Davis Cavern Gamma Flux

Luke Korley

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) time projection chamber (TPC) + Outer detector veto (OD)
- Observes scintillation light from interactions with LXe atoms
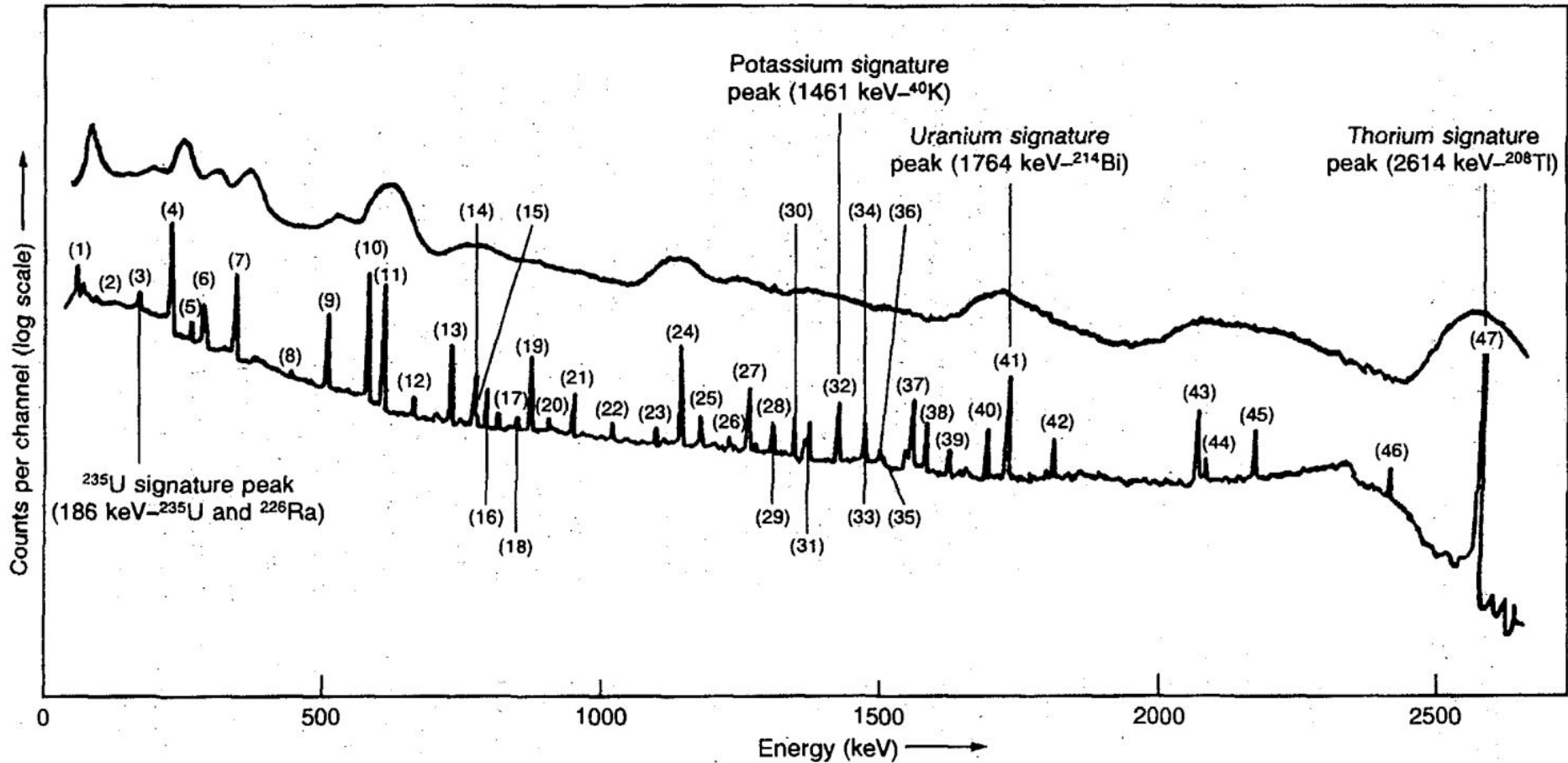- DM interaction signal is nuclear recoil
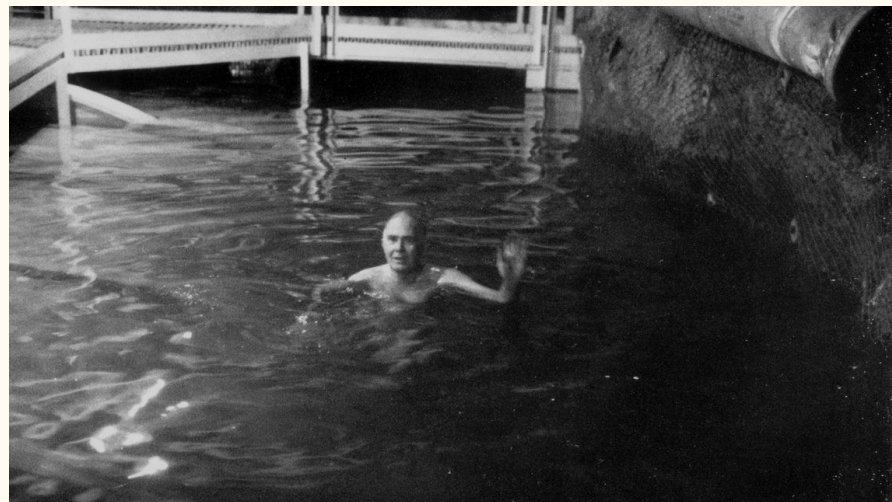
OD

- Veto for neutron backgrounds

- Organic scintillator doped with gadolinium (high neutron capture cross section of ~254 kb)

- Gd neutron capture signal → 8 MeV (in 3-4 gammas)

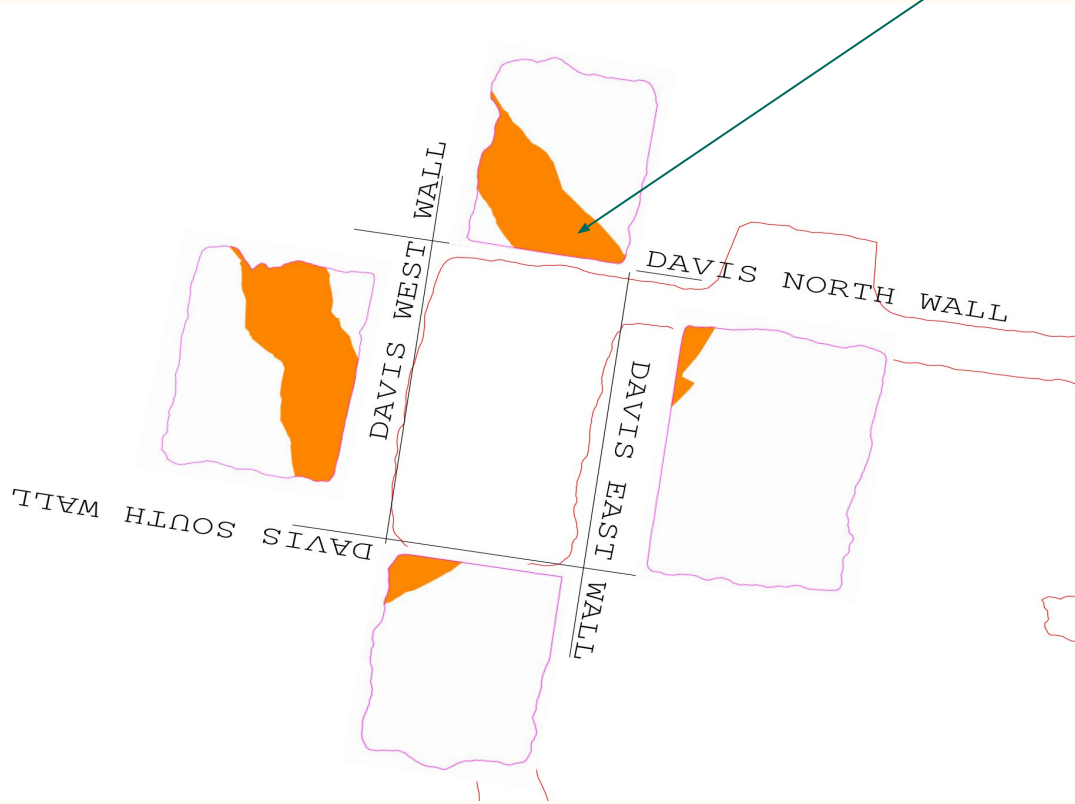- Need to characterize effect of background gammas from radioisotopes in cavern rock
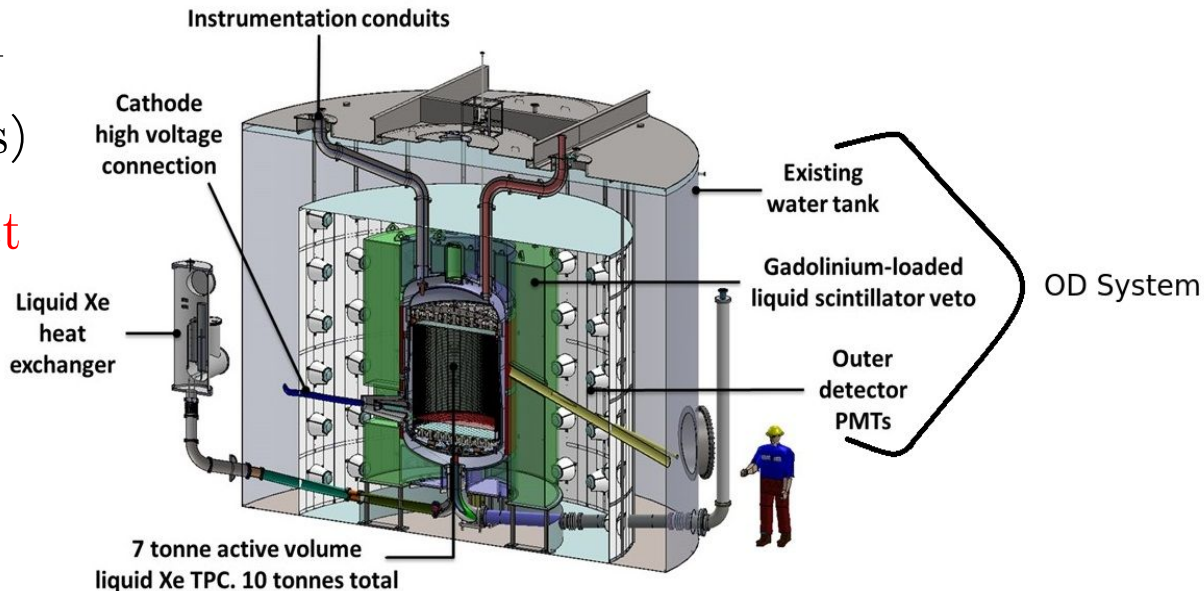
Davis Cavern

Rhyolite intrusion

DAVIS WEST WALL
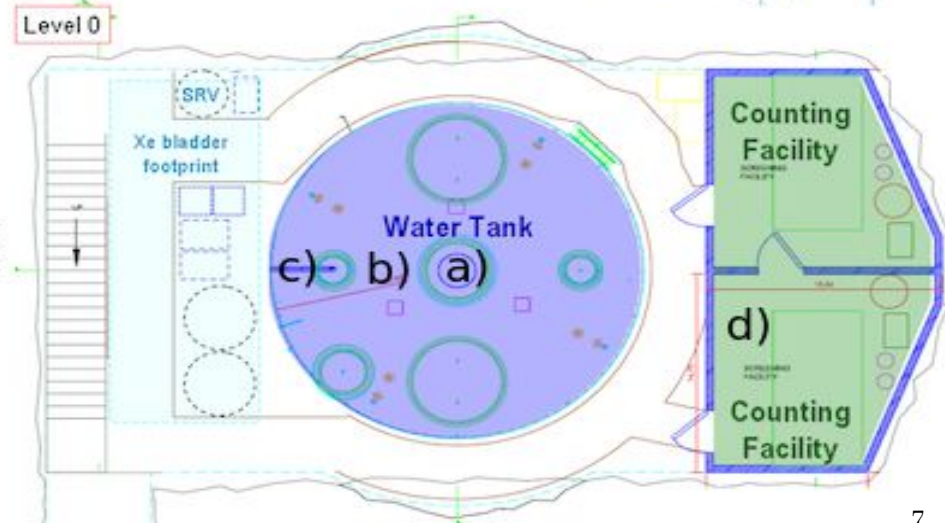
DAVIS NORTH WALL

DAVIS EAST WALL

DAVIS SOUTH WALL

Cavern measurement expedition

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

5x5 inch NaI crystal (that's 12.7 cm for us non-heathens)

Pre-amp

PMT

Centre of water tank, looking up
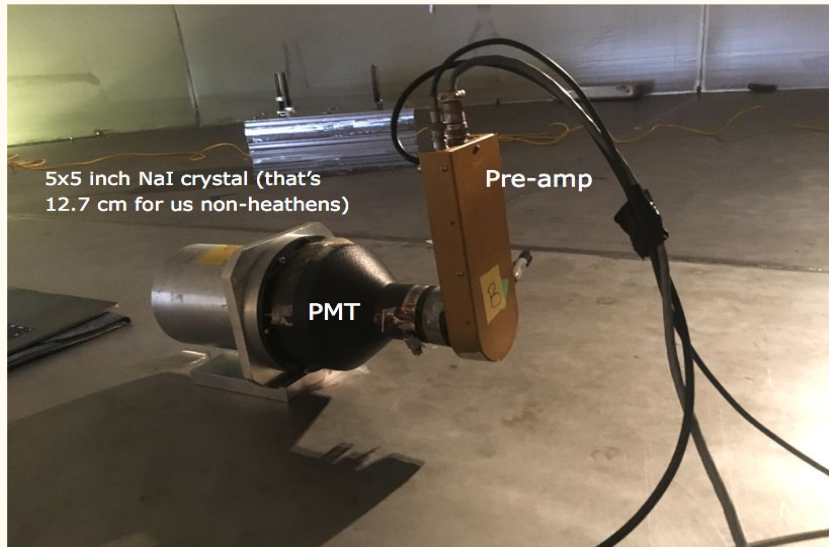
The Davis Laboratory @ Homestake

- Left: N-S vertical cross-section
- Top right: Plan view, level 1
- Bottom right: Plan view, Level 0

N

Level 1

18 m

Access Tunnel

Control Room

e)

Transition

Clean Room

10.5 m

Level 0

Access Tunnel

Control Room

Clean Room

12 m

6 m

Water Tank

Counting Facility

8 m

SRV

Xe bladder footprint

Water Tank

c) b) a)

Counting Facility

d)

Counting Facility

7
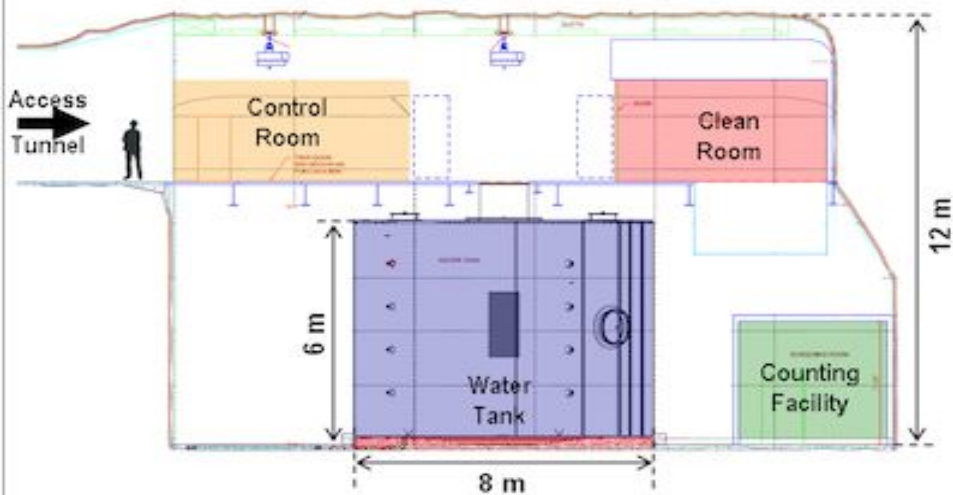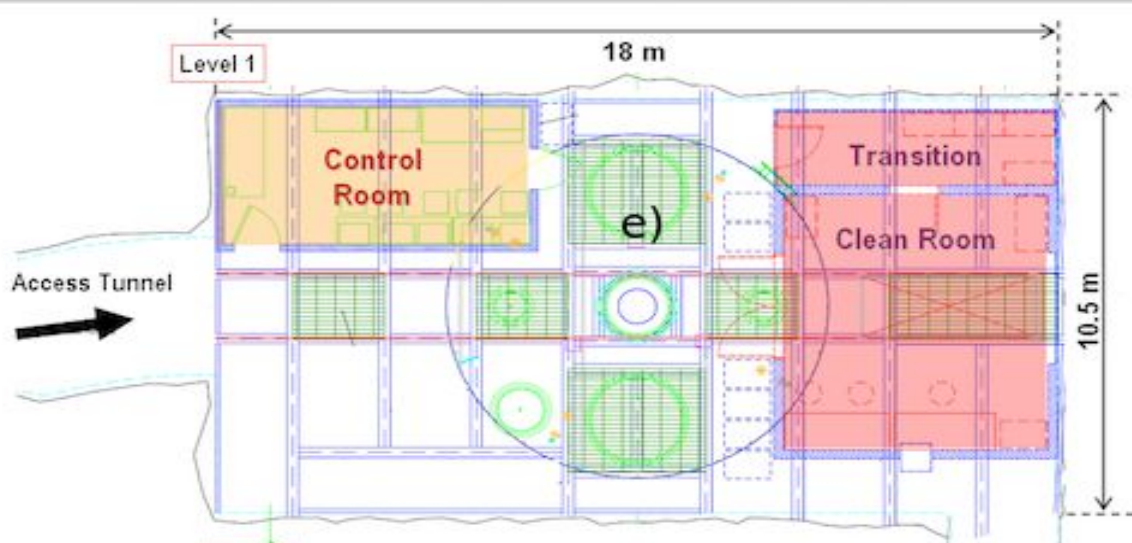
NaI Calibration

Need to determine:
- Resolution of detector
  - Smearing simulations
- Energy scale (conversion from channel no. to energy)
  - Check linearity
- Efficiency
  - Used to correct rates in simulation of rock spectra

Cs137 Calibration Spectra

Co60 Calibration Spectrum
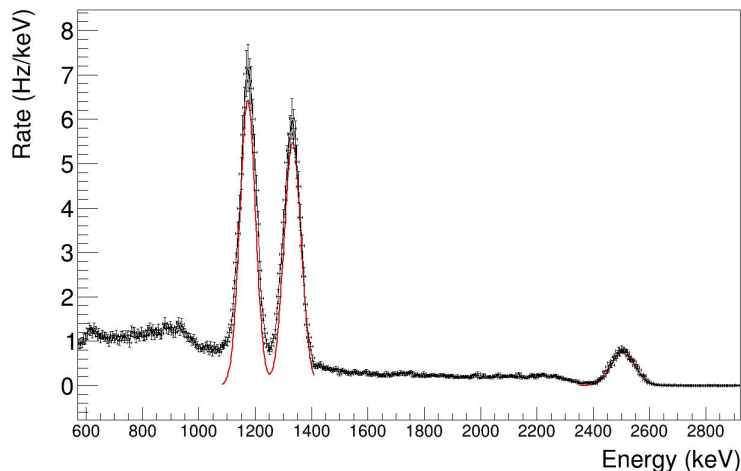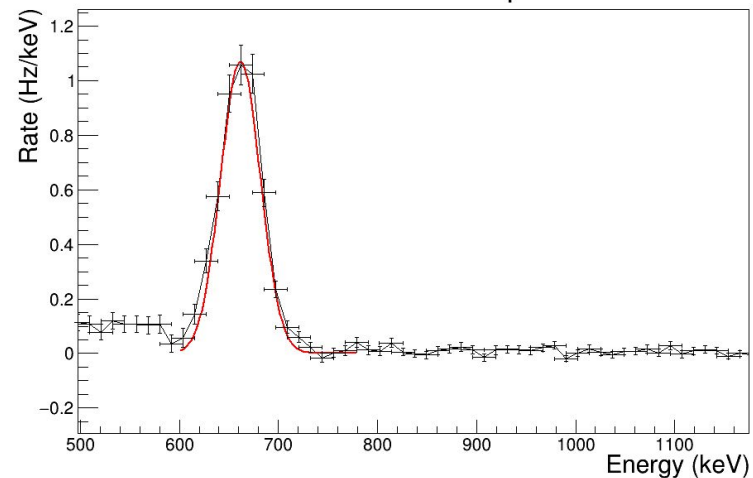
Th228 Calibration Spectra
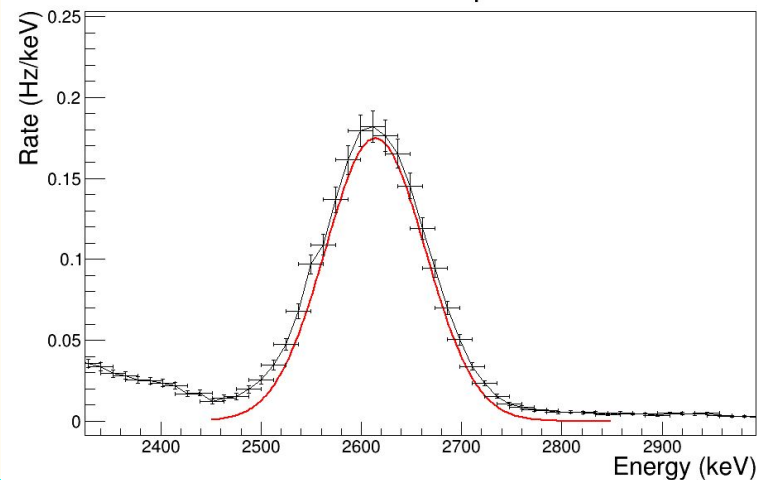
Calibration Cont.

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

$$\Gamma(E) = \sqrt{\alpha^2 + \frac{\beta^2}{E} + \frac{\gamma^2}{E^2}}.$$

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

Location	Code	Description
a	Pos0	Centre, unshielded
a	Pos1	Centre, looking up
a	Pos2	Centre, looking down
b	Pos3	Halfway to south edge, looking down
c	Pos4	South Edge, looking down
e	Pos5	Upper Davis, unshielded
d	Pos6	East Counting Room, unshielded
a	Pos7	Centre, looking east
a	Pos8	Centre, looking west
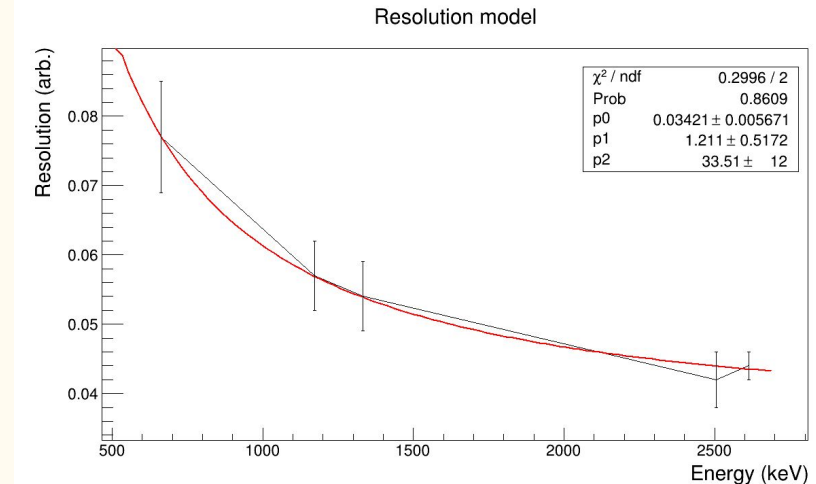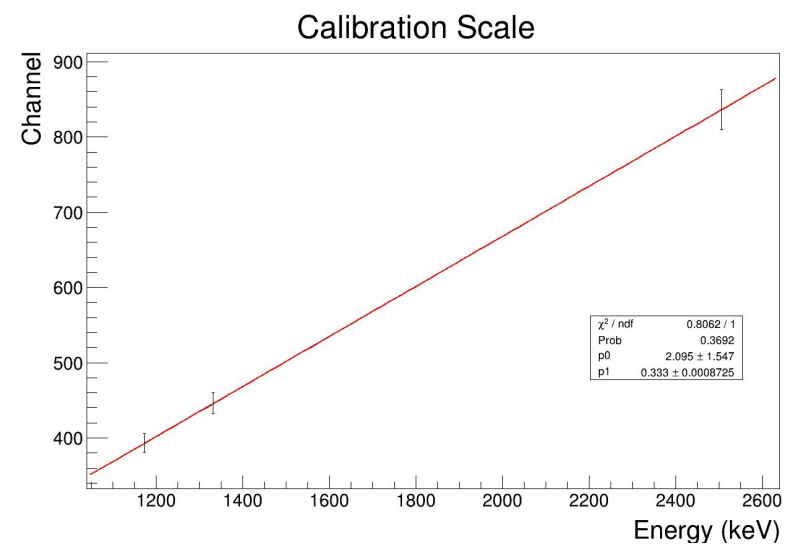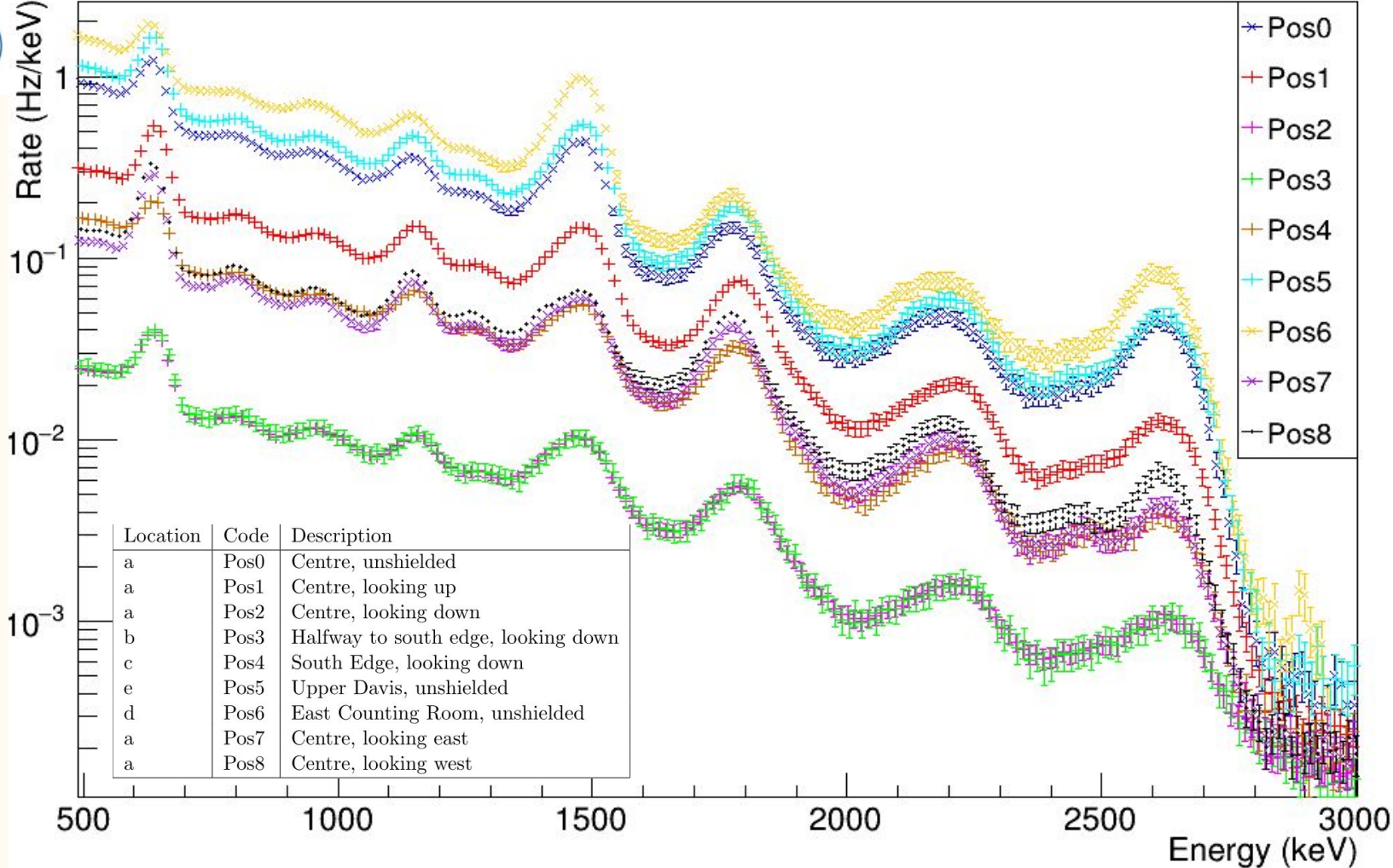
Rock Spectra Fit

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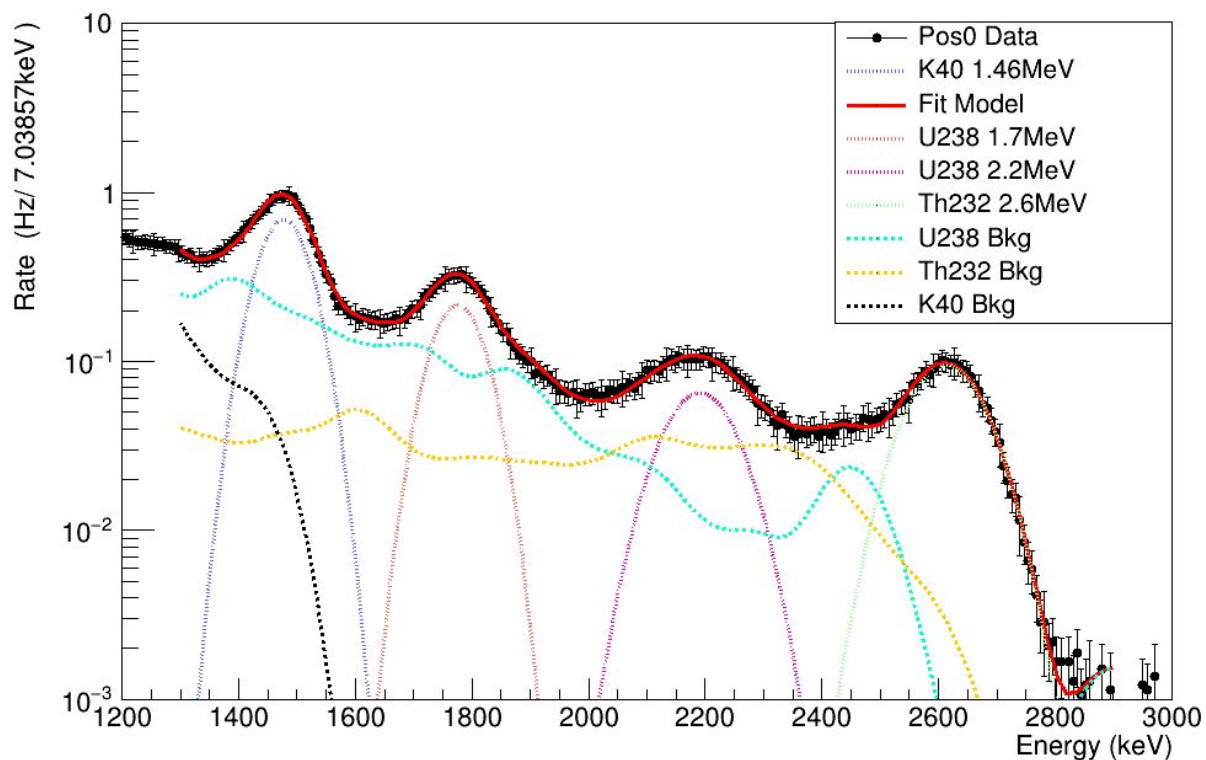
Results

- Differing activities for each position → Possibly non-uniform rock activity

	K40 Activity (Bq/kg)	Error	U238 Activity (Bq/kg)	Error	Th232 Activity (Bq/kg)	Error
Pos0	292	20	58	4	16	1.1
Pos1	205	15	80	6	12	0.8
Pos4	295	26	45	3	14	1.0
Pos5	141	17	36	4	9	0.9
Pos6	260	36	34	7	13	1.4

New

Isotope	Activity (Bq/kg)
Th232	26.1
U238	73.4
K40	716

Old Activities

Luke Korley

Water tank incident flux

Water Tank Floor
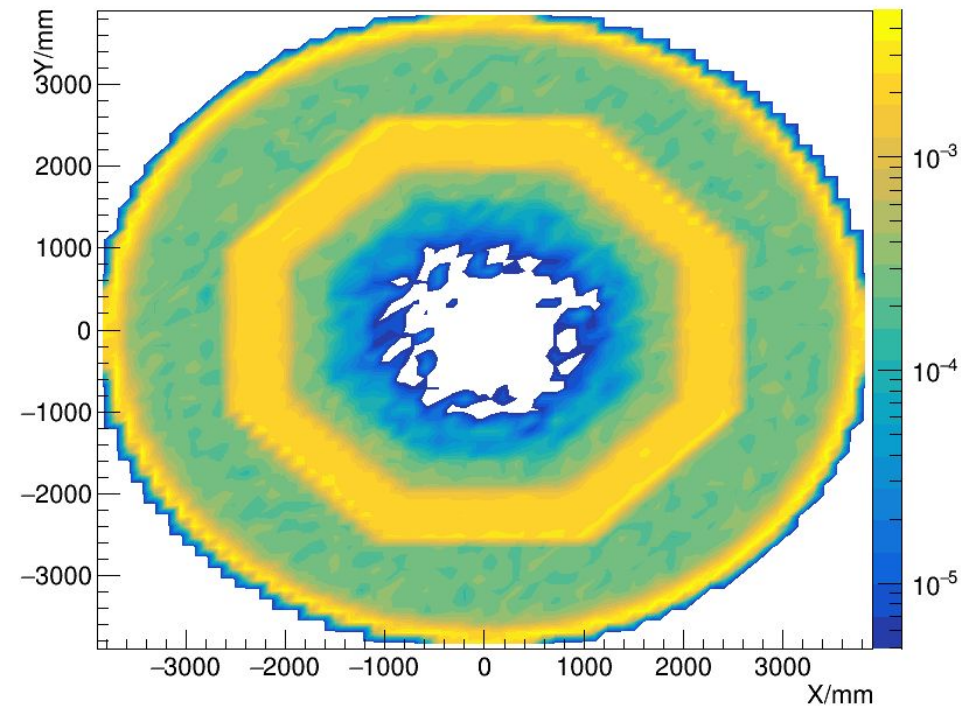
Tank Ceiling Flux
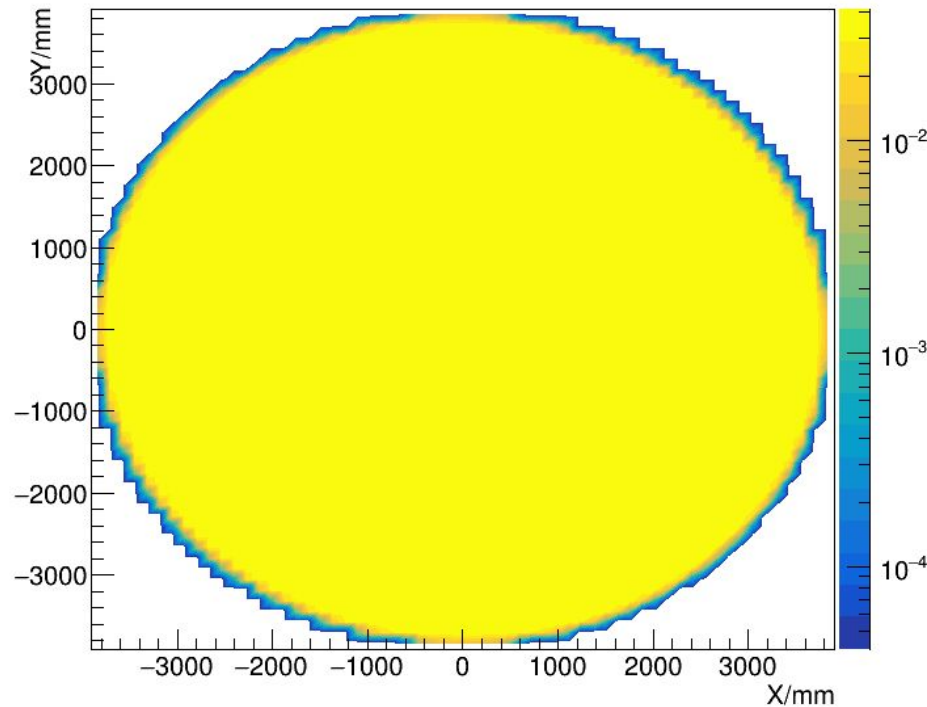
Tank Side Flux
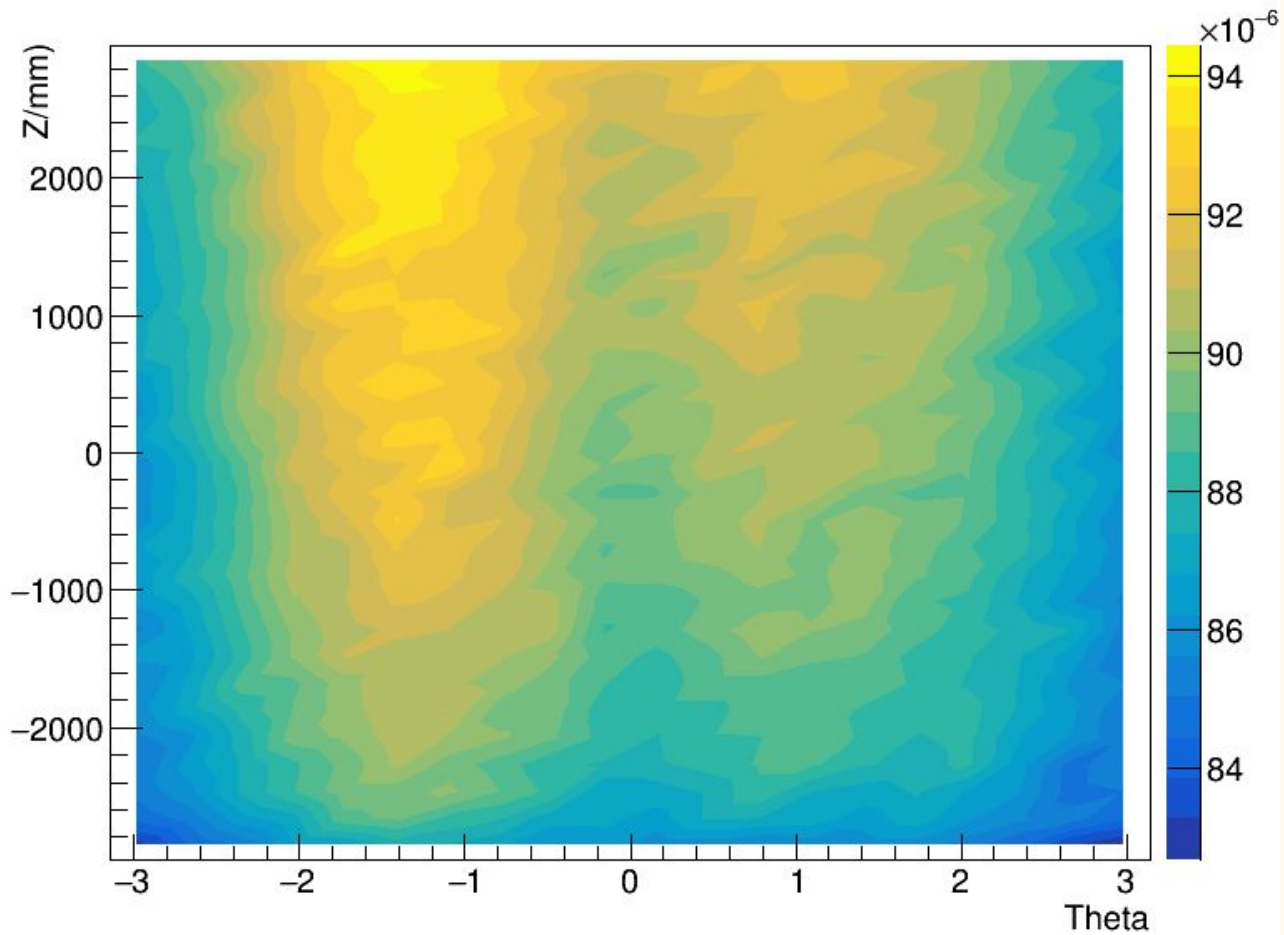
Conclusion

- OD veto efficiency heavily affected by cavern background

- Existing measurements not sufficient

- Dedicated measurements made at various locations in cavern

- Lower average wall activity than was thought

- Non-uniform wall activity suspected

- Can be used for improved gamma from rock description across detector volume

- Paper in preparation!

Melih Solmaz, Sally Shaw, Umit Utku, Scott Haselschwardt

Backups

Gamma background measurements to date

- **2006:** Dongming et al measure at SURF but not at 4850 ft level

  D.-M. Mei and A. Hime, 2006

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

  K. J. Thomas, 2014

- **2016:** Sims based on 2014 & 2006 measurements predict an unacceptably high rate in OD (~90Hz)
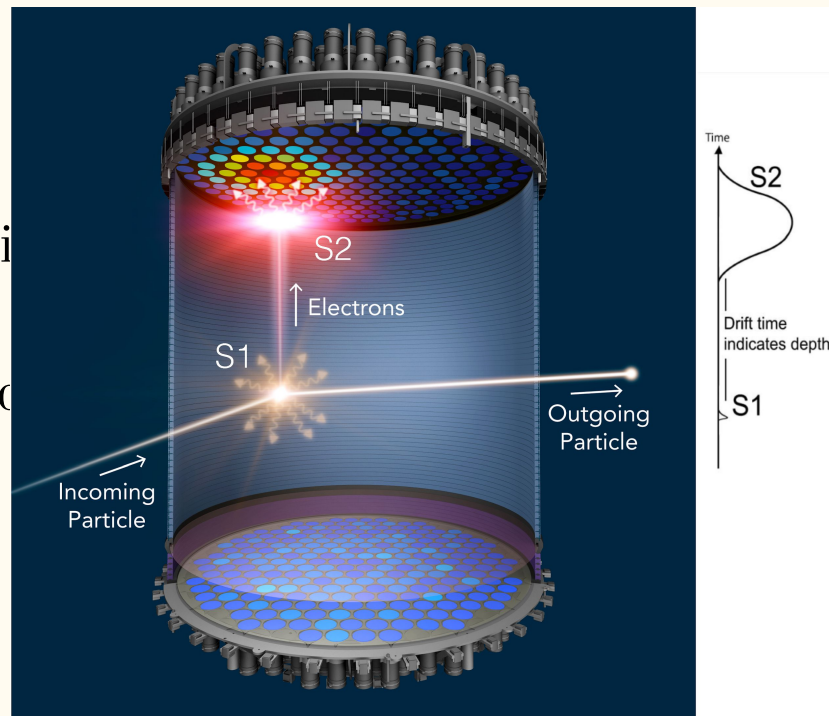
  D. Woodward; (LZ internal report)

- **2016/Early 2017:** Screener project measures much lower rate than predicted

TPC

- Energy deposits→ Scintillation light
  - Prompt (S1) signal
- Also get ionization
  - Electric field causes electrons to dri[...]
    Second light signal (S2)
- Can use drift time to determine z positio[...]
  position

Wall activity Mapping

- The fraction of counts due to source k coming from wall w given by $f_{k,w}(E)$.
- Use $f_{k,w}(E)$ to calculate activity for wall w:
- The different positions sample different parts of the walls
  - Use the $f_{k,w}(E)$ as weights in average activity over measurement positions

- Resulting weighted means of activities (5×10^8 events generated; $O(10^8)$ events with hits) :

Source	North Activity (Bq/kg)	Error	East Activity (Bq/kg)	Error	South Activity (Bq/kg)	Error	West Activity (Bq/kg)	Error	Ceiling Activity (Bq/kg)	Error	Floor Activity (Bq/kg)	Error
K	214.11	0.16	222.45	40.35	220.48	39.99	219.76	39.86	204.64	37.12	274.14	49.73
U	59.74	9.96	55.45	9.24	57.37	9.56	55.63	9.27	45.56	7.60	46.60	7.77
Th	7.96	0.14	12.69	1.81	12.82	1.83	12.74	1.82	12.01	1.71	13.39	1.91

Unfolded ←

Wall activity mapping

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Folded

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