Status of the LUX-Zeplin (LZ) Experiment

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On behalf of the LZ Collaboration

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Liquid xenon TPC

Primary goal

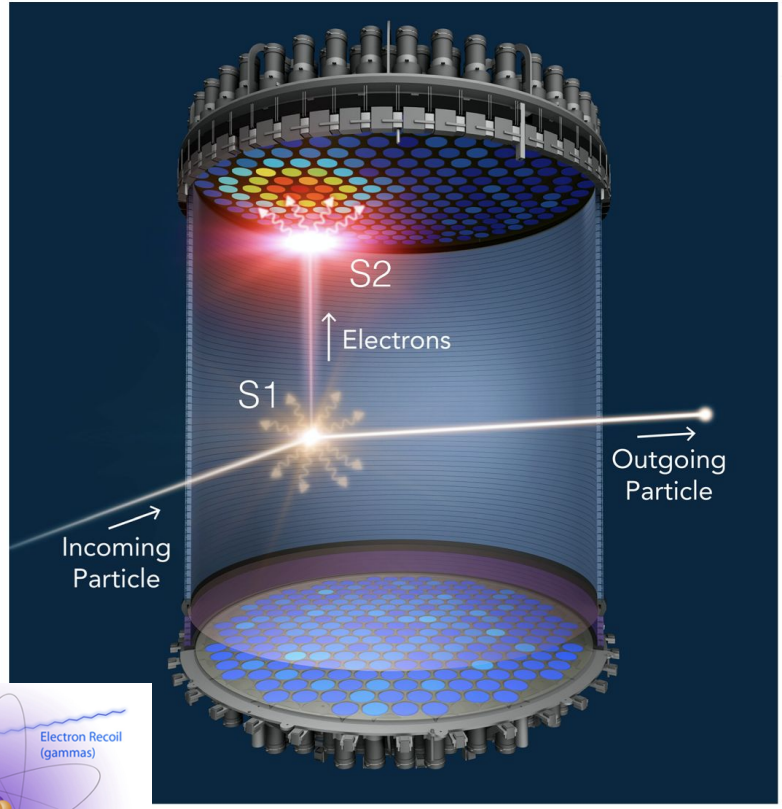
- Searching for low energy nuclear recoils from WIMP dark matter

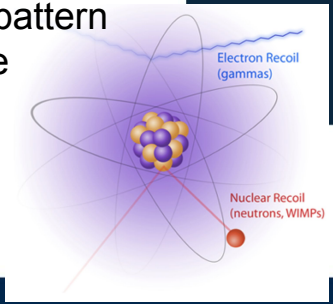
Requirements

- Large target mass
- Low energy threshold
- Backgrounds control

Dual Phase TPC Detector

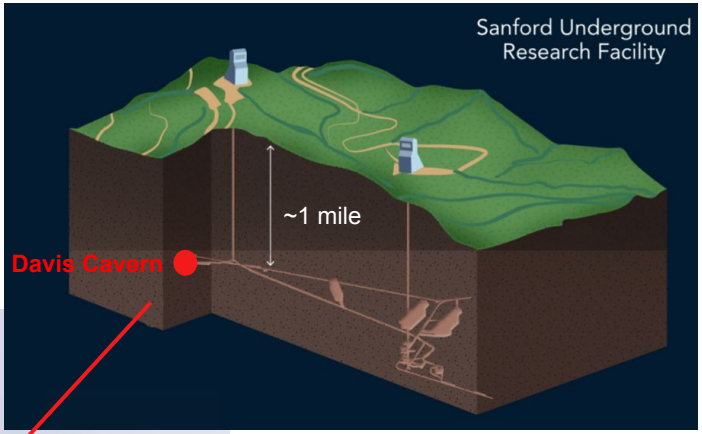
- Primary scintillation (light) → S1
- Secondary scintillation (from charge) → S2
- Radial position from top PMT array S2 pattern
- Z position determined from the drift time
- ER/NR discrimination

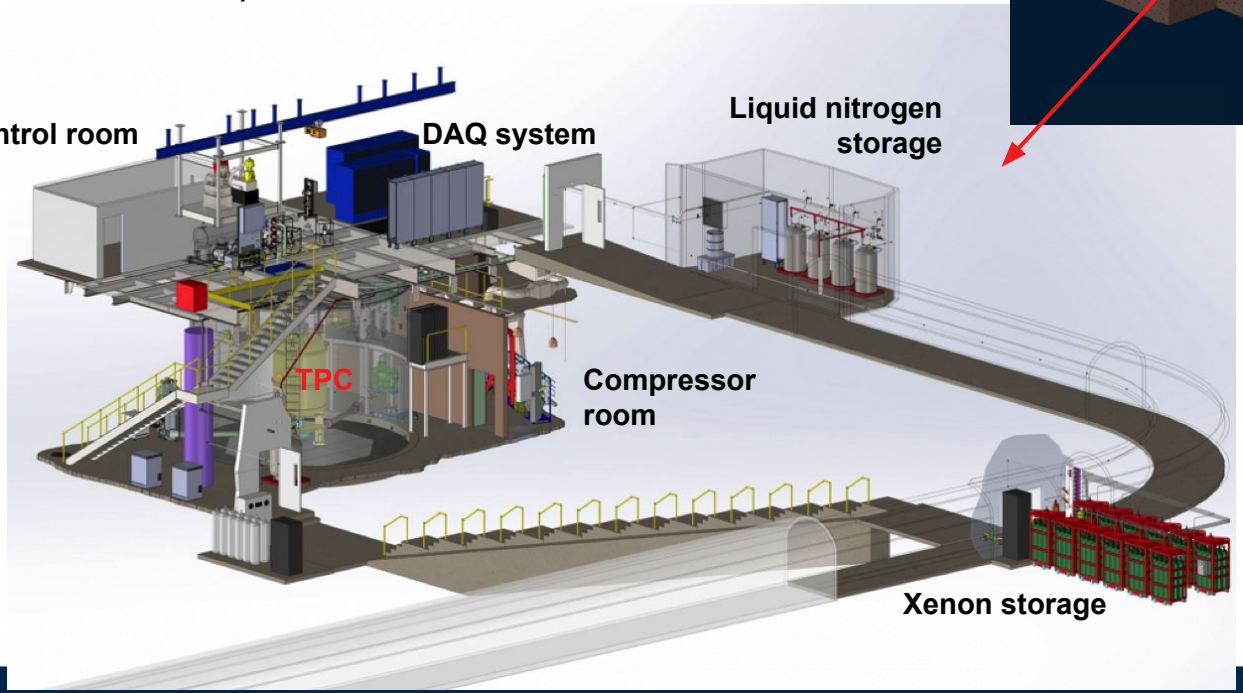




LZ detector at SURF

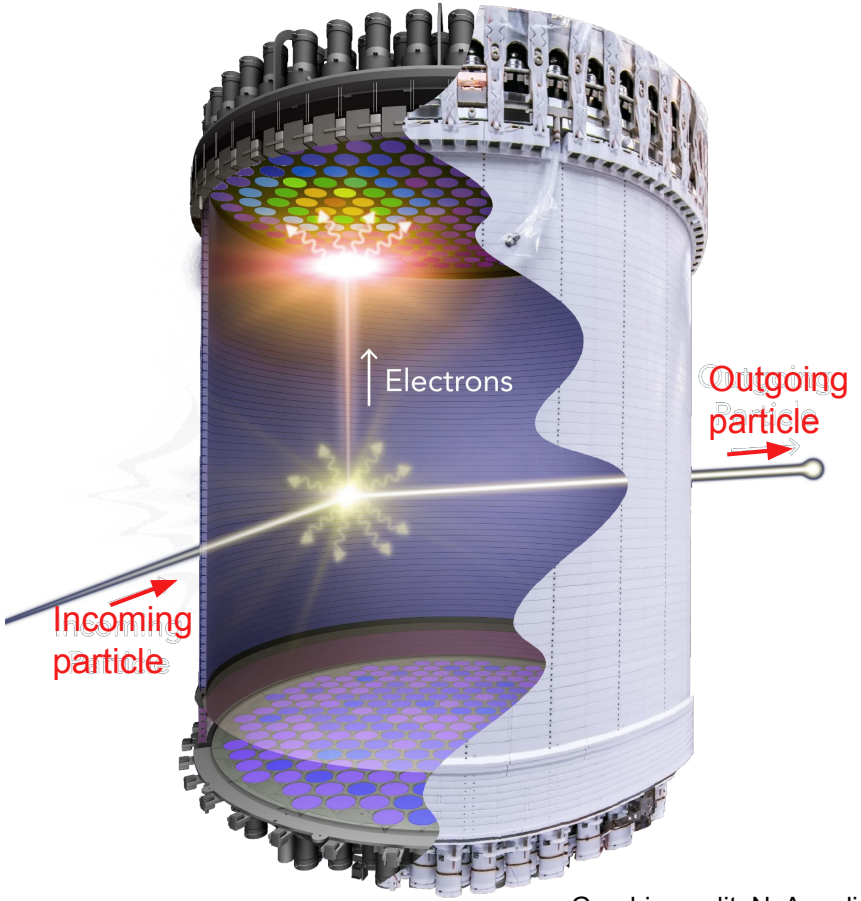
- LZ is located in the Davis cavern at Sanford Underground Research Facility (SURF) in Lead, South Dakota
- ~1 mile underground → muon flux reduced by O(10^6)
- Housed the LUX experiment from 2013-2016





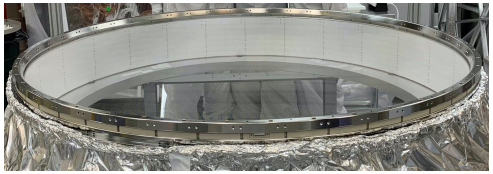
LZ TPC

- Diameter and height → ~1.5m
- PTFE walls ~97% VUV reflectivity in LXe
- 7 tonnes of active Xe mass
- 494 TPC PMTs in 2 arrays
- 4 HV electrode grids
  - Drift region
  - Extraction region

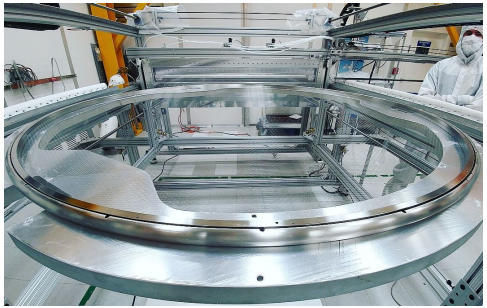


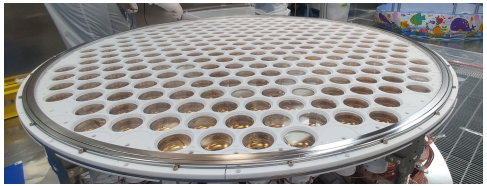
Graphic credit: N. Angelides

LZ TPC in pictures

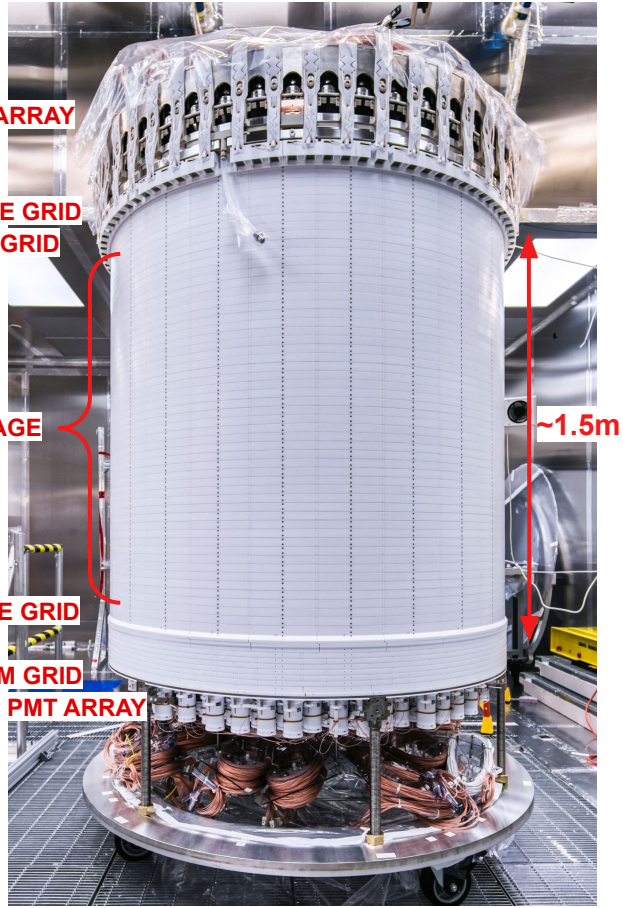


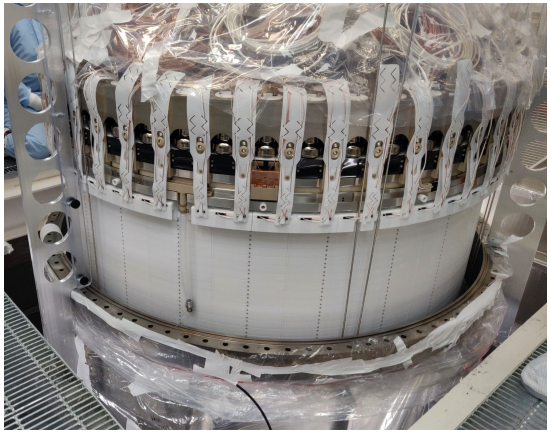
HV wire electrode grids woven at SLAC





LZ grids paper: arXiv:2106.06622

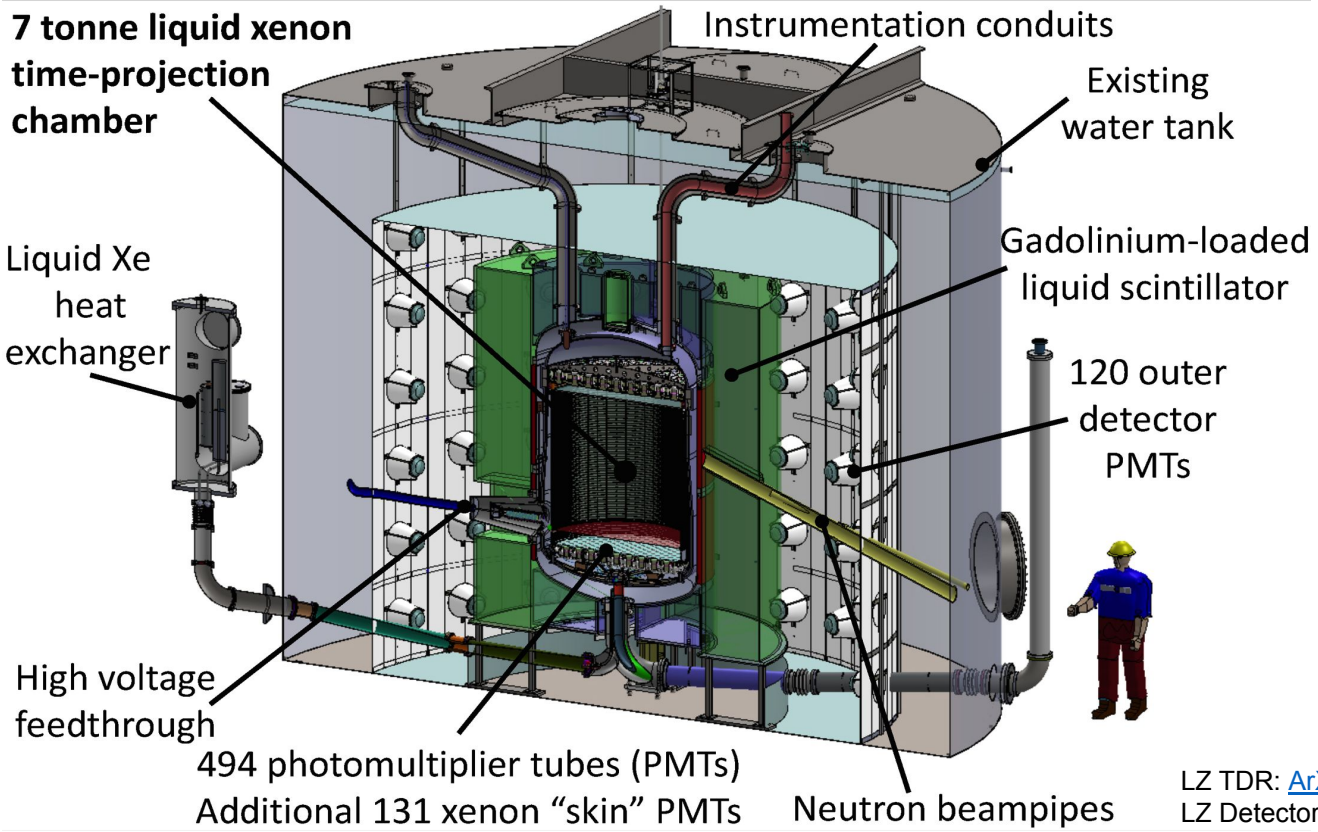




Insertion of the TPC into inner vessel

The Bottom Array and the field cage

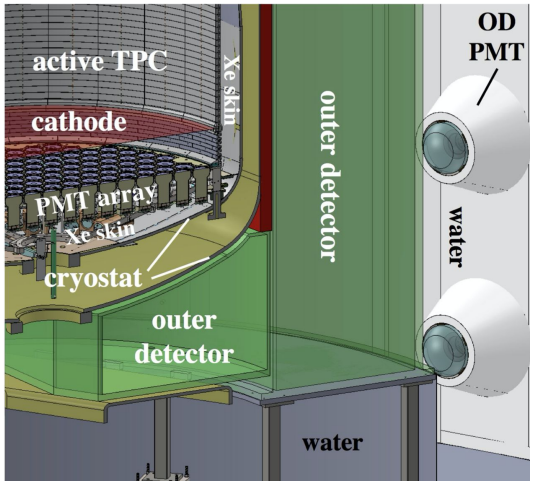
LZ detector overview



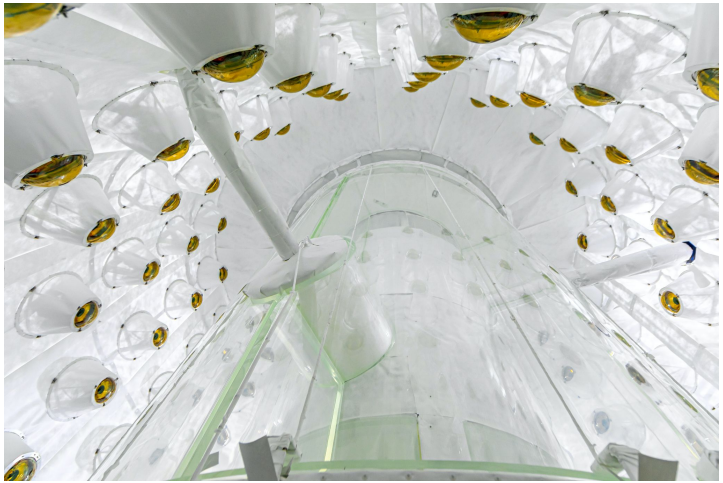
LZ TDR: ArXiv:1703.09144
LZ Detector: NIMA 953 163047 (2020)

Skin & outer detectors

- 2T active xenon mass outside of the TPC in the ICV
  - Optically isolated from the TPC
  - Expected >95% efficiency at tagging gammas
- Acrylic vessels all around the OCV
  - 17T of Gd-loaded liquid scintillator
  - Neutron capture on Gd and H leads to gammas
  - Gammas seen by OD PMTs



20 Bottom side dome PMTs in the ICV

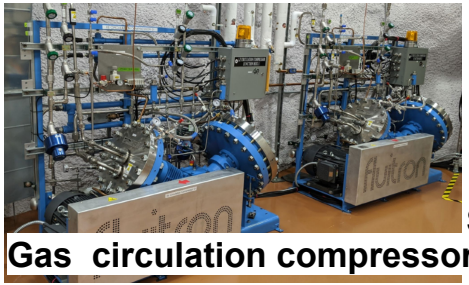


Assembled Outer Detector (OD)
Penning Group (Michigan)

93 1” PMTs at the top of the skin

LZ purification and handling

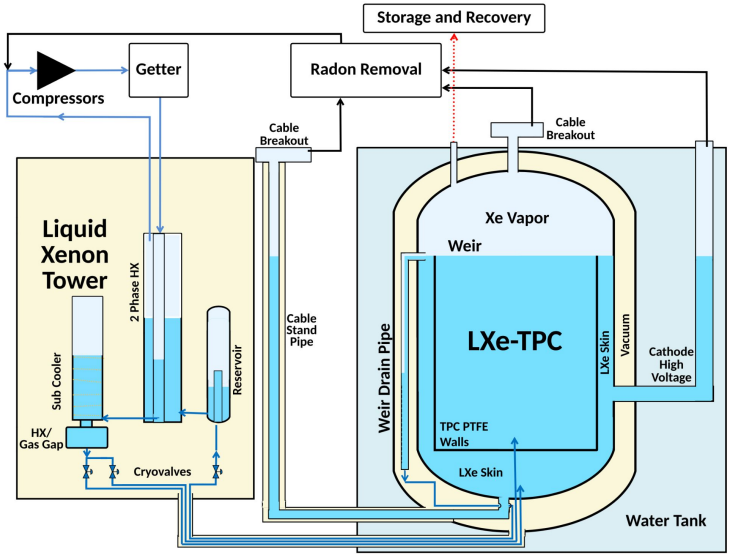

Krypton removal system at SLAC


Gas circulation compressor

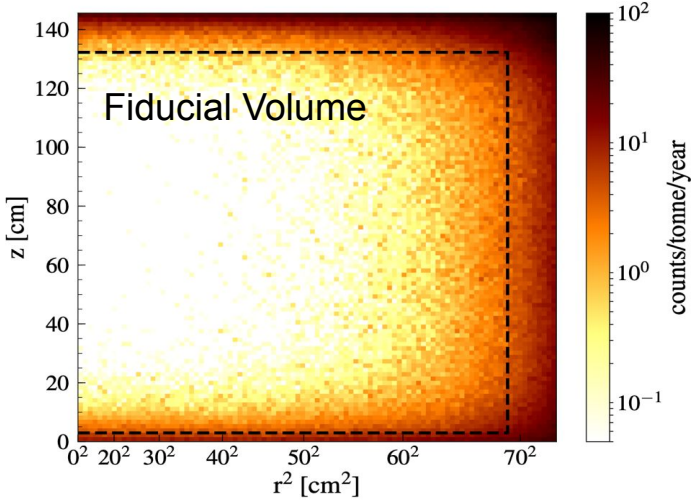
SAES getter


Inline radon reduction
Lorenzon Group (Michigan)

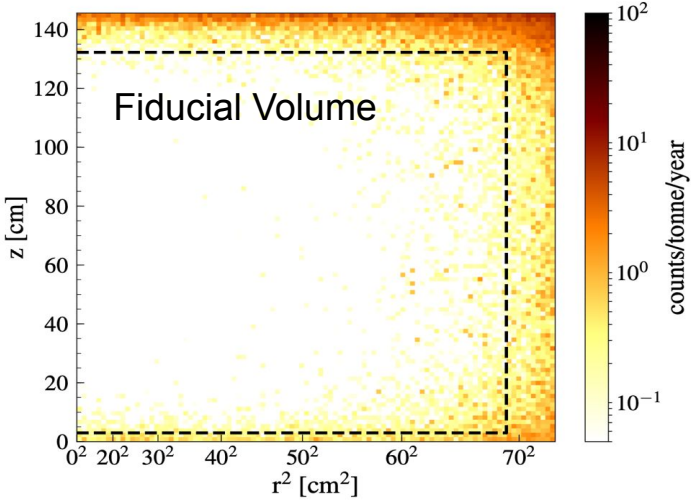
- Krypton removal using activated carbon at SLAC
  - Less than 300 ppq Kr/Xe achieved
- Continuous gas phase purification with a hot zirconium getter
  - Removes electronegative impurities
  - Ensures high electron lifetime
- Continuous radon reduction with an inline radon reduction system (iRRS)
  - Using an activated carbon trap (gas chromatography)



Anticoincidence cuts with veto detectors



No veto cuts

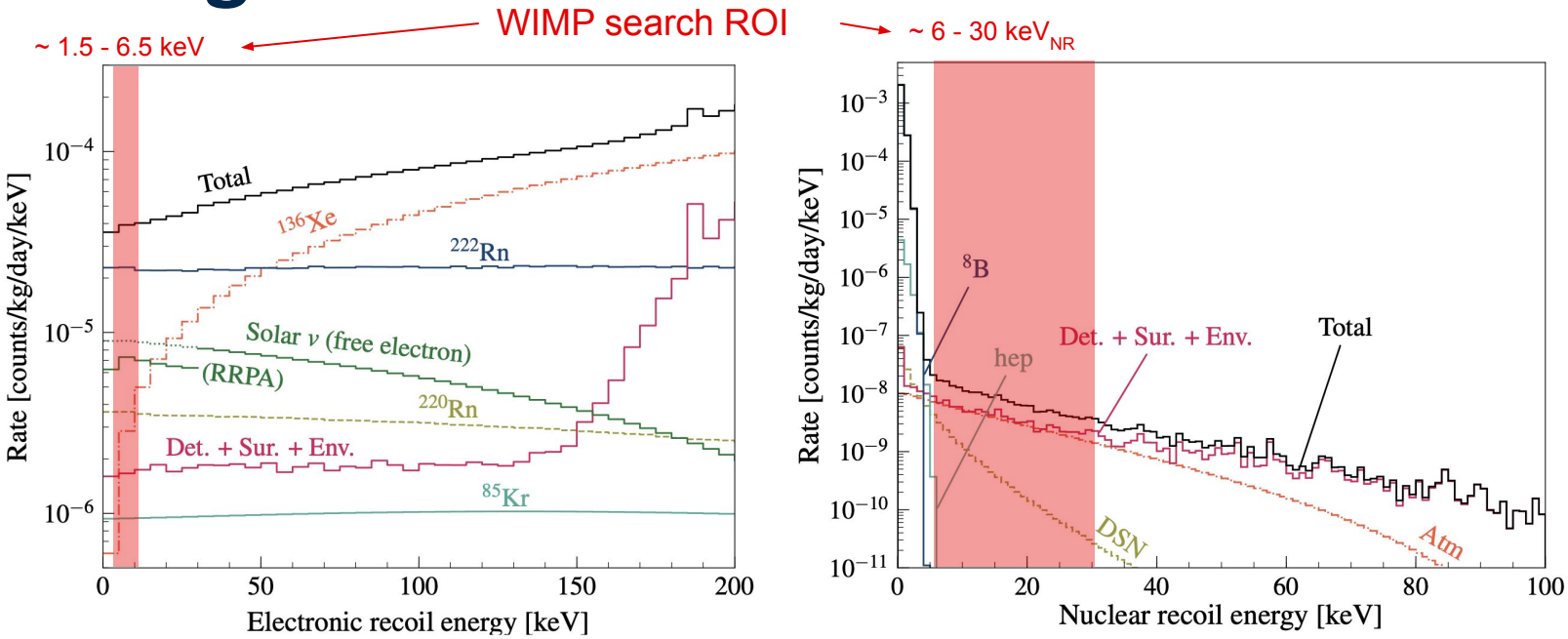


After skin + OD Veto cuts

- Single scatter event distributions for all significant NR backgrounds in the region of interest relevant to a 40 GeV/c^2 WIMP (approximately 6–30 keV)
- About factor of 10 reduction of the integrated background counts in the 5.6 tonne fiducial volume in 1000 live days
  - → larger fiducial volume

LZ background estimates

LZ background controls: EPJC 80, 1044 (2020)



Contributions from various ER backgrounds

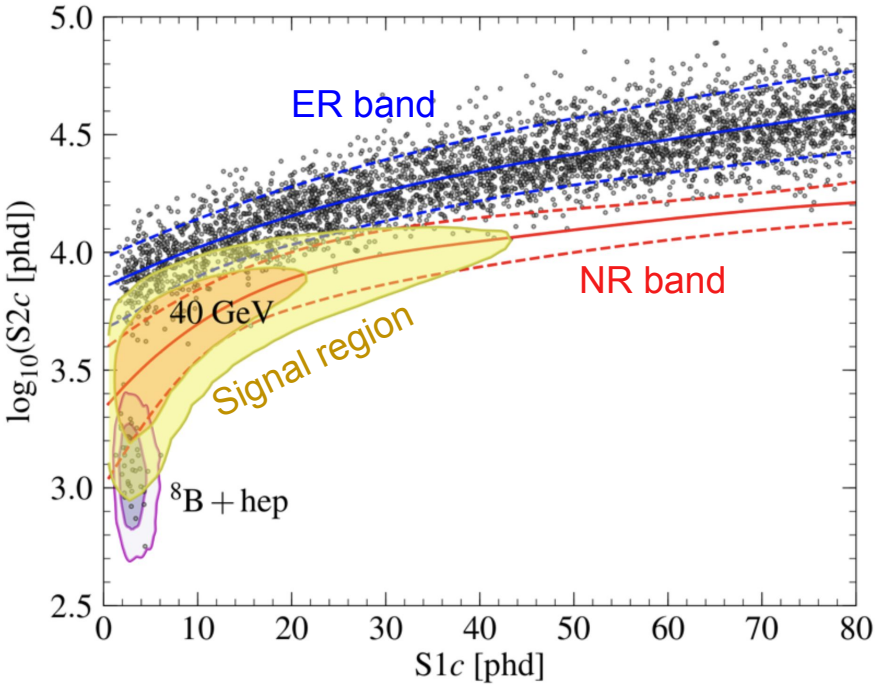
- ^{222}Rn has the largest ER contribution in WIMP search region of interest

Contributions from various NR backgrounds

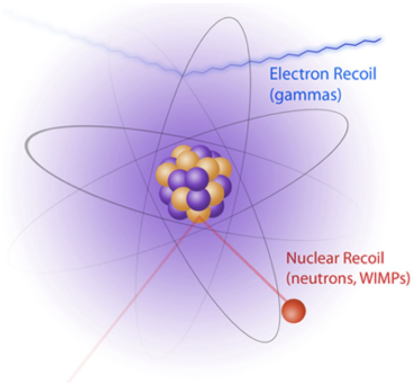
- At lower energies dominated by solar neutrino coherent scatters

In 5.6 tonnes fiducial volume in 1000 live days

Background reduction



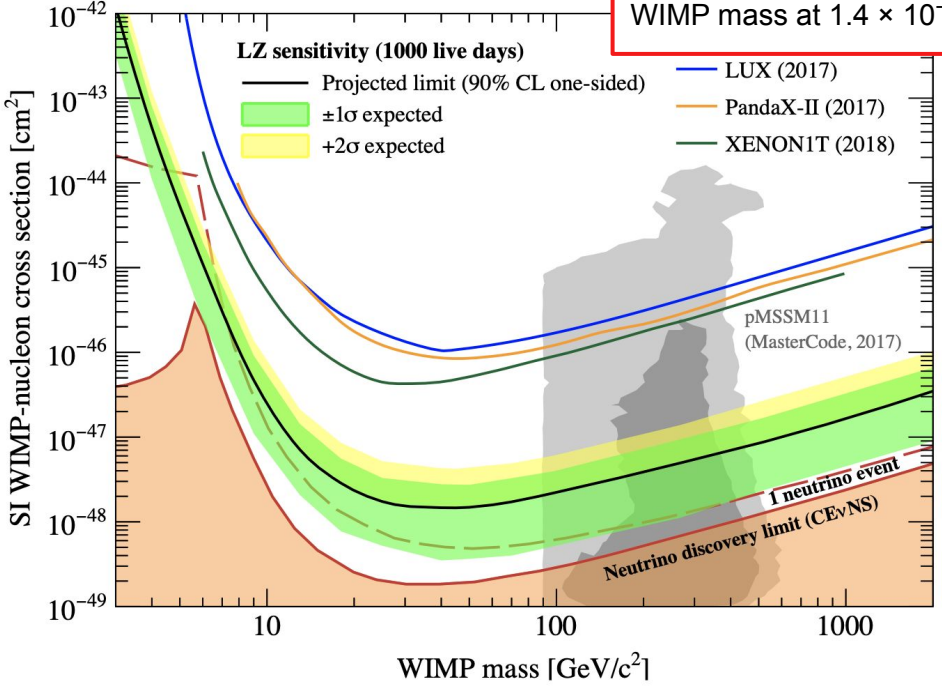
In 5.6 tonnes fiducial volume in 1000 live days

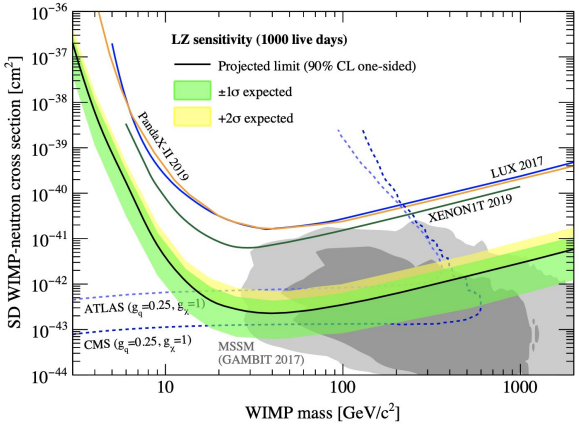


- ER and NR events can be distinguished using their different S1/S2 ratio
  - 99.5% ER discrimination with 50% NR efficiency
  - Before: 1131 ER events and 10.4 NR events
  - **After: 5.97 ER events and 0.51 NR events**

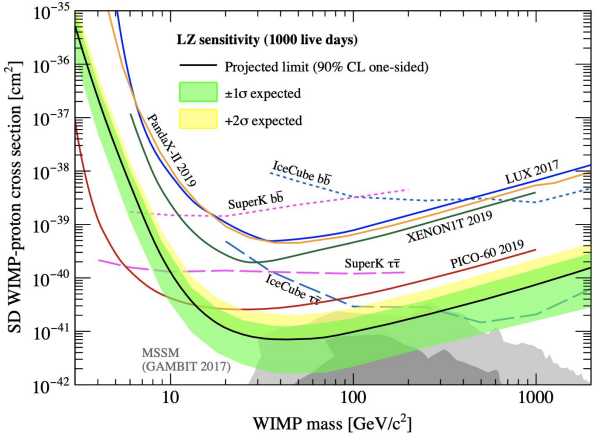
LZ projected WIMP sensitivity

Best sensitivity for 40 GeV/c^2
WIMP mass at 1.4 × 10^{-48} cm^2





Projected sensitivity to SD WIMP-n scatter



Projected sensitivity to SD WIMP-p scatter

LZ WIMP sensitivity paper: [Phys. Rev. D 101, 052002]

Physics reach of LZ

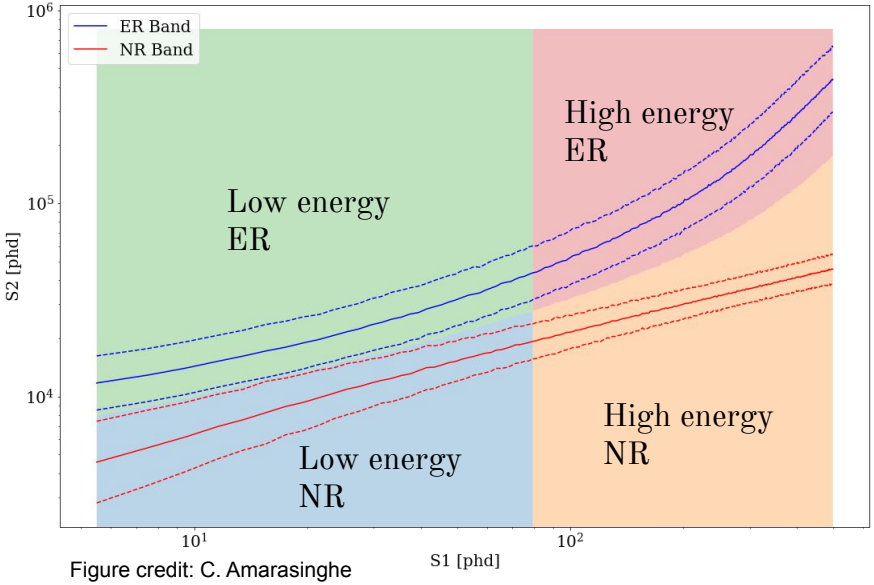


Figure credit: C. Amarasinghe

Low energy NR

WIMPS, CeνNS,

Low energy ER

Axions, ALPs

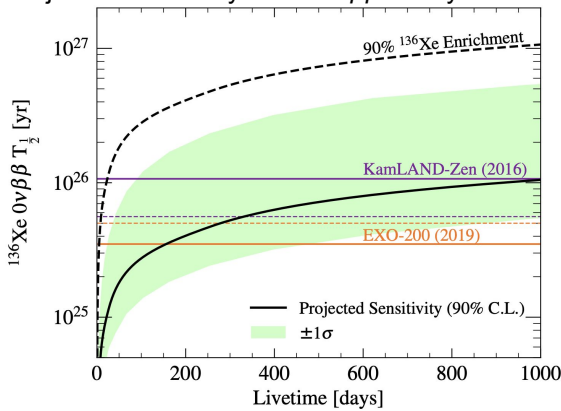
High energy NR

EFT, inelastic DM

High energy ER

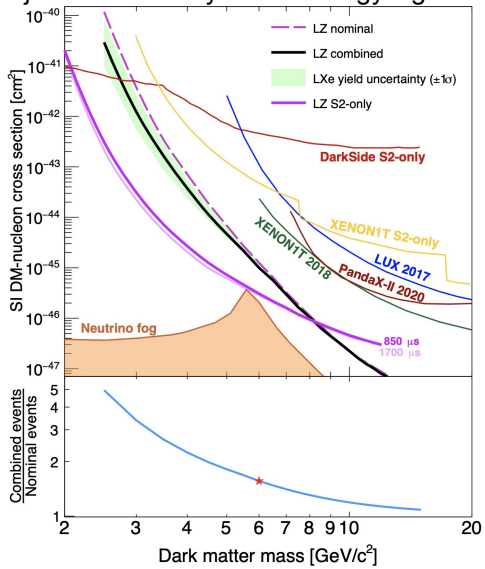
$0\nu2\beta$, rare decays

Projected sensitivity to the $0\nu\beta\beta$ decay of ^{136}Xe



Phys. Rev. C 102, 014602 (2020)

Projected sensitivity to low energy signals



arXiv:2101.08753

- Sensitivity to new physics via low-energy ER: Phys. Rev. D 104, 092009 (2021)
- Neutrino physics with the decays of ^{134}Xe: Phys. Rev. C 104, 065501 (2021)

- Black Hills State University
- Brandeis University
- Brookhaven National Laboratory
- Brown University
- Center for Underground Physics
- Edinburgh University
- Fermi National Accelerator Lab.
- Imperial 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 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 Wisconsin, Madison

LZ is a product of the heroic efforts of all of our collaborators from 34 institutions from US, UK, Portugal, and Korea!

Science and Technology Facilities Council

Sanford Underground Research Facility
South Dakota Science and Technology Authority

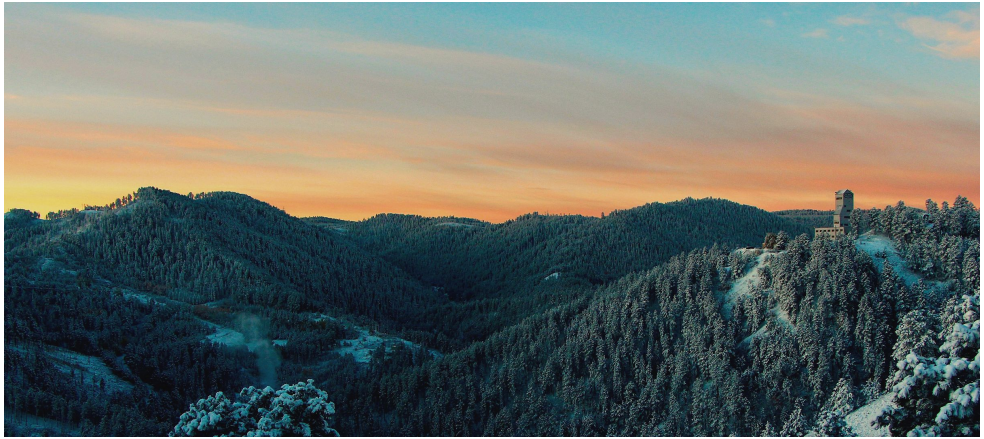
Fundação para a Ciência e a Tecnologia

기초과학연구원 Institute for Basic Science

Outlook

- Detector construction is complete
- Detector cooldown is complete
- All PMTs have been tested with LEDs
- **First Science Results expected this year**

- 2022 will be an exciting year for LZ!



Stay Tuned!

Thank you for your attention