# The LS Screener Campaign

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LZ Collaboration Meeting, SLAC

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# Motivated By OD Rate

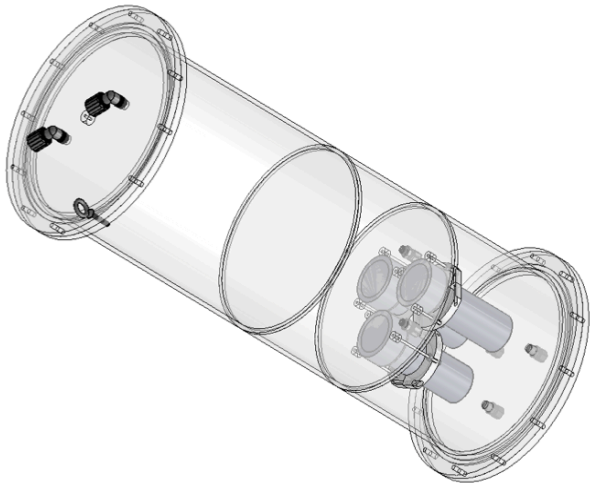
- Dead time requirements for OD constrain rate
- $^{14}C$ a main concern
  - LLNL Mass Spec down to $10^{-15}$ g/g… requirement/goal is $10^{-17}$-$10^{-18}$ g/g
- Additional verification of others: U, Th, K
- Bonus:
  - Experience with GdLS logistics
  - Z-scan

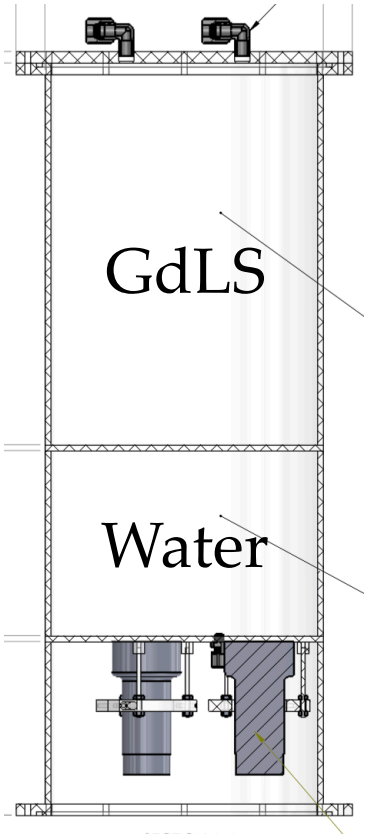
From Harry: Rate contributions in OD

| Component | Rate (Hz) |
|---|---|
| Mine/Rock Gammas | 91 (200 keV) |
| $^{152}Gd$ alphas | 34 (170 keV) |
| Gd-LS | 15 (100 keV) |
| Other LZ Components | 7 (100 keV) |
| OD Acrylic | 5 (100 keV) |
| **Total** | ≈200 (100 keV), ≈130 (200 keV) |

# The Screener

- Made of Reynolds UVT acrylic (same as OD)
- ~ 24 kg GdLS
  - ~1/700 of OD LS
- 14 kg Water Shield
- 3 LZ R11410-20 PMTs
- Wrapped in single layer Tyvek
- Goals
  - Rate from GdLS, $^{14}C$
  - Spectral info
  - Operational experience






CAD Model by Susanne Kyre

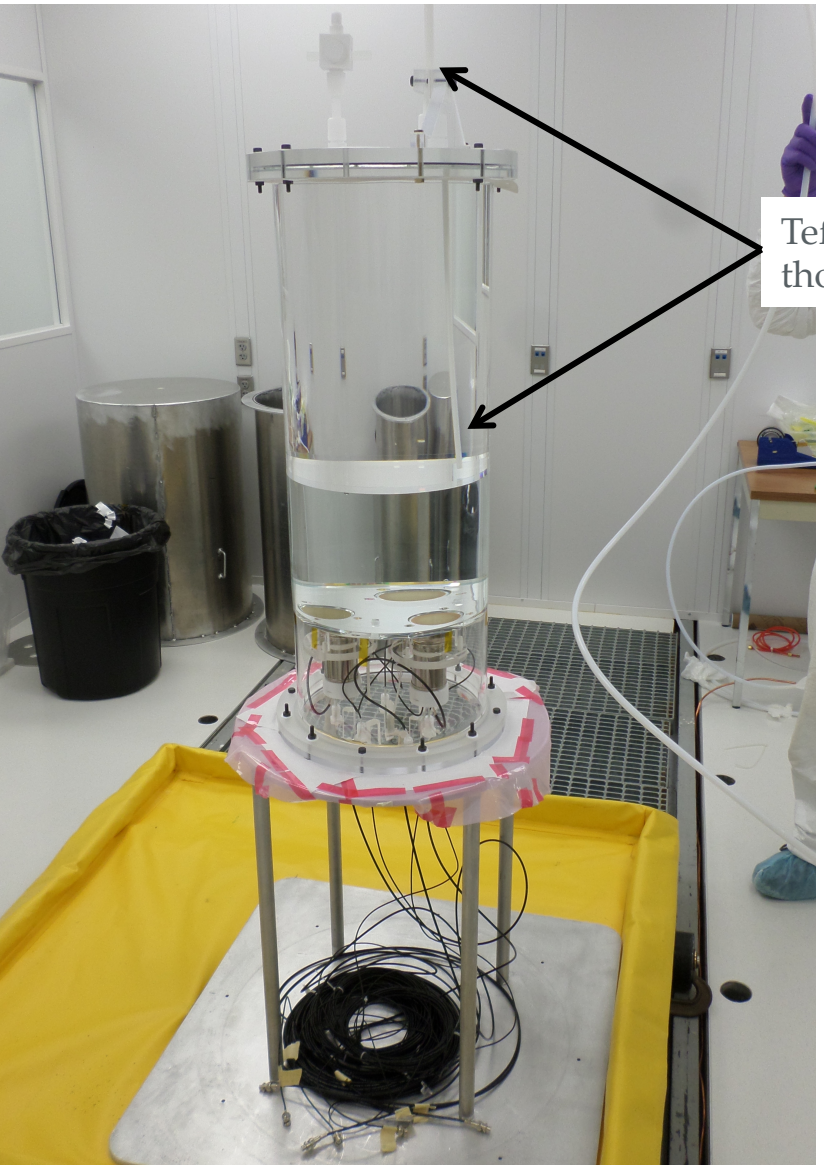
# Underground Commissioning

Water volume full, mounting PMTs

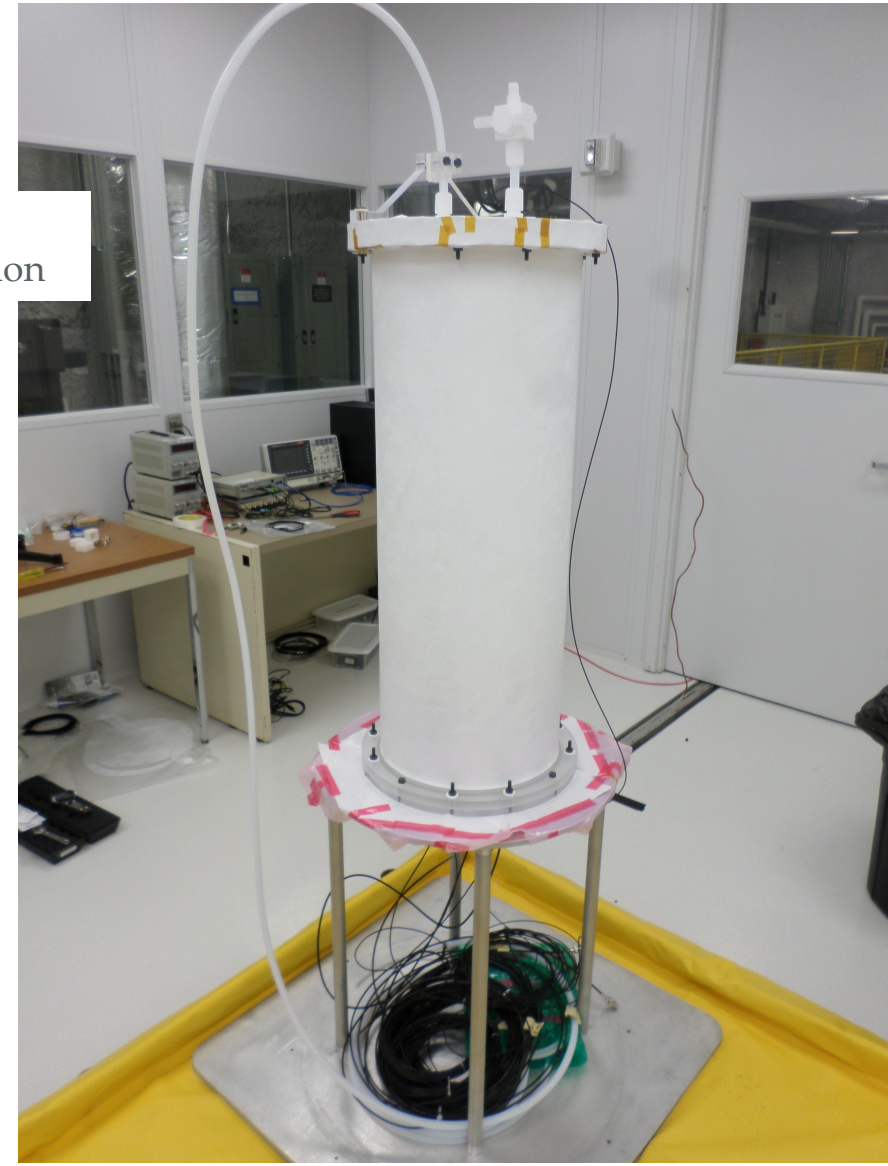
"How many physicists does it take to pump LS?"

# Ready for Water Tank Deployment

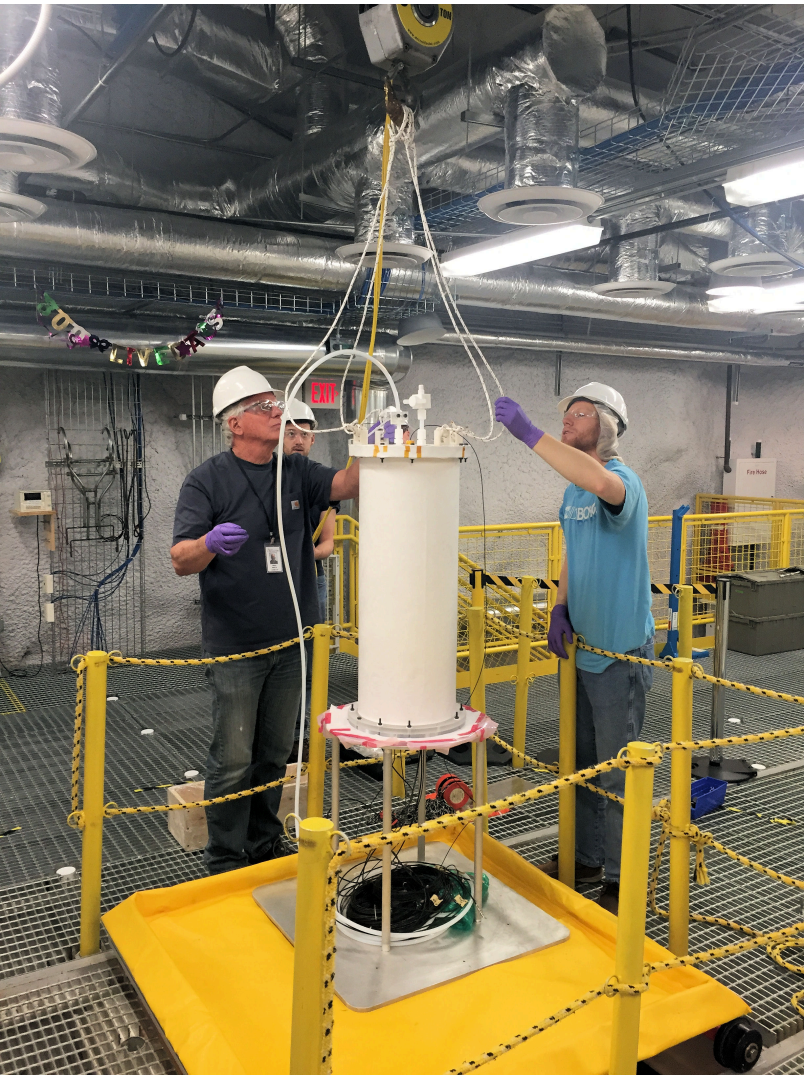
Filled w/ GdLS and water. PMTs mounted in underground cleanroom:




Wrapped in single layer tyvek, ready for deployment:



# Water Tank Deployment



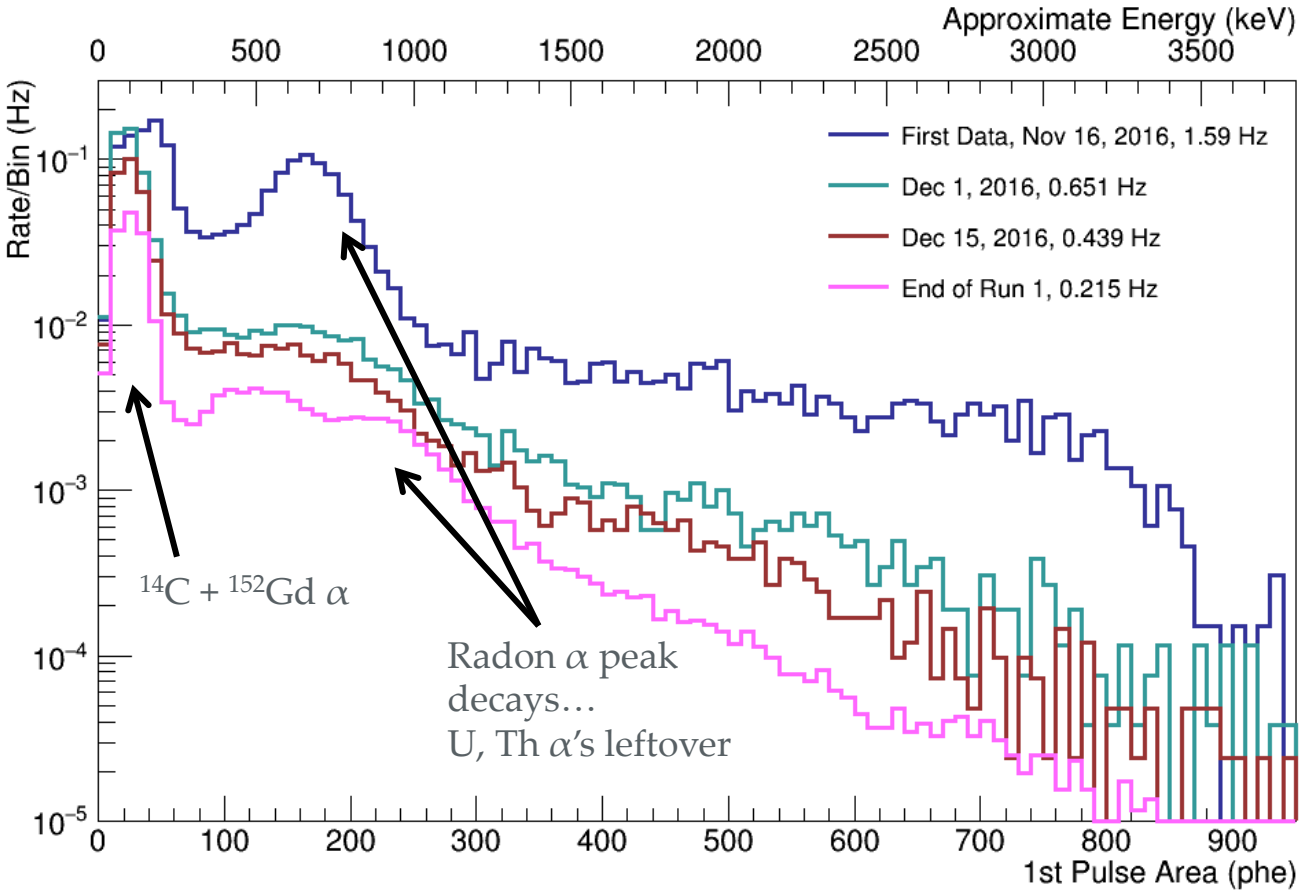
# Run 1 – First Data

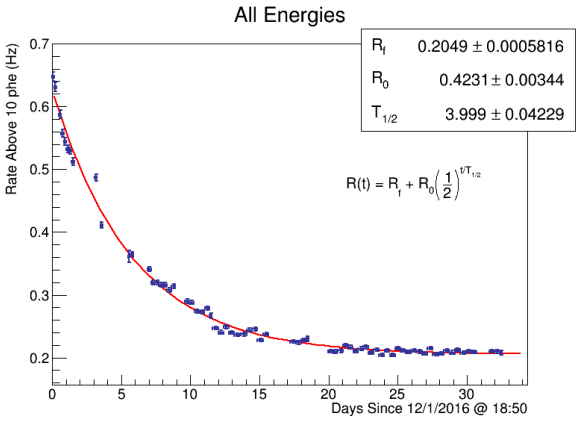
- We see $\alpha$'s, $\beta$'s and Compton deposits from $\gamma$'s
- Radon peak, starting rate ~2-3 Hz
- Gone after ~ 3 weeks
- 0.25 phe/keV → 24 keV threshold

$R_{100\ keV} = 154$ mHz
$R_{200\ keV} = 78$ mHz

↓

$R_{100\ keV\ OD} \sim 109$ Hz
$R_{200\ keV\ OD} \sim 55$ Hz



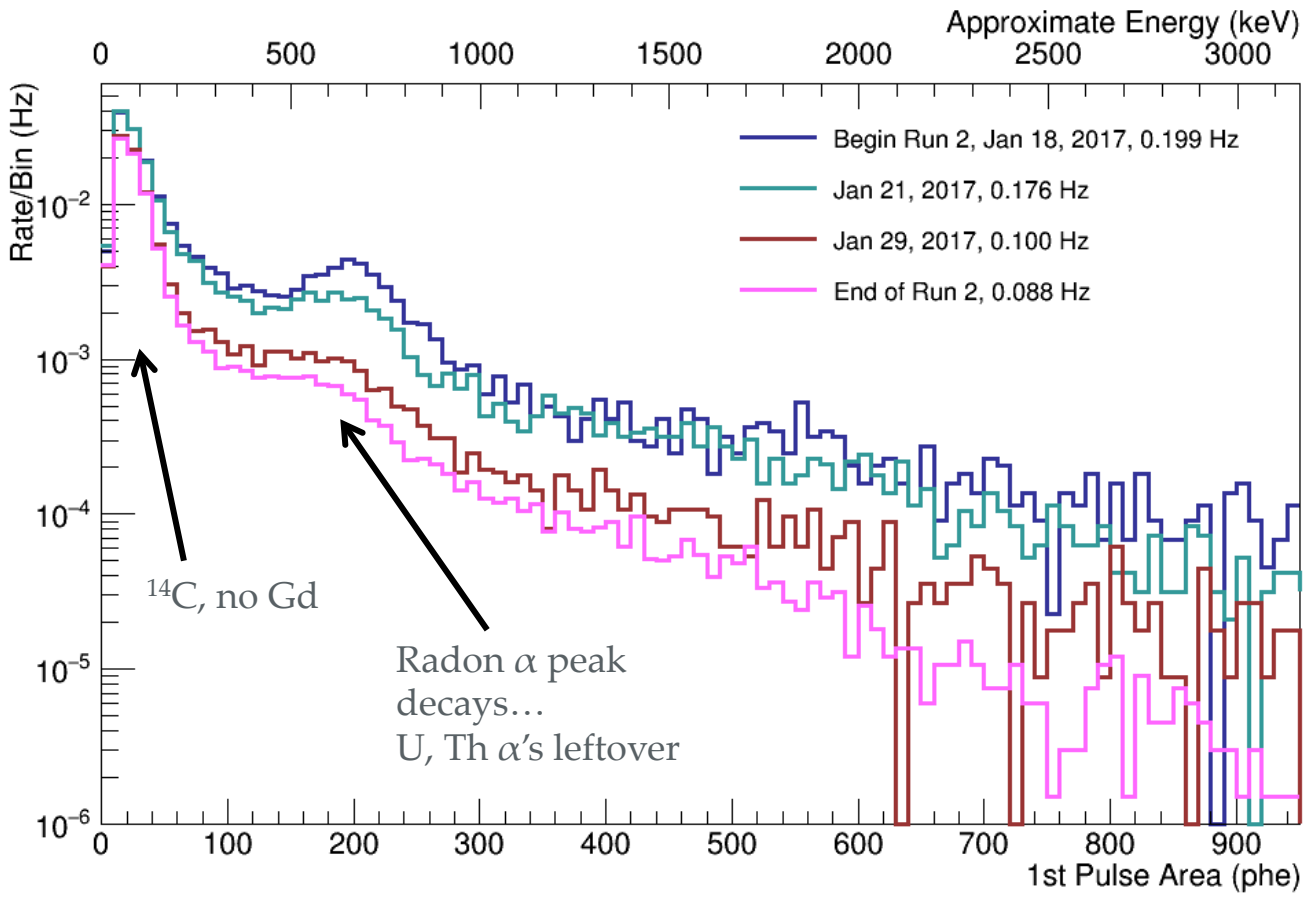



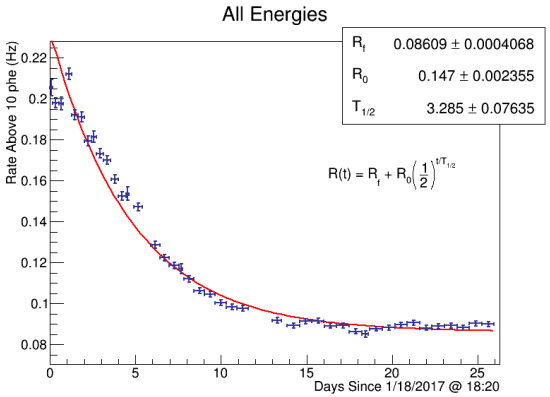
# Run 2 – No Gd

- Same cocktail minus Gd
- Less exposure during LS fill
- Again some radon initially, but rate ~0.2 Hz
- Radon gone after ~ 2 weeks
- Higher light yield, ~0.3 phe/keV

$R_{100\ keV} = 15$ mHz
$R_{200\ keV} = 9$ mHz

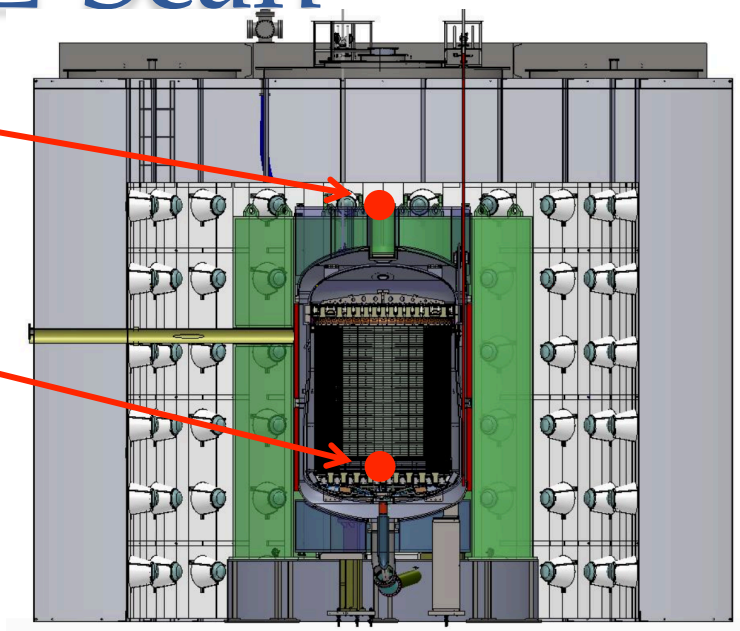
$R_{100\ keV\ OD} \sim 11$ Hz
$R_{200\ keV\ OD} \sim 7$ Hz

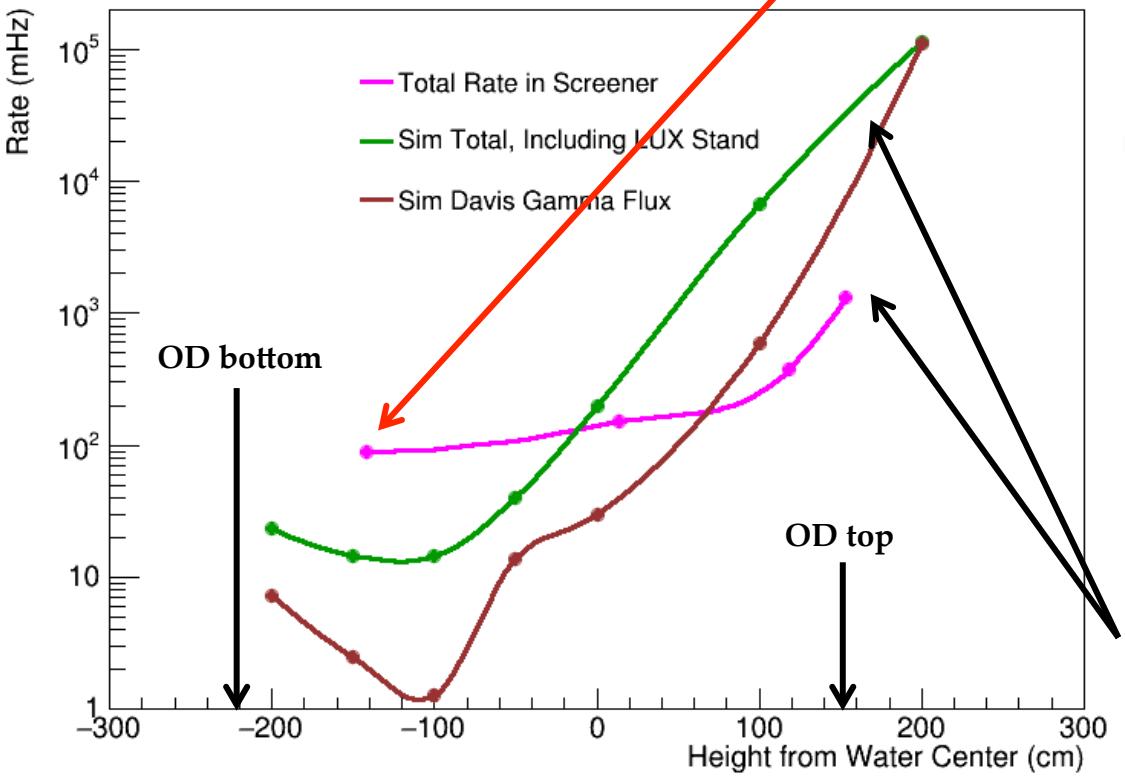


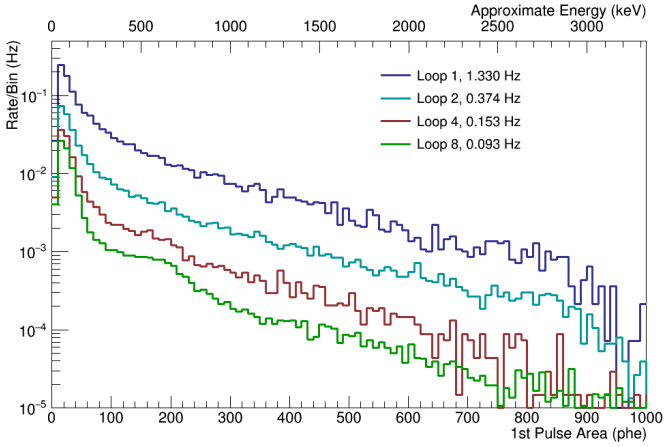



# End of Run Z-Scan

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



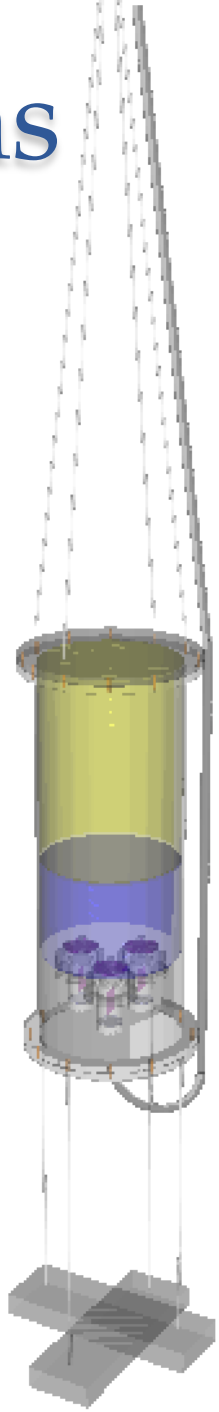




**Top of OD acrylic….**
**VERY different from sim**

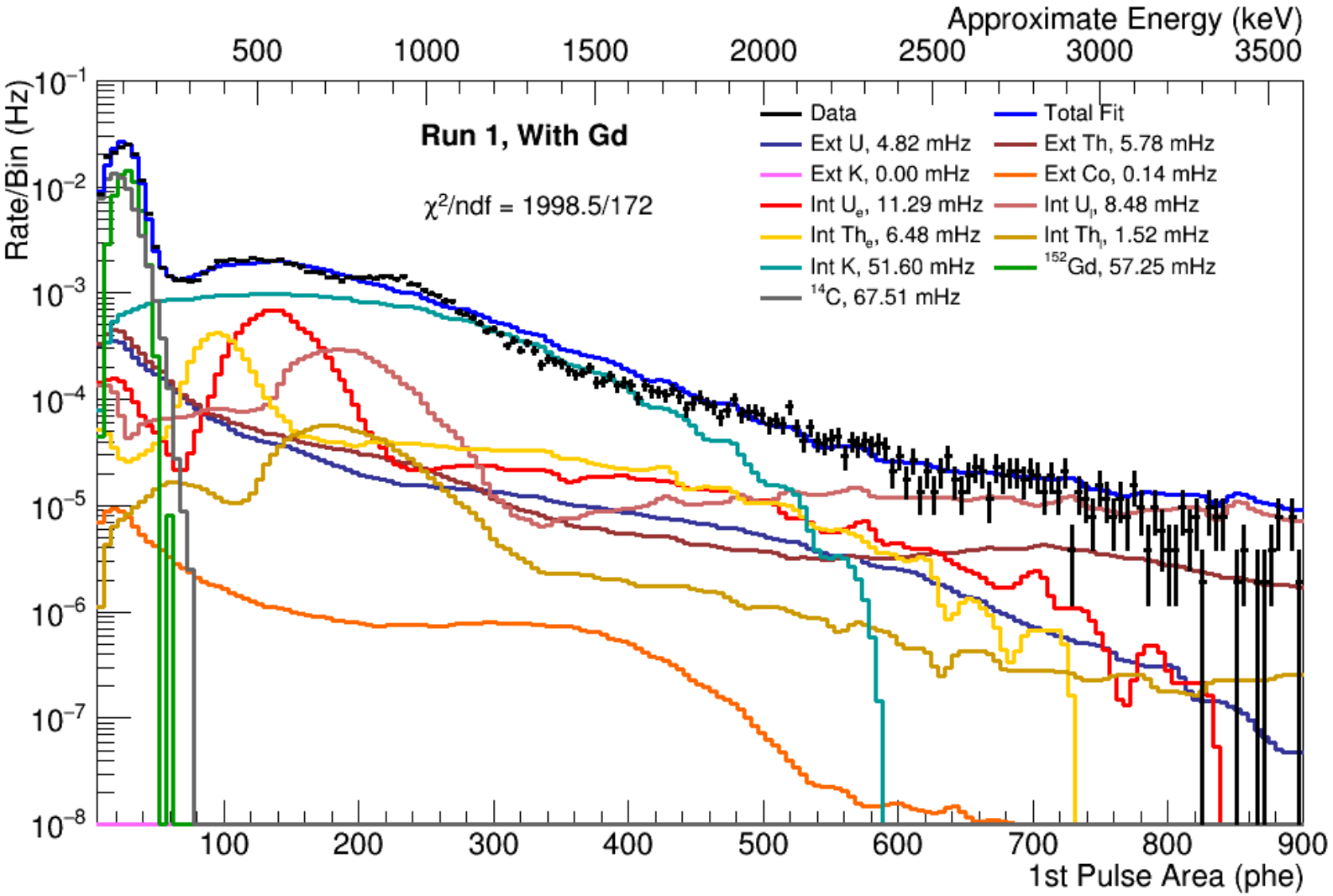
# Background Simulations

- Detailed geometry
- "First pass" round of sim <-> calibration tuning ( $\gamma$ 's & $\alpha$ 's)
- U, Th, K and Co (when applicable) simulated in:
  - Tyvek
  - Ropes
  - Titanium Ballast
  - PMTs and bases
  - PMT mounting structures
  - PMT cabling
  - Flange bolts
  - Acrylic body
  - LUX support stand
- In LS volume: U, Th, K, $^{14}C$ and $^{152}Gd$
- Direct screening results or LZ bkgs table used for normalizations



# First Fit to Run 1 Data

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



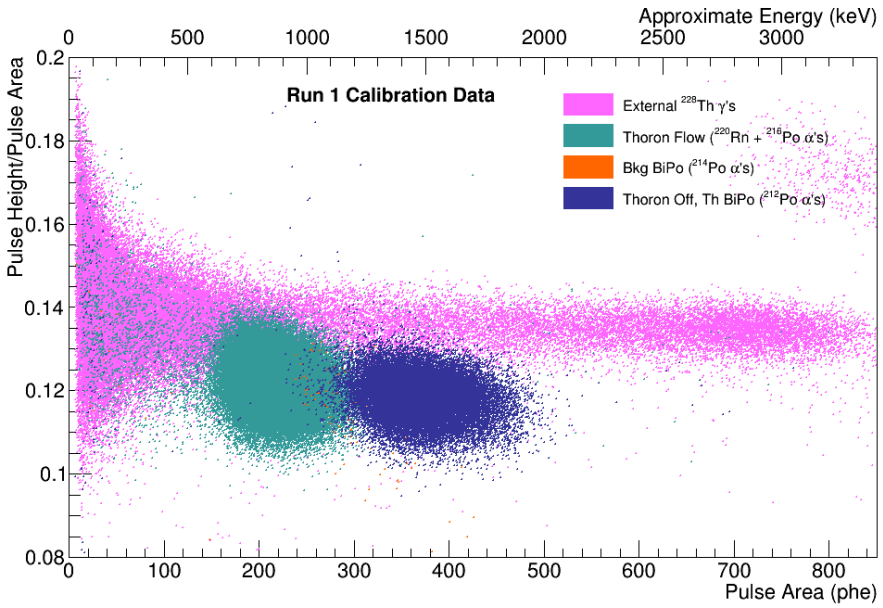
# Impurity Estimates

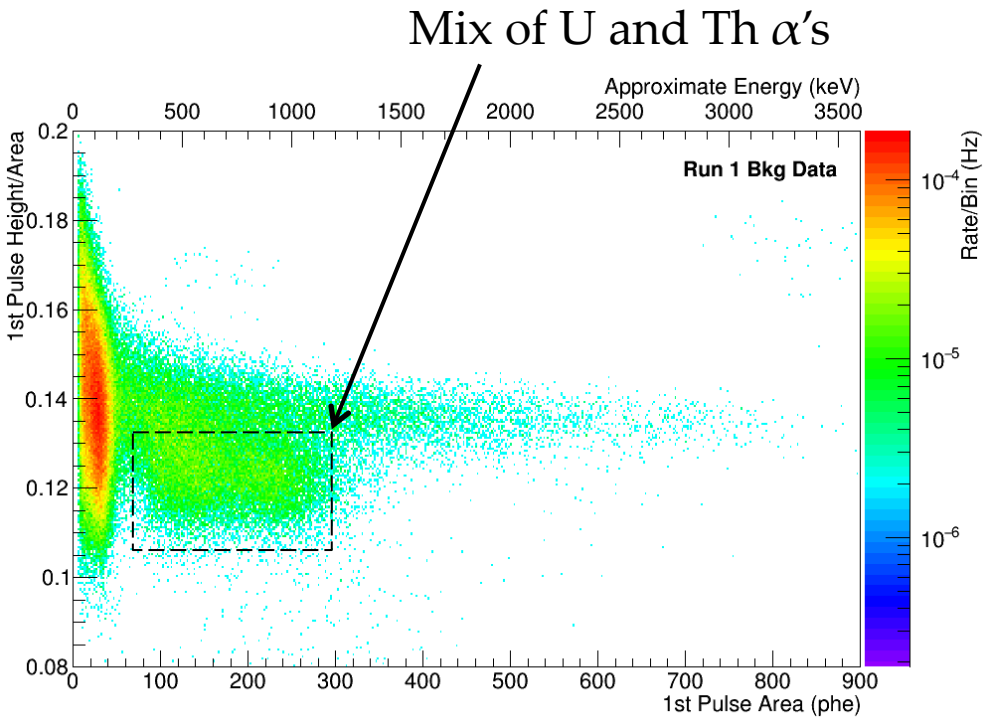
| Impurity | Level Estimate | Comes From | Goal | Requirement |
|---|---|---|---|---|
| $^{238}U$ | 6.5 ± 1.5 ppt early<br>3.1 ± 0.3 ppt late | Fit early, BiPo late | 1.3 ppt | 10 ppt |
| $^{232}Th$ | 22 ± 5 ppt early<br>1.3 ± 0.4 ppt late | Fit early, BiPo late | 4.5 ppt | 20 ppt |
| $^{40}K$ | 12 ±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

- Close to requirement on $^{14}C$
  - Crude fit to Run 2 within factor of 2
- U, Th okay…
  - Run 2 comparison shows $GdCl_3$ maybe large part here
  - HPGe screening underway
- $^{40}K$ a concern…
  - Fit says no external K...curious

# Next Steps

- Improving agreement between sim and calibration data
- Pulse shape discrimination
  - Constraint U & Th alphas (early chain)
- $GdCl_3$ screening w/ HPGe @ SURF
- Run 2 fits
- Z-scan analysis



# Conclusions

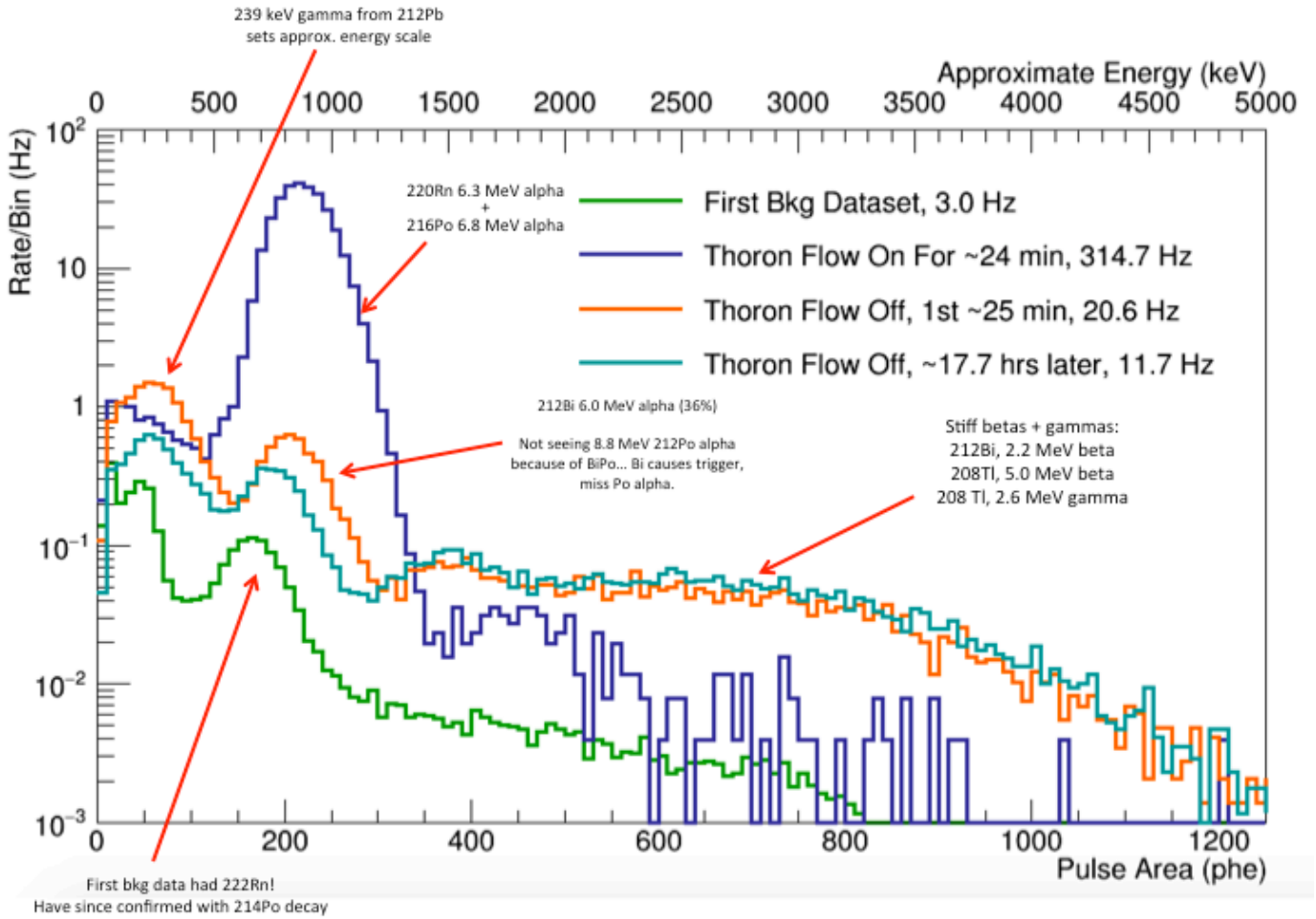
- Screener campaign a success!
- Many lessons learned
- Simulation and data analysis providing useful feedback to OD
- Z-scan constrain Davis Cavern gamma bkg

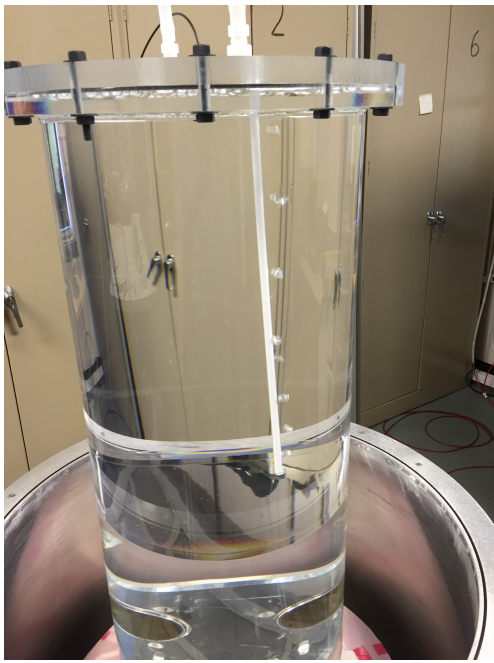
## Thank you to all who helped make this a wonderful project!

# Extra Slides

# Thoron Calibration

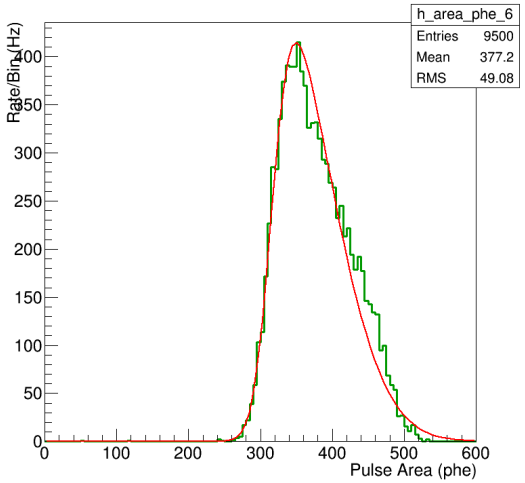
- Bubble N2 past Scott Hertel's $^{228}$Th source into LS
- Vents through concentric tubing to bubbler outside water tank
- Very useful data!



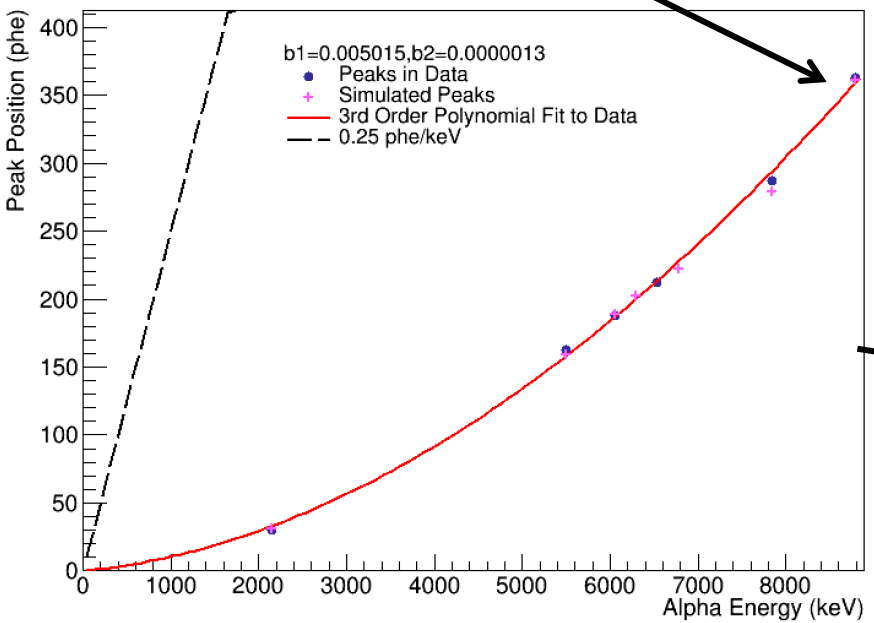



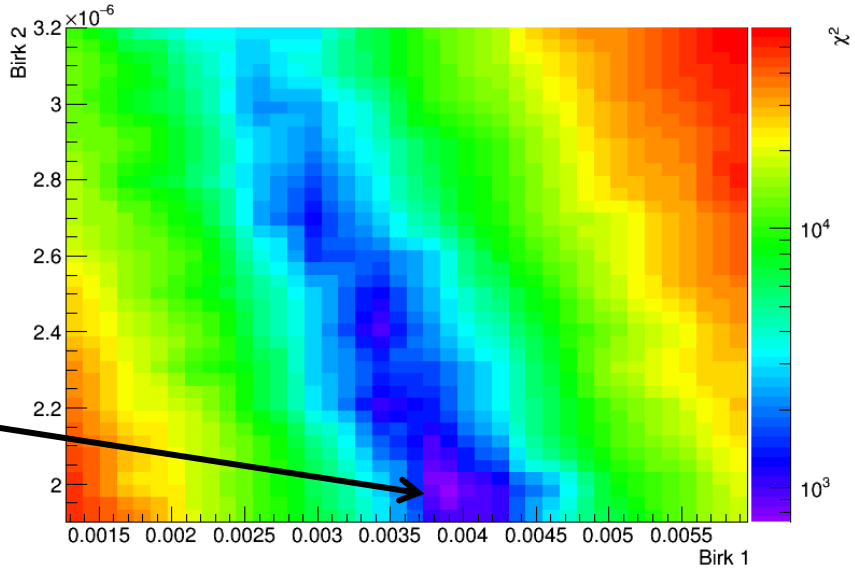
Testing at UCSB

# Alpha Scale




- Simulate $\alpha$'s seen in data
- Fit peaks with skew Gaussian
  - Skewness from light collection variation in z
- Scanning over Birk's Law parameters



# 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 | $12 \times 10^{-6}$ | 860 | 0.004 | 0.007 | 0.5 | $12 \times 10^{-6}$ |
| Gd | 100 | 100 | 52 | | 0.86 | 0.17 | 0.17 | 0.09 | |
| PPO | 150 | 640 | 27 | $110 \times 10^{-6}$ | 3 | 0.5 | 2.2 | 0.09 | $0.37 \times 10^{-6}$ |
| TMHA | 180 | 650 | 27 | $140 \times 10^{-6}$ | 3 | 0.6 | 2.1 | 0.09 | $0.44 \times 10^{-6}$ |
| bis-MSB | 210 | 190 | 50 | $19 \times 10^{-3}$ | 0.015 | 0.004 | 0.003 | 0.001 | $0.32 \times 10^{-6}$ |
| 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** | **$15 \times 10^{-6}$** |
| **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