

The LZ Liquid Scintillator Screener Detector

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APS April Meeting 2018

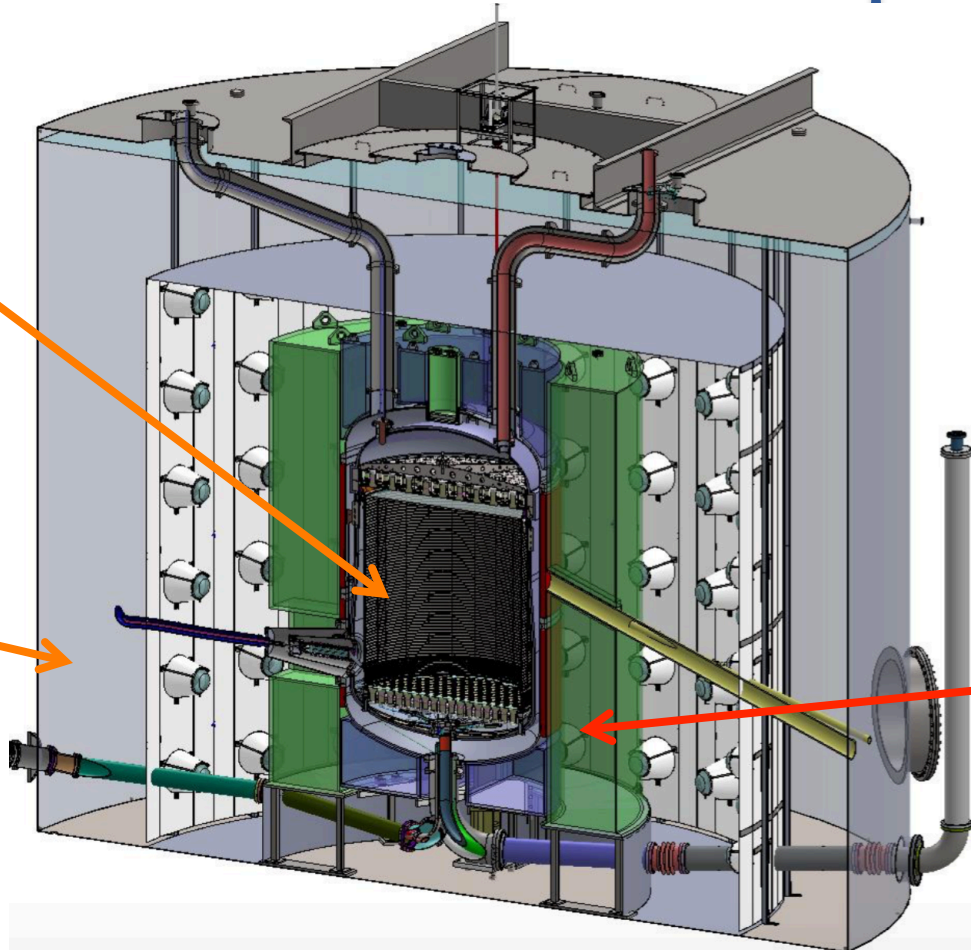
April 16, 2018

The LZ Dark Matter Experiment

Central TPC,
7 tonnes LXe

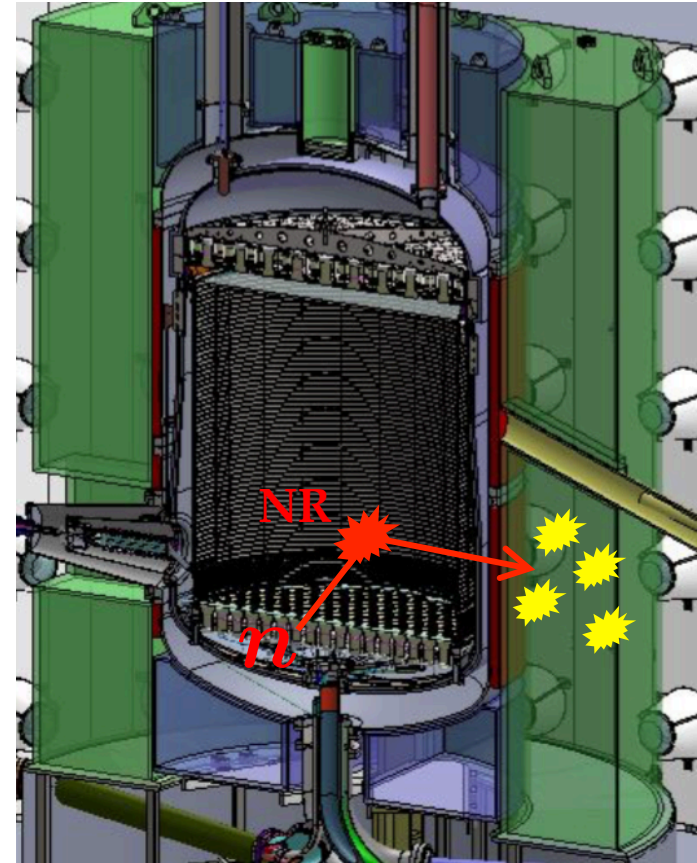
Former LUX
Water Tank

Liquid Scintillator
"Outer Detector"
Veto



The LZ Outer Detector

- ~17 tonnes Gd-loaded, LAB-based LS
 - Neutrons thermalize and capture on Gd:
 - $n + \text{Gd} \rightarrow \text{Gd} + (3-4) \gamma \sim 9 \text{ MeV}$
- 100-200 keV threshold
- Veto neutrons in $\sim 500 \mu\text{s}$
- Want $< 100 \text{ Hz}$ from all sources



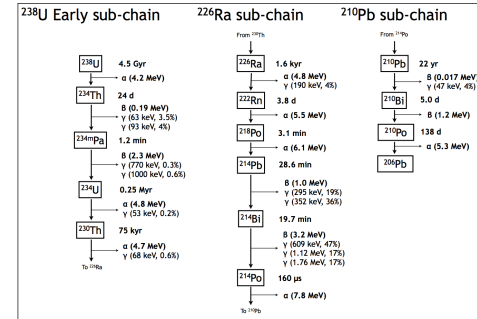
High Scintillator Purity Required

In LS counting we see everything!

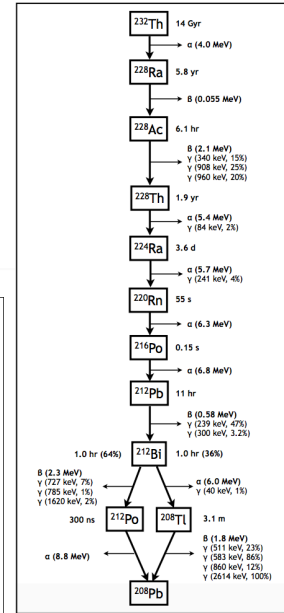
α 's, β 's & γ 's!

- ^{238}U chain, ^{232}Th chain & ^{40}K
- ^{14}C (156 keV β) a priority
 - Need to avoid atmospheric levels of ^{14}C !

^{238}U Chain



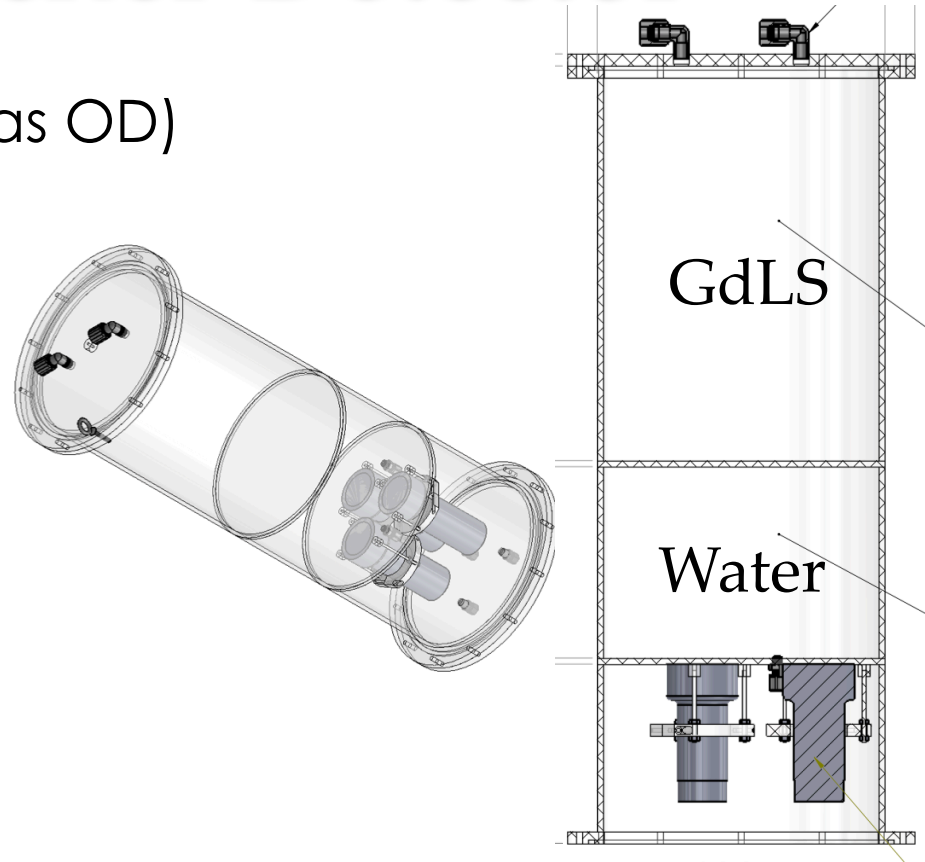
^{232}Th Chain



Rates enhanced by 14x & 10x

The LS Screener Detector

- Reynolds UVT acrylic (same as OD)
- 3x R11410-20 PMTs
 - **Very radiopure (~mBq)**
 - LZ PMT bases
- ~ 24 kg GdLS
 - ~1/700 of OD LS
 - Produced by M. Yeh at BNL
- 14 kg water shield
- Wrapped in Tyvek reflector
- ~300 photoelectrons/MeV



Underground Commissioning, Nov. 2016

Water volume full, mounting PMTs

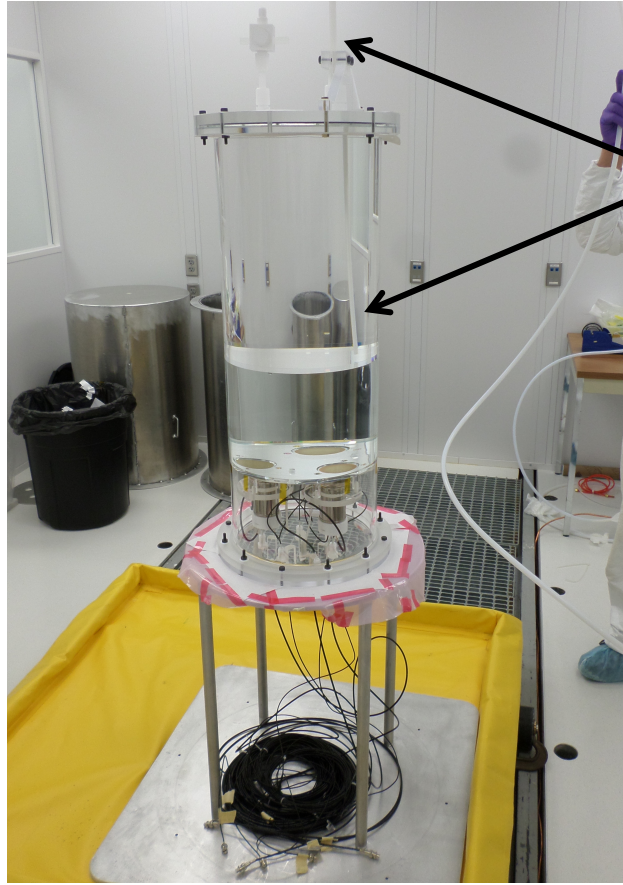


GdLS filling in underground cleanroom



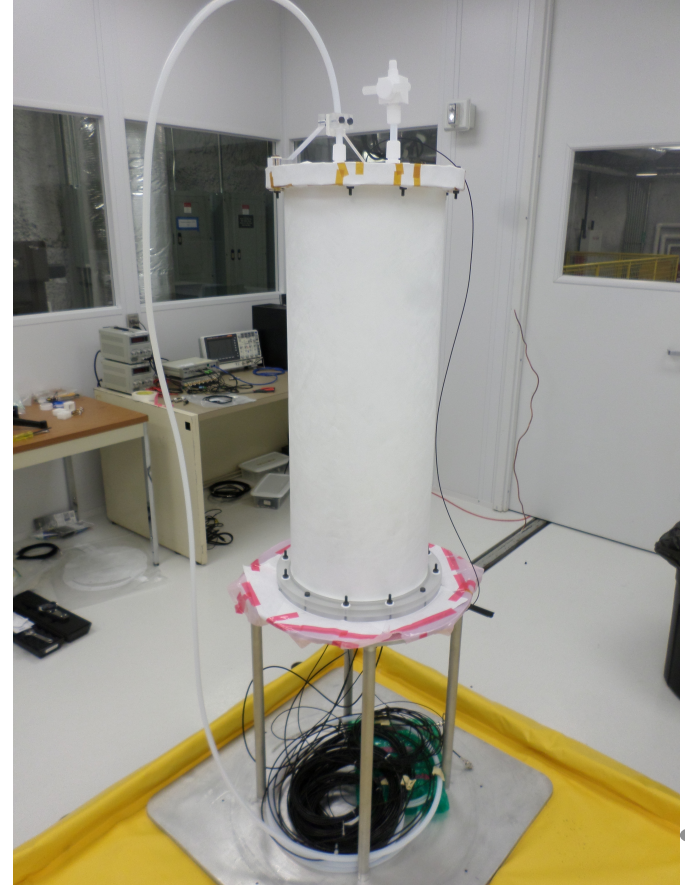
Ready for Water Tank Deployment

Filled w/ GdLS and water. PMTs mounted:



Teflon tube for
thoron calibration

Wrapped in single layer Tyvek, ready for deployment:

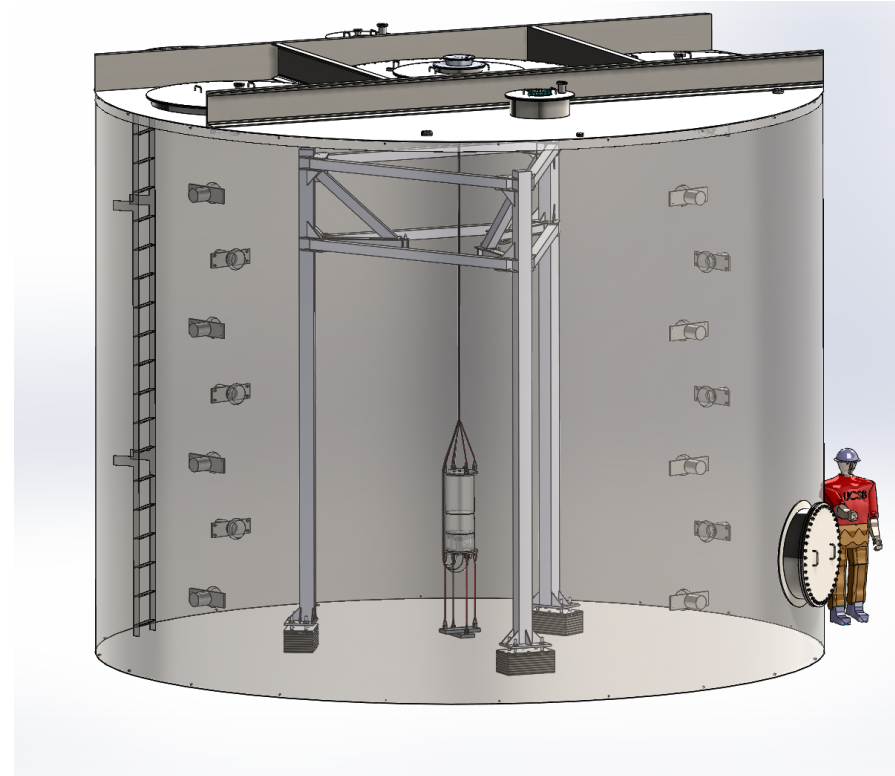


Water Tank Deployment

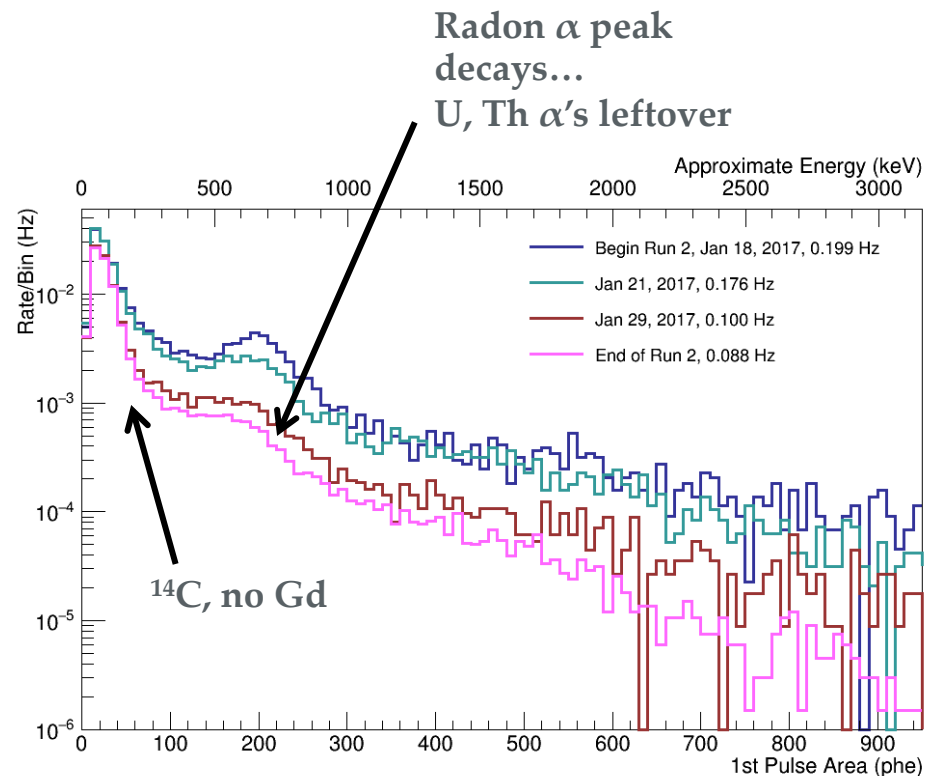
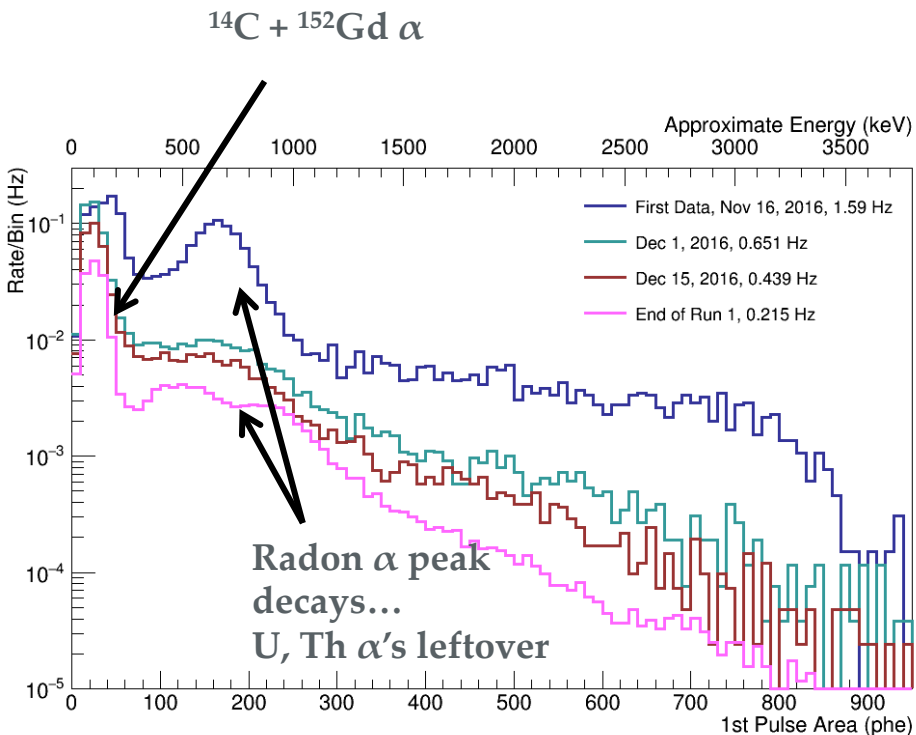


Data Taking Overview

- Deployed in LUX water shield
- Pulses amplified & digitized by LZ electronics
- Run 1: GdLS
 - Mid Nov 2016 – Early Jan 2017
- Run 2: 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

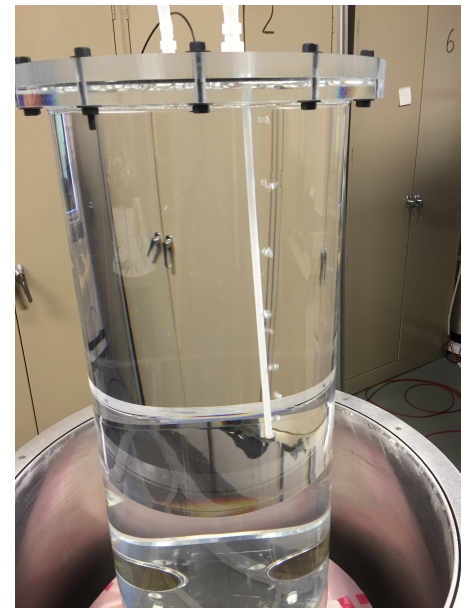
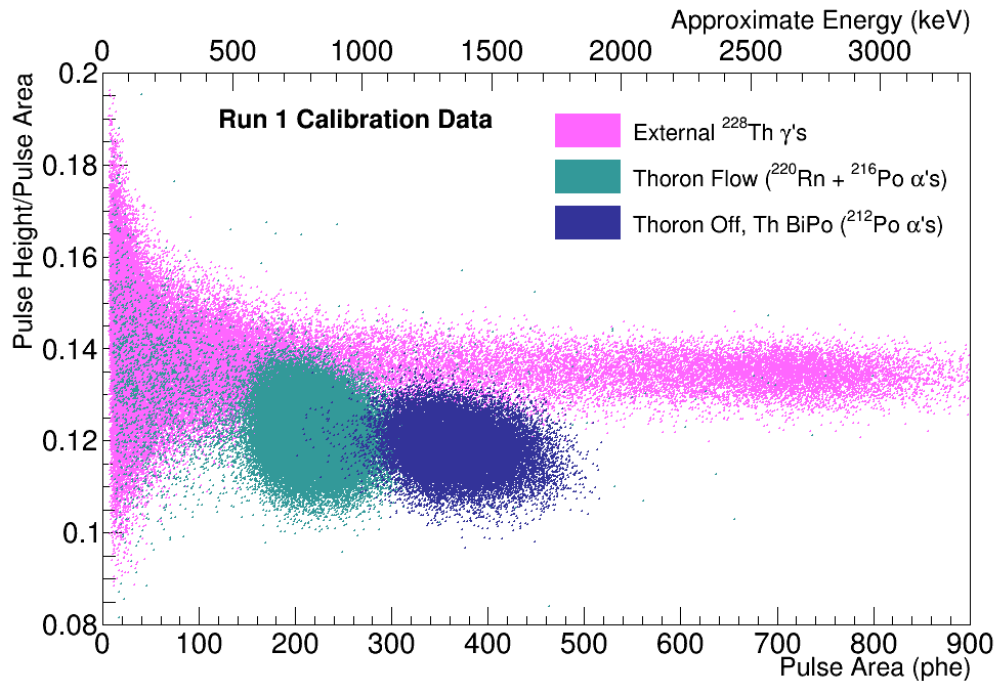


Loaded and Unloaded Spectra



Calibrations

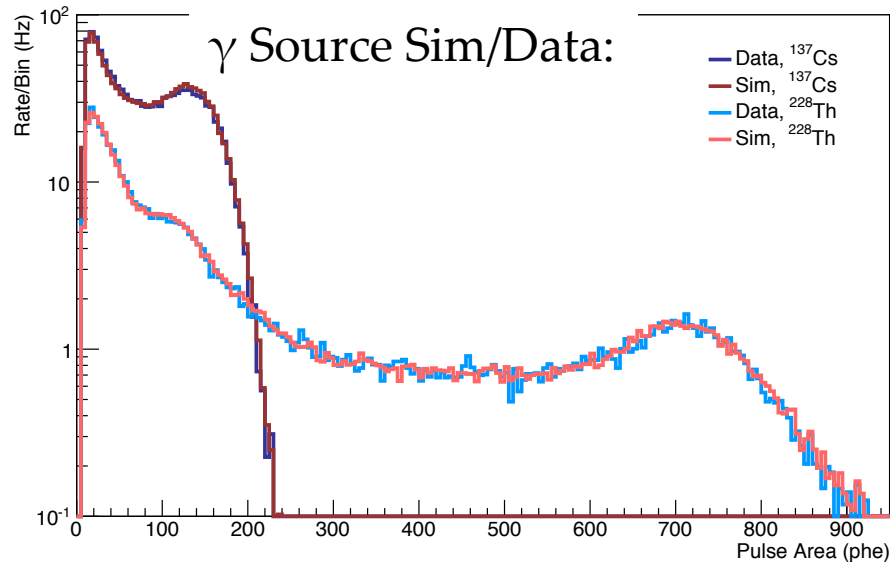
- External γ sources
- Bubble in ^{220}Rn ...entire ^{212}Pb subchain
- **Pulse shape discrimination**



Testing thoron
bubble at UCSB

Simulation Tuned to Calibrations

- Detailed geometry in Geant4-based sim
- Calibrate optical parameters:
 - LS light yield (photons/MeV)
 - Birk's Law parameters for α quenching
- External backgrounds modeled in fits

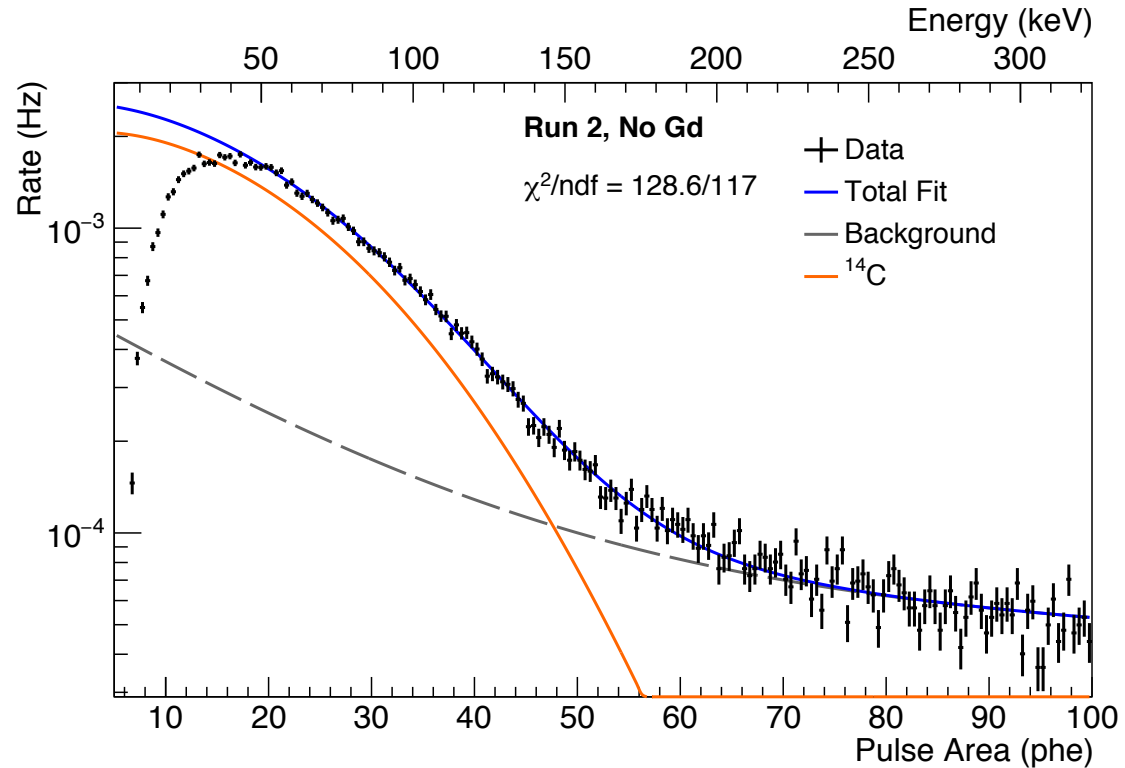


^{14}C Measurement in Run 2

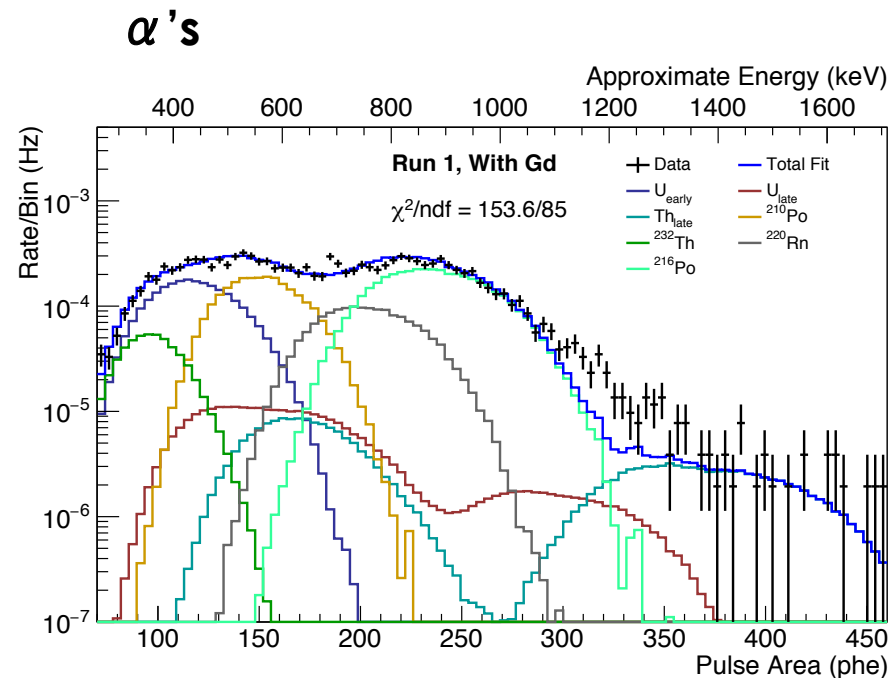
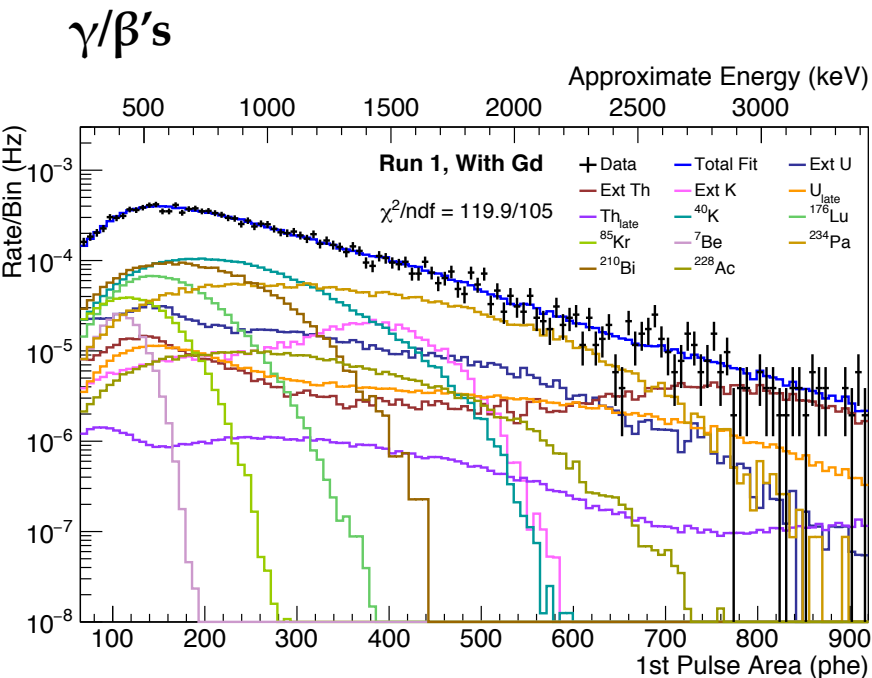
$^{14}\text{C}/^{12}\text{C}$ Measured:
 $(2.83 \pm 0.06) \times 10^{-17} \text{ g/g}$

Atmospheric $\sim 10^{-12}$

Borexino $\sim 10^{-18}$
(measured in 4 tonnes kg LS)



U, Th, Other: Fit to α & γ/β Data



It gets complicated...

Fit Results

	Isotope	Gd-Loaded LS Activity (mBq/kg)	Unloaded LS Activity (mBq/kg)	Method
²³⁸U Chain	²³⁸ U	0.302 ± 0.022	< 0.02	α Fit
	²³⁴ Pa	0.32 ± 0.08	< 0.013	γ/β Fit
	²²⁶ Ra Subchain	0.033 ± 0.003	0.019 ± 0.002	BiPo
	²¹⁰ Bi	$0.45 \pm 0.03^*$	$0.15 \pm 0.01^{**}$	γ/β Fit
	²¹⁰ Po	$0.458 \pm 0.024^*$	$0.153 \pm 0.006^{**}$	α Fit
²³²Th Chain	²³² Th	0.163 ± 0.031	0.097 ± 0.007	α Fit
	²²⁸ Ac	< 0.22	< 0.014	γ/β Fit
	²²⁸ Th Subchain	0.007 ± 0.002	0.0041 ± 0.0006	BiPo
Other	⁴⁰ K	0.49 ± 0.11	0.31 ± 0.02	γ/β Fit
	⁷ Be	1.19 ± 1.01	3.58 ± 0.43	γ/β Fit
	⁸⁵ Kr	0.23 ± 0.11	0.09 ± 0.04	γ/β Fit
	¹⁷⁶ Lu	0.20 ± 0.05	-	γ/β Fit

HPGe Results on Gd Powder:

Isotope	mBq/(kg Gd(TMHA) ₃)	mBq/(kg GdLS)
U _e	< 7.4	< 0.030
U _l	21 ± 2	0.084 ± 0.008
Th _e	< 3.3	< 0.013
Th _l	< 1.2	< 0.0048
⁴⁰ K	< 28	< 0.11
¹⁷⁶ Lu	70 ± 15	0.28 ± 0.06

- U, Th chains not in equilibrium
- A good case for $[GdLS] = [Gd] + [LS]$

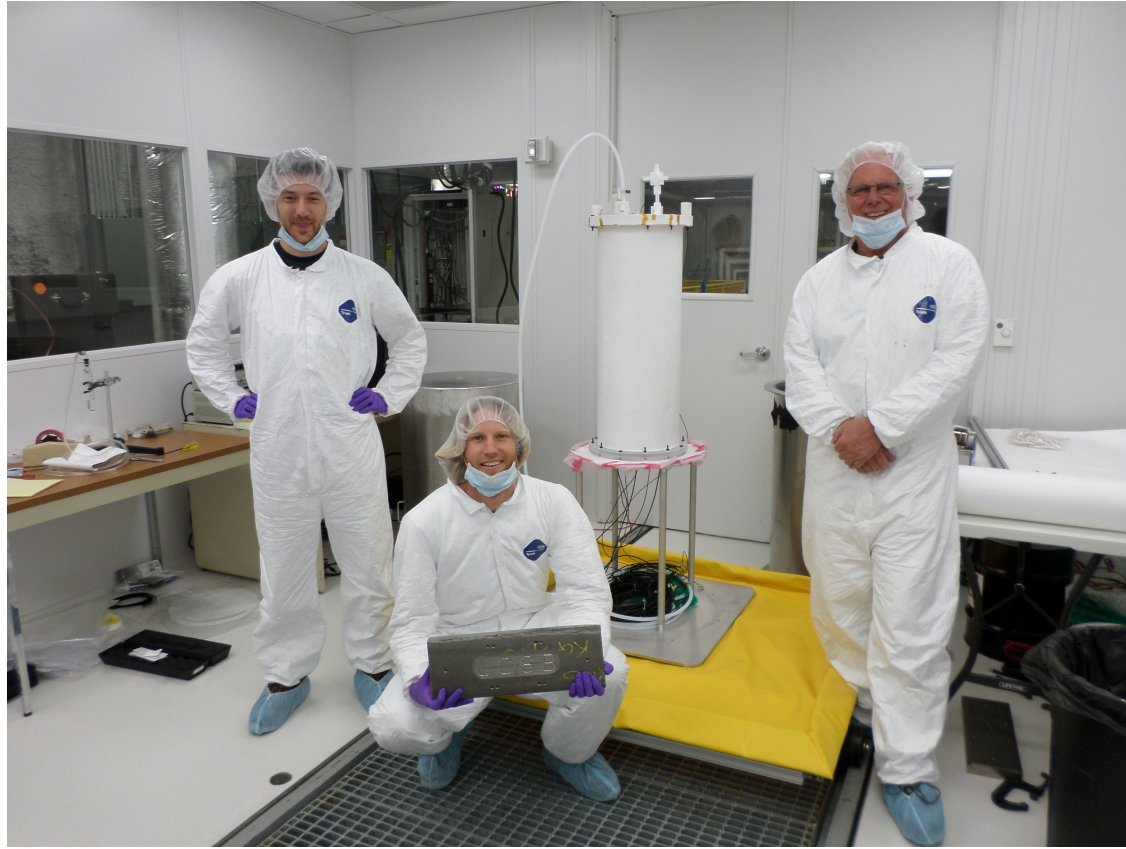
Implied Outer Detector Rates

GdLS	GdLS Impurity	Goal/Estimate (Hz)	Measurement (Hz)	Measured with Screener (zero threshold assumed)
	^{238}U	3.75	49 / 8 (BiPo)	
	^{232}Th	3.75	11 / 1.2 (BiPo)	
	^{40}K	3.75	8.5	
	^{14}C	3.75	8.1	
	^{176}Lu	-	3.5	
Cavern γ 's		91 (200 keV)	25 (200 keV)	
LZ Components		75 (100 keV)	7 (100 keV)	
Total OD		181	112.1 / 61.3	

Conclusions

- Screener campaign a success!
- Providing useful feedback to LZ
 - Operational experience with GdLS
 - Helped in design of OD filling system
 - GdLS production modifications for lower backgrounds (2x purification)
- Our understanding of backgrounds in the OD is ever improving
- **GdLS purity looking promising!**

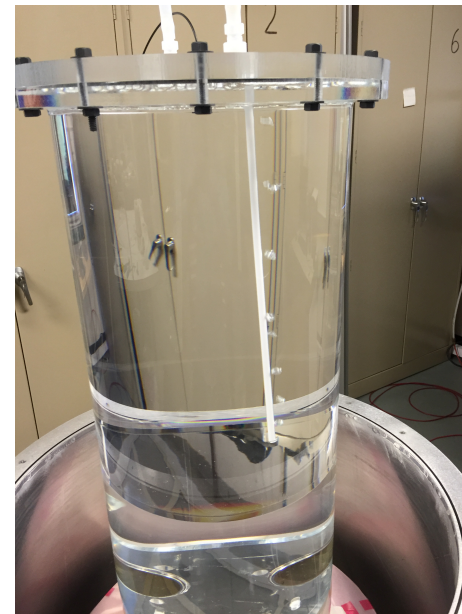
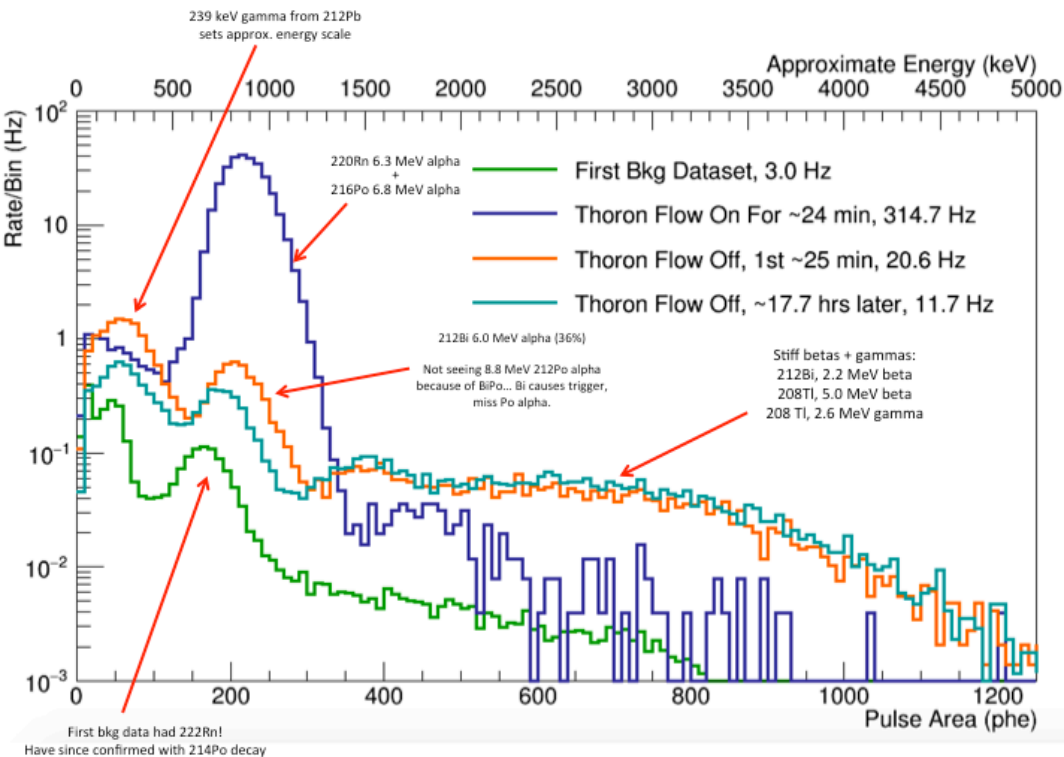
Thank You!



Extra Slides

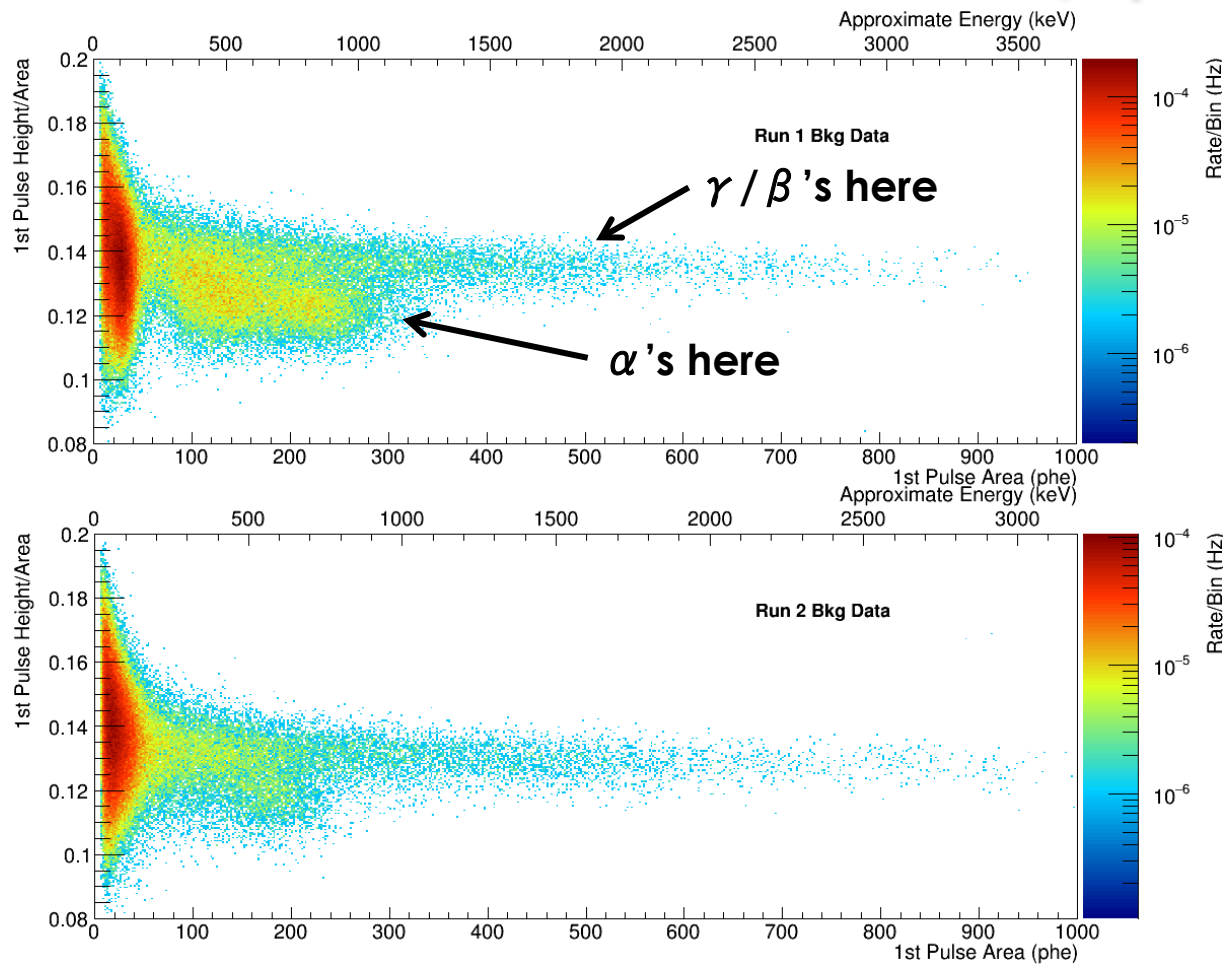
Thoron Calibration

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



Testing at UCSB

Calibrated PSD Selects α & γ/β Data

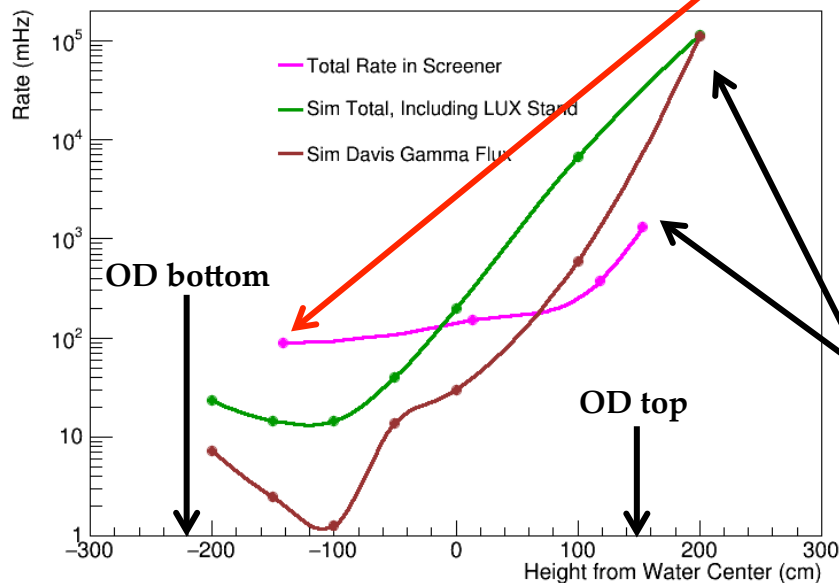
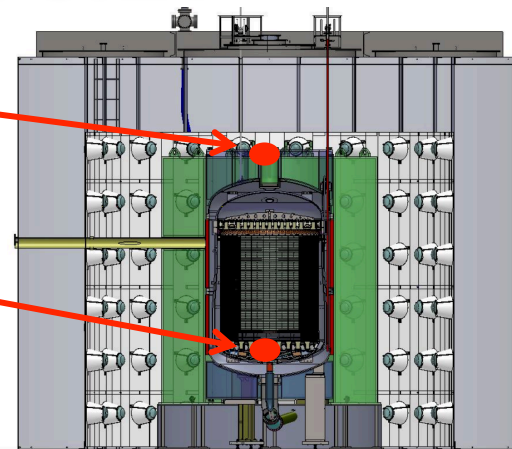


End of Run Z-Scan

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

Wanted to probe here!

Low rate spot



See S. Shaw's talk for more!

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

