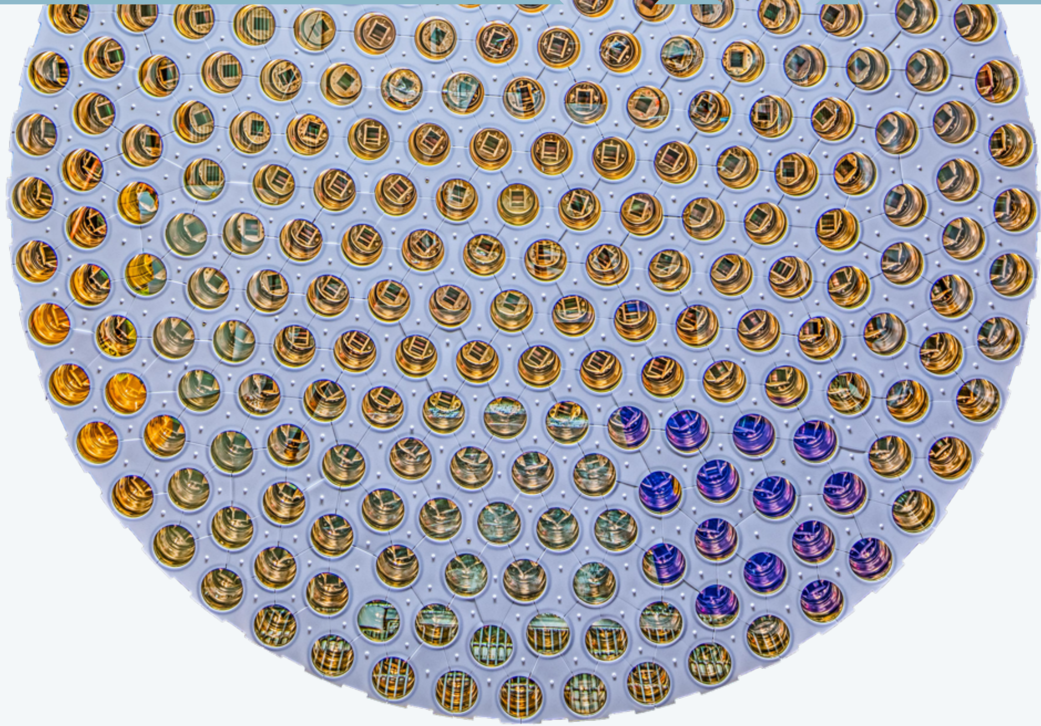
Status of the LZ Experiment

Theresa Fruth (UCL)

IoP 2021
Joint APP, HEP and NP conference

13th April 2021



LZ collaboration

1) Black Hills State University
2) Brandeis University
3) Brookhaven National Laboratory
4) Brown University
5) Center for Underground Physics
6) Edinburgh University
7) Fermi National Accelerator Lab.
8) Imperial College London
9) Lawrence Berkeley National Lab.
10) Lawrence Livermore National Lab.
11) LIP Coimbra
12) Northwestern University
13) Pennsylvania State University
14) Royal Holloway University of London
15) SLAC National Accelerator Lab.
16) South Dakota School of Mines & Tech
17) South Dakota Science & Technology Authority
18) STFC Rutherford Appleton Lab.
19) Texas A&M University
20) University of Albany, SUNY
21) University of Alabama
22) University of Bristol
23) University College London
24) University of California Berkeley
25) University of California Davis
26) University of California Santa Barbara
27) University of Liverpool
28) University of Maryland
29) University of Massachusetts, Amherst
30) University of Michigan
31) University of Oxford
32) University of Rochester
33) University of Sheffield
34) University of Wisconsin, Madison

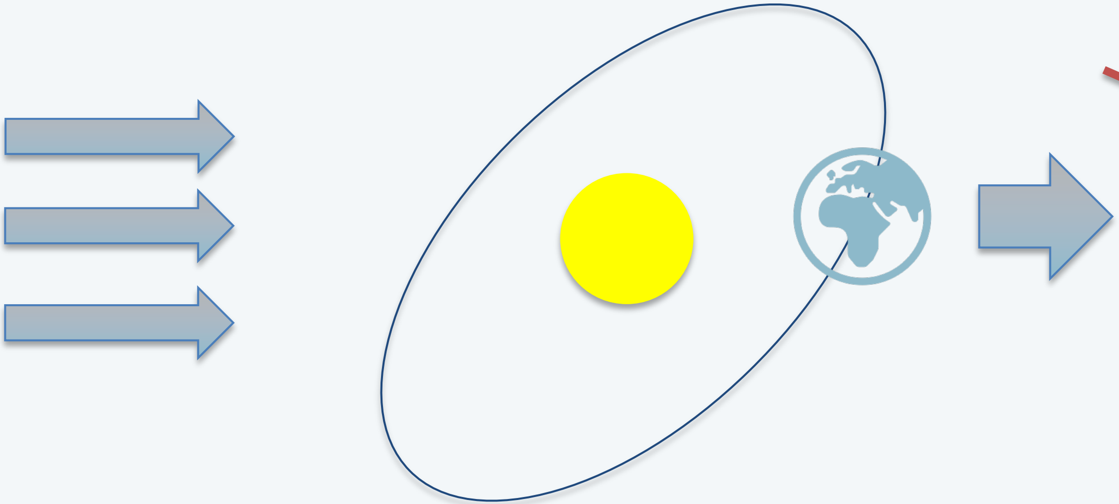
US UK Portugal Korea

Supported by DOE, STFC & SURF

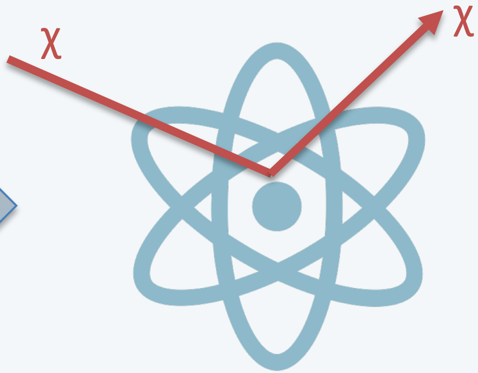
Direct Detection Search for Dark Matter

See Direct Dark Matter Searches by J. Dobson (Thursday, 1.30 pm)

Dark Matter wind



Elastic scattering:

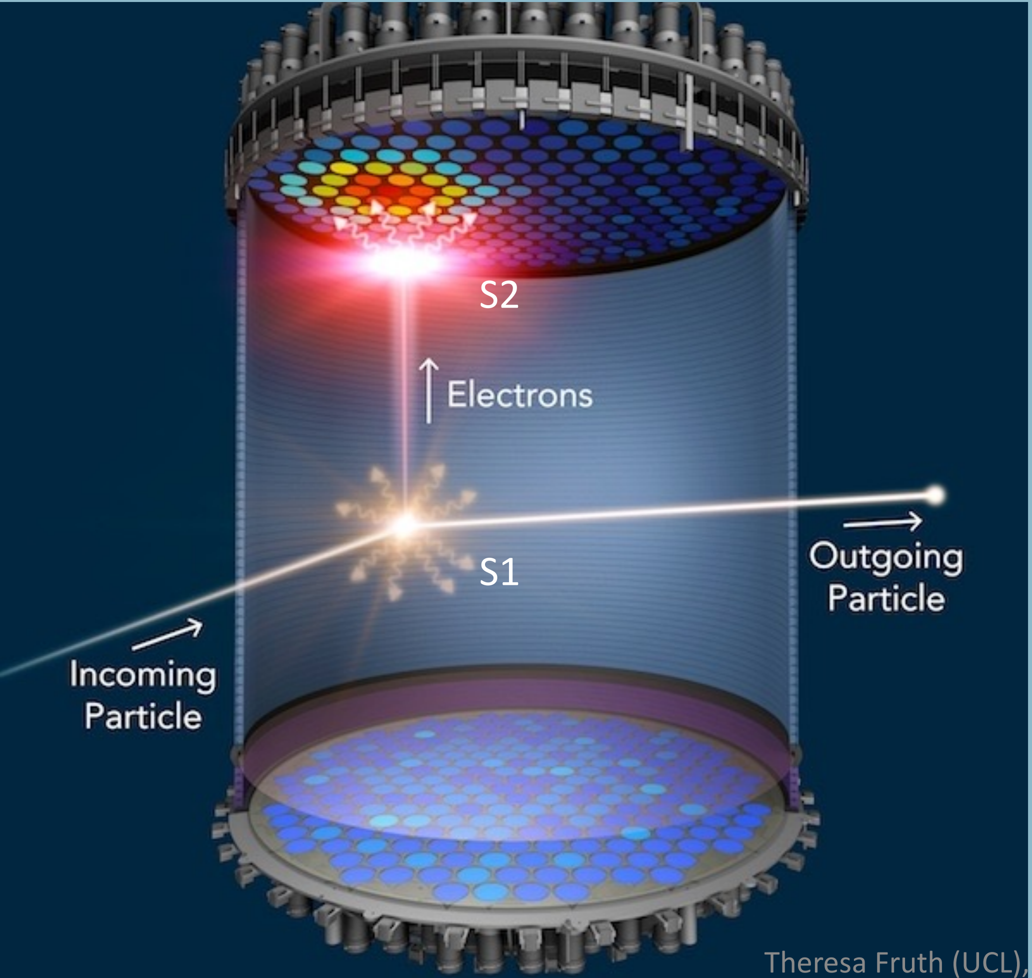


Xe atom

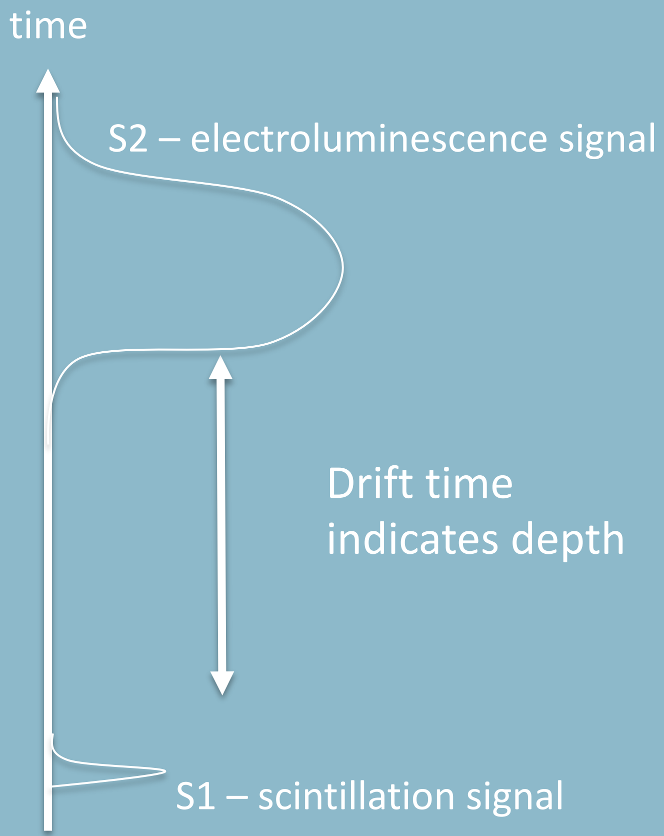
Nuclear recoil:
- Ionization (charge)
- Scintillation (light)

Milky Way – DM Halo:
- Density near sun ~ 0.3 GeV/cm^3
- Mean particle speed v ~ 300 km/s

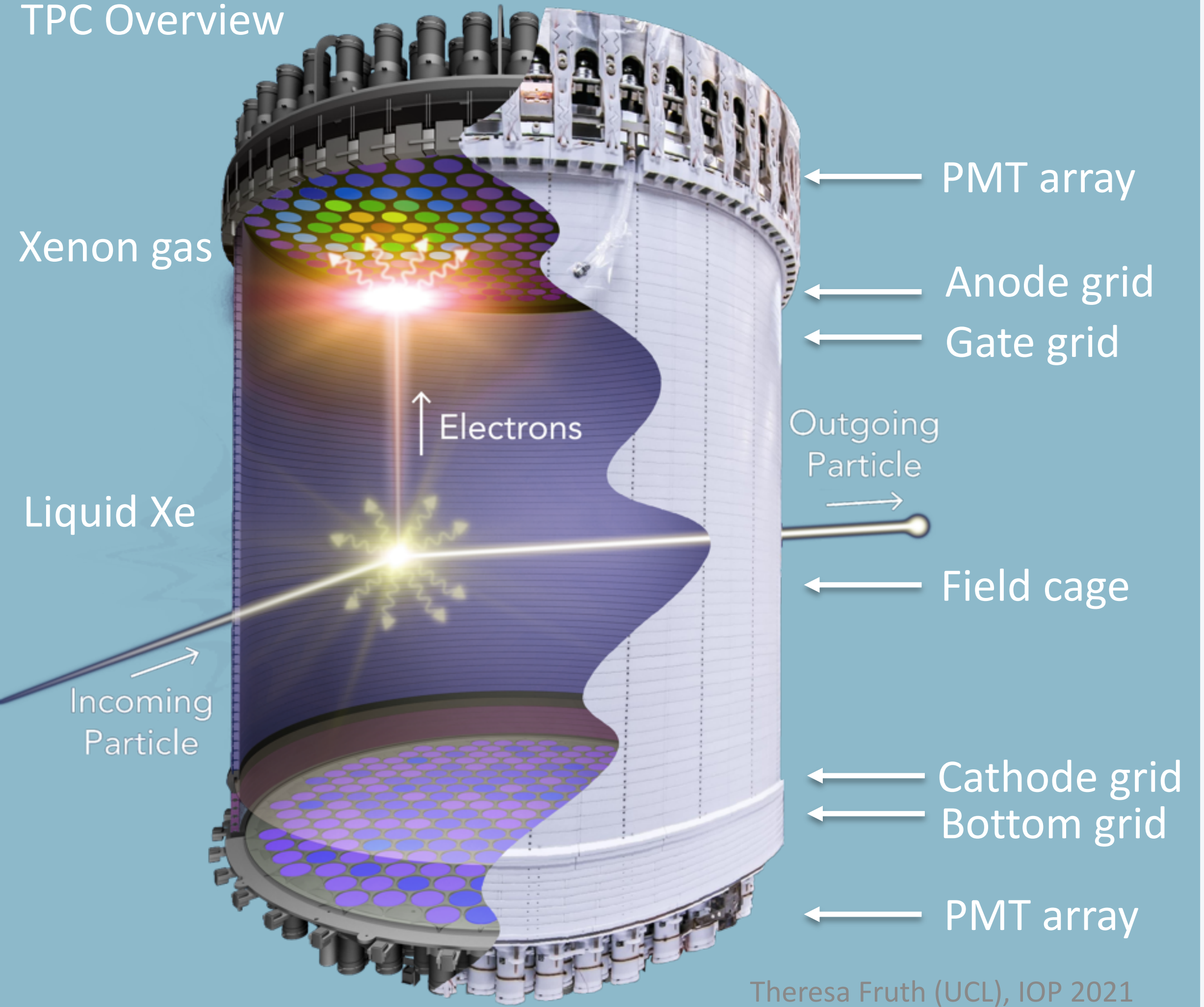
TPC Overview



Graphic © SLAC



TPC Overview

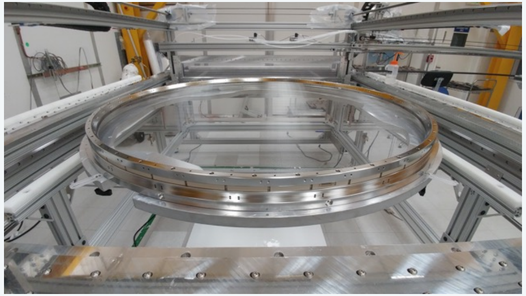


- 7 tonnes of Xenon, 5.6 tonnes fiducial volume
- Interaction leads to prompt scintillation and free electrons
- Electric field to extract electrons into gas leading to Electroluminescence light
- 3D reconstruction with S2 (XY) and S1-S2 delay (Z) allows fiducialisation

Graphic © SLAC, picture overlay N. Angelides

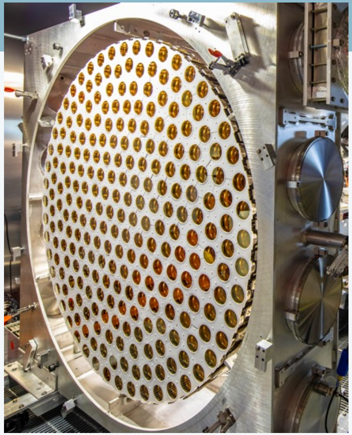
TPC Overview

Bottom PMT array with field cage

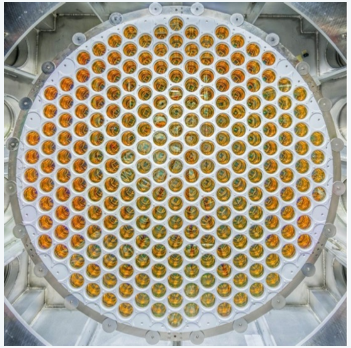


HV grid weaving at SLAC

Assembled TPC (July 2019)

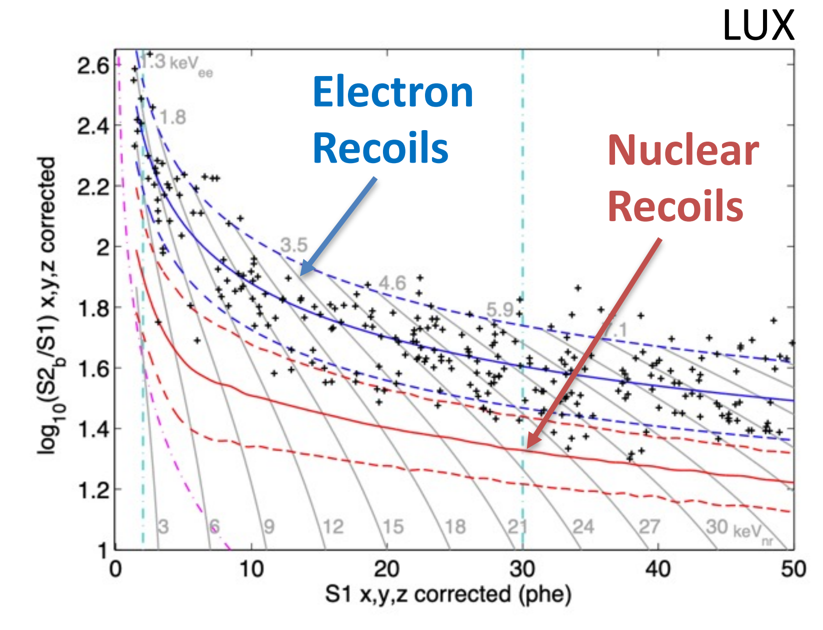


Top PMT array



Bottom PMT array

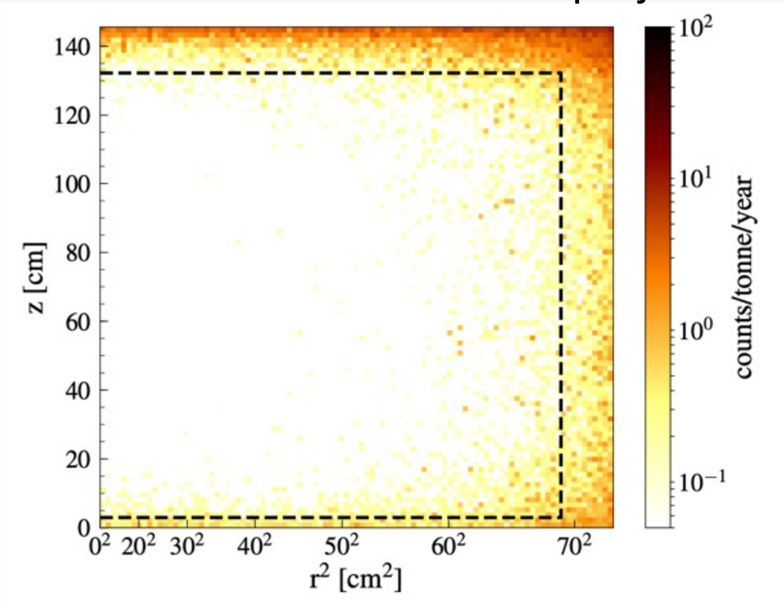
ER-NR discrimination



Phys. Rev. Lett. 112, 091303 (2014)

Fiducialization

LZ projected



Phys. Rev. D 101, 052002 (2020)

The European Physical Journal C, Volume 80, Article number: 1044 (2020)

Material Selection:

- Radio-assay campaign with gamma-screening and ICPMS
- Radon emanation:
  - 4 Rn emanation screening sites
  - Target Rn activity: 2 μBq/kg

Cleanliness during construction:

- Rn daughters and dust on surfaces
- TPC assembly in Rn-reduced cleanroom
- Dust <500 ng/cm^2 on all LXe wetted surfaces
- Rn-daughter plate-out on TPC walls <0.5 mBq/m^2

See Assembling the LZ detector by N. Angelides (Tuesday, 3.45 pm)

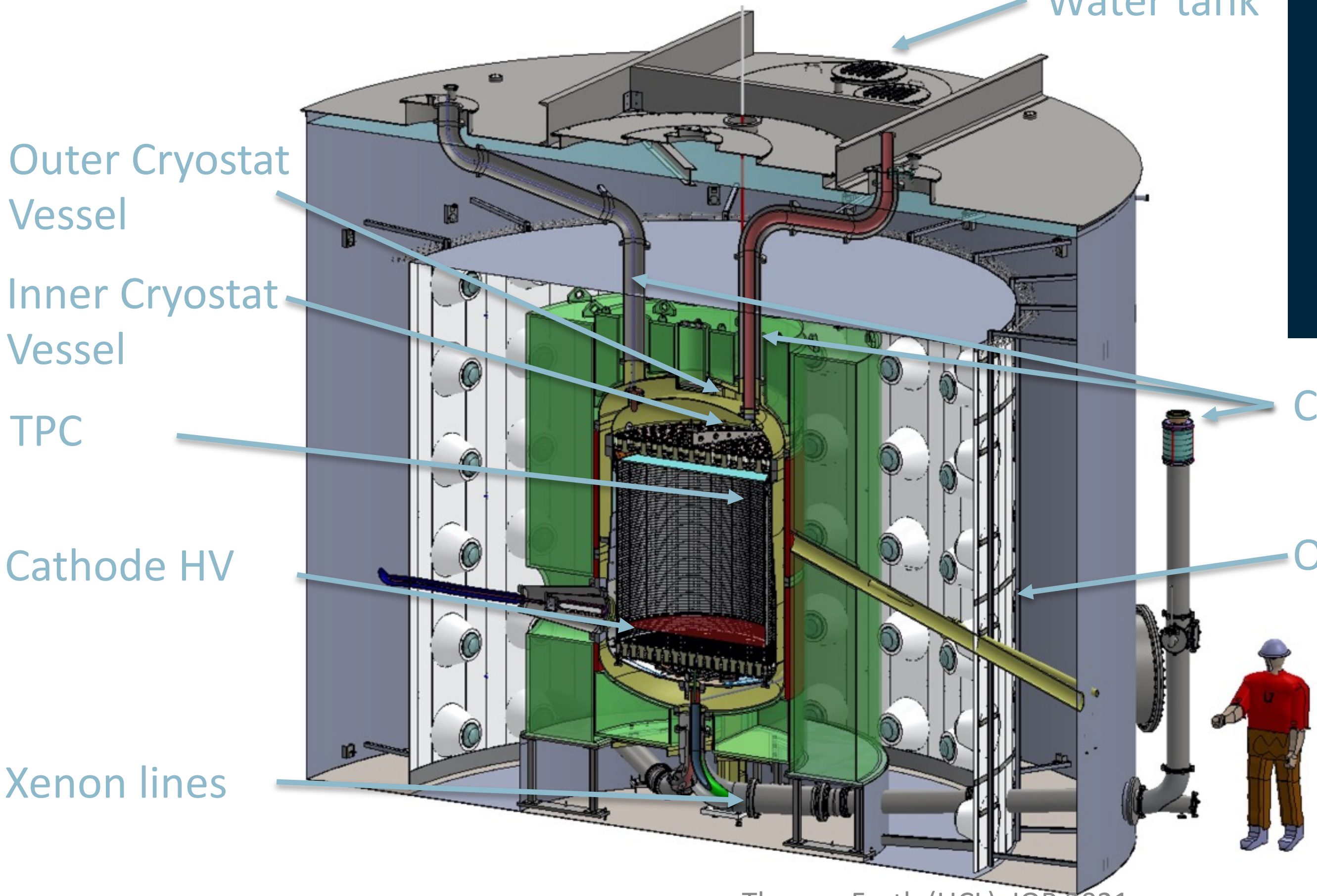
Xenon purification:

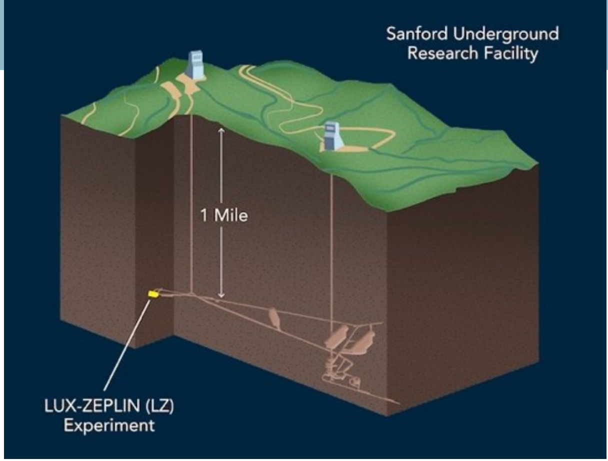
- Charcoal chromatography @ SLAC to remove Xenon contaminants – ^{85}Kr and ^{39}Ar
- Online gas purification at 500 slpm, turnover of total volume every 2.5 days

Shielding:

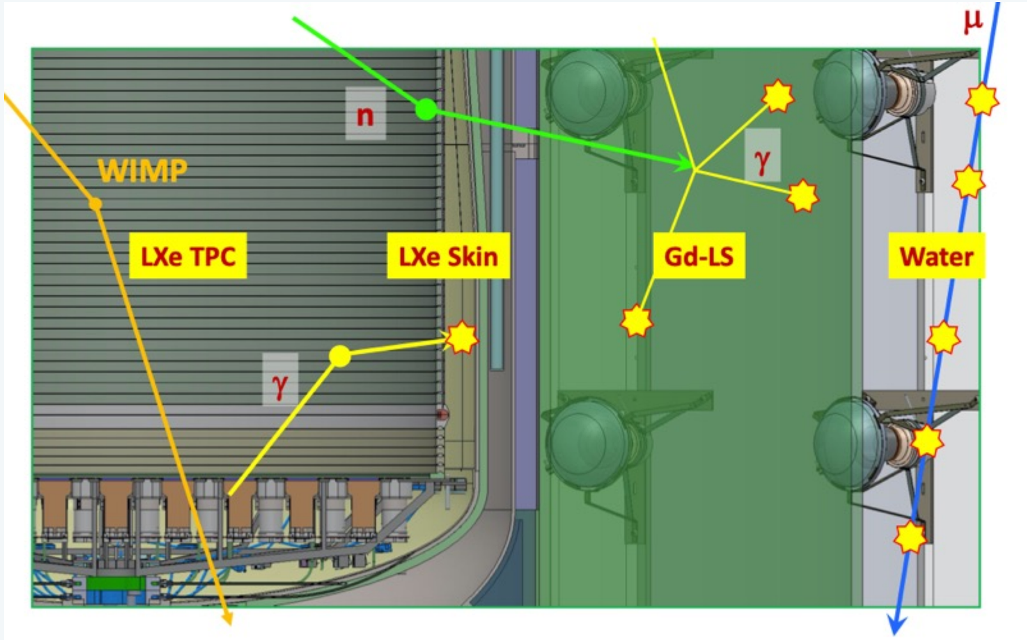
- Deep underground
- High purity water shield
- Veto detectors

Integrated detector overview





LZ TDR https://arxiv.org/abs/1703.09144



Skin:

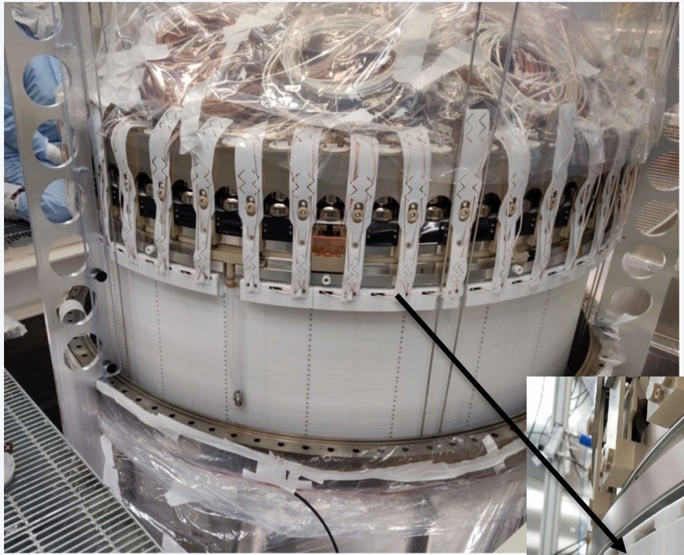
- 2 tonnes of LXe surrounding the TPC
- PMTs at top and bottom of the skin region
- Lined with PTFE to maximize light collection efficiency
- Anti-coincidence detector for γ-rays

Outer detector:

- 17 tonnes Gd-loaded liquid scintillator in acrylic vessels
- 120 8” PMTs mounted in the water tank
- Anti-coincidence detector for γ-rays and neutrons
- Observe ~8 MeV γ-rays from thermal neutron capture

Veto detectors

PTFE tiled cryostat with bottom skin PMTs



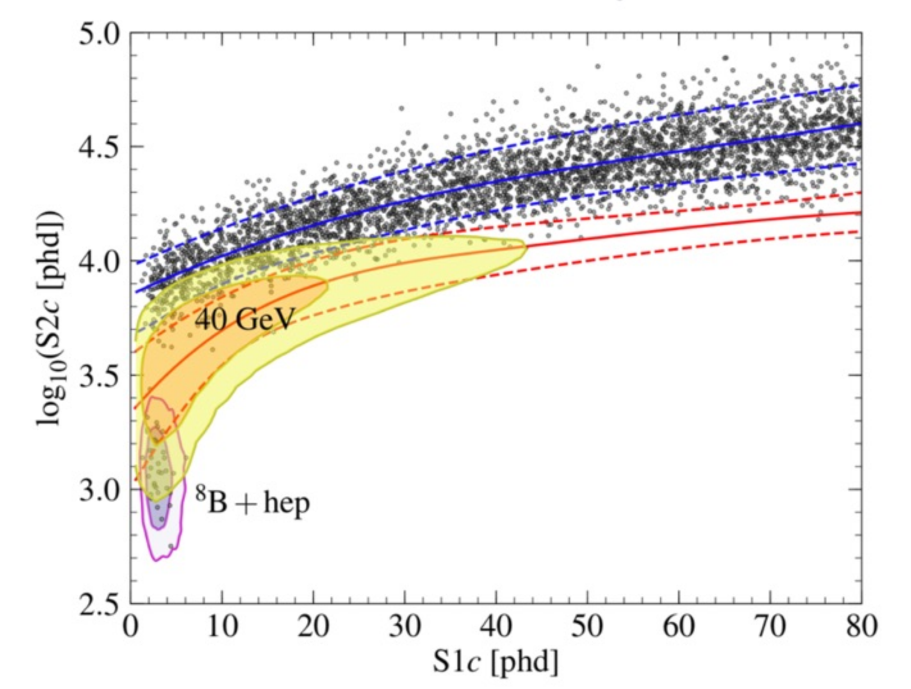
TPC insertion into the Inner Cryostat, August 2019

Top side skin PMTs

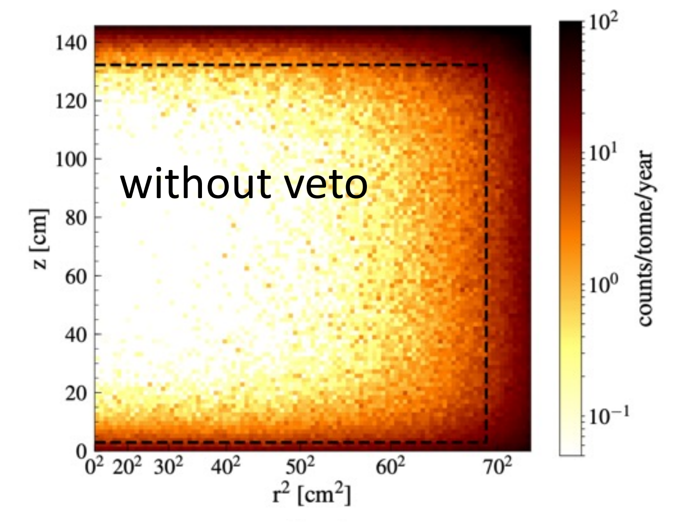
OD tanks and OCV in the water tank

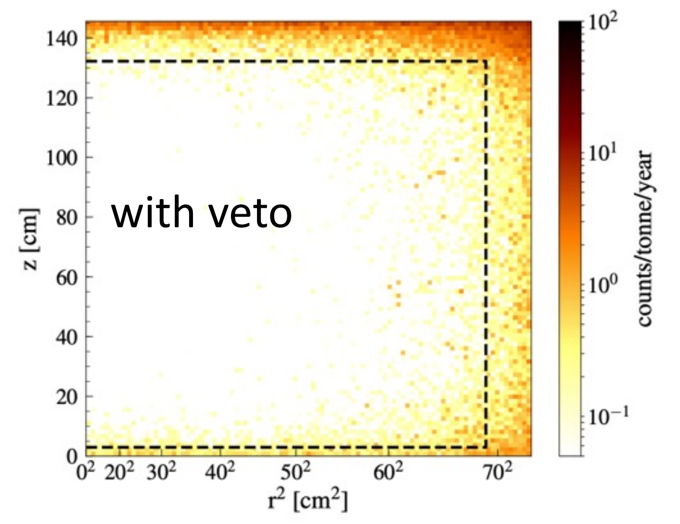
1000 day science run – expected backgrounds

[Phys. Rev. D 101, 052002 (2020)]

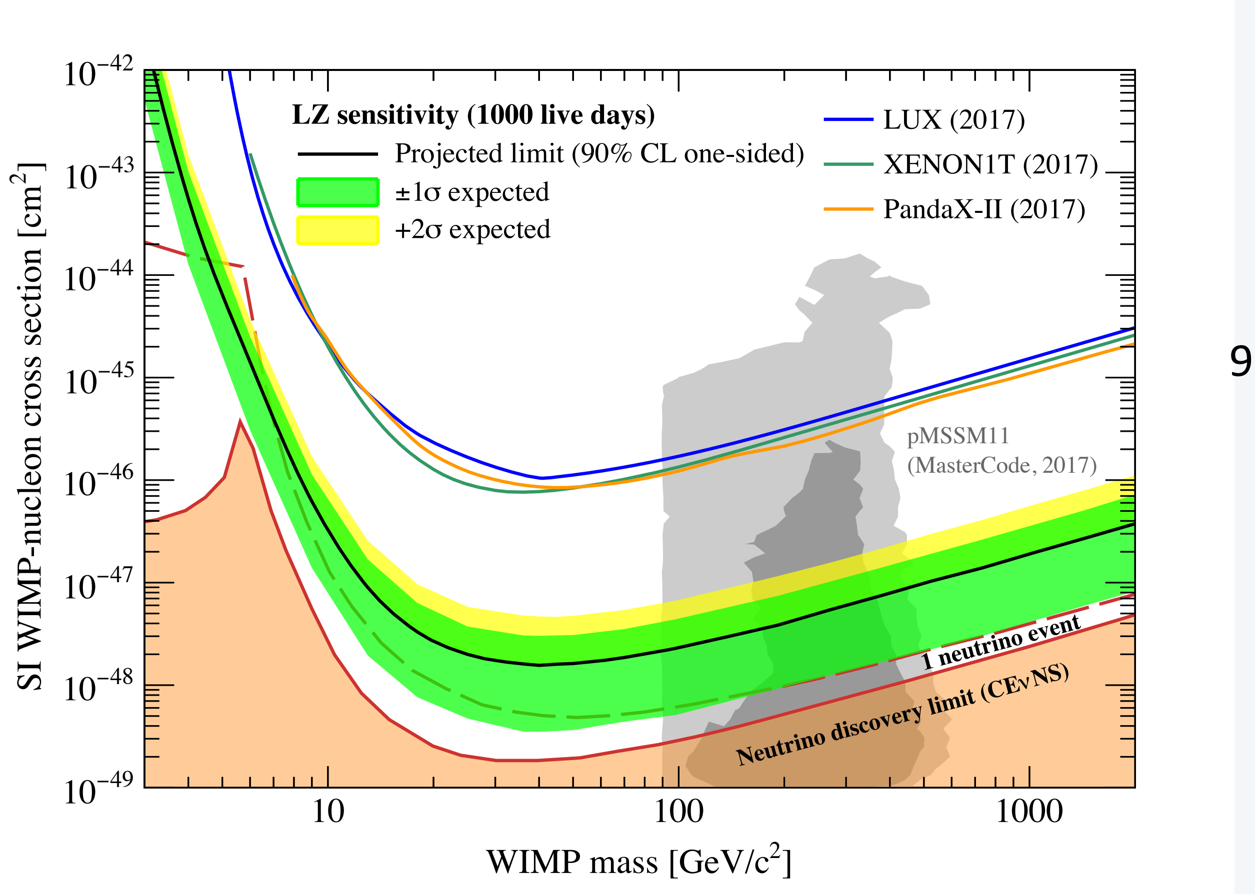


1000 day run – after discrimination:
5.97 ER events and 0.51 NR events





Phys. Rev. D 101, 052002 (2020)



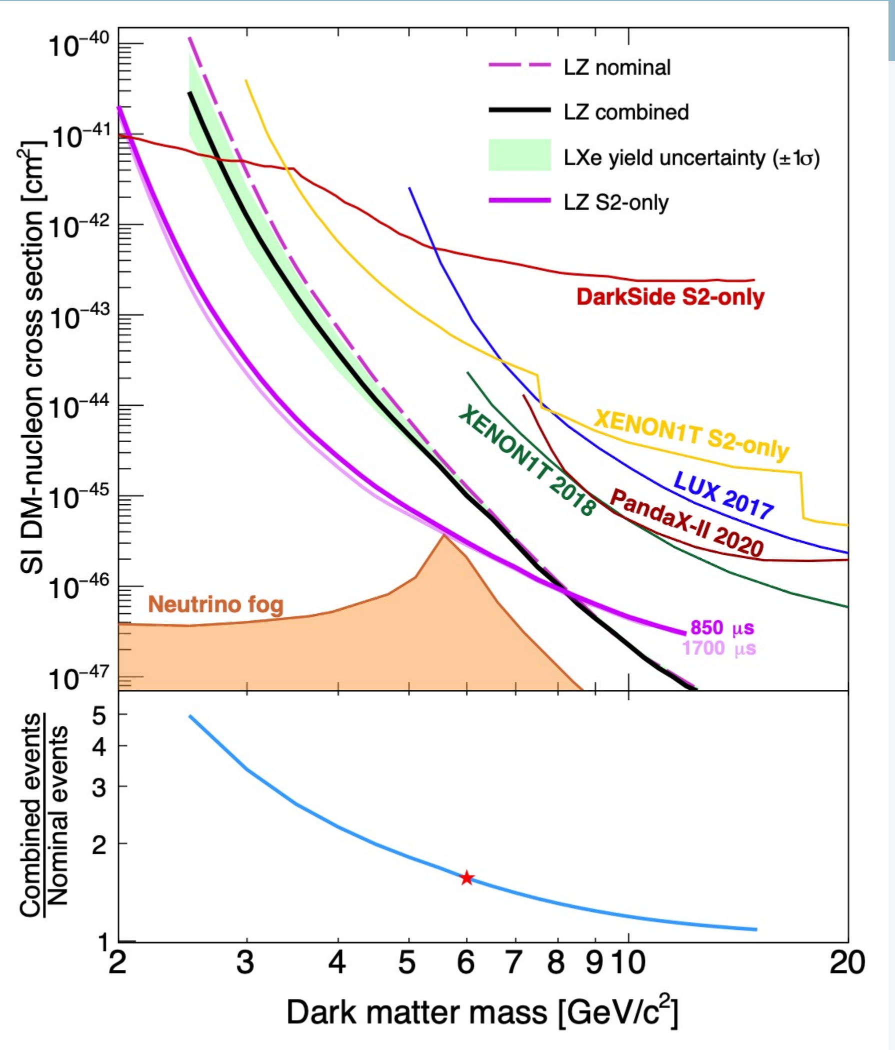
90% CL minimum of 1.4×10^{-48} cm^2 at 40 GeV/c^2

Sub-GeV Dark Matter

Enhancing sensitivity in the low WIMP mass regime by lower in the detector threshold.

- Lower S1 coincidence requirements from 3 to 2 photons (making use of the DPE effect) -> LZ combined
- S2-only analysis -> LZ S2-only (for nominal and enhanced electron lifetime)

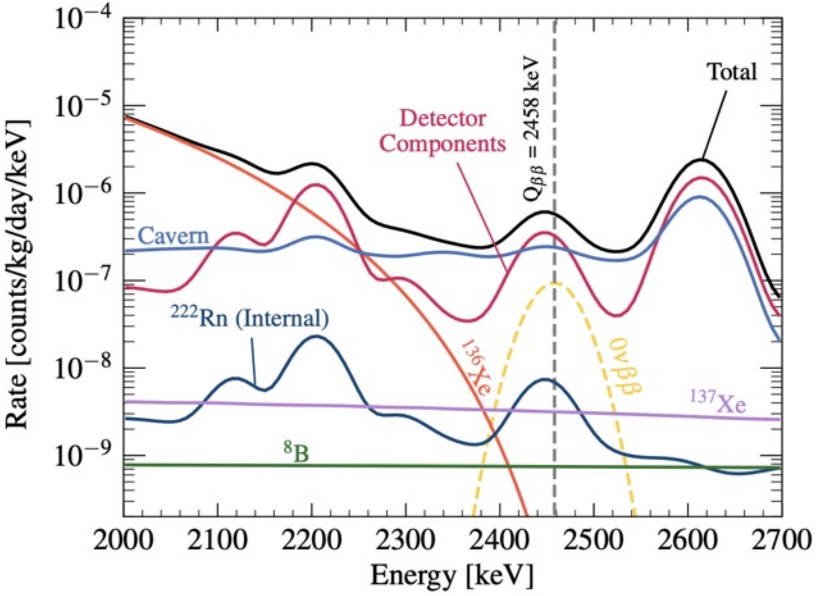
https://arxiv.org/pdf/2101.08753.pdf



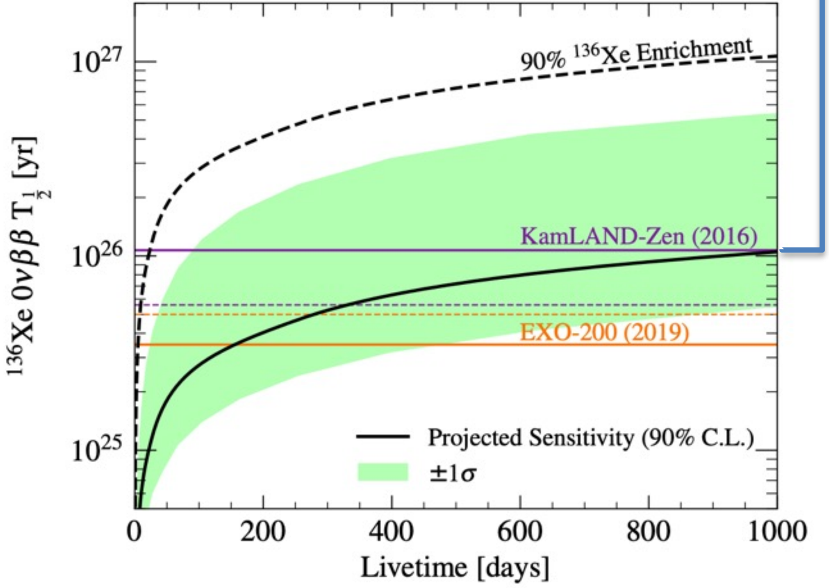
Phys. Rev. C 102, 014602 (2020)

^{136}Xe $Q_{\beta\beta}$ = 2458 keV

$T_{1/2}$ (90% C.L.) > 1.06 x 10^{26} years in 1000 live-days



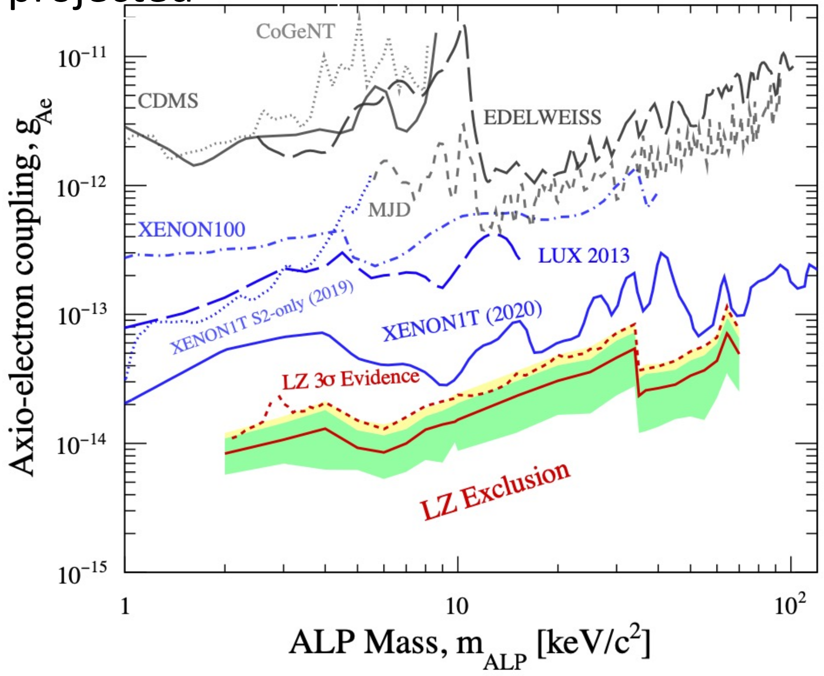
1 tonne fiducial mass:



https://arxiv.org/abs/2102.11740

See E. Leason's talk about ER band searches with LZ (Tuesday, 3:00 PM)

LZ projected



- ER band searches for axions and ALPs assuming axio-electric interaction
- ALPs – monoenergetic feature in ER band
- Plot shows expected sensitivity for 1000 live-days and 5.6 tonne fiducial mass.

LZ status

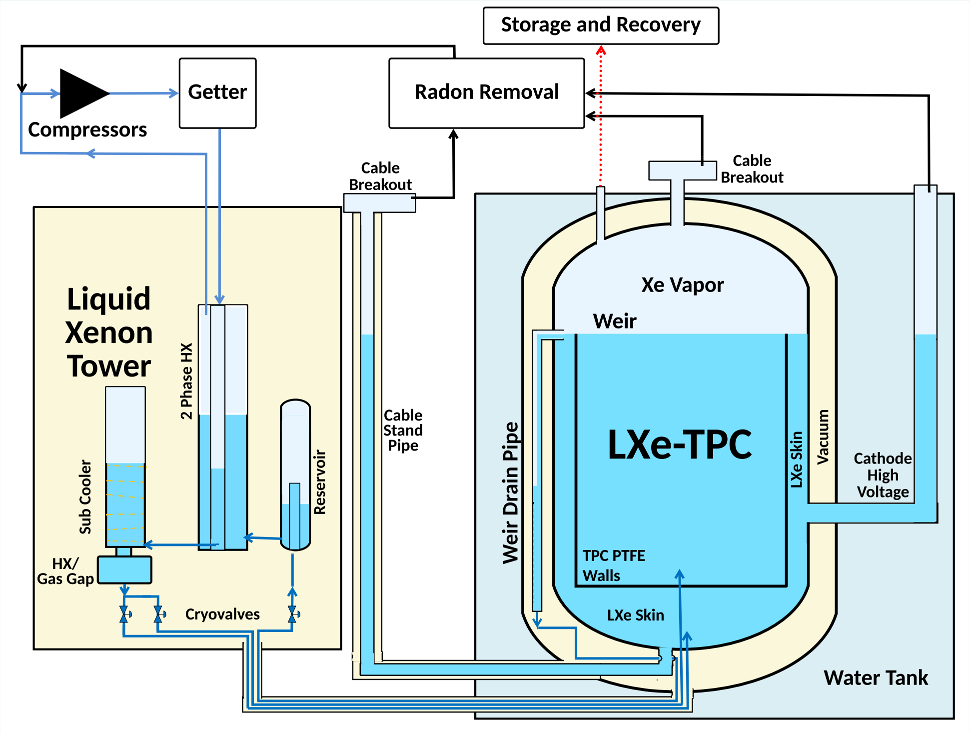
ICV transport UG, October 2019

ICV insertion into OCV, December 2019

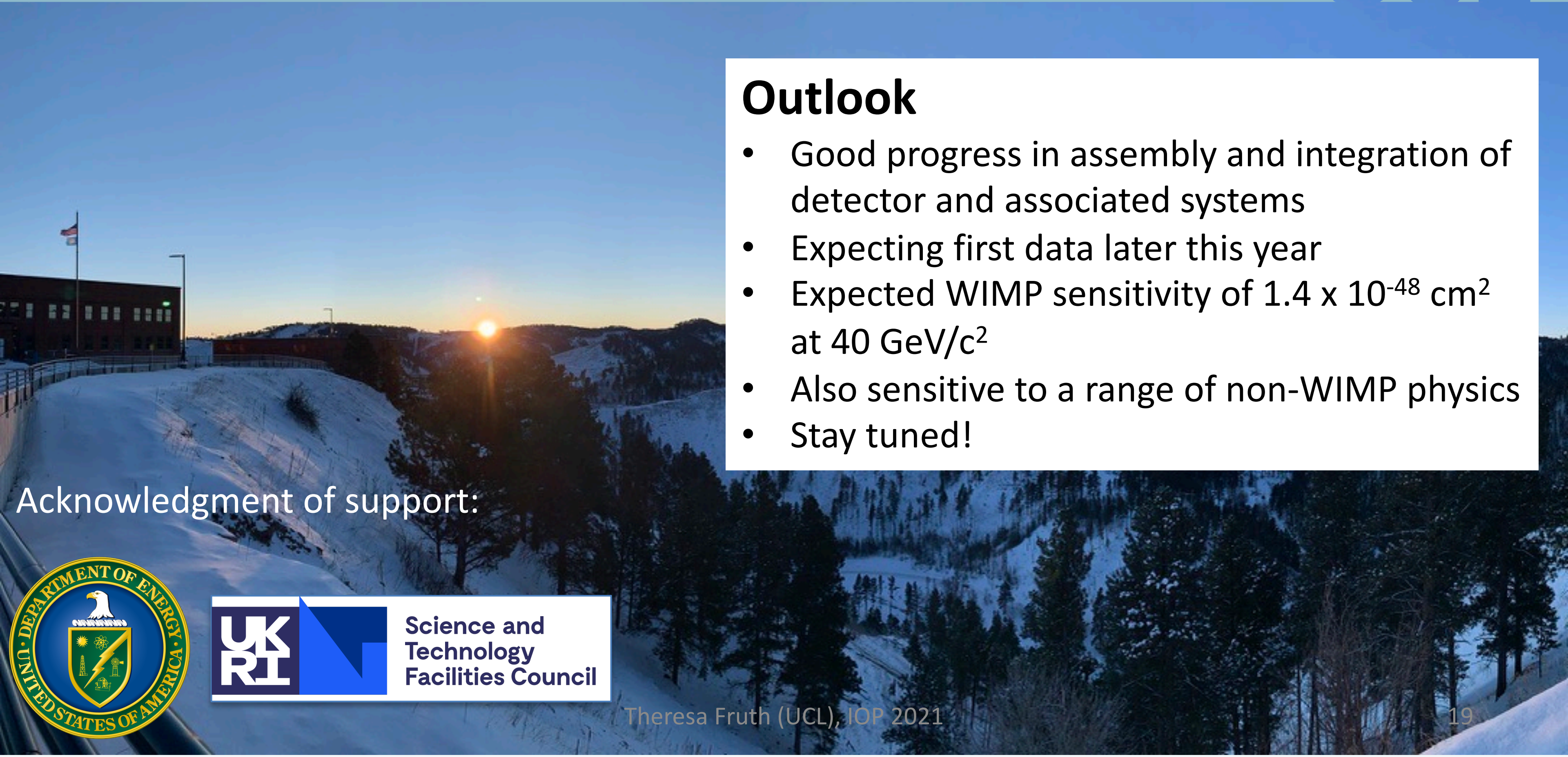
CHV delivery installation (under N2 purge), March 2020

ICV sealed and under vacuum, March 2020

LZ status



NIM A953 (2020)163047



Outlook

- Good progress in assembly and integration of detector and associated systems
- Expecting first data later this year
- Expected WIMP sensitivity of 1.4×10^{-48} cm^2 at 40 GeV/c^2
- Also sensitive to a range of non-WIMP physics
- Stay tuned!

Acknowledgment of support:

Science and Technology Facilities Council

Thank you!

Other LZ contributions this IoP conference:

Elizabeth Leason, New Physics Searches with Low Energy Electron Recoils in the LUX ZEPLIN Experiment (Tuesday, 3:00 PM, Astroparticle 2)
Nicolas Angelides, Assembling the LZ Detector (Tuesday, 3:45 PM Astroparticle 2)
Sam Eriksen, LUX-ZEPLIN optical photon simulations using GPUs (Thursday, 11:45 AM, Astroparticle 3)
Tom Rushton, Analysis of Neutron Activation Background in the LUX-ZEPLIN Experiment (Poster)

Expected backgrounds – 1000 day science run

[Phys. Rev. D **101**, 052002]

TABLE III. Estimated backgrounds from all significant sources in the LZ 1000 day WIMP search exposure. Counts are for a region of interest relevant to a 40 GeV/c^2 WIMP: approximately 1.5–6.5 keV for ERs and 6–30 keV for NRs; and after application of the single scatter, skin and OD veto, and 5.6 tonne fiducial volume cuts. Mass-weighted average activities are shown for composite materials and the ^{238}U and ^{232}Th chains are split into contributions from early- and late-chain, with the latter defined as those coming from isotopes below and including ^{226}Ra and ^{224}Ra, respectively.

Background Source	Mass (kg)	$^{238}U_e$	$^{238}U_l$	$^{232}Th_e$	$^{232}Th_l$	^{60}Co	^{40}K	n/yr	ER (cts)	NR (cts)
		mBq/kg								
Detector Components										
PMT systems	308	31.2	5.20	2.32	2.29	1.46	18.6	248	2.82	0.027
TPC systems	373	3.28	1.01	0.84	0.76	2.58	7.80	79.9	4.33	0.022
Cryostat	2778	2.88	0.63	0.48	0.51	0.31	2.62	323	1.27	0.018
Outer detector (OD)	22950	6.13	4.74	3.78	3.71	0.33	13.8	8061	0.62	0.001
All else	358	3.61	1.25	0.55	0.65	1.31	2.64	39.1	0.11	0.003
								subtotal	**9**	**0.07**
Surface Contamination										
Dust (intrinsic activity, 500 ng/cm^2)									0.2	0.05
Plate-out (PTFE panels, 50 nBq/cm^2)									-	0.05
^{210}Bi mobility (0.1 µBq/kg LXe)									40.0	-
Ion misreconstruction (50 nBq/cm^2)									-	0.16
^{210}Pb (in bulk PTFE, 10 mBq/kg PTFE)									-	0.12
								subtotal	**40**	**0.39**
Xenon contaminants										
^{222}Rn (1.8 µBq/kg)									681	-
^{220}Rn (0.09 µBq/kg)									111	-
^{nat}Kr (0.015 ppt g/g)									24.5	-
^{nat}Ar (0.45 ppb g/g)									2.5	-
								subtotal	**819**	**0**
Laboratory and Cosmogenics										
Laboratory rock walls									4.6	0.00
Muon induced neutrons									-	0.06
Cosmogenic activation									0.2	-
								subtotal	**5**	**0.06**
Physics										
^{136}Xe $2\nu\beta\beta$									67	-
Solar neutrinos: pp+^{7}Be+^{13}N, ^{8}B+hep									191	0*
Diffuse supernova neutrinos (DSN)									-	0.05
Atmospheric neutrinos (Atm)									-	0.46
								subtotal	**258**	**0.51**
Total									1131	1.03
Total (with 99.5% ER discrimination, 50% NR efficiency)									5.66	0.52
Sum of ER and NR in LZ for 1000 days, 5.6 tonne FV, with all analysis cuts									**6.18**	

* Below the 6 keV NR threshold used here.