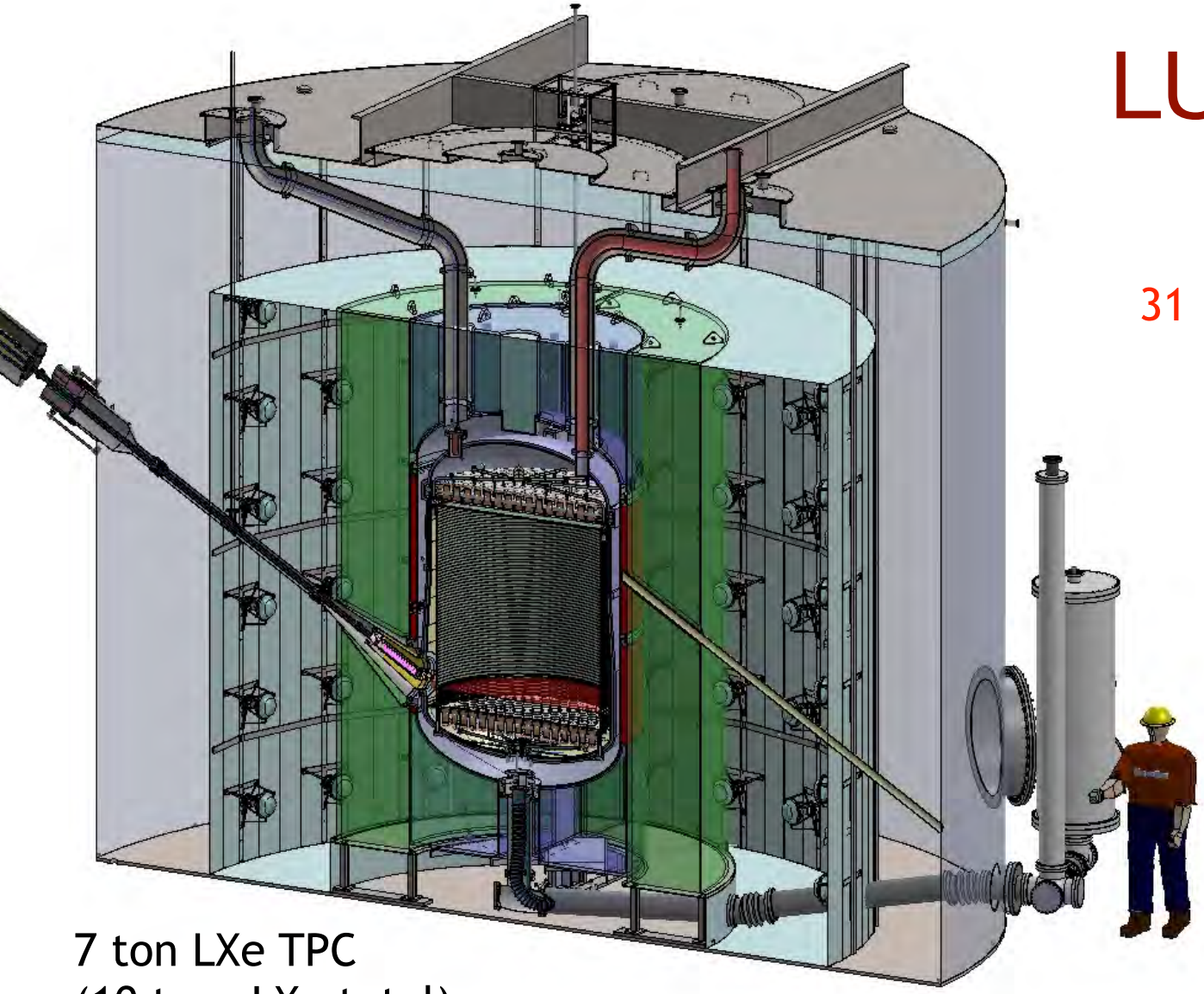
The LZ Experiment

Tom Shutt
SLAC

LUX - ZEPLIN



7 ton LXe TPC
(10 tons LXe total)

31 Institutions, ~200 people

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, Berkeley
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

Center for Underground Physics (Korea)

LIP Coimbra (Portugal)
MEPhI (Russia)
Edinburgh University (UK)

University of Liverpool (UK)

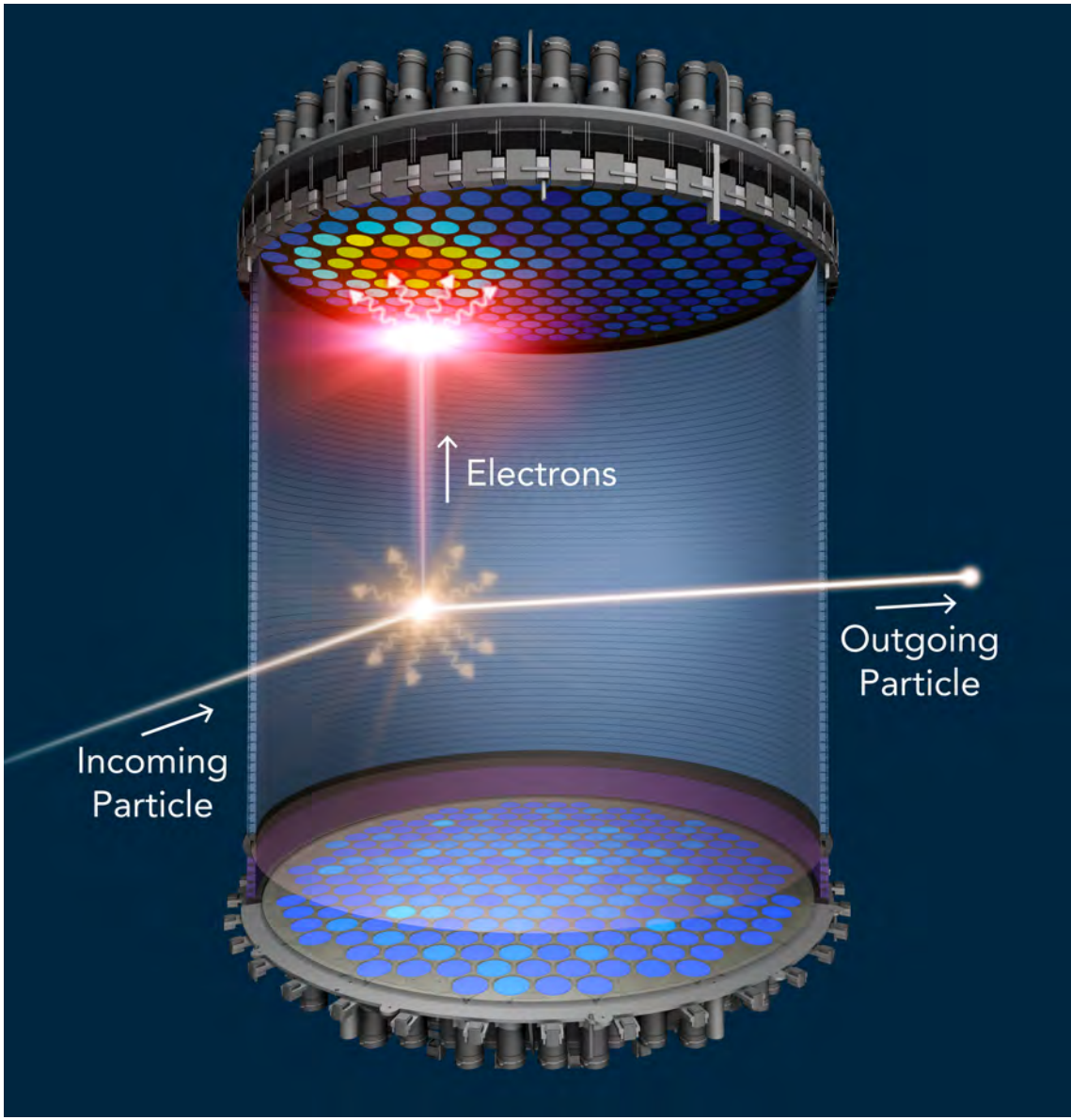
Imperial College London (UK)

University College London (UK)
University of Oxford (UK)
STFC Rutherford Appleton, and Daresbury, Laboratories (UK)

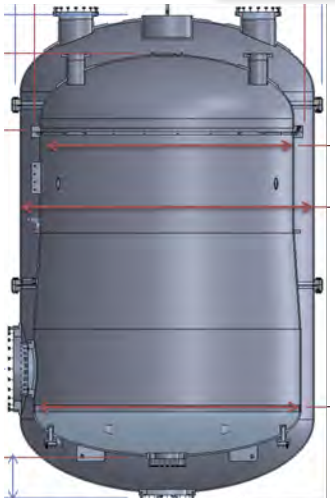
University of Sheffield (UK)

Principle of Operation

- 3D imaging rejects external backgrounds
- Electron-recoil backgrounds distinguished by ratio of charge / light ratio
- High purity LXe target
- Single photon and electron sensitivity

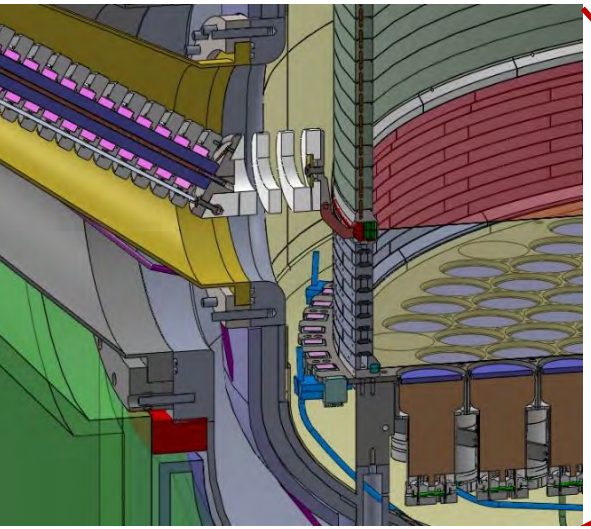


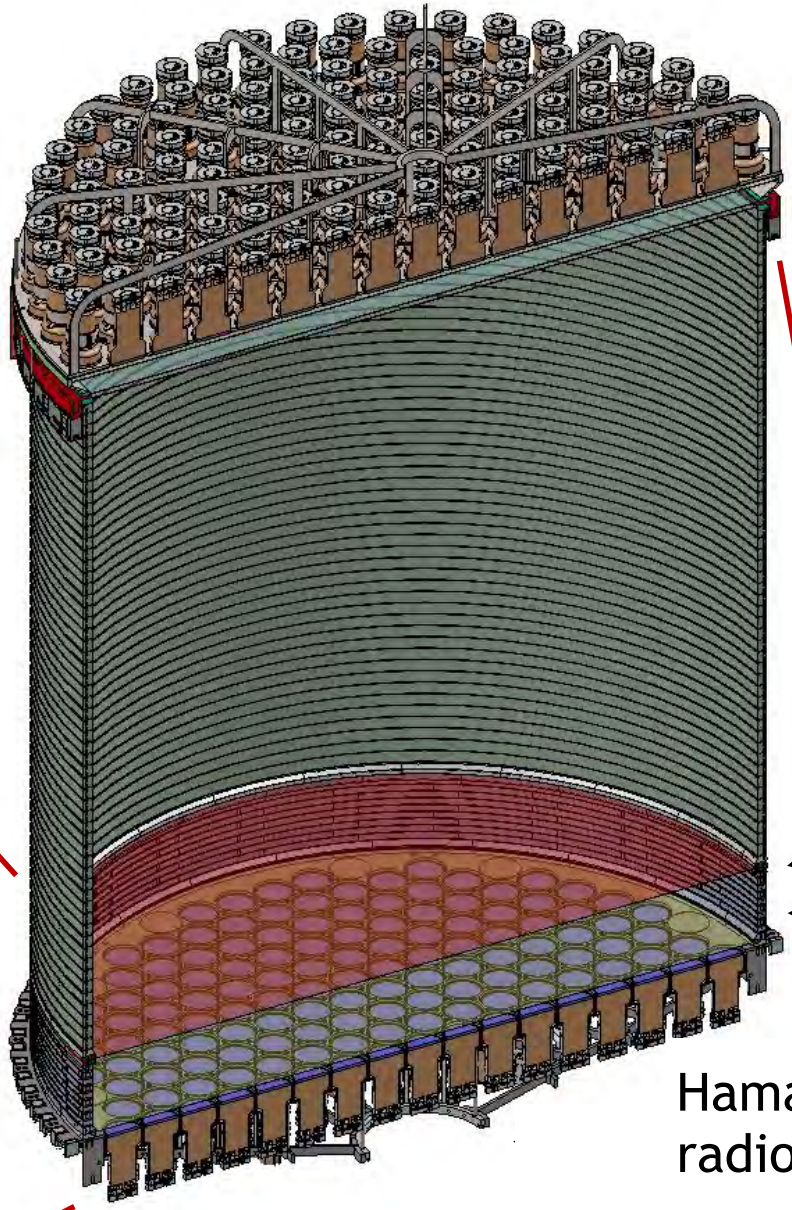
The LZ Detector



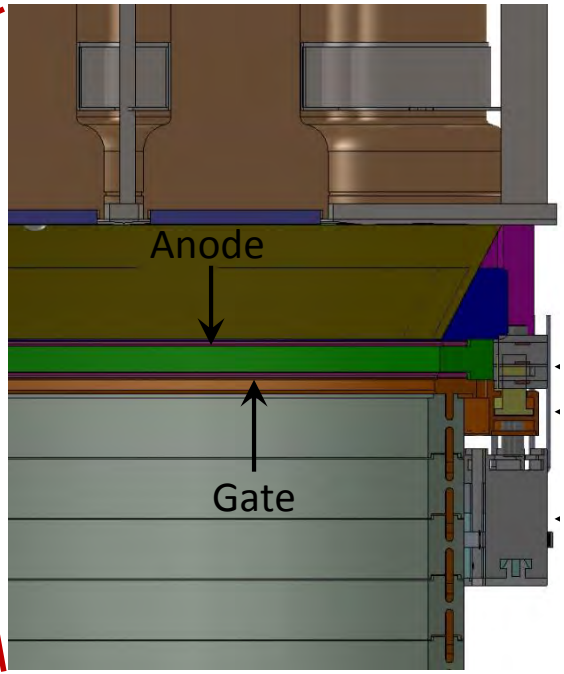
Low background
Ti vessels

HV UMBILICAL AND CONNECTION TO CATHODE





GAS PHASE AND ELECTROLUMINESCENCE REGION

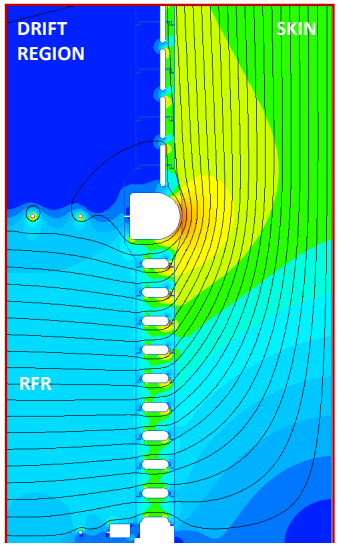


Hamamatsu R11410 3" Ø PMTs, radioactivity: ~mBq, high QE.

"Skin" between TPC and vessel

Performance drivers

- Backgrounds
- Purity for charge drift
- Light Collection
- Drift field, low electron + photon emission
  - Discrimination
  - Threshold
  - Grids: surface fields vs light collection
- Extensive test program: small chambers, HV in LAr, and System Test - T. Biesiadzinksi's talk



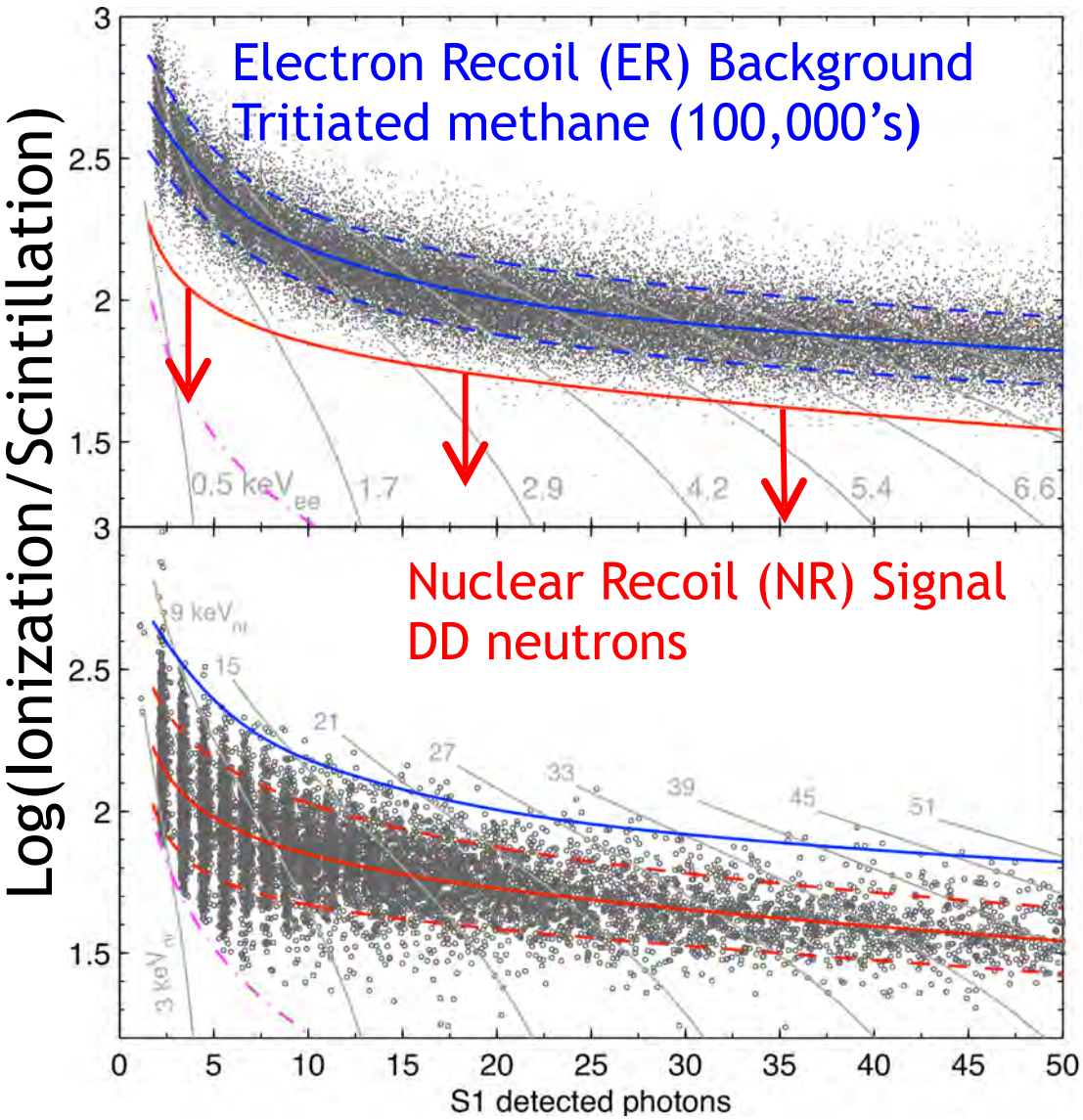
	Requirement / Baseline	Goal
Cathode HV	50 kV	100 kV
Light collection	7.5%	12%
e^- lifetime (μs)	850	2800
N-fold trigger coincidence	3	2
^{222}Rn	20 mBq	1 mBq

Prototype TPC Section

Discrimination

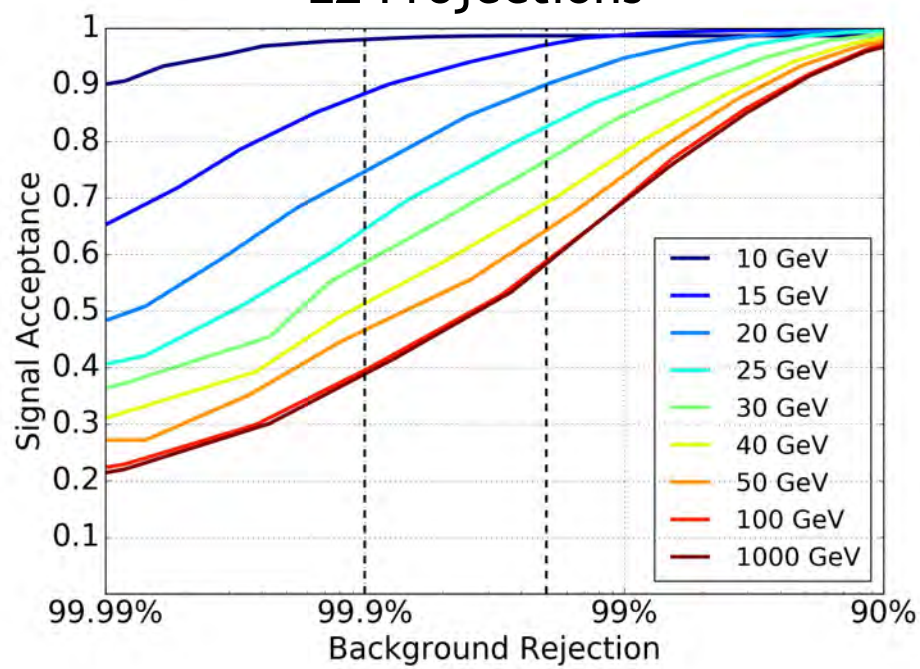
LUX - 99.8%

~50 GeV WIMP mass, 180 V/cm drift field



- LUX - new standard for discrimination calibration
- Discrimination strongest at lowest energy
- LZ requirement: ≥99.5%

LZ Projections



Signal production in liquid Xe

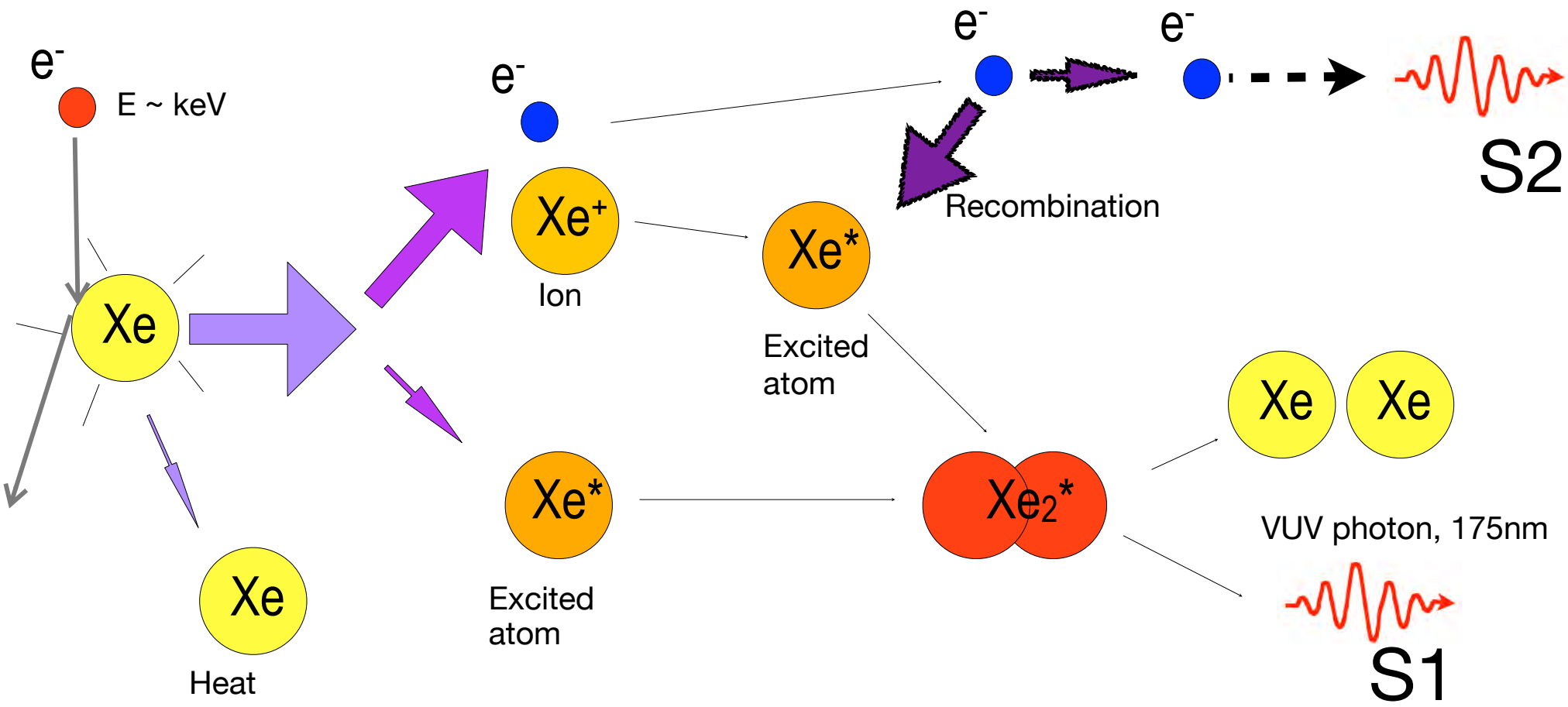


Figure: Gibson/Shutt

Electron Recoils
Low field, low energy

Signal production in liquid Xe

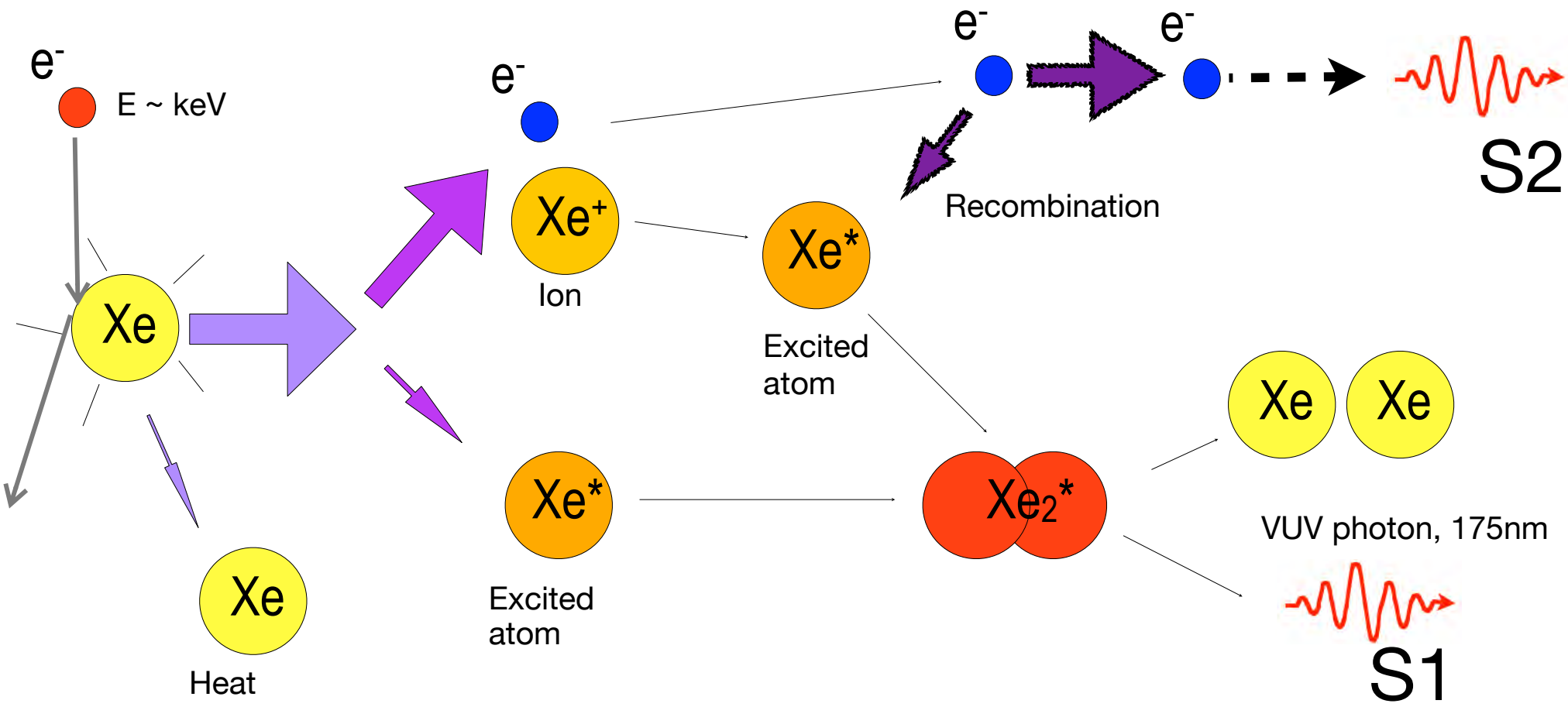


Figure: Gibson/Shutt

Electron Recoils

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Signal production in liquid Xe

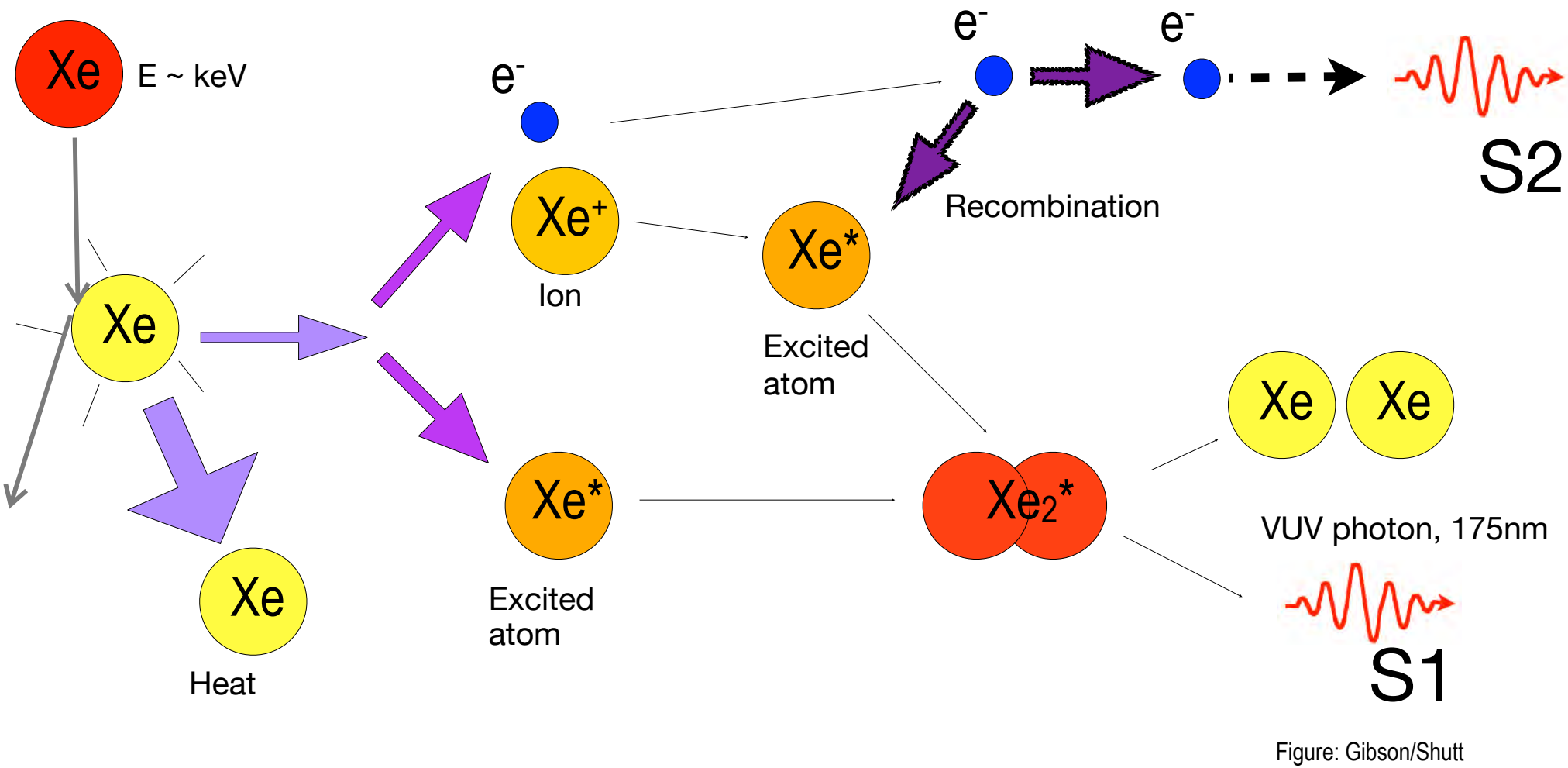
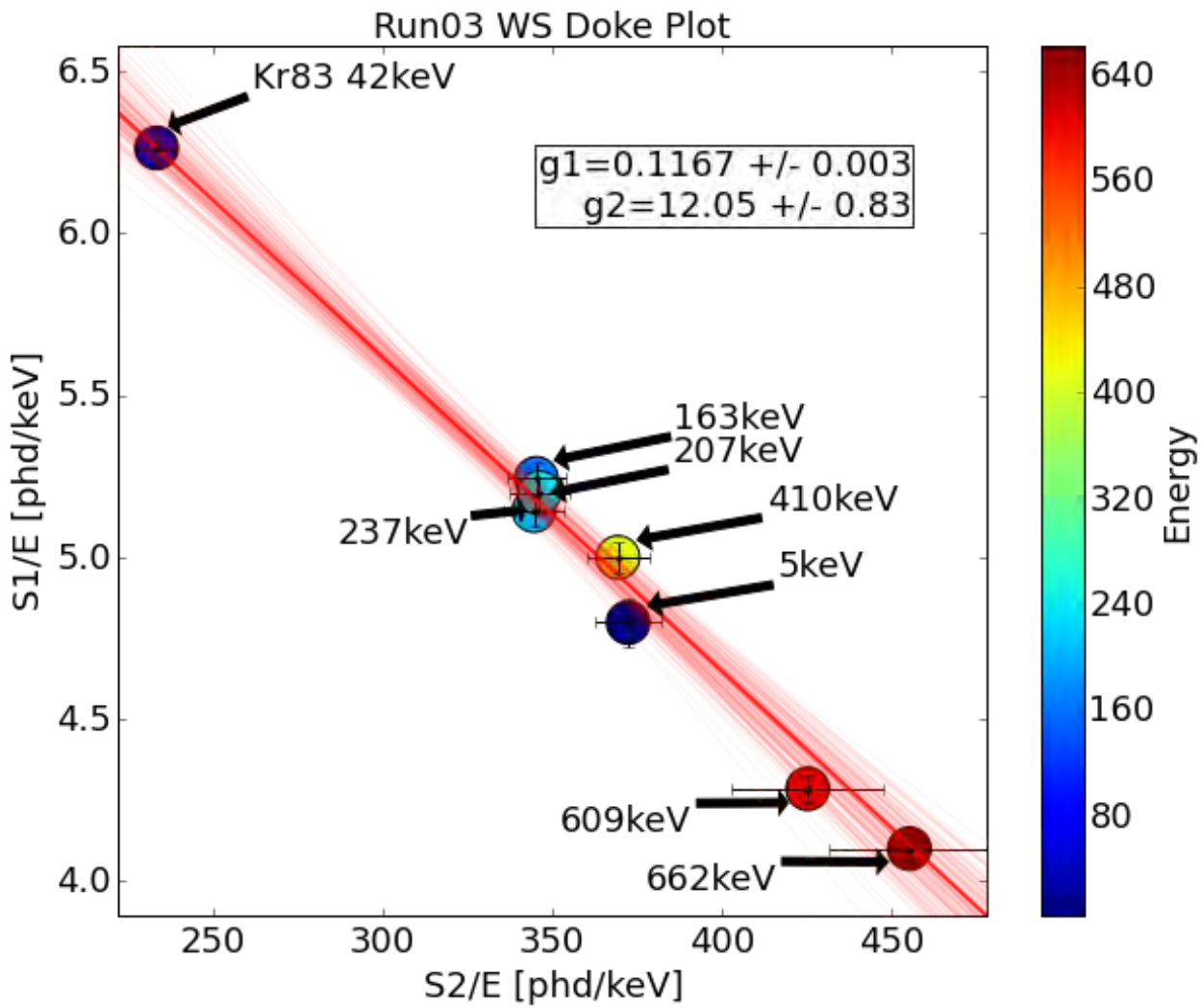


Figure: Gibson/Shutt

Nuclear Recoils

Absolute calibration: the “Doke” plot

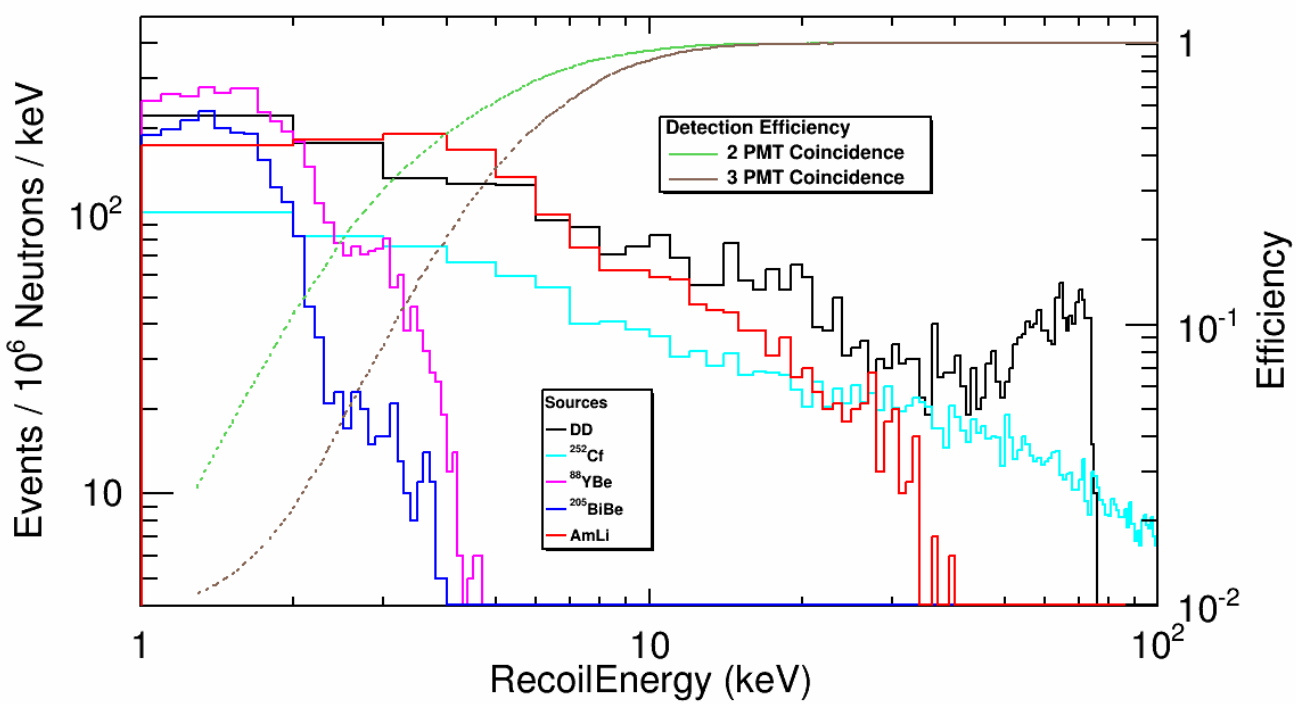


LUX Run03 -
S. Hertel talk

- Comprehensive framework captured in NEST MC package

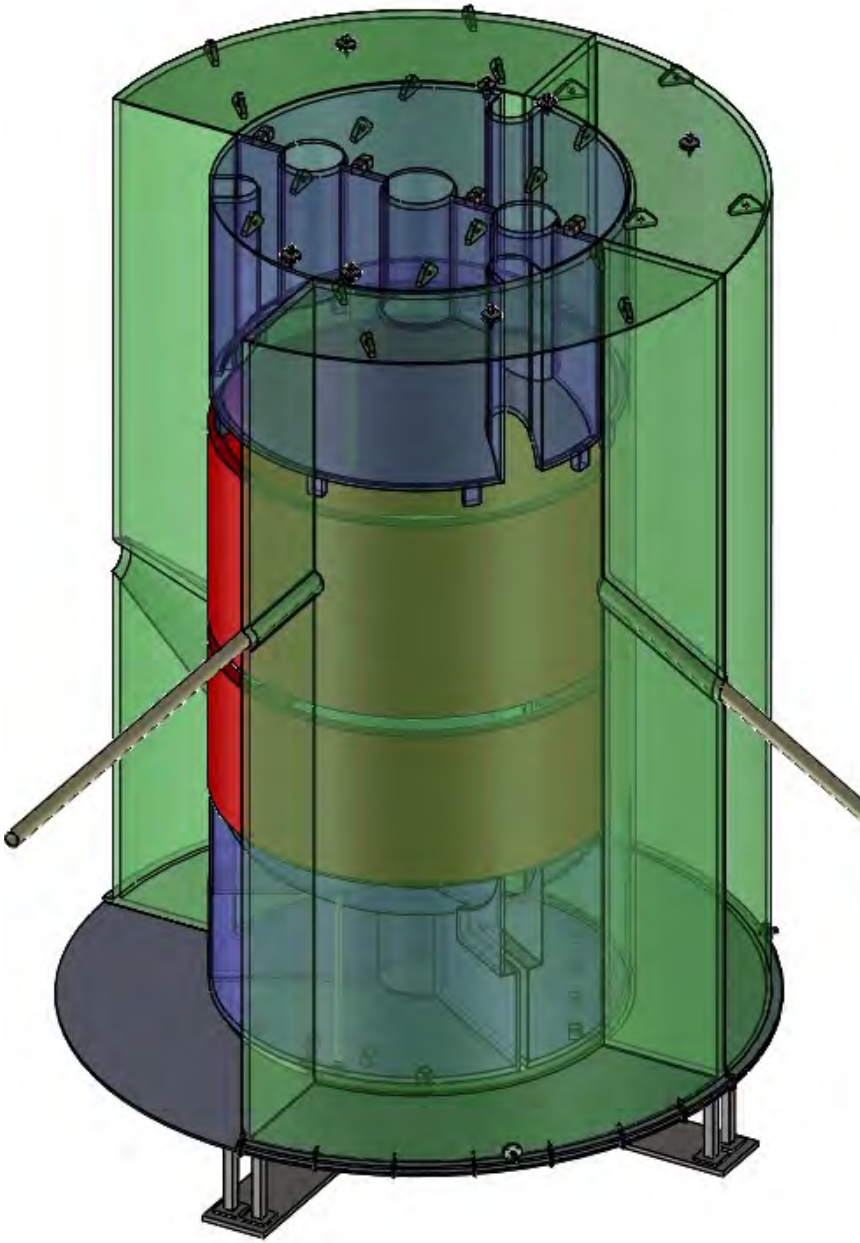
Calibrations

- 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



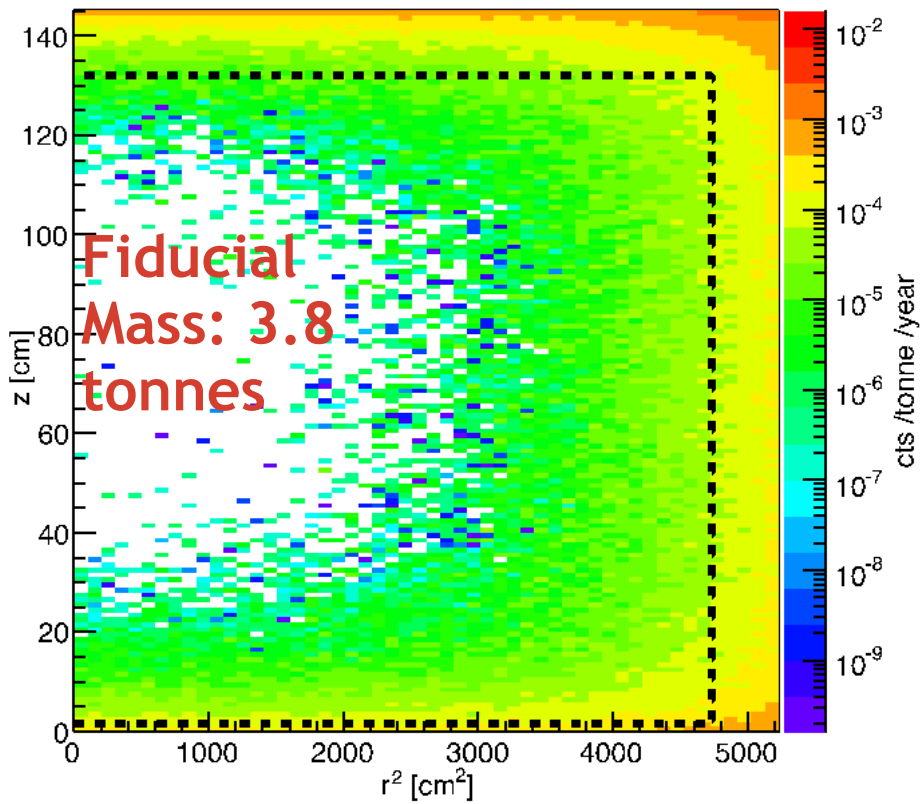
Outer Detector System

- LXe skin scintillation: 4-8 cm (walls), ~20 cm (dome)
- Gd-loaded liquid scintillator (LAB): 60 cm, 21.5 tons.
- ~97% efficient for neutrons
- *Hermetic measurement of all penetrating backgrounds*

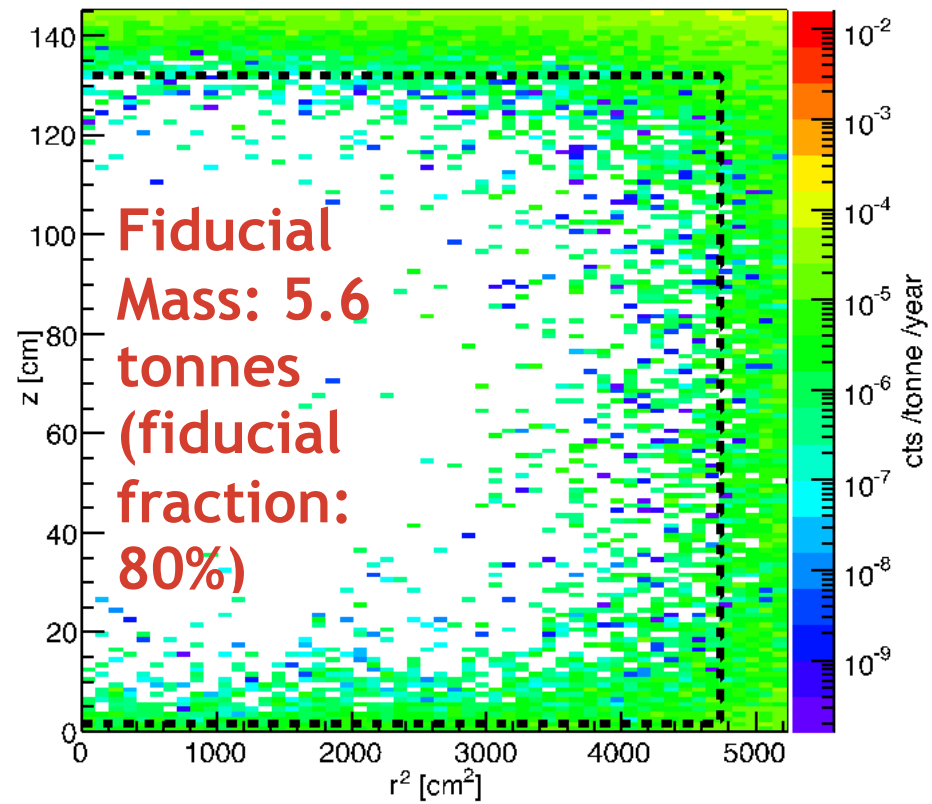


Backgrounds

Single NR scatter in TPC



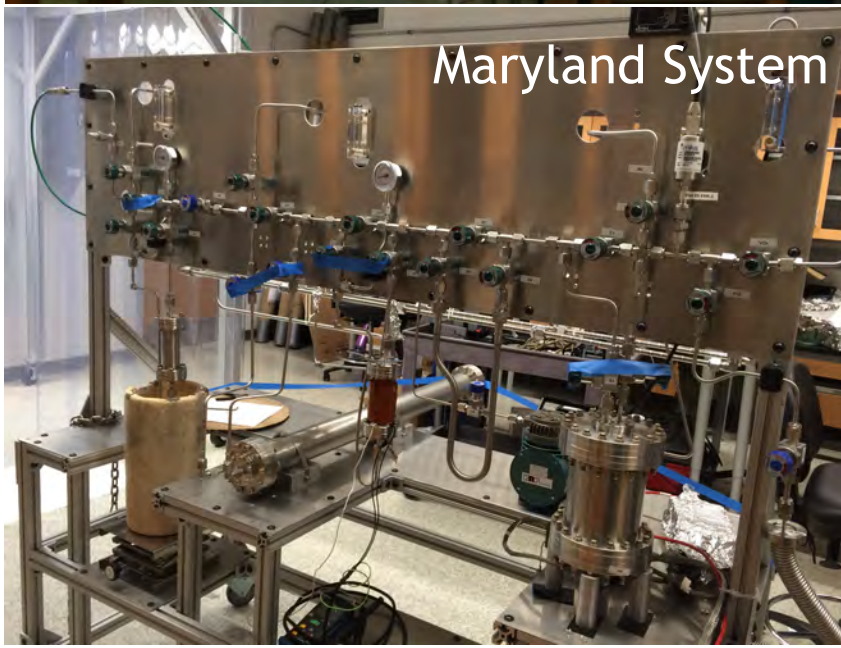
Vetoed by Gd-LS and Skin



- Significant screening effort: K. Oliver-Mallory talk
- Assessment of backgrounds: M.E. Monzani's talk
- Internal backgrounds dominate: Kr, Rn. Goal: *Neutrinos dominate!* (and are interesting signal).

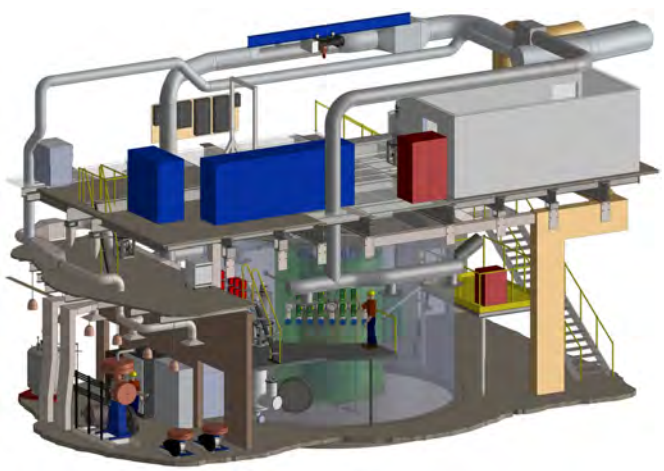
Rn Emanation

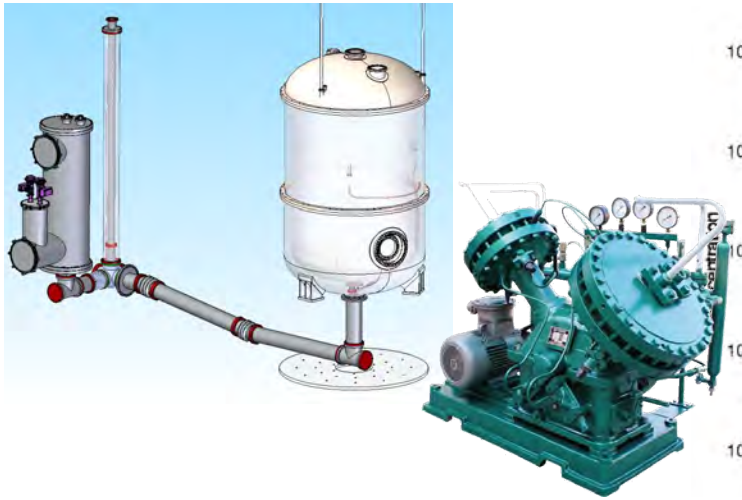
- Rn (and Kr) - dominant internal radioactive background
- Emanates from most materials
- 20 mBq requirement, 1 mBq goal
- Four separate measurements systems, ~0.1 mB sensitivity
  - Experience from SNO, KamLAND, EXO, NEMO, Borexino
- “Scrubber” processes purge Xe from warm breakout regions



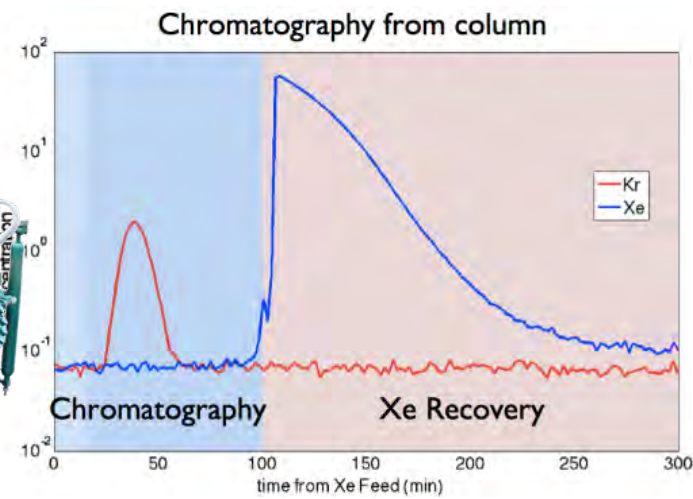
Xe Purification and Cryogenics

- Kr removal via chromatography
- Gas phase purification through getter - 10 tons / 2.5 days
- Trap-enhanced mass spec: ~ppt
- High efficiency two-phase heat exchange
- LN thermosyphon-based cryogenics - multiple cooling locations. Stirling LN refrigerator.
- Most aspects tested in System Test
- 10 tons Xe in hand or under contract for 2018 delivery



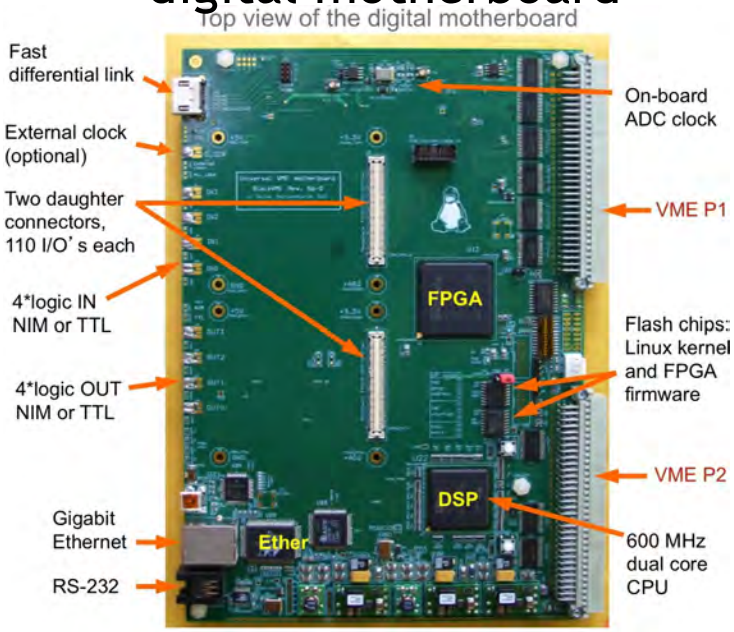


Kr removal

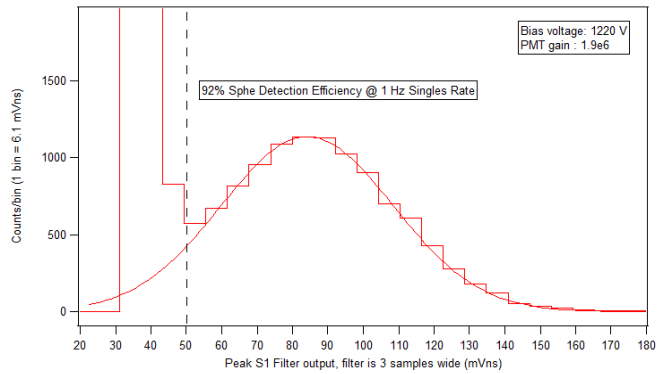


DAQ, Electronics, Control, Offline

digital motherboard

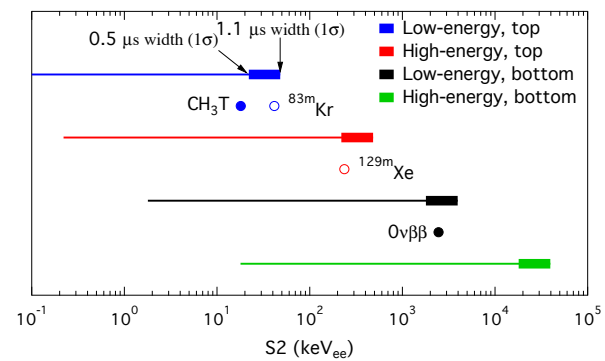


High pe efficiency

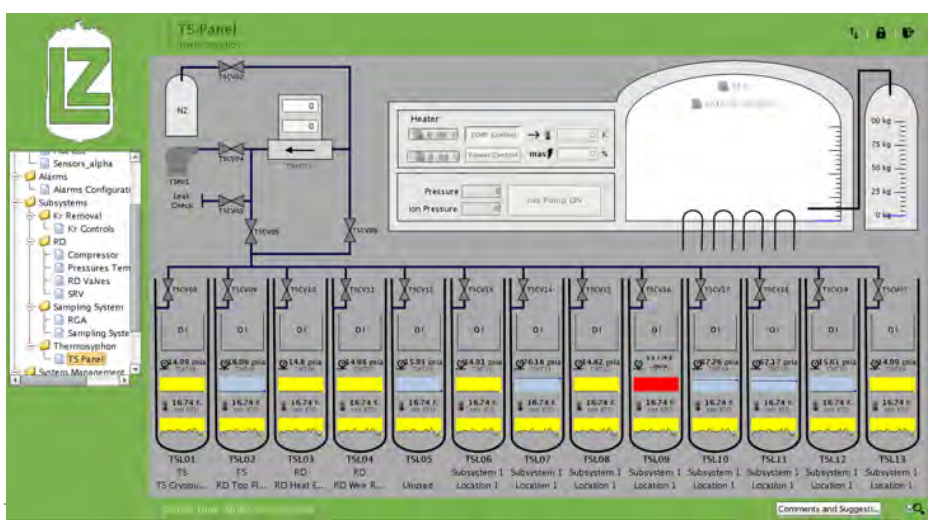


Full chain test, meets specs

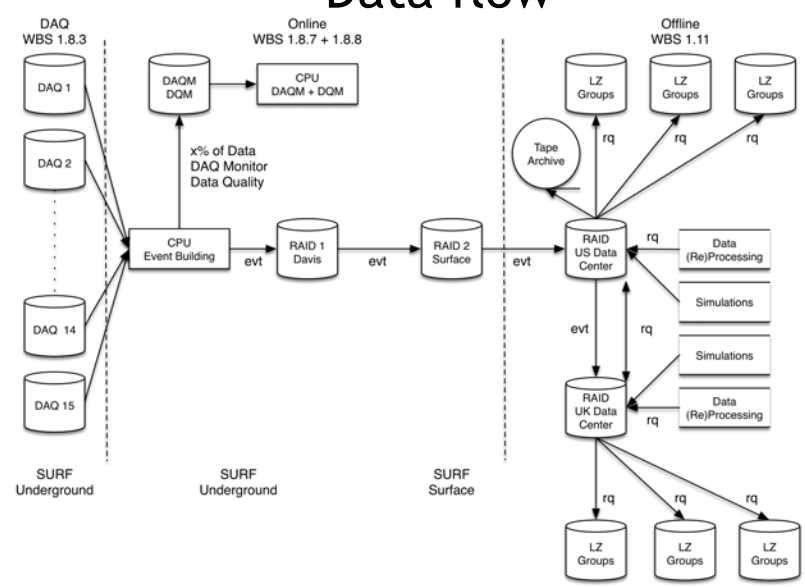
Dual channel for dynamic range



Slow control in use at System Test



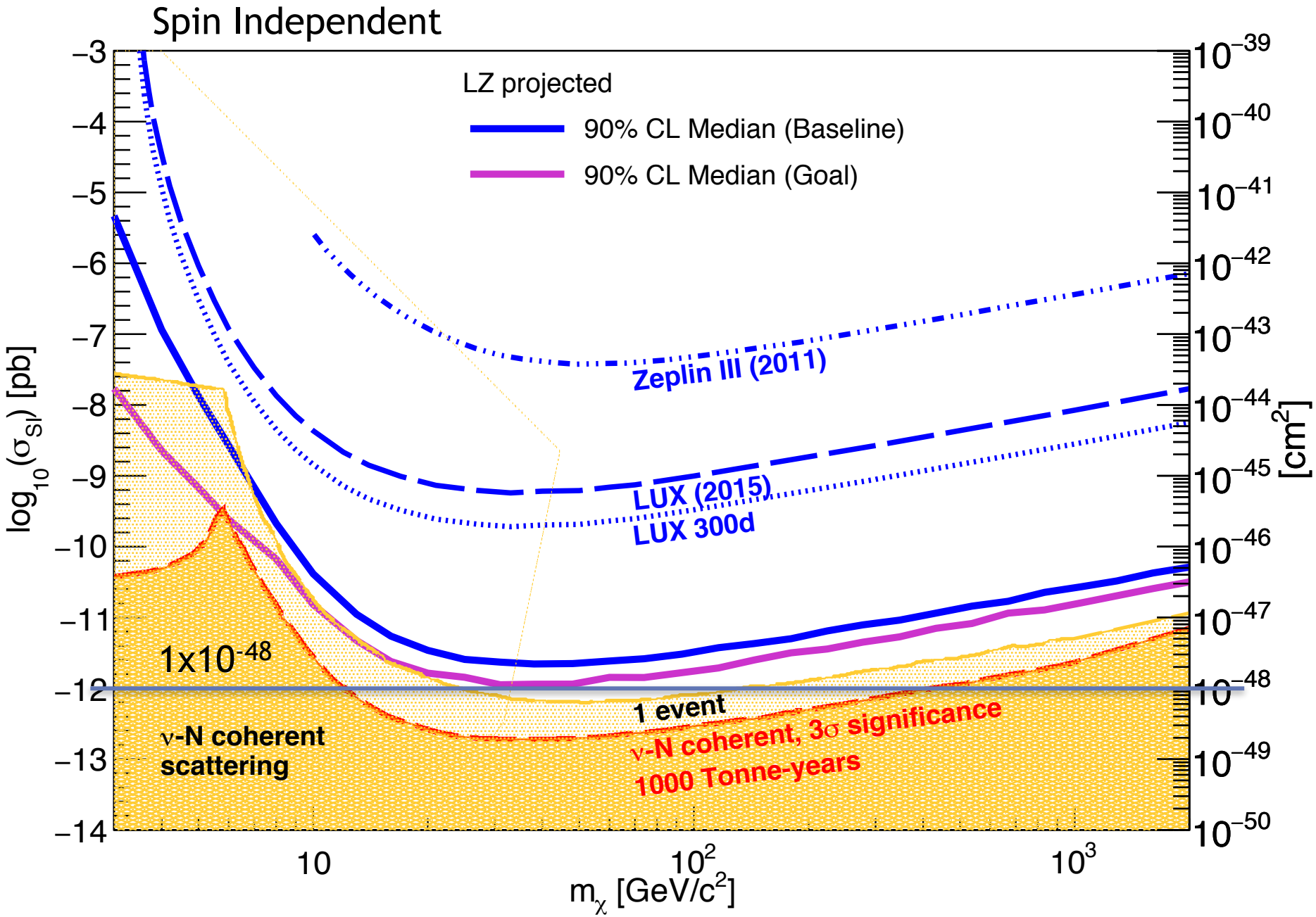
Data flow



Schedule

- CD1: March 2015
  - Conceptual Design Report arXiv:1509.02910
- CD2: April 2016
- LUX removed - Feb 2017
- Underground installation beings - May 2018
- Operations begin - May 2019

Projected Sensitivity

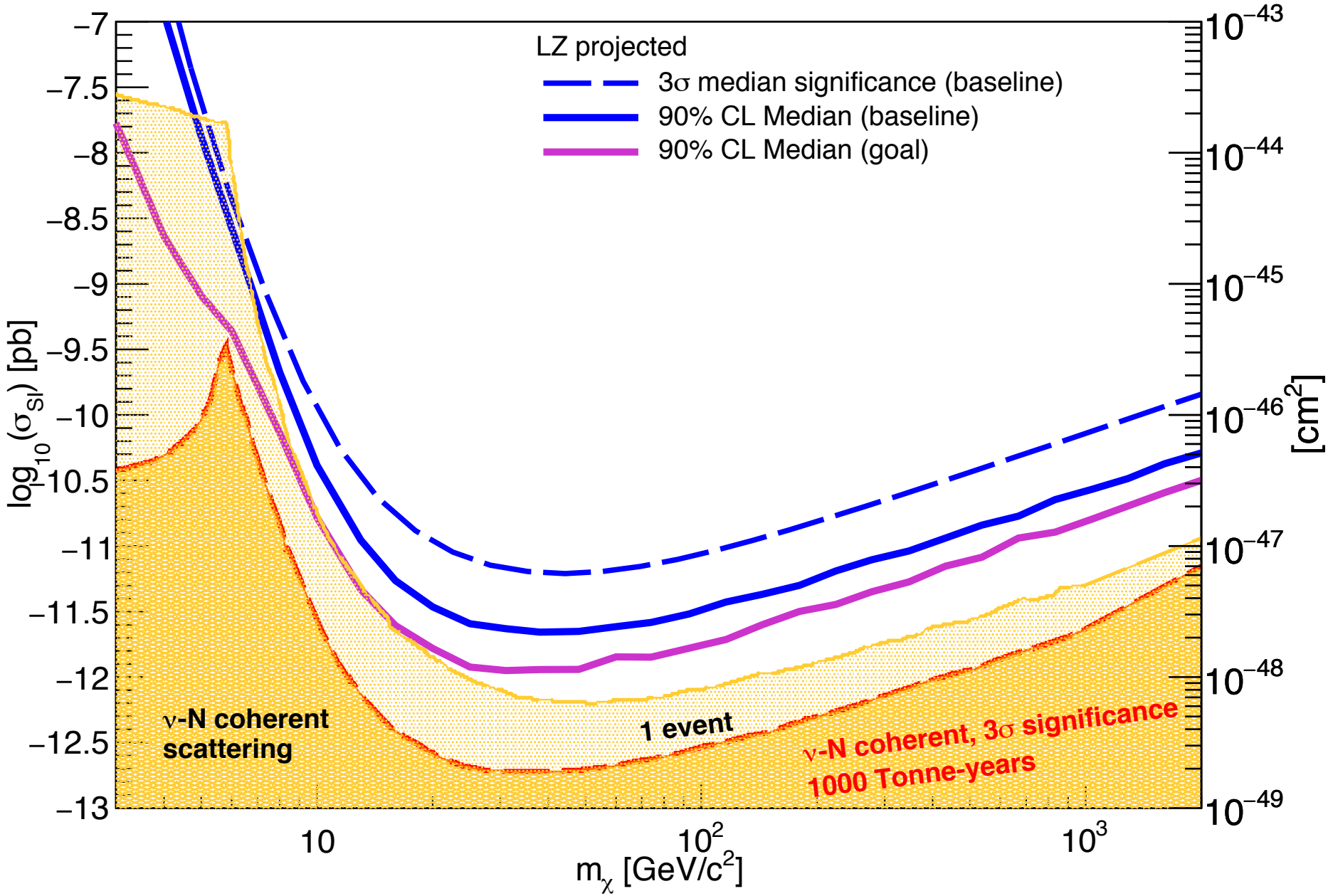


Summary

- LXe is pre-eminent target for high mass WIMPs
- LZ leverages LUX innovations in calibrations, cryogenics, purification
- Robust test program optimizing detector performance
- Very high fiducial volume fraction due to outer detector and low background cryostat
- Goal: neutrino-limited sensitivity of ~1×10^{-48} cm^2
- Goal: significant neutrino physics, including strong solar ^8B ν-nuclear coherent scattering signal

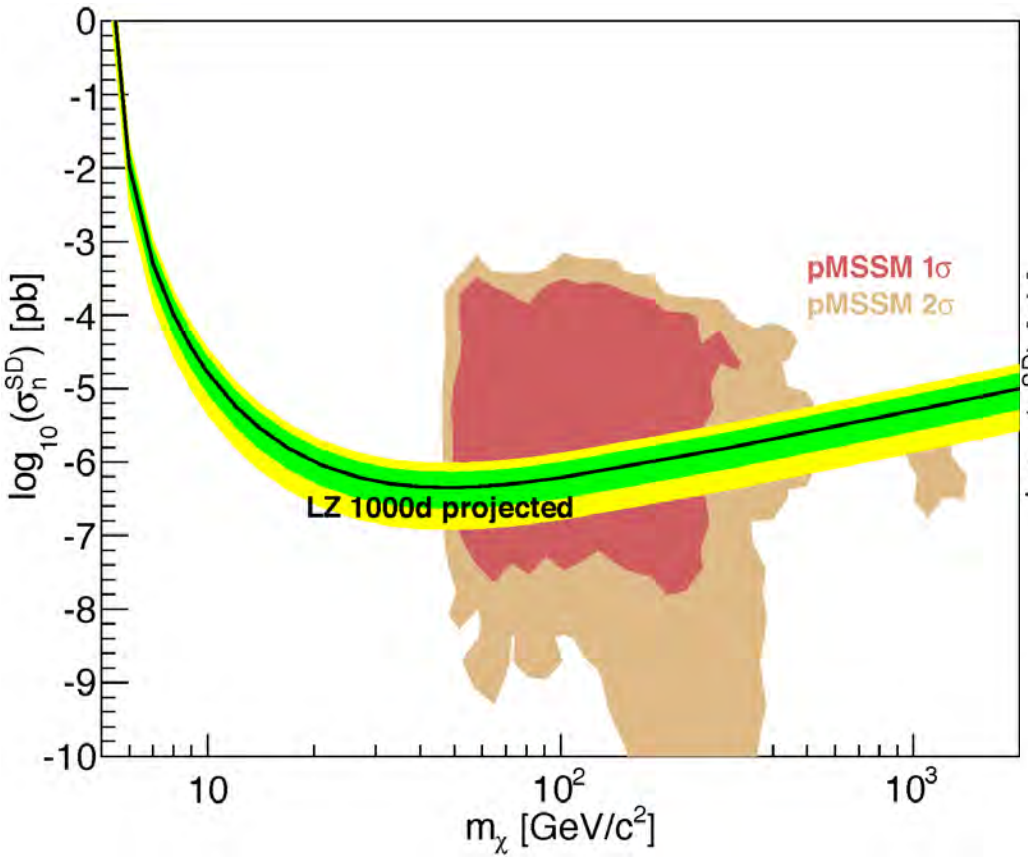
Backup

S

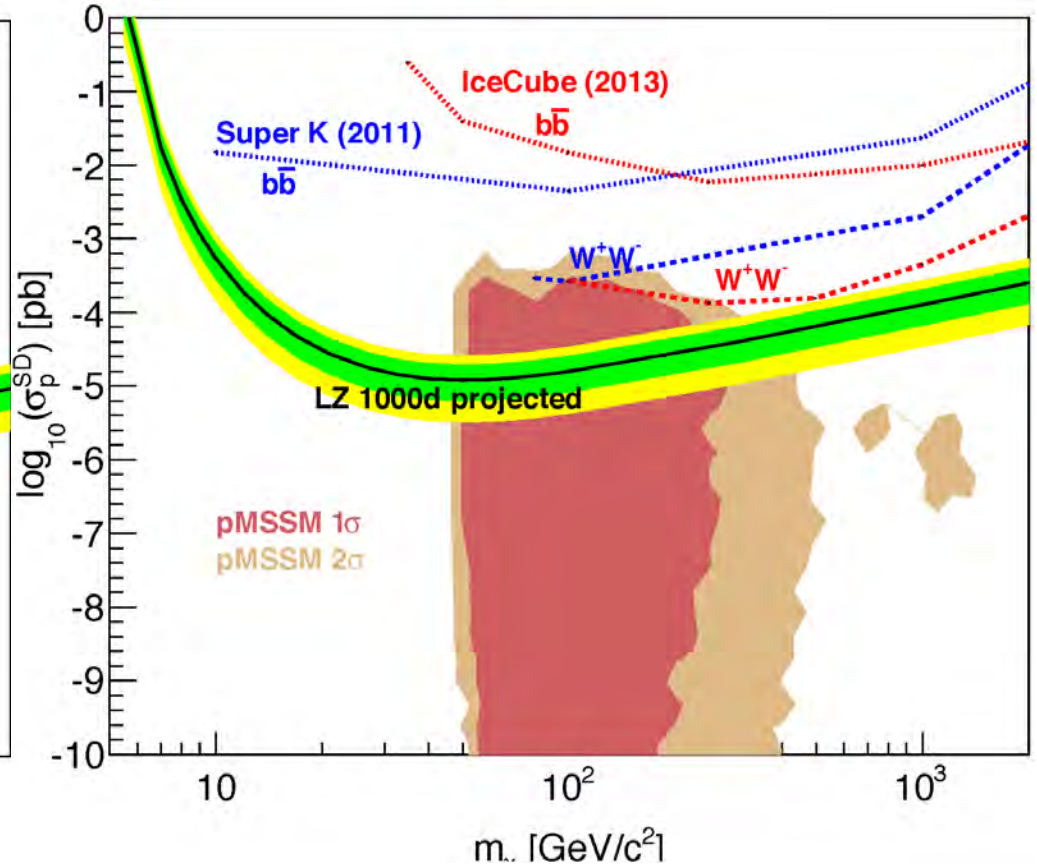

LZ projected
3σ median significance (baseline)
90% CL Median (baseline)
90% CL Median (goal)
ν-N coherent scattering
1 event
ν-N coherent, 3σ significance
1000 Tonne-years
log10(σSI) [pb]
[cm2]
mχ [GeV/c2]
−7
−7.5
−8
−8.5
−9
−9.5
−10
−10.5
−11
−11.5
−12
−12.5
−13
10
10^2
10^3
10^−43
10^−44
10^−45
10^−46
10^−47
10^−48
10^−49

Spin Dependent Sensitivity

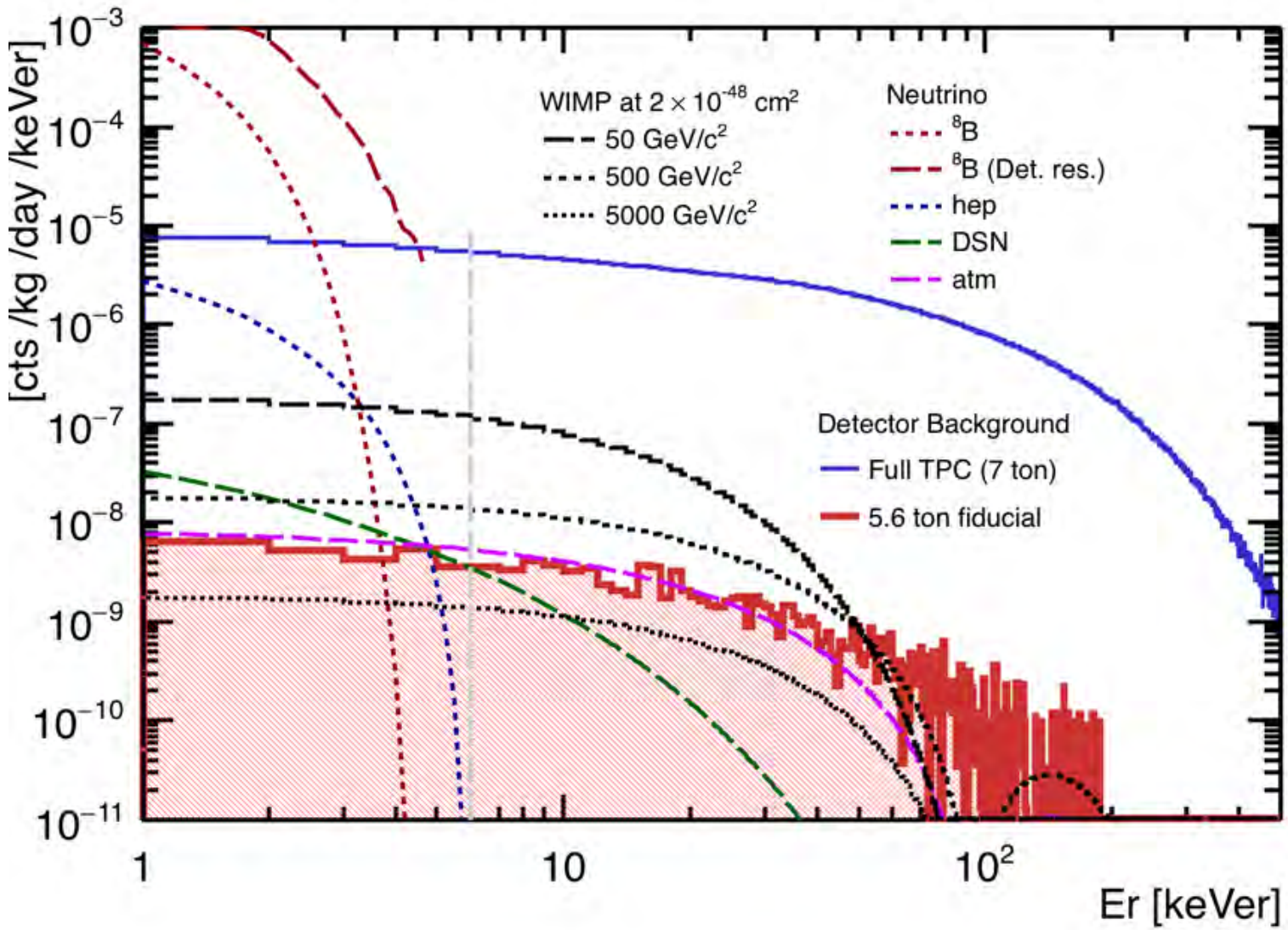
On Neutrons



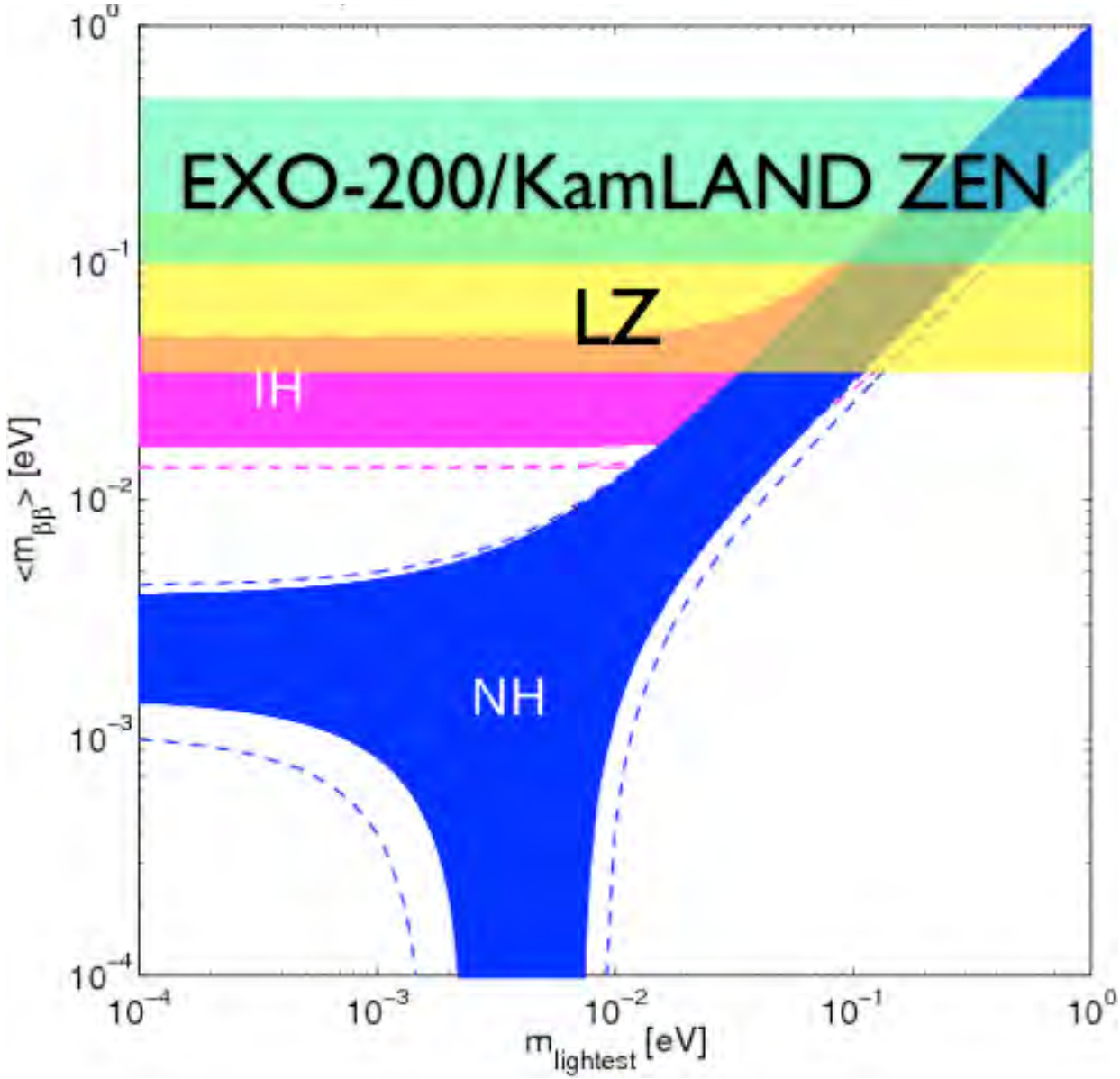
On Protons



Nuclear Recoil Spectrum



Double Beta decay Sensitivity



Solar Axions