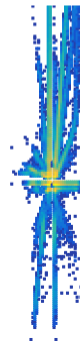
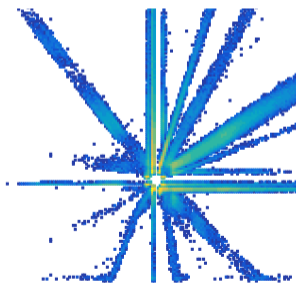
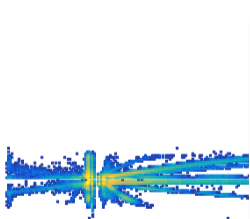


# Charge Analysis Update

Harrison Ritchie-Yates

24<sup>th</sup> of February, 2020



- ▶ This is a continued update on the current state of the charge analysis, to discuss the plots we need for the instrumentation paper, and our plan to make them.
- ▶ For the instrumentation paper, we need:
  - ▶ Amplitude spectra at different voltage settings.
  - ▶ Charge gain vs voltage for different pressures.
  - ▶ Light gain vs charge gain.
- ▶ The following slides show the effect of the current data cleaning cuts, as well as possible additional cuts which could be made to the data.
- ▶ The focus this week is on 1D distributions of the parameters on which we make cuts, and a discussion of whether these cuts are appropriate.

## Data cleaning cuts and cuts on amplitude correlation

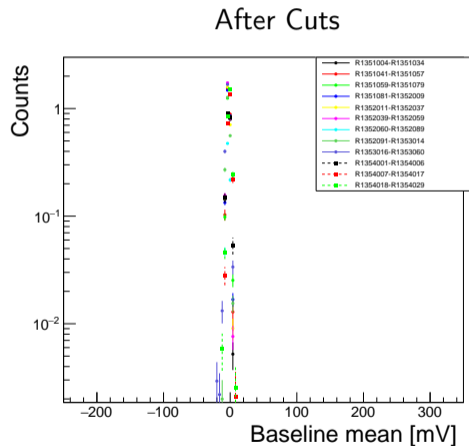
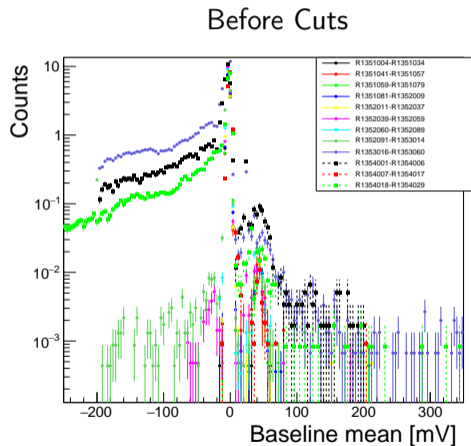
The spectra are cleaned with a series of cuts:

- ▶ Baseline cut: the baseline values of each event must be in a 5 RMS interval around the mean of all baseline values.
- ▶ BaselineRMS cut: the baselineRMS values of each event must be in a 5 RMS interval around the mean of all baselineRMS values.
- ▶ Baseline below threshold cut: the baseline must be smaller than the trigger threshold.
- ▶ Peak over threshold: the peak height must be higher than the trigger threshold.
- ▶ Max amplitude is not too close to the baseline:  $\text{maxvalue} > \text{baseline} * 1.02$  &&  $\text{maxvalue} < \text{baseline} * 0.98$ .
- ▶ Cuts on 2D amplitude spectra:  $\text{AmplitudeAnode3} / \text{AmplitudeAnode2} < 2$  &&  $\text{AmplitudeAnode3} / \text{AmplitudeAnode1} < 1$ .

## The Effect of Cuts

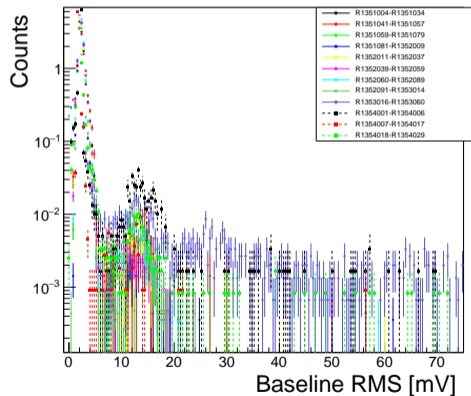
- ▶ In the following, 1D distributions of the parameters on which we make cuts are shown.
- ▶ For the baseline and baseline RMS spectra, on the vertical axis counts are shown, normalised to one event (*i.e.* a 2 s exposure)
- ▶ We compare all background and source runs, grouped by voltage setting.

# Anode 3 baseline spectra (background) after cuts

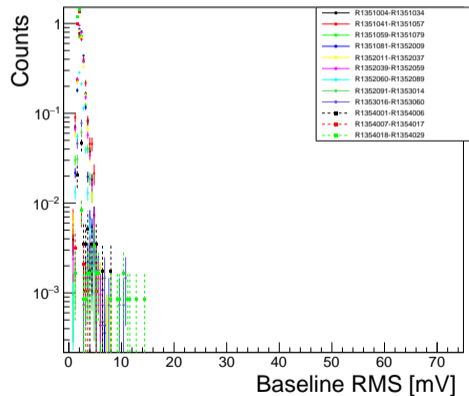


# Anode 3 baseline RMS spectra (background) after cuts

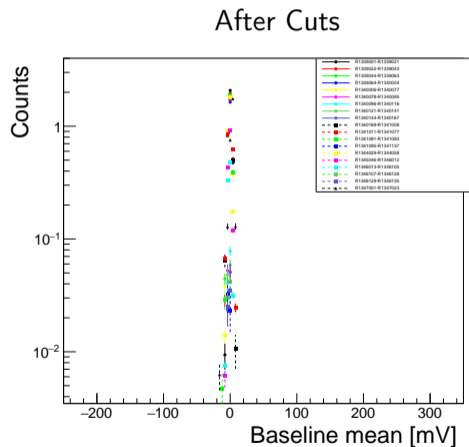
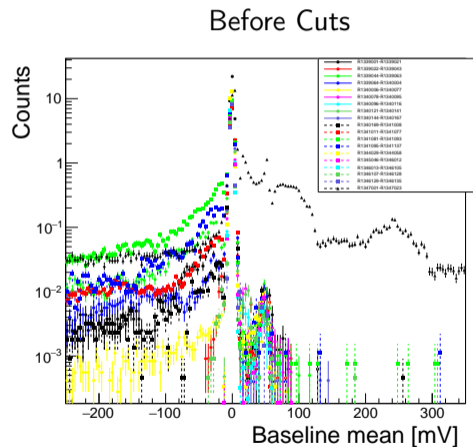
Before Cuts



After Cuts

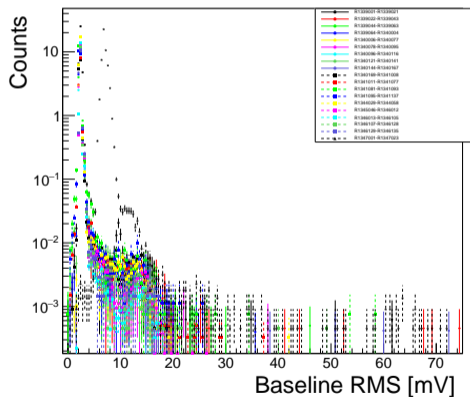


# Anode 3 baseline spectra (Fe55) after cuts

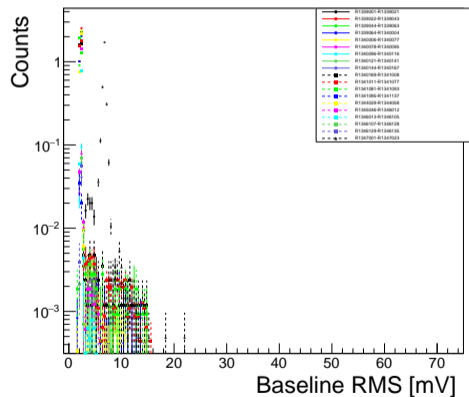


# Anode 3 baseline RMS spectra (Fe55) after cuts

Before Cuts



After Cuts



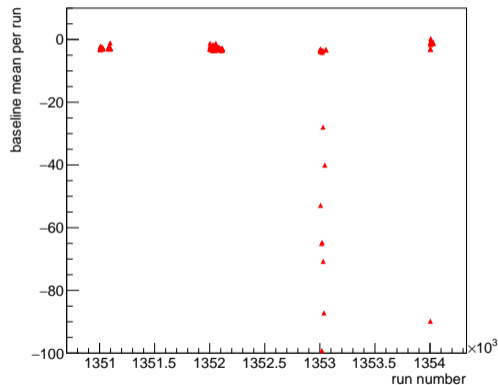


## The Effect of Cuts

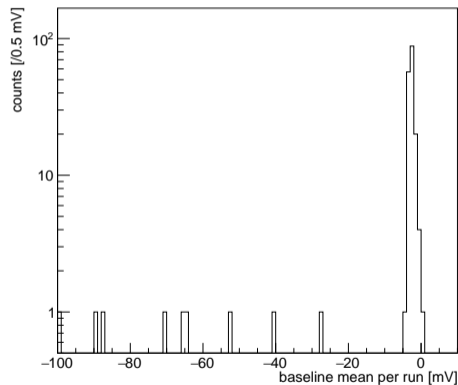
- ▶ For each run, the mean baseline mean and mean baseline RMS over the course of the run are calculated, and these values are used to make additional cleaning cuts.
- ▶ In the following, the mean baseline-mean and mean baseline-RMS for each run, and 1D distributions of these calculated values for all runs are shown.

# The mean of all baseline means over a run (background)

Mean baseline-mean by run

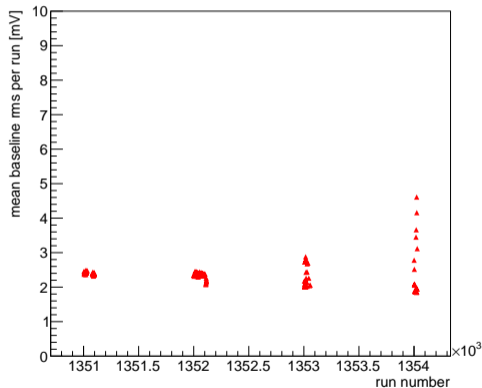


Mean baseline-mean by run

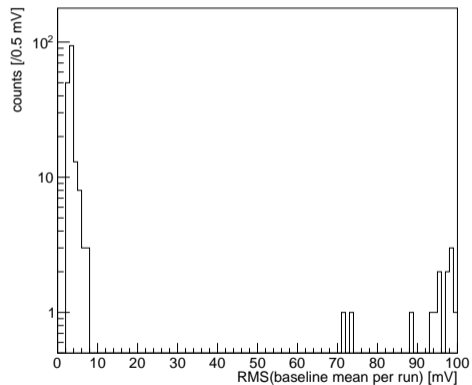


# The mean of all baseline RMSs over a run (background)

Mean baseline-RMS by run

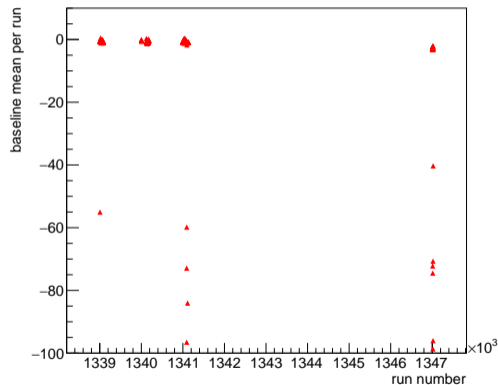


Mean baseline-RMS by run

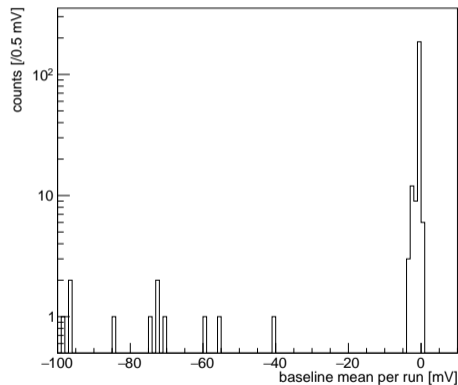


# The mean of all baseline means over a run (Fe55)

Mean baseline-mean by run

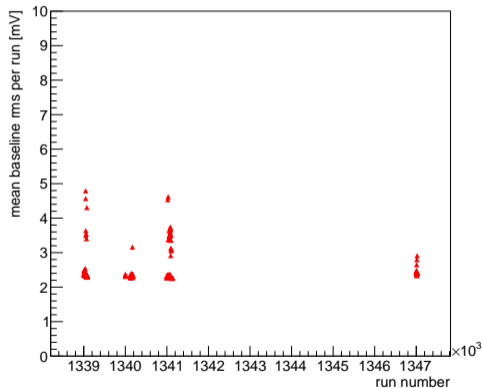


Mean baseline-mean by run

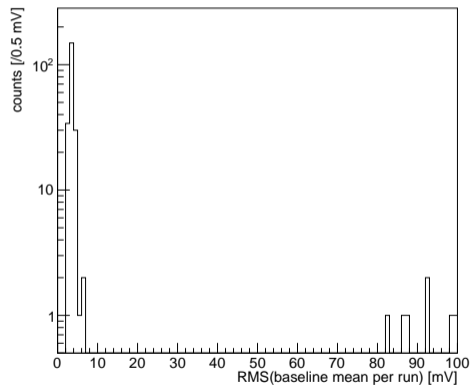


# The mean of all baseline RMSs over a run (Fe55)

Mean baseline-RMS by run



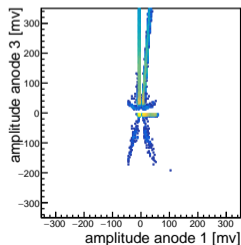
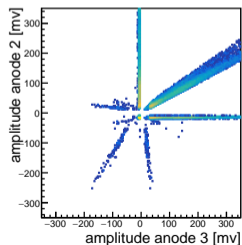
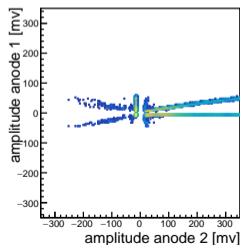
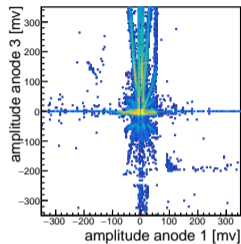
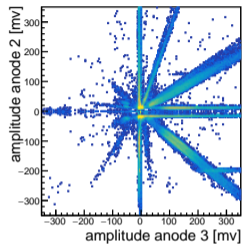
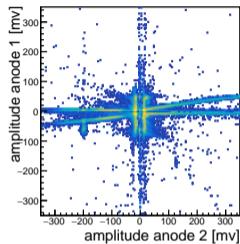
Mean baseline-RMS by run



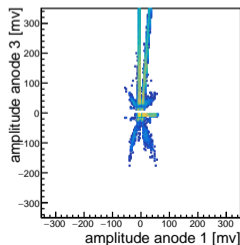
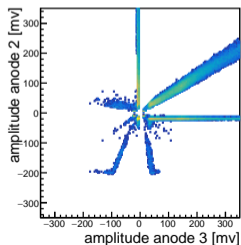
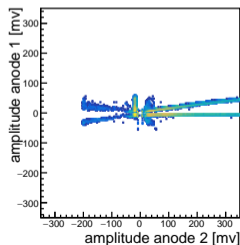
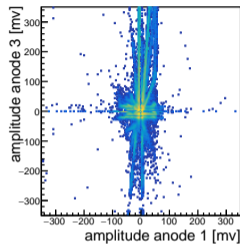
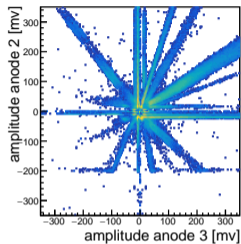
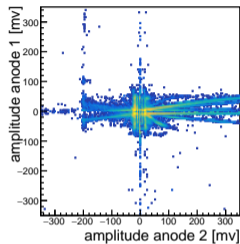
## The Effect of Cuts

- ▶ Cuts are made on the correlations between anodes.
- ▶ In the following, 2D correlation plots of amplitude between anodes are shown before and after data cleaning.

# Anode vs anode correlations (background) before and after cuts



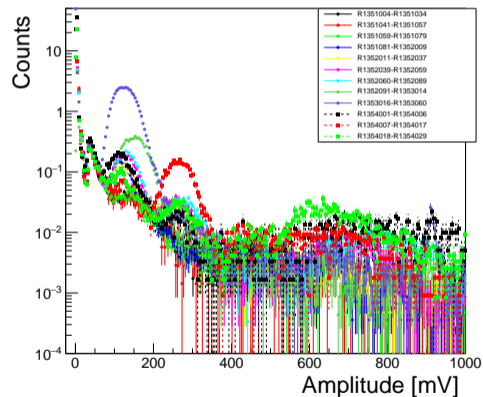
# Anode vs anode correlations (with Fe55 source) before and after cuts



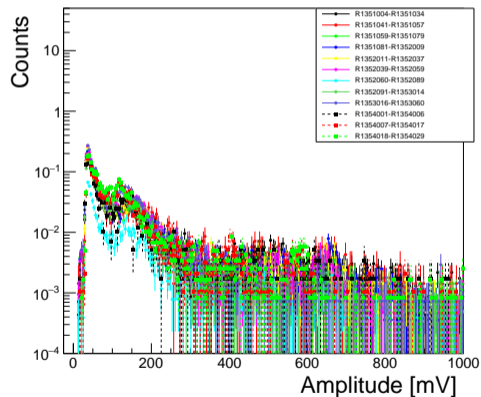


# Anode 3 spectra (background) before and after cuts

Before Cuts

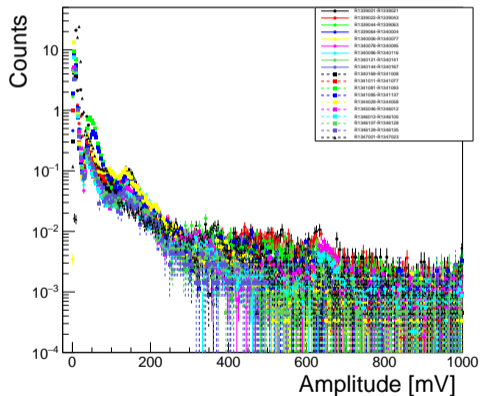


After Cuts

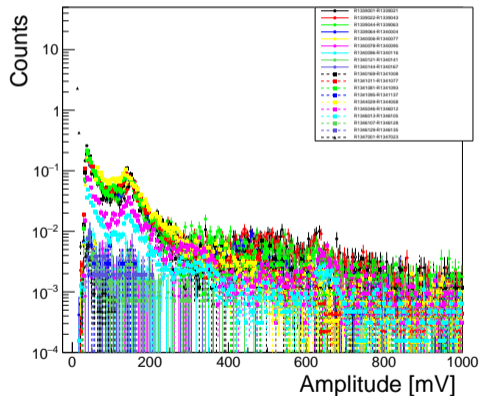


# Anode 3 spectra (Fe55) before and after cuts

Before Cuts



After Cuts



## The Effect of Cuts (Work to Continue)

- ▶ Include spectra of peak height (not just amplitude) before and after cleaning.
- ▶ Examples of waveforms rejected/ accepted by each cut.
- ▶ Refine cleaning cuts based on this study.

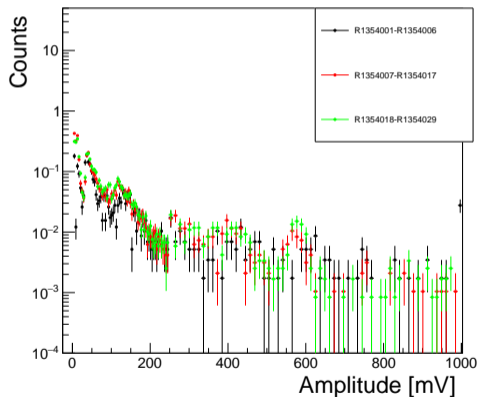
## Re-binning Amplitude Spectra for Higher Amplitudes

- ▶ The amplitude spectra are not so clear at higher amplitudes.
- ▶ In the following, anode 3 amplitude spectra are shown with a wider binning for higher amplitudes.
- ▶ The following spectra have a bin width of 4 mV for amplitudes below 250 mV, and 12 mV for amplitudes above 250 mV.
- ▶ Background and Fe55 data taken at the three highest voltages settings are compared, as well as background and Fe55 data taken at the same voltage settings.
- ▶ Currently, there is still an issue with scaling which needs to be fixed.

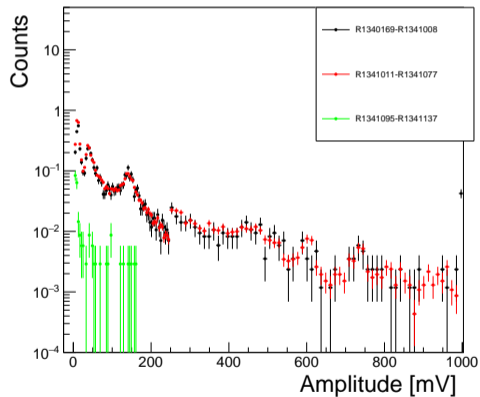


# Anode 3 spectra re-binned for higher amplitudes

## Background

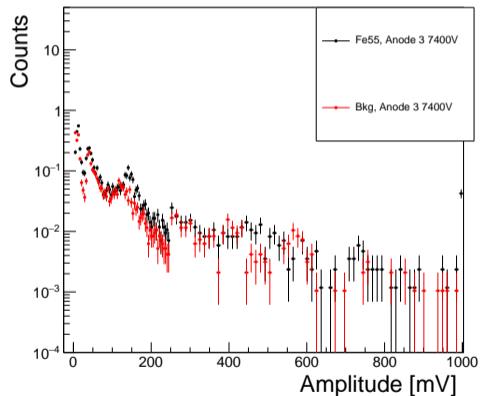


## Fe55 Source

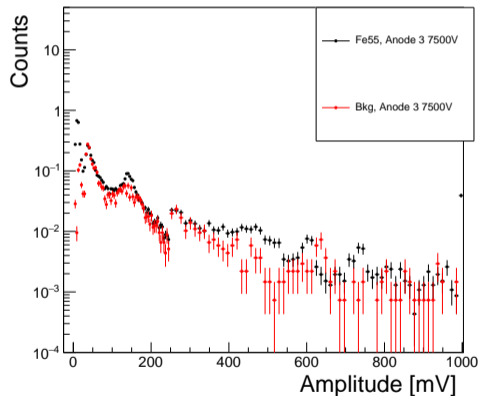


# Anode 3 spectra background vs signal

## Anode 3 7400V



## Anode 3 7500V



## Re-binning Amplitude Spectra for Higher Amplitudes

- ▶ Currently, there is still an issue with scaling which needs to be fixed.
- ▶ We should soon be able to look at background subtracted amplitude spectra for Fe55 data.
- ▶ It might be most clear to look at the spectra for each setting individually.



## Goals for next week

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- ▶ Background subtracted amplitude spectra for Fe55 data.
- ▶ Triptychs of waveforms removed by each cut.
- ▶ Continuing to search for gas settings in which we see signals in both light and charge analysis. Looking at spectra of individual runs for 4 barA argon data.
- ▶ Refined data cleaning cuts based on 1D distributions of cut parameters and discussion in this meeting.
- ▶ Cuts on rise time and fall time.

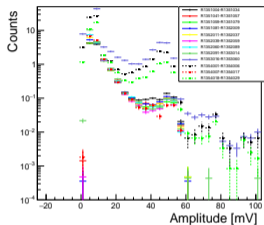
# Extra Slides

## Amplitude spectra

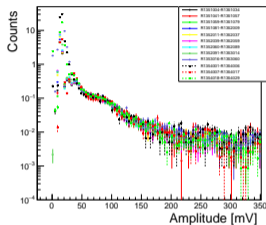
- ▶ In the following amplitude spectra for the three anodes and different cuts are shown
- ▶ On the vertical axis counts are shown, normalised to one event (*i.e.* a 2 s exposure)
- ▶ We compare all background and source runs, grouped by voltage setting.

# Amplitude spectra for all background runs before cuts

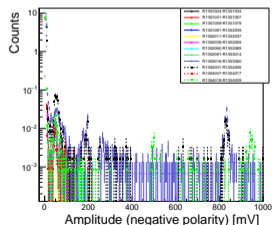
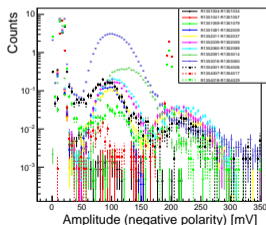
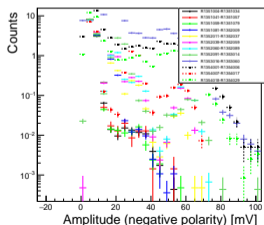
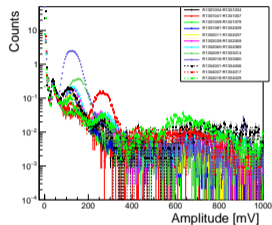
## Anode 1



## Anode 2

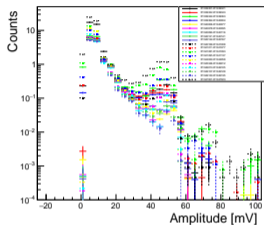


## Anode 3

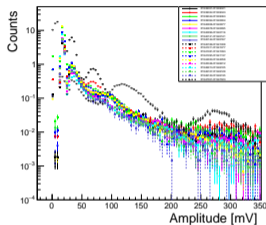


# Amplitude spectra for all runs with Fe55 source before cuts

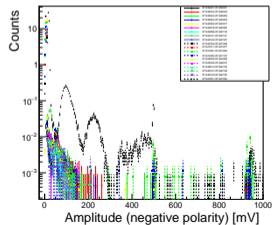
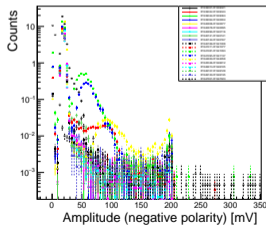
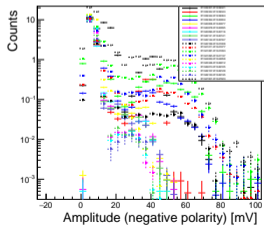
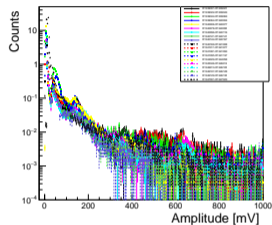
## Anode 1



## Anode 2



## Anode 3



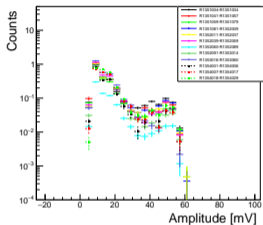
## Data cleaning cuts and cuts on amplitude correlation

The spectra are cleaned with a series of cuts:

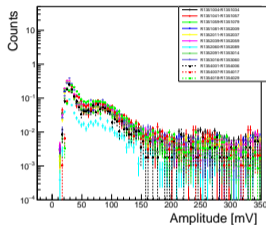
- ▶ Baseline cut: the baseline values of each event must be in a 5 RMS interval around the mean of all baseline values.
- ▶ BaselineRMS cut: the baselineRMS values of each event must be in a 5 RMS interval around the mean of all baselineRMS values.
- ▶ Baseline below threshold cut: the baseline must be smaller than the trigger threshold.
- ▶ Peak over threshold: the peak height must be higher than the trigger threshold.
- ▶ Max amplitude is not too close to the baseline:  $\text{maxvalue} > \text{baseline} * 1.02$  &&  $\text{maxvalue} < \text{baseline} * 0.98$ .
- ▶ Cuts on 2D amplitude spectra:  $\text{AmplitudeAnode3} / \text{AmplitudeAnode2} > 2$  &&  $\text{AmplitudeAnode3} / \text{AmplitudeAnode1} > 1$ .

# Amplitude spectra for all background runs after cleaning cuts

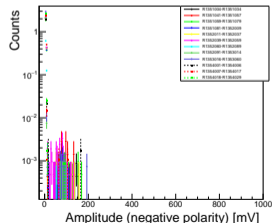
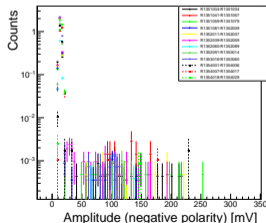
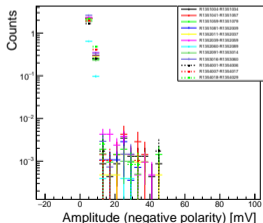
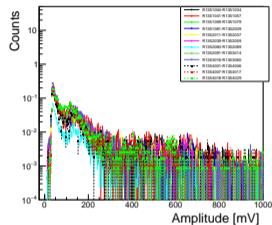
## Anode 1



## Anode 2

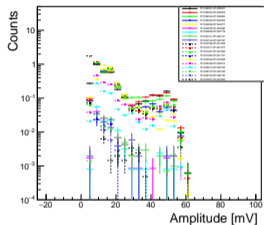


## Anode 3

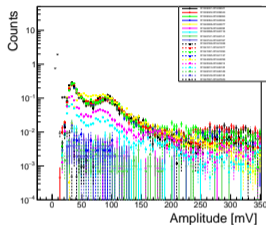


# Amplitude spectra for all runs with Fe55 source after cleaning cuts

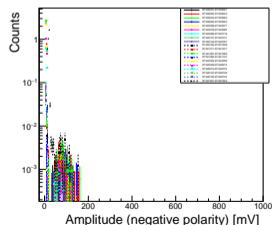
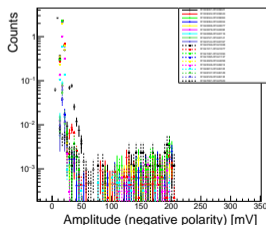
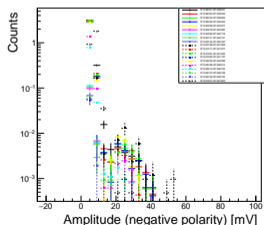
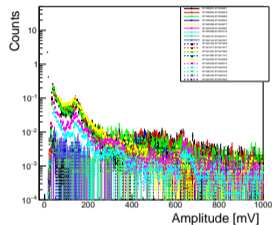
## Anode 1



## Anode 2

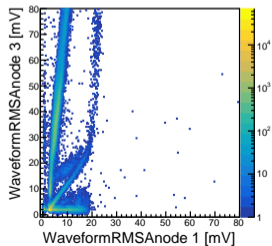
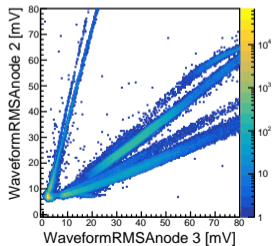
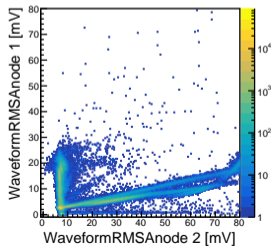
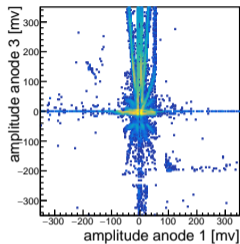
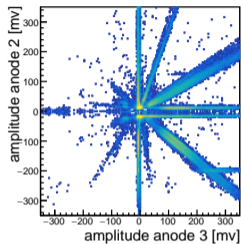
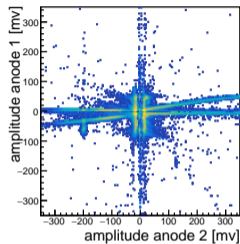


## Anode 3

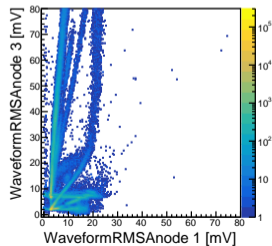
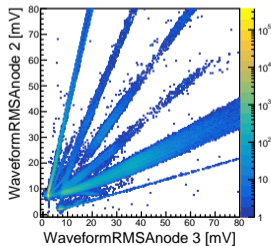
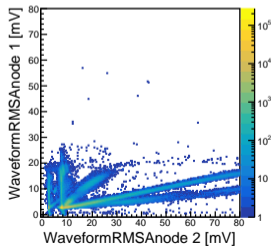
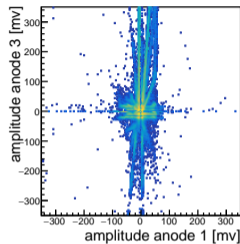
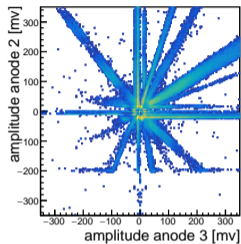
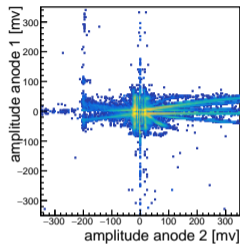




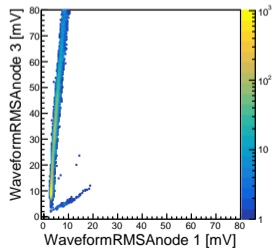
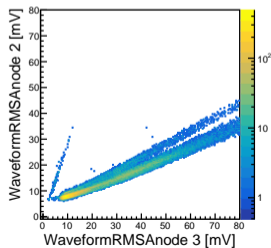
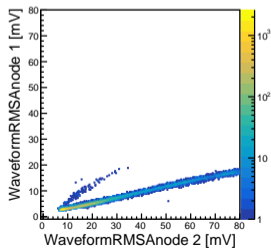
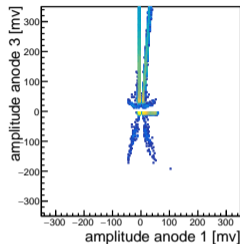
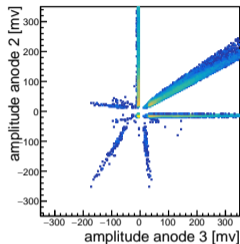
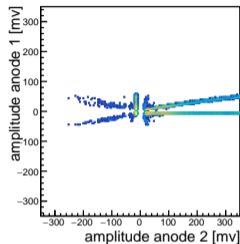
# Anode vs anode correlations (background) before cuts



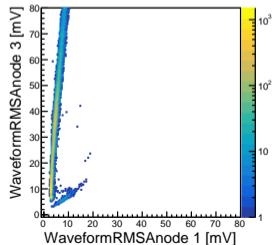
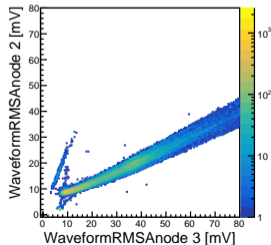
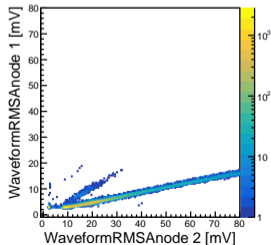
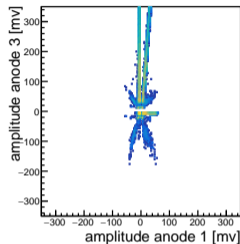
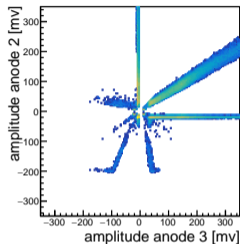
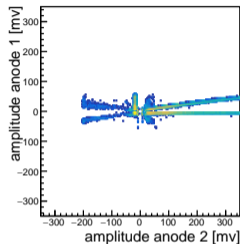
# Anode vs anode correlations (with Fe55 source) before cuts



# Anode vs anode correlations (background) after cuts

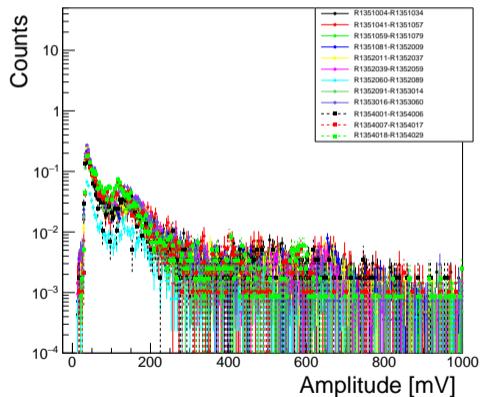


# Anode vs anode correlations (with Fe55 source) after cuts

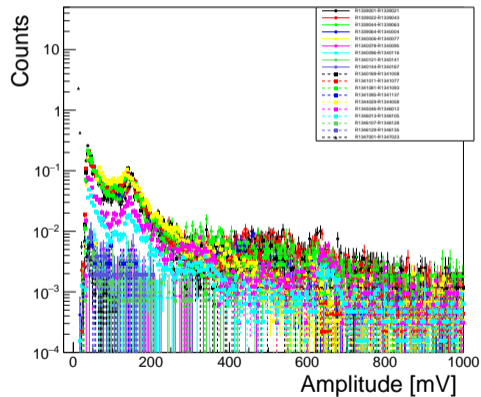


# Anode 3 spectra after cuts

## Background



## Fe55 Source

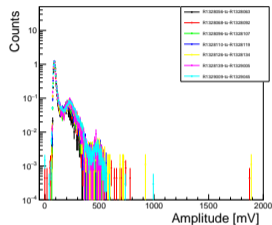


## Further possible cuts

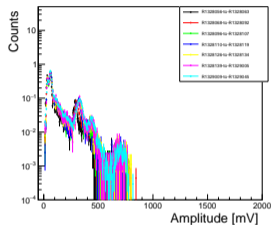
- ▶ Cuts to remove all negative waveforms ( $\text{AmplitudeAnode}_i < \text{NegAmplitudeAnode}_i$ , or  $\text{NegAmplitudeAnode}_i < x$ , where  $x$  is a value just above the noise level).
- ▶ Cuts on rise time, this should remove sparks and some additional negative waveforms (this is now implemented but hasn't yet been tested).
- ▶ Waveform fits.
- ▶ Baseline fits.
- ▶ Cuts on waveform integrals.
- ▶ We can also look further into individual background runs where we still see unwanted peaks.

# Amplitude spectra with Am241 and Cs137 at 4barA ArCO2 99%/1%

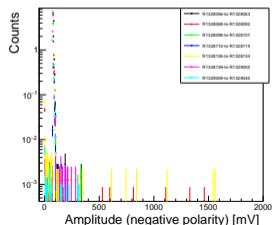
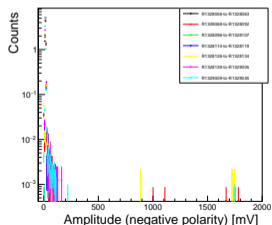
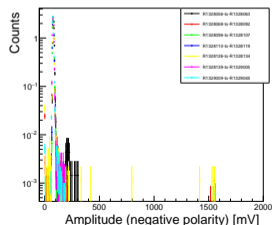
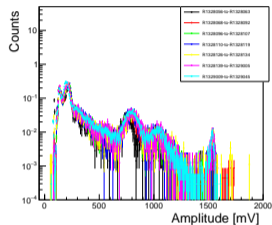
## Anode 1



## Anode 2



## Anode 3



## What we know/ plan for the future

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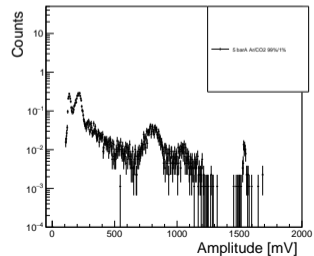
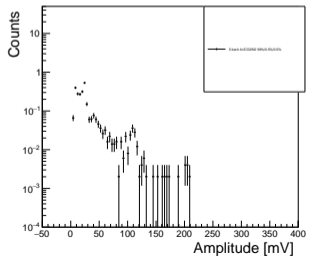
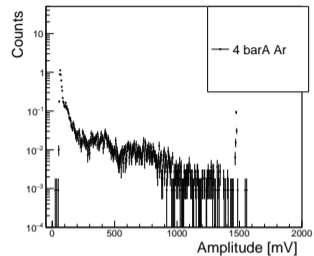
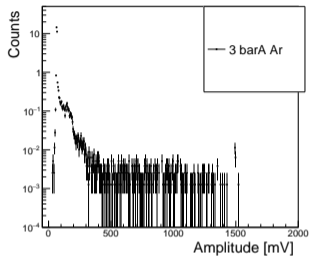
- ▶ There is still more we can do to clean the Fe55 data, but is looking increasingly likely that we do not see the iron source in the charge data.
- ▶ The data taken with Am241 and Cs137 looks more promising, however it is hard to discern the origin of the peaks in the amplitude spectra for this data.
- ▶ Team CCD have also seen gain increasing with voltage in the Am241 data.
- ▶ It is in the interest of both charge and light analysis to take more data using only the Am241 sources.



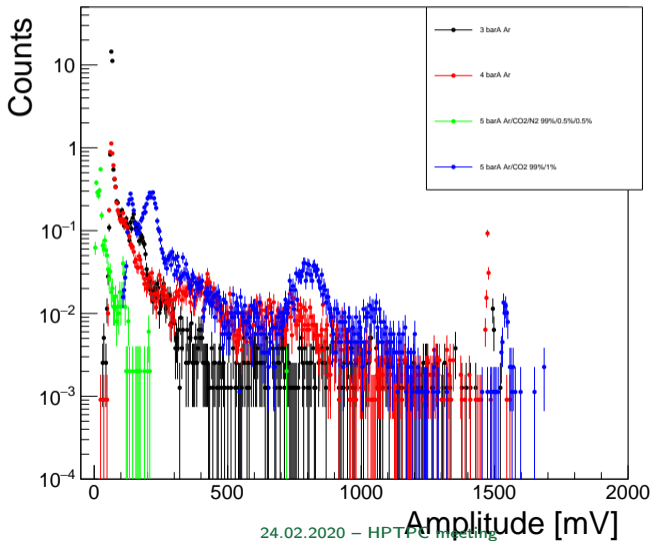
## Plan to take more data

- ▶ The plan is to run using only one Am241 source.
- ▶ Possible settings which have been discussed are 3 barA & 5 barA pure argon, and 3 barA & 5 barA argon/CO2 98%/2%.
- ▶ Looking at data taken in 2018, pure argon does not seem useful for the charge analysis, but we have so far only seen light gain in pure argon.
- ▶ For the charge analysis, the most promising gas settings are 4 and 5 barA argon with 0.5 - 2% CO2.
- ▶ If we are able to see light gain in these settings, then I would propose focusing on them.
- ▶ If not, then we may need to take data in both pure argon and Ar/CO2, but we might not be able to make a charge gain vs light gain plot.
- ▶ We already have background data at some of these settings, but it is often quite limited. If the new data looks good then we should consider taking more. The current background data was taken at settings to match data taken at CERN.

# Comparing different gas mixes (2018 Am241 Cs137 data)



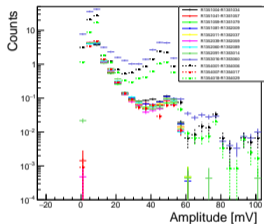
# Comparing different gas mixes (2018 Am241 Cs137 data)



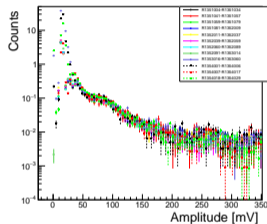
# Extra Slides

# Amplitude spectra for all background runs with cuts on amplitude correlation

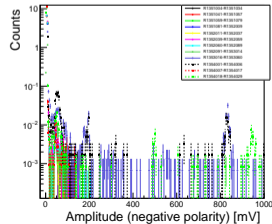
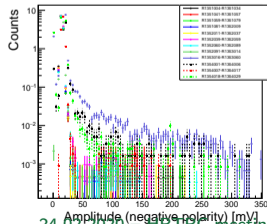
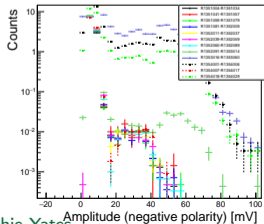
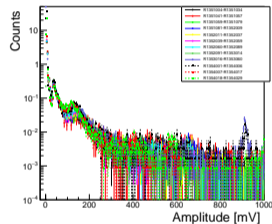
## Anode 1



## Anode 2

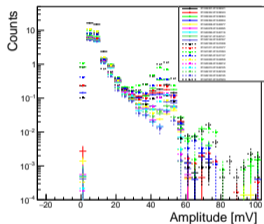


## Anode 3

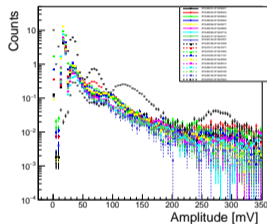


# Amplitude spectra for all runs with Fe55 source with cuts on amplitude correlation

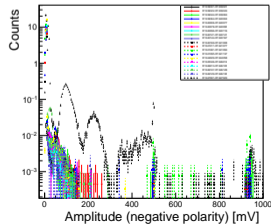
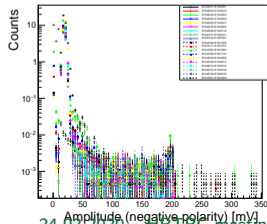
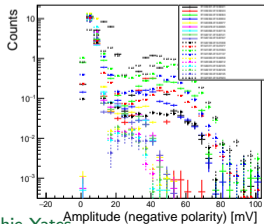
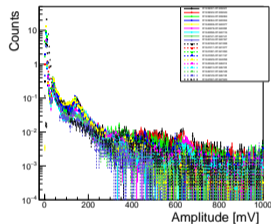
## Anode 1



## Anode 2

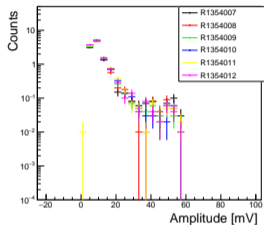


## Anode 3

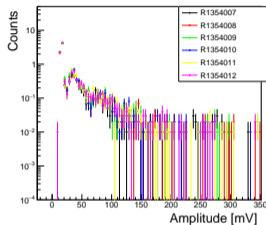


# Amplitude Spectra for runs with Anode 3 voltage 7400V R1354007-12

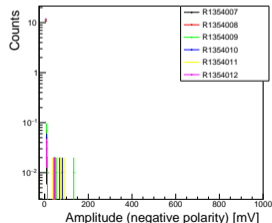
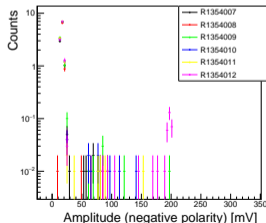
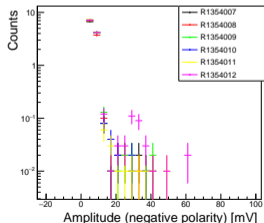
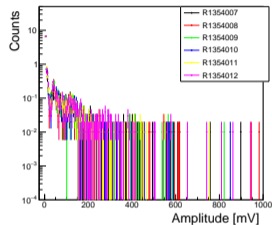
## Anode 1



## Anode 2

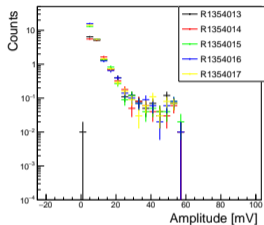


## Anode 3

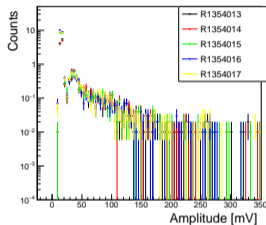


# Amplitude Spectra for runs with Anode 3 voltage 7400V R1354013-17

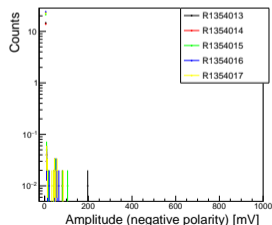
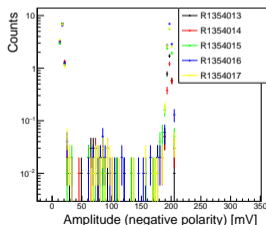
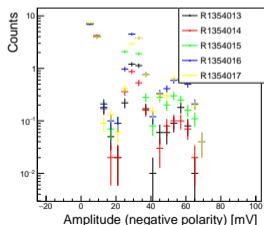
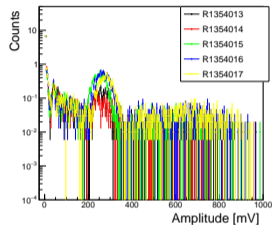
## Anode 1



## Anode 2



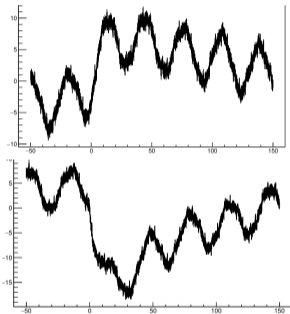
## Anode 3



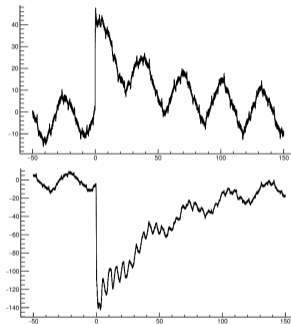


# Waveforms

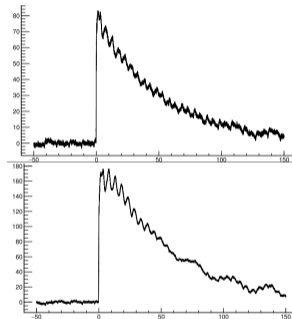
## Anode 1



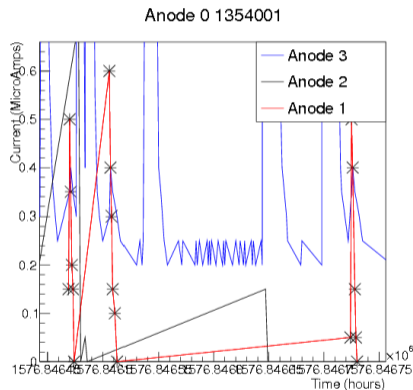
## Anode 2



## Anode 3



# Plots of current draw to investigate sparking

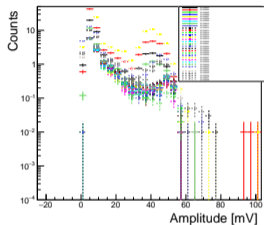


Peak?	~Peak Position (mV)	Any sparking
Y	140	N
Y	140	N
Y	140	Y
Y	140	N
Y	140	Y
Y	140	N
Y	140	N
Y	140	Y
Y	140	N
Y	140	N
Y	140	M
Y	140	Y
Y	140	N
Y	140	N
Y	140	N

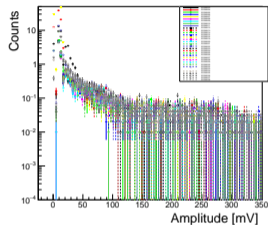
<https://docs.google.com/spreadsheets/d/1MR1Cwc-YCCCvKVTRg-pu3rC3uQaDxg-FlgERDr8tzpY/edit?range=A500#gid=1523035026>

# Running in Air

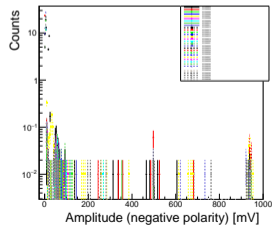
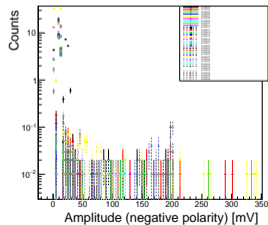
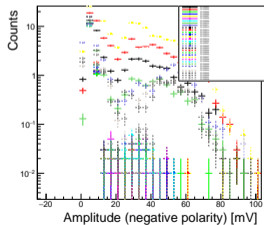
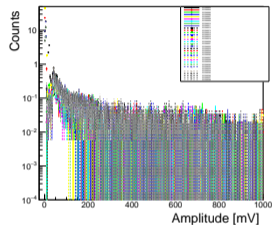
## Anode 1



## Anode 2



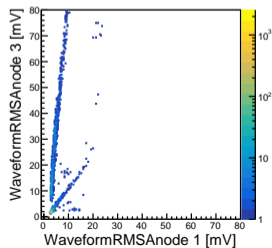
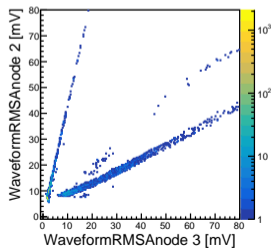
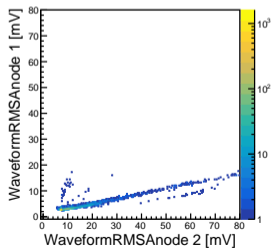
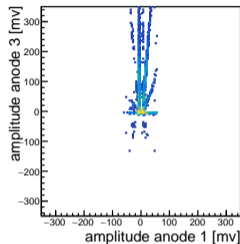
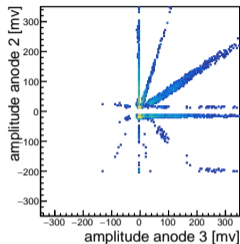
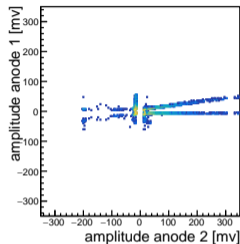
## Anode 3



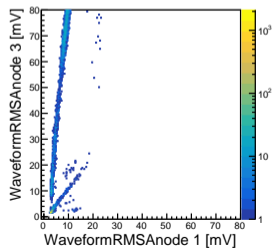
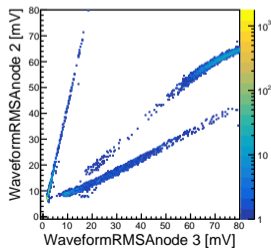
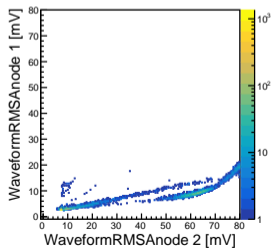
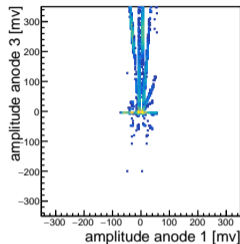
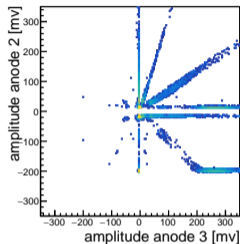
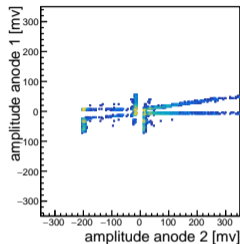
## Anode vs anode correlations (amplitude and RMS)

We calculate a positive amplitude ( $\text{AmplitudeAnode}_i$ ) value and a negative amplitude value ( $\text{NegAmplitudeAnode}_i$ ) for each waveform. Both are based on the same calculated baseline and then on the most negative (positive) value subtracted by that baseline. When correlating the amplitude values between waveforms of 2 anodes, we have four pairs to create - *i.e.* ( $\text{AmplitudeAnode}_i, \text{AmplitudeAnode}_j$ ), ( $\text{AmplitudeAnode}_i, \text{NegAmplitudeAnode}_j$ ), ( $\text{NegAmplitudeAnode}_i, \text{AmplitudeAnode}_j$ ), ( $\text{NegAmplitudeAnode}_i, \text{NegAmplitudeAnode}_j$ ). These pairs fill the respective quadrant of the plots below, where  $n\text{NegAmplitudeAnodes}$  are drawn as negative values on the amplitude axis.

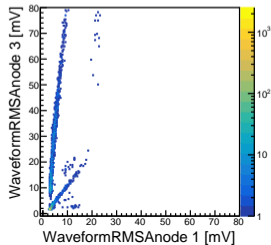
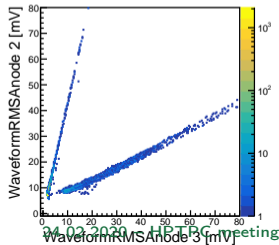
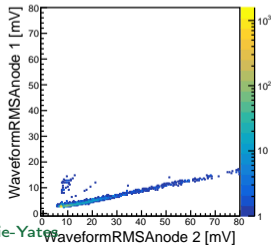
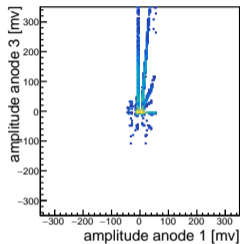
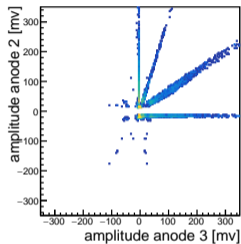
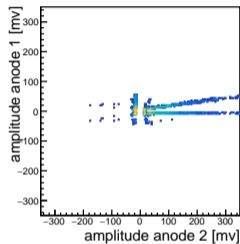
# Anode vs anode correlations (amplitude and RMS) R1354007-12



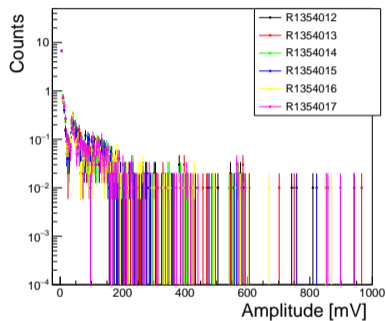
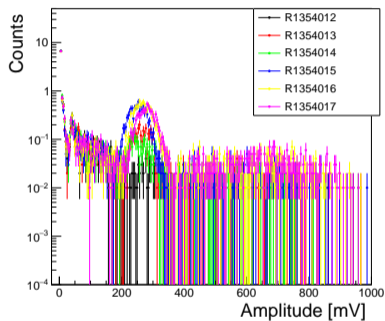
# Anode vs anode correlations (amplitude and RMS) R1354013-17



# Anode vs anode correlations (amplitude and RMS) R1354012-17 With Cuts

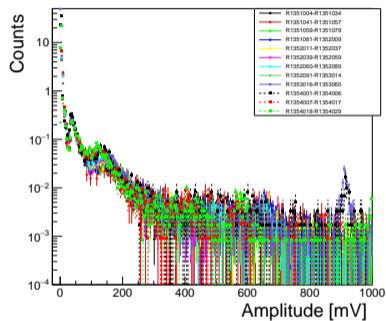
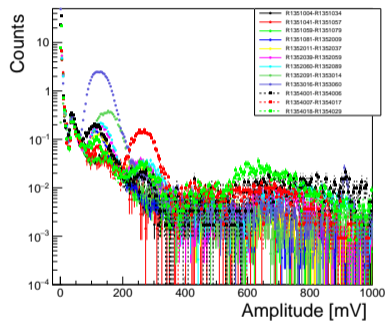


# Anode 3 spectra after cuts on anode correlation(R1354012-R1354017)

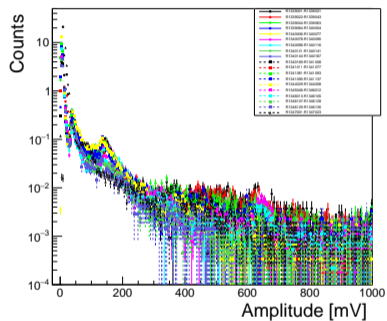
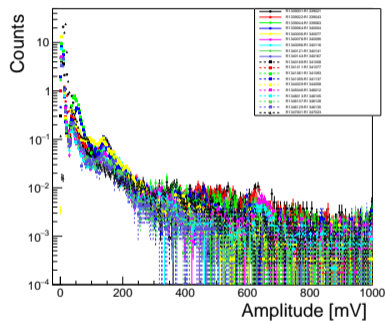




# Anode 3 spectra after cuts on anode correlation (all background runs)



# Anode 3 spectra after cuts on anode correlation (all Signal runs)



## What we know/ plan for the future

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- ▶ The extra peaks do not appear to be associated with sparking.
- ▶ We can reduce or remove the extra peaks with cuts on negative signals on anode 2.
- ▶ The peaks do not appear when when running in air, so they seem to be from signals originating inside the gas volume.
- ▶ Some of the spectra for runs taken with the Fe55 source have extra peaks, which can be removed with the same cut, leaving only a single peak.
- ▶ Following discussion in the HPTPC meeting, our focus is now on removing these peaks from the spectra.
- ▶ Ed and I are working on defining a set of cuts to remove them.