

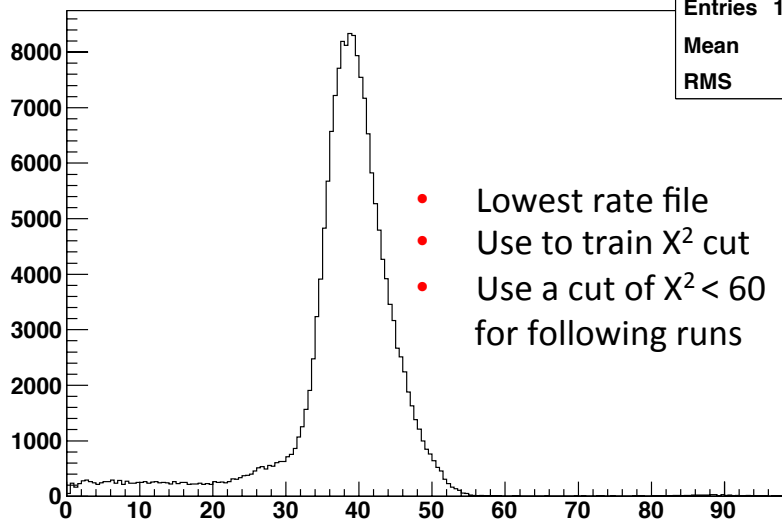
Clatterbridge 24th – 25th November 2016 Waveform Data Analysis

Anastasia Basharina-Freshville
(University College London)

Thursday 24th of November 2016: Rate Tests

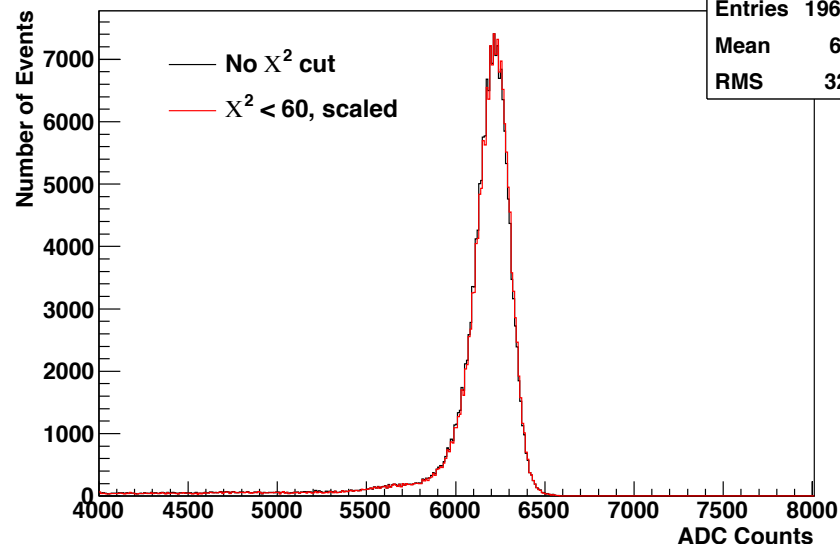
Run 003: Rate - 30 kHz, No Absorbers

Chi²/NDF of Fit to Waveform



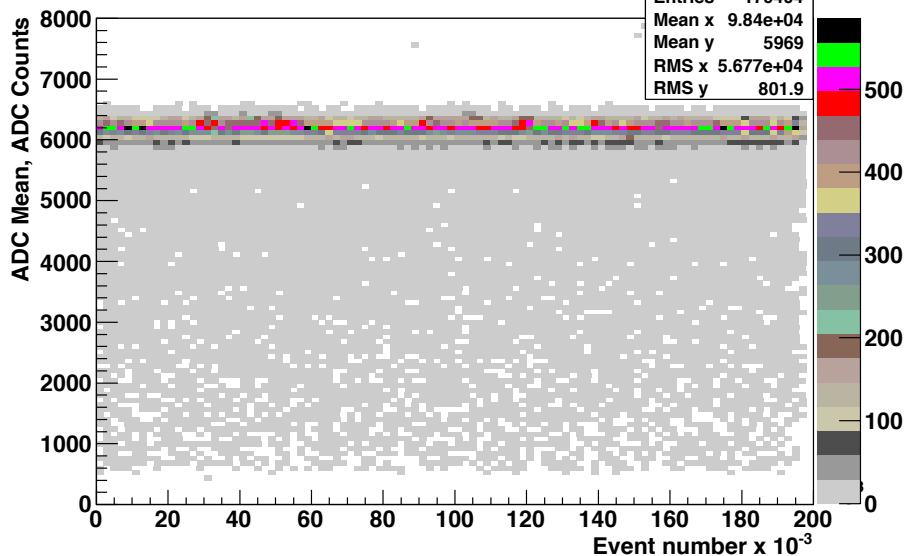
chi2	
Entries	196609
Mean	37.74
RMS	8.79

Run 003, 30 kHz: Histogram Integral for a 150 ns Gate



integral_150ns_adc	
Entries	196609
Mean	6115
RMS	328.1

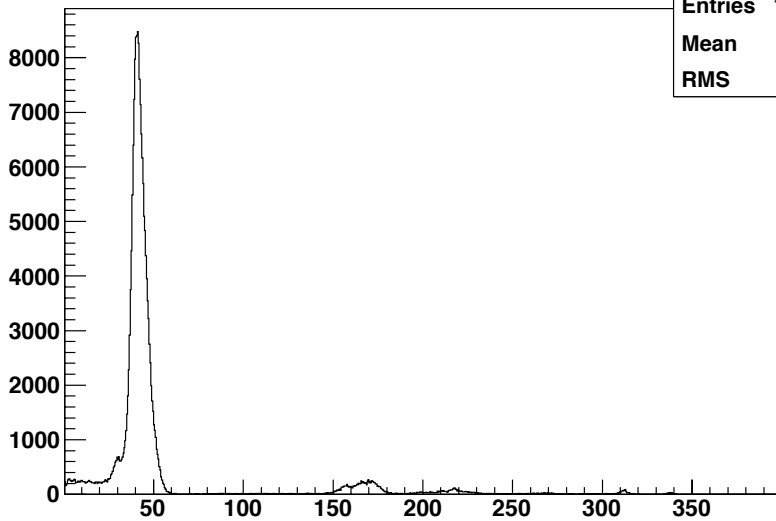
30 kHz: ADC Mean as a Function of Event Number, $X^2/\text{NDF} < 60$



X^2/NDF cut	Number of events	ADC mean, ADC counts	$\Delta E/E$ FWHM, %
None	196609	6231 ± 0.3	2.718 ± 0.015
< 60	179404	6234 ± 0.3	2.715 ± 0.015
ADC equivalent: run 001			
None	32768	6141 ± 0.1	2.544 ± 0.07

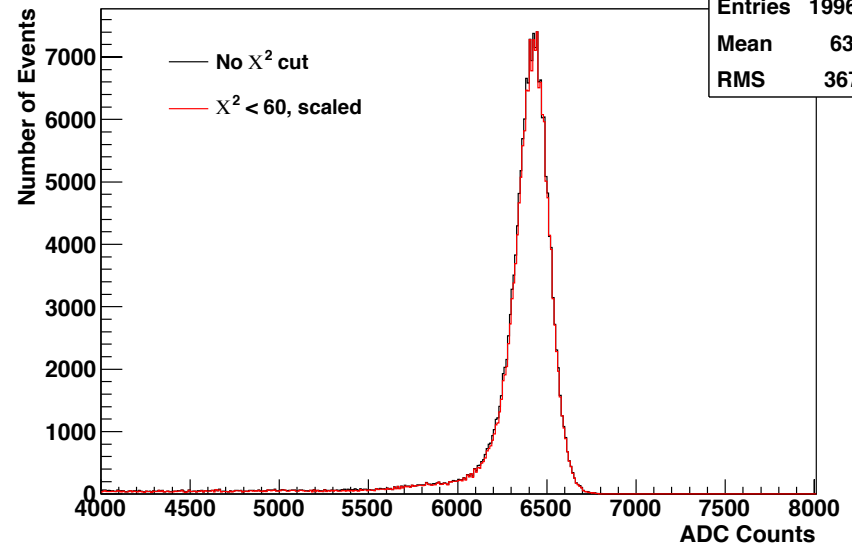
Run 006: Rate - 50 kHz, No Absorbers

Chi²/NDF of Fit to Waveform



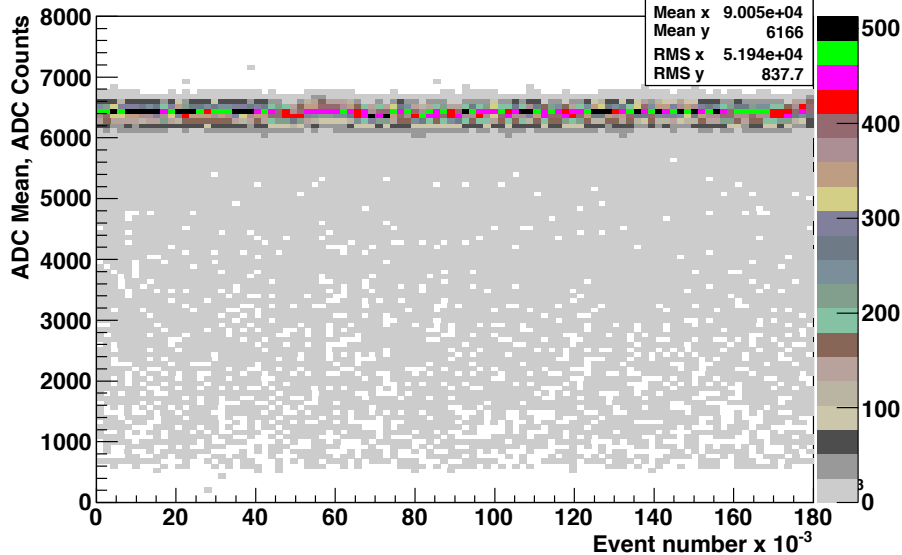
chi2	
Entries	199681
Mean	53.3
RMS	46.25

Run 006, 200 kHz: Histogram Integral for a 150 ns Gate



integral_150ns_adc	
Entries	199681
Mean	6315
RMS	367.3

50 kHz: ADC Mean as a Function of Event Number, $\chi^2/\text{NDF} < 60$

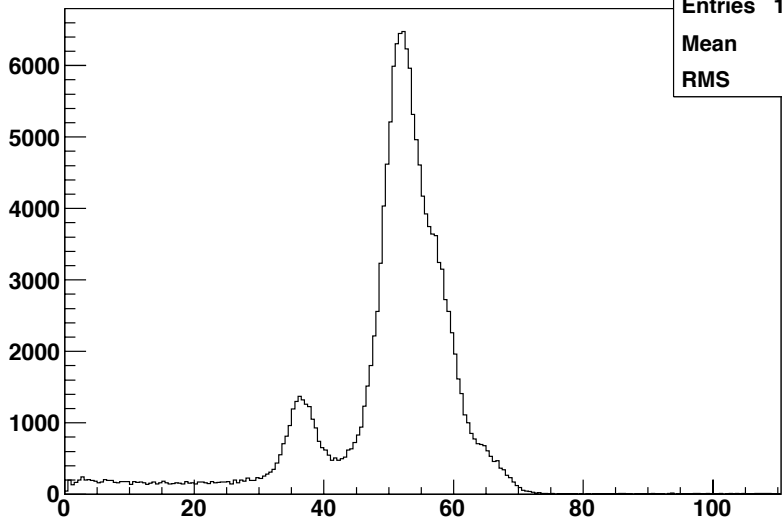


h	
Entries	177618
Mean x	9.005e+04
Mean y	6166
RMS x	5.194e+04
RMS y	837.7

χ^2/NDF cut	Number of events	ADC mean, ADC counts	$\Delta E/E$ FWHM, %
None	199681	6441 ± 0.4	2.755 ± 0.015
< 60	177618	6442 ± 0.4	2.731 ± 0.014
ADC equivalent: run 004			
None		6345 ± 0.1	2.504 ± 0.006

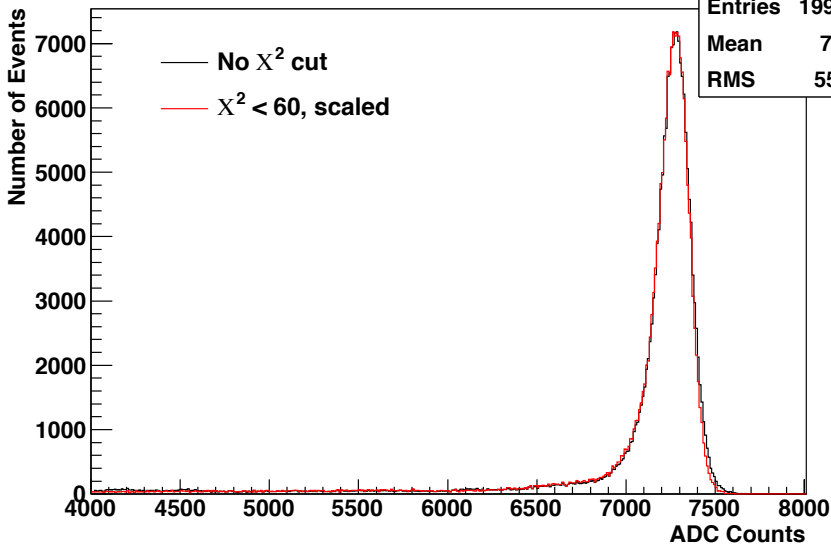
Run 009: Rate - 100 kHz, No Absorbers

Chi²/NDF of Fit to Waveform



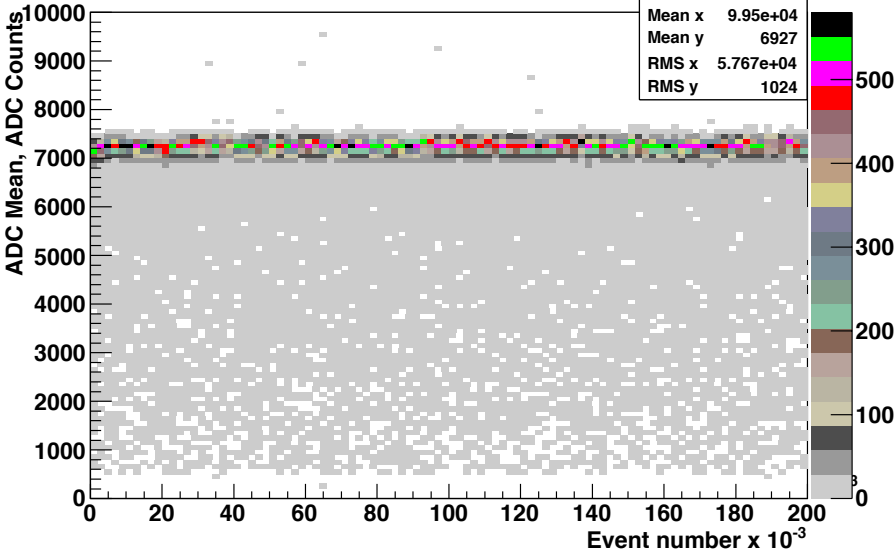
chi2	
Entries	199681
Mean	49.59
RMS	11.99

Run 009, 100 kHz: Histogram Integral for a 150 ns Gate



integral_150ns_adc	
Entries	199681
Mean	7097
RMS	553.2

100 kHz: ADC Mean as a Function of Event Number, $X^2/NDF < 60$

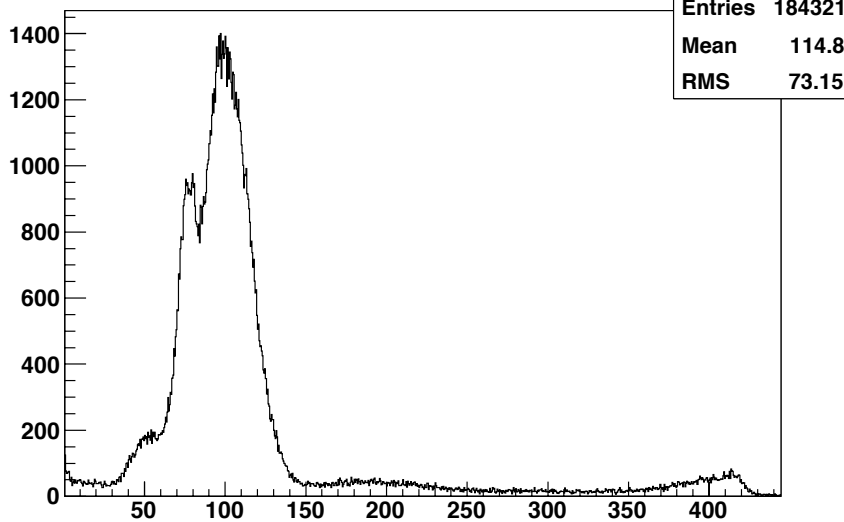


h	
Entries	145458
Mean x	9.95e+04
Mean y	6927
RMS x	5.767e+04
RMS y	1024

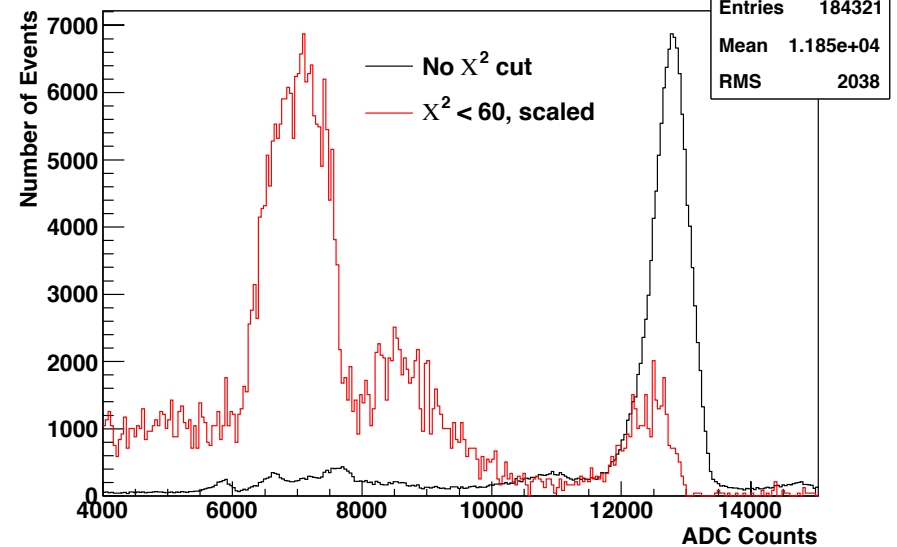
X^2/NDF cut	Number of events	ADC mean, ADC counts	$\Delta E/E$ FWHM, %
None	199681	7291 ± 0.4	2.267 ± 0.014
< 60	145458	7289 ± 0.4	2.035 ± 0.014
ADC equivalent: run 007			
None		7155 ± 0.1	2.779 ± 0.006

Run 012: Rate - 222 kHz, No Absorbers

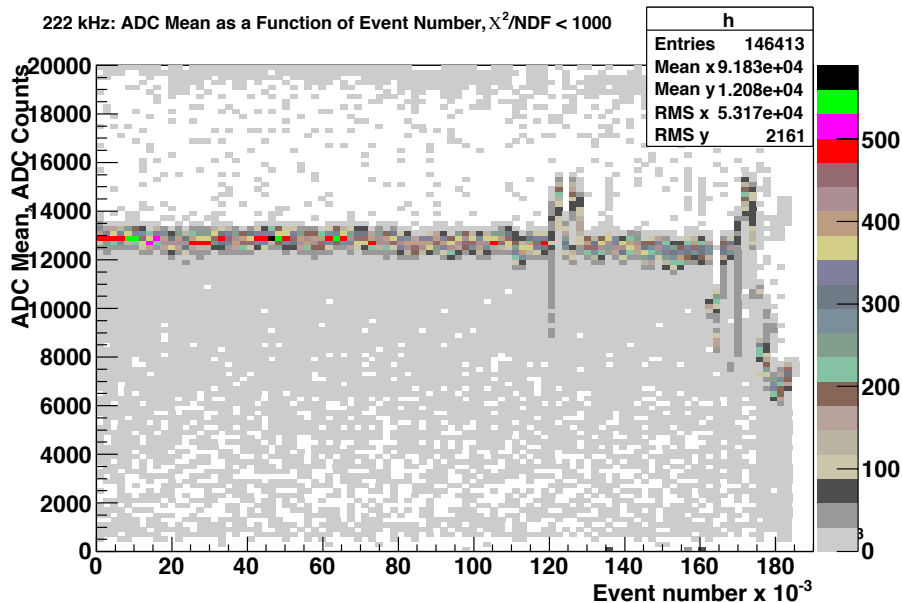
Chi²/NDF of Fit to Waveform



Run 012, 222 kHz: Histogram Integral for a 150 ns Gate

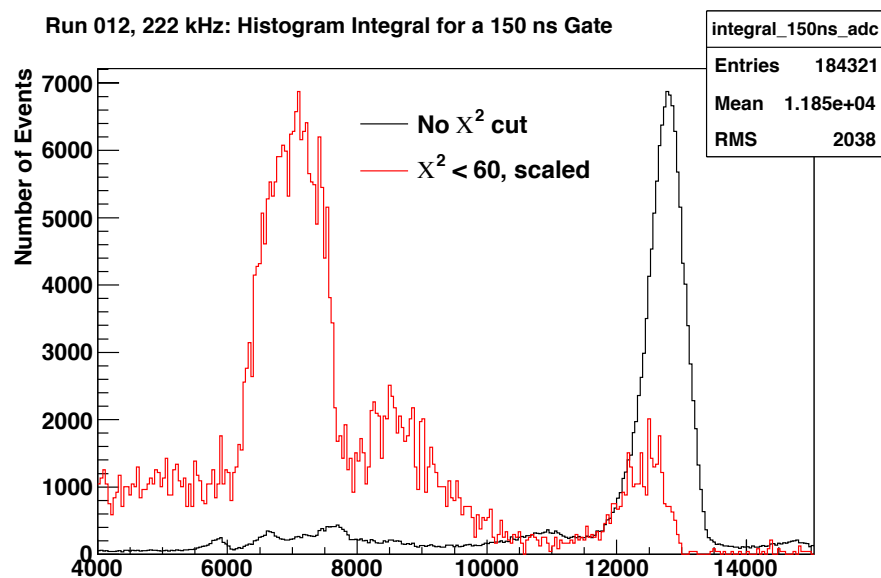


222 kHz: ADC Mean as a Function of Event Number, $\chi^2/\text{NDF} < 1000$

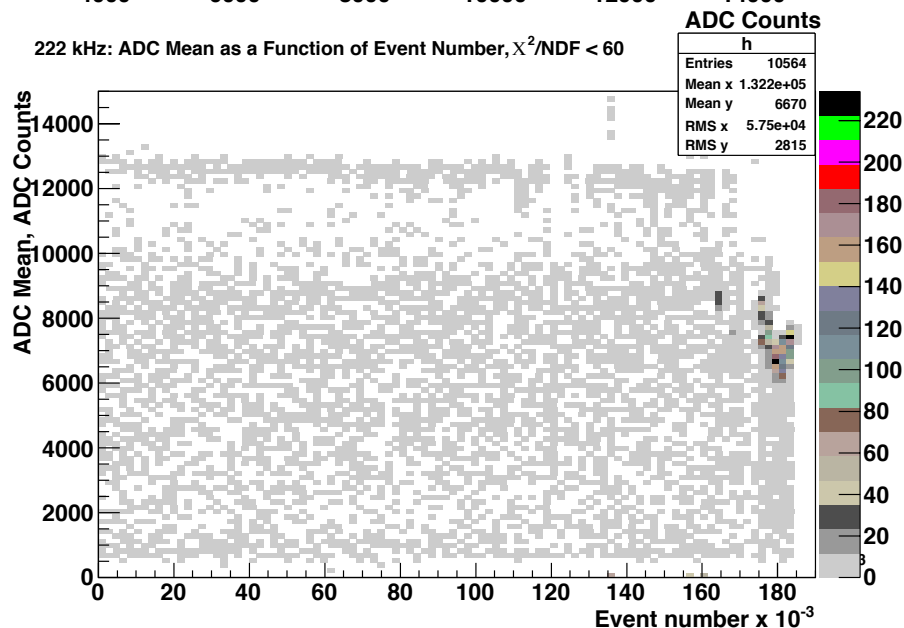


X ² /NDF cut	Number of events	ADC mean, ADC counts	ΔE/E FWHM, %
None	184321	12828 ± 1.5	3.901 ± 0.036
< 60	10564	Unable to fit due to low statistics	
ADC equivalent: run 010			
None		13015 ± 0.2	1.853 ± 0.005

Run 012, 222 kHz: Histogram Integral for a 150 ns Gate



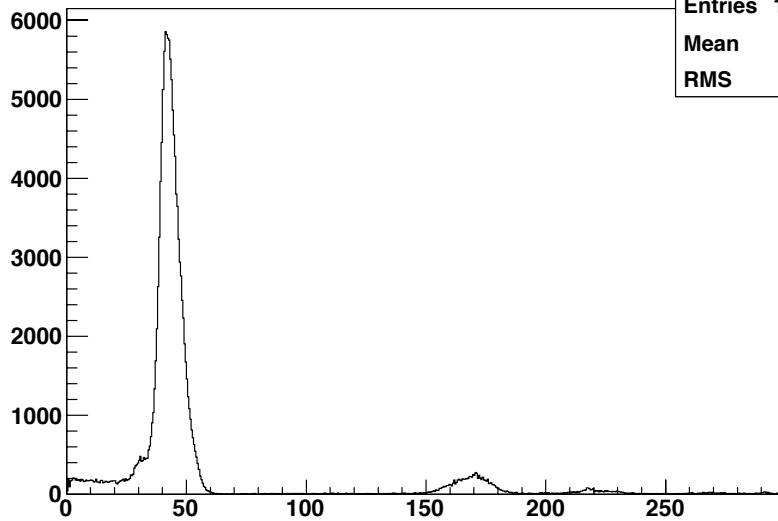
222 kHz: ADC Mean as a Function of Event Number, $X^2/\text{NDF} < 60$



- For a proton beam rate of ~ 200 kHz the pulse height of the signal drastically increases, resulting in a higher mean of the ADC distribution
- Applying a cut of $X^2 < 60$ reduces the mean of the ADC distribution from ~ 13000 to ~ 7000 , which is around the mean we see at rates < 200 kHz
- When looking at the ADC mean as a function of event number without applying a X^2 cut (Slide 6) some fluctuation is seen
- Looking at the ADC mean as a function of event number for $X^2 < 60$ (on this slide) shows that only events with an ADC mean of ~ 7000 are left
- Statistics are too low to fit the ADC spectrum with a $X^2 < 60$, but this is an interesting observation
- Similar observation in other 200 kHz runs, see later.

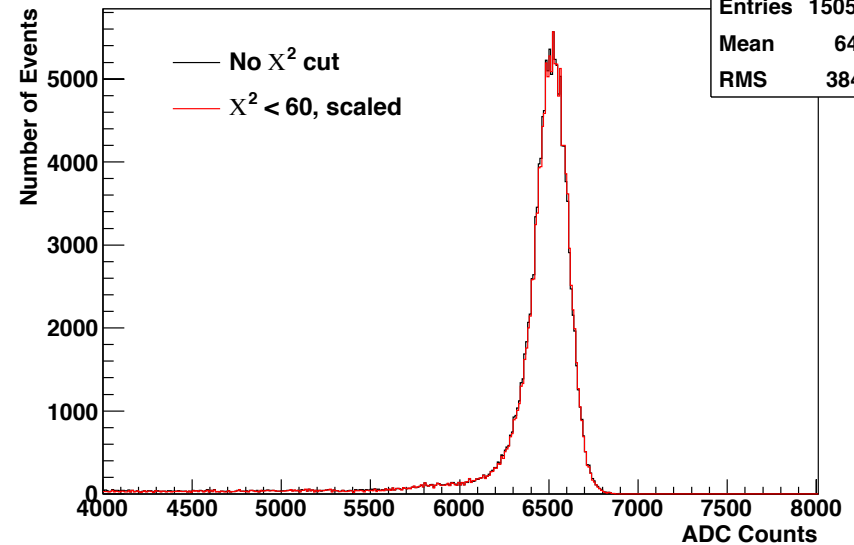
Run 015: Rate - 50 kHz, No Absorbers

Chi²/NDF of Fit to Waveform



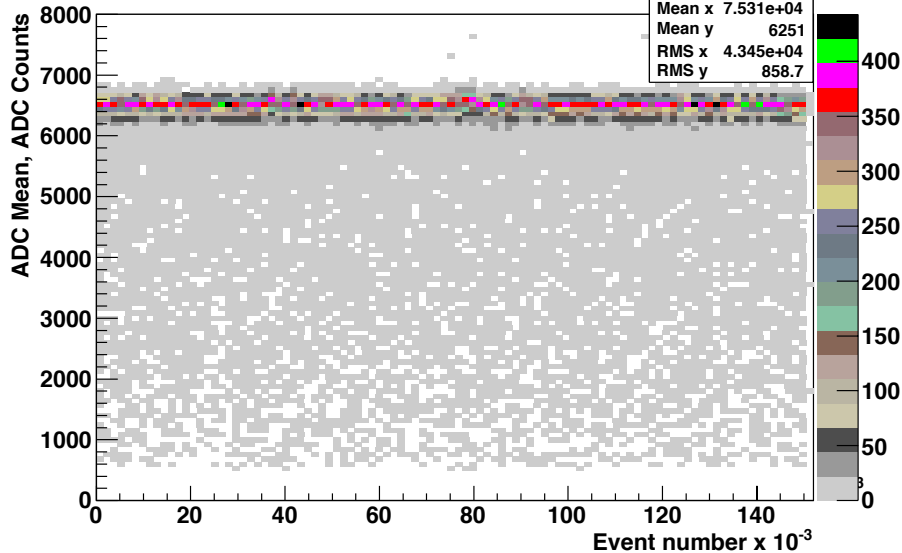
chi2	
Entries	150529
Mean	55.01
RMS	45.17

Run 015, 50 kHz: Histogram Integral for a 150 ns Gate



integral_150ns_adc	
Entries	150529
Mean	6401
RMS	384.2

50 kHz: ADC Mean as a Function of Event Number, $\chi^2/\text{NDF} < 60$

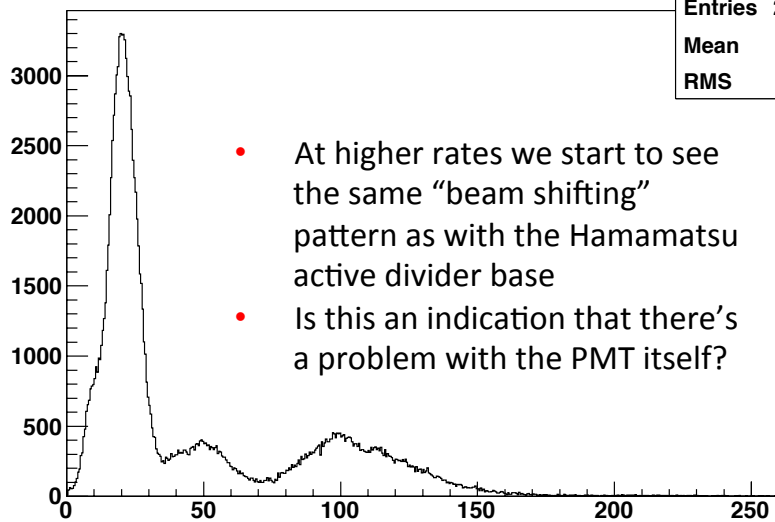


h	
Entries	130476
Mean x	7.531e+04
Mean y	6251
RMS x	4.345e+04
RMS y	858.7

χ^2/NDF cut	Number of events	ADC mean, ADC counts	$\Delta E/E$ FWHM, %
None	150529	6536 ± 0.4	2.660 ± 0.016
< 60	130476	6538 ± 0.4	2.616 ± 0.018
ADC equivalent: run 013			
None		Unable to fit spectrum due to shifting during run	

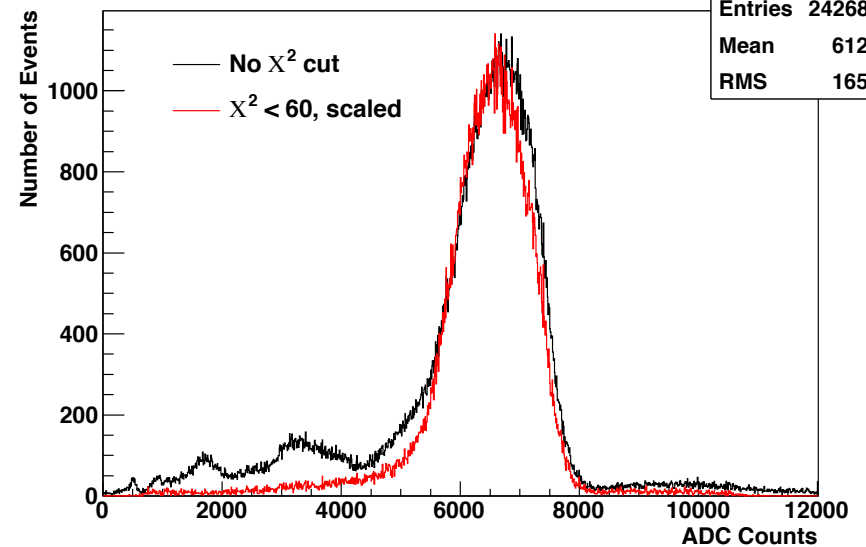
Run 018: Rate - 300 kHz, No Absorbers

Chi²/NDF of Fit to Waveform



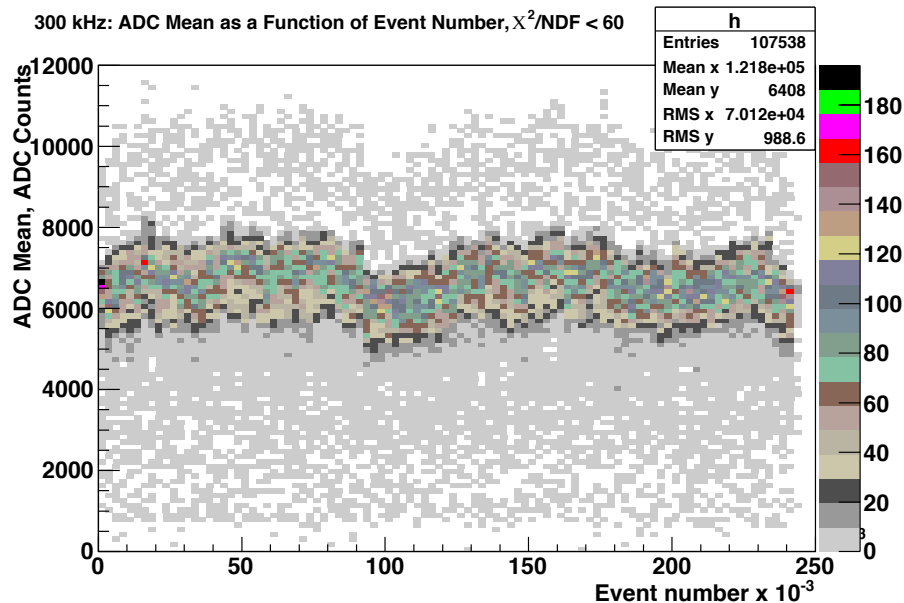
chi2	
Entries	242689
Mean	47.52
RMS	41.08

Run 018, 300 kHz: Histogram Integral for a 150 ns Gate



integral_150ns_adc	
Entries	242689
Mean	6120
RMS	1652

300 kHz: ADC Mean as a Function of Event Number, $\chi^2/\text{NDF} < 60$

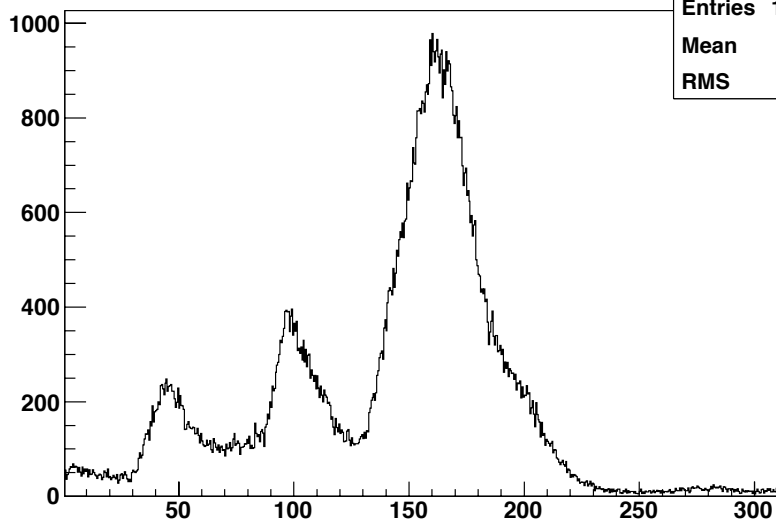


h	
Entries	107538
Mean x	1.218e+05
Mean y	6408
RMS x	7.012e+04
RMS y	988.6

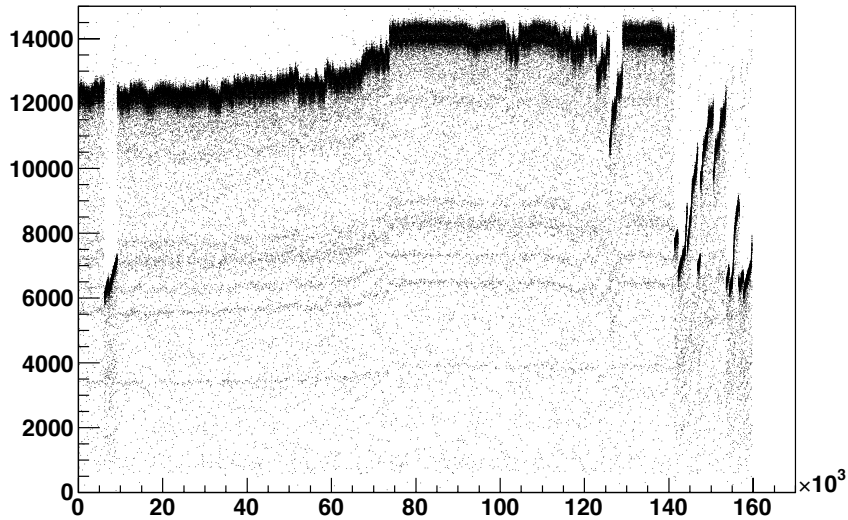
χ^2/NDF cut	Number of events	ADC mean, ADC counts	$\Delta E/E$ FWHM, %
None	242689	6789 ± 2.0	10.925 ± 0.120
< 60	10738	6709 ± 2.6	16.641 ± 0.082
ADC equivalent: run 016			
None		7155 ± 0.1	2.779 ± 0.006

Run 020: Rate - 200 kHz, No Absorbers

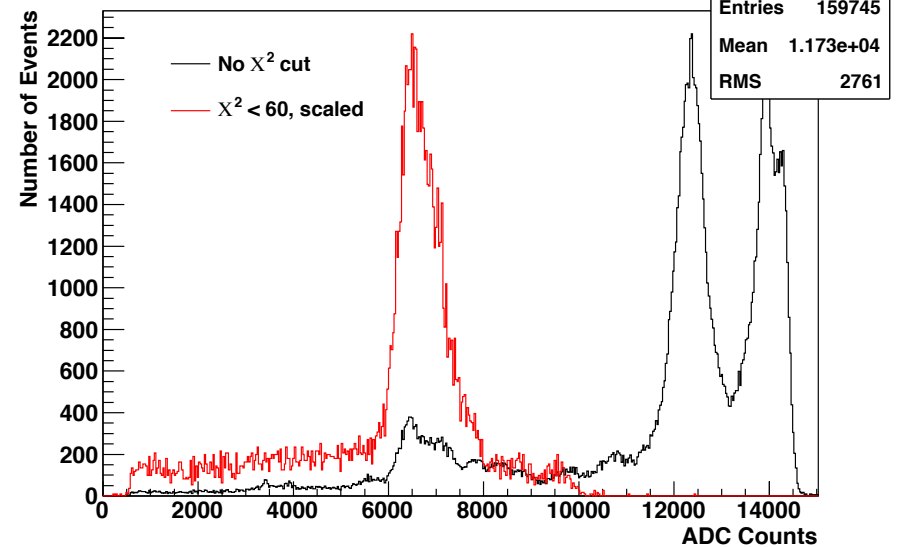
Chi²/NDF of Fit to Waveform



integral_150_adc:event_number



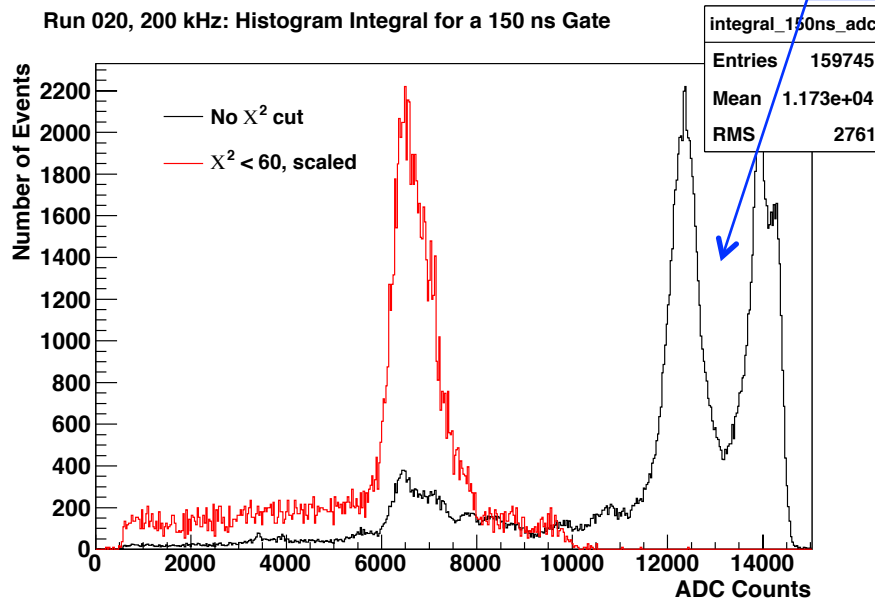
Run 020, 200 kHz: Histogram Integral for a 150 ns Gate



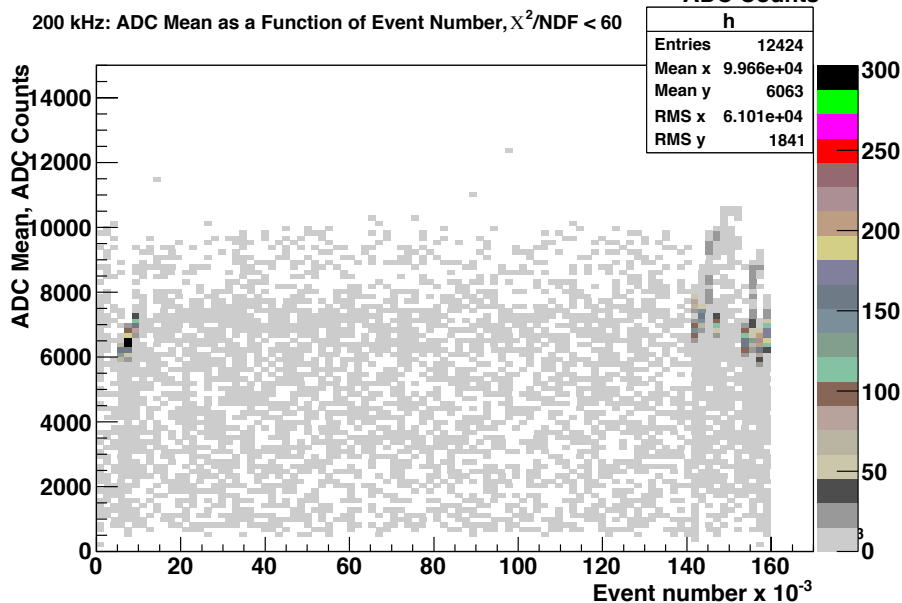
X ² /NDF cut	Number of events	ADC mean, ADC counts	ΔE/E FWHM, %
None	159745	Unable to fit due to double peak	
< 60	12424	Unable to fit due to low statistics	
ADC equivalent: run 019			
None		12291 ± 0.5	4.006 ± 0.010

Why the double peak? According to my notes the scattering foil current started to drop towards the end of the run. Subsequent ADC mode spectra also showed beam shifting.

Run 020, 200 kHz: Histogram Integral for a 150 ns Gate



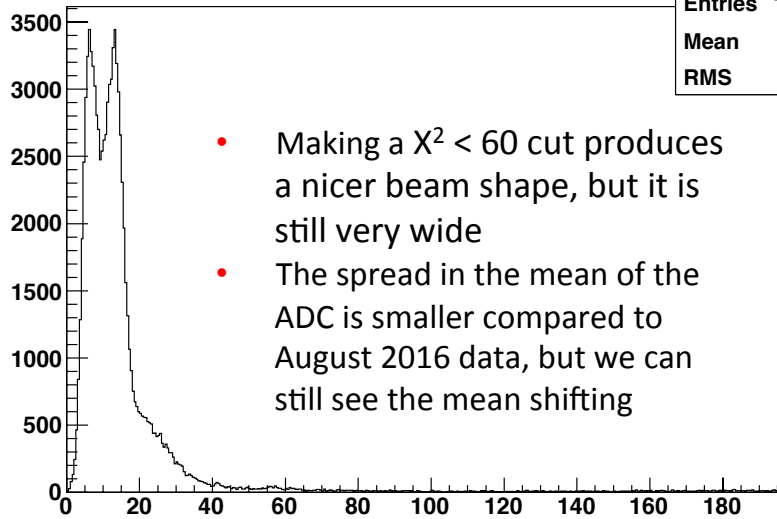
200 kHz: ADC Mean as a Function of Event Number, $X^2/\text{NDF} < 60$



- For a proton beam rate of ~ 200 kHz the pulse height of the signal drastically increases, resulting in a higher mean of the ADC distribution
- Applying a cut of $X^2 < 60$ reduces the mean of the ADC distribution from ~ 13000 to ~ 7000 , which is around the mean we see at rates < 200 kHz
- When looking at the ADC mean as a function of event number without applying a X^2 cut (Slide 10) some fluctuation is seen
- Looking at the ADC mean as a function of event number for $X^2 < 60$ (on this slide) shows that only events with an ADC mean of ~ 7000 are left
- Statistics are too low to fit the ADC spectrum with a $X^2 < 60$, but this is an interesting observation
- Similar observation in other 200 kHz runs, see earlier and later.

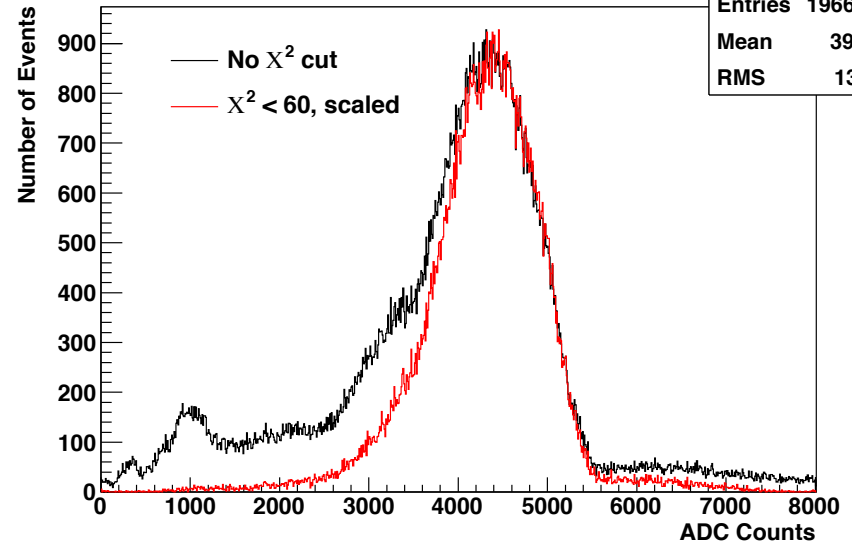
Run 025: Rate - 400 kHz, No Absorbers

Chi²/NDF of Fit to Waveform



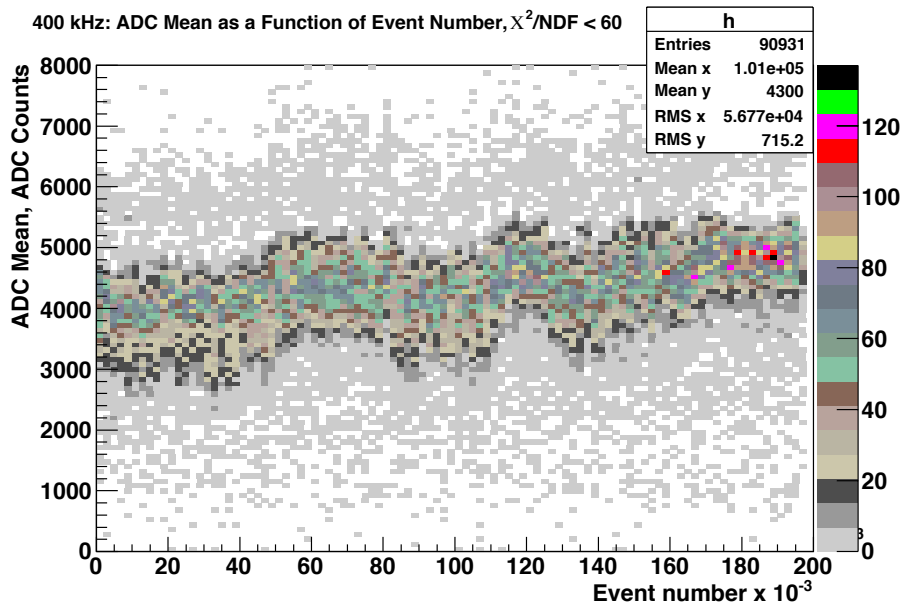
chi2	
Entries	196609
Mean	16.26
RMS	21.96

Run 025, 400 kHz: Histogram Integral for a 150 ns Gate



integral_150ns_adc	
Entries	196609
Mean	3902
RMS	1311

400 kHz: ADC Mean as a Function of Event Number, $\chi^2/\text{NDF} < 60$

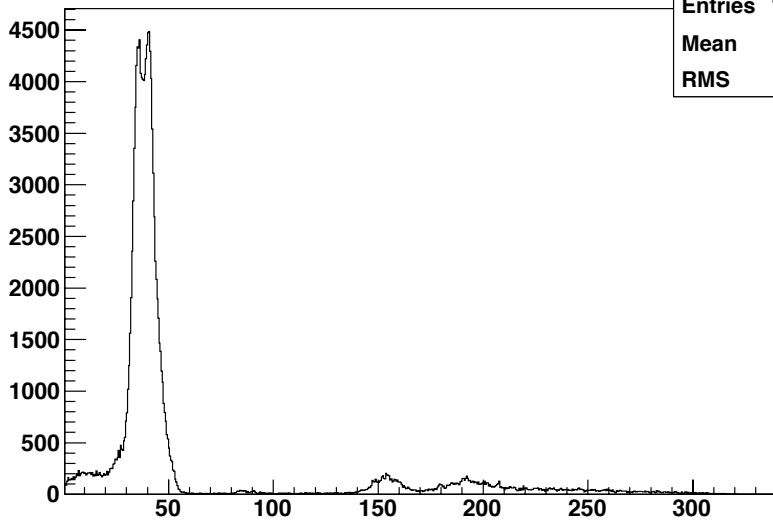


h	
Entries	90931
Mean x	1.01e+05
Mean y	4300
RMS x	5.677e+04
RMS y	715.2

χ^2/NDF cut	Number of events	ADC mean, ADC counts	$\Delta E/E$ FWHM, %
None	196609	4346 ± 3.9	8.632 ± 0.425
< 60	90931	4500 ± 3.2	21.50 ± 0.16
ADC equivalent: run 024			
None		4676 ± 0.6	11.912 ± 0.037

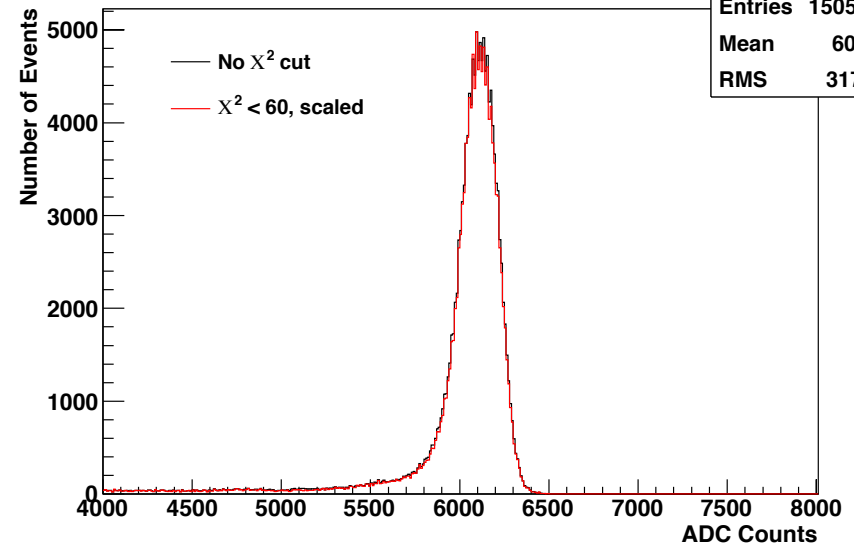
Run 027: Rate - 50 kHz, No Absorbers

Chi²/NDF of Fit to Waveform



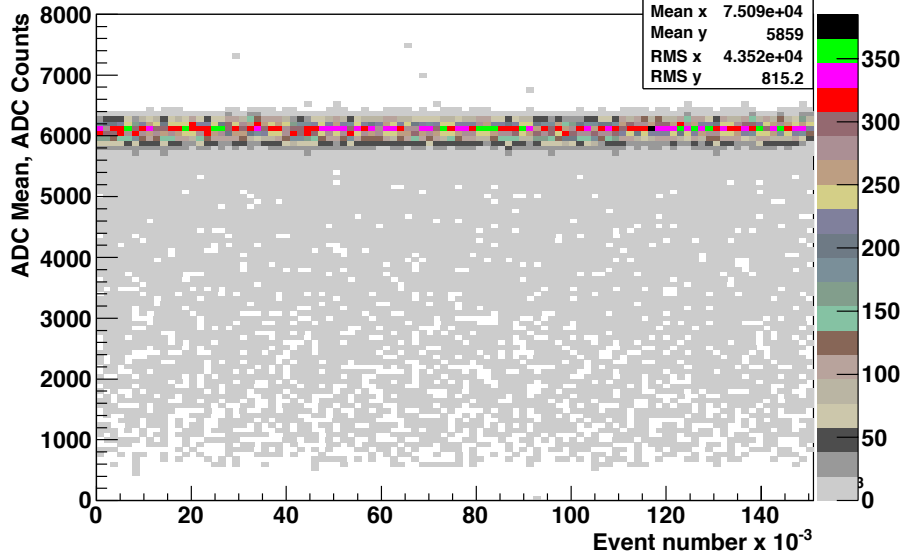
chi2	
Entries	150529
Mean	59.81
RMS	58.87

Run 027, 50 kHz: Histogram Integral for a 150 ns Gate



integral_150ns_adc	
Entries	150529
Mean	6020
RMS	317.7

50 kHz: ADC Mean as a Function of Event Number, $\chi^2/\text{NDF} < 60$



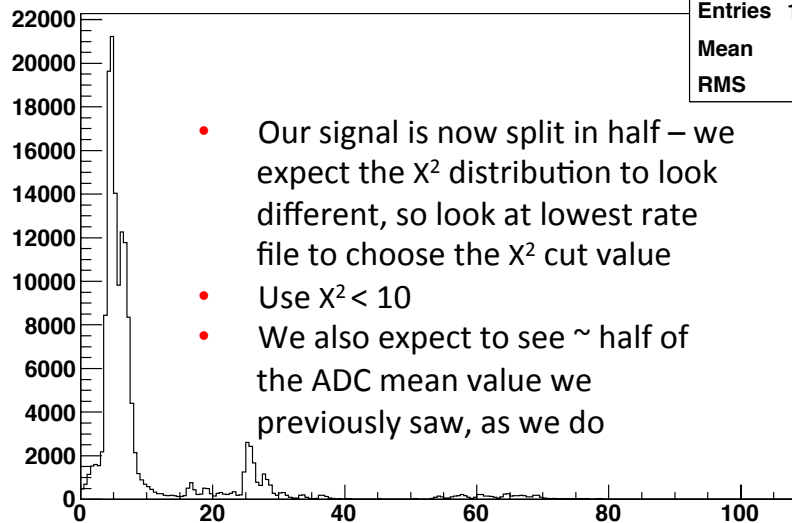
h	
Entries	124760
Mean x	7.509e+04
Mean y	5859
RMS x	4.352e+04
RMS y	815.2

χ^2/NDF cut	Number of events	ADC mean, ADC counts	$\Delta E/E$ FWHM, %
None	150529	6138 ± 0.4	3.002 ± 0.014
< 60	124760	6137 ± 0.4	3.018 ± 0.015
ADC equivalent: run 026			
None		5981 ± 0.1	2.552 ± 0.005

Thursday 24th of November 2016:
Scope and Digitiser 50 Ω LEMO Splitter Tests

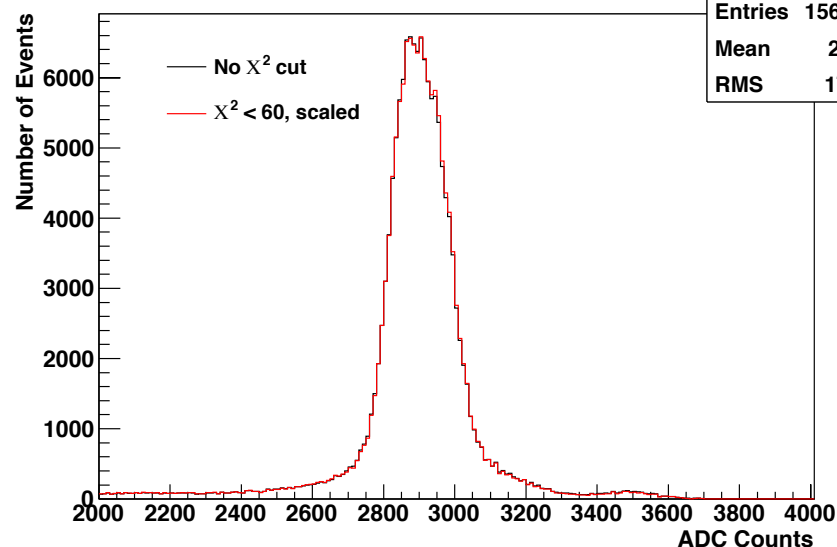
Run 029: Rate - 50 kHz, No Absorbers

Chi²/NDF of Fit to Waveform



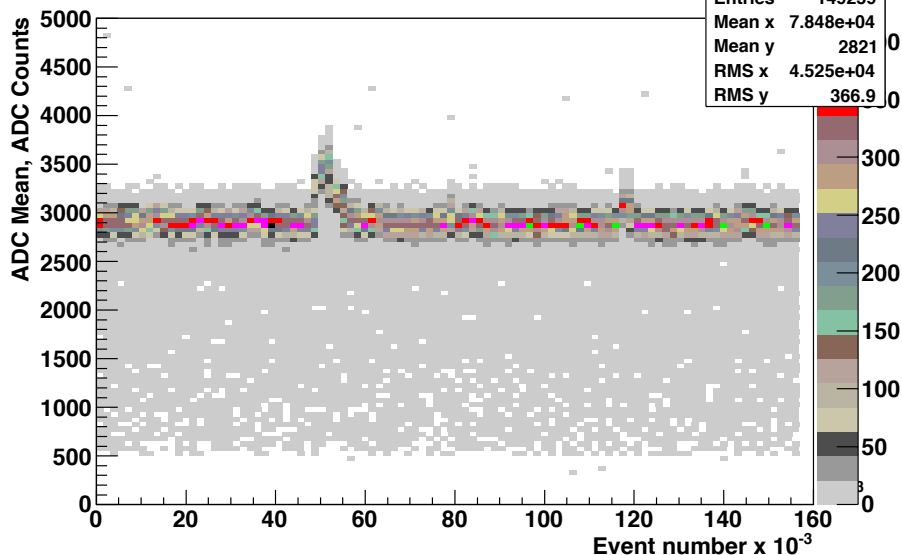
chi2	
Entries	156673
Mean	10.22
RMS	12.59

Run 029, 50 kHz: Histogram Integral for a 150 ns Gate



integral_150ns_adc	
Entries	156673
Mean	2893
RMS	170.1

200 kHz: ADC Mean as a Function of Event Number, $\chi^2/\text{NDF} < 60$

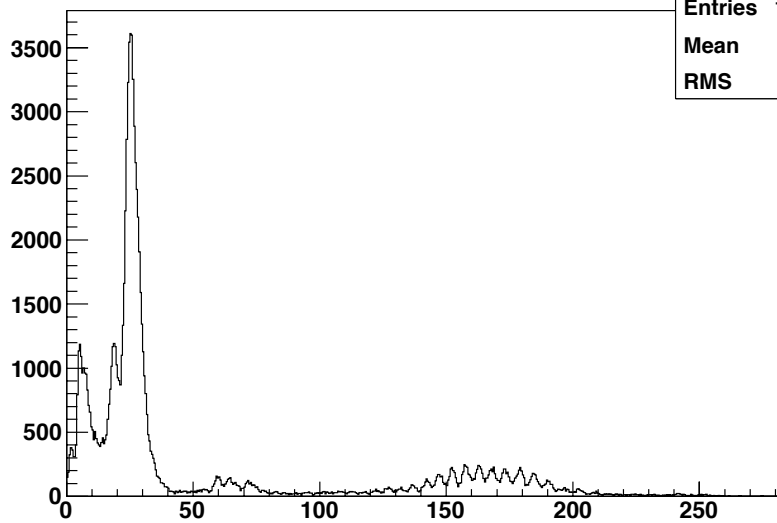


h	
Entries	149259
Mean x	7.848e+04
Mean y	2821
RMS x	4.525e+04
RMS y	366.9

χ^2/NDF cut	Number of events	ADC mean, ADC counts	$\Delta E/E$ FWHM, %
None	156673	2914 ± 0.4	4.712 ± 0.029
< 10	149259	2916 ± 0.4	4.768 ± 0.029
ADC equivalent: run 028			
None		3046 ± 0.1	3.125 ± 0.008

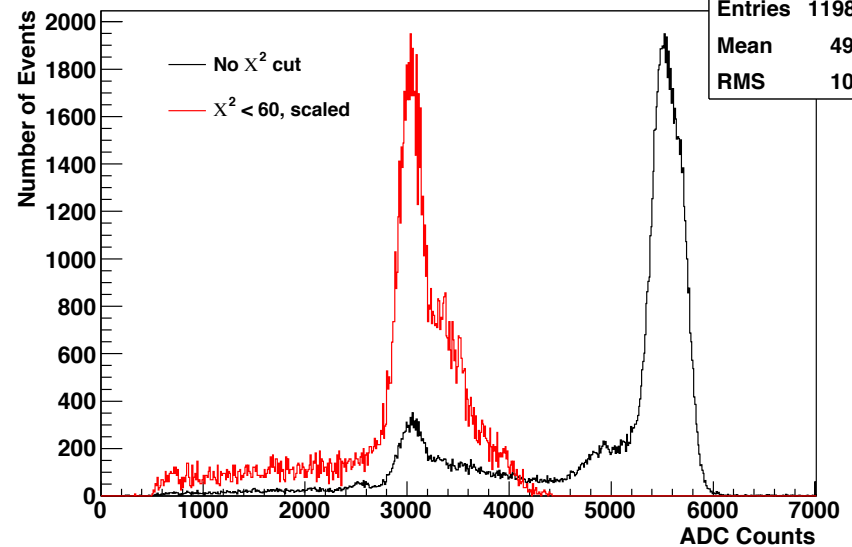
Run 031: Rate - 200 kHz, No Absorbers

Chi²/NDF of Fit to Waveform



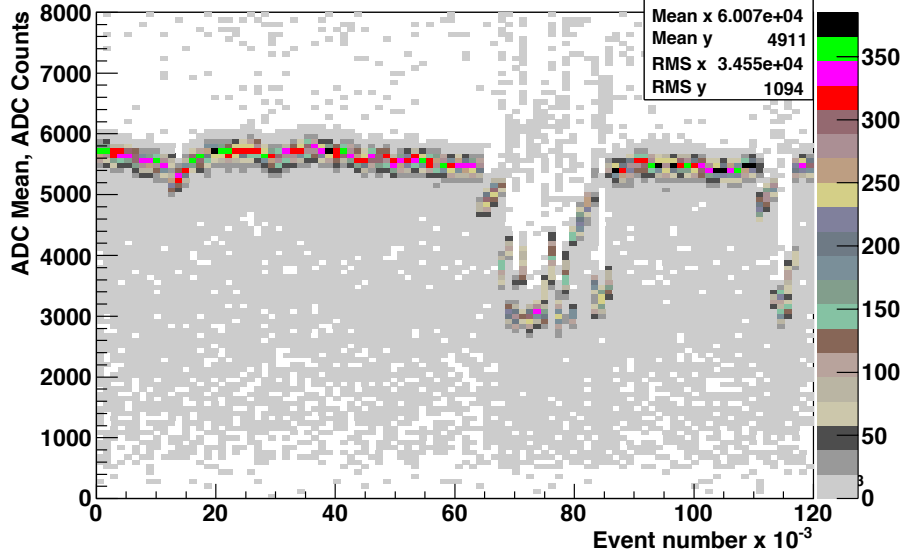
chi2	
Entries	119809
Mean	52.63
RMS	59.24

Run 031, 200 kHz: Histogram Integral for a 150 ns Gate



integral_150ns_adc	
Entries	119809
Mean	4907
RMS	1089

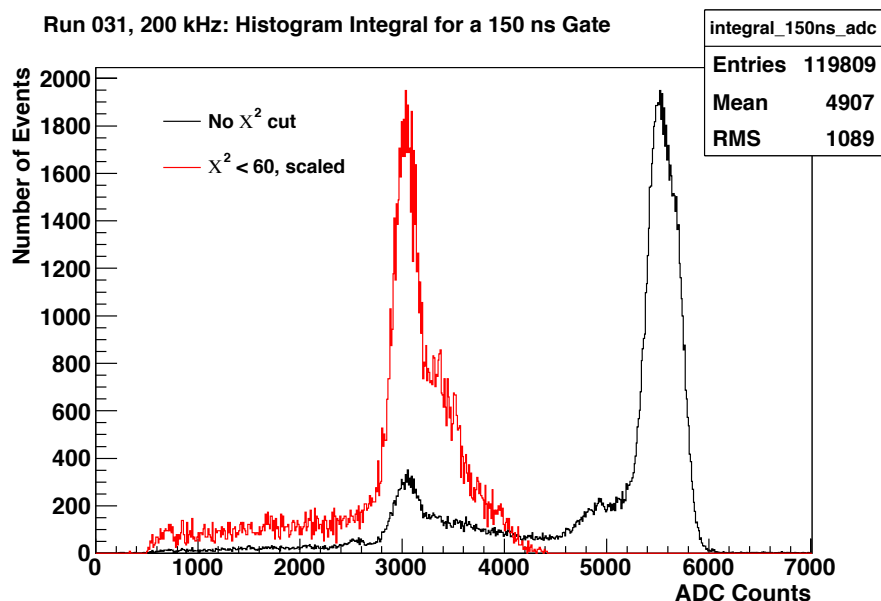
200 kHz: ADC Mean as a Function of Event Number, $X^2/NDF < 10000$



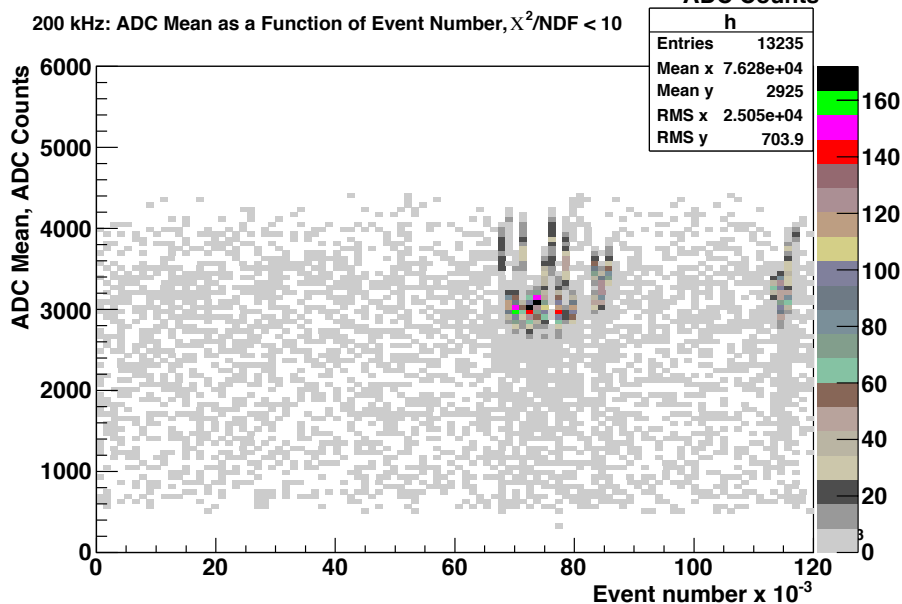
h	
Entries	118889
Mean x	6.007e+04
Mean y	4911
RMS x	3.455e+04
RMS y	1094

X ² /NDF cut	Number of events	ADC mean, ADC counts	ΔE/E FWHM, %
None	119809	5599 ± 0.7	4.482 ± 0.032
< 10	13235	Unable to fit due to low statistics	
ADC equivalent: run 030			
None		5786 ± 0.1	2.815 ± 0.007

Run 031, 200 kHz: Histogram Integral for a 150 ns Gate



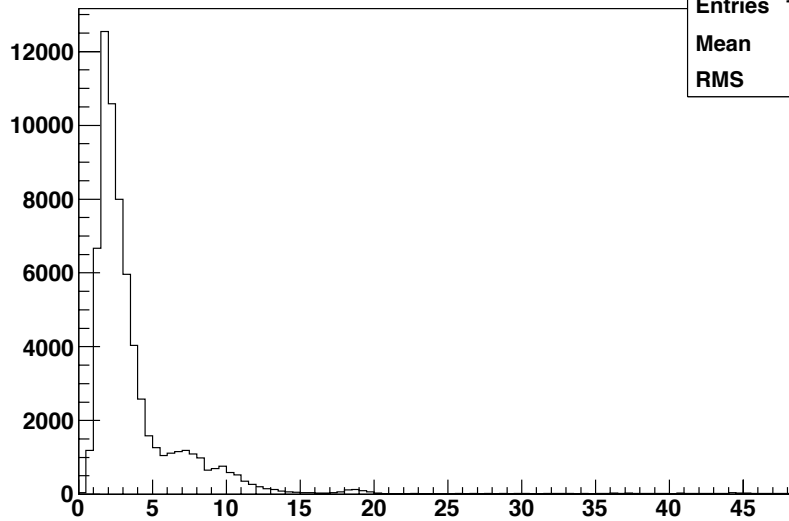
200 kHz: ADC Mean as a Function of Event Number, $X^2/\text{NDF} < 10$



- For a proton beam rate of ~ 200 kHz the pulse height of the signal drastically increases, resulting in a higher mean of the ADC distribution
- Applying a cut of $X^2 < 10$ reduces the mean of the ADC distribution from ~ 5500 to ~ 3000 , which is around half of the mean we see at rates < 200 kHz when using a splitter
- When looking at the ADC mean as a function of event number without applying a X^2 cut (Slide 16) some fluctuation is seen
- Looking at the ADC mean as a function of event number for $X^2 < 10$ (on this slide) shows that only events with an ADC mean of ~ 3000 are left
- Statistics are too low to fit the ADC spectrum with a $X^2 < 10$, but this is an interesting observation
- Similar observation in other 200 kHz runs, see earlier.

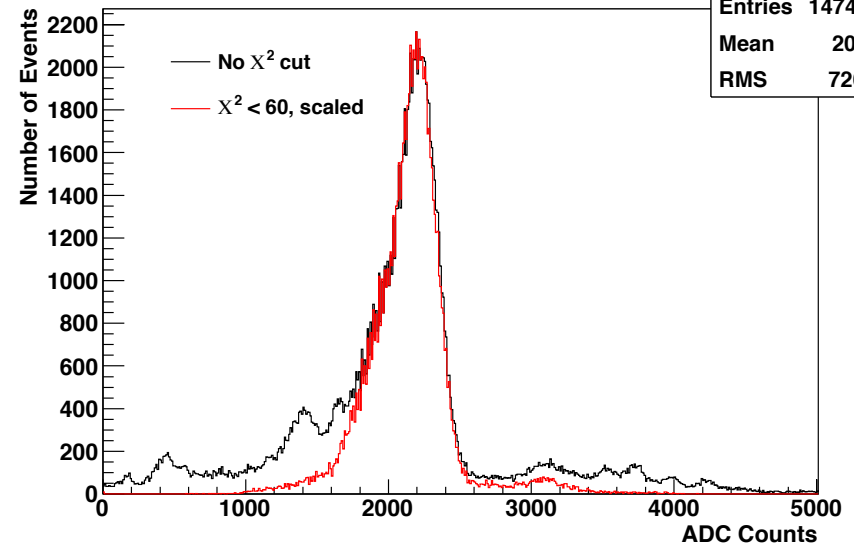
Run 033: Rate - 400 kHz, No Absorbers

Chi²/NDF of Fit to Waveform



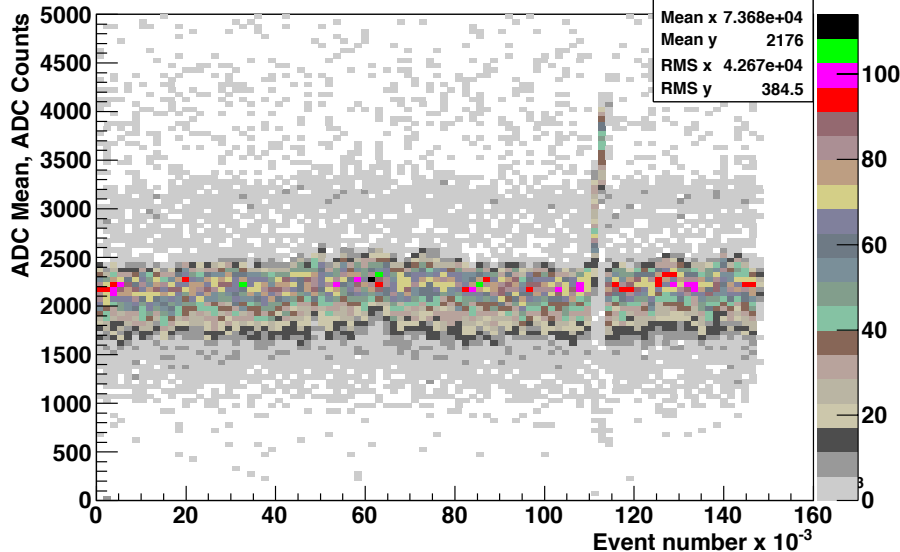
chi2	
Entries	147457
Mean	4.255
RMS	5.336

Run 033, 400 kHz: Histogram Integral for a 150 ns Gate



integral_150ns_adc	
Entries	147457
Mean	2085
RMS	726.1

400 kHz: ADC Mean as a Function of Event Number, $\chi^2/\text{NDF} < 60$



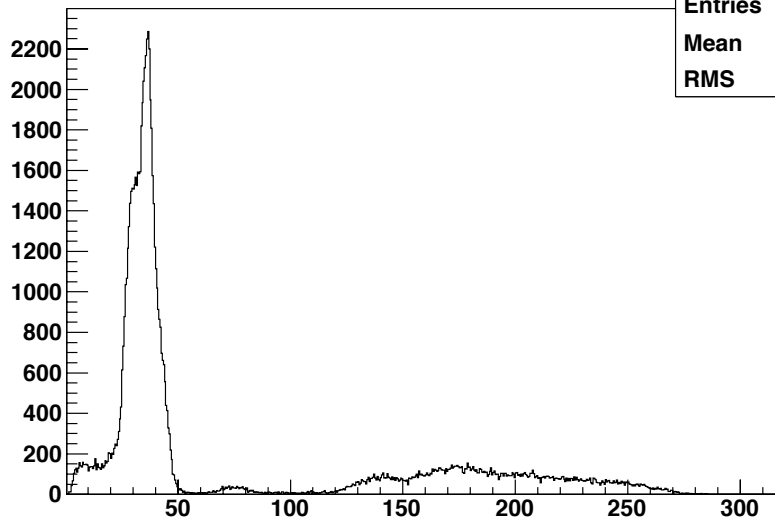
h	
Entries	68098
Mean x	7.368e+04
Mean y	2176
RMS x	4.267e+04
RMS y	384.5

χ^2/NDF cut	Number of events	ADC mean, ADC counts	$\Delta E/E$ FWHM, %
None	147457	Unable to fit spectrum	
< 10	63152	2196 ± 1.2	14.064 ± 0.162
ADC equivalent: run 032 and 034			
None	Unable to fit spectrum due to shifting during running		

Friday 25th of November 2016: Wheel Energy-Range Calibration Tests

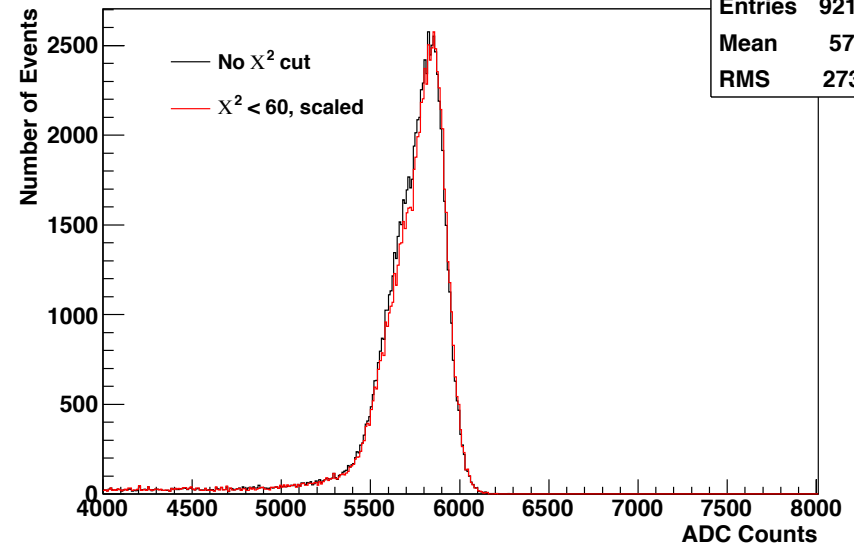
Run 002: Rate - 50 kHz, Wheel Position 0/1.4 mm WE

Chi²/NDF of Fit to Waveform



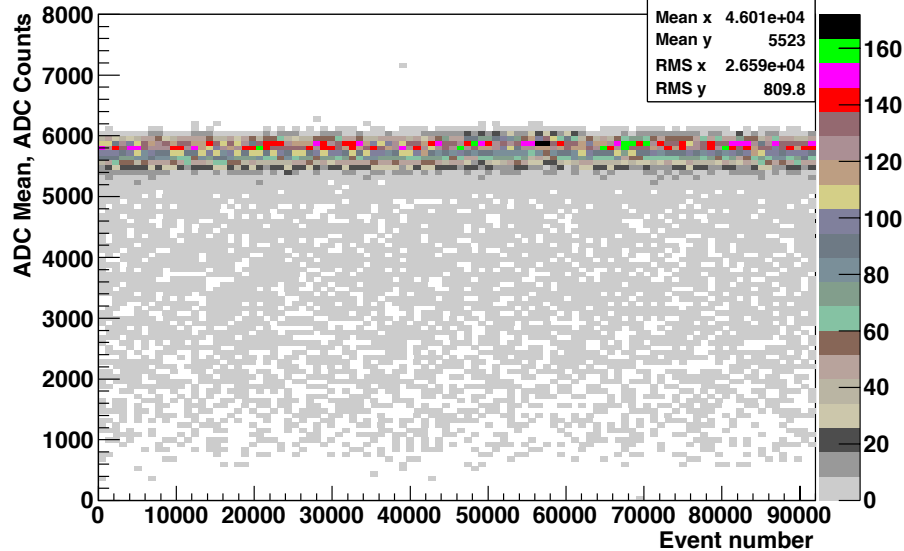
chi2	
Entries	92161
Mean	75.21
RMS	71.98

Run 002, 15 pA: Histogram Integral for a 150 ns Gate



integral_150ns_adc	
Entries	92161
Mean	5707
RMS	273.9

15 pA: ADC Mean as a Function of Event Number, $\chi^2/\text{NDF} < 60$

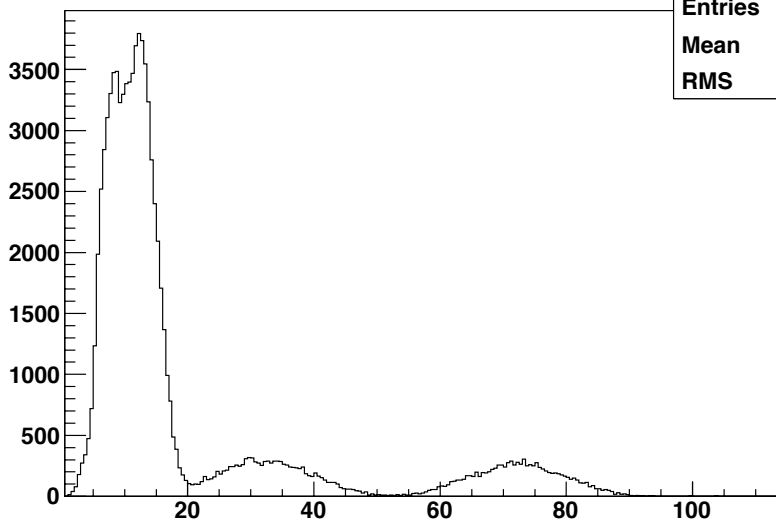


h	
Entries	64268
Mean x	4.601e+04
Mean y	5523
RMS x	2.659e+04
RMS y	809.8

χ^2/NDF cut	Number of events	ADC mean, ADC counts	$\Delta E/E$ FWHM, %
None	92161	5818 ± 0.8	3.584 ± 0.032
< 60	64268	5830 ± 0.8	$3,146 \pm 0.041$
ADC equivalent: run 001			
None		5672 ± 0.1	2.702 ± 0.007

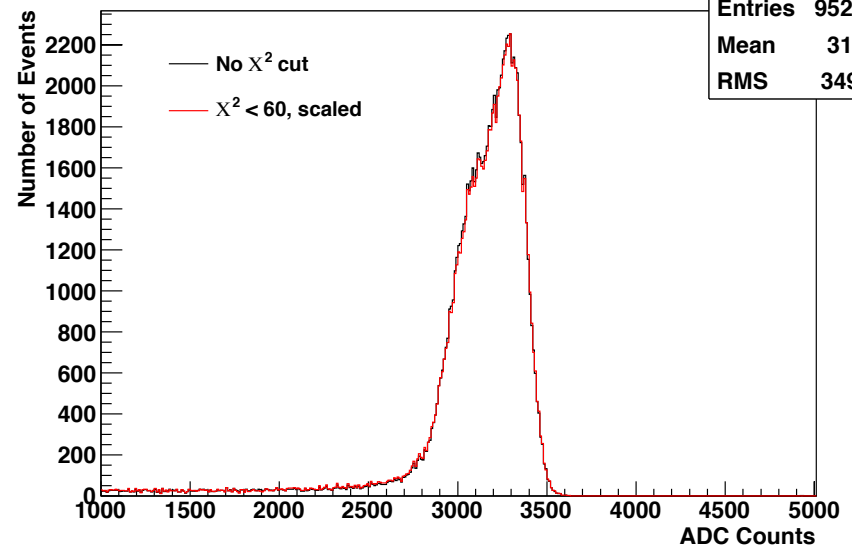
Run 008: Rate - 50 kHz, Wheel Position 100/18.9 mm WE

Chi²/NDF of Fit to Waveform



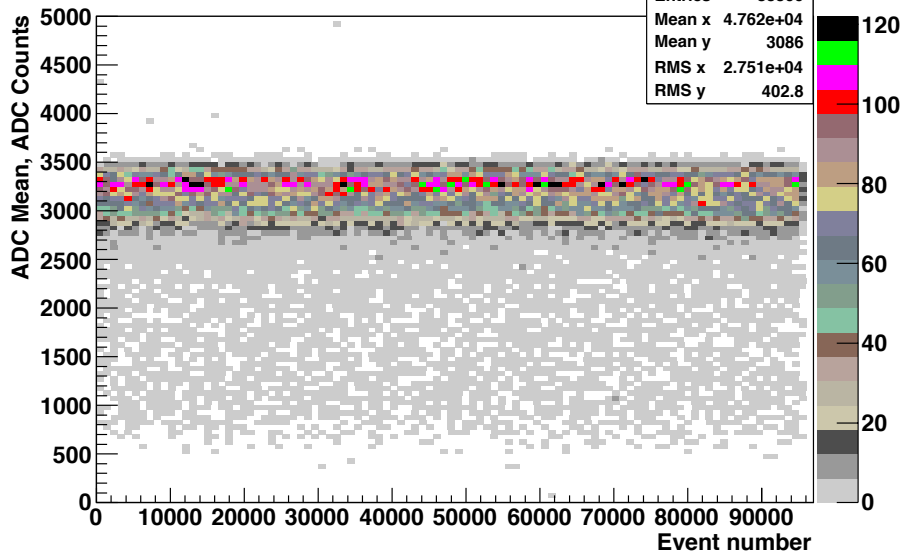
chi2	
Entries	95233
Mean	19.94
RMS	20.02

Run 008, 15 pA: Histogram Integral for a 150 ns Gate



integral_150ns_adc	
Entries	95233
Mean	3106
RMS	349.2

15 pA: ADC Mean as a Function of Event Number, $\chi^2/\text{NDF} < 60$

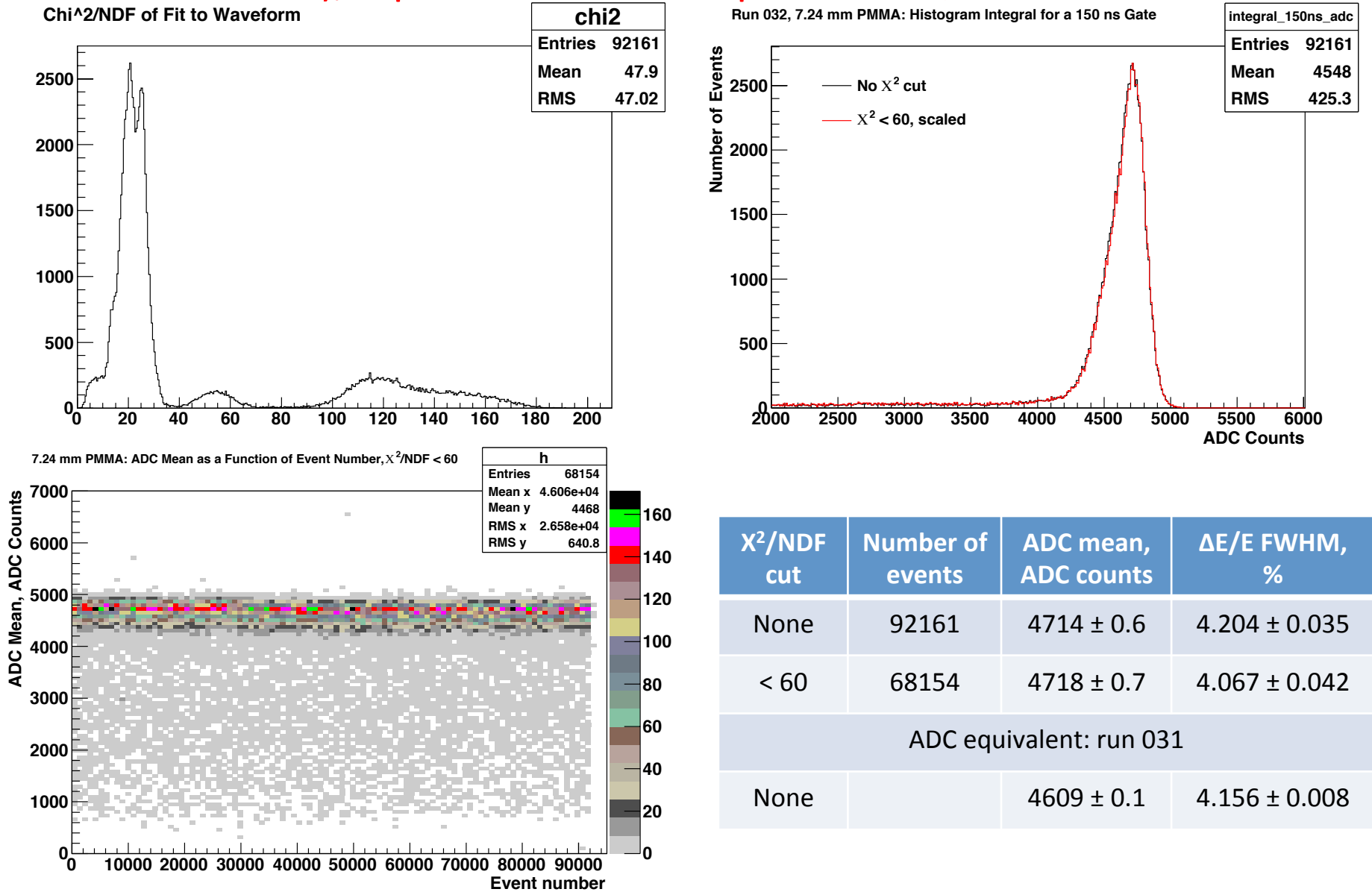


h	
Entries	83300
Mean x	4.762e+04
Mean y	3086
RMS x	2.751e+04
RMS y	402.8

χ^2/NDF cut	Number of events	ADC mean, ADC counts	$\Delta E/E$ FWHM, %
None	95233	3234 ± 1.0	8.766 ± 0.059
< 60	83300	3235 ± 1.0	7.865 ± 0.014
ADC equivalent: run 007			
None		3139 ± 0.1	6.247 ± 0.012

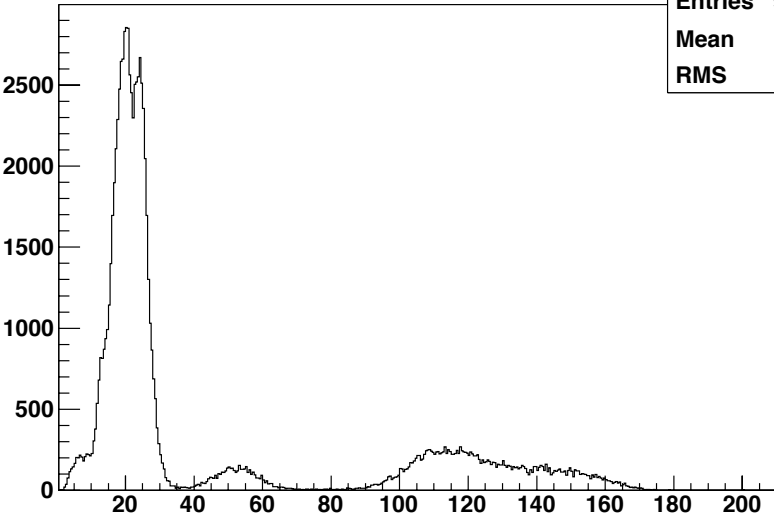
Friday 25th of November 2016: Wheel Equivalent PMMA Plates Tests

Run 032: Rate - 50 kHz, 7.2 mm PMMA Plate (placed in same position as wheel), equivalent to wheel position 40/8.4 mm WE



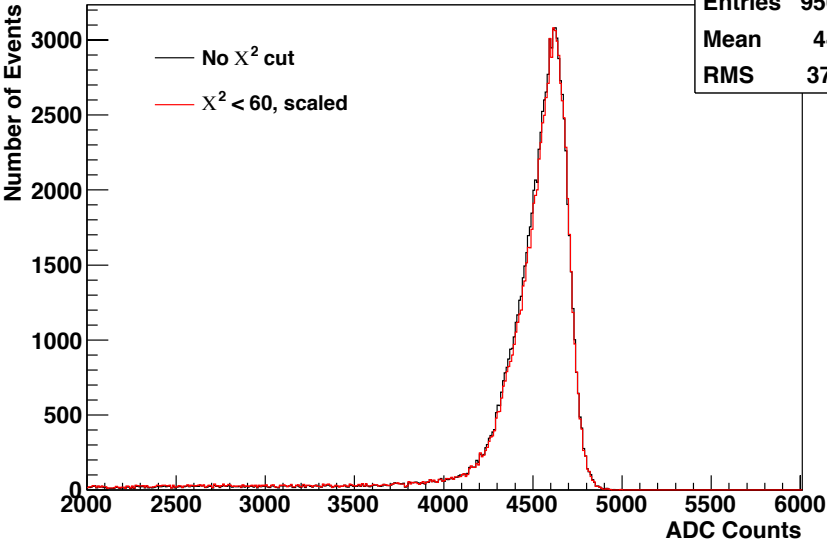
Run 034: Rate - 50 kHz, 7.2 mm PMMA Plate (placed upstream of the beam), equivalent to wheel position 40/8.4 mm WE

Chi²/NDF of Fit to Waveform



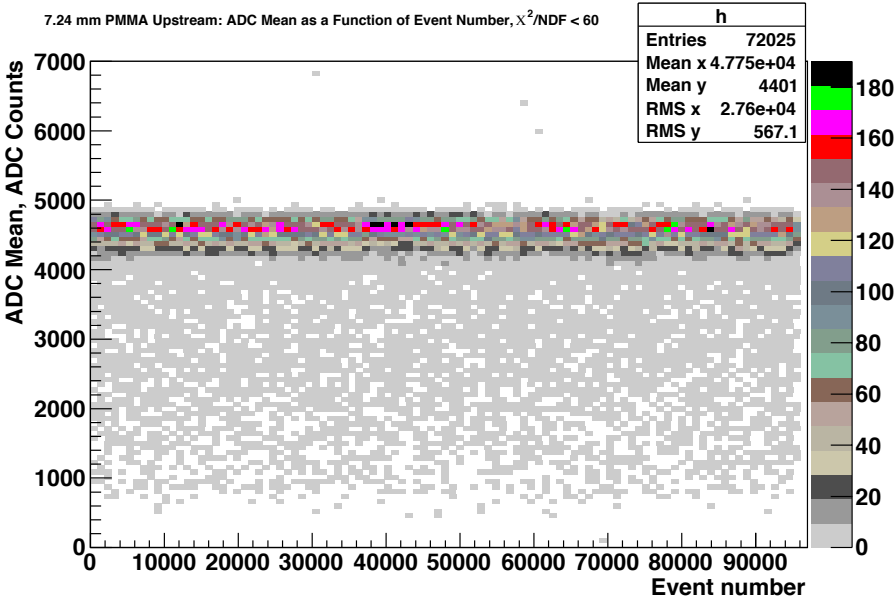
chi2	
Entries	95662
Mean	45.79
RMS	44.82

Run 034, 7.24 mm PMMA Upstream: Histogram Integral for a 150 ns Gate



integral_150ns_adc	
Entries	95662
Mean	4466
RMS	375.5

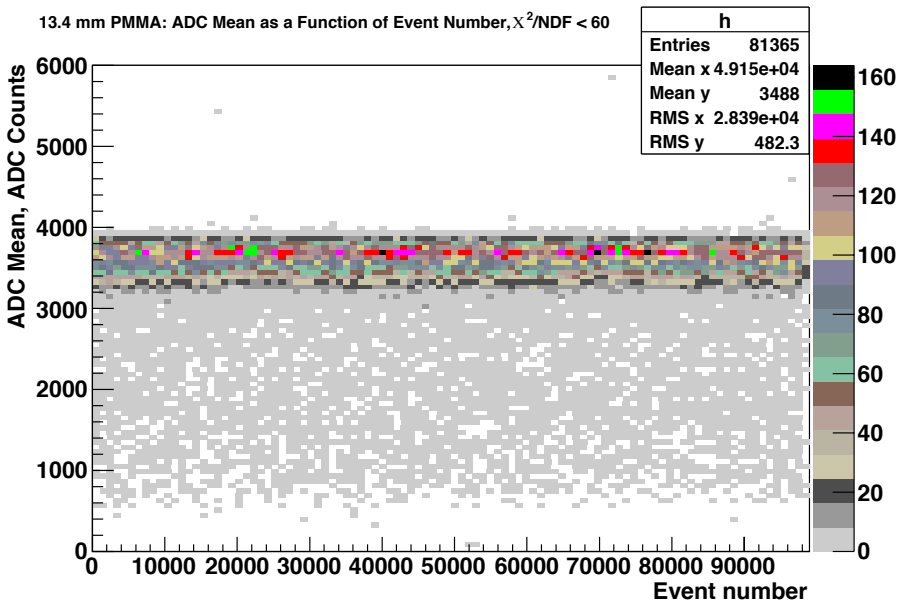
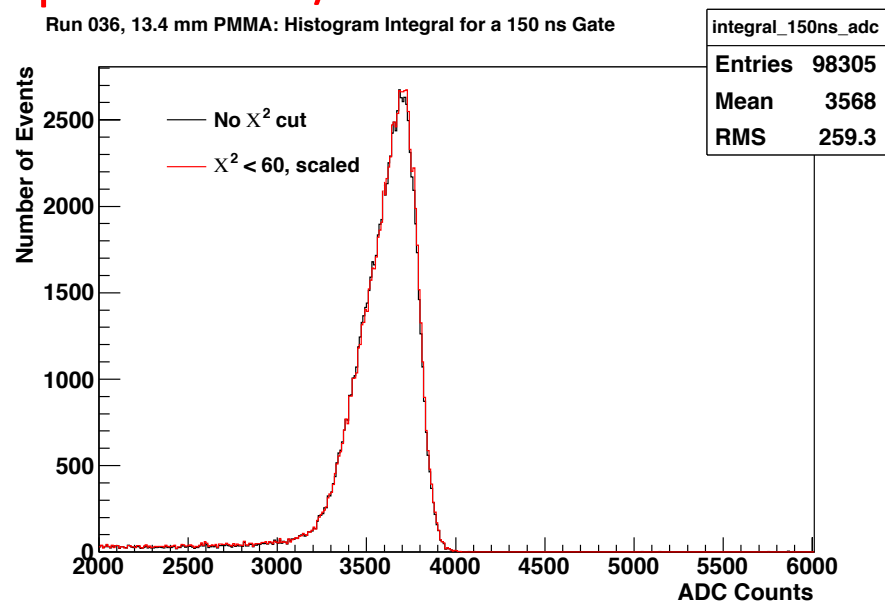
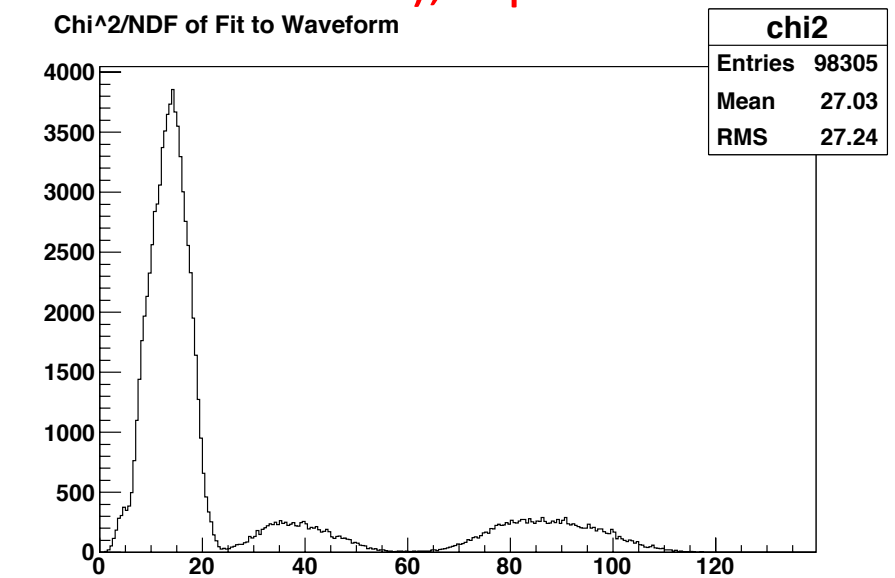
7.24 mm PMMA Upstream: ADC Mean as a Function of Event Number, $\chi^2/\text{NDF} < 60$



h	
Entries	72025
Mean x	4.775e+04
Mean y	4401
RMS x	2.76e+04
RMS y	567.1

χ^2/NDF cut	Number of events	ADC mean, ADC counts	$\Delta E/E$ FWHM, %
None	95662	4614 ± 0.5	3.442 ± 0.035
< 60	72025	4617 ± 0.5	3.341 ± 0.038
ADC equivalent: run 033			
None		4495 ± 0.1	3.478 ± 0.009

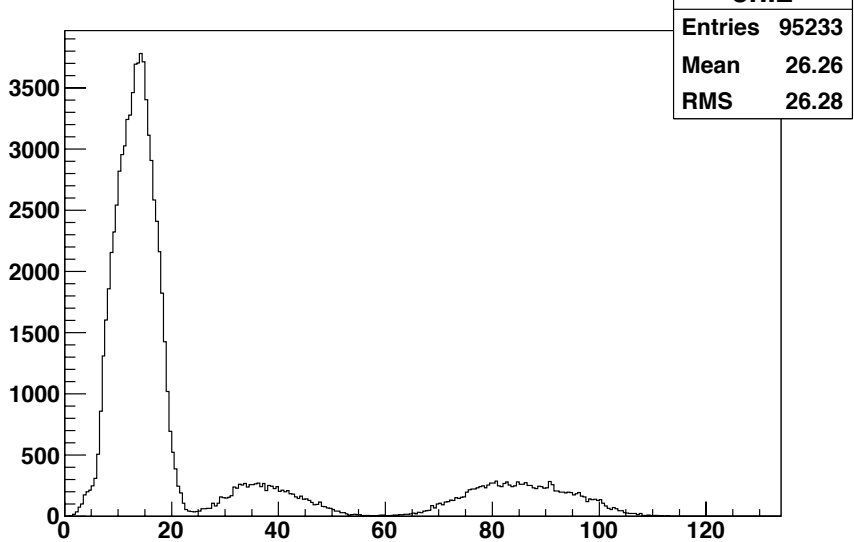
Run 036: Rate - 50 kHz, 13.4 mm PMMA Plate (placed in same position as wheel), equivalent to wheel position 80/15.4 mm WE



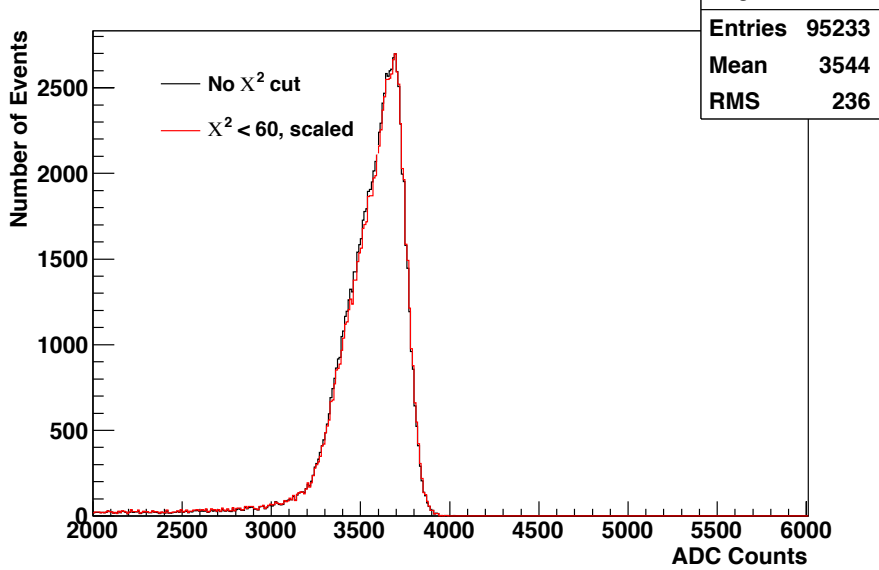
X ² /NDF cut	Number of events	ADC mean, ADC counts	ΔE/E FWHM, %
None	98305	3679 ± 0.7	5.451 ± 0.045
< 60	81365	3684 ± 0.7	4.997 ± 0.057
ADC equivalent: run 035			
None		3570 ± 0.1	5.258 ± 0.010

Run 038: Rate - 50 kHz, 13.4 mm PMMA Plate (placed upstream of the beam), equivalent to wheel position 80/15.4 mm WE

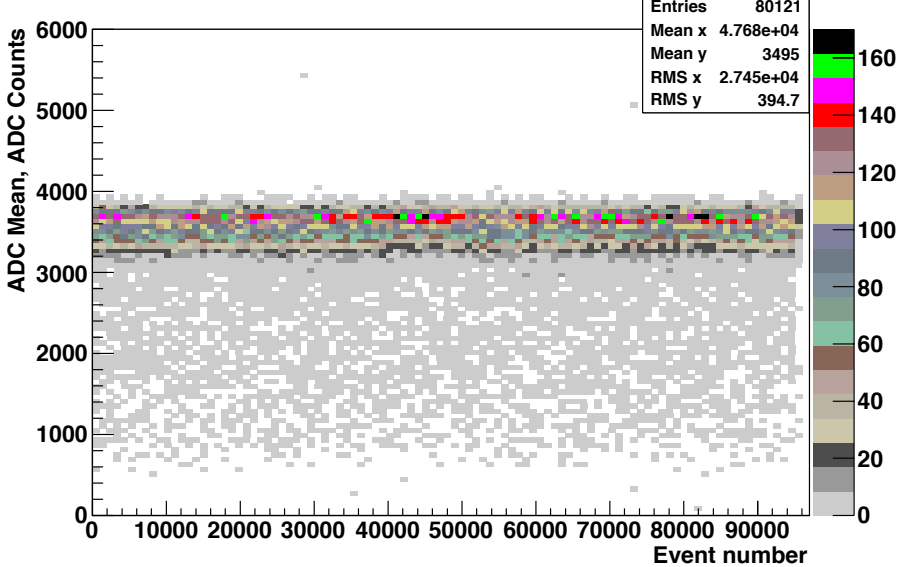
Chi^2/NDF of Fit to Waveform



Run 038, 13.4 mm PMMA Upstream: Histogram Integral for a 150 ns Gate



13.4 mm PMMA Upstream: ADC Mean as a Function of Event Number, $X^2/NDF < 60$



X ² /NDF cut	Number of events	ADC mean, ADC counts	ΔE/E FWHM, %
None	95233	3653 ± 0.6	4.376 ± 0.059
< 60	80121	3657 ± 0.5	4.087 ± 0.055
ADC equivalent: run 037			
None		3539 ± 0.1	4.930 ± 0.011

Conclusions

- Although to somewhat a lesser extent we still see the “beam shifting” problem when running at higher rates
- In order to investigate this:
 - Use the detector emulator to test the detector at various rates in a controlled environment
 - Whilst getting to know the emulator we could pulse an LED at different rates and see whether we see any effects from this