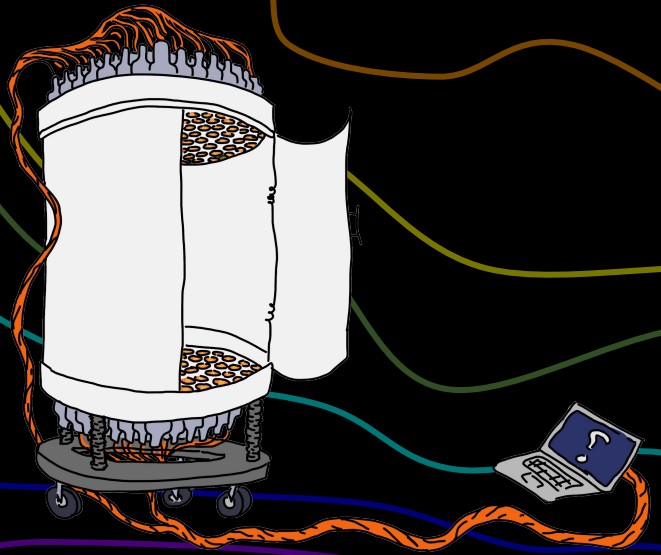
Universität Zürich[UZH]

Radon tagging in LZ



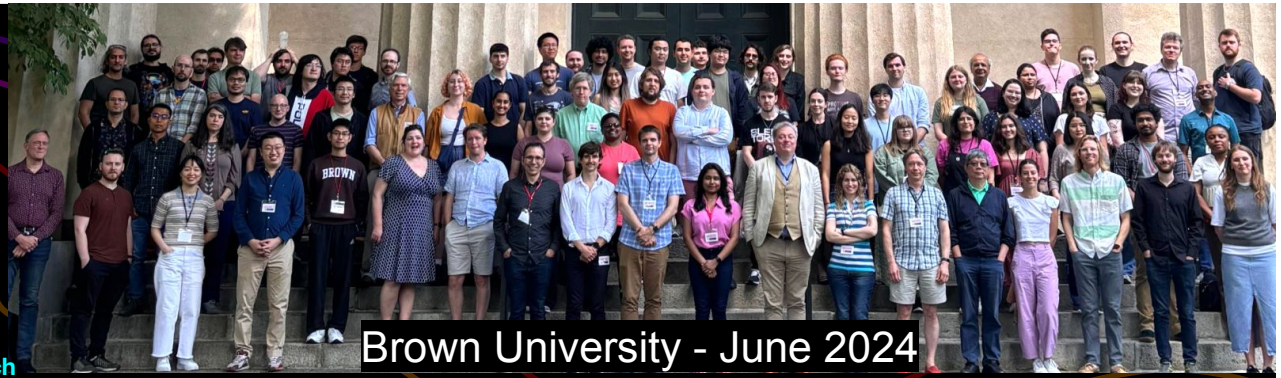
Nicolas Angelides

3rd Nov 2025

America Europe Asia Oceania

- Black Hills State University
- Brandeis University
- Brookhaven National Laboratory
- Brown University
- Fermi National Accelerator Lab.
- Lawrence Berkeley National Lab.
- Lawrence Livermore National Lab.
- Northwestern University
- Pennsylvania State University
- SLAC National Accelerator Lab.
- South Dakota School of Mines & Tech
- South Dakota Science & Technology Authority
- Texas A&M University
- University of Albany, SUNY
- University of Alabama
- University of California Berkeley
- University of California Davis
- University of California Los Angeles
- University of California Santa Barbara
- University of Maryland
- University of Massachusetts, Amherst
- University of Michigan
- University of Rochester
- University of Wisconsin, Madison

- University of Sydney



Brown University - June 2024

- Edinburgh University
- Imperial
- Royal Holloway University of London
- STFC Rutherford Appleton Lab
- University of Bristol
- University College London
- University of Liverpool
- University of Oxford
- University of Sheffield
- University of Zurich
- LIP Coimbra
- Center for UG Phys, Korea

SANFORD UNDERGROUND RESEARCH FACILITY

ibs Institute for Basic Science

Swiss National Science Foundation

FCT Fundação para a Ciência e a Tecnologia MINISTÉRIO DA EDUCAÇÃO E CIÊNCIA

UKRI Science and Technology Facilities Council

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

38 Institutions, 250+ scientists, engineers, and technical staff

The LZ experiment

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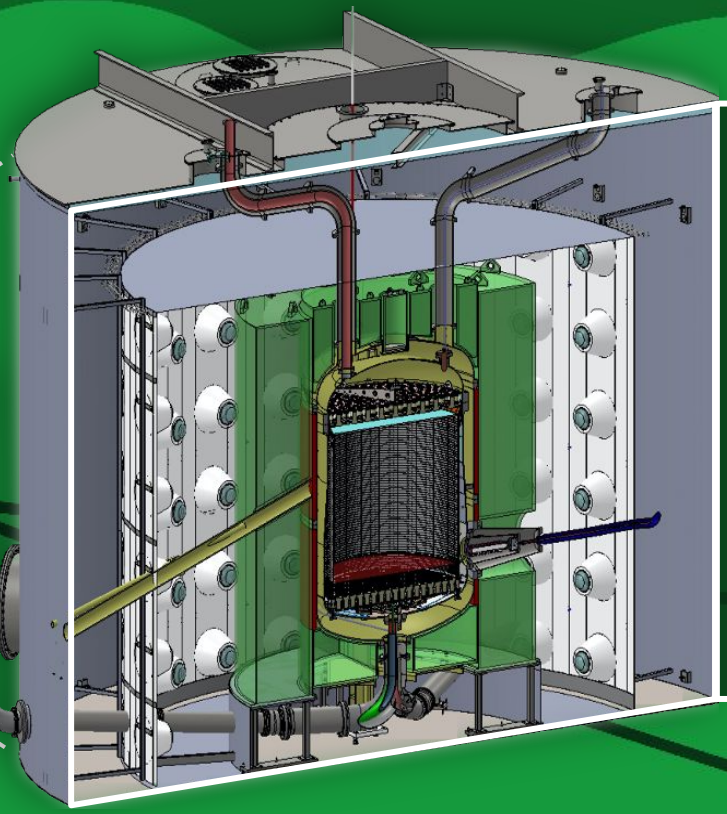
SURF
Lead, SD

↑
4850 ft.
(1.48 km)
below
ground
↓

↑
Operating
in the
Davis
Cavern



Multi-detector system:

LXe TPC
-7 tonnes of LXe in active mass
-1.5 m tall and wide

LXe Skin
-2 tonne LXe, optically isolated
-Anticoincidence - mostly γ-rays

Outer detector (OD)
-17 tonne GD-loaded liquid scintillator
-Anticoincidence - mostly neutrons

← New neighbors

Time Projection Chamber

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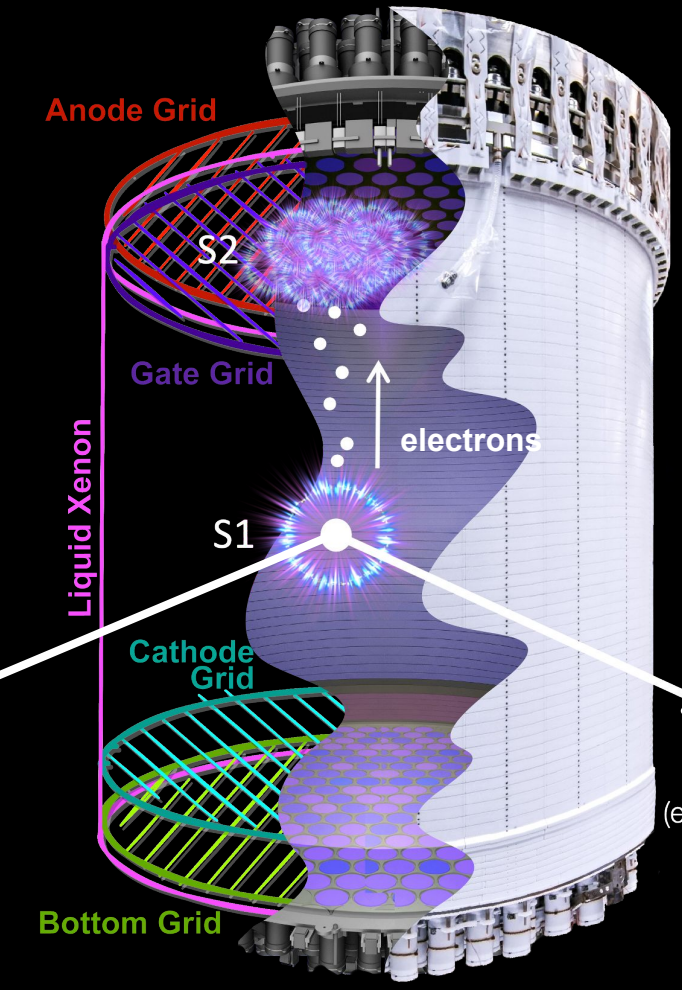
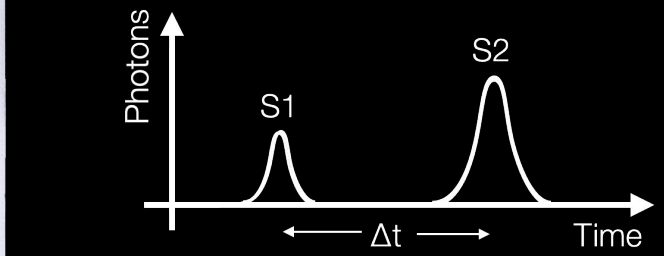




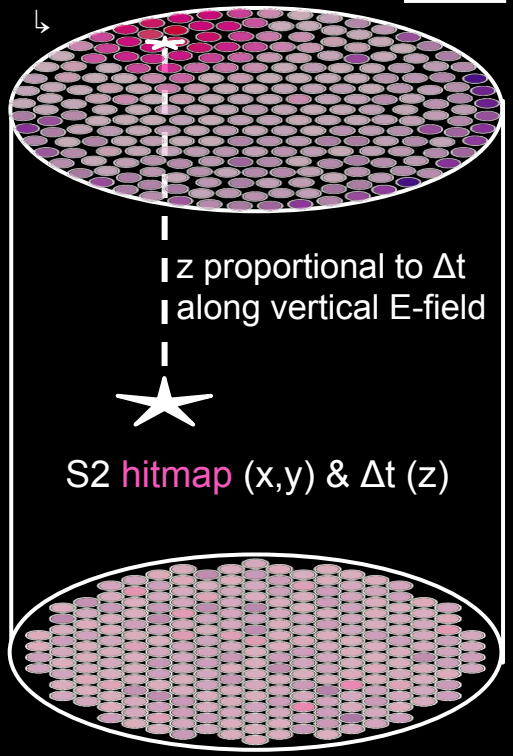
Primary Scintillation

Secondary Scintillation

Recoil (energy deposit)

Drifting Electrons

Top Photomultiplier (PMT) array



Bottom PMT array →

Discrimination & Calibration

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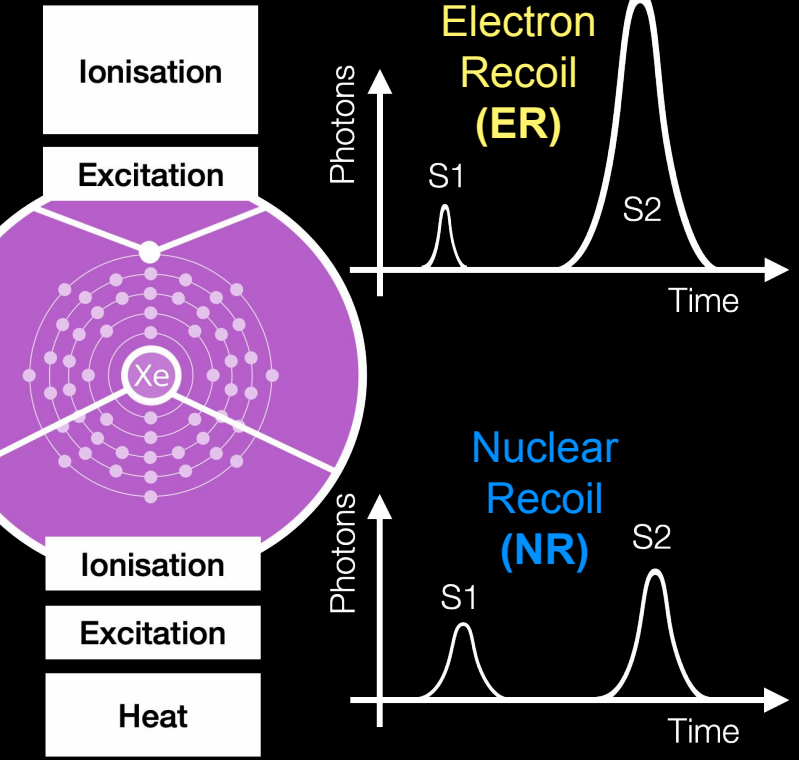
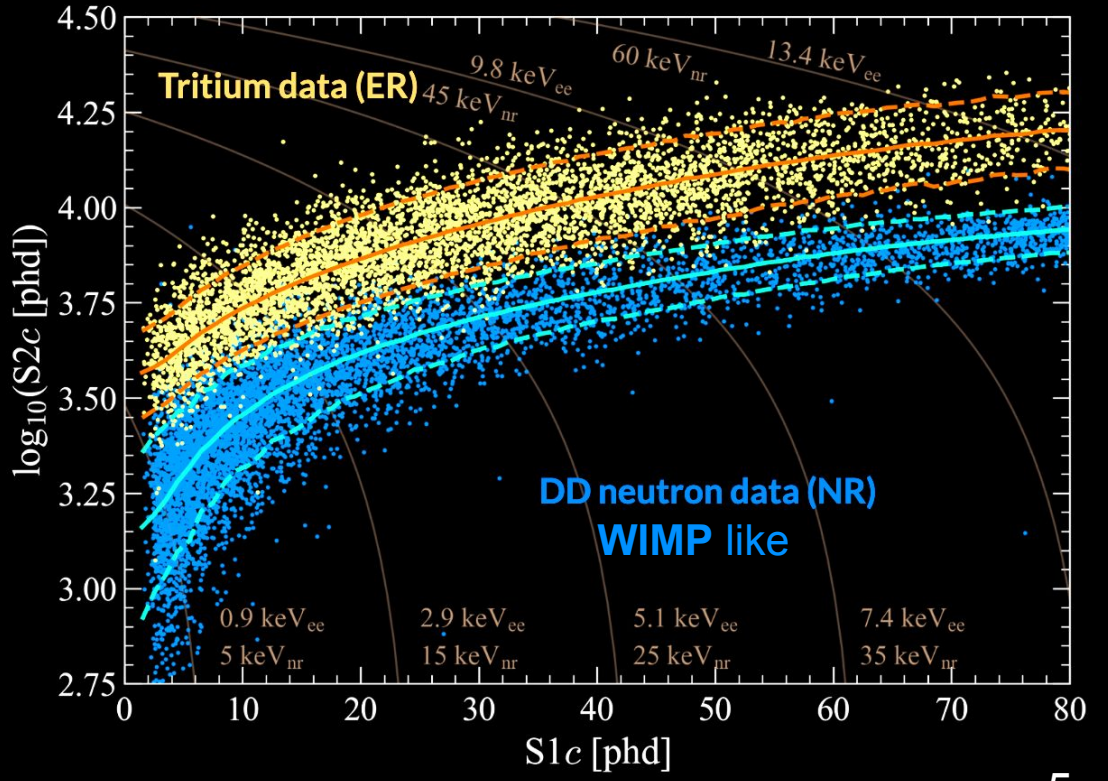
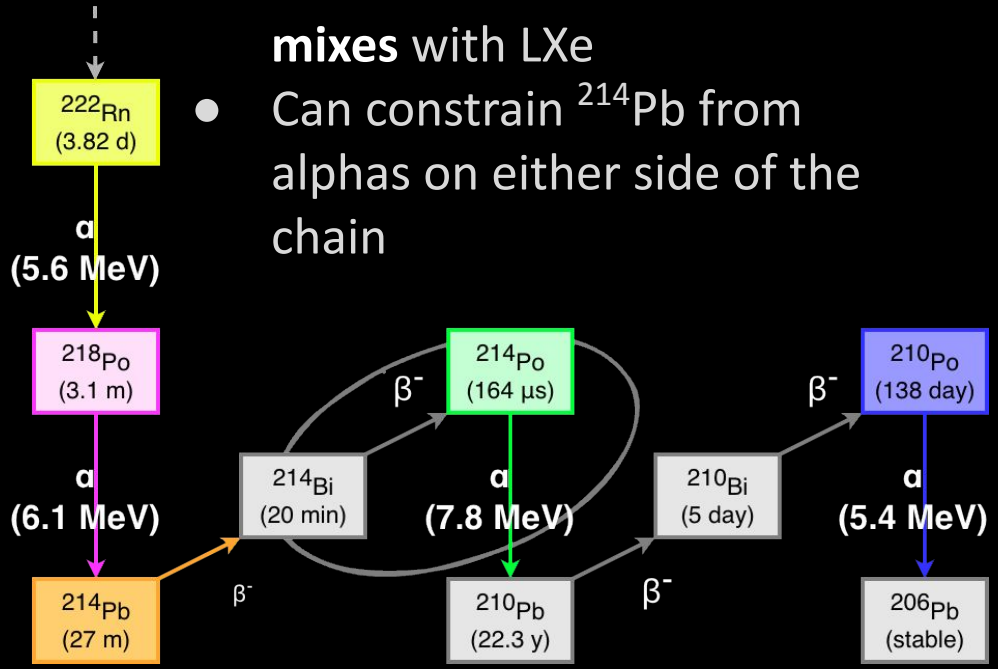




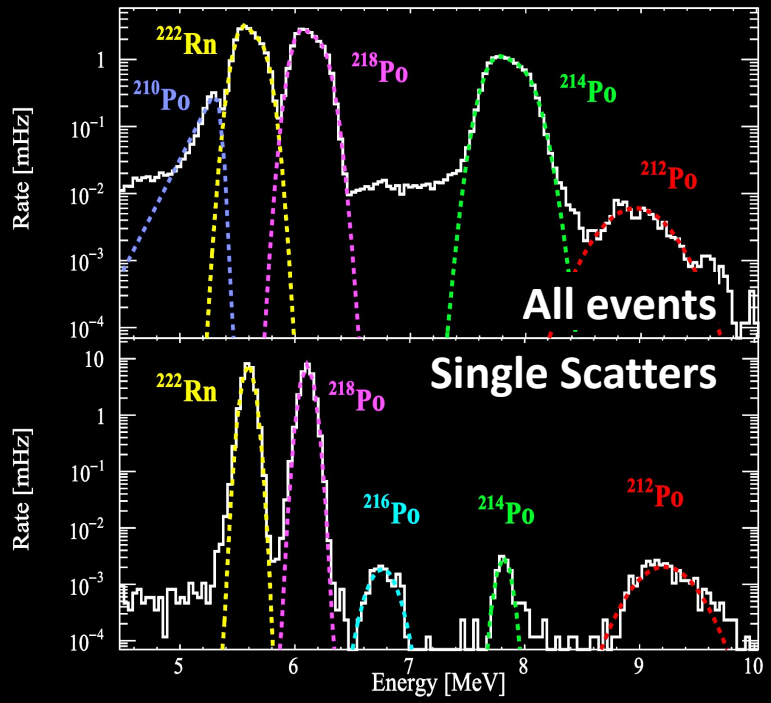
PhysRevLett.131.041002

The problem with Radon

- **Emanates** from material and **mixes** with LXe
- Can constrain ^{214}Pb from alphas on either side of the chain

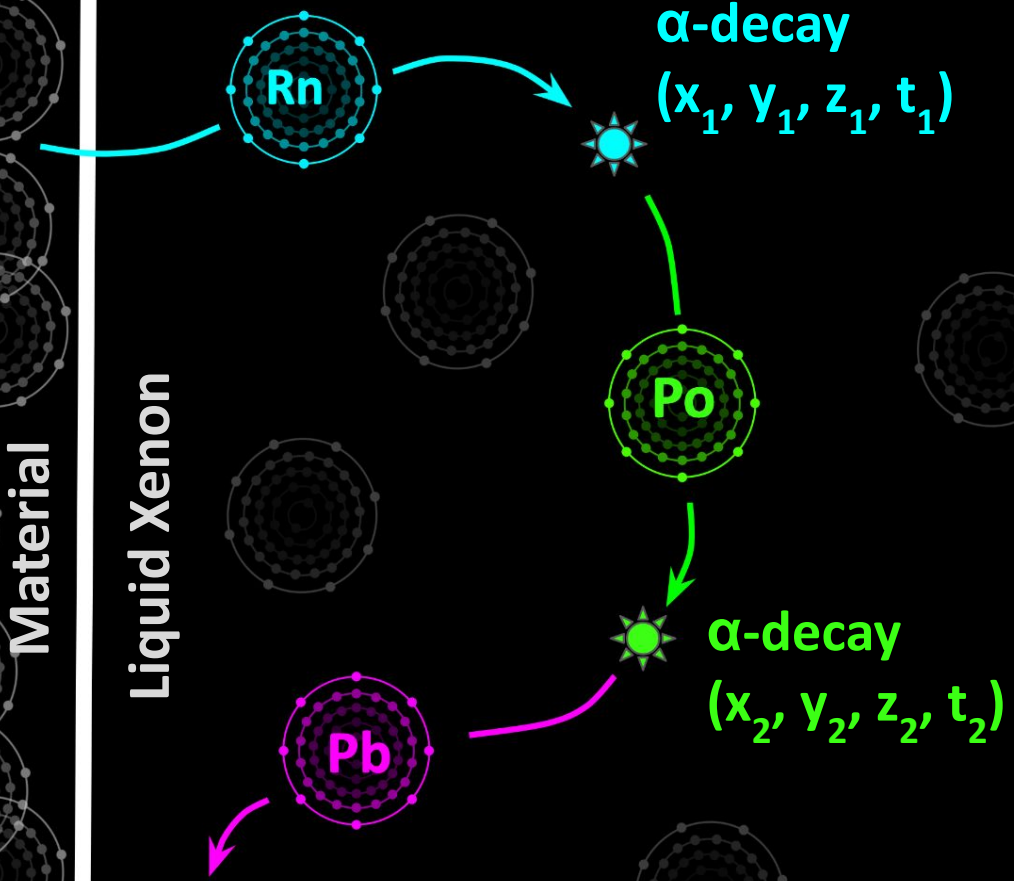


Phys. Rev. D 108, 012010 (2023)



β-decay with **11% naked** branch (no accompanying gamma) resulting in **low energy recoils -> (70% of ER BGs)**

The idea…



^{218}Po with half-life 186 s decays in **close succession and proximity** with parent, both with **large signals**

What if we could follow it?

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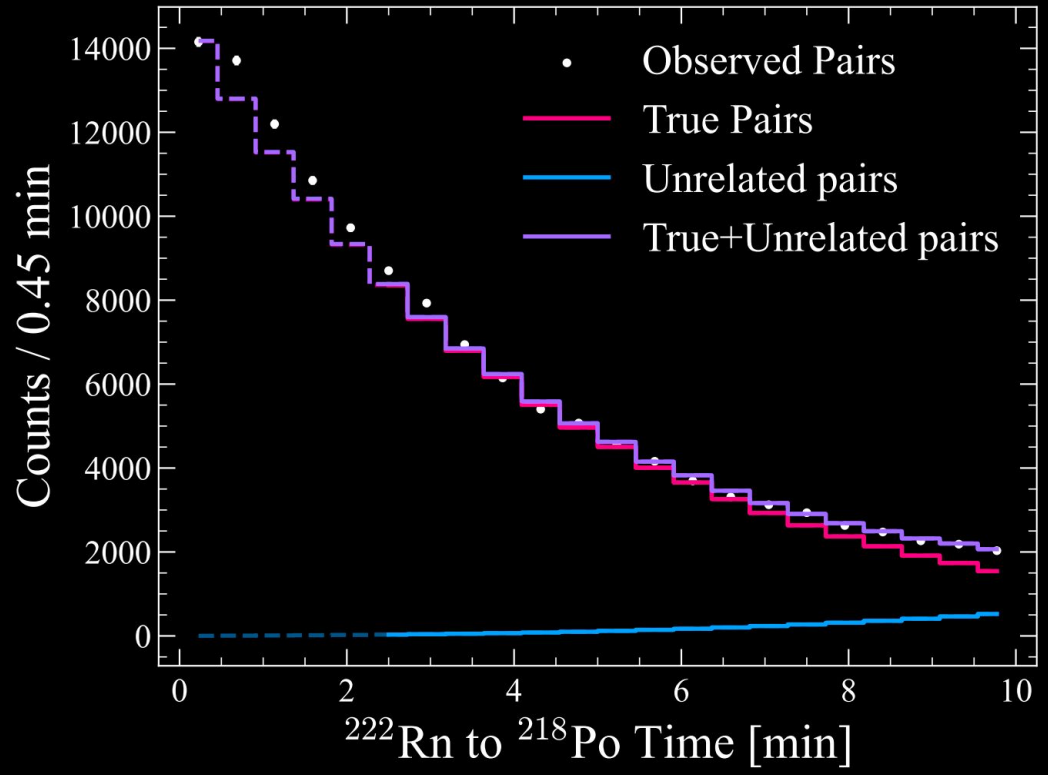

^{222}Rn-^{218}Po decay **'pairs'** can be formed from LZ data

Results in thousands of **single atom displacement vectors**

arxiv.2508.19117 (PRD review)

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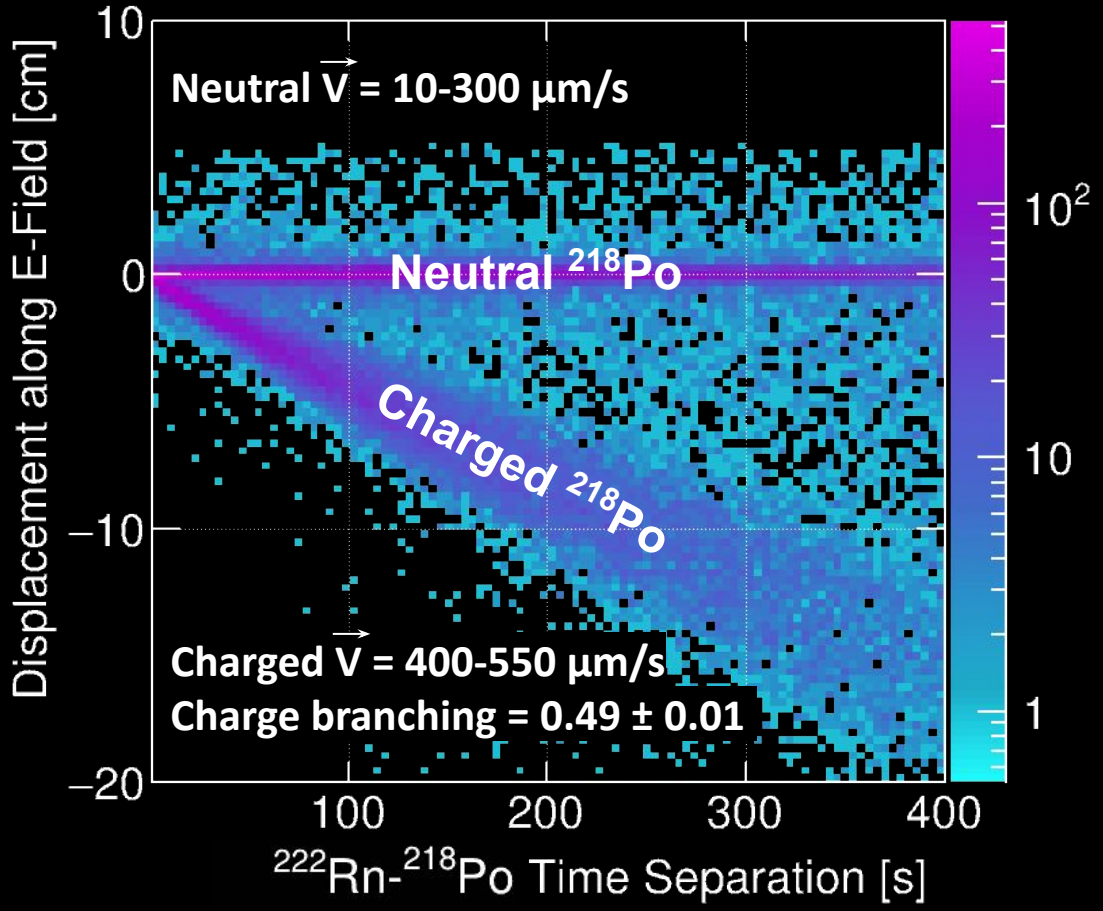
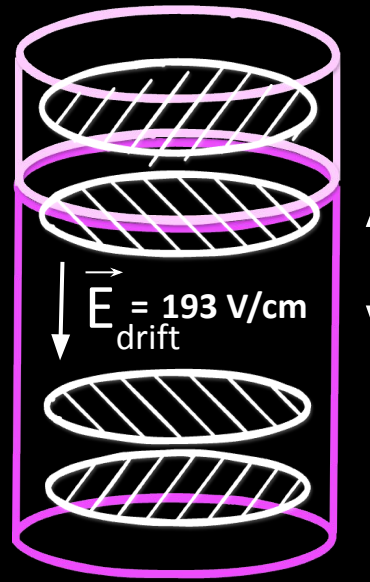
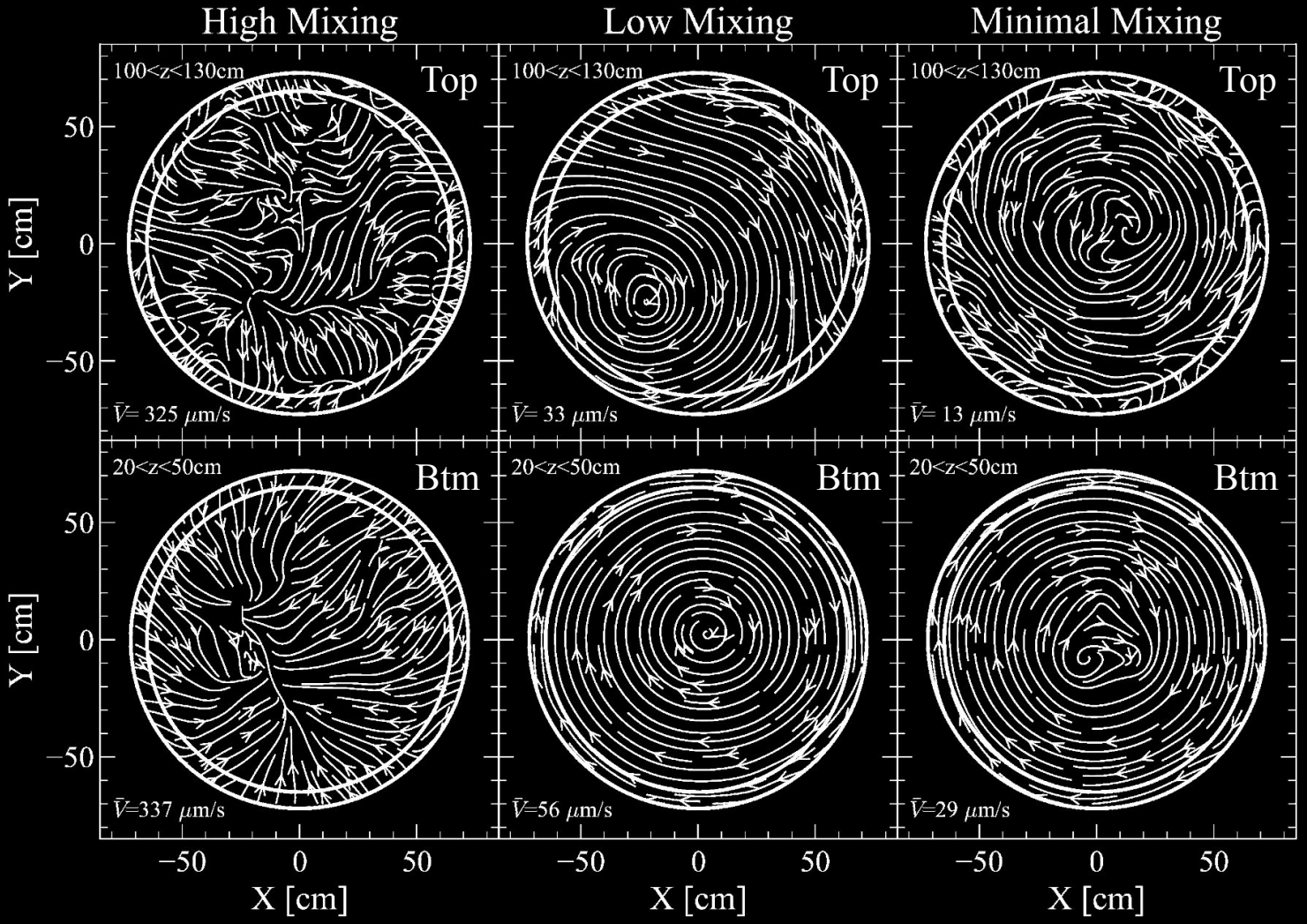




Field from first science run

Neutral ^{218}Po follow the **liquid flow**

Charged ^{218}Po are also swept by the **field**



arxiv.2508.19117 (PRD review)

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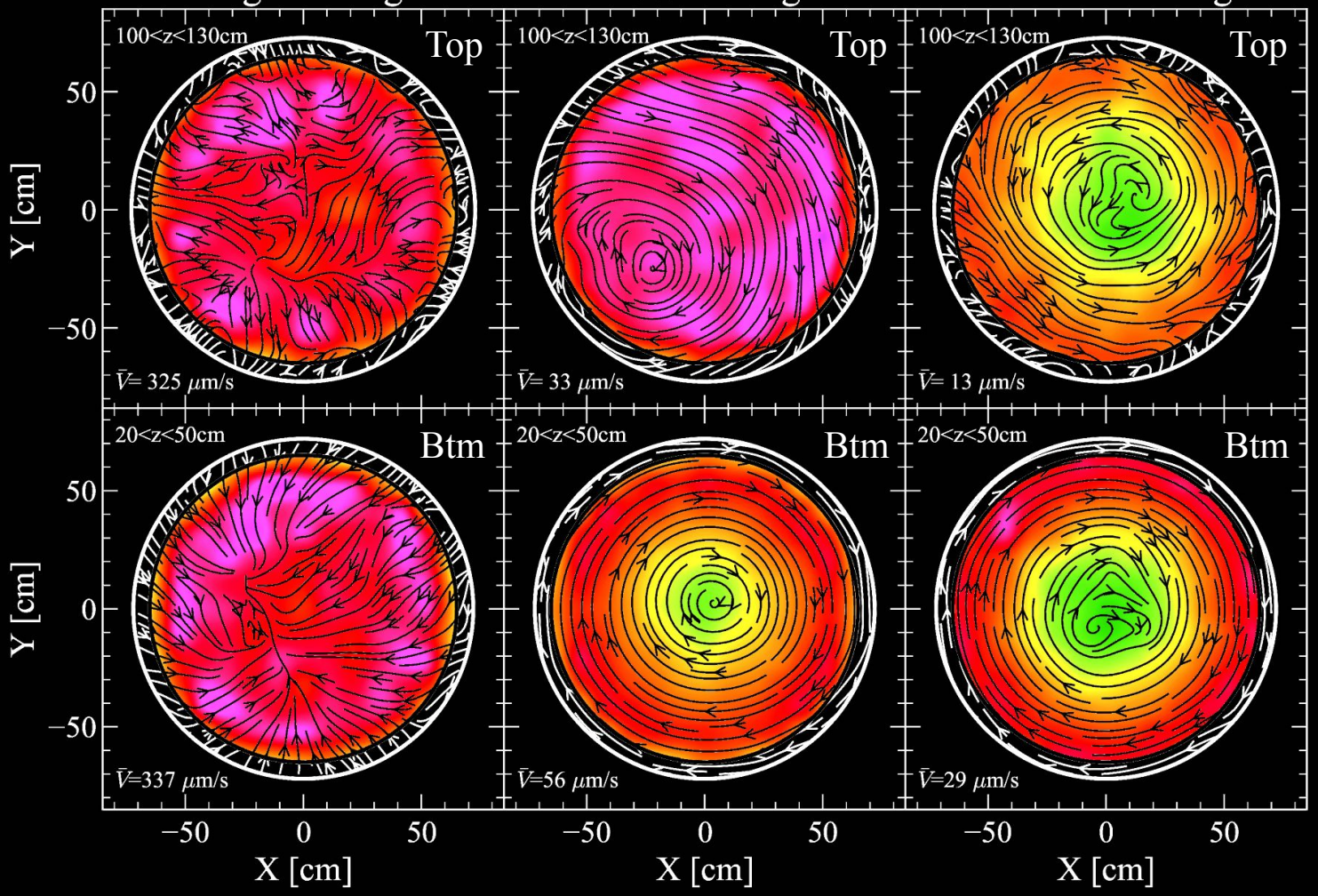
Neutral ^{218}Po pair tables **map the flow of LXe**



arxiv:2508.19117 (PRD review)

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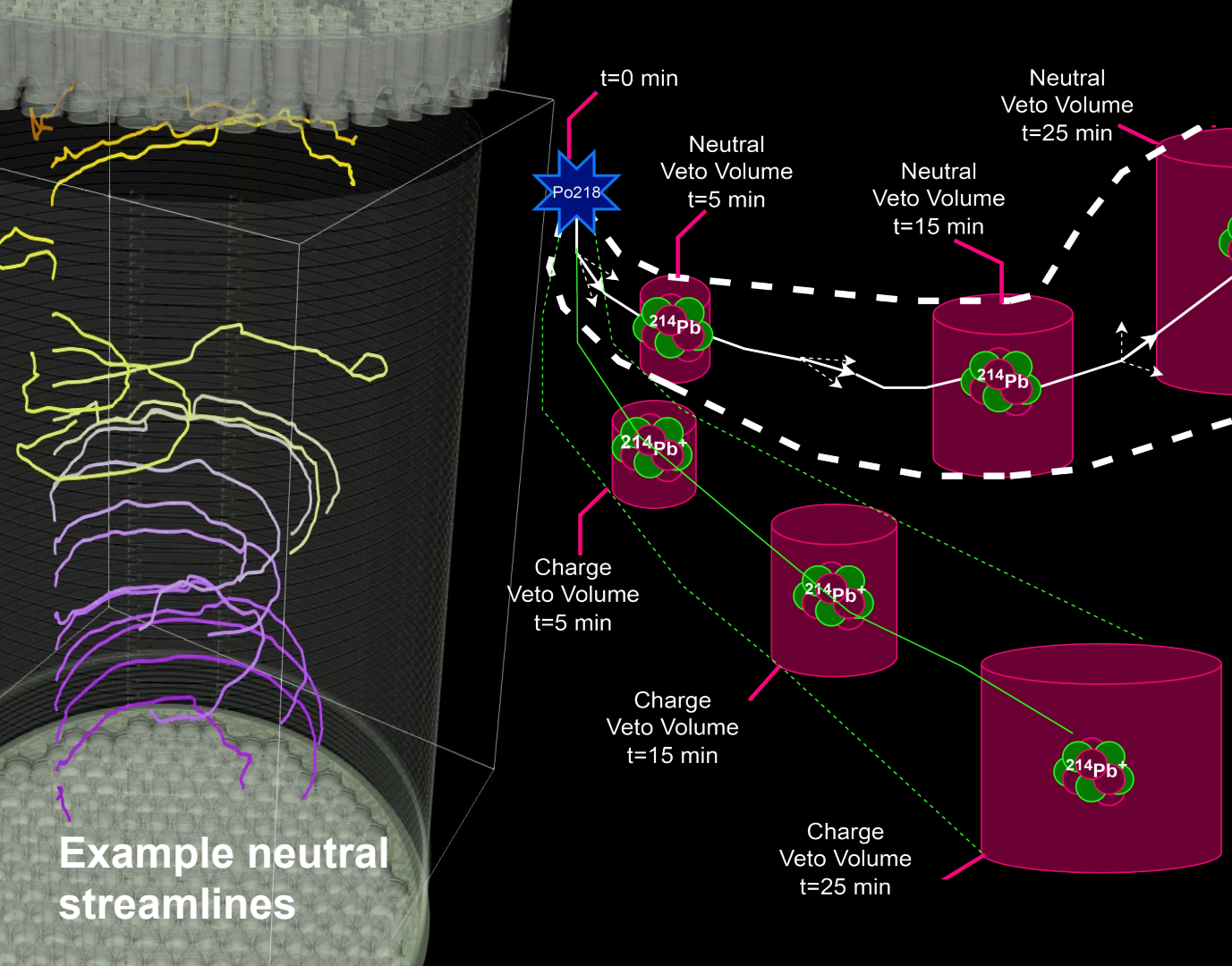

Starting at each ^{218}Po ^{214}**Pb**

Cylindrical tagging volumes follow a streamline for **neutral** and **charged** trajectories in LXe

Example neutral streamlines

^{214}Pb tag volume tuned with ^{218}Po-^{214}Po pairs

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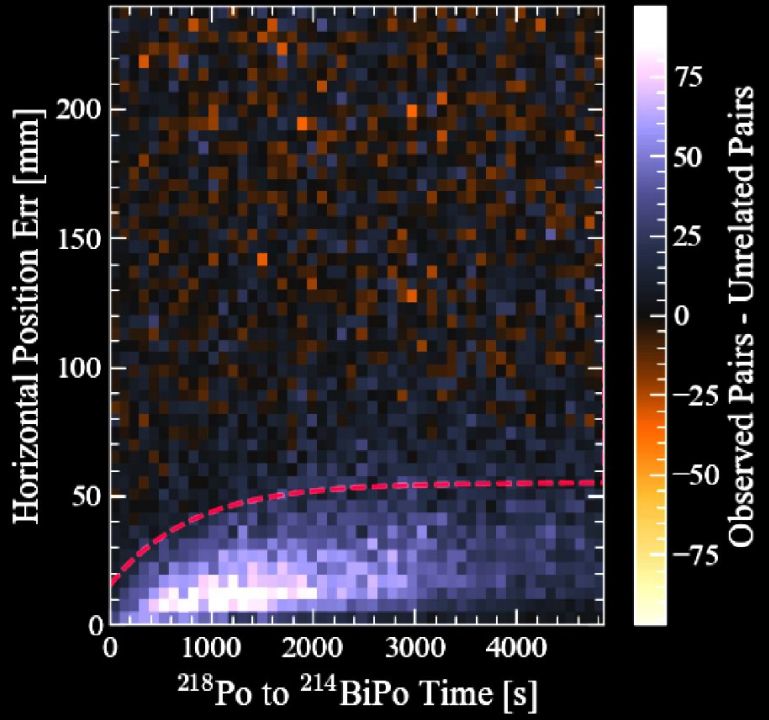

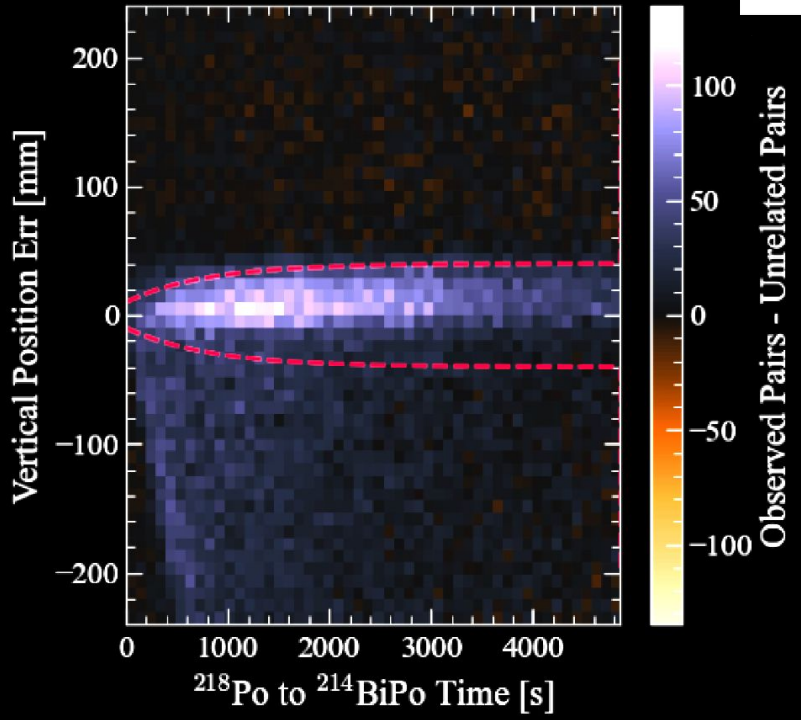

arxiv:2508.19117 (PRD review)

Validated through **unrelated pairs (shifted in time)**

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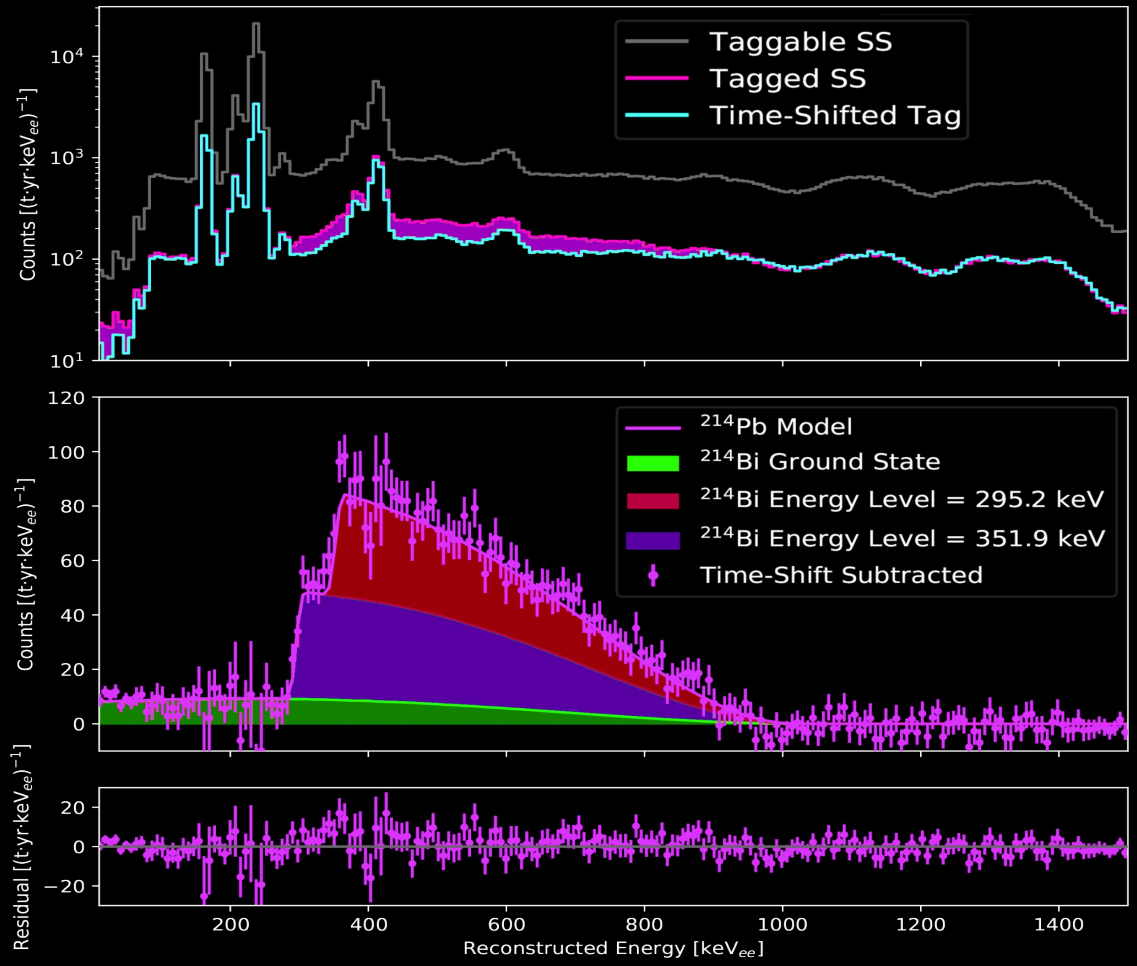


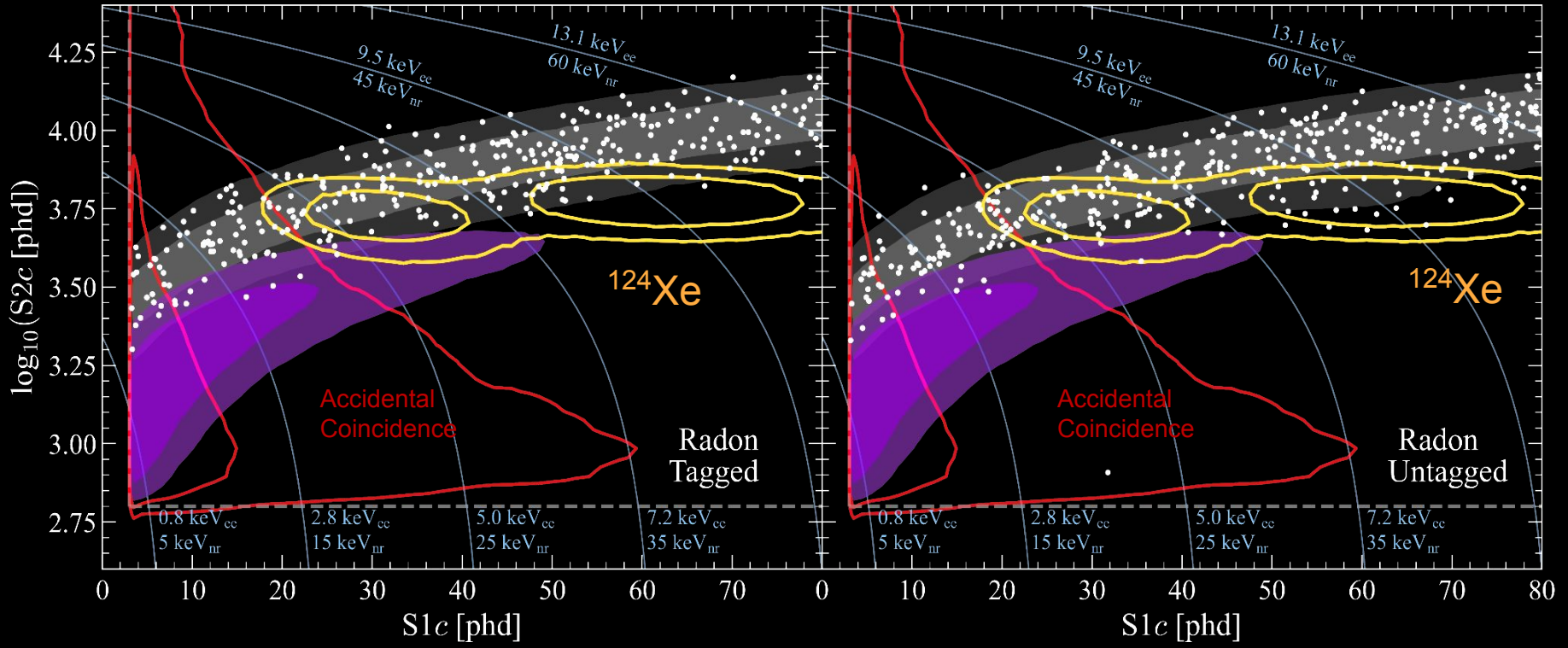
arxiv.2508.19117 (PRD review)

Tag **efficiency of (63 ± 6$_{stat}$ ± 7$_{sys}$)%,** through fit of tagged against ‘time-shifted tag’ events

(at a flat cost of ~**9% exposure**)

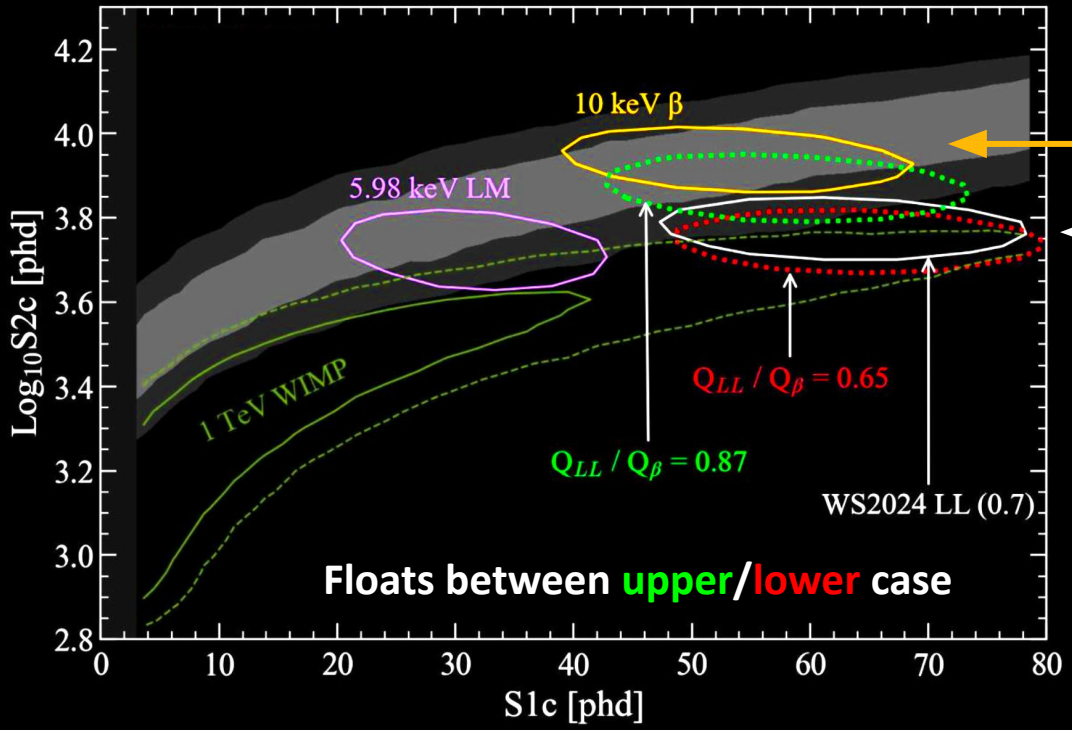
Applying tag to 2024 result for **simultaneous fit**

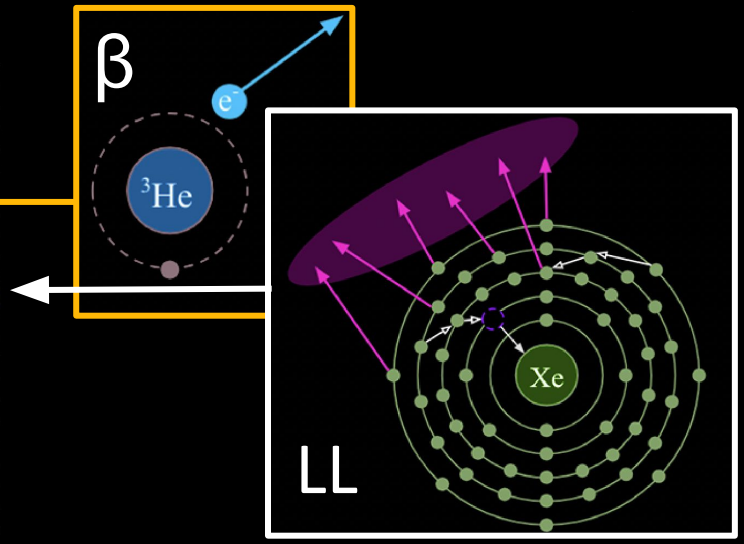
WS2024: 4.2 tonne-year exposure



Phys. Rev. Lett. 135, 011802

Enhanced recombination yield in ^{124}Xe double EC





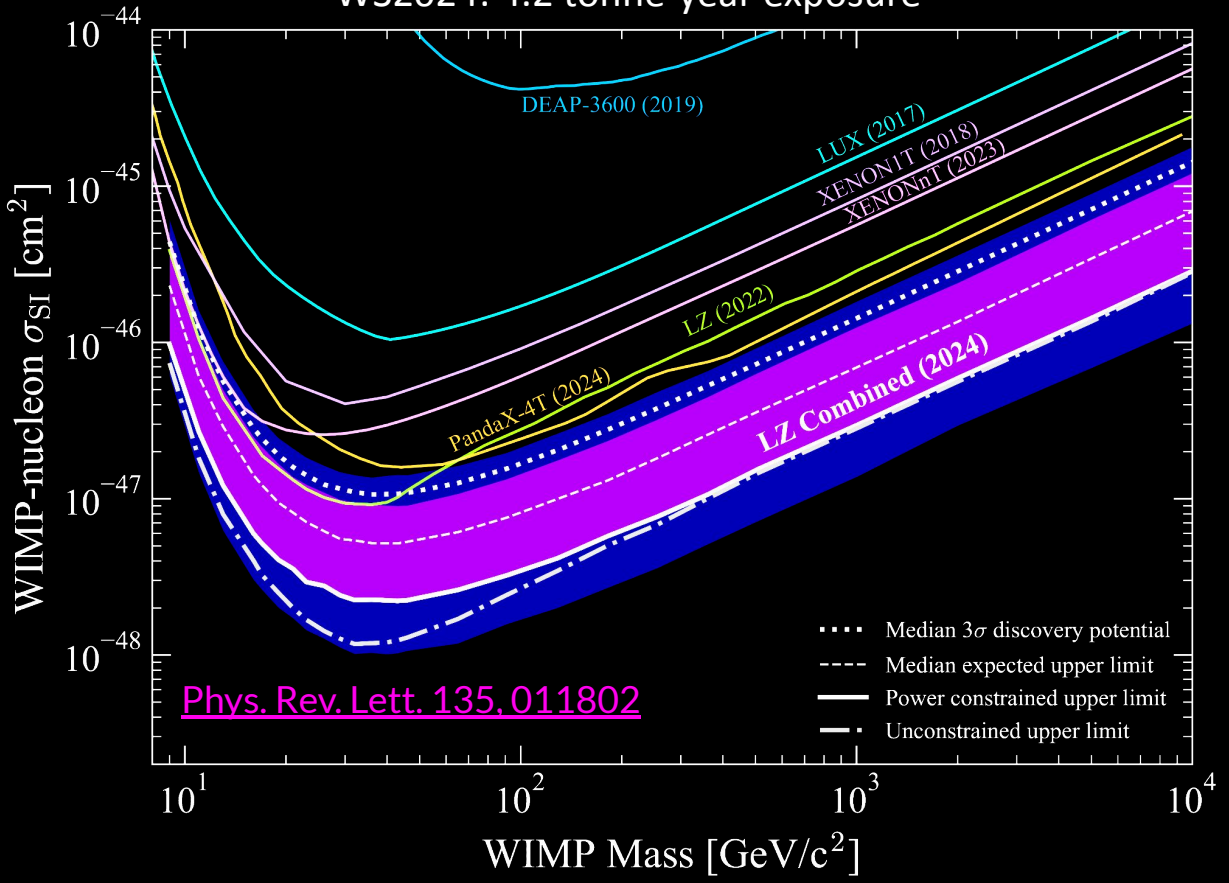
Best fit:

$Q^{LL} / Q^{\beta} = 0.70 \pm 0.04$

PRD 112, 012024

90% CL upper limit for Spin Independent WIMP-nucleon scattering

WS2024: 4.2 tonne-year exposure



Phys. Rev. Lett. 135, 011802

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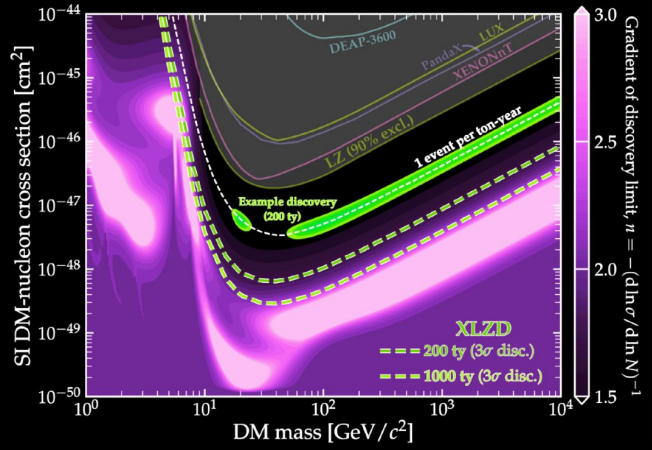
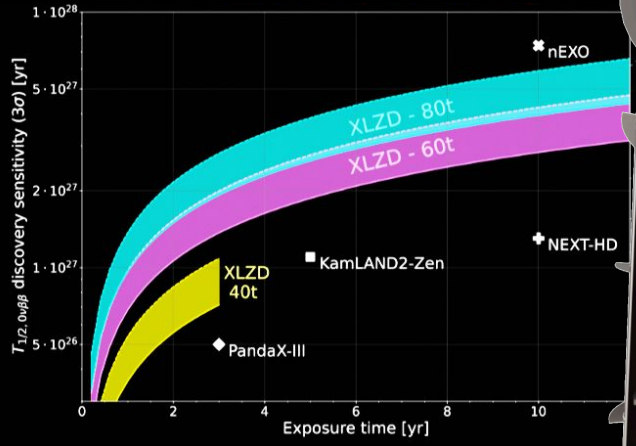
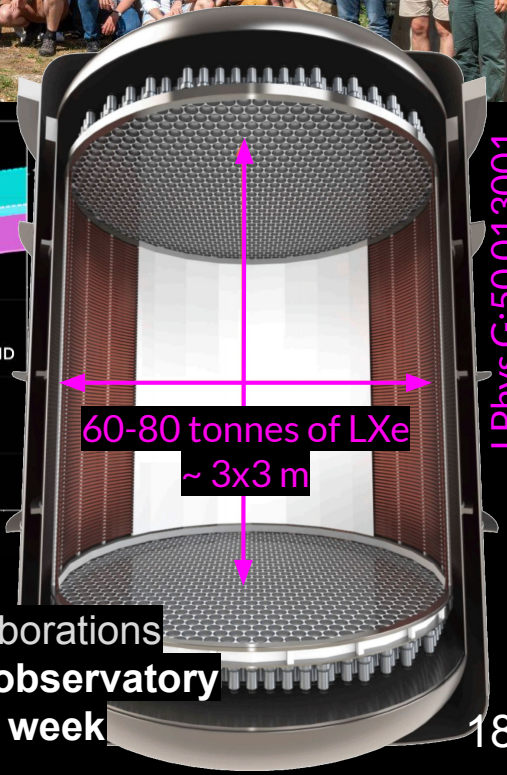
Beyond LZ

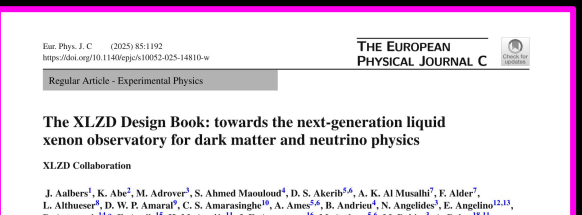
XLZD Collaboration meeting at LNGS, 2025







J.Phys.G:50.013001



Eur. Phys. J. C (2025) 85:1192
https://doi.org/10.1140/epjc/s10052-025-14810-w

THE EUROPEAN PHYSICAL JOURNAL C

Regular Article - Experimental Physics

The XLZD Design Book: towards the next-generation liquid xenon observatory for dark matter and neutrino physics

XLZD Collaboration

J. Aalbers[1], K. Abe[2], M. Adrover[3], S. Ahmed Maouloud[4], D. S. Akerib[5,6], A. K. Al Musalhi[7], F. Alder[7], L. Althueser[8], D. W. P. Amaral[9], C. S. Amarasinghe[10], A. Ames[5,6], B. Andrieu[4], N. Angelides[3], E. Angelino[12,13],

- XLZD = XENON + LZ + DARWIN collaborations
- Aim to build the **definitive rare event observatory**
- **Design book published in EPJC last week**

Summary:

- LZ **LXe flow mapped** using α-decays
- **(63 ± 6$_{stat}$ ± 7$_{sys}$)%** ^{214}Pb tagged, at ~9% exposure cost
- **Simultaneous fit** for Tagged/untagged sets

Innovation:

- ~10 cm precision in LXe flow after ~80 mins
- Reducing irreducible internal backgrounds
- Contemporaneous calibration sideband

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Back-up

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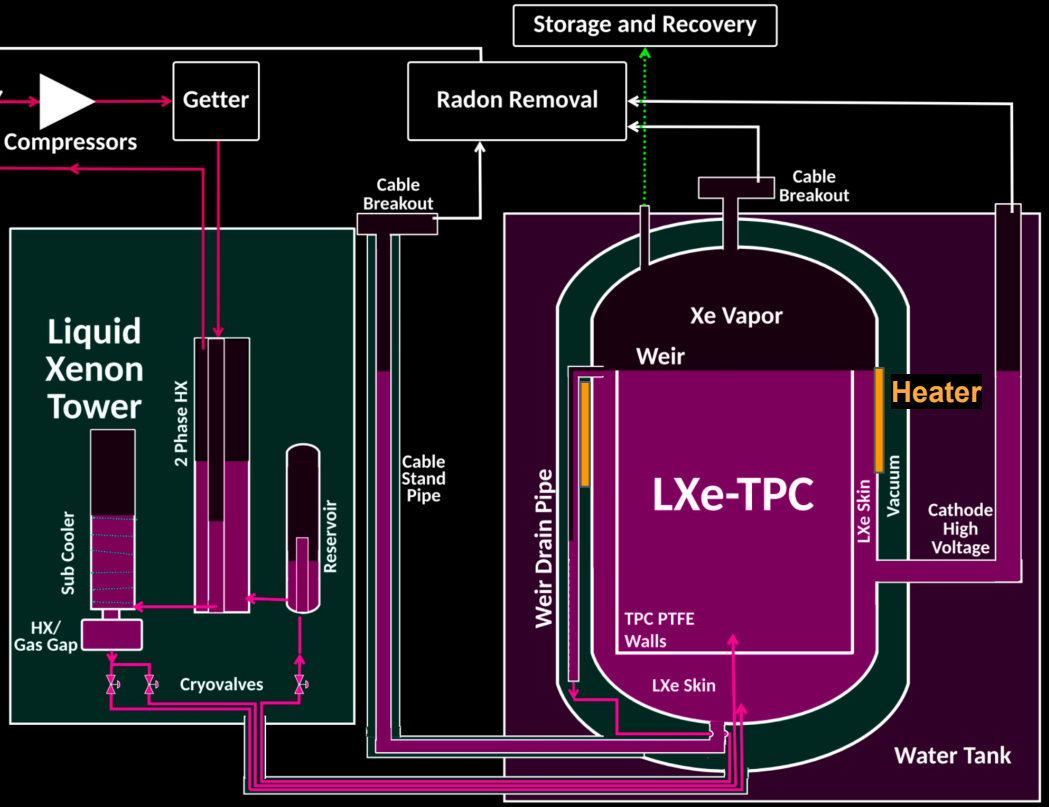
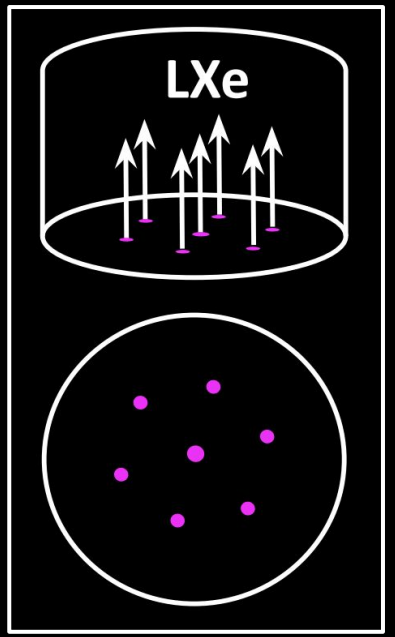
Circulation system controls:



TPC inlets

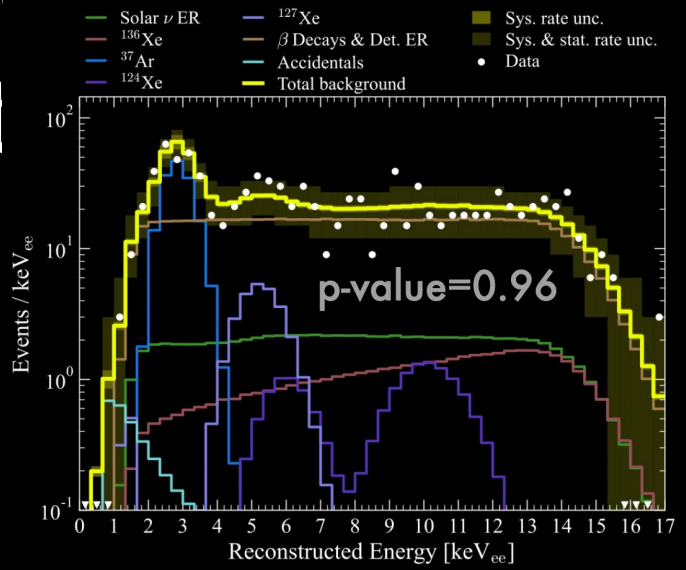


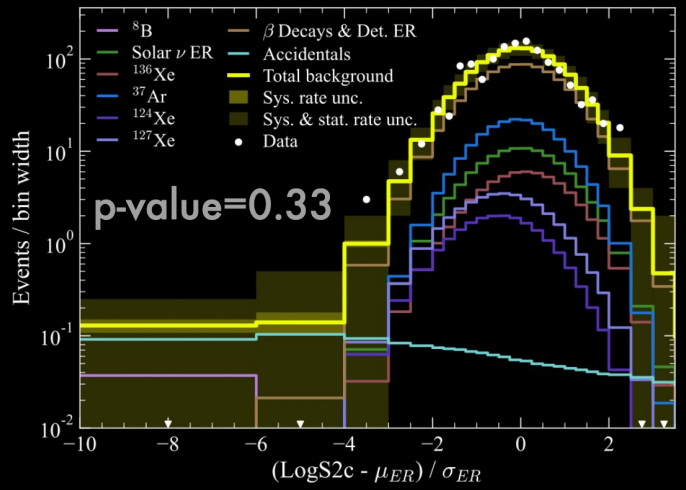
Background Model Fit

For all tested WIMP masses,
best fit is zero events

Source	Expected Events	Fit Result
β decays + Det. ER	215 ± 36	222 ± 16
ν ER	27.1 ± 1.6	27.2 ± 1.6
^{127}Xe	9.2 ± 0.8	9.3 ± 0.8
^{124}Xe	5.0 ± 1.4	5.2 ± 1.4
^{136}Xe	15.1 ± 2.4	15.2 ± 2.4
^{8}B CEνNS	0.14 ± 0.01	0.15 ± 0.01
Accidentals	1.2 ± 0.3	1.2 ± 0.3
Subtotal	273 ± 36	280 ± 16
^{37}Ar	[0, 288]	$52.5^{+9.6}_{-8.9}$
Detector neutrons	$0.0^{+0.2}$	$0.0^{+0.2}$
30 GeV/c^2 WIMP	–	$0.0^{+0.6}$
Total	–	333 ± 17

PhysRevLett.131.041002





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Beyond vanilla WIMP

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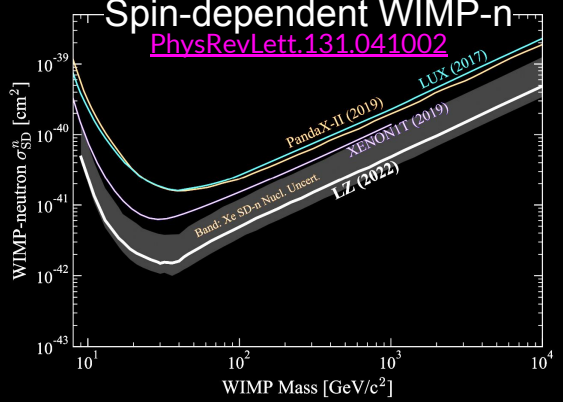
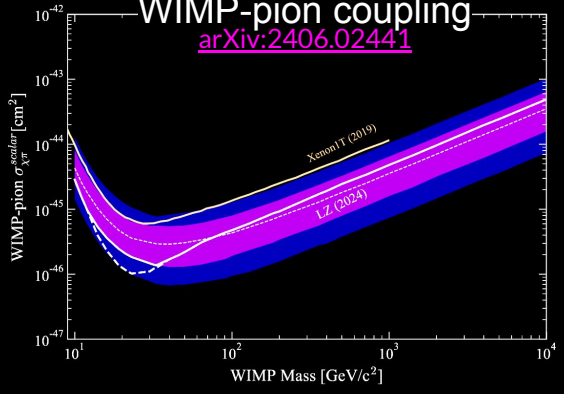
Spin-dependent WIMP-n

PhysRevLett.131.041002



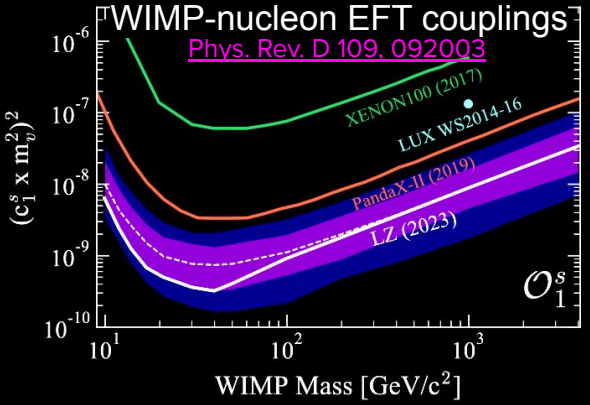
WIMP-pion coupling

arXiv:2406.02441



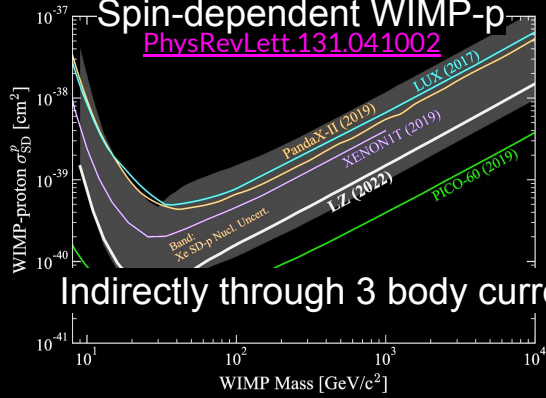
WIMP-nucleon EFT couplings

Phys. Rev. D 109, 092003



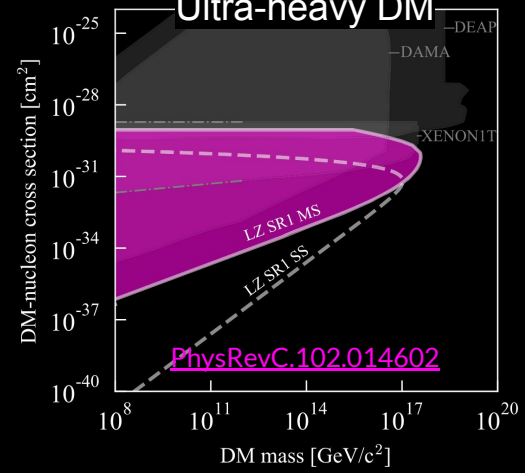
Spin-dependent WIMP-p

PhysRevLett.131.041002



Indirectly through 3 body current

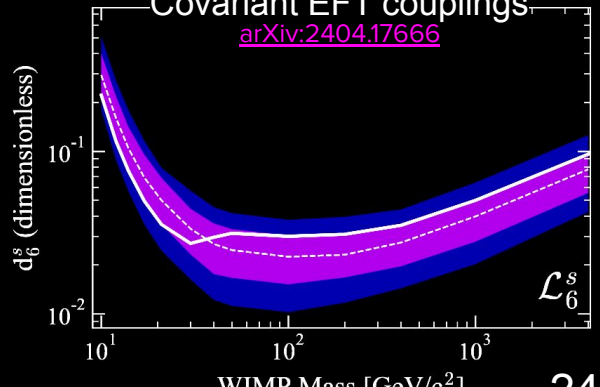
Ultra-heavy DM



PhysRevC.102.014602

Covariant EFT couplings

arXiv:2404.17666



Beyond vanilla WIMP

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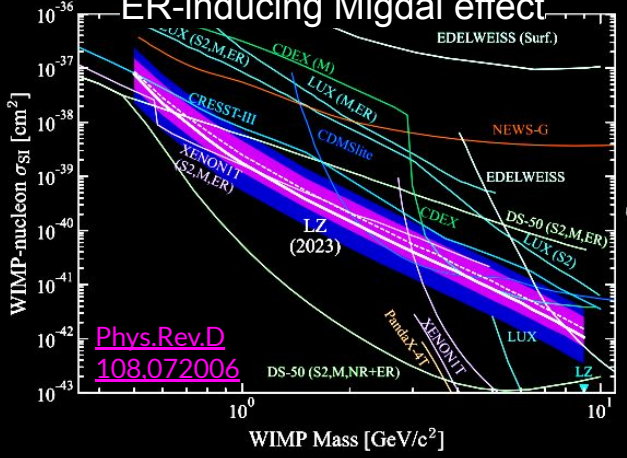
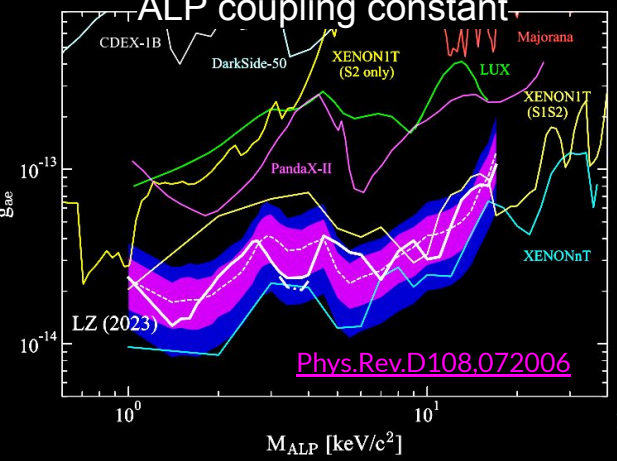
ER-inducing Migdal effect

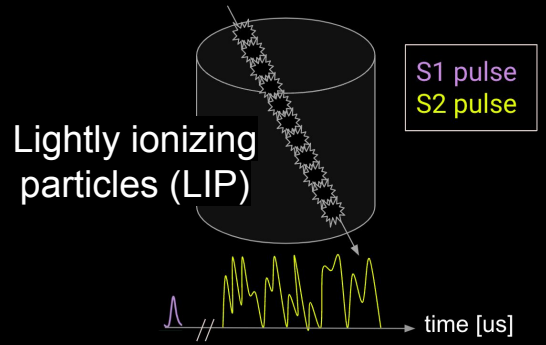


Phys.Rev.D 108,072006

ALP coupling constant

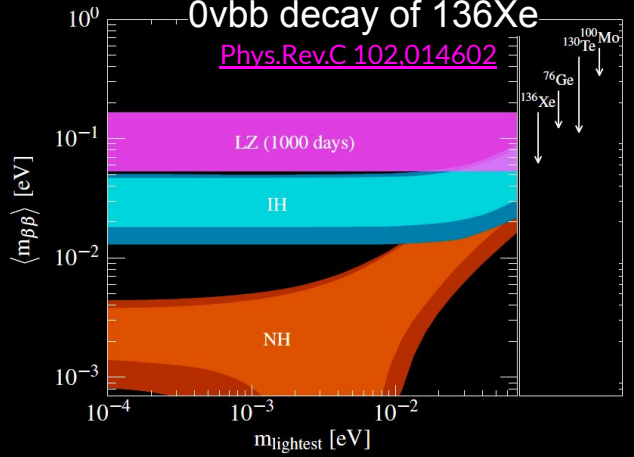


Phys.Rev.D108,072006



0vbb decay of 136Xe

Phys.Rev.C 102,014602

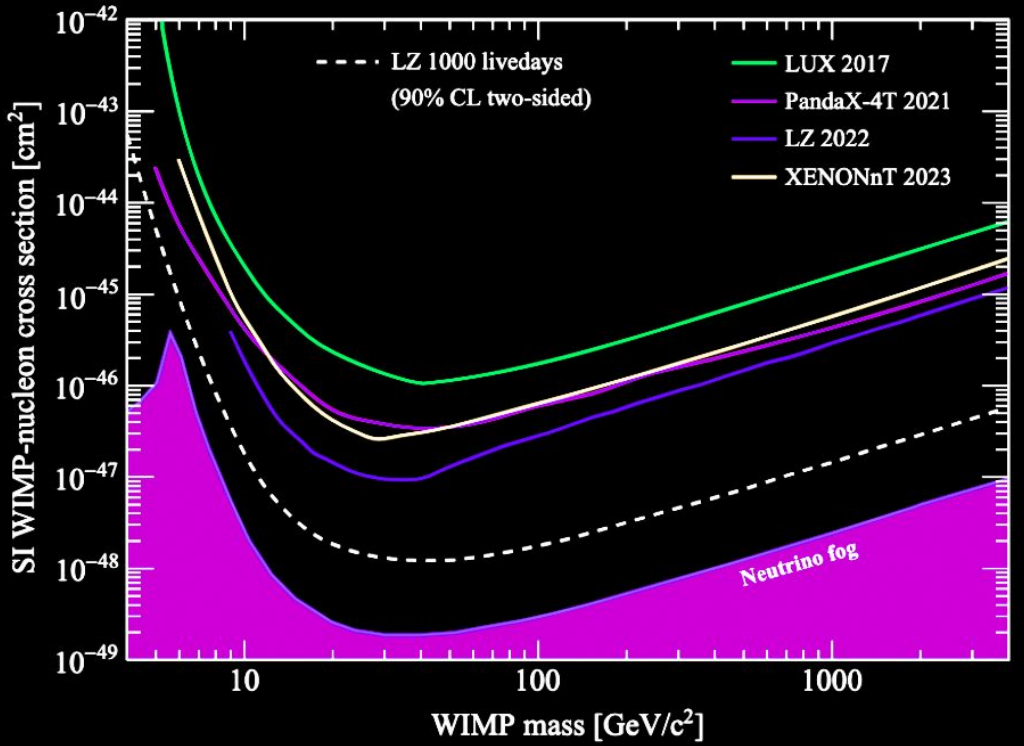


The future of LZ

Nicolas Angelides UZH

- 1000 liveday exposure goal
- Keep expanding physics output
- Keep improving analysis

New results on solar neutrino and light dark matter searches soon :3



Phys.Rev.D101,052002