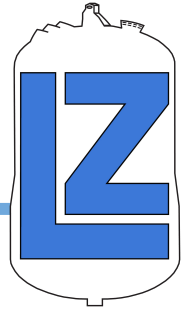
Xe and Ar Dark Matter Experiment Status and Future

Rick Gaitskell, Brown University

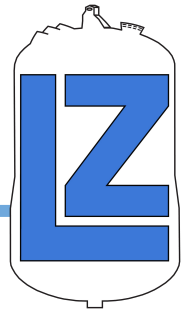


APS DPF Meeting, May 21, 2026
12 min Summary

US Dark Matter (Higher Mass) Xe/Ar Summary

- US Has Maintained Leadership in DOE Pillar 1 High Mass Dark Matter Search Sensitivity
  - LZ World leading limits for WIMP dark matter >5 GeV, LZ science running since start of 2022
  - Current LZ Schedule - Science Running to end CY2027
- Under DOE HEP No New Starts Scenario
  - LZ+ Proposal
    - DOE DM Pillar 1: Extend Sensitivity FY28, FY29, FY30…
      - Improved BG through technical upgrade/analysis
      - AI/ML Analysis Impact / via GENESIS and Direct Support
    - Additional Option if Technology Demonstrated: Could transition to HydroX FY31-FY33
      - Dope Xe with low-Z material, Leverages low mass DM sensitivity
  - Current Experiments with Existing US Component
    - XENONnT @LNGS (Xe 6 tonne)
      - Started science 2021, now being recommissioned 2026 for operation to 2028
    - Darkside DS20k @LNGS (Ar 20 tonne)
      - Under construction for commissioning start before end 2028
- XLZD
  - Site TBC, Xe 60-100 tonne / Originally formed as a combination of Xe Groups from XENON, LZ and Darwin
  - US Participation in G3 Experiment directly impacted by no new starts
  - UK has development funds to plan the hosting of XLZD in a major new underground facility at Boulby
  - Europe Awaiting the APPEC Roadmap which is released later this year

LZ at SURF and Proposal for LZ+ for 2028–



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LZ (LUX-ZEPLIN) Collaboration, 38 Institutions

250 scientists, engineers, and technical staff

@lzdarkmatter

https://lz.lbl.gov/

- 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

Thanks to our sponsors and participating institutions!

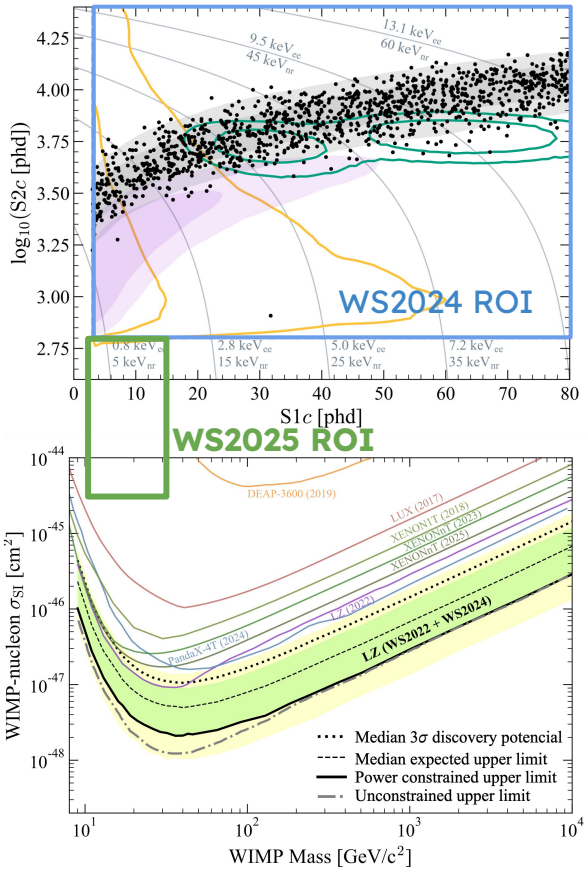
LZ WS2024 result

Phys. Rev. Lett. **135**, 011802

- ROI targeted ≥9 GeV/c^2 DM masses
- Novel features incorporated into the analysis:
  - Rn-tag reduced 60% primary ER BGs
  - Charge yield suppression modelled and measured in EC and DEC
- Bias mitigation technique
- Final exposure included in PLR: 4.2 tonne·yr
  - WS2022: 60 live days x 5.5 t = 0.9 tonne·yr exposure
  - WS2024: 220 live days x 5.5 t = 3.3 tonne·yr exposure

Result: world leading constraints → 2.2×10^{-48} cm^2 for 40 GeV/c^2 WIMP

What's next? Shift to **lighter DM masses** → WS2025
New set of challenges

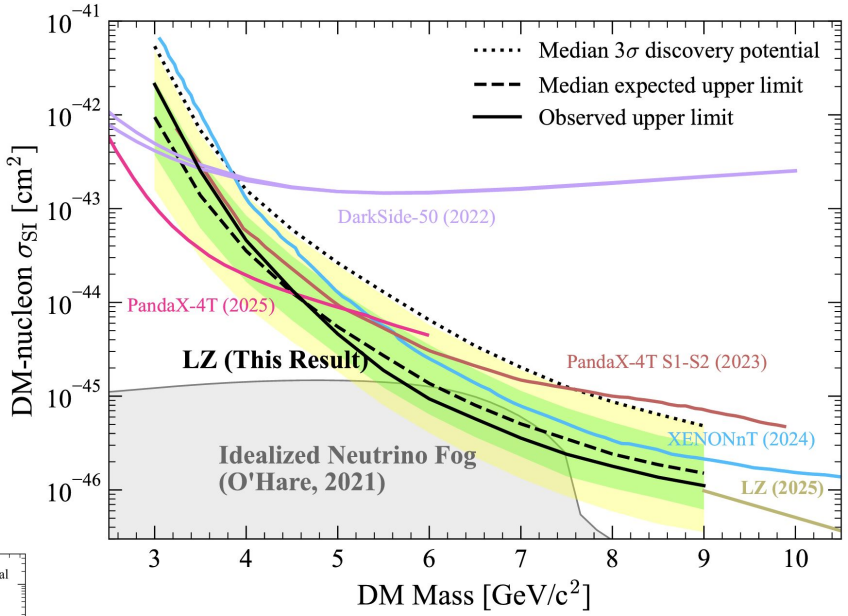


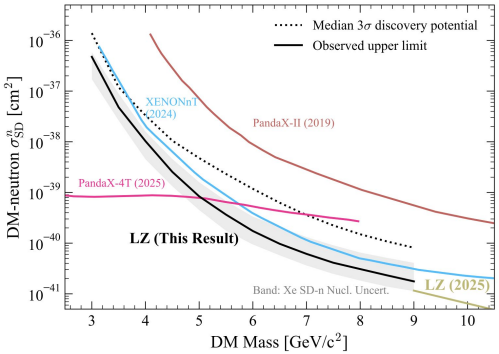
LZ WS2025 Low-mass WS search

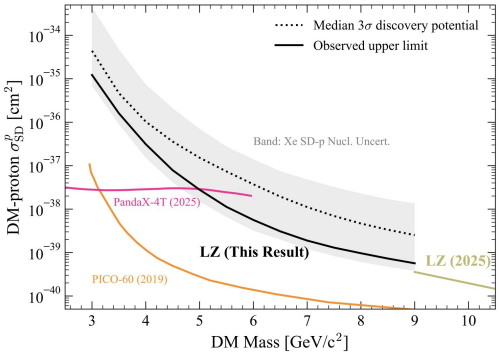
Exclusion limit with two-sided test statistic

- **Factor of two improvement in sensitivity over existing limits between 5-9 GeV/c2**
- **World-leading limits > 5 GeV/c2**

Limits on SD neutron-only and proton-only:







LZ WS2025
8B CEνNS measurement

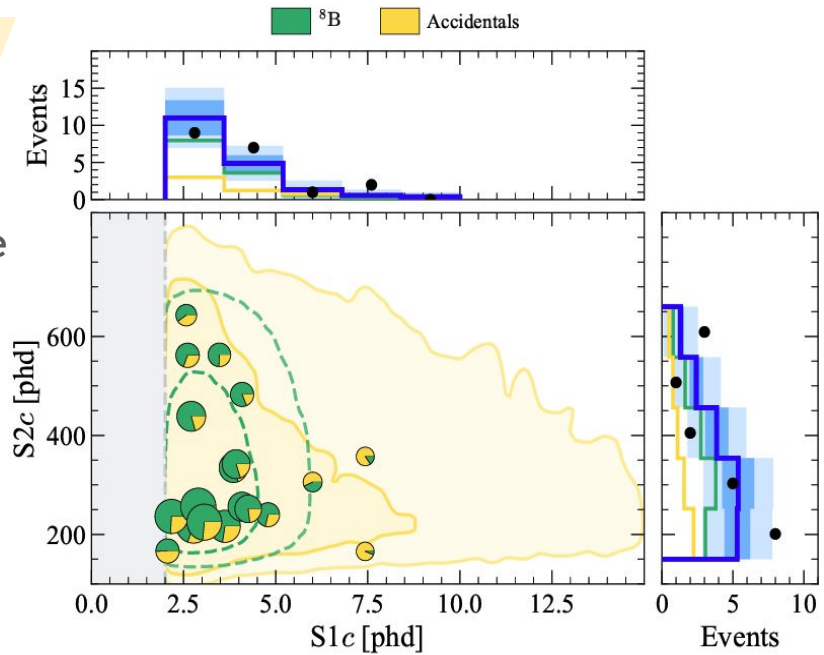
PLR test statistic to reject background-only mode

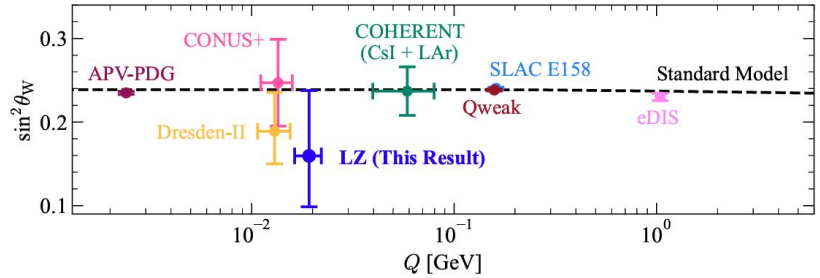
- Assumed no DM events
- Unconstrained 8B CEνNS rate

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	$18.9^{+7.0}_{-5.5}$

➔ Background-only model rejected with 4.5σ significance (expected 6.7σ)

Measure weak-mixing angle (sin2ΘW) at low momentum transfer (Q), consistent with SM





Other LZ DM searches and prospects

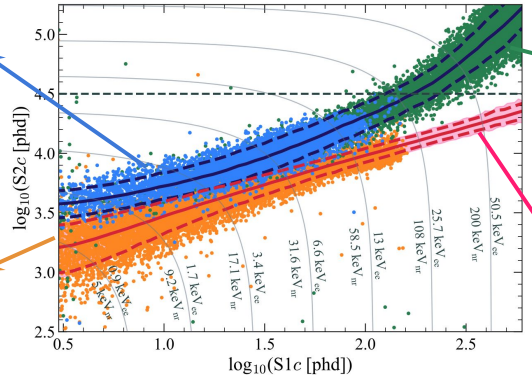
LZ can search for alternative candidates and in different energy regimes:

Low-energy ER

- LEER searches (*Phys.Rev.D* ***108***,*072006 (2023)*)
- Atmospheric millicharge particles (*PRL* ***134***, *241802 (2025)*)

Low-energy NR

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



High-energy ER

- e.g. Lightly Ionizing Particle searches

High-energy NR

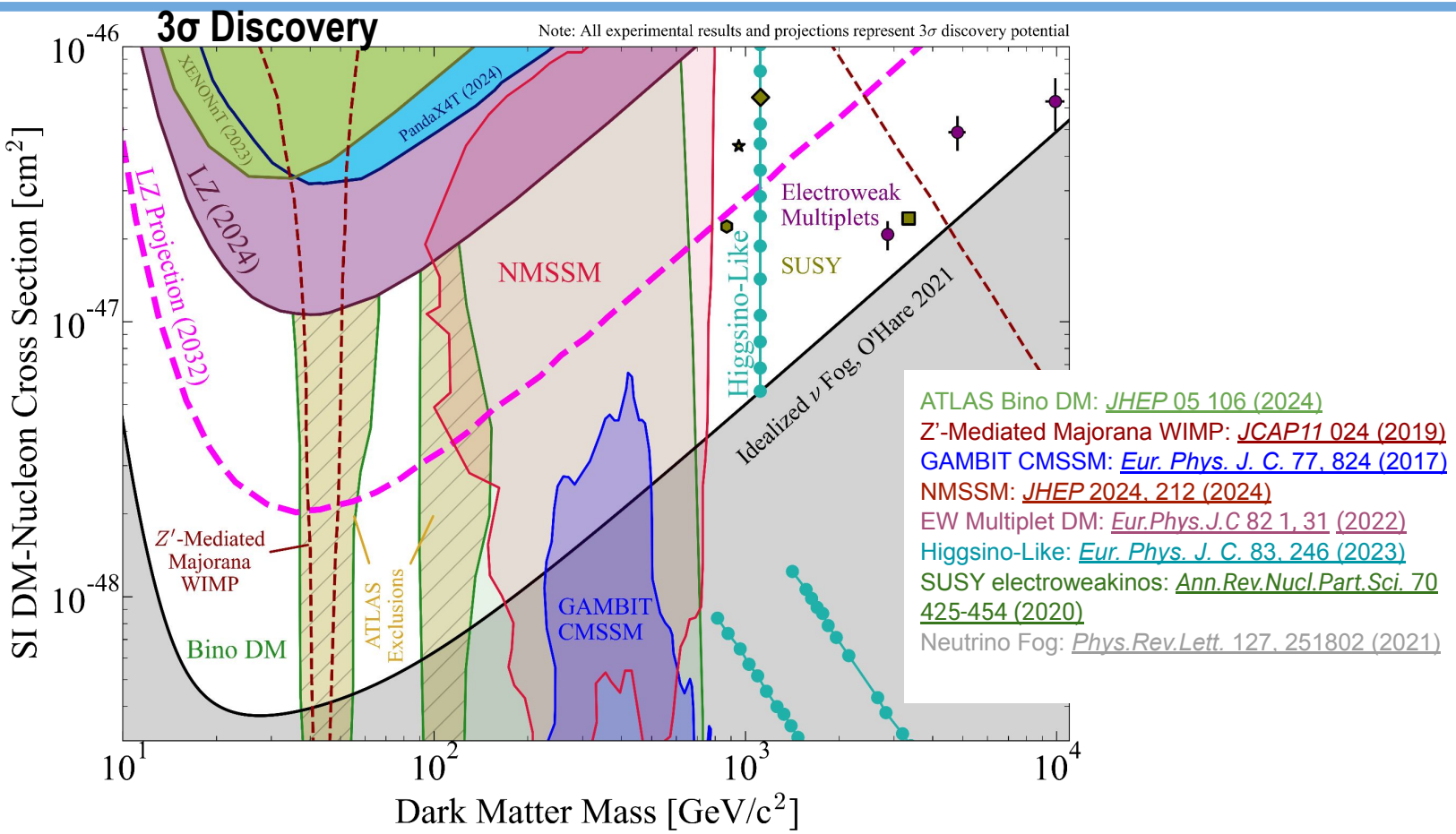
- WIMP-nucleon EFT - *PRL* ***133***, *221801 (2024)*
- Ultraheavy DM - *Phys. Rev. D* ***109***, *112010 (2024)*

Plus other non-DM searches in the horizon → $0\nu\beta\beta$

Further into the future, much larger exposures needed to fully cover the space parameter until the neutrino fog at larger DM masses…

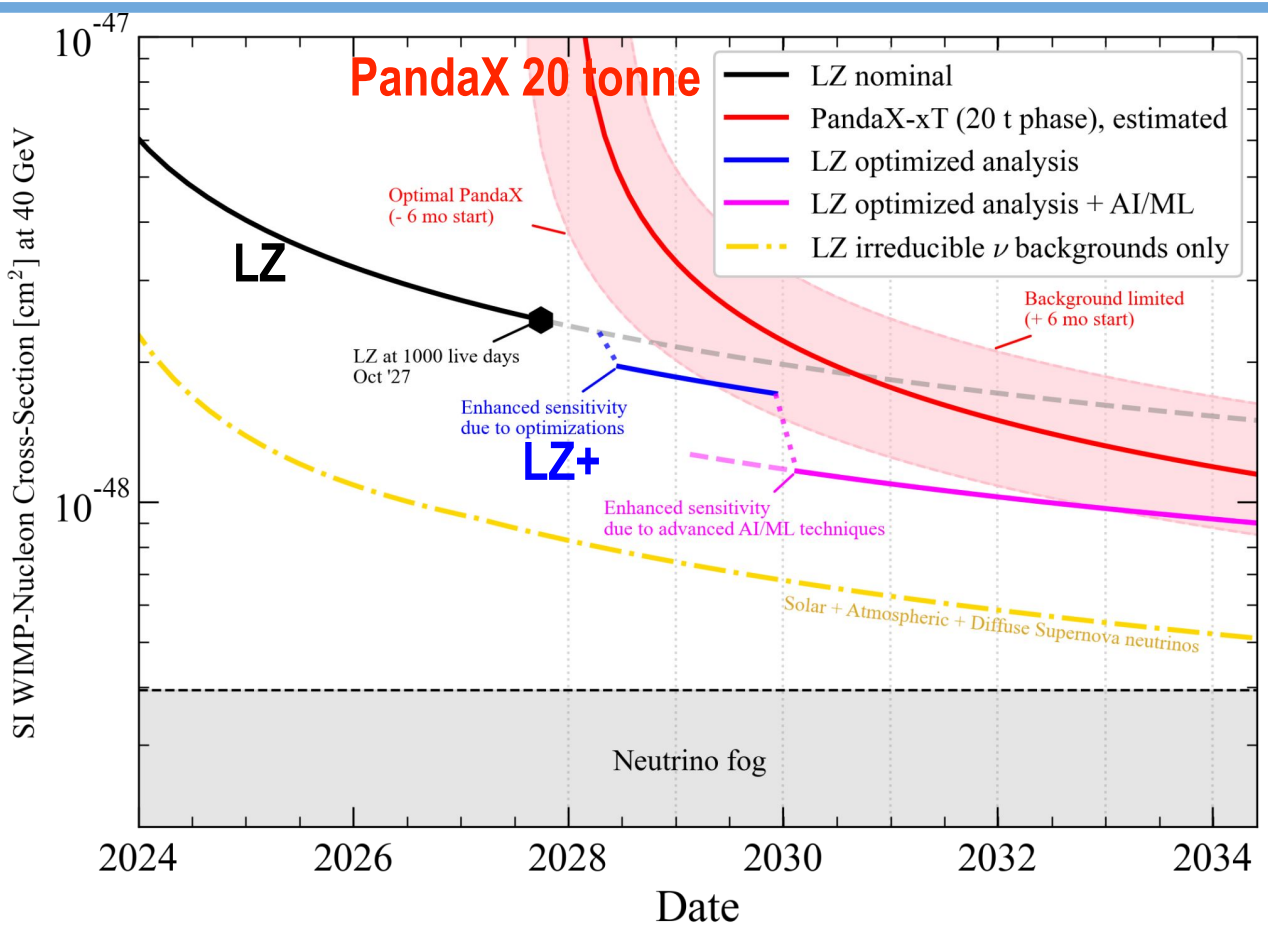
arXiv:2410.17137

LZ+ Step 1: Continued LZ running for Pillar 1 science



ATLAS Bino DM: *JHEP* 05 106 (2024)
Z'-Mediated Majorana WIMP: *JCAP11* 024 (2019)
GAMBIT CMSSM: *Eur. Phys. J. C.* 77, 824 (2017)
NMSSM: *JHEP* 2024, 212 (2024)
EW Multiplet DM: *Eur.Phys.J.C* 82 1, 31 (2022)
Higgsino-Like: *Eur. Phys. J. C.* 83, 246 (2023)
SUSY electroweakinos: *Ann.Rev.Nucl.Part.Sci.* 70 425-454 (2020)
Neutrino Fog: *Phys.Rev.Lett.* 127, 251802 (2021)

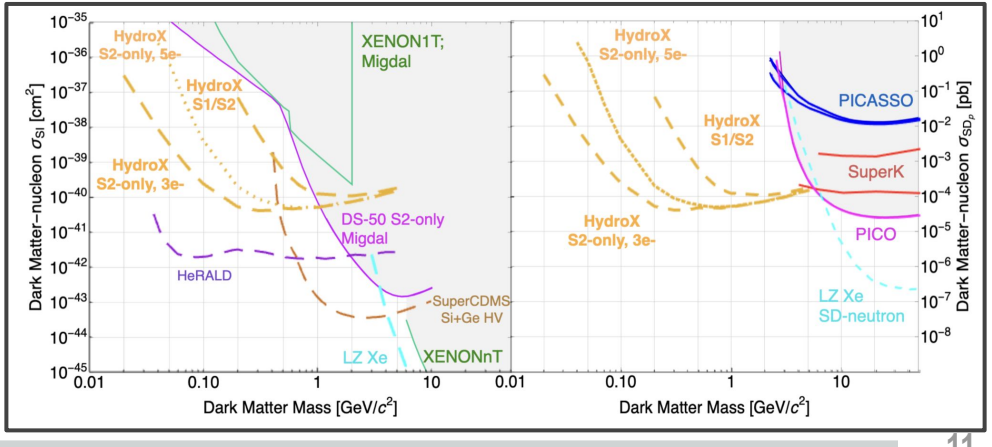
LZ+ Step 1: Continued LZ running for Pillar 1 science



LZ+ Step 2: Continued dark matter science with HydroX

- Get the benefit of simple LZ extension through ~2031, maintain Pillar 1 focus until LZ is no longer world-leading, then:
- Shift focus leveraging sensitivity to lower masses DM using low-Z dopant >kg
  - HydroX: sensitivity to low-mass dark matter (10 MeV to 1 GeV mass range).
  - Basic technical feasibility of low-Z doping of xenon: solubility, signal size
    - Under investigation now with dedicated setups
    - Technical solution for adding and removing a dopant in LZ while maintaining purification
  - Unique and complementary science goals to other DOE programs.
  - Simultaneous sensitivity to Spin-Independent and Spin-Dependent interactions; unique and complementary to other DOE programs.
  - Repurpose the LZ instrument for a different goal, still world-leading dark matter science

- HydroX is compelling:
  - LZ would be sensitive to both spin-independent and spin-dependent interactions at the same time.
  - Complementary to other experiments:
    - If a signal is seen in another low-mass DM experiment (e.g. TESSERACT), the signal in LZ/HydroX could reveal the nature of the dark matter.

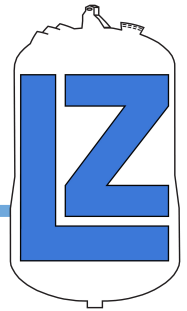


LZ+ Summary

A. LZ should do “Pillar 1 Science”; searches for dark matter with mass > 1 GeV.
   a. Our Step 1 will maintain LZ as the world’s leading experiment in this regime. We propose to keep running LZ, while improving our software and analysis capabilities, with a strong focus on AI/ML in line with the GENESIS mission.
   b. Only after world-leading Pillar 1 science is no longer viable with the LZ instrument, our Step 2 unlocks a unique dark matter space that only LZ can explore, complementary to other experiments in the DOE program.

B. The plan has support from senior leaders within the collaboration and maintains US expertise in the Xe technology
   a. Step 2 scope has emerged internally as the most appropriate extension to LZ which both brings new science reach and maintains technological progress in the community. It builds on existing efforts from the last several years and has buy-in from most major LZ institutions - HydroX workshop.

XENONnT



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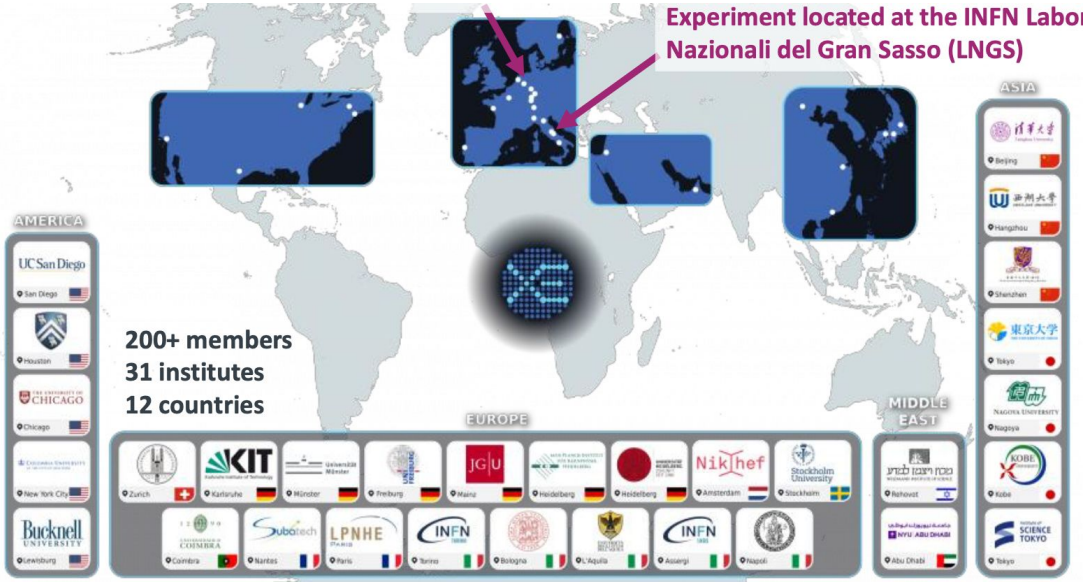
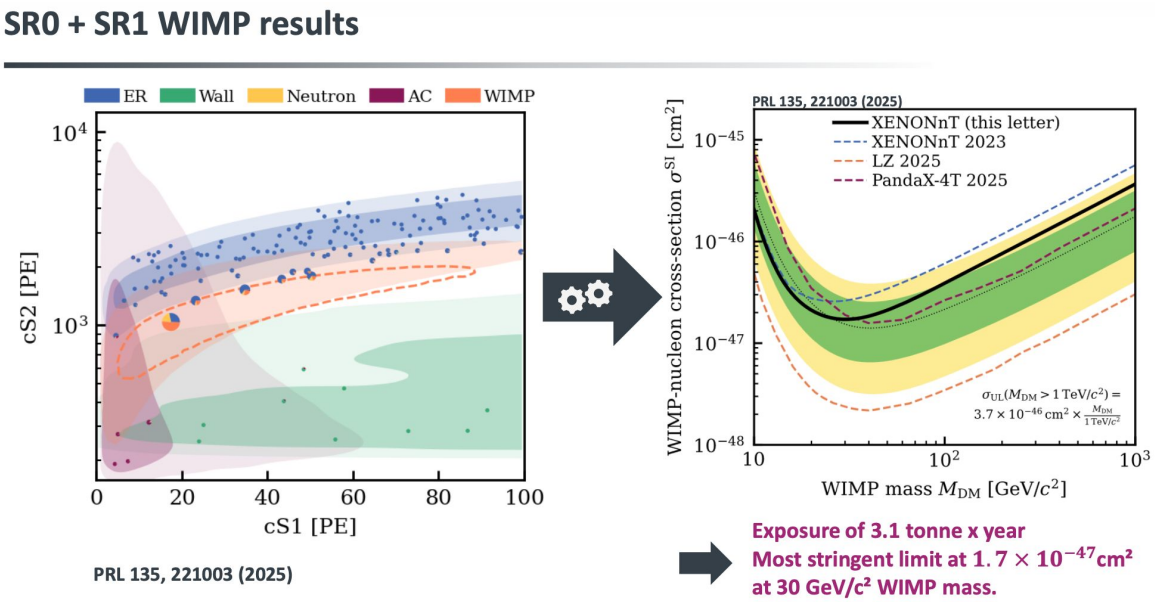

Experiment located at the INFN Laboratori Nazionali del Gran Sasso (LNGS)
200+ members
31 institutes
12 countries
AMERICA
UC San Diego
Houston
Chicago
New York City
Bucknell University
Lewisburg
EUROPE
Zurich
KIT
Karlsruhe
Münster
Freiburg
JGU
Mainz
Heidelberg
Amsterdam
Nikhef
Stockholm University
Stockholm
Coimbra
Nantes
LPNHE
Paris
INFN
Torino
Bologna
L'Aquila
Assergi
Napoli
MIDDLE EAST
Rehovot
NYU ABU DHABI
Abu Dhabi
ASIA
Beijing
Hangzhou
Shenzhen
東京大学
Tokyo
Nagoya
Kobe
SCIENCE TOKYO
Tokyo


EPJC 77, 275 (2017)
JINST 18 (2023) 07, P07054
EPJC 82, 1104 (2022)
EPJC 84, 784 (2024)

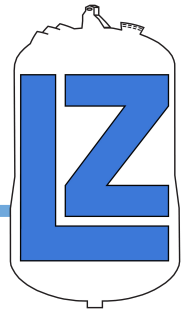
XENONnT @ LNGS

- XENON is 6 tonne LXe TPC science search since 2021



- XENON was warmed up and detector opened in 2025 to repair grids
  - Low electron drift field was significantly hampering progress in DM sensitivity
- Repairs completed, detector is now cold and re-commissioning is taking place
- Plan is continue operations 2026–2029

Darkside-20k



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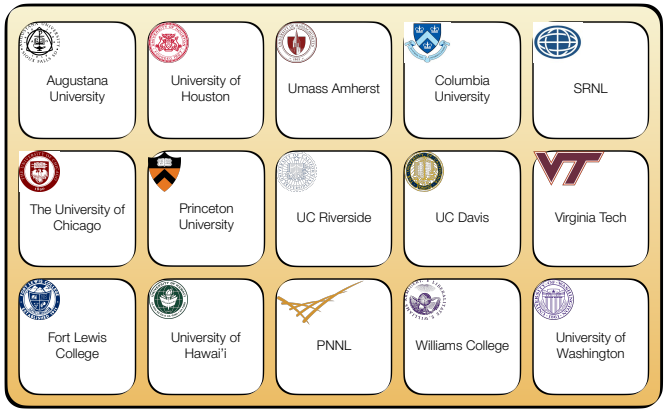
The US Leadership Roles at a Glance

- The US institutions form a single, integrated team with shared goals and governance.
- Together, they cover the full scope of DarkSide-20k's detector design, construction, and commissioning.
- The team is distributed across the entire DS-20k leadership structure, at all levels, holding critical roles, as shown in the table.
- Weekly meetings, shared document repositories, and a common project management platform ensure that all institutions are continuously aligned on the DS-20k schedule, scope, and resources.

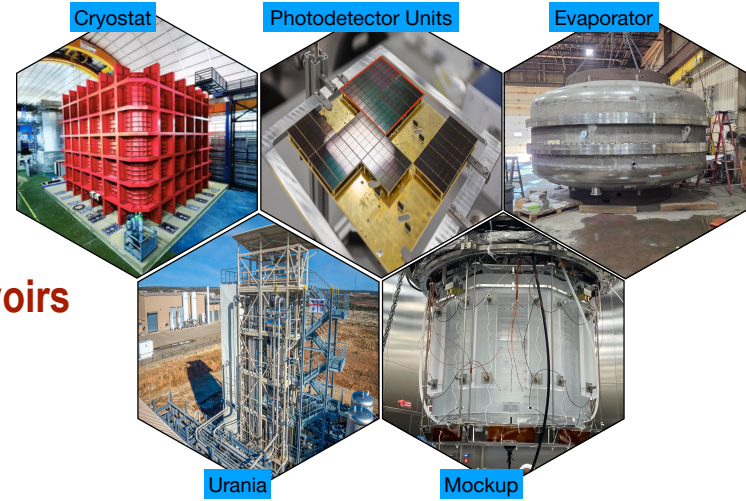


US Leadership Roles		
Institution	**Responsible**	**Coordination Role**
DS-20k Managers (DS-20k L0-L1)		
Princeton	Cristiano Galbiati	Spokesperson
Princeton	Paolo Organtini	Project Control Manager
Virginia Tech	Stephen Pordes	Review O!ce Chair
Project Leaders and Technical Coordinators (DS-20k L2)		
Virginia Tech	Camillo Mariani	DCS-DSS Technical Coordinator
Princeton	Ako Jamil	Detector Technical Coordinator
Princeton	Giacomo Gallina	Urania Technical Coordinator
Princeton	Andrea Ianni	Safety Leader & Site Manager at LNGS
WBS L1 Managers (DS-20k L3)		
Chicago	Luca Grandi	Inner Detector (ID)
Columbia	Guillaume Plante	UAr Cryogenics
Hawaii	Jelena Maricic	Calibration
UC Riverside	Shawn Westerdale	Outer Veto
Princeton	Giacomo Gallina	Infrastructure at UofA
Virginia Tech	Camillo Mariani	DCS Integration
Virginia Tech	Camillo Mariani	DSS
Virginia Tech	Harrison Coombes	Controls
Fort Lewis	Laurie Williams	Outreach
WBS L2 Managers (DS-20k L4) - All under the Inner Detector WBS		
Chicago	Luca Grandi	Optical Planes
Chicago	Luca Grandi	Spring-Loaded Support Rod System
Hawaii	Jelena Maricic	Gas-Pocket System
UC Davis	Emilija Pantic	HHV System
UMass	Andrea Pocar	Cable Tray
UMass	Andrea Pocar	Internal Reflector Cage
Virginia Tech	Bruce Vogelaar	Wire Grid
Virginia Tech	Bruce Vogelaar	Deformation Monitor System

Darkside-20k @ LNGS

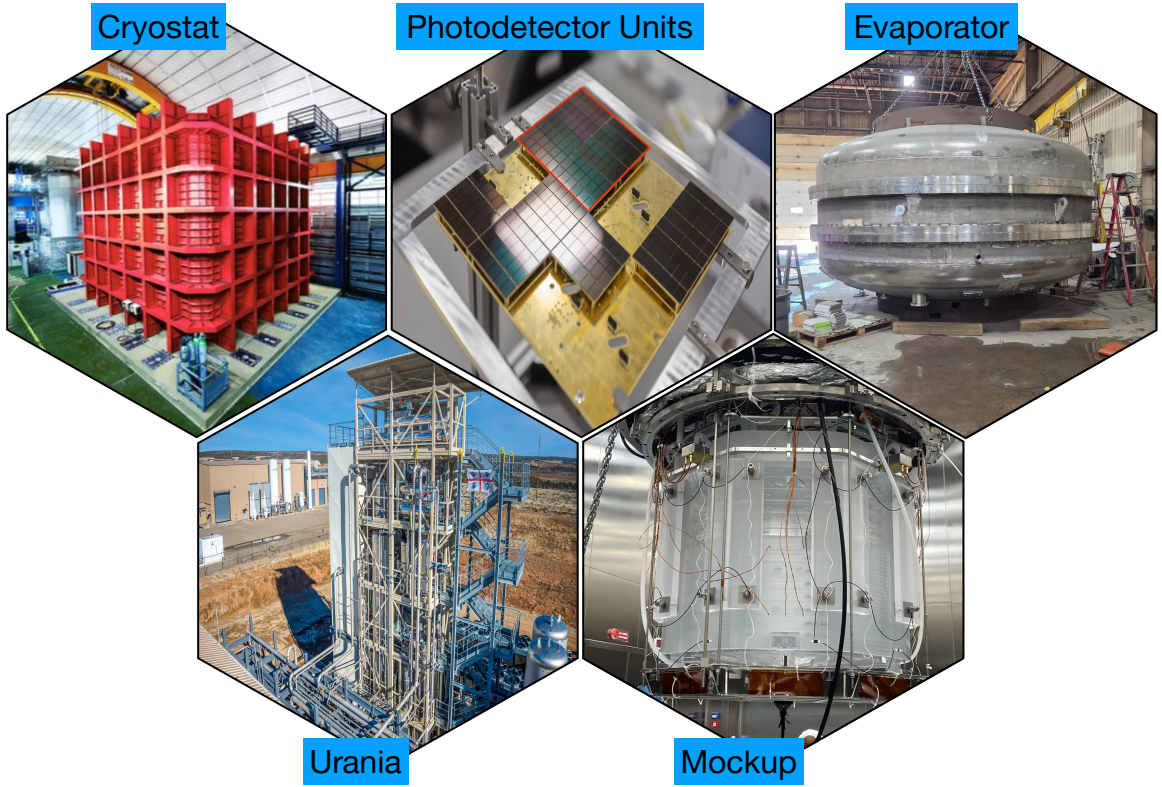
- US (NSF) ~25%, Italy 50%, Canadian+Others 25%
- Project Under Construction @ LNGS
  - Construction continues 2026-2028
- First Commissioning Run of Cold Detector
  - Expected to start commissioning run before end 2028

- Urania Project: Enabling Multi Ton-Scale UAr
  - Colorado, US, UAr from deep CO_2 underground reservoirs
  - Construction completed
  - Commissioning in summer 2026
  - Could also supply LEGEND-1000



DS-20k

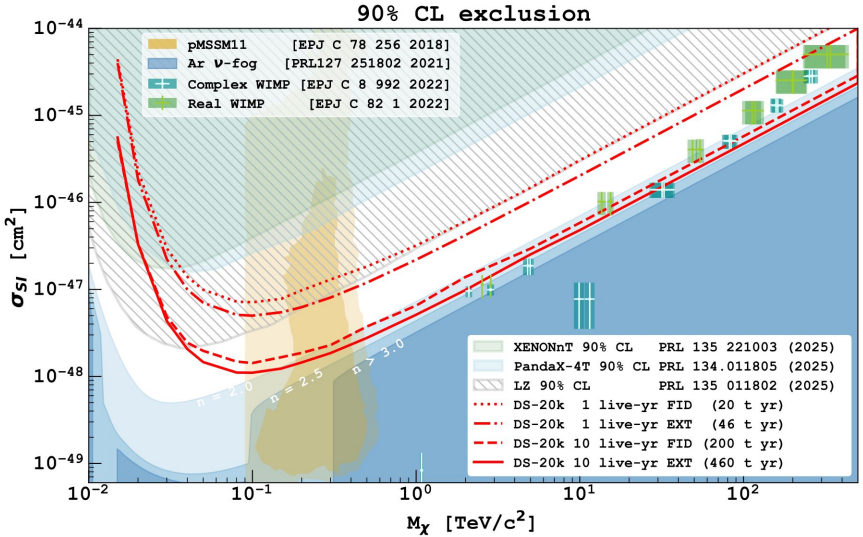
- **700-tonne Atmospheric Argon Cryostat** and related cryogenics completed;
- **>50% of SiPM-based photosensors** completed (total surface: **26 m^2**)
- Inner detector **Mockup** Test with **130% HHV** compliance test completed;
- **Urania** underground argon extraction plant completed, commissioning in summer 2026
- DArT facility for underground argon qualification completed at LSC and now taking data
- PMMA for anode, cathode, and barrel being machined
- **Evaporator** vessel for surface coatings construction completed
- All main DAQ, signal readout chimneys and feedthroughs delivered to LNGS
- Steel vessel design completed, stainless steel procured and radio-assayed
- Grid design complete, stainless steel procured and radio-assayed

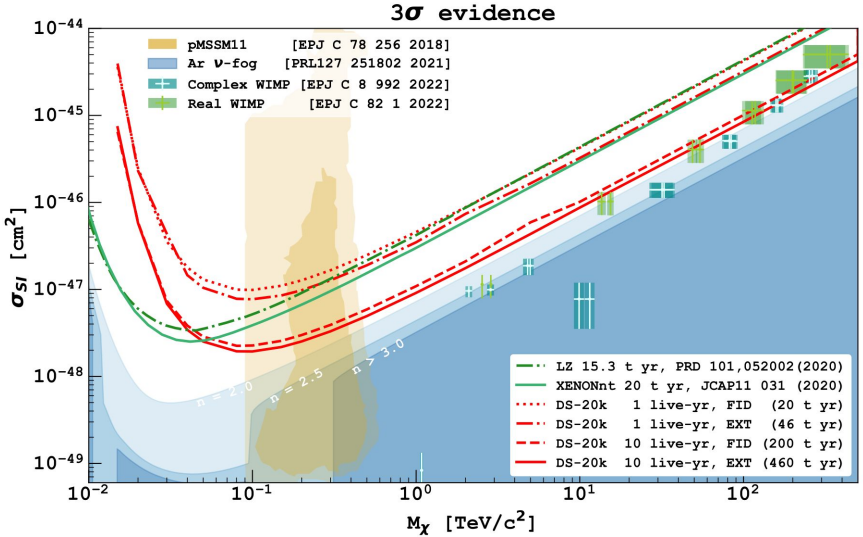


The DS-20k detector commissioning is expected to begin at the **end of 2028**.

The NSF-supported US groups played the key role in the detector development and proposal and hold leadership roles in construction and planning for a decade of operations.

Science Reach - High Mass Searches





DS-20k sensitivity (left: 90 % C.L. exclusion; right: 3 σ significance evidence for a signal) to spin-independent WIMPs for different live-times, 1 and 10 yr, and for different target volumes, fiducial and extended volume. The DS-20k projected 90 % C.L. exclusion is compared with the world-leading dark matter results published by LZ, XENONnT, and PandaX-4T. The DS-20k 3 σ detection sensitivity is instead compared against the published values of the ultimate projected sensitivities of the two U.S. experiments: for LZ, 2.7 yr run, 15.3 t yr exposure; for XENONnT, 5 yr run, 20.2 t yr exposure. Also represented are the neutrino "fog" for an argon detector, shown by the blue-shaded regions of different density, and the 1-, 2-, and 3-σ favored regions from the pMSSM11 model constrained by astrophysical measurements and the ~36/fbarn LHC dataset at 13 TeV, shown by the ochre-filled contours. Green and blue rectangles identify regions where complex and real WIMPs can be thermally produced at the relic abundance, subject to current constraints from indirect and collider searches.

XLZD -
(XENONnT, LZ, Darwin)
A Generation 3 DM Experiment

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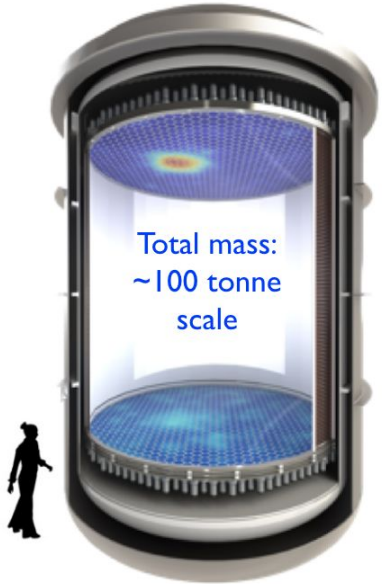
XLZD history, status and related events

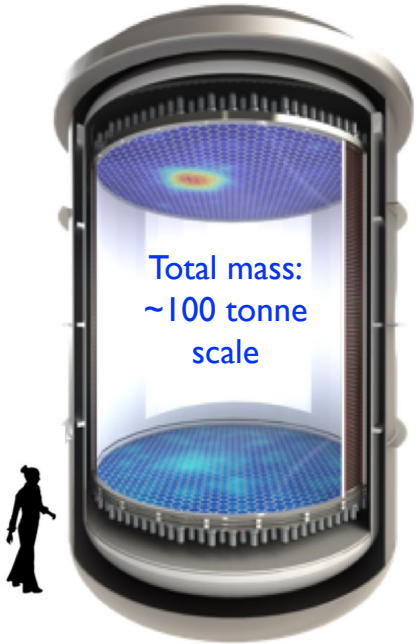
- July 2021: Consortium MOU signed by XENONnT, LUX-ZEPLIN, DARWIN
- Oct 2023: NSAC LRP recommends pursuit of 0vbb in multiple isotopes at the ton-scale
- Dec 2023: P5 recommends Generation 3 DM (G3DM) search to neutrino fog limit
- Sept 2024: XLZD Collaboration agreement signed
- Dec 2024: DOE NP announces indefinite pause of nEXO project due to funding constraints
- Dec 2025: DOE HEP announces deferring of G3DM until early 2030's due to funding constraints
- Key activities in 2026:
  - International partners continue to vigorously pursue XLZD; working towards CDR for early 2027, with ongoing US engagement
  - Significant engagement from DM and 0vbb community in Canada: 11 institutions join XLZD, bid for SNOLAB hosting
  - Technical evaluation of 4 sites to complete in the coming months: Boulby, LNGS, SURF, SNOLAB
  - US participation is a critical part of the technology base and needed to realize the full scientific reach of 80-t active target on a competitive timeline

Natural xenon in a 2-phase TPC

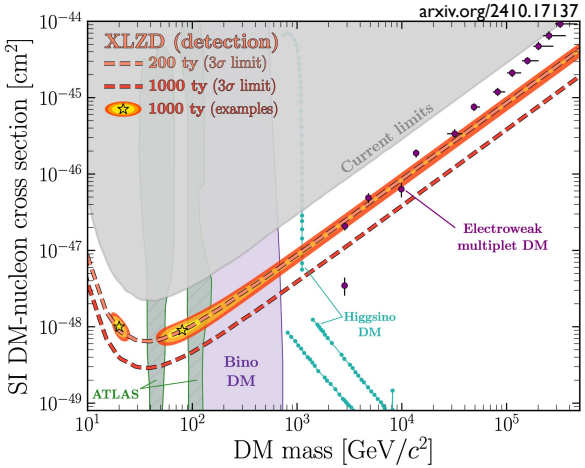


XLZD: liquid xenon observatory at the 100-tonne scale

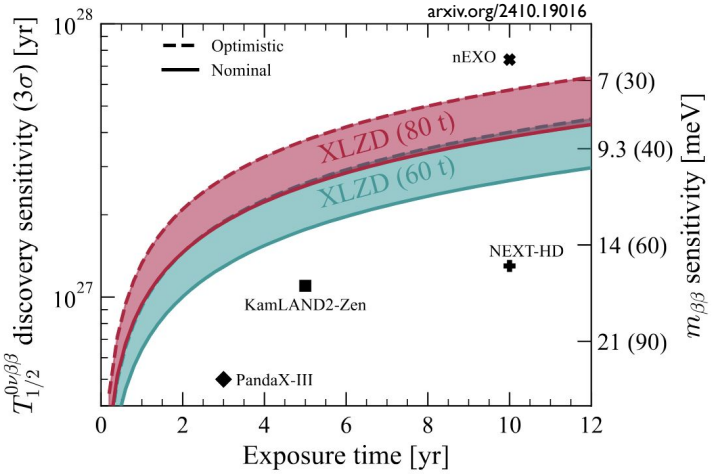
Natural xenon in a 2-phase TPC



Probe WIMP Dark Matter to neutrino fog systematic limit



DM detector w/natural xenon: Competitive sensitivity for $0\nu\beta\beta$



- Definitive WIMP search: systematics limited by ν fog at ~1000 tonne-years of exposure sets scale for ~100-tonne detector
- Xe-136 is 9% of the natural abundance, allowing a search for $0\nu\beta\beta$ with the potential to approach the nEXO design sensitivity
  - Optimization to push sensitivity to $T^{1/2} \sim 10^{28}$ years is under study

XLZD

Full Design, Radioactive Monte Carlo Studies

Site Reviews for XLZD at LNGS, Boulby, SNOLab and SURF are on going

- **UK has development funds to plan the hosting of XLZD in a major new underground facility at Boulby**
- **Europe Awaiting the APPEC Roadmap which is released later this year**

XLZD 0ν-DBD Sensitivity (Double Beta Decay)

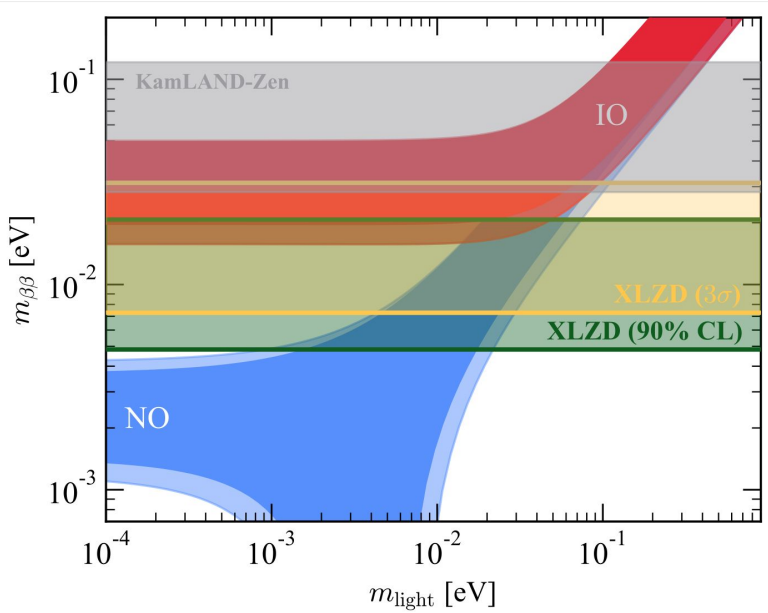


Figure 5. Sensitivity of XLZD to the effective Majorana neutrino mass as a function of the lightest neutrino mass for the 80 t configuration in the optimistic scenario with 10 years of data. The two metrics considered in this work are shown: 3σ discovery potential (yellow band) and 90% CL exclusion (green band). The width of the bands is caused by the uncertainty in the nuclear matrix element models (see main text, also for the expected sensitivity using the most recent nuclear matrix elements). The current best experimental limits from KamLAND-Zen, also from $0\nu\beta\beta$ decay in ^{136}Xe and assuming the same range of NMEs, are shown in grey [5]. The allowed regions ($\pm 3\sigma$) for the effective Majorana neutrino mass in the inverted (IO) and normal (NO) neutrino mass ordering scenarios are also shown [64, 65].

US Dark Matter (Higher Mass) Xe/Ar Summary

- **US Has Maintained Leadership in DOE Pillar 1 High Mass Dark Matter Search Sensitivity**
  - LZ World leading limits for WIMP dark matter >5 GeV, LZ science running since start of 2022
  - Current LZ Schedule - Science Running to end CY2027
- **Under DOE HEP No New Starts Scenario**
  - **LZ+ Proposal**
    - DOE DM Pillar 1: Extend Sensitivity FY28, FY29, FY30…
      - Improved BG through technical upgrade/analysis
      - AI/ML Analysis Impact / via GENESIS and Direct Support
    - Additional Option if Technology Demonstrated: Could transition to HydroX FY31-FY33
      - Dope Xe with low-Z material, Leverages low mass DM sensitivity
  - **Current Experiments with Existing US Component**
    - XENONnT @LNGS (Xe 6 tonne)
      - Started science 2021, now being recommissioned 2026 for operation to 2028
    - Darkside DS20k @LNGS (Ar 20 tonne)
      - Under construction for commissioning start before end 2028
- **XLZD**
  - Site TBC, Xe 60-100 tonne / Originally formed as a combination of Xe Groups from XENON, LZ and Darwin
  - US Participation in G3 Experiment directly impacted by no new starts
  - UK has development funds to plan the hosting of XLZD in a major new underground facility at Boulby
  - Europe Awaiting the APPEC Roadmap which is released later this year

--- END ---

APPENDICES

(Slides not shown in Talk,
but I was asked to include them in PDF)

LZ Additional Slides

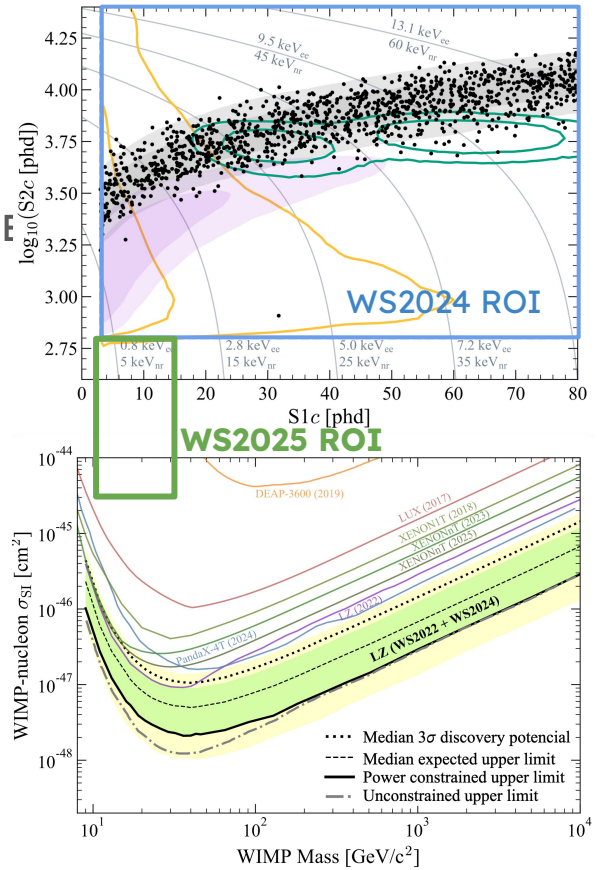
WS2024 result

Phys. Rev. Lett. **135**, 011802

- ROI targeted ≥9 GeV/c^2 DM masses
- Novel features incorporated into the analysis:
  - Rn-tag reduced 60% primary ER BGs
  - Charge yield suppression modelled and measured in E
- Bias mitigation technique
- Final exposure included in PLR: 4.2 tonne·yr
  - WS2022: 60 days x 5.5 t = 0.9 tonne·yr exposure
  - WS2024: 220 days x 5.5 t = 3.3 tonne·yr exposure

Result: world leading constraints → 2.2×10^{-48} cm^2 for 40 GeV/c^2 WIMP

What's next? Shift to **lighter DM masses** → WS2025
New set of challenges

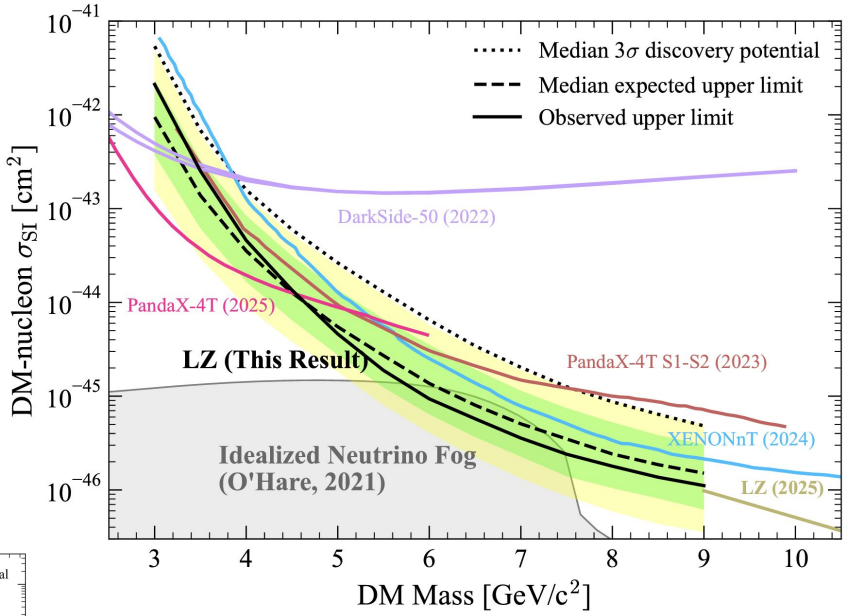


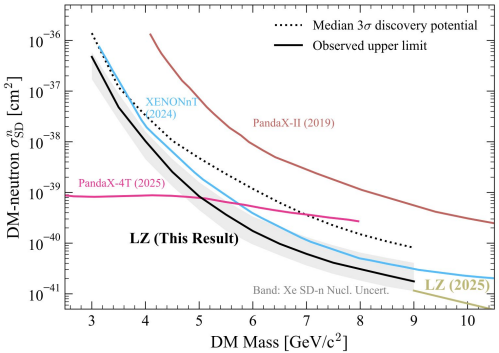
Low-mass WS search

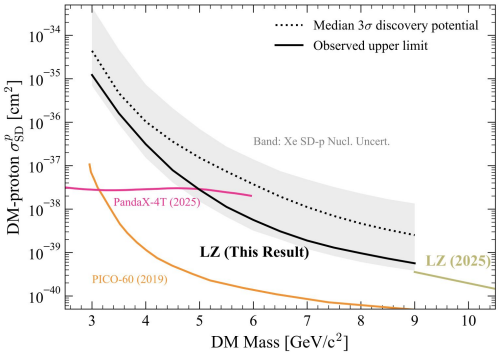
Exclusion limit with two-sided test statistic

- Factor of two improvement in sensitivity ove
  GeV/c2
- World-leading limits > 5 GeV/c2

Limits on SD neutron-only and proton-only:







LZ (Thanks to Alberto Uson)

8B CEνNS measurement

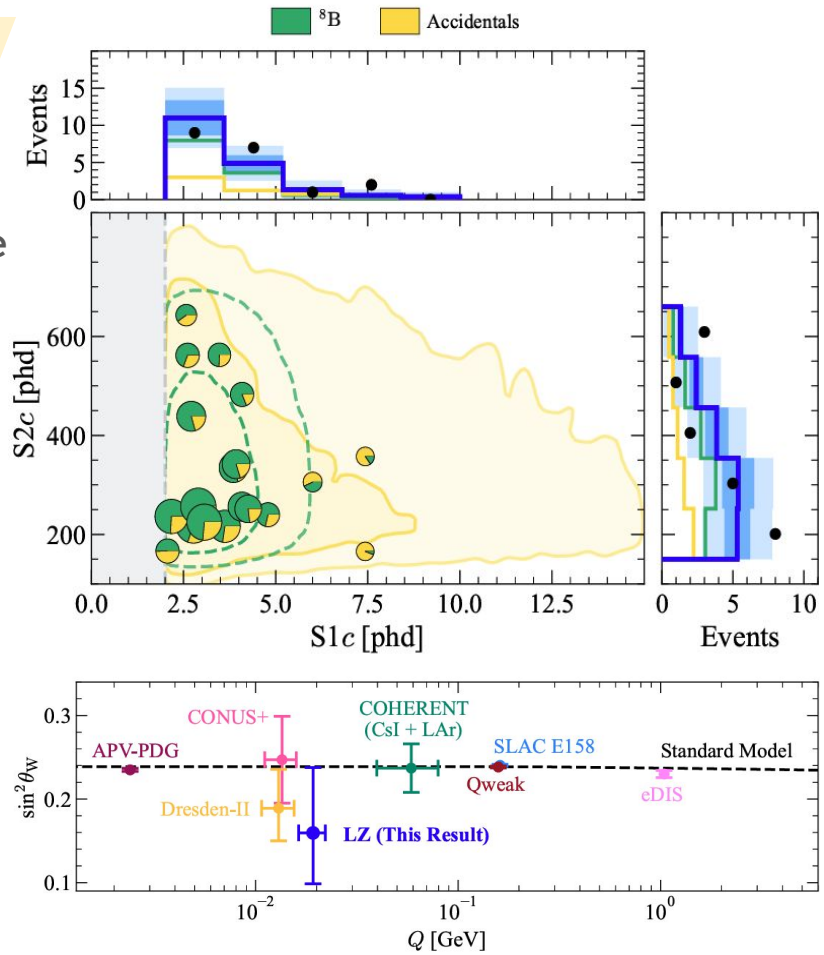
PLR test statistic to reject background-only mode

- Assumed no DM events
- Unconstrained 8B CEνNS rate

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	$18.9^{+7.0}_{-5.5}$

➔ Background-only model rejected with 4.5σ significance (expected 6.7σ)

Measure weak-mixing angle (sin2ΘW) at low momentum transfer (Q), consistent with SM



Other LZ DM searches and prospects

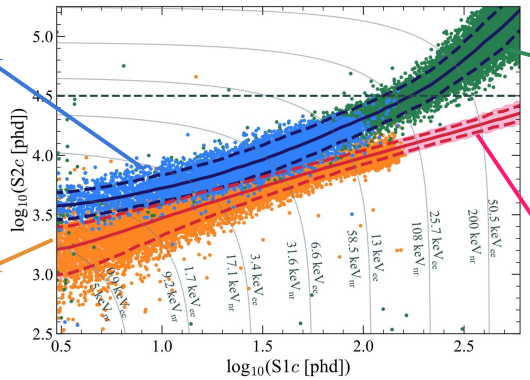
LZ can search for alternative candidates and in different energy regimes:

Low-energy ER

- LEER searches (*Phys.Rev.D **108**,072006 (2023)*)
- Atmospheric millicharge particles (*PRL **134**, 241802 (2025)*)

Low-energy NR

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



High-energy ER

- e.g. Lightly Ionizing Particle searches

High-energy NR

- WIMP-nucleon EFT - *PRL **133**, 221801 (2024)*
- Ultraheavy DM - *Phys. Rev. D **109**, 112010 (2024)*

Plus other non-DM searches in the horizon → $0\nu\beta\beta$

Further into the future, much larger exposures needed to fully cover the space parameter until the neutrino fog at larger DM masses…

arXiv:2410.17137

Step 2: Continued dark matter science with HydroX

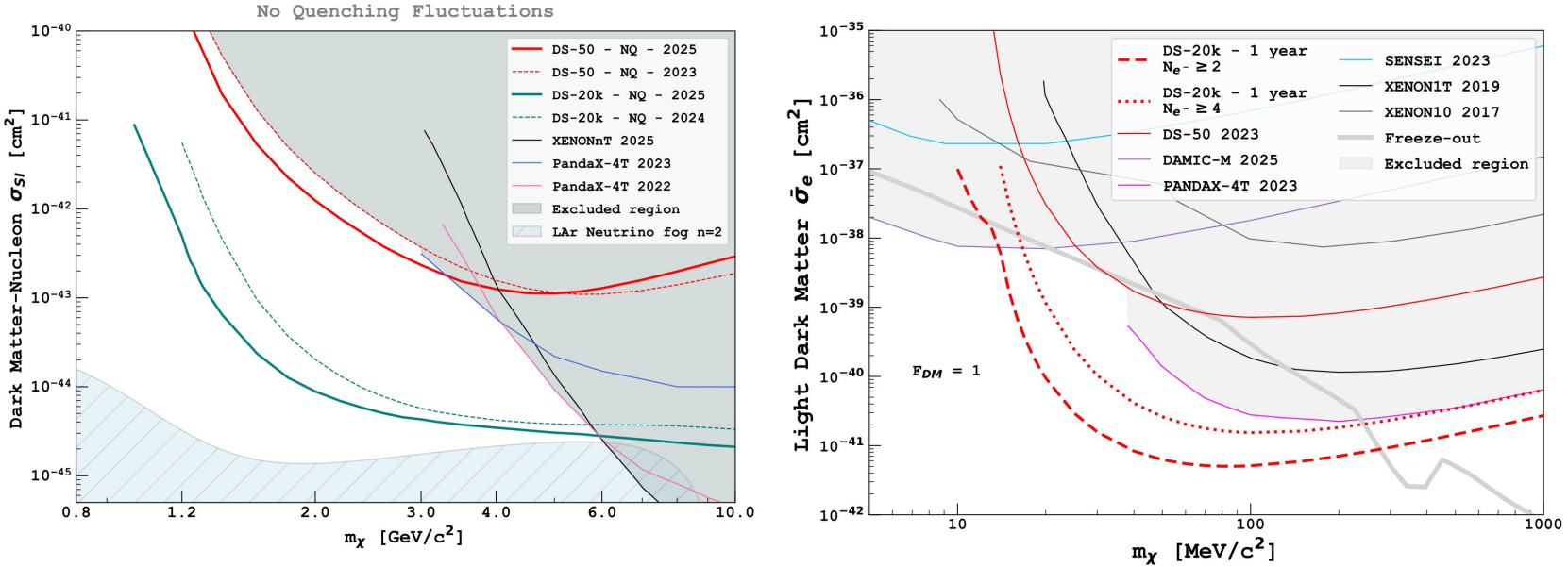
- **Motivation:**
  - Only after LZ is no longer the world-leading experiment for pillar 1; what other dark matter science can we do?
  - HydroX: sensitivity to low-mass dark matter (10 MeV to 1 GeV mass range).
  - Simultaneous sensitivity to Spin-Independent and Spin-Dependent interactions; unique and complementary to other DOE programs.
- **R&D needs:**
  - Basic technical feasibility of low-Z doping of xenon: solubility, signal size
    - Under investigation now with dedicated setups
  - Technical solution for adding and removing a dopant in LZ while maintaining purification
- **LZ Modification needs:**
  - Requires modification to circulation system
  - Unproven technology update (loading of sufficient low Z mass). Mitigation: includes a go/no-go milestone

The DarkSide-20k Experiment

Meeting with the APS DPF

May 21, 2026

Science Reach - Low Mass Searches



(Left) 90 % C.L. exclusion sensitivity to light dark matter in the S2-only channel predicted for DS-20k (green) and observed in DS-50 (red). The dashed curves assume no fluctuations in NR quenching, resulting in more conservative limits. The solid curves use an updated NR quenching model based on recent measurements. Experimental limits from PandaX-4T (blue and pink) and XENONnT (black) are shown for comparison. (Right) Projected DS-20k exclusion curves for dark matter scattering on electrons via a heavy mediator (red dashed) compared to existing experimental limits.

The Argon Extraction Facility

Urania Project: *Enabling Multi Ton-Scale UAr*

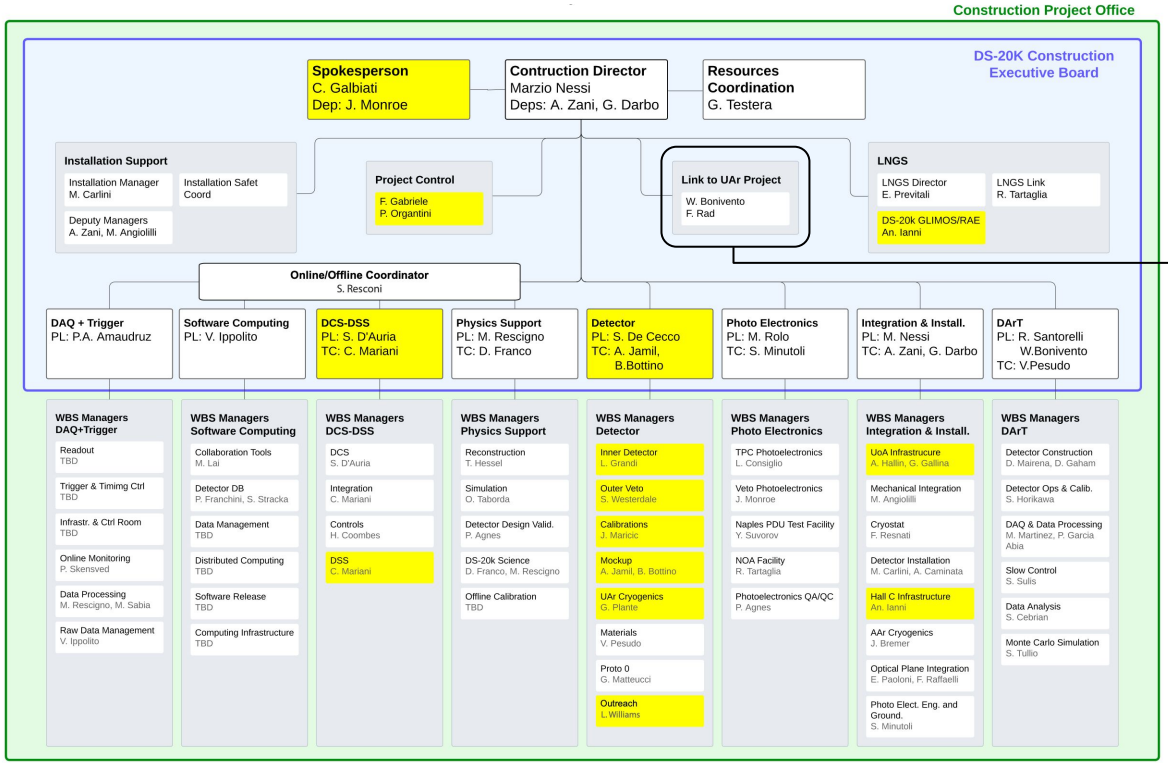
Construction completed

Commissioning in summer 2026

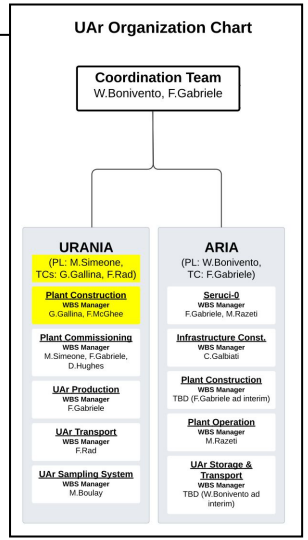
- UAr from deep CO_2 underground reservoirs
- UAr at a purity of 99.99%
- Multi-stage Purification: adsorption, cryogenic separation
- 6,667 ft^2 ≈ 619 m^2, 17 m height distillation columns
- Continuous production of 120 tons (<2 yrs)
- Expected production rate = 300 kg/day
- Scalable to future multi-ton noble-liquid detectors
- Note: DOE HENP had an important role in establishing UAr with the prototype DS-50 but is not involved in DS-20k

The US Leadership Roles

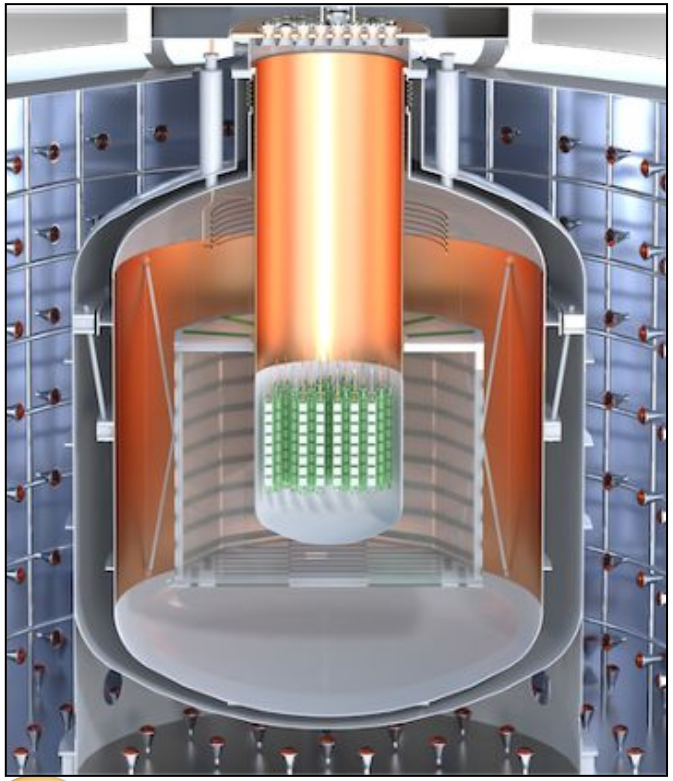
The DS-20k Organizational Structure



- US Leadership highlighted in yellow
- The organizational chart shows WBSs up to DS-20k Level 3 (or WBS L1 Managers, as reported in the previous table)



UAr: *A new Resource for LEGEND-1000*



Why Underground Ar for LEGEND-1000?

- Search for neutrinoless double beta decay ($0\nu\beta\beta$)
- Underground argon suppresses the ^{42}Ar background
- 42 strings × 8 Ge detectors
- ~20 tons of underground liquid argon

LEGEND-1000 Requirements

- Target sensitivity: 3σ discovery potential at $T_{1/2} > 10^{28}$ yr
- Modular deployment: 4 × 250 kg Ge detector modules
- Baseline UAr demand: ~18–26 tons
- Contingency scenarios: Up to ~180 tons possible

Impact of Urania

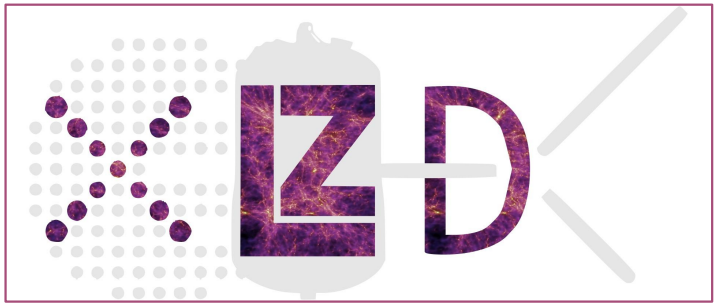
- Only existing facility capable of supplying low-^{42}Ar underground argon
- Enables immediate extraction after DarkSide-20k

XLZD: A next generation observatory for rare events

DPF Community meeting

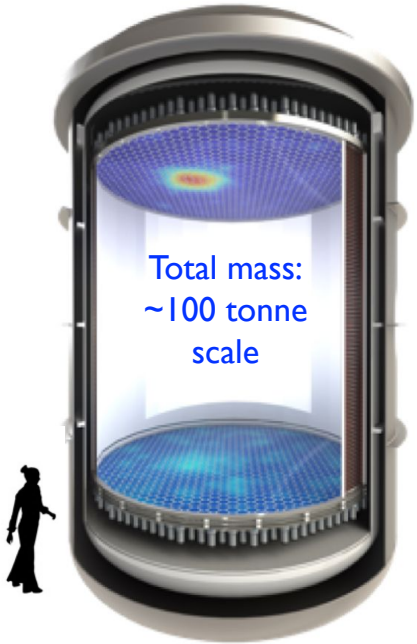
21-22 May 2026

Prepared for Rick Gaitskell on behalf of XLZD

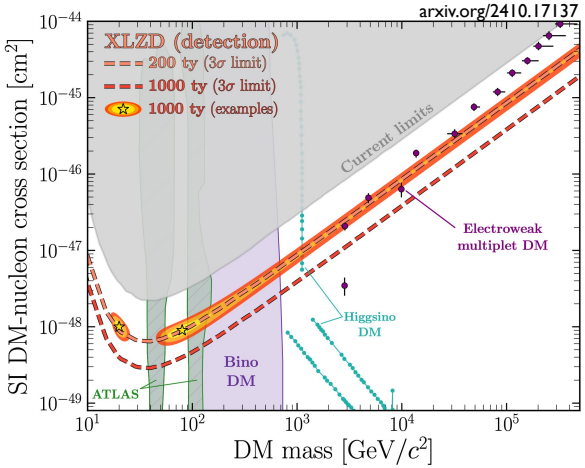


XLZD: liquid xenon observatory at the 100-tonne scale

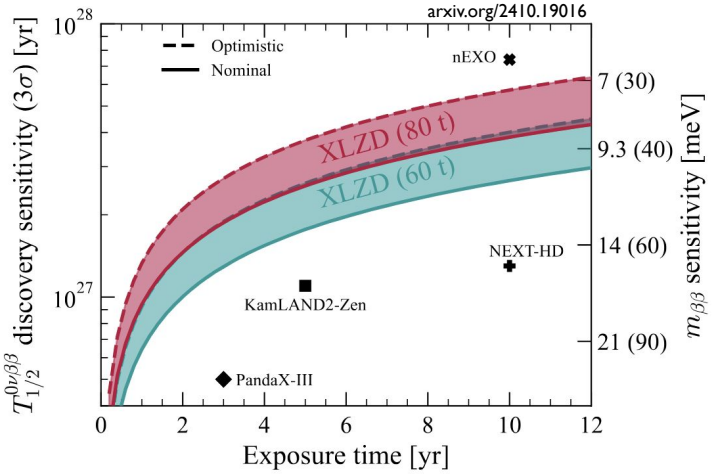
Natural xenon in a 2-phase TPC



Probe WIMP Dark Matter to neutrino fog systematic limit



DM detector w/natural xenon: Competitive sensitivity for $0\nu\beta\beta$



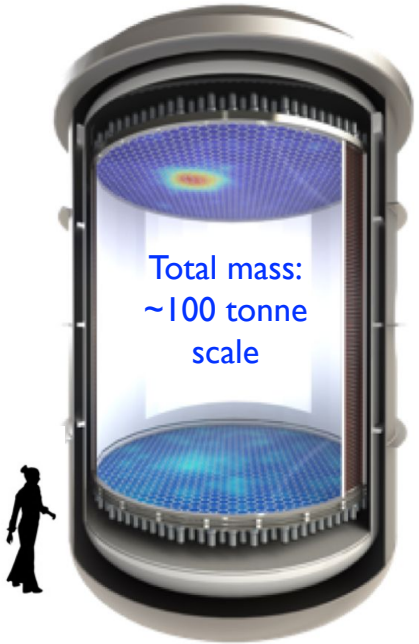
- Definitive WIMP search: systematics limited by ν fog at ~1000 tonne-years of exposure sets scale for ~100-tonne detector
- Xe-136 is 9% of the natural abundance, allowing a search for $0\nu\beta\beta$ with the potential to approach the nEXO design sensitivity
  - Optimization to push sensitivity to $T^{1/2} \sim 10^{28}$ years is under study

XLZD history, status and related events

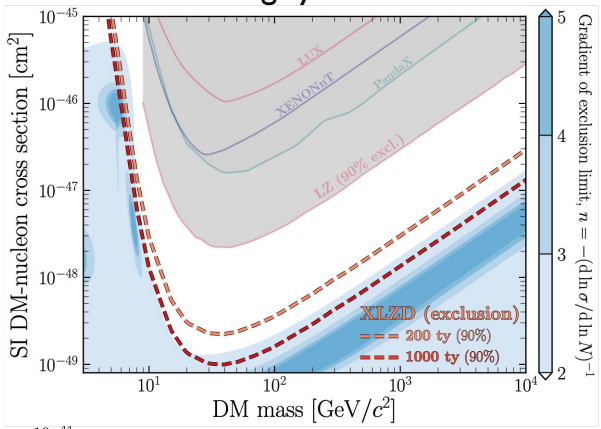
- July 2021: Consortium MOU signed by XENONnT, LUX-ZEPLIN, DARWIN
- Oct 2023: NSAC LRP recommends pursuit of 0vbb in multiple isotopes at the ton-scale
- Dec 2023: P5 recommends Generation 3 DM (G3DM) search to neutrino fog limit
- Sept 2024: XLZD Collaboration agreement signed
- Dec 2024: DOE NP announces indefinite pause of nEXO project due to funding constraints
- Dec 2025: DOE HEP announces deferring of G3DM until early 2030's due to funding constraints
- Key activities in 2026:
  - International partners continue to vigorously pursue XLZD; working towards CDR for early 2027, with ongoing US engagement
  - Significant engagement from DM and 0vbb community in Canada: 11 institutions join XLZD, bid for SNOLAB hosting
  - Technical evaluation of 4 sites to complete in the coming months: Boulby, LNGS, SURF, SNOLAB
  - US participation is a critical part of the technology base and needed to realize the full scientific reach of 80-t active target on a competitive timeline

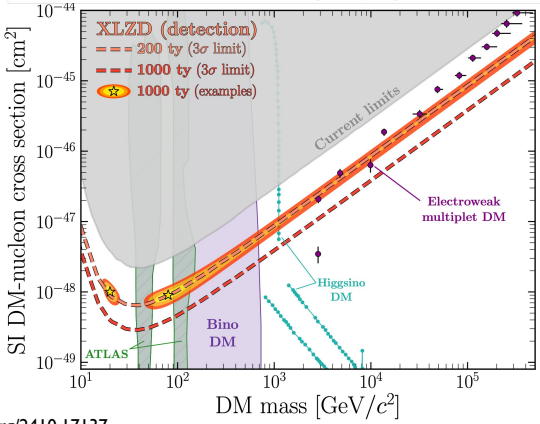
XLZD: liquid xenon observatory at the 100-tonne scale

Natural xenon in a 2-phase TPC



Probe WIMP Dark Matter to neutrino fog systematic limit





arxiv.org/2410.17137

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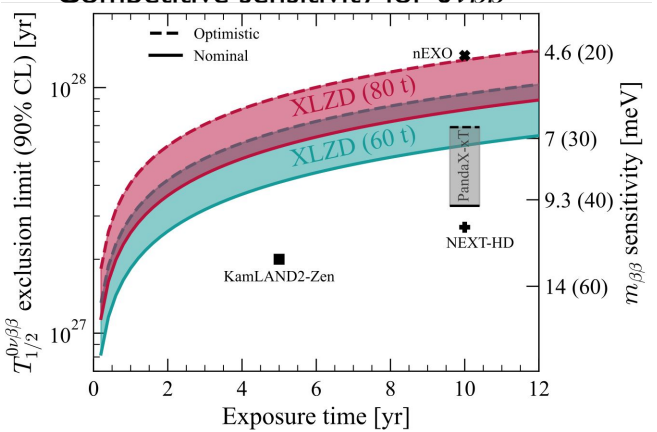
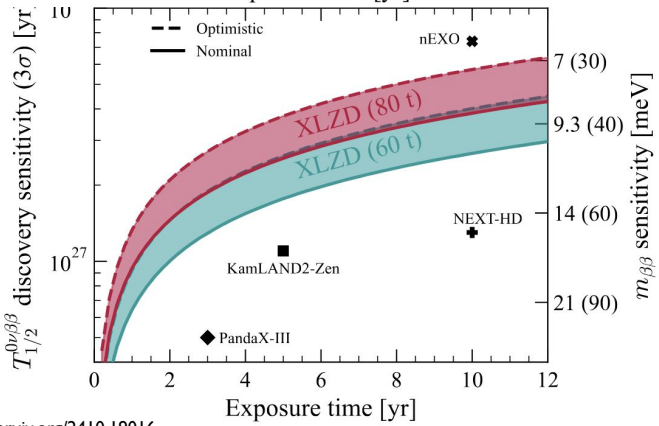
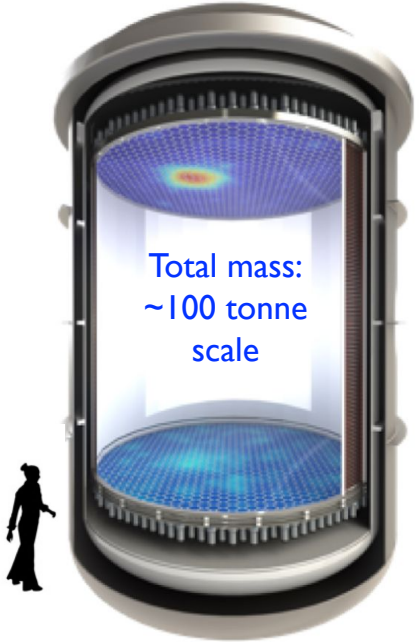




arxiv.org/2410.19016

XLZD: liquid xenon observatory at the 100-tonne scale

Natural xenon in a 2-phase TPC



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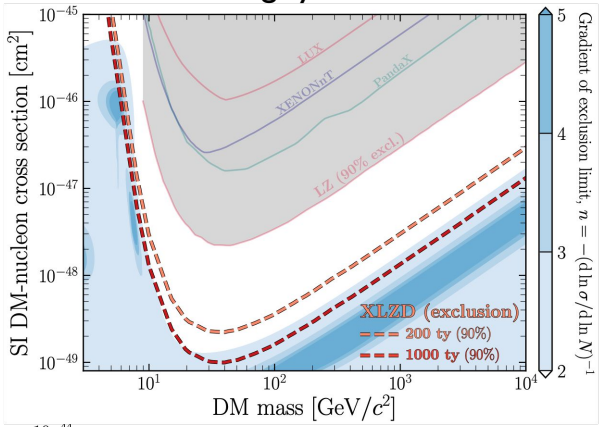

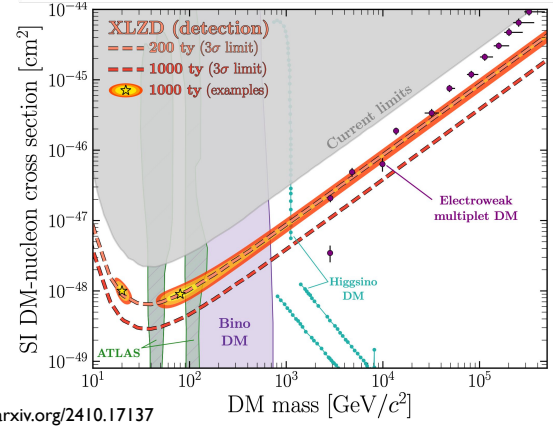

arxiv.org/2410.17137

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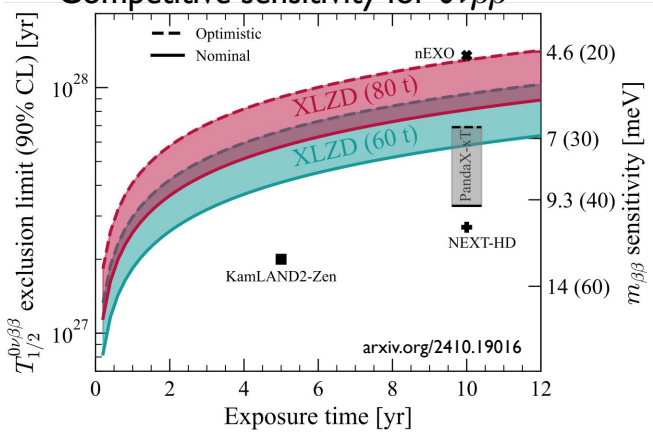

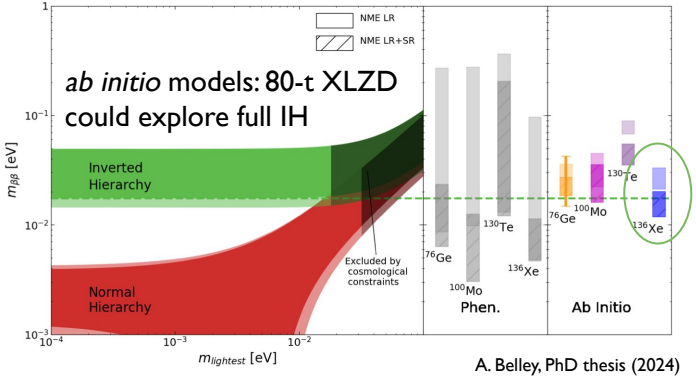

A. Belley, PhD thesis (2024)

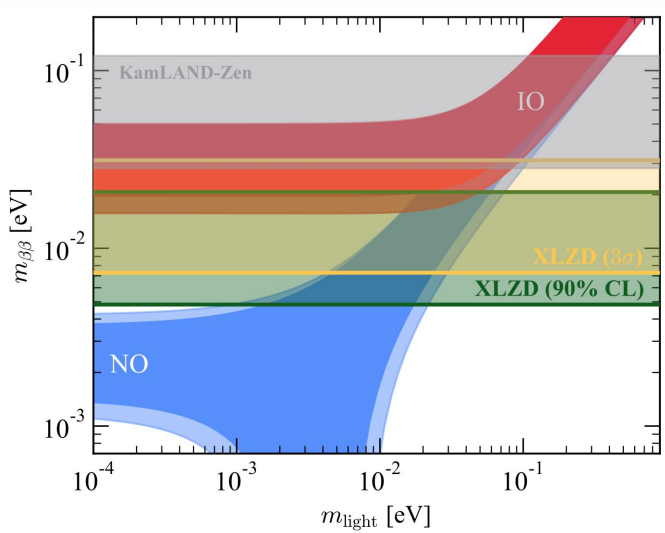

Figure 5. Sensitivity of XLZD to the effective Majorana neutrino mass as a function of the lightest neutrino mass for the 80 t configuration in the optimistic scenario with 10 years of data. The two metrics considered in this work are shown: 3σ discovery potential (yellow band) and 90% CL exclusion (green band). The width of the bands is caused by the uncertainty in the nuclear matrix element models (see main text, also for the expected sensitivity using the most recent nuclear matrix elements). The current best experimental limits from KamLAND-Zen, also from $0\nu\beta\beta$ decay in ^{136}Xe and assuming the same range of NMEs, are shown in grey [5]. The allowed regions ($\pm 3\sigma$) for the effective Majorana neutrino mass in the inverted (IO) and normal (NO) neutrino mass ordering scenarios are also shown [64, 65].