Spring 2018 Group Update

Jonathan Nikoleyczik

Todays update starts on slide 52

Current tasks

- Gamma-X events from calibration sources
  - Simulate LZ calibrations and see how they are impacted by gamma-x events
- Phase 1 optical maps
  - Improve the speed and accuracy of Phase 1 sims by adding in a map for S2 events
- Phase 1 Run 7 data analysis
- LUX 100T projection sensitivity paper
- LZ scale model

Gamma-X from calibration sources

Possible sources:

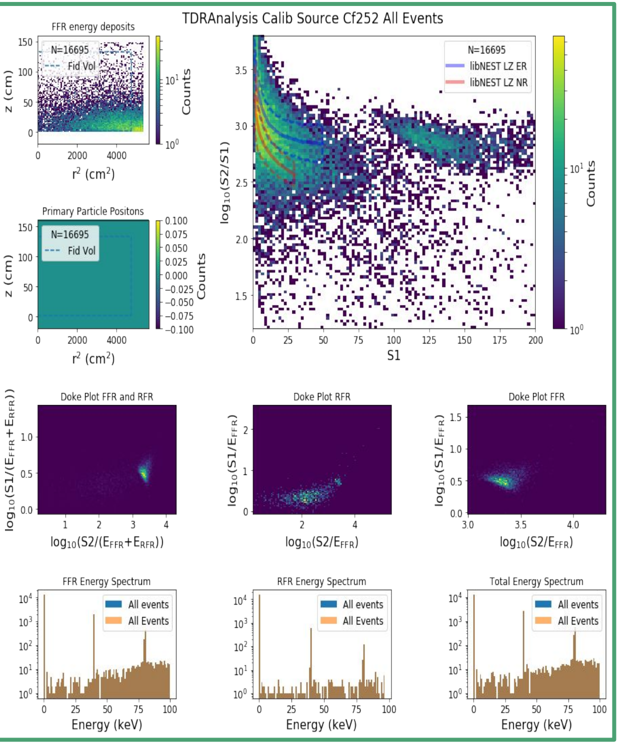
- AmLi (AmBe)
- ^{252}Cf
- ^{228}Th
- ^{57}Co (As a test)

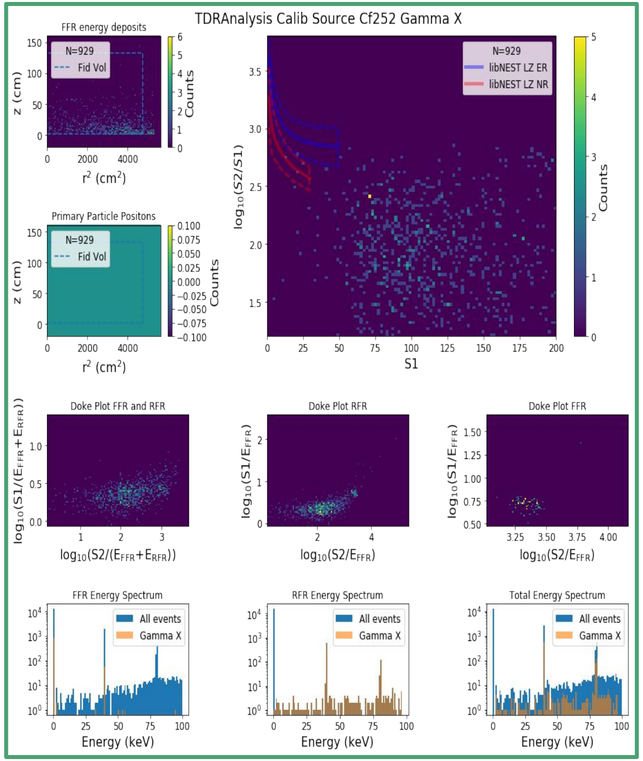
All are CSD sources. Generate them in CSD tubes, located in the vacuum space, at z=0 (cathode)

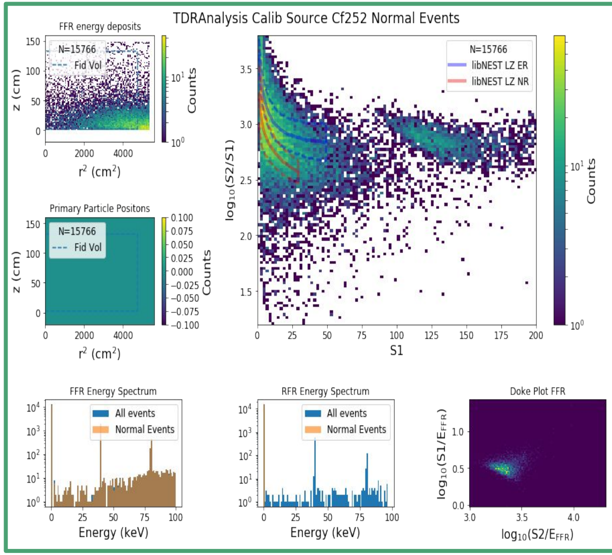
Table 7.0.1: Baseline calibration sources for LZ.

Isotope	What	Purpose	Deployment	Custom?
Tritium	beta, $Q = 18.6$ keV	ER band	Internal	N
^{83m}Kr	beta/gamma, 32.1 keV and 9.4 keV	TPC (x, y, z)	Internal	Y
^{131m}Xe	164 keV γ	TPC (x, y, z), Xe skin	Internal	Y
^{220}Rn	various α's	xenon skin	Internal	N
AmLi	(α, n)	NR band	CSD	Y
^{252}Cf	spontaneous fission	NR efficiency	CSD	N
^{57}Co	122 keV γ	Xe skin threshold	CSD	N
^{228}Th	2.615 MeV γ, various others	OD energy scale	CSD	N
^{22}Na	back-to-back 511 keV γ's	TPC and OD sync	CSD	N
^{88}Y Be	152 keV neutron	low-energy NR response	External	N
^{205}Bi Be	88.5 keV neutron	low-energy NR response	External	Y
^{206}Bi Be	47 keV neutron	low-energy NR response	External	Y
DD	2,450 keV neutron	NR light and charge yields	External	N
DD	272 keV neutron	NR light and charge yields	External	Y
^{133}Ba	356 keV gamma	OD and TPC	CSD	N
^{60}Co	1173, 1333 keV gamma	OD, TPC energy scale	CSD	N
^{124}Sb	23 keV neutron	low-energy NR response	External	N

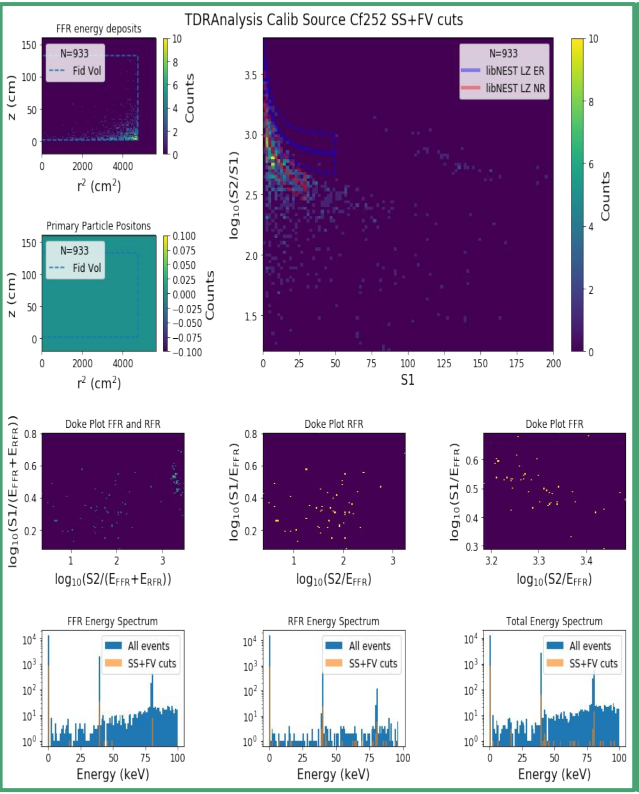
Calibration results (Cf252)

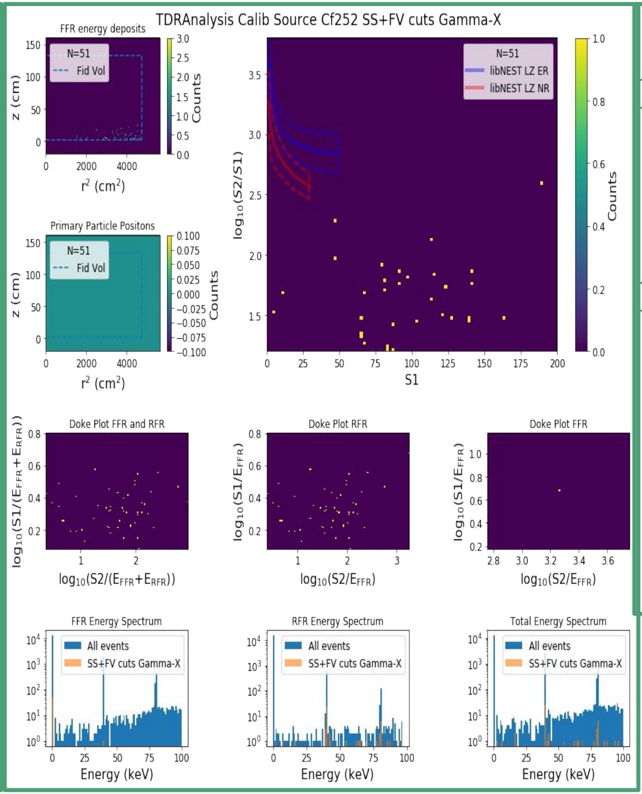


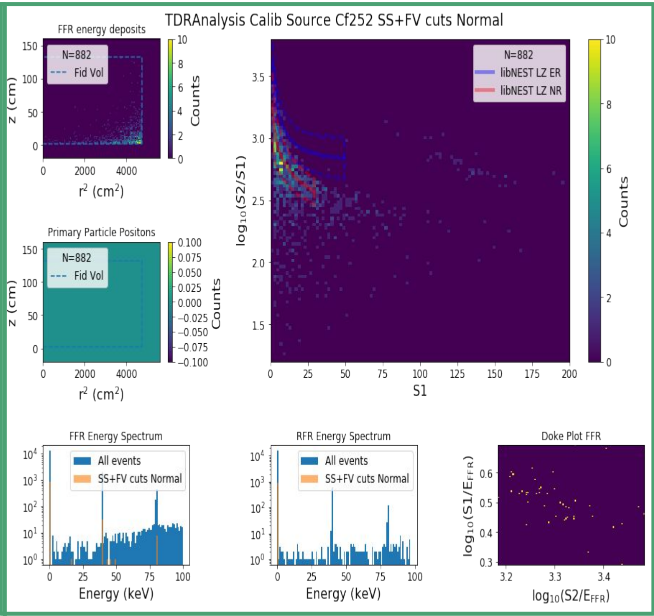




Calibration results (Cf252) Single Scatter and FV cuts







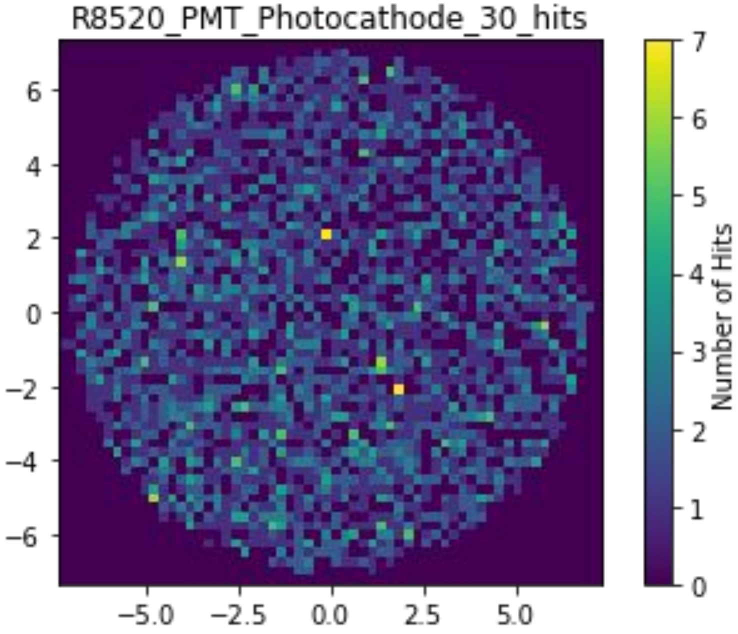
Calibration results

- AmLi (AmBe)
  - Only AmBe working in BACCARAT
  - Results are similar to shown for ^{252}Cf
- ^{252}Cf
  - Little impact of gamma-x at low energies
  - Potentially 1% gamma-x contribution at higher energies
- ^{228}Th
  - Events seen are near the walls
  - None are gamma-x
  - Nice ER band S1/S2 spectrum
- ^{57}Co
  - 2/2,000,000 events made it into the liquid
  - Neither of them were gamma-x

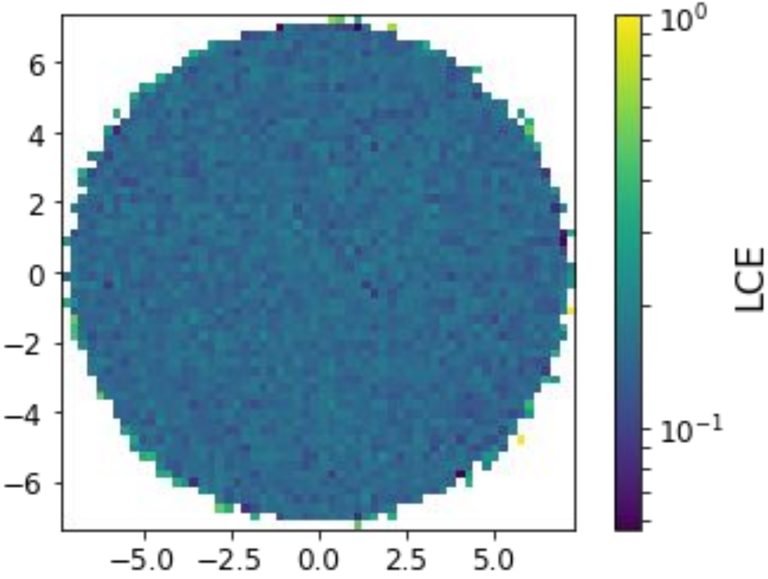
Phase 1 optical maps

- Used the scripts from Amy to make maps of ~10 million photons distributed in the liquid xenon for S1s and in the gas for S2s
- Implemented in BACCARAT
- Leaves LZ sims intact and unaffected
- Simply calls the phase 1 map instead if running phase 1 sims

Phase 1 photon maps (S1)

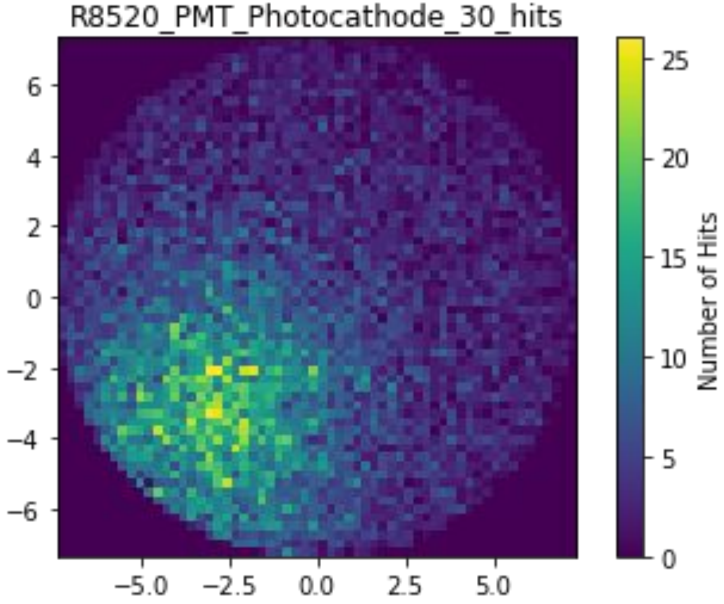


Example of a single PMT

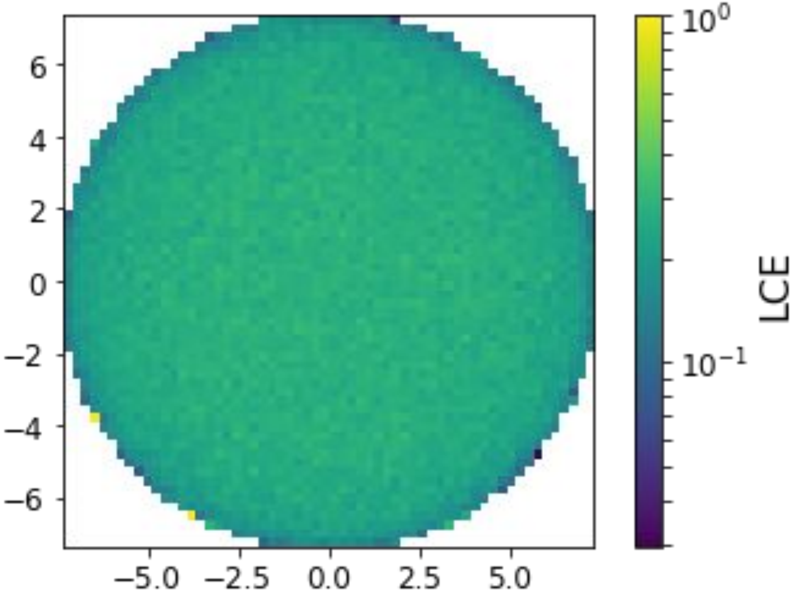


Combined light collection efficiency
Avg: 14.8% With QE: ~4.4%

Phase 1 photon maps (S2)

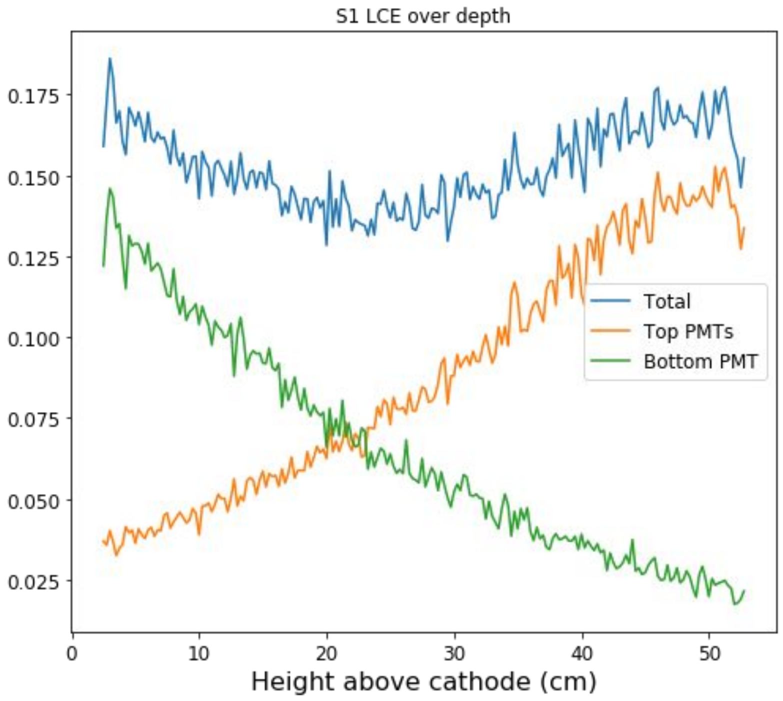


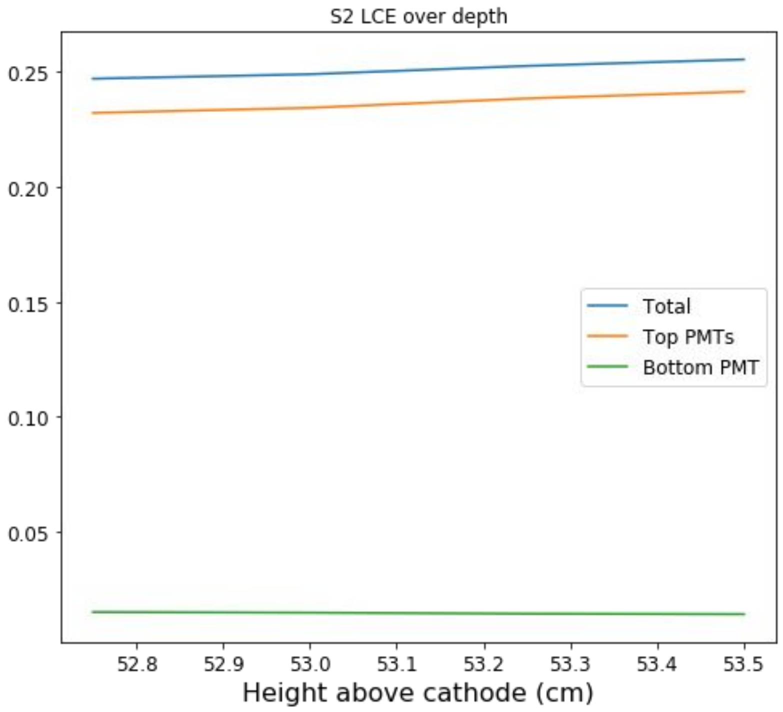
Example of a single PMT



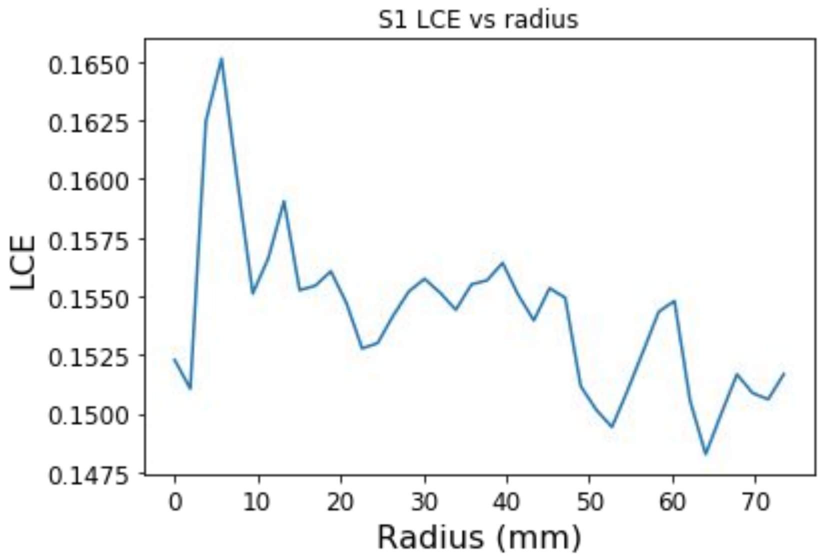
Combined light collection efficiency
Avg: 24.7% With QE: ~7.4%

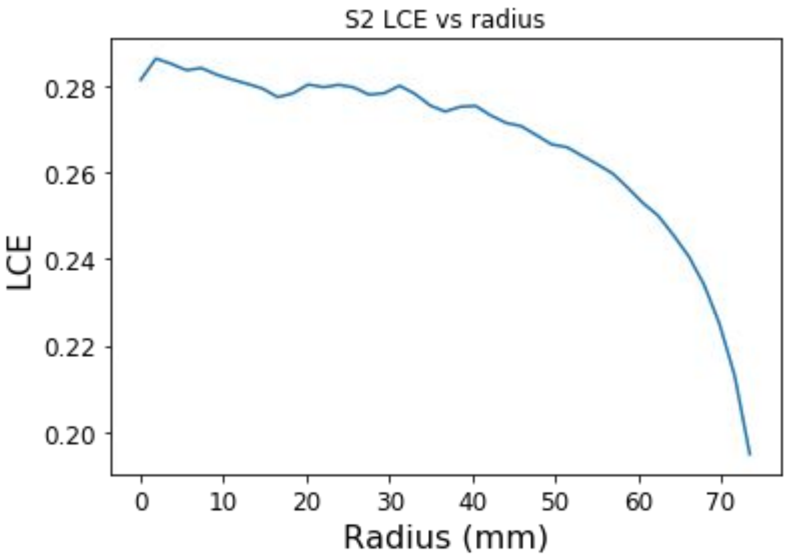
LCE as a function of depth





LCE as a function of radius

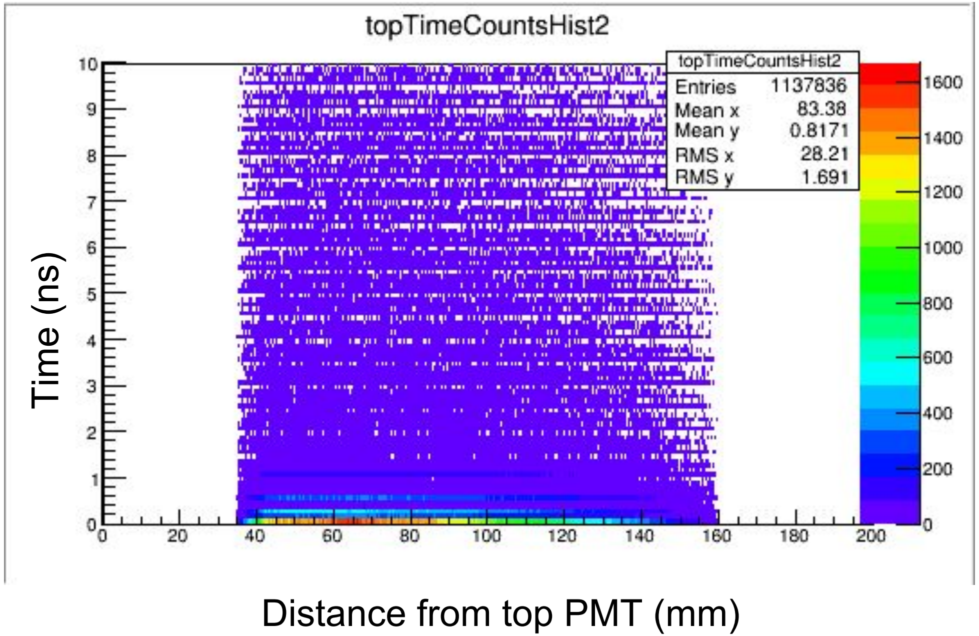




Time maps included

Time maps are needed by BaccMCTruth so needed to be simulated separately.

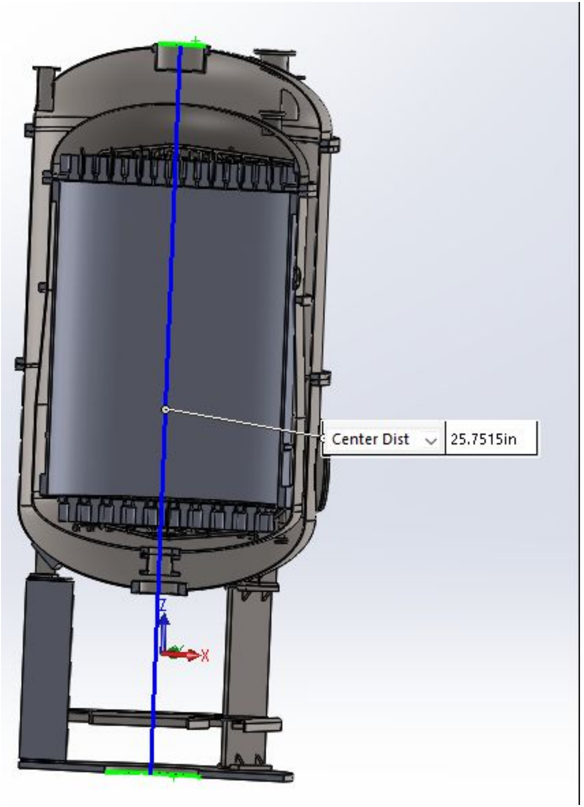
Shown here for S2 events.

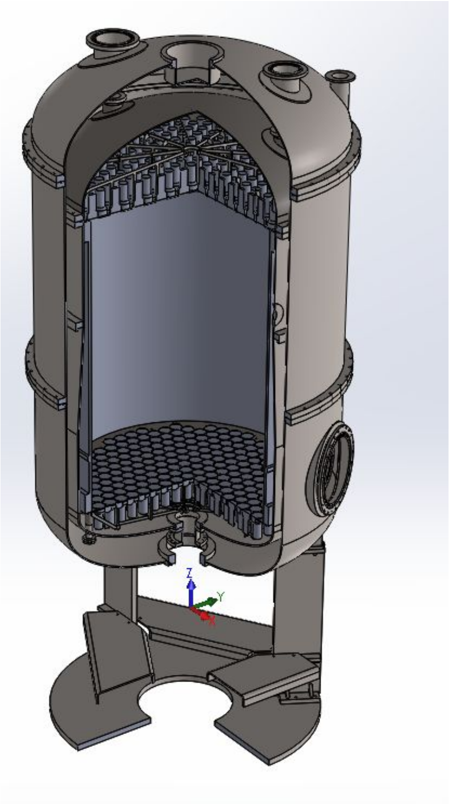


LZ Scale Model

Ready to 3D printing modifications.

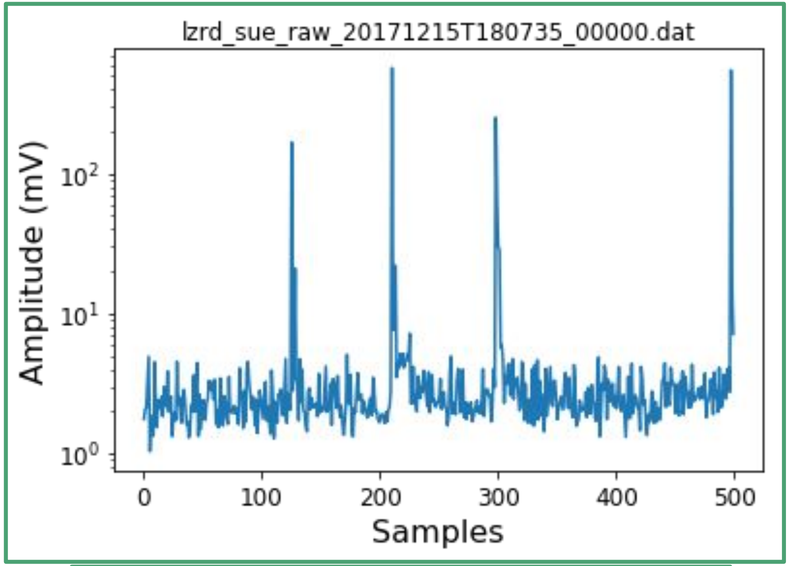
Need 3D printer specs to adjust minimum thicknesses, overdraft

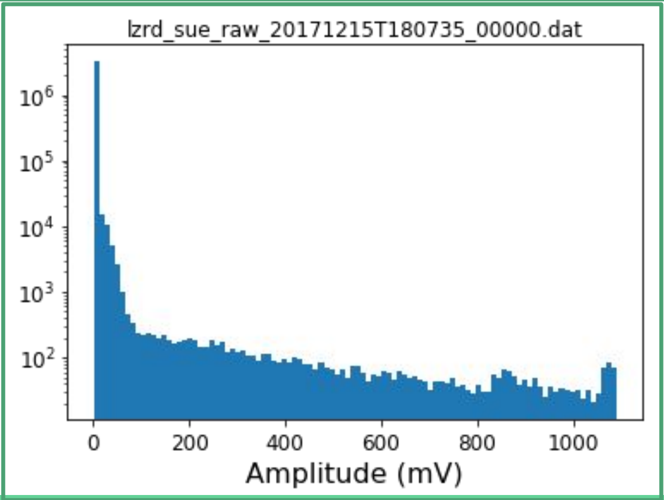




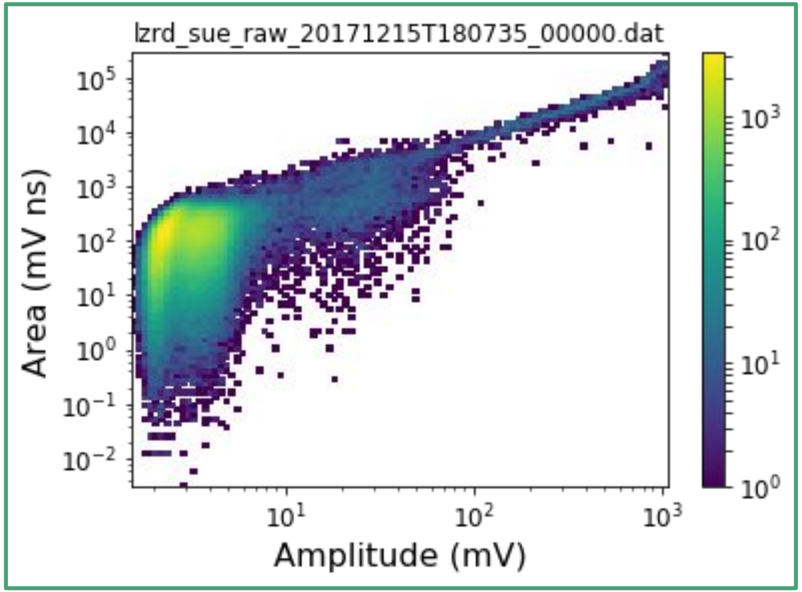
Phase 1 Run 7 analysis

- Progress has been slow
- No quick way to transfer data between SLAC and lzlogin
- Have 8 data files from run 7
- Been looking at noise that occurred while the gas test was running
- Right shows the gas test off case

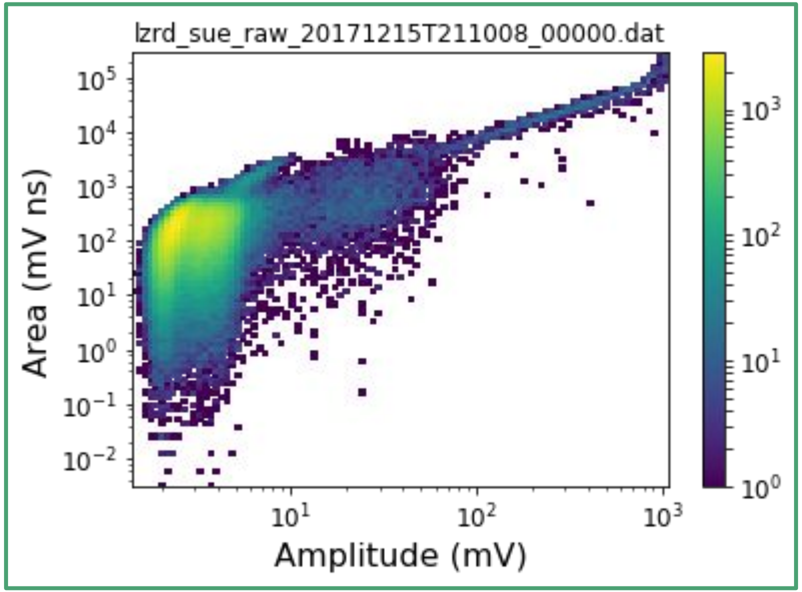




Amplitude Area plot for the two cases



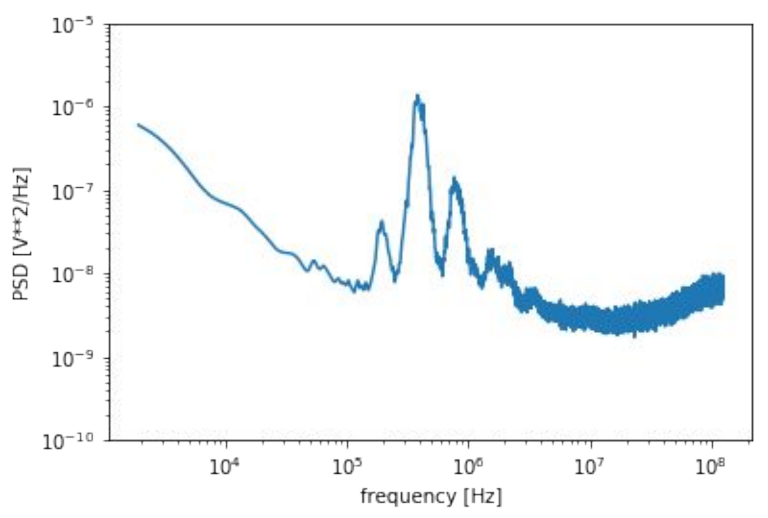
Gas test off

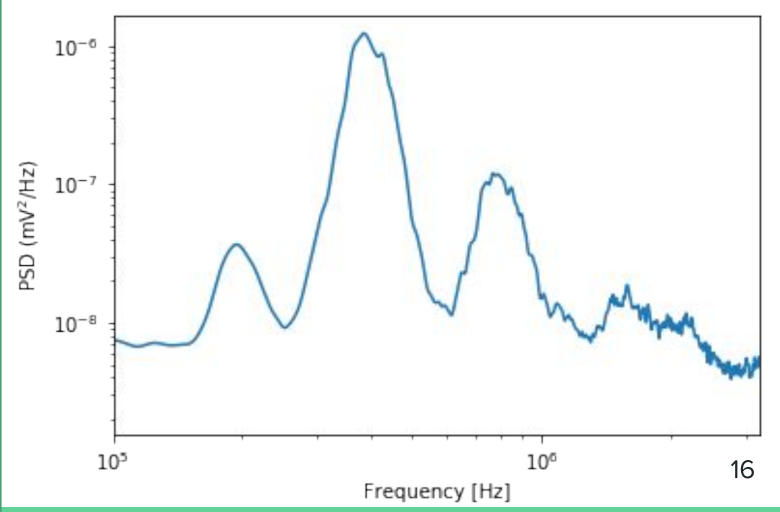


Gas test on

Digitizer noise power

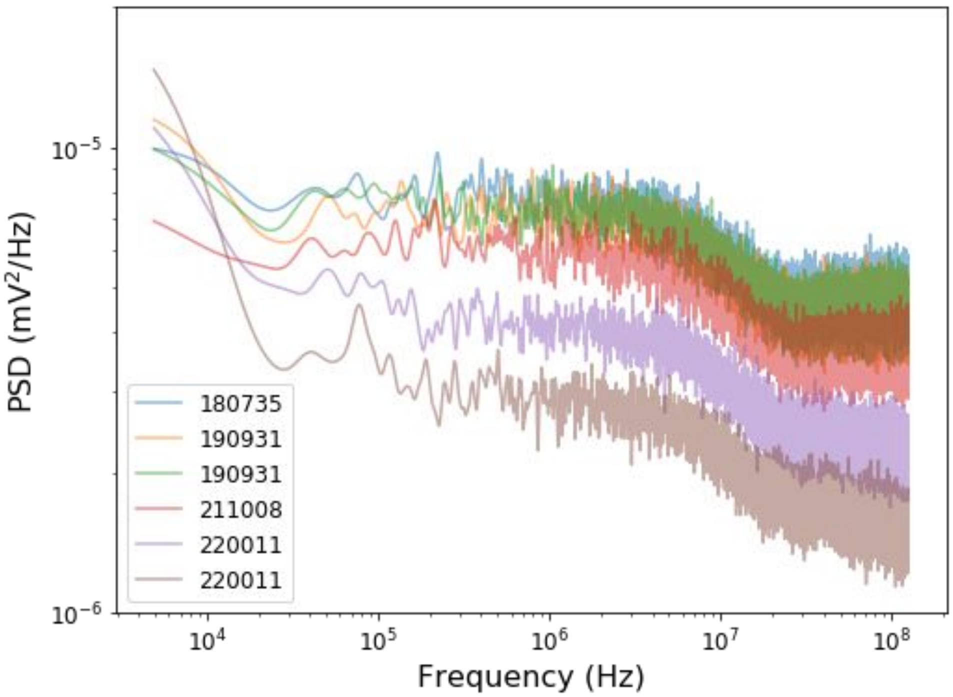
- All fields and PMTs were off
- Only digitizer noise
- See peak at 372 kHz
- Assuming that the data was collected at 250 MHz





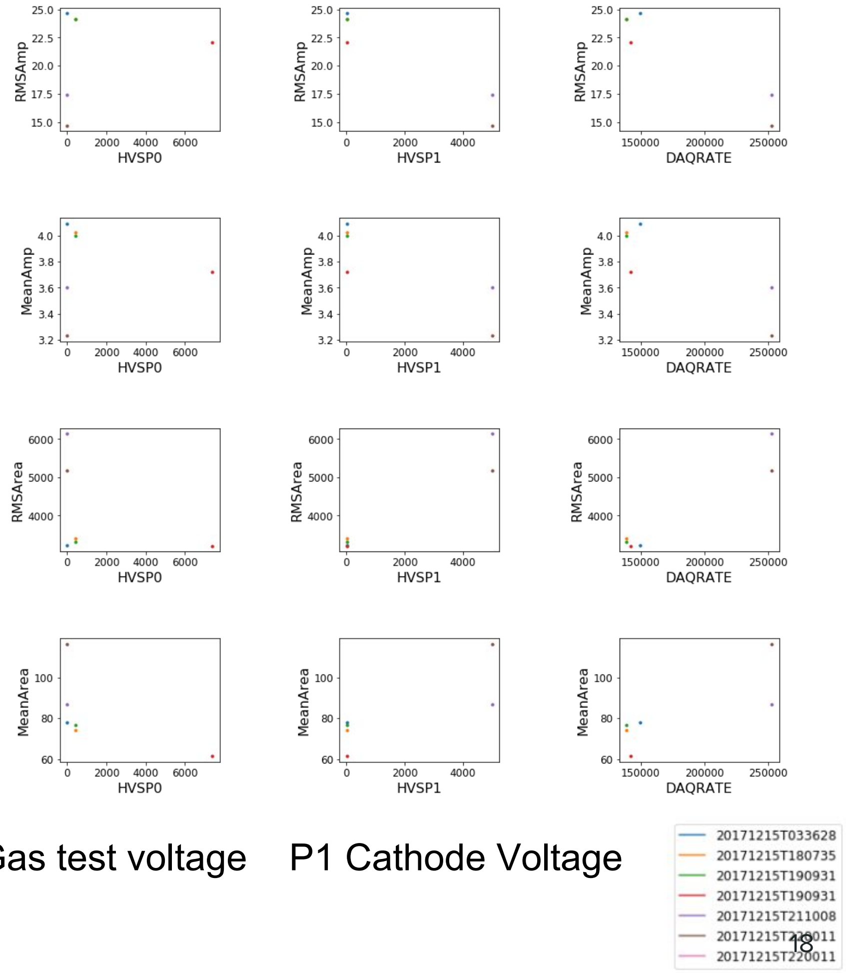
Noise Power at different gas test voltages

- Dont see a significant difference between gas test on and off
- Blue, orange and green are all the same voltage in Phase 1 with different voltages in gas test



Quantities vs. Field values

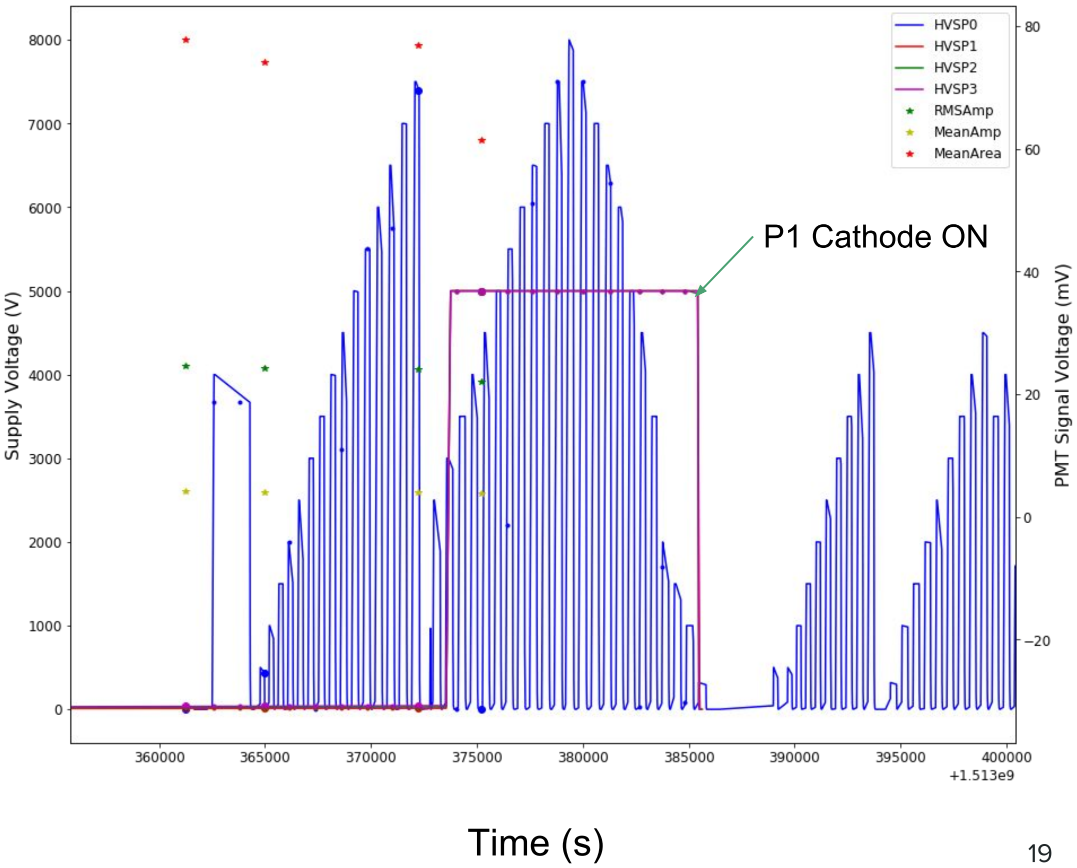
- Plots of RMS amplitude and area, and Mean amplitude and area versus power supply voltage for different channels
- Dont see a strong correlation between gas test voltage and RMS and Mean signals



Gas test voltage P1 Cathode Voltage

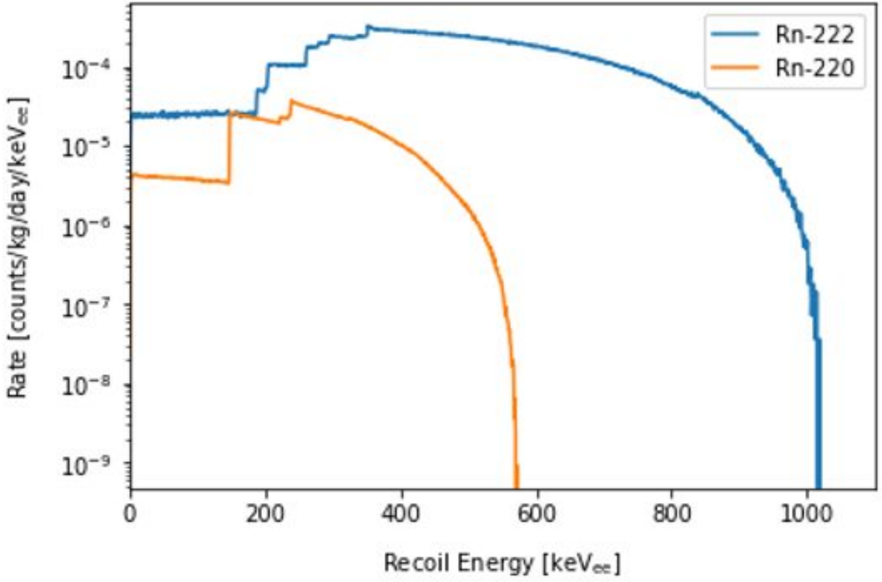
Signals over time

- Stars indicate PMT signal mean and rms values
- Blue line is gas test supply voltage
- Purple line is Phase 1 supply voltage



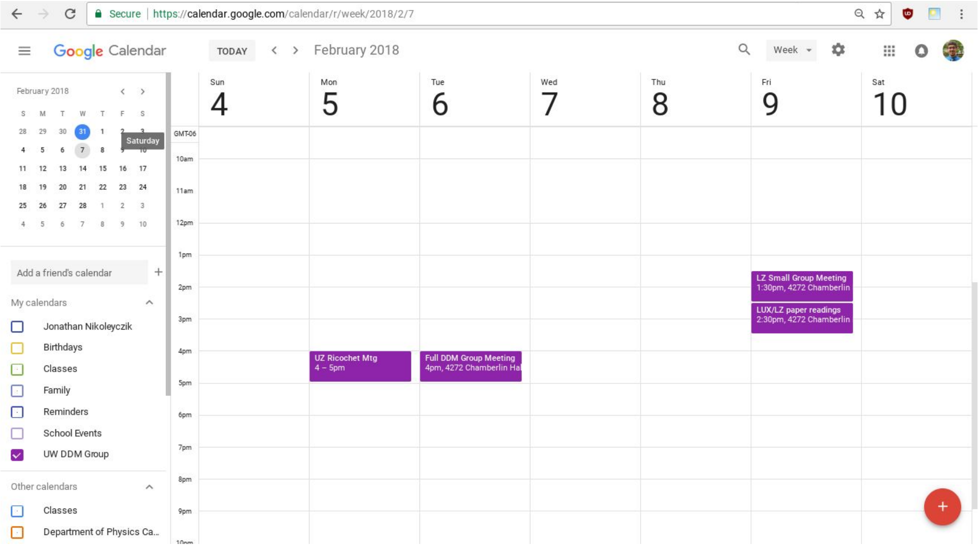
100 T sensitivity projections

- Plan to put spectra into NEST with LUX data
- Want to focus on major contributors to the background
  - Radon
  - Neutrinos
- These are 75% of LZ backgrounds
- Plan to take NEST output and feed into PLR



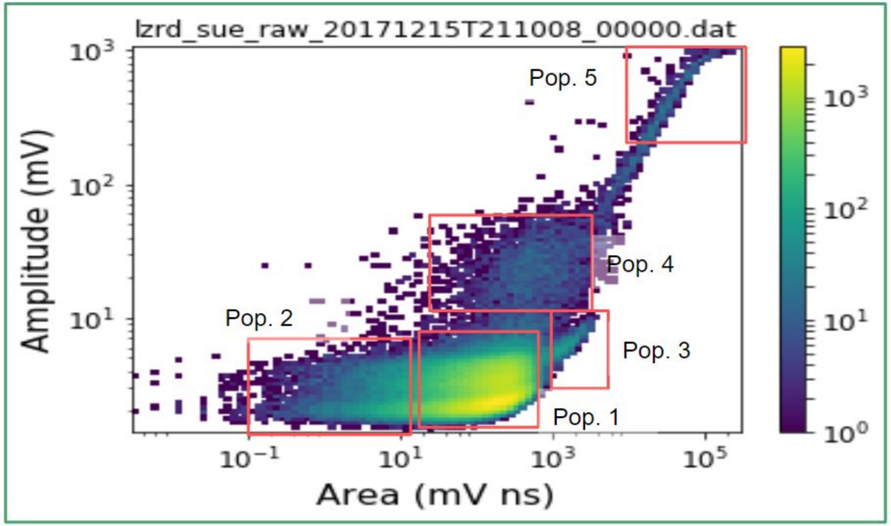
Group calendar

- The calendar is a google calendar which means I think you need a google account to view it
- I dont think there is a good way to automatically sync with outlook (sorry)
- I can add your google accounts but I need your email address

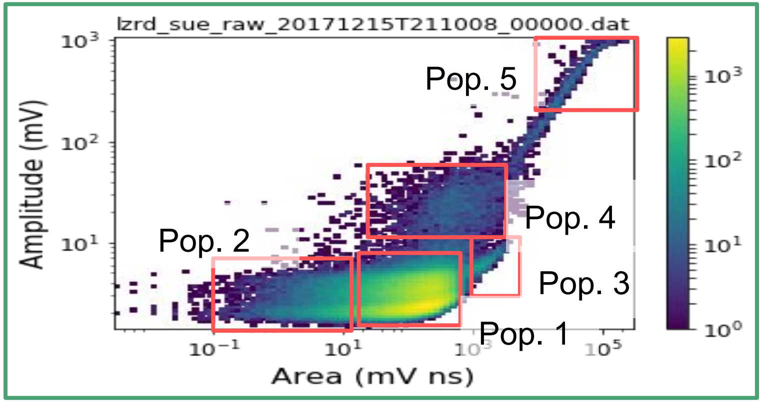


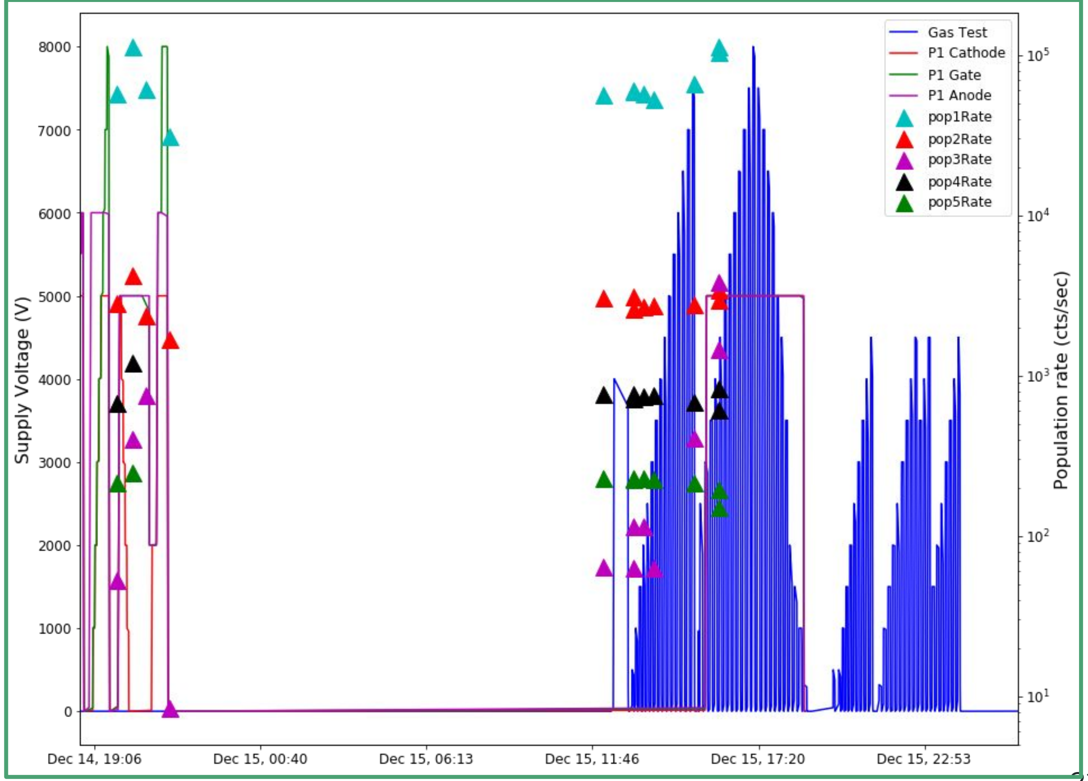
Phase 1 Run 7 Analysis

- Trying to correlate Phase 1 rates and noise with the operation of the gas test
- Divided amplitude area plot into different populations
- The rate is more correlated with the total power supply voltage than with the gas test alone
- See no significant noise power difference between gas test on and off

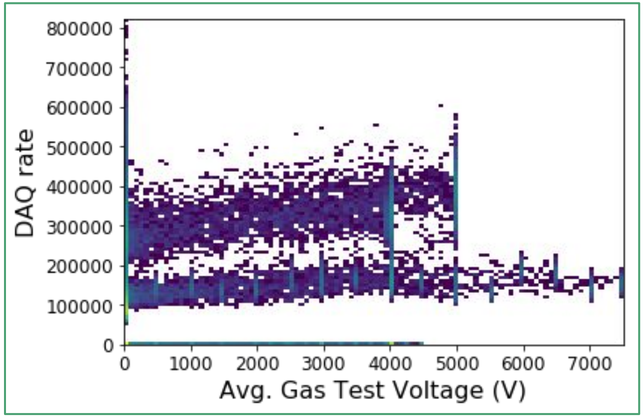


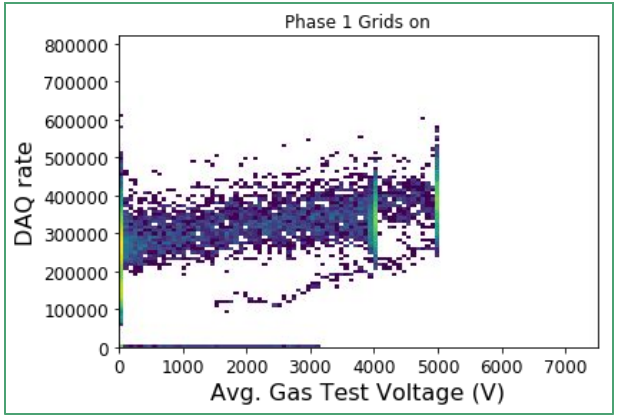
Population rates over time

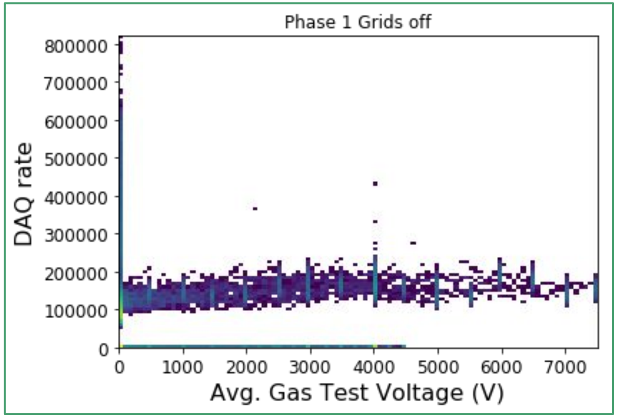




DAQ rate vs. Gas test voltage



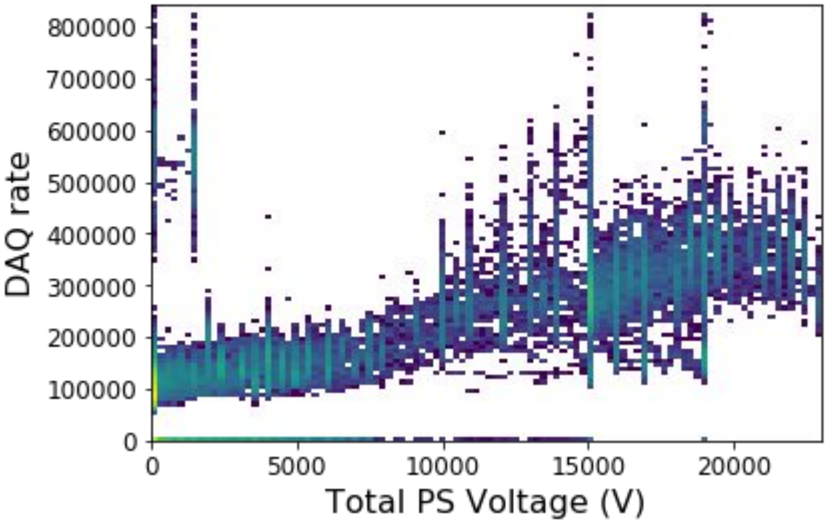




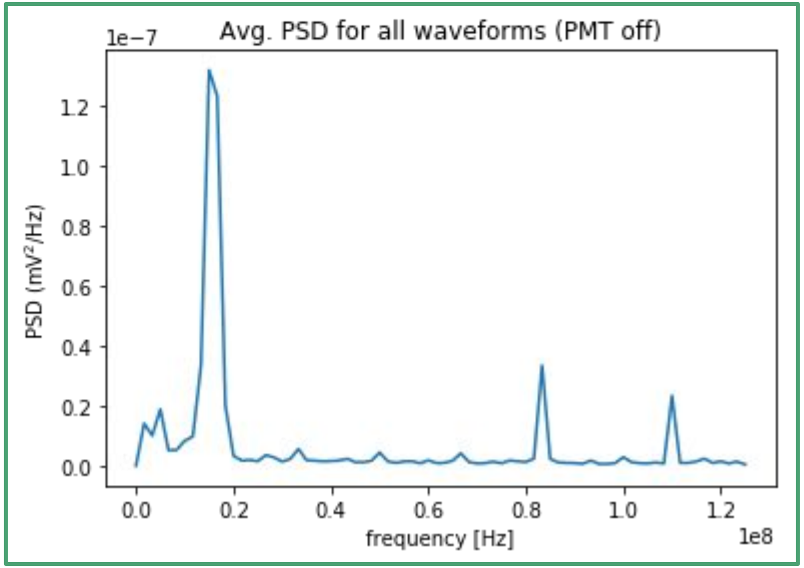
Possibly some correlation between gas test voltage and rate but only in the phase 1 grids on case

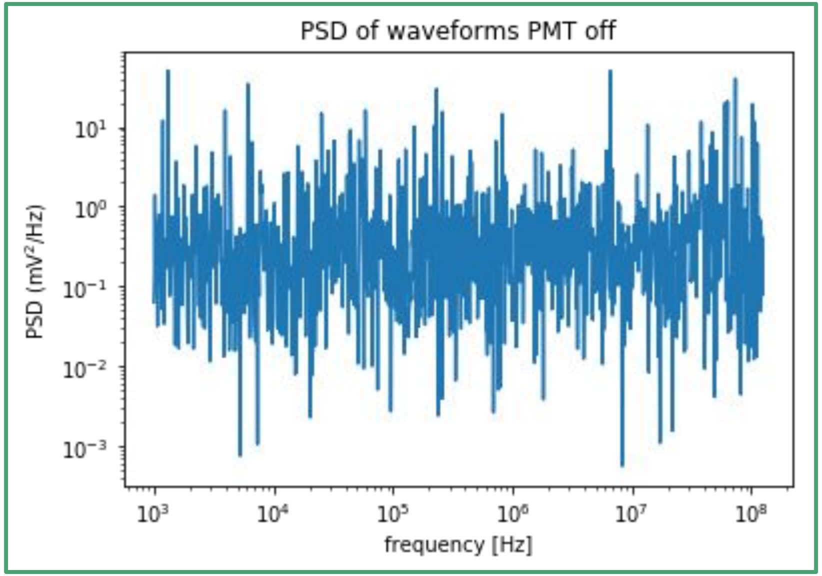
DAQ rate vs. PS voltage

- Combines physical expected rate increases (P1 grids on) with gas test voltage increases
- Color corresponds to number of samples at that point
- Outliers at low voltage are older data sets (gas only tests?)



PSD of waveforms PMT off

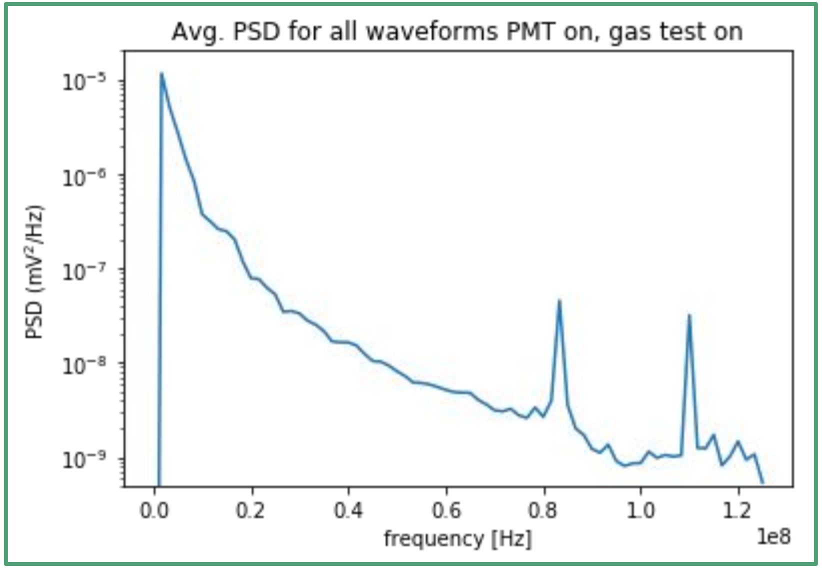


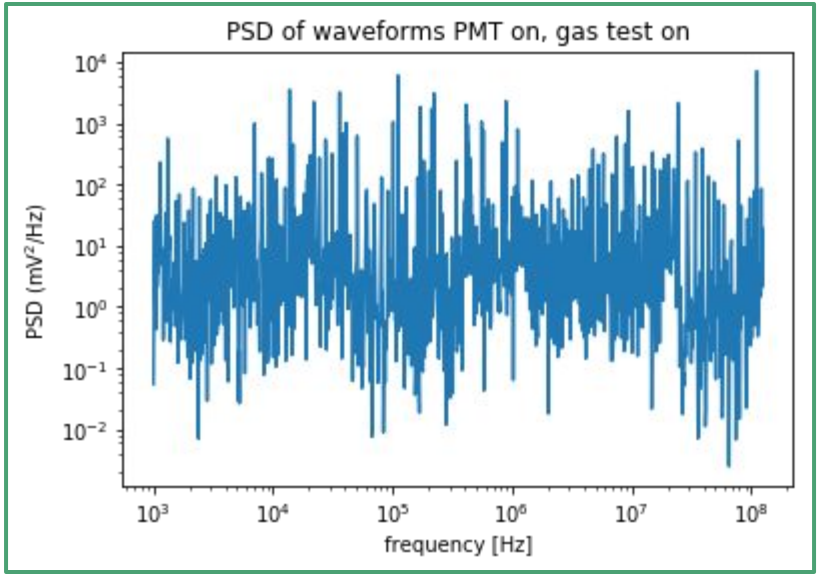


Averaging over all waveforms
Peaks at 150, 830, and 1100 MHz

Combining waveforms

PSD waveforms PMT on



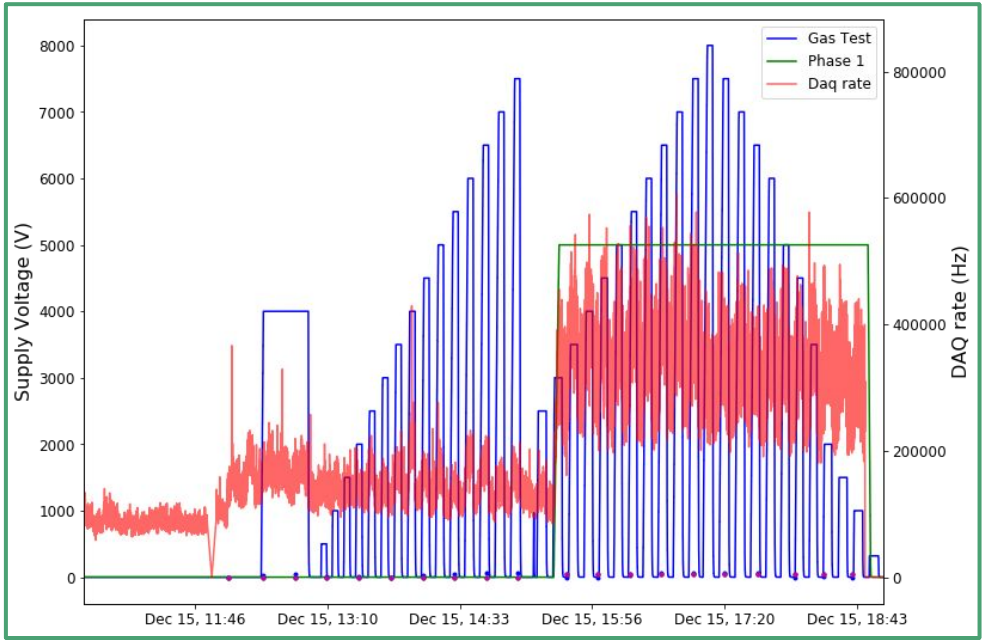


Averaging over all waveforms
Peaks at 830, and 1100 MHz
Note the change to log scale.
This is $1/f^{2.4}$ noise

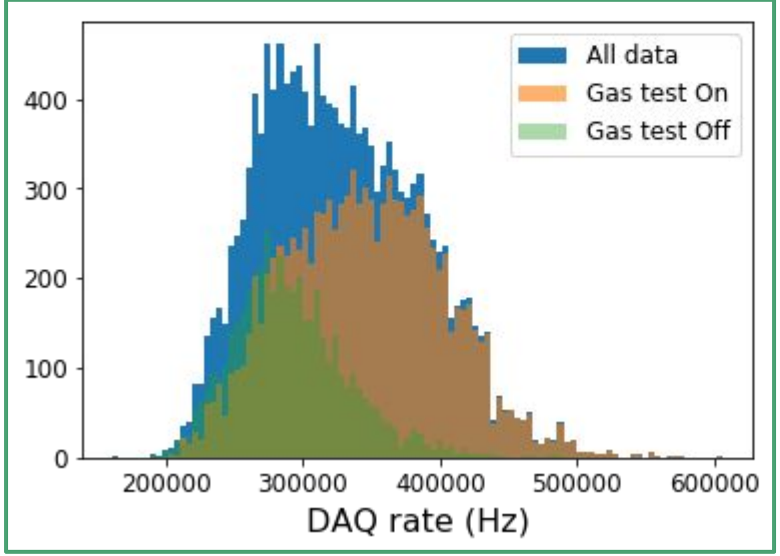
Combining waveforms

Gas test on and off has no noticeable effect on PSD from 10^3 to 10^8 Hz

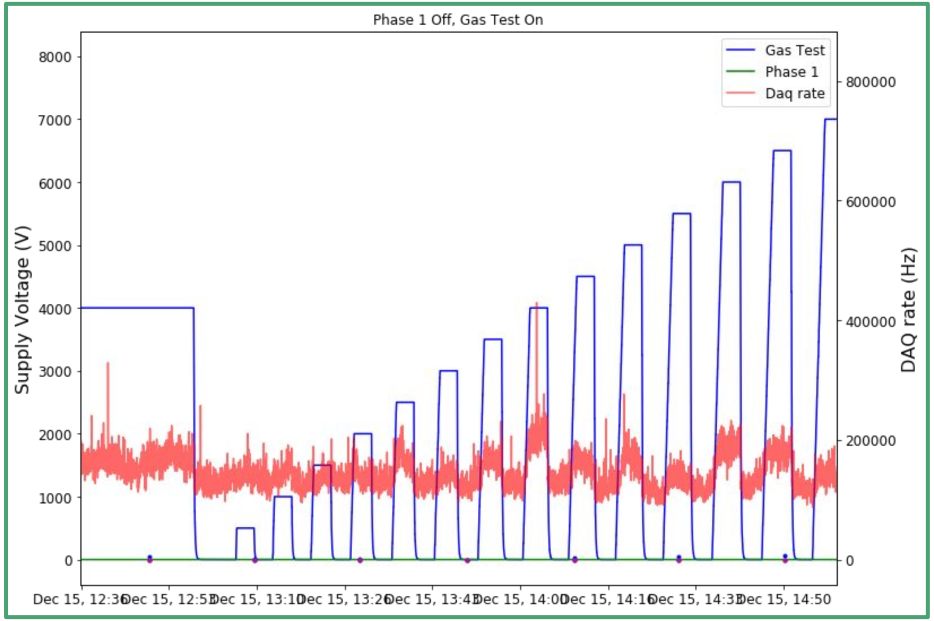
Gas test on vs off

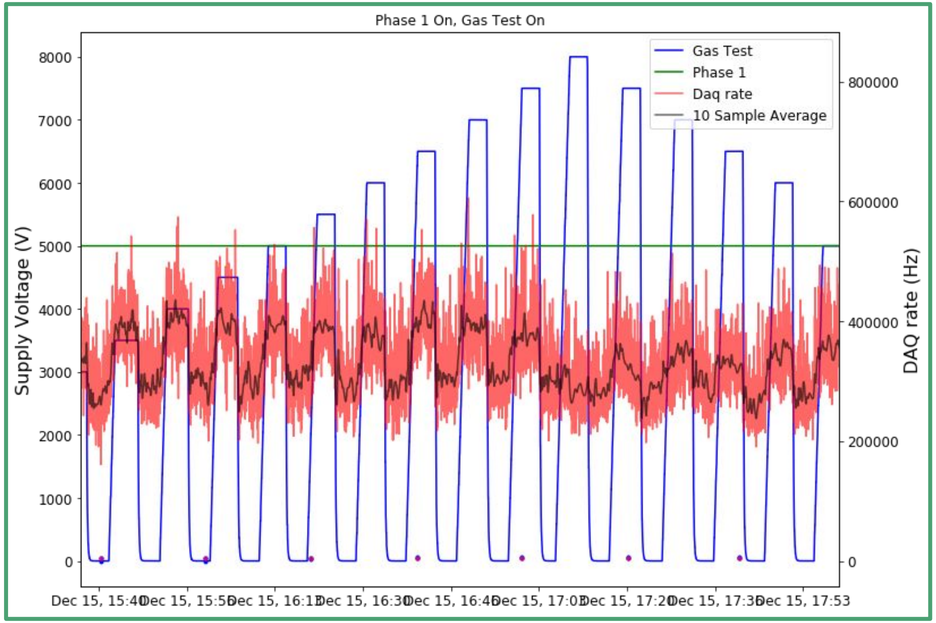


Histogram of the data shown on the left



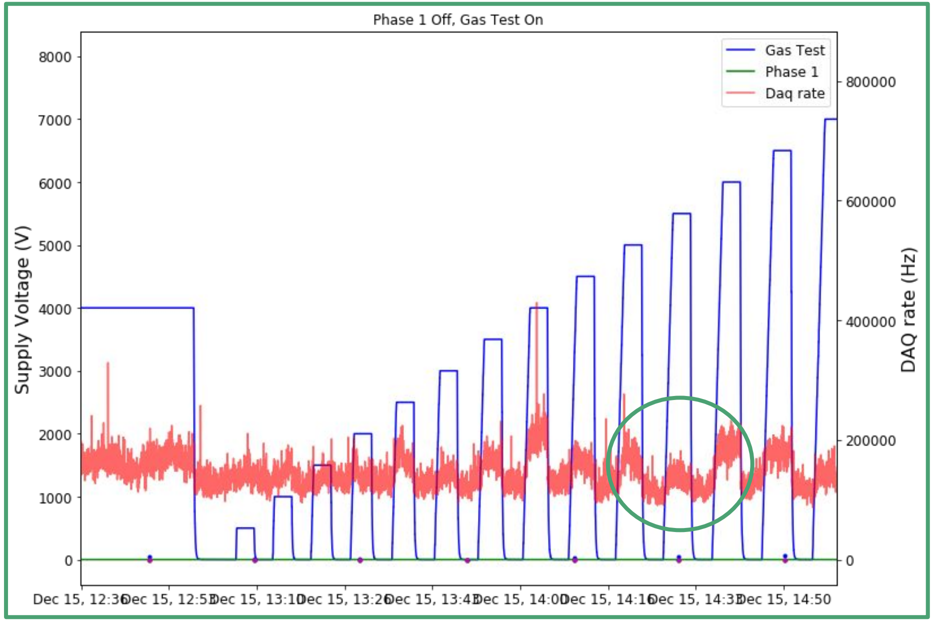
Rates and voltages over time

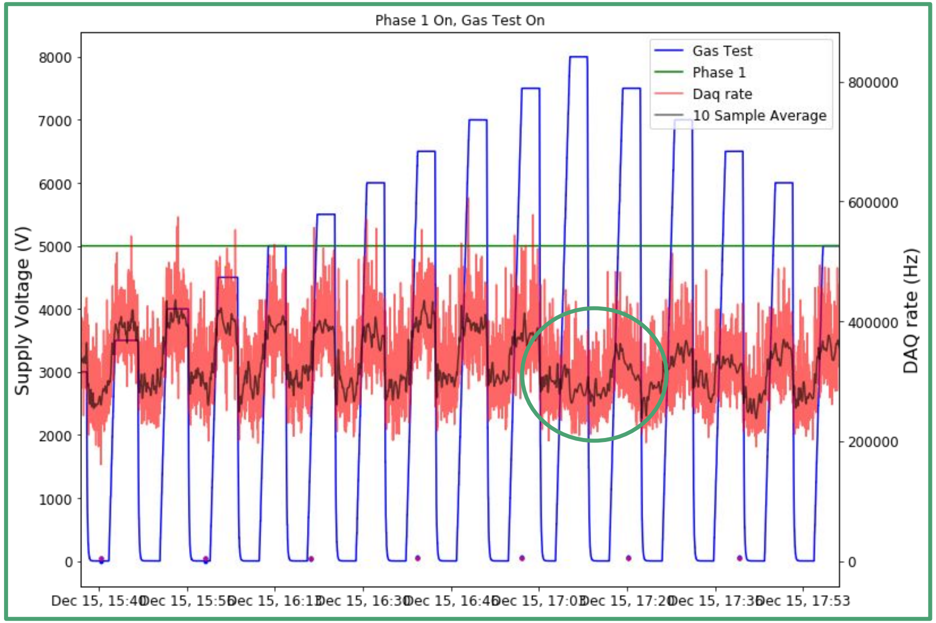




See clear increase in DAQ rate as gas test voltage ramps up increase. DAQ rate increases by ~ 50%

Rates and voltages over time

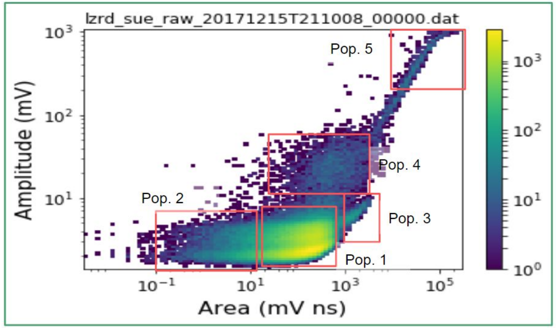


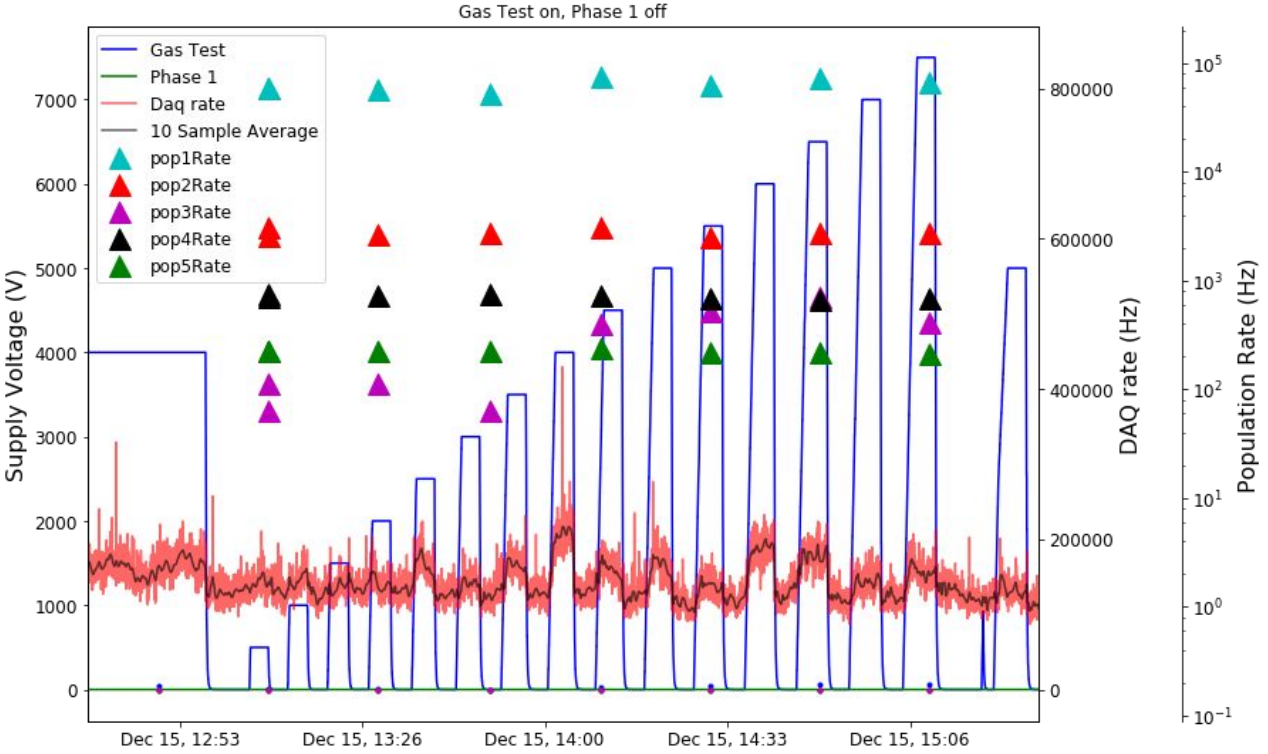


Not all gas test voltage increases correspond to DAQ rate increases

Rates and voltages over time

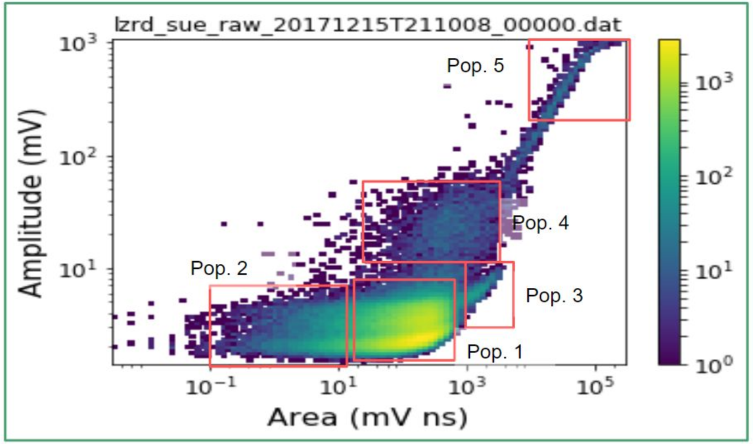
See variability in pop. 3 rate of up to an order of magnitude

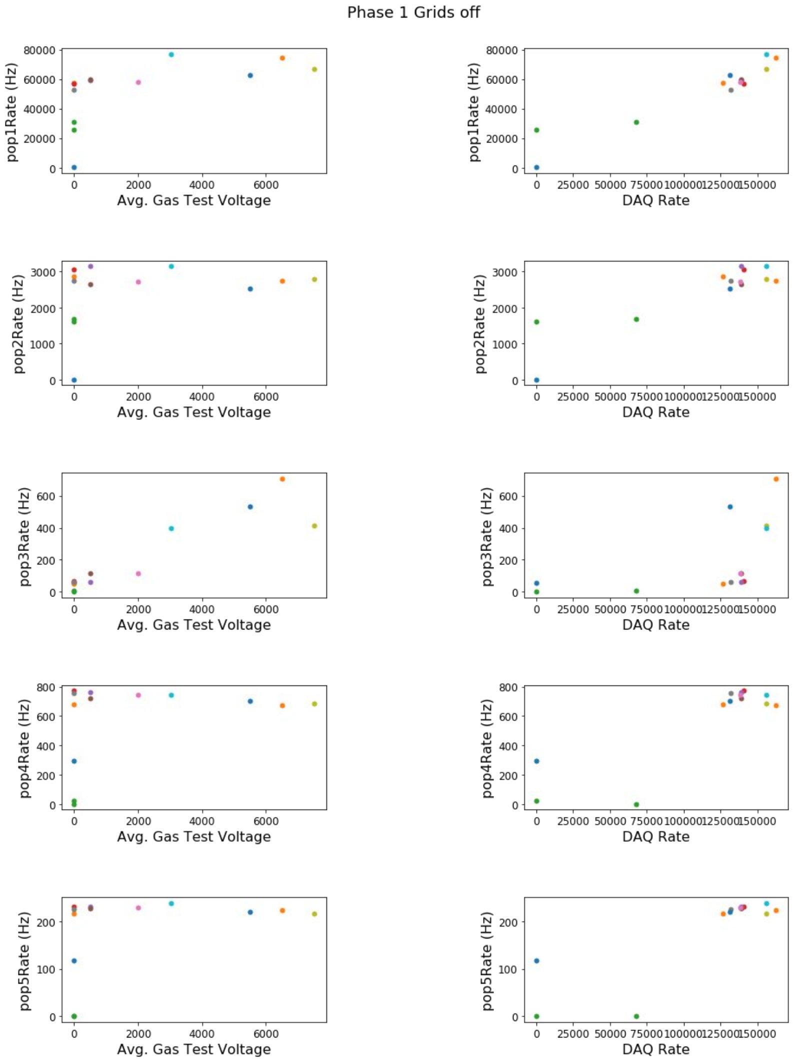




Rates versus voltage

- This is only data when the phase 1 grids are off
- We do see a correlation between the gas test voltage and the population 3 rate (high area, low amplitude)

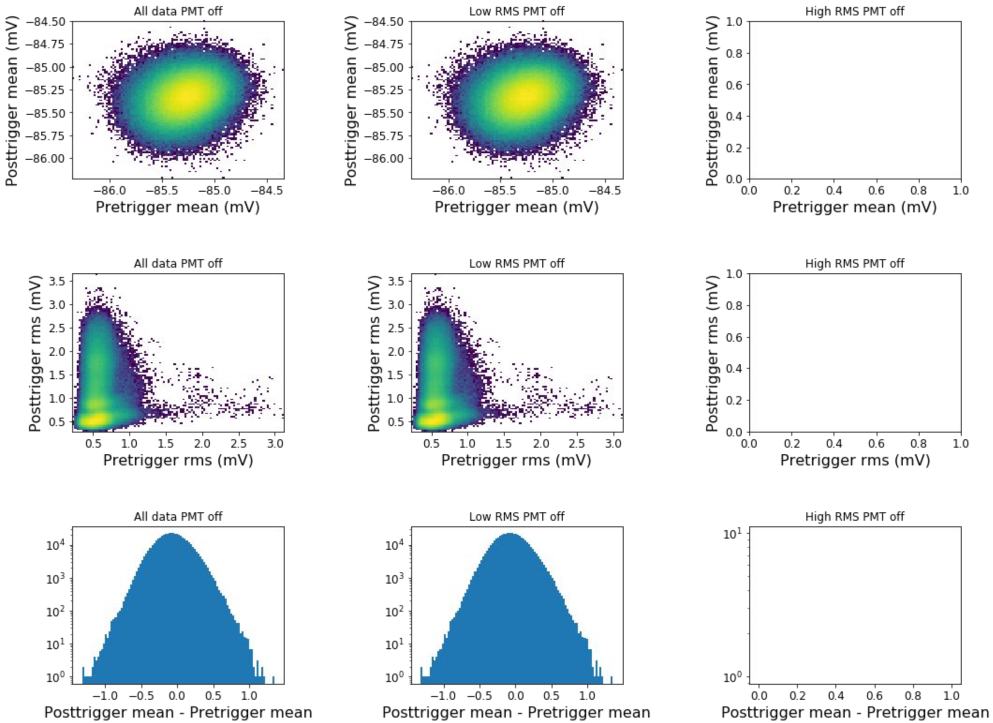




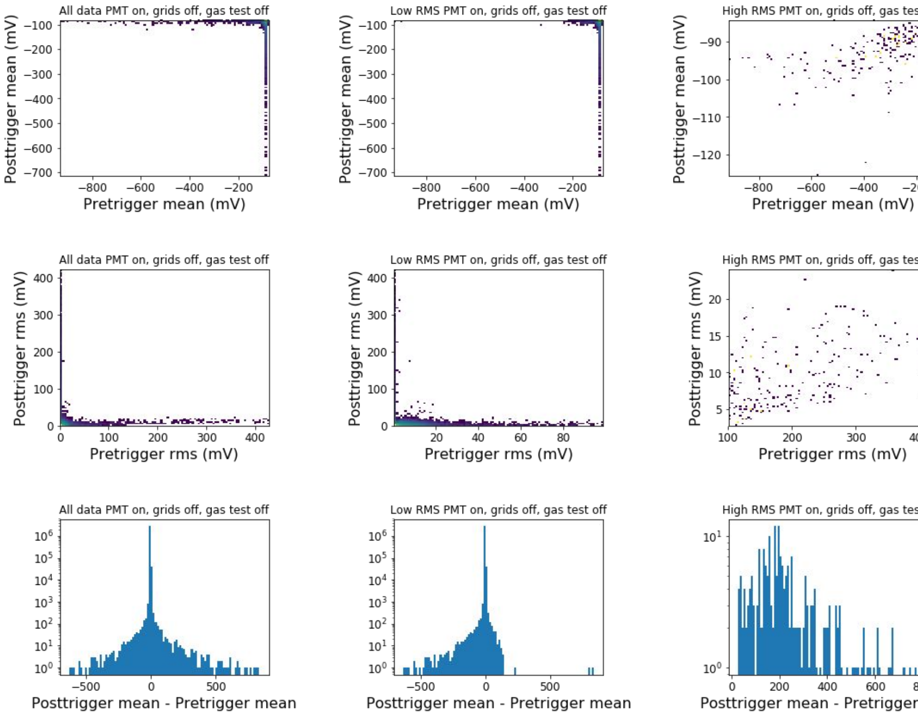
Other updates

- LZ Cables QA
  - Need to have a schedule for cable procurement and assembly by tomorrow
  - Havent heard back from Bob or Jeff about these dates
- LUX 100 Ton projections
  - Plan on using libNEST for a generic detector rather than being LZ specific
  - Means we only need energy spectra
  - Have to wait for limit code (Quentin) and updated libNEST (Matthew)
  - Can just use flat background energy spectrum to avoid using LZ sensitivity results

Pretrigger / Posttrigger Mean and RMS

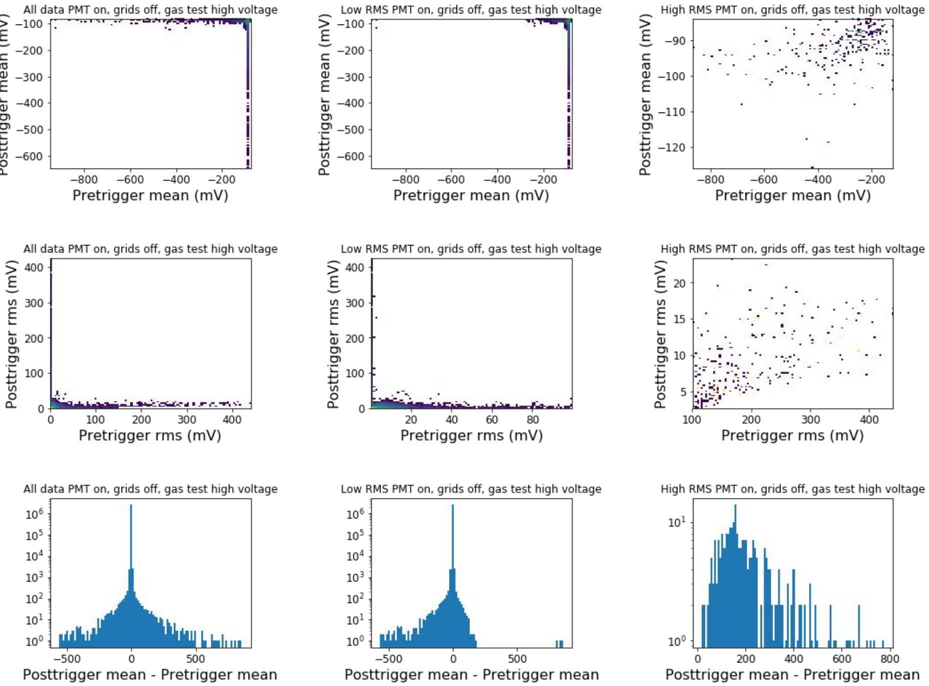


PMT off (just digitizer)

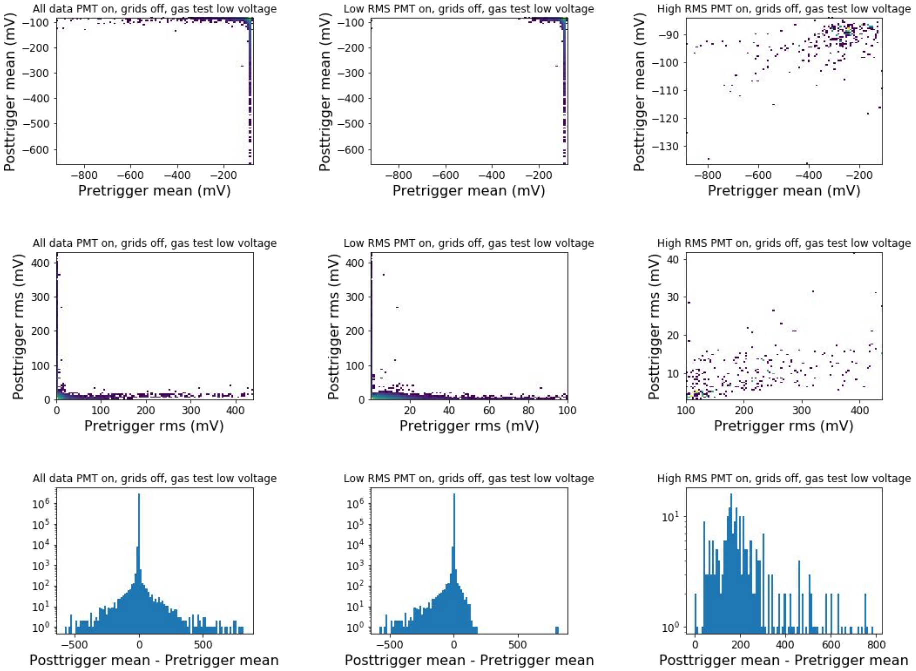


PMT on all grids off

Pretrigger / Posttrigger Mean and RMS



PMT on P1 grids off, gas test high voltage



PMT on P1 grids off, gas test low voltage

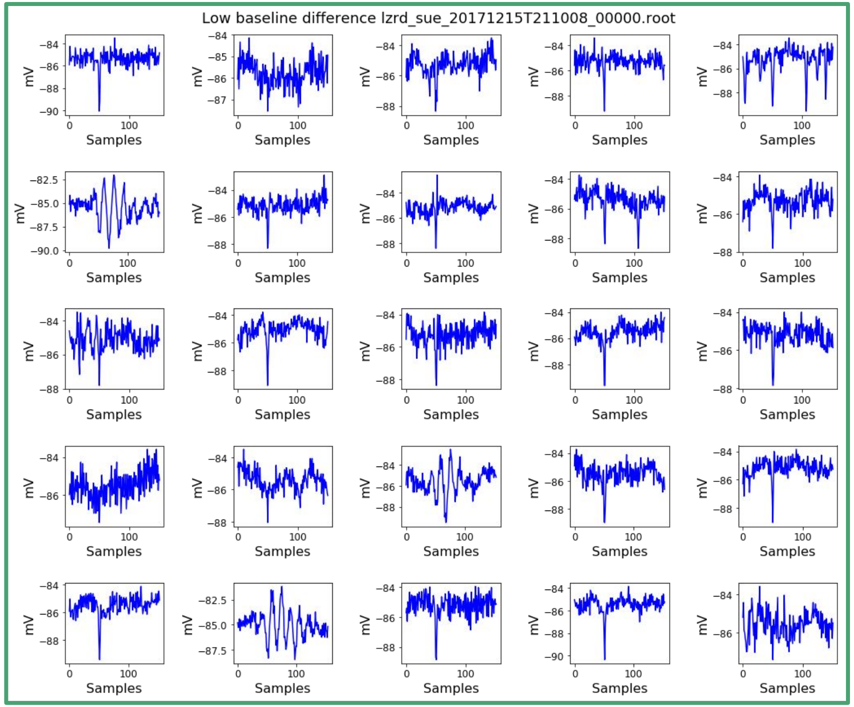
System Test Analysis

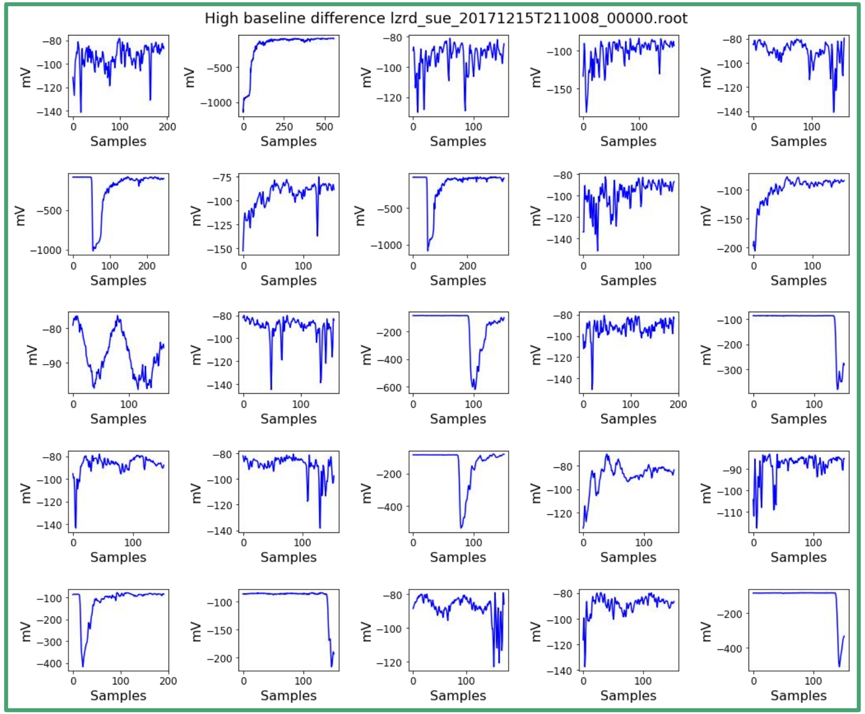
- Looking at reduced Run 7 data
  - It’s in a different form than I was expecting (DER output format, not LZAP output format)
  - Really only gives waveforms and their start and end time
  - Hoping tomorrow’s analysis meeting will clear this up
- Phase 1 optical maps are implemented in BaccMCTruth
  - Works for both Phase 1 and LZ
  - Haven’t pushed to git as the optical map file is hard coded to my directory
  - Where should it be stored? PDSF? CVMFS?

LUX 100 T projections update

- ER and NR band data as a function of voltage are progressing
- We will stick with a flat ER background and Neutrinos as the dominant NR background
    - There was some discussion of including low energy lines in the ER spectrum but this would only make the result harder to compare to other experiments and in real WIMP search data a line would get spread out anyway
- Waiting on Quentin to send his sensitivity code on git
    - Need lux git account?

Phase 1 Run 7 Baselines





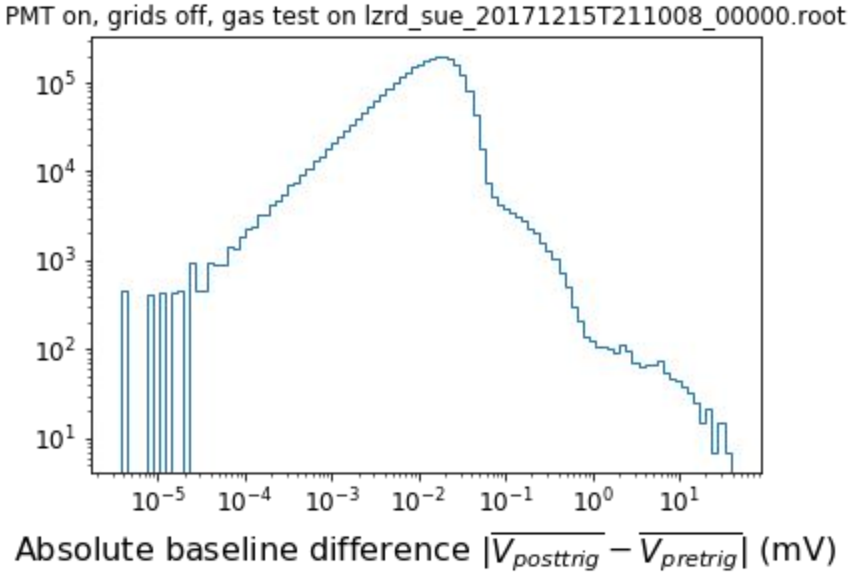
We need a way to determine the baselines in all of these cases

Phase 1 Run 7 baselines

There are three different cases of baselines shifting during a POD.

1. The baseline does not shift significantly (left side of plot) 94.9% of pods
2. Baseline shifts slightly (middle right of plot) 5% of pods
3. POD starts or ends during an event (rightmost bump in plot) 0.1% of pods

Run 8 should include less of the right most population. PODs won't end in the middle of a signal

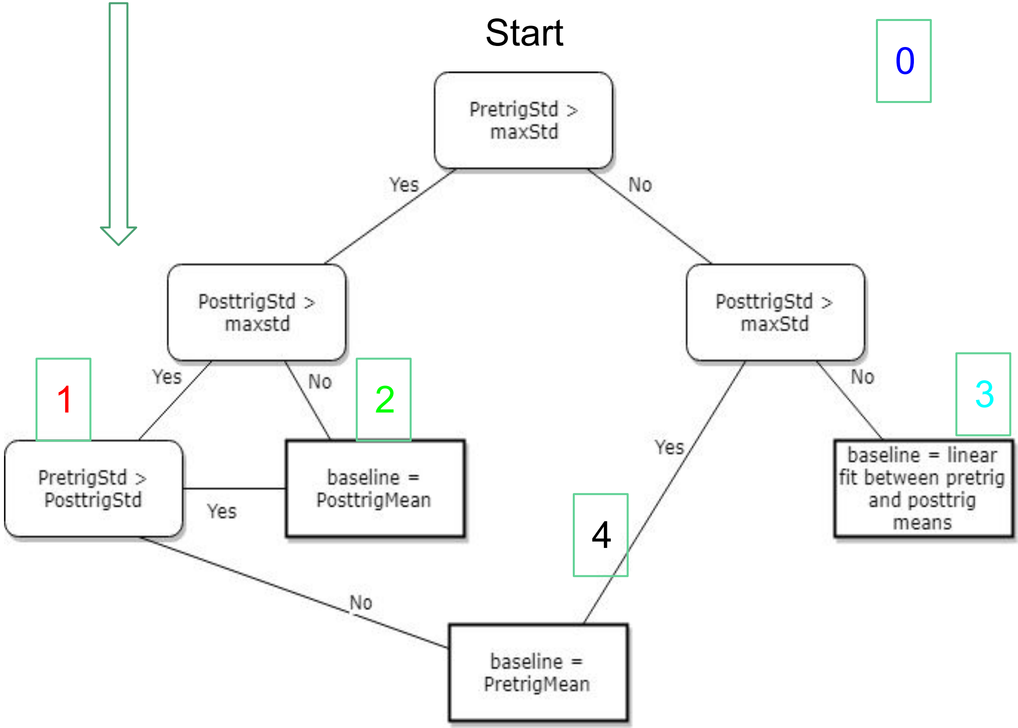


Phase 1 Run 7 Baselines

4 different cases of the baseline standard deviation relative to a maxStd variable

Use pretrigger mean and standard deviation (80 ns before trigger). Posttrigger mean and standard deviation (160 ns after trigger ends: comes back below trigger value)

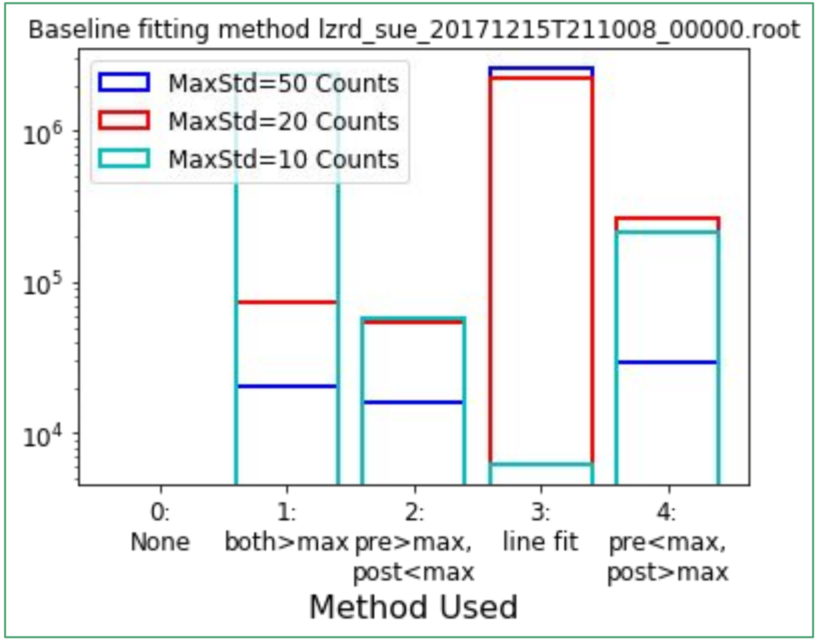
Color matches plots on following slides



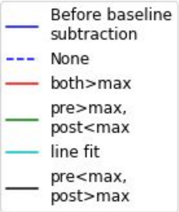
Changing the MaxStd Parameter

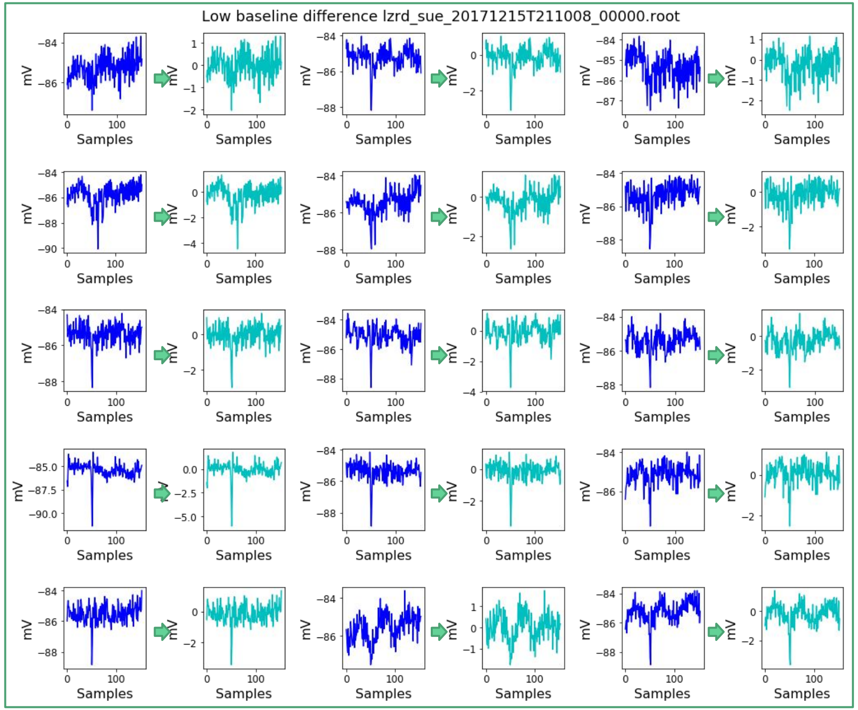
At higher maxStd the linear fit method is used. This allows more variable cases to get a linear fit

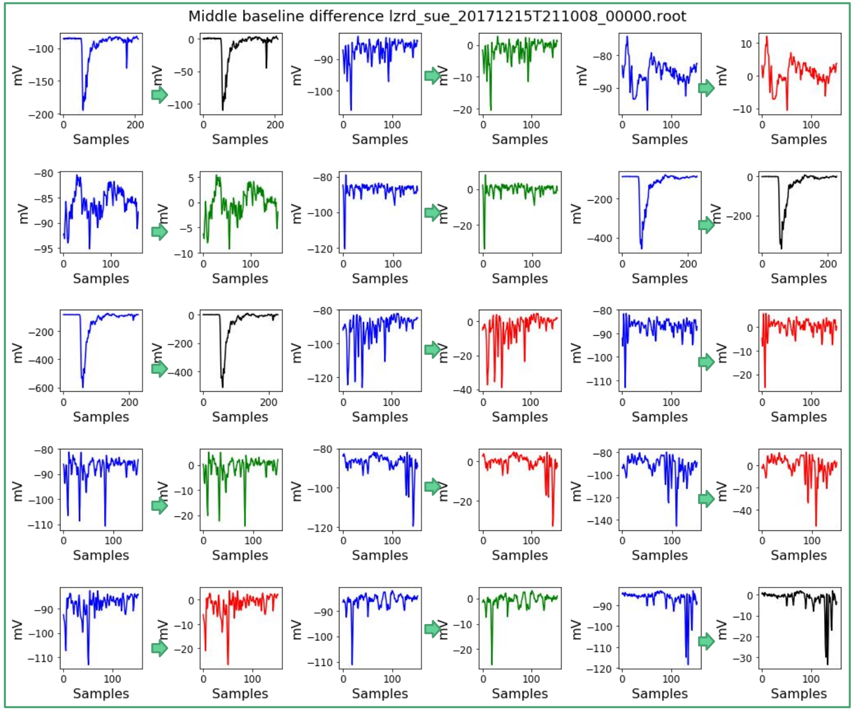
At lower maxStd the method that uses the lower Standard deviation of pre and post trigger are used



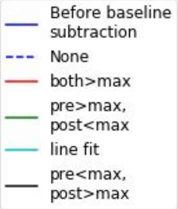
Baseline subtracted waveforms

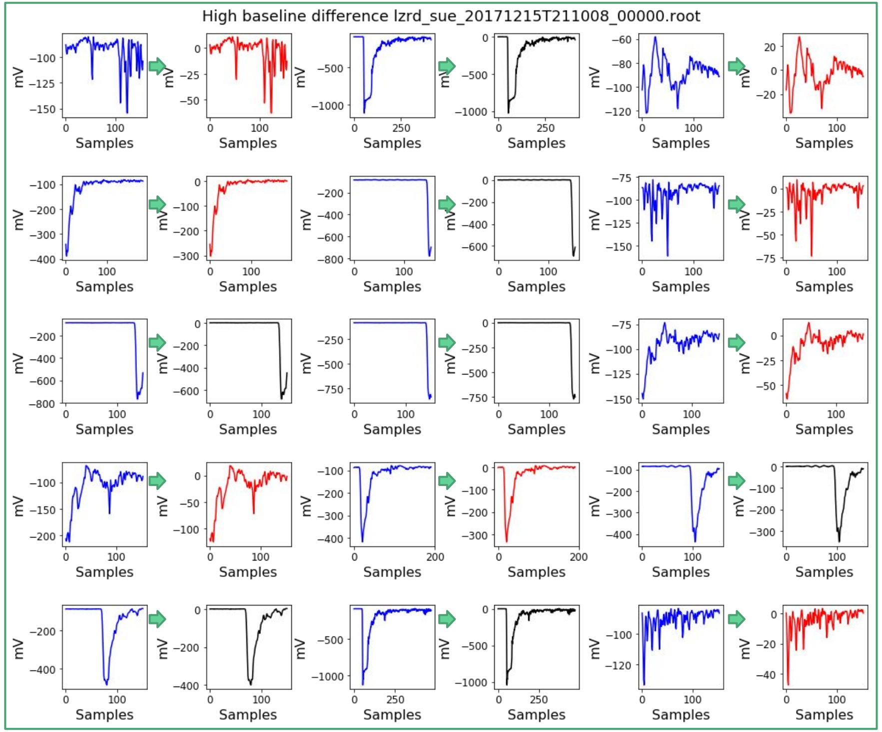


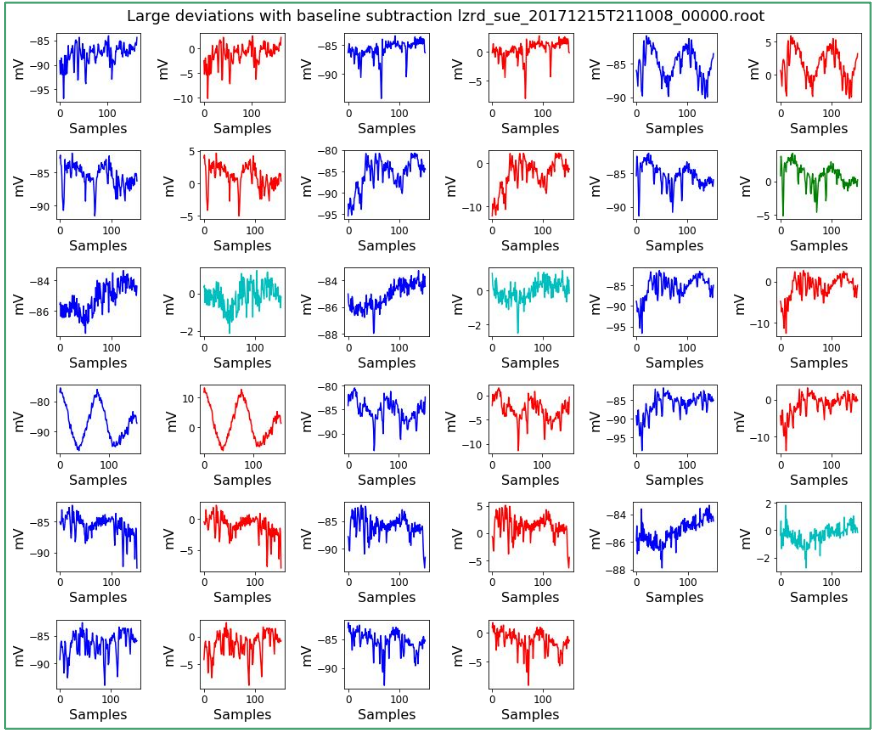




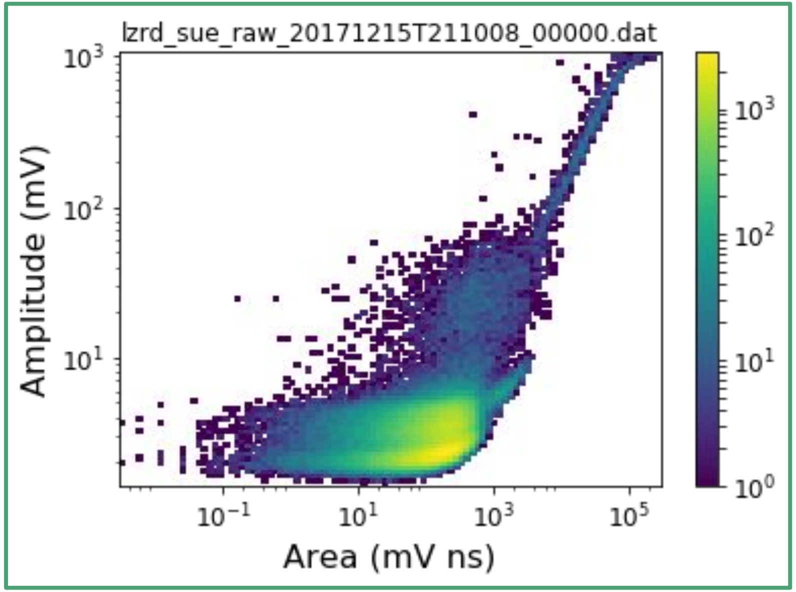
Baseline subtracted waveforms (large differences)

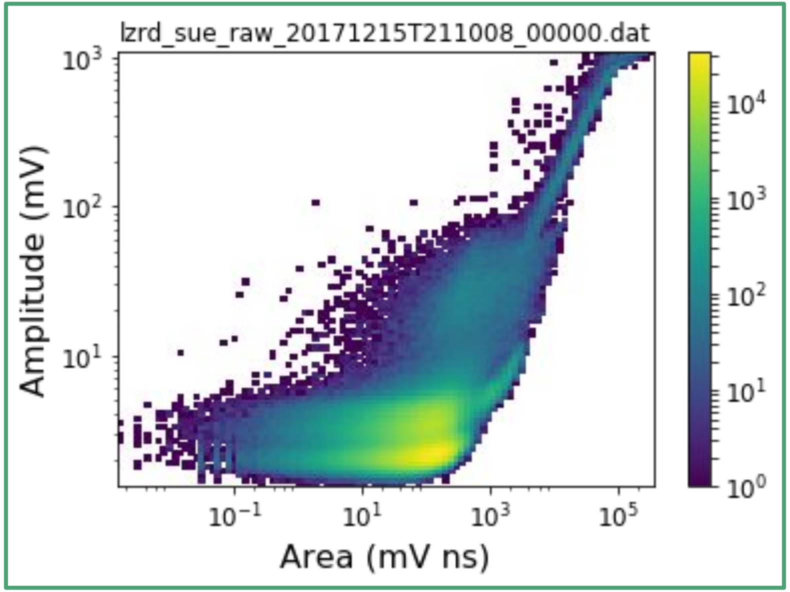






Pulse Amplitude Area comparison





Old method: Just used pretrigger mean

New method

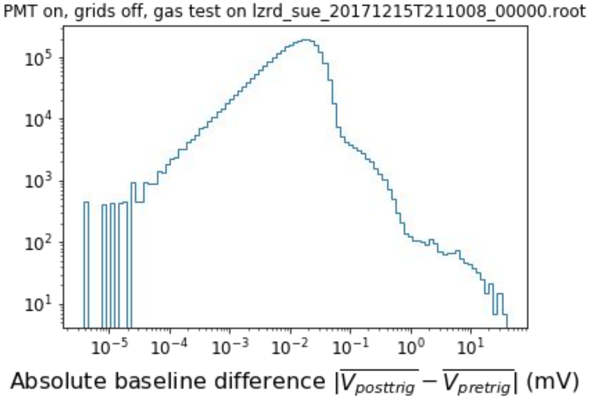
Next Steps

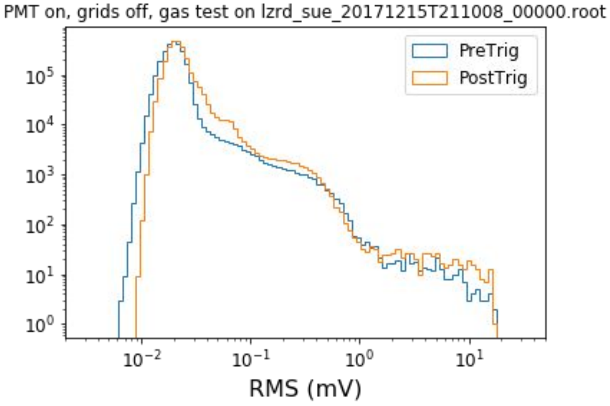
- Confirm with SLAC that this is an acceptable method for computing the baseline
- Implement in LZAP

Phase 1 Run 7 Baselines

Looking at data after first pass of cuts (on pdsf)

Divide into 3 populations in mean difference and rms





Events in different populations

Low mean difference events would likely not benefit from a linear fit to the baseline

Middle mean difference could use a baseline fit

High mean difference could just be thrown out, very small fraction of events without needing to change the code

	Low mean diff	Mid. mean diff	High mean diff
Low postTrigRMS	90.91%	3.13%	0.00%
Middle postTrigRMS	4.01%	1.72%	0.07%
High postTrigRMS	0.01%	0.10%	0.06%
Low preTrigRMS	93.47%	3.66%	0.05%
Middle preTrigRMS	1.45%	1.19%	0.03%
High preTrigRMS	0.00%	0.09%	0.06%

How to implement this in LZap

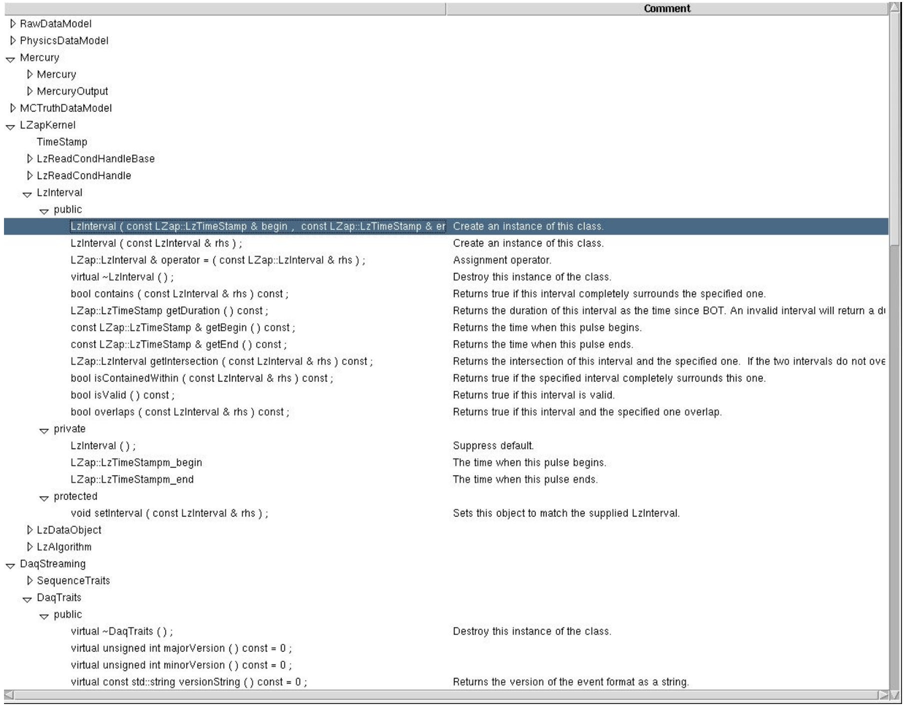
- Make a new POD for the pretrigger and posttrigger of an event
- LZap will calculate RQs for those subPODs just like any other POD
- Use those RQs to adjust the main POD as necessary
- Need to wait on the necessary RQs (POD mean and RMS) to be built into LZap

Working with LZap

Large program distributed over ~20 modules each with many files and corresponding functions

No good way to track current functions and variables available to your install of LZap

I wrote a program to list all the functions and variables associated with your working version of LZap



Radon Emanation (A real physics problem)

Radon is being released from an object at a rate R that radon is then able to decay with a halflife of 3.8 days. What is the number of atoms remaining in your volume as a function of time?

Radon Emanation Solution

See that regardless of the Radon emanation rate (R) It always takes the same amount of time to reach an equilibrium number of radon atoms.

That is why radon emanation measurements need to be run for ~30 days to reach this equilibrium value

$$\frac{dN(t)}{dt} = R - \lambda N(t)$$

$$\frac{dN(t)}{R - \lambda N(t)} = dt$$

$$-\frac{\log(R - \lambda N)}{\lambda} + C_1 = t$$

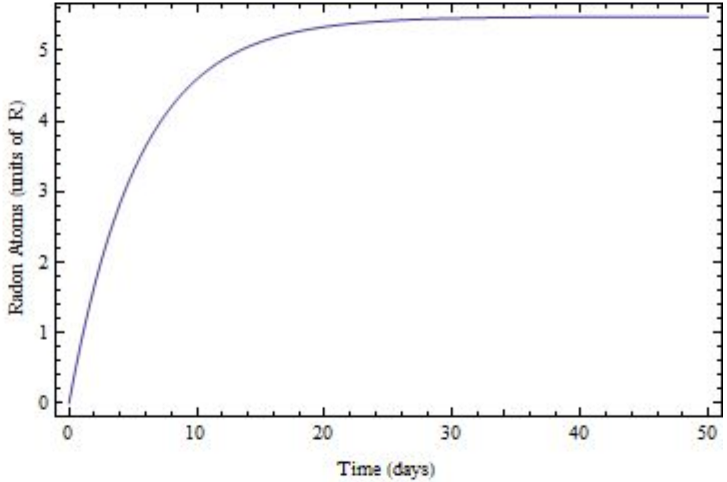
$$N(t) = \frac{R}{\lambda} + C_2 e^{-\lambda t}$$

$$N(0) = 0$$

$$N(t) = \frac{R\left(1 - e^{-\lambda t}\right)}{\lambda}$$

$$\lambda = \frac{\log(2)}{T_{1/2}} = 0.182/\text{day}$$

$$N(t) = 5.48224R\left(1 - e^{-0.182407t}\right)$$



LZap Baseline Study

- Have a basic method to calculate the baselines using data processed through LZap
- Still waiting on RMS to be implemented as an RQ
-

LUX Projections Update

- We have the ER and NR bands as a function of field
- From that we get the leakage fraction (using cut and count)
- PLR code is progressing
  - Quintin was going to use the LZ PLR but thinks it’s too complicated for what we need so he might just write his own