The LZ LS screener

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DOE Site Visit

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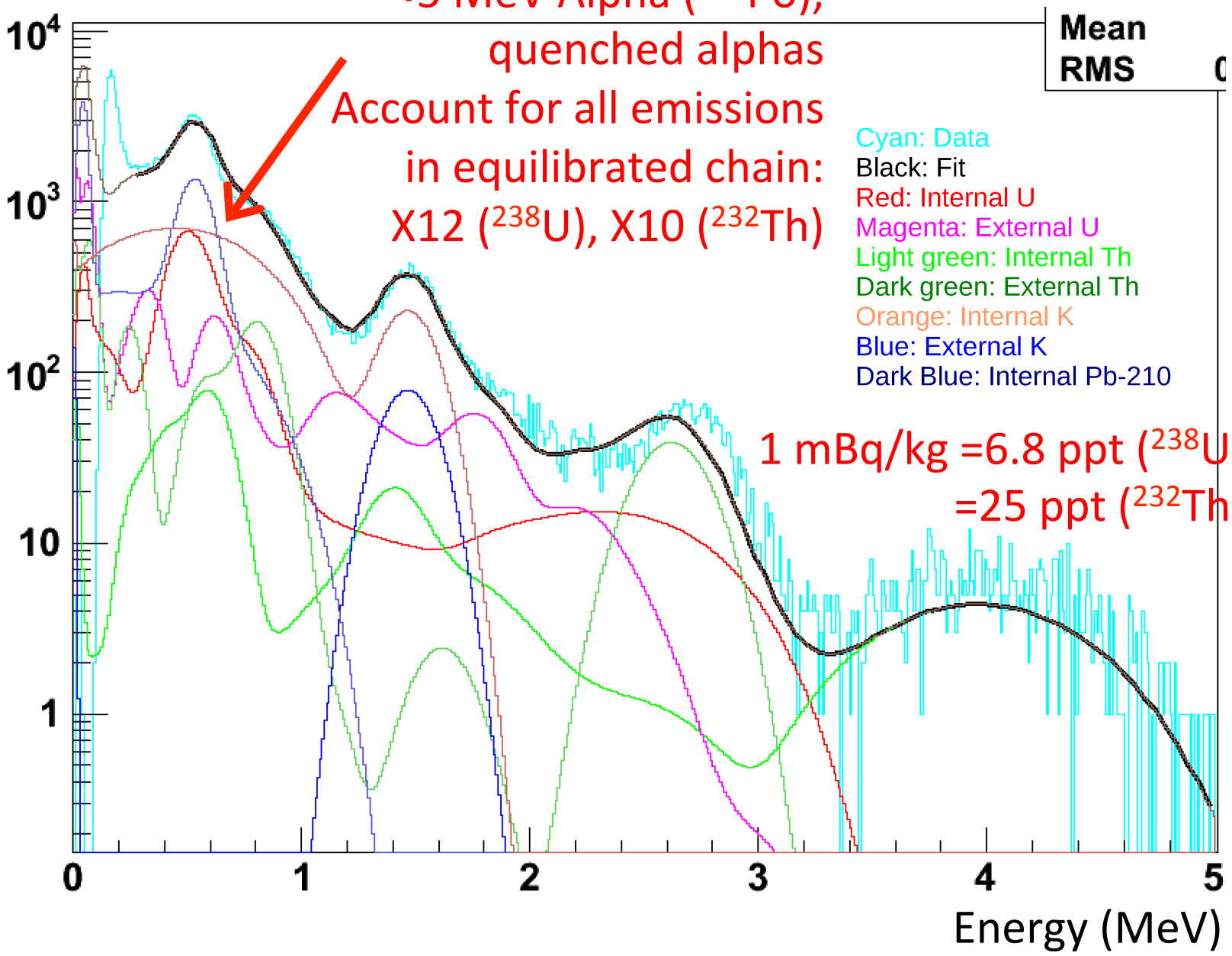
Motivation & Overview

- Low rate/dead time in LZ OD… total rate < 100 Hz for 200 keV (baseline); 100 keV (goal) threshold
- Internal contaminations: sensitive to α-particles, β's, etc
- ^{14}C especially (156 keV endpoint)… need screen 6 orders of magnitude below atmospheric (10^{-12}) level

"LS Screener"

- Goals:
  - Rate and energy spectrum from GdLS impurties...
  - Operational experience
- Concept: 1000^{th} size of OD gives 1000^{th} the rate: Hz⟶mHz
- Planned data taking in LUX/LZ water tank early November

Daya Bay… 280 Hz, 370 keV Threshold



Proposed Internal Rate Contributions Alphas, Betas, Gammas Included

Component	Rate Contribution (Hz)				Sum (Hz)
	^{238}U	^{232}Th	^{40}K	^{14}C	
LAB	3	0.4	3	3	8.8
$GdCl_3.6H_2O$	1.6	1.8	0.2		3.6
PPO	0.2	0.2	0.2	0.2	0.9
TMHA	0.2	0.2	0.2	0.2	0.9
bis-MSB	0.2	0.2	0.2	0.2	0.9
Sum	5.5	2.9	3.4	3.2	15

Radiopurity Achieved (ppt by mass)

	^{238}U	^{232}Th	^{40}K	Method	^{14}C
LAB (impure)	0.02±0.002	<0.007	ongoing	PNNL-Isotope Dilution ICP-MS	?
LAB (purified)	<0.004	<0.007	ongoing	PNNL-Isotope Dilution ICP-MS	?
$GdCl_3.6H_2O$ (purified)	<100	<100	ongoing	DayaBay-HPGe	
PPO (H_2O)	**<150**	**<640**	**25±2**	UC Davis-NAA	?
bis-MSB	<210	<190	30± 10	UC Davis-NAA	?

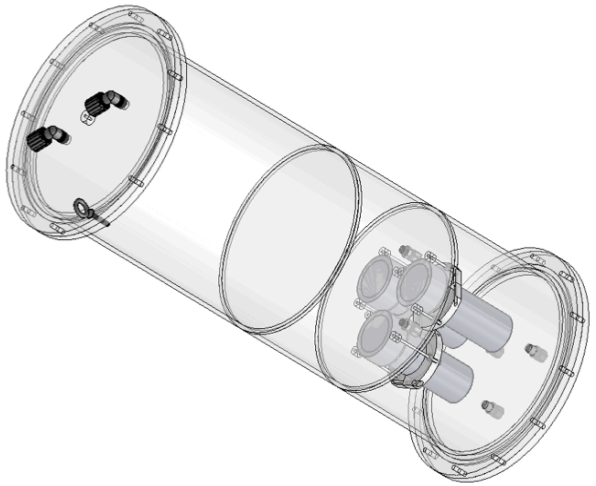
- Ongoing process for ^{40}K
- ^{14}C is a challenge:
  - (I) keep the solvent fresh (process with vendor)
  - (II) will screen to 10^{-15} with LLNL Accelerator Mass Sprectrometry
  - (III) the proposed LZ-Screener (1/1000 of total mass) will assess the activity of final Gd-LS at ~mHz

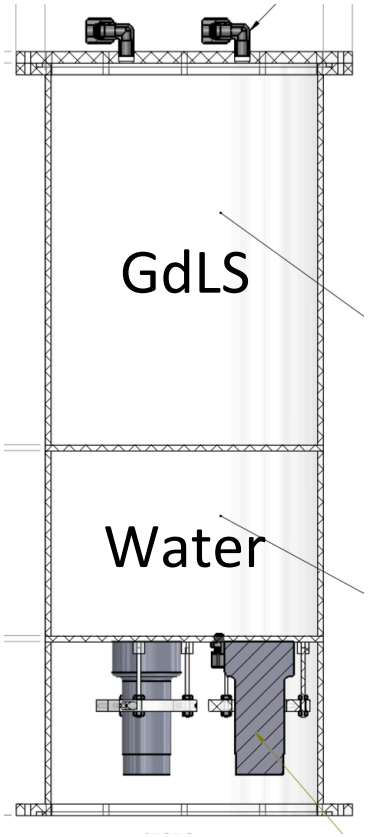
Rate Components

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)

Screener Overview

- Made of UVT acrylic
- ~ 24 kg GdLS
- ~ 14 kg Water Shield
- 3 LZ R11410 PMTs
  - **Very radiopure**
- Wrapped in highly reflective tyvek

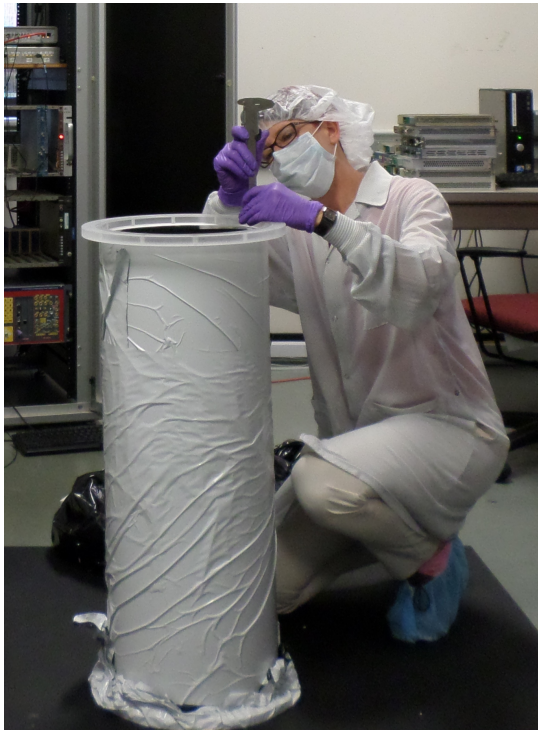




CAD Model by Susanne Kyre

Construction & Tests at UCSB

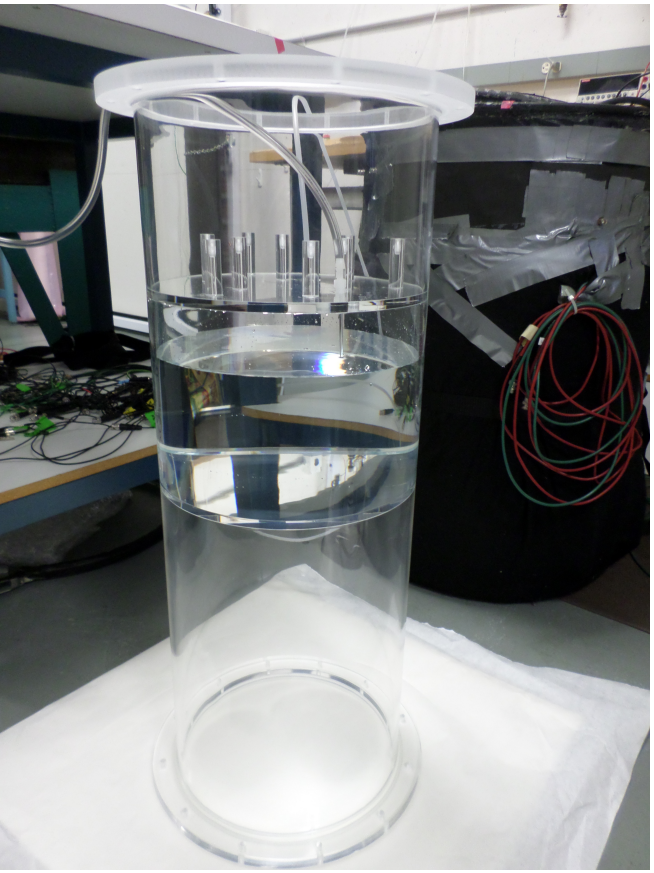
Received in May 2016



Vessel inspection - Susanne

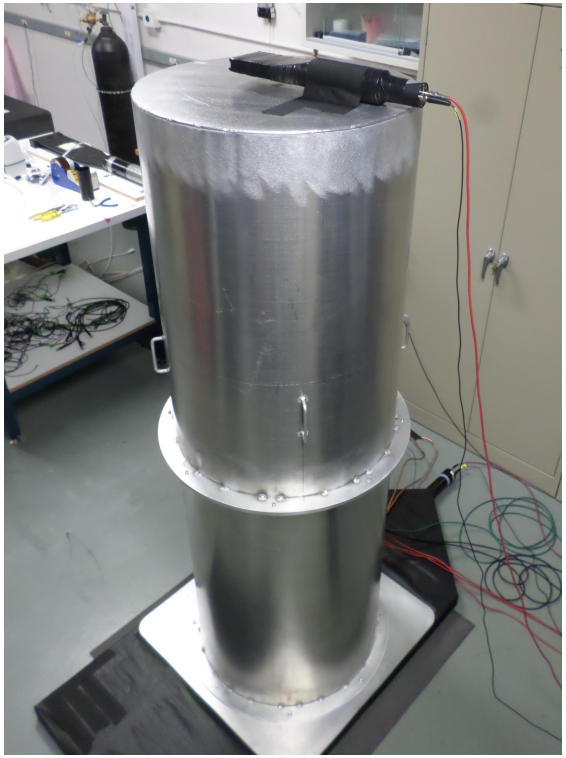
PMT Mounts Gluing w/ Susanne

Construction & Tests at UCSB



Water Fill w/ Dean White

PMTs mounted and cabled
(detector stand designed by Susanne)



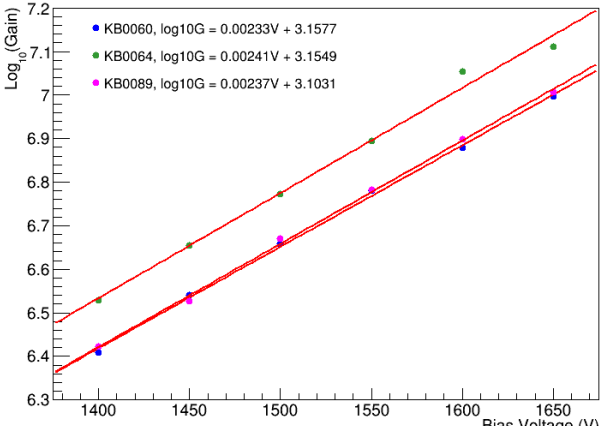
Dark box w/ muon tagging

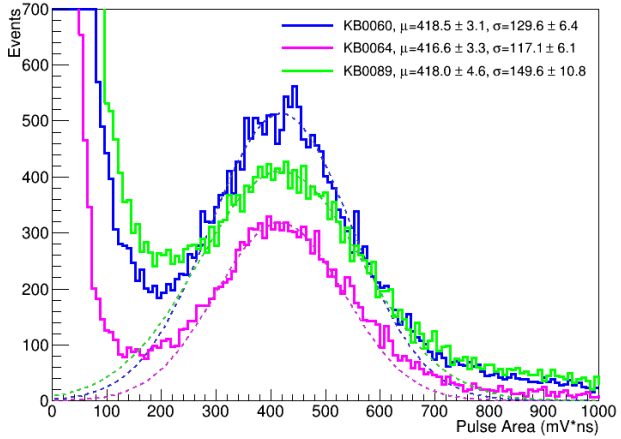
Data Taking

- Bonus: independent use/testing of LZ electronics chain:

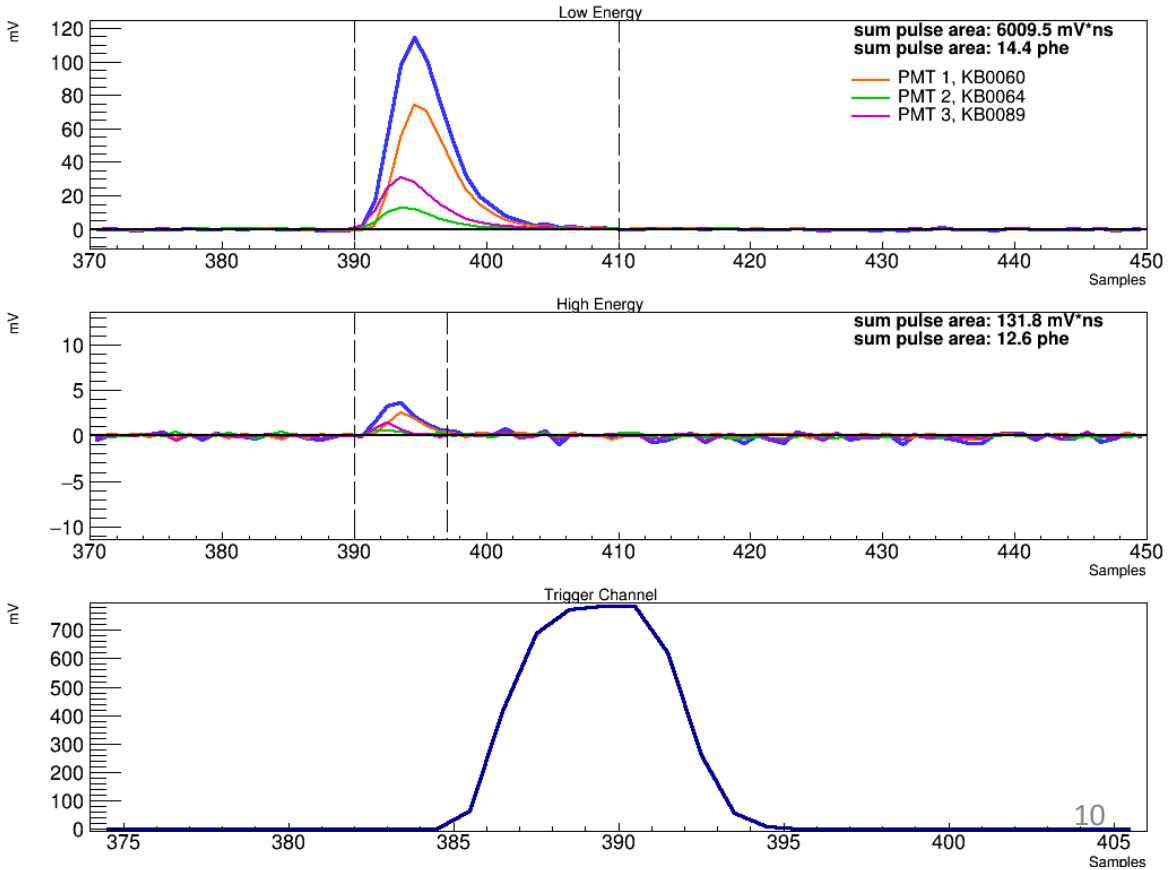
  R11410 PMT -> Amp (UCD) -> DDC10 (U. Rochester)

PMT Gain Curves and Matched sphe spectra:



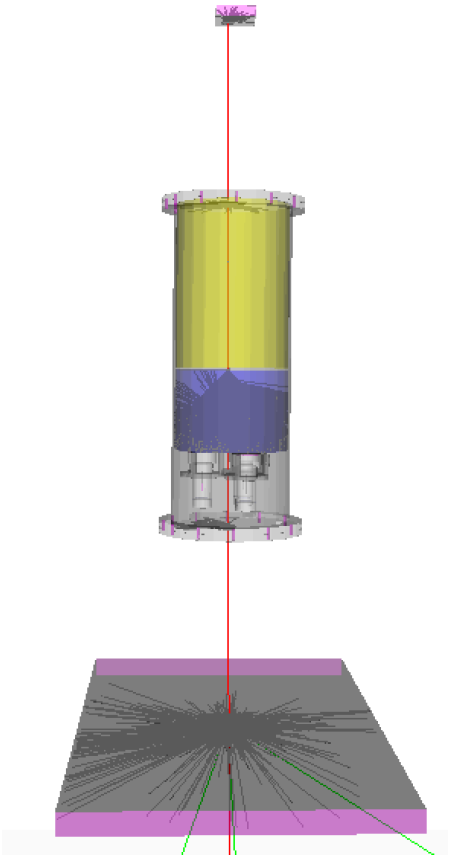


A typical event waveform:

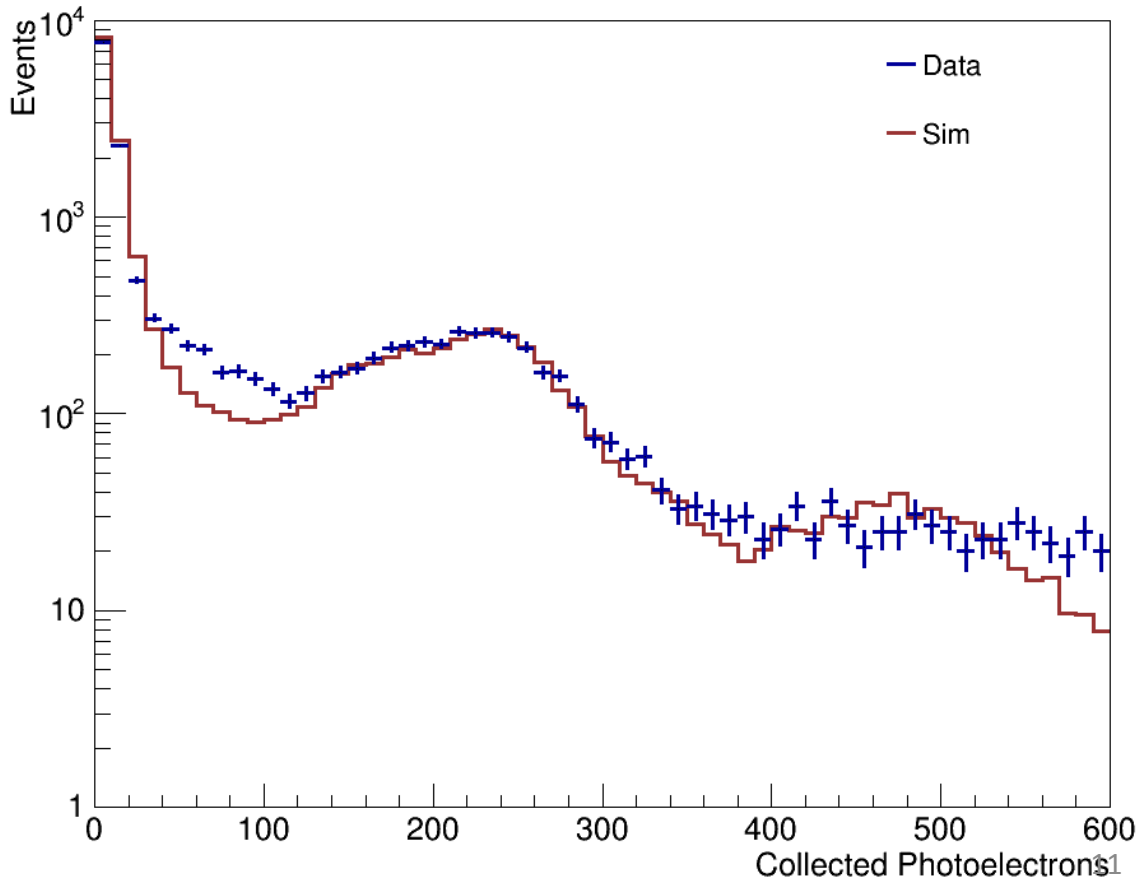


Calibration With Muons

- Cherenkov in acrylic and water gives absolute photon source!
- Calibrate simulation, work in progress

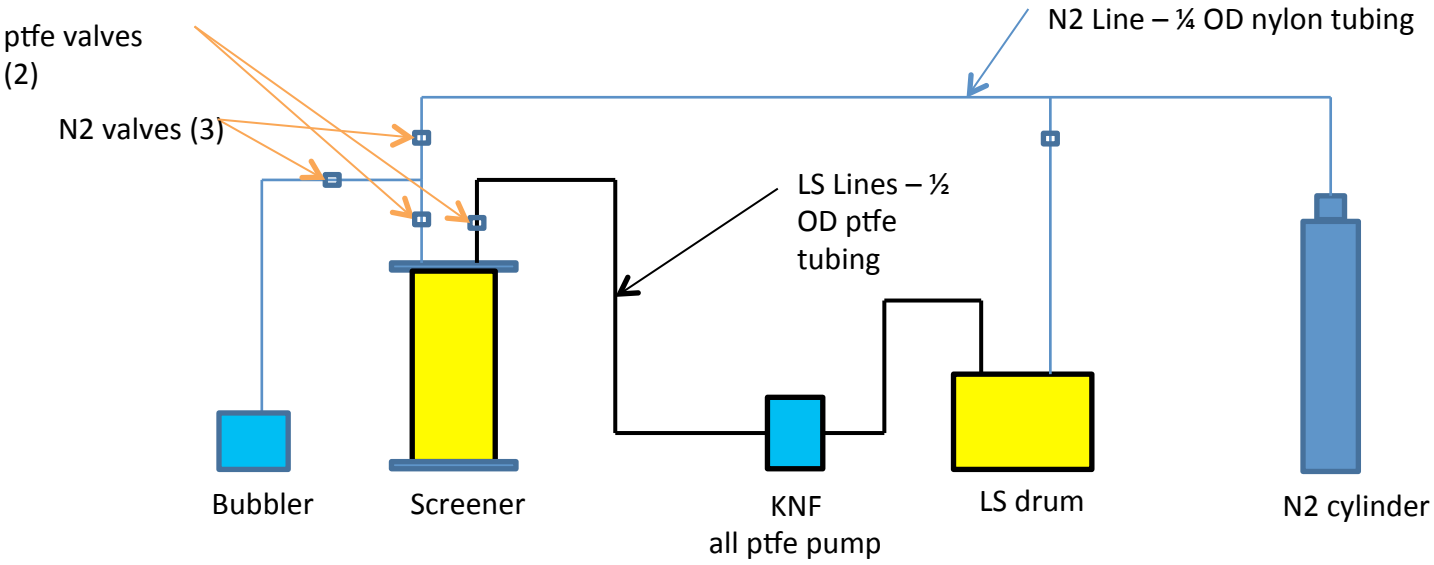


Geant4 Simulation



LS Filling

- Plan to fill w/ pure LAB this or next week
- Dean developing filling procedure
- Useful test for bugs before LZ OD filling



Conclusions

- LS Screener very advanced, excellent progress
- Crucial for LZ project
  - GdLS quality assurance
  - Operational experience
- Possible Material Screener, Economical w/r to HPGe
  - Poor energy resolution compared to HPGe
  - Issue is background rate… can't use LUX Water Shield forever
  - CDMS-II lead shield, owned by UCSB, can be employed
  - Of general interest for DM/Low Background community

Backup Slides

Radioactivity Requirements

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	1	0.5	0.4	1.6×10^{-6}	860	1	0.5	0.4	1.6×10^{-6}
$GdCl_3.6H_2O$	300	1200	20		0.86	0.5	2	0.04	
PPO	20	70	10	4×10^{-5}	3	0.07	0.2	0.04	0.15×10^{-6}
TMHA	20	70	10	6×10^{-5}	3	0.07	0.2	0.04	0.2×10^{-6}
bis-MSB	4000	14000	2000	7×10^{-3}	0.015	0.07	0.2	0.04	0.13×10^{-6}
Total						1.7	3.2	0.6	2.1×10^{-6}
DayaBay						**20**	**4**	**7**	

- Daya Bay activity was from one-pass purification of $GdCl_3.6H_2O$ and PPO
- Daya Bay ^{40}K could be from water or contamination.
- ^{14}C similar to the Borexino measurement – 1.9×10^{-6} (a puzzle in itself, 5×10^{-9} expected); had 1.5 gm/liter of PPO, apparently not the ^{14}C source. Borexino had 25 keV threshold, saw 1.5 Hz above 60 keV in 4 tonnes.
- Atmospheric ^{14}C is about 1 ppt (!!); this level is 0.2 Hz/gram.
- ^{14}C for LAB, PPO, TMHA - come from underground sources.