



Muon induced background for the LZ experiment

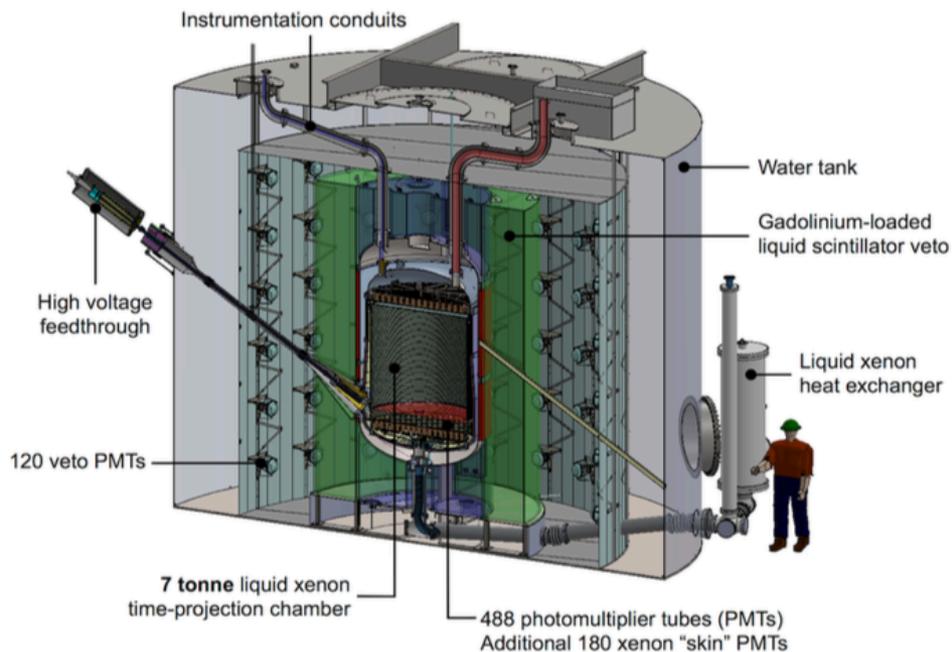
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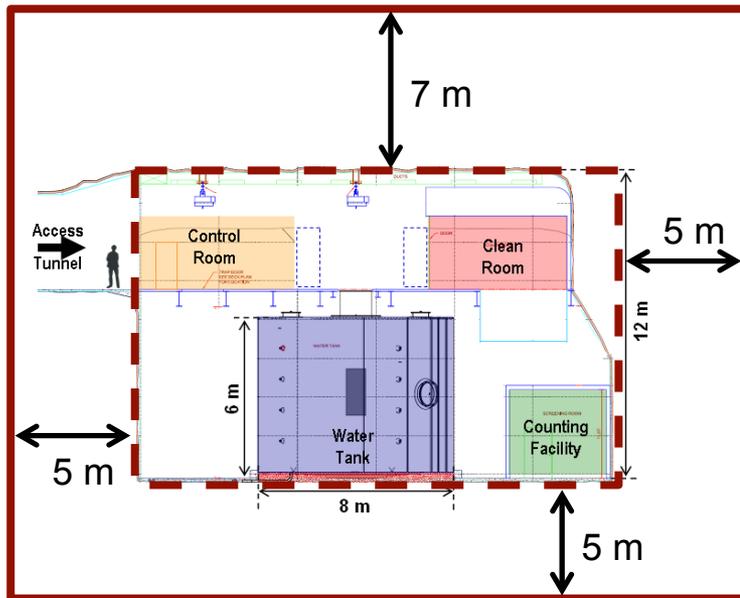
LZ Detector and Backgrounds

- Located in the Davis Cavern at SURF (USA), 4850 ft underground.
- Two-phase xenon TPC with integrated veto system composed of xenon 'skin' region, scintillator and water tank.
- Dominant background comes from radioactivity in detector components.
- Cosmic muons are vetoed by water tank but muon-induced neutrons can generate background.



Simulation Procedure

- Use GEANT4 based simulation package LZSim.
- Start muons on the surface of a cuboid surrounding the detector and propagate through rock.
- Track all secondary particles and record all hits in the detector volumes.
- Event cuts on energy deposition, fiducial volume, hit multiplicity, anti-coincidence with xenon skin and scintillator veto system.



5 m of rock surrounding the cavern on all sides and bottom, 7 m on top.

Cuboid = $24 \times 30 \times 24 \text{ m}^3$

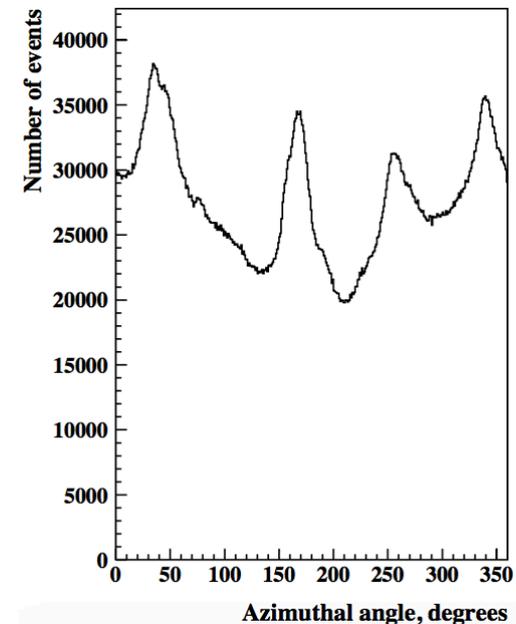
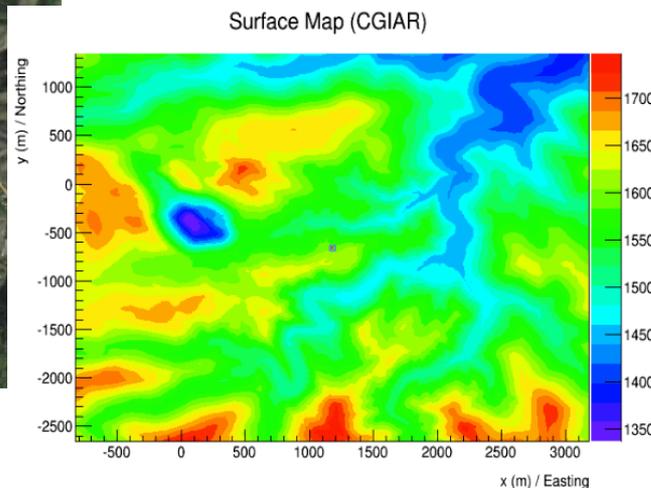
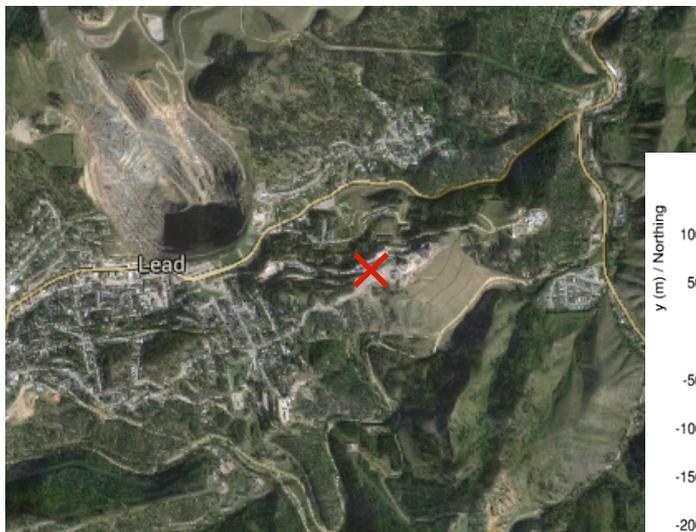
Muon flux (over surface of cuboid) = 0.06098 s^{-1}

Rock density = 2.70 g cm^{-3}



Muons at SURF

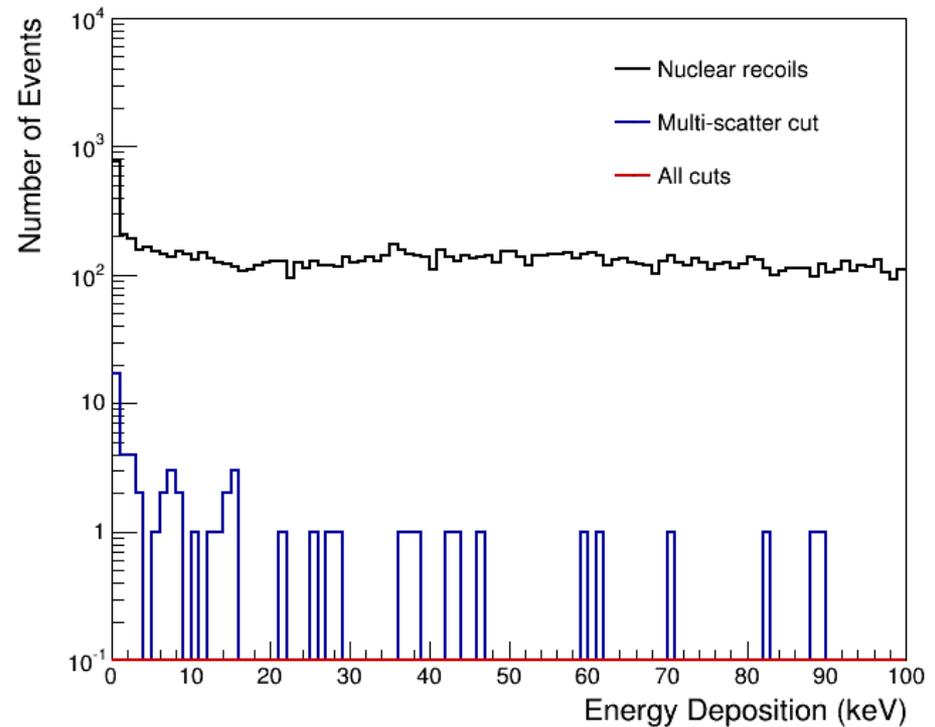
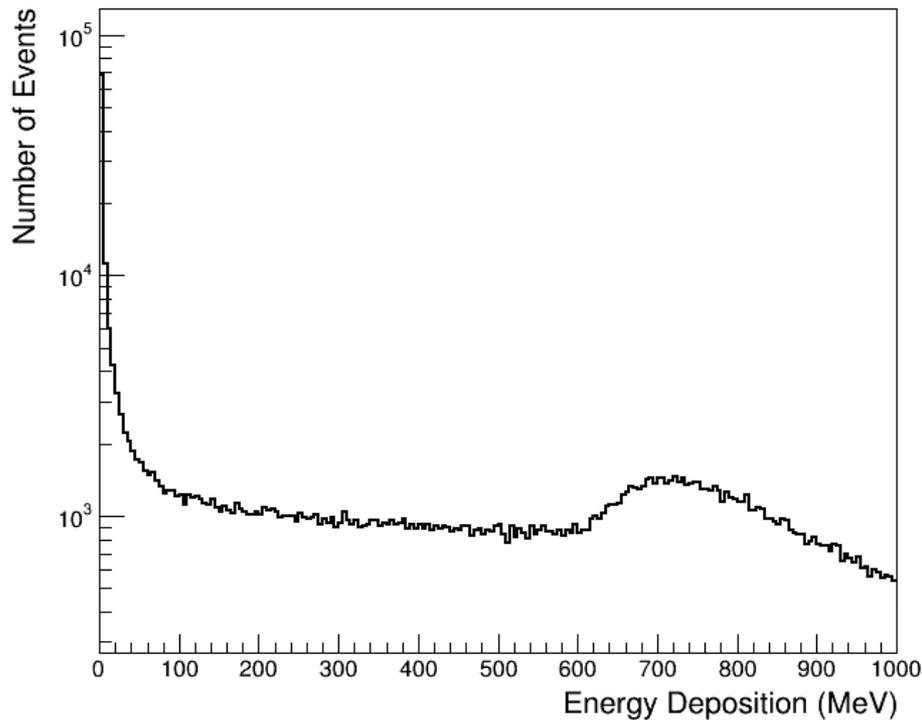
- Initial propagation of muons with different energies through various rock thicknesses using MUSIC.
- Spectra of survived muons convolved with muon spectra at the surface and slant depths.
- Vertical muon flux; simulated = $5.18 \times 10^{-9} \text{ cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1}$, measured (Davis experiment) = $(5.38 \pm 0.07) \times 10^{-9} \text{ cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1}$



Ariel photo and surface profile of the area surrounding the Davis Cavern at SURF (left) and the muon azimuthal angle distribution (right). On the surface map azimuth angle of 0° points East increasing counter clockwise.



Hit and Event Spectra

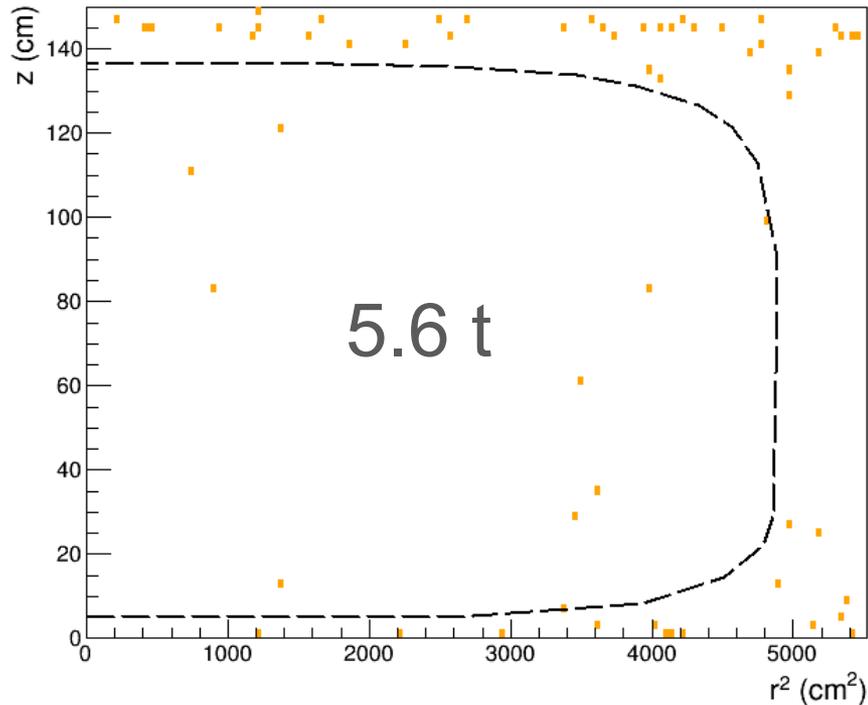


Energy spectrum of all **hits** in the LXe target (left) and **events** (0-100 keV) in the LXe target (right). Each plot shows statistics for $\sim 112 \times 10^6$ primary muons.



Event Summary

- Simulated 112×10^6 muons (~ 58 years statistics)
- Upper limit of 0.11 events / 1000 days / 5.6 ton (90% CL)



| Cut | No. Events |
|---------------------------------------|------------|
| No Cuts (all events) | 367836 |
| Nuclear Recoils | 42988 |
| Single Scatter | 69 |
| Single Scatter + Fiducial cut | 9 |
| Single Scatter + Fiducial + Veto Cuts | 0 |

Energy weighted positions of single scatter events in the Xe target for a 5.6 ton fiducial volume (left) and table summarising number of events remaining after each event cut is applied (right).