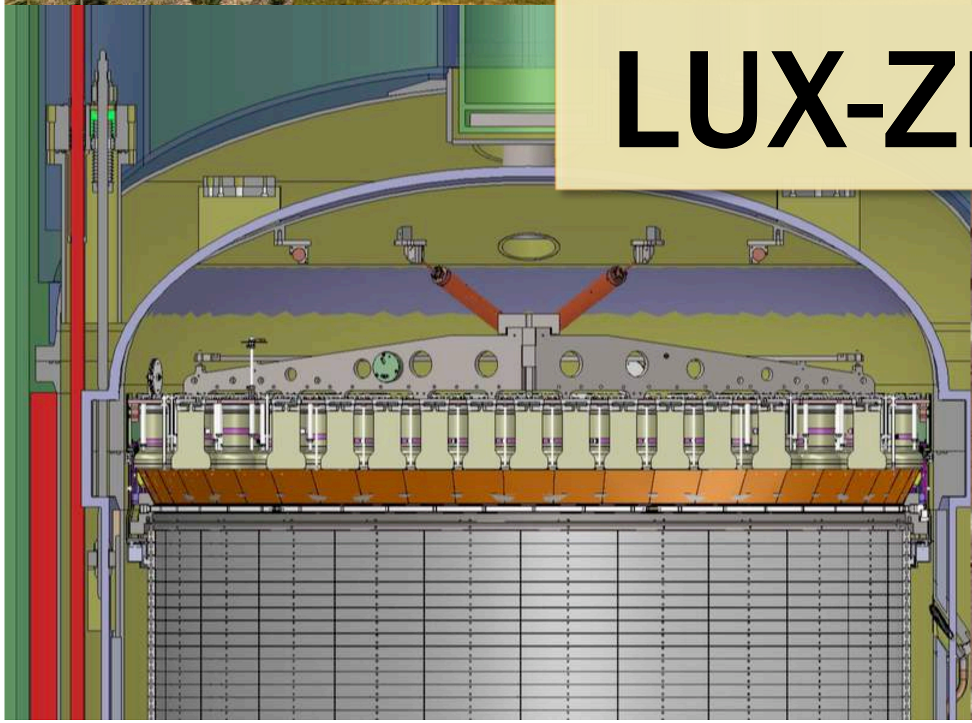
DMUK

Status of LUX-ZEPLIN

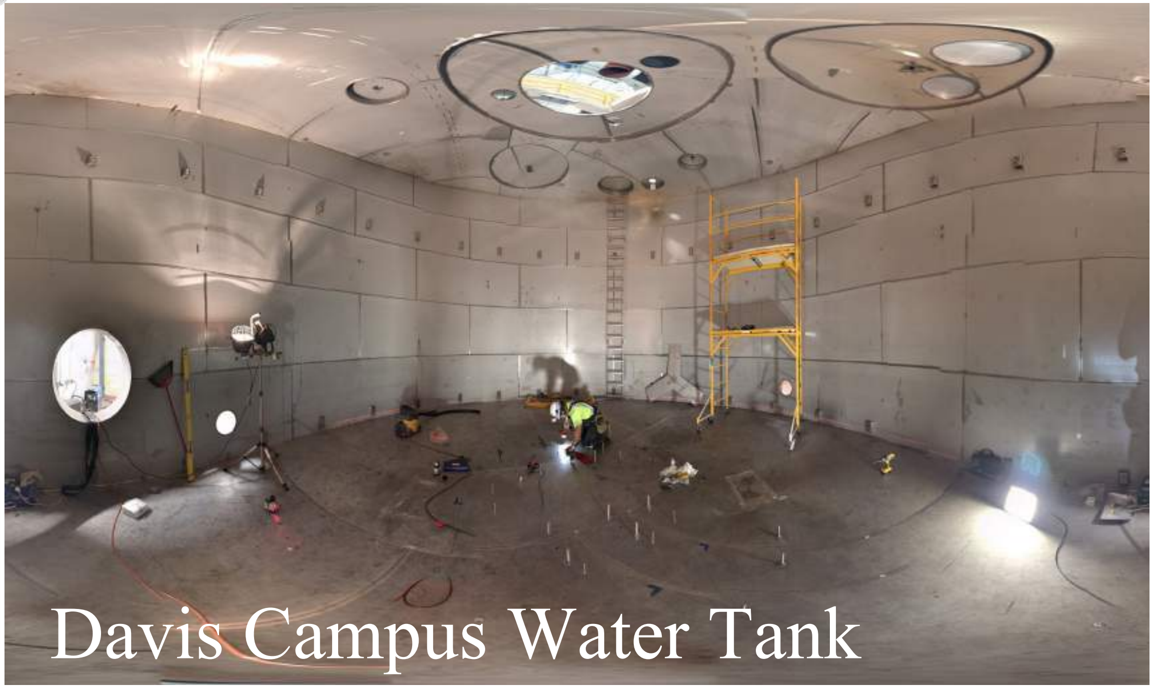


LZ…

Key Facts!

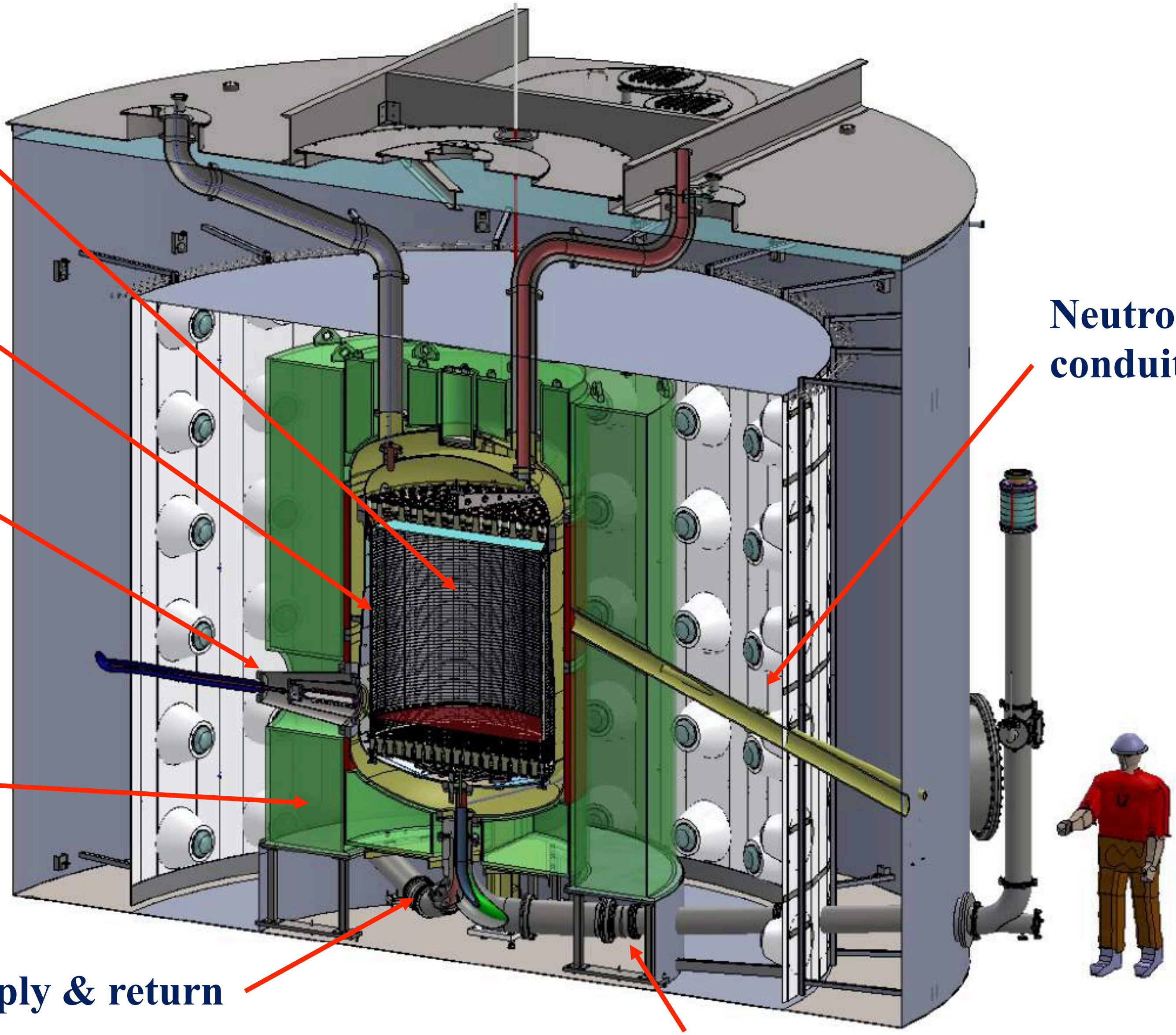
- … is the successor to LUX
- …will be hosted by the Sanford Underground Research Facility
- …will have ~9 T total, 7 T active, 5.6 T fiducial mass of liquid xenon
- …which is about 50 times that of LUX (fiducial)
- …will have a skin region, outer detector and water tank for background suppression
- …Low energy NR sensitivity limited by astrophysical backgrounds
- …will reach a SI WIMP sensitivity of 1.6×10^{-48} cm^2 at 40 GeV/c^2
- …will have sensitivity to a range of other New Physics processes
- …is being constructed NOW; will be running by 2020

Sanford Underground Research Facility
Lead, South Dakota, USA

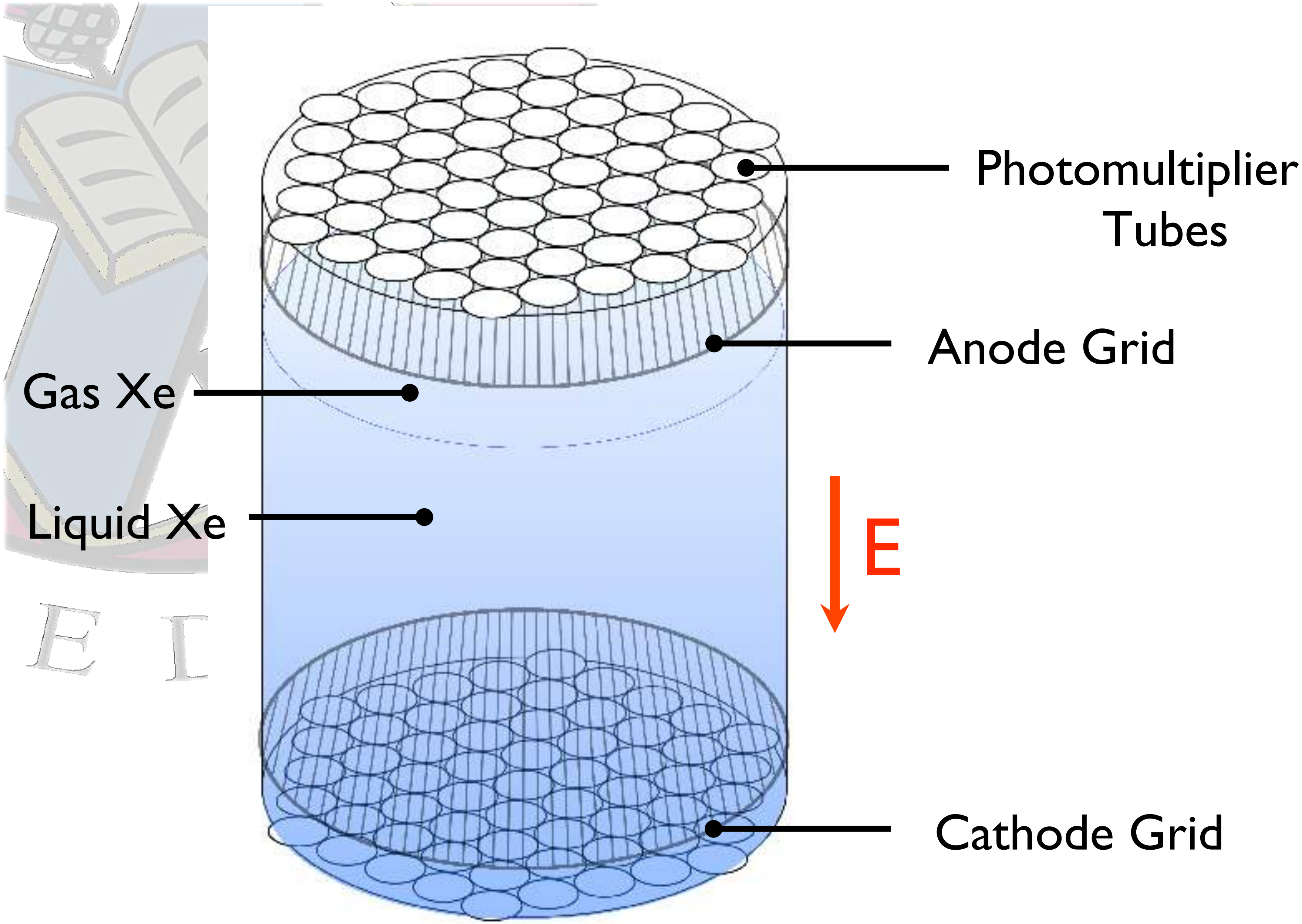


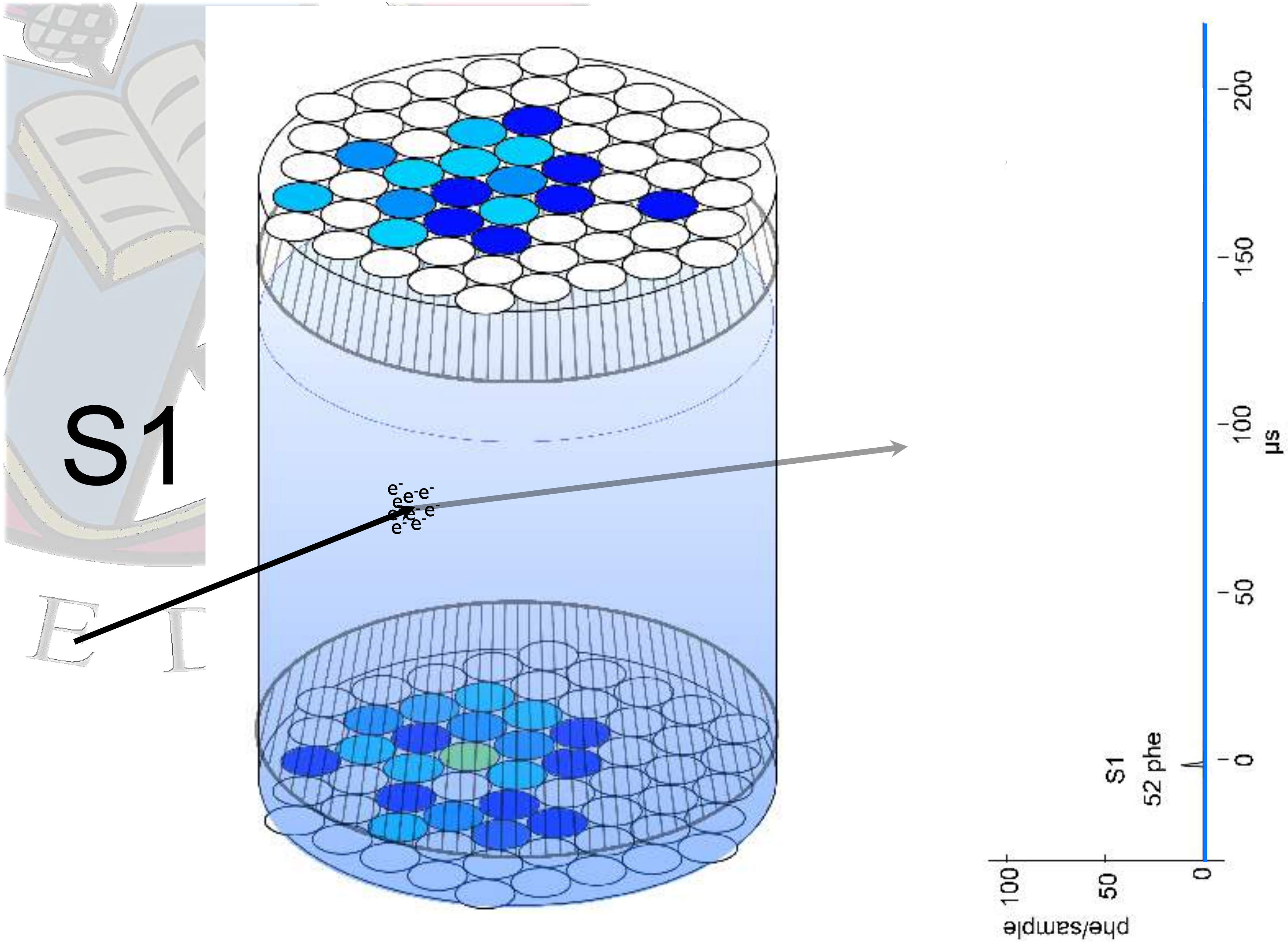
Davis Campus Water Tank

LUX-ZEPLIN (LZ) detector

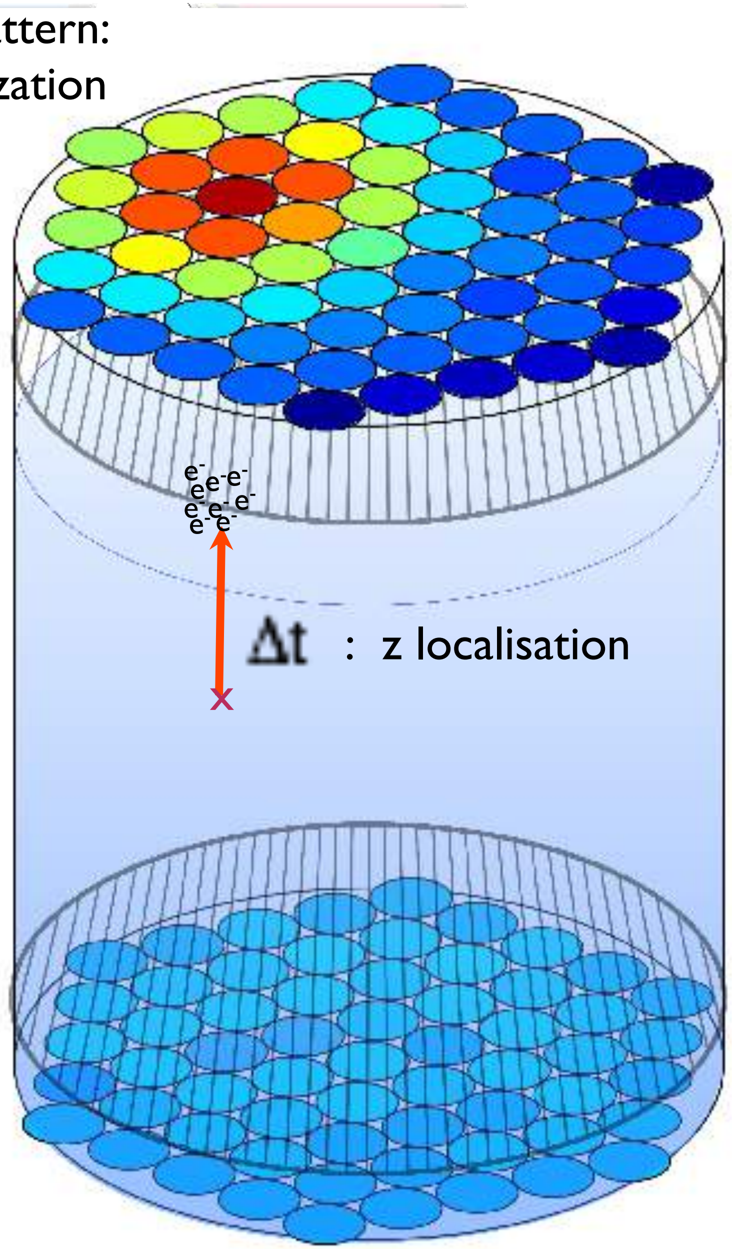


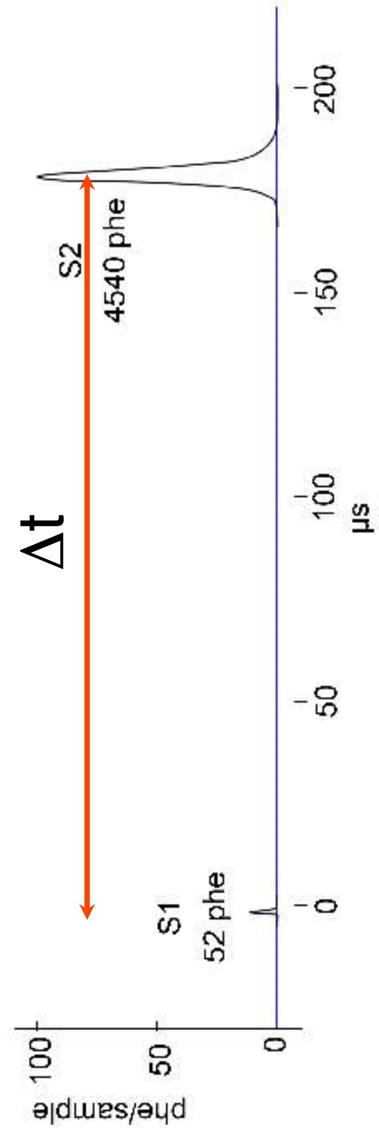
Technical Design Report, arXiv:1703.09144.

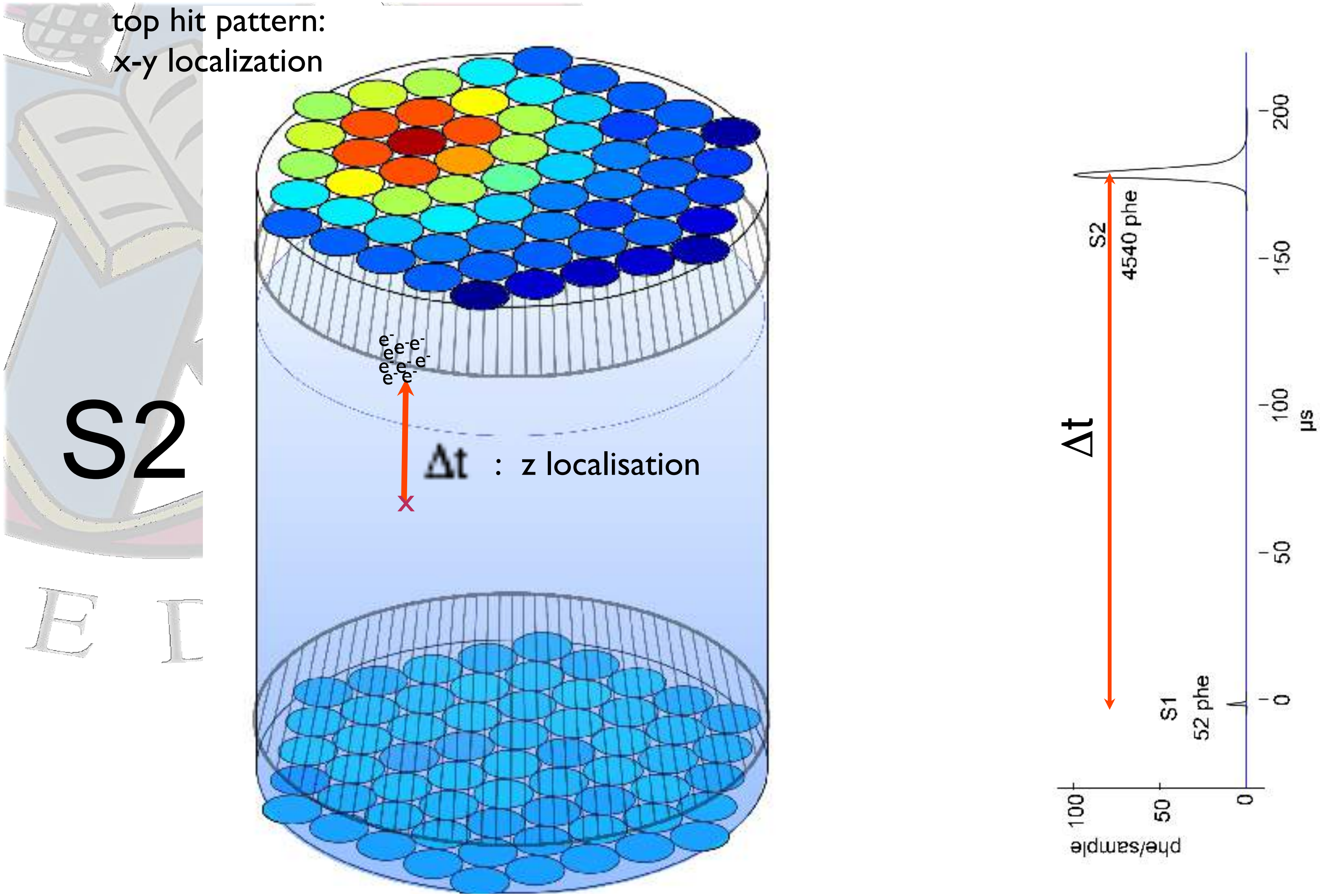

Photomultiplier
Tubes
Anode Grid
Gas Xe
Liquid Xe
E
Cathode Grid


S1
e⁻e⁻e⁻e⁻e⁻e⁻e⁻e⁻
S1
52 phe
µs
phe/sample
0
50
100
150
200

S2

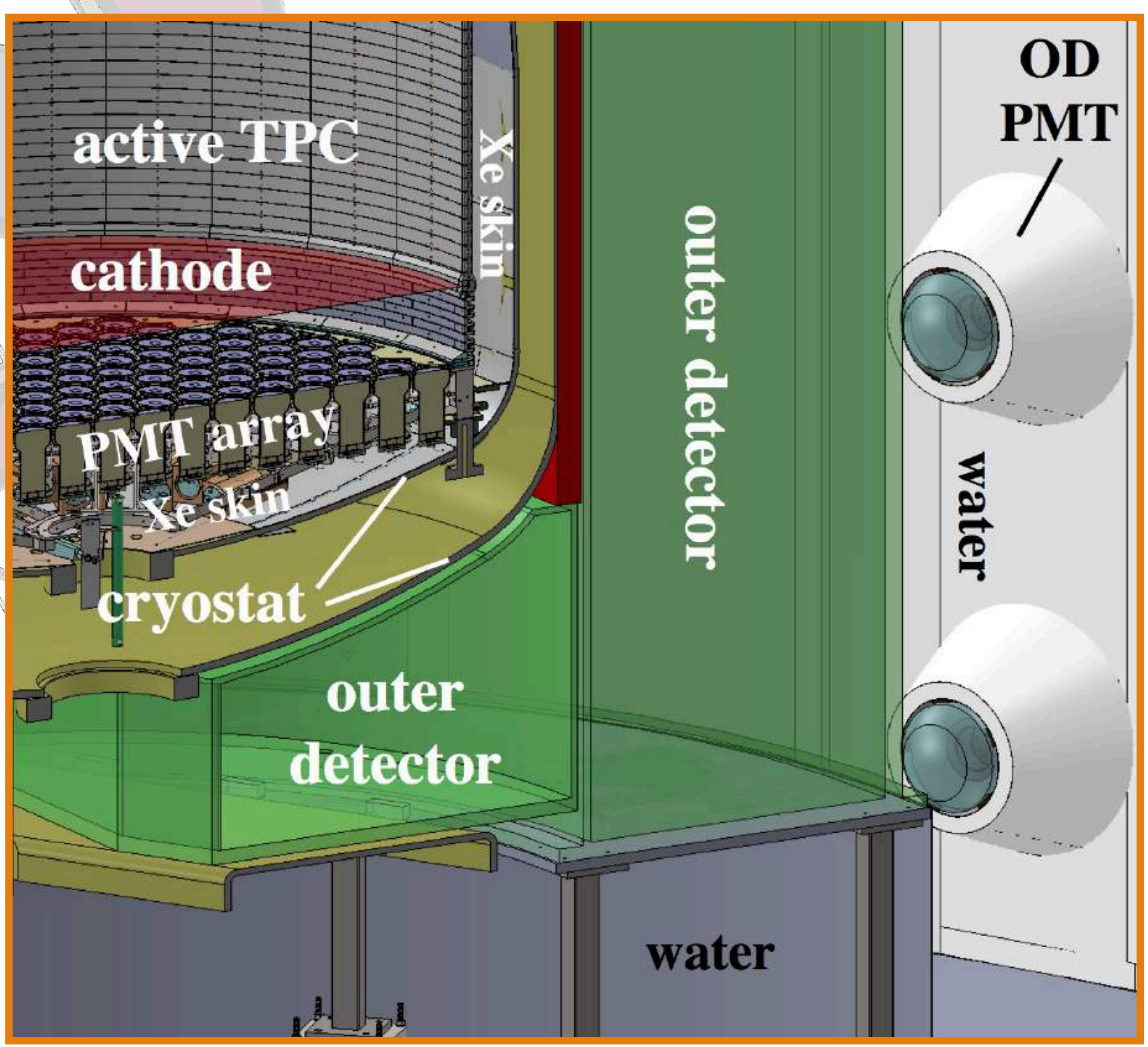

top hit pattern:
x-y localization
Δt : z localisation


Δt
S2
4540 phe
S1
52 phe
µs
phe/sample



Ratio of S2 to S1 depends on the type of incident particle - allows ER (β, gamma) : NR (neutron, WIMP) discrimination >99.5%

- "…will have a skin region, outer detector and water tank for background suppression"

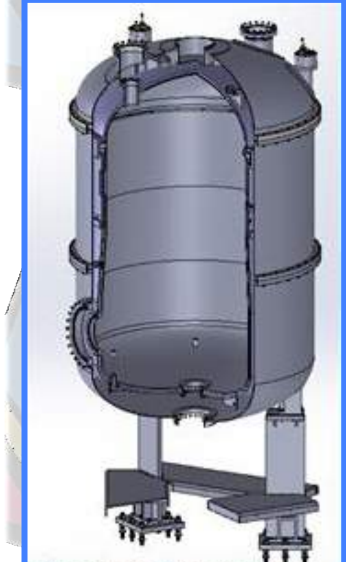


LZ-global status

- Requirements – defined
- Design – complete
- Baseline sensitivity studies – complete
- Construction – well underway
- Assay campaign – mostly completed
- Advanced sensitivity studies – well underway
- Mock data challenges: **2017**, **2018**, **2019**
- **First dark – 2019**
- **Science Data - 2020**

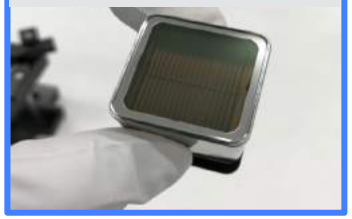
LZ-UK status

- UK hardware contributions nearly complete



Titanium Cryostat

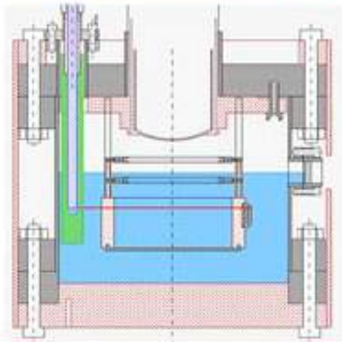
Materials Screening



Skin PMT Validation

Calibration Delivery

UK Data Centre & Simulations



Liquid Xenon Testing

TPC Monitoring Sensors

OD Optical Calibration System

1/3 TPC PMTs, Xenon Bases

UK deliverables

- Mostly reported on at the last DMUK…
  - Brais López Paredes
    https://indico.fnal.gov/event/13260/contribution/17/material/slides/0.pdf
- Cryostat – delivered to SURF
- Cleanliness – ICPMS, HPGe: Complete*
- 3” PMTs – manufactured, assayed, tested, delivered
- PMT bases – manufactured, assayed, tested, delivered
- Internal sensors – almost complete
- Calibration source delivery system – complete
- OD optical calibration system – almost complete
- Simulations
- Skin PMT testing – New responsibility – ongoing

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- Internal sensors – almost complete
- Calibration source delivery system – complete
- OD optical calibration system – almost complete
- **Simulations**
- **Skin PMT testing – New responsibility – ongoing**


SICC

- Cryostat delivery to SURF (14 May 2018)

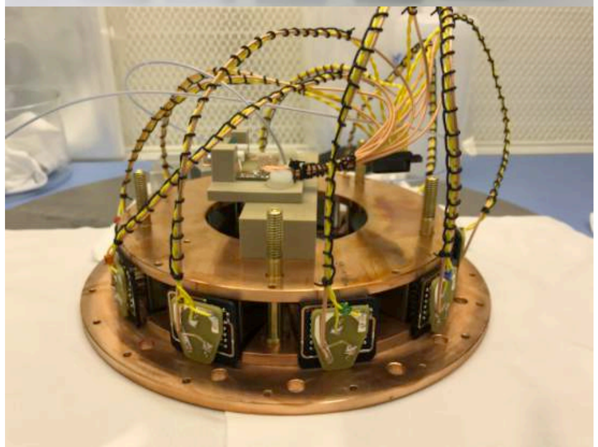


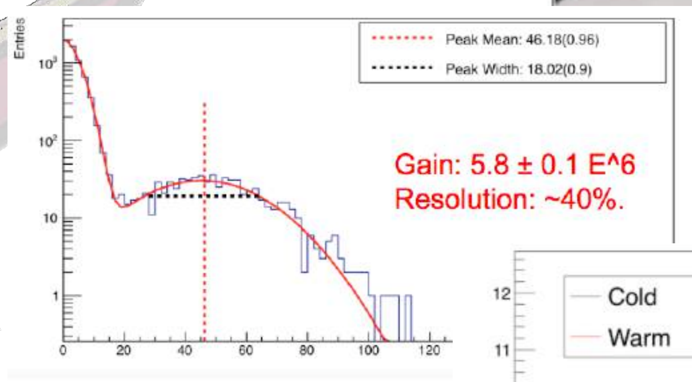


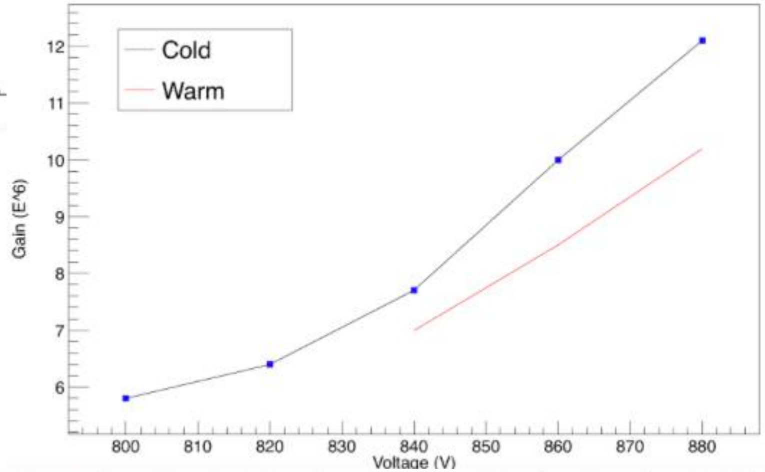
Outer cryostat vessel in the SAL at SURF

Skin PMT tests

- Validate [gain, resolution, dark rate, afterpulsing] of 93 1" PMTs before installation to LZ.
- Need to test at 170 K; maintain cleanliness







mBq/tube	U(e)	U(l)	Pb210	Th(e)	Th(l)	K40	U235	Co60	Co57	Cs137
This result	0.5(1)	0.30(4)	<1.2	<0.07	0.11(2)	6.7(6)	<0.04	0.31(3)	0.056(3)	0.04(1)
Xenon100	<1.5	0.25(4)	-	0.5(1)	0.5(1)	8.9(9)	-	0.75(8)	-	<.02

ASSAY CAMPAIGN

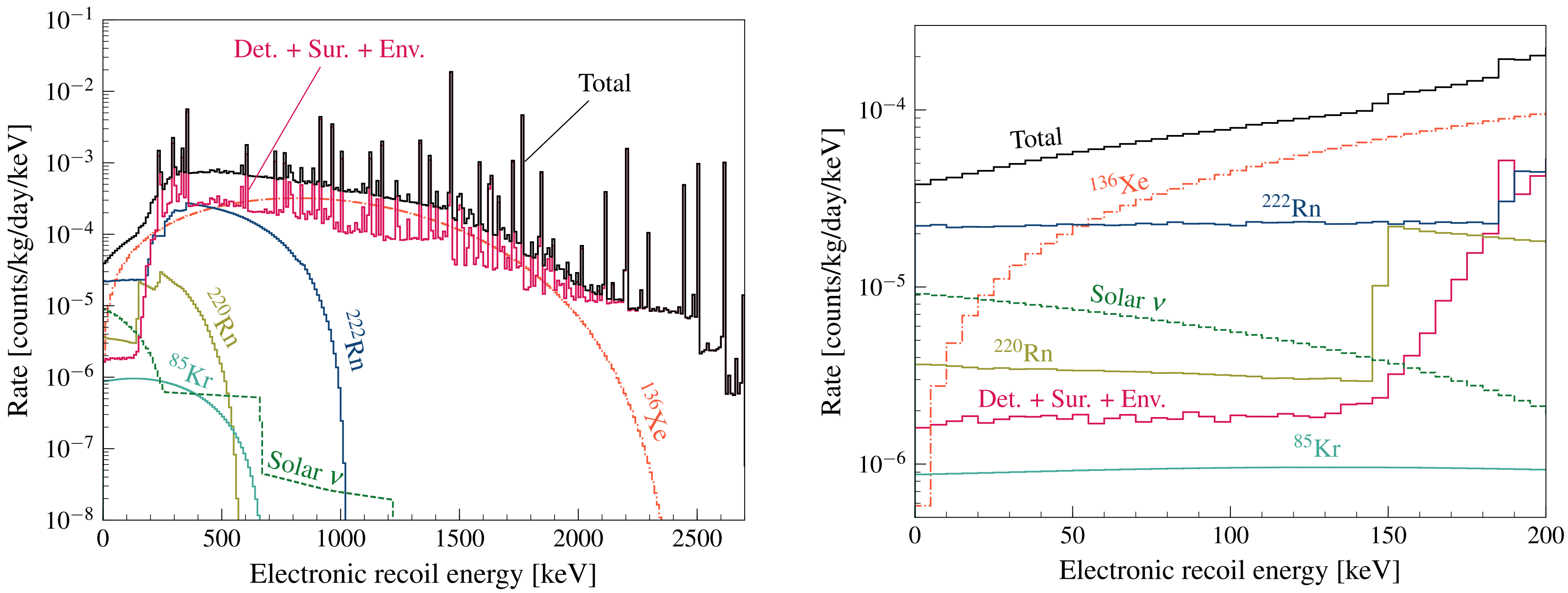
+

MONTE CARLO SIMULATION

↓

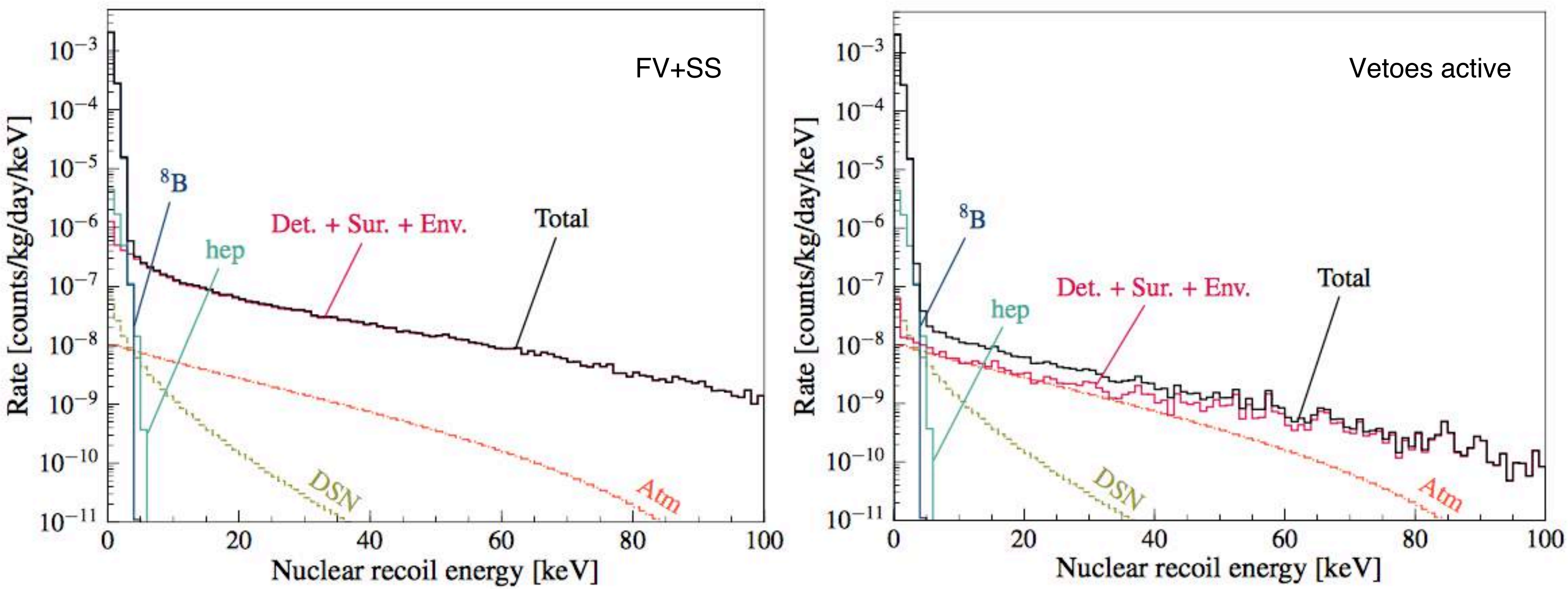
Known source event rates

Background Single Scatter **ER** events



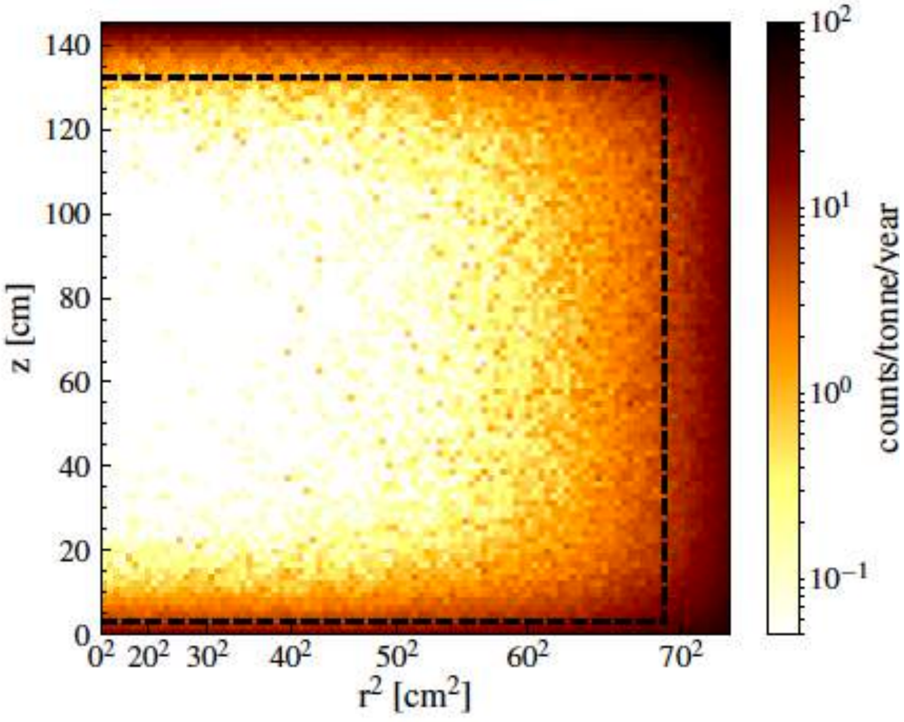
- Energy spectra of electron recoil background from various sources.
- ^{222}Rn dominates at low energies.
- Environmental background and components are not major sources of background events.

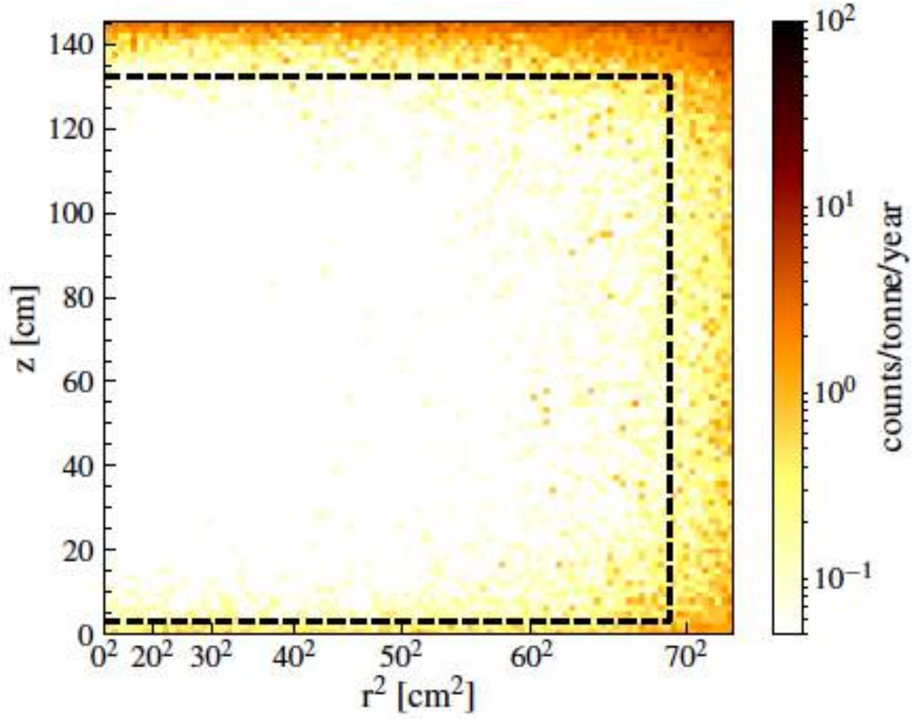
Background Single Scatter **NR** events



- Single scatter NR before (left) and after (right) skin and OD coincidence rejection
- Rate at low energy (<4 keV) dominated by ^{8}B CNNS

Background Single Scatter **NR** events





- Single scatter nuclear recoil events in the LXe active volume before (left) and after (right) rejecting events in coincidence with veto system (LXe skin and the Outer Detector (OD).

Event yields from known sources

- 5.6 tonnes
- 1000 days
- 1.5 to 6.5 keV

Background Source	ER (cts)	NR (cts)
Detector Components	**9**	**0.07**
Surface Contamination	**40**	**0.39**
Laboratory and Cosmogenics	**5**	**0.06**
Xenon Contaminants	**819**	**0**
222Rn	681	0
220Rn	111	0
natKr (0.015 ppt g/g)	24	0
natAr (0.45 ppb g/g)	3	0
Physics	**322**	**0.51**
136Xe 2νββ	67	0
Solar neutrinos (pp+7Be+13N)	255	0
Diffuse supernova neutrinos	0	0.05
Atmospheric neutrinos	0	0.46
Total	1195	1.03
with 99.5% ER discrim., 50% NR eff.	**5.97**	**0.51**

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Radon dominates ER backgrounds

νe scattering of *pp* solar ν's; (atomic electron recoils)

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Neutrons, including alpha-n on PTFE

Coherent scattering of atmospheric ν's on Xe nuclei

Event yields from known sources

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- 1000 days
- 1.5 to 6.5 keV

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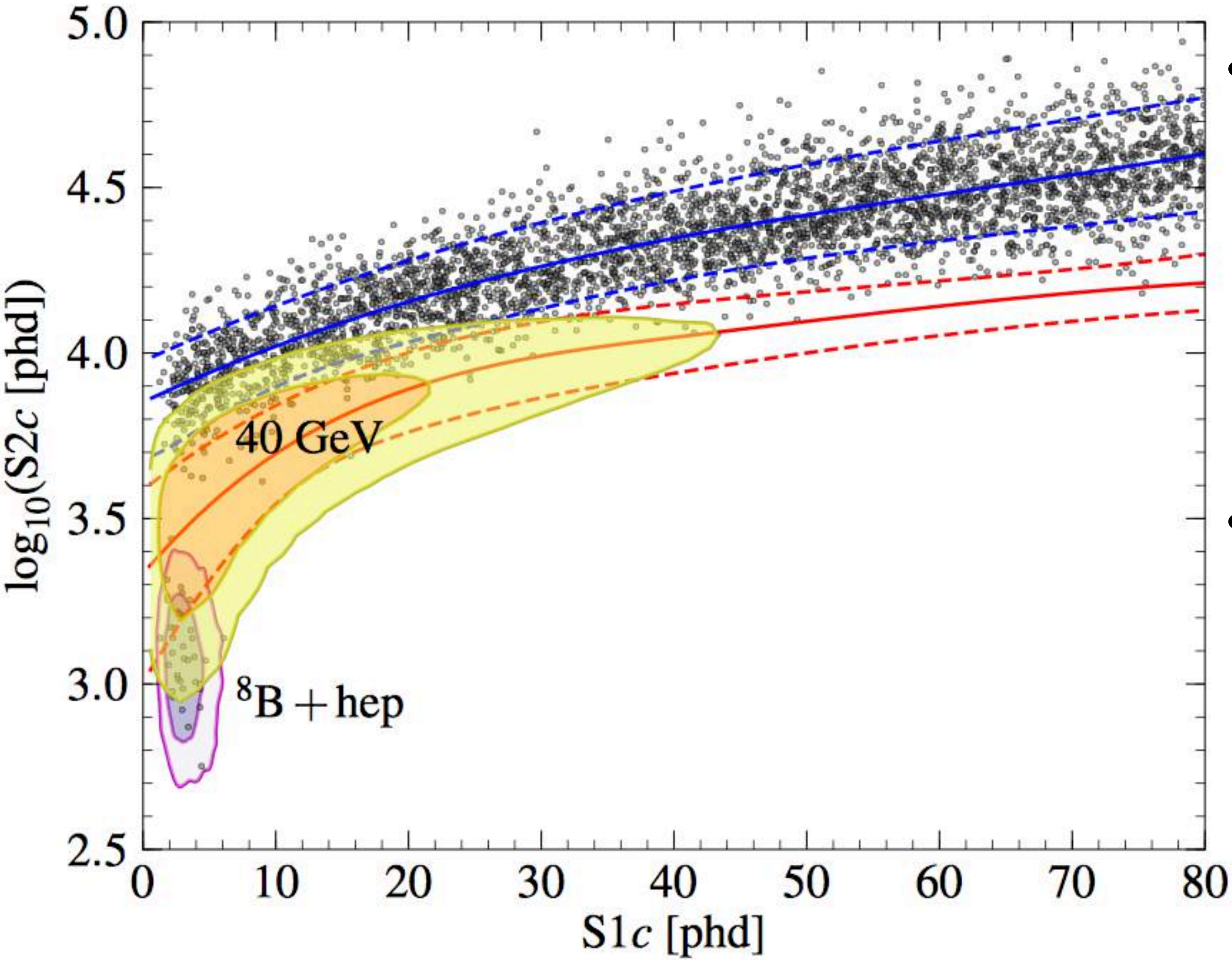
Simple WIMP search box "Cut & Count" type numbers

Backgrounds + Signal Model + PLR

↓

Science Reach (Sensitivity)

Event yields are not the whole story!



- CNNS of ^{8}B dominates at lowest energy (36 events for 5600 ton.days!)
- PLR approach to identify signal/set limits

What this means for WIMPs…

arXiv:1802.06039

039v1 [astro-ph.IM] 16 Feb 2018

Projected WIMP sensitivity of the LUX-ZEPLIN (LZ) dark matter experiment

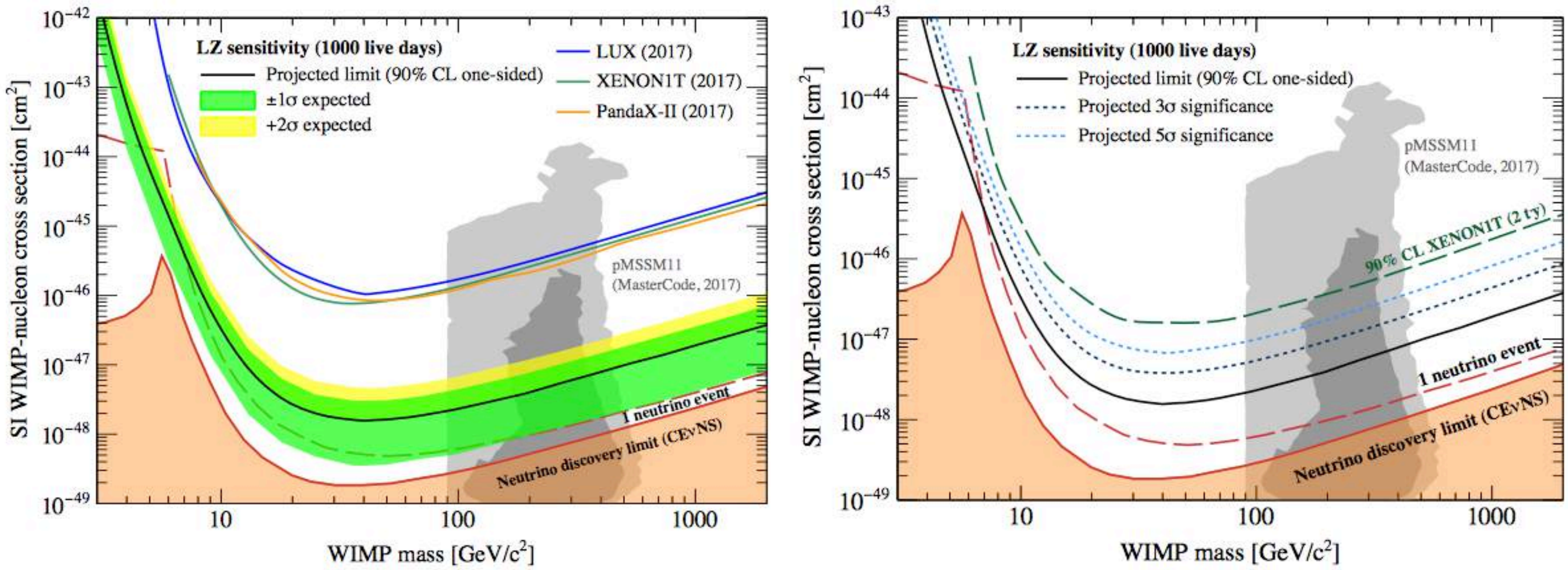
D.S. Akerib,[1,2] C.W. Akerlof,[3] S.K. Alsum,[4] H.M. Araújo,[5] M. Arthurs,[3] X. Bai,[6] A.J. Bailey,[5,a] J. Balajthy,[7] S. Balashov,[8] D. Bauer,[5] J. Belle,[9] P. Beltrame,[10] T. Benson,[4] E.P. Bernard,[11,12] T.P. Biesiadzinski,[1,2] K.E. Boast,[13] B. Boxer,[14] P. Brás,[15] J.H. Buckley,[16] V.V. Bugaev,[16] S. Burdin,[14] J.K. Busenitz,[17] C. Carels,[13] D.L. Carlsmith,[4] B. Carlson,[18] M.C. Carmona-Benitez,[19] C. Chan,[20] J.J. Cherwinka,[4] A. Cole,[12] A. Cottle,[9] W.W. Craddock,[1] A. Currie,[5,b] J.E. Cutter,[21] C.E. Dahl,[22,9] L. de Viveiros,[19] A. Dobi,[12,c] J.E.Y. Dobson,[23,d] E. Druszkiewicz,[24] T.K. Edberg,[7] W.R. Edwards,[12,e] A. Fan,[1,2] S. Fayer,[5] S. Fiorucci,[12] T. Fruth,[13] R.J. Gaitskell,[20] J. Genovesi,[6] C. Ghag,[23] M.G.D. Gilchriese,[12] M.G.D.van der Grinten,[8] C.R. Hall,[7] S. Hans,[25] K. Hanzel,[12] S.J. Haselschwardt,[26] S.A. Hertel,[27] S. Hillbrand,[21] C. Hjemfelt,[6] M.D. Hoff,[12] J.Y-K. Hor,[17] D.Q. Huang,[20] C.M. Ignarra,[1,2] W. Ji,[1,2] A.C. Kaboth,[28,8] K. Kamdin,[12,11] J. Keefner,[18] D. Khaitan,[24] A. Khazov,[8] Y.D. Kim,[29] C.D. Kocher,[20] E.V. Korolkova,[30] H. Kraus,[13] H.J. Krebs,[1] L. Kreczko,[31] B. Krikler,[31] V.A. Kudryavtsev,[30] S. Kyre,[26] J. Lee,[29] B.G. Lenardo,[21] D.S. Leonard,[29] K.T. Lesko,[12] C. Levy,[32] J. Li,[29] J. Liao,[20] F.-T. Liao,[13] J. Lin,[11,12] A. Lindote,[15] R. Linehan,[1,2] W.H. Lippincott,[9] X. Liu,[10] M.I. Lopes,[15] B. López Paredes,[5] W. Lorenzon,[3] S. Luitz,[1] J.M. Lyle,[20] P. Majewski,[8] A. Manalaysay,[21] R.L. Mannino,[33] C. Maupin,[18] D.N. McKinsey,[11,12] Y. Meng,[17] E.H. Miller,[6] J. Mock,[32,12,f] M.E. Monzani,[1,2,g] J.A. Morad,[21] E. Morrison,[6] B.J. Mount,[34] A.St.J. Murphy,[10] H.N. Nelson,[26] F. Neves,[15] J. Nikoleyczik,[4] K. O'Sullivan,[12,11,h] I. Olcina,[5] M.A. Olevitch,[16] K.C. Oliver-Mallory,[12,11] K.J. Palladino,[4] S.J. Patton,[12] E.K. Pease,[12] B. Penning,[35] A. Piepke,[17] S. Powell,[14] R.M. Preece,[8] K. Pushkin,[3] B.N. Ratcliff,[1] J. Reichenbacher,[6] C.A. Rhyne,[20] A. Richards,[5] J.P. Rodrigues,[15] R. Rosero,[25] P. Rossiter,[30] J.S. Saba,[12] M. Sarychev,[9] R.W. Schnee,[6] M. Schubnell,[3] P.R. Scovell,[13] S. Shaw,[26] T.A. Shutt,[1,2] J.J. Silk,[7] C. Silva,[15] K. Skarpaas,[1] W. Skulski,[24] M. Solmaz,[26] V.N. Solovov,[15] P. Sorensen,[12] I. Stancu,[17] M.R. Stark,[6] T.M. Stiegler,[33] K. Stifter,[1,2] M. Szydagis,[32] W.C. Taylor,[20] R. Taylor,[5] D.J. Taylor,[18] D. Temples,[22] P.A. Terman,[33] K.J. Thomas,[12,i] M. Timalsina,[6] W.H. To,[1,2] A. Tomás,[5] T.E. Tope,[9] M. Tripathi,[21] C.E. Tull,[12] L. Tvrznikova,[36,11,12] U. Utku,[23] J. Va'vra,[1] A. Vacheret,[5] J.R. Verbus,[20,j] E. Voirin,[9] W.L. Waldron,[12] J.R. Watson,[11,12] R.C. Webb,[33] D.T. White,[26] T.J. Whitis,[1,37] W.J. Wisniewski,[1] M.S. Witherell,[12,11] F.L.H. Wolfs,[24] D. Woodward,[30,k] S.D. Worm,[8,l] M. Yeh,[25] J. Yin,[24] and I. Young[9]

(The LUX-ZEPLIN Collaboration)

[1] *SLAC National Accelerator Laboratory, Menlo Park, CA 94025-7015, USA*
[2] *Kavli Institute for Particle Astrophysics and Cosmology, Stanford University, Stanford, CA 94305-4085 USA*
[3] *University of Michigan, Randall Laboratory of Physics, Ann Arbor, MI 48109-1040, USA*
[4] *University of Wisconsin-Madison, Department of Physics, Madison, WI 53706-1390, USA*
[5] *Imperial College London, Physics Department, Blackett Laboratory, London SW7 2AZ, UK*
[6] *South Dakota School of Mines and Technology, Rapid City, SD 57701-3901, USA*
[7] *University of Maryland, Department of Physics, College Park, MD 20742-4111, USA*

WIMP SI Sensitivity

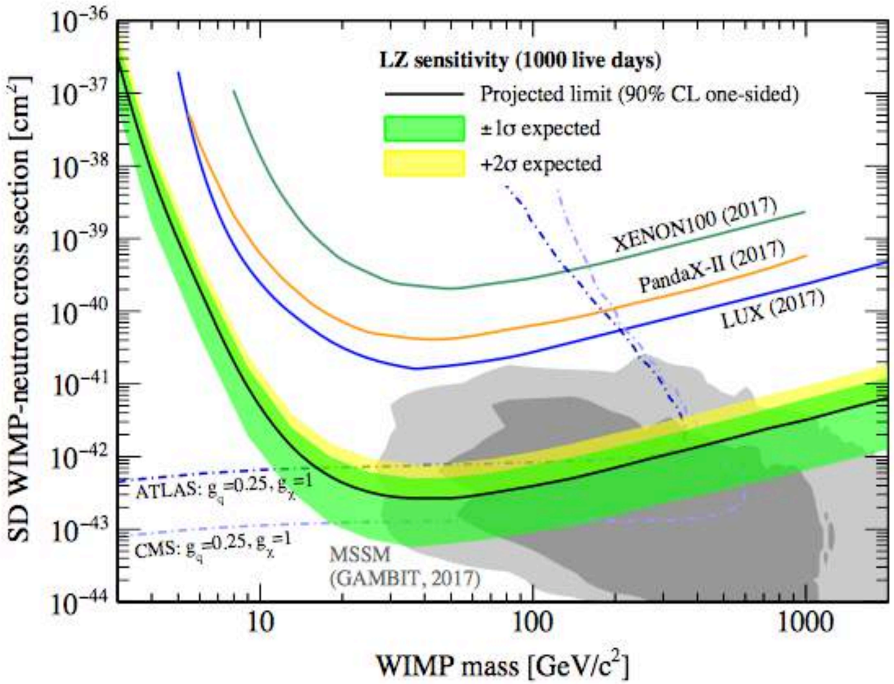
https://arxiv.org/pdf/1802.06039.pdf

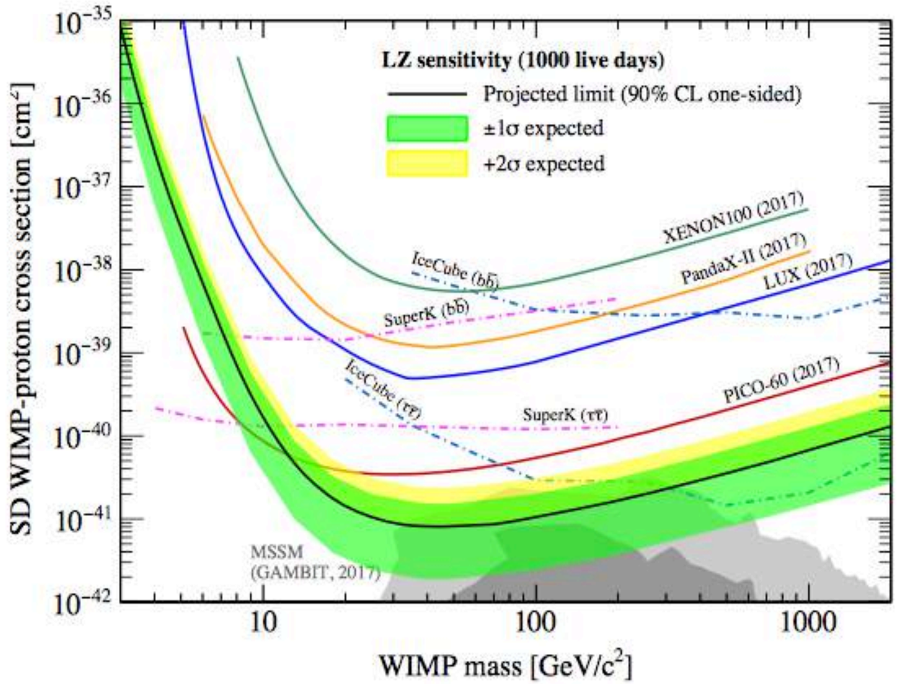


- Expected limits on spin-independent cross-sections for 1000 days of live time (left) and discovery potential (right).

More Science

SD interactions, axions, axion-like particles (ALPs), sub-GeV dark matter, leptophillic axial vector DM, astrophysical neutrinos, $0\nu\beta\beta$'s, ...



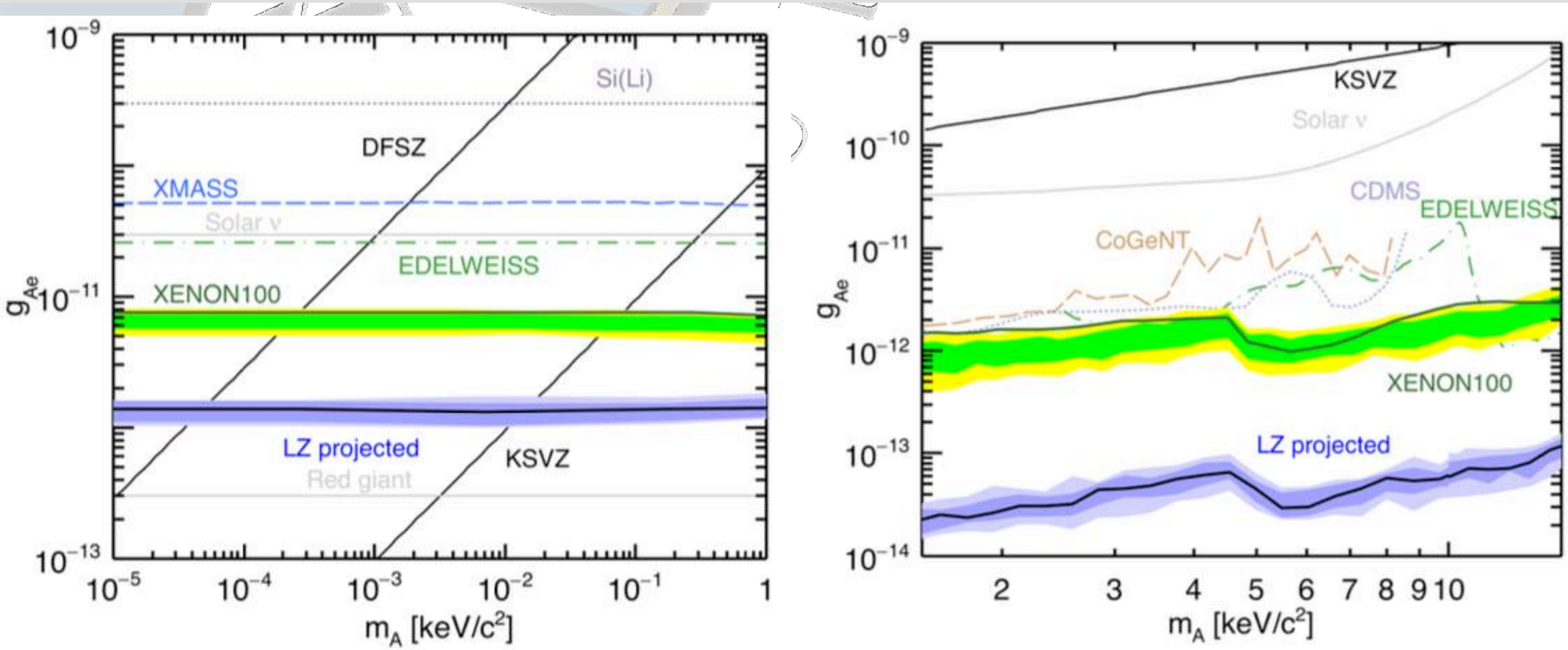


SD WIMP-neutron (left) and WIMP-proton (right) scattering for a 1000 live day run with a 5.6 tonne fiducial mass.

https://arxiv.org/pdf/1802.06039.pdf

More Science

SD interactions, **axions, axion-like particles (ALPs)**, sub-GeV dark matter, leptophillic axial vector DM, astrophysical neutrinos, $0\nu\beta\beta$'s, ...



Solar QCD axions (left) and galactic axion-like particle (right) sensitivities for a 1000 live day run with a 5.6 tonne fiducial mass.

https://arxiv.org/abs/1703.09144

To summarise…

To summarise…

Great Progress

To summarise…

Great Progress
Still lots to do

To summarise…

Great Progress

Still lots to do

Roll on 2020!

The LUX-ZEPLIN Collaboration

- Black Hills State University
- Brandeis University
- Brookhaven National Laboratory
- Brown University
- Center for Underground Physics, Korea
- Fermi National Accelerator Laboratory
- Imperial College London
- LIP Coimbra, Portugal
- Lawrence Berkley National Laboratory
- Lawrence Livermore National Laboratory
- MEPhI-Moscow, Russia
- Northwestern University
- Pennsylvania State University
- Royal Holloway, University of London
- SLAC National Accelerator Laboratory
- South Dakota School of Mines and Technology
- South Dakota Science and Technology Authority
- STFC Rutherford Appleton Laboratory
- Texas A&M University
- University at Albany, SUNY
- University College London
- University of Alabama
- University of Bristol
- University of California, Berkeley
- University of California, Davis
- University of California, Santa Barbara
- University of Edinburgh
- University of Liverpool
- University of Maryland
- University of Michigan
- University of Massachusetts
- University of Oxford
- University of Rochester
- University of Sheffield
- University of South Dakota
- University of Wisconsin – Madison
- Washington University in St. Louis
- Yale University

One day, not too far in the future…