Simulations of external backgrounds at SURF for the LUX and LZ experiments

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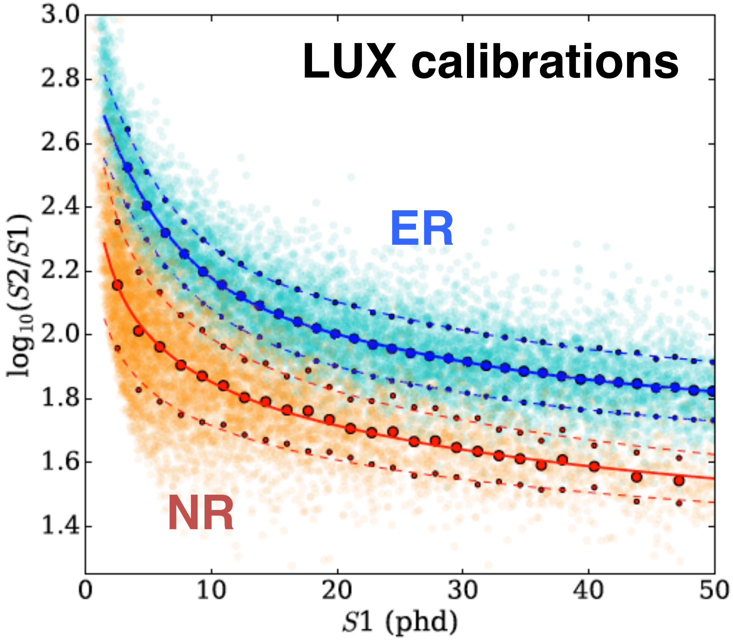
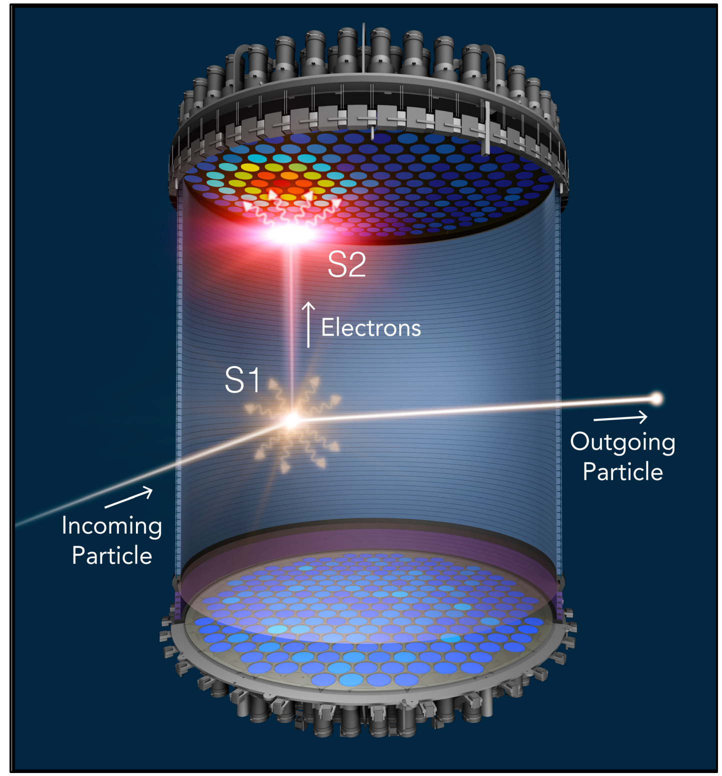
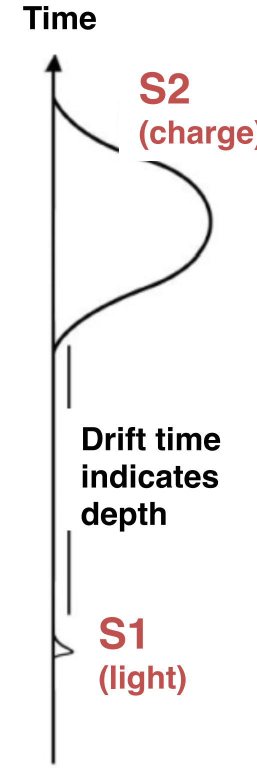
On behalf of the LUX and LZ collaborations

Dual-phase xenon TPC

- ✓ 3D position reconstruction
- ✓ Particle ID: electron recoils (ER) vs nuclear recoils (NR)
- ✓ NR: WIMP signal, neutrons, coherent neutrino scattering
- ✓ ER: Other backgrounds



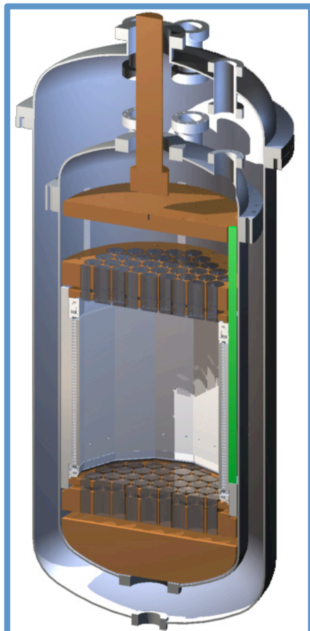




Challenge is to identify very rare (<< 1 event/kg/year) and low energy (< 100 keV) recoils.

LUX and LZ at SURF

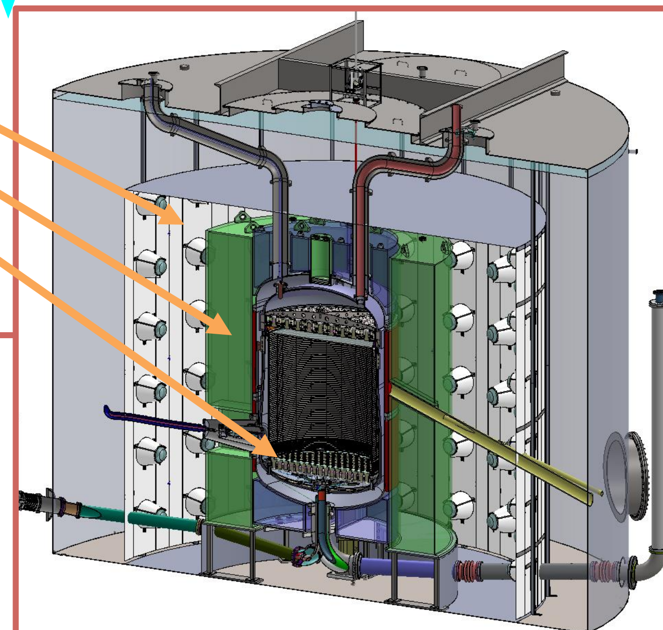
LUX



0.5 x 0.5 m dodecagon
370 kg LXe
250 kg active mass
~ 100 kg fiducial mass
122 PMTs

Veto system
Water tank
Scintillator
LXe skin

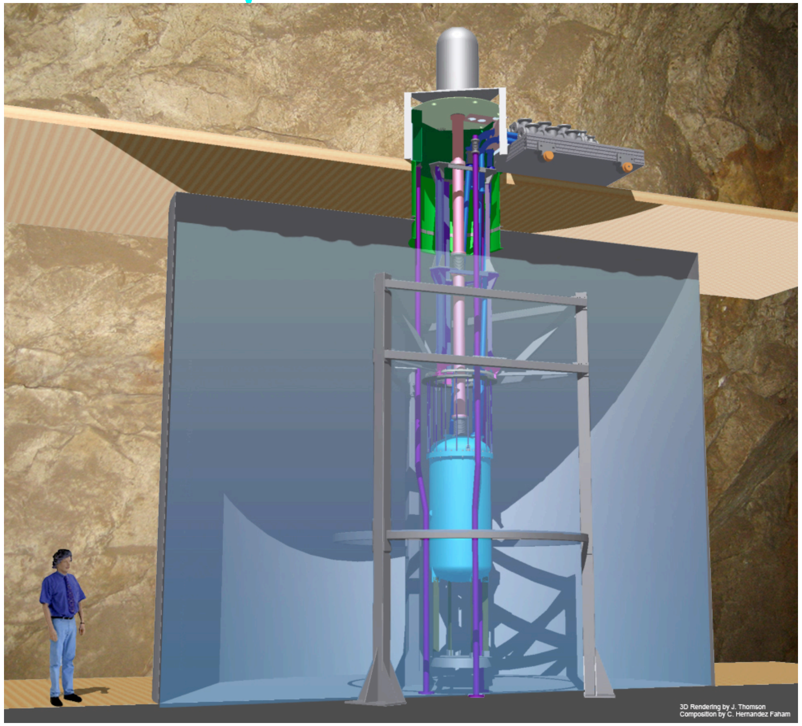
LZ



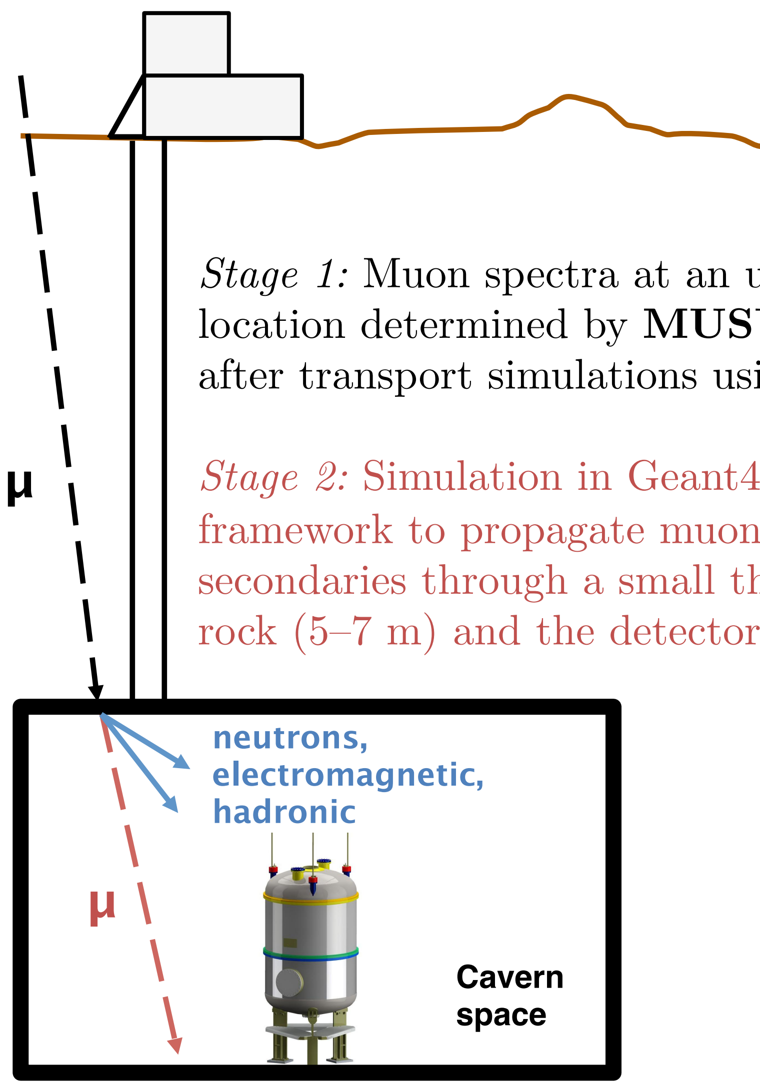
1.5 x 1.5 m cylinder
10 ton LXe
7 ton active mass
~ 5.6 ton fiducial mass
494 (131) PMTs in TPC (Skin)

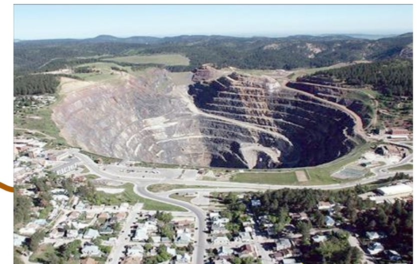
External backgrounds

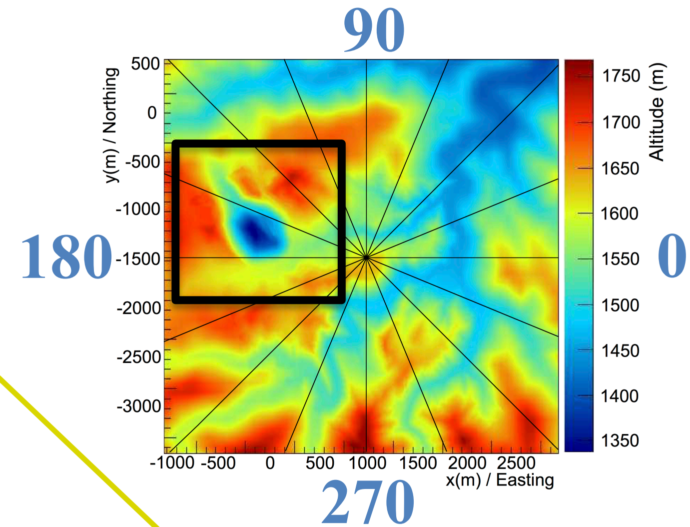
- External background - everything outside of the water tank.
- Here I will talk specifically about muon-induced neutrons and gammas from the cavern rock.



Muon simulations for SURF

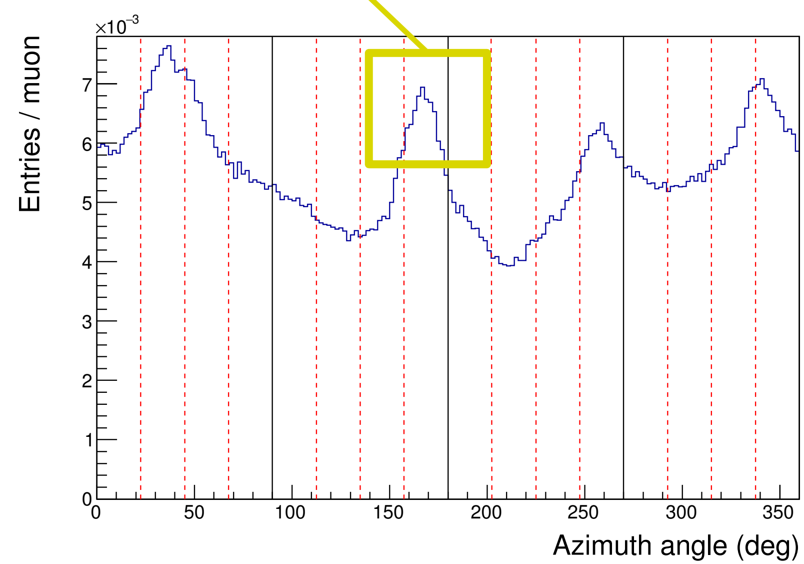




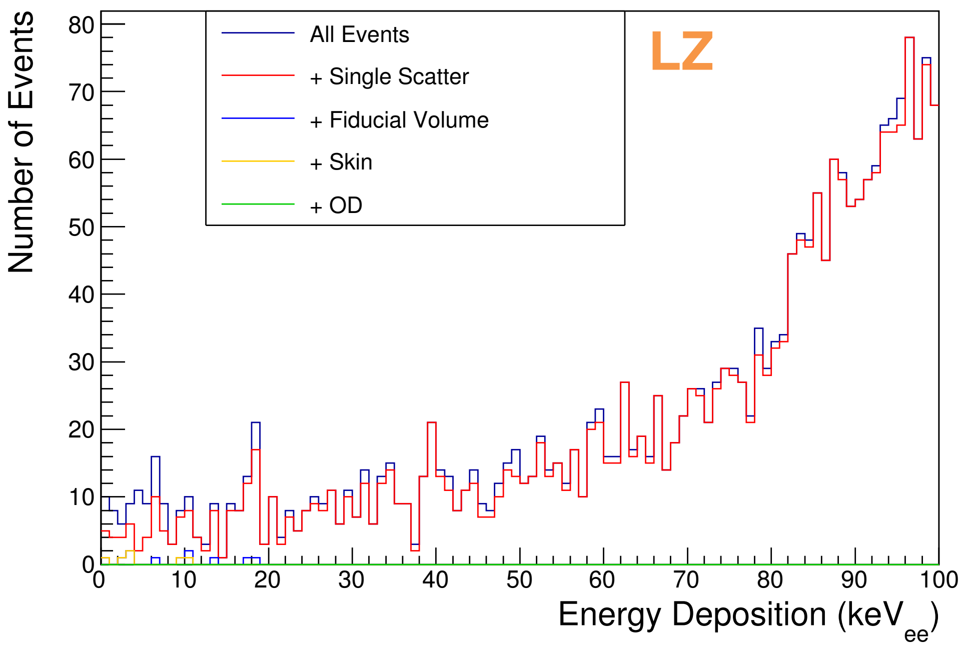


Stage 1: Muon spectra at an underground location determined by **MUSUN** code after transport simulations using **MUSIC**.

Stage 2: Simulation in Geant4-based framework to propagate muons and secondaries through a small thickness of rock (5–7 m) and the detector geometry.



Muon-induced background rate



Cut	Number of surviving events
Region of interest (< 100 keV$_{ee}$)	2235
+ single scatter	2128
+ fiducial volume	11
+ skin	6
+ outer detector	**0**

Events that look like WIMPs

- Single scatters: energy-weighted position variance $\sigma_r < 3.0$ cm and $\sigma_z < 0.2$ cm.
- Inside fiducial region: energy-weighted position $r < 68.8$ cm and $1.5 \text{ cm} < z < 132.1$ cm.
- Events without coincident signals (within 500 μs) above 200 keV$_{ee}$ (100 keV$_{ee}$) in the scintillator (skin) vetoes.

LZ: 2.44 events for the acquired statistics - upper limit of 0.06 events in 1000 days at 90% C.L.

LUX: Re-analysis of LZ simulations with 200 MeV scintillator threshold to mimic water Cherenkov - $(1.0 \pm 0.4) \times 10^{-3}$ events in 300 days.

Rock gamma simulations

- Start with the decays of ^{238}U, ^{232}Th, ^{40}K in the cavern rock to generate initial γ-ray flux.
- Simulation by brute-force is not possible – improve statistics by using several stages, with a multiplication at each surface.

$$B(\mathrm{s}^{-1}) = \overbrace{\phi_{\mathrm{wt}}(\mathrm{s}^{-1}) \cdot \alpha_{\mathrm{shield}} \cdot R_{\mathrm{cuts}}}^{10^{-9}}$$

Total background rate from this source

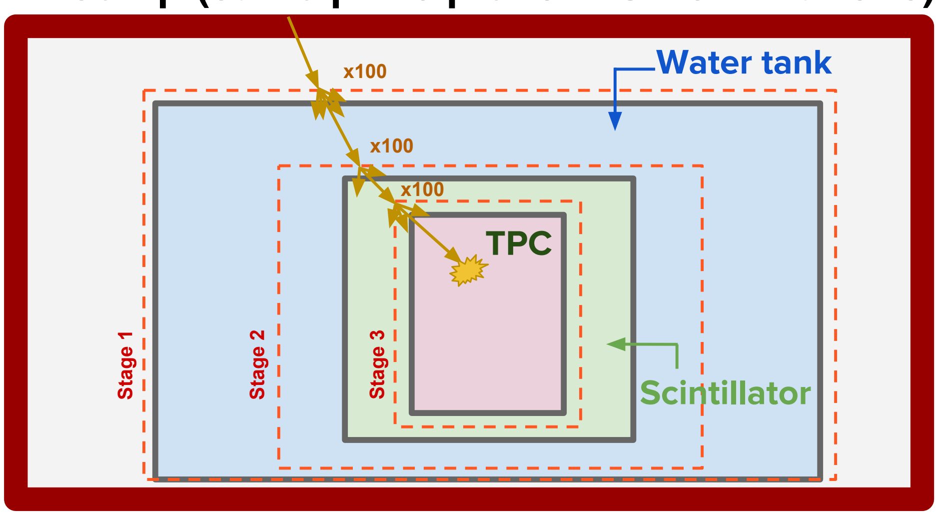
Flux at water tank

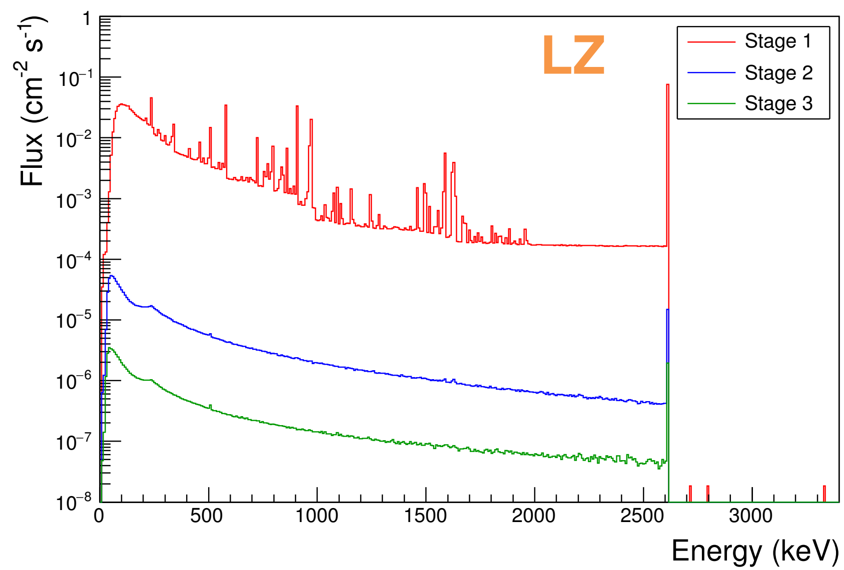
Attenuation due to shielding

Rejection due to event selections

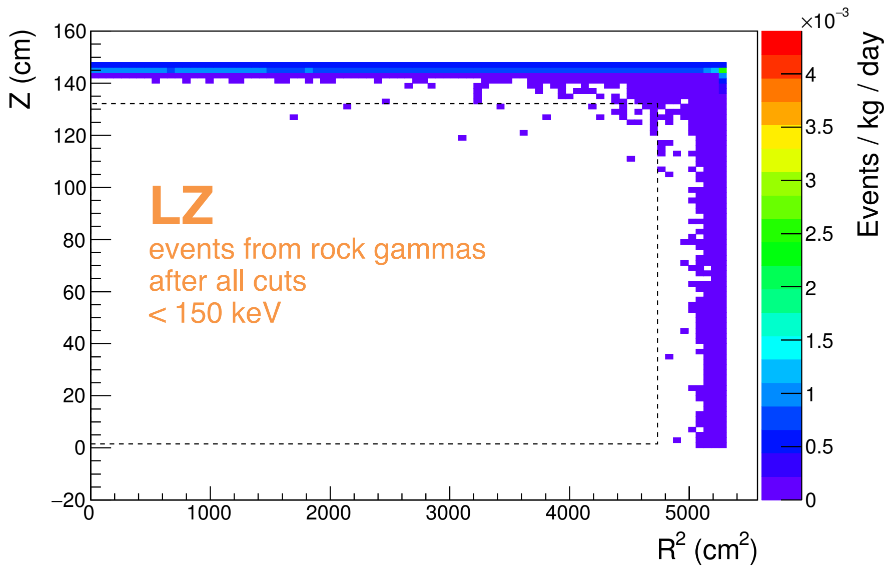
Few events after cuts in 1000 days – *O*(10^{15}) decays – computationally intensive.

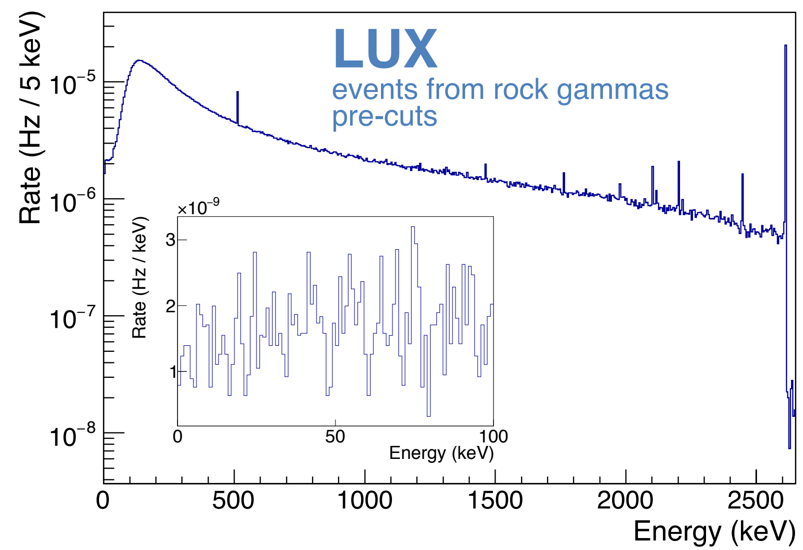
LZ setup (same principle for LUX simulations)





Rock gamma background rate





Isotope	Activity (Bq/kg)	Simulated live days		Rate (μDRU$_{ee}$)*	
		LZ	LUX	LZ	LUX
^{238}U	24.8	402	7.34×10^4	0.012 ± 0.006	0.23 ± 0.02
^{232}Th	13.6	734	4.02×10^4	0.05 ± 0.02	1.10 ± 0.04
^{40}K	381	262	2.62×10^4	0.014 ± 0.007	0.022 ± 0.009
Total				$\mathbf{0.07 \pm 0.02}$	$\mathbf{1.35 \pm 0.05}$

* Before S1/S2 discrimination (> 99%)
DRU$_{ee}$ = day^{-1} kg^{-1} keV$_{ee}$$^{-1}$

Conclusions

- External backgrounds are sub-dominant to other sources for both LUX and LZ.
- **LZ:**

	ER	NR
Laboratory and Cosmogenics		
Laboratory rock walls	4.6	0.00
Muon induced neutrons	-	0.06
Cosmogenic activation	0.2	-
subtotal	**5**	**0.06**
Total	1195	1.03
Total (with 99.5% ER discrimination, 50% NR efficiency)	5.97	0.52
Sum of ER and NR in LZ for 1000 days, 5.6 tonne FV, with all analysis cuts	**6.49**	

- **LUX:**
  - **Rock gammas: (1.35 ± 0.05) μDRU_{ee}**
  - **Muon-induced neutrons: (6.3 ± 0.3) μDRU_{ee}**
  - **Total observed rate: (3.6 ± 0.4) mDRU_{ee}**
- Generators and Monte Carlo techniques can be used for other LUX/LZ studies.