LUX-ZEPLIN

Latest Results

Ewan Fraser

September 2026

LZ (LUX-ZEPLIN) Collaboration, 39 Institutions, 250 scientists, engineers, and technical staff

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

LZ Collaboration Meeting at University of Bristol, June 2026

US Department of Energy

Science and Technology Facilities Council

Fundação para a Ciência e a Tecnologia

Sanford Underground Research Facility

Swiss National Science Foundation

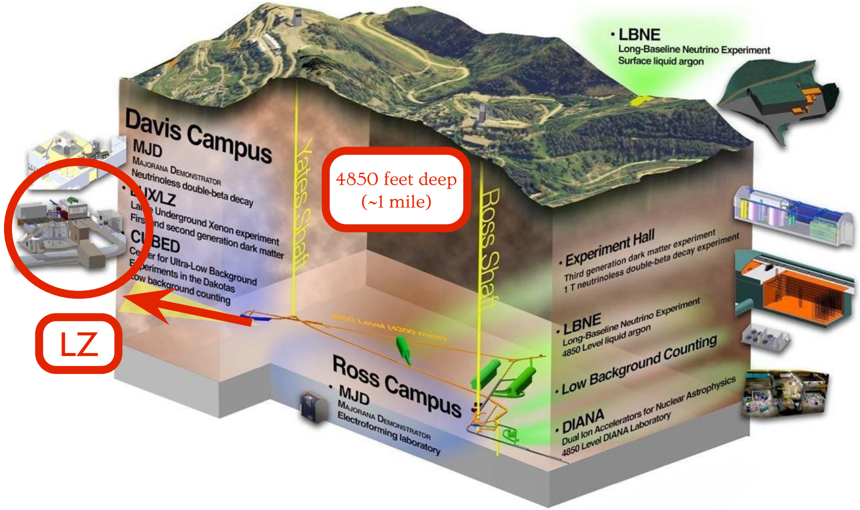
Institute for Basic Science

ARC Centre of Excellence for Dark Matter Particle Physics

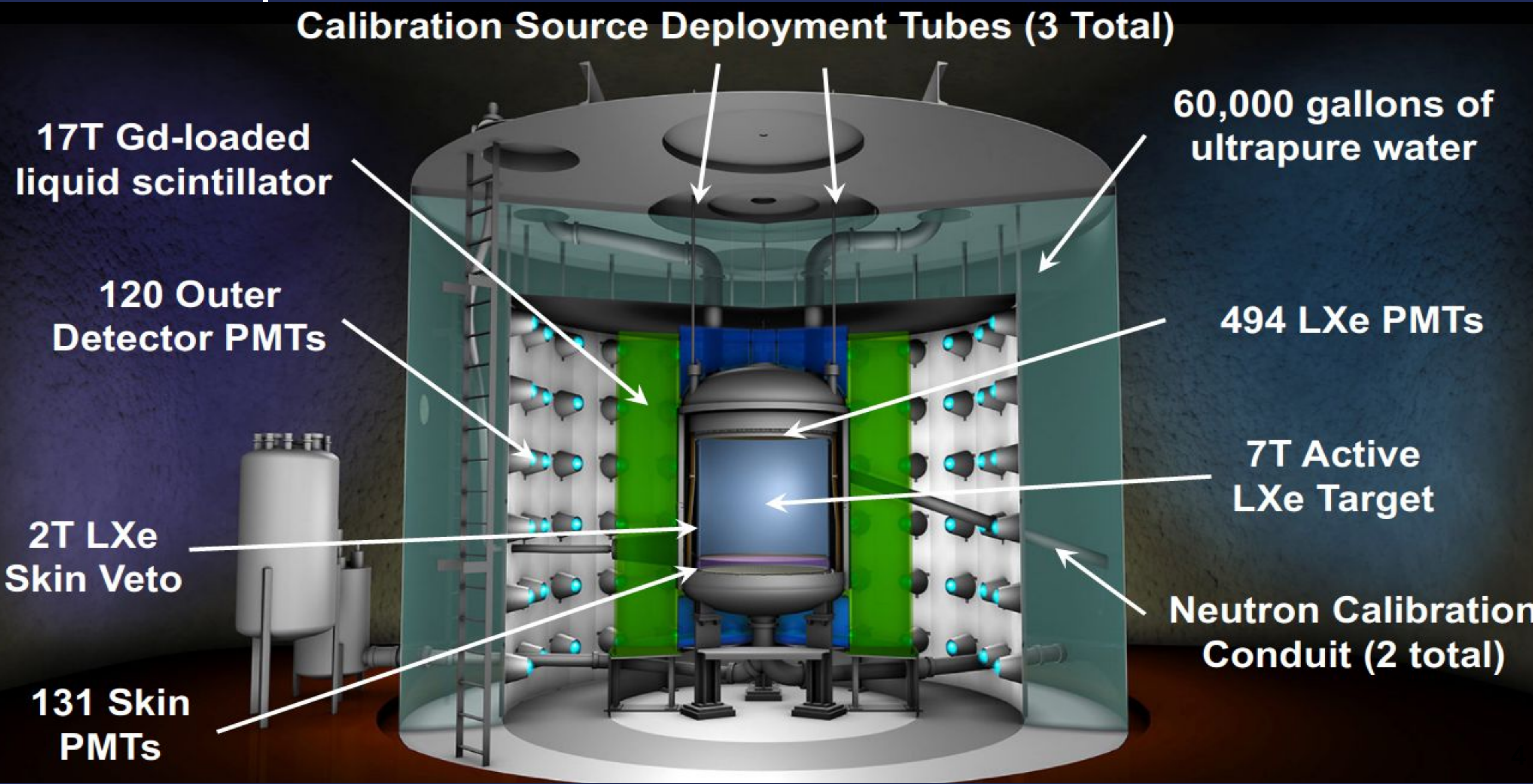
Thanks to our sponsors and participating institutions!

LZ at SURF

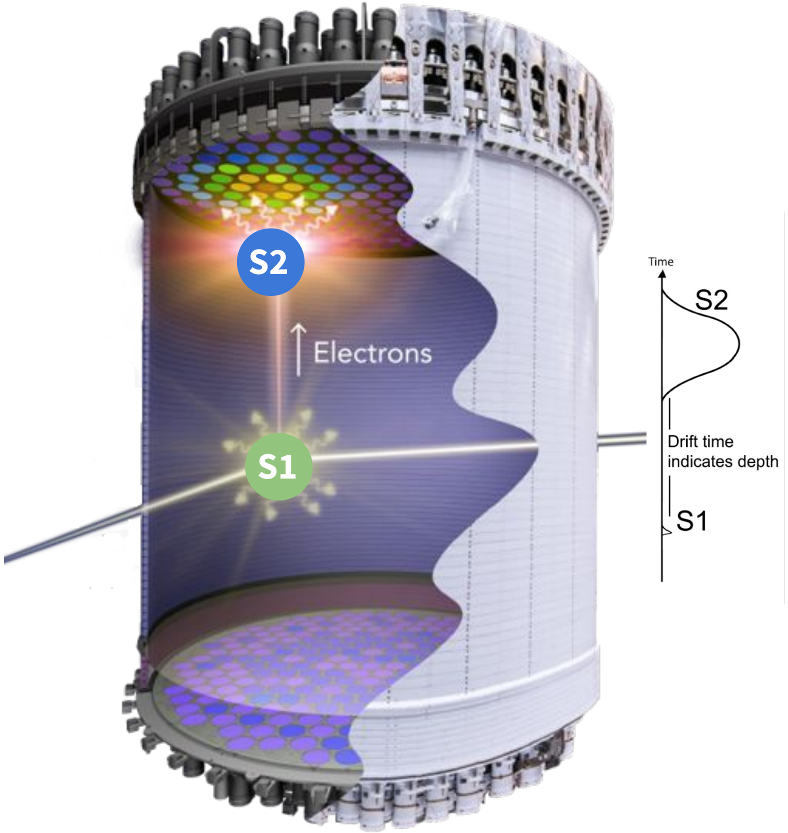
- LUX-ZEPLIN is a Dark Matter direct detection experiment
  - Rare event search - radiopure - WIMPs
  - Natural abundance of ^{136}Xe - $0\nu\beta\beta$ search
  - Running until 2028 - collecting 1000 livedays of data
- Located at Sanford Underground Research Facility
  - SURF - Homestake Mine, Lead, South Dakota
  - ~1 mile underground, Davis Cavern
  - Rock overburden reduces cosmic ray muon flux by $O(10^6)$



LZ - Experiment for Direct Detection of WIMP Dark



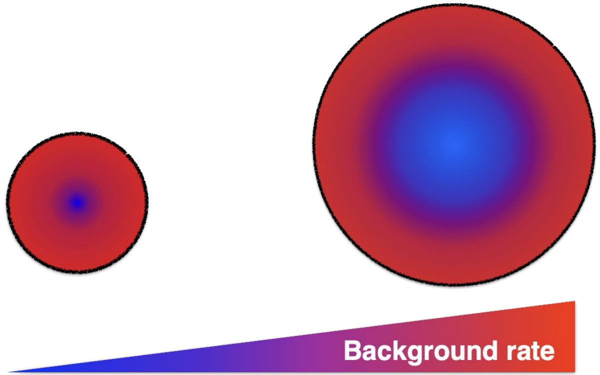
Xenon Dual Phase Time Projection Chamber



Single Scatter interaction in TPC

Xenon Dual Phase Time Projection Chamber (TPC):

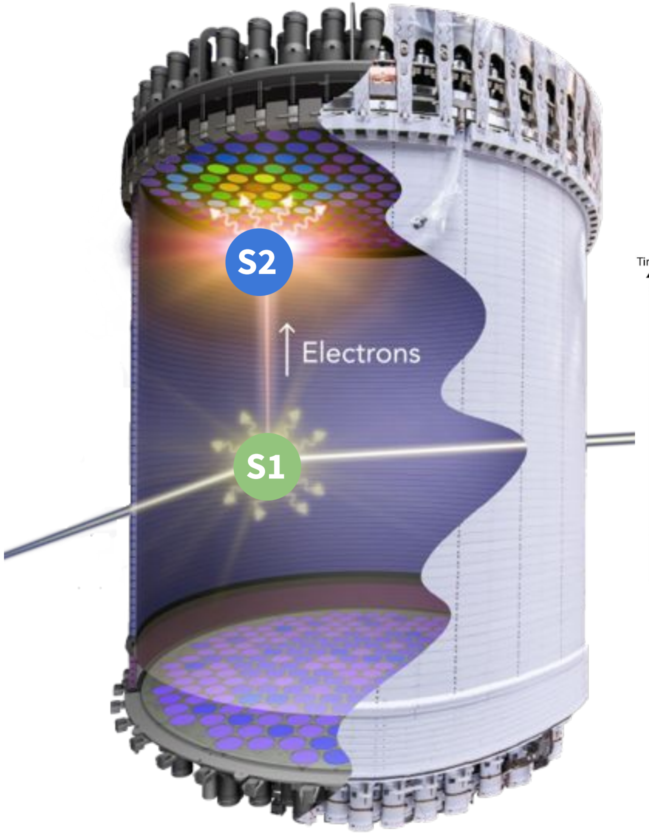
- ❑ LXe target, GXe extraction region
- ❑ S2 hit pattern, Drift Time - (x, y, z)
- ❑ Energy deposited reconstructed from - S1, S2
- ❑ **Particle discrimination - S1:S2 ratio**

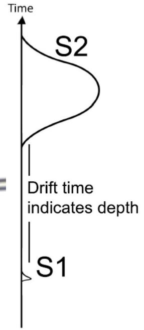


Why xenon?:

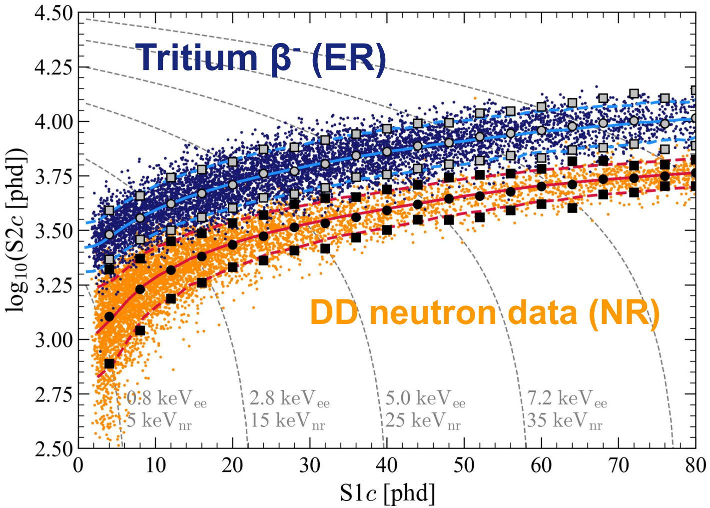
- ❑ Highest charge & light yields of stable noble elements
- ❑ Commercially available & easily purified
- ❑ **Dense → short attenuation lengths - self-shielding**
- ❑ Scalable → potential for large target mass

Xenon Time Projection Chamber Principles

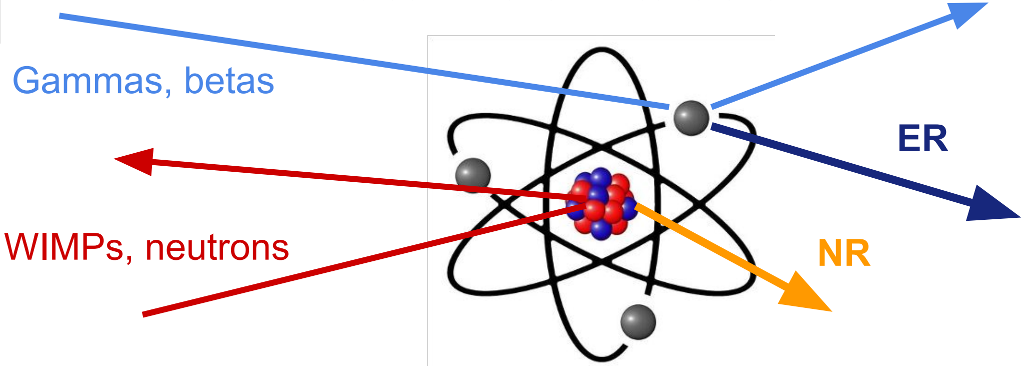




Single Scatter interaction in TPC

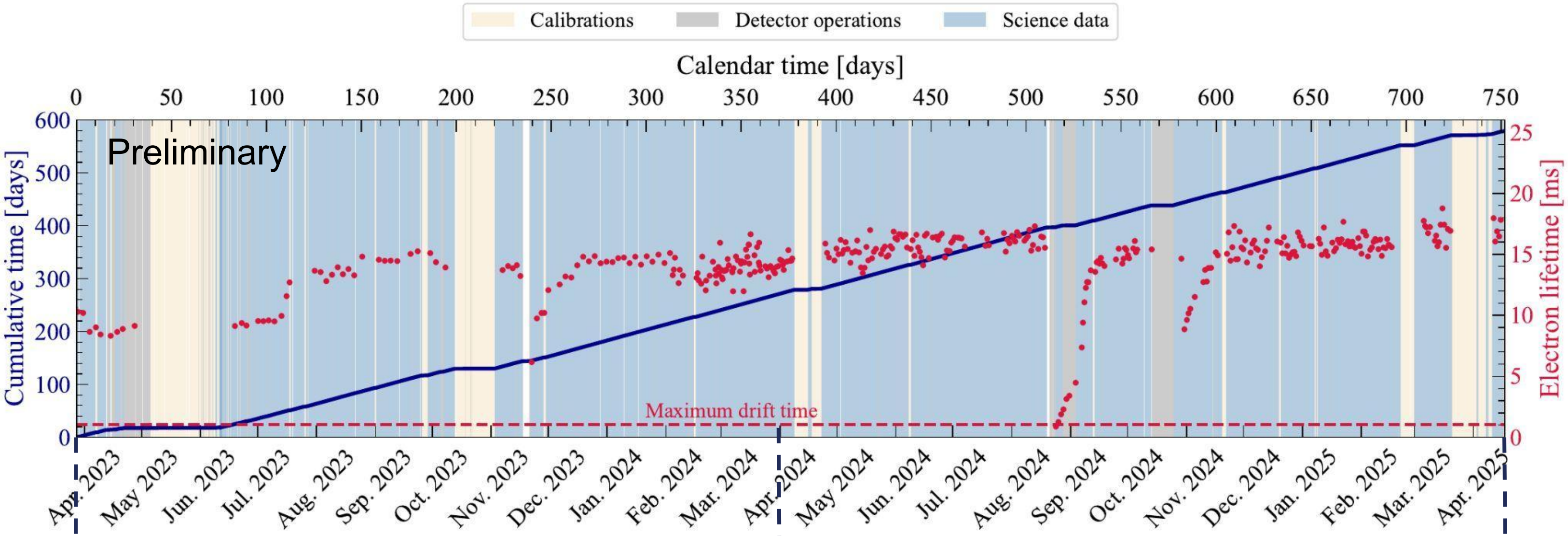


2024 Electronic Recoil (ER) and Nuclear Recoil (NR) discrimination in calibration



Direct Detection of Dark Matter

LZ Timeline



WS2024 & HENR2024

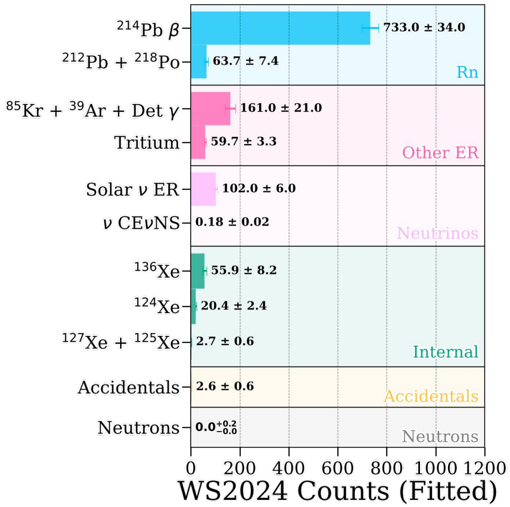
220 live-days
after exclusions

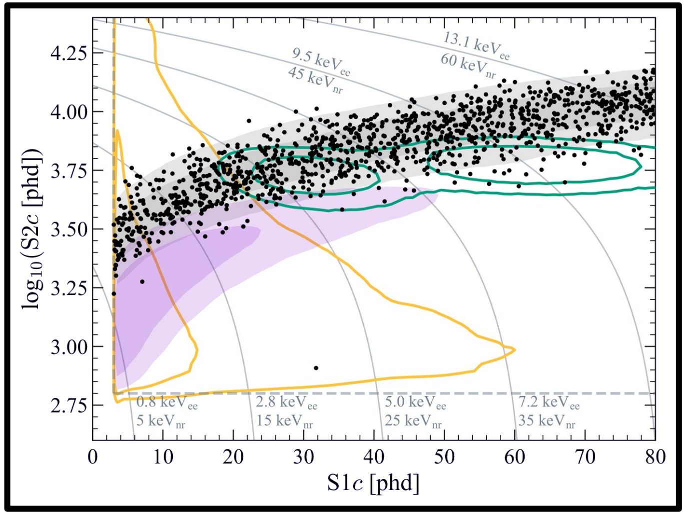
WS2025* & ^{136}Xe $0\nu\beta\beta$ Update

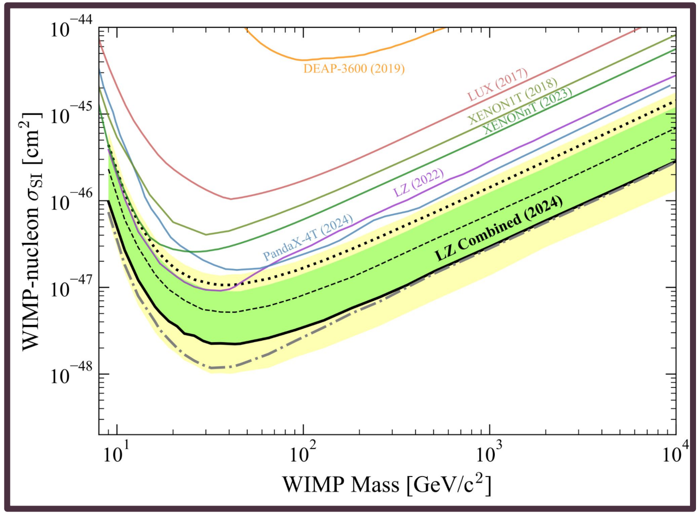
417 and 510 live-days respectively

*Light Dark Matter Search 2025

WS2024 - Result



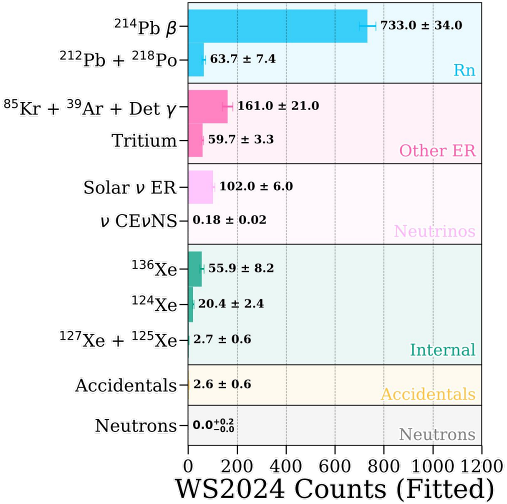


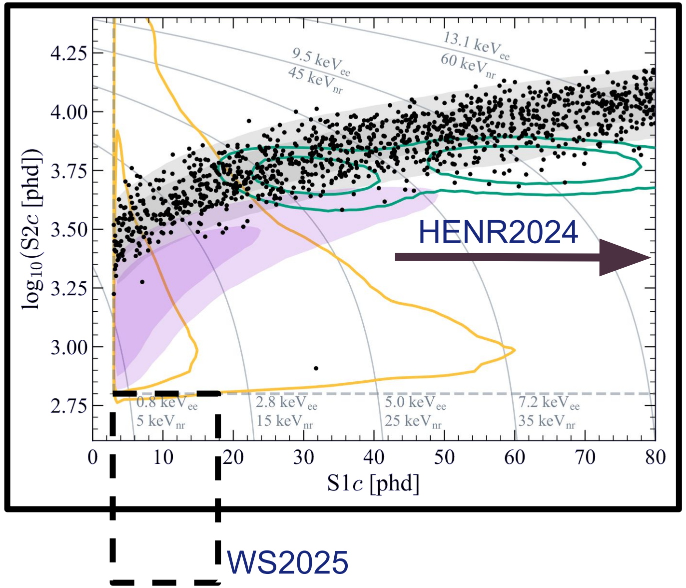


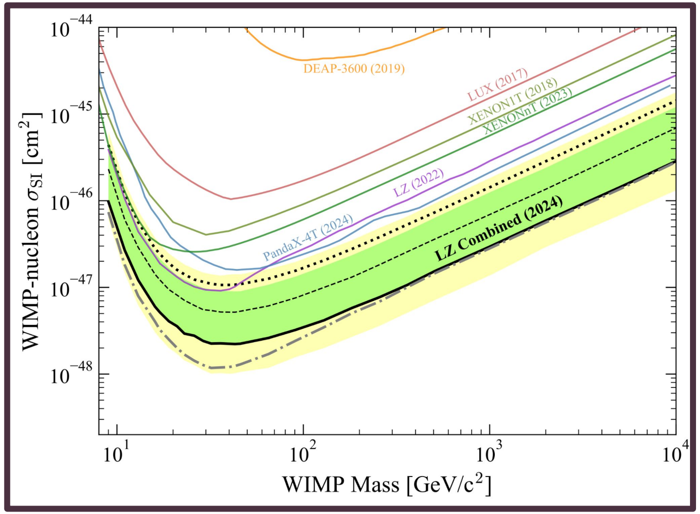
— Accidental — ^{24}Xe 2νECEC — 40 GeV/c^2 WIMP

- Region of interest ~5-55 keV$_{nr}$
- Best fit no. of WIMPs is 0 at all tested masses (9 GeV/c^2 - 10 TeV/c^2)
- World leading sensitivity to WIMP nucleon cross-section
  - Elastic spin independent & dependent interactions considered

WS2024 - Result







- WS2025 - Light Dark Matter Search
  - ~1-6 keV$_{nr}$
  - WIMP masses tested 3-9 GeV/c^2
- HENR2024 - High Energy Nuclear Recoils
  - ~5-270 keV$_{nr}$

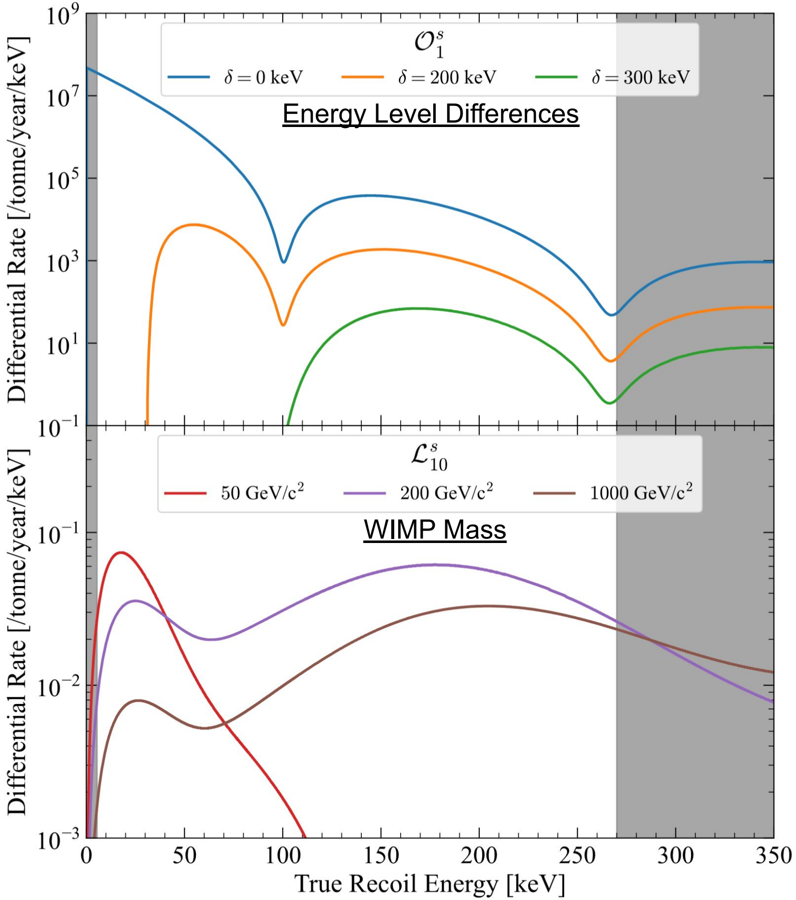
High Energy Nuclear Recoil Search - Motivation

Extension of WIMP search to higher recoil energies
- ❑ Interactions that have **momentum transfer dependence**

Operators & Lagrangians
- ❑ **Non-relativistic effective field theory**
- ❑ Fifteen independent operators $\mathcal{O}_i$
- ❑ Set of 20 Lagrangians $\mathcal{L}_i$

Inelastic Dark Matter
- ❑ Models of Dark Matter with mass states that are nearly degenerate

Specific example models shown
- ❑ Two illustrative examples for this result
- ❑ Inelastic spin independent scatter $\mathcal{O}_1^s$
- ❑ Magnetic moment interaction $\mathcal{L}_{10}^s$

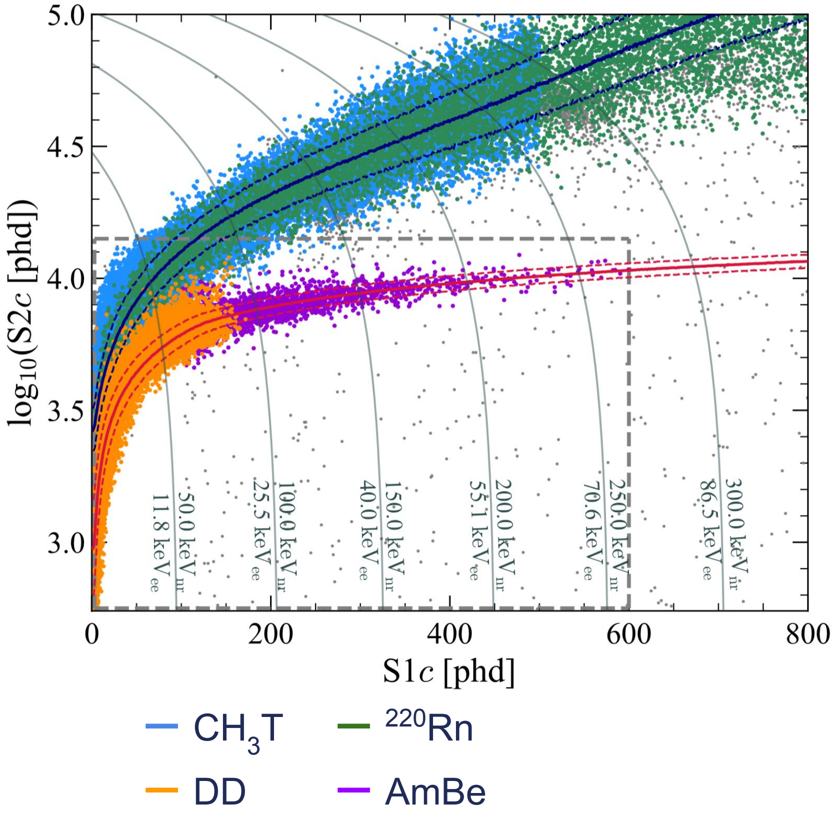


Signal Nuclear Recoil Spectra

Fitzpatrick et al. J. Cosmol. Astropart. Phys. 02, 004 (2013)
Smith et al. Phys. Rev. D **64**, 043502 (2001)
Bramante et al. Phys. Rev. D **94**, 115026 (2016)

High Energy Nuclear Recoil Search - Calibration

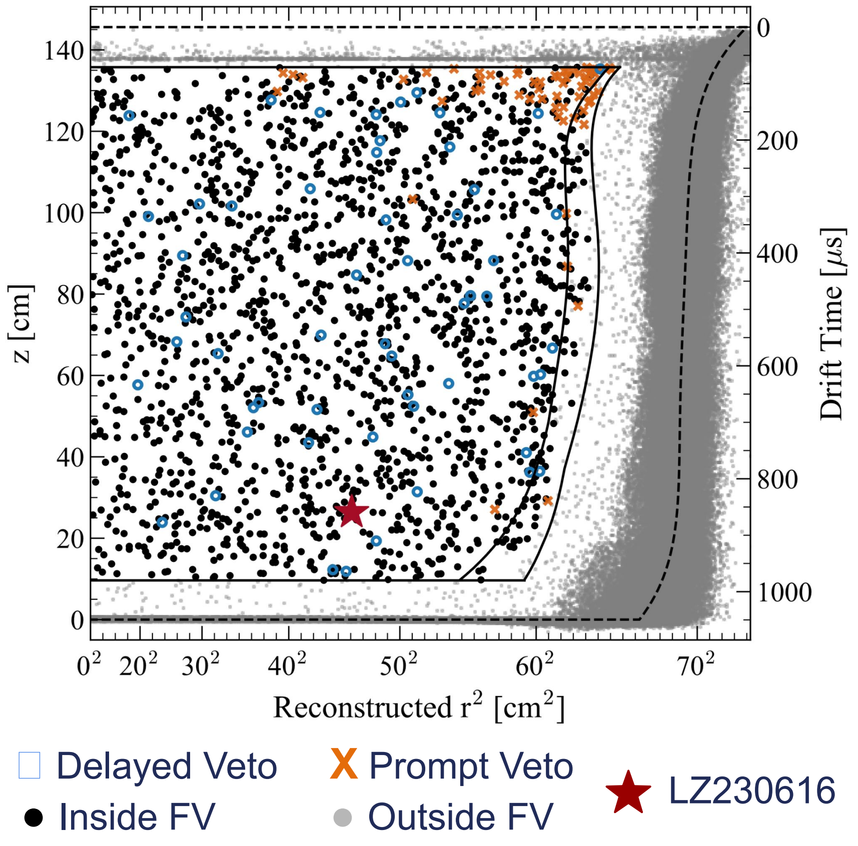
Calibrations for HENR2024



- Injected ER calibration:
  - **Tritiated methane**
    - ^{3}H (18.6 keV β^-)
    - ^{14}C (156 kev β^-)
  - **^{220}Rn Injection**
    - ^{212}Pb (569 kev β^-)
  - ^{83m}Kr, ^{131m}Xe
    - Spatial & temporal corrections
    - (xy, z) resolution at 1σ (<1cm, <1cm)
- External NR calibration:
  - Collimated DD (2.45 MeV)
  - **Deployed source AmBe (Up to ~11 MeV)**
- 99.8% discrimination of β^- under flat NR band median
  - Measured between ~5-55 keV$_{nr}$
- Electron lifetime >8ms (depends strongly on LXe purity)
  - max e^- drift time ~1ms.

High Energy Nuclear Recoil Search - Event Selection

Fiducial Volume for HENR2024



Selections:

- Single Scatter - One site of energy deposition
- Analysis cuts - Reject accidentals background

Fiducial Volume Definition:

- **∼10cm of LXe away from charge insensitive regions**
  - Reverse Field Region (RFR) below the cathode
  - LXe adjacent to the TPC wall
- 4 mean free paths for ^{214}Pb 352 keV γ-ray
  - **Suppress MSSI background**

Anti-coincidence Vetoes:

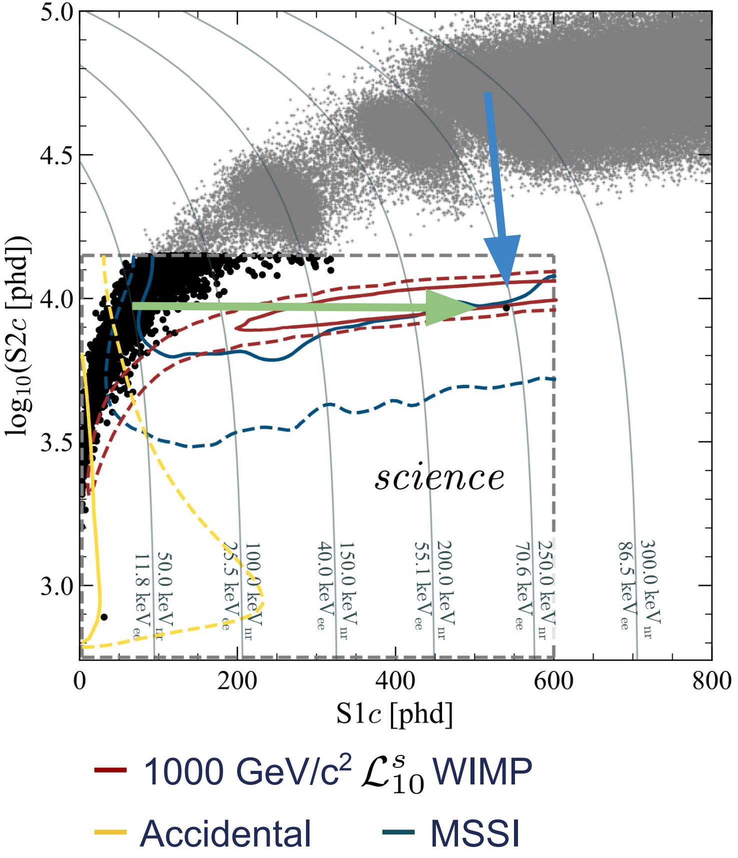
- Skin & Outer Detector
  - **Prompt Veto: ∼90% veto efficiency of γ-ray**
    - Validated against Xe127 decays
  - **Delayed Veto:∼90% veto efficiency of neutrons**
    - Neutron capture up to 600us after S1
    - ∼3% false veto rate (deadtime)

Analysis Volume:

- Mass: 4.7 ± 0.2 tonnes
- **Exposure: 2.8 ± 0.1 tonne-years**

High Energy Nuclear Recoil Search - Event Selection

Data Selection for HENR2024



Event of interest Occurred on **16 June 2023 (LZ230616)**

- 248 ± 23_{stat} ± 23_{sys} keV compatible with nuclear recoil
- ~25 cm from cathode and TPC wall

Background considerations:

Signal Suppression

- **S2** - Suppression of -70%
  - Unexpected loss of electrons in transit?
- **S1** - Enhancement of +450 phd

Instrumental

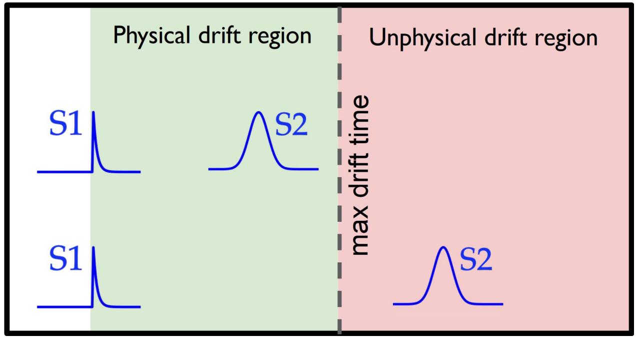
- Accidentals - random coincidence of isolated S1 and S2s
- MSSI - Multiple scatter single ionisation

Nuclear Recoil

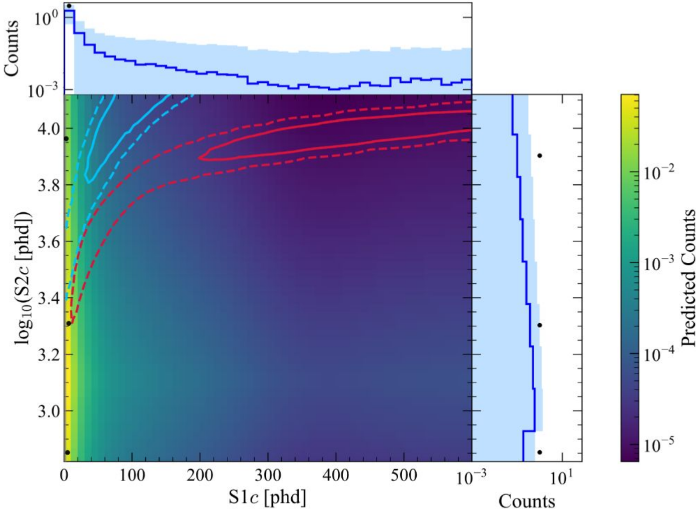
- CEνNS - ^{8}B + hep, Atmospheric neutrinos
- Neutrons from USF and (α,n) in detector materials

High Energy Nuclear Recoil Search - Accidentals

- ❑ **Accidental (random) coincidence of uncorrelated isolated S1 and S2 pulses**
  - ❑ Random drift times, some of which are unphysical
- ❑ LZ's accidentals model:
  - ❑ **Rate:** Measure rate of unphysical drift time (UDT) single scatters. Analysis cut efficiencies analysed using manufactured accidental events.
  - ❑ **Shape:** Manufactured by combining isolated S1 and S2 waveforms and applying analysis cut efficiencies.
    - ❑ High statistics manufacture dataset - chopstitch
- ❑ Analysis cuts have an 99.5% rejection power



Accidentals Cartoon



Post-Cuts Accidentals PDF and UDTs

High Energy Nuclear Recoil Search - MSSI Definition

Multiple Scatter Single Ionisation (MSSI)

- Instrumental Background
  - Scatter inside Fiducial Volume and a scatter in a charge insensitive region
- Results in a **enhanced S1**, and one S2

Charge insensitive regions

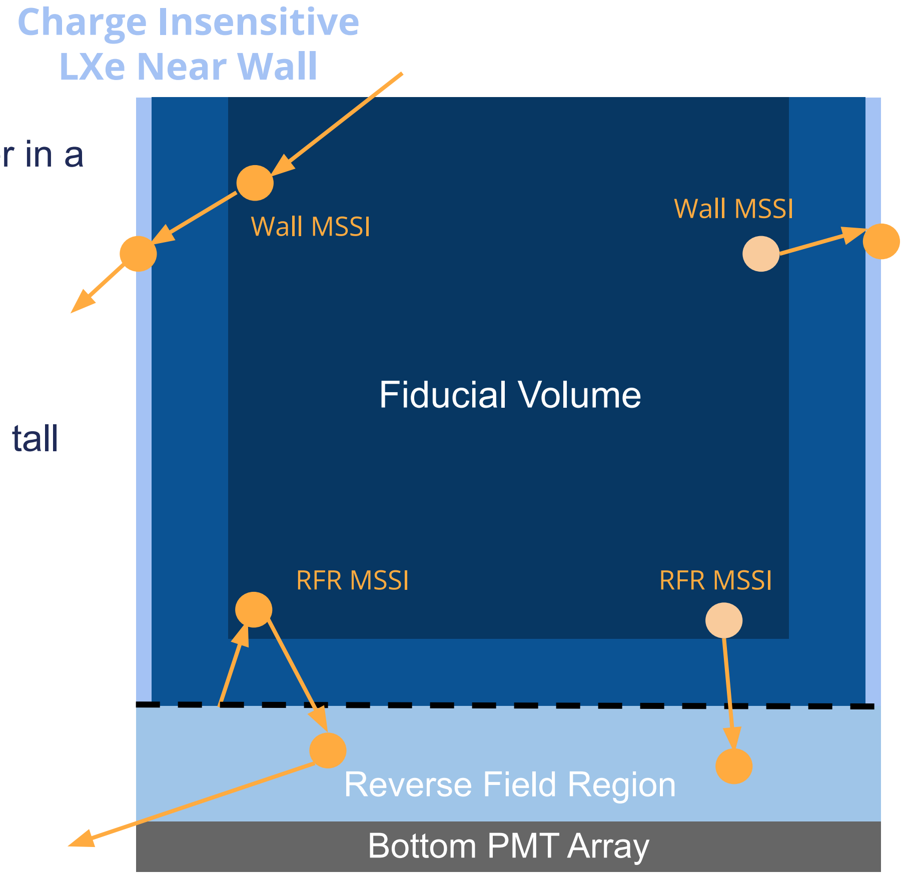
- S2 isn't drifted to the extraction region
- Reverse field region below the cathode: 13.75cm tall
- Near TPC wall: ~3mm around field rings

Background model components:

- **γ-rays from detector materials**
  - Activities from radioassay
- **^{214}Pb β^- $\rightarrow$ ^{214}Bi γ-ray**
  - Has γ-rays 87% of the time

Expectation

- 0.005 ± 0.005 counts in science sample.
- **~90% prompt veto efficiency**



MSSI Cartoon

High Energy Nuclear Recoil Search - MSSI Definition

Multiple Scatter Single Ionisation (MSSI)

- Instrumental Background
  - Scatter inside Fiducial Volume and a scatter in a charge insensitive region
- Results in a **enhanced S1**, and one S2

Charge insensitive regions

- S2 isn't drifted to the extraction region
- Reverse field region below the cathode: 13.75cm tall
- Near TPC wall: ~3mm around field rings

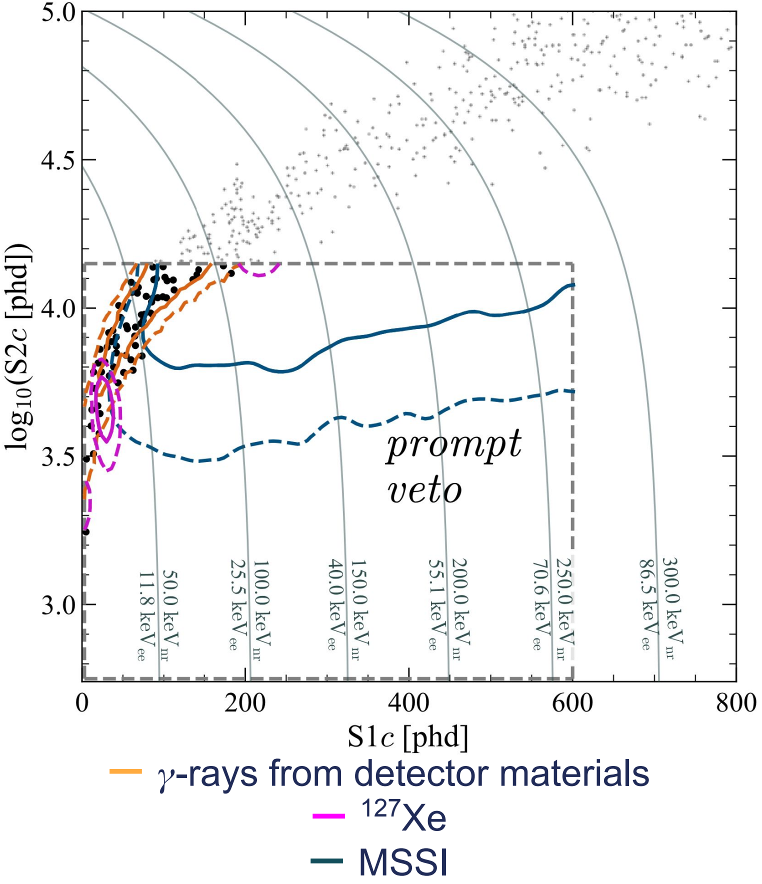
Background model components:

- **γ-rays from detector materials**
  - Activities from radioassay
- **^{214}Pb β^- → ^{214}Bi γ-ray**
  - Has γ-rays 87% of the time

Expectation

- 0.005 ± 0.005 counts in science sample.
- **~90% prompt veto efficiency**

Prompt veto tagged sample



Background Fit

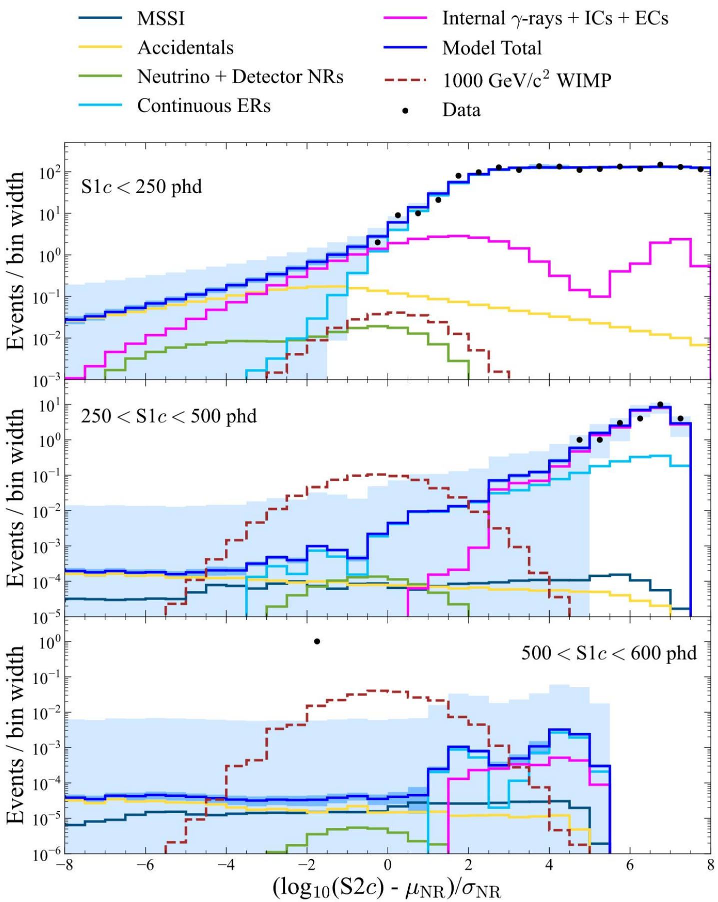
- ❑ Science, Prompt & Delayed tagged samples fit simultaneously
- ❑ Integral of 500 < S1c < 600 phd
  - ❑ **Model: 0.0106 ± 0.0008 (sys) counts**
  - ❑ **Data: 1 event, LZ230616**

Statistical Inference

- ❑ Profile likelihood ratio to test compatibility between signal and background-only hypotheses
- ❑ A **subset of models** have a background-only rejection significance of up to 3.4σ
  - ❑ **Best fit number of WIMPs of 1 ± 1.4**

Global Significance

- ❑ Look elsewhere effect significance correction
  - ❑ Required as testing many signal models
- ❑ **Global p-value 2.6σ**
- ❑ **Tension with background-only hypothesis**



1D Representation of Background Fit

High Energy Nuclear Recoil Search - Result

Background Fit

- Science, Prompt & Delayed tagged samples fit simultaneously
- Integral of 500 < S1c < 600 phd
  - **Model: 0.0106 ± 0.0008 (sys) counts**
  - **Data: 1 event, LZ230616**

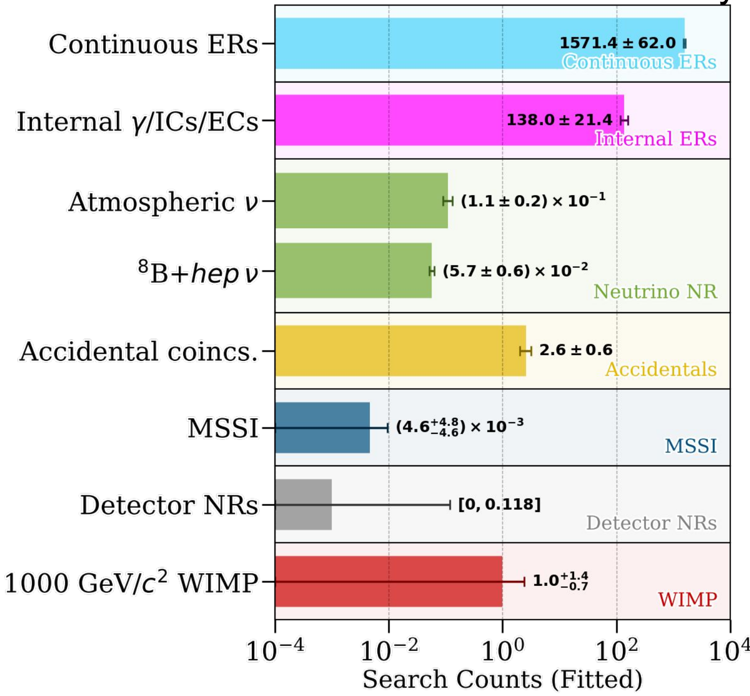
Statistical Inference

- Profile likelihood ratio to test compatibility between signal and background-only hypotheses
- A **subset of models** have a background-only rejection significance of up to 3.4σ
  - **Best fit number of WIMPs of 1 ± 1.4**

Global Significance

- Look elsewhere effect significance correction
  - Required as testing many signal models
- **Global p-value 2.6σ**
- **Tension with background-only hypothesis**

LZ Preliminary

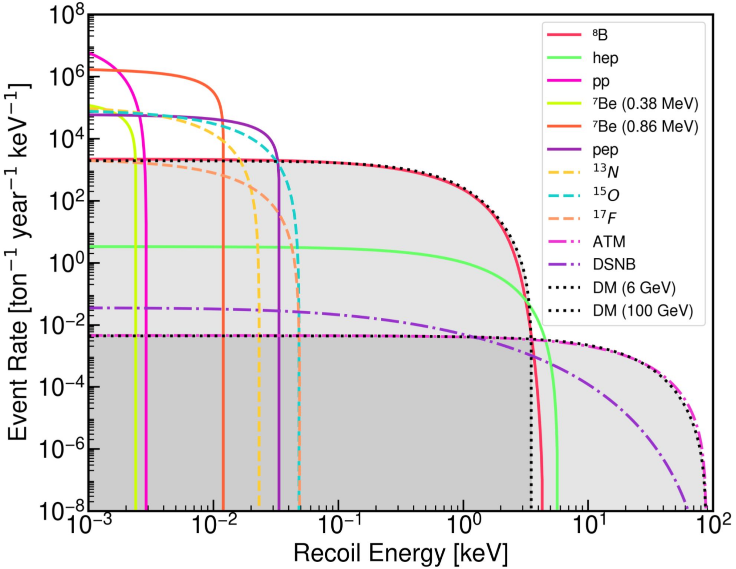


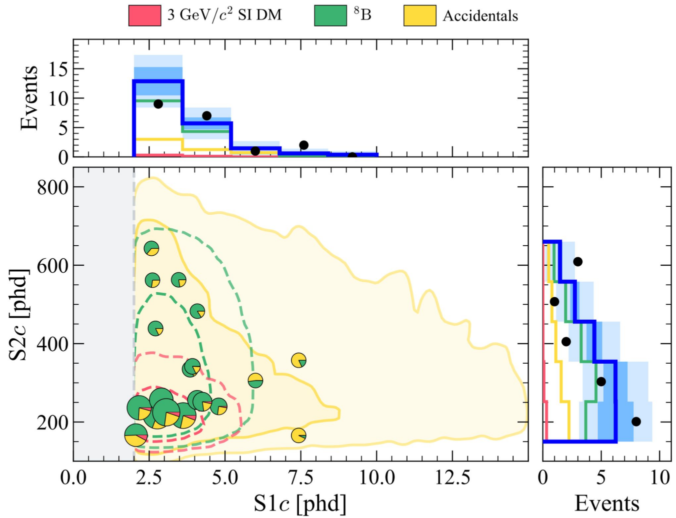
Background Fit Values

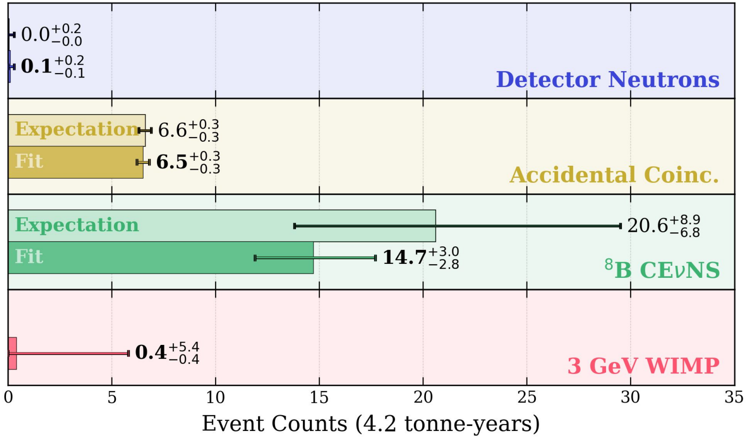
Light Dark Matter Search 2025 - CEνNS

https://arxiv.org/pdf/2512.19784

Expected neutrino nuclear recoil spectra

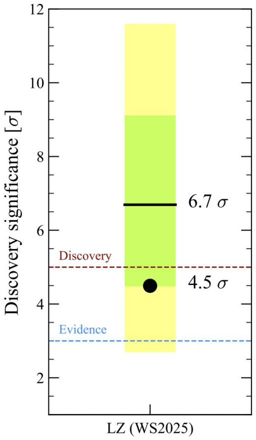


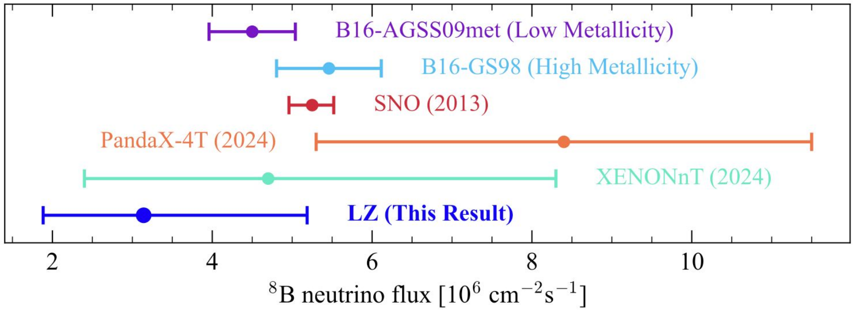


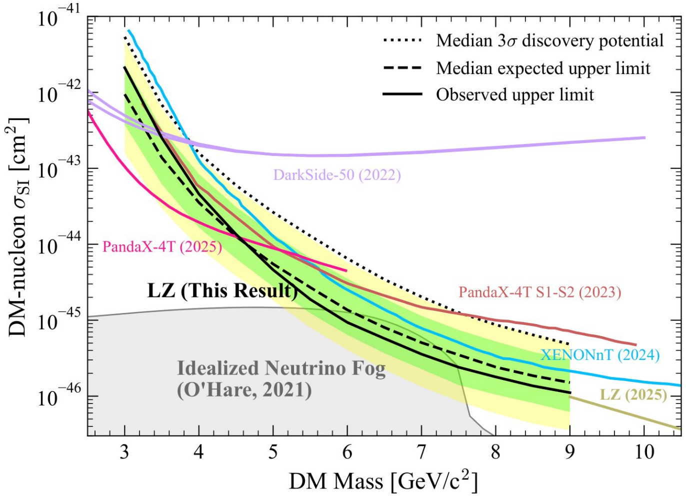


- Search for 3-9 GeV/c^2 WIMPs
  - Lower energy region of interest: ~1-6 keV$_{nr}$
- Largest background ^{8}B solar neutrinos
  - CEνNS

Light Dark Matter Search 2025 - CEνNS



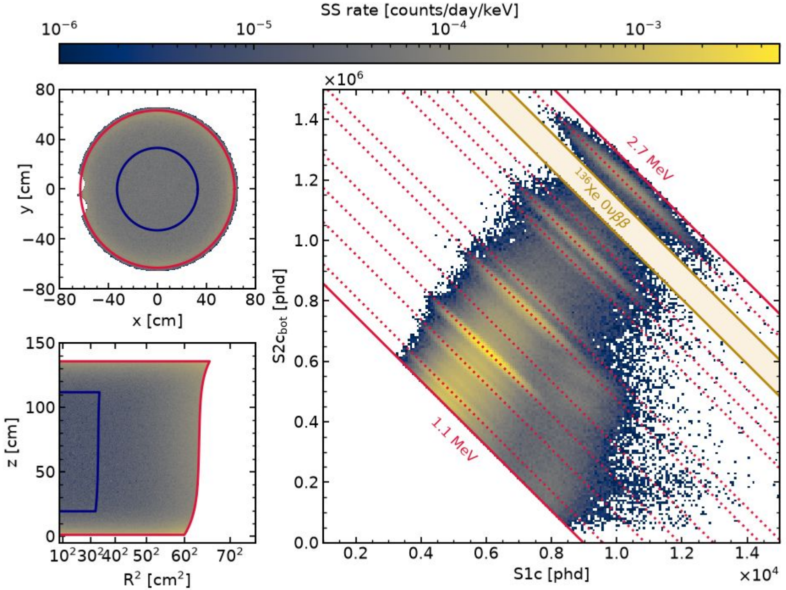




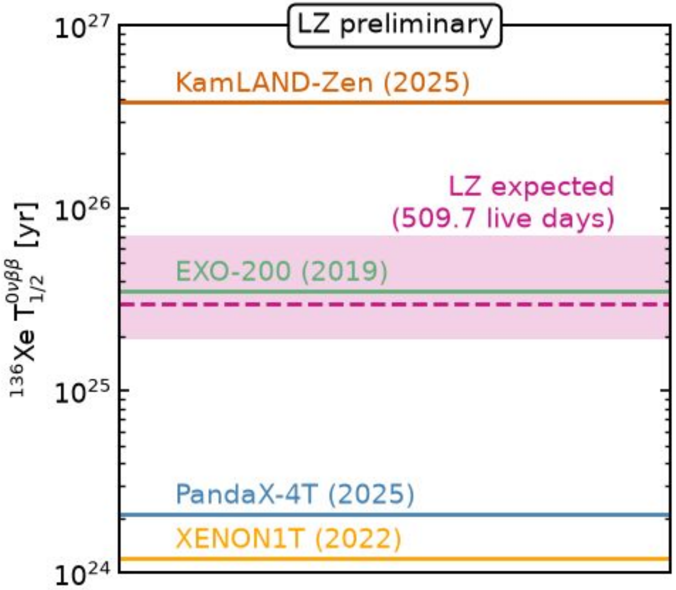
- 4.5σ discovery significance for ^{8}B CEνNS in LXe
- Flux in agreement with neutrino background predictions
- World leading sensitivity to WIMPs 5 GeV/c^2 - 9 GeV/c^2

Search for $0\nu\beta\beta$ with ^{136}Xe - Event Selection

^{136}Xe $0\nu\beta\beta$ Volumes and Extended Region of Interest



^{136}Xe $0\nu\beta\beta$ Expected Sensitivity



- Soon to be released ^{136}Xe $0\nu\beta\beta$ analysis
  - Energy only statistical inference
- Inner volume
  - Low background expectation
  - Excellent energy resolution - 0.66% $Q_{\beta\beta}$
- Competitive limit without ^{136}Xe enrichment
  - Natural ^{136}Xe abundance ~9%

Summary

WIMP Search 2024 - Phys. Rev. Lett. 135, 011802

- Region of interest ~5-55 keV_{nr}
- World leading sensitivity to WIMP-nucleon cross-section
  - (9 GeV/c^2 - 10 TeV/c^2) WIMP masses

High Energy Nuclear Recoil Search 2024 - arXiv:2609.02823

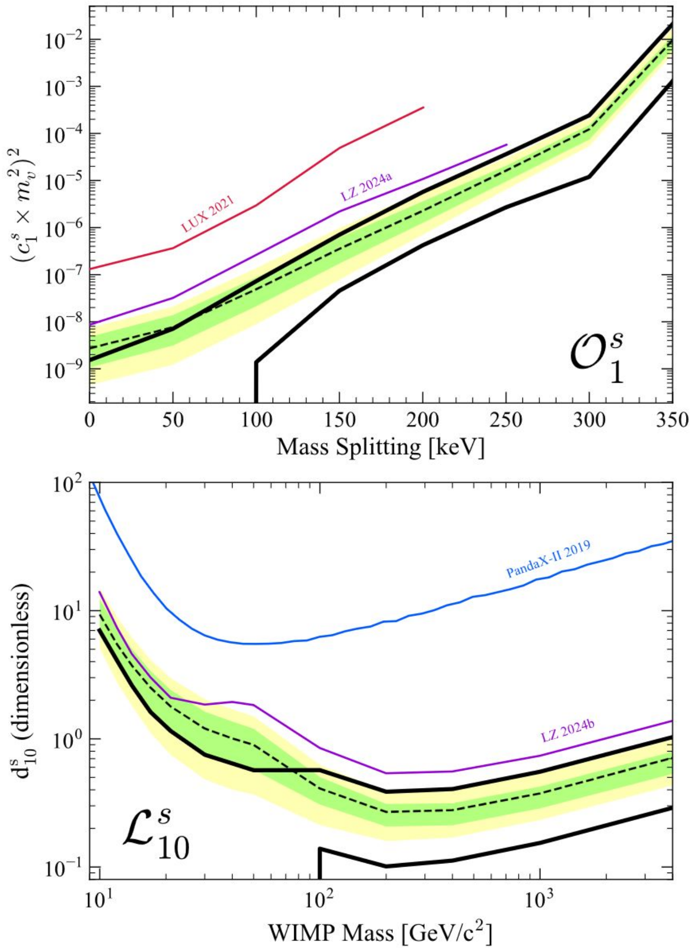
- Region of interest ~5-270 keV_{nr} with 220 livedays
- 16 June 2023 (LZ230616) - 248 ± 23stat ± 23sys keV_{nr}
- Background-only hypothesis rejected global p-value 2.6σ

Light Dark Matter Search 2025 - Phys. Rev. Lett. 137, 091806

- Lower energy region of interest: ~1-6 keV_{nr}
- World leading sensitivity to WIMPs 5 GeV/c^2 - 9 GeV/c^2
- 4.5σ discovery significance for ^{8}B CEνNS in LXe

Upcoming ^{136}Xe $0\nu\beta\beta$ Search - A. Musalhi – TeVPA 2026

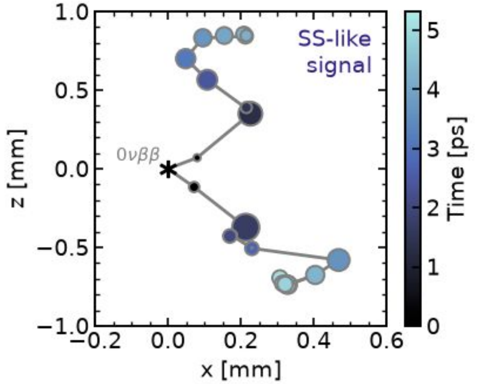
- 510 liveday search
- Competitive limit
  - ~3.0 × 10^{25} years half-life

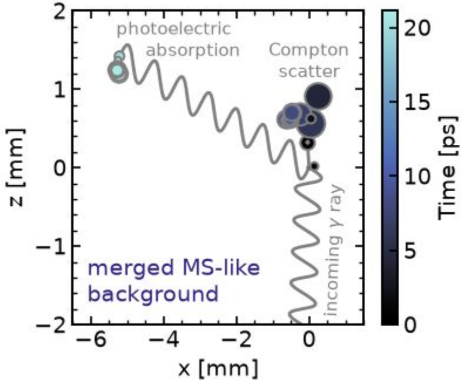


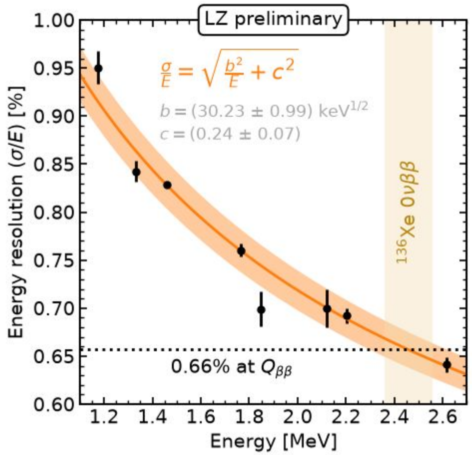
HENR2024 two-sided interaction limits

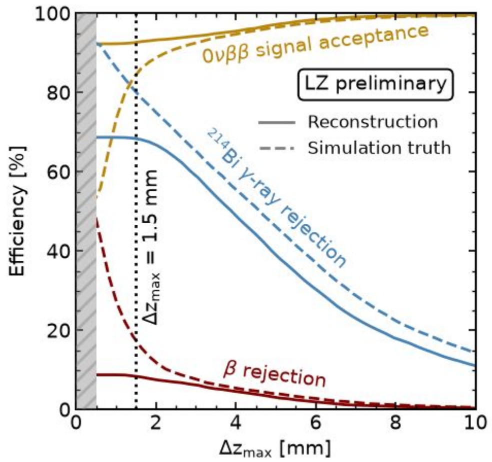
Backup for $0\nu\beta\beta$ with 136Xe

Search for $0\nu\beta\beta$ with ^{136}Xe - Resolution

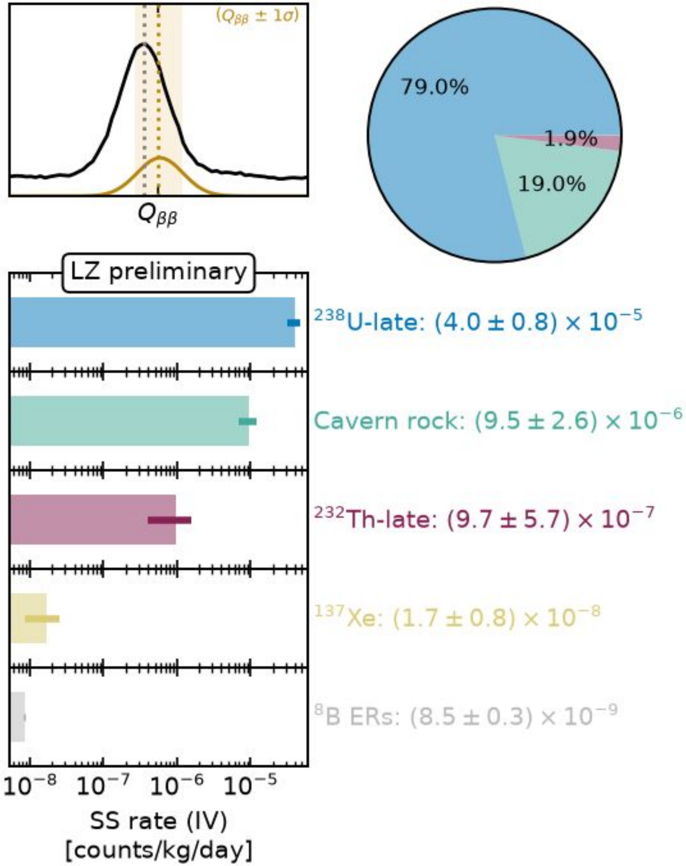




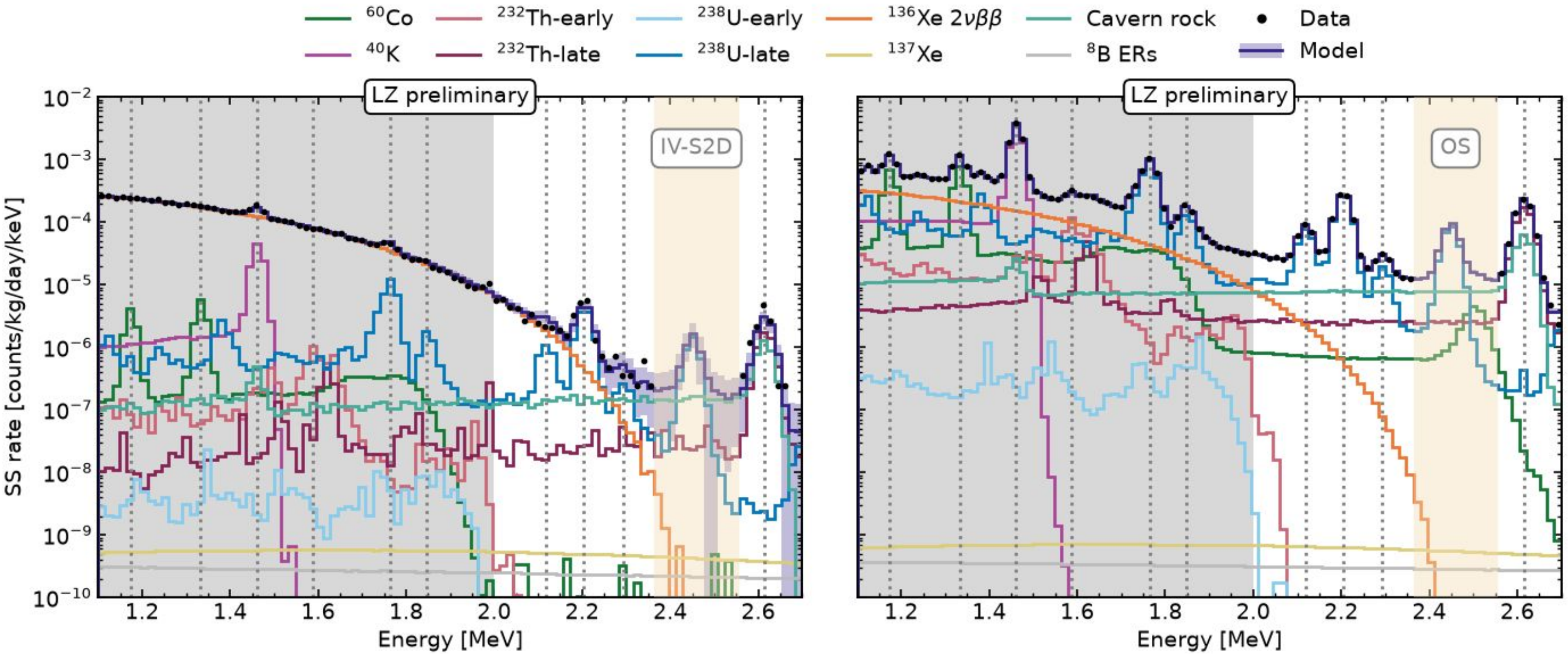




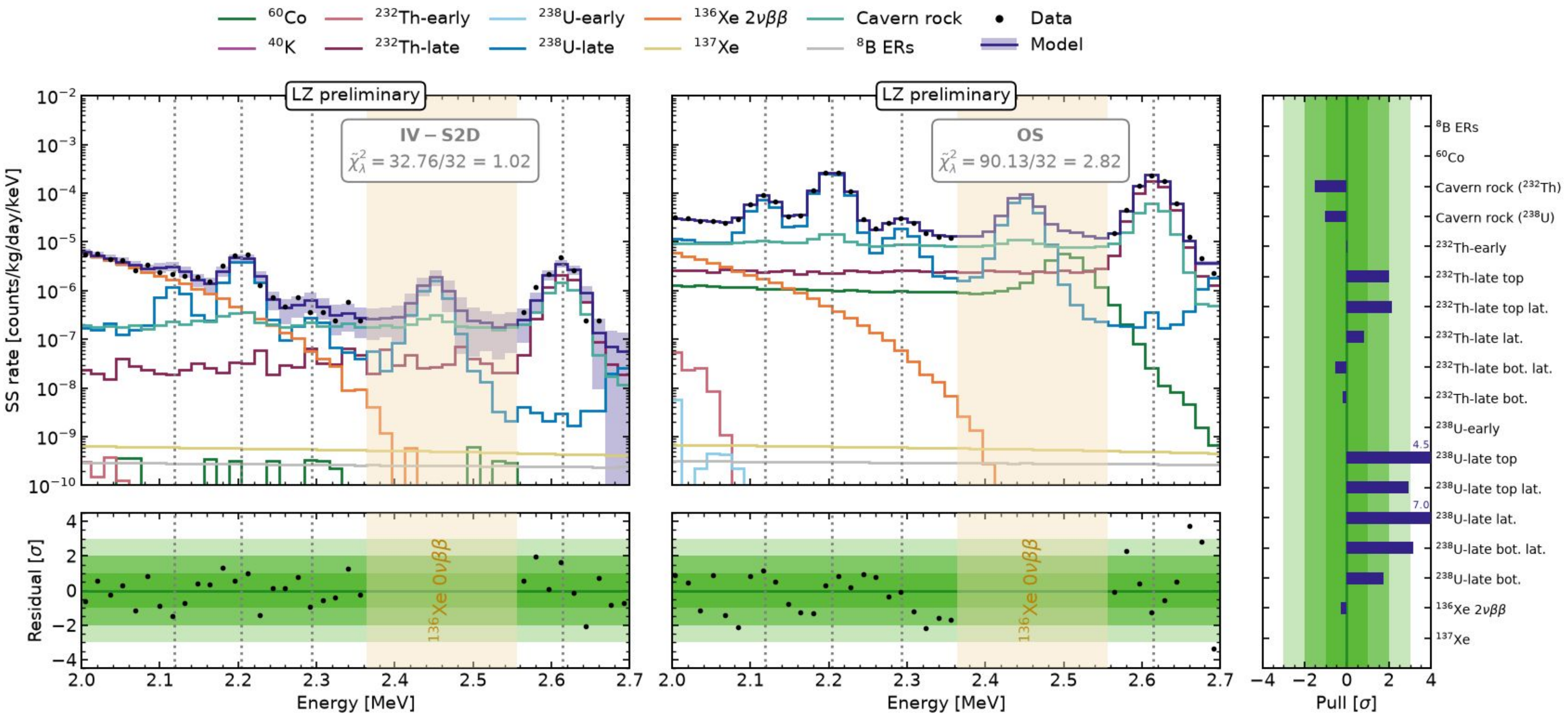
Search for $0\nu\beta\beta$ with ^{136}Xe - Backgrounds



Search for $0\nu\beta\beta$ with ^{136}Xe - Fit



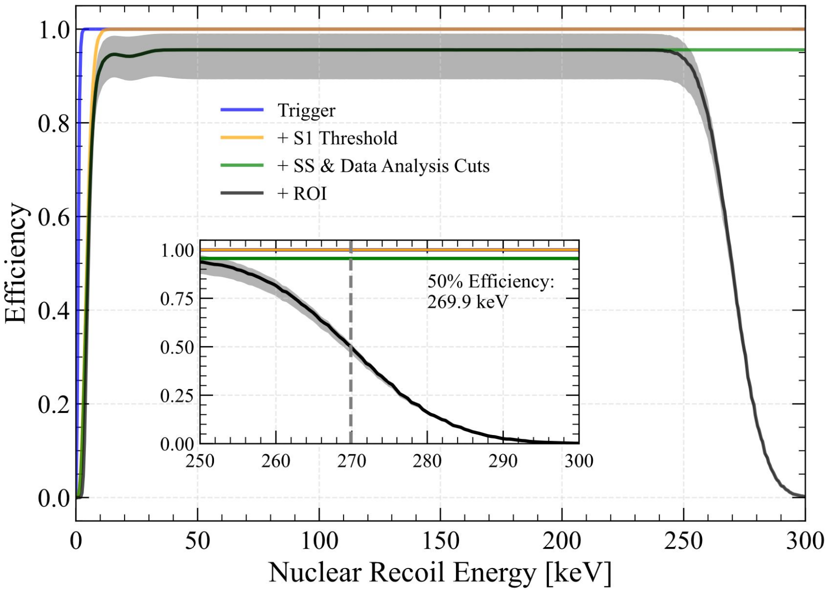
Search for $0\nu\beta\beta$ with ^{136}Xe - Result



Backup HENR2024

High Energy Nuclear Recoil Search - Signal Efficiency

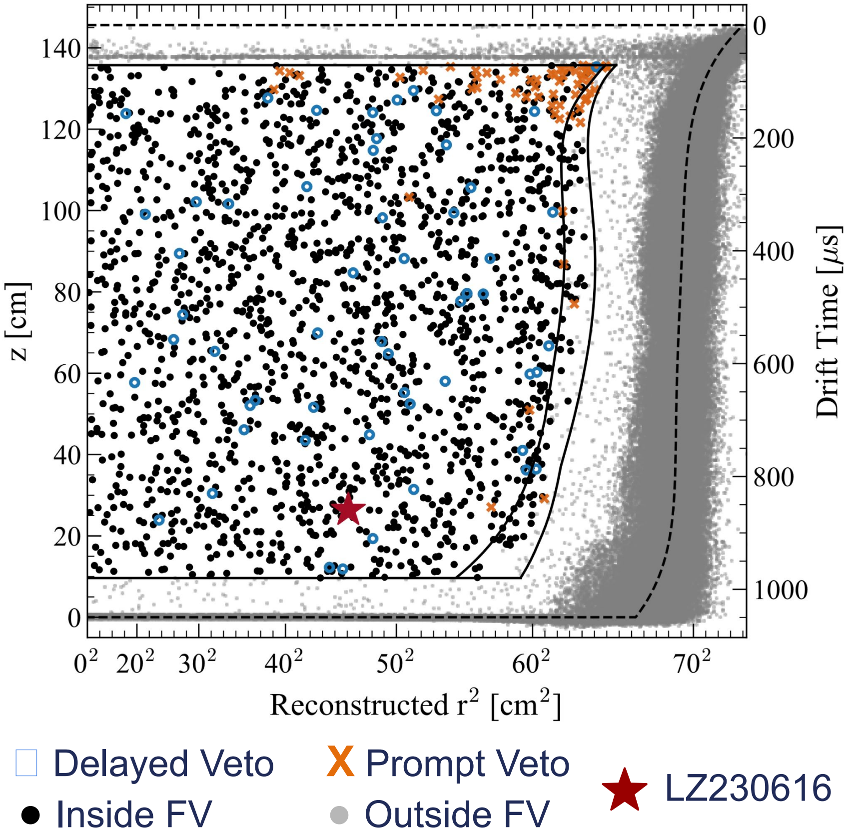
Signal Efficiency for HENR2024



- ❑ Single scatter - one interaction site
- ❑ Region of interest (ROI)
  - ❑ 3 < S1c < 600 photons detected (phd)
  - ❑ S2 > 14.5 electrons (645 phd)
  - ❑ $\log_{10}(S2c) < 10^{4.15}$
- ❑ ~5 keV < Nuclear Recoil Energy < ~270 keV
- ❑ Exclusions
  - ❑ High Rate Periods
  - ❑ Detector Instability
- ❑ Cuts on S1 & S2 parameters to remove accidentals
  - ❑ Acceptance evaluated on calibration data

High Energy Nuclear Recoil Search - Fiducial Volume

Fiducial Volume for HENR2024



Fiducial Volume Definition:

- Fiducial volume: azimuthally & drift time-dependent
  - < 10^{-4} charge loss ("wall") events
- **∼10cm of LXe away from charge insensitive regions**
  - Reverse Field Region (RFR) below the cathode
  - LXe adjacent to the TPC wall
- 4 mean free paths for ^{214}Pb 352 keV γ-ray

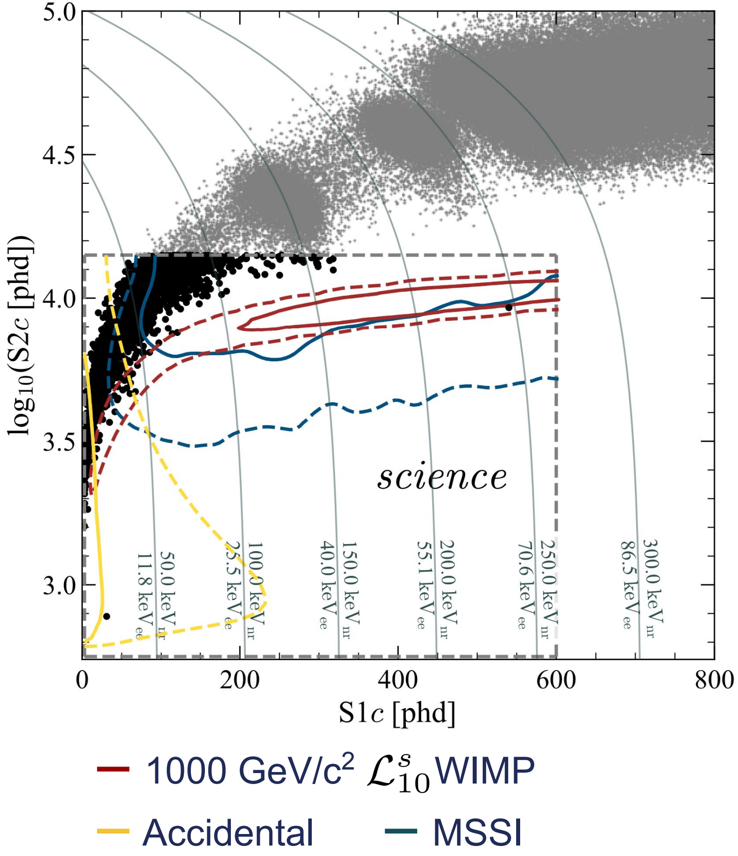
Anti-coincidence Vetoes:

- Skin & Outer Detector
  - **Prompt Veto:** ∼90% veto efficiency of γ-ray
    - Validated against Xe127 decays
  - **Delayed Veto:**∼90% veto efficiency of neutrons
    - Neutron capture up to 600us after S1
    - ∼3% false veto rate (deadtime)

Analysis Volume:

- Mass: 4.7 ± 0.2 tonnes
- **Exposure: 2.8 ± 0.1 tonne-years**

Data Selection for HENR2024

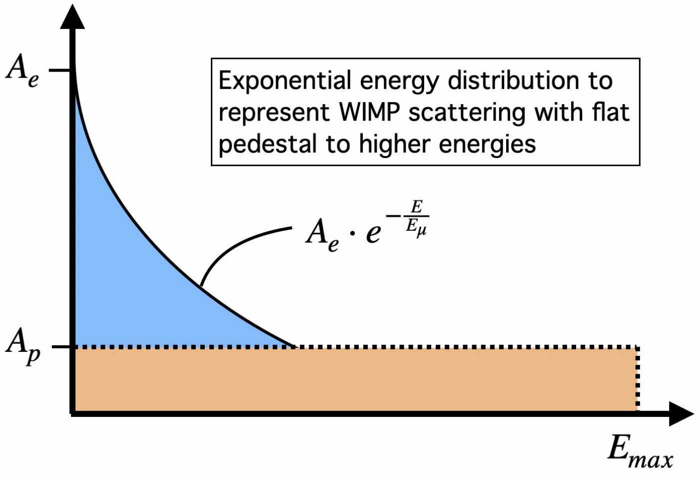


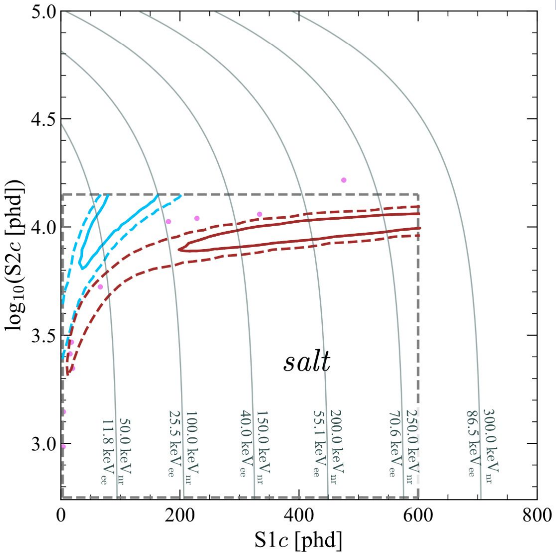
Electronic Recoil

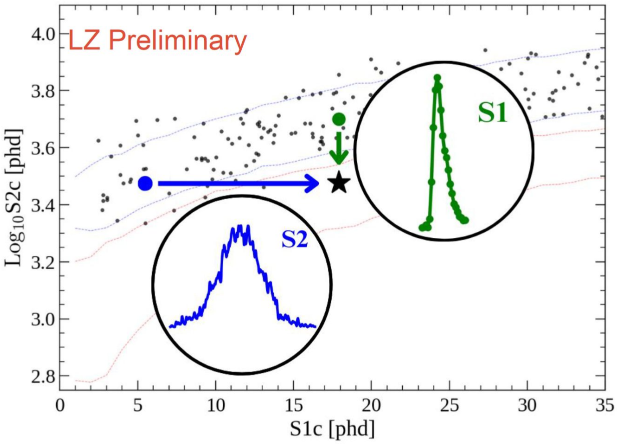
- Dissolved β emitters:
  - ^{214}Pb (^{222}Rn), ^{212}Pb (^{220}Rn), ^{85}Kr, ^{136}Xe (ββ)
- Dissolved EC decays (x-rays/Auger electrons)
  - ^{127}Xe, ^{125}Xe, ^{125}I produced by activation from neutron calibration
  - ^{124}Xe (double EC), 0.095% natural abundance
- Solar ν's: pp+^{7}Be+CNO (ER)
- Detector ER, γ emitters from detector materials
  - ^{238}U, ^{232}Th, ^{40}K, ^{60}Co decay chains

Bias Mitigation

- "Salting" - fake signal injected randomly
- Manufactured from sequestered ER & NR calibration data
- Unknown number of salt events
  - Rate capped by WS2022 cross-section limit
- Exponential WIMP recoil spectrum
  - + flat energy spectrum to cover high energy NR

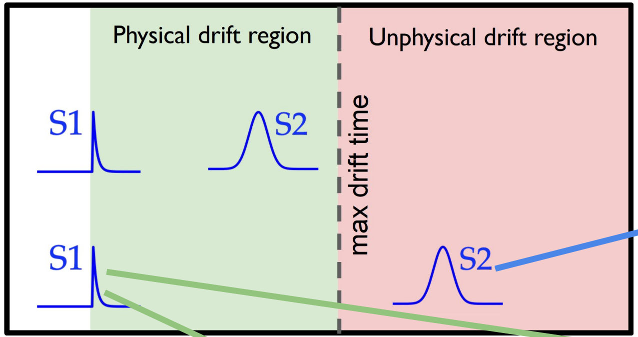




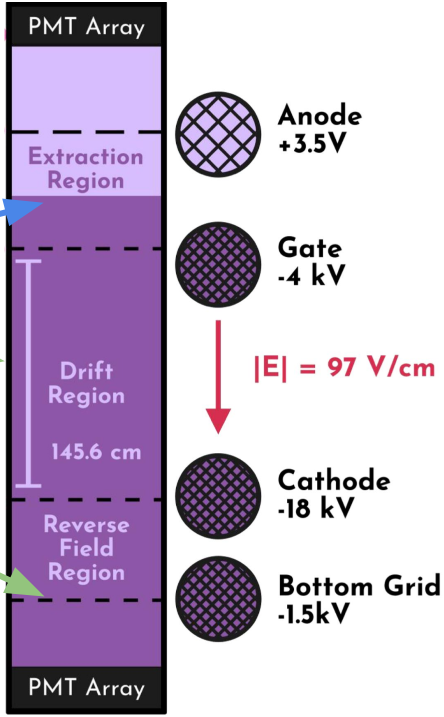


High Energy Nuclear Recoil Search - Accidentals

- Accidental (random) coincidence of uncorrelated isolated S1 and S2 pulses



Accidentals Cartoon



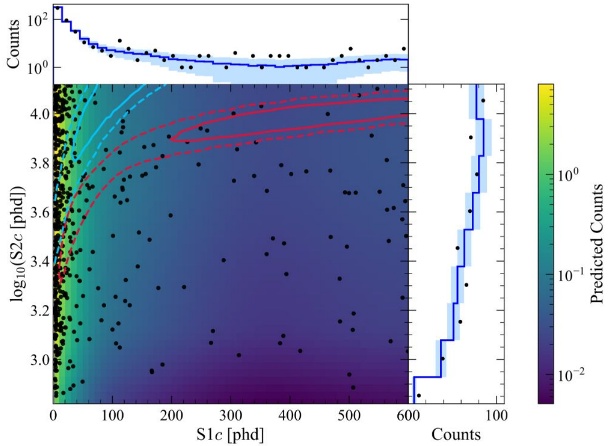
- LZ's accidentals model:
  - **Rate:** Measure rate of unphysical drift time (UDT) single scatters. Analysis cut efficiencies analysed using manufactured accidental events.
  - **Shape:** Manufactured by combining isolated S1 and S2 waveforms and applying analysis cut efficiencies.
    - High statistics manufacture dataset - chopstitch
- Analysis cuts have an 99.5% rejection power

High Energy Nuclear Recoil Search - Accidentals

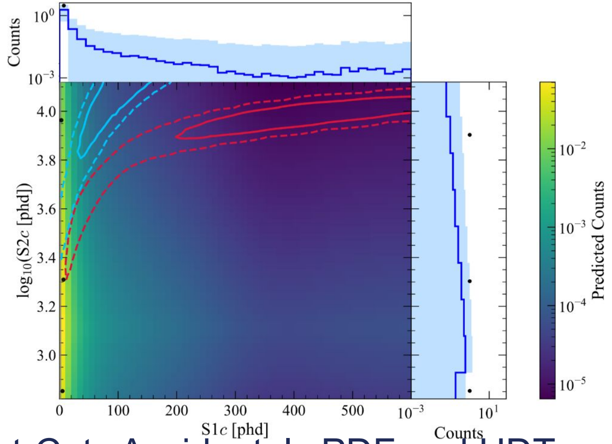
- ❑ Accidental coincidence of uncorrelated isolated S1 and S2 pulses

- ❑ LZ's accidentals model:
  - ❑ **Shape:** Manufactured by combining isolated S1 and S2 waveforms and applying analysis cut efficiencies.
  - ❑ **Rate:** Measure rate of unphysical drift time (UDT) single scatters. Analysis cut efficiencies analysed using manufactured accidental events.

- ❑ Analysis cuts have an 99.5% rejection power



Pre-Cuts Accidentals PDF and UDTs



Post-Cuts Accidentals PDF and UDTs

High Energy Nuclear Recoil Search - MSSI Definition

Multiple Scatter Single Ionisation (MSSI)

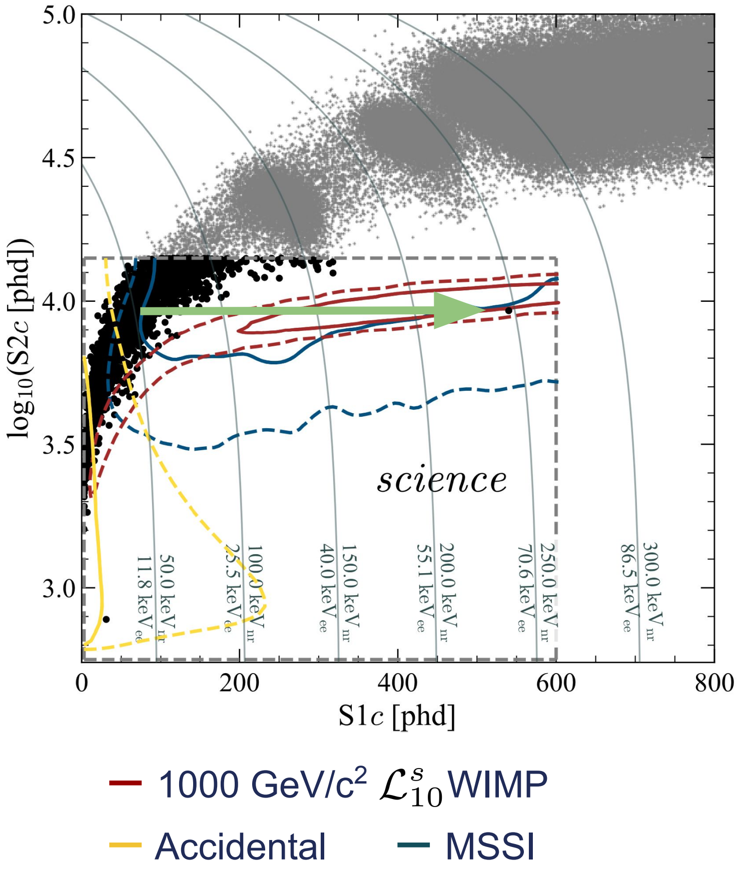
- ❑ Instrumental Background
  - ❑ Scatter inside Fiducial Volume and a scatter in a charge insensitive region
- ❑ Results in a combined S1, and one S2

Charge insensitive regions

- ❑ S2 isn't drifted to the extraction region
- ❑ Reverse field region below the cathode: 13.75cm tall
- ❑ Near TPC wall: ~3mm around field rings

S1 enhancement

- ❑ To create an event similar to LZ230616
- ❑ S2 is consistent with a 12 ± 2 keV ER
- ❑ Additional S1 from a charge insensitive region, either:
  - ❑ 78 keV ± 7 keV ER near the wall
  - ❑ 204 ± 50 keV ER in the RFR



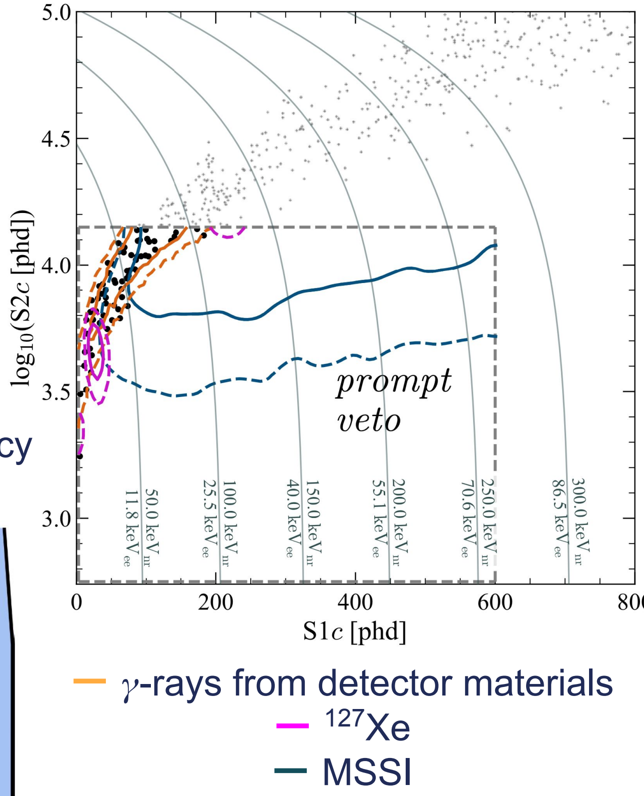
High Energy Nuclear Recoil Search - MSSI Modelling

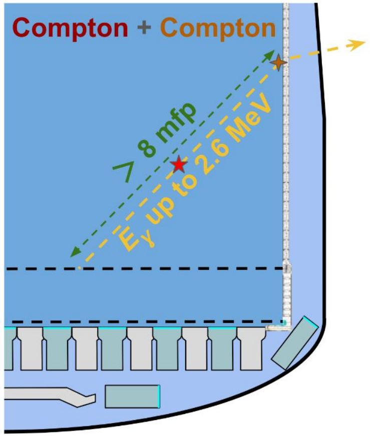
Background model components:

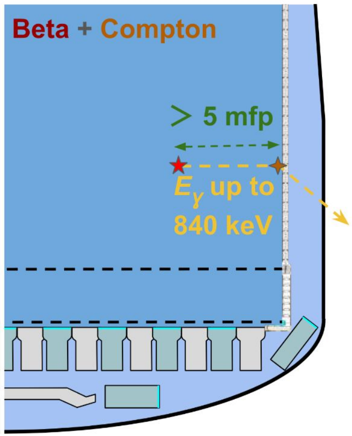
- ❑ γ-rays from detector materials
  - ❑ Activities from radioassay
- ❑ ^{214}Pb β^- → ^{214}Bi γ-ray
  - ❑ Has γ-rays 87% of the time
  - ❑ ^{214}Pb β^- activity constrained by ^{218}Po & ^{214}Po α activities

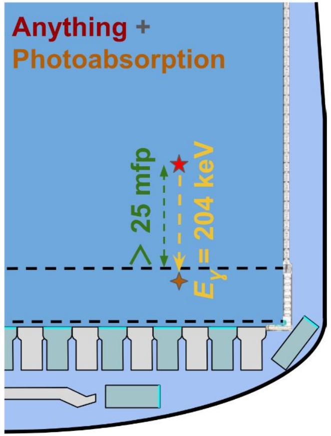
Expectation

- ❑ Suppressed by FV volume choice
- ❑ 0.005 ± 0.005 counts in science sample. ~90% prompt veto efficiency









High Energy Nuclear Recoil Search - Neutrons

Calibration:

- ❑ Single scatter neutron veto efficiency: 92 ± 4 %
  - ❑ Delayed neutron capture on Gd and H in Outer Detector
  - ❑ Also can tag prompt gammas and neutron thermalisation

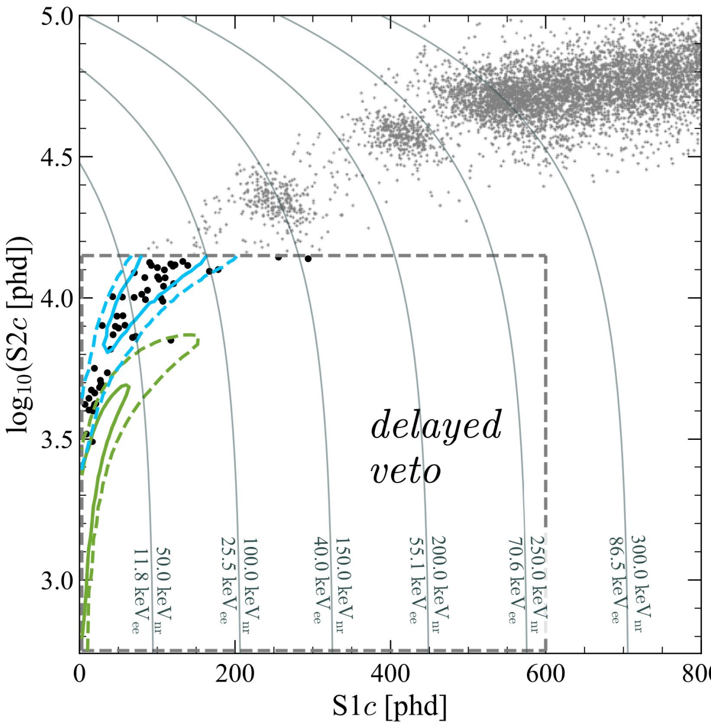
Background Model:

- ❑ (α, n) and uranium spontaneous fission (USF) simulations
  - ❑ Based on radioassay
- ❑ USF single scatters suppressed due to resulting n & γ multiplicity
- ❑ (α, n) kinetic energy predominantly low kinetic energies

Sidebands:

- ❑ To produce an 250 keV$_{nr}$ a neutron would require 8 MeV KE
- ❑ Fit of the delayed veto sample gives a result of [0-1.3] neutrons
- ❑ Multiple scatter analysis also consistent with background model
  - ❑ Both consistent with radioassay predictions

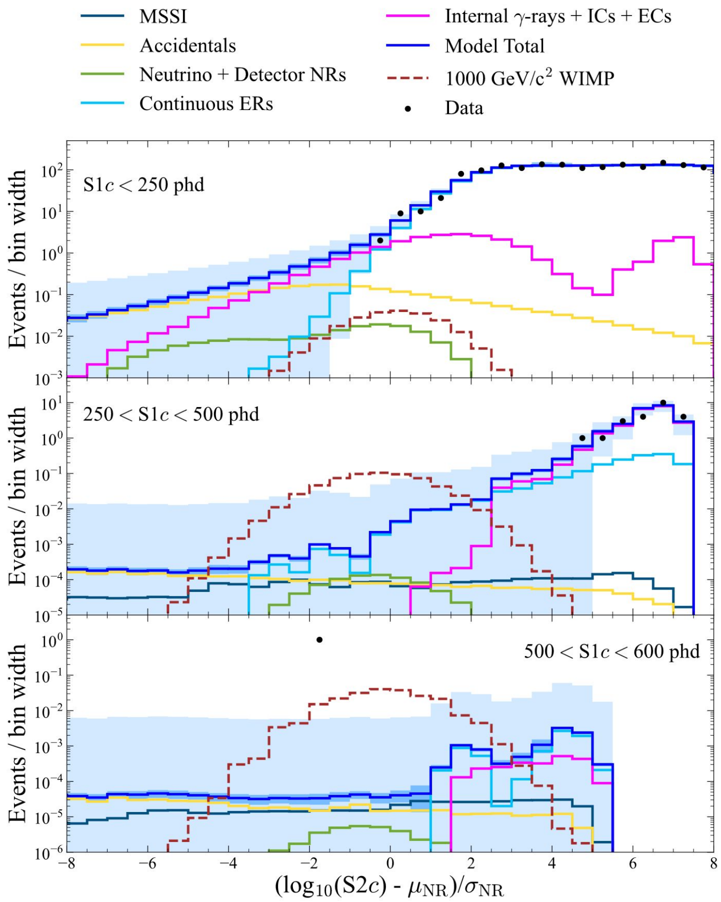
Delayed veto tagged sample



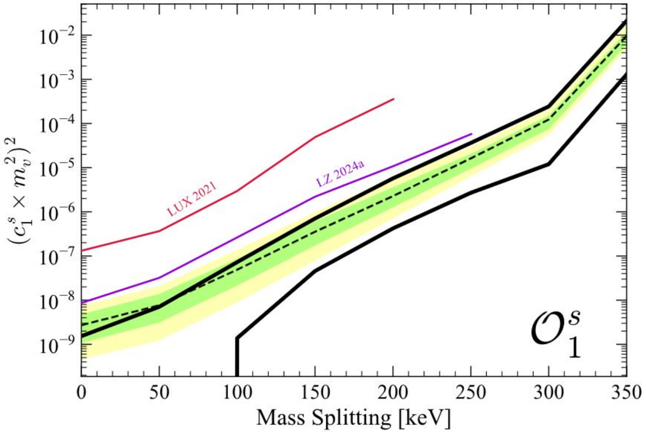
Combined ER background
Combined NR background

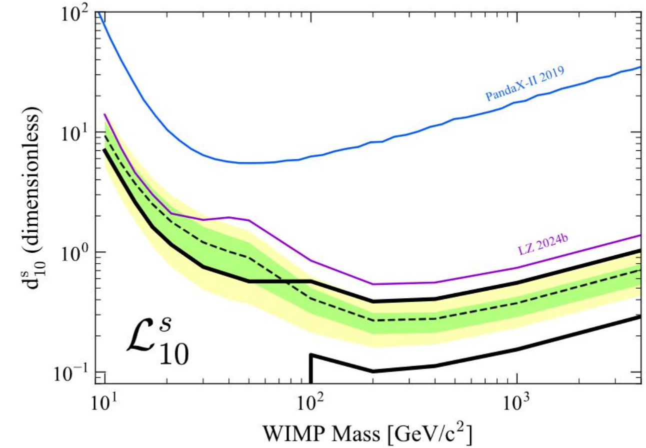
High Energy Nuclear Recoil Search - Result

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

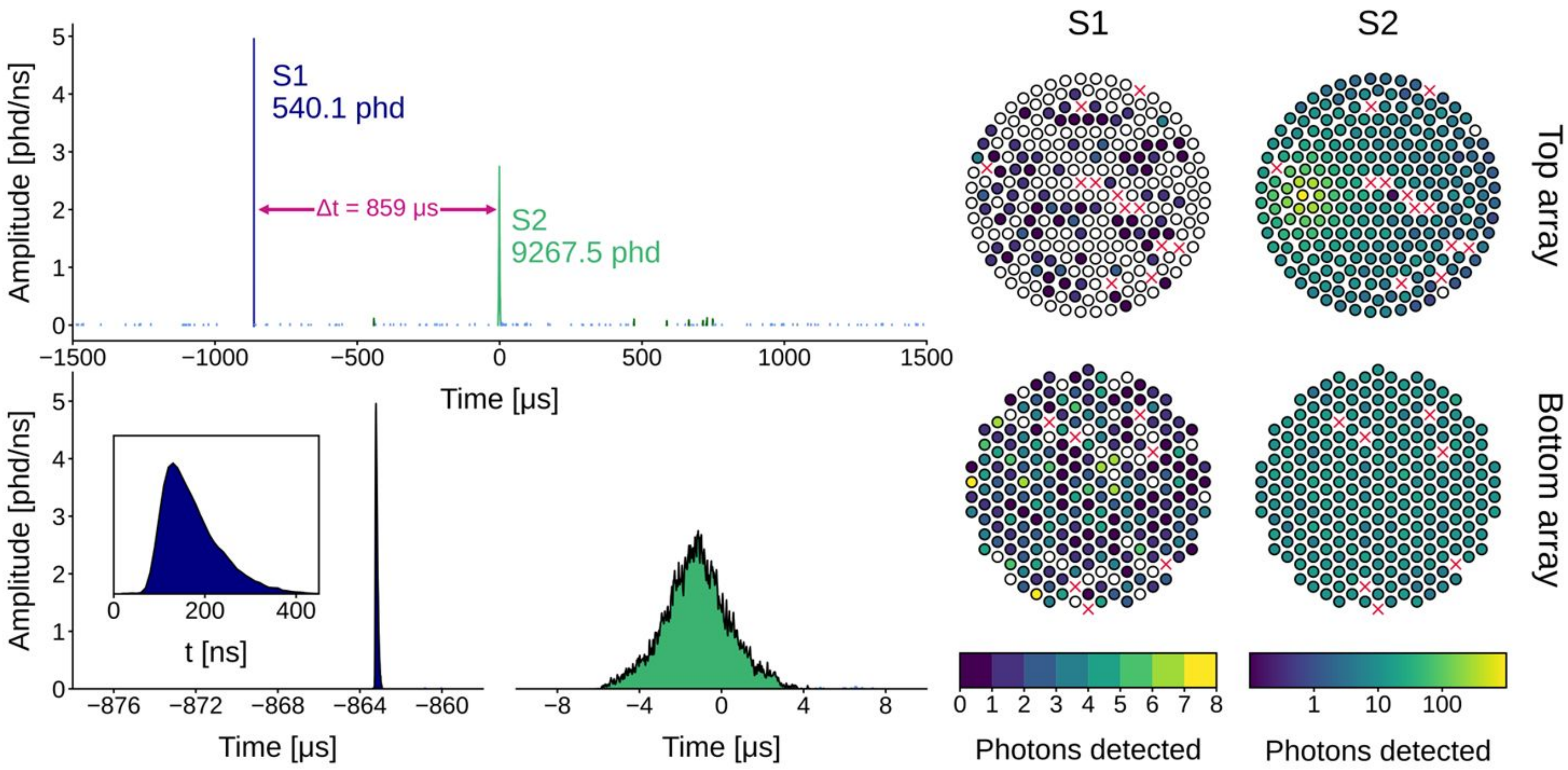


High Energy Nuclear Recoil Search - Limit





High Energy Nuclear Recoil Search - Waveform



High Energy Nuclear Recoil Search - Date of Event

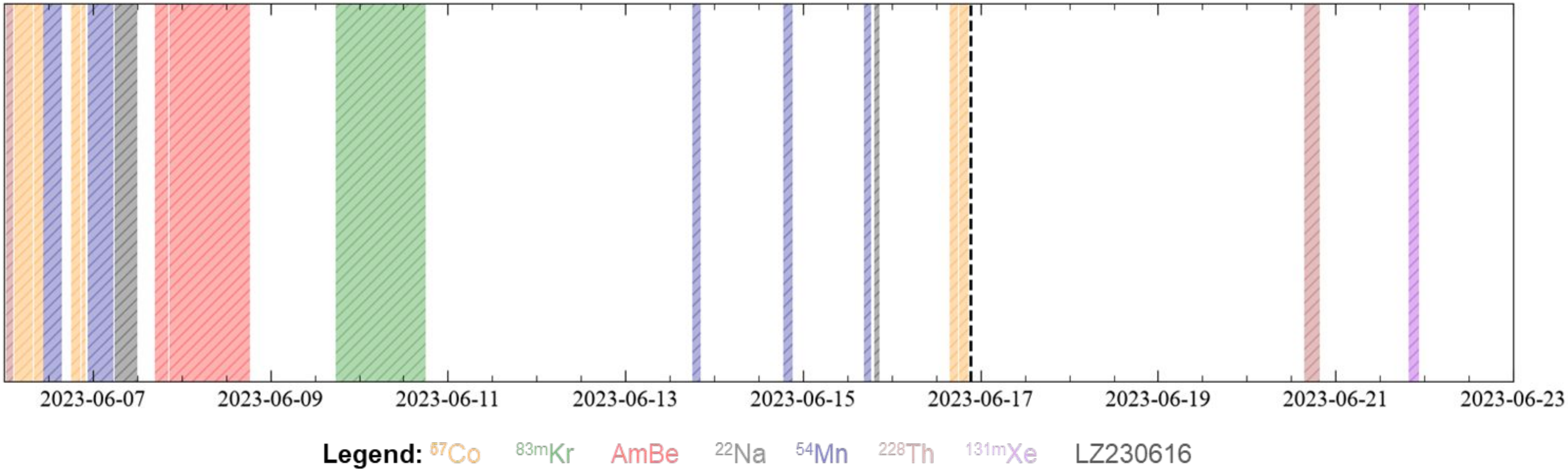
Previous calibrations in source deployment tubes:

57Co removed 25 mins earlier

- not a concern as occurred on opposite side of detector
- 57Co are low energy γ-rays used for calibrating the Skin and OD.

AmBe on 8 June 2023

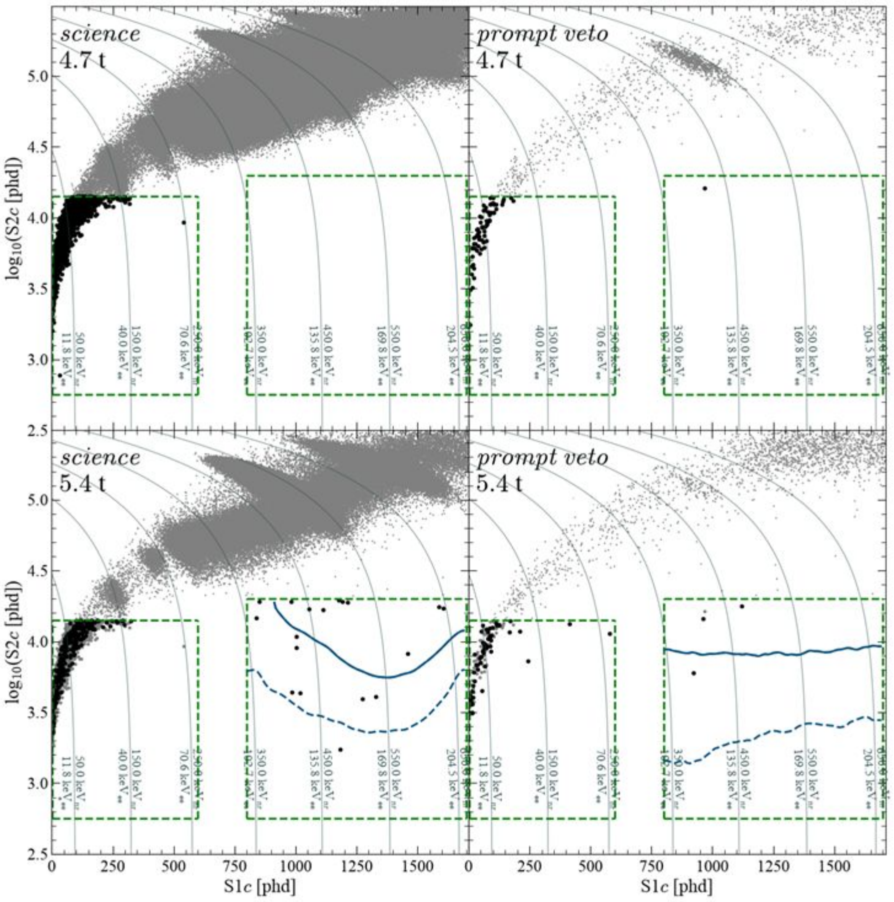
- one week before



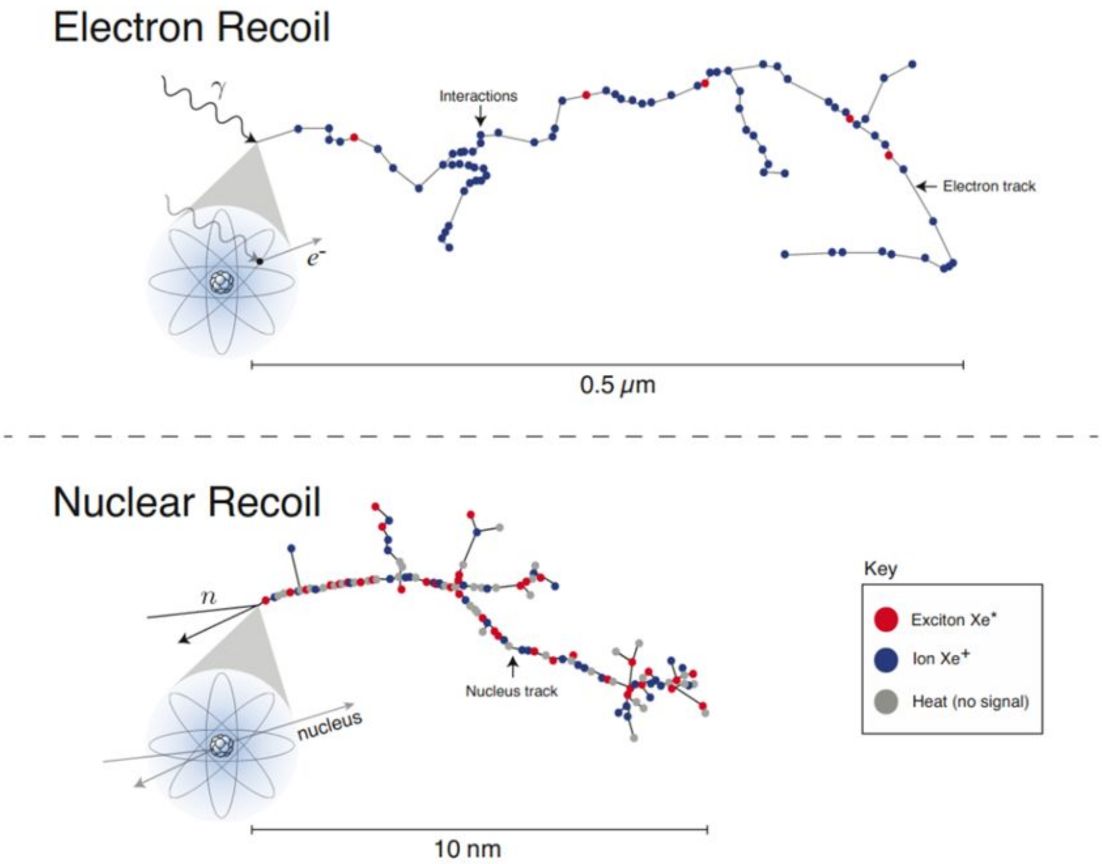
High Energy Nuclear Recoil Search - MSSI

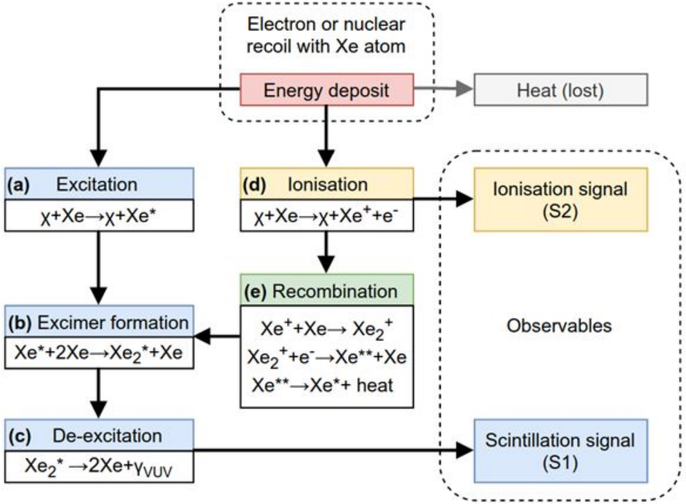
- MSSI model
  - **Rate:** Derived from simulations. Validated in higher energy region
  - **Shape:** Validated in looking at high energy region and closer to charge dead regions

- Expectation
  - FV aggressively removes MSSI events
  - **0.0049 ± 0.0049** in science sample
  - **94 ± 2%** prompt tagging efficiency



High Energy Nuclear Recoil Search - Observables





High Energy Nuclear Recoil Search - CRM

- Muons cascades can produce neutrons
  - Neutrons can be O(GeV) in energy
  - Likely aligned with muon direction
  - Accompanied by other products

- If a muon enters any of the detectors, it is observed, and the event is removed. It is only a dangerous background if
  - The neutron is the only particle to enter any detector system
  - Simulations of mono-energetic neutrons (50 MeV – 1GeV) indicate **80 $\pm$ 4%** tagging efficiency.

Contribution evaluated through simulation

- MUSUN generated distribution [1]
- 1200 years of LZ exposure simulated with no signal-like deposits
- Validated against Geant4 + FLUKA sims [2,3]
- Normalised to flux: 5.09 ($\pm$ 0.08$_{\text{stat.}}$ $\pm$ 0.10$_{\text{sys.}}$) $\times 10^{-9}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$ [4]

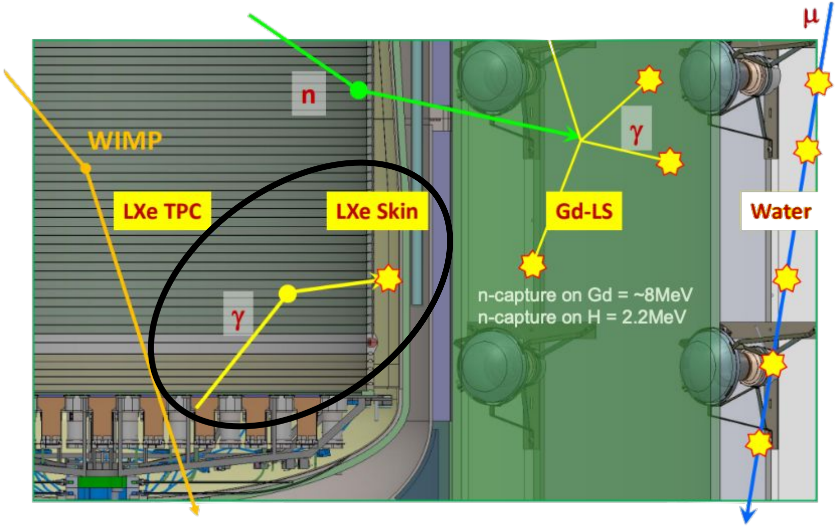
90% confidence level upper limit of $\mathbf{4.6 \times 10^{-4}}$

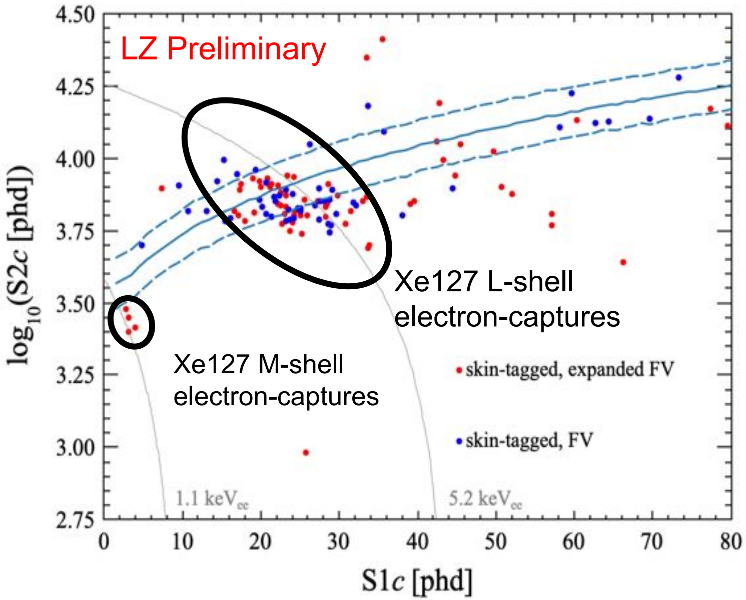
Selection	#
μ generated	2.1×10^9
+ n in Lxe	5.6×10^5
+ SS	230
+ in FV	19
+ in ROI	0

[1] Com. Phys. Comms 180 (2009)
[2] Nucl.Instrum.Meth. A545 (2005) 398-411
[3] arXiv:2310.16586
[4] arXiv:2602.16799

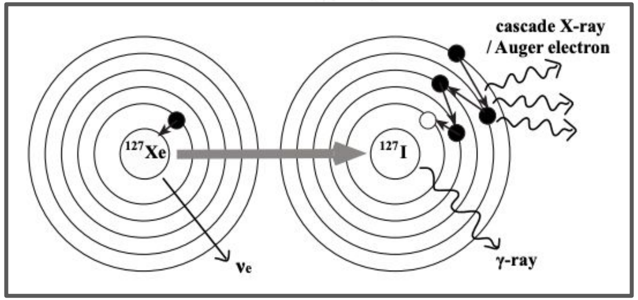
Backup WS2024

LXe Skin



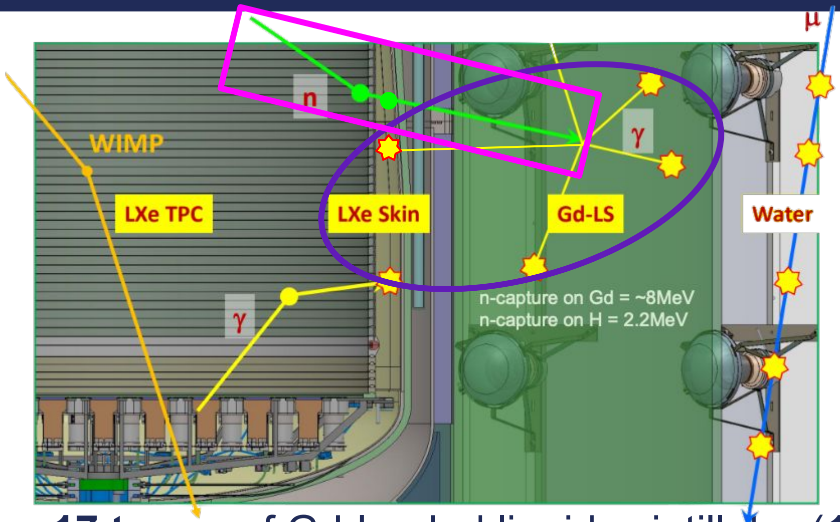


- **2 tonne** of LXe surrounding the TPC
- 131 1” or 2” PMTs
- Anti-coincidence veto for **γ-rays** with **~90% efficiency**
- Reduction of important ER background rates
  - E.g. ^{127}Xe decay via electron capture



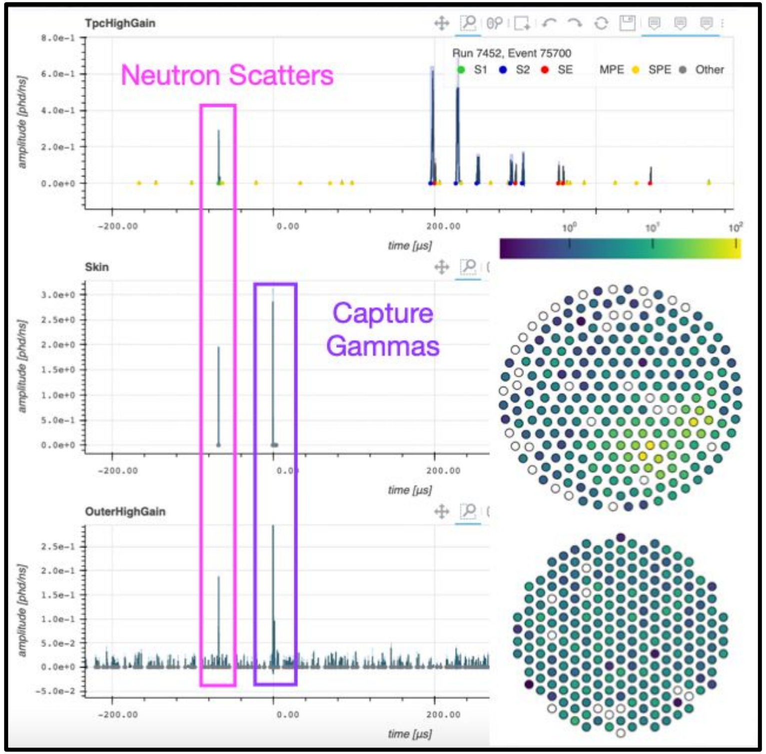
Courtesy of Jack Bargemann APS April 2023

Outer Detector



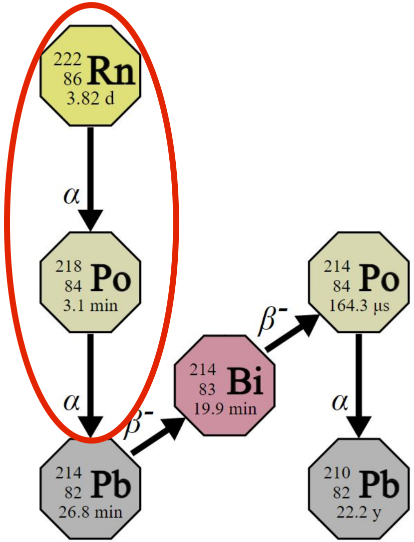
- **17 tonne** of Gd-loaded liquid scintillator (120 8" PMTs)
- Infinite volume of Gd-LS has a 30us capture time for a thermal neutron
- LZ has ~90% Single Scatter neutron veto efficiency
- ~50Hz of background above 100-200 keV threshold
  - Gd alphas, ^{14}C betas

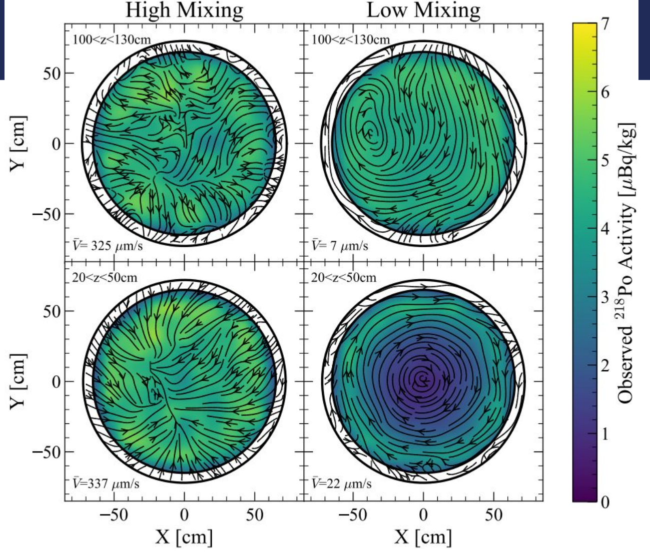
Waveform example of a tagged neutron multiple scatter:

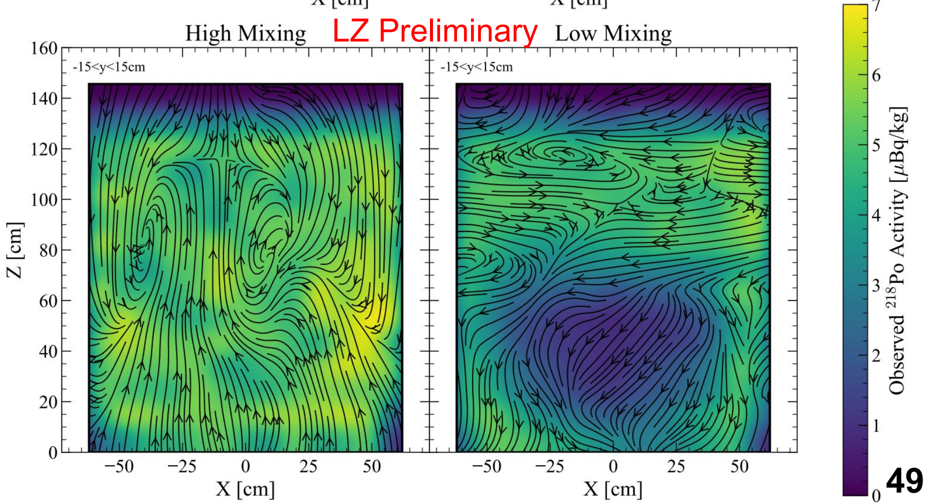


Liquid Xenon Flow

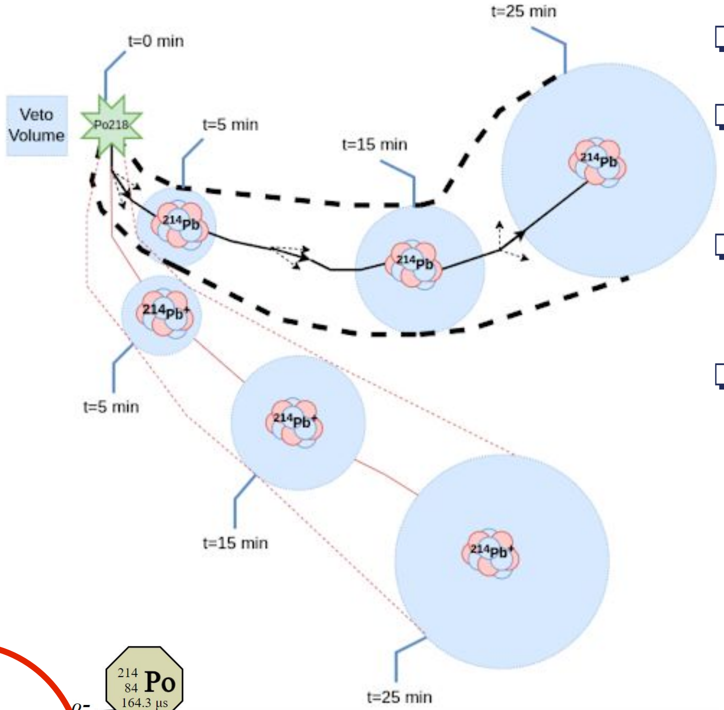
- Fine control of LXe circulation and temperature allows control of LXe flow state
- **High-mixing** state: Turbulent flow, better circulation across TPC, uniform injection of calibration sources
- **Low-mixing** state: Slower, laminar flow. Lower activity in FV, predictable "streamlines".

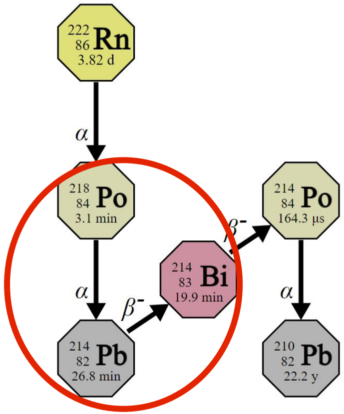






Radon Tag



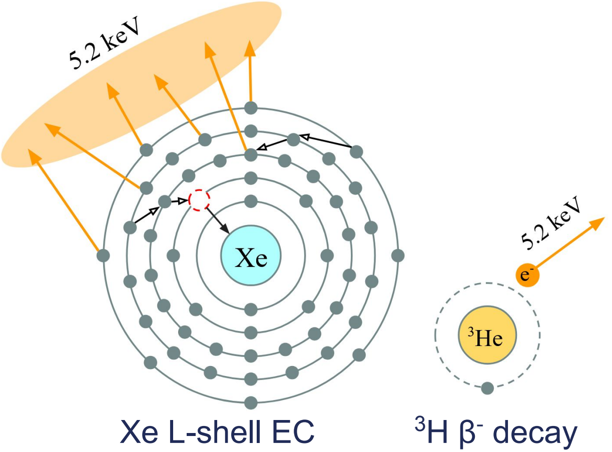


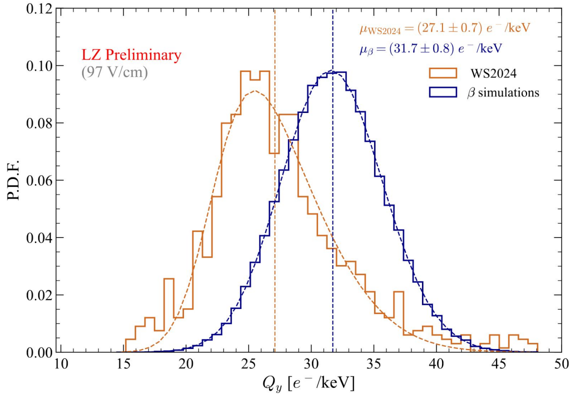
- "Naked" ^{214}Pb β make up majority of ER background
- Combine LXe flow maps & electric field maps to predict volumes likely to contain charged or neutral ^{214}Pb.
- Reduces ^{214}Pb to **1.8 ± 0.3 μBq/kg** in untagged sample
  - 3.9 ± 0.4 μBq/kg in total exposure
- Tagged and untagged samples both fitted for WS2024

Sample	% ^{214}Pb	% Exposure
Tagged	60 ± 4	15
Untagged	40 ± 4	85

Electron Capture Backgrounds

- ^{125}Xe & ^{127}Xe decay by electron capture (EC)
- Produced by activation from neutrons calibration and cosmogenics
  - Rate in WS2024 << WS2022
- L-shell electron capture (5.2 keV) is a WS background
- Electron capture has a **field-dependent suppressed charge yield**
- Higher ionization density → increased recombination
- LZ WS2022 (193 V/cm): Q_L/Q_β=0.88±0.01*
- LZ WS2024 (97 V/cm): Q_L/Q_β=0.87±0.03*
- Charge suppression first measured in XELDA
  - [PRD 104, 112001 ('21)]





- Skin tagged Xe L-shell EC
- β simulation

*Preliminary, dedicated publication in progress

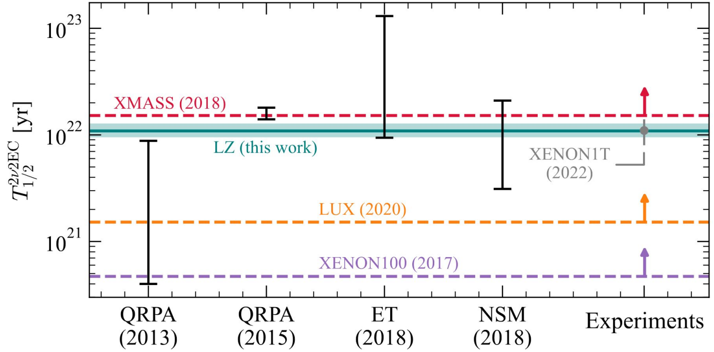
^{124}Xe Double Electron Capture

- ^{124}Xe 2νECEC $T_{1/2}=(1.09\pm0.14^{stat}\pm0.05^{sys})\times10^{22}$ years
  - Worlds longest directly measured half-life
- In-situ $T_{1/2}$ measurement of KK (64.3 keV) captures - (65 ± 5)%
- LL (10 keV) and LM (6 keV) are WS backgrounds
- LM modelled with same as single L-shell charge suppression
  - $Q_{LM}/Q_{\beta} = Q_L/Q_{\beta}$
- For LL expect further charge yield suppression due to higher ionization density.
- Vary Q_{LL}/Q_{β} in fitting of our data $0.65 < Q_{LL}/Q_{\beta} < 0.87$

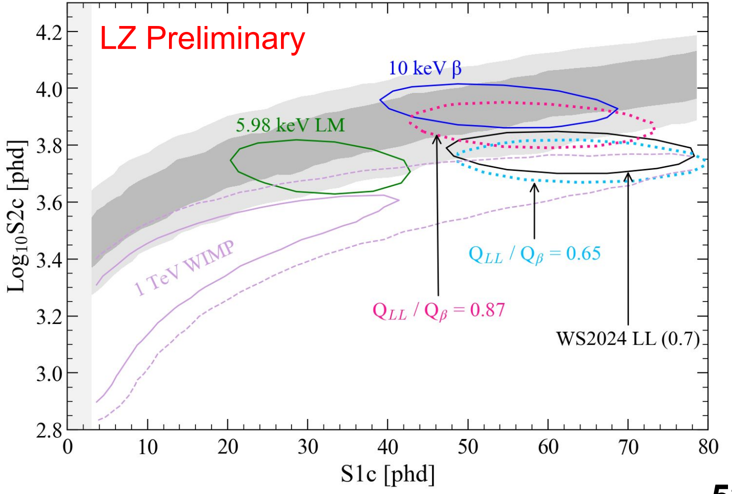
2x ionization density

Q_L/Q_{β}

- Best fit to WS2024 data: $Q_{LL}/Q_{\beta} = 0.70\pm0.04$



WS2022 J. Phys G 52, 015103



Backup WS2025