



The LUX-ZEPLIN Dark Matter Experiment

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LZ = LUX + ZEPLIN



LIP Coimbra (Portugal)

Center for Underground Physics (Korea)

MEPhI (Russia)

Edinburgh University (UK)

University of Liverpool (UK)

Imperial College London (UK)

University College London (UK)

University of Oxford (UK)

STFC Rutherford Appleton Laboratories (UK)

University of Sheffield (UK)

University of Alabama

University at Albany SUNY

Berkeley Lab (LBNL)

University of California, Berkeley

Brookhaven National Laboratory

Brown University

University of California, Davis

Fermi National Accelerator Laboratory

Lawrence Livermore National Laboratory

University of Maryland

University of Michigan

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

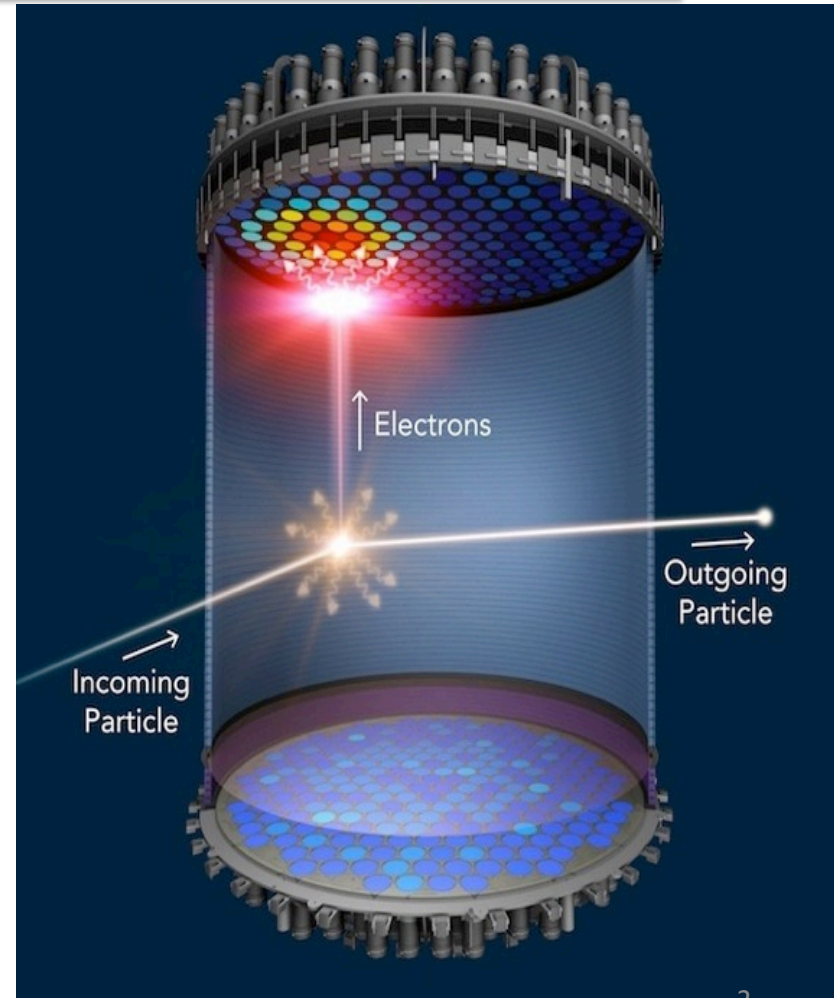
Washington University

University of Wisconsin



LZ: a Two-Phase Xenon TPC

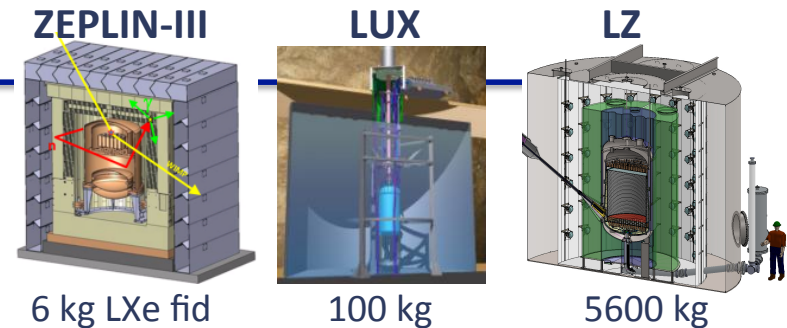
- High purity xenon target
- Electron-recoil backgrounds distinguished by ratio charge(S2)/light ratio(S1)
- 3D imaging (essential to reject background): Z position from S1 – S2 timing; X-Y positions from light pattern





ZEPLIN → LUX → LZ

LZ built on LUX & ZEPLIN programmes



- **Route to detection & study: a progressive programme**
 - ZEPLIN pioneered two-phase Xe for WIMP searches (3.9×10^{-8} pb/n)
 - LUX is present world leader in sensitivity (6×10^{-10} pb/n (0.6 zb) at 33 GeV/c² and ongoing)
 - **LZ expected sensitivity: $< 3 \times 10^{-12}$ pb/n @ 40 GeV/c² with 3-year run**
- **Experimental approach: a low risk but aggressive programme**
 - Internal background-free strategy
 - Two-phase Xe technology: high readiness level
 - Some infrastructure inherited from LUX



Scale up ≈ 50 in fiducial mass

LZ

Total mass – 10 T

WIMP Active Mass – 7 T

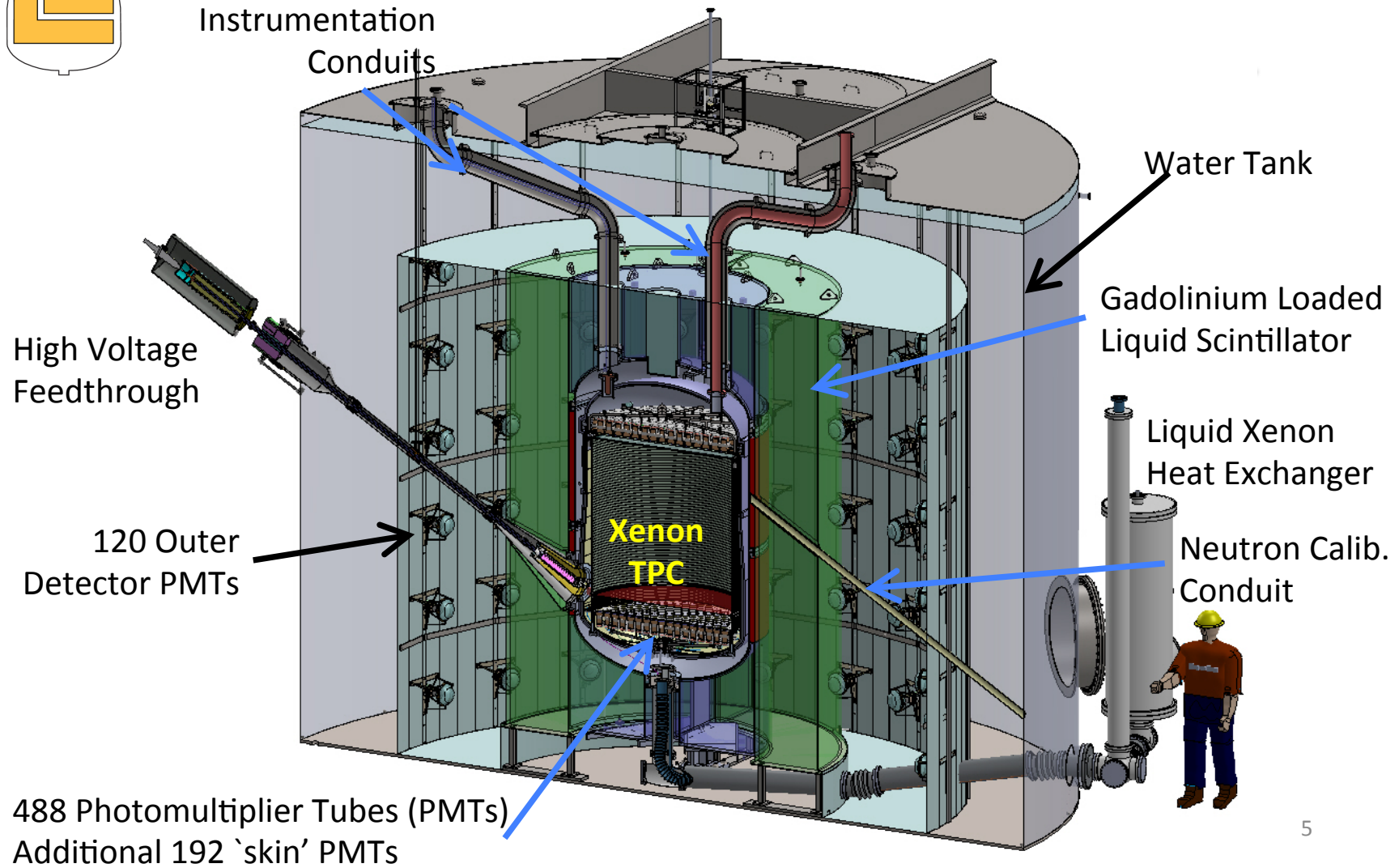
WIMP Fiducial Mass – 5.6 T



LUX

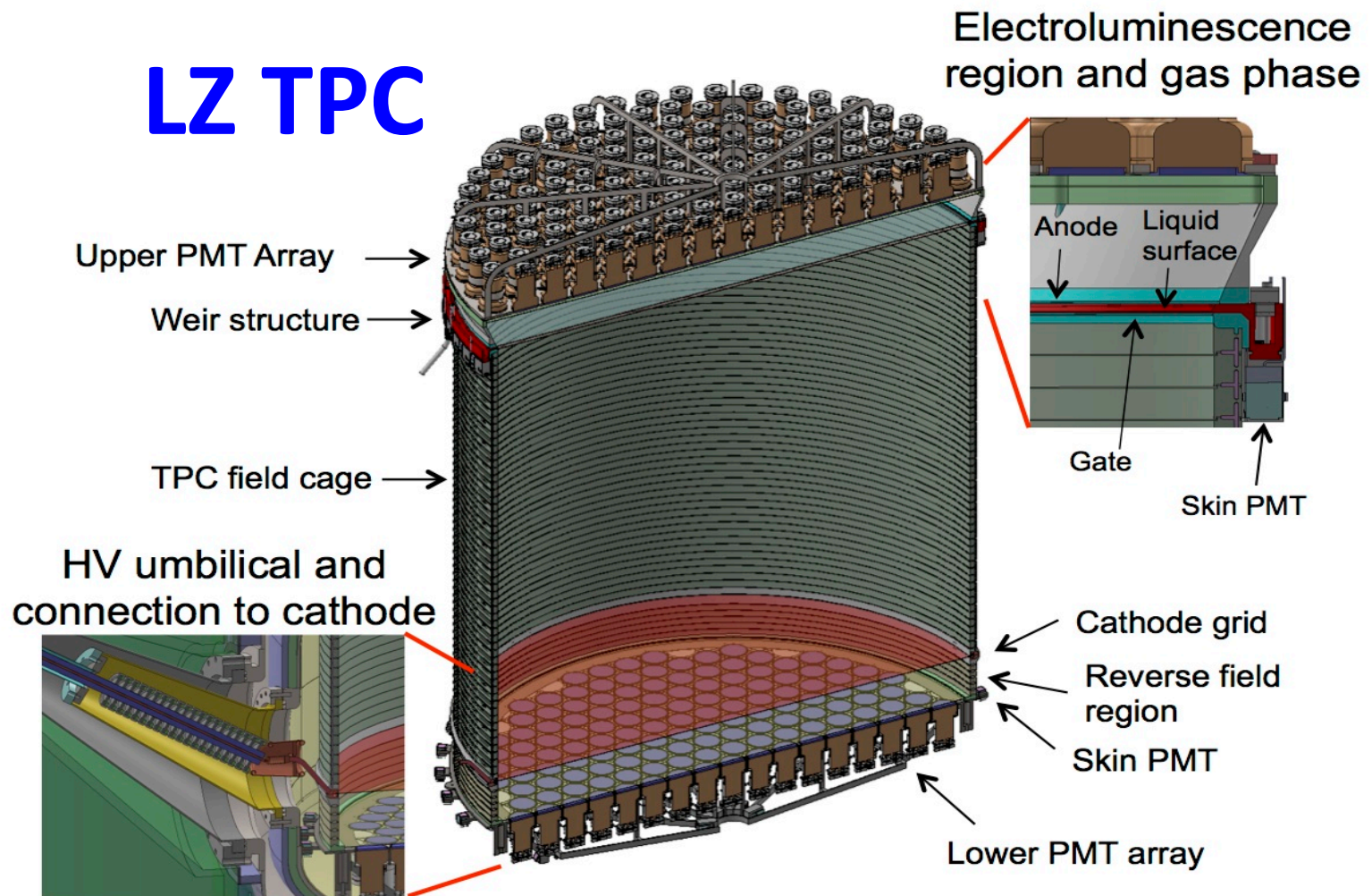


LZ Overview





LZ TPC



- 7 tonne active LXe mass; 1.5 m diameter/length
- 247 (top) and 241 (bottom) 3" ϕ PMTs (radioactivity \sim mBq; high QE)
- Highly reflective PTFE field cage ($R_{\text{PTFE}} \geq 95\%$)



Performance drivers

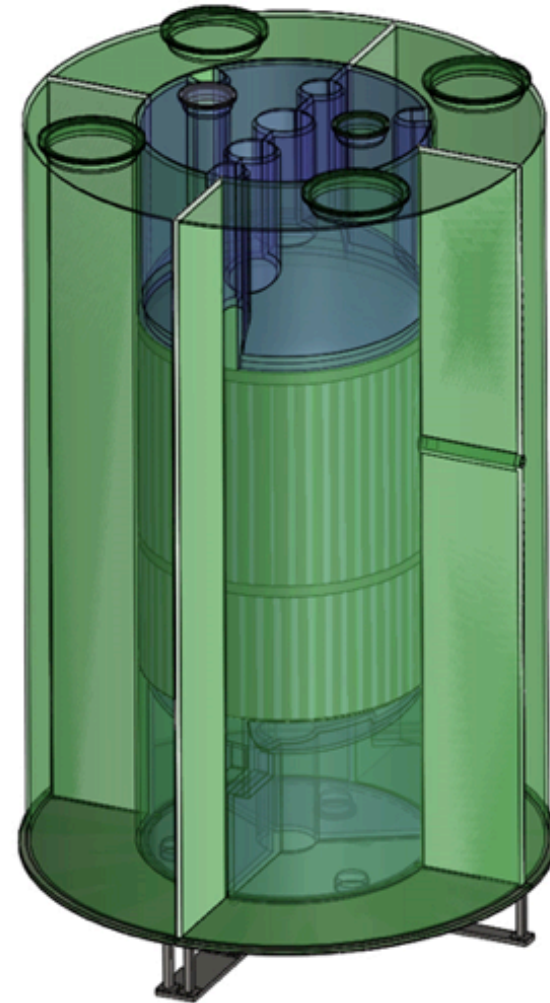
	Requirement / Baseline	Goal
Cathode HV	50 kV	100 kV
Light collection	7.5%	12%
e ⁻ lifetime (μs)	850	2800
N-fold trigger coincidence	3	2
²²² Rn	20 mBq	1 mBq

- 5.8 keVr S1 threshold (4.5 keVr LUX)
- 0.7 kV/cm drift field, 99.5% ER/NR disc. (already surpassed in LUX at 0.2 kV/cm)



Outer Detector

- Essential to utilize most Xe, maximize fiducial volume
- Segmented tanks (installation constraints)
- Gd-loaded liquid scintillator, LAB; 60 cm; 21.5 tons
- 97% efficiency for neutrons





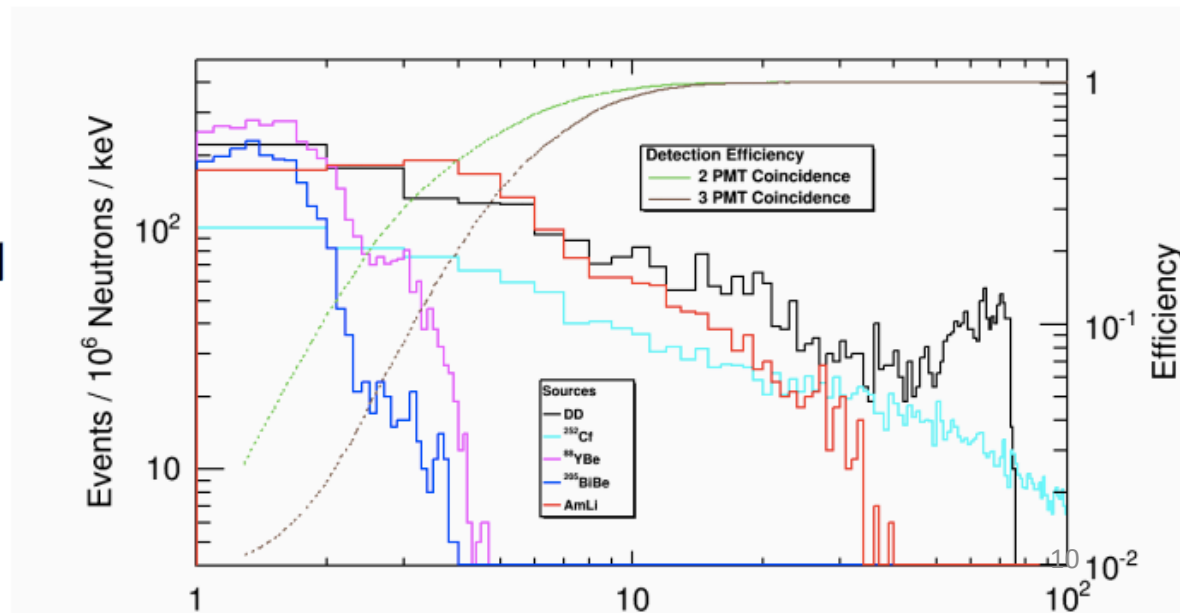
Detector Prototyping

- ✦ Extensive program of prototype development underway
- ✦ Approach:
 - Testing in liquid argon, primarily of HV elements at LBNL
 - Design choice and validation in small (few kg) LXe test chambers in many locations: LLNL, UC Berkeley, LBNL, U Michigan, UC Davis, Imperial College, MEPhI, LIP
 - System test platform at SLAC, Phase I about 100 kg of LXe, TPC prototype testing ongoing



Calibrations

- Expand upon successful LUX program
- Spatial response, temporal variation
 - ^{83m}Kr , ^{131m}Xe
- Outer LXe and Gd-scintillator
 - ^{220}Rn , movable gamma ray sources
- Electron and Nuclear recoils
 - Tritium
 - Variety of high and low energy neutron sources





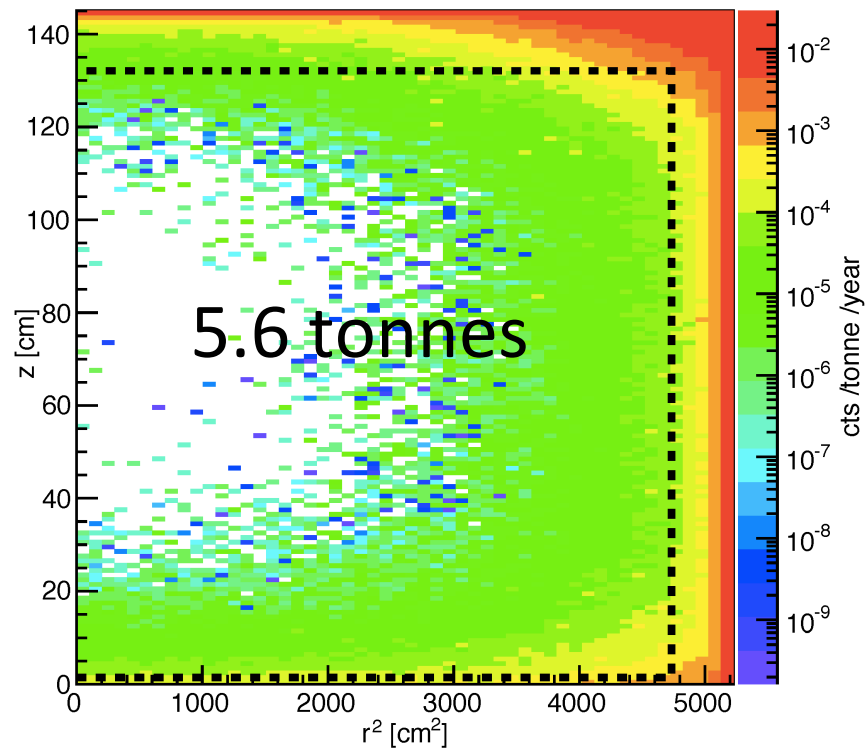
Background Reduction: key design points

- Photomultipliers of ultra-low natural radioactivity
- Low background titanium cryostack
- Instrumented “skin” region of peripheral xenon as another veto system
- LUX water shield and an added liquid scintillator active veto
- Radon suppression during construction, assembly and operations
- Unprecedented levels of Kr removal from Xe

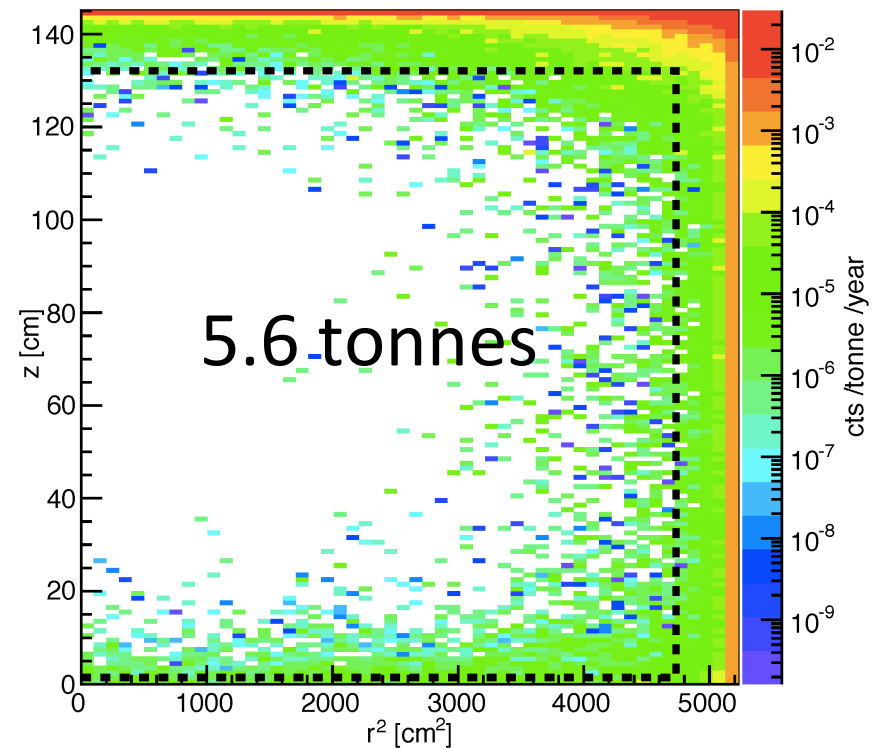


Background

Single NR scatter in TPC



Vetoed by Gd-LS and Skin



NR background plus ER leakage from sources external to the LXe (6 - 30 keVnr acceptance; 50% NR acceptance and 99.5% ER discrimination);

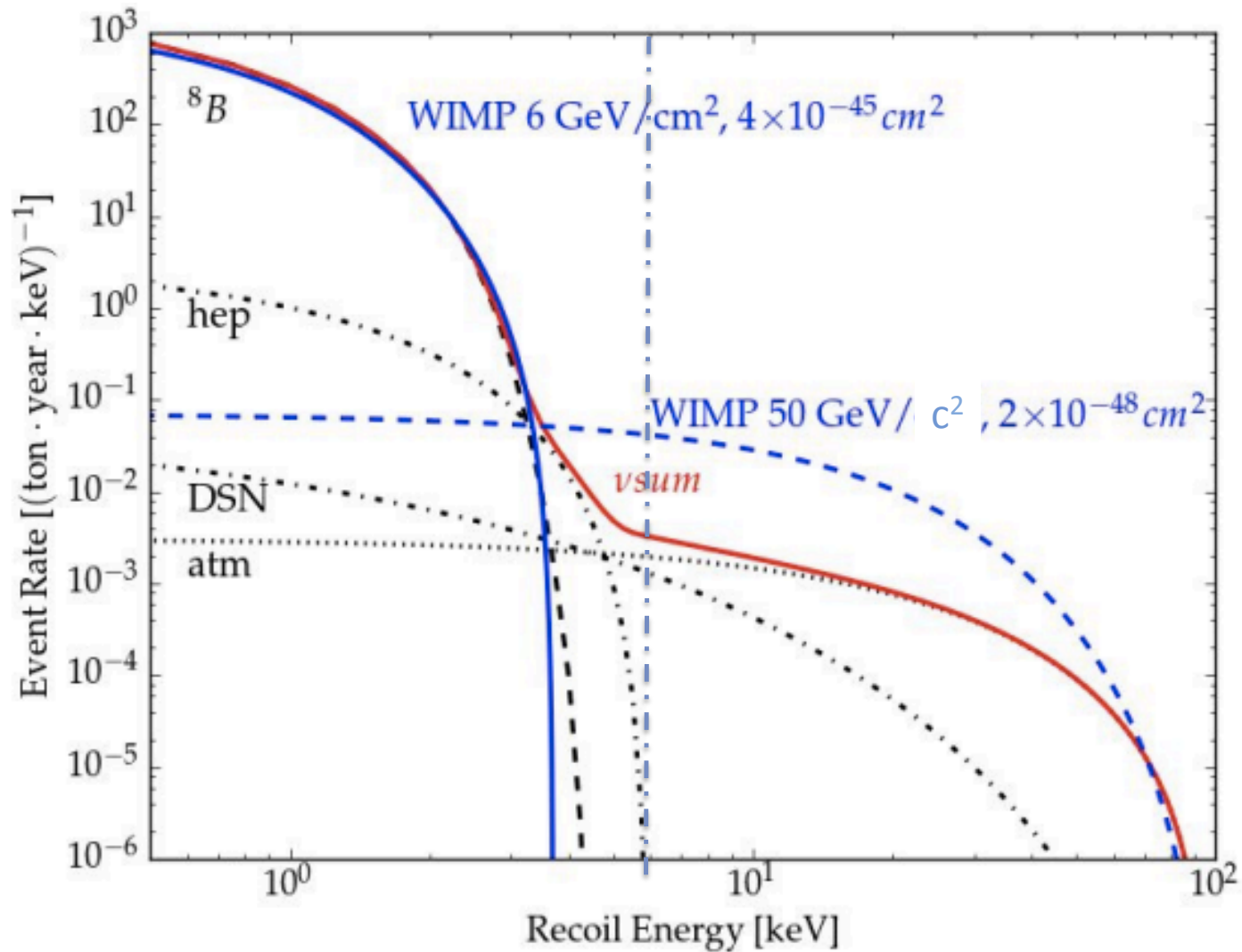


Expected backgrounds for 5.6 T fiducial - 1,000 days

Item	Mass (kg)	U (mBq/kg)	Th (mBq/kg)	Co-60 (mBq/kg)	K-40 (mBq/kg)	n/yr	ER (cts)	NR (cts)
R11410 PMTs	90.8	71.6	3.2	2.8	15.4	80.8	1.84	0.012
R11410 bases	2.6	546	31.7	2.3	82.6	44.3	0.37	0.004
Cryostat Vessels	2406	1.6	0.3	0.1	0.6	123.7	0.55	0.011
Other components							7.16	0.045
Total components							9.92	0.072
Dispersed radionuclides (Rn, Kr, Ar)							870	
Laboratory and cosmogenics							33	0.12
Surface contamination							0.2	0.37
Xe-136 $2\nu\beta\beta$							67	
Neutrinos (ν-e, ν-A)							255	0.72
Total events							1230	1.28
WIMP backgr events (99.5% ER discrimination, 50% NR acceptance)							6.17	0.64
Total ER+NR background events							6.81	



Neutrino NR contribution





Rn emanation

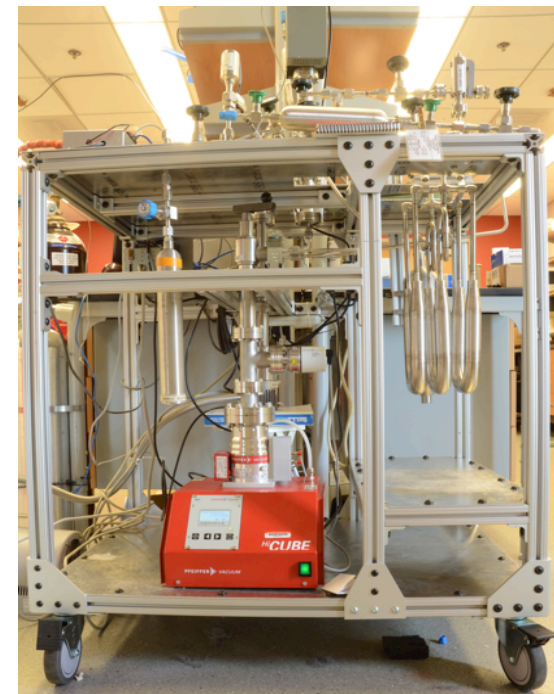
- Rn (and Kr) – dominante internal radioactive background
- Emanates from most materials
- 20 mBq requirement, 1 mBq goal
- Four separate measurement systems, ~0.1 mBq sensitivity
- Main assembly laboratory at SURF will have reduced radon air system





^{85}Kr removal

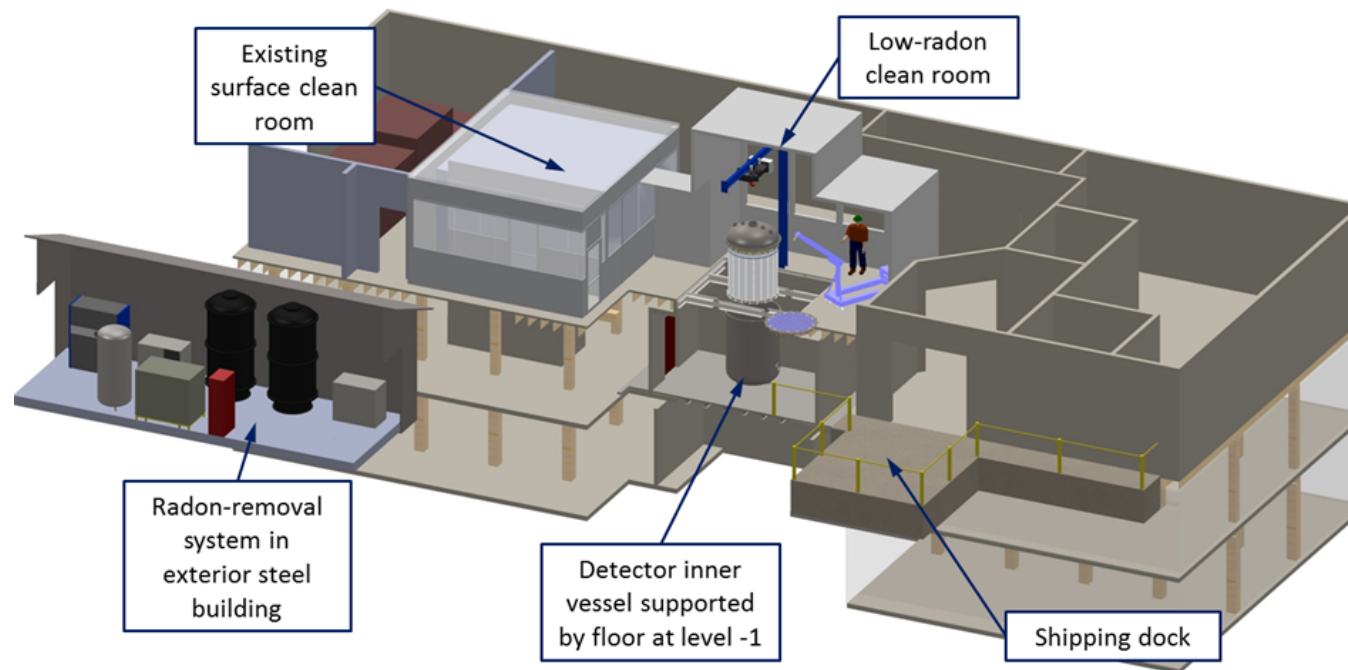
- Remove Kr to <15 ppq (10^{-15} g/g) using gas chromatography (best LUX batch 200 ppq)
- Setting up to process 200 kg/day at SLAC
- Have a sampling program to instantly assay the removal at SLAC and continuously assay in situ





LZ Underground at SURF

- Years of experience at SURF from LUX
- Dedicated onsite infrastructure improvements for LZ. Design started, construction planned.





LZ Timeline

Year	Month/Q	Activity
2012	March	LZ (LUX-ZEPLIN) collaboration formed
2014	July	LZ Project selected in US and UK
2015	April	DOE CD-1/3a approval, similar in UK Conceptual Design Report arXiv:1509.02910
2016	April	DOE CD-2/3b review passed
2017	Q2	Begin preparations for surface assembly @ SURF
2019	Q1	Begin underground installation
2020	Q4	Commissioning start

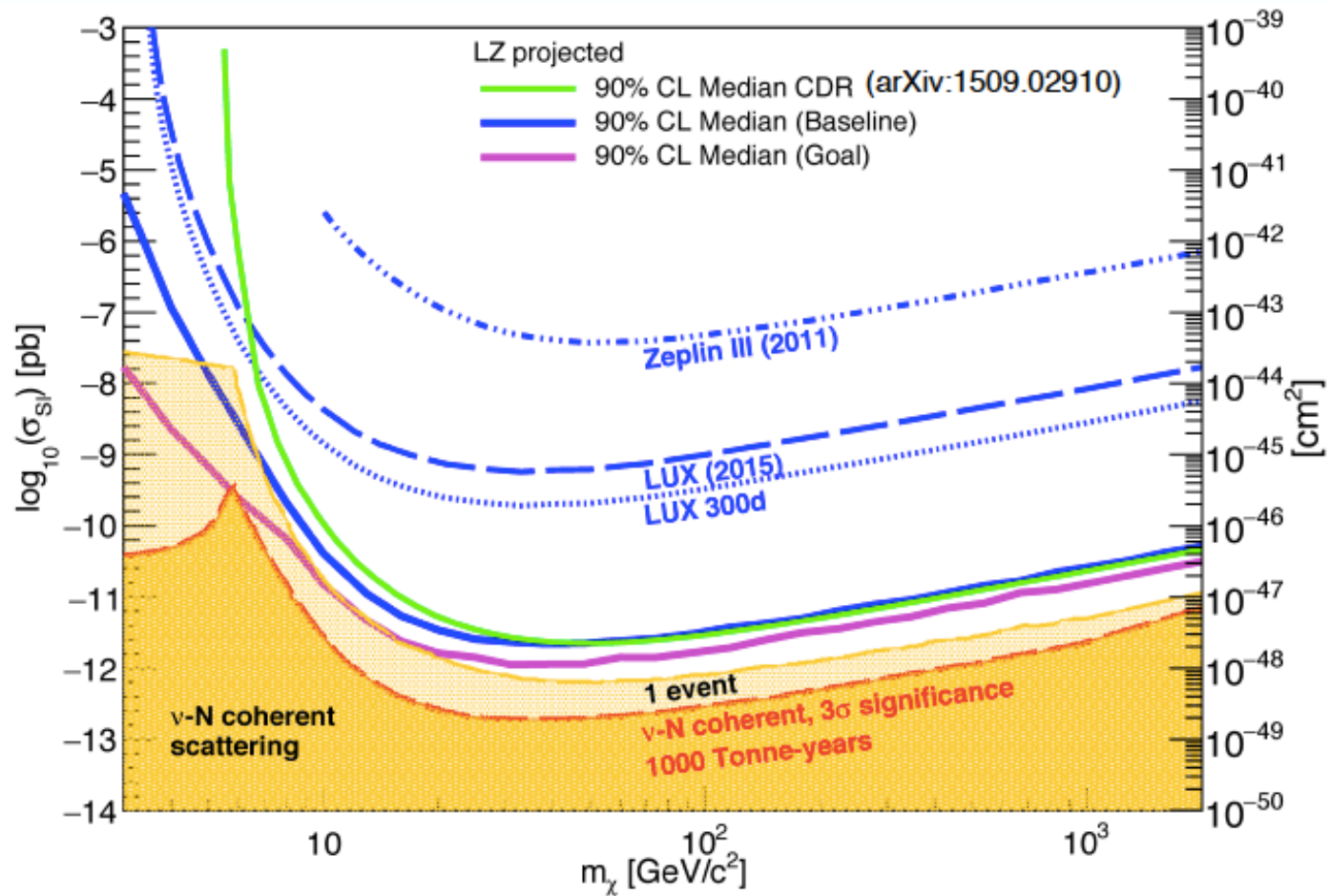


Projected Sensitivity – Spin Independent

(LZ 5.6 Tonnes, 1000 live days)

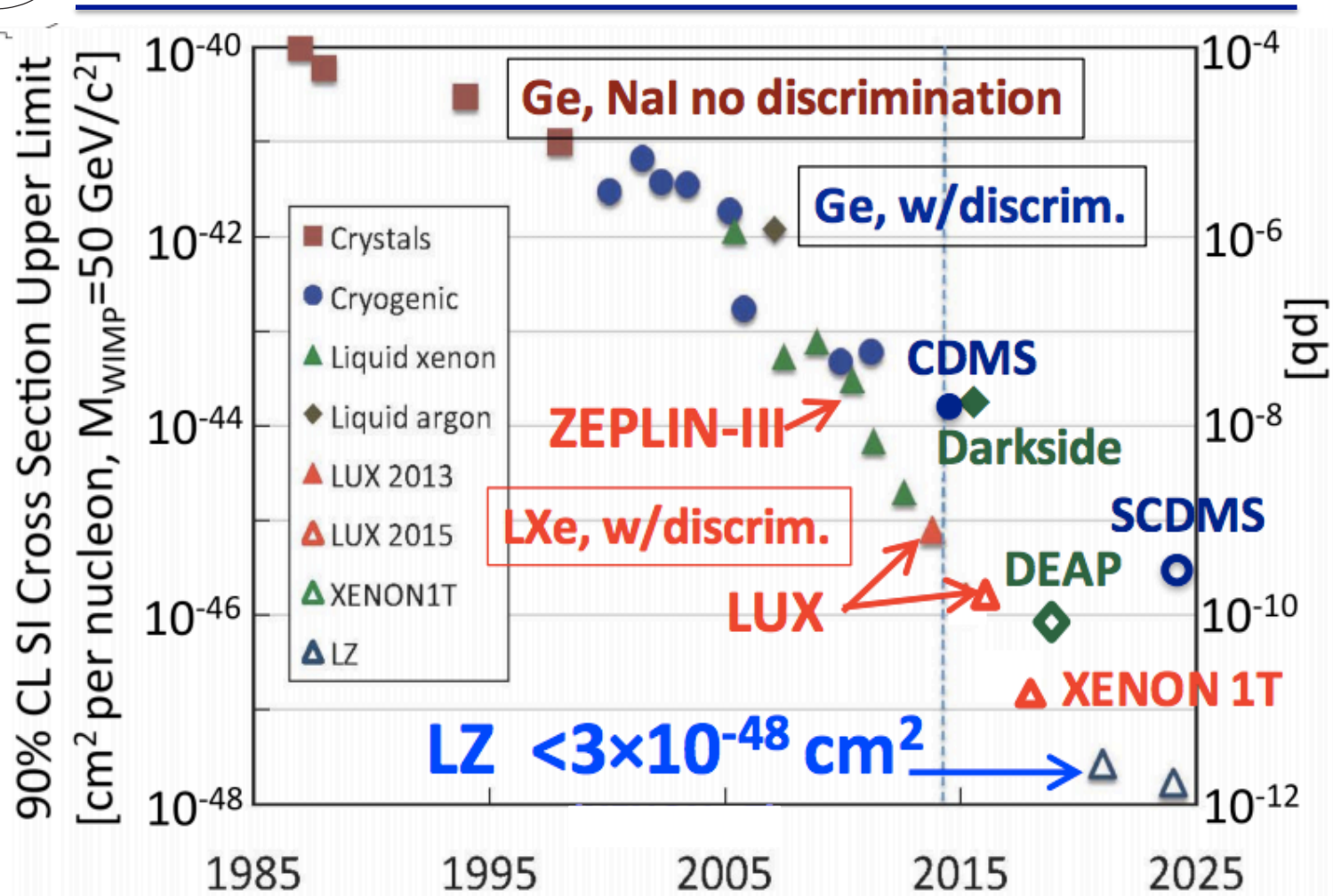
Baseline
 $\sigma_{SI} = 2.2 \times 10^{-48} \text{ cm}^2$
 B-8 = 7
 ATM $v = 0.4$

Goal
 $\sigma_{SI} = 1.2 \times 10^{-48} \text{ cm}^2$
 B-8 = 220
 ATM $v = 3$





Time Evolution





Summary

- LXe is a pre-eminent target for high mass WIMP search
- Two-phase Xe detector technology is very mature and reliable
- LZ leverages LUX innovations in calibrations, cryogenics and ^{85}Kr removal
- High fiducial volume fraction ($\sim 80\%$) due to outer detector and low background from internal materials
- Robust prototyping and test program to optimize detector performance
- Material screening programme well underway
- Limit $< 3 \times 10^{-48} \text{ cm}^2 @ 40 \text{ GeV}/c^2$ in 1000 live-days

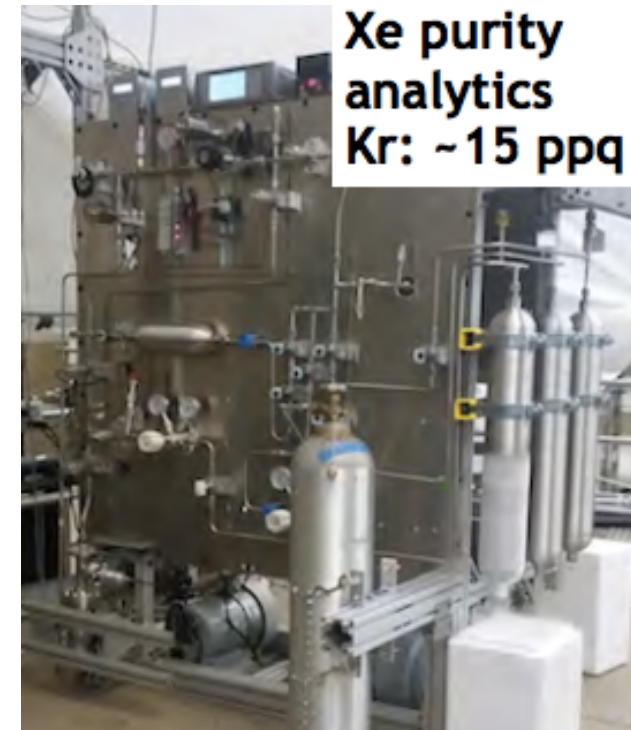


Extra Slides



Xe purification and cryogenics

- Gas phase purification through getter- 10 tons/2.5 days
- Trap-enhanced mass spec; sensitivity ~ppt
- High efficiency two-phase heat exchange
- LN thermosyphon-based cryogenics – multiple cooling locations.

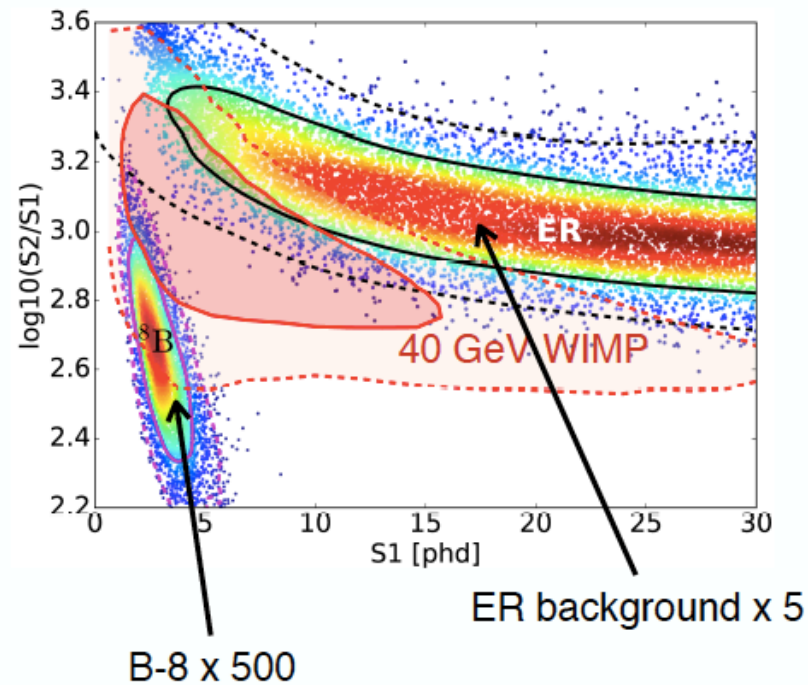




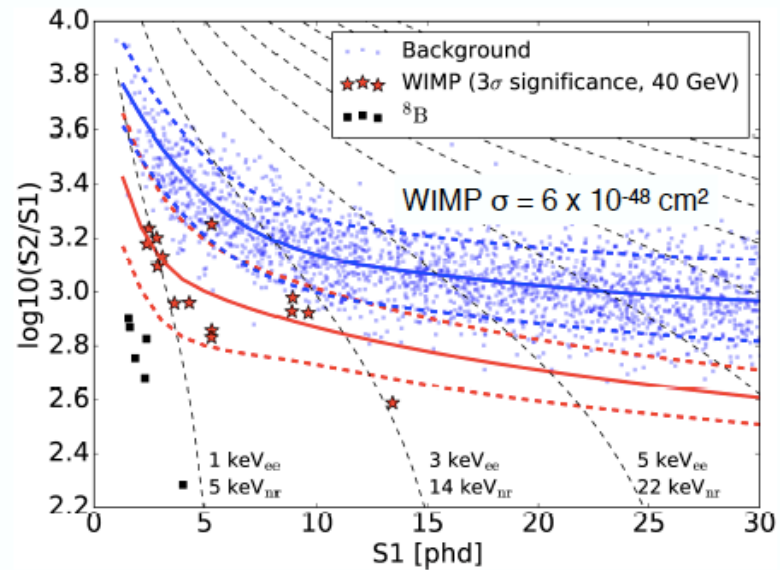
Signal and background

Advanced analysis procedure PDFs for PLR

Signal and background models distributions

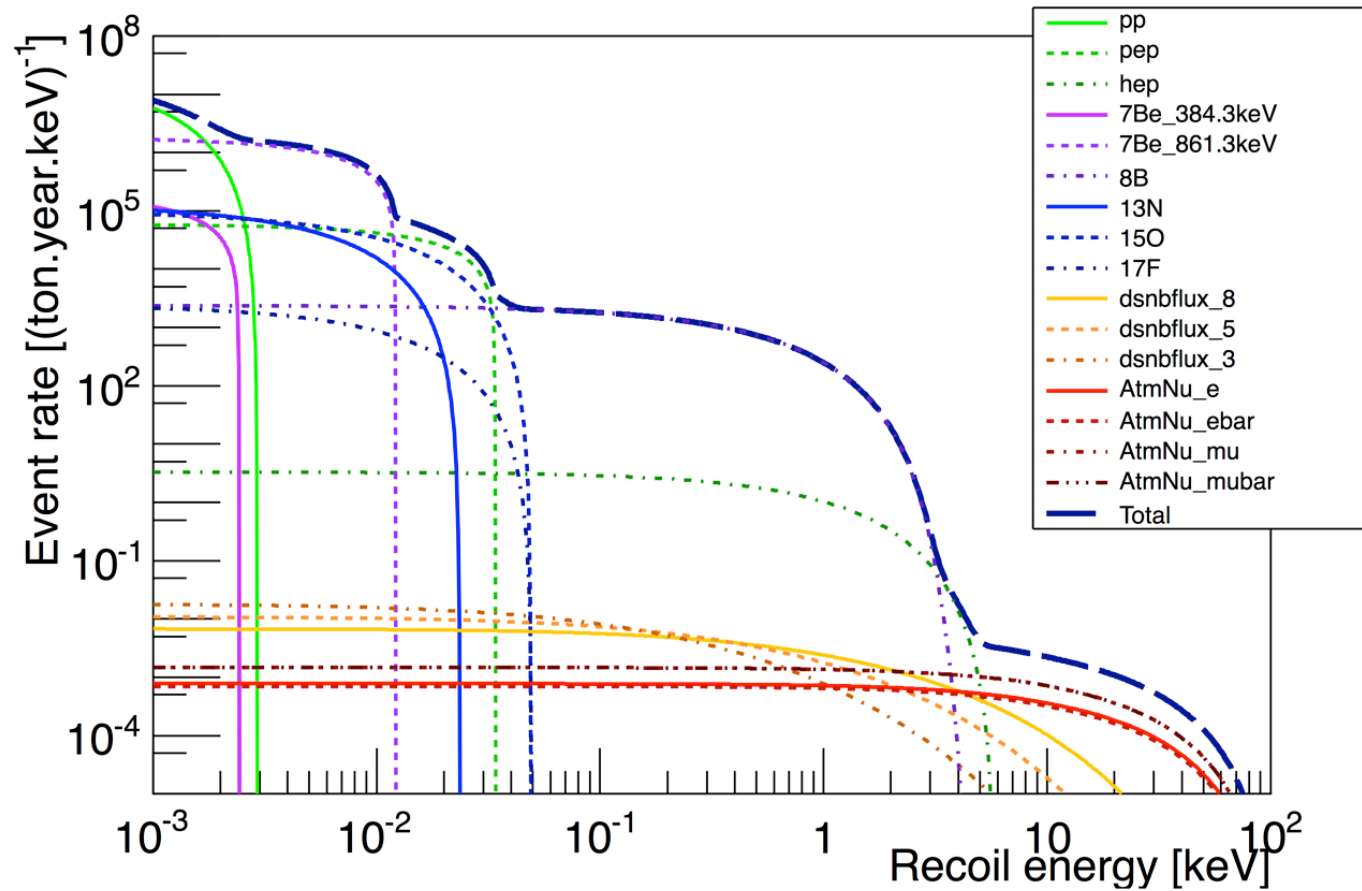


Simulated LZ experiment (1000 days, 5.6 tonnes fiducial)





Backgrounds: neutrino contribution

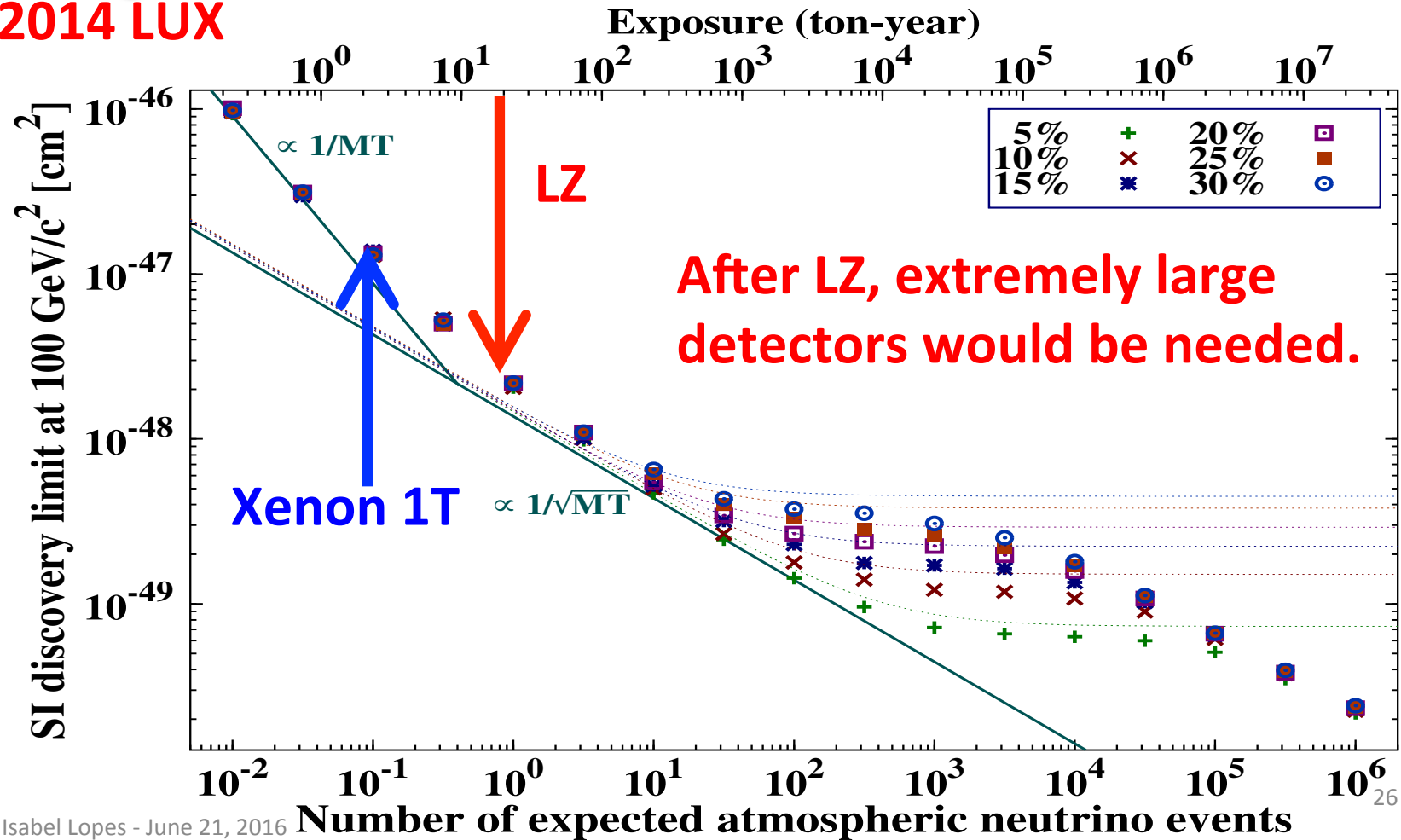




LZ – At the neutrino ‘knee’

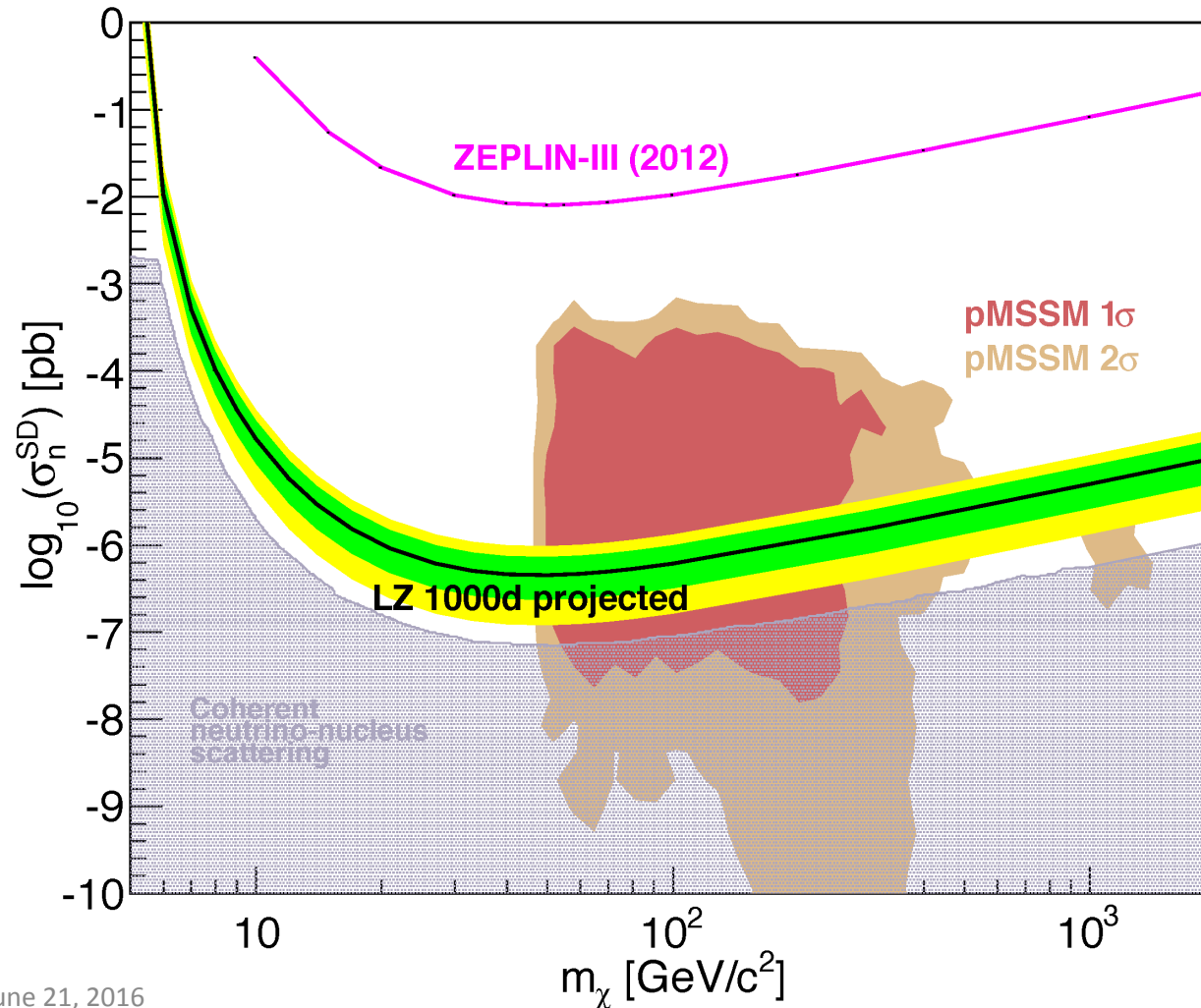
arXiv:1408.3581

2014 LUX





Spin Dependent Neutron





Spin Dependent Proton

