Status of LZ Experiment

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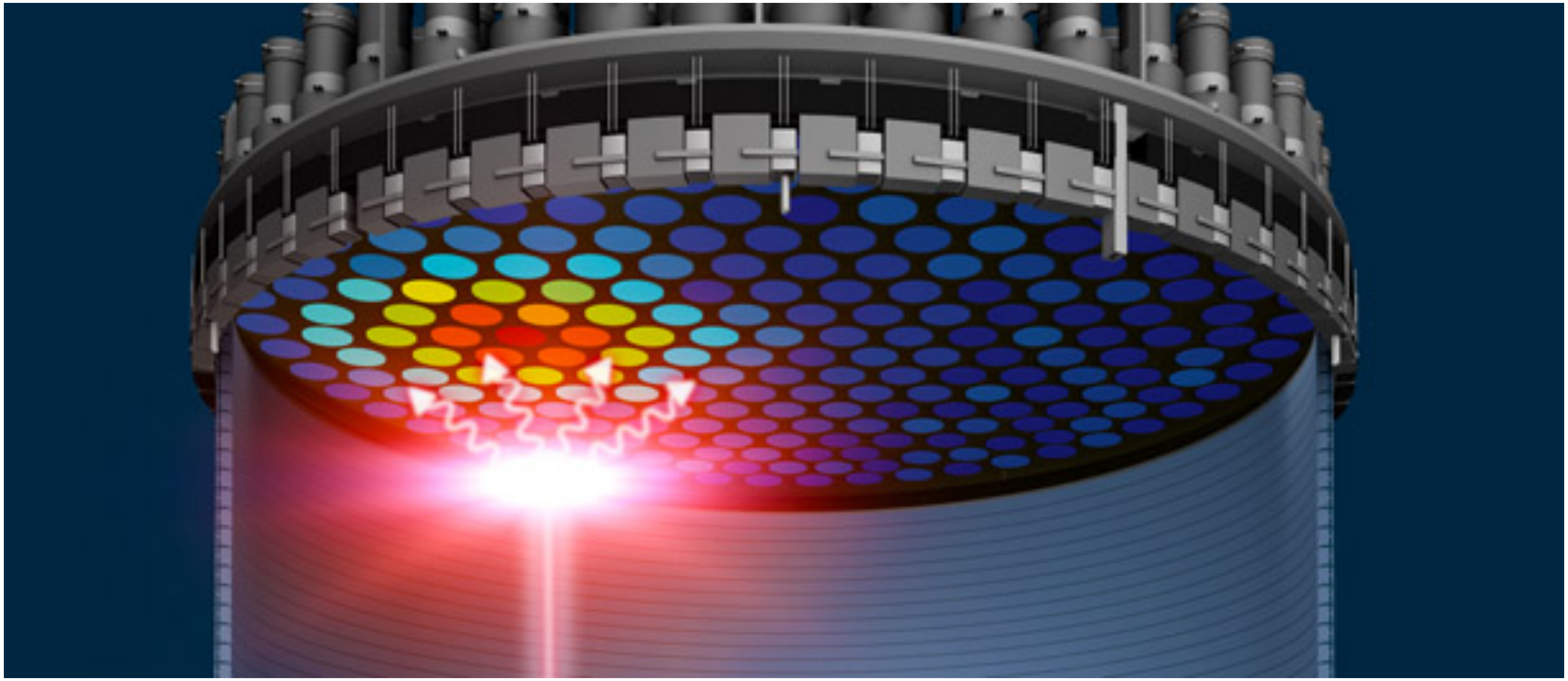
For the LZ Collaboration



Thanks to Jim Dobson (Imperial) & Kim Palladino (Wisconsin)

The LZ collaboration

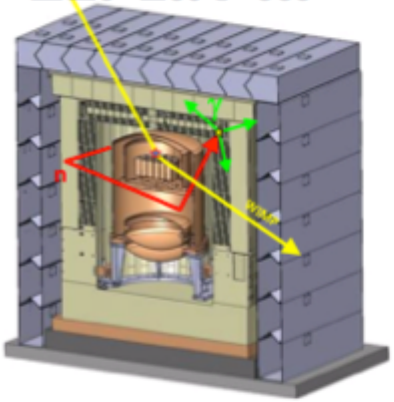
LIP Coimbra (Portugal)
Center for Underground Physics (Korea)
MEPhI (Russia)
Edinburgh University (UK)
University of Liverpool (UK)
Imperial College London (UK)
University College London (UK)
University of Oxford (UK)
STFC Rutherford Appleton Laboratories (UK)
University of Sheffield (UK)

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 = LUX+ZEPLIN

ZEPLIN pioneered WIMP-search with 2-phase Xe
3.9 ×10^3 pb/n

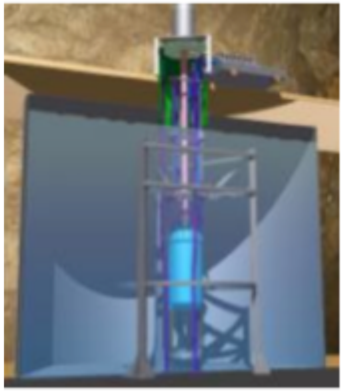
ZEPLIN-III



6 kg LXe fid

\+

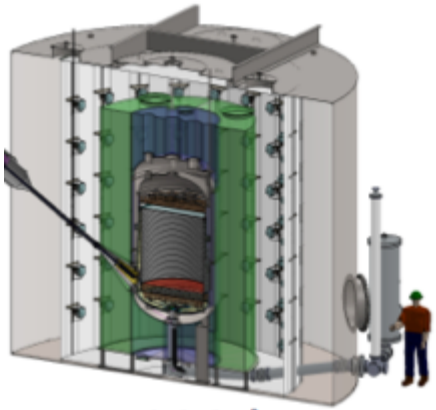
LUX



100 kg

Current world leader:
~6×10^{-10} pb/n
and counting

LZ



5600 kg

→

Total Mass: 10 T
WIMP Active Mass: 7 T
WIMP Fiducial Mass: 5.6 T

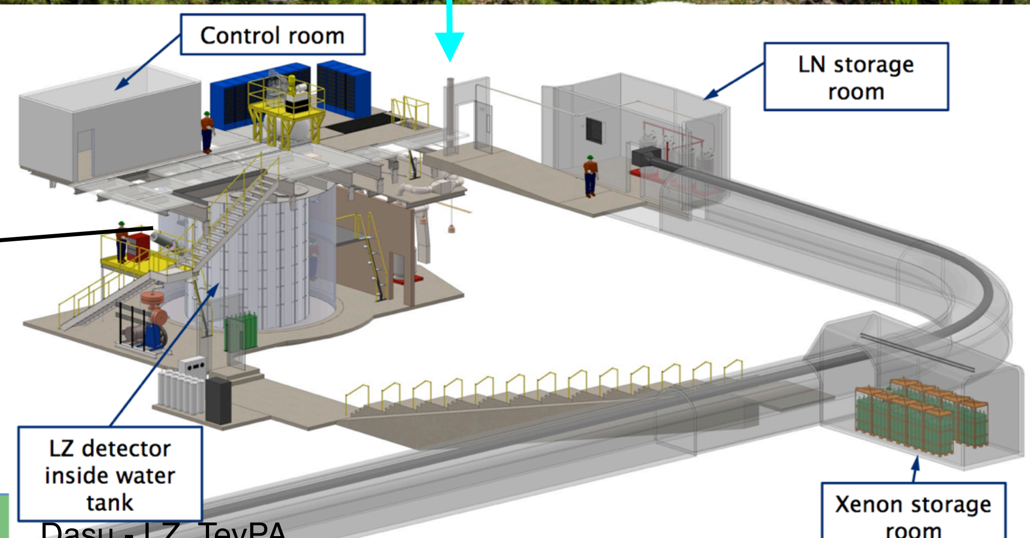
Scale-up 40X
- demonstrated technology and experience

Low-risk
- but aggressive program

Key: Maintain low backgrounds
- and low energy thresholds

Sanford Underground Research Facility (SURF) South Dakota, USA

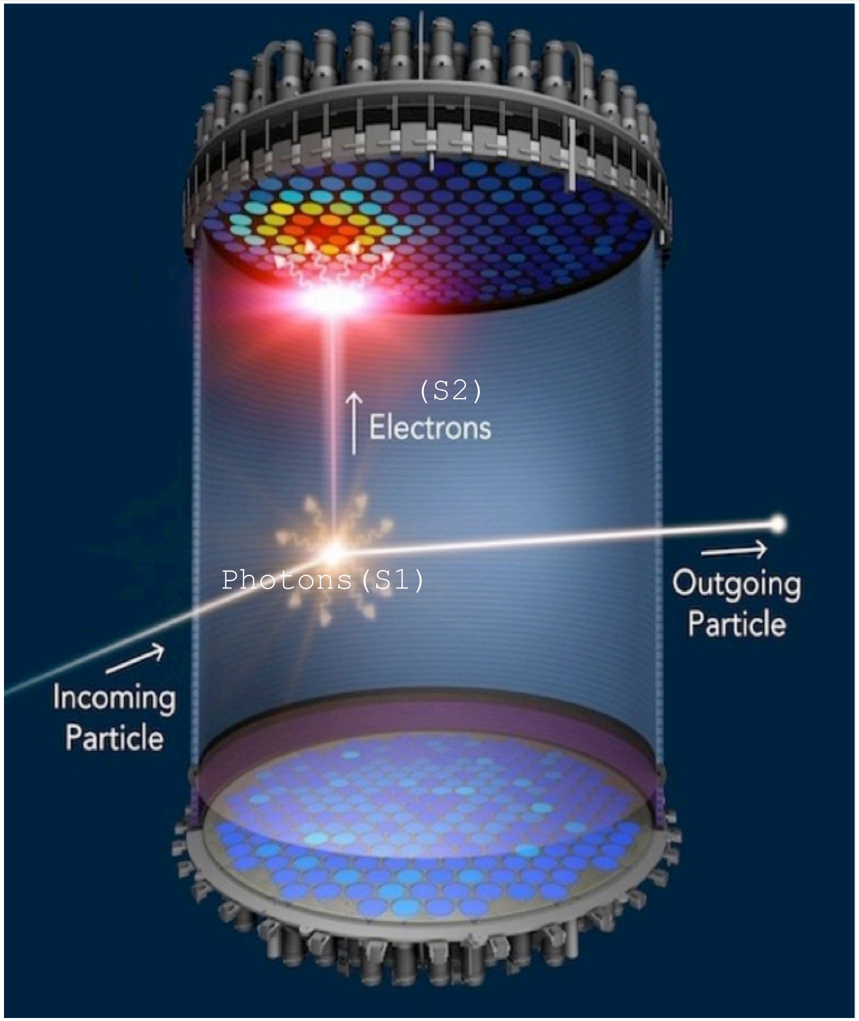
LUX removed
by early 2017
Water tank kept



LXe-TPC: principle of operation

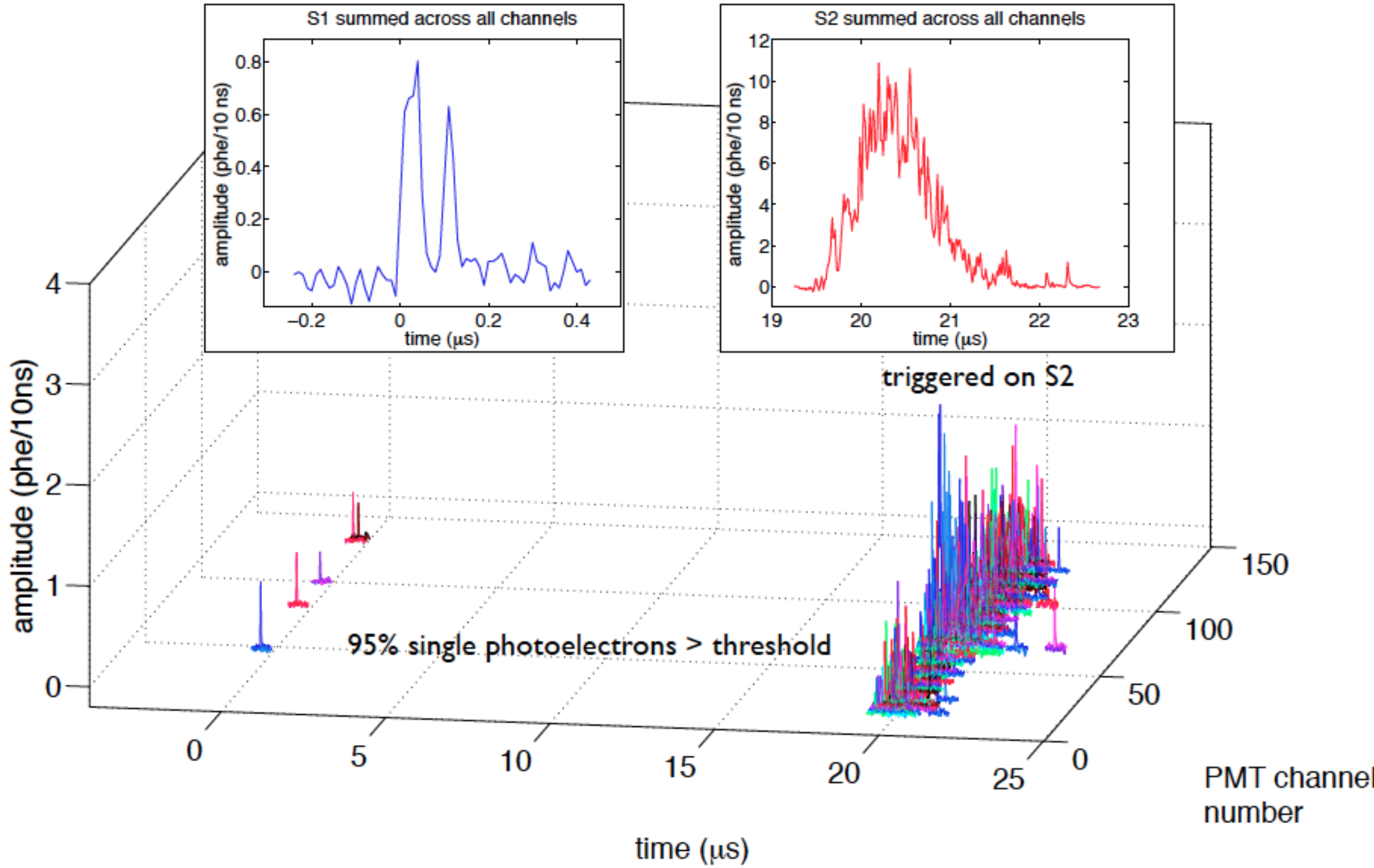
Marc Schuman Plenary for Details

- High purity liquid xenon target
- Single-photon & electron sensitivity
- Ratio S1(light) + S2(charge) → Electron Recoil (ER) to Nuclear Recoil (NR) discrimination
- Delta-t between S1/S2 and S2-light pattern give 3D position → fiducialization and multi-scatter rejection



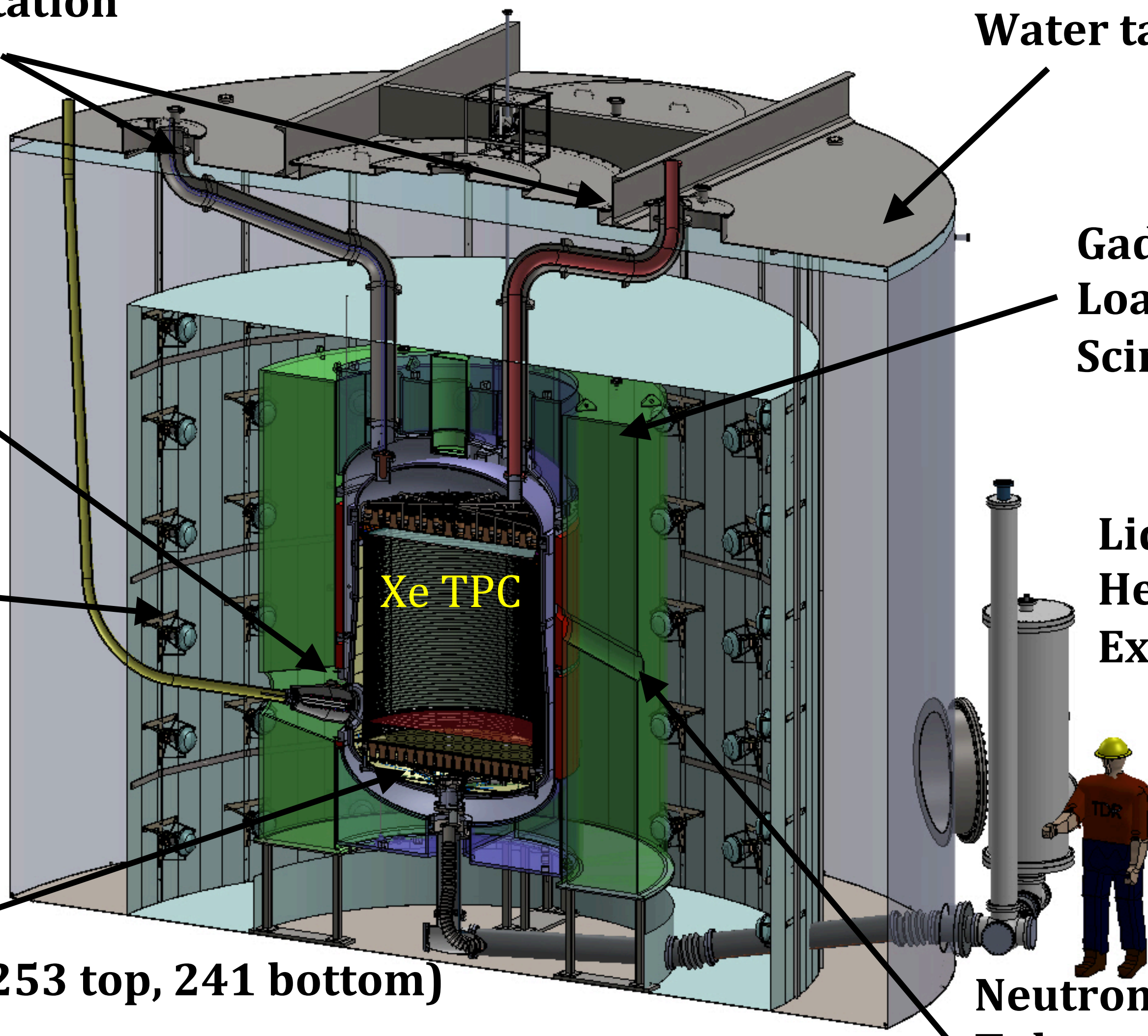
Key challenges: large mass, low-background, low-threshold

Example: 1.5 keV electron in LUX



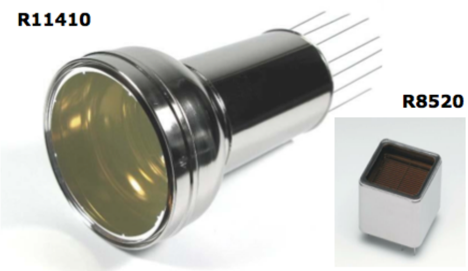
5-fold coincidence S1 + much larger S2 20 µs later

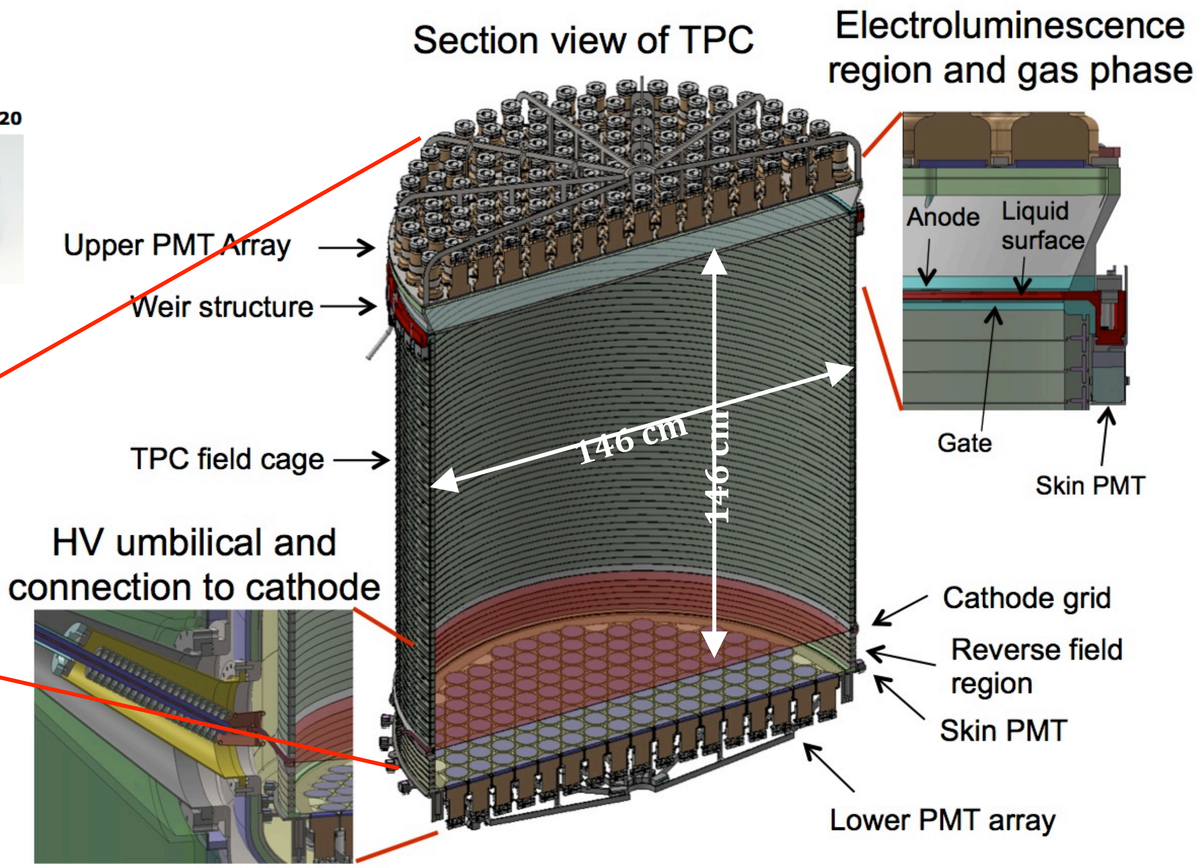
LZ detector system



Xenon TPC and Skin

- 7-tonne active region (cathode → gate), 5.6 tonne FV
- 253 top + 241 bottom 3” φ PMTs (activity ~mBq; high QE)
- TPC lined with high-reflectivity PTFE (R_{PTFE} ≥ 95%)*
- Instrumented “Skin” region optically separated from TPC





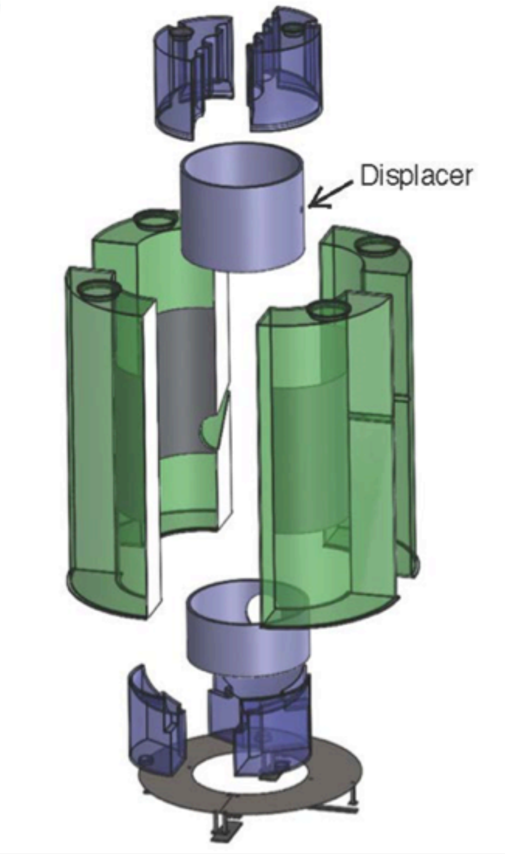
Key performance drivers

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

The Outer Detector (OD)

- Essential to maximize fiducial volume
- Hermetic measurement of penetrating backgrounds
- 60 cm thick, 17.5 tonnes Gadolinium-loaded scintillator, LAB*, OK underground
- 97% efficient for neutrons
- Daya Bay legacy, scintillator & tanks (and people)

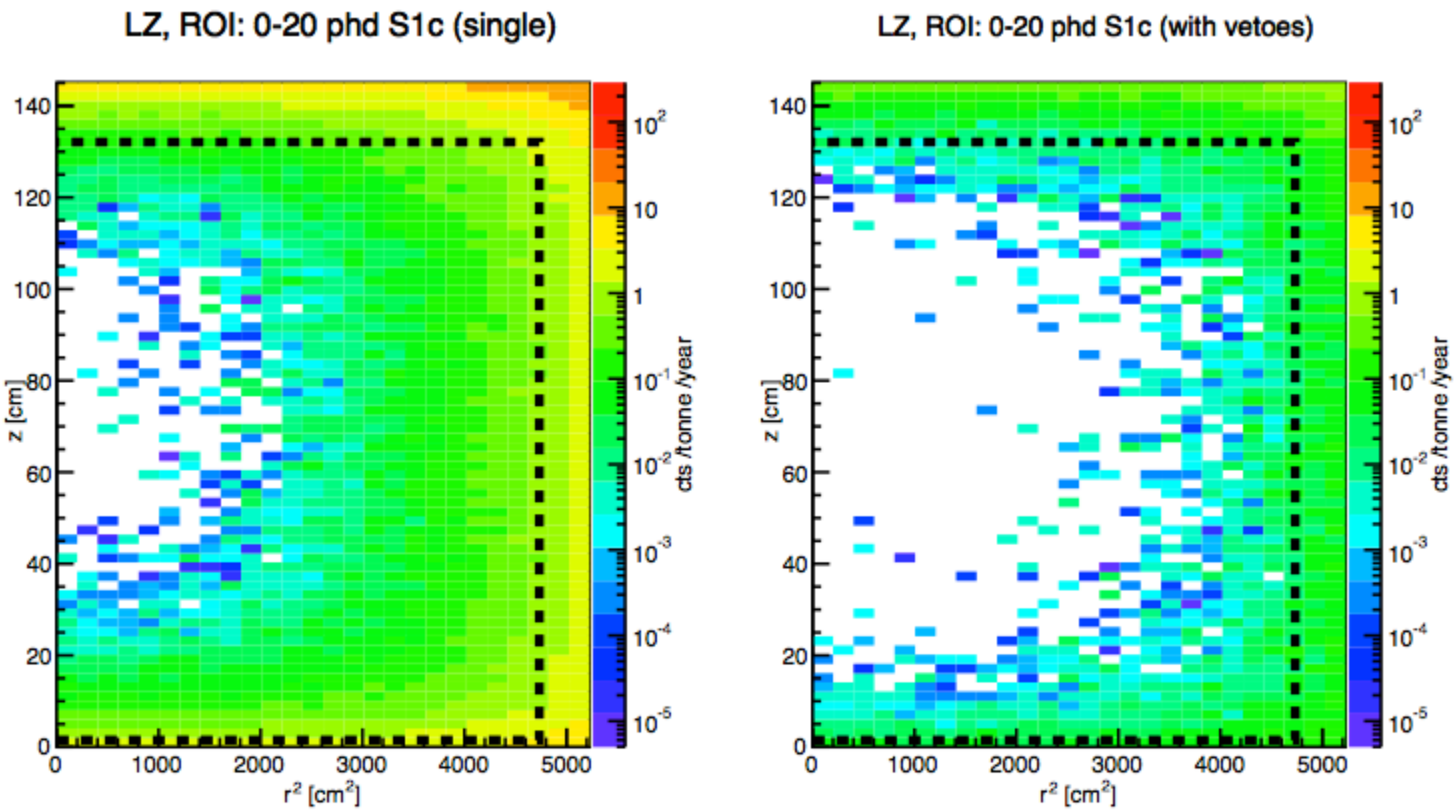


Layout of the LZ outer detector system, which consists of nine acrylic tanks. The largest are the four quarter-tanks on the sides. Two tanks cover the top, and three the bottom. The exploded view on the right shows the displacer cylinders placed between the acrylic vessels and the cryostat.

* Linear alkylbenzene

Powerful background rejection

Simulated single NR scatter in TPC before/after Skin+OD vetoes



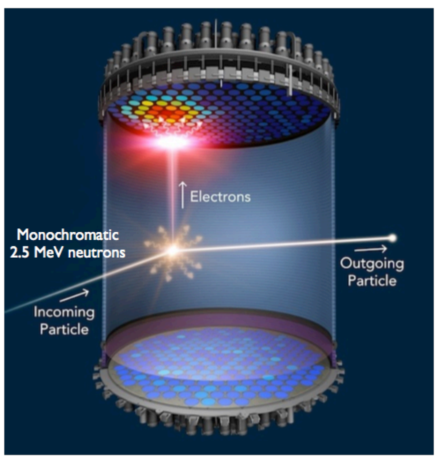
- Increases effective fiducial mass from 3.8 → 5.6 tonnes
- Internal backgrounds now dominate

Comprehensive suite of calibrations

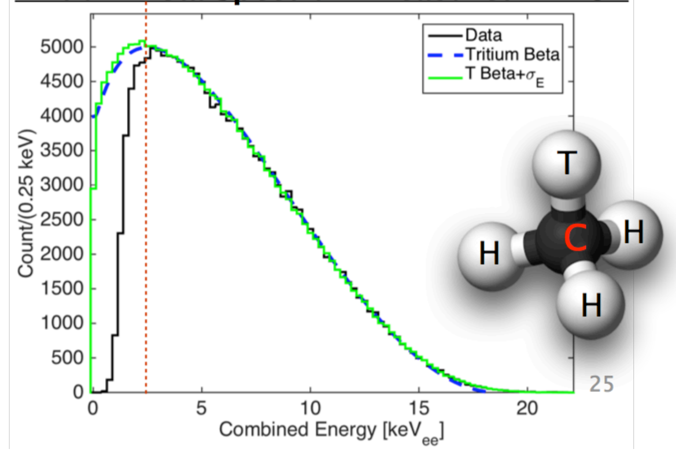
Comprehensive suite of tools for calibration of response to neutrons and electrons/photons:

- Dispersed in Xe to map out response
- Movable photon sources e.g. tubes penetrating cryostat
- Multiple neutron sources, including external neutron generator (upgraded version used in LUX)

DD neutron calibration



Tritium Beta Spectrum Measured in LUX



Build on LUX (and other experience) + test some new concepts with LUX after completion of physics running, summer this year.

Detector prototyping

Extensive R&D + Prototypes

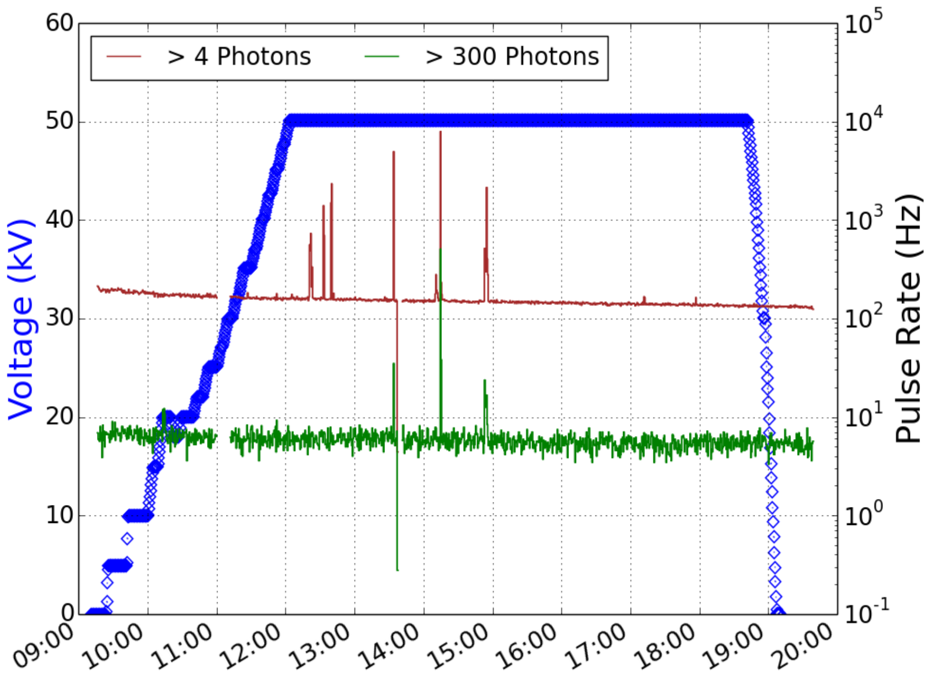
- Liquid argon at LBNL
- Few kg LXe chambers at several labs & univs

Schematic of the LZ System Test platform at SLAC.

System test platform at SLAC

- Phase-I ~120 kg of LXe
  - Full fledged setup with cooling, cleaning, …
- TPC testing ongoing
  - Strong drift field to maximize S2/S1 discrimination of background electronic recoils
  - High Voltage: 50kV demonstrated - goal 100 kV
- Phase-2 ~500 kg of LXe
  - Full scale LZ HV grids

SLAC System Test Results



Event rates for >4 photons (red) and >300 photons (green) during the system test run 2, with the cathode biased to 50 kV (blue).

Phase I TPC

Control of backgrounds

Extensive LZ materials screening campaign with many dedicated screening facilities (Gamma screeners, Rn-emanation, Mass spec)

- Assay and assess impact of all candidate detector components prior to adoption
- Work closely with suppliers and manufacturers
- All major components and materials identified

After application of vetoes internal backgrounds now dominate over those from intrinsic contamination of detector components: particularly Kr, Rn and neutrino-induced

Control of internal backgrounds

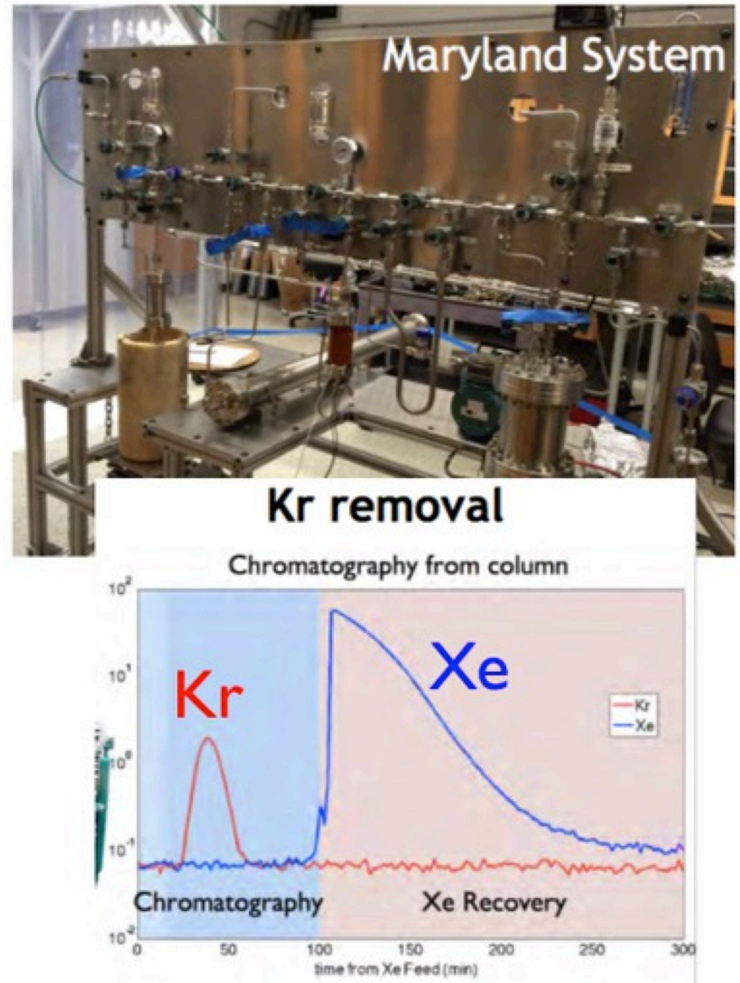
Rn (and Kr) dominant internal background sources

Rn:

- Emanates from most materials
- 20 mBq requirement, 1 mBq goal
- Four systems with ~0.1 mBq sensitivity
- Main assembly laboratory at SURF will have reduced radon air system

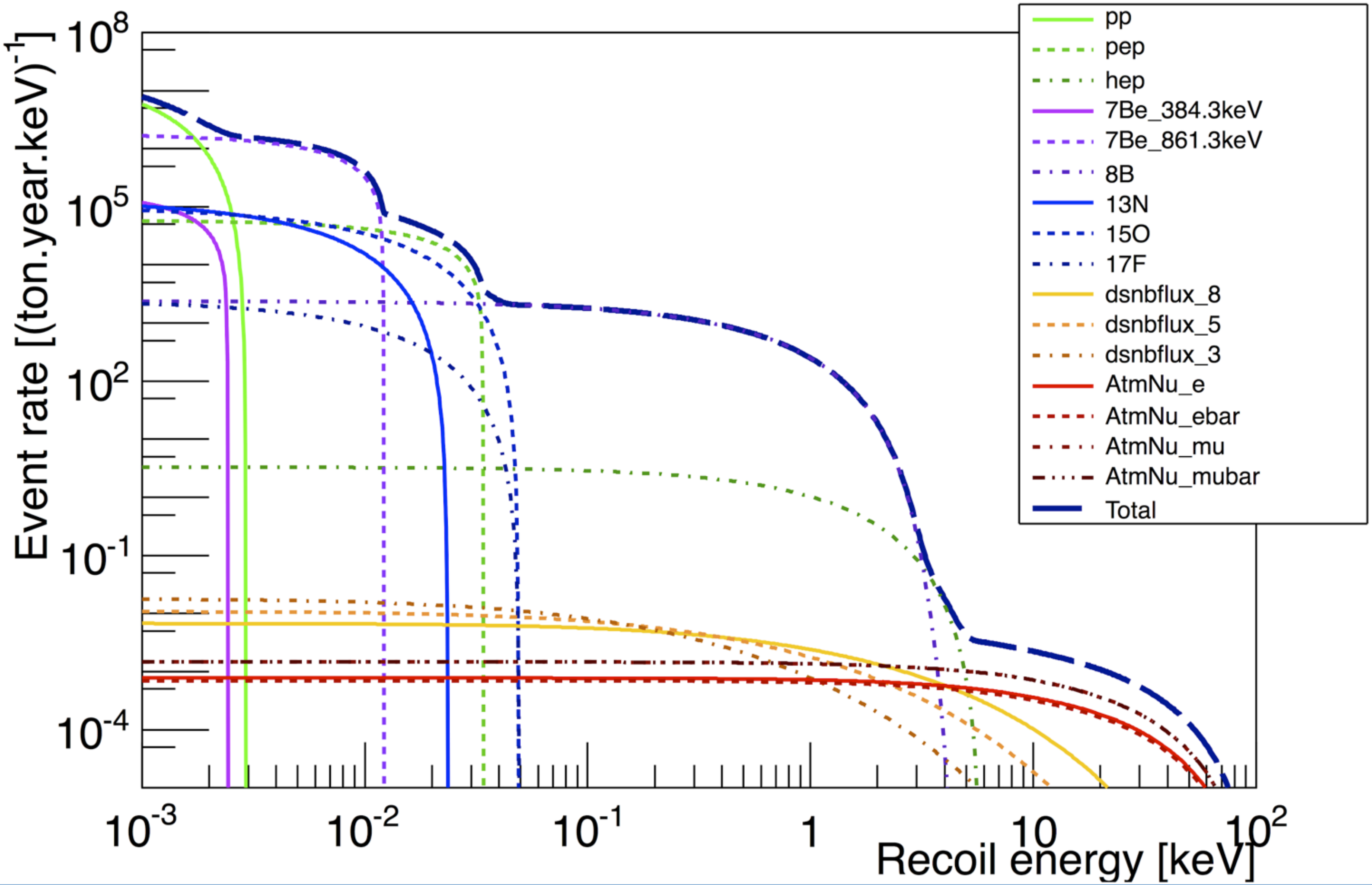
Kr:

- 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



Neutrino backgrounds

arXiv:1307:5458



Expected backgrounds

1000 live-days, 5600 kg fiducial

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
OD PMTs	122.4	400	200	0	300	3308	0.00	0.000
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**	

Simulations

- Powerful GEANT4-based simulation with realistic detector geometry
- LZ tune of Noble Element Scintillation Technique (NEST) package used for S1/S2 generation, tuned to World + LUX DD and CH3T
- Profile Likelihood Ratio for hypothesis testing: uses PDFs in S1,S2,r,z space

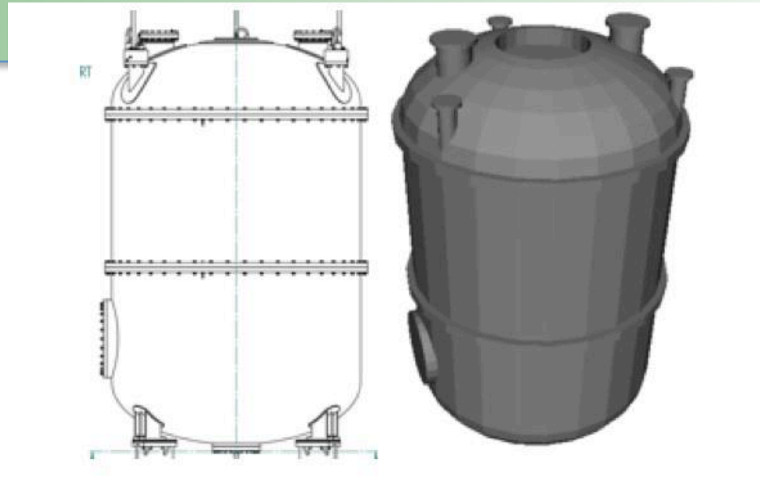
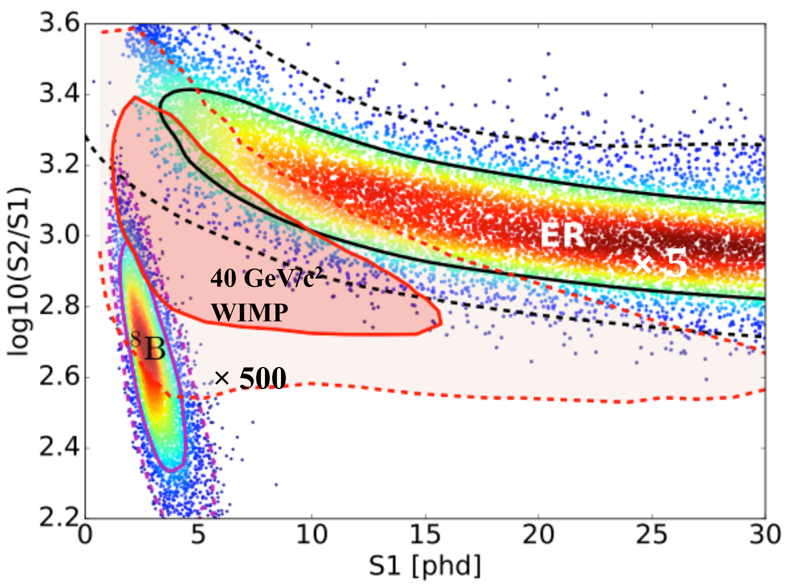


Figure 12.1.1: Engineering drawing and simulation geometry of the outer cryostat. SRDf:CryostatComp



Baseline vs goal

Baseline performance requirements:

These have to be achieved to meet top level sensitivity requirement of 3×10^{-48} cm2 @ 40 GeV/c2

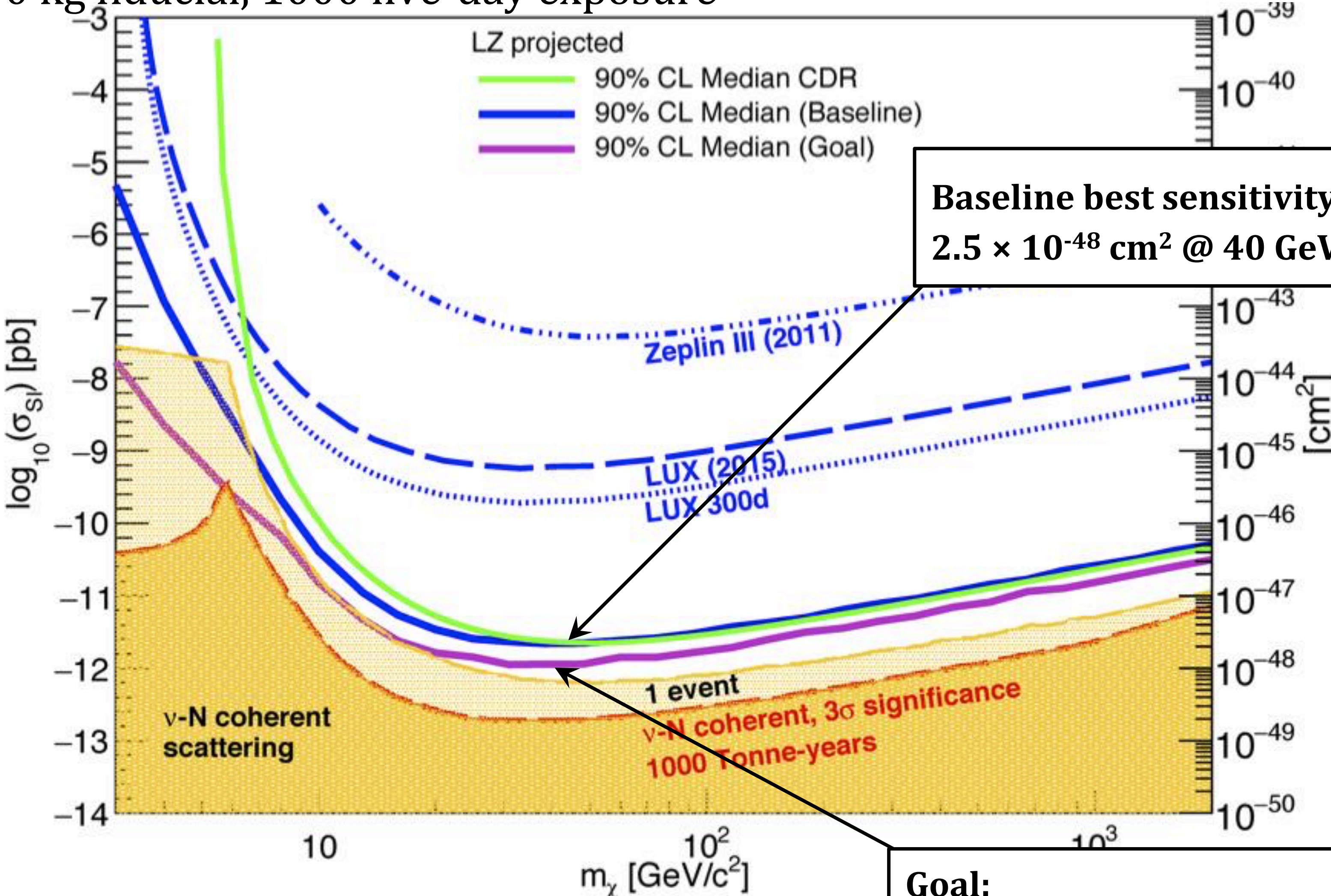
Fully expect these to be met

Goals: what we're aiming for

Detector Parameter	Baseline	Goal
Light collection (PDE)	0.075	0.12
Drift field (V/cm)	310	650
Electron lifetime (μs)	850	2800
PMT phe detection	0.9	1.0
N-fold trigger coincidence	3	2
^{222}Rn (mBq in active region)	13.4	0.67
Live days	1000	1000

Sensitivity – Spin Independent

5600 kg fiducial, 1000 live-day exposure



Baseline best sensitivity:
2.5×10^{-48} cm² @ 40 GeV/c²

Goal:
1.3×10^{-48} cm² @ 40 GeV/c²

Other physics

Effective Field Theory Interaction Decomposition

Neutrinoless Double Beta Decay

- Enriched Xe addition, Electronics with dynamic range

Axions/Axion-like-particles, leptophilic DM, fractionally charged particles

External Neutrino Physics

- Solar
- Supernova

LZ Timeline

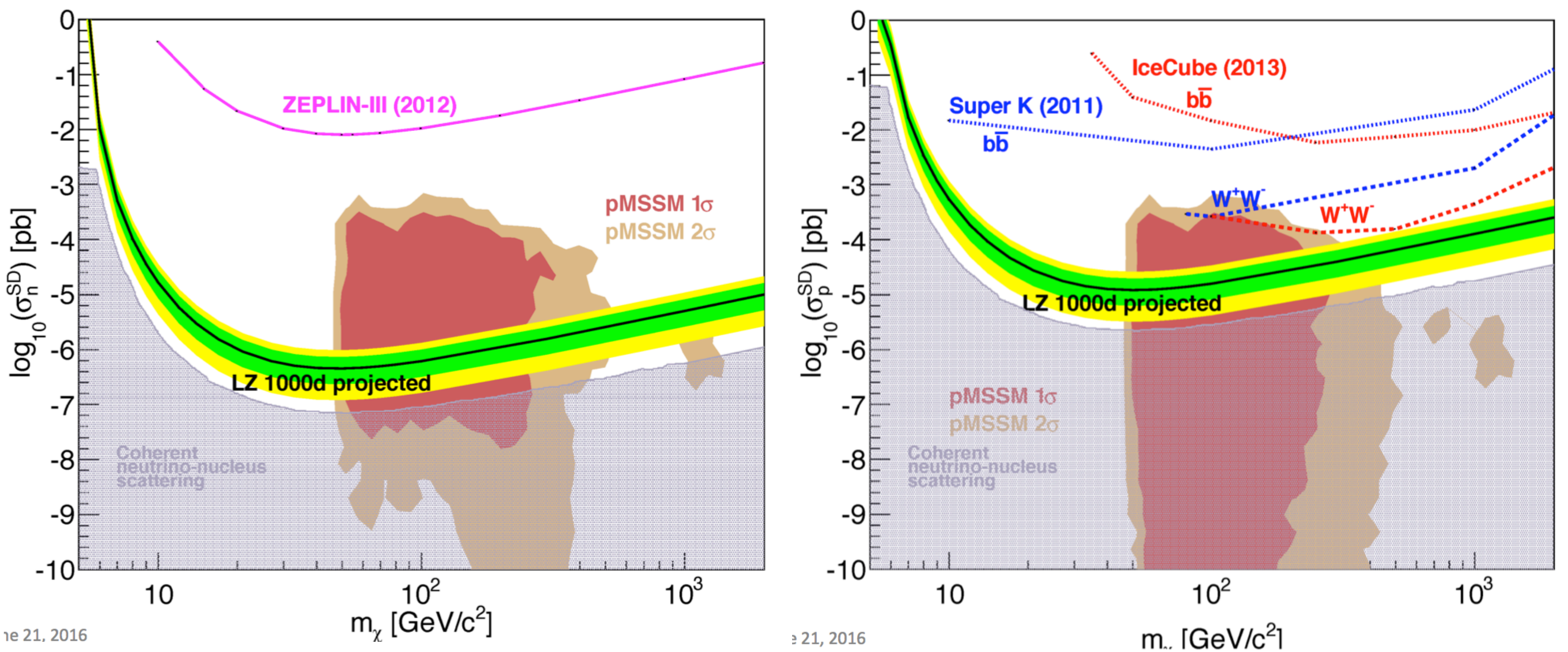
Year	Month	Activity
2012	March	LZ (LUX-ZEPLIN) collaboration formed
	September	DOE CD-0 for G2 dark matter experiments
2013	November	LZ R&D report submitted
2014	July	LZ Project selected in US and UK
2015	April	DOE CD-1/3a approval, similar in UK Begin long-lead procurements(Xe, PMT, cryostat)
2016	August	DOE CD-2/3b approval
	December	DOE CD-3c IPR
2017	March	LUX removed from underground
	August	Beneficial occupancy surface assembly building
2018	June	Beneficial occupancy for underground installation
2019		Underground installation
2020	April	Early finish CD-4. Start operations
2025+		Planning on 5+ years of operations

Conclusions

- Project well underway, with procurement of Xe, PMTs and cryostat vessels started and extensive prototype program underway
- LZ benefits from excellent LUX calibration techniques and understanding of backgrounds
- Will explore significant fraction of available phase space:
  - WIMP sensitivity 1.3×10^{-48} cm^2 @ 40 GeV/c2 and approaching neutrino floor

+ non-WIMP physics reach

Sensitivity : Spin Dependent



Spin Independent : 3σ Discovery

3σ @ 40 GeV/c^2 and 6 ×10^{-48} cm^2