LUX-ZEPLIN Status

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XIV International Conference on Topics in Astroparticle and Underground Physics

LZ = LUX + ZEPLIN

32 institutions currently
About 190 people

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 Laboratories (UK)
Shanghai Jiao Tong University (China)
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
Kavli Institute for Particle Astrophysics & Cosmology
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
Yale University

Sanford Underground Research Facility

Davis Cavern 1480 m (4200 mwe)

LZ in LUX Water Tank

South Dakota USA

LUX removed
by early 2017
Water tank kept

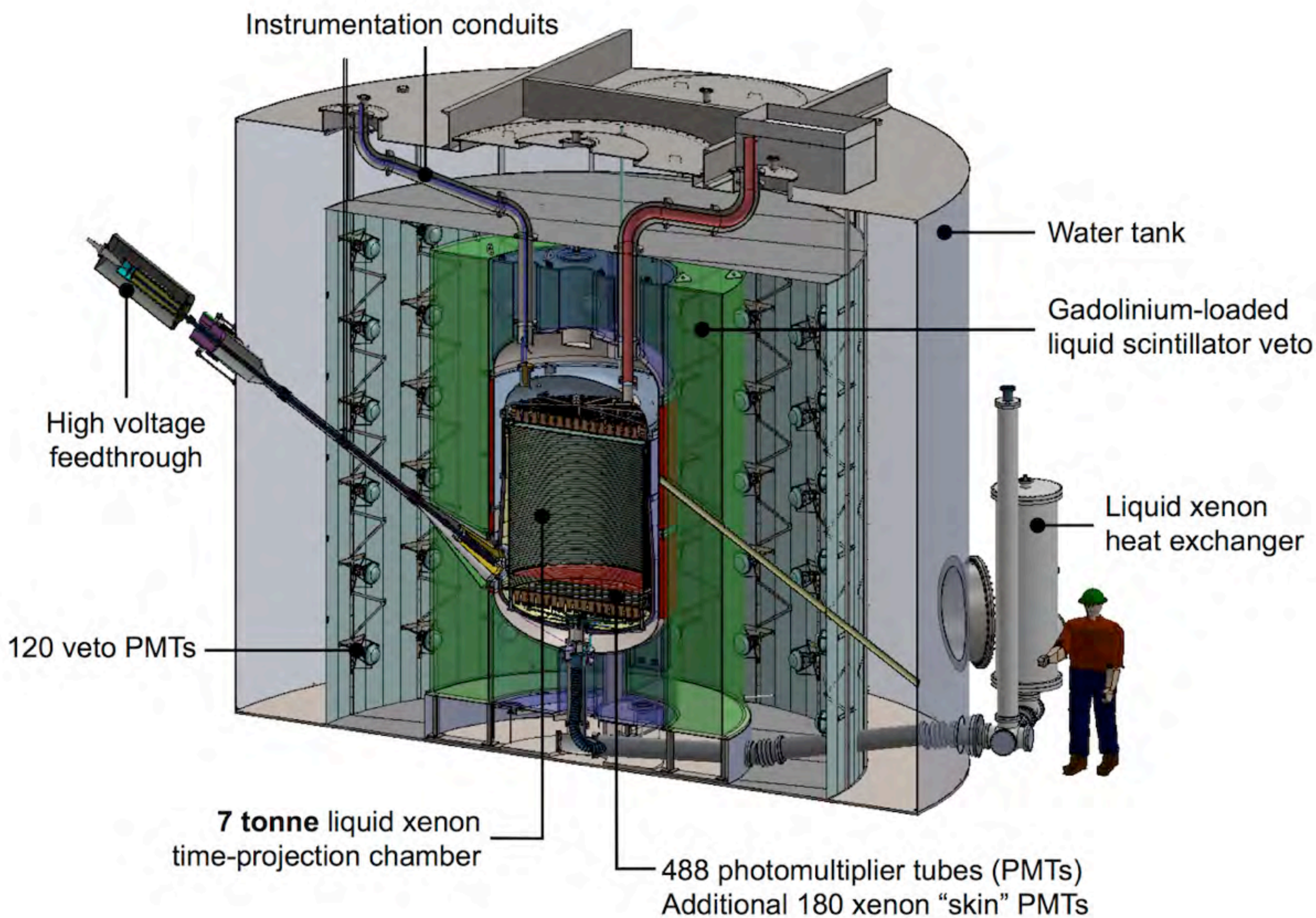
Scale Up ≈ 50 in Fiducial Mass

LZ

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

LUX

LZ Overview


Instrumentation conduits
Water tank
Gadolinium-loaded
liquid scintillator veto
High voltage
feedthrough
Liquid xenon
heat exchanger
120 veto PMTs
7 tonne liquid xenon
time-projection chamber
488 photomultiplier tubes (PMTs)
Additional 180 xenon "skin" PMTs

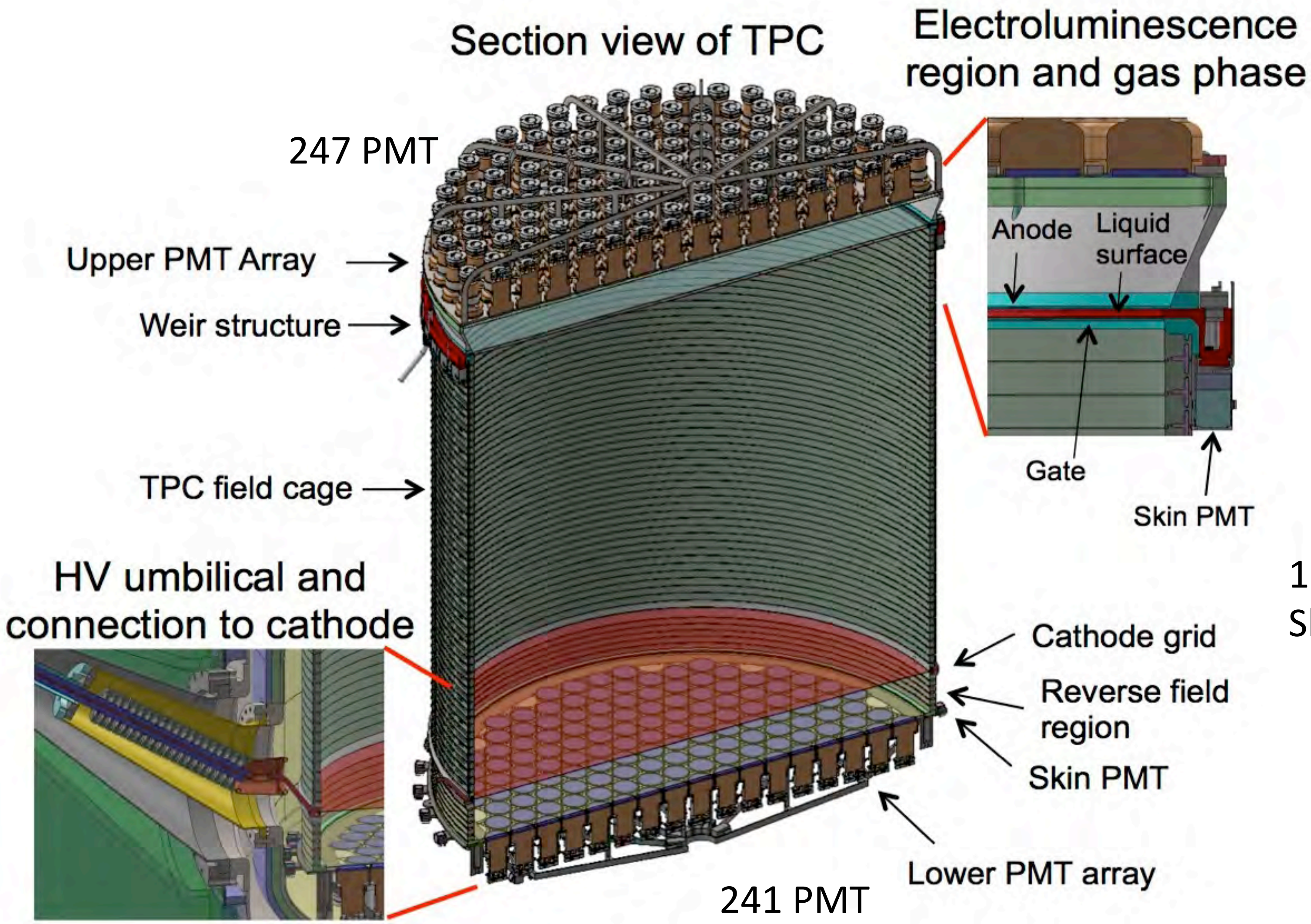
Key Design Points

- ✦ 7 active tonnes of LXe can yield 2×10^{-48} cm^2 sensitivity in about three years of running
- ✦ 5.6 tonne fiducial volume, 1000 days
- ✦ Requires all detector systems working together
  - ☐ Xe detector with good light collection, reasonable background rejection (ER discrimination) and good signal detection efficiency
  - ☐ Sophisticated veto system: skin (outside active Xe region) + scintillator/water allows maximum fiducial volume to be obtained, maximizes use of Xe and substantially increases reliability of background measurements
  - ☐ Control backgrounds, both internal (within the Xe) and external from detector components/environment

Design Status Summary

- ✦ Conceptual, and in some cases more advanced design, completed for all aspects of detector
- ✦ Conceptual Design Report about to appear on arXiv
- ✦ Acquisition of Xenon started
- ✦ Procurement of PMTs and cryostat started
- ✦ Collaboration – wide prototype program underway to guide and validate design
- ✦ Backgrounds modeling and validation well underway

Xe TPC Detector



180 total
Skin PMT

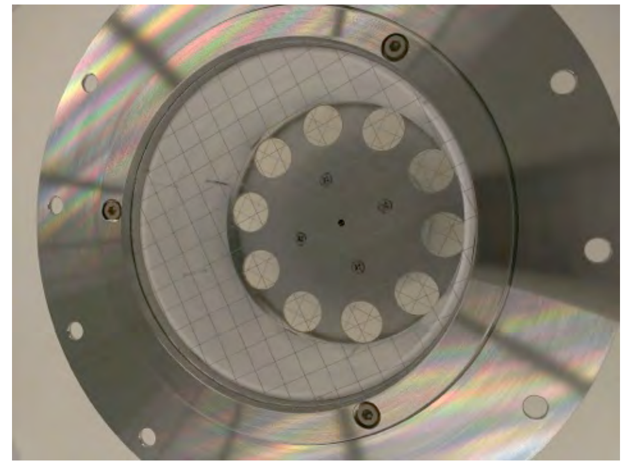
Xe Detector PMTs

- R11410-22 3” PMTs for TPC region
  - Extensive development program, 50 tubes in hand, benefit from similar development for XENON, PANDA-X and RED
  - Materials ordered and radioassays started prior to fabrication.
  - First production tubes early 2016.
  - Joint US and UK effort
- R8520-406 1” for skin region
  - Considering using 2” or 3” for bottom dome region, recycle tubes from older detectors

Xe Detector Prototyping

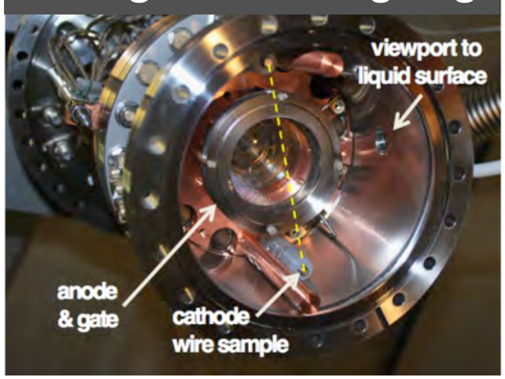
- ✦ Extensive program of prototype development underway
- ✦ Three general approaches
  - ☐ Testing in liquid argon, primarily of HV elements, at Yale and soon at LBNL
  - ☐ Design choice and validation in small (few kg) LXe test chambers in many locations: LLNL, Yale-> UC Berkeley, LBNL, U Michigan, UC Davis, Imperial College, MEPhI
  - ☐ System test platform at SLAC, Phase I about 100 kg of LXe, TPC prototype testing to begin in few months

High Voltage Studies



Prototype of highest E-field region tested in LAr

Wire grid tests ongoing



- ✦ Cathode voltage design goal: 200 kV (provides margin)
- ✦ LZ nominal operating goal: 100 kV (~ 700 V/cm)
- ✦ Feedthrough prototype tested to 200 kV
- ✦ Prototype TPC for 100 kg LXe system fabrication starting
- ✦ HV prototyping expanding at Berkeley
- ✦ Wire electron emission studies at Imperial (see talk by A. Tomas)

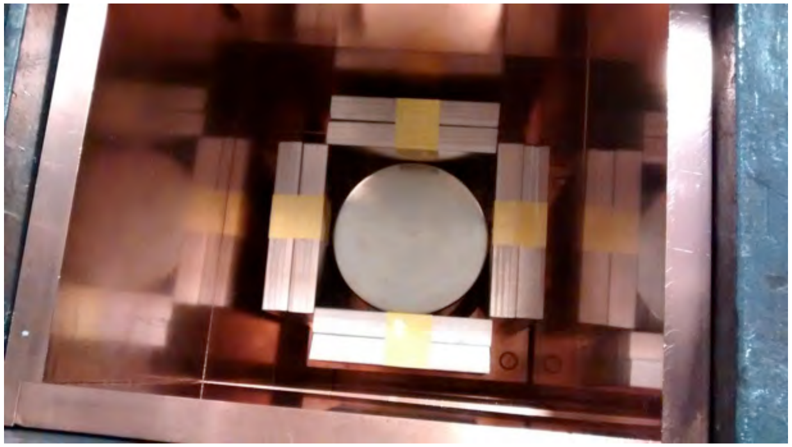
Extensive Calibration

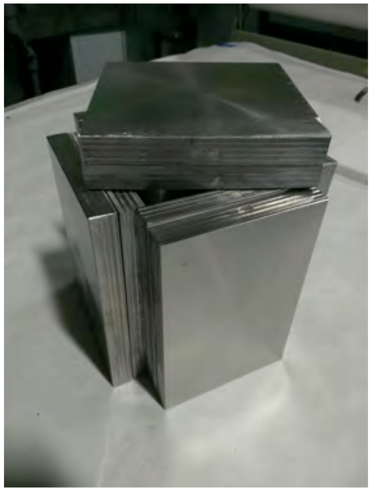
✦ LUX has led the way to detailed calibrations. LZ will build on this and do more.

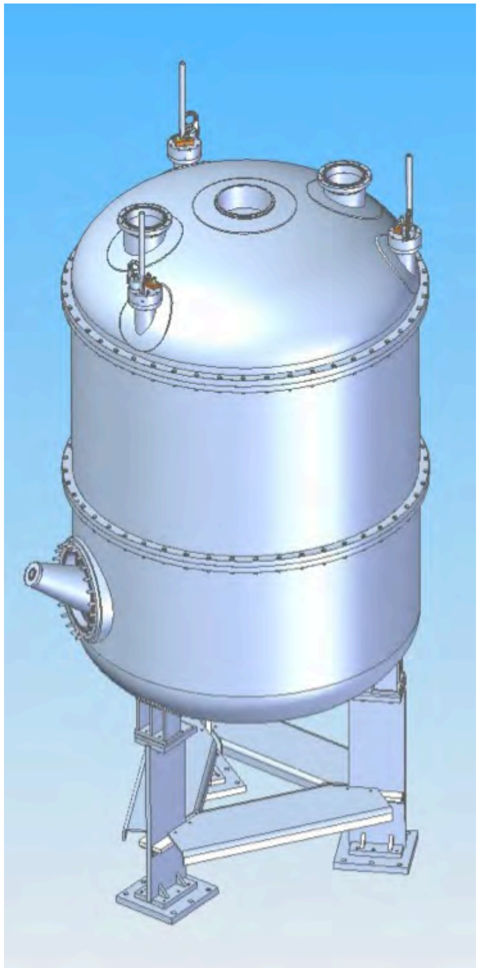
Done in LUX and will be done in LZ	Not done in LUX, but will do in LZ
^{83m}Kr (routine, roughly weekly)	Activated Xe (^{129m}Xe and ^{131m}Xe)
Tritiated methane (every few months)	^{220}Rn
External radioisotope neutron sources	AmLi
External radioisotope gamma sources	YBe
DD neutron generator(upgraded early next year to shorten pulse)	

Cryostat Vessels

- ✦ UK responsibility
- ✦ Low background Ti chosen as cryostat material
  SS alternative advanced as backup
- ✦ Ti slab for all vessels (and other parts) received and assayed
- ✦ Contributes < 0.05 NR+ER counts in fiducial volume in 1,000 days after cuts



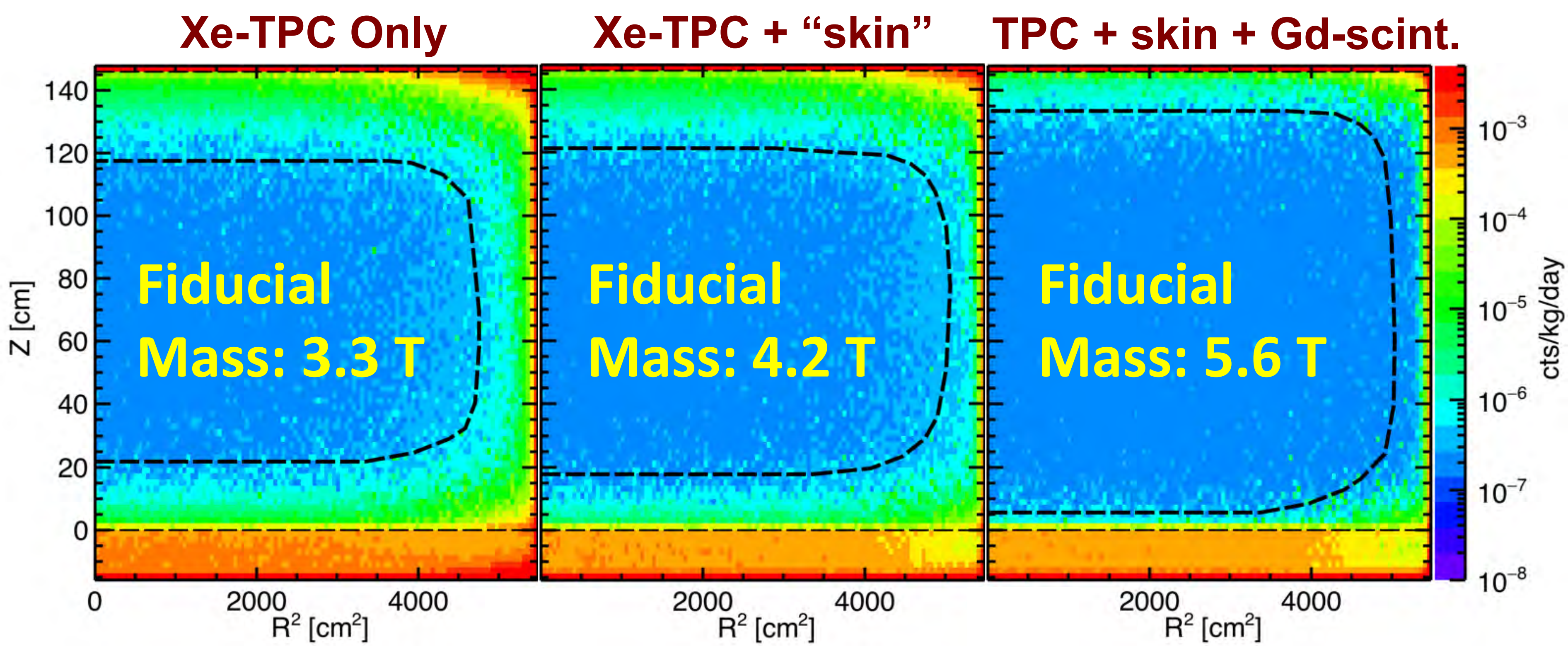




How to maximize the WIMP target mass?

- Two-component outer detector:
  - 0.75 m thick Gd-loaded scintillator
  - instrumented Xenon "skin"
  - tag neutrons and gammas

***in-situ* monitoring of residual backgrounds!!!**



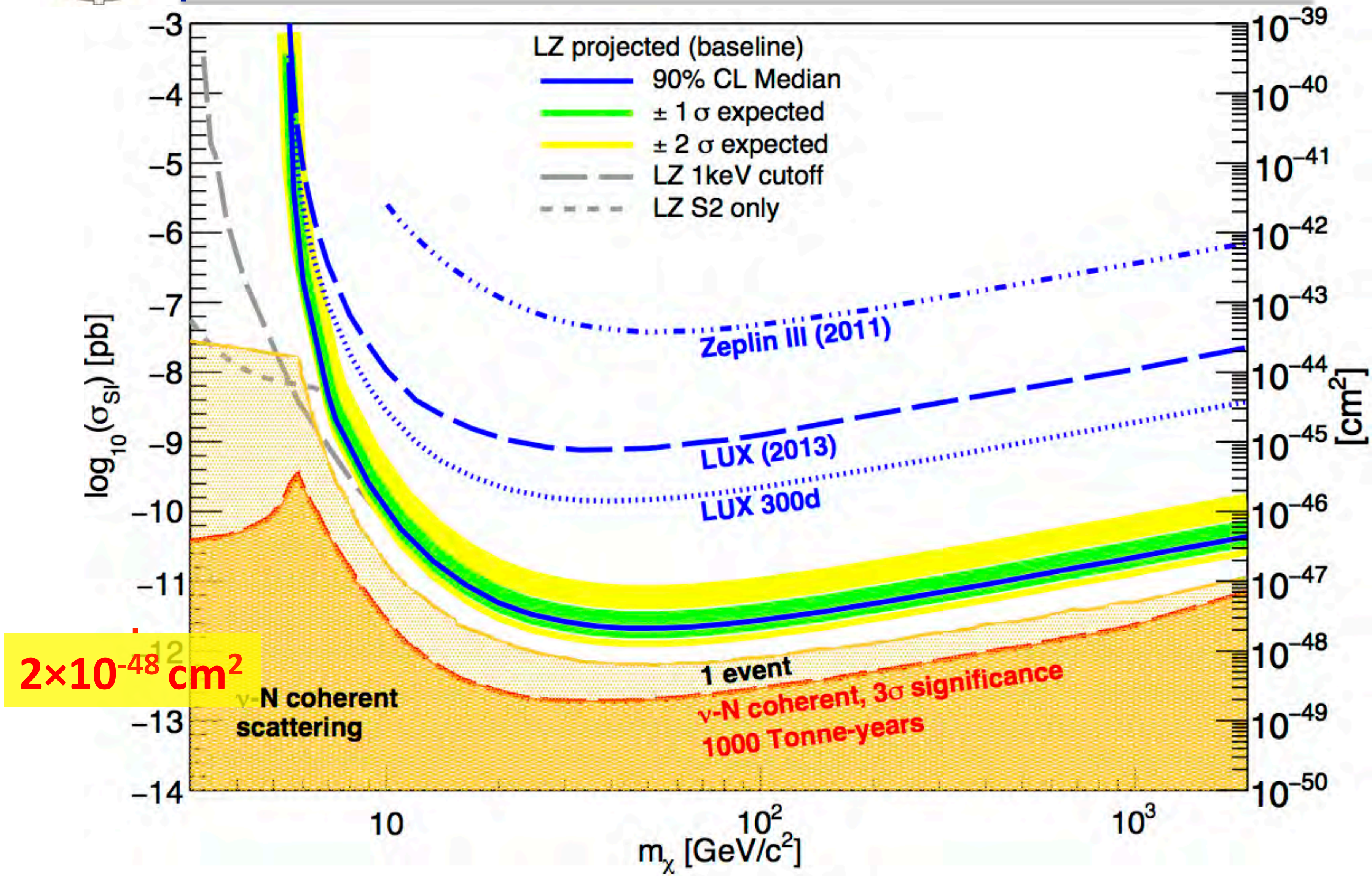
LZ Projected Backgrounds

Expected backgrounds for 5.6 T fiducial - 1,000 days

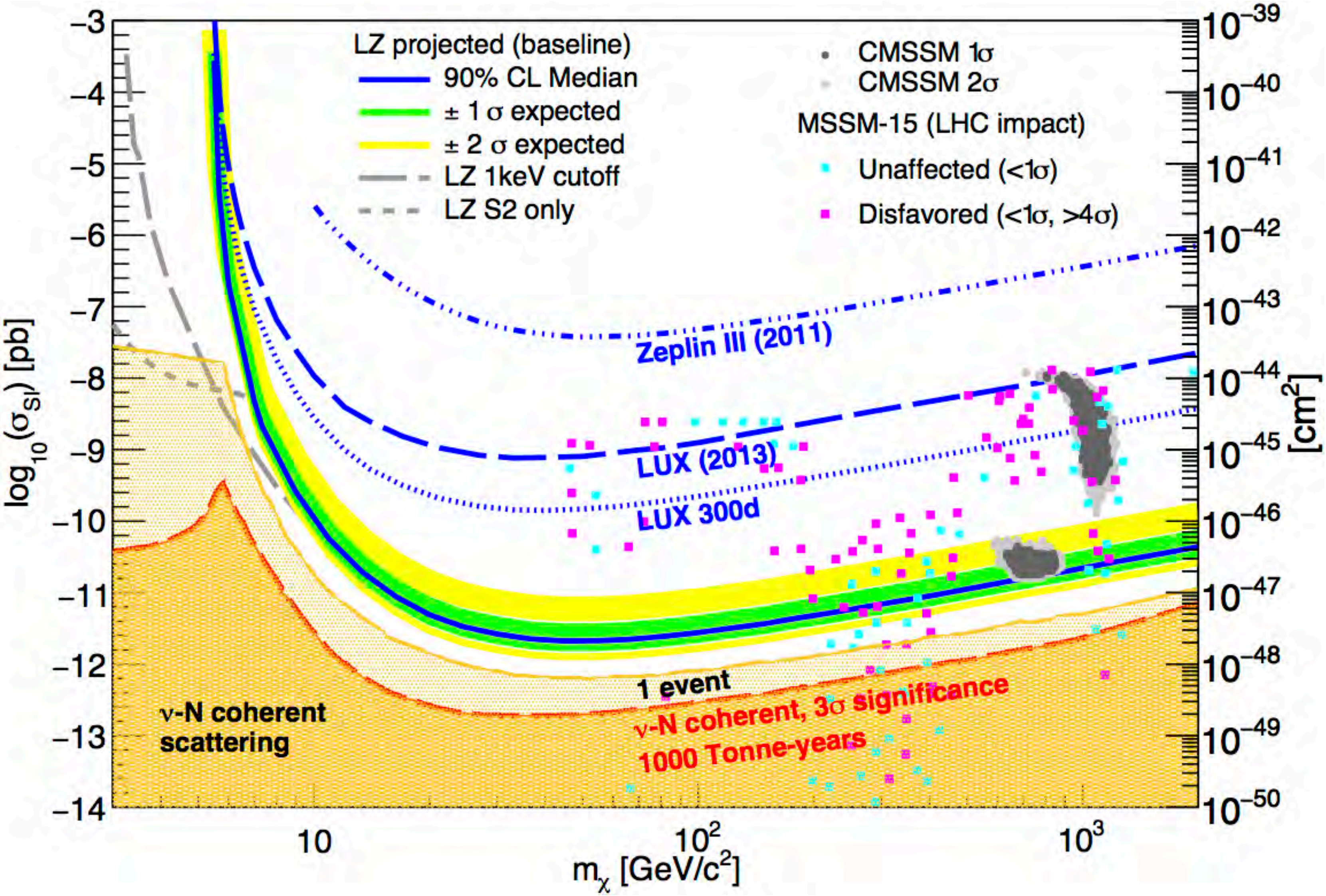
Item	Mass kg	U mBq/kg	Th mBq/kg	^{60}Co mBq/kg	^{40}K mBq/kg	n/yr	ER cts	NR cts
R11410 PMTs	93.7	2.7	2.0	3.9	62.1	373	1.24	0.20
R11410 bases	2.7	74.6	29.1	3.6	109.2	77	0.17	0.03
Cryostat vessels	2,140	0.09	0.23	≈0	0.54	213	0.86	0.02
OD PMTs	122	1,507	1,065	≈0	3,900	20,850	0.08	0.02
Other components	-	-	-	-	-	602	9.5	0.05
Total components							11.9	0.32
Dispersed radionuclides (Rn, Kr, Ar)							54.8	-
^{136}Xe 2νββ							53.8	-
Neutrinos (ν-e, ν-A)							271	0.5
Total events							391.5	0.82
WIMP background events (99.5% ER discrimination, 50% NR acceptance)							1.96	0.41
Total ER+NR background events							2.37	

Projected Sensitivity – Spin Independent

(LZ 5.6 Tonnes, 1000 live days, 6 keV_{nr} analysis threshold)



Sensitivity with SUSY Theories



Neutrino Physics with LZ

- Neutrinoless Double Beta Decay of ^{136}Xe
  - Use self-shielding to reduce gamma-ray backgrounds in a 1-2 tonne fiducial mass
  - Projected sensitivity: 90% confidence level $T^{0\nu}_{1/2}$ of 2 x 10^{26} years
  - Enriching the Xe target could increase this to ~ 2 x 10^{27} years
  - Current limit is 2.6 x 10^{25} years (preliminary) from KamLAND-Zen

- External Neutrino Physics
  - Solar neutrinos
    - Expect about 850 pp neutrino events between 1.5 and 20 keV_{ee}
  - Supernova neutrinos
    - Via flavor-blind coherent neutrino-nucleus scattering
    - For a 10 kpc SN, LZ would see about 50 events with energy > 6 keV_{nr} and 100 events > 3 keV_{nr}
  - Sterile neutrinos
    - Could use a 5 MCi ^{51}Cr source near LZ
    - Excellent position reconstruction for better source normalization, higher sterile neutrino masses.
  - Neutrino magnetic moment
    - Sensitivity near astrophysical limit of 2 x 10^{-12} Bohr magnetons.

LZ Timeline

Year	Month	Activity
2012	March	LZ (LUX-ZEPLIN) collaboration formed
	May	First Collaboration Meeting
	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 approval, baseline, all fab starts
2017	June	Begin preparations for surface assembly @ SURF
2018	July	Begin underground installation
2019	Feb	Begin commissioning

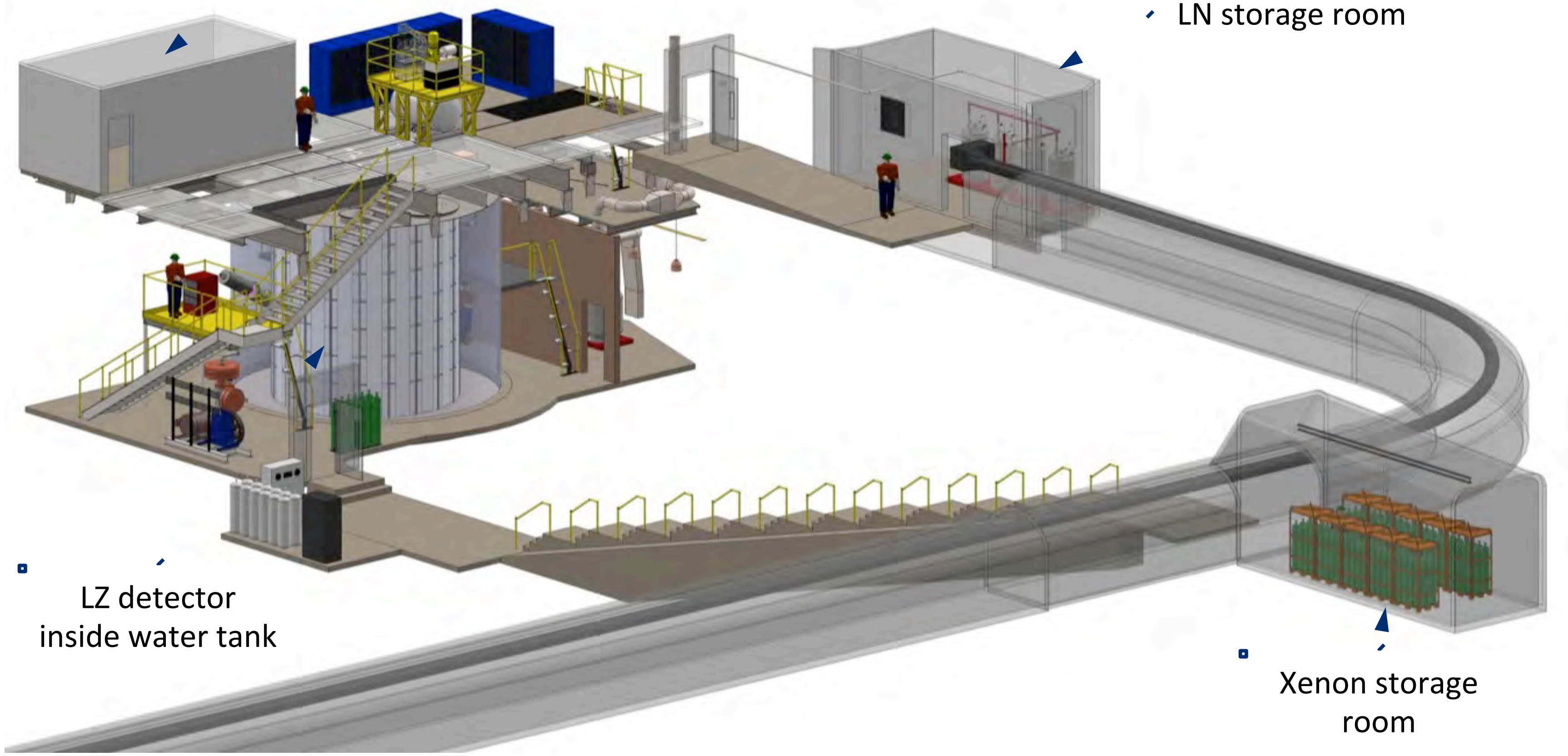
Conclusions

- LZ Project well underway, with procurement of Xe, PMTs and cryostat vessels started
- Commissioning to begin in 2019
- Extensive prototype program underway
- LZ benefits from the excellent LUX calibration techniques and understanding of background
- LZ sensitivity expected to reach **2×10^{-48} cm^2**

Extra Slides

LZ Underground at SURF

Years of experience at SURF from LUX

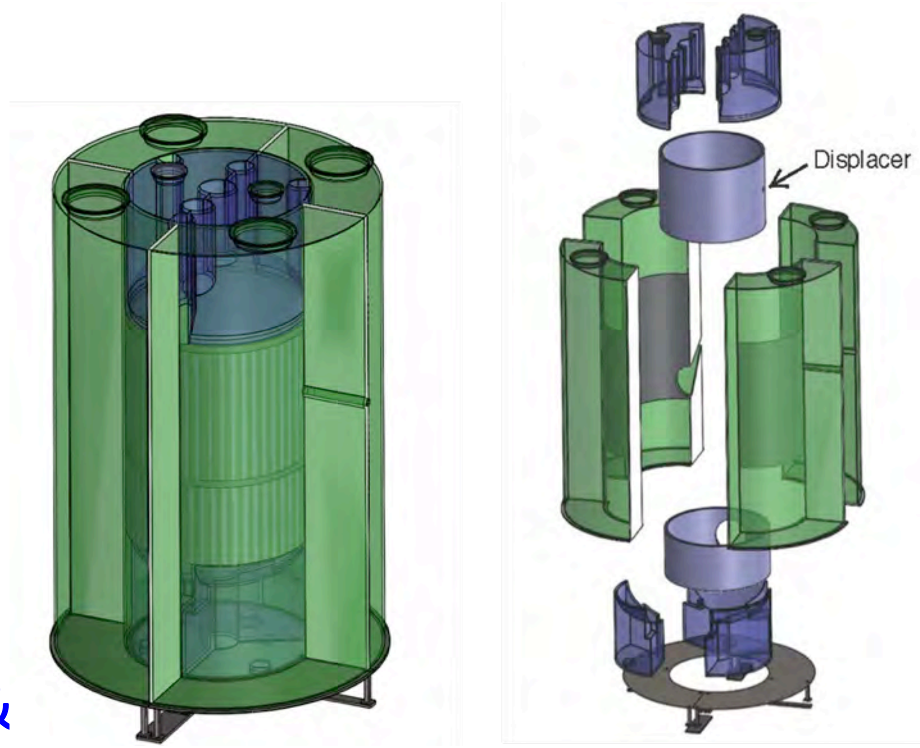


^{85}Kr Removal and Screening

- 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

Outer Detector

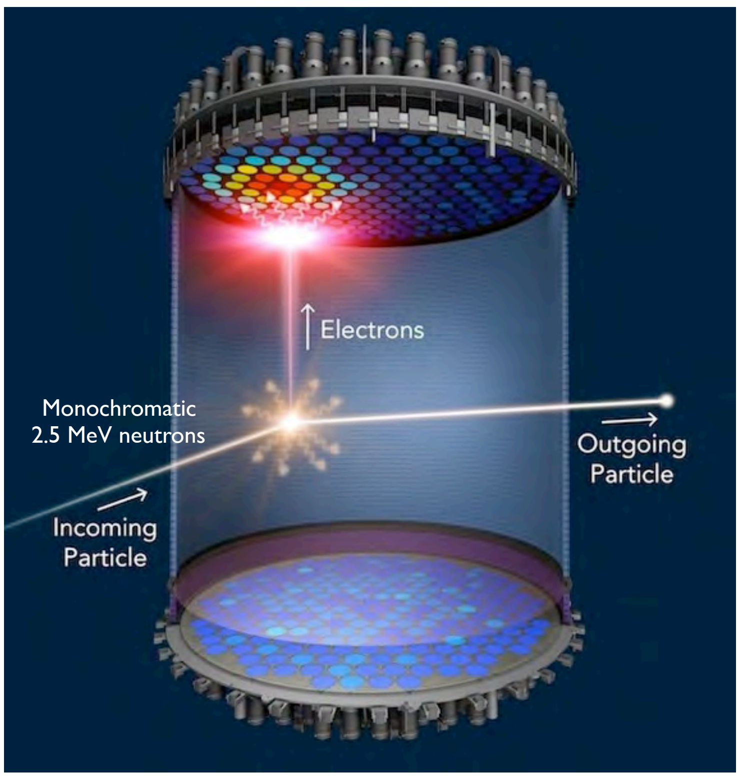
- Essential to utilize most Xe, maximize fiducial volume
- Segmented tanks – installation constraints (shaft, water tank)
- Gadolinium - loaded scintillator, LAB, OK underground
- Daya Bay legacy, scintillator & tanks (and people)
- Advanced conceptual design



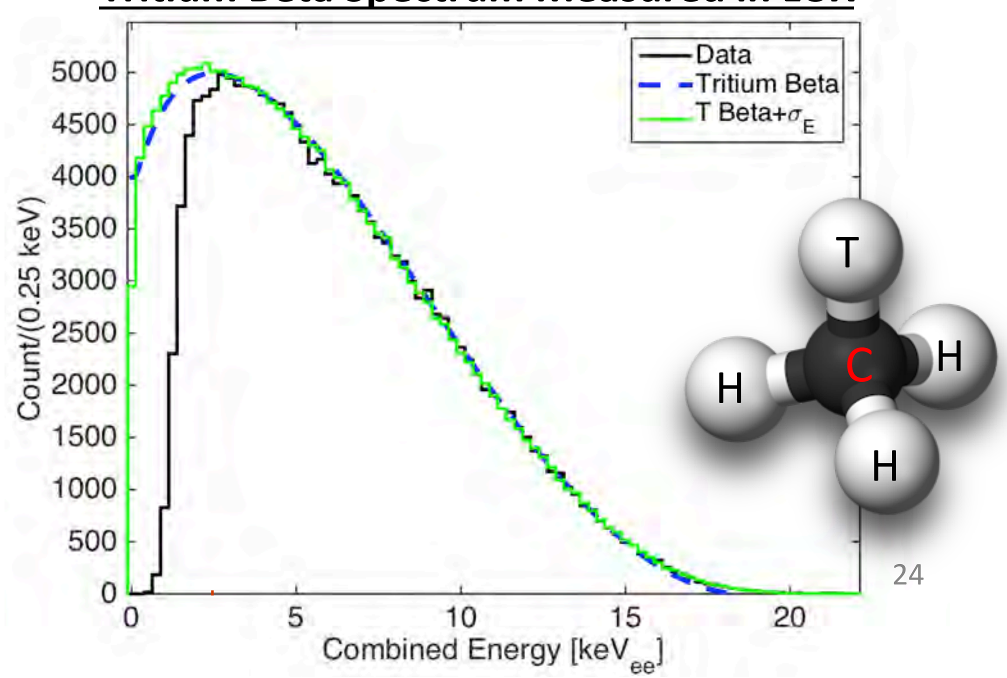
Layout of the LZ outer detector system, which consists of nine acrylic tanks. The largest are the four quarter-tanks on the sides. Two tanks cover the top, and three the bottom. The exploded view on the right shows the displacer cylinders placed between the acrylic vessels and the cryostat.

LZ Calibrations

- ✦Demonstrated in LUX. Calibrate The Signal and Background Model *in situ.*
- ✦DD Neutron Generator (Nuclear Recoils)
- ✦Tritiated Methane (Electron Recoils)
- ✦Additional Sources e.g. YBe Source for low energy (Nuclear Recoils)

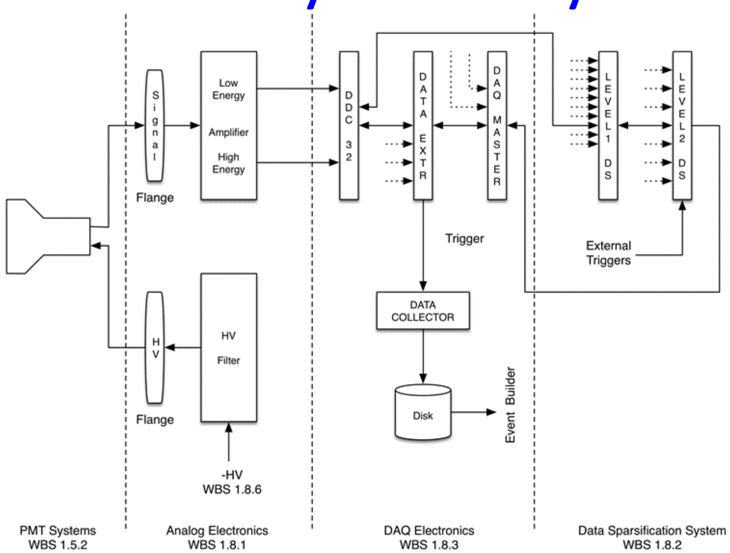


Tritium Beta Spectrum Measured in LUX

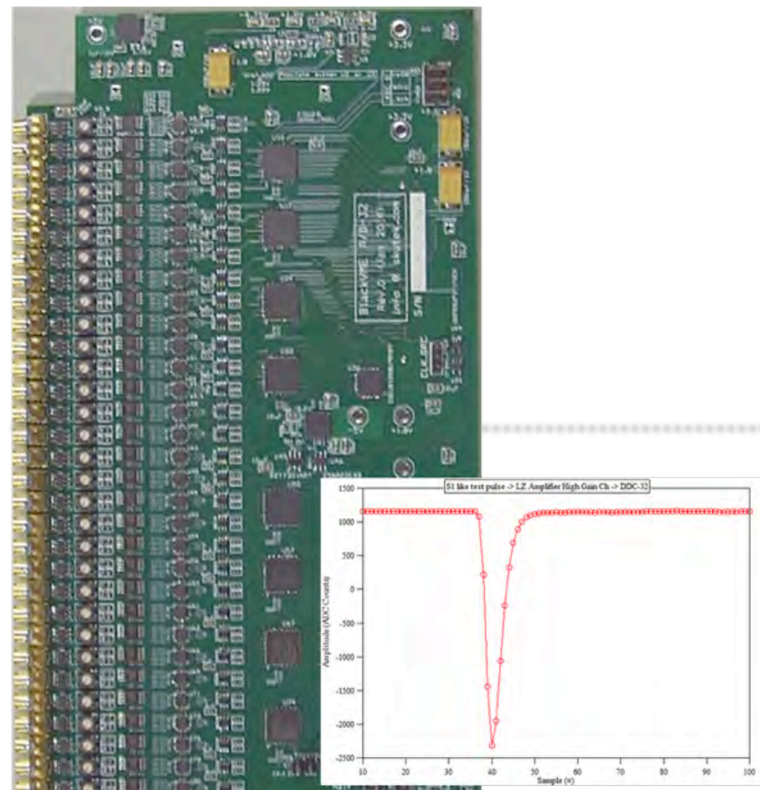


Electronics/DAQ

- LUX legacy, augmented by experienced new groups (primarily DAQ, controls)
- Prototyping underway, will lead to full – chain test of key elements by end of year



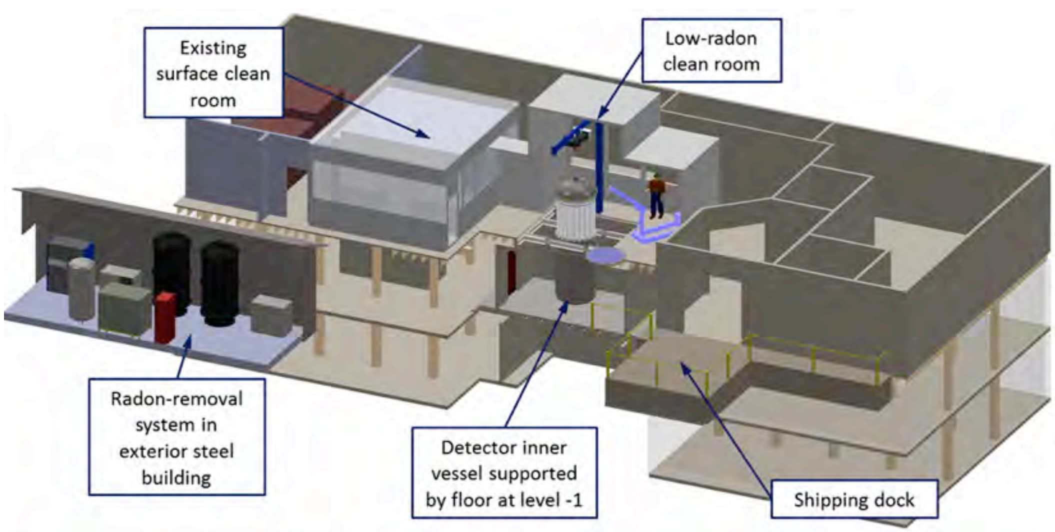
32 channel digitizer prototype

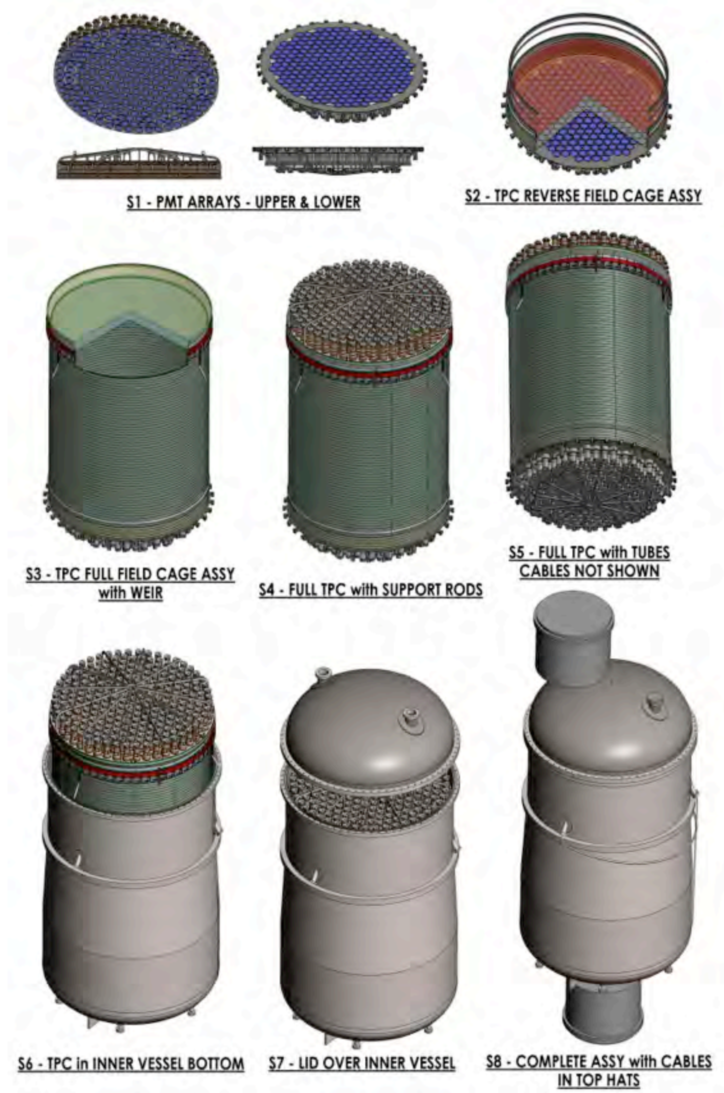


S1 test pulse from the high-gain amplifier output.
Excellent pulse response without ringing or overshoot.

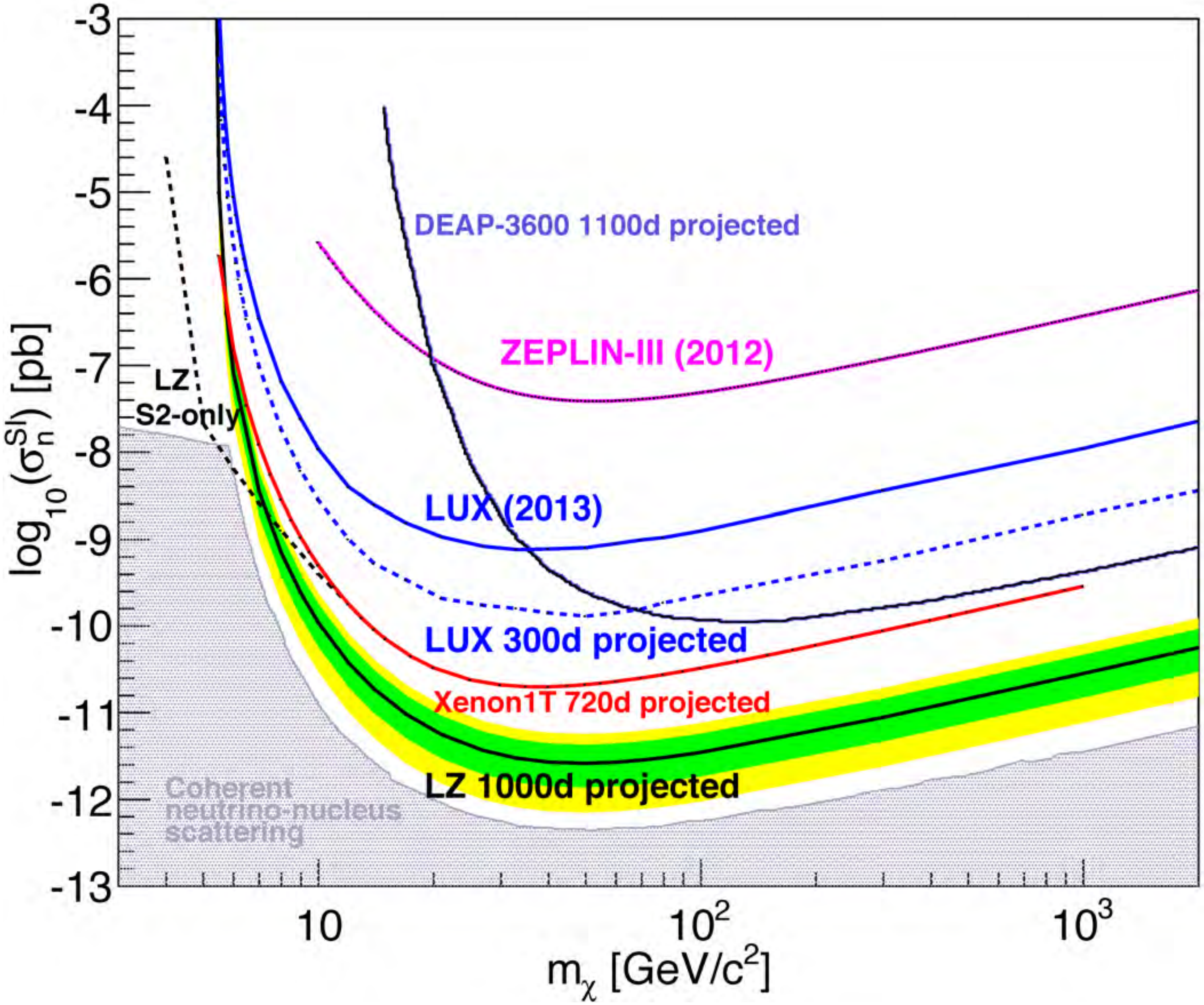
Integration/Installation

- Surface assembly of TPC into inner cryostat
- LUX experience at SURF
- Dedicated on – site infrastructure improvements for LZ. Design started, construction

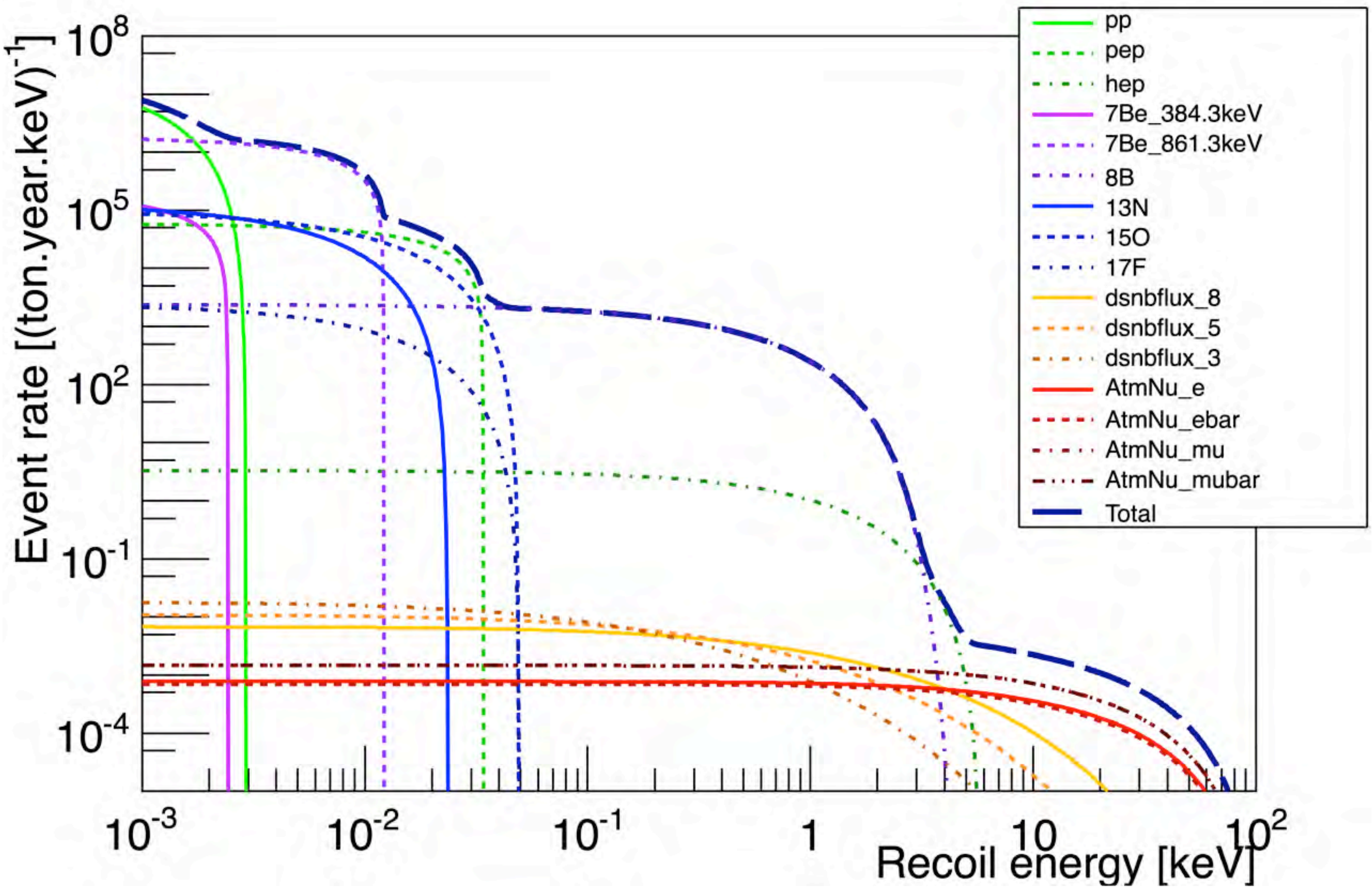




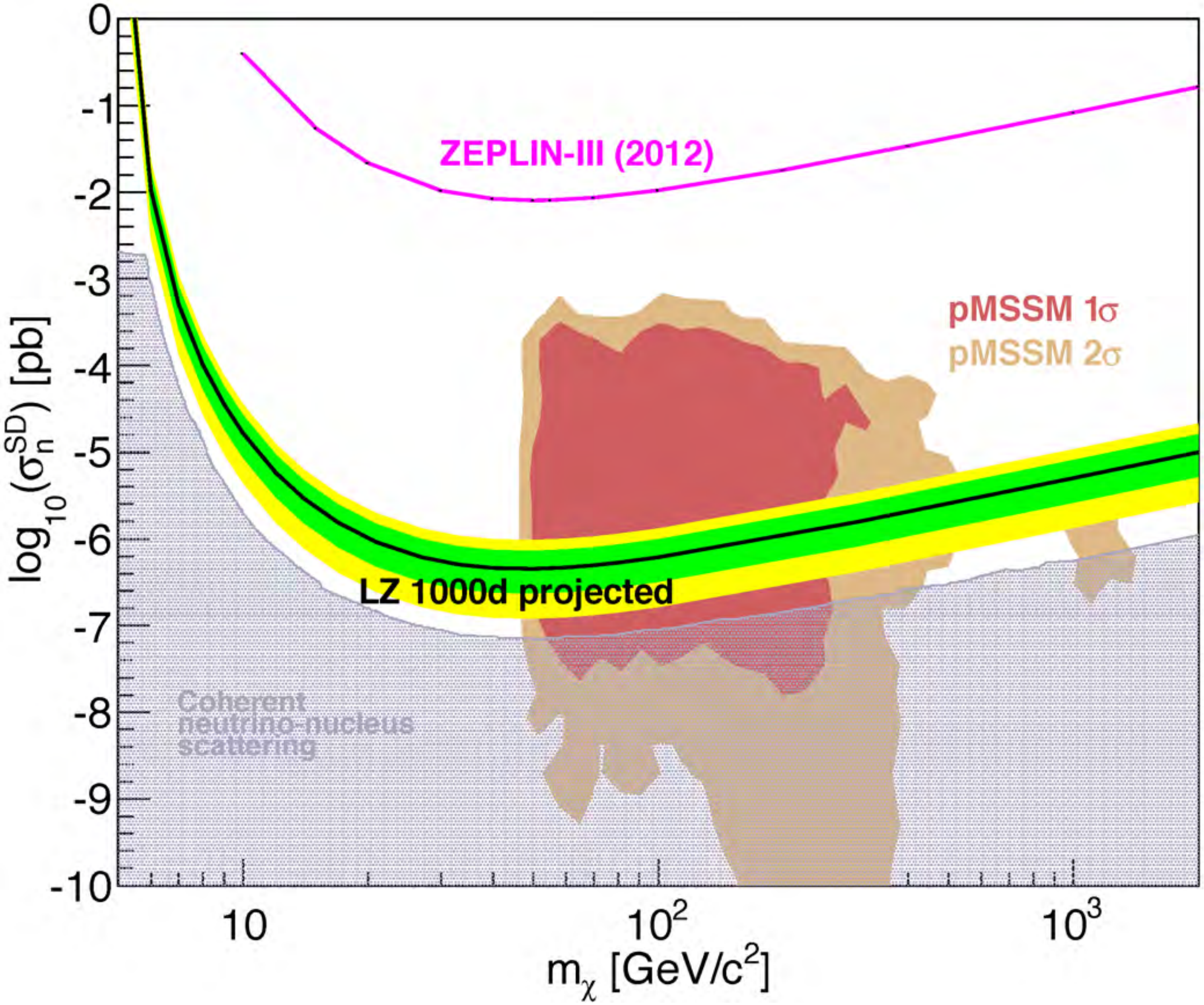
Sensitivity with Competition



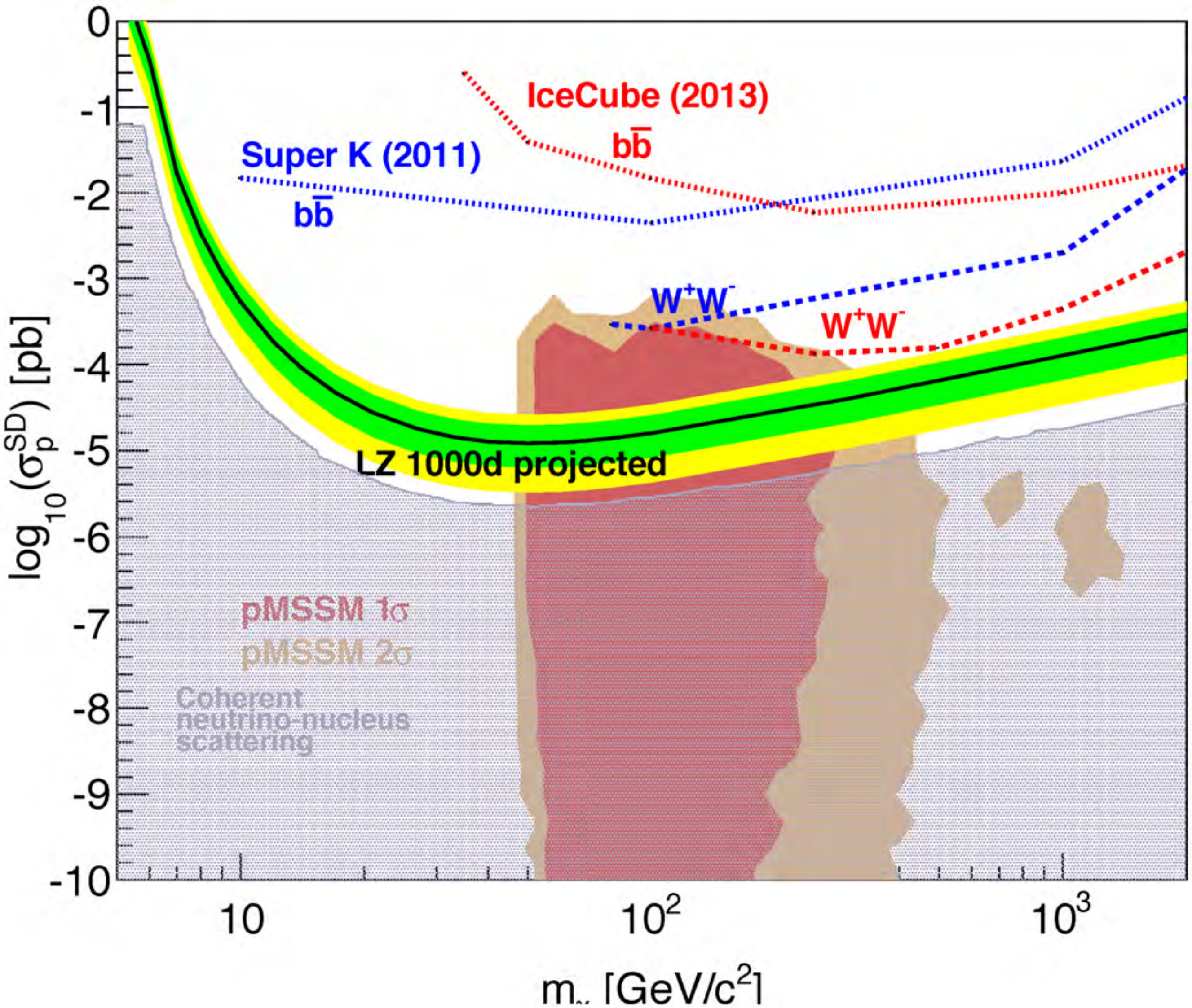
Response of Xe to Neutrinos arXiv:1307:5458



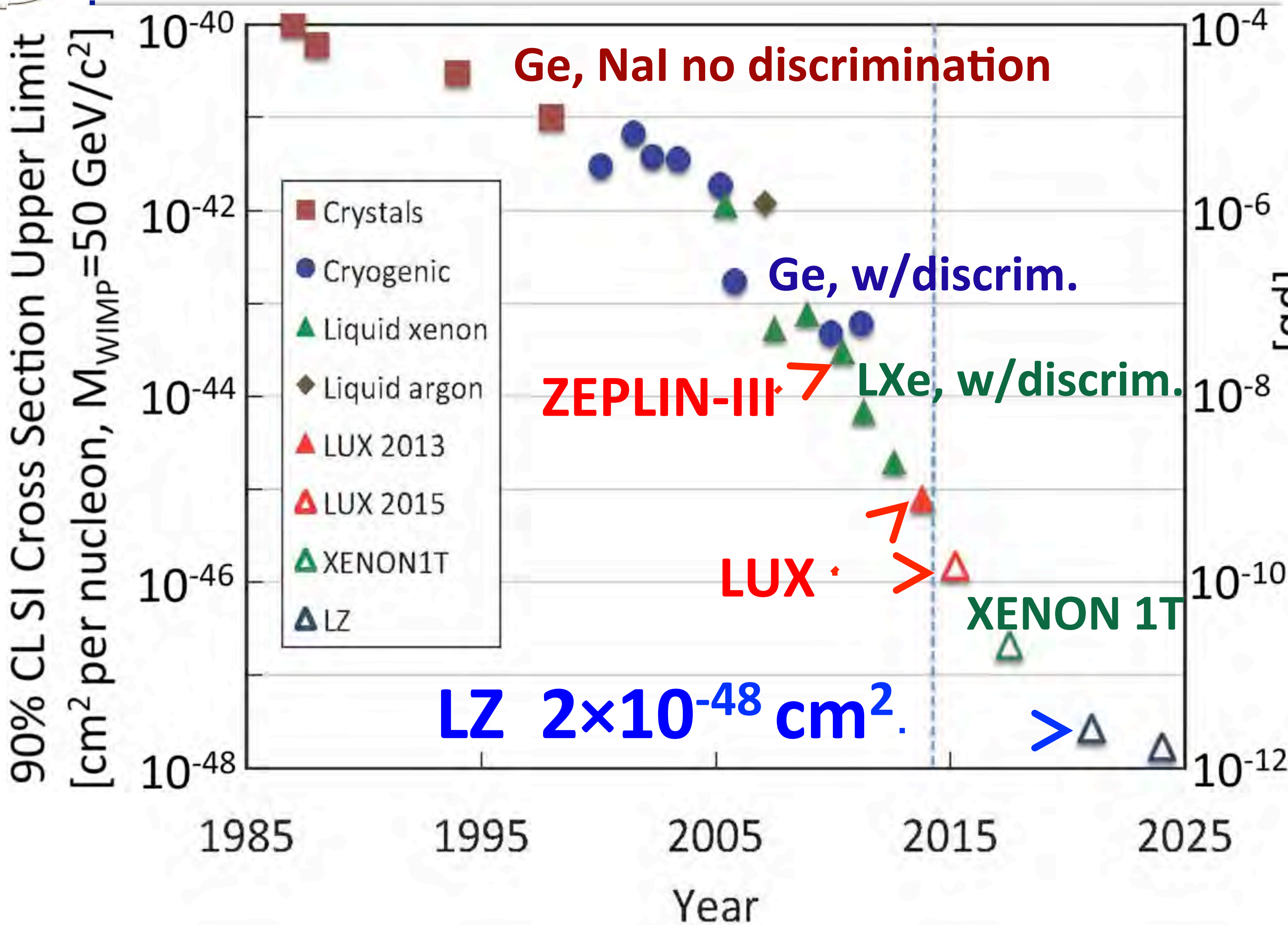
Spin Dependent Neutron



Spin Dependent Proton



Time Evolution



Running Time

- Sensitivity vs. running time.
- 1,000 days is the nominal.
- Baseline backgrounds
- Rapid improvement in sensitivity
- Potential to eventually get to ~ 1×10^{-48} cm^2