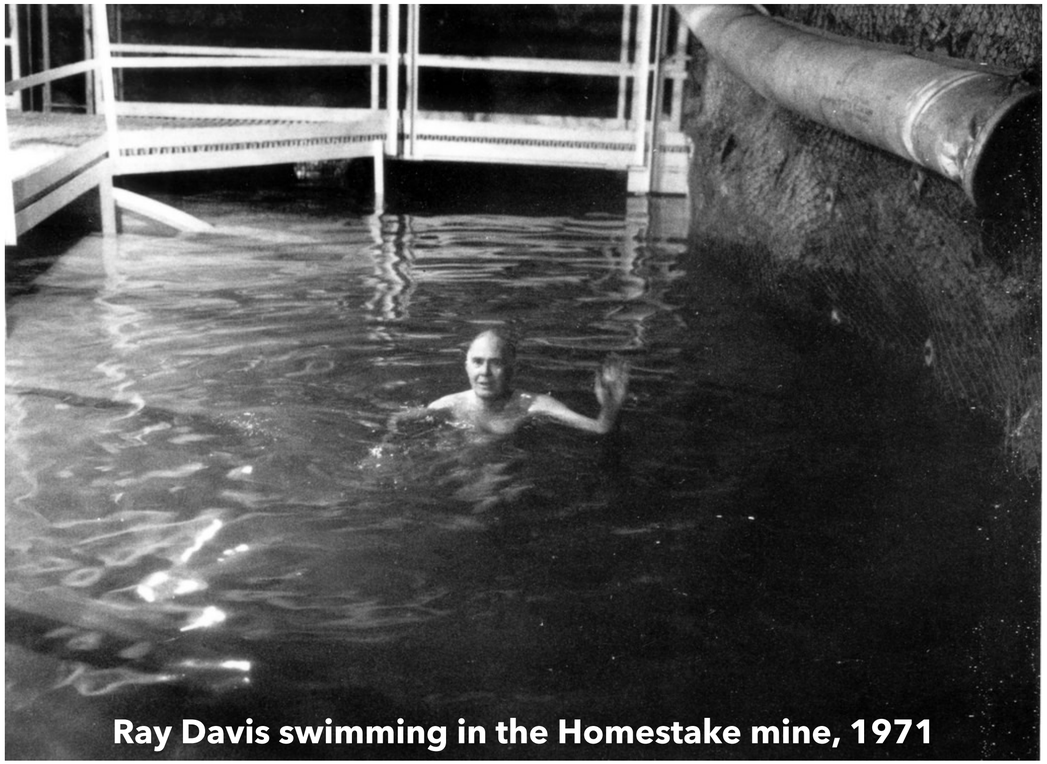


Ray Davis swimming in the Homestake mine, 1971

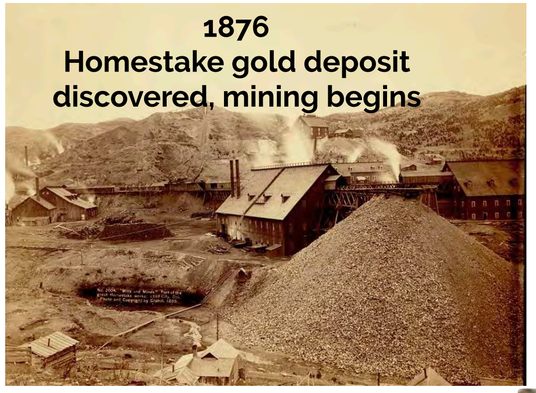
Measurement of the Davis Cavern γ-ray background at the Sanford Underground Research Facility

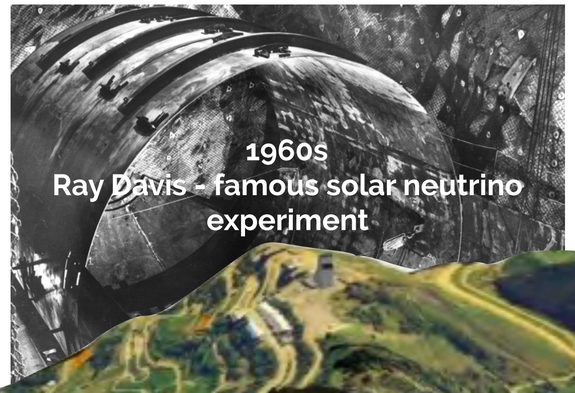
Dr. Sally Shaw
sally@physics.ucsb.edu

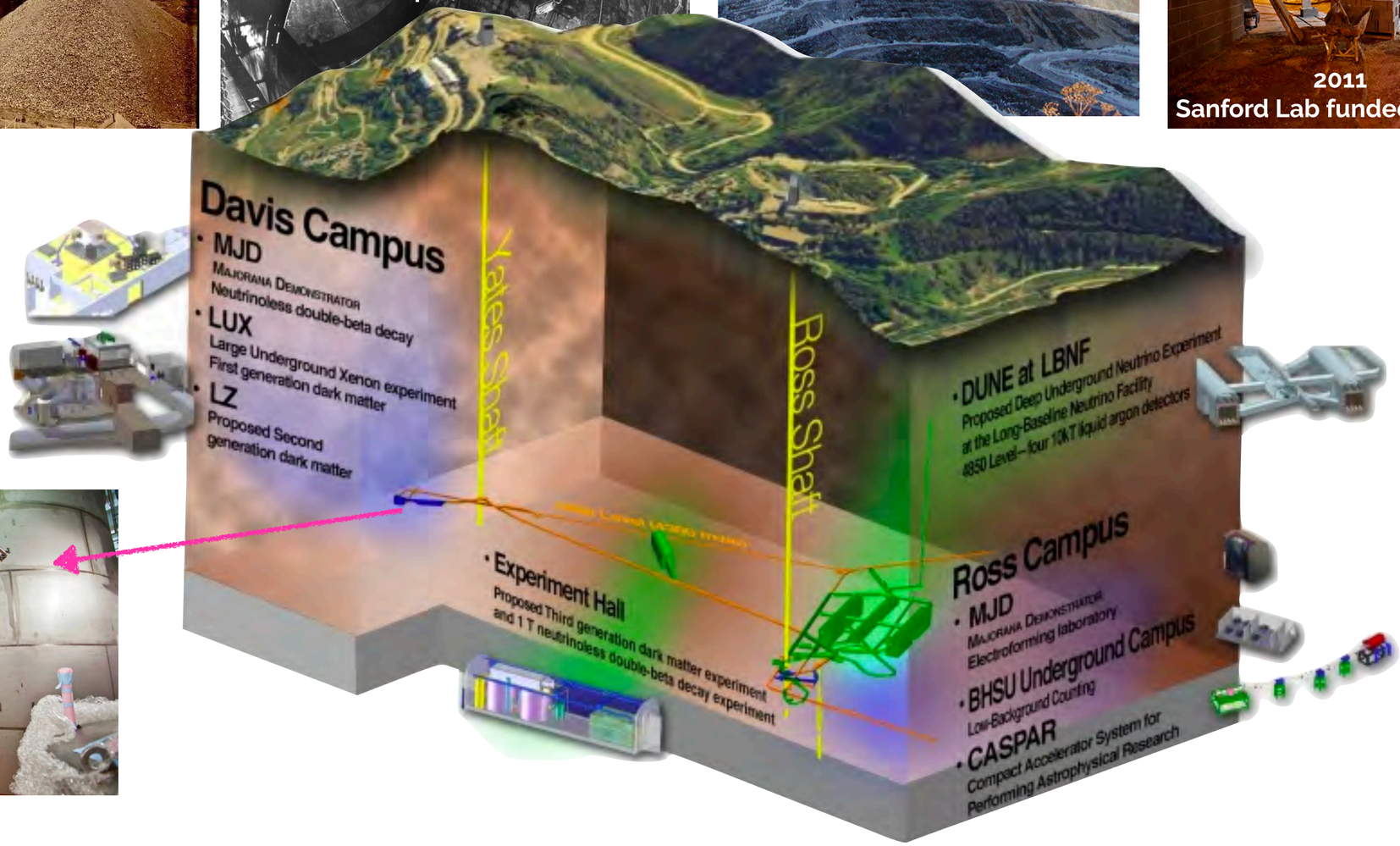
APS April Meeting
15/04/2018

UC SANTA BARBARA PHYSICS

Sanford Underground Research Facility







LZ detector will go into same water tank that was used for LUX

Sanford Underground Research Facility

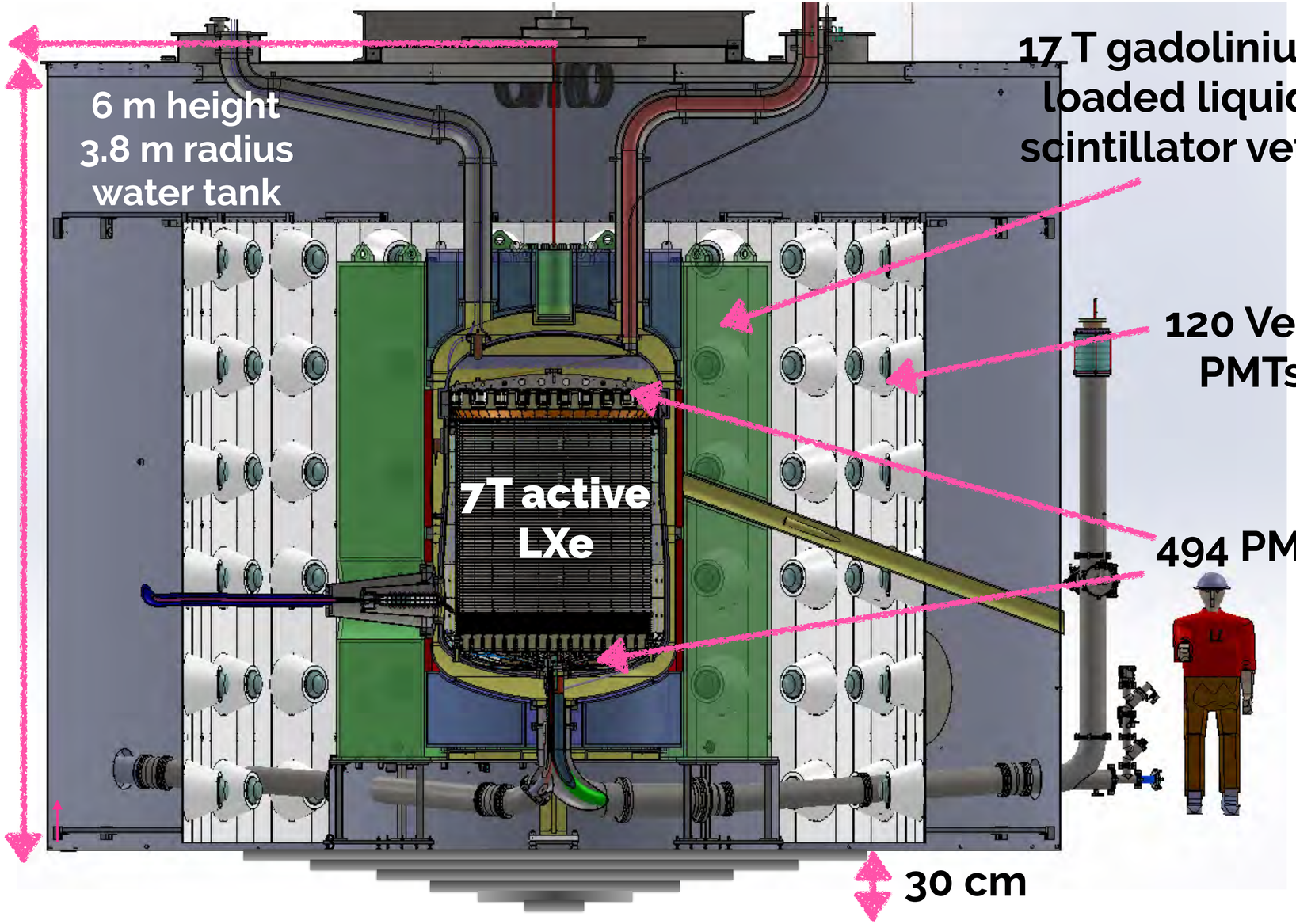
4850 ft

Cosmic muon flux reduced by 10^6

The LZ Detector

Low Background Checklist

- ☑ Shielded from cosmic (underground)
- ☑ γ-shielding (water tank & steel pyramid)
- ☑ Neutron veto
- ☑ All materials screened
- ☑ Radon emanation measured
- ☑ Detector backgrounds quantified
- ☑ Physics backgrounds quantified (neutrinos, ^{136}Xe 2νββ)
- ☐ Cavern background quantified

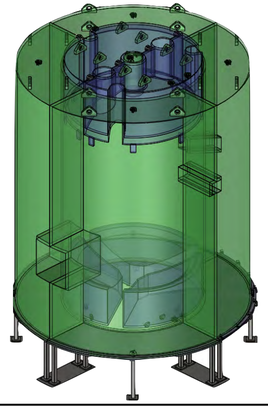


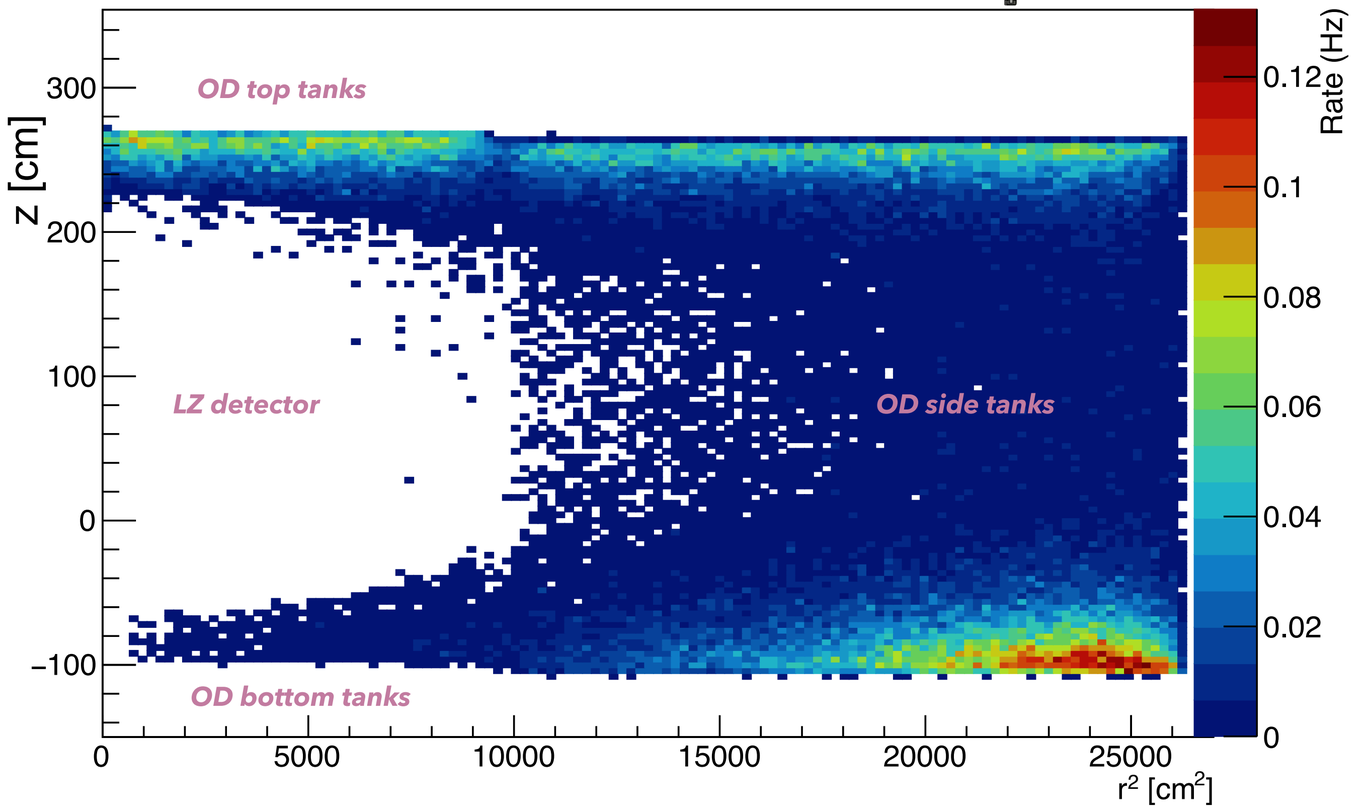
Cavern Backgrounds in LZ

Outer Detector

Need to keep deadtime low for vetoing efficiency

Cavern rate thought to be ~100Hz - dominant background in OD!

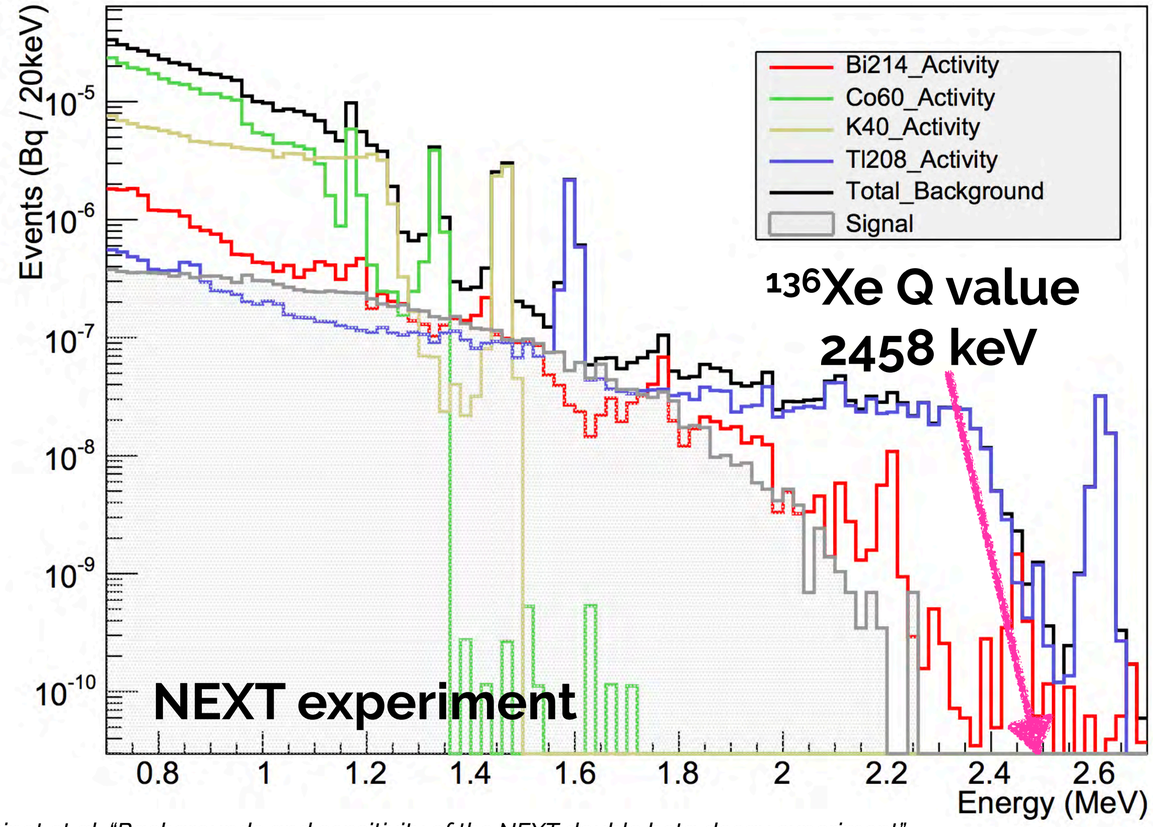




LXe Detector

Main impact is on ^{136}Xe 0νββ search

High energy γ from ^{214}Bi (^{238}U chain) and ^{208}Tl (^{232}Th chain) chains can fall into signal region for 0νββ decay



Nebot-Guinot et al, "Backgrounds and sensitivity of the NEXT double beta decay experiment"

NaI(Tl) Detector Measurement

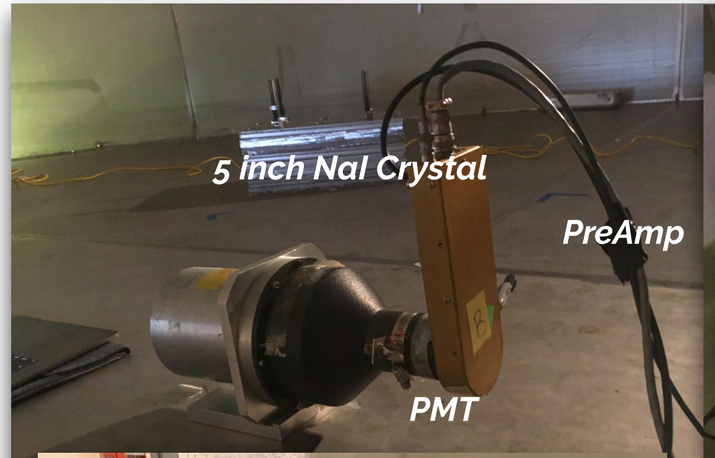
2 week campaign in October 2017 at SURF

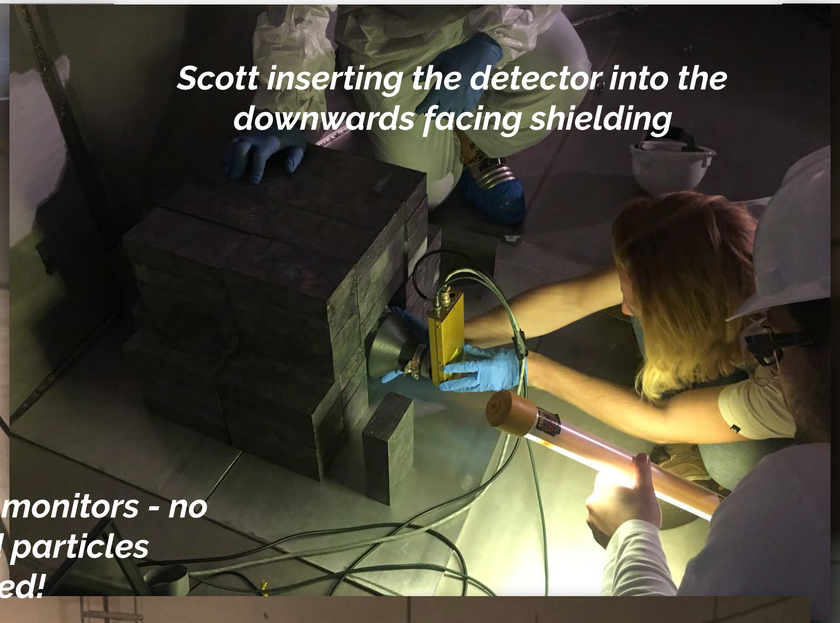
UCSB Brandeis UCL

Team (L-R)
Luke Korley (brandeis)
Melih Solmaz (UCSB)
Me (UCSB)
Umit Utku (UCL)
Scott Haselschwardt (UCSB)

Goal: collect spectra from a variety of places in the Davis cavern
Use lead shielding to focus the measurement on different directions

NaI(Tl) Detector Measurement



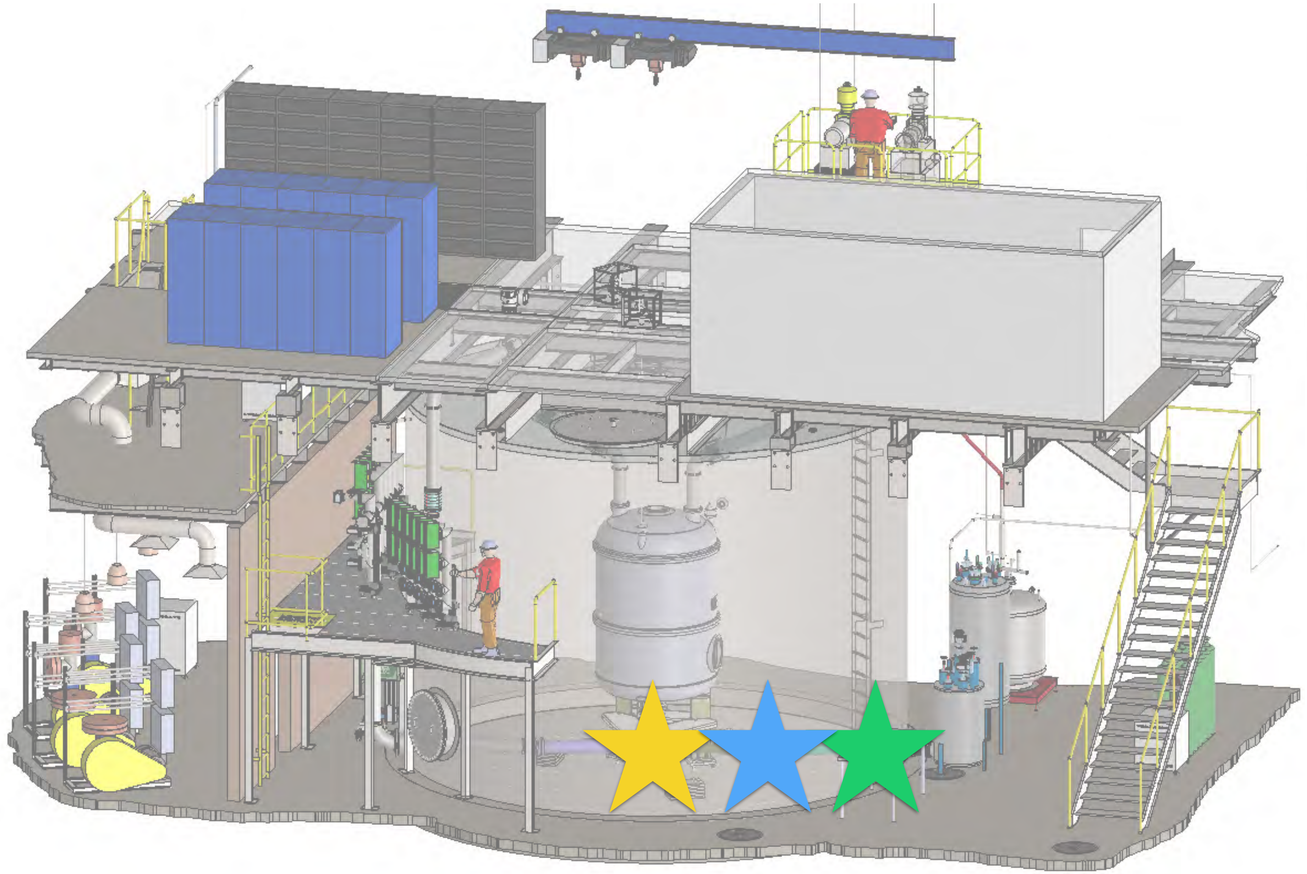


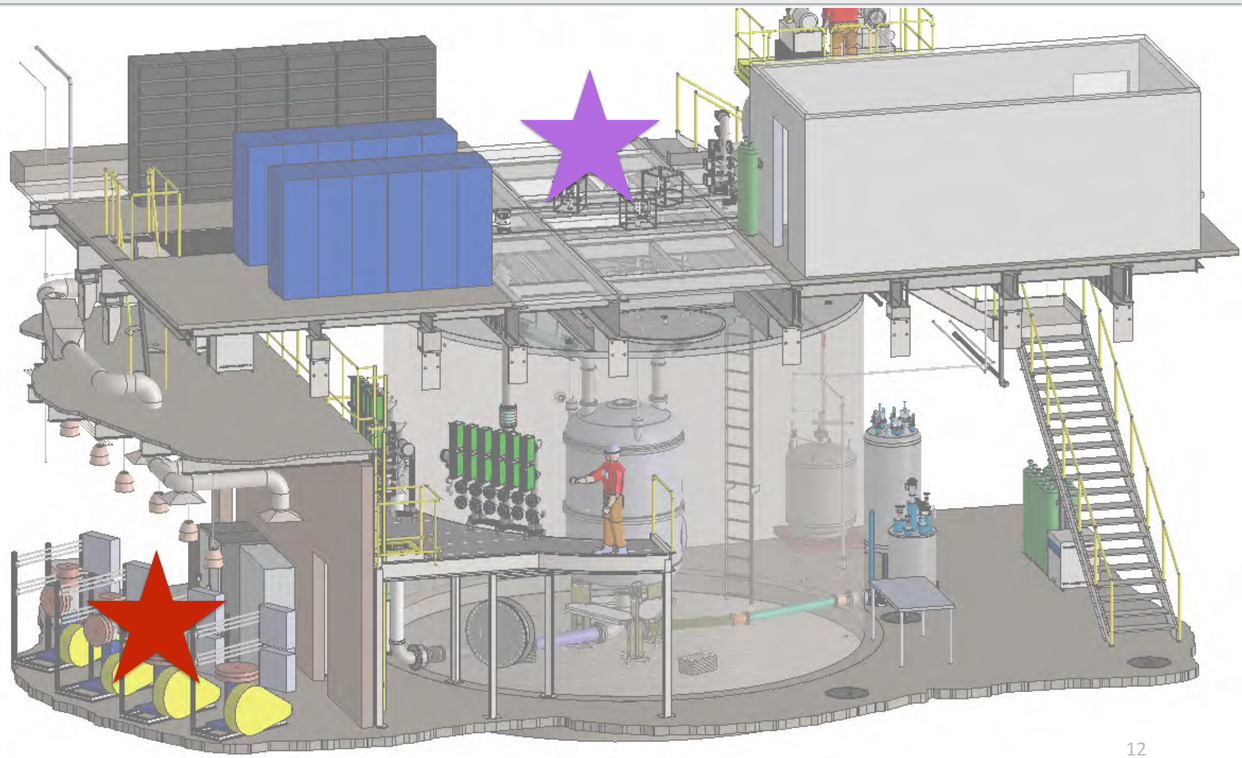
Measurement Locations

2 measurements outside tank:

Upper Davis

East Counting Room





7 measurements in tank:

Centre unshielded

Centre (downwards)

Centre (upwards)

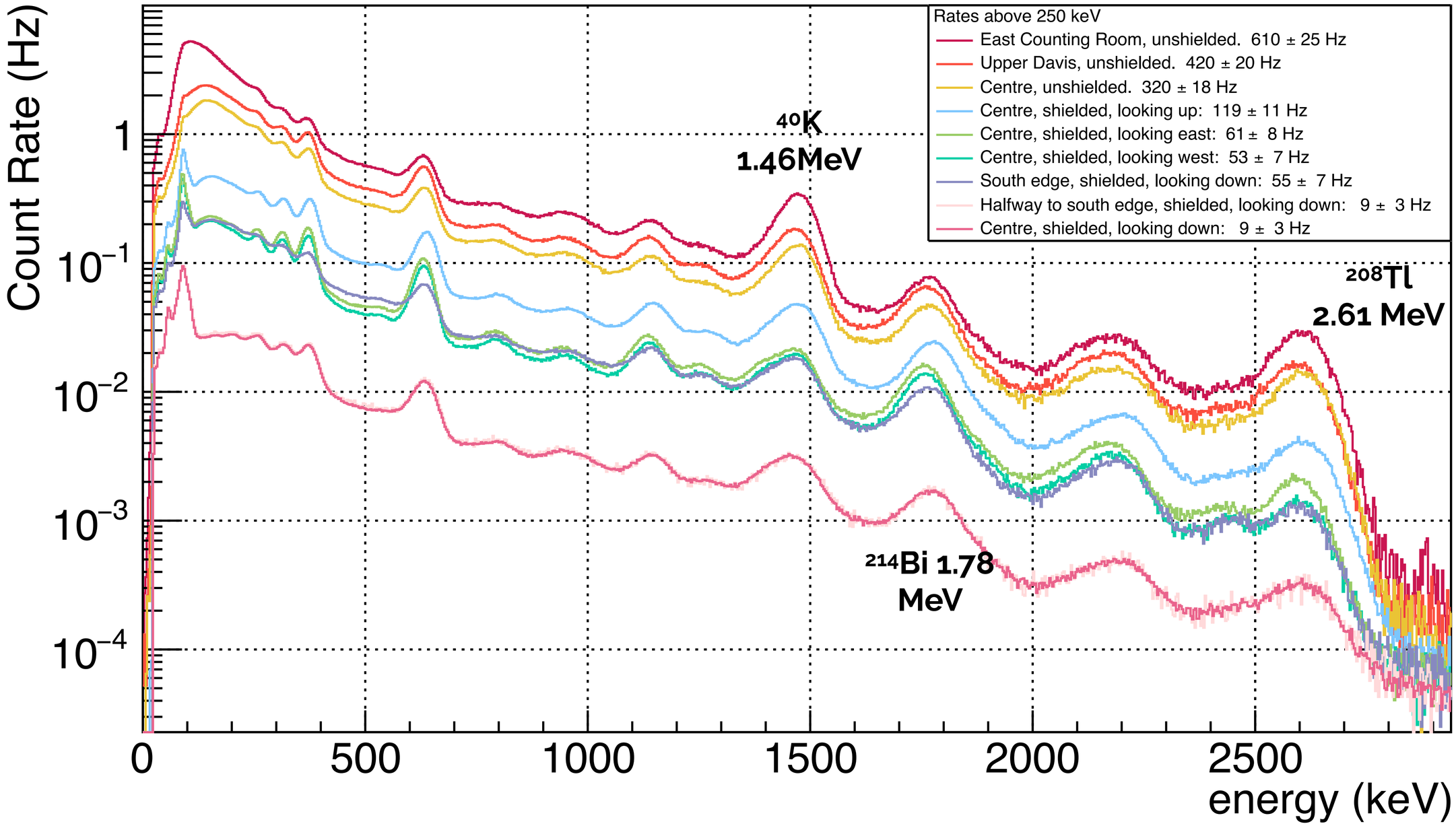
Centre (east facing)

Centre (west facing)

Halfway to edge (downwards)

Edge (downwards)

NaI γ-ray Spectra - All Measurements



Cavern Materials

- Most of cavern thought to be **amphibolite**
- extra-hot **rhyolite** intrusion passes through cavern, mostly on the floor and the west wall
- 12.7 cm (avg.) coating of **shotcrete** on walls & ceiling
- 0.5 ft of **concrete** on floor (1 ft in counting room)
- **gravel** beneath water tank

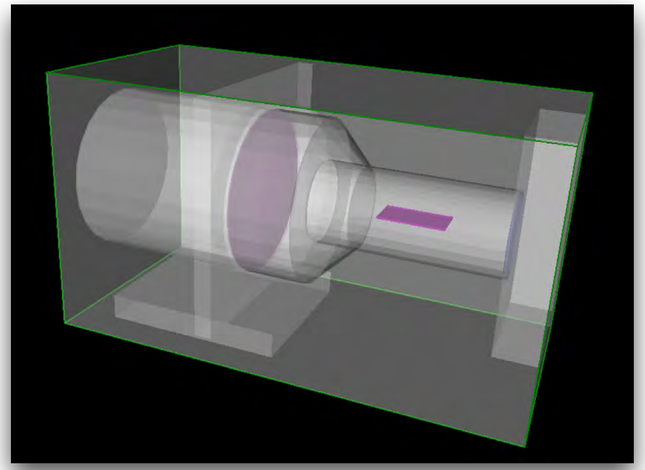
Water tank gravel sample and shotcrete sample taken whilst on-site & sent for HPGe measurements

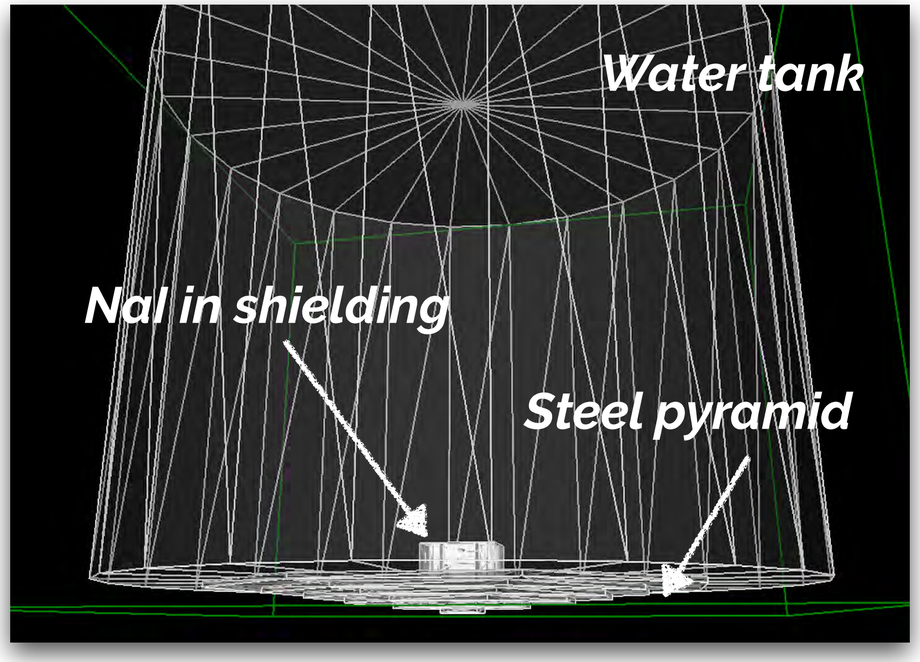
Activities	K (Bq/kg)	U (Bq/kg)	Th (Bq/kg)
Amphibolite	297.2	4.1	1.3
Rhyolite	1291.0	108.0	17.0
Shotcrete - low	170.3	18.8	8.8
Shotcrete - standard	380.8	24.7	13.6
Shotcrete - finish coat	244.6	20.0	12.5
Shotcrete	**216.7**	**22.2 (early) 21.36 (late)**	**11.4**
Gravel	**35.0**	**22.2 (early) 26.3 (late)**	**1.71**

Simulating the Cavern Background

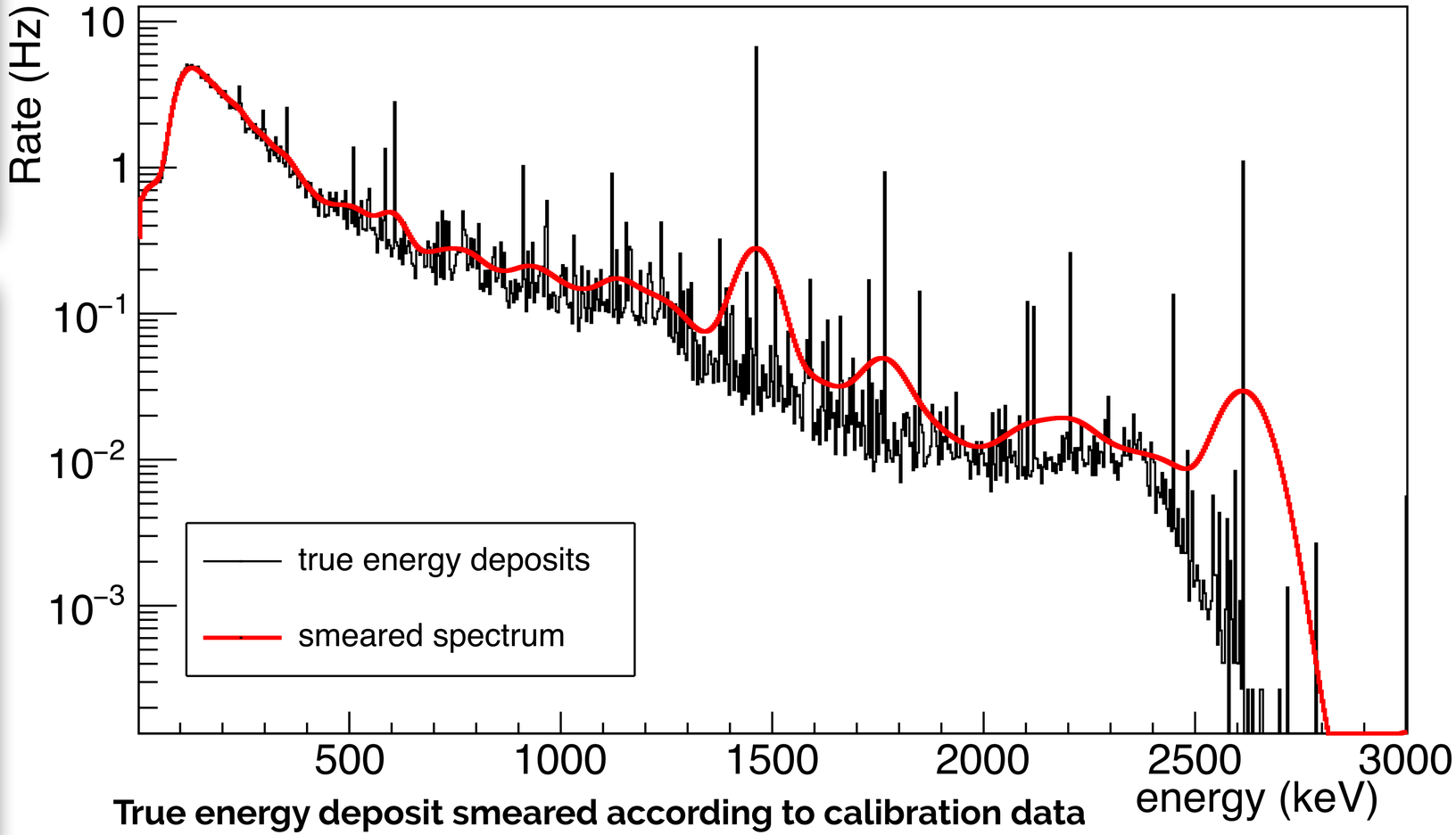
(D. Woodward's talk, next)

Custom geometry built within the BACCARAT package used for LZ simulations

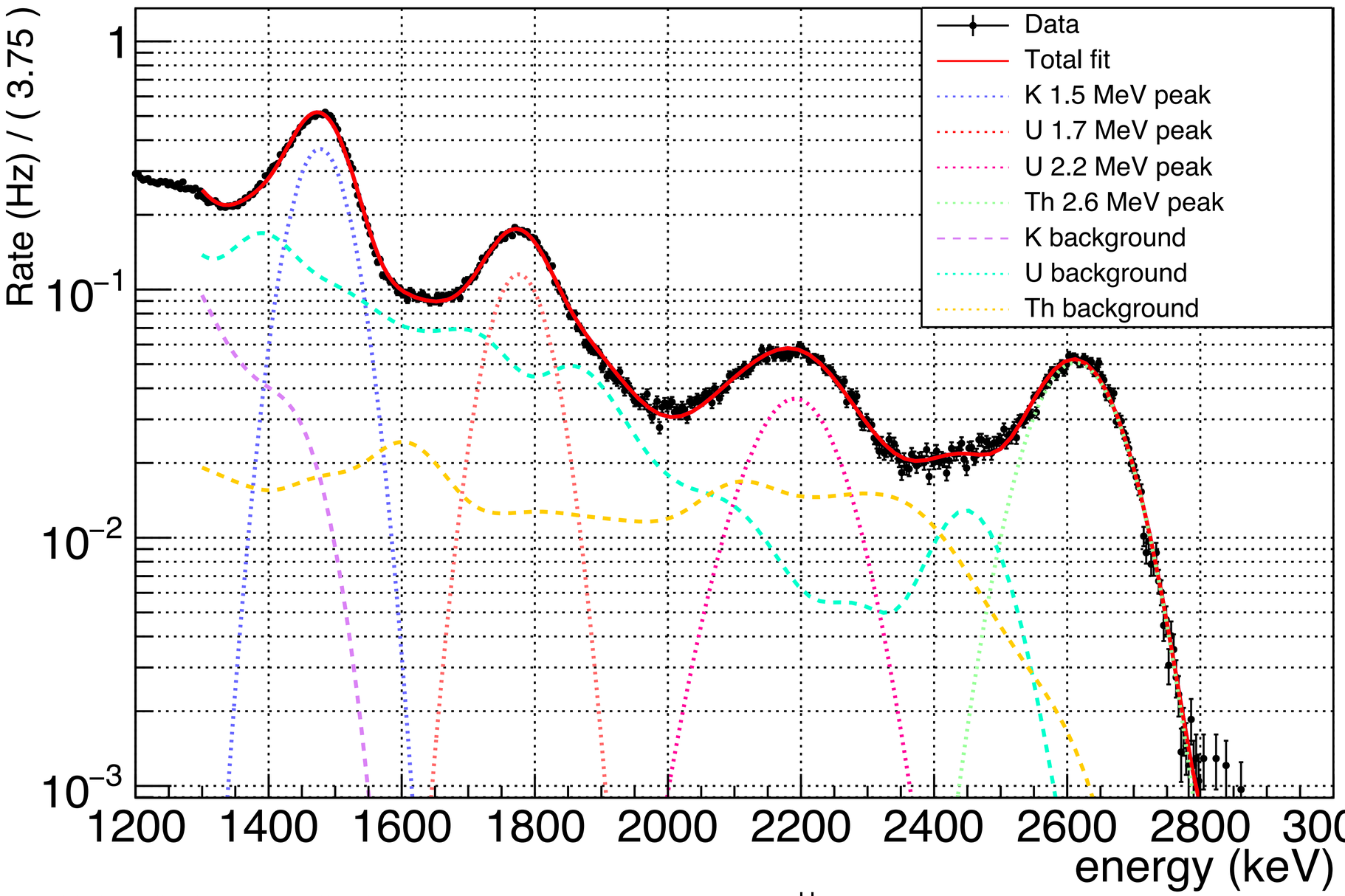




Radioactive decays (^{40}K, ^{238}U & ^{232}Th chains) are simulated in a simple model of the cavern walls & energy deposits saved in the NaI crystal



Fitting the Spectra



Centre of water tank, unshielded

Float concentrations of each isotope to to match simulated peaks to data peaks

Rock Activities

Activities	K (Bq/kg)	U (Bq/kg)	Th (Bq/kg)
Conservative estimates	716	73.4	26.1
Unshielded, centre	224	40	12.6
Unshielded, upper	127	32	8.5
Counting room	229	25	12.0
Looking Up, centre	184	72	10.6
Looking Down, edge	266	40	12.3

Two most relevant measurements for LZ

Normalization for sim differ with measurement position.

Simulation done with uniform activity in walls.

- this discrepancy may point towards a non-uniform distribution of activity
- Radioactive rhyolite intrusion covers some walls more than others

With these new activities, LZ Outer Detector cavern rate in range 20-29 Hz

No longer dominant background!

See S. Haselschwardt's talk for other OD backgrounds, this session tomorrow

Conclusions

- We measured the γ-ray background in the Davis cavern at SURF
- Cavern flux is considerably lower than previously thought
- Still pinning down distribution of radioactivity in cavern
- LZ Outer Detector Veto cavern γ rate reduced from 91 Hz to <30 Hz
  - no longer the dominant background
- 0νββ decay background expectation from γ reduce > 5x

And finally…

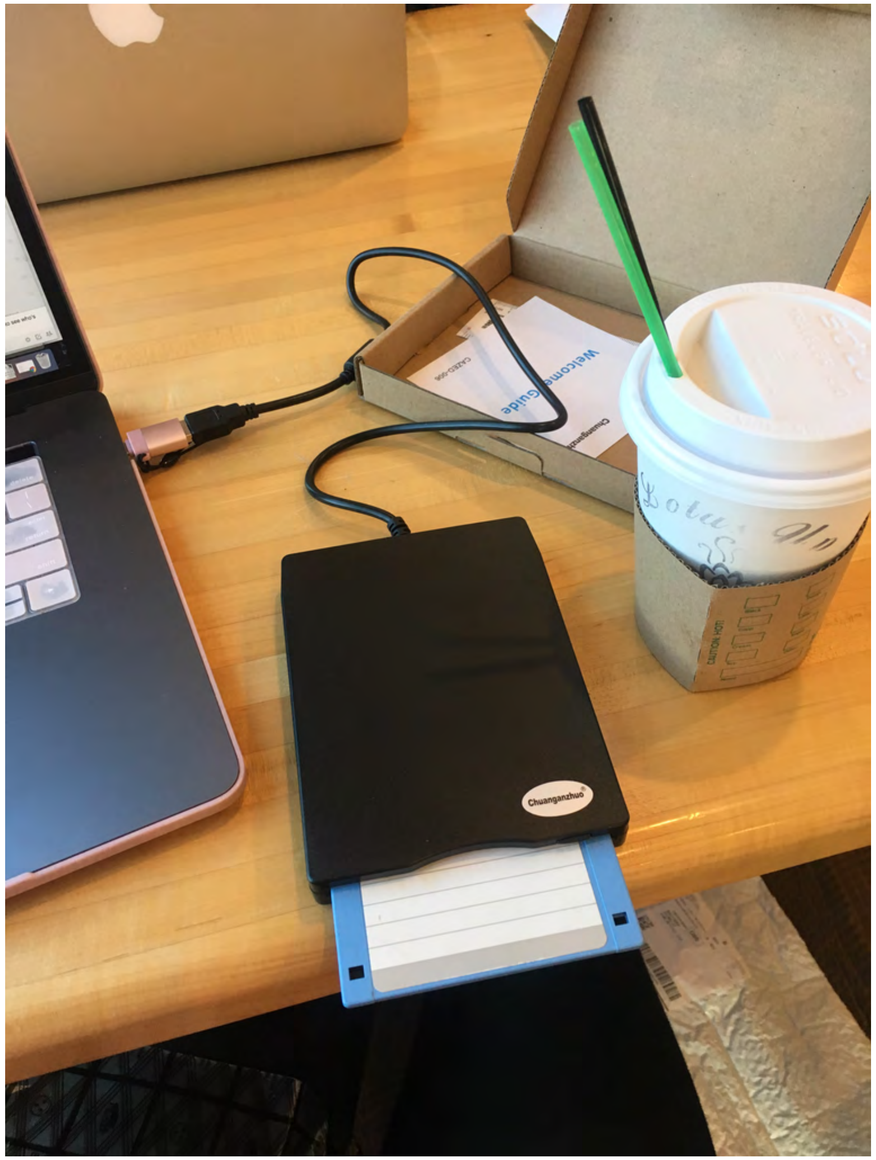
Conclusions

- We measured the γ-ray background in the Davis cavern at SURF
- Cavern flux is considerably lower than previously thought
- Still pinning down distribution of radioactivity in cavern
- LZ Outer Detector Veto cavern γ rate reduced from 91 Hz to <30 Hz
  - no longer the dominant background
- 0νββ decay background expectation from γ reduce > 5x

And finally…

- We provided proof that floppy disks are still useful for science!

World's first transfer of data from a Windows 97 laptop 4850 ft underground → floppy disk → USB →USBC→MacBook?



Thanks to…

UCSB: Scott Haselschwardt, Harry Nelson, Melih Solmaz

LBNL: Kevin Lesko, Andy Cole

Brandeis: Luke Korley, Bjoern Penning

UCL: Umit Utku, Cham Ghag

School of Mines: Doug Tiedt

SURF: John Keefner, Mark Hanhardt

Penn State: David Woodward

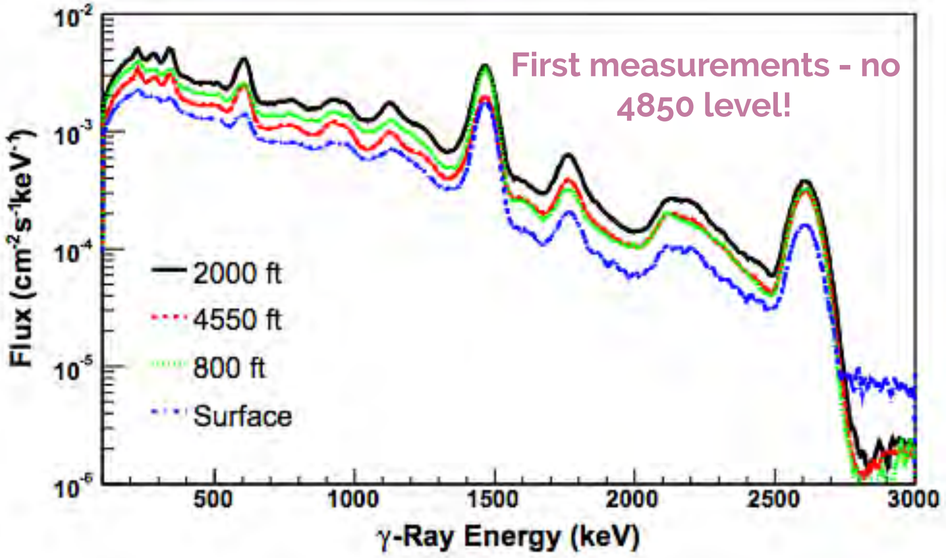
Amazon Prime (for delivering USB Floppy disk reader to Lead, South Dakota in record time)

Backup

Older Measurements

Early Results on Radioactive Background Characterization for Sanford Laboratory and DUSEL Experiments

D.-M. Mei [a], C. Zhang [a,b], K. Thomas [a], F. Gray [c]



First measurements - no 4850 level!

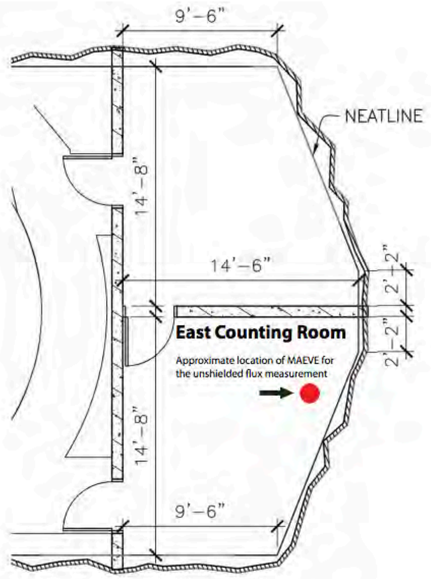
"The variation of the γ-ray flux at different locations on the same level depends on the variation of the rock formations and the radioactivity levels in the rock. This variation can be as large as 30% as seen in the measurements. This is to say that the γ- ray flux must be measured in the experimental area where a low-background experiment is to be located."

An Estimate of the Gamma Flux in the East Counting Room of the Davis Cavern

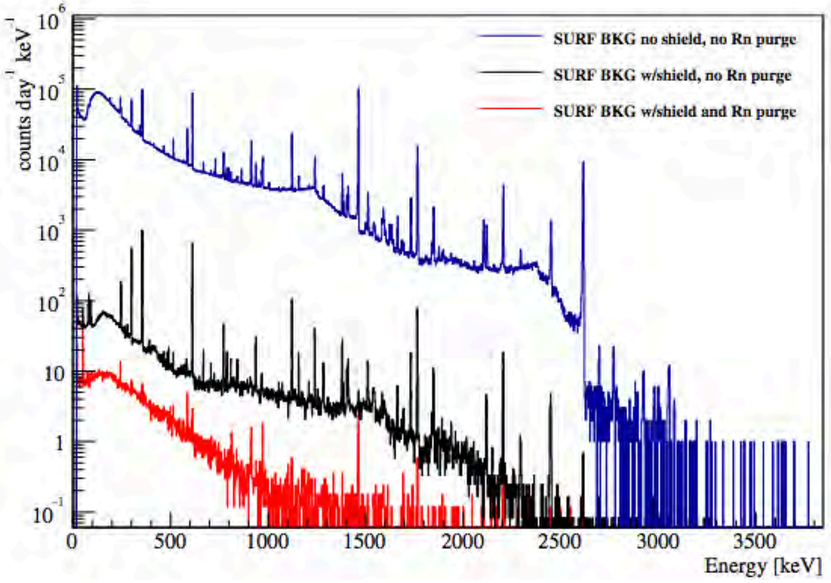
November 21, 2014

K.J. Thomas[a,b]

We took data for the east counting room in approximately the same location

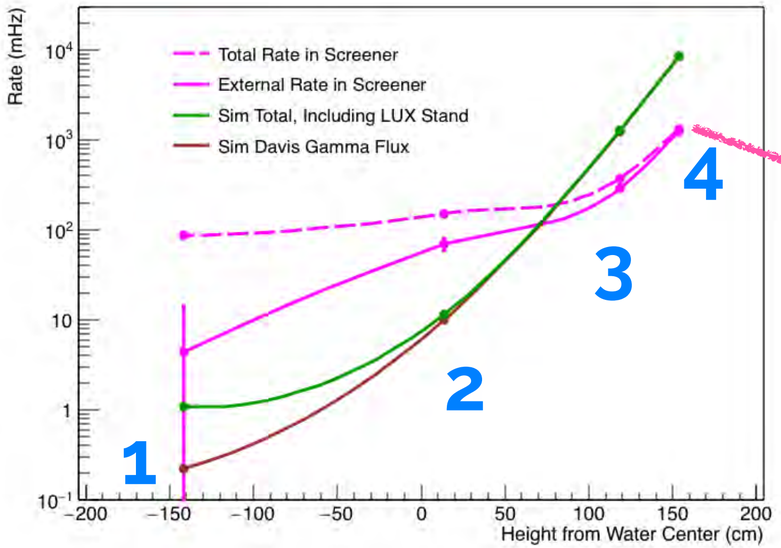


Data from blue spectrum used to obtain sim normalisations in the top row of the table on slide 12



LS Screener Measurement

(S. Haselschwardt's talk tomorrow)

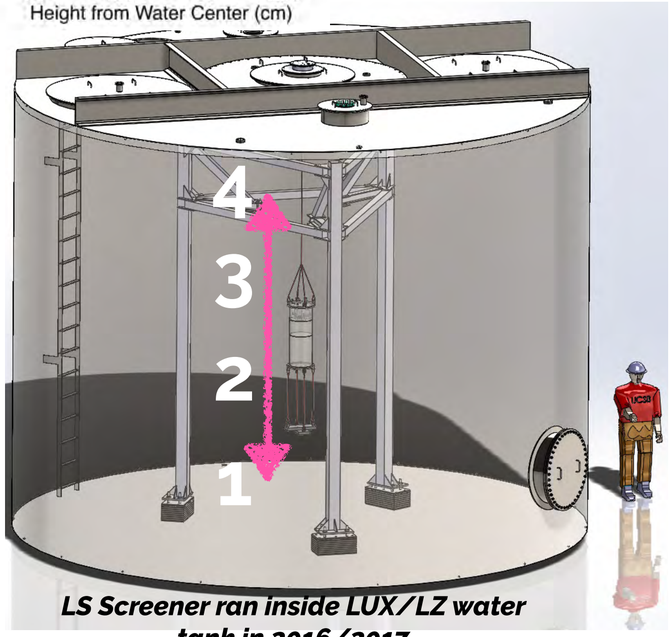


LS Screener detector measured an external γ-ray rate ~7x lower than expected at top of water tank

Sim normalisations clearly too high - based off older HPGe measurement intended for use as upper limit

Important because **rate is concentrated at top and bottom of OD tanks** (least water shielding)

LS Screener - designed to measure internal GdLS backgrounds for LZ Outer Detector



LS Screener ran inside LUX/LZ water tank in 2016/2017