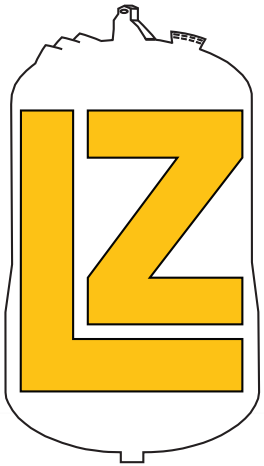
The University of Edinburgh

Sense and Sensitivity

A Dark Matter Christmas Special

Xin Ran Liu

On behalf of EdiDM



EdiDM An Introduction

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(PostDoc)

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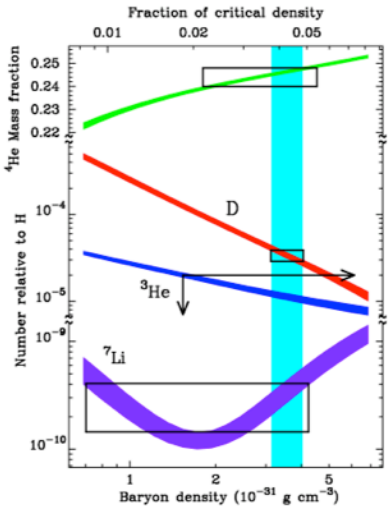
Ellen Sirks (Mphys Student)

Athoy Nilima (2nd Year PhD)

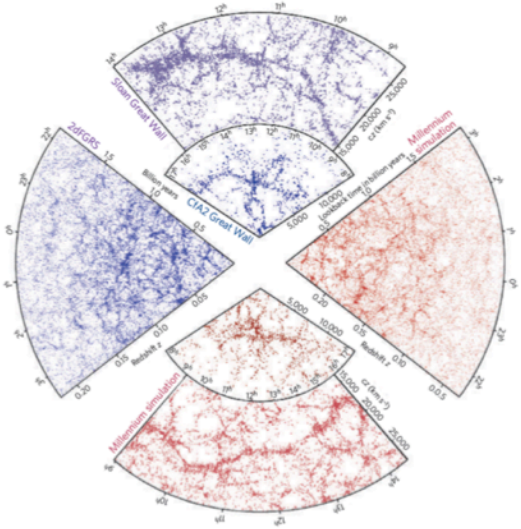
Louis Headley (Mphys Student)

Why Dark Matter?

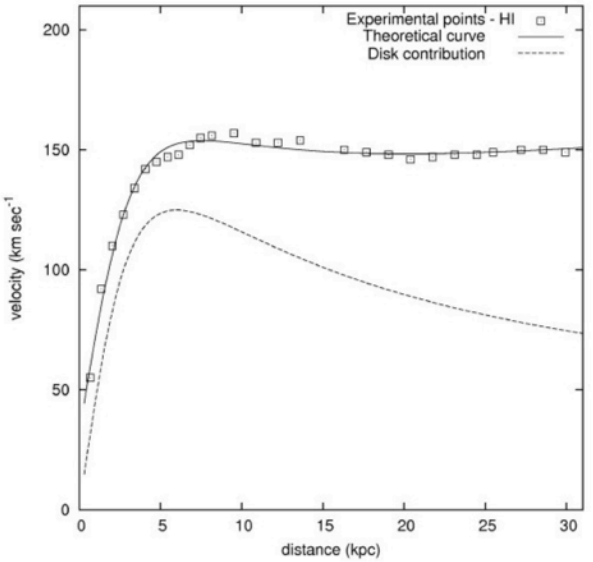
Big Bang Nucleosynthesis



Large scale structure → CDM

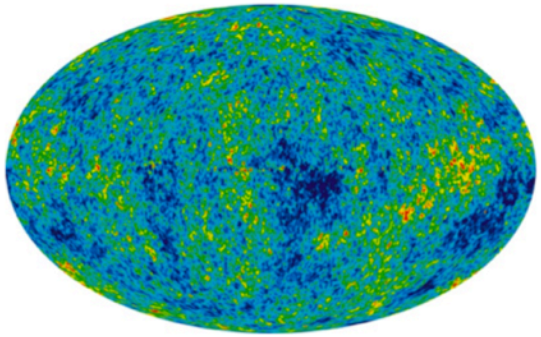


Galaxy Rotation Curves

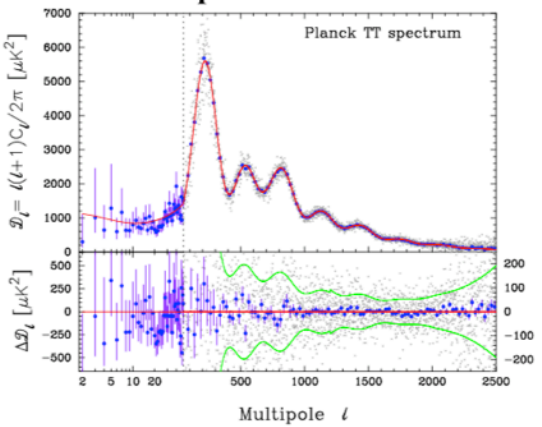


Gravitation lensing

CMB + BAO: precision tests of ΛCDM

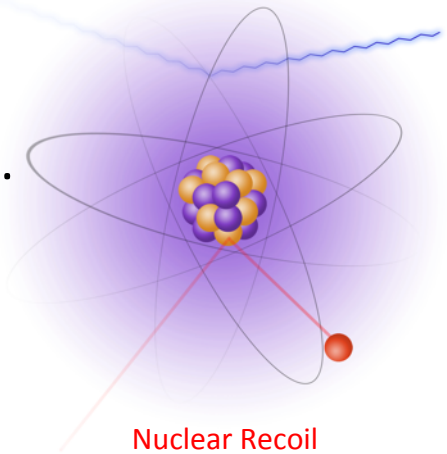


Power Spectrum of the CMB



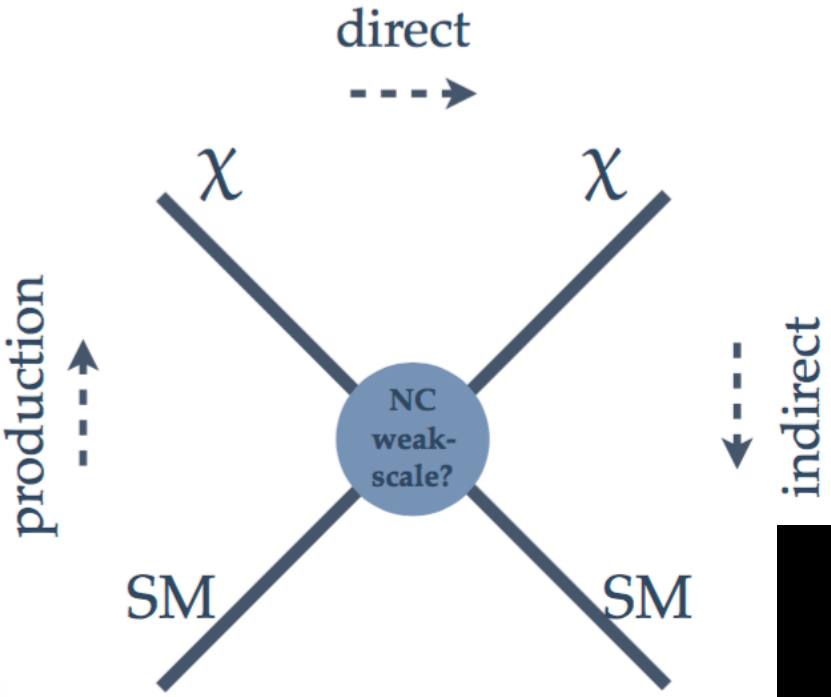
Dark Matter Interaction

Electron Recoil
(Gammas)



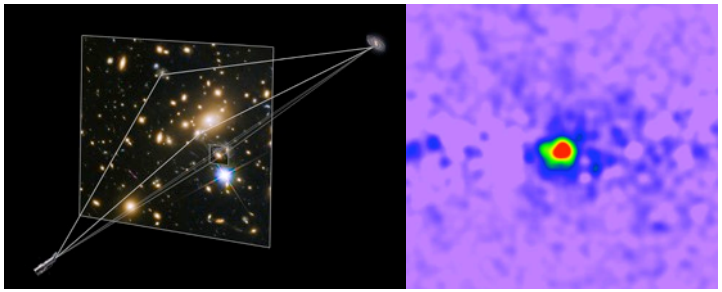
Nuclear Recoil
(Neutrons, WIMPs)

Scattering with ordinary matter (LUX and others).

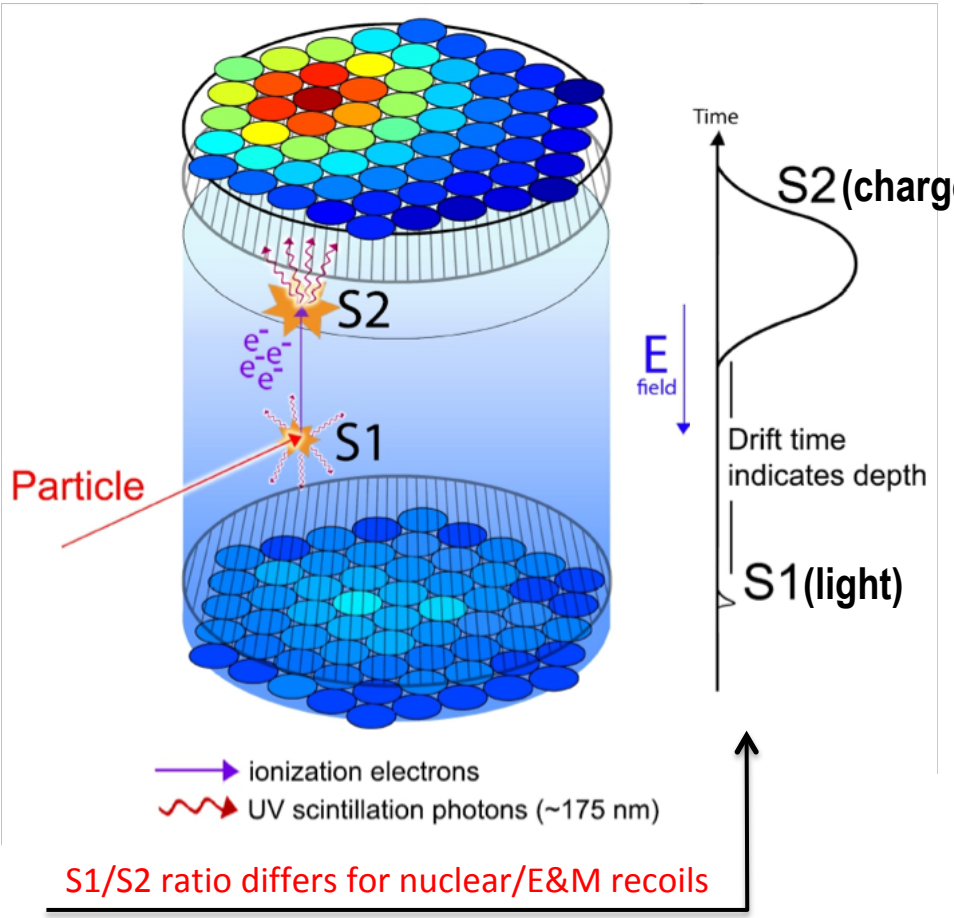


(LHC, early cosmos)

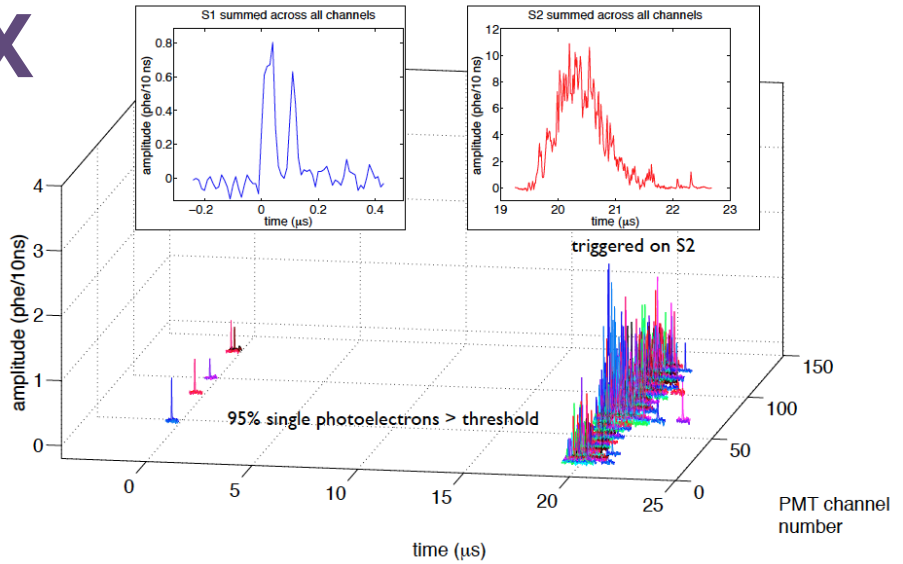
NASA (What the universe may have done/be doing)

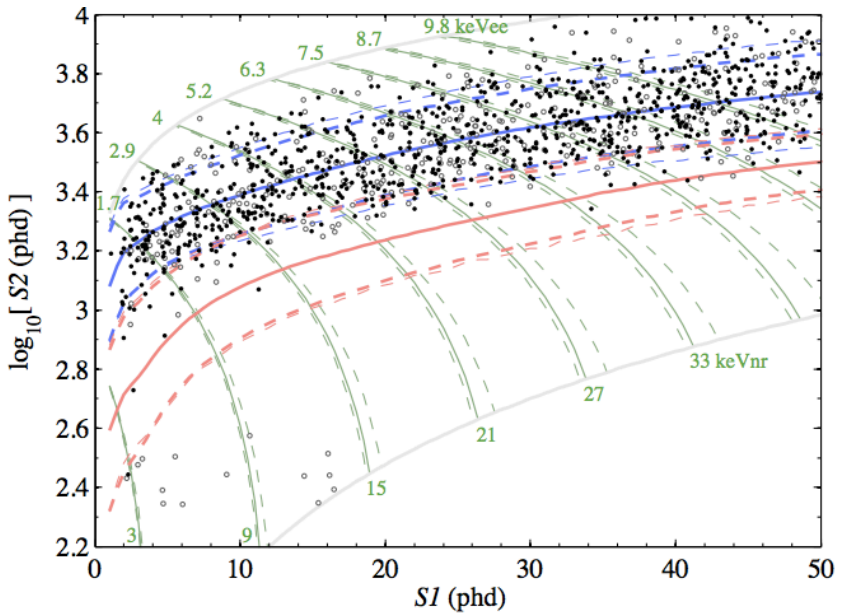


LUX



S1/S2 ratio differs for nuclear/E&M recoils





- Dual Phase Noble Liquid Time Projection Chamber.


WE'RE GOING TO NEED
A BIGGER DETECTOR

LUX to LUX ZEPLIN (LZ)

- Improved radio-purity hence reduced backgrounds.
- Outer detector consisting of 17.5 tonnes of Gadolinium loaded scintillator.
- Instrumented "Skin" region optically separated from the TPC.

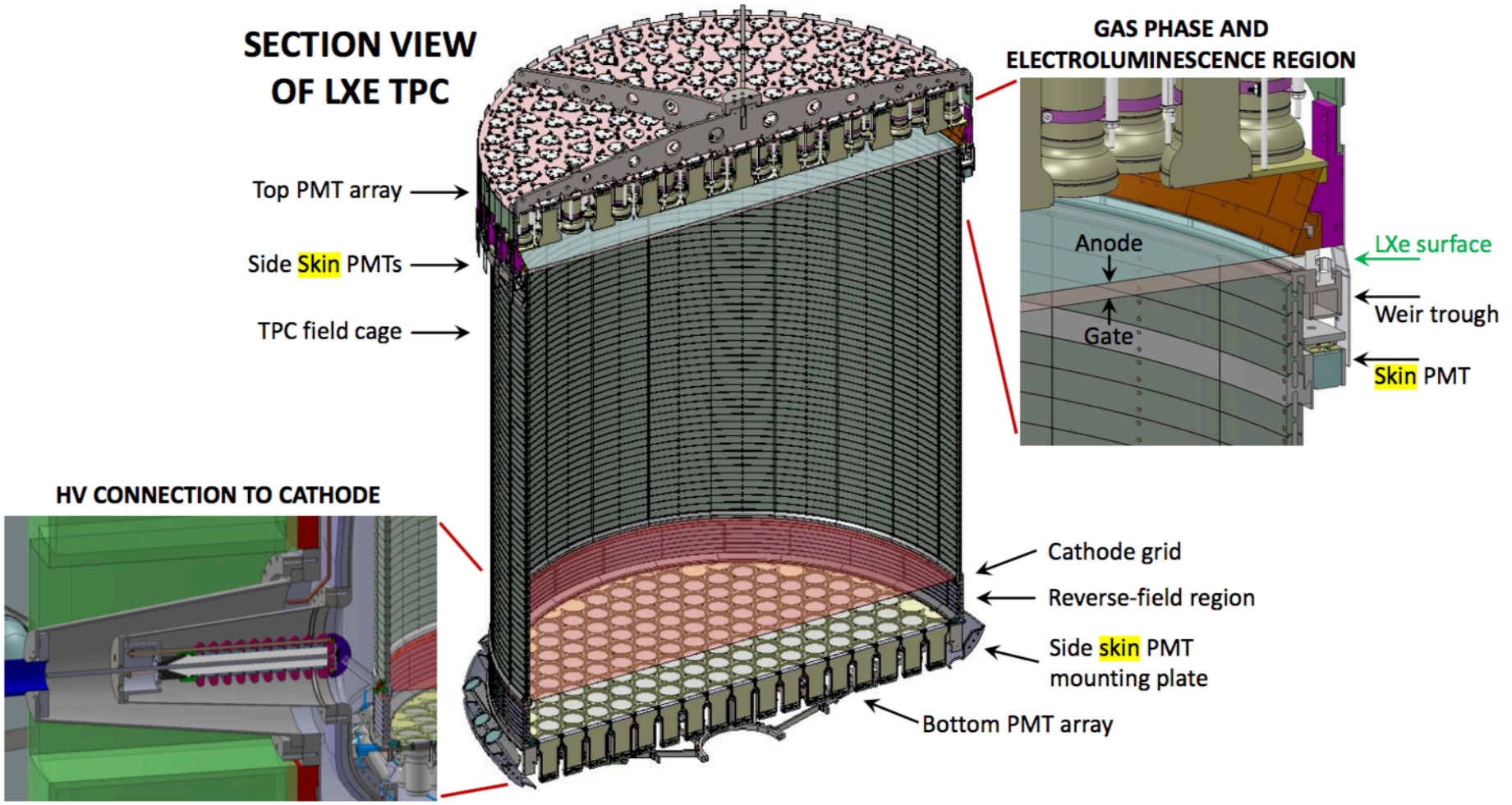
LUX

Total mass – 0.37 T
WIMP Active mass – 0.25 T
WIMP Fiducial mass – 0.145 T

LZ

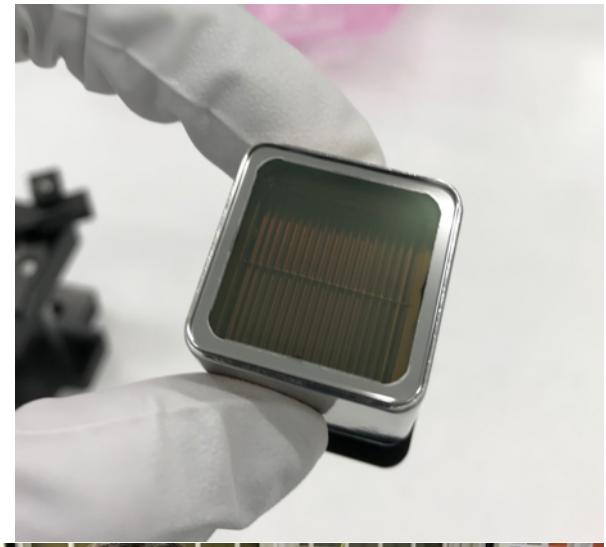
Total mass – 10 T
WIMP Active Mass – 7 T
WIMP Fiducial Mass – 5.6 T

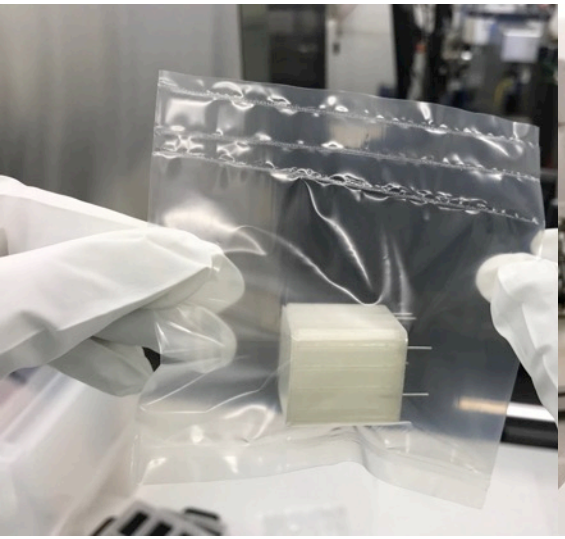
LZ Detector

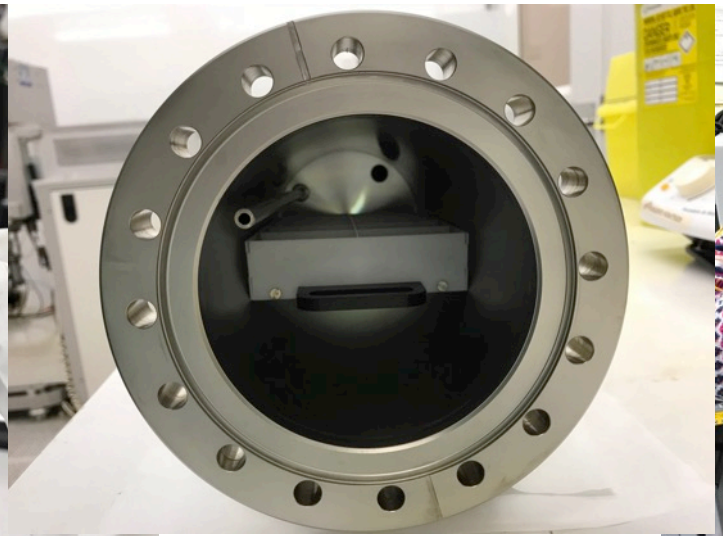

SECTION VIEW OF LXE TPC
Top PMT array
Side Skin PMTs
TPC field cage
GAS PHASE AND ELECTROLUMINESCENCE REGION
Anode
Gate
LXe surface
Weir trough
Skin PMT
HV CONNECTION TO CATHODE
Cathode grid
Reverse-field region
Side skin PMT mounting plate
Bottom PMT array

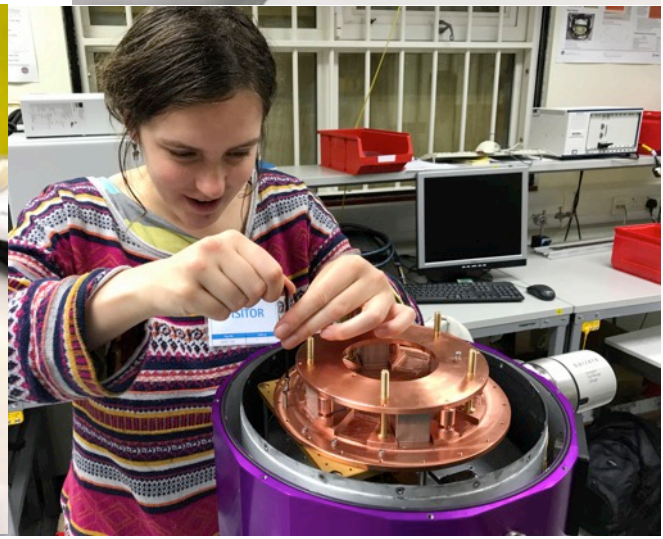
Commissioning of 1 Inch PMTs

- Assembling an experimental setup for:
  - Pressure test of PMTs to withstand 5 bars
  - Cryostat test of PMTs to − 100 C.
- Development of data acquisition system and analysis software to process the resulting data.









Axions and ALPs Search

- Axion searches in LUX 2013 data completed and published.
- World-leading limits on the axion-electron coupling obtained.
- EdiDM is leading analysis of the full LUX data set.

PRL 118, 261301 (2017) PHYSICAL REVIEW LETTERS week ending 30 JUNE 2017

First Searches for Axions and Axionlike Particles with the LUX Experiment

D. S. Akerib,[1,2,3] S. Alsum,[4] C. Aquino,[5] H. M. Araújo,[6] X. Bai,[7] A. J. Bailey,[6] J. Balajthy,[8] P. Beltrame,[5] E. P. Bernard,[9,10] A. Bernstein,[11] T. P. Biesiadzinski,[1,2,3] E. M. Boulton,[9,10] P. Brás,[12] D. Byram,[13,14] S. B. Cahn,[10] M. C. Carmona-Benitez,[15] C. Chan,[16] A. A. Chiller,[13] C. Chiller,[13] A. Currie,[6] J. E. Cutter,[17] T. J. R. Davison,[5] A. Dobi,[18] J. E. Y. Dobson,[19] E. Druszkiewicz,[20] B. N. Edwards,[10] C. H. Faham,[18] S. R. Fallon,[21] S. Fiorucci,[16,18] R. J. Gaitskell,[16] V. M. Gehman,[18] C. Ghag,[19] K. R. Gibson,[1] M. G. D. Gilchriese,[18] C. R. Hall,[8] M. Hanhardt,[7,14] S. J. Haselschwardt,[22] S. A. Hertel,[23] D. P. Hogan,[9] M. Horn,[14,9,10] D. Q. Huang,[16] C. M. Ignarra,[2,3] R. G. Jacobsen,[9] W. Ji,[1,2,3] K. Kamdin,[9] K. Kazkaz,[11] D. Khaitan,[20] R. Knoche,[8] N. A. Larsen,[10] C. Lee,[1,2,3] B. G. Lenardo,[17,11] K. T. Lesko,[18] A. Lindote,[12] M. I. Lopes,[12] A. Manalaysay,[17] R. L. Mannino,[24] M. F. Marzioni,[5,*] D. N. McKinsey,[9,18,10] D.-M. Mei,[13] J. Mock,[21] M. Moongweluwan,[20] J. A. Morad,[17] A. St. J. Murphy,[5] C. Nehrkorn,[22] H. N. Nelson,[22] F. Neves,[12] K. O'Sullivan,[9,18,10] K. C. Oliver-Mallory,[9] K. J. Palladino,[4,2,3] E. K. Pease,[9,10] L. Reichhart,[19] C. Rhyne,[16] S. Shaw,[19] T. A. Shutt,[1,2,3] C. Silva,[12] M. Solmaz,[22] V. N. Solovov,[12] P. Sorensen,[18] S. Stephenson,[17] T. J. Sumner,[6] M. Szydagis,[21] D. J. Taylor,[14] W. C. Taylor,[16] B. P. Tennyson,[10] P. A. Terman,[24] D. R. Tiedt,[7] W. H. To,[1,2,3] M. Tripathi,[17] L. Tvrznikova,[9,10] S. Uvarov,[17] V. Velan,[9] J. R. Verbus,[16] R. C. Webb,[24] J. T. White,[24] T. J. Whitis,[1,2,3] M. S. Witherell,[18] F. L. H. Wolfs,[20] J. Xu,[11] K. Yazdani,[6] S. K. Young,[21] and C. Zhang[13]

(LUX Collaboration)

2nuDEC Search

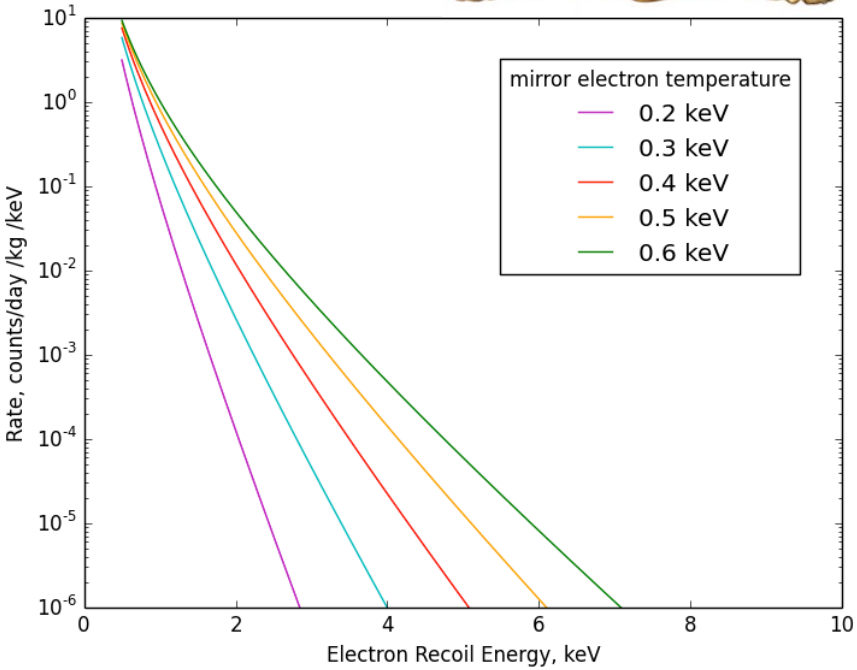
- New ER band search undertaken: 2nuDEC of Xe-124.
- Search for a mono energetic line at 63.6 keV in the LUX ER spectrum.
- Ongoing finalisation of the analysis on LUX 2013 data.
- Publication in preparation.
- EdiDM is also contributing to the analysis on the full LUX data set.

LZ-wise:

- Axion searches projections completed.
- 2nuDEC projections on to-do-list.

Mirror Mirror on the Wall…

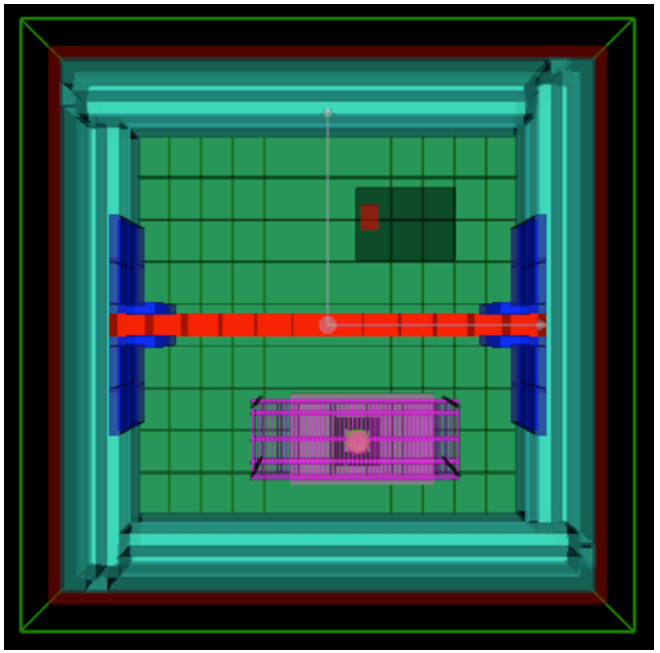
- Mirror Dark Matter:
  - DM in hidden sector isomorphic to SM – contains mirror partner of all SM particles.
  - Gauge symmetry only allows interaction via kinetic mixing term, governed by ε.
  - Mirror electrons scatter off atomic electrons in Xe giving ~keV ER signal in LUX.
- Analysis:
  - Construct signal model.
  - Simulate detector observables.
  - Compare signal + background to data.
- Goal:
  - Constrain ε.

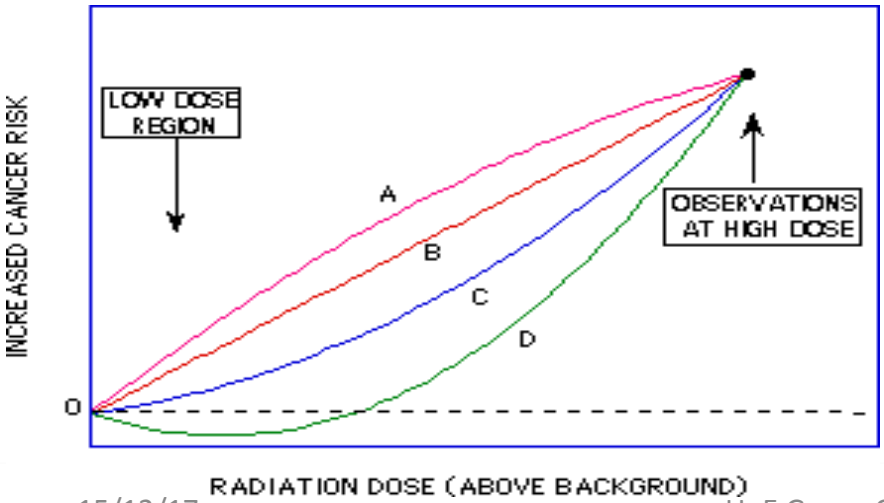


Mirror DM energy spectrum for $\varepsilon = 10^{-10}$

Low Background Studies for SELLR
(Subsurface Experiment for Life in Low-Radiation)

- Experimental set-up in the old ZEPLIN-III castle within the Boulby mine.
- Did not make direct measurement of background radiation contribution.
- Geant4 simulation of gamma doses received by the samples.



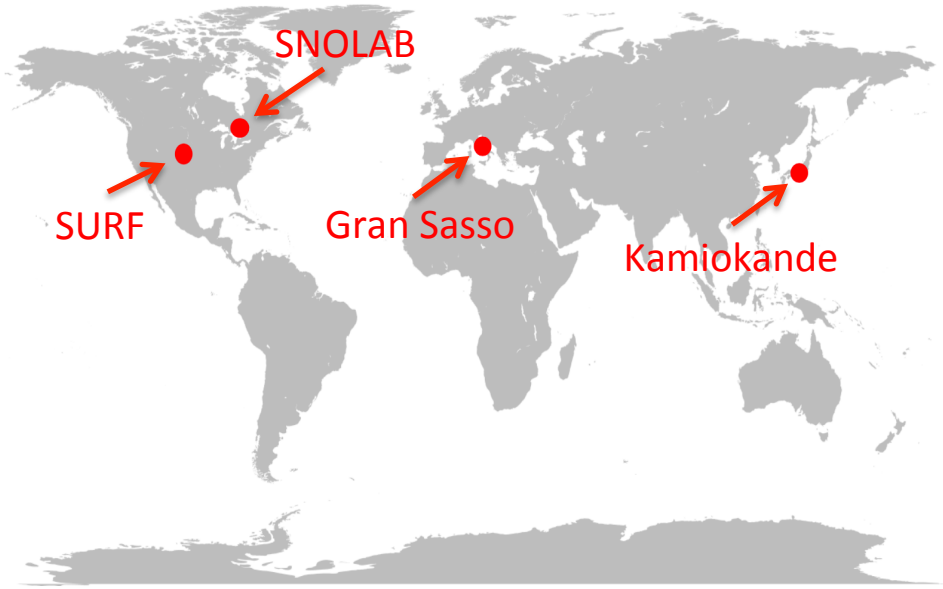


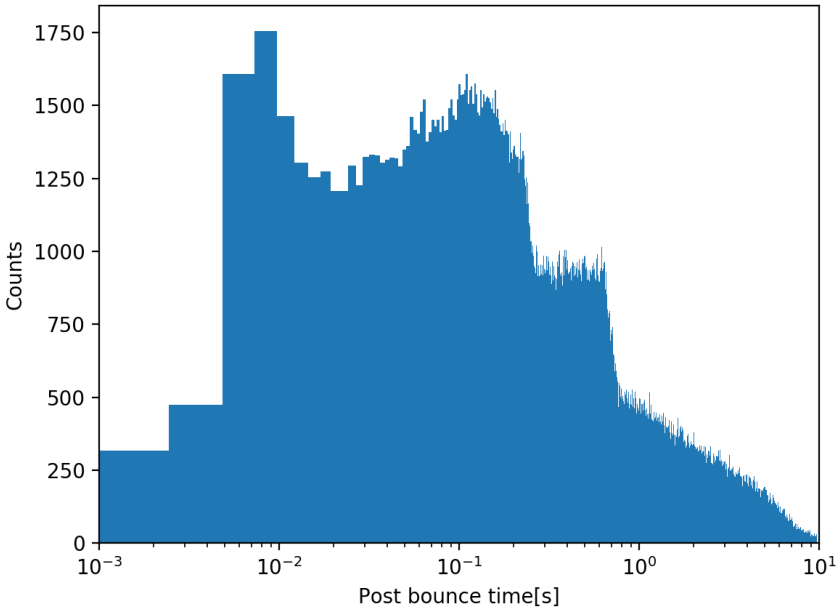
- Significant dose contribution to the background sample.

Working on Electron-Recoil Background Models for LUX and LZ.

Machine Learning for Locating Supernovae

- Produce simulated data.





Simulated probability density function of neutrino events from a supernova

- Looking at Neutrino events from supernovae in four particle detectors.
- Training regressions to predict the angular coordinates of supernovae events


HAPPY HAN-UKKAH!
MERRY FORCE BE WITH YOU!
I FIND YOUR LACK OF CHEER DISTURBING…