Welcome to Sanford Lab
Lab Director, Mike Headley

LZ Low-Mass Dark Matter and ^{8}B Solar Neutrino Results

Rick Gaitskell, Brown
Spokesperson

Scott Kravitz, UT Austin
Physics Coordinator

Dan Kodroff, LBL
Co-Analysis Lead

Ann Wang, SLAC
Co-Analysis Lead

Alvine Kamaha, UCLA
Webinar Moderator

Dec 8, 2025 - Sanford Underground Research Facility

Professor Alvine Kamaha, UCLA
@ Sanford Lab Visitors Center, Dec 9th Tues 5 pm

LZ order of presentation

Dark Matter and Neutrino Physics Primer……. Rick Gaitskell, Brown University

Detector and Signal Primer …….. Scott Kravitz, UTexas Austin

Low Energy Signal Search Results 1/2 …….. Ann Wang, SLAC

Low Energy Signal Search Results 2/2 …….. Dan Kodroff, LBL

Q&A at End of Talks
via text interface, and audio if on Zoom

LZ (LUX-ZEPLIN) Collaboration, 38 institutions

@lzdarkmatter

- 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

250 scientists, engineers, and technical staff

https://lz.lbl.gov/

US DOE

Science and Technology Facilities Council

Fundação para a Ciência e a Tecnologia

SANFORD UNDERGROUND RESEARCH FACILITY

Swiss National Science Foundation

Institute for Basic Science

DARK MATTER PARTICLE PHYSICS

Thanks to our sponsors and participating institutions!

LZ Authors

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(The LZ Collaboration)

Development of Skills/Training of Students and Postdocs on LZ

I would like to start by highlighting the important role our experiment and ones like it play in Training New Scientists - skills that are in demand/much used in both academic and commercial environments

These skills include:

- Specialized Hardware and Precision Instrumentation
- Quantum Detector Development
- Analysis of Massive Datasets / Data Science
- Development of Sophisticated Simulations
- Application of Models and Advanced Statistics
- Machine Learning for Optimum Information Extraction

SURF Support to LZ

Entire SDSTA organization supports LZ, directly involved personnel listed below

- Jaret Heise, Science Director
- Jeff Barthel, Rigging Specialist (former Engineering Technician for LZ)
- Gavin Cox, Experiment Support Scientist
- Dale Curran, Instrumentation and Control System Integrator
- Jake Davis, Director of Hoists & Shafts (former Engineering Technical Associate for LZ)
- Julia Delgaudio, Experiment Support Scientist
- Chad Dunbar, Mechanical Engineer
- Deanna Espinosa, Science Laboratory Custodian
- Alex Geffre, Engineering Technical Associate
- Markus Horn, Senior Research Scientist, Radiation Safety Officer
- Kyle Jankord, Engineering CAD Technician/Drafter
- Derek Lucero, ESH Training Supervisor (former Engineering Technician for LZ)
- Charles Maupin, Mechanical Engineer
- David Taylor, Senior Project Engineer
- Doug Tiedt, Research Scientist
- Robyn Varland, Security (former Science Laboratory Custodian)
- Wade Vissia, Laboratory Facilities Technician
- Robyn Weis, Science Laboratory Custodian
- Ryan Whittle, ESH Experiment & Construction Safety Coordinator
- Sarah Wortman, Buildings and Grounds Foreman (former Laboratory Facilities Technician, Science Laboratory Custodian)
- *Michelle Andresen (*), ESH Experiment & Construction Safety Specialist*
- *Melissa Johnston (*), Science Laboratory Custodian*
- *John Keefner (*), Underground Operations Engineer*
- *Clint Morrison (*), Laboratory Facilities Technician*
- *David Rynders (*), ESH Experiment Health & Safety Manager, Radiation Safety Officer*

SURF Communications Team - working on this live broadcast

Matt Kapust
Stephen Kenny
Kate Shelton
Mike Ray

(*) Former employee

A Particle Physics Primer for LZ Signals

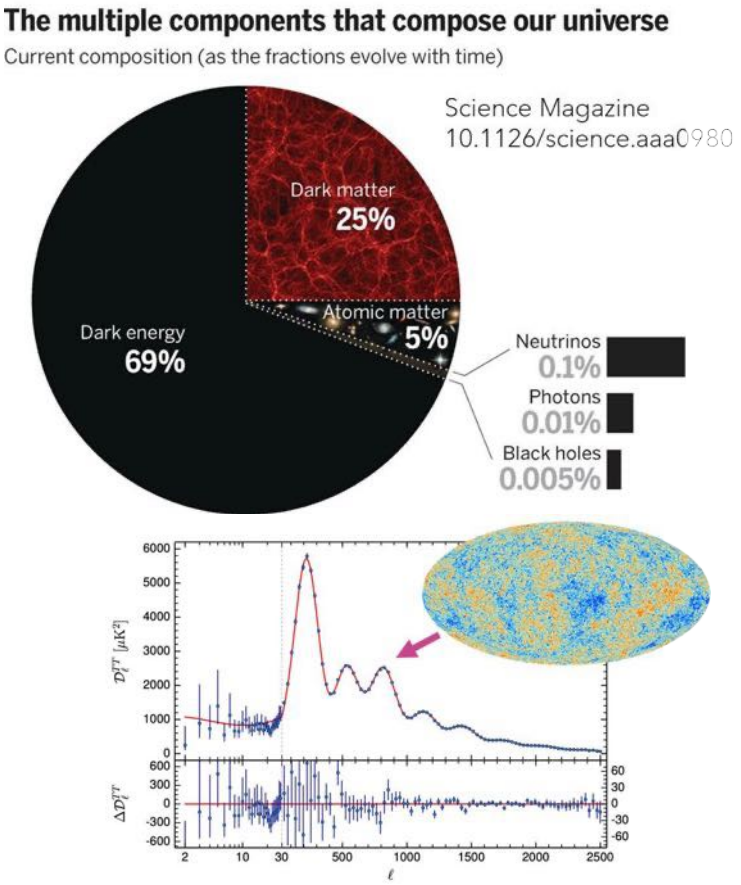
Over next 10 mins I will talk about the Fields of Science that LZ is able to inform and the role of Sanford Lab has played

- Note that at the end of this webinar the LZ Science Paper and PDF of Slides will be made available at the collaboration website https://lz.lbl.org

- The video recording of this webinar will be accessible at SURF Webinar Page

Dark Matter

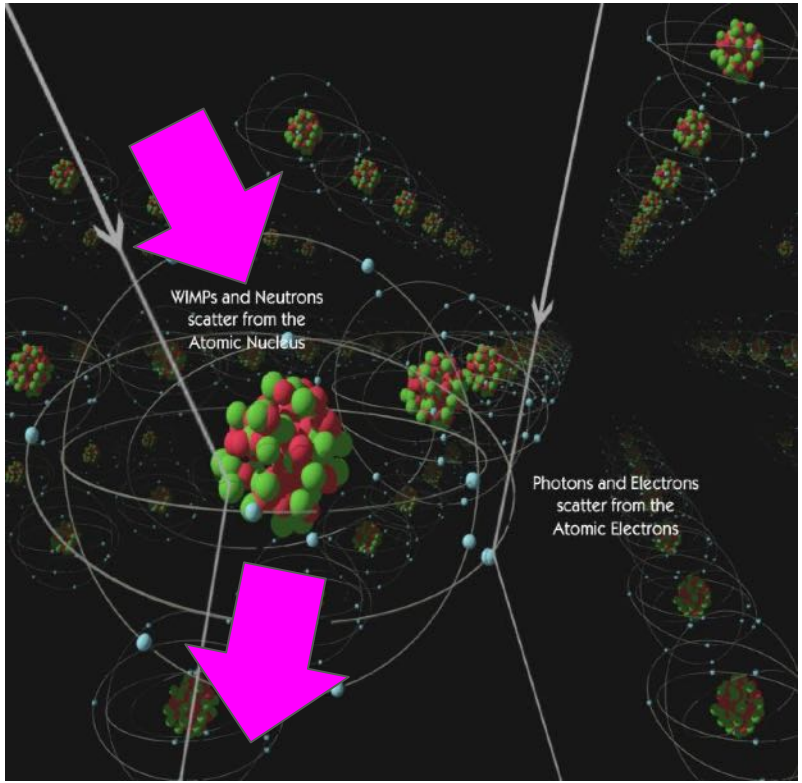
- 85% of the matter in Universe is of an unknown form
- Detected through gravitational effects - it holds our Milky Way Galaxy together
- In your room (0.1 to 100 per liter)…but typically passes right through normal matter - weakly interacting
- Particle properties remain unknown
- Direct Detection would allow us to study those properties



Planck Collab. Astron. Astrophys. 594 (2016) A13

Searching for Particle Recoils - Method of Detection

- Scattering from single particles in atoms
  - protons
  - neutrons
  - electrons
- Or from the entire Nucleus (protons and/or neutrons) through a Coherent Recoil
  - Significant Enhancement in Cross Section N^2



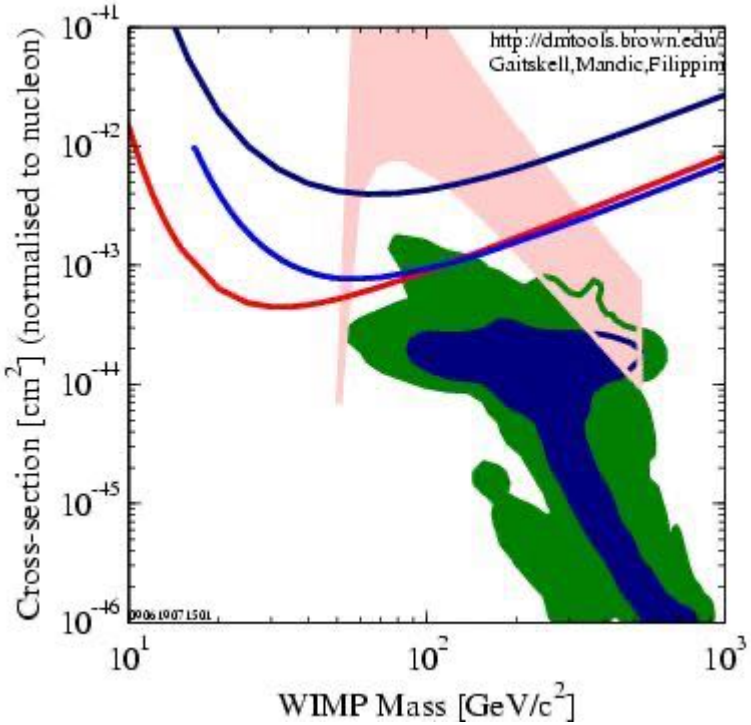
Testing Models of Particle Dark Matter in 2008

Lines show sensitivity limits of then active direct detection experiments - CDMS, XENON10, ZEPLIN III …

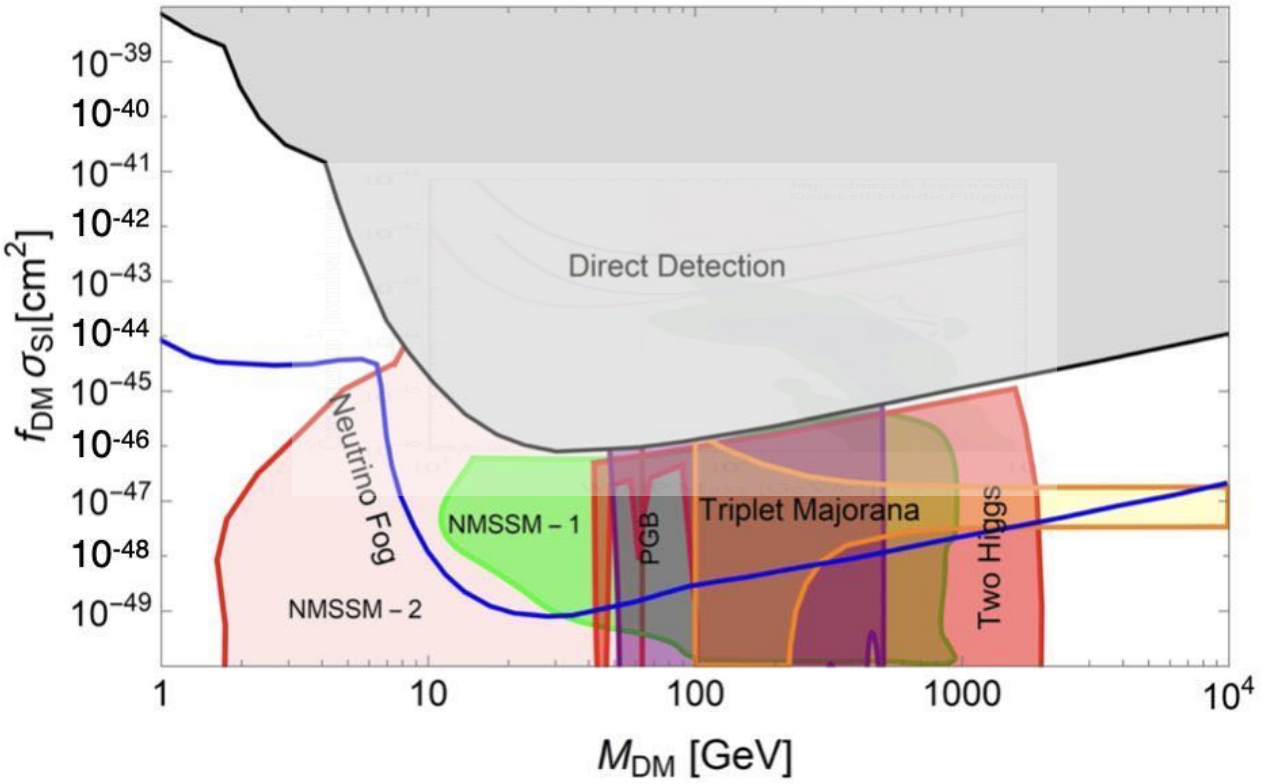
Shaded Areas are Regions from Different Theories that include Dark Matter Particles

(Red) Ellis et al MSSM

(Blue, Green) Trotta et al

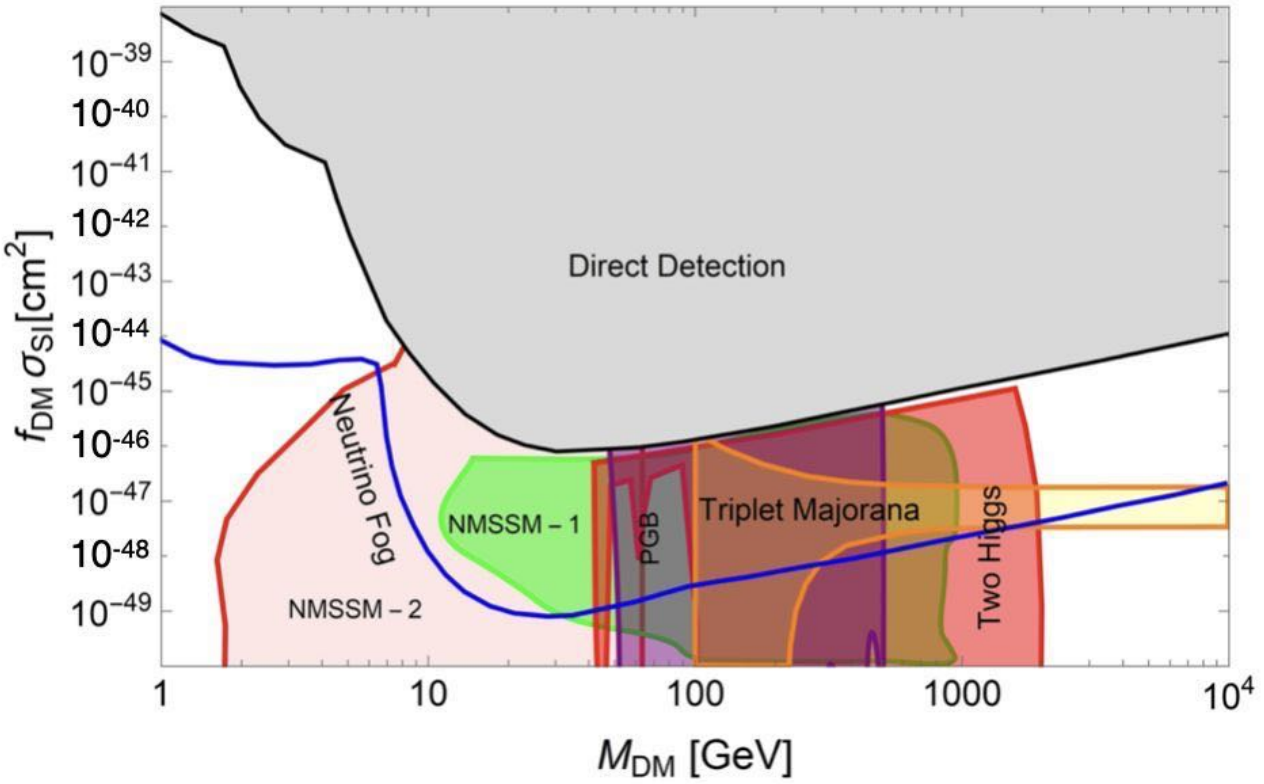


Testing Models of Particle Dark Matter (2008 -> 2016)

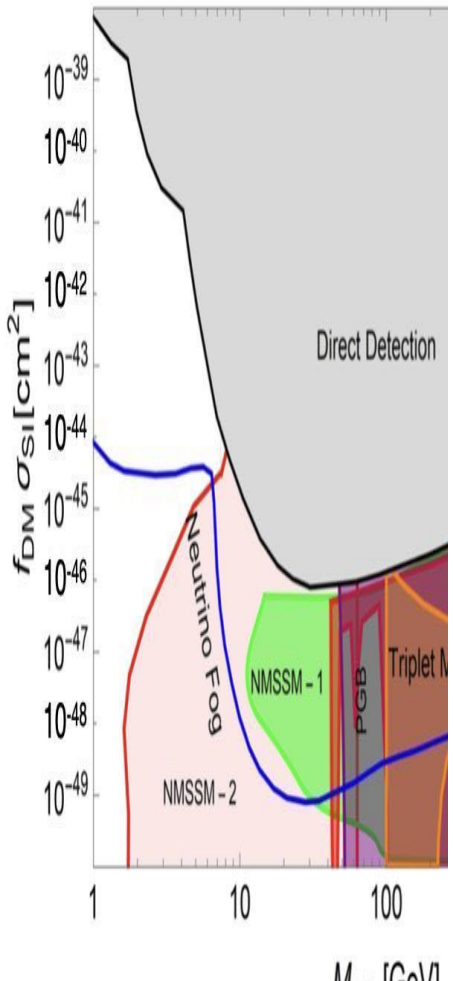


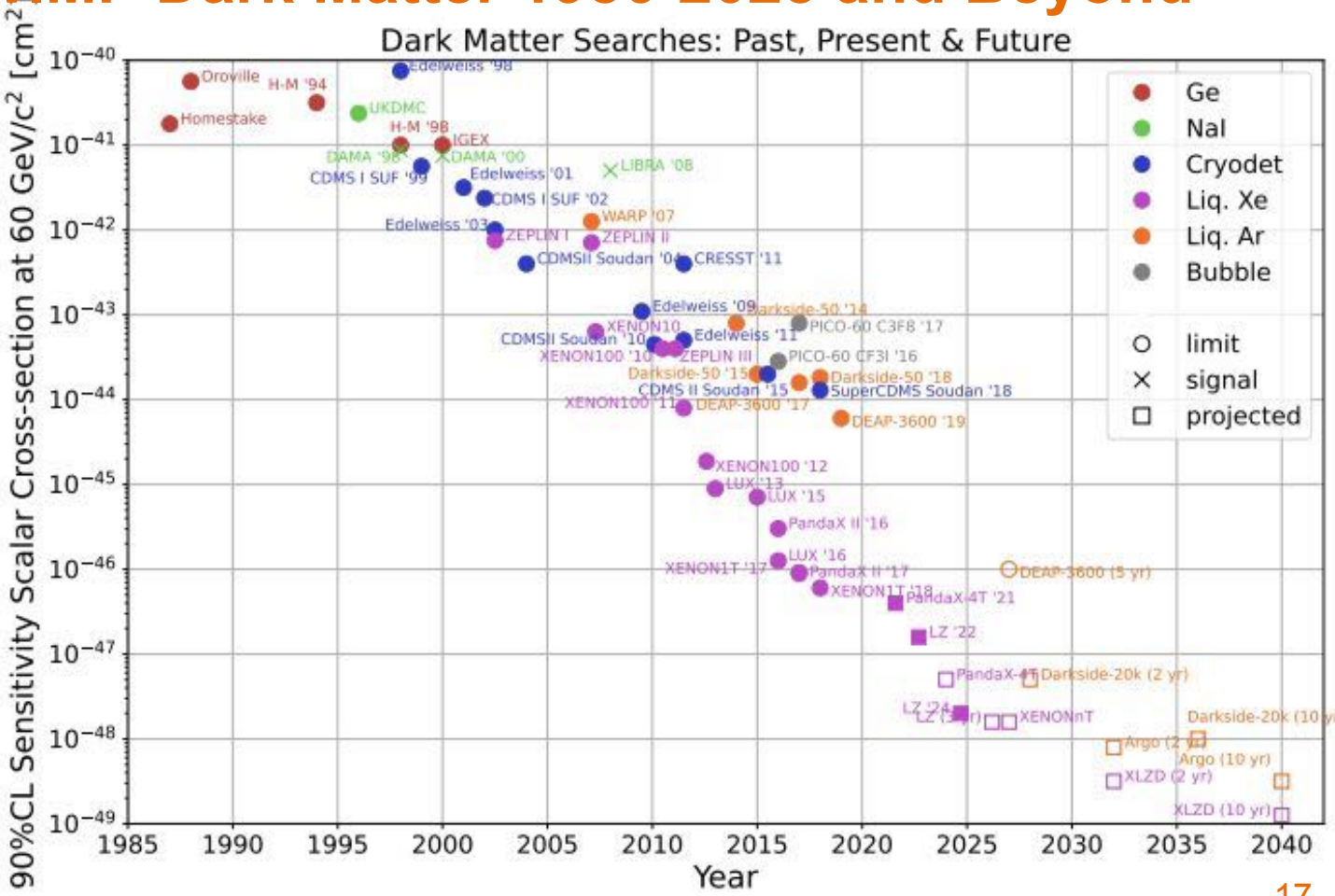
Testing Models of Particle Dark Matter in 2016

XENON100, LUX, PandaX Search Results

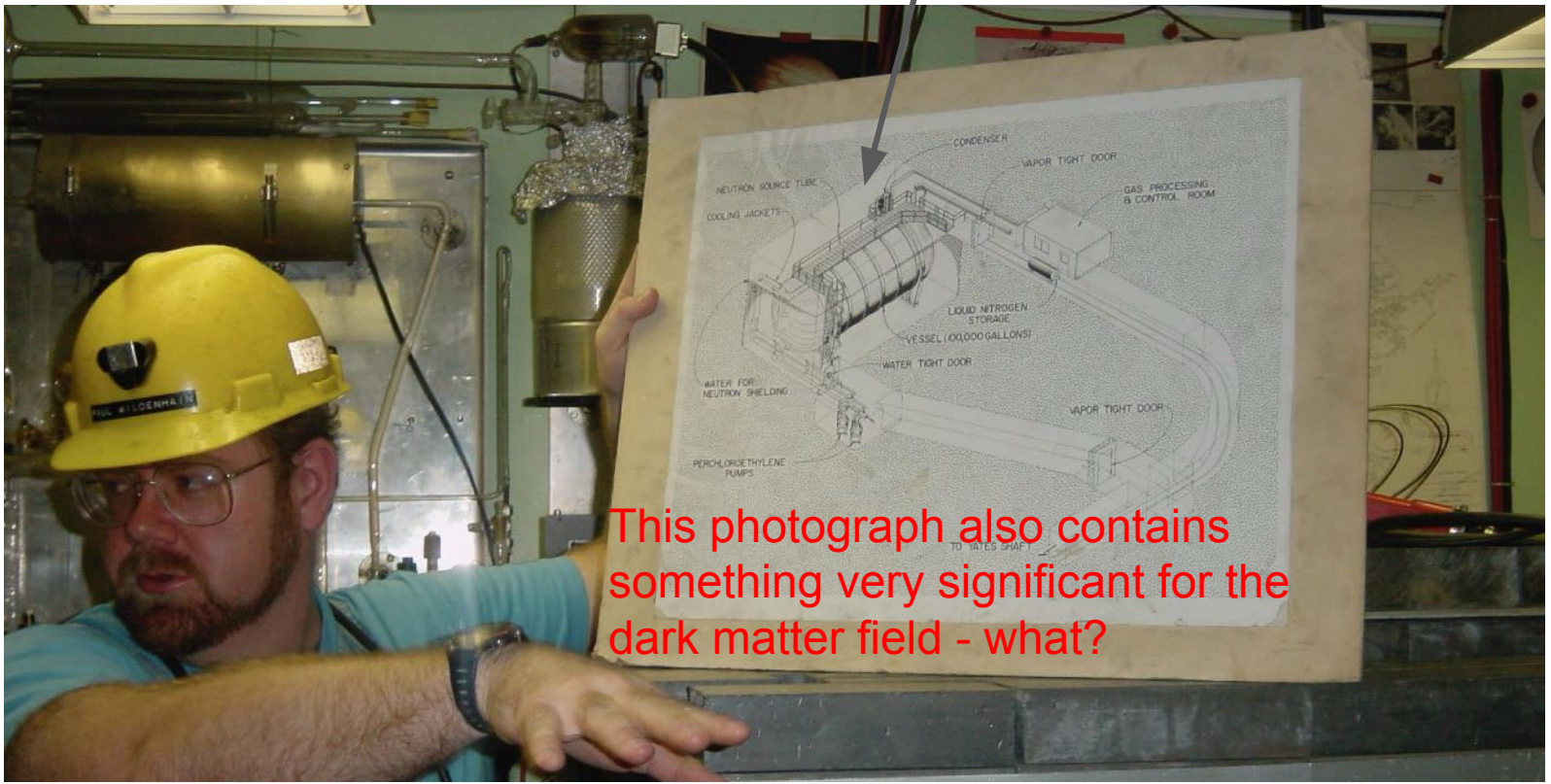


Search for WIMP Dark Matter 1986-2025 and Beyond

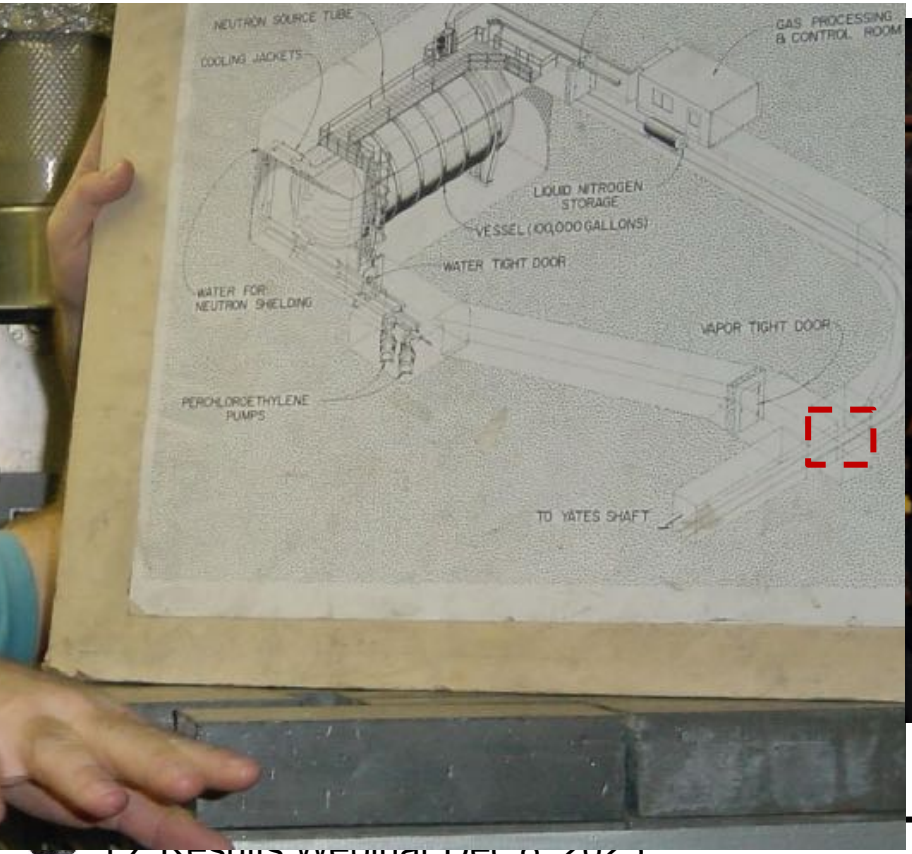




Homestake Mine - Site of the Davis Solar Neutrino Experiment (photo taken underground in 2001 prior to tank removal)



First Results from DM Direct Search Experiment (Reported 1987)
The “Other” Homestake Experiment



SIte Visit by Prof Richard Schnee, SDSMT, Rapid City (2001) Photo: Rick Gaitskell

Dark Matter: long history at SURF

- First publication on an underground experimental search for cold dark matter (Ahlen et al. 1987. PLB 195, 603-608).

http://www.pnnl.gov/physics/darkmattersymp.stm

Volume 195, number 4 PHYSICS LETTERS B 17 September 1987

LIMITS ON COLD DARK MATTER CANDIDATES FROM AN ULTRALOW BACKGROUND GERMANIUM SPECTROMETER

S.P. AHLEN [a], F.T. AVIGNONE III [b], R.L. BRODZINSKI [c], A.K. DRUKIER [d,e], G. GELMINI [f,g,1] and D.N. SPERGEL [d,h]

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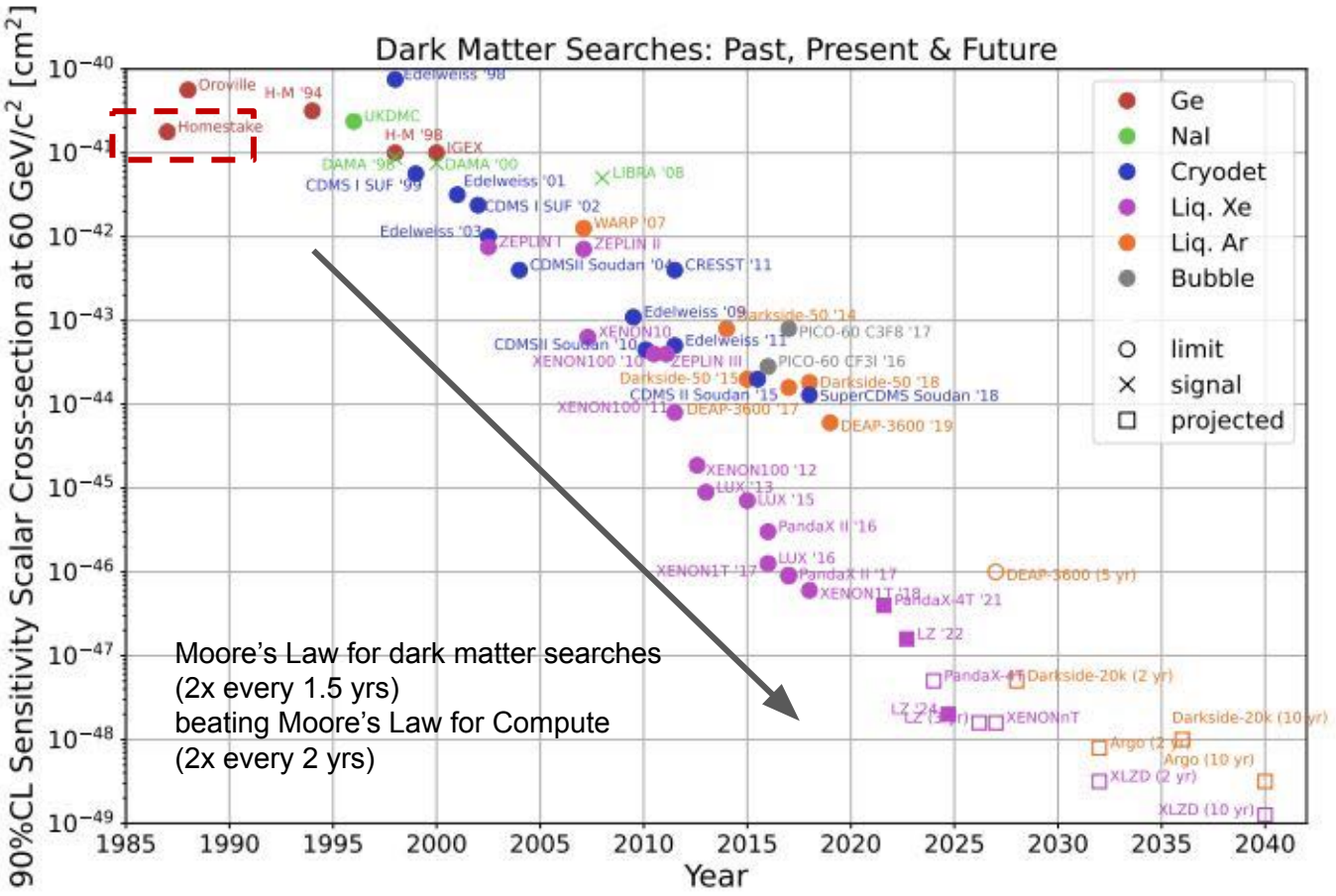
[h] *Institute for Advanced Study, Princeton, NJ 08540, USA*

Received 5 May 1987

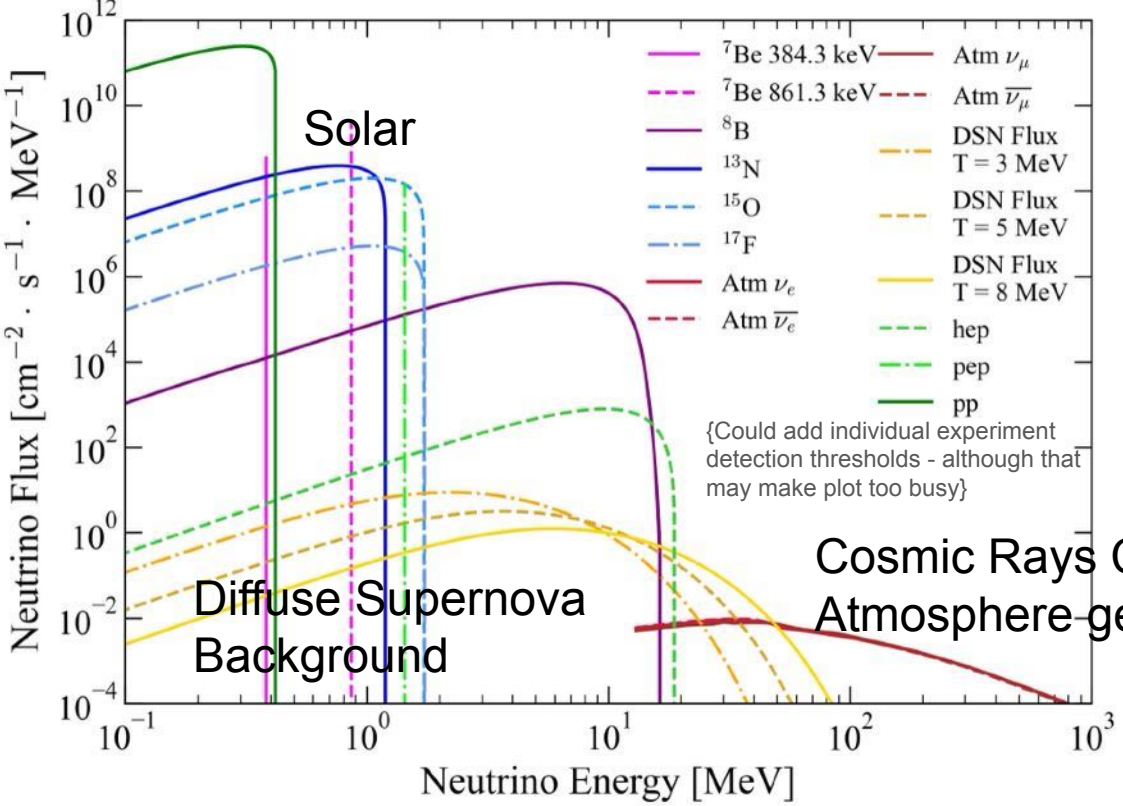
An ultralow background spectrometer is used as a detector of cold dark matter candidates from the halo of our galaxy Using a realistic model for the galactic halo, large regions of the mass–cross section space are excluded for important halo component particles. In particular, a halo dominated by heavy standard Dirac neutrinos (taken as an example of particles with spin-independent Z^0 exchange interactions) with masses between 20 GeV and 1 TeV is excluded. The local density of heavy standard Dirac neutrinos is <0.4 GeV/cm^3 for masses between 17.5 GeV and 2 5 TeV, at the 68% confidence level.

Search for WIMP Dark Matter 1986-2025 and Beyond



Neutrinos Signals: From Solar + Cosmic Sources

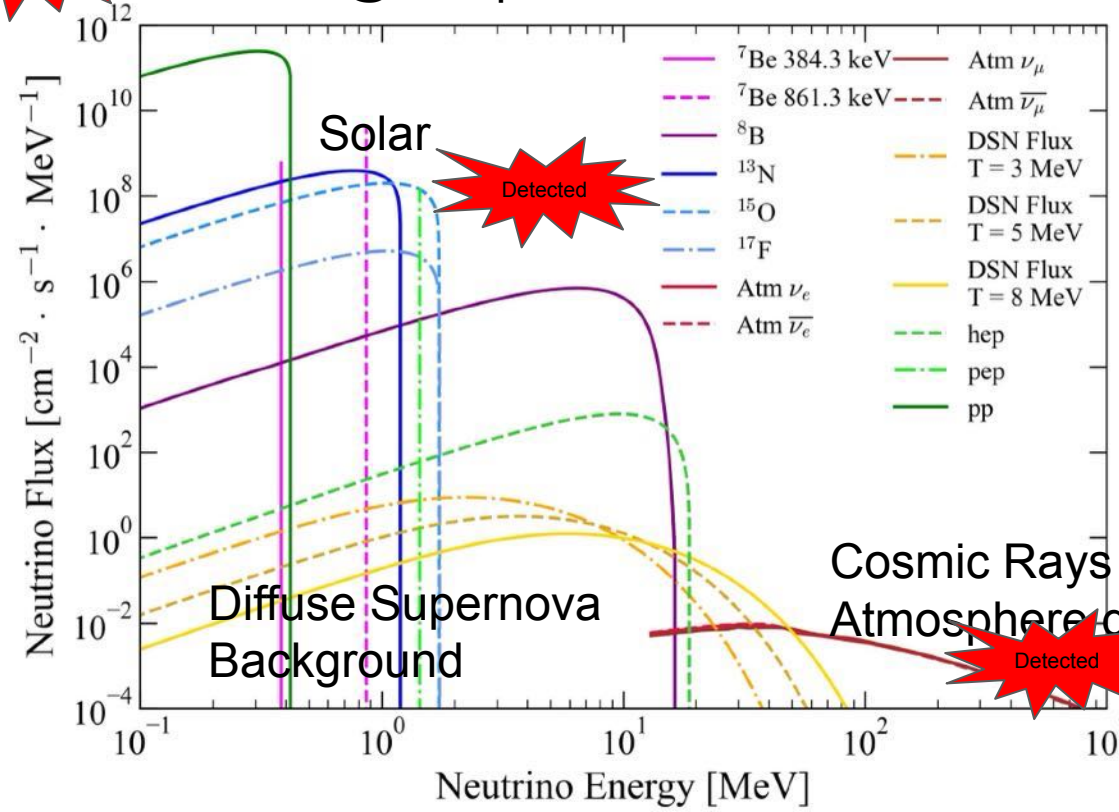
Also burst from local SN <100 kpc



Neutrinos Signals: From Solar + Cosmic Sources

Detected

1987 SN @ 50 kpc



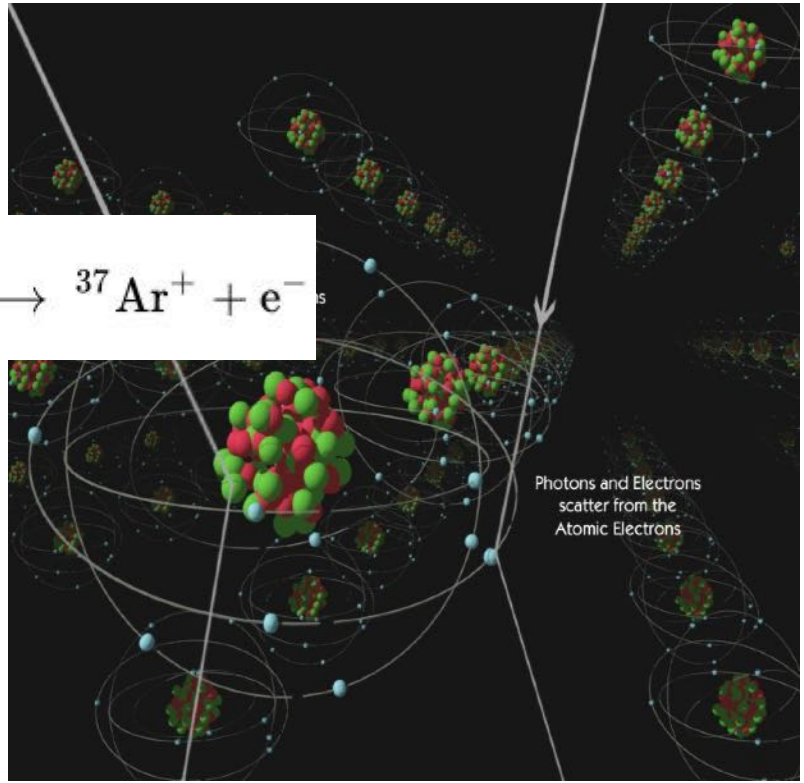
In spite of the incredible range of fluxes of neutrinos scientists have been able to detect signals in a series of experiments

Neutrinos Detection in Davis Experiment: Transmutation of Chlorine into Argon Nuclei

"Neutrino turns Neutron (Green ball) to Proton (Red ball)"

$$\nu_e + {}^{37}\mathrm{Cl} \longrightarrow {}^{37}\mathrm{Ar}^{+} + e^{-}$$

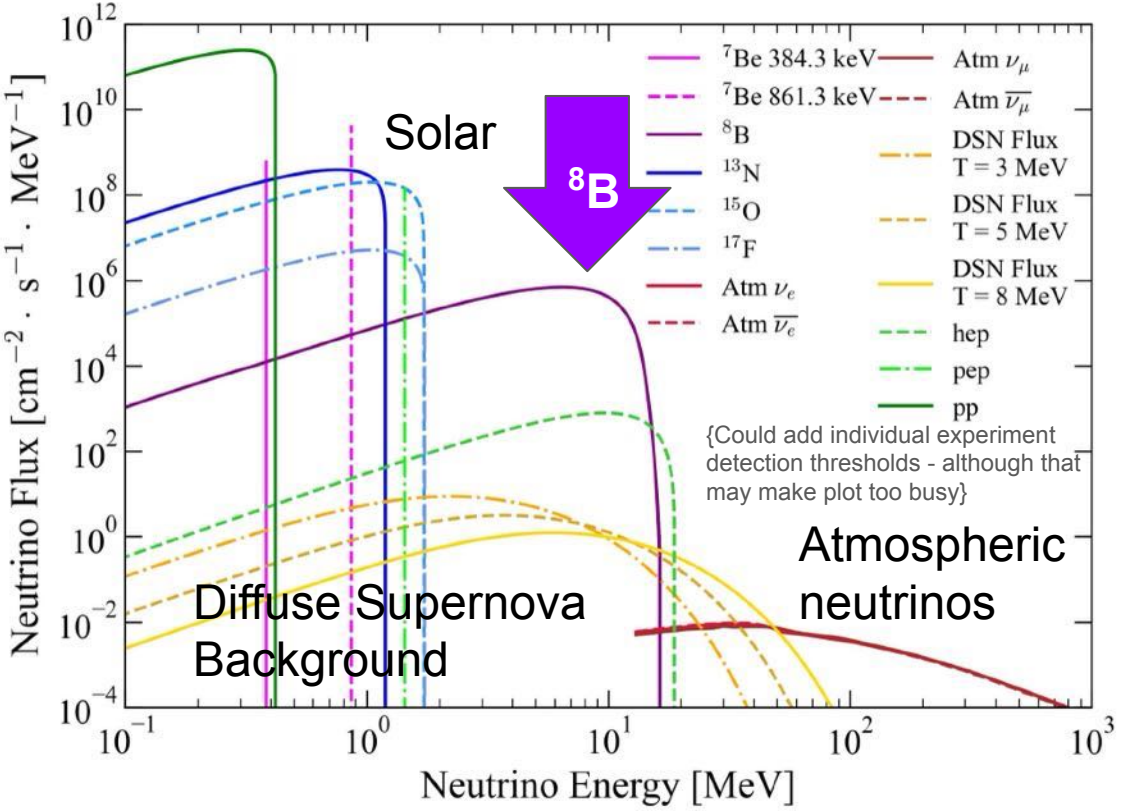
Look for the 37Ar isotope - it is radioactive with a lifetime of ~1 month, so detect decay



Solar neutrinos: long history at SURF

Solar neutrinos were first detected at the Davis experiment in the Homestake mine, leading to the **discovery of neutrino oscillations** and the **2002 Nobel Prize**

Neutrinos Signals: From Solar + Cosmic Sources



Solar ^{8}B Coherent Scattering from Xe - enhanced rate means a modest 5 tonne fiducial target can records regular events

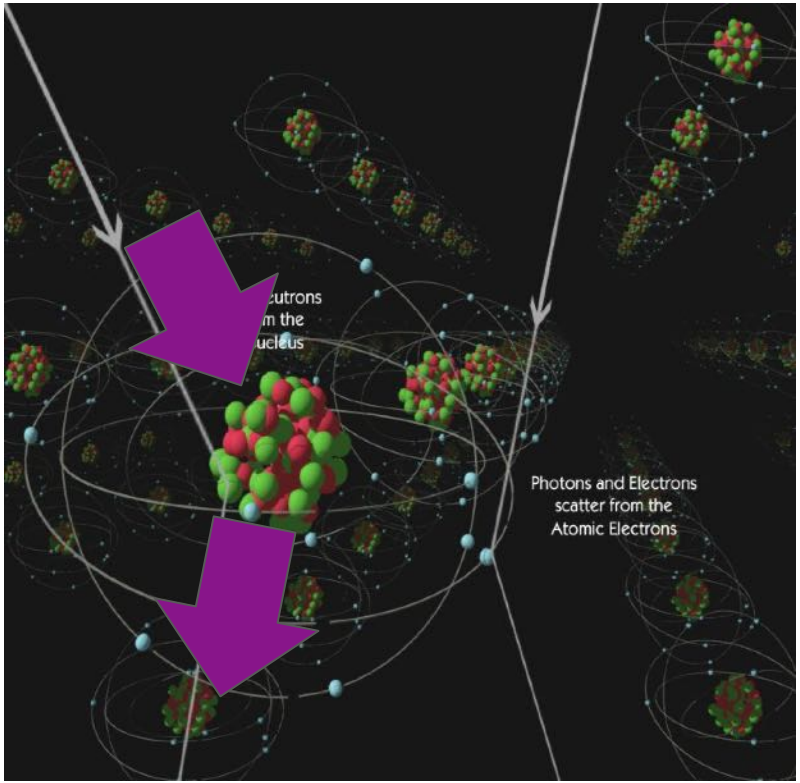
Neutrinos are High Energy so the Xe Recoils are high enough energy to be seen with keV threshold

Neutrinos Detection Through Coherent Scattering on Xe

Neutrino Scatters from entire nucleus

Significant Enhancement in Cross Section

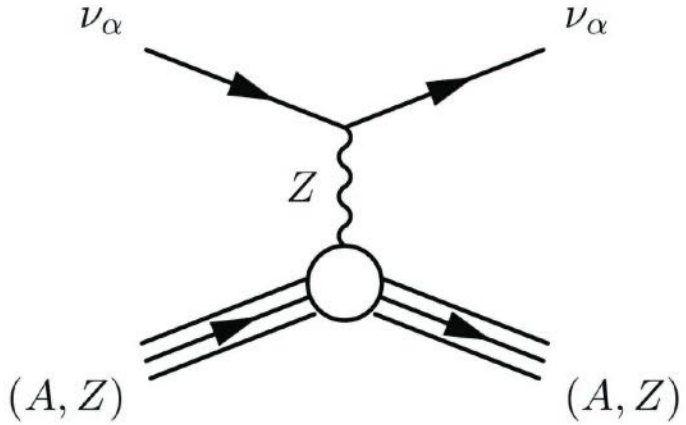
Entire nucleus has to recoil, so



Coherent Elastic Neutrino-Nucleus Scattering (CEνNS)

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

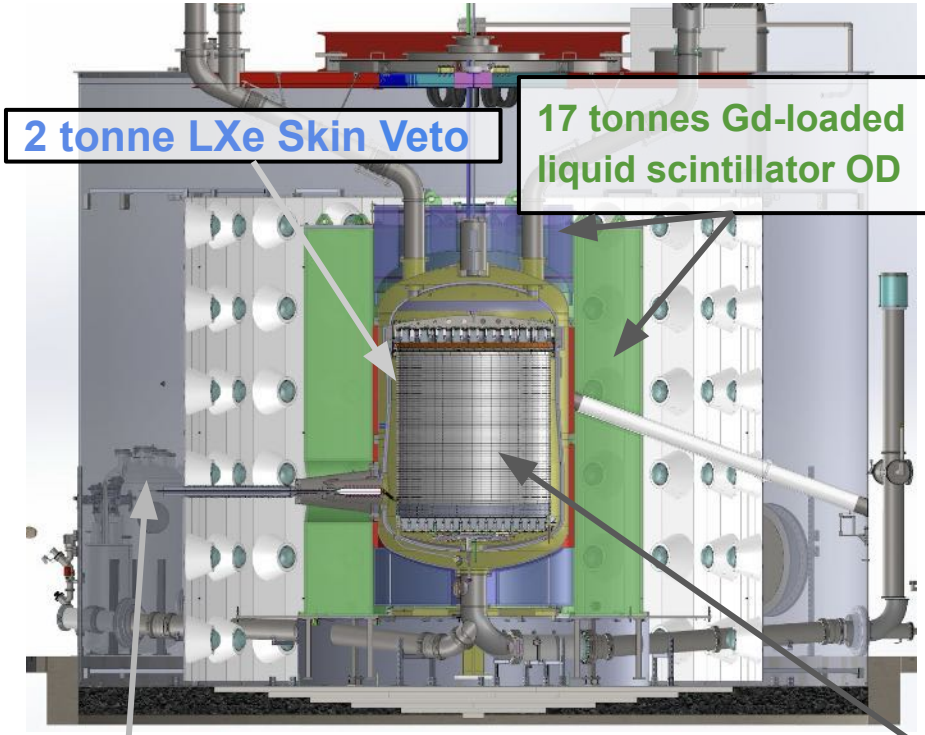
- Cross-section scales with neutrons squared
- First measured by the COHERENT experiment in 2017 using the Spallation Neutron Source *Science 357, 6356 (2017)*
- Additional measurements with reactor neutrinos, anti-neutrinos by Dresden-II *PRL 129, 211802 (2022)*, CONUS+ *Nature 643, 1229-1233 (2025)*



- First indications (< 3σ) of CEνNS with solar neutrinos from PandaX-4T *PRL 133, 191001 (2024)*, XENONnT *PRL 133, 191002 (2024)*

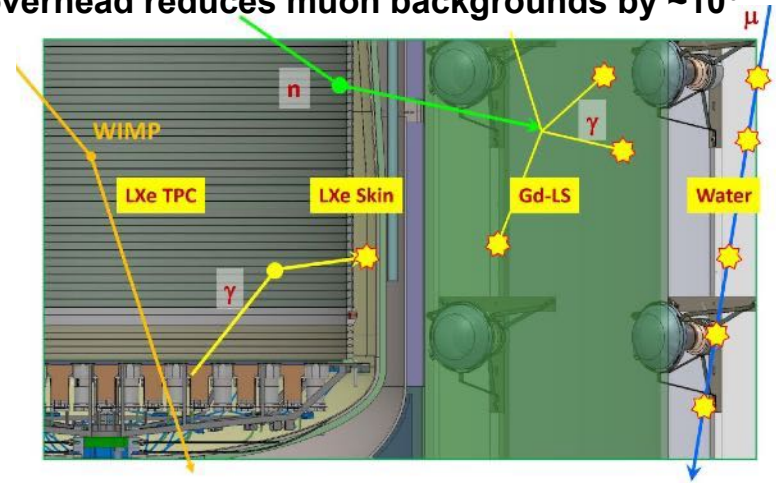
The LUX-ZEPLIN (LZ) Detector

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



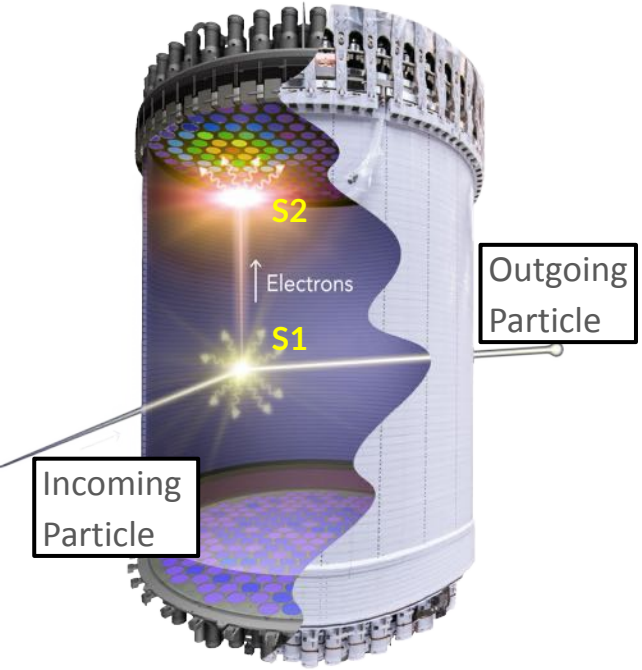
Located nearly a mile deep underground at the Sanford Underground Research Facility (SURF)

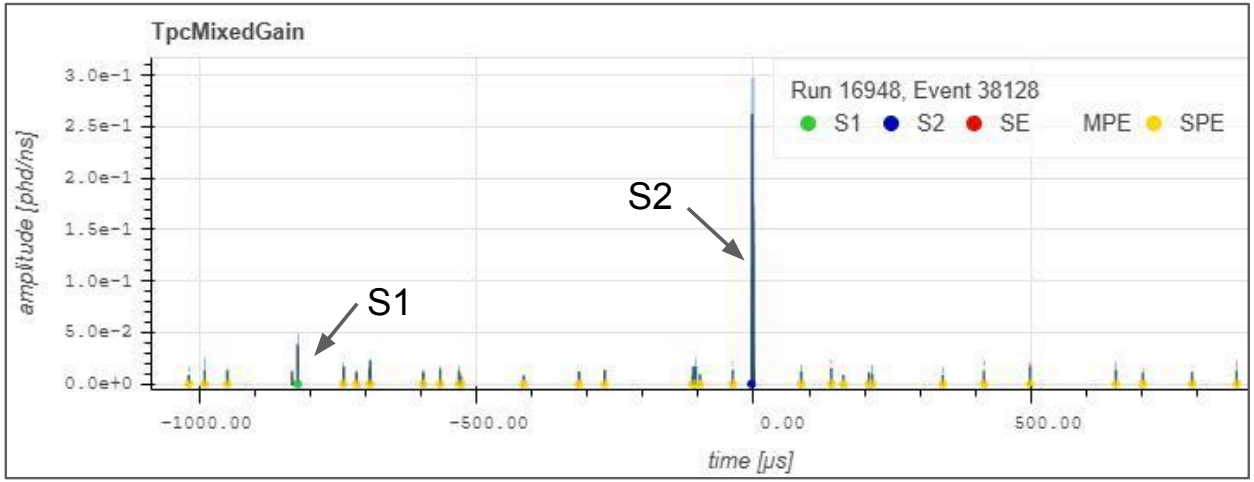
Rock overhead reduces muon backgrounds by ~10^6



Xe Skin & Outer Detector (OD) characterize and reject γ + neutron backgrounds

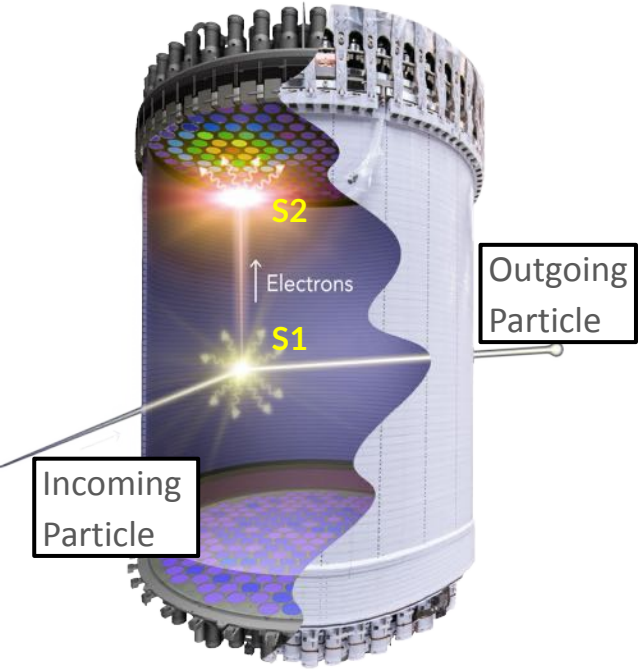
Liquid Xenon Time Projection Chamber Basics

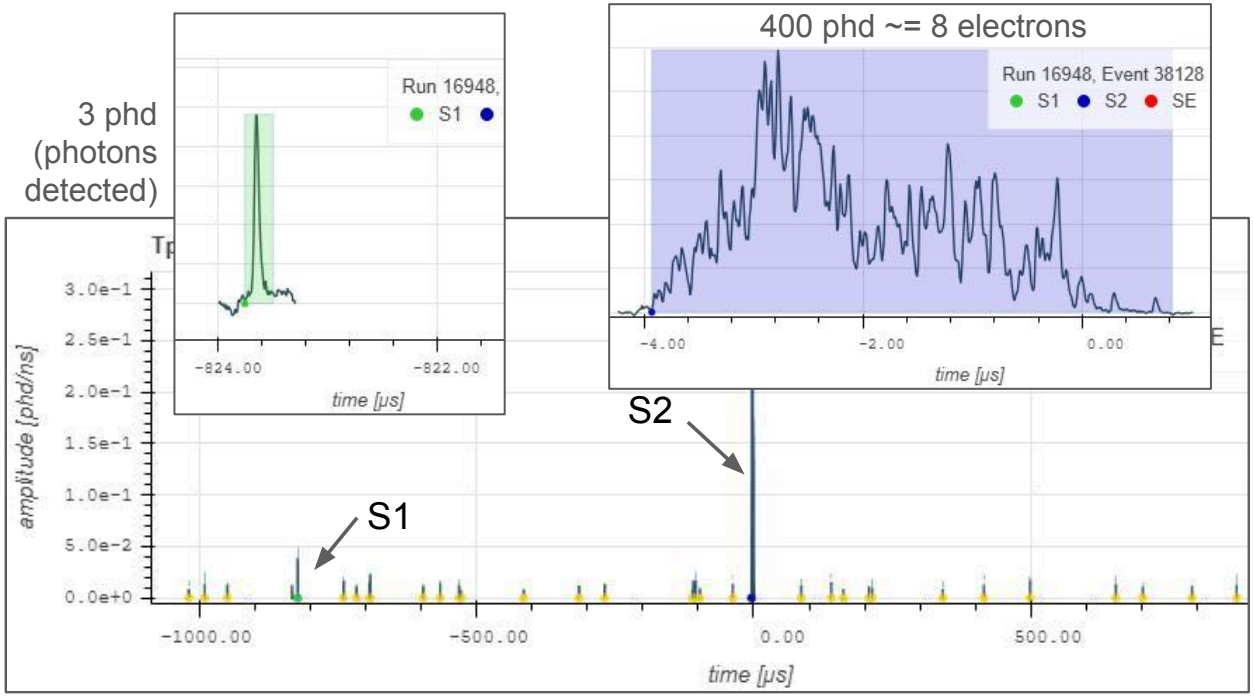




- Two signals: S1 (prompt scintillation) and S2 (scintillation from ionization = drifted electrons)

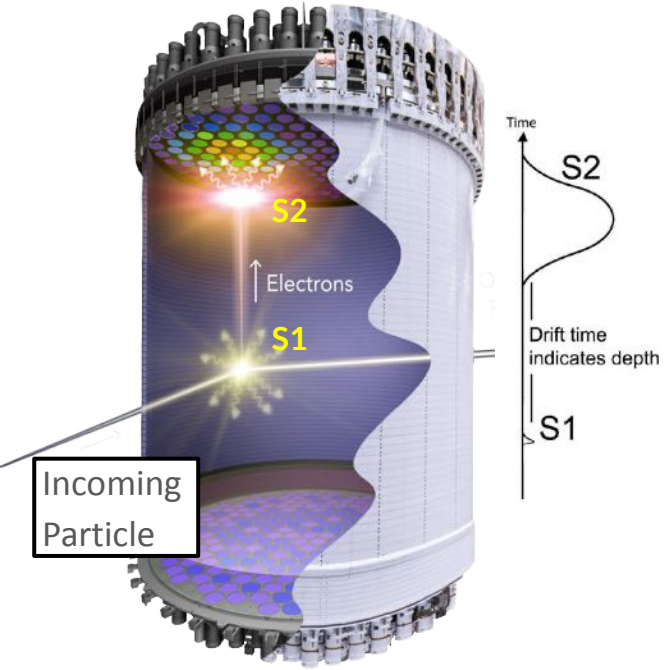
Liquid Xenon Time Projection Chamber Basics

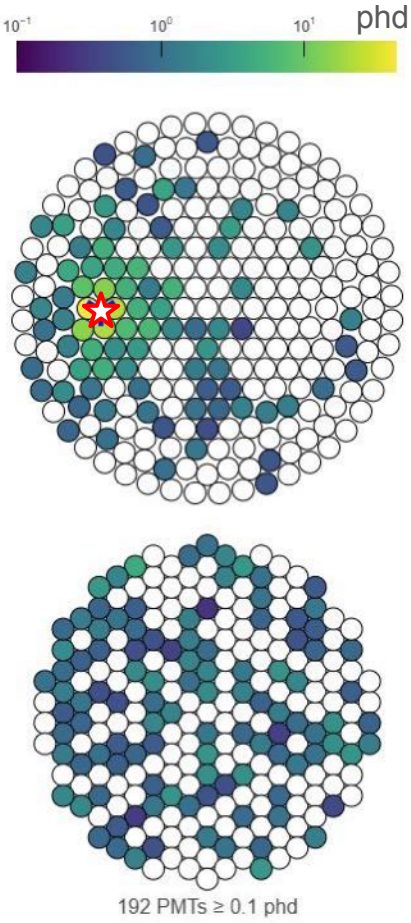




- Two signals: S1 (prompt scintillation) and S2 (scintillation from ionization = drifted electrons)

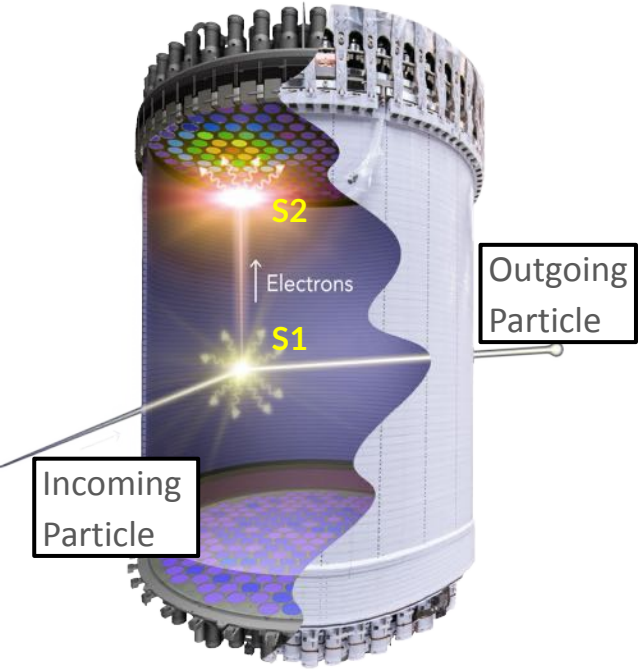
Liquid Xenon Time Projection Chamber Basics



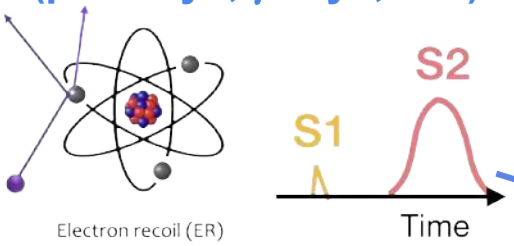


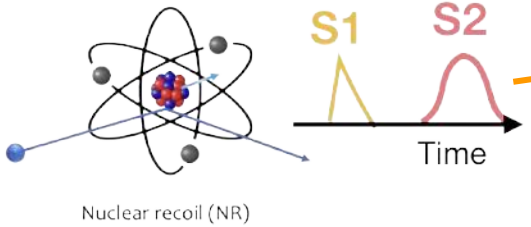
- 3D position reconstruction: x-y from S2 hitmap, z (depth) from drift time
- Xenon is self-shielding ⇒ reduced background near center
- Further discrimination from single vs multiple scatters

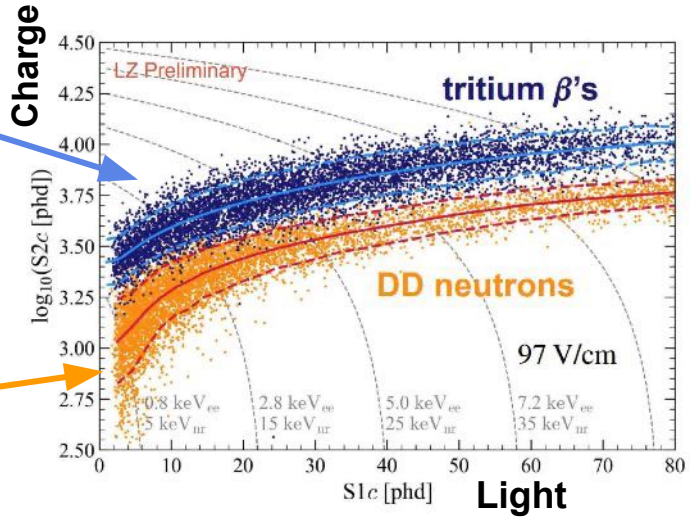
Liquid Xenon Time Projection Chamber Basics



(β decays, γ rays, ν-e$^-$)





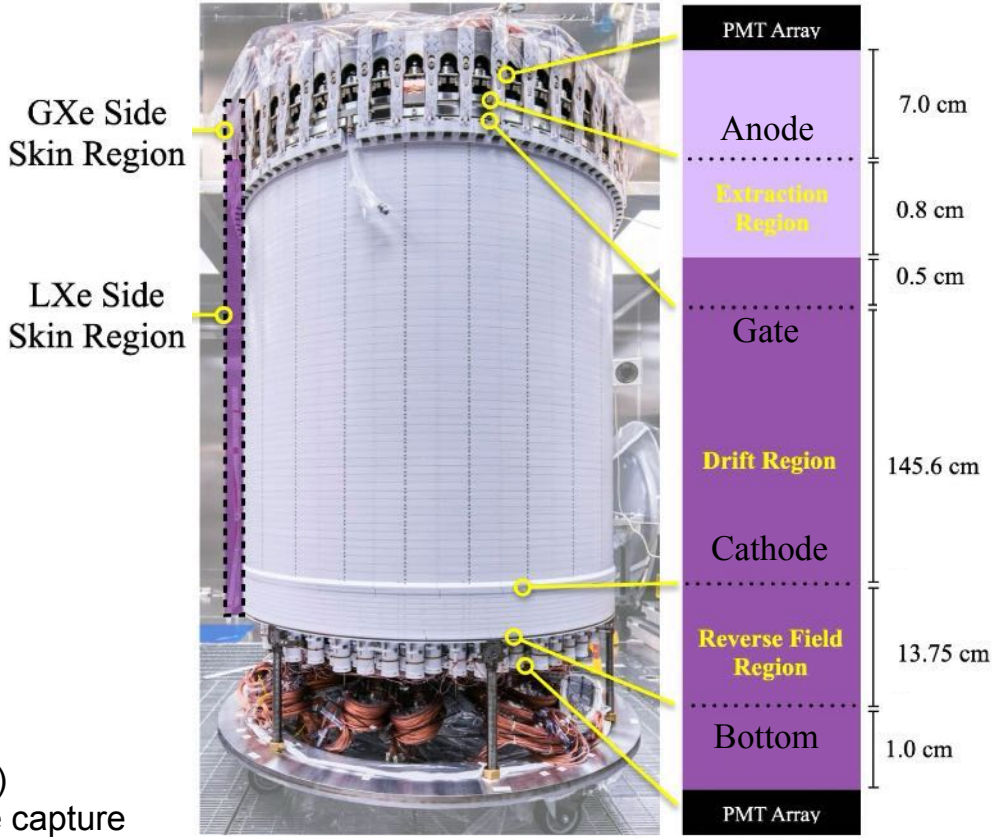


(WIMPs, CEνNS, neutrons)

- S1-S2 ratio → Particle discrimination
  - Many backgrounds are electron recoils (**ER**)
  - WIMP and neutrino signals are nuclear recoils (**NR**)
  - Instrumental backgrounds also fill a distinct region of this 2D space

LZ by the Numbers

- Key Central TPC Detector Stats:
  - TPC dimensions: **1.5 m tall x 1.5 m dia.**
  - **7 tonnes** active Xe mass -
    ~20% of world's yearly Xe production!
  - **494 PMTs** (single-photon detectors) in TPC
  - PTFE walls **~97% VUV reflectivity**
  - 4 custom-built woven electrode grids
- Operational parameters:
  - Temperature: **~175 K**
  - Gas Pressure: **1.86 bara**
  - Drift Field: **97 V/cm** (cathode at ~20 kV)
  - Electron lifetime ~15 ms (max drift time ~1 ms)
    e- could drift >20 m in Xe of this purity before capture



LZ electrode grid design:
NIM A, 165955 (2022)

Timeline of LZ Science

Commissioning begins

WS2022 results (60 live days)

WS2024 results (60 + 220 live days)

Run to end 2027 = 2x data

2021 2022 2023 2024 2025 2026

You are here

First WIMP search starts (WS2022)

WS2024 starts

WS2025 results (417 live days)

Periodic calibration throughout

Key Challenge: Extreme Background Reduction

- WIMPs may scatter only once (or less) **in hundreds of light years of lead**
- Backgrounds must be low enough to see **<10 DM events in years of data**
- Background mitigation in construction:
  - All detector components carefully screened for low radioactivity
    - **A typical person is ~100,000x more radioactive than LZ**
  - TPC assembled in Rn-reduced cleanroom - **<1 gram of dust in TPC**
  - Xe distilled off-site for Kr removal (**<300 ppq**)

HPGe counters at SURF

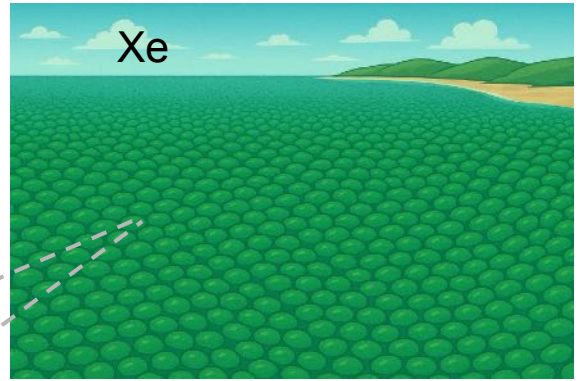
Kr removal system at SLAC

Radioassay and cleanliness: EPJC, Vol 80: 1044 (2020)

Ultrapure titanium cryostat: Astropart. Phys. 96, 1 2017

Key Challenge: Extreme Background Reduction

- Background mitigation in operation:
  - Xe continuously circulated and purified
  - WS2024: biggest background from Rn at **~2 atoms/kg of Xe**
    - **Like a single jelly bean in all the world's oceans**

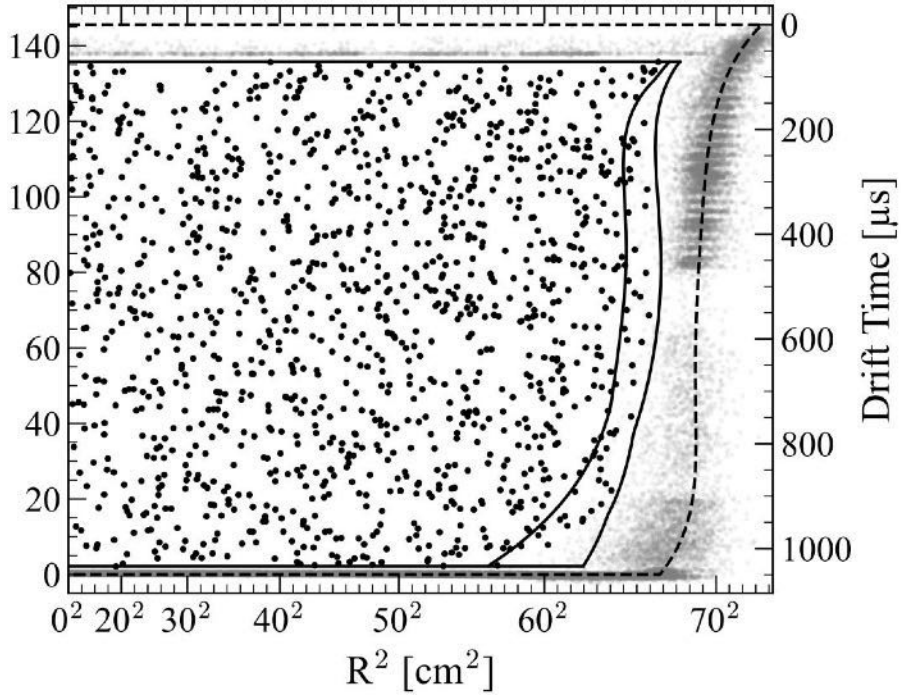


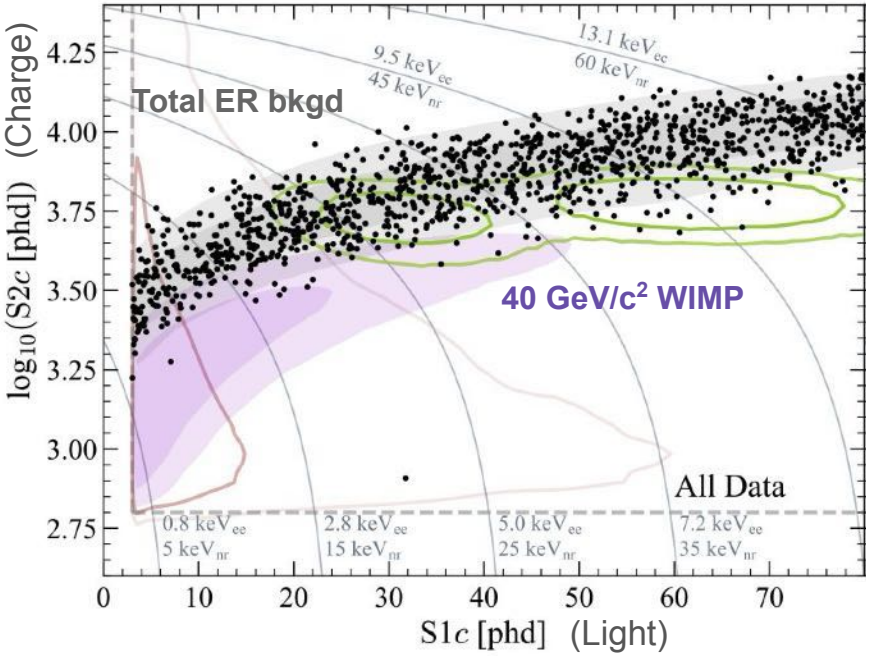
- High sensitivity = high data volume
  - Many processes produce just a few detectable photons / electrons!
  - Each PMT **read out every 10 ns** of active response
  - Data acquisition **uptime >95%** - no sleep for detector!
    - **~1 PB of data/year** = 1 MB photo every ~30 ms
  - Analysis cuts **distill data to ~1 in 50 million** - critical to success

DAQ: NIM A, 1068 169712 (2024)

LZ's Previous WIMP Search (WS2024) Dataset

220 live days x 5.5 tonne FV = 3.3 tonne-yr

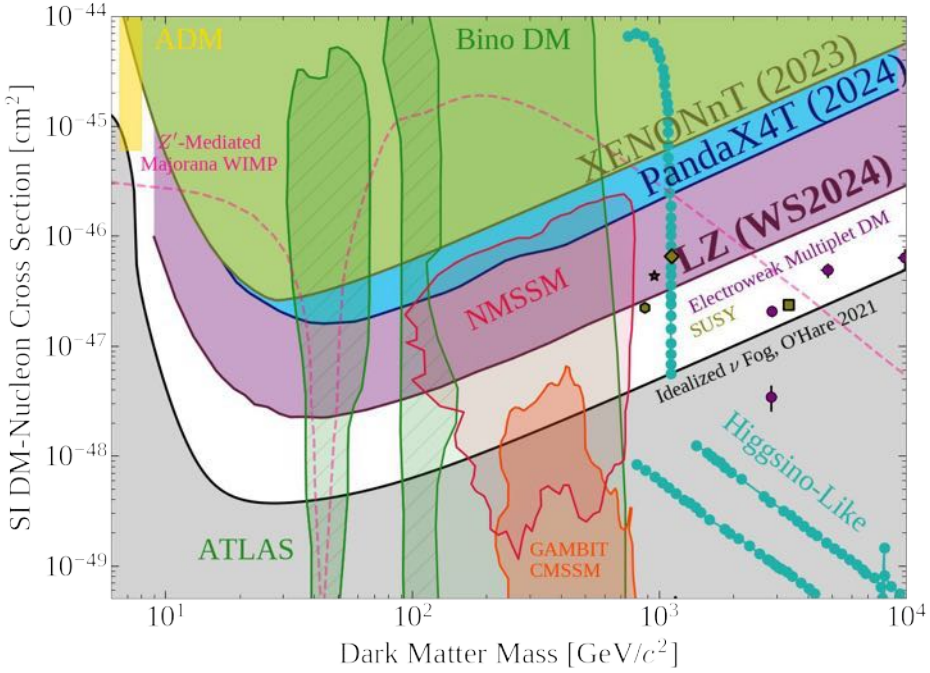




WS2024 results: *PRL 135, 011802 (2025)*

WS2024 Results

- **World-leading limits** for heavy DM (masses > 9 GeV)
- Narrowing down where DM might be hiding!



*Thanks to C. O'Hare for compiling theory models of interest

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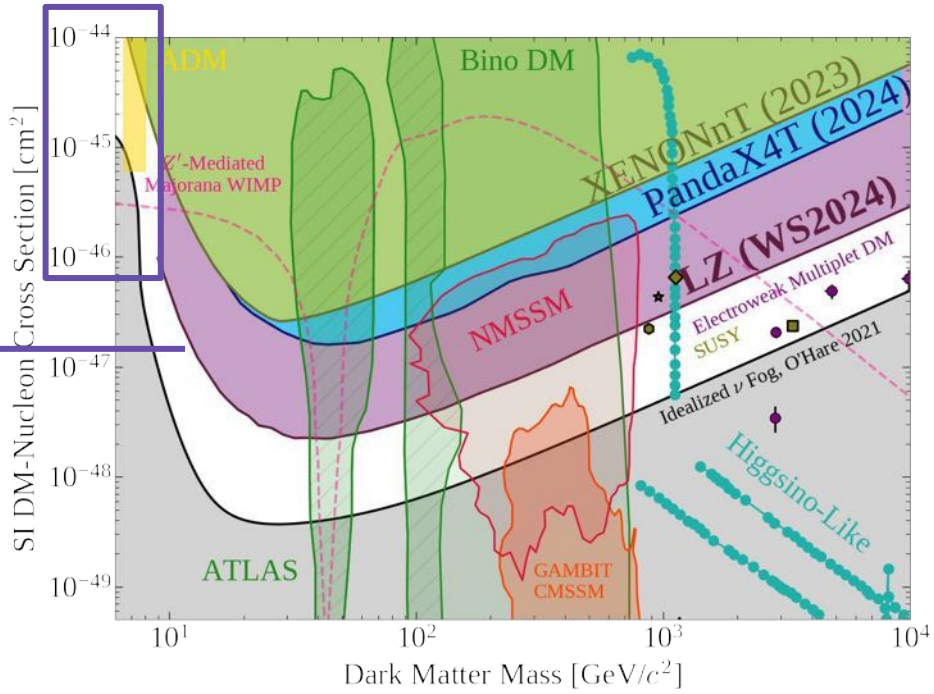
Onward,
to light DM!



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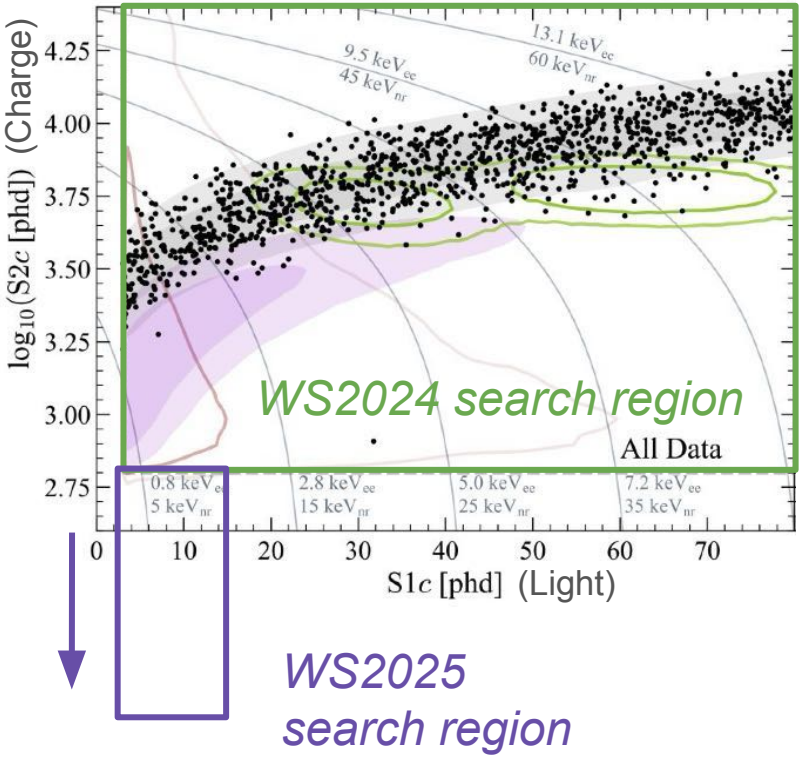
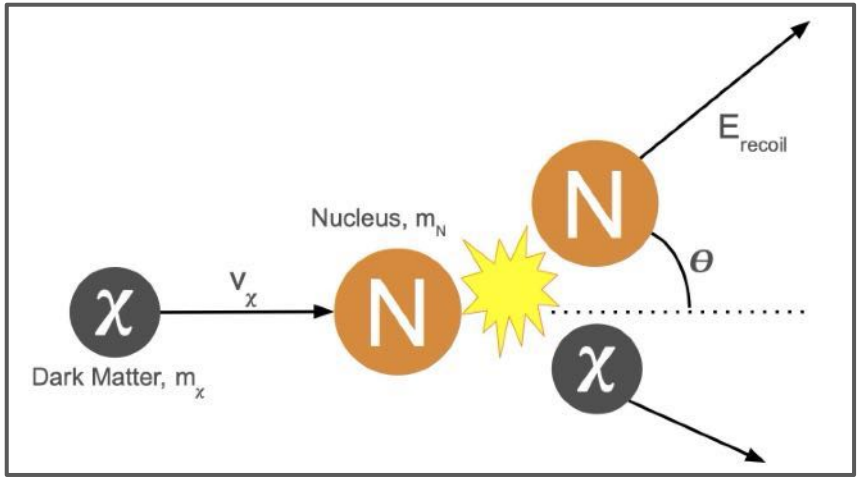


Searching for low-mass dark matter

Dark matter motivated to down to lower masses

- Lee-Weinberg bound[1] at ~GeV masses for scalar dark matter to achieve correct DM relic abundance via thermal freeze-out mechanism
- Models beyond simple WIMP also motivate lighter dark matter (e.g. asymmetric DM[2])



WIMP = Weakly Interacting Massive Particle

[1]*Lee-Weinberg bound: PRL 39, 1165 (1977)*

[2]*Asymmetric DM: PRD 79, 115016 (2009), PRD 82, 056001 (2010)*

First LZ search for < 9 GeV DM nuclear recoils: Lighter candidates produce low-energy signals with handful of photons + electrons → Unique set of challenges

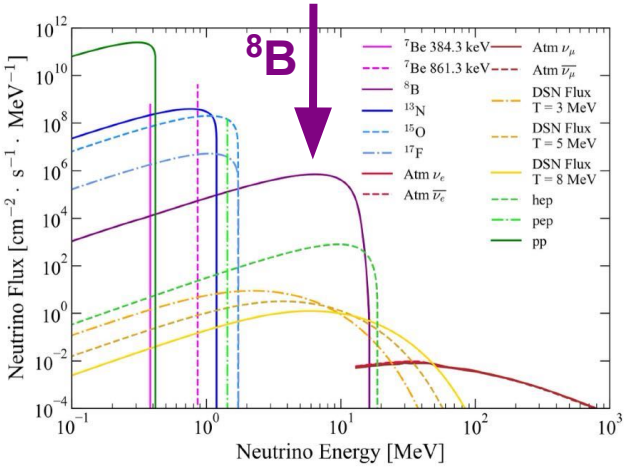
Neutrinos in this regime

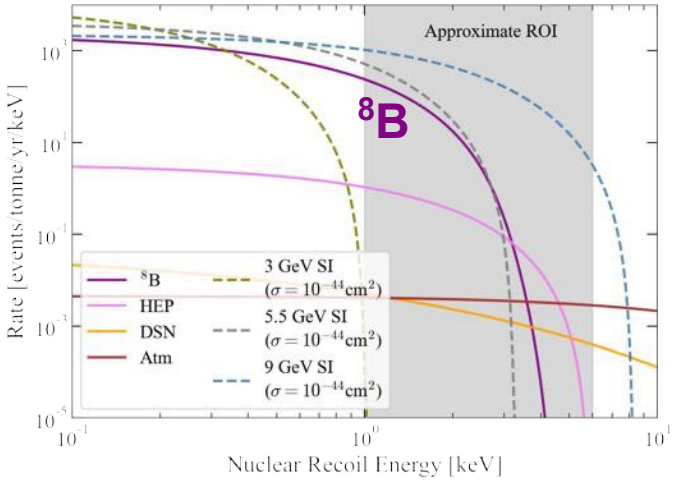
To look for low-mass dark matter → **push analysis to lower energies** (~1-6 keV)

Expect significant number of Boron-8 solar neutrino CEνNS interactions in this energy regime

- Similar detector signal spectra to to 5.5 GeV DM candidate - low-energy “neutrino fog”

Look for both ^{8}B neutrinos and dark matter with the same dataset





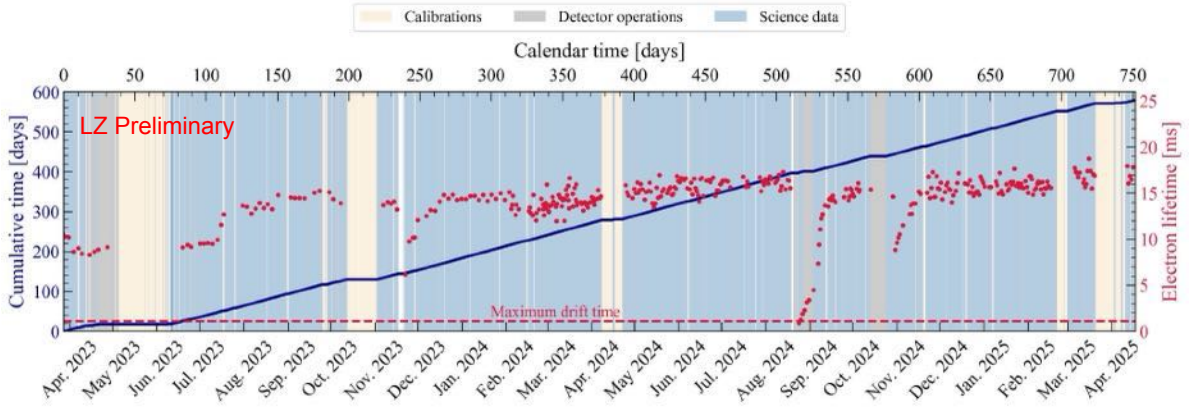
LZ Search Dataset

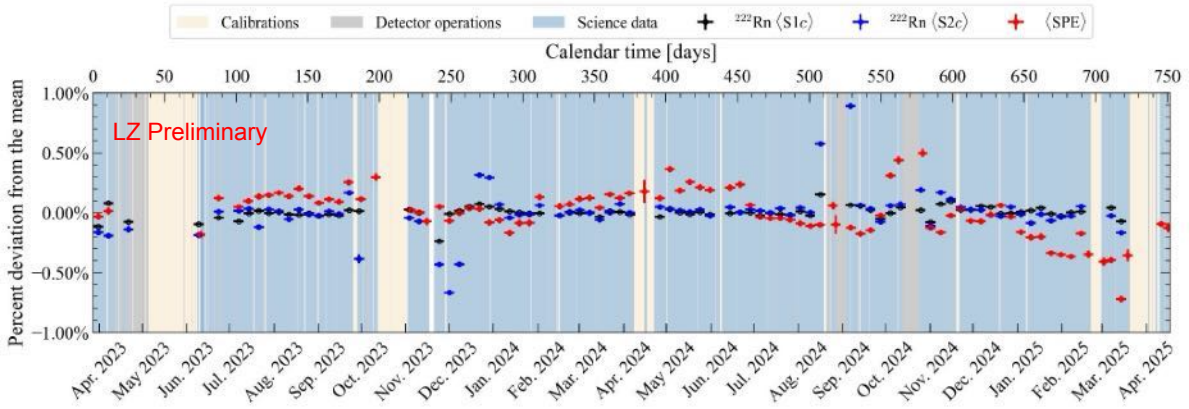
Data taken from April 2023 - March 2025

- Drift field of 97 V/cm
- Extraction field of 3.4 kV/cm

Dedicated AmBe and DD neutron calibrations

Data is calibrated for uniformity in S1 and S2 response in time and space

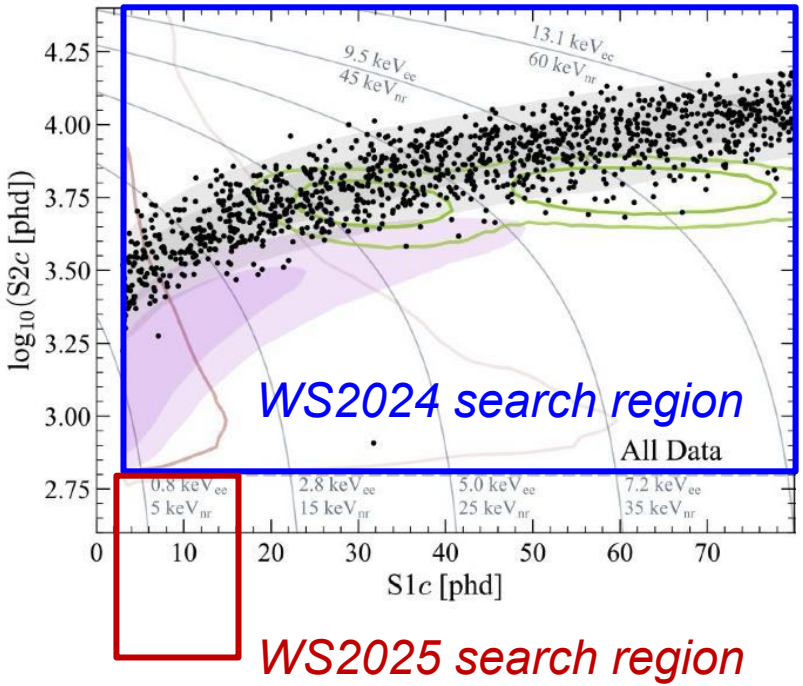




Region-of-Interest

Look for single scatters (~1-6 keV recoil energy) with

- >= 3-fold S1 (signals in >= 3 PMTs)
- S1c ∈ [2,15] photons detected (phd)
- S2 ∈ [3.5,14.5] e^- (44.5 phd/e-)



Cut overview

- **Data quality cuts**:
  - time-based exclusions, hold-offs after large energy depositions, operational issues
- **Fiducial volume**:
  - reject external backgrounds and detector edge effects
- **S1 and S2 based cuts:**
  - target accidental coincidence backgrounds
- **External vetoes:**
  - target neutrons which produce coincident signals in the OD/Skin

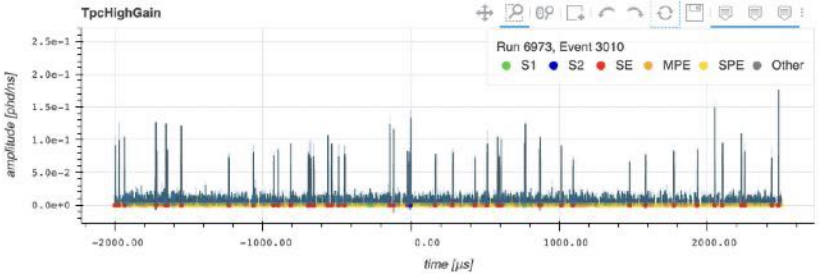
Data Quality cuts: Time-based exclusions

Remove periods of time with high detector photon/electron rates and operational instability

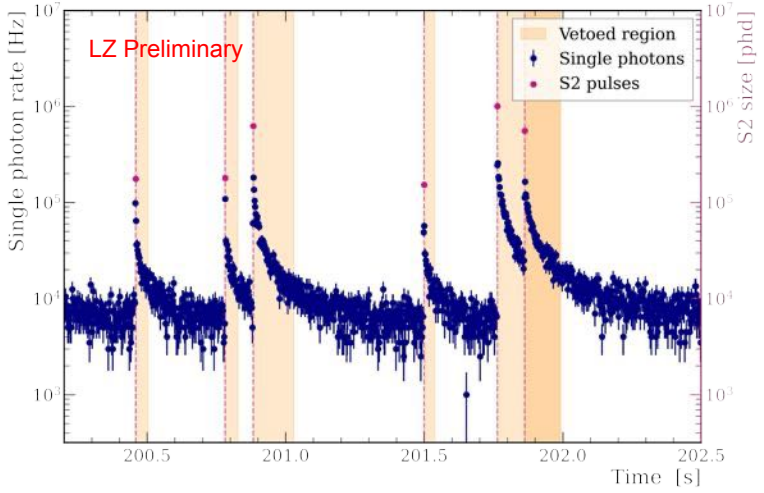
Examples:

- Time (up to ~100 ms) following large S1s/S2s
- Muons crossing the detector
- PMT high voltage trips

Final livetime is 416.5 live days
(before space-time application of hotspot cut)



Example waveform following large S2 event



Fiducial Volume

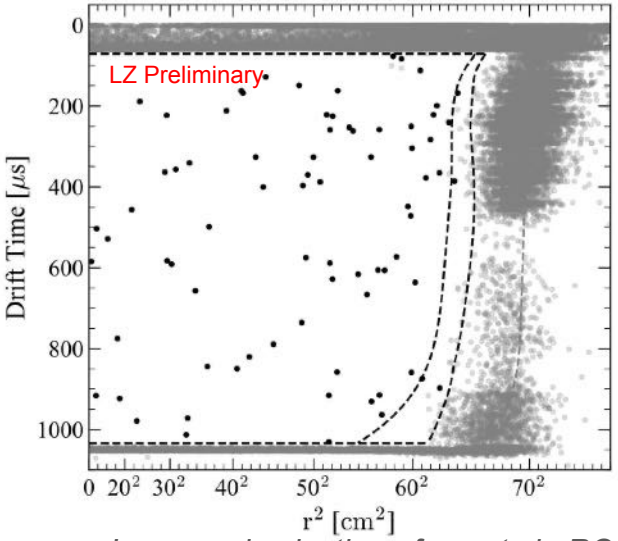
Look only in inner volume of the TPC to remove wall effects and external backgrounds

Aggressive fiducial volume defined to require < 0.01 events from wall

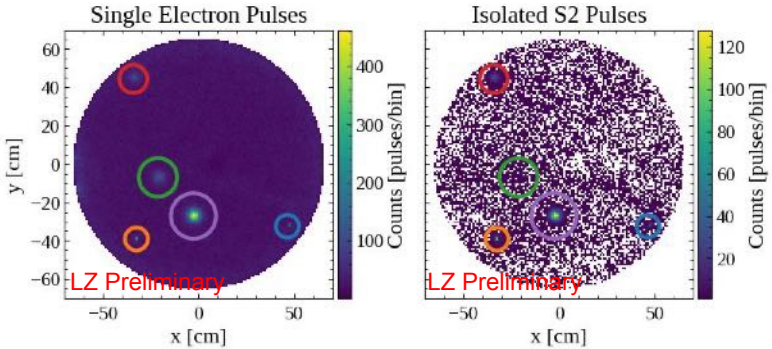
→ **Fiducial Volume = 5.09 ± 0.15 tonnes**

Additional hotspot veto removes periods in time and space due electrode electron emission, cuts out **~1% additional exposure**

→ **Final exposure: 5.7 ± 0.2 tonne-years**



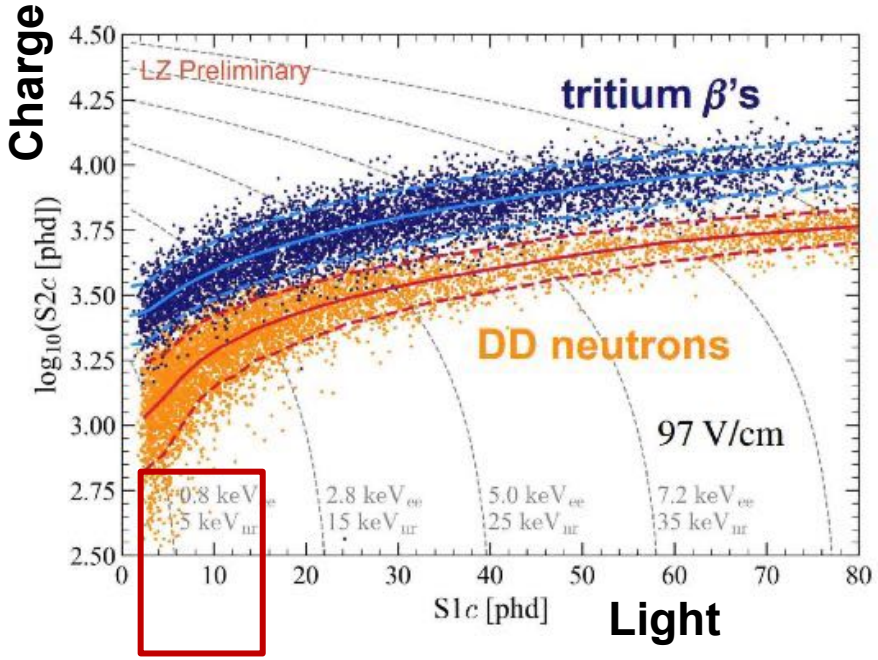
Loosened selection of events in ROI



Intense day of electrode electron emission

What are the backgrounds?

- Electron recoil (ER) backgrounds (betas, gammas) are **negligible** (>1000σ away from ER band median)
- Neutron backgrounds are < 1 event (tag with Outer Detector and Skin)
- **Dominated by accidental coincidence events**



WS2025 search region

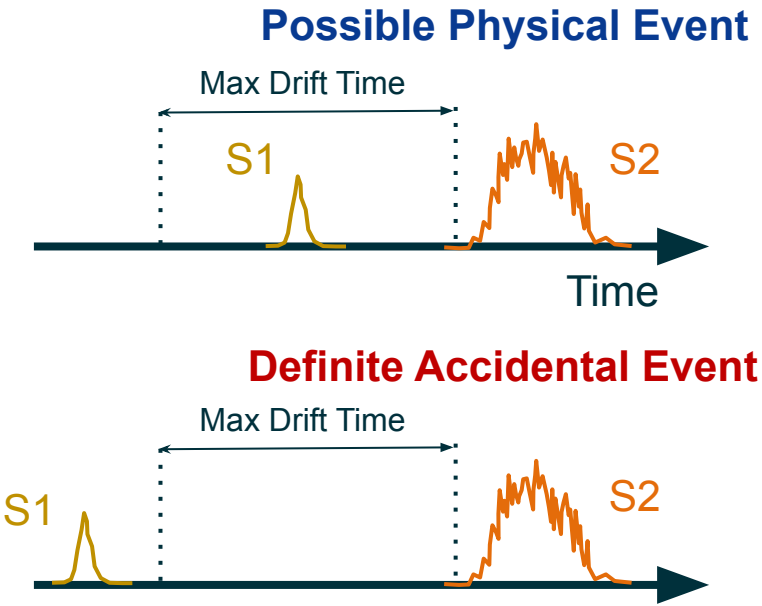
Accidental Coincidences

Isolated S1s and S2s can pile-up to fake a scatter, where the **S1 and S2 do not come from the same energy deposition**

Sources of S1s and S2s largely from a wide variety of instrumental effects, e.g.:

- PMT dark counts
- Charge loss near the TPC walls which degrades the S2 signal
- Large photon/electron rates after big energy depositions

Need to mitigate & model these backgrounds



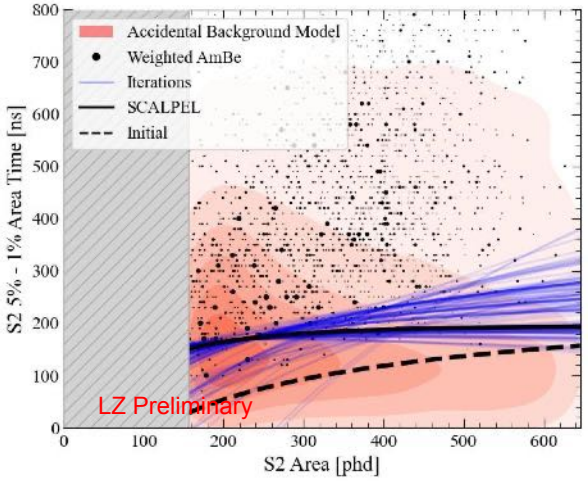
Max drift time = time for electron to drift from cathode to liquid surface (~1 ms)

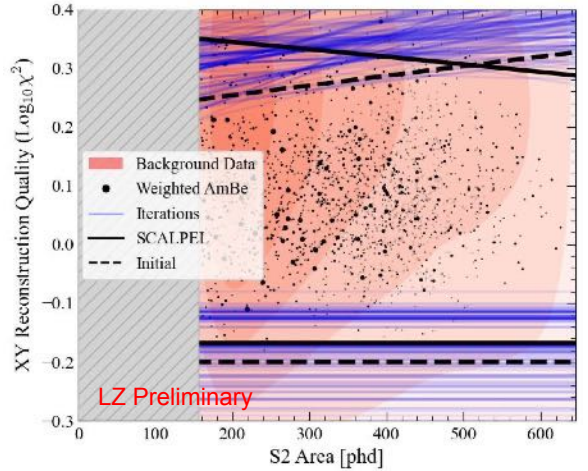
Accidental Coincidence cuts

Target accidental coincidences with selections targeting anomalous S1 and S2 characteristics (pulse shape, PMT hit map)

- Selections are designed and optimized using neutron (AmBe) calibration and fabricated background datasets
- Optimization technique (CMA-ES[1]) used to simultaneously tune several selections across multiple parameter spaces
    - Powerful, and not a black box!

Additional 90% rejection of accidental coincidences

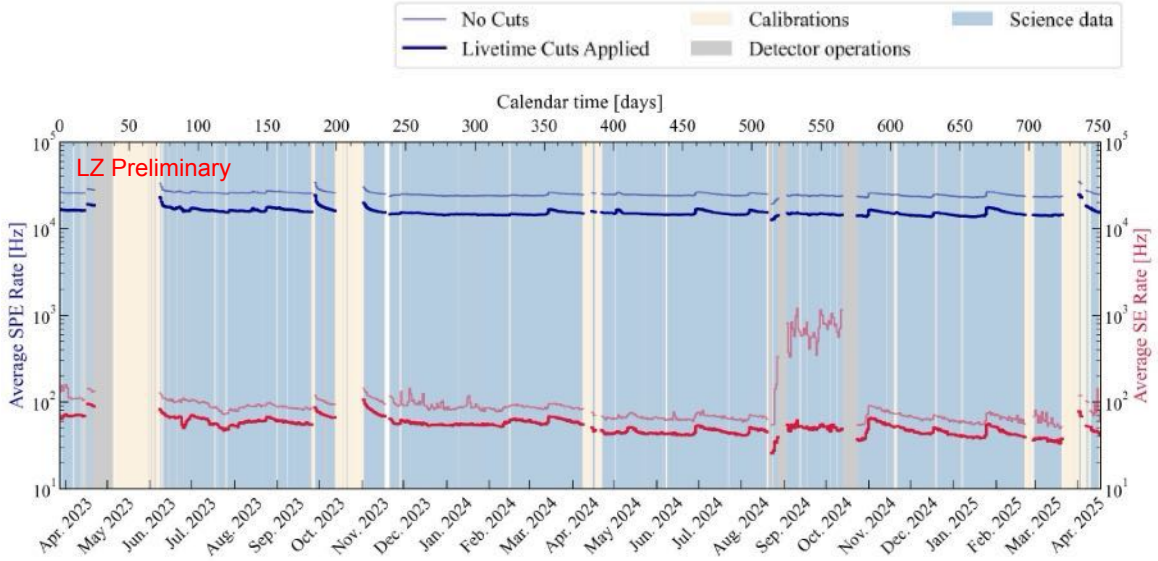




[1]Covariance Matrix Adaptation Evolution Strategy

Accidental coincidence modeling

- Photon and electron rates vary on ms time-scales→ necessitates model that *captures time-varying environment*
- Fabricate S1-S2 events from lone S1s and S2s according to ambient photon + electron rate environment



- Resulting S1-S2 spectrum is normalized by rate in sideband of known accidental events (> max drift time)

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

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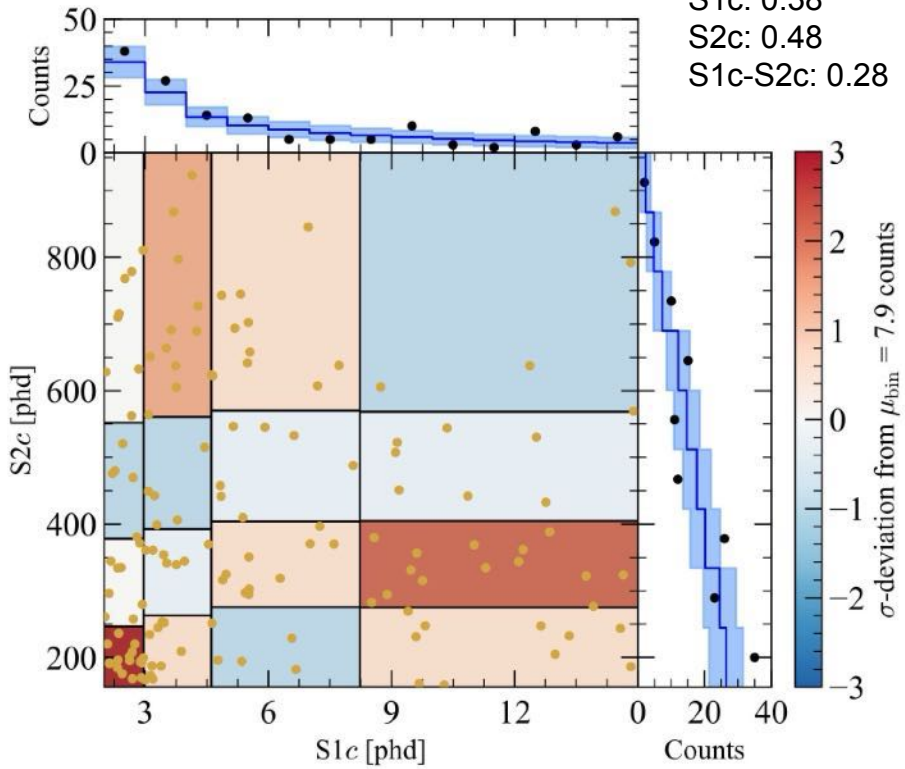
Validating the model

We stress-test the model using multiple datasets

- Events with drift time > max drift time (right)
- During high rate AmLi neutron calibration
- During increased photon/e- rate conditions
- Events in science data failing S1 and S2 pulse cuts

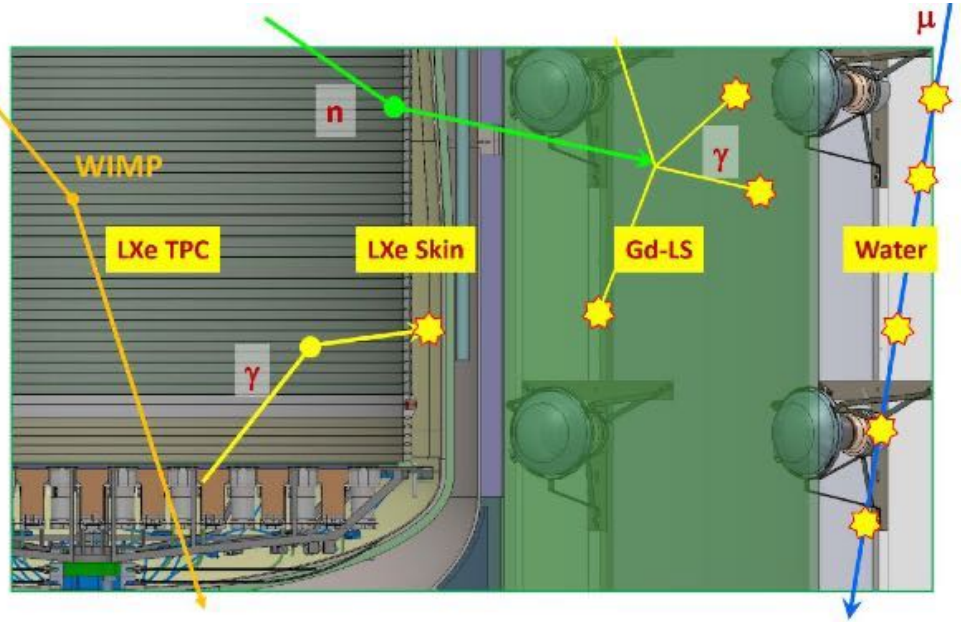
Observe excellent agreement across datasets with a variety of detector conditions

p-values:
S1c: 0.38
S2c: 0.48
S1c-S2c: 0.28



OD and Skin vetoes

- OD and Skin serve as active vetoes to reject radiogenic neutrons with prompt and delayed coincidences
- Delayed-Only neutron veto efficiency is **87 ± 2 %**
- Total neutron veto efficiency is **92 ± 4 %**
- Efficiencies validated with AmLi and AmBe neutron calibration



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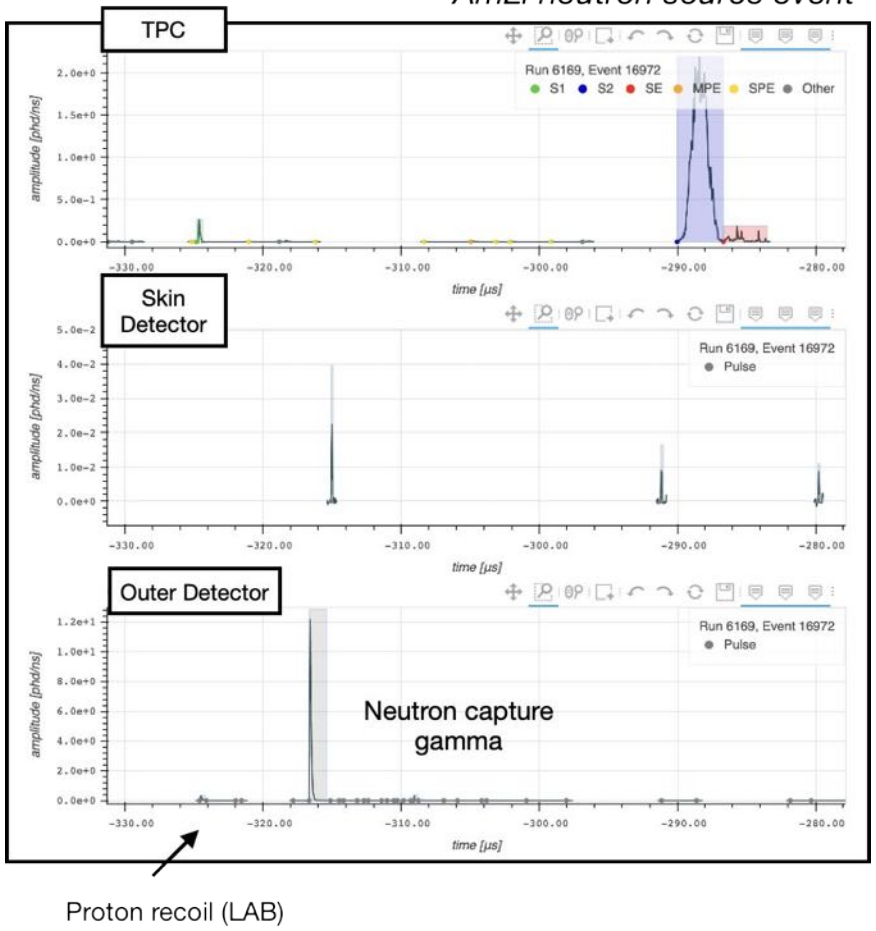
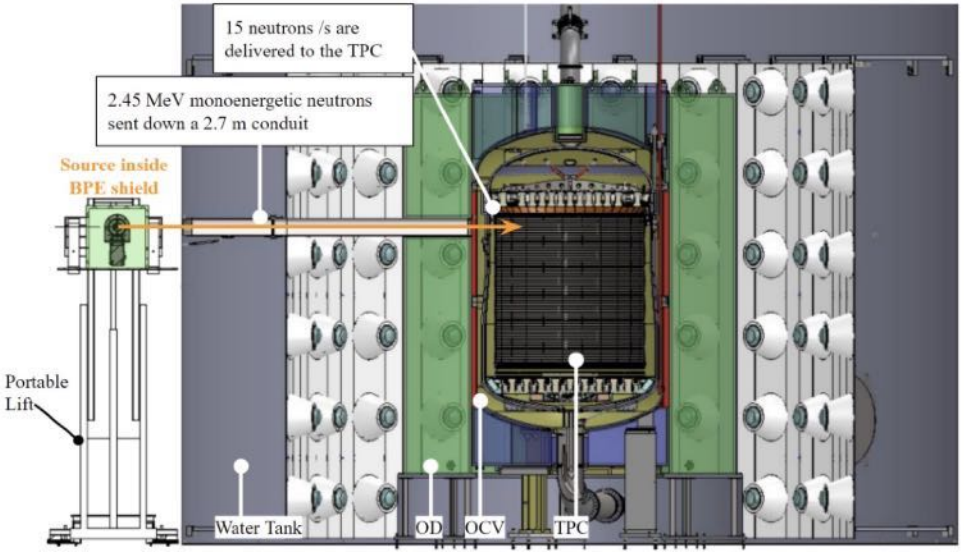
AmLi neutron source event



Calibrating nuclear recoil response

- Need to carefully calibrate low-energy nuclear recoil response and quantify systematic uncertainties associated with these models

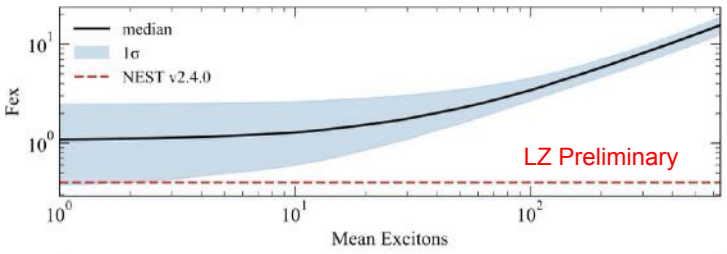
- Nearly mono-energetic 2.45 MeV neutrons are used from well-characterized Adelphi deuterium-deuterium (DD) source
  - DD Neutrons produce nuclear recoils from 1-74 keV
  - Constrain both high and low energy nuclear recoil behavior in xenon



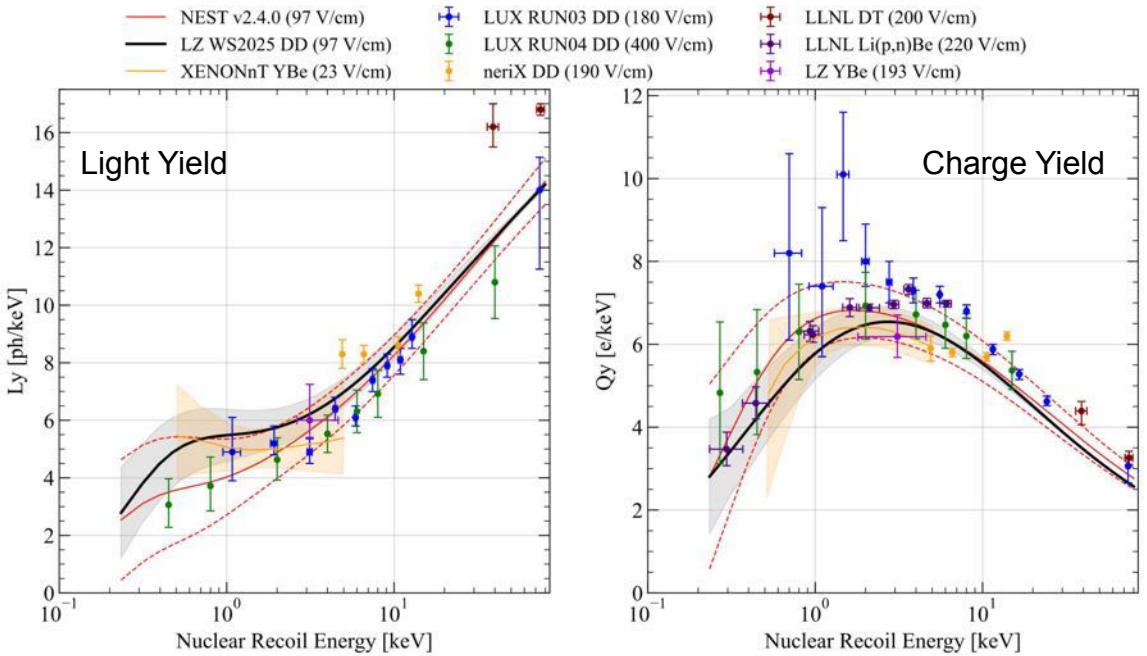
Schematic of DD neutron generator and the neutron's path into the TPC

Best-fit yields and fluctuations

- Quantified systematic uncertainty associated with yields, fluctuations and detection efficiencies



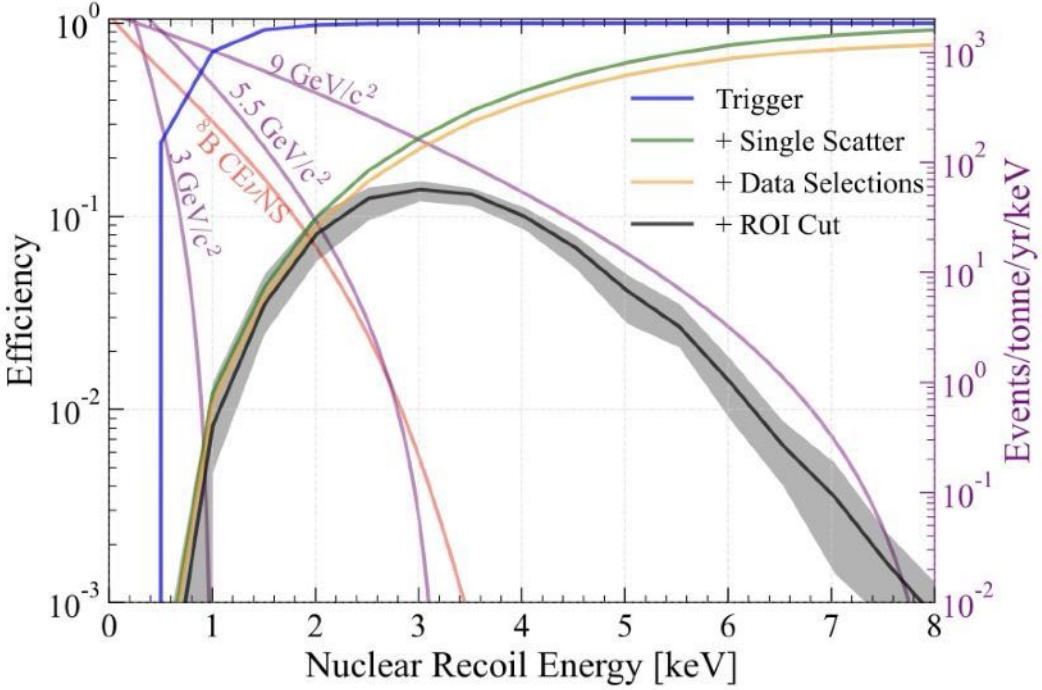
Best-fit model for exciton (photon) quanta fluctuations as a function of quanta produced



Best-fit light yields (left) and charge yield (right) from this analysis (black) compared to other experimental results

Detection efficiency

- 95% trigger efficiency to 4e$^-$ sized S2s
- Threshold predominantly set by 3-fold S1 requirement
- Reconstruction and selection of S1 and S2s determined with calibration events
- Gray uncertainty band shows quadrature of uncertainties as shown in next slide



Detection efficiency as a function of nuclear recoil energy

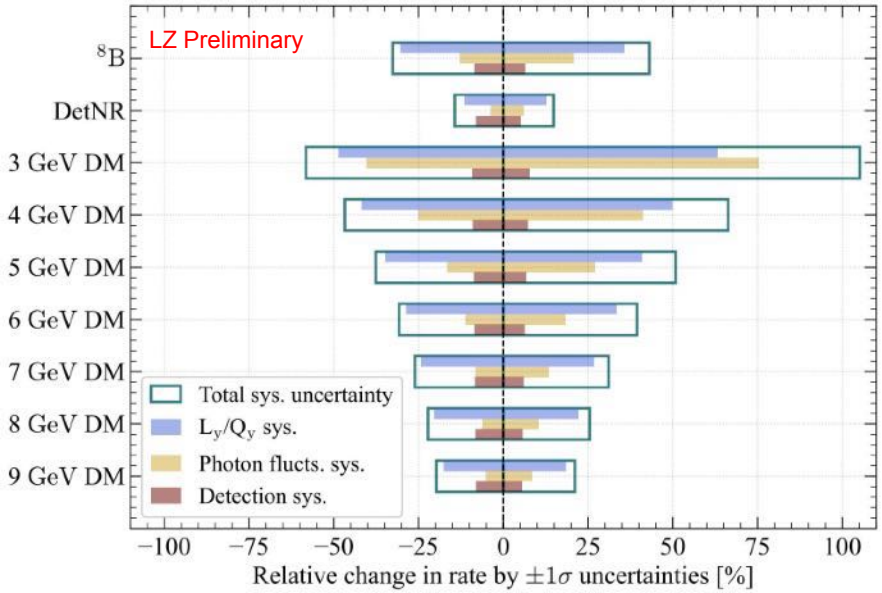
Expectations and uncertainty budget

Monte Carlo simulations to predict rates and uncertainties

Total systematic on detector response contains uncertainties from:

- Yields
- Fluctuations
- Detection ability (reconstruction and selections)

^{8}B CEνNS expectation in full exposure (5.7 tonne-yrs): **$20.6^{+8.9}_{-6.8}$ events**

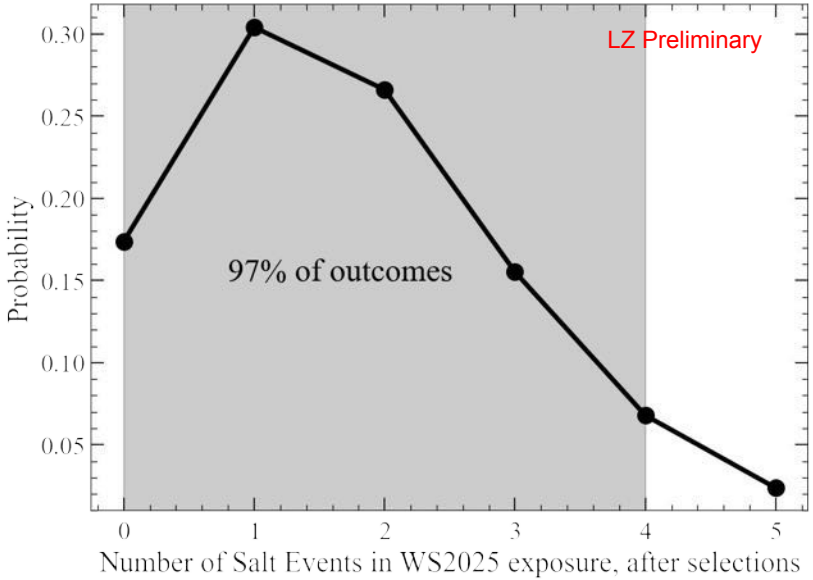


Total percent uncertainty and its breakdown by contribution for each simulated NR component

Bias mitigation

LZ uses two main strategies:

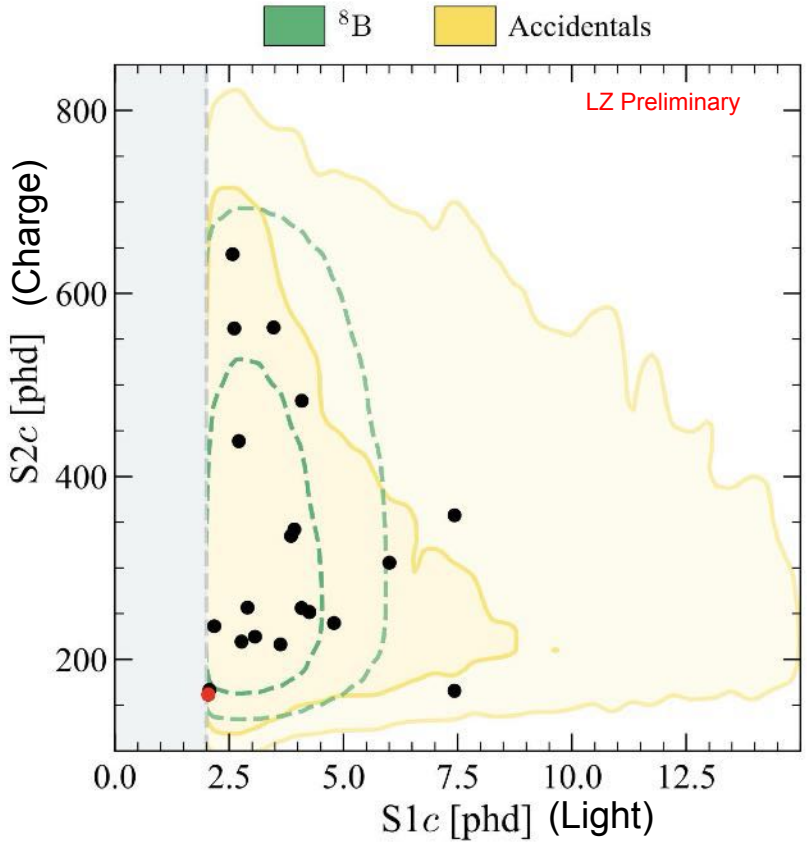
1. All data selections and background measurements are performed with sideband datasets
2. Artificial signal events (salt) are randomly injected into the datastream
    - We have both higher mass DM salt and ^{8}B CEνNS specific salt in the dataset



- Injected salt rate chosen to match Poisson uncertainty on expected ^{8}B CEνNS rate based on WS2024 NR model
- **Salt only revealed after all analysis selections and decisions are finalized!**

Final dataset

- 20 events in dataset after all selections
  - 1 revealed to be salt (red) → within expectations [0,4]
- **19 events with which to perform science search**
- Sideband dataset of “neutron-rich” data: passing all selections except delayed veto
  - **1 event** → in-situ constraint for neutrons
  - **Neutron expectation in main dataset**: $\mathbf{0.04^{+0.25}_{-0.04}}$ **events**



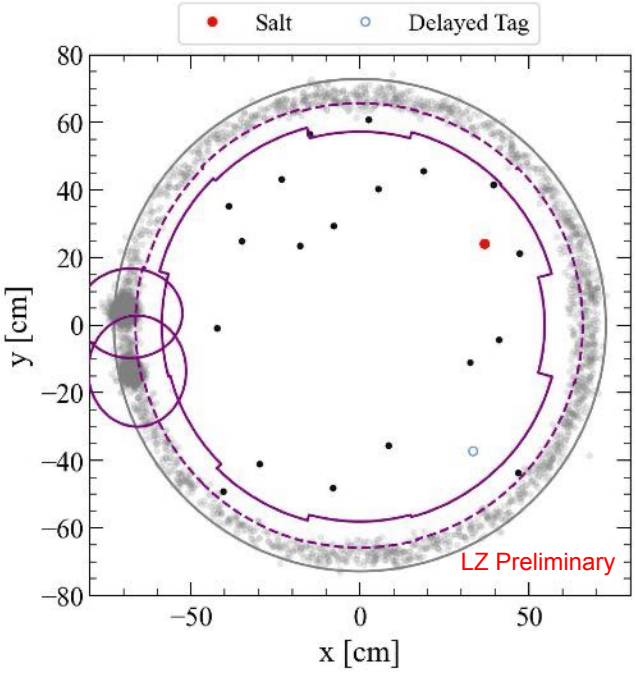
Final science dataset (black) with the one injected and recovered salt event (red)

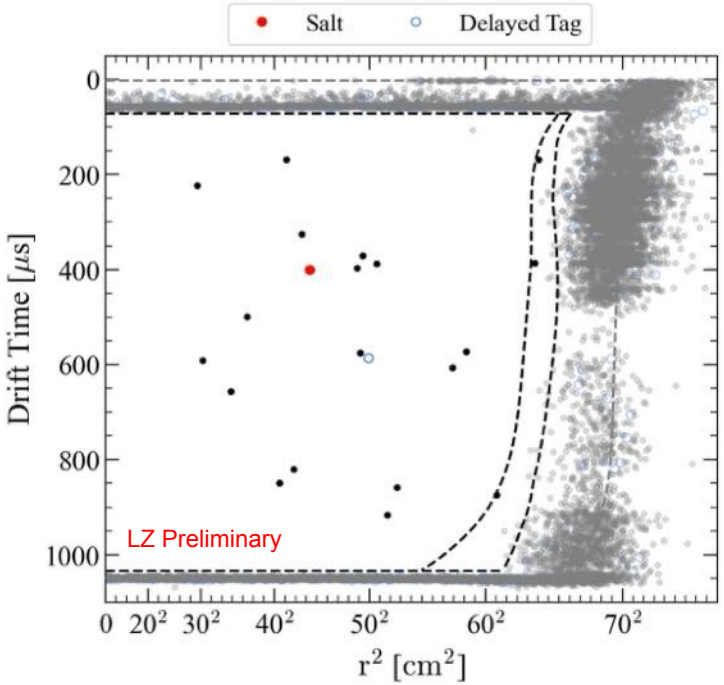
Final dataset - position distribution

Gray:
TPC edge

Purple:
FVr extents at the top and bottom of the FVz

Purple circles:
Resistor cutouts





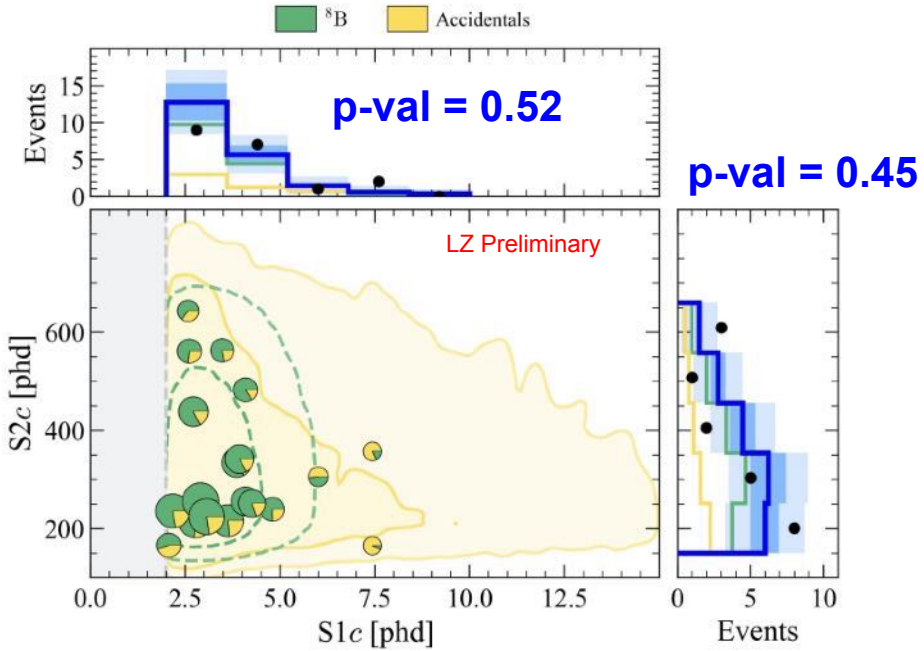
Gray:
Phi-averaged wall

Black:
Min and max FVr

Goodness of model

^{8}B CEνNS, Accidentals, and Neutrons are backgrounds in this model

- Negligible ER backgrounds in this ROI
- ^{8}B CEνNS rate is **constrained** in fits
- Excellent data-model agreement!

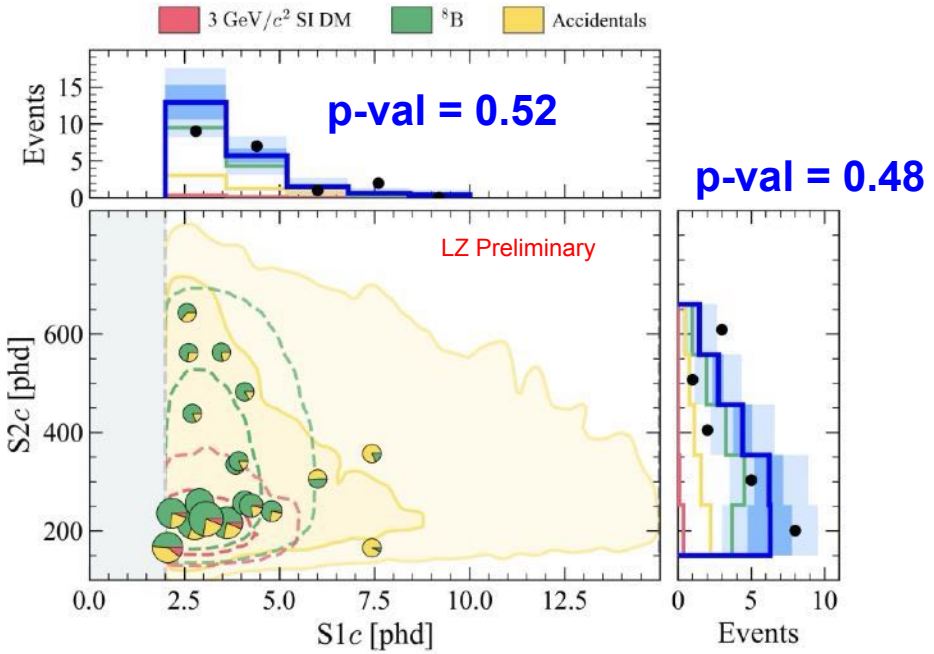


Components	Expectation	Background-Only Fit
Spin-Independent DM	-	-
^{8}B CEνNS	$20.6^{+8.9}_{-6.8}$	$15.0^{+2.9}_{-2.5}$
Accidental coincidences	6.6 ± 0.3	6.5 ± 0.3
Detector neutrons	$0.04^{+0.25}_{-0.04}$	$0.1^{+0.2}_{-0.1}$
Total	$27.2^{+9.2}_{-6.7}$	$21.6^{+4.7}_{-3.8}$

Fit for 3 GeV/c^2 DM

^{8}B CEνNS, Accidentals, and Neutrons are backgrounds in this model

- Negligible ER backgrounds in this ROI
- ^{8}B CEνNS rate is **constrained** in fits
- Best-fit number of DM events is consistent with 0 across all DM masses tested



Components	Expectation	3 GeV/c^2 Fit
Spin-Independent DM	-	$0.5^{+5.1}_{-0.5}$
^{8}B CEνNS	$20.6^{+8.9}_{-6.8}$	$14.7^{+3.1}_{-2.7}$
Accidental coincidences	6.6 $\pm$ 0.3	6.5 $\pm$ 0.3
Detector neutrons	$0.04^{+0.25}_{-0.04}$	$0.1^{+0.2}_{-0.1}$
Total	$27.2^{+9.2}_{-6.7}$	$21.7^{+7.1}_{-4.2}$

Hypothesis testing strategy

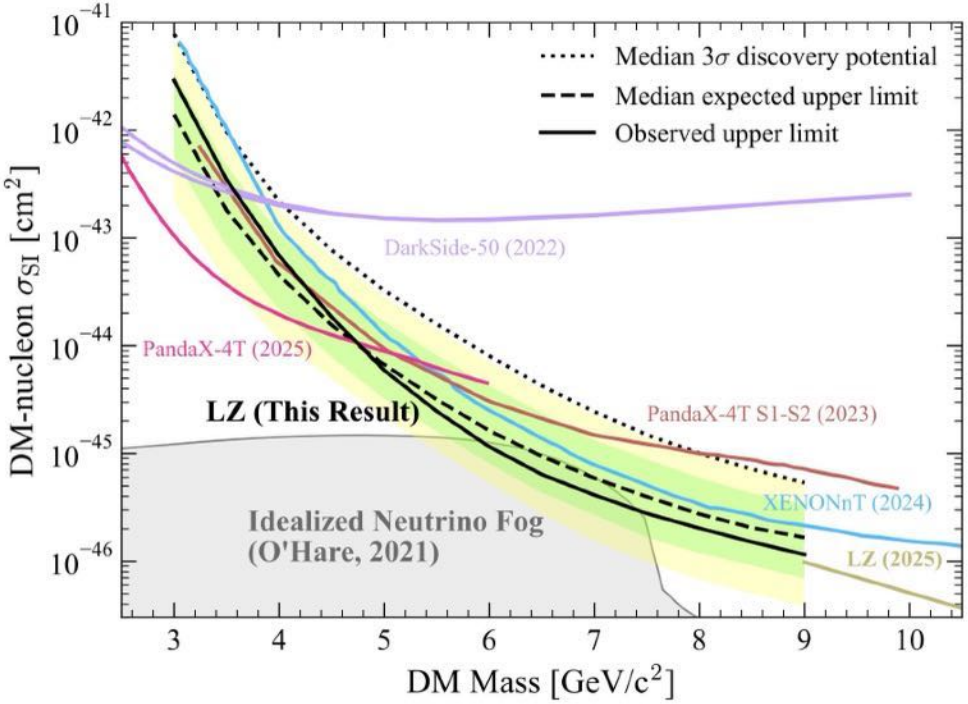
Profile-likelihood Ratio (PLR) test is used to…

1. **Perform a search for 3-9 GeV/c^2 dark matter**
   a. *2-sided 90% confidence interval based on PLR test statistic*
   b. Backgrounds: ^{8}B CEνNS, accidental coincidences, detector neutrons
   c. *^{8}B CEνNS rate is constrained based on predictions*
      i. Assumes Standard Model CEνNS cross-section[1] and ^{8}B flux measured by SNO experiment[2]
2. **Perform a search for ^{8}B CEνNS**
   a. *PLR test statistic to reject background-only model*
   b. Assume *zero* DM events
   c. Backgrounds: accidental coincidences and detector neutrons
   d. *^{8}B CEνNS rate is floated freely*

[1] Phys. Rev., D 9, 1389 (1974)
[2] Phys. Rev. C 88, 025501 (2013)

Low-Mass DM results

- Limit setting for Spin Independent (SI) DM-nucleon interaction strength using two-sided test statistic
- **World-leading limits > 5 GeV/c^2**
- Reaching into the neutrino fog
- Ask us about Spin-Dependent limits in the backup



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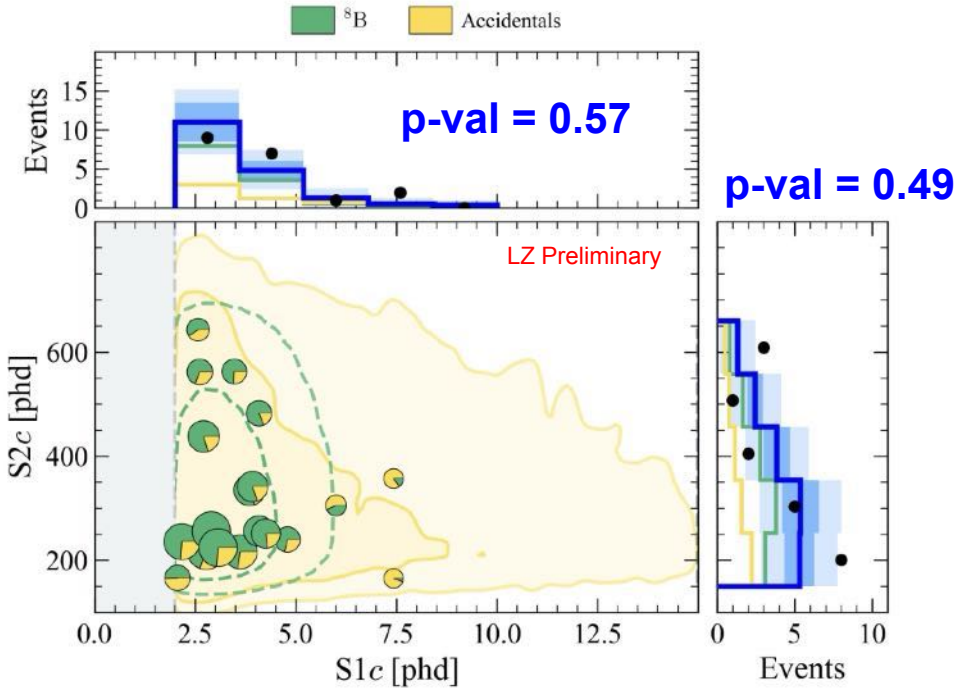
   d. *^{8}B CEνNS rate is floats freely*

Searching for ^{8}B CEνNS

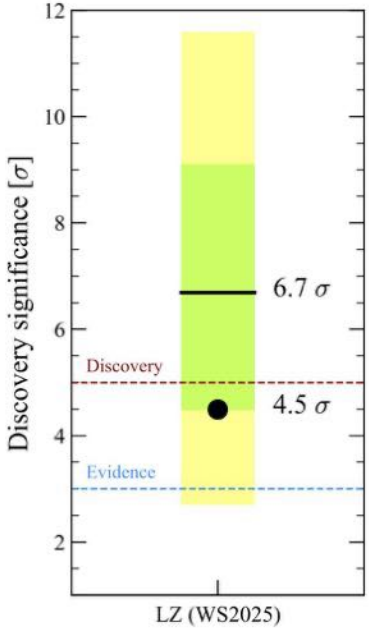
- Search for ^{8}B CEνNS events, ***assuming zero DM events***
- ^{8}B CEνNS rate is **unconstrained**, floating freely in fits
- Best-fit number of ^{8}B CEνNS events: $\mathbf{12.3^{+7.0}_{-5.4}}$
  - Consistent with prediction of $\mathbf{20.6^{+8.9}_{-6.8}}$ events

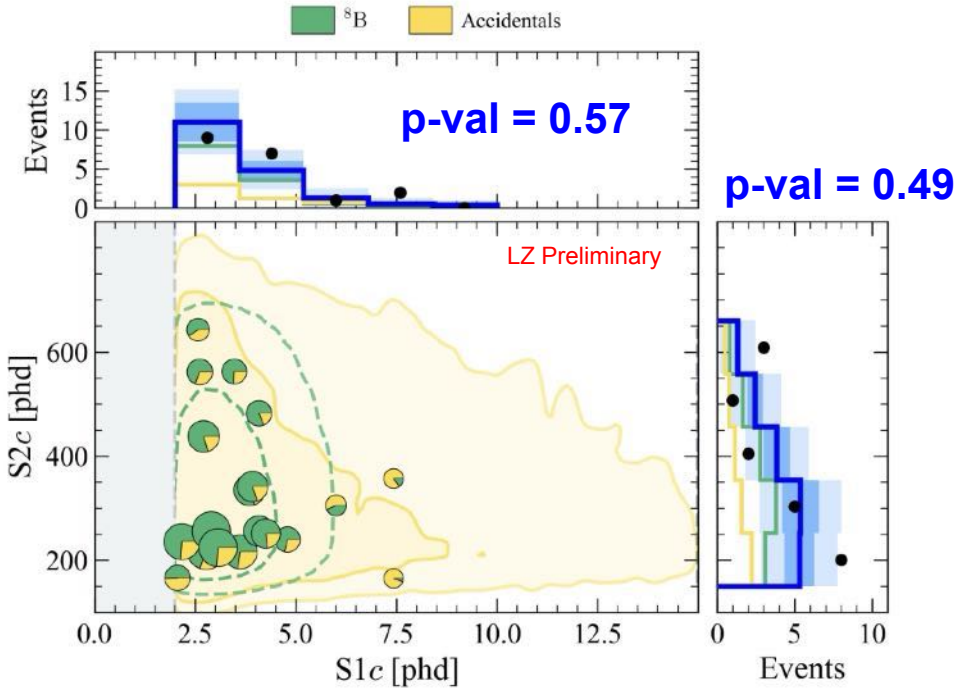


Components	Expectation	Fit Results
^{8}B CEνNS	-	$12.3^{+7.0}_{-5.4}$
Accidental coincidences	6.6 ± 0.3	6.6 ± 0.3
Detector neutrons	$0.04^{+0.25}_{-0.04}$	$0.1^{+0.2}_{-0.1}$
Total	6.6 ± 0.3	$18.9^{+7.0}_{-5.5}$

Evidence for ^{8}B CEνNS

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





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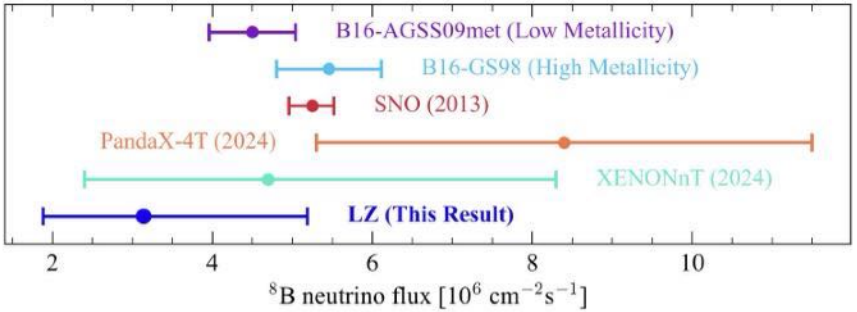
Measurements with ^{8}B CEνNS

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

- Make a flavor-independent measure of ^{8}B solar neutrino flux



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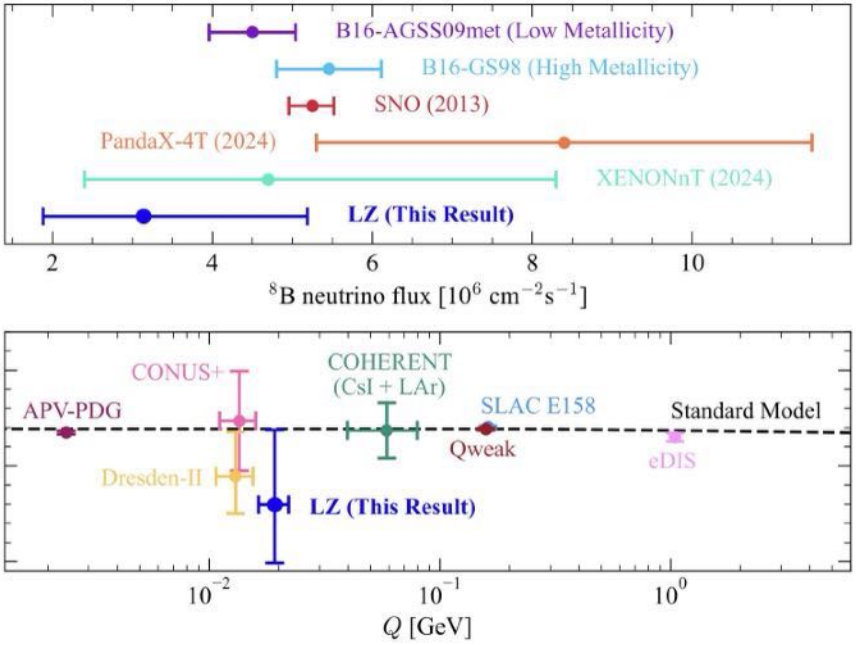
- Measure weak-mixing angle ($\sin^2\Theta_W$) at low momentum transfer (Q)

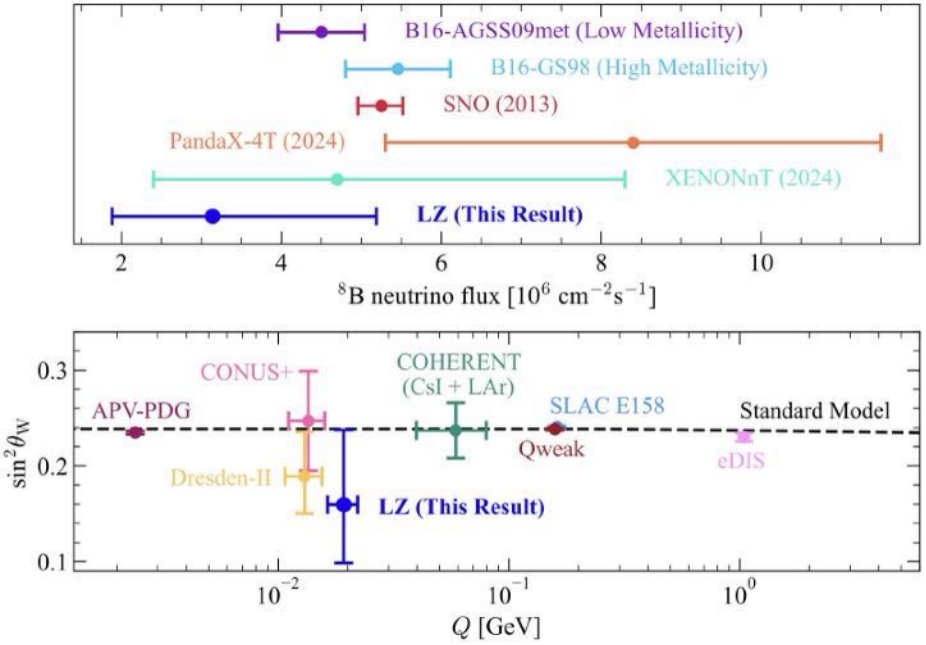


Measurements with ^{8}B CEνNS

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

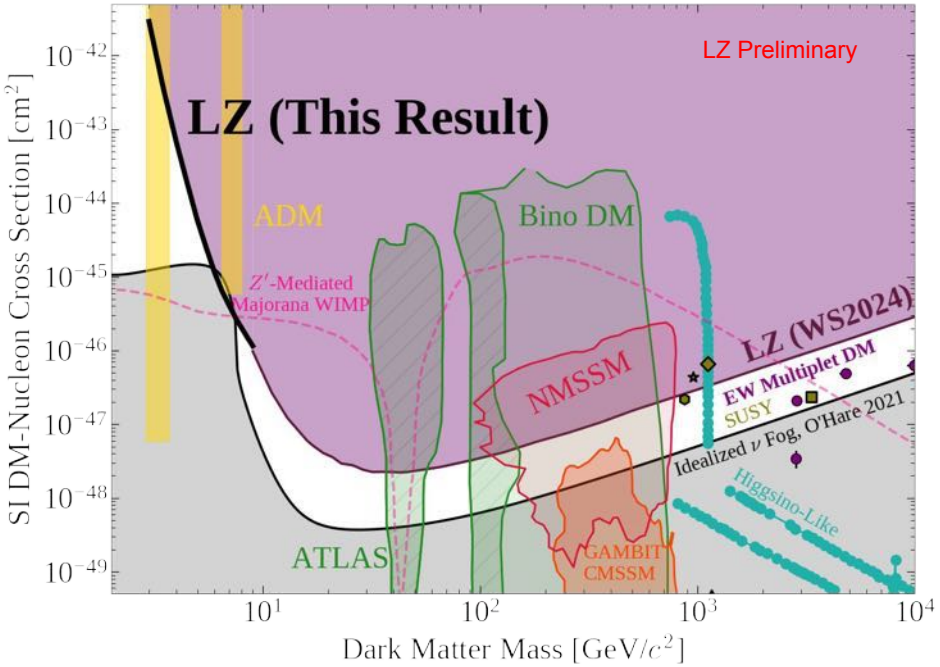
- Make a flavor-independent measure of ^{8}B solar neutrino flux
- Measure weak-mixing angle ($\sin^2\Theta_W$) at low momentum transfer (Q)

These measurements will improve with increased statistics and improved detector modeling



Future dark matter searches

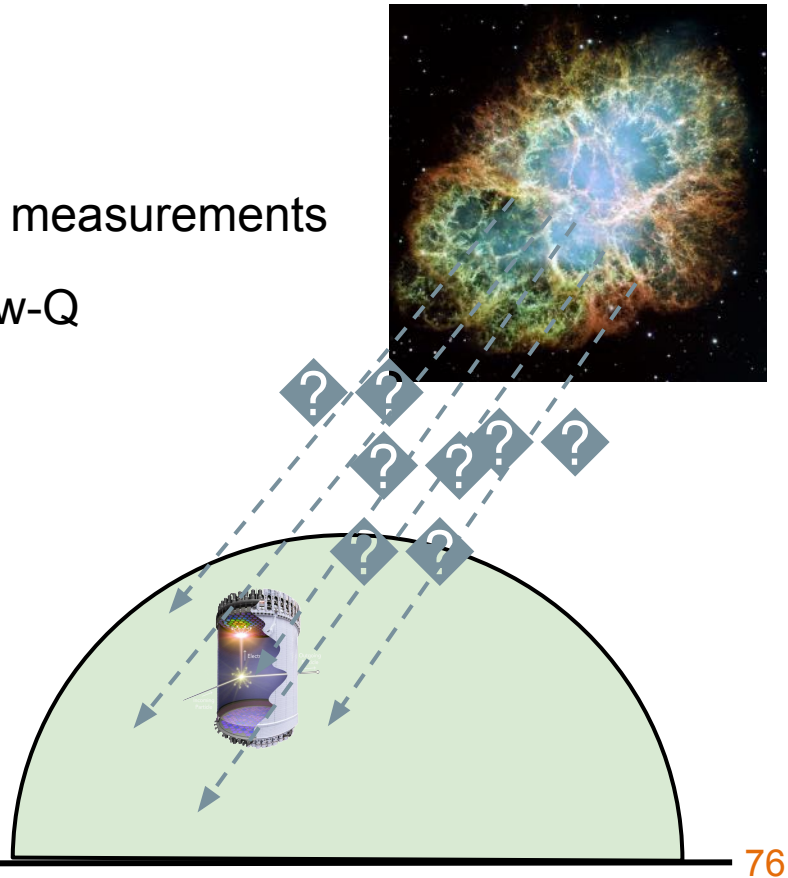
- **World-leading limits > 5 GeV/c^2**
- < 9 GeV DM searches of similar or greater cross-sections are limited by solar neutrinos
- Higher mass DM searches are not yet entering the neutrino fog
    - Fog is set by atmospheric neutrinos
- Interesting model space to probe at higher masses!



LZ continues to operate and take data towards a 1000 day DM discovery dataset by end 2027!

Future neutrino physics

- CEνNS opens a portal to…
  - flavor-independent solar neutrino flux measurements
  - Sensitivity to weak-mixing angle at low-Q
  - Non-standard neutrino interactions
  - Supernova neutrinos
    - For 27 solar-mass progenitor, 10 kpc (~33 light-years) away, predict ~80 CEνNS events in ~10 s



More physics with LZ

- LZ is the largest and most sensitive liquid xenon TPC in the world!
- Other physics searches being performed in LZ…
  - Effective field theory coupling of DM to xenon nuclei
  - Solar axions, axion-like particles, dark photons
  - ^{136}Xe $2\nu\beta\beta$ and $0\nu\beta\beta$, also DEC
  - Ultraheavy Dark matter
  - Cosmic ray boosted DM
  - Atmospheric millicharged particles
  - And much more…

Phys.Rev.Lett. 135 (2025) 1, 011802

Phys.Rev.D 109 (2024) 9, 092003

Phys.Rev.Lett. 133 (2024) 22, 221801

Phys.Rev.D 108 (2023) 7, 072006

arXiv:2511.17350

Phys.Rev.D 109 (2024) 11, 112010

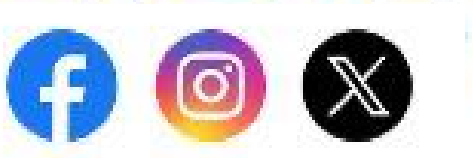
Phys.Rev.Lett. 134 (2025) 24, 241801

Phys.Rev.Lett. 134 (2025) 24, 241802

LZ socials and materials

Links to all LZ papers and presentations can be found on our collaboration website!

This LZ result paper will be posted on our website, before subsequent submissions to the arXiv and PRL.



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https://lz.lbl.gov/