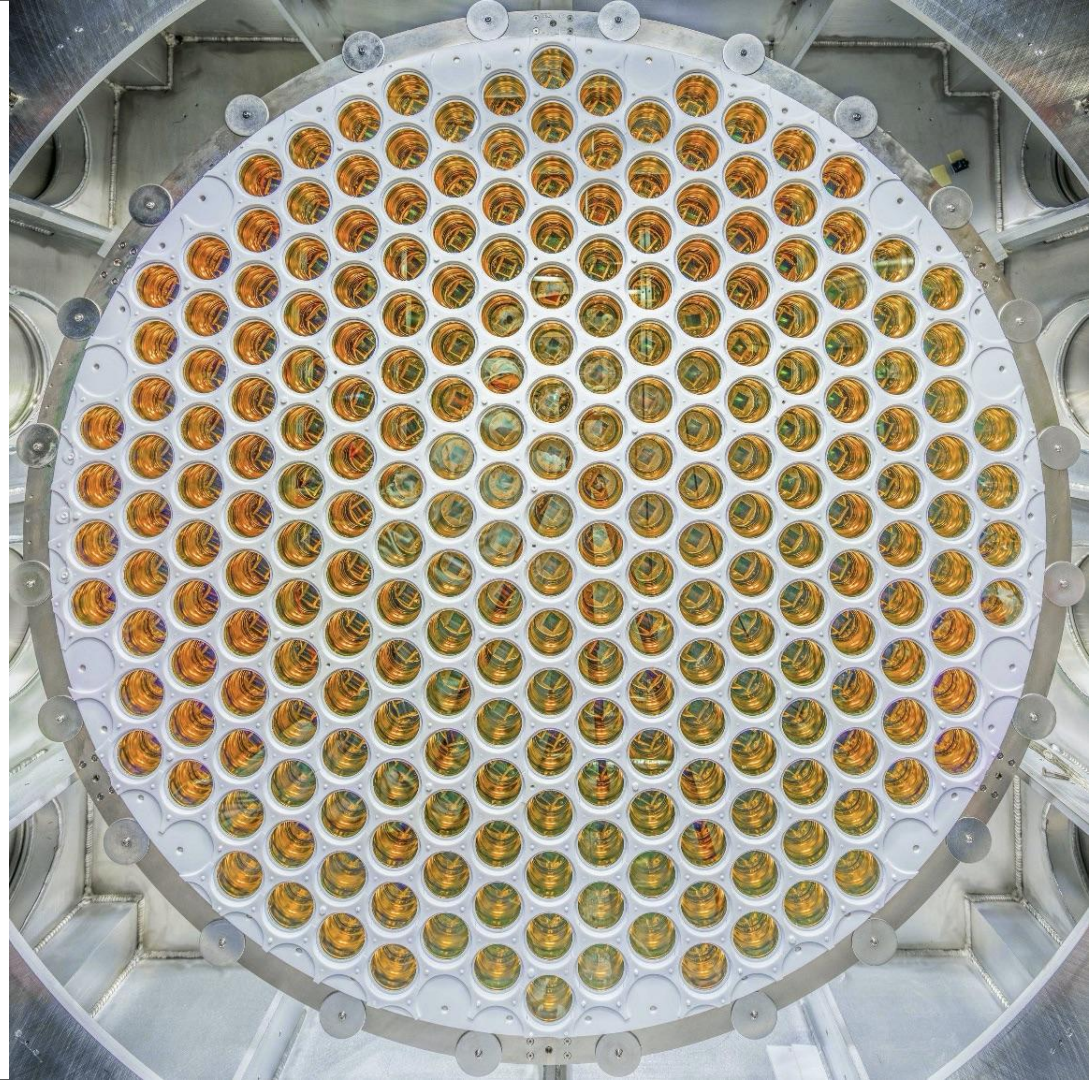
UNIVERSITY OF MICHIGAN

First Results and Status of the LUX-ZEPLIN Experiment

Michael Williams
On Behalf of the LZ Collaboration
Brookhaven Forum 2023
4th-6th October, 2023



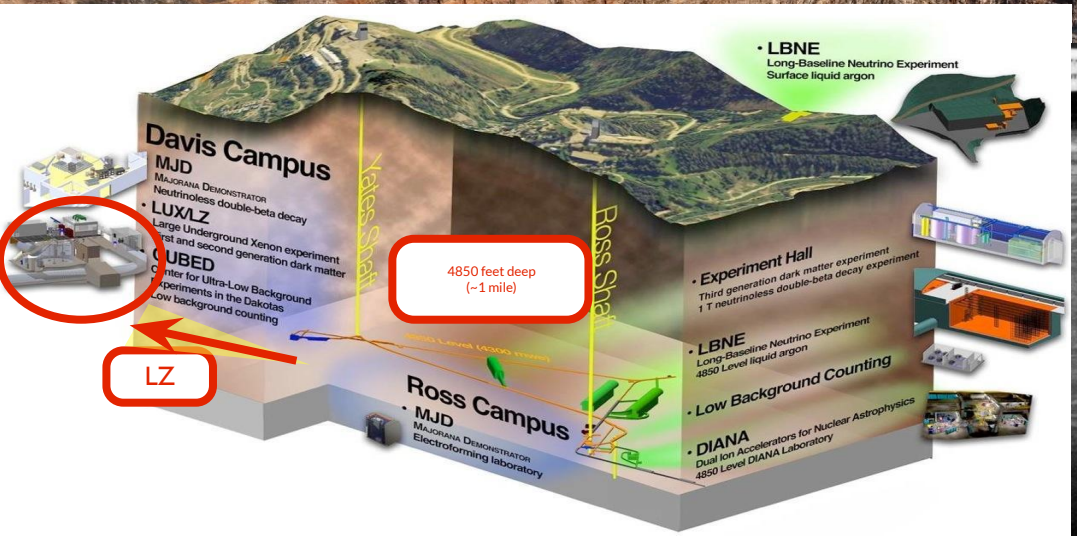
LUX-ZEPLIN (LZ) Collaboration

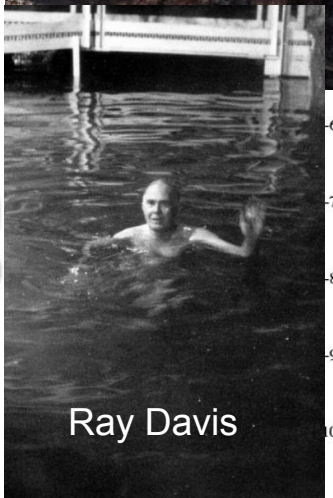
- Black Hills State University
- Brookhaven National Laboratory
- Brown University
- Center for Underground Physics
- Edinburgh University
- Fermi National Accelerator Lab.
- Imperial College London
- King's College London
- Lawrence Berkeley National Lab.
- Lawrence Livermore National Lab.
- LIP Coimbra
- 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

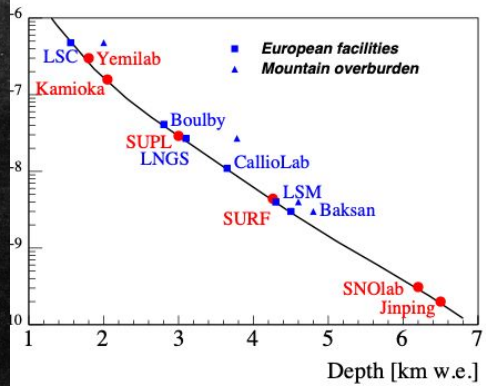
US UK Portugal Korea Australia

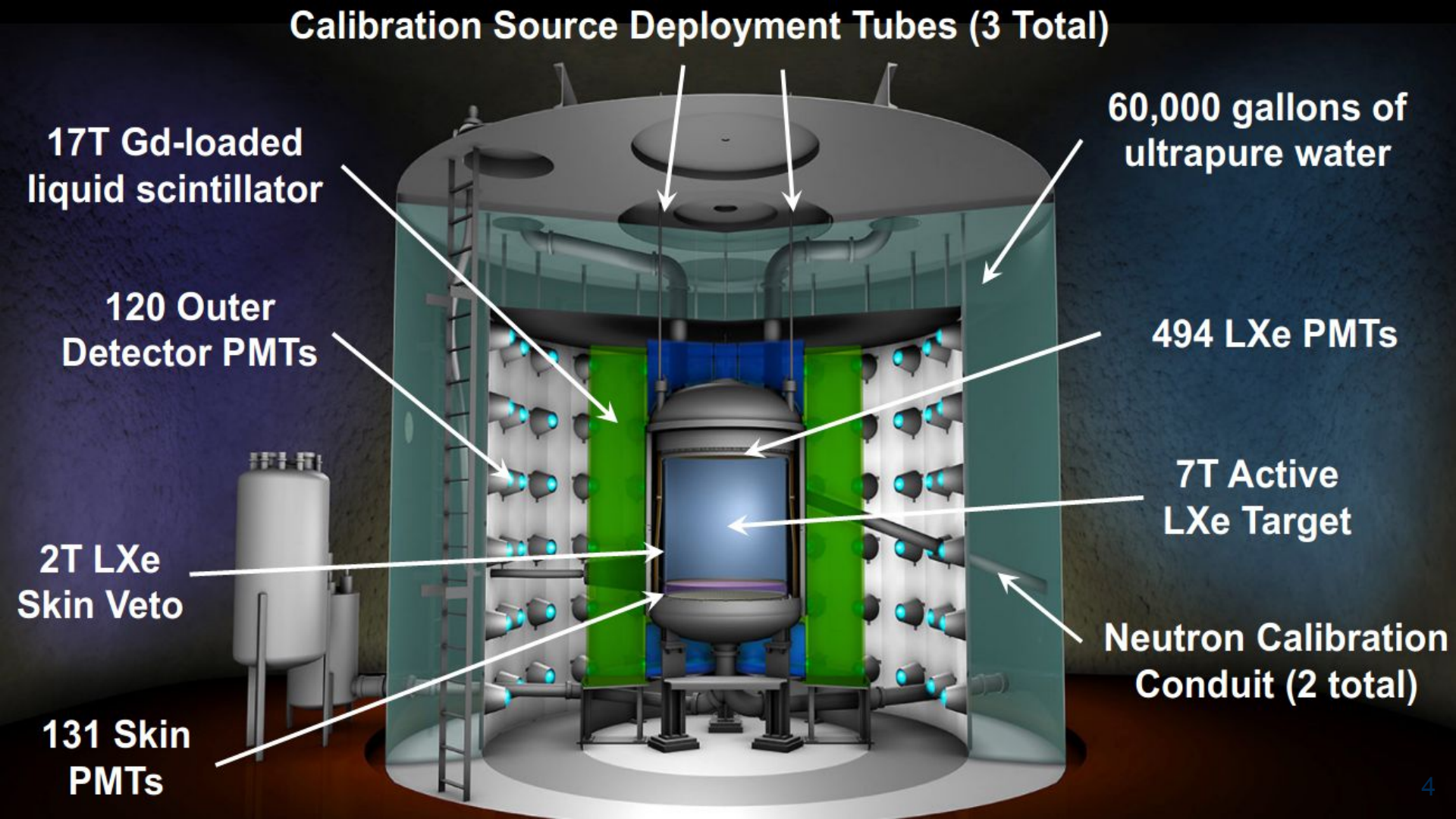
37 Institutions, 250 scientists, engineers, and technical staff

Sanford Underground Research Facility (SURF) in Lead, SD



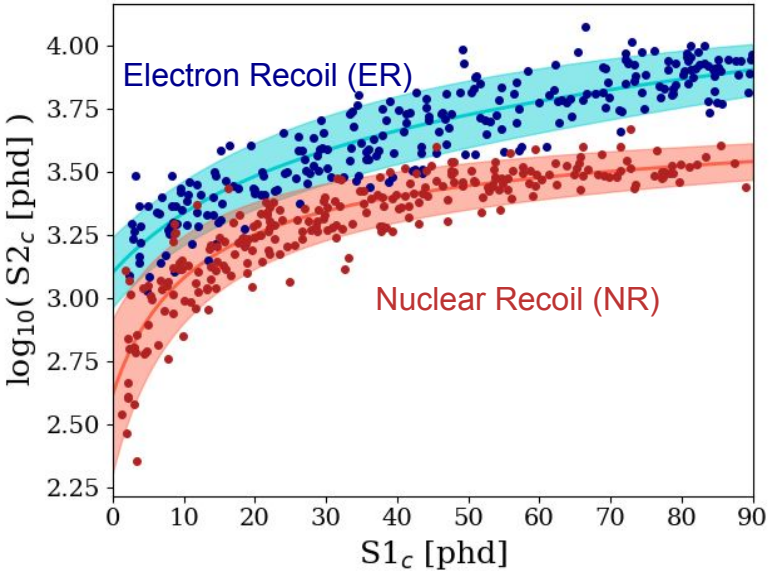


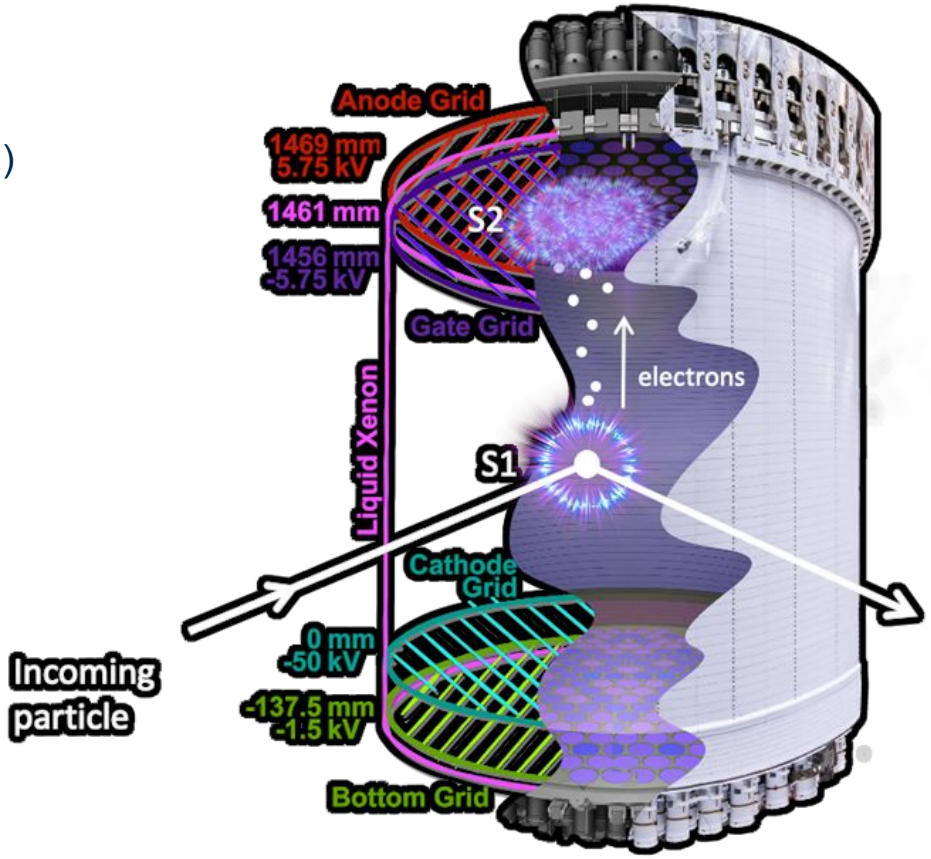



Calibration Source Deployment Tubes (3 Total)
17T Gd-loaded liquid scintillator
60,000 gallons of ultrapure water
120 Outer Detector PMTs
494 LXe PMTs
7T Active LXe Target
2T LXe Skin Veto
Neutron Calibration Conduit (2 total)
131 Skin PMTs

Dual Phase Time Projection Chamber

- Primary scintillation light (S1)
- Secondary scintillation induced from free charge (S2)
- 3D reconstruction allows for fiducialization
- ER/NR discrimination from S1:S2 ratio





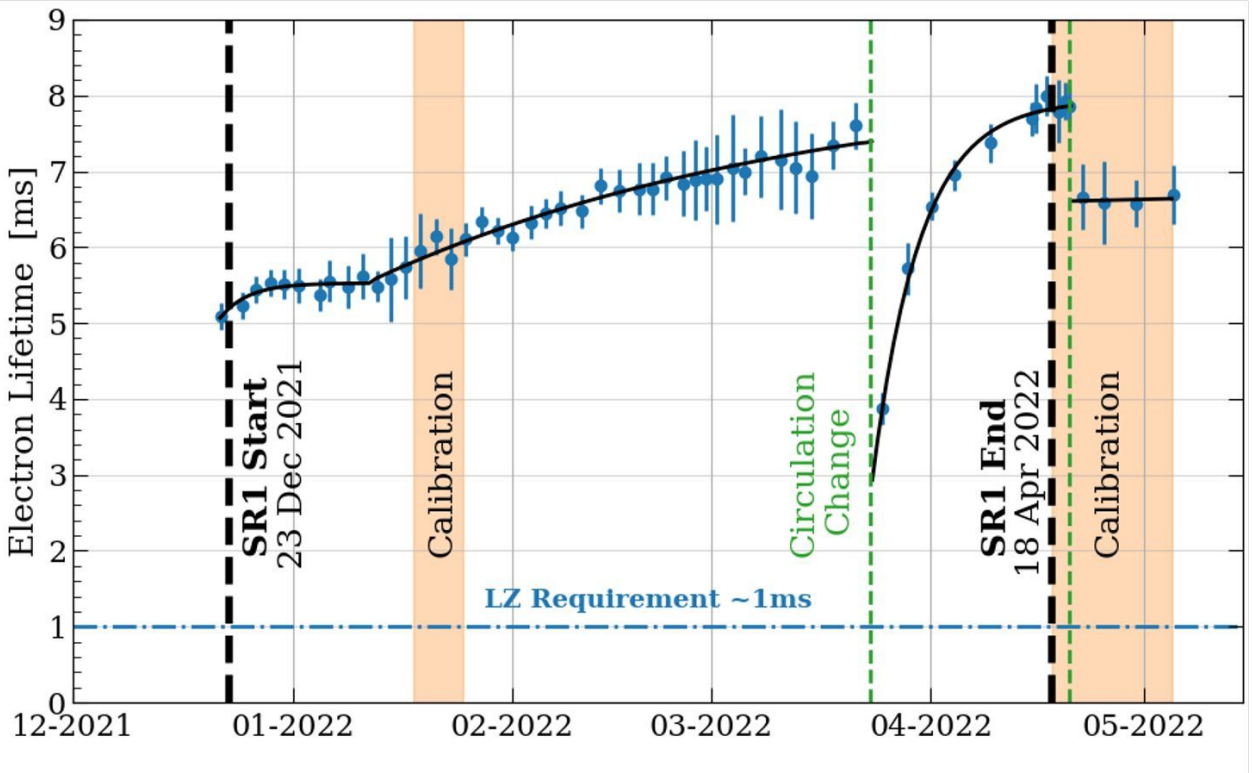
LZ Vetoes

- Skin Veto
  - 4-8cm of LXe between the TPC and inner cryostat
  - 131 2” PMTs for tagging γs that enter or leave the TPC
  - 78 +/- 5% γ tagging efficiency
    - Measured with ^{127}Xe decays

- Outer Detector (OD)
  - 6 acrylic tanks filled with 17 tonnes of Gd-loaded liquid scintillator
  - 120 8” PMTs for tagging muons in the water and neutron interactions in scintillator
  - NR tagging-efficiency of 88.5%
    - Measured with AmLi calibration

LZ's First Science Run (SR1)

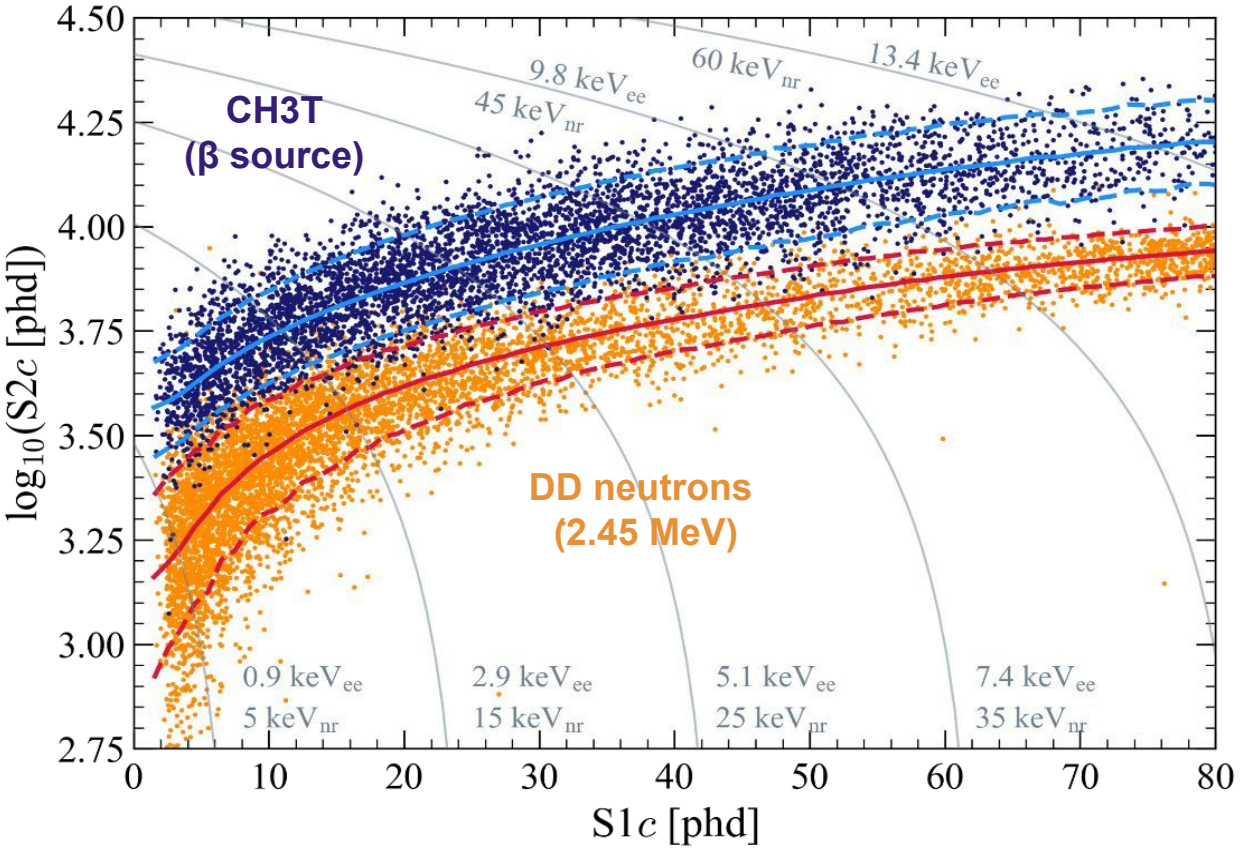
- Engineering run to show LZ's stability and potential
- Stable conditions
  - Drift field: 193 V/cm
  - Extraction Field: 7.3 kV/cm in gas
  - >97% of PMTs operational
  - Liquid temperature: 174.1K
  - Gas Pressure (1.791 bar)
  - Stable liquid level
- Continuous Xe purification
  - 3.3 t/day through getter
  - 5-8ms electron lifetime throughout run



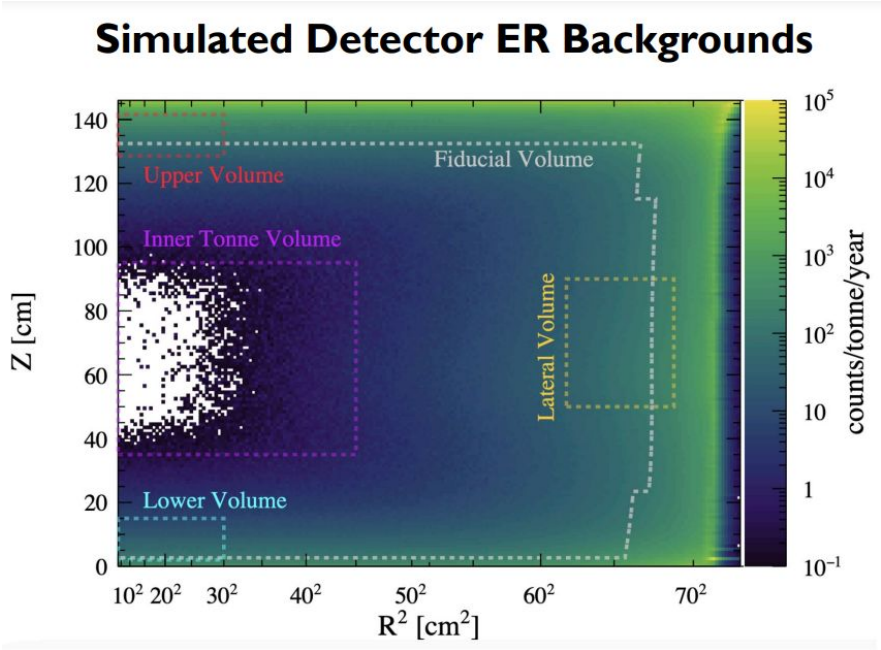
First Dark Matter Search Results from the LUX-ZEPLIN (LZ) Experiment
Phys. Rev. Lett. **131**, 041002

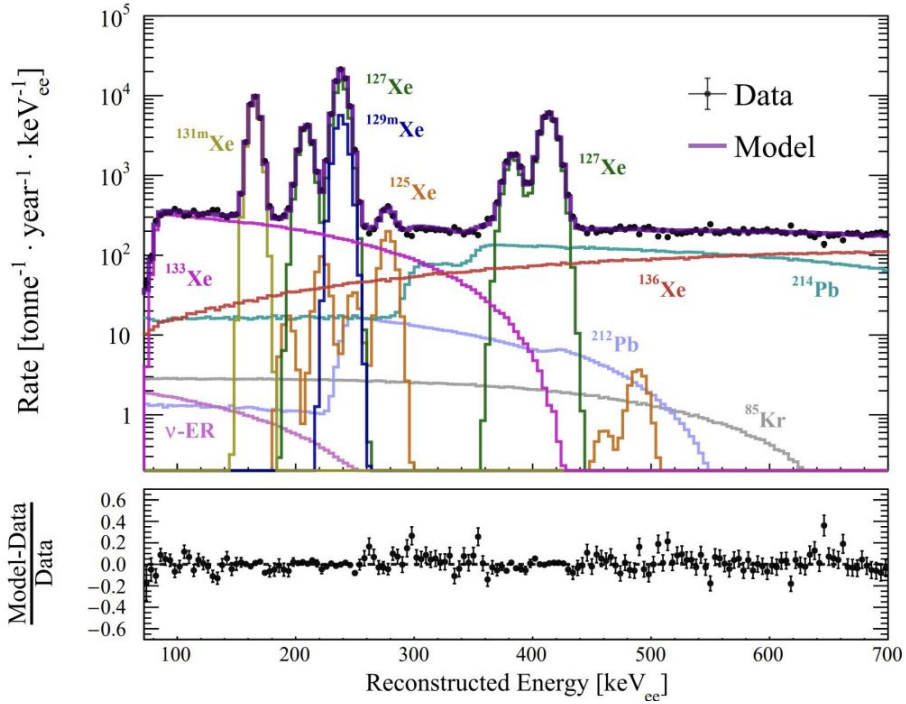
TPC Calibrations

- Calibrated with external and internal sources
- Tritiated Methane
  - Spatially homogeneous source of β ER, 0-18.6
- External D-D fusion
  - Monoenergetic 2.45 MeV neutrons
  - Up to 10^9 neutrons per second
- Tuned with NEST simulation package
  - Provides detector response model
  - g_1 = 0.114 +/- 0.002 phd/photon
  - G_2 = 47.1 +/- 1.1 phd/electron
  - Extraction Efficiency = 80.5 +/- 3.7%

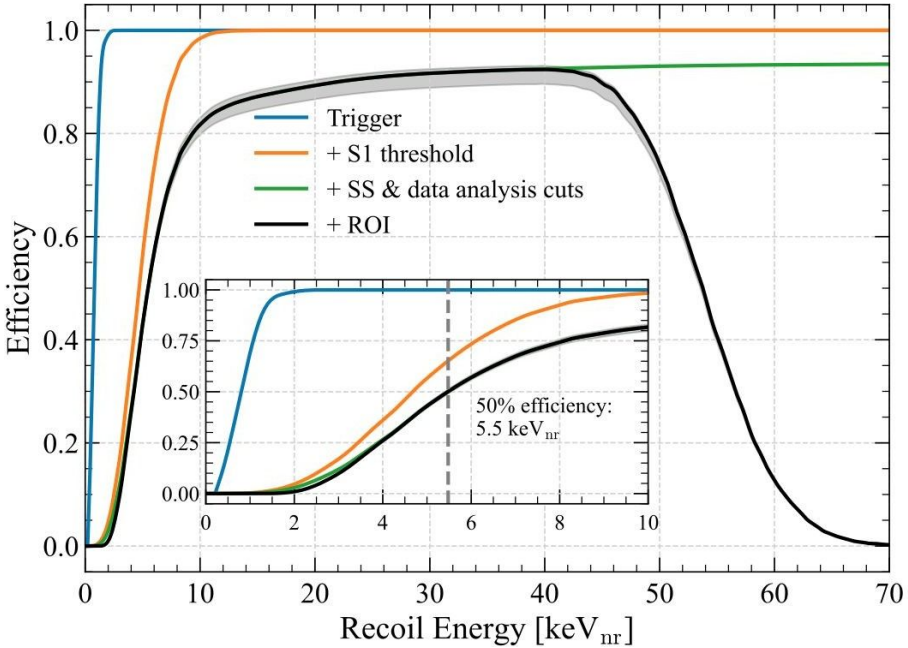


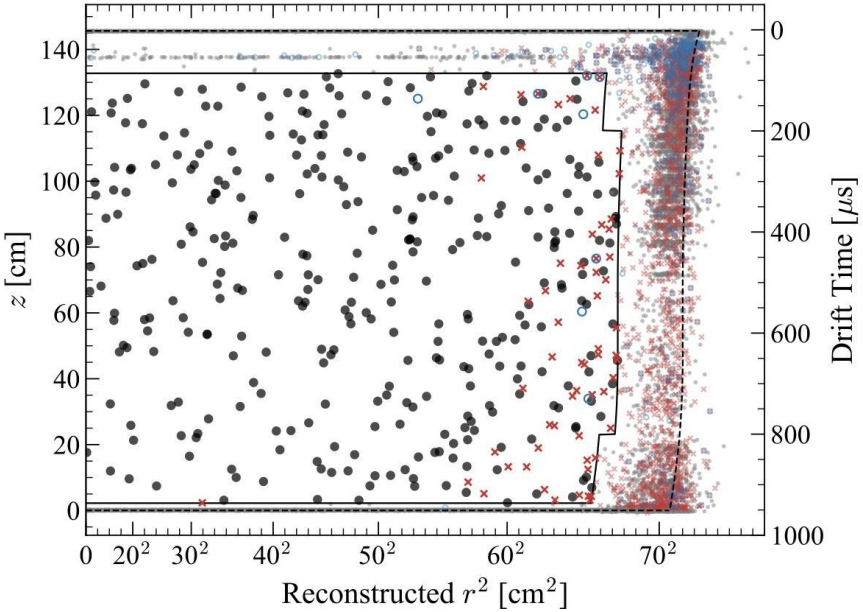
- For rare event searches, we need to understand our backgrounds!
- LXe has good self shielding - we can “fiducialize”





- Cuts developed with calibration and sideband data





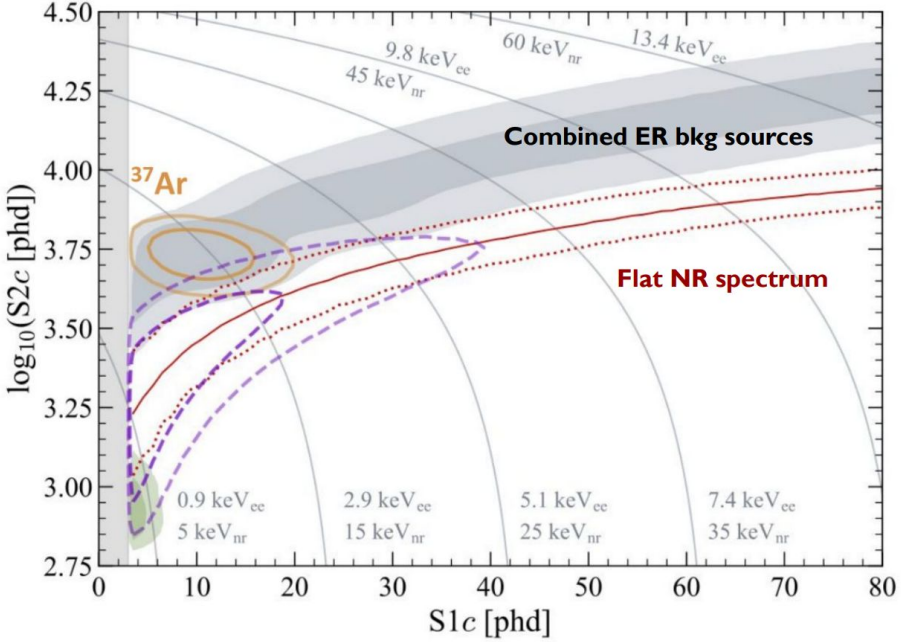
events passing all cuts

events outside of fiducial volume

events vetoed by skin (mostly ^{127}Xe)

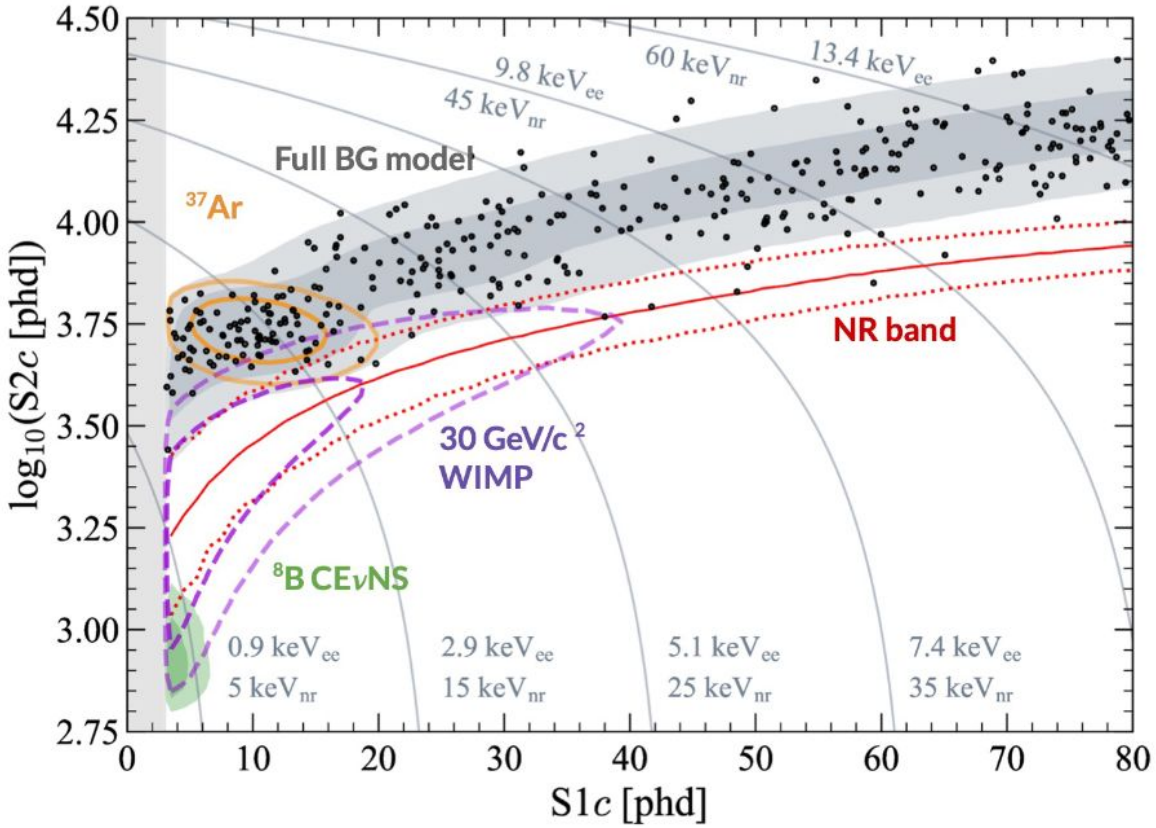
events vetoed by OD

- From data we measure activiates of background sources to create of model of backgrounds
- Note the 0 expected neutrons - most dangerous WIMP background!
  - Constrained by applying our OD efficiency on tagged fiducial single scatter events



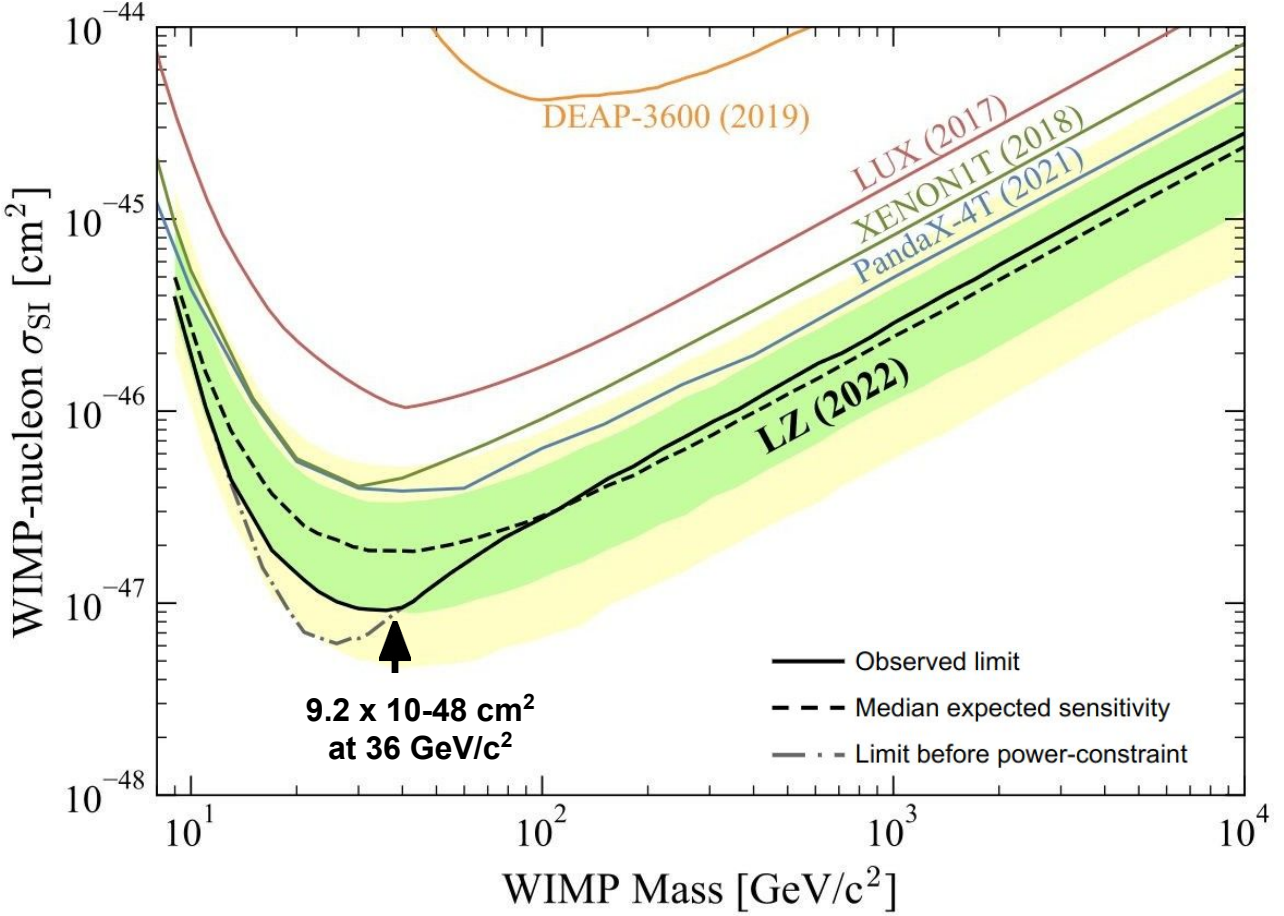
Source	Expected Events
β decays + det ER	218 ± 36
ν ER	27.3 ± 1.6
^{127}Xe	9.2 ± 0.8
^{124}Xe	5.0 ± 1.4
^{136}Xe	15.2 ± 2.4
^{8}B CEνNS	0.15 ± 0.01
Accidentals	1.2 ± 0.3
Subtotal	276 ± 36
^{37}Ar	[0, 291]
Detector neutrons	$0.0^{+0.2}$
30 GeV/c^2 WIMP	–
Total	–

60.3 +/- 1.2 live days 5.5 +/- 0.2 tonnes fiducial volume 335 events observed



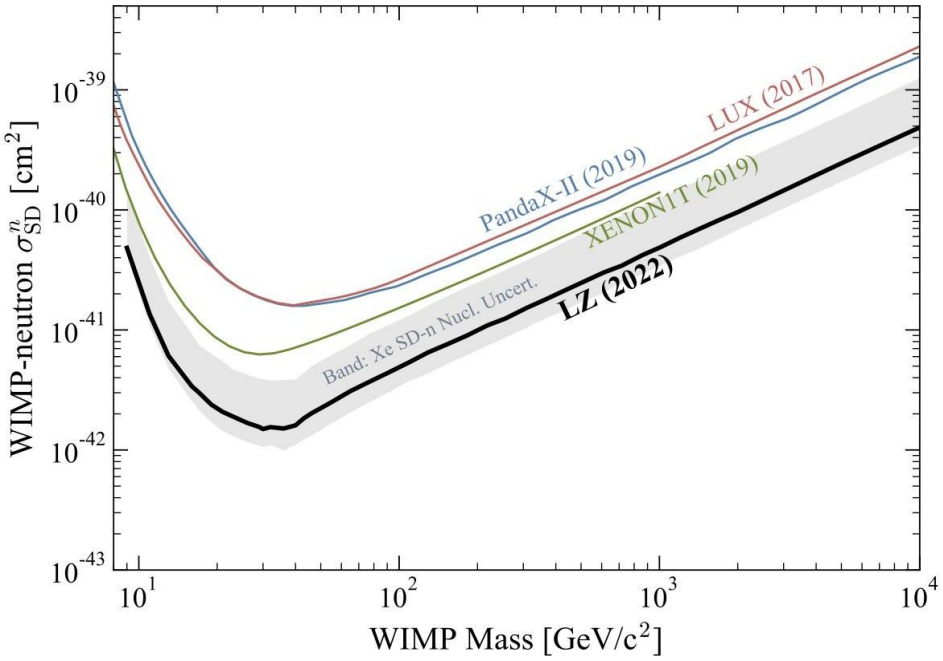
WIMP Search Results (Spin-Independent)

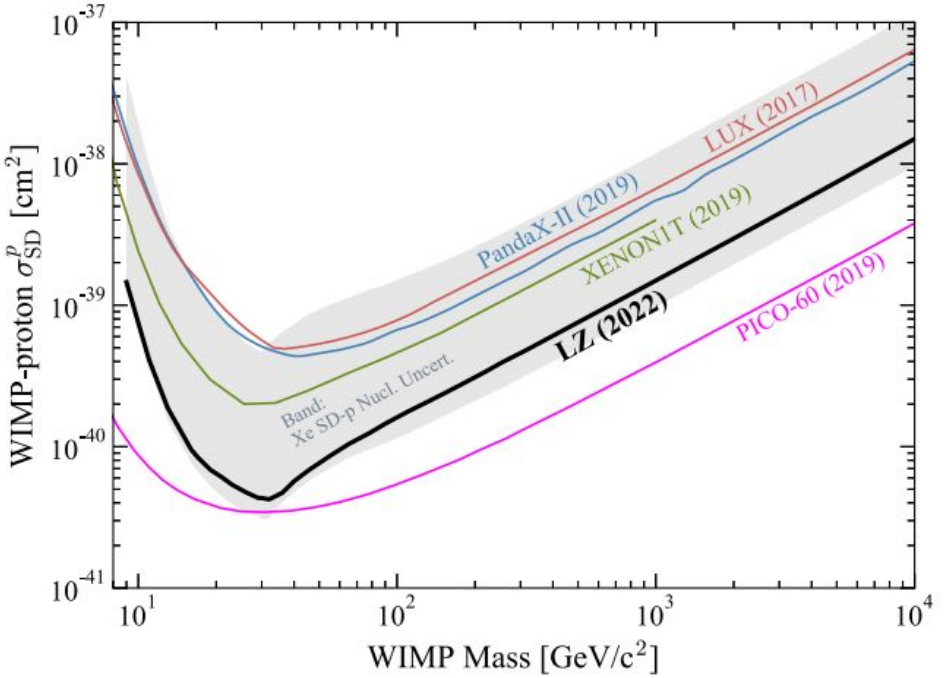
- Consistent with a background-only hypothesis
  - Two-sided PLR analysis
- Most stringent cross-section limit at 30 Gev/c^2 : 9.2x$10^{-48}$$cm^2$
- World leading exclusion limit of SI WIMPs!



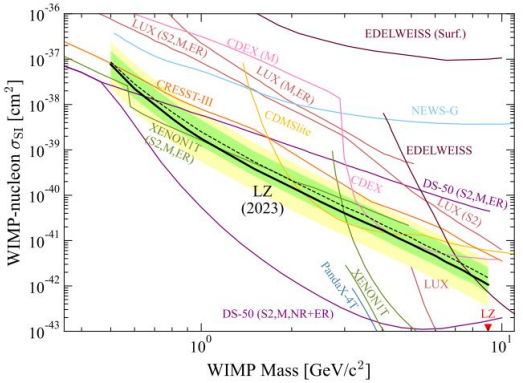
WIMP Search Results (Spin-Dependent)

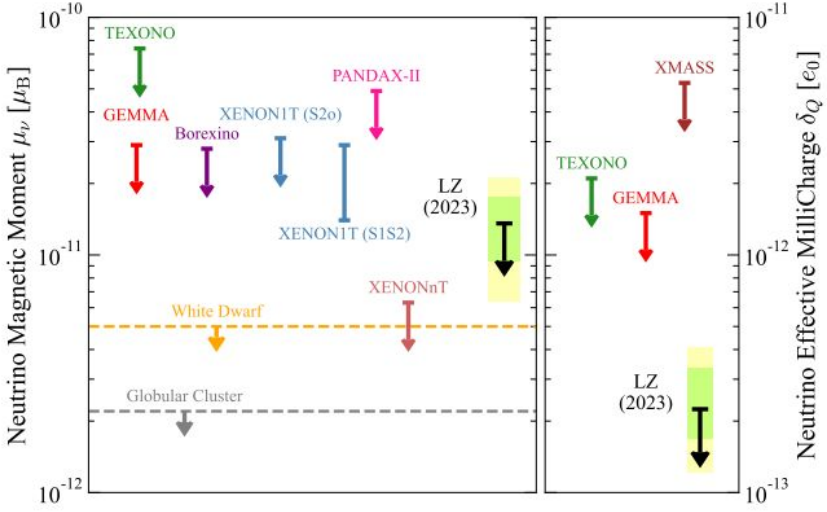
- Stringent spin dependent limits for both neutron and proton
- Gray bands represent uncertainty on the Xe form factor

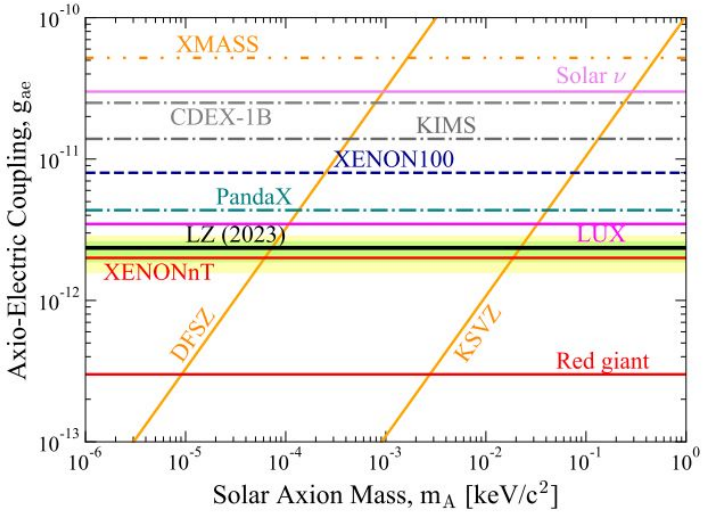




- Searches for new physics using ERs from 1-15 keV
- ALPs,Axions,Migdal-channel WIMPS, neutrino physics, hidden photons
- “A search for new physics in low-energy electron recoils from the first LZ exposure” [2307.15753]

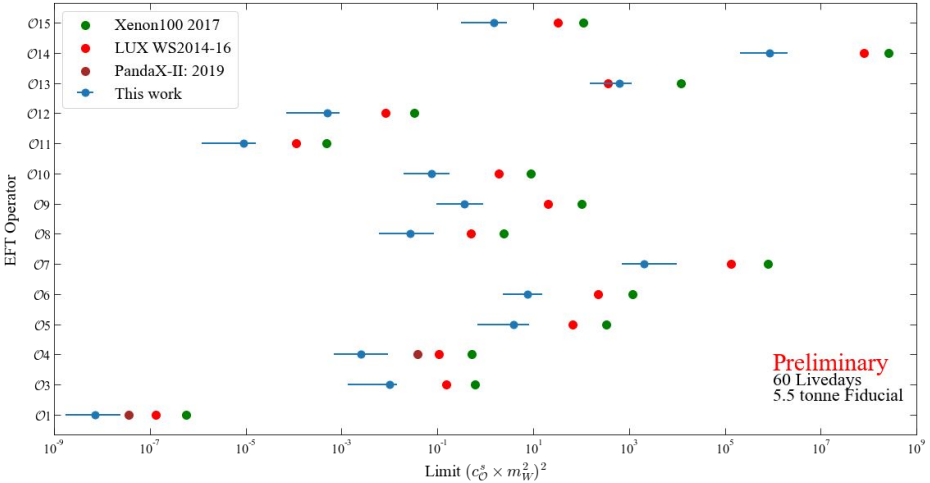






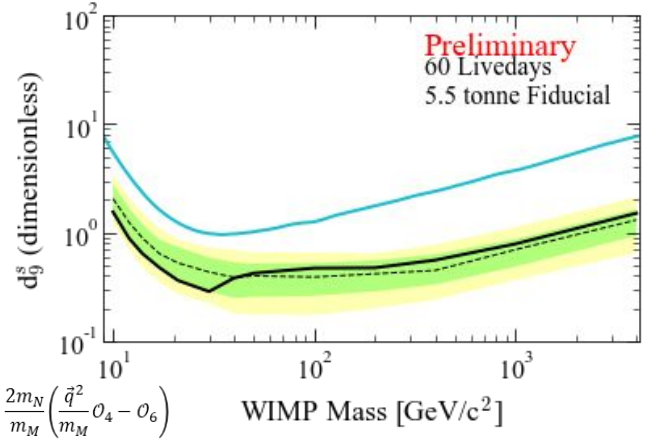
High-Energy NR Search

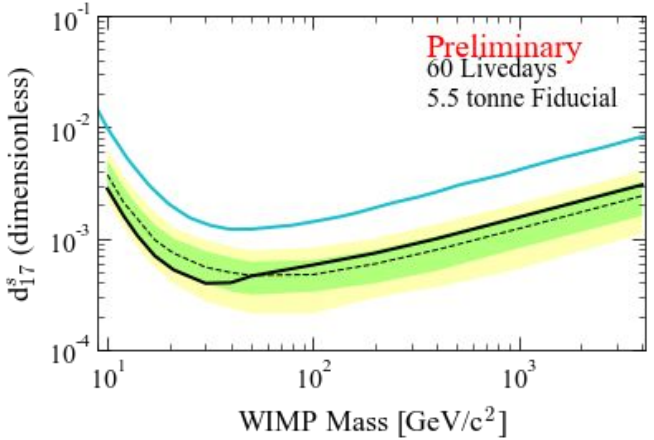
- Can also set limits on EFT WIMP models
- Measure sensitivity to a set of 15 non-relativistic operators
- Can use same operators to model interaction lagrangians for WIMPS and SM particles



$$\mathcal{L}_{int}^{9} \rightarrow -\frac{\vec{q}^2}{2m_\chi m_M}\mathcal{O}_1 + \frac{2m_N}{m_M}\mathcal{O}_5 - \frac{2m_N}{m_M}\left(\frac{\vec{q}^2}{m_M}\mathcal{O}_4 - \mathcal{O}_6\right)$$

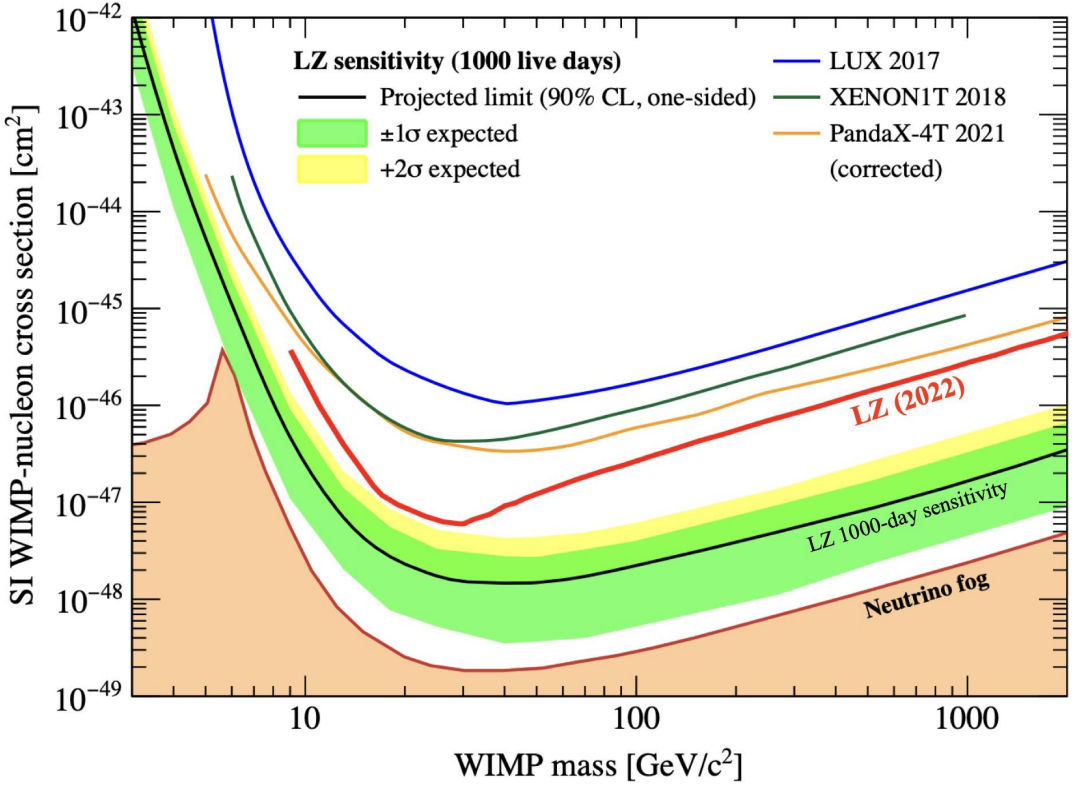
$$\mathcal{L}_{int}^{17} \rightarrow \frac{2m_N}{m_M}\mathcal{O}_{11}$$





Looking Ahead

- LZ has set world leading WIMP limits with just 60 live days
- More science can be done with the initial exposure
  - Low-Energy ER
  - High-Energy NR
  - More on the horizon
- LZ is currently taking data with a goal of 1000 live days
  - ^{8}B physics
  - $0\nu\beta\beta$ searches
  - So much more!
- Stay tuned for new results!



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Thank you

Science and Technology Facilities Council

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ibs Institute for Basic Science