

Spring 2018 Group Update

Jonathan Nikoleyczik

Today's update starts on [slide 44](#)

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:

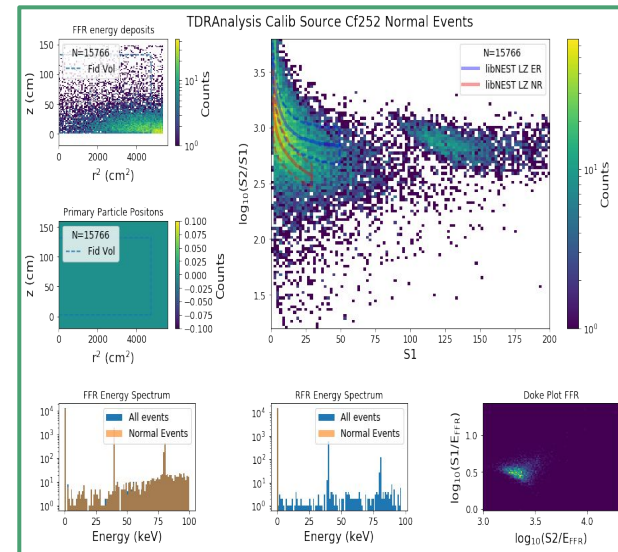
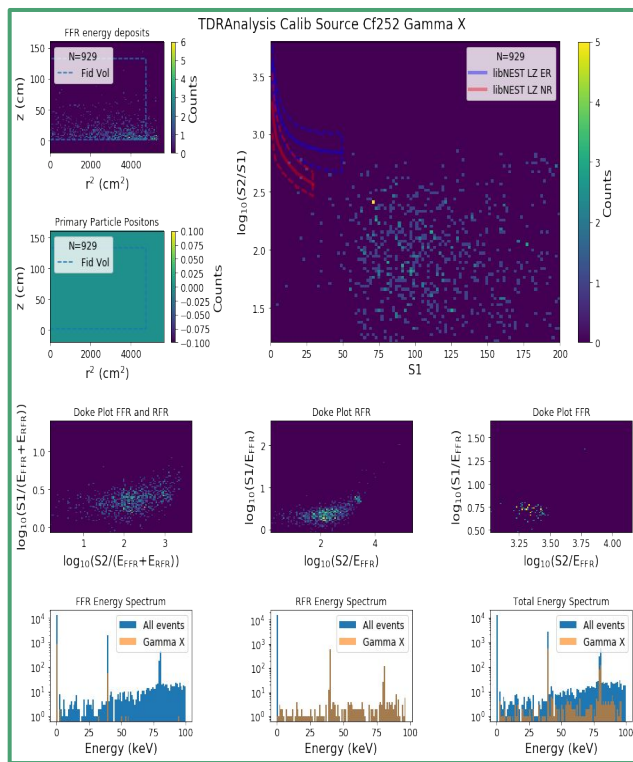
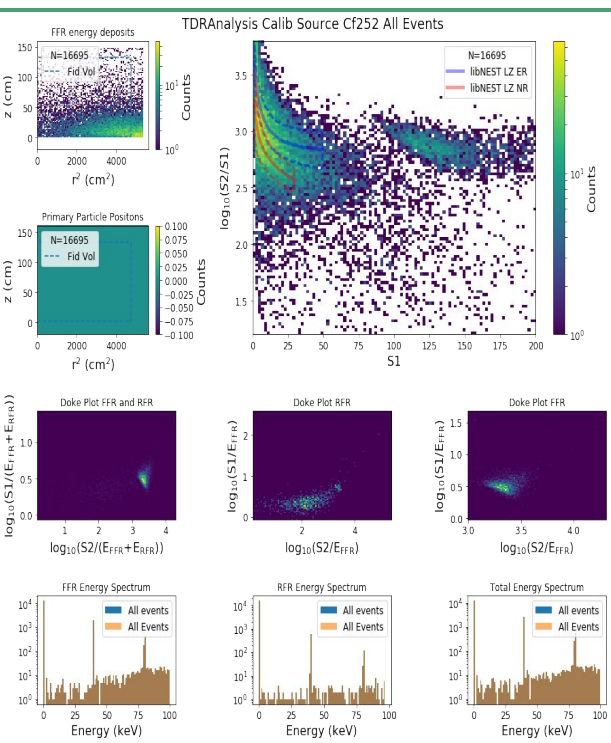
- AmLi (AmBe)
- ^{252}Cf
- ^{228}Th
- ^{57}Co (As a test)

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

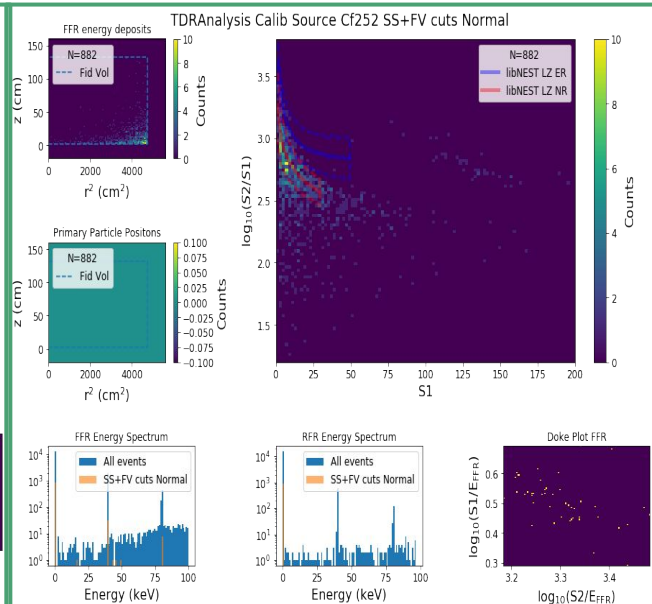
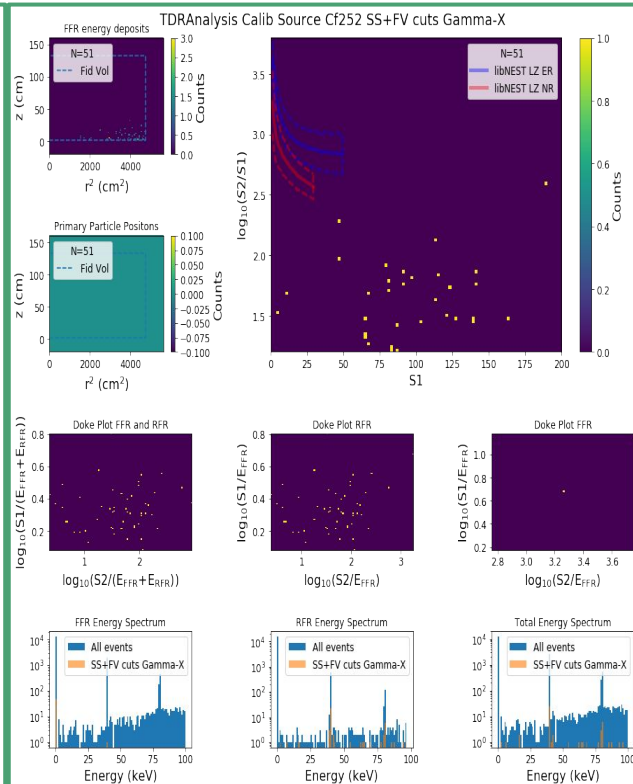
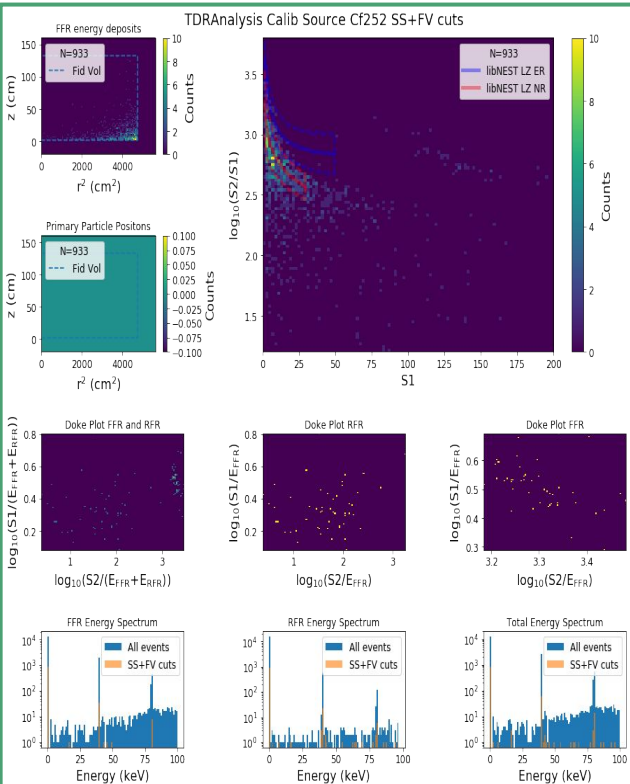
Table 7.0.1: Baseline calibration sources for LZ.

Isotope	What	Purpose	Deployment	Custom?
Tritium	beta, $Q = 18.6$ keV	ER band	Internal	N
$^{83\text{m}}\text{Kr}$	beta/gamma, 32.1 keV and 9.4 keV	TPC (x, y, z)	Internal	Y
$^{131\text{m}}\text{Xe}$	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



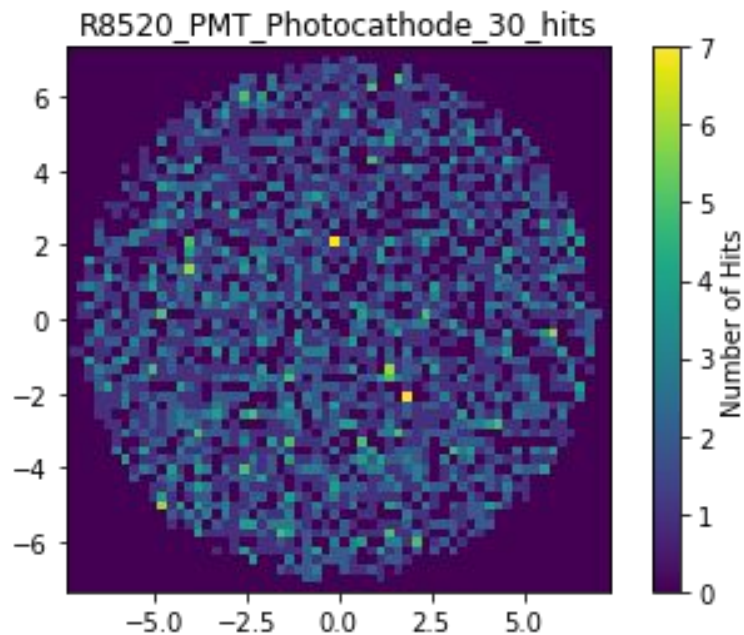
Calibration results

- 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

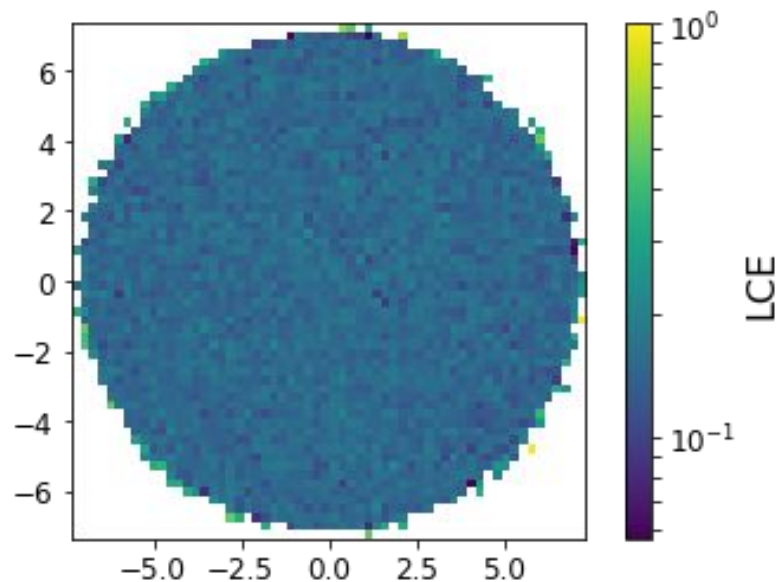
Phase 1 optical maps

- 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)

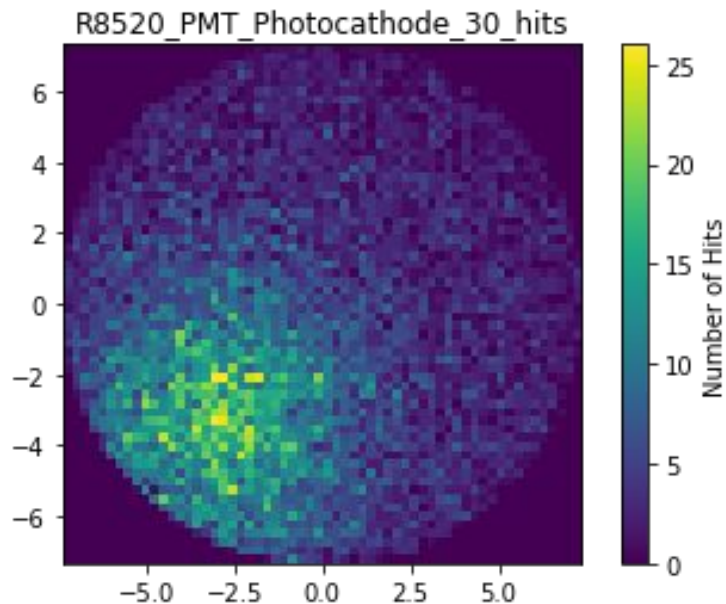


Example of a single PMT

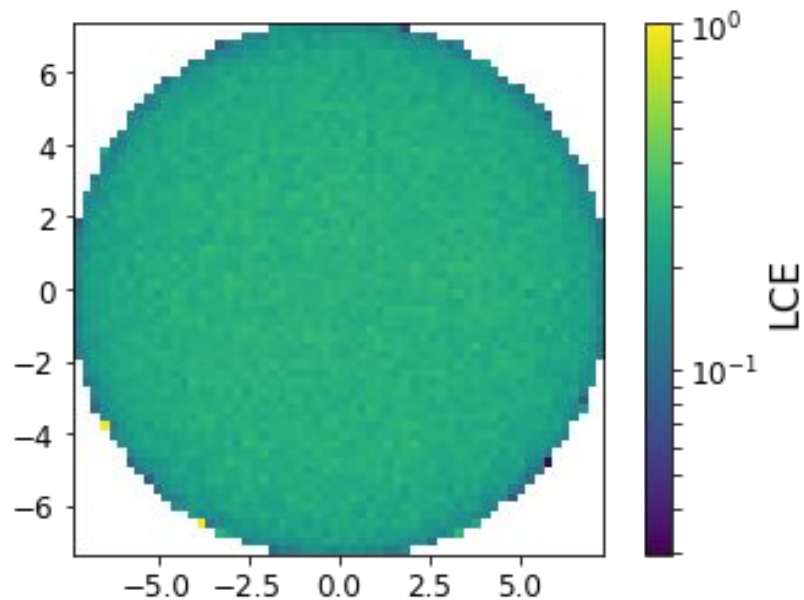


Combined light collection efficiency
Avg: 14.8% With QE: ~4.4%

Phase 1 photon maps (S2)



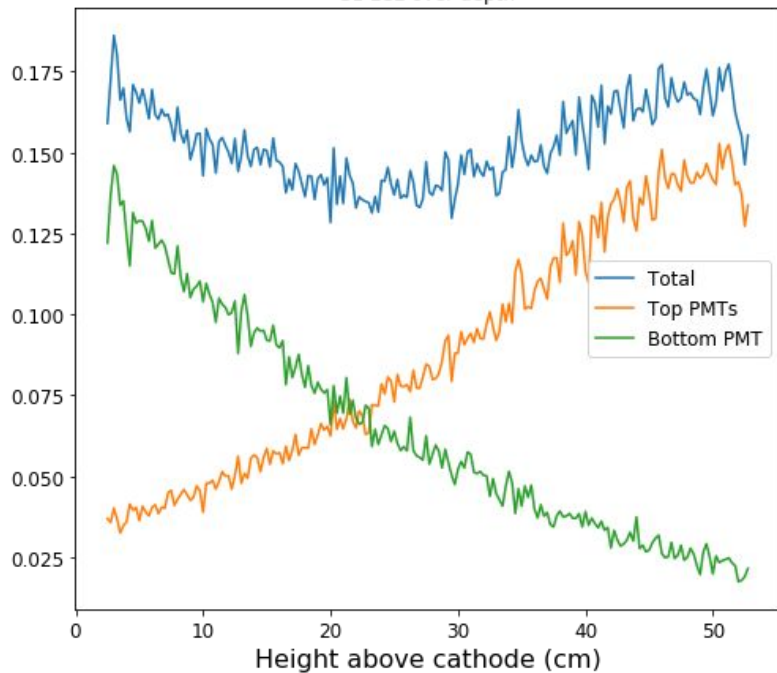
Example of a single PMT



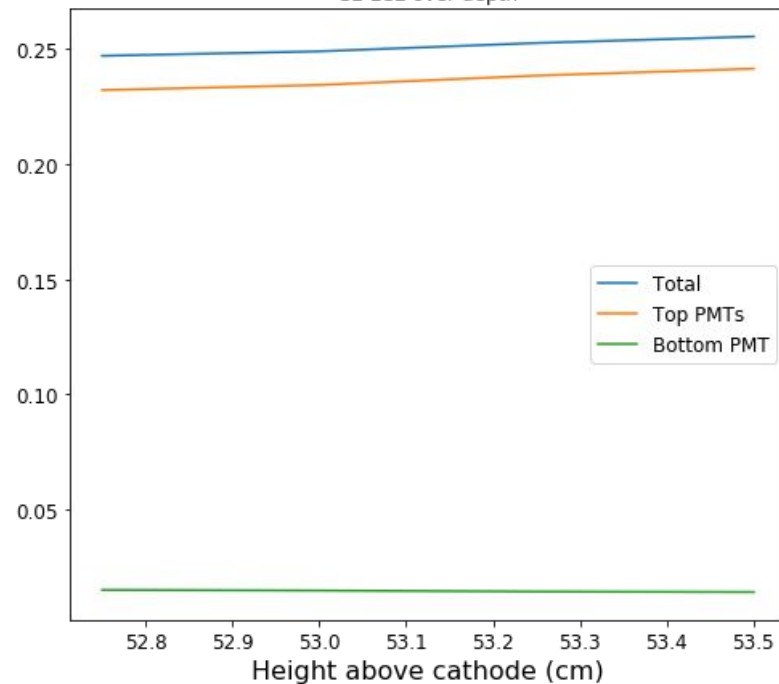
Combined light collection efficiency
Avg: 24.7% With QE: ~7.4%

LCE as a function of depth

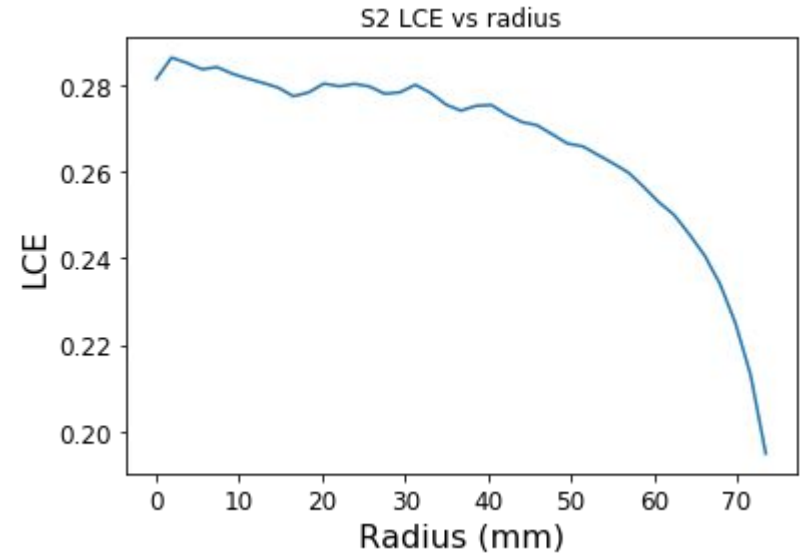
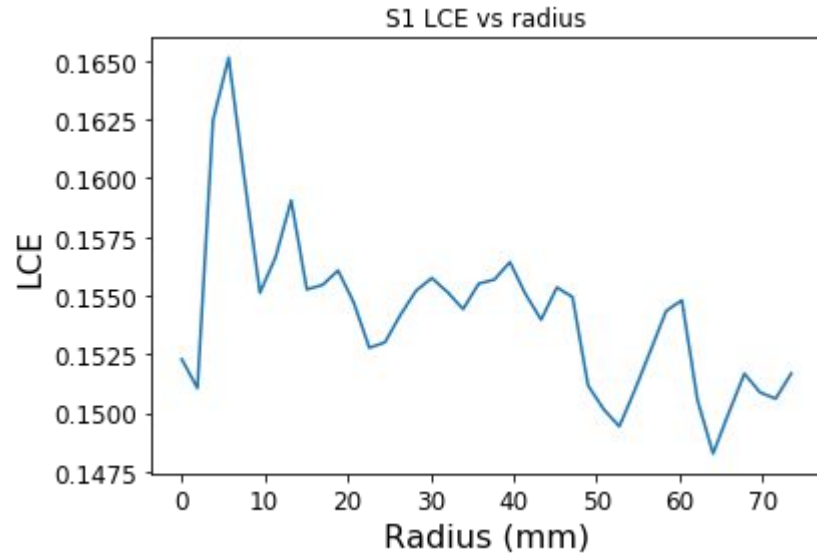
S1 LCE over depth



S2 LCE over depth



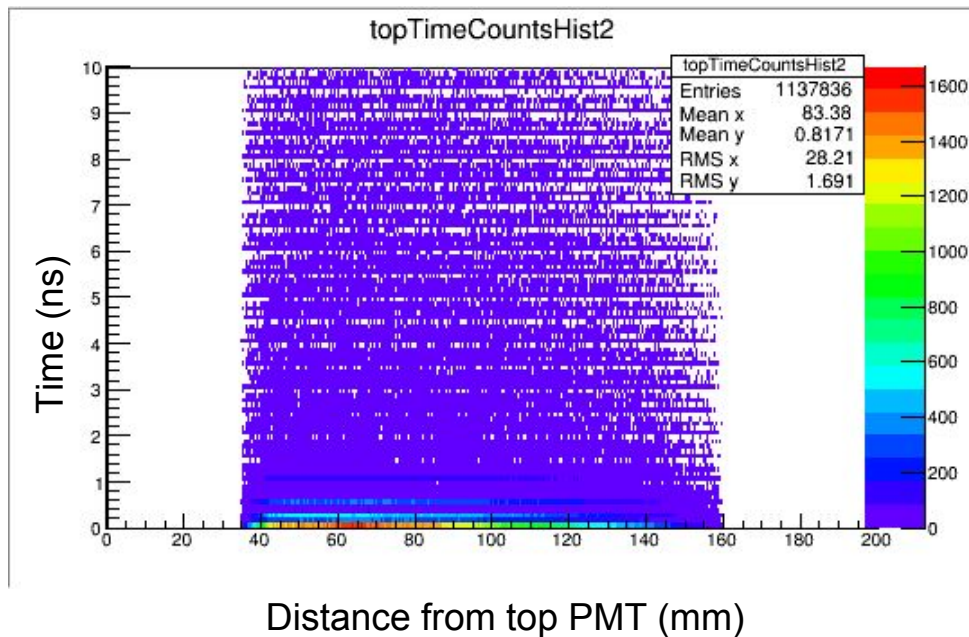
LCE as a function of radius



Time maps included

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

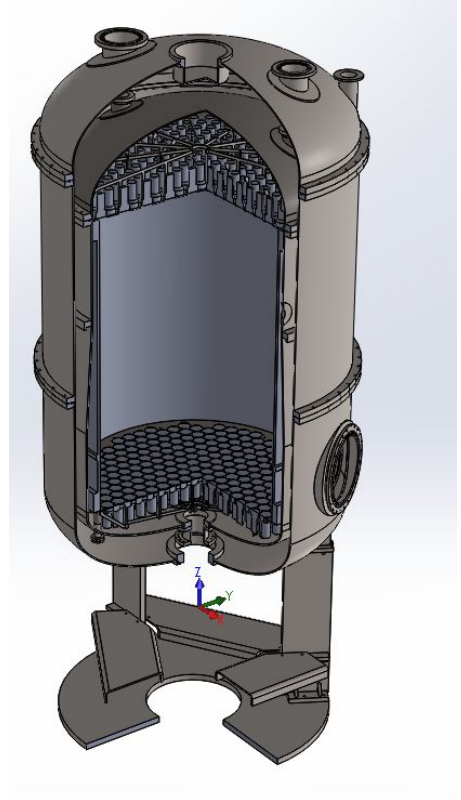
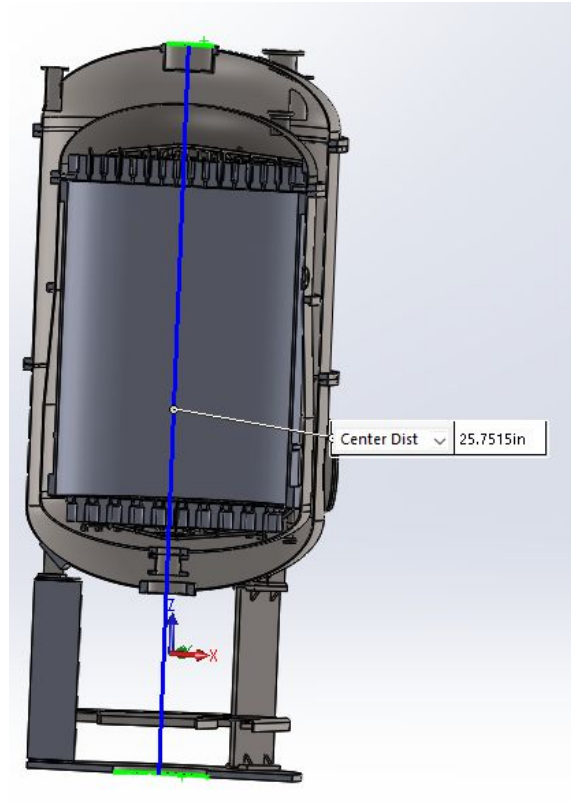
Shown here for S2 events.



LZ Scale Model

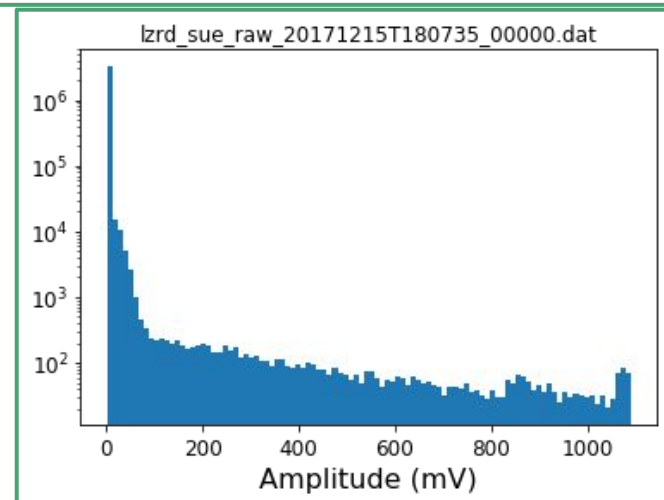
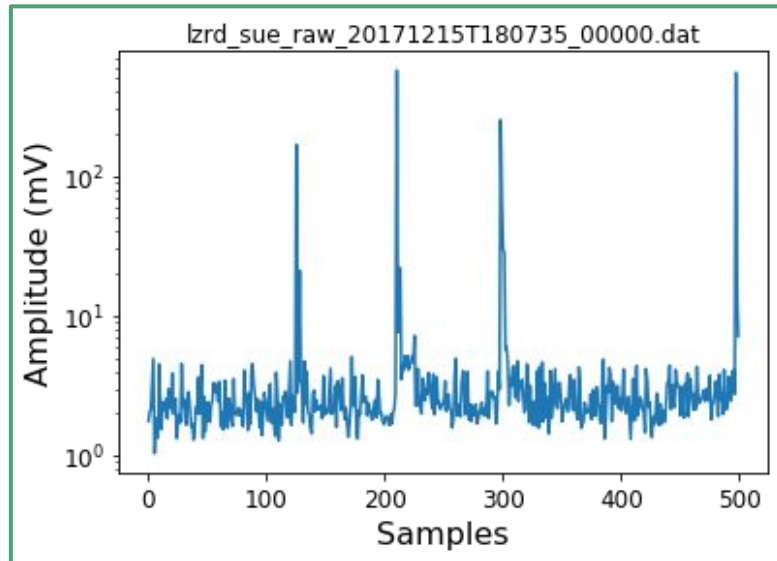
Ready to 3D printing
modifications.

Need 3D printer specs to
adjust minimum thicknesses,
overdraft

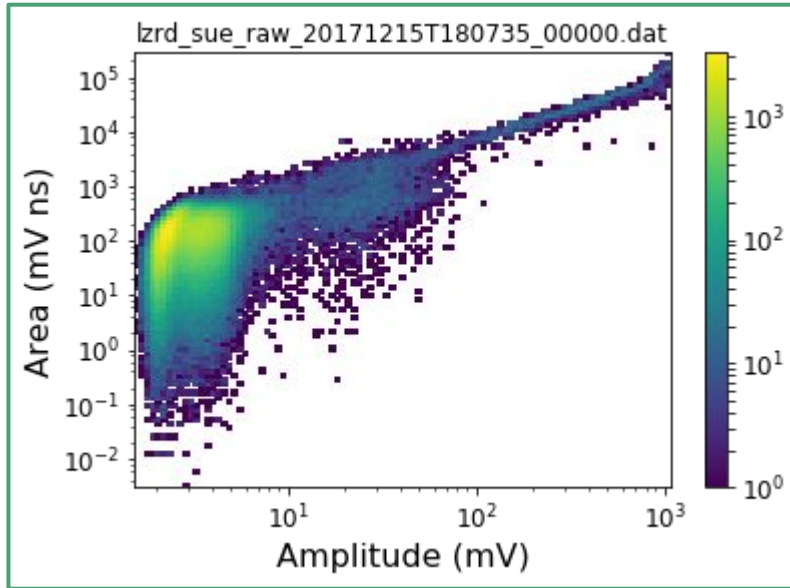


Phase 1 Run 7 analysis

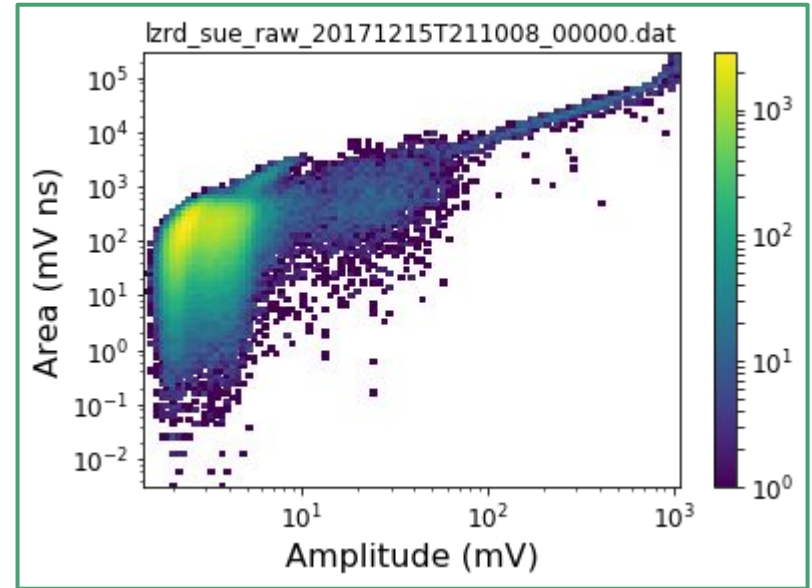
- Progress has been slow
- No quick way to transfer data between SLAC and Izlogin
- Have 8 data files from run 7
- Been looking at noise that occurred while the gas test was running
- Right shows the gas test off case



Amplitude Area plot for the two cases



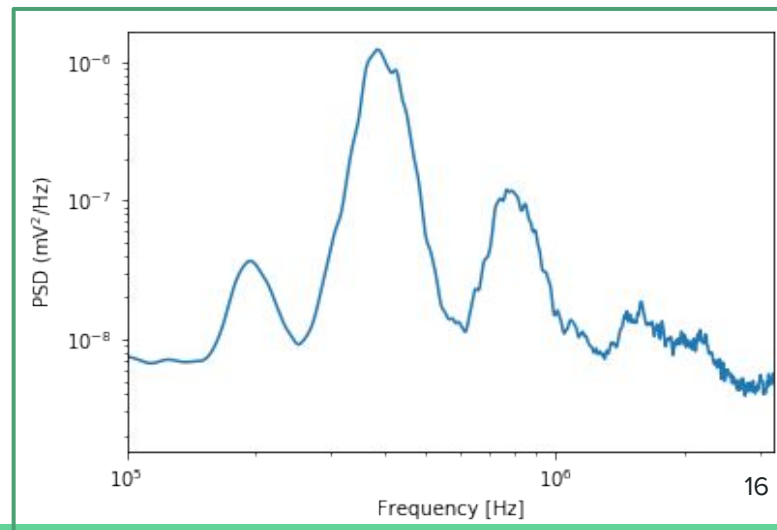
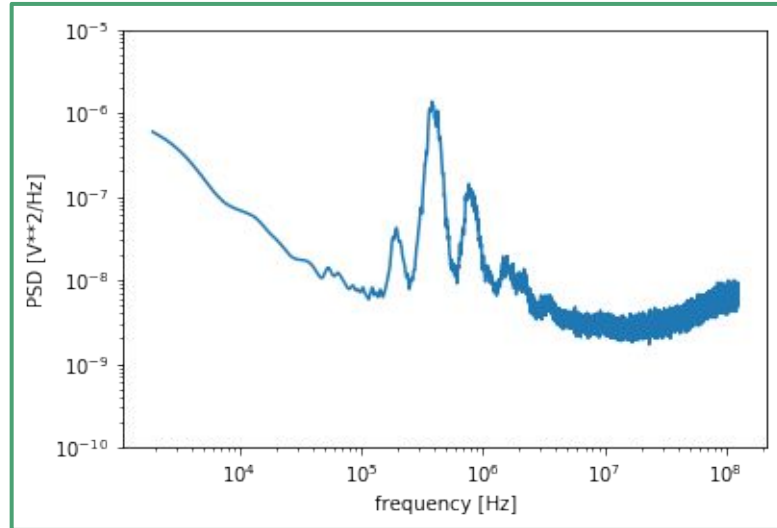
Gas test off



Gas test on

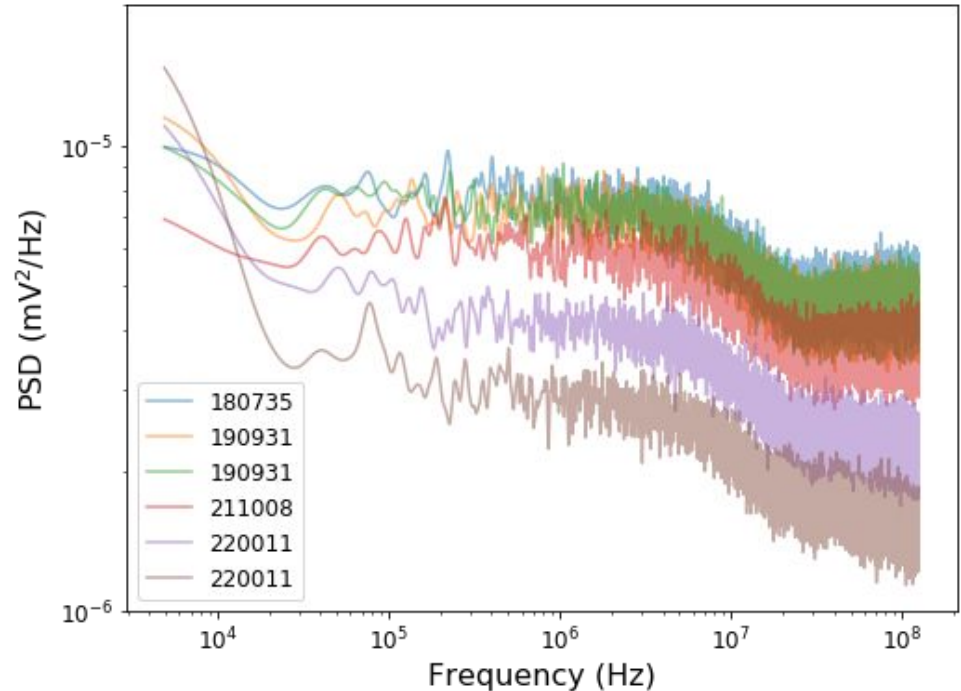
Digitizer noise power

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



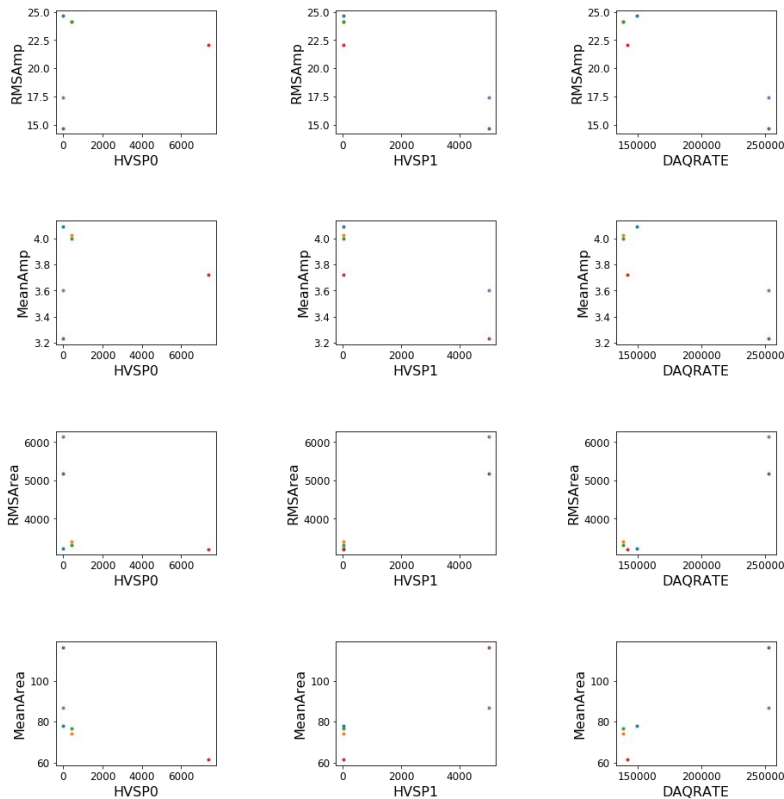
Noise Power at different gas test voltages

- Don't 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



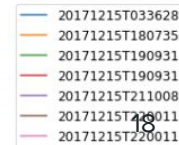
Quantities vs. Field values

- Plots of RMS amplitude and area, and Mean amplitude and area versus power supply voltage for different channels
- Don't see a strong correlation between gas test voltage and RMS and Mean signals



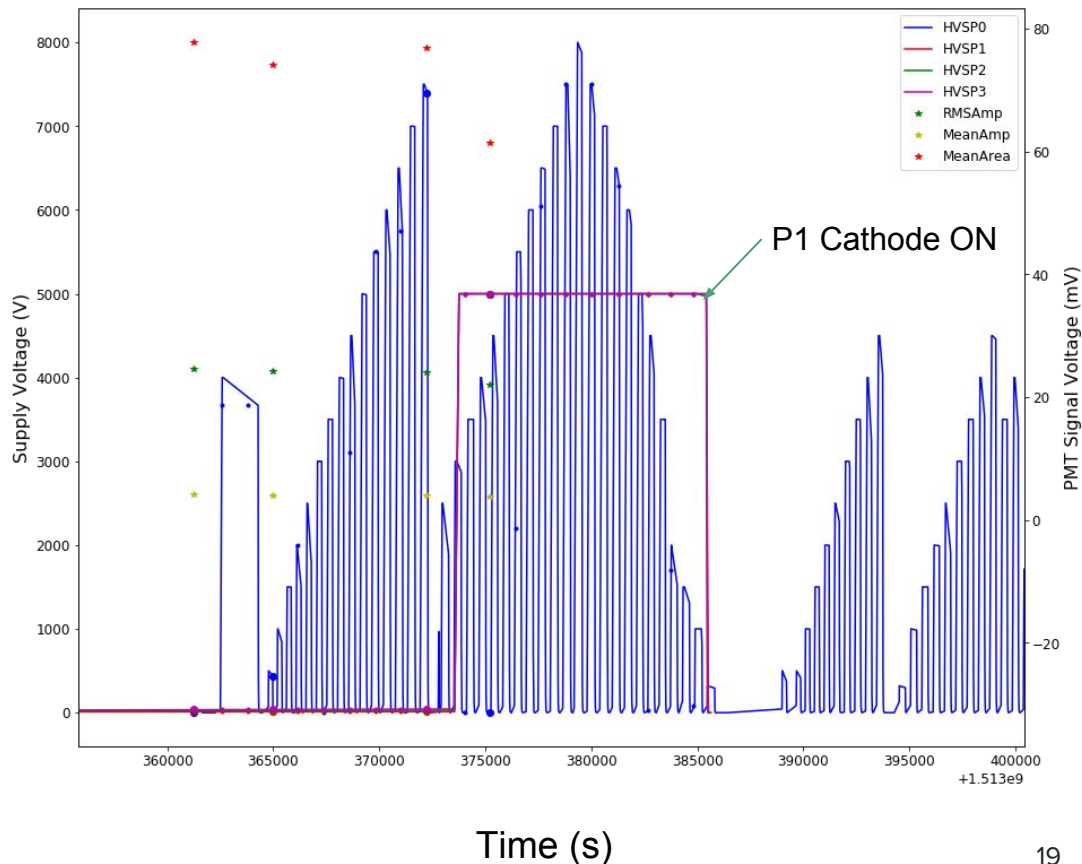
Gas test voltage

P1 Cathode Voltage



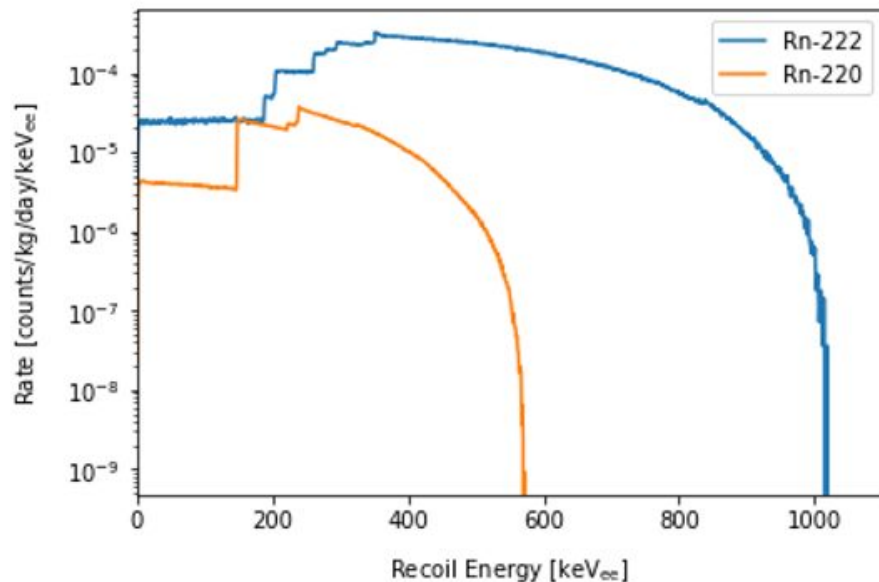
Signals over time

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



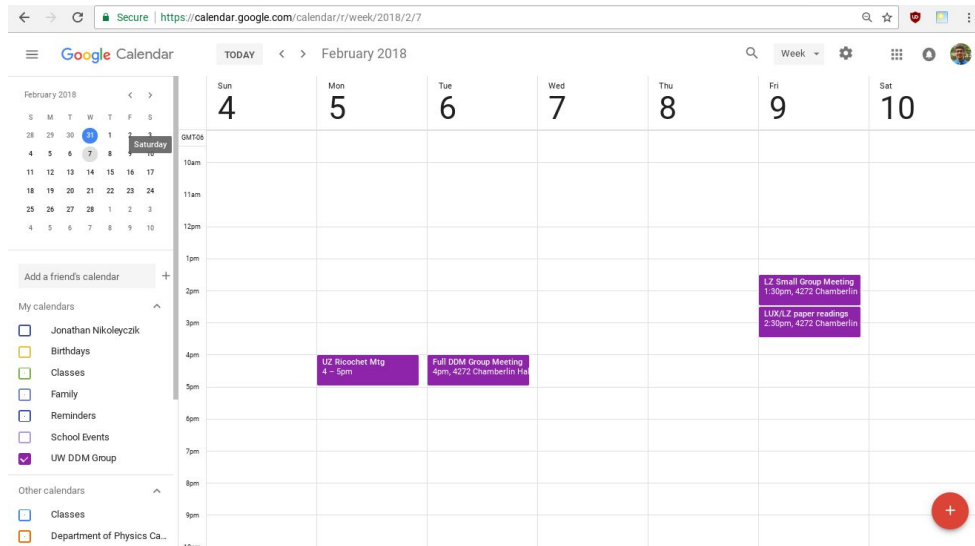
100 T sensitivity projections

- 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



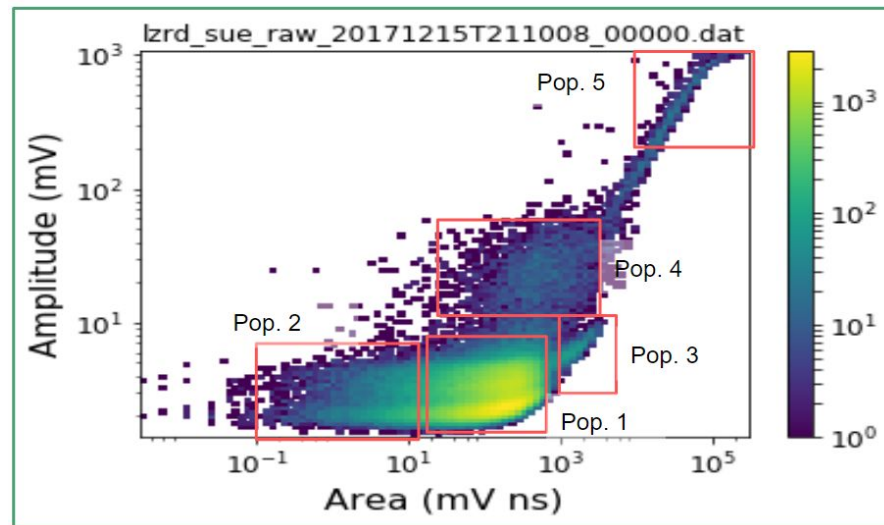
Group calendar

- 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

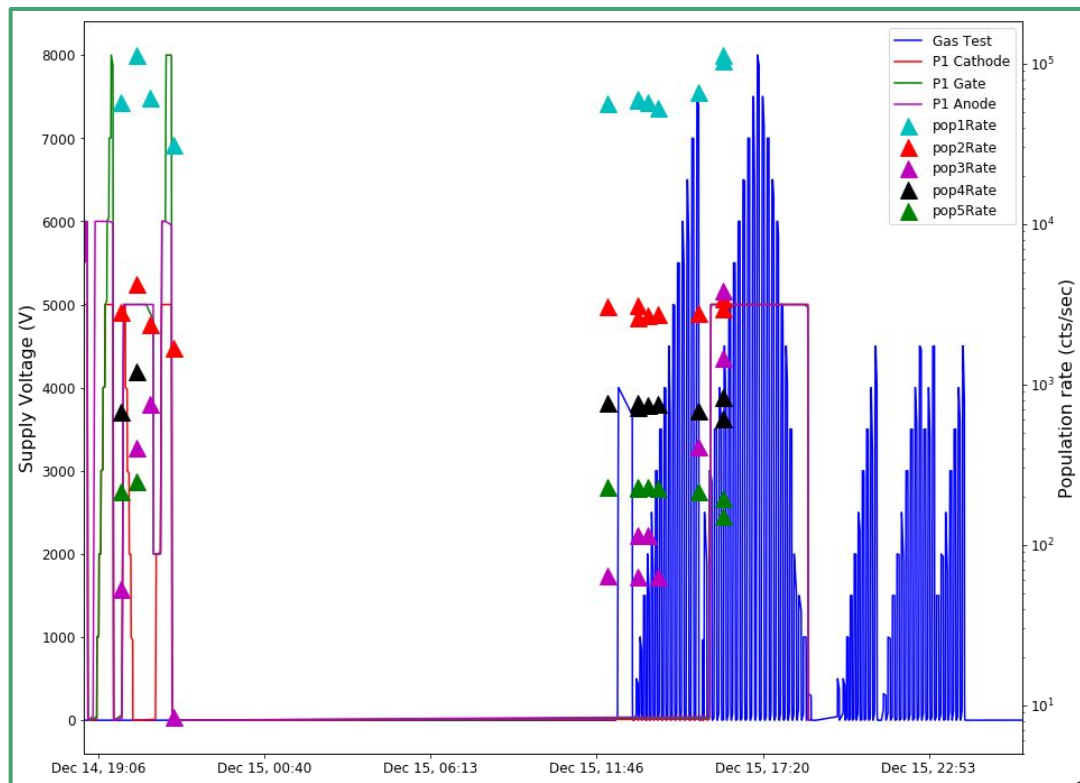
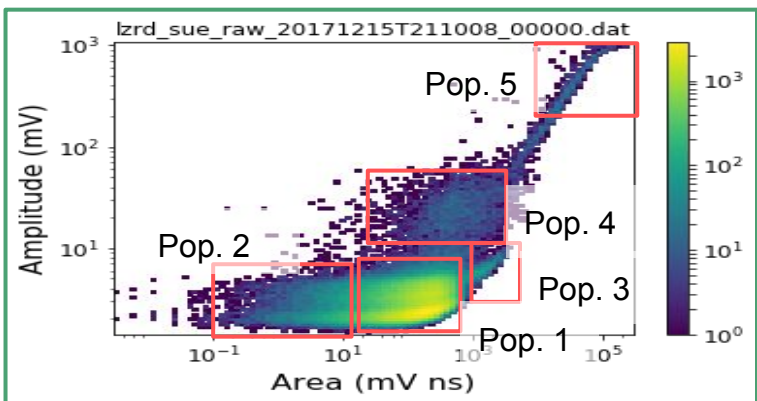


Phase 1 Run 7 Analysis

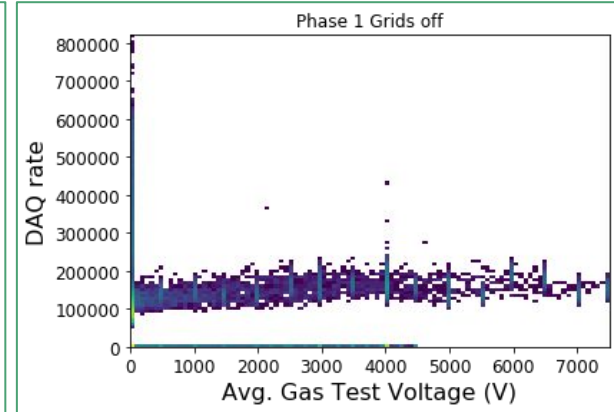
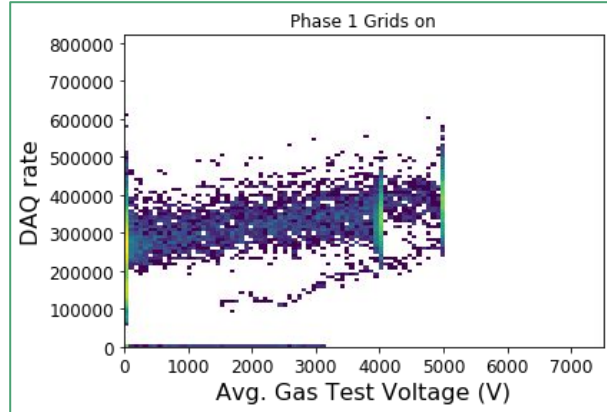
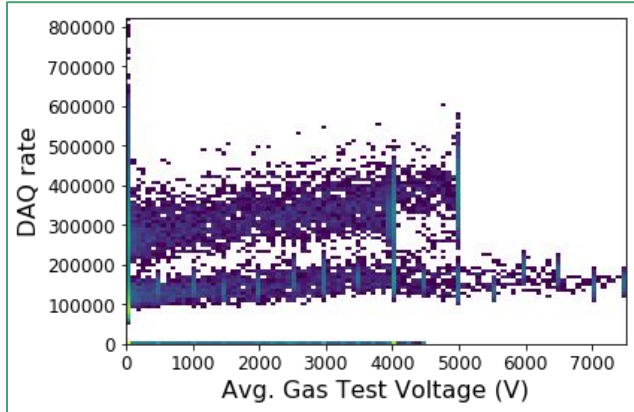
- Trying to correlate Phase 1 rates and noise with the operation of the gas test
- Divided amplitude area plot into different populations
- The rate is more correlated with the total power supply voltage than with the gas test alone
- See no significant noise power difference between gas test on and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



Population rates over time



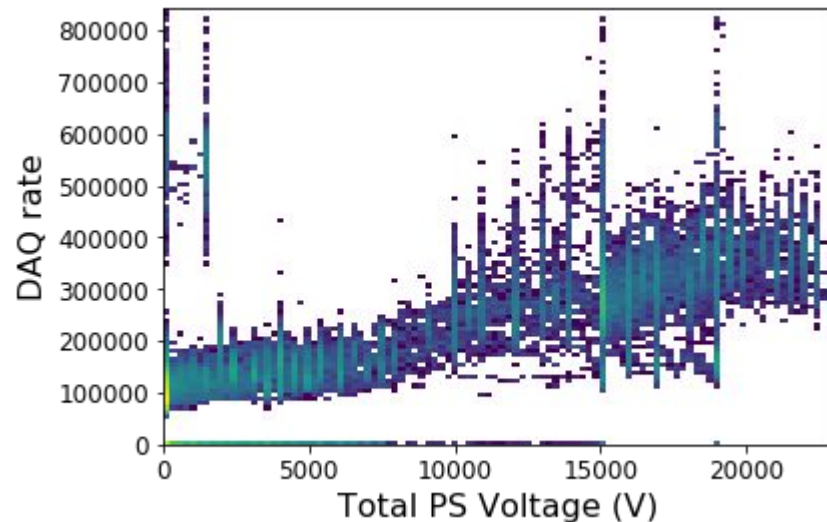
DAQ rate vs. Gas test voltage



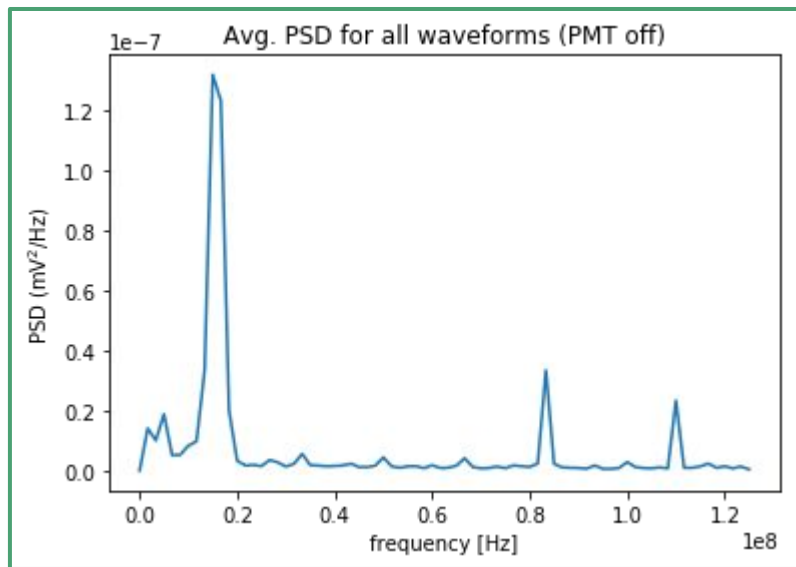
Possibly some correlation between gas test voltage and rate but only in the phase 1 grids on case

DAQ rate vs. PS voltage

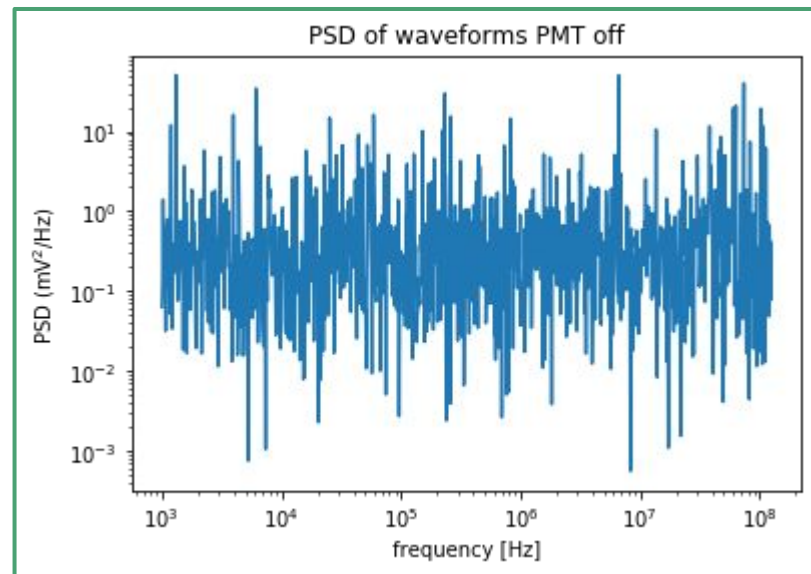
- Combines physical expected rate increases (P1 grids on) with gas test voltage increases
- Color corresponds to number of samples at that point
- Outliers at low voltage are older data sets (gas only tests?)



PSD of waveforms PMT off

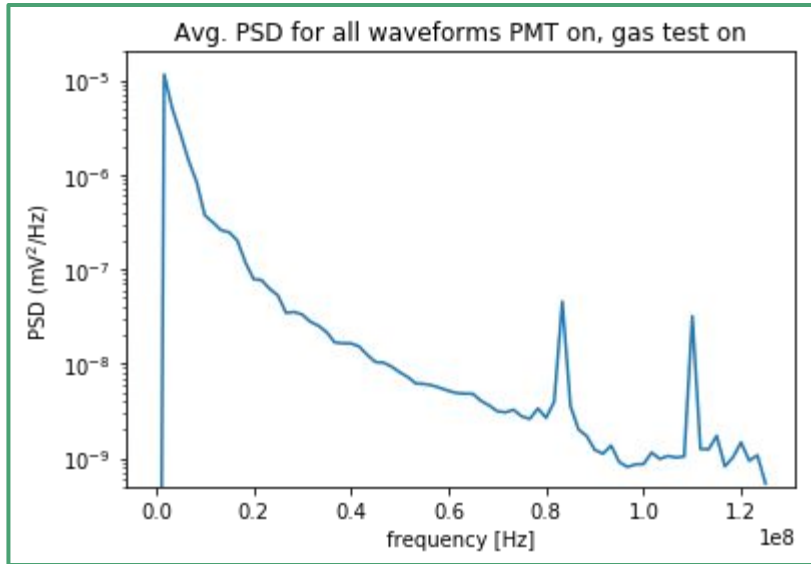


Averaging over all waveforms
Peaks at 150, 830, and 1100 MHz

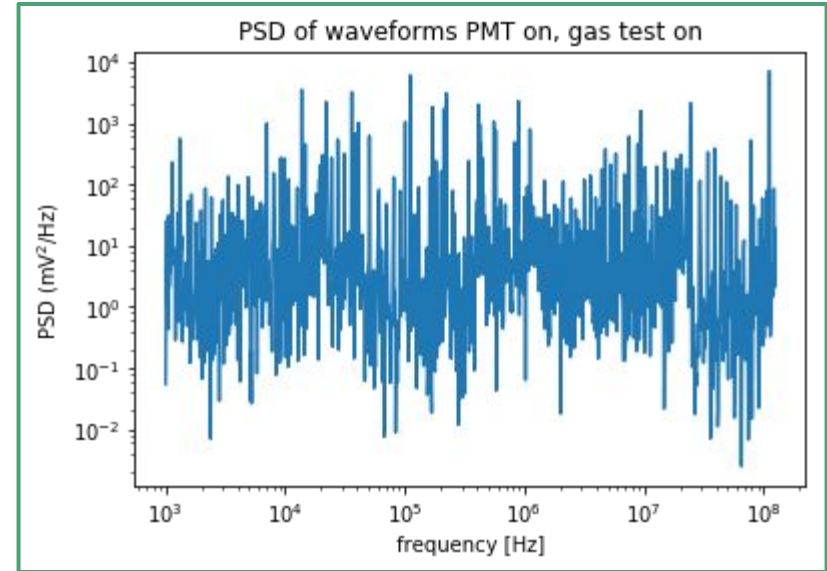


Combining waveforms

PSD waveforms PMT on



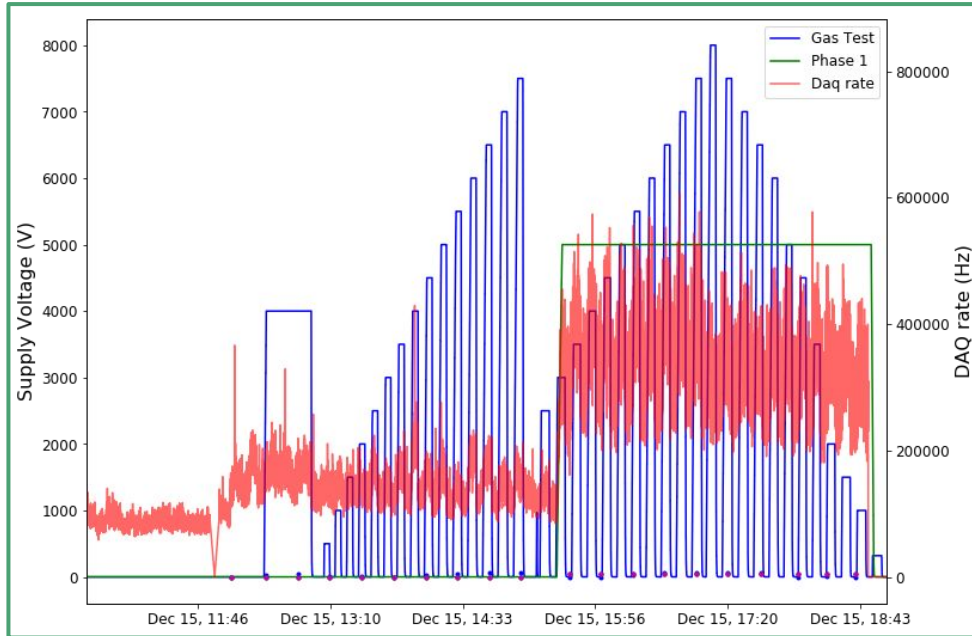
Averaging over all waveforms
Peaks at 830, and 1100 MHz
Note the change to log scale.
This is $1/f^{2.4}$ noise



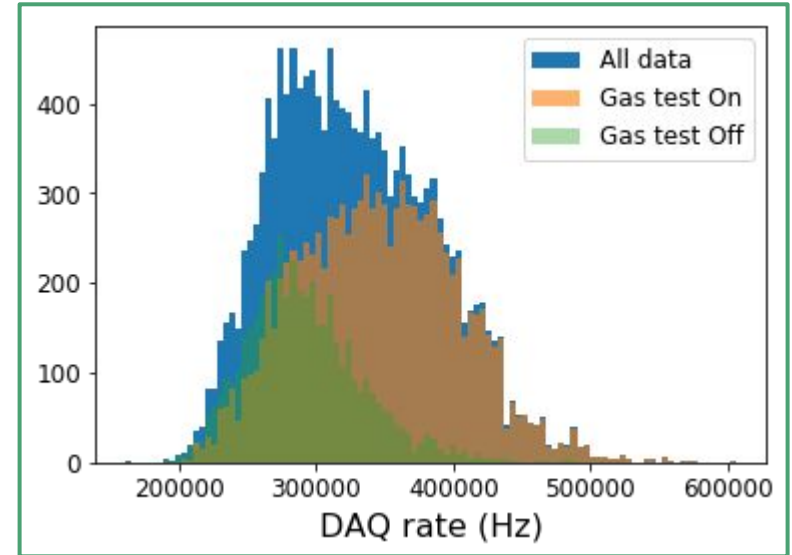
Combining waveforms

Gas test on and off has no noticeable effect on
PSD from 10³ to 10⁸ Hz

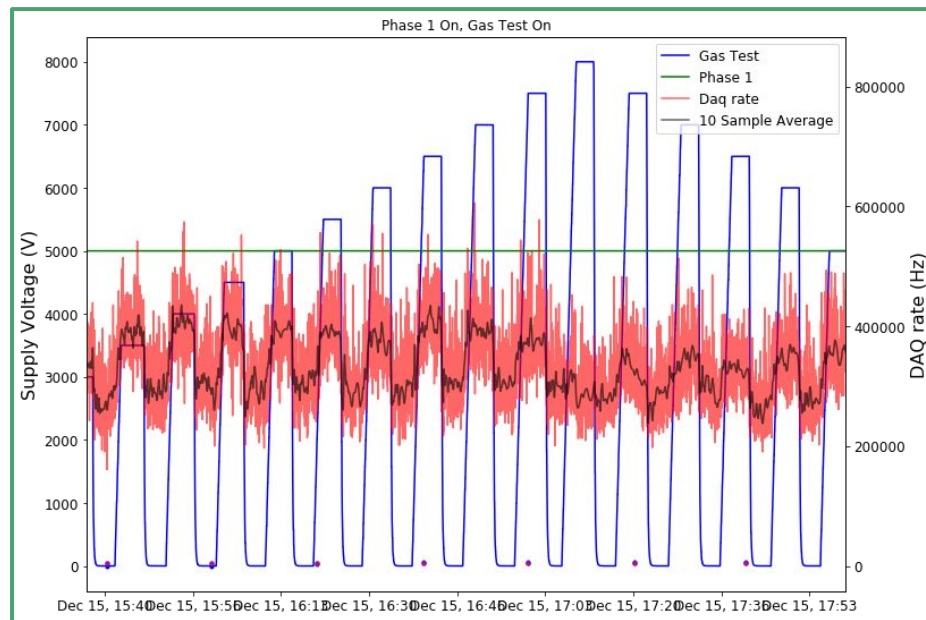
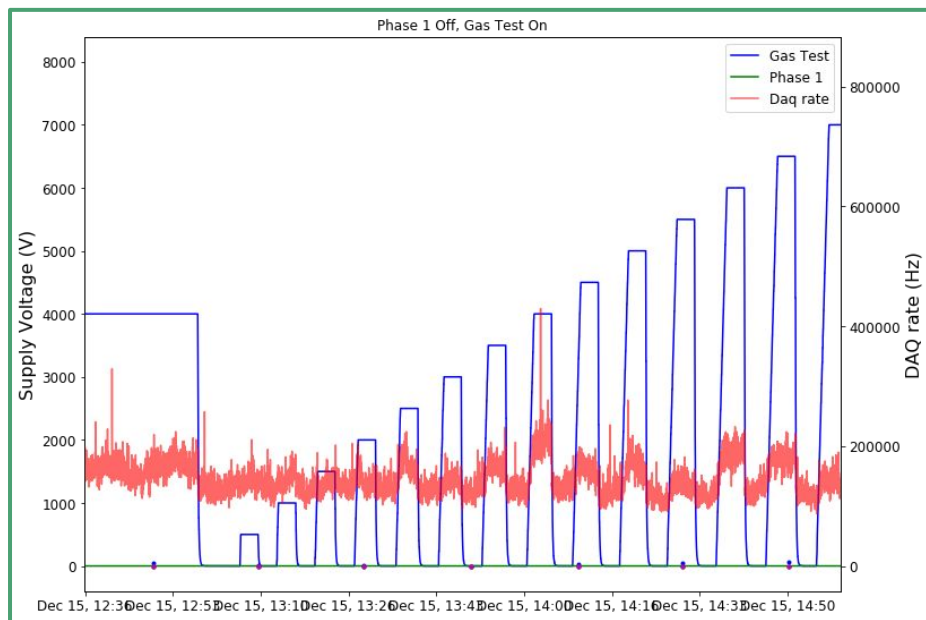
Gas test on vs off



Histogram of the data shown on the left

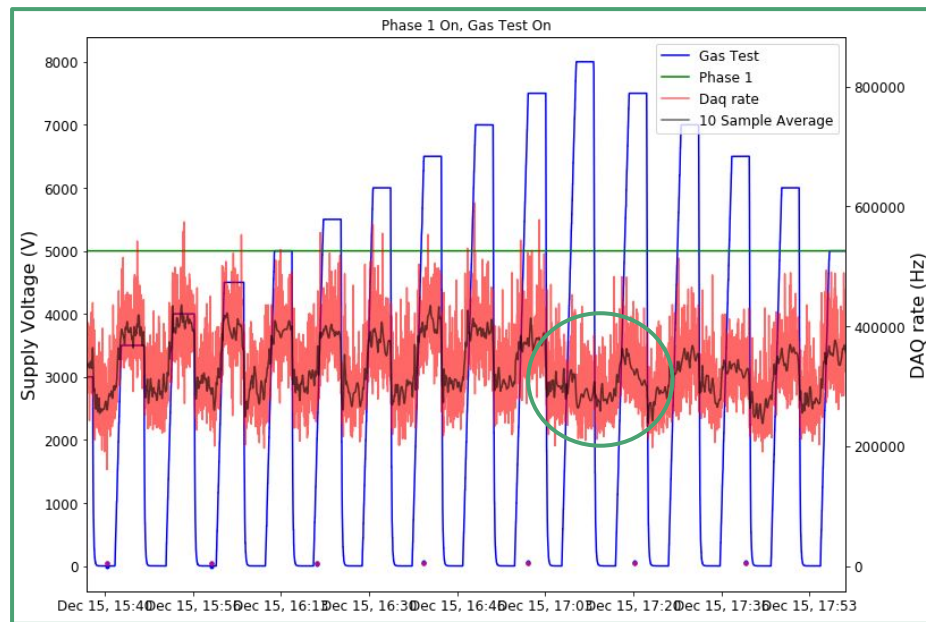
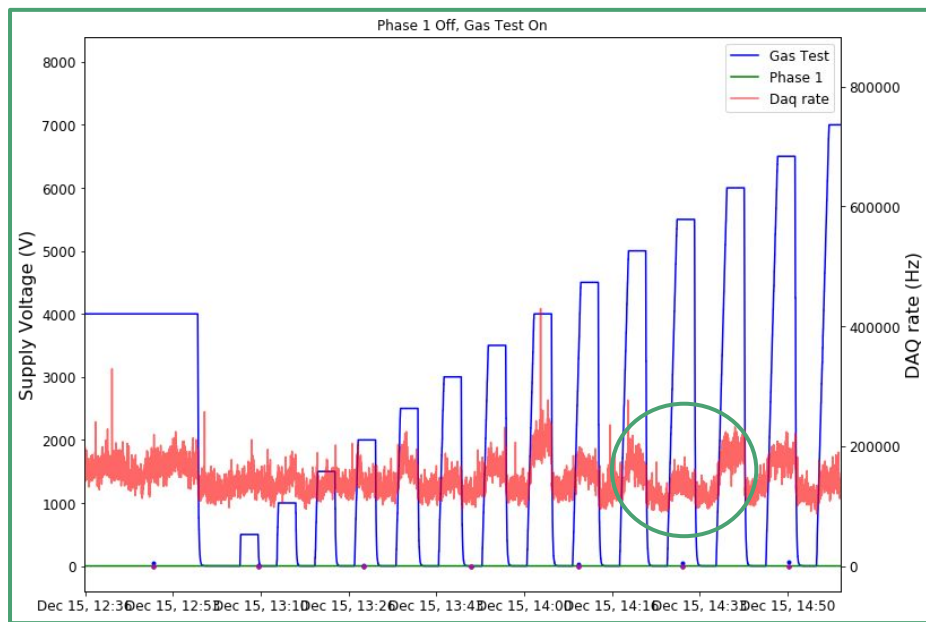


Rates and voltages over time



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

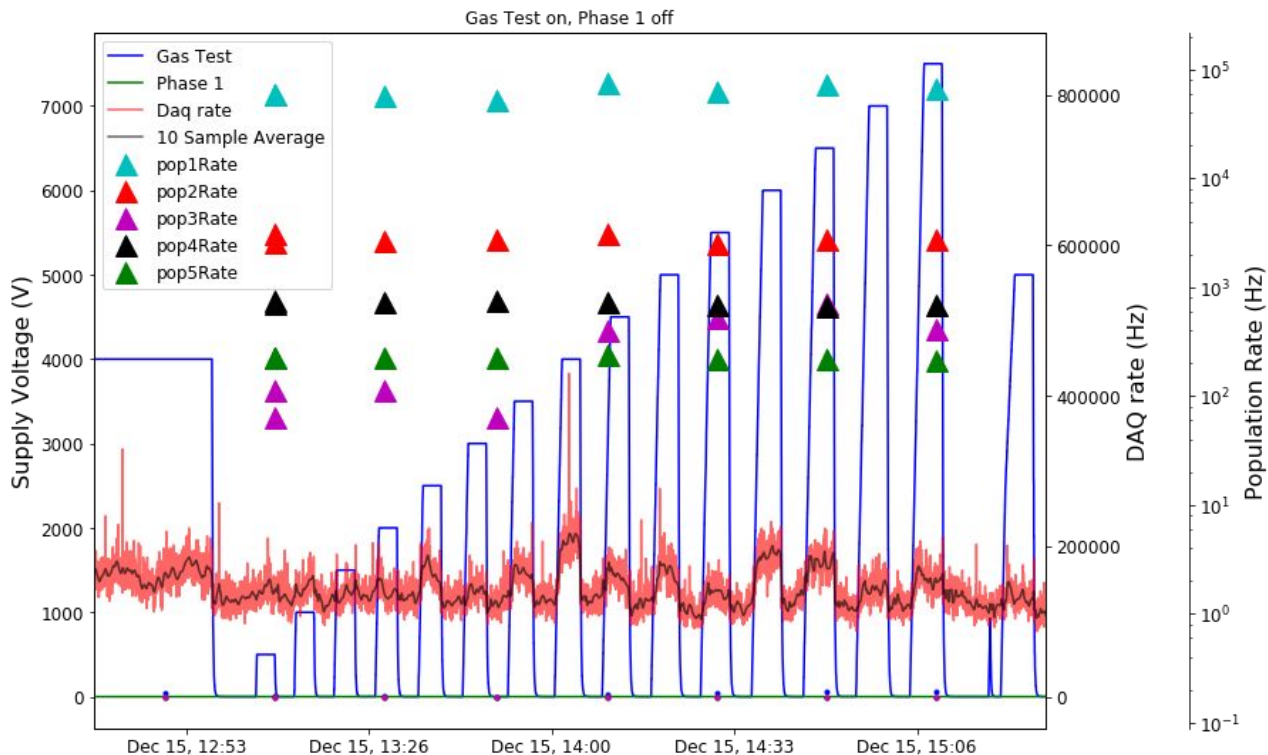
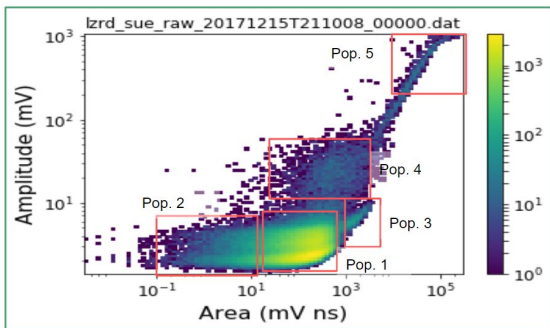
Rates and voltages over time



Not all gas test voltage increases correspond to DAQ rate increases

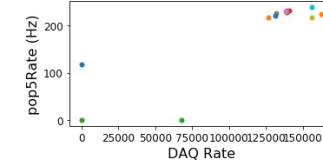
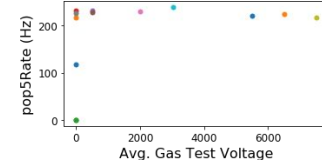
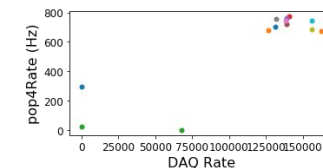
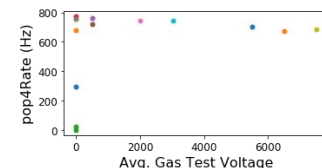
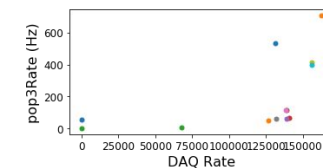
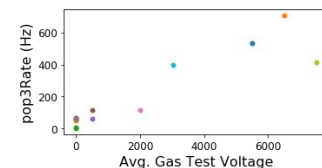
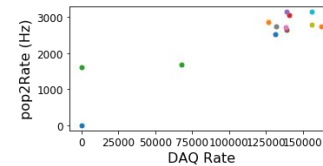
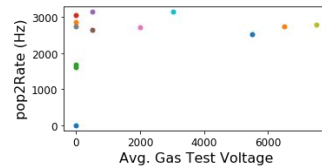
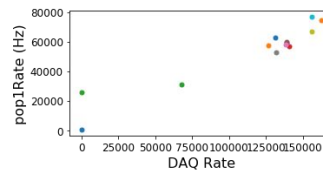
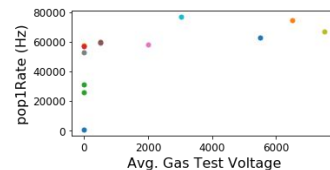
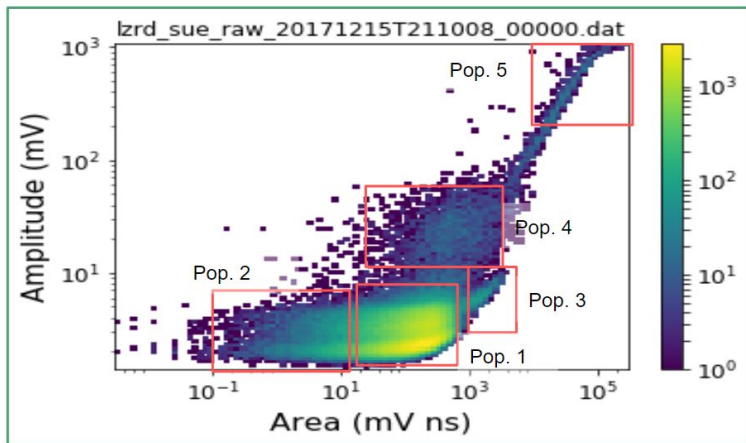
Rates and voltages over time

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

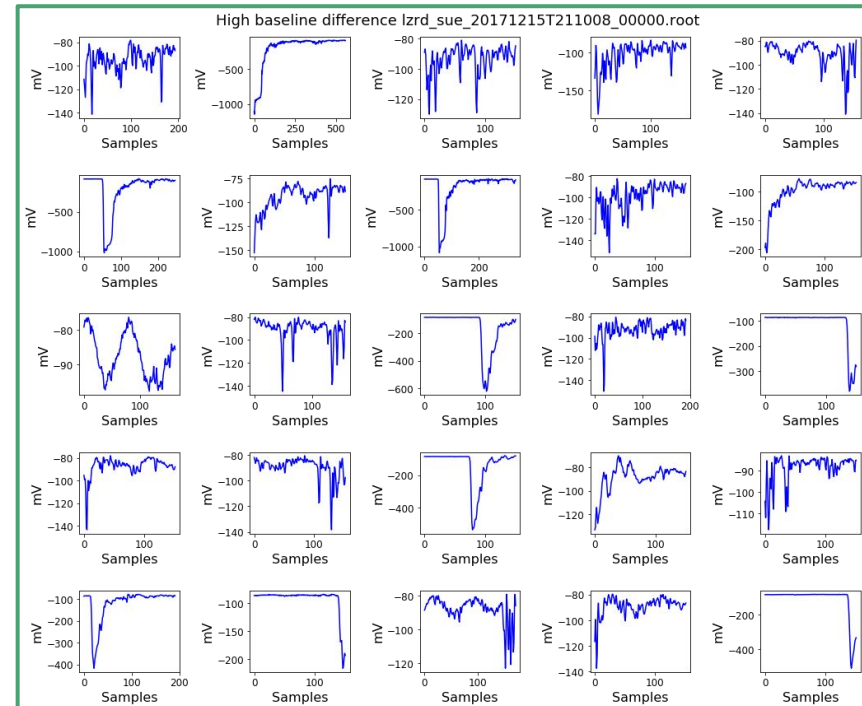
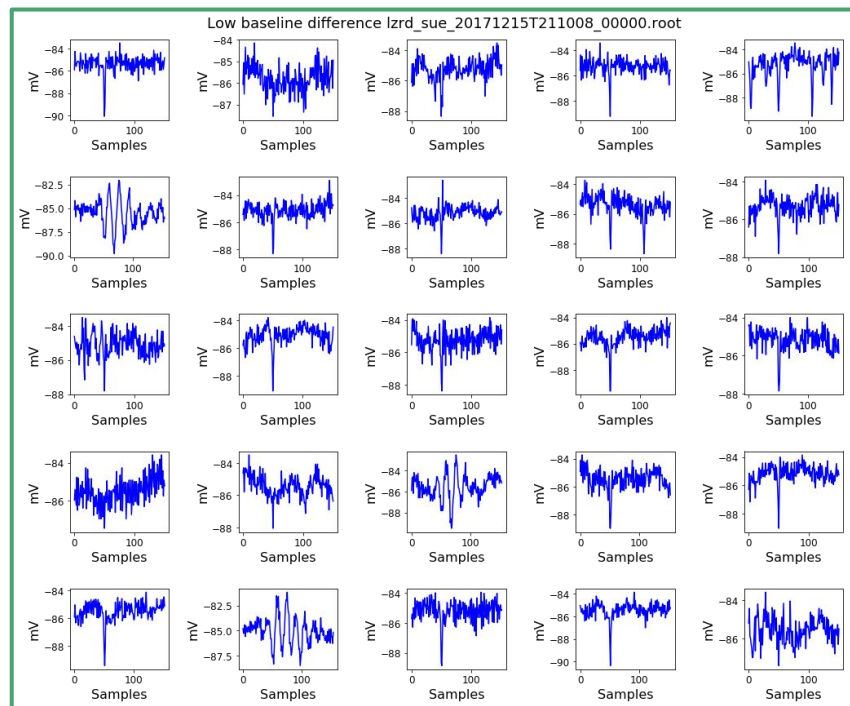
System Test Analysis

- 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

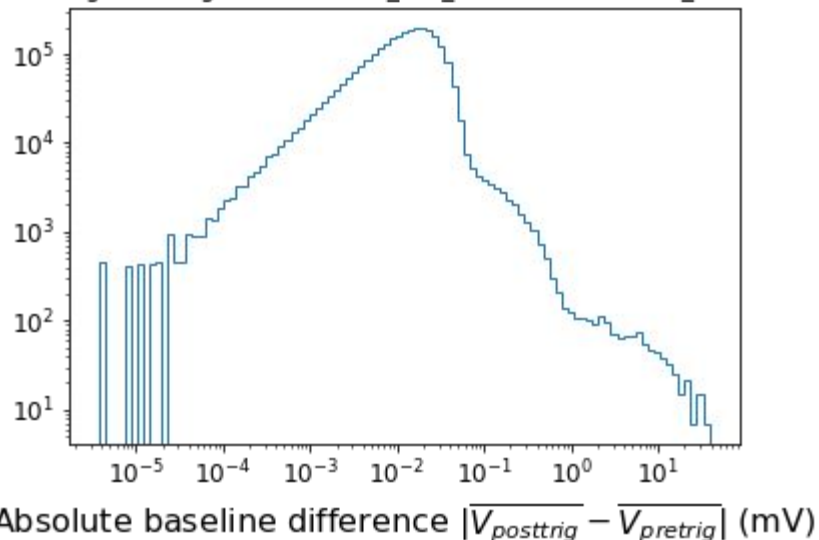
Phase 1 Run 7 baselines

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

PMT on, grids off, gas test on lzrd_sue_20171215T211008_00000.root

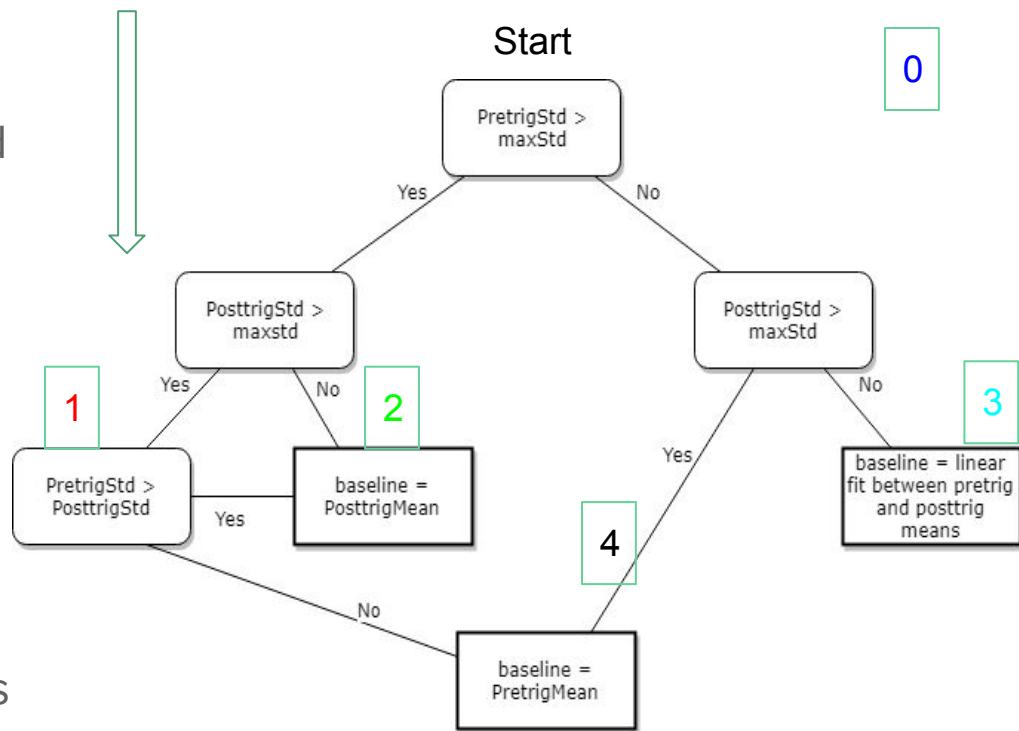


Phase 1 Run 7 Baselines

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)

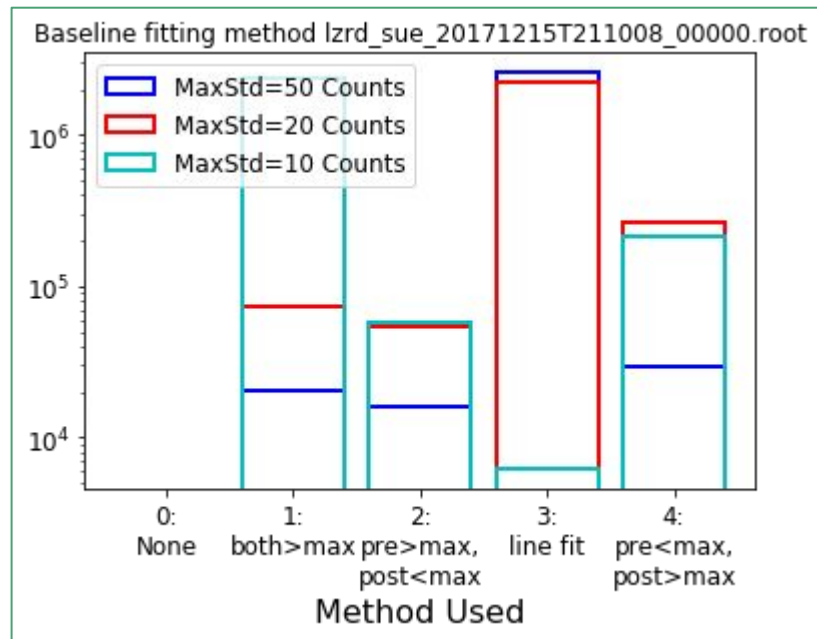
Color matches plots on following slides



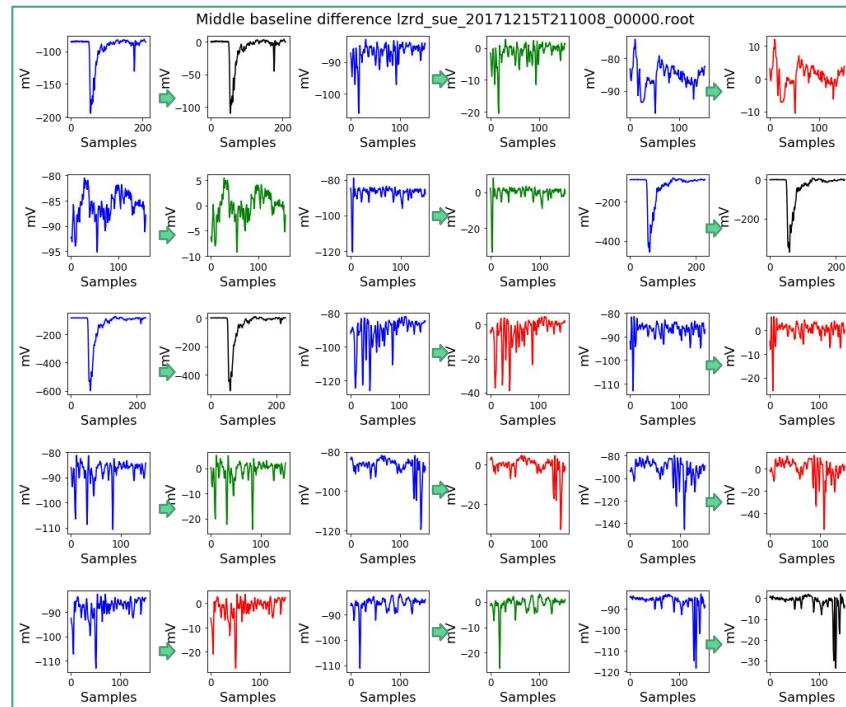
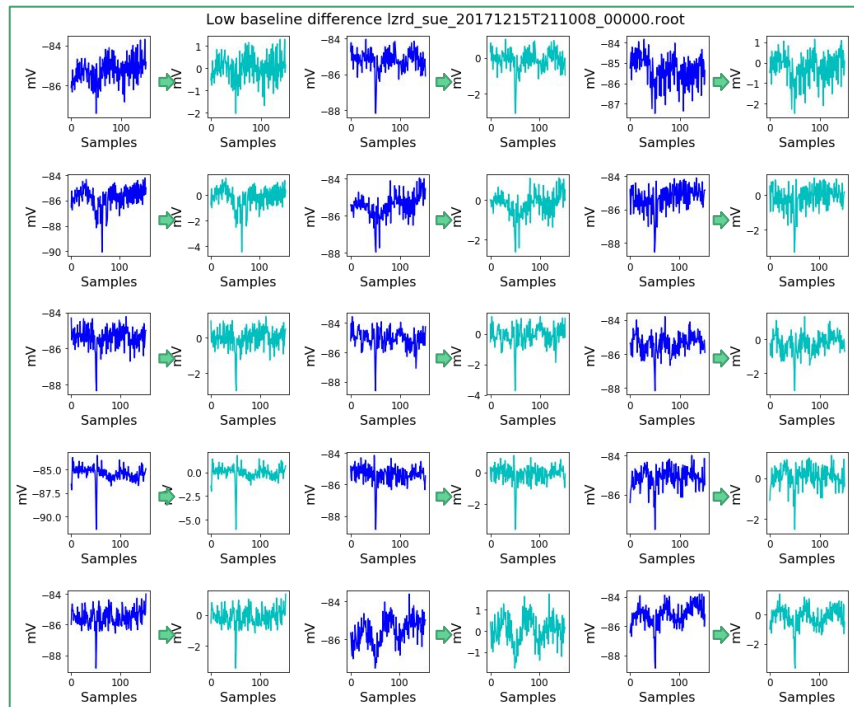
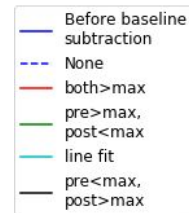
Changing the MaxStd Parameter

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

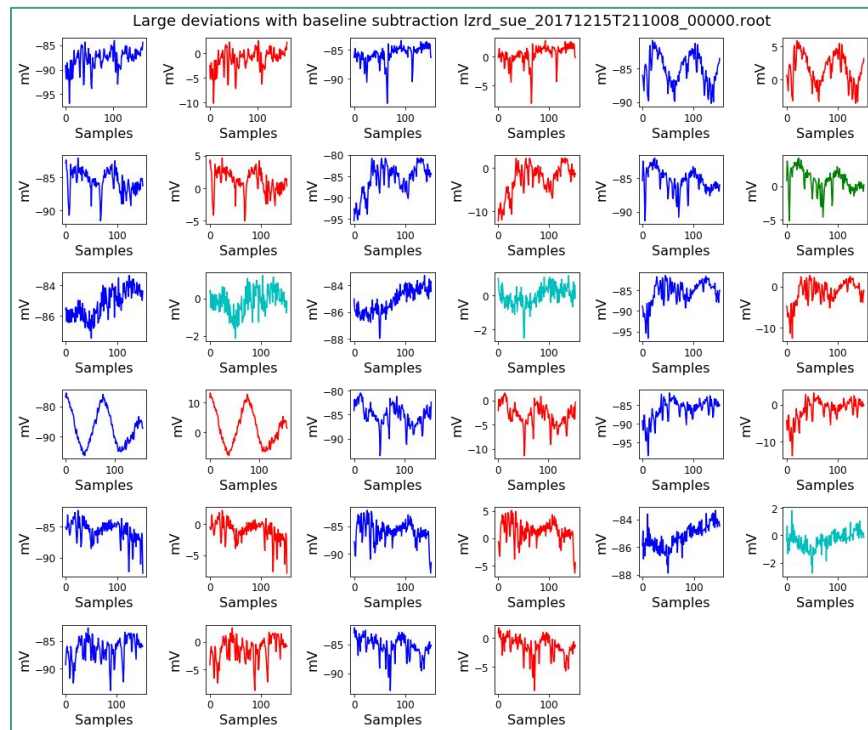
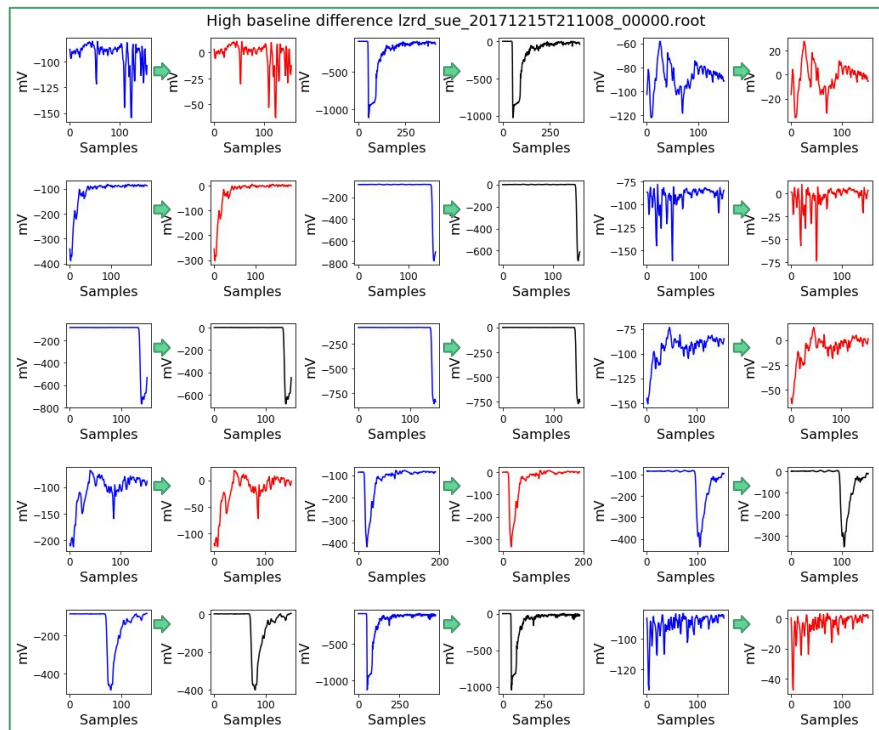
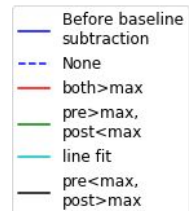
At lower maxStd the method that uses the lower Standard deviation of pre and post trigger are used



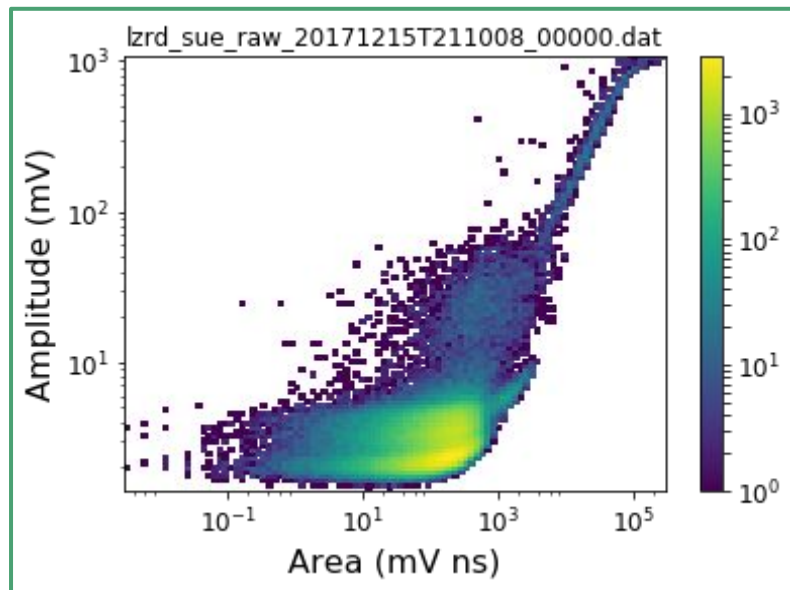
Baseline subtracted waveforms



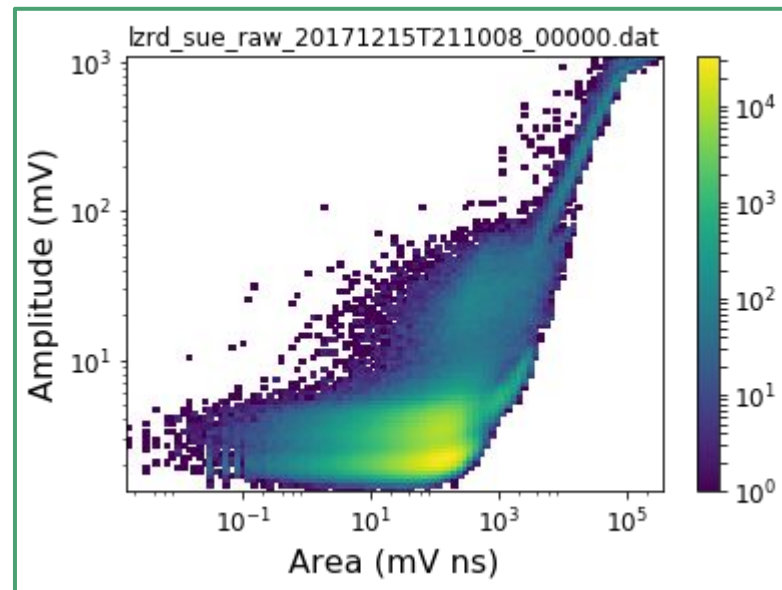
Baseline subtracted waveforms (large differences)



Pulse Amplitude Area comparison



Old method: Just used
pretrigger mean



New method

Next Steps

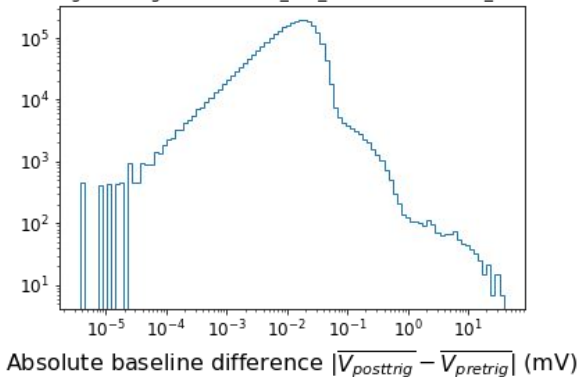
- Confirm with SLAC that this is an acceptable method for computing the baseline
- Implement in LZAP

Phase 1 Run 7 Baselines

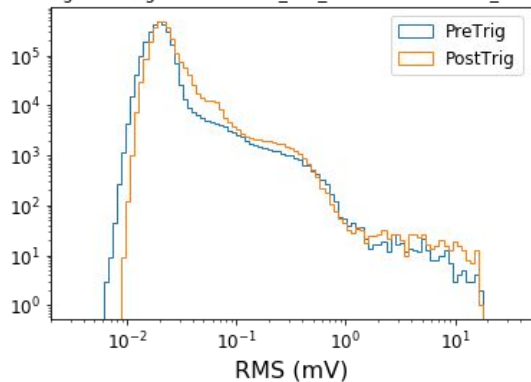
Looking at data after first pass of cuts (on pdsf)

Divide into 3 populations in mean difference and rms

PMT on, grids off, gas test on lzrd_sue_20171215T211008_00000.root



PMT on, grids off, gas test on lzrd_sue_20171215T211008_00000.root



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

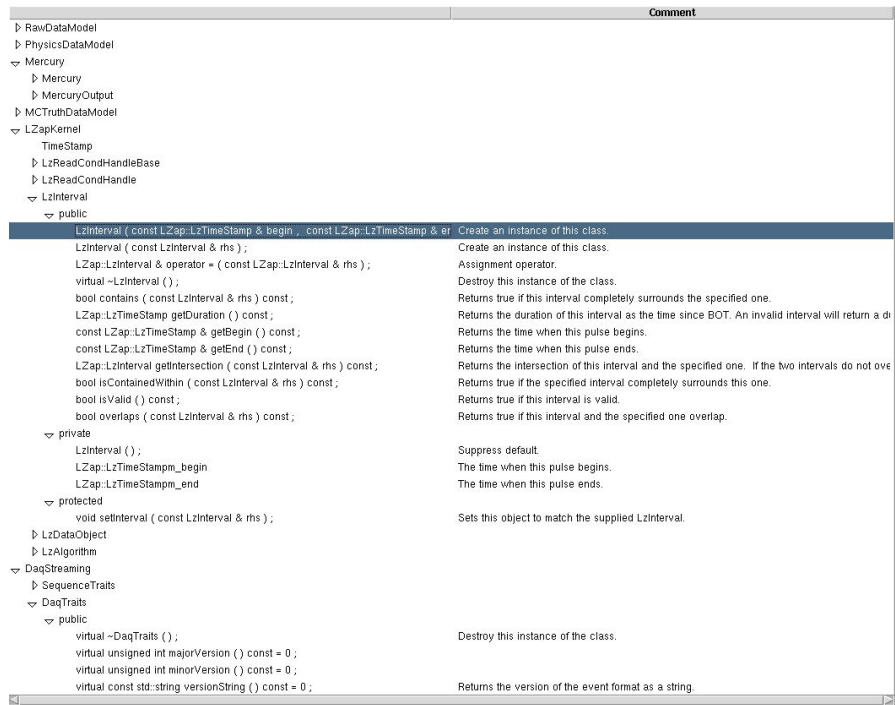
- Make a new POD for the pretrigger and posttrigger of an event
- LZap will calculate RQs for those subPODs just like any other POD
- Use those RQs to adjust the main POD as necessary
- Need to wait on the necessary RQs (POD mean and RMS) to be built into LZap

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



```
Comment
└─ RawDataModel
└─ PhysicsDataModel
└─ Mercury
  └─ Mercury
  └─ MercuryOutput
  └─ MCTruthDataModel
└─ LZapKernel
  └─ TimeStamp
  └─ LzReadCondHandleBase
  └─ LzReadCondHandle
└─ LZInterval
  └─ public
    LzInterval ( const LZap:LzTimeStamp & begin , const LZap:LzTimeStamp & end ) const; Create an instance of this class.
    LzInterval ( const LZInterval & rhs ); Create an instance of this class.
    LZap:LZInterval & operator = ( const LZap:LZInterval & rhs ); Assignment operator.
    virtual ~LZInterval (); Destroy this instance of the class.
    bool contains ( const LZInterval & rhs ) const; Returns true if this interval completely surrounds the specified one.
    LZap:LzTimeStamp getDuration () const; Returns the duration of this interval as the time since BOT. An invalid interval will return a d
    const LZap:LzTimeStamp & getBegin () const; Returns the time when this pulse begins.
    const LZap:LzTimeStamp & getEnd () const; Returns the time when this pulse ends.
    LZap:LZInterval getIntersection ( const LZInterval & rhs ) const; Returns the intersection of this interval and the specified one. If the two intervals do not ov
    bool isContainedWithin ( const LZInterval & rhs ) const; Returns true if the specified interval completely surrounds this one.
    bool isValid () const; Returns true if this interval is valid.
    bool overlaps ( const LZInterval & rhs ) const; Returns true if this interval and the specified one overlap.
  └─ private
    LZInterval (); Suppress default.
    LZap:LzTimeStamp_begin; The time when this pulse begins.
    LZap:LzTimeStamp_end; The time when this pulse ends.
  └─ protected
    void setLzInterval ( const LZInterval & rhs ); Sets this object to match the supplied LZInterval.
└─ LZDataObject
└─ LZAlgorithm
└─ DaqStreaming
  └─ SequenceTraits
  └─ DaqTraits
    └─ public
      virtual ~DaqTraits (); Destroy this instance of the class.
      virtual unsigned int majorVersion () const = 0;
      virtual unsigned int minorVersion () const = 0;
      virtual const std::string versionString () const = 0; Returns the version of the event format as a string.
```

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 half-life 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

$$\begin{aligned}\frac{dN(t)}{dt} &= R - \lambda N(t) \\ \frac{dN(t)}{R - \lambda N(t)} &= dt \\ -\frac{\log(R - \lambda N)}{\lambda} + C_1 &= t \\ N(t) &= \frac{R}{\lambda} + C_2 e^{-\lambda t} \\ N(0) &= 0 \\ N(t) &= \frac{R(1 - e^{-\lambda t})}{\lambda} \\ \lambda &= \frac{\log(2)}{T_{1/2}} = 0.182/\text{day} \\ N(t) &= 5.48224R(1 - e^{-0.182407t})\end{aligned}$$

