The LZ Liquid Scintillator Screener Campaign

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CoSSURF 2017

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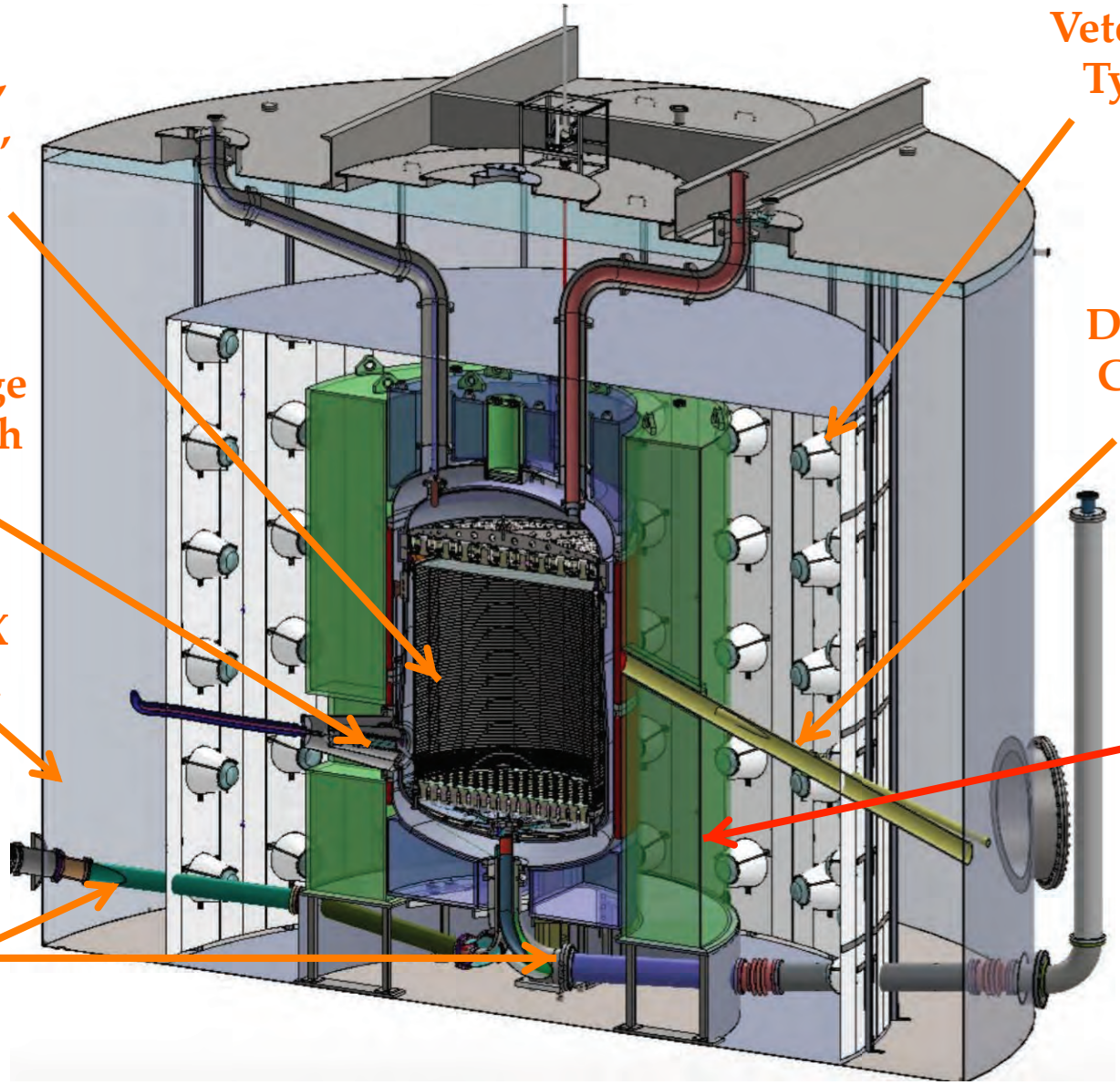
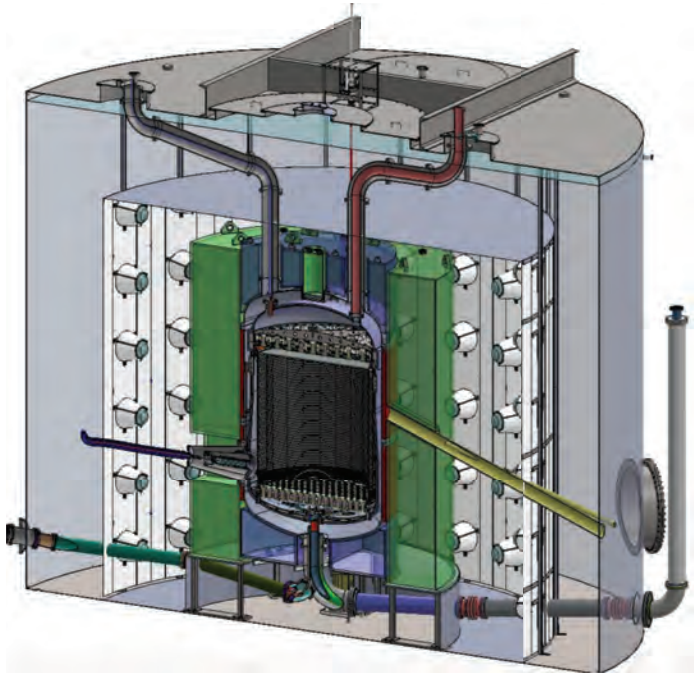
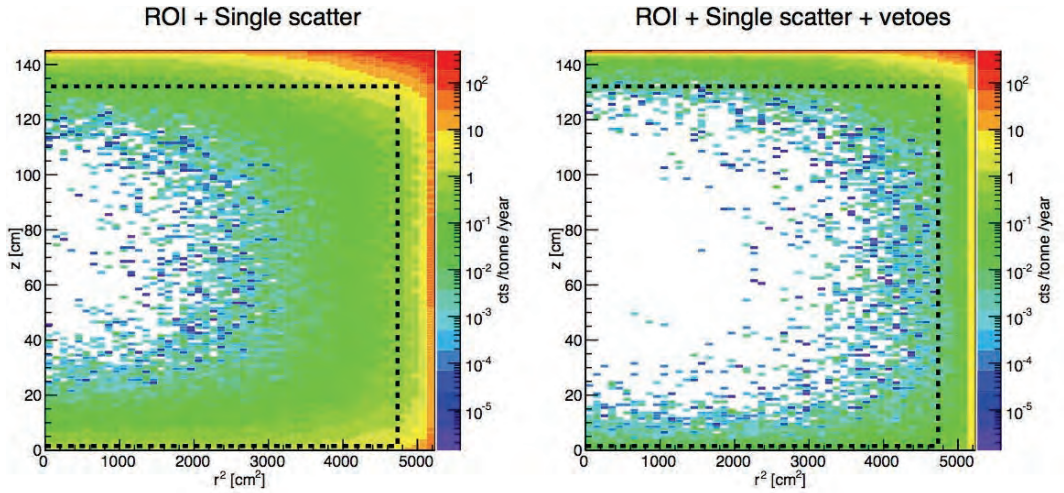
The LZ Experiment



The LZ Outer Detector

- 9 segmented UVT acrylic tanks
- ~17 tonnes Gd-loaded, LAB-based LS
  - Neutrons thermalize and capture on Gd:
  - n + Gd -> Gd + (3-4x) γ (~8 MeV)
- 120 8" PMTs in water tank
  - Surrounded by Tyvek reflector
- Together with LXe "skin", veto gammas and neutrons with high efficiency… 100-200 keV threshold
- Reduce WIMP search backgrounds





Simulated neutron background in LZ before and after application of veto cuts

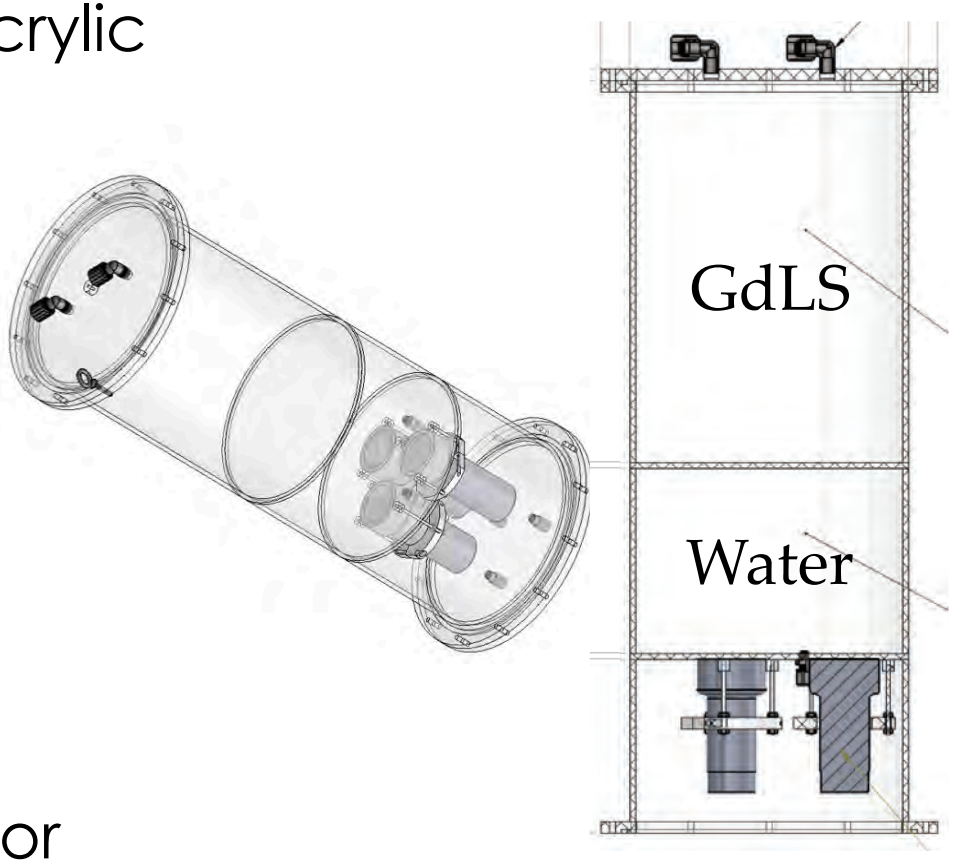
GdLS Purity

- OD rate goal drives scintillator purity requirements
- Usual suspects: ^{238}U chain, ^{232}Th chain & ^{40}K
- ^{14}C (156 keV β) measurement a main concern
  - LLNL Mass Spec down to 10^{-15} g/g
  - Requirement/goal is 10^{-17}-10^{-18} g/g

Impurity	Goal	Requirement
^{238}U	1.3 ppt	10 ppt
^{232}Th	4.5 ppt	20 ppt
^{40}K	0.8 ppt	3 ppt
^{14}C	1.3×10^{-17} g/g	1.5×10^{-17} g/g

The LS Screener

- Made of Reynolds UVT acrylic (same as OD)
- ~ 24 kg GdLS
  - ~1/700 of OD LS
  - Produced by Minfang Yeh at BNL
- 14 kg water shield
- 3 R11410-20 PMTs
  - Very radiopure
  - LZ PMT bases
- Wrapped in Tyvek reflector



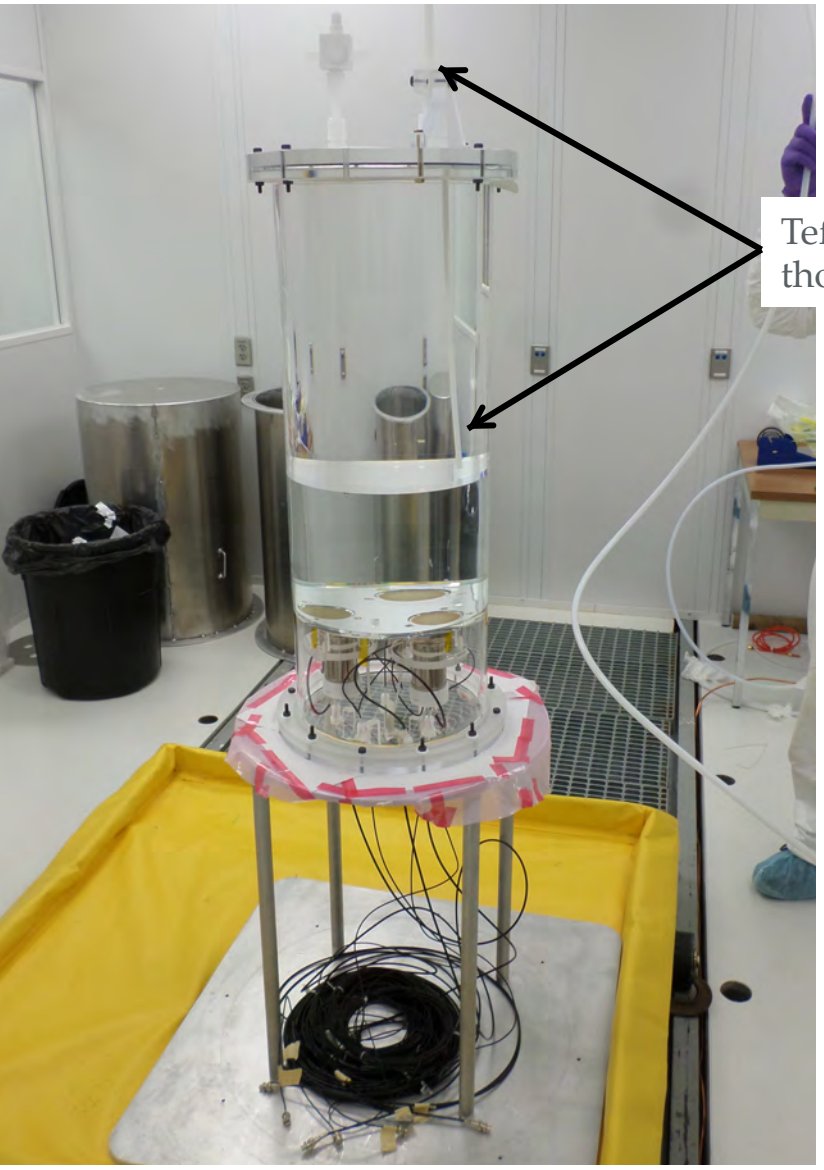
Underground Commissioning, Nov. 2016

Water volume full, mounting PMTs

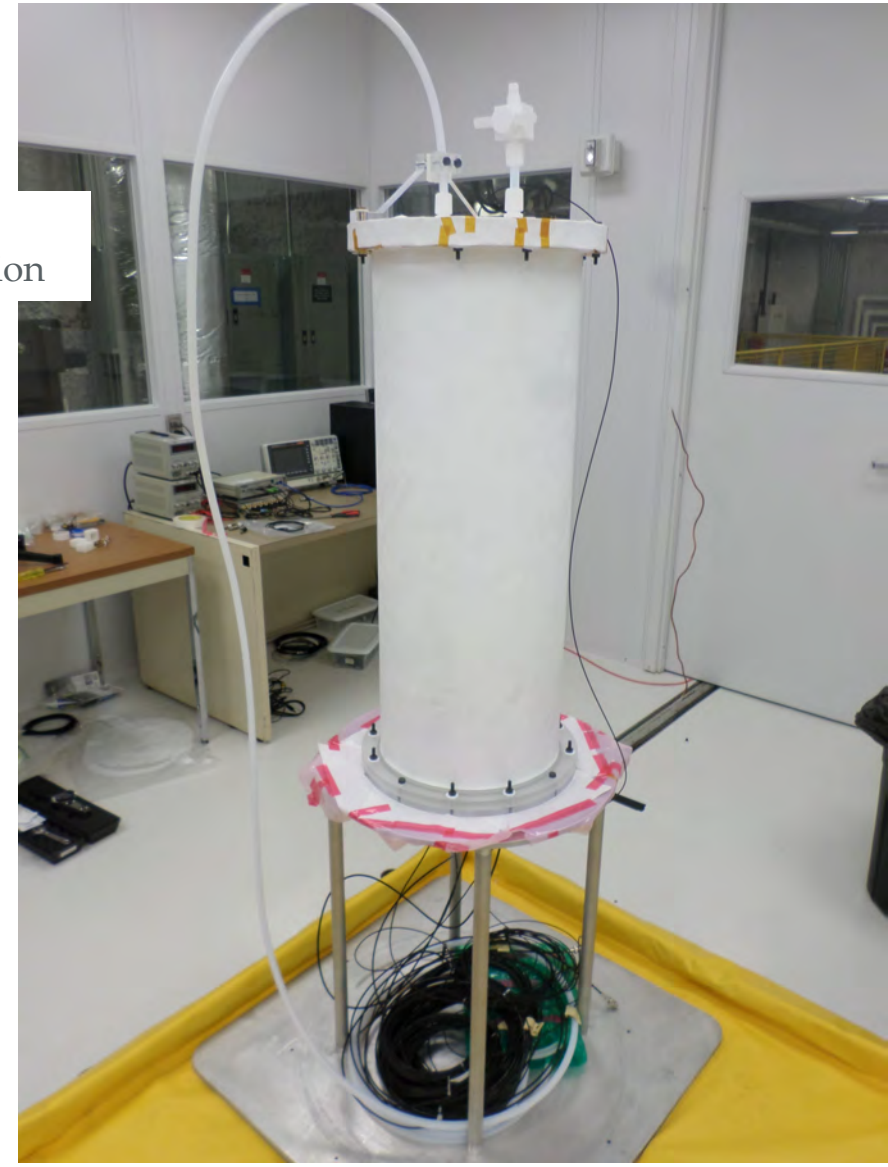
GdLS filling in underground cleanroom

Ready for Water Tank Deployment

Filled w/ GdLS and water. PMTs mounted:



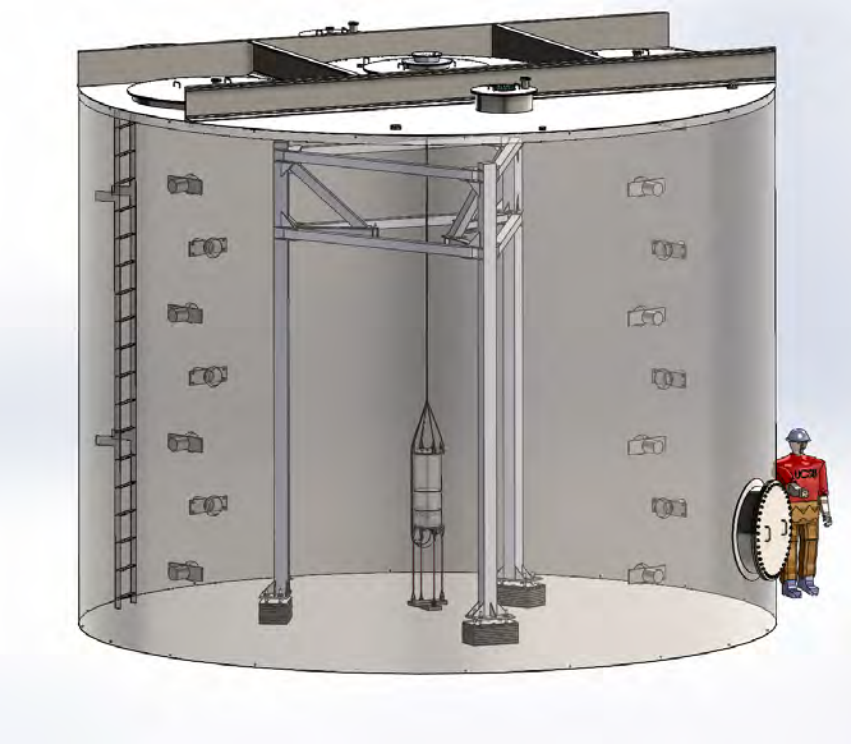
Wrapped in single layer tyvek, ready for deployment:



Water Tank Deployment

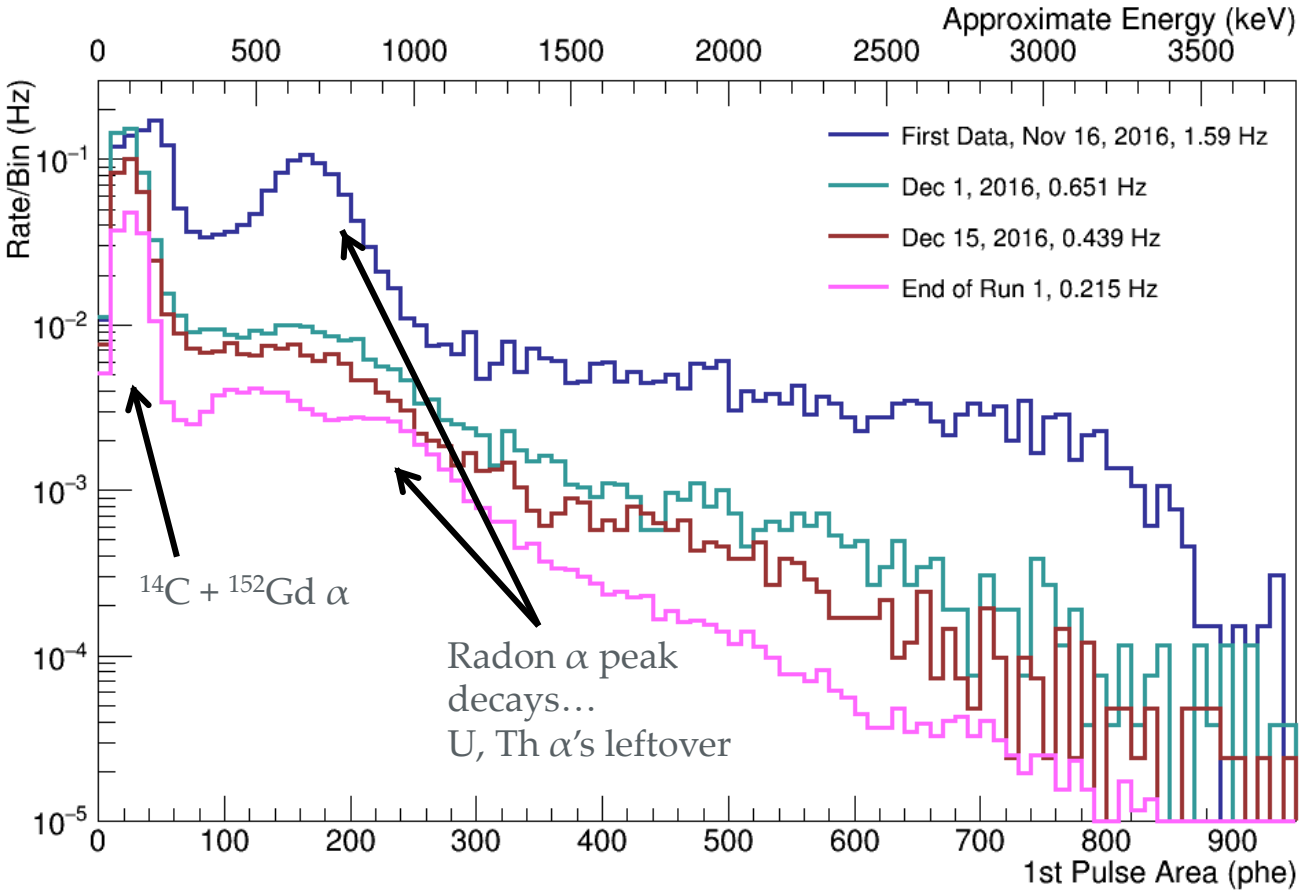
Data Taking Overview

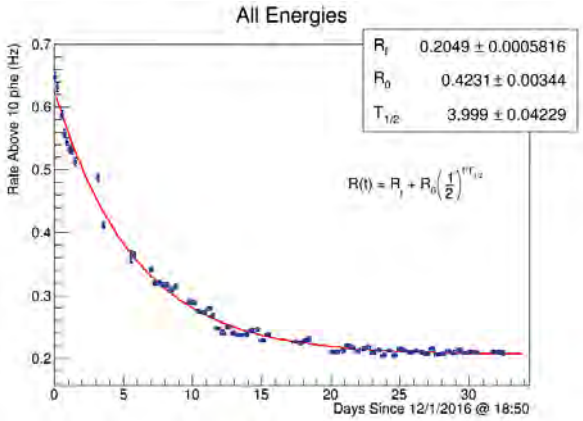
- Deployed in LUX water shield
  - LUX support stand still present
- Pulses amplified & digitized by LZ electronics
- Run 1: GdLS
  - Mid Nov 2016 – Early Jan 2017
- Run2: No Gd-loading
  - Late Jan 2017 – Late Feb 2017
- ~Weekly PMT gain monitor
- Calibrations end each run:
  - γ : ^{137}Cs, ^{22}Na, ^{40}K, ^{228}Th
  - α & β : Thoron bubbling
- End of each run "z-scan"



Run 1 – First Data

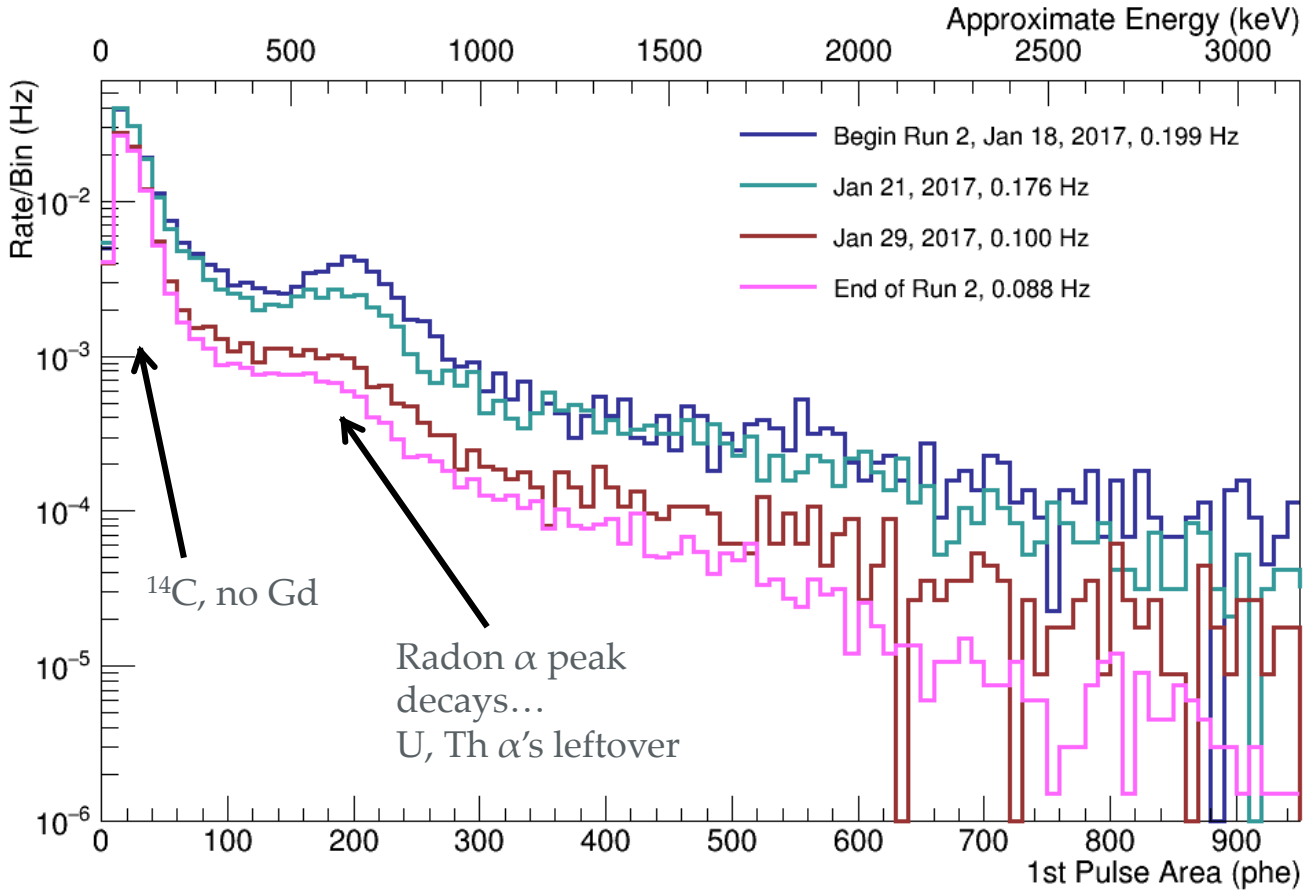
- We see α's, β's and Compton deposits from γ's
- Rate plateau after ~ 3 weeks with ^{222}Rn timescale
- 0.25 phe/keV → 3-fold coinc of > 2 phe → 24 keV threshold
- Acceptance for ~70% of ^{14}C beta spectrum

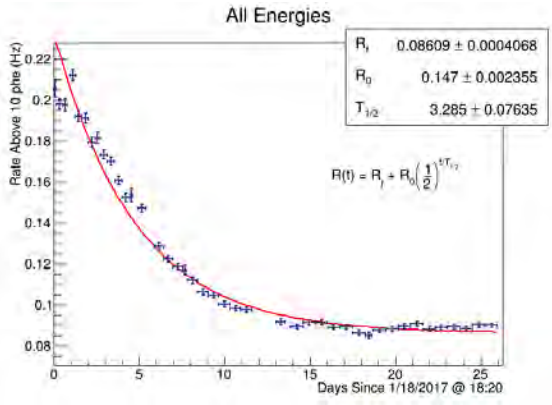




Run 2 – No Gd

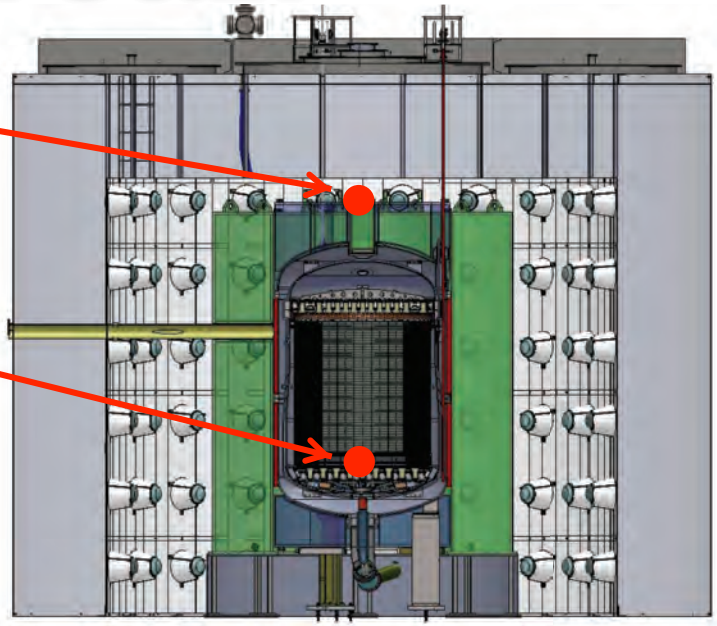
- Same cocktail without Gd
- Less exposure during LS fill
- Rate plateau after ~ 2 weeks
- Higher light yield, ~0.3 phe/keV

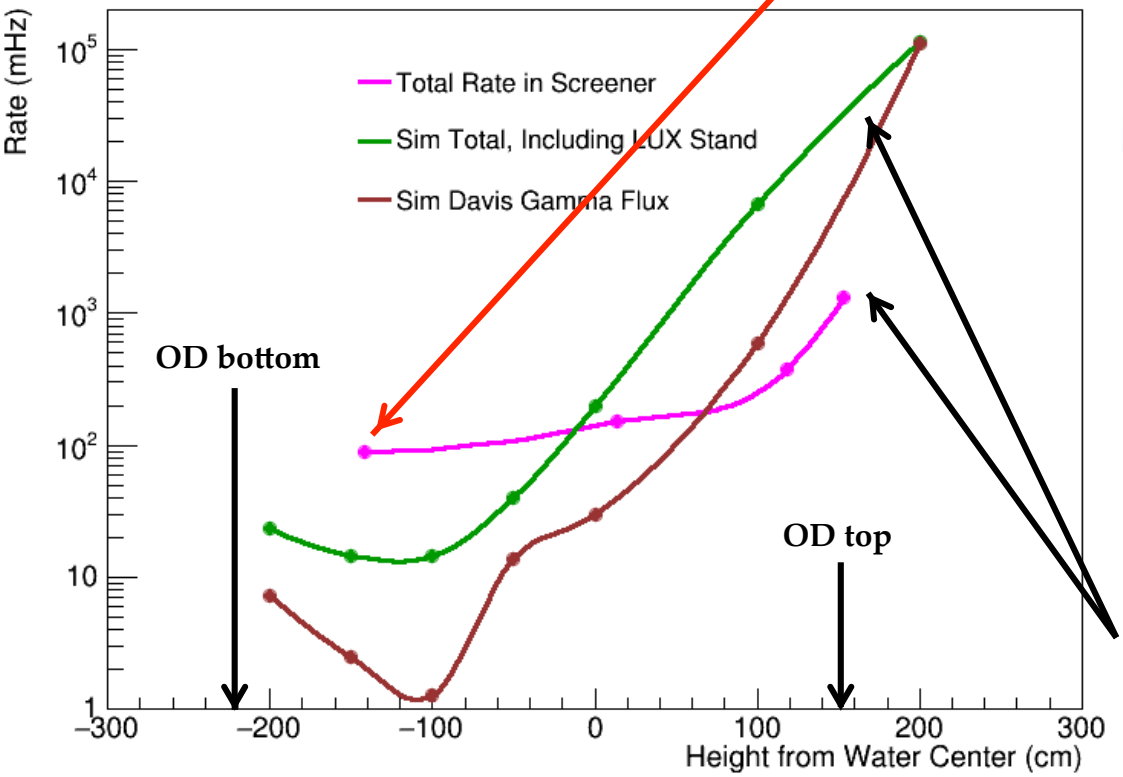


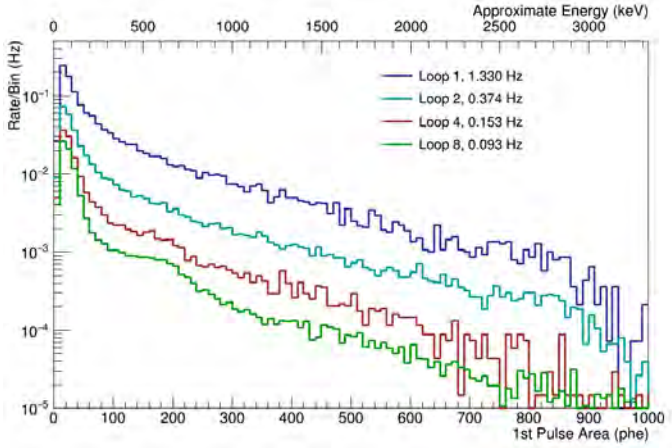


End of Run Z-Scan

- Rate in OD from cavern environment a concern
- End of each run, moved Screener vertically







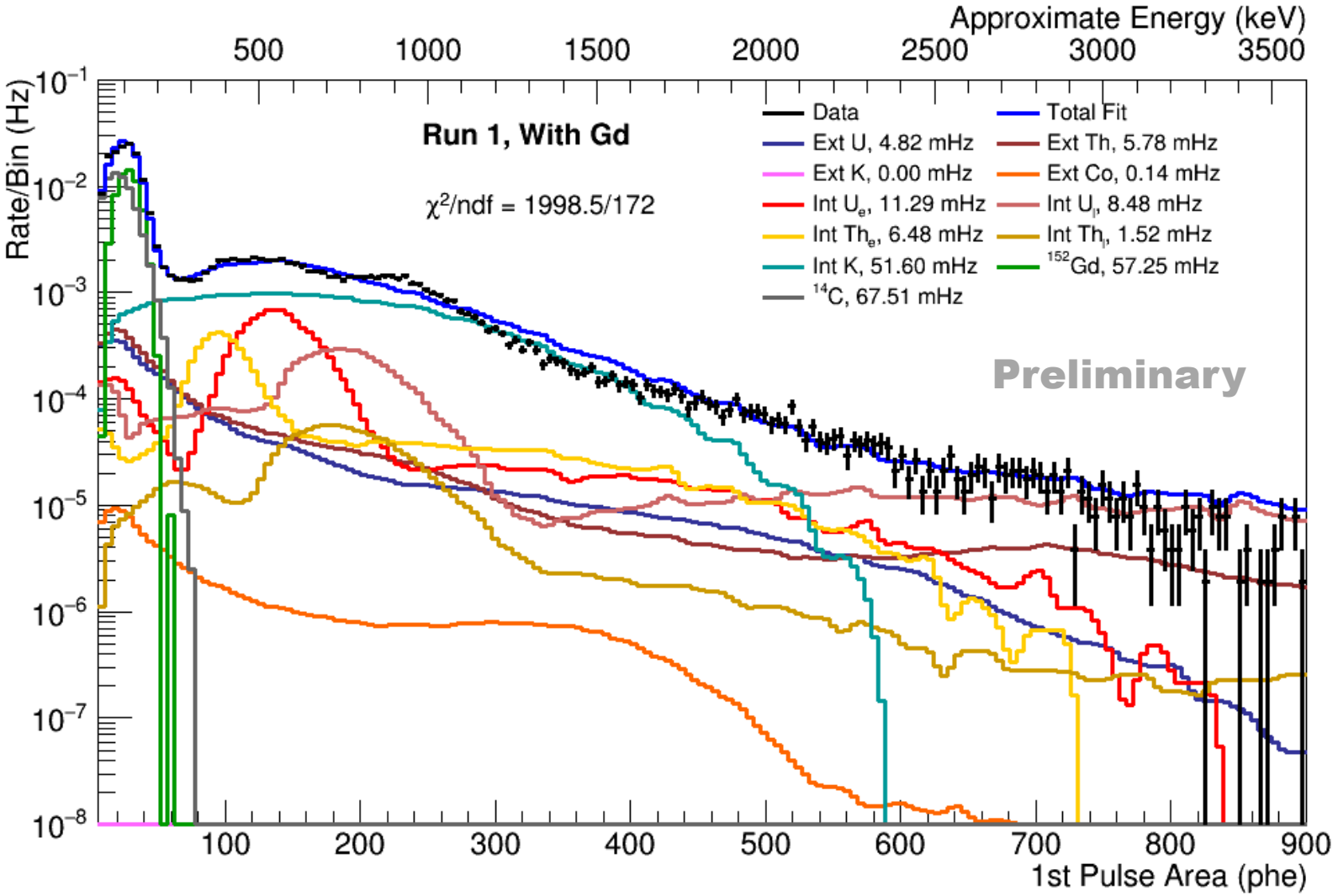
Top of OD acrylic….
4-5x lower than sim!

Background Simulations

- Detailed geometry in Geant4-based LUXSim code
- U, Th, K and Co simulated in:
  - Tyvek
  - Ropes
  - Titanium Ballast
  - PMTs and bases
  - PMT mounting structures
  - PMT cabling
  - Flange bolts
  - Acrylic vessel
  - LUX support stand
  - Davis Cavern rock
- In LS volume: U, Th, K, ^{14}C and ^{152}Gd
- Direct screening results or LZ database for normalizations

First Fit to Run 1 Data

- Simulated spectra -> RooFit PDFs grouped by internal or external to LS
- Constraints: External U, Th, K & Co from counting, ^{152}Gd rate from known concentration & late chain U & Th from BiPo rate



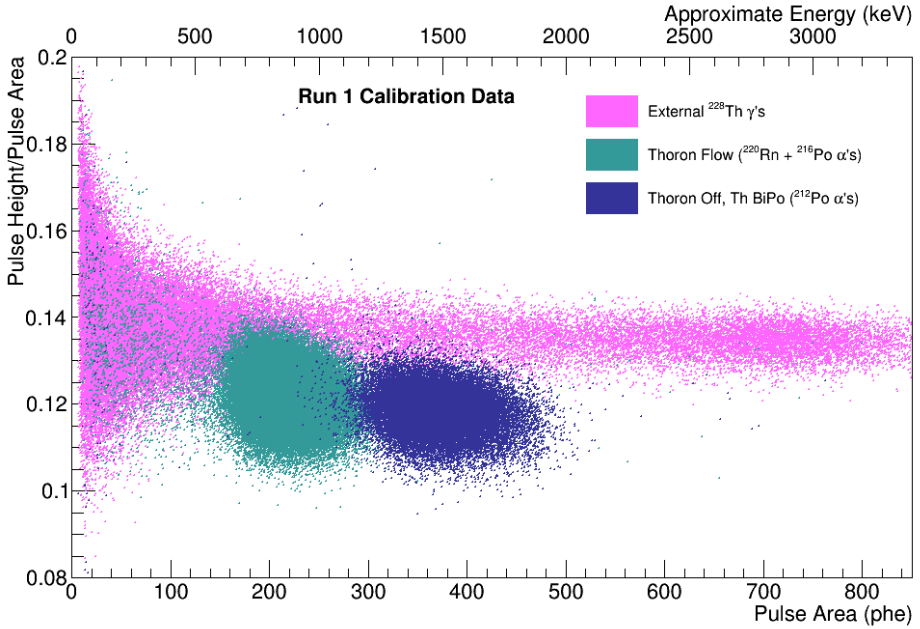
Impurity Estimates from Run 1

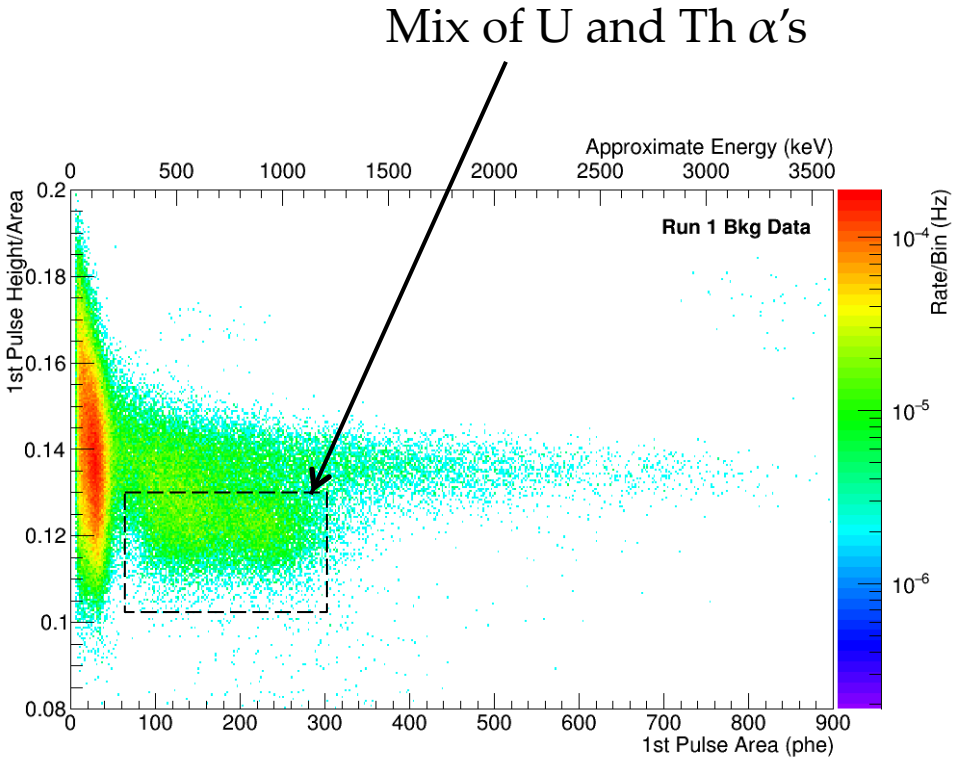
Impurity	Level Estimate	Comes From	Goal	Requirement
^{238}U	6.5 ± 1.5 ppt early 3.1 ± 0.3 ppt late	Fit early, BiPo late	1.3 ppt	10 ppt
^{232}Th	22 ± 5 ppt early 1.3 ± 0.4 ppt late	Fit early, BiPo late	4.5 ppt	20 ppt
^{40}K	12 ± 1 ppt	Fit	0.8 ppt	3 ppt
^{14}C	$(2.7 \pm 0.1) \times 10^{-17}$ g/g	Fit	1.3×10^{-17} g/g	1.5×10^{-17} g/g

- Close to requirement on ^{14}C
  - Crude fit to Run 2 within factor of 2
- U, Th okay…
  - Evidence for non-equilibriated sub-chains
  - HPGe screening of $GdCl_3$ underway
- ^{40}K expected to drop with updated fit

Next Steps

- Run 2 fits
- Pulse shape discrimination
  - Constrain U & Th alphas
- Z-scan analysis





Conclusions

- Screener campaign a success!
- Providing useful feedback to LZ
  - Operational experience with GdLS
  - GdLS production modifications for lower backgrounds
- **We are close to our purity requirements for the GdLS**
- **Z-scan constrain Davis Cavern gamma rate**

Thank You!

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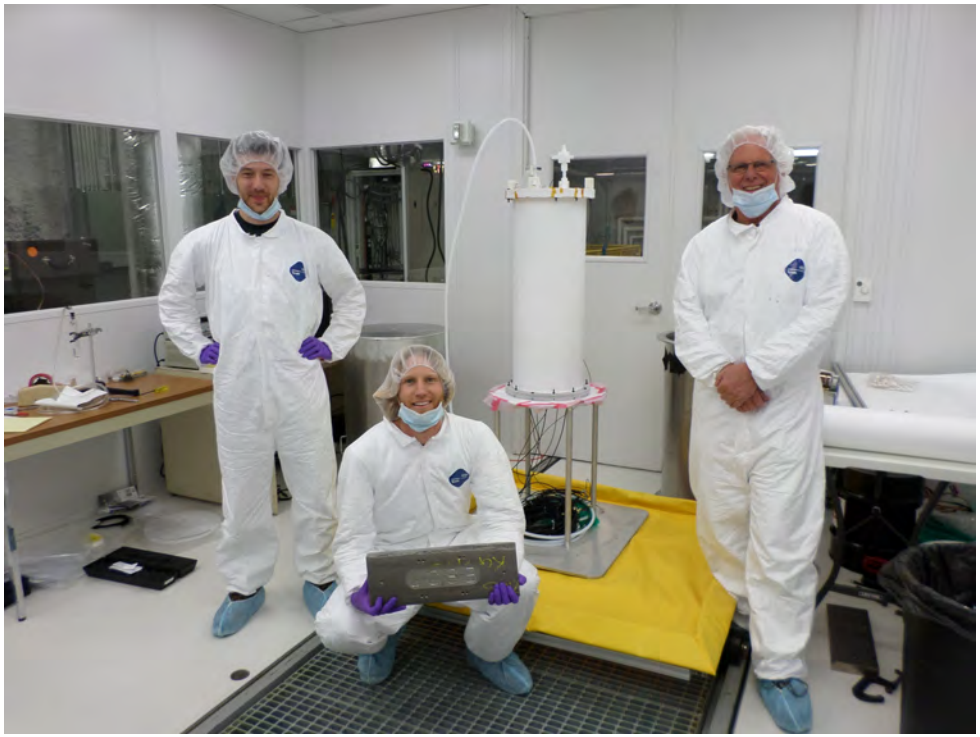
Sally Shaw
Minfang Yeh

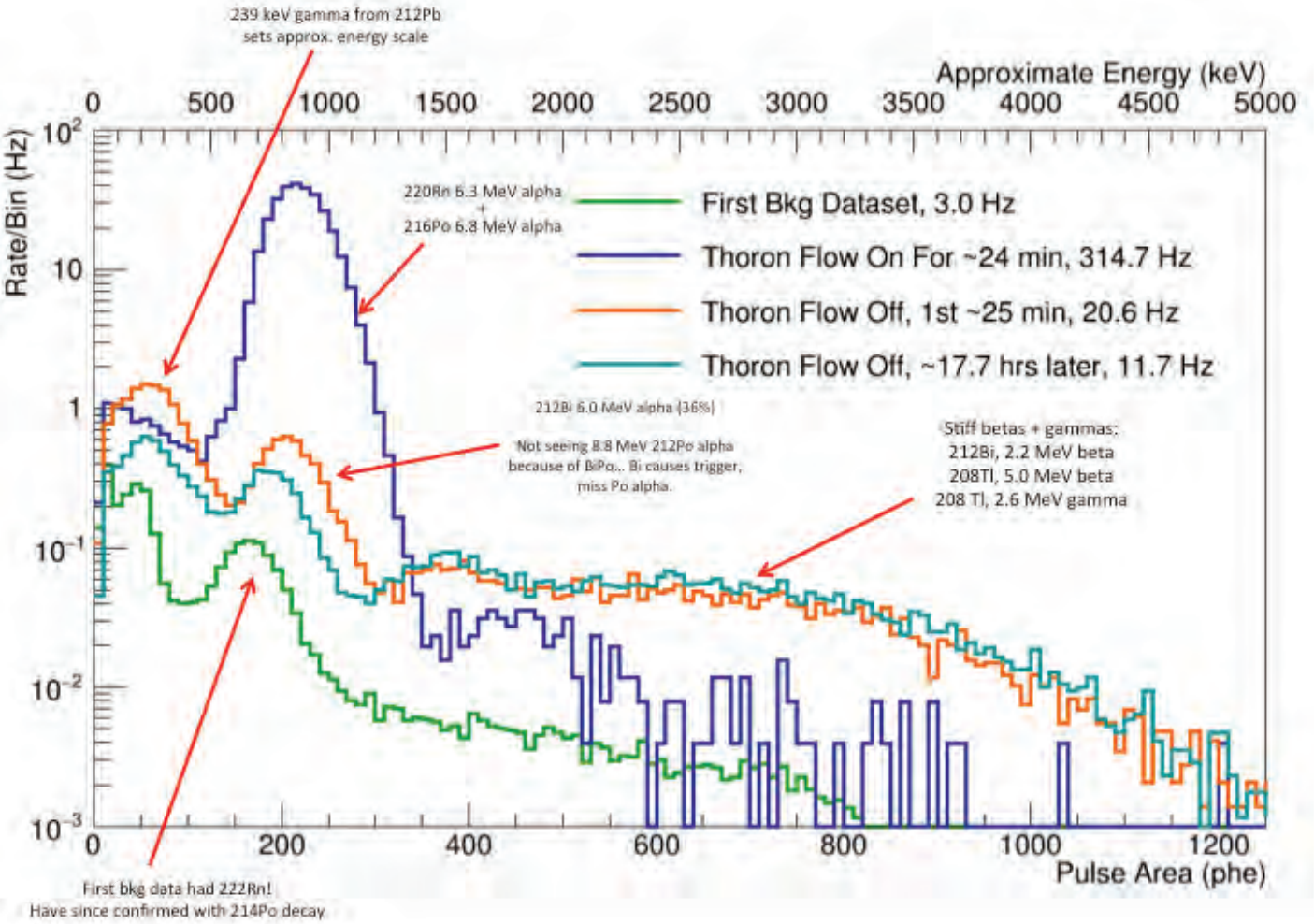
Simon Fiorucci
Markus Horn
Dave Taylor
SURF personnel
U. Rochester
Brown U.
U. Davis
LZ Screening Crew

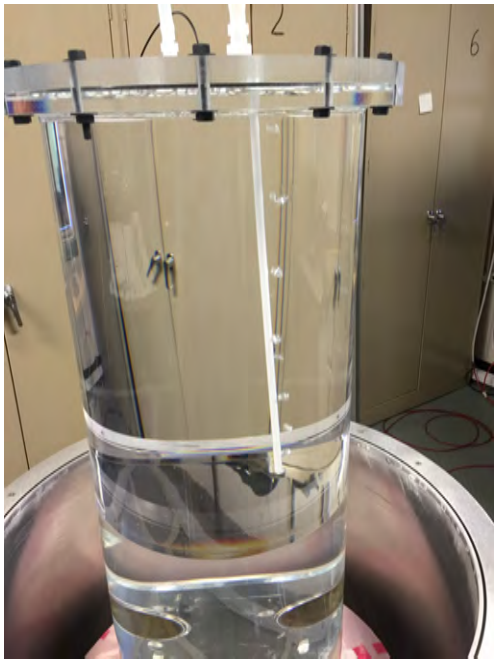


Extra Slides

Thoron Calibration

- Bubble N_2 past ^{228}Th source into LS
- Vents through concentric tubing to bubbler outside water tank





Testing at UCSB

1.06.04 – Gd-LS Impurities 2/20/2017

Yellow are measurements (ICPMS/HPGe), blue screener

Component	Raw Values (ppt)				Gram per Liter Gd-LS	0.1% Gd-LS in veto (ppt)			
	^{238}U	^{232}Th	^{40}K	^{14}C		^{238}U	^{232}Th	^{40}K	^{14}C
LAB	0.004	0.007	0.5	12×10^{-6}	860	0.004	0.007	0.5	12×10^{-6}
Gd	100	100	52		0.86	0.17	0.17	0.09	
PPO	150	640	27	110×10^{-6}	3	0.5	2.2	0.09	0.37×10^{-6}
TMHA	180	650	27	140×10^{-6}	3	0.6	2.1	0.09	0.44×10^{-6}
bis-MSB	210	190	50	19×10^{-3}	0.015	0.004	0.003	0.001	0.32×10^{-6}
Total/Goal					867.2	1.3 (≈3.1BiPo)	4.5	0.8	13 (≈27)$\times 10^{-6}$
Rate (Hz)						3.75	3.75	3.75	3.75
Requirement						**10**	**20**	**3**	**15×10^{-6}**
Rate (Hz)						**30**	**17**	**14**	**4.3**
Daya Bay						**20**	**4**	**7**	

- Daya Bay levels from one-pass purification of Gd and PPO; ^{40}K from water or contamination
- ^{85}Kr – if like KAMLAND, <20 counts per day