# Davis Cavern Gamma Flux

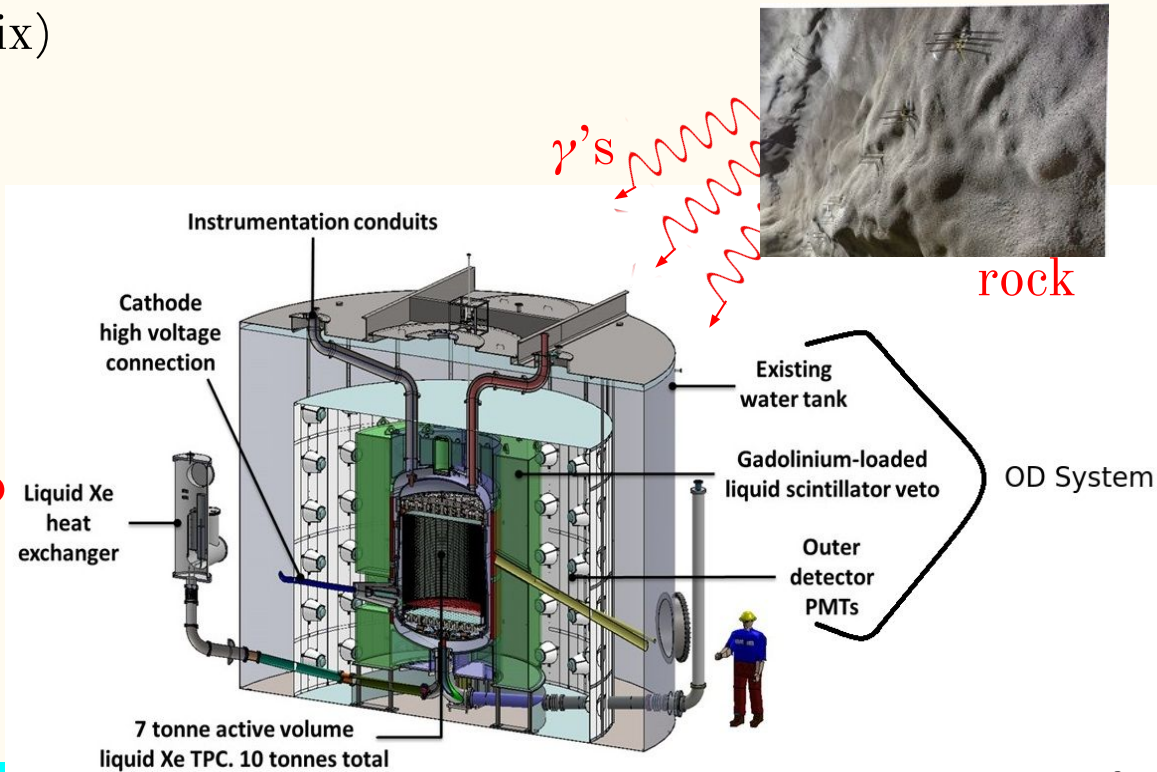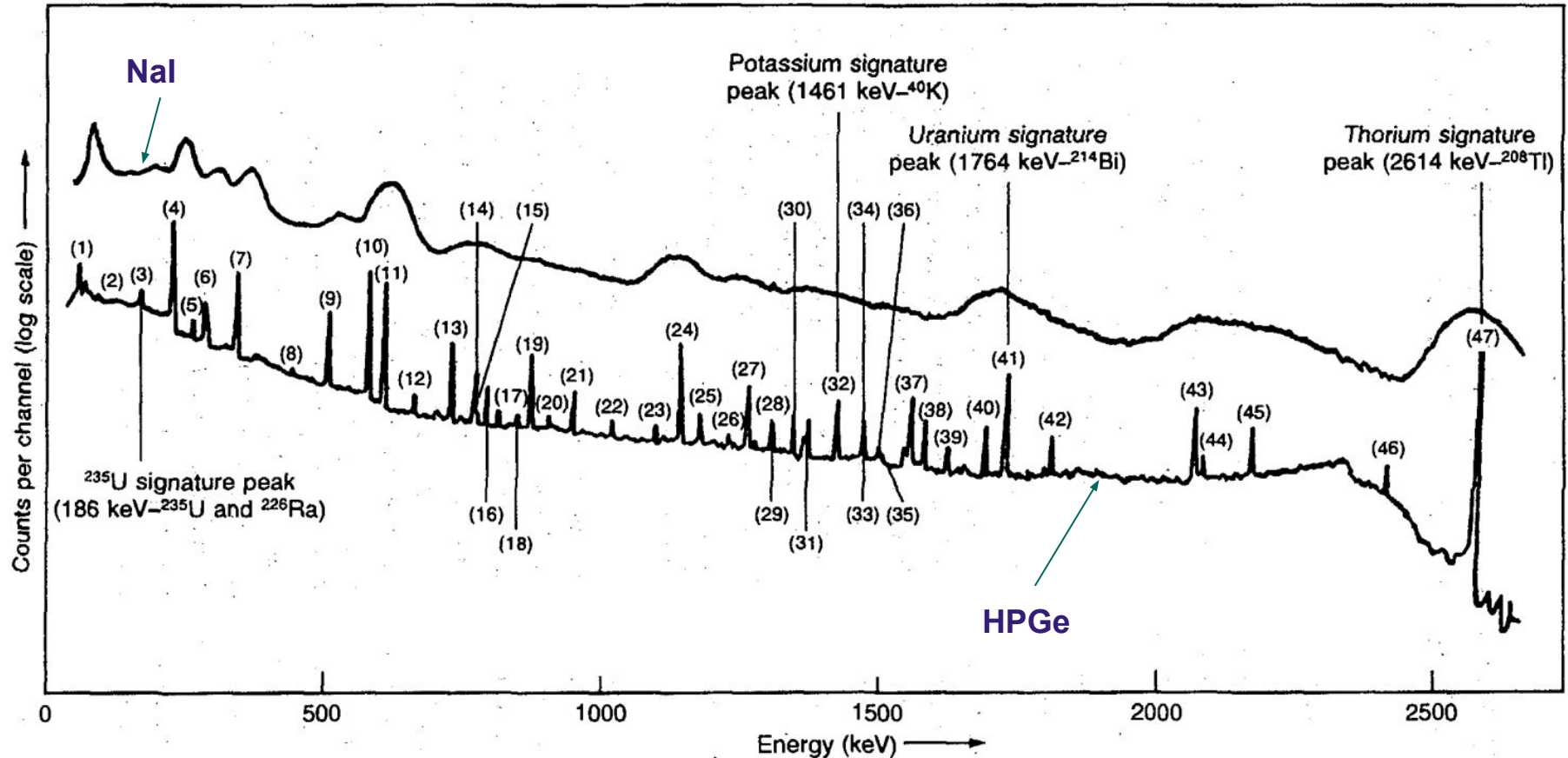Luke Korley
(for the LZ Collaboration)

LUX-ZEPLIN (LZ)

- Aims to observe interaction of DM particles with atomic nuclei
- 4850 ft below surface in Davis cavern of Sanford Underground Research facility (SURF) in south dakota
- Dual phase (LXe+GXe) TPC + instrumented LXe Skin + Outer detector (OD)
- Observes scintillation light from interactions with LXe atoms
- DM interaction signal is nuclear recoil

TPC

LXe Skin

Gd-LS

Steel Pyramid

Water PMTs

OD
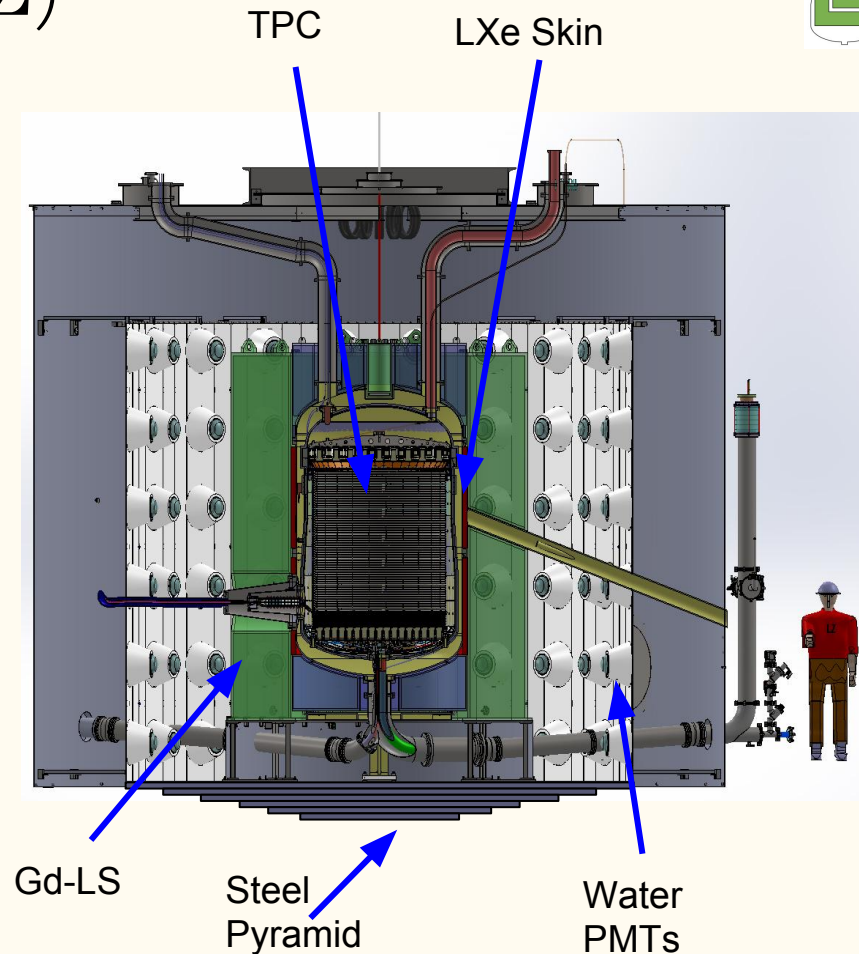
- Veto for neutron backgrounds
- Organic scintillator doped with gadolinium (high neutron capture cross section of ~50,000 barns for natural mix)
- Gd neutron capture signal → 8 MeV (in 4-5 gammas)
- Gammas from radioisotopes in cavern rock can induce false veto
- Characterisation necessary to determine deadtime/efficiency tradeoffs (<5% deadtime desired)

γ's

rock

Instrumentation conduits

Cathode high voltage connection

Liquid Xe heat exchanger

Existing water tank

Gadolinium-loaded liquid scintillator veto

Outer detector PMTs

OD System

7 tonne active volume liquid Xe TPC. 10 tonnes total

Luke Korley

^{40}K, ^{238}U and ^{232}Th spectra

Analytical Techniques in Uranium Exploration and Ore Processing",
IAEA Vienna, 1992

Gamma background measurements to date

- **2006:** Measurement at SURF but not at 4850 ft level

    Mei, D-M., and A. Hime. "Muon-induced background study for underground laboratories."
    Physical Review D 73.5 (2006): 053004.

- **2014:** Measurement in east counting room of Davis cavern with HPGe detector

    K. J. Thomas, 2014

- **2016:** Sims based on 2014 measurements predict OD rate of ~90Hz → Close to 5% deadtime requirement

    D. Woodward; (LZ internal report)

- **2017:** LZ OD prototype measures lower rate than predicted by 2016 sim

    S. Haselschwardt, The LZ Liquid Scintillator Screener Campaign

Davis Cavern

Rhyolite intrusion

DAVIS WEST WALL

DAVIS NORTH WALL

DAVIS EAST WALL

DAVIS SOUTH WALL
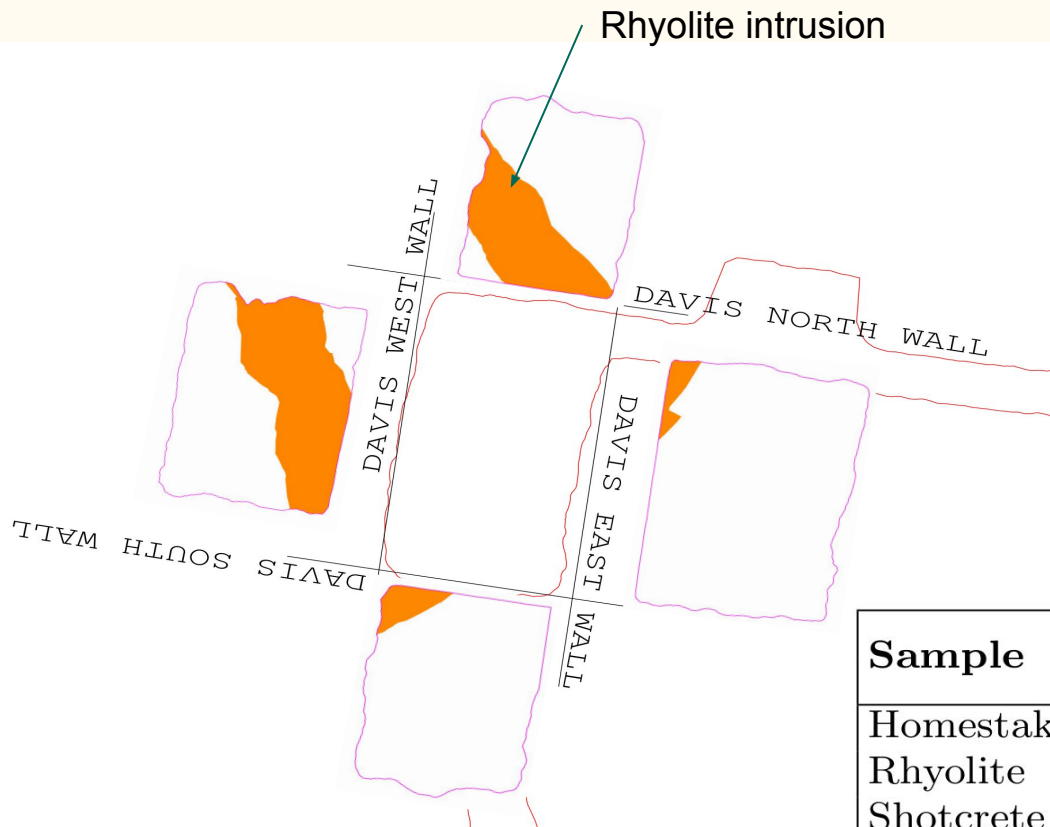
Sample	^{40}K (Bq/kg)	^{238}U (Bq/kg)	^{232}Th (Bq/kg)
Homestake	297.2	2.7	1.3
Rhyolite	1291.0	108.0	44.1
Shotcrete	216.7	21.4	11.4
Water tank gravel	35	26.4	1.7

The Band

Luke Korley

Melih Solmaz, Sally Shaw, Umit Utku, Scott Haselschwardt

Cavern measurement expedition

- Aim to conduct several measurements in the empty LZ water tank and determine how much (if any) additional shielding would be required to protect OD
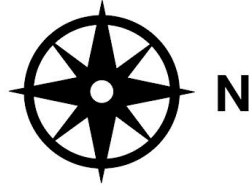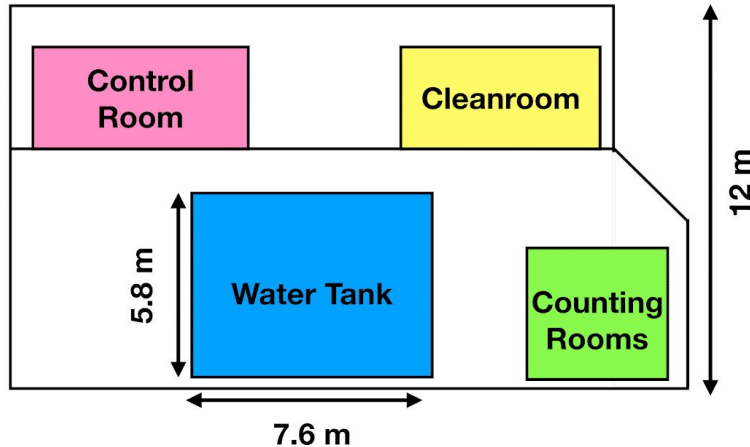- Used NaI(Tl) detector

5x5 Inch NaI(Tl) Crystal

Centre of water tank, looking up

Code	Description
Pos0	Centre, unshielded
Pos1	Centre, looking up
Pos2	Centre, looking down
Pos3	Halfway to south edge, looking down
Pos4	South Edge, looking down
Pos5	Upper Davis, unshielded
Pos6	East Counting Room, unshielded
Pos7	Centre, looking east
Pos8	Centre, looking west

N

❌ **Measurement Position**

Upper Davis

Control Room

Cleanroom

Pos5

10 m

17 m

N-S Vertical Cross Section

Control Room

Cleanroom

Water Tank

Counting Rooms

12 m

5.8 m

7.6 m

Lower Davis

Water Tank

Counting Rooms
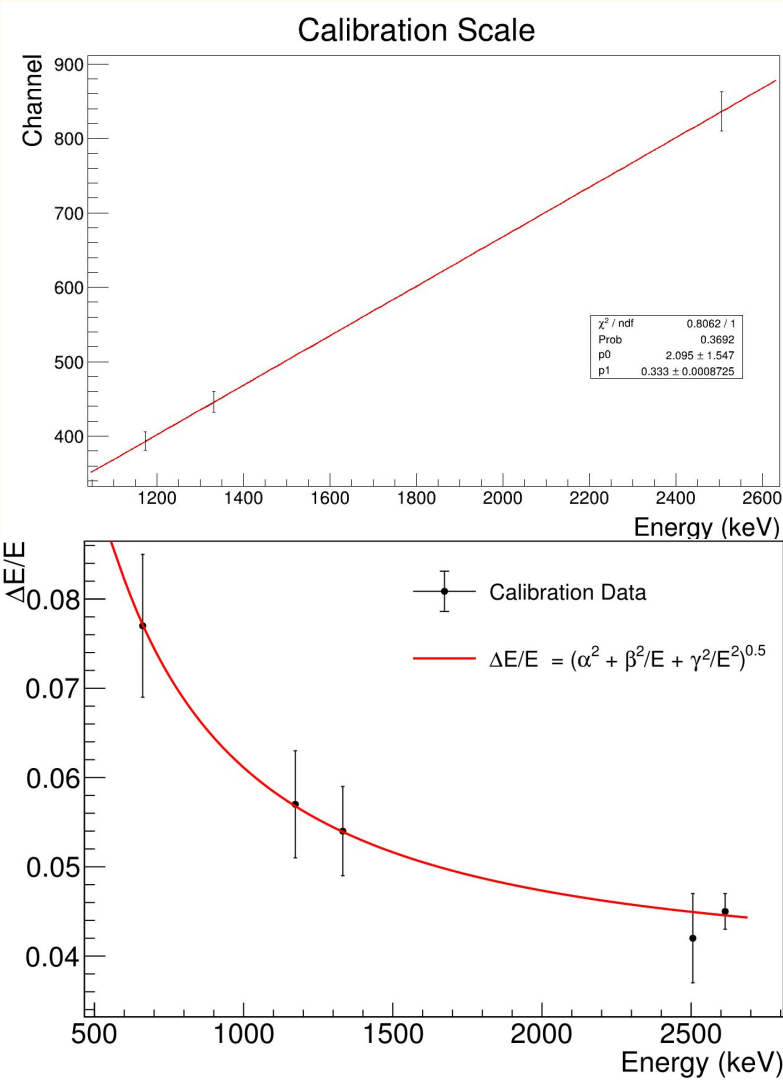
Pos4 Pos3 Pos0
Pos1
Pos2
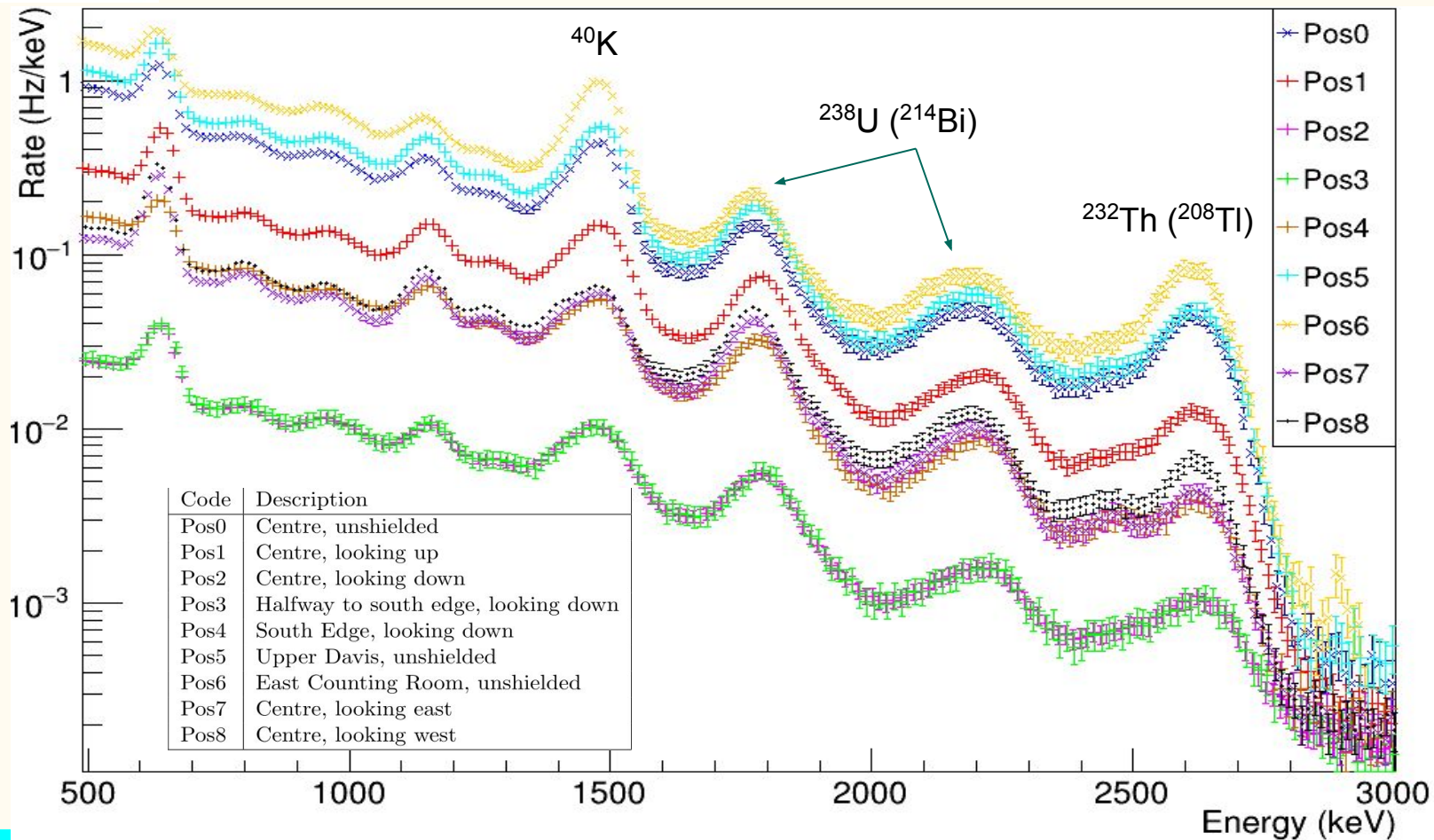Pos7
Pos8

Pos6

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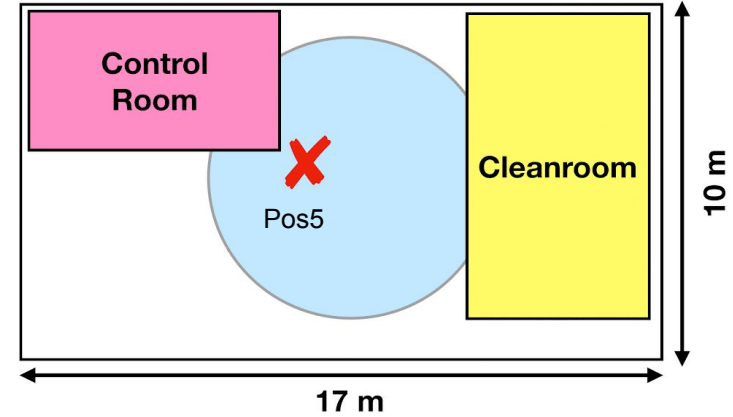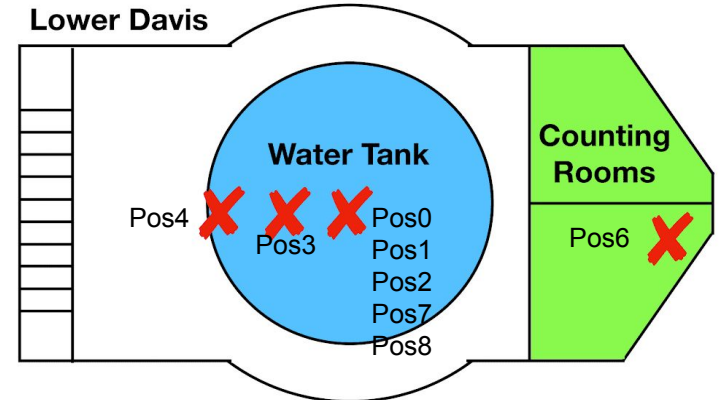
Efficiency & Resolution

- Efficiency calculated as ratio of expected rate to detected rate.
  - Correction Factor of **0.90±0.06**
- FWHM modelled with :

$$\frac{\Delta E}{E} = \sqrt{\alpha^2 + \frac{\beta^2}{E} + \frac{\gamma^2}{E^2}}.$$

M. Moszyski, "Inorganic scintillation detectors in gamma-ray spectrometry," 2003


Calibration Scale

χ² / ndf	0.8062 / 1	
Prob	0.3692	
p0	2.095 ± 1.547	
p1	0.333 ± 0.0008725	

$\Delta E/E = (\alpha^2 + \beta^2/E + \gamma^2/E^2)^{0.5}$

Simulating the Davis Cavern

- Use LZ BACCARAT[*] framework (utilizing Geant4 package)
- Isotopes placed in 30cm shell of rock, replicating surface of cavern wall
- Energy deposit spectra smeared using NaI FWHM model

Plot legend:
— true energy deposits
— smeared spectrum

Axes: Rate (Hz) vs energy (keV)
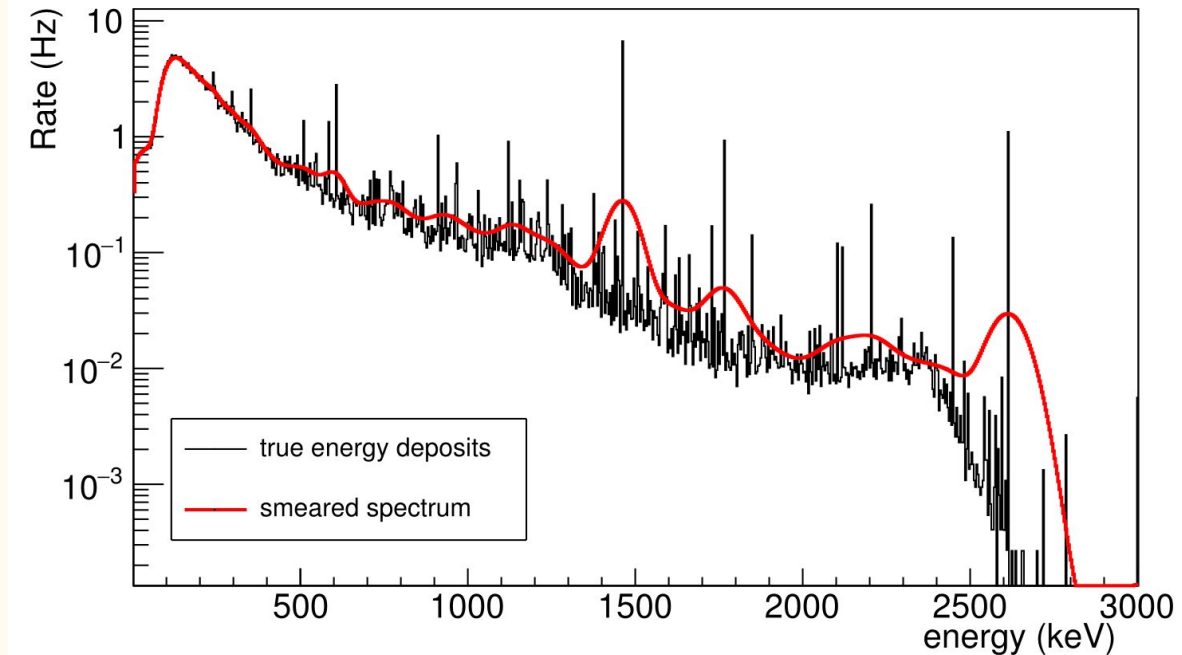
[*]See IDM talk "Simulations for the LUX-ZEPLIN Experiment" by V. Kudryavtsev

Rock Spectra Fit

- Analytic fitting function for background peaks hard to find
  - Used simulation with Geant4 to obtain templates for fitting to efficiency corrected data

Results
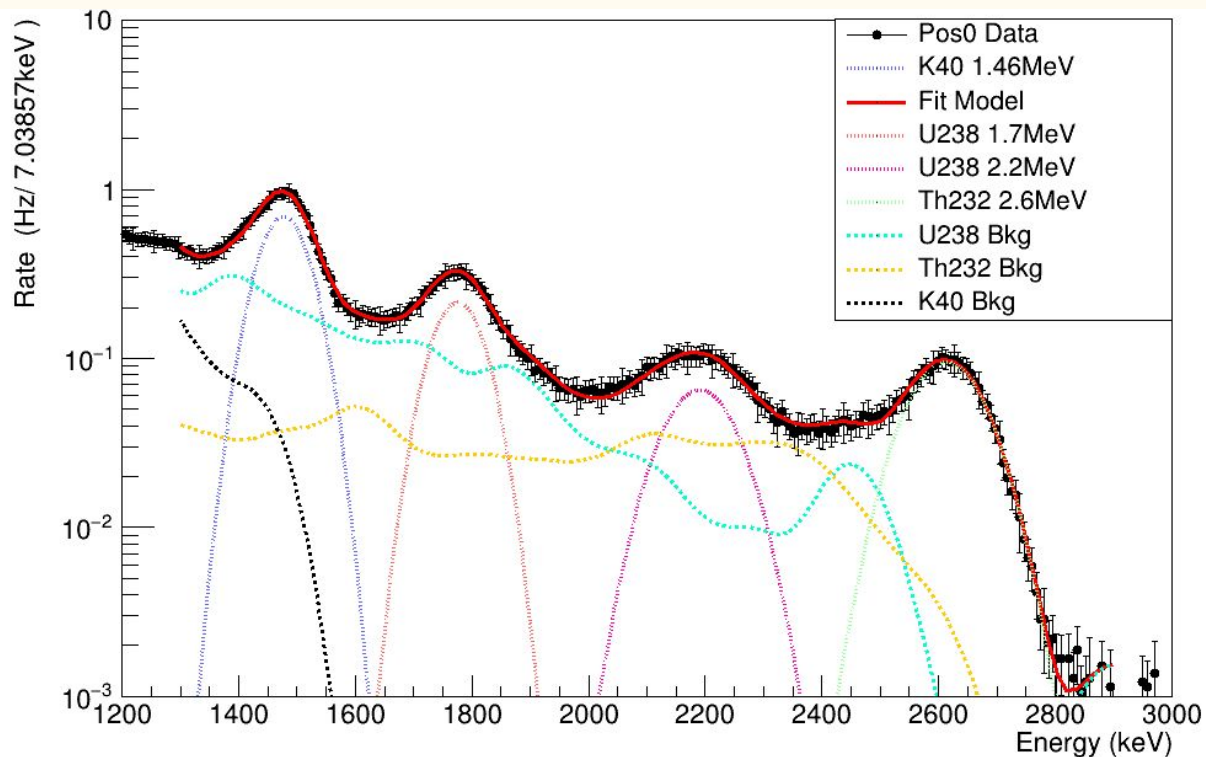
- Simulations used to determine rates from "old" activities
  - Data/Sim gives correction factor to absolute activities
- MC gamma survival rates for each position gives contribution of each wall to the spectra
- Use each walls contribution to measurements as weights to construct average activity for each wall

Very conservative estimate based on HPGe measurement

	K		U		Th	
Wall	Bq/kg	+/-	Bq/kg	+/-	Bq/kg	+/-
North	230	20	55	2	12.7	0.4
East	250	40	46	3	13	0.5
South	240	20	51	2	12.9	0.4
West	250	30	51	1	13	0.3
Ceiling	210	10	56	3	12.2	0.5
Floor	260	40	43	3	13.1	0.7
Average	**240**	**70**	**50**	**6**	**13**	**1**
Old	716		73.4		26.1	

Summary

- OD veto efficiency influenced by cavern background

- Historical measurements limited: comprehensive survey required

- Dedicated measurements made at various locations in cavern

- Lower average wall activity than conservatively predicted

- Can utilise results for gamma flux model for water tank surface

- Paper in preparation!

LZ Collaboration (2018)