LUX-ZEPLIN (LZ) Status

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June 10, 2015
WIN-2015. Heidelberg

LZ = LUX + ZEPLIN

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

29 institutions currently
About 160 people
Continuing to expand internationally

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
University of Sheffield (UK)

LZ Timeline

Year	Month	Activity
2012	March	LZ (LUX-ZEPLIN) collaboration formed
	May	First Collaboration Meeting
	Septembe	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 Beginning procurements(Xenon, 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*

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

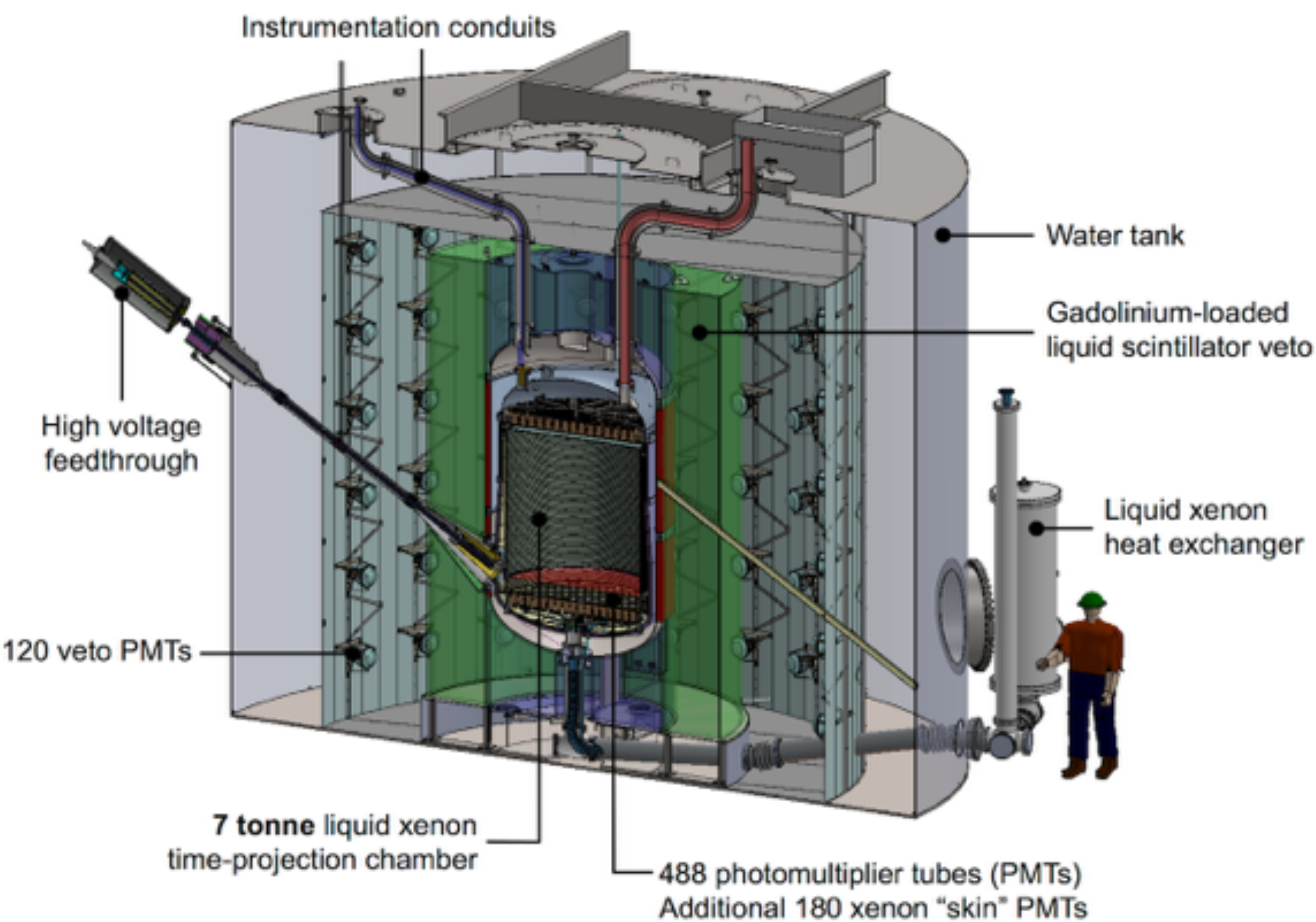
Scale Up ≈50 in Fiducial Mass

LZ

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

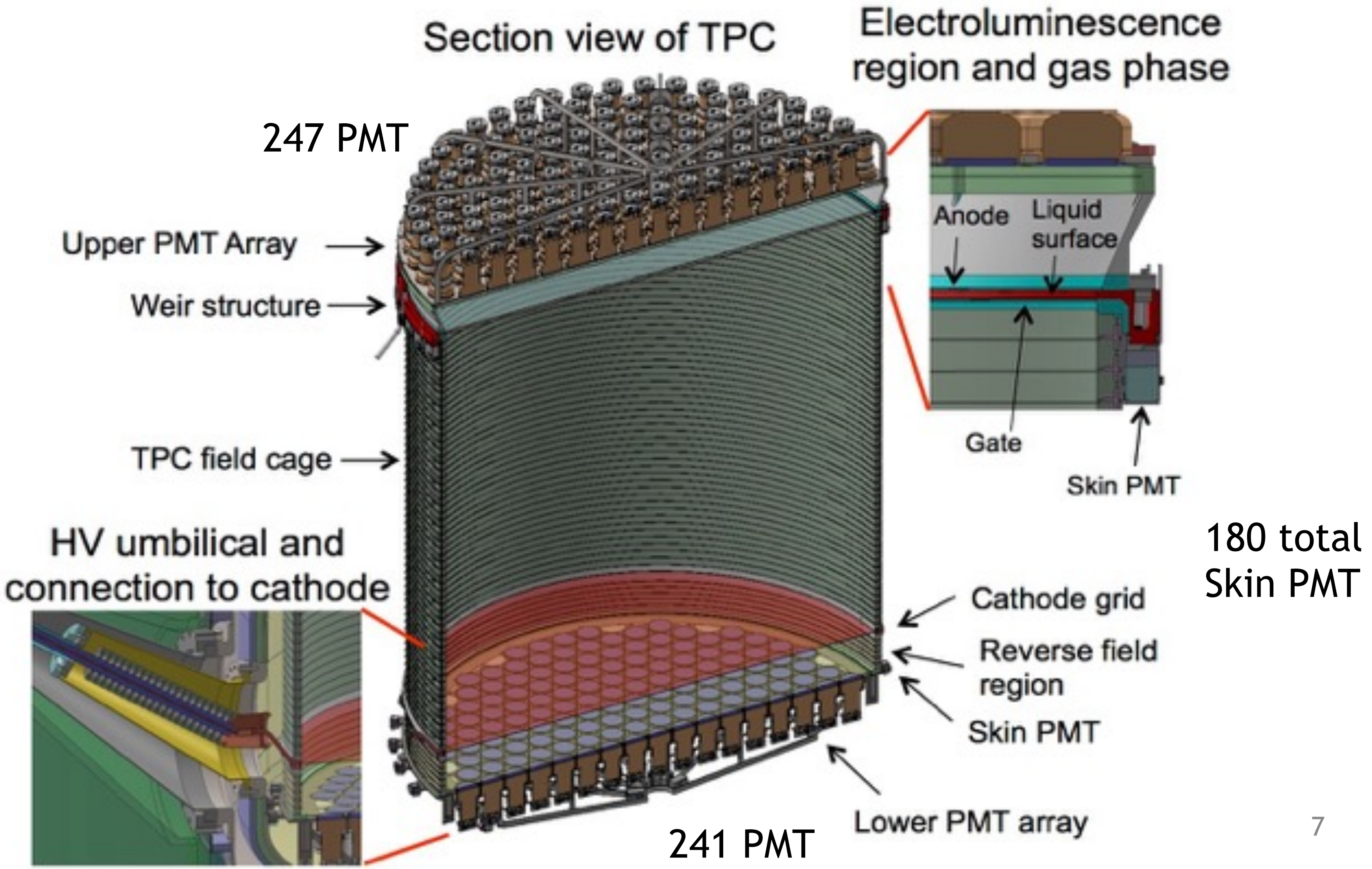
LUX

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

Xe Detector

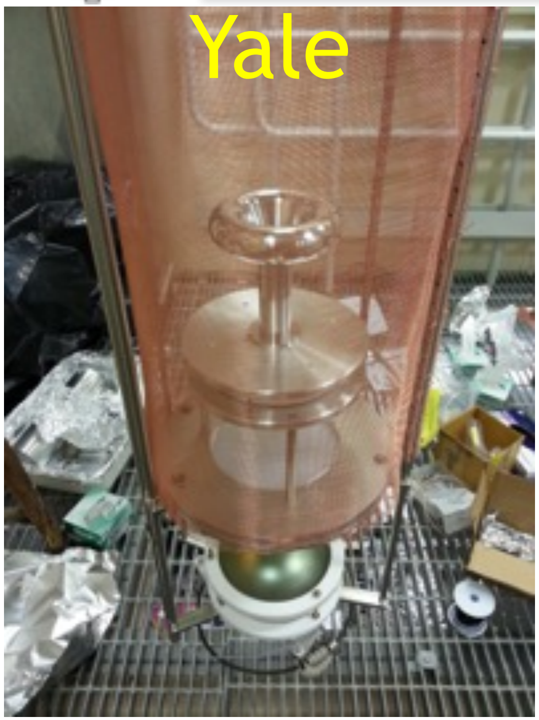

Section view of TPC
Electroluminescence region and gas phase
247 PMT
Upper PMT Array
Weir structure
Anode
Liquid surface
Gate
Skin PMT
TPC field cage
180 total Skin PMT
HV umbilical and connection to cathode
Cathode grid
Reverse field region
Skin PMT
Lower PMT array
241 PMT

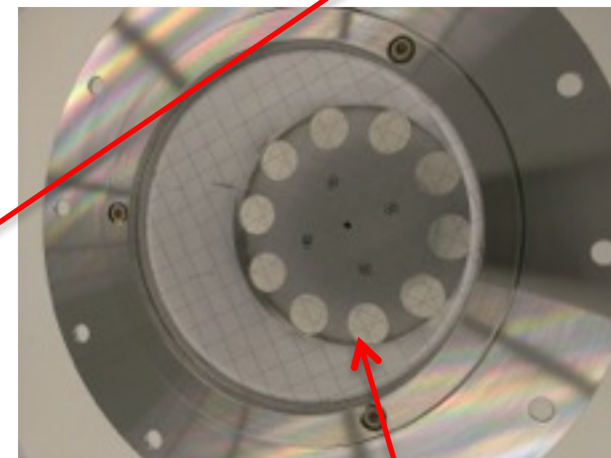
Xe Detector PMTs

- ✦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 radioassays started prior to fabrication.
  - First production tubes early 2016.
  - Joint US and UK effort
- ✦R8520-406 1” for skin region

High Voltage Studies

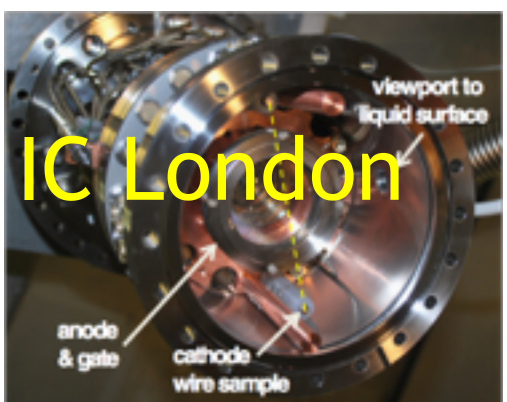
Reverse field region cathode grid





3 RFR rings (half height)

Ground grid

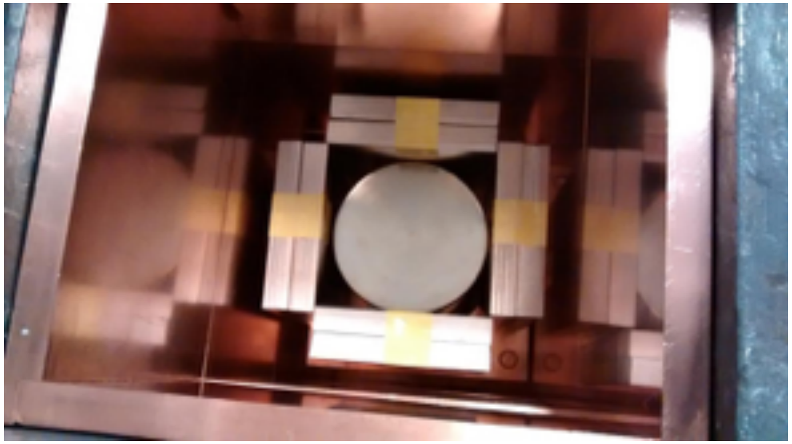


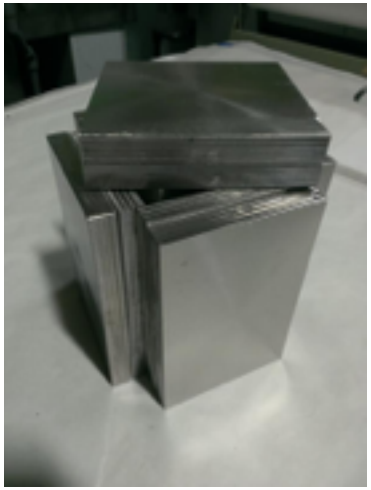
Testing for cathode HV at Yale moving to LBNL and Berkeley. Also development at IC London.

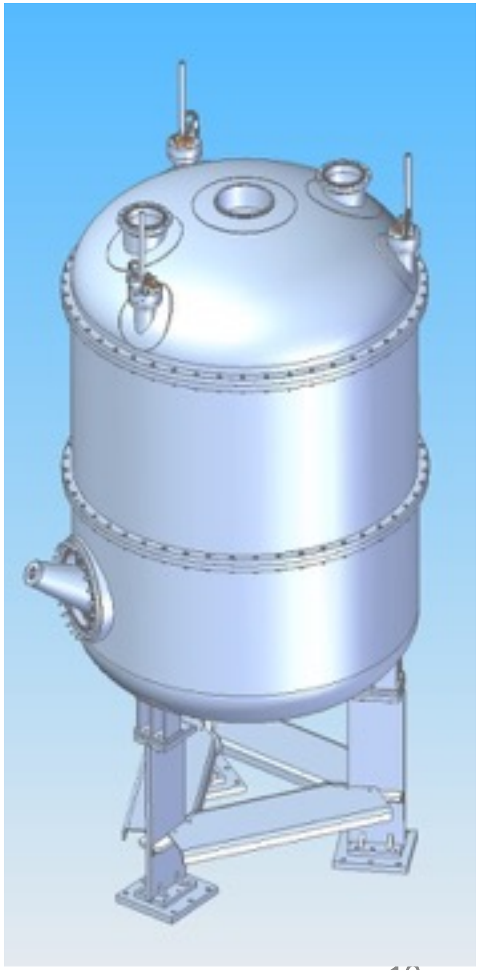
- ✦Cathode voltage Design goal: 200 kV
- ✦LZ nominal operating goal: 100 kV (750 V/cm)
- ✦Feedthrough prototype tested to 200 kV (Dielectric Sciences 2077)

Cryostat Vessels

- UK responsibility
- Low background titanium chosen
- 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





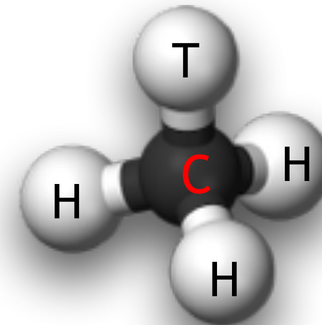


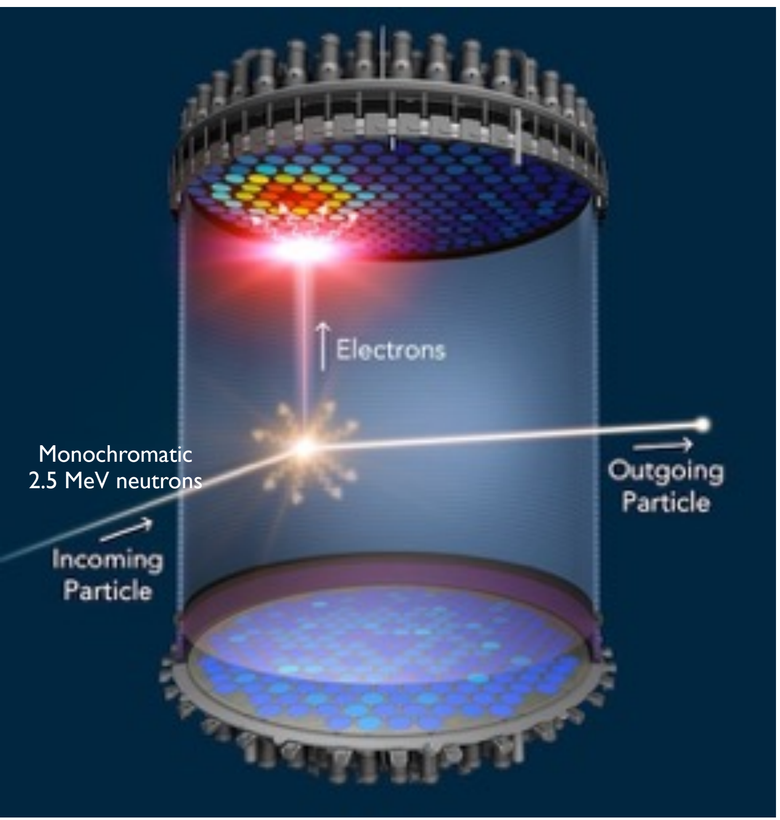
^{85}Kr Removal and Screening

- ✦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

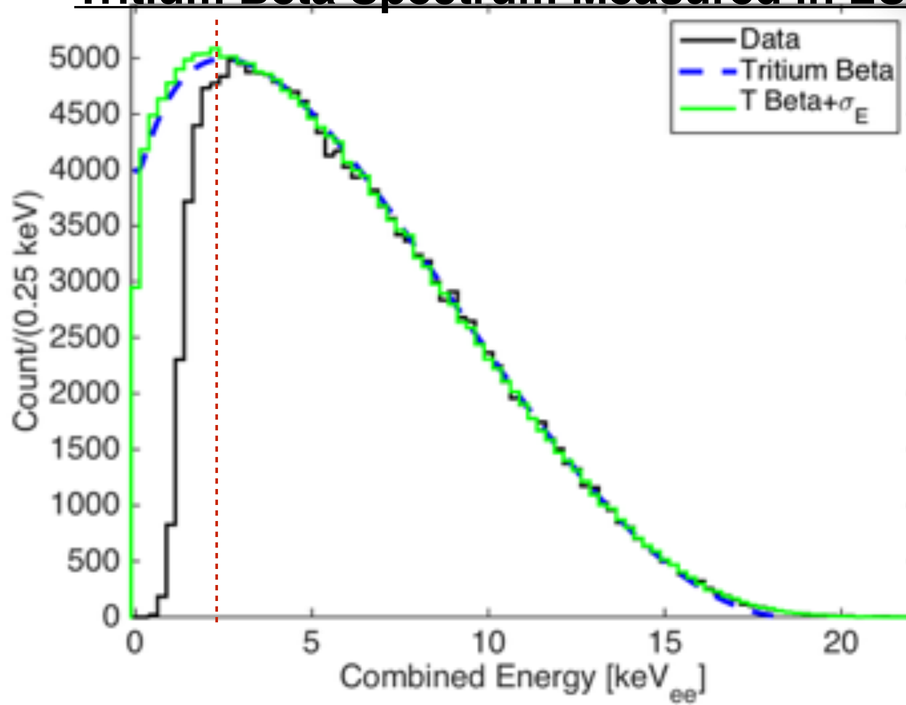
LZ Calibrations

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





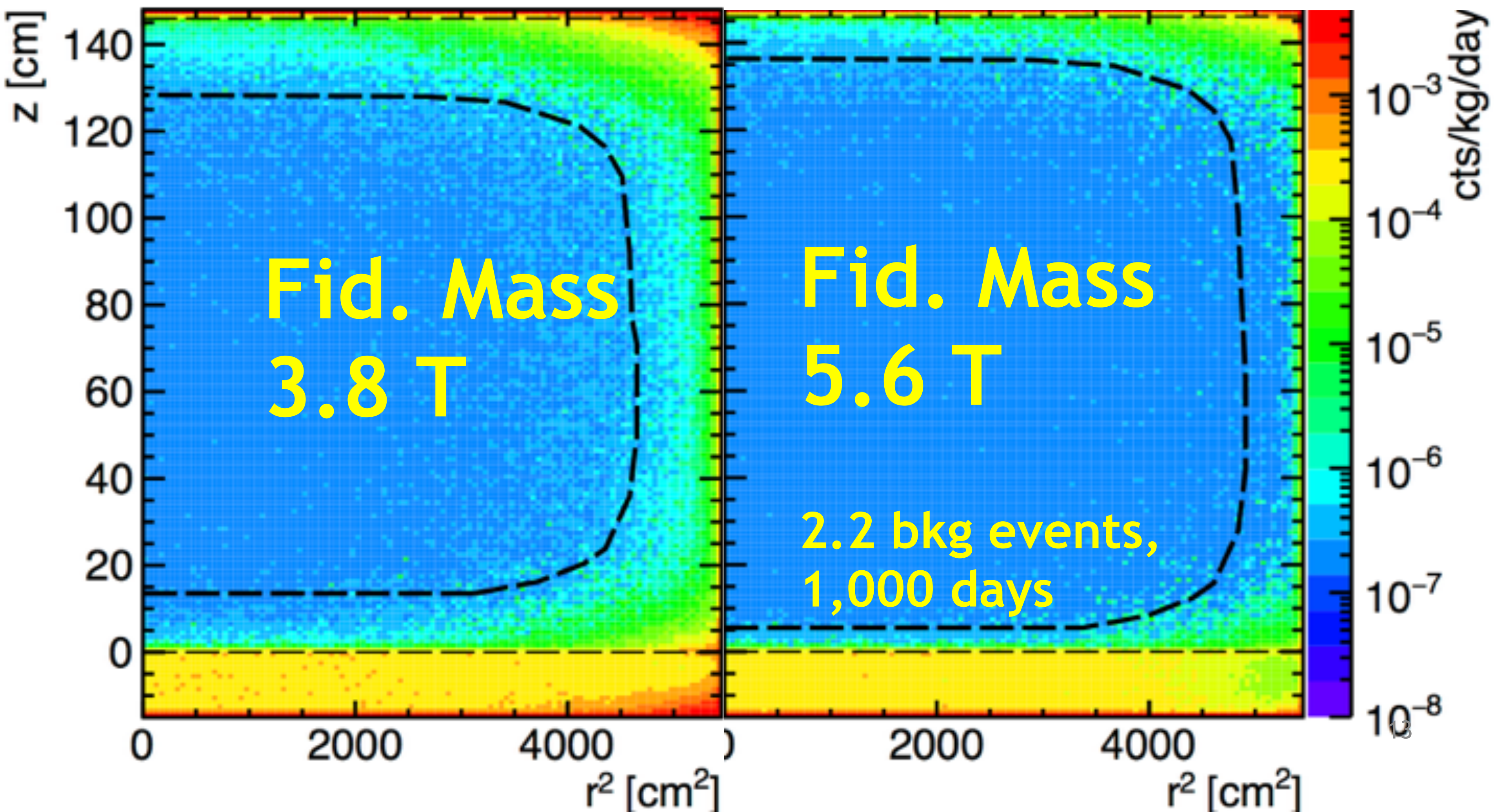
Tritium Beta Spectrum Measured in LUX



Background Modeled

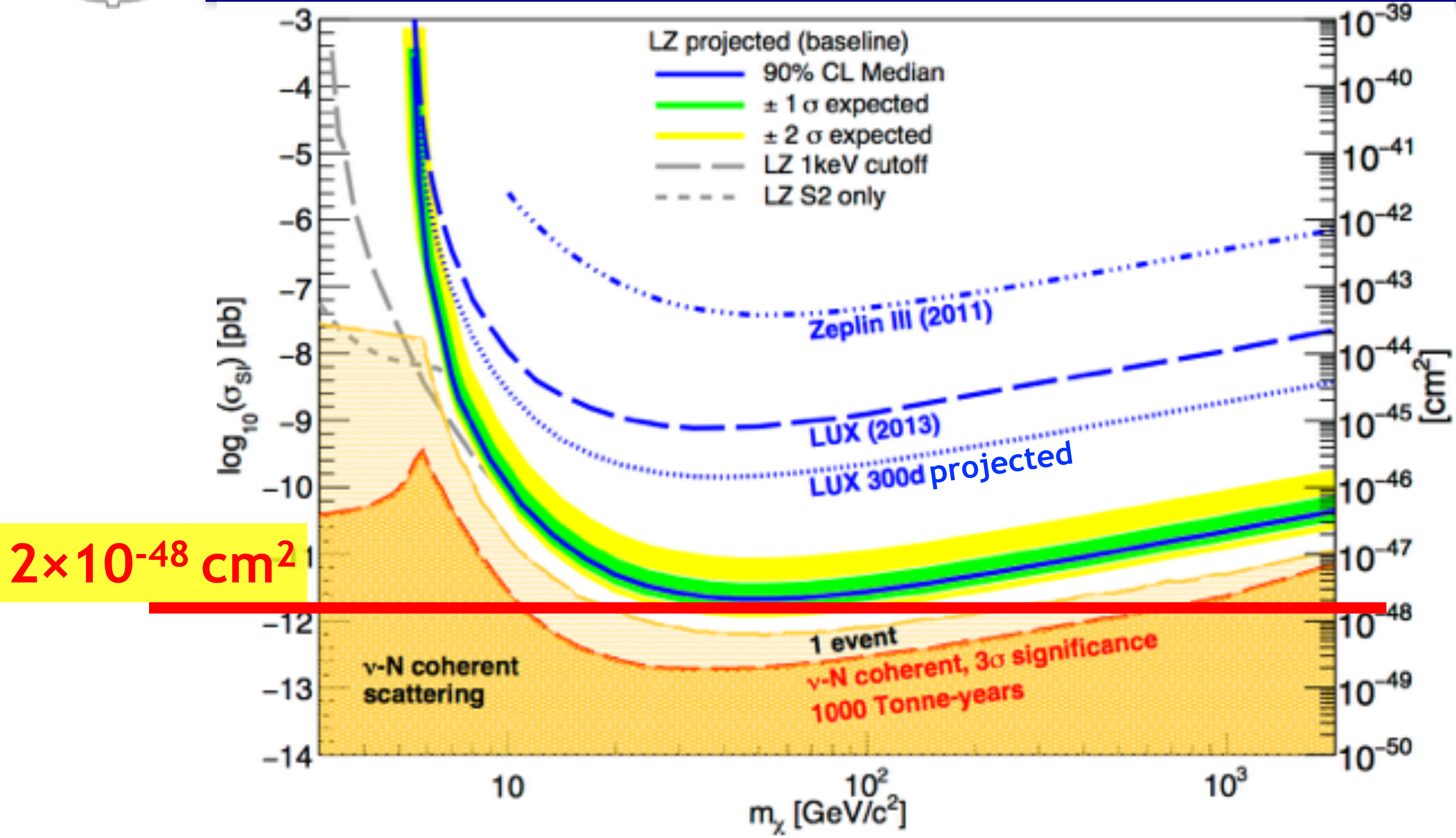
Just LXe TPC

Use LXe skin, Outer Det.



Projected Sensitivity – Spin Independent

(LZ 5.6 Tonnes, 1000 live days)



- **Excellent projected sensitivity limited by neutrinos only.**

Other Physics…

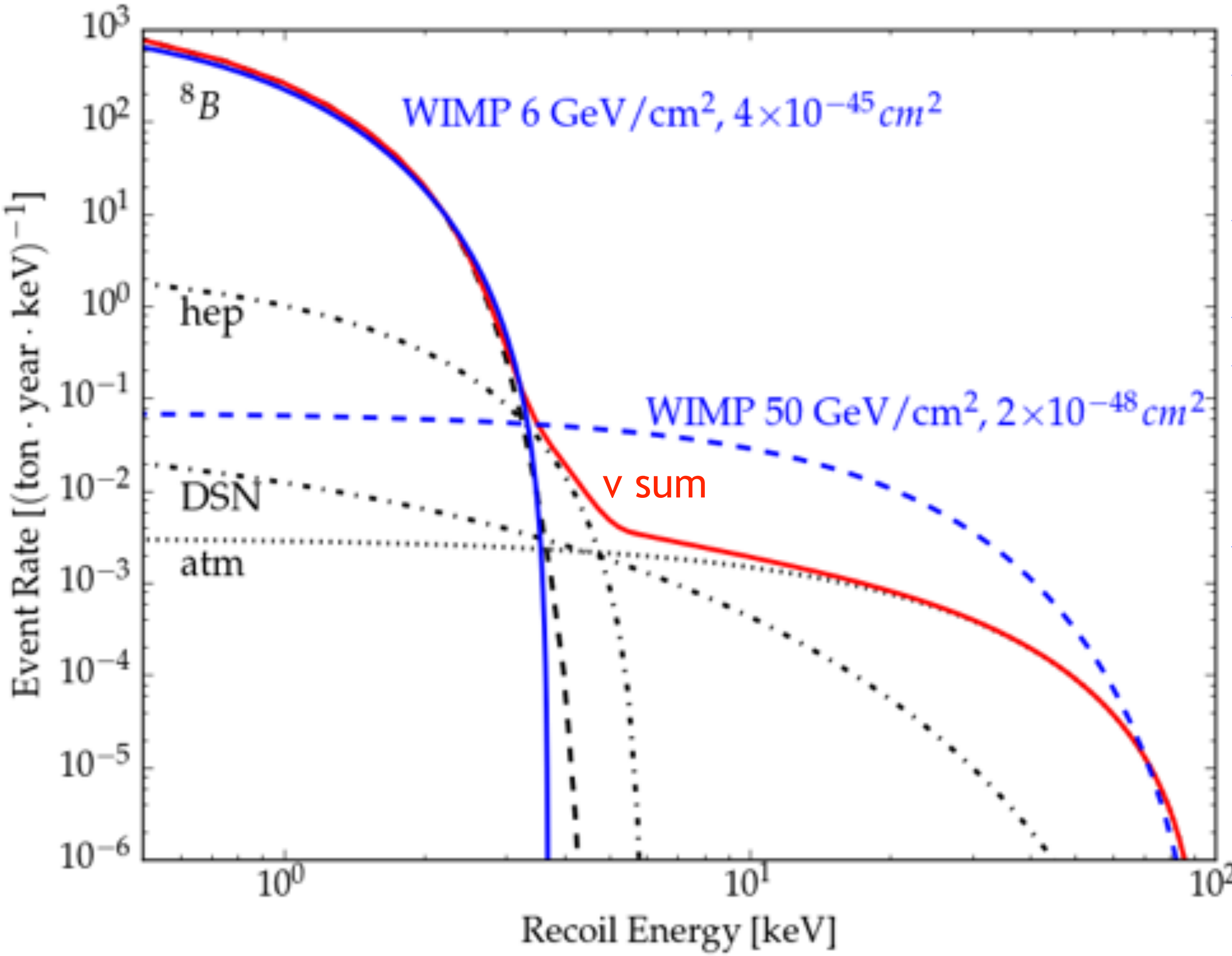
- ✦Axions

- ✦Effective Field Theory Interaction Decomposition

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

- ✦Neutrino Physics
  - ▫ Coherent neutrino-nucleus scattering
  - ▫ Solar
  - ▫ Supernova

Coherent ν-nucleus Scattering

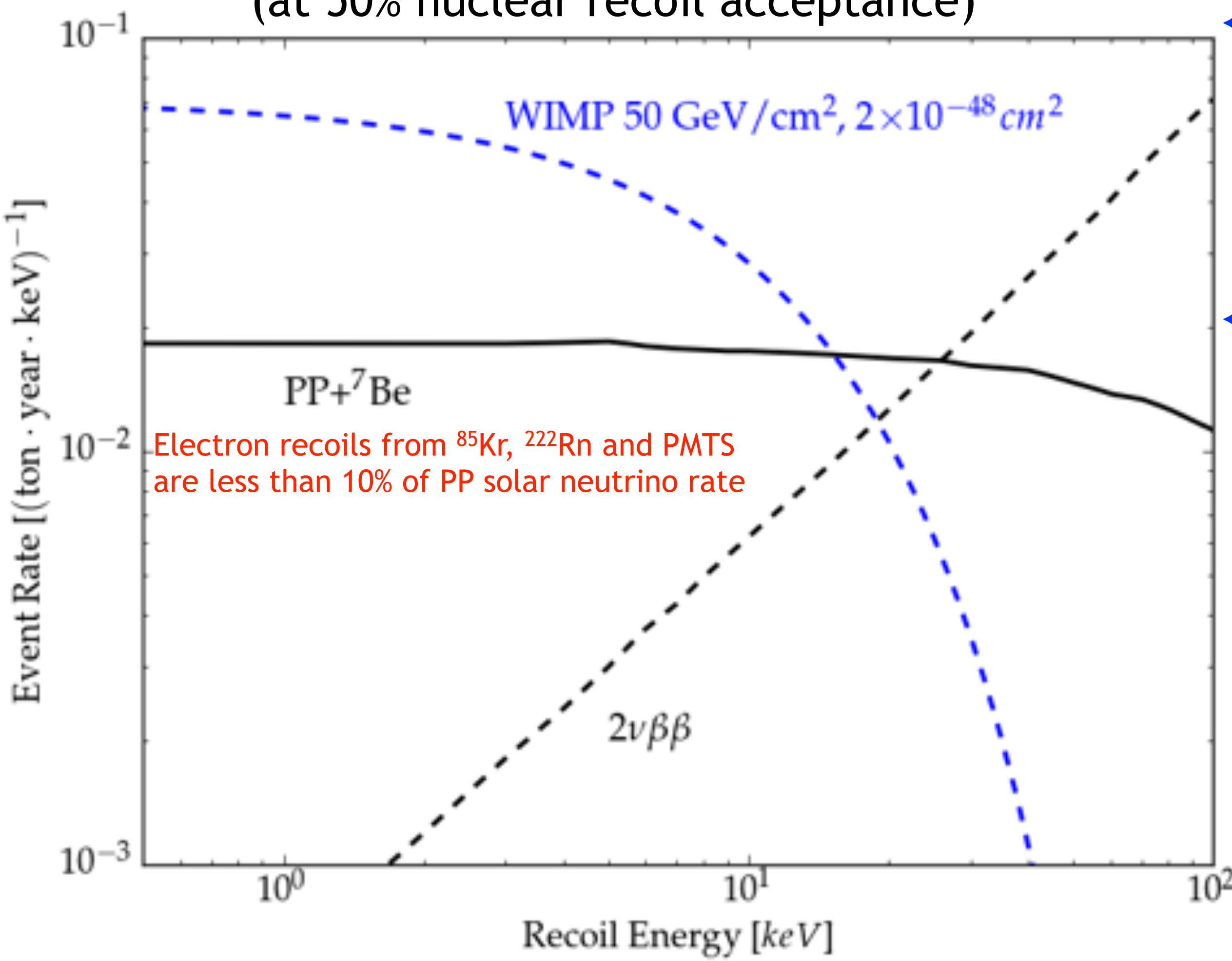


- ✦LZ may be the first to observe coherent neutrino-nucleus scattering
- ✦^{8}B Recoils mimic low mass WIMPs
- ✦WIMP Search 3-30 keV
- ✦Expect ~10 ^{8}B events and 0.5 events from others

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

ν-electron Scattering
-The dominant background

With 99.5% electron recoil rejection
(at 50% nuclear recoil acceptance)



- Wimp Search 1.5-6.5 keVee (and before 99.5% electron recoil rejection)
  - ~270 PP solar events
  - ~40 2vBB
- Improve measured solar neutrino luminosity to <5% from 10%

Conclusions

- LZ Project 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 finally limited by neutrino-induced `background'

Extra Slides

Xe Detector Prototyping

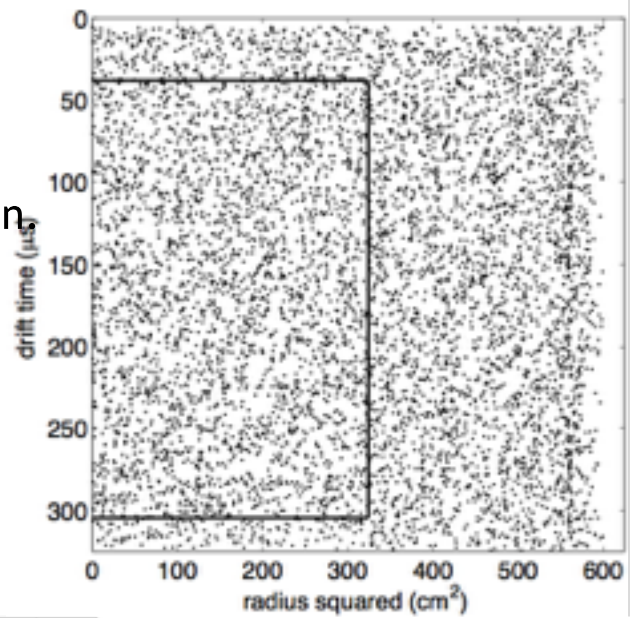
- ✦Extensive program of prototype development underway
- ✦Three general approaches
  - Testing in liquid argon, primarily of HV elements, at Yale and soon at LBNL
  - Design choice and validation in small (few kg) LXe test chambers in many locations: LLNL, Yale-> UC Berkeley, LBNL, U Michigan, UC Davis,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

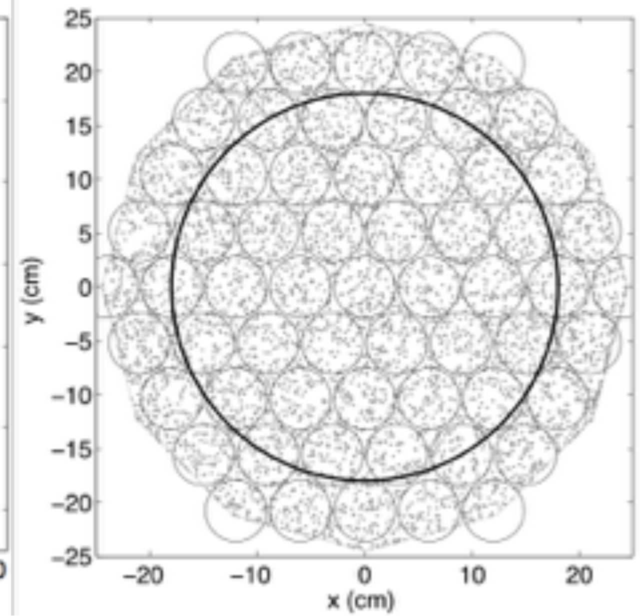
—Design Status Summary

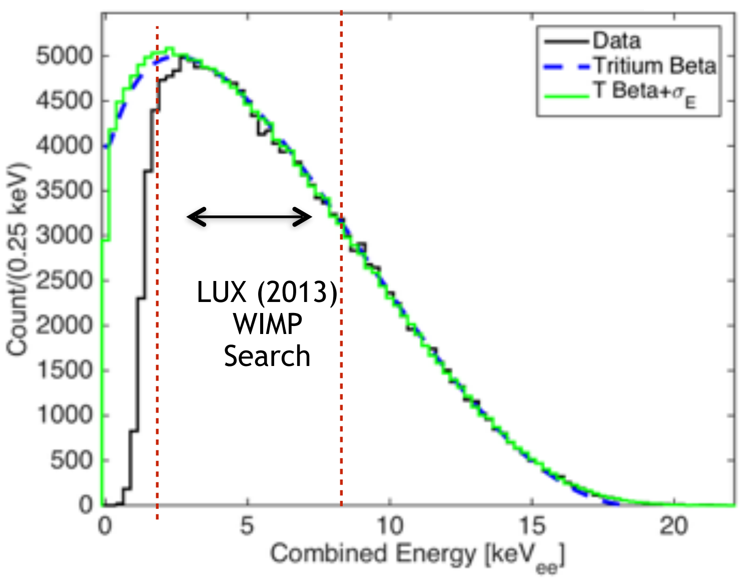
- ✦ Conceptual, and in some cases more advanced design, completed for all aspects of detector
- ✦ Conceptual Design Report to appear on arXiv
- ✦ Acquisition of Xenon started
- ✦ Procurement of PMTs and cryostat started
- ✦ Collaboration – wide prototype program underway to validate design
- ✦ Backgrounds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

Tritiated-Methane, The Ideal ER Calibration Source

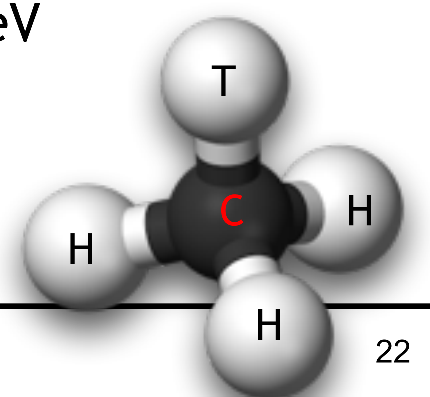
- Methane diffuses much slower than bare tritium.
- Dissolved uniformly in the xenon.
- Removed with standard purification technology.
- Used to calibrate the fiducial volume.



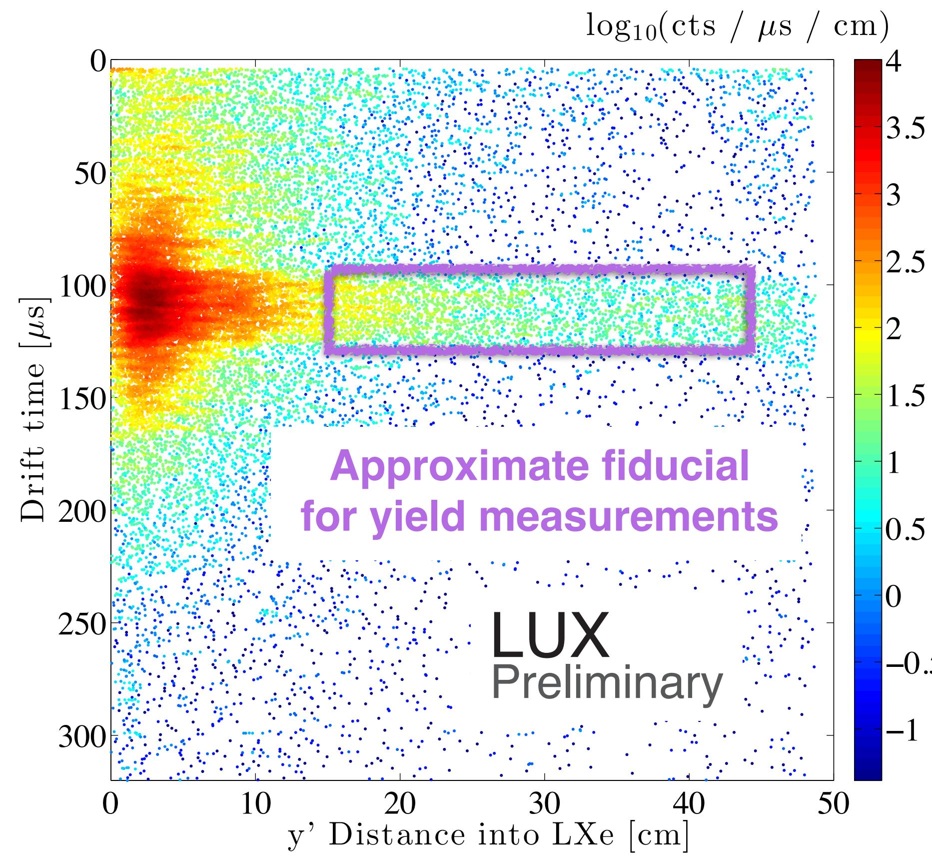




- Single Scatter ER events in energy region of interest: 0.1 keV to 18 keV
- Mean energy: 5 keV
- Peak energy: 2.5 keV



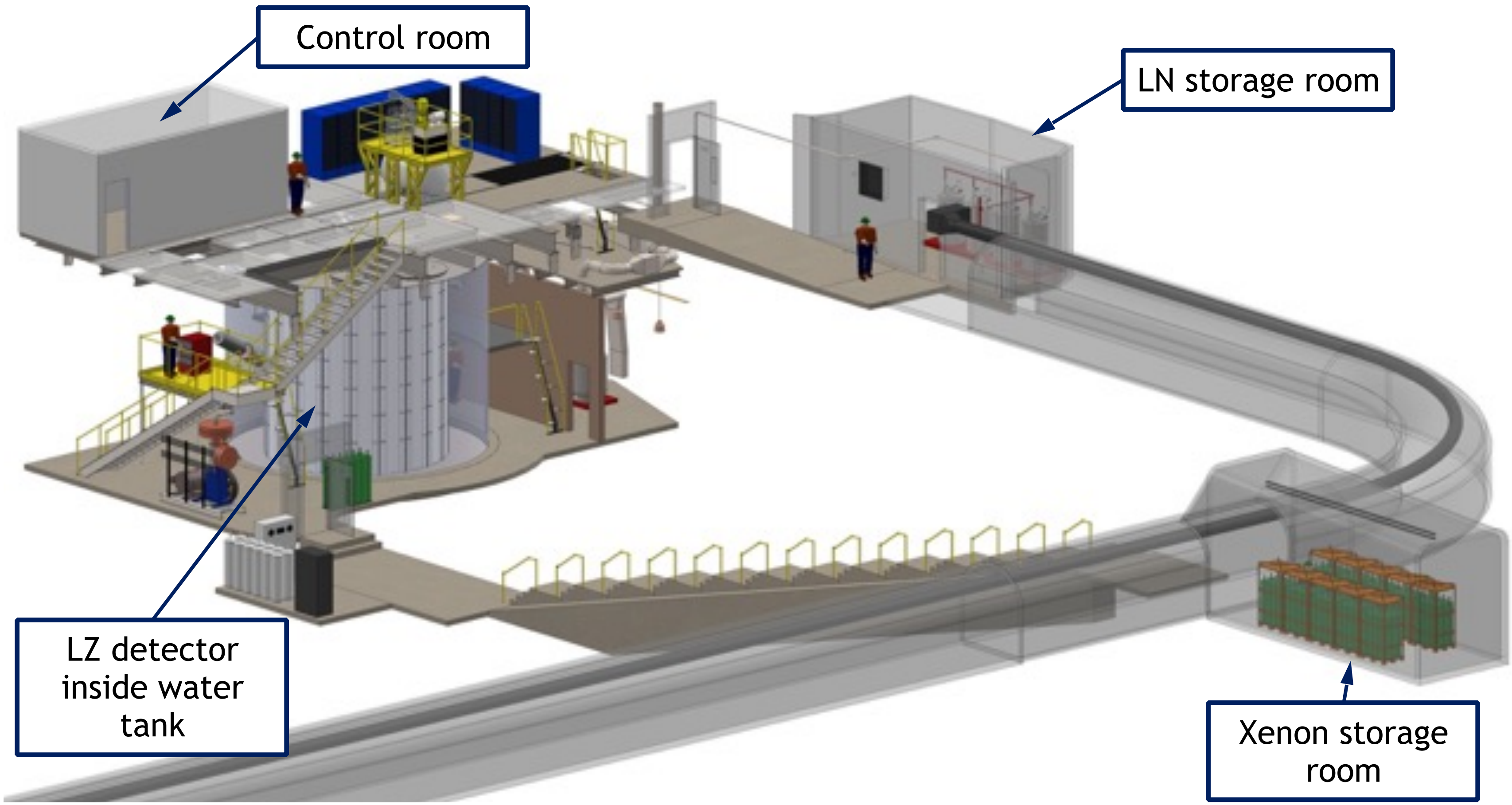
Adelphi DD108 Neutron Generator Installed Outside LUX Water Tank



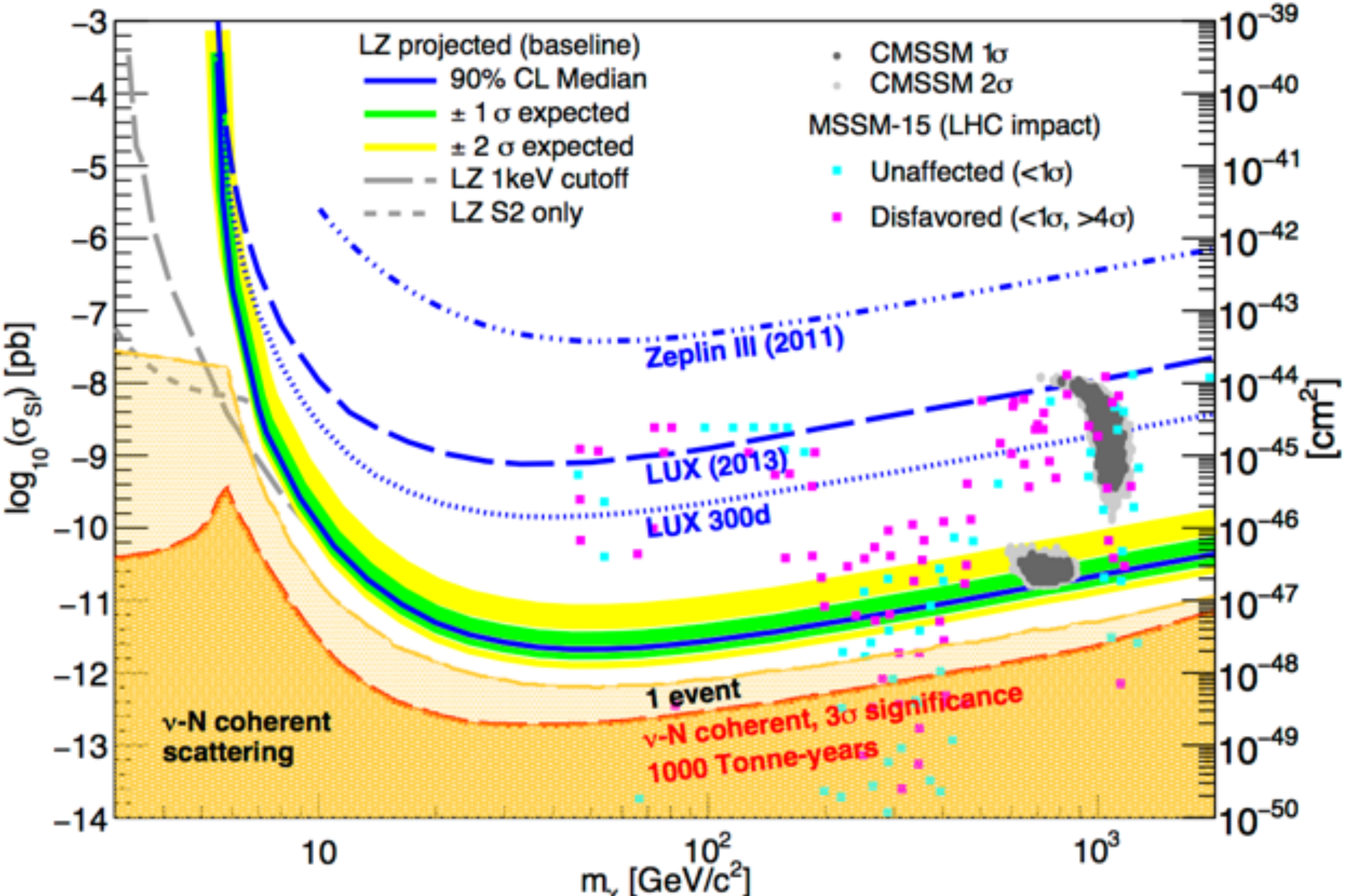
- This cut eliminates shine from passive materials and ensures 95% of neutrons in beam sample have energy within 4% of 2.45 MeV
- The mean energy of neutrons produced at 90° by the DD108 was measured to be 2.45 ± 0.05 MeV at Brown University

LZ Underground at SURF

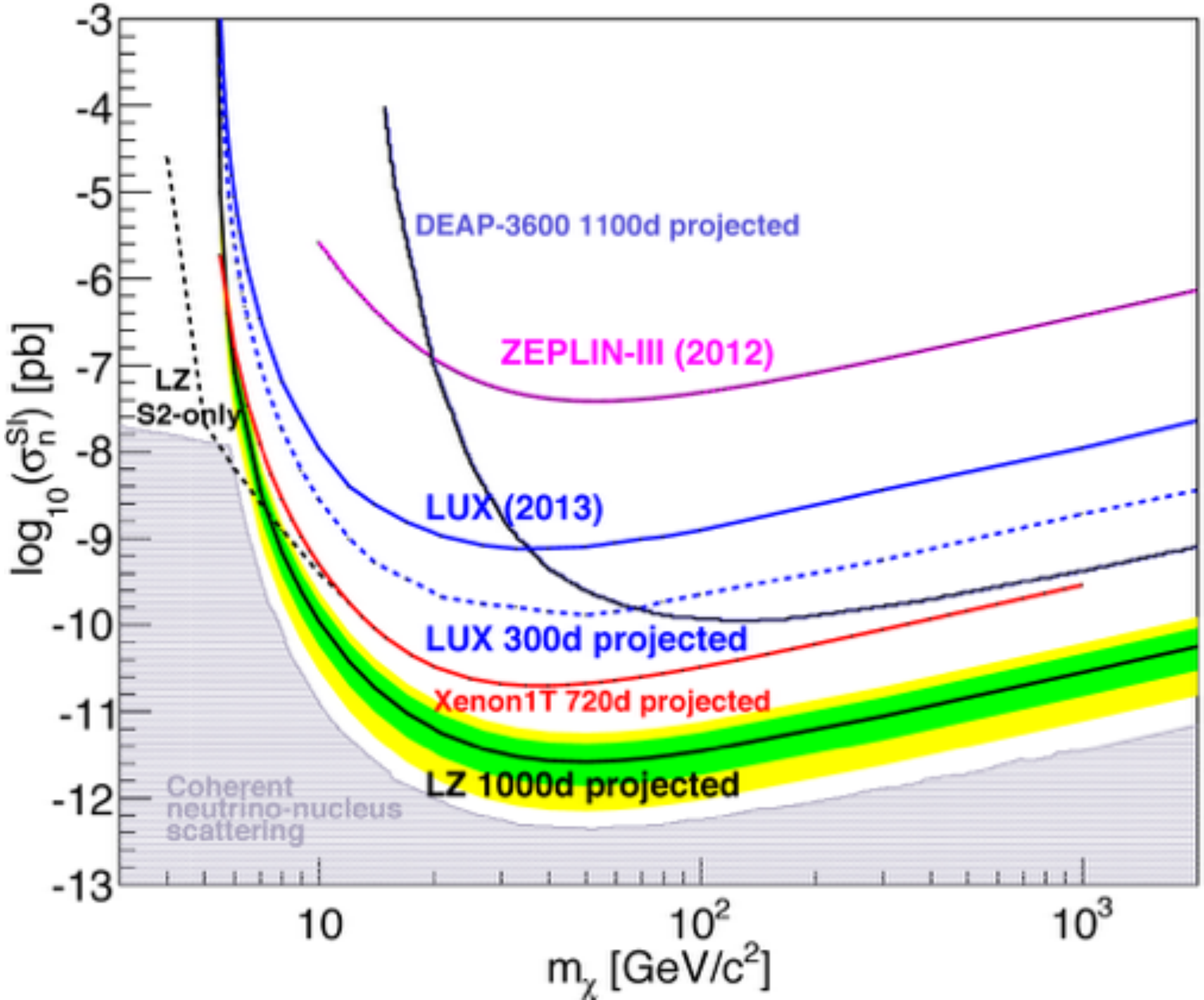
Years of experience at SURF from LUX



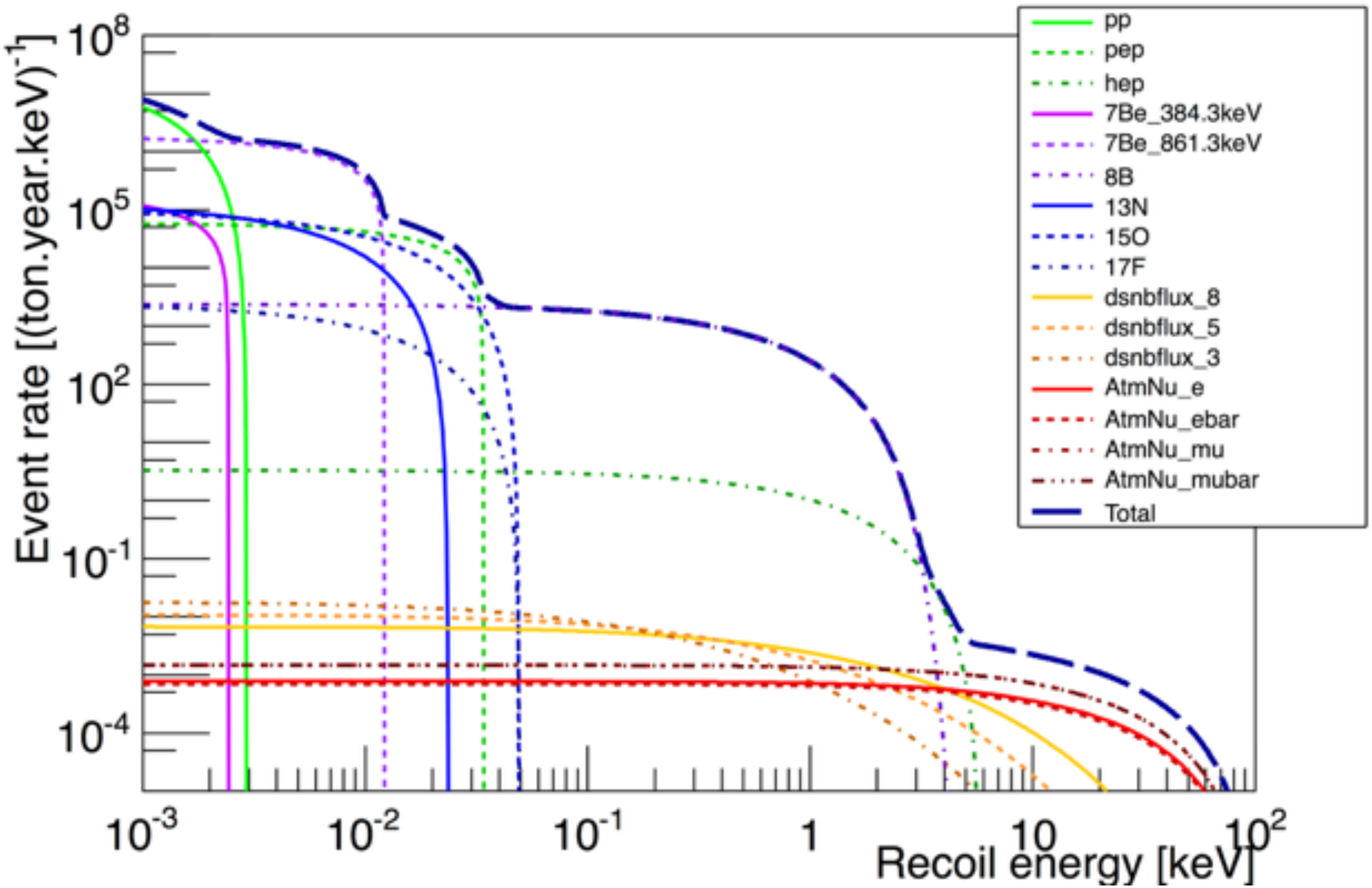
Sensitivity with SUSY Theories



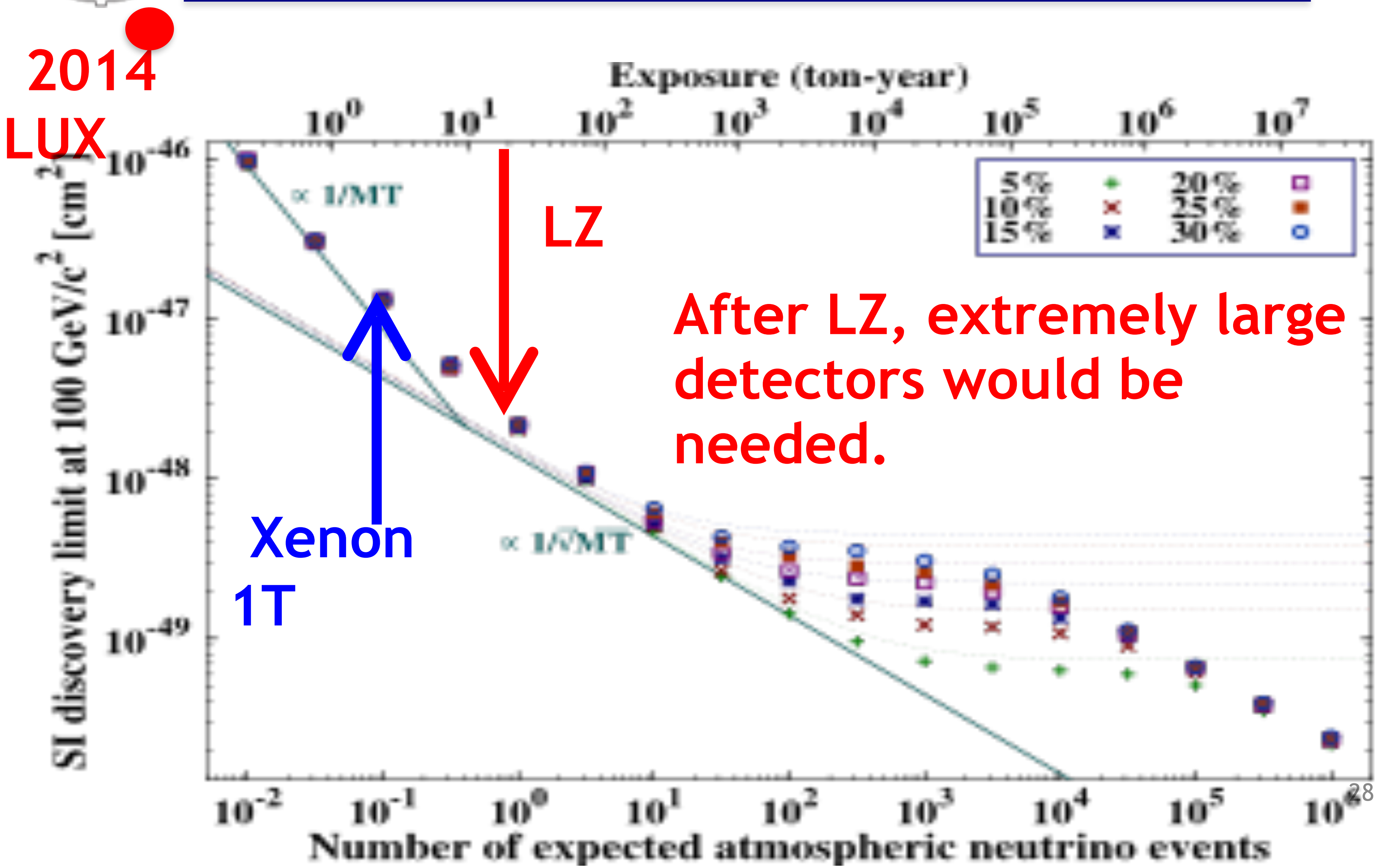
Sensitivity with Competition



Response of Xe to Neutrinos arXiv: 1307:5458

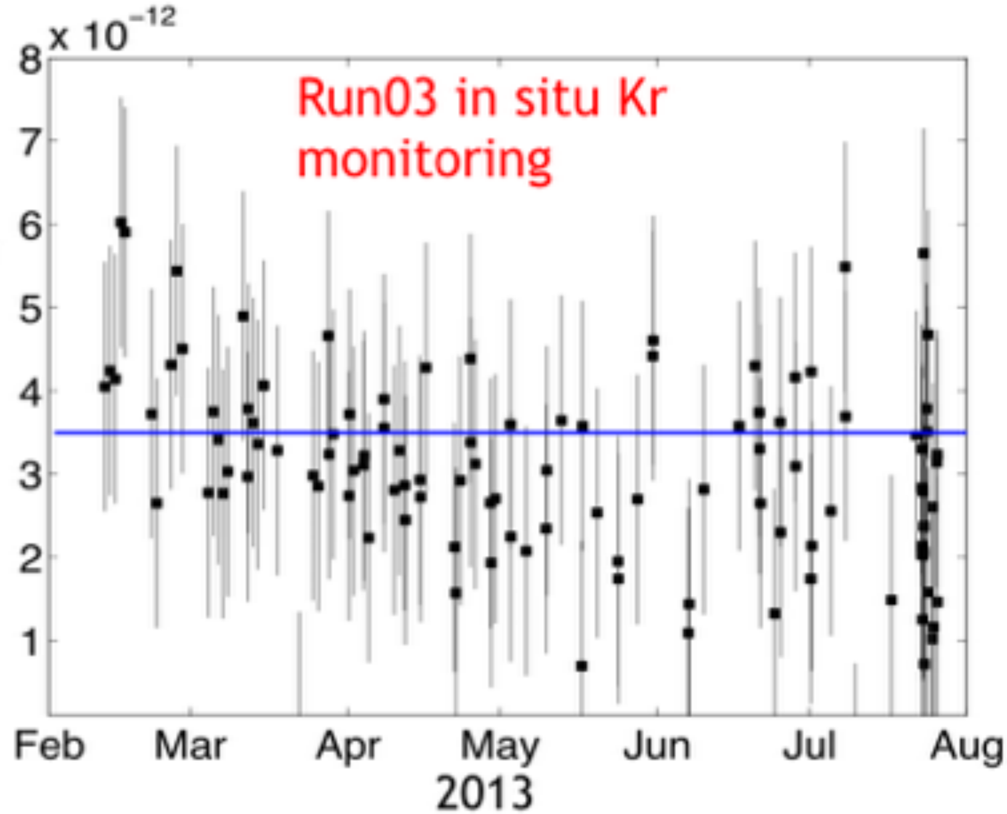


LZ – At the neutrino `knee' arXiv: 1408.3581



Monitoring ^{85}Kr background in LUX xenon

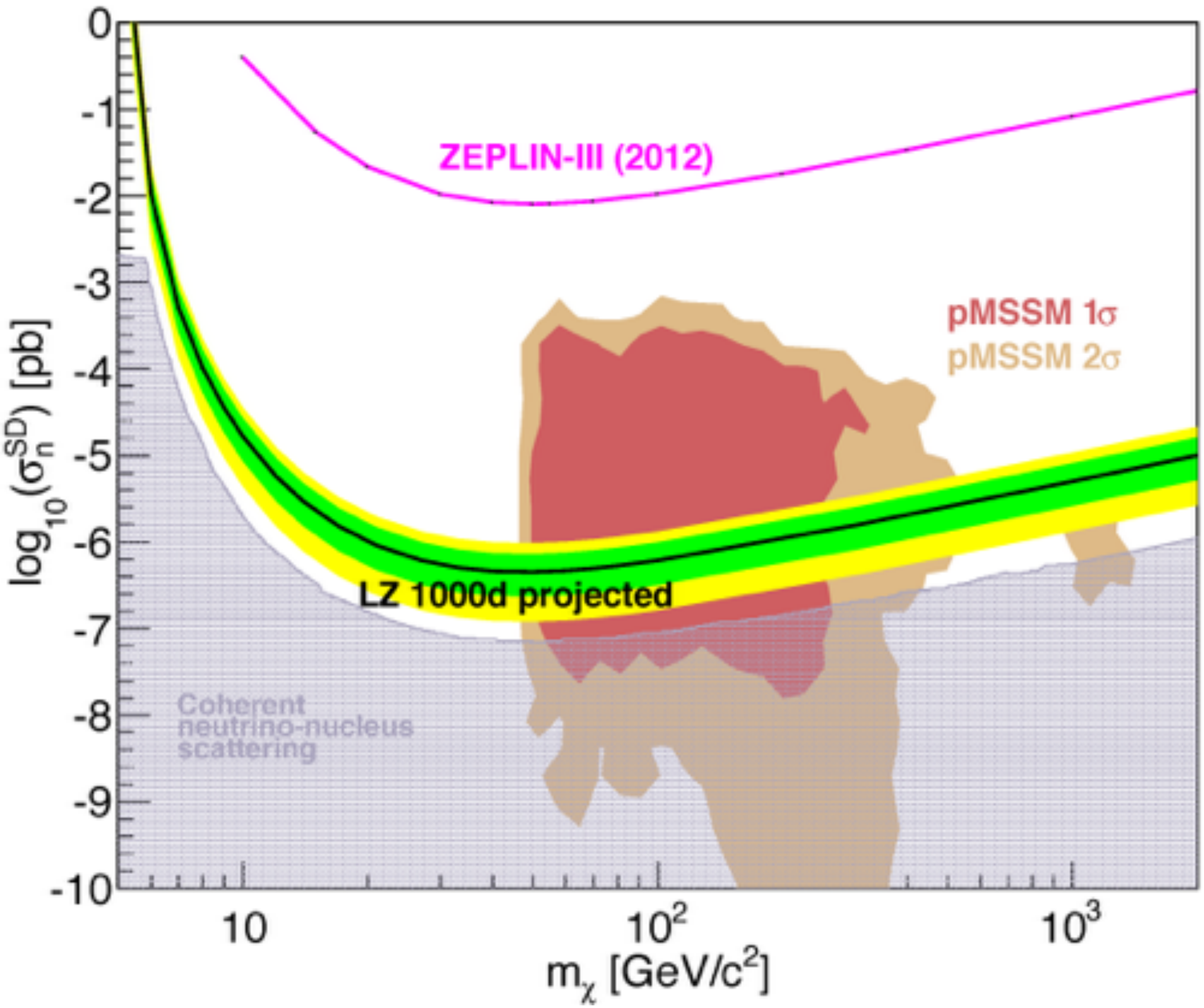
- Measure ^{84}Kr and to infer ^{nat}Kr/Xe
- Assume atmospheric abundance: ^{85}Kr/^{nat}Kr ratio: 2×10^{-11}
- Background goal: < 5 ppt Kr/Xe
- By the time ^{85}Kr decays show up in data analysis… It's too late!
  Set Xenon100 back a year
  (1 liter of air is all it takes)



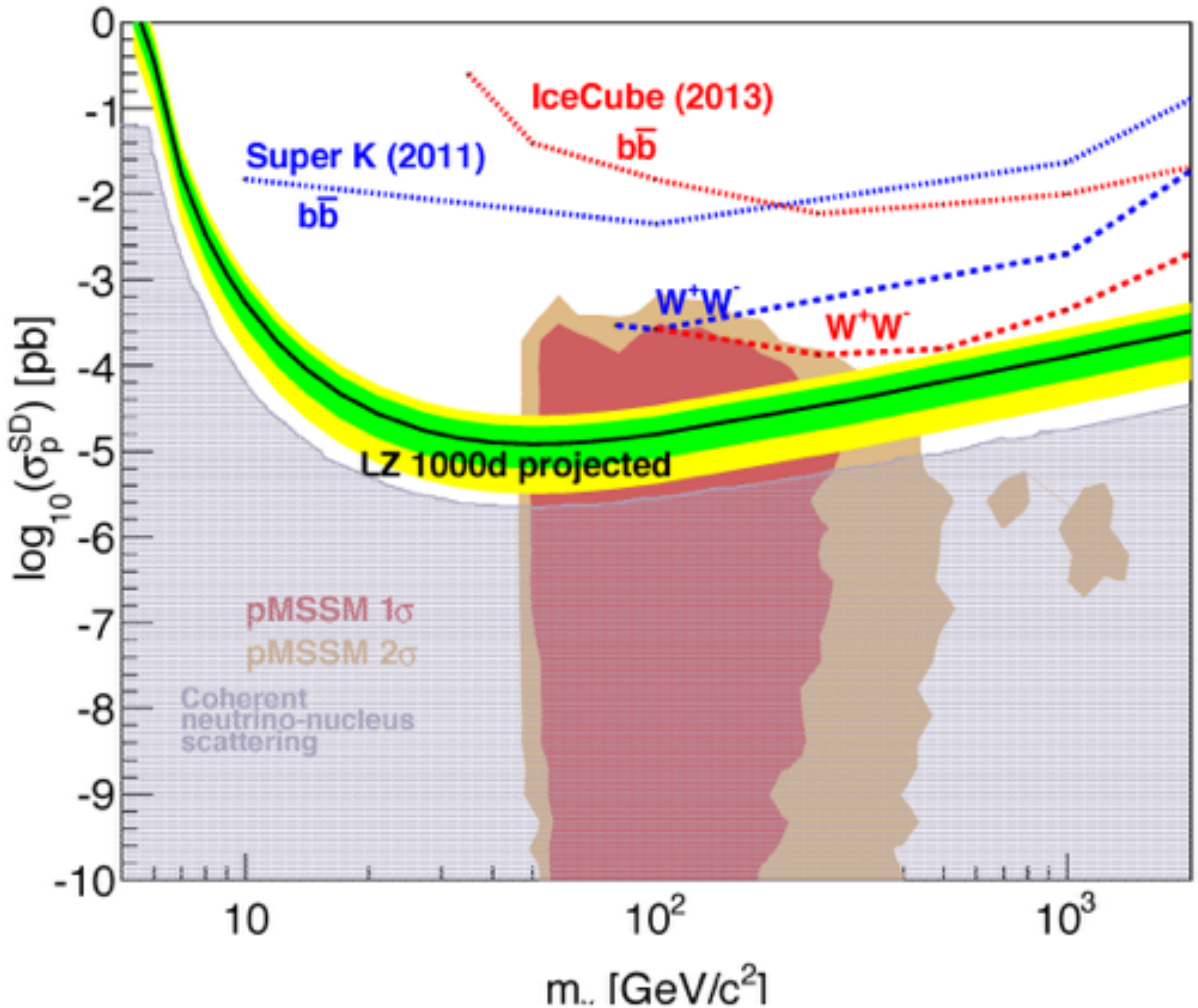
Source	Background Rate [$mDRU_{ee}$]
γ rays	$1.8 \pm 0.2_{stat} \pm 0.3_{sys}$
^{127}Xe	$0.5 \pm 0.02_{stat} \pm 0.1_{sys}$
^{214}Pb	$0.11 - 0.22$ (0.20 expected)
^{85}Kr	$0.17 \pm 0.10_{sys}$
Total predicted	$2.6 \pm 0.2_{stat} \pm 0.4_{sys}$
Total observed	$3.6 \pm 0.3_{stat}$

arXiv:1403.1299

Spin Dependent Neutron



Spin Dependent Proton



Time Evolution