The University Of Sheffield.

Expected background in the LZ experiment

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On behalf of the LUX-ZEPLIN Collaboration

LUX-ZEPLIN Collaboration

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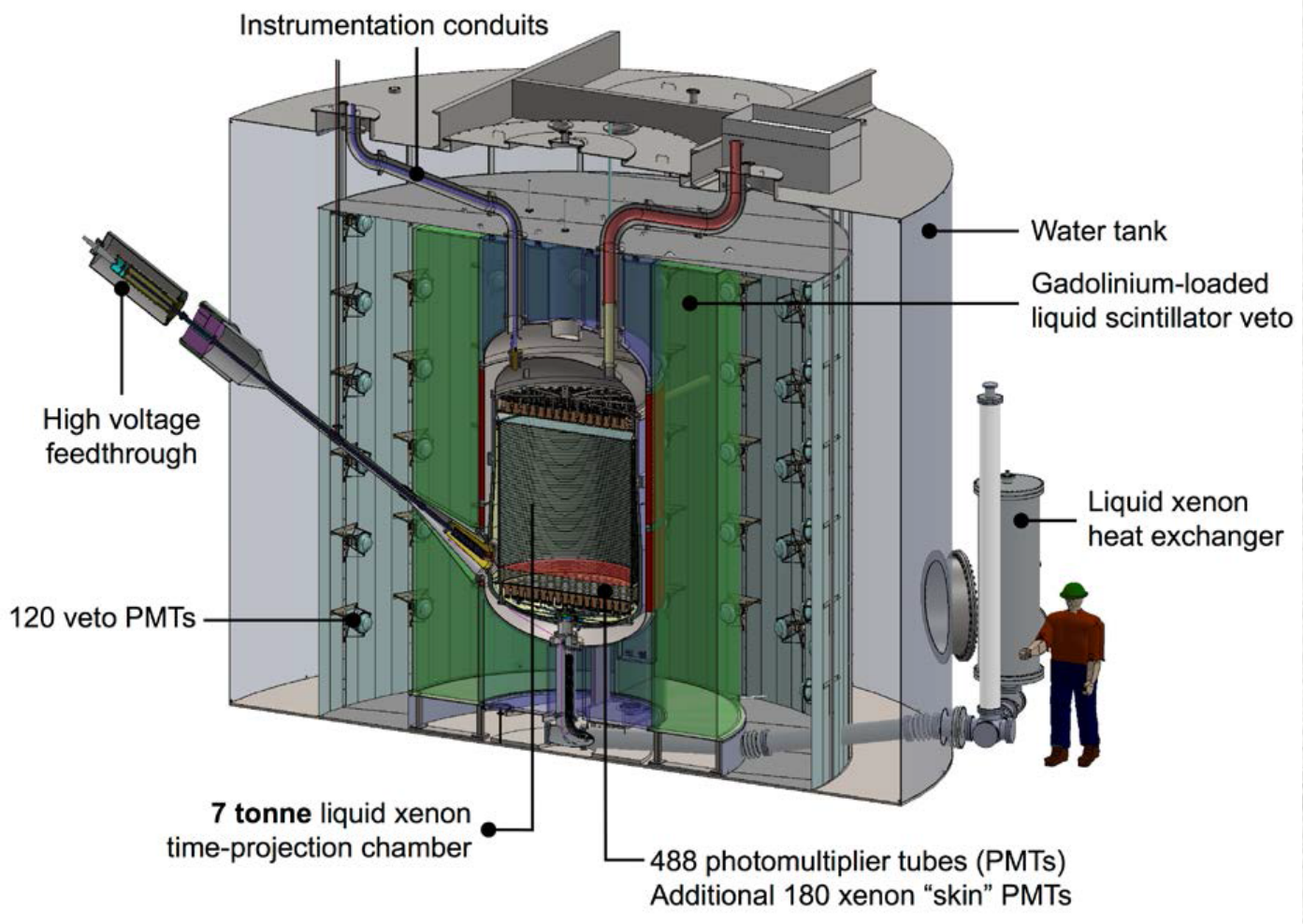
Background suppression

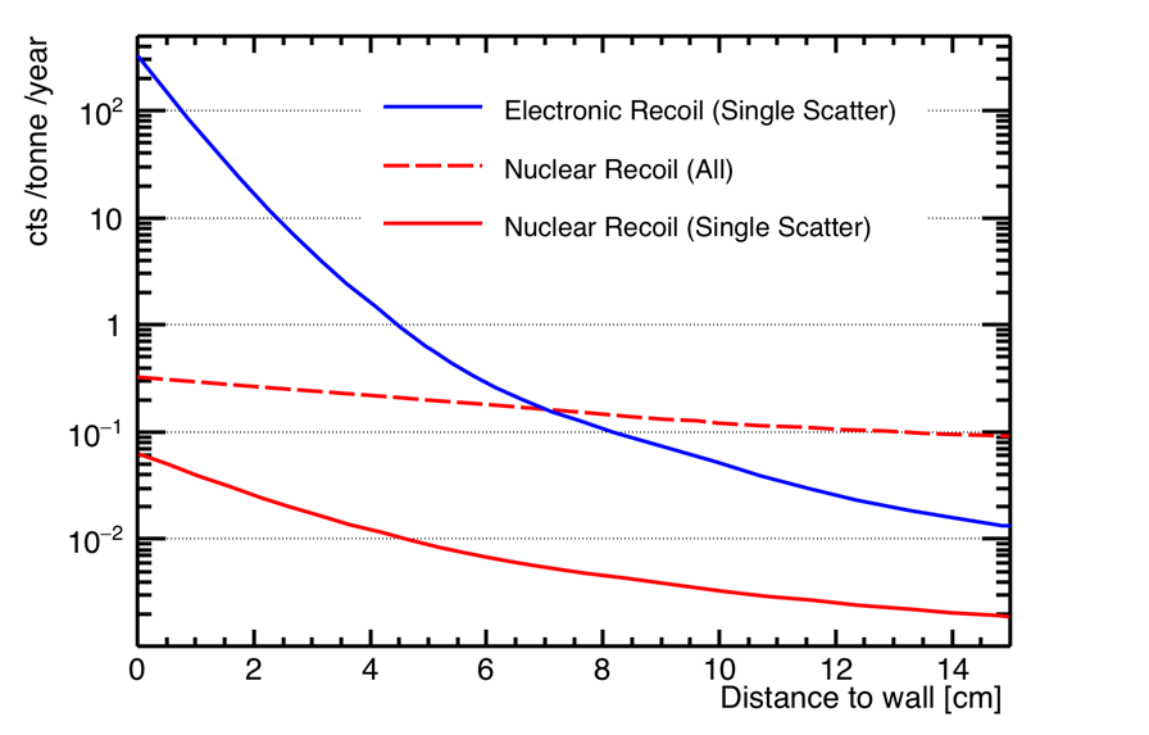
- Radio-pure materials – broad screening campaign in the US and in the UK (UK facilities covered by Chamkaur Ghag on 18 March).
- Underground location – SURF (4850 ft).
- Shielding against radioactivity in rock.
- Xe purification.
- Control of surface events (from radon daughters).
- Reduced activation.
- Rejection of multi-hit events.
- Anticoincidence (active veto) systems.
- Fiducialisation.
- Discrimination between nuclear and electron recoils.

LZ detector



- **Excellent background suppression by fiducialisation and active veto systems.**

Self-shielding



- Self-shielding of external neutrons (6-30 keV) and gamma rays (1.5-6.5 keV) in LXe.
- 2 cm and 6 cm of Xe suppress the external background (ER and NR) by an order of magnitude.
- Optimised configuration of the fiducial volume improves the rejection.

Background from major sources

Item	^{238}U	^{232}Th	^{40}K	^{60}Co	ER Counts	NR Counts
Cryostat	0.6 mBq/kg	0.6 mBq/kg	2.5 mBq/kg	-	4.1	0.07
TPC PTFE	0.01 mBq/kg	0.002 mBq/kg	0.06 mBq/kg	-	0.1	0.003
TPC PMTs	0.46 mBq/PMT	1.3 mBq/PMT	17 mBq/PMT	1.2 mBq/PMT	4.2	0.36
Other	various	various	various	-	4	0.05
Subtotal					**12.4**	**0.48**
Kr + Rn + Ar					52	-
Neutrinos					234	0.6
Total	Total number of interactions				**299**	**1.08**
	99.5% ER rejection, 50% NR acceptance				**1.49**	**0.54**
	Combined background counts				**2.03**	

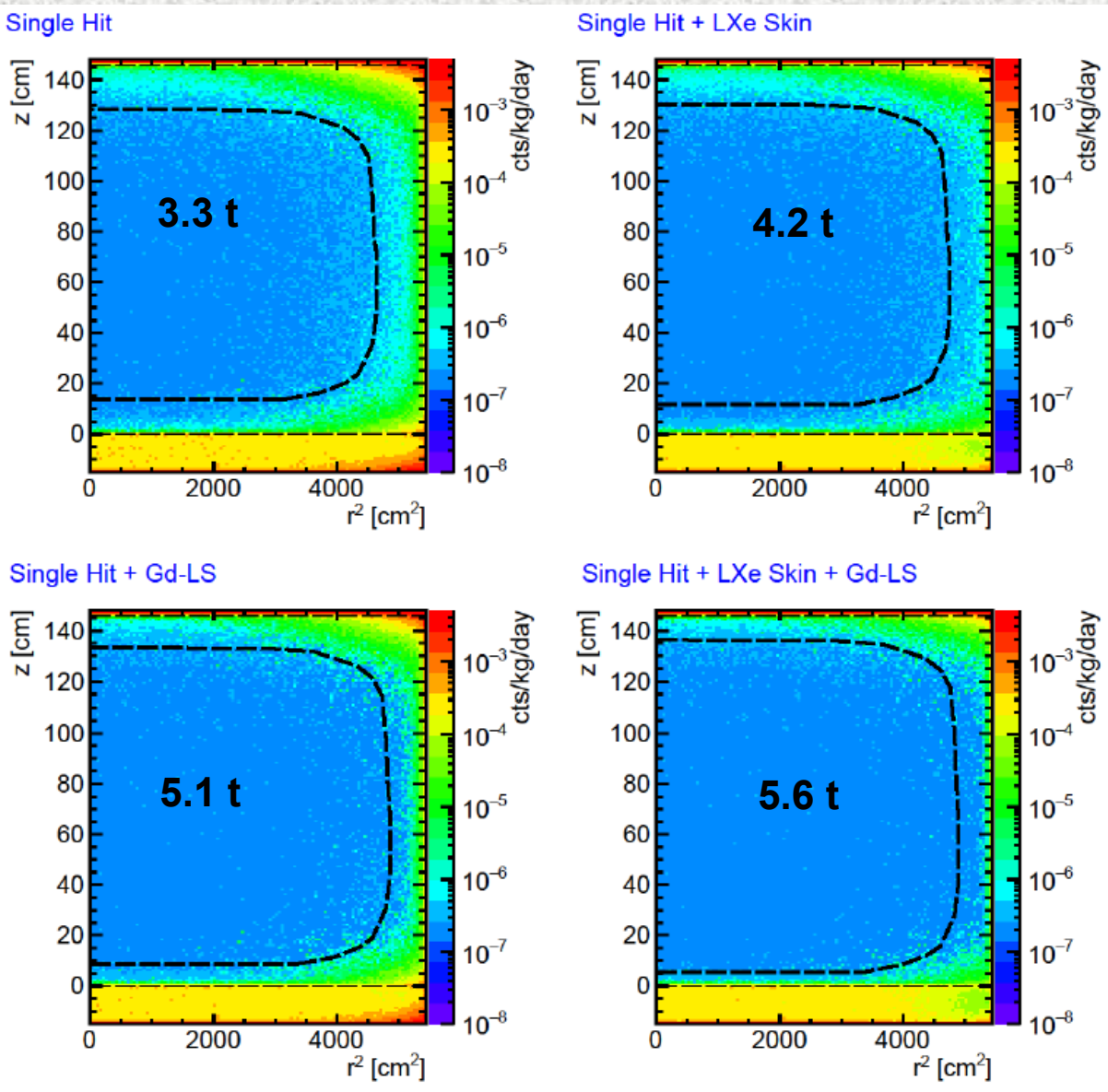
- **LUXSim simulations (code tested with LUX) using LZ model.**
- **Recent screening results (PMTs) and literature values.**
- **Optimised 5.6 ton fiducial volume.**
- **1.5-6.5 keV ER and 6-30 keV NR.**
- **Anti-coincidences with xenon 'skin' and scintillator veto (100 keV threshold for both).**
- **Single scatters in fiducial volume.**

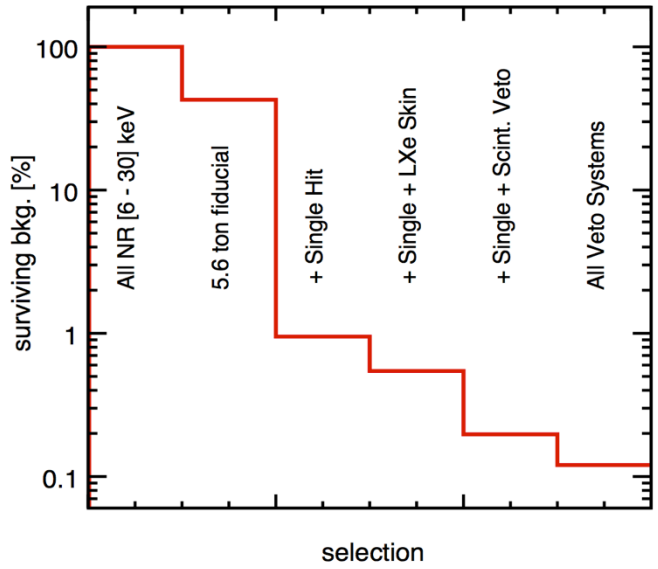
Total background

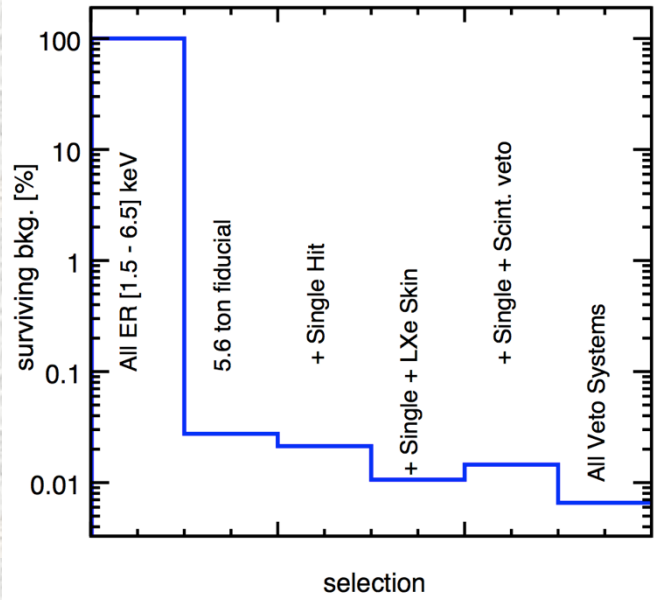
	Mass or #	U mBq/kg or mBq/unit	Th mBq/kg or mBq/unit	^{60}Co mBq/kg or mBq/unit	^{40}K mBq/kg or mBq/unit	Emitted n/year/(kg or unit)	ER (cts)	NR (cts)
R11410 3" PMTs	488 units	0.46	1.3	1.2	17.00	0.18	4.2	0.36
Ti cryostat, incl. flanges	1645 kg	0.62	0.61	0.00	2.48	0.16	4.1	0.07
PTFE internals	260 kg	0.01	0.002	0.00	0.06	0.03	0.1	0.006
PMT bases	488 units	1.40	0.13	0.03	1.20	0.002	0.65	0.003
PMT cables	2.1 kg	17.00	13.00	11.00	0.00	2.6	0.1	0.0015
Field-shaping rings	215 kg	0.22	0.16	0.20	1.34	0.01	0.14	0.015
LXe skin 1" PMTs	180 units	0.32	0.23	1.70	8.60	0.04	0.17	0.003
Grid supports	75 kg	1.90	1.00	8.50	10.00	0.13	0.65	0.002
PMT mounting plates	54 kg	0.60	0.60	0.00	2.50	0.06	0.1	0.002
HV umbilical	199 kg	1.90	1.00	8.50	10.00	0.2	0.3	0.005
Utility conduits	597 kg	1.90	1.00	8.50	10.00	0.36	0.25	0.001
Heat-exchanger conduit	199 kg	1.90	1.00	8.50	10.00	0.36	0.35	0.005
Liquid scintillator	27000 kg	0.74	0.81	0.00	0.00	0.0002	1.15	0.006
Acrylic tanks	4600 kg	0.04	0.10	0.00	0.00	0.27	0.05	0.0005
Veto stand	491 kg	0.60	0.60	0.00	2.50	0.13	0.1	0.003
Veto base	938 kg	1.90	1.00	8.50	10.00	0.16	0.18	0.003
nat Kr (0.015 ppt), ^{222}Rn (0.67 mBq), ^{220}Rn (0.07 mBq), and ^{39}Ar (2.7 μBq)							52.00	
Subtotal (Non-ν counts)							64.6	0.49
(^{136}Xe 2νββ)							(38)	
Astrophysical ν counts (pp, atmospheric, diffuse supernova, and ^{8}B)							234	0.61
Total (excluding 2νββ)							299	1.10
Total (with 99.5% ER discrimination, 50% NR efficiency) Total: 2.0 events							1.49	0.54

- Preliminary calculations.
- Dominated by neutrinos.
- Main 'external' contributors (radioactivity): cryostat and PMTs.
- If the cryostat is made of stainless steel, the background is similar.
- External backgrounds are smaller than internal (Kr, Rn).
- Activation: Xe, Ti etc should be kept to the minimum.

Effect of veto systems







Xe purification

- Beta-emitters: ^{85}Kr, ^{39}Ar.
- Kr concentration requirement: < 0.015 ppt; typically 20 ppt of ^{85}Kr in natural Kr but large variations from sample to sample.
- Ar concentration requirement: < 1 ppb (activity of ^{39}Ar <10% of that of ^{85}Kr); typically 0.0008 ppt of ^{39}Ar in natural argon (Benetti et al. NIMA 574 (2007) 83).
- Kr and Ar removal using chromatography.

	LZ Requirement	Unit
Nominal Kr concentration of vendor-supplied Xe	~(0.1-1) x 10^{-7}	g/g
Allowed Kr concentration	1.5 x 10^{-14}	g/g
Required Kr rejection factor of removal system	~(0.7-7) x 10^{6}	
Processing rate of removal system	200	kg/day
Allowed Kr mass in 10 ton Xe	1.5 x 10^{-7}	g
Air allowed in 10 ton of Xe (from Kr spec.)	40	std. cc
Allowed ^{85}Kr decay rate in 6 tonnes fiducial Xe mass	0.026	mBq
^{85}Kr decays in 1000 days in 6 tonnes fiducial Xe mass	2283	events
After energy cut (ΔE = 5 keVee)	26	events
After ER discrimination (99.5%)	0.13	events

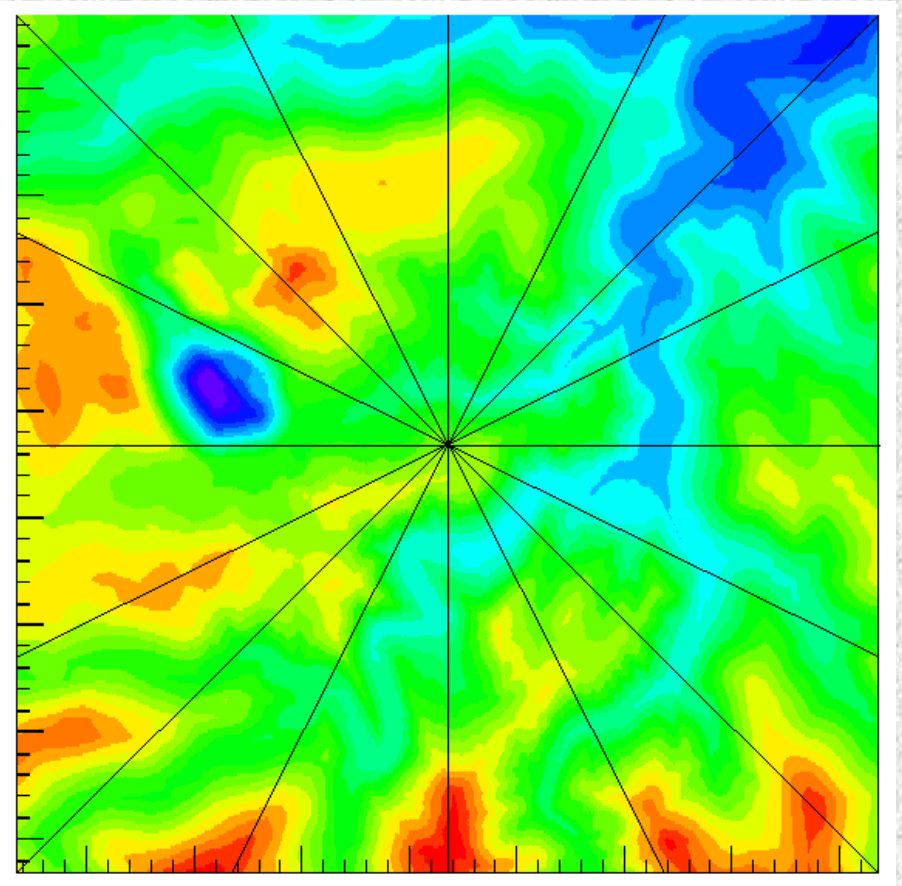
Radon

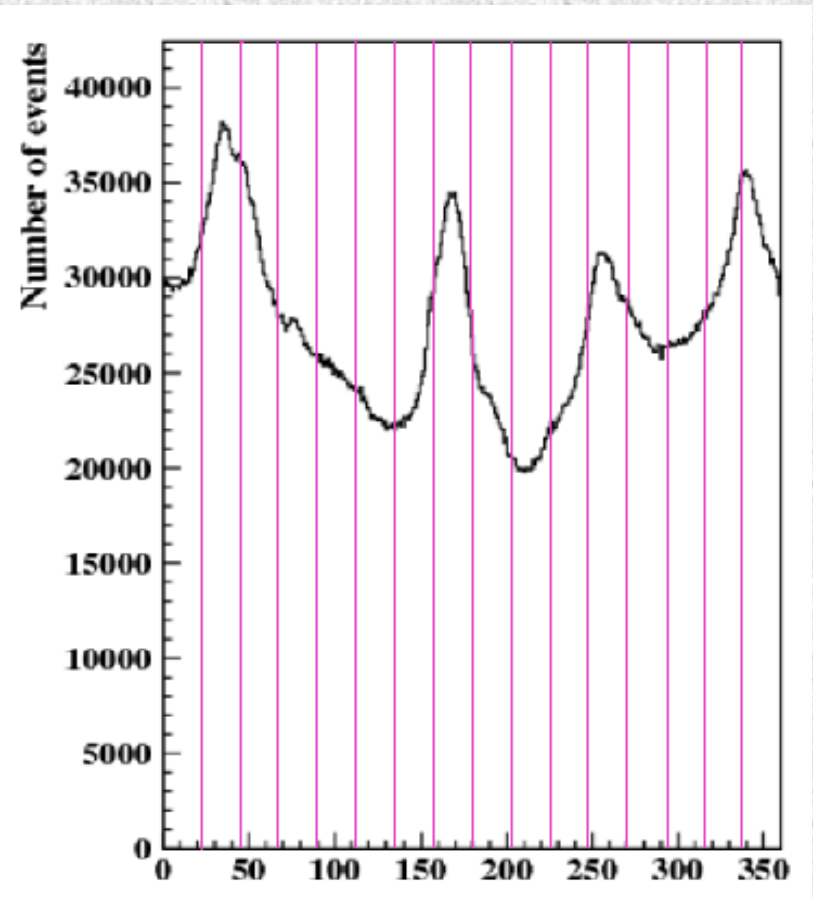
- Radon plate-out and emanation.
- Radon plate-out:
  - On a PTFE surface – danger from (α,n) reactions on fluorine.
  - On any surface in contact with target Xe – recoiling nuclei from the decay of daughter isotopes may be mis-reconstructed as being in the fiducial volume; possible reduction of the fiducial volume.
  - Surface cleaning.
- Radon emanation:
  - Tolerated (steady-state) level of ^{222}Rn/^{220}Rn in xenon 0.67/0.07 mBq (from LUX measurements).
  - ^{210,214,212}Pb -> ^{210,214,212}Bi contribute the most.
  - Bi-Po chains are easily identified within the LZ event time window.
  - Programme for radon emanation measurements (poster by R. Schnee et al.).

Activation

- ^{127}Xe, 36.4 days half-life, factor of 30 reduction every 6 months of cool-down.
  - Measured by LUX, consistent with GEANT4 MC.
  - Expected background rate in 5.6 t fiducial volume after all cuts – 13 events/day in the range of interest 1.5-6.5 keV.
  - Underground commissioning – about 8 months -> 0.13 events/day.
  - For 1000 day run -> < 10 events in 5.6 tonnes.
  - Should be stored underground, possibly at 10 m w.e.
  - Very useful for calibration purposes and eventually will determine the start of a science run.
- ^{46}Sc from Ti, 83.8 days half-life, 2 gamma-rays 1120 keV and 889 keV, 2.4 mBg/kg (measured by LUX and simulated), reduced to 0.3 mBq/kg after 8 months.
  - Simultaneous emission of 2 gamma-rays helps rejecting events using veto systems.
  - Background rate is comparable to some small components.

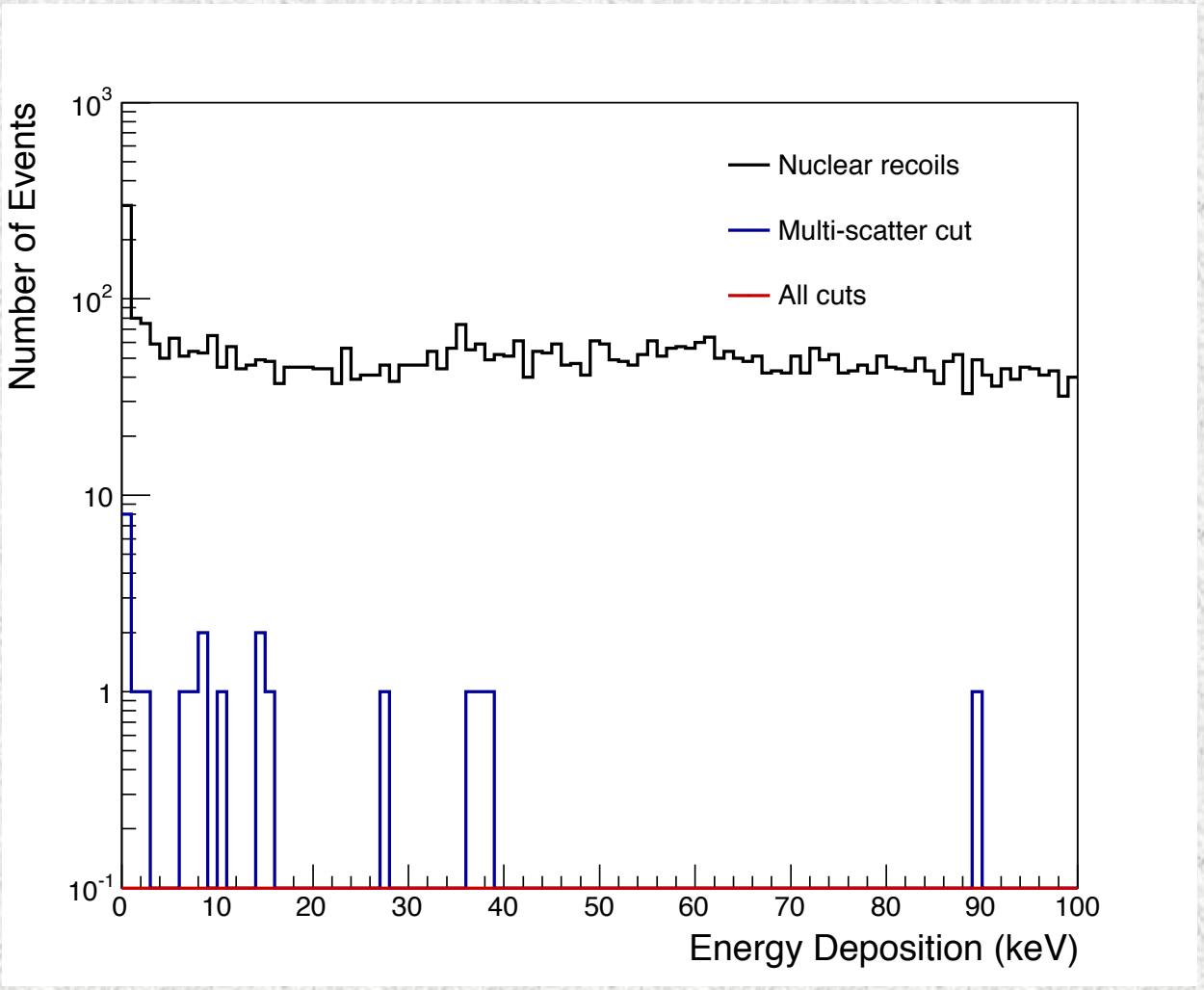
Muon-induced neutrons





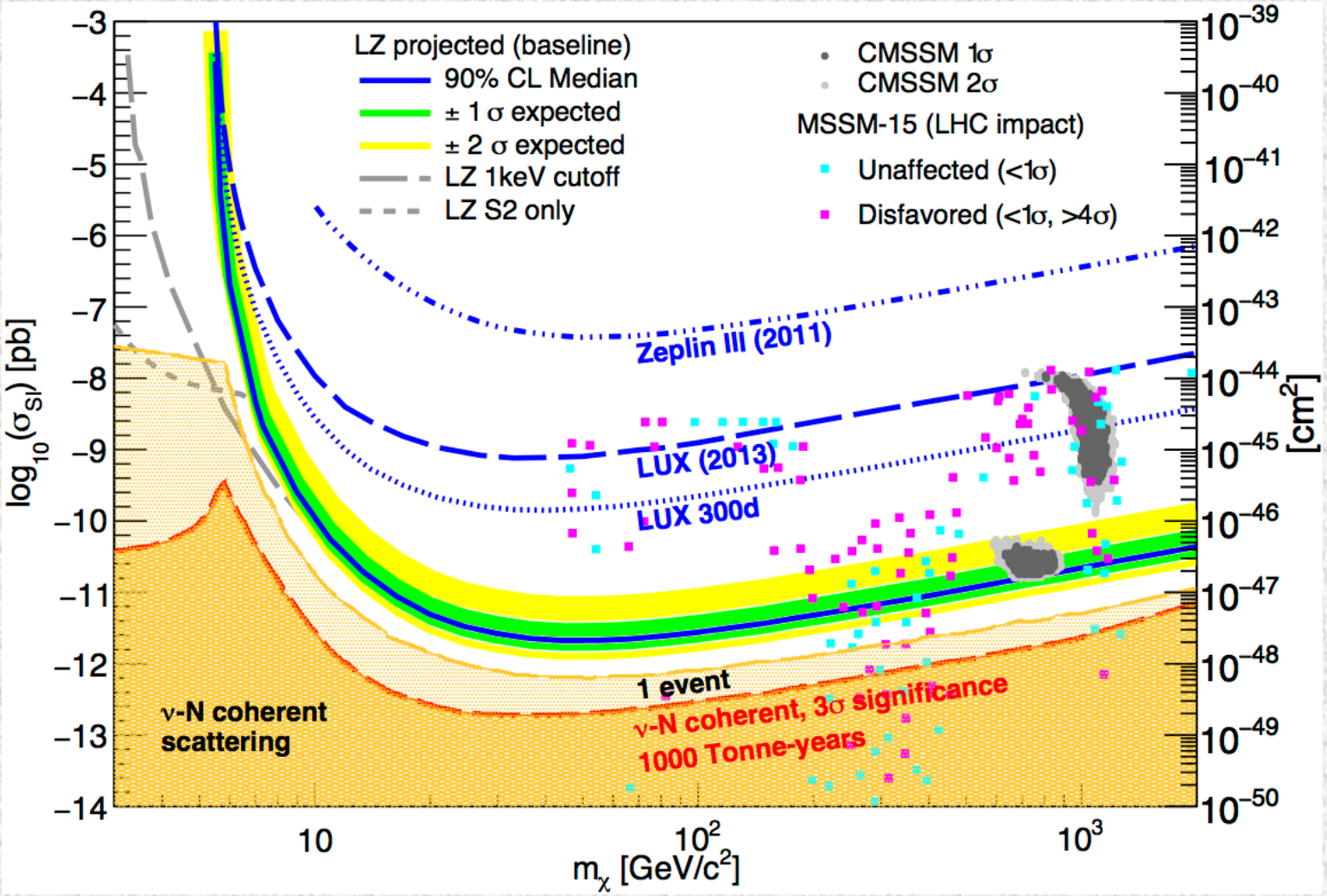
- **Muon generator for SURF.**

Muon-induced neutrons



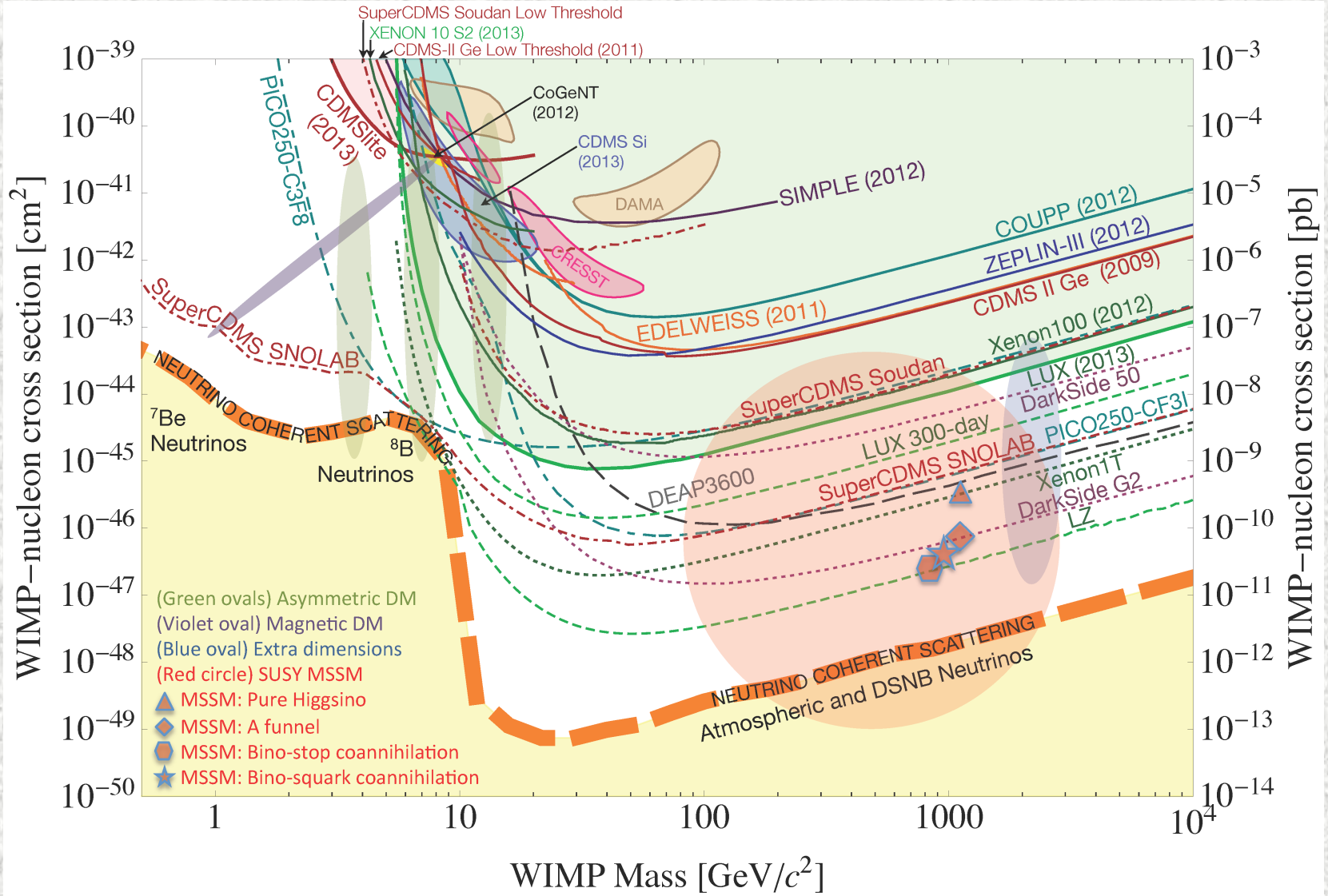
- Detector model with cavern and rock.
- All analysis cuts included, except water Cherenkov signal.
- 22 years of statistics.
- No single hits at 6-30 keV in the 5.6 tonnes after all cuts.

LZ sensitivity



- Excellent projected sensitivity limited by neutrinos.
- LZ project has been down-selected by DoE and STFC.

LZ sensitivity



Summary

- Goal: background to be dominated by neutrinos.
- Achievable with
  - High radio-purity
  - Xenon purification
  - Shielding
  - Active veto systems (xenon skin, scintillator, water Cherenkov)
  - Deep underground location
  - Fiducialisation
  - Analysis cuts
  - Care to minimise activation and Rn emanation.
- Sensitivity down to irreducible neutrino background.
- Construction starts this year.