

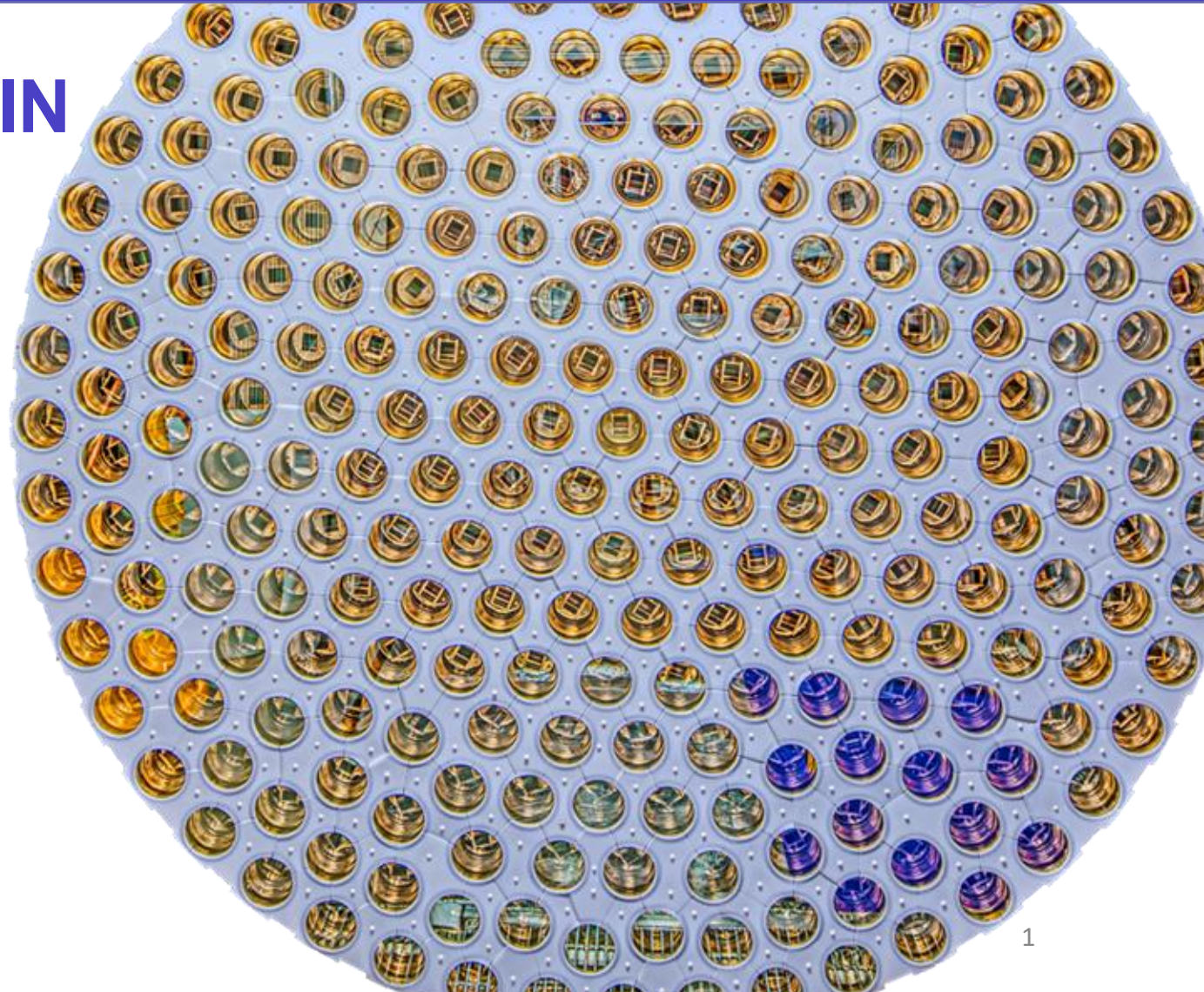


Results from the LUX-ZEPLIN dark matter experiment

Theresa Fruth

On behalf of the LZ collaboration

PPC 2026, Sydney



THE UNIVERSITY OF
SYDNEY



LZ collaboration - 39 Institutions: more than 250 scientists, engineers, and technical staff

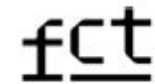
Black Hills State University
Brookhaven National Laboratory
Brown University
Center for Underground Physics
Edinburgh University
Fermi National Accelerator Lab.
Imperial College London
King's College London
Lawrence Berkeley National Lab.
Lawrence Livermore National Lab.
LIP Coimbra
Northwestern University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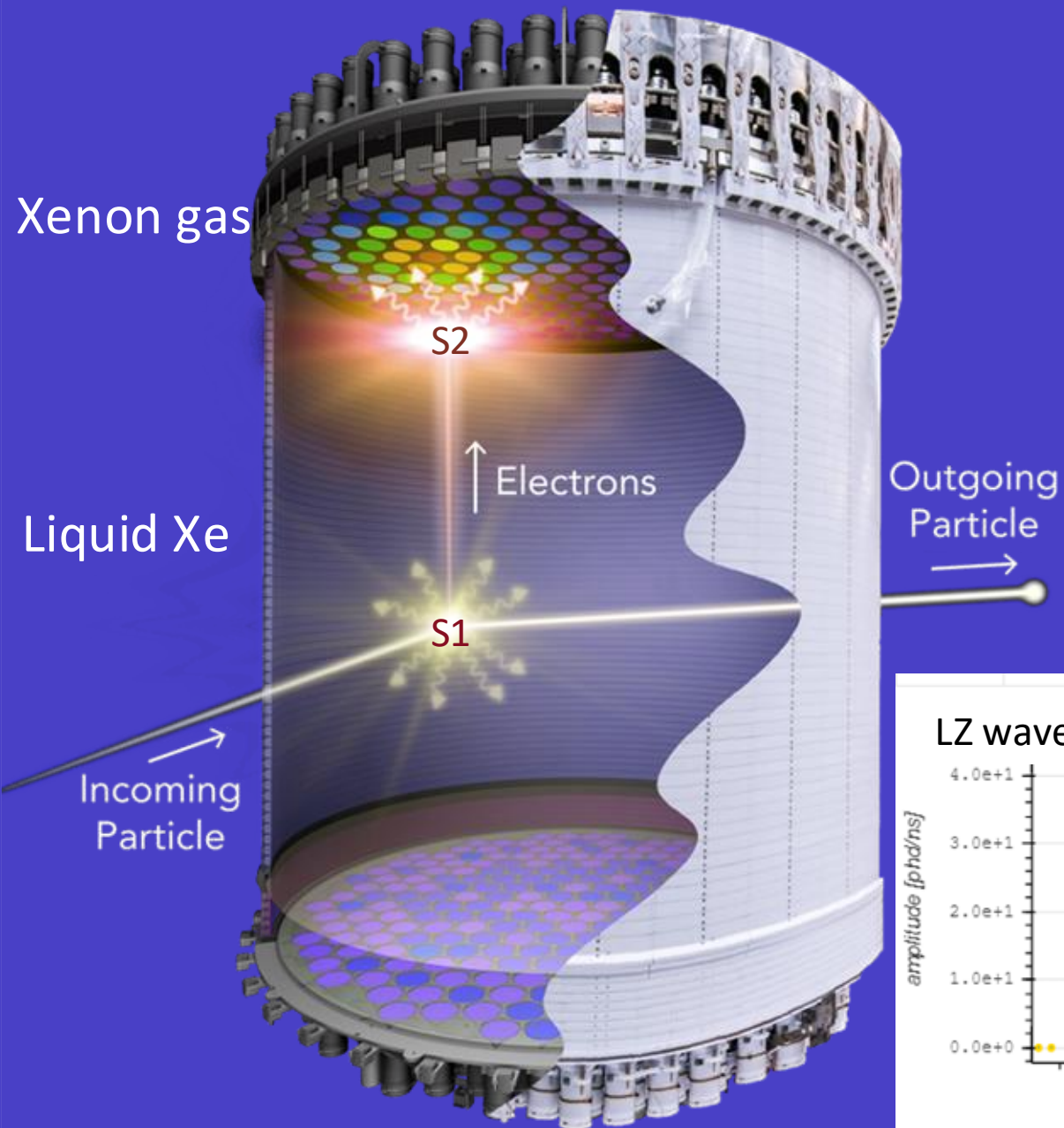
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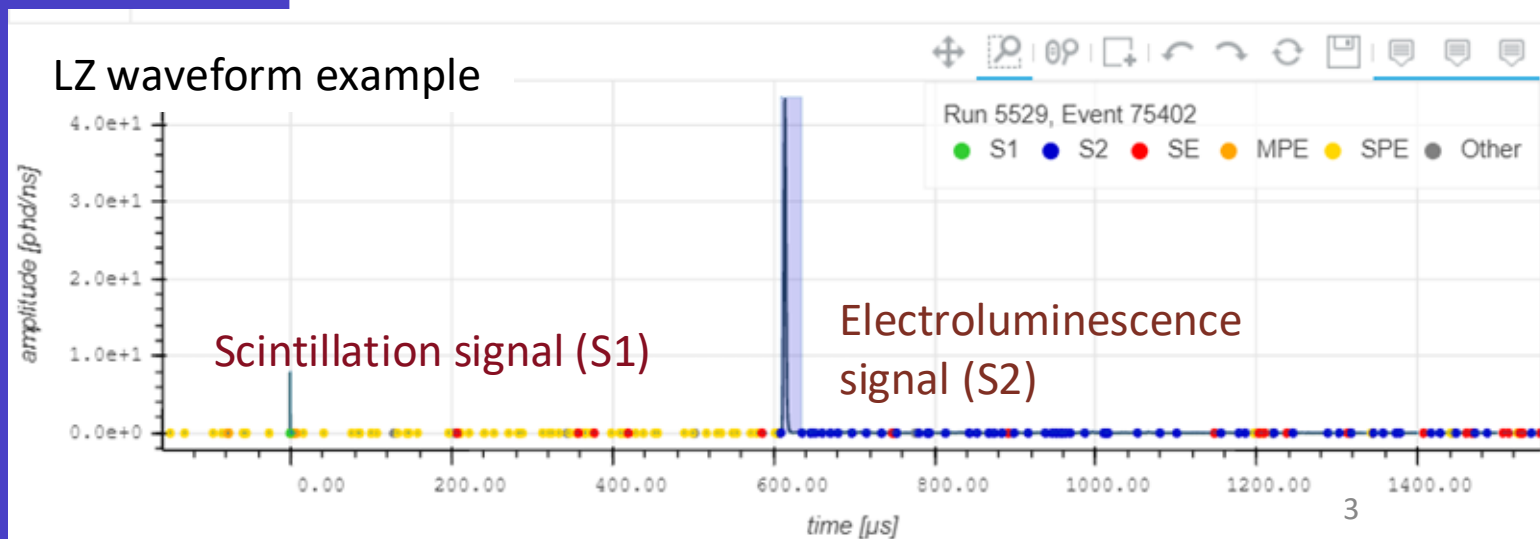
Institute for
Basic Science

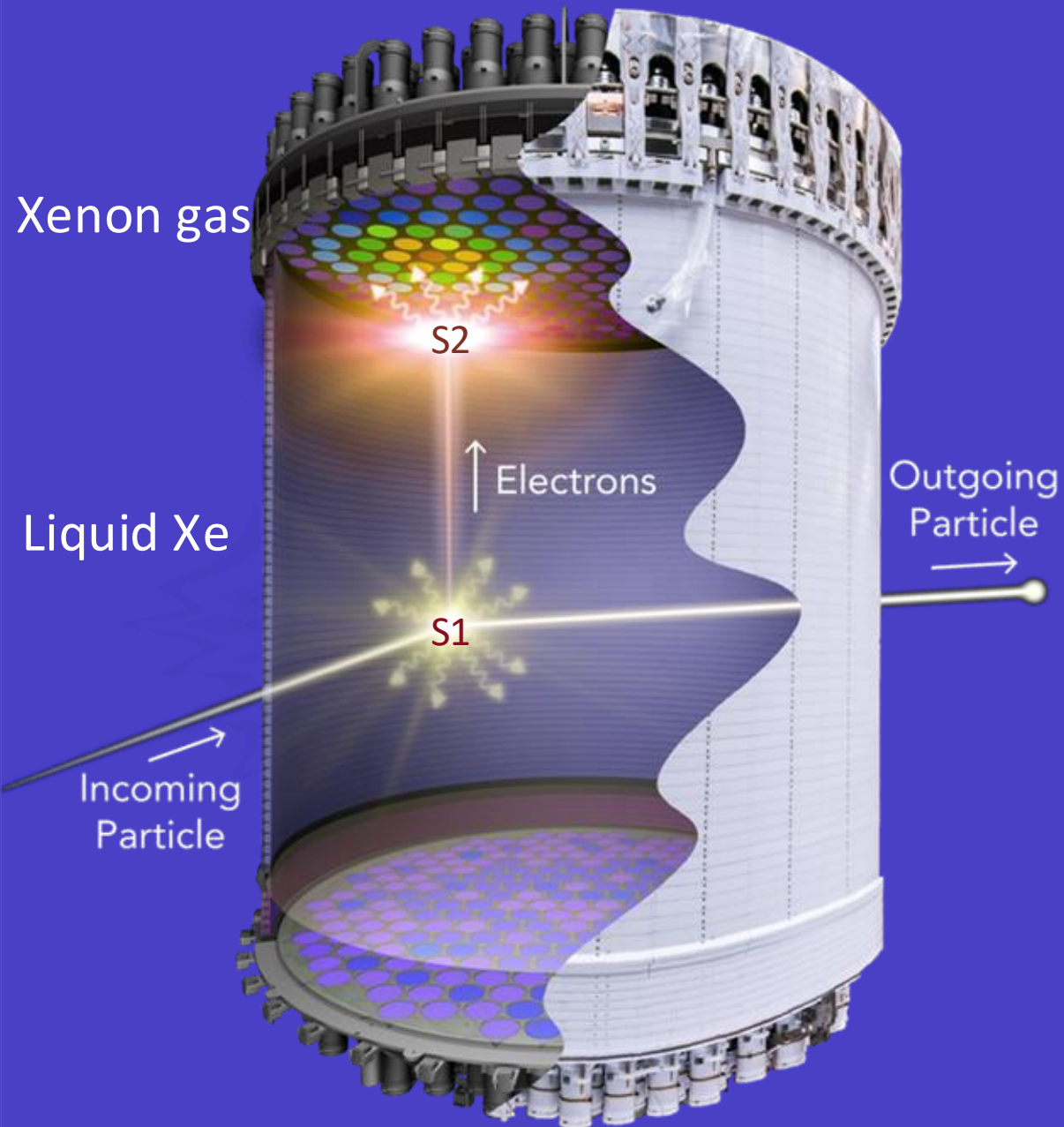


|Detector

Overview

- Principal goal: the direct detection of dark matter via nuclear recoils
- Scintillation & charge (via electroluminescence) signals
- 3D event reconstruction

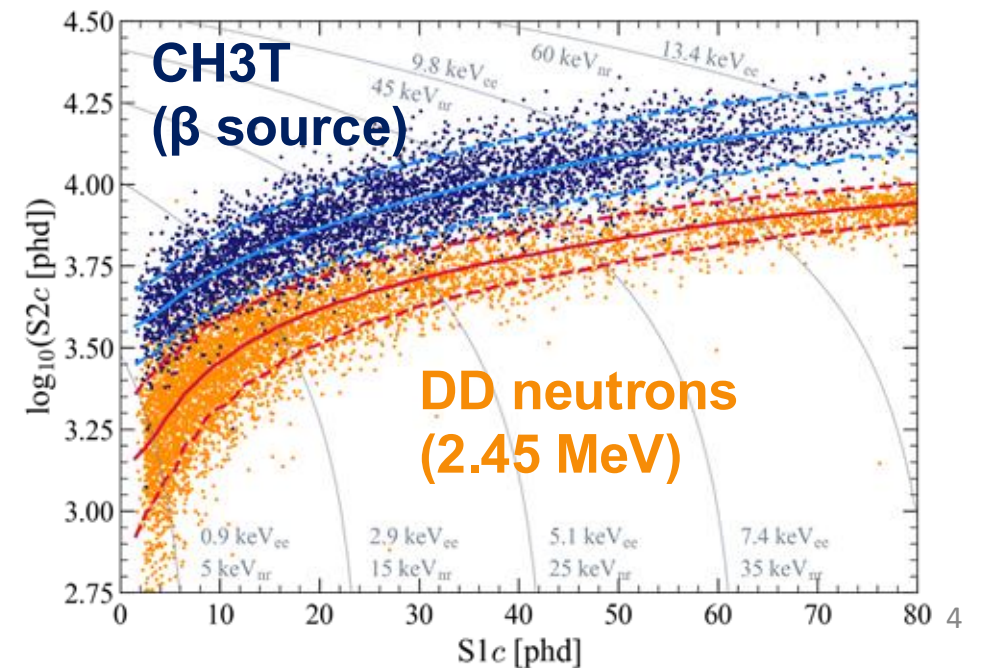




|Detector

Overview

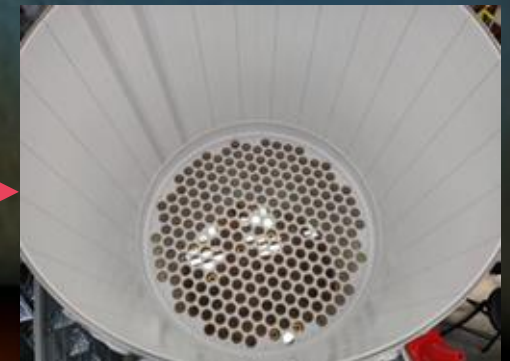
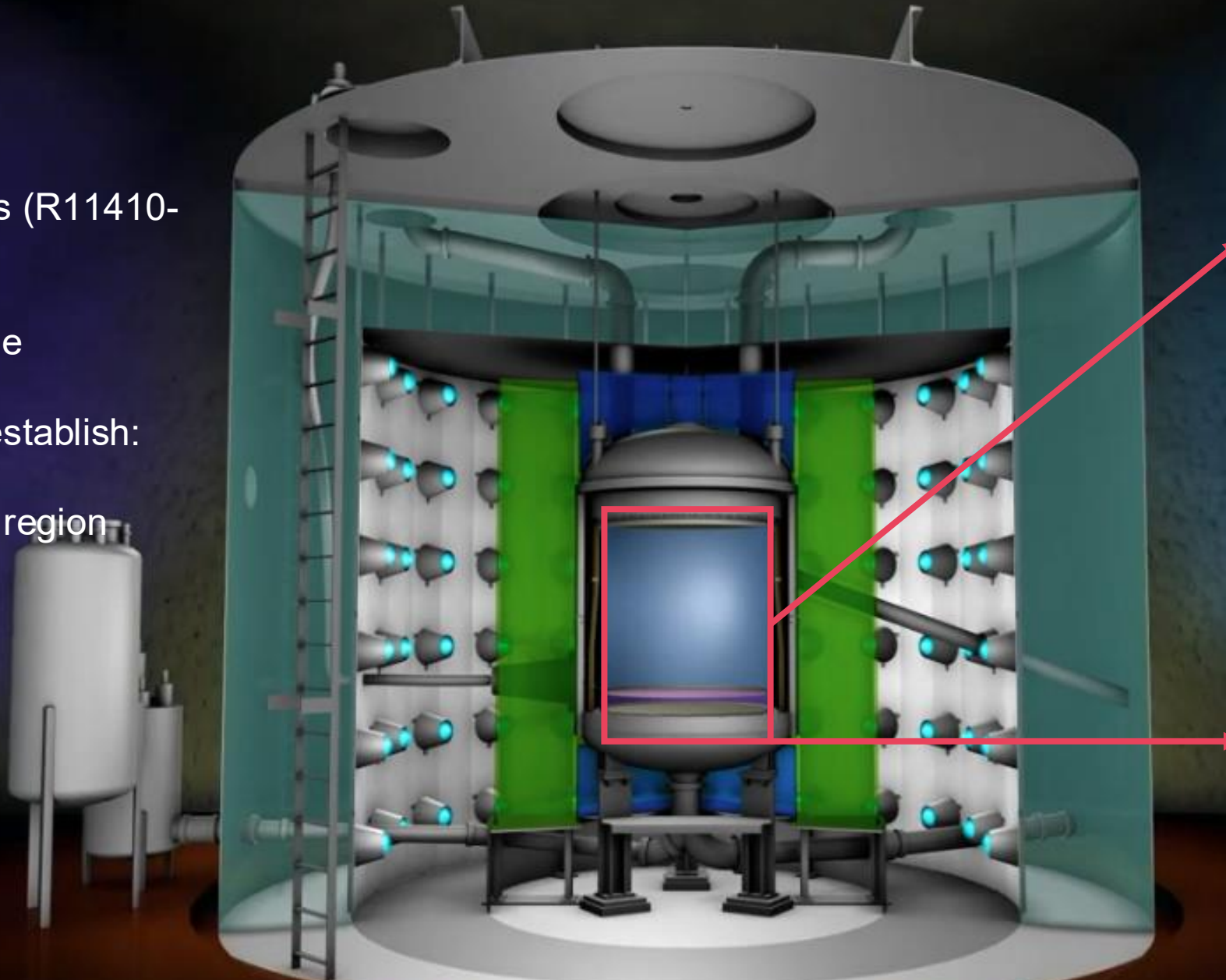
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- 3D event reconstruction



|Detector

TPC

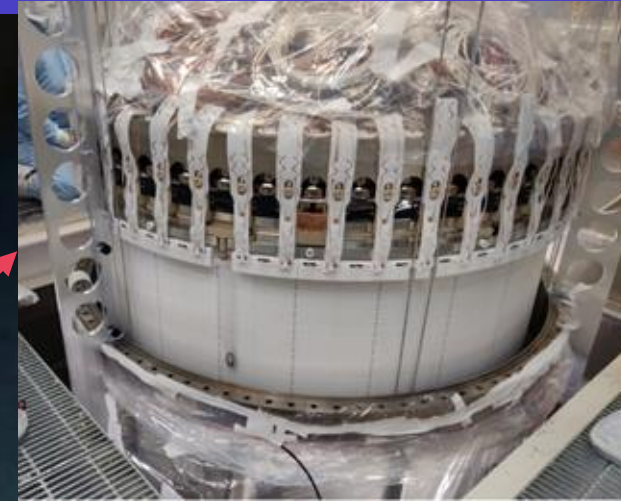
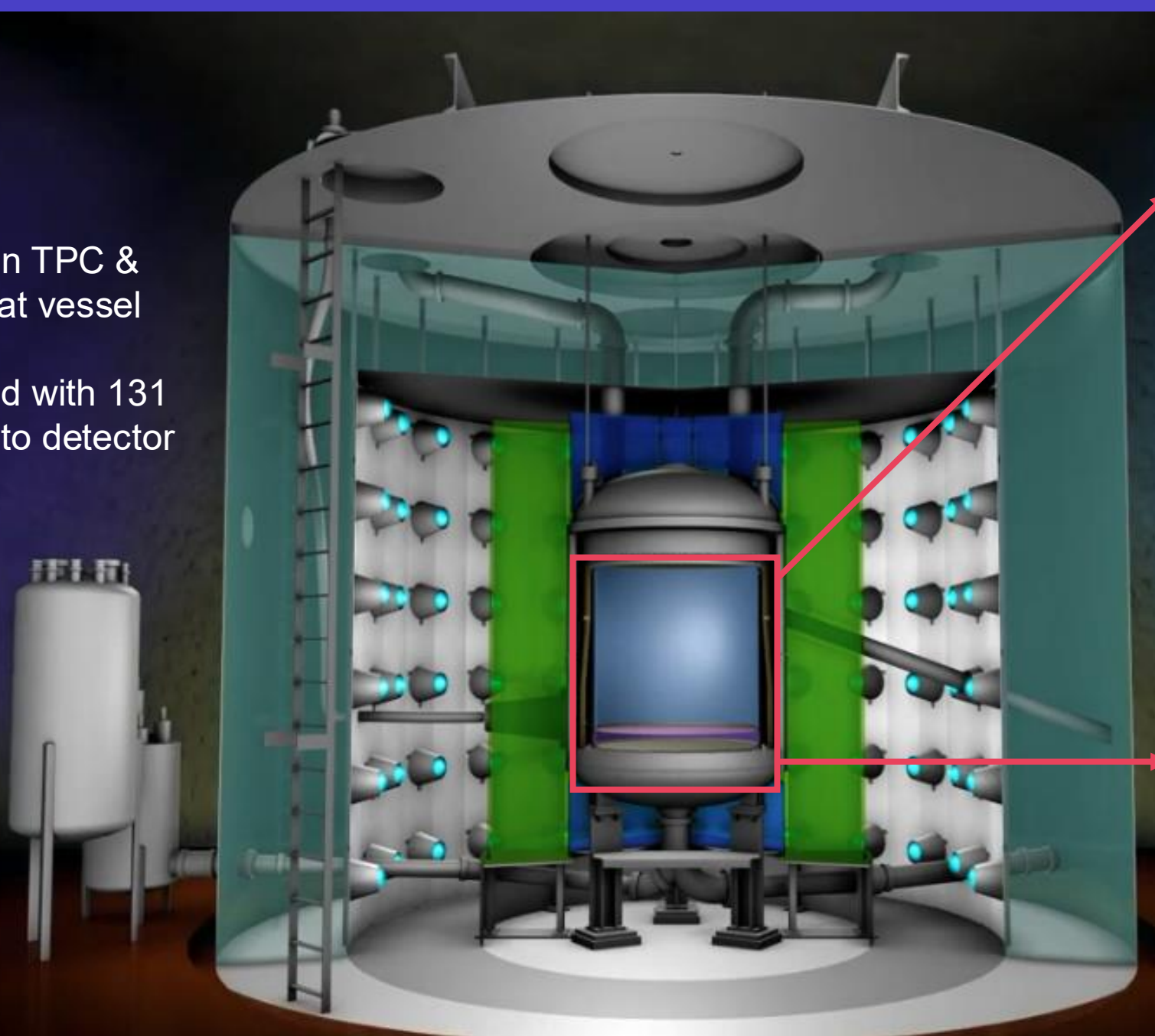
- 494 TPC PMTs (R11410-22)
- PTFE field cage
- 4 HV grids to establish:
 - drift field
 - extraction region



|Detector

Skin

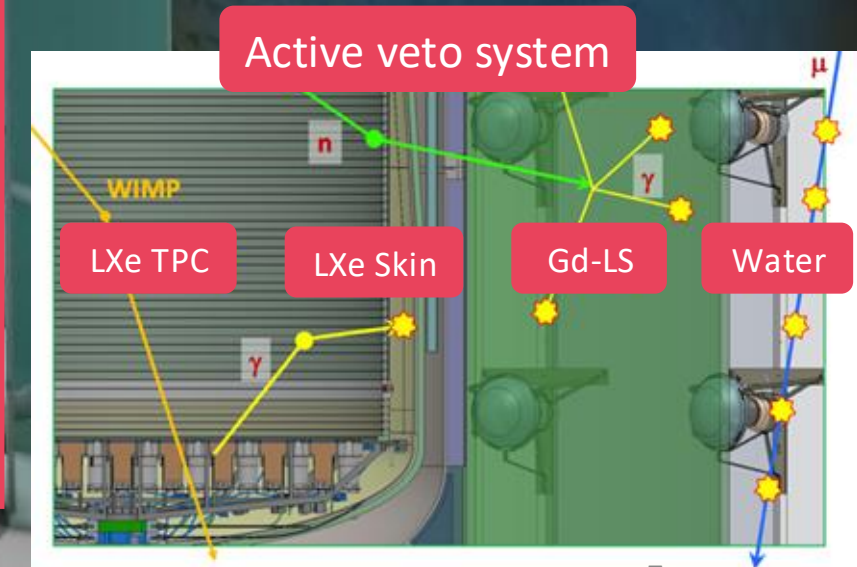
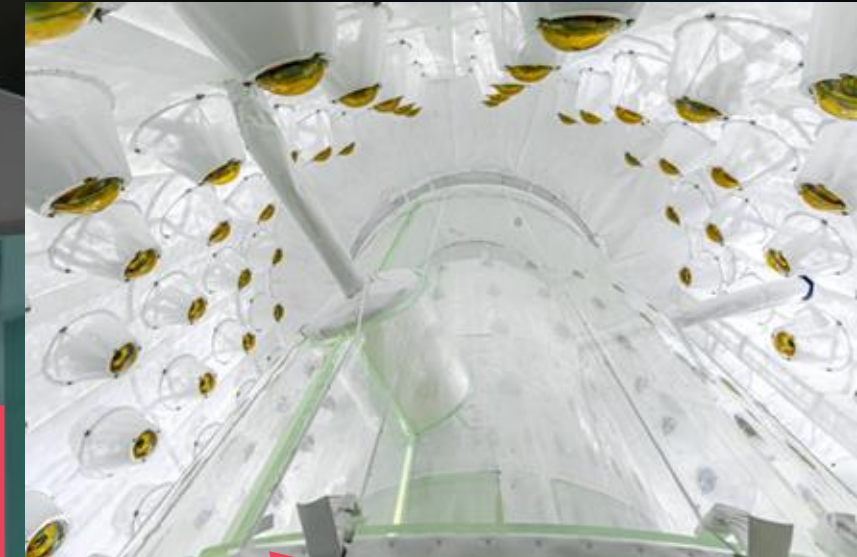
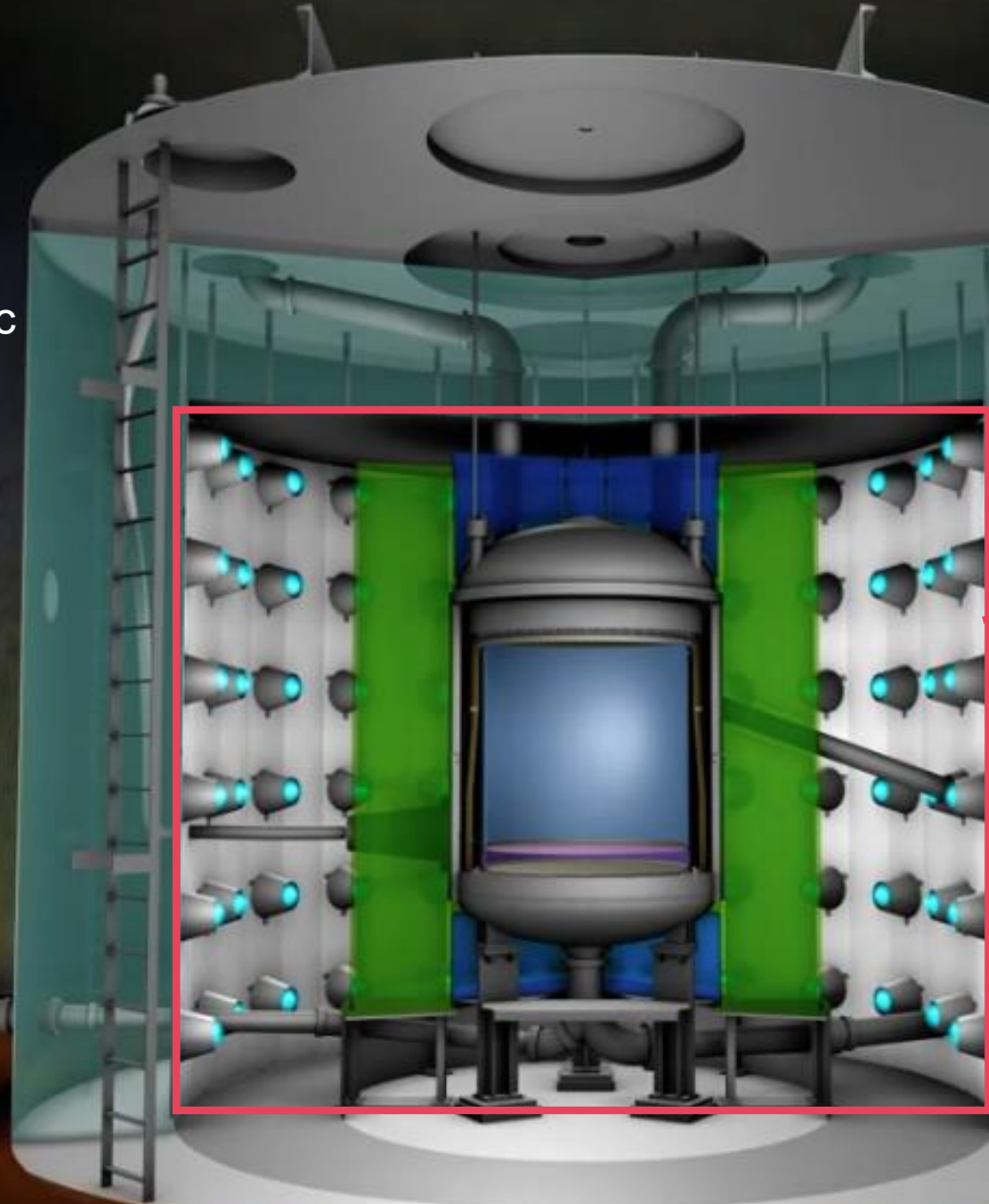
- LXe between TPC & inner cryostat vessel
- Instrumented with 131 PMTs as veto detector



|Detector

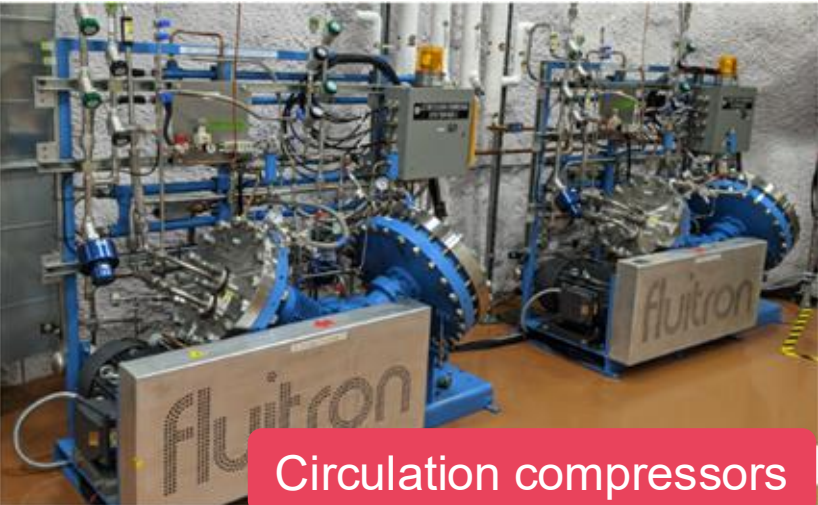
Outer Detector

- 17 tonnes Gd-loaded liquid scintillator in acrylic vessels
- 120 8" PMTs (R5912)

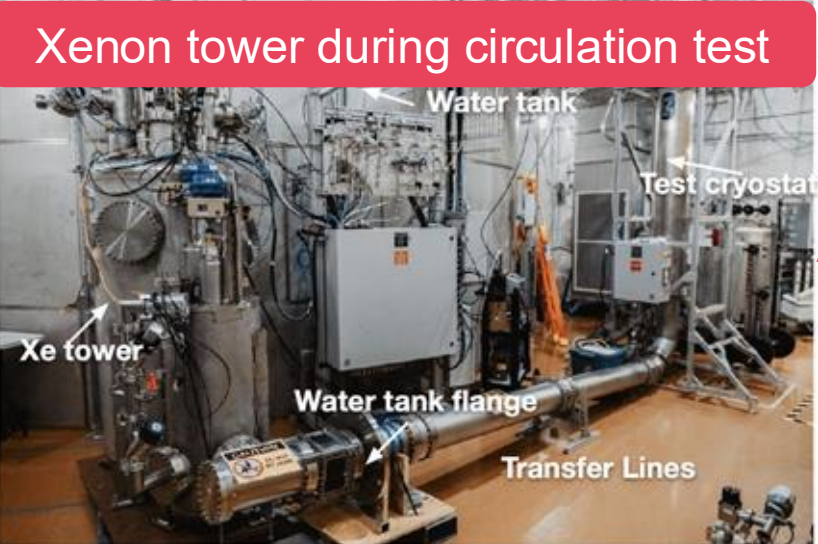


|Detector

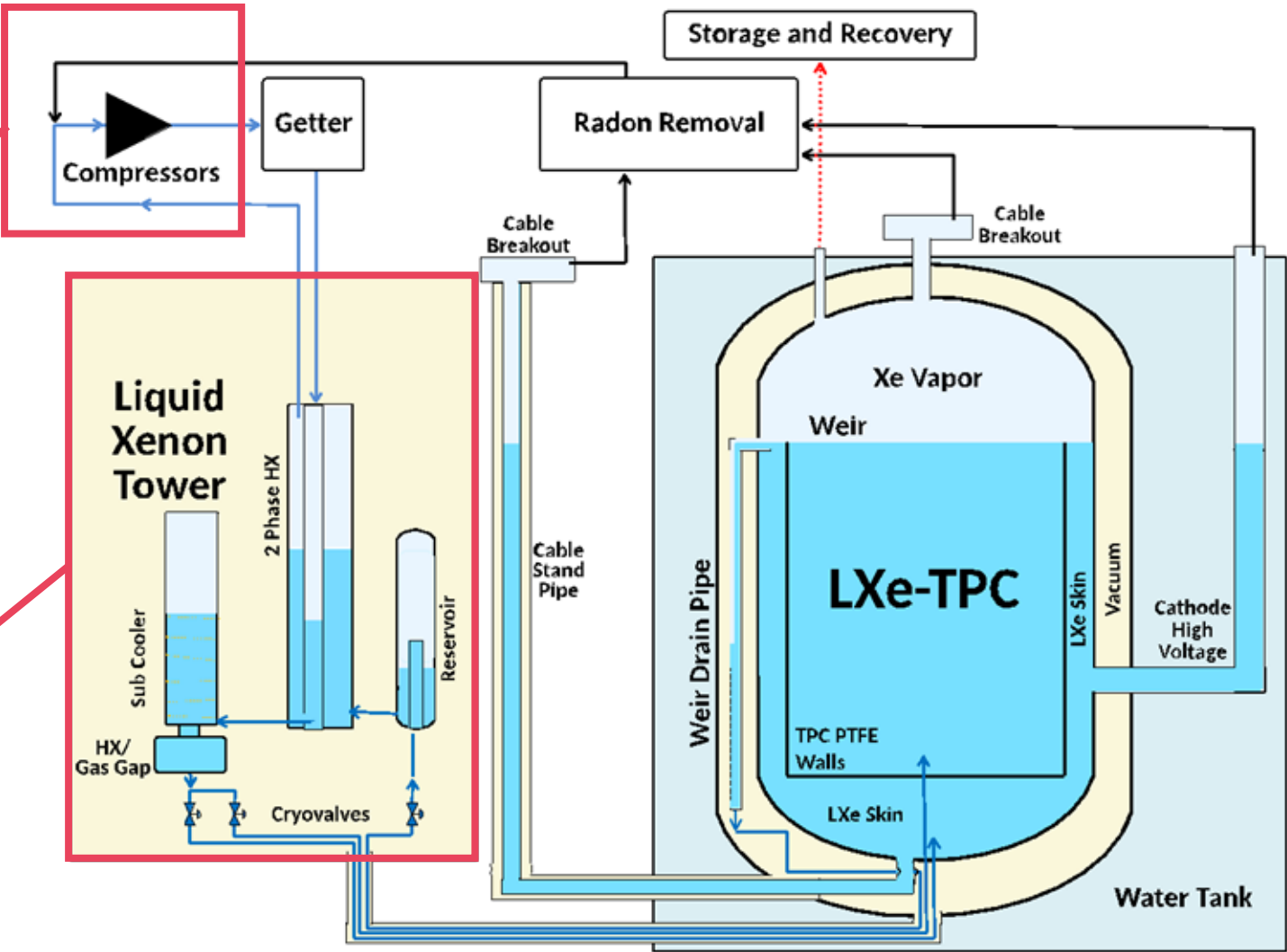
Circulation System



Circulation compressors

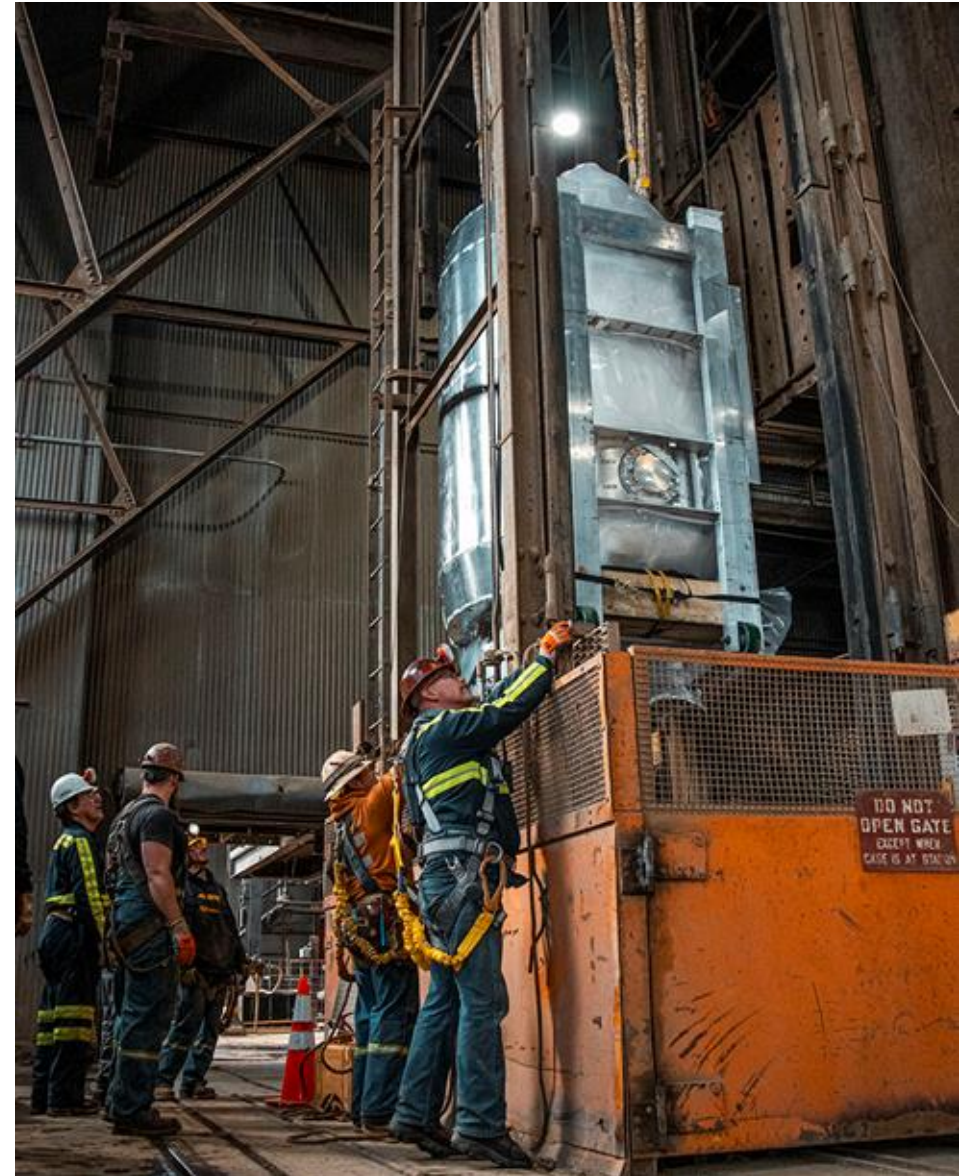
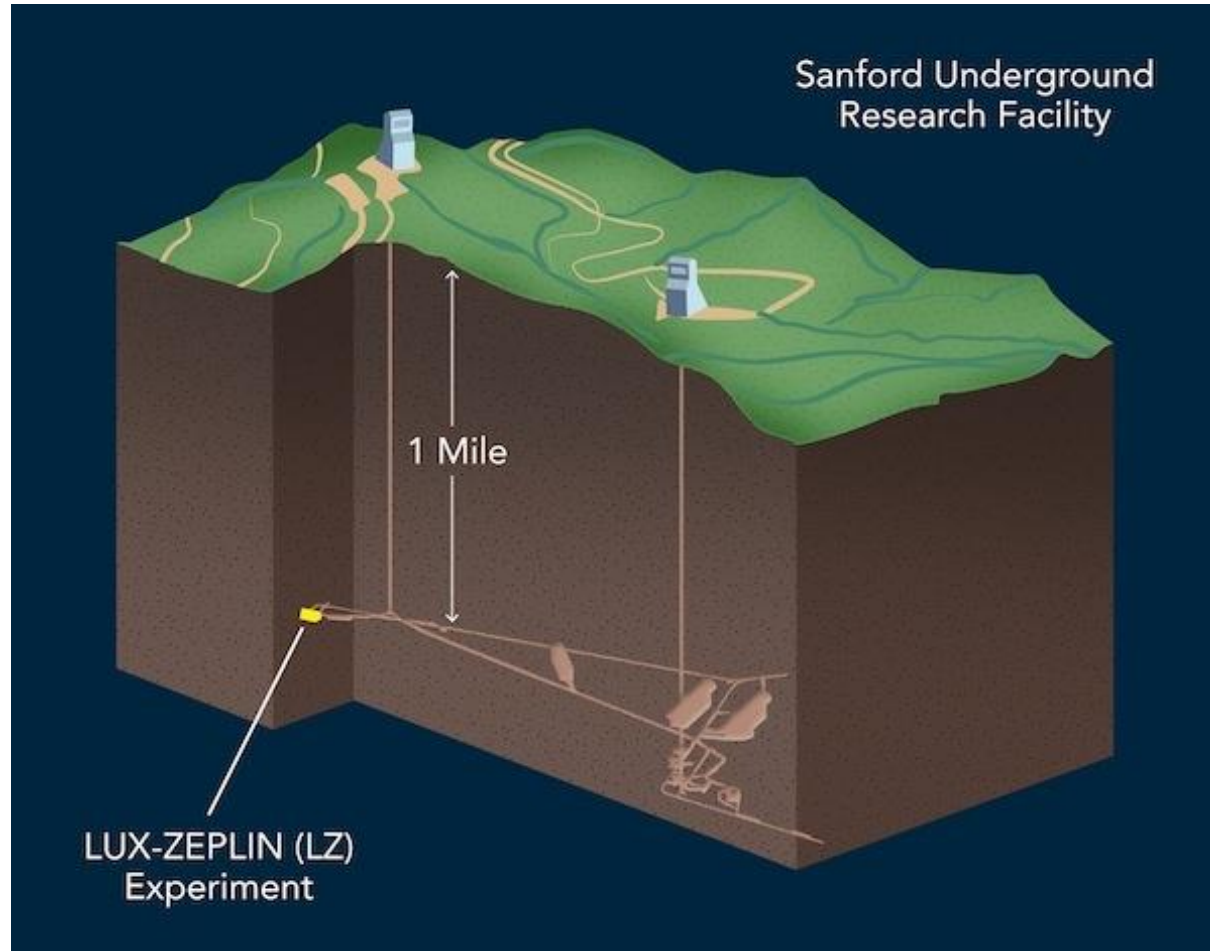


Xenon tower during circulation test



|Detector

Sanford Underground Research Facility



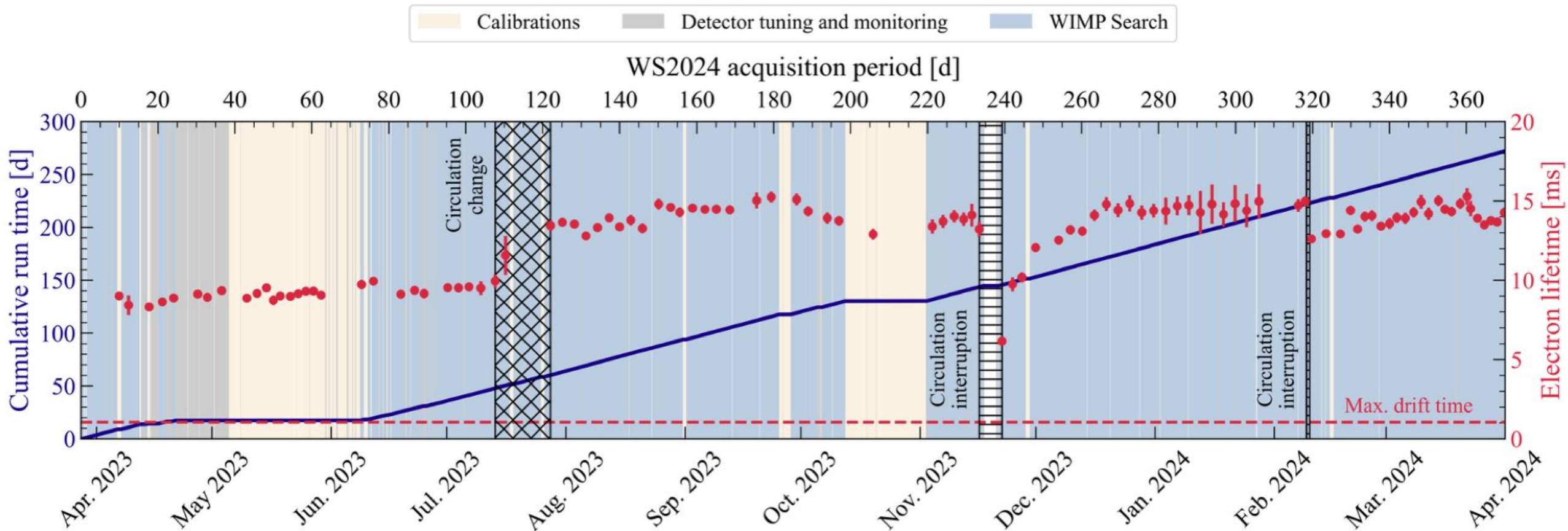
Overview

WS2022: Dec 2021 to May 2022, LZ: [PRL 131, 041002 \(2023\)](#)

- 60 live-days
- 193 V/cm drift field

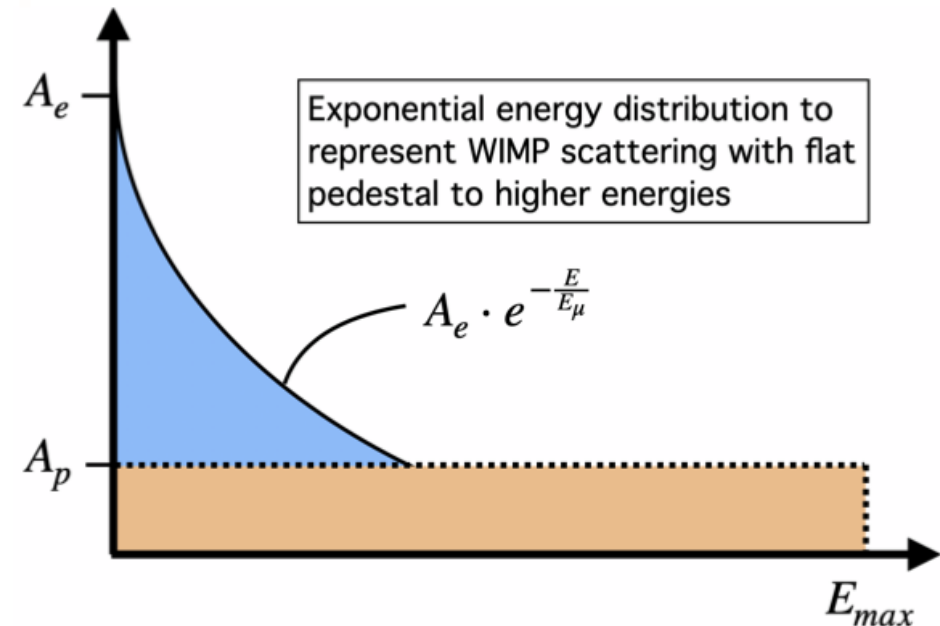
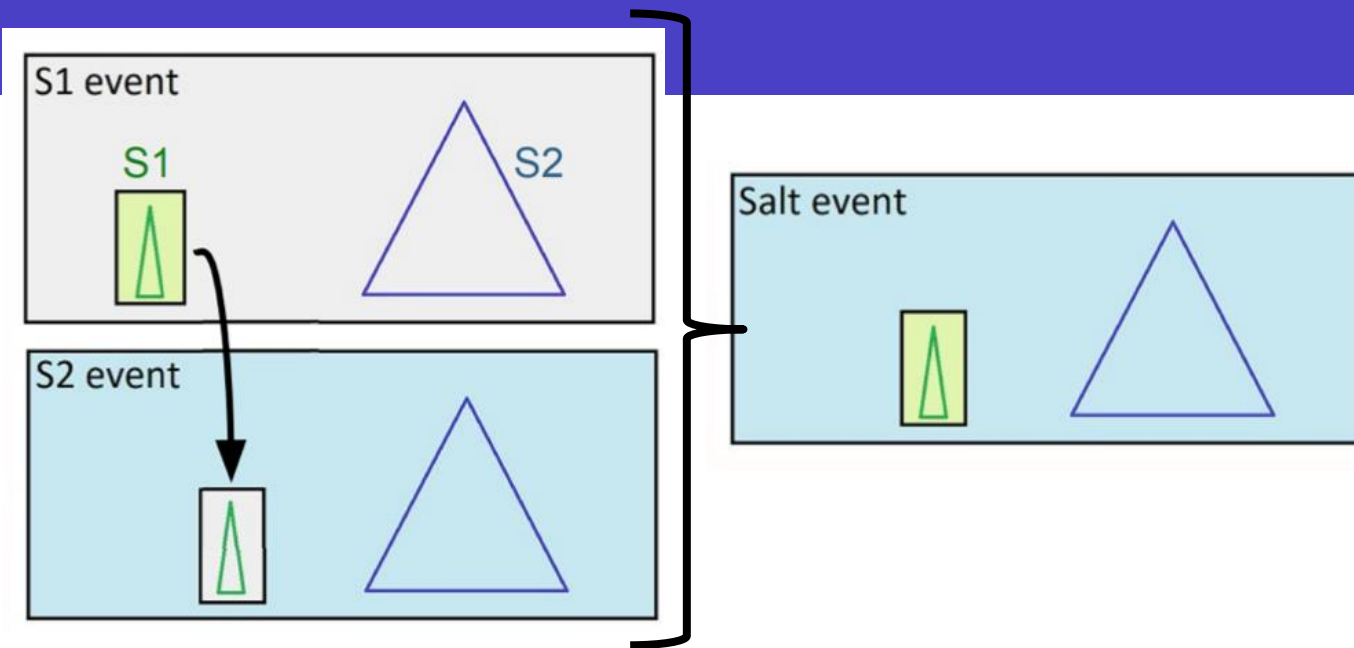
WS2024: Mar 2023 to Mar 2024, LZ: [PRL 135, 011802 \(2025\)](#)

- 220 combined live-days
- 97 V/cm drift field



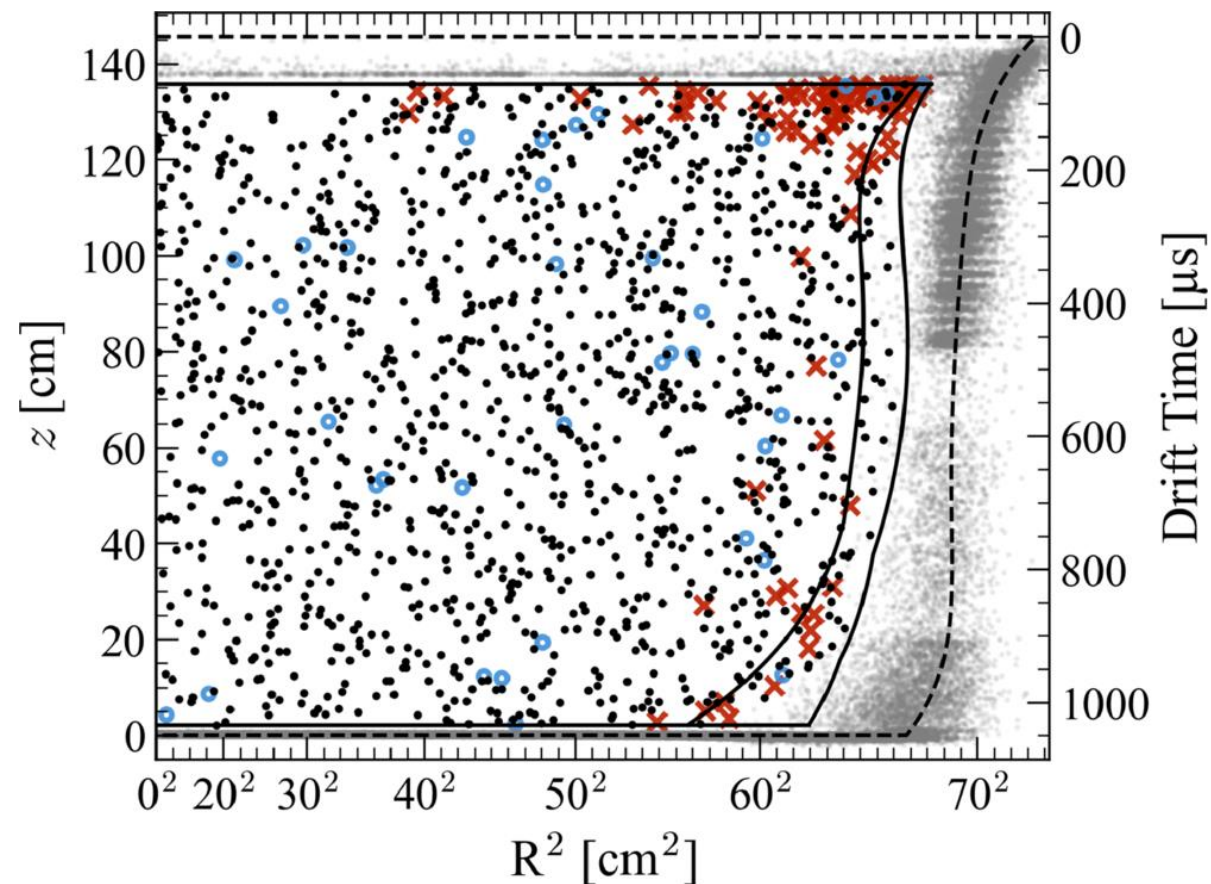
Bias Mitigation

- Bias mitigation strategy: randomly inject fake signals (“salt”) during science data taking.
- Events manufactured using S1s & S2s from sequestered calibration data.
- Salt rate is drawn from a Poisson distribution with a mean rate randomly set between 0 and the WS2022 upper limit.
- Exp+flat spectrum (parameters randomly generated & hidden).
- Salt events are revealed after the analysis inputs are finalised.



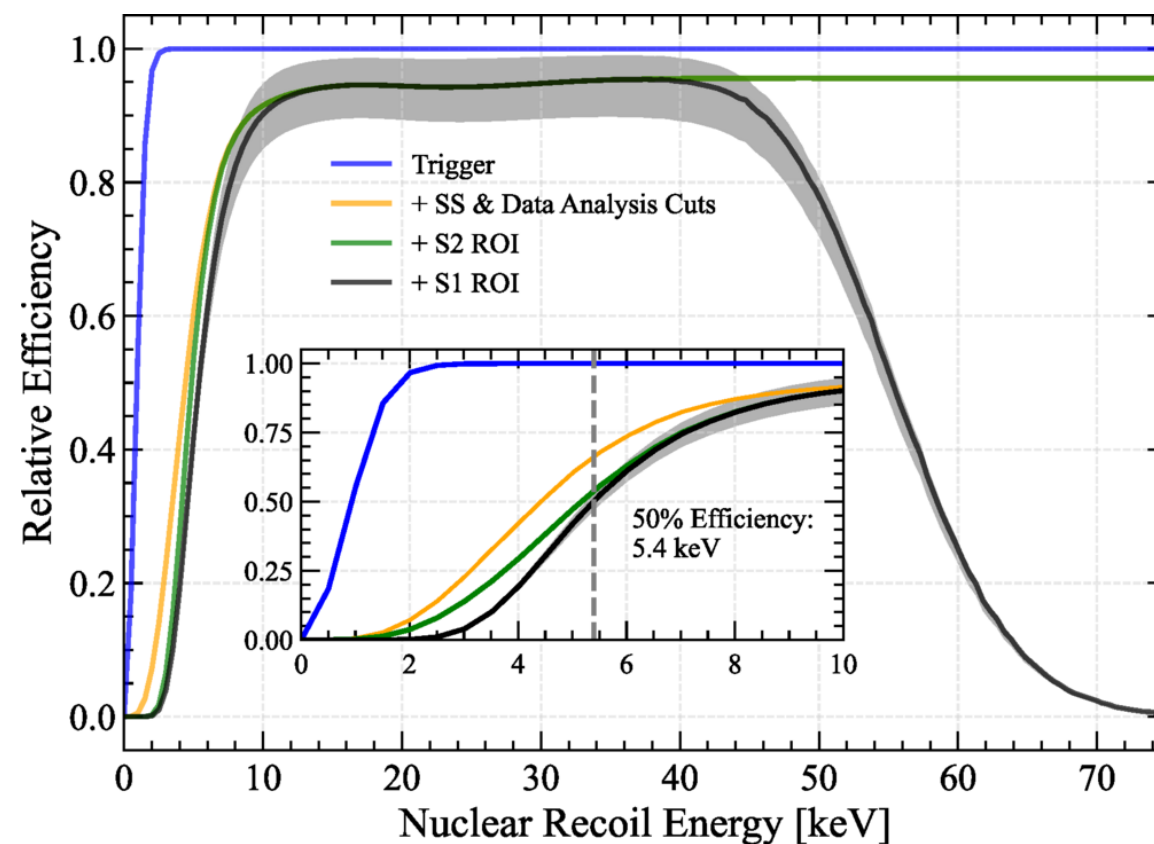
Data selection cuts

- events passing all cuts
- events outside of fiducial volume
- × prompt events vetoed by Skin/OD
- delayed events vetoed by Skin/OD



Analysis frozen before “un-salting”

Unsalting: 7 salt events pass all analysis cuts out of 8 total injected in WS2024



|WIMP Search 2024

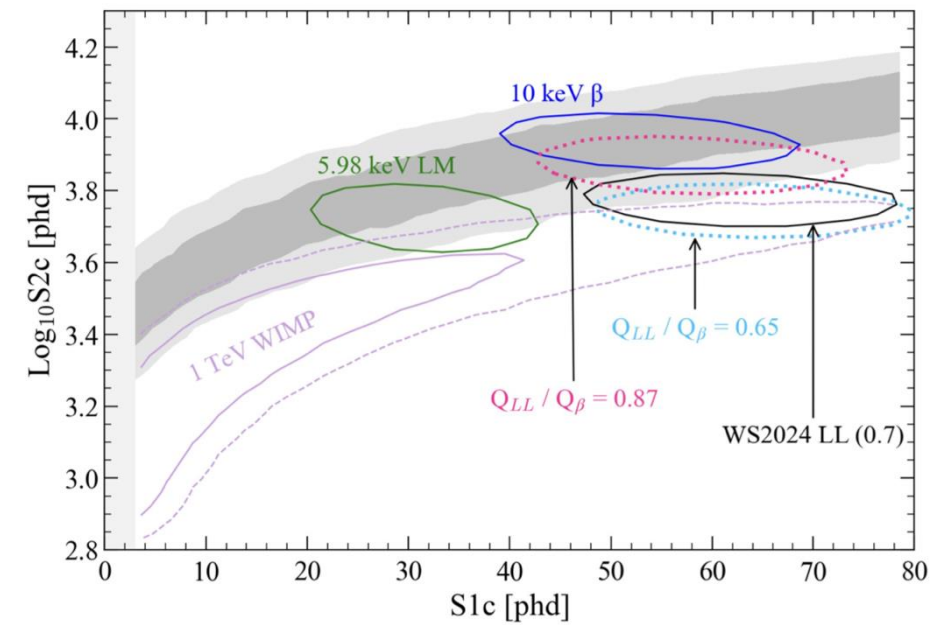
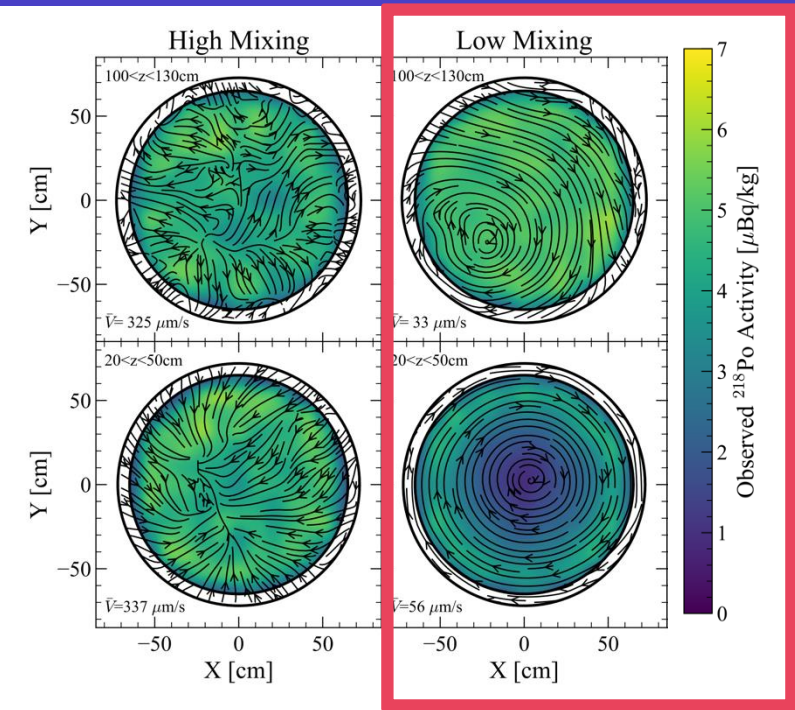
Background mitigation

Radon tagging¹:

- Low-mixing state allows mapping
- Flow vectors mapped using ^{222}Rn - ^{218}Po pairs
- Simulations of neutral and charged ^{214}Pb movement using flow and field maps to create a “radon tag” in low-mixing state
- Tagged and untagged data both in WIMP analysis, no loss of exposure

Electron Capture Decay Backgrounds²:

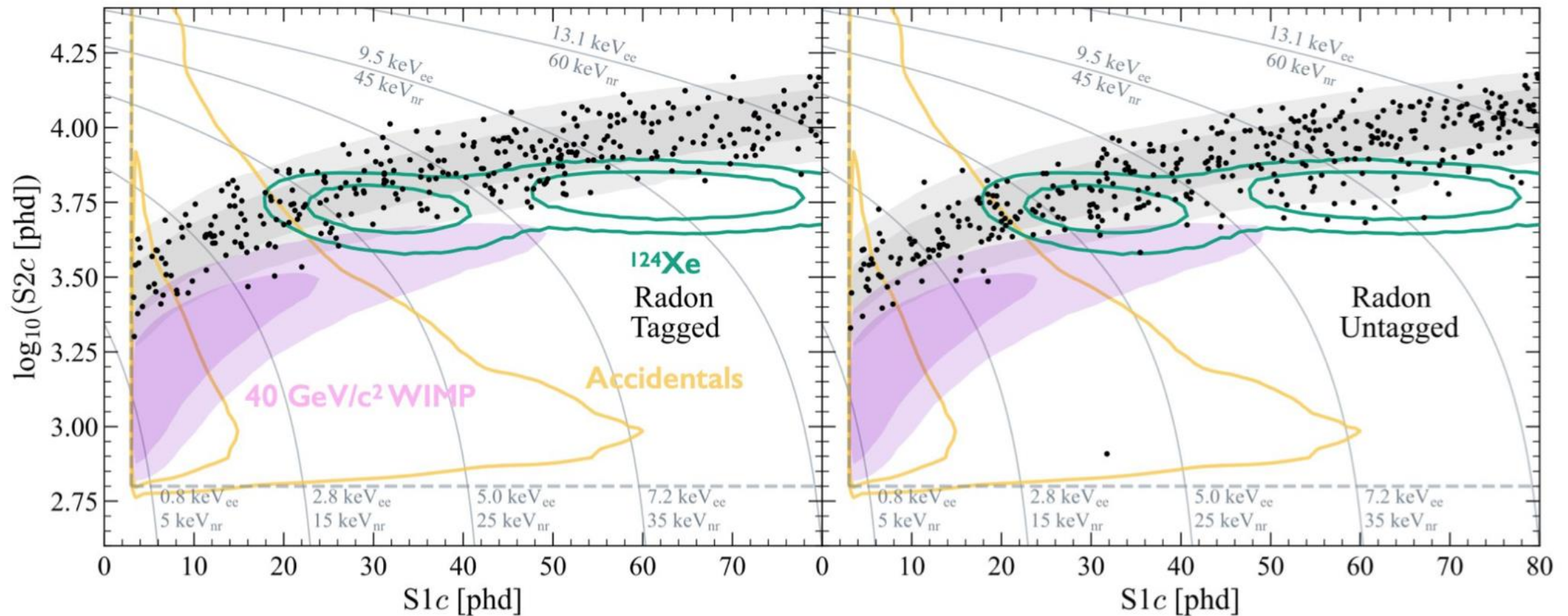
- Charge yield suppression for EC compared to β 's of the same energy due to higher ionisation density from X-ray & Auger
- Measured in-situ for ^{127}Xe & ^{125}Xe L-shell EC, modelling ^{124}Xe LL-capture suppression



Final data set

WS2024 final exposure:

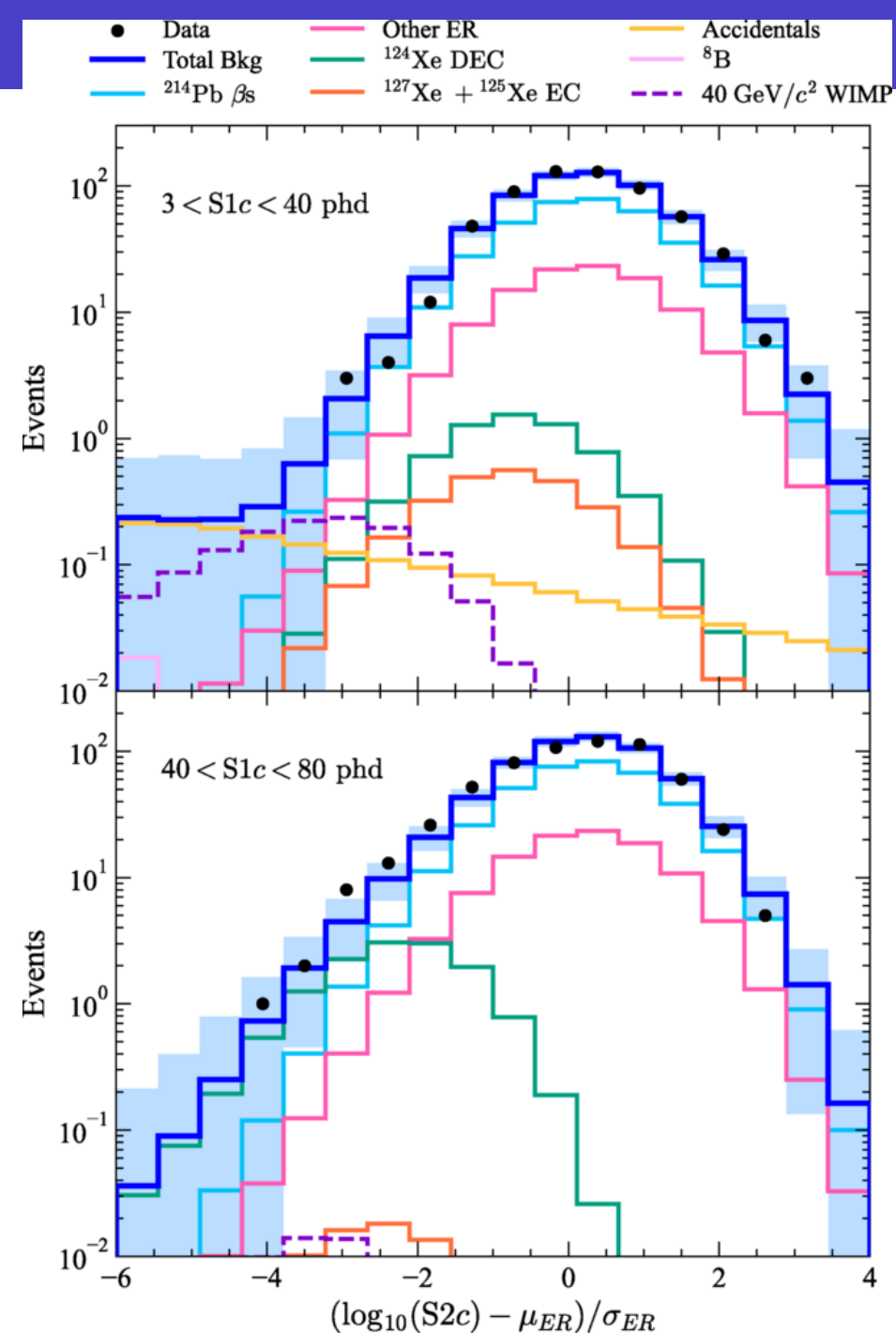
- 220 live days * 5.5 fiducial tonnes = 3.3 tonne-years
- Observed 1220 events (expected 1210)



|WIMP Search 2024

Background Model

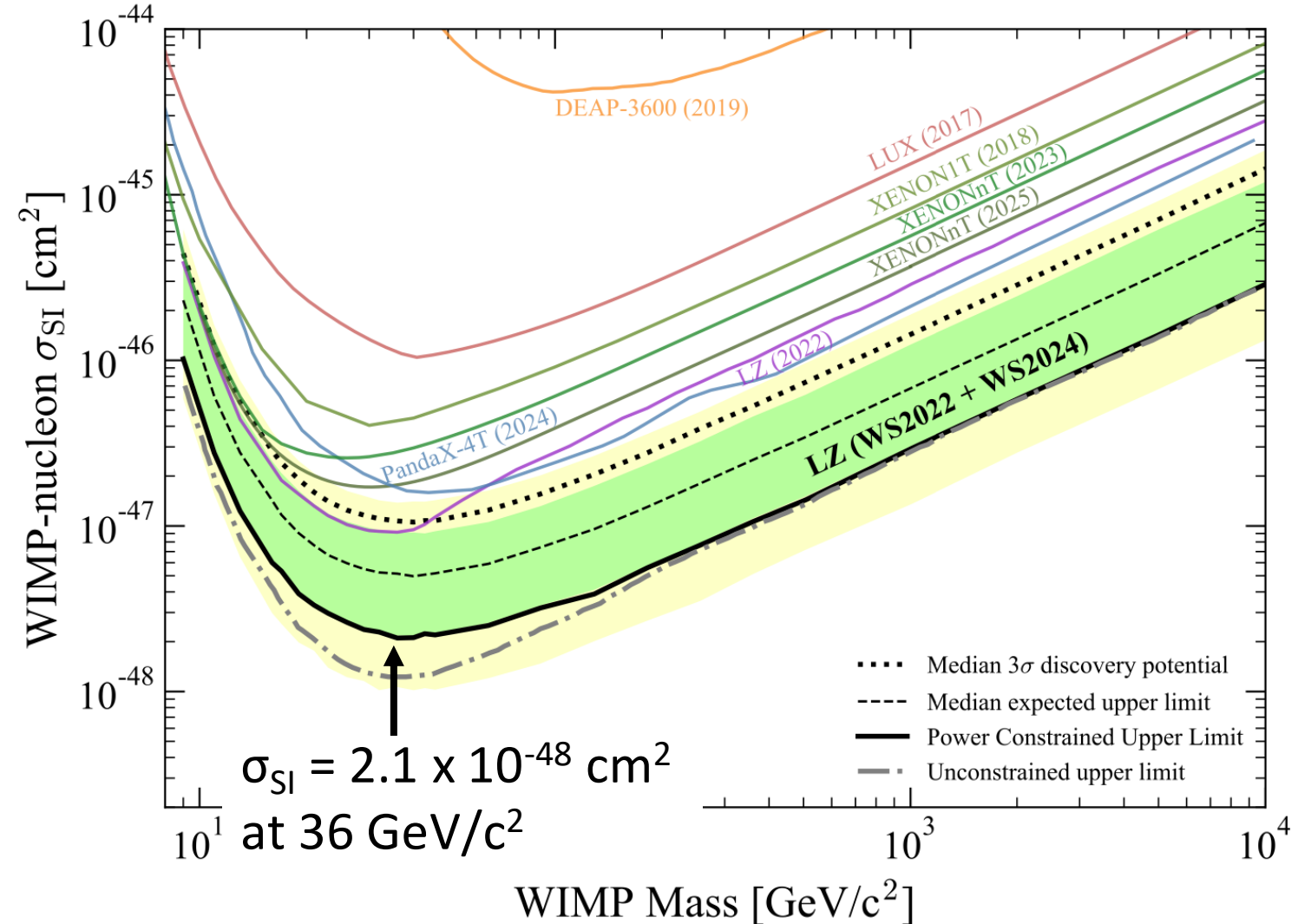
Source	Prefit expectation	Fit result
$^{214}\text{Pb } \beta\text{s}$	743 ± 88	733 ± 34
$^{85}\text{Kr} + ^{39}\text{Ar } \beta\text{s} + \text{det. } \gamma\text{s}$	162 ± 22	161 ± 21
Solar ν ER	102 ± 6	102 ± 6
$^{212}\text{Pb} + ^{218}\text{Po } \beta\text{s}$	62.7 ± 7.5	63.7 ± 7.4
Tritium + $^{14}\text{C } \beta\text{s}$	58.3 ± 3.3	59.7 ± 3.3
$^{136}\text{Xe } 2\nu\beta\beta$	55.6 ± 8.3	55.9 ± 8.2
$^{124}\text{Xe DEC}$	19.4 ± 2.5	20.4 ± 2.4
$^{127}\text{Xe} + ^{125}\text{Xe EC}$	3.2 ± 0.6	2.7 ± 0.6
Accidental coincidences	2.8 ± 0.6	2.6 ± 0.6
Atm. ν NR	0.12 ± 0.02	0.12 ± 0.02
$^8\text{B} + \text{hep } \nu$ NR	0.06 ± 0.01	0.06 ± 0.01
Detector neutrons	$^a0.0^{+0.2}$	$0.0^{+0.2}$
$40 \text{ GeV}/c^2$ WIMP	...	$0.0^{+0.6}$
Total	1210 ± 91	1202 ± 41



|WIMP Search 2024

Results

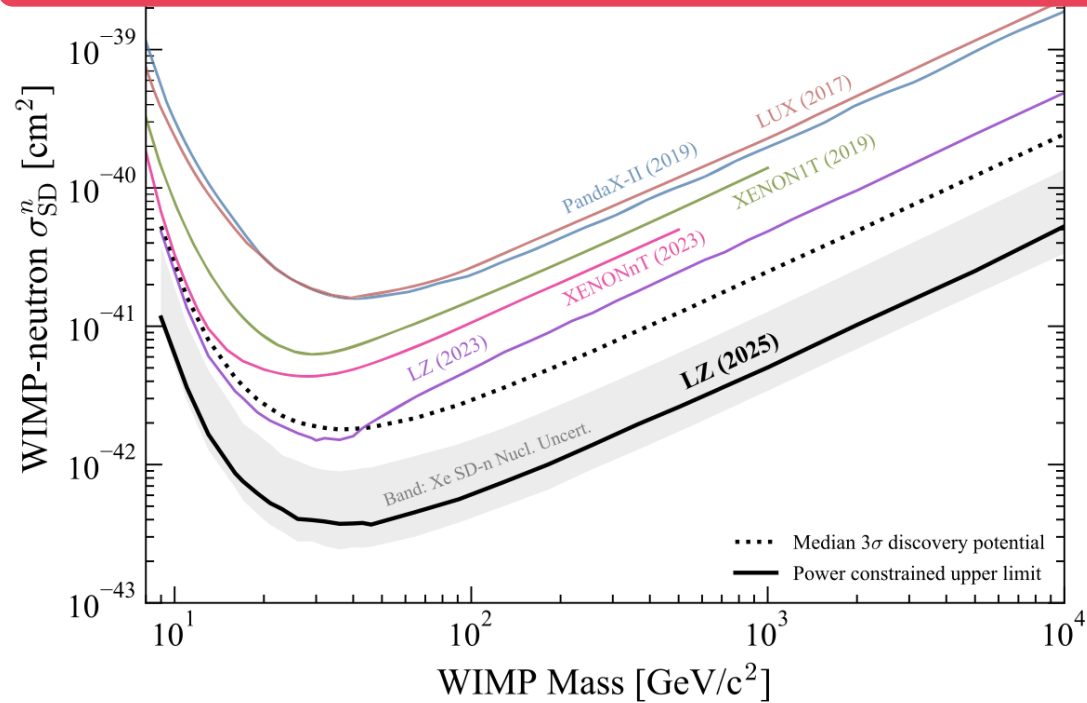
- Consistent with background-only hypothesis
- Best fit of zero WIMPs at all tested masses (9 GeV – 10 TeV)
- Two-sided PLR [EPJC 81, 907 \(2021\)](#)
- Power constraint (-1σ)
G. Cowan et al. [arxiv/1105.3166](#)
- Additional under fluctuation from combination with WS2022 result



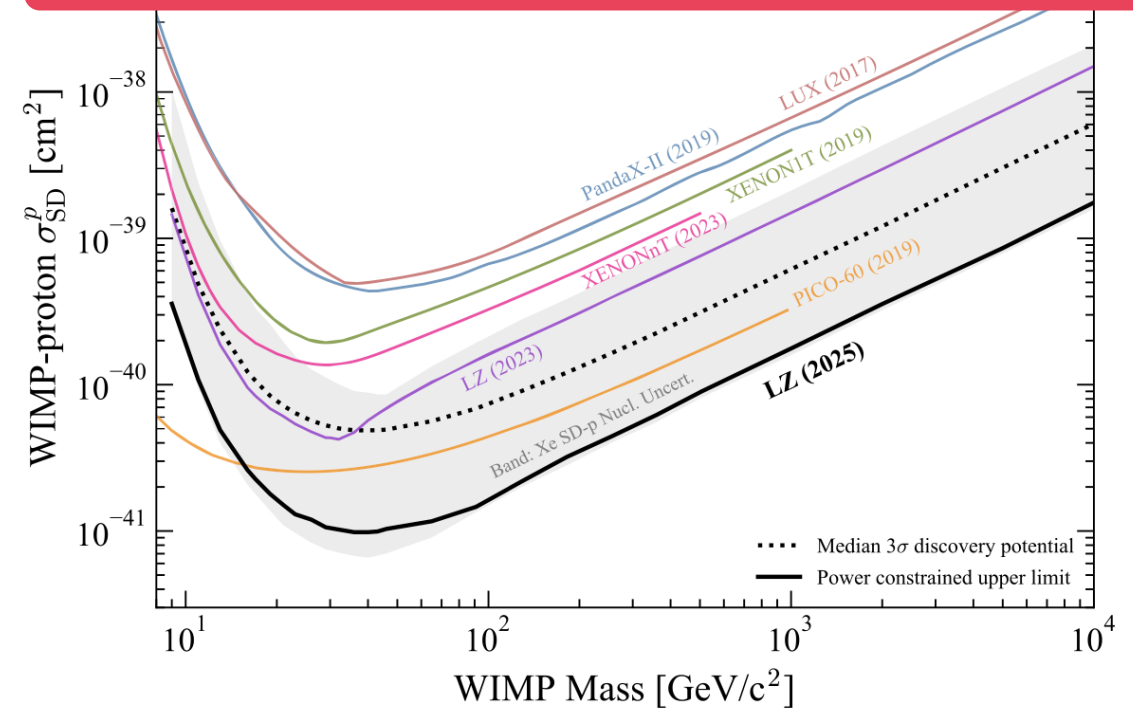
|WIMP Search 2024

Spin-Dependent Limits

Spin-dependent WIMP-neutron scattering

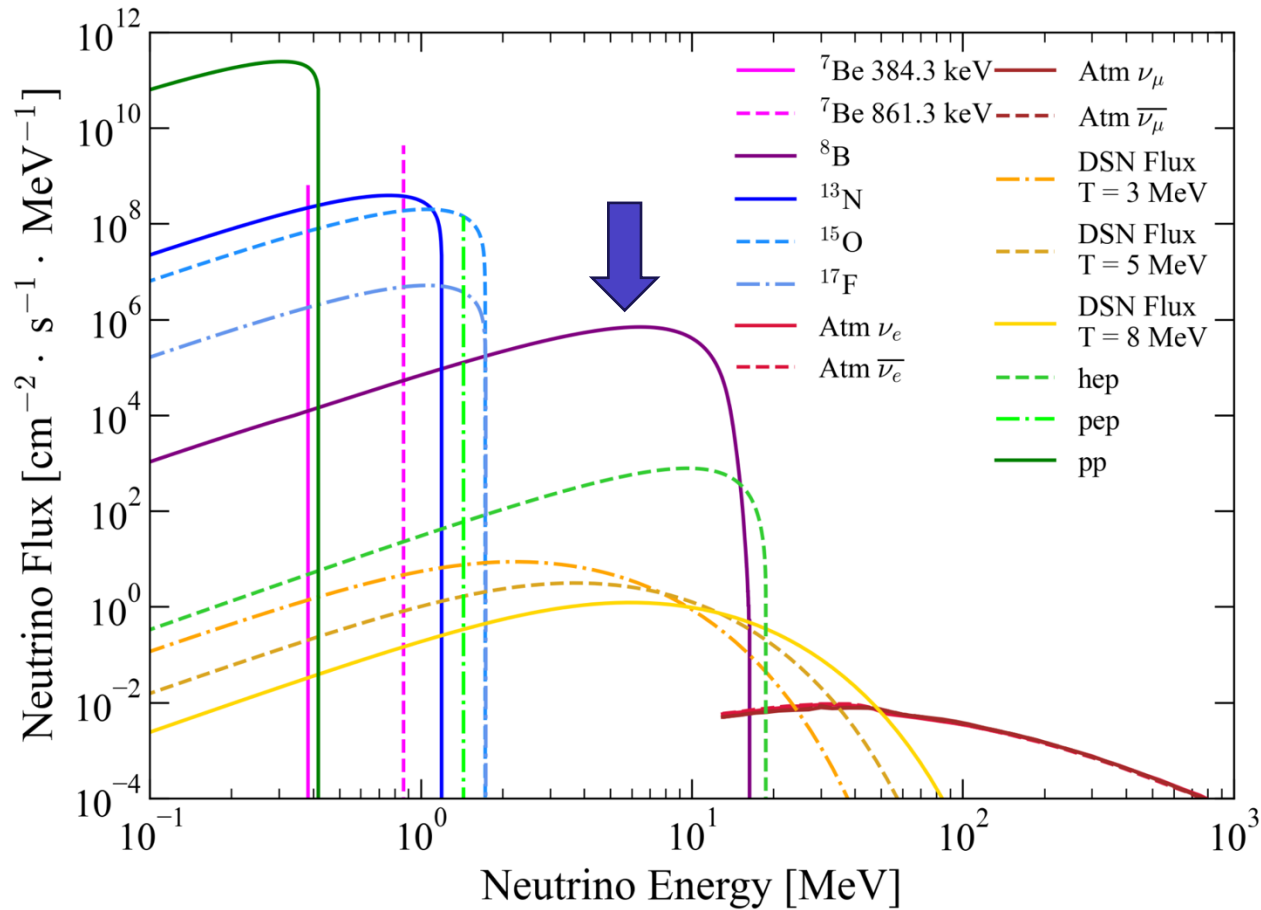


Spin-dependent WIMP-proton scattering



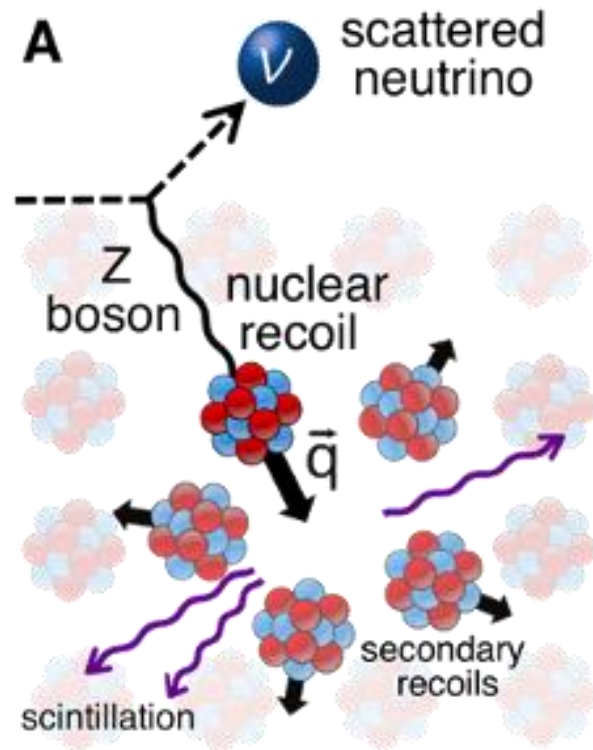
Grey uncertainty band represents uncertainty on Xe form factor

Pushing to lower energies

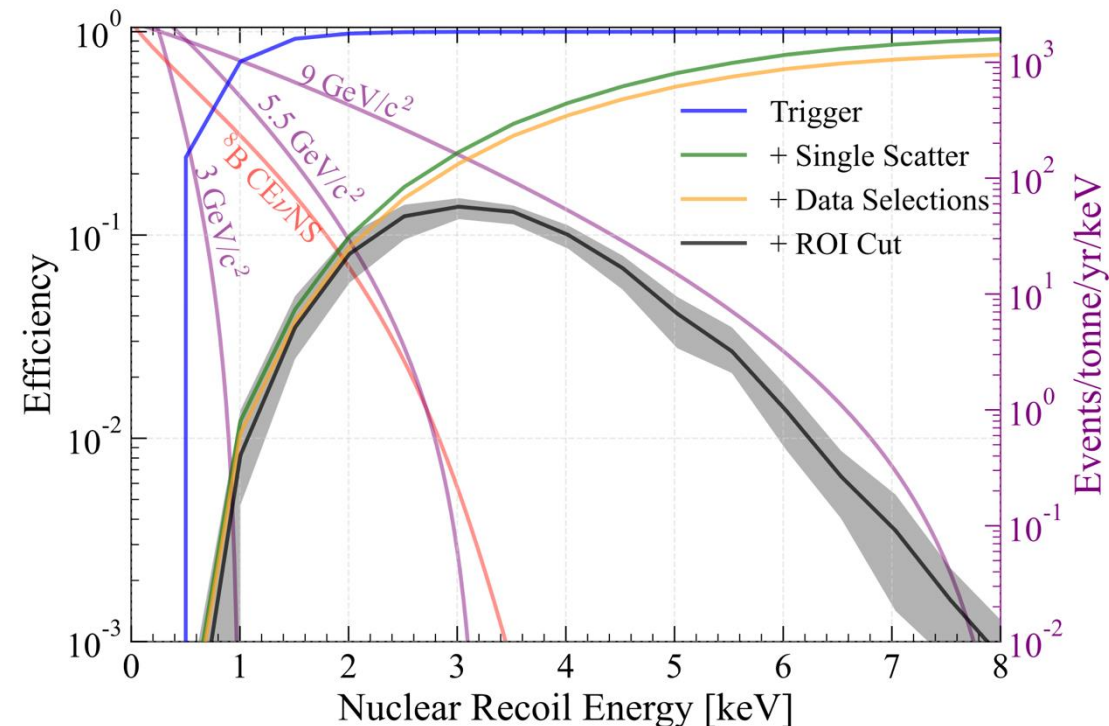


- Pushing analysis to lower energies (1-6 keV) allows for searching for low-mass dark matter
- Additional science: Expect a significant number of Boron-8 solar neutrino $\text{CE}\nu\text{NS}$ interactions in this energy regime
- Previous measurements:
 - 2.64σ by PandaX-4T [*PRL 133, 191001 \(2024\)*](#),
 - 2.73σ by XENONnT [*PRL 133, 191002 \(2024\)*](#)

Solar Neutrinos - CEvNS



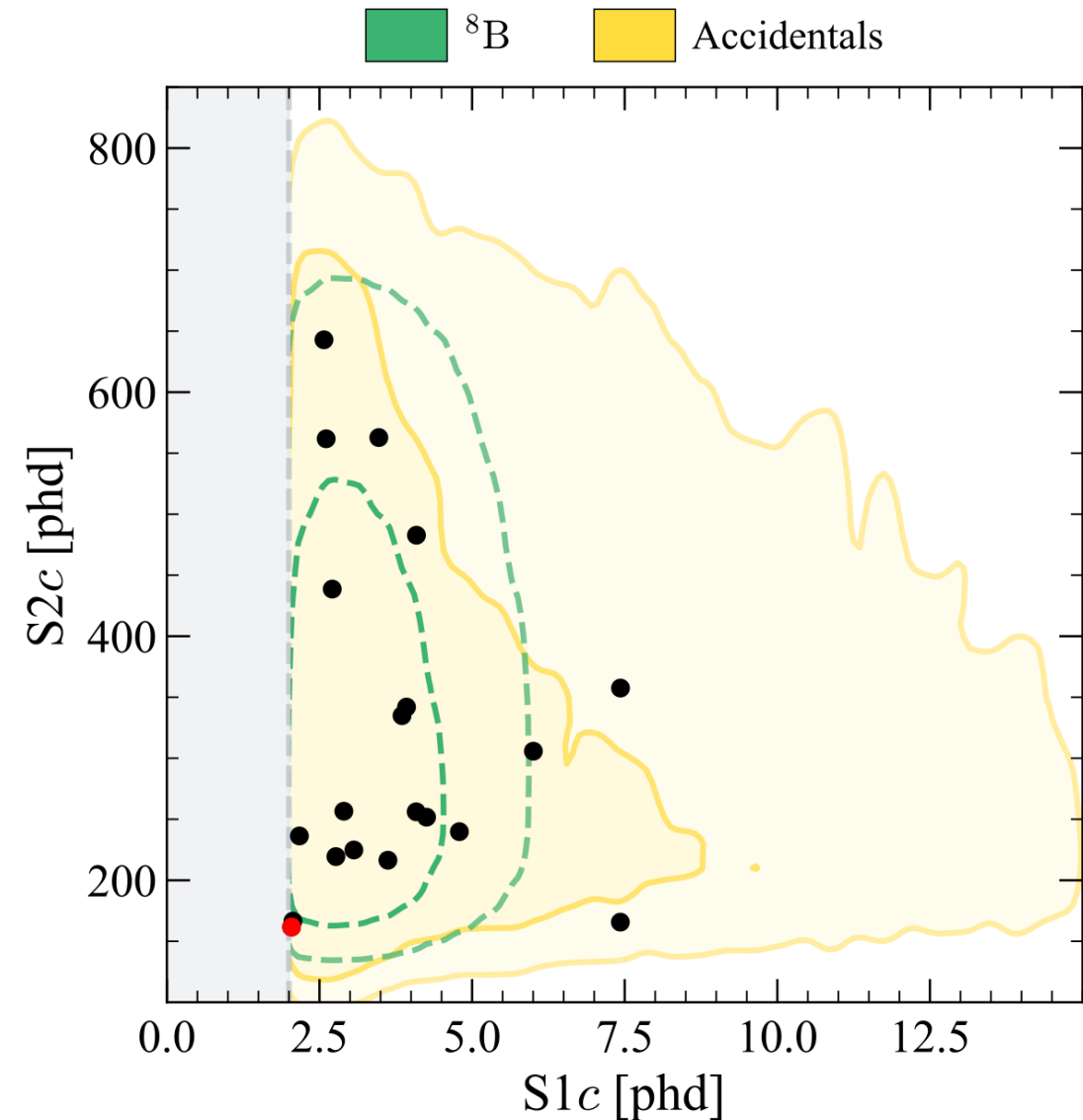
- Coherent neutrino-nucleus scattering
- Well-predicted neutral current SM process
- First measured by COHERENT with a spallation neutron source ([*Science* 357, 6356 \(2017\)](#))



|Boron-8 Search

Data selection

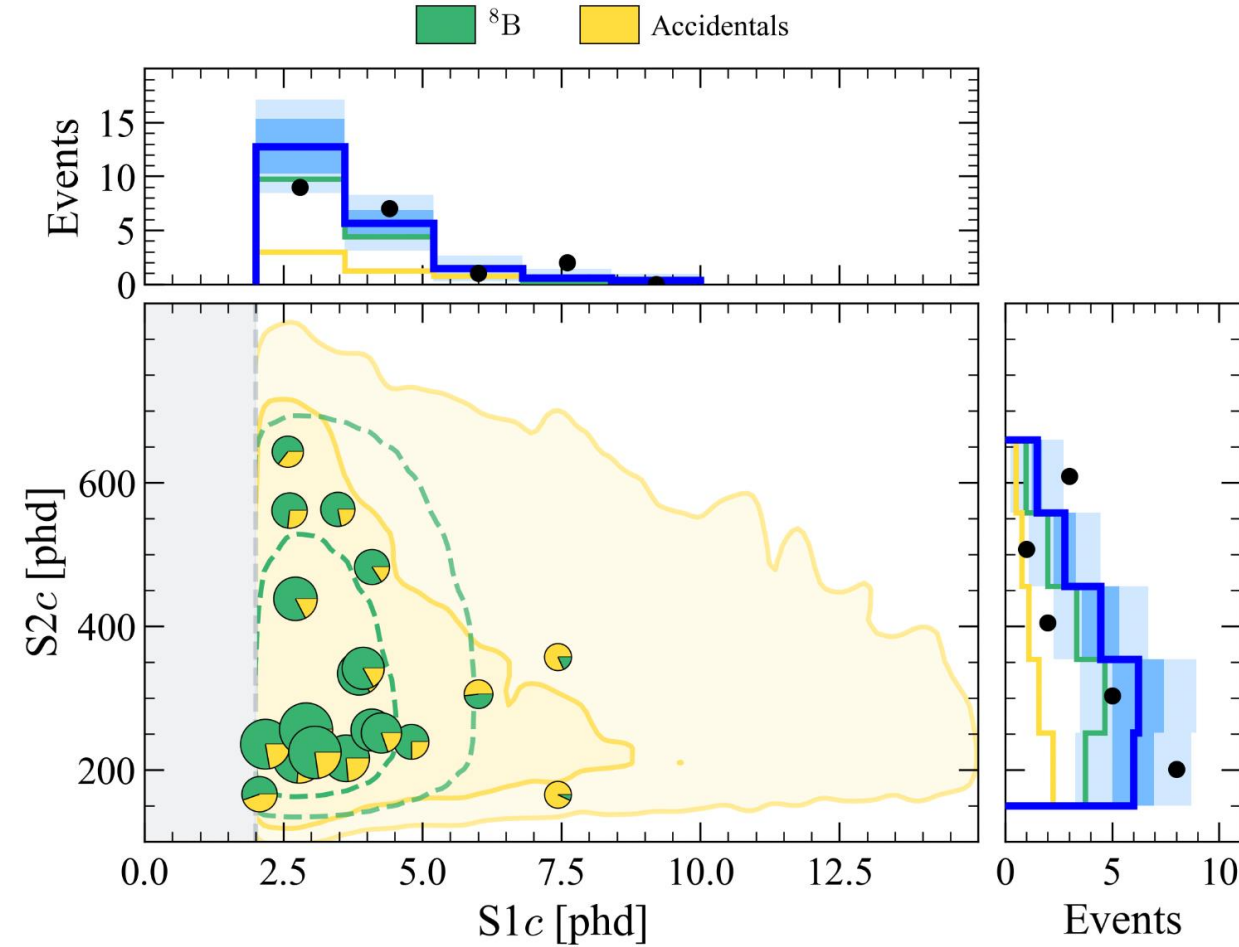
- 20 events in dataset after all selections
 - Red event is salt $\rightarrow$ within expectations [0,4]
- 19 events with which to perform science search
- Sideband dataset of “neutron-rich” data: passing all selections except delayed veto
 - 1 event $\rightarrow$ in-situ constraint for neutrons
 - Neutron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



|Boron-8 Search

Statistical analysis

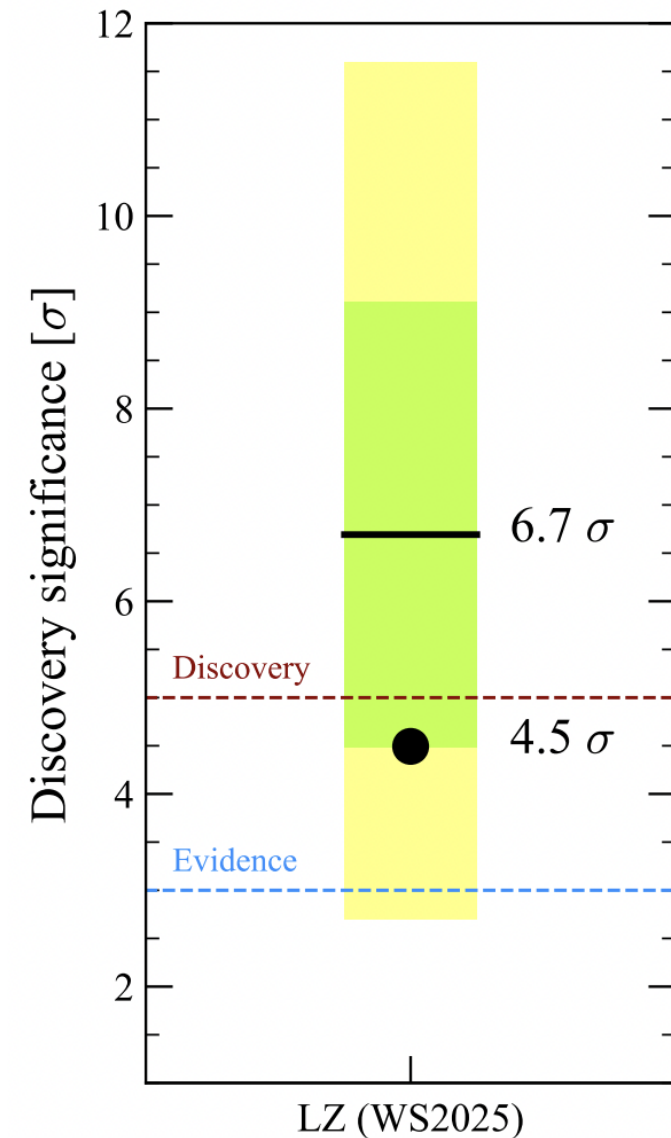
- Search for ^8B CE ν NS events, assuming zero DM events
- ^8B CE ν NS rate is unconstrained, floating freely in fits
- Best-fit number of ^8B CE ν NS events:
 $12.3^{+7.0}_{-5.4}$
- Consistent with prediction of $20.6^{+8.9}_{-6.8}$ events



|Boron-8 Search

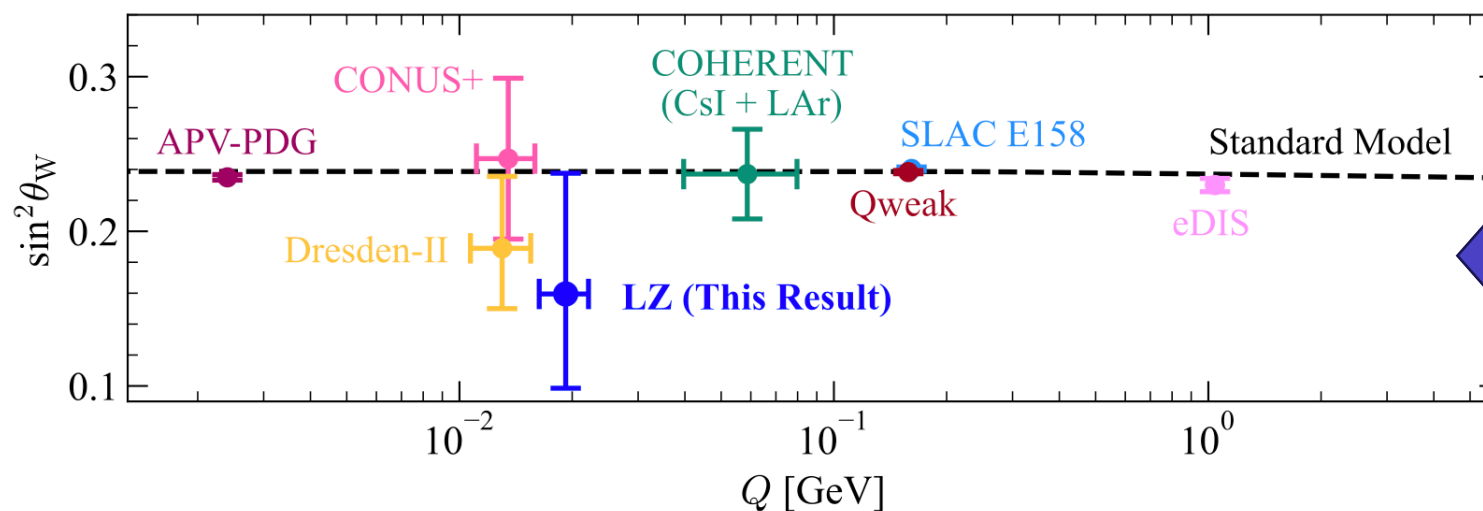
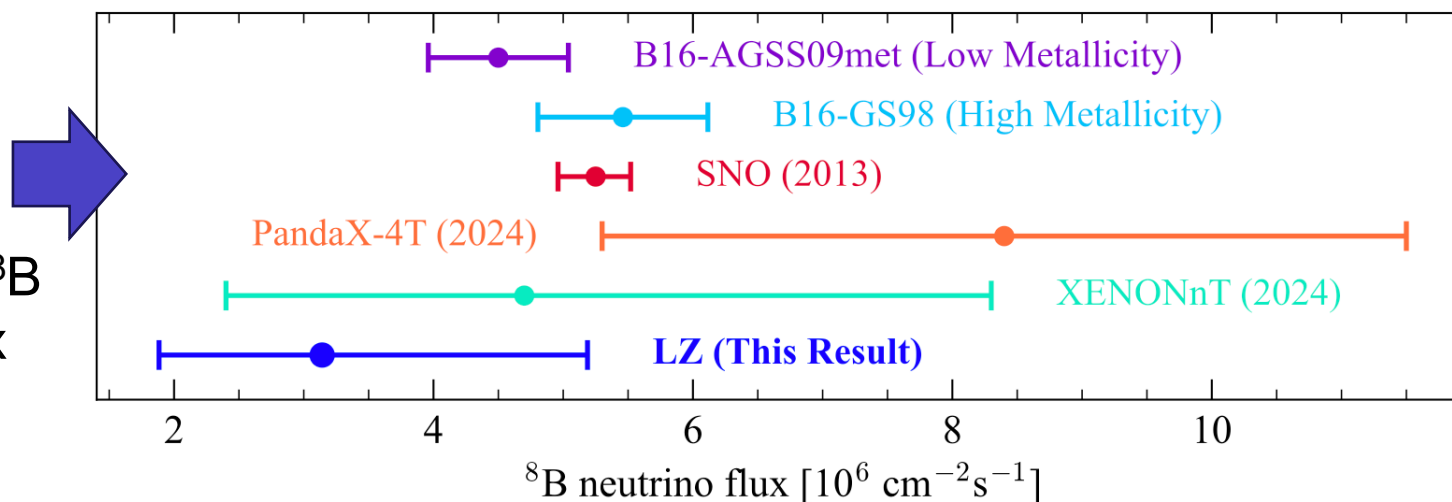
Discovery significance

- Search for ^8B CE ν NS events, assuming zero DM events
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- Best-fit number of ^8B CE ν NS events:
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- Consistent with prediction of $20.6^{+8.9}_{-6.8}$ events



So what?

Flavour
independent
measurement of ^8B
solar neutrino flux

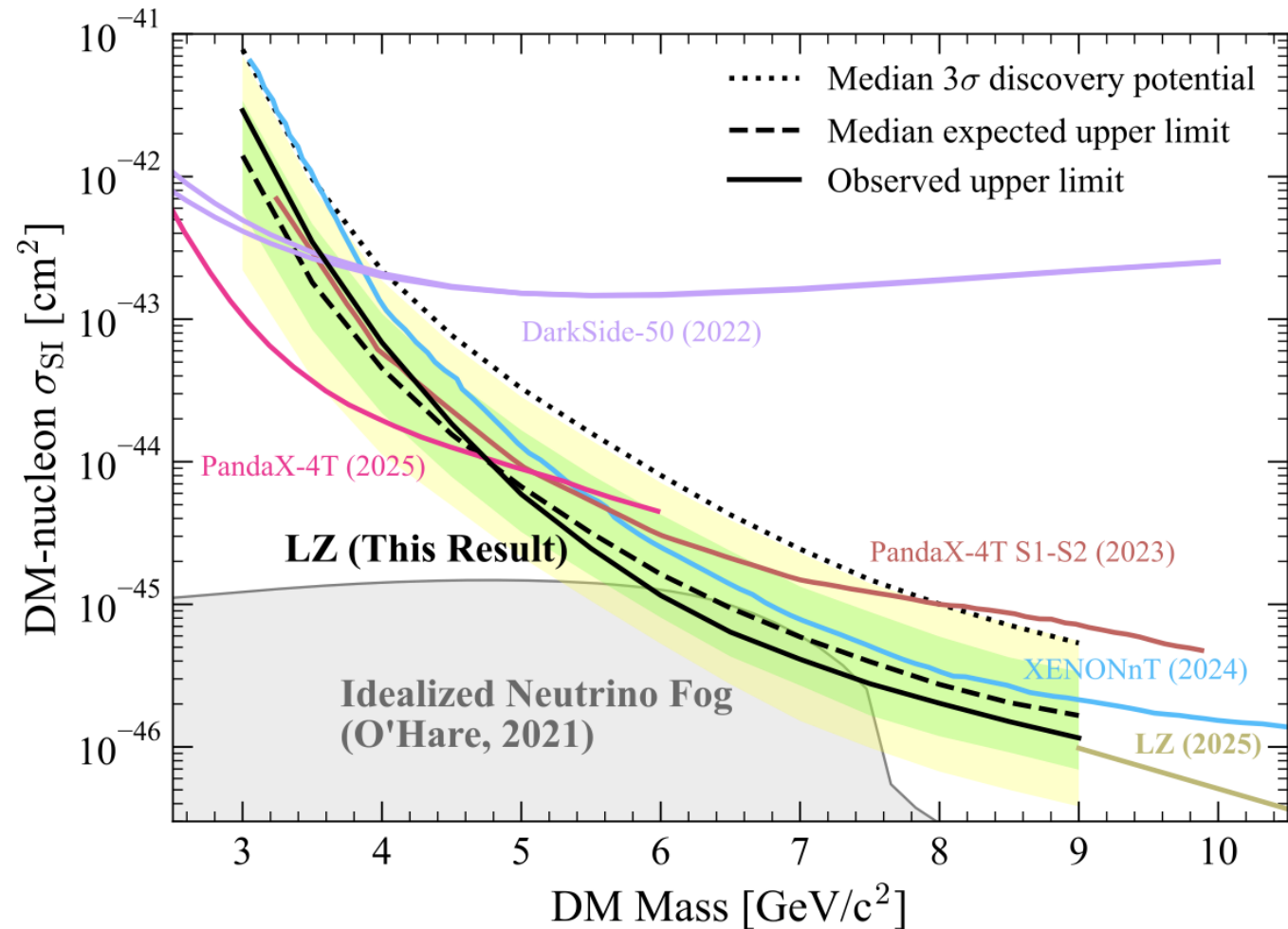


Measure weak-
mixing angle
($\sin^2 \theta_W$) at low
momentum transfer

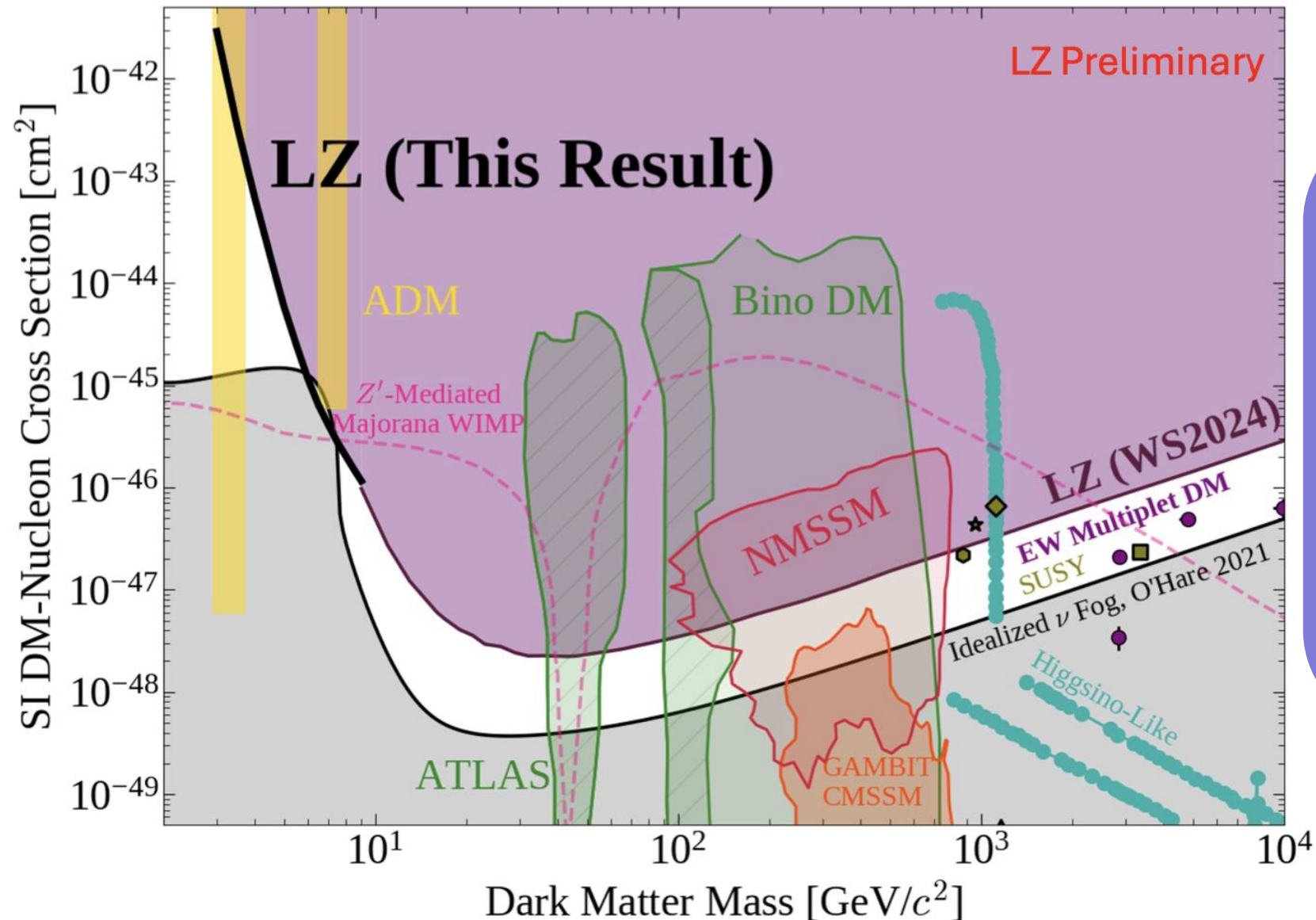
|Low Mass Dark Matter Search

Final result

- ^8B CE ν NS events treated as background
- World-leading spin-independent (SI) DM-nucleon cross-section limits for WIMPs $> 5 \text{ GeV}/c^2$
- Reaching into the neutrino fog



What's next?



- LZ is discovery-ready!
- **Beyond LZ:** planning a next-generation detector with XLZD collaboration
- XLZD Design Book:
EPJC 85: 1192 (2025)



<https://lz.lbl.gov/>

@lzdarkmatter

Low-energy NR

- Cosmic ray-boosted Dark Matter
PRL 134, 241801 (2025)
- WIMP-pion coupling
Commun Phys 7,292 (2024)

Low-energy ER

- Solar axions, ALPs, hidden photons
Phys.Rev.D 108,072006 (2023)
arXiv:2511.17350 (2025)
- Atmospheric millicharge particles
PRL 134, 241802 (2025)
- Electron capture decays
Phys. Rev. D 112, 012024 (2025)

High-energy NR

- Dark matter-nucleon EFT
PRL 133, 221801 (2024)
New results: [paper](#), [slides](#)
- Ultraheavy DM
Phys. Rev. D 109, 112010 (2024)

High-energy ER

Neutrinoless double beta decay searches, etc.