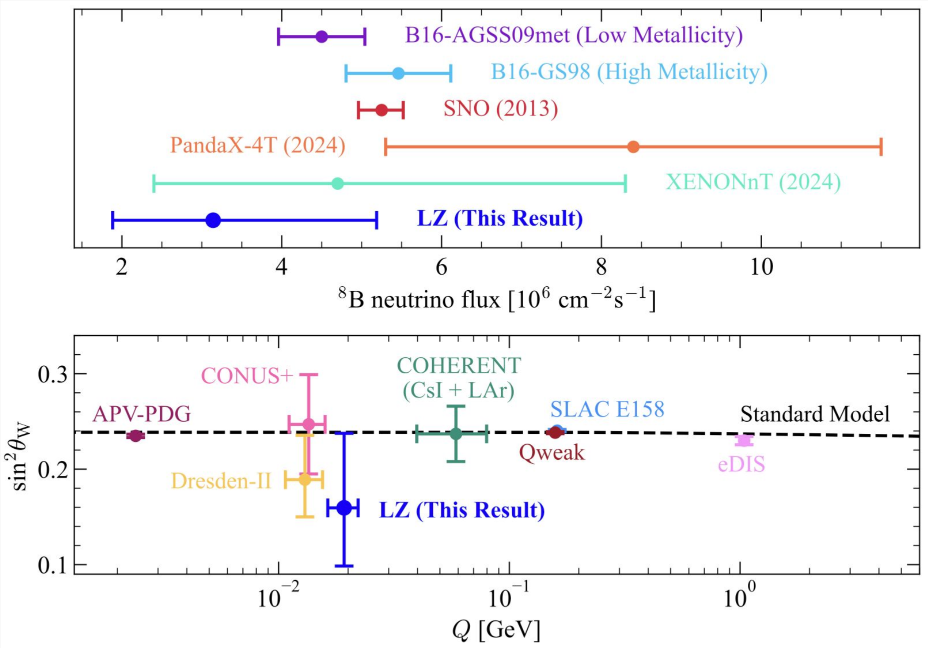
Measurements with ^{8}B CEνNS

LZ Phys. Rev. Lett. 137, 091806

Measurement of ^{8}B CEνNS can be used to …

- Make a flavor-independent measure of ^{8}B solar neutrino flux
- Measure weak-mixing angle ($\sin^2\Theta_W$) at low momentum transfer (Q)

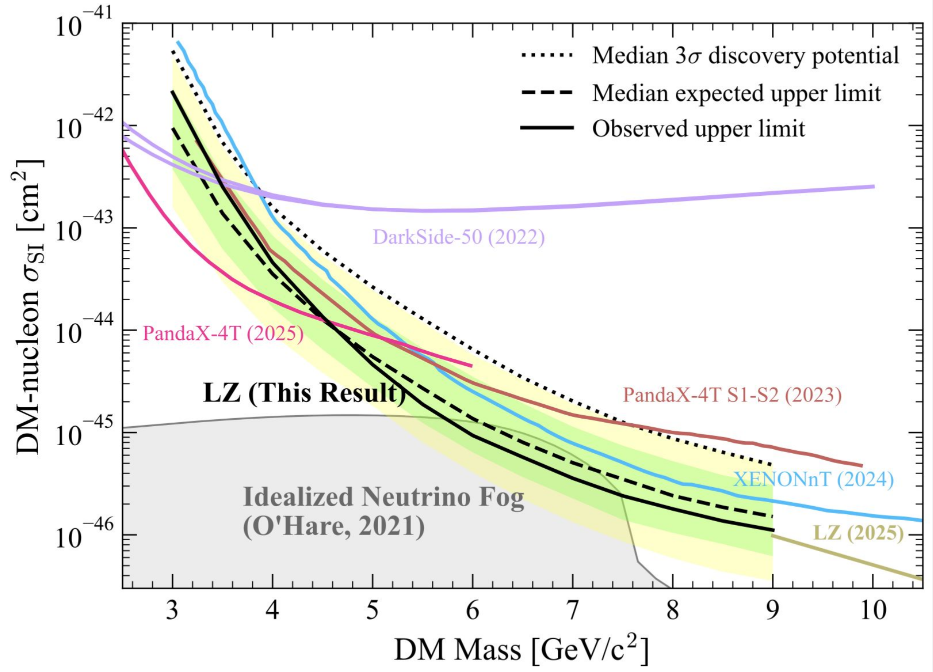
Illustrates current potential as multimessenger neutrino detector (e.g. supernova)



Low-Mass DM results

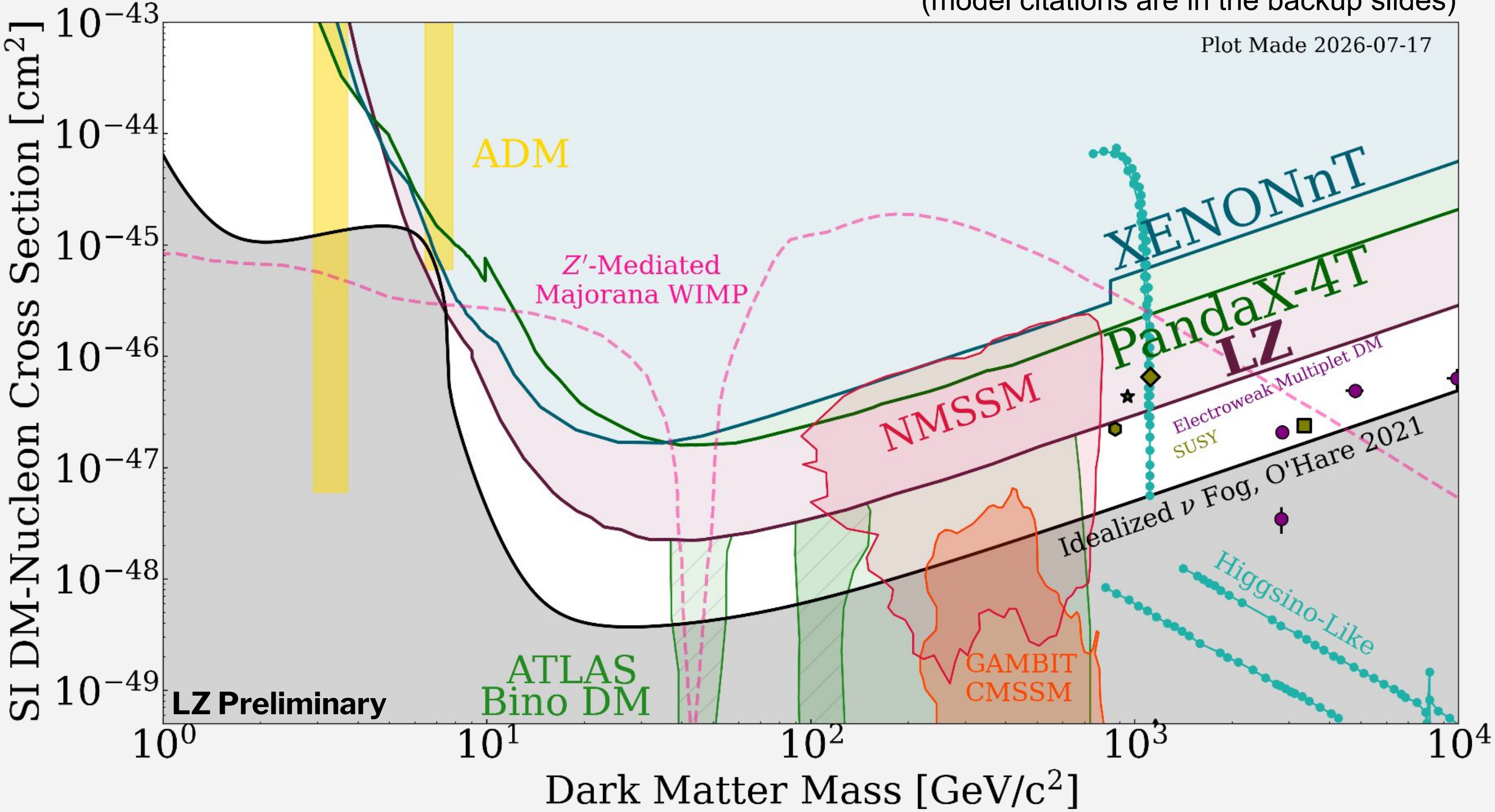
LZ Phys. Rev. Lett. 137, 091806

- ^{8}B CEνNS rate **constrained** based on SNO flux measurements
- Limit setting for Spin Independent (SI) DM-nucleon interactions using two-sided test statistic
- **World-leading limits > 5 GeV/c^2**
  - Spin dependent limits in backup
- Reaching into the neutrino fog
  - Ask me after for all the caveats about the neutrino fog…



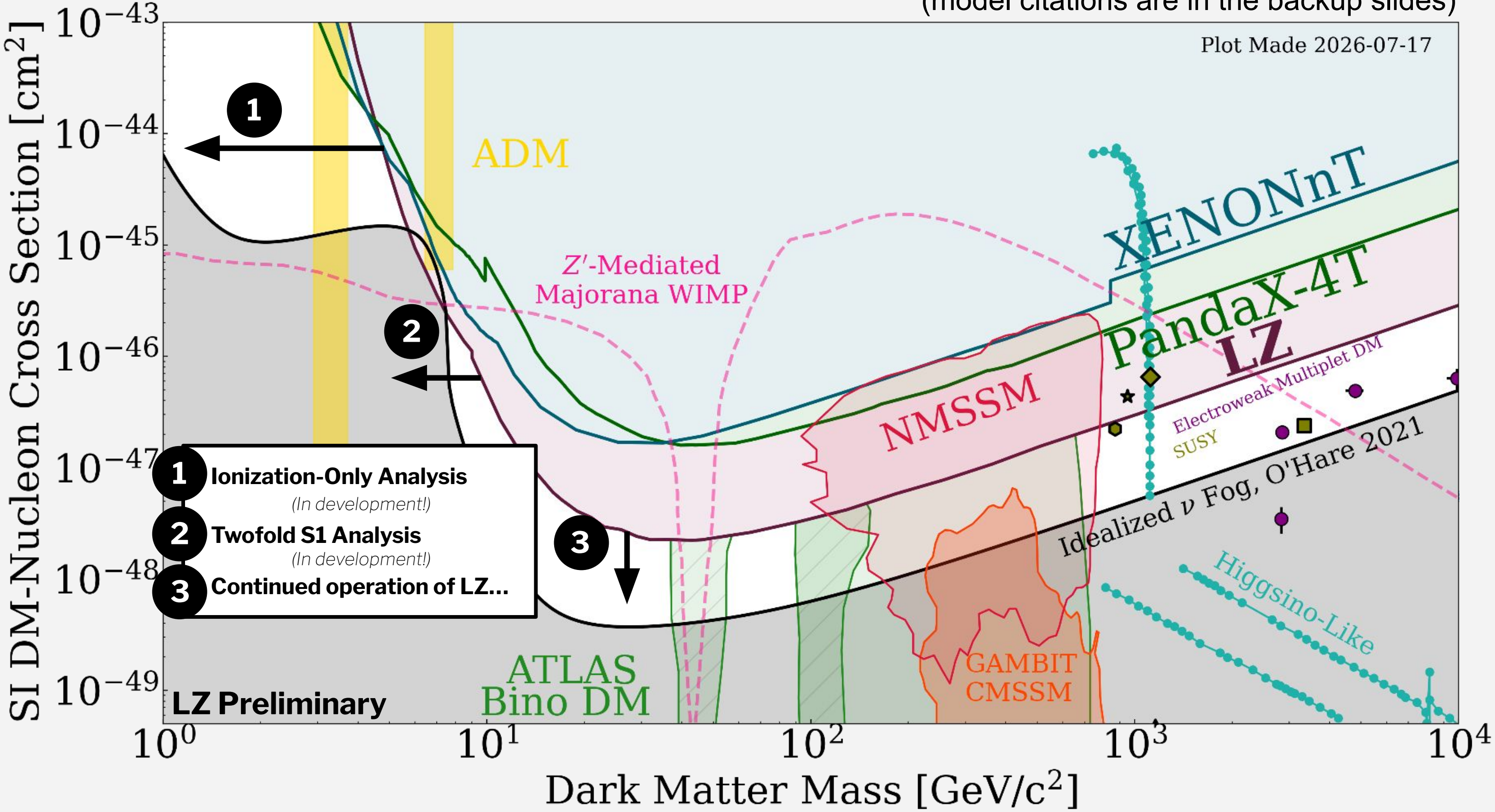
Future of LZ DM searches

(model citations are in the backup slides)



Future of LZ DM searches

(model citations are in the backup slides)



Conclusions

LZ has set world-leading limits on dark matter with masses >5 GeV/c^2

LZ, and xenon detectors in general, are world-class multi-physics rare-event observatories!

- Effective Field Theories of DM
- Low-energy ER signals
- Astrophysical neutrino CEvNS on xenon
- Rare xenon decays
- ^{136}Xe 0vBB decays

LZ Talks at TevPA

- **Sam Eriksen**
  - *EFT DM Searches*
  - *Tuesday 9:00 (Plenary)*
- **Aiham Al Musalhi**
  - *^{136}Xe 0vBB searches*
  - *Wednesday 2:15*
- **Yongheng Xu**
  - *Boosted DM searches*
  - *Wednesday 4:18*

Thank you!

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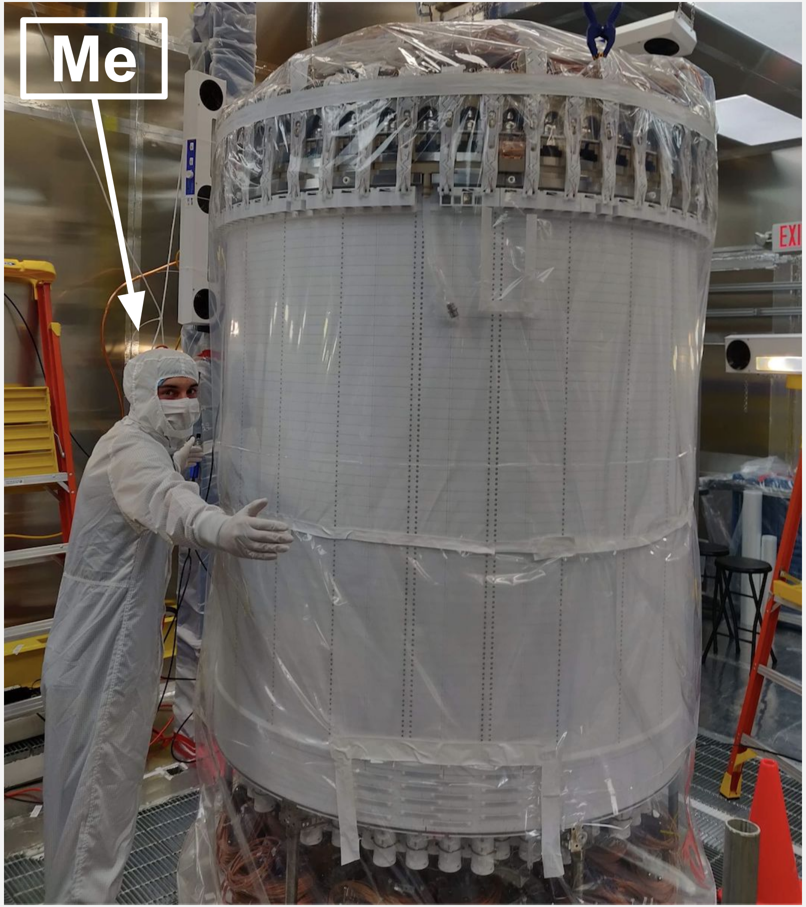
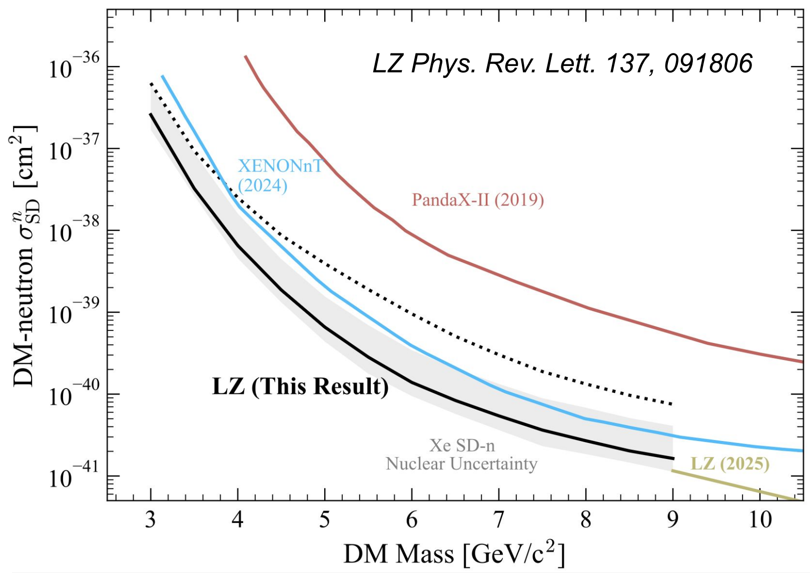
https://lz.lbl.gov/

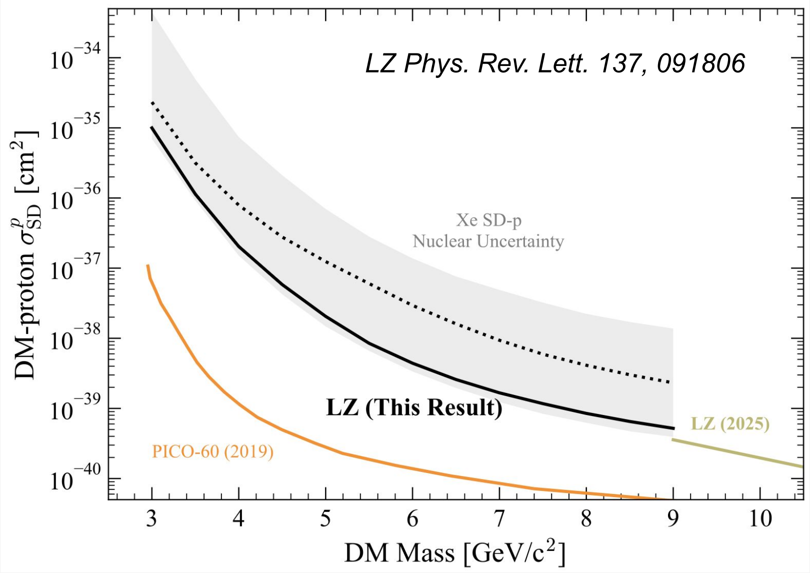


Backup

Low-mass DM results

- Limits set on neutron-only or proton-only coupling to ^{129}Xe (26%) and ^{131}Xe (21%) which have unpaired neutrons leading to non-zero nuclear spin





DM results and theory models

- **ADM**
  - Phys. Rev. D 82, 056001
- **Z’**
  - DOI 10.1088
- **ATLAS Bino Limits**
  - J. High. Energ. Phys. 2024, 106 (2024)
- **NMSSM**
  - arxiv:2405.07036
- **GAMBIT CMSSM**
  - Eur. Phys. J. C 77, 824 (2017)
- **Higgsino-Like**
  - Eur. Phys. J. C 83, 246 (2023)
- **SUSY**
  - Ann. Rev. Nucl. Part. Sci. 70, 425-454 (2020)
- **Electroweak Multiplet**
  - J. High Energ. Phys. 2025, 216 (2025)