LUX-ZEPLIN (LZ) Status

Attila Dobi
Lawrence Berkeley National Laboratory
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Outline

- LZ Detector
- Backgrounds
- Calibration
- Sensitivity
- Beyond WIMP Search

LZ = LUX + ZEPLIN

Counts: 31 Institutions
≈ 200 Headcount

Center for Underground Physics (Korea)
LIP Coimbra (Portugal)
MEPhI (Russia)
Edinburgh University (UK)
University of Liverpool (UK)
Imperial College London (UK)
University College London (UK)
University of Oxford (UK)
STFC Rutherford Appleton, and Daresbury, Laboratories (UK)
University of Sheffield (UK)

University of Alabama
University at Albany SUNY
Berkeley Lab (LBNL)
UC Berkeley
Brookhaven National Laboratory
Brown University
University of California, Davis
Fermi National Accelerator Laboratory
Lawrence Livermore National Laboratory
University of Maryland
Northwestern University
University of Rochester
University of California, Santa Barbara
University of South Dakota
South Dakota School of Mines & Technology
South Dakota Science and Technology Authority
SLAC National Accelerator Laboratory
Texas A&M
Washington University
University of Wisconsin
Yale University

LZ Timeline

Year	Month	Activity
2012	March	LZ (LUX-ZEPLIN) collaboration formed
	September	DOE CD-0 for G2 dark matter experiments
2013	November	LZ R&D report submitted
2014	July	LZ Project selected in US and UK
2015	April	DOE CD-1/3a approval, similar in UK Begin long-lead procurements(Xe, PMT, cryostat)
2016	April	DOE CD-2/3b review(scheduled)
2017	February	LUX removed from underground
2017	July	Begin setup for assembly in surface lab @ SURF
2018	May	Begin underground installation
2019	May	Begin commissioning
2021	Q3FY21	CD-4 milestone (early finish July 2019)
2025+		Planning on ~ 5 year of operations

Sanford Underground Research Facility in South Dakota

Davis Cavern 1480 m (4300 mwe)
LZ in LUX Water Tank

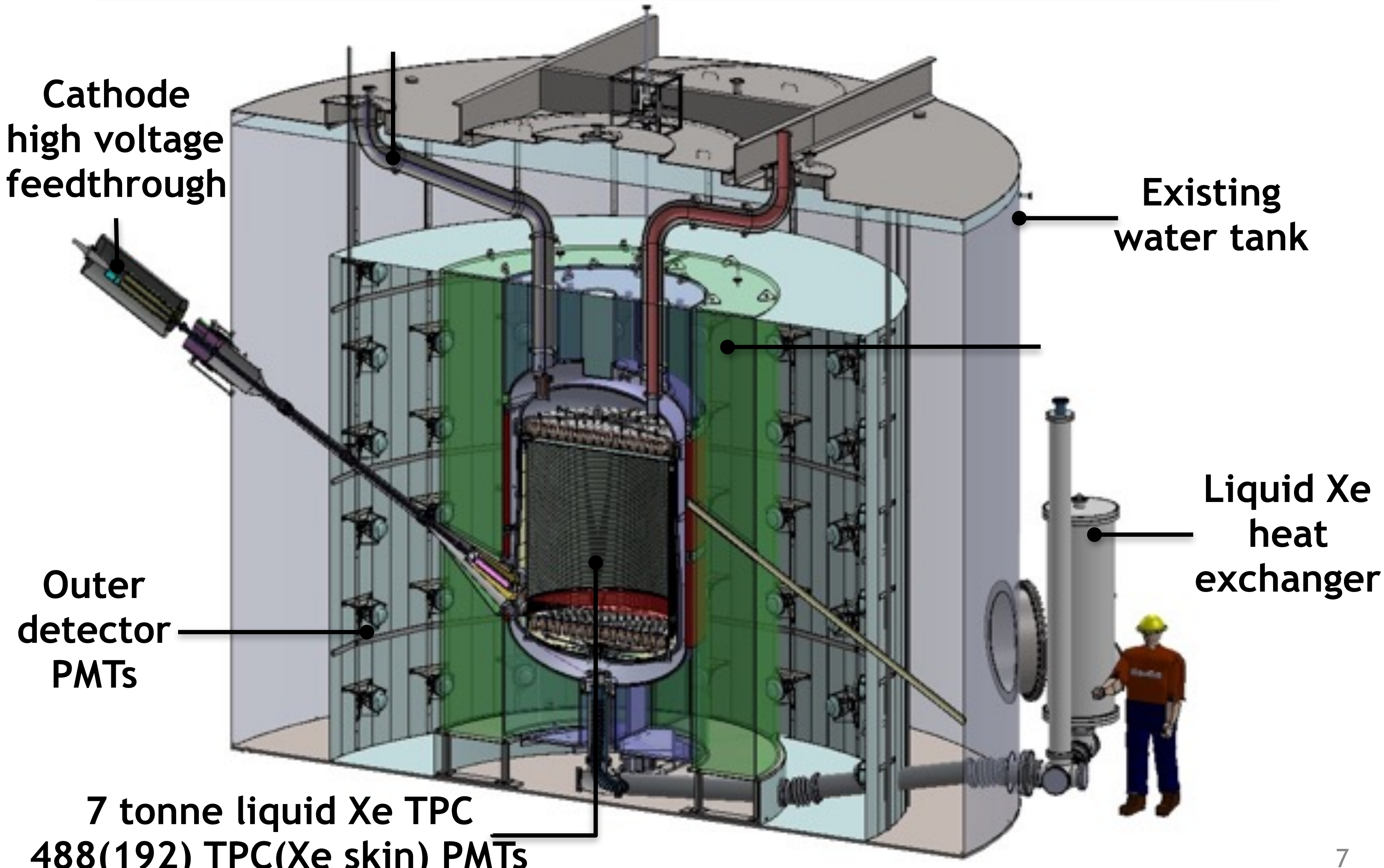
LUX to be removed by early 2017
Water tank kept

Scale Up ≈50 in Fiducial Mass

LZ

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

LZ Detector Overview

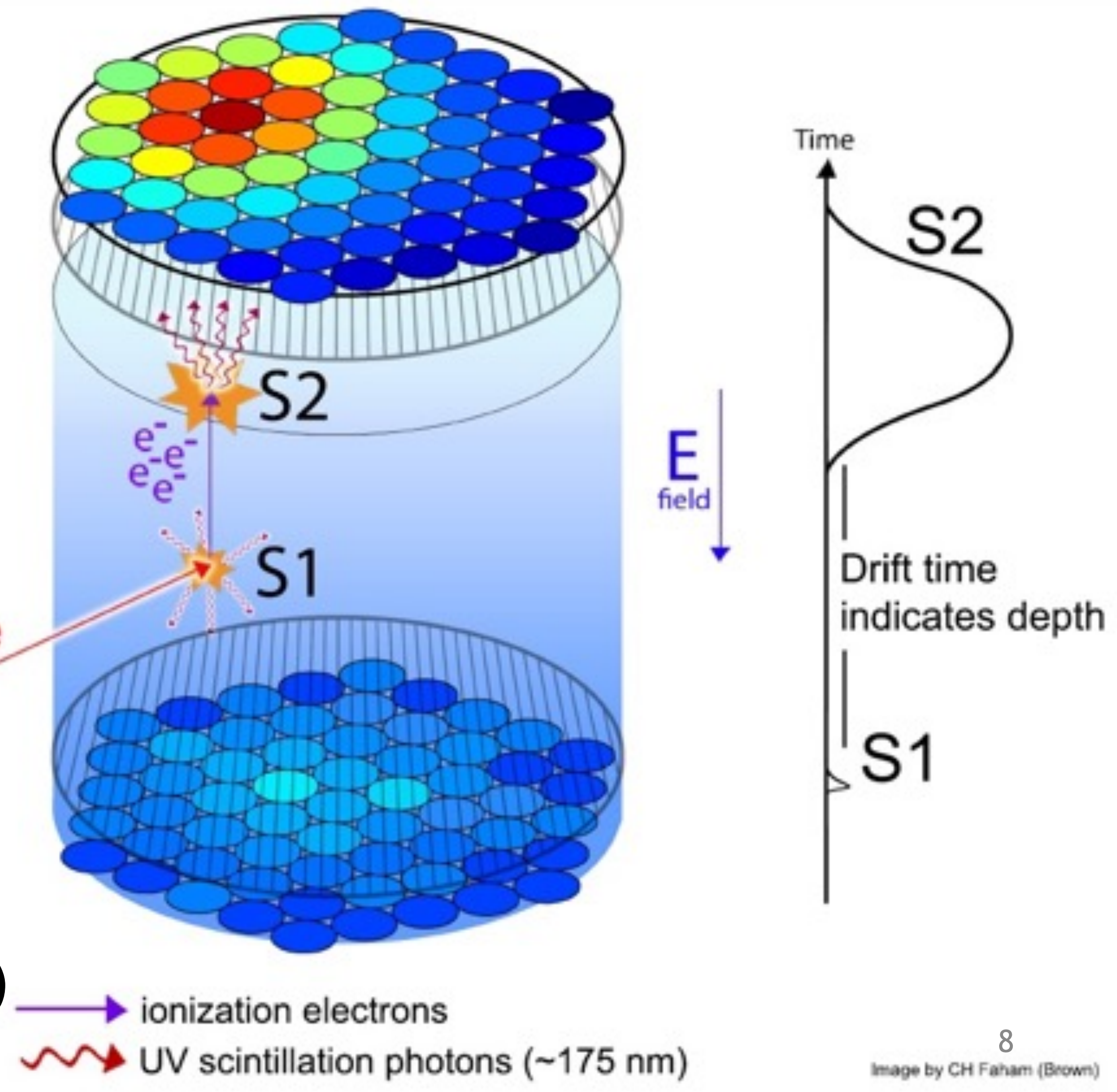


Principle of Operation

Z position from S1 – S2 timing

X-Y positions from S2 light pattern

`Discriminate' WIMP-caused nuclear recoils from gamma-caused electron recoils by ionization (S2) to light (S1) ratio.



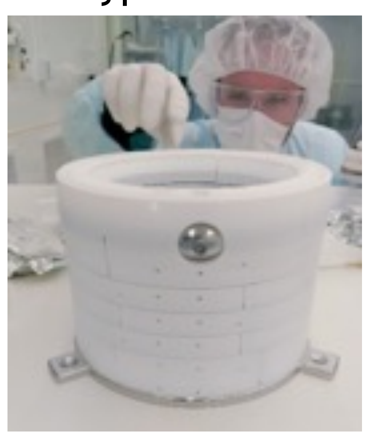
Xe Detector PMTs

- R11410-22 3” PMTs for TPC region
  - Extensive development program, 50 tubes in hand, benefit from similar development for XENON1T, PANDA-X and RED
  - Materials ordered and radio assays complete
  - Materials meet background requirements
  - First production tubes by Fall 2016.
  - Joint US and UK effort
- R8778 2” from LUX for skin region

Detector Prototyping

- ✦ Extensive prototype/design verification program underway
  - SLAC LXe, 100's kg capacity, circulation, recovery, control..
  - LBNL LAr for cathode HV, moved from Yale, enhanced
- ✦ Design verification testbeds of HV and grids

Prototype TPC Section



LBNL HV Test Platform

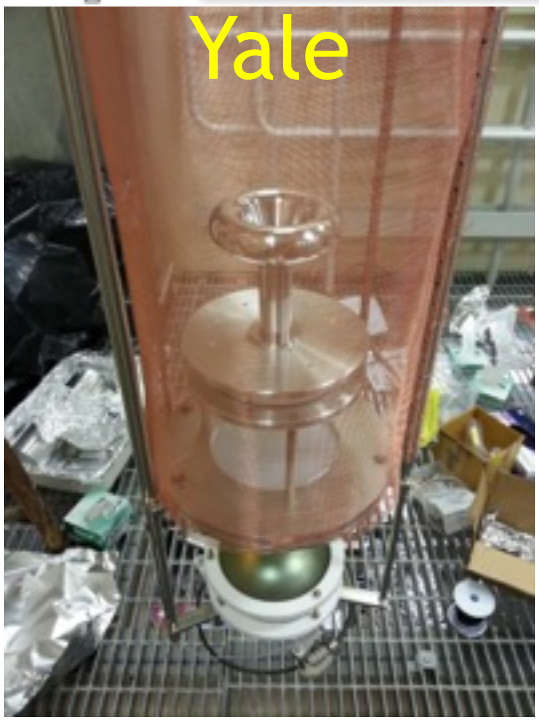
SLAC System Test Facility operational. Prototype TPC tests underway.

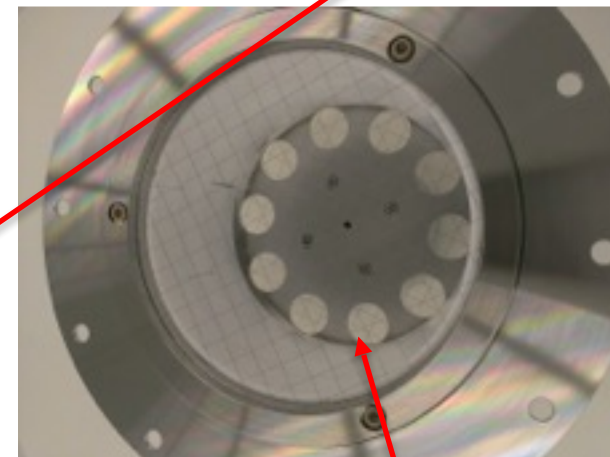
Integrated with Kr removal

^{85}Kr Removal and Screening

- Remove Kr to <15 ppq (10^{-15} g/g) using gas chromatography.
  - Best LUX batch 200 ppq
- Setting up to process 200 kg/day at SLAC
- Have a sampling program to instantly assay the removal at SLAC and continuously assay in situ

High Voltage Studies

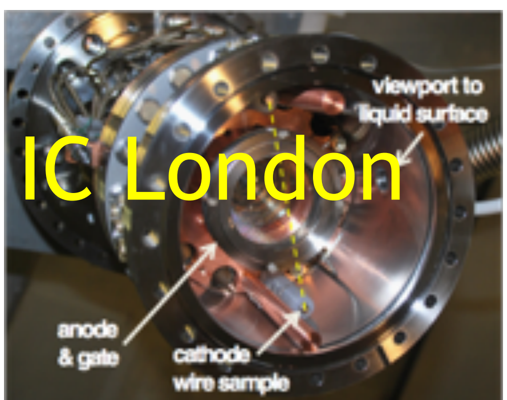




Reverse field region cathode grid

3 RFR rings (half height)

Ground grid

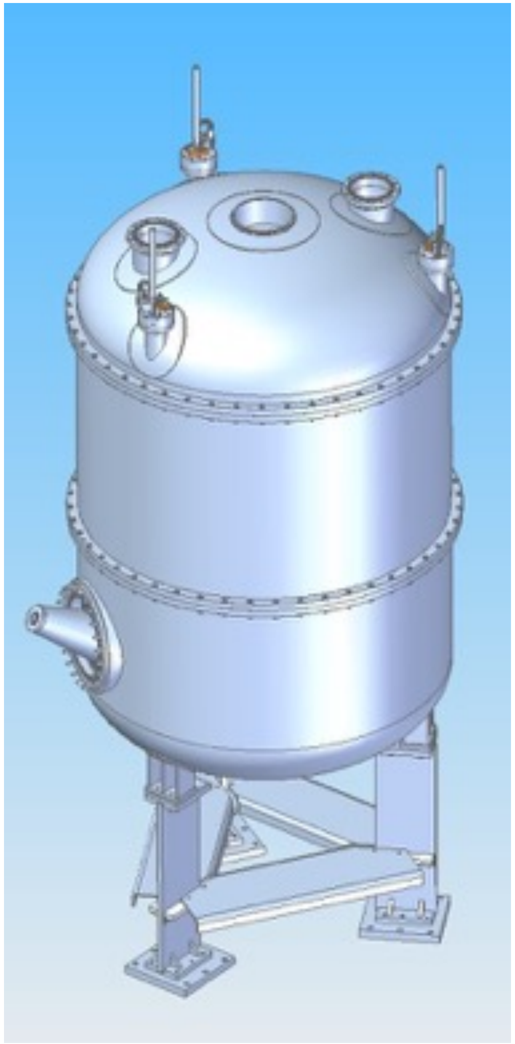


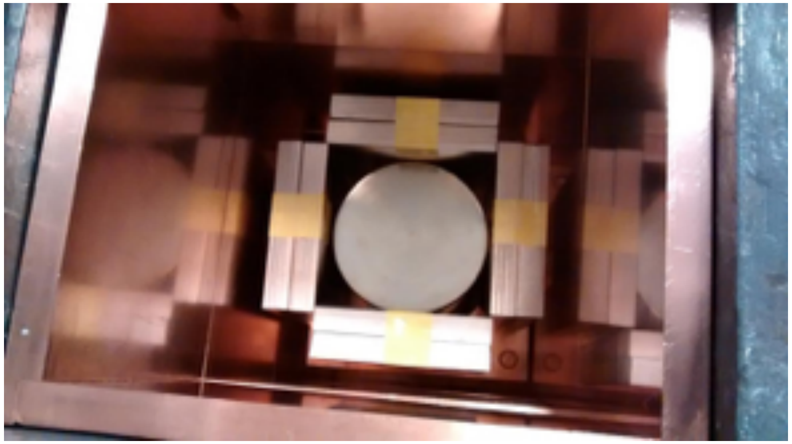
Testing for cathode HV at Yale moving to LBNL and Berkeley. Also development at IC London.

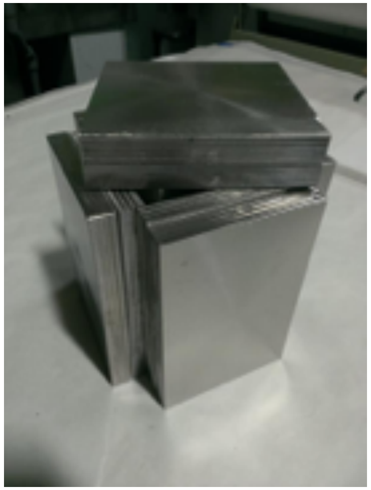
- ✦Cathode voltage Design goal: 100 kV
- ✦LZ nominal requirement: 50 kV (300 V/cm)
- ✦Feedthrough prototype tested to 200 kV (Dielectric Sciences 2077)

Cryostat Vessels

- UK responsibility
- Radio-pure, 5 tonnes in hand
- Vendor, Loterios (Italy)
- Ti slab for all vessels(and other parts) received and has been assayed
- Contributes < 0.05 NR+ER counts in fiducial volume in 1,000 days after cuts

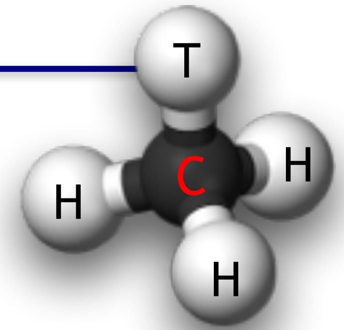


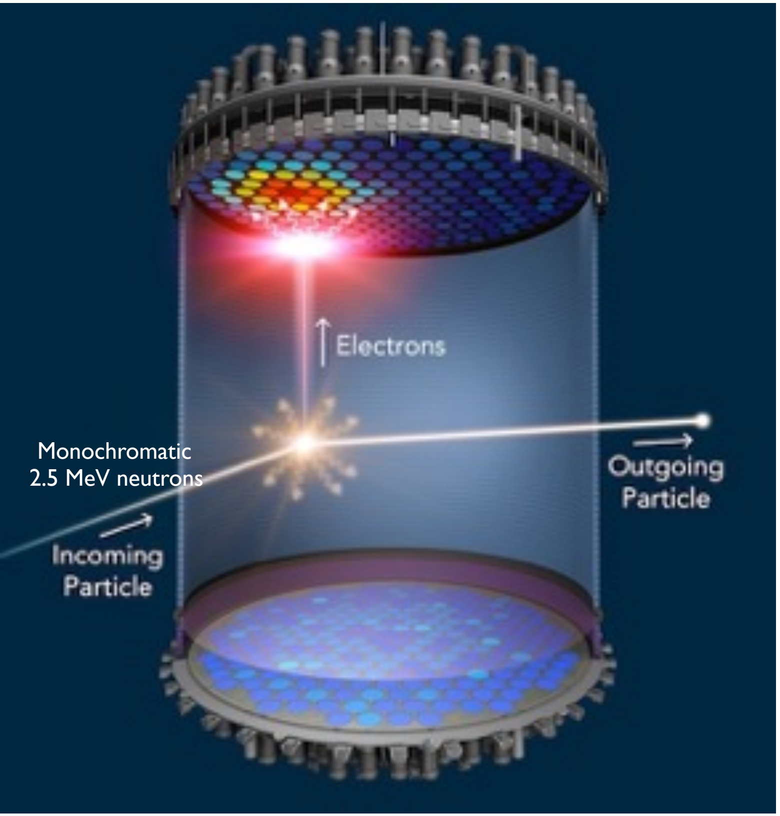


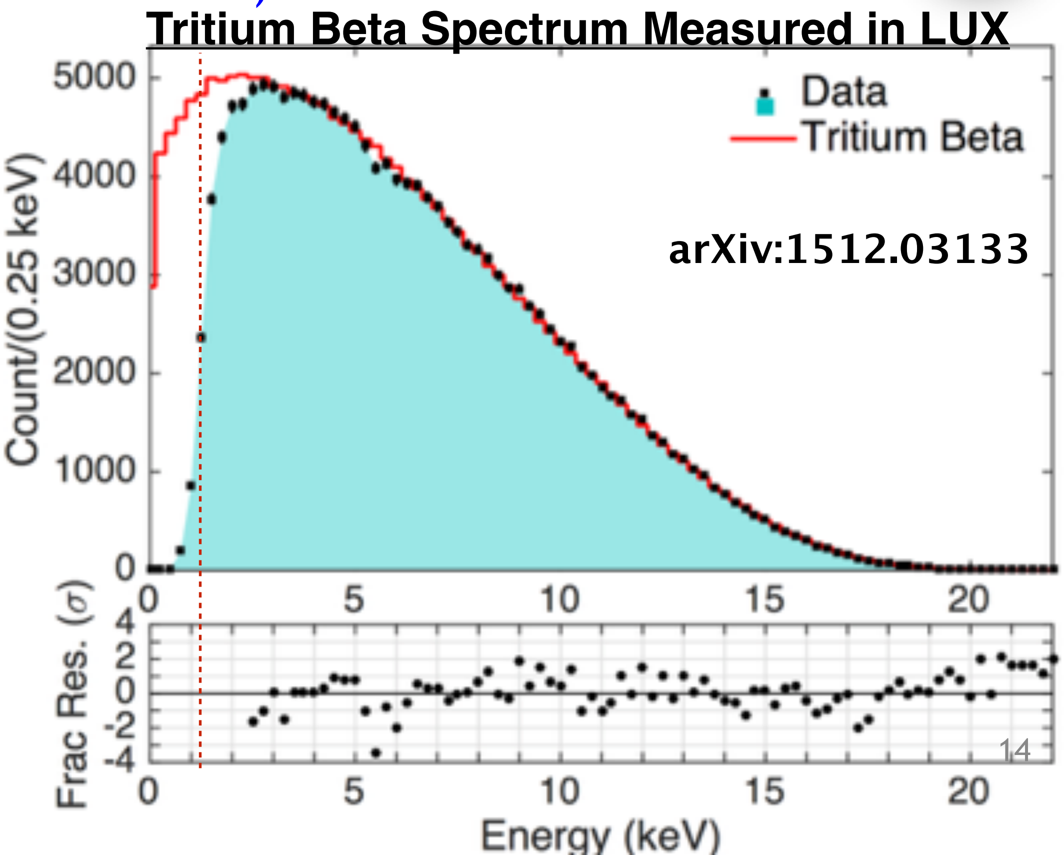


LZ Calibrations

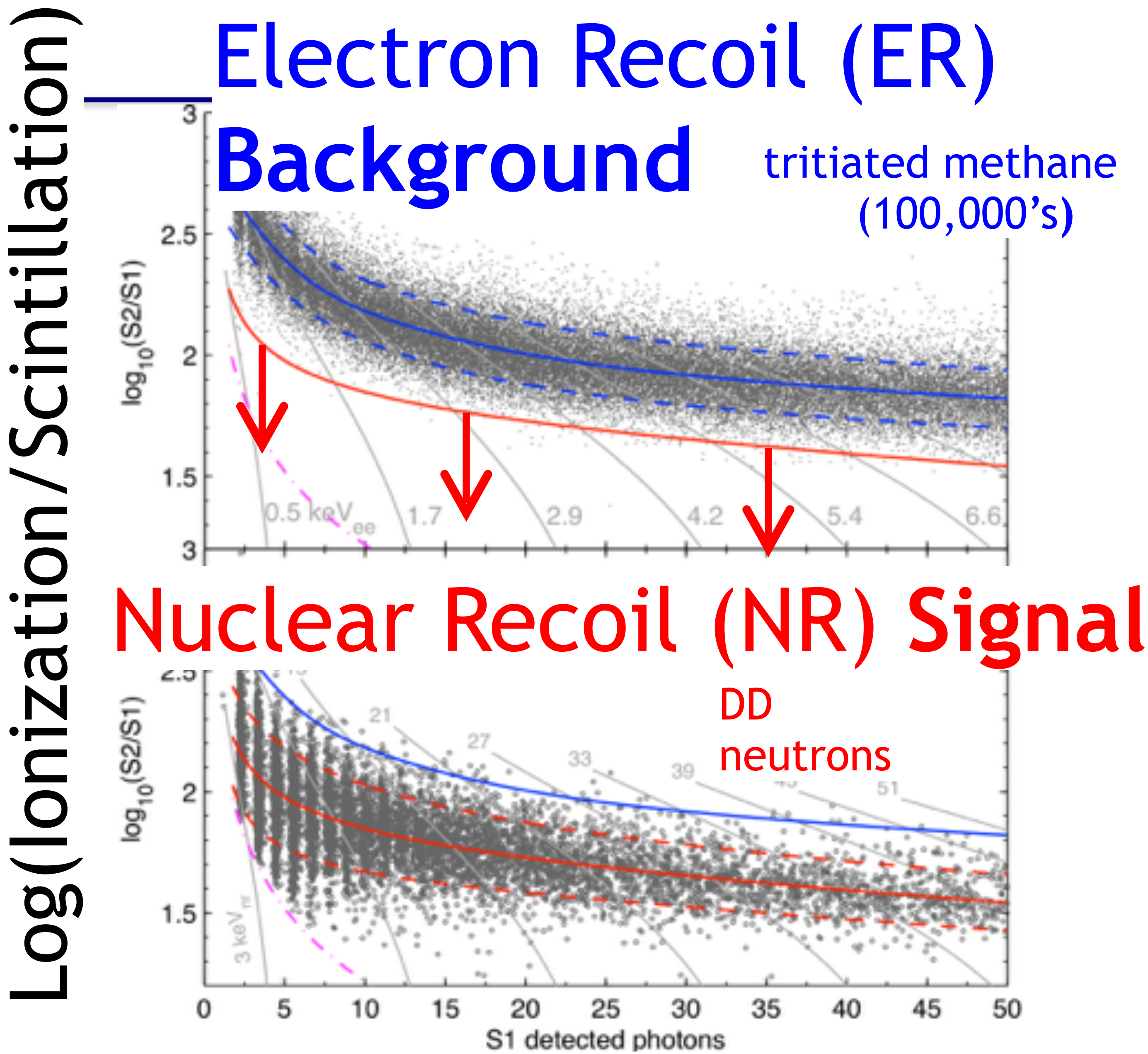
- ✦ Demonstrated in LUX.
- ✦ Calibrate The Signal and Background Model *in situ*.
  - ✦ DD Neutron Generator (Nuclear Recoils)
  - ✦ Tritiated Methane (Electron Recoils)







High Statistics LUX Calibrations



Backgrounds

Background	Type	Counts in LZ nominal exposure (5,600 tonne-days)	Nuisance parameter uncertainty
^{8}B ν	NR	7	$\pm 10\,\%$
hep ν	NR	0.21	$\pm 30\,\%$
DSN ν	NR	0.05	$-50\,\%$
ATM ν	NR	0.46	$+33\,\%$
pp + ^{7}Be + ^{14}N solar ν	ER	255	$\pm 1\,\%$
^{136}Xe ($2\nu\beta\beta$)	ER	67	$\pm 7\,\%$
^{85}Kr	ER	24.5	$\pm 5\,\%$
^{222}Rn	ER	783	$\pm 10\,\%$
^{220}Rn	ER	129	$\pm 10\,\%$
Detector components + Environmental	ER	21	$\pm 10\,\%$
Detector components + Environmental	NR	0.56	$\pm 10\,\%$

Dominant Nuclear Recoil BG (^{8}B ν)

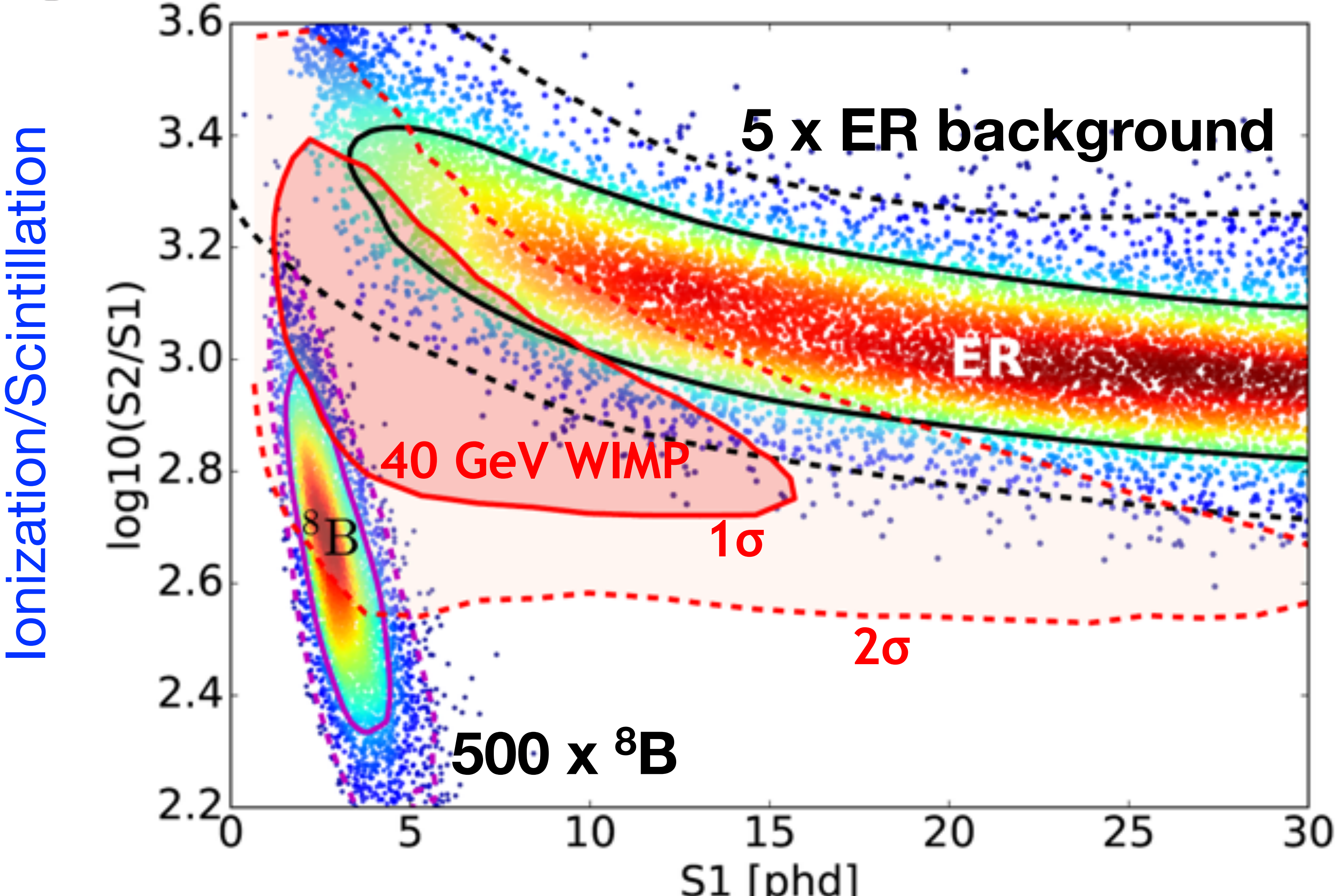
Solar Neutrinos (^{8}B ν, hep ν, DSN ν, ATM ν, pp + ^{7}Be + ^{14}N solar ν)

Internal (^{136}Xe, ^{85}Kr, ^{222}Rn, ^{220}Rn)

Dominant Electron Recoil BG (^{222}Rn, ^{220}Rn)

- Set sensitivity projections using profile likelihood method
- Use S1 (light), S2 (charge) and fiducial cut information to construct PDFs
- Light and Charge is generated using NEST (LXe response simulation)
- Use profile likelihood method to set the 90% CL

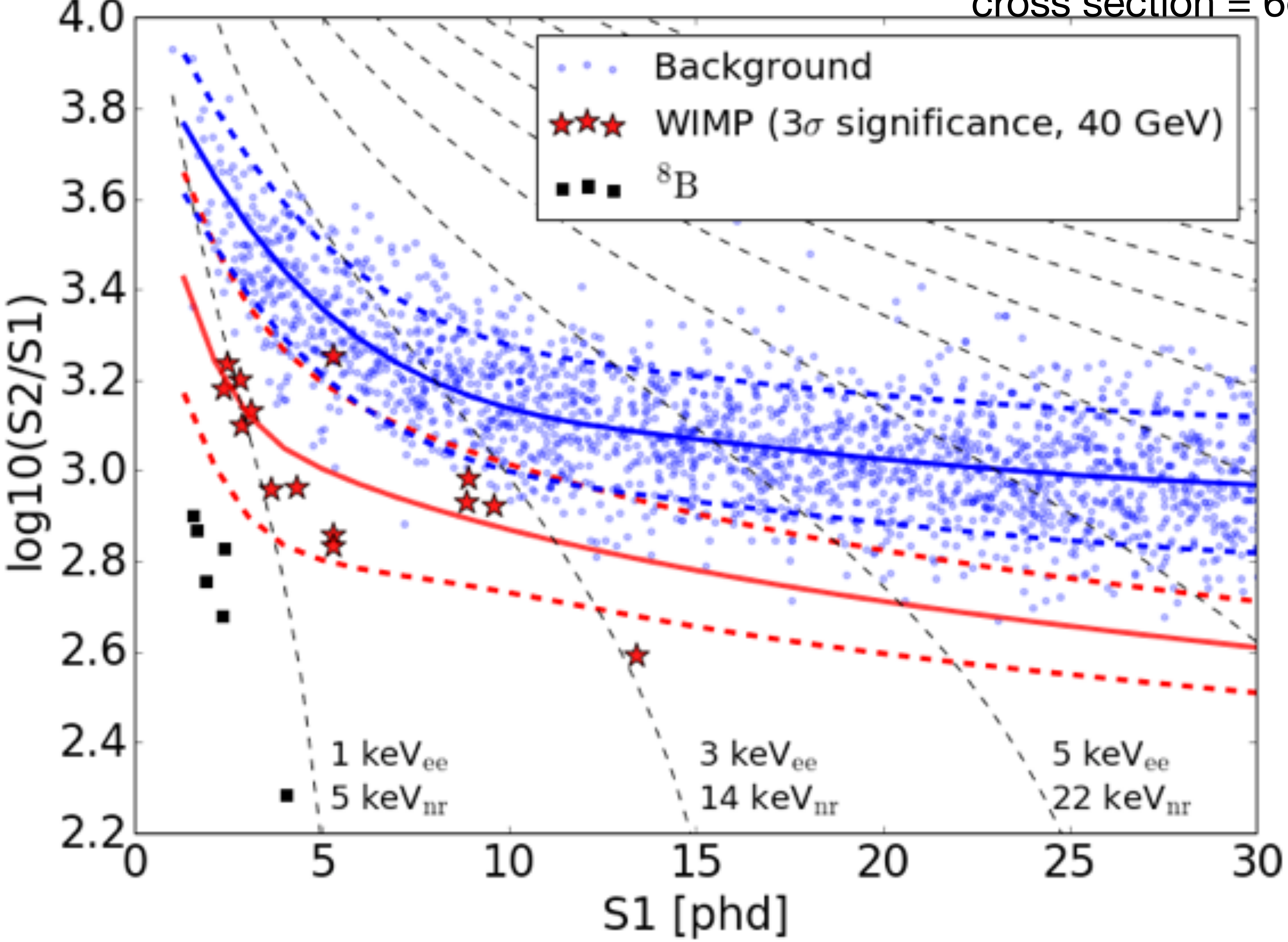
WIMP Signal Region Profile



Example LZ Exposure (5.6 Ton - 1000 days)

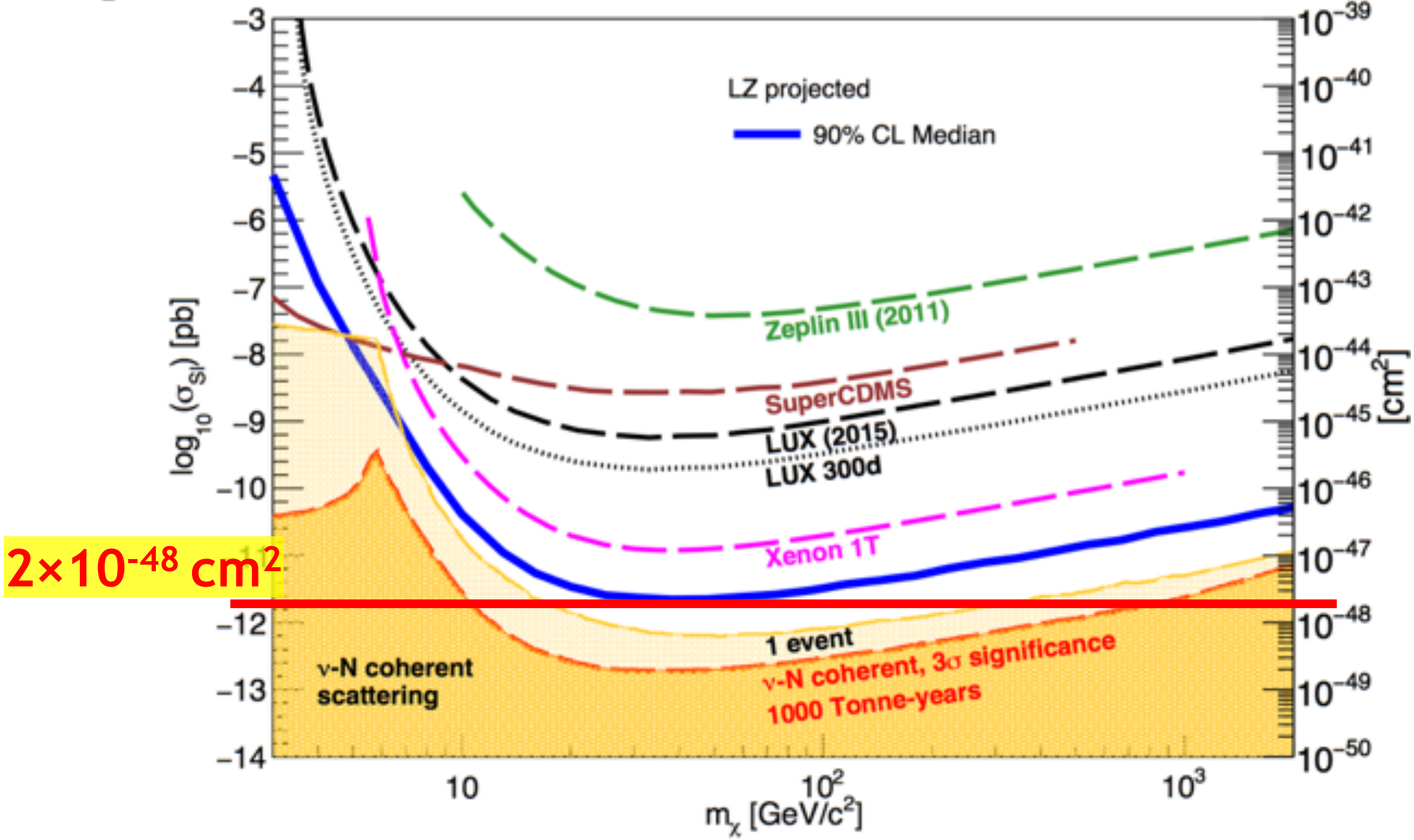
cross section = 6e-48 cm^2

Ionization/Scintillation



Projected Sensitivity – Spin Independent

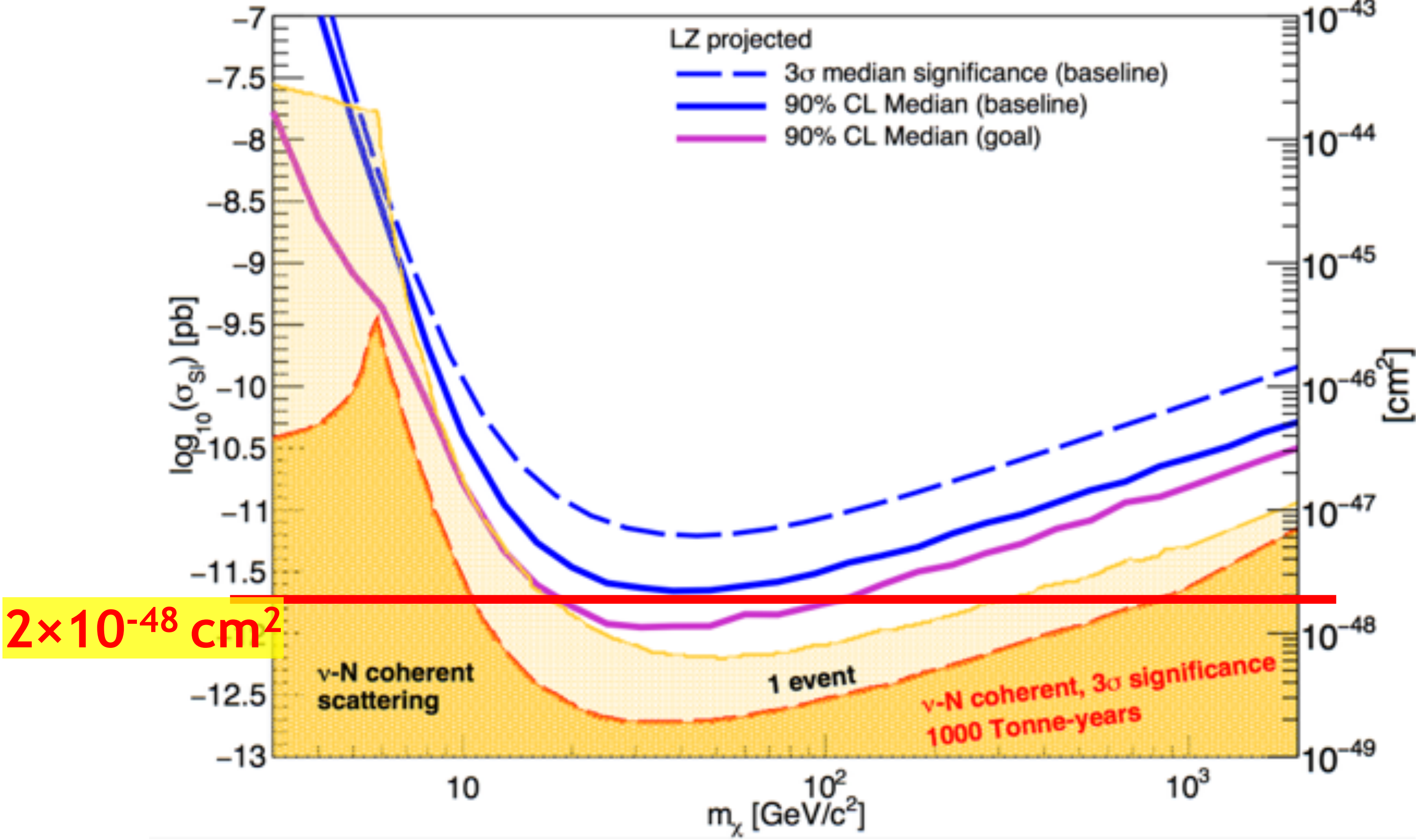
(LZ 5.6 Tonnes, 1000 live days)



- **Excellent projected sensitivity. Probing ^{8}B neutrino floor**

Projected Sensitivity – Spin Independent

(LZ 5.6 Tonnes, 1000 live days)



Other Physics…

- Axions

- Effective Field Theory Interaction Decomposition

- Neutrinoless Double Beta Decay
  - ~600 kg of ^{136}Xe in active volume
  - 2-5x10^{26} year half life

- External Neutrino Physics
  - Coherent elastic neutrino-nucleus scattering (~10 of ^{8}B events)
  - Neutrino-electron scattering (~300 of PP-solar neutrino events)
  - Supernova

Conclusions

- LZ Project at SURF well underway, with procurement of Xenon, PMTs and cryostat vessels started along with Prototype and assay programs

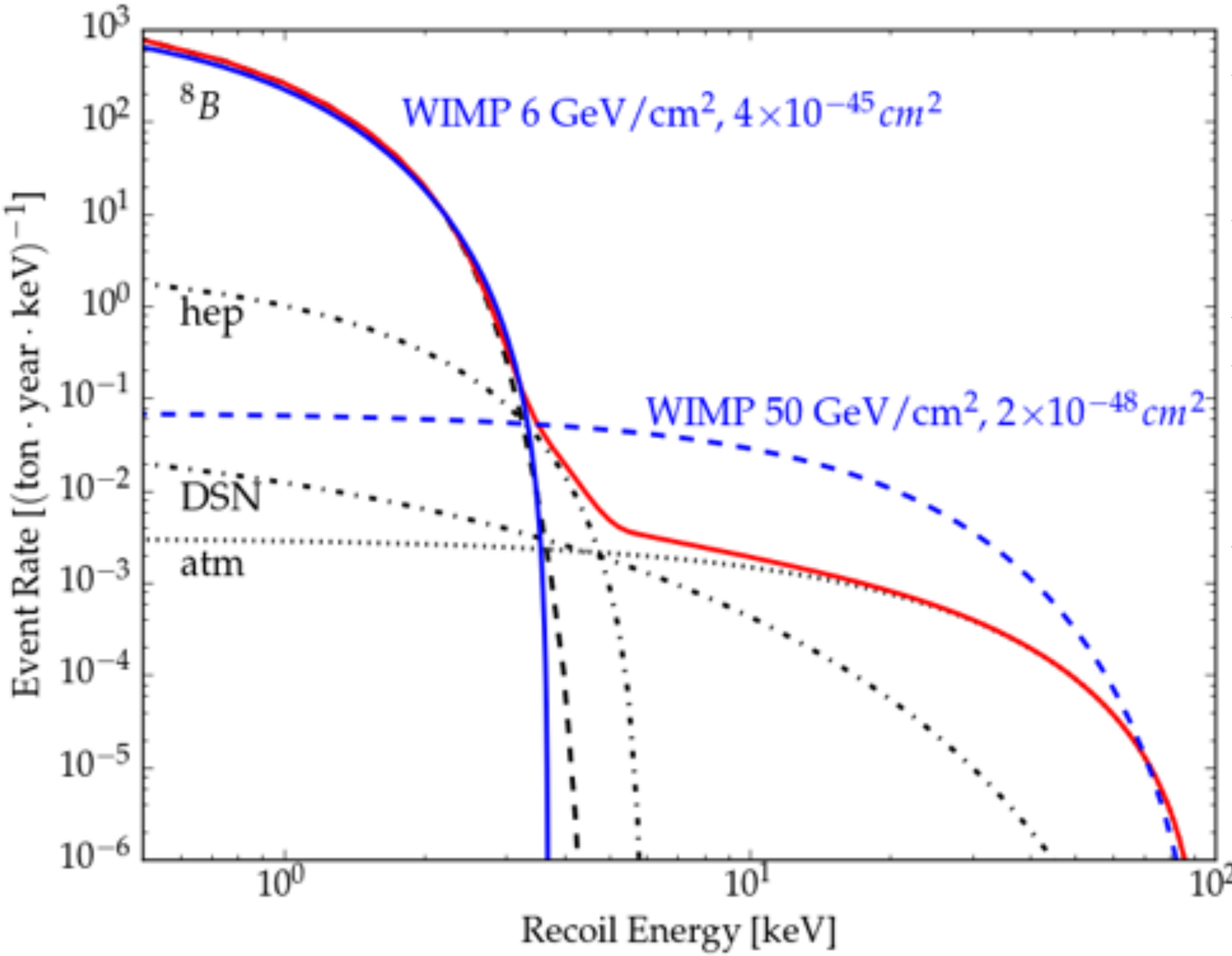
- LZ benefits from the excellent LUX calibration techniques and understanding of background

- LZ sensitivity expected to be probing the neutrino floor

Thanks!

Extra Slides

Coherent ν-nucleus Scattering

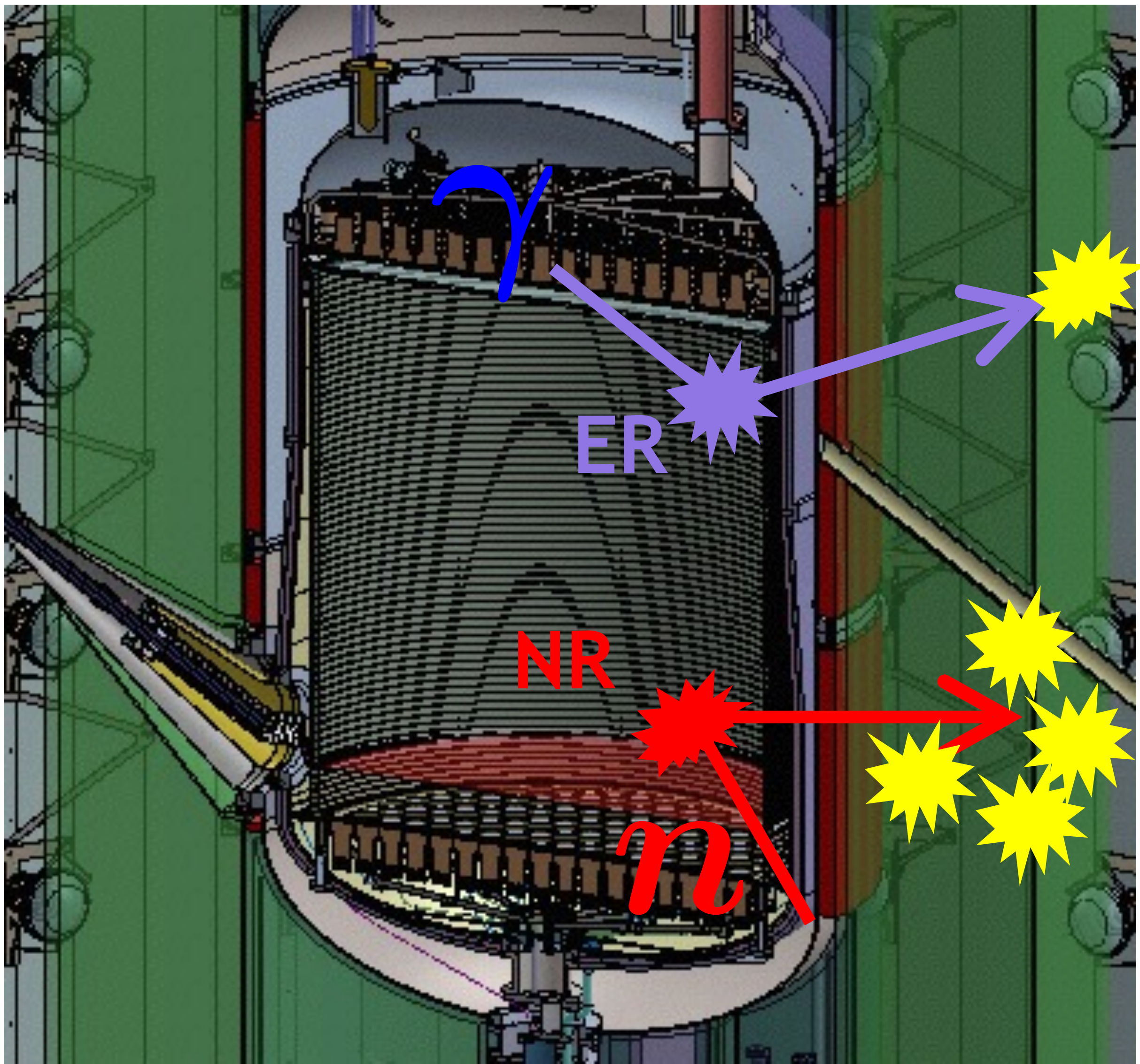


- LZ may be the first to observe coherent neutrino-nucleus scattering
- ^8B Recoils mimic low mass WIMPs
- WIMP Search 6-30 keV
- Expect ~10 CENNS ^8B events and 0.5 events from others

- DSN and atmospheric neutrinos will become the dominant background for experiments beyond LZ.

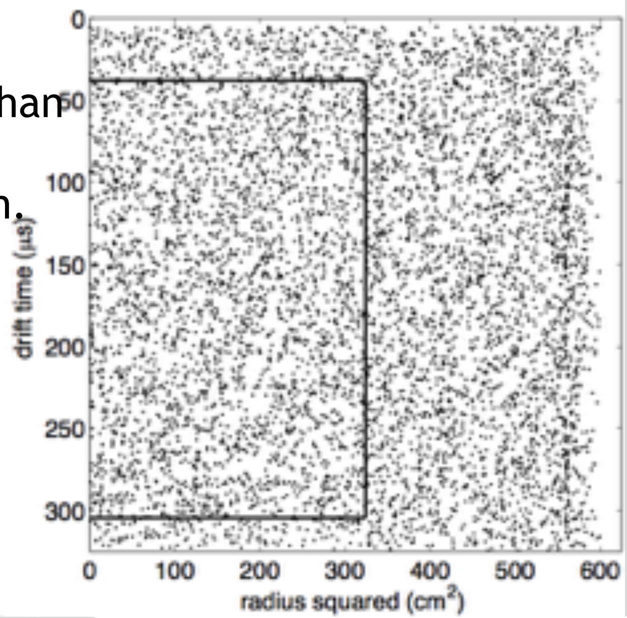
Backgrounds – External Material

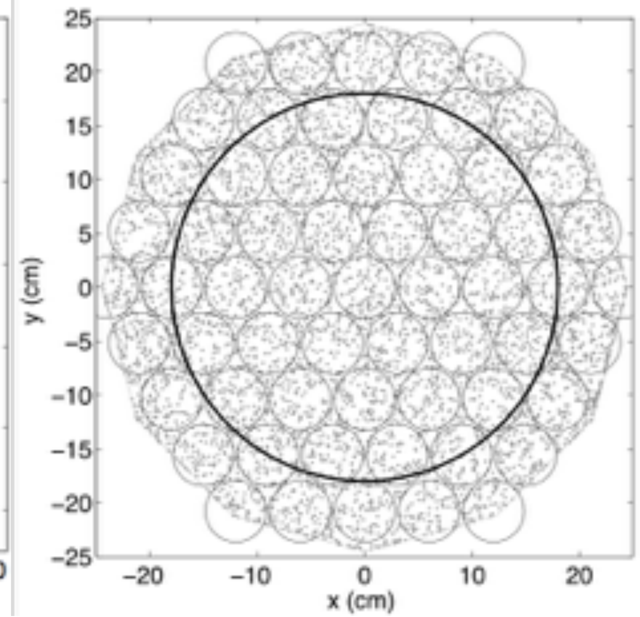
Populate Edges - Skin and Outer Detector Tag

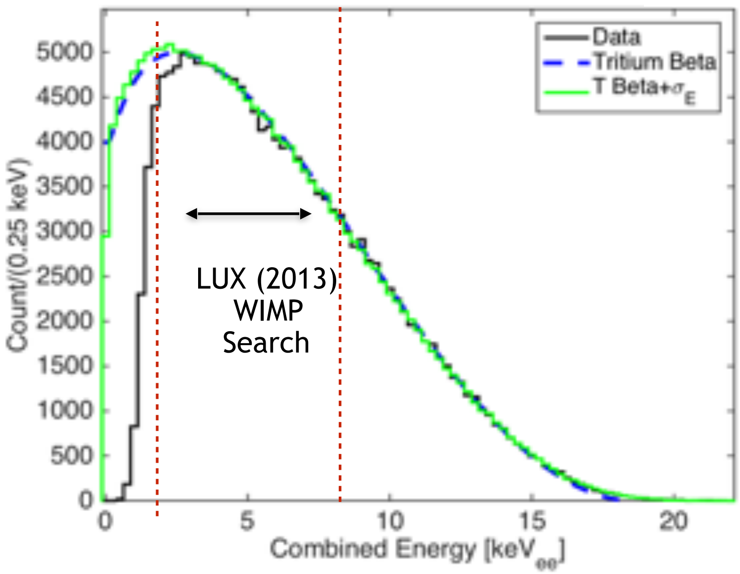


Tritiated-Methane, The Ideal ER Calibration Source

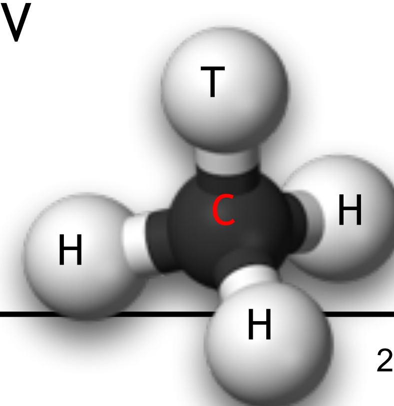
- Methane diffuses much slower than bare tritium.
- Dissolved uniformly in the xenon.
- Removed with standard purification technology.
- Used to calibrate the fiducial volume.



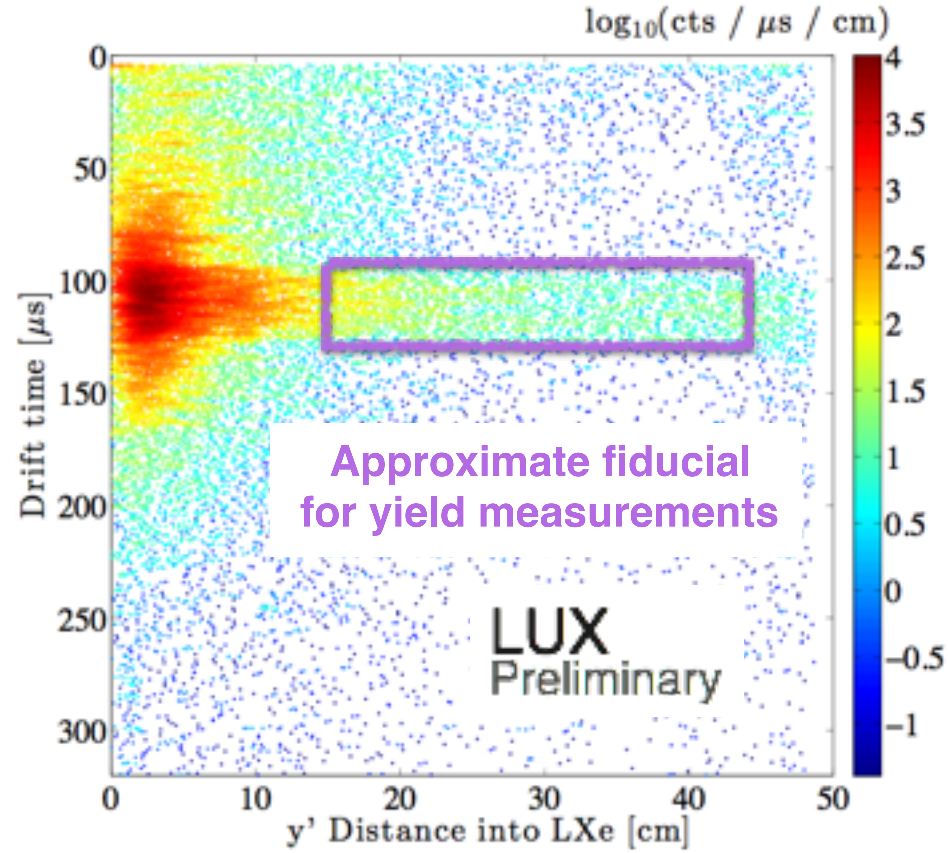




- Single Scatter ER events in energy region of interest: 0.1 keV to 18 keV
- Mean energy: 5 keV
- Peak energy: 2.5 keV



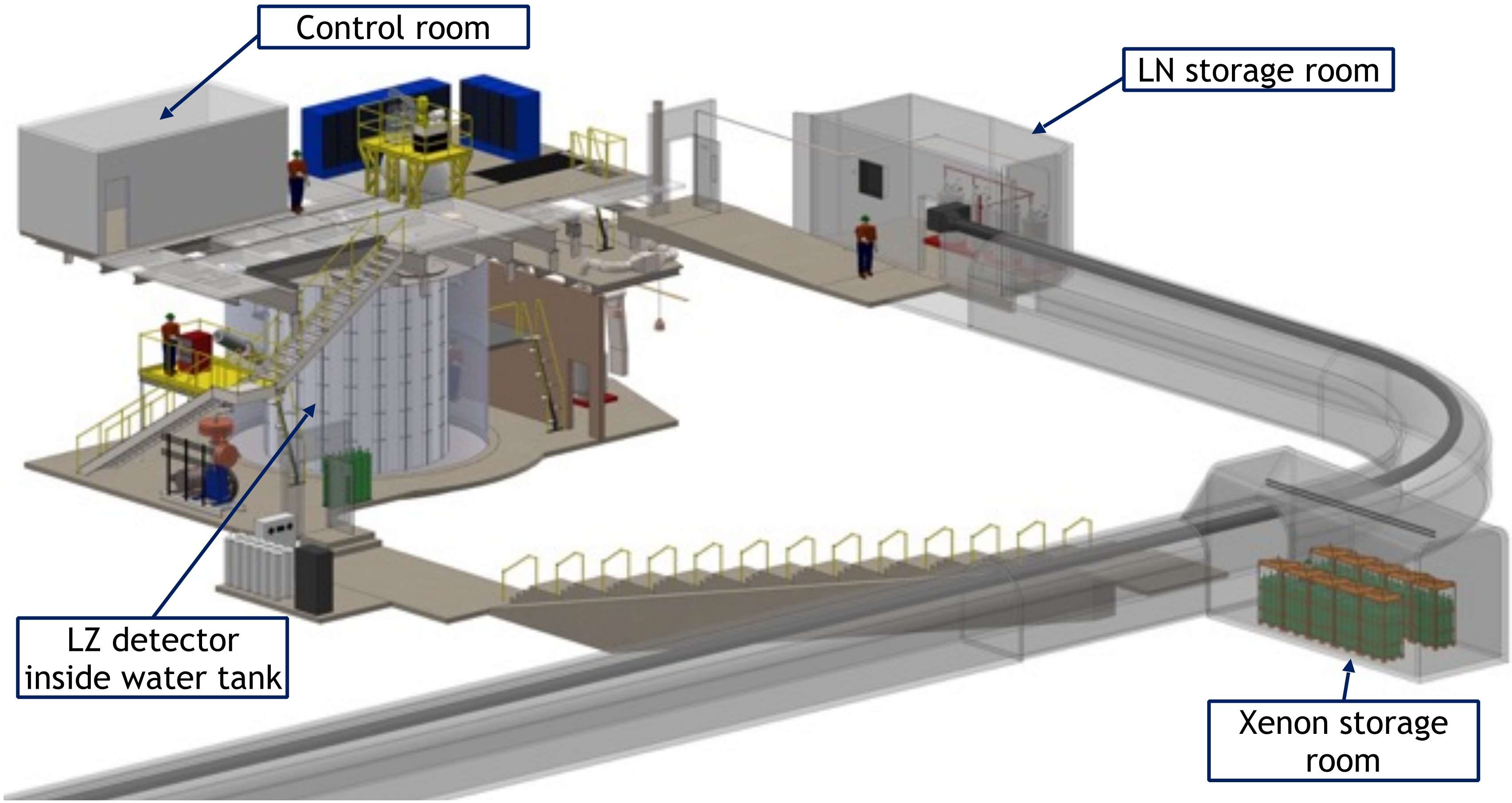
Adelphi DD108 Neutron Generator Installed Outside LUX Water Tank



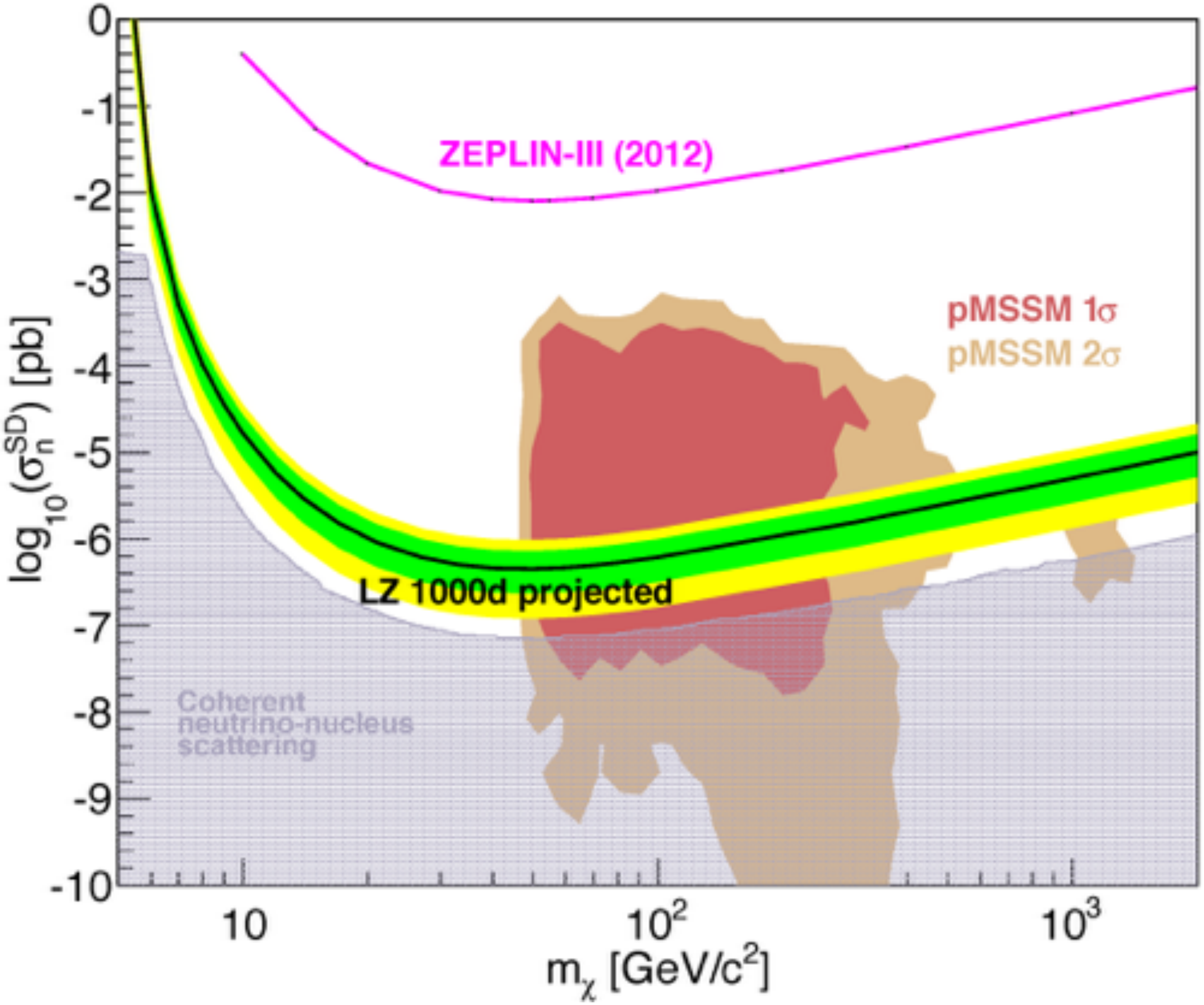
- This cut eliminates shine from passive materials and ensures 95% of neutrons in beam sample have energy within 4% of 2.45 MeV
- The mean energy of neutrons produced at 90° by the DD108 was measured to be 2.45 ± 0.05 MeV at Brown University

LZ Underground at SURF

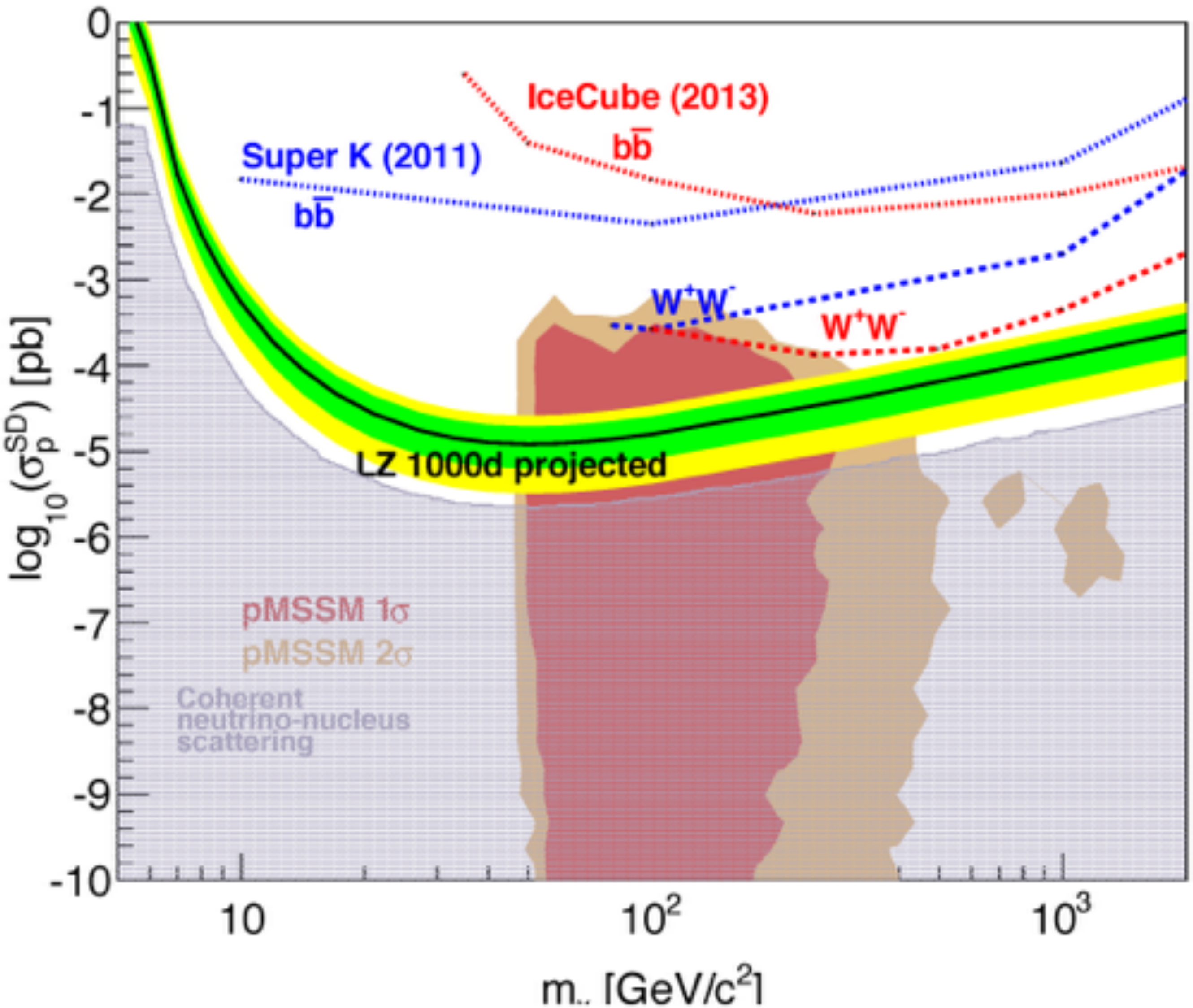
Years of experience at SURF from LUX



Spin Dependent Neutron



Spin Dependent Proton



Time Evolution